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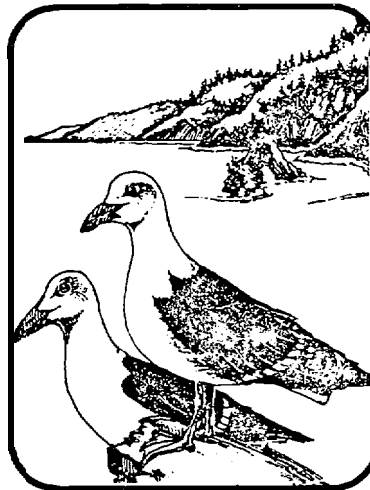
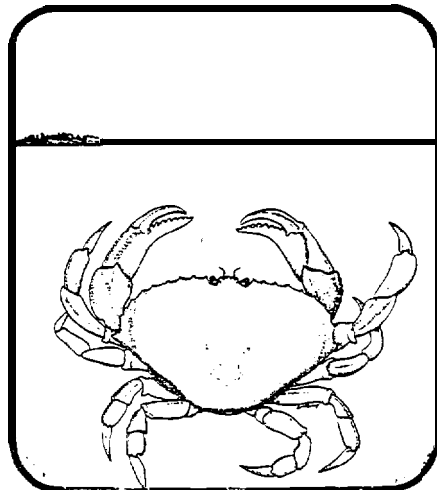
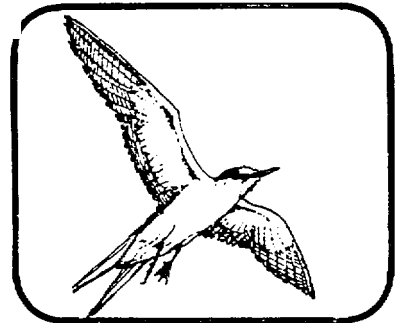
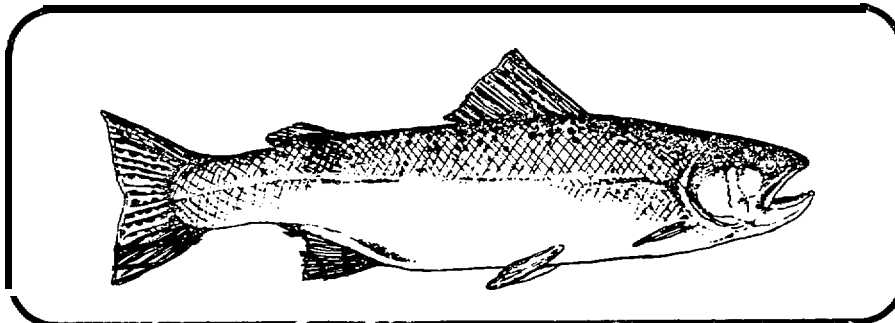
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Biological Services Program

FWS/OBS-80/47

An **Ecological Characterization** **of the Central and Northern** **California Coastal Region**

VOLUME III, PART 1 **HABITATS**



Bureau of Land Management
Pacific Outer Continental Shelf Office
and
Fish and Wildlife Service

U.S. Department of the Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

- To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.
- To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major changes in land and water use.
- To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decisionmaking process to prevent or minimize the impact of development on fish and wildlife. Research activities and technical assistance services are based on analysis of the issues, a determination of the decisionmakers involved and their information needs, and an evaluation of the state of the art to identify information gaps and determine priorities. This is a strategy that will ensure that the products produced and disseminated are timely and useful.

Projects have been initiated in the following areas: coal extraction and conversion; power plants; geothermal, mineral, and oil-shale development; water resource analysis, including stream alterations and western water allocation; coastal ecosystems and Outer Continental Shelf development; and systems inventory, including National Wetland Inventory, habitat classification and analysis, and information transfer.

The Biological Services Program consists of the Office of Biological Services in Washington, D. C., which is responsible for overall planning and management; **National Teams**, which provide the Program's central scientific and technical expertise and arrange for contracting biological services studies with states, universities, consulting firms, and others; Regional Staff, who provide a link to problems at the operating level; and staff at certain Fish and Wildlife Service research facilities, who conduct in-house research studies.

October 1981

ECOLOGICAL CHARACTERIZATION OF THE
CENTRAL AND NORTHERN CALIFORNIA
COASTAL REGION

Volume III, Part 1
Habitats

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PREFACE

The objective of this study is to obtain and synthesize environmental and socio-economic data which identify, describe, and analyze the important living resources, ecological processes, and their interrelationships in the middle and northern California coastal region.

This report was prepared for the U. S. Fish and Wildlife Service and the Bureau of Land Management of the Department of the Interior. The report will be used primarily by these agencies to evaluate the potential ecological consequences of urban, industrial, and commercial development plans for the study area. The report also will be useful for a much larger audience. Coastal zone, river basin, and harbor planners, scientists, and the general public should find this document useful.

This report is a compilation of existing information assembled to meet the objective of preparing an integrated ecological data base. The information is prepared as an overview of ecological concepts, components, and processes. The bibliography also provides a data base which readers can use in their search for more information concerning environmental problems.

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ORGANIZATIONAL OUTLINE - VOLUMES I-V

- APPROXIMATE STUDY AREA: Coastal California from the California-Oregon border south approximately 550 miles to Point Conception and from the minus 1,000 meter contour line offshore inland to the crest of the coastal mountain ranges, for a total of about 22,500 square miles.
- APPROACH: Ecological integration of information into one data base on physical-chemical features and processes, biological resources, and socio-economic activities of the central and northern California coastal region.
- REPORT: Volume I - Basic Ecological Concepts
Refresher and short courses in basic physical-chemical, ecological, and socio-economic concepts.
- Volume II - Part 1 - Regional Characterization
Description of physical-chemical processes and features, ecosystems and species and areas of concern, and socio-economic features and activities of central and northern coastal California.
- Volume II - Part 2 - Species Accounts
Species accounts emphasizing natural and human factors limiting distribution and abundance for rare, endangered, threatened, fully protected, commercial, and recreational species, and other species of ecological interest.
- Volume III - Part 1 - Habitats
Descriptions of each of the habitats comprising the marine, estuarine, lacustrine, palustrine, and terrestrial ecosystems of the study area including characteristic species, ecosystem models, food webs and descriptions of abiotic and socio-economic factors.
- Volume III - Part 2 - Community Composition Lists
Computer generated annotated listings of the important species that occur in each major type of habitat within the study area. Species listings include life history information and references.
- Volume IV - Watersheds and Basins
Site-specific information and maps on the 22 watersheds and 5 ocean basins that comprise the study area, illustrating physical, biotic, and socio-economic data.
- Volume V - Data Source Appendix
Definitions and descriptions of forms, methodology, and products of automated data processing of bibliographic and annotated species information and description of gaps in the physical, biological and socio-economic data in the literature.

SUMMARY OF THE ECOLOGICAL CHARACTERIZATION STUDY

The objective of this study is to describe and integrate information on the physical-chemical, biological, and socio-economic features of central and northern coastal California. The emphasis is ecological, stressing the interrelationships among plants and animals and their environment. Special emphasis for the central and northern coastal California regional characterization was directed toward providing sufficient information to evaluate potential impacts of man's activities in the coastal region. Coastal zone management plans, water resource projects, and outer continental shelf oil and gas development are examples of significant and potential man-induced changes proposed for the study region.

This study was undertaken as part of a national program to characterize the coastal regions of the United States. Although styles of presentation and format of the various studies differ with geographic area and intended use of the study results, the ecological characterization concept remains consistent. The study area was described as coastal California from the California-Oregon border south to Point Conception and from the minus 1,000-meter contour line offshore inland to the crest of the coastal mountain ranges.

The study culminated in a report on the following topics:

- Volume I - Basic Zoological Concepts
- Volume II - Part 1 - Regional Characterization
- Part 2 - Species
- Volume III - Part 1 - Habitats
- Part 2 - Community Composition Lists
- Volume IV - Watersheds and Basins
- Volume V - Data Source Appendix

Site-specificity of data presented in the report increases as the reader progresses from Volumes I through IV. The report volumes, however, are not necessarily meant to be read from cover to cover, but rather to serve as a reference work. An individual reader can refer to the report at any one of the following levels: generalized explanation of basic ecological concepts (Volume I), regional description of coastal California (Volume II, Part 1), individual species accounts (Volume II, Part 2), habitat description (Volume III, Part 1), community composition (Volume III, Part 2), or watershed or ocean basin description (Volume IV). The contents of each volume are briefly described below.

VOLUME I - BASIC ECOLOGICAL CONCEPTS

Volume I outlines the basic ecological components, processes and activities that are operating in the natural and men-made world of the study area. Volume I serves as a refresher or short course on basic ecological concepts that can help to put the rest of the report in perspective. It was anticipated that the reader of this volume would, through academic training and/or expedience, have a general understanding of basic physical-chemical, biological and socio-economic concepts.

Volume I is not a summary of the other volumes of the report. The other volumes may be used without the benefit of the concepts described in Volume I. An understanding of each basic component of an ecosystem, however, will further the reader's comprehension of the interrelationships among physical-chemical, biological and socio-economic components of the ecosystem.

The authors were requested in the preparation of this volume to use the conceptual planning model developed for the Ecological Characterization of the Pacific Northwest Coastal Region (Rye, Kmen, Edgerley, Tomlinson & Associates, 1977). They urged to use as much of Volume I of the Pacific Northwest report as possible in preparing the California Zoological Characterization. In some respects the basic

request has been followed , except the authors felt it necessary to start anew on the chapters on biological concepts (Chapter 2) and on air quality (Chapter 5) and to modify Chapters 3 and 4, physical-chemical processes. The impact of deteriorating air quality on plants and animals (including man) is a significant issue in California as are the concepts associated with air pollutants and their effects on natural and man-made systems.

The biological concepts chapter (Chapter 2) discusses how ecological processes may be viewed at the level of the individual organism, the species population, biotic community, or the ecosystem. Volumes II through IV of this report view organisms as components of ecosystems but draw from all approaches in viewing ecological principles. Many valuable references are cited in both Chapters 2 and 5 to provide the interested reader with recent pertinent literature.

Chapters 6 through 9 of this volume introduce the reader to major socio-economic topics by use of models (e.g. , natural resource, basic industry, services, population, transportation, forest practices, commercial fisheries, recreation, agriculture, extractive and mineral industries) , A section on the modeling of offshore oil and gas production is provided.

VOLUME II, PART 1, REGIONAL CHARACTERIZATION

This volume consists of five chapters. Chapter 2 is a regional overview of central and northern coastal California. It is a brief summary of the material contained in the rest of the report. The approach is ecological, combining physical-chemical, biological, and socio-economic features, processes, and activities. Chapter 2 identifies and places in perspective the important features and processes that characterize northern and central coastal California.

Chapter 3 in this volume outlines all of the important physical-chemical features and processes that form, control, or influence the central and northern California coastal region. Major topics included geological, physical, and chemical Oceanography; estuarine processes; hydrology and water quality; climatology and air quality; and geology and seismology.

Chapter 4 uses models of each of the major kinds of systems - marine, estuarine, riverine, lacustrine (lakes) , palustrine (shallow ponds) , and terrestrial - to characterize the biological environment of the study area. Each model shows the inter-relationships among physical-chemical, biological, and socio-economic features and processes. Emphasis has been placed on the physical factors that control or influence biological features and processes. Important species and areas of ecological concern are identified. Important species are those that have received legal distinction as rare, endangered, threatened, or fully protected species or as commercial or recreational (sport) species or are representative or characteristic species of specific habitat types. Each designated species is described in a species account in Volume II, Part 2. Areas of ecological concern are specific sites designated by governmental agencies or private organizations. Such sites are recognized as important wildlife habitat, critical habitat of a rare or endangered plant or animal species, research areas, refuges (marine life or wildlife) , preserves, anadromous salmonid fish habitat. Descriptions and specific locations of hundreds of areas of ecological concern may be found in Volume IV of this report.

Chapter 5 describes important socio-economic features of the northern and central California coast including forestry and forest products, fisheries, recreation, agriculture, extraction and mineral industries (e.g. , offshore oil and gas development) , transportation and energy utilities, service activities, social and cultural features, and land use.

The Regional Characterization (Volume II, Part 1) is meant to serve two purposes. First, it is a transition between the basic concepts and models described in Volume I and the more specific information found in the rest of the volumes. It applies these basic concepts to the central and northern coastal California study area. Secondly, it provides an overview of the environmental setting of the study area. The wide diversity of the study area is revealed in discussions on climatic conditions; geology and soils; land use and population distribution; plants, animals and their habitats; economic and employment conditions; resources, and many other topics.

Volume II, PART 2, SPECIES ACCOUNTS

This volume of the report contains accounts of approximately 200 plant and animal species that live within the central and northern California coastal region. Plants and animals that have been designated as rare, endangered, threatened or fully protected by the state or federal governments are described. Also described are sport species that are hunted or fished, and Commercial fish, shellfish, fur-bearers and trees. The accounts also include descriptions of pest or fouling species. Other plant or animal species included in this volume are dominant or characteristic species in their respective habitats.

A brief account for each species includes information on distribution, abundance, resource use and ecological characteristics. Whenever data were available, a discussion of the natural and human factors affecting abundance and distribution of the species is included. The concept of limiting factors is important considering the potential threat to a species posed by man-made developments and habitat disturbance. Management techniques and studies which are or will be used to influence species numbers are identified.

Information on species in this volume should be used in two different ways. First, the potential for man- or nature-induced changes can be ascertained for some species. Such an analysis would be particularly significant for rare, endangered, or threatened species. Secondly, the information may be used to help ascertain the effects of man- or natural-induced changes on a habitat type and how the changes affect the more dominant or characteristic species.

VOLUME III, PART 1, HABITATS

Ecosystem models prepared for each of the five aquatic systems and for the terrestrial system were presented in Volume II, Part 1, Regional Characterization. To apply these generalized system models to the California coastal region, classification schemes were used to identify each of the specific and recognized habitat types within each system. Each of the habitat types was described in some detail. Aquatic areas were classified into five systems: marine, estuarine, riverine, lacustrine (lakes), and palustrine (ponds), and then into many finer categories (habitat types) based on a modified version of Cowardin, et al. (1979), Classification of Wetlands and Deep Water Habitats of the United States. Terrestrial areas were classified into 15 cover types and 46 habitat types based on a modified version of Cheatham and Hailer (1975), An Annotated List of California Habitat Types.

To use Volume III, Part 1 most effectively when examining a site-specific project, Volume IV - Watersheds and Basins, Chapters 3 through 29 should be consulted to ascertain from the vegetation or surficial geology maps the distribution of habitats for a specific location. The reader then can review the appropriate habitat sections(s) of Volume III. Each habitat type includes a description of characteristic plants and animal species as well as food webs that identify the interrelationships among the species. Important habitat-specific abiotic processes and features that control habitat operations are discussed. Socio-economic activities which may infringe on the operation of the habitat type are also identified. Land use categories are described in the last chapter of this volume.

VOLUME III, PART 2, COMMUNITY COMPOSITION LISTS

In addition to the brief listings of characteristic plant and animal species found in each habitat type discussion of Volume III, Part 1, a more extensive listing of species for each habitat type is offered in this volume of the report.

Many thousands of plant and animal species are found within the central and northern California coastal region. Preparation of a useful list of species required identifying and recognizing the most common or characteristic species of the region. In addition to the common or characteristic plants and animals, the list also included commercial, recreational, and rare, threatened, endangered, and fully protected species. An annotated species data entry form was prepared for each species chosen. Entries on the form include scientific and common names, taxonomic division, intermediate group name, distribution by watershed or basin, legal status, habitat, feeding habits, trophic level, abundance, habitat use, and literature references.

VOLUME IV, WATERSHEDS AND BASINS

Central and northern coastal California is such a large and diverse region that it is subdivided into smaller units for ease in presenting site-specific information. Land areas were subdivided into watershed units and ocean areas into basins determined by offshore geology.

A separate chapter was prepared for each of 22 watersheds and 5 offshore basins, and each contain site-specific information. Chapters on the watersheds contain information on terrestrial, freshwater and estuarine physical-chemical processes and features, biological resources and socio-economic activities. Chapters about the basins contain information on intertidal, pelagic and subtidal benthic physical-chemical processes and features, biological resources, and socio-economic activities.

Watershed chapters contain descriptions of geology, soils, climate, tsunami hazard, hydrology, water quality, and other topics. The biological resources section of each watershed description contains information on selected species and areas of ecological concern. Preserves, reserves, refuges, conservation areas, sites of known scientific and educational value, anadromous fish spawning areas, wild and scenic rivers, important nesting sites, and waterfowl and shorebird concentrating locations are described and mapped as areas of ecological concern. Socio-economic descriptions include land use, economics, population, environmental issues and other topics, both existing data and trends.

The vegetation and areas of ecological concern were mapped for each watershed. By inspecting the appropriate vegetation map for a specific area and referring to the habitat descriptions (Volume III, Part 1), community composition lists (Volume III, Part 2) and species accounts (Volume II, Part 2), the reader can ascertain the kinds of plants and animals occurring in an area, including possible rare or endangered species. The maps of areas of ecological concern along with the maps and narratives of physical and socio-economic conditions can complete the background picture for any general area chosen for inspection.

The basin chapters (24 through 29) contain similar kinds of information, but with a greater emphasis on substrate distribution maps which can be used with Volume III, Habitats, and Volume II, Part 2, Species, to determine the kinds of organisms present at a specific site. Emphasis has been placed on areas of biological significance (designated by California State Water Resources Control Board), marine refuges and ecological preserves (California Fish and Game Commission) as areas of ecological concern.

VOLUME V, DATA SOURCE APPENDIX

Volume V provides the reader with information about the methods used to prepare the bibliographies and annotated species lists (i.e., community composition lists). It contains a list of persons contacted during data gathering. It also discusses the lack of information known about the central and northern coastal California region.

The bibliographies that accompany Volume I through IV of this report were prepared using automated data processing. Each volume includes a complete list of references cited. Chapter 2 in this volume describes the forms used to arrange the bibliographic information into a computer-accessible format. While the bibliographic entries are listed alphabetically, the computer records may be searched and sorted for the various types of information included on the bibliographic data entry form. This chapter also contains the documentation for the use of FAMULUS, the computer program utilized in manipulating the bibliographic data. FAMULUS was developed for and is being used by the U. S. Forest Service, Pacific Southwest Forest and Range Experimental Station, Berkeley, California.

Chapter 3 of Volume V describes the computer input form and documents the use of SYSTEM 2000, the computer program that was used to manipulate the information on the annotated species list forms. The contents of these forms were outlined earlier in this summary. Rather than preparing a list of species, the species were aggregated by habitat types into community composition lists. These lists are to be found in Part 2 of Volume III. With the assistance of automated data processing the species can be sorted by trophic level, legal status, species group or other parameters on the data entry form.

Chapter 4 of Volume V is the Data Gaps Report. It contains an appraisal of the state of knowledge on the central and northern California coastal region. The consensus in the report is that ecological data are sorely lacking. While basic data vary from totally inadequate on some topics to comprehensive for others, the understanding of interrelationships among physical-chemical, biological, and socio-economic parameters has not begun to be adequately explored in the literature. The influences of man and his activities on the natural environment are not at all well understood. In the Data Gaps Report emphasis was given to identifying the informational inadequacies in the literature related to potential onshore and offshore impacts of OCS oil and gas exploration and development,

SUMMATION

The study was undertaken to draw together the basic information needed to evaluate the environmental consequence of any action proposed for central and northern coastal California. The study itself did not evaluate projects and was not intended to be an environmental impact assessment, report, or statement prepared under state or federal regulations. The documents that comprise this report provide the reader with a basic reference for coastal California and the bibliographies provide lists of more specific references that can be consulted if needed.

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Chapter 1

USER'S GUIDE

In this volume, a hierarchical classification system is used to define and describe the types of recognizable habitats in the **study** area. In Volume II, **Part 1**, of this study, six different kinds of ecosystems were modeled and their **physical-chemical**, biological and **socio-economic** components were characterized. For each of these ecosystems, a number of more specific categories are identified. For example, open water (pelagic) or rock, sand or mud bottom **subtidal** benthic are all part of the **marine** system. Subcategories of each kind of ecosystem are called "habitats" for the purpose of this study. These kinds of habitats represent recognizable **units** of the land or seascape that are characterized by specific, describable physical and biotic conditions.

The classification systems used to define and describe each of the "habitats" are described in Chapter 2 of this volume. Particular attention should be paid to the tables in Chapter 2 that list habitats. The rest of this volume describes the various types of habitats starting with the marine types and progressing through the estuarine, freshwater aquatic, and terrestrial and ending with the man-modified habitats of urban and agricultural areas. Each "habitat" description includes a description of physical-chemical conditions specific to **the** habitat, characteristic plant and animal species, and food webs. **Socio-economic** activities that affect the habitat are also discussed.

To realize maximum utility from this volume, the reader first **should** become familiar with the contents of Volume IV, Watersheds and Basins, where the vegetation and **surficial** geological maps show the distribution of **habitats** for a specific location.

At the end of this volume, there is a glossary.

Chapter 2

HABITAT CLASSIFICATIONS

HABITAT CLASSIFICATIONS USED IN THIS REPORT

Aquatic

Aquatic habitats in this report are classified and discussed according to a hierarchical classification based primarily on Cowardin, et al. (1979). The major modification to Cowardin, et al., was the addition of open water (pelagic/pelagial) and artificial (piers and pilings) habitats to some of the ecosystems. The aquatic classification scheme developed for this report, and equivalent categories from Cowardin, et al. (1979) and other recognized sources for California, are listed in Table 2-1. The classification system used in this report separates aquatic habitation into five major kinds of ecosystems (the "systems" of Cowardin, et al. (1979): marine, estuarine, riverine, lacustrine, and palustrine. In Volume II, Part 1, Regional Characterization, each of the kinds of ecosystems are described by conceptual model and then related to conditions in California. These kinds of ecosystems are further divided and subdivided into a number of categories. Physical and chemical characteristics (depth, water regime, substrate particle size, salinity) are the main criteria used in defining categories. In some cases, biological characteristics are used (e.g., emergent vegetation). In this report, the categories chosen for description are called "habitats."

Terrestrial

The terrestrial habitats in this report are classified and discussed according to a hierarchical classification scheme based primarily on Cheatham and Hailer (1975). Because of the number of terrestrial habitats in California, they qualify as an ecological classification. Some modifications were made (Table 2-2). Corresponding classification units with those of Munz and Keck (1973), Thorne (1976), Kuchler (1977), and Parker and Matyas (1978) are also indicated in Table 2-2.

Table 2-1. Aquatic **Habitat** Categories Used in This Report and Equivalents from Other Sources

California Coastal Characterization	Cowardin, et al., 1979	Ricketts & Calvin (1968)	Cheatham and Haller (1975)	Mason (1957)	Hedgpeth (1957)
MARINE	Marine			Oceans	
Pelagic (water column)					Pelagic
Subtidal (substrate)	Subtidal	Subtidal zone			Sublittoral; bathyal; Abyssal; hadal
Rock bottom	Rock bottom				
Bedrock	Bedrock				
boulder	Rubble (old name boulder)				
Unconsolidated bottom	Unconsolidated bottom				
cobble/gravel	Cobble/gravel				
sand	Sand				
mud	Mud				
Aquatic bed submerged	Aquatic bed				
algal beds	Algal				
submerged vascular plants	Rooted vascular				
Intertidal (substrate)	Intertidal	Intertidal zone			Littoral
Rocky shore	Rocky shore	Rocky shores	Rocky shore		
bedrock/ boulder	Bedrock, rubble (old name boulder)				Rocky intertidal
Unconsolidated shore	Unconsolidated shore				
cobble/gravel	Cobble/gravel				
sand	Sand	Sandy beaches	Cobble beach Sandy beach		sandy beaches
Pilings		Wharf piling			
ESTUARINE	Estuarine		Bays and bays; coastal estero,	Estuaries; bays	Estuaries and lagoons
Intertidal & Subtidal (substrate)	Intertidal; subtidal	Intertidal zones 1-4; Subtidal zone			
Unconsolidated bottom	Unconsolidated bottom				

Table 2-1 (continued)

California Coastal Characterization	Cowardin, et al. , 1979	Ricketts & Calvin (1968)	Cheatham and Hailer (1975)	Mason (1957)	Hedgpeth (1957)
Rocky shore Emergent vegetation	Rocky bottom, rocky shore Emergent wetland, persistent		Salt marshes	Saltwater marshes; seasonally salt and freshwater marshes	
Eelgrass (sub- tidal aquatic bed) Piers & pilings	Subtidal rooted vascular	Eelgrass flats wharf piling			Eelgrass
RIVERINE	Riverine		coastal streams ; coastal rivers		
Tidal (tidally influenced flow)	Tidal			Live streams	
Lower Perennial (perennial flow; lower, slow- flowing reaches)	Lower perennial		Slow meandering	Live streams	
Upper perennial (perennial flow; upper, faster flowing reaches)	Upper perennial		Rapidly flowing	Live streams	
Intermittent (seasonal flow)	Intermittent		Intermittent	Intermittent streams	
LACUSTRINE (lakes)	Lacustrine		Lakes; man-made reservoirs	Freshwater lakes; salt lakes	
Littoral (near - shore)	Littoral				
Limnetic (lake bottom)	Limnetic				
Pelagial (off- shore water column)					

Table 2-1 (Continued)

California Coastal Characterization	Cowardin, <u>et al.</u> , 1979	Ricketts & Calvin (1968)	Cheatham and Hailer (1975)	Mason (1957)	Hedgpeth (1957)
PAUSTRINE (ponds, vernal pools, inland wetlands)	Paustine		Vernal pools; bogs and marshes; ponds	Freshwater ponds; marshes, bogs, swamps, vernal pools, vernal marshes, streamside marshes; freshwater marshes subject to tidal influence	

Table 2-2. Terrestrial Ecosystem Categories Used in This Report and
Equivalents from Other Sources

California Coastal Characterization	Cheatham & Hailer (1975)	Munz & Keck (1973)	Theme (1976)	Kuchler (1977)	Parker & Matyas (1978)
<u>Grassland</u>					
Coastal Prairie Valley & Foothill Grassland	Coastal Prairie Valley & Foothill Grassland	Coastal Prairie Valley Grassland	No. Coastal Prairie Coast Range Valley Grassland	Coastal Prairie (California Prairie)	Annual Grass
<u>Meadow & Seep</u>					
Montane Meadow Freshwater Seep	Montane Meadow Freshwater Seep	(Valley Grassland)	Montane Meadow (California Grassland)		Perennial Grass (Sedge - Rush)
<u>SCRUB LAND</u>					
<u>Coastal Scrubland</u>					
Coastal Dune Scrub	Coastal Dune Scrub	(Coastal strand)	(Coastal Dune Sand Plant)	No. & Central Dune Scrub	(Soft Chaparral)
Coastal Bluff Scrub	No. Coastal Bluff Scrub	(No. Coastal Scrub)	(No. Coastal Scrub)	(No. Coastal Scrub)	
No. Coastal Scrub Coastal Sage Scrub	No. Coastal Scrub Central Coastal & Coastal Sage scrubs	No. Coastal Scrub (Coastal Sage Scrub)	No. Coastal Scrub (Maritime Sage Scrub)	No. Coastal Scrub (Coastal Sagebrush)	(Coast Mixed Shrub) (Soft Chaparral)
<u>Chaparral</u>					
Mixed Chaparral	Mixed Chaparral	(Chaparral)	Mixed Chaparral	(Chaparral)	(Chaparral)
Chamise Chaparral	Chamise Chaparral	(Chaparral)	Chamise	(Chaparral)	Chamise Chaparral
Serpentine Chaparral	Serpentine Chaparral	(Chaparral)	Serpentine Chaparral	(Chaparral)	(Chaparral)
coastal Mixed shrub		(Chaparral)		(No. Coastal Scrub)	Coastal Mixed Shrub
<u>BROAD-LEAVED FOREST & WOODLAND</u>					
<u>Broad-Leaved Ever- green Forest</u>					
Mixed Evergreen Forest	Mixed Evergreen Forest	(Mixed Evergreen Forest)	(No. Mixed Evergreen Forest)	(Mixed Evergreen Forest & Mixed Hardwood Forest)	Tanoak - Madrone Forest
California Bay Forest	California Bay Forest	(Mixed Evergreen Forest)	(No. & So. Mixed Evergreen Forest)	(Mixed Hardwood Forest)	(Laurel - Buckeye Woodland)
Coast Live Oak Forest	Coast Live Oak Forest	(Foothill Woodland)	(No. & So. Mixed Evergreen Forest)	(Southern Oak Forest)	Coast Live Oak Forest
Canyon Live Oak Forest ²	Canyon Live Oak Forest & Santa Lucia Fir Forest	(Mixed Evergreen Forest)	(No. & So. Mixed Evergreen Forest)	(Mixed Hardwood Forest)	Canyon Live Oak Forest

Table 2-2 (Continued)

California Coastal Characterization ¹	Cheatham & Hailer (1975)	Munz & Keck (1973)	'Theme (1976)	Kuchler (1977)	Parker & Matyas (1978)
<u>Oak Woodland</u> Northern Oak Woodland Blue Oak Woodland	Northern Oak Woodland Blue Oak Woodland	Northern Oak Woodland (Foothill Woodland)	Northern Oak Woodland (Foothill Woodland)	Oregon Oak Forest Blue Oak-Digger Pine Forest (Valley Oak Savanna)	Oregon White Oak Forest Blue Oak Woodland
Valley Oak Woodland/ Savanna so. Coastal Oak Woodland	Valley Oak Woodland so. coastal oak Woodland	(Foothill Woodland) (Foothill Woodland)	(Foothill Woodland) (Foothill Woodland)	(Southern Oak Forest)	Valley Oak Woodland (Coast Live Oak Forest)
<u>Riparian Forest</u> Mixed Riparian Forest Red Alder Forest	Mixed Riparian Woodland Red Alder Groves		(Riparian Woodland) (Riparian Woodland)	(Riparian Forest)	(Cottonwood & Willow Woodland & Forest) Red Alder Forest
<u>CONIFEROUS FOREST</u> <u>Coastal Conifer Forest</u> Alluvial Redwood Forest Slope Redwood Forest	Alluvial Redwood Forest Upland Redwood Forest	(Redwood Forest) (Redwood Forest)	(Redwood Forest) (Redwood Forest)	Redwood Forest (Redwood Forest & Mixed Hardwood and Redwood Forest) Grand Fir-Sitka Spruce Forest	Redwood Forest Redwood-Douglas Fir Forest
Sitka Spruce- Grand Fir Forest Western Hemlock Forest	Sitka Spruce- Grand Fir Forest Western Hemlock Forest	(No. Coastal Coniferous Forest) (No. Coastal Coniferous Forest)	(No. Coastal Coniferous Forest) (No. Coastal Coniferous Forest)	(Redwood Forest & Grand Fir-Sitka Spruce Forest)	Sitka Spruce-Grand Fir Forest
Douglas Fir Forest <u>Lower Montane Conifer Forest</u>	Douglas Fir Forest	Douglas Fir Forest	Douglas Fir Forest		Douglas Fir Forest
Coast Range Mixed Conifer Forest Coast Range Ponderosa Pine Forest Coulter Pine Forest <u>Closed-Cone Conifer Forest</u>	Coast Range Mixed Conifer Forest Coast Range Ponderosa Pine Forest Coulter Pine Forest	(Yellow Pine Forest) (Foothill Woodland)	(Yellow Pine Forest) Coulter Pine Forest	(Mixed Evergreen Forest with Rhododendron) Coulter Pine Forest	Mixed Conifer- Pine Forest Ponderosa Pine Forest Coulter Pine Forest
Knobcone Pine Forest	Knobcone Pine Forest		(Inland Closed-Cone Coniferous Woodland) (Coastal Closed-Cone Coniferous Woodland)		Knobcone Pine Forest
Bishop Pine Forest	Bishop Pine Forest	(Closed-Cone Pine Forest)	Shore Pine Woodland	(Coastal Cypress and Pine Forest) (Coastal Cypress and Pine Forest)	Bishop Pine Forest
Shore Pine Forest	Shore Pine-Bishop Pine Forest	(Closed-Cone Pine Forest)			

Table 2-2 (Continued)

California Coastal Characterization ¹	Cheatham & Hailer (1975)	Munz & Keck (1973)	Theme (1976)	Kuchler (1977)	Parker & Matyas (1978)
Monterey Pine Forest	Monterey Pine Forest	(Closed-Cone Pine Forest)	(Coastal Closed-cone Coniferous Woodland)	(Coastal Cypress and Pine Forest)	Monterey Pine Forest
Cypress Forest ²	Monterey Cypress Forest & No. Interior Cypress Forest	(Closed-cone Pine Forest)	(Coastal Closed-cone Coniferous Woodland)	(Coastal Cypress and Pine Forest)	(Cypress Forest)
Pygmy Conifer Forest	Pygmy Cypress Forest	(Closed-Cone Pine Forest)	Pygmy Forest Coniferous Woodland	(Coastal Cypress and Pine Forest)	(Cypress Forest)
WETLANDS					
<u>Perennial Wetlands</u>					
Freshwater Marsh	Coastal and Valley Freshwater Marsh	(Freshwater Marsh)	(Freshwater Marsh)	(Tule Marsh)	(Sedge - Rush)
Freshwater Swamp Bog & Fen ²	Freshwater Swamp Bogs & Fen		Bogs		
<u>Seasonal Wetlands</u>					
Vernal Pool	Coast Range Vernal Pools	(Valley Grassland)	(Vernal Pool Ephemeral)	(California Prairie)	(Annual Grass)
Vernal Marsh	Vernal Marsh	(Valley Grassland)	(Vernal Pool Aquatic)	(Tule Marsh)	(Sedge - Rust)
COASTAL STRAND					
<u>Supratidal Beach²</u>	{Sandy Beach}			(No. & So. Beach)	
<u>Coastal Foredune Complex</u>					
Active Dune Deflation Area ²	Active Coastal Dune (Coastal Foredunes)	(Coastal Strand)	(Coastal Dune Sand Plant)	(No. & So. Beach) (No. & Central Dune scrub)	(Beachgrass - Ryegrass)
Partially Stabilized Dune ²	(Coastal Foredunes)	(Coastal strand)	(Coastal Dune Sand Plant)	(No. & Central Dune Scrub)	(Beachgrass - Ryegrass)
<u>Coastal Dune Scrub</u>	Coastal Dune Scrub	(Coastal strand)	(Coastal Dune Sand Plant)	(No. & Central Dune Scrub)	(Soft Chaparral)

- Key: () Indicates only Partial overlap.
 . Indicates no corresponding classification unit.
 1 Format: HABITAT CLASS
 cover Type
 Habitat Type
 2 Indicates habitat type is modified from Cheatham and Hailer, 1975.

(Reserved)

IIIIC
Part 1

Chapter 3

MARINE ECOSYSTEM

GENERAL CHARACTERISTICS

CONCEPTUAL MODEL

The marine ecosystem consists primarily of two environments: the pelagic (from sea surface to just above the **benthos**) and **benthic** (the ocean floor from high intertidal to the **deepest** oceanic depths). Physical, chemical and biological processes of these environments are diverse **though many** interactions occur. The pelagic environment is fluid, with organisms migrating and switching **trophic** levels, whereas the **benthic** environment is characterized by a comparatively static substratum. The Regional Description (Volume 11, Part 1) discusses these environments, the habitats they contain, and their occurrence along the central and northern California coast.

The following habitat descriptions are focused on applying static presentations, such as the **pelagic** ecosystem model (Figure 3-1) , to the actual ecological processes they represent. Where possible, food webs have been diagramed (though they are often seen as "idealized dreams," merely representing the types of **trophic** interactions that may be occurring) . The coast of central and northern California is presented as containing a mixture of substratum types (ranging from rock to mud) and a vast, productive pelagic region. **Though the benthic** habitats **intergrade** with each other and with the pelagic habitat, they are presented separately in this section to clarify processes specific to a particular habitat (e.g., the **infauna** of unconsolidated sediments, the photosynthetic productivity of an aquatic bed, or the effect of **upwelling** on **phyto-plankton** productivity in the pelagic habitat). The discussion on the marine ecosystem in Volume II, Part 1 shows on a broader scale how these habitats are integrated.

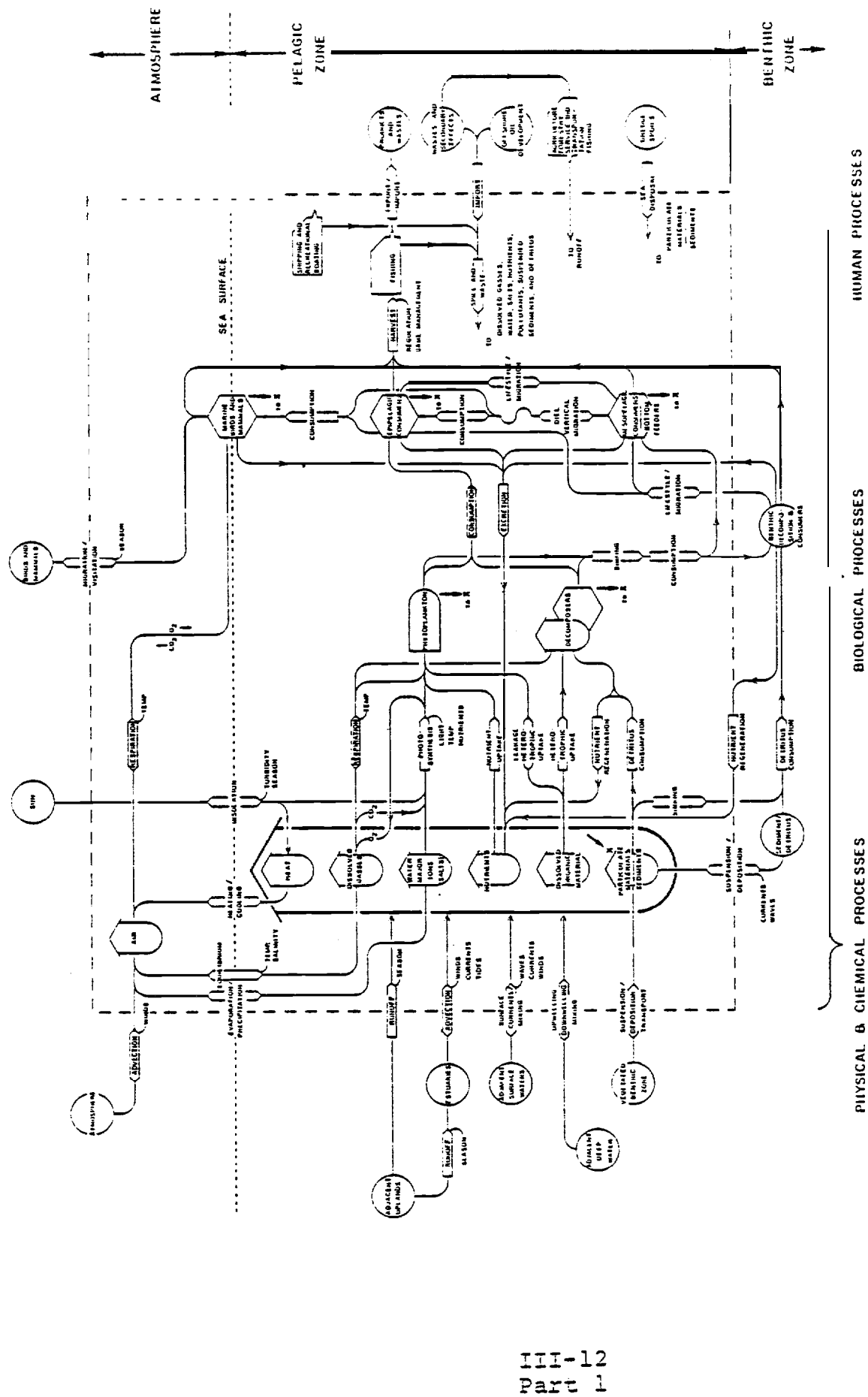


Figure 3-1. Pelagic Ecosystem Model

SUBSYSTEMS

CLASSIFICATION SCHEME AND HABITAT TYPES

Any system of classifying environmental habitats is likely to be more arbitrary and artificial since natural habitats are seldom isolated and compartmentalized, but rather intergrade with one another. Such classification systems are, however, almost universally applied in the course of environmental investigations and are valid approaches for the accumulation and integration of information. Major distinctions and categories, such as between marine, terrestrial, and atmospheric systems are obvious and relatively clear cut. As these major systems are subsequently broken down for classification purposes into smaller subunits, increasing problems are encountered. Such problems may be semantic in character or may be reflective of the integrated nature of the environment itself at these levels. The boundary, for instance, between the euphotic and aphotic zones in the ocean are almost never clear cut but are nebulous and variable within both time and space. The same applies to substratum types, which often grade into one another, occur in mixed distributions, and are altered through time.

For purposes of discussion of the marine system in general, the following classification scheme (Figure 3-2) may be useful. This system is intended to be illustrative in nature and is somewhat arbitrary. This classification network is a modification of Cowardin, et al (1979), which uniformly describes wetland and deep water habitats throughout the United States. Major modifications suitable to the coast of central and northern California are the addition of the pelagic zone of the marine ecosystem and the deletion of the reef class, since there are no true biological reefs in central and northern California. This habitat classification system includes the marine environment from the intertidal zone to the abyssal depths, though presently the discussion is directed towards the outer continental shelf of central and northern California (to 200 meters depth).

The first division of this major system is into two zones, referred to as pelagic and benthic. The pelagic includes all of the water column, from the air/sea interface to directly above the benthos; the benthic includes all of the sea floor, from intertidal to the extreme depths of the oceanic trenches. The pelagic zone may be further subdivided into the euphotic and aphotic zones. The euphotic is the near-surface zone of variable depth, which receives sufficient solar light energy to support photosynthesis. The aphotic zone is all depths beyond the range of light penetration. Further divisions in the pelagic zone are discussed in the pelagic habitat description.

The benthic zone is further segregated into two subsystems: intertidal and subtidal. Intertidal refers to that area lying within the range of tidal fluctuation: subtidal refers to the zone below the low-low water tide line. Within the euphotic zone, these intertidal/subtidal classifications are further split into subclasses depending on whether or not they support marine vegetation. Because of severe physical conditions or nutrient limitations, the euphotic zone does not always give rise to plant growth. The vegetated subclass is then split into two types, depending on vegetation type: vascular and non-vascular. Vascular refers to flowering, generally rooted plants which receive all or part of their nutrients from the substratum itself; non-vascular plants consist of macrophytic algal forms which receive all of their nutrients from the water column and normally have a holdfast but never a true root system. Examples of vascular plants are marine grasses and mangroves. Non-vascular plants include all of the kelps and seaweeds (algae).

The pelagic zone includes none of the class, subclass, or type distinctions applied to substratum conditions, nor do the subdivisions used in connection with plant communities apply to the aphotic subtidal benthic.

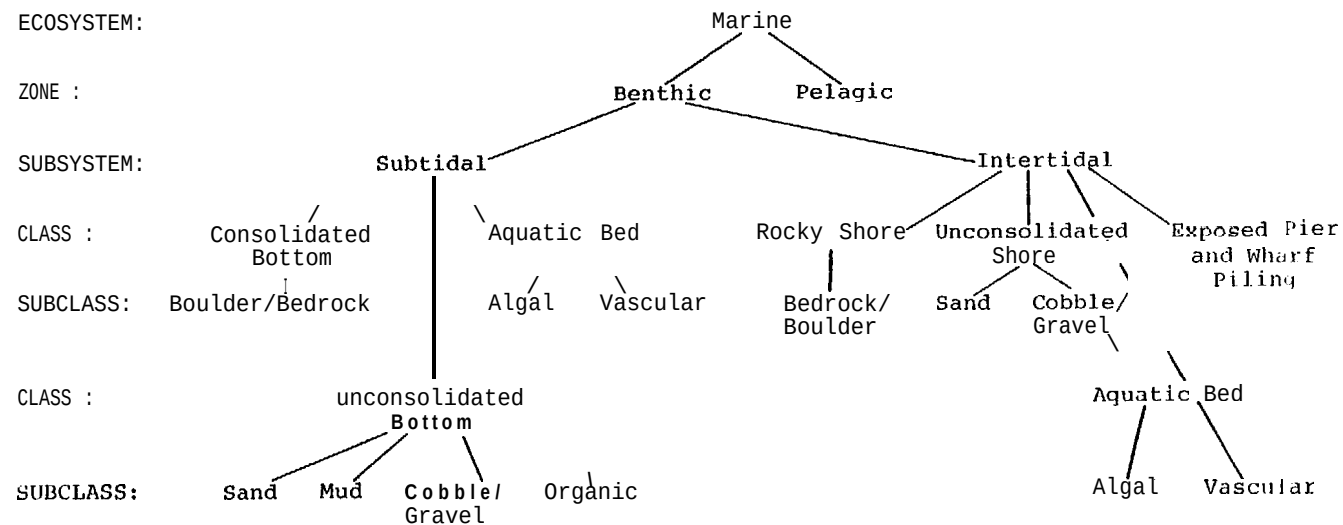


Figure 3-2. Hierarchical Classification of Marine Habitats
(Modified from Cowardin et al, 1979).

On the habitat level, there are several categories which apply to each of the zone, class, subclass, or type divisions. In the benthic zone, these classifications are based on substratum type and include consolidated bedrock and boulder) and unconsolidated (sand, mud, gravel/cobble, and organic). In the case of vascular plants, bedrock and boulder habitats are seldom colonized since they offer no opportunity for root growth. All of these habitat classifications are arbitrary and in nature most of these substratum types are ill-defined, intergrade with one another, and are frequently intermixed.

Cowardin et al (1979) devised a classification scheme for all wetlands and deep-water habitats of the United States. To better apply this system to the coast of northern and central California, a few changes were made and are described here. See Figure 3-2 for a schematic diagram of the habitat hierarchy.

The pelagic zone has historically been separated further into different zones which are dependent on amount of light penetration and, therefore, primary productivity levels. Light penetration is a function of turbidity and depth, factors which are constantly changing. There are no abrupt divisions between zones. Since pelagic species are often vertical and/or horizontal migrators, for the purpose of this study, the pelagic zone is treated as a habitat which supports many different communities and assemblages.

Benthic habitat types are defined primarily by substratum and degree of algal cover. Benthic habitats are divided according to degree of consolidation and amount of algal cover, further refined by size of components (boulder, cobble, gravel) .

Consolidated bottoms include boulder and bedrock habitat types. The areal cover of boulders or bedrock is greater than 75 percent with a vegetative cover of less than 30 percent. The amount of vegetative cover is determined by percent light penetration. Below the photic zone (influenced by turbidity) , all consolidated bottoms are either bedrock or boulder. Within the photic zone if more than 30 percent of the substratum is covered by algae, it is considered an Aquatic Beds habitat. Boulders (termed "rubble" in Cowardin et al, 1979) are defined as anything greater than 25.4 cm. Bedrock is consolidated rock, most commonly granite and sedimentary rock along the California coast. In terms of associated communities the two subclasses are very similar and are discussed together. Subtle differences between the two habitats are related to water movement and will be discussed in the detailed habitat description.

Unconsolidated bottoms include areas with at least 25 percent cover of particles smaller than stones (less than 25.4 cm) and a vegetative cover of less than 30 percent. Habitat types in the unconsolidated bottom classification include: mud, sand, cobble/gravel, and organic habitats. Organic and cobble/gravel habitats are uncommon along the central and northern California coast,

Submerged aquatic beds include habitats with predominantly algae (kelp beds) and vascular plants (Phyllospadix spp.) The kelp beds occur on rock and boulder substratum and are considered the predominant habitat type when more than 30 percent of the substratum is covered with attached plants. Phyllospadix spp. do not occur in the subtidal benthic class in sufficient quantity to be discussed as a specific habitat type, though they are commonly found in intertidal and estuarine zones.

Intertidal unconsolidated sand habitats are characterized by few organic indications of zonal differentiation. The fauna are mostly burrowing forms, and few algal species are able to secure attachment in the shifting substratum. Nevertheless, interstitial algae provide some of the nutrient for the common burrowing polychaete Euzonus, the blood worm. Another common inhabitant of this habitat is the mole crab (Emerita analoga) which varies its location with tidal fluctuation and feeds on suspended materials. Scavengers are also prevalent, primarily the beach hoppers (Orchestoidea spp.). The ecology of the sand beaches depends on nutrient input from outside the habitat. Beaches are subject to loss or addition of materials depending on both natural and human factors and are in constant motion. Sand is classed as particles of from 0.07 millimeters to 5 millimeters in diameter. The coarseness of a particular beach is also dependent on several factors, including wave and current energy source of sediments.

Because active oceanic forces rapidly erode gravel (5 mm to 76 mm) and cobbles (76 mm to 256 mm) of the unconsolidated shore habitat type to sand size, they are relatively uncommon components of California beaches and flats. Also, because of

these active forces and the grinding of gravels and cobbles, there is little established biota on this type of beach. Organisms that are found will include scavengers which use the abundant flotsam and detritus deposited by wave and current action.

In addition to sandy beaches, rocky shores (boulder/bedrock) are the other major components of California coasts. The stability of this habitat type provides substrata suitable for a diverse and prolific array of intertidal forms. Zonation is particularly marked in this habitat, and organisms adapted to the various physical parameters are presented in the zones. Zones are a function of tidal cycles and represent various degrees of exposure to numerous forces and effects of the land-sea interface. Algae become abundant from zone 2, and a wide variety of animals make use of the hard, stable substrata. The most common fauna include Mytilus californianus, Blanus spp., Pisaster spp., and the numerous gastropods. However, representatives of all major and most minor phyla are also represented.

Wood or concrete piers and wharves provide a soft substrata for intertidal and boring organisms. Limnoria and Teredo infest wood, and Adula and Penitella bore into concrete. Attempts to remove these "fouling organisms" have been very expensive. Various types of protective coatings have been tried without complete success.

MAJOR TOPICS DISCUSSED FOR EACH HABITAT TYPE

In a habitat characterization, a number of important topics need to be discussed. Emphasis on topics varies with each habitat. In the Submerged Algal Beds habitat, the most important concept is the high amount of primary productivity produced by the upper story of the kelp bed. In the Unconsolidated habitats, primary productivity is very low and most usable energy drifts down from the higher producing epipelagic zone. Energy flow and trophic structures are consequently diverse and highly characteristic of each of these habitats.

The following outline indicates topics to be addressed in defining, physically and biologically, the parameters which are used to indicate the particular characteristics of a habitat:

- I. Introduction (definition of the habitat being described)
 - A. Substratum type and size
 - B. Areal extent (frequency of occurrence along or off the California coast)
 - C. Dominant species that typify habitat
 - D. Habitat "descriptors" or identifiers other than substratum used to characterize habitat (zonation, physical processes specific to habitat)
- II. Habitat Characterization
 - A. Geographic aspects
 1. Physical size along coast or within specific geographic site (whichever applies)
 2. Natural or man-made factors that define (or limit) spatial area (if applicable)
 3. Other
 - B. Physical aspects
 1. Subtidal
 - a. Substratum type
 - b. Water movement (currents, circulation)
 - c. Dissolved oxygen
 - d. Dissolved salts and nutrients
 - e. Light penetration
 - f. Temperature
 - g. Other
 2. Intertidal
 - a. Substratum
 - b. Vertical and horizontal zonation
 - c. Exposure
 - d. Temperature
 - e. Dissolved oxygen
 - f. Wave shock
 - g. Slope
 - h. Other
 - C. Biological aspects
 1. Dominant species and percent cover in habitat (stress inter-relationships)
 2. Rare, endangered and species of concern occurring in this habitat
 3. Community composition
 - a. First trophic level
 1. Producers
 2. Biomass
 3. Productivity
 4. Transfer rate to second trophic level and scavengers and decomposers

b. Second trophic level

1. Herbivores, omnivores, filter feeders
2. Biomass
3. Productivity
4. Transfer rate to third trophic level and scavengers and decomposes

c. Third trophic level

1. Predators
2. Biomass
3. Productivity
4. Transfer rate to scavengers and decomposes

d. Species important to this habitat but cannot be assigned to one level

4. Community dynamics

- a. Summary of community composition with emphasis on trophic levels
 - b. Use of one or two species in each level as an example to indicate the kinds of interrelationships occurring
 - c. Succession
 - d. Use of 25 to 30 species that compose approximately 90 percent of the community and are representative of the food web dynamics
 - e. Information that stresses "sensitive" areas of species in this habitat. "Sensitive" meaning those species more susceptible to changes in the environment and how alteration or elimination of this species would affect community structure and eventually humans. Also, emphasis should be put on adverse effects to species of concern and particularly sensitive areas in their life histories (refer to species of concern section).
5. Migration and visitation into the habitat and effect on community structure
6. Interactions with neighboring habitats: "grey zones"

111. Human effects on this habitat (general)

- A. Waste discharge, oil pollution, harvesting, temperature pollution, dredged spoils disposal, anything that has a real or potentially adverse effect on marine communities.
1. Particularly sensitive areas in food webs that may drastically alter species composition.
 2. Identification of species that can cause direct harm to humans if contaminated (radionuclide uptake and concentration in edible species, petroleum hydrocarbons, physical and biological effects).

Human effects can be generally discussed for all habitats. The information presented in the literature is sparse in this study area and extrapolating information from different geographic regions can be risky. The effects of current and temperature differences, species ranges, and presence of pollutants in an area can alter species distribution and community composition such that studies completed may be site- or area-specific. Laboratory studies, though valuable as a tool to indicate the processes and mechanisms by which species are controlled through environmental regulation are often difficult to duplicate or verify in the field. Ecological field studies are useful in quantifying species occurrences and abundances to establish the baseline knowledge needed to determine changes and degree of human-induced perturbations. There are a few regions in the study area that have had a number of marine environmental impact studies performed (San Francisco Bay, Monterey Bay, the Gulf of the Farallones). This information is often present in the "grey" literature and is inaccessible to the public. Statewide comprehensive monitoring or field study programs are not currently being undertaken in order to identify and assess the real or potential effects of man-induced stress on the marine ecosystem.

A program has been developed by the California Department of Fish and Game (also recently coordinated with the Environmental Protection Agency) to monitor bioaccumulation of potentially toxic pollutants (Martin, pers. comm.). The concept is to be able to quantitatively determine the amount and effect of pollutants on an indicator

organism, in this case the mussel (Mytilus californianus), along the coast and enclosed bays. This program will be invaluable in quantifying possible effects of pollutants and may be used to supplement ecological observations of changes in marine communities resulting from man-induced perturbations.

PELAGIC HABITAT

This habitat includes the water column from the air-sea interface to the sea bottom or benthos.

GENERAL INTRODUCTION

The pelagic habitat is three-dimensional and constitutes the largest biosphere on earth. The habitat is composed of seawater and consequently provides a relatively unstructured physical environment. The buoyancy and movement of water provides a transport mechanism for small organisms, food materials, reproductive products, and other materials. Only the surface layer receives sufficient light to support plant growth. This lighted layer, or euphotic zone, extends to depths of 150 meters. Solar heating is also restricted to the upper layer. As a result, the pelagic habitat is a two-layered system: most of the habitat is cold and dark with a relatively thin, warm, lighted surface layer. Plant populations in the surface layer provide food (primary production) to support organisms in the surface layer as well as in the deeper pelagic and benthic zones. As a consequence of this, primary productivity cycles are of fundamental importance in determining the nature of biological communities in the pelagic habitat.

Ecological Divisions of the Habitat

The pelagic habitat may be described in terms of a number of ecological zones (Figure 3-3, Table 3-1). The boundary between the neritic and oceanic provinces is approximately the limit of the continental shelf; however, coastal water and coastal populations frequently extend further offshore. The depth of the epipelagic-mesopelagic boundary (Table 3-1) is defined by the euphotic zone. The euphotic zone varies with water transparency and ranges from greater than 100 meters depth in offshore regions to less than five meters in shallow water. The lower limit of the mesopelagic zone used here differs from the traditional division at 100 meters (see Lavenburg and Ebeling, 1967).

Biological Components

The biological components of the pelagic habitat are:

Plankton. (Greek "to drift") Small forms which drift with ocean currents.

Meroplankton. Organisms which spend only a portion of their life cycle in the plankton (e.g., larvae of benthic invertebrates or larval stages of fishes,

holoplankton. Organisms which spend their entire life cycle as plankton (e.g., krill, "arrow worms", salps).

Phytoplankton. ("plant plankton") Primary producers which fix the sun's energy through photosynthesis.

Zooplankton. ("animal plankton") Secondary producers which feed on phytoplankton or other producers.

Nekton. Swimming forms (e.g., cephalopods, fish, and marine mammals).

Plankton include an entire size spectrum of organisms and are frequently referred to as size categories (see Parsons et al, 1977; Table 3-2).

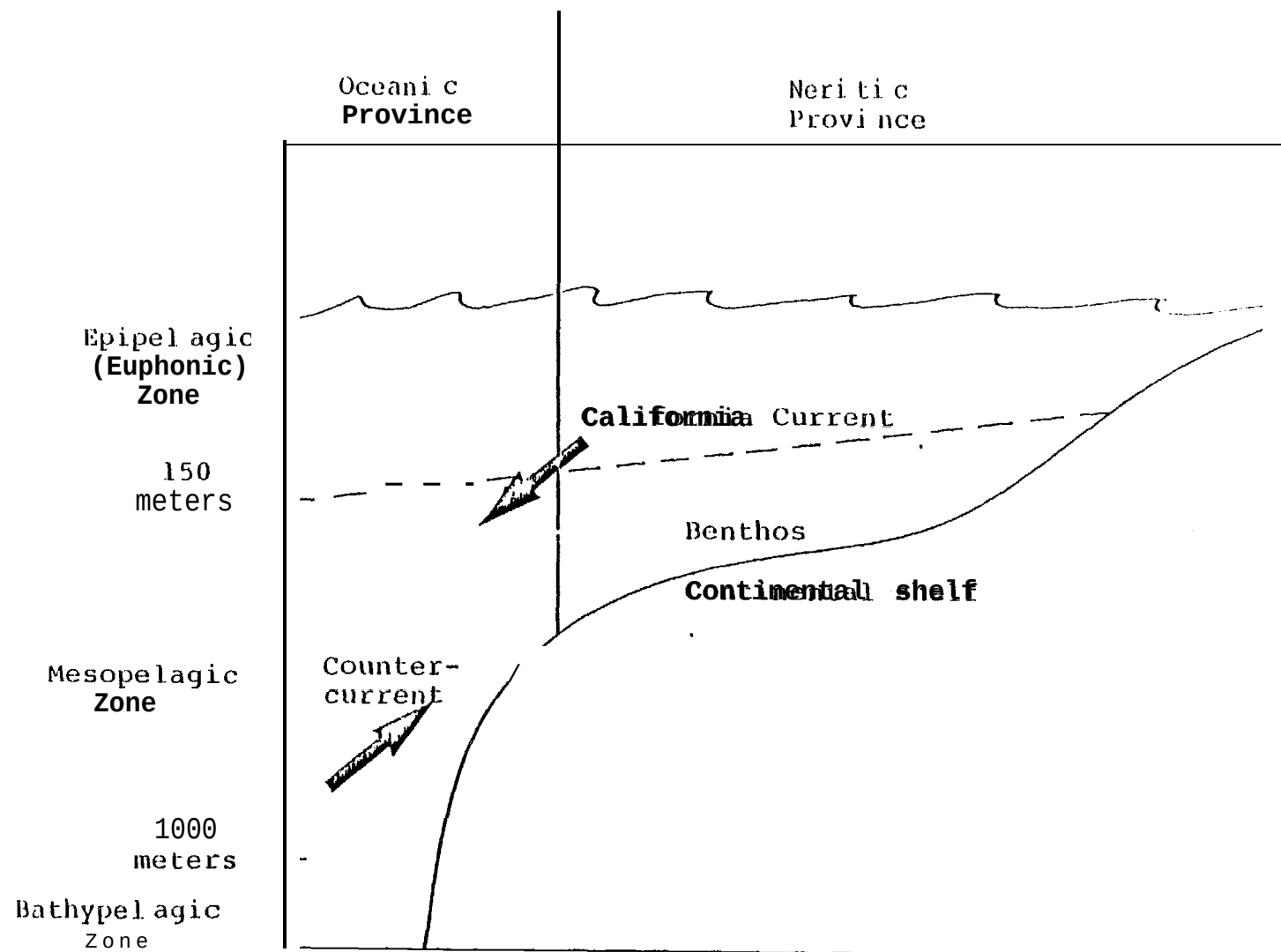


Figure 3-2. Water Current Relationships of the
Oceanic and Neritic Provinces of Central and
Northern California (Modified from Hedgpeth, 1957b)

Table 3-1. The Characteristics of Onshore, Offshore and Vertical Divisions of Ecological Zones or Provinces
(Modified from Hedgpeth, 1957b; Lavenburg and Ebeling, 1967; Parsons et al, 1977)

Onshore and Offshore Divisions		
Province	Boundary	Characteristics
Neritic (Coastal)	Coastline to outer edge of continental shelf (approx. 200 meters)	Strongly influenced by land: freshwater runoff suspended materials nutrients pollutants Tidal and current mixing processes important
Oceanic	Beyond continental shelf	Little influence from land Oceanic processes predominate

Vertical Divisions		
Zone	Approximate Depth Range	Characteristics
Epipelagic (Euphotic)	Surface to approx. 150 meters	Sufficient light to support plant growth Seasonal changes in physical characteristics
Mesopelagic (Disphotic, Midwater)	150 meters to 500 meters	Dimly lighted in upper region Temperatures 6°C to 9°C with little seasonal change
Bathypelagic (Aphotic)	500 meters to 1000 meters	Temperatures less than 6°C No surface light reaches this zone

Table 3-2 . Characteristic Forms and Size Groups of Planktonic Organisms
(Modified from Parsons et al, 1977)

Group	Size	Characteristic Forms
Phytoplankton		
Ultraplankton	<2 μ m	Bacteria
Nannoplankton	2-20 μ m	Microflagellates Small diatoms
Microplankton (netplankton)	20-200 μ m	Dinoflagellates Large diatoms
Zooplankton		
Microzooplankton (macroplankton)	.0.2-2 mm	Radiolarians Foraminifera Ciliates
Macrozooplankton (megaplankton)	>2 mm	Copepods Chaetognaths Amphipods Euphausiids Thaliaceans Pteropods Ctenophores

Geographic Aspects

Areal Extent and Topography. The study area extends between 35° and 42° latitude, from the shore line to the 1000 meter depth contour. The continental shelf break is approximately at the 200 meter (or 100 fathom) depth contour. The areas are divided between continental shelf and continental slope as follows:

Region	Area	
	Square Nautical Miles	Percentage
Total Area	10800	100
Continental Shelf (neritic)	5600	52
Continental Slope (approximately oceanic)	5200	48

Physical Aspects

Currents. The area of study is a neritic region of the California Current system. The California Current is a complex eastern boundary current which receives water from several sources. Upper waters (less than 500 meters deep) derive their characteristics from subarctic and transition zone water masses which make up the southward-flowing California Current. Near shore these characteristics may be markedly altered by freshwater runoff. At depths greater than 500 meters, there is a northward-flowing countercurrent; and at these intermediate depths there is an input from north central Pacific water and Pacific equatorial water. Seasonal coastal upwelling

bringing cold nutrient-rich water to the surface . from depths less than 200 meter s is an important feature of the region (Sverdrup, et al, 1942; Reid et al, 1958) .

Ir. offshore waters the California Current flow is predominately to the south. This southward flow reaches a maximum during the summer when it is reinforced by the northwest wind regime. Nearshore water flow varies seasonally. During the upwelling period, surface waters move offshore and southward. With intermittent upwelling periods there may be alternate onshore and offshore flows. During the winter months the northward flowing countercurrent (which for the rest of the year occurs at depths greater than 500 meters) surfaces between the coast and the southward flowing California Current (Reid et al, 1958; Bolin and Abbott, 1963).

Physical and Chemical Characteristics. Surface water characteristics of this region are determined by the subarctic water mass which forms the California Current and by seasonal modifications clue to upwelling and advective (horizontal transport) processes (Reid et al, 1958). The ranges for various parameters in the surface water follow:

Parameter	Range	Source
Surface temperature	E to 18° C	Oregon State University, 1971
Salinity	32 to >34 ‰	"
NO ₃	0 to >10 μ -M/l	"
PO ₄	1 to >3 μ -M/l	"
SiO ₂	0 to >20 μ -M/l	"
O ₂	usually >6.0 ml/l	"

There are marked seasonal changes in the distribution of chemical (e.g., nutrients, O₂) and physical (e.g., temperature, salinity) parameters in the upper 100 to 200 meters. Throughout the winter months this upper layer is well mixed and parameters are relatively uniform. During the summer months a well defined seasonal thermocline (a depth where temperature changes rapidly) forms near the base of the epipelagic zone (approximately 50 meters) resulting in a marked and rapid change in chemical and physical properties between the epipelagic and mesopelagic zones. Surface characteristics are regionally modified by seasonal coastal upwelling; these effects are more pronounced during the spring and summer months (Smith, J.E., 1968).

Below the surface layer there is little seasonal variation. Temperatures in mid-depths and deep water range from less than 6° C to 9° C. A nutrient maximum (NO₃ greater than 40 μ -M/l) and oxygen minimum (O₂ less than 1 to 2 ml/l) occurs between 600 and 800 meters.

Hydrographic Seasons. Seasonal changes in surface waters are primarily a result of seasonal wind patterns which develop over the north Pacific Ocean. Three distinct seasons or hydrographic periods have been outlined (Skogsberg, 1936; Bolin and Abbott, 1963) :

Hydrographic Period	Approximate Dates	Characteristics
Upwelling	March - August	Low temp (<12° C) High salinity (>33.7 ‰) Low O ₂ (1.5 to 6 ml/l) Shallow thermocline
Oceanic	September - November	High temp (>12 to 18° C) Low salinity (<33.5 ‰) High O ₂ (>6 ml/l) Well developed thermocline
Davidson Current	December - February	Low temp (11 to 12° C) Low salinity (<33.5 ‰) Moderate nutrients Well mixed in upper 100 meters

Seasonal Cycles

Many of the regional or geographic characteristics of pelagic ecosystems are the result of the duration and amplitude of productivity, cycles (Ryther, 1963; Cushing, 1975). Classic examples of contrasting cycles are the productivity cycles in arctic, temperate, and tropical regions (see Figure 3-4).

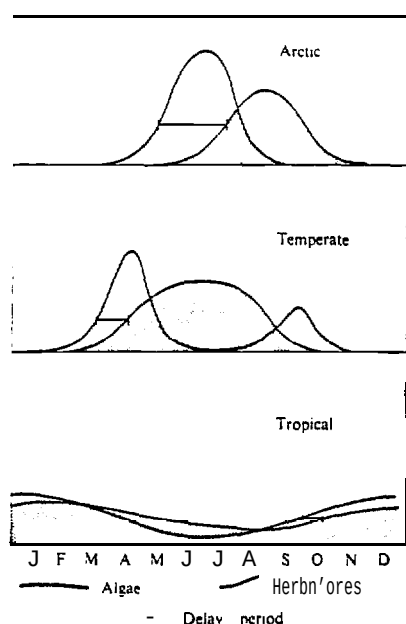


Figure 3-4. Characteristic Productivity Cycles in Arctic, Temperate, and Tropical Regions

In temperate regions, such as the study area, there are spring and fall modes in heating, cooling, and mixing of the upper water column. These seasonal changes in the physical environment are largely responsible for seasonal cycles in biological populations. A summary of physical and biological seasonal events in temperate pelagic regions is presented in Figure 3-5.

Biological Aspects

Biogeographical Characteristics. The study area is part of the California Current region which may be considered an "ecotone" or an area of mixing of biological components from a variety of biotic provinces. Characteristic species in the area are largely derived from subarctic and transition zone provinces. There are a few endemic species and distinct neritic assemblages. Occasionally warm-water species from the central Pacific province and warmer water cosmopolitan species are found in the region.

Community Composition and Dynamics.

Primary Productivity and Phytoplankton Biomass. Too few measurements have been made to adequately characterize the primary production of the area (Winzler and Kelley, 1977a). Primary productivity measurements by Owen (1974) indicated productivity rates of 0.34 to 0.59 g Carbon fixed/meter²/day. Owen's average values extrapolated for the year would be approximately 150 grams carbon fixed/meter²/year.

Ryther (1969) suggests primary productivity levels in coastal waters are approximately 150 grams carbon fixed meter⁻² year⁻¹, and may reach 300 grams carbon fixed meter⁻² year⁻¹ in upwelling regions. Depending on the extent and duration of upwelling in the study region, primary productivity may be higher than the estimate (150 grams carbon meter²/year) derived from Owen's (1974) average values.

Phytoplankton biomass (as indicated by chlorophyll a concentrations) show generally low standing stocks offshore, 15-20 mg chlorophyll a meter⁻³ in the upper 150

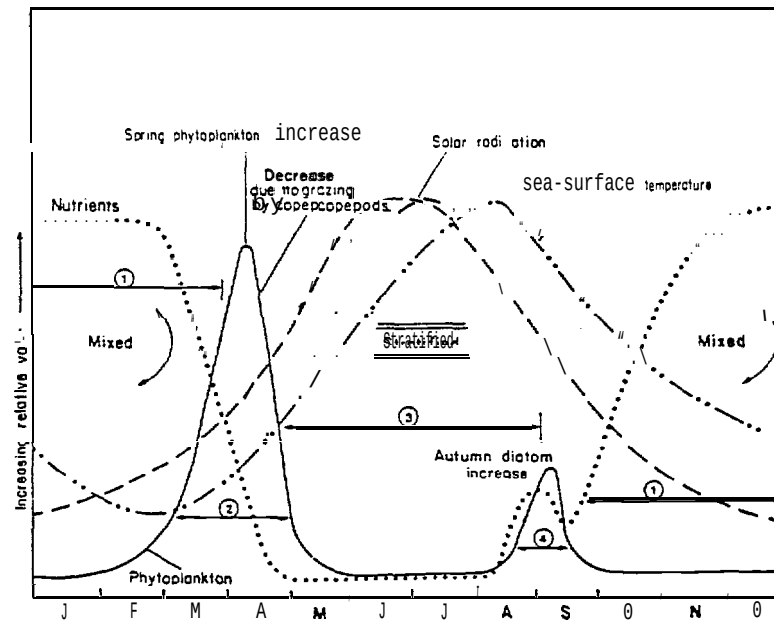


Figure 3-5 . Annual Oceanic Phenomena in a Temperate Pelagic Region

Figure 3-5 Discussion

- (1) Winter Minimum: Solar radiation and sea-surface temperatures are at their seasonal low during this part of the year. The water column is well mixed by storms and wind. Nutrient levels are high in the upper layers as a result of deep mixing. Plant productivity and biomass are low because plants are carried out of the lighted surface zone by mixing.
- (2) Spring Bloom: Increasing solar radiation begins to warm the surface waters, and a stable density layer forms above the seasonal "thermocline" (the depth where temperature changes rapidly). Mixing by storms and winds is less prevalent at this time which allows the stability to persist. Since plants are retained in the lighted surface layer, they increase rapidly. Plant growth (primary production = photosynthesis) is accompanied by uptake of dissolved nutrients. With an increase in plant biomass, nutrient levels in the water column decline. Grazing zooplankton begin to increase with the availability of plant biomass as a food source. Phytoplankton populations reach their highest levels at this time and then begin to decline as a result of nutrient limitation and/or grazing pressure by zooplankton. Spring bloom conditions will be prolonged in regions of upwelling because of the upward transport of nutrients.
- (3) Summer Minimum: Sea surface temperatures reach their maximum for the year. The surface layer is strongly stratified above the "thermocline", and mixing between the upper warm layer and cold lower layers is minimal. Plant growth has depleted nutrients in the upper layers, and plant biomass has declined to a low level because of both nutrient limitation and ingestion by grazers.
- (4) Fall Bloom: Fall storms may result in some mixing of nutrients into the upper water column. Remineralization of nutrients and excretion of nutrients by zooplankton may also be significant sources. The increase in nutrients allows a moderate increase in phytoplankton populations, although grazing pressure may remain high during this period.

meters) increasing to relatively high levels (approximately 300 mg chlorophyll a meter⁻²) nearshore (Owen, 1974). The characteristic size of phytoplankton forms varies seasonally and with distance from shore (Malone, 1971; Garrison, 1976). In general, offshore regions are dominated by nanoplankton (phytoplankton less than 20 µm), and netplankton (greater than 20 µm) dominated populations may be limited to inshore regions during seasonal blooms (Garrison, 1976).

Characteristic Phytoplankton. Phytoplankton copulations in this region are characteristically dominated by diatoms with the dinoflagellates composing a less conspicuous, seasonal component [Garrison, pers. comm.]. Smaller phytoplanktonic forms (nanoplankton) are taxonomically not well known but are often the dominant forms (Malone, 1971). In addition to sources cited in Winzler and Kelly (1977a), species reported by Garrison (pers. comm.) and Schrader (pers. comm.) are as follows:

Diatoms

Asterionella japonica
Biddulphia longicruris
Chaetoceros compressus
Chaetoceros debilis
Chaetoceros diadema
Chaetoceros didymus
Chaetoceros radicans
Chaetoceros socialis
Chaetoceros vanheruchii
Ditylum brightwellii
Eucampia zoodiacus
Nitzschia spp.
Skeletonema costatum
Thalassionema nitzschioides
Thalassiosira spp.

Dinoflagellates

Ceratium pulchellum
Ceratium tripos
Ceratium furca
Ceratium spp.
Dinophysis caudata
Gonyaulax polyedra
Gonyaulax scrippsae
Gymnodinium splendens
Noctiluca scintillans
Peridinium trochoideum
Peridinium spp.
Prorocentrum micans

Silicoflagellates

Dictyocha fibula
Distephanus speculum

Haptophytes

Phaeocystis pouchetti

Redtide Redtides refer to the discoloration of the water produced by high densities of microplankton and are most frequently composed of dinoflagellates. Dinoflagellates are usually of low numerical importance in the area; however, red-tides which occur in the late summer and fall are reported by Silver (pers. comm.), Waidelech (1976), and Garrison (pers. comm.). Species associated with red-tides along the California coast include: Gonyaulax polyedra, Prorocentrum micans, Ceratium furca, C. dens, and several species of Peridinium (Sweeney, 1975). None of the red-tide species in this area appear to be toxic, and the only reported incidence of red-tide associated fish mortality was made by Carlisle (1968). Paralytic shellfish poisoning (PES) does occur in the area as a result of Gonyaulax canteneila, and for this reason, mussels are quarantined during the summer months (Clem, 1975). However, this dinoflagellate species has not been reported to reach red-tide population densities (i.e., its toxins accumulate in mussels, but it does not form conspicuous "red-tides").

Zooplankton Production. Zooplankton biomass estimates are available for several years as a result of the California Cooperative Oceanic Fisheries Investigations program in the California Current (Smith, 1971). This sampling program is limited to the upper 140 meters, and the 505 μ m mesh net used does not adequately sample smaller forms. Representatives of four groups (copepods, thealiaceans, euphausiids, and chaetognaths) compose greater than 75 percent of the samples. Biomass distribution for several groups are presented in Issacs et al. (1971) and Fleminger et al. (1974). There appears to be some seasonality in total zooplankton abundance: for the year 1955 to 1959, summer biomass levels ranged from 60-370 grams/1,000 meters³ (Fleminger et al. 1974) and winter values from 20-90 grams/1,000 meters³ (Issacs et al., 1971). Zooplankton populations are extremely patchy; and it is difficult to generalize about distributions, although Percy (1972) suggests that maximum abundance may occur over the continental slope. Much of the variation in zooplankton populations appears to be a result of large scale advective (current) effects (Wickett, 1967).

Zooplankton populations nearshore, the production biomass, and its distributions of smaller macrozooplankton and microzooplankton are not well known for the study area (Winzler and Kelly, 1977a).

Characteristic Zooplankton.

Microzooplankton. Microzooplankton includes planktonic protozoans and larval stages of several benthic and planktonic invertebrates (Hardy, 1965, chapter 6). Microzooplankton consume small phytoplankton (nanoplankton) and form one of the initial links in food webs. In general this group has not been adequately sampled or examined in the study area, so only characteristic forms have been listed. Larval stages of benthic and pelagic invertebrates have not been included.

PROTOZOA



Radiolaria

Foraminifera : Globigerina spp.

Radiolaria : Acanthometron spp.

Mastigophora : Favella spp.
(ciliates and Mesodinium spp.
tintinids) Tintinopsis spp.

Macrozooplankton. The macrozooplankton of the area include most of the recognized (or known) categories of zooplankton organisms. Some of the groups, for example copepods and euphausiids (krill), are extremely abundant and are important links in marine food webs. Zooplankton components of the region have been summarized in Percy (1972), and Winzler and Kelly (1977a). Specific references for major groups have been cited where there is substantial informational

COELENTERATA [Jellyfish (Medusae) and Siphonophores]

Jellyfish and siphonophores are carnivorous and feed on a wide size range of other zooplankton and small fishes.

Jellyfish (Medusae):



Medusae

Chrysaora fuscresens
Leuckartiara octona
Pelagia coloroto
Aurelia aurita
Eutonia sp.

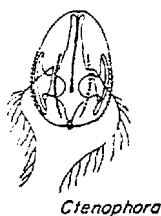
Siphonophores:



Siphonophora

Velella velella
Muggiaea sp.
Nanomia sp.
Gudionoides spiralis

¹ Drawings for these sections (excluding Polychaeta) from: CalCOFI Atlas No. 14, (Issacs et al., 1971).



Ctenophora

CTENOPHORA (Comb Jellies)

Ctenophores are carnivorous. Their abundance is highly seasonal. They consume small zooplankton, fishes or other ctenophores.

Pleurobranchia brachei
Beroe sp.
Leucothea sp.
Bolinopsis sp.

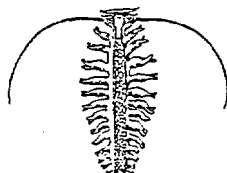


Chaetognatha

CHAETOGNATHA (Arrow Worms, see Alvarino, 1965)

Chaetognaths are extremely abundant and are important active predators in the pelagic environment, feeding on many sizes of zooplankton and fishes.

Sagitta scrippsae
Eukrohina hamata
Krohnita subtilis



ANNELIDA (POLYCHAETA: Segmented worms)

Pelagic worms are carnivores, feeding on a wide range of small zooplankton and fishes.²

Tomopteris pacifica



Cladocera

ARTHROPODA (CRUSTACEA)

Crustacea dominate the zooplankton in abundance and diversity. Only major groups are listed.

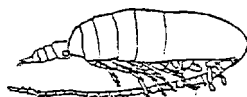
Brachiopoda (Cladocerans)

Cladocerans are small, omnivorous filter feeders that remove small plants and animals from the water.

Evadne sp.
Podon sp.

Copepoda (see Fleming, 1964, 1967)

Copepods are an extremely important group in the pelagic habitat. They are among the most abundant zooplankton forms. Copepods are considered the classic herbivores (phytoplankton grazers, although some species are omnivorous). There are many species in the area; the list is representative, but not exhaustive.



Acartia spp.
Calanus spp.
Eucalanus Spp.
Eucnaeta spp.
Metridia spp.
Pleuromomma spp.
Pseudocalanus spp.
Rhincalanus nastus
Temora discaudata

²Polychaeta drawing from Meglitsch, 1972.

Euphausiacea (Krill, in Brinton 1967a, 1967 b)

Euphausiids are abundant forms and are important links in the food web. They are omnivorous, feeding on phytoplankton and other zooplankton. Many species are known to undertake extensive daily vertical migrations.

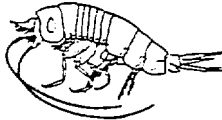


Euphausiacea

Euphausia pacifica
Thysanoessa spinifera
Thysanoessa longipes
Thysanoessa gregaria
Nematoscelis difficilis
Nyctiphanes simplex

Amphipoda

Amphipods are scavengers and are often associated with and feeding on other zooplankton such as jellyfish and salps.



Amphipoda

Parathimisto pacifica
Hypera spp.
'ma sp.
Streetsia challenger

Mysidacea (Mysid shrimp)



Mysidacea

Decapoda (Pelagic Shrimp)

Pelagic shrimp are primarily carnivorous and are known to migrate from mid-depths into the surface waters at night to feed.

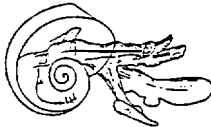


Decapoda

Parisphaea pacifica
Sergestes similis

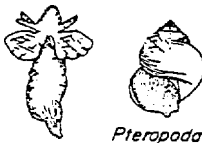
MOLLUSCA (Heteropods and Pteropods)

The heteropods and one group of pteropods (Gymnosomata) are carnivores, and one pteropod group (Thecosomata) are particulate feeders.



Heteropoda

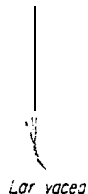
Limacina helicina
Clione spp.
Corolla spectabilis
Atlanta peroni
Carinaria japonica



Pteropoda

CHORDATA (Salps and Larvaceans)

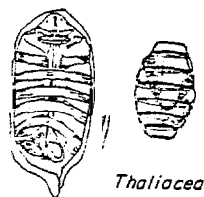
All members of the group are filter feeders and feed primarily on phytoplankton. They are important components of the zooplankton.



Larvacea

Larvacea

Oikopleura spp.



Thaliacea (Salps, in Berner, 1967)

Doliolum sp.
Pyrosoma atlanticum
Cyclosalpa bakeri
Dolioletta aegenbauri
Ritterella picteti
Salpa fusiformis
Thalea democratica
Thetys vagina

Ichthyoplankton. The larvae of most fish species are planktonic. These form the ichthyoplankton ("fish plankton") portion of the zooplankton. The larvae of a large number of fish species occur together in the surface layers of the ocean. These include the young of epipelagic, demersal (bottom living), and mesopelagic adult species (Ahlstrom, 1965, 1969; Richardson and Percy, 1977). In the surface layers these larvae eat small-sized plankton (such as larval copepods) and are preyed upon by larger zooplankton, fish, and cephalopods. The mortality rates of these early life stages are very important in determining recruitment to the adult populations. The following are some of the more abundant fish species represented in the ichthyoplankton in the study area:

Larvae of demersal and epipelagic adult species

<u>Sebastes spp.</u>	Rockfishes
<u>Sebastes jordani</u>	Shortbelly rockfishes
<u>Sebastes paucispinis</u>	Bocaccio
<u>Merluccius productus</u>	Pacific hake
<u>Engraulis mordax</u>	Northern anchovy
<u>Sciaenidae</u>	Croakers
<u>Citharichthys stigmaeus</u>	Speckled sanddab
<u>Citharichthys sordidus</u>	Pacific sanddab
<u>Parophrys vetulus</u>	English sole

Larvae of mesopelagic adult species

<u>Cyclothone signata</u>	Showy bristlemouth
<u>Argyropelecus spp.</u>	Hatchet fishes
<u>Bathylagus milleri</u>	Robust blacksmelt
<u>Bathylagus ochotensis</u>	Popeye blacksmelt
<u>Bathylagus pacificus</u>	Pacific blacksmelt
<u>Leuroglossus stilbius</u>	California smoothtongue
<u>Diaphus theta</u>	California headlightfish
<u>Lampanyctus ritteri</u>	Broadfin lampfish
<u>Protomyctophum crockeri</u>	California flashlightfish
<u>Stenobrachius leucopsaras</u>	Northern lampfish
<u>Tarletonbeania crenularis</u>	Blue lanternfish
<u>Ichthyosoma lockingtoni</u>	Medusafish
<u>Tactostoma macropus</u>	Longfin dragonfish

Nekton.

Fishes. The pelagic fishes are made up of epipelagic (surface dwelling) and mesopelagic (mid-water) species. The epipelagic fishes are typically fast swimming, schooling fishes. Because of their abundance, wide distribution, broad feeding habits, and many predators, various species (e.g., anchovies, hake, saury and herring) are extremely important in complex pelagic food webs. Other less abundant and larger fishes (e.g., blue shark, salmon, albacore, and bonito) are important migrating predators.

The mesopelagic fishes include species which remain at depth (e.g., Cyclothone spp.) and species which undertake nightly vertical migrations to the surface layer to feed (e.g., Stenobrachius leucopsaras, Diaphus theta and Tactostoma macropus). Most of these fishes feed on zooplankton; however, some species (e.g., Chauliodus macouni and Tactostoma macropus) feed on other nekton.

The following list includes some of the common sharks and fishes of the epipelagic zone and some of the more abundant mesopelagic fish species occurring in this area. For more information see Berry and Perkins, 1966; Fitch and Lavenberg, 1968, 1971; Frey, 1971; Miller and Lea, 1972; Percy, 1972; Mais, 1974; and Welsh, 1977.

Epipelagic Species

<u>Prionace glauca</u>	Blue shark
<u>Cetorhinus maximus</u>	Basking shark
<u>Alpias vulpinus</u>	Common thresher shark
<u>Galeorhinus zyopterus</u>	Soup fin shark
<u>Engraulis mordax</u>	Northern anchovy
<u>Merluccius productus</u>	Pacific hake
<u>Clupea harengus pallasii</u>	Pacific herring
<u>Cololabis saira</u>	Pacific saury
<u>Trachurus symmetricus</u>	Jack mackerel
<u>Thunnus alalunga</u>	Albacore tuna
<u>Sarda chiliensis</u>	Pacific bonito
<u>Sardinops sagax</u>	Pacific sardine
<u>Atherinopsis californiensis</u>	Jacksmelt
<u>Morone saxatilis</u>	Striped bass
<u>Oncorhynchus tshawytscha</u>	King salmon
<u>Oncorhynchus kisutch</u>	Silver salmon
<u>Mola mola</u>	Ocean sunfish

Mesopelagic Species

<u>Leuroglossus stilbius</u>	California smoothtongue
<u>Cyclothone acclinidens</u>	Benttooth bristlemouth
<u>Cyclothone signata</u>	Showy bristlemouth
<u>Chauliodus macouni</u>	Pacific viperfish
<u>Tactostoma macropus</u>	Longfin dragonfish
<u>Stenobrachius leucopsaras</u>	Northern lampfish
<u>Diaphus theta</u>	California headlightfish
<u>Tarletonbeania crenularis</u>	Blue lanternfish
<u>Symolophorus californiensis</u>	California lanternfish

Cephalopods. Squids are important and abundant pelagic predators on zooplankton, fish, and other squid. In turn squids are very important forage organisms for marine fishes, sea birds and marine mammals. Twenty-three species of squid have been identified from the study area, but little is known of all but one (Loligo opalescens; Recksiek and Frey, 1978a). The following five species are found most frequently in this area (see Pearcy, 1965; Okutani and McGowan, 1969; Laevastu and Fiscus, 1978).

<u>Loligo opalescens</u>
<u>Abraliopsis felis</u>
<u>Gonatus fabricii</u>
<u>Onychoteuthis boreali japonicus</u>
<u>Chiroteuthis veranyi</u>

Marine Mammals. A variety of seals, sea lions, whales and porpoises frequent the pelagic habitat in northern and central California. These are listed below. Except for the baleen whales, these organisms primarily live on fish and cephalopods; the baleen whales filter feed zooplankton, consuming copepods, euphausiids and other crustacea as well as squid and fish. The killer whale is a top carnivore, ingesting sea lions, seals, porpoises, and sharks as well as cephalopods and fishes (Daugherty, 1965; Morejohn, 1977). Table 3-3 indicates the common species with peak abundance periods.

Table 3- 3 . Peak Abundances and Habits of Marine Mammals of Central and Northern California (Taken from Volume II, Part 2: Species)

Species Name	Common Name	Peak Abundance (R = resident)	Remarks
Seals and Sea Lions			
<u>Eumetopias lunatus</u>	Stellar sea lion	R; May-Aug. peak	Mating on offshore rocks and islands
<u>Zalophus californianus</u>	California sea lion	R; Sept.-June peak	Migrate south to mate June-Aug.
<u>Callorhinus ursinus</u>	Alaska (north ern) fur seal	R; Nov.-March peak	San Miguel breeding colony feeding females and juveniles onshore

Table 3-3 (contd.)

Species Name	Common Name	Peak Abundance (R = resident)	Remarks
Seals and Sea Lions (contd.)			
<u>Arctocephalus townsendi</u>	Guadalupe fur seal		Range is from Baja California to Channel Islands
Whales and Porpoises			
<u>Ziphius cavirostris</u>	Culvier's beaked whale	R	Offshore
<u>Berardius bairdi</u>	Baird's beaked whale		Offshore
<u>Physeter catodon</u>	Sperm whale	Apr. -June Aug. -Nov. Peak mid-May and mid-Sept.	Feeding migrations sea mounts.
<u>Kogia breviceps</u>	P igmy sperm		
<u>Delphinus delphis</u>	Common dolphin	Dec. -Ott .	Far offshore
<u>Grampus griseus</u>	Risso's dolphin		In southern California fall-winter
<u>Lagenorhynchus obliquidens</u>	Pacific striped dolphin	Winter	California Current
<u>Orcinus orca</u>	Killer whale	Year round, sporadic	
<u>Pseudorca crassidens</u>	False killer whale	Probable R	
<u>Globicephalus macrorhynchus</u>	North Pacific (short-fin) pilot whale	Winter R	Southern California bight
<u>Phocaena phocoena</u>	Harbor porpoise	Year round	Close inshore
<u>Phocoenoides dalli</u>	Dan's porpoise	Year round; largest winter	
<u>Lissodelphis borealis</u>	Right-whale dolphin	R; winter	Resides central coast, inshore winter
<u>Eschrichtius robustus</u>	Gray whale	Dec. -Jan. Feb. -March	Non-feeding migration to and away from calving grounds
<u>Balaenoptera musculus</u>	Blue whale	Fall and summer	Migrating
<u>Balaenoptera physalus</u>	Fin whale	May-Sept.	Migrating
<u>Balaenoptera borealis</u>	Sei whale	Winter and summer	Southern California, northern and central California

Table 3-3 (contd.)

Species Name	Common Name	Peak Abundance (R = resident)	Remarks
Whales and Porpoises (contd.)			
<u>Balaenoptera acutorostrata</u>	Minke whale	Winter and summer	Migrating
<u>Megaptera novaeangliae</u>	Humpback whale	Fall and spring	Migrating
<u>Balaena glacialis</u>	Northern right whale	Winter	

Birds. Occurrence and abundance of pelagic and nearshore birds in the study area are indicated in Table 3-4.

Table 3-4. Pelagic and Nearshore Birds of Central and Northern California (CNACC, 1975; Stallcup, 1976; Page et al., 1977; Varoujean, 1979).

Species Name	Common Name	Peak Abundance	Remarks
<u>Gavia arctica</u>	Arctic loon	Mid-Oct.-May	Winter offshore
<u>Gavia stellata</u>	Red-throated loon	Nov.-March	Winter inshore
<u>Gavia immer</u>	Common loon	Nov.-Apr.	Winter inshore
<u>Aechmophorus occidentalis</u>	Western grebe	Sept.-Apr.	Winter inshore
<u>Phalacrocorax penicillatus</u>	Brandt's cormorant	Late summer-early winter	Breeds inshore
<u>Pelecanus occidentalis</u>	Brown pelican	July-Jan.	Fall and winter inshore; post-breeding migrant from off southern California
<u>Puffinus griseus</u>	Sooty-tailed shearwater	July-Jan.	Ubiquitous offshore
<u>Puffinus creatopus</u>	Pink-footed shearwater	July-Nov. Jan.-Feb.	Oceanic
<u>Oceanodroma homochroa</u>	Ashy storm-petrel	Sept.-Ott.	Breeds on offshore rocks Feb.-July
<u>Oceanodroma melania</u>	Black storm-petrel	Sept.-Ott.	Autumn visitor; post-breeding from "Mexico"
<u>Fulmaris glacialis</u>	Northern fulmar	June (Dec. -March)	Numbers vary greatly year to year
<u>Melanitta deglandi</u>	White-winged scoter	Nov. -Apr.	Inshore - erratic in occurrence
<u>Melanitta perspicillata</u>	Surf scoter	Late Oct.-Apr.	Inshore
<u>Branta nigricollis</u>	(Black) Brant	Late Feb.-May	Common locally in winter

Table 3-4 (contd.)

Species Name	Common Name	Peak Abundance	Remarks
<u>Phalaropus</u> <u>fulicarius</u>	Red phalarope	Mid-Apr.- mid June Late Sept.- early Nov.	Offshore migrant, but in some years, many appear inshore
<u>Lopipes</u> <u>lobatus</u>	Northern phalarope	Late Apr.- mid-May	Spring and fall migrant
<u>Stercorarius</u> <u>pomarinus</u>	Pomarine jaeger	Mid-Sept.- Nov.	Oceanic, casual north of Sonoma County
<u>Stercorarius</u> <u>parasiticus</u>	Parasitic jaeger	Mid-Aug.- mid-Ott.	Inshore
<u>Larus</u> <u>heermanni</u>	Heermann's gull	June-March	Northward post-breeding migrant from Mexico
<u>Larus</u> <u>canus</u>	Mew gull	Oct.-March	Winter resident
<u>Larus</u> <u>glaucescens</u>	Glaucous-winged gull	Oct.-March	Winter resident
<u>Larus</u> <u>occidentalis</u>	Western gull	Entire year	Breeding on coastal rocks
<u>Larus</u> <u>argentatus</u>	Herring gull	Winter: mid-Ott.-mid-Apr.	Most common offshore
<u>Larus</u> <u>californicus</u>	California gull	Aug.-May	Year round resident; nests inland (Mono Lake)
<u>Larus</u> <u>philadelphia</u>	Bonaparte's gull	Mid-March- late May Sept.-mid-Nov.	Winter resident; but more abundant migrant
<u>Rissa</u> <u>tridactyla</u>	Black-legged kittiwake	Sept.-May	Numbers vary year to year
<u>Sterna</u> <u>paradisaea</u>	Arctic tern	May Mid-Aug.-Ott.	Spring-fall, migrant offshore
<u>Sterna</u> <u>hirundo</u>	Common tern	Mid-Apr.-mid-May Mid-Aug.-mid-Ott.	Spring-fall, migrant offshore
<u>Sterna</u> <u>forsteri</u>	Forster's tern	March-Oct.	Summer breeder; inshore in numbers all year
<u>Sterna</u> <u>-</u>	Caspian tern	Apr.-Nov.	Summer breeder; locally common and inshore
<u>Sterna elegans</u>	Elegant tern	Aug.-Sept.	Summer visitor from Mexico inshore
<u>Cerorhinca</u> <u>monocerata</u>	Rhinoceros auklet	Sept.-May	Winter resident; rare breeder offshore rocks
<u>Ptycoramphus</u> <u>aleuticus</u>	Cassin's auklet	Resident all year	Abundant breeder on offshore islands
<u>Uria</u> <u>aalge</u>	Common murre	July-May resident	Abundant breeder on offshore rocks and islands

Trophic Relationships. Energy flow in the pelagic environment from primary producers (e.g., phytoplankton) through consumers (e.g., zooplankton and fish) and ultimately to decomposers (e.g., bacteria and fungi) goes through a complex network known as a food web (Figure 3-6). Food webs in the pelagic environment are complex and are not at all well known.

A conceptual simplification, which aids the identification of energy and material flow, has been developed to consider the characteristic number of steps (trophic links) in a food web from producers through consumers (Ryther, 1969). Steps in a food web are determined by the size of available food, and the characteristic number of steps may be primarily determined by the characteristic size of primary producers. Because the characteristic size of primary producers is different in oceanic, coastal, and upwelling areas, there are fundamental differences in the food webs in these regions (Table 3-5).

Table 3- 5. Food Webs in Oceanic, Nearshore anti Upwelling Areas
(After Ryther, 1969; Parsons et al, 1977)

<u>Oceanic Region</u>			
Nanoplankton (small flagellates)	-	Microzooplankton (Herbivorous protozoa)	Macrozooplankton (Carnivorous crustacean zooplankton)
Megazooplankton (e.g. Chaetognaths & euphausiids)		Planktivores (e.g. lantern fish & saury)	Piscivores (e.g. squid, salmon & tuna)
<u>Coastal Region (Nearshore)</u>			
Microphytoplankton (large diatoms & dinoflagellates)	(pelagic)	Microzooplankton (herbivores zooplankton)	Planktivores (e.g. herring)
and	or		
Nanoplankton	(benthic)	Benthic herbivores (e.g. clams, oysters, & polychaetes)	Benthic carnivores - (e.g. cod)
	→	Piscivores (e.g. salmon & dogfish)	
<u>Upwelled Region</u>			
Macrophytoplankton (large diatoms and dinoflagellates including chain forming species)	→	Planktivores (e.g. anchovy)	
	or		
	→	Megazooplankton - (e.g. <u>Euphausia superba</u>)	Planktivores (e.g. whales)

Food Webs. Pelagic food webs tend to be complex and are difficult to specify. Feeding relationships may change as a result of seasonal changes in food availability (Figure 3-7) or as a result of the life stage of an organism (Figure 3-8). Characteristic food webs which have been identified for the area are shown in Figures 3-7, 8, and 9. Food webs in coastal and upwelling regions are characterized by larger primary producers and shorter food webs. As a result, fish harvests in these areas are considerably larger than in oceanic regions (Table 3-6) .

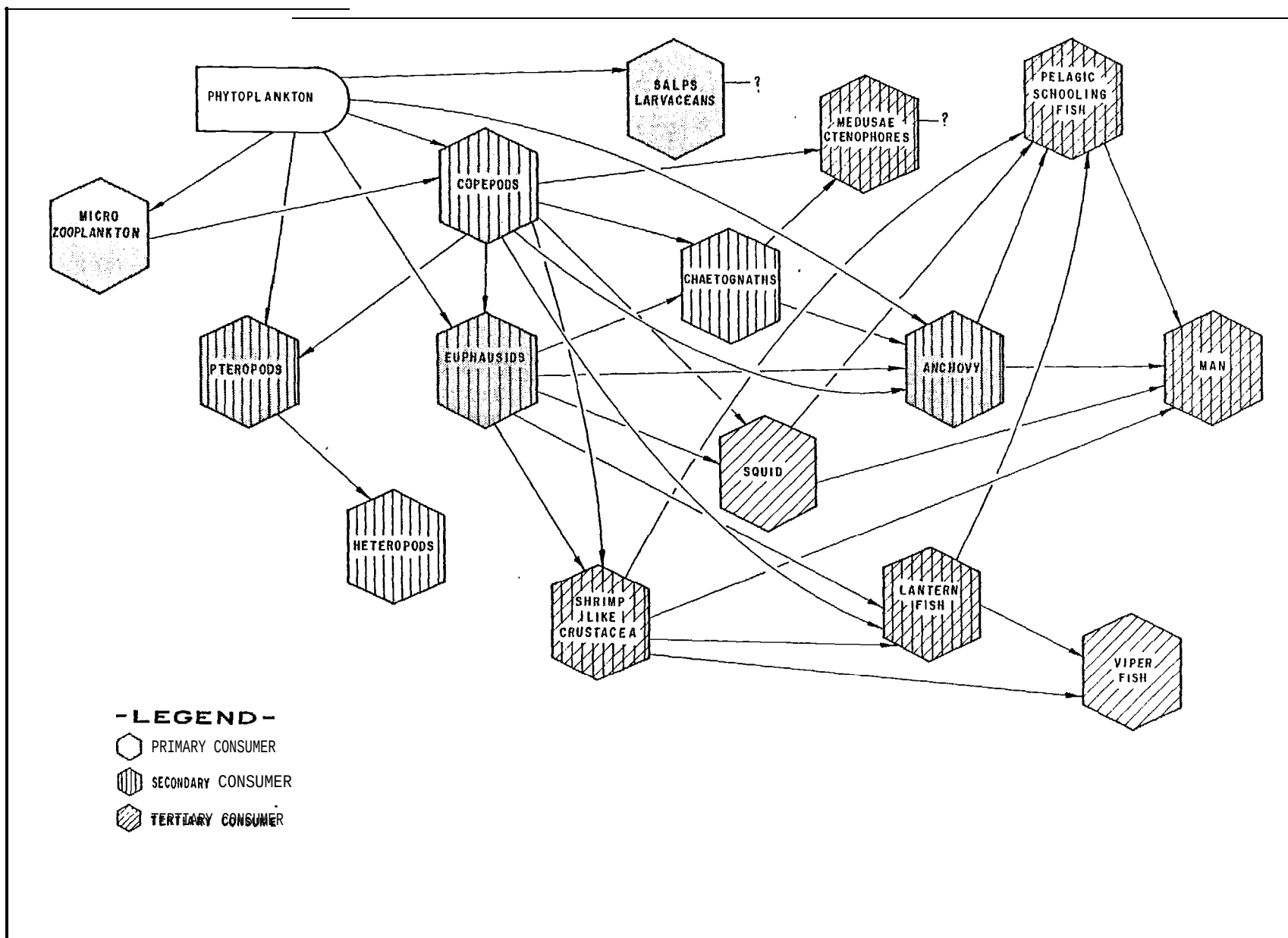


Figure 3-6. Pelagic Habitat General Food Web Model

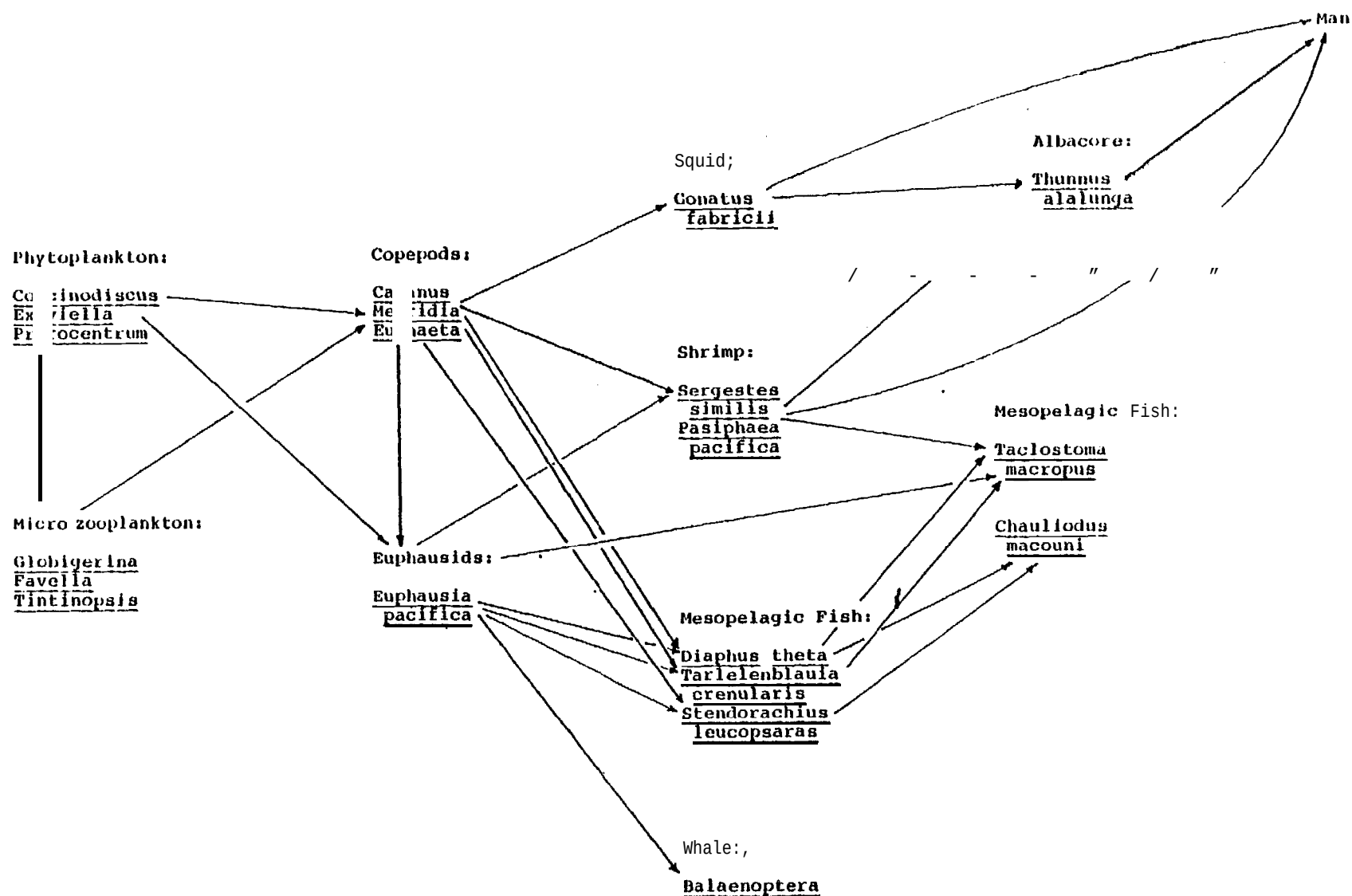


Figure 3-7. Simplified Example of Food Web Including Mesopelagic and Epipelagic Fishes
(Adapted from Percy, 1972)

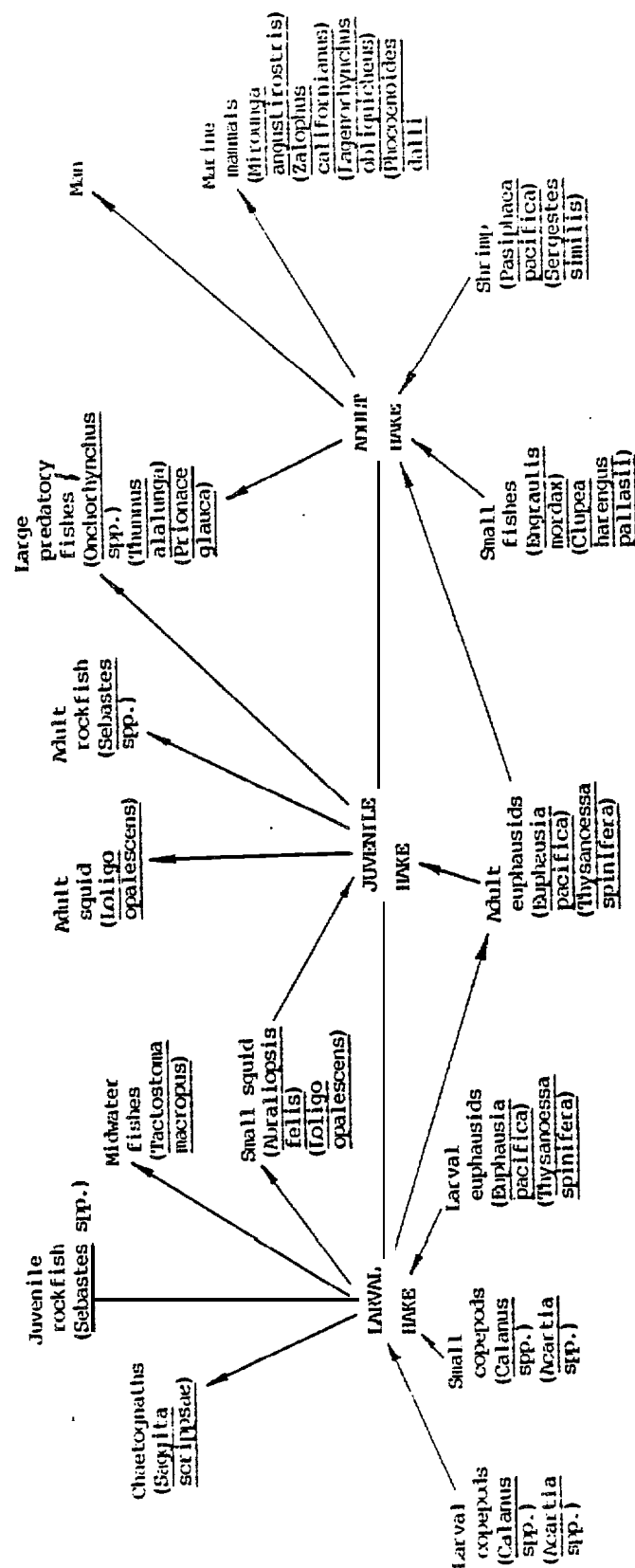


Figure 3-8. An Example of the Change in Predator and Prey Relations of the Pacific Hake (Merluccius productus) During Its Development from Larval to Adult Stages

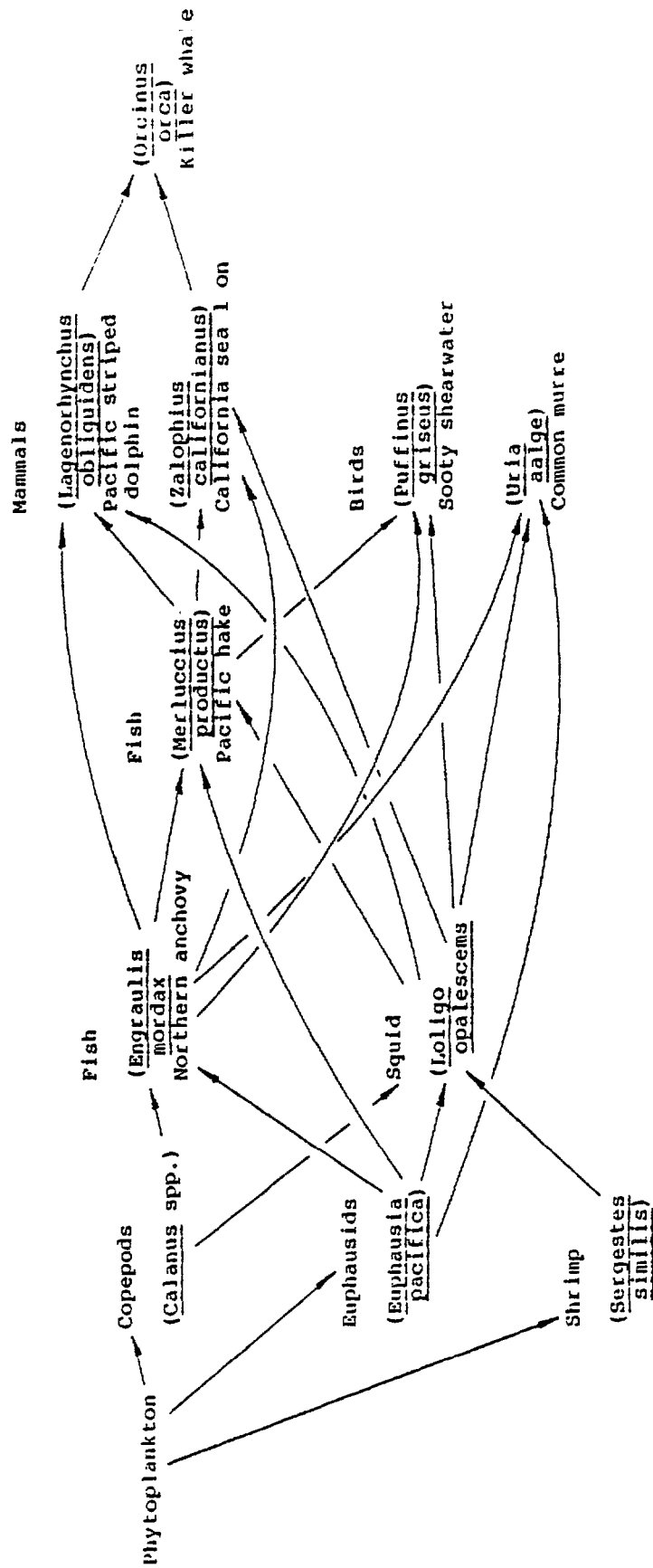


Figure 3-9. Simplified Food Webs of Pelagic Cephalopods, Mammals, and Birds

Table 3-6. Productivity, Trophic Levels, and Fish Production in Three Ocean Communities

Marine environment	Mean primary productivity (g C/m ² /yr)	Number of Trophic levels	Fish production mg C/m ² /yr
Oceanic	50	5	0.5
Continental shelf	100	3	340
Upwelled region	300	1.5	36000

Succession. Succession in the pelagic habitat is associated with progressive, seasonally related changes in the species composition of phytoplankton and zooplankton populations. In temperate regions, succession begins in the early spring following winter minima of phytoplankton biomass and productivity.

Succession begins at a time when the water column is well-mixed and nutrient rich, and may continue into the summer until the water column has become stratified and stable with a nutrient depleted surface layer. Succession may be reinitiated at any point by mixing events which restore nutrients in the surface waters.

During the early stages of succession, phytoplankton populations reach high densities which characterize a "spring-bloom." The increase in available food permits an increase in phytoplankton-grazing (herbivorous) zooplankton. Changes in the physical environment, nutrient levels, and increased zooplankton grazing are all thought to be responsible for the observed changes in phytoplankton species compositions. A general successional model for planktonic populations has been proposed by Margalef (1967).

Migration and Visitation. Many pelagic organisms change their distributions within the pelagic habitat through seasonal, daily or occasional migrations. Migrations may also take place between habitats (e.g., from benthic habitats to the pelagic habitat). Larger pelagic organisms such as marine mammals, schooling pelagic fishes, and marine birds are known to undertake extensive geographic migrations.

Seasonal migrations include changes in onshore-offshore distributions and changes in latitudinal distribution. Organisms may also change their distributions as a function of developmental stage (ontogenetic migration). Ontogenetic migrations can involve changes in onshore-offshore distribution and/or changes in depth distributions. For example, the larval forms of many rockfish species, which as adults live in shallow neritic areas, are abundant in the plankton in offshore areas. Midwater fishes are another classic example of ontogenetic migration: larval stages, which are found in the epipelagic zone, migrate to mesopelagic regions as adults.

Daily vertical migrations are well known for a number of pelagic organisms. The general pattern is for organisms to move toward the surface waters at night and to return to depths during the day. A wide variety of organisms including copepods, euphausiids, cephalopods, and lantern-fish (myctophids) make diel vertical migrations. The actual changes in depth range from tens to hundreds of meters, depending on the organism involved.

The environmental cue for migration appears to be light; however, the entire phenomenon of vertical migration is not completely understood (see Hardy, 1965, chapter 11). Vertical migrators are important in pelagic food webs and increase the rate of transport of energy from the surface to the deeper layers.

Migrations of primarily benthic invertebrates and demersal (bottom-associated) fishes into the pelagic habitat to feed or spawn are also known to occur.

Large scale migrations of marine mammals and birds may involve geographically extensive (i.e., transoceanic or from sub-polar to sub-tropical latitude) changes in distribution. Often these are feeding migrations, and the organisms have important predator roles in local food webs.

Vertical Migration. Vertical migration is a characteristic feature of many zooplankton and fishes, and the importance of vertical migration in relation to food webs has previously been presented (see General Introduction). A partial list of abundant species in the study area that are known to make vertical migrations is presented in Table 3-7.

Table 3-7. A Partial List of Vertically Migratory Species
(Winzler and Kelly, 1977a and other sources)

Fishes (Pearcy, 1972)

Stenobranchius leucopsarus (Northern lampfish)
Diaphus theta (California headlightfish)
Tarletonbeania crenularis (Blue lanternfish)
Tactostoma macropus (Longfin dragonfish)

Invertebrates

Euphausiids (Brinton, 1967a; 1973)

Euphausia pacifica
Thyssonessa spinifera
T. longipes
Nematoscellis difficilis
Nyctiphanes simplex

Copepods

Calanus spp.
Pleuromamma spp.

Salps

Salpa fusiformis

Decapods

Sergestes similis
Pandalus 3 ordani
 (benthic to pelagic migration)

Seasonal Migrations. Various species of pelagic fishes, marine birds, and mammals do not remain in the study area through the year, but seasonally occur either for reproductive purposes or in response to increased prey densities. These seasonal visitors are listed in Table 3-8. Many of the migrating organisms are active predators and have an impact on pelagic food webs when they are present in abundance.

Table 3-3 . Seasonal Abundances of Migrating Fish in Central
ant? Northern California (Frey, 1971; Mais, 1974; Dewitt and
Walsh, 1977)

Species Name	Common Name	Peak Abundance in Pelagic Zone	Remarks
<u>Merluccius</u> <u>productus</u>	Pacific hake Adults : Larvae:	Apr. -Dec. Feb.-Apr.	Southward spawning migration in winter; absent Dec.-March
<u>Clupea</u> <u>harengus</u>	Pacific herring Adults : Larvae:	Summer Not present	Spawning migration to bays and estuaries fall-spring
<u>Cololabis</u> <u>saira</u>	Pacific saury Adults : Larvae:	Year round Feb.-July	Northward ontogenetic migration occurs during the summer months in response to increasing sea surface temperatures.
<u>Trachurus</u> <u>symmetricus</u>	Jack mackerel Adults : Larvae:	Summer Not present	Uncommon in the study area. Occurs principally during warm water years.
<u>Thunnus</u> <u>alalunga</u>	Albacore Adults : Larvae:	July-Oct. Not present	Consists primarily of two-year- olds migrating northward on transpacific migrations.
<u>Sarda</u> <u>chiliensis</u>	Pacific bonito Adults : Larvae:	Summer Not present	Uncommon in the study area. Occurs principally during warm water years.
<u>Sardinops</u> <u>sagax</u>	Pacific sardine Adults : Larvae:	Summer-fall Not present	Once very abundant in the study area, now only occurs occasion- ally.
<u>Atherinopsis</u> <u>californiensis</u>	Jacksmelt Adults : Larvae:	Throughout year Not present	Move inshore in the summer to spawn in shallow water areas including bays and estuaries.
<u>Morone</u> <u>saxatilis</u>	Striped bass	May-Aug.	Anadromous fish.

Table 3-8 (contd.)

Species Name	Common Name	Peak Abundance in Pelagic Zone	Remarks
<u>Onchorhynchus</u> <u>tsnawytscna</u>	King salmon Adults:	Year round	Anadromous fish -- year round spawning
<u>Oncorhynchus</u> <u>kisutch</u>	Silver salmon	Apr.-Aug .	Anadromous upstream spawning migration Sept. to March
<u>Mola mola</u>	Ocean sunfish	Summer	
<u>Prionace</u> <u>glauca</u>	Blue shark	Summer (June-Oct.)	Females predominate
<u>Cetorhinus</u> <u>maximus</u>	Basking shark	Fall-spring	
Cephalopods			
<u>Loligo</u> <u>opalescens</u>	Market squid	Year round (Apr.-Nov.)	Spawning at inshore sites Apr. -Nov.

EFFECTS OF HUMAN ACTIVITIES

Human activities which affect the pelagic environment include such activities as commercial and sport fishing. For these activities, management policies are necessary to ensure that populations are not excessively exploited.

There is also concern about human activities which introduce potentially detrimental substances (pollutants) into the pelagic environment. Pollutants may be categorized by their actions as aesthetically displeasing, ectomorphic (environment altering), and toxic (Williams, 1979). Toxic pollutants are the more serious pollutants, and there is considerable concern regarding toxins which enter, or are accumulated in, marine organisms that are harvested for human consumption.

Pollutants which are of concern in the region of study include petroleum, chlorinated hydrocarbons, heavy metals, sewage and industrial wastes, dredge spoils, radioactivity, and heat. Some of the potential effects of pollutants in the region are summarized by Winzler and Kelly (1977b). Other general references which may be useful include Hood (1971), Revelle and Revelle (1974), Bernhard and Zattera (1975), National Academy of Sciences (1975), Clark (1977), and Williams (1979). The following narrative is intended to provide an overview and should not be considered a definitive review of pollution problems in the region.

The Effects of Pollutants

The effect of pollutants in the pelagic environment may be difficult to assess. For example, toxic pollutants in sufficient concentrations may show acute effects such as immediate mortality, and the interpretation is reasonably clear. However, toxic pollutants are more frequently found at low concentrations, and there may be effects of chronic exposure to low concentrations that may not be immediately

apparent. There may also be synergistic effects of toxins and natural pathogens. For example, the chronic effects of exposure to pollutants may reduce an organism's capacity to resist diseases, escape predators, or successfully reproduce.

It is also easier to identify effects on individual organisms or populations than to assess the effect on the entire biological system. For example, several toxins have been shown to reduce photosynthetic capacity in phytoplankton and some are toxic to certain phytoplankton forms. Greve and Parsons (1977) cite studies showing that some pollutants selectively eliminate diatoms resulting in phytoplankton populations dominated by small flagellates. These authors suggest that changes in the characteristic size of primary producers have the potential to alter the structure of entire food webs.

Many pollutants are known to be accumulated as a result of materials passing through food webs. The predictability of bioaccumulation appears to be dependent on having a structured food web (Young and Mearns, 1978). Pelagic carnivores, such as schooling fishes and marine mammals, are on terminal ends of pelagic food webs and bioaccumulation is expected and has been demonstrated. However, bioaccumulation at intermediate steps in marine food webs has not been consistently demonstrated (Knauer and Martin, 1972). Finally, some compounds such as mercury enter the marine environment through natural biogeochemical processes and their accumulation in biological populations cannot entirely be attributed to human activities.

Some Important Marine Pollutants

Petroleum. Petroleum enters the pelagic environment from biogenic sources, from oil seepages, through activities associated with the production and transport of oil, and through waste disposal. Petroleum compounds are toxic, and the extent of toxicity depends on the constituent compounds. Toxic effects have been demonstrated for several pelagic organisms including phytoplankton, zooplankton, and fishes. Heavy metals are added to the environment along with petroleum compounds, and detergents and dispersants which are used to emulsify oil spills may be more toxic than the petroleum alone. Marine birds, which become covered with oil at the sea-surface interface, are the most visibly affected pelagic organisms. Reviews in Winzler and Kelly (1977a) are particularly addressed to problems associated with petroleum pollution.

Chlorinated Hydrocarbons (see Risebrough et al, 1970). Chlorinated hydrocarbons of importance in the pelagic environment include DDT compounds and PCB's (polychlorinated biphenyls). DDT is a pesticide; PCB's are widely used as industrial compounds. Chlorinated hydrocarbons reach the marine environment through atmospheric transport, runoff, and sewage waste disposal. DDT compounds and PCB's affect photosynthesis and phytoplankton populations (Winzler and Kelly, 1977a) and a variety of other organisms depending on their sensitivity (Lincer, 1977).

Chlorinated hydrocarbons are passed through food webs and high concentrations are found in piscivorous fishes, fish-eating birds, and marine mammals. The reproductive failure of brown pelican populations in the Channel Islands of California in 1969 has been associated with increases in concentrations of DDT compounds in these populations (Risebrough et al, 1970). Premature parturition in California sea lions has also been associated with increased body concentrations of DDT and PCB compounds, although heavy metal imbalances and diseases may have also been contributing factors (Gil-martin et al, 1976; Martin et al, 1976).

Heavy Metals. Heavy metals include elements such as mercury, lead, cadmium, copper, zinc, chromium, and silver. Some heavy metals enter the marine environment through natural biogeochemical processes; however, the rates of input and the pathways have been altered by human activity. Heavy metals reach the marine environment along with petroleum and through atmospheric transport, runoff, sewage and waste disposal, and dumping of dredge spoils.

Toxic effects of heavy metals on phytoplankton (Bernhard and Zattera, 1975; Winzler and Kelly, 1977a) and a variety of other organisms have been reported (e.g., Merlini, 1971; Patterson, 1971; Martin et al, 1976; Lincer, 1977). Heavy metals are accumulated by organisms, but accumulation of heavy metals in pelagic food webs is uncertain (Knauer and Martin, 1972), i.e., mercury does not appear to accumulate in planktonic food webs in the area.

Sewage and Industrial Wastes. Domestic and industrial wastes are collected and discharged as municipal sewage effluents. The constituents of sewage effluent can vary tremendously, depending on the type of waste and on the level of treatment the effluent receives before it is discharged into the environment. Considerable quantities of heavy metals, chlorinated hydrocarbons, and other toxins may be released with sewage effluent. Other constituents of municipal waste discharges include inorganic nutrients and particulate organic material. Nutrients added to the environment may stimulate increased plant production if plant populations are nutrient limited. However, chlorine, which is added to reduce pathogens, may inhibit photosynthesis; and turbidity increases as a result of suspended particles may reduce light penetration, which may also limit plant production. Particulate organic material will eventually be decomposed by bacteria with removal of oxygen from the water and further release of nutrients.

Dredge Spoil Sediments. Sediments from dredging operations are frequently dumped in the pelagic habitat. The impact of dumping dredge spoils is heaviest on the benthic community where sediment settles. Dredge spoil sediments, particularly if they are from estuaries and harbors, have high concentrations of heavy metals, chlorinated hydrocarbons, and organic materials. These substances can be released when sediments are discharged. There is also turbidity from the discharge, and this may limit light penetration and phytoplankton production.

Radioactivity (Rice and Wolfe, 1971). Natural sources of radiation enter the ocean as a result of isotope formation in the upper atmosphere and from geochemical leaching of radioactive elements. Radioactive substances which are presently being added to the pelagic environment by human activity are largely the result of nuclear power generation and the operation of nuclear reactors. The Hanford Plant in Washington state is the only nuclear reactor (not nuclear power generator) that discharges into the California Current system (via the Columbia River). In the routine operation of nuclear plants, low levels of radioactivity are routinely discharged. Gases such as krypton are released into the atmosphere and will eventually enter the ocean as dissolved gases. Low level radioactive substances are leaked into cooling waters or are formed in the cooling water by neutron activation. Most of these products are recovered, but some of the products (primarily tritium) cannot be completely removed and are released into the receiving waters. Because of flocculation and precipitation processes, most of the radioactive materials probably remain in the coastal zone. Radioactive elements can be accumulated and transported by organisms.

Heat. Heat is a byproduct of power generation in fossil fuel and nuclear plants. There are regulations which govern the temperature differential between discharged waters and receiving waters, so the effect on the environment may be localized in oceanic waters. Chlorine or other substances are frequently used as an algal-retardant in the cooling system and may be discharged with the cooling waters. Chlorine may affect phytoplankton populations by reducing photosynthetic rates. Organisms are carried through the cooling systems and are variously affected depending on the exposure time and temperature increase.

CONSOLIDATED BOTTOM

BEDROCK AND BOULDER

Introduction

Two habitats comprise consolidated bottom areas: bedrock and boulder (rubble) (Cowardin et al, 1979). The bedrock habitat consists of all subtidal bottoms of greater than 75 percent cover of bedrock and less than 30 percent of algae. The boulder habitat consists of rocks greater than 25.4 cm in diameter which may or may not occur with bedrock, such that no more than 25 percent of the bottom is covered by unconsolidated sediments of less than 25.4 cm particle size and with less than 30 percent cover of algae.

The bedrock and boulder habitats do not support communities which differ basically from one another. However, in some cases certain physical parameters may act more strongly upon one of these habitats than on the other, and thus induce subtle differences between them in community composition. The bedrock and boulder habitats will not be treated separately, but differences between them will be noted, as appropriate.

Substratum Type. Along the northern and central California coast the consolidated bottom substratum is composed of granitic or sedimentary (mudstone or sandstone) material.

Areal Extent. Consolidated bottom is found along the entire coast interrupted at numerous points by unconsolidated bottom.

Dominant Species. The biota of consolidated bottoms is characterized by a broad range of invertebrates which are found upon the substratum, or, in the case of softer sedimentary rocks, within the substratum. The organisms which numerically and spatially dominate are typically suspension feeders, with species composition being highly variable between locations.

Habitat Characterization

Geographic Aspects. The bedrock habitat occurs predominantly in a band from 0.5 to 1.5 km wide along the coast, coinciding with the submerged algal beds but also occurring below the depth at which available light allows dominating growth of algae. The inner limit of the habitat occurs from 12.5 to 30 meters deep. The outer limit occurs typically at 18 to 55 meters depth where the rock bottom gives way to unconsolidated bottom (Welday and Williams, 1975). The boulder substratum is not indicated by Welday and Williams (1975) but can be presumed to occur in association with the bedrock habitat. It is known that areas of boulder occur to the 30 meter contour between Point Santa Cruz and Terrace Point (Hardin, pers. comm.; Brown and Caldwell, 1978).

There are areas of bedrock habitat scattered offshore of the central and northern California coast from 12.5 to 1000 meters deep which contribute to habitat area approximately equal to the nearshore band. There are approximately 1100 to 1200 square kilometers of rock bottom from Point Arguello to the Oregon border between the submerged algal beds and 1000 meters depth.

Physical Aspects. Direct influences of substratum type upon rock bottom community composition are not easily demonstrated except for the presence of boring pholad clams in sedimentary rocks and their virtual absence from granitic rocks. Extensively pockmarked mudstone substratum bored by pholads, probably during the Pleistocene, provides numerous microhabitats for many species of epifauna at the 30 meter contour near Santa Cruz (Hardin, pers. comm. j).

Rock type and water movement combine to provide more subtle influences on consolidated bottom communities and surrounding habitats. Strong water movement and suspended sand particles act to erode the softer sedimentary bedrock into very fine suspended particles which increase water turbidity. Increased turbidity

limits the depth to which sufficient light penetrates for the growth of submerged algal beds. Thus the bedrock habitat occurs at shallower depths in areas of suitable substratum where the bedrock is sedimentary (increased turbidity leads to predominance of bedrock habitat over submerged algal bed habitat).

Water movement of several types profoundly influences the bedrock habitat and its interactions with neighboring habitats. Longshore currents serve to disperse pelagic larvae of benthic organisms, aiding the colonization of available habitat and providing for genetic exchange between distant locations. Sea mounts such as Cordell Bank, which rise steeply to near the surface from much deeper surroundings, may accentuate longshore currents in their immediate vicinity as the moving water is displaced by the bank. While down-current productivity may be locally enhanced, the clear oceanic water rising up and over the bank allows the presence of several species of algae at depths to 60 meters (Moe and Silva, 1979).

Wind-induced coastal upwelling enhances nearshore productivity by introducing deep, nutrient rich water into the photic zone, thus increasing planktonic flora and the fauna which feeds upon it. These planktonic organisms are the primary food source for benthic suspension feeders that populate the consolidated bottom habitats. On the average 1.5 cubic meters of water per hour are required to adequately feed one square meter of substratum covered by suspension feeders (Riedl, 1971).

Swell-induced surge acts upon the bedrock community in two ways: 1) in regions of strong surge, suspended sand may scour organisms from the substratum (Weaver, 1977); 2) strong surge tends to present more food laden water to benthic suspension feeders, enhancing biomass (Pequegnat, 1964, 1968; and Riedl, 1971). Furthermore, Crisp (1962) has shown that total growth and reproductive potential of the barnacle (Balanus balanoides) is very positively related to the rate of water replacement around the organisms.

Strong wave action may kill organisms by moving rocks in the boulder habitat, with shallower areas or areas of smaller rocks being more easily disturbed. The timing and frequency of these disturbances may greatly influence boulder habitat species diversity and community composition (Osman, 1977). In areas typified by encrusting epifauna, periodic disturbances may actually enhance a higher species diversity on a smaller spatial scale by preventing domination by quickly growing colonial forms.

Minimum water movement may also limit rock bottom communities in a number of ways as discussed comprehensively by Riedl (1971). A few seconds of in situ experimentally-induced stagnation were sufficient to narcotize by asphyxiation small sabbellid polychaetes. Low water movement may also facilitate deposition of unconsolidated substrata, thus burying rock bottom habitat.

The rock bottom habitats experience seasonal fluctuations of dissolved oxygen, salinity, temperature, and nutrients as the three oceanographic seasons come and go (see Pelagic habitat), but longshore currents tend to depress short-term fluctuations. The reproductive cycles of many epifaunal species correlate with peak productivity in the pelagic habitat. This correlation facilitates greater utilization by adult forms for the production of gametes as well as enhanced food sources for those meroplankton (planktonic larvae) which may feed. Dissolved oxygen is typically lower within the rock bottom habitats than within the overlying pelagic habitat. Not only do the epifauna respire and settled organic matter oxidize (which consumes oxygen), but peak photosynthesis and wave induced oxygen dissolution occur near the water's surface. The higher carbon dioxide concentrations associated with respiration typically lower the pH of the water in rock bottom habitats relative to the overlying pelagic habitat.

Light penetration to the rock bottom habitats is affected not only by the synergism between water movement and substratum type (turbidity) previously described but also by the blooms of plankton associated with periods of upwelling. Light penetration may also be locally limited by suspended particles introduced to the upper water layers during heavy storm runoff from land.

Biological Aspects.

Dominant Species and Community Composition. Any discussion of the dominant species comprising bedrock communities must be tempered by our very incomplete understanding of the complex physical and biological factors which determine the distribution of individual species. Each species has a range of requisite physical conditions for survival, while the range of physical requirements may be different for reproductive success. Not only do physical parameters help determine rock bottom

community composition, but 'biological interactions (most importantly, competition for available substratum) powerfully influence the abundance and diversity of resident species. The time during which substratum becomes available for colonization may affect the ultimate composition of the inhabiting community. Different species with planktonic larvae may have different reproductive periodicities, and therefore have different densities of larvae available for settlement (Osman, 1977). In short, rocky substratum community composition is the result of stochastic processes.

Central to our lack of knowledge about the physical and biological interactions which determine rock substratum community composition has been the difficulty of quantitatively sampling rocky substratum organisms. In order to measure percent cover, it is necessary to quantify an intact sample, which dredging does not provide. Recent developments of a photographic sampling technique has enabled efficient sampling to depths which can be reached with SCUBA (Kinnetic Laboratories, 1977, 1979). Areas much deeper than 35 meters are best photographed remotely.

Given the natural variability of consolidated bottom communities and the scant quantitative data available, we can only construct a hypothetical list of dominant species. Except in areas where light penetrates sufficiently to allow up to 30 percent cover of algae, there are few producers which occur in rock bottom habitats. Their contribution to consolidated bottom energetic is assumed to be minimal. Algal species which are known to occur at depths to 55 meters include Polysiphonia laticornis, Callophyllis flabellulata, Desmarestia tabacoides, and others (Moe and Silva, 1979).

Consolidated bottom communities are dominated by sessile suspension feeders, with an assortment of omnivores, predators, and scavengers (see Figure 3-10 for food web diagram). Suspension feeders may utilize both phyto- and zooplankton, as well as detritus, for food. Therefore, the trophic status of many species cannot be clearly defined. The phyla which comprise the bulk of the suspension feeding community component and their most common species are:

Porifera	
<u>Acarnus erithacus</u>	(red volcano sponge)
<u>Lucilla nuttingi</u>	(urn sponge)
<u>Polymastia pathymastia</u>	(aggregated vase sponge)
<u>Sigmatocia</u> spp.	(no common name)
Cnidaria	
<u>Aglaophenia</u> spp.	(ostrich plume hydroid)
<u>Allopora californica</u>	(California hydrocoral)*
<u>Balanophyllia elegans</u>	(orange cup coral)*
<u>Corynactis californica</u>	(strawberry anemone)*
<u>Metridium senile</u>	(white plumed anemone)
<u>Paracyathus stearnsii</u>	(brown cup coral)*
<u>Psammogorgia torreyi</u>	(Torrey's red gorgonian)
Mollusca, Bivalvia	
<u>Hinnites giganteus</u>	(purple hinged rock scallop)*
Arthropoda, Crustacea	
<u>Balanus</u> spp.	(acorn barnacles)
Ectoprocts (Bryozoa)	
<u>Celleporaria brunnea</u>	(no common name)
<u>Hippodiplosia pta</u>	(fluted ectoproct)
<u>Phidolopora pacifica</u>	(lacey ectoproct)
Echinodermata, Holothuroidea	
<u>Cucumaria miniata</u>	(orange sea cucumber)
Chordata, Ascidiacea (Tunicates)	
<u>Cystodytes lobatus</u>	(lobed tunicate)
<u>Archidistoma psammion</u>	(no common name)

*See Volume II, Part 2 for Species Account.

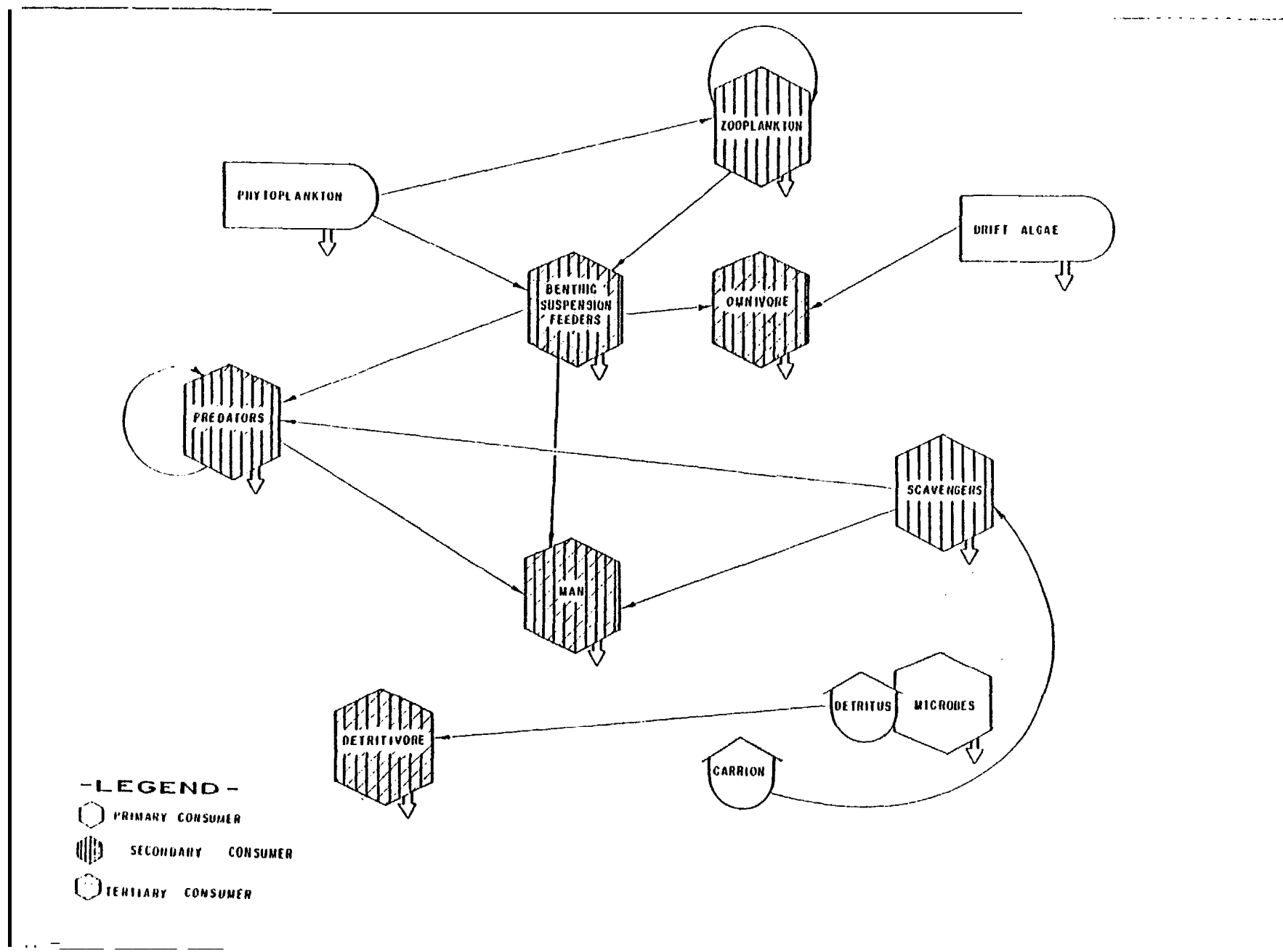


Figure 3-1.0. General Consolidated Bottom Food Web Model

Non-suspension feeding omnivores include the ornate tube worm (*Diopatra ornata*)*, the purple ringed top shell (*Calliostoma annulatum*), and the bat star (*Patiria miniata*)*. *D. ornata* feeds on material it captures from the water as it is swept by, whereas *C. annulatum* and *P. miniata* feed on benthic material. The herbivory of each is enhanced in consolidated bottom habitats by algal drift.

Motile predators typical of consolidated bottom communities include the following:

Mollusca, Gastropods	
<u>Anisodoris nobilis</u>	sea lemon
<u>Calliostoma annulatum</u>	purple ringed top shell
<u>Dendrodoris albopunctata</u>	white-spotted nudibranch
<u>Discodoris sandiegensis</u>	ringed nudibranch
<u>Triopha carpenter</u>	orange-tipped nudibranch

Mollusca, Cephalopoda
octopus spp.

Echinodermata, Asteroidea	
<u>Evasterias troschellii</u>	false ochre star
<u>Henricia leviuscula</u>	blood star
<u>Orthasterias koehleri</u>	rainbow star
<u>Pisaster brevispinus</u>	short-spined star *
<u>Pisaster giganteus</u>	giant-spined star *
<u>Pycnopodia helianthoides</u>	sunflower star
<u>Stylasterias forreri</u>	fish eating star

Vertebrate, Pisces

<u>Ophiodon elongatus</u>	lingcod *
<u>Scorpaenichthys marmoratus</u>	cabezon *
<u>Sebastes goodei</u>	chilipepper *
<u>S. pinniger</u>	canary rockfish *
<u>S. miniatus</u>	vermillion rockfish *
<u>S. paucispinis</u>	bocaccio *
<u>S. serranoides</u>	olive rockfish

Vertebrata, Mammalia
Homo sapiens

man

The fish and man participate to varying degrees in consolidated bottom food webs. The fish are included in our discussion, however, because they are all found in association with consolidated bottoms and, at the least, may derive shelter from the topographic irregularities of consolidated bottom habitats.

Scavengers found in rock bottom habitats include species which eat dead and dying organisms as well as detritivores:

Arthropoda, Crustacea	
<u>Cancer antennarius</u>	rock crab
<u>Pagurus</u> spp.	hermit crabs

Echinodermata, Holothuroidea	
<u>Parastichopus californicus</u>	California cucumber - detritus

The amount of food available to benthic populations is highly variable seasonally and spatially and depends upon productivity, density stratification, and water movement. The degree to which this material is actually assimilated into epifaunal biomass is not known, largely because of the difficulty of quantitatively sampling encrusting colonial organisms. However, the feeding efficiencies and rates of assimilation of several species of intertidal barnacles have been studied and may be illustrative, if not typical, of other epifaunal suspension feeders.

Wu and Levings (1979) found an energy flow of 6667 kilocalories/meter²/year through an intertidal population of *Balanus glandula* in British Columbia, resulting in a production of body tissue, eggs, and shell equal to 2896.5 kcal/m²/year. Shell material accounted for 53.5 percent of the production, probably available only to decomposers. Elaboration of body tissue accounted for 10.6 percent of production, while eggs accounted for 35.3 percent of production. Both body tissue and eggs would

*See Volume II, Part 2 for Species Account.

be available to predators. Griffiths and King (1979) found that individuals of the ribbed mussel Aulacomya ater may contribute up to 0.161 Kcal per year or 81 percent of their annual production to reproductive output. Thus, the high allotment of energy to reproduction in these two species indicates the importance of gametes and larvae as a mode of recycling energy and nutrients from benthic populations back into the pelagic habitat, since benthic organisms may also feed on planktonic larvae, within the benthic habitats themselves.

Wu and Levings (1979) also found that the younger age classes of Balanus glandula made a greater contribution to the energy flow, egg production and total production of the population than the older age classes. Thus, while periodic disturbances like predation and damage by floating logs resulted in a loss of 2522.8 Kcal/m²/year in mortality, this mortality tended to maintain high levels of productivity by providing substratum for settlement by barnacle larvae.

Community Dynamics. A few producers of little energetic consequence occur in consolidated bottom areas. The dominant but variable cover of suspension feeders on consolidated bottoms feed upon phyto- and zooplankton transport[<] to them by water movement. These suspension feeders may in turn be fed upon by a variety of predators. Several species of barnacles (Balanus spp.)* feed upon phytoplankton and zooplankton. They may be preyed upon by Ceratosstoma foliatum (leafy horn-mouth snail) which may, in turn, be preyed upon by a number of sea stars. The stars also prey directly upon the barnacles. An alternate path through consolidated bottom food webs might be as follows: zooplankton and small planktivorous fish may be eaten by Corvynactis californica (strawberry anemone), which are then fed upon by Calliostoma annulatum (purple ringed top shell), which may, in turn, be fed upon by predacious sea stars. Crabs such as Cancer antennarius (rock crab) scavenge dead organisms, and young C. antennarius may be fed upon by Octopus spp. A number of fish species including the lingcod and vermilion rockfish eat octopuses and are themselves eaten by humans. Humans may also feed directly upon suspension feeders such as Hinnacles giganteus (rock scallop). Ultimately, dead tissue and detritus, including fecal material, are broken down by decomposing bacteria, all of which may be consumed by detritivores such as Parastichopus californicus (sea cucumber).

Succession in consolidated bottom habitats does not conform to the classic models developed for terrestrial systems in which successive edaphic modifications by dominant species may produce predictable, one-directional patterns of community development. Instead, available substratum in consolidated habitats is occupied by the species whose larvae or asexually produced colonies get there first. The work of Osman (1977) and Foster (1975a) indicate that there may be predictable patterns of changes in species richness and diversity associated with colonization and competition for newly available substratum. These patterns seem to be modulated seasonally. Typically the species diversity upon newly available substratum increases rapidly during the initial phases of colonization as numerous larvae settle. Thereafter, there is a slow, steady decline in species diversity to a point of equilibrium as certain species come to dominate the area. The ultimate dominant of any new substratum is probably determined by the ability of colonial or very opportunistic forms to outgrow or overgrow other species.

Work in Carmel Bay (Kinnetic Laboratories, 1977) indicates that even in the absence of detectable influences by a small domestic wastewater discharge, consolidated bottom communities may undergo dramatic long-term fluctuations in species composition. A dominating cover of colonial ascidians diminished over several years to be replaced largely by a sand tube building worm (Phragmatopoma californica) and a barnacle (Balanus crenatus). Fluctuations in rock bottom community composition may be more common than previously assumed. Only through long-term studies can the magnitude and frequency of such occurrences be documented and their effect on the energy flow and secondary productivity of benthic communities be known.

Migration, Visitation, and Interactions with Neighboring Habitats. It has previously been emphasized that sessile consolidated bottom communities rely for food and oxygen upon the transport to them of products of the pelagic habitat. The quantity and quality of food items provided to the consolidated bottom communities varies not only seasonally, as a result of upwelling and the reproductive periodicities of benthic species themselves, but also daily as the diel rising and falling of plankters takes place in the water column. Fish species, such as the blue rockfish (Sebastes mystinus) also migrate up and down from the bottom, on a daily basis.

*See Volume II, Part 2 for Species Account.

A number of species are associated with more than one habitat, like the rockfishes (*Sebastes* spp.) . The commercially and recreationally important lingcod (*Ophiodon elongatus*) migrates from deeper to shallower consolidated habitats, including submerged algal beds, to spawn during November through March. The short-spined star (*Pisaster brevispinus*), is found in both consolidated and unconsolidated bottom habitats, although seasonal or daily patterns of distribution have not been reported. By virtue of the definition of consolidated bottom habitats (Cowardin et al, 1979), they may be covered up to 25 percent by unconsolidated substratum. As discussed in the "Physical Aspects" section of this habitat characterization, the proximity of unconsolidated sediment may contribute to the scouring or smothering of consolidated bottoms through the action of maxima and minima of water movement, respectively.

The broadcasting of gametes by benthic organisms in all habitats, consolidated and unconsolidated, intertidal and subtidal, makes an unquantified, but undoubtedly significant contribution to stocks of zooplankton from which all habitats derive food. The high energy budget reported for egg production in a barnacle (*Balanus glandula*) suggests the importance of reproductive processes, and concomitant interactions between habitats, for ecosystem stability.

Human Influences on Consolidated Bottom Habitats

Adverse human influences on consolidated bottom communities can occur primarily in two ways. The first is through physical degradation of habitat. The second is through release of pollutants which may have acute or chronic effects on species in bottom habitats or on interactions between habitats.

Physical degradation of consolidated bottom habitats could occur due to jetty or pipeline construction which would create protected areas and allow sediment build-up. Weaver (1977) showed that the greatest demonstrable effect of a wastewater outfall near Monterey was just such a "pipe effect." Also suspect should be the discharge into deeper, quieter waters of any waste which is high in suspended solids. Seasonal littoral drift is not well understood along the central and northern California coast; and, as in the case of construction of small craft harbors, nearshore construction may inadvertently cause unconsolidated sediments to accumulate. Any offshore activities such as dredging or mining which would increase levels of suspended sediment near consolidated bottom habitats may affect increased rates of sediment deposition and lead to smothering. Similarly, dredge spoil material should be disposed well away from consolidated habitats so as not to increase sediment transport or deposition above ambient levels. Such a prohibition obviously implies a need to know the current and circulation patterns in any construction or disposal areas.

Onshore construction or logging activities which would lead to greatly increased erosion and nearshore levels of suspended sediments could also adversely affect consolidated bottom habitats.

The acute or chronic effects on consolidated bottom communities of the release of pollutants are not only species specific, but also pollutant specific. The complexity of possible chronic and acute pollutant effects on consolidated bottom habitats dictates a discussion in general terms only.

Some pollutants may be acutely toxic, but hold little danger for the ecosystem, in general. For instance, while abalone mortality in Diablo Cove in 1975 (Martin et al, 1977) was linked to the discharge of water high in copper causing acute toxicity, mercury is the only trace metal which actually accumulates up food chains creating a chronic level of toxicity (Young and Mearns, 1978). This is probably due to the ease with which it complexes with organic compounds.

Different components of sewage may have opposing effects upon a single species. For instance, low levels of chlorine have been shown to inhibit sea urchin fertilization (Muchmore and Epel, 1973), while adult Populations may derive benefits from dissolved nutrients in the effluent (North and Pearse, 1970) . While the presence of many organic pollutants can be demonstrated in various species, their effects in very low levels are not known, and deserve much further attention. Since many organic compounds are fat soluble, they may be concentrated in the yolk of eggs and thus dispersed to all marine habitats by planktonic larvae.

Particular attention needs to be focused upon the possible effects of pollutants on the reproductive abilities of benthic invertebrates. For instance, while adverse impacts of chronic oil pollution on invertebrate populations are not readily demonstrable (Spies et al, 1979; and Littler, pers. comm.), recent work indicates

a possible effect upon gonad size. Gonadal indices of the bat star (Patiria miniata) were significantly lower in an area of a natural oil seep near Santa Barbara as opposed to a nearby comparison area (Davis, pers. comm.).

There is evidence that other species are reproductively affected by petroleum pollution, but in general, there is much need for additional studies (National Academy of Sciences, 1975). Such needs correlate with the gaps in the knowledge of the reproductive energy budgets of benthic invertebrates and their roles in nearshore plankton dynamics.

UNCONSOLIDATED BOTTOM

The unconsolidated bottom habitat category contains sediments which have not been bound together by geologic processes to form rock. In general, the sediment types can be described as sands and muds (Table 3-9). Sands are present along the innermost edge of the continental shelf. Muds containing silt or a mixture of silt and clay are found progressively further offshore, extending out to the shelf margin. Finer silts extend down the continental slope, reaching a depth of 1000 meters or deeper (Welday and Williams, 1975). Below 1000 meters the substratum increases in clay content and decreases in the amount of organic material present (Sokolova, 1972).

Rivers and river deltas are the principal sources of terrigenous (land-derived) sediments found on the continental shelves. Approximately 75-80 percent of river sediment consists of silt and clay which is lost to deep water (Komer, 1976). The remainder becomes deposited on the shelves where it provides subtidal sand and subtidal mud habitats. Added to these terrigenous sediments are organic sediments derived from biological processes occurring in the overlying waters.

Infaunal communities are characteristic of unconsolidated bottoms and include polychaete worms, crustaceans, bivalve molluscs, and other burrowing and tube-dwelling organisms.

SUBTIDAL MUD HABITAT

Introduction

Substratum Type. The mud habitat type consists of a substratum containing sediments (muds) composed of a high percentage of silt and clay. Median grain size for muds is 0.0625 mm or less (Table 3-9). The mud habitat is also rich in organic detritus which is derived from sedimentation of planktonic material.

Table 3-9. Classification of Sediment Grain Size (from Folk, 1968)

Diameter (millimeters)	Wentworth Size Class	Classification
4096 - 256 256 - 64 64 - 4 4 - 2	Boulder Cobble Pebble Granule	Gravel
2 - 1 1.0 - 0.5 0.5 - 0.25 0.25 - 0.125 0.125 - 0.0625	Very coarse sand Coarse sand Medium sand Fine sand Very fine sand	Sand
0.0625 - 0.031 0.031 - 0.0039 0.0039 - 0.00006	Coarse silt Medium-very fine silt Clay	Mud

Areal Extent. The shallow continental shelves are the principal sites of subtidal mud habitats; however, mud habitats are also present in bays and estuaries.

Dominant Species. Numerous species of polychaete worms (Annelida) are the most abundant macrofauna at all depths. They are generally followed in order of abundance by crustaceans, molluscs, echinoderms, and a variety of miscellaneous phyla. Ophiuroids (brittle stars) are the dominant organisms on the shelf in terms of biomass. The majority of all organisms in the mud habitat are deposit feeders.

Habitat Characterization

Geographic Aspects. The subtidal mud habitat occurs along the entire California coast where it is found on the continental shelf and slope at depths ranging from 100-1000 meters. Major interruptions occur where submarine canyons bisect the shelf and act as sinks for littoral sand which is trapped and funneled offshore to deeper waters (Shepard, 1963). Other variations in the habitat are caused by rivers and river deltas which, because of their high discharge volumes, form flat terraces extending out from river mouths to depths of at least 100 meters. These terraces consist of muddy sediment along the coast and sandy sediments further offshore, instead of sand grading to mud with increasing depth (Komer, 1976).

Physical Aspects.

Substratum. Folk (1968) defines mud as sediment with a grain size diameter of 0.0625 mm or less. Mud is further separated into silt (0.0625 mm - 0.0039 mm) and clay (0.0039 mm - 0.00006 mm). The importance of grain size and percentage of sand, silt, and clay composition in the distribution of benthic organisms has been well documented. One type of substratum will favor the feeding methods, mobility, tube-building activities, size, and other morphological and behavioral patterns of certain benthic organisms and prove less suitable to the biological needs of others (Gray, 1974; Rhoads, 1974).

The organic content of the mud in the deeper waters of the continental shelf and slope is of far greater importance to benthic organisms than substratum type itself, because the organic material supplies energy to the biological community. The importation of dissolved and particulate organic material through the water column is the only energy source for benthic communities not exposed to light (Parsons et al, 1977). This material settles out from the overlying water and consists primarily of partially decomposed phytoplankton, zooplankton, and macroalgal detritus.

Water Movement. The process of upwelling which begins in early spring and continues through summer brings nutrients to the surface from deeper offshore regions. These nutrients are utilized by phytoplankton, enhancing productivity of the area. This enhanced productivity is beneficial to the benthic fauna, because the producers eventually die and settle to the bottom (as discussed above).

Surface water turbulence affects sedimentation rate by preventing the sinking of dense particles such as diatoms (Parsons et al, 1977). Near-bottom water movements and changes in bottom topography also affect particle settlement. Generally, sediments tend to accumulate in depressions and on flat surfaces of the ocean floor resulting in a dominance of deposit-feeding invertebrates in these areas. In areas of high relief, the movement of bottom water is more intense, causing sedimentation to slow down or cease altogether and suspension feeding forms to be dominant (Sokolova, 1972).

Dissolved Oxygen. Reduced oxygen levels in deep basins with restricted circulation may limit total biomass and species composition in benthic communities. In some cases the zonation of meiofauna, tiny organisms living interstitially within

the sediments) is related to the availability of oxygen in the overlying water. Also, the number of macrofauna versus meiofauna decreases with increasing depth. This general reduction in organism body size with increasing depth may reflect a morphological adaptation to limitations on growth imposed by restrictions in food and oxygen supply (Parsons et al, 1977).

Dissolved Salts and Nutrients. The metabolic activities of bacteria and other micro-organisms are largely responsible for high concentrations of biologically important nutrients such as silicate, nitrate, and phosphate. These dissolved inorganic ions are located in the interstitial water and increase with depth in the substratum.

Recent evidence indicates that diffusion and hydraulic pumping may play important roles in the transport of soluble nutrients out of the sediment, especially on continental shelves where internal waves and other currents impinge on the bottom. This recycling of nutrients into the overlying water may be a significant source of nutrition to the plankton in the pelagic waters and implies a coupling between pelagic and benthic systems which reflects water column depth and circulation patterns (Parsons et al, 1977).

Light. The mud habitat is primarily aphotic, occurring in depths of 100 meters or greater where light is extinct. However, when light is available to mud-dwelling organisms it allows algal and photosynthetic bacterial populations to thrive, permitting primary production to occur directly in the sediment (Parsons et al, 1977).

Temperature. Temperature affects the bottom-dwelling organisms indirectly by producing thermoclines which act as barriers to sinking particles, thus slowing down the process of sedimentation (Parsons et al, 1977). Temperature decreases with depth and directly affects the distribution and occurrence of organisms since it is the single most important factor affecting the physiology, growth, reproduction, and behavior of animals (Gunter, 1957). Correlation studies of bottom fauna show that the distribution of meiofauna and nematodes can be affected by temperature and sediment grain size (Parsons et al, 1977).

Biological Aspects.

Dominant Species. The mud habitat along the shelves and slopes of the Pacific coast from just north of Point Conception to the California-Oregon border is virtually unstudied. Most studies have been in the sand habitat on the shallow shelf. Data on the biology of the dominant species described are sketchy or altogether unknown as is the case for Listriolobus pelodes, an echiurid worm (Fauchald, 1972). Certain animal groups have been found in high abundance on the shelves of Monterey Bay, but cannot be identified past phyla due to the lack of taxonomists or biologists specializing in these animals. Enteropneusts, commonly known as acorn worms, are a specific example of this problem. The depth of the water overlying the mud habitat is most likely responsible for this gap in knowledge of benthic biology. The boats and sampling gear required for deep water sampling are expensive and very specialized. However, certain hypotheses on the changes in distribution of dominant phyla with depth have been supported by the sampling that has occurred on the continental shelves, slopes, and canyons of central California. It is therefore convenient to speak of the dominant species of phyla in terms of their depth-related distributions on the continental shelf and slope.

On the shallow shelf, one of the most abundant and widespread groups of animals are ophiuroids (brittle stars). These creatures are so numerous in some areas that the mud habitat takes on the appearance of a snake-pit with massive numbers of discs and outstretched, entangled arms (Barnard and Ziesenhenné, 1961). Most mud-bottom ophiuroid communities lie at a depth of 50 meters or more, where major perturbations in substratum are minimized. In Monterey Bay, a large portion of the shelf lies in 60 meters to 100 meters where very fine sand and silt are deposited. The brittle star Amphioplus hexacanthus dominates in much of this area (Barnard and Ziesenhenné, 1961).

Another animal which can occur in high numbers is the echiurid worm Listriolobus pelodes. This deposit feeder prefers finer sediments than Amphioplus hexacanthus, but is still a reasonably shallow shelf dweller. This species forms massive beds on the Santa Barbara shelf and is known to range from Monterey, Monterey County, to Isla Cedros, Mexico (Jones, 1969; Fauchald, 1972). However, the abundance of this animal on the central California shelf has not been measured.

Even though ophiuroids may be dominant in biomass on the shallow California shelves, polychaete worms are still the most numerous animals among the macrofauna followed in order by crustacea, mollusca, echinodermata, and a mixture of less

numerous phyla. With an increase in depth, this order of abundance for macrofauna remains about the same, but there is a concomitant increase in meiofauna until they are the most numerous animals (with nematodes and copepods comprising the majority). However, the meiofauna are not significant in biomass when compared to the other macrofauna (Hessler and Jumars, 1974).

Jumars and Fauchald (1970) presented the hypothesis that sessile animals have restricted foraging capabilities which are limited by the length of their feeding appendages or their tubes. Since utilizable organic material decreases with depth, these sessile animals will be at a disadvantage and the advantage will go towards motile deposit-feeding organisms. Sokolova (1972) maintains that deposit feeders prevail generally everywhere on the gently sloping, undulating plains of ocean basins, but suspension feeders play an important part only occasionally where there are considerable elevations of the bottom. The idea of an increase in deposit feeders with depth on the shelves of central California has been strongly supported by the box core samples of Hessler and Jumars (1974) and also by Hartman's (1963) studies of the Monterey submarine canyon.

Another observation is the increase in numbers of isopods and the decrease in amphipods with depth. With the increase in isopod numbers there is also a concurrent increase in the number of specialized taxa (Hessler et al, 1979). Deep water box core samples along the central California coast support this observation. Large numbers of isopods and tanaids were present in the core samples, while amphipods were absent (Hessler and Jumars, 1974).

Mud Bottom Associated Fishes. The fishes associated with the mud bottom habitat within the study area are basically the same type as are found in the sandy habitats (demersal and nekto-benthic forms), but with deeper depth distributions (i.e., > 100 meters). Some species which are abundant in the sand bottom areas (e.g., sanddabs and surfperches) are rare or absent here and are replaced by deeper-water and/or mud bottom species such as the sablefish and petrale sole. Some species (e.g., the rex sole, spiny dogfish, big skate, and ratfish) are present in both habitats. Nekto-benthic and mid-water column rockfishes are more abundant in this deeper habitat.

As in the sand bottom habitat, a variety of food sources are utilized. Benthic invertebrates (polychaete worms, small bivalve mollusca, echinoderms, sea cucumbers) are the food for some fish species (e.g., clover sole, curlfin turbot), while zooplankton (copepods, shrimp, euphausiids, larvaceans) and small fishes are food for others (e.g., petrale sole, arrowtooth flounder, rockfishes, big skate). Important predators include sharks, skates, and other fishes. The Pacific hagfish is found only in mud bottom habitats and lives on the visceral muscles of the larger fishes. For more information see Frey, 1971; Hart, 1973; Kravitz et al, 1976; and Pearcy and Hancock, 1978.

Characteristic Mud Bottom (Fine Sand > 100 Meters) Fishes:

<u>Sebastes diploproa</u>	Splitnose rockfish
<u>S. goodei</u>	Chilipepper rockfish
<u>S. paucispinis</u>	Bocaccio
<u>S. jordani</u>	Shortbelly rockfish
<u>S. entomelas</u>	Widow rockfish
<u>Glyptocephalus zachirus</u>	Rex sole
<u>Parophrys vetulus</u>	English sole
<u>Eopsetta jordani</u>	Petrable sole
<u>Microstomus pacificus</u>	Dover sole
<u>Pleuronichthys decurrens</u>	Curlfin turbot
<u>Lyopsetta exilis</u>	Slender sole
<u>Atharestes stomias</u>	Arrowtooth flounder
<u>Anoplopoma fimbria</u>	Sablefish
<u>Hydrologus coliei</u>	Ratfish
<u>Raja rhina</u>	Longnose skate
<u>Raja binoculata</u>	Big skate
<u>Squalus acanthias</u>	Spiny dogfish
<u>Eptatretus stouti</u>	Pacific hagfish

Community Composition. In the mud habitat, diversity is believed to increase with depth reaching a maximum between 1000 and 2000 meters and then declining. The increased environmental stability and cropping by predators is thought to be a major factor which contributes to a higher diversity (Hessler and Jumars, 1974).

The sediments on the continental shelf provide a mixed environment of mud and sand. This substratum heterogeneity is thought to be an important factor which adds

to the structural complexity of the environment. An environment with structural complexity, small fluctuations but predictable conditions, and with biological interactions such as predation or competition, would be expected to have maximum diversity (Gray, 1974).

The fauna on the continental shelf of California are indeed very diverse. It is therefore necessary to limit the trophic level descriptions to broad taxonomic categories. See Figure 3-11 for a graphic presentation of the community food web.

First Trophic Level.

Primary Producers

Phytoplankton (see Pelagic Habitat for species)

Photosynthetic bacteria

Chromatium

Achromobacter

Chlorobium

Other autotrophic bacteria which
are able to reduce CO₂ to
organic molecules

Primary consumers

Zooplankton (see Pelagic Habitat for species)

Second Trophic Level.

Detritus Feeders

Phylum Nematoda	Nematodes
Phylum Sipuncula	Peanut worms
Phylum Annelida	Segmented worms
Class Polychaeta	Polychaete worms
Family Capitellidae	
Family Cirratulidae	
Family Spionidae	
Family Paraonidae	
Family Maldanidae	
Family Terebellidae	
Class Oligochaeta	
Phylum Arthropoda	
Class Crustacea	Crustaceans
Subclass Copepoda	
Subclass Ostracoda	
Superorder Pericarida	
Order Isopoda	
Order Tanaidacea	
Order Amphipoda	
Phylum Mollusca	
Class Aplacophora	
Class Bivalvia	clams
Class Gastropoda	Snails
Class Scaphopoda	Tusk shells
Phylum Hemichordata	Acorn worms, Tongue worms
Phylum Echinodermata	
Class Holothuroidea	Sea cucumbers
Class Echinoidea	Sea urchins

Filter Feeders and Suspension Feeders

Phylum Annelida	Segmented worms
Class Polychaeta	
Family Sabellidae	Tube worms
Phylum Echiura	Spoon worms

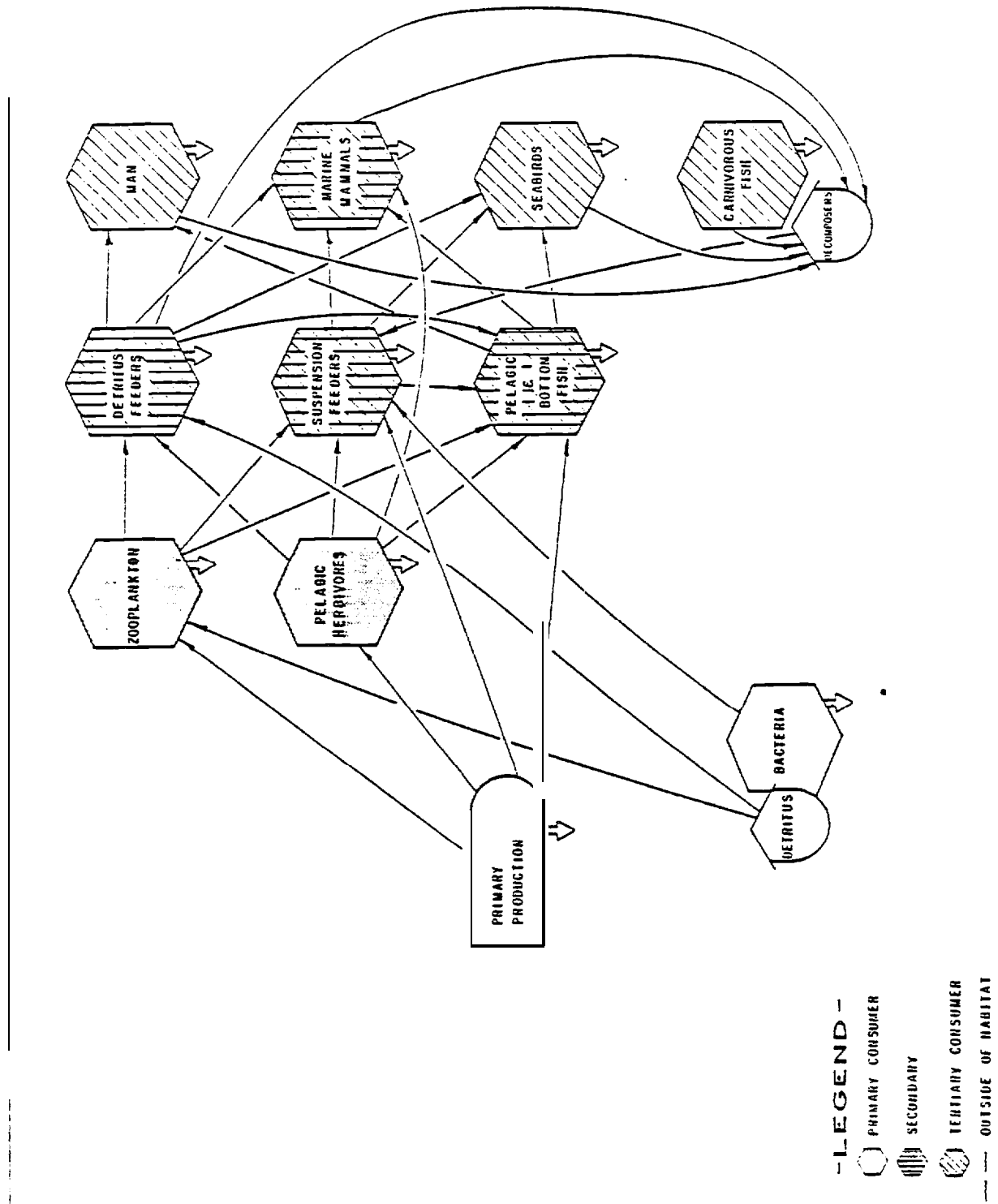


Figure 3-11. Food Web Model of the Unconsolidated Mud Bottom Habitat

Filter Feeders and Suspension Feeders (continued)

Phylum Brachiopoda	Lamp shells
Phylum Chordata	
Class Ascidiacea	Tunicates, Sea squirts
Phylum Porifera	Sponges
Phylum Cnidaria	Hydroids, Anemones, Sea pens
Phylum Ectoprocta	Bryozoans

Third Trophic Level.

Phylum Annelida	Segmented worms
Class Polychaeta	
Family Nereidae	Clam worms
Family Glyceride	Blood worms
Family Lumbrineridae	

Phylum Arthropoda
 Order Amphipoda
 Order Decapoda
 Section Brachyura

Phylum Mollusca	
Class Gastropoda	Snails

Phylum Echinodermata	
Class Ophiuroidea	Brittle stars
Class Asteroidea	Sea stars

Demersal Fish

Seabirds

Marine Mammals

Man

Community Dynamics. The major energy inputs and available resources to the sub-tidal mud habitat come from imported organic material produced elsewhere (e.g., phytoplankton, sediment, algal and animal detritus, feces). This organic material can be utilized directly by meio- and macrofauna which function as deposit and suspension feeders. Bacteria can also act on debris, transforming it into other products which provide food or substrate for other organisms capable of using the organic material directly (e.g., other bacteria).

Many species of bacteria living in both the upper aerobic and deeper anaerobic sediments are capable of producing organic compounds by reducing CO₂. The energy for this process comes not from sunlight but from the oxidation of inorganic ions (e.g., ammonia to nitrite, nitrite to nitrate, sulfide to sulfur, ferrous to ferric iron) by these same bacteria. These chemoautotrophs or chemosynthetic bacteria are often considered to be "producers", since they convert inorganic carbon into organic molecules and require no other organic compounds for growth. In organic-rich sediments, the action of the anaerobic chemoautotrophs is often dominated by the sulfur cycle (see Figure 3-12). The diversity of bacterial forms and their metabolic processes ensures continued transformation of sedimentary organic material into a form utilizable by organisms listed in the second trophic level (see Parsons et al., 1977 for a complete discussion).

Filter feeders and suspension feeders comprise the bulk of organisms in the second trophic level. However, the terms "filter feeder" and "suspension feeder" are not easily separable since animals tend to combine the two methods by feeding on both small organisms (filter feeding) and on particulate organic material or detritus (suspension feeding) (Hessler and Jumars, 1974; Fauchald and Jumars, 1979). Filter feeding is also enhanced by the burrowing activities of deposit feeders. The process of bioturbation, whereby actively digging organisms resuspend organic detritus and feces, contributes to the food available to filter feeders (See Rhoads, 1974, for a complete discussion).

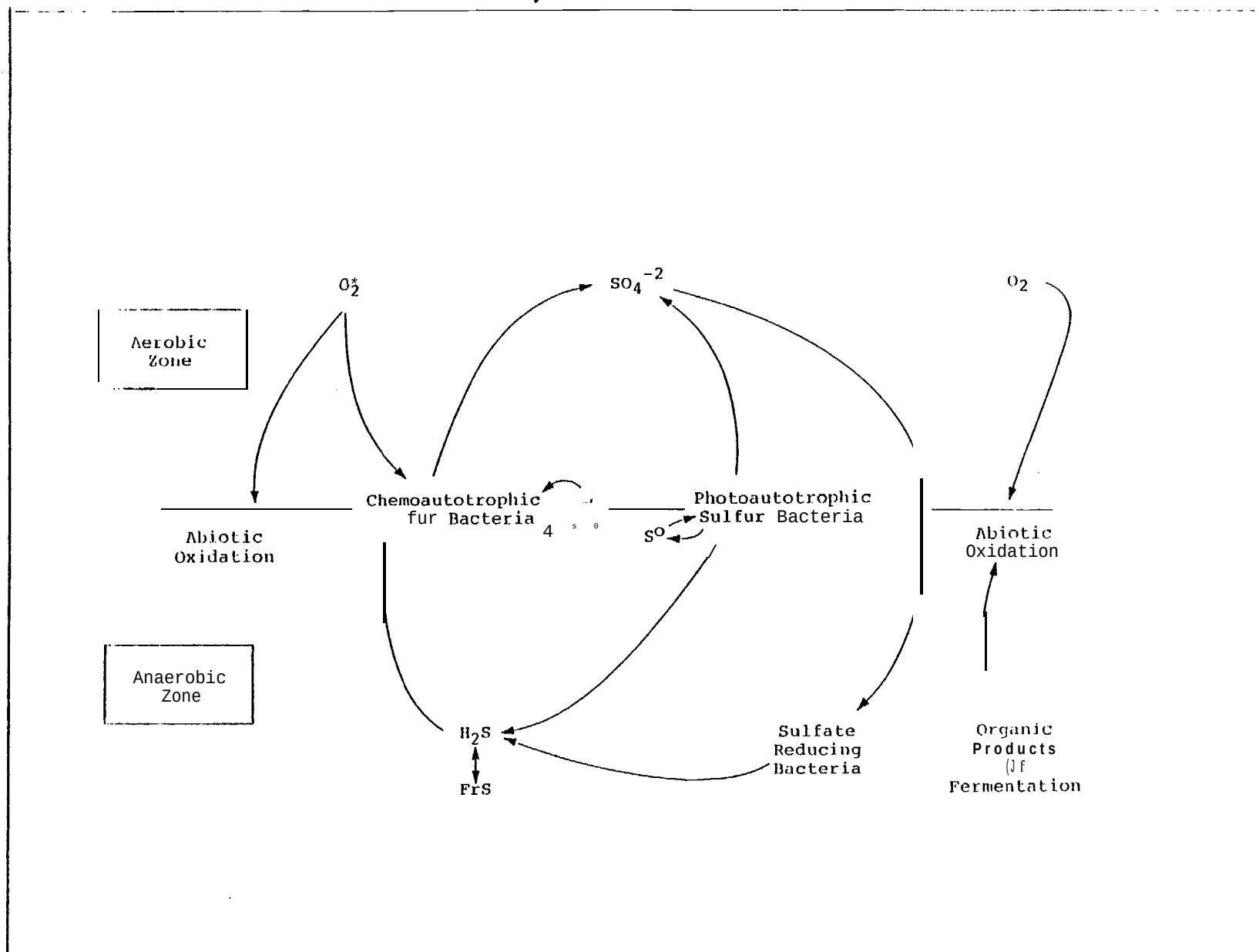


Figure 3-12. The Sulfur Cycle in an Aquatic Environment

Polychaete worms are second in numbers only to microbenthic nematodes, yet they comprise over one-third the number of macrobenthic species (Fauchald and Jumars, 1979). About 95 percent of the polychaete population on the shelf is composed of detritus feeders, as are most of the animals in this habitat (Sanders and Hessler, 1969; Hessler and Jumars, 1974). However, gut content analysis of deep sea animals and laboratory research suggest a wide range of feeding modes for many animals (Sokolova, 1972; Hessler and Jumars, 1974; Fauchald and Jumars, 1979). Hence it is not accurate to categorize animals in the mud as adhering to strictly one mode of feeding.

The habits of predators and scavengers in the mud environment are not well understood. Polychaetes often show detrital feeding and predation in species within the same genus (Fauchald and Jumars, 1979). Gut analyses of reported predators indicates that ophiuroids (brittle stars), asteroids (sea stars), and decapod crustaceans (crabs) are the major predatory groups as evidenced from the large number of taxa in their guts (Sokolova, 1972; Hessler and Jumars, 1974).

Underwater camera studies conducted on the benthos of southern California continental shelves reveal that predators and scavengers become highly motile with depth. The baited camera revealed the presence of demersal fish, octopods, shrimp, amphipods, sea stars, polychaete worms, and other active swimmers congregating on the bait (fish carrion). Similar studies proposed by Hessler and Jumars (1974) for central and northern California would probably yield results similar with those in southern California.

In Monterey Bay, California ophiuroids occur in massive numbers and are active predators on smaller organisms. Predation by ophiuroids is thought to be a contributing factor to the high diversity of taxa in the area (Thornson, 1957; Barnard and Ziesenheim, 1961).

Succession. Succession has been defined by Connell and Slatyer (1977) as the changes observed in an ecological community following a perturbation that opens up a relatively large space. Changes occur in biomass, productivity, diversity, and other features of the community. The mud habitat is a relatively stable environment, and this stability increases with depth. The lack of large perturbations in this environment is partly responsible for the high diversity (Barnard and Ziesenheim, 1961; Sanders and Hessler, 1969; Hessler and Jumars, 1974).

Relatively little is known about natural disturbances that would result in succession in the deep mud habitat; however, man is probably the biggest violator of stability with dredge disposal and the construction of deep water sewage discharge systems. Connell and Slatyer (1977) and Pearson and Rosenberg (1978) give a very complete account of the causes of human-induced perturbations and the resulting processes of succession. It is therefore suggested that the reader see these two excellent papers for a more comprehensive understanding of the complex and controversial subject of succession.

A very basic successional event in the mud habitat would begin with a disturbance which opens a relatively large space. The first animals to arrive would be a few opportunistic species such as capitellid polychaetes (Grassle and Grassle, 1974). The diversity of taxa in these first stages of succession would be very low, but the number of individuals of most species would be high (Pearson and Rosenberg, 1978). These early occupants would modify the environment making it less suitable for other early succession species and more suitable for the recruitment of late succession species. Eventually the early stage species are eliminated with the concurrent maturation of the later succession animals. This process of recruitment of new species continues until the resident species no longer tolerate the invasion and growth of other species. Upon reaching this last stage (and assuming the environment has been stabilized), further invasion and growth to maturity can only occur when a resident individual is removed (Connell and Slatyer, 1977; see Figure 3-13).

Migration and Visitation. Migration and visitation into the mud habitat of the central and northern coast of California is unknown. Demersal fish, squid, octopods, and other fast swimming invertebrates which can adjust to pressure changes are potential visitors to this habitat. Box cores are useless in sampling these elusive animals. A baited camera system would be an effective means of studying the fast-moving fauna of the deep (Hessler and Jumars, 1974).

Another form of migration that cannot be ruled out is vertical migration. Plankton and fish are capable of moving great distances and may possibly come into contact with the bottom (Isaacs et al, 1974; Parsons et al, 1977). Sanders and Hessler (1969) propose that downward movement by means of diurnal migration would increase the

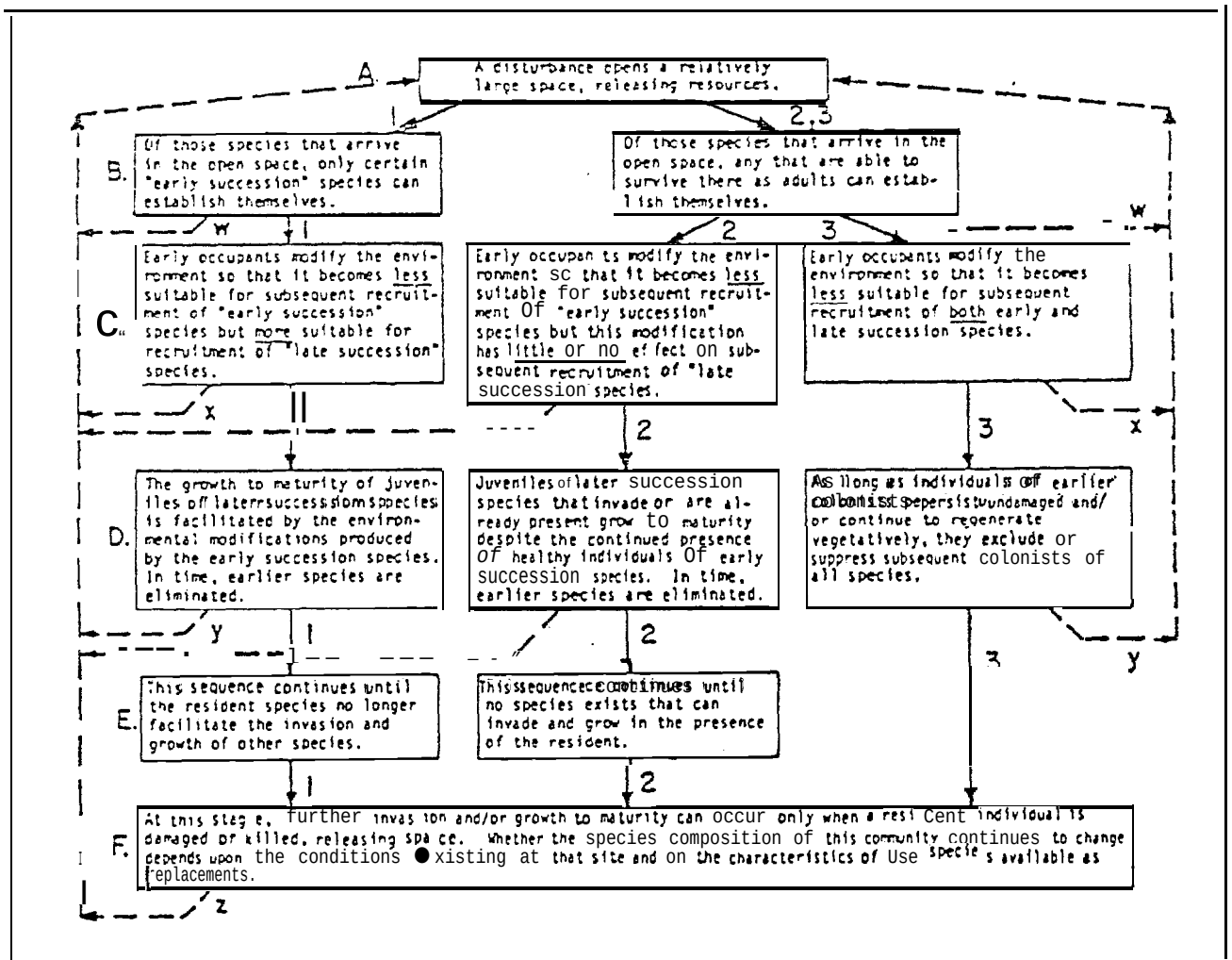


Figure 3-13. Three Models of the Mechanisms Producing the Sequence of Species in Succession. The Dashed Lines Represent Interruptions of the Process, in Decreasing Frequency, in the Order w, x, y, and z (From Connell and Slatyer, 1977).

efficiency of food transport. The problem with this hypothesis is that the chain of migrating animals might be less efficient than passive settling since it entails large energy losses in every change of trophic level.

Human Influences on this Habitat

The majority of shallow-shelf bottom invertebrates possesses pelagic larval development, and these larvae form an important annual or seasonal component of the neritic plankton. The survival and maintenance of these species is therefore strongly dependent on the survival and distribution of the larvae during their planktonic phase and their period of settling on the substratum. The most common pollutants of marine waters are oil, its by-products, and oil residues. Other major forms of pollution are sewage discharge, industrial wastes, pesticides, heavy metals, and thermal pollution. In natural environments these pollutants become widely dispersed so that they only mildly affect free-swimming larvae. It is when these larvae are settling on the substratum that they are jeopardized, since much higher concentrations of different pollutants may be present on the substratum than in the water mass above it (Mileikovsky, 1970.)

Sewage and other sources of organic input can affect adults as well as larvae. Anoxic conditions are created when organic enrichment from sources such as sewage discharges and pulp mills goes unchecked allowing the complete uptake of oxygen by bacteria. Sites of organic enrichment alter the habitat considerably by lowering the diversity of taxa and allowing only high numbers of a few pollutant-tolerant species to survive near the outfalls (Pearson and Rosenberg, 1978).

Benthic organisms exhibit some plasticity for occasional pollution mishaps, but prolonged fouling of the environment lengthens the process of succession and increases the size of the affected area. The mud environment is a species-rich habitat and therefore an area where a great deal of energy is passed through the complex trophic structure. Pollution of this environment may have an impact on the continental shelf greater than can be comprehended with the current level of understanding.

SUBTIDAL SAND HABITAT

Introduction

Unconsolidated subtidal sand habitats occur from the MLLW tidal datum to approximately 100 meters depth (the sublittoral zone). Mud communities are predominant at depths of 100 meters or greater.

Substratum Type. The substratum type can vary from very coarse sand (2.0 mm) to very fine sand (0.0625 mm) depending upon the geology of the area (particle size information from Wentworth scale, in Folk, 1968). Granitic geological formations produce coarser sand particles (as in Monterey Bay and Farallon Islands areas). Sandstone due to ease of erosion, produces finer sand particles bordering on the silt index (as in the Santa Cruz area). The majority of the northern California coast is fine sand (0.25-0.125 mm). Occasionally the unconsolidated areas along the northern California coast are interspersed with rocky and boulder substratum.

Areal Extent. Unconsolidated sand substratum is prevalent along the entire coast of California. The occurrence of sandy substratum along the California coast has been mapped by Welday and Williams (1975) and Shepard (1963).

Dominant Species. The dominant species of this habitat are highly variable, depending upon substratum type and organic content as well as other physical factors. Communities of Diopatra ornata, a tube-worm, can be found in coarse sandy habitats associated with high organic content. Another tube-worm, Nothria elegans, is characteristic of finer sands. Communities of Dendraster excentricus, a sand dollar, can be found in coarse to medium sand. Amphipod communities are also characteristic of a variety of sand habitats. Ophiuroids (brittle stars), which can inhabit both gradations of sand and mud are discussed in the Subtidal Mud Habitat section of this report.

Habitat Indicators. Infaunal organisms which live within the sediment communities are characteristic of an unconsolidated sand habitat. The presence of infauna usually compacts the substratum. This compaction occurs predominantly as a result of tube-building organisms in this substratum. Both the compaction and the tube-building organisms have the effect of increasing species diversity by increasing the number of micronhabitats. The sand shifts less with the presence of tubes making the substratum

amenable to more organismal population. 'Tubes, vertically rising above the substratum, provide increased spatial area for attachment of plants or animals (a tube microhabitat).

Habitat Characterization

Physical Aspects. Sediment particle size, water movement, temperature, light, dissolved oxygen content in sediment, and organic siltation are all important physical aspects of this habitat. It has been shown (with some exceptions) that Species are associated with a particular sediment. type and size. The reader is referred to Gray (1574) and Parsons et al (1977) for a detailed and a general treatment, respectively, of animal-sediment relationships.

Sediment particle size is a particularly important physical characteristic. The specific sediment size has an effect on how compact the sand is. This "compactness" can delimit the amount of water movement through the substratum. The water movement, in turn, affects temperature, food (organics), dissolved oxygen, and dispersion of biological wastes through the substratum (see Riedl, 1971).

Substratum "compactness" also has an effect on the vertical distribution of organisms. It affects the burrowing ability of clams and worms, meiofauna (interstitial organisms) zonation, ingestion of particles by deposit feeders, as well as oxygen penetration. The interaction between particle size and other physical factors affects the biological community. For example, fine sand, with high organics and low water movement, has a H₂S layer close to the surface. This sulfide layer, in some respects, prevents most organisms from occupying space in the substratum. The relative lack of organisms results from a lack of oxygen as well as other chemical factors. Sulfide-producing bacteria contribute greatly to the production of the sulfide layer (see Parsons et al, 1977 for further information).

The benthic sand substratum is usually a movable one; it is at the whim of surge, currents, storms, and organismal perturbations. Transient communities are quite common due to these disturbances.

Biological Aspects.

Dominant Species. Various sand communities have different dominance patterns depending upon the physical nature of the substratum, depth, organic nutrients, and biological interactions. Basically, in sand habitats, the majority of infaunal organisms are polychaetes and crustaceans. The tube-building polychaetes, like Diopatra ornata and Nothria elegans, inhabit sandy benthic areas. However, Diopatra is more prevalent in areas of coarse sand material and high organic composition and occurs at depths less than 100 meters. Nothria prefers finer sediments (but it is also found in coarse sand), and dominates inshore sand bottoms to depths of less than 30 meters (Barnard, 1966). Both these species consolidate the sandy bottom by the construction of tubes. Diopatra tubes can extend to a length of 50 cm into the substratum whereas Nothria tubes are about 15 cm in length. Amphipod communities also build tubes visible on the surface of the substratum. Their tubes are usually of finer sand composition and are easily disrupted by slight physical disturbances. Refer to Barnard's (1966) study on the Monterey Bay amphipods for a more detailed account.

The "common" or Pacific sand dollar (Dendraster excentricus) can be found in extensive densely-packed beds at depths from 0 to 100 meters on the northern and central California coast (Pearse, 1975). They are known to migrate depending upon sea conditions (Oliver and Slattery, 1976). In calm ocean conditions the Dendraster are found in shallow water. During storm conditions the Dendraster migrate offshore.

Burrowing clams, polychaetes (other than Diopatra or Nothria), oligochaetes and nematodes are found within the sediment and are not visible unless a sediment core of the area is taken. Lesser-studied organisms, but important to the sand habitat, are the meiofauna (interstitial organisms) and bacteria which are found among the sand grains, a microhabitat in itself.

Epifaunal organisms, such as crabs and sea stars, may not be indigenous to the sand community per se, but have been found with enough sampling frequency in this habitat to be included here. The shore-s?med sea star (Pisaster brevispinus), and the Dungeness crab (Cancer magister) are two examples of the epifaunal species. Various benthic fish such as sanddabs, skates, and rays may visit the area as well.

Species of Concern. The Dungeness crab (Cancer magister) is the most studied and well-documented species in the sand habitat (Dean, 1971; Dahlstrom, 1973b; and for a literature review, see Winzler and Kelly, 1977a). It has high commercial importance in terms of a food resource for humans.

The short-spined (or pink) sea star (Pisaster brevispinus) may be an important subtidal predator in northern and central California (as well as in southern California) coastal waters (Van Veldhuizen and Phillips, 1978). It may have a major effect on the number and distribution of prey species within its habitat, but its "ecological impact" as such has not been studied. It has been shown to feed upon Dendraster excentricus (Farmanfarmaian et al, 1958); but the extent to which it is used is unknown. During the end of its larval cycle, approaching metamorphosis on the substratum, it has been shown to consume juvenile Cancer magister (van Veldhuizen and Phillips, 1978).

It is more difficult to ascertain the biological-ecological importance of lesser-studied species (e.g. Diopatra ornata). There are too few studies on this species to give a clear-cut description of its ecological effects. Diopatra occurs prevalently in areas of high organic input (e.g. near sewer outfalls; Emerson, pers. comm.). Research on Diopatra communities could provide information on the effect of the outfalls on the benthic subtidal sand community. Studies may be able to determine whether this species assumes dominance (from a successional viewpoint) in sewer outfall areas.

Community Composition. Very few ecological studies exist concerning the composition of subtidal sand communities. The information that is known is presented below, and a graphic presentation of the food web model can be seen in Figure 3-14.

First Trophic Level. This habitat has a virtually non-existent production effort in terms of biomass (especially when compared to a kelp forest).

Producers

Non-Vascular Plants

Episammic (restricted to sand grains) microalgae
Diatoms (attached to sand grains)
Macroalgae (Rhodophyta [red algae] characteristically attached to sand tubes constructed by worms (e.g. Diopatra ornata))

Consumers

Zooplankton (see Pelagic Habitat for species names)

Second Trophic Level.

Herbivores

Dendraster excentricus (detritivore) Sand dollar
Amphipods
Bivalves
Clams

Omnivores

Nothria elegans Tube-building polychaete
Diopatra ornata¹ Ornata tube worm
Amphipods

Third Trophic Level.

Predators

Pisaster brevispinus Short-spined sea star
Cancer magister Dungeness crab
- s flatfish: sole, sanddabs
Birds
Humans

¹Confusion exists in the literature concerning the Diopatra ornata feeding mode (see Fauchald and Jumars, 1979) .

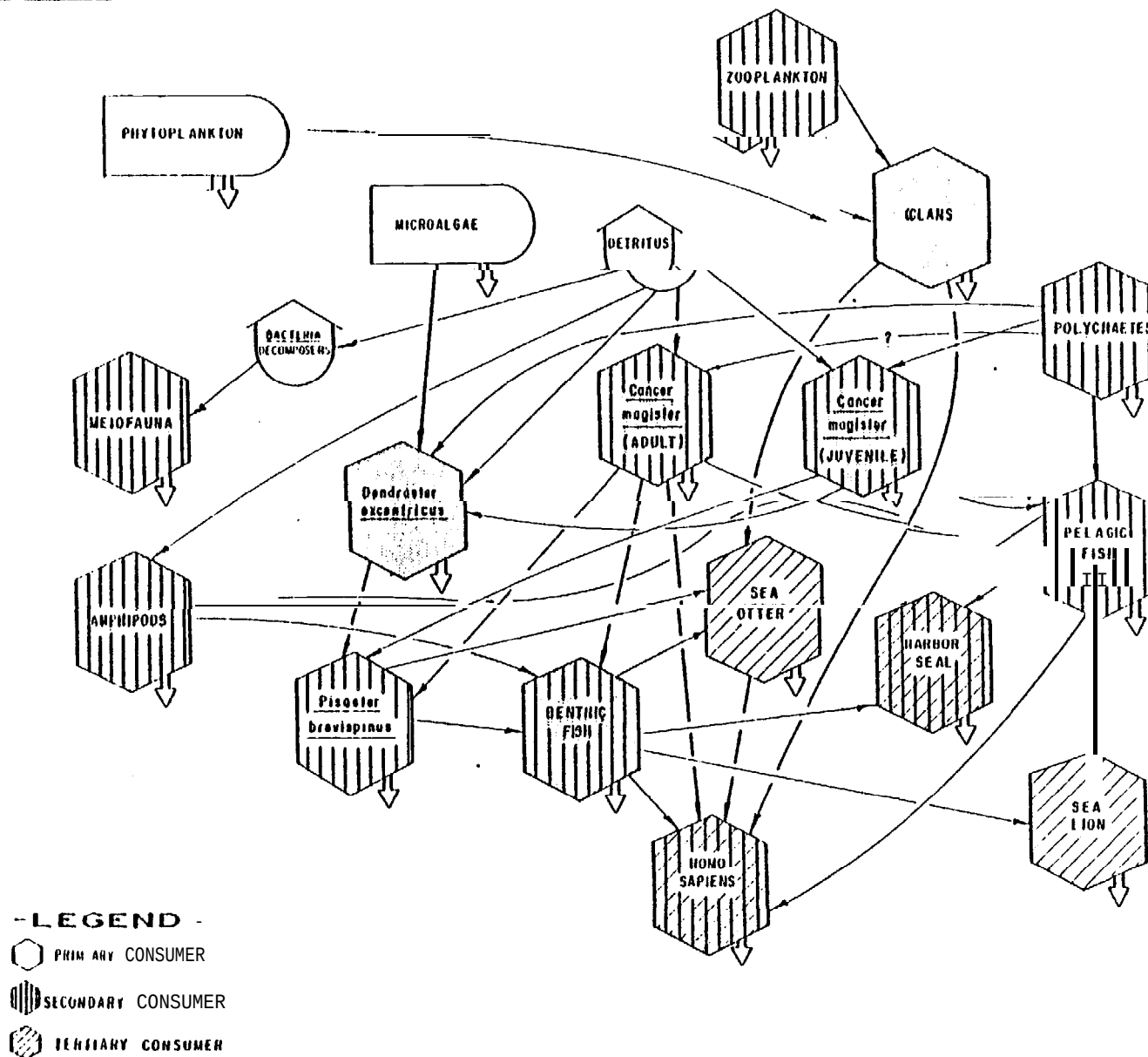


Figure 3-14 . Food Web Model of the [Unconsolidated Sand Bottom Habitat]

Scavengers

Amphipods
Diopatra ornata¹

Decomposes

Bacteria
Meiofauna

Species that are important to the subtidal sand habitat but cannot be assigned to any one trophic level include the meiofauna and amphipods. They enter the trophic system at all levels.

Community Dynamics. The contributions of episammic (restricted to sand grains) microalgae and diatoms to the food sources of the majority of dominant species in this area is relatively minor. The dominant species, like the tubiculous polychaetes, are largely dependent on detrital wash into their area for food. However, the importance of episammic microalgae and diatoms should not be underrated, as they probably provide a major portion of the food source of meiofauna and deposit feeders (e.g. Dendraster excentricus) in this habitat. Their importance to the system has not been studied to a great extent.

Another probable food resource for Diopatra is the macroalgae that are usually attached to sand grains that comprise the tubes of Diopatra. In southern California Diopatra ornata has been observed to "glue" drift giant kelp (Macrocystis) fragments to its tube. It utilizes the Macrocystis as a food resource and as a "canopy" to prevent detection by predators (Emerson, pers. comm.)

Both Diopatra ornata and Nothria elegans partake in the detrital food resource. Both have been observed to eat plant material (Fauchald and Jumars, 1979). Nothria elegans uses this resource at an early age in its development, but as it becomes older, it becomes omnivorous (Blake, 1975). Diopatra ornata has also been described as a scavenger (Rosenthal et al, 1974). Feeding experiments have shown that it will "accept any plant or animal material, dead or alive, fresh or rotten" (Emerson, in Fauchald and Jumars, 1979).

Amphipods can be placed in both the second and third trophic levels depending upon the particular species. Many of them are detritivores, as detritus is the most common nutrient resource to the sand habitat. They also utilize the episammic organic material as a food resource. Amphipods are an abundant, major food source for organisms in this habitat. J. L. Barnard's work (1961, 1963, 1966) contains extensive information on amphipods, and the reader is referred to his works for detailed information.

Predators in this habitat include the sea star Pisaster brevispinus and the Dungeness crab (Cancer magister). P. brevispinus is important as a predator and has been discussed above (see Biological Aspects, Species of Concern) in this section. It preys upon bivalves within the subtidal sand habitat, utilizing elongated tube feet to reach the animal (van Veldhuizen and Phillips, 1978). It also preys upon recently-settled organisms; such behavior could greatly affect the community structure of an area (van Veldhuizen and Phillips, 1978). Since P. brevispinus has such a wide diet preference, it affects many of the organisms which live in the sand habitat. The quantitative effects it has in this habitat have not been studied. Cancer magister is quite catholic in its diet. The major food source consists of other crabs, non-crab crustaceans, and worms (Dean, 1971). Its effects on community dynamics have not been researched.

Various pelagic and benthic fish feed upon the benthic organisms found in this habitat. The California sheephead (Pimelometopon pulchrum) is known to prey upon Diopatra ornata in southern California (Emerson, pers. comm.). The sheephead is not as abundant in northern California, and it is not known whether it is a major predator on Diopatra ornata in this region. Bottom-dwelling fish feed upon the crustaceans and worms in the area. Cancer magister has numerous fish predators (Dean, 1971) as well as its own cannibalistic tendencies during the soft-shell stage.

¹Confusion exists in the literature concerning the Diopatra ornata feeding moae (see Fauchald and Jumars, 1979).

Sandy Bottom Associated Fishes. The fish fauna of sand bottom habitats include species associated with shallow inshore and surf zones, demersal (or bottom dwelling) species, and species in the water column over deeper sandy bottoms. Within the study area, characteristic inshore fishes include the shiner and walleye surfperch, night smelt, and leopard shark (Engineering-Science and Moss Landing Marine Laboratory, 1979; Feder et al, 1974). The demersal fishes include the flatfish (sanddabs, soles halibut, and flounders) and skates and rays. The Pacific and speckled sanddabs are especially abundant species in sandy bottom habitats (Pearcy, 1978; Engineering-Science and Moss Landing Marine Laboratory, 1979). Fishes occurring within the water column over deeper sandy areas ("nekrobenthic" species; Pearcy, 1978) include rockfishes and spiny dogfish. These sandy bottom associated fishes include both live-bearing forms (perch, rockfish, and sharks) and egg-laying forms. The pelagic flatfish and rockfish larvae are important components of the ichthyoplankton.

Many of the fishes in this habitat feed upon organisms living in or on the sand, such as polychaete worms, amphipods, clams and echinoderms. Examples of such benthophagous ("bottom feeding") fishes are the rex and English sole, starry flounder, white croaker, Pacific butterfish, and bat ray. Other species, such as the shiner surfperch, Pacific and speckled sanddab, eat both planktonic and benthic organisms. Larger zooplankton (primarily euphausiids), squid, and other fish make up the diets of the sharks and rockfish. Seals, sea lions, and porpoises, as well as the California halibut, are important fish predators in this habitat.

Characteristic Sandy Bottom (Surf zone to 100 meters) Fishes:

<u>Hyperprosopon argenteum</u>	Walleye surfperch
<u>Cymatogaster aggregata</u>	Shiner surfperch
<u>Amphistichus rhodotermis</u>	Redtail surfperch
<u>Paralichthys californicus</u>	California halibut
<u>Parophrys vetulus</u>	English sole
<u>Psettichthys melanostictus</u>	Sand sole
<u>Platichthys stellatus</u>	Starry flounder
<u>Glyptocephalus zachirus</u>	Rex sole
<u>Citharichthys sigmaeus</u>	Speckled sanddab
<u>C. sordidus</u>	Pacific sanddab
<u>Chilara taylori</u>	Spotted cusk-eel
<u>Porichthys notatus</u>	Plainfin midshipman
<u>Microgadus proximus</u>	Pacific tomcod
<u>Pezilius similimus</u>	Pacific butterfish (pompano)
<u>Genyonemus lineatus</u>	White croaker
<u>Spirinchus starksi</u>	Night smelt
<u>Juvenile Sebastes goodei</u>	Chillipepper rockfish
<u>Juvenile S. paucispinis</u>	Bocaccio
<u>Squalus acanthias</u>	Spiny dogfish
<u>Triakis semifasciata</u>	Leopard shark
<u>Mustelus heniei</u>	Brown smoothhound shark
<u>Raja binoculata</u>	Big skate
<u>Myliobatis californica</u>	Bat ray

Bacteria and meiofauna contribute to the decomposer level of the food chain. Bacteria are most important because they "largely control the chemical nature of sedimentary environments" (Parsons et al, 1977). The "major impact of this meiofaunal community is its consumption of organic carbon and production of waste products such as CO₂ and remineralized nitrogen and phosphorus in the decomposer based food chain" (Cox, 1976).

Succession. Deeper water sand substratum communities tend to be in an equilibrium state, as they are not subject to major physical effects from water movement. They can, however, be disturbed by current pattern changes, or (on a microhabitat scale) by physical perturbations of benthic fish, or even by the infaunal organisms themselves turning over the sediment and/or producing waste products.

There is little quantitative information about succession in sandy bottom communities. It is known that temperature plays a major part in organismal succession (as does physical disturbance of the substratum). Certain organisms are sensitive to temperature variations, and their distributional patterns reflect this sensitivity. Amphipods are exemplary of this phenomenon as much of their distributional patterns are temperature-related (Barnard, 1966). Seasonality of certain species also contributed to succession.

Pearson and Rosenberg (1978) and Gray (1974) provide excellent coverage of the subject of succession, and the reader is referred to their works. Succession within a benthic community in Monterey Bay (as it relates to dredging and disposal) has been studied by Oliver and Slattery (1976) and Oliver et al. (1977).

Migration and Visitation. It has been shown that Dendroaster excentricus "migrates" inshore during periods of calmer water and offshore during turbulent waters (Oliver and Slattery, 1976). Amphipods may essentially have the same migrational pattern (Oliver and Slattery, 1976).

Cancer magister shows a south-to-north movement within its range from January to June. It also migrates along the coast and moves between inshore and offshore areas. Many tagging studies have been done on this highly mobile creature (Dean, 1971).

Pisaster brevispinus has not been studied as to migrational patterns, but due to their wide distribution (rocky reefs, wharf pilings and sand substratum), it would seem likely that they migrate at least in search of prey items.

Visitation from pelagic and benthic fish, as well as diving pelagic birds also occurs in this habitat.

Human Influences on this Habitat

The majority of benthic invertebrates possess a pelagic part of their life cycle. The pelagic part of the life cycle is extremely sensitive to environmental disturbances, including pollutants. Species of this habitat have pelagic larvae and are subject to pollutants in nearshore waters. Mileikovsky (1970) states that all aspects of pollution affects pelagic larvae under experimental conditions. Under natural conditions, however, pollutants affect the pelagic larvae only slightly. It is upon settlement that the larvae become subject to deleterious effects (on the assumption that higher concentrations of the various pollutants are found on the substratum). Mileikovsky presents an overview of the experiments which have been done concerning pelagic larvae and pollution.

Waste Discharge. Numerous studies have been conducted on the effects of waste discharge. Data from such studies are difficult to interpret, and comparisons are hard to make. It is known that benthic invertebrate numbers tend to increase near ocean sewage outfalls, possibly due to the added organics in the area. Associated with this increase in animals numbers is a general reduction in species diversity. This reduction may, in part, be due to die-off from the more numerous sensitive species, with the hardier species taking over the vacated "space." Refer to Winzler and Kelly (1977a) for a general treatment of waste discharge information related to subtidal benthic communities.

Diopatra ornata, one of the subtidal sand habitat's important species, is found near sewer outfalls in southern California (Emerson, pers. comm.). They also have been observed near Carmel Bay and Santa Cruz sewer outfalls (Kinnetic Laboratories, 1978, 1979). Little quantitative research has been done on this worm-outfall association.

Pesticides. Many studies have been done on the effect of pesticides on Cancer magister. Its numbers, in terms of commercial catch, have declined in recent years, and it is suggested that pesticides from agricultural run-off are one of the major causes of this decline. It has been shown that the stage in the crab's life cycle which is most sensitive to pesticides is the young larval stage of the crab (zoea stage). The insecticide Sevin has numerous deleterious effects upon different stages of the crab's life cycle besides the zoeal stage (Buchanan et al, 1970). Methoxychlor insecticide effects have also been studied (Armstrong et al, 1976). It has been shown that the fungicide Captan used in agricultural applications has less severe effects than the other pesticides (Caldwell et al, 1978). It was suggested by Caldwell et al that Captan, due to its low toxicity to the crab's larval stages and its high rate of degradation in the marine environment, did not affect the natural crab populations.

Oil. An extensive discussion of oil pollution is found in Winzler and Kelly's (1977a) summary of knowledge of the central and northern California coastal zone and offshore areas. Most of the effects of oil pollution have been studied for the intertidal zone, with few studies done for the subtidal region. Easton (1972) reported that the benthic infaunal community two years after the Santa Barbara oil spill still

had not re-established itself. It is very unusual for a benthic substratum to remain uninhabited for such a long period of time under normal conditions. It appears that the effects of oil pollution persist in the marine environment, and that little biodegradation of the oil occurs. The area around an oil spill tends to be anoxic due to the presence of oil-eating bacteria. This condition could severely restrict certain organisms from inhabiting a substratum in proximity to an oil spill due to lack of enough oxygen to support a large biomass.

Dredge Spoils Disposal. There has been little research concerning the effects of dredge spoils disposal on marine subtidal benthic communities. Much of what has been done only raises more questions, e.g., how can we tell what kinds of community disturbances are caused by disposal of dredged materials when we don't ever know what the community structure is? One dredge spoils disposal study in Monterey Bay (Oliver et al., 1977) identifies the problems needing further study. They point out that even though natural disturbances (e.g., wave-induced substratum motion, turbidity currents, bottom-feeding marine animals) are "extremely important in establishing and maintaining biological communities," there is still little information about the interactions of natural disturbances and communities. They did reach a generalized conclusion from this Monterey Bay work: benthic recovery from a dredge disposal deposition occurs within one to three years. They found that most of the infauna were destroyed at the center of the disturbance (the experimental disturbance was depositing a large amount of control sediment on an area of study). The first species that settled in the disturbed area were polychaetes and mobile crustaceans.

In another study in Monterey Bay, Oliver and Slaterry (1976) found that after a 15 cm layer of control sediment had been deposited at a control station, the polychaete Nothria elegans was one of the few animals whose abundance was not decreased by burial. In fact, Nothria not only burrowed through the substrate, it also constructed new tubes from this sediment.

Thermal Pollution. There are few studies on the direct implications of thermal changes to the species in the sandy habitat. Detailed studies have been conducted on thermal effects in selected species and are discussed below.

The effects of temperature on Cancer magister have been well documented. The crab's distribution is reported to be bounded by surface water isotherms of 75° and 40° F (see Dean, 1971). Reed (1969) found that C. magister larvae (zoea stage) growth rates were directly related to temperature. As temperature decreases, the zoea growth rate decreases. See Winzler and Kelly (1977a) for a literature review of this topic and Dean (1971) for more information about temperature effects and ranges for C. magister. The species of concern write-up in Volume II, part 2 of this report on Cancer magister discusses the Reed (1969) study in more detail.

It has been shown that temperature affects the thickness and structure of the tests (exoskeletons) of Dendraster excentricus (Raup, 1958). Generally, exoskeletons were found to weigh more in cold water than in warm water. Whether thinner shells would be detrimental to the species was not discussed, as Raup's paper dealt with the paleoecology of this species.

Temperature greatly affects the distribution of benthic amphipods (Barnard, 1966). From a successional viewpoint, amphipods would be very important animals to investigate in studying the disturbance created by a thermal outfall, although such studies are yet to be undertaken. Since they are highly sensitive to changes in the environmental regime (such as temperature) they could provide useful information concerning succession. They are ubiquitous and are abundant in marine environments.

Recreational Uses. The sandy habitat is used recreationally as a fishing base for benthic fish and Cancer magister. Trawling is the most common method for capturing these creatures. Trawling also disturbs the ocean floor. No studies have been done on trawling's effects on sandy subtidal benthic communities.

COBBLE/GRAVEL HABITAT

The cobble/gravel habitat consists of unconsolidated substratum with particle sizes ranging from 2 mm to 4.6 cm (gravel) and 4.6 cm to 25.4 cm (cobble). Cobble and gravel are usually found with a mixture of sand or silt and are characteristic of high energy beaches or areas of river deposition (Shepard, 1963; Komer, 1976).

Gravel is an uncommon substratum in the subtidal areas of northern and central California, and no cobble is indicated (Welday and Williams, 1975). Most of the

known gravel deposits occur 60 to 80 meters deep, but one area off Cape Mendocino is at 345 meters. Many of the shallower areas of gravel may be Pleistocene beach deposits which resulted from the lowered sea level during that period (Susan Chinberg, pers. comm.).

Galliher (1932) and Hartman (1963) found gravel overlaid with silt in the Monterey submarine canyon. Galliher theorized that these substrata were reworked material from river or delta deposits which were originally transported from the bordering coastal mountains.

Cobble/gravel communities have been little studied for reasons in addition to the fact that the substrata are rare in the study area. Cobble/gravel substrata usually contain very few species or organisms (Galliher, 1932; Hartman, 1963; Kinnetic Laboratories, 1976). The particles are too large to provide acceptable habitat for the typical infauna in the absence of finer particles. This would be especially true for detritivores. In areas where cobble and gravel dominate, the species tend toward those sessile forms typical of rock bottoms (Kinnetic Laboratories, 1977, 1978). Another reason that cobble/gravel substrata have not been studied to any degree is the difficulty with which quantitative grab samplers penetrate them. Devices designed to sample softer substrata do poorly in cobble and gravel.

In the nearshore areas cobble and gravel are often indicative of a high energy region in which water movement is great enough to prevent the finer particles from settling and accumulating. The strength of wave action is usually great enough to also periodically move the cobble and gravel as well. This mechanical disturbance, depending on its frequency, may also prevent the establishment of any stable or breeding populations. The species which are found in these areas are an indication of the period between disturbances (Osman, 1977).

In conclusion, subtidal cobble and gravel substrata deserve habitat status in definition only. They result from numerous causes, precluding a common, unifying community of organisms. Only in deeper, quieter waters in association with sand or silt do they support much life, and then it is that typical of the finer substrata.

ORGANIC HABITAT

Cowardin et al (1979) describe the organic subclass as unconsolidated material smaller than stones, predominantly composed of organic material. The subtidal benthic regions (excluding enclosed bays and estuaries) that have greater than 50 percent organic material occur outside of the present study area (below 1000 meters depth and/or outside of central and northern California). The subtidal organic material in the study area is a component of the substratum rather than a representative benthic habitat.

The composition of organic material and its distribution in the subtidal benthic zone (excluding enclosed bays and estuaries) is determined by plankton productivity and sedimentation rates. Normally coastal waters have high productivity and high rates of sedimentation (Sokolova, 1972). High organic input to coastal sediments is expected with high primary productivity and shallow water depth (Parsons et al, 1977). However, because of high bacterial numbers and metabolic processes occurring in surface sediment layers, the turnover of organic material into inorganic compounds is rapid. If oxidation is incomplete on the sediment surface, the interdependence of the carbon, nitrogen and sulfur cycles in sediments ensures that the end products serve as substrata for other metabolic processes (Parsons et al, 1977). There seems to be no correspondence between faunal abundance and total organic sediment content; the variations in biomass are related to other controlling factors (Parsons et al, 1977).

In the open ocean, most organic material produced in the upper layers is broken down in the upper 200 meters (Sokolova, 1972). Parsons et al (1977) suggest that 70-90 percent of the organic material is mineralized in the upper layers. Organic material that does reach the bottom serves as food for detritus- and filter-feeders or is oxidized into inorganic forms. In areas of low rates of sedimentation organic material may accumulate, but this occurs only in the deep sea. Oligotrophic conditions can occur in these areas. The organic material remains on the bottom surface long enough to be buried in a transformed state resistant to biochemical oxidation and hence it is of little nutritive value (Sokolova, 1972).

In southern California a Globigerina ooze occurs on the ridge separating the continental slope from the outer borderland. Globigerina spp., planktonic foraminiferans, are the dominant organisms. These oozes have not been found in central or northern California (Uchupi and Emery, 1963).

In summary, organic material is viewed as a component of the subtidal benthic substratum and not as an individual habitat. Biological processes (feeding of benthic invertebrates, bacterial decomposition), physical processes (sedimentation and resuspension), and chemical processes (oxidation, carbon and nitrogen cycles) serve to break down organic materials that are not mineralized in the upper water layers. The subtidal organic sediments that do occur are deeper than 1000 meters or are geographically out of the study area (Uchupi and Emery, 1963).

AQUATIC BEDS

Aquatic beds occur on rocky substrata along the Pacific coast and consist of three major groups of marine algae and one group of vascular plants (seagrasses). The algae form extensive communities in the subtidal regions while the seagrasses are primarily intertidal or in bays or estuaries.

SUBMERGED VASCULAR PLANTS

Three species of vascular plants are found along the coast of California. Zostera marina (eel grass) occurs in bays and estuaries and anchors itself in muddy substratum. Phyllospadix scouleri and P. torreyi (surf grasses) occur along the outer coast where they form extensive intertidal communities attached to rock or hard substratum at about the MLLW (0.0 feet) tidal level. There are no well-defined subtidal populations of these flowering plants along the outer coast of northern or central California (Turhollow, pers. comm.). Isolated subtidal individuals occur down to 10 meters depth, but not in dense enough numbers to describe as a habitat type. Subtidal populations of Phyllospadix do occur south of Point Conception and are important as nurseries for lobsters, sediment traps, and as sources of plant detritus. Refer to the intertidal section for the biology and distribution of marine angiosperms along northern and central California.

SUBMERGED ALGAL BEDS

Introduction

The submerged algal bed habitat type is characterized by communities of algal species that occur below MLLW tidal datum.

Substratum Type. Submerged algal beds grow attached to rocky bottoms or other solid objects. They are usually not found in areas of soft substratum (e.g. sand, mud) although in southern California giant kelp (Macrocystis) is reported to grow from a muddy substratum (State Water Quality Control Board, 1964a; North, 1971).

Areal Extent. Submerged algal beds are present along the entire California coast where suitable substratum is available.

Dominant Species. The most prevalent and conspicuous species include giant kelp (Macrocystis pyrifera), bull kelp (Nereocystis luetkeana), pea pod kelp (Cystoseira osmundacea), feather boa kelp (Egregia menziesii), and coralline red algae (numerous species).

Habitat Indicators. This habitat type is recognized by the presence of numerous species of relatively small bladelike algae (seaweeds) covering the bottom and most conspicuously by nearshore beds of large brown algae (kelps) which often reach the surface and are visible from land.

Habitat Characterization

Geographic Aspects. Submerged algal beds occur along the entire California coast from the lowest reaches of the intertidal zone to depths of over 30 meters in certain areas. Hence they are restricted to mostly shallow depths of the subtidal region immediately adjacent to the shoreline where there is sufficient light penetration for photosynthesis. California Department of Fish and Game estimated that 15.5 square miles of Macrocystis canopy exist from Point Arguello to Half Moon Bay, California (Miller and Gelbel, 1973).

Physical Aspects. Substratum type has both a direct and indirect effect on the distribution of submerged algae. Macroalgae need a firm substratum for attachment, and large populations will be found only where suitable hard bottom is available. Water transparency, which determines the depth to which algae can photosynthesize is affected by substratum type. Turbidity of the water column is much higher in regions of shale or mudstone bottom than in regions of granitic substratum. The softer shale or mudstone strata erode faster and release silt and clay particles which remain suspended. The coastline of California has both granitic material and softer sedimentary substrata. The offshore basin descriptions of this report map the geographic ranges of substratum type.

Water movement through submerged algal beds can be very strong because the beds occur in shallow water (generally less than 30 meters). Algal beds are exposed to large swells during winter storms which impact the coast with considerable force. These storms are responsible for uprooting algal plants and reducing the biomass of attached algae over large areas (Gerard, 1976).

All marine algae require inorganic nutrients for growth. Since algae lack true roots they must obtain these nutrients by diffusion from the water. For algal beds to flourish there must be an ample supply of nutrients available to the plants during their peak growing season. Upwelling along the California coast during spring and summer replaces surface waters with cold nutrient-rich water from deeper depths. Since upwelling occurs during the period of maximum solar radiation, photosynthesis is maximal and algal growth is enhanced (Miller and Geibel, 1973; Gerard, 1976). The geographic distribution of submerged algal beds roughly correlates with areas of the world where upwelling occurs. Nutrient values in nearshore aquatic beds, however, fluctuate randomly with no apparent trends or seasonal changes (Gerard, 1976). The supply and concentration of nutrients is related to biological processes, oceanographic events (upwelling), and local effects such as runoff and concentrations of bird and mammal populations.

Salinities in aquatic beds approach those of the open ocean and range between 33 to 35 o/oo (parts per thousand). Where aquatic beds occur along the open coast salinities are fairly constant and therefore is not a factor in the overall distribution of species.

According to North (1971) the outer limit of kelp beds is probably determined by light intensity at the bottom. Light penetration to the bottom depends on water turbidity (which is influenced by substratum type), plankton blooms which increase turbidity, and shading by certain algal species which have part of their biomass at or near the surface. In turbid waters algal beds are limited to depths of 10 to 15 meters, while in clear waters they often occur at depths of 25 to 30 meters.

On a geographic level, temperature is perhaps most important in determining species distribution of algae (North, 1971). The mean temperature difference at 10 meters depth between Cape Mendocino and Point Conception is 3° C (Winzler and Kelly, 1977a). This temperature range is not as extreme as terrestrial temperature differences between the two areas. Consequently, many algal species are found throughout the entire coastal range. However, localized surface temperature increases greater than 18° C occurring during summer may contribute to the deterioration of Macrocystis and other algal species (State Water Quality Control Board, 1964b). The typical California marine flora contains a mixture of warm- and cold-water species, the proportions varying according to the local temperature climate. Intertidal communities have a higher proportion of warm-water species compared to subtidal populations in the same vicinity, and proportions of warm-tolerant species are higher where geographic and oceanographic conditions create locally warmer climates (i.e., areas of downwelling, gulfs, inlets, and bay entrances) (Abbott and North, 1971).

Biological Aspects. A vertical profile through a typical healthy submerged algal bed would reveal a four-layered system. The top or surface layer consists of one or more of the following species: Macrocystis, Nereocystis, Cystoseira, and Egregia. These algae have fronds which grow from the bottom towards the surface and are buoyed up by gas-filled floats (pneumatocysts). On reaching the surface these fronds continue to grow and extend horizontally along the surface forming a canopy. This layer may be as much as a meter in thickness depending on the species present. A second layer extending one to three meters above the bottom is dominated by species of Laminaria and Pterygophora which form a midwater canopy. These algae lack gas-filled floats for buoyancy, but instead have semi-rigid stalks (stipes) for support. Numerous species of red, brown, and sometimes green algae form a third layer of a submerged algal bed. These species are generally smaller in size than those forming the surface and midwater canopies, and many are blade-like, jointed, or filamentous in appearance. These species cover the immediate bottom and are often so numerous as to completely obscure

the underlying substrata . These bottom two layers are commonly referred to as "understory." The fourth component of this system is the encrusting layer composed primarily of crustose coralline and other encrusting red algal species. These algae grow over the surface of exposed rock rather than sending the vegetative part up into the water column. This layered system is comparable to the vertical structure of vegetation in terrestrial forests (Neushul, 1971) . The term kelp forest has been used to represent an algal bed dominated by Macrocystis because of this close analogy.

Community Composition. Submerged algal beds in California are dominated by species of kelps and in central and southern California the dominant kelp is Macrocystis. Gerard (1976) studied the seasonal cycles of kelp growth and decay from a kelp bed at Hopkins Marine Life Refuge in southern Monterey Bay. The biomass of Macrocystis ranged between 0.7 to 6.3 kg wet weight/meter². The annual productivity (unt of Macrocystis produced) of this bed was estimated at 23 kg/meter² or 230 wet metric tons/hectare/year. Miller and Geibel (1973) estimated the productivity of a nearby Macrocystis bed in Monterey at 34.1 wet tons/acre/year (or 76.4 wet metric tons/hectare/year) . However, Miller and Geibel's estimate was from a Macrocystis bed which they harvested three times per year. North (1971) estimated the biomass of a southern California Macrocystis bed at 3 to 22 kg/meter² wet weight.

According to Gerard (1976), "only a small proportion of the net primary production (probably less than ten percent) is directly consumed by grazers. Part of the production is lost as detritus and dissolved organic material, but most becomes drift algae. This drift component may add stability to the community structure, because drift consumers utilize material which has already been lost from the producer biomass, and do not directly affect or limit the primary productivity." Pearse and Hines (1977) have been looking at the primary, secondary, and tertiary consumers within a Monterey Bay kelp forest in an attempt to quantify the energy flow through these trophic levels.

Following is a list of representative kelp bed species of central and northern California and their position in the trophic structure of the community.

First Trophic Level.

Producers

<u>Macrocystis pyrifera</u>	Giant kelp
<u>Nereocystis luetkeana</u>	Bull kelp
<u>Pterygophora californica</u>	Tree kelp
<u>Cystoseira osmundacea</u>	Pea pod kelp
<u>Laminaria dentigera</u>	Oak kelp
Other macroalgal species	
Phytoplankton	

Second Trophic Level.

Herbivores

<u>Haliotis</u> spp.	Abalones
<u>Strongylocentrotus</u> spp.	Sea urchins
<u>Tegula</u> spp.	Turban snails
<u>Pugettia products</u>	Northern kelp crab
<u>Cryptochiton stelleri</u>	Pacific giant chiton
<u>Tonicella lineata</u>	Lined chiton

Omnivores

<u>Patiria miniata</u>	Bat star
<u>Calliostoma canaliculatum</u>	Channeled top shell
<u>Calliostoma annulatum</u>	Purple-ringed top shell
<u>Diopatra ornata</u>	Ornate tube worm
<u>Loxorhynchus crispatus</u>	Masking crab

Filter Feeders and Suspension Feeders

<u>Eudistylia polymorpha</u>	Feather duster worm
<u>Acanus erichacus</u>	Red volcano sponge
<u>Balanus</u> spp.	Barnacles
<u>Tethya aurantia</u>	Orange puffball sponge
<u>Serpula vermicularis</u>	Plume worm

Hinnites giganteus
Hippodiplosia insculpta
Phidolopora pacifica
Cucumaria miniata
Styela monterevensis
Cystodytes lobatus
Clavelina huntsmani
Petalconchus monterevensis
Corynactis californica
Balanophyllia elegans
Paracyathus stearnsii

Rock scallop
Wavy bryozoan
Lacy bryozoan
Orange sea cucumber
Stalked tunicate
Lobed tunicate
Light bulb tunicate
Worm shell
Strawberry anemone
Orange cup coral
Brown cup coral

Third Trophic Level.

Predators:

Pisaster giganteus
Pycnopodia helianthoides
Solaster dawsoni
Tealia spp.
Anthopleura xanthogrammica
Ceratostoma foliatum
Calliostoma ligatum
Anisodoris nobilis
Dendrodoris albopunctata
Discodoris sandiegensis
Octopus spp.
Henricia leviuscula
Demasterias imbricata
Marine mammals
Various fish species

Giant-spined sea star
Sunflower star
Morning sun star
Sea anemones
Giant green anemone
Leafy hornmouth snail
Blue top shell
Sea lemon
White-speckled nudibranch
Ringed nudibranch
Octopuses
Blood star
Leather star

Scavengers:

Cancer antennarius
Mimulus foliatus
Pagurus spp. and allies
Parastichopus californicus
Ophiothrix spiculata

Rock crab
Mimicking crab
Hermit crabs
California sea cucumber (detritus)
Spiny brittle star (detritus)

Representative Fishes. Kelp beds provide fishes with shelter and food. The individuals of some species (e.g., the clingfish) go through their entire life history within a kelp bed, while other species enter the kelp bed after a pelagic larval stage (e.g., the rockfishes). Kelp beds provide a refuge for the juvenile stages of a number of rockfish species. In general, kelp bed fishes are predators on the small crustaceans associated with the kelp plants such as gammarid and caprellid amphipods, isopods, and small crabs. Ingestion of algae appears occasionally and may be coincidental to predation upon the associated invertebrates. Kelp bass, kelp rockfish, grass rockfish, and olive rockfish prey upon cephalopods (squid and octopuses) and smaller fish as well as crustacea.

Brachyistius frenatus
Damalichthys vacca
Embiotoca lateralis
Rimicola muscarum
Oxyjulis californica
Hexagrammos decagrammus
Ophiodon elongatus
Scorpaenichthys marmoratus
Oligocottus rimensis
Gibbonsia metzi
Heterostichus rostratus
Apodichthys flavidus
Paralabrax clathratus
Sebastes atrovirens
S. carnatus
S. onrysomelas
S. mystinus
S. rosenblatti
S. serranoides

Kelp surfperch
Pile surfperch
Striped surfperch
Kelp clingfish
Señorita
Kelp greenling
Lingcod
Cabezon
Saddleback sculpin
Striped kelpfish
Giant kelpfish
Penpoint gunnel
Kelp bass
Kelp rockfish
Gopher rockfish
Black-and-yellow rockfish
Blue rockfish
Grass rockfish
Olive rockfish

Also juvenile rockfishes:

<u>Sebastes mystinus</u>	Blue rockfish
<u>S. jordanii</u>	Shortbelly rockfish
<u>S. entomelas</u>	Widow rockfish
<u>S. serranoides</u>	Olive rockfish
<u>S. flavidus</u>	Yellowtail rockfish
<u>S. pinniger</u>	Canary rockfish
<u>S. caurinus</u>	Copper rockfish
<u>S. melanops</u>	Black rockfish
<u>S. ovalis</u>	Speckled rockfish

Marine Mammals Associated with Kelp Beds. The sea otter and harbor seals are year-long residents of the kelp bed and rocky shoreline areas. Both are involved in the kelp bed food web dynamics. The sea otter preys primarily on benthic molluscs (abalone, limpets, chitons, snails), echinoderms (sea urchins) and crabs. The harbor seal preys upon the kelp fishes.

<u>Enhydra lutris</u>	Sea otter
<u>Phoca vitulina</u>	Harbor seal

Community Dynamics. A typical submerged algal bed is represented by a kelp forest with Macrocystis occurring as the dominant species in the south and Nereocystis in the northern part of California. These two algae are the primary producers within the habitat, and together with other algal species form the base of the food web (see Figures 3-15 and 3-16). Three pathways lead to the next trophic level. The first is direct grazing on the plants by snails (Tegula spp.), sea urchins (Strongylocentrotus spp.), and to some extent crabs (Pugettia products). This pathway probably amounts to no more than about four percent of the total production (Pearse and Hines, 1977). A second pathway involves consumption of decaying kelp detritus by animals such as the snail Petalochonchus and sea cucumbers (Cucumaria spp.). A third and major pathway is the consumption of detached drift algae by benthic herbivores, such as abalones (Haliotis spp.), sea urchins, bat stars (Patiria), crabs (Loxorhynchus), and snails (Tegula spp.). Consumption of drift algae by these species may account for up to 30 percent of the total algal production, effectively recycling this resource within the food web of the kelp forest (Pearse and Hines, 1977). The herbivores are preyed upon by sea stars (Pycnopodia and Pisaster) and more heavily by the sea otter (Enhydra lutris). Scavengers of dead organisms include crabs (Cancer spp.) and the omnivorous sea star Patiria. Decomposition and nutrient recycling occur by the action of marine bacteria on dead organic material.

The ecology of kelp beds is discussed by North (1971). He lists five roles that Macrocystis plays in the community:

- 1) Primary producer of organic matter.
- 2) Provider of shelter and crevice environments. Macrocystis holdfasts support an assemblage of organisms of their own (Ghelardi, 1971).
- 3) Provider of substratum for encrusting organisms (see Wing and Clendenning, 1971).
- 4) Shades the bottom, modifying vegetation by affecting photosynthesis, and attracting animals that avoid high light intensity.
- 5) Competes with water in radiant energy absorption by means of floating material (canopy).

Macrocystis is an important species not only because it supplies food to a large number of animals, but also because it provides organisms with additional surface area for attachment and concealment in an environment where there is much competition for space. In this regard, Macrocystis is a keystone species, and its disappearance results in the absence of many organisms.

Heavy grazing by benthic herbivores, particularly sea urchins, has resulted in disappearances of entire kelp beds in southern California. Urchins feed on newly recruited juvenile plants, preventing re-establishment of an adult canopy, and on the holdfasts of adult plants, weakening them and increasing the chance of being dislodged during storm swells (Leighton, 1971). When urchins are removed from a kelp forest, there is a dramatic increase in the structure and production of the community (State Water Quality Control Board, 1964a; Pearse and Hines, 1977).

The re-establishment of the sea otter (Enhydra lutris), the major predator of benthic herbivores in central California, has reduced the population of large herbivores to the extent that there is no commercial or sport fishery for abalones or sea

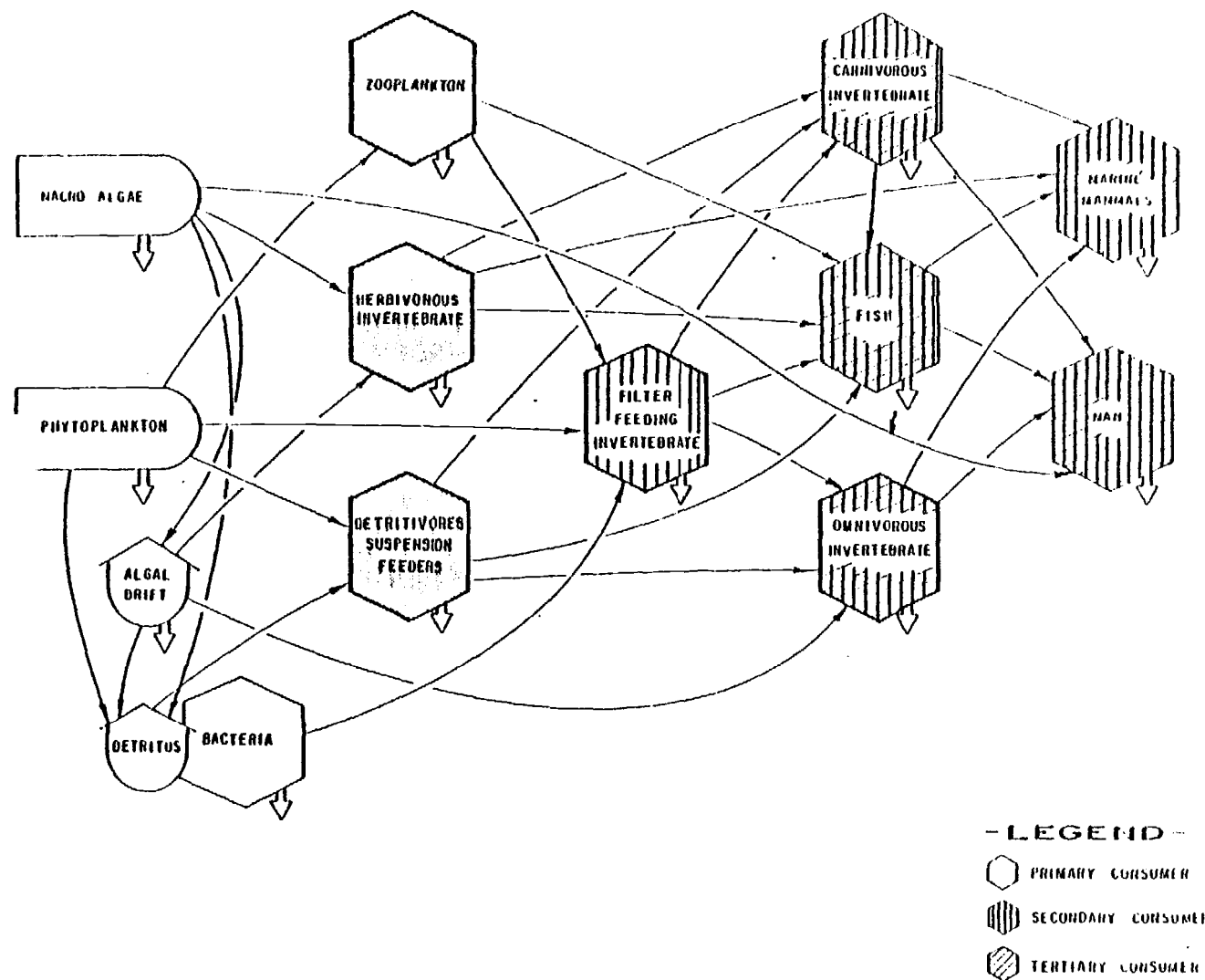


Figure 3-15. General Food Web Model of the Submerged Aquatic Beds Habitat.

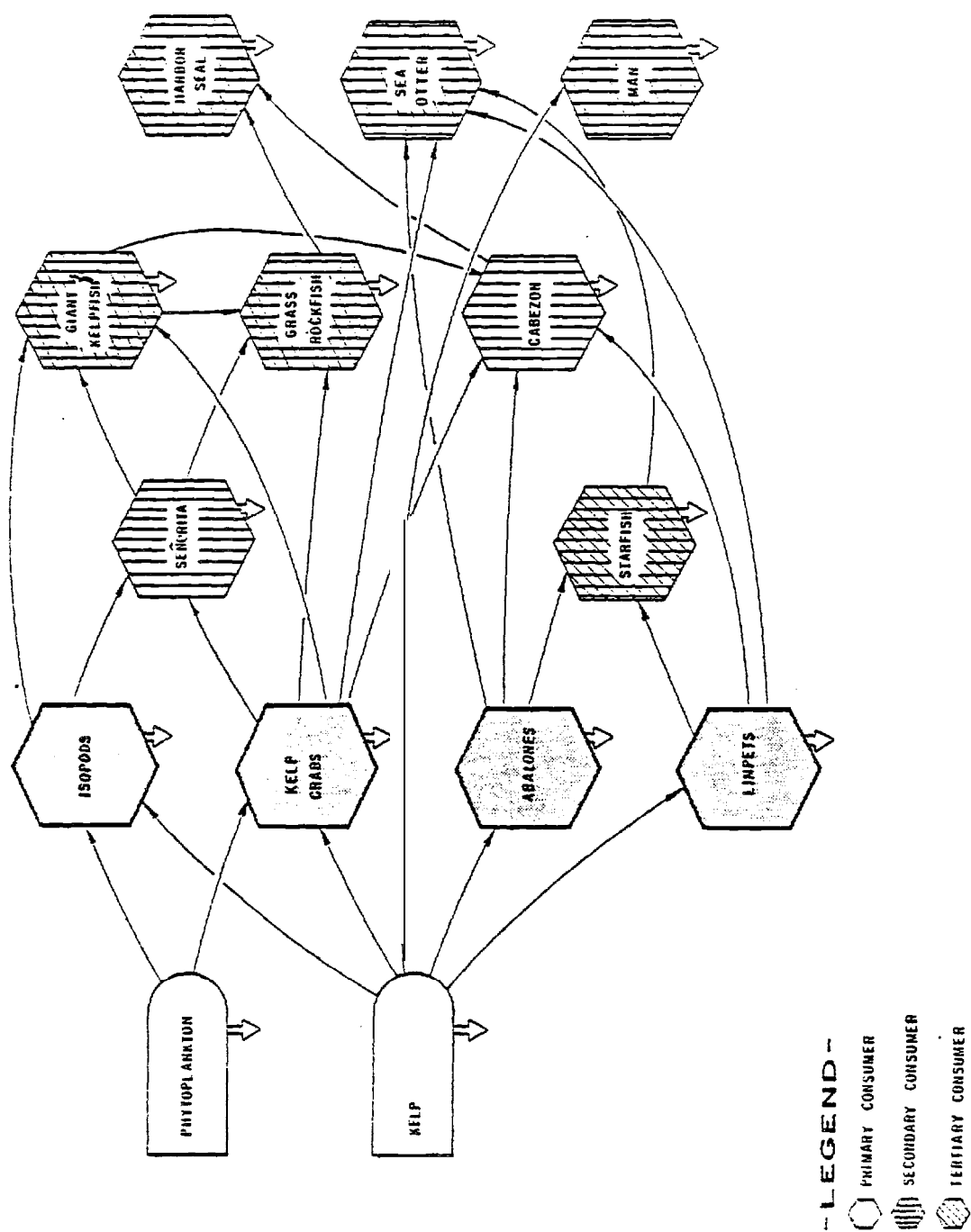


Figure 3-16. Food Web Model of the Kelp Bed Habitat

urchins within the heavy foraging range of the sea otter (Miller and Geibel, 1973). Ongoing research in central California is attempting to evaluate the effects of sea otter foraging in kelp beds by comparing kelp bed communities within the sea otter's range with those outside the current range Yellin *et al*, 1977; Foster *et al*, 1979). Additional studies are being conducted to develop a cohesive model of the energy flow and material cycling within a kelp forest in Monterey Bay within the present range of the sea otter, and to investigate the roles of sea otters, fish, sea stars, and predatory anthozoans in regulating the populations of herbivores (Pearse and Hines, 1977).

Succession. Successions in *Macrocystis* beds do not follow a single well-defined pattern (North, 1971). "Recruitment of juvenile kelp plants is typically low in a dense kelp forest, because shading by the canopy prevents their growth. Periodically, high plant losses, due to storms, reduce plant density to an extremely low level and allow sufficient amounts of light to reach the forest floor for the growth of juvenile sporophytes. This large recruitment results in a kelp population characterized by a high density of small plants (up to 200/meter²). If no extremely stormy years occur, the mean density will decrease and the mean size increase, as individual plants grow larger. Eventually, equilibrium density and size distributions are reached, and these may be maintained until a period of intense storms initiates a new cycle" (Gerard, 1976).

In other cases kelp plants disappear completely and not even juveniles are present. This pattern may occur in areas where there is intensive grazing by sea urchins (North, 1971). The urchins consume all vegetation except for coralline algae and prevent recolonization by juveniles. When urchin concentrations diminish due to starvation or migration, conditions again become favorable for massive algal development. However, there is no predictable succession series. Rather, colonization is fortuitous and probably determined by the species of plant spores present. Small filamentous algal forms (*Ectocarpus*, *Polysiphonia*) or diatoms often dominate the early stages of plant restoration. Which species will follow, however, is unpredictable. The climax is not always *Macrocystis*, even in areas where giant kelp formerly had been dominant. Understory species, once established, can form thick covers that prevent establishment of juvenile *Macrocystis*. If, however, a few *Macrocystis* develop before other species effectively shade the bottom, the succession usually proceeds to a climax forest of giant kelp (North, 1971). For an account of the succession of benthic foliose and encrusting species see Foster (1975a).

Migration and Visitation. Many of the filter feeding invertebrates living in an aquatic bed are sessile forms that rely on currents and water circulation for their food supply. Seasonal successions of plankton which occur along the entire California coast supplement the local availability of planktonic forms within the aquatic bed habitat. There are generally pulses of phytoplankters and zooplankters throughout the year which migrate through aquatic beds such that food supply for filter feeders is rarely limiting. Species of commercially important fish such as the lingcod often migrate into kelp beds from deeper offshore areas to spawn (Miller and Geibel, 1973). Other fish species (e.g., rockfishes) spend their juvenile life stages in kelp beds before moving out. Marine mammals (sea otters, harbor seals, sea lions) occasionally visit kelp beds to feed.

Interactions with Neighboring Habitats. 'Erie export products from a submerged algal bed are gametes, spores and larvae from living organisms, dissolved organics from plants, and detritus and nutrients from dead and decaying forms. Probably the most important export item is algal drift, which is an available energy source utilized by organisms within an algal bed, but is also carried by currents and surge to other benthic habitats that have no primary productivity of their own. In these other habitats, it can be consumed directly by omnivorous feeders or broken down and utilized by other organisms such as detritus feeders and suspension feeders. Large numbers of the persimmon eelpout (*Myxine californica*), heretofore a rarely reported fish, have been found inhabiting *Macrocystis* drift at depths of 119 meters in the Monterey submarine canyon, a location over 15 km from the nearest kelp beds (Cailliet and Lea, 1977). This is evidence that drift algae can be carried long distances and be made available to a large number of communities.

Human Influences on this Habitat

Waste Discharge. Domestic and industrial wastes discharging into the ocean were thought to have harmful effects on a kelp bed in southern California (State Water Quality Control Board, 1964a). Several mechanisms for the observed deterioration were proposed by the State Water Quality Control Board (1964a). These were:

- 1) Toxicity to Macrocystis and other algal sporophytes and gametophytes.
- 2) Turbidity of the water within the discharge field of the outfall resulting in reduced photosynthesis.
- 3) Concentrations of grazers, pathogens, or parasites might be increased by the effluent with adverse effects on kelp and other algae.
- 4) Siltation from settling of suspended solids discharged by the outfall might reduce photosynthesis within the leaves and prevent spores and gametophytes from finding a suitable settling location.

Studies done in southern California of these municipal waste discharge areas concluded that an adverse influence had been exerted on the kelp beds by discharge wastes. Of the mechanisms investigated, toxic effects, sedimentation, and disease or deleterious action by microorganisms were less likely to destroy kelp beds than grazing herbivores whose populations flourished in the vicinity of the outfalls due to uptake of dissolved organics present in the effluent (State Water Quality Control Board, 1964a). Monitoring studies of a low volume domestic sewage outfall in central California have failed to reveal any changes in the community composition of a kelp bed that can be directly related to the presence of effluent (Kinnetic Laboratories, Inc., 1977).

Oil. The effects of oil on submerged algal beds are poorly known. The oil spill from the wrecked tanker Tampico Maru left little evidence of damage to the giant kelp Macrocystis and, in fact, Macrocystis plants increased in number after the oil spill. This increase was attributed to the release of grazing pressure on Macrocystis plants following destruction of sea urchins by the oil (Winzler and Kelly, 1977a). Laboratory experiments by Clendenning and North (1960) demonstrated that 100 ml/liter (10 percent) of boiler fuel oil and diesel fuel oil were injurious in 12 to 48 hours to Macrocystis, and concentrations of emulsified fuel oils greater than 10 ml/liter (one percent) were also deemed to be deleterious. Other studies following oil spills have dealt primarily with impacts on the intertidal zone (Winzler and Kelly, 1977a).

Thermal Pollution. The California marine flora contain a mixture of warm and cold water species. Intertidal communities have a higher proportion of warm water species compared to subtidal communities in the same vicinity (Abbott and North, 1971). These authors concluded that an elevation of the offshore natural ambient water temperature by 1° to 6° C, resulting from electrical generating plants, would result in the proliferation of warm tolerant species, and the disappearance of cold water species. Others believe that thermal enrichment of coastal waters could result in severe damage to seaweed communities, especially kelps. When water temperatures reach 19° C and above, Macrocystis growth is slowed down and the plant begins to deteriorate. If the temperature of the water rises much above 20° C, whole beds may disappear entirely (Chapman, 1950). If thermal wastes are injected into the environment, water temperatures may remain above 19° C for some distance from the warm water effluent. Any kelp beds within an area so influenced will soon disappear along with the community of marine organisms associated with them (Frey, 1971).

Kelp Harvesting. Giant kelp, Macrocystis pyrifera, has been harvested commercially in California since 1911 (Scofield, 1959). The major Macrocystis beds of California have been numbered, and designated beds may be leased from the State for 20-year periods. Commercial kelp harvesters may lease 72 percent of the kelp beds in California. The remaining 28 percent are not leased and may be harvested by any company. Present kelp harvesting restrictions are: the harvester must obtain a permit issued by the California Fish and Game Commission, kelp may not be cut to a depth to exceed four feet beneath the surface, all kelp cut must be taken aboard the harvesting vessel, and drift kelp may be harvested. North of Point Arguello no more than five percent Nereocystis can be present in any load of kelp cut in the leased beds. There are no restrictions on tonnage that can be removed each year nor on the frequency of cutting (Miller and Geibel, 1973). Though there are no state limits to harvesting frequency, a maximum of two harvests per year is often a condition of the kelp bed lease agreement.

The use of marine algae for extraction of chemical products is continuing to expand (see the Species of Concern/Interest discussion for commercial uses of kelp). Because of the increasing demand for kelp and kelp products, studies have been conducted to assess the effects of kelp harvesting and canopy removal on the kelp bed community (North and Hubbs, 1968) and on the kelp plants themselves and their ability to survive and degenerate new tissue after harvesting (Miller and Geibel, 1973). The question of harvesting frequency is one that has not yet been resolved. None of the experiments conducted on giant kelp have adequately determined the optimum number of times a canopy can be removed each year from each kelp bed as not to adversely affect the kelp plants or the juvenile fishes and other organisms frequenting the area.

Southern California experiments have indicated three cuttings per year are maximum, but studies in Monterey Bay indicate three cuttings per year are excessive (Miller and Geibel, 1973). Recent experiments in Monterey Bay (McCleneghan and Houk, unpublished manuscript) have indicated that loss of entire Macrocystis plants as a direct result of harvesting should be minimal in healthy kelp beds. They advise, however, that in order to maximize survivorship of Macrocystis in central California, canopy cutting should be carried out during the fast growth periods of late spring and early summer, and that no plants be cut more than once annually.

Recreational Uses. Human activities on or in a kelp bed do not necessarily affect the species of algae growing there, but may impinge on other members of the kelp bed community. Because of the rich marine life found associated with submerged algal beds and the ever-increasing sport of SCUBA diving, more and more people are entering the kelp forest firsthand both for game procurement, diving instruction, and general recreation and observation (Miller et al, 1974). It is difficult to assess the direct impacts resulting from these activities because records of fish and shellfish taken in this manner are not as readily available as they are from the commercial fishing industry. One would expect, however, that the greatest impact would be seen in those areas which have the highest frequency of use. Reductions in bag limits, shortening of the season, and limiting the range of capture for certain commercially important species have been attempted by California Department of Fish and Game to protect kelp bed resources in heavily utilized areas where overfishing seems possible.

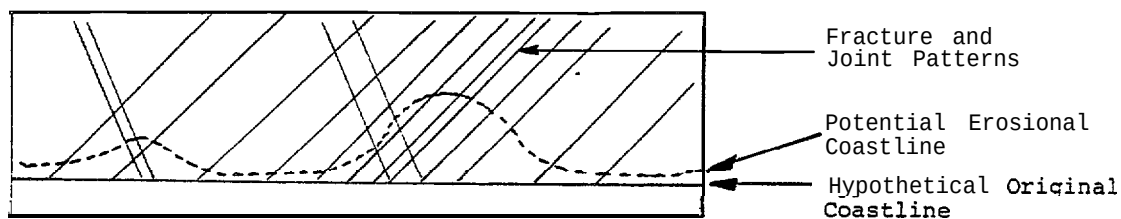
Another impact on kelp bed communities comes from the sport fishery and party-boats which remove large numbers of kelp-dwelling fish each year. Present laws attempt to regulate the number and kind of species taken, but Miller and Geibel (1973) suggest that stricter controls are necessary to prevent overfishing of certain species in certain areas. However the California Department of Fish and Game has made no provisions in its current laws to accommodate Miller and Geibel's suggestions.

ROCKY SHORE BOULDER/BEDROCK HABITATS

INTRODUCTION

In the Classification of Wetlands and Deep Water Habitats of the United States (Cowardin, et al., 1977) there is a differentiation between boulder and bedrock substrates. Along the California coast these two habitats are so intimately related both geographically and biologically that significant differences between them cannot be differentiated. They comprise an essentially stable substrate upon which organisms can develop to maturity and thus propagate a more or less continuous population. While erosion of the bedrock substratum or the reduction of boulders to moveable size will disrupt the adherent populations, this, in the general context of the coast must be considered of insignificant importance. These habitats are erosional; the sand and cobble/gravel habitats discussed elsewhere in this section are depositional. The dimensions of the wave cut platforms which comprise the lateral extent of the intertidal rocky shore habitats are determined by the interplay of several factors, among them the hardness of the rocky substrata, its formation and/or degree of jointing and faulting and the rapidity with which the shoreline is emerging or submerging. The emergent nature of the California coast is easily recognized in the strongly developed marine terraces observable at almost any point along the coast. These are often accompanied by raised seastacks as well.

Joint and fault systems are taken advantage of by the hydraulic and pneumatic pressures of wave shock, eroding landward at a rate proportional to the degree of fracture.



Geologic formations (folds) may expose softer rocks, causing more rapid erosion in that area with a subsequent wider, more exposed shelf.

The rocky shore habitats also include the structures called "reefs.*" There are, however, no classical reefs to be found in the area along the central and northern California coast. A "classical reef" is one of biogenic origin, built of the calcareous skeletons of corals and/or worm tubes and used as a habitat by a distinctive fauna. Several navigational "reefs", greater than normal projections seaward of hard rock layers, do occur such as at Pt. St. George and Blunts Reef. "Reefs" caused by geological structures such as at Duxbury Reef are also present, and there are even "reefs" so named because of the abundance of fish in certain areas attracted to sewage outfall. Most of the "reefs" (so-called) that appear on charts and maps of the California coast fall into the existing rocky habitat descriptions without the need to further delineate their characteristics in a separate section.

Though man-made structures, jetties fall into the category of rocky or bedrock substrata and will also be considered later in this section. The only significant difference between jetties and other rocky shore habitats are the generally calcareous nature of their material (concrete) and their generally angular orientation to the coast. Since few organisms show significant preference for substratum composition and since there are examples of the same angular orientations in almost any intertidal zone, these differences are not deemed important enough to warrant considering "jetties" a separate habitat.

HABITAT CHARACTERIZATION

The major and striking observable feature of this habitat is the vertical arrangement of organisms in response to the periodic effects of tidal flow. The zonation is described by Ricketts and Calvin (1968) and represents biological communities variously adapted to the varying conditions of length of exposure, salinity change, oxygen-carbon dioxide differences and exposure to wave action. The zonation of Ricketts and Calvin are discussed in more detail in Vol 11, Part 1 (Features and Processes of Special Significance to Intertidal Habitats). Because of the complexity and nature of this habitat, the zones will be discussed in detail individually, and an attempt will be made to deal with the habitat in its entirety in the concluding paragraphs. Indeed, the most striking feature of this habitat is the wide variety of organisms to be found.

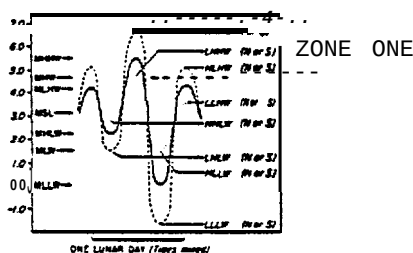
Several environmental factors can be recognized as being important determinants of the abundance and variety of this habitat. The relative stability of the substratum, as opposed to the sand or gravel habitats, provides organisms a suitable base upon which to settle as larvae and grow to sexual maturity. Also, nutrients and dissolved gases are, under normal conditions, provided in such abundant quantities, that the organisms can grow in large, closely packed populations if they can meet the other rigorous demands of the habitat. The ability to "close pack" is one approach taken by several forms in solving the problem of withstanding wave shock.

Each zone presents a different set of parameters to which organisms must adapt. The fact that different communities of organisms have successfully adapted to the requirements presented at varying levels, and have evolved ranges of tolerance that allow them to compete within those levels, gives rise to the easily noted groupings so characteristic of the rocky intertidal. It is these groupings that will be considered in the zone discussions to follow.

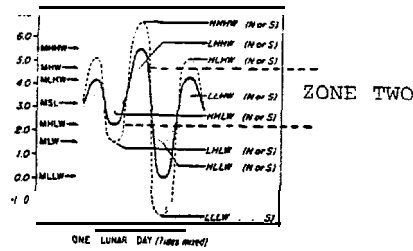
Physical Aspects

Zonation. The intertidal can be divided into four zones. Depending on slope, tidal range, wave activity, and orientation to waves, these vertical limits will delineate wider or narrower bands of more or less well defined nature. While the top of zone 1 and the bottom of zone 4 are easy to describe, the rest of the boundaries are less definite and less defined by community composition in different areas.

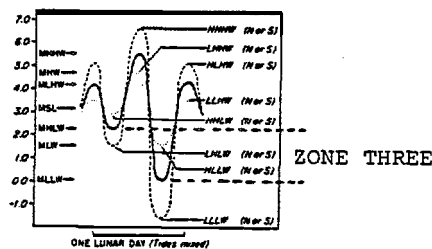
Zone one is defined as that area from the upper limits of the occurrence of Littorina sp. generally referred to as the "splash zone" down to the mean high tide level (Mean High Water [MHW]).



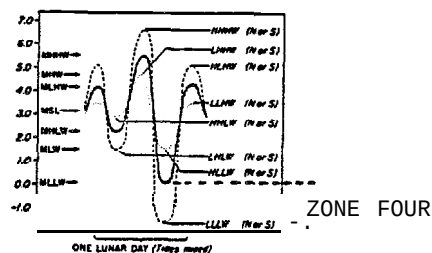
Zone two is established from the mean high tide level (MHW) at the top to a lower limit at the mean higher low water (MHLW; see next page).



Zone three is that area covered between the mean high low water (MHLW) and the mean low low water (MLLW).



Zone four ranges vertically from mean low low water (MLLW) to the lowest low tide (LLLW), or the last level that is exposed to the air for any length of time.



The width of any of these zones will vary from location to location, dependent on the average tidal fluctuation and the shape of the shore.

The zones, as outlined above, are generally recognizable and indicated by typically occurring biotic assemblages. These typical assemblages, however, do not necessarily represent the tolerance limits of the organisms found there; a "zone 1 organism", while being ecologically restricted to its zone, may in fact have physiologic tolerances that would permit abundant use of more than one zone. What is the case, however, is that organisms are successful where they can compete not only with the physical factors, but the biologic, as well. As illustrated below, an organism may in fact be living in a zone that represents the extreme limits of its tolerances simply because other organisms more successfully compete for the available space in other zones (Figure 3-1?) .

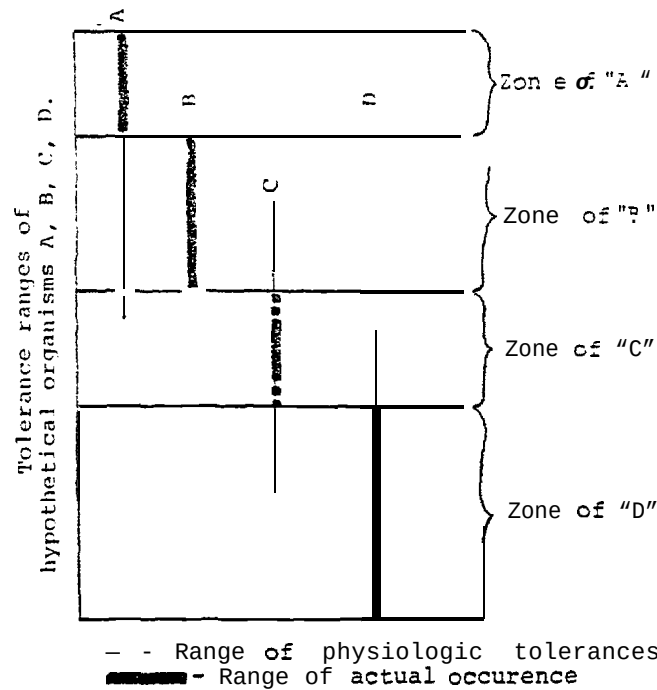


Figure 3-17. Tolerance Ranges of Hypothetical Organisms
Illustrating Possible Versus Actual Zonal Distributions

Microhabitats; Niches. The exposed rocky intertidal habitat has been noted for its zonation and extremes in reference to physical factors. In an attempt to describe the overall ecologic diversity of these areas, the characteristics of microhabitats should also be considered. Generally, areas noted as microhabitats include: **under-rocks**, crevices, **byssal threads** and/or holdfasts of **sessile** animals or plants, **tidepools**, under algal canopy, on or within other organisms and leeward sides of rocks. These microhabitats may occur temporarily or be permanent, or they may be used by an organism only during a certain life stage.

These microhabitats (or niches) alter certain physical characteristics including: light intensity, temperature ranges, relative humidity, tidal exposure and exposure to wave shock. By altering these factors, a particular microhabitat may allow **organisms** to expand their vertical distribution, lending them protection or a suitable living space in an area which normally would not be satisfactory.

In zone 1 an organism that exemplifies this utilization of microhabitat is the rock louse Ligia. On hot summer afternoons exposed rock surfaces in zone 1 can reach **temperatures of up to 35°C**, while air temperatures register approximately 24°C with a relative humidity of about 60 percent. Ligia, which exhibits a negative response to intense ultraviolet (UV) light and high **temperature** can find sanctuary in crevices which register only 15°C, with a 100 percent relative humidity (Carefoot, 1977). Ricketts and Calvin (1968) note that the conspicuous flatworm Alloioplana californica, a relatively abundant organism of zone 1, could not survive the stress factors of this upper zone when the tide is out, if it weren't able to use the undersides of large boulders (an important zone 1 microhabitat).

Zone 2 of the rocky intertidal, though still a region that tolerates more air than water, exhibits a high diversity of species that utilize both under-rock and crevice microhabitats. Also, since there is still a high intensity of UV light (which in large doses is deadly to most living organisms) in this region, along with a more intense but periodic wave shock factor, any canopy (even from the algae found here) is utilized for protection. Use of protected microhabitats can be seen by any observer who investigates zone 2 at low tide. By looking into the crevices one will find such organisms as Pachygrapsus crassipes, the lined snore crab (refer to Species Volume II, Part 2) peering out. Lifting the thallus (undifferentiated plant body) of any algae

present will usually uncover a number of different animals including periwinkles. Ricketts and Calvin (1968) note that certain rockweeds, including Pelvetia and Fucus, serve juvenile periwinkles as a nursery, and that limpets use the canopy for protection from dessication. During high tide periods when wave shock is a factor, these under-rock, crevice, or leeward microhabitats lend zone 2 organisms the sanctuary that is necessary for their survival.

Zone 3 of the rocky intertidal is characterized as being largely uncovered by most low tides and covered by most high tides. Plant life grows in great profusion here, thus providing the great diversity of animals in this zone with protection from UV light and dessication during exposed periods and absorbing some of the wave shock during incoming tides. Because of the tremendous variety and diversity of both organisms and habitats in this zone, it is often more desirable to study it in terms of microhabitats rather than to group everything together as representative of the zone.

Seasonally, protection in exposed areas is offered by the seaweeds that annually form great beds, offering both a protective canopy, plus a holdfast or root (Phyllospadix) niche. Here will be found a number of interzonal organisms (between zones 3 and 4) including nemerteans and occasional nestling clams that live in the inner parts of the holdfast or root, and bryozoans, hydroids, sponges, tunicates, small anemones, holothurians, and chitons which cover the outside. Also, numbers of snails, hermit crabs, brittle stars, seastars, amphipods, and isopods crawl over and through the vegetative mass.

The under-rock microhabitat consists of the underside of loosely embedded rocks and boulders where there is no accumulation of unconsolidated materials (Ricketts and Calvin, 1968). This is a niche noted for offering a maximum of protection from such factors as wave shock, sunlight, and dessication, and which displays a characteristic group of animals including the brittle stars, the porcelain crab, (Petrolisthes cinctipes), species of ribbon worms (Nemerteans); species of the scaleworm Halosydna; eel-like blennies, sponges, tunicates, and numerous small isopods (pill bugs) and amphipods (beach hoppers) (Ricketts and Calvin, 1968).

An abundance of tidepools, many of them permanent, occur in zone 3. Here many of the local and interzonal organisms which require constant submersion find refuge. Tidepools can include other microhabitats including holdfast, roots, and crevices, so often one can observe a mass of activity and diversity. Organisms presented by Ricketts and Calvin (1968) as common inhabitants of these pools include the minute red flatworm, Polychaerus carmelensis, species of the transparent shrimp Spirontocaris, and, of course, any of the intertidal fish. Tidepools are not a simple component of this habitat but rather are complex units themselves. Organisms inhabiting these standing water niches must be adapted to another set of variables. Temperature increases, especially in the upper tidepools, are sometimes significant and are probably the main limiting factor of the tidepool niche.

Klugh (1924) has shown that there is definite stratification among tidepool inhabitants relative to duration of exposure. Tidepools in lower zones will have a population of largely lower zone organisms adapted to narrower temperature fluctuations. Higher zone tidepools, while affording the constant moisture required by lower zone occupants nonetheless exceed their temperature tolerances and are occupied by upper zone organisms.

Variations in salinity due to evaporation and pH changes do not seem to be limiting factors for organisms (Klugh, 1924) as the variations noted generally fall within the normal variability range of seawater. Reduction of salinity due to freshwater (rain) influx has been little studied; however, it is estimated that the variation would be of such relatively short duration and of such minor amount that it would fall within the normal tolerance ranges of the tidepool organisms.

The leeward or protected rock microhabitat, with all its cracks, ledges and crevices, along with low wave shock, is noted for its diverse and productive biomass.

The lowest intertidal horizon, zone 4 is a region where factors such as dessication from exposure and wave action (except in regions of heavy surf), are seldom of concern. Instead, factors such as overcrowding, predation, and spatial competition cause the organisms found here to seek specific microhabitats. Cracks, crevices, and ledges of pools and rock faces lend more surface area and protection from predation for organisms lower on the food chain. Roots and holdfasts collect soft sediment for burrowing organisms or act as microhabitats themselves. As in zone 3, the surfgrass and algae found here add substrata for animals and epiphytic algae. The hydroid colonies of this area are substratum formers, as they are characteristically populated by numerous small skeleton shrimp (Caprellidae).

succession. The succession or maturity of habitats within the rocky intertidal is initially dependent on physical factors such as wave surge, zonal distribution in reference to duration of exposure and location of substratum in reference to the sun. Time of year is equally critical in determining what organisms will settle and, ultimately, the length of time until maturity. "Maturity" is meant to imply not the idea of the terrestrial climax vegetation, but rather the relatively stable, normally encountered biota at any given zonal level. Such biological factors as predation from neighboring areas, or proximity of mature organisms (possible chemical or pheromone interactions), may also determine the length of time for completion of an intertidal succession.

Time length should also be considered when comparing the reestablishment and complete recovery rates of populations in different zones of the intertidal. The biotic communities of the extreme environments of zone 1 and 4 are formed very quickly (in comparison of zones 2 and 3) and, once mature, are stable and long lasting. Zones 2 and 3, on the other hand, if disrupted, take a long time for normal populations to re-establish, being under variable and extreme stresses (i. e., wave shock, periodic exposure and submersion), while progressing toward a most diverse stable community.

An interesting and well studied example of community succession was done by Dayton (Carefoot, 1977). Although he artificially cleared an area, natural denuding by fierce wave action, overgrazing, or introduction of new substratum (by landslide or placement of jetties) are recognized causes for initiating repopulation and re-organization of an area.

The description of the successional events that occur in the repopulation of the dominant Mytilus Californicus from a bare rock substratum can be observed in Figure 3-18 and in Table 3-10.

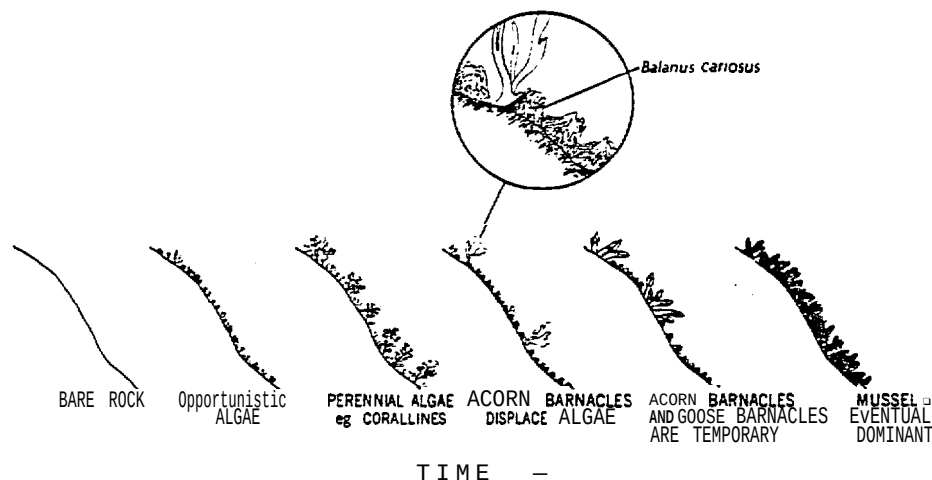


Figure 3-18. Possible Succession of Plant and Animal Species in a Mussel-Bed Community (Carefoot, 1977).

Initial transformation occurs when various "fugitive" algae (predominantly filamentous Rhodophyceans and Porophyceans) appear on the denuded space. These opportunistic algae soon give way to the more competitive perennial algae (e.g., Corallines), which are in turn soon outcompeted for light and space by other macrophytic algae. With time, the barnacles, Chthamalus dalli, Balanus glandula, and B. cariosus gradually grow into and undercut these existing algae. None of these barnacles or Pollicipes polymerus, which may become established in some areas, can actively compete with Mytilus californicus. The final formation of a stable M. californicus community is reached when all other organisms are overgrown and smothered, and the tertiary predator Pisaster ochraceus (refer to Species, Volume II, Part 2) becomes established.

Further competition for space is noted by Dayton (1973) between the mature mussel and the sea palm (*Postelsia palmaeformis*) (refer to Species, Volume II, Part 2). In regions of surf-swept rocky points where the two vie for space, *Postelsia* sporophytes grow on and between *Mytilus*, often supplying enough resistance to wave surge to cause their host substratum (e.g., *Mytilus*) to be torn loose from the rocks. When this happens, other suppressed sporophytes settle to quickly colonize the freshly cleared area.

Another discussion of intertidal ecological succession was presented by Hewatt (1935). His description of the *Mytilus* habitat succession sequence coincides fairly well with that of Dayton's study (though performed in different geographic regions), except that Hewatt's observations include specific reference to numerous herbivores (e.g., limpets) and the predacious whelk, *Thais emarginata*, during the intermediate stages. Also, inspection of the study area two and one-half years after the initial cleaning showed that the rehabilitation of the rock surface by the mussel and their associated fauna was far from complete. In fact, some studies have indicated that to re-establish a population similar to the pre-existing one may take from five to seven years.

Table 3-10. Number of Organisms in a Mussel Bed in 1931 and Their Recovery in 1932 (Hewatt, 1935)

Species	1931	1932						
	Nov. 23	Feb. 19	Mar. 4	Apr. 25	June 3	July 18	Oct. 13	Dec. 28
Algae		Xx3						
<i>Acmaea</i> spp.	319	61	232	314	353	331	997	792
<i>Amphissa versicolor</i>	39							
<i>Balanus glandula</i>	872		95	2126	1967	1904	2175	2374
<i>Cirolana harfordi</i>	926							
<i>Leptasterias aequalis</i> , ...	6							
<i>Lotia gigantea</i>		10	17	8	11	11	15	15
<i>Mytilus californianus</i>	1612			55	51	7	53	89
<i>Nuttallina californica</i>					2	34	14	9
<i>Pachygrapsus crassipes</i>	14							
<i>Petrolisthes cinctipes</i>	416							
<i>Phascolosoma agassizi</i>	327							
<i>Pollicipes polymerus</i>	356		76	109	109	109	109	106
<i>Tegula brunnea</i>	17							
<i>Tetraclita squamosa</i>	78		423	416	378	371	359	329
<i>Thais emarginata</i>	218			2	J	367*	47	59

• Average size, 5 mm.

From a more practical standpoint than the method or sequence of succession, is the time required for re-establishment and maturity. Evaluation of both studies proved that *Mytilus* will regain dominance in an area, given time and inductive natural factors, but the time required for re-establishment is obviously far greater than the time Hewatt allowed (two and one-half years). The re-establishment of a denuded area depends upon: (a) when assemblages of the members of the original species settle; (b) when this assemblage reaches reproductive maturity, and can perpetuate normal populations; and (c) when the pre-denuded or "normal" stature of the population (i.e., species composition, percent cover, size, and age range of species individuals) is reached.

It should also be noted that *Phyllospadix* displays a cyclic type of succession with both *Macrocystis* and coralline algae (refer to Species, Volume II, Part 2) and that there are many other examples of succession in the literature.

Biological Aspects

Intertidal Fishes of Northern California. In the brief discussion of selected fishes which follows, the species have not been assigned to specific zones because the nobility of these organisms allows many of them a somewhat unrestricted distribution. They can be found in more than one intertidal or subtidal habitat.

A practical, limited list (Table 3-11) of coastal intertidal fishes for working biologists and others with a general interest in these species has been prepared.

There are more species of fish than species of any other class of vertebrates. More than 550 kinds have been recorded as "inshore marine fishes" from California waters (Miller and Lea, 1972 and 1976 addendum). Some 400 of these species could be encountered in northern California, and about 175 of them are considered common, readily available, and frequently taken by sport and commercial fishermen, or in biologists' collections.

A set of representative species was selected. The selection includes most truly intertidal fishes, those that remain between the high and low water marks even when the tide is out. These are mainly rocky habitat forms. The remaining species are better called inshore fishes, since they move back and forth in the intertidal zone with the water: these are typically beach habitat and surge channel forms such as the surf perch. The choice of the inshore species to include on the list was somewhat arbitrary, based on such varied criteria as commonness, importance in the sport fishery, or just zoological interest.

Excluded from the list are practically all pelagic forms (e.g., sharks, mackerels) which may occur casually or adventitiously in the intertidal zone. Similarly, deeper water demersal species are omitted. Diadromous forms are not included.

Scientific and common names generally follow Bailey et al. (1970) and Gates and Frey (1974). The common names "wolf eel" and "monkeyface eel" are retained for Anarrhichthys ocellatus and Cebidichthys violaceus, respectively (instead of "wolffish" and "monkeyface prickleback" preferred by some authorities) because the "-eel" usage is so ingrained in this region (Roedel, 1962).

Undoubtedly, there will be instances where a species on the list will not be found and when excluded species will occur. Miller and Lea's, (1972) comprehensive keys to the families and species of coastal marine fishes are suggested for species identification; the keys are illustrated. Especially useful for identifying tidepool forms is the key given in Bolin et al. (1975).

Table 3-11. Selected Northern California Coastal Intertidal and Inshore Fishes

Family	Scientific Name	Common Name
RHINOBATIDAE	<u>Rhinobatos productus</u>	Guitarfishes Shovelnose guitarfish
DASYATIDIDAE	<u>Urolophus halleri</u>	Stingrays Round stingray
OSMERIDAE	<u>Hypomesus pretiosus</u> <u>Spirinchus starksi</u>	Smelts Surf smelt Night smelt
ATHERINIDAE	<u>Atherinopsis californiensis</u> <u>Leuresthes tenuis</u>	Silversides Jacksmelt California grunion
BOTHIDAE	<u>Citharichthys stigmaeus</u>	Lefteye flounders Speckled sand-dab
PLEURONECTIDAE	<u>Hypsopsetta guttulata</u> <u>Platichthys stellatus</u> <u>Psettichthys melanostictus</u>	Righteye flounders Diamond turbot Starry flounder Sand sole
CENTROLOPHIDAE	<u>Icichthys lockingtoni</u>	Medusafish Medusafish

Table 3-11. (continued)

Family	Scientific Name	Common Name
EMBIOTOCIDAE	<u>Amphistichus argenteus</u> <u>Amphistichus koelzi</u> <u>Amphistichus rhodoterus</u> <u>Cymatogaster aggregata</u> <u>Embiotoca jacksoni</u> <u>Embiotoca lateralis</u> <u>Hyperprosopon argenteum</u> <u>Micrometrus aurora</u> <u>Micrometrus minimus</u>	Surfperches Barred surfperch Calico surfperch Redtail surfperch Shiner surfperch Black surfperch Striped surfperch Walleye surfperch Reef surfperch Dwarf surfperch
SCORPAENIDAE	<u>Sebastes chrysomelas</u> <u>Sebastes melaops</u> <u>Sebastes mystinus</u> <u>Sebastes paucipinis</u> <u>Sebastes rastrelliger</u>	Scorpionfishes Black and yellow rockfish Black rockfish Blue rockfish Bocaccio Grass rockfish
HEXAGRAMMIDAE	<u>Hexagrammos decagrammus</u> <u>Hexagrammos superciliosus</u> <u>Oxylebius pictus</u>	Greenings Kelp greenling Rock greenling Painted greenling
COTTIDAE	<u>Artedius corallinus</u> <u>Artedius craseri</u> <u>Artedius fenestralis</u> <u>Artedius harringtoni</u> <u>Artedius lateralis</u> <u>Clinocottus analis</u> <u>Clinocottus embryum</u> <u>Clinocottus globiceps</u> <u>Clinocottus recalvus</u> <u>Hemilepidotus hemilepidotus</u> <u>Hemilepidotus spinosus</u> <u>Jordaia zonocephala</u> <u>Leptocottus armatus</u> <u>Oligocottus maculosus</u> <u>Oligocottus</u> <u>Oligocottus rubellio</u> <u>Oligocottus snyderi</u> <u>Orthonopias triacis</u> <u>Scorpaenichthys marmoratus</u> <u>Snychirus gilli</u>	Sculpins Coralline sculpin Roughcheek sculpin Padded sculpin Scalyhead sculpin Smoothhead sculpin Woolly sculpin Calico sculpin Mosshead sculpin Bald sculpin Red Irish lord Brown Irish lord Longfin sculpin Staghorn sculpin Tidepool sculpin Saddleback sculpin Rosy sculpin Fluffy sculpin Snubnose sculpin Cabezon Manacled sculpin
LIPARIDAE	<u>Liparis florae</u> <u>Liparis rutteri</u>	Snailfishes Tidepool snailfish Ringtail snailfish
GASTEROSTEIDAE	<u>Aulorhynchus flavidus</u>	Sticklebacks Tubesnout
SYNGNATHIDAE	<u>Synathus californiensis</u>	Pipefishes and Seahorses Kelp pipefish
GOBIIDAE	<u>Clevelandia ios</u> <u>Coryphopterus nicholsi</u> <u>Lethops connecters</u>	Gobies Arrow goby Black goby Kelp goby
BATRACHOIDIDAE	<u>Porichthys notatus</u>	Toadfishes Plainfin midshipman

Table 3-11. (continued)

Family	Scientific Name	Common Name
GOBIESOCIDAE	<u>Gobiesox maeandricus</u> <u>Rimicola eigenmanni</u>	Clingfishes Northern clingfish Slender clingfish
ANARRHICHADIDAE	<u>Anarrhichthys ocellatus</u>	Wolf eel Wolf eel
BLENNIIDAE	<u>Hypsoblennius gilberti</u>	Combtooth blennies Rockpool blenny
CLINIDAE	<u>Gibbonsia metzi</u> <u>Gibbonsia montereyensis</u> <u>Heterostichus rostratus</u>	Clinids Striped kelpfish Crevice kelpfish Giant kelpfish
STICHAEIDAE	<u>Anoplarchus purpureus</u> <u>Chirolophis nugator</u> <u>Plagiogrammus hopkinsi</u> <u>Phytichthys chirus</u> <u>Xiphister atropurpureus</u> <u>Xiphister mucosus</u>	Pricklebacks High cockscomb Mosshead warbonnet Crisscross pricklyback Ribbon pricklyback Black pricklyback Rock pricklyback
CEBIDICHTHYIDAE	<u>Cebidichthys violaceus</u>	Monkeyface-eel Monkeyface-eel
PHOLIDIDAE	<u>Apodichthys flavidus</u> <u>Xerorpes fucorum</u>	gunnels Penpoint gunnel Rockweed gunnel
SCYTILINIDAE	<u>Scytalina cerdale</u>	Graveldivers Graveldiver
AMMODYTIDAE	<u>Ammodytes hexapterus</u>	Sandlances Pacific sandlance

Zone 1. As can be noted from the tidal chart of zone 1 earlier in this section, this zone may be subjected to long periods of emergence, possibly as much as several tidal cycles. The upper limits of the zone are only marine in their affinities because of the abundant spray associated with wave action along the California coast. The organisms making up the community of this zone (Table 3-12) are adapted to the widest range of environmental factors, not the least of which is competition for living space. The ranges of the barnacles of this zone (Balanus glandula and Chthamulus sp.) are limited not only by their relative tolerance for dessication, but by their relative growth rates and the upper limits of their predators (Figure 3-19). Chthamulus is smaller and slower growing than Balanus, so is able to compete for space at the upper limits of the Balanus range which is limited by dessication. The lower range of Balanus, on the other hand, is determined by the activity of the major predators of the area, namely the carnivorous gastropod Thais and others such as Pisaster (Ricketts and Calvin, 1968).

Temperature changes are most significant in this zone as the inhabitants are subject to the longest periods of direct solar radiation. Many, such as the Littorina (periwinkle) and sparsely settled barnacles and limpets of the upper limits of this zone do not even have the advantage of partial shading enjoyed by the closely packed barnacles lower in the zone.

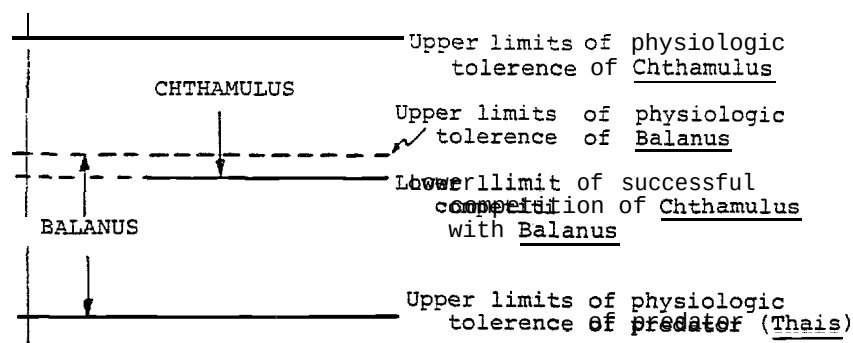


Figure 3-19. The Overlapping Physiological and Ecological Vertical Range of the Barnacles Chthamulus and Balanus (Ricketts and Calvin, 1968)

The effects of exposure to sun and wind are well illustrated in Figures 3-20 and 3-21 on Mytilus californianus (Carefoot, 1977). The significant difference between sunny and foggy days may indicate that the characteristic summer coastal fogs on the northern and central California coast are a more critical environmental factor than heretofore considered.

As mentioned above, there is considerable predation of sessile organisms by Thais and others, from which the organisms are saved by the lesser tolerance of predators to exposure. The increased exposure, however, has a negative corollary; they are subject to increased predation by terrestrial predators.

Dessication and temperature fluctuations appear to be the major limiting factors of this zone. The periwinkles (Littorina sp.) and rock louse (Ligia sp.) are so adapted to exposure to air that they will drown if kept in water, so greatly has their internal chemistry evolved. Ligia has a strongly developed negative phototropism, an adaptation well suited to this harsh environment. A factor little discussed and studied is the prevalent coastal fogs experienced along the northern and northcentral coast of California which provide cooling and slower evaporation, thus permitting organisms such as Littorina and Ligia to exist at higher levels. Wave shock is largely dissipated in the upper reaches ("splash zone") of the zone while it may be of significant nature lower in the zone. Among the barnacles which grow lower in the zone one of the strongest attachment devices has evolved, a cement so powerful it is being investigated for use in dentistry. This strong attachment, along with the tendency to grow in close-packed colonies, is a successful adaptation to the force of waves. Other adaptations include the streamlined shape of limpets and the extremely low profile of the encrusting algae.

Primary Trophic Level. Primary food sources for the inhabitants of zone 1 (Ricketts and Calvin, 1968) consist of both endemic and introduced organic matter (Figure 3-22). Bare rock surfaces are often coated with detritus and microscopic plants, the foodstuffs of the radula equipped periwinkle and limpets. The algae of the upper part of zone 1 are, for the most part, encrusting forms. A persistent feature of this zone, found in cracks, but not usually on open rock, is the dark red encrusting alga, Hildenbrandia occidentalis. The irregular blackish areas are usually encrusting algae that are formed by different species in different areas and include species such as: Entophysalis granulosa, Calothrix crustacea and Plectonema battersii. Other, somewhat larger algae found in the spray zone include Prasiola, Enteromorpha and, rarely, Pelvetiopsis (Stephenson and Stephenson, 1972).

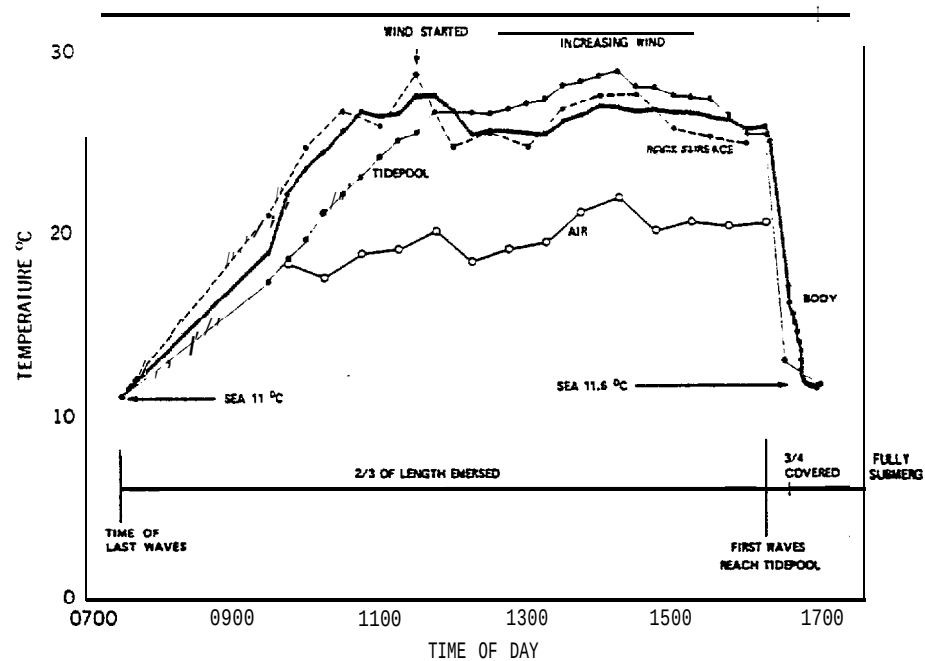


Figure 3-20. Internal Body Temperature of Mytilus californianus During Sunny Day Exposure. (Carefoot, 1977)

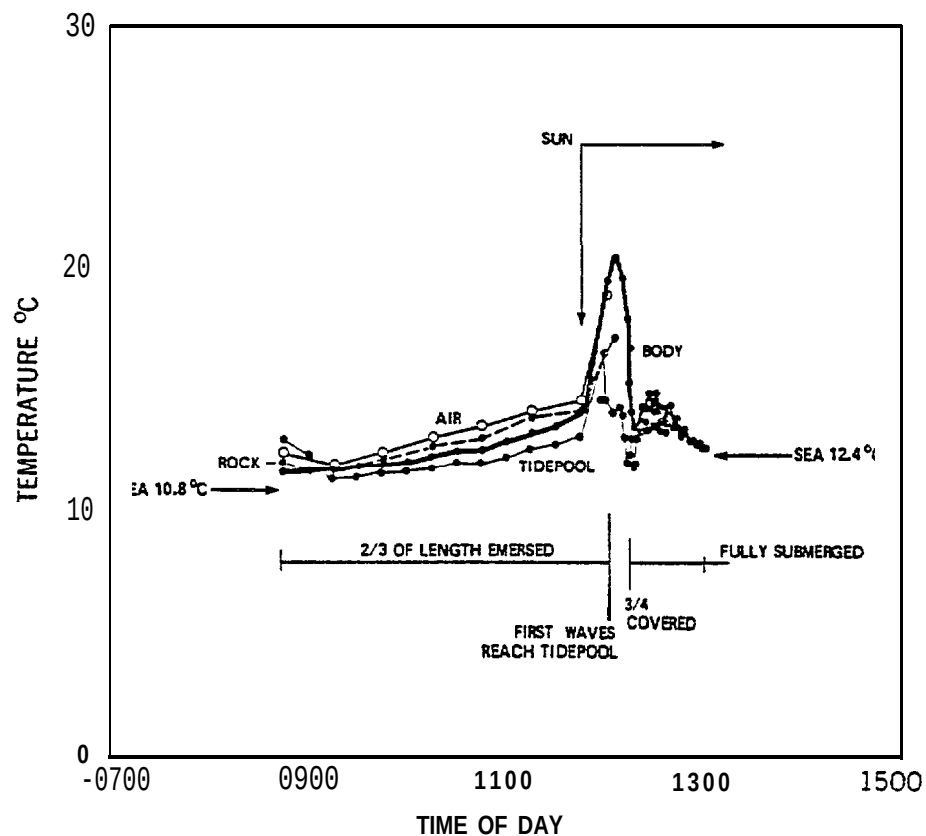


Figure 3-21. Internal Body Temperature of Mytilus californianus, on a Foggy Day (Carefoot, 1977)

Other food items utilized by organisms of zone 1 are those of periodic availability, introduced at high tide and high surf. These include the suspended, minute *organic* materials collected by the brightly colored appendages of *Balanus glandula* and the decaying flotsam used for both food and sanctuary by scavengers, such as *Ligia occidentals* (Ricketts and Calvin, 1968).

Higher Trophic Levels. The remainder of the community in this highest of the rocky intertidal zones is primarily grazing herbivores represented by the limpets (*Collisella* sp., *Acmaea* sp. and *Lottia* sp.) and the periwinkles (*Littorina* sp.) or sessile omnivorous barnacles (*Chthamulus*, *Balanus*). Because of serious limits placed on organisms in this (sea-land) transitional zone, there is little inter- or intraspecific competition at higher trophic levels; there is enough "competition" with the physical environment. Few predators other than the occasional bird or racoon are adapted to take advantage of this habitat. Fish have little ecologic impact in/on this zone.

In areas where the *Balanus* population is sufficient to provide microfiches among the interstices of their packed shells, or where rock crevices promise protection from drying, relatively large flatworms (*Alloioiplana*) may occur. *Alloioiplana*, along with the barnacles, are omnivorous, using anything their extensible pharynx can surround including algae and *Littorina*. The adaptation of *Alloioiplana* for the long exposed habitat is that it tends to be heavier bodied (thicker) than its relatives in lower zones, reducing the ratio between area and total volume. *Balanus* (spp.), *Littorina*, *Acmaea*, and *Entromorpha*, as the major biologic elements of this habitat, are treated in detail among the species of concern/interest (Volume II, Part 2).

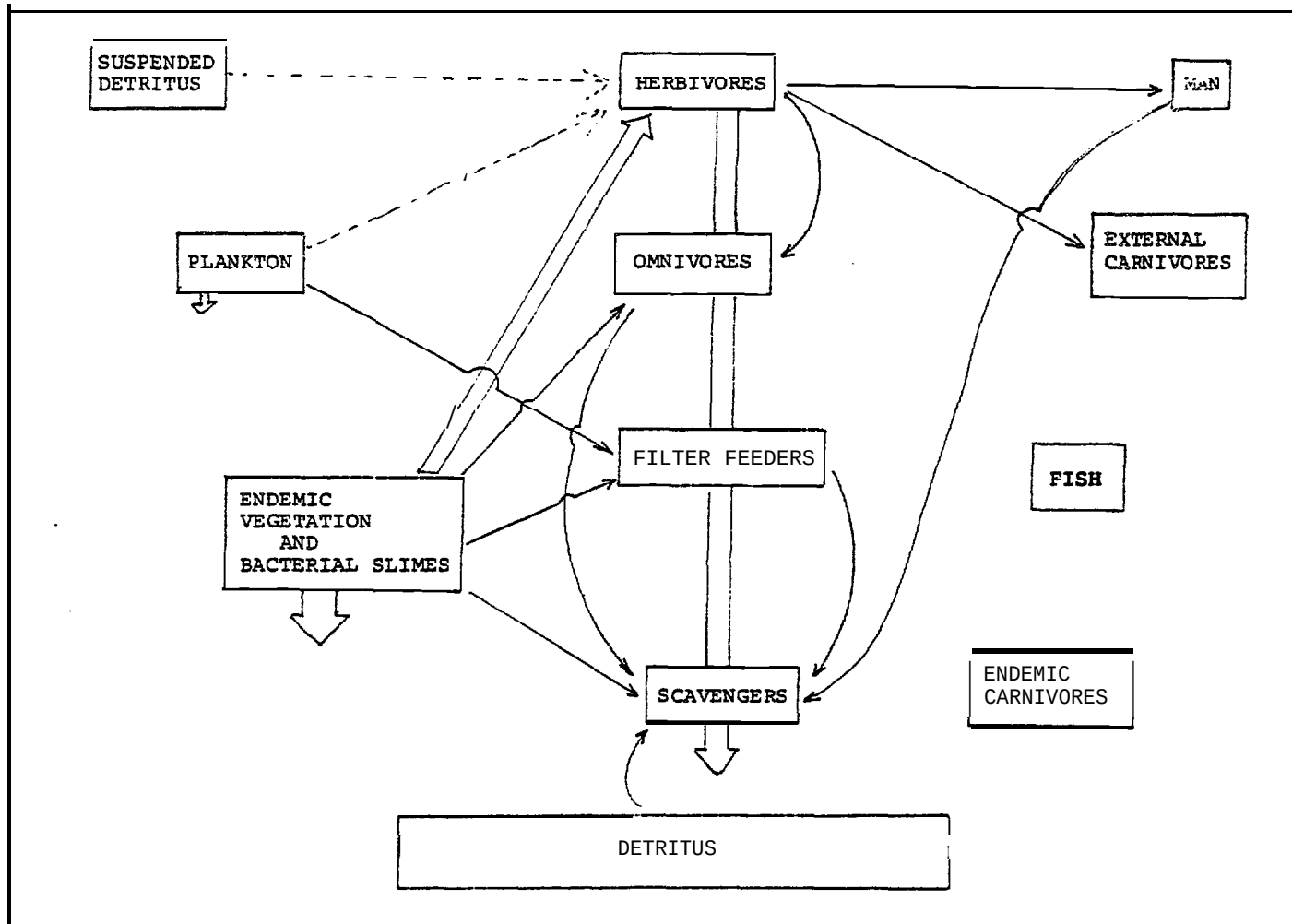


Figure 3-22. Characteristic Food-chain Diagram for Zone One

Table 3-12. Common Saltwater Species of Plants and Animals of Zone One

Trophic Status	Scientific Name	Common Name
Algae	<u>Hildenbrandia occidentals</u> <u>Entophysalis granulosa</u> <u>Calothrix crustacea</u> <u>Plectonema battersii</u> <u>Prasiola meridionalis</u> <u>Enteromorpha sp.</u> <u>Pelvetiopsis sp.</u>	Red algae
Herbivores	<u>Acmaea digitalis</u> <u>Lottia gigantea</u> <u>Littorina planaxis</u>	Fingered limpet Giant owl limpet Periwinkle
Omnivores	<u>Alloioplane californica</u>	Flatworm
Filter Feeders	<u>Chthamulus dalli</u> <u>C. fissus</u> <u>Balanus glandula</u>	Barnacle Barnacle Acorn barnacle
Scavenger	<u>Ligia occidentals</u>	Rock louse

Zone 2. Zone 2 can be considered a transition zone, with the upper physical limits overlapping those of zone 1. Even though during some neap (equatorial) tidal cycles there may be several tides during which the upper limit of this zone is not covered, there is little, if any, time that the organisms are not at least dampened by abundant wave surge and spray. Dessication, as a physical parameter of this zone, while still of some importance, is reduced in severity relative to zone 1.

It is within this zone that the amount of time subjected to exposure takes its biggest jump, so that the upper limits of this zone will have physical parameters akin to zone 1 with a progressive change toward less dessication with vertical descent. There are adaptations among organisms to thwart the drying effects of wind and sun similar to those mentioned earlier (negative phototropism, decreased surface to volume ratio, thickened epidermis) but other factors become important, especially the pressure of wave shock, toward the lower limits of this zone.

In zone 2, one finds the first abundant occurrence of algae. While in zone 1 there are sparsely occurring algae supporting a relatively low biomass of herbivores, zone 2 is marked by a decided increase in algal productivity. As would be expected, the number of herbivores and omnivores and their predators, relative to both biomass and species diversity, also make a significant increase.

Compared to zone 1, one finds in zone 2 the first abundant utilization of micro-environments. In zone 1, micro-environment utilization is greatly restricted because the predominant factor, dessication, applied to even the cracks and crevices of the splash zone and there are too few algae to afford significant shade and/or moisture retention. At zone 2 levels however, the algae are abundant and cracks and crevices are kept moist enough to support a varied biota. Consequently, soft-bodied organisms and ones requiring constant moisture are found here, occupying niches within the zone that provide their required life conditions (e.g., cryptic habitats).

First Trophic Level. Zone 2 is marked with an algal growth more varied than that of zone 1, but more dispersed than found in the lower zones. The algae found in zone 2 consist mainly of irregular patches generally comprised of the same species that form the luxuriant lower beds. The commonest and most conspicuous of these algae include: Endocladia muricata, Gigartina papillata, Cladophora columbiana (the green cushion), plus Fucus, and small plants of Pelvetia sp., Porphyra s?., and Rhodoglossum affine. These algae are all macroscopic forms that offer a source of food and canopy (protection from dessication) for the many local opportunistic herbivorous and omnivorous animals (Table 3-13). Also prevalent in zone 2 are the encrusting Lithothamnium sp. which, due to its need to remain moist, is limited to clefts and angles in sheltered areas and exposed rocks in areas of strong wave action. Some blue-

green algal colonies (cyanophytes) are also represented, forming a valuable food source for organisms of rock-scraping feeding behavior (Ricketts and Calvin, 1968; Stephenson and Stephenson, 1972).

Other producers in this zone are collectively present with only periodic availability. They include the plankton and other suspended organic materials that at high tide are available for collection by filter feeding consumers. Analogous with zone 1, flotsam, often cast up at high tide and left stranded, as the tide recedes, is utilized by scavengers (Figure 3-23).

Second Trophic Level. The herbivorous (first order consumers) organisms in this zone as in other zones, are primarily gastropod, limpets such as Acmaea digitalis and A. scabra and snails such as Littorina scutulata and Tegula funebris. Other gastropod include the first appearance of chitons (Nuttallina californica). Also at this level would be the filter feeders, primarily Balanus (Barnacles) and Mytilus (mussels) toward the lower parts of this zone. Dependent on wave carried plankton the barnacle and the mussel have many similar environmental requirements and, because of their competition, are usually found in defined bands. Once a Mytilus bed has a number of large individuals, Balanus will be seen making use of the mussel shells as a substrate, illustrating that potential ranges are usually broader than zonation would make it appear. A filter feeder, the encrusting tube worm Spirorbis, is also found here in its sinuous tightly attached tubes on rocks or shells of other animals.

Higher trophic levels. Second and third order consumers are well represented in this zone. There are omnivorous anemones, carnivorous nemerteans, flatworms and the predacious snails Thais and Acanthinae to be seen feeding on barnacles and mussels.

Scavengers, too, take on a diversity at this zone level attesting to the abundant biomass that can support such dependent species. Arthropods (crabs, amphipods, isopods), brittle stars (Amphipholis) and polychaetes (Cirriformia) are also present in protected niches.

Fish make their first intertidal appearance in this zone (Table 3-11). In these higher intertidal tidepools can be found the snail-fish, clingfish and sculpins occupying various trophic levels as their feeding habits dictate.

This zone is, like all others, subject to predation by non-resident carnivores and scavengers. Birds and terrestrial mammals may make use of the abundant biomass available. It is man, however, who probably accounts for the major depredations along the rocky intertidal, indiscriminately climbing over massed and encrusting forms in his recreational activities.

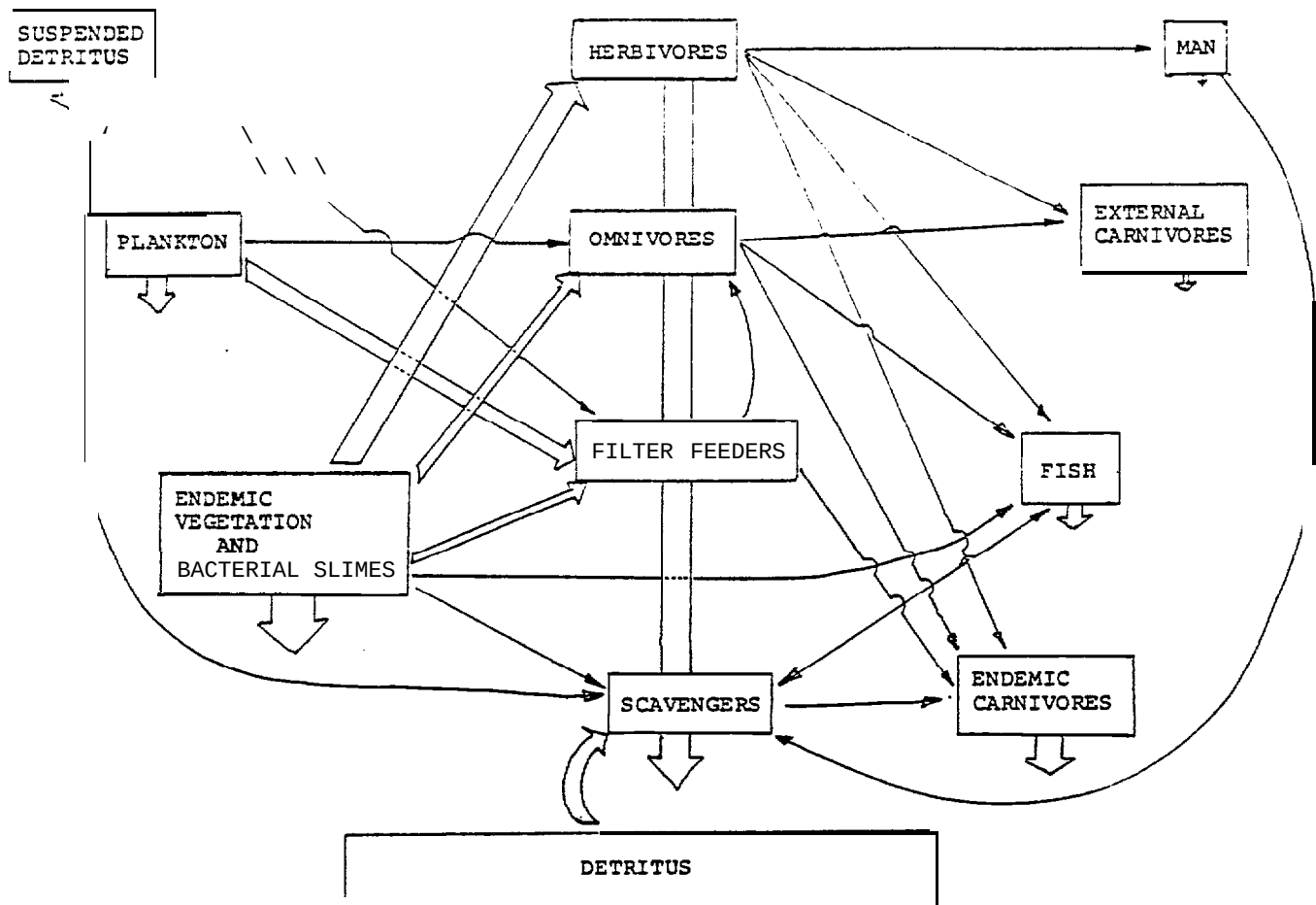


Figure 3-23. Characteristic Food-chain Diagram for Zone Two.

Table 3-13. Common Saltwater Species of Plants and Animals of Zone 2.

Trophic Status	Scientific Name	Common Name
Algae	<u>Endocladia muricata</u>	Rock weed
	<u>Gigartina papillata</u>	
	<u>Cladophora columbiana</u>	
	<u>Fucus sp.</u>	
	<u>Pelvetia sp.</u>	Laver, Nori
	<u>Porphyra sp.</u>	
	<u>Rhodoglossm affine</u>	
	<u>Lithothamnium sp.</u>	
Herbivores	<u>Littorina scutulata</u>	Periwinkle
	<u>Acmaea pelta</u>	Shield limpet
	<u>scabra</u>	Rough limpet
	<u>Collisella sp.</u>	Black turban
	<u>Tegula funebris</u>	
Omnivores	<u>Nuttallina californica</u>	Nuttall Chiton
	<u>Notoplana acticola</u>	Flatworm
	<u>Anthopleura elegantissima</u>	Aggregating Anemone

Table 3-13, (continued)

Trophic Status	Scientific Name	Common Name
Filter Feeders	<u>Spiroboris</u> sp. <u>Mytilus californianus</u> <u>Balanus cariosus</u>	Encrusting tubeworm California mussel Acorn barnacle
Carnivores	<u>Acanthina spirata</u> <u>Thais</u> sp. <u>Pisaster ochraceus</u> <u>Fabia subquadrata</u> (commensal in <u>Mytilus</u>) <u>Achelia chelata</u> (parasite in <u>Mytilus</u>)	Spotted thorn drupe Oyster drill Ochre star Mussel crab Sea spider
Scavengers	<u>Cirriiformia luxuriosa</u> <u>Amphipholis pudentana</u> <u>Pagurus samuelis</u> <u>Pachygrapsus crassipes</u> <u>Petrolisthes cinctipes</u> <u>Melita palmata</u> <u>Cirolana harfordi</u>	Hermit crab Lined shorecrab Porcelain crab Drab pill bug I sopod

Zone 3. Zone 3 organisms are subject to the full impact of incoming waves, being covered and uncovered during each tidal cycle. The pressures exerted are extreme; wave energy varies proportionally to the square of the wave height. Thus a four foot wave contains 65,000 foot-pounds of energy (33 foot-tons) per foot of wave crest, while an eight-foot wave delivers 131 foot-tons (Bascom, 1964). Endemic species have found various means by which to adapt to the impact of the waves. Pisaster and other sea stars (Dermasterias, Lepasterias) use a well developed water-vascular system (tube-feet) to hold tightly to the substratum. Almost all the organisms adapt very streamlined shapes such as the low cone of the limpets, the low domes of the chitons and the wedge shape of the mussels, all shapes which divert and disperse the wave energy. All the gastropod have well developed muscular feet. Characteristic species of Zone 3 are listed in Table 3-14. A food chain diagram is depicted in Figure 3-24.

Many soft-bodied worms survive the rigors of these wave-swept zones by secreting encrusting tubes or masses of tubes that, combined, afford protection. others, too, use the massed colony to thwart the pressure of waves. Barnacles, anemones and mussels, as well as the tube worm Phragmatopoma, exhibit this colonial adaptation. Mussels have also the unique adaptation of tough but elastic byssal threads by which they attach to rocks, allowing them to give slightly in the wave shock.

Many other organisms with body structures or tissues that could not otherwise resist the rigors of this zone adapt to life in microfiches where they are afforded protection. Anemonies, sponges, tunicates, crabs, nemertean worms, isopods and/or similar species are found under rocks, within holdfasts or under the canopy of algae and/or among the massed colonies of larger organisms.

First Trophic Level (Autotrophs). Zone 3 (Ricketts and Calvin, 1968) is often typified by its dense, even luxuriant, growths of primary producers. Many of the zone 2 algal representatives are also found here, but unlike the former where growth is varied, but dispersed or reduced, the vegetation of this level grows in much greater profusion.

In appearance (because of the prominent dark, almost blackish-brown color), one would expect to find a majority of phaeophyceans (brown algae), but in actuality, the "turf" is composed primarily of rhodophyceans (red algae). Also, the chlorophyceans, represented by the mosslike cushions of Cladophora trichotoma, and various species of the cosmopolitan Ulva with their vivid green color can be found in this zone.

Though not dominant forms, the phaeophyceans are common, usually interspersed among the rhodophyceans. Some of the brown algae likely to be present here include: Pelvetiopsis limitata, Fucus (at top of the zone, occasionally associated with Hesperophycus narveyaus), Pelvetia (a large plant, capable in sheltered areas of overgrowing the rhodophycean turf), and Egregia menziesii (found at the lower limits of the zone).

As for the rhodophyceans, commonest of these turf-formers (according to Stephenson and Stephenson, 1972) are: Gigartina sp., Porphyra, Endocladia muricata (a moss-like brown plant), Irridaea, and Rhodoglossum affine. Other members of this zone that Abbott and Hollenberg (1976) refer to as common constituents are: Cryptopleura lobulifera, Gastroclonium coulteri, Gelidium coulteri, Hymenena multiloba, Mirocladia borealis and Pikea californica. Although these are all typical inhabitants of the lower littoral, by no means do they comprise a complete listing. ?1s0, though typically found in very dense stands, Stephenson and Stephenson (1972) point out that the turf is not necessarily continuous. Appearing in some areas as patchy or reduced, in other places it alternates with regions of rock inhabited by encrusting algae or sessile animals.

Also present are various coralline algae, and, although zone 3 is the upper limit for many, they appear quite commonly. Representative of the corallines are: Calliarthron tuberculosum, Corallina officinalis and Bossiella orbigniana ssp. dicotoma.

Finally, the brown algae, Postelsia palmaeformis (sea palm), must be mentioned. Unlike some of the algae in the lower littoral turfs mentioned above, that demonstrate concentrated growth in relatively sheltered areas (Stephenson and Stephenson, 1972), the sea palm occurs only where the surf is continuous and strong (refer to Species, Volume II, Part 2, Postelsia palmaeformis). Although the lower reaches of zone 3 change with changes in local topography, P. palmaeformis is often a marker of its lower limits. In areas too steep and exposed for favorable growth of P. palmaeformis there may exist a distinct pink belt, composed of lithothamnia and corallines. However, in many places where the sea palm continues down to the zone 4 laminarians, an undergrowth of lithothamnia, corallines, and noncalcareous rhodophyceans also continue into and below zone 4 (Stephenson and Stephenson, 1972).

Second Trophic Level. This zone is visually marked by the abundant presence of Mytilus californianus, it is the "Mytilus Zone" of Ricketts and Calvin (1968) and an easily recognized characteristic of intertidal habitats. The large beds of mussels, filter feeders dependent on the wave surge, provide microhabitats among their innumerable byssal threads for numerous other organisms, soft bodied analogs of the exposed, sturdier organisms. Within and among the mussels will be found carnivorous nemerteans, filter feeding barnacles, omnivorous flatworms and small scavenging crabs, amphipods and isopods.

Larger herbivores include several Acmaea species, Tegula brunnea and, in tidepools, the tidepool blenny (Epigeeichthys atro-purpureus) and the Goby (Gobisox sp.). The gastropod use their rasping tongues (radulae) to scrape algae mats from the rock or to actually graze on mature plants.

Also taking advantage of the abundant store of energy at this trophic level are many of the omnivorous forms. Many organisms usually considered carnivorous are now known to be opportunistic in feeding habits and should be more accurately listed among the omnivores. Such predacious forms as the sea stars, for instance, have been observed feeding on encrusting algae and detrital vegetation. Other feeders at this first consumer level would include nudibranchs (Rostanga pulchra, Triopha carpenneri, Diaulula sandiegensis) and the chitons, such as Tonicella lineata.

Also competing for both space and food supply with Mytilus are the barnacles. While the abundant amounts of suspended and planktonic materials provide sufficient nutrients for all the filter feeders, space is in short supply. The gooseneck barnacle (Pollicipes polymerus) has a vertical distribution almost identical to the mussel and clusters of Pollicipes are often seen wedged among the mussels. When this condition exists, it is usually only a transitional stage in what is ultimately a losing battle for space on the part of the barnacle. The potential ranges of other barnacles, too, intersect the mussel range, and they are equally subject to displacement by the large California mussel. The barnacles (Tetraclita and Balanus) will occupy substrata not overrun by Mytilus, or use the mussel shells themselves as a growth surface (Carefoot, 1977).

Mytilus, along with most other filter feeders along the open coast, is subject to ingestion and concentration of the toxins of the dinoflagellate Gonyalax, making them toxic during the summer months. This relationship is further discussed in the Species, Volume II, Part 2, on Mytilus California.

Higher Trophic Levels. While Pisaster sp. have been mentioned at lower trophic levels, their role as carnivores is most important in this "Mytilus Zone." The Pisaster-Mytilus relationship is well documented (Paine, 1976). The ochre star (Pisaster ochraceus) is known to feed successfully on the California mussel below certain sizes, beyond which predation is apparently less than complete. Pisaster is recognized as a major limiting factor on the vertical range of the Mytilus beds, freely feeding among young Mytilus settled outside the confines of the major mussel beds.

Other carnivorous residents include the oyster drill (Thais sp.), a predacious gastropod which uses its radula to scrape holes in the shells of mussels, barnacles and other sessile forms, and feed on the soft tissues within. There are soft bodies carnivores, unprotected by shell, that live in this zone. Nemertean worms, almost exclusively carnivorous, use the abundantly supplied shelter of the mussel beds and prey on organisms making similar use of this protected micro-habitat.

In addition to finding shelter under, among, and on Mytilus, other organisms make use of yet another niche provided by the abundant mussels. This is "within" Mytilus, a niche used both parasitically (by a pycnogonid, Achelia chelata, which feeds on Mytilus gills) and commensally (by the mussel crab, Fabia subquadrata).

Scavengers in this zone are predominantly crustaceans, crabs, shrimp (Spirontocaris) and amphipods. The hermit crabs (Pagurus sp.) are found in abundance in this zone making use of vacant shells of Thais sp., Olivella sp.

Table 3-14. Characteristic Species of Zone 3.

Trophic Status	Scientific Name	Common Name
Algae	<u>Cladophora trichotoma</u>	
	<u>ulva</u> sp.	Sea lettuce
	<u>Pelvetiopsis limitata</u>	
	<u>Fucus</u> Sp.	Rock weed
	<u>Hesperophycus harveyanus</u>	
	<u>Pelvetia</u> sp.	
	<u>Egregia menziesii</u>	Feather boa
	<u>Gigartina</u> sp.	
	<u>Porphyra</u> sp.	Nori, Laver
	<u>Endocladia muricata</u>	
	<u>Irridaea</u> sp.	
	<u>Rhodoglossum affine</u>	
	<u>Cryptopleura lobulifera</u>	
	<u>Gastroclonium coulteri</u>	
	<u>Gelidium coulteri</u>	
	<u>Hymnera multiloba</u>	
	<u>Microcladia borealis</u>	
	<u>Pikea californica</u>	
	<u>Postelsia palmaeformis</u>	Sea palm
	<u>Calliarthron tuberculosum</u>	
	<u>Corallina officinalis</u>	
	<u>Bossiella orbigniana</u> spp. <u>dicotoma</u>	
Herbivores	<u>Acmaea scutum</u>	Plate limpet
	<u>Acmaea limatula</u>	File limpet
	<u>Tegula brunnea</u>	Brown turban
	<u>Epigeichthys atro-purpureus</u>	Tidepool blenny
	<u>Gobiesox meandricus</u>	Northern clingfish

Table 3-14, (continued)

Trophic Status	scientific Name	Common Name
Omnivores	<u>Anthopleura elegantissima</u>	Aggregating anemone
	<u>Leptasterias pusilla</u>	
	<u>Rostanga pulchra</u>	Pretty doris
	<u>Triopha carpen</u>	Carpenter's doris
	<u>Diaulula sandiegensis</u>	San Diego doris
	<u>Tonicella lineata</u>	Lined red chiton
	<u>Pisaster ochraceus</u>	Ochre star
	<u>Epiactis prolifera</u>	Proliferating anemone
	<u>Tubularia marina</u>	
	<u>Balanophyllia elegans</u>	
	<u>Corynactis californica</u>	
	<u>Amphiodia occidentals</u>	
	<u>Amphiodia pagetana</u>	
	<u>Ophioplocus esmarki</u>	
	<u>Leptosynapta albicans</u>	
	<u>Polychoerus carmelensis</u>	
	<u>Patiria miniata</u>	Bat star
Filter Feeders	<u>Phragmatopoma californica</u>	Tube worm
	<u>Phascolosoma agassizi</u>	Peanut worm
	<u>Haliclona permollis</u>	Purple Sponge
	<u>Ophlitaspongia penna ta</u>	
	<u>Plocaia karykina</u>	
	<u>Mytilus californianus</u>	California mussel
	<u>Pollicipes polymerus</u>	Gooseneck barnacle
	<u>Tetraclita squamosa</u>	Barnacle
Carnivores	<u>Balanus sp.</u>	Acorn barnacle
	<u>Emplectonema gracile</u>	Nemertean
	<u>Halosydna brevisetosa</u>	Scale worm
	<u>Thais sp.</u>	Oyster drill
Scavengers	<u>Nereis vexillosa</u>	Mussel worm
	<u>Spirontocaris picta</u>	Brokenback shrimp
	<u>Pachygrapsus crassipes</u>	Lined shore crab
	<u>Hemigrapsus nudus</u>	Purple shore crab
	<u>Pagurus samuelis</u>	Hermit crab
	<u>Pagurus hemphilli</u>	Hermit crab
	<u>Strongylocentrotus purpuratus</u>	Purple sea urchin

Zone 4. Organisms in this zone can be considered transitional forms as is the case 'one' 1 inhabitants. whereas in zone 1 the organisms are adapted to long periods of exposure and adopt almost terrestrial characteristics in some cases, the organisms encountered in zone 4 must be adapted to long periods of submersion, being covered almost 90 percent of the time. Exposed only at extreme low tides and not subject to the heavies: wave shock (as is the biota of zones 2 and 3), many organisms that are equally at home in the upper subtidal zones (covered 100 percent) are characteristic inhabitants here. Characteristic species of this zone are listed in Table 3-15 and a diagrammatic food chain is depicted in Figure 3-24.

Red algae (Rhodophyceans) are illustrative of this condition. Common in zone 4, they are also representative of subtidal zones because of their ability to absorb shorter wave lengths of light which penetrate deeper into the water. Among animals illustrative of this zone would be the red sea urchin (Strongylocentrotus franciscanus) and the "rock crab" (Cancer antennarius).

Producers. The primary producers of zone 4, though variable in constituents from place to place, can, for the most part, be characterized as a region of predominantly laminarians containing a pink background of lithothamnia, corallines, and other red algae.

In this low intertidal region, (corresponding to the upper limits of the "Laminarian Zone") one is able to observe a transition in the population and dominant algal species in a transect from the roughest to most sheltered waters. According to Stephenson and Stephenson (1972) this region passes from a domain of Lessoniopsis in the roughest water, through one of Alaria and Egregia in the intermediate parts, to a turf of mixed small algae and again Egregia in sheltered regions. Also, the upper limits of this zone are clearly marked in the roughest regions by the effective upper limits of the laminarians (other than Postelsia), but in the sheltered waters this distinction is much less perceptible.

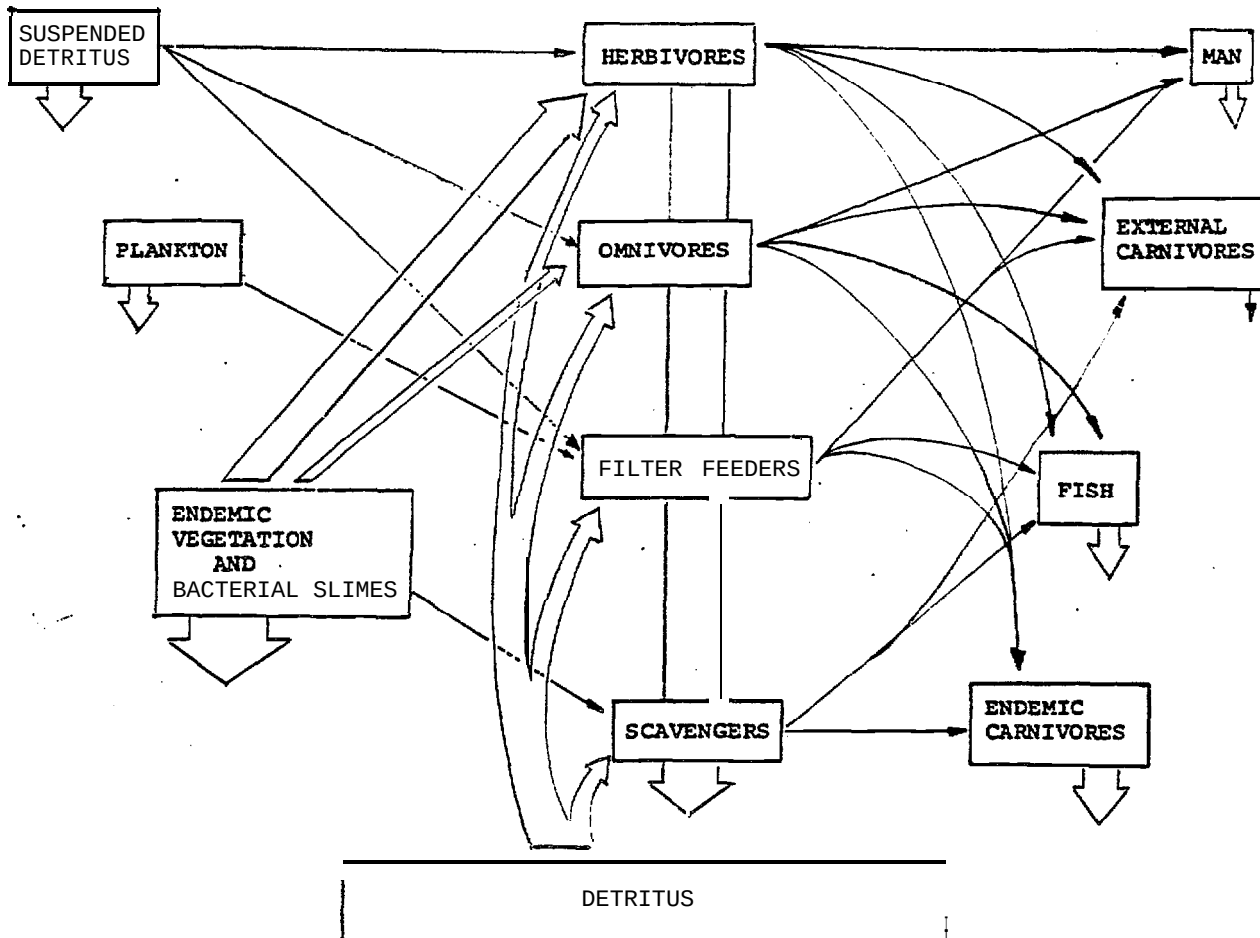


Figure 3-24. Schematic Food-chain Diagram of Zones Three and Four.

Some of the commonest Laminarianes found in zone 4 include: Egregia menziesii (refer to Species, Volume II, Part 2), Alaria marginata, Lessoniopsis littoralis, and Costaria costata (Abbott and Hollenberg, 1976). These, plus a number of less abundant Laminarians, combine to form a blanket-type canopy in many areas.

Also prevalent, often living under the wavy curtain of the larger Laminarians are the Rhodophyceans. Many of these algae can also be found higher, in zone 3; encountering them in the sublittoral is not uncommon. Some of these red algae include Prionotis lanceolata, P. australis, Irridia cordata and Gigartina corymbifera.

Members of the Chlorophyta (green algae) may also be found in this lowest littoral zone. Spongomorpha sp. and Ulva sp. can both be encountered, possibly owing to the activation of their accessory pigments (Dawson, 1966b) or to low respiration rates. (Blinks, 1955).

A flowering plant, the brilliant green eelgrass, Phyllospadix (refer to Species, Volume II, Part 2), can be found living in both sheltered and rougher areas (Stephenson and Stephenson, 1972).

Second Trophic Level. As this zone is less subject to the rigors of wave shock and exposure, it is the habitat for greater numbers of larger and softer bodied organisms that are higher zones. The herbivores of zone 4 are often larger than their more exposed relatives. Here one finds the large gumboot chiton (Cryptochiton stelleri) and the large black abalone (Haliotis cracherodii). The Acmaeids (limpets) are higher domed and thinner walled than their higher-zoned relatives, also reflecting the less stringent environmental parameters. These Acmaeids include the dunce-cap limpet, "the tallest of the limpets" (Ricketts and Calvin, 1968), Acmaea mitra and Acmaea fenestra.

Also well represented are various filter feeders. These include the tunicates (Hemichordata) such as the solitary Styela montereyensis, hanging by its slender base from the lower sides of boulders, the social transparent tunicate (Clavelina huntsmani) and several encrusting colonial forms such as Amaroucium californicum and Eudistoma psammion.

Also found in zone 4 are the small, encrusting colonies of Bryozoa, colonial individuals separately encased in small, intricate, calcareous cubicles. They raise their ciliated rings of tentacles (lophophores) to feed from the suspended detritus and plankton.

Higher Trophic Levels. Often seen in zone 4 are delicate colonies of the hydroids (Aglaophenia struthionides, Eudendrium californicum) and, associated with them, the skeleton shrimp (Caprella sp., Metacaprella sp.). These aberrant amphipods use the hydroid colonies in the same way as the kelp crab (Pugettia producta) uses beds of Phyllospadix and Egregia, grasping securely with their strongly curved rear appendages, thus freeing their antennae and front appendages for the constant task of food gathering. Exactly how the caprellids contribute to the overall community dynamics is still of some question. Various authors have described them as being wholly predacious while others have called them grazers on diatoms and bits of algae or feeders on the zooids of their hosts.

One of the most obvious carnivores is the large green anemone (Anthopleura xanthogrammica) opened and ready for any chance encounter with a hapless prey species, which can be fish, worm, or crab. The large sea urchins are known to be particularly unselective about food taken.

As in zone 3, the scavengers of zone 4 are predominantly decapods (crabs) and also include the sea urchins (Strongylocentrotus sp.).

Table 3-15. Characteristic Species of Zone 4.

Trophic Status	Scientific Name	Common Name
Algae	<u>Egregia menziesii</u>	Feather boa
	<u>Laminaria dentigera</u>	Oar weed
	<u>L. farlowii</u>	Oar weed
	<u>Alaria marginata</u>	
	<u>Lessoniopsis littoralis</u>	
	<u>Costaria costata</u>	
	<u>Gigartina corymbifera</u>	
	<u>Irredia cordata</u>	
	<u>Prionotis lanceolata</u>	
	<u>P. australis</u>	
	<u>Sponomorpha</u> sp.	
	<u>Ulva</u> sp.	Sea lettuce
	<u>Phyllospadix</u> sp.	Surf grass

Table 3-15, (continued)

Trophic Status	Scientific Name	Common Name
Herbivores	<u>Haliotis cracherodii</u> <u>Haliotis rufescens</u> <u>Cryptochiton stelleri</u> <u>Aplysia californica</u> <u>Acmaea mitra</u> <u>Acmaea fenestrata</u> <u>Katharina tunicata</u>	Black abalone Red abalone Gumboot chiton Sea hare White-cap limpet Windowed limpet Black chiton
Filter Feeders	<u>Spheciospongia confoederata</u> <u>Leuicosolenia eleanor</u> <u>Rhabdodermella nuttingi</u> <u>Leuconia heathi</u> <u>Lissodendoryx firma</u> <u>Eudistoma psammion</u> <u>Clavelina huntsmani</u> <u>Euherdmania claviformis</u> <u>Styela montereyensis</u> <u>Membranipora membranacea</u> <u>Flustrella cervicornis</u> <u>Tricellaria occidentals</u> <u>Bugula californica</u> <u>Bugula pacifica</u>	Colonial tunicate Social tunicate Monterey pencil Bryozoa Branching bryozoan Branching bryozoan
Scavengers	<u>Strongylocentrotus franciscanus</u> <u>Metacarprella kennerlyi</u> <u>Cancer antennarius</u> <u>Cancer productus</u> <u>Pagettia productus</u> <u>Hemigrapsus nudus</u> <u>Pagurus hemphilli</u>	Red urchin Caprellid Hermit crab Hairless rock crab Hermit crab
Omnivores	<u>Stichopus californicus</u> <u>Polycheria antartica</u> <u>Diaulula sandiegensis</u> <u>Anisodoris nobilis</u> <u>Archidoris montereyensis</u> <u>Hopkinsia rosacea</u> <u>Triopha maculata</u> <u>Hermisenda crassicornis</u> <u>Diodora aspera</u> <u>Anthopleura xanthogrammica</u> <u>Tealia crassicornis</u> <u>Epiactis prolifera</u>	 San Diego doris Noble doris Monterey doris Hopkins doris Maculated doris Large horned hermissenda Keyhole limpet Giant green anemone
Carnivores	<u>Eudendrium californicum</u> <u>Tubularia marine</u> <u>Carveia annulata</u> <u>Aglaophenia struthionides</u> <u>Pycnopodia helianthoides</u> <u>Solaster dawsoni</u> <u>Leptasterias sp.</u> <u>Henricia leviuscula</u> <u>Lecythorhynchus marginatus</u> <u>Ceratostoma foliatum</u> <u>Stenoplax sp.</u> <u>Mopalia sp.</u> <u>Ampnipholis sp.</u> <u>Hinnites giganteus</u> <u>Chama pellucida</u> <u>Eudistylia polymorpha</u> <u>Loxorhynchus crispatus</u> <u>Octopus sp.</u>	 Ostrich plume hydroid Sunstar Six-rayed star Red seastar Chiton Fringed chiton Brittle star Octopus

UNCONSOLIDATED SHORE : COBBLE/GRAVEL

INTRODUCTION

Much that has been said previously about the sand habitats applies to the cobble/gravel habitat type also; some does not. The cobble/gravel habitat type consists of unconsolidated, actively shifting sediments that are relatively less susceptible to transport due to *larger* particle size. Transport is also diminished because of the increased porosity of the sediments, greatly reducing the backwash so important in the longshore movement of finer particles. Sand has been shown to be remarkably stable as to size; gravels and cobbles rapidly erode to sand size (Figure 3-25).

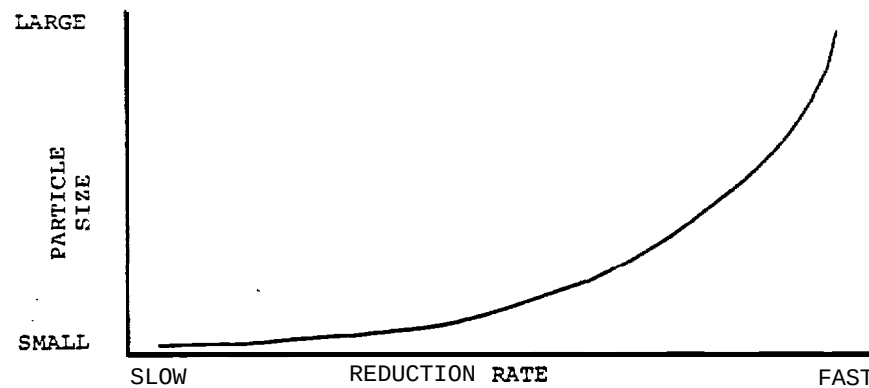


Figure 3-25. Particle Size and Rate of Reduction in the Size of Rock Fragments

RATE OF REDUCTION IN SIZE OF ROCK FRAGMENTS

Gravels are classified as erosion particles between 5 millimeters and 76 millimeters, and may occur in various states of angularity and sphericity dependent on the forces applied and the duration of application. Cobbles are generally considered to be particles of between 76 and 200 to 256 millimeters. The smaller figure for the upper range is the U.S. Corps of Engineers' standard, the larger is the generally accepted lower limit of "boulder."

Marshall (Trask, 1955) states that fragments of over one-half inch (12.7 millimeters) will tend to flatten during erosion because when sized above that dimension they would tend to slide rather than roll. This tendency gives rise to the "shingle beach" recognized at points along the coast. The occurrence, at all, of rounded boulders and cobbles along California coasts attests to the force applied to the shores by the long-reach Pacific wave system. The small percentage of the coast littered with these larger fragments attests to the rapidity with which they are broken and abraded into smaller grains.

Geographic Aspects

Beaches of the type described are sparsely represented on the northern and central California coast and, as suggested, should be considered transitional forms simply representing larger particles not yet eroded to sand size. While there are few beaches that may be construed as of a cobble nature along the subject coasts, there are localized gravel beaches where steep and/or highly fragmented cliffs provide material faster than it can be broken down or where the mineralogic composition of the derived erosional products are of such a nature as to resist rapid reduction. Such beaches are represented by Ft. Cronkite Beach; Agate Beach and the Farrallones in the Bodega Basin just north of the Golden Gate; Pebble Beach just south of Monterey in the Santa Maria Basin; and at Pt. St. George, northwest of Crescent City in the Eel River Basin. Although the areal extent of this type of beach is probably of the nature of one percent of the coast totality, in the Pacific Northwest north of the subject area this habitat is of a more significant nature. A few cobble beaches occur in the northern Eel River Basin (Humboldt County) at Spanish Flat. The mouths of some of the steep short rivers and streams emptying their heavy transported materials onto the coast such as at Cooksie and Randall Creeks have cobble beaches. There is also a cobble beach at the point on Pt. Reyes.

The extent of gravel/cobble beaches may be misleading by a significant factor. As discussed in the section on sand habitats, the generally weaker summer wave patterns deposit sand on all beaches, and sands may indeed be covering winter exposed beaches of a coarser nature. This can be recognized on many sand beaches by digging vertically. In doing so, one would see that sediments coarsen with depth and may, in fact, end in cobbles resting on bedrock. The following was written to explain the paucity of specimens collected in winter, but well illustrates the seasonally varying nature of beaches.

The number (of specimens) was lowest in January...because much of the sand forming each beach was gone and samples could not be collected. The lower intertidal region of Ellwood Beach was composed of rocks from two to five inches in diameter, and other rocky areas were present all along the transect line in January. Coal Oil Point Beach also had exposed rock piles along the transect where there was sand in October; solid rock was all that remained of the upper sandy beach. At Carpinteria State Beach the removal of sand by winter conditions exposed a hard substrate of rocks and asphalt that could not be penetrated by a shovel. No organisms were observed living on the rocky substrates of any of the beaches. (Trask, in Straughn, 1971).

Thus it can be seen that the relative apparent scarcity of cobble/gravel beaches may be a function of less study during winter months. Then, too, cobbles and gravels may become more significant subtidally (see Subtidal Cobble/Gravel). They will at no point, however, be as significant an element of the substrata as sands and muds. In a recent survey an analysis of the percentage of types of coast only dealt with rocky and sandy intertidal habitats and did not recognize the occurrence of gravel/cobble beaches. This emphasizes both the limited areal extent and ephemeral nature of these habitats.

Physical Aspects

Because of the more rapid reduction in size inherent in beach deposits of the gravel/cobble size, it is understandable that they would occur over far less area than beaches composed of sand and that they would tend to have an interstitial occurrence of much smaller grain sizes. These smaller sized materials are both directly derived as breakdown products and trapped sediments. The gravel/cobble and sand (previously discussed) habitats thus tend to grade more or less imperceptibly into one another. This gradation between beaches of differing grain sizes can occur both laterally and seasonally. In other words, the erosion, transportation, and sorting caused by waves and currents "string out" the derived sediments along a strand. Given an uninterrupted and smooth coast, these actions would result in a virtually imperceptible lateral gradation.

Seasonally, the differing amounts of energy applied to the coast between summer and winter could result in a winter cobble/gravel beach being covered with finer sediments in the summer. Regardless of substratum (sand or larger particles) the upper sand levels are removed by the more active winter wave and current systems.

Beach profiles are the result of a variety of factors, including wave direction, amplitude and period, and the ability of backwash (wave retreat) to drag particles down shore. As this latter ability is directly related to the slope of a given beach, one can understand that, characteristically, beaches composed of larger grain sizes will have a steeper slope (Berg, in Clark, 1977). This, in fact, is the situation along the northern and central California coasts; gravel beaches are steeper than sand. The effect of the backwash is reduced because of the greater energy required to move the larger particle sizes and because the larger grain sizes permit more rapid percolation of the water, reducing, often to nothing, the volume of water flowing back on the surface.

Biologic Aspects

While there may be some settling of pelagic larvae and zoospores on the larger elements of this habitat during times of relative quiet (e.g., summer, or periods of extended meteorologic calm) it would be a rare event indeed to find any well developed attached fauna, as there are few organisms that can withstand the "ball-mill effect" of gravels put in motion by wave action. The only fauna that may develop would be among the interstitial sands, though one may encounter small incrustations of algae, barnacles or other encrusting forms at the appropriate seasons of larval settling. Among the potential interstitial fauna may be found representatives of the Mysidacea, Cumacea, Nematoda and Platyhelminthes.

The ubiquitous scavengers, the beach hoppers (Orchestoidea spp. and Orchestia sp.) are sure to be found making use of the abundant detritus and others, such as some subtidal crabs migrate shoreward with the tides, making use of this habitat much as mole crabs (Emerita) make use of the sand.

Boney (1966) discusses the effect of the scouring of sand grains on Enteromorpha s??. such that the alga is "molded to its particular form", a form so different that it has been identified as a separate genus, "Collinsella". Such profound effect by sand grains easily leads to the understanding of the even greater effects that moving gravel and cobble-sized particles would have on any resident biota.

Invasion of the gravel/cobble habitat by terrestrial organisms would also fit the pattern of the sand habitat, but on a more limited scale, reduced in extent proportional to the potential success of foraging.

Probably the most significant feature of this habitat is the grinding of the relatively heavy elements against each other. This accounts for two of the characteristics mentioned earlier, the rapid disintegration of particles and lack of permanently established biota. Also characteristic of gravel/cobble beaches is the steeper slope than one would find in sandy areas. Not only is the angle of repose of the sediments steeper, but the previously mentioned high porosity and its attendant reduction in the backwash results in minimal force acting to move the sediments either laterally or away from the coast.

Community Dynamics

The reader is referred to the discussion of the intertidal sand habitat, following. Cobble/Gravel substrata are so sparsely settled and so little studied as to make comments here almost purely conjectural.

Effects of Man

Again, it would be difficult to make other than the broadest generalizations about the effect of man on the biota of this habitat. However, the gravels along the coast (especially at river mouths) have an economic importance far exceeding their relative geographic extent. Relatively easy to dredge, and of value to the construction industry, these gravels are thought of as a resource to be exploited. However, unlike terrestrial sedimentary deposits which can be quarried easily and with less environmental impact (other than aesthetic), the mining of intertidal marine sediments can have far reaching effects on the configuration of downdrift beaches and faunas through change in flow patterns and severe silting.

UNCONSOLIDATED SHORE: SAND

INTRODUCTION

This habitat type is characterized by a loose, actively shifting and unstable mass of detrital material of from 5 millimeters (coarse) to .07 millimeters (fine). (Bascom, 1964). This designation is within normal visual limits, so if one can see the individual particles it is safe to classify a sediment as sand. Particles of a finer nature are classed as silt and mud. Silt and mud sediment classifications rarely, if ever, are major elements of exposed Pacific coasts, being largely restricted to protected bays and estuaries and to subtidal regions. A small percentage of smaller grain sizes will be found interstitially among sand grains, as will larger particles as well. The material is derived from several sources: alluvial material added to the coastal supply by the numerous rivers flowing to the coast from mountains as far east as the Sierras and distributed southward by longshore currents; erosion particles derived by wave, wind, and corrosion from the coastal rocks; in-place disintegration of larger particles (gravels, cobbles) and materials transplanted by wave action shoreward along the continental shelf.

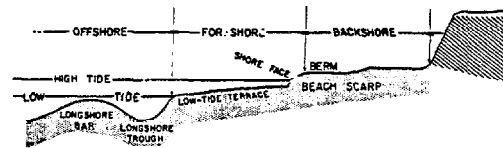


Figure 3-26. Classification and Terminology of Beach Features (Shepard, 1967)

This sandy material will be found distributed primarily due to wave action, but also subject to movement by wind (causing the numerous incidents of sand dunes at various points along the coast). The area designated "beach" occurs, geologically, in a wide variety of forms but, due to the narrow shelves, strong and persistent wave action, numerous submarine canyons, and rocky intervals along the California coast, the sandy habitat is restricted to pocket beaches, spits and bars across coastal breaks such as harbors and river mouths, and longshore beaches beautifully represented at Pt. Reyes in the Bodega basin. The barrier beaches, so characteristic of the East coast, are nowhere evident along the California coast. Geographically, it is estimated that sand - as beaches and bay mouth bars - covers at least 50 to 60 percent of the California coast.

Due to the loose nature of the substratum and the strength of the forces acting upon it, the unconsolidated sand habitat is only conducive to utilization by a relatively few highly specialized forms. Ricketts and Calvin (1968) call these sandy beaches "the next barren of the various intertidal regions." This designation "barren" is never safe to use relative to a coastal environment with its chemical, physical, and biotic richness. A more defensible statement relative to sand flats and beaches would be that, while there may be considerable biomass, it will be found to be composed of relatively few species. These species include the seldom seen mole crab (*Emerita analoga*) so aptly named for its ability to rapidly bury itself in its

constantly shifting niche. Other characteristic inhabitants of this habitat are the often abundant bloodworm (Euzonus mucronata) and the innumerable and pestiferous beach-hoppers (Orchestoidea spp.).

HABITAT CHARACTERIZATION

Geographic Aspects

As stated earlier, the incidence of sand habitats is probably of a nature of 50 percent of the extent of the coast. With few exceptions, sand habitats will be found interspersed with others along the entirety of the California coast. Every little indentation along this rugged coastal strand will create changes in wave and longshore current energy that will result in the settling of transported materials. Since sand is generally the largest transported material it will be the first to be deposited upon loss of energy. The presence of sand along the coast at any point can be understood as a result of an attempt at equilibrium between sand supply (rate of addition to coastal systems) and the forces of beach drift (long shore currents, wave action, wind) and configuration.

South of Pismo Beach, essentially the southern quarter of the Santa Maria basin and the most southern elements of interest in this report, the sand environment all but disappears due primarily to the numerous submarine canyons trending away from the coast. Any sand added to the environment is quickly siphoned off to depth and the coast there is characterized by very steep, often 100 foot cliffs rising sharply from the water's edge.

Physical Aspects

The shifting nature of the substratum has previously been emphasized, but beyond this there are numerous other physical attributes that characterize this environment. For a thorough understanding of this habitat one must consider particle size and shape which affect permeability, nutrient penetration, oxygen transfer and other factors. If the sediments composing the sand habitat are primarily of alluvial (stream derived) origin, the chances are that they will be more rounded and relatively well sorted. On the other hand, if the sediments are derived from the local disintegration of coastal rocks, they will tend to be less well sorted and more angular. With close packing of either of the two types, the more rounded and sorted grains would have a higher percentage of interstitial space permitting more rapid and complete exchange of nutrients as a positive factor.

A negative factor from a biotic standpoint would be the less stable nature of the rounded and sorted particles. This type of substratum is susceptible to effect by currents, wave action and like factors, creating an even less stable environment less likely to be inhabited by any significant number of organisms. Where a sandy substratum is less subject to current and wave action, as in protected bays, it becomes a habitat for an unbelievable diversity of fauna. Such bays are considered in another section of this report.

A second special characterization of the sand habitat, also a result of the unconsolidated nature of the material, is the seasonal variation of the cross-sectional profile of beaches. With heavier wave activity during the winter months there is more active transport of sediments and, in general, the beach is lowered, the volume of sediments removed deposited in the form of submergent longshore bars some distance offshore. Exactly how far offshore is determined by several factors, including subtidal bedrock profile, size of sediments, energy incorporated in waves and rate of addition of new materials. In the summer, on the other hand, with relatively less energy incorporated in the waves, they are less able to move the sediments and a broader beach and reduced longshore bar are the result (see Figure 3-27). These factors may also result in the very localized and temporary occurrence of sediments smaller than sand-size (especially silts and, rarely, muds). Upon the restoration of more active longshore activity or increased wave activity such smaller sediments would be carried off to be deposited in areas less subject to these physical factors. In no case, however, would these silts and muds be a permanent enough feature of an exposed coast to allow the development of a characteristic fauna.

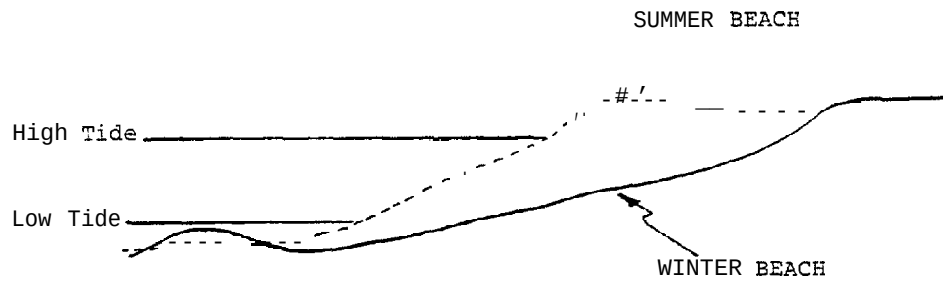


Figure 3-27. Diagrammatic Contrasts in Winter and Summer Beach Profiles

Zonation. Due to the already explained seasonal change in beach profile, factors that determine zonation will change in the sand habitat, however, such factors are of limited significance. Burrowing organisms will be concentrated in or near the wave line and migrate to a small degree with it. The mole crab (*Emerita*), stays directly associated with the breaker line, migrating landward and seaward with the tides. Zonation then, in this habitat, is a migratory adjustment to substrate moisture content either landward-seaward or vertically. The moisture content is, of course, dependent on depth of the seawater tables, but is also a function of capillarity. Figure 3-28 below illustrates the effect on capillarity of one of the many applicable characteristics.

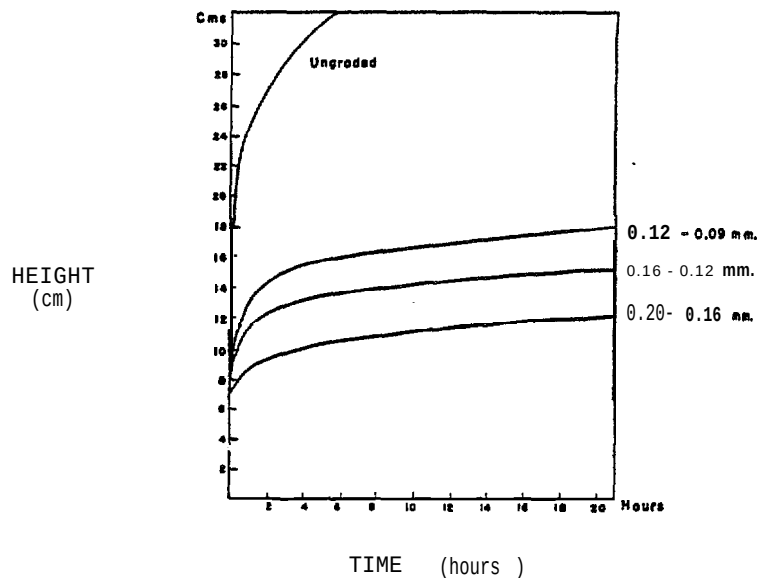


Figure 3-28. Effect of Sand Size Upon Rate of Capillary Rise of Seawater (Hedgepeth, 1957b)

Exposure. Depending on the angle of the slope of the offshore surface, waves will strike the shore with varying degrees of energy. The drag effect caused by a long, gently sloping offshore will dissipate wave energy, thus keeping dislodgement and transportation to a minimum. Larger waves and/or a more steeply trending offshore slope will allow more energy to be delivered to the shore with understandably greater disturbance of organisms. Other than these general remarks, the diversity of

~~occurrences~~ make it impossible to make any precise statements other than site-specific ones.

Other than wave shock, the sand environment is peculiar, among the intertidal environments being considered, in its exposure to insolation. While it may be expected that exposure to the drying effects of sun and wind without any cover or shade (as found on coasts with more relief and richer biota) would cause pronounced variations in temperatures experienced within the habitat, it does not seem to be a particularly relevant factor. Due to the usually light color of the sands along the central and northern California coasts there is a high degree of reflection of solar energy and this, coupled with the reduced conductivity through the mineral grains of absorbed infrared energy, the temperature fluctuations other than at near-surface levels of the beach are probably minimal. Studies of beach temperatures have indicated that temperatures "within a few centimeters may be several degrees lower" and that "at 20 centimeters approached seawater temperatures" (Hedgpeth, 1957b). The subsurface forms that would be most affected by temperature fluctuations have the ability to alter their positions to retain optimum parameters, while the ubiquitous beach-hoppers burrow into the sand or crawl under massed vegetation.

There is a significant difference between the biotic utilization of sandy beaches of differing degrees of exposure. Apparently, protected sandy beaches between rocky outcrops do not support even the limited number of species found in the larger, more open beaches (Ricketts and Calvin, 1968). The organisms adapted to exposure to direct wave action find the dispersed waves of the small pocket beaches not to their liking, while other organisms, adapted to quiet bays and estuaries, cannot deal with even this diminished wave activity.

Because of the movement and mixing with every wave break, this environment is less subject to the problems of metabolic waste buildup and presence of reducing zones (zones of no oxygen). Dissolved oxygen remains at a consistently high level and reducing zones so common in protected bays are not a concern.

Jetties. Jetties are man-made structures of steel, concrete or rock, designed specifically to inhibit the longshore flow of sand especially in relation to harbors. Because of the many fine harbors along the California coast and the economic reliance on harbor related enterprises (shipping, marinas), there are numerous examples of jetties. Jetties as habitat substrata are dealt with in the rocky shore habitat type. Here, their effect on sand beaches is considered.

Jetties are developed to modify or control sand movement. Because they do so effectively, they should only be constructed after critical study of the intended site. Final construction should be designed to take into consideration the numerous peculiar characteristics of the site such as foundation conditions, wave direction and amplitude, sand supply, and economic and aesthetic considerations.

Jetties aid navigation by reducing the flow of sand into a channel. What is often not considered with jetties, as with the smaller groins, is that in slowing the influx of sand into a channel, the flow is also stopped for the down-drift shore, causing sometimes severe erosion of beaches south of jetties (Figure 3-29). These are some of the "economic and aesthetic" factors that must be considered in any analysis of a jetty site. As explained by Berg (Clark, 1977), "to eliminate undesirable downdrift erosion, some projects provide for dredging the sand impounded by the updrift jetty and pumping it through a pipeline to the eroding downdrift beach. This ensures an uninterrupted flow of sand along the shore to nourish the downdrift beach and also prevents shoaling of the entrance channel."

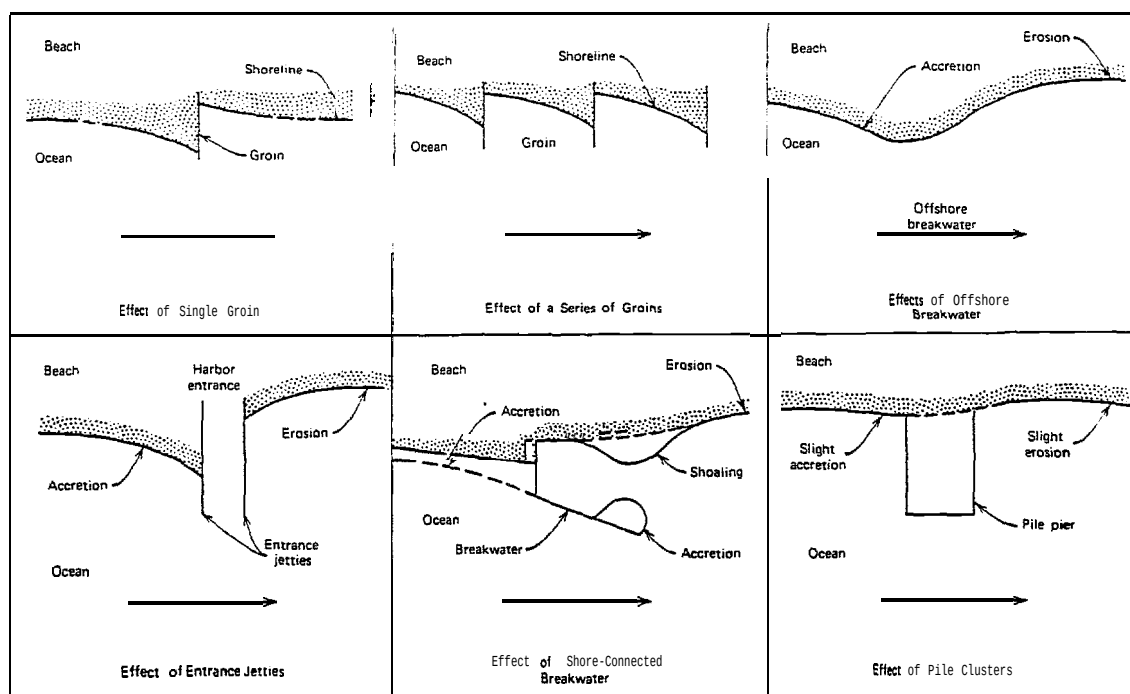


Figure 3-29. The Effects of Jetties and Other Structures on The Transport of Sand Along Ocean Shorelines (Littoral Drift) (Clark, 1977).

With such obvious profound effects on the integrity of the sand environment, it is easy to recognize the restraint and concern that should necessarily be applied to the development of any such structure. The sand habitats are naturally transitory; any further man-caused change could have significant and possibly irreversible effects on incorporated faunas.

Biologic Aspects

Primary Trophic Level. Besides minute interstitial algae (which can only be utilized by organisms adapted to ingest sand grains and digest whatever may adhere to the surface), little is actually produced and food is truly uncertain for inhabitants of sandy beaches. The major source of primary production for this environment is that derived from more luxuriant neighboring habitats in the form of settling detritus, plankton, or flotsam washed ashore by waves (McConnaughey, 1974). This third source of food, flotsam, is often found in very abundant supplies, consisting of occasional corpses of macroscopic organisms, detached submergent seaweeds, sessile animals dislodged by strong tide and wave action from nearby rocky areas, or plankters and nekton such as *Velella* and "jelly fish" washed ashore. However, Hedgpeth (1957b) suggests that the finely divided decomposed materials leached into the sands from the surface and the interstitial microflora are more important to the beach economy than may appear to be the case.

Although the majority of the marine algae are restricted to the more favorable rocky intertidal and subtidal, there are a few species that actually appear to favor the ever unstable situation found in this sandy environment. Most notable of these species are *Gymnogongrus linearis*, *Ahnfeltia plicata* and *Gigartina volans* of the phylum Rhodophyta and *Phaeostrophion irregular* of the phylum Phaeophyta (Abbott and Hollenberg, 1976). These, plus a few other seaweeds found mostly in the mid-tidal zones, being limited in occurrence to an occasional rocky outcropping, tend to provide the sand habitat with only scattered vegetation and a very low biomass. Although intriguing in their ability to withstand constant scouring and seasonal burials, these algae cannot be considered as predominant producers in this environment.

Second Trophic Level. Due to the few in-place producers of any significance other than possibly some interstitial microscopic algae, the organisms at higher trophic levels in this environment are almost entirely dependent upon the forces of the sea to bring their nutrients to them, almost as cave organisms are dependent on surface environments.

The transfer rate of these foodstuffs must be considered as instantaneous for such organisms as Emerita analoga, the mole crab, who, by use of feathery antennae extended into the current, accumulate planktonic food particles for ingestion (Ricketts and Calvin, 1968). For scavengers like the amphipods, such as Orchestoidea californiana, which feed on any organic material washed ashore, the transfer rate from primary to secondary trophic levels would be variable, but longer. These organisms must wait for the cooler temperatures of the night or cloudy days before they can leave their burrows to feed along the beach. While seemingly "at a midpoint in an evolutionary emergence from sea to land" (McConnaughey, 1974), these scavengers still apparently require the dampness associated with proximity to the breaker zone and should probably be considered inhabitants of zone one - the splash/spray zone of Ricketts and Calvin, (1968). An analogous position would be held by the small periwinkle, Littorina on rocky shores.

There is an interesting sub-zonation among the amphipod inhabitants of this habitat. The smaller (about 1/2 inch) Orchestia traskiana occupies the most landward niche, being found as high as 20 feet above tidewater at Santa Cruz (Ricketts and Calvin, 1968). It is more prevalent during the day than the larger Orchestoidea spp., apparently relying on its smaller size to avoid Predation. The two major representatives of the 'beach-hoppers,' Orchestoidea californiana and O. corniculata, divide the beach between them. O. corniculata, the short horned beach-hopper, frequents the narrower steeper beaches and more sheltered ends of long beaches where particle size is larger (being closer to rocky outcrops) while O. californiana, the long-horned beach-hopper, scavenges along the more open beaches.

From Monterey Bay south, one may find the much sought after Pismo clam (Tivela stultorum). While greatly reduced in numbers due to predation by man, this clam is not greatly affected by other predators. Its shell is thick, adapted to withstand the pressures of surf-swept beaches, making it particularly immune to most predatory assaults that may be successful with other, less stoutly invested forms. Tivela illustrates the interesting phenomenon of a food chain stopping at the second trophic level until man enters the picture. This is the reason that a Tivela was found that was 53 years old. (Ricketts and Calvin, 1968).

There is a clam that is the ecologic correlative of Tivela in more northern basins. Said to occur as far south as San Luis Obispo County (Ricketts and Calvin, 1968) the razor clam (Siliqua) is nonetheless a rare element of sandy habitats that far south. While it remains a minor element of sand habitats along California coasts, it is abundant further north and has been commercially harvested.

Another mollusc, Donax gouldi, the bean clam, is locally abundant on shores south of San Luis Obispo. Like Tivela, Donax has been greatly reduced in number by man. Unlike Tivela, however, it is also subject to parasitization of its gonads by a trematode larva (MacGinnitie and MacGinnitie, 1949) which may result in periodic fluctuation in its population densities.

From the Bodega Basin (especially from Drake's Beach) south, there is found another interesting species of arthropod - the spiny sand crab (Blepharipoda occidentalis). They are found from extreme low tide to subtidal levels and are apparently primarily scavengers. There is some unsubstantiated evidence that they may be as eclectic in their feeding habits as are many more generalized crabs (Ricketts and Calvin, 1968). They do, however, occupy a niche similar to Emerita, but are not in competition, being found at lower tidal levels and not migrating with the tides as do the mole crabs.

Another occurrence, while of little significance in the community as a whole, is of interest biologically. This is the commensal attachment of a small hydroid, Clytia bakeri, on the shells of both Tivela and Donax. The interesting feature of this occurrence is the nature of the adaptation of this soft-bodied organism to this environment of active wave exposure and constant scouring by sand grains.

Of considerable significance in the community is the appearance, sometimes in considerable abundance, of the polychaete "worm" Euzonus (Thoracophelia mucronata), the blood worm. It is found commonly at about the mid-tide level in damp, firm sand. Euzonus feeds by passing sand grains through its alimentary canal and digesting adherent nutrient materials. An estimate of the abundance of Euzonus (McConnaughey,

1974) of from 2,500 to 3,000 per square foot illustrates two important factors. First, that this environment is inhabited by relatively few species not because of lack of nutrients but rather because of the harshness of its physical characteristics, and, second, that even though it appears barren, there is sufficient biomass to support large numbers of organisms at the third trophic level.

Third Trophic Level

Since much of the life inhabiting sandy beaches is comprised of burrowing organisms, direct predation of these species is accomplished by predators specifically adapted for probing this substrate. Most notable of these predators are the long-billed shorebirds such as sandpipers, godwits and curlews which successfully utilize the blood worms and beach hoppers (McConnaughey, 1974). Another common bird of the sandy beaches is the sanderling (Calidris alba). These birds can often be observed probing frantically along the lowest points of the receding waves for amphipods, isopods and small mole crabs before racing back up the beach ahead of the next wave. Also, the omnipresent predators - the scavenger gulls - like the California gull (Larus californicus) and the western gull (L. occidentalis) patrol sandy beaches for any foodstuffs left stranded or exposed (or unwatched) (Udvardy, 1977).

Still other small but prevalent numbers of predators and scavengers of more terrestrial affinities use the sandy habitat. Nesting on coastal bluffs, cliff swallows often sweep low over beaches, taking kelp flies and other flying insects; the deer mouse (Peromyscus sp.), common to woods neighboring the beaches, ventures onto the sand to search through flotsam in search of food; skunks and raccoons frequent the habitat in many areas (McConnaughey, 1974).

Each in their own way, the scavengers found on sandy substrata have become well adapted to life in this stressful environment. In fact, because of its physical characteristics, this habitat has truly limited the number of species able to exploit its food resources. Thus, the few species that occur in the sand habitat type find themselves virtually without interspecific competition and often dominate their environment in overwhelming numbers. The most ubiquitous and successful exploiters of this habitat are the amphipod crustaceans noted earlier and are the only scavengers of truly marine affinities.

Of a more terrestrial nature, the kelp fly (Fucilia sp.), frequently seen in swarms about the windrows of beached seaweeds, is as plentiful as the beach hoppers. Not only does Fucilia profligately use this habitat as an adult, but their maggots may also be found 'reposing' algae. Finally, the small, elongate rove beetle (Bledius sp.), along with a number of other beetles, can be regularly encountered (McConnaughey, 1974).

A final group that should be considered to complete the list of organisms that utilize sandy beaches and bars are those that periodically visit from the sea. From the class Mammalia there are three species, all from the suborder Pinnipedia, that use this habitat to "haul out." The most common of these in our range are the steller sea lion (Eumatopias stelleri), the smaller, darker California sea lion (Zalophus californianus) and the sea elephant (Mirounga angustirostris). From the class Osteichthyes, the small grunion (Leuresthes tenuis) seasonally comes ashore on southern sandy beaches to deposit and fertilize their eggs in a moon driven ritual.

None of these latter vertebrates can be considered other than transients in the sandy habitats. None are recognized as predators (in contrast to the birds) among the resident fauna; they do, however, add to the detrital mass, especially in the form of feces.

Community Dynamics

The interesting feature of this environment is its dependence on derived and not inherent primary nutrients. Because of the abundance of algal beds along the coast and the activity of the surf and currents, there is no shortage of detrital material to support locally abundant faunas. Another interesting factor is the lack of clear-cut predator-prey relationships. It would appear that, except for the possible predation of Euzonus by Nephtys californiensis, the predator niche falls to species not restricted to this habitat.

Because of the relatively few species occupying this habitat, the phenomenon of competition is little recognized. The numerous beach hoppers, which, though in often direct competition both intra- and inter-specifically, are nonetheless so amply supplied with nutrients as to negate any ideas of competitive pressure. The other inhabitants of the sandy habitat type occupy niches as the sole incumbent.

Effects of Man

Probably the best examples of the impact man has upon an environment can be found in the sandy habitat. First, there are relatively few species to monitor and second, the beaches, bars and sand flats are the prime recreationally used areas of all coastal environments. As a result, declines can be recognized in the populations, if not in the ranges, of both the pismo clam and the bean clam (*Tivela anti Donax*), because of their gastronomic high marks. There are records of *Tivela* being taken commercially by plow, being harvested like a potato patch. The relatively small number of species inhabiting the sand habitat should be a clue to man that this is an environment in which to practice restraint.

The periodically abundant grunion is also taken in great numbers. The nocturnal habits of the grunion have made its predation by other species almost negligible, but man, able to predict their arrival, waits to take these fish.

Other than predation, man also impacts the sand environment through vehicular compaction. There is little other than visual evidence as yet recorded as to the effect of removal of dune stabilizing plants by vehicular and pedestrian traffic. The removal of dunes behind beaches can have significant impact on beach configuration and is an area of management concern. Direct use of the sandy beaches by vehicles is prohibited in California, so is insignificant in the overall consideration of man's impact. Certainly accessibility of the coastal environments, the relief they offer from nearby urban centers and their obvious recreational uses will continue the pressures upon this transient environment. However, as most of the organisms are buried and/or scavengers, there will be a minimum of disturbance of the ecologic community. Indeed, man's propensity to leave behind his picnic remnants is an additional food source for the beach-hoppers and their terrestrial competitors.

The threat of oil on the sandy strand, while it is looked upon with displeasure by the human users of the beach, can be expected to have devastating impact on subsurface inhabitants. Most, being filter feeders, would be directly affected both by the poisonous qualities of ingested hydrocarbons and by the clogging of the finer features of feeding mechanisms. Despite the numerous, often spectacular oil spills throughout the world there is relatively little written about the long term effects of oil fractions on marine organisms. What can be said at this point is that often the well-intentioned efforts of man to disperse the oils (i.e., by detergents) are often more disastrous to the organisms than the oil itself (Smith, J.E., 1968).

Also of consequence are the numerous examples along the California coast of other types of pollution; chemical, thermal, and sewage. Because of the high oxygen levels, of this ecosystem and wave, current and tidal action, the potentially lethal increases in organic compounds and the subsequent oxygen starvation one expects in more closed systems (bays, lakes) are probably of less consequence here.

Often, the only time man becomes concerned with pollution of any type is when he finds the pollutants incorporated in the tissues of edible species. Marine organisms do concentrate various pollutants - sometimes to alarming concentrations and the long-range effects of such concentrations need extensive and careful study.

Of increasing importance along the coast is the effect on organisms of thermal effluents, i.e., heated waste water used for cooling of power plants primarily, and other manufacturing processes. The effects are disruption of breeding times, growth rates and ranges. The thermal effluents are directly lethal to attached organisms whose temperature tolerances are exceeded. Other organisms have breeding cycles artificially triggered with probably disastrous results relative to out of season larvae.

EXPOSED PIER AND WHARF PILINGS

INTRODUCTION

Along the California coast south to Pt. Conception, there are a very few exposed areas where wharf or pier pilings occur. The term "exposed pilings" refers to pilings which are directly exposed to the full force of oceanic waves. Historically, pilings have been constructed from wood; however, some of the newer pilings are made from concrete and steel. Piers and wharves are not typically built *in* areas fully exposed to the full impact of the waves as there are few structures of man that can withstand the energy delivered to the coast by ocean waters. Storms routinely cause severe damage to the exposed piers and wharves, even in sheltered bays and estuaries where more of these structures are found. Storm waves and, on rare occasions, tsunamis, do considerable damage. Pacifica, Santa Cruz, and Monterey Bay represent areas where piers and/or outer piles of long piers exist. Historically, exposed piers - often replaced - were used at Fort Ross (in the Bodega basin) during the Russian occupation for fur trading and subsequently by the Americans for shipping.

The organisms inhabiting these pilings are commonly referred to as "fouling organisms." Fouling organisms are not unique to exposed pilings: they occur on harbor pilings, floats, and ship bottoms. Many of these species naturally inhabit rocky surfaces in the intertidal zone and are only opportunistically expanding their range in the presence of suitably stable substrata. Thus "fouling organisms" occupy a niche similar to "weeds" in the terrestrial lexicon.

HABITAT CHARACTERIZATION

Physical Aspects

The substratum of the fouling organisms on pilings is typically wood, steel, or cement. Unless treated with toxicants or other protective covering, nearly all fouling organisms are capable of settling and attaching themselves to the structures. The nature of the substratum does affect which marine boring organisms may penetrate the pilings. The wood boring organisms such as Limnoria and Teredo are obviously restricted to a wood substratum. In turn, concrete pilings may become infested with the rock boring molluscs (Penitella spp; Adula sp).

There are two physical factors which have the greatest influence on the inhabiting fauna: the degree of exposure and tidal height differences. In areas where wave action or wave exposure is intense, such as the outer coast, the only organisms that can remain attached to the pilings are barnacles and mussels. Under normal conditions, species variety tends to increase with decreased wave action and/or exposure.

The piling fauna is arranged along a conspicuous vertical zonation. Since the pilings are themselves distinct vertical structures, horizontal **zonation** does not exist to any appreciable extent. However, as a result of lessened wave shock on the leeward side of the piers, the species composition may be occasionally greater on this protected half of the piling. As in the rocky and beach intertidal habitats, vertical zonation on pilings is divided into various zones by the factors of tidal exposure and the organisms are subject to the same physical parameters. Zones 1 and 2, the spray and storm-wetted area and the high-tide horizon, respectively, (Ricketts and Calvin, 1968) represent the uppermost portion of marine invertebrate attachment on pilings. (species list follows). Zone 3, or the mid-tide zone, occurs next and the lowest is Zone 4 which represents the low-tide horizon. The vertical depth of each zone is controlled by the tidal height differences (tidal exposure) resulting from the daily tidal cycle, and in part by the degree of wave action for the uppermost splash zone. For explanation of "Zones" see Features and Processes of Special Significance to Intertidal Habitats, Vol II, Part 1.

A physical characteristic of concern to piling faunas (as opposed to those on rocky substrata) is the effect of sand scour and burial. Current, tidal, and wave actions have free reign to move the sand particles commonly associated with pier locations. With little or no obstruction, the sand can have more erosive effect than in even more exposed rocky areas where crevices, protrusions, and algal masses serve to trap the sand and settle it as the water loses its carrying power in turbulent flow.

Whereas the effects of jetties on sand distribution are often profound (see Rocky Shore; Jetties), piers have little such effect. The open nature of piers permits relatively uninterrupted movement of currents and longshore movement of sand through the structure with only minor disruptions due to the slight turbulence created by flow past the cylindrical pilings.

Other physical factors such as water temperature, dissolved oxygen, and salinity associated with marine pilings are similar to the general characteristics applicable to the coast as a whole.

Biologic Aspects

Organisms that predominantly inhabit exposed pilings are acorn barnacles (Balanus sp.) and the California mussel (Mytilus californianus) (Table 3-16). Other organisms commonly found upon exposed pilings are the hydroid (Obelia), the clam worm (Nereis sp.), the solitary tunicate (Styela) and various boring organisms such as the gribble (Limnoria), the shipworm (Teredo) and the piddocks (Penitella spp.)

As previously stated, the degree of wave exposure greatly affects faunal development on pilings. The fauna listed below are those that, according to Ricketts and Calvin (1968), inhabit "exposed" pilings. One may note that the faunal assemblage compares in many details with the fauna of the rocky shore habitats. Too, the community dynamics of pilings will adhere closely to that discussed in the above mentioned section.

Table 3-16. Principal Organisms of Exposed Piers and Pilings

Zone	Tidal Height	Scientific Name	Common Name
1&2	Spray Area and High Intertidal	<u>Balanus glandula</u> <u>Anthopleura elegantissima</u> <u>Pachygrapsus crassipes</u> <u>Ulva</u> sp. <u>Enteromorpha</u> sp.	Barnacle Aggregating Anemone Lined Shore Crab Sea Lettuce Alga
	Middle Intertidal	<u>Mytilus californianus</u> <u>Balanus nubilis</u> <u>Obelia tintinnabulum</u> <u>O. longissima</u> <u>Halosoma viridintestinale</u> <u>Barentsia ciracilis</u> <u>Alcyonidium mytili</u> <u>Pachycheles rudis</u> <u>Anthopleura xanthogrammica</u> <u>Nereis mediator</u> <u>Pycnogonum stearnsi</u>	California Mussel Barnacle Hydroid Hydroid Sea spider Entoproct Bryozoan Porcelain crab Giant Green Anemone Mussel worm Pycnogonid

Table 3-16, (continued)

Zone	Tidal Height	Scientific Name	Common Name
4	Low Intertidal	<u>Macrocystus</u>	Kelp
		<u>Metridium senile</u>	White Anemone
		<u>Style~ p -</u>	Tunicates
		<u>Bugula neritina</u>	Bryozoan
		<u>Pisaster brevispinus</u>	Small Spined Seastar
		<u>Eupentacta quinquesemita</u>	White cucumber
		<u>Pododesmus sp.</u>	Rock oyster
		<u>Betaeus setosus</u>	Pile shrimp
		<u>Pugettia products</u>	Kelp crab
		<u>Teredo navalis</u>	Shipworm
		<u>Limnoria lignorum</u>	Gribble
		<u>Bankia setacea</u>	Wood borer
		<u>Nereis vexillosa</u>	Mussel worm

Community Dynamics

All three major trophic levels are represented in the feeding habits of piling faunas (Table 3-17). The only primary producers are the algae (Macrocystis, Ulva) that may grow on the pilings and the phytoplankton and flotsam outside the habitat which add to the abundant store of suspended and detrital material.

Table 3-17. Trophic status, Zonation, and Food of Piling Fauna

Trophic Level	Species	Intertidal Zone (s)	Feeding Type Or Food
Secondary	<u>Balanus spp.</u>	1,2	Filter feeder
	<u>Mytilus californianus</u>	2; 3	Filter feeder
	<u>Alcyonidium mytili</u>	3	Filter feeder
	<u>Barentsia gracilis</u>	3	Filter feeder
	<u>Styela spp.</u>	4	Filter feeder
	<u>Bugula neritina</u>	4	Filter feeder
	<u>Pododesmus sp.</u>	4	Filter feeder
	<u>Eupentacta quinquesemita</u>	4	Plankton (?)
	<u>Bankia setacea</u>	4	Filter feeder
	<u>Teredo navalis</u>	4	Filter feeder
	<u>Limnoria lignorum</u>	4	Wood, Fungus feeder
Tertiary	<u>Anthopleura sp.</u>	1,2	Small fish invert.
	<u>Pachygrapsus</u>	1,2	Scavenger
	<u>Obela spp. 'p'</u>	3	Larvae
	<u>Halosoma viridentestinale</u>	3	Scavenger
	<u>Pachycheles rudis</u>	3	Scavenger
	<u>Nereis spp.</u>	3	Crustaceans, larvae
	<u>Pisaster brevispinus</u>	4	Mussels, barnacles
	<u>Metridium senile</u>	4	Small fish, invertebrates
	<u>Pugettia producta</u>	4	Worms, scavenger

Of the species listed in the tertiary trophic level, the crustaceans (Pachygrapsus, Halosoma, Pachycheles, Pugettia) and the polychaete (Nereis) are considered as both scavengers and predators. They have been placed in the third trophic level as a result of their predacious activity.

Succession for the exposed piers is similar to that discussed in the Rocky Shore Habitats and the reader is referred to that section. The pier habitat will vary only in minor details relative to the few boring species added and to the confined, vertical nature of the substratum.

Effects of Man

Because the pier habitat is strictly of human origin and because piers are obviously not placed in the marine environment for the convenience of intertidal organisms, any biotic attachment is considered detrimental. Consequently, much time, effort and money is spent by man in his usually unsuccessful attempts to control such attachment (See "Limnoria" under Species, Volume II, Part 2 for an account of such methods).

Faunal populations on pilings probably deserve much more critical study in light of their common association with loading facilities, especially those concerned with oil transfer. These factors are of more concern with wharves and pilings in protected and estuarine habitats and will be covered in more detail there, but the obvious effects of pollution will be apparent and easily studied and codified on and around these structures.

CHAPTER 4 ESTUARINE ECOSYSTEM

GENERAL CHARACTERISTICS

Estuaries develop in partially enclosed bodies of marine water, including lagoons, river mouths, and protected bays, drowned subsequent to the post-glacial rise in sea level. Approximately 10 to 20% of the Pacific coast is comprised of estuarine habitats (Chapman, 1977). More extensive development is precluded by the tectonically active nature of the Pacific coast formation in coastal California. San Francisco Bay represents 88 to 89% of the total area covered by estuaries in California (Macdonald, 1977). Four to five percent occurs north of San Francisco Bay. Humboldt Bay is the major estuary of northern California. Seven percent of the total estuarine area occurs between San Francisco Bay and the Mexican border, including Morro Bay and Elkhorn Slough.

Estuaries are transitional zones (ecotones) between fresh water and marine habitats, characterized by the mixing of seawater with fresh water by tidal exchange and diffusion. Biotic zonation reflects the stressful physical conditions to which the organisms are subjected, and is especially related to salinity and elevation. Estuarine organisms display wide tolerances to regularly changing physical conditions by specific adaptive mechanisms. High productivity in the estuary is maintained by "pulse-stabilization" or regular periodic fluctuations of physical conditions, especially water levels (Odum, 1971).

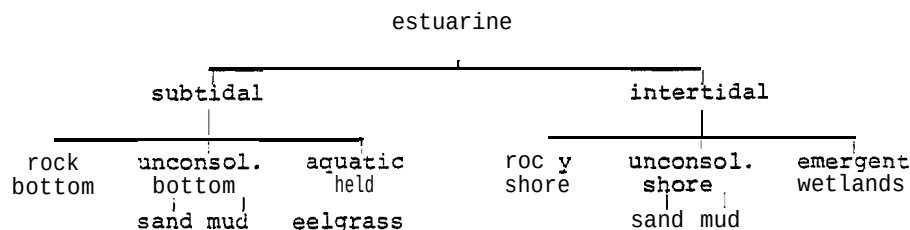
Figure 4-1 is a model of estuarine ecosystem structure and function. The physical-chemical processes of the water column and the substrate are defined. Dominant parameters include temperature, light, wave action, sedimentation, and salinity. The functional influence of other ecosystems (oceanic and riverine) on these estuarine processes is delineated by the model. A general discussion of the structure and function of the estuarine ecosystem as a unit is presented in Volume II, Part 1, (Regional Characterization). Detailed information on specific California estuaries is presented in Volume IV (Watersheds and Basins).

The biological component of this model stresses interaction with the physical and socio-economic processes. The photosynthetic process is largely influenced by physical parameters. Biological processes, such as burrowing by animals, the growth of plant roots, and the decomposition of organic matter, impact the physical environment.

Human activities, which are defined as socio-economic processes, can directly influence the biota by removal of individuals or habitat. They can also indirectly influence the biological component through altering the physical conditions of the estuarine ecosystem. The introduction of toxic substances to the water column or substrate, the employment of land management practices which increase sedimentation, and alteration of habitat by draining, dredging, or filling are examples.

SUBSYSTEMS

The subsystems, or habitats, discussed for the estuarine ecosystem include the unconsolidated bottom, rocky bottom, emergent vegetation, eelgrass (subtidal aquatic bed), and piers/pilings. The U. S. Fish and Wildlife Service wetland classification system by Cowardin *et al.* (1979) was used as the basis for identifying those habitats to be discussed. The following diagram indicates how the habitats discussed in this chapter are associated, based on Cowardin *et al.* (1979).



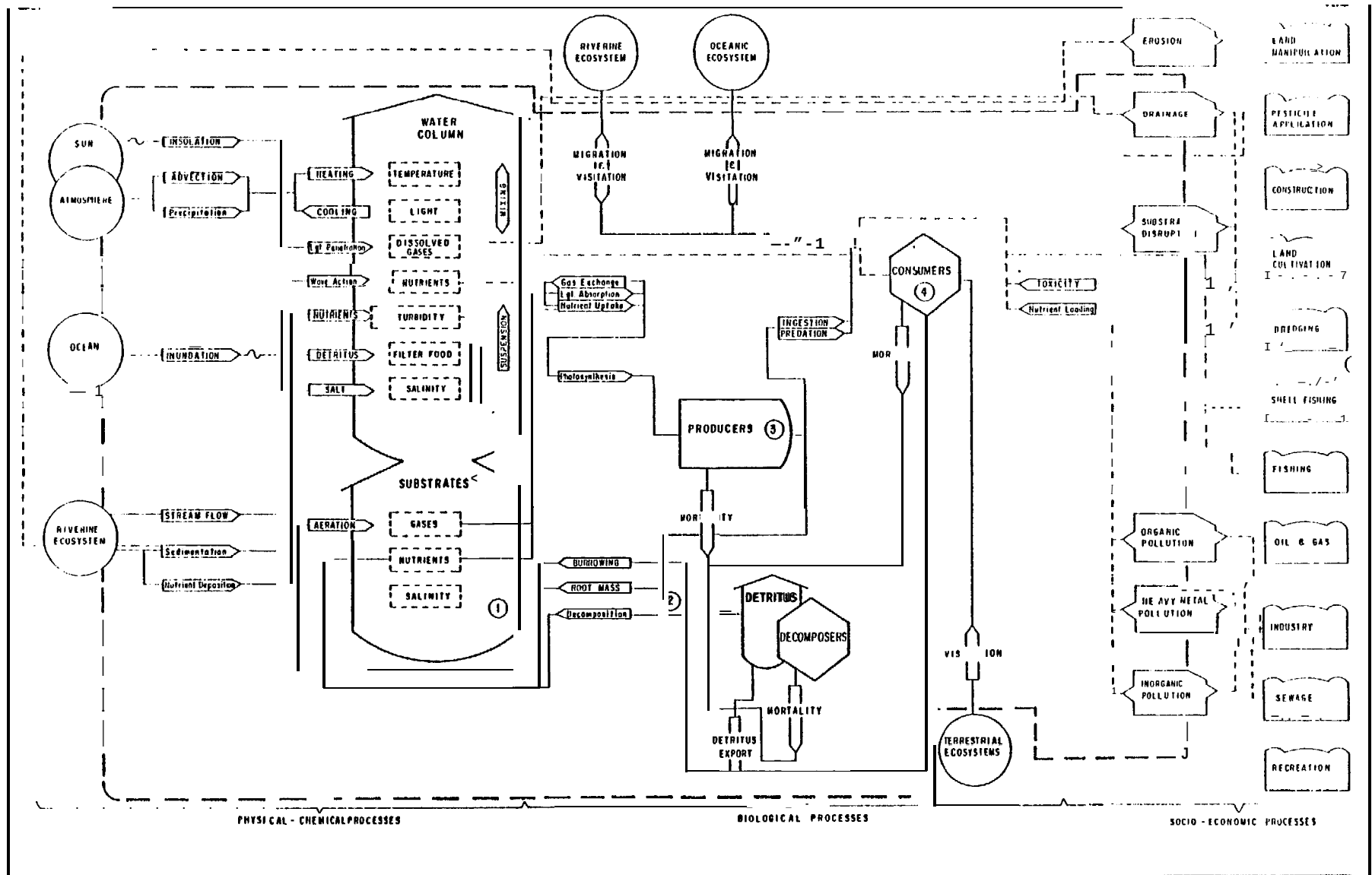


Figure 4-1. Ecosystem Model of an Estuary.

Footnotes for Figure 4-1.
Ecosystem Model for the Estuary
Highlighted Processes and Components are Annotated Below

1. PHYSICAL-CHEMICAL PROCESSES: Weather influences the water column by stirring up the bottom which increases turbidity and dissolved gases, and by introducing fresh water which decreases salinity. Fresh water is introduced from the riverine ecosystem at the upper (river) end of the estuary. Nutrients and sediments are added to the substrate from settling of the water column. The degree of settling depends on the turbulence of the water column. Artificial substrates (piers, pilings, jetties, riprap) are a new source of substrates for the estuarine flora and fauna. Physical influences on biological processes include temperature, light, and salinity as controlling factors for submerged vegetation and phytoplankton. Wave action, which is a function of the tides and wind, influences turbidity which in turn influences the degree of light penetration. Turbulence of the water column and deposition of detritus and nutrients from ocean and riverine ecosystems is the source of food for filter-feeding organisms. Nutrient deposition and aeration of the substrate is important to the growth of vascular plants.
2. BIOLOGICAL INTERACTION: Burrowing by invertebrates that inhabit the mudflats aerate the substrate for vascular plants. Root mass of plants is an important factor in soil development.
3. PRODUCERS: Vascular plants, phytoplankton and benthic algae compose the producer component of the estuary.
4. CONSUMERS: Consumers in the estuary consist of invertebrates (zooplankton, insects, crustaceans, mullusks), fish, birds, and mammals.
5. INPUTS TO THE ESTUARY FROM OTHER ECOSYSTEMS AND HAN: Riverine ecosystems deposit sediments into the estuary. Upstream land manipulation has added to the natural deposition of sediments resulting in increased coverage of mud-inhabiting organisms and increased turbidity. Dredging and construction has drained some marshlands and covered others with disposal material and landfill. Dredging disrupts the bottom and introduces toxins to the estuary. Oil and gas development and release of oil pollution can smother bottom or attached organisms. Other pollution from industry is toxic to estuarine organisms. Anadromous fish use the estuary to acclimate to fresh water before moving upstream. Many fish and birds utilize the estuary on a seasonal basis.

The habitats presented in the following sections most closely relate to the "class" of the Cowardin system hierarchy. The differentiating criterion is the general appearance of the habitat, which may be in terms of the dominant life form of the vegetation (emergent vegetation and eelgrass or subtidal aquatic bed) or in terms of the physiography and composition of the substrate (unconsolidated bottom, rocky bottom, piers and pilings).

The emergent vegetation habitat occupies only intertidal elevations conducive to the growth of vascular halophytes. The remaining habitats occupy both subtidal and intertidal areas, although eelgrass is primarily associated with the subtidal zone. These habitats are differentiated by their substrate composition; sand and mud (unconsolidated bottom), rock or hard substrate (rocky bottom), artificial (piers and pilings), or vegetated (eelgrass beds). It was not practical to separate intertidal and subtidal communities for the habitats. However, the differences in physical factors and organisms of the intertidal and subtidal zones of each habitat have been discussed where appropriate.

The unconsolidated bottom habitat discussion covers the physical, biological, and socio-economic aspects of subtidal and interstitial elevations where mud or sand dominate as the substrate. The overlying water column, not related to any particular bottom type, has been included in this discussion as well.

The rocky bottom habitat describes the physical environment, the interactions of the biota, and the socio-economic activities that might influence ecosystem functions. This section also reviews the artificial substrates such as jetties and shoreline riprap. These have been included as rocky bottom because the artificial structures provide a site for attachment of organisms similar to that of the natural rock bottoms.

The eelgrass bed habitat, or, as defined in the Cowardin system of wetland classification, the subtidal aquatic bed-rooted vascular (although it also occurs in the lower intertidal zone), also considers physical, biological, and socio-economic aspects of the ecosystem. Eelgrass has been singled out as the most important subtidal aquatic plant in estuaries throughout the study area.

The emergent vegetation discussion of the physical and biological parameters related to this ecosystem is, of necessity, concerned with both terrestrial and aquatic processes. As a transitional ecosystem, the inputs from and interactions with other ecosystems are complex. Socio-economic activities affecting adjacent or functionally related ecosystems as well as those activities directly impacting marshes are considered.

Piers and pilings have been discussed as a habitat type, as they offer physical conditions not entirely similar to the other habitats. A specialized biota, discussed in this section, is developed on the piers and pilings.

UNCONSOLIDATED BOTTOM

INTRODUCTION

Substratum

A number of different habitats are included under the general heading of unconsolidated bottom. The nature of the substrate exerts considerable influence upon community composition. The substrate may be composed of gravel and cobble, sand, mud, or organic matter. A new habitat is created when the vascular plant eelgrass (*Zostera marina*) becomes rooted on sand and mud bottoms, a habitat classified as emergent vegetation. An additional habitat is the water column, a habitat not associated with a particular substrate, but one which usually overlies unconsolidated bottoms within the estuary. Three types of unconsolidated bottom habitats are discussed in the following sections: sandflats, mudflats, and the water column. The community composition lists do not distinguish between intertidal and subtidal sandflat and mudflat communities. The lack of information concerning the preferences of certain species and the overlap between zones of others made it impractical to divide the community along these lines. However, the zonation preferences of particular species are noted within the general sandflat and mudflat discussions.

Areal Extent

Unconsolidated bottom is generally the most common substrate type found in the estuarine environment. Most of the bottom sediments are mud rather than sand. Intertidal mudflats are only extensive in a few large estuaries. This habitat has been reduced due to natural sedimentation and human reclamation activities. Subtidal mudflats fringe the shoreline of most estuaries. The open water habitat occurs throughout the estuary, including both deep central channels and shallower areas.

Dominant Species

The tidal flat communities (sand and mud) are dominated by similar types of organisms. The primary producers are algae, including both microscopic diatoms and macroalgae. The invertebrate fauna is characterized by two types of organisms, those living on the substrate (epifauna) and those living in the substrate (infauna). The epifauna includes snails, nematodes, crustaceans, and polychaete worms. The infauna includes bivalves, polychaete worms, crustaceans, and echinoid worms. The fish community associated with sand and mudflats consists largely of bottom fish, including flounders, gobies, rays, and sharks. A number of species of birds feed intertidally, especially on mudflats and during low tide.

The open water community is dominated by pelagic organisms. The primary producers are members of the phytoplankton community, largely single-celled diatoms. The zooplankton community is dominated by copepods, but also includes other crustaceans and the larvae of mollusks, crustaceans, and fish. Adult pelagic fish include anchovy, herring, smelts, silversides, and several anadromous species. Some of these species use the estuary on a seasonal basis, while others are resident species. A number of birds inhabit or feed in the open water environment. These birds include those that swim on the surface and those that dive from the air.

Habitat Descriptors

Tidal influence helps determine zonation within the sand and mudflat communities. Although conditions within the mud or sand remain relatively stable regardless of the tidal state, many infaunal organisms exhibit preferences for intertidal or subtidal zones. Epifaunal organisms must either abandon the intertidal zone during periods of exposure or tolerate the resulting conditions. Fish tend to occupy the intertidal zone during high

tides, while birds often feed on the tidal flats during low tides. The main variable factor in the open water habitat is salinity. The inhabitants of this community can either change their geographic position within the estuary in response to tidal-induced variations in salinity, or, if euryhaline (tolerant of wide ranges in salinity), can remain in place and make physiological adjustments. Figure 4-2 provides a generalized model of the physio-chemical, biological, and socio-economic processes operating in the unconsolidated bottom ecosystem.

HABITAT CHARACTERIZATION

Geographic Aspects

Physical Size. Unconsolidated bottom habitat occurs on nonvegetated sand or mud sediments. They are commonly referred to as mudflats or sandflats, depending on the substrate composition. The more general term is tidal flat. Their location includes the shallow subtidal and the intertidal zone, extending landward to the mean high tide level.

Natural, Artificial Factors that Define/Limit Area. Extensive mudflat and sandflat development within estuaries along the coast of California is limited. Protected estuaries, small bays, lagoons, and river mouths that offer gentle profiles and a quiet depositional environment conducive to tidal flat development, are infrequent along the tectonically active northern and central California coast.

Physical Aspects - Subtidal

Substratum. Tidal flats are described by the average grain size of the sediments. Sandflats and mudflats are most common, but tidal flat development can occur by deposition of coarser materials, such as gravel or cobbles.

Local sand dune systems may provide a source of sand, or sand may be transported by littoral drift from other locations. The areas near the mouth of the estuary provide a suitable depositional environment for the development of sandflats (Barbour, et al., 1973). Water is slowed as it enters the confines of the estuary; since coarser particles settle faster, sand grains may accumulate.

Mudflats, composed of finer-grained particles, silts, and clays, are more common than sandflats in the estuarine environment. Particle size distribution is characterized by decreasing size from the major bay or estuary channel in the subtidal zone landward to the vegetated intertidal flats. In a study of San Francisco Bay mudflats, the channels transversing the tidal flats have been found to contain the coarsest materials. These coarse particles are concentrated in the bedload, and consist of 5% sand, 5% gravel-sized particles of shell and wood debris, 20% silt and 70% clay. The channel levees contained less clay (60%) and a greater amount of silt (40%). This particle size distribution contributes to the higher shear strength and density on the levees (Pestrong, 1967-8).

The tidal flats are dominated by impermeable clays, consisting of 80% clay and 20% silt. Pestrong (1967-8) determined that most of the silt fraction was composed of clay floccules. Nearly uniform mean diameter and sediment size is common throughout the tidal flat, except where it is crossed by tidal channels. A small decrease in particle size may be noted landward, but the magnitude is insignificant.

Water Movement. Below the elevation of periodic exposure, the subtidal mud and sandflats are subjected to the oscillating flows of tidal inundation. Tidal currents have been measured at the entrance to San Francisco Bay and have been found to reach a maximum during flood tide of up to 169.9 cm per second (3.3 knots) (Pestrong, 1967-8). Ebb tide currents are considerably less, as are the currents near the mudflats and distant from the estuary mouth. No data are available on current speeds specifically over sandflats. It is possible that they are greater than those over the mudflat, due to the proximity of sandflats to the mouth of the estuary.

Dissolved Oxygen. Estuarine water is typically high in dissolved oxygen. Ocean waters near the entrance to the estuary are mixed with the atmosphere by action of the surf in shallow locations. The subtidal substrate, therefore, has an ample supply of dissolved oxygen from the overlying water column and is replenished by tidal exchange.

The oxygen supply in the mud or sand may frequently become depleted under certain conditions. The respiration of bottom-dwelling organisms may consume large quantities of dissolved oxygen in the interstitial water of the substrate. This, combined with the lack of oxygen-producing plants, could create an oxygen deficiency until the onset of the next flood tide. The breakdown of organic matter by bacteria also may deplete the oxygen supply. (McLusky, 1971).

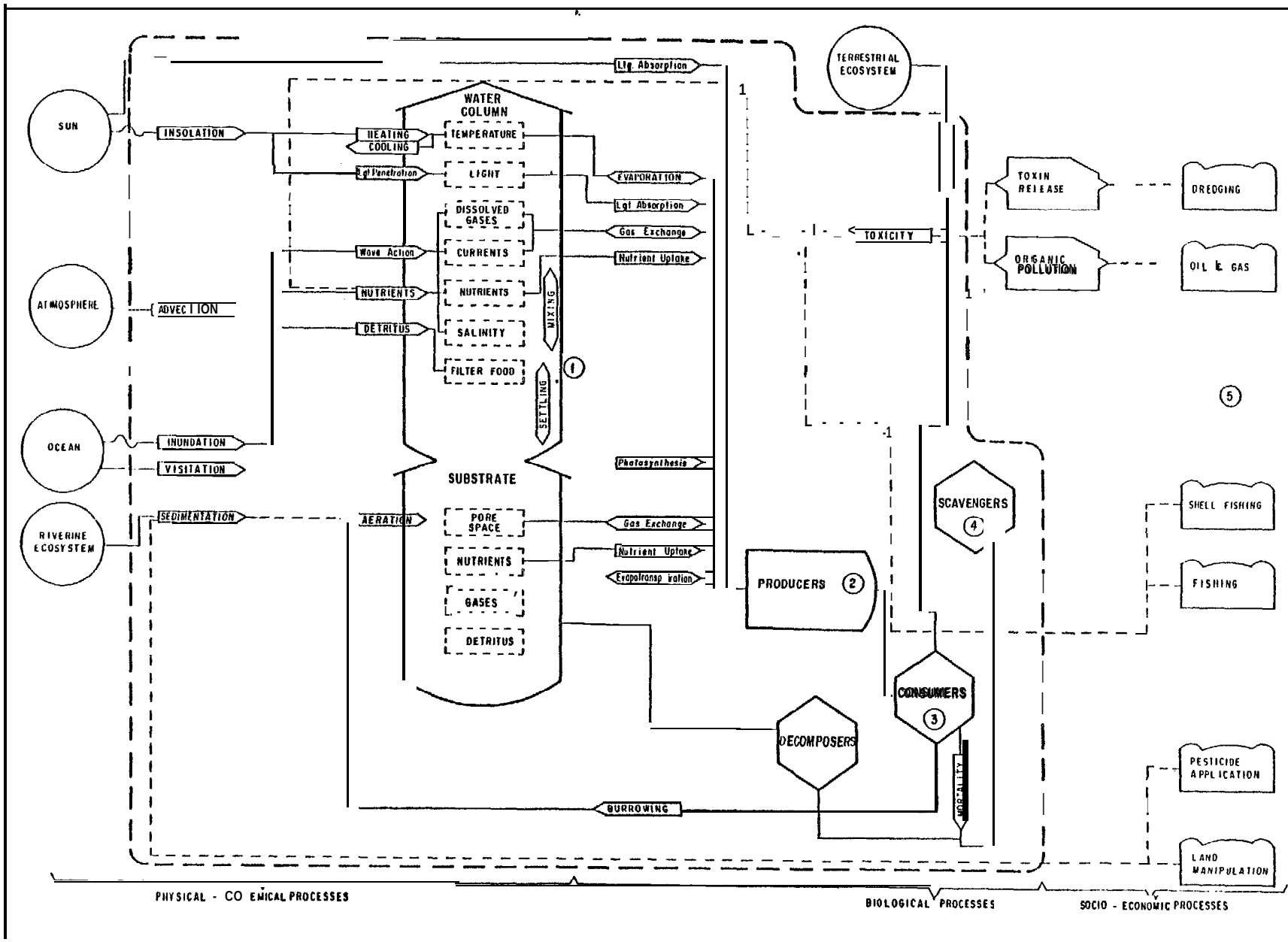


Figure 4-2. Ecosystem Model of an Unconsolidated Bottom Habitat

Footnotes for Figure 4-2
Ecosystem Model for the Unconsolidated Bottom Habitat
Highlighted Processes and Components Are Annotated Below

1. PHYSICAL-CHEMICAL PROCESSES: The substrate for the unconsolidated bottom consists of gravel, cobble, sand, mud or organic matter.
2. PRODUCER ORGANISMS : Aquatic producers are phytoplankton suspended in the water column and serve as the source of filter food. Mudflat producers include micro- and macro-algae that inhabit the mudflat. Diatoms grow on the surface. Green and red algae attach to the mud substrate. The attached producer component is 'As.sally absent from the sandflat.
3. CONSUMER ORGANISMS: Herbivorous species are represented by dwarf surfperch and American wigeon. Filter-feeding consumers are the most well represented component, including clam, echiuroid worm, shrimp, amphipod, and polychaete worm. Some of these species are also occasionally deposit-feeders. Secondary consumers include channelled basket shell, sea slug, ribbon worm, shark, bat ray, smoothhound, goby, sanddab, sole, flounder, surfperch, great blue heron, gull, dunlin, sandpiper, godwit, and willet.
4. SCAVENGERS; These may be represented by the yellow shore crab.
5. IMPACTS OF HUMAN ACTIVITIES: Dredging releases toxins buried in sediments which kill sand and mudflat organisms.

Dissolved Salts and Nutrients. As with the oxygen supply, dissolved salts and nutrients are provided to the bottom-dwelling subtidal communities through tidal inundation. The flooding tide introduces water predominately marine origin with high salinity. During periods of heavy runoff or large freshwater flows, salinity may be very low.

This pattern of a widely fluctuating salinity regime of the overlying water column is not as severe in the interstitial waters of mud and sandflats. Changes in the water column are reflected in the interstitial water, but occur at a much slower rate of change (McLusky, 1971). Other factors that result in modification to the typical salinity regime include the proximity to and complexity of tidal and fresh water drainages, the porosity and permeability of sediments, the differences of tidal and freshwater drainages, and the aeration and reduction of organic matter and its abundance (Frey and Basan, 1978).

The salinities along a vertical gradient from the tidal flat to approximately the mean high water spring flood tide level increase landward (Frey and Basan, 1978). The lower elevations may be more influenced by fresh water at lower states of the tide (McLusky, 1971).

The ionic composition of estuarine water depends, as does salinity, on the ratio of sea water to fresh water. Sodium and chloride ions dominate the sea water fraction. Nitrates, sulfates, and phosphates may be present in large concentrations in fresh water runoff. Leaching of agricultural fertilizers and addition of sewage or other wastes from the watershed would result in greater concentrations of nitrates, sulfates, and phosphates. Calcium may be limited in the dilute salinities dominated by fresh water flows. Large quantities of nutrients may be added to estuarine waters from oceanic sources during periods of coastal upwelling. Along the California coast this is a potentially significant source; however, little documentation is available (Winzler and Kelly, 1977a). Elsewhere, the sea is not considered to be a large contributor of sediments and absorbed nutrient supply to the estuary (Biggs, 1978).

Light Penetration. Light penetration decreases with increased depth over mud and sand flats, since wave length bands display characteristic rates of extinction. Estuarine waters commonly exhibit high turbidity, which further reduces light penetration. The turbidity, or suspended clay, silt, detritus, and other small particles suspended in the water column, increases as a result of eddies formed by the interaction of incoming fresh water flows and tidal action. Light availability may limit algal growth in the subtidal zone.

Temperature. Temperatures of the estuarine water body are dependent on incoming sea water temperatures, fresh water temperatures, and the relative proportion of each in the overlying water column. Water temperature over tidal flats is strongly influenced by land air temperature and in situ solar radiation due to shallow depth (Johnson, 1967). The flooding of mud and sandflats causes temperatures to be more directly influenced by the overlying water column, and the ebbing tide imposes a greater influence of air temperature and solar radiation.

Temperature of sediments display similar ranges and seasonal trends as the overlying water column. The diel cycle is similar to that of terrestrial soils, but amplitudes are decreased by the buffering effects of the overlying water column. A phase shift in the timing of daily maximum and minimum temperatures also occurs as a result of the ameliorating influence of the water column (Johnson, 1967).

Vertical temperature profiles tend to reflect a buffering effect. When surface substrate temperatures are high (e.g., during exposure on a warm day), temperatures decrease with depth. An increase with depth may be noted when surface temperatures are low (e.g., exposure during winter).

Physical Aspects - Intertidal

Substratum. The substrate of the intertidal, unconsolidated shore is similar to that described above for the subtidal segment. As previously discussed, particle size may be somewhat finer in the landward intertidal zone.

Zonation. The distribution of fauna of the intertidal unconsolidated shore is determined by tidal submergence. Two major zones may be identified. The lower zone occupies the area between mean lower low water (MLLW) and mean higher low water (MHLW) and is dominated by suspension feeders adapted to longer submergence times. The upper zone, between MHLW and mean lower high water (MLHW) is characterized by increased times of emergence. Deposit feeders, adapted to feeding on or in the substrate, are typical of this zone (Barbour et al., 1973).

Dissolved Salts and Nutrients. The salinity regime of the overlying water column of intertidal communities differs little from that of the subtidal zone. The salinity

of interstitial waters in the substrate is also similar, but exposure at low tides can cause evaporation and increased salinity concentrations (Frey and Basan, 1978). Silty sands tend to hold more saline waters as the tide ebbs than do other substrates.

Ion concentrations of an unconsolidated bottom substrate vary according to the quantity and quality present in the overlying water column. Availability of nutrients may be limited to that adsorbed on to substrate particles or dissolved in the interstitial water.

Temperature. The diel and seasonal temperature regime of the overlying water column has been described previously in the discussion of the subtidal zone. The temperatures of the substrate differ, however. Increased periods of exposure to solar radiation with increased elevation results in both increased daily and monthly temperature ranges (Johnson, 1967).

Dissolved Oxygen. Dissolved oxygen is supplied by tidal flood waters. Oxygen supply in the interstitial waters of the mud or sandflats may be low during periods of emergence. The curtailment of circulation with the oxygen-rich water column and the continued respiration of the bottom-dwelling organisms may result in a reduction of the dissolved oxygen content (McLusky, 1971).

Biological Aspects - Mudflat

Dominant Species. The dominant species of the mudflat community are presented in Table 4-1. These include 4 taxa of algae, 19 species of invertebrates, 11 species of fish, and 7 species of birds. The problems of respiration and feeding and the lack of attachment sites in the soft substrate of mud bottoms favor a specialized fauna. Information on the feeding habits and habitat preferences of these organisms was taken from several sources (MacGinitie, 1935; Ricketts and Calvin, 1968; Moyle, 1976; Smith and Carlton, 1975; Standing et al., 1975; Nybakken et al., 1977). This information is presented in the following sections.

Table 4-1. Dominant Organisms of a Mudflat Community¹

Algae	Birds
Diatoms (BA)	Great blue heron (CWB) <u>Ardea herodias</u>
Sea lettuce (BA) <u>Ulva</u> spp.	Herring gull (CWB) <u>Larus argentata</u>
Green algae (BA) <u>Enteromorpha</u> Spp.	American wigeon (CWB, HWB) <u>Anas americana</u>
Red algae (BA) <u>Gracilaria sjoestedtii</u>	Dunlin (CWB) <u>Calidris alpina</u>
	Western sandpiper (CWB) <u>Calidris mauri</u>
	Marbled godwit (CWB) <u>Limosa fedoa</u>
	Willet (CWB) <u>Catoptrophorus semipalmatus</u>

Table 4-1. (Continued)

Fish	Invertebrates
Brown smoothhound (SCF) <u>Mustelus henlei</u>	Geoduck (FI) <u>?anopea generosa</u>
Dwarf surfperch (SCF, HF) <u>Micrometrus minimus</u>	Gaper clam (FI) <u>Tresus nuttallii</u>
Leopard shark (LCF) <u>Triakis semifasciata</u>	Common Washington clam (FI, DI) <u>Saxidomus nuttallii</u>
Bat Ray (LCF) <u>Myliobatis californica</u>	Soft-shell clam (FI) <u>Mya arenaria</u>
Speckled sanddab (SCF) <u>Citharichthys stigmaeus</u>	Bent-nose clam (FI) <u>Macoma nasuta</u>
English sole (SCF) <u>Parohrys vetulus</u>	Fat innkeeper (FI, DI) <u>Urechis caupo</u>
Starry flounder (SCF) <u>Platichthys stellatus</u>	Blue mud shrimp (FI, DI) <u>Upogebia pugettensis</u>
Pile surfperch (SCF) <u>Rhacochilus vacca</u>	Polychaete worm (FI) <u>Capitella capitata</u>
Bay goby (SCF) <u>Lepidogobius lepidus</u>	Polychaete worm (FI) <u>Cirriformia spirabranca</u>
Pacific staghorn sculpin (SCF) <u>Leptocottus armatus</u>	Polychaete worm (DI) <u>Chaetopterus variopedatus</u>
Arrow goby (SCF) <u>Clevelandia ios</u>	Anemone (FI, CI) <u>Pachycerianthus fimbriatus</u>
	Sea hare (HI) <u>Aplysia californica</u>
	Channeled basket shell (CI) <u>Nassarius fossatus</u>
	Cephalaspidean (CI) <u>Chelidonura inermis</u>
	Nudibranch (CI) <u>Hermisenda crassicornis</u>
	Ribbon worm (CI) <u>Paranemertes peregrina</u>
	Yellow shore crab (DI, CI) <u>Hemigrapsus oregonensis</u>
	Amphipod (DI) <u>Corophium</u> spp.
	Pink ghost shrimp (FI, DI) <u>Callinassa californiensis</u>

¹Refer to Figure 4-3 for definition of abbreviations.

Rare, Endangered and Species of Concern. A number of species of ecological concern are found in the mudflat community. These species are listed in Table 4-2. The species of concern include three species of birds, four species of invertebrates, five species of fish and two genera of algae. Species accounts of all these species may be found in Volume II, Part 2, of this report. No species designated as rare or endangered occur in the mudflat community.

Table 4-2
Species of Concern Occurring in a Mudflat Community

Group and Common Name	Scientific Name
Algae	
Sea lettuce	<u>Ulva</u> spp.
Green algae	<u>Enteromorpha</u> spp.
Invertebrates	
Gaper clam	<u>Tresus nuttallii</u>
Common Washington clam	<u>Saxidomus nuttallii</u>
Soft-shell clam	<u>Mya arenaria</u>
Yellow snore crab	<u>Hemigrapsus oregonensis</u>
Fish	
Leopard shark	<u>Triakis semifasciata</u>
Bay goby	<u>Lepidogobius lepidus</u>
Starry flounder	<u>Platichthys stellatus</u>
Pile surfperch	<u>Rhacochilus vacca</u>
Pacific staghorn sculpin	<u>Leptocottus armatus</u>
Birds	
Willet	<u>Catoptrophorus semipalmatus</u>
Western sandpiper	<u>Calidris mauri</u>
Marbled godwit	<u>Limosa fedoa</u>

Community Composition.

Producers. The primary producers of the mudflat community are algae. Many species of diatoms (microscopic algae) can be found on the mud surface, often occurring in dense patches. The macro-algae include green algae (Ulva spp., Enteromorpha spp.) and red algae (Gracilaria spp.). All of these species occur both intertidally and subtidally, although subtidal abundance may be limited by light penetration. Algal growth occurs primarily during the summer, with algae particularly abundant by late summer or early fall.

Filter Feeders, Omnivores, Herbivores. Filter feeders are extremely well-represented in the mudflat. Many of these species are also deposit feeders at times. Several species of clams are characteristic of the mudflat. These include the geoduck (Panopea generosa), gaper clam (Tresus nuttallii), common Washington clam (Saxidomus nuttallii), '11 clam (Mya arenaria), and bent-nose clam (Macoma nasuta). These clams are typically found in the low intertidal and subtidal zones, except for the soft-shell clam which is more common in the high intertidal zone. The geoduck, common Washington and gaper clams are all relatively large and deeply buried species. The soft-shell and bent-nose clams are smaller and occur nearer to the surface of the mud. The fat innkeeper (Urechis caupo), the blue mud shrimp (Upogebia pugettensis), and pink ghost shrimp (Callinassa californiensis) all inhabit semi-permanent burrows. The pink ghost shrimp occurs in the high and mid-intertidal zones. Amphipods (Corophium spp.) live in tubes on the surface of the mud. An anemone (Pachycerianthus fimbriatus) occupies tubes in the subtidal zone, capturing food on tentacles spread on the mud surface.

Several species of polychaete worms occur in burrows in the mud, filtering food particles from the water or feeding directly on the mud. Occurring primarily in the middle intertidal zone are a capitellid (Capitella capitata), and a cirratulid (Cirriiformia spirabranchea). A chaetopterid worm (Chaetopterus variopedatus) inhabits the lower intertidal zone.

The sea hare (Aplysia californica) is an herbivorous species, feeding on algae on the mudflat. Omnivorous species feeding on the mudflat include a fish, the dwarf surfperch (Micrometrus minimus) and a bird, the American wigeon (Anas americana). The dwarf surfperch feeds on algae and small invertebrates in the intertidal and subtidal zones. American wigeons swim on the water surface, diving to the bottom to feed on algae, clams, crabs, and worms.

Predators. Many predators are associated with mudflats. Those feeding on the surface of the mud include the channelled basket shell (Nassarius fossatus), two opisthobranchs (Chelidonura inermis, Hermisenda crassicornis), and a ribbon worm (Paranemertes peregrina). The channelled basket shell is most common in the middle intertidal zone, while the two opisthobranchs and the ribbon worm are more common in the low intertidal and subtidal zones. Predatory fish, which feed intertidally and subtidally, include the leopard shark (Triakis semifasciata), bat ray (Myliobatis californica), brown smoothhound (Mustelus henlei), bay goby (Lebidogobius lepidus), speckled sanddab (Citharus stigmæus), English sole (Parophrys vetulus), starry flounder (Platichthys stellatus), staghorn sculpin (Leptocottus armatus), arrow goby (Clevelandia ios), and pile surfperch (Rhacochilus vacca). A number of shorebirds feed upon the mudflats, including the great blue heron (Ardea herodias), herring gull (Larus argentata), dunlin (Calidris alpina), western sandpiper (Calidris mauri), marbled godwit (Limosa fedoa), and willet (Catoptrophorus semipalmatus).

Scavengers. The yellow shore crab (Hemigrapsus oregonensis) is a typical scavenger of mudflats. This species feeds on detritus, dead organisms and occasionally live organisms. The yellow shore crab occurs in the high intertidal zone.

Community Dynamics. The mudflat community is composed of both epifaunal and infaunal organisms. Sunlight is converted into organic matter by the diatoms and algae growing on the surface of the mud. Detritus produced within the community and transported from other habitats provides a major food source. Some herbivorous species and many small organisms graze on the algae. A few predatory species feed upon the mud surface. Most of the community is found within the mud. Adaptations to feeding include living in burrows and filtering food particles from the water, or ingesting mud and extracting food. The birds and fish feeding on the mudflat may capture food on the mud surface or probe the mud. The general feeding patterns of the mudflat community are illustrated in Figure 4-3. A specific food web is illustrated in Figure 4-4.

The main species grazing on algae over the mudflats are fish and birds. The dwarf surfperch (Micrometrus minimus) is an omnivorous species. This small fish swims about in the algal beds, selectively feeding on small crustaceans and pieces of algae. The American wigeon (Anas americana) is also omnivorous. It swims along the surface of the water periodically diving to the bottom to feed on clams, polychaete worms and algae (Cogswell, 1977; Johnson, 1979).

Most of the filter feeders construct burrows in the mud. The pink ghost shrimp (Callinassa californiensis) lives in the high intertidal zone. It digs a burrow with the claws of the first and second pair of legs, collecting the mud in a receptacle formed by another pair of legs. Detritus is extracted from this continuous stream of mud. The pink ghost shrimp constructs extensive burrows, constantly adding new tunnels or extending old ones. Several commensal species occur in the ghost shrimp burrow, including the scale worm (Hesperonoe complanata) and pea crab (Scleroplax granulata). Another burrower is the blue mud shrimp (Upogebia pugettensis). This species constructs permanent burrows in the lower intertidal and subtidal zone. The burrow extends downward from the surface of the mud, horizontally for some distance, then returns to the surface. The mud shrimp employs several pairs of legs as paddles to circulate water through the burrow. The first two pairs of legs are provided with hairs, which serve as a strainer to filter food particles from the water. Several commensals, a small clam (Orebitella rugifera), pea crab (Scleroplax granulata), scale worm (Hesperonoe sp.) and gobies (Clevelandia ios, Lepidogobius lepidus) occur in the blue mud shrimp burrows.

The fat innkeeper (Urechis caupo) also constructs a fairly permanent burrow in the low intertidal and subtidal zone. The fat innkeeper, an echiuroid worm, pumps water through its burrow by peristaltic contractions of its body. The worm spins a slime net at the entrance of the burrow. This net allows the passage of water but filters out particles as small as one micron in diameter. When sufficient food has collected on the net (after approximately one hour of pumping), the worm moves up its burrow and swallows the net. All larger particles are discarded by the worm. Two of the commensals inhabiting the burrow, the scale worm (Hesperonoe adventor) and the pea crab (Scleroplax granulata), depend on food discarded by the fat innkeeper. Gobies (Clevelandia ios, Lepidogobius lepidus) inhabit the burrow for shelter, foraging for food on the mudflat. A diagram of the fat innkeeper and its burrow is shown in Figure 4-5.

Clams and worms are common burrowers in the mudflat. Large clams, like the gaper clam (Tresus nuttallii), are found deeply buried in the mud. The siphon is extended to the surface of the mud. The clam pumps water through its body, extracting suspended food

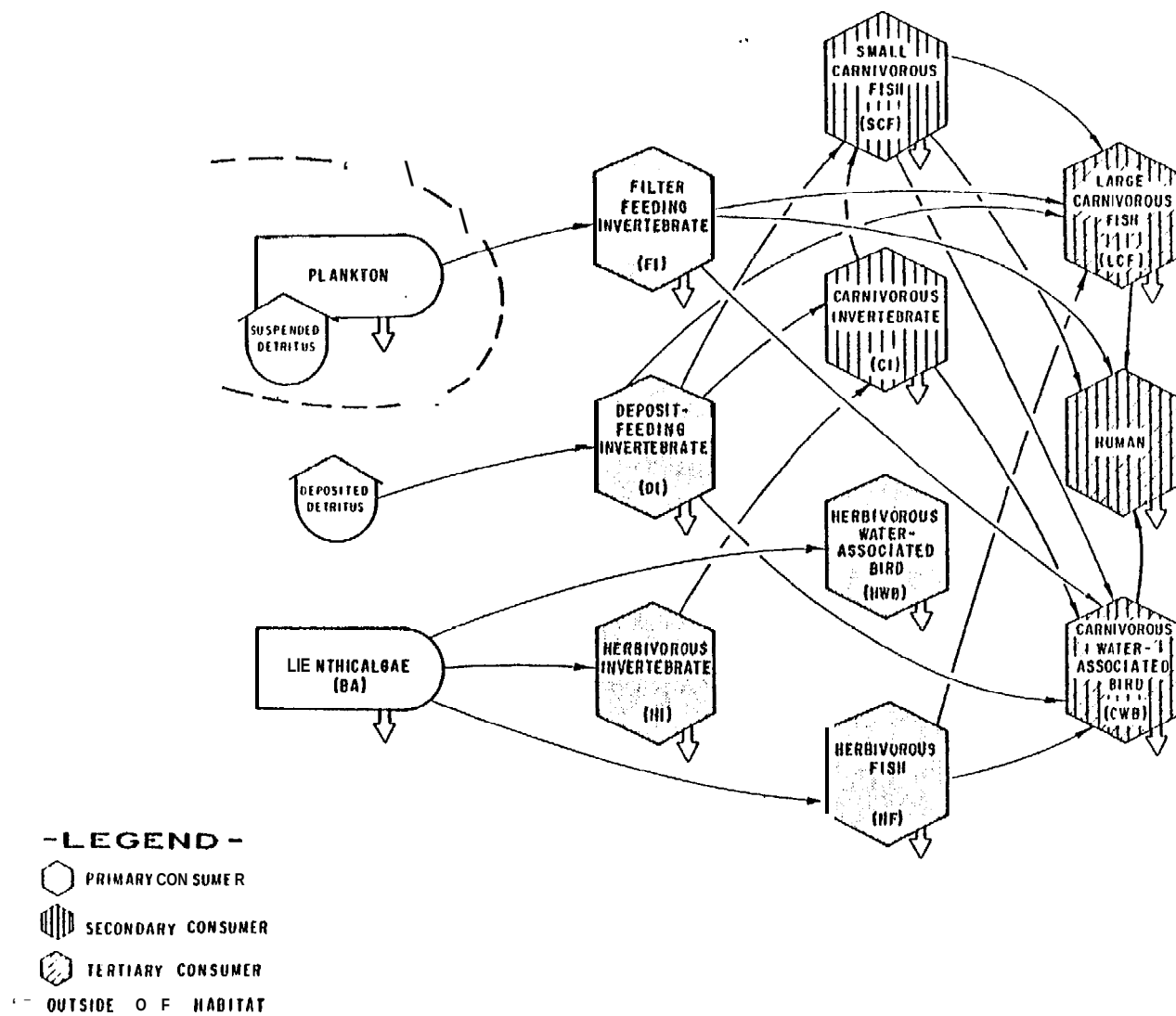


Figure 4-3. General Food Web - Mudflat

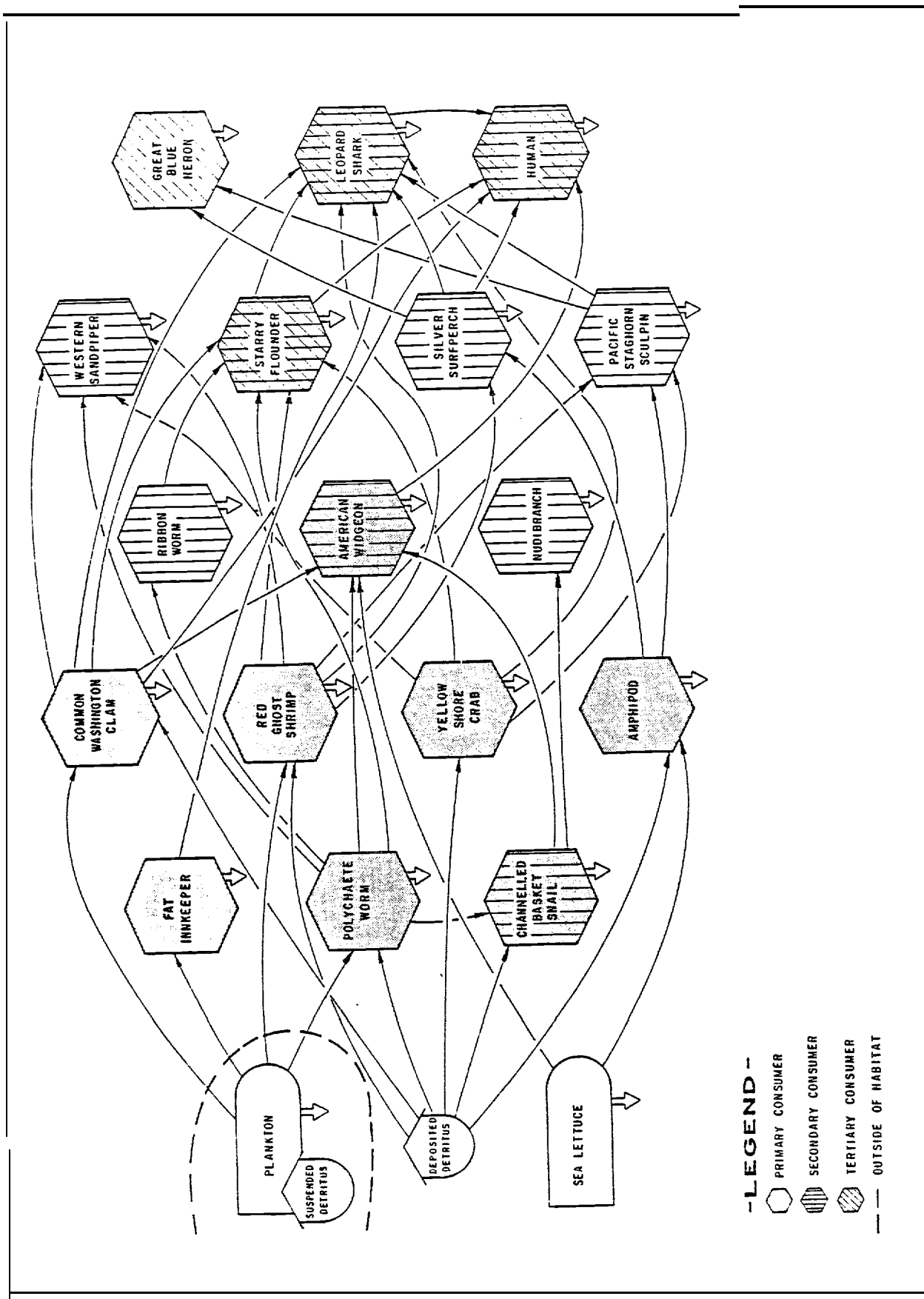


Figure 4-4. Example of a Mudflat Food b

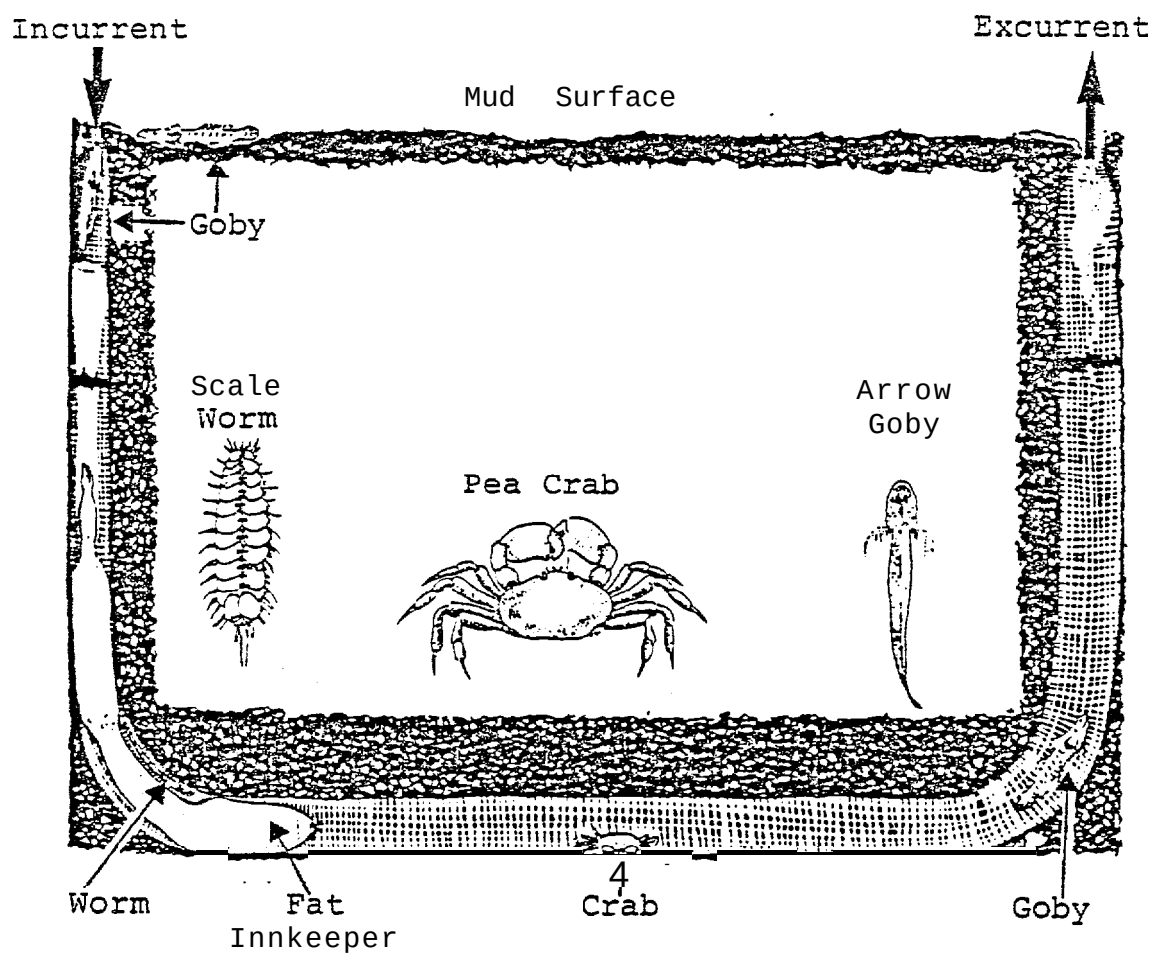


Figure 4-5. Diagram of a Fat Innkeeper Burrow and Position of Typical Commensal Organisms (from Ricketts and Calvin, 1968)

particles from the water. The siphon tip may also be used to collect particles from the surface of the mud, making the clam a deposit feeder as well as filter feeder. Smaller clams are not deeply buried, but feed in a similar fashion. Some polychaete worms, such as the cirratulid (Cirriformia spirabrancha), occupy burrows in the mud and spread tentacles over the surface to filter food particles from the water. Others, like the chaetopterid worm (Chaetopterus variopedatus), are deposit feeders, ingesting mud and extracting food.

Several predatory species feed on the surface of the mudflat. The channelled basket shell (Nassarius fossatus) plows through the mud in search of food. It is readily attracted to both fresh or decaying meat (MacGinitie, 1935). When feeding, this snail wraps its foot completely around the food, probably to avoid attracting other predators. The sea slug (Aglaja inermis) feeds on other snails, tracking them by following their mucus trails. It is a voracious predator, feeding mostly on shelled snails and other nudibranchs, and occasionally capturing small fish. The ribbon worm (Paranemertes peregrina) feeds on the surface of the mudflat, mainly capturing polychaete worms (especially Platynereis bicanaliculata).

Most of the fish feeding on the mudflat are bottom fish. The bat ray (Myliobatis californica) feeds on a variety of burrowing invertebrates, including worms, crustaceans, and clams (Feder et al., 1974). The bat ray uncovers its prey by flapping its "wings" while cruising over the bottom. The leopard shark feeds on worms, crustaceans, and clams, often nosing in the mud for food. Some organisms, including the fat innkeeper, are apparently removed from their burrows by suction. The siphon tips of clams are often eaten, rather than the entire organism. Leopard sharks (Triakis semifasciata) also feed on fish species encountered on the mudflat.

Numerous bird species utilize mudflats for feeding. The great blue heron (Ardea herodias) stalks its prey by slowly wading over the mudflat and lunging at crustaceans and fish with its beak (Cogswell, 1977; Willard, 1977). The herring gull (Larus argentata) is a scavenger and predator. It feeds on living or dead fish, crustaceans and mollusks, and also consumes fish eggs. The dunlin (Calidris alpina) is typical of many shorebirds feeding on the mudflat. It captures polychaete worms, small crustaceans, and small mollusks by probing into the mud with its beak (Cogswell, 1977).

Interactions with Other Habitats. The mudflat community is visited by many predatory species at different tidal stages. Various fish species remain in deeper channels during low tides, moving onto the mudflats to feed during high tides. The exposure of the intertidal mudflats at low tide allows many bird species to feed there. Shallow subtidal mudflats are also accessible to birds during low tide.

Tidal action carries nutrients from other habitats onto the mudflats. Detritus imported from the rocky bottom habitat and from the emergent vegetation habitat helps enrich the mudflats. Tidal currents are also important as a means of dispersal for sedentary organisms, which release planktonic larvae to be transported to other habitats or areas by this method.

EFFECTS OF HUMAN ACTIVITIES

One of the factors affecting mudflats is increased sedimentation. Human activities in the upland areas, such as logging, can increase the sediment load of tributary streams entering the estuary, accelerating the sedimentation rate on mudflats. Dredging activities within the estuary can also have an impact on mudflat communities (Peddicord and McFarland, 1978). The dredging operation itself or subsequent disposal of dredged material can increase sedimentation rates. Activities which increase sedimentation may result in short-term impacts, smothering existing organisms and altering the habitat.

The discharge of toxic wastes into the estuary, as might occur during sewage pollution or oil pollution, can stress or kill benthic organisms. Dredging activities may release toxic wastes accumulated in the substrate. The impact of toxic wastes (short-term or long-term impacts) will be dependent on the nature of the wastes, the type of organism included, and the duration of exposure (Winzler and Kelly, 1977a). Pollution of the mudflat sometimes results in the domination of the infaunal community by large numbers of a few tolerant species (such as the capitellid worm Capitella capitata).

Man harvests many of the infaunal organisms of the mudflat for food or to use as fishing bait. Continual digging of the mudflat in high-use areas could disturb the habitat sufficiently to reduce the abundance of mudflat organisms. Pollution of the estuary can result in the accumulation of toxic substances by residents of the mudflat community, rendering them unfit for human consumption (Winzler and Kelly, 1977a).

Biological Aspects - Sandflats

Dominant Species. The dominant species of the sandflat community are listed in Table 4-3. The dominant organisms of the sandflat include 8 species of fish, 15 species of invertebrates, and 4 species of birds. Information on the feeding habits and habitat preferences of these organisms was derived from several sources (MacGinitie, 1935; Ricketts and Calvin, 1968; Smith and Carlton, 1975; Standing *et al.*, 1975; Moyle, 1976; Nybakken *et al.*, 1977).

Table 4-3
Dominant Organisms of a Sandflat Community¹

Birds	Fish	Invertebrates
Black-bellied plover (CWB) <u>Pluvialis squatarola</u>	Leopard shark (LCF) <u>Trakis semifasciata</u>	Sand dollar (DI, FI) <u>Dendraster excentricus</u>
Willet (CWB) <u>Catoptrophorus semipalmatus</u>	Brown smoothhound (SCF) <u>Mustelus henlei</u>	Basket cockle (FI) <u>Clinocardium nuttallii</u>
Marbled godwit (CWB) <u>Limosa fedoa</u>	Bat ray (LCF) <u>Myliobatis californica</u>	Scallop (FI) <u>Pecten circularis</u>
Sanderling (CWB) <u>Calidris alba</u>	Speckled sanddab (SCF) <u>Citharichthys stigmaeus</u>	Moon snail (CI) <u>Polinices lewisii</u>
	Starry flounder (SCF) <u>Platichthys stellatus</u>	Olive snail (CI) <u>Olivella biplicata</u>
	English sole (SCF) <u>Parophrys vetulus</u>	Polychaete worm (DI) <u>Nephtys</u> spp.
	Pile surfperch (SCF) <u>Rhacochilus vacca</u>	Polychaete worm (DI) <u>Armandia brevis</u>
	Silver surfperch (SCF) <u>Hyperprosopon ellipticum</u>	Slack-tailed shrimp (S1, CI) <u>Crangon nigricauda</u>
	Pacific staghorn sculpin (SCF) <u>Leptocottus armatus</u>	Dungeness crab (S1, CI) <u>Cancer magister</u>
		Phoronid worm (FI) <u>Phoronopsis viridis</u>
		White sand clam (FI, DI) <u>Macoma</u> sects
		Sunflower starfish (CI) <u>Pycnopodia helianthoides</u>
		Starfish (CI) <u>Pisaster brevispinus</u>
		Polychaete worm (DI) <u>Arenicola cristata</u>
		Polychaete worm (FI) <u>Axiiothella rubrocincta</u>

1

CWB = carnivorous water-associated birds
LCF = large carnivorous fish
SCF = small carnivorous fish
DI = deposit feeding invertebrate
FI = filter feeding invertebrate

CI = carnivorous invertebrate
SI = scavenger invertebrate
P = phytoplankton
BA = benthic algae
RB = raptorial bird

Rare, Endangered and Species of Concern. Species of ecological concern that utilize the sandflats are given in Table 4-4. They include 2 species of birds, 3 species of fish, and 2 species of invertebrates. None of these are designated as endangered species. Species accounts of all of the species listed in Table 4-4 may be found in Volume II, Part 2, of this report.

Table 4-4
Species of Concern Occurring in a Sandflat Community

Common Name	Scientific Name
Invertebrates	
Dungeness crab	<u>Cancer magister</u>
Starfish	<u>Pisaster brevispinus</u>
Fish	
Leopard shark	<u>Triakis semifasciata</u>
Starry Flounder	<u>Platichthys stellatus</u>
Pile Surfperch	<u>Rhacochilus vacca</u>
Birds	
Willet	<u>Catoptrophorus semipalmatus</u>
Marbled godwit	<u>Limosa fedoa</u>

Community Composition.

Producers. The shifting nature of sands and the coarseness of the substrate do not favor the accumulation of nutrients nor provide good attachment sights. No primary producers are characteristic of this habitat.

Filter Feeders, Omnivores, Herbivores. A number of filter feeders exist in the sand bottom. The sand dollar (Dendraster excentricus) feeds on suspended material in areas with moderate water movement (Merrill & Hobson, 1970). The basket cockle (Clinocardium nuttallii) and scallop (Pecten circularis) are also suspension feeders. These species occur in the lower intertidal and subtidal zone. The white sand clam (Macoma secta) occurs in the mid-intertidal zone, feeding on both suspended and deposited detritus. The phoronid worm (Phoronopsis viridis) occurs in the mid and low intertidal zones. The sandy tubes of this species are often present in large numbers, helping to stabilize the sediments. A polychaete worm (Axiiothella rubrocincta) lives in sandy tubes and filters food through its tentacles.

Predators. A few predatory species dominate in the sandflats. The moon snail (Polinices lewisi) and the olive snail (Olivella biplicata) are usually found on the sand or partially buried. The sunflower starfish (Pycnopodia helianthoides) and the starfish (Pisaster brevispinus) occur on the surface of the sand. Many of the predatory fish found on mudflats also forage over sandflats, including the leopard shark (Triakis semifasciata), brown smoothhound (Mustelus henlei), bat ray (Myliobatis californica), Pacific staghorn sculpin (Leptocottus armatus), speckled sanddab (Citharichthys stigmaeus), starry flounder (Platichthys stellatus), English sole (Parophrys vetulus), and pile surfperch (Rhacochilus vacca). The silver surfperch (Hyperprosopon ellipticum) is a predatory fish exclusively associated with sandflats. The birds feeding on the sandflat include the blackbellied plover (Pluvialis squatarola), willet (Catoptrophorus semipalmatus), marbled godwit (Limosa fedoa), and sanderling (Calidris alba). Except for the sanderling, which exhibits a strong preference for sand, these birds forage on both sand and mudflats.

Others. A number of species inhabiting the sandflats are deposit feeders. In sheltered waters, the sand dollar (Dendraster excentricus) becomes a deposit feeder (Merrill & Hobson, 1970). Other deposit feeders are the nephtiid worms (Nephtys spp.), the opheliid worm (Armandia brevis), and the lugworm (Arenicola cristata). The black-tailed shrimp (Crangon nigricauda) is usually associated with sandy habitats, either in the water column above the substrate or shallowly buried. The Dungeness crab (Cancer magister) is usually found on sandy bottoms in deeper water. The black-tailed shrimps and the Dungeness crab are opportunistic scavengers, feeding on whatever food source is available.

Community Dynamics. Shifting of the sandflat substrate generally excludes primary producers from this habitat. The inhabitants of the sandflat community rely upon nutrients imported from other areas. Tidal action carries plankton and suspended organic matter onto the sand flats, supporting the filter feeders and deposit feeders. These organisms are eaten by invertebrate predators, fish, and birds. The food web of sandflat communities is illustrated in Figures 4-6 and 4-7.

The sand dollar (*Dendraster excentricus*) is a characteristic filter and deposit feeder of the sandflat. Orientation and feeding are related to water currents (Merrill & Hobson, 1970). In sheltered habitats with little water movement, sand dollars frequently move about, lie flat on the bottom, and feed on deposited detritus. In exposed habitats with moderate water movement, the sand dollars are more stationary, remaining in an upright inclined position, and feeding on suspended detritus.

The purple olive shell (*Olivella biplicata*) plows along just beneath the surface of the sand, searching for living or dead organisms to prey upon. Another active predator on the sandflat is the moon snail (*Polinices lewisi*). The moon snail also plows through the sand just beneath the surface. The moon snail generally preys upon clams (especially *Macoma* spp.) by drilling a countersunk hole through the shell with its radula. The moon snail can also suffocate its prey with its large foot, inserting its proboscis between the shells and consuming the dead animal. The sunflower starfish (*Pycnopodia helianthoides*) preys largely on moon snails. Birds and fish feed over sandflats in the same way they do on mudflats.

Interactions with Other Habitats. Organisms migrate into the sandflat community in the same pattern as notes for mudflats. Fish move onto the sandflats to feed primarily during high tide, with birds foraging over the sandflats at low tide. As previously noted, the sandflat community is dependent upon other habitats for the import of nutrients in the form of plankton and detritus.

EFFECTS OF HUMAN ACTIVITIES

Sandflats are not an extensive habitat in the estuary. Human activities such as dredging and waste discharge can have the same deleterious effects on sandflat organisms that were described for mudflat organisms. Alteration of current patterns by the construction of jetties and breakwaters can eliminate sandflats by cutting off their source of replenishment or create new ones by interrupting littoral currents.

Biological Aspects - Water Column Community

Dominant Species. The dominant species of the water column community are listed in Table 4-5. They include 9 genera of phytoplankton, 6 species of zooplankton, 5 species of birds, 1 species of mammal, and 13 species of fish. Information on the feeding habits and habitat preferences was taken from several references (Standing et al., 1975; Moyle, 1976; Winzler and Kelley, 1977a; Wang, personal communication). This information is presented in the following sections.

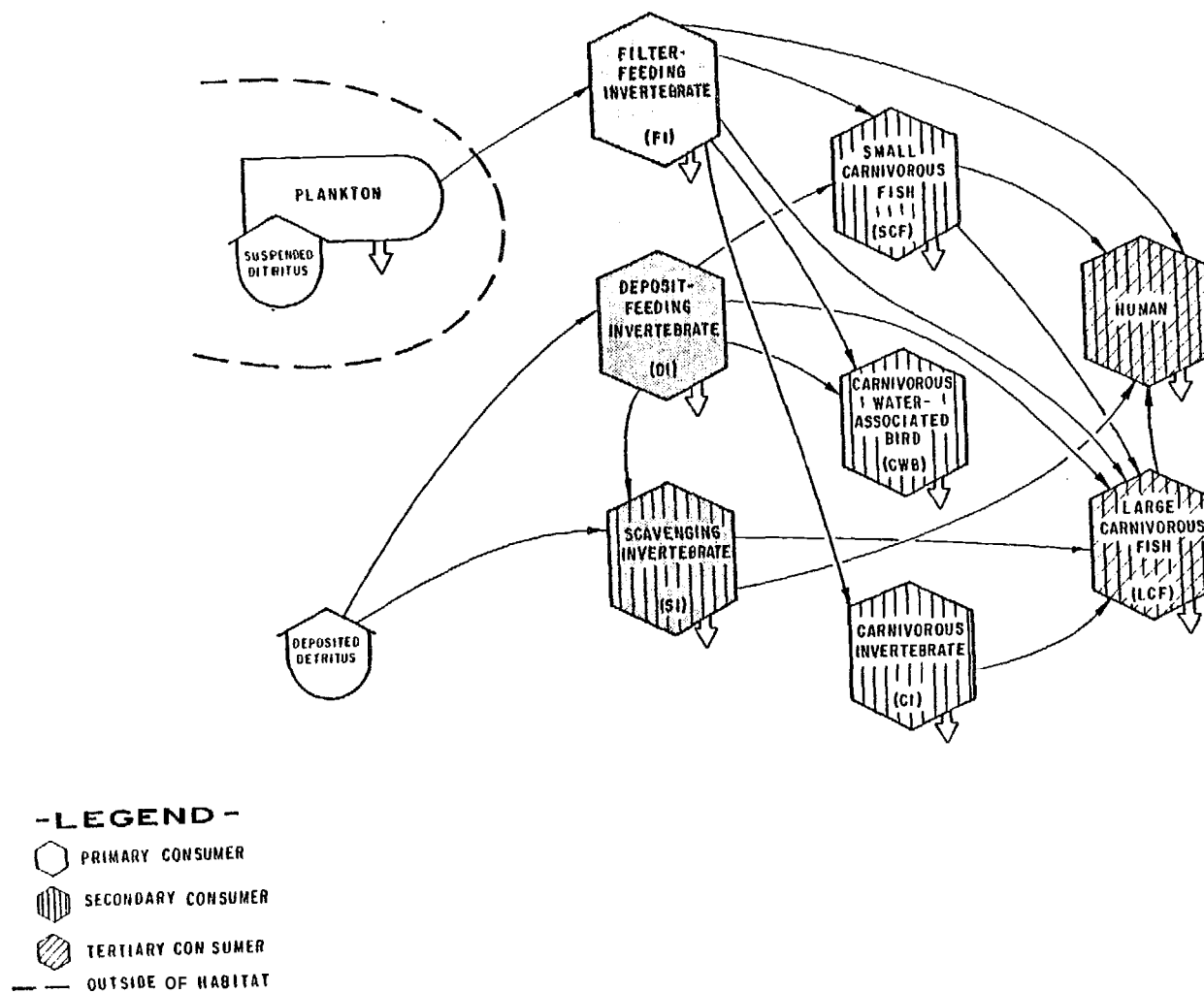


Figure 4-6. General Food Web - Sandflat.

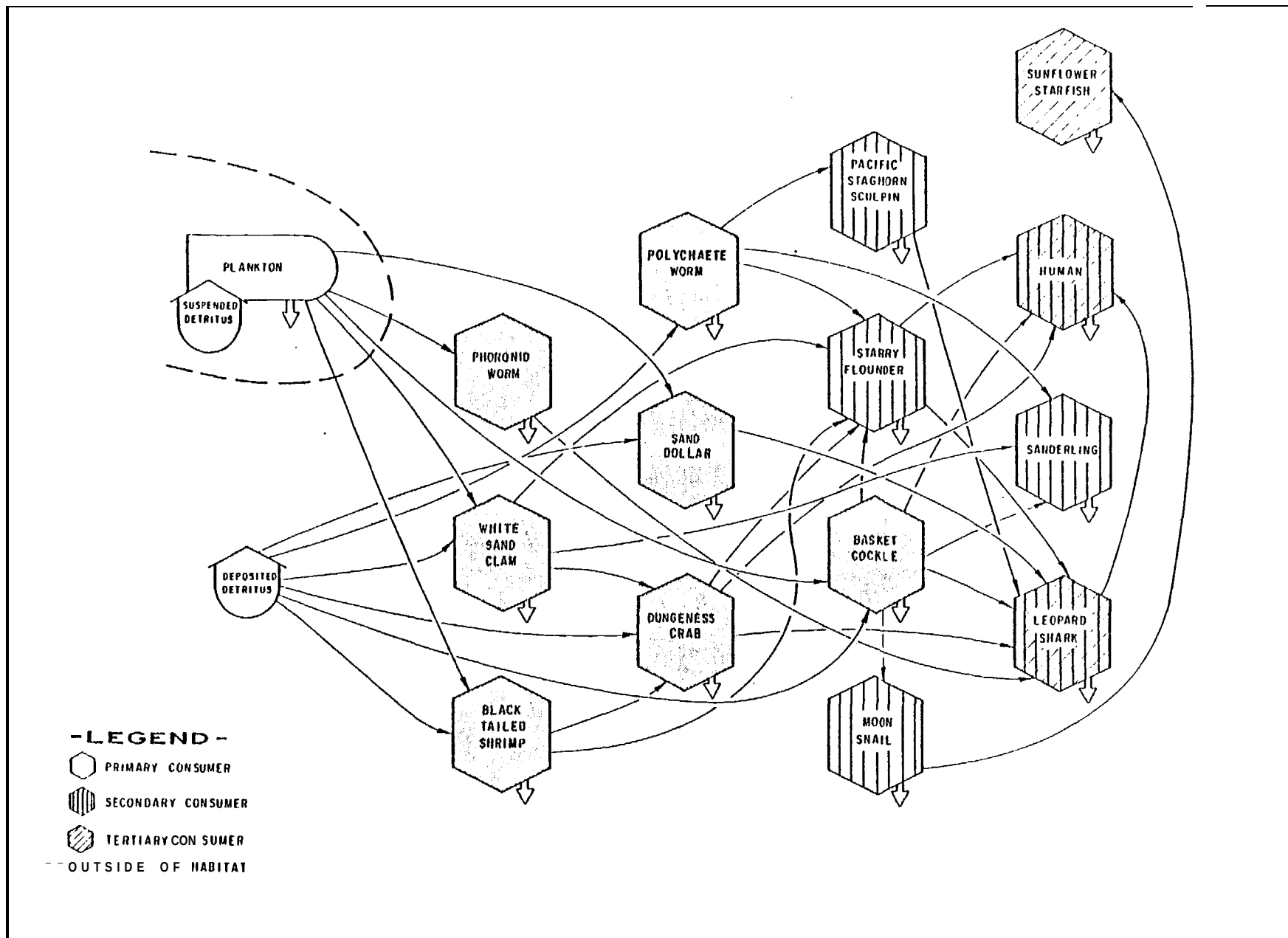


Figure 4-7. An Example of a Sandflat Food Web

Table 4-5 . Dominant Species of a Water Column Community¹

Phytoplankton	Zooplankton	Birds
Diatom (P) <u>Chaetoceros</u>	Copepod (Z) <u>Acartia clausi</u>	Loons (CWB) <u>Gavia spp.</u>
Diatom (P) <u>Coscinodiscus</u>	Copepod (Z) <u>Acartia tonsa</u>	Western grebe (CWB) <u>Aechmophorus occidentalis</u>
Diatom (P) <u>Nitzschia</u>	Copepod (Z) <u>Eurytemora affinis</u>	Brown pelican (CWB) <u>Pelecanus occidentalis</u>
Diatom (P) <u>Skeletonema</u>	Opossum shrimp (Z) <u>Neomysis mercedis</u>	Osprey (RB) <u>Pandion haliaetus</u>
Diatom (P) <u>Thalassiosira</u>	Bay shrimp (CI) <u>Cranaon franciscorum</u>	Double crested cormorant (CWB) <u>Phalacrocorax auritus</u>
Dinoflagellate (P) <u>Ceratium</u>	Grass shrimp (CI) <u>Palaemon macrodactylus</u>	
Dinoflagellate (P) <u>Gonyaulax</u>		
Dinoflagellate (P) <u>Gymnodinium</u>		
Dinoflagellate (P) <u>Peridinium</u>		
Fish	Mammals	
Northern anchovy (FF) <u>Engraulis mordax</u>	Harbor seal (CM) <u>Phoca vitulina</u>	
Pacific herring (FF) <u>Clupea harengus pallasii</u>		
Surf smelt (SCF) <u>Hypomesus pretiosus</u>		
Longfin smelt (SCF) <u>Spirinchus thaleichthys</u>		
Topsmelt (HF, SCF) <u>Atherinops affinis</u>		
Jacksmelt (HF, SCF) <u>Atherinopsis californiensis</u>		
Shiner surfperch (SCF) <u>Cymatogaster aggregata</u>		
Pile surfperch (SCF) <u>Rhacochilus vacca</u>		
White surfperch (SCF) <u>Phanerodon furcatus</u>		
Striped bass (LGF) <u>Morone saxatilis</u>		
Chinook salmon (LGF) <u>Oncorhynchus tshawytscha</u>		
Coho salmon (LGF) <u>Oncorhynchus kisutch</u>		
Steelhead (LCF) <u>Salmo gairdneri</u>		

¹See Figure 4-8 for definition of abbreviations.

Rare, Endangered and Species of Concern. A number of ecological species of concern use the water column habitat. These species are listed in Table 4-6. They include 2 species of birds, 10 species of fish, and 3 invertebrate species. The brown pelican is designated as a federally endangered species. Species accounts for all species listed in Table 4-6 may be found in Volume II, Part 2 of this report.

Table 4-6. Species of Concern Occurring in a Water Column Community

Birds	Fish	Invertebrates
Brown pelican ¹ <u>Pelecanus occidentalis</u>	Northern anchovy <u>Engraulis mordax</u>	Copepod <u>Acartia tonsa</u>
Osprey <u>Pandion haliaetus</u>	Pacific herring <u>Clupea harengus pallasii</u>	Opossum shrimp <u>Neomysis mercedis</u>
	Longfin smelt <u>Spirinchus thaleichthys</u>	Bay shrimp <u>Crangon franciscorum</u>
	Topsmelt <u>Atherinops affinis</u>	
	Shiner surfperch <u>Cymatogaster aggregata</u>	
	Pile surfperch <u>Rhacochilus vacca</u>	
	Striped bass <u>Morone saxatilis</u>	
	Chinook salmon <u>Oncorhynchus tshawytscha</u>	
	Coho salmon <u>Oncorhynchus kisutch</u>	
	Steelhead <u>Salmo gairdneri</u>	

¹Designated Federal Endangered Species

Community Composition.

Producers. The primary producers of the water column community are all members of the phytoplankton community. The phytoplankton community is largely composed of two groups, the division Chrysophyte and the division Pyrrophyta. The division Chrysophyte is dominated by the non-motile diatoms, including species of the genera Chaetoceros, Coscinodiscus, Nitzschia, Skeletonema, and Thalassiosira. The division Pyrrophyta is dominated by the motile dinoflagellates, including species of the genera Ceratium, Gonyaulax, Gymnodinium, and Peridinium.

Filter Feeders, Omnivores, Herbivores. Two species of pelagic fish are filter feeders, the northern anchovy (Engraulis mordax) and Pacific herring (Clupea harengus pallasii). These species feed on both phytoplankton and zooplankton. Omnivorous species, feeding on phytoplankton, algae, and small invertebrates, include the surf smelt (Hypomesus pretiosus), longfin smelt (Spirinchus thaleichthys), topsmelt (Atherinops a - a n d jacksmelt (Atherinopsis californiensis).

Predators. Several species of surfperch are predators in the open water community, occurring throughout the water column. These include the shiner surfperch (Cymatogaster aggregata), the walleye surfperch (Hyperprosopon ellipticum), black surfperch (Embiotoca jacksonii), pile surfperch (Rhacochilus vacca), and white surfperch (Phanerodon furcatus). Many of these species feed on the bottom, primarily taking polychaete worms, clams and bivalves. Predatory birds include the loons (Gavia spp.), western grebes (Aechmophorus occidentalis), brown pelicans (Pelecanus occidentalis), osprey (Pandion haliaetus), and double-crested cormorants (Phalacrocorax auritus). Loons and western grebes swim on

the surface before diving after prey, while the other species dive from the ski." Harbor seals (Phoca vitulina) are opportunistic, preying on fish and large invertebrates.

Other. The zooplankton community is an assemblage of many different types of organisms. Zooplankton can be divided into two major components, the holoplankton and the meroplankton. Holoplankters (permanent plankton) complete their entire life cycle as planktonic organisms. Chaetognaths, copepods, euphausiids, and mysids are the dominant groups of the holoplankton. Species of particular importance include Acartia tonsa, A. clausi, Eurytemora affinis, and Neomysis mercedis. Meroplankters spend only a portion of their life cycle as planktonic organisms. The larvae of mollusks, crustaceans and fish dominate the meroplankton. Two decapod crustaceans, the grass shrimp (Palaemon macrodactylus) and the bay shrimp (Crangon franciscorum), are often members of the plankton community. They are generally closely associated with the bottom during the daytime, entering the water column at night.

Several anadromous fish utilize the water column habitat of the estuary. The typical species include steelhead trout (Salmo gairdneri), chinook salmon (Oncorhynchus tshawytscha), and coho salmon (O. kisutch). The adults of these three species pass through the estuary during their spawning migration from the ocean to freshwater, utilizing the estuary to acclimate themselves. Young salmon and trout may use the estuary both as a nursery ground and for acclimation. The striped bass (Morone saxatilis) is another common anadromous fish. The adults of this species may remain in the estuary throughout the entire year.

Community Dynamics. The open water community relies upon phytoplankton to convert sunlight into organic matter. Members of the zooplankton community feed on phytoplankton and suspended detritus. Phytoplankton and zooplankton are consumed by many fish. Some of the fish may abandon their pelagic habits at times in order to move to the bottom and feed. Open water birds are almost entirely dependent on fish, feeding primarily on pelagic species. A typical food web is illustrated in Figures 4-8 and 4-9.

The bay shrimp (Crangon franciscorum) is typical of larger zooplankters. It feeds on detritus and smaller zooplankters, especially on the opossum shrimp (Neomysis mercedis). The feeding habits vary seasonally, as detritus predominates in the guts of bay shrimp during the winter, and zooplankton predominates in the guts during the summer.

The Pacific herring (Clupea harengus pallasii) feeds exclusively on plankton. This fish swims with its mouth open, passing water over the gills and filtering out plankton with its gill rakers. The primary food items are late stage copepodites and adult copepods.

The topsmelt (Atherinops affinis) is a typical omnivorous grazing fish. It moves to the bottom to feed on diatoms, algae, and small invertebrates, and can also feed on euphausiids and copepods in the plankton community. Topsmelts are grazers rather than filter feeders.

The pile surfperch (Rhacochilus vacca) is a predatory species, feeding on hard-shelled bottom invertebrates, such as clams and crabs. Other surfperch, such as the shiner surfperch (Cymatogaster aggregata), feed mainly on small epifaunal invertebrates and other soft-bodied forms.

The western grebe (Aechmophorus occidentalis) is characteristically seen swimming on the surface of the water. It dives after prey, pursuing fish while swimming underwater. The western grebe feeds on anchovies, sculpins, and surfperch (Cogswell, 1977). The brown pelican (Pelecanus occidentalis) flies low over the surface of the water, plunging into the water to catch fish in its bill. The pelican feeds on a variety of pelagic fish, including anchovies, herring and smelts. The osprey (Pandion haliaetus) hovers above the water surface prior to diving and seizing fish with its talons. Osprey feed on large surface-dwelling fish, including trout, surfperch and other species.

Interactions with Other Habitats. Phytoplankton and zooplankton species have limited swimming abilities. Their distribution is largely determined by currents within the estuary. Plankton is carried into several habitats, providing a food supply for many sessile invertebrates. Many species of fish which are usually pelagic may feed on the bottom, often moving onto tidal flats during high tide. A number of birds can use the open water either to feed or simply to rest.

EFFECTS OF HUMAN ACTIVITIES

Toxic wastes can affect the open water community. The toxic components of oil may slow the growth and cell division rates of phytoplankton species. Oil is extremely toxic

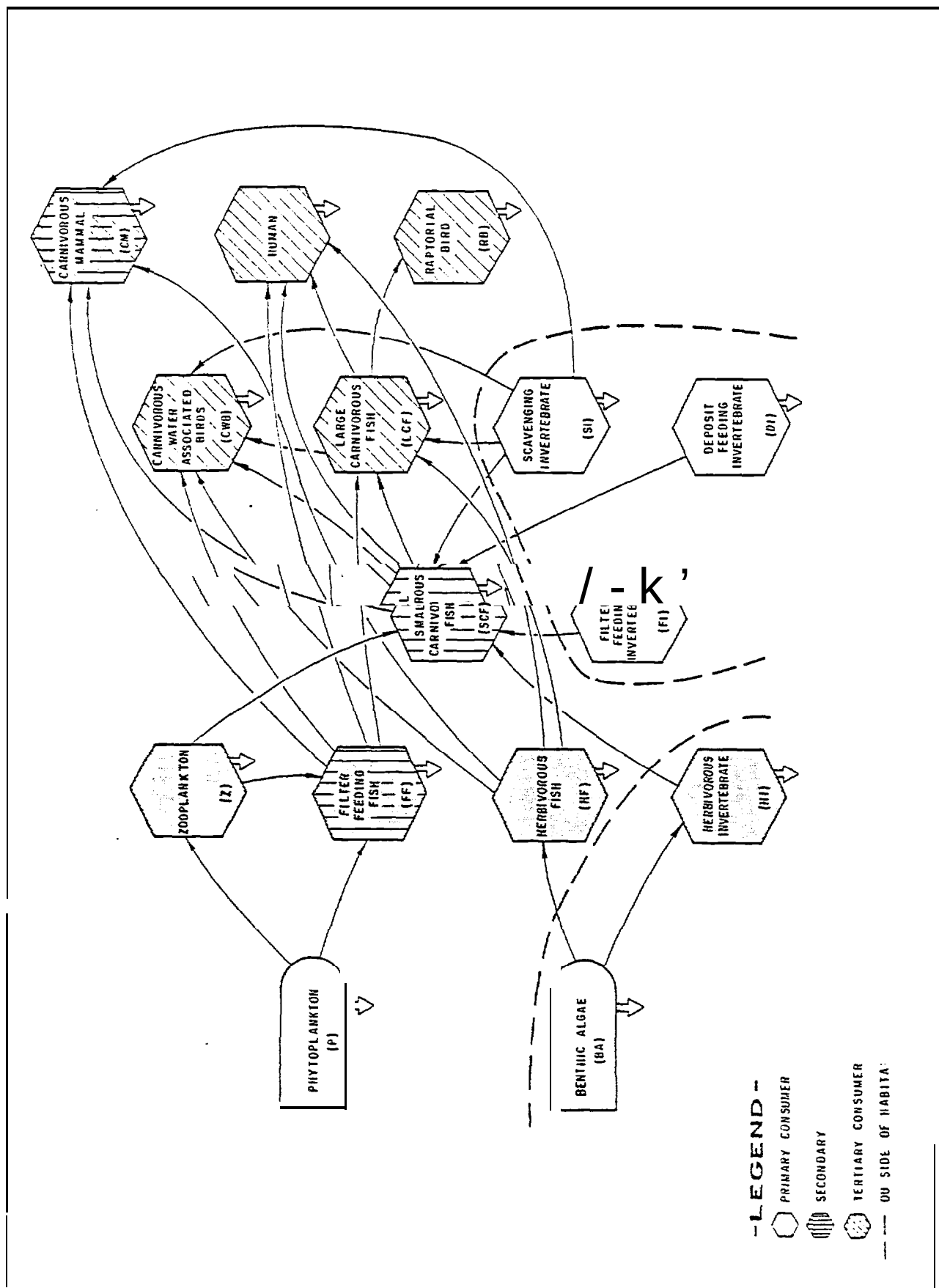


Figure 4-8. General Food Web in Open Water

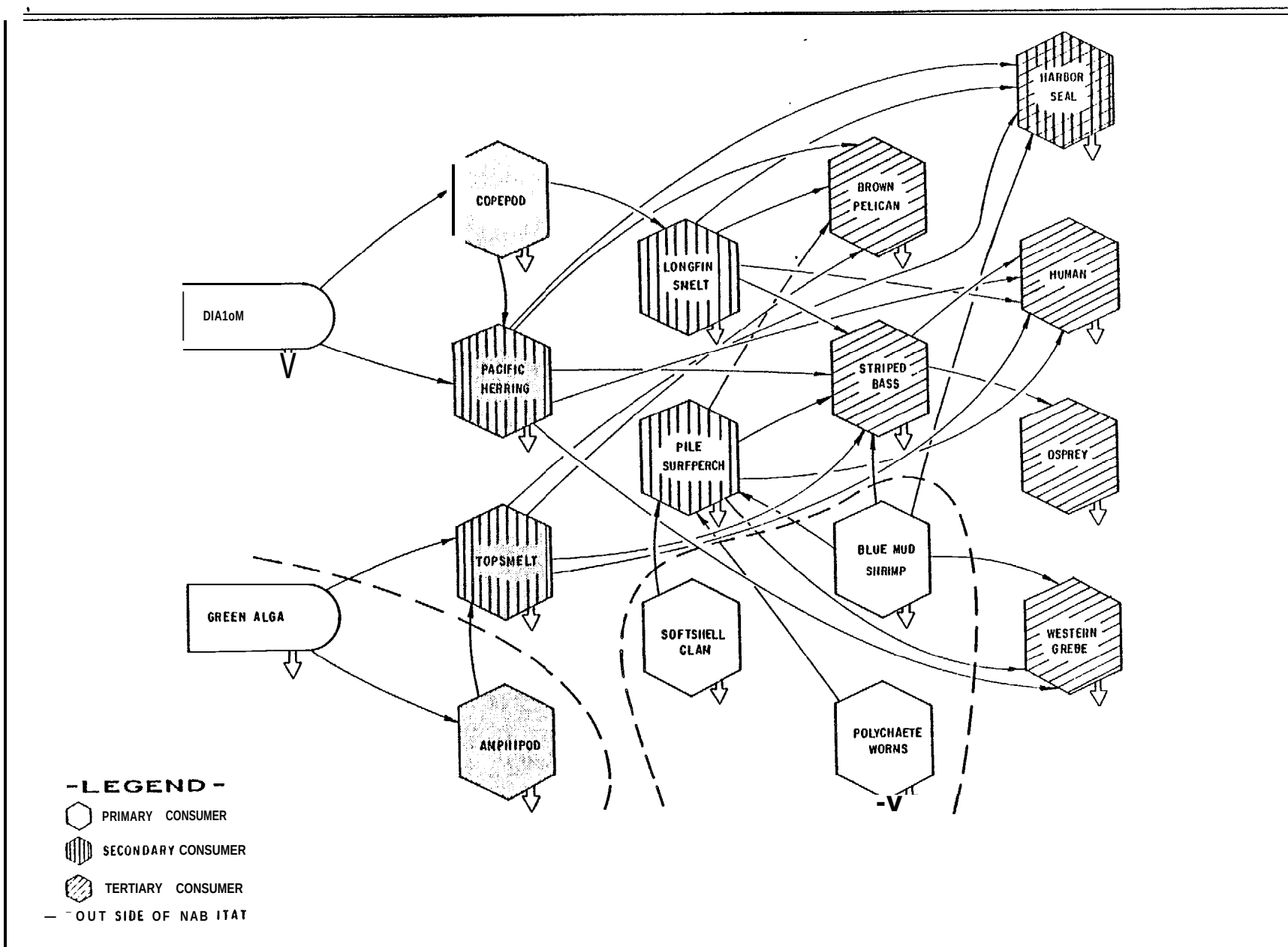


Figure 4-9. An Example of an Open Water Food Web

to holoplankton and meroplankton species. The plankton community provides food for many organisms in the estuary and the larvae of some commercially important species are present in this community. A reduction in the plankton community due to oil pollution could seriously affect the productivity of an estuary (Winzler and Kelly, 1977a).

Industrial activities can impact the water column community. The use of large volumes of water for cooling purposes, such as occurs at power plants, can result in the entrainment of small planktonic organisms through the plant and the impingement of larger organisms on the travelling screens at the intake. Losses of organisms through entrainment and impingement may affect population sizes. Other industries, such as pulp mills and sewage treatment plants, may impact the open water community through the release of toxic wastes (Winzler and Kelly, 1977a).

Humans harvest some of the open water species, including the salmon, trout, striped bass, Pacific herring, surfperch, smelts, and top smelts. This activity could affect the population size. Those species consumed by humans could become inedible due to pollution of their habitat.

ROCKY BOTTOM

INTRODUCTION

Substrate

The rocky bottom habitat is composed of two basic types of substrate: natural rock and artificial. The artificial substrate is generally the result of construction of jetties or shoreline riprap. There are differences in the habitat offered by natural and artificial rock bottoms, but the community composition is similar in both cases.

Areal Extent

Rocky bottom occurs along the coast of California primarily in areas of considerable water motion, where silt, sand, and mud have been scoured from the bottom to expose bed-rock. Rocky bottoms are therefore more characteristic of the open coast than of protected estuaries, bays, and lagoons. Natural rocky bottoms are most prevalent in the estuarine environment along headlands at the entrance to bays. Artificial rocky bottoms, such as jetties and shoreline riprap, are associated with urbanization. The location and extent of artificial rocky bottoms in the estuary is dependent on the degree of human development of the area.

Dominant Species

The rocky bottom community is dominated by organisms that are adapted to a hard substrate. Many of the organisms are sessile attached forms. These include macroalgae, barnacles, mussels, and anemones. Many of the motile organisms are capable of firm attachment to the substrate, including limpets, abalone and other snails, chitons, and starfish. The nonattached organisms are usually cryptic in their habits, living in the areas under and around the rocks. These organisms include various crab species and many fish, including sculpins (Cottidae), clinids (Clinidae), pricklebacks (Stichaeidae), and gunnels (Pholididae). Two invertebrate groups, clams and polychaete worms, are not well-represented on rocky bottoms.

Habitat Descriptors

Wave action plays an important role in determining rocky bottom community composition, although wave action within the estuary is generally less than on the open coast. Exposed habitats tend to be dominated by barnacles, mussels, and limpets, while sheltered habitats are dominated by macro-algae (Seapy and Littler, 1978). Bottom-dwelling organisms possess adaptations that permit them to remain in place. Most organisms either resist currents by attaching themselves to the rock or avoid currents by hiding between and under rocks. Tidal levels help determine zonation patterns on rocky bottoms. Organisms inhabiting the intertidal zone must be able to tolerate exposure to air or be able to move and avoid it. Tidal currents are also important as a food source, since many of the rocky bottom inhabitants are dependent on plankton and detritus brought to them by the tide. The community is less diverse in rocky areas lacking strong tidal currents than in areas with strong tidal currents (Boyd and DeMartini, 1977). A model of the structure and function of the rocky bottom community is presented in Figure 4-10.

HABITAT CHARACTERIZATION

Geographic Aspects

Physical size. The rocky bottom habitat may be of limited extent in the estuary. In the typical shallow depositional environment of the estuary currents and wave action are

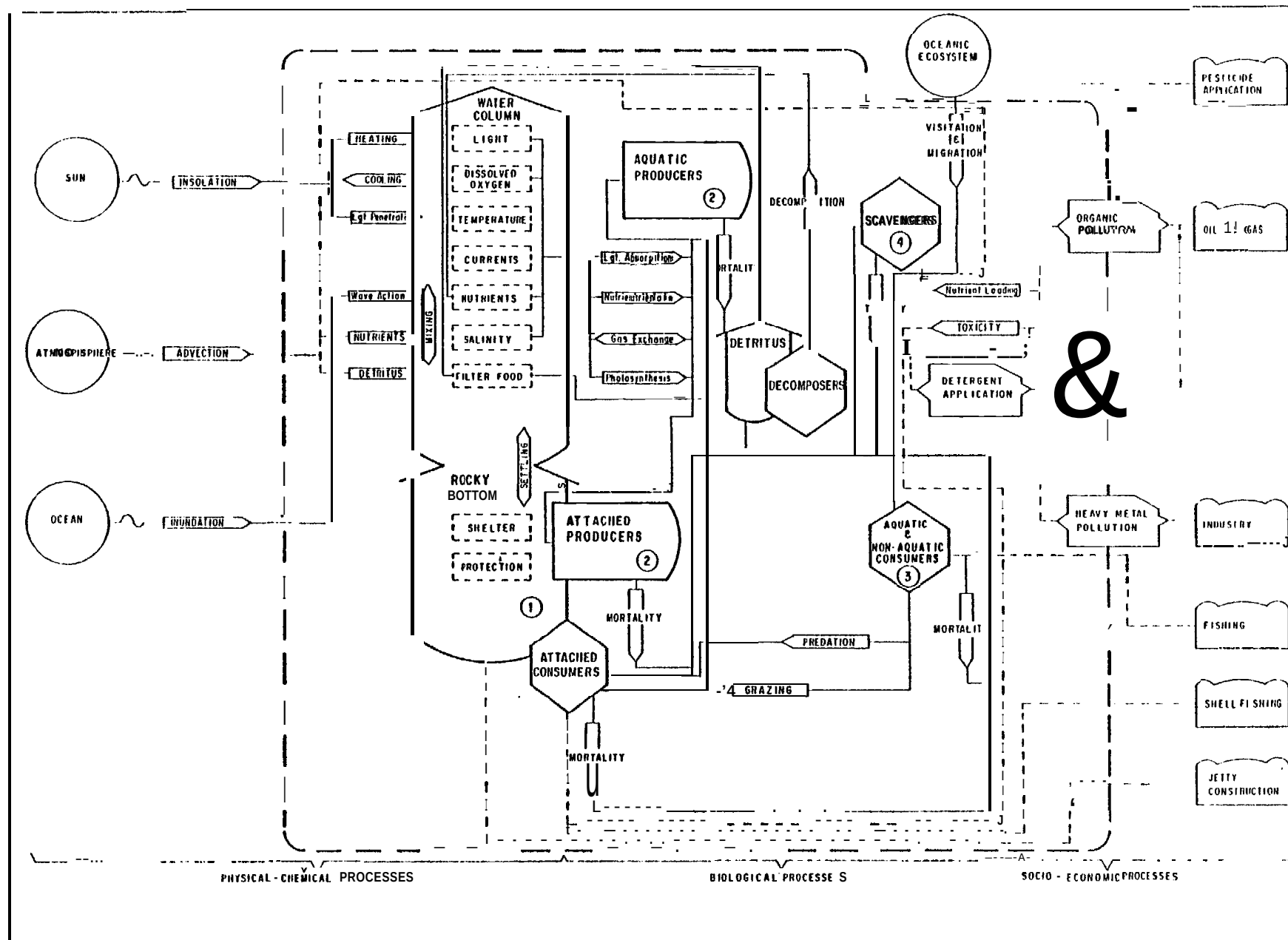


Figure 4-10. Ecosystem Model of a Rocky Bottom Habitat.

Footnotes for Figure 4-10.
Ecosystem for the Rocky Bottom Habitat
highlighted Processes and Components are Annotated Below

- i. PHYSICAL-CHEMICAL ASPECTS: These are described for the general estuary ecosystem model. The substrate is a rocky substrate and sediment and nutrients are limited. Artificial substrates are an additional type of rocky substrate. Light penetration is important in algal zonation.
2. PRODUCERS: Aquatic producers are phytoplankton. Attached producers are green, brown, and red algae, and surfgrass.
3. CONSUMERS: Attached consumers are filter feeders (e.g., mussel, barnacle), and grazers (e.g., limpet, abalone, snail, and chiton). Cryptic consumer species include crabs, and small fish such as sculpin, clinid, prickleback, and gunnel. Aquatic consumers include starfish, snail, rockfish, lingcod, cabezon, and gunnel. Birds that feed in this habitat include oystercatcher, turnstone, tattler, surfbird, and cormorant.
4. SCAVENGERS: These include the rock louse and crab.

generally not strong enough to prevent sedimentation.

The artificial habitat provided by jetties and shoreline riprap is dependent on human activities associated with the development of these areas.

Physical Aspects - Subtidal and Intertidal

The physical environment of the rocky bottom is similar to that described for the subtidal and intertidal unconsolidated bottom habitat, with regard to water circulation, light penetration, temperature, dissolved oxygen content, and concentrations of dissolved salts and minerals in the overlying water column. Physical features unique to the rocky bottom habitat are described below.

Substratum. This habitat is characterized by a firm substrate of natural (rock) or artificial (jetties, shore riprap) origin. The substrate does not differ from subtidal to intertidal elevations. Lack of pore space and impermeability prevent circulation of estuarine waters within the substrate. Dissolved oxygen, salts, and nutrients are confined to the water column.

Zonation. The rocky bottom habitat community displays zonation that reflects differences in light penetration and tidal exposure. The distribution of macro-algae is affected by light availability. Various species of algae absorb or reflect light differentially according to the cellular pigment content. Algal distribution reflects this varying ability to use available light.

Species distribution generally varies according to the duration of tidal exposure. Adaptation mechanisms of organisms are generally suitable for a limited range of exposure times. Community composition is therefore partially determined by average tidal exposure.

Biological Aspects

Dominant Species. The organisms that characterize the rocky bottom habitat are presented in Table 4-7. The dominant organisms include 8 taxa of plants and macro-algae, 20 species of invertebrates, 11 species of fish and 5 species of birds. Information on the habitat preferences and feeding habits of these organisms was taken from several references (Ricketts and Calvin, 1968; Burge and Schultz, 1973; Smith and Carlton, 1975; StanZing et al, 1975; Moyle, 1976; Boyd and DeMartini, 1977). This information is presented in the following sections.

Table 4-7. Dominant Organisms of a Rocky Bottom Community¹

Invertebrates	Fish
California mussel (FI) <u>Mytilus californianus</u> Bay mussel (FI) <u>Mytilus edulis</u> Barnacle (FI) <u>Chthamalus dalli</u> Acorn barnacle (FI) <u>Balanus glandula</u> Barnacle (FI) <u>Balanus crenatus</u> Limpet (HI) <u>Collisella digitalis</u> Red abalone (HI) <u>Haliotis rufescens</u> Turban snail (HI) <u>Tegula funebris</u> Chiton (HI) <u>Mopalia hindsii</u> Starfish (CI) <u>Pisaster ochraceus</u> Snail (CI) <u>Thais</u> spp. Rock louse (DI, S1) <u>Ligia occidentalis</u> Lined shore crab (DI, S1) <u>Pachygrapsus crassipes</u> Hermit crab (DI, S1) <u>Pagurus</u> spp. Green anemone (FI, CI) <u>Anthopleura elegantissima</u> Anemone (FI, CI) <u>Anthopleura xanthogrammica</u> Rock crab (S1, CI) <u>Cancer antennarius</u> Porcelain crab (FI, HI, DI) <u>Petrolisthes cinctipes</u> Purple shore crab (DI, S1) <u>Hemigrapsus nudus</u> Sunflower starfish (CI) <u>Pycnopodia helianthoides</u>	Striped kelpfish (HF, SCF) <u>Gibbonsia metzi</u> Lingcod (LCF) <u>Ophiodon elongatus</u> Greenling (HF, LCF) <u>Hexagrammos</u> spp. Cabezon (LCF) <u>Scorpaenichthys marmoratus</u> Pacific staghorn sculpin (SCF) <u>Leptocottus armatus</u> Black prickleback (HF, SCF) <u>Xiphister atropurpureus</u> Saddleback gunnel (SCF) <u>Pholis ornata</u> Monkeyface-eel (HF, SCF) <u>Cebidichthys violaceus</u> Copper rockfish (SCF) <u>Sebastes caurinus</u> Brown rockfish (SCF) <u>Sebastes auriculatus</u> Bocaccio (SCF) <u>Sebastes paucispinus</u>
Birds	Plants and Algae
Black oystercatcher (CWB) <u>Haematopus bachmani</u> Wandering tattler (CWB) <u>Heteroscelus incanus</u> Surfbird (CWB) <u>Aphriza virgata</u> Brandt's cormorant (CWB) <u>Phalacrocorax penicillatus</u> Black turnstone (CWB) <u>Arenaria melanocephala</u>	Green algae (A) <u>Enteromorpha</u> spp. Sea lettuce (A) <u>Ulva</u> spp. Giant kelp (A) <u>Macrocystis integrifolia</u> Red algae (A) <u>Gigartina</u> spp. Red algae (A) <u>Porphyra perfora</u> (A) Red algae (A) <u>Iridaea</u> spp. (A) Red algae (A) <u>Microcladia coulterii</u> Surf grass (A) <u>Phyllospadix</u> spp.

¹See Table 4-3 for explanation of abbreviations

Rare, Endangered and Species of Concern. A large number of species of ecological concern utilize the rocky bottom habitat. These species are listed in Table 4-8. They include 9 species of invertebrates, 6 species of fish, 1 genus of plant, and 2 genera of algae. None of these is designated as a rare or endangered species. Species accounts of all the species of concern may be found in Volume II Part 2 of this report.

Table 4-8. Species of Concern Occurring on Rocky Bottoms

Algae	Plants	Invertebrates	Fish
Sea lettuce <i>Ulva</i> spp.	Surfgrass <i>Phyllospadix</i> spp.	Rock crab <i>Cancer antennarius</i>	Rockfish <i>Sebastes</i> spp.
Green algae <i>Enteromorpha</i> spp.		California mussel <i>Mytilus californianus</i>	Lingcod <i>Ophiodon elongatus</i>
		Bay mussel <i>M. edulis</i>	Kelp greenling <i>Hexagrammos decagrammus</i>
		Barnacle <i>Balanus</i> spp.	Cabezon <i>Scorpaenichthys marmoratus</i>
		Limpet <i>Collisella</i> spp.	Pacific staghorn sculpin <i>Leptocottus armatus</i>
		Red abalone <i>Haliotis rufescens</i>	Monkeyface-eel <i>Cebidichthys violaceus</i>
		s tarfish <i>Pisaster</i> spp.	
		Lined shore crab <i>Pachygrapsus crassipes</i>	
		Anemone <i>Anthopleura</i> spp.	

Community Composition.

Producers. Algal distribution is partly determined by the type of pigments contained in different types of algae. Light penetration decreases with increasing water depths, as different wavelengths of light are attenuated. Red and brown algae contain pigments (not present in green algae) that allow them to absorb more light and transfer more energy to their chlorophyll (Ricketts and Calvin, 1968). This gives red and brown algae a competitive advantage over green algae at greater water depths. Green algae (*Ulva*, *Enteromorpha*) tend to occur in the shallow upper and middle intertidal zones, while red algae (*Microcladia*, *Iridaea*, *Porphyra*, *Gigartina*) dominate in the deeper and lower intertidal and subtidal zones, and brown algae (*Macrocystis*) dominates the deepest subtidal zone. The vascular plant surfgrass (*Phyllospadix*) is distributed according to tidal level, occupying the area corresponding to the mean lower low water mark.

Filter feeders, Herbivores, Omnivores. The dominant attached forms are all filter feeders, utilizing phytoplankton, zooplankton and suspended detritus as a food source. These include the California mussel (*Mytilus californianus*), bay mussel (*M. edulis*), and barnacles (*Chthamalus dalli*, *Balanus* 'a, *B. crenatus*). Mussels are found intertidally, usually occurring in clumps. The California mussel, characteristic of the open coast, is often found in the estuary on semi-protected rocky bottoms. The bay mussel is more characteristic of protected rocky bottoms, although both species are often found together. Competitive interactions may determine which mussel species dominates in a given location (Bayne, 1976b). Barnacles exhibit distinct zonation according to species. A very small species (*Chthamalus dalli*) dominates on the rocks at the high intertidal zone. This species is best adapted to withstand tidal exposure. The acorn barnacle (*Balanus glandula*) is found throughout the mid and low intertidal zone, at times overlapping the range of *Chthamalus*. The acorn barnacle determines the lower limit of *Chthamalus*. The faster growing acorn barnacle outcompetes the smaller species, generally excluding it from the mid-intertidal zone. At the very low intertidal and subtidal zones another barnacle species (*Balanus crenatus*) dominates.

A number of herbivorous species graze on the algae found on rocky bottoms. These include the limpet (Collisella digitalis), red abalone (Haliotis rufescens), turban snail (Tecula funebris), and chiton (Mopalia hindsii). The limpet is characteristic of the high intertidal zone. The limpet feeds during high tide, moving around and grazing on various species of macro-algae. As the tide recedes the limpet returns to its "home spot" on the rock, an area that conforms to the contours of its shell. The limpet also secretes a mucus sheet to help prevent desiccation. The turban snail is found in the mid to high intertidal zone, often competing with the limpet for food. The chiton is found throughout the intertidal zone, grazing on diatoms and macro-algae. The red abalone is characteristic of the open coast, but can be found subtidally on the rocky estuarine bottom. This species grazes on a variety of microscopic and macroscopic algae.

Several omnivorous fish species occur in the rocky habitat. These species, including the striped kelpfish (Gibbonsia metzi), the greenlings (Hexagrammos spp.), the black prickleback (Xiphister atropurpureus), and the monkeyface eel (Cebidichthys violaceus), graze on algae and feed on small invertebrates. These fish occur between and underneath the rocks, both intertidally and subtidally.

Carnivores. Three major invertebrate predators are the common starfish (Pisaster ochraceus), the basket starfish (Pycnopodia helianthoides), and the snails (Thais spp.). These predators occur both intertidally and subtidally, although exposure to air restricts their ability to feed. The starfish feed on several types of invertebrates, including mussels, barnacles, and snails. The snails (Thais) feed primarily on barnacles. Predatory fish include copper rockfish (Sebastes caurinus), brown rockfish (S. auriculatus), bocaccio (S. paucispinus), lingcod (Ophiodon elongatus), cabezon (Scorpaenichthys marmoratus), Pacific staghorn sculpin (Leptocottus armatus), and saddleback gunnel (Pholis ornata). These fish occur intertidally and subtidally, often moving into the intertidal zone during high tide and remaining in tide pools or moving into deeper water during low tide. The saddleback gunnel and staghorn sculpin are small fish, usually feeding on small invertebrates and small fish. The rockfish, lingcod, and cabezon are larger fish more characteristic of open coast rocky bottoms. Juveniles of these species are common in the estuary, with adults occurring occasionally. Juvenile and adult rockfish, lingcod, and cabezons feed on crustaceans, mollusks, and fish. Birds using the rocky bottom habitat include the black oystercatcher (Haematopus bachmani), black turnstone (Arenaria melanocephala), wandering tattler (Heteroscelus incanus), surfbird (Aphriza virgata), and Brandt's cormorant (Phalacrocorax penicillatus). Brandt's cormorant actively pursues fish by swimming underwater. The other bird species feed on invertebrates in the intertidal zone.

Others. Several scavengers occur on rocky bottoms, including the rock louse (Ligia occidentalis), lined shore crab (Pachygrapsus crassipes), hermit crabs (Pagurus spp.), purple shore crab (Hemigrapsus nudus), and rock crab (Cancer antennarius). These species are opportunistic feeders, taking detritus, dead organisms, or live organisms if available. The rock louse occurs in the high intertidal zone, almost always crawling on rocks above the water line. The lined shore crab is also found in the high intertidal zone. Hermit crabs occur throughout the intertidal and subtidal zones. They are soft-bodied forms, utilizing the shells of dead snails for protection. The rock crab occurs in the low intertidal and subtidal zone.

The porcelain crab (Petrolisthes cinctipes) is primarily a filter feeder on plankton, but it also feeds on macro-algae and detritus. This crab is usually found under rocks in the high and mid-intertidal zones. Anemones (Anthopleura elegantissima, A. xanthe, A. grammica) feed by filtering zooplankton from the water, or by entangling and killing small invertebrates and small fish in their stinging tentacles. Anemones are attached to rocks throughout the intertidal and subtidal zones.

Community Dynamics. The food web of a rocky bottom community is illustrated in Figures 4-11 and 4-12. Sunlight is used by the plants and algae of the rocky bottom to convert carbon dioxide and nutrients into organic matter. These primary producers are grazed on directly by herbivores, and provide detritus that is eaten by scavengers in the rocky habitat and exported to other habitats. Phytoplankton and zooplankton, along with suspended detritus, are carried into the rocky bottom habitat by tidal currents and provide food for the various sessile filter feeders of the rocky bottom community. Carnivores feed upon the various grazers, filter feeders, scavengers, and on other predators.

A typical herbivore is the limpet (Collisella digitalis). The limpet grazes directly on the blades of several species of macro-algae (including Porphyra, Ulva, Fucus, Pelvetiopsis, and Iridaea). Grazing by the limpets and other molluscan herbivores is important in structuring the algal community, restricting the occurrence of certain species to particular intertidal zones (Boyd and DeMartini, 1977). Filter feeders are dependent on water currents for food. 3ay mussels (Mytilus edulis) and acorn barnacles (Balanus glandula) ingest large quantities of water, removing plankton and organic detritus. Predators feed primarily upon herbivores and filter feeders. Starfish (Pisaster ochraceus) feed

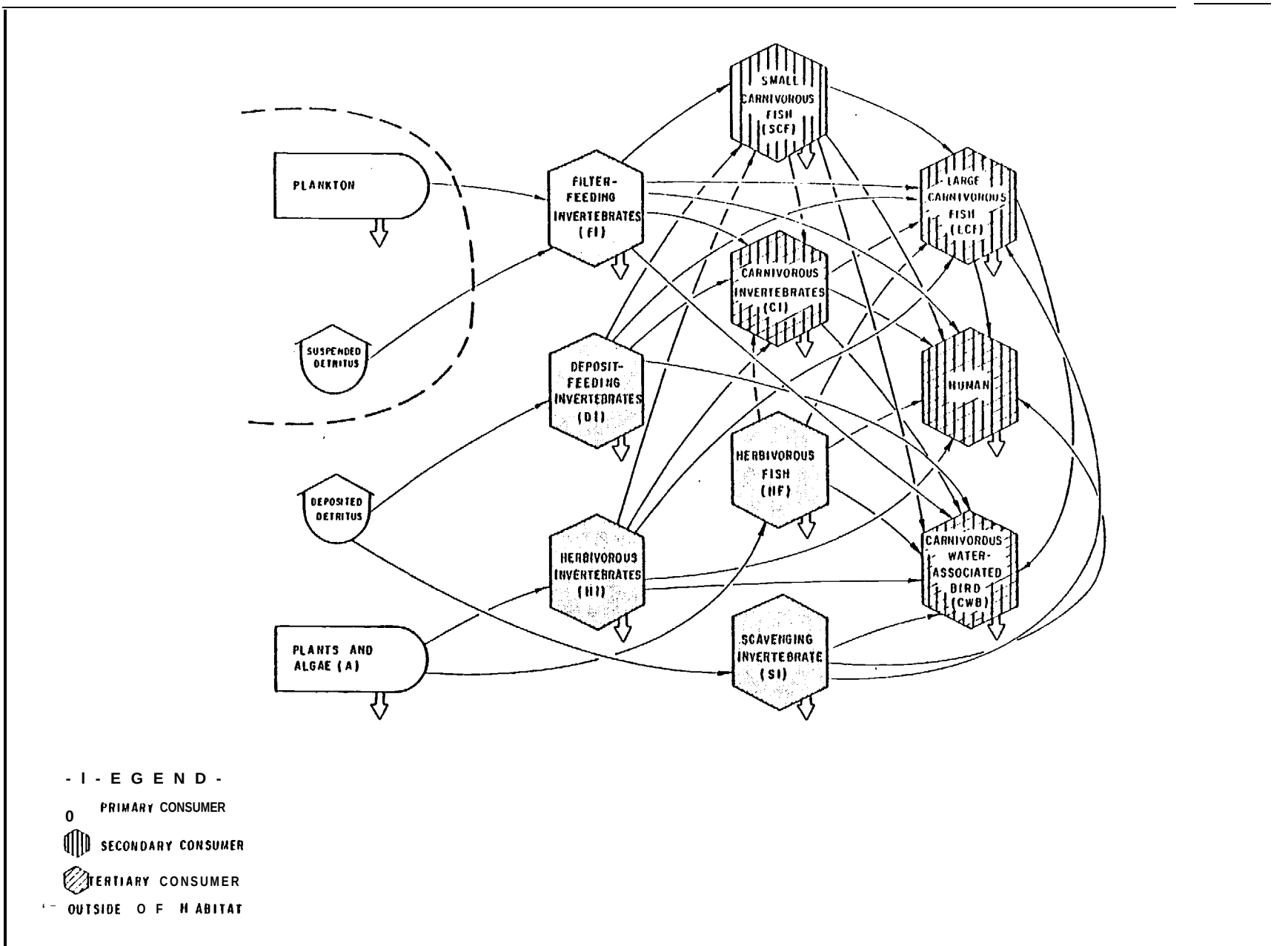


Figure 4-11. General Food Web - Rocky Bottom

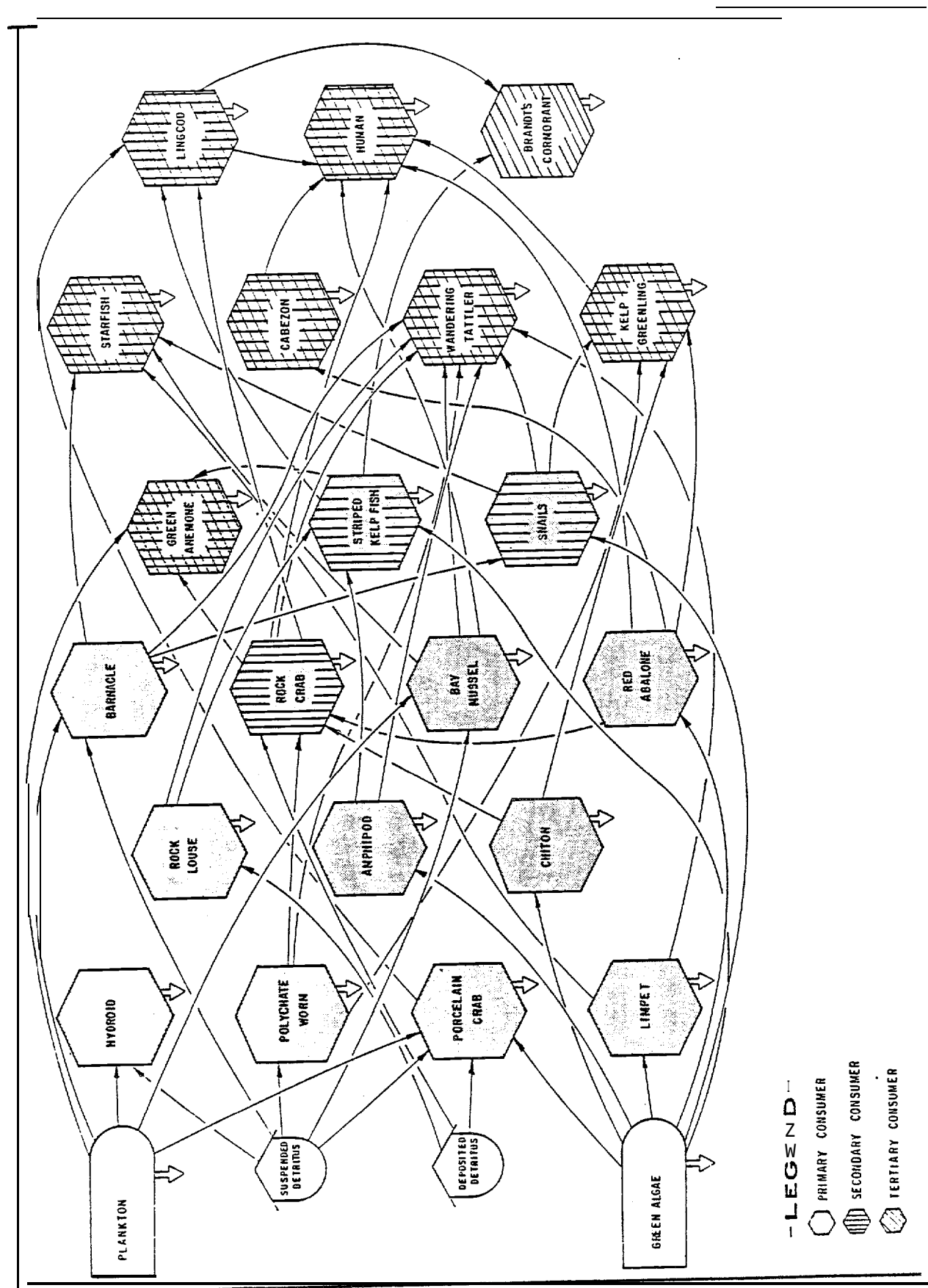


Figure 4-12. An Example of a Rocky Bottom Food Web

on mussels, opening the valves by pressure from its tube feet and engulfing the contents in its eversible stomach. Starfish also prey on barnacles, limpets and snails. Other predators, such as the snails (*Thais* spp.) feed on mussels and barnacles by drilling a hole through the shell and consuming the meat. Many fish, including the lingcod (*Ophiodon elongatus*) and the Pacific staghorn sculpin (*Leptocottus armatus*), feed on a variety of bottom invertebrates, especially crustaceans, and other fish. Small fish, like the saddleback gunnel (*Pholis ornata*), generally feed on small bottom invertebrates. Omnivorous fish, like the striped kelpfish (*Gibbonsia merzii*), feed on both algae and small invertebrates. Scavengers, such as the hermit crabs (*Pacurus* spp.), are opportunistic feeders. They will feed on detritus and dead or live organisms. Birds primarily eat invertebrates in the rocky intertidal zone. The black oystercatcher (*Haematopus bachmani*) dislodges mussels, limpets and barnacles with its chisel-like beak. The wandering tattler (*Heteroscelus incanus*) and surfbird (*Aphriza virgata*) feed on isopods, polychaete worms, amphipods and crabs, which are collected from crevices, algae, and mussel beds. Brandt's cormorant (*Phalacrocorax penicillatus*) feeds primarily on bottom fish captured by swimming underwater.

Interactions. Many organisms move in and out of the rocky bottom habitat. Wading and shore birds and fish may utilize this habitat during certain tidal stages, birds preferring low tides and fish high tides. These and other predators may be particularly evident in the rocky habitat during calm periods.

The rocky habitat exports detritus in the form of plant and algae parts to other habitats. Plant detritus enters the rocky habitat from other environments. The influx of phytoplankton and zooplankton from the open water habitat is extremely important as a food supply.

EFFECTS OF HUMAN ACTIVITY

Pollution can have a serious impact on the rocky bottom community. This community is dominated by many sessile forms, which cannot escape unfavorable conditions. Filter feeders are especially susceptible to pollution since their feeding mechanism necessitates the ingestion of large quantities of water. Oil pollution can affect rocky bottoms in several ways (Winzler and Kelley, 1977a). A heavy spill can smother organisms in a layer of oil. The toxic components of oil, especially the water-soluble phenolic fraction, may be lethal to marine organisms. Oil pollution has been shown to reduce the breeding rates of barnacles and mussels and inhibit the settlement of barnacle larvae. The detergents and oil dispersants used to contain and mitigate the effects of an oil spill are also toxic to most forms of marine life. Pesticides enter the estuary, often as a result of runoff during winter rains. The toxic elements of pesticides may be lethal to marine life or produce sublethal effects, including prolonged or abnormal larval development. Heavy metal pollution (including elements such as mercury, lead, copper, and zinc) has a similar effect on marine life. Power plant operations may impact rocky bottom communities, through the release of thermal effluents and by entrainment of planktonic larvae through the plant.

Humans harvest certain of the species from the rocky shore habitat, especially lingcod, greenings, rockfish, abalone, and rock crabs. These species can be harmful to humans if they have fed upon other organisms that accumulate toxic substances, such as filter-feeding mussels and barnacles.

EELGRASS BEDS

INTRODUCTION

Substratum

Eelgrass (Zostera marina) can take root in a variety of substrates, ranging from soft mud to gravel mixed with coarse sand.

Areal Extent

Eelgrass beds occur in most of the estuaries along the California coast. The most extensive beds are in Humboldt Bay, Bodega Harbor, Tomales Bay, and Morro Bay.

Dominant Species

Eelgrass beds are dominated by eelgrass (Zostera marina), a vascular plant. The narrow leaves of the eelgrass provide an attachment site for many organisms (epiphytes). This extensive epiphytic community includes diatoms, algae, hydroids, amphipods, snails and nudibranchs. Many organisms also occur in or on the sediment trapped by the eelgrass root system. These organisms include polychaete worms, snails, nudibranchs and brittle stars. A few species of fish and birds are associated with eelgrass beds, using the area for feeding and protection. Bivalves are not common in eelgrass beds.

Habitat Descriptors

Eelgrass beds may be present on a variety of substrates, occurring intertidally and subtidally. The primary factors governing the occurrence of eelgrass beds appear to be tidal exposure and light penetration. Eelgrass is not tolerant of extended periods of exposure to air, which determines its upper limit in the intertidal zone. The lower limit is regulated by light penetration, which is largely dependent on water clarity. In turbid waters, eelgrass beds are rarely found below a depth of 3 to 4 meters. A model of the structure and function of the eelgrass ecosystem is presented in Figure 4-13.

HABITAT CHARACTERIZATION

Geographic Aspects

Physical size. Eelgrass beds are limited to the quiet waters of bays and estuaries. Limited eelgrass beds may occur in many estuaries, but extensive beds occur only in Humboldt Bay, Bodega Harbor, Tomales Bay, Morro Bay, and to the south of the study area, in Newport Bay. Eelgrass beds cover approximately 3,017 acres in Humboldt Bay (Harding and Butler, 1979) and approximately 483 acres in Morro Bay (Gerdes et al., 1974).

Physical Aspects

The majority of the eelgrass beds are located in the subtidal zone, and most of the physical parameters are related to the conditions in the subtidal area.

Substratum. Eelgrass may root in a variety of substrates, ranging from gravel mixed with sand to fine mud. The roots are efficient in trapping sediment, resulting in an accumulation of deposited material within the eelgrass bed.

Water movement. Tidal currents are important as a mechanism for carrying nutrients

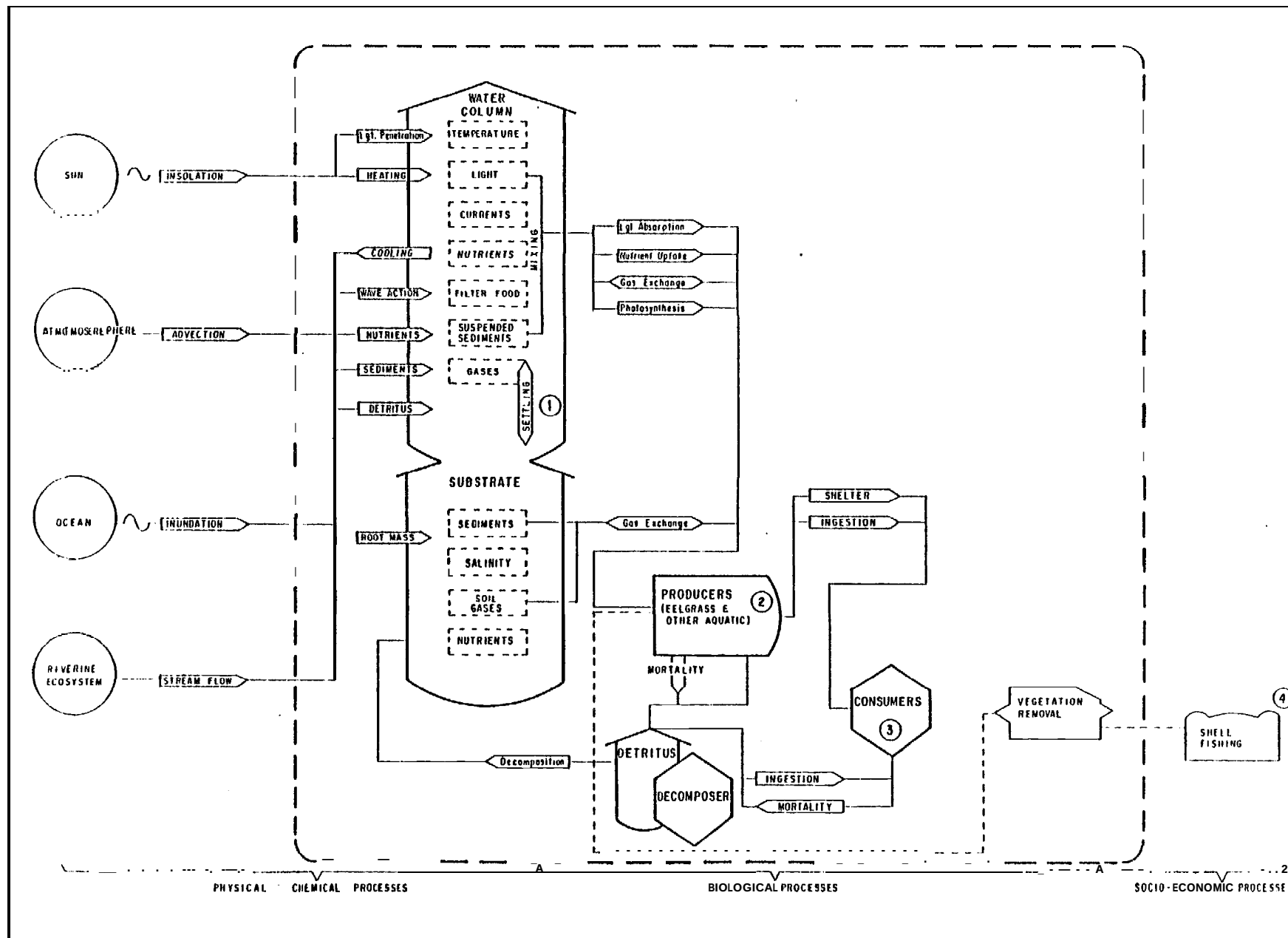


Figure 4-13. Ecosystem Model of an Eelgrass (Subtidal Aquatic Bed) Habitat

Footnotes for Figure 4-13.
Ecosystem Model for the Eelgrass (Subtidal Aquatic Bed) Habitat
Highlighted Processes and Components Are Annotated Below

1. PHYSICAL CHEMICAL PROCESSES: These processes are described for the general estuary model. Light penetration and water clarity are important factors in the growth of eelgrass.
2. PRODUCERS: Eelgrass is the basis of the producer component for this ecosystem, but the component also includes epiphytic marine algae.
3. CONSUMERS: Primary Consumers include hydrozoans, polychaete worms, crustaceans, mollusks, and bryozoans. Secondary Consumers include fish that utilize the eelgrass for shelter and feed on consumers in the eelgrass community.
4. IMPACTS OF HUMAN ACTIVITIES: Particular to this ecosystem is sedimentation from riverine ecosystems. The impacts of shellfishing on eelgrass occur through uprooting of vegetation by clam diggers.

and sediment into the eelgrass community. Tidal currents also export surplus detrital material produced by decaying eelgrass.

Exposure. The upper limit of eelgrass is determined by the degree of drying to which the leaves are subjected. The upper limit generally occurs in the lower intertidal zone at approximately 0.3 meter (1.0 foot) above mean lower low water, where exposure to air occurs approximately 13% of the time (Keller and Harris, 1966).

Light penetration. The maximum depth to which eelgrass will grow is correlated with light penetration, which is determined by water transparency. In turbid waters eelgrass usually occurs at an average depth of 2 meters, rarely present below 3 to 4 meters. In clear offshore waters eelgrass has been recorded to a depth of 30 meters or more (Cottam and Munro, 1954). Available light can also be reduced by the epiphytes growing on the surface of eelgrass leaves, limiting the total surface area involved in photosynthesis.

Biological Aspects

Dominant Species. The organisms that characterize the eelgrass community are presented in Table 4-9. The dominant organisms include 1 species of plant, 20 species of invertebrates, 5 species of fish and 2 species of birds. Information on the habitat preferences and feeding habits of these organisms was gathered from several sources (Ricketts and Calvin, 1968; Feder et al., 1974; Smith and Carlton, 1975; Standing et al., 1975; and Moyle, 1976). This information is presented in the following sections.

Table 4-9. Dominant Organisms of the Eelgrass Community¹

Plants/Birds	Fish	Invertebrates
Plants	Bay pipefish (SCF, HF)	Hydroid (FF)
Eelgrass (VP)	<u>Syngnathus</u>	<u>Plumularia</u> spp.
<u>Zostera</u>	<u>leptorhynchus</u>	Hydroid (FF)
<u>marina</u>	Kelp greenling	<u>Obelia</u> spp.
	(LCF)	Anemone (FF)
	<u>Hexagrammos</u>	<u>Epiactis prolifera</u>
	<u>decagrammus</u>	Polychaete worm (FF)
Birds	Shiner surfperch	<u>Nereis procera</u>
	(SCF)	Polychaete worm (CI)
Black brant (HWB)	<u>Cymatogaster</u>	<u>Glycera americana</u>
<u>Branta bernicla</u>	<u>aggregata</u>	Polychaete worm (DI)
<u>nigricans</u>	Dwarf surfperch	<u>Cistenides brevicoma</u>
American wigeon	(SCF, HF)	Polychaete worm (FI)
(mm)	<u>Micrometrus</u>	<u>Eupolyvmnia Crescents</u>
<u>Arias americana</u>	<u>minimus</u>	Polychaete worm (CI)
	Black surfperch	<u>Paraeurythoe californica</u>
	(SCF)	Isopod (DI)
	<u>Embiotoca</u>	<u>Idotea resee.eta</u>
	<u>jacksoni</u>	Kelp crab (HI)
		<u>Pugettia Products</u>
		Red crab (SI, DI)
		<u>Cancer productus</u>
		Snail (HI)
		<u>Lacuna marmorata</u>
		Snail (SI, DI)
		<u>Nassarius fossatus</u>
		Snail (HI)
		<u>Nassarius mendicus</u>
		Nudibranch (HI)
		<u>Phyllaplysia taylori</u>
		Leptostracan (HI)
		<u>Nebalia puggetensis</u>
		Sickle razor clam (FF)
		<u>Solen sicarius</u>
		Brittle star (DI)
		<u>Amphiodia occidentalis</u>
		Caprellid (HI)
		<u>Caprella californica</u>
		Broken-back shrimp (SI, DI)
		<u>Heptacarpus baludicola</u>

¹See Table 4-3 for definition. of abbreviations.

Rare, Endangered and Species of Concern. Seven species of ecological concern occur in eelgrass beds. These species are listed in Table 4-10. They include one plant species, four species of fish, and one bird species. No species designated as rare or endangered regularly occur in the eelgrass habitat. Species accounts of all the species listed below may be found in Volume II, Part 2 of this report.

Table 4-10. species of concern Occurring in Eelgrass Beds

Plants	Fish	Bird
Eelgrass <u>Zostera</u> <u>marina</u>	Pacific herring <u>Clupea harengus</u> <u>pallasii</u> Topsmelt <u>Atherinops affinis</u> Kelp greenling <u>Hexagrammos</u> <u>decagrammus</u> Shiner surfperch <u>Cymatogaster</u> <u>aggregata</u>	Black brant <u>Branta bernicla</u> <u>nigricans</u>

Community composition.

Producers. The major producer of the eelgrass community is eelgrass (Zostera marina), a vascular plant. Other primary producers are epiphytes, utilizing the leaves of eelgrass as attachment sites. These epiphytes include many species of diatoms and a few species of red, brown, and green algae.

Herbivores, Omnivores, Filter Feeders. Several of the dominant eelgrass community organisms are filter feeders. Hydroids (Obelia spp., Plumularia spp.) and an anemone (Epiactis prolifica) are found attached to the blades of eelgrass. One of the hydroids (Obelia spp.) is characteristically found on the tips of the blades. A nereid worm (Nereis procer) lives in membranous tubes attached to the blades and roots of eelgrass, while a terebellid worm (Eupolyornia crescents) constructs parchment-like sandy tubes and lives in the mud surrounding eelgrass beds. The sickle razor clam (Solen sicarius) commonly burrows in the mud around the roots of eelgrass.

Many of the species in the eelgrass community are herbivores, grazing on the epiphytic diatoms and algae growing on the eelgrass leaves. These grazers include snails (Lacuna marmorata, Nassarius mendicus), an opisthobranch (Phyllaphysia taylori), a caprellid amphipod (Caprella californica), and a leptostracan crustacean (Nebalia puggettensis). Larger organisms grazing on the eelgrass include the kelp crab (Pugettia producta) and two birds, the black brant (Branta bernicla nigricans) and the American wigeon (Anas americana). Two species of omnivorous fish, the bay pipefish (Syngnathus leptorhynchus) and dwarf surfperch (Micrometrus minimus), inhabit the eelgrass beds. Both of these species feed primarily on small crustaceans, but also eat algae.

Predators. A number of predatory species occur in the eelgrass habitat. Two worms, a glycerid (Glycera americana) and an amphinomid (Paraeurythoe californica), pursue prey in and on the mud around the roots of eelgrass beds. Two species of fish, the kelp greenling (Hexagrammos decagrammus) and the shiner surfperch (Cymatogaster aggregata) feed on organisms living on the eelgrass or within the substrate.

Others. Several species of the eelgrass community feed on detritus or act as scavengers. The pectinariid worm (Cistenides brevicoma) and the brittle star (Amphiodia

occidentalis) live in the substrate beneath the eelgrass bed and feed on detritus. An isopod (Idotea resicata) clings to the eelgrass and feeds on detritus. The red crab (Cancer productus), broken-back shrimp (Heptacarpus paludicola), and snail (Nassarius fossatus) are opportunistic scavengers, feeding on detritus, dead organisms, or live organisms. The red crab lives in shallow burrows on the tidal flats around eelgrass beds; the snail occurs on the surface of the mud; and the broken-back shrimp clings to the leaves of the eelgrass.

Community Dynamics. The food web of the eelgrass community is shown in Figures 4-14 and 4-15. Sunlight is converted into organic matter primarily by the eelgrass with a lesser contribution by epiphytic diatoms and algae. Many herbivorous species graze directly on the eelgrass or feed on the epiphytes. The root systems of eelgrass trap sediment, including organic detritus. This material, along with dead and decaying eelgrass leaves, supports scavengers and detrital feeders. Some filter feeders exist within the substrate, while others occur as epiphytes on the eelgrass leaves. The se organisms feed on plankton and suspended detritus carried into the eelgrass habitat by tidal currents. The various predators feed on the grazers, scavengers, and filter feeders.

The black brant (Branta bernicla nigricans) is a bird that feeds almost exclusively on eelgrass. This small goose swims along the surface of the water, browsing on eelgrass that can be reached without deep diving.

The caprellid amphipod (Caprella californica) is characteristic of the small grazers found in the eelgrass habitat. The caprellid clings to the blades of the eelgrass, matching their color, while grazing on the microscopic diatoms growing on the leaves.

The anemone (Epiactis prolifera) is a characteristic epiphytic predator. This small anemone is attached to the blades of eelgrass. It feeds on small planktonic organisms, captured by its stinging tentacles.

The sickle razor clam (Solen sicarius) is a filter feeder inhabiting the substrate among the roots of eelgrass. This clam is an active animal, capable of rapid burrowing. It is also capable of rapid movements through the water, accomplished by forcibly expelling water from the siphons. Feeding occurs by filtering food particles from water taken in through the siphon.

The pectinariid worm (Cistenides brevicoma) lives in a slender, cone-shaped tube of cemented sand grains. The worm is usually found in a head-down position in the substrate. It digs through the substrate using the bristle-combs which project from its head. Sand or mud is ingested during the digging process and food particles removed.

The red crab (Cancer productus) lives in shallow burrows constructed in the mud, "usually at the edges of eelgrass beds. The crab feeds on detrital material, dead organisms, or live organisms. It is an opportunistic feeder, exploiting the most readily available food source.

The glycerid worm (Glycera americana) is a typical predator, occurring in the black mud around the roots of eelgrass. This worm possesses an introvert, a device armed with four terminal jaws for biting, which can be extended approximately one-third of the body length of the worm. This species usually preys upon other worms.

The bay pipefish (Syngnathus leptorhynchus) is a characteristic fish of the eelgrass habitat. This slender fish is cryptically among the eelgrass leaves, resembling a blade of eelgrass. It feeds on small crustaceans, such as amphipods and leptostracans (Nebalia). Prey organisms are captured by using suction created by the intake of water into the narrow tube-like snout.

The kelp greenling (Hexagrammos decagrammus) is a larger predatory fish. It lives and feeds primarily on the bottom, eating polychaete worms, crustaceans and small fish.

Interactions with Other Habitats. Eelgrass beds are generally located in the subtidal zone. Constant submergence of the beds favors visitation of this habitat by fish. In addition to seeking food and protection within the eelgrass beds, many fish attach their eggs to the leaves of eelgrass. The Pacific herring (Clupea harengus pallasii), an important commercial species, spawns primarily on eelgrass in Tomales Bay. Other fish, including the jacksmelt (Atherinopsis californiensis) and topsmelt (Atherinops affinis), also attach their eggs to this plant. Several species of snails and nudibranchs lay eggs on the blades of eelgrass.

Eelgrass beds are highly productive (Phillips, 1978). Surplus energy in the form of dead plant leaves is exported to other habitats, including the salt marsh, mudflats, and rocky bottom. The eelgrass beds are efficient in trapping sediment and detritus carried in from other habitats.

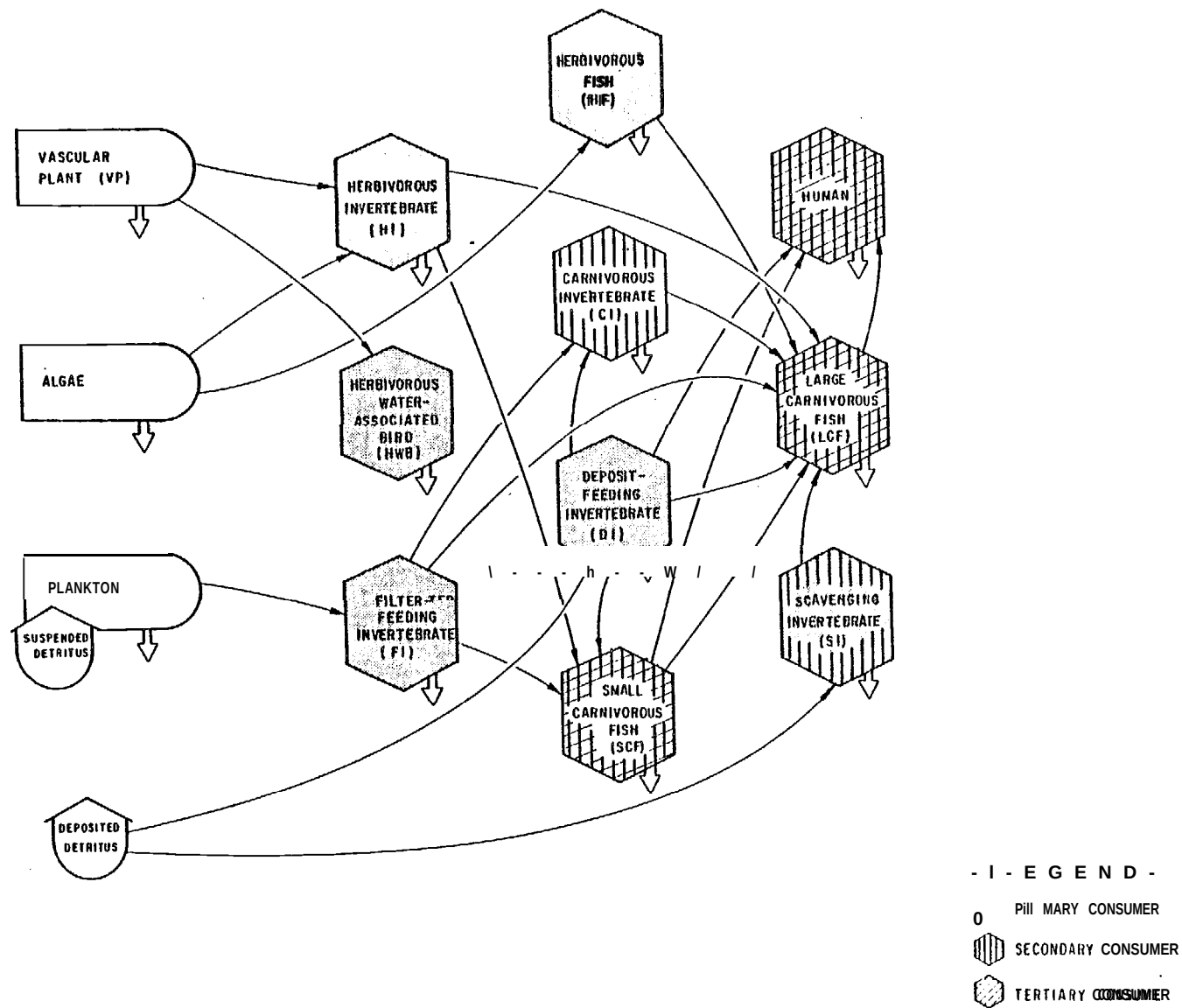


Figure 4-14. General Food Web - Eelgrass

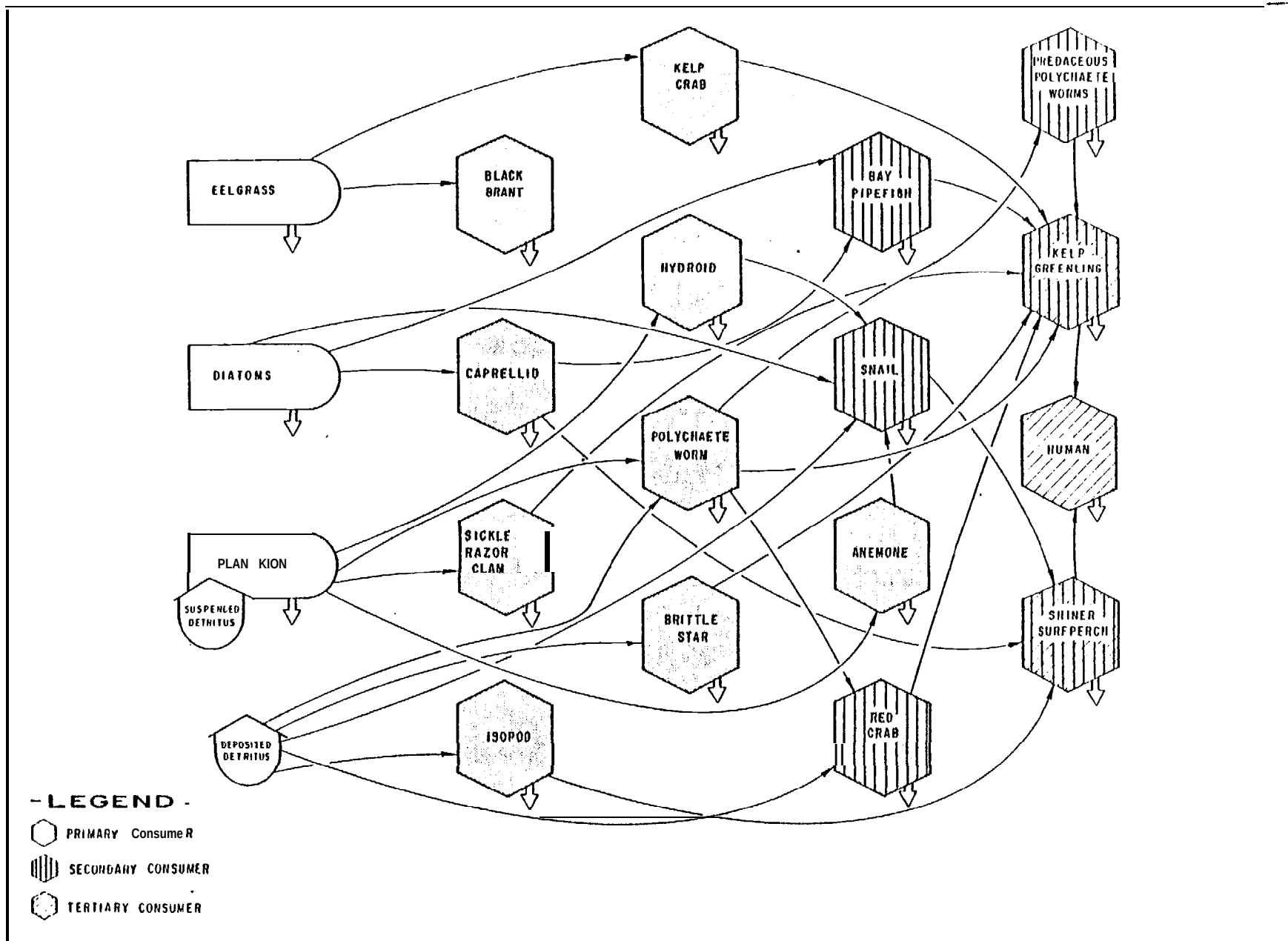


Figure 4-15. An Example of an Eelgrass Food Web

EFFECTS OF HUMAN ACTIVITY

The eelgrass communities of the west coast of the United States have not been studied in as much detail as have those of the east coast. The effects of oil, thermal, or sewage pollution on eelgrass communities have not been documented. It is possible that activities which increase the turbidity of the water, such as logging or dredging, would have an impact on eelgrass beds by reducing light penetration. Ships arriving from ports of the east coast of the United States may have been responsible for the introduction and spread of the wasting disease that caused considerable destruction of eelgrass beds during the 1930's and 1940's.

EMERGENT VEGETATION

INTRODUCTION

Physiognomy

Intertidal emergent vegetation (i.e., salt marsh) is inhabited by specifically adapted aquatic vegetation and fauna. Sparse to dense stands of grasses, sedges, rushes, and succulent vegetation, varying in height from nearly prostrate to two meters, are the visually dominant life forms.

Areal Extent

Aquatic and emergent vegetation grows in the subtidal and intertidal zones of protected bays, estuaries, lagoons, or behind barrier spits and islands. Intertidal emergent vegetation is well-developed near Humboldt Bay, San Francisco Bay, and Morro Bay.

Substratum

Fine-grained, well-sorted sediments with particle sizes ranging from silty-sand to silty-clay generally characterize the substrate of the salt marsh. Soil organic content and soil moisture may be high compared to that of upland habitats.

Dominant Species

Dominant life forms of the emergent vegetation include a dense cover of vascular halophytes (i.e., plants inhabiting salty soils) such as pickleweed (*Salicornia* sp.) and California cordgrass (*Spartina foliosa*). These plants may be occasionally interspersed with macro-algae (e.g., *Ulva* spp.). Marsh fauna is commonly comprised of detritus feeders, including clams, mollusks, marine worms, and other mud dwellers. Scavengers, such as crabs, isopods, and amphipods, are also important. Several resident and visiting birds, mammals, and fish, attracted by the availability of large invertebrate populations as a food source, are commonly associated with this habitat.

Habitat Descriptors

Influence of topography and tidal exchange dominates the intertidal physical conditions; zonation of lifeforms commonly follows elevational gradients or zones of tidal submergence. Sedimentation may be a determining factor in the development and maintenance of emergent vegetation. Salinity distributions, as determined by tidal inundation, evaporation, and capillary action, influence plant zonation. Nutrient cycling is characterized by the functioning of the marsh substrate as a nutrient sink. Figure 4-16 presents an ecosystem model for this habitat.

HABITAT CHARACTERIZATION

Geographic Aspects

Physical Size. Coastal salt marshes at present occupy 365 to 370 km² of the California coast (Macdonald, 1977). This represents a 60% to 85% reduction in area since the 1850s, due to extensive dredging and filling. Marsh development is limited to the intertidal zone, extending from approximately mean high water (MHW) landward to extreme high water (EHW).

Natural/Artificial Factors That Define or Limit Area. The steep, narrow continental shelf that characterizes much of the California coast, with the exception of San

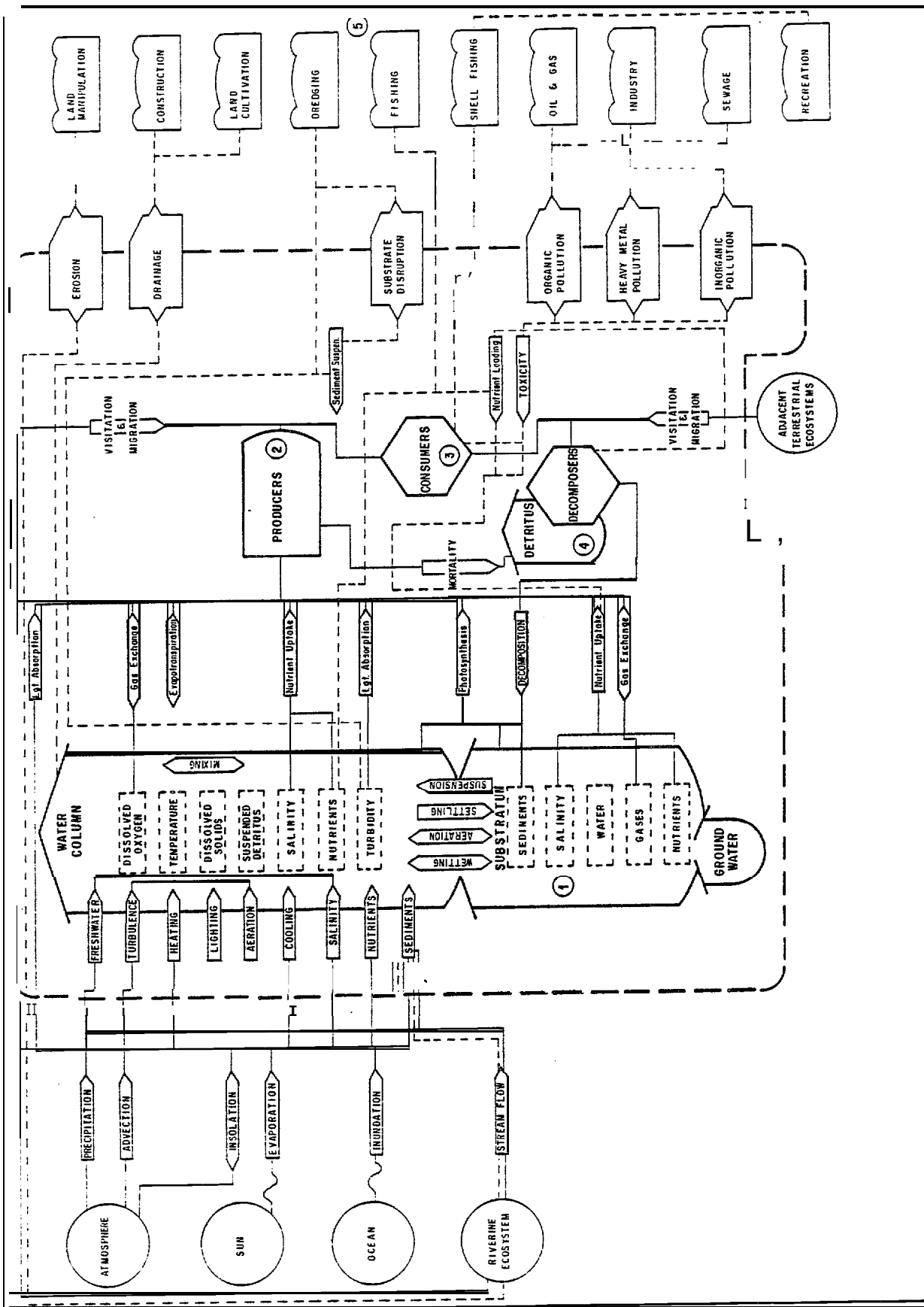


Figure 4-16. Ecosystem Model of an Emergent Vegetation Habitat

Footnotes for Figure 4-16.
Ecosystem Model for the Emergent Vegetation Habitat
Highlighted Processes and Components are Annotated Below

1. PHYSICAL-CHEMICAL PROCESSES: These are described for the general estuary model. Tidal gradients are important factors in the zonal distribution of emergent vegetation. Drainage of the substrate is through groundwater flow.
2. PRODUCERS : Aquatic producers include diatoms, flagellates, blue-green algae. Benthic producers are green algae and yellow-green algae. Vascular producers consist of cordgrass and pickleweed.
3. CONSUMERS: Aquatic primary consumers are zooplankton, ciliates, nematodes, foraminifera, ostracodes, fish. Aquatic secondary consumers include fish, shorebirds, crabs. Aquatic tertiary consumers include fish, grebes, herons, gulls, and terns. Terrestrial primary consumers are black-tailed hare, meadow mouse, harvest mice, deer mouse, coots, rails, ducks, and insects. Terrestrial secondary consumers include insects, spiders, lizards, ornate shrew, opossum, ducks, shorebirds, weasel, snakes, great blue heron. Terrestrial tertiary consumers include raptors, grey fox, coyote, and bobcat.
4. DETRITAL FOOD CHAIN: The detrital food chain is a significant part of the energy flow in the emergent vegetation ecosystem. Bacteria and microbiota ingest detritus and are in turn consumed by insects, nematodes, ostracodes, insects, and macroinvertebrates.
5. HUMAN ACTIVITIES: Most of the human activities that affect the estuary also affect the emergent vegetation ecosystem.

San Francisco Bay, precludes extensive marsh development. Emergent vegetation is restricted to small bays and river mouths isolated from intense wave action. The extent of emergent vegetation areas is defined by the natural processes of tidal inundation and sedimentation. Human activities that affect the normal functioning of these processes alter the extent of habitat development. Land cultivation, changes in watershed drainage, or internal drainage patterns, reclamation, and the introduction of pollutants are among the activities that modify the conditions necessary for habitat maintenance to the extent that habitat is destroyed. Past hydraulic mining practices, on the other hand, increased sedimentation that promoted marsh creation (Atwater, et al., 1979).

Physical Aspects

Substratum. Well-sorted, fine-grained muds, dominated by the clay minerals montmorillonite, kaolinite, and illite, characterize the substrate of the intertidal emergent vegetation. Grain size generally decreases landward with distance from the estuary. Finer-grained particles are also known to accumulate in pans or depressions within the marsh (Pestrong, 1967-8). Phleger and Bradshaw (1966) found textures ranging from silty sand to silty clay in southern California at Mission Bay. Pestrong (1965) measured the particle size of bay muds in San Francisco Bay at two to four microns in diameter.

Pestrong's (1965) measurements of clay mineral content indicated a dominance of montmorillonite. The ratio of montmorillonite, kaolinite, and illite was determined to be 47:31:22. The color of marsh muds reflects soil aeration conditions. Surface color is usually brown or light grey, indicating oxidizing conditions. Oxidation by plant roots and burrowing mud-dwellers is restricted, however, to the upper 0.5 to 0.75 m. Below this zone of aeration, muds are darker, often black to blue-black, indicative of a reducing environment.

Variation in several soil characteristics is the result of the influences of elevation and tidal exchange. Observations by Pestrong (1965) of soil moisture indicated decreasing moisture content with respect to increasing elevation and decreasing tidal inundation (from 130 to 100% of dry weight sediment). Soil organic content was found to increase with elevation, values ranging from 13% in the lower cordgrass (Spartina sp.) soils to 16.4% in the higher pickleweed (Salicornia sp.) dominated soils.

Marsh soils at higher elevations also show increased shear strength and firmness. This appears to be the result of the binding effect of in situ root systems. Similarly, channel levees have greater densities and higher shear strength as a result of the longer periods of desiccation (Pestrong, 1967-8).

Sedimentation is an important process in marsh development and maintenance and a primary determinant of estuarine habitat succession. Shallow, protected coastal areas, conducive to the settling out of fine-grained muds, afford the opportunity for mudflat development. Further sedimentation creates a substrate suitable for the growth of pioneer marsh plants, such as Spartina foliosa. The stabilizing effect of the root systems of vascular plants and the slowing of tidal waters by the presence of these plants provides an environment for increased sedimentation. As deposition of muds continues, Spartina may be replaced by upland marsh grasses. Sedimentation rates for marshes have been measured in two southern California sites by Emery and Stevenson (1957) and Warne (1971) at 0.5 cm/year for a Spartina marsh and 0.1 to 0.3 cm/year for Salicornia virginica marshes. Pestrong (1965) noted a sedimentation rate of 2 cm/year for San Francisco Bay marshlands.

Vertical Zonation/Exposure. Vertical zonation in plant and animal life of marshes is largely determined by tidal submergence and elevation. Chapman (1960) and Ranwell (1972) noted significant differences between salt marsh communities in the upper and lower tidal areas. Hinde (1954) studied marsh zonation in a site near Palo Alto, and was unable to differentiate between an upper emergent and lower submergent zone. He concluded that uniform zonation of dominant plant species, characteristic of his study site near Palo Alto, may be common only to the alluvial fan deposits of San Francisco Bay. Marsh zonation, as it relates to tidal elevation, appears to be site specific. Generally, at least two zones are typically associated with California marshes, the lower zone dominated by cordgrass and the upper zone by pickleweed in pure stands or mixed with other high marsh species (e.g., Atriplex sp., Distichlis spicata).

Other investigations (Doty, 1946; MacDonald, 1969) have demonstrated the effect of increasing elevation on the maximum duration of submergence and exposure. Pacific coast marshes, influenced by a tidal regime of marked inequities between the two daily high tides and low tides, are characterized by significant reduction in submergence near mean lower high water (MLHW), approximate lower limit of halophyte growth, and a significant increase in exposure near mean higher high water (MHHW), separating the low marsh from the high marsh.

Salinity. The salinity levels of marsh soils result from the combined influences of tidal inundation, freshwater runoff, evaporation, leaching, and capillary action. MacDonald (1977) presents a soil salinity model of California salt marshes based on the past research efforts of Phleger and Bradshaw (1966), Lane (1969), Mall (1969), Barbour, et al. (1973), Zedler (1975), Mahall and Park (1976), and others. The model has three basic elements:

(1) Soil salinities tend to increase landward to a maximum near MHW. A gradual decline of salinity levels occurs from MHW to the adjacent uplands.

(2) Seasonal variation in soil salinities are affected by local precipitation and runoff. Soil in the wet season is characterized by an increase in salinity with increasing depth, whereas a decrease in salinity with depth is associated with the dry season.

(3) Regional climatic trends influence soil salinity levels. Where evaporation exceeds precipitation, from approximately San Francisco south, surface soil salinity increases and salt pans are more common. North of San Francisco, increased leaching effects, resulting from greater precipitation, cause a steady decline in soil salinity.

A discussion of local deviations from the model concluded that satisfactory explanations could be presented in most cases. Differences in proximity to tidal creeks, micro-topography, and soil characteristics were among the explanations offered.

Nutrient Cycling. The ability of a marsh to act as a nutrient "trap" or sink and to export the excess nutrient load to adjacent ecosystems has been documented in studies on the Atlantic and Gulf coasts. Much of this work has been completed in conjunction with dredge spoils disposal studies. Gunnison (1978) prepared a report that models mineral cycling in the salt marsh-estuarine ecosystems and describes the components in relation to their structure and function within the ecosystem. Little work has been done to document similar processing of nutrient cycling on the Pacific coast. MacDonald (1977) summarizes the research pertaining to Pacific coast estuaries.

Estuarine sources of nutrients and other non-essential elements may be of atmospheric, oceanic, or riverine origin. Eastern estuaries and coastlines are dominated by terrestrially-produced allochthonous (i.e., deposits that originated elsewhere) material transported by river flow. The Pacific coastline is characterized by offshore upwelling of nutrients. However, the role of these marine elements in estuarine mineral cycling is unclear. New elements entering the salt marsh ecosystem may follow one of several pathways. The high cationic exchange capacity of the montmorillonite clay lattice is conducive to adsorption of ions. These adsorbed ions may be stored in the clay, taken up by plant roots, or leached from the surface soil horizons.

Decomposition of detritus is an important function of a marsh ecosystem. Most of this is in the form of decaying plant material which is oxidized by bacteria. This, in turn, is consumed by a large number of invertebrate detritus feeders that inhabit the muds of the marsh. These organisms provide an abundant food source for higher terrestrial and aquatic trophic level feeders.

Temperature. Little is known about the effects of temperature on the establishment and maintenance of emergent vegetation in a marsh. However, Ranwell (1972) postulates that the lower marshes, which are subject to increased submergence, must experience lower mean temperatures and smaller rates of fluctuation than the less-regularly inundated upper marsh. In addition, Ranwell has summarized all the studies that deal with the effect of temperature on seed germination in salt marsh halophytes.

Dissolved Oxygen. Oxygen concentrations in the muds are important for the maintenance of mud-dwelling species. Dissolved oxygen is supplied from algal/vascular plant photosynthesis and through the influx of tidal and fresh water. An upper, aerated zone, noted by Chapman (1960) is associated with soil biological remains at root depth. Anaerobic conditions can develop in tidally-submerged muds or at soil depth by saturation with stagnant water (Ranwell, 1972). The position of the aerobic and anaerobic zones is critical for the completion of the nitrogen, phosphorous, and sulfur biogeochemical cycles (Gunnison, 1978).

Biological Aspects

Dominant Species. Vascular halophytes dominate the salt marsh habitat both with respect to standing crop (biomass) and to percentage cover. Two of the most important species in California are California cordgrass (Spartina foliosa) and pickleweed

(Salicornia virginica). The former grows along creek banks and elevations from mean high water (MHW) to mean higher low water (MHLW). Salicornia extends from below MHW, nearly to MHHW (Hinde, 1954) . It is also found in non-tidal areas, especially in diked marshes or other disturbed habitat.

Several good summaries of salt marsh plants along the coast of California are available. Macdonald (1977) , Macdonald and Barbour (1974) , and the U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory (1978) list species distributions and cite habitat relationships of salt marsh plants. Chapman (1977) discusses animal communities of marsh ecosystems, as well as plant distributions. The California Department of Fish and Game Coastal Wetland Series provides extensive species lists for individual estuarine localities in California.

Invertebrates associated with the emergent vegetation habitat are covered in Smith and Carlton (1975) , Macdonald (1969), and Phleger (1967). Lane (1969) and Cameron (1972) review salt marsh insects in San Francisco Bay. Cogswell (1977) and Small (1974) cover the birds of this habitat.

Most species found in the estuary are also associated with terrestrial or aquatic habitats. Terrestrial and aquatic fauna are generally more abundant in estuaries than species restricted to the estuarine habitats.

Table 4-11. Dominant Species of the Emergent Vegetation Community

PLANTS	BIRDS	MAMMALS
California cordgrass <u>Spartina foliosa</u>	Snowy egret (CWB) <u>Egretta thula</u>	Meadow mouse (HM) <u>Microtus californicus</u>
Pickleweed <u>Salicornia virginica</u>	American coot (HB) <u>Fulica americana</u>	Western harvest mouse (HM) <u>Reithrodontomys megalotis</u>
Salt grass <u>Distichlis spicata</u>	Savannah sparrow (HB, CLB) <u>Passerculus sandwichensis</u>	Ornate shrew (HM) <u>Sorex ornatus</u>
Frankenia <u>Frankenia grandifolia</u>	Song Sparrow (HB, CLB) <u>Melospiza melodia</u>	Rabbit (HM) <u>Lepus californicus</u>
Jaumea <u>Jaumea carnosa</u>	Virginia rail (CWB) <u>Rallus limicola</u>	Striped skunk (HM) <u>Mephitis mephitis</u>
Bulrush <u>Scirpus</u> spp.		Raccoon (CM) <u>Procyon lotor</u>
Australian saltbush <u>Atriplex semibaccata</u>		
Saltbush <u>Atriplex patula</u> var. <u>hastata</u>		
Gum plant <u>Grindelia</u> sp.		
Cattail <u>Typha latifolia</u>		
Sea lettuce <u>Ulva</u> spp.		
Green algae <u>Enteromorpha</u> spp.		

Table 4-11. (Continued)

REPTILES	INVERTEBRATES
Garter snake (R) <u>Thamnophis</u> spp.	Snail (CM) <u>Assiminea californica</u>
	Snail (CM) <u>Ovatella myosotis</u>
	Newcomb's littorine snail (CM) <u>Littorina newcombiana</u>
	Horn snail (CM) <u>Cerithidea californica</u>
	Snail (CM) <u>Batillaria attramentaria</u>
	Yellow shore crab (CM) <u>Hemigrapsus oregonensis</u>
	Red ghost shrimp (SHI) <u>Callinassa californiensis</u>
	Insect (HI) <u>Prokelisia</u> sp.
	Insect (S1) <u>Xenylla baconae</u>

¹See Table 4-3 for definition of abbreviations

Rare, Endangered, and Species of Concern. Several rare, endangered, or fully protected species occur in the salt marsh. These have been identified in the following table.

Table 4-12. Rare, Endangered or Fully Protected Species
Occurring in the Emergent Vegetation Habitat

Common Name	Scientific Name	R	E	FP	F	PE	T
Salt marsh harvest mouse	<u>Reithrodontomys raviventris</u>		X		X		
California clapper rail	<u>Rallus longirostris obsoletus</u>		X		X		
California least tern	<u>Sterna albifrons browni</u>		X		X		
Black rail	<u>Laterallus jamaicensis coturniculus</u>	X					
Peregrine falcon	<u>Falco peregrinus</u>		X		X		
White-tailed kite	<u>Elanus leucurus</u>			X			
California brackish-water snail	<u>Trvonia imitator</u>					X	
Newcomb's littorine snail	<u>Littorina newcombiana</u>						X

* R = rare, E = endangered, FP = fully protected, PE = proposed endangered, P? = proposed threatened

Species occurring in this habitat that have been identified as "species of concern" and are of ecological interest have been listed in Table 4-13.

Table 4-13. Species of Ecological Interest Occurring in the Emergent Vegetation Habitat

Common Name	Scientific Name
Harbor seal	<u>Phoca vitulina</u>
Black brant	<u>Branta bernicla nigricans</u>
Salt marsh yellow throat	<u>Geothlypis trichas</u>
Migratory and wintering waterfowl	
Western sandpiper	<u>Ereuneter mauri</u>
Marbled godwit	<u>Limosa fedoa</u>
Soft-shell clam	<u>Mya arenaria</u>
Eelgrass	<u>Zostera marina</u>
Pickleweed	<u>Salicornia virginica</u>
California cordgrass	<u>Spartina foliosa</u>

Species accounts of all the species listed in Tables 4-12 and 4-13 can be found in Part 2 of Volume II of this report.

Community Composition.

Producers (First Trophic Level). Primary producers use solar energy to transform carbon dioxide into organic compounds and oxygen through the process of photosynthesis. The organic compounds *not* used by the producers may be stored and are then eaten by herbivores and so become available as food to **higher trophic level** organisms.

Vascular **halophytes**, Spartina foliosa and Salicornia virginica, are the dominant primary producers in the salt marsh. These plants support a **diverse**, largely terrestrial herbivore community, including herbivorous insects, birds, and small mammals which feed directly on the leaves, shoots, or seeds. **However**, a substantial portion of the biomass produced is not consumed directly. Oxidation of decaying plant parts occurs by micro-organisms which **form** a **detrital** food chain.

Biomass and productivity of marsh **macrophytes** have been studied extensively on the Atlantic and Gulf coast wetlands (Keefe, 1972). Net aerial production for Spartina spp. has been measured in several studies (see Table 4-14). The California species of cordgrass (Spartina foliosa) is generally considered to be less productive than its East Coast counterpart (S. alterniflora). Other studies have considered the biomass and productivity of minor marsh plants, such as salt grass (Distichlis spicata), common reed (Phragmites communis), pickleweed (Salicornia virginica), and cattails (Typha latifolia) (Keefe, 1972, Reimold et al., 1974).

Table 4-14. Net Aerial Production of Spartina spp.

Site	g/m ² /yr	Author
Delaware	445	Morgan, J.I.H., 1961
North Carolina	1,296	Stroud and Cooper, 1969
Georgia	973	Smalley, 1959
Georgia	1,959	Teal, 1962
Georgia	2,000	Odum, 1961
California	1,400-1,700 ₂	Cameron, 1972
(San Francisco Bay)	(Biomass-g/m ²)	
California	274-689	Mahall and Park. 1976
(San Francisco Bay)	920	Zedler, et al., 1978
California	(Biomass=1006 g/m ²)	
(Tijuana Estuary)		

Pickleweed (Salicornia virginica) has been studied near San Francisco Bay. Mahall and Park (1976) determined the annual net production to be 550 to 960 g/m². Mall (1969), however, estimated 722 g/m² for the same species, and 276 g/m² on highly saline soils. Biomass (standing crop) measurements of pickleweed in Palo Alto, California, have been reported to range from 730 g/m² to 1,870 g/m² (ABAG et al., 1979b).

A second group of producers are the algae. These act both as a food source for lower forms of organisms and as a place of attachment for eggs. They include diatoms, flagellates, and blue-green algae. Larger benthic algae, such as green algae (Enteromorpha) and sea lettuce (Ulva) also contribute to total algal productivity.

Zedler et al. (1978) has measured algae net productivity in the Tijuana estuary. The annual contribution of algae to total productivity was 560 g/m². The estimates for low, middle, and high elevations in the marsh represent 40%, 50% and 50%, respectively, of the total productivity. In channels, algae are the only source of production. Benthic diatoms provide the greatest contribution, an estimated 240 g/m²/yr. In contrast, channel phytoplankton contributed 1 g/m²/yr.

Primary Consumers (Second Trophic Level). Primary consumers use the stored organic compounds of the producers. Through oxidation of these compounds, energy is made available to be directly used by the organism for respiration or it is stored in its tissue for possible later use.

There are four main food chains. One consists of the primary consumers grazing on vascular marsh plants, such as cordgrass (Spartina foliosa), and pickleweed (Salicornia virginica). The herbivores feed directly on the leaves, shoots, and seeds of the plants and include the black-tailed hare (Lepus californicus), the California meadow mouse (Microtus californicus), and the western harvest mouse (Reithrodontomys megalotis), and several species of ducks (Chapman, 1977). Larval and adult insect herbivores and saprovores (i.e., feeds on decaying organic material) are also abundant (Cameron, 1972).

A second grazing food chain is supported by the benthic algae and includes more aquatic than terrestrial organisms. Nematodes, foraminifera, ostracodes, amphipods, annelids, bivalves, and gastropods feed on diatoms and other microscopic algae. The gastropods, snail (Batillaria zonalis) and horn snail (Cerithidea californica) and several fish including topsmelt (Atherinops affinis) and longjaw mudsucker (Gillichthys mirabilis) feed on the larger benthic algae.

A third grazing food chain, supported by phytoplankton during periods of tidal submergence, includes herbivorous zooplankton.

The last major source of energy is the detrital food chain, which has been found to possess a greater community energy flow than the grazing food chains (Teal, 1962). Decaying plant material provides the medium and substrate for bacteria and microbiota action. These micro-organisms are food for higher organisms. They also break down complex organic compounds to simpler forms, more usable by other organisms. Detritus produced in the marsh in San Francisco Bay by Spartina foliosa (Cameron, 1972) was exported to adjacent habitats, with 7% moving landward to the upland marsh and 50% transported to adjacent estuarine waters. The balance remained in the marsh where it originated.

Detritus feeders in the marsh are many. Nematodes, ostracodes, many species of insects, and marine macroinvertebrates, such as the polychaete worms, Capitella capitata and Streblospio benedicti, and mollusks and crustaceans such as yellow shore crab (Hemigrapsus oregonensis), fiddler crab (Uca crenulata) and amphipod (Orchestia traskiana) rely on detritus as their major source of nourishment (Ricketts and Calvin, 1968).

Predators (Third Trophic Level). The abundance of lower organisms provides an ample food source for many terrestrial species of mammals, birds, reptiles, and carnivorous insects. Herbivorous insects are preyed upon by carnivorous insects, spiders, lizards, opossum (Didelphis virginiana), ducks, shorebirds, and a wide variety of land birds. The small mammals are, in turn, preyed upon by the long-tailed weasel (Mustela frenata), snakes, and birds, such as the great blue heron (Ardea herodias). Large raptors, such as the marsh hawk (Circus cyaneus) and red-tailed hawk (Buteo jamaicensis), and the white-tailed kite (Elanus leucurus) feed on rabbits and coots. Grey fox (Urocyon cinereoargenteus), coyote (Canis latrans), and bobcat (Lynx rufus) were once important apex (i.e., at the top of the food chain) carnivores, feeding on a wide variety of small mammals and birds. As non-residents, however, their access to marsh habitats has been largely limited by development and human activity (Chapman, 1977).

The algae-eaters are consumed by their predators, mostly fish and shorebirds. Marsh gastropods are fed upon by the crab, Pachygrapsus sp. Small fish, which may consume algae or small invertebrates, are preyed upon by larger fish, grebes, herons, gulls, and terns. Herbivorous plankton are consumed by carnivorous plankton, which are fed upon by the fish, killifish (Fundulus) and goby (Gillichthys) (Chapman, 1977). The marine macroinvertebrates, supported by the large supply of detritus, are consumed by shorebirds, waterfowl, and fish.

A summary of food web interactions is shown in Figures 4-17 and 4-18.

Community Dynamics.

Community Composition Summary. The food webs of the emergent vegetation in coastal California closely resemble that of similar environments along the Atlantic and Gulf coast of the United States, in Europe, and other parts of the world (Chapman, 1960). Producers are characterized by their unusually high productivity. Most supporting data, however, have been drawn from Atlantic and Gulf coast studies. One study in San Francisco Bay has, however, confirmed the large detrital export by the salt marsh community (Cameron, 1972). Zedler et al. (1978) indicated the importance of year-round algae production in total marsh productivity of the Tijuana Estuary, California. Diatoms proved most important in marsh channels.

Emergent wetland producers are best characterized by the marsh macrophyte, Spartina foliosa. The plant supports two types of food chains, a grazing food chain and a detrital food chain. Herbivorous insects, birds, and small mammals feed directly on the plant leaves, shoots, or seeds. A greater portion of the plant production, however, becomes detritus through decomposition by bacteria. As detritus, the plant provides energy for deposit feeders, suspension feeders, and other mud-dwellers inhabiting the marsh and adjacent habitats.

Primary consumers are most commonly represented by small invertebrates, although insects, several birds, and small mammals also consume plant material or detritus. Lower forms of animals in the estuarine environment are characterized by low species diversity but high population densities (Odum, 1971). This is typical of environments with stressful physical conditions.

Primary consumers may be exemplified by a number of herbivorous insects that graze on Spartina plants, or by the detritus feeders found in the muddy marsh soils. The herbivorous insect, Prokelisia sp., found in the low marshes of San Francisco Bay, (Cameron, 1972) feeds on Spartina by sucking juices from the plant (Teal, 1962). The salt marsh harvest mouse (Reithrodontomys raviventris), endemic to the marshes of San Francisco Bay, feeds directly on Salicornia plants. The polychaete worms, Capitella capitata and Streblospio benedicti, feed directly on the mud and obtain their energy from detritus consumption.

Birds, fish, and small mammals are the most common predacious organisms in the emergent wetland habitat. Some of these predators are residents of the marsh. These include the clapper rail and the savannah and song sparrows. Many species of birds, fish, and mammals, however, are more mobile and frequent the marsh for feeding while other activities are carried out in adjacent habitats. This is typical of migrating waterfowl and shorebirds, black-tailed jackrabbits, raccoons, topsmelt (Atherinopsis affinis), the Pacific staghorn sculpin (Leptocottus armatus), and others.

Many species of birds are predators of the large invertebrate population, including residents such as the clapper rail (Rallus longirostris), and the savannah sparrow (Passerculus sandwichensis) (primarily during spring and summer), and migrants such as the willet (Catoptrophorus semipalmatus). The raccoon (Procyon lotor), the striped skunk (Meophitis mephitis), and the long-tailed weasel (Mustela frenata) are important carnivores in the marsh (Chapman, 1977).

Migration and Visitation. Migrating and visiting organisms are an important component of the marsh habitat. Migrating waterfowl frequently use the marsh as a resting and feeding area. Other species may winter in marshes located in the warmer latitudes. Visitors from upland habitats are also common. Raptors, including the white-tailed kite and several species of hawks, hunt the marsh looking for prey such as shorebirds, insects, and small mammals. Terrestrial mammals, such as black-tailed jackrabbits, raccoons, deer, bobcat, weasel, and coyote visit the marsh to prey upon invertebrates, fish, small mammals, birds. Fish migrate from the marine habitat into marsh channels to feed or to spawn.

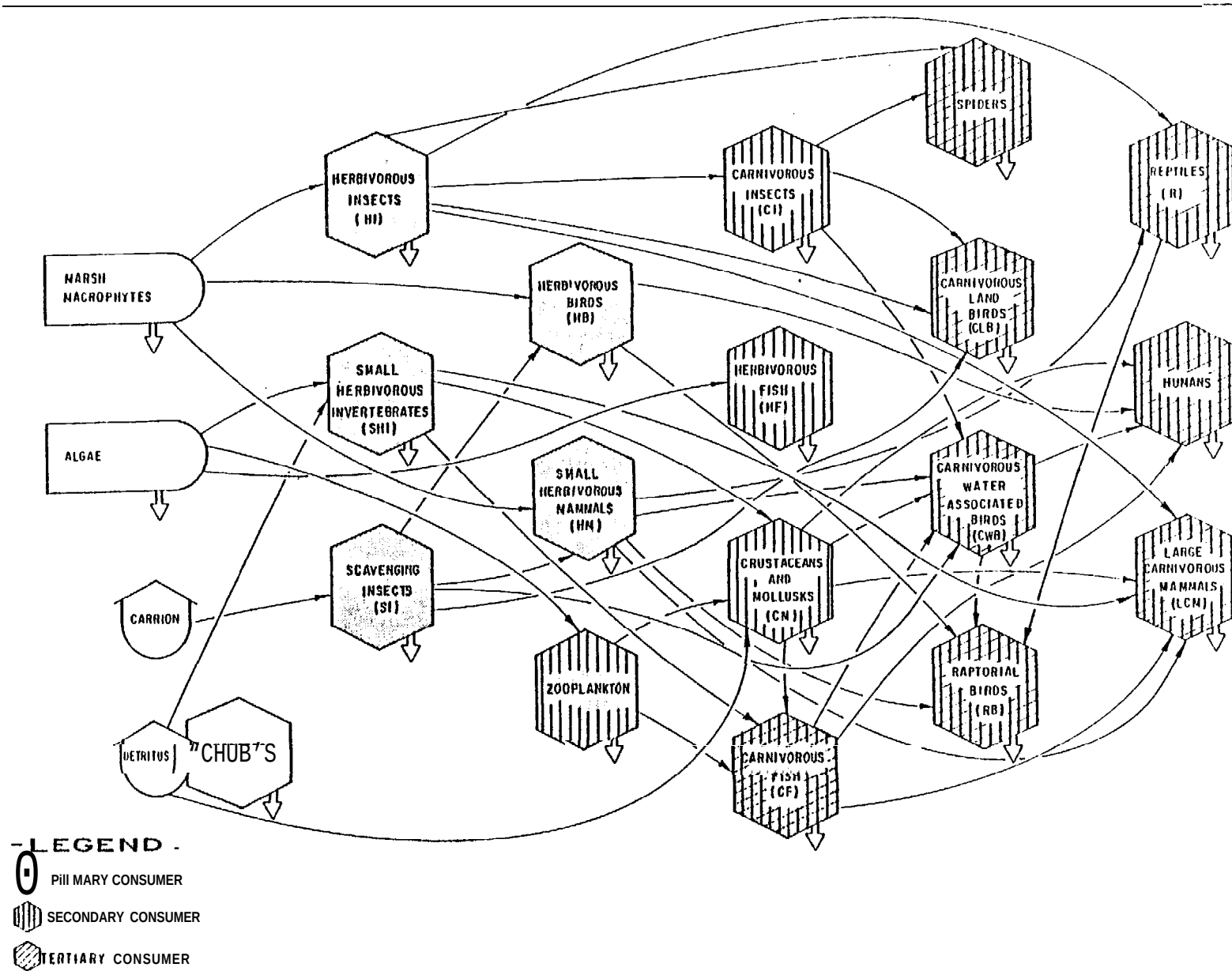


Figure 4-17. General Food Web - Emergent Vegetation (Salt Marsh)

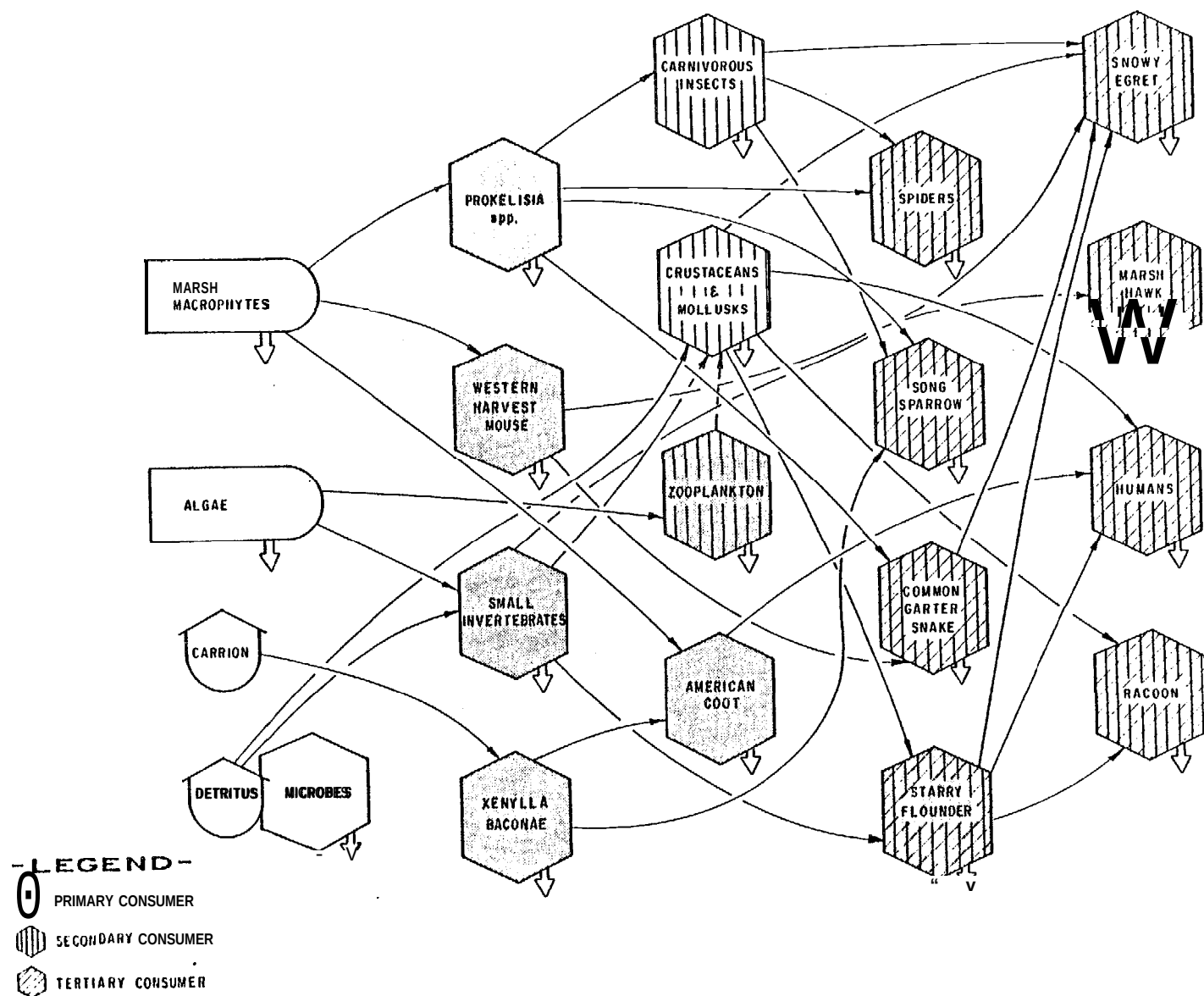


Figure 4-18. An Example of an Emergent Vegetation (salt Marsh) Food Web

Interactions with Adjacent Habitats. The marsh, characterized by its high productivity, exports large quantities of detritus to adjacent ecosystems. Cameron (1972) estimated that 50% of the annual *Spartina foliosa* production in San Francisco Bay was exported to the rest of the estuary in the form of detritus. The detritus may be transported to adjacent mudflats or other estuarine habitats for consumption by deposit feeders or may remain in suspension where it is available for use by filter feeders and open-water zooplankton.

EFFECTS OF HUMANS ON EMERGENT VEGETATION

The marsh habitat is especially vulnerable to perturbation by human activities. Ranwell (1972) discusses the effect of various activities on marsh ecology. Effects may be felt from activities not only in the marsh itself, but also from those occurring in the adjacent watershed from which the freshwater flows originate, or from oceanic sources that affect the marsh through tidal exchange.

An obvious source of impact to the marsh environment is pollution. Toxic wastes, introduced from land or ocean, may kill organisms. Alternatively, sublethal dosages may be consumed and accumulated in body tissues. This threatens the entire food chain as the toxicant is mobilized and bioconcentrated as it proceeds from predator to predator up the food chain. Ultimately, this pollutant may affect humans, the apex consumers. Fish, shellfish, or birds, used for human consumption, may become contaminated beyond safe levels (Winzler and Kelly, 1977a).

A second effect of pollution is biostimulation and the resulting uncontrolled growth of certain species. Sewage effluent, for example, acts as a fertilizer in the estuary and may promote excessive algae growth. The algae can deplete the available oxygen supply and effectively "smother" other estuarine organisms.

Activities in the watershed may contribute to disruption of normal ecosystem functions. Land cultivation, clearing for development, and mining activities increase the rate of erosion and may result in accelerated sediment deposition and successional progressions. The lower vertical limit to which salt marsh plants will grow may be raised by increased erosion and drainage of upland areas. Increased turbidity limits light penetration and may affect faunal zonation.

Marsh diking and draining for land reclamation destroys marsh habitat (USFWS, 1979a). Restricting the flow of water into and out of the marsh results in replacement of marsh-adapted species with terrestrial species and in the elimination of detrital export to adjacent systems. The channels of the emergent vegetation habitat may be used extensively as nursery sites by shrimp and fish. Destruction of this habitat may seriously affect off-shore fishing.

Potential impacts of activities associated with oil and gas supply development, mitigation measures, and alternative methods have been reviewed in a recent publication by Longley et al. (1978). This primarily dealt with construction activities associated with drilling onshore wells.

Oil spills may have deleterious effects on the salt marsh habitat. Depending on the kind of oil spilled, it may have direct toxic effects on organisms. If oil covers the surface of the mud, the exchange of gases between the substrate and the atmosphere will be reduced or eliminated. This will smother both mud-dwelling invertebrates and marsh plant roots. The marsh, often noted for its ability to function as a "tertiary treatment facility", has the potential to recover from some oil spills. No information is available, however, as to the quantity or type oil spill that the marsh might withstand.

PIERS, PILINGS

INTRODUCTION

Substrate

The artificial habitats provided by the construction of piers, pilings, and floats are utilized by marine plants and animals. Tidal action creates intertidal and subtidal zones on piers and pilings, which are permanent structures. Floats are semi-permanent structures free to move up and down with the action of the tide, supporting a community similar in composition to the subtidal community of piers and pilings.

Areal Extent

Piers, pilings and floats occur in most estuaries. The more urbanized estuaries will contain a number of these structures. While the areal extent of these structures is small, by providing unique attachment sites for organisms they allow the development of a community that would otherwise be absent.

Dominant Species

The habitat provided by piers, pilings and floats is usually a wooden or concrete substrate. This hard substrate generally harbors many of the same organisms found on rocky bottoms. Piers, pilings, and floats are dominated by attached organisms, including algae, hydroids, barnacles, byozoans, anemones, tubeworms, mussels, and tunicates. A number of motile forms, including crabs, chitons, limpets, starfish, nudibranchs, and polychaete worms are also common. Fish are attracted to these structures for protection and feeding, with surfperch and juvenile rockfish predominating. Two wood borers, an isopod and a clam, are common pests inhabiting wooden structures,

Habitat Descriptors

Several factors affect community composition on piers and pilings. These structures are usually placed in areas with reduced wave action, although some piers may be located where wave action is strong. Organisms must be able to withstand the pounding of waves in exposed environments. Depending on the location of the piers, pilings, and floats within the estuary, salinity may affect community composition by limiting the distribution of some species. Since many of the organisms found on piers, pilings, and floats are sedentary, tidal currents are important to supply food, carry away metabolic wastes, and transport larvae to other areas.

HABITAT CHARACTERIZATION

Geographic Aspects

Piers, pilings, and floats may be found in any estuarine location, but are especially abundant near developed areas.

Physical Aspects

Prior discussions of water movement, dissolved oxygen, dissolved salts and nutrients, light penetration, and temperature of the water column (see unconsolidated bottom habitat) describe the environmental conditions near piers, pilings, and floats. Zonation on piers, pilings, and floats is similar to that found in the rocky bottom habitat.

Substratum. Substrate composition of the piling habitat is the only condition that differs significantly from the rocky bottom or unconsolidated bottom habitat. The artificial structures are generally composed of wood or concrete. The porous nature of wood is attractive to boring organisms. Most wooden piers, pilings, and floats are coated with a special treatment (such as creosote) to discourage use by boring organisms. In general, treatment is effective only until tidal action removes the coating. Organisms may be repelled or killed by the substances used in treatment.

Biological Aspects

Dominant Species. The organisms characteristic of pier, piling, and float communities are shown in Table 4-15. The dominant organisms include 1 algal species, 17 species of invertebrates, 8 species of fish, and 4 species of birds. Habitat and feeding preferences were derived from several references (Ricketts and Calvin, 1968; Burge and Schultz, 1973; Smith and Carlton, 1975; Standing et al., 1975; Moyle, 1976). This information is presented in the following sections.

Table 4-15. Dominant Organisms of the Pier and Piling Community

Fish	Invertebrates
Walleye surfperch (SCF) <u>Hyperprosopon argenteum</u>	California mussel (FI) <u>Mytilus californianus</u>
Shiner surfperch (SCF) <u>Cymatogaster aggregata</u>	Bay mussel (FI) <u>Mytilus edulis</u>
Pile surfperch (SCF) <u>Rhacochilus vacca</u>	Barnacle (FI) <u>Chthamalus dalli</u>
White surfperch (SCF) <u>Phanerodon furcatus</u>	Barnacle (FI) <u>Balanus glandula</u>
Black surfperch (SCF) <u>Embiotoca jacksoni</u>	Barnacle (FI) <u>Balanus crenata</u>
Copper rockfish (SCF) <u>Sebastes caurinus</u>	Bryozoan (FI) <u>Bugula</u> spp.
Brown rockfish (SCF) <u>Sebastes auriculatus</u>	Hydroid (FI) <u>Obelia</u> spp.
Bocaccio (SCF) <u>Sebastes paucispinus</u>	Tunicate (FI) <u>Ascidia ceratodes</u>
	Tunicate (FI) <u>Botryllus</u> spp.
	Shipworm (HI, DI) <u>Bankia setacea</u>
	Chiton (HI) <u>Mopalia hindsii</u>
	Gribble (HI) <u>Limnoria</u> spp.
	Starfish (CI) <u>Pisaster ochraceus</u>
	Starfish (CI) <u>Pisaster brevispinus</u>
	Nudibranch (CI) <u>Dendronotus frondosus</u>
	Kelp crab (HI, CI) <u>Pugettia producta</u>
	White anemone (FI) <u>Metridium senile</u>

Table 4-15 (continued)

Plants	Birds
Giant kelp (A) <u>Macrocystis integrifolia</u>	Surf scoter (CWB) <u>Melanitta perspicillata</u> White-winged scoter (CWB) <u>Melanitta deglandi</u> Herring gull (CWB) <u>Larus argentatus</u> Double-crested cormorant (CWB) <u>Phalacrocorax auritus</u>

Rare, Endangered and Species of Concern. Several species of ecological concern use the habitat provided by piers, pilings, and floats. These species are shown in Table 4-16. Included are five species of invertebrates and three species of fish. None of these species are designated as rare or endangered. Species accounts of all listed species may be found in Volume II, Part 2 of this report.

Table 4-16. Species of Concern Occurring in the Pier and Pilings Community

Invertebrates	Fish
California mussel <u>Mytilus californianus</u> Bay mussel <u>Mytilus edulis</u> Barnacle <u>Balanus</u> spp. Gribble <u>Limnoria lignorum</u> Starfish <u>Pisaster</u> spp.	Rockfish <u>Sebastes</u> spp. Pile surfperch <u>Rhacochilus vacca</u> Shiner surfperch <u>Cymatogaster aggregata</u>

Community Composition.

Producers. Algae are the primary producers found on piers, pilings, and floats. The macro-algal community is not particularly diverse. The dominant species, especially on pilings, is usually the giant kelp (Macrocystis integrifolia), a brown algae. Microscopic algae (diatoms) are also common.

Filter Feeders, Omnivores, Herbivores. A large portion of the pier, piling, and float community is comprised of sessile filter feeders. These organisms utilize phytoplankton, zooplankton, or suspended detritus. Five species found on pilings are also characteristic of the rocky shore: the California mussel (Mytilus californianus), bay mussel (Mytilus edulis), and barnacles (Chthamalus dalli, Balanus glandula, B. crenata). The zonation patterns of these species have already been discussed in the rocky bottom habitat. Other filter feeders include bryozoans (Bugula spp.), tunicates (Ascidia ceratodes, Botryllus spp.), shipworms (Bankia setacea), white anemones (Metridium senile) and hydroids (Obelia spp.). Hydroids tend to be located in the mid-intertidal zone. They feed by extending their tentacles, which capture zooplankton. White anemones, bryozoans, and tunicates occur in the low intertidal and subtidal zones. Shipworms also occur in the lower intertidal and subtidal zones. Larvae settle onto wood and bore into the piling. As they grow, the burrow is expanded. The shipworm, actually a bivalve, burrows by scraping the wood with its shells. They may digest wood or feed on suspended organic particles.

A few herbivores occur in this habitat. The limpet (Acmaea digitalis) is found on piers and pilings in the high intertidal zone. The chiton (Mopalia hindsii) grazes on diatoms and algae on piers, pilings, and floats. The kelp crab (Pugettia producta) crawls about the intertidal and subtidal zones grazing on algae. Another organism which might be considered an herbivore is the gribble (Limnoria spp.). These tiny animals burrow into wood and derive nourishment from the ingested wood particles.

Predators. Predatory species are not particularly numerous in the pier, piling and float community. Three species crawl about on the substrate; two starfish (Pisaster ochraceus, P. brevispinus) and a nudibranch (Dendronotus frondosus). The starfish are located mainly in the lower intertidal and subtidal zones, feeding on mussels and barnacles. The nudibranch feeds largely on the hydroid (Obelia), which occurs mostly in the mid-intertidal zone. Several species of fish, mostly surfperch and juvenile rockfish, are attracted to piers, pilings, and floats for protection and for feeding. The most common surfperch include shiner surfperch (Cymatogaster aggregata), walleye surfperch (Hyperprosopon argenteum), black surfperch (Embiotoca jacksoni), pile surfperch (Rhacochilus vacca), and white surfperch (Phanerodon furcatus). Common juvenile rockfish include the copper rockfish (Sebastes caurinus), brown rockfish (S. auriculatus), and bocaccio (S. paucispinus). Surfperch and rockfish feed on a variety of organisms, including crustaceans, mollusks, and fish. Herring gulls (Larus argentatus) and double-crested cormorants (Phalacrocorax auritus) commonly roost on wharves and pilings, and feed on fish. Surf scoters (Melanitta perspicillata) and white-winged scoters (M. deglandi) may feed on mussels attached to pilings, but their activity is limited by human disturbance (Cogswell, 1977).

Community Dynamics. The food web of a typical piling community is illustrated in Figures 4-19 and 4-20. Sunlight is converted into organic material by the algae growing on the pilings, and herbivores graze on this algae. However, much of the piling community is dependent on a food source produced outside the community. The numerous filter feeders ingest plankton and suspended detritus carried to them by tidal currents. The predators feed upon the herbivores and filter feeders, as well as on each other.

The kelp crab (Pugettia producta) is an omnivorous species. It can be found on both pilings and floats. The kelp crab usually feeds at night, grazing on algae (MacGinite, 1935). Larger individuals may feed on other animals among the float fauna. The gribbles (Limnoria spp.) are rather unique herbivores. These small isopods burrow into wood, chewing their way by using their mouthparts. Although cellulose is highly indigestible, gribbles do derive nourishment from wood. The particles pass rapidly through the intestine, due to the low food value of the wood.

The many filter feeders of the piling community derive their nourishment from phytoplankton, zooplankton, and suspended detritus. All of these organisms must possess a mechanism for filtering small particles from the water. They must also insure that a sufficient volume of water passes through their filtering device. Some filter feeders, including barnacles (Balanus spp., Chthamalus dalli), hydroids (Obelia spp.), bryozoans (Bugula spp.), and white anemones (Metridium senile), simply extend their feeding structures (tentacles or appendages) and allow water to pass over them. Others, including mussels (Mytilus spp.) and tunicates (Ascidia ceratodes, Botryllus sp.), pump water through their bodies and collect food internally.

The starfish (Pisaster spp.) and nudibranch (Dendronotus frondosus) both move about on the substrate until they encounter food; they then proceed to engulf the prey organism. The shiner surfperch (Cymatogaster aggregata) is a typical predatory fish. It swims around the pilings selectively feeding on individual organisms. The shiner surfperch feeds mainly on zooplankton, small crustaceans, barnacles, and mussels. Other surfperch and juvenile rockfish also feed on crustaceans, mollusks, and occasionally small fish.

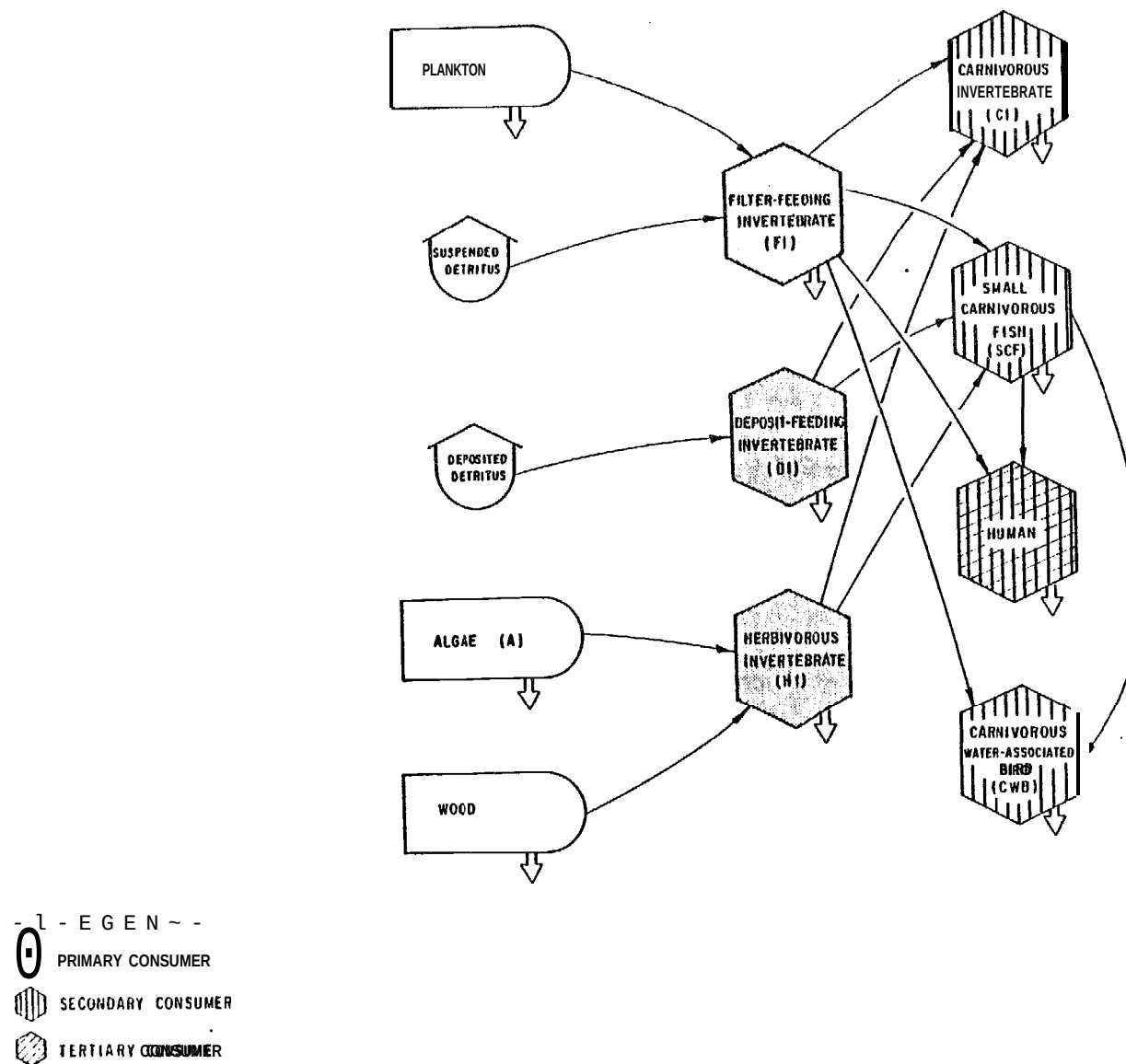


Figure 4-19. General Food Web - Pier and Piling

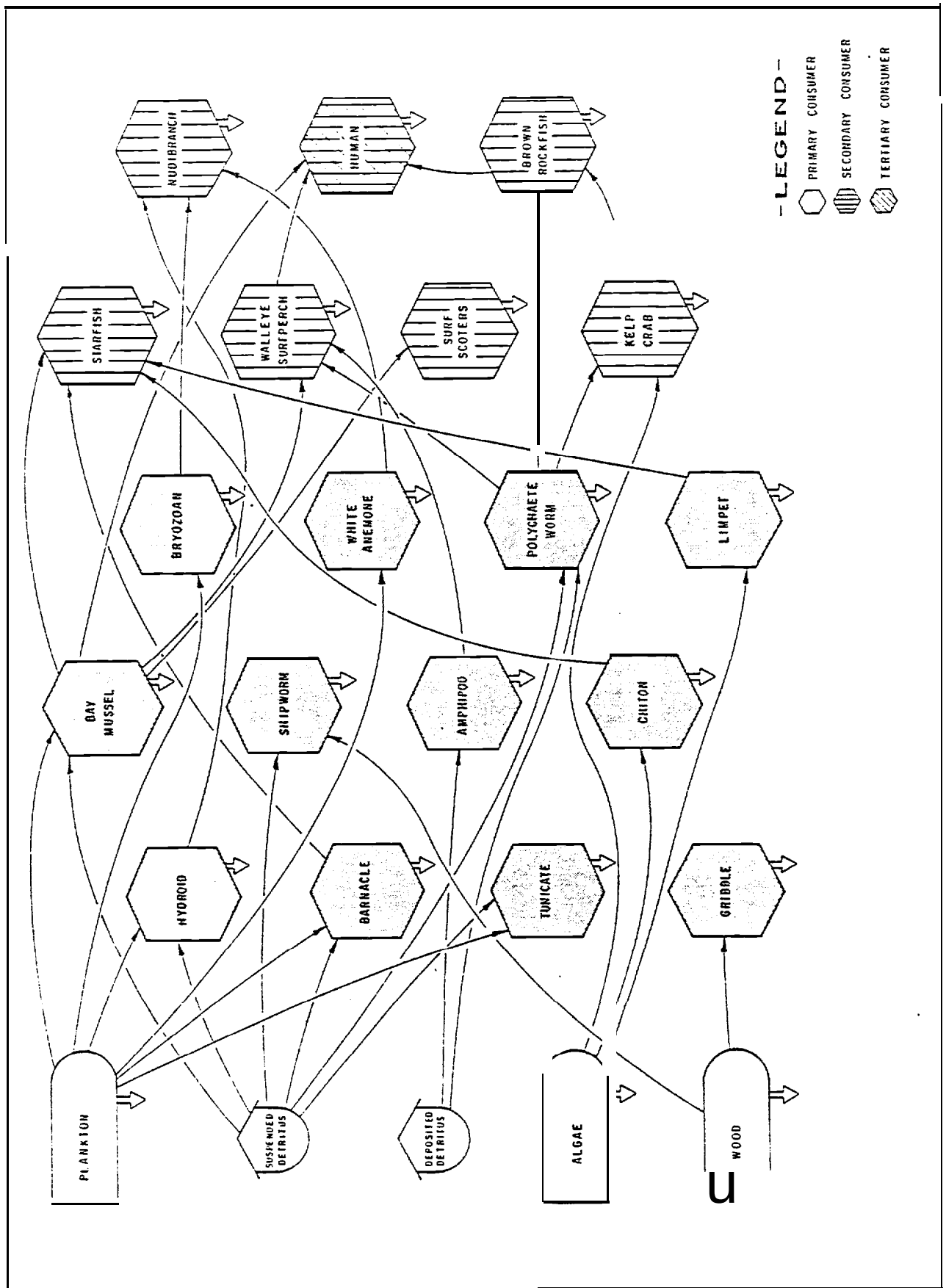


Figure 4-20. An Example of a Pier and Piling Community Food Web

Interactions with other Habitats. The primary migrants into the piling and float community are fish. Various midwater and surface pelagic fish species may occasionally feed on piling or float organisms. The planktonic larvae of numerous invertebrate species are carried into the piling community. Those individuals not consumed by filter feeders may settle on the pilings but face competition from the already established community.

The piling and float community does not export large quantities of particulate organic matter to other habitats. The sessile invertebrates do produce large numbers of planktonic larvae. These larvae can serve as food for organisms in other habitats and also as the stock to colonize other favorable habitats. The sessile filter feeders depend on an input of phytoplankton, zooplankton, and suspended detritus from other areas.

EFFECTS OF HUMAN ACTIVITY

The potential impacts of oil pollution and waste discharges on the piling and float community are similar to those on the rocky bottom community. The numerous filter-feeders in the piling and float community are most vulnerable.

Recolonization of an area may occur after the effects of a specific pollution incident are eliminated, as planktonic larvae from unaffected areas will settle there. Chronic exposure to oil or other toxic wastes could be serious, as it might eliminate unaffected areas and prevent recolonization. Recreational fishing from piers, especially for surfperch, is a popular human activity. Pollution can limit this activity by eliminating the resource. Fish caught in a polluted area may be unsafe for human consumption.

III-190
Part 1

CHAPTER 5 RIVERINE ECOSYSTEM

GENERAL CHARACTERISTICS

DEFINITION

Cowardin *et al.* (1979) defined the *riverine* system as including "... all wetlands and deep-water habitats contained within a channel, with two exceptions: 1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and 2) habitats with waters containing ocean-derived salts in excess of 0.5 o/oo [parts per thousand] A channel is 'an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water' The Riverine system is bounded on the landward side by upland, by the channel bank (including natural and man-made levees), or by wetland dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens. In braided streams, the system is bounded by the banks forming the outer limits of the depression within which the braiding occurs. . . . Water is usually, but not always, flowing in the Riverine system." As used herein, the term "stream" refers to riverine habitats of all sizes, from large rivers to small creeks.

GEOGRAPHY

The study area on the California coast contains for the most part relatively small streams draining the coastal mountain ranges. The only streams draining extensive inland areas are the Klamath River and the Sacramento-San Joaquin system which flows into San Francisco Bay. Most streams flow in a northwesterly direction due to the geography of the coastal ranges. A typical coastal stream would have its headwaters in the coastal ranges about 25 kilometers (km) inland, and flow northwesterly through the hills more or less directly to the ocean. There would be few steep drops or waterfalls. The floodplain area along the lower reaches would be small, and the estuary would be poorly developed.

Annual precipitation and annual stream flow on the coast decrease from north to south. With exception of the Klamath River, annual streamflow fluctuation is generally great. Highest flows occur with winter storms, and lowest flows occur about late summer or early fall. Snowmelt is generally not a significant source of runoff, especially in the smaller coastal streams. Most streams are poor in rooted aquatic vegetation due to the scouring effects of winter storm peak runoff.

The coastal streams are of prime importance as supporters of aquatic life. Even the smaller streams usually support populations of anadromous (spawning in fresh water, but having periods of feeding and growth in salt water) and euryhaline (moving freely between fresh and salt water, but not for spawning purposes) fishes and a diverse community of algae and invertebrates. Larger streams support true freshwater fishes (intolerant of salinities greater than about 1,000 mg/l) in addition to anadromous and euryhaline species.

USES

The most direct human uses dependent on the coastal riverine habitats are water supply and the sport and commercial fisheries that exploit the anadromous fishes. Riverine habitats are also valued for boating, swimming and intrinsic scientific, cultural and aesthetic values.

ECOSYSTEM AND FOOD WEB MODELS

An ecosystem model for riverine habitats has been developed (Figure 5-1) to illustrate the natural ecology of coastal riverine habitats and the processes in those habitats. A detailed discussion of the general ecosystem model is presented in Volume II, Part 1. The model is a schematic summary of the functioning of a hypothetical segment of stream. Not every process and activity is shown; the ones that are shown are generally those that significantly determine the nature of the ecosystem or affect or are affected by, a human use of the ecosystem. The model is divided into three general regions: physical and chemical processes, biological processes, and socio-economic processes and activities. The effects of these processes are sometimes direct inputs or outputs of materials as indicated by the solid lines in the model, and sometimes indirect as indicated by the dashed lines in the model. Processes and activities region of the model, general activities are shown on the right, and specific processes affecting the ecosystem are shown directly to their left. Appendix A at the end of this volume contains an explanation of the symbols used in the model.

Riverine ecosystems are greatly affected by processes occurring in, and characteristics of, their watersheds, especially the riparian edge. Gravity is the force directing water and other materials from the watershed through the riverine ecosystem. In the riverine ecosystem model, "riparian" means the strip of hydrophilic terrestrial vegetation bordering the hypothetical stream segment. "Watershed" means the area of land contributing direct runoff, tributary flow, and groundwater accretions to the hypothetical stream segment. The upstream watershed areas contribute materials to the hypothetical stream segment via upstream riverine ecosystems, not via "watershed." The ecosystem model will be used in examining the various riverine subsystems by shading and footnoting processes and activities that are in each subsystem.

A general food web model for riverine habitats has also been developed (Figure 5-2). It will be used in examining each riverine habitat subsystem by highlighting important producer groups, consumer groups, and energy flow pathways. Lists of food web organisms will also be given.

Actual research studies investigating quantitative ecological relationships are lacking in the study area streams. The relationships and pathways indicated in the riverine ecosystem and food web models are basic features of typical temperate streams, and should be viewed as qualitative. Much of this information is drawn from Hynes (1970) an excellent reference on the principles of riverine ecology.

EMS

Cowardin, et al. (1979) recognized four major habitat subsystems in the riverine system: the tidal, lower perennial, upper perennial, and intermittent subsystems. Within each subsystem there are appropriate classes and subclasses, defined mainly by bottom substrata or vegetation (Table 5-1). Like any habitat classification system, the riverine classification system presented here is based on some arbitrary characteristics. Many actual stream habitats do not neatly fit into any one category. The system is nevertheless useful for describing general habitat characteristics of California coastal streams. Other stream habitat characterization systems have also been devised which fit into the subsystems of Cowardin, et al. (1979) (Table 5-2).

RIVERINE "

Changes in riverine systems can be viewed from two temporal perspectives and one spatial perspective. The two temporal perspectives are annual (yearly) changes and long-term (hundreds or thousands of years) changes. These changes are not true successional changes in the botanical sense, where the organisms create the conditions for successional changes. Rather, riverine "successional" changes are caused by topographic and climatic factors. The spatial perspective is viewed as a continuum from a stream's headwaters to the point where it meets ocean-derived salinity.

Annual "successional" changes are a function of yearly climatic factors including photoperiod, temperature and precipitation. Some features of annual changes in rivers are shown in Figure 5-3.

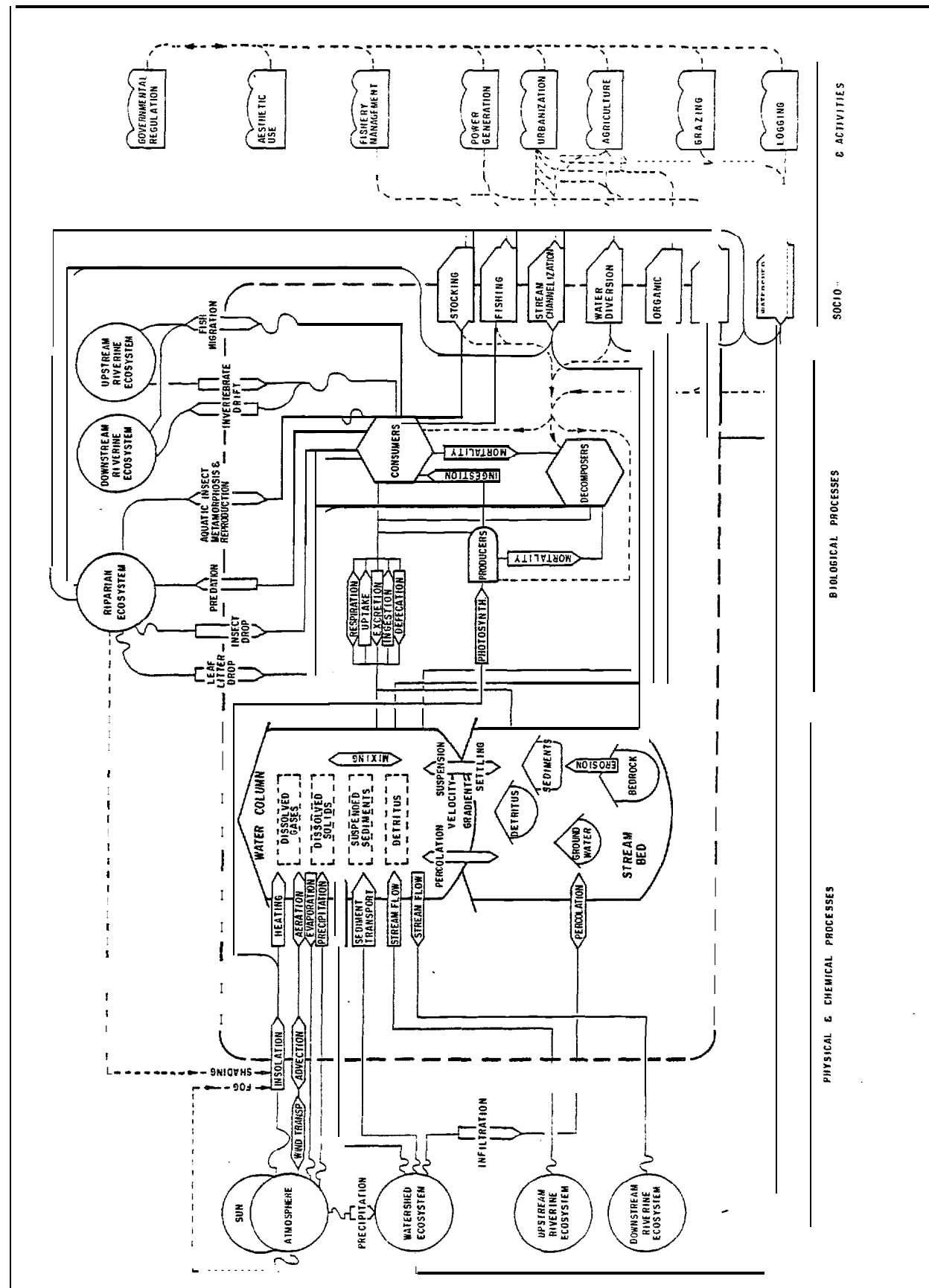


Figure 5-1. An Ecosystem Model of a Riverine System

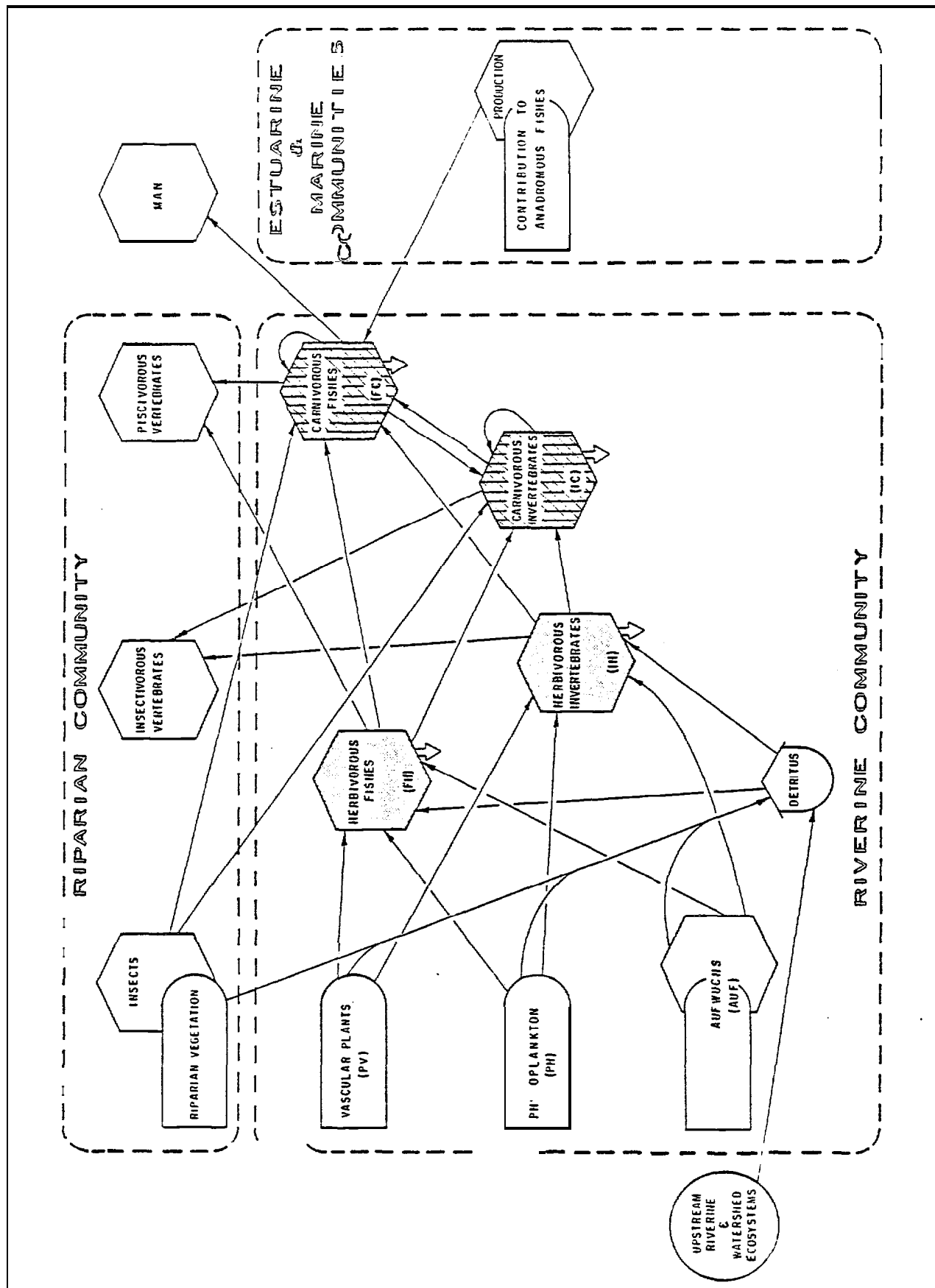


Figure 5-2. General Food Web of a Riverine Habitat and Its Relationship to Estuarine-Marine Habitats.

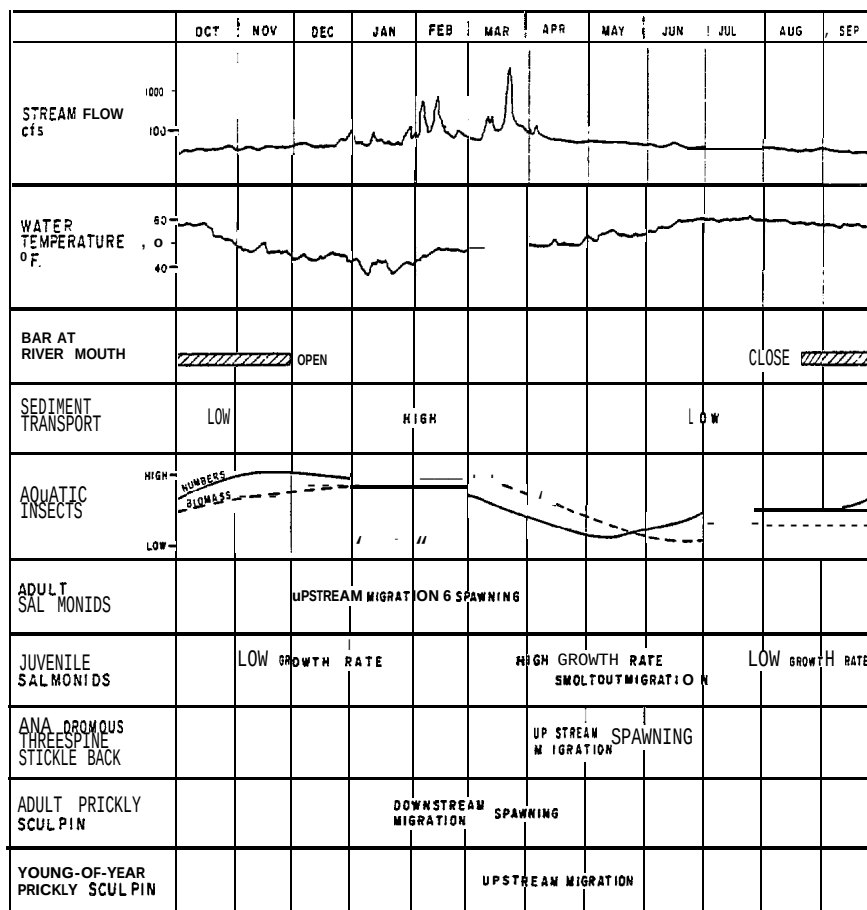
Table 5-1. Riverine Habitat Classification System
(Adapted From Cowardin, et al., 1979)

Subsystem	Class	Subclass
Tidal	Rock bottom	Bedrock Rubble
	Unconsolidated bottom	Cobble-gravel
		Sand
		Mud
		Organic
	Aquatic bed	Algal
		Aquatic moss
		Rooted vascular
	Rocky shore	Floating
		Bedrock
Unconsolidated shore	Rubble	
	Cobble-gravel	
	Sand	
	Mud	
Emergent wetland (nonpersistent)	Organic	
	Vegetated	
Lower perennial	Rock bottom	Bedrock Rubble
	Unconsolidated bottom	Cobble-gravel
		Sand
		Mud
		Organic
	Aquatic Bed	Algal
		Aquatic moss
		Rooted vascular
	Rocky shore	Floating
		Bedrock
Unconsolidated shore	Rubble	
	Cobble-gravel	
	Sand	
	Mud	
Emergent wetland (nonpersistent)	Organic	
	Vegetated	
Upper perennial	Rock bottom	Bedrock Rubble
	Unconsolidated bottom	Cobble-gravel
		Sand
		Mud
		Organic
	Aquatic bed	Algal
		Aquatic moss
		Rooted vascular
	Rocky shore	Floating
		Bedrock
Unconsolidated shore	Rubble	
	Cobble-gravel	
	sand	
	Mud	
Streambed	Organic	
	Vegetated	
Intermittent	Streambed	Bedrock Rubble
	Streambed	Cobble-grave 1
		Sand
		Mud
		Organic
	Streambed	Vegetated
		Bedrock
	Streambed	Rubble
		Cobble-grave 1
		Sand
Mud		

Table 5-2. Riverine Habitat Classification and Characteristics*

Riverine Habitat Classification and Characteristics					
Classification Systems	Cowardin, et al. (1979)	Tidal	Lower Perennial	Upper Perennial	Intermittent
	Hynes (1970)		Potamon	Rhithron	
Characteristics	Moyle (1976)	Intertidal Zone	Anadromous Fishes Zone		
			Barrier to Anadromous Migration		
			Resident Fishes Zone		
Characteristics	Gradient	≈ 0 m/km	0-1 m/km	1-25 m/km	0-25 m/km
	Bottom Sediment	Mud to Sand	Mud to Sand	Sand to Boulders	Mud to Boulders
	Material Budget	Positive	Positive	Neutral or Negative	Positive to Negative
	Typical channel pattern	Often Branched	Sinuuous	Braided or fixed	Fixed
					

*This is an idealized situation. Not all streams exhibit all the zones shown here, nor are they necessarily in the order shown.



HYDROLOGY, WATER TEMPERATURE AND BAR DATA ARE FROM THE 1936-37
 SEASON IN WADDELL CREEK, SANTA CRUZ COUNTY (SHAPOVALOV AND TAFT, 1954).
 AQUATIC INSECT DYNAMICS ARE APPROXIMATIONS FOR TEMPERATE STREAMS
 FROM HYNES (1970).

Figure 5-3. Annual Cycles of Some Physical and Biological Events in Riverine Habitats

Long-term riverine "succession" is a function of the geologic processes affecting stream morphology. In the absence of geologic uplifting or other mountain-building processes, a stream and its watershed will erode to a more gentle gradient. The result may be change from upper perennial habitats to lower perennial or tidal habitats.

A hypothetical unit of water moving downstream from a stream's headwaters to its mouth undergoes changes as it passes through longitudinal habitat zones. The unit of water passes from intermittent to upper perennial to lower perennial to tidal habitats, accumulating dissolved salts, dissolved organics, possibly suspended solids and detritus, and warming in temperature as it proceeds. Cycling of materials occurs in a downstream direction. Biological uptake may hold materials stationary for a period of time, but when released by death, decay, excretion or defecation, materials again move downstream (Hynes, 1970).

TIDAL RIVERINE SUBSYSTEM

INTRODUCTION

Definition

Cowardin, et al. (1979) defined tidal riverine habitats:

The riverine system terminates at the downstream end where the concentration of ocean-derived salts in the water exceeds 0.5 o/oo [parts per thousand] during the period of annual average low flow. . .

Tidal. The gradient is low and the water velocity fluctuates under tidal influence. The streambed is mainly mud with occasional patches of sand. Oxygen deficits may sometimes occur and the fauna is similar to that in the Lower Perennial Subsystem. The floodplain is typically well developed.

Thus the tidal riverine system is always fresh, but water height (stage) and velocity are hydraulically influenced by the tides from adjacent estuarine and marine waters.

Substrata

The substrata of tidal riverine habitats is typically mud or sand, but areas of coarser substrate may also exist (Table 5-1) . Rubble bottom habitats, in particular, may be formed by rip-rapped channel banks (where rubble and boulders have been used in channelization and bank stabilization projects) .

Geography

Freshwater tidal habitats are well developed in streams that have extensive floodplains and a gentle gradient as they approach the ocean. The Sacramento-San Joaquin Delta is the largest area and best example of tidal riverine habitat in California, though habitat area and diversity have been greatly decreased by channelization. Other examples of coastal streams with relatively well developed tidal riverine habitat areas are the Klamath, Eel, and Big Rivers. Tidal riverine habitats in the coastal streams are generally poorly developed because the coastal ranges rise abruptly from the coast line.

Characteristic Species

Characteristic species for tidal riverine habitats consist mainly of planktonic forms, forms found in mud or sand substrata, and euryhaline fishes from adjacent estuaries.

Water Column

Chlorophyta - green algae
Chrysophyte - diatoms
Calanoida - planktonic copepods
Cladocera - cladocerans
Hypomesus transpacificus -
delta smelt
Cyprinus carpio - carp
Notemigonus crysoleucas -
golden shiner

Sand-Mud Bottom

Corophium stimpsoni - amphipod
Gammarus - amphipod
Oligochaeta - earthworms
Tendipedidae - midge fly larvae
Exosphaeroma - aquatic sowbug
Harpacticoida - benthic copepods
Pelecypoda - freshwater clams
Eucyclogobius newberryi
tidewater goby

Rubble Bottom (Rip-rap Channel)

Pacifastacus - crayfish
Corophium spinicorne - amphipod

HABITAT DYNAMICS

Important Processes

The riverine habitats ecosystem model is used here to illustrate important processes occurring in tidal riverine habitats (Figure 5-4).

Detritus Cycling (Footnote #1). Tidal riverine habitats are generally heterotrophic; they consume more energy in the form of organic materials than they produce. The source of the excess organic material consumed is mainly detritus of terrestrial origin from upstream riverine ecosystems (Hynes, 1970). Detritus is a principal food source for invertebrates such as *Neomysis* and may outweigh phytoplankton in importance at the base of the food web. Detritus may be cycled several times by detrital feeders by ingestion, partial digestion, defecation, and re-ingestion by other detrital feeders (Hynes, 1970).

Substrate Type (Footnote #2). The materials budget for tidal riverine habitats is usually positive; there is a net gain of streambed materials imported from upstream areas over time. Slow current velocities permit suspended sediments to settle, forming the characteristic mud or sand bottom.

Upstream Transport (Footnote #3). A major difference between tidal riverine habitats and other riverine habitats is that potential for upstream transport due to tidal currents exists. Although net streamflow and material transport is in a downstream direction, net current velocity may be upstream when the tide is incoming. Some organisms use these currents to travel upstream by attaching or burrowing into the bottom during periods of downstream flow, and rising into the water column during periods of upstream flow.

Fog and Water Temperature (Footnote #4). Tidal riverine habitats in coastal streams are in the coastal fog belt. Fog is an important factor attenuating insolation and preventing high summer water temperatures detrimental to coldwater fishes (e.g., salmonids). Stream shading by riparian vegetation is minimal in most tidal riverine habitats due to the width of the channel. Summer water temperatures in unshaded interior stream habitats often exceed 30°C, which is lethal to salmonids and probably other coldwater resident species as well. The influence of fog along the coast generally keeps summertime stream temperature maxima in tidal riverine habitats below 25°C.

Fish Migration (Footnote #5). Tidal riverine habitats in coastal streams play an important role in the migrations of anadromous fishes. Downstream migrant fishes move through them fairly rapidly enroute to the ocean. The Sacramento-San Joaquin Delta is important in the feeding of ocean bound fish due to its areal extent and high invertebrate productivity. In late summer and fall, tidal riverine habitat areas in medium and large size coastal streams with no bar at the mouth (e.g., Mad River) are important holding areas for returning adult anadromous salmon and steelhead waiting for upstream water temperatures to cool and water levels to rise.

Food Web

The relative trophic positions of the following food web organisms are shown by the acronyms in Figure 5-5. The listing is generalized; a particular habitat area may not contain all of these organisms.

Plants

Chlorophyta - green algae (PH)
Chrysophyta - diatoms (PH)
Elodea - Brazilian waterweed (PV)
Potamogeton - pondweed (PV)
Myriophyllum - water milfoil (PV)
Nuphar - yellow water lily (PV)
Lemna - duckweed (PV)
Eichhornia - water hyacinth (PV)

Animals

Corophium stimsoni - amphipod (IH)
C. spinicorne - amphipod (IH)
Gammarus - amphipod (IH)
Oligochaeta - aquatic earthworms (IH)
Tendipedidae - midges (IH)
Odonata - dragonflies (IC)
Exosphaeroma - aquatic sowbug (IH)
Pacifastacus - crayfish (IH, IC)
Calanoida - planktonic copepods (IH)
Cladocera - cladocerans (IH)
Pelecypoda - clams (IH)
Atari - mites (IC)
Alosa sapidissima - American shad (FC)

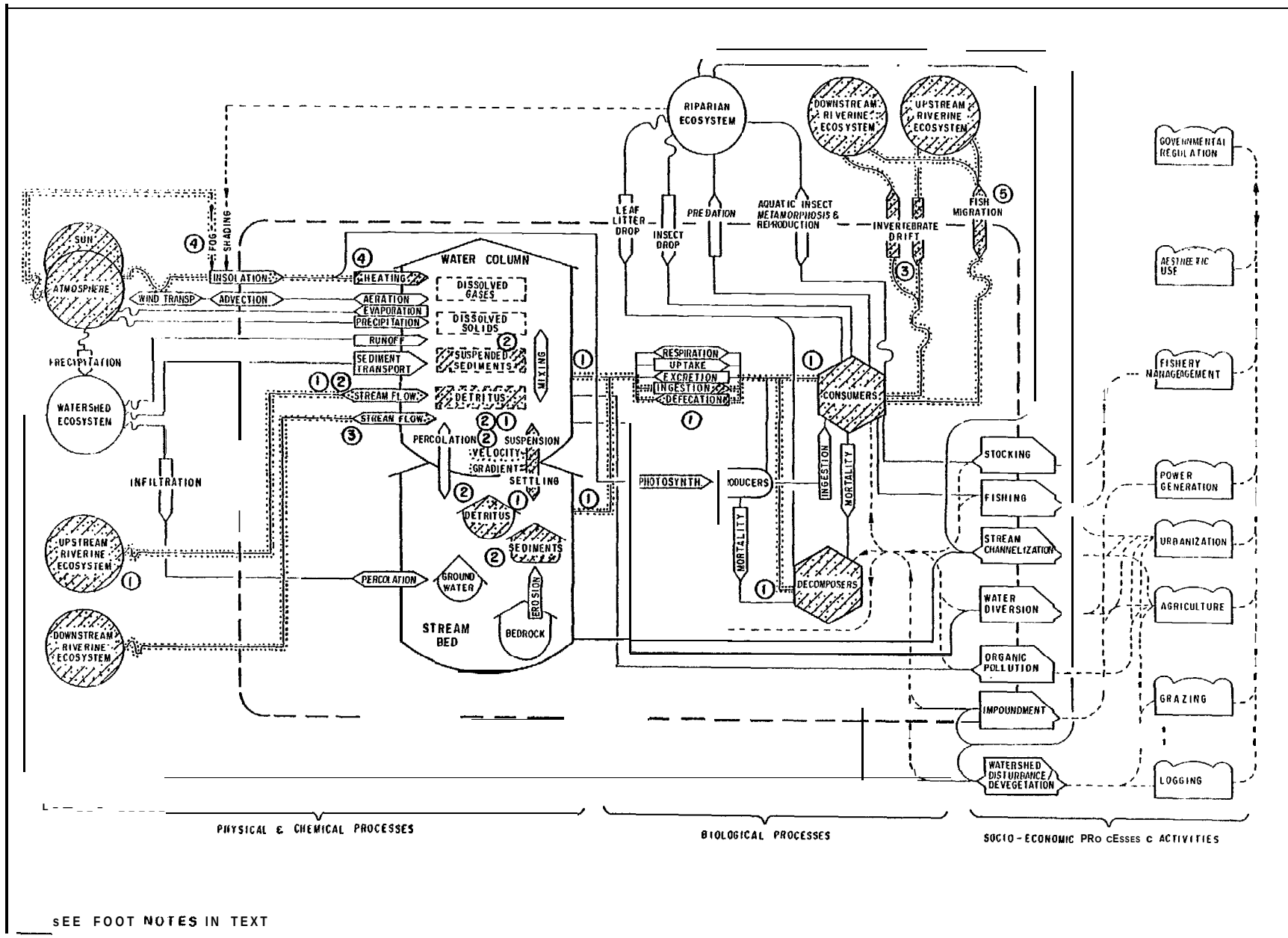


Figure 5-4. Ecosystem Model: Riverine Habitats - Important Processes in Tidal Habitats

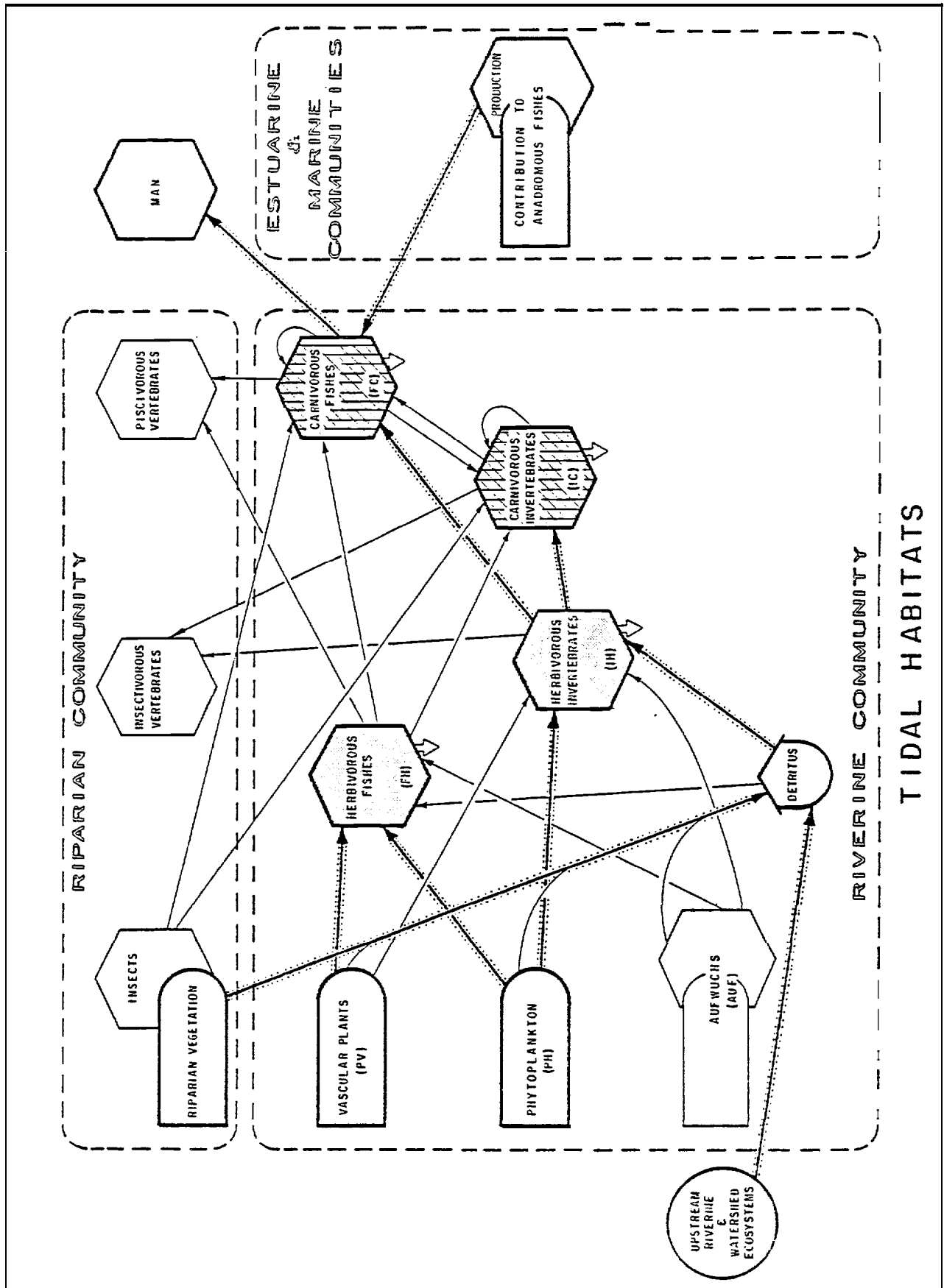


Figure 5-5. Riverine Habitats Food Web

Plants

Animals (continued)

Hypomesus transpacificus - delta smelt (FC)
Gasterosteus aculeatus - threespine
 stickleback (FC)
Leptocottus armatus - staghorn sculpin (FC)
Platichthys stellatus - starry flounder (FC)
Eucyclogobius newberryi - tidewater goby (FC)
Cyprinus carpio - carp (FH, FC)
Notemigonus crysoleucas - golden shiner
 (FH, FC)
Orthodon microlepidotus - Sacramento blackfish
 (FH, FC)

Detritus of terrestrial origin from upstream areas is probably the most important source of energy at the base of the food web in tidal riverine habitats. Contribution of phytoplankton and submergent plants to the food web depends in part on water turbidity. The Sacramento-San Joaquin Delta is turbid year-round. Coastal streams are generally clear except during the winter storm season.

EFFECTS OF HUMAN ACTIVITIES

The effects of human activities in tidal riverine habitats stem primarily from stream channelization, water diversion, and watershed disturbances due to urbanization, agriculture, and grazing. The riverine habitat ecosystem model illustrates these effects (Figure 5-6) .

Stream Channelization (Footnote #1)

Stream channelization due to urbanization and agriculture is a frequent cause of habitat degradation of tidal habitat in coastal streams. The principal effects of stream channelization are losses in aquatic habitat volume and species diversity. Decreases in riparian litter fall and insect drop may decrease aquatic productivity. Decreases in habitat diversity of tidal areas can be detrimental to anadromous fisheries. Returns of coho salmon and coastal cutthroat trout declined greatly after a channelization project in the lower areas of Redwood Creek (Sanders, pers. comm.) .

Water Diversion (Footnote #2)

Water diversion accompanies urbanization and irrigated agriculture. Upstream water diversion may cause further seawater intrusion into tidal freshwater habitats and change species composition. Diversion also can physically remove and kill aquatic organisms. Diversion from the Sacramento-San Joaquin Delta to the San Joaquin Valley and southern California by the federal Central Valley Project and State Water Project has been, and will continue to be, a significant environmental issue.

Watershed Disturbance (Footnote #3)

Watershed disturbance and devegetation accompany urbanization, agriculture and grazing. The principal effects on freshwater tidal habitats are increased sedimentation and decreased input of leaf litter and terrestrial insects due to removal of riparian vegetation.. Productivity can decrease due to siltation of gravelly or rocky substrata and to decreased energy input from the riparian zone.

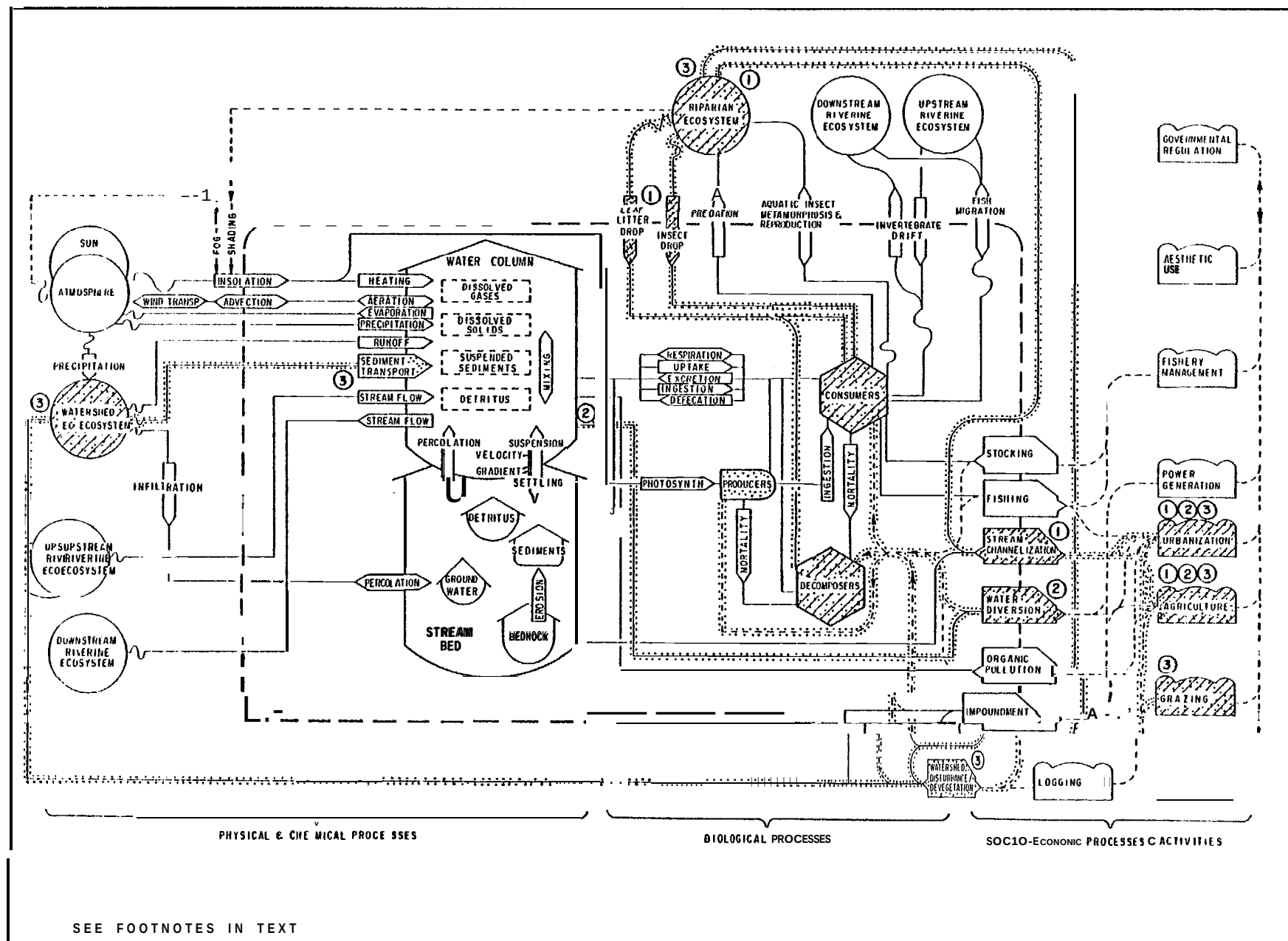


Figure 5-6. Ecosystem Model: Riverine Habitats - Tidal Habitats: Effects of Human Activities

LOWER PERENNIAL RIVERINE SUBSYSTEM

DESCRIPTION

Definition

Coward, et al. (1979) defined lower perennial riverine habitats:

Lower Perennial. The gradient is low and water velocity is slow. There is no tidal influence, and some water flows throughout the year. The substrate consists mainly of sand and mud. Oxygen deficits may sometimes occur, the fauna is composed of species that reach their maximum abundance in still water and true planktonic organisms are common. The gradient is low compared to that of the Upper Perennial Subsystem and the floodplain is well-developed.

Substrata

The bottom type in lower perennial habitats is nearly always mud or sand, but areas of coarser substrata may also exist (Table 5-1). Rubble bottom habitats may be formed by rip-rapped channel banks (where rubble and boulders have been used in channelization and bank stabilization projects) .

Geography

Lower perennial habitats are most developed in streams that have extensive floodplains and a gentle gradient as they approach the ocean. The Russian River between Healdsburg and Duncan Mills is a good example of lower perennial habitat in the study area, though habitat diversity there has been decreased by development. Lower perennial habitats are probably the least extensive of the four habitat subsystems (tidal, lower perennial, upper perennial, intermittent) in California coastal streams because the coast ranges rise abruptly from the coast line. Often upper perennial habitats are succeeded directly by tidal habitats, especially in small coastal creeks.

Characteristic Species

Characteristic species of lower perennial riverine habitats consist mainly of planktonic forms and forms found in mud or sand substrata. The community is similar to that of tidal riverine habitats except there is less invasion of euryhaline estuarine and marine species.

Water Column

Chlorophyta - green algae
Chrysophyte - diatoms
Calanoida - planktonic copepods
Cladocera - cladocerans
Cyprinus carpio - carp
Notemigonus crysoleucas
golden shiner

Sand-Mud Bottom

Oligochaeta - earthworms
Harpacticoida - benthic copepods
Gammarus - amphipod
Tendipedidae - midges
Pelecypoda - freshwater clams

Rubble Bottom (Rip-rap Channel)

Pacifastacus - crayfish
Corophium spinicorne - amphipod

HABITAT DYNAMICS

Important Processes

The riverine habitats ecosystem model is used here to illustrate important processes occurring in lower perennial habitats (Figure 5-7).

Detritus C/feline (Footnote #1). Lower perennial habitats are generally heterotrophic; they consume more energy than they produce. The source of the excess organic material consumed is mainly detritus of terrestrial origin from upstream riverine ecosystems (Hynes, 1970). Detritus can be cycled and recycled several times in a downstream direction by detrital feeders. Bacteria and fungi are important decomposers of detritus.

Streamflow (Footnote #2). Streamflow is a key factor in riverine habitats. Volume of streamflow (discharge) is directly associated with water temperature, habitat volume, flow velocity, transport of sediments and detritus, and streambed meandering. All these factors affect both the species composition and individual species population numbers of this habitat.

Bottom Type (Footnote #3). The materials budget for lower perennial habitats is positive; there is a net gain of streambed materials imported from upstream areas over time. Slow current velocities permit suspended sediments to settle, forming the characteristic mud or sand bottom. These bottom types are habitat for characteristic benthic organisms.

Fog and Water Temperature (Footnote #4). Lower perennial habitats in coastal streams are in the coastal fog belt. Fog attenuates insolation and prevents high summer water temperatures detrimental to coldwater fish. Summer water temperature maxima in unshaded interior stream habitats often exceed 30°C, which is lethal to salmonids and probably other coldwater resident species as well. The influence of fog along the coast generally keeps summer stream temperature maxima below 25°C.

Food Web

The relative trophic positions of the following food web organisms are indicated by the acronyms in Figure 5-8. This listing is generalized, a particular habitat area may not contain all these organisms.

Plants

Chlorophyta - green algae (PH)
Chrysophyte - diatoms (PH)
Elodea - Brazilian waterweed (PV)
Potamogeton - pondweed (PV)
Myriophyllum - water milfoil (PV)
Nuphar - yellow water lily (PV)
Lemna - duckweed (PV)

Animals

Gammarus - amphipod (IH)
Oligochaeta - aquatic earthworms (IH)
Hirudinea - leeches (IC)
Tendipedidae - midges (IH)
Odonata - dragon flies (IC)
Pacifastacus - crayfish (IH, IC)
Copepoda - copepods (IH)
Cladocera - cladocerans (IH)
Pelecypoda - clams (IH)
Atari - mites (IC)
Gasterosteus aculeatus - threespine sticklebacks (FC)
Cyprinus carpio - carp (FH, FC)
Notemigonus crysoleucas - golden shiner (FH, FC)
Orthodon microlepidotus - Sacramento blackfish (FH, FC)

Detritus of terrestrial origin from upstream areas is probably the most important source of energy at the base of the food web in lower perennial riverine habitats (Figure 5-8). The contribution of phytoplankton and submergent plants depends in part on water turbidity. Coastal streams generally run clear except in the winter storm season.

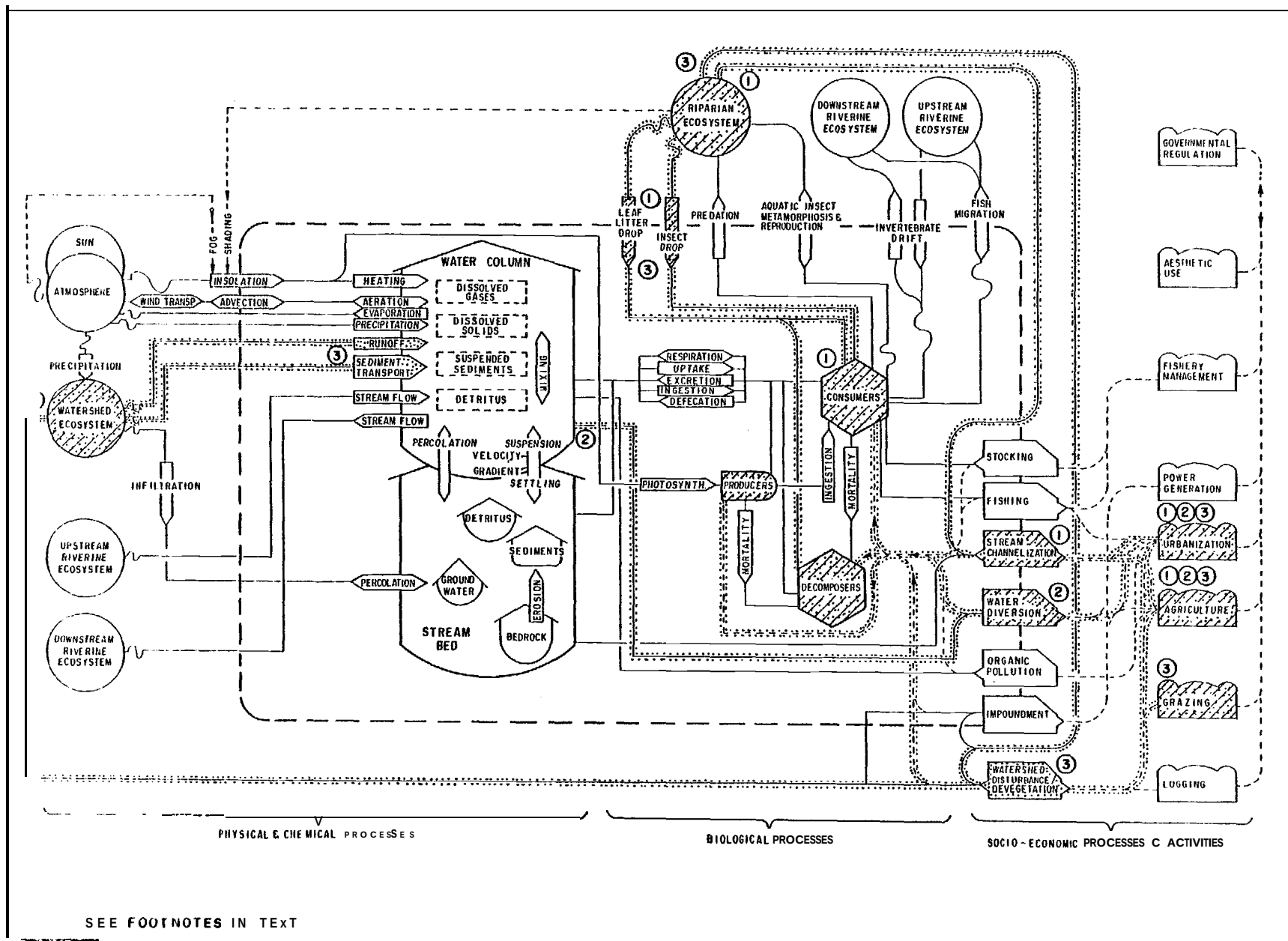


Figure 5-7. Ecosystem Model: Riverine Habitats - Effects of Human Activities in Lower Perennial Habitats

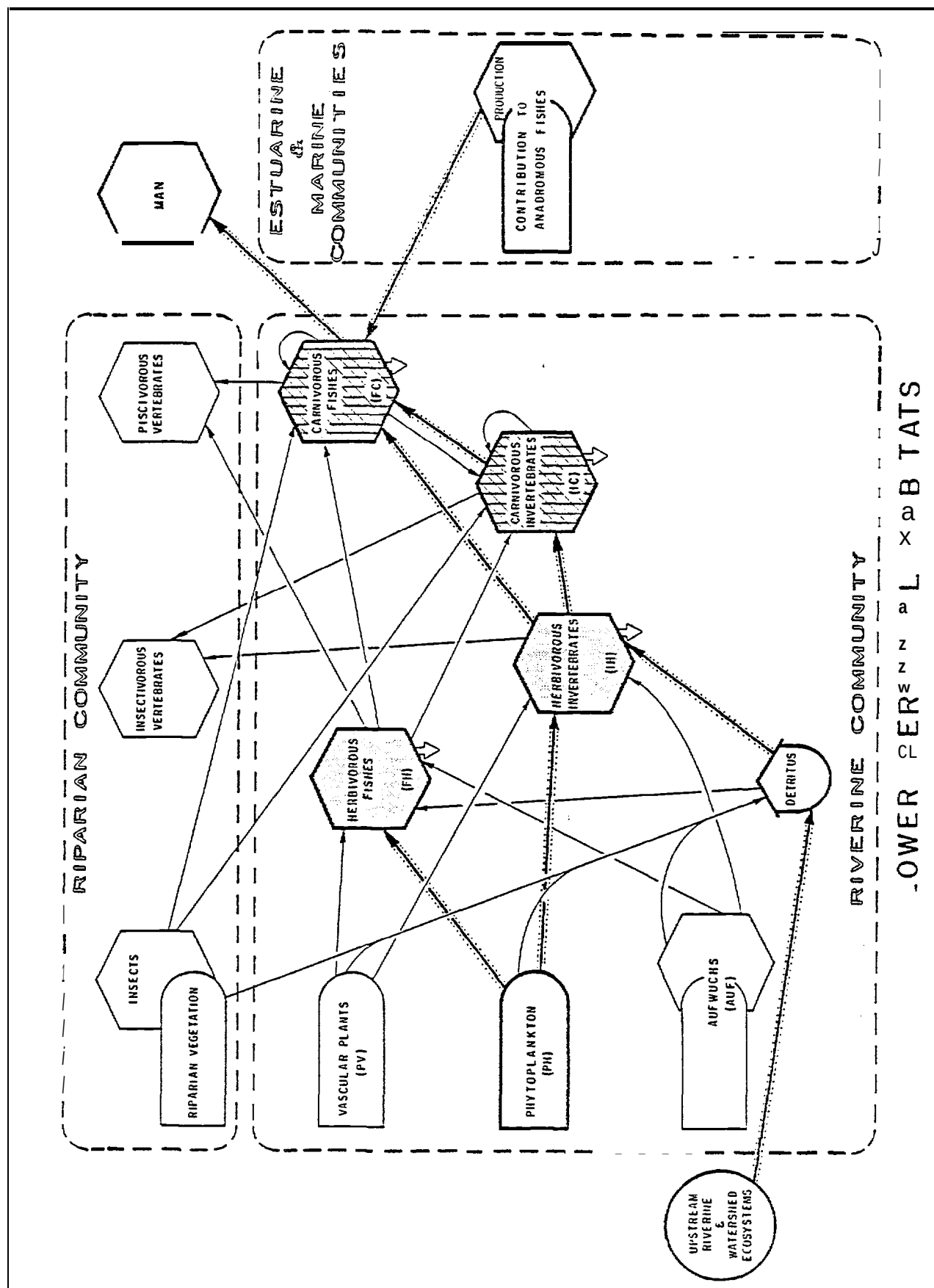


Figure 5-8. Riverine Habitats Food Web

EFFECTS OF HUMAN ACTIVITIES

The effects of human activities on lower perennial habitats stem primarily from stream channelization, water diversion, and watershed disturbances due to urbanization, agriculture, and grazing. The riverine habitat ecosystem model illustrates these effects (Figure 5-9) .

Stream Channelization (Footnote #1)

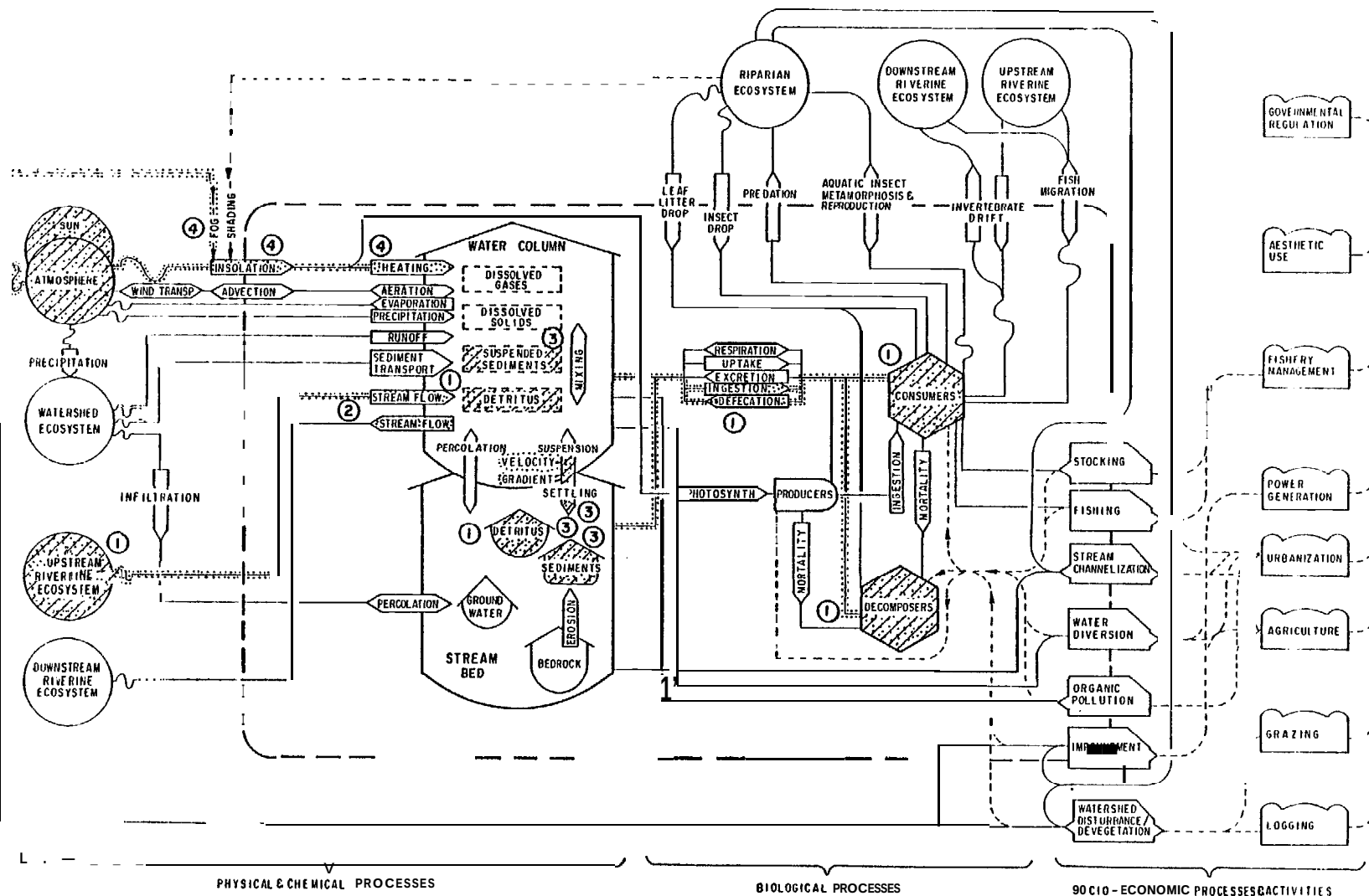
Stream channelization due to urbanization and agriculture is a frequent cause of habitat degradation in lower perennial habitats. The principal effects of channelization are losses in aquatic habitat volume and diversity. The riparian vegetation destruction that frequently accompanies channelization can lower consumer productivity by decreasing leaf litter and insect drop.

Water Diversion (Footnote #2)

Water diversion accompanies urbanization and irrigated agriculture. The principal effects of water diversion are decreases in habitat volume, physical removal of stream organisms, and increases in summer stream temperatures.

Watershed Disturbance (Footnote #3)

Watershed disturbance and devegetation accompany urbanization, agriculture, and grazing. The principal effects on lower perennial habitats are increased sedimentation and decreases in riparian insect and leaf litter input. Massive watershed alterations can result in greater peak flows and lower summer flows. Excessive peak flows can create excessive stream scouring, creating a wider and shallower stream channel which may have fewer deep pools and less habitat diversity. Lower summer flows reduce physical habitat volume and may increase water temperatures.



SEE FOOTNOTES IN TEXT

Figure 5-9 . Ecosystem Model: Riverine Habitats - Important Processes in Lower Perennial Habitats

UPPER PERENNIAL RIVERINE SUBSYSTEM

DESCRIPTION

Definition

Cowardin, et al. (1979) defined upper perennial riverine habitats:

Upper Perennial. The gradient is high and the velocity of the water fast. There is no tidal influence and sores water flows throughout the year. The substrate consists of rock, cobbles, or gravel with occasional patties of sand. The natural dissolved oxygen concentration is noms.lly near saturation. The fauna is characteristic of running water, and there are few or no planktonic forms. The gradient is high compared with that of the Lower Perennial Subsystem, and there is very little floodplain development.

Substrata

The bottom type *in* upper perennial habitats is usually sand, gravel, rubble or bedrock. Other bottom types may also exist (Table 5-1). Substratum size composition is generally correlated with maximum annual flow velocity.

Geography

Upper perennial habitats are probably the most widespread riverine habitats on the California coast due to the mountainous character of the area. They generally lie upstream of lower perennial and tidal habitats, and downstream of intermittent habitats.

Characteristic Species

Characteristic species in upper perennial habitats generally fall into three categories: those occurring on the sand and mud bottoms of pools, those occurring on the coarser substrates of riffles, and those occurring in the interstices of unconsolidated substrata.

Sand, Mud Bottom (Pool)

Potamogeton - pondweed
Myriophyllum - water milfoil
Oligochaeta - aquatic earthworms
Gammarus - amphipod
Tendipedidae - midges
Odonata - dragonflies
Gastropoda - snails
Pelecypoda - freshwater clams
Corixidae - water boatmen
Notonectidae - backswimmers
Catostomus occidentals -
Sacramento sucker
Hesperoleucus symmetricus -
California roach

Gravel, Boulder, Bedrock Bottom (Riffle)

Chrysophyte - attached diatoms
Chlorophyta - attached green algae
Ephemeroptera - mayflies
Plecoptera - stoneflies
Trichoptera - caddisflies
Simuliidae - black flies
Salmo gairdneri - steelhead/rainbow trout

Intergravel

Turbellaria - flatworms
Nematoda - nematodes
Oligochaeta - aquatic earthworms
Tardigrada - tardigrades
Harpacticoida - copepods
Ostracoda - seed shrimp
Tendipedidae - midges

HABITAT DYNAMICS

Important Physical and Chemical Processes

The riverine habitats ecosystem model is used here to illustrate important physical and chemical processes occurring in upper perennial habitats (Figure 5-10).

Stream Temperature Dynamics (Footnote #1) . Stream temperature in a given stream segment is a function of the interplay of many factors including insolation, aspect, air temperature, streamflow, groundwater inflow, evaporation, and upstream temperature conditions. In the coastal fog belt, fog attenuates sunlight and generally prevents summer stream temperature maxima from exceeding 25°C, which would be deleterious to salmonids and probably other coldwater fishes as well. In smaller streams, riparian shading is very important in maintaining cool summer temperatures. Summer temperature maxima in the main stems of larger streams inland of the fog belt often exceed 30°C. Salmonids avoid these lethal temperatures by holding in deep, thermally stratified pools; in areas of cool tributary or groundwater inflow; or by migrating into cool shaded tributaries.

Hydrologic Processes (Footnote #2) . The hydrologic environment greatly affects riverine habitat. The annual streamflow regime is a key factor: it is determined by timing and amount of precipitation, by amount of evapotranspiration, and by the relationships among infiltration, groundwater percolation, and direct runoff.

Virtually all precipitation occurs in the winter storm season in California coastal watersheds; during these times direct runoff is high and peak flows result. These peak flows are extremely important in the maintenance and rejuvenation of upper perennial habitats. Peak flows flush fine sediments from spawning gravels, scour sediment from pool habitats, and prevent the encroachment of riparian vegetation into the stream channel.

Streamflow is particularly important to anadromous salmonids during the late fall and spring seasons. Increasing flows from late fall and early winter storms permit upstream migration of adult salmonids; spring flows permit downstream migration of juveniles. River outflow in spring is a key stimulus to downstream migration of juvenile chinook salmon in the San Joaquin River system (California Department of Fish and Game, 1976).

Summer and early fall flows in coastal streams are generally low and consist mainly of groundwater accretion. Augmented summer flows are not always desirable because flow augmentation may break down thermal stratification in deep pools and render the habitat unsuitable for salmonids.

Substrate Type (Footnote #3) . Sediment transport is largely a function of direct runoff, streamflow velocity, and stream gradient. Stream channel sediments in upper perennial habitats are generally coarse (sand, gravel, rubble, boulder, or bedrock) because relatively steep gradients and high flow velocities cause fine sediments to be transported downstream.

Important Biological Processes

The riverine habitats ecosystem model is used here to illustrate important biological processes occurring in upper perennial habitats [Figure 5-11].

Riparian Inputs (Footnote #1) . Contributions of leaf litter and terrestrial insects from the riparian zone are important to upper perennial stream ecosystems. Leaf litter is eaten directly by many invertebrates. The litter of broad-leaf vegetation, particularly that of alder (*Alnus*), is a better and more important source of nutrition than the litter of coniferous species (Hynes, 1970) . Partially decomposed leaf litter (detritus) is also an important food source for invertebrates. Detritus is cycled and recycled as it is transported downstream (Hynes, 1970) . Terrestrial insects that fall into the stream from the riparian zone are important food items for carnivorous fishes.

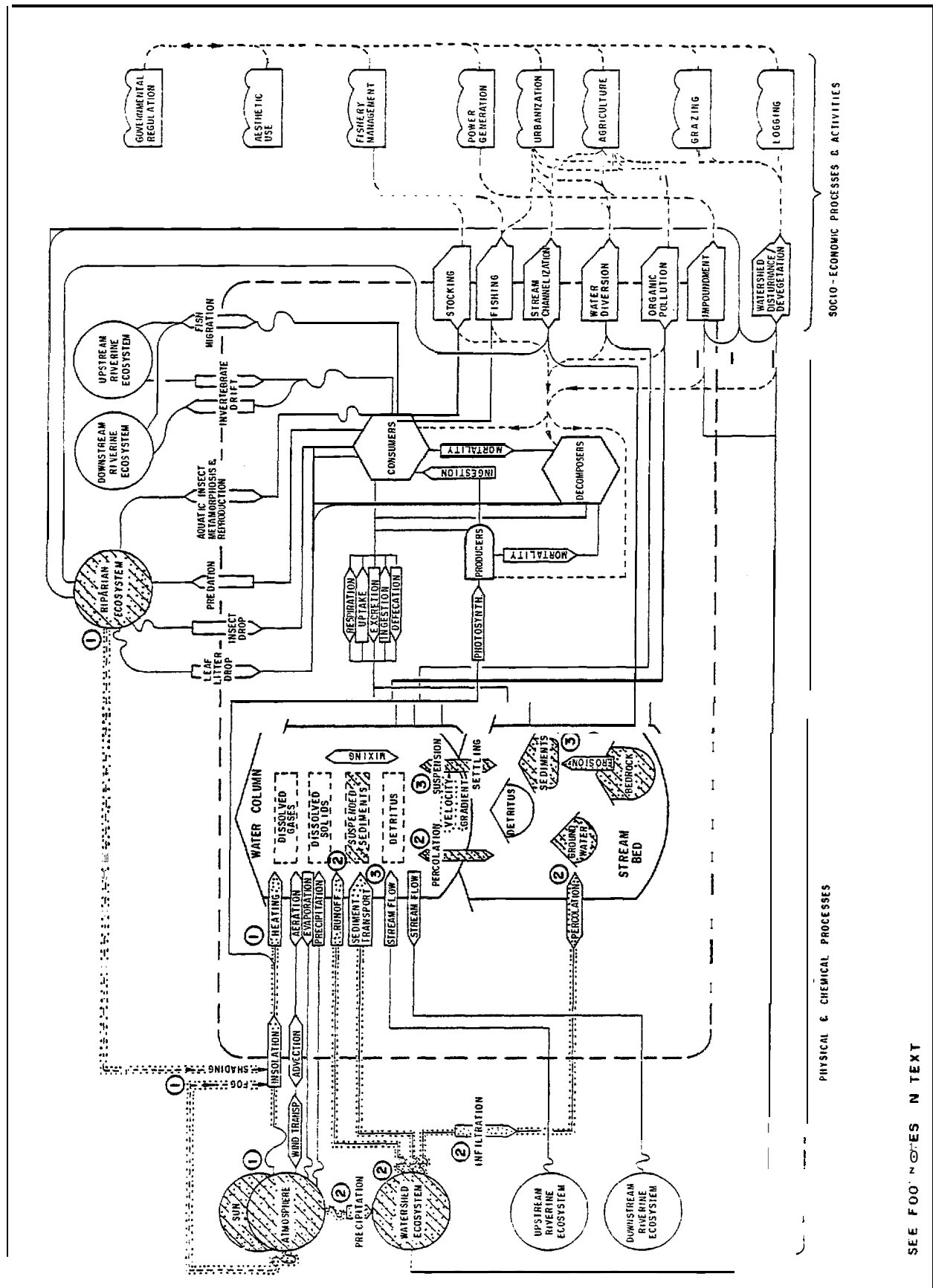


Figure 5-10. Ecosystem Model: Riverine Habitats - Important Physical and Chemical Processes in Upper Perennial Habitats

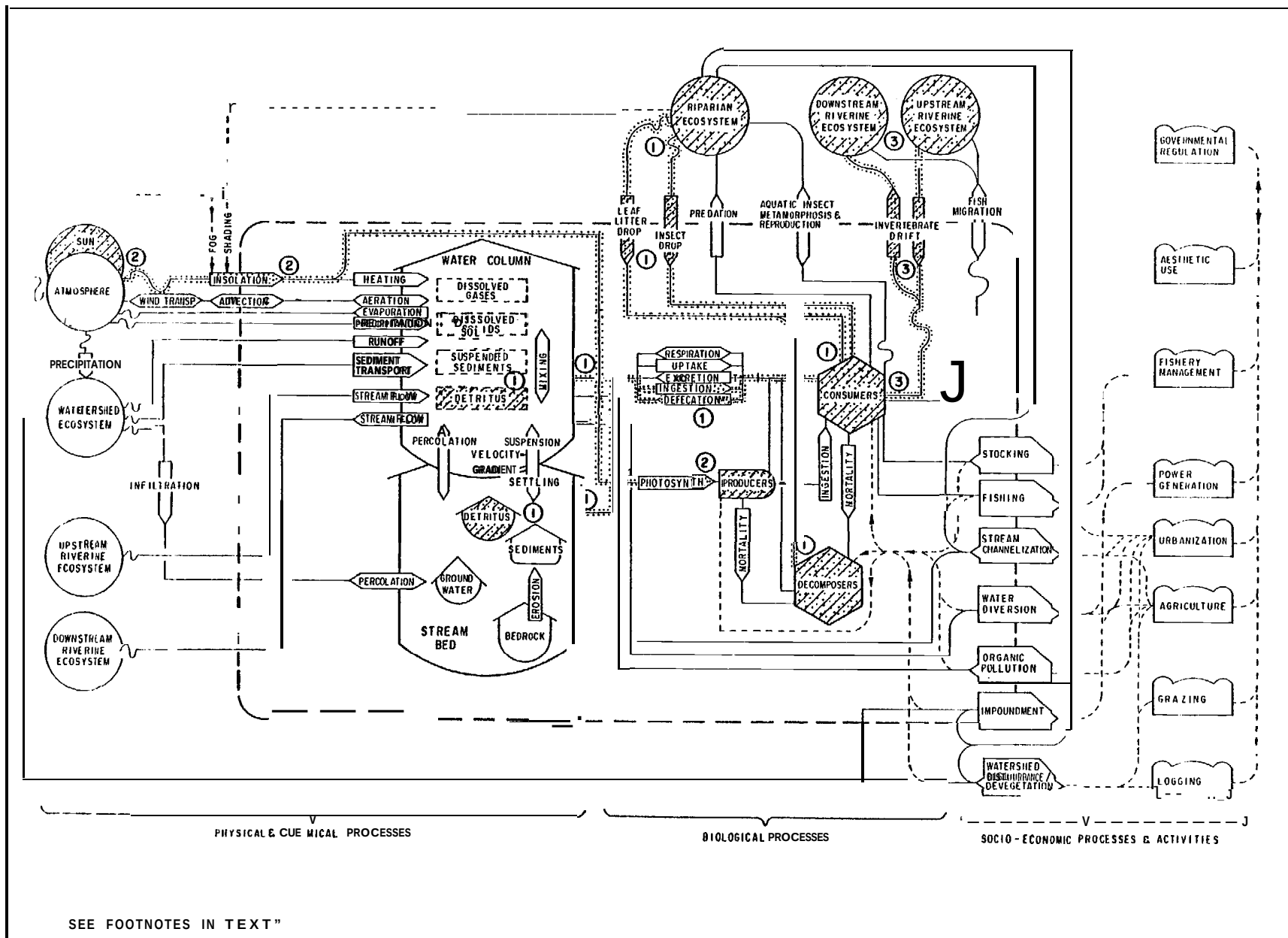


Figure 5-11, Ecosystem Model: Riverine Habitats - Important Biological Processes in Upper Perennial Habitats

Primary Production (Footnote #2) . Photosynthesis that occurs within the riverine ecosystem generally contributes less energy to upper perennial ecosystems than does terrestrial photosynthesis. Primary production occurring in the stream is important nevertheless. Aquatic macrophytes grow in pools, backwater areas, and along stream margins. In areas of more rapid current, the main instream primary producers are the attached diatoms and green algae of the aufwuchs (periphyton) community found on the surface of gravel and larger-sized sediment particles. The aufwuchs is the community of sessile plants and animals found growing attached to hard substrata, and also the free-living forms found within the mat of sessile organisms (Ruttner, 1953) .

Invertebrate Drift (Footnote #3). Nearly all taxa of benthic stream invertebrates exhibit periodic downstream drift, including Oligochaeta (earthworms) , Amphipoda (amphipods) , Isopoda (sowbugs) , Ephemeroptera (mayflies) , Plecoptera (stoneflies) , Odonata (dragonflies and damselflies) , Hemiptera (true bugs) , Diptera (true flies) , Coleoptera (beetles) , Atari (mites) and Mollusca (molluscs) (Hynes, 1970). Drifting is stimulated by freshets, by drifting ice, by temperature changes, and by diurnal changes in light. Most species are night-active, triggered by light intensity. The direct significance of invertebrate drift to fish is an increase in food availability to midwater feeders such as juvenile steelhead (Waters, 1969) .

Foot? Web

The relative positions of the following food web organisms are indicated by the acronyms in Figure 5-12. The listing is generalized; a particular habitat area may not contain all these organisms.

Plants

Chlorophyta - attached green algae (AUF)
Chrysophyte - attached diatoms (AUF)
Elodea - Brazilian Waterweed (PV)
Potamogeton - pondweed (PV)
Myriophyllum - water milfoil (PV)

Invertebrates

Turbellaria - flatworms (IC)
Oligochaeta - aquatic earthworms (IH)
Harpacticoida - benthic copepods (IH)
Ephemeroptera - mayflies (IH)
Odonata - dragonflies, damselflies (IC)
Plecoptera - stoneflies (IC, IH)
Trichoptera - caddisflies (IH)
Tendipedidae - midges (IH)
Simuliidae - black flies (IH)
Atari - mites (IC)

Fish

Salmo gairdneri - rainbow trout (FC)
Oncorhynchus kisutch - coho salmon (FC)
Hesperoleucus symmetricus - California roach (FH, FC)
Catostomus occidentals - Sacramento sucker (FH, FC)
Gasterosteus aculeatus - threespine sticklebacks (FC)
Cottus asper - prickly sculpin (FC)
C. aleuticus - coast range sculpin (FC)

Materials of terrestrial origin are an important energy source in upper perennial habitats. Detritus is consumed by many invertebrates (e.g., mayflies, caddisflies, black fly larvae). Insects of terrestrial origin are important to carnivorous fishes; including salmonids. Instream primary production is also important; attached diatoms of the aufwuchs are food sources for many mayfly (Ephemeroptera) species, and for California roach and Sacramento sucker. Among the carnivorous fishes, sculpins are especially important consumers of aquatic invertebrates and the young stages of fishes including salmonids.

Fish Uses of Different Habitats

Different fish species make different uses of the habitats found within the upper perennial zone. Figure 5-13 illustrates some of the following species habitat uses:

Pacific Lamprey. Adults spawn in gravel of about 5 cm diameter. Larvae (ammonoetes) are found burrowed into soft mud banks.

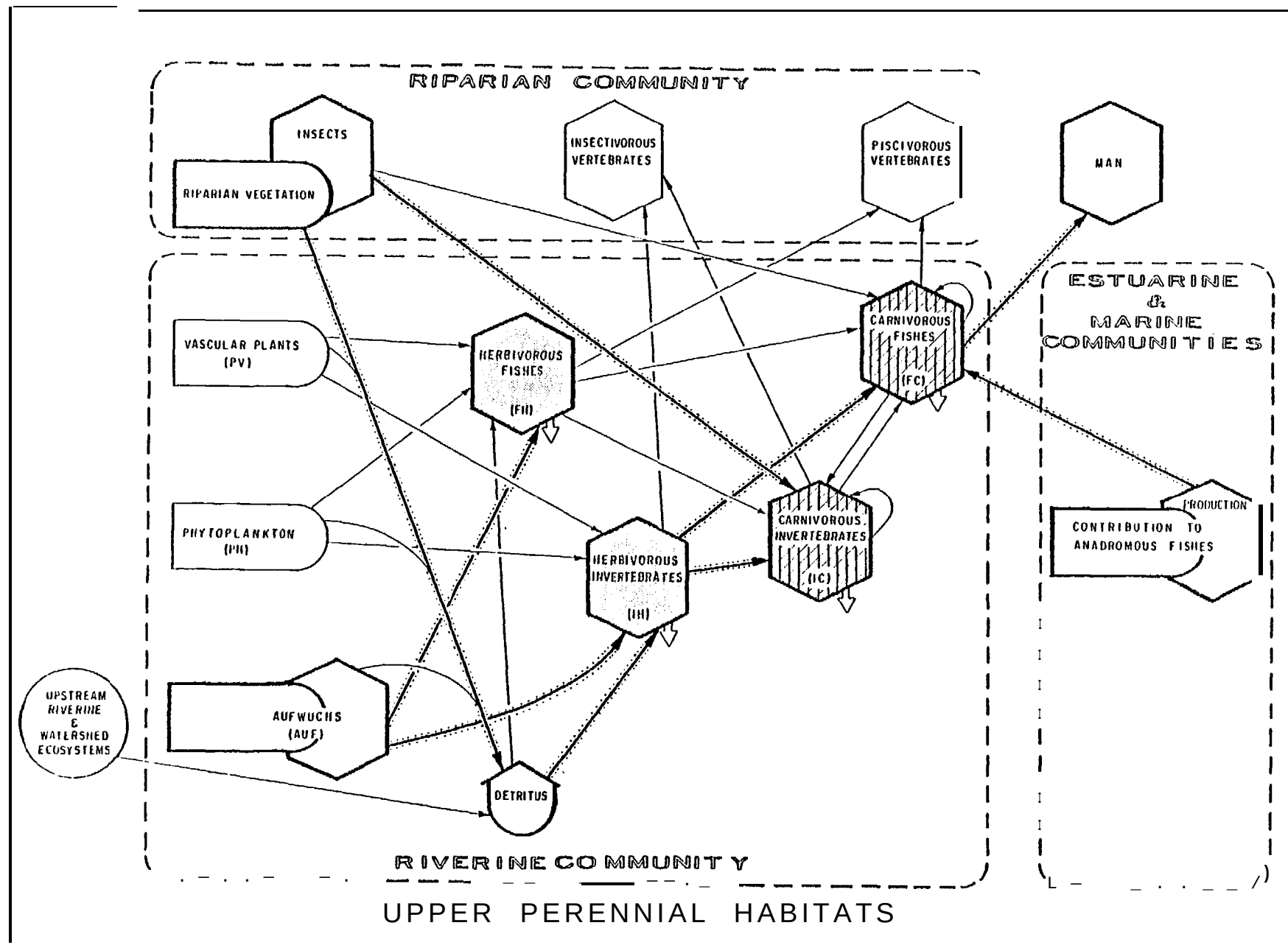


Figure 5-12. Riverine Habitats Food Web .

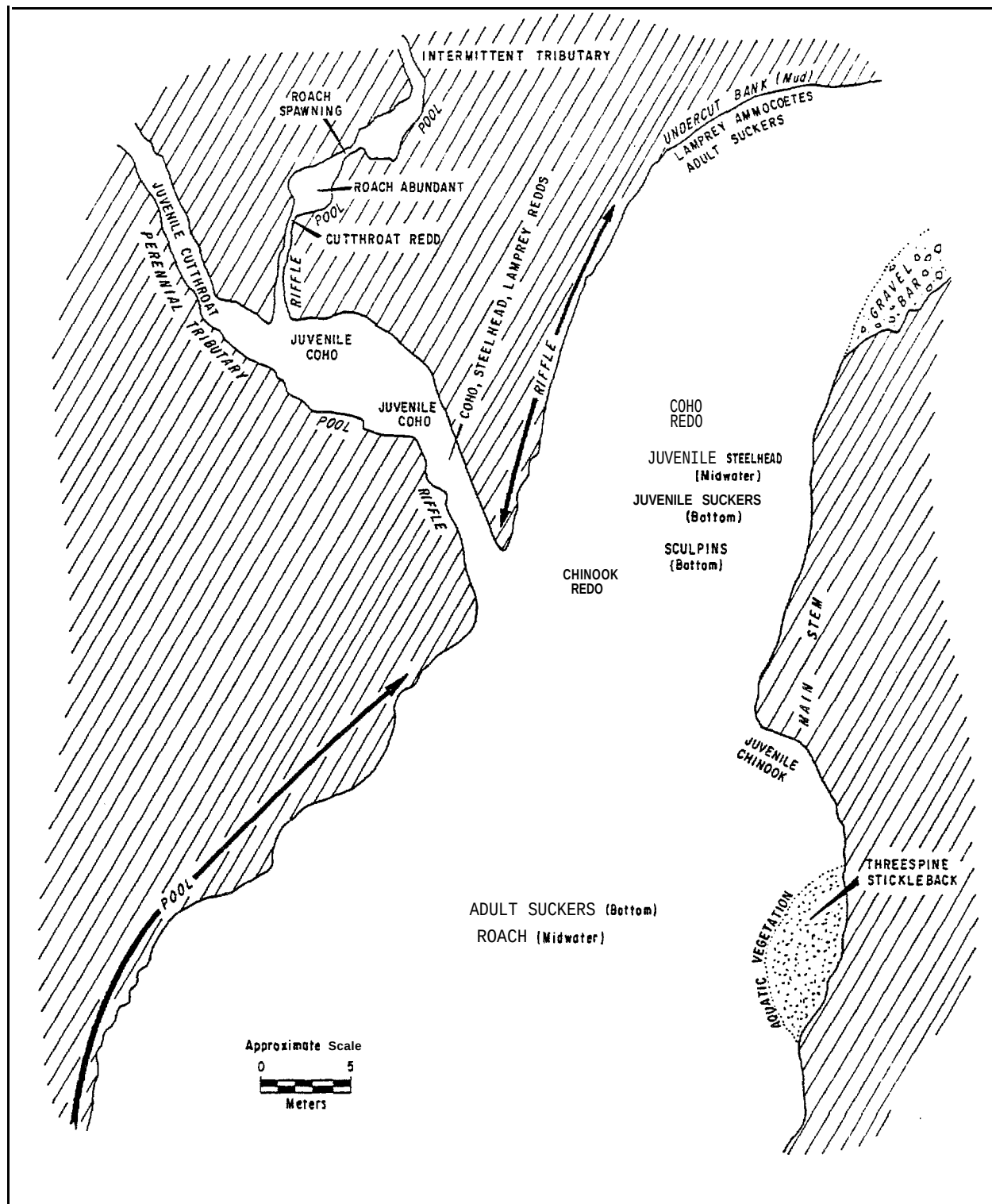


Figure 5-13. Fish Uses of Upper Perennial Habitats (Generalized)

Chinook Salmon. Adults spawn in riffle areas of gravel about 10-15 cm diameter, depth about 0.5 meters (m) and current velocities about 0.5 m per second. Young are reared along stream margins and in 'backwater areas, mainly over silt substrates in water velocities less than 0.15 m per second and depths of 0.15-0.30 m (Everest and Chapman, 1972).

Coho Salmon. Adults spawn in somewhat smaller gravel than chinook salmon. Juveniles feed in early spring and summer near the heads and tails of pools. Juveniles spend late summer and winter in deep pools (Hartman, 1965).

Steelhead Trout. Adults spawn in gravel of about 3-8 cm in diameter. Age 0 (young of the year) fish are generally found over rubble substrate in water depths less than 0.15 m and velocities less than 0.15 m per second (Everest and Chapman, 1972). Older juveniles are found at midwater depths in riffles in the growing season, and in deep pools in late summer and winter.

Cutthroat Trout. Spawning occurs in small gravel of headwater areas. Juveniles are most abundant in small headwater streams (Hartman and Gill, 1968).

California Roach. Adults spawn in areas of small gravel near the home pool. Adults and juveniles are most abundant in pools, especially in small intermittent streams.

Sacramento Sucker. Spawning occurs over gravel riffles. Post larvae are found along stream margins with detritus bottoms. Juveniles are found in sand bottom stream margins or at the bottom of the water column in riffles. Adults are found on the bottom in deep pools or beneath undercut banks.

Threespine Stickleback. Spawning and greatest abundance occur in areas of rooted aquatic vegetation.

EFFECTS OF HUMAN ACTIVITIES

The effects of human activities in upper perennial habitats in California coastal streams stem primarily from water diversion, impoundment, and watershed disturbance, revegetation and illegal fishing. The riverine habitat ecosystem model illustrates these effects (Figure 5-14).

Water Diversion (Footnote #4)

Urbanization and agriculture are the main causes of water diversion in California coastal streams. The effects are most severe in streams from the Russian River south. Where no impoundment facilities exist, the principal effects of direct diversion are greatest in the low flow period in late summer and early fall. Direct diversion may significantly reduce habitat volume, sometimes to the point of changing a formerly perennial stream to an intermittent stream. Direct diversion may also cause elevated water temperatures and reduce the pollutant assimilation capacities of a stream.

Impoundment (Footnote #2)

Municipal water supply storage, flood control, and stock watering are the main purposes of impoundment facilities on the smaller coastal streams. On the larger streams (the Eel, Trinity and Klamath) inland of the study area, there are existing and planned impoundment facilities for power generation and transbasin diversions.

Effects of impoundment facilities on upper perennial habitats vary. A direct effect is inundation of riverine and watershed habitats and replacement with reservoir habitat. In some cases reservoirs may be beneficial to fisheries if the reservoir is located above barriers to fish migration, there is no transbasin diversion, and sufficiency seasonal flows are provided. Ruth Reservoir on the Mad River may be an example. In many cases, however, the effects of impoundment are harmful. Migrations of anadromous and resident fishes may be blocked. Greatly decreased winter peak flows can prevent adequate flushing of fine sediments from spawning gravels and cause encroachment of riparian vegetation into the stream channel. Decreased flows in spring and early summer can cause elevated water temperatures and provide inadequate stimulus for outmigration of anadromous salmonids. Optimum hydrologic conditions for the life cycles of anadromous fishes have not been well defined, but flow regimes in undisturbed watersheds that produce many fish may be a good guideline (e.g., Prairie Creek, Humboldt County).

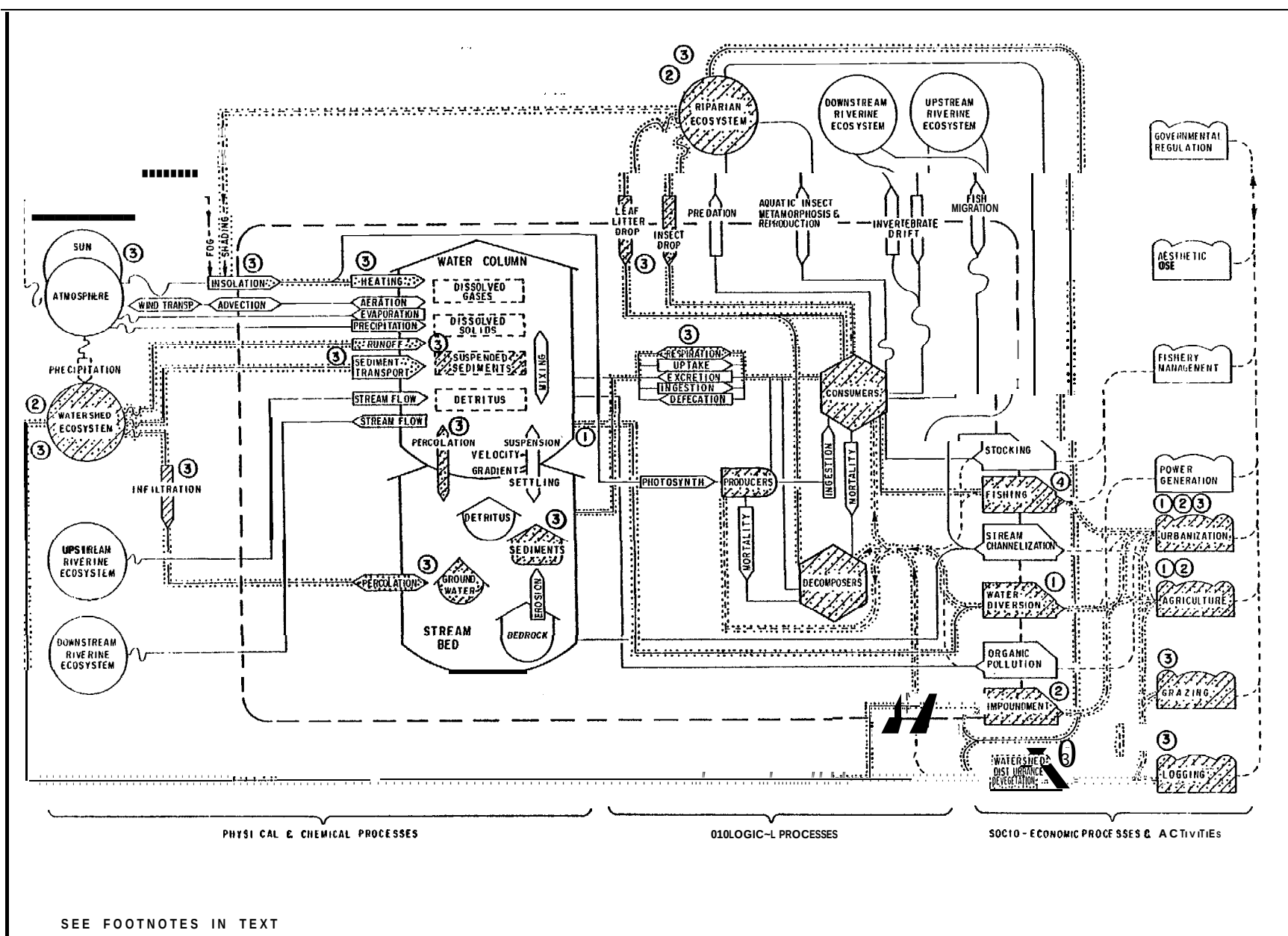


Figure 5-14. Ecosystem Model: Riverine Habitats - Effect of Human Activities on Upper Perennial Habitats

Watershed Disturbance (Footnote #3)

Urbanization, grazing and logging are the main causes of watershed disturbance and devegetation in California coastal streams. The principal effects on upper perennial habitats are hydrologic alterations and increased sedimentation through effects on the entire watershed, and increased water temperatures and decreased leaf litter and insect drop through effects on the riparian zone.

The hydrologic alterations due to watershed disturbance result mainly from increased direct runoff and decreased infiltration. A result is higher peak winter flows. Higher peak flows can cause increased scouring and streambank erosion. Summer flows may be higher or lower depending on the nature of the disturbance. In cases of devegetation of the riparian zone, summer flows may also increase due to reduced evapotranspiration. In cases of urbanization where the watershed is largely covered with buildings, blacktop and cement, infiltration may decrease so much that the water table drops and summer flows decrease or cease, whether or not riparian vegetation remains. The effects of lower summer flows can be decreased habitat volume and higher water temperatures.

Increased sedimentation due to watershed disturbances causes filling of gravel interstices. Fish egg suffocation and decreased benthic invertebrate habitat and productivity can result.

The effects of logging can be mitigated somewhat by leaving streamside buffer strips. Erman *et al.* (1977) found that logging without buffer strips caused increases in some benthic invertebrate taxa and a decrease in invertebrate diversity. Logging with buffer strips at least 30 m wide caused no significant changes in the benthic invertebrate community. Logging with buffer strips less than 30 m wide caused changes similar to those occurring in streams with no buffer strips. Moring and Lantz (1975) found a decrease in resident cutthroat trout in a stream in a clear-cut watershed with no buffer strip, and no decreases in a stream in a patch-cut watershed with buffer strips. Lampreys and sculpins were also decreased by clear-cut logging.

Fishing (Footnote #4)

Illegal fishing for adult salmonids in small creeks and tributaries frequently occurs in urbanized areas. Such fish are easy prey and are taken by spear, hand or dog. Such pressure puts an additional burden on fish populations already suffering from habitat degradation.

INTERMITTENT RIVERINE SUBSYSTEM

DESCRIPTION

Definition

Cowardin, et al. (1979) defined intermittent riverine habitats:

Intermittent. In this subsystem, the channel contains nontidal flowing water for only part of the year. During those periods when the water is not flowing, it may remain in isolated pools or surface water may be absent.

Intermittent streams contain flowing water throughout the winter storm season and into spring. Flow may cease anytime from late spring to early autumn, depending on the stream and the water year. Standing water may or may not remain in pools. Some streams which are normally intermittent may flow year round in wetter years, and some normally perennial streams may become intermittent in drier years.

Substrata

The bottom type of intermittent streams may range from mud to bedrock. Usually it is similar to that of upper perennial streams.

Geography

Intermittent habitats typically occur upstream of upper perennial habitats; however, intermittence may also occur in lower reaches of a stream. Many small intermittent creeks discharge directly to the ocean. Intermittent streams are increasingly common as one proceeds south along the California coast, due to decreasing annual average precipitation, lowered groundwater tables, and increasing out-of-stream appropriations.

Characteristic Species

The fauna of intermittent streams is similar to that of perennial streams, but some differences do exist. The fauna of intermittent streams is comprised of species that survive in stagnant pools, species that survive by burrowing into the substratum, species with drought-resistant eggs, and species that migrate downstream during dry periods (Hynes, 1970). Drought conditions favor stoneflies over mayflies because stonefly eggs are more drought-resistant. Many insects such as mayflies and black flies recolonize intermittent habitats by the adults flying upstream and laying eggs in the fall when the flow has resumed (Hynes, 1970). Intermittent streams are often suitable habitat for spawning and seasonal rearing of anadromous salmonids (Kralik and Sowerwine, 1977) and contribute a significant portion of the total salmonid production.

Survive in Pools

Chlorophyta - green algae
Turbellaria - flatworms
Trichoptera - caddisflies
Tendipedidae - midges
Corixidae - water boatmen
Notonectidae - backswimmers
Oligochaeta - aquatic earthworms
Gastropoda - snails
Pelecypoda - freshwater clams
Hesperoleucis symmetricus -
California roach

Burrow into Substrate

Turbellaria - flatworms
Nematoda - nematodes
Oligochaeta - aquatic earthworms
Harpacticoida - copepods
Tendipedidae - midges
Atari - mites

Drought-Resistant Eggs

Plecoptera - stoneflies

Avoidance Migrations

Ephemeroptera - may flies

Simuliidae - black flies

Oncorhynchus tshawytscha - chinook salmon

O. kisutch - coho salmon

Salmo gairdneri - steelhead/rainbow trout

HABITAT DYNAMICS

Important Processes

With the exception of hydrology, virtually all *processes* of interest in intermittent habitats are similar to those in upper perennial habitats (Figures 5-10 and 5-11). The hydrologic relations among precipitation, direct runoff, infiltration, and groundwater level determine whether or not a stream becomes intermittent in the dry season. If there is sufficient infiltration during the wet season and the groundwater level remains higher than the streambed during the dry season, then the stream will be perennial. If the groundwater surface falls below the streambed level, then the stream will be intermittent.

Food? Web

The trophic relations in intermittent habitats are similar to those in upper perennial habitats (Figure 5-12) .

EFFECTS OF HUMAN ACTIVITIES

Man's effects on intermittent habitats are similar to those on upper perennial habitats, (Figure 5-14) except intermittent habitats are somewhat more vulnerable. Water courses dry in summer are often not recognized as streams and are not given appropriate protection. This has been a problem with timber harvest operations.

CHAPTER 6 LACUSTRINE ECOSYSTEMS

GENERAL CHARACTERISTICS

DEFINITION

Lacustrine (lake) habitats are defined by all the following criteria: wetlands and deepwater habitats situated in a depression or dammed river channel; no more than 30 percent areal cover by vegetation (trees, shrubs, persistent emergents, or emergent mosses or lichens); total area in excess of 8 hectares (20 acres), unless active wave-formed or bedrock shoreline feature forms all of boundary, or depth of water in deepest part of basin exceeds 2m (6 feet) at low water; ocean-derived salinity less than 0.5 o/oo (parts per thousand) (Cowardin, et al., 1979). Lacustrine systems in the study area include lakes and reservoirs.

ECOSYSTEM MODEL

An ecosystem model has been developed to illustrate important natural processes and human activities in lacustrine ecosystems (Figure 6-1). The model divides processes and activities into three areas: physical and chemical processes, biological processes, and socio-economic processes and activities. Physical and chemical sources and sinks are shown on the left side of the model; biological exchanges are shown at the upper middle of the model.

Physical-Chemical Parameters

Insolation, evaporation, precipitation, advection, wind, erosion, runoff, percolation, inundation, exchange, and discharge are all important processes in lacustrine ecosystems. Insolation is important in photosynthesis, thermodynamics, and stratification. Wind is important in generating water currents, mixing, and also in the formation of eroded shoreline features which, in some cases, distinguish lacustrine ecosystems from palustrine (pond) ecosystems.

Biological Features and Processes

Producers consist of lichens, liverworts, mosses, macrophytes (vascular plants and macroscopic algae) and microalgae (attached and free-floating). In small shallow systems, vascular emergent macrophytes of the littoral zone can be responsible for the majority of the total system primary production (Wetzel, 1975).

Consumers typically belong to four animal groups: molluscs, aquatic insects, crustacea, and fish (Odum, 1971). Usually less significant in terms of systemwide biomass but important ecologically are annelids, rotifers, protozoa and helminths (Odum, 1971).

Decomposers consist of bacteria and fungi. The size of the decompose population on a systemwide basis is increased in eutrophic (nutrient-rich) systems.

Socio-economic Activities

The lacustrine system model (Figure 6-1) illustrates that human activities result in three basic kinds of processes acting upon lacustrine ecosystems: consumer removal, addition, and regulation; water or substrate modification; and producer removal and addition and regulation. Fishing and fish stocking are examples of consumer removal and addition, respectively. Construction and filling is an example of water and substrate modification. Shoreline filling and water diversion are examples of producer removal and also of habitat removal.

FOOD WEB MODEL

The lacustrine food web model (Figure 6-2) illustrates some general trophic relationships occurring in lacustrine ecosystems. The acronyms shown in the trophic categories will be used to illustrate the relative trophic positions of characteristic species later in this chapter.

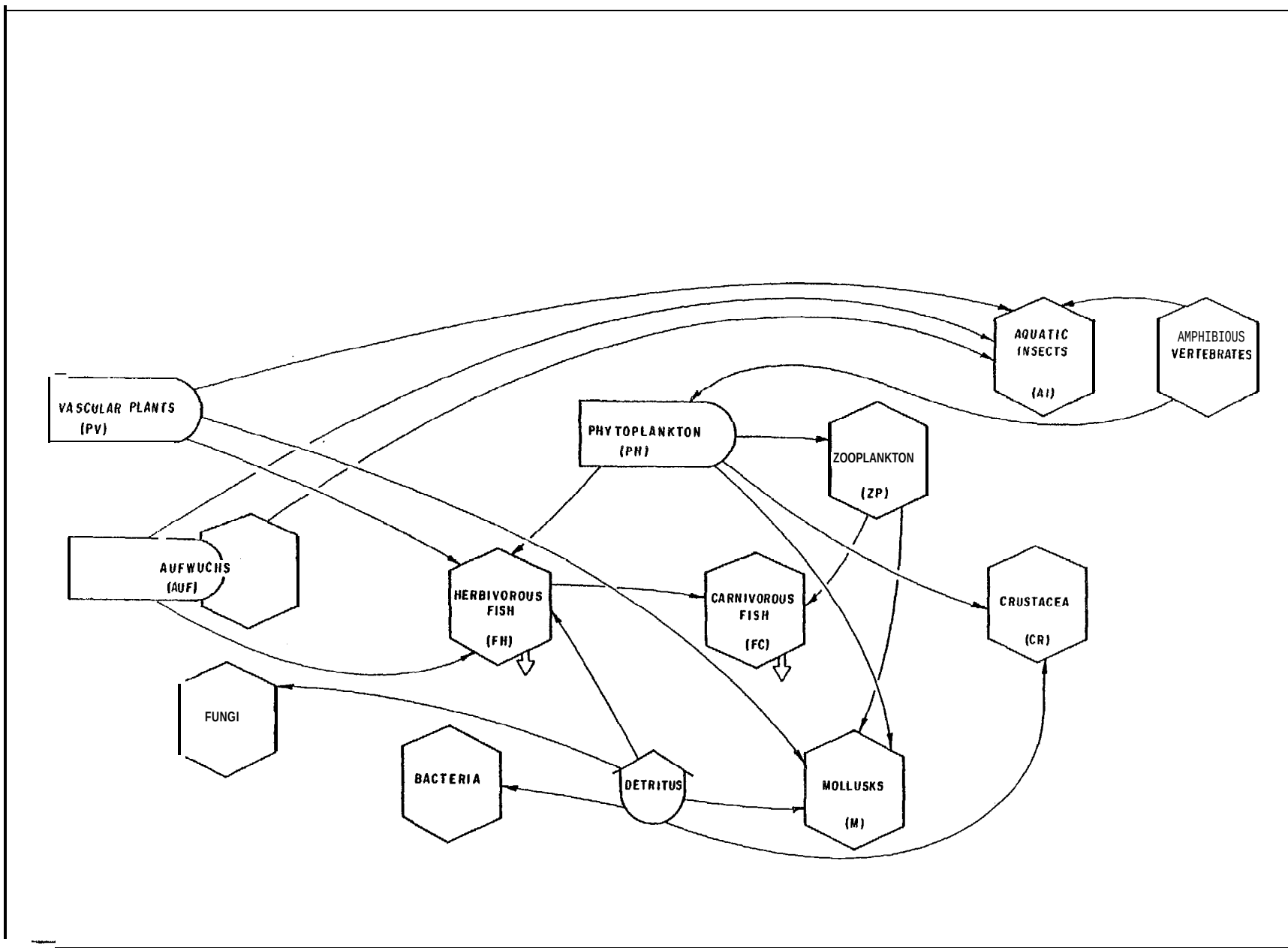


Figure 6-2. Lacustrine Ecosystem Food Web

Succession Model

The lacustrine succession model (Figure 6-3) illustrates some aspects of lake succession. Basin morphology and rates of external nutrient and sediment loading are primary factors in the rate of succession. Oligotrophic lakes are generally deep, clear, low in nutrients, and high in hypolimnetic (refers to the deep portion of the lake that does not warm in summer) oxygen. Eutrophic lakes are generally shallower, not clear, high in nutrients and low in hypolimnetic oxygen. Dystrophic lakes are generally low in productivity due to high amounts of humic materials (products of plant decomposition).

GEOGRAPHY

There are a number of small freshwater lakes and reservoirs scattered along the study area. Biological information, if available at all, on these water bodies consists largely of file data, unpublished reports, theses and dissertations found in local colleges and universities, libraries and in water district offices. Most of this site-specific data has not been incorporated into this report.

SUBSYSTEMS AND HABITAT TYPES

The lacustrine system consists of three subsystems: the littoral zone, the limnetic zone, and the pelagial zone. The littoral and limnetic zones are further divided into habitat types. The three subsystems and some of their habitat types are shown in Figure 6-4. A complete listing is given in Table 6-1.

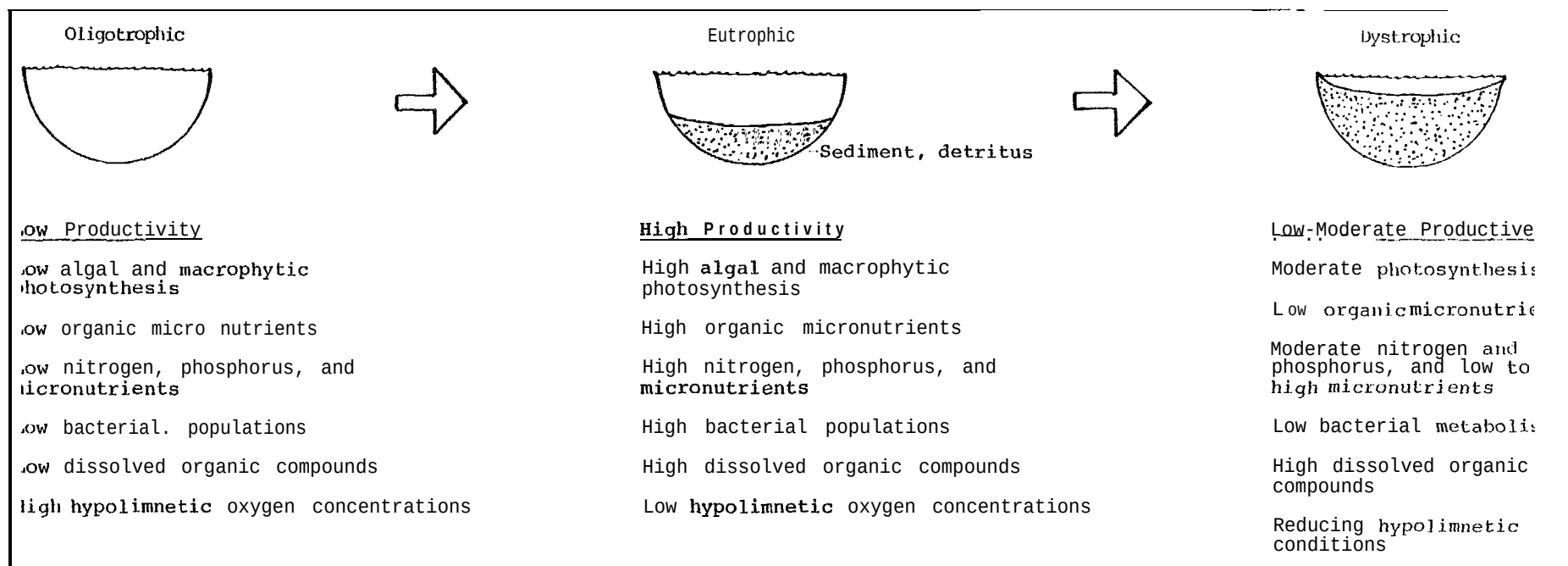


Figure 6-3. Lacustrine Succession Model

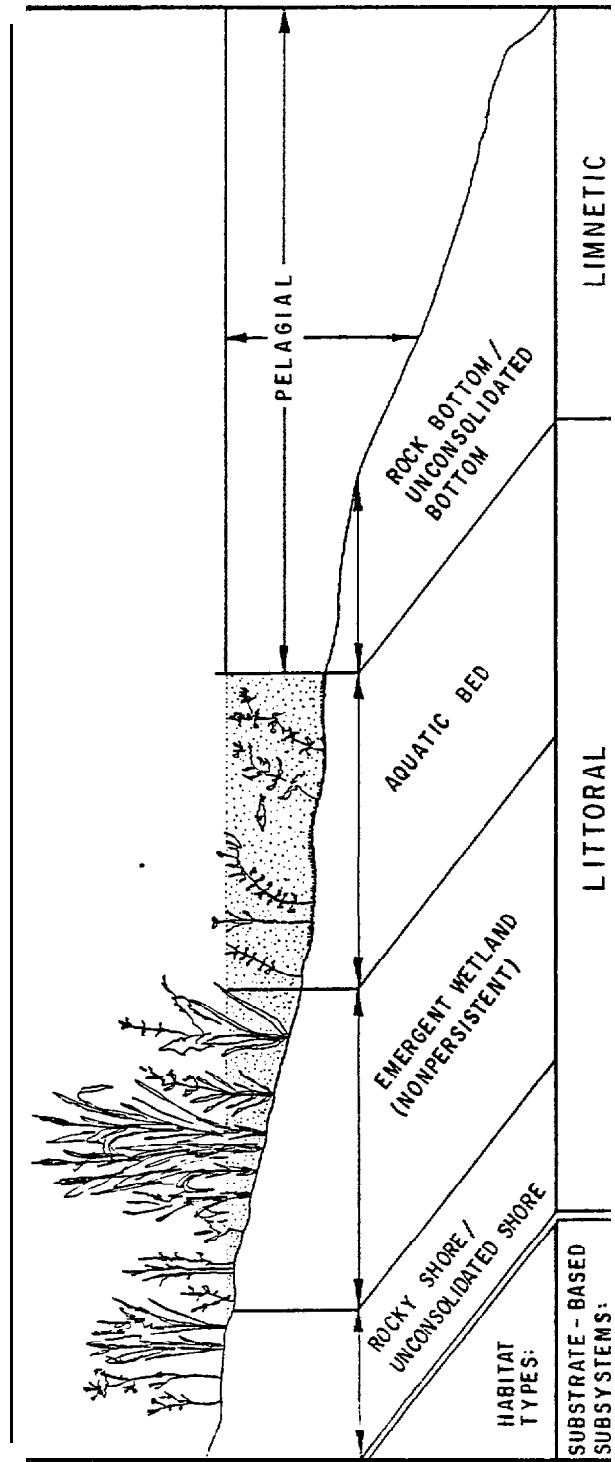


Figure 6-4. Lacustrine Subsystems and Habitat Types

Table 6-1. Lacustrine Subsystem, Class and Habitat Types
(Adapted From Cowardin, et al., 1979)

Subsystem	Class	Habitat Type
Littoral	Rock bottom:	Bedrock
	Unconsolidated bottom:	Rubble
		Cobble/gravel
		Sand
		Mud
Limnetic	Aquatic bed:	Organic
		Algal
		Aquatic moss
		Rooted vascular
		Floating
	Rocky shore:	Bedrock
	Unconsolidated shore:	Rubble
		Cobble/gravel
		Sand
		Mud
		Organic
	Emergent wetland:	Vegetated
	Rock bottom:	Nonpersistent
		Bedrock
	Unconsolidated bottom:	Rubble
		Cobble/gravel
		Sand
		Mud
		Organic
Pelagial	(Water Column)	Algal
		Aquatic moss
		Rooted vascular
		Floating

LITTORAL SUBSYSTEM

DEFINITION

The littoral subsystem is the shoreward portion of the lacustrine ecosystem extending from the high water line to a depth of 2 m (6 feet) below low water or, if deeper, to the maximum extent of nonpersistent emergents.

CHARACTERISTIC BIOTA

The following are characteristic organisms typically found in littoral habitat types. Their relative trophic positions are indicated by the acronyms on the lacustrine food web model (Figure 6-2).

Rock Bottom:
Chlorophyta - attached green algae (AUF)
Chrysophyte - attached diatoms (AUF)
Gastropoda - aquatic snails (M)

Unconsolidated Bottom - Cobble/Gravel:
Chlorophyta - attached green algae (AUF)
Chrysophyte - attached diatoms (AU)
Trichoptera - caddisflies (AI)

Unconsolidated Bottom - Sand:
Harpacticoida - benthic copepods (CR)
Oligochaeta - aquatic earthworms
Pelecypoda - freshwater clams (M)

Unconsolidated Bottom - Mud/Organic:
Harpacticoida - benthic copepods (CR)
Oligochaeta - aquatic earthworms
Isopoda - aquatic sowbugs (CR)
Tendipedidae - midge fly larvae (AI)
(formally Chironomidae)

Aquatic Bed:
Nuphar - yellow water lily (PV)
Potamogeton - pondweed (PV)
Elodea - waterweed (PV)
Lemna - duckweed (PV)

Rocky Shore:
Trichoptera - caddisflies (PV)
Gastropoda - snails (M)

Unconsolidated Shore:
Harpacticoida - benthic copepods (CR)
Oligochaeta - aquatic earthworms
Pelecypoda - freshwater clams (M)
Isopoda - sowbugs (CR)
Tardigrada - tardigrades
Nematoda - nematodes

Emergent Wetland:
Typha - cattail (PV)
Juncus - rush (PV)
Carex - sedge (PV)

Producers

Emergent macrophytes are an important ecological link between terrestrial and aquatic ecosystems. They are effective as soil binders; they provide food (seeds, shoots, tubers) and cover for amphibians, birds (ducks), and mammals (muskrats, beavers); and they provide entry and exit habitat for some aquatic insects with life cycles that include both aquatic and terrestrial stages. Because these plants frequently retrieve nutrients lost to deep anaerobic sediments and return them to the system, they have been referred to as "nutrient pumps" (Odum, 1971).

Floating algae (phytoplankton) are present in the littoral zone but are not characteristic of it because the same species may be found throughout the entire lacustrine system. Certain filamentous green algae (Chlorophyta), commonly referred to as pond scums, are characteristically found in the littoral zone.

The primary productivity of the littoral zone has been shown to be a considerable portion of the total productivity of some lacustrine systems (Wetzel, 1975). The extent of the littoral contribution is determined primarily by basin morphology, i.e., the extent and development of the littoral zone relative to the pelagial zone. Emergent macrophytes have been found to account for as much as 73 percent and attached algae in the littoral zone for an additional 20 percent of the primary production in some shallow lakes (Straakraba, 1963 in Wetzel, 1975). Epiphytic (growing on macrophytes) microalgae appear to have the highest rate of aquatic primary production, probably due to a combination of light availability, wave-action sediment movement, and inorganic-organic nutrient exchanges between macrophytes and their attached algae. Attached algae often form the dominant algal biomass in shallow lakes because the phytoplankton is poorly developed (Wetzel, 1975).

Effects of Eutrophication on Species Composition and Primary Productivity. Productivity of the littoral zone often plays a major role in the early and final stages of increasing fertility of lacustrine systems (Wetzel, 1975). Nutrient enrichment (eutrophication) of lacustrine systems tends to stimulate the proliferation of phytoplankton and submerged macrophytes (along with their attendant epiphytic and nonattached microflora) until their respective populations become limited by self shading. As this process continues, the emergent macrophytes assume an increasingly more dominant role over the entire ecosystem eventually encompassing a majority of the lacustrine basin.

Consumers

Animals present in the littoral zone are dependent upon the type of substrate. The psammon is the community of animals characteristic of sand substratum. The psammon is represented mainly by tardigrades, nematodes and harpacticoid copepods.

Typical epiphytic (on plants) consumers are pond snails, damselfly and dragonfly nymphs (Odonata), flatworms (Turbellaria), bryozoa, hydras and midge larvae (Tendipedidae). Pond snails and midge larvae are primary consumers (herbivores), and feed on attached microalgae and detritus, respectively. Damselfly and dragonfly nymphs are carnivores.

The surfaces of nonliving littoral substrata are inhabited by Odonata nymphs, isopods, and certain mayfly nymphs. Consumers living within mud substrata consist of burrowing Odonata, Ephemeroptera (mayflies), clams, annelid worms, snails, and especially characteristic of littoral muds, the larvae of Tendipedids (midges) and other Diptera.

Consumers swimming or resting on the surface are primarily insects. Most representative are the water striders of the family Gerridae.

Zooplankton, found throughout the waters of the littoral zone, are most commonly represented by species of Cladocera and of Cyclopoid and Harpacticoid copepods. The zooplankton of the littoral zone differ from those of the pelagial zone in being less buoyant, frequently clinging to plants or resting on the bottom when inactive.

Typical representatives of free-swimming forms are predacious diving beetles (Dytiscidae), water boatmen (Corixidae), and tadpoles of frogs.

Effects of Eutrophication on Species Composition. As lacustrine systems become more nutrient-rich and primary productivity is increased (causing hypolimnetic waters to become anoxic during stratified periods and increasing the metabolic products of decomposition), the number and diversity of animal species increase in the well-oxygenated littoral zone. In turn, habitat diversity increases and species interactions become more complex (Wetzel, 1975). If the phytoplankton becomes so abundant that the submerged macrophytes are shaded out, habitat and species diversity are reduced.

Decomposers

Populations of bacteria are considerably more dense and faster growing in the littoral zone than the pelagial zone (Wetzel, 1975) . The difference between the two zones is greatest in spring (the period of active growth of emergent macrophytes) and in fall (during senescence). The difference is probably due to extensive quantities of organic materials released by plants during growth and senescence. Rates of decomposition are slower for emergent macrophytes than for floating leaved and submergent macrophytes due to the greater quantities of lignin in the tissues of the emergents (Sculthorpe, 1967 in Wetzel, 1975) . Lignin decomposition is dependent upon fungi.

SPECIAL ECOLOGICAL CHARACTERISTICS

The littoral subsystem is an interface between terrestrial and lacustrine systems. Its extent relative to the rest of the system depends on basin morphology. Where the lacustrine system is small and shallow the littoral vegetation constitutes a major source of synthesis of organic matter that contributes significantly to the productivity and regulation of metabolism of the whole system. "The littoral region can be viewed as functioning as an effective but selective metabolic sieve or sink for certain dissolved organic compounds and inorganic nutrients from littoral and external sources before they reach the pelagic zone" (Wetzel, 1975).

LIMNETIC SUBSYSTEM

DEFINITION

The limnetic subsystem consists of bottom sediments extending from the edge of the littoral zone to the bottom of the lacustrine basin.

Any one or a combination of three habitat types characterize this subsystem: aquatic bed, rock bottom, and unconsolidated bottom (Table 6-1). The nature of the substrate is a significant factor in determining the abundance, variety, and distribution of benthic organisms (Cowardin et al., 1979).

CHARACTERISTIC BIOTA

Producers

Plants species composition is a function of substrate type and light available for photosynthesis. Plants of the aquatic bed habitat type are discussed under the littoral zone subsystem. Plants associated with rock bottoms and unconsolidated bottoms are rare; when present they consist mainly of benthic-attached microalgae.

Consumers

Animals of the limnetic subsystem are typically distributed in relation to their requirements for feeding, growth, and reproduction. Protozoa are a significant component. Their food consists mainly of bacteria, detritus, algae, and other protozoa. Oligochaetes (earthworms) and Tenthredinid (midge) larvae are often the two dominant faunal groups on lake bottoms (Wetzel, 1975).

Effects of Eutrophication on Species Composition. As lacustrine systems become more productive, limnetic species diversity, respiration rates, growth, and survival of adapted benthic animals are reduced, and some insect larvae increase the duration of their life cycles from 1-2 years (Wetzel, 1975). Extreme eutrophication can result in the total elimination of all aquatic insects. The only benthic fauna tolerant of these conditions are oligochaete annelids.

Decomposers

Bacteria comprise the majority of the decompose component of this subsystem. Bacteria are of major importance in the dynamics of phosphorus cycling; and, along with fungi and planktonic and benthic invertebrates, determine the amount of oxygen present in the sediments.

SPECIAL ECOLOGICAL CHARACTERISTICS

The oxygen content in the mud-water interface is an important ecological feature regulating chemical exchanges at the sediment boundary. A well-oxygenated interface prevents significant releases of soluble components (e.g., iron, manganese) from the sediments, and scavenges materials such as phosphorus from the overlying water (Wetzel, 1975). The exchange of phosphorus between the sediments and water column is a major component of the phosphorus cycle in natural lacustrine systems. The sediments act as a phosphorus sink. A variety of physical, chemical and biotic factors affect the transport of phosphorus in the sediments back to the water.

PELAGIAL SUBSYSTEM

DEFINITION

The pelagial subsystem is the open water region of the lacustrine ecosystem from the edge of the littoral zone to the center of the basin, and down to, but not including, the bottom sediments.

CHARACTERISTIC BIOTA

Producers

Producers consist entirely of phytoplankton. The main taxa are the Cyanophyta (blue-green algae), the Chlorophyta (green algae) and the Chrysophyta (diatoms). Many environmental factors interact to control and regulate growth of the phytoplankton. The major factors are light, temperature, and nutrients (primarily nitrogen and phosphorus). Seasonal patterns of species succession relate to changes in these physical and chemical factors. Blue-green algae, for example, can persist through periods of nitrate impoverishment by fixing nitrate-nitrogen from atmospheric elemental nitrogen. Consequently, blue-green algae are usually found dominating the phytoplankton at the end of the growing season when nitrate has been depleted by non-nitrogen fixing forms.

The highest densities of phytoplankton typically occur in spring and fall in response to favorable conditions of light, temperature, and nutrient availability. Low water temperatures and reduced light during winter result in lower growth and reproduction rates. This results in the accumulation of regenerated and introduced nutrients which form available surplus for rapid algal growth when light and temperature become favorable again in spring.

Consumers

Consumers in the pelagial subsystem consist of a diverse assemblage of organisms representing nearly all animal phyla. Predominant are planktonic (drifting) and nektonic (swimming) forms. The zooplankton are dominated by three major groups: Rotifera, Cladocera, and Copepoda. Zooplankton are distributed primarily by water movements. Strong, persistent winds typically result in an accumulation of the crustacean zooplankton in the shallower waters at the leeward end of lacustrine basins. Zooplankton are also found concentrated in the epilimnion in upwelling areas between foamline streaks where adjacent convectional helices converge (Langmuir troughs) (Wetzel, 1975). In turn, zooplanktivorous fish often assume the same patchy distribution.

Although fish are an integral part of the lacustrine system, the amount of energy and carbon flux through this component is small in most lacustrine systems (Wetzel, 1975).

Effects of Eutrophication on Species Composition. Eutrophication can bring about shifts from cold water, high oxygen requiring fish, (e.g., salmonids) to species such as carp, which are more tolerant of eutrophic conditions. Carp can so modify the substrate that the submergent macrophytes are eliminated. The resulting increase in turbidity and reduced light penetration cause primary production to decline. Survival of larval fish is also reduced by changes in the littoral zone and increased organic deposition brought about by eutrophication. Coldwater fish are restricted to relatively nutrient-poor (oligotrophic) systems in which hypolimnion does not become oxygen-limiting for them. Such fish are typically among the first organisms to disappear in response to eutrophication.

Decomposers

The decomposers of the pelagial zone are predominately bacteria. Compared with the lignified tissue of littoral vegetation, pelagial detritus is decomposed more readily and completely as it descends through the water column.

SPECIAL ECOLOGICAL CHARACTERISTICS

Lacustrine systems in the study area, being in the temperate zone, are subject to thermal stratification during summer as a result of differential heating and cooling of upper and lower regions of the water column. Stratification is characterized by the upper waters (epilimnion) becoming temporarily isolated from the lower waters (hypolimnion) by a thermocline (metalimnion) where temperature declines abruptly with depth. The waters of the epilimnion continue to circulate in response to wind friction over its surface, but the thermocline prevents the extension of mixing to the hypolimnion. The thermocline thus acts as a barrier to the exchange of solids, liquids and gases between the epilimnion and hypolimnion. Nutrients accumulate in the hypolimnion and become potentially limiting to phytoplankton growth in the epilimnion. Oxygen may become limiting to certain biota. The extent of oxygen depletion during summer stratification depends on the depth of the thermocline and the amount of detritus. The greater the amount of detritus, the more subject the system is to oxygen depletion. Spring and fall are characteristically accompanied by wind-generated mixing of the entire water column (overturn), made possible by the obliteration of the thermocline when isothermal conditions are approached through seasonal cooling or warming of the surface waters. The fall and spring overturns are extremely important physical processes, affecting lacustrine metabolism by reoxygenating the lower waters and enriching the upper waters with nutrients. The heat budget in reservoirs may differ greatly from that of natural lakes if water is released from the bottom of the dam, as in the case of dams associated with hydroelectric power generation. Bottom water is cold, nutrient-rich and oxygen poor, and its discharge causes the reservoir to stay warm and nutrient-poor.

Detritus is a major component of lacustrine systems, constituting most of the organic matter. Very little of the total organic component of the system is living. Of detritus, about 90 percent is dissolved organic matter and the remaining 10 percent is particulate. Most of the soluble components of dissolved organic matter are rapidly used by bacteria in usually less than 5 days. Particulate organic matter is decomposed at the rate of about 10 percent per day (Saunders, 1972 in Wetzel, 1975). "The metabolism of detrital organic matter results in a complex carbon cycle that dominates both the structure and function of aquatic ecosystems" (Wetzel, 1975).

CHAPTER 7 PALUSTRINE ECOSYSTEMS

GENERAL CHARACTERISTICS

Definition

Palustrine habitats are comprised of all nontidal wetlands dominated by trees, shrubs, persistent emergent vegetation, emergent mosses or lichens, and all such tidal wetlands where ocean-derived salinity is less than 0.5 ‰ (parts per thousand). They are also wetlands which may lack such emergent vegetation, but have all the following characteristics:

- o size less than 8 hectares (20 acres)
- o active wave-formed or bedrock shoreline features are lacking
- o maximum depth is less than 2 meters at low water
- o ocean-derived salinity less than 0.5 ‰ (Cowardin, et al., 1979)

Habitat Types

The palustrine definition was developed to group the vegetated wetlands traditionally known as marshes, swamps, bogs, fens, and prairies, as well as vernal pools and small, shallow water bodies traditionally known as ponds. Habitat types within the palustrine system are listed in Table 7-1. No hierarchical divisions are made at the subsystem level (Cowardin et al., 1979). There is only a single unnamed subsystem that includes all the habitat types of the littoral (nearshore) subsystem of the lacustrine system except rocky shore habitat types, and also includes vegetated wetlands and vernal pool habitat types.

Detailed descriptions of littoral habitats are given in Chapter 6, and vegetated wetlands and vernal pools are given in Chapter 8. Refer to the equivalent habitats as listed in Table 7-1 for detailed discussions of those palustrine habitats. The remainder of this chapter presents general discussion of ponds.

Ecosystem Model

Permanent ponds are essentially small lakes. The physical-chemical, biological and socio-economic processes and activities working in pond ecosystems are similar to those working in lake ecosystems; only the magnitudes of some parameters are different due to the difference in size of the water body. These general differences are illustrated in the palustrine ecosystem model (Figure 7-1), which is identical to a lacustrine ecosystem model (Figure 6-1). The following discussions refer to the numbered footnotes in Figure 7-1.

Heating (Footnote #1). Heating from insolation can affect a relatively larger portion of the water body in ponds than in lakes because ponds are generally more shallow. Some shallow ponds may develop an even temperature profile from top to bottom in summer. Thermal stratification may not occur, and the ponds may remain well mixed throughout the summer. The absence of thermal stratification may preclude the pond's use as habitat for coldwater fishes (e.g., salmonids) that would occupy the cool, deeper waters in summer.

Turbulence (Footnote #2). Part of the definition of open-pond palustrine habitats is that active wave-formed shoreline features (beaches) are lacking. Due to the small size of ponds, there is insufficient wind fetch to form waves large enough to affect shoreline features. Lack of wave action is conducive to the colonization of the shoreline by floating-leaved and emergent aquatic plants.

Table 7-1. Palustrine Habitat Types and Equivalent Habitat Types in Lacustrine and Terrestrial Systems

<u>Palustrine System¹</u>		<u>Littoral Lacustrine¹ (chapter 6)</u>		<u>Terrestrial ²</u> <u>(chapter 8)</u>
<u>Class</u>	<u>Subclass</u>	<u>class</u>	<u>Subclass</u>	
Rock bottom:	Bedrock Rubble	Rock bottom:	Bedr Rubble	
Unconsolidated bottom:	Cobble/gravel sand Mud Organic	Unconsolidated bottom:	Cobble /gravel sand Mud Organic	
Aquatic bed:	Algal Aquatic nwss Rooted vascular Floating	Aquatic Bed:	Algal Aquatic moss Rooted vascular Floating	
Unconsolidated shore:	Cobble/gravel Sand Mud Organic Vegetated	Unconsolidated shore:	Cobble/gravel Sand Mud organic Vegetated	
Moss wetland				Bogs and fens
Emergent wetland :	Persistent-seasonally fluctuating moisture Persistent--ennial moisture Nonpersistent			Vernal marsh Freshwater marsh Vernal pool
Scrub/shrub wetland				Freshwater swamp
Forested wetland				Freshwater swamp

¹From Cowardin et al. (1979).

²Modified from Cheatham and Haller (1975).

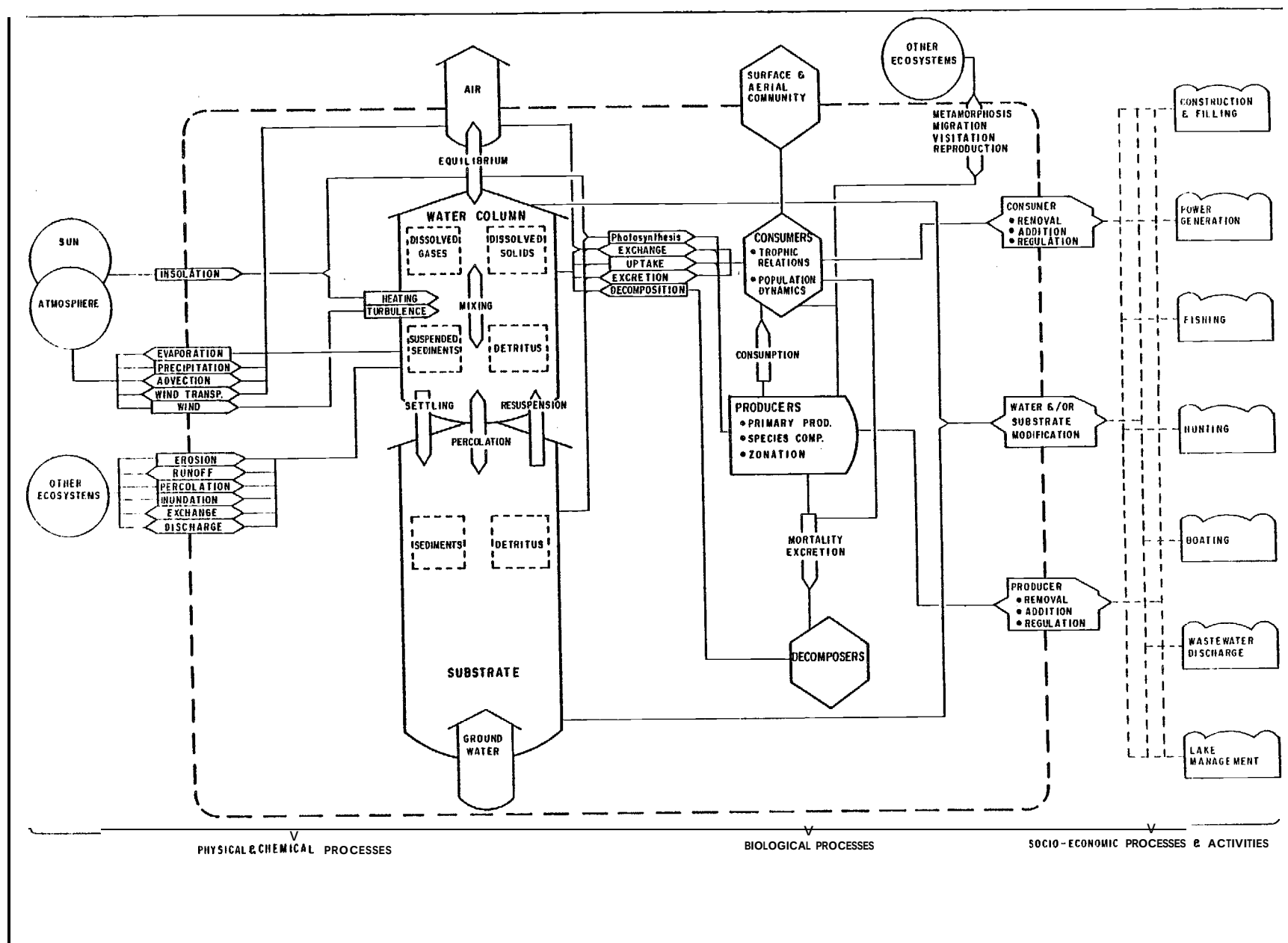


Figure 7-1. Model of Palustrine Ecosystem

Effects of Human Activities (Footnote #3). Small ponds are generally more susceptible than large lakes to the effects of human activities because the ratio of shoreline length to water volume is greater in ponds. Human activities which have their points of impact along the shoreline of ponds include logging, grazing, urbanization, and agriculture.

CHAPTER 8 TERRESTRIAL ECOSYSTEMS

GENERAL CHARACTERISTICS AND ECOSYSTEM MODELS

Terrestrial ecosystems are distinguished from aquatic ecosystems by the presence of soil and air as the life-mediums for living organisms. The "dominant" organisms in terrestrial ecosystems are characteristically vascular plants. They are dominant in the sense that their removal would cause the greatest alteration in the abiotic and biotic properties of the ecosystem (Daubenmire, 1968b). For example, removal of trees from forested ecosystems radically alters both microclimatic and soil conditions for other plants and animals. The vertical extent of terrestrial ecosystems is determined by the height of the dominant vascular plants (Mueller-Dombois and Ellenberg, 1974).

Characterization of terrestrial ecosystems is enhanced by diagrammatic representations (i.e., models) of ecosystem components and processes. An ecosystem model focuses attention on objects and phenomena that directly determine ecosystem structure and function. A terrestrial ecosystem model was developed for this report; it is introduced in Vol. II, Part 1 and is described briefly below.

Terrestrial ecosystems in the study region exhibit tremendous variability in topography, local climate, soils, flora and fauna. Processes that link these abiotic and biotic components are also extremely diverse. Meaningful characterization of terrestrial ecosystems also requires a classification scheme to categorize "ecosystem types" and thereby illustrate the similarities and differences between the types. In effect, a classification scheme partitions the apparent regionwide variability in ecosystem properties into categories that can be comprehended. The terrestrial ecosystem classification scheme is introduced in Vol. III, Chapter 2 and is discussed in the following section.

To characterize ecosystem structure and function, it is useful to consider the operational environments of terrestrial organisms. An operational environment is comprised of the abiotic and biotic phenomena that directly affect an organism during its life cycle and determine its survival and reproductive output (Mason and Langenheim, 1957). Operational environments of terrestrial organisms can be subdivided into microclimate and substrate. Microclimate is the atmospheric portion of an ecosystem and is a function of vegetation and soil conditions as well as a function of local topography and regional climate (Major, 1951). Substrate is the soil (or other rooting medium) portion of a terrestrial ecosystem. The effective factors that determine plant growth and distribution are moisture (microclimate and substrate), chemical (microclimate and substrate), light, heat (microclimate and substrate), and mechanical (from both biotic and abiotic sources) (Waring and Major, 1964).

The generalized terrestrial ecosystem model (Figure 8-1) depicts the important biological processes that link producer organisms to their operational environments. The physical-chemical processes through which microclimate and substrate are linked to each other and to sources and sinks outside the ecosystem are also indicated. Important properties of microclimate (e.g., radiant energy available to photosynthetic surfaces) and substrate (e.g., soil gases available for root and decomposer respiration) are depicted as well.

The biotic component of a terrestrial ecosystem includes producers, consumers, decomposers, and dead organic matter (i.e., both detritus and dissolved organic compounds). The model shows processes linking these organisms and organic products to each other; to microclimate and substrate; to other ecosystems as sources of seed, consumer migrants, and spores; and to other ecosystems as sources of fire, wind, and flood disturbances.

Human activities interact with natural ecosystems through socio-economic processes (Figure 8-1). These processes are identified by their specific and direct effects on internal ecosystem components. For example, a socio-economic activity commonly known as road-building has at least two direct impacts within a terrestrial ecosystem.

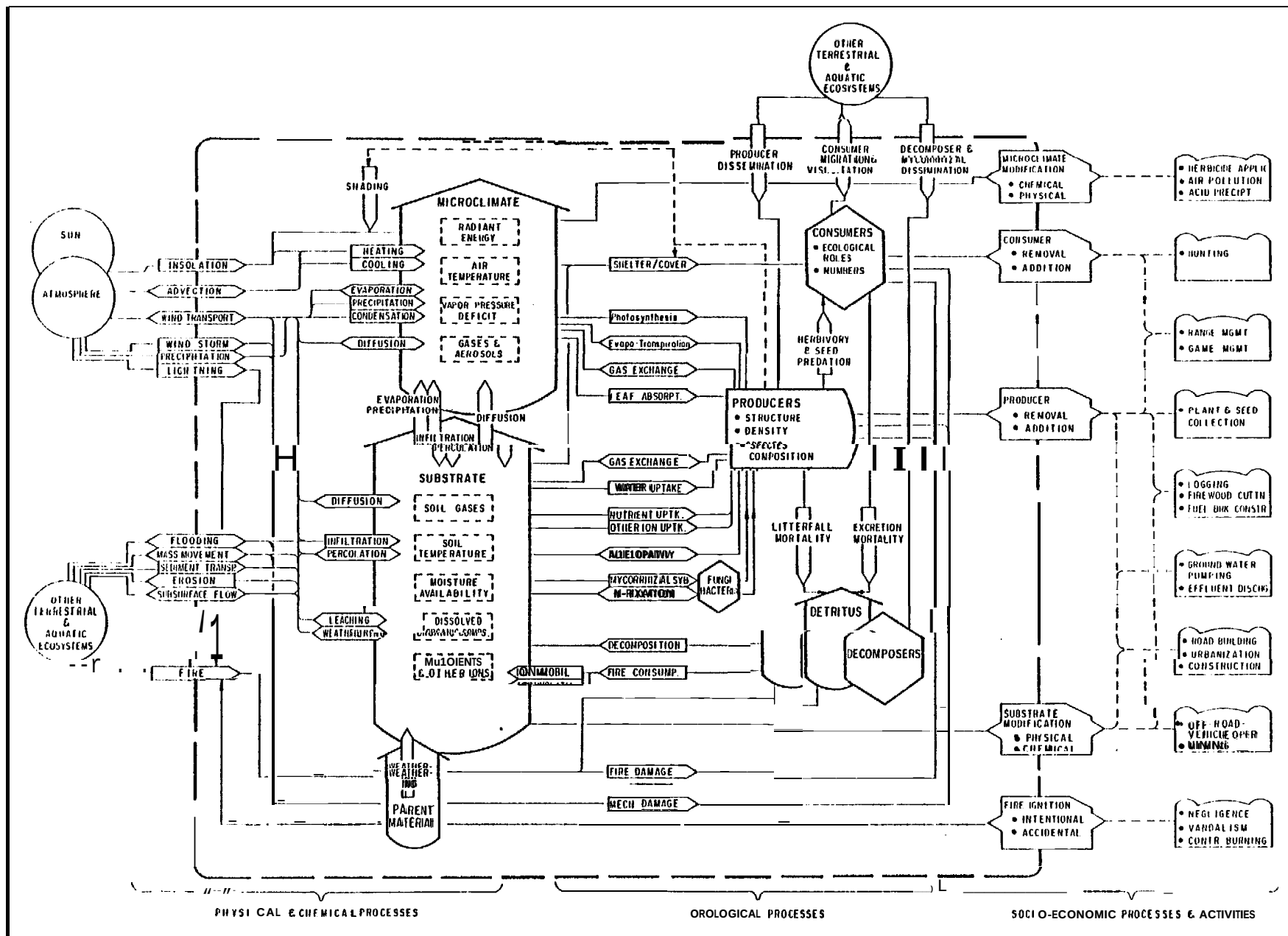


Figure 8-1. Model of a General Terrestrial Ecosystem

It removes producer organisms in clearing right-of-way, and it physically modifies the substrate in grading the road bed. It should be noted that artificial ecosystems in which human activities have essentially supplanted natural ecosystem processes are not represented by Figure 8-1.

All processes, components, and symbols in the generalized terrestrial ecosystem model are more fully explained in Volume II, Part 1, Chapter 4. A key to the symbols used in the model may be found in Appendix A of this volume. Important processes and flows of energy and matter across ecosystem boundaries and to and from ecosystem components have been diagrammed. No attempt was made to incorporate all possible processes and components of terrestrial ecosystems.

The following sections of this chapter characterize the 15 terrestrial cover types (Volume 111, Part 1, Chapter 2 details the classification system and the following section treats it briefly). For each cover type, the terrestrial ecosystem model is made specific by highlighting a number of processes and components that are prominent in causing the distinctive character of that particular cover type. Each highlighted process or component is then annotated with a description of its importance in the cover type. Not all important processes or components are emphasized in this way, only those most prominent in distinguishing one cover type from another. The cover type ecosystem models will be most useful if flows of energy and matter are traced forwards and backwards from highlighted processes and components. In this way, important relationships in cover type ecosystem functioning can be revealed.

ECOSYSTEM CLASSIFICATION

The terrestrial classification scheme is based on the ecosystem concept that structural and functional features of organisms are adaptive to the environmental complexes they encounter. Vascular plants dominate terrestrial ecosystems. The vegetation component of an ecosystem is an integrated expression of the multiple environmental factors operating on it. Therefore, an ecological classification of terrestrial ecosystems identifies areas of land that support vegetation with similar structural and functional adaptations to environmental conditions (Daubenmire, 1978). Similarity of features such as dominant plant life form (e.g., coniferous tree, broad-leaved tree, shrub, herb), vegetation physiognomy (i.e., external appearance which is a function of biomass structure, height, and density), and dominant plant species composition is used to indicate similar types of terrestrial ecosystems.

A primary objective of the classification scheme is to link habitat type information in this chapter with perceivable natural units of the study region landscape. The classification scheme facilitates habitat type information retrieval by means of a three-level hierarchical arrangement of classification units (Chapter 2). The scheme is modified from the classification system for California habitat types of Cheatham and Hailer (1975).

At the most general level, a "habitat class" groups areas of similar dominant plant lifeform (or of similar substrate characteristics for wetland and dune ecosystems). Six habitat classes represent grassland, shrubland, broad-leaved forest and woodland, conifer forest, wetland, and coastal strand ecosystem types. The habitat classes are subdivided into 15 cover types. A "cover type" is based on similarity of the external appearance of vegetation (e.g., height, density, spacing, numbers of layers) and similarity of gross environmental characteristics (e.g., local climate, topography, and substrate). At the most specific classification level, the cover types are subdivided into 46 habitat types based on a common dominant plant species or a common set of dominant plant species. The classification hierarchy is depicted in Table 2-2 of Chapter 2 of this volume.

Habitat type information is retrieved by matching a field site with the classification unit that best describes it at each progressively more specific level of the hierarchy. Ecosystems classified in the same habitat type are expected to have similar biotic components and similar conditions of microclimate, substrate, seed availability, and disturbance history.

The study region extends over nearly 8 degrees of latitude. The regional climate of southern watershed units is hotter and drier than the regional climate of the northern watershed units. A wide diversity of topography, soils, local climates (e.g., exposure to marine air flows), elevations, and disturbance histories is superimposed on the latitudinal variation in regional climate. The resulting heterogeneity of local site conditions often produces geographically discontinuous types of vegetation and associated fauna. Complex mosaics of radically different kinds of ecosystems are common.

Early efforts to classify California's vegetation and landscape delineated broad continuous geographic zones based on regional climates, geomorphic provinces, or floristic associations. For example, Munz and Keck (1949) proposed five "biotic provinces" for California, two of which encompass the study region.

The "Oregonian" biotic province includes the cool moist coastal strip extending southward from the Oregon border to the San Lorenzo River watershed unit with small areas in the Morro Bay watershed unit. Floristic and faunal elements of the Oregonian biotic province are related over evolutionary time to plants and animals common to more northern latitudes. The "Californian" biotic province encompasses the areas of Mediterranean-type climate where winters are cool and wet and summers are hot and rainless. It includes interior valleys and foothills, and the coast ranges and coastal areas southward from the San Lorenzo River watershed unit. Many plant species of the Californian biotic province are California endemics. In general, the flora of this province is evolutionarily related to plants typical of southern California and Mexico (Raven and Axelrod, 1978).

A number of classifications of California vegetation types or plant communities have been developed. Munz and Keck (1973) classified "plant communities" as defined by the presence of certain dominant species. Seventeen of their plant communities occur in the study region. Thorne (1976) classified California "plant communities," using Munz and Keck's (1949) definition, but subdividing many of their classification units. Thirty of Thorne's plant communities occur in the study region. Kuchler (1977) produced a map of the "natural vegetation" of California with 21 of his vegetation types occurring in the study region.

The CALVEG system of the U. S. Forest Service, Region 5 will eventually classify and map all of California's vegetation at three hierarchical levels (Parker and Matyas, 1978). At its completion, "formation," "plant communities," and "associations" will be mapped and classified throughout California. A "plant community" level vegetation map has been produced at a scale of 1:250,000. Color infrared LANDSAT imagery (at scales of 1:1,000,000 and 1:250,000) was visually interpreted to produce the map. Verification of map delineations was minimal, consisting of reference to existing soil-vegetation maps and to knowledge of persons with previous field experience.

Parker and Matyas (1978) estimate an approximate 80 percent accuracy for their plant community map. Sources of inaccuracy include errors in image interpretation, inclusions of small vegetation units within large areas of different plant communities, and the small imagery and mapping scales used. Given the knowledge that inaccuracies may exist, the CALVEG map is still considered a useful approximation and was used as the source of the watershed unit cover type maps (see Chapters 3 through 24 of Volume IV).

One of the purposes of this report was to characterize terrestrial ecosystems. This objective requires classification and identification of land areas that are relatively equivalent with respect to ecosystem structure and function. An ecological classification scheme (as opposed to a geographical scheme) uses similarities of vegetation morphology and physiology as well as taxonomy to indicate ecological equivalence among discontinuous and often widely scattered land areas (Daubenmire, 1968b). A plant's adaptive structure and function constitutes an integrated expression of the multiple environmental factors operating on it (Daubenmire, 1968b; Kuchler 1977).

Cheatham and Hailer (1975) developed a "habitat type" classification scheme to be used by the University of California Natural Land and Water Resources System. A "habitat type" is defined by them to be "an assemblage of natural features of the landscape" that is "sufficiently different to warrant separate description". Each designated "habitat type" was annotated with descriptions of its distribution, ecological features, and characteristic species.

The Cheatham and Haller (1975) classification was modified and used as the terrestrial ecosystem classification scheme for this report. Of the available systems, the authors of this report felt it was most appropriate as an ecological classification. Modifications involved grouping or subdividing classification units in some cases to make the modified list of habitat types conform to the distribution of habitat types in the study region. The chosen terrestrial ecosystem classification scheme is presented in Table 2-2. Correspondence of classification units with those of Munz and Keck (1973), Thorne (1976), Kuchler (1977), and Parker and Matyas (1978) is also indicated.

ECOSYSTEM CHARACTERIZATION

Cover Types

A cover type encompasses all ecosystems with similar external appearance of vegetation, or, in some cases, similar gross environmental characteristics. A habitat type is a subdivision of a cover type and is based on a common dominant plant species or a common set of dominant plant species. Cover type characterizations (that comprise the rest of this chapter) discuss phenomena common to all habitat types included in each cover type. The following topic headings will be found in each cover type discussion.

Physiognomy. Typical appearance of cover type vegetation, general environmental settings, and the most salient functional characteristics of the cover type are described.

Habitat Types Included in the Cover Type. Habitat type subdivisions of the cover type are listed, with characteristic dominant plant species and regional distribution in North and South Coast Ranges.

Climate. Regional climatic parameters are indicated. In general, regional climates are not distinctive between cover types in the study region. Exceptions to this lack of climatic distinction are several habitat types restricted to coastal sites of high precipitation and frequent summer fogs.

Topography. Typical landforms, aspects, slope angles, elevation range, and distance from the ocean are described.

Substrate. Where possible, information is given on typical soil types, soil depth, texture, nutrient status, drainage characteristics, and parent materials. Substrate conditions are often significant in causing distribution patterns of cover types in local areas.

Vegetation. Typical structural features of cover type vegetation are described. Height, density, and life-form composition of the vegetation strata are indicated.

Vegetation Seasonality and Modes of Reproduction. This section characterizes functional aspects of cover type vegetation. Leaf characteristics (e.g., "deciduousness" versus "evergreenness," drought-deciduous versus winter-deciduous), seasons of primary photosynthetic activity, and reproductive modes (e.g., obligate seeders versus sprouters, wind-distributed versus gravity-dispersal) are noted.

Characteristic Fauna. Mammals, birds, amphibians, and reptiles characteristic of the cover type are listed.

Biomass Productivity and Food Web. Patterns of energy flow in ecosystems of the cover type are described. Data on typical rates of primary productivity are available for several cover types.

Important Biotic Interactions. This section considers interactions between biotic components (i.e., producers, consumers, decomposers, dead organic matter) that distinguish ecosystems of one cover type from ecosystems of another.

Important Abiotic Interactions. Soil development and abiotic disturbance events (e.g., fire, wind, flood) constitute important interactions in many cover types.

Associated Cover Types. The landscape of the study region exhibits wide variability in local site conditions. Often several cover types are associated in local mosaics due to differences in topography, substrate, and disturbance histories.

Vegetation Succession. Succession is a plant-by-plant replacement process whereby some species replace other species (Horn, 1974). In a successional sequence, species characteristic of one cover type replace species characteristic of a previous cover type. Directions and rates of replacement are determined by:

- 1) Favorability of site conditions (i.e. , microclimate and substrate) .
- 2) Seed supply (species composition and abundance) .
- 3) Disturbance patterns (presence or absence; intensity; frequency of disturbances such as fire, seed and seedling predators, flood, wind) .
- 4) Chance (Whittaker, 1953).

A steady-state is achieved when the species replacement process ends. Species composition and total standing crop of living and dead biomass oscillate about a mean (Bormann and Likens, 1979; Whittaker, 1953).

In cases where information is available, typical successional patterns are suggested for cover type vegetation. Several widespread cover types are maintained by recurrent disturbance factors. Without disturbance these cover types will be replaced by others. In ecosystems of some cover types, steady-state conditions of biomass accumulation and species composition may be possible. Some cover types may be successional in certain environmental situations and steady-state in others.

Typical Land Uses. Historical and current land uses are noted.

Sensitivity to Disturbance. This section considers the resiliency of ecosystems in the cover type to human-induced disturbance. Resiliency is the ability of an ecosystem to absorb disturbance and return to its original condition over a relatively short period of time (Bormann and Likens, 1979). Low soil erodibility and ability to revegetate rapidly after disturbance are primary aspects of ecosystem resiliency.

Ecosystem Model. Ecosystem processes and components that are significant in the cover type are highlighted on the generalized terrestrial ecosystem model and annotated (see Figure 8-1).

Habitat Types

A habitat type groups all ecosystems that are dominated by the same plant species or set of plant species. Forty-six terrestrial habitat types have been described in the study region. Habitat type descriptions specify conditions and features unique to each habitat type. The following topics are described for each habitat type.

Distribution. This section describes important geographic, topographic, and substrate characteristics of the habitat type. Typical spatial associations with other habitat types or cover types are noted.

Watershed Units. Watershed units of the study region where the habitat type occurs are listed.

Vegetation. Structural and functional features of habitat type vegetation are described.

Characteristic Plants. Plants that characteristically occur in the habitat type are listed by lifeform (i.e. , trees, shrubs, forbs, grasses). Some plants listed in this section may be "characteristic" but not universally found over the entire distribution of the habitat type.

Succession. Successional relations of habitat type vegetation are discussed. For example, if the habitat type is typically in a successional sequence with other habitat types, this is noted.

Discreteness and Intergradation

Throughout this report, cover types and habitat types are classified and characterized as if they occur as discrete units on the landscape. In some cases, cover types and habitat types exhibit discrete boundaries, such as occur at parent material contact zones or at historical fire perimeters. However, in many cases, cover types and habitat types intergrade both spatially and temporally with each other. For example, "boundaries between Douglas fir forest, slope redwood forest, and mixed evergreen forest habitat types are frequently indistinct in the North Coast Ranges. Temporal intergradation occurs when young plants of a future cover type occur among older individuals of the present cover type.

Although not normally discrete in the field, cover types and habitat types represent modal points on real world continuums of vegetation composition, vegetation density, and other ecosystem characteristics.

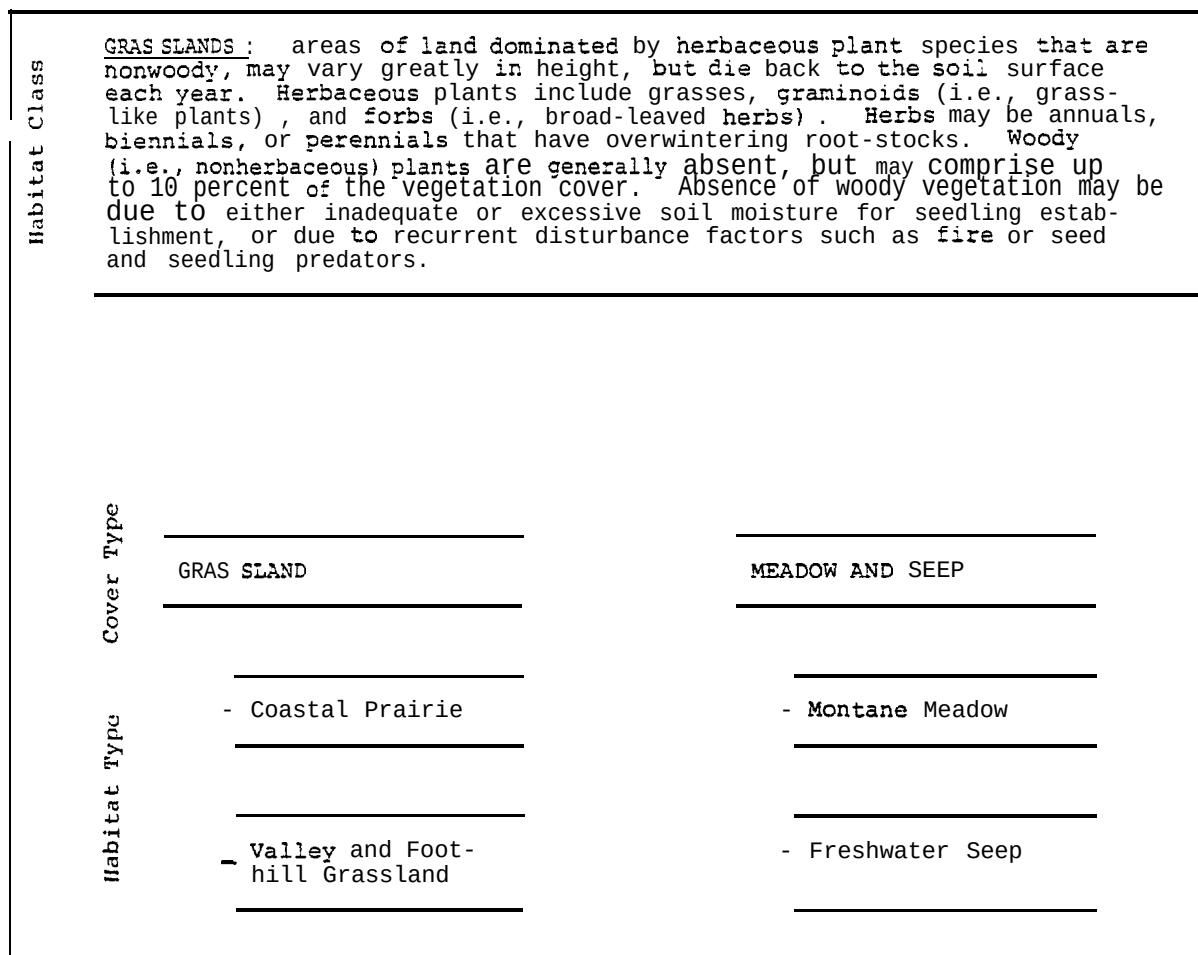


Figure 8-2. Hierarchical Dendrogram of Component and Cover Types for Grasslands.

GRASSLAND HABITAT CLASS

The grassland habitat class is comprised of two cover types; the Grasslands and Meadow and Seep which are described in the next two sections.

GRASSLAND COVER TYPES

Physiognomy.

Land areas in the grassland cover type are dominated by *annual* and perennial grasses and forbs. Herbaceous cover ranges from dense to sparse and plant heights range up to 1.8 meters (m) or 6 feet (ft) in years of moist, warm spring seasons. Common species include both natives and exotics introduced from other Mediterranean-type climates (e.g., southern Europe, Australia). Many of the natives are perennial bunchgrasses and were more abundant and widespread previous to European settlement of California (Heady, 1977). The grassland cover type intergrades with and forms the herbaceous ground cover in the oak woodland cover type. It also intergrades with chaparral and coastal scrubland cover types on soils of coarser texture or where range burning has been practiced. The habitat types are given in Table 8-1.

Table 8-1. Habitat Types in Grasslands

Habitat	Dominant Plants	Regional Distribution
Coastal prairie	California oatgrass (<u>Danthonia californica</u>) Red Fescue (<u>Festuca rubra</u>) Idaho fescue (<u>Festuca idahoensis</u>)	North and South Coast Ranges
Valley and foothill grassland	Wild oats (<u>Avena fatua</u>) Soft chess (<u>Bromus mollis</u>) Filaree (<u>Erodium</u> spp.)	North and South Coast Ranges

Climate.

Annual precipitation is highly variable and may range from 200 centimeters (cm) or 80 inches (in) in north coastal California to less than 10 inches in inland valleys of the South Coast Ranges. Total precipitation may vary by as much as 64 cm (25 in) from one year to the next, depending on local weather patterns (Pitt and Heady, 1978). Virtually no precipitation falls between June and September. The growing season is 7-11 months; mean maximum summer temperatures are 27°C-35°C (80°F-95°F) and mean minimum winter temperatures are 0°-3°C (32°F-38°F). Precipitation is higher and temperature fluctuations are narrower in areas of the coastal prairie habitat type (Barbour, et al., 1973).

Topography.

The grassland cover type occupies coastal terraces, inland valleys, foothills, ridges, and south-facing slopes. Coastal prairie habitat type extends up to 100 km (60 mi) inland and grades into valley and foothill grassland habitat type near the inland margin of the coastal conifer forest cover type. Elevations range from sea level up to 900 m (3,000 ft).

Substrate.

The characteristic feature of undisturbed grassland ecosystems is the presence of fine textured clay soils. Heady (1977) reports that most grassland soils are medium to heavy in texture, granular in structure, moderate in organic matter content, several feet deep, and with good fertility. Grassland soils are moist to water saturated during the winter rainy season. Regardless of the annual amount of precipitation, upper horizon soil moisture is depleted for 4-8 summer months each year (Heady, 1977). Coastal prairie soils are often strongly acid due to leaching of bases from the soil profile by high rainfall.

Soils in grassland habitat types are often subject to slumping due to a combination of the following conditions. Heavy clay horizons become saturated with moisture, lubricated, and susceptible to the pull of gravity. Bedding planes of parent materials are parallel to slope faces, and tree roots are not present to bind soil layers. Frequent soil slippage prevents establishment and survival of trees.

Vegetation.

Land areas in this cover type are dominated by annual and perennial grasses and forbs. Density, productivity, and species composition vary spatially.

Vegetation Seasonality and Modes of Reproduction. Perennial species initiate active growth with warm temperatures in early spring (March-April). Peak growth activity and flowering is from late spring through early summer for coastal prairie species and from winter through late spring for valley and foothill grassland species. Perennial species are generally dormant through the June-October dry season. Annual species germinate and initiate growth with first substantial rains of late fall (November-December). Except when limited by low temperatures, annual growth continues through winter and spring, with maturity and seed set by early summer (Cheatham and Hailer, 1975). The period of rapid spring growth brings on a progression of different dominant species, with significant changes in plant density and biomass per unit area as the season progresses (Heady, 1977). Relative dominance of grasses versus forbs in a particular year depends on temperature and precipitation patterns following fall germination (Pitt and Heady, 1978).

Characteristic Fauna. Characteristic mammals of grassland cover types are taken from Ingles (1965). Small (1974) and Van Velzen (1971) provide information on common California birds in grassland habitats. Common or characteristic reptiles and amphibians are derived from Stebbins (1966). Species listed below in Table 8-2, although characteristic of grasslands, are not found exclusively in this cover type. Abbreviations (e.g., TI, TIE, TA, etc.), following species common names refer to types of consumers in the general food web for this cover type (see food web, Figure 8-3, for explanation of abbreviations). See the Community Composition List, Volume III, Part 2, for more information on species listed below, and for information on characteristic invertebrate species.

Table 8-2. Characteristic Fauna of a Grassland Cover Type¹

Mammals	Birds	Reptiles and Amphibians
Ornate shrew (TI)	Western meadowlark (TIE) (SFE)	Rough-skinned newt (TA)
Broad-handed mole (TI)	Horned lark (S'FE) (TIE)	California newt (TA)
Black-tailed hare (SH)	Burrowing owl (CB) (TIE)	California slender salamander (TA)
Audubon cottontail (SH)	Grasshopper sparrow (SF's) (TIE)	Western toad (TA)
Beechey ground squirrel (SE) (SH) (TI) (SC)	savanna Sparrow (SFE) (TIE)	Western fence lizard (TR)
Pocket gopher (SH)	Long-billed curlew (SFE) (TIE)	Western skink (TR)
Heermann's kangaroo rat (SE) (SH)	Brewer's blackbird (TIE) (SFE)	Alligator lizard (TR)
Western harvest mouse (SE) (TI)	Western bluebird (TIE) (SFE)	Rubber boa (TR)
California meadow mouse (SH)	Ring-necked pheasant (SFE) (TIE)	Racer (TR)
Townsend meadow mouse (SH)	American kestrel (CB) (TIE) (SS)	Gopher snake (TR)
Coyote (LC) (TI)	Red-tailed hawk (CB) (SB)	Western terrestrial garter snake (TR)
Long-tailed weasel (SC)	Turkey vulture (SB)	
Badger (SC)	White-tailed kite (CB)	
Striped skunk (SC) (TI)		

¹See Figure 8-3 for definition of abbreviations.

Biomass Productivity and Food Web. Annual biomass productivity in the valley and foothill grassland habitat type varies significantly as a function of weather patterns and amounts of residual mulch (Heady, 1977). Low amounts of mulch (i.e., dead biomass from previous year) result from grazing food chains. High amounts of mulch supply detrital food chains. Mulch affects biomass production through its influence on soil surface physical conditions that favor seedling establishment, soil micro-organisms, water infiltration, and rapid organic matter decomposition.

Primary consumers of herbaceous foliage include mammals, such as the black-tailed hare, pocket gopher, and California meadow mouse and phytophagous insects, such as the field cricket (see Figures 8-3 and 8-4). Seed production is consumed by mammals, such as the beechey ground squirrel, Heermann's kangaroo rat, and western harvest mouse; and birds, such as the horned lark and savanna sparrow. Important secondary consumers include insectivores, such as the ornate shrew, broad-handed mole, western

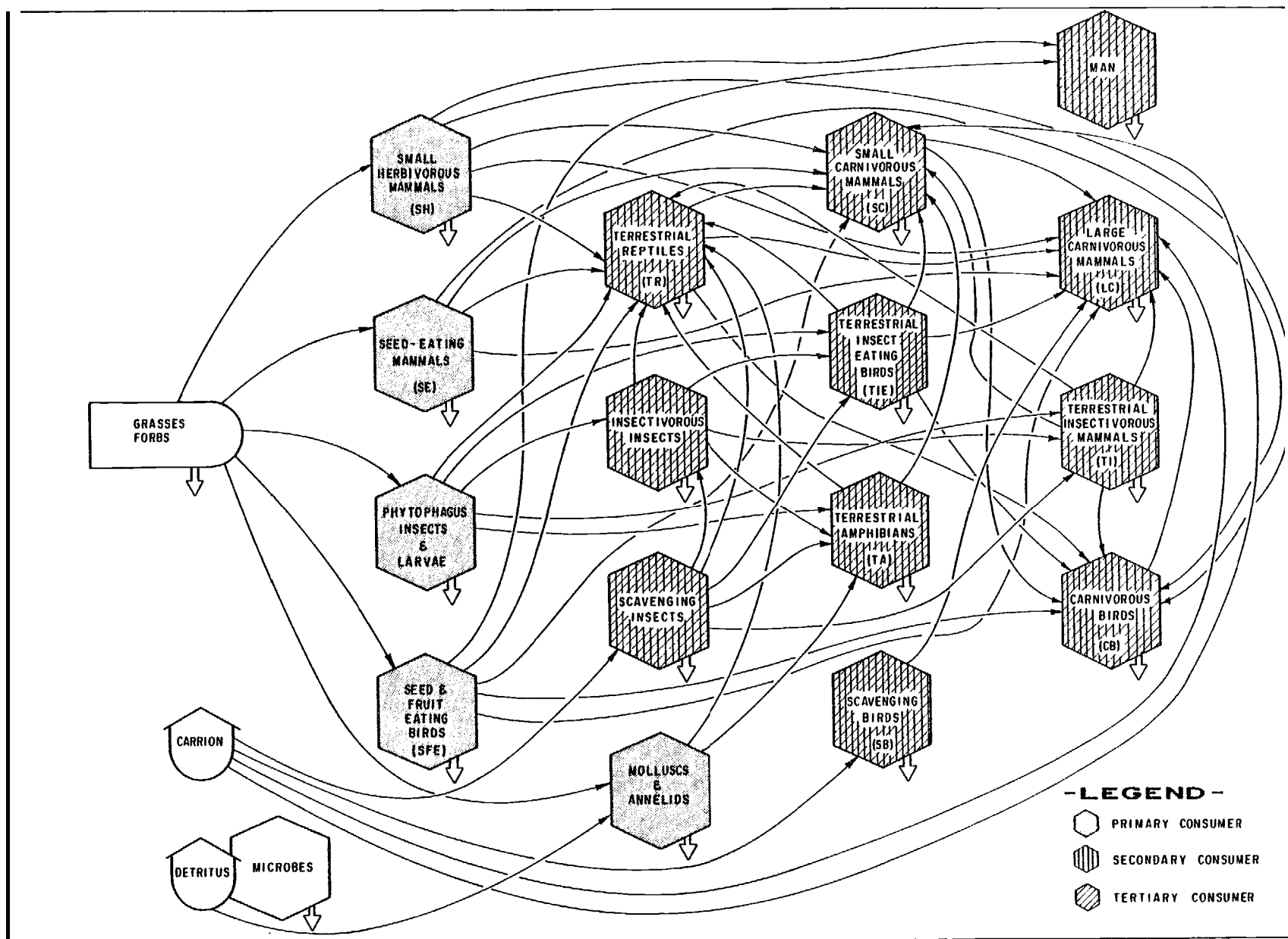


Figure 8-3. General Food Web - Grasslands

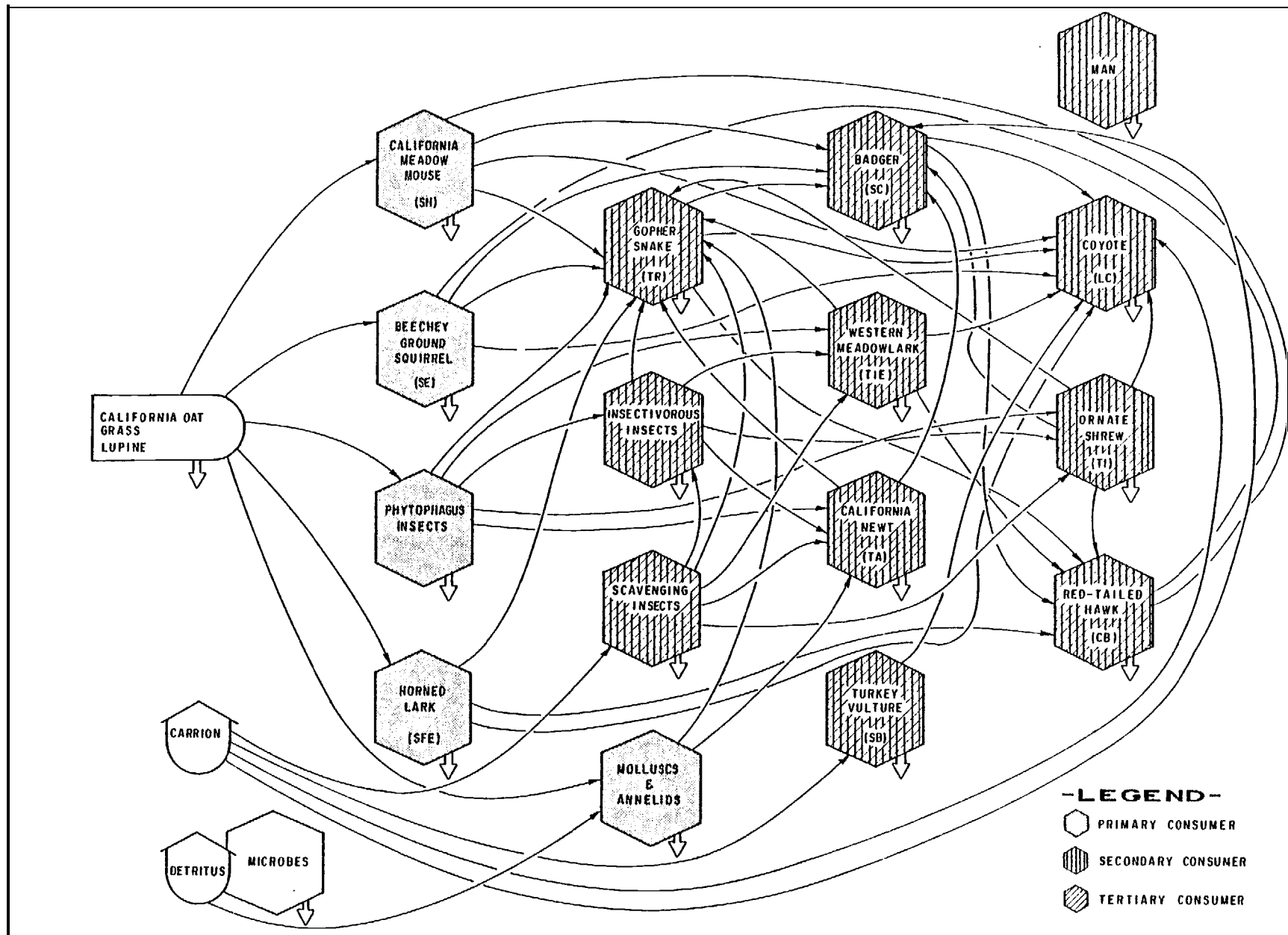


Figure 8-4. An Example of a Grassland Food Web

skink, western toad, western meadowlark and western bluebird; and carnivores, such as the long-tailed weasel, badger, red-tailed hawk and gopher snake. The turkey vulture is a common scavenging bird. These, as well as other secondary consumers, also function as tertiary consumers, feeding on secondary as well as primary consumers. For example, the badger may feed on the pocket gopher (a primary consumer) as well as the broad-handed mole (a secondary consumer). The beechnut ground squirrel is an excellent example of an omnivore, consuming seeds, vegetative parts, insects and bird eggs. Many functions primarily as a carnivore, consuming various game birds and mammals (LC).

Important Biotic Interactions. The primary biotic interaction in habitat types of the grassland cover type is the effect of grazing animals on biomass productivity and species composition. For example, meadow mice (*Microtus californicus*) may significantly affect vegetation structure and composition, seed production, and arthropod abundance in grassland ecosystems (Batzli and Pitelka, 1970). Introduction of domestic grazing animals had a major role in converting grasslands dominated by native perennial bunchgrasses to introduced annual grasses and forbs. Cessation of grazing allows recovery of native perennials (Heady, et al., 1977).

Important Abiotic Interactions. Weather patterns, fire frequency, and substrate characteristics constitute important abiotic influences in grassland ecosystems. Fire and weather patterns have been discussed above. Grasses are better adapted to heavy clay soils than other life forms such as shrubs and trees. Clay soils are relatively impervious to both water and oxygen once they are saturated with moisture during the rainy season. Therefore, during the wet season, shallow rooted plants are favored on soils of high clay content. Clay soils dry more rapidly than coarser soils, favoring plants that pass through the dry season in a dormant stage (bunchgrasses) or a seed stage (annual grasses and forbs). Grassland habitat types are more common on south-facing aspects due to higher soil and air temperatures, more rapid soil drying, and greater fire frequency.

Associated Cover Types. Ecosystems of the meadow and seep cover type occupy sites of perennially high soil moisture within the grassland cover type. The grassland cover types may occupy sites of higher clay content and south aspects within all other cover types of the study region.

Vegetation Succession. The grassland cover type may be either seral or steady state (Figure 8-5), depending primarily on substrate characteristics and the availability of seeds of shrubs and trees. Many ecosystems currently in the grassland cover type may require fire or heavy grazing pressure to prevent shrub and tree establishment. Only the most xeric sites (e.g., heavy clay soils, south aspects) can be considered steady state grassland ecosystems over the long term.

Typical Land Uses. Many grassland areas have been used for agriculture and grazing over the last hundred years. More recently, many valley floor and coastal terrace grassland ecosystems have been developed for residential and commercial uses.

Sensitivity to Disturbance. Grassland ecosystems in the North Coast Ranges are highly susceptible to slumping due to the presence of heavy clay soils on steep slopes. Road building activities may greatly increase problems of soil instability. Ability of annual grass species to regenerate from seed stored in the soil facilitates rapid vegetation recovery following disturbances such as fire and overgrazing. Perennial species recover more slowly.

Ecosystem Model. Important processes and components of ecosystems in the grassland cover type are highlighted in Figure 8-6.

Habitat Type Description: Coastal Prairie

Distribution. The coastal prairie habitat type occurs on coastal terraces, ridges, and south-facing slopes from Del Norte to Marin County, with a scattered distribution southward to Monterey County. It extends inland to near the inner margin of the coastal conifer forest cover type. At inland and southern limits, it intergrades with the valley and foothill grassland habitat type. Ridgetop sites of coastal prairie in the midst of coastal conifer forest are called "bald hills." This habitat type intergrades with coastal scrubland, coastal conifer forest, and broad-leaved evergreen forest cover types on coarser soils with less clay, or on sites previously cleared for agriculture or grazing.

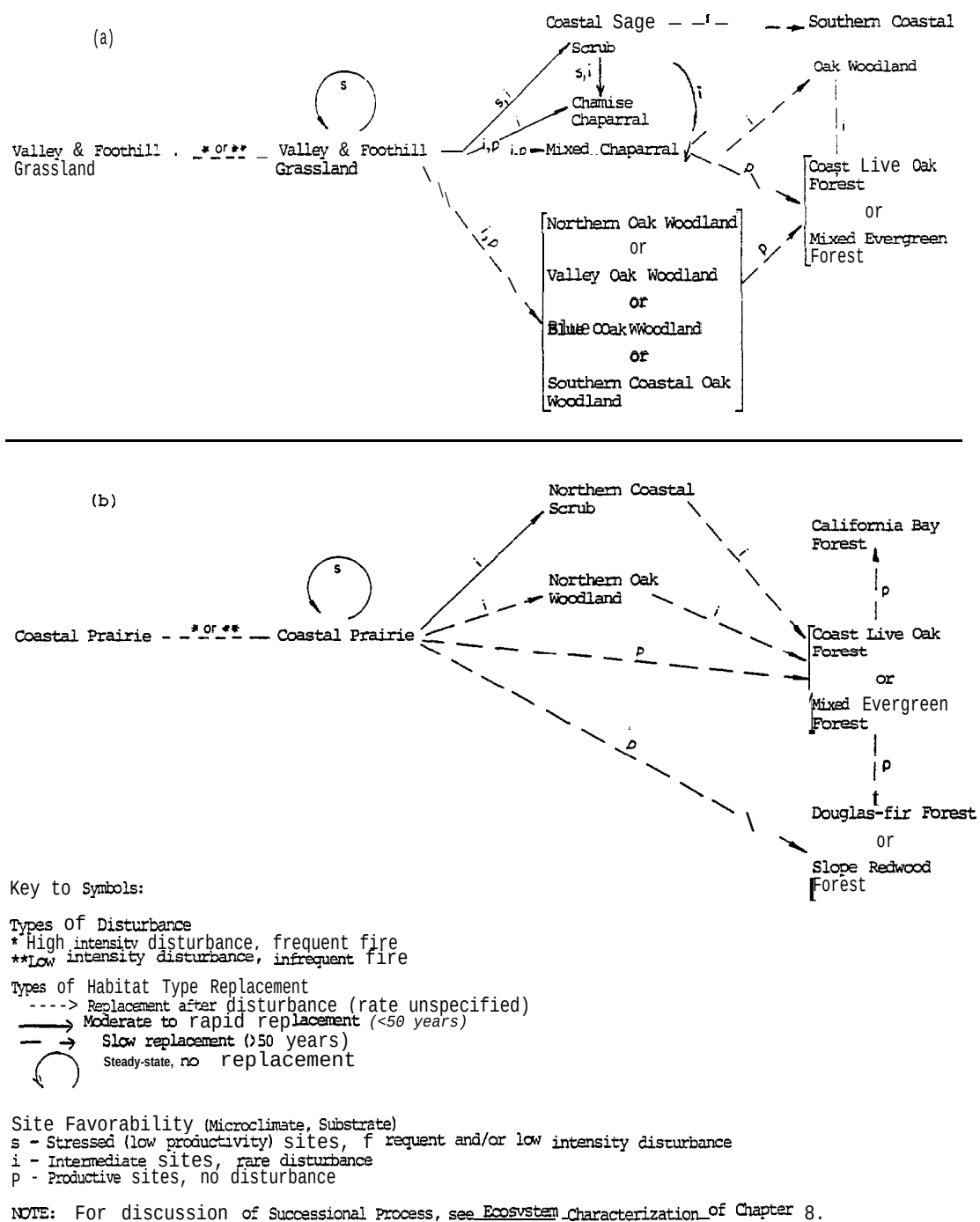


Figure 8-5. Successional Sequences (a-b) Suggested for Grassland Habitat Types

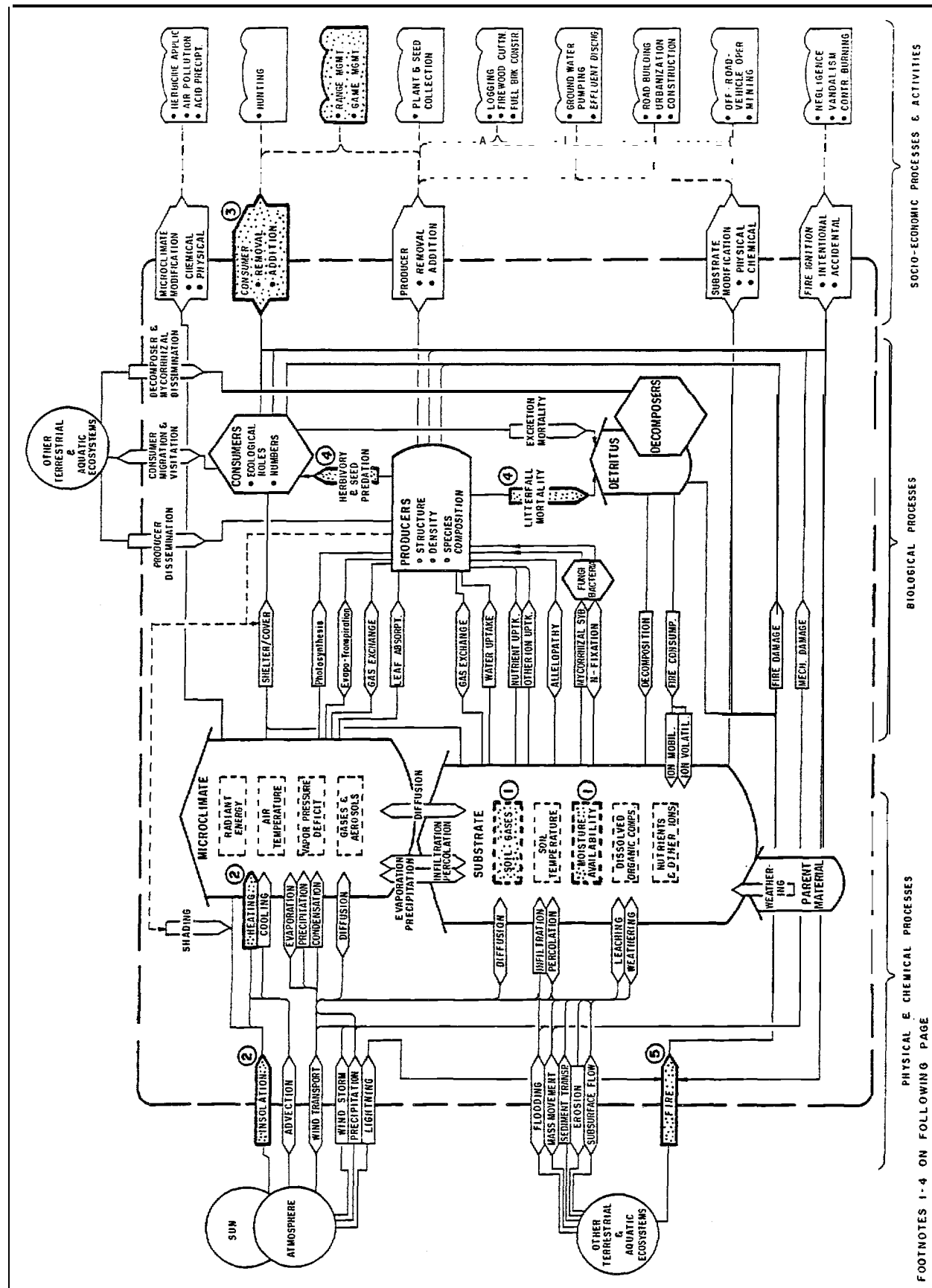


Figure 8-6. Ecosystem Model - Grassland Cover Type

Footnotes for Figure 8-6.
Ecosystem Model for the Grassland Cover Type-
Highlighted Processes and Components are Annotated Below

1. SOIL GASES AND MOISTURE AVAILABILITY: Typical grassland soils are fine textured and heavy with clay. These soils often become water-logged during the winter rainy season. Waterlogging prevents adequate aeration of soil gases such as oxygen necessary for deep root growth. When soil moisture is depleted during the summer dry season, annual grasses set seed and perennial grasses enter dormancy. Shallow-rooted trees and shrubs are usually unable to survive summer drought. Invasion of trees and shrubs, therefore, is inhibited on heavy, clay soils (Wells, 1962).
2. INSOLATION AND HEATING: South-facing slopes receive more intense insolation throughout the year. As a result, soils on south-facing aspects are hotter and drier, earlier in the season, than north-facing aspects. Fuels are also dried earlier in the season, allowing more rapid spread and intensity of fires when they do occur. These conditions often maintain grassland "balds" on south-facing slopes within forested regions of the North Coast Ranges.
3. CONSUMER ADDITION AND REMOVAL: Historically, overgrazing by domestic cattle facilitated replacement of native grass species by introduced annual grasses. Reduction in grazing pressure may allow native bunchgrasses to reestablish on some sites of the coastal prairie habitat type (Heady, 1977). Livestock browsing on seedlings may prevent invasion of grassland ecosystems by shrubs and trees in some areas.
4. LITTERFALL AND HERBIVORY: Grassland biomass can either be consumed by herbivores or fall as litter to decomposes. Balance of litterfall (i.e., mulch) versus herbivory in a particular year determines biomass productivity and plant species composition in the subsequent year (Heady, 1977).
5. FIRE: Grass species are well adapted to fire because they pass through the summer and fall fire season either as fire-proof seeds (annuals) or as dormant root-crowns (perennials). Frequent fire may be necessary to maintain the grassland cover type on sites where trees and shrubs can establish (e.g., coarser soils, greater soil moisture availability).

Watershed Units. Smith River, Klamath River, Mad River, Eel River, Mattole River, Noyo River, Gualala River, Russian River, Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo River, Pajaro River, Elkhorn Slough, Salinas River, Camel River, Morro Bay.

Vegetation. Coastal prairie vegetation is typically a dense cover of native perennial bunchgrasses and perennial herbs to 1 m (3 ft) tall. Relatively cool summer temperatures favor native grass species of genera common at more northerly latitudes and at medium to high elevations in interior mountains (Crampton, 1974). Introduced Mediterranean grasses and forbs are also locally common. Dominant species vary with latitude and with distance from the ocean (Heady et al., 1977).

Table 8-3. Characteristic Plants of a Coastal Prairie

Plant Type/Common Name	Scientific Name
<u>Native Grasses</u>	
California oatgrass	<u>Danthonia californica</u>
Hairgrass	<u>Deschampsia caespitosa</u> spp. <u>holciformis</u>
Pacific reedgrass	<u>Calamagrostis nutkaensis</u>
Idaho fescue	<u>Festuca idahoensis</u>
Red fescue	<u>F. rubra</u>
<u>Introduced Grasses</u>	
Sweet vernal grass	<u>Anthoxanthum odoratum</u>
Velvet grass	<u>Holcus lanatus</u>
Hairy oatgrass	<u>Danthonia pilosa</u>
<u>Forbs</u>	
Douglas iris	<u>Iris douglasiana</u>
Buttercup	<u>Ranunculus californicus</u>
Blue-eyed grass	<u>Sisyrinchium bellum</u>
Bracken fern	<u>Pteridium aquilinum</u>
Ribgrass (introduced)	<u>Plantago lanceolata</u>

Succession. Successional patterns in the coastal prairie habitat type are unclear due to unknown effects of past disturbances. The presence of typical grassland soils in many coastal prairie sites, as well as the existence of a number of locally endemic native species suggest that coastal prairie vegetation is possibly steady state in these sites (Heady et al., 1977). Grazing pressure from domestic animals, elimination of annual fires, cultivation, and introduction of highly competitive exotic species have radically altered the composition of coastal prairie vegetation. Heady et al., (1977) suggest that native coastal prairie species may have evolved with only light grazing pressure but with frequent fires set by local Indian groups. Reduction in grazing pressure on some sites has allowed a return to dominance of native perennial species. Elimination of grazing and fires may allow successional progression to coastal scrubland and broad-leaved evergreen forest cover types (McBride, 1974). Many grassland sites on north coastal terraces were previously cleared for agriculture and will develop successional to coastal conifer forest cover type.

Habitat Type Description: Valley and Foothill Grassland

Distribution. The valley and foothill grassland habitat type occupies valley floors, surrounding foothills, and upper south-facing slopes in scattered locations throughout the coast ranges south from Mendocino County. This habitat type intergrades with coastal prairie habitat type along the central coast; with oak woodland cover type on moister, better drained soils; and with chaparral cover type on rockier soils or where annual range burning has occurred (Cheatham and Hailer, 1975).

Watershed Units. Noyo River, Gualala River, Russian River, Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo River, Pajaro River, Elkhorn Slough, Salinas River, Carmel River, Morro Bay, Santa Maria River, San Antonio Creek, Santa Ynez River, Point Arguello.

Vegetation. Originally, vegetation of this habitat type consisted of a dense to sparse cover of native perennial bunchgrasses (Table 8-4). Native species have largely been replaced by annual grasses and forbs introduced from other Mediterranean type climates.

Introduced annuals appear better adapted to overgrazing and periodic severe drought by surviving these intense forms of disturbance in the seed stage (Heady, 1977). Species composition and biomass productivity of this essentially annual habitat type vary from year to year depending on temperature patterns, precipitation patterns, amount of mulch from the previous year, and local site conditions.

Table 8-4. Characteristic Plants of the Valley and Foothill Grasslands

Plant Type/Common Name	Scientific Name
<u>Introduced Grasses</u>	
Wild oats	<u>Avena fatua</u>
Soft chess	<u>Bromus mollis</u>
Foxtail fescue	<u>Festuca megalaria</u>
<u>Native Grasses</u>	
Purple needlegrass	<u>Stipa pulchra</u>
Pine bluegrass	<u>Poa scabrella</u>
<u>Introduced Forbs</u>	
Filaree	<u>Erodium cicutarium</u>
Cat's ear	<u>Hypochoeris glabra</u>
Burclover	<u>Medicago hispida</u>
<u>Native Forbs</u>	
Lupine	<u>Lupinus bicolor</u>
California poppy	<u>Eschscholzia californica</u>
Goldfields	<u>Baeria chrysostoma</u>

Succession. Successional trends among annual species of the valley and foothill grassland have been related to differences in grazing pressure. Dominance by forbs, especially in early to middle spring, indicates heavy grazing pressure and lack of residual mulch. Dominance by tall grass species indicates light grazing and plentiful mulch (Heady, 1977). Some areas presently in this habitat type were previously occupied by chaparral or oak woodland cover types, and were cleared to improve grazing resources. Wells (1962) has described interactions of fire frequency and soil characteristics in determining the dominant vegetation life form on a site. Frequent fires on sites of heavy clay soil maintain this habitat type. Less frequent (greater than 10-year interval) fires on coarser soils allow development of oak woodland and broad-leaved evergreen forest cover types. Overgrazing in combination with a greater fire interval may convert grassland ecosystems to chaparral cover type (Dodge, 1977). Overgrazing removes the fuel matrix required to carry frequent, low intensity ground fires which would kill chaparral seedlings and sprouts.

Meadow and Seep Cover Types

Physiognomy. Ecosystems of the meadow and seep cover type are characterized by more or less permanently moist soils and are typically dominated by sedges (Carex spp.) and other perennial herbs (Cheatham and Hailer, 1975). Vegetation is usually dense and the taller species may reach 2m (6 ft) in height (Table 8-5). Soils are fine textured with somewhat restricted drainage. Distinguishing characteristics for the two habitat types are size and associated cover types. Montane meadows may be quite extensive and are generally associated with shrubland, broad-leaved forest, or conifer forest habitat classes on coarser, better drained soils. Montane meadow habitat may be associated with ecosystems of the wetland habitat class (e.g., marshes, swamps, bogs, and fens) on extremely waterlogged soils. Freshwater seeps are usually quite small and confined to areas around perennial springs. They are typically associated with ecosystems of the grassland, chaparral, or oak woodland cover types on fine textured but seasonally drier soils.

Table 8-5. Habitat Types in Meadows and Seeps

Habitat Type	Dominant Plants	Regional Distribution
Montane meadow	Sedges (<u>Carex</u> spp.) Corn-lily (<u>Veratrum californicum</u>) Camas (<u>Camassia quamash</u>)	North Coast Ranges
Freshwater seep	Sedges (<u>Carex</u> spp.)	North and South Coast Ranges

Climate. Climate of this cover type is not distinguishable from that of surrounding associated cover types.

Topography. Montane meadows are typically located in sites of high water tables along slow-moving streams and beside lakes and ponds. Meadows may also occur where impervious underground geologic formations have forced subsurface water movement to the surface. Meadows sometimes result from filling of former lake beds by sedimentation. Freshwater seeps are often located on grassland slopes where outcropping of geologic strata have created perennial springs. Elevations of this cover type range from near sea level to 2,100 m (7,000 ft).

Substrate. Meadows and seeps are characterized by more or less perennially moist, but not waterlogged, fine-textured, mineral soils of alluvial origin. Soils are typically deep, high in organic matter content, and high in fertility. Meadow soils are aerated sufficiently to allow organic matter decomposition, thereby preventing peat accumulation.

Vegetation. Vegetation of this cover type is typically comprised of a dense cover of perennial herbs, with sedges, grasses and rushes particularly important. The relative importance of forbs increases with soil moisture. Meadows and seeps provide suitable sites for plant species that may be limited elsewhere in a large general area by lack of adequate soil moisture (Table 8-5).

Vegetation Seasonality and Modes of Reproduction. The active growth period is delimited by temperature and runs from late spring through summer with most flowering in summer. Winter is typically the dormant season, although growth may occur year round in areas with mild winters. Characteristic plants are perennials, spreading by lateral growth of rhizomes, stolons, or bunchgrass tufts.

Characteristic Fauna. Fauna characteristic of grassland cover types would also be characteristic of meadow and seep cover types. However, because of moister soil conditions, species adapted to this condition, such as the California meadow mouse, California newt and western toad, would be most abundant.

Biomass Productivity and Food Web. Plentiful soil moisture availability and deep, fertile soils facilitate high biomass productivity. Meadows and seeps provide conditions of microclimate, soil, vegetation structure and plant species composition that are often unique to a wide general area. These unique conditions may frequently constitute important habitat requirements for a number of birds, mammals, reptiles and amphibians. Whenever meadows and seeps are associated with more xeric cover types, local wildlife populations are attracted to the greater diversity of bordering vegetation (i.e., the "edge" effect). Therefore, meadow and seep food webs are generally more complex than food webs of surrounding habitat types, but similar to food webs of the grassland cover type.

Important Biotic Interactions. Montane meadows and freshwater seeps are crucial to many wildlife species. For example, they produce abundant, succulent forage throughout the dry summer months when herbaceous components of other cover types are often dormant. The dense vegetative growth of meadows and seeps also provides necessary escape and nesting cover for many species.

Important Abiotic Interactions. Height of water table determines ecosystem productivity, success or failure of tree and shrub seedling establishment, and rate of organic matter decomposition. Failure of organic matter decomposition begins the process of swamp formation (i.e., paludification) (Hasler, 1975). Successful tree seedling establishment begins conversion of meadow ecosystems to forest cover types.

Vegetation Succession. See habitat type descriptions that follow and Figure 8-7.

Typical Land Uses. Meadows and seeps are an important grazing resource. Range livestock concentrate in these sites during late summer when forage in other areas has matured and dried. Campgrounds, residential developments, and roads are often located in meadows because of the high aesthetic quality of these forest openings and ease of construction.

Sensitivity to Disturbance. Stock trails, drainage ditches, and road construction may disturb hydrologic regimes in ecosystems of this cover type. Alteration of hydrologic regimes may upset equilibrium between water table height and dependent ecosystem processes such as biomass accumulation and organic matter decomposition. For example, lowering of meadow water table due to stock trail erosion may accelerate tree invasion and succession of meadow to a forest cover type. Soil compaction caused by foot, animal, or vehicle traffic will diminish meadow and seep productivity.

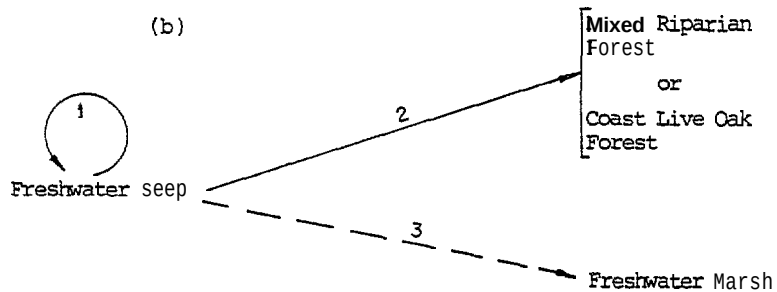
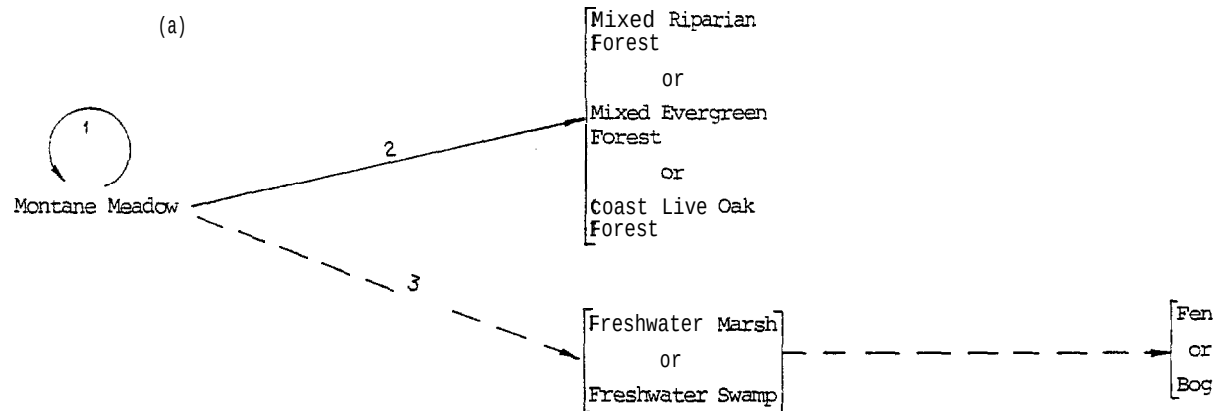
Ecosystem Model. Important processes and components of ecosystems in the meadow and seep cover type are highlighted in Figure 8-8.

Habitat Type Description: Montane Meadow

Distribution. The montane meadow habitat type is scattered throughout the North Coast Ranges within the coastal conifer forest, lower montane conifer forest, and broad-leaved evergreen forest cover types. Occasionally montane meadows may occur within coastal scrubland, chaparral, or oak woodland cover types. Elevations range from 150-2,100 m (500-7,000 ft) (Cheatham and Hailer, 1975).

Watershed Units. No information is available concerning the distribution of montane meadows on individual watershed units. Six Rivers National Forest is currently mapping montane meadows within the forest.

Vegetation. Montane meadow vegetation consists of perennial herbs, especially sedges and grasses, typically dense but more open where meadow ecosystems intergrade with adjacent better drained substrates. Forbs increase in importance with higher soil moisture.



Key to Footnotes and Symbols:

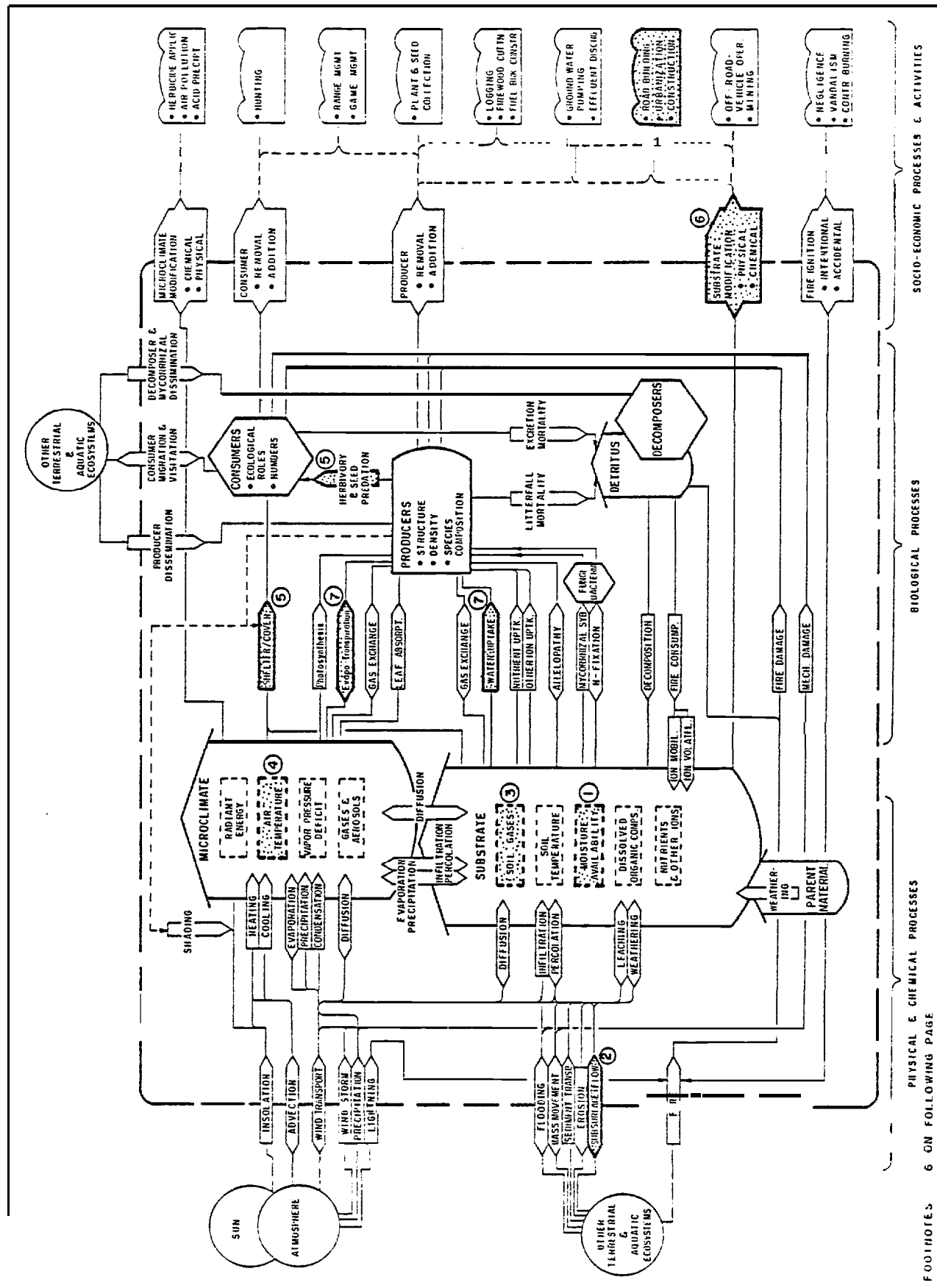
- 1 No alteration of water table, fire and grazing may occur
- 2 Lowering of water table
(e. g., ditching, trail erosion, water diversion, tree establishment and transpiration)
- 3 Rising of water table
(e.g., damming, climatic or geologic change)

Types of Habitat Type Replacement

-> Replacement after disturbance (rate unspecified)
- > Moderate to rapid replacement (< 50 years)
- > slow replacement (>50 years)
- ⬤————> Steady-state, no replacement

NOTE: For discussion of Successional Process, see Ecosystem Characterization of Chapter 8.

Figure 8-7. successional Sequences (a-b) Suggested for Meadows and Seeps



Footnotes for Figure 8-8.
Ecosystem Model for the Meadow and Seep Cover Type-
Highlighted Processes and Components are Annotated Below

1. SOIL MOISTURE AVAILABILITY: Meadow and seep ecosystems are distinguished from surrounding cover types by the presence of more or less permanently moist, but not water-logged, soils. See section on Important Abiotic Interactions in meadow and seep cover type characterization.
2. SUBSURFACE FLOW: Source of perennial soil moisture in this cover type is often subsurface flow of groundwaters from surrounding land areas.
3. SOIL GASES: The extent of circulation of soil gases determines other ecosystem processes. Typically, meadow and seep soils are adequately aerated to allow organic matter decomposition and to prevent peat accumulation. Availability of oxygen in the soil profile determines the forms and amounts of nutrients available to plants.
4. TEMPERATURE : Since soil moisture is perennially available for plant growth, temperature patterns delimit the periods of active growth in meadow and seep ecosystems. In contrast, soil moisture availability delimits growth period in most other cover types of the study region.
5. SHELTER/COVER and HERBIVORY: The meadow and seep cover type is critical to many wildlife species. Meadow and seep ecosystems typically produce greater herbaceous biomass than surrounding cover types, and maintain succulent forage throughout the summer dry season. Plant species composition and vegetation structure of meadows and seeps provide habitat diversity within large areas of other forest, shrubland, or grassland cover types. Meadow and seep ecosystems exhibit unique microclimates due to increased soil moisture availability and increased transpiration by plants. Value of meadows and seeps to wildlife is enhanced by the phenomenon of "edge effect" (Marcot, 1979).
6. SUBSTRATE MODIFICATION: Ditching, road construction, and other substrate modifications will upset the equilibrium between hydrological regimes and other ecosystem processes in this cover type.
7. WATER UPTAKE and EVAPOTRANSPIRATION: Establishment of trees and shrubs in meadows and seeps may increase evapotranspiration, lower water tables, and thereby facilitate conversion to forest cover types.

Table 8-5. Characteristic Plants of a Montane Meadow

Plant Type/Common Name	Scientific Name
<u>Grasses and Grasslike Plants</u>	
Sedges	<u>Carex spp.</u>
Rush	<u>Juncus patens</u>
Tall mannagrass	<u>Glyceria elata</u>
Pacific reedgrass	<u>Calamagrostis nutkaensis</u>
<u>Forbs</u>	
Corn-lily	<u>Veratrum californicum</u>
Camas	<u>Camassia guamash</u>
Bracken	<u>Pteridium aquilinum</u>
Lupine	<u>Lupinus polyphyllus</u>
False hellebore	<u>Veratrum fimbriatum</u>

Succession. Vegetation in montane meadow ecosystems may be steady state where herbaceous cover is sufficiently dense and soil moisture sufficiently high to prevent the establishment of trees and shrubs whose seeds are available. However, succession may proceed in two different directions depending on which of two positive feedback processes is initiated. Tree seedling establishment and growth may lower the meadow water table through transpiration and thus facilitate increased tree invasion of the meadow. In contrast, a slight rising of the water table through climatic or geologic change may begin a process of peat accumulation and succession of meadow to marsh, swamp, bog or fen.

Habitat Type Description: Freshwater Seep

Distribution. Freshwater seep ecosystems are scattered throughout the North and South Coast Ranges within grassland, chaparral, or oak woodland cover types. Freshwater seeps have permanently moist soil, encompass very small areas, and are localized around springs where the water table has been forced to the surface by geologic strata. Seeps are easy to spot in late summer when surrounding grassland has turned to brown but seep vegetation is still succulent and green. Seeps can supply critical forage and water to wildlife during the late summer drought period.

Watershed Units. Distribution of freshwater seeps on individual watershed units is unknown, but they presumably occur wherever springs surface in grassland, chaparral, or oak woodland cover types.

Vegetation. Vegetation of freshwater seep ecosystems is primarily a dense cover of low growing perennial grasses, sedges and forbs.

Table 8-6. Characteristic Plants of a Fresh Water Seep

Common Names	Scientific Names
Sedge	<u>Carex spp.</u>
'Rushes	<u>Juncus spp.</u>
Spike bentgrass	<u>Agrostis exarata</u>
Common monkeyflower	- <u>guttatus</u>
Cinquefoil	<u>Potentilla gracilis</u>
Cowparsnip	<u>Heracleum lanatum</u>

Succession. Height of water table, accessibility of tree and shrub seeds, and fire frequency determine seral or steady state nature of seep vegetation. Without fire and with tree and shrub seed access, freshwater seep habitat type will develop toward the mixed riparian forest habitat type.

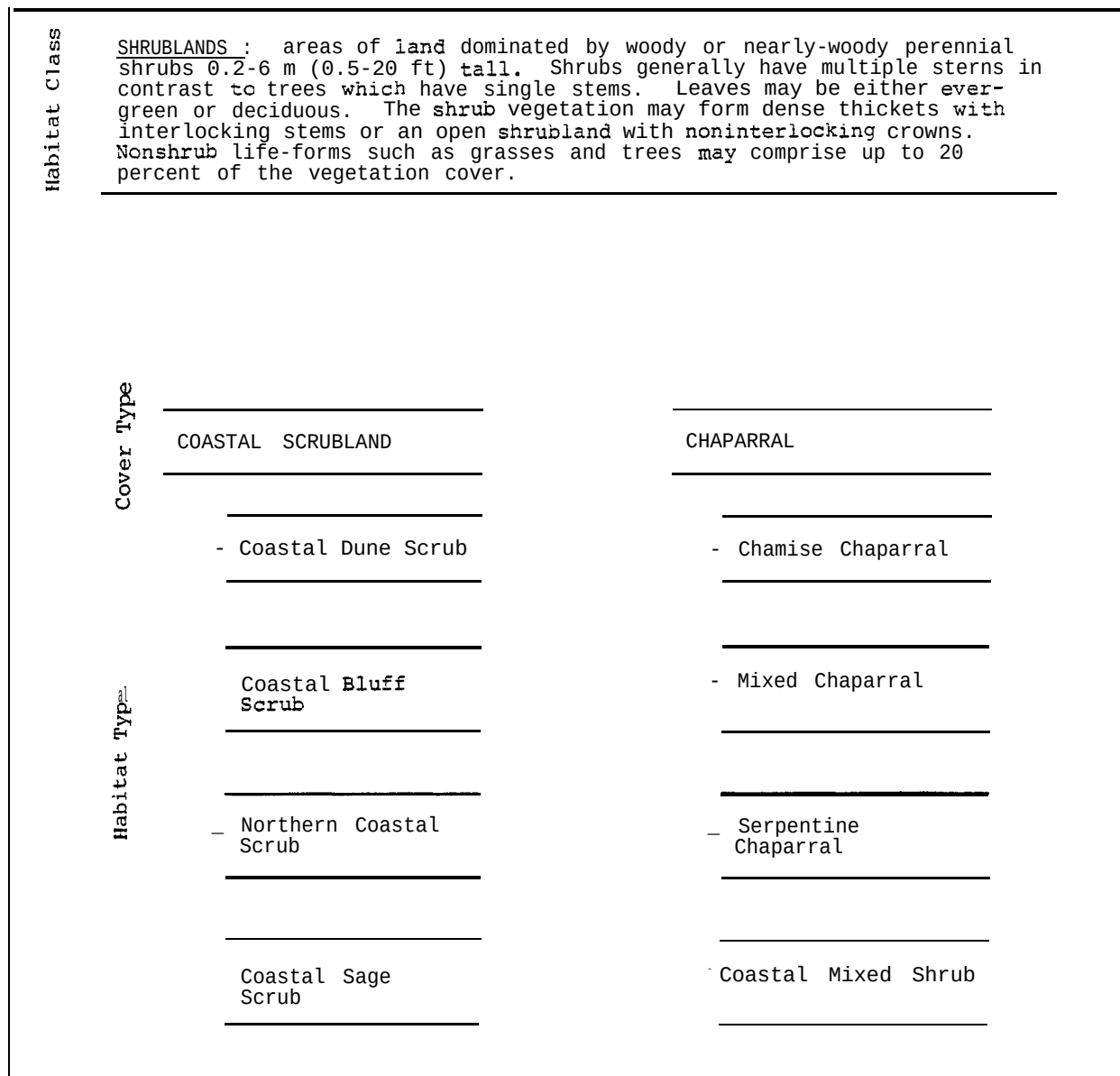


Figure 8-9. Hierarchical Dendrogram of Component and Cover Types for Shrublands

COASTAL SHRUBLANDS HABITAT CLASS

The coastal shrublands habitats described in this section are comprised of scrublands and chaparral.

Coastal Scrubland Cover Type

Physiognomy. Ecosystems of the coastal scrubland cover type described in Figure 8-9 are dominated (70-100 percent cover) by open to dense stands of low evergreen and drought-deciduous shrubs. Shrub heights may range from prostrate to 2.4 m (8 ft) tall. Several common shrub species are semiwoody subshrubs (Wells, 1962). Herbaceous perennials and ferns often comprise a significant proportion of total vegetation cover. Patches of coastal prairie habitat type sometimes occur within the coastal shrubland cover type. Habitat types are given in Table 8-7.

Table 8-7. Habitat Types in Coastal Scrublands

Habitat Type	Dominant Plants	Regional Distribution
Coastal dune scrub	Tree lupine (<u>Lupinus arboreus</u>) Beach sagewort (<u>Artemisia</u> <u>trinocephala</u>)	North and central coasts
Coastal bluff scrub	B u . <u>chamissonis</u> Sea pink (<u>Armeria maritima</u> var. <u>californica</u>)	North and central coasts
Northern coastal scrub	Live-forever (<u>Dudleya farinosa</u>) Coyote brush (<u>-is vilularis</u> Ssp. <u>consanguine</u>)	North and central coasts
Coastal sage scrub	Salal (<u>Gaultheria shallon</u>) Poison oak (<u>Rhus diversiloba</u>) California sagebrush (<u>Artemisia</u> <u>californica</u>) Black Sage (<u>Salvia mellifera</u>)	Central coast only

Climate. Annual precipitation averages 38-100 cm (15-40 in) in this cover type. Fog is common; up to 80 percent of summer days are foggy (Barbour, et al., 1973). Salt-laden winds occur year round but peak during wintertime storms. Mean winter minimum temperatures are 1.6°C-4°C (35°F-40°F) while mean summer maximums are 17°C-24°C (63°F-75°F) (Munz and Keck, 1949). There is little temperature fluctuation on immediate coastal sites. Difference between the mean of the coldest and warmest months is 6°C-8°C (10°F-13°F) (Barbour et al., 1973). Temperatures fluctuate more widely on inland and higher elevation sites. Fog condensation on scrub foliage reduces summer evaporative stress and may supplement soil moisture.

Topography. Coastal scrubland cover type occurs on bluffs, terraces, stabilized sand dunes, and lower mountain slopes in the immediate coastal strip (several km wide in north; 15-30 km [10-20 mi] in south). Elevations range from sea level to 600 m (2,000 ft). The cover type occurs on all aspects but habitat type, density, and species composition may vary with aspect (i.e., direction of slope face) in a local area.

Substrate. Soils differ significantly between the habitat types included in the coastal scrubland cover type. Coastal dune scrub is found on stabilized sand dunes or where wind-blown sand overlies other parent materials. Soils may be deep but are little developed; coarse sandy loams are typical. Coastal bluff scrub occurs on rocky bluffs and outcrops at the ocean front. Soils are extremely shallow due to constant wind and water erosion of soil particles. Soil salinity is high except during winter rainy season and moisture holding capacity of the soil is minimal. Northern coastal and coastal sage scrub habitat types occur on a variety of parent materials. Soils are generally of residual origin (i.e., developed in place from parent materials) rather than wind transported. Textures may vary from coarse to clayey; depths vary from shallow to deep. Where soil conditions are favorable for establishment and growth of tree species, coastal scrub habitat types may be seral to either broad-leaved or conifer forest cover types.

Vegetation. Coastal scrubland cover type is dominated by low shrubs and subshrubs. Most shrub species are evergreen and are more common in the northern coastal areas. In contrast, subshrubs are drought-deciduous, semiwoody, and more common in the central coastal areas. Northern coastal scrub habitat type typically has a two-level shrub canopy with patches of coastal prairie grass species and little bare ground. In contrast, coastal sage scrub is typically single-layered with bare ground common but without grassy patches. Coastal bluff scrub vegetation cover is usually sparse, dominated by semiwoody prostrate shrubs and perennial herbs.

Vegetation Seasonality and Modes of Reproduction. Growth activity is limited by seasonal rainfall patterns and by the low moisture-holding capacity of typical coastal scrubland soils. Most growth occurs from late winter through early summer. Seed germination peaks in midwinter following the first substantial rains. Most shrub and subshrub species sprout from root crowns following fire damage. Subshrub species are typically light-seeded, wind-dispersed, and therefore able to colonize burned and otherwise disturbed sites (Wells, 1962). Drought-deciduous subshrubs are better adapted than evergreen shrubs to sites of long drought duration (Mooney, 1977c).

Characteristic Fauna. Characteristic mammals of coastal scrubland cover types are taken from Ingles (1965). Van Velzen (1971-1975) provides information on common California birds in coastal scrublands. Common or characteristic reptiles and amphibians are derived from Stebbins (1966). Species listed in Table 8-8, although characteristic of coastal scrubland ecosystems, are not found exclusively in this cover type. Abbreviations (e.g., LH, SFE, TA) following species names refer to types of consumers in the general food web for this cover type (for explanation of abbreviations, see Figure 8-10. See the Community Composition List, Volume III, Part 2, for more information on species listed below, and for information on characteristic invertebrate species.

Table 8-8. Characteristic Fauna of a Coastal Scrubland¹

Mammals	Birds	Reptiles and Amphibians
Black-tailed deer (LH)	Rufous-sided towhee (SFE) (TIE)	Tiger salamander (TA)
Gray fox (LC)	White-crowned sparrow (SFE) (TIE)	Western fence lizard (TR)
Coyote (LC) (TI)	Song sparrow (SFE) (TIE)	Sagebrush lizard (TR)
Long-tailed weasel (SC)	Wrentit (TIE) (SFE)	Coast-horned lizard (TR)
Dusky-famed weed.rat (SE) (SH)	Bewick's wren (TIE)	Alligator lizard (TR)
Sonoma chipmunk (SE)	Black-chinned sparrow (SFE) (TIE)	California legless lizard (TR)
Merriam chipmunk (SE)	Orange-crowned warbler (TIE)	Striped. racer (TR)
Pacific kangaroo rat (SE) (SH)	Allen's hummingbird (NE) (TIE)	Common gopher snake (TR)
Vagrant shrew (TI)	House finch (SFE) (TIE)	Western rattlesnake (TR)
Brush rabbit (SH)	American goldfinch (SEE) (TIE)	Ringneck snake (TR)
Deer rouse (SE) (TI)	Peregrine falcon (CB) (SB)	
Western harvest mouse (SE) (TI)		
California bat (FI)		
Desert woodrat (SS) (SH)		
California meadow mouse (SH)		
Pocket gopher (SH)		

¹See Figure 8-10 for definition of abbreviations

Biomass Productivity and Food Web. Net primary productivity is low in coastal scrubland ecosystems. Low temperature and low soil moisture are responsible for limiting productivity (Barbour et al., 1973). Optimum temperature for net photosynthesis in two species of lupine characteristic of the coastal dune scrub habitat type is approximately 21°C (70°F) (Heady et al., 1977). Coastal scrubland temperatures rarely reach 21°C (Barbour et al., 1973). Subshrub species typical of coastal

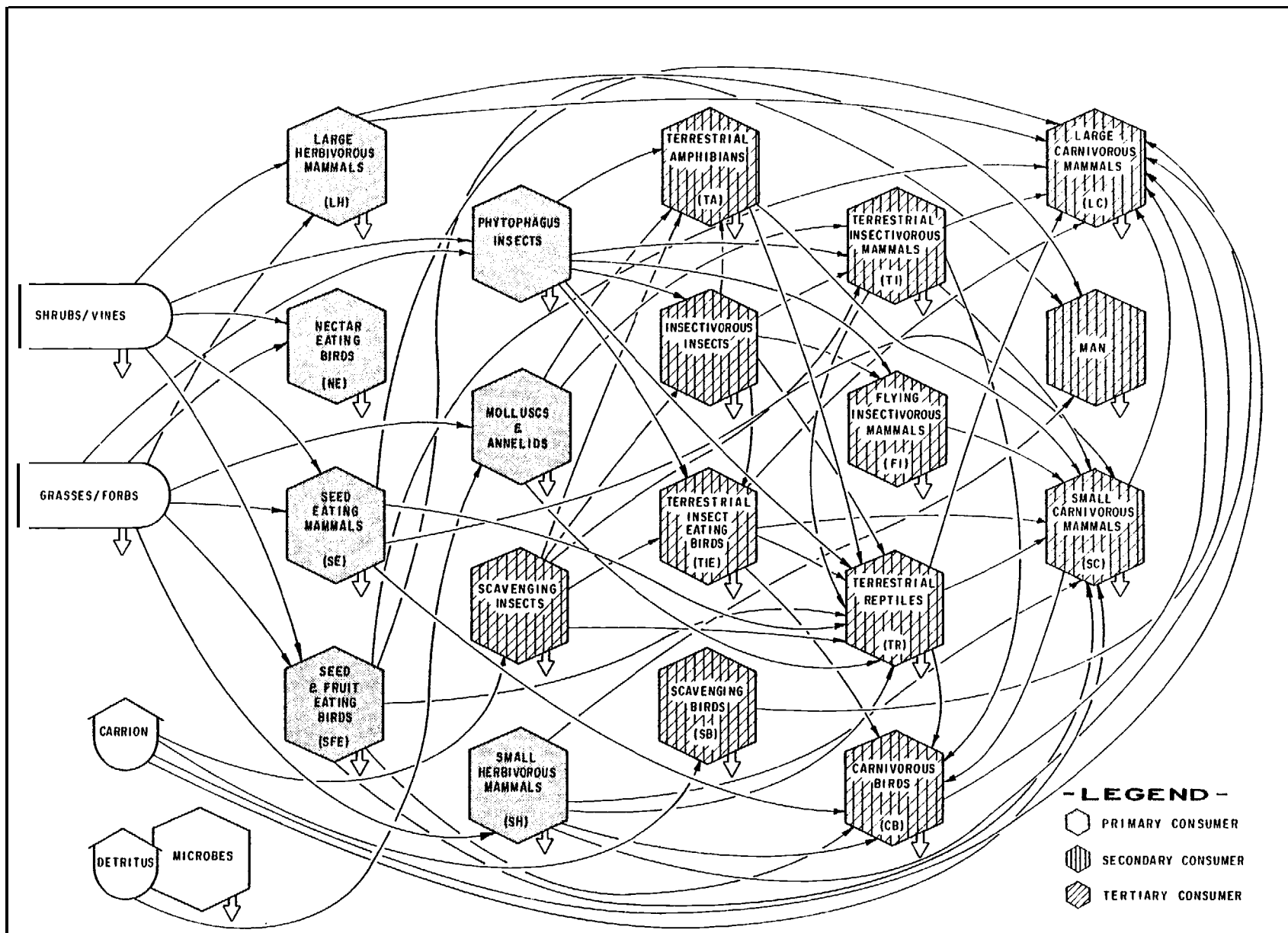


Figure 8-10. General Food Web - Shrublands

sage scrub habitat type photosynthesize at four times the rate of chaparral species but productivity is germinated by drought-deciduousness in response to summer soil moisture depletion (Harrison, et al., 1971). Volatile terpene compounds are produced by several species of the coastal sage scrub habitat type. These allelopathic substances may influence food webs and ecosystem energy pathways by reducing herbivory and by inhibiting decomposer organisms (Mooney, 1977c).

Primary consumers of shrub and herbaceous vegetation are mammals, such as the black-tailed deer, brush rabbit and pocket gopher; and phytophagous insects, such as the swift moth larvae (see discussion under Important Biotic Interactions; and Figure 8-11. Seed Production is consumed primarily by small mammals, such as the deer mouse and Sonoma chipmunk; and birds, such as the white-crowned sparrow and rufous-sided towhee. Important secondary consumers in the food web include insectivores, such as the Bewick's wren, coast horned lizard, tiger salamander, vagrant shrew and California myotis; and carnivores, such as the gray fox, long-tailed weasel, and peregrine falcon, which also may act as scavengers in the food web. These secondary consumers as well as other such consumers also function as tertiary consumers, feeding on secondary as well as primary consumers. For example, the long-tailed weasel may feed on the vagrant shrew (a secondary consumer) as well as the deer mouse (a primary consumer). Man functions primarily as a carnivore, consuming game mammals and birds (LC).

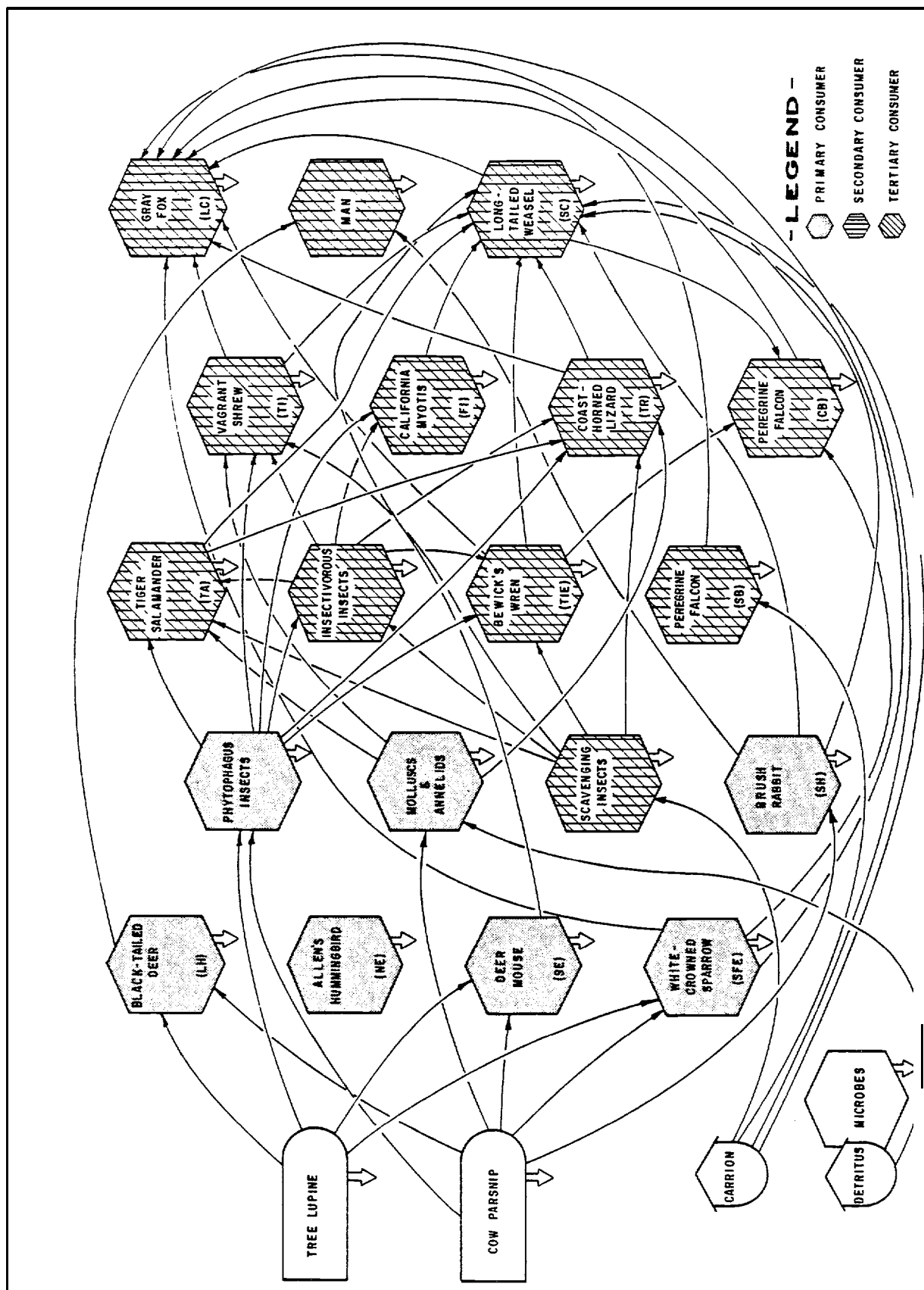
Important Biotic Interactions. Herbivorous organisms may control seedling establishment and mature plant survival rates of tree lupine (Lupinus arboreus) in the coastal dune scrub habitat type. Deer mice (Peromyscus maniculatus) and California voles (Microtus californicus) consume seeds and seedlings, pocket gophers (Thomomys bottae) kill both seedlings and mature plants, and swift moth larvae (Hepialus behrensi) and the California tussock moth caterpillar (Hermerocampa vetusta) cause substantial mortality in mature lupines (Davidson and Barbour, 1977). Vertebrate predation on seeds and seedlings may be responsible for "bare zones" around stands of coastal sage scrub. These bare zones have also been attributed to allelopathy (Mooney, 1977c).

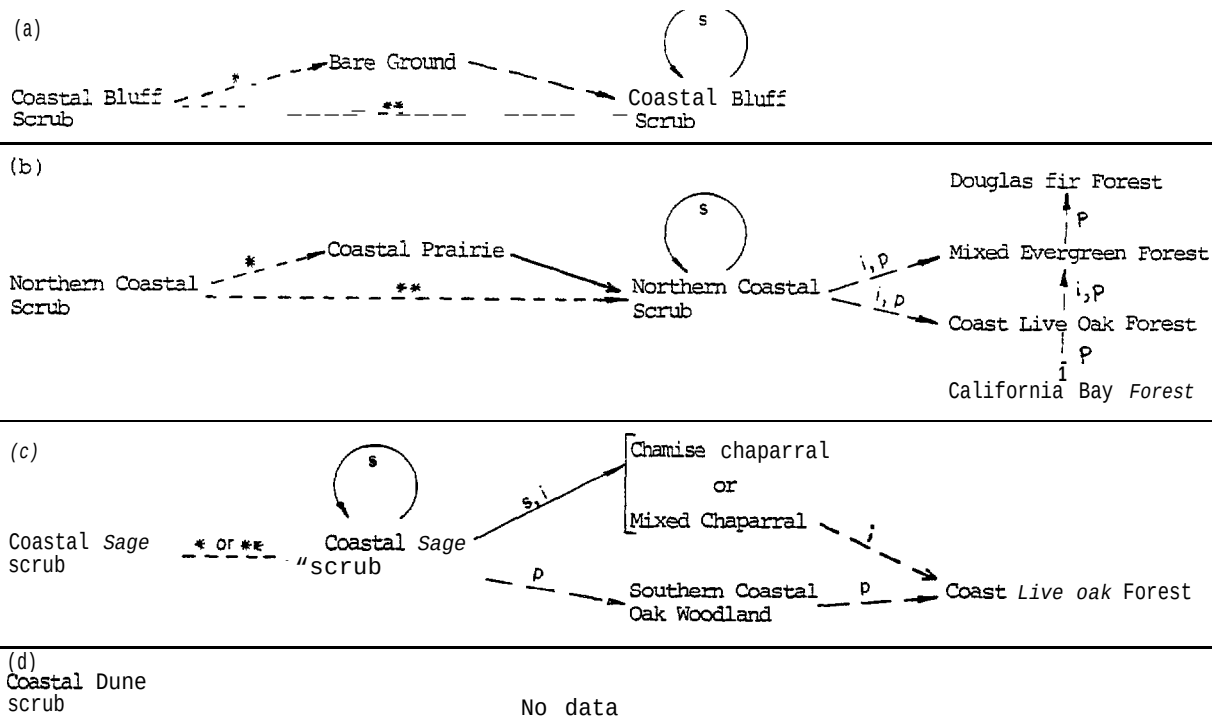
Important Abiotic Interactions. A primary abiotic interaction in the coastal scrubland cover type involves plant-water relations. Plant internal moisture stress may be caused by high soil salinity (osmotic moisture stress), by wind (high vapor pressure deficit at plant leaf surfaces), and by low soil moisture storage (due to coarse soil texture and/or low precipitation). Distribution of plant growth forms (evergreen sclerophyll shrubs, drought-deciduous subshrubs, and succulents) on a moisture stress gradient is determined by their photosynthetic capacities and by their control of evapotranspiration rates. Sclerophyll shrubs are adapted to withstand drought while subshrubs are adapted to evade drought (Mooney, 1977c). In the northern coastal scrub habitat type, slope aspect correlates with variations in vegetation composition due to its influence on plant moisture stress.

Associated Cover Types. Coastal scrubland cover type is spatially and temporally associated with chaparral cover type on central coastal terraces and lower mountain slopes. Scrubland occupies more xeric sites on moisture stress gradients and invades former chaparral ecosystems as a pioneer cover type following disturbance (Mooney, 1977c). Coastal scrublands are also associated spatially and temporally with grassland, broad-leaved evergreen forest, coastal conifer forest, and closed-cone conifer forest cover types.

Vegetation Succession. Coastal scrubland ecosystems may be seral or steady state, depending on favorability of site conditions and seed supply (Figure 8-12). Fire and substrate conditions determine successional patterns in central coastal areas (Wells, 1962). Northern coastal scrub habitat type may replace coastal prairie habitat type and subsequently be replaced by broad-leaved or conifer forest vegetation on sites of deeper soils, adequate soil moisture, and less exposure to wind and salt spray. Several studies have postulated replacement of coastal dune scrub by closed-cone conifer forest and ultimately by coastal conifer forest or broad-leaved evergreen forest (Barbour and Johnson, 1977). Chaparral may be an intermediate cover type in this successional sequence in central coast areas (Barbour and Johnson, 1977).

Typical Land Uses. Dune areas suitable for establishment of northern coastal dune scrub have been severely disturbed by trampling and operation of off-road vehicles (Barry, Fox and MacElfresh, 1977). In some areas, agricultural operations occupy former coastal scrubland ecosystems. Other coastal scrublands have been converted to grassland for grazing. Urbanization (both residential and recreational developments) has occurred in many former coastal scrubland sites.





Key to Symbols:

Types of Disturbance

- * High intensity disturbance, frequent fire
- ** Low intensity disturbance, infrequent fire

Types of Habitat Type Replacement

- ... → Replacement after disturbance (rate unspecified)
- Moderate to rapid replacement (<50 years)
- - - → Slow replacement (>50 years)
- ⤿ Steady-state, no replacement

Site Favorability (Microclimate, Substrate)

- s - Stressed (low productivity) sites, frequent and/or low intensity disturbance
- i - Intermediate sites, rare disturbance
- p - Productive sites, no disturbance

NOTE: For discussion of Successional process, see Ecosystem characterization of Chapter 8.

Figure 8-12. Successional Sequences (a-d) Suggested for Coastal Scrubland Habitat Types

Sensitivity to Disturbance. Removal of dune scrub vegetation leads to severe wind erosion of dune topography and soil. Vegetation removal in northern coastal and coastal sage scrub habitat types will generally be followed by rapid recolonization by either annual grasses or by wind-dispersed subshrubs.

Ecosystem Model. Important processes and components of ecosystems in the coastal scrubland cover type are highlighted in Figure 8-12.

Habitat Type Description: Coastal Dune Scrub

The coastal dune scrub habitat type is described under the Coastal Dune Scrub Cover Type of the Coastal Strand Habitat Class.

Habitat Type Descriptions: Coastal Bluff Scrub

Distribution. This habitat type occurs at localized sites on immediate coastal headlands exposed to constant winds of high salt content. Typical sites are rocky cliffs at the ocean front and rocky outcrops on coastal terraces. All sites have little soil development. In less exposed sites with greater soil depth, coastal bluff scrub intergrades with coastal prairie and other coastal scrubland habitat types and with coastal conifer forest and closed-cone conifer forest cover types (Cheatham and Hailer, 1975).

Watershed Units. Smith River, Mad River, Mattole River, Noyo River, Gualala River, Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo River, Carmel River, Morro Bay, San Antonio Creek and Point Arguello.

Vegetation. Plant cover of coastal bluff scrub ecosystems varies from scattered individuals to continuous mats of low, compact, often prostrate, herbaceous and subshrub (i.e., semiwoody) perennials (Howell, 1970; Cheatham and Hailer, 1975). Some common species are succulent (e.g., Dudleya farinosa). Annuals and true shrubs are rare. Soil salinity derived from salt spray may create severe osmotic water stress during rainless summer months. High soil salinity inhibits seed germination. Sea pink seeds, for example, germinate in December after winter rains have leached salts from top soil layers (Barbour et al., 1973). Flowering and growth occur from spring through early summer.

Table 8-9. Characteristic Plants of a Coastal Bluff Scrub Type

Plant Type/Common Name	Scientific Name
<u>Semiwoody subshrubs</u>	
Wild buckwheat	<u>Eriogonum latifolium</u>
Golden yarrow	<u>Eriophyllum staechadifolium</u>
Gum plant	<u>Grindelia stricta</u> ssp. <u>venulosa</u>
Paint-brush	<u>Castilleja</u> spp.
<u>Herbaceous Perennials</u>	
Sea pink	<u>Armeria maritima</u> var. <u>californica</u>
Live-forever	<u>Dudleya farinosa</u>
Seaside daisy	' <u>n glaucus</u>
Angelica	<u>Angelica hendersonii</u>
Polypody fern	<u>Polypodium scolieri</u>

Succession. Stressed conditions (salt, wind, drought) of coastal bluff scrub and resulting low productivity preclude replacement of characteristic plants by other less stress-tolerant species (Figure 8-12a).

Habitat Type Description: Northern Coastal Scrub

Distribution. The northern coastal scrub habitat type occupies coastal terraces and slopes in a narrow and intermittent strip from Del Norte to Monterey County. Areas of this habitat type typically have shallow, rocky soils, are below 150 m (500 ft) elevation, and are within several miles of the ocean. Northern coastal scrub intergrades with coastal bluff scrub (on rockier sites exposed to more wind and salt spray), with coastal dune scrub (on sandier, less developed soils), with coastal sage scrub (in San Mateo, Santa Cruz, and Monterey Counties) and with coastal prairie (on heavier soils). It also intergrades with coastal conifer forest and closed-cone conifer forest cover types on more protected sites with deeper soils. Where distributions of northern coastal and coastal sage scrub habitat types overlap, northern coastal scrub occupies north-facing slopes while coastal sage scrub occupies south-facing slopes.

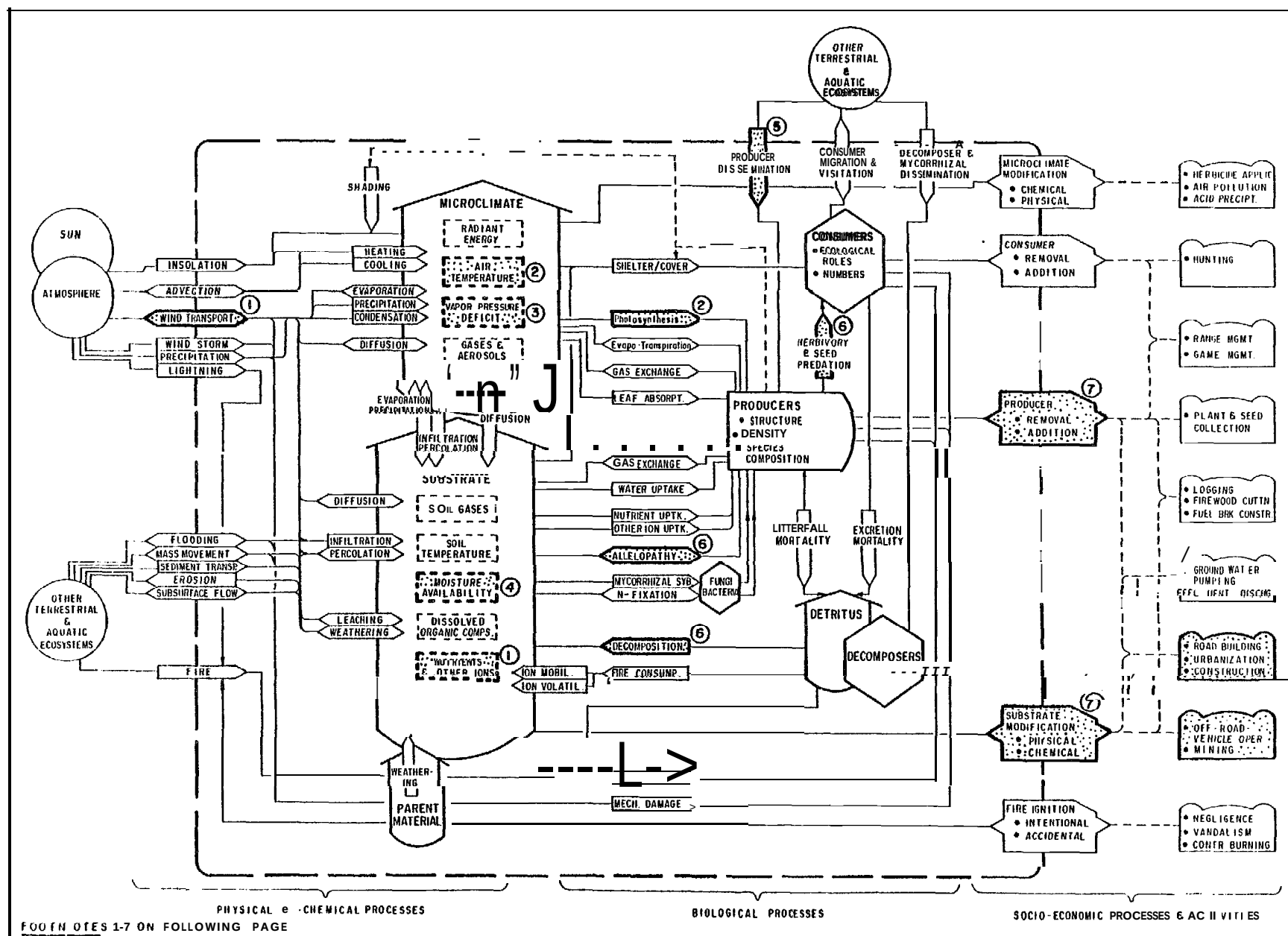


Figure 8-13. Ecosystem Model - Coastal Scrubland Cover Type
(Footnotes on Following Page)

Footnotes for Figure 8-13
Ecosystem Model for the Coastal Scrubland Cover Type
Highlighted Processes and Components are Annotated Below

1. WIND TRANSPORT AND NUTRIENTS AND OTHER IONS: Soil salinity is high in ecosystems exposed to salt-laden winds. High concentrations of salt ions in the soil cause osmotic moisture stress in plant tissues. Germination of some coastal bluff scrub species corresponds to initiation of winter rains and decrease in soil salt concentration (Barbour et al., 1973) .
2. AIR TEMPERATURE AND PHOTOSYNTHESIS: Temperatures in the coastal scrubland cover type fluctuate little on either diurnal or seasonal time scales due to marine influence. Photosynthesis is limited in species of lupine by ambient temperatures below their photosynthetic optimums (Barbour et al., 1973).
3. VAPOR PRESSURE DEFICIT: Vapor pressure deficit at plant leaf surfaces is increased by drying winds. However, fogs which occur on up to 80 percent of summer days decrease vapor pressure deficits and thereby help reduce plant moisture stress.
4. SOIL MOISTURE AVAILABILITY: Availability of soil moisture in coastal scrubland ecosystems is typically low. Low precipitation, low moisture-holding capacity of the typically coarse-textured soils and high soil salinity contribute to low soil moisture availability. Subshrub species characteristic of the coastal sage scrub habitat type evade depletion of soil moisture by being drought-deciduous.
5. PRODUCER DISSEMINATION: Many subshrub species of the coastal sage scrub habitat type produce light, wind-dispersed seeds. These species (e.g., coyote-brush, California sagebrush) readily colonize burned and other disturbed sites within areas previously occupied by chaparral.
6. ALLELOPATHY, HERBIVORY AND DECOMPOSITION: Allelopathic terpene compounds are produced by several aromatic species of the coastal sage scrub habitat type. Production of these compounds may have evolved to reduce herbivory. They also inhibit decompose organisms (Mooney, 1977c) .
7. PRODUCER REMOVAL AND SUBSTRATE MODIFICATION: Vegetation and substrates of coastal dune scrub ecosystems are disturbed by trampling and ORV operation. Once vegetative cover is removed, wind erosion will dislocate formerly stabilized dune substrates.

Watershed Units. Smith River, Mad River, Eel River, Mattole River, Noyo River, Gualala River, Russian River, Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo River, Pajaro River, Elkhorn Slough, Carmel River, Morro Bay.

Vegetation. The northern coastal scrub habitat type is dominated by low shrubs, 0.6-1.8 m (2-6 ft) tall, usually occurring in dense stands, but sometimes including patches of grasses typical of the coastal prairie habitat type (Table 8-10). Shrub cover is typically comprised of two layers, an upper partially-open canopy of primarily coyotebrush (Baccharis pilularis ssp. consanguine) and a lower closed canopy of low shrubs, ferns, and herbaceous perennials (Heady et al., 1977). Evergreen shrub species and absence of bare ground distinguish this habitat type from coastal sage scrub where drought-deciduous subshrubs and bare ground become more common.

Table 8-10. Characteristic Plants of a Northern Coastal Scrub Type

Plant Type/Common Name	Scientific Name
<u>Shrubs</u>	
Coyotebrush	<u>Baccharis pilularis</u> ssp. <u>consanguine</u>
Coffeeberry	<u>Rhamnus californica</u>
Salal	<u>Gaultheria shallon</u>
Poison oak	<u>Rhus diversiloba</u>
Blackberry	<u>Rubus vitifolius</u> and <u>R. ursinus</u>
Sticky monkey flower	<u>Mimulus aurantiacus</u>
<u>Herbs and Ferns</u>	
Sword fern	<u>Polystichum munitum</u>
Yerba buena	<u>Satureja douglasii</u>
Cow-parsnip	<u>Heracleum lanatum</u>
Bracken	<u>Pteridium aquilinum</u>

Succession. Fire, landslides, and grazing are important sources of disturbances in northern coastal scrub ecosystems (Figure 8-12b). Although characteristic shrubs sprout following fire, repeated burning in combination with grazing will maintain the coastal prairie habitat type. Northern coastal scrub habitat may be replaced after 50-100 years by mixed evergreen forest, coast live oak forest, or California bay forest habitat types (McBride, 1974). Replacement depends on suitability of site conditions and seed accessibility for species characteristic of these habitat types. North-facing slopes provide the most suitable conditions for replacement due to lower evapotranspiration during rainless summer months. Conditions for tree seedling establishment occur less frequently on south-facing slopes.

Habitat Type Description: Coastal Sage Scrub

Distribution. The coastal sage scrub habitat type is common along the immediate coast from Marin County to Santa Barbara County. It occurs on all aspects in the south but is restricted to exposed south-facing slopes from Monterey County northward where it intergrades with northern coastal scrub. Soils are typically shallow, rocky, and dry; elevations are below 600 m (2,000 ft). Coastal sage scrub intergrades with mixed and chemise chaparral habitat types on higher elevation, more mesic, rocky sites (Cheatham and Hailer, 1975).

Watershed Units. Salmon Creek, Lagunitas Creek, San Gregorio, San Lorenzo, San Antonio Creek, Pajaro, Elkhorn Slough, Carmel River, Morro Bay, Santa Maria River, Santa Ynez River, Point Arguello.

Vegetation. Vegetation typically consists of a mixture of evergreen shrubs and drought-deciduous subshrubs 1-2 m (3-6 ft) tall, in usually dense stands (Table 8-11). The two characteristic dominants, California sagebrush and black sage, are halfwoody subshrubs. These two drought-deciduous species become more widespread in southern California. Facultative summer drought-deciduousness enables these species to evade late summer drought. During the moist, cool spring season, these same species exhibit a high rate of primary productivity, in contrast to chaparral species which typically photosynthesize year round but at a low rate (Harrison et al., 1971). Most growth activity and flowering occurs from late winter through early summer.

Table 8-11. Characteristic Plants of a Coastal Sage Scrub

Plant Type/Common Name	Scientific Name
<u>Shrubs and Subshrubs</u>	
California sagebrush	<u>Artemisia californica</u>
Black sage	<u>Salvia mellifera</u>
Coyotebrush	<u>Baccharis pilularis</u> ssp. <u>consanguinea</u>
Sticky monkey flower	<u>Mimulus aurantiacus</u>
Poison oak	<u>Rhus diversiloba</u>
Haplopappus	<u>Haplopappus squarrosus</u>
<u>Herbs and Ferns</u>	
Wood fern	<u>Dryopteris arguta</u>
Giant wildrye	<u>Elymus condensatus</u>
Cinque foil	<u>Potentilla glandulosa</u>

Succession. All characteristic shrubs and subshrubs are adapted to fire by having sprouting root crowns. Most shrub and subshrub species are also light seeded and therefore adapted to disperse widely into newly disturbed sites (Wells, 1962) . Where seeds of tree species are available and disturbance is absent for a long interval, coastal sage scrub may be replaced by southern coastal oak woodland (Figure 8-12c). On less favorable sites (drier, shallower soils) in San Luis Obispo and Santa Barbara Counties, and where fire is recurrent at a 40-60 year interval, coastal sage scrub may be replaced by chemise or mixed chaparral habitat type (Mooney, 1977c) . On the most unfavorable sites, coastal sage scrub may comprise a steady-state habitat type.

Chaparral Cover Type

Physiognomy. The chaparral cover type occurs as an open-to-dense shrubland (30 to 100 percent cover) of primarily evergreen, "sclerophyll" shrub species; 1-5 m (3-15 ft) tall (to 10 ft in coastal mixed shrub habitat type). Sclerophyll leaves are typically small, evergreen, and have a thick waxy cuticle to eliminate significant cuticular water loss (Rundel, 1977). Sclerophyll species are adapted to Mediterranean-type patterns of climate and fire. Vegetation of this cover type is commonly dense and impenetrable with little or no understory of herbaceous species or shrub seedlings; it may be open on extremely infertile sites. Annual herbs and grasses may dominate for several years after fire or in occasional shrub openings in the shrub canopy. The habitat types are described in Table 8-12.

Table 8-12. Habitat and Plant Types in Chaparral

Habitat Type	Dominant Plants	Regional Distribution
Chamise chaparral	Chamise (<u>Adenostoma fasciculatum</u>)	North and South Coast Ranges
Mixed chaparral	Manzanitas (<u>Arctostaphylos</u> spp.) Wild lilacs (<u>Ceanothus</u> spp.) Oaks (<u>Quercus</u> spp.)	North and South Coast Ranges
Serpentine chaparral	Chamise Manzanitas (often endemics) Ceanothus (often endemics) Leather oak (<u>Quercus durata</u>)	North and South Coast Ranges
Coastal mixed shrub	Blue blossom (<u>Ceanothus thyrsiflorus</u>) Salal (<u>Gaultheria shallon</u>)	North and South Coast Ranges

Climate. This cover type is characterized by a Mediterranean-type climate of cool, moist winters and hot, dry summers. Average annual precipitation is 36-64 cm (14-25 in) with essentially no rain from May to November. Growing season is 8-12 months. Mean summer maximum temperatures are 28°C-34°C (82°F-94°F) and mean winter maximum temperatures are -2°C-7°C (29°F-45°F) (Munz and Keck, 1949). Severe drought stress may occur in autumn months when hot, dry foehn-type winds occur. Foehn winds result when regional air currents passing over a mountain range are forced to descend on the lee side; the descending air is heated and dried (Barry and Chorley, 1976). Relative humidities below 5 percent have been recorded (Hanes, 1977). The exception is the coastal mixed shrub habitat type where climatic parameters are identical to those of the coastal conifer forest cover type.

Topography. Chaparral cover type occurs on hills and lower mountain slopes of North and South Coast Ranges. It is found inland and on south-facing aspects in the north, and in coastal as well as inland areas and on all aspects in the south. The cover type occurs up to 900 m (3,000 ft) elevations in the north and to 1,500 m (5,000 ft) in the south. Typically, it is located on steep, rocky slopes throughout its range.

Substrate. Substrates are typically coarse-textured, shallow, and rocky residual soils characterized by high porosity, low water-holding capacity, and low organic matter content. They are often very low in nutrients (e.g., serpentine chaparral habitat type); and highly erodible, especially after fire removes vegetation on steep slopes. "Dry creep" moves materials on slopes greater than the angle of repose. Winter rains may cause severe surface erosion. Many chaparral shrub species grow extensive root systems that penetrate to deeply-held groundwater.

Vegetation. vegetation is usually dense except on infertile sites (Table 8-12). Presence or absence of understory vegetation of shrub seedlings, herbs, and grasses depends on substrate, species of dominant shrub, and openness of shrub canopy. Important determinants of shrub species composition in a local area are substrate, elevation, aspect, and fire history (Hanes, 1977).

Vegetation Seasonality and Modes of Reproduction. All important shrub species are evergreen. Distinctive features of sclerophyll species enable them to maintain some growth activity throughout the year, although net production peaks in late spring (Harrison, et al., 1971; Rundel, 1977). These features include thick waxy leaf cuticles to prevent cuticular water evaporation, efficient stomatal control mechanisms to minimize transpirational water loss, extensive root systems to maintain contact with deep groundwater, small leaf size, and vertical leaf orientation. Most chaparral species sprout vigorously after fire, although many manzanita and Ceanothus species reproduce from seed only. Evolutionary loss of sprouting ability is associated with widespread speciation and rapid adaptation to local conditions in these two genera (Wells, 1969). Seed germination of many shrub and herb species is controlled by dormancy mechanisms which minimize germination during periods of low survival probability. Fire greatly improves survival probability by improving light and nutrient conditions, and by removing allelopathic growth inhibitors. In many chaparral species fire is necessary to stimulate seed germination (Hanes, 1977).

Characteristic Fauna. Characteristic mammals of chaparral cover types are taken from Ingles (1965). Small (1974) and Ryder and Ryder (1976) provide information on common California birds in chaparral. Common or characteristic reptiles and amphibians are derived from Stebbins (1966). Species listed in Table 8-13, although characteristic of chaparral communities, are not found exclusively in this cover type. Abbreviations (e.g., LC, TIE, TA) following species names refer to types of consumers in the general food web for this cover type (see Figure 8-8 for explanation of abbreviations). See the Community Composition List, Volume 111, Part 2, for more information on species listed below, and for information on characteristic invertebrate species.

Table 8-13. Characteristic Fauna of a Chaparral Cover Type¹

Mammals	Birds	Reptiles and Amphibians
Black-tailed deer (LH)	Wrentit (SFE)	Tiger salamander (TA)
Coyote (LC) (TI)	Rufous-sided towhee (SFE) (TIE)	Western fence lizard (TR)
Gray fox (LC)	Sage sparrow (TIE) (SFE)	Side-blotched lizard (TR)
Long-tailed weasel (SC)	Bewick's wren (TIE)	Alligator lizard (TR)
Bobcat (LC)	Poor-will (TIE)	Striped racer (TR)
Vagrant shrew (TI)	Anna's hummingbird (NE) (TIE)	Coachwhip (TR)
Brush rabbit (SH)	California thrasher (SFE) (TIE)	Gopher snake (TR)
Desert woodrat (SE) (SH)	Brown-headed cowbird (SFE)	Common kingsnake (TR)
Bushy-tailed woodrat (SE) (SH)	(TIE)	Night snake (TR)
Brush mouse (SE) (SH)	Lesser goldfinch (SFE) (TIE)	Western rattlesnake (TR)
California mouse (SE) (SH)	California quail (SFE) (TIE)	
California pocket mouse (SE)	Mountain quail (SFE)	
Sonoma chipmunk (SE)	(TIE)	
Merriam chipmunk (SE)	Band-tailed pigeon (SFE)	
California myotis (FI)	Blue-gray gnatcatcher (TIE)	
Dusky-footed woodrat (SE) (SH)	Orange-crowned warbler (TIE)	
	Brown towhee (SFE) (TIE)	
	Turkey vulture (SB)	
	Red-tailed hawk (CB) (SB)	

¹See Figure 8-14 for definition of abbreviations.

Biomass Productivity and Food Web. Above ground primary productivity of chaparral ecosystems is relatively low (ea. 400 g/m²/yr.) even though most chaparral shrubs photosynthesize year-round (Mooney, 1977c). Productivity is limited by inherently low photosynthetic rates of sclerophyll shrubs, reduction of photosynthetic rate by summer drought, large proportion of photosynthate allocated to roots (for deep root penetration and for root crown sprouting capacity), and high shoot tissue construction

costs. Shoot tissue construction costs are high due to high specific weight of sclerophyll leaves (small, thick, and dense) and due to high energy compounds (e.g., terpenes and phenolics) that may have evolved as protection from herbivory. These compounds increase chaparral flammability. Allelopathic compounds produced by chaparral shrubs may inhibit decompose organisms in old stands of chaparral shrubs (Hanes, 1977).

Primary consumers of shrub and herbaceous vegetation are mammals, such as the black-tailed deer and brush rabbit; and phytophagous insects, such as larvae of the gray hairstreak butterfly (see Figures 8-10 and 8-14). Mast and seed production is consumed primarily by seed gathering beetles and ants; mammals, such as the black-tailed deer and bushy-tailed woodrat; and birds, such as the California quail, band-tailed pigeon, rufous-sided towhee and California thrasher. Secondary and tertiary consumers in the food web include insectivores, such as the wren-tit, sage sparrow, Anna's hummingbird (also a nectivore, a primary consumer), vagrant shrew and California myotis; and carnivores, such as the striped racer, coyote, long-tailed weasel and red-tailed hawk. The turkey vulture is a common scavenging bird in "open" chaparral habitat. The coyote is also an important scavenger. Man functions primarily as a carnivore (LC), consuming various game mammals and birds.

Important Biotic Interactions. Browsing by animals such as mule deer, brush rabbits, and wood rats on shrub seedlings and sprouts may significantly affect the rate of regrowth and the species composition of chaparral vegetation (Hanes, 1977). Nitrogen fixation by species of Ceanothus, mountain mahogany, lupine, and birds-foot-trefoil may be important on sites of very low fertility and give these plants an advantage in early regrowth following fire. Mycorrhizal symbiosis is important to chaparral shrub species that lack root hairs and on sites of low fertility.

Important Abiotic Interactions. Fire and chaparral adaptations to the eventuality of fire constitute the important abiotic interaction. Fire occurs once every 10-40 years in chaparral ecosystems (Hanes, 1977). Effects of fire include removal of senescent vegetation, removal of accumulated allelopathic compounds, stimulation of seed germination and crown sprouting, mobilization and volatilization of nutrients, formation of water repellent layers in soil, and stimulation of decompose organisms. Three regeneration strategies adapted to fire have been recognized among chaparral species: early age of first seed production, seed dormancy mechanisms that are only removed by fire, and ability to sprout from roots and root crowns (Hanes, 1977).

Associated Cover Types. Ecosystems of the chaparral cover type are spatially associated with ecosystems of nearly all other cover types in the study region. Chaparral vegetation often occupies sites of rocky, infertile substrates that occur as patches within areas able to support less stress-tolerant plant species.

Vegetation Succession. Chaparral succession patterns are modelled in Figure 8-15. Under a disturbance regime of recurrent fire at 10- to 40-year intervals, all chaparral habitat types are well adapted to reestablish site dominance following a short period of dominance by fire-dependent annual grasses and forbs. With recurrent fire at less than a 10-year interval, grassland cover type will be maintained. At coastal, low elevation sites in Santa Barbara and San Luis Obispo Counties, coastal sage scrub habitat type may temporarily dominate after fire (for 10-20 years) due to its rapid dispersal ability and rapid growth rate (Wells, 1962). Without recurrent fire, chaparral cover type vegetation may be either steady-state (e.g., serpentine habitat type) or seral (e.g., coastal mixed shrub habitat type on disturbed sites within the coastal conifer forest cover type). Seral or steady-state nature of particular ecosystems depends on site conditions and seed availability from potentially replacing species.

Typical Land Uses. The primary historical land use of the chaparral cover type has been watershed protection. The nation's first Forest reserves were set up in 1892 to protect chaparral ecosystems in watersheds above Los Angeles. Early ranchers frequently burned brush to convert chaparral habitat type to grassland as a grazing resource. Fire suppression since the early 1900s has allowed chaparral ecosystems to become huge storehouses of highly flammable fuels. Watershed management activities include fuel break construction and prescribed burning (see Mooney and Conrad, 1977).

Sensitivity to Disturbance. Steep, highly erodible sites of typical chaparral ecosystems indicate this cover type has a high sensitivity to disturbance. Increased length of intervals between fires due to fire suppression efforts may lead to significant site degradation (Vogl, 1977).

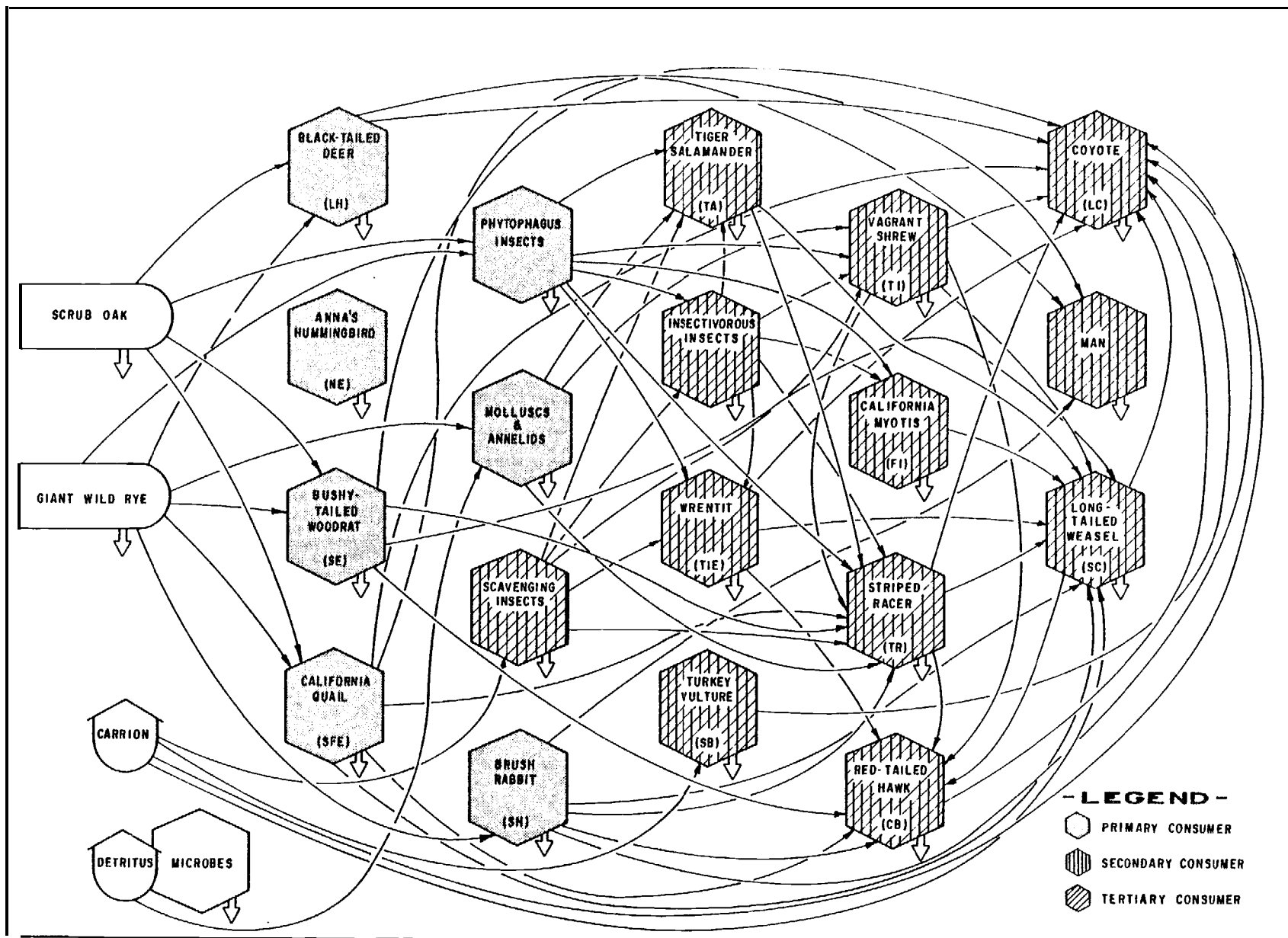
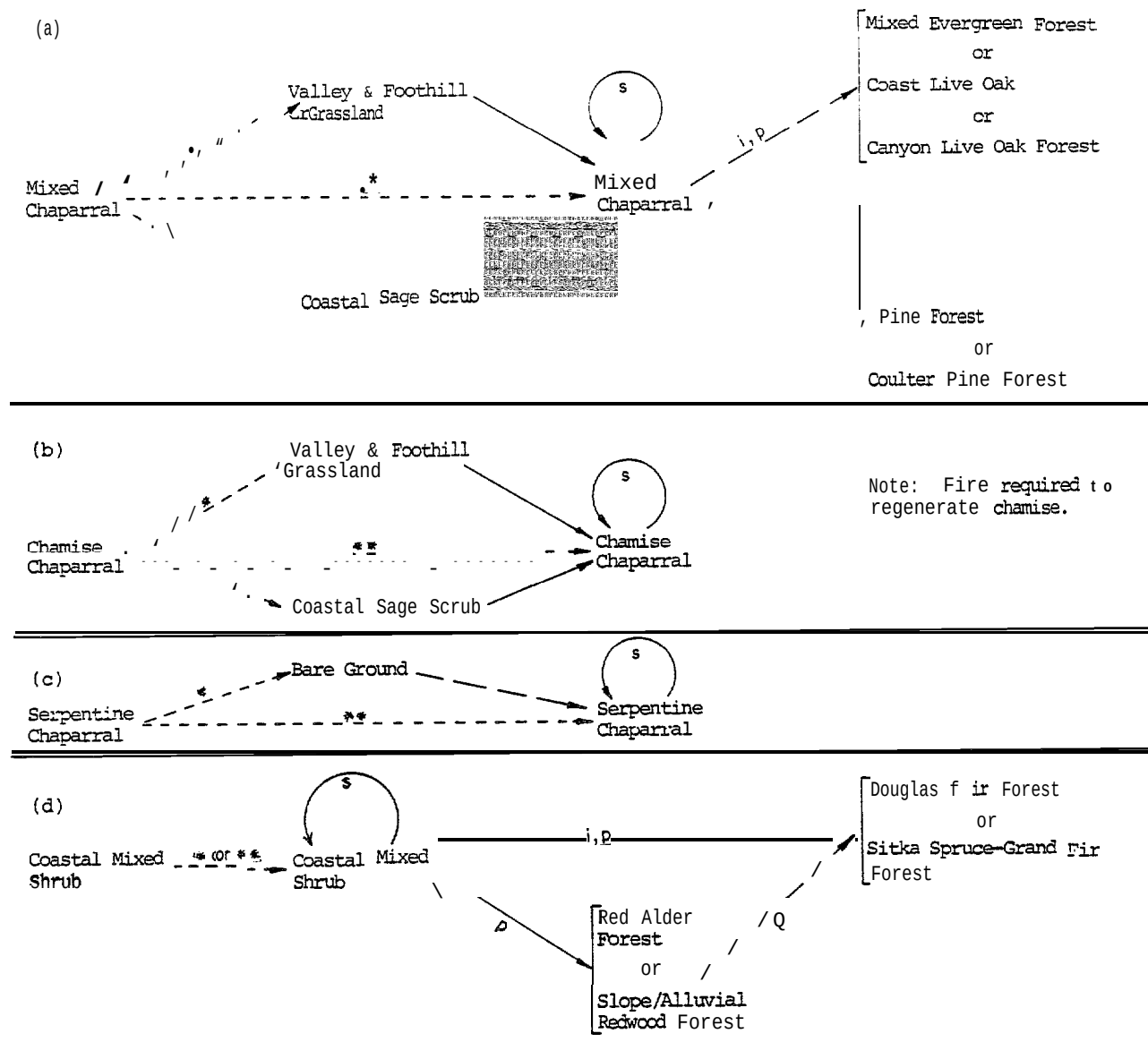


Figure 8-14. An Example of a Chaparral Food Web



Key to Symbols :

Types of Disturbance

- * High intensity disturbance, frequent fire
- ** Low intensity disturbance, infrequent fire

Types of Habitat Type Replacement

- > Replacement after disturbance (rate unspecified)
- > Moderate to rapid replacement (<50 years)
- > Slow replacement (>50 years)
- ⤿ Steady-state, no replacement

Site Favorability (Microclimate, Substrate)

- s - Stressed (low productivity) sites, frequent and/or low intensity disturbance
- i - Intermediate sites, rare disturbance
- p - Productive sites, no disturbance

NOTE: For discussion of Successional Process, see Ecosystem Characterization of Chapter 8.

Figure 8-15. Successional Sequences (a-d) Suggested for Chaparral Habitat Types

Ecosystem Model. Important interactions among chaparral ecosystem components are highlighted in Figure 8-16 .

Habitat Type Description: Chamise Chaparral

Distribution. Chamise chaparral habitat type is scattered in North Coast Ranges inland from the coast. on dry, rocky substrates and south-facing slopes, generally below 900 m (3,000 ft) in elevation. It is widespread and common in South Coast Ranges on hot, dry south- and west-facing slopes. Chamise chaparral intergrades with mixed chaparral habitat type on moister, cooler slopes and with serpentine chaparral habitat type on serpentine-derived soils. It also intergrades with coastal sage scrub habitat type on more coastal, lower elevation, drier sites (Cheatham and Hailer, 1975) . This habitat type often occurs in mosaics of grassland, broad-leaved evergreen forest, and oak woodland cover types in North Coast Ranges.

Watershed Units. Distribution of the chamise chaparral habitat type has not been documented. However, it probably occurs in the following watershed units: Noyo River, Gualala River, Russian River, Lagunitas Creek, San Gregorio Creek, San Lorenzo River, Pajaro River, Elkhorn Slough, Salinas River, Carmel River, Morro Bay, Santa Maria River, San Antonio Creek, Santa Ynez River, and Point Arguello.

Vegetation. Chamise chaparral vegetation consists of dense shrub stands, 1-3 m (3-10 ft) tall at maturity. Often shrub crowns interlock in extensive impenetrable thickets with no understory herbs and sparse litter. Chamise typically comprises 80 percent or greater of total cover, with scattered individuals of other chaparral species constituting the balance (Hanes, 1977) . Characteristic plants are given in Table 8-14.

Table 8-14. Characteristic Plants of a Chamise Chaparral Type

Plant Type/Common Name	Scientific Name
<u>Shrubs</u>	
chamise	<u>Adenostoma fasciculatum</u>
Shaggy-barked manzanita	<u>Arctostaphylos tomentosa</u>
Buckbrush	<u>Ceanothus cuneatus</u>
Huckleberry oak	<u>Quercus vaccinifolia</u>
Black sage	<u>Salvia mellifera</u>
<u>Herbs</u>	
Giant wildrye	<u>Elymus condensates</u>

Succession. Chamise sprouts readily after fire' (Figure 8-15b). Fire stimulates germination of chamise seeds and seeds of annual herbs and grasses stored in duff and soil. Repeated fire at a several-year interval will maintain the valley and foothill grassland habitat type. Regrowth of chamise chaparral vegetation from sprouts and seeds is slow relative to other chaparral habitat types due to stressed site conditions where it is dominant. At low elevations, near the coast in San Luis Obispo and Santa Barbara Counties, disturbance by fire or mechanical destruction may allow temporary establishment of the coastal sage scrub habitat type. After 20-30 years without fire, chamise chaparral will return to dominance (Hanes, 1977) . After approximately 60 years, chamise individuals become senescent and die. Allelopathic biochemical produced by chamise plants inhibit germination of chamise seed as well as interfere with decomposition, humification, and vitrification. This naturally-induced ecosystem degradation may also prevent invasion by species that might otherwise replace chamise. Fire is necessary to neutralize the allelopathic compounds, to mobilize nutrients, and to stimulate germination of seeds and chamise root crowns (Hanes, 1977).

Habitat Type Description: Mixed Chaparral

Distribution. Mixed chaparral habitat type occurs inland in North Coast Ranges on generally south-facing slopes to 900 m (3,000 ft) elevations. In coastal and inland South Coast Ranges, it is more common on north-facing slopes, to 1,500 m (5,000 ft) elevations. It is typically found on steep slopes with dry, shallow, rocky soils. It often occurs in mosaics with oak woodland and grassland cover types but on rockier soils where deep root penetration is facilitated. Mixed chaparral also intergrades with coastal scrubland cover type on drier but less rocky soils near the coast and with broad-leaved evergreen forest and lower montane conifer forest cover types on cooler and moister sites (Cheatham and Hailer, 1975).

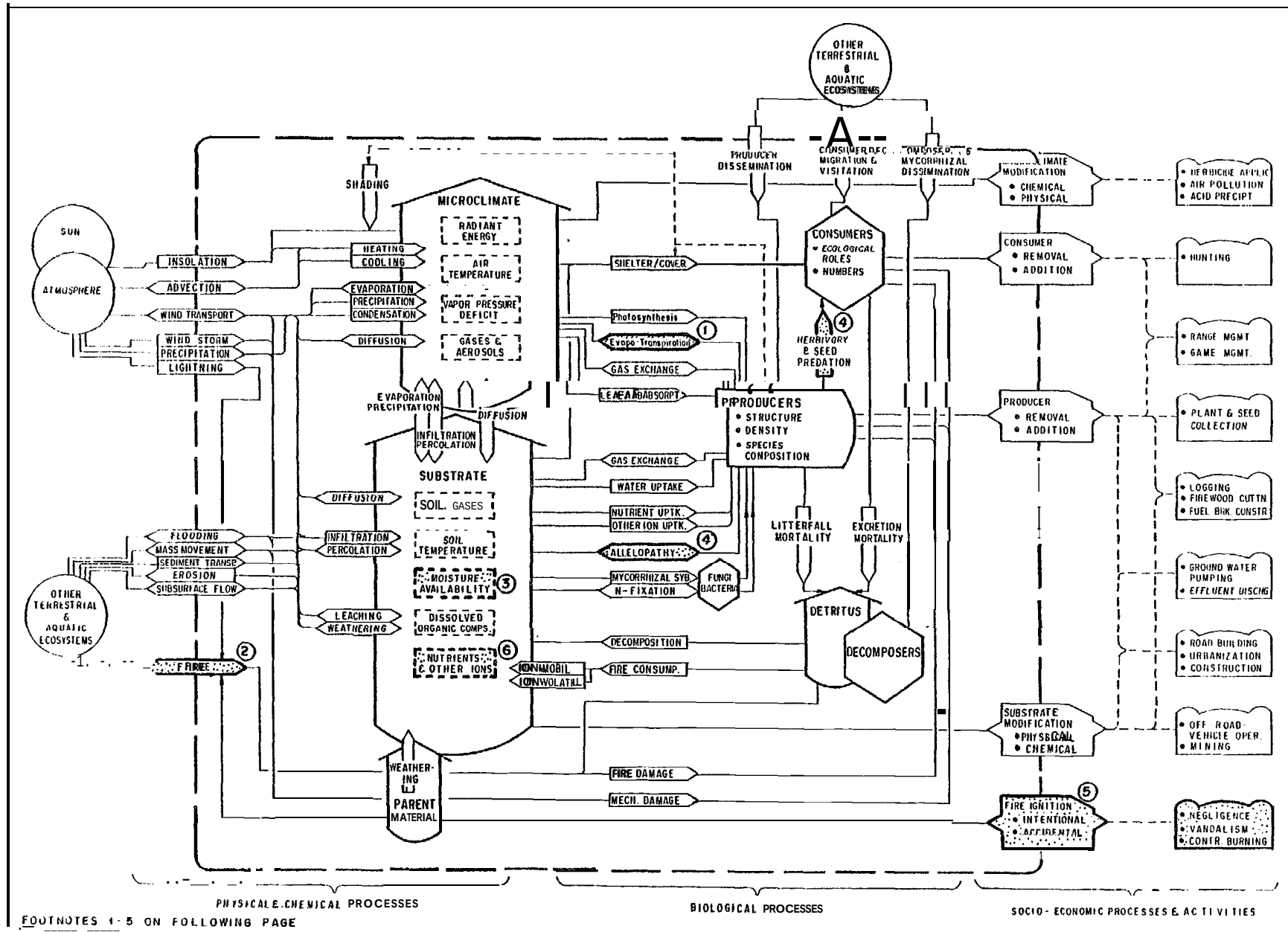


Figure 8-16. Ecosystem Model - Chaparral Cover Type
(Footnotes on Following Page)

Footnotes for Figure 8-16
Ecosystem Model for the Chaparral Cover Type-
Highlighted Processes and Components are Annotated Below

1. EVAPOTRANSPIRATION : Sclerophyll shrub species have evolved thick, waxy leaves in response to severe evapotranspirational loads in typical chaparral ecosystems. Waxy cuticles prevent evaporation through leaf walls and efficient stomatal control mechanisms restrict transpirational moisture loss during summer period of low soil moisture availability. See chaparral cover type section on Vegetation Seasonality.
2. FIRE : Fire occurs every 10-40 years in the typical chaparral ecosystem. See chaparral cover type section on Important Abiotic Interactions.
3. MOISTURE AVAILABILITY: Parent materials, steep topography, and short time span of weathering interact to produce soils of coarse texture in chaparral ecosystems. Coarse-textured soils hold little soil moisture in surface horizons but allow root penetration by chaparral shrubs to deeply-held groundwater.
4. ALLELOPATHY and HERBIVORY: Several species of chaparral shrubs are known to produce allelopathic chemicals that can limit the germination and growth of plants as well as the activities of soil micro-organisms. These chemicals may be metabolic waste products or may have evolved to prevent herbivory or replacement by other plant species over time (Hanes, 1977) .
5. FIRE IGNITION: Under fire suppression policies in force since the early 1900s, many chaparral ecosystems have not burned in 50-80 years. Large accumulations of highly flammable chaparral vegetation will produce catastrophic fires when finally ignited. Newly-developed fire management policies are prescribing controlled burns of low intensity at 10-20 year intervals (Mooney and Conrad, 1977) .
6. NUTRIENTS: Soils of chaparral ecosystems are low in fertility due to low nutrient content of parent materials and due to coarse texture. Coarse soil texture has small amounts of surface area to hold available nutrient ions (Laacke, 1979).

Watershed Unit Distribution of the mixed chaparral habitat type is unknown, but it probably can be found in all watershed units, except the Eel River.

Vegetation. Mixed chaparral is typically a dense shrubland of broad-leaved sclerophyll shrubs, 2-6 m (6-20 ft) tall (depending on species and age of stand). Although it generally occurs as mixtures of many chaparral species, it may consist of nearly pure stands of manzanitas, Ceanothus, or oaks (Table 8-15). Ceanothus species are relatively short-lived and most are obligate seeders (i.e., they do not sprout after fire). Although half of manzanita species are also obligate seeders, they are generally longer-lived and become more important in stands older than 50 years. Also, manzanita is more common on deeper soils and at higher elevations (Hanes, 1977). Chaparral oaks include dwarfed varieties of normally tree-form oak species as well as scrub oak. All oak species sprout vigorously after fire, regrow rapidly in response to more mesic site conditions, and are relatively long-lived. Understory herbaceous vegetation is generally sparse in mixed chaparral ecosystems. Litter depths may be substantial on more productive sites.

Table 8-15. Characteristic Plants of a Mixed Chaparral Type

Plant Type/Common Name	Scientific Name
<u>Shrubs</u>	
Chaparral whitethorn	<u>Ceanothus leucodermis</u>
Deer brush	<u>C. integriramus</u>
Coast <u>Ceanothus</u>	<u>C. ramulosus</u>
Buckbrush	<u>C. cuneatus</u>
Parry manzanita	<u>Arctostaphylos manzanita</u>
Silverleaf manzanita	<u>A. silvicola</u>
Hoary manzanita	<u>A. canescens</u>
Shaggy-barked manzanita	<u>A. tomentosa</u>
Scrub oak	<u>Quercus dumosa</u>
Dwarf coast live oak	<u>Q. agrifolia</u> var. <u>frutescent</u>
Dwarf interior live oak	<u>Q. wislizenii</u> var. <u>frutescent</u>
Leather oak	<u>Q. durata</u>
Toyon	<u>Heteromeles arbutifolia</u>
Chaparral pea	<u>Pickeringia montana</u>
Hollyleaf cherry	<u>Prunus ilicifolia</u>
Birchleaf mountain-mahogany	<u>Cercocarpus betuloides</u>
<u>Herbs (after fire)</u>	
<u>Cryptantha</u>	<u>Cryptantha</u> spp.
Bird's foot trefoil	<u>Lotus</u> spp.
Whispering bells	<u>Emmenanthe penduliflora</u>
Eucrypta	<u>Eucrypta chrysanthemifolia</u>
Poppy	<u>Papaver californicum</u>

Succession. Ceanothus species and chaparral pea are nitrogen-fixers, enabling more rapid growth than non-nitrogen fixing species in the years following fire. Obligate-seeding Ceanothus species may dominate mixed chaparral habitat type for several decades following disturbance but eventually decrease in importance relative to longer-lived manzanitas and oaks. Manzanitas and oaks may form 100 percent canopy cover after 40 years and reach small tree size in very old stands. Without fire on more favorable sites and where seeds of tree species characteristic of the broad-leaved evergreen forest or lower montane conifer forest are available, mixed chaparral may be replaced by these cover types (Figure 8-15a). Replacement of mixed chaparral by forest species is facilitated by litter accumulation and partial shade under very old deteriorating chaparral canopies.

Habitat Type Description: Serpentine Chaparral

Distribution. Serpentine chaparral is scattered throughout the North and South Coast Ranges on rocky soils derived from ultra-basic serpentine parent materials between 300-1,500 m (1,000-5,000 ft) in elevation (Cheatham and Hailer, 1975). Serpentine soils are intolerable to many plant species because of extremely low calcium and other nutrients, and high levels of magnesium and toxic elements such as chromium and nickel. Serpentine soils are commonly thought to be exceptionally dry because of the sparse vegetative cover and the xeromorphic structure of plants growing in these ecosystems (Hanes, 1977). However, Raven and Axelrod (1978) argue that serpentine soils have higher moisture content than adjacent zonal soils. This feature, along with the unusual nutrient conditions, enables serpentine endemics to escape

replacement by more widespread species that have successfully adapted to the increasing aridity of California's climate. The serpentine chaparral habitat type often intergrades with other chaparral habitat types, and with closed-cone conifer forest, lower montane conifer forest, oak woodland, and broad-leaved evergreen forest cover types.

Watershed Units. Serpentine chaparral habitat type occurs in all watershed units where sites of ultra-basic parent materials are found.

Vegetation. vegetation is typically scattered, low (1-2 m in height) shrubs, with openings between shrubs and occasional trees occupied by herbaceous annuals and perennials, or by bare ground and rock outcrops (Table 8-16). Many common shrub species have xeromorphic appearance (small thick leaves, curled leaf margins, waxy or pubescent leaf surfaces) induced by poor nutrient conditions (Hanes, 1977). Many species of both shrubs and herbs are restricted to serpentine soils as widespread serpentine indicators (e.g., leather oak) or as local serpentine endemics (e.g., serpentine manzanita) (Cheatham and Hailer, 1975). Whittaker (1960) described vegetation of serpentine ecosystems in the Siskiyou Mountains; different species of the same genus occurred on adjacent serpentine and nonserpentine sites.

Table 8-16. Characteristic Plants of a Serpentine Chaparral Type

Plant Type/Common Name	Scientific Name
<u>Shrubs or Small Trees</u>	
Chamise	<u>Adenostoma fasciculatum</u>
Leather oak	<u>Quercus durata</u>
Knobcone pine	<u>Pinus attenuata</u>
Sargent cypress	<u>Cupressus sargentii</u>
Serpentine manzanita (endemic in San Luis Obispo County)	<u>Arctostaphylos obispoensis</u>
Mexican manzanita (endemic in Marin County)	<u>A. pungens</u> var. <u>montana</u>
Baker's manzanita (endemic in Sonoma County) (California rare and endangered plant)	<u>A. bakeri</u>
Muskbrush (endemic in Marin County)	<u>Ceanothus jepsonii</u>
Buckbrush	<u>C. cuneatus</u>
<u>Herb</u>	
Beargrass (indicator in North Coast Ranges)	<u>Xerophyllum tenax</u>

Succession. Productivity of serpentine chaparral ecosystems is extremely low and regrowth from disturbance is slow due to infertility of the substrate. Low vegetative cover (often less than 30 percent cover) and lack of plant litter provide sites of bare mineral soil for continued regeneration of characteristic species (Figure 8-15c). Occasional fire may be necessary to stimulate germination of some species. In North Coast Ranges, the serpentine chaparral habitat type may contain scattered individuals of lower montane conifer forest species such as Jeffrey pine (Pinus jeffreyi) and western white pine (Pinus monticola). Whittaker (1960) regarded such stands as steady-state and self-maintaining.

Habitat Type Description: Coastal Mixed Shrub

Distribution. The coastal mixed shrub habitat type occupies sites on coastal slopes and ridges of North and South Coast Ranges from Del Norte County to Monterey County. Its distribution is similar to that of the coastal conifer forest cover type, occurring on exposed coastal slopes, and on rocky sites and disturbed areas within the coastal conifer forest cover type. It may be found up to 50 miles inland.

Watershed Units. Smith River, Klamath River, Mad River, Eel River, Mattole River, Noyo River, Gualala River, Russian River, Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo Creek, Pajaro River, Carmel River, and Morro Bay.

Vegetation. Vegetation is typically comprised of tall shrubs (to 10 m tall), mostly evergreen but some deciduous, woody vines, and herbs, forming dense stands following removal of coastal conifer forests (Table 8-17). Individual shrub species may be locally dominant.

Table 2-17. Characteristic Plants of the Coastal Mixed Shrub Type

Plant Type/Common Name	Scientific Name
<u>Shrubs</u>	
Blueblossom (dominant on burned sites)	<u>Ceanothus thvrsiflorus</u>
Salal	<u>Gaultheria shallon</u>
Coyote brush	<u>Baccharis pilularis</u> ssp. <u>consanguine</u>
Hairy manzanita	<u>Arctostaphylos columbiana</u>
Cascara sagrada	<u>Rhamnus purshiana</u>
Silk-tassel	<u>Garrya elliptica</u>
Wax-myrtle	<u>Myrica californica</u>
Cream bush	<u>Holodiscus discolor</u>
Sticky monkey-flower	<u>Mimulus aurantiacus</u>
Red elderberry	<u>Sambucus callicarpa</u>
Pacific rhododendron	<u>Rhododendron macrophyllum</u>
<u>Vinelike Shrubs</u>	
California blackberry	<u>Rubus vitifolius</u>
Salmonberry	<u>R. spectabilis</u>
Thimbleberry	<u>R. parviflorus</u>
Red-flowering currant	<u>Ribes sanguineum</u>
Huckleberry	<u>Vaccinium ovatum</u>
Red bilberry	<u>V. parvifolium</u>
<u>Herbs and Ferns</u>	
Cow parsnip	<u>Heracleum lanatum</u>
Pearly everlasting	<u>Anaphalis margaritacea</u>
Sword fern	<u>Polystichum munitum</u>
Douglas iris	<u>Iris douglasiana</u>
Bracken	<u>Pteridium aquilinum</u>

Succession. Coastal mixed shrub habitat type is typically seral to coastal conifer forest, but may be steady-state on exposed coastal slopes or where substrate conditions do not support forest species (Figure 8-15d). Blueblossom is more prevalent after fire due to fire-stimulated germination of seeds stored in litter and duff (Zinke, 1977). On sites where coastal conifer forest cover type has been harvested, coast mixed shrub may comprise a temporary pioneer habitat type, rather rapidly (within 10-20 years) being replaced by red alder forest or by one of the coastal conifer forest habitat types.

Habitat Classification

BROAD-LEAVED FORESTS AND WOODLANDS: areas of land dominated by broad-leaved trees (i.e., woody perennials at least 5m tall) with either deciduous or evergreen leaves. Trees comprise greater than 70 percent of the vegetation cover in forests and 30-70 percent in woodlands.

Cover Type

BROAD-LEAVED
EVERGREEN
FOREST

OAK WOODLAND

RIPARIAN
FOREST

Habitat Type

Mixed Ever-
green Forest

Northern Oak
Woodland

- Mixed Riparian
Forest

- California Bay
Forest

- Valley Oak
Woodland/
Savanna

- Red Alder
Forest

- Canyon Live
Oak Forest

- Blue Oak
Woodland

- Coast Live
Oak Forest

- Southern
Coastal Oak
Woodland

Figure 8-17. Hierarchical Dendrogram of Component Cover and Habitat Types of Broad-leaved Forests and Woodlands

BROAD-LEAVED FORESTS AND WOODLANDS

The broad-leaved forest and woodlands, described in Figure 8-17, are comprised of three cover types; broad-leaved evergreen forest, oak woodlands, and riparian forest, which are described in the following sections.

Broad-Leaved Evergreen Forest

Physiognomy. The broad-leaved evergreen forest cover type is typically a closed forest (70-100 percent overstory cover) of predominantly broad-leaved evergreen tree species 9-36 m (30-120 ft) tall. In the North Coast Ranges it often includes a significant proportion of Douglas fir (<50 percent of overstory tree cover) as scattered mature trees, to 70 m (230 ft) tall or as understory seedlings or saplings. The shrub layer is dense to absent; herb layer is sparse to absent. It often forms extensive mosaics with grasslands, oak woodlands, chaparral, and conifer forests. Included habitat types are not distinct entities, but rather modal points on compositional and environmental continua. The habitat types are given in Table 8-18.

Table 8-18. Habitat Types in Evergreen Forests

Habitat Type	Dominant Plants	Regional Distribution
Mixed evergreen forest	Tanoak (<u>Lithocarpus densiflorus</u>) Douglas-fir (<u>Pseudotsuga menziesii</u>)	North and South Coast Ranges
California bay forest	California bay (<u>Umbellularia californica</u>)	North and South Coast Ranges
Coast live oak forest	Coast live oak (<u>Quercus agrifolia</u>) Madrone (<u>Arbutus menziesii</u>)	North and South Coast Ranges
Canyon live oak forest	Canyon live oak (<u>Q. chrysolepis</u>)	North and South Coast Ranges

Climate. Average annual precipitation is 64-165 cm (25-65 in) and the growing season is 7-11 months. Mean summer maximum temperatures are 24°C-32°C (75°F-90°F) and mean winter minimum temperatures are -2°C-4°C (29°F-39°F) (Munz and Keck, 1949).

Topography. This cover type typically occurs on steep to very steep (25-80 percent) slopes, canyon sides, and ridges throughout coast ranges to 1,200 m (4,000 ft) in elevation. It may occur at somewhat higher elevations in the South Coast Ranges. Canyon live oak forest is found at 900-1,800 m (3,000-6,000 ft) elevations in the South Coast Ranges. Where environmental conditions are more xeric (i.e., to the south: on shallower, coarser soils; inland) this cover type is found primarily on moister, north facing slopes. The best development of broad-leaved evergreen forest is inland in the north; closer to the coast in the south.

Substrate. Soils are typically well drained, coarse textured, and of colluvial or residual origin. This cover type is often restricted to rock outcrops in areas of heavier soils. The Hugo soil series is most common under the broad-leaved evergreen forest cover type in Mendocino and Humboldt Counties. This soil is 76-150 cm (30-60 in) deep, a gravelly sandy clay loam, moderately to strongly acidic with little horizon development, and derived from hard sedimentary Franciscan rocks (Delapp, 1960). Waring and Major (1964) found soil moisture availability to be the primary correlate of plant species distributions on environmental gradients from redwood forest through mixed evergreen forest to oak woodland and grassland.

Vegetation. The overstory tree canopy is typically closed and comprised primarily of broad-leaved evergreen trees. Canyon live oak (*Quercus chrysolepis*) and California bay (*Umbellularia californica*) (both evergreen) and bigleaf maple (*Acer macrophyllum*) (winter deciduous) are widespread in this cover type throughout the study region, although only locally dominant. Douglas fir (*Pseudotsuca menziesii*) is widespread from the Santa Cruz Mountains northward in the mixed evergreen forest habitat type. Where Douglas fir occurs as mature trees, a two-layered overstory exists: Douglas fir forms an open upper overstory above a more closed lower broad-leaved overstory layer. Presence of shrub and herb vegetation is highly variable, depending on available light and soil moisture conditions. Sprouting broad-leaved species may form dense chaparral-like thickets (less than 30 feet tall) where exposed to constant winds, on high elevation south aspects, or where catastrophic fires occur frequently.

Vegetation Seasonality and Modes of Reproduction. All important dominants are evergreen, enabling some growth activity during warm periods in winter. Growth increases rapidly in spring and continues at a reduced rate through summer. To the south, growth begins earlier and is reduced to a greater extent during late summer drought. In higher elevation canyon live oak forests, growth extends from late spring into summer. All broad-leaved tree species sprout vigorously when burned, often creating multiple-stemmed sprout clumps around fire-killed trees.

Characteristic Fauna. Characteristic mammals of the broad-leaved evergreen forest cover type are taken from Ingles (1965). Small (1974), Van Velzen (1972-1975) and Ryder and Ryder (1976) provide information on common California birds by habitat type. Common or characteristic reptiles and amphibians are derived from Stebbins (1966). Species in Table 8-19, although characteristic of broad-leaved evergreen forests, are not found exclusively in the habitat type(s) indicated. Abbreviations (e.g., LH, SFE, TA), following species common names refer to types of consumers in the general food web for this cover type (see Figure 8-18 for explanation of abbreviations). See the Community Composition List, Volume III, Part 2, for more information on species listed below, and for information on characteristic invertebrate species.

Table 8-19. Characteristic Fauna of a Broad-Leaved Forest¹

Mammals	Birds	Reptiles and Amphibians
Black-tailed deer (LH)	California Bay Forest/ Coast Live Oak Forest	Ensatina (TA)
Coyote (LC) (TI)	Common bushtit (TIE) (SFE)	California slender salamander (TA)
Gray fox (LC)	White-crowned sparrow (SFE) (TIE)	Arboreal salamander (TA)
Spotted skunk (SC) (TI)	Lesser goldfinch (SFE) (TIE)	Western toad (TA)
Dusky-footed woodrat (SE) (SH)	House finch (SFE) (TIE)	Western fence lizard (TR)
Western gray squirrel (SE)	Ruby-crowned kinglet (TIE)	Western skink (TR)
Brush rabbit (SH)	Brown towhee (SFE) (TIE)	N. Alligator lizard (TR)
Pocket gopher (SH)	Song sparrow (SFE) (TIE)	Gopher snake (TR)
California mouse (SE) (TI)	Wrentit (TIE) (SFE)	Common garter snake (TR)
Pinyon mouse (SE) (TI)	Acorn woodpecker (SFE) (TIE)	Common kingsnake (TR)
Ornate shrew (TI)	Anna's hummingbird (NE) (TIE)	
Hoary bat (FI)	Black phoebe (TIE)	
Western pipistrelle (FI)	Scrub jay (SFE) (TIE) (CB) (SB)	
	Plain titmouse (SFE) (TIE)	
	Bewick's wren (TIE)	
	Yellow-rumped warbler (TIE)	
	Rufous-sided towhee (SFE) (TIE)	
	Nuttall's woodpecker (TIE) (SFE)	
	Mixed Ews.-tree.r.I Forest	
	Common bushtit (TIE) (SFE)	
	Black-headed grosbeak (SFE) (TIE)	
	Western flycatcher (TIE)	
	Chestnut-backed chickadee (TIE) (SFE)	
	warbling vireo (TIE)	
	Wrentit (TIE) (SFE)	
	Wilson's warbler (TIE)	
	Orange-crowned warbler (TIE)	
	Wince Wren (TIE)	
	Swainson's thrush (TIE) (SFE)	
	American robin (SF'S) (TIE)	
	Bewick's wren (TIE)	
	Brown towhee (SFE) (TIE)	

¹See Figure 8-18 for definitions of abbreviations.

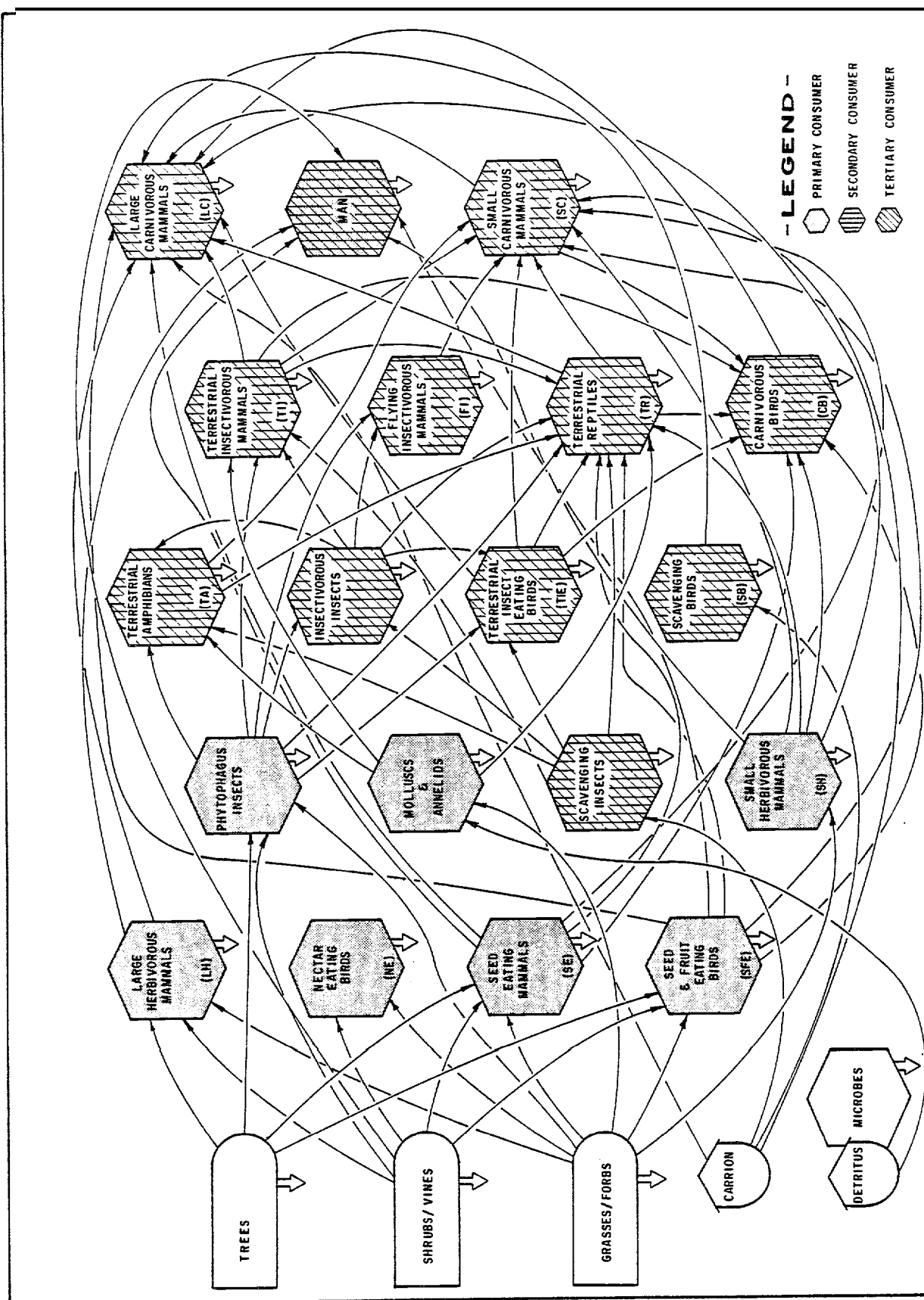


Figure 8-18. General Food Web - Broad-leaved Forests and

Table 8-19, cont'd

Mammals	Birds	Reptiles and Amphibians
	Songsparrow (SFE) (TIE)	
	Brown-headed cowbird (SE) (TIN)	
	Purple finch (SFE) (TIE)	
	Pine siskin (SFE) (TIE)	
	Rufous-sided towhee (SFE) (TIE)	
	California quail (SFE) (TIE)	
	Dark-eyed junco (SFE) (TIE)	

Biomass Productivity and Food Web. Net primary productivity varies widely depending on local temperature and soil moisture conditions. Mast (i. e., acorns, nuts, fruits), production of oaks, tanoak, madrone and California bay is utilized by a number of primary consumers in the food web (see Figure 8-19). These include mammals, such as the black-tailed deer, California mouse, and a dusky-footed woodrat; and birds, such as the brown towhee and California quail. Tree, shrub, and herbaceous foliage provides food primarily for herbivores, such as the black-tailed deer and brush rabbit and phytophagous insects, such as the California laurel borer. Deer browsing on sprout shoots may be locally heavy. Important secondary consumers in the food web include insectivores such as the Nuttall's woodpecker, western fence lizard, ensatina, ornate shrew and hoary bat; and carnivores, such as the gray fox, spotted skunk and scrub jay, which also act as scavengers in the food web. These secondary consumers may also function as tertiary consumers, feeding on secondary as well as primary consumers. For example, the gray fox may feed on the ornate shrew (a secondary consumer) as well as the brush rabbit (a primary consumer). The scrub jay is a good example of an omnivore, feeding on seeds and fruit (SFE), insects (TIE), bird eggs and small mammals (CB) and carrion (SB). Man functions as an omnivore, consuming some fruit (e.g., huckleberry) (SE) and game mammals and birds (LC).

Important Biotic Interactions. Seed predators may eliminate viable seed supplies of Douglas-fir, tanoak, and oaks in years of low to moderate seed production (Fowells, 1965). Allelopathic chemicals produced by California bay may limit understory vegetation in California bay stands (Sawyer et al., 1977).

Important Abiotic Interactions. Intensity and frequency of fire interacts with available seed supply, viability and density of sprouts, and site conditions to determine species composition and density of regenerating forest stands. Windthrow and mass wasting on steep slopes are also significant disturbance factors. Snow damage can be particularly destructive to broad-leaved species that maintain leaves through winter. Wind pruning is common in coastal stands of California bay forest and coast live oak forest.

Associated Cover Types. Broad-leaved evergreen forest ecosystems are associated with coastal conifer forest (lower elevation, more mesic sites), lower montane conifer forest (higher elevation, more mesic sites), grassland (more xeric sites with heavier soils), chaparral (more xeric sites, rockier soils), oak woodlands (more xeric sites), and coastal scrublands (more xeric sites near coast).

Vegetation Succession. Interpretation of the successional status of this cover type is complex due to unknown effects of past disturbances by fire, range clearing and logging. All included habitat types re-establish readily after fire and logging due to the sprouting behavior of characteristic broad-leaved dominants. Where mixed evergreen forest intergrades with coastal conifer forest, and in the absence of disturbance for more than 100-150 years, this cover type may be seral to coastal conifer forest cover type. Under similar conditions, canyon live oak forest may be seral to the lower montane conifer forest cover type. Hypothetical successional patterns for the broad-leaved evergreen forest cover type are portrayed in Figure 8-20.

Typical Land Uses. Ecosystems of the broad-leaved evergreen cover type have been cleared for livestock range, logged for Douglas fir timber, and used as wildlife habitat. At the turn of the century, large areas of tanoak were harvested for the tanning chemicals in tanoak bark. Some areas of the mixed evergreen forest habitat type are now being converted to conifer timber production.

Sensitivity to Disturbance. Sprouting capability of common dominant broad-leaved species ensures relatively rapid revegetation following fire or logging. Typical steep slopes produce high erosion hazard after soil disturbance, even though common soil types are rated as low in erodibility (Laacke, 1979).

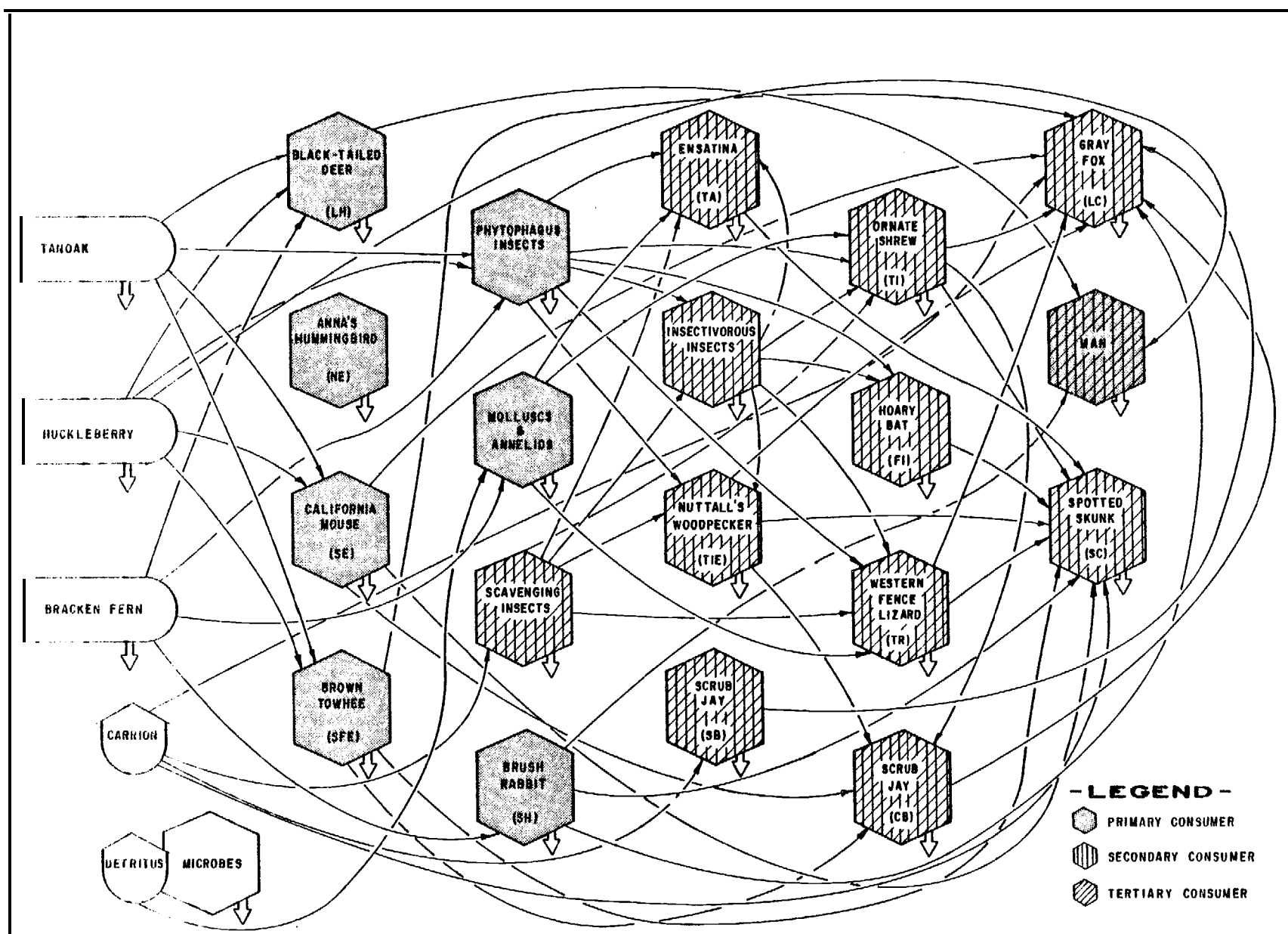


Figure 8-19. An Example of a Broad-leaved Evergreen Forest Food Web

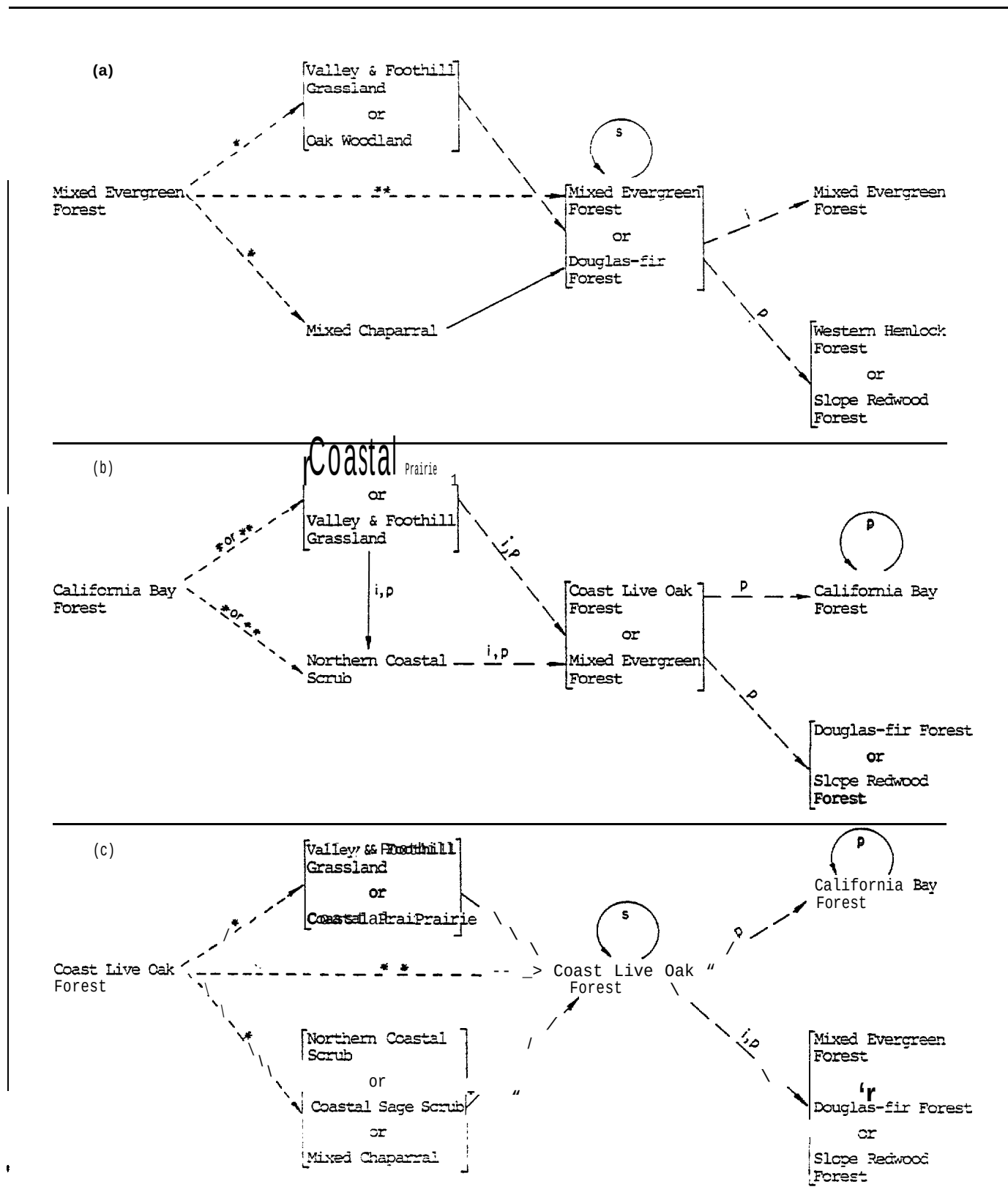
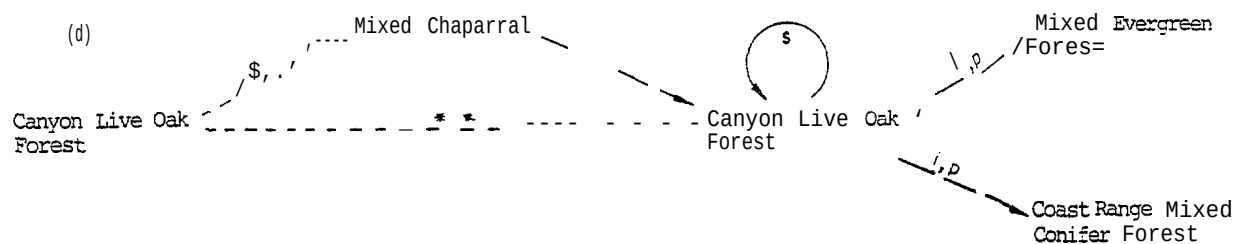


Figure 3-10. Successional Sequences (a-d) Suggested for Broad-leaved Evergreen Forest Habitat Types



Key to Symbols:

Types of Disturbance

- * High intensity disturbance, frequent fire
- % Moderate intensity disturbance, frequent fire

Types of Habitat Type Replacement

- ... → Replacement after disturbance (rate unspecified)
- Moderate to rapid replacement (<50 years)
- Slow replacement (>50 years)
- ↻ Steady-state, no replacement

Site Favorability (Microclimate, Substrate)

- s - Stressed (low productivity) sites, frequent and/or low intensity disturbance
- i - Intermediate site, rare disturbance
- p - Productive site, no disturbance

NOTE: For discussion of Successional Process, see Ecosystem Characterization of Chapter 8.

Figure 8-20 (continued)

Ecosystem Model. Important interactions and components of typical broad-leaved evergreen forest ecosystems are highlighted in Figure 8-21.

Habitat Type Description: Mixed Evergreen Forest

Distribution. The mixed evergreen forest habitat type is found in the North and South Coast Ranges from Del Norte County to Santa Cruz County with scattered occurrences in the Santa Lucia Mountains of Monterey County. It occurs at elevations of 60-900 m (200-3,000 ft) in the north and 300-1,200 m (1,000-4,000 ft) in the south (Cheatham and Hailer, 1975).

Watersheds. Smith River, Klamath River, Mad River, Eel River, Mattole River, Noyo River, Gualala River, Russian River, Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo River, Morro Bay.

Vegetation. This habitat type is spatially and ecologically transitional between coastal conifer forests (Douglas fir forest, slope redwood forest, western hemlock forest) and oak woodlands (northern oak woodland). It intergrades with all of the above as well as with lower montane conifer forests. Typical ecosystems of this habitat type have a two-level canopy; an irregular upper stratum of Douglas fir to 70 m (220 ft) tall and a more continuous lower stratum of tanoak to 36 m (120 ft) tall. The shrub layer is typically dense; the herb layer is sparse. Species composition of this habitat type is similar to that of Douglas fir forest habitat type, but with a lesser proportion of Douglas fir (i.e., <50 percent of total tree cover). Characteristic plants are given in Table 8-20.

Table 8-20. Characteristic Plants of a Mixed Evergreen Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Tanoak	<u>Lithocarpus densiflorus</u>
Douglas fir	<u>Pseudotsuga menziesii</u>
Madrone	<u>Arbutus menziesii</u> (slopes and ridges)
Giant chinquapin	<u>Chrysolepis chrysophylla</u> (north slopes)
Bigleaf maple	<u>Acer macrophyllum</u> (moister sites)
Canyon live oak	<u>Quercus chrysolepis</u>
California bay	<u>Umbellularia californica</u>
Western hemlock	<u>Tsuga heterophylla</u> (Humboldt and Del Norte Counties)
Coast redwood	<u>Sequoia sempervirens</u>
<u>Shrubs</u>	
Tanoak	<u>Lithocarpus densiflorus</u> (understory shrub form)
Hazelnut	<u>Corylus cornuta</u>
Salal	<u>Gaultheria shallon</u>
Huckleberry	<u>Vaccinium ovatum</u>
Oregon grape	<u>Berberis nervosa</u>
Wild rose	<u>Rosa gymnocarpa</u>
Rose bay	<u>Rhododendron macrophyllum</u>
<u>Herbs</u>	
Redwood sorrel	<u>Oxalis oregana</u> (moister slopes)
Sword fern	<u>Polystichum munitum</u> (moister slopes)
Bracken fern	<u>Pteridium aculeatum</u> (drier slopes)
Yerba de selva	<u>Whipplea modesta</u>

Succession. Several different successional sequences have been postulated for typical mixed evergreen forest stands following fire or logging (Sawyer et al., 1977). Determining factors may include fire or logging intensity, availability of Douglas fir seed to the site, substrate and microclimate conditions during establishment period for Douglas fir seedlings, and tanoak sprout viability. Serai stands

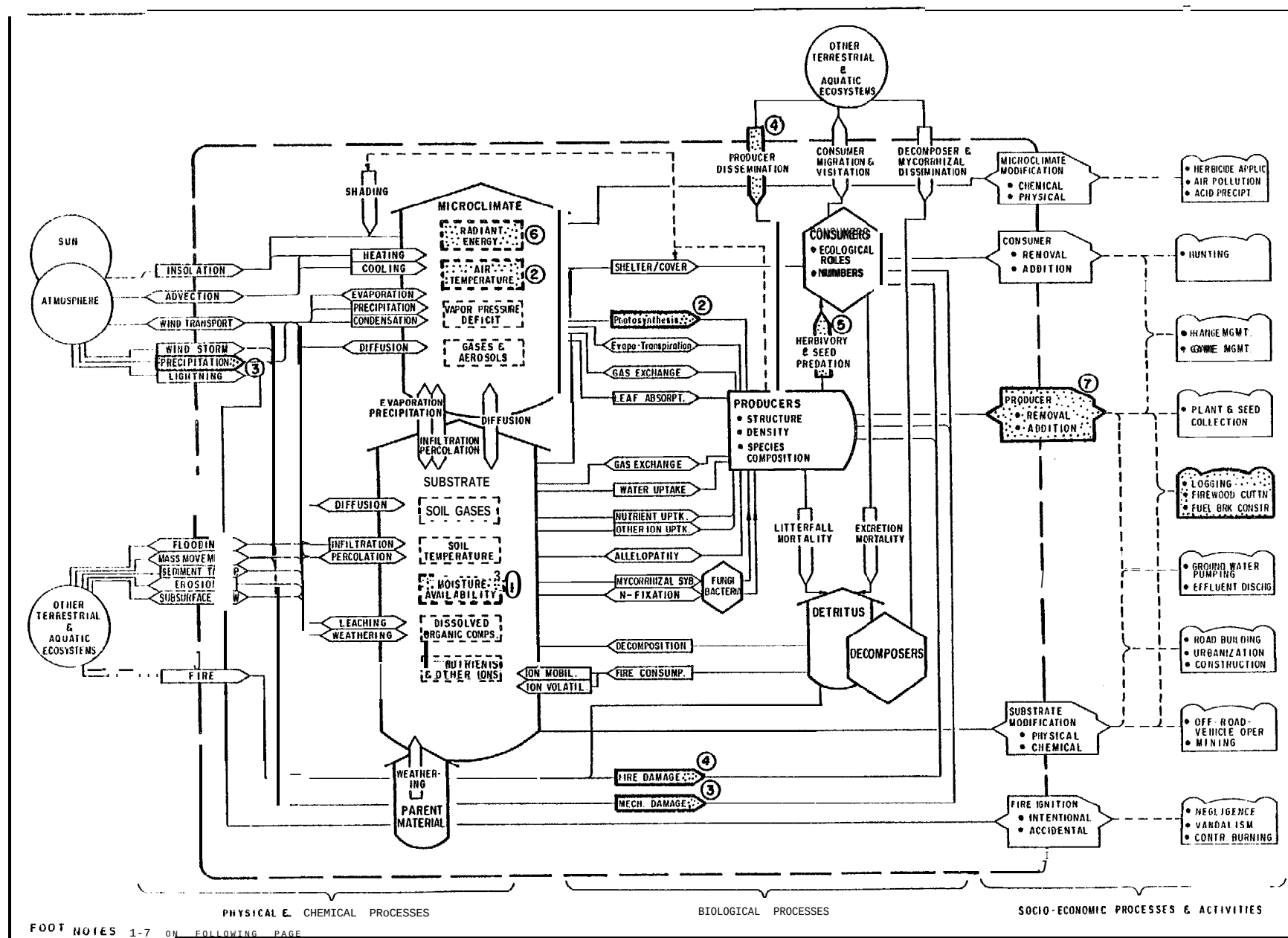


Figure 8-21. Ecosystem Model - Broad-leaved Evergreen Forest Cover Type

Footnotes for Figure 8-21
Ecosystem Model for the Broad-Leaved Evergreen Forest Cover Type-
Highlighted Processes and Components are Annotated Below

1. SOIL MOISTURE AVAILABILITY: Dry season soil moisture availability may constitute the major distinguishing environmental variable between broad-leaved evergreen forest and coastal conifer forest (moister) and oak woodland (drier) (Waring and Major, 1964). Year-to-year variations in soil moisture availability cause overlaps in seedling distributions for species characteristic of each of the three cover types.
2. AIR TEMPERATURE AND PHOTOSYNTHESIS: The evergreen foliage of characteristic dominants allows photosynthesis during warm periods in winter when soil moisture and soil nutrients are plentiful.
3. PRECIPITATION AND MECHANICAL DAMAGE: Evergreen foliage becomes a liability when unusually heavy snowfalls cause breakage of broad-leaved evergreen trees. Broken tree debris becomes highly flammable fuels for catastrophic fires in subsequent years (Griffin, 1978).
4. FIRE DAMAGE AND PRODUCER DISSEMINATION: After destruction by fire, this cover type typically replaces itself due to the sprouting ability of characteristic broad-leaved tree species. Douglas fir, a characteristic species of the mixed evergreen forest habitat type, reproduces by seed only. The proportion of Douglas-fir in a regenerating stand depends on the availability of Douglas fir seed to the site and the conditions of substrate and microclimate occurring during the establishment period for Douglas fir seedlings.
5. HERBIVORY AND SEED PREDATION: Mammals and birds consume mast (e.g., oak acorns, madrone berries) produced by the tree species characteristic of this cover type. In years of low to moderate seed production, all viable seed may be utilized by seed predators.
6. RADIANT ENERGY: The amount of radiant energy reaching the forest floor governs the establishment and growth of tree seedlings. Radiant energy available beneath California bay forest is typically inadequate for seedlings of other tree species. Beneath mixed, two-level overstories of Douglas fir and tanoak, both of these moderately shade-tolerant species can regenerate.
7. PRODUCER REMOVAL: Logging, range clearing, and burning have removed vegetation cover and converted areas of this cover type to grassland or chaparral (especially in the Mattole River watershed unit).

of pure Douglas fir, pure tanoak, or mixed composition may establish immediately. Eventually a steady-state mixed stand will develop due to the ability of both species to tolerate moderate shade as seedlings and to respond with increased growth to opening of the overstory canopy from natural mortality after 100-150 years. In lower elevation ecosystems of this habitat type where seeds of western hemlock are available, mixed evergreen forest may be seral to the western hemlock forest habitat type after a sufficient interval without disturbance.

Habitat Type Description: California Bay Forest

Distribution. California bay forest habitat type occurs in the outer coast ranges from Humboldt County to San Luis Obispo County. It is usually away from the coast in the North Coast Ranges, near the coast in South Coast Ranges, and to 900 m (3,000 ft) in elevation (Cheatham and Hailer, 1975).

Watershed Units. Smith River, Klamath River, Mad River, Eel River, Mattole River, Noyo River, Gualala River, Russian River, Salmon Creek, Lagunitas Creek, San Francisco Bay, San Gregorio Creek, San Lorenzo River, Carmel River, Morro Bay.

Vegetation. Pure, dense (100 percent tree cover) stands of California bay up to 11 m (35 ft) tall with little or no understory vegetation are typical (Table 8-21). These stands often occur as small areas of multistemmed clusters (from sprout origin after fires) within other habitat types (such as slope redwood forest or mixed chaparral).

Table 8-21. Characteristic Plants of a California Bay Forest

Plant Types/Common Names	Scientific Names
<u>Trees</u>	
California bay	<u>Umbellularia californica</u>
<u>Shrubs</u>	
Poison oak	<u>Rhus diversiloba</u>
<u>Herbs</u>	
Fairy bells	<u>Disporum hookeri</u>
Star flower	<u>Trientalis latifolia</u>

Succession. Once the tree canopy has closed, understory light intensity is reduced to less than 10 percent of full sunlight; no tree species other than California bay is able to establish seedlings in such low light. McBride (1974) has postulated a successional sequence in coastal hills of the San Francisco Bay area from grassland to coastal scrubland to coast live oak forest to a steady state California bay forest (Table 8-20b). Windthrow of large California bay trees may allow establishment and growth of seedlings of other broad-leaved (e.g., tanoak) or conifer (e.g., redwood) species, resulting in replacement of California bay forest by mixed evergreen forest or coastal conifer forest.

Habitat Type Description: Coast Live Oak Forest

Distribution. This habitat type occurs in the outer coast range from Sonoma County south to Santa Barbara County, at elevations from sea level to 900 m (3,000 ft). It intergrades with mixed evergreen forest in the North Coast Ranges and with southern coastal oak woodland in the South Coast Ranges (Cheatham and Hailer, 1975).

Watershed Units. Gualala River, Russian River, Salmon Creek, Lagunitas Creek, San Francisco Bay, San Gregorio Creek, San Lorenzo River, Pajaro River, Carmel River, Morro Bay, Santa Maria River, San Antonio Creek, Santa Ynez River, Point Arguello.

Vegetation. This habitat type is typically a moderately dense (70-90 percent tree cover) mixed forest of broad-leaved evergreen trees dominated by coast live oak, and sometimes with a partial understory shrub cover (Table 8-21). Coastal stands may be severely wind pruned.

Table 8-21. Characteristic Plants of Coast Live Oak Forests

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Coast live oak	<u>Quercus agrifolia</u>
Madrone	<u>Arbutus menziesii</u>
California bay	<u>Umbellularia californica</u>
Tanoak	<u>Lithocarpus densiflorus</u>
Interior live oak	<u>Quercus wislizenii</u>
<u>Shrubs</u>	
Poison oak	<u>Rhus diversiloba</u>
Coyote brush	<u>Baccharis pilularis</u> ssp. <u>consanguine</u>
Toyon	<u>Heteromeles arbutifolia</u>
Coffeeberry	<u>Rhamnus californica</u>
Sticky monkeyflower	<u>Mimulus aurantiacus</u>

Succession. Coast live oak forest is seral to the California bay forest habitat type where California bay seed supply is available and a long interval without fire (more than 100 years) occurs. Such circumstances are rare except in local sites such as moist, shaded canyon bottoms. Recurrent low intensity fires will eliminate California bay seedlings without damaging coast live oak overstory. Coast live oak forest may be seral to mixed evergreen forest habitat type where seeds of moderately shade-tolerant species such as Douglas fir and tanoak have access (Table 8-20c). After severe disturbance by catastrophic fire or range clearing, coastal scrubland or chaparral cover types may dominate for up to 60 years before re-establishment of the coast live oak forest habitat type (Wells, 1962).

Habitat Type Description: Canyon Live Oak Forest

Distribution. Canyon live oak forest occurs in the coast ranges from Del Norte County to Monterey County, usually away from the coast, at 300-1,200 M (1,000-4,000 ft) elevations in the north and at 900-1,800 m (3,000-6,000 ft) elevations in the south (Cheatham and Hailer, 1975).

Watershed Units. Smith River, Klamath River, Eel River, Mattole River, Noyo River, Gualala River, Russian River, San Francisco Bay, San Lorenzo River, Carmel River, Morro Bay.

Vegetation. This is a heterogeneous habitat type unified solely by dominance (i.e., >50 percent of total tree cover) of canyon live oak (Table 8-22). It intergrades with coast live oak forest, mixed evergreen forest, and mixed chaparral in canyons and on rocky north slopes at low elevations. It intergrades with lower montane conifer forest on dry or rocky slopes at higher elevations. Closed forest canopy with sparse understory vegetation is typical. Dense sprout thickets may occur on frequently burned steep slopes and summits.

Table 8-22. Characteristic Plants of a Canyon Live Oak Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Canyon live oak	<u>Quercus chrysolepsis</u>
Tanoak	<u>Lithocarpus densiflorus</u>
Madrone	<u>Arbutus menziesii</u>
California bay	<u>Umbellularia californica</u>
Interior live oak	<u>Q. wislizenii</u>
Bigleaf maple	<u>Acer macrophyllum</u> (in moist ravines)
Douglas fir	<u>Pseudotsuga menziesii</u> (in North Coast Ranges)
Coulter pine	<u>Pinus coulteri</u> (in Santa Lucia Mountains)
Sugar pine	<u>P. lambertiana</u>
Santa Lucia fir	<u>Abies bracteata</u> (on rocky outcrops and steep summits in Santa Lucia Mountains)
Bigcone Douglas fir	<u>Pseudotsuga macrocarpa</u> (on steep, rocky, north and east slopes in San Rafael Mountains)

Succession. Low productivity of canyon live oak ecosystems and great longevity of canyon live oak trees indicates very slow change in the dominant vegetation over time (Figure 8-20d). Theoretically, high elevation ecosystems of this habitat type will develop toward lower montane conifer forest but several hundred years without fire would be required to allow establishment, growth, and dominance of conifer species. Intervals of this duration are rare given frequency of lightning strikes in high elevation areas, and given accumulations of highly flammable fuels over long periods of time. Low elevation ecosystems of canyon live oak forest may gradually develop toward mixed evergreen forest as more shade-tolerant species (e.g., tanoak, Douglas fir) attain dominance.

OAK WOODLANDS

Ph vs iocnomv. The oak woodland cover type is characterized by a fairly open (20-70 percent cover) overstory tree canopy, 8-23 m (25-75 ft) tall of various oak species, sometimes with other broad-leaved or conifer trees; little or no understory shrub vegetation; and a generally uniform herbaceous matrix (80-90 percent cover) of grasses and forbs characteristic of the valley and foothill grassland habitat type. It is located at intermediate positions on environmental gradients, and sometimes in successional sequences, between grassland and broad-leaved evergreen forest. Ecological distinctions between the four oak woodland habitat types are not well understood (Griffin, 1977). Descriptions of the habitat types are given in Table 8-23.

Table 8-23. Habitat Types in the Oak Woodlands

Habitat Type	Dominant Plants	Regional Distribution
Northern oak woodland	Oregon white oak (<u>Quercus carrvana</u>) winter deciduous California black oak (<u>Q. kelloggii</u>) winter deciduous	North Coast Ranges only
Valley oak woodland/ savanna	Valley oak (<u>Q. lobata</u>) winter deciduous	North and South Coast Ranges
Blue oak woodland	Blue oak (<u>Q. douglasii</u>) drought deciduous Digger pine (<u>Pinus sabiniana</u>) evergreen	North and South Coast Ranges
Southern coastal oak woodland	Coast live oak (<u>Q. agrifolia</u>) evergreen	South Coast Ranges only

Climate. Annual precipitation averages 38-100 cm (15-40 in); growing season is 6-10 months; mean summer maximum temperatures are 24°C-36°C (75°F-96°F) and mean winter minimum temperatures are -2°C-6°C (29°F-42°F) (Munz and Keck, 1949).

Topography. This cover type occurs on coastal terraces in inland valleys anti on foothill slopes up to 900 m (3,000 ft) elevation. It occurs on all aspects, but is denser with more species on north and east slopes. Occasionally it is found on warmer ridgetops and south aspects to 1,500 m (5,000 ft) elevation.

Substrate. Typical soils range from deep alluvium to rocky outcrops, neutral to basic, heavy clays to gravelly loams, and fertile to nutrient-poor. Optimal development occurs on deep loams at bottoms of foothill slopes. Blue oaks are able to exploit sites where root zone soil moisture is depleted by late summer; valley oaks and coast live oaks maintain root contact with water tables throughout summer (Griffin, 1973).

Vegetation. Vegetation density and species composition vary in relation to environmental gradients of substrate moisture, soil nutrients, and soil temperatures. At the most stressed sites, the vegetation takes the form of an open overstory of oaks above an herbaceous ground layer of grasses and forbs. At more favorable sites, oak density is greater; other tree species such as California buckeye (Aesculus californica) and bigleaf maple (Acer macrophyllum) occur, and shrub density is greater as well.

Vegetation Seasonality and Modes of Reproduction. Trees include species that are drought-deciduous (blue oak and California buckeye), winter deciduous (valley oak, Oregon white oak), and evergreen (coast live oak, digger pine). Herbaceous species germinate in early winter with the first substantial rains, grow slowly through the winter, grow rapidly with warm spring temperatures, and mature and set seed as moisture is depleted in upper soil horizons during summer. Most common broad-leaved trees sprout vigorously when burned or browsed.

Characteristic Fauna. Characteristic mammals of oak woodland cover types are taken from Ingles (1965). Small [1.974] provides information on common California birds by habitat type (Table 8-24). Common or characteristic reptiles and amphibians are derived from Stebbins (1966). Species listed below, although characteristic of oak woodlands, are not found exclusively in the habitat type indicated. Abbreviations (e.g., LH, TIE, SFE), following species common names refer to types of consumers in the general ZOOS web for this cover type (see Figure 8-18 for explanation of abbreviations). See the Community Composition List, Volume III, Part 2, for more information on species listed "below, and for information on characteristic invertebrate species.

Table 8-24. Characteristic Fauna of an Oak Woodland Forest ¹

Mammals	Birrs	Reptiles and Amphibians
Slack-tailed deer (LH)	<u>Northern Oak Woodland</u>	Ensatina (TA)
Coyote (LC) (TI)	Plain titmouse (SFE) (TIE)	Arboreal salamander (TA)
Gray fox (LC)	White-breasted nuthatch (TIE) (SFE)	Slender salamander (TA)
Striped skunk (SC) (TI)	Western bluebird (TIE) (SFE)	California newt (TA)
Audubon's cottontail (SH)	Band-tailed pigeon (SFE)	western toad (TA)
Western gray squirrel (SE)	Anna's hummingbird (NE) (TIE)	Foothill yellow-legged
Beechey ground squirrel		frog (TA)
(SE) (SH) (TI) (SC)	<u>Valley Oak Woodland/Savanna</u>	Western fence lizard (TR)
Pocket gopher (SH)	Mourning dove (SFE)	Northern alligator
Broad-handed mole (TI)	Common flicker (TIE) (SFE)	lizard (TR)
Ornate shrew (TI)	Acorn woodpecker (SFE) (TIE)	Ringneck snake (TR)
California mouse (SE) (TI)	Lewis' woodpecker (TIE) (SEE)	Common kingsnake (TR)
Badger (LC)	Western kingbird (TIE) (SEE)	Common garter snake (TR)
Hoary bat (FI)	Western bluebird (TIE) (SFE)	Gopher snake (TR)
Pallid bat (FI)	Loggerhead shrike (CB) (TIE) (SS)	Sharp-tailed snake (TR)
Raccoon (SE) (SC) (TI)	Plain titmouse (SFE) (TIE)	Western rattlesnake (TR)
	Warbling vireo (TIE)	
	Turkey vulture (SB)	
	Golden eagle (CB) (SB)	
	Red-tailed hawk (CB) (SB)	
	Swainson's hawk (CB) (TIE) (SB)	
	American kestrel (CB) (TIE) (SB)	
	White-tailed kite (CB) (TIE) (SB)	
	Barn owl (CB) (TIE)	
	<u>Blue Oak Woodland</u>	
	Band-ailed pigeon (SEE)	
	Scrub jay (SFE) (TIE) (CB) (SS)	
	Acorn woodpecker (SFE) (TIE)	
	Lewis' woodpecker (TIE) (SFE)	
	California quail (SFE) (TIE)	
	Lark sparrow (SFE) (TIE)	
	White-breasted nuthatch (TIE) (SFE)	
	Dark-eyed junco (winter) (SFE) (TIE)	
	Mite-crowned sparrow (winter) (SFE) (TIE)	
	Purple finch (winter) (SFE) (TIE)	
	<u>Southern Coastal oak Woodland</u>	
	Red-shouldered hawk (CB) (TIE) (S3)	
	Great-horned owl (CB) (TIE)	
	Acorn woodpecker (SFE) (TIE)	
	Nuttall's woodpecker (TIE) (SFE)	
	Band-tailed pigeon (SFE)	
	Scrub jay (SFE) (TIE) (CB) (SB)	
	Hutton's vireo (TIE)	
	Common bushtit (TIE) (SFE)	
	Western wood pewee (TIE)	
	Ash-throated flycatcher (TIE)	
	Orange-crowned warbler (TIE)	
	Black-headed grosbeak (SFE) (TIE)	
	Anna's hummingbird (NE) (TIE)	

¹See Figure 8-22 for definitions of abbreviations.

Biomass Productivity and Food Web. Net primary productivity is low due to soil moisture depletion during mid to late summer. The ecosystem is characterized by a "grazing food chain", which supports numerous consumers of foliage and mast (see Figure 8-22). Primary consumers of tree, shrub and herbaceous foliage (herbivores) include black-tailed deer; domestic cattle, small mammals, such as the pocket gopher and Audubon's cottontail; and phytophagous insects, such as the California oak moth and California sister in larval stages. Mast and seed production provides food for the black-tailed deer; rodents, such as the western gray squirrel and California mouse; and birds, such as the acorn woodpecker, scrub jay and band-tailed pigeon. Important secondary and tertiary consumers include insectivores, such as the western bluebird, common bushtit, western toad and ornate shrew; and carnivores, such as the red-tailed hawk, gopher snake, coyote, and striped skunk. The turkey vulture is a common scavenger in "open" woodland habitat. An excellent example of an omnivore is the beechnut ground squirrel, which feeds on seeds (SE), herbaceous vegetation (SH), insects (TI) and bird eggs (SC). Man functions primarily as a carnivore (LC), consuming game mammals and birds.

Important Biotic Interactions. Oak regeneration success is a function of interactions between acorn production cycles, density of grass cover, annual precipitation, and populations of seed and seedling predators (Griffin, 1971, 1976). Preference of cattle and deer for deciduous foliage may have a differential effect on species composition and density of overstory oak trees. Oak trees alter microclimatic and soil conditions beneath their crowns. This causes significant differences in herbaceous species composition and productivity between sites under oak canopies and sites in open grassland (Holland, 1974).

Important Abiotic Interactions. Low intensity ground fires do not damage mature oaks but are effective at eliminating tree and shrub seedlings. High intensity fires (resulting from heavy fuel build-ups) can eliminate all woody vegetation on a site. Local vegetation distribution patterns may reflect interactions between positions on environmental gradients (e.g., soil texture, substrate moisture) and fire frequency and intensity at particular locations on the landscape (Wells, 1962).

Associated Cover Types. Cover types spatially associated with oak woodland include grassland (on heavier soils), chaparral (on shallower, rockier soils), mixed evergreen forest (on more mesic, more fertile soils), closed-cone conifer forest (on exceptionally sterile soils), and riparian forest (adjacent to perennial streams).

Vegetation Succession. This cover type is seral or steady state, depending on species composition of seed supply, favorability of microsites for establishment and growth of additional plant species, and the frequency and intensity of disturbance factors (e.g., fire, seed and seedling predators). Without disturbance, vegetation in ecosystems with abundant favorable microsites (e.g., adequate soil moisture, low evaporative stress) can be expected to change in the direction of broad-leaved evergreen forest (see Figure 8-23). Rate of change is a function of the number and favorability of such microsites and the quantity and composition of the seed supply.

Typical Land Uses. This cover type has been used as livestock range for several hundred years, as game habitat (e.g., deer, band-tailed pigeon, mourning dove) and more recently, for residential development and firewood cutting.

Sensitivity to Disturbance. Oak woodland ecosystems will recover slowly from tree removal and mechanical disturbance to soils because of the typical low rate of oak regeneration success. However, seeds of herbaceous species are stored in soil and will regenerate in abundance following first winter rains. Soils on steep slopes will be susceptible to erosion following removal of vegetation.

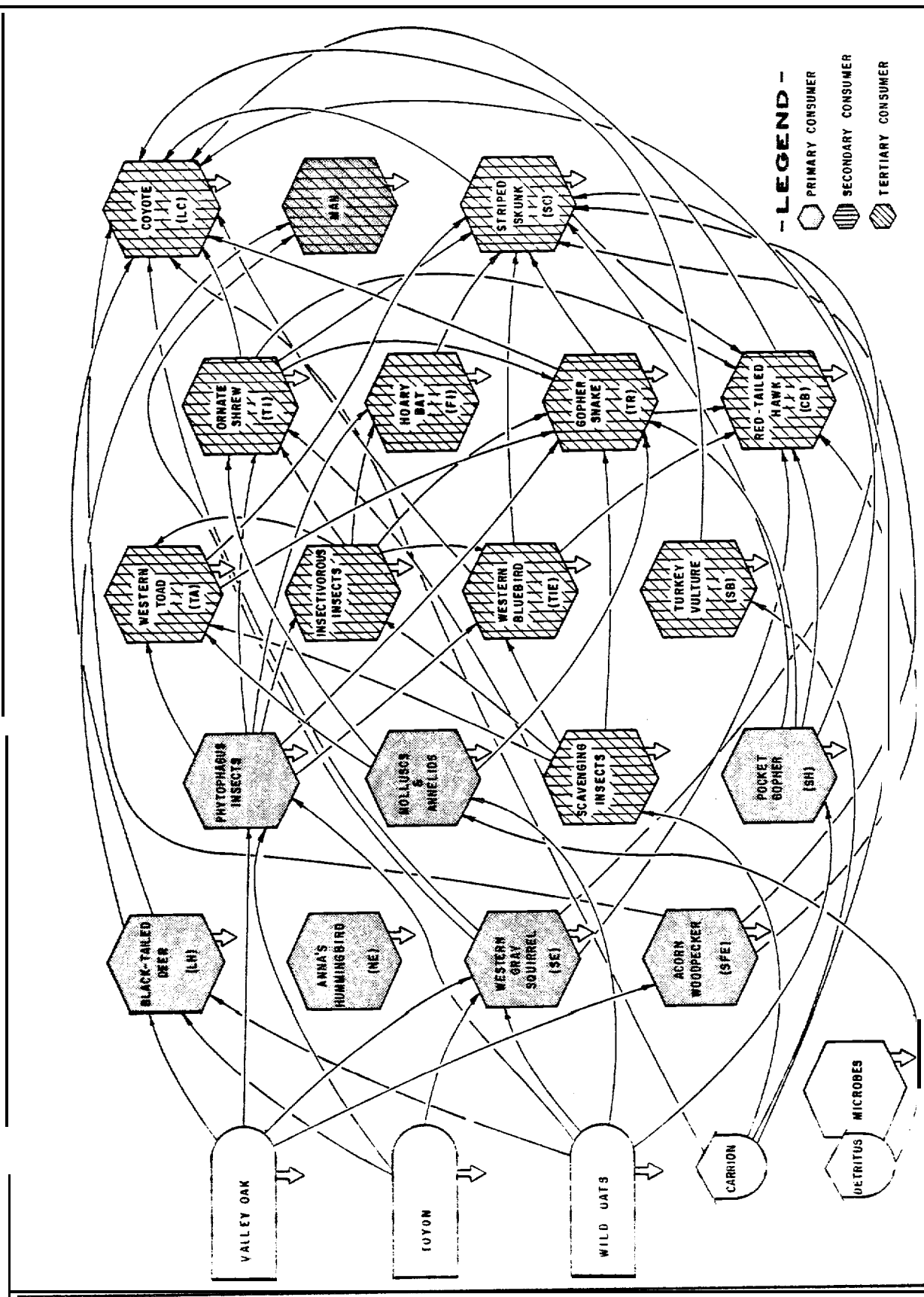
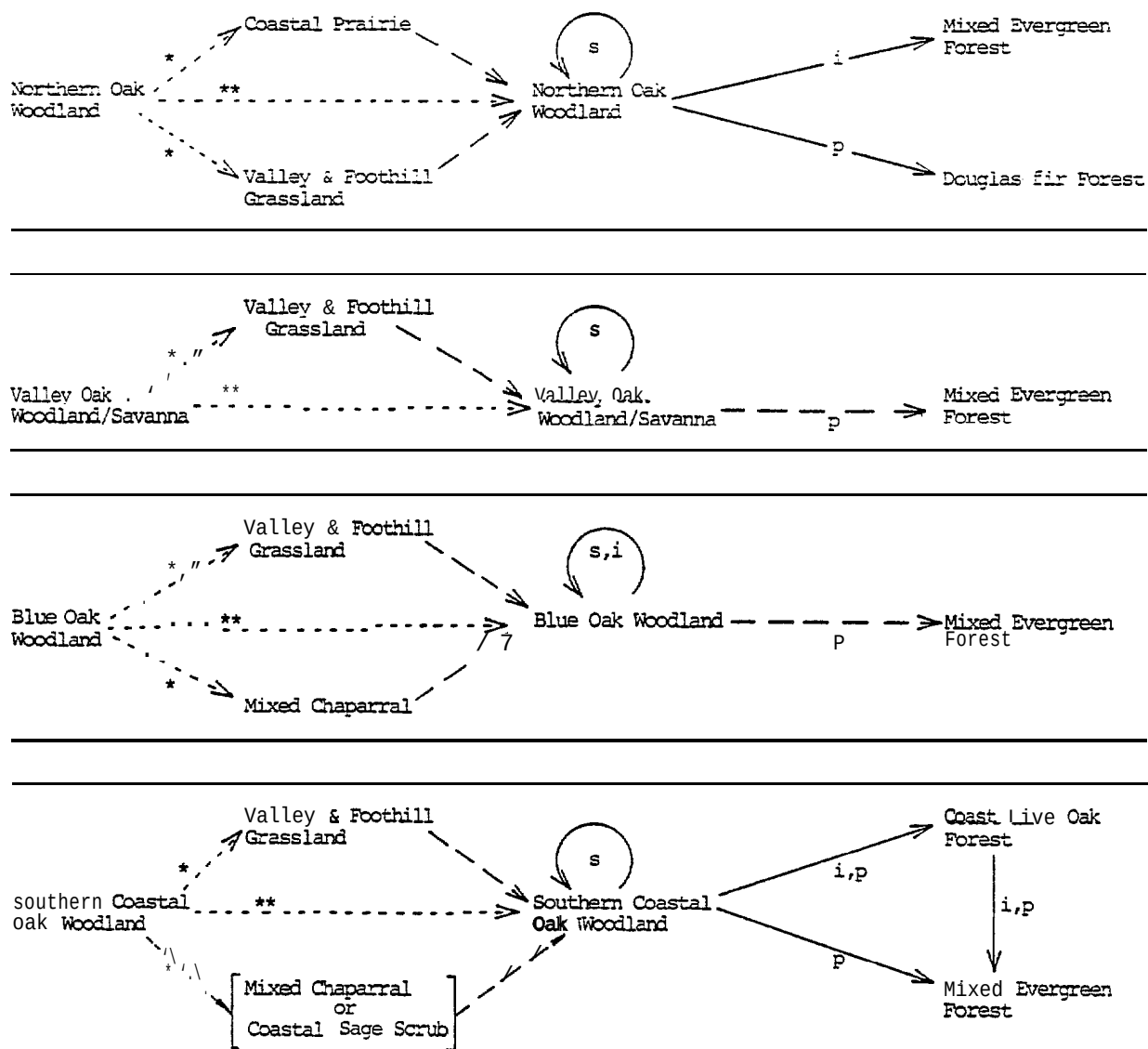


Figure 8-22. An Example of an Oak Woodland Feed Web



Key to Symbols:

Types of Disturbance

- * High intensity disturbance, frequent fire
- ** Low intensity disturbance, infrequent fire

Types of Habitat Type Replacement

- > Replacement after disturbance (rate unspecified)
- > Moderate to rapid replacement (<50 years)
- - -> Slow replacement (>50 years)
- ⬤ Steady-state, no replacement

Site Favorability (Microclimate, Substrate)

- s - Stressed (low productivity) sites, frequent and/or low intensity disturbance
- i - Intermediate sites, rare disturbance
- p - Productive sites, no disturbance

NOTE: For discussion of Successional Process, see Ecosystem Characterization of Chapter 3.

Figure 3-23. Successional Sequences Suggested for Oak Woodland Habitat Types

Ecosystem Model. Important processes and components of typical oak woodland ecosystems are portrayed in Figure 8-24,

Habitat Type description: Northern Oak Woodland

Distribution. Northern oak woodland habitat type occurs in the inner North Coast Ranges from Humboldt County to Marin County, at elevations of 150-900 in (500-3,000 ft).

Watershed Units. Smith River, Klamath River, Mad River, Eel River, Mattole River, Noyo River, Gualala River, Russian River.

Vegetation. Vegetation is typically an open to moderately dense woodland (30-80 percent cover) dominated by Oregon white oak, often with a high proportion of California black oak. Understory shrub cover is generally low; cover of grasses and forbs is usually high.

Table 8-25. Characteristic Plants of a Northern Oak Woodland Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Oregon white oak	<u>Quercus garryana</u>
California black oak	<u>Q. kelloggii</u>
Bigleaf maple	<u>Acer macrophyllum</u>
(moister microsites)	
California buckeye	<u>Aesculus californica</u>
(sites of high early-season water table)	
Canyon live oak	<u>Q. chrysolepis</u>
(steep, rocky slopes)	
Interior live oak	<u>Q. wislizenii</u>
Douglas-fir	<u>Pseudotsuga menziesii</u>
<u>Shrubs</u>	
Poison oak	<u>Rhus diversiloba</u>
Wild honeysuckle	<u>Lonicera hispidula</u>
Buck brush	<u>Ceanothus cuneatus</u>
Parry manzanita	<u>Arctostaphylos manzanita</u>
<u>Herbs</u>	
California oatgrass	<u>Danthonia californica</u>
Red fescue	<u>Festuca rubra</u>

Succession. Northern oak woodland vegetation may be steady state where environmental conditions of substrate and microclimate do not allow establishment of less stress-tolerant species such as Douglas fir or madrone or where seeds of such species are not available. Where seeds of these species are available and appropriate environmental conditions exist, northern oak woodland will develop toward mixed evergreen forest (Figure 8-23. Extensive areas of northern oak woodland (e.g., Mattole River valley) are being invaded by Douglas fir, possibly as a result of discontinued use of fire for range improvement (Zinke, 1977) .

Habitat Type Description: Valley Oak Woodland/Savanna

Distribution. This habitat type is found in valleys and occasionally on ridgetops in North and South Coast Ranges from Mendocino County southward, generally below 600 m (2,000 ft) elevation, but sometimes to 1,500 m (5,000 ft) in Santa Lucia Mountains.

Watershed Units. Noyo River, Gualala River, Russian River, Lagunitas Creek, San Gregorio Creek, San Lorenzo River, Carmel River, Morro Bay, San Antonio Creek, Santa Ynez River.

Vegetation. Valley oak is the sole tree species in typical valley oak savanna (less than 30 percent cover). In valley oak woodland (greater than 30 percent tree cover; , other tree species may occur. Valley oaks appear to be restricted to sites 'where roots can penetrate to a perennial water table.

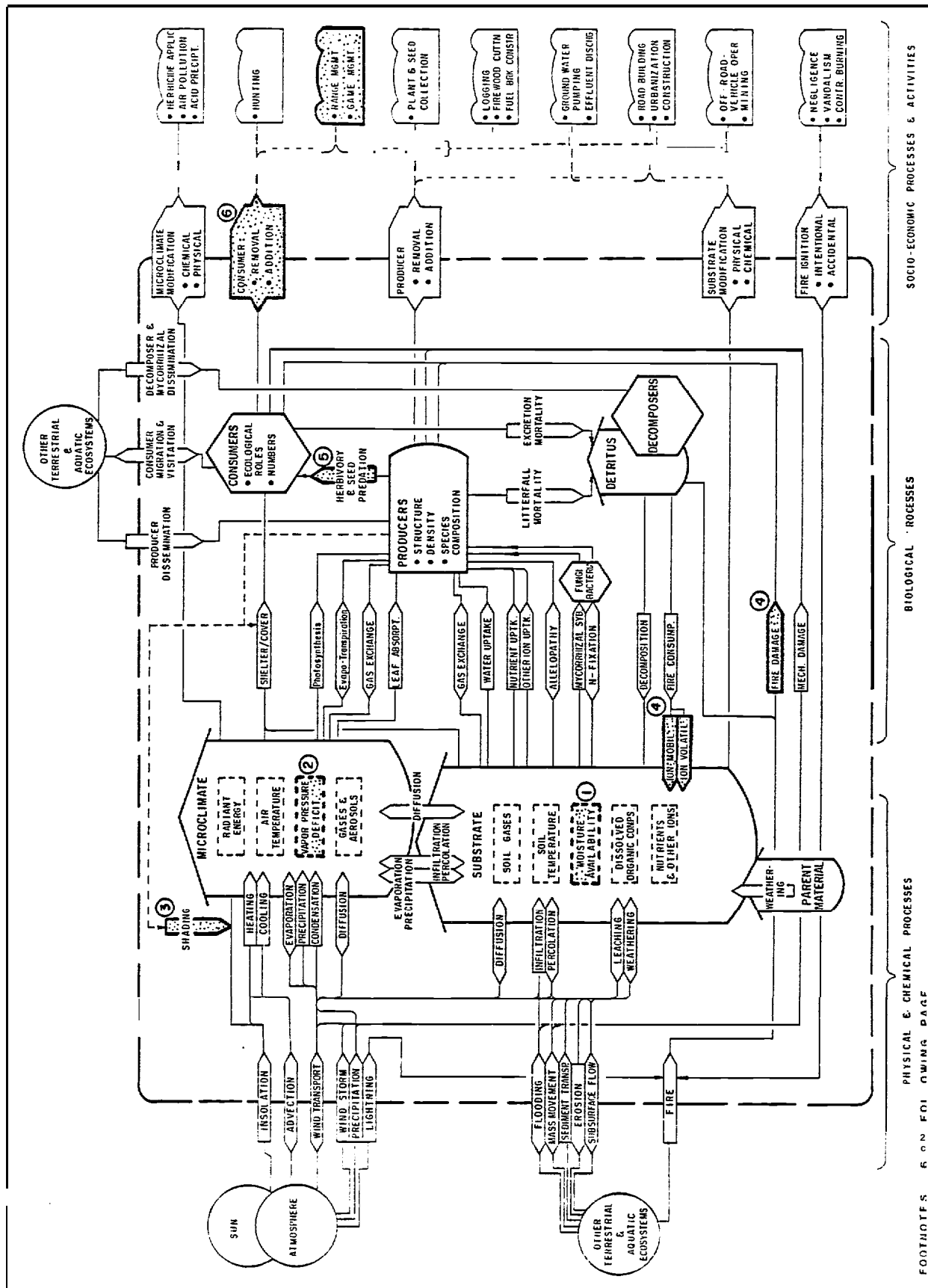


Figure 8-24. Ecosystem Model - Oak Woodland Cover Type

Footnotes on following page)

Footnotes for Figure 8-24.
Ecosystem Model for the Oak Woodland Cover Type-
Highlighted processes and components are Annotated Below

1. SOIL MOISTURE AVAILABILITY: Although oak woodland ecosystems occur on a wide variety of soil textures, all typically suffer depletion of upper horizon soil moisture by midsummer. Understory herbaceous annual vegetation has generally matured and set seed by this time. Tree regeneration may only be successful in years of high precipitation or on coarse soils where deep root penetration is facilitated. In ecosystems where soil moisture storage is adequate, species of the mixed evergreen forest habitat type may establish and replace oak woodland vegetation over time.
2. VAPOR PRESSURE DEFICIT: Oak woodland ecosystems have high vapor pressure deficits from midsummer until the first winter rain. Plants undergo a high transpirational load during this period. Annual species complete their life cycles by early summer. Drought-deciduous blue oaks drop their leaves in response to the combination of high transpirational load and root zone soil moisture depletion. Valley oaks maintain root contact with water tables and are thus able to balance transpirational water loss with water uptake. South aspects have higher vapor pressure deficits than north aspects.
3. SHADING : In successional oak woodland ecosystems, shading of overstory oaks may be important in moderating soil surface conditions of vapor pressure deficit and temperature, thereby enabling establishment of less stress-tolerant plant species (e.g., tanoak, Douglas fir).
4. FIRE DAMAGE, ION MOBILIZATION: Fires have been a natural and recurrent phenomena of oak woodland ecosystems. Fire intensity determines the amount of plant tissue destroyed. Fire intensity is a function of fuel buildup and fire weather (which determines fuel moisture content). Fuel buildups occur where biomass productivity is relatively higher (e.g., more mesic, more fertile sites) or when long intervals occur between fires. Although mature oaks are resistant to fire damage, oak seedlings are readily consumed. The typical open oak woodland vegetation may be maintained by frequent but low intensity ground fires. Fire consumption of soil organic matter and detritus mobilizes nutrients. Nitrogen is volatilized into the atmosphere; calcium, phosphorus, and potassium are mobilized into water-soluble forms. Winter-active herbaceous annuals are best able to utilize the increased nutrient availability following late summer or fall fires.
5. HERBIVORY, SEED PREDATION: Consumer utilization of oak acorns and seedlings can have a major influence on the success and species composition of oak regeneration (Griffin, 1977). Important consumers are cattle, deer, feral pigs, birds, rodents, rabbits, and insects.
6. CONSUMER ADDITION: Many oak woodland ecosystems are used as livestock range. High populations of cattle may significantly affect tree regeneration through seed and seedling predation and by compacting soils. They also may reduce fire intensity through consumption of grass biomass.

Table 9-26. Characteristic Plants of Valley Oak Woodland/Savannah Forests

Plant Types/Common Name	Scientific Name
<u>Trees</u>	
Valley oak	<u>Quercus lobata</u>
Blue oak	<u>Q. douglasii</u>
Coast live oak (sites with lower evaporative stress)	<u>Q. agrifolia</u>
Canyon live oak (higher elevations)	<u>Q. Chrvsolepsis</u>
Interior live oak	<u>Q. wislizenii</u>
Coulter pine (ridges in Santa Lucia Mountains)	<u>Pinus coulteri</u>
<u>Shrubs</u>	
Poison oak	<u>Rhus diversiloba</u>
<u>Herbs</u> (valley and foothill grassland species)	
Wild oat	<u>Avena fatua</u>
Ripgut brome	<u>Bromus rigidus</u>
California poppy	<u>Eschscholzia californica</u>
Filaree	<u>Erodium cicutarium</u>

Succession. Typical valley bottom **savannahs** of valley oak are steady-state (over 50-100 years) with no perceptible increases in density or species diversity, with or without fire and grazing (Figure 8-23b). Valley oaks are long lived. Infrequent coincidence of heavy acorn production, abundant precipitation, and low pressure from seed and seedling predators may be adequate to regenerate valley oaks and maintain the overstory. Where site conditions are less stressful (e.g., north aspect slopes, high elevations) , species of the mixed evergreen forest may establish and survive (Griffin, 1976) .

Habitat Type Description: Blue Oak Woodland

Distribution. The blue oak woodland habitat type occurs in valleys and on lower slopes of the North and South Coast Ranges from Sonoma County to Santa Barbara County. Elevations are generally below 3,000 feet, but may reach 5,000 feet on warm south-facing slopes. Blue oak woodland habitat type occurs on pockets of sterile soils within the mixed evergreen forest habitat type. Blue oak woodland may also intergrade with chaparral cover type on deeper, rocky soils (Griffin, 1977).

Watershed Units. Noyo River, Lagunitas Creek, Carmel River, Morro Bay, San Antonio Creek.

Vegetation. Blue oak woodland vegetation is typically an open to moderately dense overstory (20-80 percent cover) of blue oaks and digger pines above an open to dense overstory of chaparral shrub species (Table 8-27). Openings in shrub understory are occupied by sparse to dense cover of valley and foothill grassland species. Drought-deciduous blue oaks are able to exploit sites where root zone soil moisture is depleted by late summer (Griffin, 1973). Holland (1974) reported effects of blue oaks on microclimate, soil conditions, and herbaceous vegetation below tree canopies.

Table 8-27. Characteristic Plants of a Blue Oak Woodland

Plant Type/Common Name	Scientific name
<u>Trees</u>	
Blue oak	<u>Quercus douglasii</u>
Digger Pine	<u>Pinus sabiniana</u>
Valley oak (on deeper soils)	<u>Q. lobata</u>
California buckeye (on north slopes)	<u>Aesculus californica</u>
Coast live oak (at higher elevations, to the south)	<u>Q. agrifolia</u>
California black oak (at high elevations)	<u>Q. kelloggii</u>

Table 8-27 (continued)

Shrub s

Poison oak	<u>Rhus diversiloba</u>
Toyon	<u>Heteromeles arbutifolia</u>
Buck brush	<u>Ceanothus cuneatus</u>
Scrub oak	<u>Quercus dumosa</u>

Herbs

Valley and foothill
grassland species

Succession. This habitat type has low probability of development to broad-leaved evergreen forest cover type due to extreme soil moisture stress and soil sterility in many blue oak woodland ecosystems (Figure 8-23c). In some areas, burning for range improvement and high populations of range cattle and deer have prevented blue oak regeneration, and, over the long run, may convert this habitat type to valley and foothill grassland.

Habitat Type Description: Southern Coastal Oak Woodland

Distribution. This habitat type is found in the outer South Coast Ranges, usually below 1,200 m (4,000 ft) elevation. It intergrades with blue oak woodland away from the coast, with coastal scrubland and chaparral cover types on drier sites and with coast live oak forest and mixed evergreen forest cover types on moister sites (Cheatham and Hailer, 1975).

Watershed Units. Morro Bay, Santa Maria River, San Antonio Creek, Santa Ynez River, Point Arguello.

Vegetation. Coast live oak, an evergreen, is the dominant tree species (i.e., >70 percent of tree cover). Other tree species occur on north slopes where soil moisture and soil depth are greater (Table 8-28). Shrub density is typically greater than in other oak woodland habitat types.

Table 8-28. Characteristic Plants of a Southern Coastal Oak Woodland Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Coast live oak	<u>Quercus agrifolia</u>
California walnut	<u>Juglans californica</u> (north aspects in Santa Ynez Mountains)
California bay	<u>Umbellularia californica</u>
Madrone	<u>Arbutus menziesii</u>
<u>Shrubs</u>	
Toyon	<u>Heteromeles arbutifolia</u>
Coffeeberry	<u>Rhamnus californica</u>
Poison oak	<u>Rhus diversiloba</u>
Elderberry	<u>Sambucus mexicana</u>
Coyote brush	<u>Baccharis pilularis</u> ssp. <u>consanguinea</u>
<u>Herbs</u>	
Valley and foothill grassland species	

Succession. In the absence of frequent fire, vegetation of this habitat type will develop into coast live oak forest as the density of coast live oak increases (Figure 8-23d). Other shade-tolerant species such as California bay anti tanoak (Lithocarpus densiflorus) may be able to establish in the moderated microclimate beneath coast live oak canopies. Examples of this habitat type that appear to be steady state may result from an interaction of fire frequency and stressed substrate conditions (Wells, 1962). After catastrophic fire or other disturbance, mixed chaparral or coastal sage scrub may occupy sites for 20-50 years (Figure 8-23).

RIPARIAN FOREST

Physiognomy. The riparian forest cover type consists of both dense groves and narrow strips of broad-leaved, winter deciduous trees and shrubs along streambanks and on river floodplains. Trees are up to 30 m (100 ft) tall and understory of shrubs and herbs is sparse except where the overstory canopy is open. Soil moisture is more or less permanently available, and flooding and sediment deposition occur at irregular intervals. Habitat types are given in Table 8-29.

Table 8-29. Habitat Types in a Riparian Forest.

Habitat Type	Characteristic Dominant(s)	Regional Distribution
Mixed riparian forest	Black cottonwood (<i>Populus trichocarpa</i>) California sycamore (<i>Platanus racemosa</i>) White alder (<i>Alnus rhombifolia</i>) Willows (<i>Salix</i> spp.)	North and South Coast Ranges
Red alder forest	Red alder (<i>Alnus rubra</i>)	North and South Coast Ranges

Climate. Average annual precipitation is 38-350 cm (15-100 in); growing season is 6-12 months; mean summer maximum temperatures are 20°C-36°C (68°F-96°F); and mean winter minimum temperatures are -2°C-4°C (29°F-40°F). Mixed riparian forest habitat type exhibits an "azonal" distribution pattern, occurring under a wide range of climatic conditions but restricted to riparian sites of plentiful soil moisture. The red alder forest habitat type is restricted to the coastal fog zone where temperatures and evapo-transpiration are moderated.

Topography. The riparian forest cover type is found on river floodplains and along stream margins below 1,500 m (5,000 ft) elevation. Red alder forest also occurs on wind-swept headlands, on moist upland sites and up to 80 miles inland along the Eel River in the coastal fog zone (Cheatham and Hailer, 1975).

Substrate. The cover type is found on a wide range of substrates but always with high moisture status. Soils are typically coarse textured, well drained, well aerated, and of alluvial origin. They may contain high proportions of gravel and rock. Red alder forest occasionally occurs on poorly-aerated marshy soils. Nutrients are plentiful both in ionic solution as well as in the form of unweathered sediments (Roberts et al., 1977). Periodic flood events create bare mineral soils through bank erosion, sediment deposition, and uprooting of existing trees. Sediment deposits are often highly variable with interbedded layers of fine and coarse materials, creating a mosaic of substrate textures and soil moisture availabilities (Stone, 1971).

Vegetation. Deciduous trees, shrubs, and vines comprise typical riparian forest vegetation (Table 9-29). The tree overstory is usually dense (70-100 percent cover), in which case the shrub and herbaceous understory may be poorly developed. Patterns of tree occurrence are related to frequency and intensity of disturbance (flood, fire), seed availability at time of disturbance, and the mosaic of substrate conditions. Common dominant trees are "opportunistic" species with wide seed dispersal, rapid height

growth, and short life spans. Tree species typical of adjacent nonriparian habitat types (e.g. , mixed evergreen forest and coastal conifer forest) may establish and become dominant after long intervals without disturbance.

Vegetation Seasonality and Modes of Reproduction. Growth activity extends from spring into late fall when winter deciduous plants lose their leaves. Many of the common shrubs and trees (e.g. , alders, cottonwoods, sycamores, willows, and several species of *Baccharis*) are opportunistic in that they produce large quantities of wind-dispersed seeds for rapid establishment on newly-exposed disturbance sites. Most common tree species also regenerate by root or stem sprouting.

Characteristic Fauna. Characteristic mammals of the riparian forest cover type are taken from Ingles (1965) . Small (1974) and Van Velzen (1972) provide information on common California birds in riparian forests. Common or characteristic reptiles and amphibians are derived from Stebbins (1966). Species listed in Table 8-30, although characteristic of riparian ecosystems, are not found exclusively in this cover type. Abbreviations (e.g., LH, TIE, TR) following species common names refer to types of consumers in the general food web for this cover type (see Figure 8-18 for explanation of abbreviations). See the CommunityC opposition List, Volume III, Part 2, for more information on species listed below, and for information on characteristic invertebrate species.

Table 8-30. Characteristic Fauna of a Riparian Forest.

Mammals	Birds	Reptiles and Amphibians
Black-tailed deer (LH)	Chestnut-backed chickadee (TIE) (SFE)	Ensatina (TA)
Striped skunk (SC) (TI)	Bewick's wren (TIE)	Western spadefoot (TA)
Spotted skunk (SC) (TI)	Rufous hummingbird (NE) (TIE)	Southwestern toad (TA)
Raccoon (SE) (SC) (TI)	Scrub jay (SFE) (TIE) (CB) (SS)	Pacific treefrog (TA)
Beaver (SH)	Western wood pewee (TIE)	California newt (TA)
Mink (SC)	Song sparrow (SFE) (TIE)	Foothill yellow-legged frog (TA)
Audubon cottontail (SH)	Swanson's thrush (TIE) (SFE)	Rubber boa (TR)
Western gray squirrel (SE)	Wilson's warbler (TIE)	Sharp-tailed snake (TR)
Dusky-footed woodrat (SE) (SH)	Yellow warbler (TIE)	Ringneck snake (TR)
Deer mouse (SE) (TI)	Warbling vireo (TIE)	Common garter snake (TR)
Ringtailed cat (SC) (TI) (SE)	Black-headed grosbeak (SFE) (TIE)	
Coyote (LC) (TI)	Rufous-sided towhee (SFE) (TIE)	
Opossum (SC) (SE) (TI)	Western flycatcher (TIE)	
Ornate shrew (TI)	Northern oriole (TIE) (SFE)	
Pallid bat (FI)	Cliff swallow (TIE)	
	Tree swallow (TIE)	
	Rough-winged swallow (TIE)	
	Common flicker (TIE) (SFE)	
	- - - (TIE) (SFE)	
	American goldfinch (SFE) (TIE)	
	Black phoebe (TIE)	
	Yellow-breasted chat (TIE)	
	Great horned owl (CB) (TIE)	
	screech owl (CB) (TIE)	
	Wood duck (SFE) (TIE)	

Biomass Productivity and Food Web. Productivity is high due to optimum conditions of water, nutrients, and sunlight. Dense, rapidly transpiring vegetation creates microclimatic conditions similar to a "greenhouse" (Roberts et al., 1977) . Food chains are detrital. Alder litter decomposes rapidly to improve soil structure and fertility (Fowells, 1965).

Primary consumers of tree, shrub, and herbaceous vegetation are mammals, such as the black-tailed deer and Audubon cottontail; and phytophagous insects, such as the spotted tree borer, box elder bug and larvae of the Lorquin's admiral and mourning cloak butterflies (see Figure 8-25). Fruit and seed production is consumed by mammals, such as the deer mouse and western gray squirrel; and birds, such as the rufous-sided towhee and black-headed grosbeak. Secondary and tertiary consumers include insectivores, such as the western wood pewee, the rufous hummingbird (also a nectivore-primary consumer), ornate shrew, pallid bat, and foothill yellow-legged frog; and carnivores, such as coyote, opossum, and great horned owl. The scrub jay is a common scavenging bird. An excellent example of an omnivore in riparian habitat is the raccoon, that feeds on seeds and fruits (SE) , insects (TI) , bird eggs and carrion (SC) . Man functions as an omnivore, consuming fruits and seeds (SE) and various game mammals and birds (LC) .

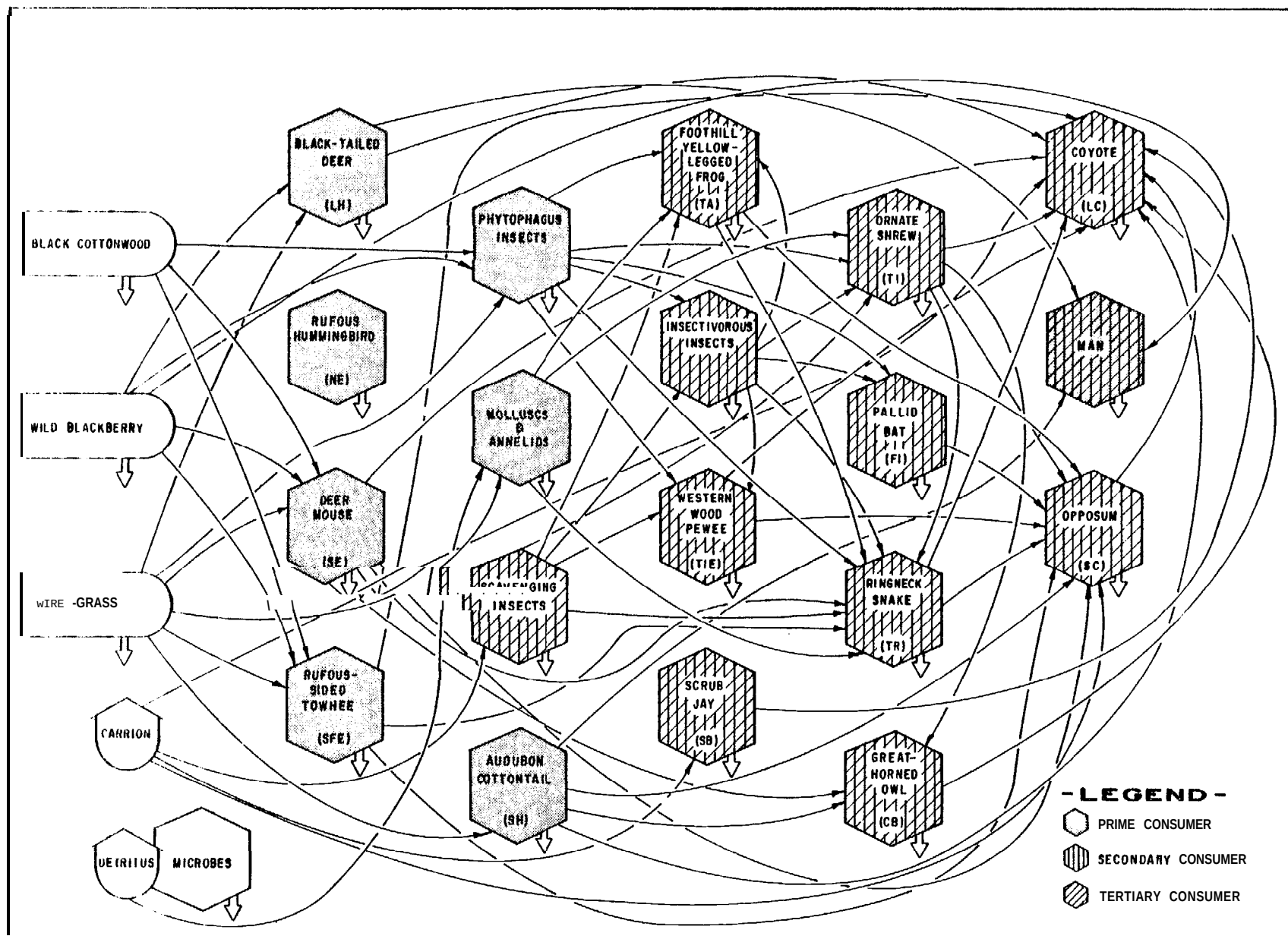


Figure 8-25. An Example of a Riparian Forest Food Web

Important Biotic Interactions. Nitrogen-fixing bacteria associate symbiotically with alders in alder root nodules. The resulting enhancement of soil nitrogen status may enable red alder seedlings to initially outgrow Douglas fir seedlings following catastrophic losses of nutrients due to fire and subsequent leaching by precipitation (Waring and Franklin, 1979). Heart rot pathogens are reported to infect 85 percent of cottonwood trees greater than 50 years old, making them susceptible to stem breakage and mortality (Stone, 1971).

The riparian forest cover type is often highly valuable to wildlife for the following reasons:

1. Water, food and cover, critical habitat requirements, are all supplied in riparian cover types.
2. The availability of water increases plant productivity and structural diversity, thereby providing a complex of wildlife microhabitats.
3. The shape of riparian zones (i.e., narrow corridors) maximizes the extent of edge habitat for wildlife. (An edge is a place where two plant communities meet. Edges are usually richer in wildlife due to greater richness of border vegetation.)
4. Riparian zones act as "connectors" (i.e., travel lanes) between cover types for species migration.

Important Abiotic Interactions. Frequency and intensity of flood events determine the availability of seedling establishment sites for characteristic riparian tree species. Boundaries of riparian ecosystems have been placed at the "50-year flood" limits due to the relation between life history modes ("opportunistic") of common dominants and the natural disturbance pattern of flood events (Stone, 1971). Fire may be important in creating regeneration sites for red alder.

Associated Cover Types. Red alder groves associate spatially with all coastal conifer forest habitat types, being restricted to streamside sites where flood disturbances prevent conifer forest development. Mixed riparian forests are often adjacent to more xeric habitats of oak woodland, valley grassland, and mixed evergreen forest.

Vegetation Succession. Riparian forest is normally seral to other habitat types, given sufficient time without flood or fire (see Figure 8-26). Most common dominants are opportunistic. Recurrent disturbances are necessary to create light openings and bare mineral soil in order to maintain these species in riparian ecosystems. In some cases, riparian forest habitat types may be steady state if seeds of less opportunistic species do not have access (e.g., mixed riparian forest in midst of extensive valley grassland).

Typical Land Uses. Agriculture, residential development, and transportation corridors have eliminated much riparian forest vegetation. Groundwater pumping has lowered water tables in some South Coast Range riparian areas.

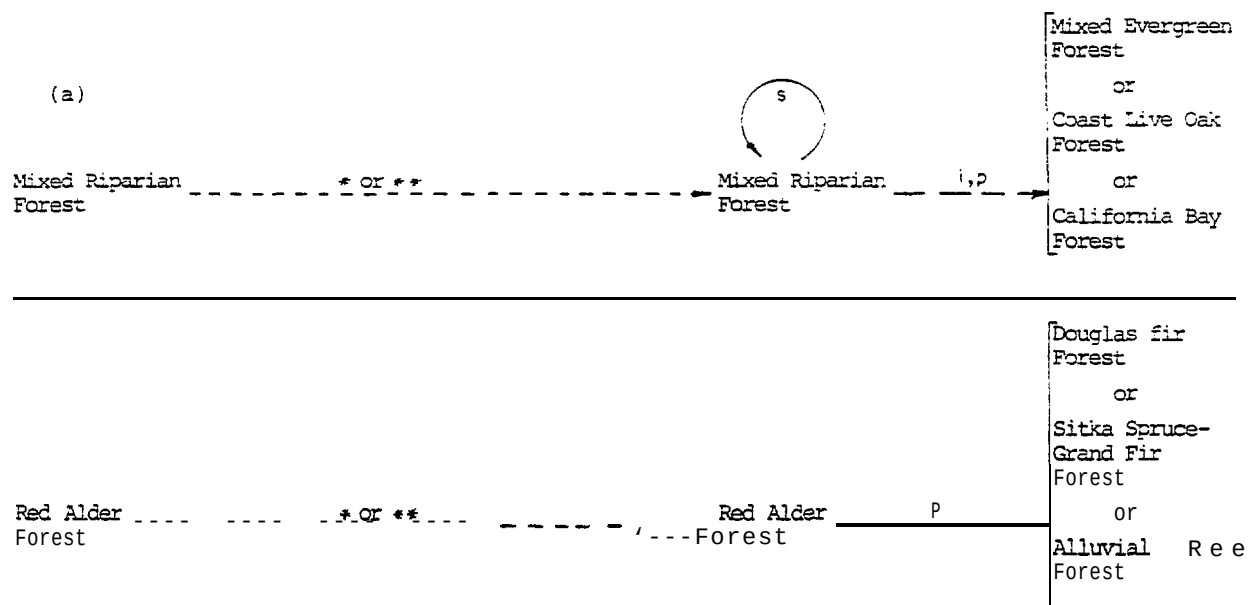
Sensitivity to Disturbance. Riparian cover types are highly sensitive to disturbance. Alterations in the vegetative cover may affect habitat microclimate, leading to significant changes in the character of the cover type. Lowering of water tables may speed mortality of cottonwoods and sycamores (Stone, 1971). Channelization and other bank stabilization projects remove existing riparian vegetation and may replace streamside habitats with concrete lining or rip-rap. Channelization may also prevent creation of flood-induced disturbance sites for seedling regeneration of opportunistic species.

Ecosystem Model. Figure 8-27 highlights important processes and components in riparian forest ecosystems.

Habitat Type Description: Mixed Riparian Forest

Distribution. Mixed riparian forest habitat type is located along streambanks in valleys and canyons, generally below 1,500 m (5,000 ft) elevations. In the North Coast Ranges, it is found inland from the red alder forest habitat type and the coastal fog zone. In the South Coast Ranges, it occurs near the coast as well as inland (Cheatham and Hailer, 1975).

Watershed Units. All watershed units in study region.



(b)

Key to Symbols:

Types of Disturbance

- * High intensity disturbance, frequent fire
- ** Low intensity disturbance, infrequent fire

Types of Habitat Type Replacement

- > Replacement after disturbance (rate unspecified)
- > Moderate to rapid replacement (<50 years)
- > Slow replacement (>50 years)

⬤ Steady-state, no replacement

Site Favorability (Microclimate, Substrate)

- s - Stressed (low productivity) sites, frequent and/or low intensity disturbance
- i - Intermediate site, rare disturbance
- p - Productive sites, no disturbance

NOTE: For discussion of Successional Process, see Ecosystem Characterization of Chapter 8.

Figure 8-26. Successional Sequences (a-b) Suggested for Riparian Forest Habitat Types

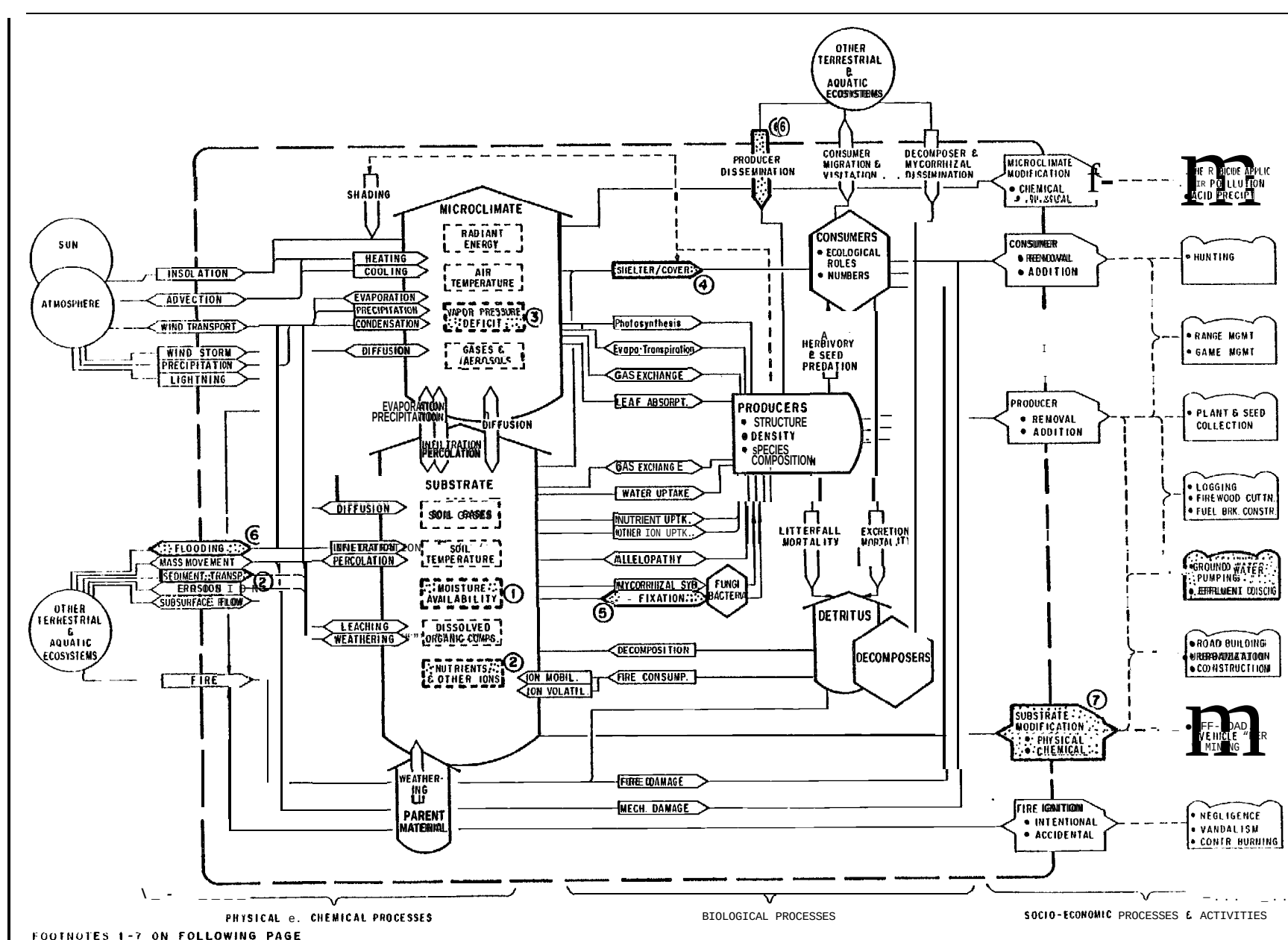


Figure 8-27. Ecosystem Model - Riparian Forest Cover Type

Footnotes for Figure 8-27
ECOSYSTEM MODEL FOR THE RIPARIAN FOREST COVER TYPE-
HIGHLIGHTED PROCESSES AND COMPONENTS ARE ANNOTATED BELOW

1. SOIL MOISTURE AVAILABILITY: Riparian forest ecosystems have high water tables, often maintained by subsurface flow from adjacent stream channels.
2. NUTRIENTS AND SEDIMENT TRANSPORT: High nutrient contents of riparian forest soils result from weathering of sediments deposited by floods and from subsurface flow of riverine waters with nutrients in solution.
3. VAPOR PRESSURE DEFICIT: Plentiful soil moisture and rapidly transpiring deciduous vegetation creates a "greenhouse" type microclimate with low vapor pressure deficit. Biomass productivity is typically high.
4. SHELTER/COVER : Dense riparian vegetation is often critical to wildlife because of its distinctive plant species composition, vegetation structure, and microclimate, and because of "edge effect" between riparian forest and surrounding cover types (Marcot, 1979) .
5. NITROGEN FIXATION: Red and white alders, both characteristic of the riparian forest cover type, improve soil fertility through symbiotic fixation of nitrogen by micro-organisms contained in root nodules. High nitrogen content of alder foliage influences productivity of adjacent riverine ecosystems.
6. FLOODING AND PRODUCER DISSEMINATION: Flooding creates bare mineral sites for establishment of riparian vegetation by eroding banks, by depositing sediments, and by uprooting existing trees. Characteristic tree species such as alders, sycamores, cottonwoods, and willows, are opportunistic with light, wind-dispersed seeds, rapid height growth, and short life spans. Periodic flooding is necessary to provide establishment sites for these species.
7. SUBSTRATE MODIFICATION: Groundwater pumping may significantly alter riparian forest vegetation by lowering water tables and thereby eliminating tree species that require high water tables. Distinctive qualities of the vegetation and microclimate that are critical to wildlife species for cover and forage may also be eliminated.

Vegetarian. Vegetation is typically a narrow band of deciduous trees and shrubs along stream banks. Mixed riparian forest habitat type is often adjacent, at an abrupt transition, to other cover types such as grassland, chaparral, or coastal conifer forest. Characteristic tree species are widespread in occurrence but often only locally dominant (Table 8-31). Mixed riparian forest ecosystems are subject to wide temperature fluctuations in contrast to coastal fog zone ecosystems of red alder forest.

Table 8-31. Characteristic Plants of a Mixed Riparian Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Black cottonwood	<u>Populus trichocarpa</u>
Fremont cottonwood	<u>P. fremontii</u>
California sycamore	<u>Platanus racemosa</u> (South Coast Ranges only)
White alder	<u>Alnus rhombifolia</u>
California bay	<u>Umbellularia californica</u>
Box elder	<u>Acer negundo ssp. californicum</u>
Bigleaf maple	<u>A. macrophyllum</u>
Oregon ash	<u>Fraxinus latifolia</u> (North Coast Ranges only)
Coast live oak	<u>Quercus agrifolia</u> (South Coast Ranges only)
Valley oak	<u>Q. lobata</u> (South Coast Ranges only)
Willow	<u>Salix lasiandra</u>
Willow	<u>S. laevigata</u>
<u>Shrubs</u>	
False willow	<u>Baccharis viminea</u>
Red osier dogwood	<u>Cornus occidentals</u>
Wild blackberry	<u>Rubus vitifolius</u>
Elderberry	<u>Sambucus caerulea</u>
Willow	<u>Salix scouleriana</u>
<u>Herbs</u>	
Mugwort	<u>Artemisia douglasiana</u>
Wire-grass	<u>Juncus</u> spp.

Succession. Initially dominant 'opportunistic' species such as cottonwoods, white alder, and willows are short-lived and shade-intolerant. Although longer lived (more than 100 years), sycamore is equally shade-intolerant. Without periodic flood or fire, and with seed access of more shade-tolerant species such as coast live oak and California bay, mixed riparian forest will develop toward the mixed evergreen forest habitat type (Figure 8-26a). Groundwater pumping may speed this successional replacement by depleting soil moisture for survival of cottonwoods, alders, and willows (Stone, 1971).

Habitat Type Description: Red Alder Forest

Distribution. Red alder forest habitat type occurs along stream banks, on alluvial floodplains, and on moist coastal slopes from Del Norte County south to Monterey County. This north-south range is synonymous with that of the coastal conifer forest cover type. Red alder forest is found up to 130 km (80 mi) inland along the Eel River. All sites are characterized by narrow seasonal temperature fluctuations, high humidity, and high soil moisture. Red alder forest may occur on poorly aerated soils around marshes in Del Norte, Humboldt, and Mendocino Counties. This habitat type often intergrades with Sitka spruce-grand fir forest habitat type along the north coast (Cheatham and Hailer, 1975).

Watershed Units. Smith River, Klamath River, Mad River, Eel River, Mattole River, Noyo River, Gualala River, Russian River, Lagunitas Creek, San Gregario Creek, San Lorenzo River, and Morro Bay.

Vegetation. Red alder forest occurs both as narrow streamside strips and as extensive forests on coastal floodplains and moist slopes. It is often dense and to 24 m (80 ft) tall, but may form scrubby thickets where exposed to ocean winds. Red alder comprises at least 50 percent of the tree canopy cover. Herbs are sparse to abundant, depending on light intensity through canopy openings (Table 8-32).

'Table 8-32. Characteristic Plants of a Reci Alder Forest.

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Red alder	<u>Alnus rubra</u>
Black cottonwood	<u>Populus trichocarpa</u>
Willow	<u>Salix lasiandra</u>
Willow	<u>S. laevigata</u>
Bigleaf maple	<u>Acer macrophyllum</u>
California bay	<u>Umbellularia californica</u>
Redwood	<u>Sequoia sempervirens</u>
Sitka spruce	<u>Picea sitchensis</u>
Grand fir	<u>Abies grandis</u>
<u>Shrubs</u>	
Wax myrtle	<u>Myrica californica</u>
False-willow	<u>Baccharis viminea</u>
Elderberry	<u>Sambucus callicarpa</u>
Salmonberry	<u>Rubus spectabilis</u>
<u>Herbs</u>	
Mugwort	<u>Artemisia douglasiana</u>
Wire-grass	<u>Juncus spp.</u>
Spikenard	<u>Aralia californica</u>

Succession. Red alder is a shade-intolerant, short-lived (less than 100 years) species, that requires bare mineral seedbed and canopy openings for successful seedling establishment. Red alder seedlings grow *more* rapidly in height than all conifer associates. However, at approximately 25 years, Douglas fir saplings overtop red alder saplings of the same age (Fowells, 1965). After 25-100 years without disturbance, red alder forest will be replaced by one of the coastal conifer forest habitat types, depending on site conditions and the species composition of the seed supply reaching the site (Figure 8-26b). Flood or fire disturbances are required to create areas for red alder regeneration. Red alder forest may also establish as an early successional habitat type on cutover sites formerly supporting coastal conifer forest cover type.

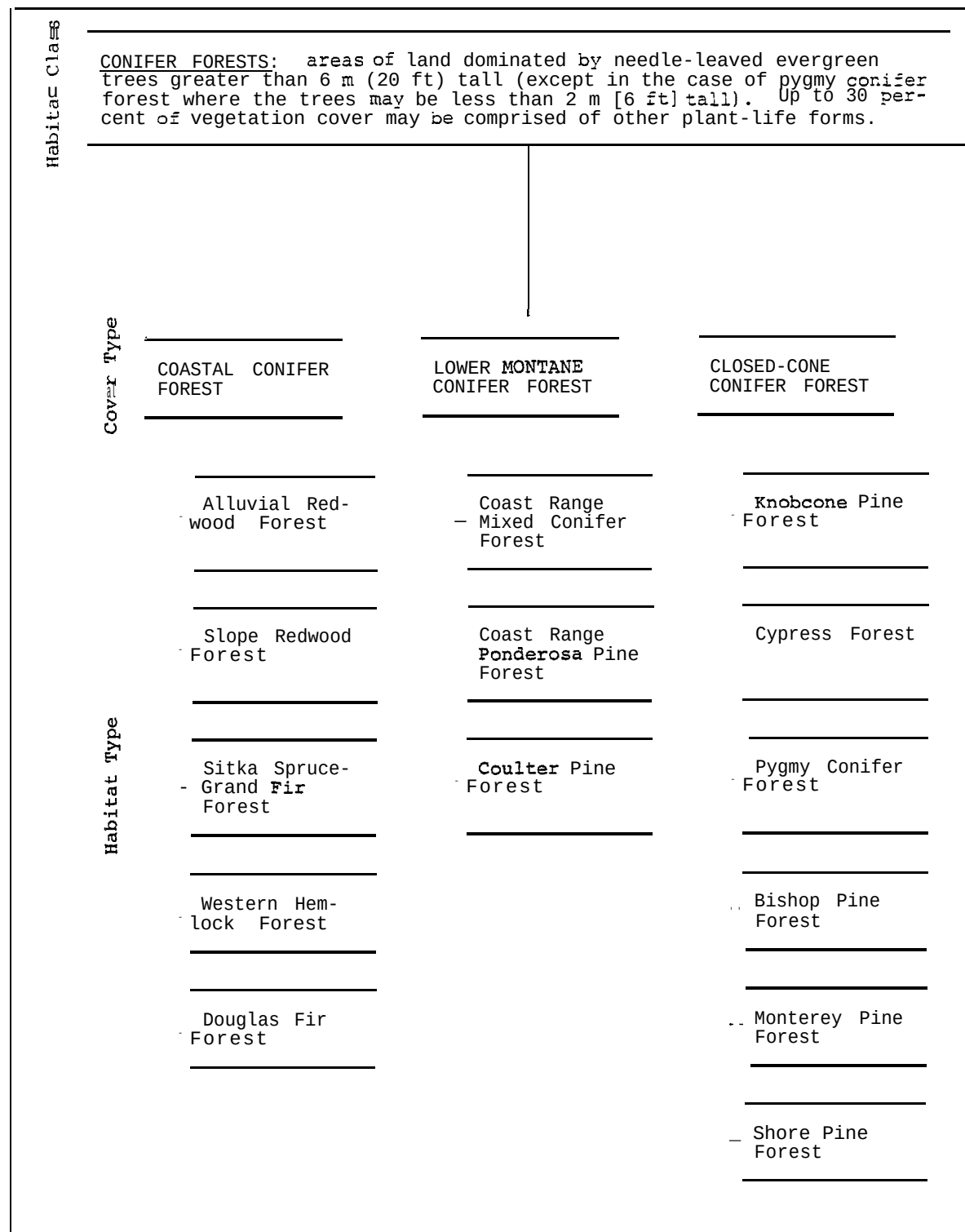


Figure 8-28. Hierarchical Dendrogram of Component Cover and Habitat Types of Conifer Forests

COASTAL CONIFER FOREST HABITAT CLASS

This habitat class, described in Figure 8-28, is comprised of three cover types: coastal conifer forest, lower montane coastal forest, and close-covered conifer forest, which are described in the following sections.

Coastal Conifer Forest

Physiognomy. 'This cover type occurs as dense coniferous forests occupying the coastal fog zone, with dense to sparse understory of shade-tolerant broad-leaved trees, shrubs, and herbs. Overstory canopy height ranges from 36 m (120 ft) to more than 90 m (300 ft) tall. This cover type is the southernmost extension of the temperate mesophytic conifer forest biome centered in the Pacific Northwest. Immense size and great age of conifer species have evolved in response to north coastal regimes of moisture, temperature, and nutrients (Waring and Franklin, 1979). Coastal conifer forest is the only California cover type unique to the "Oregonian" biotic province of Munz and Keck (1949).

Table 8-33. Habitat Types in a Coastal Conifer Forest.

Habitat Type	Dominant Plants	Regional Distribution
Alluvial redwood forest	Coast redwood (<u>Sequoia sempervirens</u>)	North Coast Ranges
Slope redwood forest	Coast redwood/ Tanoak (<u>Lithocarpus densiflorus</u>)	North and South Coast Ranges
Sitka spruce - Grand fir forest	Sitka spruce (<u>Picea sitchensis</u>) Grand fir (<u>Abies grandis</u>)	North Coastal Strip
Western hemlock forest	Western hemlock (<u>Tsuga heterophylla</u>)	North Coast Ranges
Douglas fir forest	Douglas fir (<u>Pseudotsuga menziesii</u>) Tanoak (<u>Lithocarpus densiflorus</u>)	North Coast Ranges and Santa Cruz Mountains

Climate. Annual precipitation is 90-280 cm (35-110 in), often supplemented by fog drip during summer; growing season is 7-12 months. The mean summer maximum temperature is 17°C-29°C (62°F-84°F), and mean winter minimum is 0.5°C-6°C (33°F-42°F). Seasonal and diurnal temperature fluctuations are small. Less than 10 percent of total precipitation falls during summer.

Topography. The cover type occurs on coastal terraces, slopes, ridges, and river valleys to 900 m (3,000 ft) elevations. Douglas fir forest may reach 1,200 m (4,000 ft). The cover type is found on all aspects near the coast, and on northern aspects to the south and inland. The slope redwood forest habitat type extends inland to the limits of regular summer fog.

Substrate. Substrates are usually moist, well drained soils of alluvial flats, or of residual origin derived from soft sedimentary parent materials. Empire is a typical soil series in Mendocino and Humboldt Counties; it is more than 150 cm (60 in) deep, fine sandy loam to fine sandy clay, moderately acid to strongly acid, and high in organic matter contents (Laacke, 1979). Slope redwood forest and Douglas fir forest are often on shallower soils on steep slopes.

Vegetation. Vegetation is typically tall, dense coniferous forest consisting of several vegetative strata, including overstory conifers, understory broad-leaved and conifer trees, understory shrubs and conifer seedlings, a herbaceous ground layer, and occasionally epiphytic mosses and ferns.

Vegetation Seasonality and Modes of Reproduction. The coniferous lifeform (massive size, evergreenness, large total leaf area, needle shaped leaf) is functionally advantageous under moisture, temperature, and nutrient regimes of northern coastal California (Waring and Franklin, 1979). Photosynthesis and nutrient uptake are possible during mild, wet fall and winter months when deciduous plants are dormant. During warm, dry summer months, photosynthesis is limited by high evaporative demand and soil drought. Peak growing season is late spring to early summer. Coast redwood reproduces vegetatively from roots and crowns when damaged by fire, logging or windthrow. All other dominant conifers reproduce by seedlings only.

Characteristic Fauna. Characteristic mammals of coastal conifer forest cover types are taken from Ingles (1965). Small (1974) and Van Velzen (1971-1975) provide information on common California birds in redwood, Sitka spruce-grand fir, western hemlock and Douglas fir forests. Common or characteristic reptiles and amphibians are derived from Stebbins (1966). Species in Table 8-34, although characteristic of coastal conifer forests, are not found exclusively in this cover type. Abbreviations (e.g., TI, SFE, TA) following species common names refer to types of consumers in the general food web for this cover type (see Figure 8-29 for explanation of abbreviations). See the Community Composition List, Volume III, Part 2, for more information on species listed below, and for information on characteristic invertebrate species.

Table 8-34. Characteristic Fauna of a Coastal Conifer Forest.¹

Mammals	Birds	Reptiles and Amphibians
Trowbridge shrew (TI)	Redwood/Sitka Spruce/Grand Fir/ Western Hemlock Forest	Pacific giant salamander (TA)
Pacific shrew (TI)	Varied thrush (SFE) (TIE)	Olympic salamander (TA)
Coast mole (TI)	Vaux's swift (TIE)	Tailed frog (TA)
Shrew mole (TI)	Allen's hummingbird (NE) (TIE)	Sagebrush lizard (TR)
Little brown bat (FI)	Chestnut-backed chickadee (TIE) (SFE)	Northwestern garter snake (TR)
Townsend chipmunk (SE)	Rufous hummingbird (NE) (TIE)	
Northern flying Squirrel (SE)	Winter wren (TIE)	
(M) (SC)	Ruffed grouse (SFE) (VE) (TIE)	
White-footed vole (SH)	Stellar's jay (SFE) (TIE) (CB) (SB)	
Western red-backed vole (SH)	Pygmy nuthatch (TIE) (SFE)	
Oregon meadow mouse (SH)	Hermit thrush (TIE) (SFE)	
Pacific jumping mouse (SE)	Hairy woodpecker (TIE) (SFE)	
Black bear (SE) (TI) (LC)	Red crossbill (SFE) (TIE)	
Marten (SC) (TI) (SE)	Pygmy owl (CB) (TIE)	
Ermine (SC)	Spotted owl (CB)	
Elk (LH)	Pileated woodpecker (TIE)	
Mountain beaver (SH)	Brown creeper (TIE)	
Brush rabbit (SH)	Golden-crowned kinglet (TIE)	
Black-tailed* (LH)	Purple finch (SFE) (TIE)	
western gray squirrel (SE) (SH)	Band-tailed pigeon (SFE)	
	Douglas Fir Forest	
	Wilson's warbler (TIE)	
	Western flycatcher (TIE)	
	Wrentit (TIE) (SFE)	
	Song sparrow (SFE) (TIE)	
	Rufous-sided towhee (SEE) (TIE)	
	Chestnut-backed chickadee (TIE) (SFE)	
	Golden-crowned kinglet (TIE)	
	Dark-eyed junco (SFE) (TIE)	
	Pine siskin (SFE) (TIE)	
	Purple finch (SFE) (TIE)	
	Brown creeper (TIE)	
	Orange-crowned warbler (TIE)	
	Winter wren (TIE)	
	Band-tailed pigeon (SFE)	

¹See Figures 8-29 and 8-30 for definition of abbreviations.

Biomass Productivity and Food Web. Net primary productivity is high to very high, depending on site quality. Westman and Whittaker (1975), measured redwood forest net productivity on alluvial sites (1,440 g/m²/yr) and on slope sites (1,270 g/m²/yr). Large biomass accumulations result from the ability of conifer species in coastal sites to develop and maintain large amounts of foliage over long life spans of sustained height growth. A large proportion of total ecosystem nutrients is tied up in standing crop. Most decomposition occurs during mild winter season when moisture is not limiting to decomposer organisms (Waring and Franklin, 1979). Food webs are detrital.

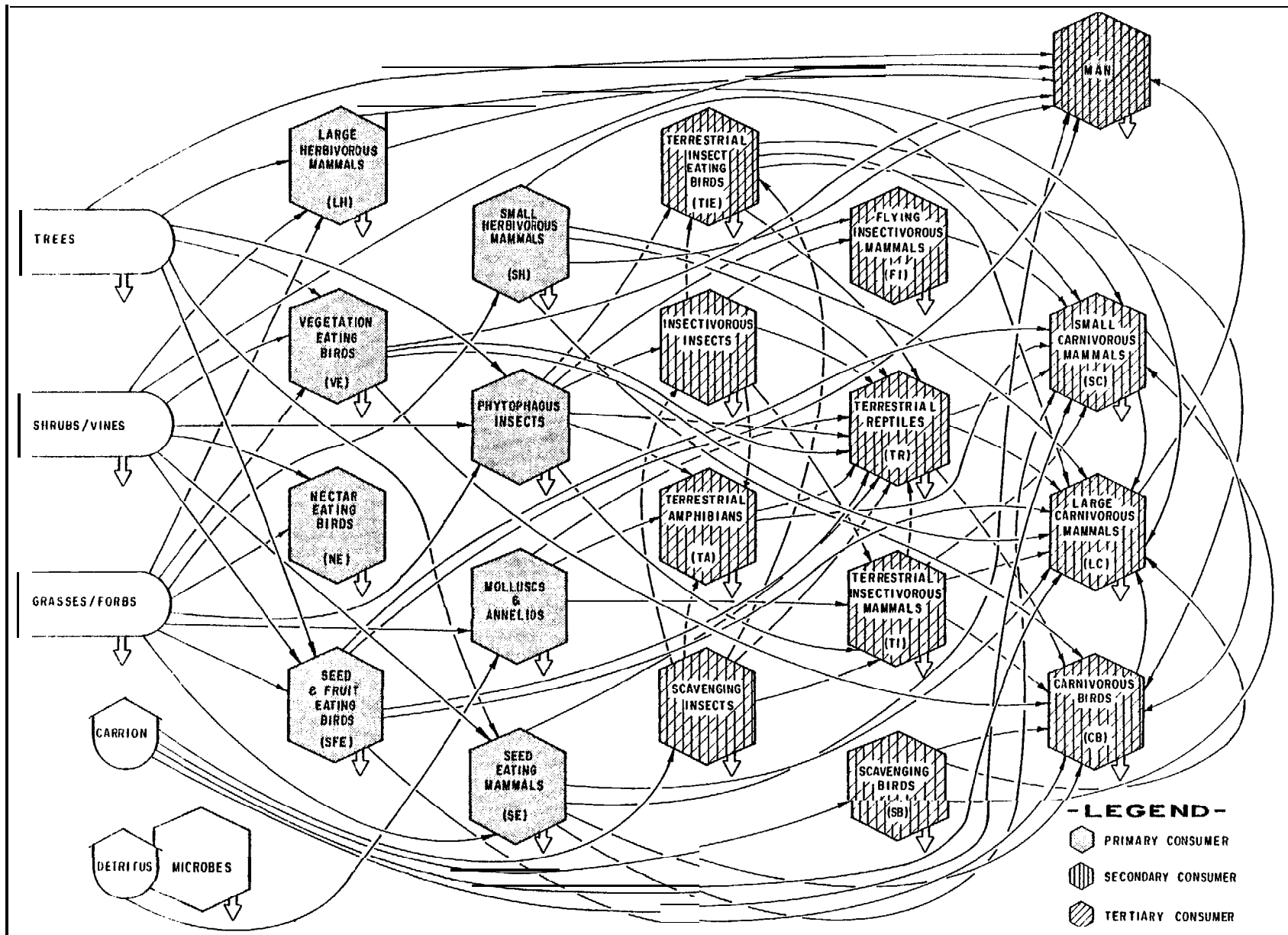


Figure 8-29. General Food Web - Conifer Forest

Primary consumers of tree, shrub and herbaceous foliage include mammals, such as the Roosevelt elk, black-tailed deer, brush rabbits and red-backed vole; birds such as the ruffed grouse; phytophagous insects, such as the Douglas-fir bark beetle and molluscs, such as banana slugs (see Figures 8-29 and 8-30). Seed and fruit production is consumed by mammals, such as the Pacific jumping mouse and northern flying squirrel; and birds, such as the varied thrush and red crossbill. Important secondary consumers include insectivores, such as the Trowbridge shrew, little brown bat, northwestern garter snake, Olympic salamander, chestnut-backed chickadee and Allen's hummingbird.1 (also a nectivore - primary consumer) ; and carnivores, such as the black bear, ermine and pygmy owl. The Stellar's jay is a common scavenging bird. These as well as other secondary consumers also function as tertiary consumers, feeding on secondary as well as primary consumers. For example, the ermine may feed on the Trowbridge shrew (a secondary consumer) as well as the Pacific jumping mouse (a primary consumer). The black bear, although a common carnivore in coastal conifer forests, also may function as an omnivore, consuming seeds, fruits and insects. Man also functions as an omnivore in the food web, consuming seeds and fruits (SE) and various game birds and mammals (LC).

Important Biotic Interactions. Damping-off fungi are common in cool, moist litter accumulations beneath coastal conifer forests. These pathogens attack seedlings weakened by deep understory shade and prevent redwood seedling establishment under old growth redwood stands. Redwood litter may depress soil microbiological processes and thereby inhibit nutrient mineralization under old-growth redwood stands (Florence, 1965). Because of these biotic interactions, redwood seedling regeneration is restricted to sites of bare mineral soil (from fire, flood, or tree uprooting) and overstory canopy openings. Herbivores cause mortality and deformity in coastal conifer species; for example, black bears strip bark from young redwood saplings, gray squirrels harvest succulent lead shoots of redwood trees, and deer and brush rabbits browse heavily on tree seedlings (especially Douglas fir).

Important Abiotic Interactions. Windthrow is a primary mortality agent for Sitka spruce and western hemlock (Fowells, 1965). Fire, landslides, dune encroachment, and flooding also disturb existing old growth forests and create sites for forest regeneration. Even-aged waves of seedlings in alluvial redwood groves are related to 30-60 year intervals in historical fire-flood sequences (Zinke, 1977). Summer fog precipitation may contribute large amounts of moisture to coastal conifer forest ecosystems (Azevedo and Morgan, 1974). Summers of high fog precipitation may facilitate waves of seedling regeneration at grassland margins of slope redwood forests. Wind-transported salt spray limits occurrence of some characteristic dominants in immediate coastal sites.

Associated Cover Types. Lowland habitat types (alluvial redwood forest, western hemlock forest, and Sitka spruce - grand fir forest) are spatially associated with coastal scrublands, closed-cone conifer forests, coastal prairies, and coastal mixed shrub habitat type on coastal headlands and terraces. Upland habitat types (slope redwood forest, Douglas fir forest, and occasionally western hemlock forest) are spatially associated with mixed evergreen forest, mixed chaparral, coastal mixed shrub, and coastal prairie habitat types.

Vegetation Succession. Successional patterns (Figure 8-31) in the coastal conifer forest cover type are complex due to typical high site productivity and low levels of disturbance in comparison to other cover types in the study region. Succession in alluvial redwood forest and slope redwood forest habitat types is controlled by sprouting ability of redwoods, shade tolerance of redwood seedlings, and redwood's long life span (greater than 1,000 years). Redwood appears able to maintain site dominance, with or without disturbance. However, fire-flood disturbance sequences may be necessary to maintain old-growth alluvial redwood forests (Zinke, 1977). High site productivity (low evapotranspiration, high soil moisture) of Sitka spruce - grand fir forest and western hemlock forest habitat types often favors early successional stands of coastal mixed shrub and/or red alder forest following disturbance. However, shade-tolerance of the characteristic conifer species facilitates their eventual return to dominance. Most ecosystems in the Douglas fir habitat type appear to be seral to either mixed evergreen forest or western hemlock forest. Douglas fir is moderately intolerant of shade. It cannot regenerate under a closed conifer canopy, but can under the partially open two-level canopy typical of mixed evergreen forest habitat type (Sawyer et al., 1977).

Typical Land Uses. Timber production is the major land use in areas of the coastal conifer cover type from Sonoma County northward. Many sites of the alluvial redwood forest habitat type are preserved in state and national parks. Some of the more level areas of coastal conifer forest on coastal terraces or alluvial flats have been cleared for agriculture (especially dairy and sheep production).

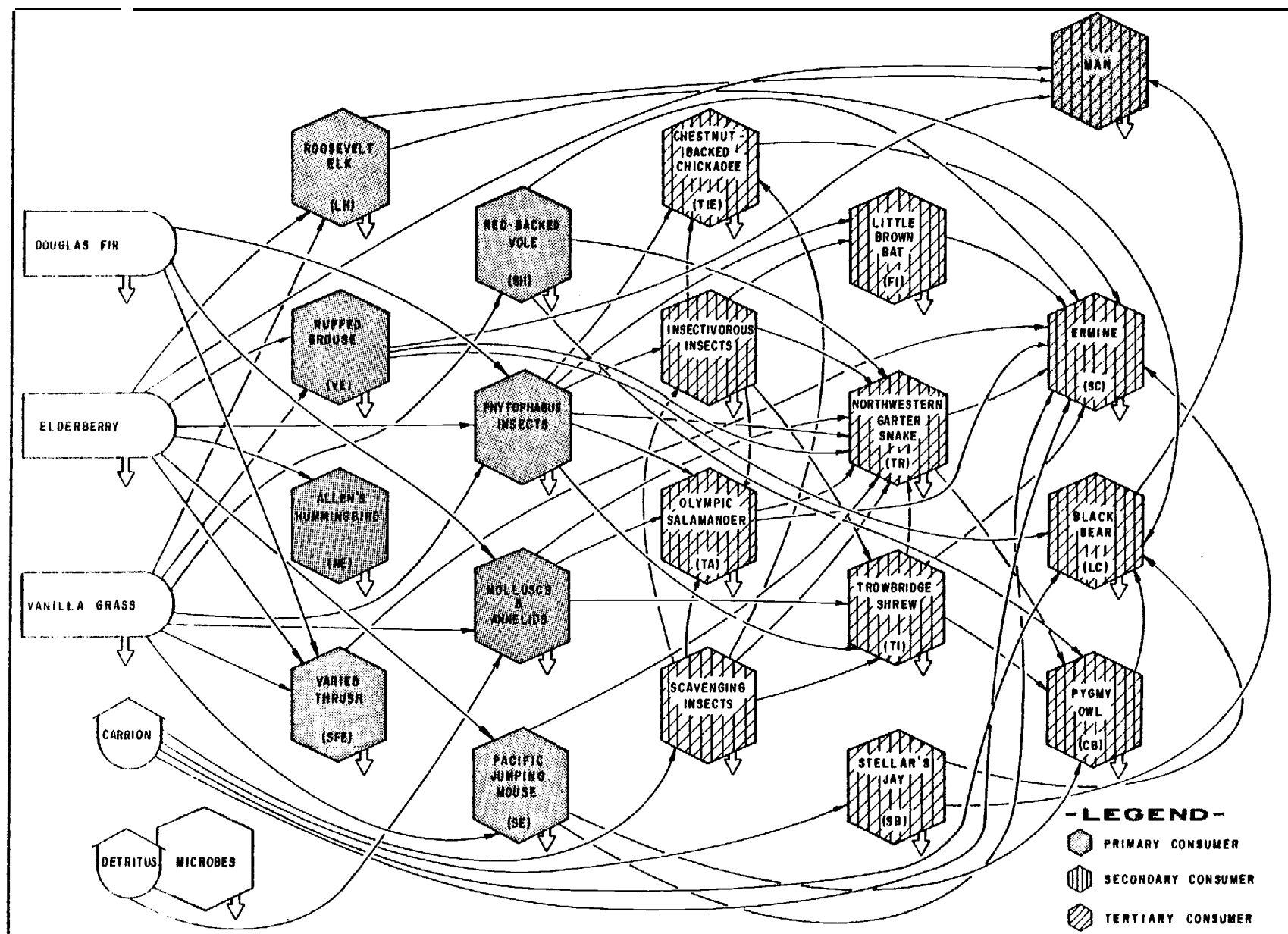


Figure 8-30. An Example of a Coastal Conifer Forest Food Web

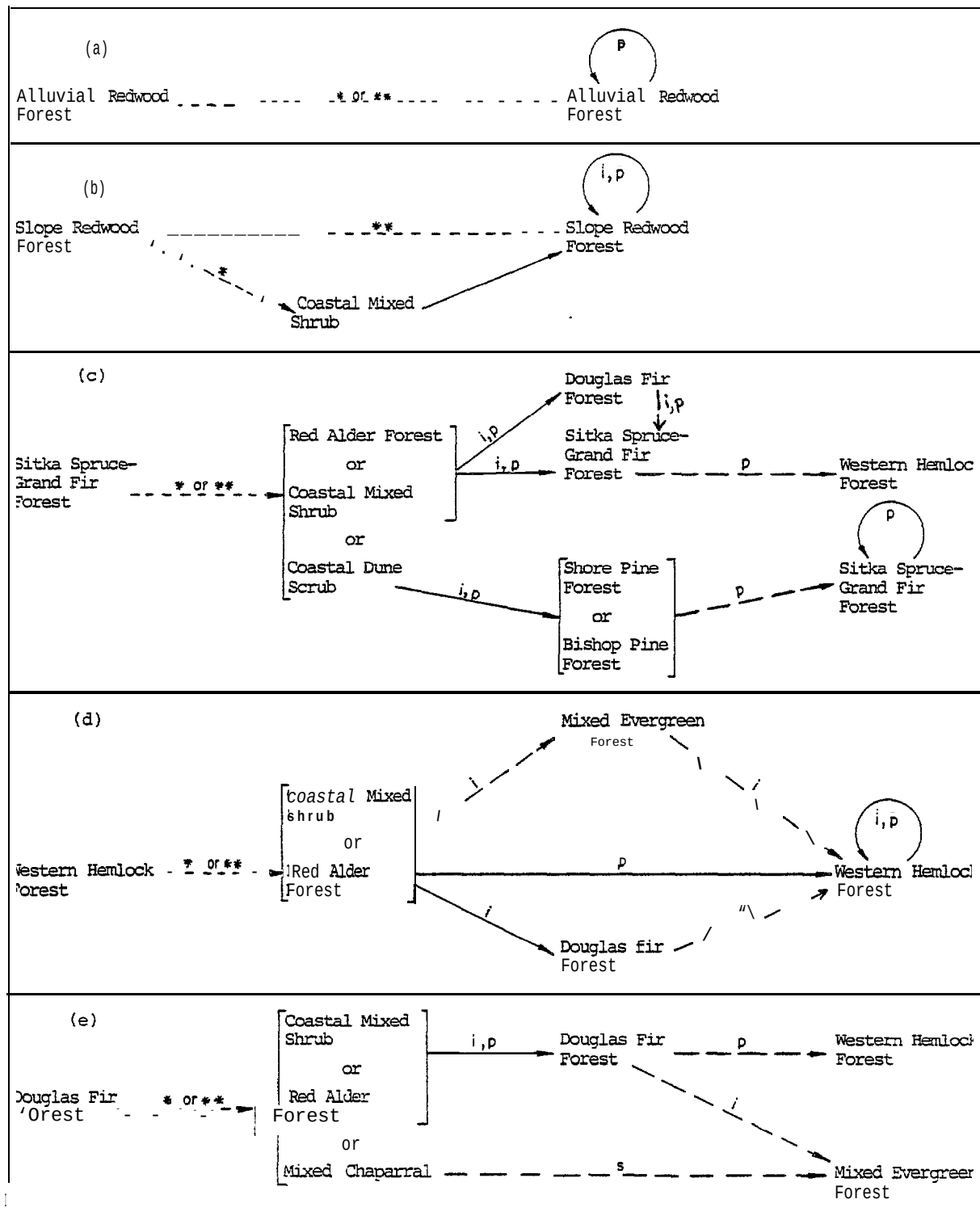


Figure S-3 1. Successional Sequences (a-e) Suggested for Coastal Conifer Forest Habitat Types

Key co Symbols :

Types of Disturbance

- * High intensity disturbance, frequent fire
- ** intensity disturbance , infrequent fire

Types of Habitat Type Replacement

... > Replacement after disturbance (rate unspecified)

—————> Moderate to rapid replacement (< 50 years)

- - - - -> Slow replacement (>50 years)



Steady-state, no replacement

Site Favorability (Microclimate, Substrate)

s - Stressed (low productivity) sites, frequent and/or low intensity disturbance

i - Intermediate sites, rare disturbance

p - Productive sites, no disturbance

NOTE: For discussion of Successional Process, see Ecosystem Characterization of Chapter 8.

Figure 8-31 (continued)

Sensitivity to Disturbance. High site productivity of ecosystems in coastal conifer forest cover types favors rapid recovery from disturbance except on steep, unstable slopes. However, high rainfall in combination with slope and soil instability has led to severe erosion and site degradation following vegetation removal and soil disturbance (e.g., by logging and road building) in many north coastal watersheds. Rapid revegetation reduces erosion and nutrient loss. Sites of higher stress (hotter, drier) in interior and southern areas of the North Coast Ranges often are very slow to regenerate, even under intentional human management. Soil surface microclimate appears to be critical to conifer seedling regeneration.

Ecosystem Model. Important interactions among system components are highlighted in Figure E-32.

Habitat Type Description: Alluvial Redwood Forest

Distribution. The alluvial redwood forest habitat type is dominated by coast redwood (>80 percent of tree cover). It is located on floodplains and alluvial flats along rivers and creeks, primarily in Del Norte and Humboldt Counties, but also scattered along other streams as far south as Santa Cruz County. This habitat type intergrades with western hemlock forest and Sitka spruce - grand fir forest habitat types on wetter, more coastal sites and with slope redwood forest on drier, shallower substrates (Cheatham and Hailer, 1975).

Watershed Units. Smith River, Klamath River, Mad River, Eel River, Noyo River, Gualala River, Russian River, Lagunitas Creek, San Gregorio Creek, and San Lorenzo River.

Vegetation. Alluvial redwood stands are moderately dense to very dense, very tall 76-100 m (250-330 ft) forests of coast redwood on well drained, deep alluvial soils (e.g., sandy loams). Such stands are restricted to areas of frequent summer fogs which reduce transpiration loads on very tall trees. Periodic flooding and fire are historical ecosystem processes (Zinke, 1977). Flood-deposited sediments exclude tree species other than redwood by smothering root systems. Redwood trees are able to grow roots upward into new sediment layers where soil aeration is adequate for root respiration (Zinke, 1977). Understory trees and shrubs are rare in old-growth alluvial redwood forest ecosystems; however, ground cover of herbaceous perennials and ferns is usually abundant (Table 8-35).

Table 8-35. Characteristic Plants of an Alluvial Redwood Forest.

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Coast redwood	<u>Sequoia sempervirens</u>
<u>Shrubs</u>	
California rose bay	<u>Rhododendron macrophyllum</u>
Huckleberry	<u>Vaccinium ovatum</u>
<u>Herbs and Ferns</u>	
Vanilla grass	<u>Hierochloa occidentalis</u>
Sword fern	<u>Polystichum munitum</u>
Redwood sorrel	<u>Oxalis oregana</u>
Wild ginger	<u>Asarum caudatum</u>
Trillium	<u>Trillium ovatum</u>
Fetid adder's tongue	<u>Scoliopus bigelovii</u>
Fairy bells	<u>Disporum smithii</u>

Succession. Periodic fire and flood events are associated with redwood alluvial flat sites (Zinke, 1977). Redwood seedling regeneration requires bare mineral soil. Fallen tree sites and flood-deposited sediments provide suitable conditions for seedling establishment. Redwood trees readily sprout from stems and stumps after damage by fire, logging, or windthrow. Because of redwood's long life span (greater than 1,000 years on alluvial sites), a low rate of replacement of overstory trees by younger redwoods may be sufficient to maintain redwood stands (Viers, 1973). With disturbance by fire, flood, or logging, redwood is usually able to reestablish site dominance in 30-60 years (Figure 8-31a). No associated tree species (e.g., tanoak, western hemlock) can overtop or outlive mature redwoods (Franklin and Dyrness, 1973). Shade-tolerance of redwood seedlings, redwood sprouting ability, and necessity for low replacement rate indicate redwood can maintain steady-state dominance of alluvial flat sites.

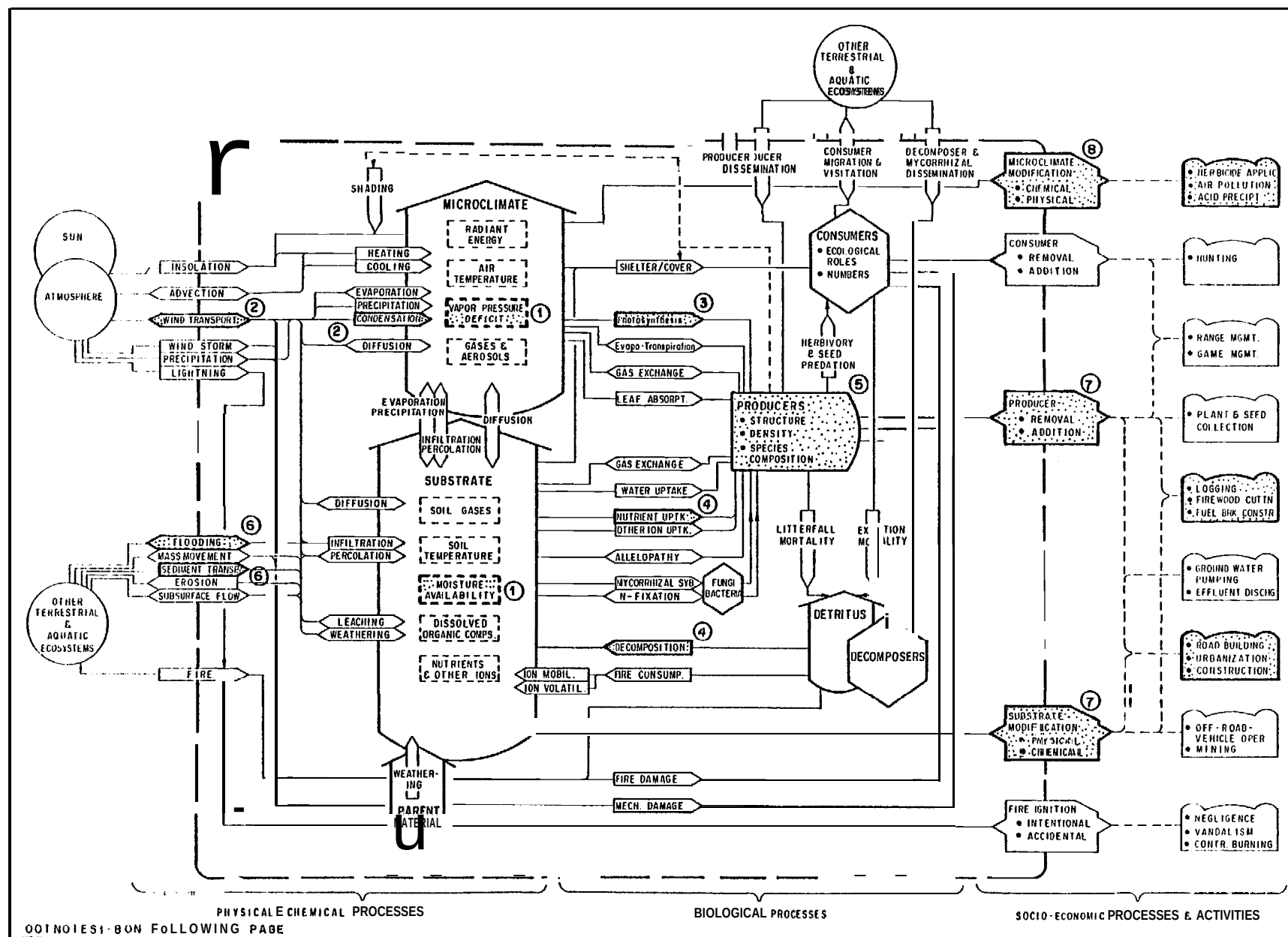


Figure 8-32. Ecosystem Model - Coastal Conifer Forest Cover Type.

Footnotes for Figure 8-32
Ecosystem Model for the Coastal Conifer Forest Cover Type-
Highlighted Processes and Components are Annotated Below

1. VAPOR PRESSURE DEFICIT AND SOIL MOISTURE AVAILABILITY: High precipitation, moderate temperatures, summer fogs, and deep soils of medium texture interact to maintain lower vapor pressure deficits and higher soil moisture availabilities than for other cover types in the study region.
2. WIND TRANSPORT AND CONDENSATION: Summer ocean breezes transport fog inland to lower vapor pressure deficits in ecosystems of this cover type. Fog drip resulting from condensation of fog on tree foliage may contribute significantly to soil moisture availability during summer dry season (Azevedo and Morgan, 1974) .
3. PHOTOSYNTHESIS : High vapor pressure deficits and low soil moisture availabilities cause stomatal closure and thereby restrict photosynthesis during dry "Mediterranean-type" summers. Mild winter temperatures allow evergreen coniferous species to photosynthesize during winter months (Waring and Franklin, 1979) .
4. DECOMPOSITION AND NUTRIENT UPTAKE: Most decomposition and mobilization of nutrients occurs during mild, moist winter months. Decompose organisms are inhibited by summer desiccation of forest litter on dry sites (Waring and Franklin, 1979).
5. PRODUCERS: Patterns of nutrient mobilization and photosynthesis facilitate high biomass productivity and immense standing crops in undisturbed ecosystems of this cover type (Waring and Franklin, 1979) .
6. FLOODING AND SEDIMENT TRANSPORT: Flooding creates sites of bare mineral soil for redwood seedling regeneration in alluvial redwood forest ecosystems. Sediment deposition may be important in adding nutrients to old-growth redwood forest sites depleted by storage of nutrients in standing biomass.
7. PRODUCER REMOVAL AND SUBSTRATE MODIFICATION (PHYSICAL): Timber harvesting removes some or all vegetation from ecosystems of this cover type. Road construction and log skidding disturb soil profiles. Steep slopes, high precipitation, vegetation removal, and soil disturbance may interact to cause high rates of erosion, mass wasting, and nutrient loss.
8. MICROCLIMATE MODIFICATION (CHEMICAL): Application of herbicides to suppress non-timber vegetation may lead to substantial losses of nutrients from coastal conifer forest ecosystems. Accumulation of nutrients in rapidly growing hardwood species (e.g., tanoak, red alder) and protection of the soil surface by hardwood foliage and litter may prevent both particulate and solute loss after timber harvesting (Bormann and Likens, 1979).

Habitat Type Description: Slope Redwood Forest

Distribution. This habitat type is widespread from Del Norte to Santa Cruz Counties in outer coast ranges. It also occurs in coastal canyons of Monterey County. Distribution extends inland to limits of summer fog zone and extends up coastal mountains to 3,000 feet elevations. Substrates are shallow to deep, well drained soils of slopes and canyons. The slope redwood forest habitat type intergrades with Sitka spruce - grand fir forest, western hemlock forest, or alluvial redwood forest habitat types on more mesic sites (to the north, on more coastal, deeper soils, and at lower elevations) with Douglas fir forest, mixed evergreen forest, or mixed chaparral habitat types on more xeric sites (to the south, on more inland, shallower soils, and at higher elevations) (Cheatham and Hailer, 1975).

Watershed Units. Smith River, Klamath River, Mad River, Eel River, Noyo River, Gualala River, Russian River, Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo River, Pajaro River, Carmel River, and Morro Bay.

Vegetation. Slope redwood forest habitat type occurs as moderately dense conifer forest, dominated by coast redwood (>50 percent of tree cover) to 75 m (250 ft) tall. Typical stands also include significant proportions of Douglas fir and broad-leaved evergreen trees, and often dense understory vegetation of evergreen and deciduous shrubs. Herbaceous vegetation is typically sparse to absent. Presence of coast redwood distinguishes this habitat type from the mixed evergreen forest habitat type.

Table 8-36. Characteristic Plants of a Slope Redwood Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Coast redwood	<u>Sequoia sempervirens</u>
Douglas fir	<u>Pseudotsuga menziesii</u>
Tanoak	<u>Lithocarpus densiflorus</u>
California bay	<u>Umbellularia californica</u>
Madrone	<u>Arbutus menziesii</u>
Bigleaf maple	<u>Acer macrophyllum</u>
Chinquapin	<u>Chrysolepis chrysophylla</u>
<u>Shrubs</u>	
Tanoak	<u>Lithocarpus densiflorus</u> (shrubby undergrowth form)
California hazelnut	<u>Corylus cornuta</u> var. <u>californica</u>
Huckleberry	<u>Vaccinium ovatum</u>
Wild rose	<u>Rosa gymnocarpa</u>
Thimbleberry	<u>Rubus parviflorus</u>
Salal	<u>Gaultheria shallon</u>
<u>Herbs and Ferns</u>	
Clintonia	<u>Clintonia andrewsiana</u>
Fairy bell	<u>Disporum smithii</u>
Trillium	<u>Trillium sessile</u>
False Solomon's seal	<u>Smilacina racemosa</u>
Deer foot	<u>Achlys triphylla</u>
Sword fern	<u>Polystichum munitum</u>
Bracken	<u>Pteridium aquilinum</u>
Redwood sorrel	<u>Oxalis oregana</u>

Succession. All characteristic tree species (except Douglas fir) readily crown sprout following destruction by fire or logging. For the first 10-20 years following disturbance regenerating vegetation is mixture of shrub species from the coastal mixed shrub habitat type and sprouts of redwood, tanoak, madrone, California bay, along with Douglas fir seedlings (Zinke, 1977). On shallow soils at margins of slope redwood forest, frequently burned sites will sometimes support dense, stunted sprout thickets of redwood. Redwood seedlings and saplings are tolerant of shade and able to respond with rapid growth when released from overstory shading (Roy, 1966). Shade-tolerance, sprouting ability, and long life span of redwood maintain it as a dominant species in steady-state and disturbed ecosystems. Redwood seedlings may successfully establish in oak woodland or mixed evergreen forest habitat types in sites and years of heavy summer fog drip.

Habitat Type Description: Sitka Spruce - Grand Fir Forest

Distribution . This habitat type is found on immediate coastal terraces, slopes, lowlands, headlands, and old stabilized dunes from Del Norte County south to Mendocino County. Characteristic dominants, Sitka spruce and grand fir comprise at least 70 percent of the tree cover. Both tolerate salt-laden sea winds to a greater extent than other conifers. This habitat type intergrades with western hemlock forest and the redwood forest habitat types in more protected coastal sites, with north coastal scrub on headlands of drier, shallower soil, and with shore pine and Bishop pine forests in coastal terraces and stabilized dunes (Cheatham and Hailer, 1975) .

Watershed Units. Smith River, Klamath River, Mad River, Eel River, Matthole River, Noyo River, Gualala River.

Vegetation. Vegetation of this habitat type is typically dense conifer forest to 36 m (120 ft) tall, with dense understory of broad-leaved trees, shrubs, and perennial herbs (Table 8-37). Trees are often wind-pruned on exposed headlands. Because of dense understory vegetation, most tree seedlings establish on rotting logs. Epiphytic mosses and ferns are common.

Table 8-37. Characteristic Plants of a Sitka Spruce-Grand Fir Forest.

Plant Types/Common Name	Scientific Name
<u>Trees</u>	
Sitka spruce	<u>Picea sitchensis</u>
Grand fir	<u>Abies grandis</u>
Western hemlock	<u>Tsuga heterophylla</u>
Red alder	<u>Alnus rubra</u>
<u>Shrubs</u>	
Wax-myrtle	<u>Myrica californica</u>
Vine maple	<u>Acer circinatum</u>
Cascara sagrada	<u>Rhamnus purshiana</u>
Salal	<u>Gaultheria shallon</u>
Huckleberry	<u>Vaccinium ovatum</u>
<u>Herbs and Ferns</u>	
Sword fern	<u>Polystichum munitum</u>
False lily-of-the-valley	<u>Maianthemum dilatatum</u>
Western whipplea	<u>Whipplea modesta</u>

Succession. Logging or clearing of Sitka spruce - grand fir forest habitat type allows establishment of coastal mixed shrub habitat type (Figure 8-31a). Shrubs regenerate from residual understory plants, from seeds stored in the soil, or from seeds brought in by birds. Alternatively, red alder forest may establish after disturbance. Both Sitka spruce and grand fir are shade-tolerant species and are able to regenerate beneath moderately dense shrubs or tree cover. Sitka spruce and grand fir will return to site dominance in 40-100 years after disturbance, depending on site conditions and seed supply. This habitat type may also replace shore pine forest and Bishop pine forest habitat types on old stabilized dunes in Humboldt County (Barbour and Johnson, 1977). Sitka spruce is long lived (700-800 years). It may eventually be replaced by the more shade-tolerant western hemlock unless natural canopy openings from windthrow and mortality allow continued Sitka spruce regeneration (Franklin and Dyrness, 1973) .

habitat Type Description: Western Hemlock Forest

Distribution. Western hemlock forest habitat type occurs on lowlands, slopes, and valleys within 50 km (30 mi) of the coast in Del Norte and Humboldt Counties. Scattered small stands also occur in Mendocino County. The habitat type is typically found 'below 600 m (2,000 ft) elevation on moist, 'well drained substrates, but may occur on swampy sites. Western hemlock forest intergrades with Sitka spruce - grand fir forest toward the coast, and with slope redwood forest, Douglas fir forest, anti mixed evergreen forest habitat types on more xeric sites (to the south, inland, anti at higher elevations) (Cheatham and Hailer, 1975) .

Watershed Units. Smith River, Klamath River, Mad River, and Noyo River.

Vegetation. This "habitat type occurs as dense, tall (to 200 feet) conifer forest with a high diversity of tree species (Table 8-38). Western hemlock contributes at least 50 percent of the overstory tree cover. Both overstory and understory species composition varies with local moisture conditions and seed availabilities (Franklin and Dyrness, 1973). Dense understory of shrubs, herbs, and ferns often prevents tree seedling establishment in soil. Tree seedlings commonly establish on downed and rotting logs. Epiphytic cryptogams (i.e., ferns, mosses, lichens) are common on trunks and branches of large trees.

Table 8-38. Characteristic Plants of a Western Hemlock Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Western hemlock	<u>Tsuga heterophylla</u>
Douglas fir	<u>Pseudotsuga menziesii</u> drier sites, young stands
Western red cedar	<u>Thuja plicata</u> wetter sites
Port-Orford-cedar	<u>Chamae cyparis lawsoniana</u> wetter sites
Sitka spruce	<u>Picea sitchensis</u>
Bigleaf maple	<u>Acer macrophyllum</u>
Tanoak	<u>Lithocarpus densiflorus</u> drier inland sites
<u>Shrubs</u>	
Vine maple	<u>Acer circinatum</u>
Cascara sagrada	<u>Rhamnus purshiana</u>
Huckleberry	<u>Vaccinium ovatum</u>
Red bilberry	<u>V. parvifolium</u>
Salal	<u>Gaultheria shallon</u>
Snowbrush	<u>Ceanothus velutinus</u>
Oregon grape	<u>Berberis nervosa</u>
<u>Herbs and Ferns</u>	
Sword fern	<u>Polystichum munitum</u>
Indian lettuce	<u>Montia sibirica</u>
Redwood sorrel	<u>Oregana</u>
Fairy bell	<u>Disporum smithii</u>
Bracken	<u>Pteridium aquilinum</u>

Succession. Western hemlock tolerates more shade during its seedling stage than any other conifer in the study region. It is able to reproduce beneath a closed forest canopy (Figure 8-31d). Various successional sequences have been postulated following disturbance to western hemlock ecosystems, depending on type of disturbance (logging or fire), seed availability, and site conditions (especially substrate moisture) (Franklin and Dyrness, 1973). Removal of western hemlock forest may result in initial establishment of coastal mixed shrub habitat type (sites of intermediate moisture), red alder forest (moist to wet sites), Douglas fir forest (drier sites), or western hemlock forest (wetter sites). Sawyer et al. (1977) discussed relationships between western hemlock forest, Douglas fir forest, and mixed evergreen forest on drier, inland, higher elevation sites. On stressed sites, western hemlock may not reestablish immediately after disturbance, but once other seral habitat types have modified local microclimate, site conditions may be suitable for western hemlock regeneration.

Habitat Type Description: Douglas fir Forest

Distribution. Douglas fir forest habitat type is widespread in the coast ranges from Del Norte to Santa Cruz Counties. Scattered stands occur in coastal Monterey County as well. The habitat type is generally found between 150-1,350 m (500-4,300 ft) elevations. It forms a transition between slope redwood forest and mixed evergreen forest habitat types. On moist sites in coastal North Coast Ranges, Douglas fir forest may be successional to western hemlock forest habitat type. Douglas fir forest also intergrades with coastal prairie habitat type on heavier soils, with chaparral and coastal scrubland cover types on drier sites, and with lower montane conifer forest type at higher elevations (Cheatham and Haller, 1975).

Watershed Units. Smith River, Klamath River, Mad River, Eel River, Mattole River, Noyo River, Gualala River, Russian River, Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo River, Pajaro River, Carmel River, and Morro Bay.

Vegetation. Douglas fir forest species (Table 8-39) composition and site conditions (e.g., soil moisture, temperature, vapor pressure deficit) differ only slightly from those of slope redwood forest and mixed evergreen forest. Douglas fir forest habitat type is distinguished from the former by absence of coast redwood and from the latter by a greater predominance of Douglas fir. Douglas fir contributes at least 50 percent of tree canopy cover in this habitat type. Associated tree, shrub, and herbaceous species are similar for all three habitat types. Understory vegetation may be absent in dense, even-aged stands of Douglas fir.

Table 8-39. Characteristic Plants of a Douglas Fir Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Douglas fir	<u>Pseudotsuga menziesii</u>
Tanoak	<u>Lithocarpus densiflorus</u>
Madrone	<u>Arbutus menziesii</u>
Giant chinquapin	<u>Chrysolepsis chrysophylla</u>
<u>shrubs</u>	
Tanoak	Shrubby undergrowth form
Coffeeberry	<u>Rhamnus californica</u>
Poison oak	<u>Rhus diversiloba</u>
Huckleberry	<u>Vaccinium ovatum</u>
Hazelnut	<u>Corylus cornuta</u> var. <u>californica</u>
Red elderberry	<u>Sambucus callicarpa</u>
<u>Herbs and Ferns</u>	
Hound's tongue	<u>Cynoglossum grande</u>
Redwood sorrel	<u>Oxalis oregana</u>
Inside-out flower	<u>Vancouveria hexandra</u>
Rattlesnake plaintain	<u>Goodyera oblongifolia</u>
Yerba de selva	<u>Whipplea modesta</u>

Succession. In the Smith, Klamath, and Mad River watersheds, Douglas fir forest may occur in a successional sequence that begins with red alder forest or coastal mixed shrub habitat types, through Douglas fir forest, and ultimately to western hemlock forest habitat type (Figure 8-31c). This sequence will occur on lowland, moist sites where western hemlock seeds have access. Because Douglas fir is long-lived, several hundred years are required for western hemlock to achieve dominance. Pure, dense, even-aged stands of Douglas fir typically originate after disturbances such as fire or landslides. On more stressed sites, pure stands gradually deteriorate due to natural mortality and allow development of the mixed evergreen forest habitat type as associated hardwoods (tanoak, in particular) respond to canopy openings (Sawyer et al., 1977).

Lower Montane Conifer Forest

Physiognomy. The lower montane conifer forest cover type occurs as an open to closed forest (30-100 percent cover) dominated by various conifer species, to 52 m (170 ft) tall. Considerable cover of broad-leaved tree species (both evergreen and deciduous) is often present but sometimes completely absent. Understory shrub and herbaceous vegetation is sparse to absent. This habitat type occupies sites of most severe cold stress in the study region. Included habitat types are not discrete but rather are modal points on gradients of species composition, vegetation density, and environmental conditions. The habitat types are listed in Table 8-40.

Table 8-40. Habitat Types in a Lower Montane Conifer Forest

Habitat Type	Dominant Plants	Regional Distribution
Coast range mixed conifer forest	Sugar pine (<u>Pinus lambertiana</u>) Douglas fir (<u>Pseudotsuga menziesii</u>) (North Coast Ranges only) Incense cedar (<u>Calocedrus decurrens</u>)	North Coast Ranges and Santa Lucia Mountains
Coast range ponderosa pine forest	Ponderosa pine (<u>Pinus ponderosa</u>) California black oak (<u>Quercus kelloggii</u>)	North and South Coast Ranges
Coulter pine forest	Coulter pine (<u>Pinus coulteri</u>) Canyon live oak (<u>Quercus chrysolepis</u>)	South Coast Ranges

Climate. Annual precipitation averages 64-200 cm (25-80 in) , partly as snow. Less than 10 percent of annual precipitation falls during the growing season which lasts 4-7 months. Mean summer maximum temperature is 27°C-34°C (80°F-93°F); mean winter minimum temperature, -6°C-1°C (22°F-34°F) (Munz and Keck, 1949 data from "yellow pine forest").

Topography. This cover type occurs on mountain slopes and ridges from 450-1,200 m {1,500-4,000 ft} elevation in North Coast Ranges and from 1,000-1,800 m (3,500-5,800 ft) in South Coast Ranges (Cheatham and Haller, 1975) . Slopes are steep to gentle. Density and species diversity increase from south-facing to north-facing aspects.

Substrate. Soils are typically well-drained and range from xeric to mesic as a function of aspect, soil depth, soil texture, and parent material. Sheetiron series, a typical soil type in north coast counties, is 50-100 cm (20-40 in) deep, gravelly loam to gravelly clay loam, moderately to strongly acid 'with 30-60 percent base Saturation (Laacke, 1979) . Whittaker (1960) found structure and composition of montane conifer forests in the Siskiyou Mountains controlled primarily by parent material and secondarily by elevation and soil moisture. Lower montane conifer forest habitat types are occasionally found on locally anomalous soil types (such as derived from serpentine or ancient sand deposits) at lower elevations (see Griffin, 1964) .

Vegetation. Overstory canopy of conifer species may be open to closed, in pure or mixed stands, 36-61 m (120-200 ft) tall. Coast range mixed conifer forest habitat type typically has a lower overstory strata of broad-leaved tree species while ponderosa pine forest habitat type typically is "open and park-like" with few broad-leaved trees. Coulter pine forest habitat type frequently has shrub understory of species characteristic of the mixed chaparral habitat type. Herbaceous vegetation is sparse; much ground area is bare or covered with tree litter.

Vegetation Seasonality and Modes of Reproduction. Growing season is from late spring through early summer and is delimited by cold winter temperatures and summer-fall drought (Cheatham and Hailer, 1975). Associated broad-leaved trees and shrubs are both evergreen (sclerophyllous) and winter deciduous. Characteristic conifer species do not reproduce by sprouting but are rated as medium to high in fire resistance (Sawyer and Thornburgh, 1977). Low intensity fires facilitate conifer regeneration by removing shading understory vegetation and exposing bare mineral soil.

Characteristic Fauna. Characteristic mammals of the lower montane conifer forest cover type are taken from Ingles (1965). Small (1974) provides information on common California birds in montane conifer forests. Common or characteristic reptiles and amphibians are derived from Stebbins (1966). Species listed in Table 8-41, although characteristic of lower montane conifer forests, are not found exclusively in this cover type. Abbreviations (e.g., TI, TIE, TA), following species common names refer to types of consumers in the general food web for this cover type (see Figure 8-33 for explanation of abbreviations). See the Community Composition List, Volume III, Part 2, for more information on species listed below, and for information on characteristic invertebrate species.

Table 8-41. Characteristic Fauna of a Lower Montane Conifer Forest

Mammals	Birds	Reptiles and Amphibians
Trowbridge shrew (TI)	Common nighthawk (TIE)	Tiger salamander (TA)
Long-eared myotis (FI)	Western wood pewee (TIE)	Ensatina (M)
Silvery-haired bat (FI)	Olive-sided flycatcher (TIE)	Western fence lizard (TR)
Sonoma chipmunk (SE)	Violet-green swallow (TIE)	Side-blotched lizard (TR)
Townsend chipmunk (SE)	American robin (SFE) (TIE)	Western akink (TR)
Douglas Squirrel (SE)	Solitary vireo (TIE)	Alligator lizard (TR)
Bushy-tailed woodrat (SE) (SH)	Nashville warbler (TIE)	Ringneck snake (TR)
Gray fox (LC)	Hermit warbler (TIE)	Gopher snake (TR)
Coyote (LC) (TI)	Western tanager (TIE) (SFE)	Mountain kingsnake (TR)
Black bear (SE) (TI) (LC)	chipping sparrow (SFE) (TIE)	Common kingsnake (TR)
Fisher (SC) (SS) (TI)	Stellar's jay (SFE) (TIE) (CB) (SS)	Western terrestrial
Long-tailed weasel (SC)	Blue grouse (SFE) (VE) (TIE)	garter snake (TR)
spotted skunk (SC) (TI)	Mountain quail (SFE) (TIE)	Western rattlesnake (TR)
Mountain lion (LC)	Band-tailed pigeon (SFE)	
Bobcat (LC)	Hairy woodpecker (TIE) (SFE)	
Black-tailed deer (LH)	Gray jay (SFE) (TIE) (CB) (SB)	
Pocket gopher (SH)	White-breasted nuthatch (TIE) (SFE)	
Beechey ground squirrel (SE)	Pygmy nuthatch (TIE) (SFE)	
(SK) (TI) (SC)	Dark-eyed junco (SFE) (TIE)	
Western gray squirrel (SE)	Sharp-shinned hawk (CB) (SB)	
	Screech owl (CB) (TIE)	
	Allen's hummingbird (NE) (TIE)	

¹See Figure 8-33 for definition of abbreviations.

Biomass Productivity and Food Web. Net primary productivity is relatively low due to 1) soil moisture depletion from mid-summer through fall and 2) limitation of growth by low temperatures during winter. Primary consumers of tree, shrub and herbaceous foliage include mammals, such as the black-tailed deer and pocket gopher; birds, such as the blue grouse, phytophagous insects, such as the pine sawyer (Figure 8-33). Seed and fruit production is consumed by mammals, such as the douglas squirrel or chickaree, western gray squirrel, and bushy-tailed woodrat; and birds, such as the mountain quail, band-tailed pigeon, and slate-colored junco. Important secondary and tertiary consumers include insectivores, such as the solitary vireo, trowbridge shrew, silvery-haired myotis and ensatina; ana carnivores, such as the common kingsnake, sharp-shinned hawk, Long-tailed weasel and mountain lion. The stellar's jay is a common scavenging bird. The beechey ground squirrel is a good example of an omnivore, feeding on seeds and fruits (SE), herbaceous vegetation (SH), insects (TI) and bird eggs (SC). Man also may function as an omnivore in the food web, consuming seeds and fruits (SE) and various game birds and mammals (LC).

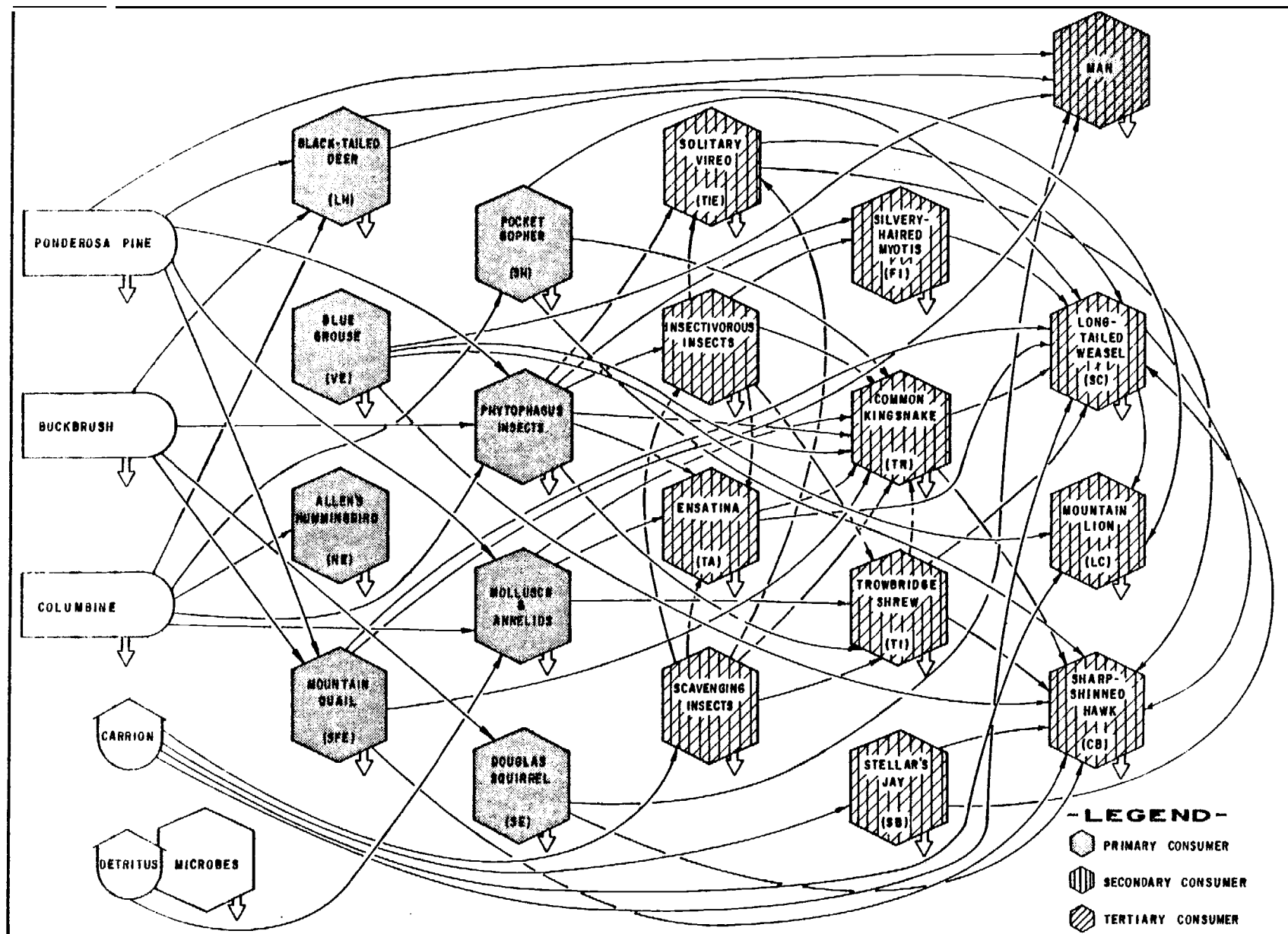


Figure 8-33. An Example of a Lower Montane Forest Food Web

Important Biotic Interactions. Insects (e.g., bark beetles, *Dendroctonus* spp.) and fungi (e.g., root and butt rot, *Fomes annosus*) may be important in recycling nutrients otherwise tied up in standing biomass. Chickarees (*Tamiasciurus douglasii*) and gray squirrels (*Sciurus griseus*) may consume all pine seed production in some years. Symbiotic nitrogen fixation by species of wild lilac (*Ceanothus* spp.) and lupine (*Lupinus* spp.) may be important in replacing nitrogen volatilized by fires.

Important Abiotic Interactions. Fire frequency interacts with site productivity as a major determinant of forest structure and composition in this cover type. In similar Sierra Nevada montane conifer forests, fire has four major ecological functions: 1) maintenance of fire-adapted tree species as stand dominants, 2) creation of uneven-aged mosaics of even-aged clumps of tree and shrub vegetation, 3) nutrient cycling, and 4) reduction of insect and disease infestation centers (Rundel et al., 1977).

Associated Cover Types. This cover type intergrades with Douglas fir forest and mixed evergreen forest habitat types on lower elevation, more mesic sites; with oak woodland cover type on lower elevation, more xeric sites; and with mixed chaparral and knobcone pine forest habitat types on more sterile soils and where subject to frequent fire (Cheatham and Hailer, 1975).

Vegetation Succession. Patterns of vegetation change in lower montane conifer forest habitat types are determined primarily by interactions of fire frequency, site productivity and the relative growth and reproductive abilities of tree species whose seeds are available (Figure 8-34). High site productivity and long fire intervals lead to heavy fuel build-ups and catastrophic fires. In general, sites of low productivity and relatively frequent fire will be maintained indefinitely in the lower montane conifer forest cover type, due to the low intensity of fires that occur and the regeneration requirements (open overstory, bare mineral soil) of characteristic conifer species. Sites of higher productivity and infrequent fire may shift to other cover types (e.g., broad-leaved evergreen forest or chaparral), either through elimination of suitable regeneration conditions for conifers by dense understory vegetation or through elimination of conifer seed trees by catastrophic fire.

Typical Land Uses. Inaccessibility of most areas in this cover type has prevented most types of human land use. Some grazing has occurred. Some areas have been logged in the North Coast Ranges but low site productivity (low soil moisture, cold temperatures) has limited suitability of these sites for continued timber production. At a number of sites, this cover type occurs at low elevations on unusual substrates of low fertility and/or low soil moisture availability. Several of these sites, for example in central Santa Cruz County (San Lorenzo River watershed unit) are being mined for sand and other minerals (Griffin, 1964).

Sensitivity to Disturbance. Typical low biomass productivity prevents rapid recovery from disturbance to vegetative cover or to soil profile. Topography is often steep and soils are moderately to highly erodible.

Ecosystem Model. Important processes and components of typical lower montane conifer forest ecosystems are highlighted in Figure 8-35.

Habitat Type Description: Coast Range Mixed Conifer Forest

Distribution. This habitat type occurs in the North Coast Ranges from Del Norte County to Sonoma County and is scattered on high ridges of the Santa Lucia Mountains in Monterey County. It is located from 600-1,200 m (2,000-4,000 ft) elevation in the north and at 1,000-1,760 m (3,500-5,800 ft) elevations in the Santa Lucia Mountains. Coast range mixed conifer forest is found on well drained, coarse textured soil; on rocky outcrops, and occasionally on serpentine-derived soils. It intergrades with mixed evergreen forest and Douglas fir forest at lower elevation, more mesic sites; with coast range ponderosa pine forest, knobcone pine forest, and Coulter pine forest habitat types on more xeric or more recently burned sites within the same elevational range; and with the canyon live oak forest habitat type on more mesic, upper elevation sites (Cheatham and Hailer, 1975).

Watershed Units. Smith River, Klamath River, Mad River, Mattole River, Noyo River, Gualala River, Morro Bay.

Vegetation. Vegetation is typically a partially open to closed forest, dominated by conifers to 52 m (170 ft) tall, with lower overstory strata of evergreen and deciduous broad-leaved trees (Table 8-42). Understory vegetation of shrubs and herbs is typically sparse, but may be dense on more mesic sites (such as north slopes and stream canyons; and on sites that have not burned for many years).

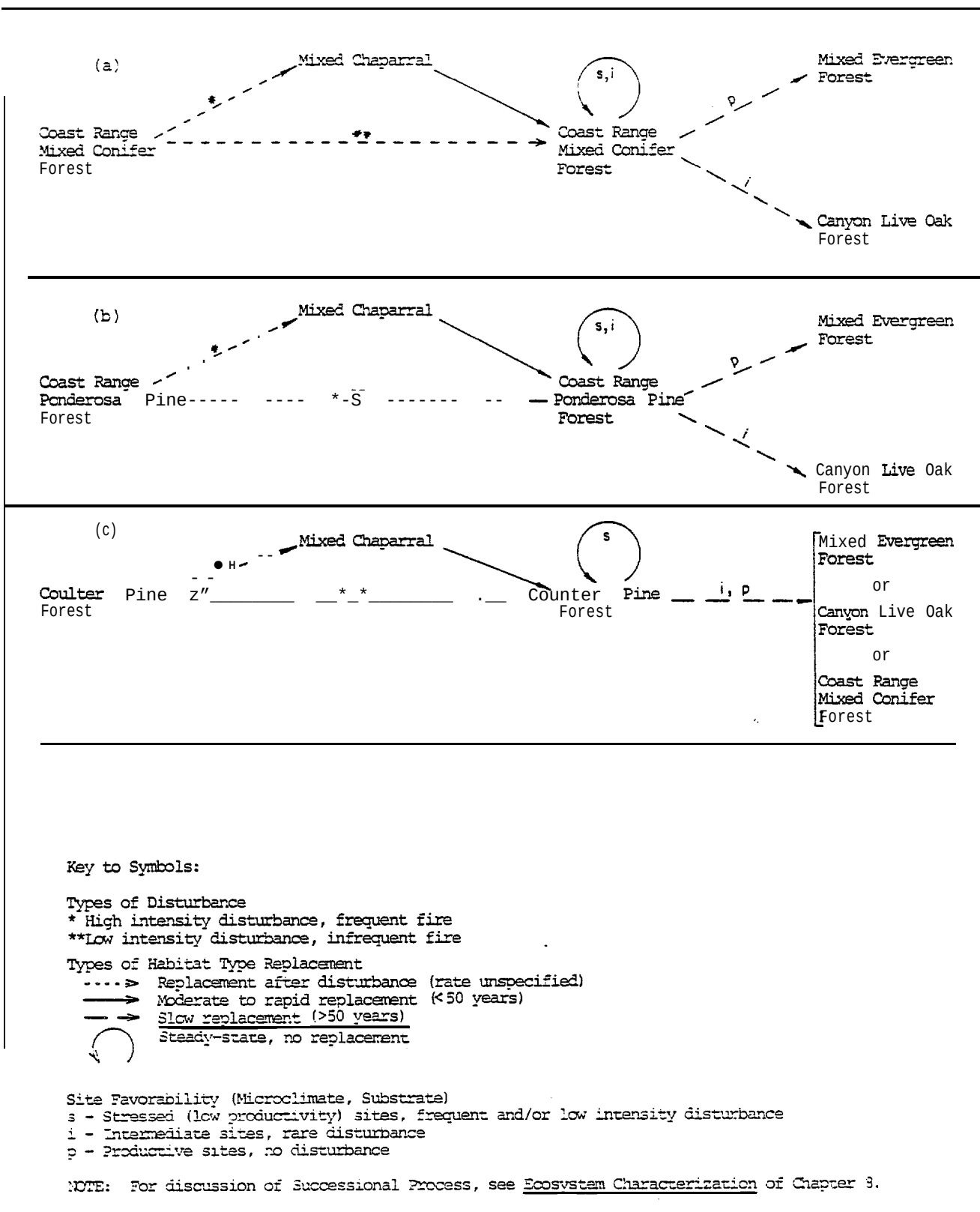


Figure 3-34. Successional Sequences (a-c) Suggested for Lower Montane Conifer Forest Habitat Types

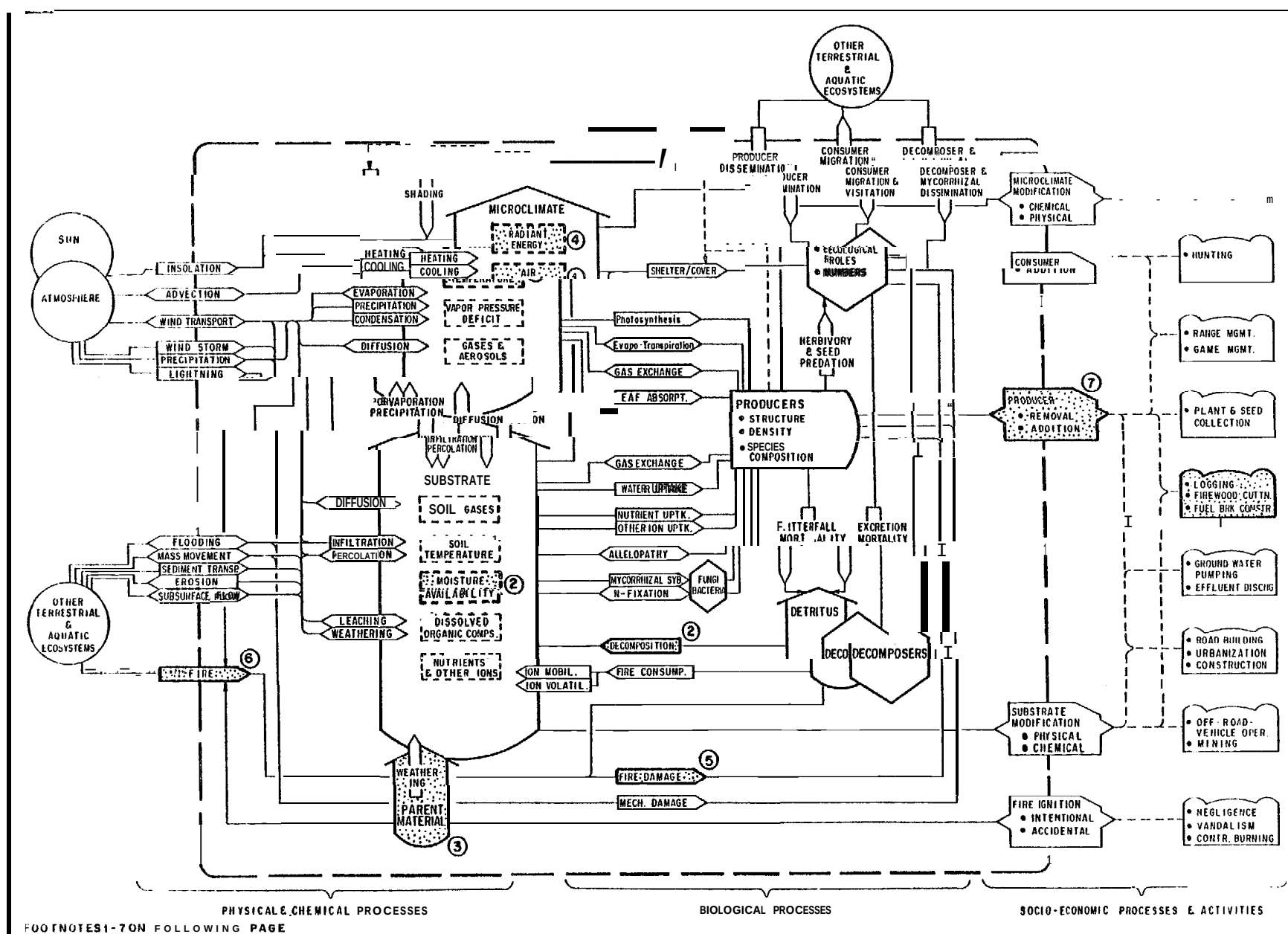


Figure 8-35. Ecosystem Model - Lower Montane Conifer Forest Cover Type

Footnotes for Figure 8-35
Ecosystem Model for the Lower Montane Conifer Forest Cover Type-
Highlighted Processes and Components are Annotated Below

1. AIR TEMPERATURE: Ecosystems of this cover type undergo greater seasonal extremes of temperature and greater daily temperature fluctuations than ecosystems of the other conifer forest cover types in the study region. Even so, characteristic conifer dominants photosynthesize at a substantial level throughout the winter season (Waring and Franklin, 1979) .
2. SOIL MOISTURE AVAILABILITY AND DECOMPOSITION: Photosynthesis is restricted by low soil moisture availability during summer months. Low soil moisture also constrains activity of decompose organisms. Substantial decomposition of litter takes place beneath wintertime snow packs (Waring and Franklin, 1979) .
3. PARENT MATERIALS: Lower montane conifer forest is found at low elevations on particularly sterile or dry soils derived from unusual parent materials (Griffin, 1964) . Examples of this cover type are found on serpentine parent materials at low elevation sites within the coastal conifer forest cover type.
4. RADIANT ENERGY: Seedlings of most characteristic dominants require high levels of radiant energy in order to rapidly grow deep roots and avoid summer soil moisture depletion in upper soil layers.
5. FIRE DAMAGE: Mature trees characteristic of this cover type are protected from damage by low-intensity fires by thick fire-resistant bark. These characteristic species have evolved under regimes of relatively frequent but low-intensity fires.
6. FIRE: Fire removes shading understory vegetation and creates bare mineral soil suitable for conifer seedling regeneration. Other ecological functions of fire are discussed under Important Abiotic Interactions in the Cover Type Characterization.
7. PRODUCER REMOVAL: Low productivity of many sites in this cover type prevents rapid revegetation after logging or other vegetation removal.

Table 8-42. Characteristic Plants of a Coast Range Mixed Conifer Forest

Plant Type/Common Names	Scientific Names
<u>Trees</u>	
Sugar pine	<u>Pinus lambertiana</u>
Douglas fir	<u>Pseudotsuga menziesii</u>
Incense cedar	<u>Calocedrus decurrens</u>
Ponderosa pine	<u>Pinus ponderosa</u>
Jeffrey pine	<u>Pinus jeffreyi</u>
	(on serpentine soils)
Madrone	<u>Arbutus menziesii</u>
Tanoak	<u>Lithocarpus densiflorus</u>
Black oak	<u>Quercus kelloggii</u>
Canyon live oak	<u>Q. chrysolepis</u>
Giant chinquapin	<u>Chrysolepis chrysophylla</u>
Coulter pine	<u>Pinus coulteri</u>
<u>Shrubs</u>	
Salal	<u>Gaultheria shallon</u>
Snowbrush	<u>Ceanothus velutinus</u>
Oregon grape	<u>Berberis nervosa</u>
Greenleaf manzanita	<u>Arctostaphylos patula</u>
Huckleberry oak	<u>Quercus vaccinifolia</u>
Hoary manzanita	<u>A. canescens</u>
	(on serpentine soils)
Buck brush	<u>C. cuneatus</u>
	(on serpentine soils)
Sierra gooseberry	<u>Ribes roezlii</u>
	(in Santa Lucia Mountains)
<u>Herbs</u>	
Pipsissewa	<u>Chimaphila umbellata</u> and <u>C. menziesii</u>
Adenocaulon	<u>Adenocaulon bicolor</u>
Wintergreen	<u>Pyrola picta</u>
Inside-out flower	<u>Vancouveria planipetala</u>
Columbine	<u>Aquilegia formosa</u>

Succession. Typical partially open overstory allows continued regeneration of moderately shade-intolerant species such as Douglas fir, sugar pine and incense cedar (Figure 8-34a). Where site conditions are more favorable and canopy is more closed, Douglas-fir and incense cedar will eventually dominate to exclusion of pines. Typical open overstory of stands in Santa Lucia Mountains (where Douglas fir is absent) allows maintenance of steady state mixed composition of pines, incense cedar and broad-leaved trees. After many years without fire, heavy fuel loadings from broad-leaved trees and understory shrubs may lead to high intensity fires and resulting elimination of mature conifers as seed sources (Griffin, 1978). Characteristic conifers are typically resistant to frequent low intensity fires. Broad-leaved tree and shrub species all sprout vigorously after fire to form a seral mixed chaparral habitat type. Rate of return to steady state mixed conifer habitat type depends on conifer colonizing ability (a function of seed production, seed dissemination, and seedling establishment ability) and site conditions (Sawyer and Thornburgh, 1977). Repeated fires at long intervals may eliminate conifer seed sources over wide areas and allow replacement of this habitat type by canyon live oak forest habitat type.

Habitat Type Description: Coast Range Ponderosa Pine Forest

Distribution. Coast range ponderosa pine forest occurs at scattered locations in North Coast Ranges at elevations from 450-1,050 m (1,500-3,500 ft): at several locations in Santa Cruz Mountains on weakly consolidated marine sand deposits (Griffin, 1964) and on higher ridges in the Santa Lucia Mountains at elevations from 750-1,350 m (2,500-4,500 ft). Ponderosa pine contributes at least 50 percent of the tree cover. It is typically found on well-drained, dry substrates of slopes and ridges. It intergrades with mixed evergreen forest and Douglas fir forest habitat types on low elevation moist sites, with oak woodland habitat types on low elevation dry sites, and with coast range mixed conifer forest habitat type on high elevation, more mesic sites (Cheatham and Hailer, 1975).

Watershed Units. Klamath River, Mad River, Noyo River, Gualala River, San Lorenzo River, Carmel River, Morro Bay.

Vegetation. Vegetation is typically an open, park-like forest of ponderosa pine, occasionally with evergreen and deciduous broad-leaved trees and with a sparse understory of shrubs and herbaceous plants.

Table 8-43. Characteristic Plants of a Coast Range Ponderosa Pine Forest

Plant Types/Common Names	Scientific Names
<u>Trees</u>	
Ponderosa pine	<u>Pinus ponderosa</u>
Madrone	<u>Arbutus menziesii</u>
Canyon live oak	<u>Quercus chrysolepis</u>
slack oak	<u>Q. kelloggii</u>
Coulter pine	<u>P. coulteri</u> (in Santa Lucia Mountains)
<u>Shrubs</u>	
Coffeeberry	<u>Rhamnus californica</u>
Poison oak	<u>Rhus diversiloba</u>
Creambush	<u>Holodiscus microphyllus</u>
Silverleaf manzanita	<u>Arctostaphylos silvicola</u> (in Santa Cruz Mountains)

Succession. Open, park-like stands have developed under regimes of frequent but low intensity ground fires. Mature pines are resistant to these fires and ponderosa pine seedlings regenerate best on bare mineral soil at high light intensities (Figure 8-34b). Waves of seedling establishment occur on such sites in years of heavy seed production and above average growing season precipitation (Fowells, 1965). In the absence of fire, increasing density of broad-leaved trees and understory shrubs may preclude pine regeneration. Because of typical low site productivity, several hundred years would be required for total prevention of pine regeneration. With increase in understory vegetation and associated fuel loadings, subsequent fires are of high intensity with increased likelihood of killing mature pines. This occurred on some sites in the 1977 Marble-Cone fire in the Santa Lucia Mountains (Griffin, 1978). All associated broad-leaved tree and shrub species sprout readily after fire damage.

Habitat Type Description: Coulter Pine Forest

Distribution. Coulter pine forest habitat type is found in the Santa Lucia Mountains of the South Coast Ranges (Monterey and San Luis Obispo Counties) on slopes and ridges from 2,500-5,000 feet in elevation. It is most common on dry, rocky soils of south-facing slopes where fires occur fairly frequently, and is often in mixtures with species of the mixed chaparral habitat type. On moister sites, it intergrades with canyon live oak forest, coast range ponderosa pine forest, and coast range mixed conifer forest habitat types. On drier low elevation sites, it intergrades with blue oak woodland and on more sterile substrates, it intergrades with knobcone pine forest habitat type (Cheatham and Hailer, 1975).

Watershed Units. Carmel River, Morro Bay.

Vegetation. Vegetation is typically an open forest dominated by Coulter pine (at least 50 percent of tree cover) to 30 m (100 ft) tall. Abundant shrub understory of chaparral species may be present where overstory is sparse, but little or no understory vegetation will occur where Coulter pines form a more closed canopy (Table 8-44).

Table 8-44. Characteristic Plants of the Coulter Pine Forest

Plant Type/Common Names	Scientific Names
<u>Trees</u>	
Coulter pine	<u>Pinus coulteri</u>
Canyon live oak	<u>Quercus chrysolepis</u>
Sugar pine	<u>P. lambertiana</u>
Digger pine	<u>P. sabiniana</u>
Black oak	<u>Q. kelloggii</u>
<u>Shrubs</u>	
Eastwood manzanita	<u>Arctostaphylos glandulosa</u>
Chamise	<u>Adenostoma fasciculatum</u>
Coffeeberry	<u>Rhamnus californica</u>

Succession. Coulter pine is a relatively short-lived species that begins to produce seeds at 20-30 years of age. Seedling establishment requires bare mineral soil and moderate to high light intensity. Less light intensity is required where soil moisture is more plentiful and there is less need for deep root penetration. Where longer-lived species (e.g., canyon live oak) develop a closed canopy, further Coulter pine regeneration is precluded (Figure 8-34c). Where fires, other disturbances, or low site productivity create or maintain canopy openings, Coulter pines will continue to regenerate. High intensity fires on sites with large fuel build-ups may eliminate Coulter pine seed sources and create mixed chaparral or canyon live oak forest from sprouting root crowns (Griffin, 1978). Coulter pines are reported to regenerate under chaparral (Sudworth, 1967) and under valley oaks (Griffin, 1976).

Closed-Cone Conifer Forest

Physiognomy. The closed-cone conifer forest cover type is extremely variable in density, height and presence of understory vegetation: the type is unified by its typical occurrence as disjunct, relict stands, dominated by single endemic closed-cone conifer species and restricted to various kinds of infertile substrates. Closed-cone habit involves storage of seeds on trees for many years until released from cones by heat of fire. Stands are very open with little to no understory vegetation on the most xeric and infertile sites, but may form dense even-aged thickets following fire on better sites. All characteristic dominants require bare mineral soil and full sunlight for successful seedling establishment. Evidence from the fossil record indicates that most closed-cone species (e.g., Sargent cypress) formerly had wide distributions in California during Miocene and Pliocene geologic eras. Their present discontinuous distributions and restrictions to serpentine and other infertile substrates, often near the coast, resulted from their inability to compete with other tree species on more fertile sites as the climate became gradually warmer and drier after the Pliocene (Raven and Axelrod, 1978). See Table 8-45 for habitat types.

Table 8-45. Habitat Types of a Closed-Cone Conifer Forest

Habitat Type	Dominant Plants	Regional Distribution
Knobcone pine forest	Knobcone pine (<u>Pinus attenuata</u>)	North and South Coast Ranges
Cypress forest	Santa Cruz cypress (<u>Cupressus abramsiana</u>) Monterey cypress (<u>C. macrocarpa</u>)	Santa Cruz Mountains only Monterey Peninsula only
	Sargent cypress (<u>C. sargentii</u>)	North and South Coast Ranges
Pygmy conifer forest	Mendocino cypress (<u>Cupressus pygmaea</u>) Gowen cypress (<u>C. goveniana</u>)	Mendocino and Sonoma coasts only Monterey Peninsula only
	Bolander pine (<u>Pinus contorta</u> ssp. <u>bolanderi</u>)	Mendocino coast only
Bishop pine forest	Bishop pine (<u>Pinus muricata</u>)	North and central coasts
Monterey pine forest	Monterey pine (<u>Pinus radiata</u>)	South coast only
Shore pine forest	Shore pine (<u>Pinus contorta</u> ssp. <u>contorta</u>)	North coast only

Climate. Annual precipitation is 50-150 cm (20-60 in), often with much fog, and the growing season is 9-12 months; cool climate with mean summer maximum temperatures of 20°C-30°C (68°F-84°F) and mean winter minimum temperatures of 0.5°C-4°C (33°F-40°F) typify the cover type (Munz and Keck, 1949). Most ecosystems in this cover type are exposed to various amounts of marine influence (Vogl et al., 1977). Temperature extremes are greater for more inland and higher elevation ecosystems dominated by knobcone pine or Sargent cypress.

Topography. Topographic settings differ significantly among the various habitat types; see the following habitat type descriptions.

Substrate. The substrates for this cover type are typically infertile, acidic, poorly drained, and locally anomalous. Unique substrates of low productivity allow closed-cone species to escape replacement by less stress-tolerant species within the natural fire interval. Substrate conditions differ significantly between included habitat types (see following habitat type descriptions) .

Vegetation. This cover type can be an open to dense, moderately tall to dwarfed conifer forest dominated by closed-cone species (Table 8-45). Typically, it forms pure stands, but sometimes is mixed in some habitat types. Occurrence of understory vegetation is highly variable with herbaceous species often scarce due to the coarse texture of typical substrates.

Vegetation Seasonality and Modes of Reproduction. Most growth activity is in spring and early summer, but may occur nearly year round in coastal forests of Monterey pine, Bishop pine and shore pine habitat types. Growth activity in pygmy conifer forest ecosystems is severely limited by soil moisture depletion above hardpans in typical podzolized soils. Nearly all characteristic tree and shrub species are ever-green. Evergreen foliage allows winter-time photosynthesis and may be of significant adaptive advantage where summer drought and nutrient poverty are characteristic (Westman and Whittaker, 1975) . Dominant conifer species generally require fire to release seeds from closed-cones stored on the trees and to prepare a suitable seed bed. Most typical shrub associates sprout vigorously from root crowns after fire destruction of aboveground biomass.

Characteristic Fauna. Characteristic mammals of closed-cone conifer forest cover types are taken from Ingles (1965). Van Velzen (1972-1975) provides information on common California birds in Bishop pine and Monterey pine forests. Common or characteristic reptiles and amphibians are derived from Stebbins (1966). Species in Table 8-46, although characteristic of closed-cone conifer forests, are not found exclusively in this cover type. Abbreviations (e.g., TI, TIE, TA) following species common names refer to types of consumers in the general food web for this cover type (see Figure 8-36 for explanation of abbreviations) . See the Community Composition List, Volume III, Part 2, for more information on species listed below, and for information on characteristic invertebrate species.

Table 8-46. Characteristic Fauna for a Closed-Cone Conifer Forest ¹

Mammals	Birds	Reptiles and Amphibians
Vagrant shrew (TI)	Wilson's warbler (TIE)	Northwestern salamander (TA)
Gray fox (LC)	Wrentit (TIE) (SFE)	
Black-tailed deer (LH)	Pine siskin (SFE) (TIE)	Rough-skinned newt (TA)
Dusky-footed woodrat (SE) (SH)	Rufous-sided towhee (SFE) (TIE)	Coast horned lizard (TR)
Townsend chipmunk (SE)	Western flycatcher (TIE)	Ringneck snake (TR)
Douglas squirrel (SE)	Chestnut-backed chickadee (TIE) (SFE)	
Big brown bat (FI)	Dark-eyed junco (SFE) (TIE)	
Spotted skunk (SC)	Orange-crowned warbler (TIE)	
	Purple finch (SFE) (TIE)	
	Hutton's vireo (TIE)	
	Bewick's wren (TIE)	
	Common bushtit (TIE) (SFE)	
	Pygmy nuthatch (TIE) (SFE)	
	Violet-green swallow (TIE)	
	Song sparrow (SFE) (TIE)	
	Swainson's thrush (TIE) (SFE)	
	Great horned owl (CB) (TIE)	
	Allen's hummingbird (NE) (TIE)	
	Stellar's jay (SFE) (TIE) (CB) (SB)	

¹See Table 8-36 for definition of abbreviations.

Biomass Productivity and Food Web. Westman and Whittaker (1975) reported biomass and net primary productivity estimates for pygmy conifer forest, Bishop pine forest, and slope redwood forest ecosystems in the Mendocino coastal area. Annual productivity for pygmy conifer forest averaged 310 g/m²/yr, Bishop pine forest 1,090 g/m²/yr, and slope redwood forest 1,270 g/m²/yr. Pygmy conifer forest productivity was comparable to expected values for open, dry woodlands. Pygmy conifer forest ecosystems also exhibited a high productive efficiency per unit leaf area even though leaf areas were small.

Primary consumers of tree, shrub and herbaceous vegetation include mammals, such as the black-tailed deer and dusky-footed woodrat; birds, such as the ruffed grouse; and insects, such as the Monterey pine aphid, Monterey pine midge, western pine engraver, and larvae of the tortoise shellbutterfly (Figure 8-32). Seed and fruit production is consumed by mammals, such as the Townsend chipmunk and Douglas squirrel; and birds, such as the pine siskin and purple finch. Secondary and tertiary consumers in the food web include insectivores, such as the Wilson's warbler, rough-skinned newt, vagrant shrew and big brown bat and Allen's hummingbird (also a nectivore, a Primary consumer); and carnivores, such as the spotted skunk, great horned owl and gray fox. The Stellar's jay is a common scavenging bird, but primarily functions as an omnivore, feeding on seeds and fruits (SFE), insects (TIE) and bird eggs (CB). Man functions as an omnivore, consuming fruits and seeds (SE) and game mammals and birds (LC).

Important Biotic Interactions. Seed ant? seedling predation may adversely affect regeneration of closed-cone conifer species; rabbits, deer, porcupines, squirrels, and cattle may be locally important (Vogl et al., 1977). Successful seedling regeneration of closed-cone conifer species is possibly restricted to bare mineral soil and full sunlight because damping-off fungi inhabit shaded sites where litter has accumulated (Vogl et al., 1977).

Important Abiotic Interactions. Catastrophic fire is necessary to release seed from closed-cones, to prepare bare mineral seed bed, and to remove competing vegetation. Most closed-cone conifer species (e.g., Bishop pine, Monterey pine) are short-lived. Absence of recurrent fire will lead to elimination of present closed-cone conifer stands through failure of seedling regeneration (Vogl et al., 1977). Acidic conifer and ericaceous plant litter contributes to the progressive acidification and podzolization of pygmy conifer forest soils (Westman, 1975).

Associated Cover Types. Closed-cone conifer forest ecosystems are commonly restricted to unusual (i.e., azonal) substrates and occur as inclusions within more widely distributed cover types (see habitat type descriptions for common associates of each habitat type).

Vegetation Succession. Replacement of closed-cone conifer forests by other cover types requires total absence of fire for some period longer than the life span of the dominant closed-cone species. The rate of replacement depends on the favorability of sites for establishment of potentially replacing species within an ecosystem as modified by shade and litter of the closed-cone forest vegetative cover. For example, Monterey pine forest will be replaced fairly rapidly by coast live oak forest because sites within such ecosystems are favorable for coast live oak establishment. However, sites within the knobcone pine forest habitat type are highly unfavorable for coast live oak establishment and the rate of replacement will be much slower, if at all. Hypothetical successional patterns are portrayed in Figure 8-37.

Typical Land Uses. Sand and gravel mining are extensive at sites of this cover type. Some Monterey and Bishop pine stands have been logged in the past. The most serious current threat to this cover type is urbanization and road building in the vicinities of cities in Monterey, Mendocino, Santa Cruz, and San Luis Obispo Counties.

Sensitivity to Disturbance. Ecosystems of this cover type are highly sensitive to disturbance because of the necessity of fire for closed-cone conifer regeneration. Vegetative destruction without fire-induced seed release will lead to elimination of this cover type. Substrates are shallow and infertile; rapid regeneration of vegetation may be necessary to retain nutrients in the ecosystems.

Ecosystem Model. Important processes and components of typical closed-cone conifer forest ecosystems are highlighted in Figure 8-38.

Habitat Type Description: Knobcone Pine Forest

Distribution. Knobcone pine forest habitat type is scattered but locally abundant in North Coast Ranges away from the coast, common in the Santa Cruz Mountains and occasionally southward through Santa Lucia Mountains to San Luis Obispo County at 300-1,500 m (1,000-5,000 ft) elevations. It is typically localized on dry, infertile, rocky slopes (often on serpentine soils) and is adapted to frequent fire by abundant annual seed production, early age of first seed production (5-12 years), and the nest extreme closed-cone habitat of the closed-cone conifers (Vogl et al., 1977). Cones

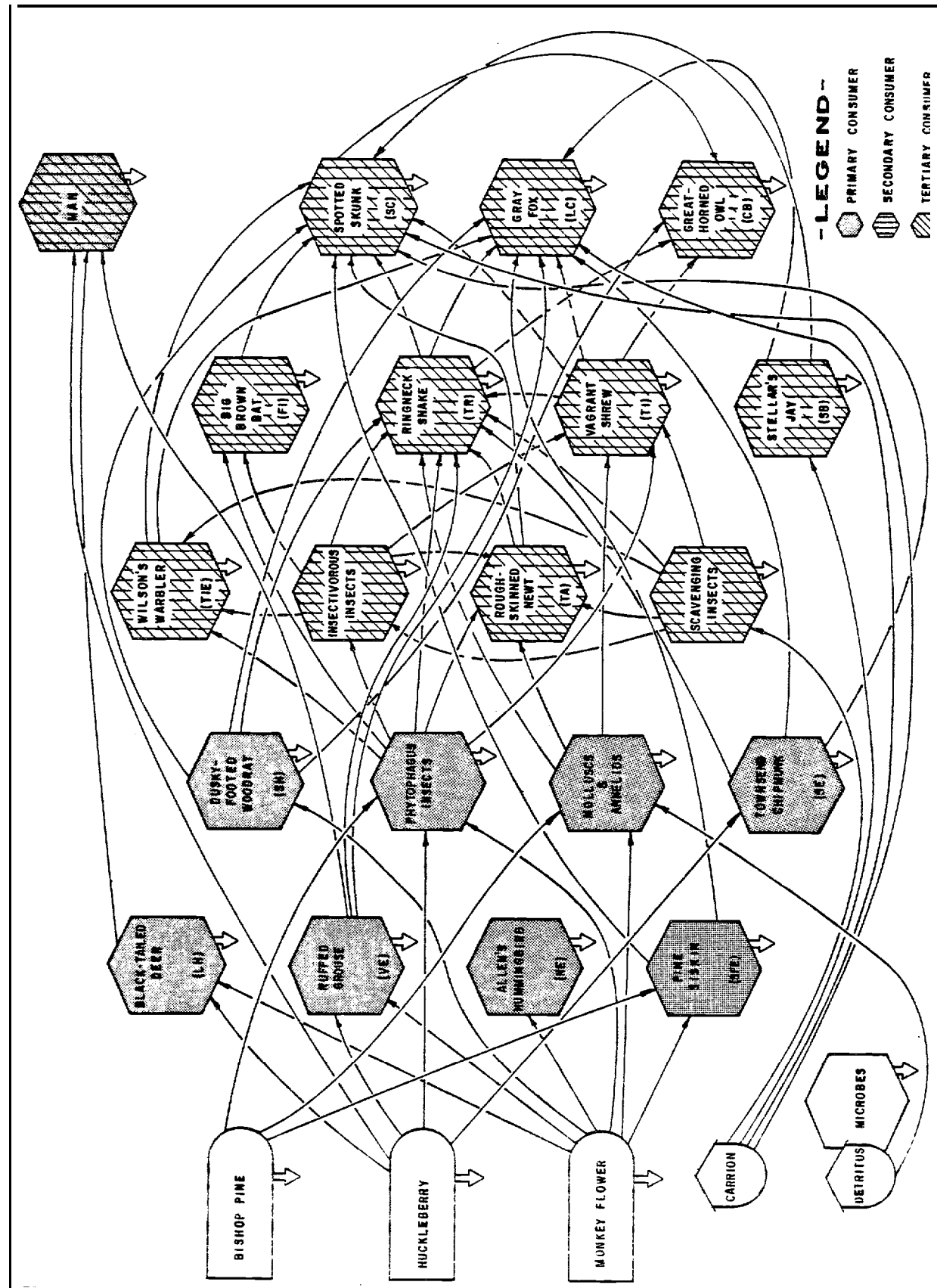


Figure 8-36. An Example of a Closed-Cone Conifer Forest Food Web

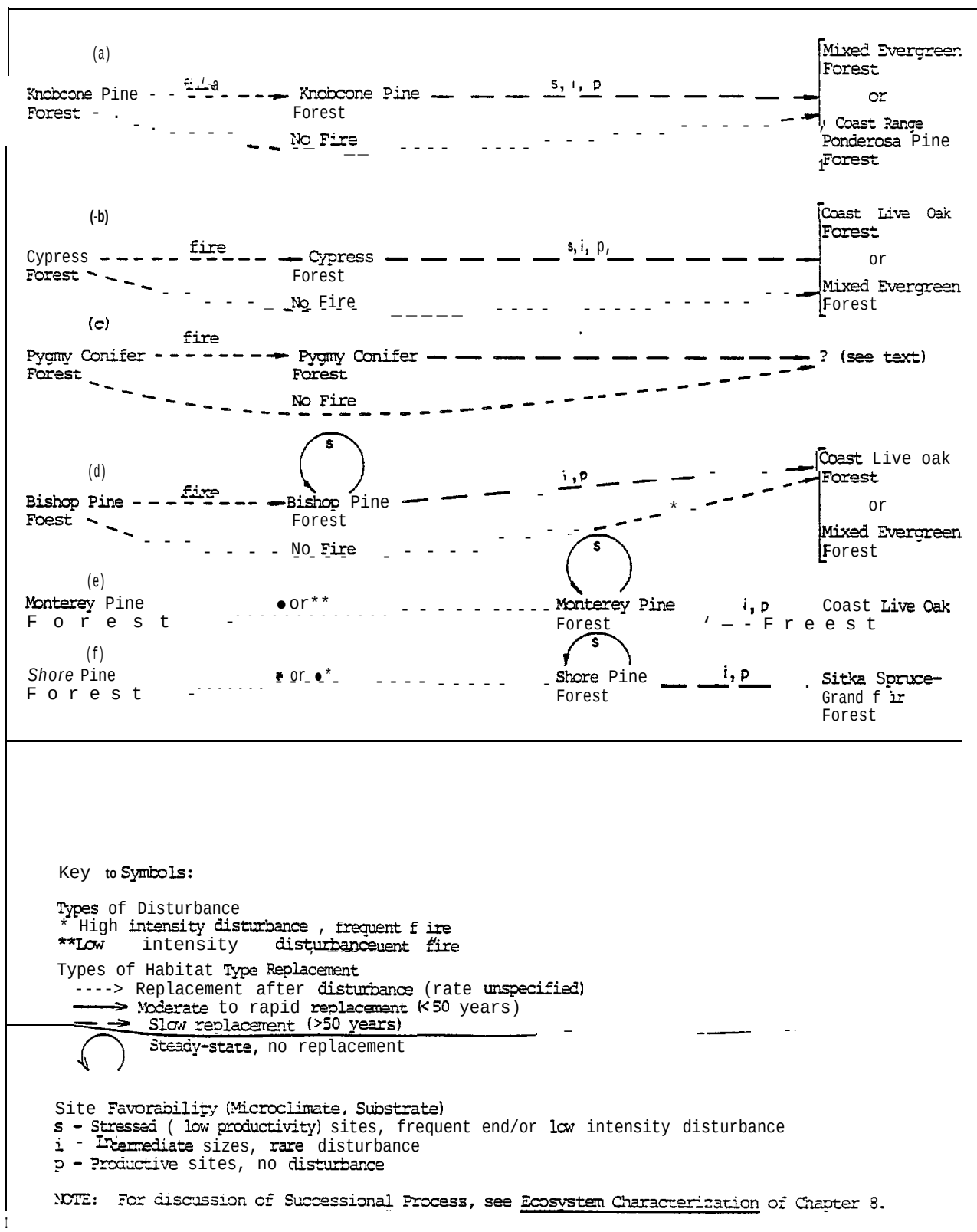


Figure 8-37. Successional Sequences (a-f) Suggested for Closed-Cone Conifer Forest Habitat Types

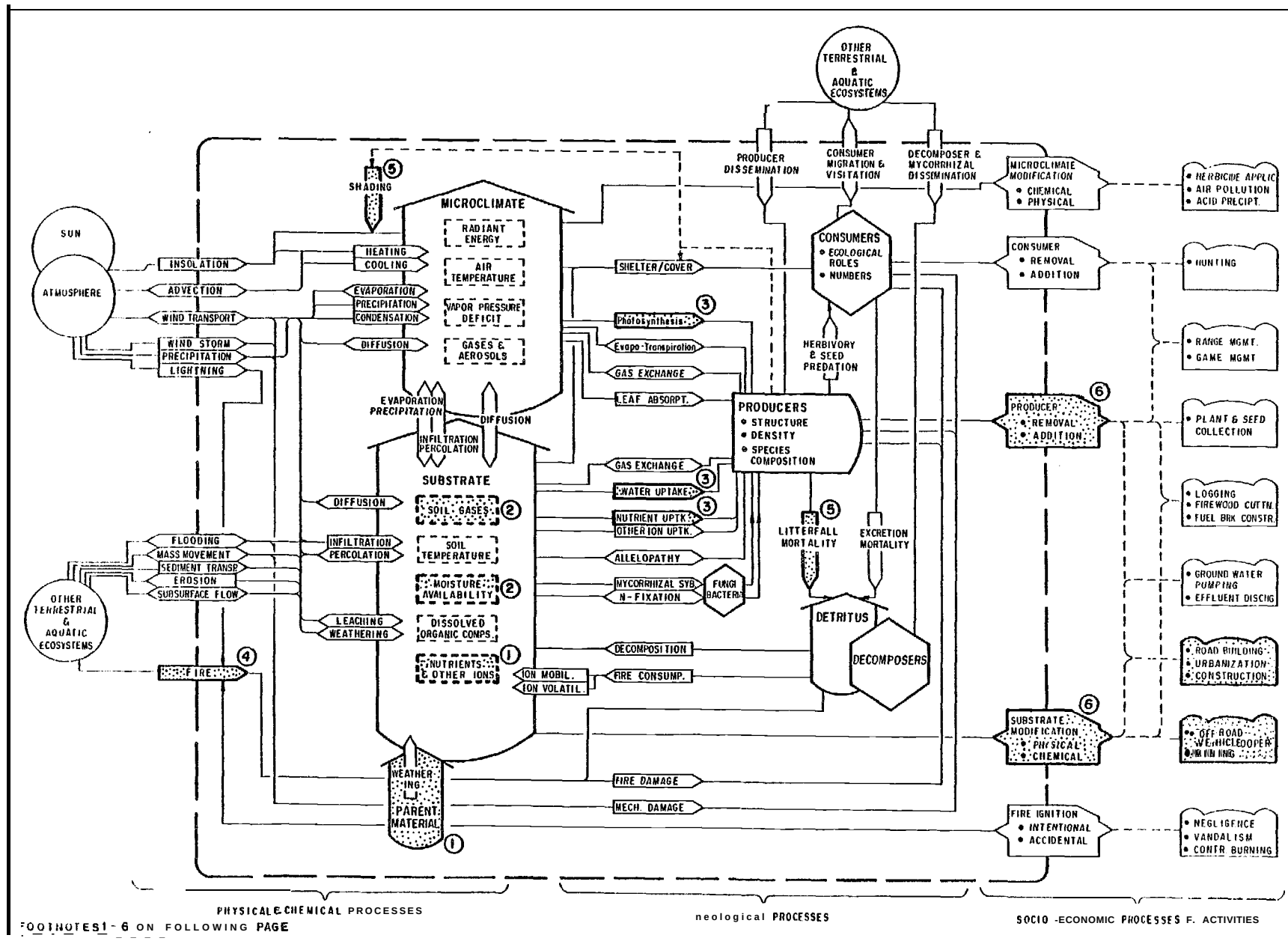


Figure 8-38. Ecosystem Model - Closed-Cone Conifer Forest Cover Type

Footnotes for Figure 8-38
Ecosystem Model for Closed-Cone Conifer Forest Cover Type-
Highlighted Processes and Components are Annotated Below

1. **PARENT MATERIALS AND NUTRIENTS:** Ecosystems of this cover type are restricted to substrates weathered from various kinds of infertile parent materials. Coarse-textured, nutrient-poor, acidic soils derived from sandstone or serpentine are representative.
2. **SOIL MOISTURE AVAILABILITY AND SOIL GASES:** Substrates commonly have iron-cemented hardpans in the B horizon. Substrates with hardpans are water-logged and poorly aerated during the winter rainy season and desiccated above the hardpan during summer. These conditions are most extreme in the pygmy conifer forest habitat type.
3. **PHOTOSYNTHESIS, WATER UPTAKE AND NUTRIENT UPTAKE:** Evergreen tree and shrub species characteristic of this cover type photosynthesize throughout the year. Where soil moisture is depleted during the summer, most photosynthesis occurs during winter and spring when water and nutrients are available.
4. **FIRE:** Closed-cone conifer species exhibit a number of characteristics that have evolved in conjunction with frequent catastrophic fire. Fire is required to release seeds from cones, prepare seedbeds, and remove competing vegetation. Other adaptations to frequent disturbance by fire are shade intolerance, rapid growth, early seed production, and short life spans.
5. **SHADING AND LITTERFALL:** Absence of fire in ecosystems of this cover type over long intervals allows accumulation of litter to ameliorate substrate conditions and vegetative shading to ameliorate microclimate conditions. Less stressful conditions of substrate and microclimate prevent regeneration of closed-cone conifers but may permit establishment of less stress-tolerant species and successional replacement by other cover types.
6. **PRODUCER REMOVAL AND SUBSTRATE MODIFICATION:** Closed-cone conifer forests exhibit unique patterns of ecosystem development and are extremely limited in extent. For example, the Santa Cruz cypress occurs in only four small stands in the Santa Cruz Mountains and has been designated a California endangered plant. Urbanization is eliminating closed-cone conifer forests in many areas. Other sites of this cover type are being mined for gravel and sand.

remain unopened and attached for the life of the tree. Fire is necessary to open cones as well as to prepare bare mineral seed bed and free knobcone pine seedlings from competing vegetation. This "habitat type is often associated with serpentine, chamise, or mixed chaparral habitat types. It may intergrade with or occur as localized stands within broad-leaved evergreen forest, coastal conifer forest, or lower montane conifer forest cover types (Cheatham and Hailer, 1975) ; it also intergrades with cypress forest habitat type on infertile substrates.

Watershed Units. Smith River, Klamath River, Mad River, Mattole River, San Gregorio Creek, San Lorenzo River, Pajaro River, and Morro Bay.

Vegetation. This habitat type forms an open-to-dense forest dominated by knobcone pine up to 15 m (50 ft) tall on the best sites. Following fire on better sites, this habitat type may form dense even-aged thickets; while on the most infertile and xeric sites, it typically forms very open, stunted stands with abundant to sparse chaparral shrub understory (Table 8-47).

Table 8-47. Characteristic Plants of a Knobcone Pine Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Knobcone pine	<u>Pinus attenuata</u>
<u>Shrubs</u>	
Chemise	<u>Adenostoma fasciculatum</u>
Eastwood manzanita	<u>Arctostaphylos glandulosa</u>
Wild lilacs	<u>Ceanothus</u> spp.
Leather oak	<u>Quercus durata</u> (on serpentine soils)
Interior live oak	<u>Q. wislizenii</u>
Huckleberry	<u>Vaccinium ovatum</u> (North Coast Ranges)

Succession. Knobcone pine is a short-lived (50-80 years), early-seeding (5-12 years), opportunistic species adapted to regenerate rapidly on bare mineral substrates following fire. Although it seems to grow equally well on both fertile and infertile soils, it is soon replaced by taller or more shade-tolerant species on better sites. Periodic high intensity fire (33-50 year intervals) is necessary to remove potentially competing vegetation, consume plant litter and mobilize nutrients; thereby, creating suitable conditions for germination and establishment of abundant knobcone pine seedling reproduction immediately after fire. An interaction of fuel accumulation (from litter and natural mortality) and fuel flammability virtually assures fire within the period of stored seed viability. Without fire, knobcone pine forest habitat types may gradually develop into other habitat types (e.g., mixed evergreen forest, coast range ponderosa pine forest) as substrate and microclimate conditions are ameliorated by vegetative shading of the soil surface, organic matter accumulation, nutrient accumulation, and increased pH (Figure 8-37a). Gradually, sites become suitable for regeneration and establishment of less stress-tolerant species (e.g., madrone).

Habitat Type Description: Cypress Forest

Distribution and Soil Conditions. This habitat type occurs as scattered ecosystems, each dominated by a single cypress species and each characterized by soils which are typically shallow, podzolized, poorly-drained, and infertile (Vogl et al., 1977). Monterey cypress occurs in two natural stands in the Monterey Peninsula area on rocky granitic soils of coastal headlands where constant winds, salt spray, and fog are characteristic. These stands intergrade with Monterey pine forest and coastal bluff scrub habitat types. Santa Cruz cypress, an officially-designated California rare and endangered plant, occurs in four natural stands in the Santa Cruz Mountains on very shallow sandstone-derived soils. It occurs at elevations of 300-750 m (1,000-2,500 ft) and above the summer fog belt. Santa Cruz cypress individuals are typically dwarfed. Stands intergrade with knobcone pine forest, coast range ponderosa pine forest, and mixed chaparral habitat types. Sargent cypress is common in scattered sites in the North and South Coast Ranges on serpentine soils. Sargent cypress stands intergrade with serpentine chaparral, mixed chaparral, mixed evergreen forest, and blue oak woodland habitat types (Cheatham and Hailer, 1975).

Watershed Units: Russian River (Sargent cypress), Lagunitas Creek (Sargent cypress), San Gregorio Creek (Santa Cruz cypress), San Lorenzo River (Santa Cruz cypress), Carmel River (Monterey cypress), and Morro Bay (Monterey cypress, Sargent cypress).

Vegetation. Monterey cypress stands are moderately dense forest (60-90 percent cover) to 21 m (70 ft) tall where sheltered but wind pruned where exposed (Table 8-48). They occur typically with a pure overstory of Monterey cypress and with little understory vegetation. Santa Cruz cypress and Sargent cypress stands are similar in appearance although each is dominated by a different cypress species. Each has a typically open and dwarfed cypress overstory with a scattered understory of chaparral shrub species. Cypressess may reach 15 m (50 ft) in height on better sites (Cheatham and Hailer, 1975).

Table 8-48. Characteristic Plants of a Cypress Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u> (Note: each cypress species dominates different stands)	
Monterey cypress	<u>Cupressus macrocarpa</u>
Santa Cruz cypress	<u>C. abramsiana</u>
Sargent cypress	<u>C. sargentii</u>
Knobcone pine	<u>Pinus attenuata</u> (with Santa Cruz and Sargent cypress only)
<u>Shrubs</u>	
<u>Monterey cypress associates</u>	
Coyote brush	<u>Baccharis pilularis</u> ssp. <u>consanguinea</u>
Sticky monkeyflower	<u>Mimulus aurantiacus</u>
<u>Santa Cruz cypress associates</u>	
Littleberry manzanita	<u>Arctostaphylos nummularia</u> ssp. <u>sensitiva</u>
Silverleaf manzanita	<u>A. silvicola</u>
Bush chinquapin	<u>Chrysolepis chrysophylla</u> ssp. <u>minor</u>
<u>Sargent cypress associates</u>	
Hoary manzanita	<u>Arctostaphylos canescens</u>
Pointleaf manzanita	<u>A. pungens</u> ssp. <u>montana</u>
<u>Common associates of both Santa Cruz and Sargent cypress</u>	
Chemise	<u>Adenostoma fasciculatum</u>
Buckbrush	<u>Ceanothus cuneatus</u>

Succession. Cypress cones remain unopened on the tree until heat of fire releases the seeds. Cypress seedling establishment requires fire to open cones, to prepare a bare mineral substrate, and to remove shading or moisture-depleting ground vegetation (Figure 8-37b). Without fire, gradual accumulation of organic matter and alteration of soil surface microclimate by shading might eventually allow establishment of less stress-tolerant species on more favorable microsites. Rate of species replacement would be very slow due to stressed conditions in typical cypress-dominated ecosystem. Because of the unique character and the scattered distribution of ecosystems in this habitat type, management plans should consider vegetation preservation to ensure continued regeneration of the dominant cypress species. Controlled burning programs could be used to simulate the natural regeneration process.

Habitat Type Description: Pygmy Conifer Forest

Distribution and Soil Conditions. The pygmy conifer forest habitat type is highly localized in two widely separated areas: the Monterey Peninsula-Point Lobos area and the Mendocino coastal terraces between Albion and Fort Bragg. It is also found in four small stands scattered along the southern Mendocino coast near Anchor Bay. It is located up to several miles inland from the immediate coast on partially-to-highly podzolized soils developed from ancient beach sand and clay deposits (Mendocino terraces), or from coarse sandstones (Anchor Bay and Monterey Peninsula). All substrates are poorly drained due to iron-cemented hardpan in B horizon, highly acidic, and extremely low in nutrients. In the Mendocino pygmy forest ecosystems, a characteristic perched water table is created by a cemented iron-pan at 46-76 cm (18-30 in) depth (Blacklock podzol soil) or by stratified beach clay deposits (Aborigine soil) (Genny et al., 1969). In winter, upper soil horizons are flooded and boglike; in summer, extremely xeric. Inclusions of typical Bishop pine forest habitat type within Mendocino pygmy forests result from gaps in the iron and clay pans, allowing root penetration to better-drained and more fertile lower soil strata. The pygmy conifer forest habitat type intergrades with Bishop pine forest at all locations, with slope redwood forest and mixed evergreen forest in Mendocino County and with Monterey pine forest on the Monterey Peninsula (Cheatham and Haller, 1975).

Watershed Units. Noyo River, Gualala River, Carmel River, and Morro Bay.

Vegetation. Vegetation is typically short and stunted, with canelike conifers to 3 m (10 ft) tall (Table 8-49). Sometimes mature cone-bearing trees are less than 1 m (4 ft) tall and 50-60 years old (Vogl et al., 1977). The closed-cone conifer overstory may be open to dense with a generally sparse understory dominated by dwarfed ericaceous shrubs. Lichen encrustations are abundant on the soil surface and on plant structures (Westman, 1975). Several characteristic plants are endemic with different, but related, species in the Mendocino and Monterey localities (Cheatham and Hailer, 1975). On more favorable sites of deeper soils adjacent to pygmy conifer forest ecosystems, individuals of the two characteristic cypress species may grow to normal tree size (Vogl et al., 1977).

Table 8-49. Characteristic Plants of a Pygmy Conifer Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Mendocino cypress	<u>Cupressus pygmaea</u> (Mendocino County)
Bolander pine	<u>Pinus contorta</u> ssp. <u>bolanderi</u> (Mendocino County)
Gowen cypress	<u>Cupressus goveniana</u> (Monterey County)
Bishop pine	<u>Pinus muricata</u> (both localities)
<u>Shrubs</u>	
Monterey manzanita	<u>Arctostaphylos hookeri</u> (Monterey County)
Shaggy-barked manzanita	<u>A. tomentosa</u> (Monterey County)
Fort Bragg manzanita	<u>A. nummularia</u> (Mendocino County)
Hairy manzanita	<u>A. columbiana</u> (Mendocino County)
Salal	<u>Gaultheria shallon</u>
Labrador-tea	<u>Ledum glandulosum</u> ssp. <u>columbiana</u>
California rose-bay	<u>Rhododendron macrophyllum</u>
Huckleberry	<u>Vaccinium ovatum</u>
<u>Herbs</u>	
Bear-grass	<u>Xerophyllum tenax</u>
Bracken	<u>Pteridium aquilinum</u>

Succession. Vegetation change over time occurs very slowly in ecosystems of this habitat type; 50-125 years old cypresses and pines may be less than 3 m (10 ft) tall (Westman, 1975). Bolander pine exhibits a strong closed-cone habit in contrast to the weak closed-cone habit of the closely-related shore pine (Pinus contorta ssp. contorta). Both Gowen and Mendocino cypress retain unopened cones on trees until burned (Figure 8-37c). Successful reproduction of cypress and Bolander pine is normally restricted to burned sites; often dense, even-aged thickets originate after fire (Vogl et al., 1977). Most characteristic shrub species have root systems adapted to resprouting after fire (Westman and Whittaker, 1975). Pygmy conifer forest ecosystems on Mendocino coastal terraces exhibit the closest approximation to steady-state systems of balanced inputs and outputs known for temperate regions (Jenny et al., 1969). Effects of complete exclusion of fire from these ecosystems are unknown (Vogl et al., 1977).

Habitat Type Description: Bishop Pine Forest

Distribution and Soil Conditions. This habitat type is abundant in scattered localities from Humboldt County to Santa Barbara County on headlands, low hills, old sand dunes, and terraces within 13 km (8 mi) of the coast. It occurs below 400 m (1,300 ft) elevation under maritime influence of persistent cloud cover, fog, and moist air at all localities (Vogl et al., 1977). It is typically on shallow, acidic, and poorly-drained soils. On Mendocino coastal terraces, this habitat type intergrades with slope redwood forest and mixed evergreen forest on weakly-podzolized slope substrates and with pygmy conifer forest on strongly podzolized terrace soils. Best development of Bishop pine forest is on old terrace foredunes (Westman, 1975). In Santa Barbara and San Luis Obispo Counties, this habitat type is best developed on diatomaceous shale soils that are shallow, highly acid, and have high water-retaining capacity (Vogl et al., 1977). On Monterey Peninsula, Bishop pine forest intergrades with pygmy conifer forest and Monterey pine forest habitat types on more and less podzolized soils, respectively. Bishop pine forest also intergrades with coastal scrubland cover type on dry, rocky sites and with coastal prairie habitat type on heavier soils (Cheatham and Hailer, 1975).

Watershed Units. Mad River, Noyo River, Lagunitas Creek, Carmel River, Morro Bay, San Antonio Creek, Santa Ynez River, and Point Arguello.

Vegetation. This habitat type occurs as partially open-to-dense conifer forests up to 24 m (80 ft) tall under best conditions, often in pure, even-aged stands of Bishop pine from fire origin (Table 8-50). Understory or shrubs and herbs may be very dense on moist sites with canopy openings, or very sparse on rocky, xeric sites. Many ericaceous shrub species are found on the typically acidic substrates.

Table 6-50. Characteristic Plants of a Bishop Pine Forest

Plant Types/Common Name	Scientific Name
<u>Trees</u>	
Bishop pine	<u>Pinus muricata</u>
Shore pine	<u>P. contorta ssp. contorta</u> (north coast)
Douglas fir	<u>Pseudotsuga menziesii</u> (north coast)
Coast live oak	<u>Quercus agrifolia</u> (central coast)
Madrone	<u>Arbutus menziesii</u>
<u>Shrubs</u>	
Coffeeberry	<u>Rhamnus californica</u>
Blackberry	<u>Rubus vitifolius</u>
Poison oak	<u>Rhus diversiloba</u>
Huckleberry	<u>Vaccinium ovatum</u>
Brittleleaf manzanita	<u>Arctostaphylos crustacea</u>
Toyon	<u>Heteromeles arbutifolia</u>
Salal	<u>Gaultheria shallon</u>
California rose-bay	<u>Rhododendron macrophyllum</u>
Wax myrtle	<u>Myrica californica</u>

Succession. Bishop pine exhibits a strong closed-cone habit; typical stands are even-aged from fire origin (Figure 8-37d). Bishop pines require fire to regenerate, are short-lived, and suffer much disease-caused mortality after about 80 years (Vogl et al., 1977). A fire-free period of approximately 100 years may allow Bishop pine to be replaced by more shade-tolerant species such as coast live oak (in central coast ecosystems) or Douglas fir (in north coast ecosystems). On stressed sites with low overstory density, sparse understory vegetation and exposed mineral soil, a low rate of seed release occurring without fire may be sufficient to maintain a steady-state Bishop pine forest habitat type. On the Mendocino coast, Westman and Whittaker (1975) concluded that stable Bishop pine stands occupied positions on nutrient gradients intermediate between slope redwood forest and pygmy conifer forest. However, fires extended the occurrence of Bishop pine forest onto sites where less stress-tolerant species are steady-state.

Habitat Type Description: Monterey Pine Forest

Distribution. Natural stands are restricted to three localities in the California coastal region (Santa Cruz, Monterey, and San Luis Obispo Counties) and to one locality on Guadalupe Island off Baja California. Stands are within 8 km (5 mi) of the coast, below 300 m (1,000 ft) elevation, and on all exposures. Typical substrates are coarse-textured, strongly acid, sandy loams. Summer fog maintains average minimum July relative humidity between 60 and 70 percent (Fowells, 1965).

At the three California localities, Monterey pine forest intergrades with slope redwood forest, knobcone pine forest, cypress forest, Bishop pine forest, and mixed chaparral habitat types (Cheatham and Hailer, 1975).

Watershed Units. San Lorenzo River (near Año Nuevo Point), Carmel River (Monterey Peninsula anti vicinity), Morro Bay (Cambria and vicinity).

Vegetation. This habitat type forms a moderately dense forest to 30 m (100 ft) tall dominated by Monterey pine, but may include significant proportions of coast live oak in older stands. Abundant understory vegetation of shrubs and herbaceous plants (up to 70 percent cover) is found, except in older stands where mixed pine-oak overstory reduces understory light intensity (Vogl et al., 1977).

Table 8-51. Characteristic Plants of a Monterey Pine Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Monterey pine	<u>Pinus radiata</u>
Coast live oak	<u>Quercus agrifolia</u>
<u>Shrubs</u>	
Coffeeberry	<u>Rhamnus californica</u>
Poison oak	<u>Rhus diversiloba</u>
Blackberry	<u>Rubus vitifolius</u>
Sticky monkeyflower	<u>Mimulus aurantiacus</u>
Wooly-leafed manzanita	<u>Arctostaphylos tomentosa</u>
Huckleberry	<u>Vaccinium ovatum</u>
Wax myrtle	<u>Myrica californica</u>

Succession. Monterey pine is short-lived (80-90 years) and has a moderate closed-cone habit. Although cones are held on trees for many years, they open periodically to drop seeds at a low but constant rate even without fire. Small numbers of low vigor pine seedlings are found in most stands of this habitat type (Figure 8-37e). Optimum Monterey pine regeneration occurs on seed beds prepared by light surface fires beneath an overstory canopy of mature pines (Vogl et al., 1977). Monterey pine is more tolerant of shade than any other western pine species (Fowells, 1965). Without fire to retard shade-tolerant seedlings of coast live oak, Monterey pine forest habitat type may eventually be replaced by the coast live oak forest habitat type. Periodic fire does not kill coast live oak seedlings, but may retard their growth sufficiently to allow deer to keep them suppressed in the understory (Stone and McBride, 1969). Monterey pine may invade and replace coastal dune scrub habitat type (Stone and McBride, 1969).

Habitat Type Description: Shore Pine Forest

Distribution. The shore pine forest habitat type is abundant on stabilized dunes and headlands along the immediate coast in Mendocino, Humboldt, and Del Norte Counties. These sites are characterized by constant onshore winds, salt spray, and fog throughout summer months. The habitat type also occasionally occurs at margins of brackish and freshwater marshes (Vogl et al., 1977). It intergrades with northern coastal scrub habitat type on rocky, exposed sites, and with Sitka spruce-grand fir forest and slope redwood forest habitat types on more protected sites with deeper soil (Cheatham and Hailer, 1975).

Watershed Units. Smith River, Mad River, and Noyo River.

Vegetation. The habitat type forms moderately dense forest to 20 m (65 ft) tall with shore pine comprising at least 50 percent of tree cover. Stands are often wind-pruned and hedge-like in exposed sites or stunted by poorly-drained, acid soils (Vogl, et al., 1977). Where overstory is partially open, an abundant understory of ericaceous shrubs and perennial herbs can occur (Table 8-52).

Table 8-52. Characteristic Plants of a Shore Pine Forest

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Shore pine	<u>Pinus contorta</u> ssp. <u>contorta</u>
Bishop pine	<u>P. muricata</u>
Sitka spruce	<u>Picea sitchensis</u> (sites with less acid soil)
<u>Shrubs</u>	
Bearberry	<u>Arctostaphylos uva-ursi</u>
Salal	<u>Gaultheria shallon</u>
Wax myrtle	<u>Myrica californica</u>

Succession. Shore pine has a variable closed-cone habit. In most populations, cones open readily at maturity. Other populations are reported to have typical closed cones (Vogl et al., 1977). The role of fire in maintaining or initiating shore pine forest stands is unknown. However, it appears that in protected sites and where podzolization has not overly restricted substrate drainage, Sitka spruce-grand fir forest may eventually replace the shore pine forest habitat type (Figure 8-37f).

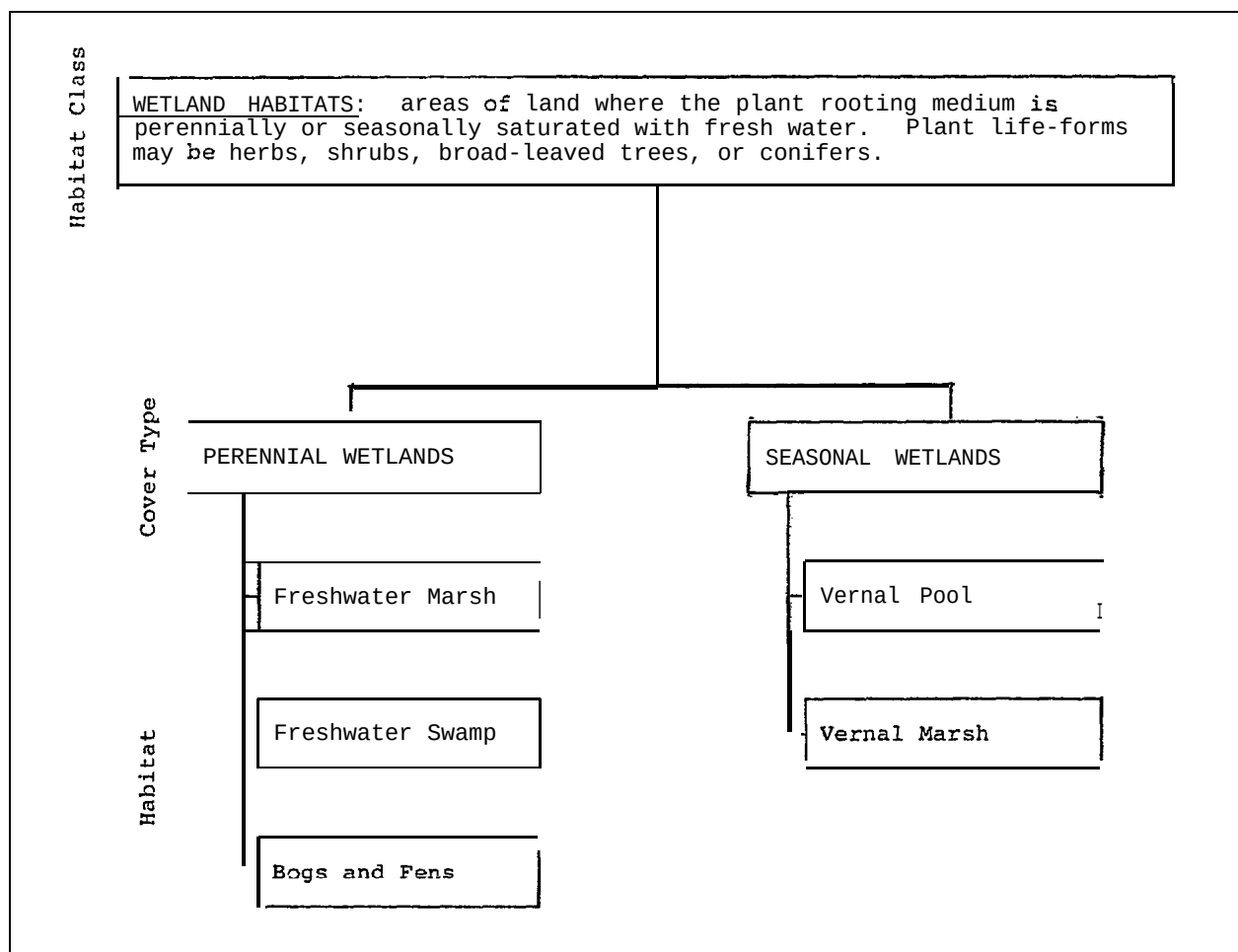


Figure 8-39. Hierarchical Dendrogram of Components and Habitat Types of Wetland Habitats.

WETLAND HABITATS

This habitat class, described in Figure 8-39, is comprised of two cover types; Perennial Wetlands and Seasonal Wetlands, which are described in the following sections.

Perennial Wetlands

Physiognomy. Ecosystems of the perennial wetlands cover type are characterized by substrates that are saturated with moisture throughout the year. Perennial wetlands can be subdivided on the basis of substrate material. Mineral substrates constitute the rooting medium for plants in the freshwater marsh and freshwater swamp habitat types. Wet peat (i.e., partially decomposed organic matter) serves as the rooting medium in the bog and fen habitat type (Daubenmire, 1968b). Freshwater marshes are dominated by herbaceous vegetation, while freshwater swamps are dominated by woody shrubs and trees (Table 8-53). Bog and fen ecosystems are typically dominated by herbaceous perennials, although woody vegetation may be present. Freshwater marshes and swamps intergrade with brackish marshes along coastal estuaries (see discussion of estuarine/emergent wetland habitat type).

Table 8-53. Habitat Types of a Perennial Wetland

Habitat Type	Dominant Plants	Regional Distribution
Freshwater marsh	Sedges (<i>Carex</i> spp.) Rushes (<i>Juncus</i> spp.) Common c (<i>Typha latifolia</i>) Common tule (<i>Scirpus acutus</i>)	North and South Coast Ranges
Freshwater swamp	Spike rush (<i>Heleocharis palustris</i>) Red alder (<i>Alnus rubra</i>) Wax myrtle (<i>Myrica californica</i>) Dune willow (<i>Salix piperi</i>)	North coastal areas
Bogs and fens	Buckbean (<i>Menyanthes trifoliata</i>) Western labrador-tea (<i>Ledum glandulosum</i> ssp. <i>columbianum</i>) Mosses (<i>Sphagnum</i> spp.) Sedge (<i>Carex obnupta</i>) Bog bilberry (<i>Vaccinium uliginosum</i>)	North Coast Ranges only

Climate. Freshwater swamp habitat type and bog and fen habitat type are restricted to areas of the coastal conifer forest and lower montane conifer forest cover types (see characterizations of these cover types for climatic parameters). The freshwater marsh habitat type occurs under a variety of climatic conditions, ranging from those characteristic of the grassland cover type to those of the coastal conifer forest cover type.

Topography. Freshwater marshes and swamps occur along rivers, lakes, streams, or in other areas of saturated mineral substrates. Elevations may range up to several thousand feet. Bogs and fens are frequently located in depressions or on seepage slopes where cold, acidic waters accumulate and restrict organic matter decomposition. Inglenook Fen, in the Novo River watershed unit, is situated where coastal sand dunes have impeded drainage of acid waters (Schlinger et al., 1977). Bogs occur inland beyond the influence of salt spray (Daubenmire, 1968b). Elevations of bog ecosystems range from several hundred feet on the coastal terraces of Mendocino County (Rigg, 1933), to 1,800 m (6,000 ft) in inland mountains (Cheatham and Hailer, 1975; .

Substrate. All ecosystems of this cover type are characterized by substrates saturated with moisture throughout the year. Marshes and swamps are formed on mineral soils of usually alluvial origin that have been deposited at the margins of rivers, lakes, and slow-moving streams. These mineral soils are fertile and may contain large amounts of organic matter. In bogs and fens, decomposition of organic matter is severely restricted by cool temperatures, and by high acidity and low oxygen content of ground-water. Failure of decomposition causes peat accumulation and creation of an organic, acidic, and nutritionally-poor rooting medium for bog and fen vegetation (Daubenmire, 1968b). Fen substrates have less accumulated peat and are somewhat less acidic and more fertile than bogs (Baker, 1972).

Vegetation. Vegetation of this cover type is typically comprised of herbaceous perennials and low shrubs (Table 8-55). Vegetation cover is commonly dense. Stunted trees may occur in bogs and fens and in freshwater swamps.

Vegetation Seasonality and Modes of Reproduction. Growth activity occurs throughout the spring, summer, and fall seasons except where restricted by low temperatures (e.g., at high elevations). Many herbaceous perennials are grass-like monocots and reproduce by vegetative expansion of clumps. Sphagnum moss vegetatively expands to form large hummocks and successive layers of living moss atop dead moss (Rigg, 1933). Shrub and tree seedlings in swamps typically establish on rotting logs rather than in water-logged soils (Cheatham and Hailer, 1975).

Characteristic Fauna. Characteristic mammals of the perennial wetland cover type are taken from Ingles (1965). Small (1974) provides information on common California birds of wetlands. Common or characteristic reptiles and amphibians are derived from Stebbins (1966) and Schlinger et al. (1977). Species listed below, although characteristic of perennial wetlands, are not found exclusively in this cover type. Abbreviations (e.g., TI, SFE, AA) following species common names, refer to types of consumers in the general food web for this cover type (see food web, Figures 8-40 and 8-41, for explanation of abbreviations). See the Community Composition List, Volume III, Part 2, (palustrine) for more information on species listed below, and for information on characteristic invertebrate species.

Table 8-54. Characteristic Fauna of a Perennial Wetland ¹

Mammals	Birds
Marsh Shrew (TI)	Red-winged blackbird (SFE) (TIE)
Raccoon (SE) (SC) (TI)	Long-billed marsh wren (TIE)
Mink (SC)	Song sparrow (SFE) (TIE)
Striped skunk (SC) (TI)	American coot (HB)
Muskrat (SH)	Sora (AIE) (SFE) (AIE) (FE) (CB)
River otter (SC) (TI)	Western grebe (FE) (AIE)
Coyote (LC) (TI)	Eared grebe (AIE) (CB)
	Black tern (FE)
<u>Reptiles and Amphibians</u>	Ruddy duck (HB) (AIE)
Long-toed salamander	Black-crowned night heron (FE) (CB) (SS)
California newt (AA) (TA)	Common yellowthroat (TIE)
Pacific treefrog (AA) (TA)	Great blue heron (CB) (FE) (AIE)
Red-legged frog (AA) (TA)	Virginia rail (AIE) (FE) (SF'S)
Foothill yellow-legged frog (AA) (TA)	Yellow-headed blackbird (SFE) (TIE)
Bullfrog (AA) (TA)	Marsh hawk (CB) (SB)
Western pond turtle (AR)	Common crow (SFE) (TIE) (CB) (SS)
Common garter snake (TR)	
Western aquatic garter snake (AR) (TR)	<u>Fish</u>
	Carp (HF) (CF)
	Largemouth bass (CF)
	Golden shiner (CF)
	Bluegill (CF)
	Brown bullhead (CF)
	Mosquitofish (CF)

¹See Figures 8-40 to 9-43 for definition of abbreviations.

Biomass Productivity and Food Web. Freshwater marshes on fertile substrates are capable of very high values of annual biomass productivity (Wetzel, 1975). Productivity in swamps, fens, and bogs is limited by high levels of substrate acidity and low levels of nutrient availability. Nutrient availability is a function of nutrient concentration and the rate of flow of the substrate solution (Gosselink and Turner, 1978).

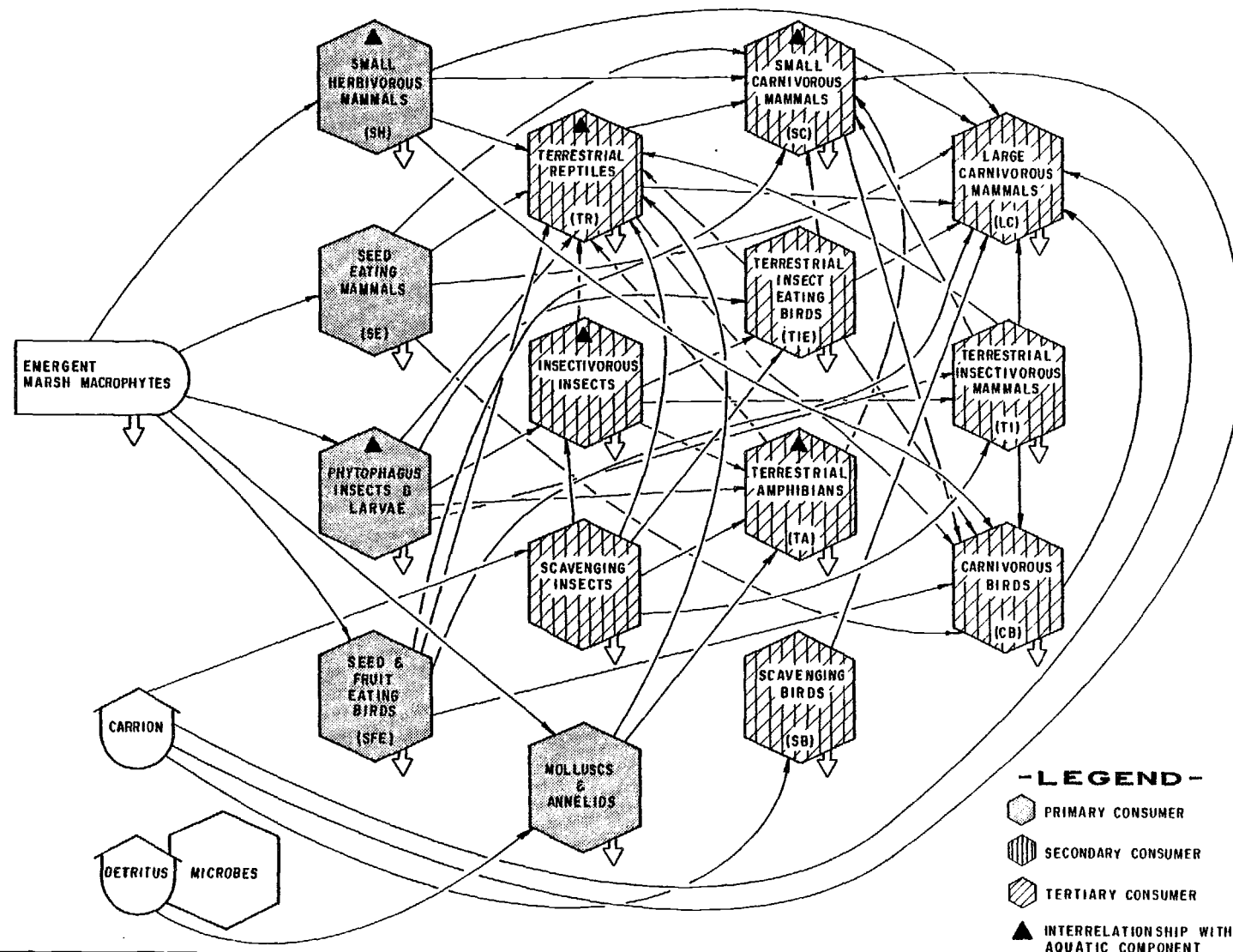


Figure 8-40. General Food Web - Wetlands (Terrestrial Component)

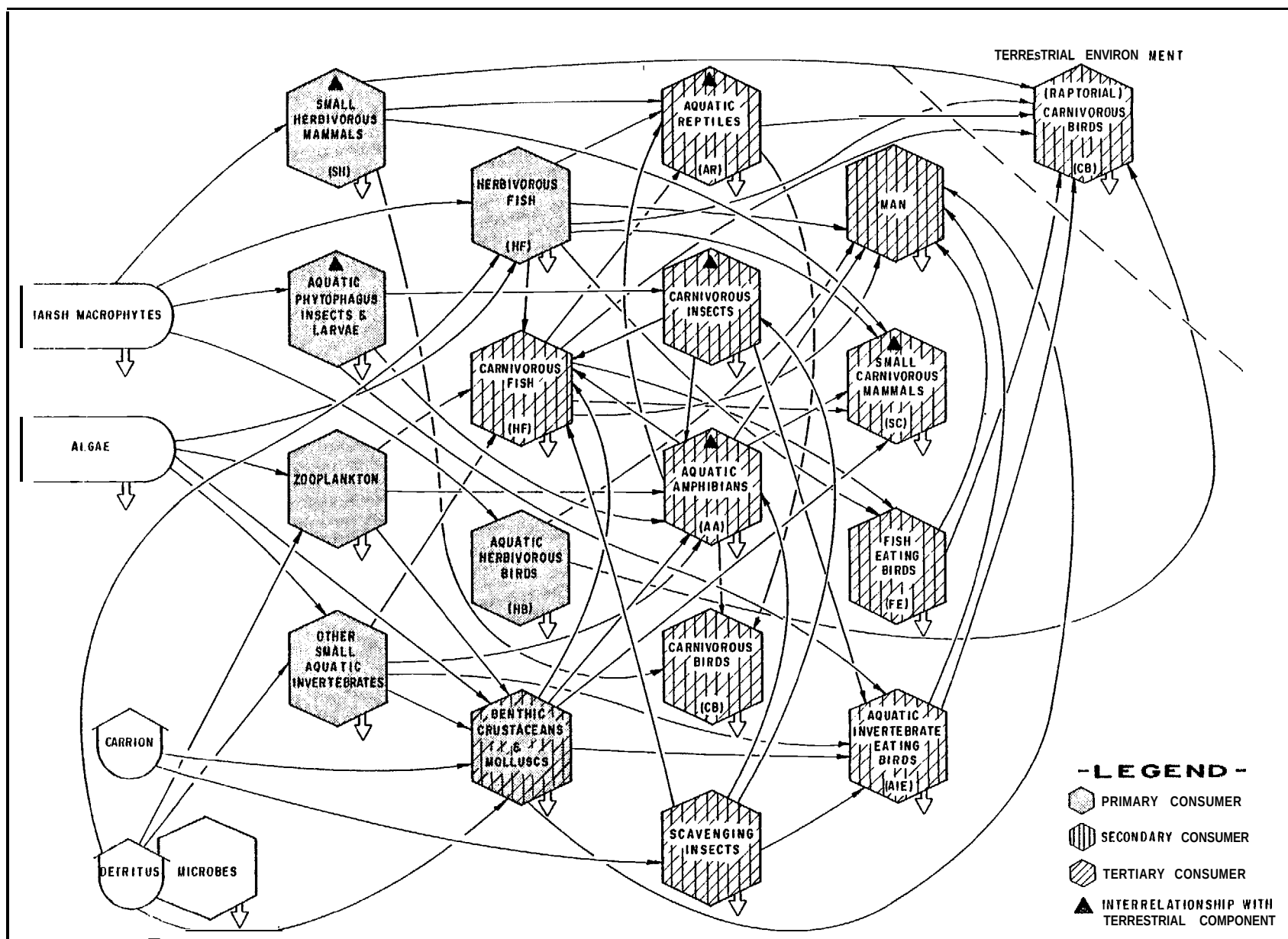


Figure 8-41. General Food Web - Wetlands (Aquatic Component)

To simplify the following discussion, the food web for the wetland cover type has been divided into a terrestrial (Figure 8-40) and aquatic component (Figure 8-41), keeping in mind, however, that these components are not discrete units of a wetland, but are complexly interrelated. Direct interrelationships between terrestrial and aquatic components are denoted in the food webs by an asterisk in the appropriate consumer hexagon. Direct interrelationships include species or species groups that require both the aquatic and terrestrial environment to complete a life cycle, and species that are adapted to utilizing both aquatic and terrestrial environments for foraging. For example, the common garter snake moves freely between the terrestrial and aquatic components of a wetland to forage, while amphibians require both aquatic and terrestrial environments to complete their life cycles. Interrelationships of this nature will be pointed out in the discussion that follows.

In the terrestrial component of a perennial wetland, primary consumers of vegetation include the muskrat and numerous species of terrestrial phytophagous insects (see Figures 8-40 and 8-42). Seed production is consumed by mammals, such as the raccoon; and birds, such as the red-winged blackbird and song sparrow. Important secondary consumers include insectivores, such as the marsh shrew, bullfrog, and long-billed marsh wren; and carnivores, such as the mink, common garter snake, coyote, and marsh hawk. These as well as other secondary consumers also function as tertiary consumers, feeding on secondary as well as primary consumers. For example, the coyote may feed on the marsh shrew (a secondary consumer) as well as the muskrat (a primary consumer). The raccoon is also a good example of an omnivore, feeding on small mammals and terrestrial insects as well as seeds. The common crow is a characteristic scavenging bird.

In the aquatic component of a perennial wetland, the primary consumers of algae, aquatic vegetation and seeds include birds, such as the American coot and ruddy duck; small invertebrates; zooplankton; molluscs; crustaceans; herbivorous fish, such as the carp; phytophagous insects and/or larvae, many of which have an aquatic larval stage and terrestrial adult stage; and mammals, such as the muskrat, which functions as a consumer in both the aquatic and terrestrial components of the wetland (see Figures 8-41 and 8-43). Important secondary and tertiary consumers include fish-eating birds, such as the western grebe; aquatic invertebrate and crustacean-eating animals, such as the sora, eared grebe and the bullfrog, which also functions as a consumer in the terrestrial component; and carnivores, such as the great blue heron, carnivorous fish, such as the largemouth bass, carnivorous insects, many of which have an aquatic larval stage and terrestrial adult stage; and the common garter snake and mink, which both function as consumers in the terrestrial component as well. The raccoon is a good example of an omnivore functioning in both the terrestrial and aquatic components when it consumes seeds, small mammals, terrestrial and aquatic insects and aquatic crustaceans and molluscs. Man functions in the aquatic component of a perennial wetland as a carnivore, consuming game fish, amphibians, and birds.

Important consumers from nearby terrestrial environments that obtain food from the aquatic component of a wetland include carnivorous birds, such as the bald eagle and osprey. Important predators of waterbirds nesting in both terrestrial and aquatic components of a perennial wetland, include the coyote, striped skunk, mink, and raccoon.

Important Biotic Interactions. The major biotic interaction in perennial wetlands occurs between primary production and wetland ecosystem hydrology, decomposition processes, and nutrient cycling. Organic accumulation alters the hydrologic regime by raising wetland elevation and by blocking and diverting water flows. Through a series of feedback loops between plant production and the hydrological regime, marshes may successionaly develop into fens and finally into steady-state bog ecosystems where plant species composition and biomass accumulation rates are stable over time (Gosselink and Turner, 1978).

Important Abiotic Interactions. Important attributes of hydrologic regimes are nutrient composition, oxygen content, and flow rate of the substrate solution. Marshes exhibit relatively high levels of nutrients, oxygen, and flow rate. Bogs exhibit the lowest levels of these characters because peat accumulation has raised the plant rooting level above the water table. Therefore, all moisture and nutrient inputs to bogs come from precipitation alone (Daubenmire, 1968b).

Associated Cover Types. The perennial wetland cover type frequently intergrades with the meadow and seep cover type in less water-logged soils, with coastal conifer forest and lower montane conifer forest cover type on drier, better-drained soils, and with riverine and estuarine systems.

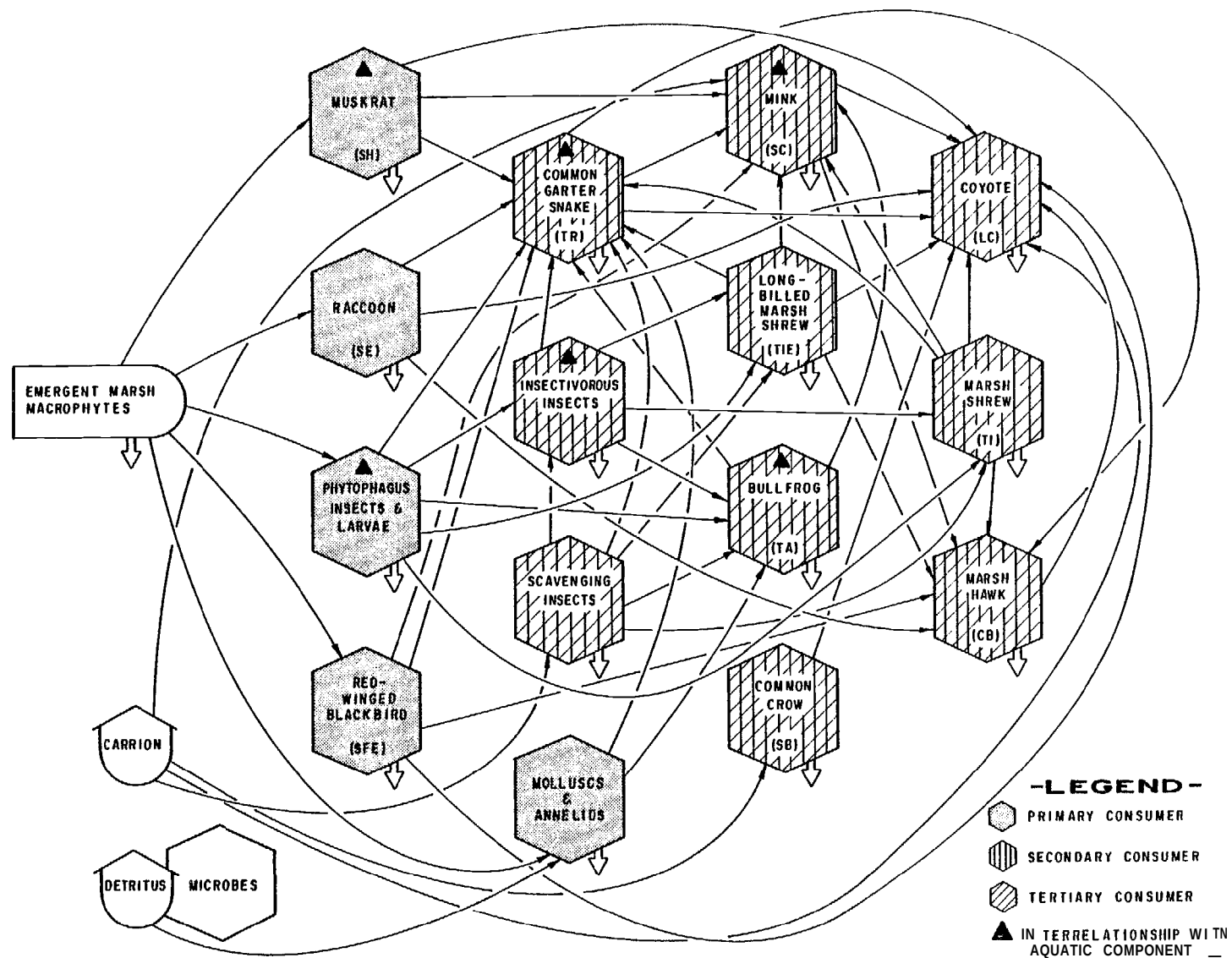


Figure 8-42. An Example of a Perennial Wetland (Terrestrial Component) Food Web

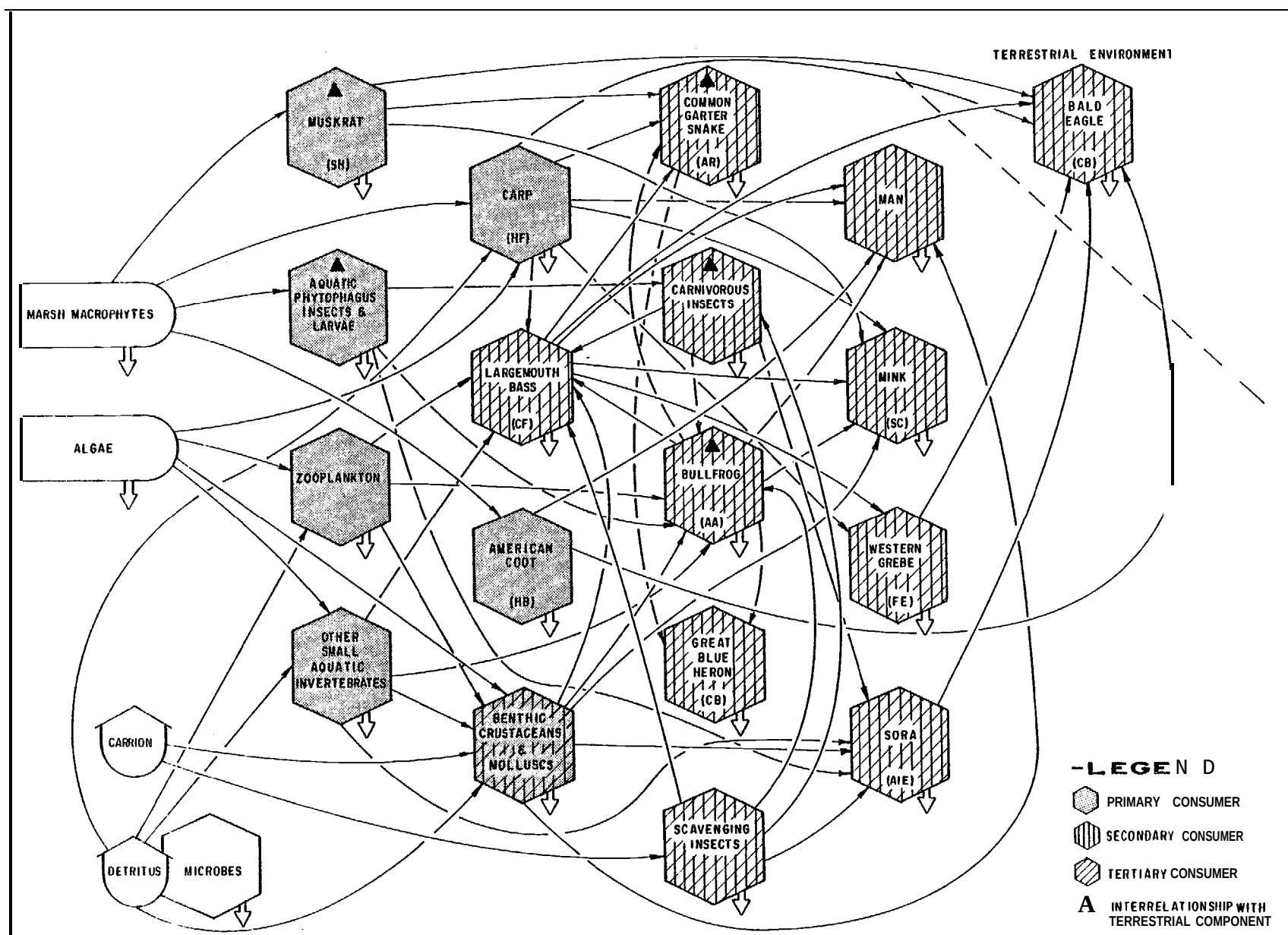


Figure 8-43. An Example of a Perennial Wetland (Aquatic Component) Food Web

Vegetation Succession. The classic successional pattern for perennial wetlands progresses from open water ecosystems (e.g., lakes or ponds) to marshes and fens (Figure 8-44). Depending on rates of sedimentation, decomposition, and peat accumulation, marshes and fens can develop either into terrestrial ecosystems or into steady-state bog ecosystems (Wetzel, 1975; Gosselink and Turner, 1978).

Typical Land Uses. Most ecosystems of this cover type have been traditionally viewed as wastelands and dumping grounds or as areas to be drained and filled to create cropland.

Sensitivity to Disturbance. Hydrologic regimes of perennial wetlands control or influence all other ecosystem processes. Any disturbance to hydrologic regimes may lead to permanent alterations of the structure and function of these ecosystems.

Ecosystem Model. Important processes and components of ecosystems in this cover type are highlighted in Figure 8-45.

Habitat Type Description: Freshwater Marsh

Distribution. The freshwater marsh habitat type is scattered along the coast near river mouths, around lakes and ponds, along slow-moving streams, and at large springs and seeps (Cheatham and Hailer, 1975). This habitat type intergrades with brackish marshes at river estuaries, with the meadow and seep cover type, with the vernal marsh habitat type, and with the freshwater swamp habitat type.

Watershed Units. Distribution of this habitat type on individual watershed units has not been mapped.

Vegetation. Vegetation is dominated by perennial herbs in dense stands to 2.5 m (8 ft) tall (Table 8-55). Many characteristic species are called "emergent anchored hydrophytes," indicating that they are rooted under water up to 1 m (3 ft) deep, but project their shoots and leaves into the air above the water level. Most typical species are grasslike monocots and spread by rhizomes (i.e., underground stems) or by vegetative expansion of clumps and tussocks. Rubtsoff (1953) described plant species composition of the Pitkin Marsh in the Russian River watershed unit.

Table 8-55. Characteristic Plants of a Perennial Wetland

Plant Type/Common Name	Scientific Name
<u>Grasslike Perennials</u>	
Sedge	<u>Carex tracyi</u>
Rush	<u>Juncus dubius</u>
Spike-rush	<u>Heleocharis palustris</u>
Common cattail	<u>Typha latifolia</u>
Common tule	<u>Scirpus acutus</u>
<u>Other Perennials</u>	
Oenanthe	<u>Oenanthe sarmentosa</u>
Cinquefoil	<u>Potentilla palustris</u>
Monkeyflower	<u>Mimulus guttatus</u>
Horsetail	<u>Equisetum arvense</u>

Succession. Mason (1957) describes floristic changes in marsh vegetation over time. Cattail is a common colonizing species on newly flooded or disturbed sites due to its wind-dispersed seeds. Stems and rhizomes of typical species catch sediments and organic debris, causing both horizontal and vertical succession of freshwater marshes to terrestrial cover types. However, if acid waters and cold temperatures cause failure of organic matter decomposition, freshwater marsh may develop into the fen and bog habitat type (Figure 8-44a).

Habitat Type Description: Freshwater Swamp

Distribution. The freshwater swamp habitat type occurs in scattered locations along rivers and in low places around lakes and springs from Mendocino County north. This habitat type intergrades with many other habitat types such as freshwater marsh, bogs and fens, red alder forest, and western hemlock forest. Freshwater swamp ecosystems are unified by the occurrence of woody shrubs and trees in low places with water-logged soils.

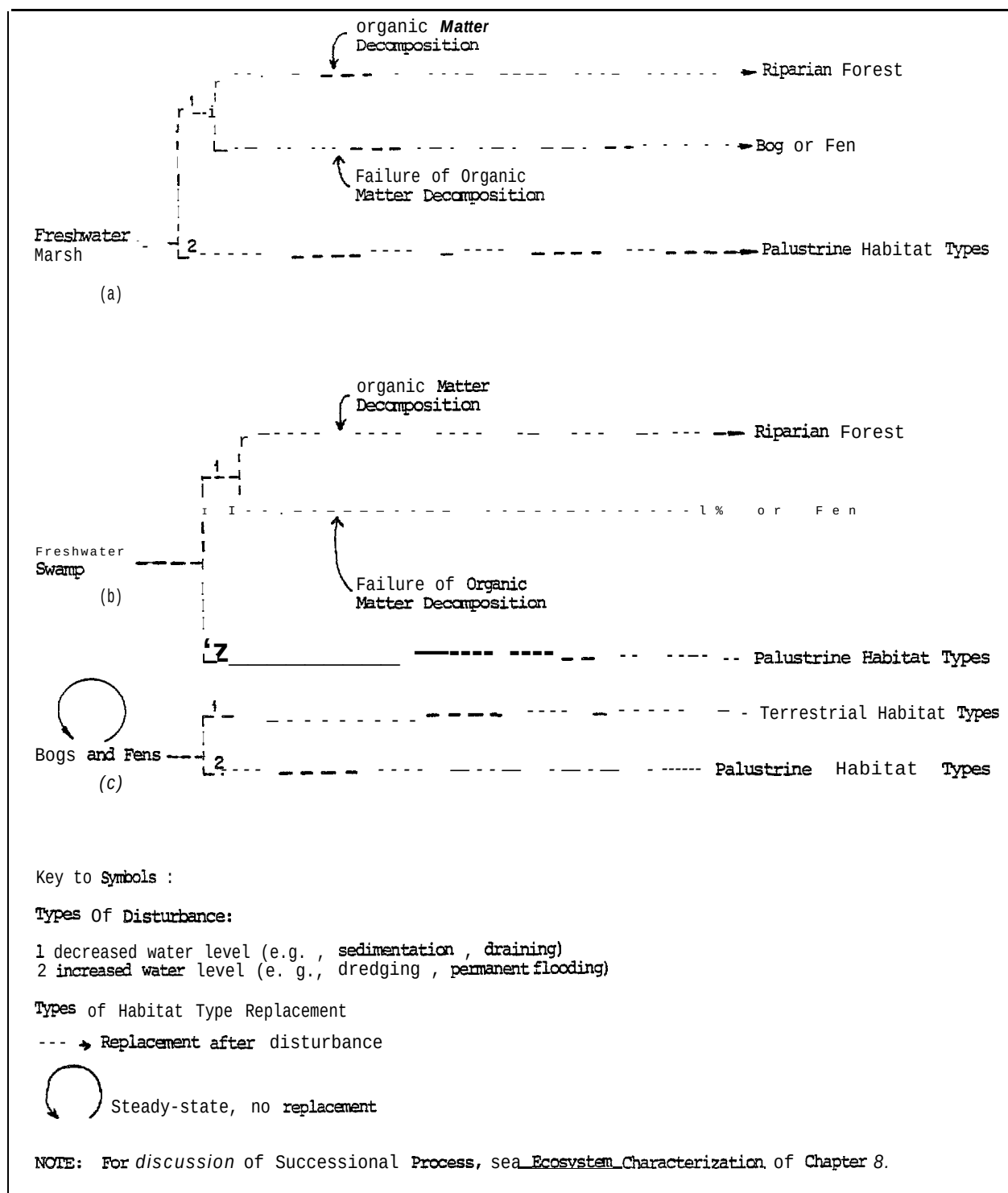


Figure 8-44. Successional Sequences (a-c) Suggested for Perennial Wetland Habitat Types

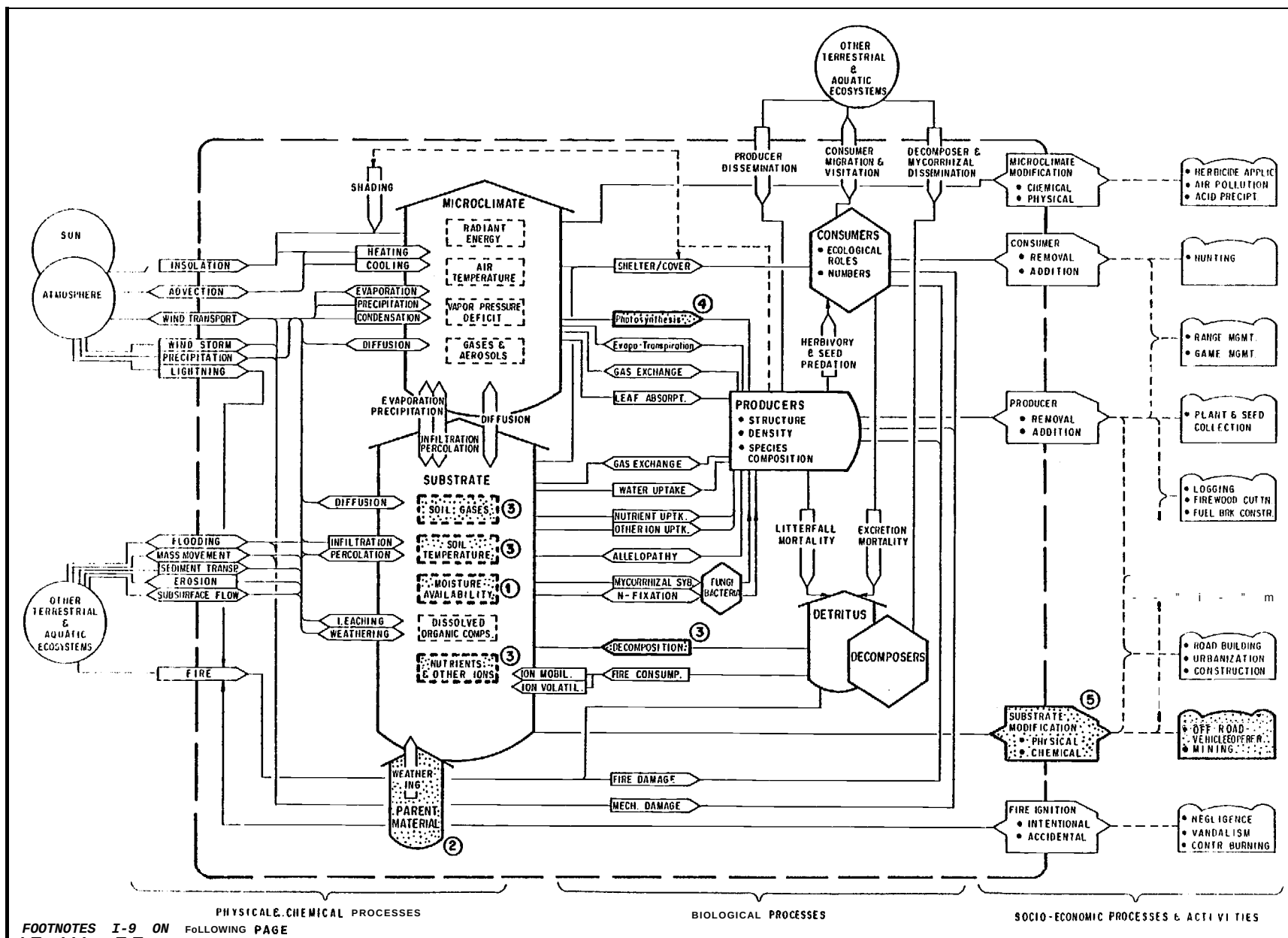


Figure 8-45. Ecosystem Model - Perennial Wetlands Cover Type

Footnotes for Figure 8-45.
Ecosystem Model for Perennial Wetland Cover Type-
Highlighted Processes and Components are Annotated Below

1. SOIL MOISTURE AVAILABILITY: Perennial wetland ecosystems are characterized by substrates saturated with moisture throughout the year.
2. PARENT MATERIAL: Freshwater marshes and freshwater swamps occur on mineral substrates deposited as sediments in lakes, ponds, and along streams. Substrates in bogs and fens are comprised of partially decomposed organic matter (i.e., peat). Accumulation of peat over long periods of time raises the plant rooting level above contact with mineral substrate.
3. DECOMPOSITION, SOIL TEMPERATURE, NUTRIENTS AND OTHER IONS, SOIL GASES: Peat accumulation in perennial wetland ecosystems is promoted by substrate conditions of cold temperatures, high acidity, and low oxygen content. High acidity may result from vegetation and parent material characteristics in the drainage basin above the wetland ecosystem. Low oxygen content may result from a low flow rate of drainage waters through the ecosystem. Low acidity and adequate oxygen allow decomposition of plant litter in marsh and swamp ecosystems (Gosselink and Turner, 1978).
4. PHOTOSYNTHESIS: Freshwater marsh productivity is typically high due to perennial substrate moisture, plentiful nutrients, low acidity, and adequate oxygen in the substrate solution.
5. SUBSTRATE MODIFICATION: Construction, filling, and road building in and around wetland ecosystems may significantly alter hydrologic regimes. Changes in hydrologic regimes may cause changes in vegetation and in ecosystem productivity.

Watershed Units. Noyo River, Mattole River, Eel River, Mad River, Smith River, and Klamath River.

Vegetation. A dense to open cover of small trees with a dense shrub understory characterizes this habitat type (Table 8-56) . Where this habitat type intergrades with the bog and fen habitat type, trees and shrubs are often stunted by infertile substrate conditions.

Table 8-56. Characteristic Plants of a Freshwater Swamp

Plant Type/Common Name	Scientific Name
<u>Trees</u>	
Red alder	<u>Alnus rubra</u>
Western redcedar	<u>Thuja plicata</u>
Western hemlock	<u>Tsuga heterophylla</u>
Black cottonwood	<u>Populus trichocarpa</u>
<u>Shrubs</u>	
Wax myrtle	<u>Myrica californica</u>
Dune willow	<u>Salix piperi</u>
Western labrador-tea	<u>Ledum glandulosum</u> ssp. <u>columbianum</u>
Bilberry	<u>Vaccinium arbuscula</u>
<u>Herbs</u>	
Sedge	<u>Carex obnupta</u>
Yellow skunk cabbage	<u>Lysichiton americanum</u>

Succession. Where present, red alder and western redcedar may dominate in a vegetation steady-state, due to their tolerance of high water tables (Franklin and Dyrness, 1973). Where peat has begun to accumulate and waters are acidic, Sphagnum moss may eventually invade and create a bog (Rigg, 1933) .

Habitat Type Description: Bogs and Fens

Distribution. Bog and fen ecosystems are scattered in the North Coast Ranges from Sonoma County north (Cheatham and Haller, 1975). Elevations range from near sea level to 1,800 m (6,000 ft). Bogs and fens are distinguished from other wetlands by having water-logged peat as the rooting medium for plants. The substrate solution is cold, acidic, and nutrient poor. This habitat type intergrades with freshwater marshes and swamps on water-logged mineral soils, with montane meadows and freshwater seeps on moist but not saturated soils, and with coastal conifer forests and lower montane conifer forests on well-drained soils.

Watershed Units. Distribution of this habitat type on individual watershed units has not been mapped. It may occur in watershed units from the Russian River north.

Vegetation. Vegetation of this habitat type is typically dominated by low perennial herbs and shrubs (Table 8-57). All species tolerate acidic, nutrient-poor conditions. Sphagnum mosses and ericaceous (i.e., members of the heath family) shrubs are common and cause increased acidity of the soil solution. Several insect-ivorous plant species (e.g., sundew, California pitcher plant) compensate for the lack of nitrate in the soil solution by dissolving insects that are trapped by sticky surfaces or imprisoning hairs of the plant. Fens are somewhat less extreme than bogs in acidity and nutrient-poverty and therefore support a greater diversity of plant species (Baker, 1972) .

Table 57. Characteristic Plants of Bogs and Fens

Plant Type/Common Name	Scientific Name
<u>Shrubs</u>	
Western labrador-tea	<u>Ledum glandulosum ssp. columbianum</u>
Bog bilberry	<u>Vaccinium uliginosum</u>
Wax myrtle	<u>Myrica californica</u>
<u>Herbs</u>	
Buckbean	<u>Menyanthes trifoliata</u>
Sedge	<u>Carex obnupta</u>
Cinquefoil	<u>Potentilla palustris</u>
S undew	<u>Drosera rotundifolia</u>
California pitcher plant	<u>Darlingtonia californica</u>
Spike rush	<u>Heleocharis acicularis</u>
<u>Mosses</u>	
Sphagnum	<u>Sphagnum</u>

Succession. Freshwater marshes and swamps **successionally** develop into fens when peat accumulation has raised the rooting zone and supplanted mineral soil as the plant rooting medium (Figure 8-44c). Fens may be replaced by terrestrial vegetation (Schlinger et al., 1977) or by bogs (Daubenmire, 1968b). Bogs represent a **steady-state endpoint** of peat accumulation, acidification, nutrient-depletion, and vegetation succession (Gosselink and Turner, 1978).

Seasonal Wetlands

Physiognomy. Seasonal wetlands are shallow depressions, normally small in area, characterized by standing water during the winter rainy season and soil moisture depletion during the summer (Holland, 1976). Vernal marshes maintain subsurface soil moisture for longer into the summer dry season than vernal pools. Vegetation is comprised of low growing annual herbs, as well as some taller perennial herbs in vernal marshes. Ecosystems of this cover type intergrade with the grassland cover type and with the freshwater marsh habitat type.

Table 8-58. Habitat Type and Vegetation in Seasonal Wetlands

Habitat Type	Dominant Plants	Regional Distribution
Vernal pools	Blennosperma (<u>Blennosperma nanum</u>) Downingia (<u>Downingia cuspidata</u>) Meadow foam (<u>Limnanthes douglasii</u>) Navarretia (<u>Navarretia prostrata</u>) Eryngium (<u>Eryngium armatum</u>)	North and South Coast Ranges
Vernal marshes	Sedges (<u>Carex</u> spp.) Tules (<u>Scirpus</u> spp.) Eryngium (<u>Eryngium aristulatum</u>) Downingia (<u>Downingia</u> spp.) Rushes (<u>Juncus</u> spp.)	North and South Coast Ranges

Climate. Most vernal pools and vernal marshes are located within areas of the grassland cover type. For typical climatic conditions, see the grassland cover type characterization. A Mediterranean-type climate with low precipitation and high evapotranspiration is characteristic.

Topography. Ecosystems of this cover type are located within shallow depressions on valley floors or foothill terraces. Many are very small in size, less than 6 m (20 ft) in diameter, while some are quite large. For example, Laguna Lake, a vernal marsh in the Lagunitas Creek watershed unit, is nearly 1.6 km (1 mi) long when filled in winter.

Substrate. Substrate conditions are chiefly responsible for the creation of vernal pool and marsh ecosystems. Soils of this cover type are very old. Over thousands of years, dense, impervious hardpans or claypans have formed to inhibit percolation of rainwater. Water is confined at or above the soil surface until gradually depleted by evapotranspiration during the summer dry season (Holland and Jain, 1977). Progressive evapotranspiration of poolwater concentrates water soluble ions in bottom soils, resulting in higher alkalinities and salinities in the pool center than on the periphery. Year-to-year fluctuations in precipitation create highly variable pool water regimes.

Vegetation. Vegetation of this cover type is comprised of low growing annual herbs in vernal pools and both annual herbs and herbaceous perennials in vernal marshes (Table 8-58). Vegetation cover is low, often less than 30 percent. The progressively declining water level creates a gradient of physical-chemical conditions along the topographic gradient from winter high water level down to the pool or marsh bottom. Individual plant species are specialized to the various combinations of soil moisture, temperature, and alkalinity that occur along this gradient as the season progresses. Many characteristic species are narrow endemics of recent evolutionary origin and are restricted to the unique conditions of vernal pool and marsh ecosystems. Of 200 species restricted to or characteristic of vernal pools, 55 percent were found to be endemic to California (Holland, 1976). In contrast to the dominance by introduced species in the valley and foothill grassland habitat type, 91 percent of these 200 species are natives.

Vegetation Seasonality and Modes of Reproduction. Annual vernal pool and vernal marsh species have short life cycles with timing of germination, flowering and fruiting related to different combinations of soil moisture and temperature as the growing season progresses. Some species germinate and grow while submerged during winter and early spring (Cheatham and Hailer, 1975). Because of hardpans beneath vernal pools, all moisture in the shallow soil profiles is depleted by midsummer. Longer duration of soil moisture availability allows some perennial species to survive in vernal marshes. In both vernal pools and vernal marshes, flowering of annual species progresses inward in concentric rings as soil drying advances (Cheatham and Hailer, 1975).

Characteristic Fauna. Characteristic mammals of the seasonal wetland cover type are taken from Ingles (1965). Small (1974) provides information on common California birds of wetlands. Common or characteristic amphibians and reptiles are derived from Stebbins (1966). Species in Table 8-59, although characteristic of seasonal wetlands, are not found exclusively in this cover type. Abbreviations (e.g., TI, SFE, TA) following species common names, refer to types of consumers in the general food web for this cover type (see food webs, Figures 8-40 and 8-41 for explanation of abbreviations). Fauna of vernal pools and marshes also include invertebrate species that are able to tolerate extremes of temperature and alkalinity, are resistant to desiccation, have efficient dispersal mechanisms, and lack protective mechanisms against large predators (Alexander, 1976). See the Community Composition List, Volume 111, Part 2, (palustrine) for more information on species listed below and for information on characteristic invertebrate species.

Table 8-59. Characteristic Fauna of a Seasonal Wetland¹

Mammals	Birds
Marsh shrew (TI)	Red-winged blackbird (SFE) (TIE)
Western harvest mouse (SE) (TI)	Long-billed marsh wren (TIE)
California meadow mouse (SH)	Song sparrow (SFE) (TIE)
Raccoon (SE) (SC) (TI)	Green heron (AIE) (CB)
Long-tailed weasel (SC)	American bittern (CB) (AIE) (TIE)
Striped skunk (SC) (TI)	Mallard (HB) (AIE)
Coyote (LC) (TI)	Cinnamon teal (HB) (AIE)
	Common snipe (AIE) (SFE)
Reptiles and Amphibians	Snowy egret (SIE) (CB) (TIE)
Rough-skinned newt (TA) (AA)	Northern shoveler (AIE) (HB)
Pacific treefrog (TA) (AA)	Marsh hawk (CB) (SB)
Common kingsnake (TR)	Short-eared owl (CB) (TIE)
Common garter snake (TR)	Long-billed curlew (AIE) (SFE) (TIE)
	Common crow (SFE) (TIE) (CB) (SB)
	Fish
	For seasonal marsh adjoining permanent marsh, see characteristic fauna - perennial wetland.

¹See Figures 4-46 and 4-47 for definition of abbreviations.

Biomass Productivity and Food Web. Biomass productivity of vernal pools and vernal marshes is very low because of the limited duration of conditions suitable for plant growth. For many plant species, life cycles are completed in less than 3-4 months.

To simplify discussion, the food web for the wetland cover type has been divided into a terrestrial (Figure 8-40) and aquatic component (Figure 8-41), keeping in mind, however, that these components are not discrete units of a wetland, but are complexly interrelated. Direct interrelationships between terrestrial and aquatic components are denoted in the food webs by an asterisk in the appropriate consumer hexagon. Direct interrelationships include species or species groups that require both the aquatic and terrestrial environment to complete a life cycle, and species that are adapted to utilizing both aquatic and terrestrial environments for foraging. For example, the common garter snake moves freely between the terrestrial and aquatic components of a wetland to forage, while many carnivorous insects complete their life cycles partially in the aquatic and partially in the terrestrial environment. Interrelationships of this nature will be pointed out in the discussion that follows.

In the terrestrial component of a seasonal wetland, primary consumers of vegetation include the meadow mouse and numerous phytophagous insect species (Figures 8-40 and 8-46). Seed production is consumed by mammals, such as the western harvest mouse; and birds, such as the song sparrow and red-winged blackbird. Important secondary and tertiary consumers include insectivores, such as the marsh shrew, rough-skinned newt, and long-billed marsh wren; and carnivores, such as the long-tailed weasel, common garter snake, coyote and marsh hawk. The raccoon is a good example of an omnivore, feeding on small mammals, seeds and insects. The common crow is a characteristic scavenging bird.

A seasonal wetland differs from a perennial wetland in having an aquatic component of variable duration. Thus, the characteristic fauna and food web of a seasonal wetland are dependent upon the duration of inundation and source of water, but also on the wetland's location and size. The community of a closed-system seasonal wetland (e.g., a vernal marsh), which is not directly connected to a permanent or perennial body of water, would not support water-dependent species, such as fish or their consumers, such as fish-eating birds or aquatic carnivorous mammals. A seasonal wetland adjoining and fed by a perennial water source, such as a perennial wetland, would support many species characteristic of the perennial wetland, with the exception that species dependent on a perennial aquatic environment would have to retreat from the seasonal wetland as it drew down. Other seasonal wetlands of small size and/or brief inundation, such as vernal pools, would most often attract species typical of surrounding cover types rather than characteristic wetland species.

The following example of a seasonal wetland (aquatic component) food web (Figure 8-47) depicts a closed-system vernal marsh, which would not support fish, fish-eating birds or small aquatic carnivorous mammals. Primary consumers of algae, aquatic vegetation and seeds include birds, such as the mallard and cinnamon teal; small invertebrates; zooplankton; molluscs, crustaceans; phytophagous insects and/or larvae, many of which have an aquatic larval stage and terrestrial adult stage; and mammals, such as the meadow mouse, which functions as a consumer in both the aquatic and terrestrial components of the wetland (see Figures 8-46 and 8-47). Important secondary and tertiary consumers include aquatic invertebrate and crustacean-eating animals, such as the snowy egret, common snipe and the rough-skinned newt, which also functions as a consumer in the terrestrial environment; and carnivores, such as the American bittern; carnivorous insects, many of which have an aquatic larval stage and terrestrial adult stage; and the common garter snake, which also functions as a consumer in the terrestrial component. The raccoon is a good example of an omnivore functioning in both the terrestrial and aquatic environments when it consumes seeds, small mammals, terrestrial and aquatic insects, and aquatic crustaceans and molluscs. Man functions as a carnivore, consuming primarily game birds.

Important consumers from nearby terrestrial environments that obtain food from the aquatic component of a wetland include carnivorous birds, such as the peregrine falcon. Important predators of water birds nesting in both terrestrial and aquatic components of a seasonal wetland, include the coyote, mink and raccoon.

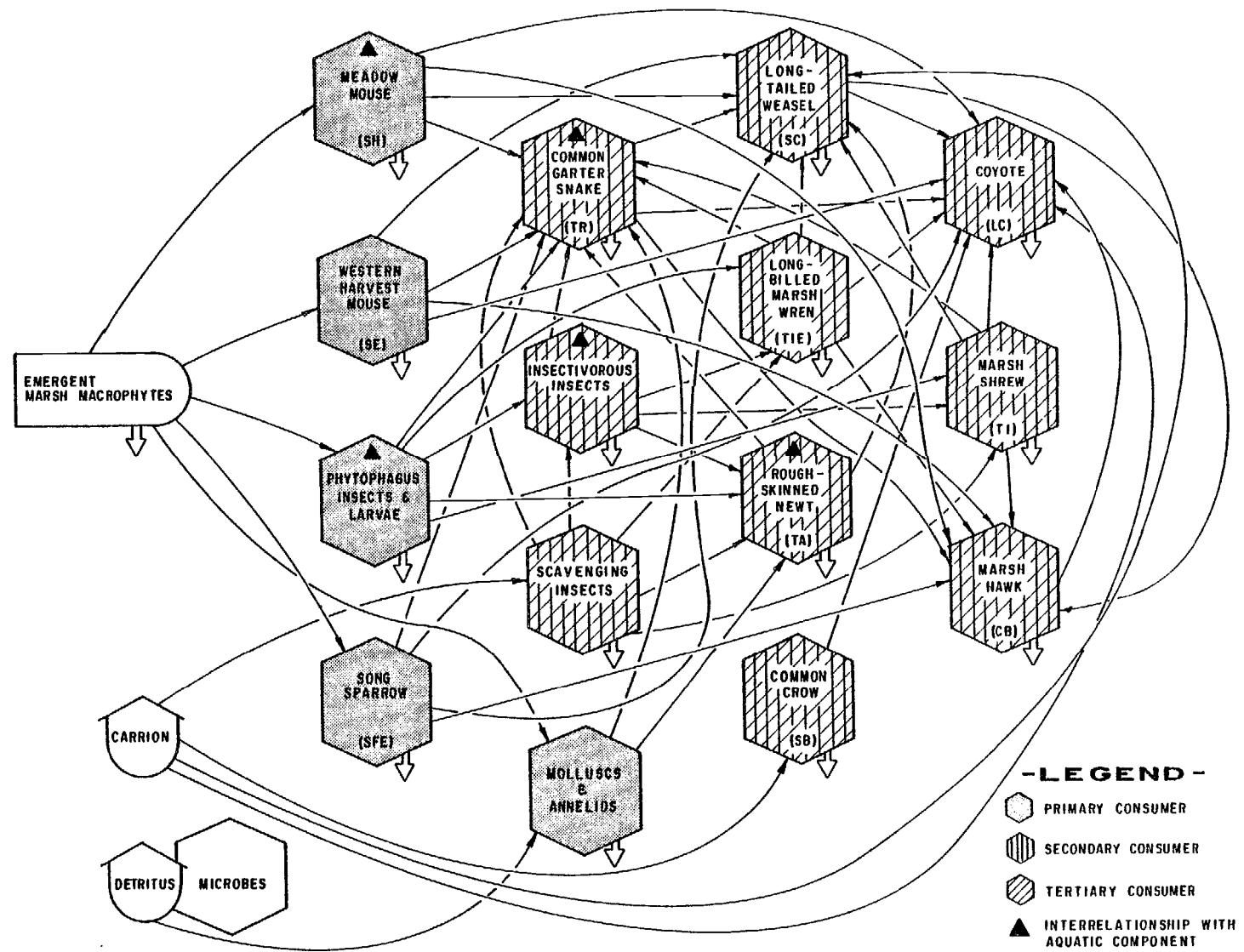


Figure 8-46. An Example of a Seasonal Wetland (Terrestrial Component) Food Web

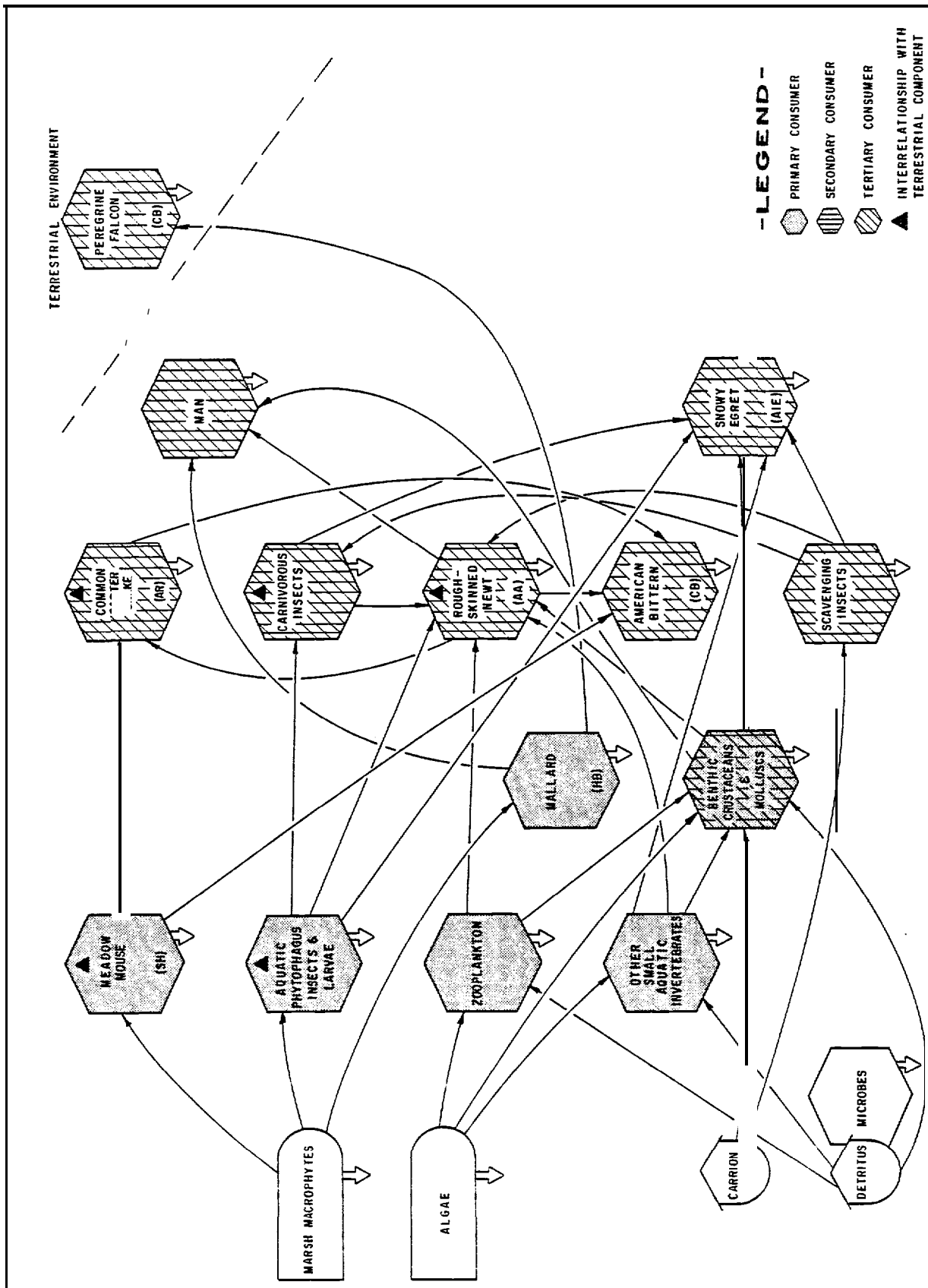


Figure 8-47. An Example of a Seasonal Wetland (Aquatic Component) Food Web

Important Biotic Interactions. Waterfowl may be important dispersal agents for the many species of plants and animals that are restricted to widely scattered vernal pools and marshes (Alexander, 1976) . Many principal pollinators of plant species restricted to vernal pools are host-specific bees with limited foraging ranges. This probably restricts gene flow between separated vernal pool ecosystems (Thorpe, 1976).

Important Abiotic Interactions. Low precipitation, poor drainage, and high evapotranspiration interact to create the distinctive soil moisture regimes and alkalinities of vernal pools and marshes (Holland and Jain, 1977) .

Associated Cover Types. Vernal pools and vernal marshes are located typically in the midst of grassland ecosystems. Vernal marshes sometimes intergrade with freshwater marshes. Ecosystems of this cover type also occasionally occur within chaparral and oak woodland cover types.

Vegetation Succession. Biomass accumulation patterns and plant species compositions are typically in equilibrium with the hydrologic regimes and chemical compositions of vernal pools and marshes (Figure 8-48).

Typical Land Uses. Vernal pools and marshes have been used for livestock grazing and agricultural crops. Urbanization is currently eliminating vernal pools and marshes in coastal valleys.

Sensitivity to Disturbance. Vernal pools and marshes are typically small in size, are scattered in distribution, and have only temporary and irregular conditions suitable for plant growth. These characteristics result in high rates of species extinction for any one ecosystem of this cover type (Holland, 1976) . Recolonization must come from other vernal pools in the vicinity. Groups of several to many vernal pools must be preserved in a general area to maintain floral and faunal species compositions over the long-term.

Thousands of years of soil profile development under a Mediterranean-type climate are necessary for creation of a vernal pool ecosystem. Breaking of hardpans or claypans beneath vernal pools by plowing or construction activities will permanently destroy examples of this cover type.

Ecosystem Model. Important processes and components of vernal marsh and vernal pool ecosystems are highlighted in Figure 8-49.

Habitat Type Description: Vernal Pools

Distribution. Vernal pool ecosystems are scattered through the valleys and lower foothills of the coast ranges from Mendocino County south (Cheatham and Hailer, 1975). They are typically located in shallow depressions with restricted internal drainage in the midst of grassland ecosystems.

Watershed Units. Distribution of vernal pools on individual watershed units has not been mapped.

Vegetation. Low-growing annual herbs dominate the vegetation of vernal pools. Plant cover is typically sparse. Many characteristic species are narrow endemics restricted to vernal pool ecosystems.

Table 8-60. Characteristic Plants of a Vernal Pool

Common Name	Scientific Name
Blennosperma	<u>Blennosperma nanum</u>
Downingia	<u>Downingia cuspidata</u>
Meadow-foam	<u>Limnanthes douglasii</u>
Navarretia	<u>Navarretia prostrata</u>
Eryngium	<u>Eryngium armatum</u>
Pogogyne	<u>Pogogyne douglasii</u>
Plagiobothrys	<u>Plagiobothrys undulatus</u>
Buttercup	<u>Ranunculus lobbii</u>

Succession. Vernal pools are typically in a steady state equilibrium between species composition and ecosystem hydrologic regimes (Figure 8-48).

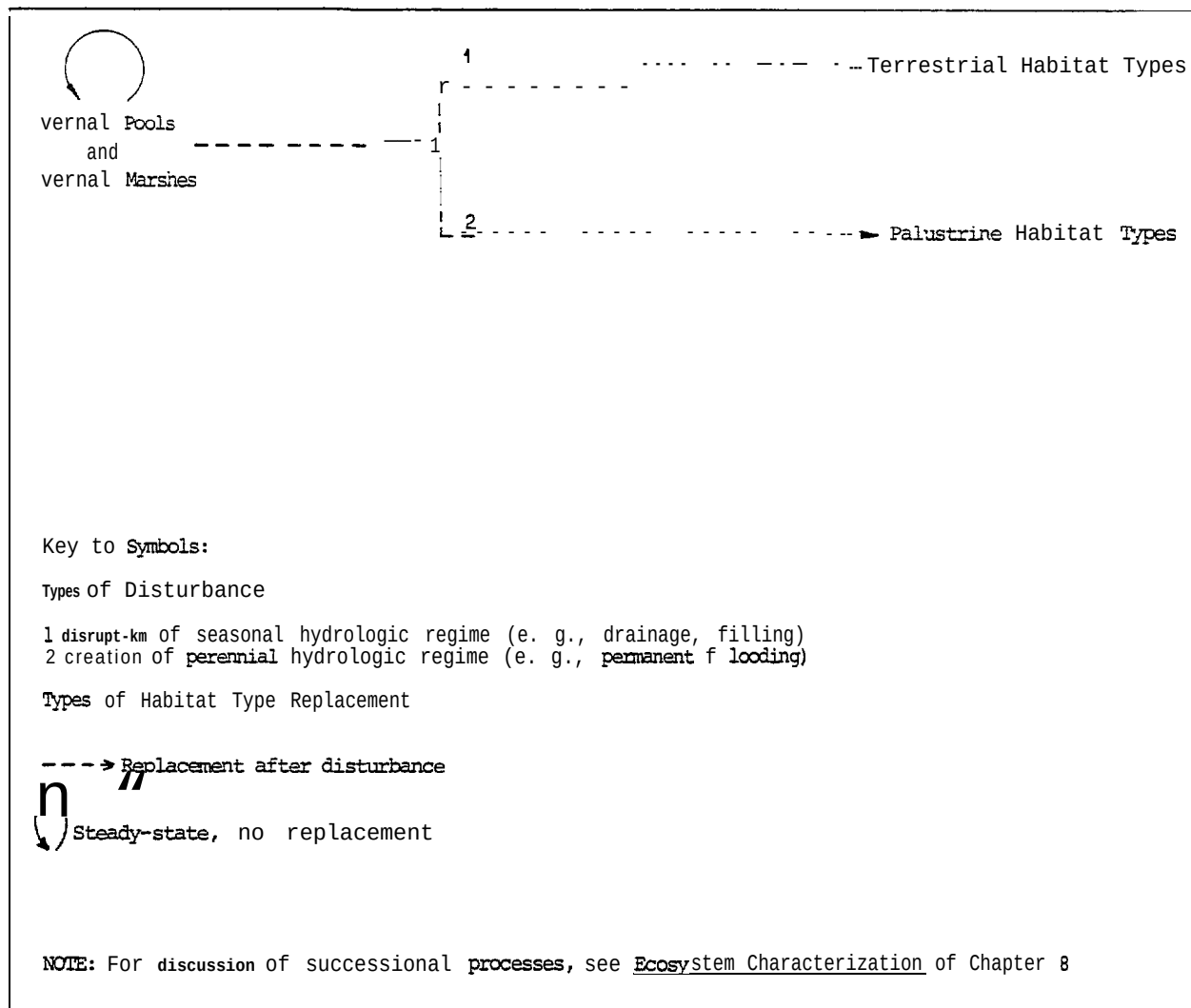


Figure 8-48. Successional Sequences Suggested for Seasonal Wetlands

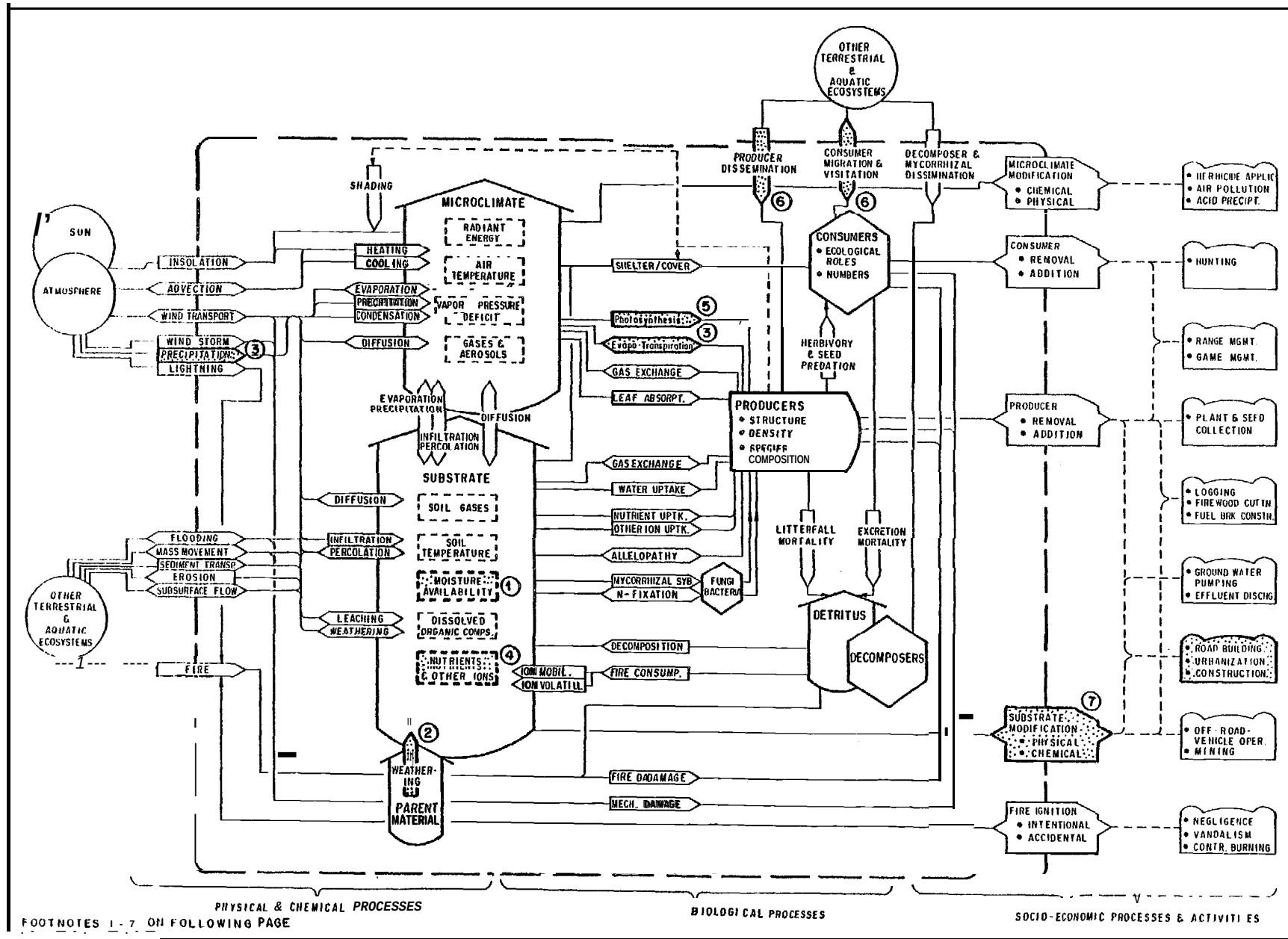


Figure 8-49. Ecosystem Model - Seasonal Wetlands Cover Type

Footnotes for Figure 8-49
Ecosystem Model for Seasonal Wetlands Cover Type-
Highlighted Processes and Components are Annotated Below

1. SOIL MOISTURE AVAILABILITY: Standing water during the winter rainy season and soil moisture depletion during the summer dry season characterize the hydrologic regime of this cover type. The life histories of flora and fauna endemic to this cover type have evolved in conjunction with the distinctive seasonal hydrologic regime.
2. WEATHERING: Soils in seasonal wetland basins have weathered over thousands of years to create claypans impervious to water percolation and plant root penetration. Claypans maintain standing water in the basins during the rainy season.
3. PRECIPITATION AND EVAPOTRANSPIRATION: Vernal pools and marshes are restricted to areas of low precipitation and high evapotranspiration. By early summer, soil profiles in seasonal wetlands are depleted of moisture by evaporation and transpiration.
4. NUTRIENTS AND OTHER IONS. As water in seasonal wetlands is lost by evapotranspiration, nutrients and other ions in solution are progressively concentrated toward the pool bottom. Different plant species have evolved to grow at different positions on vernal pool salinity and alkalinity gradients.
5. PHOTOSYNTHESIS : Timing of plant life cycles in seasonal wetlands is keyed to particular combinations of soil moisture and temperature. Seasonal wetlands are low in productivity due to short plant life cycles and stressed growth conditions.
6. PRODUCER DISSEMINATION AND CONSUMER MIGRATION AND VISITATION: Small areas and extreme environmental fluctuations produce high extinction rates in any one seasonal wetland ecosystem. Waterfowl may provide the most efficient means of seed dissemination and recolonization between widely separated vernal pools and marshes.
7. SUBSTRATE MODIFICATION: Urbanization and the conversion of lands to agriculture has obliterated many seasonal wetland ecosystems in the past and continue to do so today. Groups of several to many vernal pools should be preserved in an area to facilitate recolonization between pools after chance or deliberate extinctions of plant species in any one pool.

Habitat Type Description: Vernal Marshes

Distribution. Vernal marsh ecosystems are widely scattered in coastal valleys of the coast ranges (Cheatham and Hailer, 1975). Vernal marshes are water-logged or submerged during the winter rainy season but more or less dry by midsummer. Vernal marshes occasionally intergrade with freshwater marshes where perennial soil moisture is available.

Watershed Distribution. Distribution of vernal marshes on individual watershed units has not been mapped.

Vegetation. Annual herbs typical of vernal pools and taller perennial herbs dominate vernal marsh vegetation. Perennial species occupy lowest points of vernal marsh depressions where soil moisture duration is longest.

Table 8-61. Characteristic Plants in a Vernal Marsh

Plant Type/Common Name	Scientific Name
<u>Perennial Herbs</u>	
Sedges	<u>Carex spp.</u>
Rushes	<u>Juncus spp.</u>
Tules	<u>Scirpus Spp.</u>
<u>Annual Herbs</u>	
Eryngium	<u>Eryngium aristulatum</u>
Downingia	<u>Downingia spp.</u>
Navarretia	<u>Navarretia prostrata</u>

Succession. Vegetation of vernal marshes is successionaly stable, given typical hydrologic regimes (Figure 8-48).

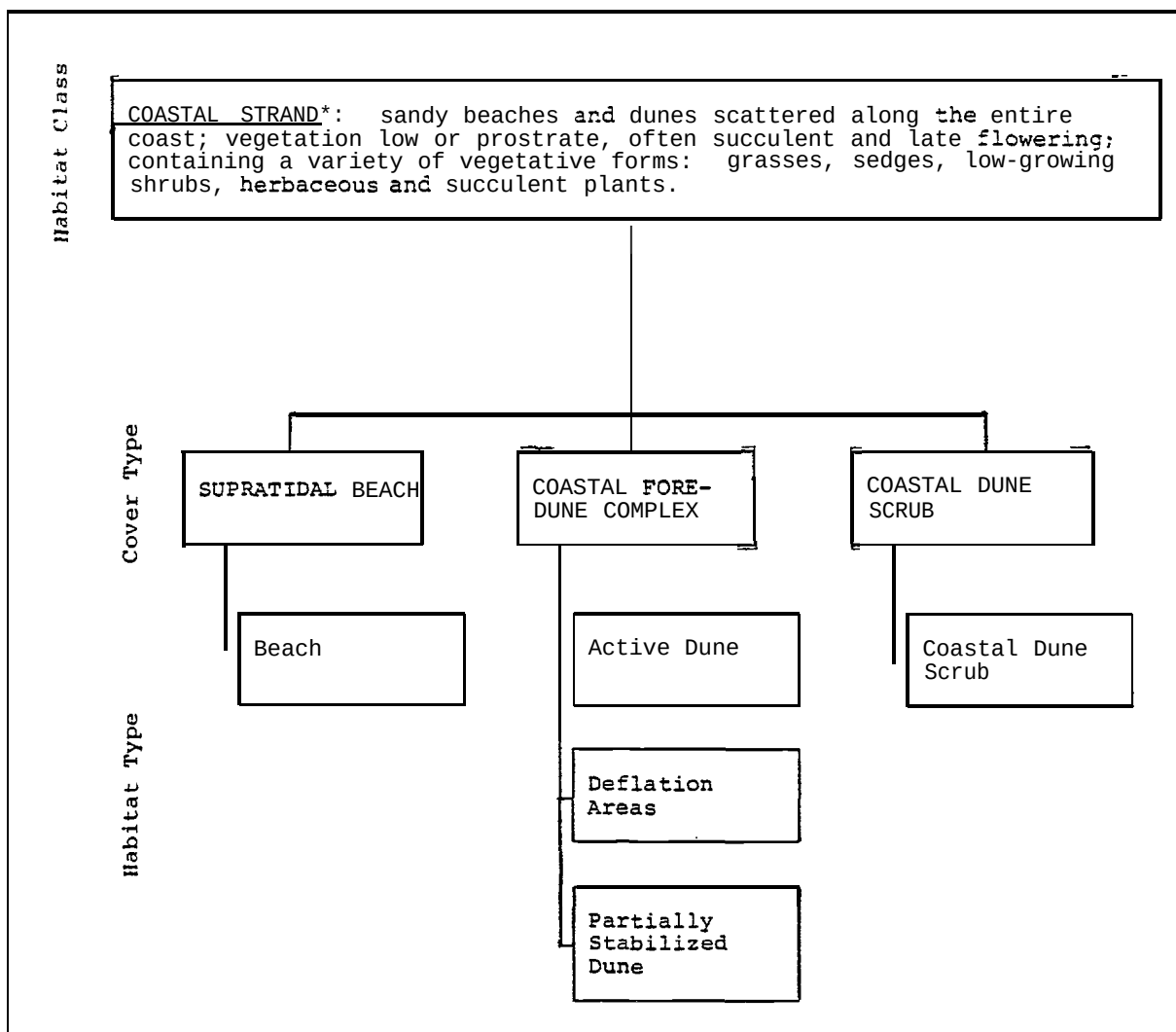


Figure 50. Hierarchical Dendrogram of Component and Habitat Types of Coastal Strands.

*The coastal strand encompasses the sandy beaches and dunes scattered along the coastline of California. Munz and Keck (1973) treated the coastal strand as one vegetation type. Barbour and Johnson (1977) however, found the vegetation and microclimate different enough to describe beaches and dunes as two distinct vegetation types. The distinction between supratidal beach and the coastal foredune complex will be maintained for the purposes of this report. A third cover type, the coastal dune scrub, represents the fully stabilized dune scrub communities of the coastal strand and sandy Coastal terraces.

Table 8-64 (continued)

First Third	Last Third
Saltbush (<u>Atriplex leucophylla</u>)	Salt grass (<u>Distichlis spicata</u>)
Sand verbena (<u>Abronia latifolia</u>)	Wild beach strawberry (<u>Fragaria chiloensis</u>)
	Purple-flowered beach pea (<u>Lathyrus littorals</u>)
	Sand blue grass (<u>Pea douglasii</u>)

Considerable latitudinal variation also exists in the taxa found on California beaches. Cooper (1967), Breckon and Barbour (1974), and Barbour and Johnson (1977), have surveyed the regional differences in dominant species. For additional local studies see Ramely (1918) (San Francisco); Williams and Potter (1972) and Williams (1974) (Morro Bay); and Barbour (1978) (Pt. Reyes).

Vegetation Seasonality and Modes of Reproduction. The flora of beaches is essentially a pioneer community due to the harsh abiotic environment. However, most beach taxa are perennials, unlike the annually reproducing pioneer communities of most terrestrial habitats.

Breckon and Barbour (1974) attribute the occurrence of perennial species instead of annuals to the limited number of suitable micro-habitats, which are selected by plants capable of retaining a site by perennial growth. The prominent beach plant, sea rocket (Cakile spp.) is an annual, but is functionally a perennial. The lower fruit of the sea rocket is borne low on the plant and tends to germinate adjacent to the parent plant in "proven" habitats. The fruit borne high on the plant is not readily held to the parent plant and is consequently dispersed by seawater (Barbour, 1972).

Species of the leading edge of the beach tend to have annual (Cakile) or biennial (Abronia) reproduction. The annual or biennial reproductive habit serves the dual purpose of retaining seeds in a suitable microsite (the parental plant location) while at the same time having frequent seed production and dispersal (yearly or biennially) for recolonization in the event that the parental plant site is lost to sand erosion (Williams, 1974).

The winter rains stimulate an overall growth response in beach vegetation. The peak growing season is late spring to early summer (Williams, 1974). Silver beachweed (Franseria chamissonis) dies back during winter to avoid inundation by storm waves (Barbour and DeJong, 1977).

Characteristic Fauna. Beaches provide marginal habitat for many mammals and reptiles due to a lack of food and cover. Beach mammalian and reptilian species compositions are based on Barbour et al., (1973) and Burt and Grossenheider (1976). Shorebirds use the beaches to forage for invertebrate food, and are characteristic and important inhabitants of the community. The bird species are derived from Recher (1966) and Small (1974). Invertebrates were taken from Ricketts and Calvin (1968) and Barbour et al., (1973). Species listed below, although characteristic of beaches, may not be found exclusively in this cover type (see food web Figure 8-51 for explanation of abbreviations). See the Community Composition List, Volume III, Part 2, for more information on species in Table 8-65.

Table 8-65. Characteristic Fauna of Supratidal Beaches¹

Mammals	Birds
Pacific water shrew (SMB)	Snowy plover (SMB)
Deer mouse (SMB)	Black-bellied plover (SMB)
California vole (SMB)	Dunlin (PS)
Black-tailed jack rabbit (SMB)	Willet (PS)
Northern elephant seal	Marbled godwit (G)
(Ano Nuevo Beach only (SMB))	Sanderling (SS)
Harbor seal (SMB)	Western gull (SS)
	Red-tailed hawk (R)

¹See Figure 8-51 for definition of abbreviations.

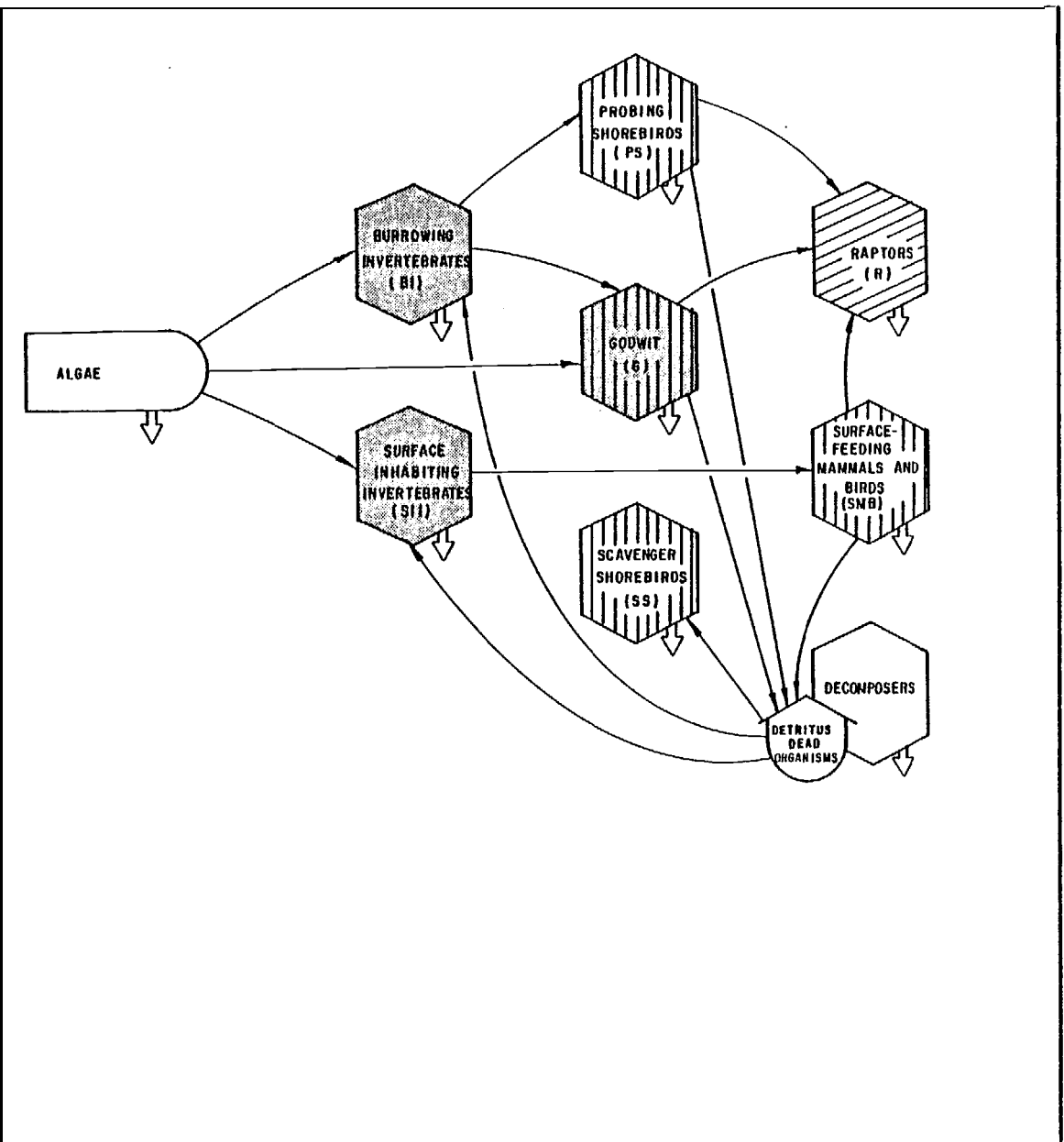


Figure 8-51. General Food Web--Supratidal Beach

Table 8-65 (continued)

Reptiles	Invertebrates
Western garter snake (SMB)	Little pill bug (S11)
Northern alligator lizard (SMB)	<u>Alloniscus perconvexus</u>
	Great beach hopper (S11)
	<u>Orchestoidea californiana</u>
	Sand crab (BI)
	<u>Emerita analoga</u>

Biomass Productivity and Food Web. The net primary productivity of beaches is extremely low. Above ground phytomass ranges from 26 to 348 grams per square meter (Barbour and Johnson, 1977). The supratidal beach food web is illustrated in Figure 8-51. Shorebirds feed on insects, invertebrates, and crustaceans inhabiting the sand. Probing birds (willet, marbled godwit, whimbrel) feed on burrowing sand crabs, marine worms, bivalves, and crustaceans. Sanderlings and plovers feed on insects or crustaceans that come up to the surface and scurry into the open. The red-tailed hawk preys upon shorebirds, in addition to other prey from adjacent habitat types. Beach wrack, seaweed and other debris washed onto the beach by storm waves, is decomposed by bacterial action. Insects and birds feed on the decaying organic matter.

Important Biotic Interactions. Several introduced taxa are important components of beach vegetation. Two species of sea rockets, the Atlantic coast Cakile edentula and the Mediterranean Cakile maritima, have spread north and south from San Francisco, where they were first introduced (Barbour and Rodman, 1970; Barbour and Johnson, 1977). There is evidence that prior to the introduction of marram grass (Ammophila arenaria), the foredune, formerly dominated by rye grass (Elymus mollis), was a low, gradually rising, open community. Elymus foredunes leave a dune system behind them with ridges arranged perpendicular to the coast. In contrast, Ammophila dunes are high and steep, with ridges parallel to the coast. The changes in topography may have altered the coastal foredune complex cover type (Breckon and Barbour, 1974; Barbour and Johnson, 1977). Ammophila-dominated beaches have half the species richness of Elymus-dominated beaches (Barbour et al., 1976; Barbour and Johnson, 1977). Furthermore, Ammophila may harbor nitrogen-fixing bacteria in its root system, allowing it to produce more dense growth to the exclusion of native taxa (Barbour et al., 1976; Barbour and Johnson, 1977).

Low organic matter and lack of nitrogen are limiting factors for growth of beach vegetation. The relatively high pH and rapid drainage of beach substrates encourages rapid decomposition of organic matter. Accumulation of organic matter accelerates with the presence of vegetative cover, since the above-ground vegetation produces litter and also traps wind-blown particles (Ranwell, 1972). However, excessive nitrogen may have a detrimental effect. Boyce (1954) showed that nitrogen caused a more luxuriant growth of vegetation, which made foliage and stems more susceptible to mechanical injury from salt spray and wind.

Important Abiotic Interactions. Salt spray is a controlling factor in the distribution of beach plants. Rye grass (Elymus mollis), marram grass (Ammophila arenaria), and wild beach strawberry (Fragaria chiloense) are found in areas of high salt spray, whereas silver beachweed (Franseria chamissonis) inhabits areas of less salt spray (Williams, 1974; Barbour, 1978). Salt spray also influences the height and growth form of the plants. Since salt spray increases vertically from the sand surface, plants tend to have a more prostrate habit in exposed windy areas. This allows them to avoid the higher salt spray occurring above the sand surface. Salt deposited on the windward side of plants can cause death of leaves and twigs, leading to a characteristic asymmetric appearance (Boyce, 1954; Barbour, 1978). Sand movement, soil salinity and moisture are important factors controlling colonization of bare areas. Winter moisture is a critical factor in seed germination and establishment (Ranwell, 1972; Barbour, 1978).

Associated Cover Types. The top of the foredune is the dividing line between the beach and the associated inland dune system (represented by the coastal foredune complex cover type). Riverine and estuarine cover types are associated with the supratidal beach where streams and bays enter the ocean.

Vegetation Succession. The flora of beaches are permanently disturbed plant communities, which entirely consist of colonizing species (Breckson and Barbour, 1974) . The beach is not seral to the active dune, partially stabilized dune, or stabilized coastal dune scrub at a given location. Instead, each habitat type is set back from the tide line due to abiotic site conditions. Further succession over time would only occur if the sea level fluctuated (Williams and Potter, 1972; Barbour and Johnson, 1977) . Limited succession on the beach occurs following local blowouts, where plants are uprooted, leaving bare sand. The colonizers of the beach are Elymus, Ammophila, Atriplex (north coast); Cakile (entire coast); and Abronia (south coast). These species cause small hillocks to form creating protected lee slopes. Franseria chamissonis and Mesembryanthemum (south coast) subsequently invade these protected areas (Williams and Potter, 1972; Barbour, 1978).

Typical Land Uses. Grazing was the primary historical use of beaches; recreation is the current primary use. Several workers have documented increases in bare sand and changes in species composition as a result of trampling by human foot traffic or off-road vehicles (Cowan, 1975; Barbour and Johnson, 1977).

Sensitivity to Disturbance. Vegetation establishment is important to the stabilization of moving sand. Uprooting of vegetation, either naturally or by human activities, exposes an area to subsequent blowouts by wind. Sand formerly held by vegetation is then free to move and bury more plants. Thus, once a dune starts to move, a wider area is disturbed. Wind blowouts and sand burial are a natural part of the beach environment. Human activities, however, have greatly accelerated this process.

Ecosystem Model. The biotic and abiotic interactions between the supratidal beach components are diagrammed in Figure 8-52.

Habitat Type Description: Supratidal Beach

Distribution. Beaches extend throughout the coastal strand. Many areas that lack dune systems are wholly comprised of expanses of sandy beach.

Watershed Units. Smith River, Klamath River, Mad River, Eel River, Mattole River, Noyo River, Gualala River, Russian River; Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo, Pajaro, Elkhorn Slough, Salinas River, Carmel River, Morro Bay, Santa Maria River, San Antonio Creek, Santa Ynez River, Point Arguello.

Table 8-66. Characteristic Plants of a Supratidal Beach

Location/Plant	Type/Common-Name	Scientific Name
North of Pt. Reyes		
<u>Herbs-Perennial</u>		
	Silver beachweed	<u>Franseria chamissonis</u>
	Yellow sand verbena	<u>Abronia latifolia</u>
	Beach morning-glory	<u>Calystegia soldanella</u>
<u>Herbs-Annual</u>		
	Sea rocket	<u>Cakile maritima</u>
<u>Grasses</u>		
	Marram grass	<u>Ammophila arenaria</u>
	Rye grass	<u>Elymus mollis</u>

Table 8-66 (continued)

Location/Plant Type/Common Name	Scientific Name
Point Reyes to Morro Bay	
<u>Herbs-perennial</u>	
Silver beachweed	<u>Franseria chamissonis</u>
Sea-fig	<u>Mesembryanthemum chilense</u>
Yellow sand verbena	<u>Abronia latifolia</u>
Purple-flowered beach pea	<u>Lathyrus littoralis</u>
Salt bush	<u>Atriplex leucophylla</u>
<u>Herbs-Annual</u>	
Sea rocket	<u>Cakile maritima</u>
<u>Grasses</u>	
Marram grass	<u>Ammophila arenaria</u>
rye grass	<u>Elymus mollis</u>
South of Morro Bay	
<u>Herbs-Perennial</u>	
Yellow sand verbena	<u>Abronia maritima</u>
Sea-fig	<u>Mes embryanthemum chilense</u>
Silver beachweed	<u>Franseria chamissonis</u>
<u>Herbs-Annual</u>	
Sea rocket	<u>Cakile maritima</u>

Figure 8-52. Ecosystem Model Supratidal Beach

Footnotes for Figure 8-52.
Ecosystem Model for the Supratidal Beach Habitat
Highlighted Processes and Components are Annotated Below

1. PHYSICAL-CHEMICAL PROCESSES. The dominant physical factors of the supratidal beach habitat are temperature, moisture, tides, wind, and salt spray.
2. SOILS. Soils are predominately fine-grained sands with rapid permeability (low moisture content) and high effective salinity. They are typically low in organic matter content and nitrogen, which is limiting to plant growth.
3. MICROCLIMATE. The microclimate is characterized by temperature extremes. The lack of vegetative cover and low moisture content of the substrate are primary causal factors.
4. TIDES. Tidal action influences temperature, substrate salinity and the zonal distribution of vegetation along the beach.
5. PRECIPITATION. Winter precipitation is important to germination and seedling establishment.
6. SALT SPRAY. Salt *spray*, originating from ocean wave splash and transported by wind action, is an important physical process of the supratidal beach. The salt spray affects vegetation distributional patterns and growth forms and creates a **dessicating** force on established plants.
7. PRODUCERS. These include a variety of beach taxa; most representative are sea rockets and beach grasses. Most of the producers are **herbaceous** prostrate plants. Algae and shrub or tree forma are not represented.
8. DECOMPOSES. Beach wrack, or seaweed and other debris washed up by storm waves are an important food source for insects and birds which feed on them. Turnover rates of organic matter and detritus on the beach are characteristically rapid.
9. CONSUMERS. The consumer component of the beach ecosystem consists of insects, invertebrates, and the shorebirds that feed upon **them**.
10. EFFECTS OF HUMAN ACTIVITIES. Recreation pressures on the beach are high. Trampling of beach vegetation destroys plant life and disturbs wildlife. **Shell-**fishing activities remove consumers as well.

Off-road-vehicle operation has been a major source of habitat destruction.

Offshore oil development has introduced petroleum pollutants which affect the decomposition process by bringing in petroleum-decomposing bacteria. Pollution associated with oil spills kills consumers, including shorebirds.

Urbanization has developed areas formerly occupied by beach vegetation.
11. LOGGING. Logging is not a human activity associated with **the supratidal** beach habitat.
12. BURNING. Controlled or accidental burning imposes a negligible impact on this habitat.

COASTAL FOREDUNE COMPLEX

Cover Type Characterization

Physiognomy. This cover type, referred to as dunes by most workers, includes the area from the top of the foredune to the edge of the coastal dune scrub cover type. Dunes have relatively low standing crop and cover compared to most other habitats, but greater cover than sandy beaches. Cover ranges from 0 to 15 percent on active dunes to 70 percent on partially stabilized dunes (Barbour and Johnson, 1977). The vegetation includes a variety of lifeforms from grasses and herbs to shrubs. Plants exhibit a characteristic asymmetrical growth because of wind-kill on the windward side of the dunes (Boyce, 1954).

Table 8-67. Habitat Types in a Coastal Foredune Complex

Habitats	Dominant Plants	Regional Distribution
Active dune	Yellow sand verbena (<u>Abronia latifolia</u>) Pea (<u>Lathyrus littoralis</u>) Sand blue grass (<u>Pea douglasii</u>)	North Of Bodega Bay
Active dune	Yellow sand verbena (<u>Abronia latifolia</u>) Silver beach weed (<u>Franseria chamissonis</u>)	South of Bodega Bay
Deflation areas	Willow (<u>Salix hookeriana</u>) Sedge (<u>Carex obnupta</u>) Sedge (<u>Carex</u> " - Coyote bush (<u>Baccharis pilularis</u>)	North of Bodega Bay South of Bodega Bay
Partially stabilized dune	Goldenrod (<u>Solidago spathulata</u>) Yellow bush lupine (<u>Lupinus arboreus</u>)	North of Monterey Bay throughout study area

(from Barbour and Johnson, 1977; nomenclature after Munz & Keck, 1973) .

Climate. The dunes are in the maritime climatic region of the California coast (see Table 8-63. Annual rainfall ranges from 250 mm to 780 mm, declining southward. The growing season is 12 months, with the number of frost-free days increasing in the southern portion of the state. Summer temperatures range from 16°C to 22°C; winter temperatures range from 4°C to 8°C. Dunes are characterized by less salt spray and lower soil salinity than the beach. An additional microclimatic feature of dunes is wide daily fluctuations in surface temperatures (Barbour and Johnson, 1977). Barbour et al. (1973) recorded average maximum and minimum temperatures of 20°C and 3°C compared to 17°C and 7°C on the beach. High summer temperatures and colder winter temperatures stress dune plants and may affect total production, but most dune species can tolerate these conditions.

Topography. Dunes are noted for a varied topography. The foredune is the first small hill or hillock that marks the seaward edge of the dune community. Active dunes are mobile, and are in the process of building or eroding. Active dunes may have two orientations: ridges parallel to the shore are called transverse dunes; ridges perpendicular to the shore are called longitudinal dunes. Behind the foredune or active dunes are eroded regions called deflation areas, which sometimes lie below sea level. Older, more inland dunes are partially or fully stabilized. A gradual increase in elevation occurs from the foredune to the partially stabilized dunes (Barbour and Johnson, 1977) .

Substrate. Dune soils are derived from sand. The substrate is generally low in moisture capacity, high in salinity, and low in organic matter and nutrients. These parameters vary among the different habitats. The moisture content is low in active dunes (7%), medium in partially stabilized dunes, and high in deflation areas (25 to 50%) . Soil moisture increases with depth to about 1 meter (m) in the active dunes. In partially stabilized dunes, moisture is evenly distributed because organic matter retains moisture closer to the surface. In deflation areas the ground surface closely parallels the water table, indicating the limit to which wind deflation can occur. Organic matter is low in active dunes, medium in partially stabilized dunes, and high in deflation areas (Ranwell, 1972) . Soil pH ranges from 6.8 in active dunes to 6.5 in partially stabilized dunes to 5.9 in deflation areas. Nutrients increase and salinity decreases with stabilization of the dunes. Deflation areas contain greater proportions of nutrients as a result of drainage from higher adjacent dunes (Barbour and Johnson, 1977'). Higher fluctuations in subsurface soil temperatures occur in the active dunes, compared to partially stabilized, deflation, or beach areas. Average temperature is 16°C, but reaches a maximum of 21°C in the active dunes.

Vegetation. Coastal foredune vegetation, in contrast to the supratidal beach, is dominated by low-growing shrubs. Subshrubs and perennial herbs are also present. Mesophytic trees may grow in moist deflation areas (Table 8-67) .

Vegetation Seasonality and Modes of Reproduction. A lack of annual plant species is a characteristic of dunes as well as beaches (Rameley, 1918). Williams (1974) noted seasonal variation in maximum abundance of dune species at Morro Bay. Wallflowers (*Erysimum insulare*) peaked in March; evening primrose (*Oenothera cheiranthifolia*) peaked in May; live-forever (*Dudleya caespitosa*) and mock heather (*Haplopappus ericoides*) peaked in June. In addition, some species maintained rapid growth throughout the rainy season (bird's foot trefoil, *Lotus scoparius*; lupine, *Lupinus chamissonis*) .

Characteristic Fauna. Fauna of the dunes are taken from Barbour et al. (1973) , Burt and Grossenheider (1976), and Ingles (1976) (mammals); Small (1974) (birds); and Barbour et al. (1973) (reptiles and amphibians). Some species are restricted, due to food availability or other environmental factor, to a particular habitat, which is indicated in the species list. Species listed in Table 8-68, although characteristic of dunes, may not be found exclusively in this COVER type (see food web Figure 8-53 for explanation of abbreviations). See the Community Composition List, Volume III, Part 2, for more information on species listed in Table 8-68.

Table 8-68. Characteristic Fauna of a Coastal Foredune Complex¹

Mammals	Birds	Reptiles and Amphibians
Deer mouse (HM)	Marsh hawk (P)	Northern alligator lizard (OA)
California vole (CHM)		Western garter snake (OA)
Black-tailed jack rabbit (HM)		Bullfrog (OA)
Striped skunk (OA)		
Gray fox (OA)		
Raccoon (OA)		
Long-tailed weasel (P)		
Mule deer (BM)		

¹See Figure 8-53 for definition of abbreviations.

Biomass Productivity and Food Web. Net primary production is low in the active dunes and somewhat higher in the partially stabilized dune and deflation areas. No comprehensive surveys of dune biomass have been reported. Barbour and Robichaux (1976) reported unit biomass for some dune species. Examples are 309 grams per square meter for Abronia latifolia, 551 grams per square meter for Atriplex leucophylla and 1,104 grams per square meter for Poa douglasii. Although the dunes are depauperate in numbers of species, the food web consists of more trophic levels than found on beaches (Figure 8-53). Omnivores such as foxes, raccoons, and skunks feed on a complex insect community. Strictly herbivorous species, such as mice, jack rabbits, and meadow mice are prey for the marsh hawk and the long-tailed weasel. Deer visit the entire dune complex, browsing on bushes and other plants (Martin et al., 1951; Barbour et al., 1973).

Important Biotic Interactions. Biological processes are important in the stabilization of dunes and development of dune soils. Dune pioneers, such as sand verbena (Abronia latifolia), pea (Lathyrus littoralis), and sand blue grass (Poa douglasii) bind the sand and initiate the accumulation of organic matter by dropping their litter, trapping air-borne organic particles, and root death and decay. Decomposition is rapid in active dunes but slows with dune stabilization. Accumulation of byproducts such as humic acids lowers the pH. Low pH values decelerate the decomposition process, creating a soil higher in litter, organic matter, and nutrients. Moisture retention is increased with organic matter accumulation (Ranwell, 1972). Subsequent invasion of more stabilized areas by species such as lupine (Lupinus) and goldenrod (Solidago) increases the depth of the root zone, improves the stability of the sand, and causes organic matter to accumulate at greater depths. In addition, lupines fix nitrogen, which increases soil nitrogen content.

Important Abiotic Interactions. Water drains rapidly through dune soils to the water table at about 1 meter below the surface. As a result, many dune shrubs have root systems that extend to the water table. Seedlings and shallower-rooted herbs depend on rainfall to wet the soil surface, although many can tolerate daily wilting. Gravity causes water and dissolved nutrients to move into deflation areas (Ranwell, 1972). There is some evidence that soil temperature gradients in dry periods cause some upward movement of water vapor at night, providing some moisture to plants (Ranwell, 1972). Condensation of water at low temperatures, dew, and fog are additional sources of moisture (Ranwell, 1972). High summer soil temperatures in the active dunes may have a detrimental effect on plant roots and sand microorganisms (Barbour et al., 1973).

Associated Cover Types. The coastal foredune intergrades into the supratidal beach seaward and the coastal dune scrub inland. Riverine and estuarine cover types may be associated with the dunes where streams enter the ocean.

Vegetation Succession. Succession is complex in the dunes due to the zonation of habitat types above the tide line. Blowouts occur in the active dunes or partially stabilized dunes and destabilize the sand, allowing pioneers to re-invade formerly stabilized dunes. Blowing sand also fills deflation areas, causing a shift to active dune vegetation (Barbour and Johnson, 1977). Barbour and Johnson (1977) review dune succession for the north and south coasts. Both northern and southern successions lead to a forest climax (see discussion on coastal dune scrub).

Typical Land Uses. Dunes in California were historic grazing areas. Today, use is confined to recreational activities. Many dune areas have been developed for housing. Golden Gate Park in San Francisco is established on a formerly extensive dune system.

Sensitivity to Disturbance. Dune plants cannot withstand trampling from foot traffic, off-road vehicles, and motorcycles. When the plant cover is destroyed the dunes begin to move, burying more vegetation. If developments or roads are nearby, blowing sand can be a nuisance. To stabilize the dunes, exotic plants such as marram grass (Ammophila arenaria) and Hottentot-fig or ice plant (Mesembryanthemum edulis) have been planted. These plants are replacing native vegetation (Cowan, 1975).

Ecosystem Model. Major ecosystem processes are represented in a terrestrial ecosystem model in Figure 8-54.

Habitat Type Description: Active Dune

Distribution. Active dunes were scattered throughout the coastal strand of California. Many of these dune systems have been developed for housing. The remaining active dune areas are at Trinidad Head, Arcata, Fort Bragg, Point Arena, Bodega Head, Pt. Reyes, San Francisco Peninsula, Monterey peninsula, Morro Bay, and Vandenberg Air Force Base (Barbour and Johnson, 1977).

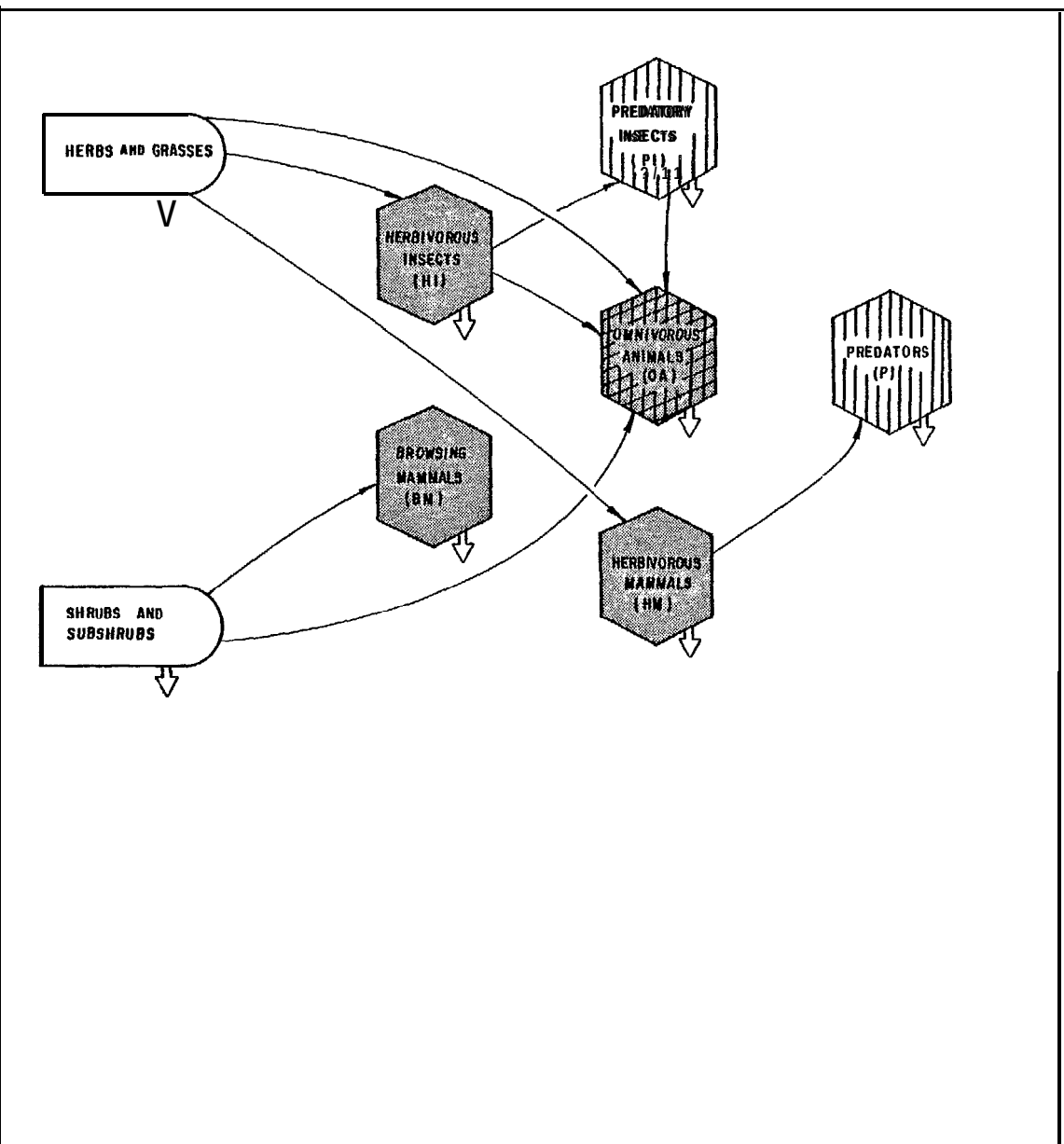


Figure 8-53. Coastal Foredune Complex Food Web

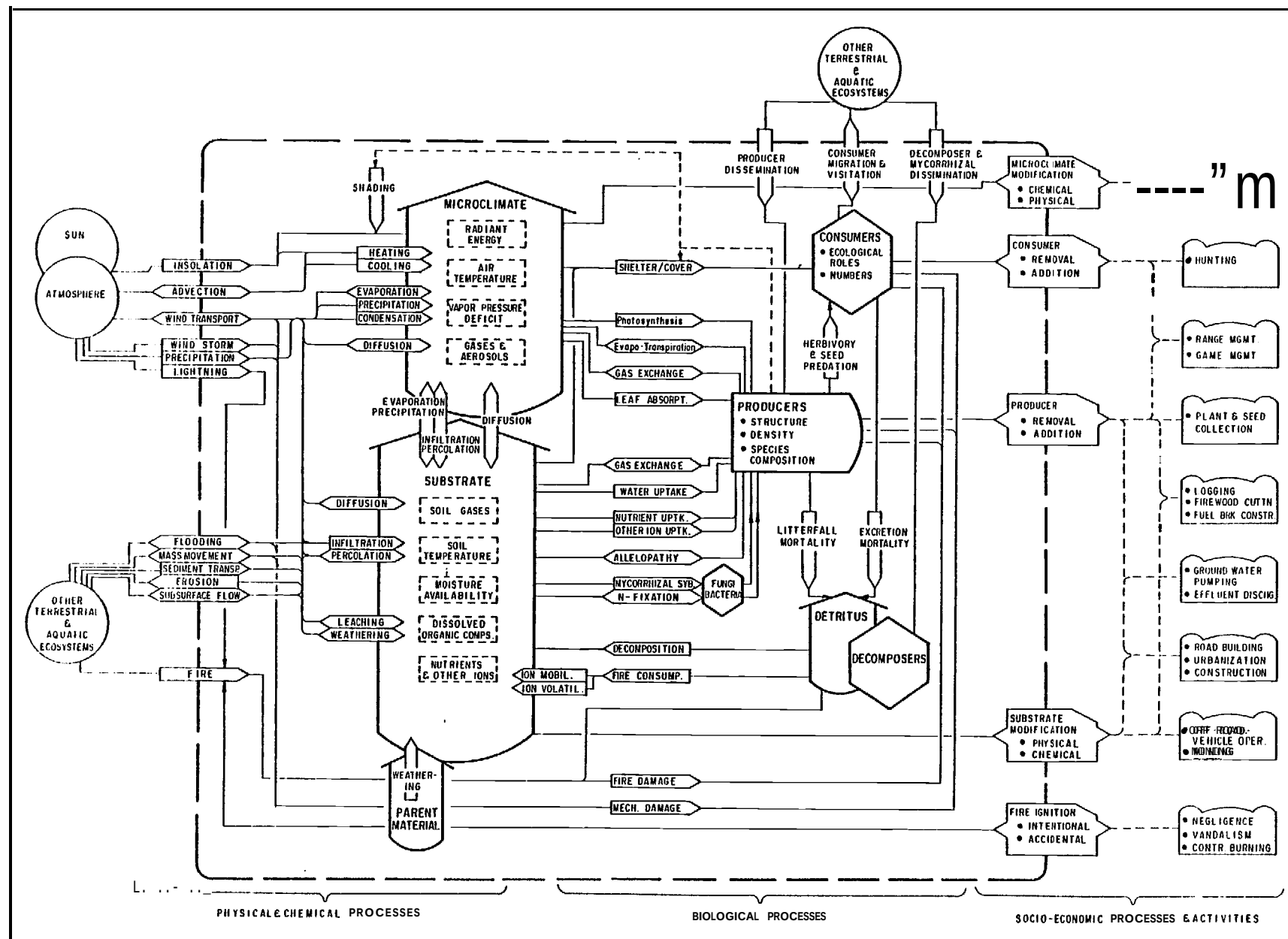


Figure 8-54. Coastal Fore dune Complex and Coastal Dune Scrub Ecosystem Model

Footnotes for Figure 8-54
Ecosystem Model for the Coastal Fore-dune and
Coastal Dune Scrub Habitats.
Highlighted Processed and Components are
Annotated Below

1. **PHYSICAL-CHEMICAL PROCESSES:** Most of the physical-chemical components of the coastal fore-dune and coastal dune scrub are similar to the **supratidal** beach. Dominant factors are temperature, moisture, wind, and salt spray.
2. **TEMPERATURE AND SALINITY:** Temperature and substrate salinity are less extreme than that experienced in the supratidal beach habitat.
3. **SUBSTRATE:** Coastal fore-dune and coastal dune scrub substrates become progressively lower in salinity and higher in *organic* matter, **moisture** and nutrients.
4. **SALT SPRAY:** Salt spray, originating from ocean *wave* splash and transported by wind action, is an important process of the coastal fore-dune habitat and, to a lesser extent, of the coastal dune scrub habitat. The salt spray affects vegetation distributional patterns and growth forms and creates a desiccating force on established plants.
5. **PRODUCERS:** The producers characteristic of dune habitats are represented by a greater variety of forms than the **supratidal** beach. Dominant dune producers are sub-shrubs, shrubs and low-growing trees. Lichens are part of the coastal dune scrub producer component. The wind-salt kill of branches on the windward side of trees and shrubs produces the characteristic asymmetrical growth form of dune vegetation.
6. **NITROGEN FIXATION:** Nitrogen fixation occurs where leguminous shrubs are part of the producer component, especially in the coastal dune scrub.
7. **CONSUMERS:** The food web of the dune habitats is quite different from that of the **supratidal** beach. **Mammals** are present, (fox, raccoon, skunk, badger) consuming insects and vegetation. Other mammals, deer, mice, voles, shrews, jack rabbits, and deer, are strictly herbivorous. Shorebirds are absent. Carnivorous mammals (weasel, marsh hawk, red-tailed hawk) and **raptors** are present, feeding on herbivorous and omnivorous mammals.
8. **DECOMPOSES:** The decomposers are primarily **fungi**, rather than bacterial. Turn-over rates are slower, leading to higher accumulations of organic matter, nutrients and **humic** acids.
9. **EFFECTS OF HUMAN ACTIVITIES.** Recreation pressures are high in the dune habitats. Trampling of dune vegetation destroys plant life, disturbs wildlife and causes dune instability. No fishing or shell-fishing occur in these habitats. Off-road vehicle use is a major cause of habitat loss in the dune habitats. Vegetation is killed and dunes become **unstable**.

Offshore oil development has introduced petroleum pollutants which affect the decomposition process by bringing in petroleum-decomposing bacteria. Pollution associated with oil spills **kills** consumers.
10. **LOGGING AND BURNING:** Logging and controlled or accidental burning are not associated with the dune habitats.
11. **URBANIZATION :** Urbanization has developed areas formerly occupied by the coastal **fore-dune** and coastal dune scrub habitats.

Watershed Units. Smith River, Klamath River, Mad River, Mattole River, Noyo River, Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo River, Salinas River, Carmel River, Morro Bay, San Antonio Creek, and Point Arguello.

Vegetation. Active dunes contain only sparse vegetative cover interspersed with open areas of bare sand. Plants are low-growing, wind-pruned or prostrate perennial herbs or shrubs. Active dunes are most common in the zone between the supratidal beach and the partially stabilized dune habitats. The major factors controlling the vegetation of active dunes are wind, salt spray, and sand movement.

Table 8-69. Characteristic Plants of an Active Dune

Location/Plant Type/Common Name	Scientific Name
<u>North of Bodega Bay</u>	
<u>Herbs-Perennial</u>	
Yellow sand verbena	<u>Abronia latifolia</u> (wind slopes)
Silver beachweed	<u>Franeria chamissonis</u> (wind slopes)
Purple-flowered beach pea	<u>Lathyrus littoralis</u>
Wild beach strawberry	<u>Fragaria chiloensis</u> (lee slopes)
<u>Grasses</u>	
Sand blue grass	<u>Poa douglasii</u>
<u>South of Bodega Bay</u>	
<u>Shrubs</u>	
Mock heather	<u>Happlopappus ericoides</u> (wind slopes)
Purple-flowered beach lupine	<u>Lupinus chamissonis</u> (wind slopes)
<u>Subshrubs</u>	
Beach sagewort	<u>Artemesia pycnocephala</u> (wind slopes)
<u>Herbs-Perennial</u>	
Yellow sand verbena	<u>Abronia latifolia</u> (wind slopes)
Silver beachweed	<u>'ia chamissonis</u> (wind slopes)
Sedge	<u>Carex pansa</u> (lee slopes)
Sea-fig	<u>Mesembryanthemum chilense</u> (wind slopes)
Evening primrose	<u>Oenothera cheiranthefolia</u> (wind slopes)
Live forever	<u>Dudleya farinosa</u> (wind slopes)

Succession. The successional trend in the active dunes is to a more stabilized dune system (see partially stabilized dune habitat type below). Wind blowouts frequently uproot or bury plants, creating an active dune system from formerly stabilized dunes. When the vegetative cover is removed, the dune begins to migrate, burying adjacent stabilized dunes and spreading out from the site of the original disturbance. The primary colonizers of bare sand are the wind slope species (see characteristic plant list above). Once they become established and build up a lee protected slope, the lee species invade.

Habitat Type Description: Deflation Areas

Distribution. Deflation areas are scattered throughout the coastal strand of California in dune systems where erosion behind the dune has lowered the surface close to the water table. The major dune systems with deflation areas are Trinidad Head, Arcata, San Francisco Peninsula, Monterey Peninsula and Morro Bay (Barbour and Johnson, 1977).

Watershed Units. Mad River, San Gregorio Creek, Carmel River, and Morro Bay.

Vegetation. Deflation areas are inhabited by mesophytic (growing in moderately wet conditions) or hydrophytic (growing in extremely wet conditions) herbs and shrubs. Plants grow to full height due to protection by the adjacent ridges. Cover is usually dense.

Table 8-70. Characteristic Plants of a Deflation Area

Location/Plant Type/Common Name	Scientific Name
North of Bodega Bay	
<u>Shrubs</u>	
Willow	<u>Salix hookeriana</u>
<u>Herbs-Perennial</u>	
Sedge	<u>Carex obnupta</u>
Rush	<u>Juncus lesueurii</u>
South of Bodega Bay	
<u>Shrubs</u>	
Arroyo willow	<u>Salix lasiolepis</u>
Coyote bush	<u>Baccharis pilularis</u>
<u>Herbs-Perennial</u>	
Spike rush	<u>Heleocharis acicularis</u>
Rush	<u>Juncus lesueurii</u>
Rush	<u>Juncus phaeocephalus</u>
Monkey flower	<u>Mimulus guttatus</u>
Yarrow	<u>Achillea millefolium</u>
Yellow sand verbena	<u>Abronia latifolia</u>
Sedge	<u>Carex pansa</u>
<u>Grasses</u>	
Rye grass	<u>Elymus mollis</u>

Succession. Deflation areas are successional to the coastal dune scrub cover type in the absence of any disturbance. Under conditions of a wind blowout, deflation areas may revert to an active dune system.

Habitat Type Description: Partially Stabilized Dune

Distribution. Partially stabilized dunes are distributed throughout the coastal strand: Trinidad Head, Arcata, Fort Bragg, Point Arena, Bodega Head, Pt. Reyes, San Francisco Peninsula, Morro Bay, Monterey Bay, portions of San Luis Obispo County, and Vandenberg Air Force Base (Barbour and Johnson, 1977).

Watershed Units. Smith River, Klamath River, Mad River, Mattole River, Noyo River, Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo Creek, Salinas River, Carmel River, Morro Bay, San Antonio Creek, and Point Arguello.

Vegetation. Vegetative **cover** is more dense and more continuous than that found on active dunes, with little or no barren areas. Plants are primarily low-growing shrubs and subshrubs. Partially stabilized dunes occupy a zone between the active dune system and fully stabilized coastal dune scrub cover type. The major factors controlling the vegetation of partially stabilized dunes are soil development and distance and elevation from the tide line.

Table 8-71. Characteristic Plants of a Partially Stabilized Dune

Location/Plant Type/Common Name	Scientific Name
North of Bodega Bay	
<u>Shrubs</u>	
Yellow bush lupine	<u>Lupinus arboreus</u>
<u>Subshrubs</u>	
	<u>Polygonum paronychia</u>
<u>Herbs-Perennial</u>	
Goldenrod	<u>Solidago spathulata</u>
South of Bodega Bay	
<u>Shrubs</u>	
Chemise	<u>Adenostoma fasciculatum</u>
Purple-flowered beach lupine	<u>Lupinus chamissonis</u>
Wild buckwheat	<u>Eriogonum parvifolium</u>

Succession. Partially stabilized dunes are intermediate between active dunes and fully stabilized dunes. Active dunes will be created by wind destabilization. If left undisturbed, the coastal dune scrub will develop.

COASTAL DUNE SCRUB

Physiognomy. This cover type represents the fully stabilized dune system, typically occupying elevated coastal terraces between the coastal foredune and adjacent terrestrial types (e.g., coastal conifer forest, closed-cove conifer forest, and coastal scrub cover types). The vegetation consists of low-growing shrubs (some trees), sometimes dense, but lower in total biomass than terrestrial scrub types. Cover is 70 to 100% (Barbour and Johnson, 1977; Mooney, 1977c). Asymmetrical growth on the windward-facing side of the plants is characteristic (Boyce, 1954).

Table 8-72. Dominant Plants of a Coastal Dune Scrub Type

Regional Distribution	Dominant Plants
North of Bodega Bay	Yellow bush lupine (<u>Lupinus arboreus</u>) Sand berry (<u>Arctostaphylos uva-ursi</u>) Coyote brush (<u>Baccharis pilularis</u>)
South of Bodega Bay	Yellow bush lupine (<u>Lupinus arboreus</u>) Beach sagewort (<u>Artemisia pycnocephala</u>) Coffeeberry (<u>Rhamnus californica</u>) Mock heather (<u>Haplopappus ericoides</u>)

(from Barbour and Johnson, 1977; Mooney, 1977c; nomenclature after Munz & Keck, 1973).

Climate. Rainfall ranges from 250 mm to 1780 mm, declining southward. The growing season is 12 months, with the number of frost-free days increasing southward. Summer temperatures are 16°C to 22°C; winter temperatures are 4°C to 8°C (Munz and Keck, 1973). The amount of salt spray and wide temperature fluctuations are ameliorated in the coastal dune scrub by the distance from the ocean and the closure of vegetative cover.

Topography. The cover type occurs on level coastal terraces, bluffs, and ridges above the sandy beaches and dunes, as well as on the more inland extent of the active dunes (Cooper, 1967; Barbour and Johnson, 1977; Heady et al., 1977).

Substrate. The cover type soils are developed sandy loams with a very small clay fraction. Soils are porous and friable, forming a crusty surface in places. Soils are relatively low in moisture capacity (30%) compared to other cover types, but significantly higher than the coastal foredune complex (Ranwell, 1972; Barbour et al., 1973). The water table is much further from the surface compared to the coastal foredune due to the higher elevation. Soil pH is approximately 6.5 (Barbour and Johnson, 1977).

Vegetation. The coastal dune scrub is dominated by a dense cover of low-growing shrubs (Table 8-72). The plants on bluffs such as lupine (*Lupinus variicolor*), may be prostrate. On terraces and protected places, shrubs such as yellow bush lupine (*Lupinus arboreus*) may reach 2 meters in height. Mature coastal scrub has an understory of annual grasses and forbs (Heady et al., 1977).

Vegetation Seasonality and Modes of Reproduction. This cover type is dominated by perennial short-lived shrubs. The plants are dormant during the summer dry period. Mature plants revive and seeds germinate with the onset of winter rains. Shrub seedlings compete with annual grass seedlings. Survival of shrub seedlings is enhanced by burial before germination and protection from herbivores provided by the shrub canopy (Davidson and Barbour, 1977). The peak growing season is late spring, with most species flowering in May or June (Barbour et al., 1973).

Characteristic Fauna. The coastal dune scrub supports a larger number of species than the coastal foredune complex, because the greater density of the vegetation provides more forage and cover. Mammals are taken from Ingles (1965), Barbour et al., (1973), and Davidson and Barbour (1977). Birds are taken, from Barbour et al. (1973). Reptiles and amphibians are taken from Barbour et al. (1973). Species listed below, although characteristic of coastal dune scrub, may not be found exclusively in this cover type (see food web Figure 8-55 for explanation of abbreviations). See the Community Composition List, Volume III, Part 2, for more information on species listed below.

Table 8-73. Characteristic Fauna of a Coastal Dune Scrub.¹

Mammals	Birds
Deer mouse (OA) House mouse (HM) Black-tailed jack rabbit (HM) Brush rabbit (HM) California vole (HM) Meadow mouse (vole) (HM) Pocket gopher (HM) Mule deer (HM) Gray fox (CA) Long-tailed weasel (CA) Bobcat (CA) Raccoon (OA) Striped skunk (OA)	California quail (HA) Marsh hawk (CA) Red-tailed hawk (CA) American kestrel (CA) Turkey vulture (S) White-crowned sparrow (HA) Savannah sparrow (HA) Song sparrow (HA) American goldfinch (AA)
Reptiles and Amphibians	Invertebrates
Common garter snake (CA) Tree frog (CA) Alligator lizard (CA)	Common black millipede (Hi) <u>Narceus</u> sp.

¹Refer to Figure 8-55 for definition of abbreviations.

Biomass Productivity and Food Web. Biomass productivity has only been measured for a few dune scrub communities. Davidson and Barbour (1977) reported above ground biomass of yellow bush lupine (*Lupinus arboreus*) between 4.1 grams (g) per plant for young plants to 6,853 g for mature plants. Overall, biomass production in the dune scrub is higher than the coastal foredune but lower than the coastal scrub cover types. The coastal dune scrub supports a complex community of insects and herbivorous mammals which feed on different parts of the plants (seeds, stems, and roots), and in turn supports a variety of primary and secondary predators. Barbour et al. (1973) studied the food web of the *Lupinus* scrub which is the basis for the food web diagrammed in Figure 8-55.

Important Biotic Interactions. The biological processes of the coastal dune scrub have been poorly studied (Ranwell, 1972; Heady et al., 1977). Research in Europe indicates that a switch occurs from bacterial-based decomposition in dunes to fungal-based decomposition in dune scrub, with a mycorrhizal association with the dune shrubs. The significance of this switch is unclear (Ranwell, 1972). Another feature of stabilized dune scrub is the growth of lichens on terrace rock outcrops and crusty soil patches (Ranwell, 1972; Barbour et al., 1973). These lichens may be important for soil development, but their specific function in the dune scrub ecosystem has not been studied. Because of the short life span of dune scrub shrubs, seedling establishment is an important factor for maintenance of the cover type. Davidson and Barbour (1977) reported loss by herbivores, as well as both intra-specific and inter-specific (between grasses and herbs) competition as limiting factors for seedling establishment. Some herbaceous cover is important to protect seeds from herbivores.

Important Abiotic Interactions. Wind-blown salt and sand, although considerably less severe than in the beach and active dune habitat, are still factors in controlling distribution of dune scrub vegetation. The presence of a sandy substrate allows the dune scrub to dominate on the coastal terraces, instead of the more inland grasslands or coastal scrub (Heady et al., 1977). Summer drought can be a mortality factor for younger shrub seedlings, lacking well-developed root systems (Davidson and Barbour, 1977).

Associated Cover Types. In northern California the coastal conifer forests are spatially associated with dune scrub. In central California the lupine scrub is closely associated with the coastal prairie. Chaparral and coastal scrub are associates of dune scrub in southern California.

Vegetation Succession. The pattern of vegetation succession in the coastal dune scrub habitat type depends on geographic location along the coast. From the Eel River watershed unit to the Oregon border, coastal dune scrub is typically invaded and replaced by shore pine forest. Eventually, shade-tolerant Sitka spruce and grand fir may invade favorable stabilized dune sites and replace the shade-intolerant shore pine. Sitka spruce-grand fir forest may constitute a steady-state ecosystem on productive dune sites. In the Noyo River and Gualala River watershed units, coastal dune scrub is typically invaded and replaced by Bishop pine forest (Barbour and Johnson, 1977). At some sites (e.g., Bodega Head), dynamic mosaics of coastal dune scrub and coastal prairie may dominate steady-state ecosystems (Davidson and Barbour, 1977). However, the effect of a lack of tree seed sources on the process of succession is unknown.

On the Monterey peninsula (Carmel River watershed unit), coastal dune scrub is commonly replaced by the Monterey pine forest habitat type and subsequently by the coast live oak forest habitat type. If a closed canopy of coast live oak is formed, regeneration of Monterey pine is precluded. However, periodic fire and high browsing pressure from deer may retard invasion of coast live oak and maintain the Monterey pine forest habitat type (McBride and Stone, 1976).

To the south of the Morro Bay watershed unit, mixed chaparral often invades and may replace coastal dune scrub. Eventually, if fire is relatively infrequent, coast live oak forest may replace mixed chaparral (Wells, 1962). Frequent fires (1-5 year intervals) will maintain the coastal dune scrub habitat type.

At all sites along the coast, extreme exposure to salt-laden ocean winds can prevent forest replacement of coastal dune scrub by desiccating and killing lead shoots of tree seedlings.

Typical Land Uses. Recreation is the major land use of the coastal dune scrub. Off-road vehicle use is the most popular (and destructive) recreational form. Level terraces have been converted to agricultural use in the central coast region.

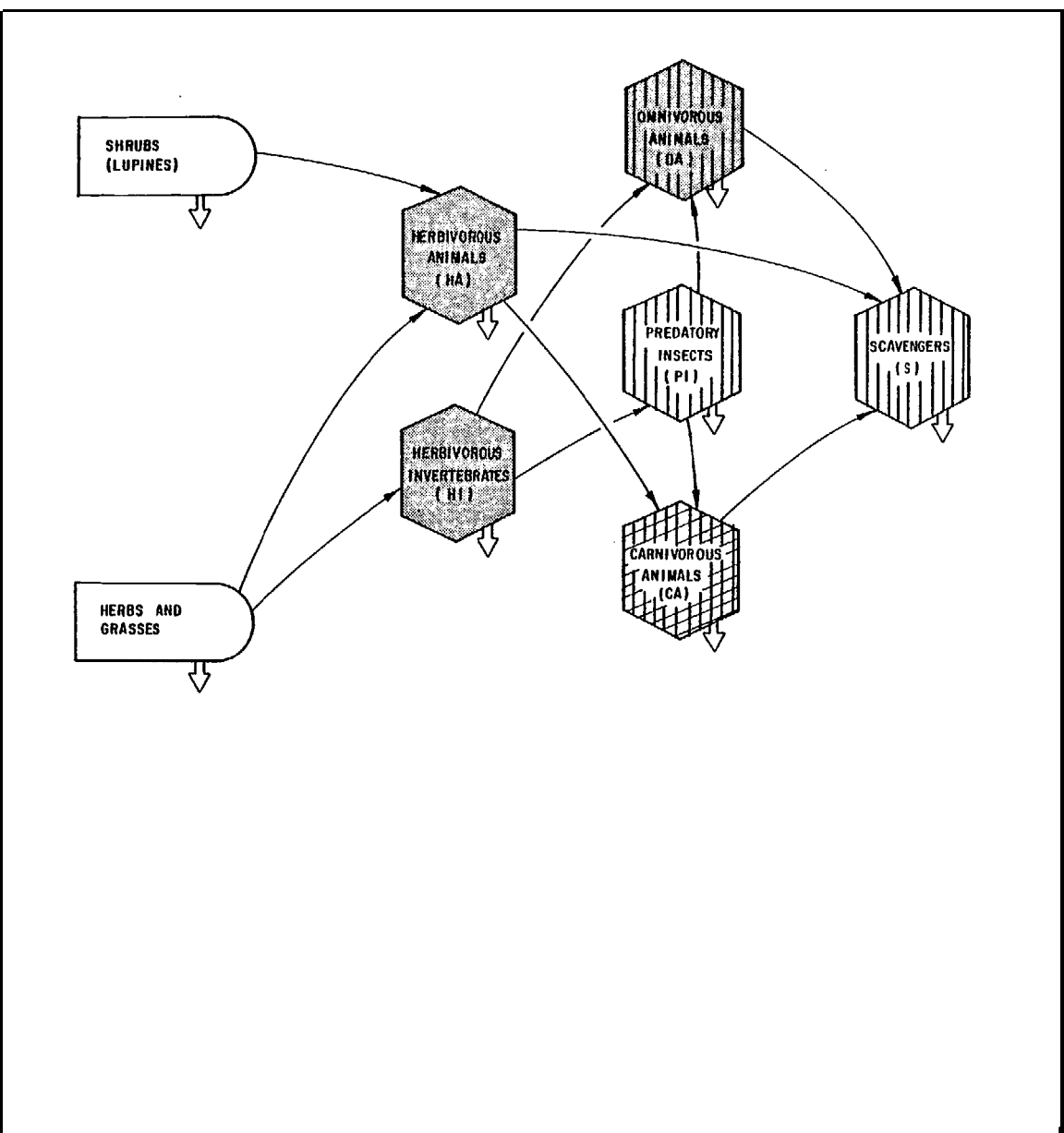


Figure 8-55. Coastal Dune Scrub Food Web

Sensitivity to Disturbance. The coastal dune scrub, although fully vegetated and seemingly stable, is nevertheless sensitive to disturbance by vehicles. If the cover is removed, sandy soils begin to migrate as in the active dunes. Beach sage-wort (Artemesia pycnocephala) and mock heather (Haplopappus ericoides) are native species easily established by artificial plant (Cowan, 1975), and may be important species for dune stabilization programs.

Ecosystem Model. Ecosystem processes for the coastal dune scrub are represented in the terrestrial ecosystem model, Figure 8-54. Differences between the coastal foredune complex and the coastal dune scrub are described in the footnotes.

Habitat Type Description: Coastal Dune Scrub

Distribution. Stabilized dunes are found with the major dune systems at Trinidad Head, Arcata, Fort Bragg, Point Arena, Bodega Head, Pt. Reyes, San Francisco Peninsula, Monterey Peninsula, Morro Bay, portions of San Luis Obispo County, and Vandenberg Air Force Base (Barbour and Johnson, 1977). Terrace dune scrub types are common in Santa Cruz, San Francisco, Marin, Sonoma, Humboldt, and Mendocino Counties (Heady et al., 1977).

Watershed Units. Smith River, Klamath River, Mad River, Mattole River, Noyo River, Salmon Creek, Lagunitas Creek, San Gregorio Creek, San Lorenzo, Salinas River, Carmel River, Morro Bay, San Antonio Creek, and Point Arguello.

Table 8-74. Characteristic Plants in a Coastal Dune scrub

Location/Plant Type/Common Name	Scientific Name
North of Santa Cruz	
<u>Shrubs</u>	
Yellow bush lupine	<u>Lupinus arboreus</u>
Lupine	<u>variicolor</u>
Sand berry	<u>Arctostaphylos uva-ursi</u>
Coyote brush	<u>Baccharis pilularis</u>
Mock heather	<u>Happlopappus ericoides</u>
Purple-flowered beach lupine	<u>Lupinus chamissonis</u>
<u>Subshrub</u>	
Lizard tail	<u>Eriophyllum staechadifolium</u>
<u>Herbs-Perennial</u>	
Thrift, sea pink	<u>Armeria maritima</u>
Live forever	<u>Dudleva farinosa</u>
Sea fig	<u>Mesembryanthemum chilense</u>
Bracken fern	<u>Pteridium aquilinum</u>
<u>Herbs-Annual</u>	
Scarlet pimpernel	<u>Anagallis arvensis</u>
Sow thistle	<u>Sonchus asper</u>
Ripgut brome	<u>Bromus diandrus</u>
South of Santa Cruz	
<u>Shrubs</u>	
Purple-flowered beach lupine	<u>Lupinus chamissonis</u>
Coffeeberry	<u>Rhamnus californica</u>
Coyote brush	<u>Baccharis pilularis</u>
Mock heather	<u>Happlopappus ericoides</u>
Poison oak	<u>Rhus diversiloba</u>
<u>Subshrubs</u>	
Beach sagewort	<u>Artemesia pycnocephala</u>
California sagebrush	<u>Artemesia californica</u>
Lizard-tail	<u>Eriophyllum staechadifolium</u>
	<u>Corethrogyne filaginifolia</u>
Bird's foot trefoil	<u>Lotus scoparius</u>
<u>Herbs-Perennial</u>	
Purple-flowered beach pea	<u>Lathyrus littorals</u>
Live forever	<u>Dudleva caespitose</u>
Live forever	<u>Dudleva farinosa</u>

CHAPTER 9 LAND-USE ACTIVITIES AND MAN-CREATED HABITATS

LAND USE

Human activity has had so great an effect on the natural environment, altering ground cover, soils, hydrology and topography and affecting the habitats and food webs of other organisms, that it would seem improper to attempt to fully integrate human habitats with natural habitats in a classification scheme. The equilibrium achieved among natural (non-human) habitats has the potential for being disrupted by human activities. The disruption may range in intensity from total destruction of plant and animal communities and replacement by human activities, to minor disturbances of plant and animal inhabitants. Intensive urban development is likely to destroy existing vegetation and kill or drive out many animal species, replacing them with domesticated plants and animals or pest species. At the other extreme, the following examples illustrate different types of modification of the natural environment.

- 1) Moderate domesticated animal grazing (a human-directed activity) precipitates changes in the species composition of the plant and animal community.
- 2) Rural residential development may change the natural habitat only in the immediate vicinity of buildings, and may drive away the most secretive wild-lands animal species.
- 3) Activities in wilderness areas by humans may modify the wild land species composition in very localized areas (campgrounds and trails) and may modify behavior of species near to facilities.

Because human activities have had such overwhelming impacts on natural systems, it seems proper to classify these activities not alongside natural zones and habitats, but "overlying" them. Human activity has the potential for disruption or modifying of any of the habitats discussed in previous sections of this volume. This section organizes human activities by land use the major uses being agricultural, recreational, non-urban build-up, urban build-up, suburban subdivision, transportation/utilities/communications and military reservations. These land use activities are further divided into subcategories as illustrated in Table 9-1. Each land use subcategory is defined and major natural system impacts identified in this section.

AGRICULTURAL

The category of agricultural land use may be broadly defined as land used primarily for production of food and fiber, including cropland, pastureland, commercial forests, horticultural gardens and the like. Agricultural uses generally have modifying impacts on the natural environment, usually lower in intensity than built-up areas.

Rangeland

Definition. Rangelands are grazing areas for domesticated livestock and are predominantly composed of natural vegetation of grasses, grasslike plants, forbs, and shrubs. Over time the plant and animal species composition may become markedly changed from ungrazed grasslands. Rangelands may have steep slopes in coastal areas. Grazing of dairy stock generally occurs on slopes less than 20 percent; grazing of other stock may occur on slopes of up to 50 percent or more.

Impacts. Moderate grazing pressure tends to favor annual rather than perennial grasses and herbs and may prevent growth of trees and some shrubs. Heavy grazing may allow invasion by shrubs and favors the growth of thistles and similar herbaceous plants.

Trampling soil compaction and other habitat disturbance may damage or eliminate biotic communities of concern through the alteration of abiotic elements of the habitats.

Table 9-1. Land Use Activities

Major Categories	Subcategories	
AGRICULTURAL		Rangeland
		Pasture
		Feedlots
		Cropland
		Orchards
		Commercial Forestland
RECREATIONAL		Wilderness Roadless Areas
		Parks and Beaches
		Second Home and Cabin Development
NON-URBAN BUILT-UP		Rural Residential
		Agricultural/ Industrial Logging Camps L Mines and Mine Tailings
URBAN	[Small Town Large Urban Area Suburban]	Residential
		Commercial and Services
		Institutional
		Industrial
		Parkland and Open Space
		L Vacant
TRANSPORTATION/ UTILITIES/ COMMUNICATIONS	[Corridors Facilities]	Highways, Roads
		Power Transmission Lines and Pipelines
		Utilities
		Ports, Harbors, Marinas
		Airports
MILITARY RESERVATIONS		

Livestock concentrating at streams, seeps and marshes can destroy habitats for common as well as threatened wildlife species through trampling of area, muddying of water, heavy grazing of adjacent vegetation. Disturbance of ground dwelling or nesting species by livestock is possible.

Livestock concentrations can also damage stream banks, accelerate erosion and sedimentation and cause problems of water pollution from animal wastes. Accelerated erosion is most likely in upland areas. Harmful impacts may be expected on water quality from runoff into bays and estuaries from animal wastes, accelerated erosion and sedimentation.

Pasture

Definition. Pasturelands are domesticated species of grasses or other vegetation eaten by grazing animals or harvested for feed. Pastures are generally enclosed areas, may be irrigated, are often used within a crop rotation regime, and are likely to be found in gradually sloping areas.

Impacts. Depending on the intensity of cultivation, introduction of pastureland domesticated plant species is likely to eliminate or reduce available habitat for many wildlife species through the conversion of plant communities. Other impacts are similar in nature to croplands, (described below) and will vary in intensity depending on crop rotation, irrigation, location and intensity of grazing. These harmful impacts may include water quality impacts from pesticide and herbicide use and drainage, lowering of the groundwater table or surface water for irrigation, and drainage and filling of wetlands.

Feedlots

Definition. Feedlots are specialized hog, beef, poultry and fur-bearing animal enterprises. They are usually restricted to relatively small areas and often are built-up with buildings, fencing, access paths and waste-disposal areas. Feedlots may be part of a larger livestock enterprise, including rangeland, pastureland and croplands for feed production.

Impacts. Feedlots produce large quantities of animal waste, which may be used for fertilizers. Impacts of feedlot operations may include accelerated erosion and sedimentation of wetlands, water pollution from runoff or percolation of animal wastes, and elimination or damage to wildland vegetation (habitats) and animal species.

Cropland

Definition. Croplands are irrigated or dry areas of plants including grains, vegetables and fruits cultivated for agricultural produce.

Impacts. Croplands cause replacement of natural vegetation with domesticated and pest species and the elimination or reduction in available habitat for wildlife species. Improvement in habitat for some species (i.e. pheasants, some waterfowl, s hawks, raccoons) may also result, depending on the type of crops and agricultural practices. Cropland uses may also produce offsite impacts, including the introduction of herbicides and pesticides into the local environment and food webs. Irrigation impacts on local hydrology can include surface water diversions and lowering of the groundwater table, deterioration of water quality of local surface waters from agricultural drainage, accelerated erosion and resulting sedimentation of waterways. Development of cropland may require drainage or filling of wetlands and removal of native vegetation.

Orchards

Definition. This category includes orchards, groves, vineyards, bush fruit and horticultural areas which produce various fruits, nuts and berry crops. Horticultural areas include nurseries and floricultural areas, which may be open or under glass.

Impacts. Natural system impacts in this category are similar to those of croplands.

Commercial Forestland

Definition. Forest lands, private or public, are used predominantly for commercial logging. Public commercial forestlands are found mainly within national forests. Cutover lands refer to forestlands previously logged at least once and in process of regeneration; old growth lands refer to forestlands never logged. The most valuable commercial species along the coast are softwoods (conifers), especially Douglas fir and redwood. National forestlands are generally, multiple-use areas, managed for grazing, mining, recreation, wilderness preservation, wildlife enhancement, cultural preservation and logging; however, various uses often conflict.

Impacts. Adverse impacts include wildlife habitat disturbance, native plant species interference, soil nutrient depletion, accelerated erosion impacts associated with road building, sedimentation of stream beds and disturbance of fishery habitat and salmon spawning gravel beds. Water quality deterioration may potentially impact agricultural water uses. Impacts generally are of greater magnitude on steeper slopes.

RECREATIONAL

Wilderness or Roadless Areas

Definition. These areas are generally remote scenic and mountainous regions with minimal human disturbance. The predominant human activities are recreational, including hiking, camping, fishing, and hunting. Many areas are officially designated as Wilderness Areas by the U.S. Forest Service or proposed for wilderness designation or for further planning under Roadless Area Review and Evaluation (RARE II). Potentially competing uses such as logging, mining, and grazing are generally banned or restricted in these areas.

Impacts. Minimal disturbance usually occurs in these areas. Impacts include trampling from hikers or equestrians, forest fire risk, erosion from construction of trails, and littering.

Parks and Beaches

Definition. Parks and beaches in rural areas vary greatly in intensity of development and disturbance. Generally, impacts on natural systems are in proportion to visitor use. Low-intensity parks and beaches are characterized by minimal development (unpaved or roadside parking areas, trails, signs, primitive campgrounds) and, usually, where access is controlled or difficult, light use. High-intensity parks and beaches may include developed campgrounds (fireplaces, showers, landscaping), cabins, off road parking areas, boat landing facilities, visitor centers, and shops.

Impacts. Potential harmful impacts include dune and other vegetation disturbance, landscape modification in parking areas and developed campgrounds, deleterious runoff from parking areas, vegetation trampling, erosion and litter.

Second Home Cabin Development

Definition. These uses range from low-intensity cabin development in more remote and steeper areas of the coast to second home development and recreational subdivisions. The latter are typically higher priced and higher density (1 unit per acre or more) recreational residences often located along the coastal plain, near towns, and along coastal highways. Recreational subdivisions may be characterized by suburban-like infrastructure. Older second home communities (including new units in older developments) and all scattered developments are likely to be serviced by wells and septic systems.

Impacts. Landscape alterations including roads, curbs, and lawns are likely. Erosion potential on steep slopes is possible. Waste and sewage disposal complications may be expected, especially with septic tanks or adjacent to steeper slopes. Other impacts include natural vegetation and wildlife disturbance, and groundwater quantity or surface water diversion impacts.

NONURBAN BUILDUP

This category includes isolated rural residences; rural hamlets and villages not large enough to have significant commercial development; and built-up rural, industrial, extractive, processing, and storage activities including lumber mills, food processing plants, mines, and silos.

Residential

Definition. Rural residences are generally low-density development along major or secondary highways and are often associated with agricultural activities. Included in this subcategory are farmsteads, small holdings, and rural single-family homes.

Impacts. impacts generally include landscape alteration, replacement of natural vegetation and wildlife with domesticated varieties, groundwater quantity reduction,

groundwater quality deterioration, sewage and waste disposal problems, and additional road building and associated erosion impacts, especially on steep slopes.

Agricultural/Industrial

Definition. This subcategory is characterized by rural industrial developments along main highways or secondary routes. These are generally processing facilities for rural economic activities, including lumber mills, paper mills, dairy and food processing plants, silos and other storage facilities, and mineral processing operations such as sand and gravel plants and cement plants.

Impacts. Effects on natural systems may include harmful air quality, water quantity and water quality impacts, landscape alterations, and solid waste disposal problems.

Logging Camps

Definition. Logging camps are temporary campgrounds set up for logging operations. They are nearly obsolete due to improved access roads to coastal forestlands.

Impacts. Harmful impacts on natural systems include campfire, littering, waste and sewage disposal, and erosion.

Mines and Mine Tailings

Definition. This subcategory includes ongoing extractive activities and historic extraction areas, including mines and mine tailings. Along the coast, these include sand and gravel operations, stone quarries, diatomite mines, limestone quarries, oil wells, and placer mines.

Impacts. Harmful impacts may include potentially significant and long-lasting land alterations, accelerated erosion, and potentially serious water quality impacts resulting from mining operation runoff.

URBAN

Urban built-up land comprises areas of intensive use with much of the land covered by structures, roadways, domesticated vegetation and parking lots. Included in this category are large urban areas and small town residential, commercial, institutional, industrial, and parkland uses. Cities and towns range greatly in size and intensity of development.

Urban Residential

Definition. Small town residential areas are characterized by older housing surrounding the town center, generally including some older small multi-unit residences mixed in with single-family units. Density may range from 1 unit per acre to perhaps as much as 12 units/acre, with vacant spaces not uncommonly found near centers of some coastal towns. Relatively high-density single-family new suburban-style developments (4 to 6 units/acre) may be found just beyond the core of some towns, with low-density single-family (1 to 3 units/acre), found in developed and developing areas beyond. Mobile home parks are generally found along major arterials at the outskirts of intensive development. Large multi-unit dwelling areas or institutional residential complexes include nursing homes and motels.

In large urban areas multi-unit structures are more prevalent than in towns. Mixed multi-unit and single-family areas are common. Low-density single-family residences range from 3-4 units per acre; high-density areas range from 5-10 units per acre. Large multi-unit structures (megastructures, high-rises) may reach a density of 50-100 units per acre. Rehabilitation of older, decaying inner city structures by professional redevelopers (known as "gentrification") has become popular. Institutional residential structures include nursing homes, college dormitories, hospital dormitories, hotels and motels and other transient lodging. Mobile home parks are found at outskirts.

Suburban subdivision residences are generally of post-World War II construction. Single-family areas may range from less than 2 units per gross acre (low-density) and

detached residences to 8 units/acre (high-density) townhouses and court clusters. Multi-unit structures in coastal communities range from 10 to 12 units/acre and are less common than in more urbanized areas where land is not as readily available.

Impacts. Harmful impact to natural systems are similar in type but vary in scale for small towns, suburban subdivisions and large urban areas. They include land alteration, near elimination of natural wildlife and vegetation and replacement by domesticated varieties and pests, groundwater and surface water diversions, water quality deterioration, air quality deterioration, sewage and solid waste disposal concerns, and accelerated erosion in coastal areas.

Urban Commercial and Services

Definition. In small towns, the downtown commercial center is often a strip development on main arterials, with additional development extending to adjacent blocks. Shopping centers are located at outskirts or adjacent to newer single-family development. Additional commercial strips along major arterials and other small commercial developments may exist depending on size of the town.

In large urban areas downtown commercial area may cover many square miles, and include high-density office structures, mixed use residential and commercial development, parking areas and structures, and multi-unit residences. Major arterials may be characterized by intensive strip development and small commercial areas at some intersections. Shopping centers may be found in some more recently developed areas.

In suburban subdivisions, shopping centers often serve the function of downtown centers with business and financial activities locating in and around them. Strip development and smaller commercial areas are often found in older suburban neighborhoods.

Impacts. Harmful impacts to natural system by commercial development in urban areas are very similar in type to urban residential impacts, including significant landscape alterations, replacement of natural vegetation and wildlife with domesticated varieties, water supply and quality deterioration, air quality deterioration and sewage and solid waste disposal problems. Vegetation may occur less in commercial areas than in residential areas.

Urban Institutional

Definition. Institutional uses include schools, hospitals, government buildings, churches, libraries, cemeteries, college campuses.

Impacts. Harmful impacts to natural systems are very similar to urban residential and commercial.

Urban Industrial

Definition. Industrial uses in urban areas include light industry (light manufacturing, food or cheese processing, fish processing, electronics, fabrics, etc.) or heavy industry (cement plants, oil refineries, paper mills, etc.).

In small towns, heavy industries are likely to be found at outskirts of the town, or in special industrial zones or parks. Zoning for light and heavy industry is also common in large urban areas. Industrial subdivisions are found in some suburban areas which attract industry with special tax and service incentives.

Impacts. Harmful impacts to natural systems of industrial uses may include significant air and water quality deterioration, water quantity reductions and solid waste disposal or noise problems in addition to landscape alterations and harmful impacts on natural vegetation and wildlife. In industrial parks, zones and subdivisions, impacts (noise, landscape alterations) may be confined separating them from residential or commercial areas. Other impacts (air and water pollution, water quantity) may affect wider areas.

Urban Parkland/Open Space

Definition. This category includes parks, recreational areas, highway buffer strips and other areas generally landscaped for urban uses. They may be found in small towns, large urban areas or suburban subdivisions. Land costs, planning and later development have allowed suburban subdivisions to take advantage of modern open space concepts.

Impacts. Harmful impacts to natural systems include landscape alteration, substitution of natural vegetation and wildlife with domesticated varieties, and littering.

Urban Vacant

Definition. In small towns, vacant land may occur in undeveloped portions of the town, among existing development (empty lots), or in fields at outskirts of the town.

In large urban areas and suburban subdivisions, vacant land may be found 1) at the outskirts of large urban areas, 2) where leapfrog development has taken place, or 3) in areas where dilapidated structures have been removed.

Vacant areas at the outskirts of cities and towns may be in transition from agricultural or other uses to urban uses.

Impacts. Vacant areas may exhibit land alteration, replacement of natural vegetation and wildlife, and littering.

TRANSPORTATION/UTILITIES/COMMUNICATION

Uses in this category may be subdivided into two major groups, corridors and facilities. Corridors include highways and roads, railroads, power transmission lines and pipelines. Facilities include utilities (power plants, sewage treatment plants, water purification plants) and ports, harbors, marinas, and airports.

Highways, Roads, Railroads

Definition. This subcategory includes: major transportation highways, either limited access multi-lane divided highways of the interstate or state system or two to four lane primary well-graded, uncontrolled access highways of the state system; secondary highways, generally two-lane paved connector or access highways of the state or county system; rural roads, local, often unpaved, commercial or residential access roads including logging roads, recreational service roads. Railroads are also included in this subcategory.

Impacts. Harmful impacts to natural systems include landscape alterations, losses of native vegetation and wildlife, air quality degradation (vehicle exhaust), accelerated erosion and associated stream sedimentation. Access created by road construction tends to induce rural or urban development.

Utilities

Definition. This subcategory includes power plants (hydroelectric, geothermal, nuclear, oil, fossil fuel), water storage facilities (water tanks, reservoirs), water purification plants, ^{sewage} treatment plants, solid waste treatment plants, communication transmission facilities (radio and television towers), power transmission facilities.

Impacts. Power plants often have large water requirements (particularly nuclear, oil-burning, fossil fuel, hydroelectric power plants); air quality impacts (oil, fossil fuel); waste disposal problems (nuclear, fossil fuel) and potential for disaster (hydroelectric, nuclear). Utilities Facilities in general tend to have adverse aesthetic and land alteration impacts.

Power Transmission Lines and Pipelines

Definition. This subcategory includes overhead or underground transmission lines and oil, natural gas, water and slurry pipelines, both at grade and underground, covered or uncovered.

Impacts. Harmful impacts to natural systems include land alteration, erosion, vegetation and wildlife losses, and viewshed alterations for overhead transmission lines,

Airports

Definition. Airports range in size, type (commercial, private, military), activity, and support facilities.

Impacts. Major harmful impacts to natural systems include landscape alteration, air quality deterioration, and water supply diminishment.

Ports, Harbors, and Marinas

Definition. Marine vessel docking facilities vary greatly in intensity of development and size of facilities. Marinas are generally simple wooden docks and mooring equipment sufficient for small and moderate-sized recreational vessels and services (fuel, bait). Harbors may be characterized as moderately-sized docking and mooring facilities sufficient for small and medium-sized commercial activity including commercial fishing boats, lumber export, oil and gas receiving facilities, and recreational vessel activity. Harbors may include warehouses, supply facilities, fish canning facilities, and restaurants. Ports usually are associated with major urban area marine shipping and receiving facilities, characterized by large ships, docks, major storage facilities, mechanized loading and unloading equipment and extensive shore land use requirements for railroad spurs, truck loading facilities, offices, restaurants and service facilities.

" Harmful impacts to natural systems may include shore and seabed alteration ranging in intensity from embankment construction to major dredging and landfill. Harmful impacts to water quality, marine habitats, terrestrial vegetation and wildlife, and potentially serious effects on wetlands and estuaries are possible.

MILITARY RESERVATIONS

Military reservations vary greatly in type, intensity of development, and size. They include radar stations on a few acres and air force bases covering many thousands of acres. Naval bases generally resemble ports in appearance and activity. Military lands may contain rangeland which is leased to private ranches. Development may be similar to small town residential and commercial development, include underground shelters or concrete air strips. Military reservations may contain wilderness areas or may be located in a large urban areas and contain open space land. Harmful impacts vary by type of military activity (see rangeland, rural, residential, institutional, residential, commercial, and wilderness impact discussions). A primary effect of all military reservations is the limitation of public access to coastal areas.

CHARACTERISTIC FAUNA AND FOOD WEBS

Although man's activities alter the floral and faunal composition and abundance on lands under his manipulation, "wild" plants and animals usually continue to exist. To show the interrelationships among species that are supported in the man-altered habitats, characteristic fauna lists and general and example food webs have been prepared for urban and agricultural land uses. These lists and diagrams utilize the same format as developed for the terrestrial ecosystem (Chapter 8 of this volume) discussions of habitats.

Characteristic mammals of agricultural and urban areas are taken from Ingles(1965). Small (1974) provides information on common California birds in agricultural and urban settings. Common or characteristic reptiles and amphibians are derived from Stebbins (1966). Species listed below, although characteristic of agricultural and urban environments, may not be found exclusively in these cover types. Abbreviations (e.g., LH, TIE, TA), following species common names refer to types of consumers in the general food webs. for these cover types,.

Table 9-2. Characteristic Fauna of Agricultural Lands ¹

Mammals	Birds	Reptiles and Amphibians
Black-tailed deer (LH)	western kingbird (TIE) (SFE)	California slender salamander (TA)
Black-tailed hare (SH)	Brewer's blackbird (TIE) (SFE)	Western toad (TA)
Coyote (LC) (TI)	Starling (TIE) (SFE)	Pacific treefrog (TA)
Raccoon (SE) (SC) (TI)	Common crow (SFE) (TIE) (CB) (SB)	Western fence lizard (TR)
Striped skunk (SC) (TI)	Yellow-billed magpie (TIE) (SFE) (CB) (SB)	Western skink (TR)
Broad-handed mole (TI)		Racer (TR)
Pocket gopher (SH)	American kestrel (CB) (TIE) (SB)	Gopher snake (TR)
Beechey ground squirrel (SE) (SH) (TI) (SC)	White-tailed kite (CB) (TIE) (SB)	Common garter snake (TR)
Western harvest mouse (SE) (TI)	Red-tailed hawk (CB) (SB)	western terrestrial garter snake (TR)
Deer mouse (SE) (TI)	Turkey vulture (SB)	
California meadow mouse (SH)	Brown-headed cowbird (SFE) (TIE)	
	Mourning dove (SFE)	
	Ring-necked pheasant (SFE) (TIE)	
	Killdeer (TIE) (MCE) (SFE)	
	Horned lark (S'FE) (TIE)	
	Western meadow lark (TIE) (SFE)	
	Barn owl (CB) (TIE)	
	Barn swallow (TIE)	
	Lesser goldfinch (SFE) (TIE)	
	Canada goose (SFE) (VE)	
	American wigeon (SFE) (VE)	
	Long-billed curlew (SFE) (TIE)	

¹See Figure 9-1 for definition of abbreviations.

Table 9-3. Characteristic Fauna of an Urban Environment. ¹

Mammals	Birds	Reptiles and Amphibians
Norway rat (SE) (SC) (TI)	House finch (SEE) (TIE)	California slender salamander (TA)
Black rat (SE) (SC) (TI)	House sparrow (SFE) (TIE)	Western toad (TA)
House mouse (SE)	Skiing (TIE) (SFE)	

Table 9-3 (continued)

Raccoon (SE) (SC) (TI)	White-crowned sparrow (SFE)	Pacific treefrog (TA)
Striped skunk (SC) (TI)	Rock dove (SEE)	Western fence lizard (TR)
Pocket gopher (SH)	Mourning dove (SFE)	Ringneck snake (m)
Broad-handed mole (TI)	Scrub jay (SFE) (TIE) (CB) (SB)	Gopher snake (TR)
Domestic cat (SC)	Mockingbird (SFE) ('Tin)	Common gas snake (TR)
	Dark-eyed junco (SFE) (TIE)	Alligator lizard (TR)
	Common flicker (TIE) (SFE)	Western rattlesnake (TR)
	American robin (SFE) (TIE)	
	Allen 's hummingbird (NE) (TIE)	
	Chestnut-backed chickadee (TIE) (SFE)	
	varied thrush (SFE) (TIE)	
	Hermit thrush (m) (SFE)	
	American kestrel (CB) (IE) (SB)	

¹See Figures 9-1 to 9-4 for explanation of abbreviations.

In the agricultural environment, primary consumers of tree, shrub and herbaceous foliage include mammals, such as the black-tailed deer and pocket gopher; and numerous phytophagous insects, such as the field cricket, grasshopper and cabbage butterfly (see Figure 9-1 and 9-3). Seed and fruit production is consumed by mammals, such as the beechey ground squirrel and deer mouse; and birds, such as the mourning dove, ring-necked pheasant and lesser goldfinch. Important secondary and tertiary consumers include insectivores, such as the broad-handed mole, western toad, and Brewer's blackbird; and carnivores, such as the striped skunk, coyote, common garter snake, and white-tailed kite. The common crow is an example of a scavenging bird. The raccoon functions primarily as an omnivore in agricultural lands, consuming seeds, fruits, insects and small mammals, reptiles and amphibians. Man plays a significant role in the agricultural land ecosystem as an omnivore, consuming the products of his agricultural efforts as well as various game mammals and birds that are attracted to croplands.

In the urban environment, where native vegetation has often been replaced by ornamental, nonnative plants, the resulting food web is less complex and dominated by species that are highly adaptable to man's environment. Primary consumers of tree, shrub and herbaceous foliage are primarily phytophagous insects and their larva (see Figures 9-2 and 9-4). Seeds and fruits, produced by vegetation are consumed by mammals, such as the house mouse and raccoon; and birds, such as the house finch, house sparrow and rock dove. Important secondary and tertiary consumers include species such as the Norway rat, western toad, Allen's hummingbird (also a primary consumer), and common flicker, which consume insects as all or part of their diet; and species, such as the American kestrel, gopher snake and domestic cat, which are primarily carnivores in the ecosystem. The scrub jay is a common scavenging bird. A number of species act as omnivores in the urban environment, including the raccoon, Norway and black rats, and scrub jay. Man is generally not a consumer in the food web.

Characteristic fauna and resulting food webs for other land use types, such as recreational, military reservations, and nonurban build up would reflect surrounding habitat types, with the exclusion of species that are highly sensitive to human disturbance. Transportation/utilities/communication land uses would in most cases support fauna and food web characteristic of the urban environment.

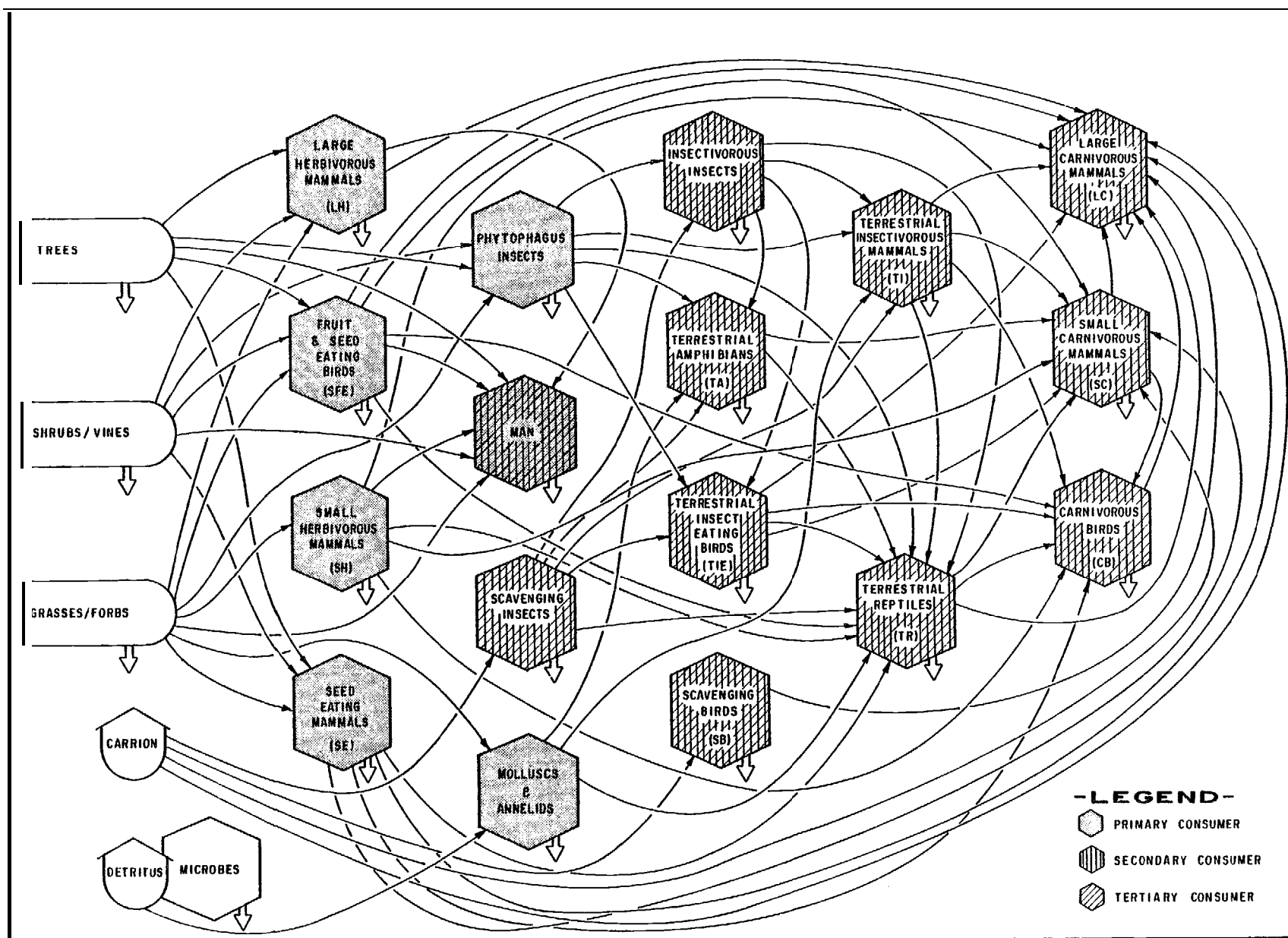


Figure 9-1. General Food Web - Agricultural Lands

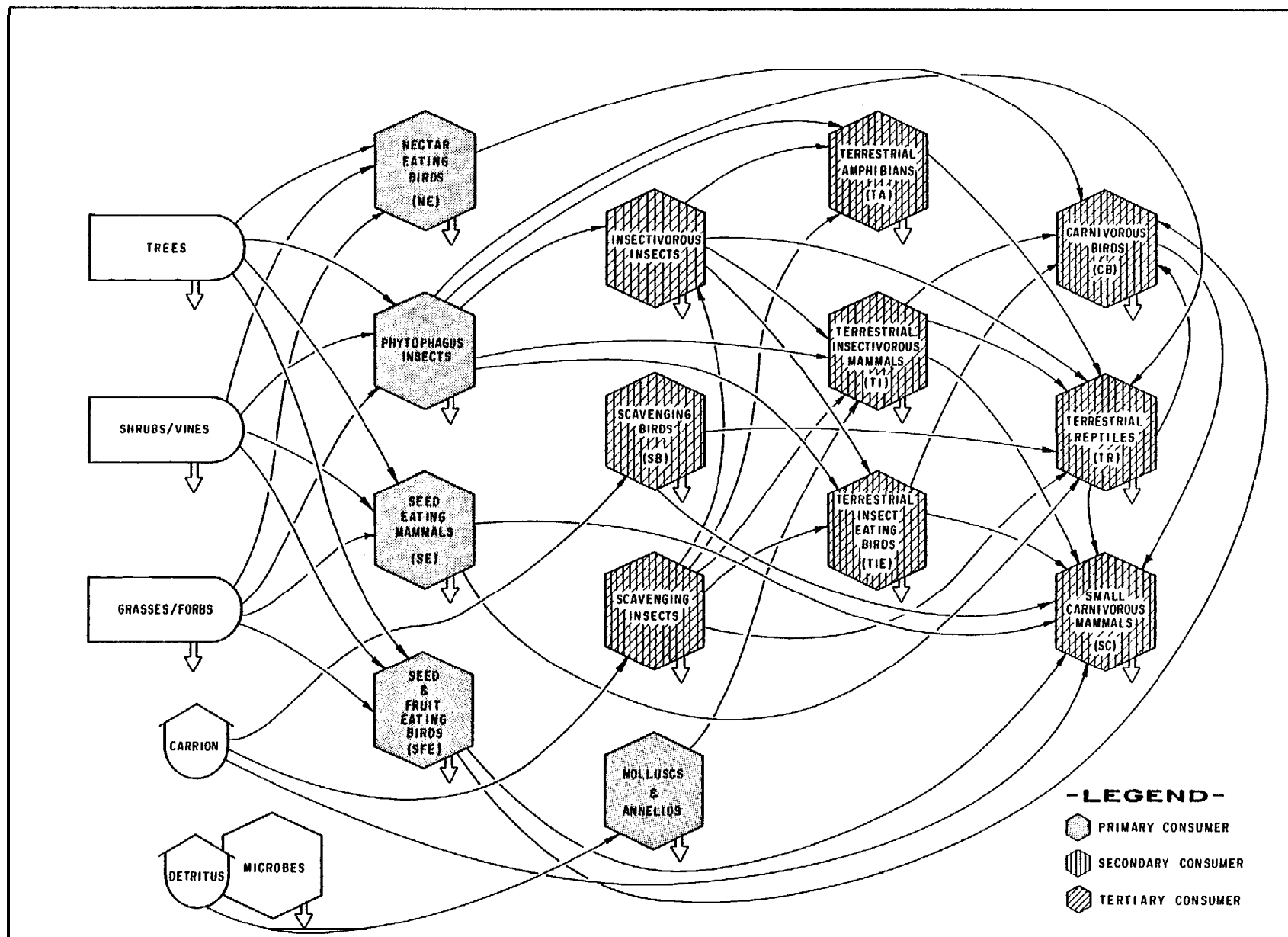


Figure 9-2. General Food Web - Urban

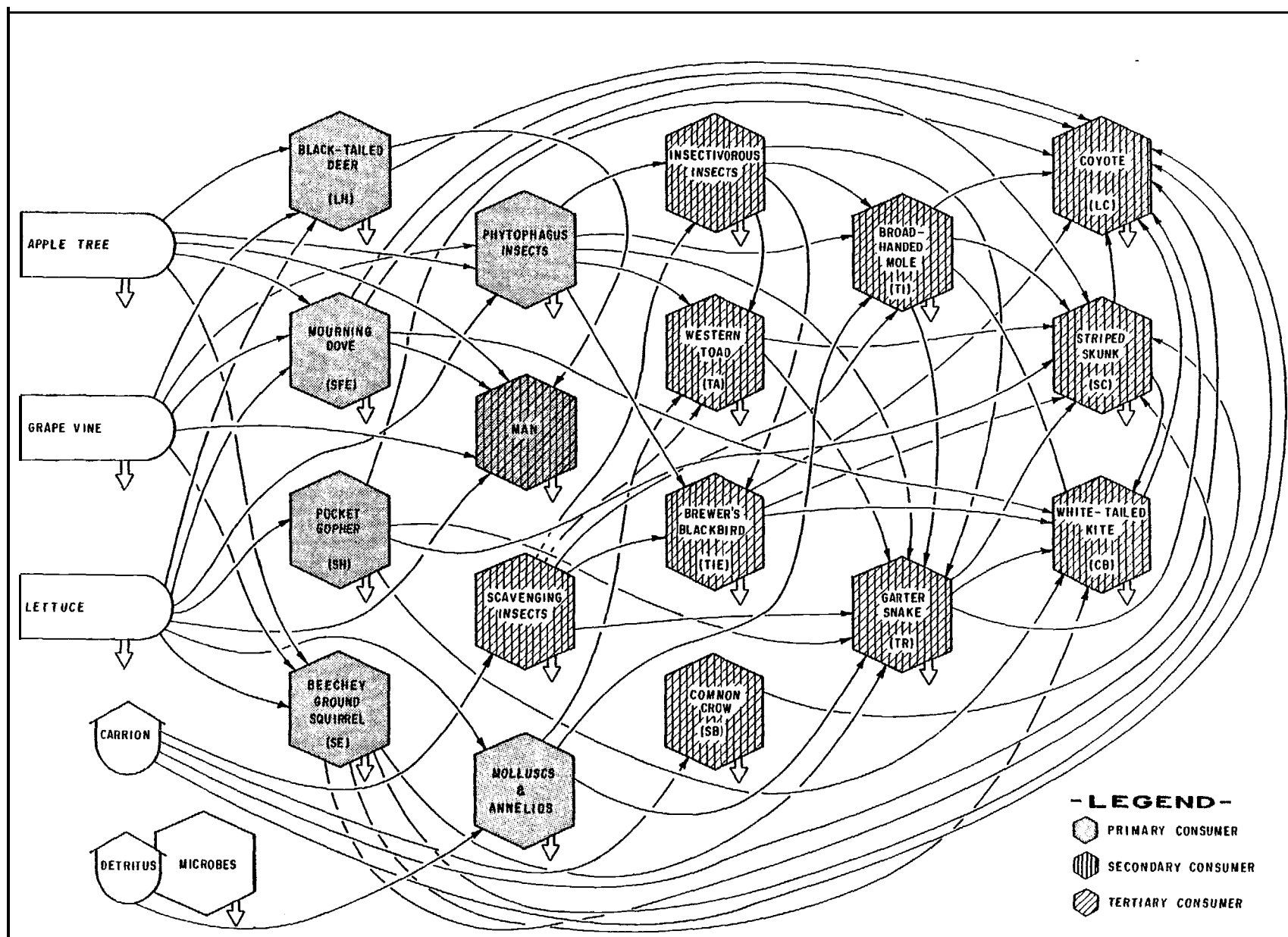


Figure 9-3. An Example of an Agricultural Land Food Web

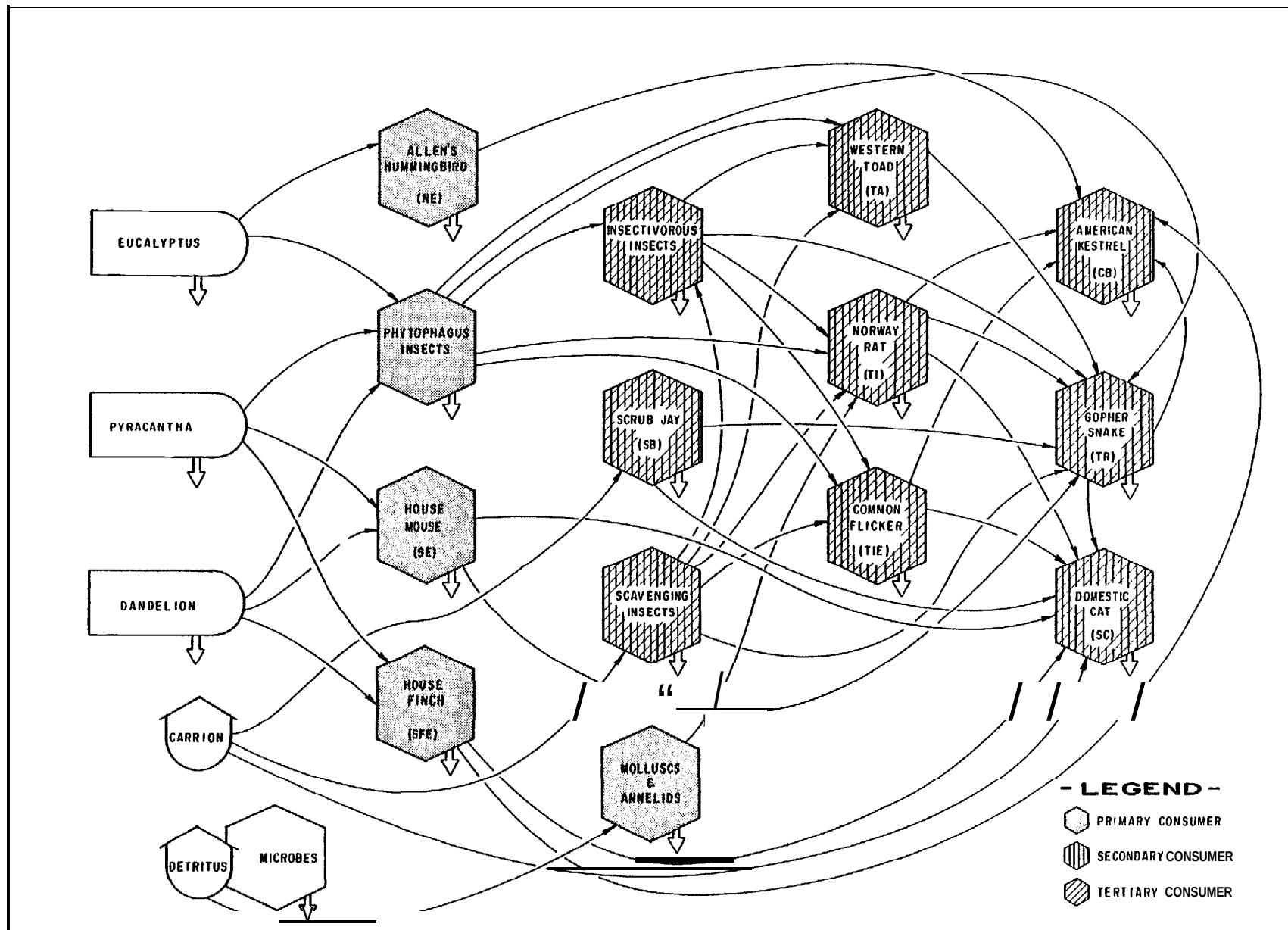
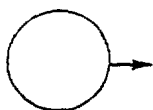


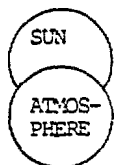
Figure 9-4. An Example of an Urban Food Web

Appendix A

GLOSSARY OF SYMBOLS



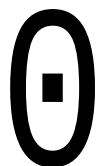
Source of energy or matter external to the system or portion of a system being modeled. This symbol, and many of the others here, are based on H. T. Odum (1971) .



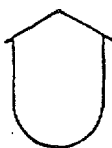
Atmospheric source of energy and matter, including solar radiation and various atmospheric disturbances.

D

Producer: plant or plant community.



Converter: animal, microbe, or community of animals or microbes; can be consumers or decomposers or both.



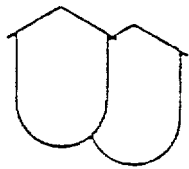
Storage compartment or substrate. Note: Symbol for storage compartment or substrate may be used within a larger storage compartment for discrete materials that are not dispersed throughout the compartment.



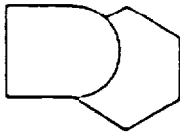
Effects of socio-economic activities on specific ecosystem components.



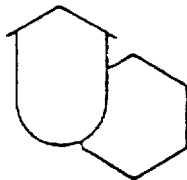
Socio-economic activity. Used to represent the conventionally named human activities (e.g., logging, road construction).



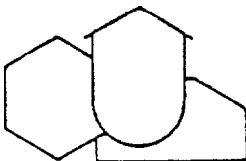
Multi-compartment storage.



Biological community: producers and converters. The boundary between the compartments may be omitted and their relative positions may vary. "



Substrate-converted combination, such as the detritus-decomposer union, where the distinction between the two is not essential for the system being modeled.



Composite human community and activity: a combination of conversion, storage, and socio-economic functions.



To detritus. Indicates a flow of material and energy to the nonliving compartment. Combines mortality and flow to detritus, thus simplifying models.



Boundary for the specific ecological unit being modeled.



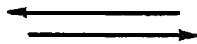
Flow path for energy or matter or dollars.



Flow path for regulating influence or effect
(i.e., net flow of energy, matter, or dollars) .



Materials in storage compartments that are
distributed homogeneously.



Directional flows.



Converging or combining flows.



Diverging or branching flows.



Switch. Incoming flow is divided into two or
more different paths by a primary regulating
process, or goes one way or another depending
on the regulating factors.



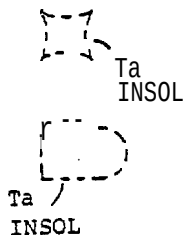
One-way valve. Flow in one direction along a
single path occurs through and is controlled
by a primary regulating process, and depends
on its secondary regulating factor.



Two-way valve. Flow in two directions along a single path occurs through and is controlled by a primary regulating process and its secondary regulating factors. Flow can go in either or both directions. e.g., materials in and out. This symbol often represents a complex group of interacting processes.



Sequential valve. Flow occurs through and is regulated by a series of primary regulating processes acting in sequence with little or no interaction. (Previous two valves are used for consequential or complex interacting processes.)



Secondary regulating factor. The controlling factors that regulate a primary regulating process (represented by either a switch or a valve, as above). Examples illustrated here represent the regulating factors air temperature (Ta) and insolation (INSOL).



Cyclical or periodic flow from source, such as tides, daily and seasonal cycles of the sun.



Boundary between ecosystem model areas (physical-chemical, biological, socio-economic). Locate at bottom of the page.



Emphasizes important processes.

PERSONAL CCM4UNICATIONS

- AMES, Jack. September 17, 1979. Biologist. Marine Resources Branch, California Department of Fish and Game, Monterey.
- Anderson, Carl. November 2, 1979. Assistant District Superintendent. California Department of Parks and Recreation, Eureka.
- Arnkopf, James. October 31, 1979. Supervisor of System Operations, Marin Municipal Water District, Corte Madera.
- Arnold, Richard. October 11 and November, 1979. Graduate Student. Department of Entomology, University of California, Berkeley.
- Baker, Phil. November 8, 1979. Fisheries Biologist. California Department of Fish and Game, Yountville.
- Bechtel, Jack. November 1979. Planner. California Department of Parks and Recreation, Sacramento.
- Bendix, Gilbert. November 2, 1979. Manager of Suburban Operations. San Francisco Water Department, San Francisco.
- Benz, Carl. September 17, 1979. Wildlife Biologist. Endangered Species Office, U. S. Fish and Wildlife Service, Sacramento.
- Borgwardt, Rick. December 20, 1979. Senior Planner. Marin County Planning Department, San Rafael.
- Bourke, Robert. May 28, 1980. Professor. Naval Post Graduate School, Monterey.
- Boyd, Greg. January 9, 1980. Caltrans.
- Bradshaw, Ted. October 15, 1979. Assistant Professor. Institute of Governmental Studies, University of California, Berkeley.
- Briggs, K. T. November 8, 1979. Professor. University of California, Santa Cruz.
- Britten, Lynn. October 26, 1979. Soil Conservationist. USDA, Soil Conservation Service, Santa Cruz.
- Brode, John. September 18, 1979. Fisheries Biologist. California Department of Fish and Game, Rancho Cordova.
- Broenkow, William. December 21, 1979. Professor. Moss Landing Marine Laboratories, Moss Landing.
- Buchanan, Robert. July 1, 1978. Professor. Department of Cell Physiology, University of California, Berkeley.
- Burge, Richard. December 5, 1979. Associate Marine Biologist. California Department of Fish and Game, Morro Bay.
- Burley, William. October 13, 1979. Coordinator. California Natural Diversity Data Base, the Nature Conservancy, Sacramento.
- Cabaluna, Gene. December 20, 1979. Planner. Monterey County Planning Department.
- Cameron, A. December 1, 1979. Ph.D. Invertebrate Zoologist. University of California, Santa Cruz.
- Chappell, Paul. January 14, 1980. Fisheries Biologist. California Department of Fish and Game, Monterey.

Chinberg, Susan. October 7, 1979. Research Assistant, Geology. Moss Landing Marine Laboratory, Moss Landing.

Clark, Lee. November 2 and 9, 1979. Supervising Ranger. California Department of Parks and Recreation, Santa Cruz.

Cokeley, Peter. November 2, 1979. President. Carmel Valley Chamber of Commerce.

Collins, Ed. December 18, 1979. U. S. Fish and Wildlife Service, Sacramento.

Coots, Millard. December 19, 1979. Fisheries Biologist. California Department of Fish and Game, Redding.

Dahlstrom, Walt. November 16, 1979. California Department of Fish and Game, Menlo Park.

Davis, Paul. December 27, 1979. Lawrence Livermore Laboratory, Livermore.

Dean, Harry. January 21, 1980. Chief, Park Planning and Management. County of San Mateo, Parks and Recreation.

Dollahite, Ned. December 21, 1979. Chief, Wildlife Protection Branch. California Department of Fish and Game, Sacramento.

Dowhan, Joseph. January 5, 1980. Assistant Field Supervisor. Endangered Species Office, U. S. Fish and Wildlife Service, Sacramento.

Doyen, J. T. November 1979. Department of Entomology, University of California, Berkeley.

Eimoto, Dennis. November 2, 1979. Assistant Fishery Biologist. California Department of Fish and Game, Monterey.

Emerson, Ray. November 9, 1979. Biologist. Bureau of Land Management, Anchorage.

Emrie, Bill. November 8, 1979. California Department of Parks and Recreation, Sacramento.

Engle, J. December 11, 1979. Ph.D. Invertebrate Biologist. Catalina Marine Lab.

Fadlallah, Y. December 1, 1979. Invertebrate Zoologist. University of California, Santa Cruz.

Farrel, 3. November 7, 1979. Coastal Planner. Monterey County Planning Department.

Farrow, Bill. January 8, 1980. Monterey County Planning Department, Salinas.

Foster, Michael. December 15, 1979. Associate Professor, Marine Biology. Moss Landing Marine Laboratory, MOSS Landing.

Garrison, David L. December 1, 1979. Ph.D. Biological Oceanographer. University of California, Santa Cruz.

Gorman, Dennis. October 31, 1979. Assistant City Engineer. Department of Public Works, Monterey.

Gould, Gordon. January 2, 1980. Wildlife Biologist. California Department of Fish and Game, Nongame Wildlife, Sacramento.

Gustafson, John. October 2, 1979. Wildlife Biologist, California Department of Fish and Game, Sacramento.

Hagen, K. S. November 1979. Division of Biological Control, Department of Entomology, University of California, Berkeley.

Hardin, Dane. November 9 and December 14, 1979. Marine Biologist. Kinnetic Laboratories, Santa Cruz.

Harlow, D. December 3, 1979. Wildlife Biologist. Endangered Species Office, U. S. Fish and Wildlife Service, Sacramento.

Harper, Harold. January 2, 1980. Wildlife Biologist. Upland Game, California Department of Fish and Game, Sacramento.

Harrold, Chris. December 15, 1979. Ph.D. candidate, biology. University of California, Santa Cruz.

Hazeltine, Art. November 19, 1979. Associate Marine Biologist. California Department of Fish and Game, Marine Culture Laboratory, Long Beach.

Hofsheier, Gary. Octanes 31, 1979. Engineer Aide. California American Water Company, Carmel Valley.

Holsting, Joe. January 9, 1980. Mendocino County, Ukiah.

Hunter, Brian. January 2, 1980. Wildlife Biologist. Big Game Wildlife, California Department of Fish and Game, Sacramento.

Johnston, James. November 1, 1979. Base Agronomist. Vandenberg Air Force Base, Vandenberg.

Jurek, Ron. October 2, 1979. Wildlife Biologist. California Department of Fish and Game, Sacramento.

Jurick, Fred. January 9, 1980. Marine Advisor. Humboldt State University, Marine Extension.

Kastendiek, J. December 14, 1979. Ph.D. Invertebrate Biologist, University of California, Santa Cruz.

Kelly, Randolph. December 20, 1979. Marine Biologist, Resource Preservation and Interpretation Division. California Department of Parks and Recreation, Sacramento.

Kitayama, C. Y. November 1979. Division of Biological Control, Department of Entomology Control, University of California, Berkeley.

Knight, Alan. January 15, 1980. Department of Water Science and Engineering, University of California, Davis.

Knox, L. December 1, 1979. Planner. Santa Barbara County Planning Department, Santa Barbara.

Kolhorst, Dave. September 1979. Fisheries Biologist. California Department of Fish and Game, Stockton.

LaFauce, Don. September 27, 1979. Fisheries Biologist. California Department of Fish and Game, Eureka.

Lagle, Robert. November 15, 1979. Planner. California Coastal Commission, San Francisco.

Lawn, Art. October 25, 1979. Manager. Rowdy Creek Fish Hatchery, Humboldt County.

LeBoeuf, Burney. December 10, 1979. Professor. University of California, Santa Cruz.

Littler, Mark. December 7, 1979. Professor. University of California, Irvine.

Loehr, Lincoln. May 12, 1980. Consultant, Seattle, Washington.

Marelli, Dan. January 4, 1980. Ecological Analysts, Concord.

Marquez, Ron. January 8, 1980. Planner. Santa Cruz County Planning Department, Santa Cruz.

Martin, Michael. December 1, 1979. Ph.D. Fisheries Biologist. California Department of Fish and Game, Monterey.

Meinz, Mike. October 1979. Fisheries Biologist. California Department of Fish and Game, Sacramento.

Miller, Daniel. December 3, 1979. Supervisor-Operations Research Branch. California Department of Fish and Game, Monterey.

Miller, Lee. September 1979. Fisheries Biologist. California Department of Fish and Game, Stockton.

Milne, Clinton. November 1, 1979. Deputy County Engineer. San Luis Obispo County Engineering Department, San Luis Obispo.

Nadeau, Doug. Chief Planner. National Park Service, San Francisco.

Nealson, K. December 11, 1979. Ph.D. Invertebrate Biologist. Scripps Institute of Oceanography, La Jolla, California.

Nighswonger, J. December 7, 1979. Environmental Specialist. Regional Water Quality Control Board, San Luis Obispo.

Norris, Kenneth. December 1979. Professor. Department of Environmental Studies, University of California, Santa Cruz.

Nutter, Richard. November 2, 1979. Agricultural Commissioner. Monterey County Agricultural Commission.

O'Hagan, Joe. November 1, 1979. Assistant Planner. San Luis Obispo County Planning Department, San Luis Obispo.

Orsak, Larry. November 1979. Graduate Student. Department of Entomology, University of California, Berkeley.

Parker, David. November 28, 1979. Associate Marine Biology Manager, Sea Urchin Project. California Department of Fish and Game, San Diego.

Paulsen, Ivan. December 18, 1979. Fisheries Biologist. California Department of Fish and Game, Menlo Park.

Pearse, John S. November 20 and December 1, 1979. Professor, biology. University of California, Santa Cruz.

Perry, Melanie. January 3, 1980. Planner. Sonoma County Planning Department, Santa Rosa.

Pinkas, Leo. January 3, 1980. Marine Resources Division. California Department of Fish and Game, Long Beach.

Powell, J. A. November 1979. Department of Entomology, University of California, Berkeley.

Rae, Stephen ?. September 12, 1979. Plant Ecologist. Endangered Plant Program, California Department of Fish and Game, Sacramento.

Ransdell, Jerry. November 7, 1979. California Department of Parks and Recreation, Sacramento.

Rendal, Kay. January 9, 1980. Caltrans.

Roth, Barry. October 9, 1979. Professor. California Academy of Sciences, San Francisco.

Rotz, William. January 5, 1980. Biologist. Annatec Laboratories, Santa Rosa.

Sanders, Steve. October 25, 1979. Prairie Creek Fish Hatchery, Yountville.

Sasaki, Shoken. January 11, 1980. Fisheries Biologist. California Department of Fish and Game, Goleta.

Schrader, C. December 1, 1979. M.S. Phytoplankton. Moss Landing Marine Laboratories, Moss Landing, California.

Schultz, Steven. November 21, 1979. Associate Marine Biology Unit Manager. California Department of Fish and Game, Fort Bragg.

Sermon, Richard. November 2, 1979. Ranger 1. California Department of Parks and Recreation, Mendocino.

Silver, M. December 1, 1979. Ph.D. Biological Oceanographer. University of California, Santa Cruz.

Simpson, Victor. November 8, 1979. Wildlife Biologist. California Department of Fish and Game, Sacramento.

Slosson, Jack. December 31, 1979. Wildlife Biologist. Upland Game, California Department of Fish and Game, Sacramento.

Smart, Neil. November 2, 1979. Parks and Recreation Se.mites Manager. Santa Cruz County Parks and Recreation, Santa Cruz.

Stevenson, M.L. December 1, 1979. Fisheries Biologist. Kinnetic Laboratories, Inc., Santa Cruz.

Swanson, J. November 15, 1979. Wildlife Biologist. California Department of Fish and Game, Yountville.

Tavares, Ed. November 14, 1979. Acting Chief Ranger. California Department of Parks and Recreation, Mendocino.

Taylor, Dwight. November 1979. Professor. Biology Department, San Francisco State University.

Thomas, David. November 14, 1979. California Department of Fish and Game, Menlo Park.

Thompson, Ron. January 2, 1980. Director, Animal Damage Control Center. U. S. Fish and Wildlife Service, Sacramento.

Tilghman, Noah. November 1979. Planner. California Coastal Commission, San Francisco.

Turhollow, Anne. November 2, 1979. Graduate Student, biology. Hopkins Marine Station of Stanford University, Pacific Grove.

Varoujean, Daniel H. November 8, 1979. Graduate Student. Department of Wildlife and Fisheries Biology, University of California, Davis.

Volks, Robert. October 15, 1979. Coordinator. Unique Wildlife Ecosystems Program, U. S. Fish and Wildlife Service, Sacramento.

Wang, Johnson. November 6, 1979. Ecological Analysts, Concord.

Wild, Paul. January 2, 1980. Marine Biologist. California Department of Fish and Game, Long Beach.

Willson. January 1980. Chief Mate. U. S. Navy, Port Chicago.

Word, J. December 11, 1979. Ph.D. Invertebrate Biologist. Southern California Coastal Water Resource Project. Los Angeles.

Wymer, Sill. November 2, 1979. Port Director. Moss Landing Harbor District, Moss Landing.

BIBLIOGRAPHY

Introduction

This annotated bibliography was prepared with the assistance of automated data processing. Information on how it was produced is presented in Volume V of this report, Data Source Appendix.

User's Aids to the Bibliography

No personal communications are included in the bibliography: they are listed in the preceding section entitled "Personal Communications".

"See references" are provided within the bibliography from abbreviated forms of corporate authors to the full form used in the citation. For example, a text reference may be (ABAG, 1979). Looking in the bibliography for "ABAG" one would locate the following "see reference": A3AG SEE ASSOCIATION OF BAY AREA GOVERNMENTS. One would locate the full citation by looking for "ASSOCIATION OF BAY AREA GOVERNMENTS" in the bibliography.

The abbreviation "CA." appearing before numbers of pages in many citations stands for "circa". This indicates that the number following is approximate because the document being cited was either unnumbered or in various pagings.

In addition to the standard bibliographic information, most citations also have watershed unit/offshore basin abbreviations, descriptors, an annotation, and a note on the document's availability.

- a) Expansions for the three-or-four character watershed unit/offshore basin abbreviations are listed below in order of geographical position (north to south) with offshore basins following watersheds.

<u>Watershed Unit/Offshore Basin</u>	<u>Abbreviation</u>
Smith River Watershed	SMI
Klamath River Watershed	KLA
Mad River Watershed	'MAD
Eel River Watershed	EEL
Mattole River Watershed	MAT
Noyo River Watershed	NOY
Gualala River Watershed	GUA
Russian River Watershed	RUS
Salmon Creek Watershed	SMN
LagunitasCreek Watershed	LAG
San Francisco Bay Watershed	FRA
San Gregorio Creek Watershed	GRE
San LorenzoCreek Watershed	LOR
Pajaro Watershed	PAJ
Elkhorn Slough Watershed	ELK
Salinas River Watershed	SLS
Carmel River Watershed	CAR
Morro Bay Watershed	MOR
Santa Maria River Watershed	MAR
San Antonio Creek Watershed	ANT

Watershed Unit/Offshore BasinAbbreviation

Cont ' d .

Santa Ynez River Watershed

YNZ

Point Arguello Watershed

ARG

Eel River Basin

OEEL

Point Arena Basin

OARE

Bodega Basin

OBOD

Santa Cruz-Outer Santa Cruz Basin

OCRZ

Santa Maria Basin

OMAR

- b) Among the descriptors are habitat names, some of which have terms abbreviated. The following is a List of abbreviated habitat name terms along with the full terms.

AQUAT	Aquatic
COBBLE	Cobble/gravel
COBBLE /G	Cobble/gravel
COBBLE /GR	Cobble/gravel
COBBLE /GRA	Cobble/gravel
COBBLE/GRAV	Cobble/gravel
EM	Emergent
FLOATING	Floating vegetation
FRESHWA	Freshwater
MAR	Marsh
MO IS	Moisture
Mos	Moss
NONPERS	Nonpersistent
NONPERSIS	Nonpersistent
NONURB	Nonurban
PAL	Palustrine
PER	Perennial
PEREN	Perennial
PERS	Persistent
PERSIS	Persistent
SEAS	Seasonal
UNCON	Unconsolidated
VA	Vascular plants
VAS	Vascular plants
VASC	Vascular plants
VEG	Vegetated
WE	Wetland
WET	Wetland

- c) The note in parentheses () at the end of many of the citations gives one or more locations where the document being cited was obtained. When an academic institution is named within the parentheses, the document often is available in a library at that institution, even though the term "LIBRARY" may be omitted. For example, "U. C. BERKELEY - BIOLOGY" refers to the Biology Library at the University of California at Berkeley.

- 1* ABBOTT, J.A.; HOLLENBERG, G.J. 1976. MARINE ALGAE OF CALIFORNIA. STANFORD, CA. STANFORD UNIVERSITY PRESS. 827 P. DEEL, DARE, CBOD, OCPZ, OMAR ALGAE, MARINE-SUBTIDAL-AQUATIC BED-ALGAL, MARINE-INTERTIDAL-AQUATIC BED-ALGAL. TEXT AND KEY TO MARINE BIOLOGY OF CALIFORNIA. (CALIF. STATE COLLEGE, SONOMA STATE J. AIV [? SIT % LIB.])
2. ABBOTT, J.A.; NORTH, W.J. 1971. TEMPERATURE INFLUENCES ON FLORAL COMPOSITION IN CALIFORNIA COASTAL WATERS. IN NISIZUA, K. (ED.). PROCEEDINGS OF THE SEVENTH INTERNATIONAL SEAWEED SYMPOSIUM. P. 72-79. NEW YORK. JOHN WILEY AND SONS. DEEL, DARE, CBOD, OCPZ, OMAR ALGAL, TEMPERATURE--WATER, COMMUNITIES (BIOLOGICAL), KELP, TAXONOMY, MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (STANFORD UNIVERSITY.)
3. AHLSTROM, E.H. 1965. KINDS AND ABUNDANCE OF FISHES IN THE CALIFORNIA CURRENT REGION BASED ON EGGS AND LARVAL SURVEYS. CALIF COOP OCEANIC FISH INVEST REP. 10: 31-52. CALIFORNIA CURRENT, ABUNDANCE, LARVAE, LIFE HISTORY, DIVERSITY (ECOSYSTEM), FISH, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
4. AHLSTROM, E.H. 1969. MESOPELAGIC AND BATHYPELAGIC FISHES IN THE CALIFORNIA CURRENT REGION. CALIF COOP OCEANIC FISH INVEST REP. 13: 39-44. CALIFORNIA CURRENT, FISH, ABUNDANCE, DISTRIBUTION, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
5. ALEXANDER, D.G. 1976. ECOLOGICAL ASPECTS OF THE TEMPORARY ANNUAL POOL FAUNA. IN JAIN, S. (ED.). VERNAL POOLS: THEIR ECOLOGY AND CONSERVATION, 4 SYMPOSIUM. INSTITUTE OF ECOLOGY, UNIVERSITY OF CALIFORNIA, DAVIS. MAY 1-2, 1976. P. 32-36. INSTITUTE OF ECOLOGY PUBLICATION NO. 9. RUS, SMN, LAG, FRA, GRE, LOK, PAJ, ELK, SLS, CAR, MCR, MAR, ANT, YNZ, ARG INVERTEBRATES, ECOLOGY, LIFE HISTORY, PALUSTRINE-EMERGENT WETLAND-PERMANENT, PALUSTRINE-EMERGENT WETLAND-NONPERMANENT. SURVEY OF FAUNAL COMPOSITION AND ECOLOGY IN VERNAL POOLS. (UC DAVIS.)
6. ALVARINO, A. 1965. DISTRIBUTIONAL ATLAS OF CHAETOGNATHA IN THE CALIFORNIA CURRENT REGION. SPONSORED BY CALIF. MARINE RESEARCH COMMITTEE. CALIF COOP OCEANIC FISH INVEST ATLAS NO. 3. 291 P. DEEL, DARE, CBOD, OCPZ, OMAR DISTRIBUTION, CHAETOGNATHA, CALIFORNIA CURRENT, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
7. ARMSTRONG, D.A.; BUCHANAN, D.V.; MALLON, M.H.; CALDWELL, R.S.; MILLEMAN, R.F. 1976. TOXICITY OF THE INSECTICIDE METHOXYCHLOR TO THE DUNGENESS CRAB CANCER MAGISTER. MAR BIOL (BERL) 38: 235-252. TOXICITY, WATER QUALITY, PESTICIDES, METHOXYCHLOR, DUNGENESS CRAB, CANCER MAGISTER, LIFE HISTORY, MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
8. ASSOCIATION OF BAY AREA GOVERNMENTS; METCALF & EDDY, INC.; KAMIT ASSOCIATES. 1979B. TREATMENT OF STORMWATER RUNOFF BY A MARSH/FLOOD BASIN: INTERIM REPORT AUGUST 1979. 116 P. FRA PLANTS, PRODUCTIVITY, WATER QUALITY, SOIL, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. WATER QUALITY IMPROVEMENT OF STORMWATER RUNOFF FLOWING THROUGH A MARSH/FLOOD BASIN WAS INVESTIGATED. SOIL AND PLANT SAMPLES WERE ANALYZED. PICKLEWEED BIL MASS MEASURED. (ASSOCIATION OF BAY AREA GOVERNMENTS.)
9. ATWATER, R.F.; CONARD, S.G.; DOWDEN, J.N.; HEDEL, C.W.; MACDONALD, R.L.; SAVAGE, W. 1979. HISTORY, LANDFORMS, AND VEGETATION OF THE ESTUARY'S TIDAL MARSHES. IN CONNORS, T.J. (ED.). SAN FRANCISCO BAY: THE URBANIZED ESTUARY. P. 347-355. FRA PLANTS, ZONATION (BIOLOGICAL), DISTRIBUTION, GEOMORPHOLOGY, HYDROLOGY, PRODUCTIVITY, ESTUARINE.
10. AZEVEDO, J.; MORGAN, D.L. 1974. FOG PRECIPITATION IN COASTAL CALIFORNIA FORESTS. ECOLOGY 55(5): 1135-1141. SM, KLA, MAC, EEL, MAT, NIJ, GUA, RUS, SMN, LAG, FRA, GRE, LOK, PAJ, CAR, MCR PLANTS, FOG, NUTRIENTS, PRECIPITATION, COASTAL CONIFER FOREST. STUDY OF AMOUNTS AND NUTRIENT CONTENTS OF FOG DROPS IN COASTAL CONIFER FOREST. (UC BERKELEY - FORESTRY.)
11. BAKER, H.G. 1972. A FEN ON THE NORTHERN CALIFORNIA COAST. MADRONO 21(6): 405-416. NGY, LAG PLANTS, ECOLOGY, DISTRIBUTION, HYDROLOGY, TAXONOMY, PALUSTRINE-MOSS WETLAND (IE DOGS + FENS), PAL-EMERGENT-PERMANENT (IE FRESHWATER), PAL-SCRUB/SHRUB WETLAND (IE FRESHWATER SWAMP), PAL-FORESTED WETLAND (IE FRESHWATER SWAMP). DESCRIPTION OF THE VEGETATION AND INTERRELATIONSHIPS OF INGLENOCK FEN AND LEDUM SWAMP. (UC BERKELEY - BIOLOGY.)
12. BARBOUR, M.G. 1970. IS ANY Angiosperm AN OBLIGATE HALOPHYTE? AM MIDL NAT 84(1): 105-120. PLANTS, SALINITY,

ZONATION (BIOLOGICAL), SUPRATIDAL BEACH, ACTIVE DUNES. A SHORT DISCUSSION OF HALOPHYTES IN COASTAL STRAND. (UC BERKELEY - BIOLOGY.)

13. BARBOUR, M.G. 1972. SEEDING ESTABLISHMENT OF *CAKILE MARITIMA* AT BODEGA HEAD, CALIFORNIA. BULL TORREY BOT CLUB. 99(1): 11-16. SMI, KLA, MAD, MAT, NOY, SMN, LAG, GRE, LOR, SLS, CAR, MOR, ANT, ARG. REGENERATION, PLANTS, SUPRATIDAL BEACH. (UC BERKELEY - BIOLOGY.)
14. BARBOUR, M.G. 1978. SALT SPRAY AS A MICROENVIRONMENTAL FACTOR IN THE DISTRIBUTION OF BEACH PLANTS AT PLEINTEYES, CALIFORNIA. OECOLOGIA 32: 215-224. LAG, MICROCLIMATE, NUTRIENTS, PLANTS, ZONATION (BIOLOGICAL), SUPRATIDAL BEACH. MEASUREMENTS OF SALT SPRAY WERE CORRELATED WITH PLANT DISTRIBUTION, WIND SPEED AND DIRECTION, RAINFALL, TIDE LEVEL, TOPOGRAPHY. (UC BERKELEY - BIOLOGY, MOST UNIV. LIBS.)
15. BARBOUR, M.G.; CRAIG, R.O.; DRYSDALE, F.R.; GHISELIN, M.T. 1973. COASTAL ECOLOGY: BODEGA HEAD. BERKELEY, CA. UNIVERSITY OF CALIFORNIA PRESS. 338 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG. OBOD PLANTS, ECOLOGY, ANIMALS, CLIMATOLOGY, COASTAL PRAIRIE, COASTAL STRAND, COASTAL SCRUBLANDS, ESTUARINE-INTERTIDAL-ROCKY SHORE, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. SURVEY OF ECOLOGICAL STUDIES OF HABITATS AT BODEGA HEAD BUT APPLICABLE TO ALL COASTAL ECOSYSTEMS. (UC BERKELEY - BIOLOGY.)
16. BARBOUR, M.G.; DE JONG, T.M. 1977. RESPONSE OF WEST COAST BEACH TAXA TO SALT SPRAY, SEAWATER INUNDATION, AND SOIL SALINITY. BULL TORREY BOT CLUB 104(1): 29-34. SMI, KLA, MAD, MAT, NOY, SMN, LAG, GRE, LOR, SLS, CAR, MOR, ANT, ARG. HABITATS, SALINITY, WAVES (OCEAN), TIDES, ZONATION (BIOLOGICAL), SUPRATIDAL BEACH. LABORATORY STUDIES.
17. BARBOUR, M.G.; DE JONG, T.M.; JOHNSON, A.F. 1976. SYNECOLOGY OF BEACH VEGETATION ALONG THE PACIFIC COAST OF THE UNITED STATES OF AMERICA: A FIRST APPROXIMATION. J BIOGEOGRAPHY 3(1): 55-69. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG. ZONATION (BIOLOGICAL), DISTRIBUTION, PLANTS, MICROCLIMATE, SUPRATIDAL BEACH. TRANSVERSE STUDIES OF BEACH VEGETATION BETWEEN MEXICO AND CENTRAL WASHINGTON PROVIDE DATA ON DISTRIBUTION AND ZONATION; COMMUNITY CGXP[?] POSITION CORRELATED WITH MICROCLIMATE AND OTHER LOCAL CONDITIONS. (UC BERKELEY - BIOLOGY, MOST UNIV. LIBS.)
18. BARBOUR, M.G.; JOHNSON, A.F. 1977. BEACH AND DUNE. IN BARBOUR, M.G. (ED.): MAJOR, J. (ED.) TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILEY & SONS. P. 223-261. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG. PLANTS, ECOLOGY, SUCCESSION, DISTRIBUTION, SOILS, COASTAL FOREDUNE COMPLEX, COASTAL DUNE SCRUB, CHAPARRAL, COAST LIVE OAK FOREST, MONTEREY PINE FOREST, SHORE PINE FOREST, SITKA SPRUCE-GRAND FIR FOREST. SURVEY OF ECOLOGICAL RELATIONS OF BEACH AND DUNE VEGETATION. (UC BERKELEY - BIOLOGY.)
19. BARBOUR, M.G.; ROBICHAUX, R.H. 1976. BEACH PHYTOMASS ALONG THE CALIFORNIA COAST. BULL TORREY BOT CLUB 103(1): 16-20. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG. COMMUNITIES (BIOLOGICAL), DISTRIBUTION, PLANTS, PRODUCTIVITY, SUPRATIDAL BEACH. NINETEEN BEACHES, IN SCATTERED LOCATIONS ALONG THE CALIFORNIA COAST, WERE SAMPLED FOR ABOVE-GROUND PLANT COMMUNITY BIOMASS. STATISTICAL ANALYSES INDICATED WEIGHT RELATED TO COVER RATHER THAN LATITUDINAL GRADIENTS IN MICROCLIMATE. (UC BERKELEY - BIOLOGY, MOST UNIV. LIBS.)
23. BARBOUR, M.G.; RUDMAN, J.E. 1970. SAGA OF THE WEST COAST SEA-ROCKETS: *CAKILE EDENTULA* SSP. CALIFORNICA AND C. MARITIMA. RHODORA 72: 370-386. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG. *CAKILE EDENTULA* VAP. CALIFORNICA, *CAKILE MARITIMA*, SEA ROCKET, DISTRIBUTION, SUPRATIDAL BEACH. HERBARIUM RECORDS AND FIELD OBSERVATIONS USED TO SUPPORT DISCUSSION OF THE INTRODUCTION, HISTORICAL AND PRESENT DISTRIBUTION OF TWO SPECIES OF SEA ROCKET ON THE WEST COAST OF NORTH AMERICA. (UC BERKELEY - BIOLOGY, MOST UNIV. LIBS.)
21. BARNARD, J.L. 1963. RELATIONSHIP OF BENTHIC AMPHIPODA TO INVERTEBRATE COMMUNITIES OF INSHORE SUBLITTORAL SANDS (SOUTHERN CALIFORNIA). PAC NAT 3(15): 439-468. AMPHIPODA, INVERTEBRATES, ANIMALS, COMMUNITIES (BIOLOGICAL), INTERRELATIONSHIPS, MARINE-SUBTIDAL-UNCONSOLIDATED BOTTOM. (UC SANTA CRUZ, MOST UNIV. LIBS.)

22. BARNARD, J.L. 1966. BENTHIC AMPHIPODA OF MONTEREY BAY, CALIFORNIA. PROCEEDINGS OF THE U.S. NATIONAL MUSEUM SMITHSONIAN INSTITUTION. 119: 1-41. CCRZ AMPHIPODA, TAXONOMY, DISTRIBUTION, ABUNDANCE, MARINE-SUBTIDAL.
23. BARNARD, J.L.; ZIESENHENNE, F.C. 1961. OPHIURID COMMUNITIES OF SOUTHERN CALIFORNIAN COASTAL BOTTOMS. PAC NAT 2(2): 131-152. OPHIURIDEA, BRITTLE STARS, TAXONOMY, DISTRIBUTION, MARINE-SUBTIDAL. (UC SANTA CRUZ, MEST UNIV. LIBS.)
24. BARRY, R.G.; CHORLEY, R.J. 1976. ATMOSPHERE, WEATHER AND CLIMATE. THIRD EDITION. LONDON. METHUEN & CO. 432 P. CLIMATOLOGY, INSOLATION, INVERSION, STORMS, CURRENTS--OCEAN, WIND, PRECIPITATION.
25. BARRY, W.J. (ED.); SCHLINGER, E.I. (ED.). 1977. INGLENOCK FEN: A STUDY AND PLAN. SACRAMENTO. CALIF. DEPT. OF PARKS AND RECREATION. 212 P. NOY COMMUNITIES (BIOLOGICAL), HYDROLOGY, CLIMATOLOGY, NUTRIENTS, SOIL, COASTAL FOREDUNE COMPLEX. (UC BERKELEY - BIOLOGY.)
26. BARRY, W.J.; FOX, M.; MACELFRESH, D. 1977. MAN'S IMPACT ON NATURAL ECOSYSTEMS. IN BARRY, W.J. (ED.); SCHLINGER, E.I. (ED.). INGLENOCK FEN: A STUDY AND PLAN. CALIFORNIA DEPARTMENT OF PARKS AND RECREATION, SACRAMENTO, F. 83-99. NOY DISTURBANCE, DEVELOPMENT, PLANTS, LAND USE, COASTAL FOREDUNE COMPLEX. DISCUSSION OF VARIOUS TYPES OF HUMAN-INDUCED DISTURBANCE IN DUNE ECOSYSTEMS.
27. BATZLI, G.O.; PITELKA, F.A. 1970. INFLUENCE OF MEADOW MOUSE POPULATIONS ON CALIFORNIA GRASSLAND. ECOLOGY 51(6): 1327-1039. SMI, KLA, MAC, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, HERBIVORY, PRODUCTIVITY. GRASSLANDS. STUDY (1) - EFFECTS OF RECENT GRAZERS ON VEGETATION STRUCTURE AND COMPOSITION. (UC BERKELEY - FORESTRY.)
28. BAYNE, B.L. 1976B. MARINE MUSSELS: THEIR ECOLOGY AND PHYSIOLOGY. CAMBRIDGE. CAMBRIDGE UNIVERSITY PRESS. 506 P. SMI, KLA, MAC, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG BAY MUSSEL, MYTILUS EDULIS, CALIFORNIA MUSSEL, MYTILUS CALIFORNIANUS, LIFE HISTORY, DISTRIBUTION, TAXONOMY, [] L POLLUTION, MARINE-SUBTIDAL-ROCK BOTTOM, MARINE-INTERTIDAL-ROCKY SHORE, MARINE-INTERTIDAL-JETTIES, PILINGS, ESTUARINE-SUBTIDAL-ROCK BOTTOM, ESTUARINE-INTERTIDAL-ROCKY SHORE, ESTUARINE-INTERTIDAL-PIERS+PILINGS. GOOD GENERAL REFERENCE ON MUSSELS. (UC BERKELEY - BIOLOGY.)
29. BERNHARD, M.; ZATTERA, A. 1975. MAJOR POLLUTANTS IN THE MARINE ENVIRONMENT. IN MARINE POLLUTION AND MARINE WASTE DISPOSAL. NEW YORK. PERGAMON PRESS. P. 195-300. PESTICIDES, CHLORINATED HYDROCARBONS, WATER QUALITY, OIL POLLUTION, MARINE.
30. BERRY, F.H.; PERKINS, H.C. 1966. SURVEY OF PELAGIC FISHES OF THE CALIFORNIA CURRENT AREA. U.S. FISH WILDL. SERV. FISH BULL. 65(3): 625-682. CALIFORNIA CURRENT, FISH, MARINE-PELAGIC.
- 31* BIGGS, R.B. 1978. COASTAL BAYS. IN DAVIS, R.A. JR. (ED.) COASTAL SEDIMENTARY ENVIRONMENTS. NEW YORK. SPRINGER-VERLAG. P. 69-99. SEDIMENTATION, HYDROLOGY, ESTUARINE.
32. BLAKE, J.). 1975*. THE LARVAL DEVELOPMENT OF POLYCHAETA FROM THE NORTHERN CALIFORNIAN COAST. II. NOTHRIA ELEGANS (FAMILY ONUPHIDAE). OPHELIA 13: 43-61. LARVAE, LARVAL DEVELOPMENT, POLYCHAETA, NOTHRIA ELEGANS, ONUPHIDAE, MARINE. (UC SANTA CRUZ, MEST UNIV. LIBS.)
33. BLINKS, L.R. 1955. PHOTOSYNTHESIS AND PRODUCTIVITY OF LITTORAL MARINE ALGAE. JOURNAL OF MARINE RESEARCH 14(4): 363-373. ALGAE, PRODUCTIVITY, MARINE-SUBTIDAL-AQUATIC BED-ALGAL, MARINE-INTERTIDAL-AQUATIC BED-ALGAL. Relationships BETWEEN LIGHT AND ALGAE. (UC BERKELEY - ETIOLOGY.)
34. BOLIN, R.L.; REVISED BY BRADBURY, M.G.; DEMPSTER, L.J. 1975. PHYLUM CHORDATA: INTERTIDAL FISHES. IN SMITH, R.L.; CARLTON, J.T. (EDS.) LIGHT'S MANUAL: INTERTIDAL INVERTEBRATES OF THE CENTRAL CALIFORNIAN COAST, THIRD EDITION. BERKELEY. UNIVERSITY OF CALIFORNIA PRESS. P. 656-668. OAFE, OBOO, CCRZ INVERTEBRATES, TAXONOMY, NATURAL HISTORY. GLOSSARY, ILLUSTRATIONS, KEYS, REFERENCES ON INTERTIDAL FISHES, TREATMENT OF FISHES IS BRIEF SINCE THE

MANUAL PRIMARILY PERTAINS TO INVERTEBRATES. (MOST LIBS.)

- 35* BDLIN, R.L.; ABBOTT, D.P. 1963. STUDIES ON THE MARINE CLIMATE AND PHYTOPLANKTON OF THE CENTRAL COASTAL AREA OF CALIFORNIA, 1954-1960. CALIF COOP OCEANIC FISH INVEST REP 9: 23-45. OCRZ, CMAR MONTEREY BAY, CLIMATELOGY, HYDROGRAPHY, TEMPERATURE--WATER, SALINITY, PHYSICAL OCEANOGRAPHY, UPWELLING, DAVIDSON CURRENT, PACIFIC COVE, SANTA CRUZ, PHYTOPLANKTON, NUTRIENTS, SEASONAL VARIATION, ABUNDANCE, DISTRIBUTION, DIVERSITY (ASSOCIATION), MARINE-PELAGIC. THIS SERIAL MAY BE CATALOGUED UNDER CALIF. DEPT. OF FISH AND GAME MARINE RESEARCH COMMITTEE OR CALIF. MARINE RESEARCH COMMITTEE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
36. BONEY, A.D. 1966. A BIOLOGY OF MARINE ALGAE. ENGLAND. HUTCHINSON EDUCATIONAL. 216 P. ALGAE, MARINE-SUBTIDAL-AQUATIC RED-ALGAL, MARINE-INTERTIDAL-AQUATIC RED-ALGAL. TEXT ON LOGIC (LOGY AND SEASONAL ECOLOGY OF MARINE ALGAE. (COLLEGE OF MARIN LIB., UNIVERSITY LIBS.)
37. BORMANN, F.H.; LIKENS, G.E. 1979. PATTERN AND PROCESS IN A FORESTED ECOSYSTEM; DISTURBANCE, DEVELOPMENT AND THE STEADY STATE BASED ON THE HUBBARD BROOK ECOSYSTEM STUDY. NEW YORK. SPRINGER-VERLAG. 253 P. FORESTRY, ECOSYSTEMS, DISTURBANCE, BIOMASS, NUTRIENTS, PRODUCTIVITY, REGENERATION, DIVERSITY (ECOSYSTEM), STABILITY (ECOSYSTEM), SUCCESSION, LOGGING, HYDROLOGY, BROAD-LEAVED EVERGREEN FORESTS, COASTAL CONIFER FOREST.. WHITE MOUNTAINS, NEW HAMPSHIRE. SYNTHESIS, 15 YEAR ECOSYSTEM STUDY. (UC BERKELEY - FORESTRY.)
- 38J. BOYCE, S.G. 1954. THE SALT SPRAY COMMUNITY. ECOL MONOGR 24(1): 67-67. SMI, KLA, MAD, MAT, NLY, SPN, LAG, GRE, LOR, SLS, CAR, MUR, ANT, ARG PLANTS, HABITATS, SALINITY. (UC BERKELEY - BIOLOGY.)
39. BOYD, M.J.; DEMARTINI, J.D. 1977. INTERTIDAL AND SUBTIDAL BIODIVERSITY OF REDWOOD NATIONAL PARK. REPORT TO U. S. NATIONAL PARK SERVICE UNDER CONTRACT NO. CX8480-4-0665. 162 P. DEEL REDWOOD NATIONAL PARK, INVERTEBRATES, COMMUNITIES (BIOLOGICAL), FISH, ANIMALS, PLANTS, ALGAE, DISTRIBUTION, ABUNDANCE, ECOLOGY, MARINE-SUB TIDAL, MARINE-INTERTIDAL. BIOLOGICAL SURVEY OF THE INTERTIDAL AND SHALLOW (TO APPROXIMATELY TEN METERS) SUBTIDAL COASTAL BOUNDARY OF REDWOOD NATIONAL PARK, CALIFORNIA.
40. BRECKON, G.J.; BARBOUR, M.G. 1974. REVIEW OF NORTH AMERICAN PACIFIC COAST BEACH VEGETATION. MADRONO 22: 323-360. SMI, KLA, MAD, EEL, MAT, NOY, GJA, RUS, SMN, LAG, FRA, GRE, L O P, PAJ, ELK, SLS, CAR, MOR, M A R, ANT, YNZ, ARG ZONATION (BIOLOGICAL) DISTRIBUTION, PLANTS, MICROCLIMATE, CLIMATELOGY, SUPRATIDAL BEACH. REVIEW OF BEACH VEGETATION AND ITS PHYTOGEOGRAPHY ALONG PACIFIC COAST OF NORTH AMERICA, USING DATA FROM FLORAS AND OTHER LITERATURE; DISCUSSES LATITUDINAL ZONATION. (UC BERKELEY - BIOLOGY, MOST UNIV. LIBS.)
- 41* BRINTON, E. 1967A. DISTRIBUTIONAL ATLAS OF EUPHAUSIACEA (CRUSTACEA) IN THE CALIFORNIA CURRENT REGION, PART I. SPONSORED BY CALIF. MARINE RESEARCH COMMITTEE. CALIF COOP OCEANIC FISH INVEST ATLAS NO. 5. 275 P. EEL, GARE, OROO, OCRZ, OMAR DISTRIBUTION, EUPHAUSIACEA, CRUSTACEA, CALIFORNIA CURRENT, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
42. BRINTON, E. 1973* DISTRIBUTIONAL ATLAS OF EUPHAUSIACEA (CRUSTACEAN IN THE CALIFORNIA CURRENT REGION, PART II. SPONSORED BY CALIF. MARINE RESEARCH COMMITTEE. CALIF COOP OCEANIC FISH INVEST ATLAS NO. 18. 336 P. EEL, GARE, OROO, OCRZ, OMAR DISTRIBUTION, EUPHAUSIACEA, CRUSTACEA, CALIFORNIA CURRENT, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
- 43* BROWN AND CALDWELL CONSULTING ENGINEERS, WALNUT CREEK, CA.; HARRIS, J.A. (PROJECT OFFICER). 1978. OCEANOGRAPHIC PREDESIGN PHASE REPORT, SANTA CRUZ WASTEWATER FACILITIES PLANNING STUDY. PREPARED FOR CLEAN WATER GRANT NO. C-36-1106. SACRAMENTO, CA. CALIF. WATER RESOURCES CONTROL BOARD, CA. 250 P. OCRZ PHYSICAL OCEANOGRAPHY, CURRENTS--OCEAN, TEMPERATURE--WATER, SALINITY, DISSOLVED OXYGEN, WATER QUALITY, WIND, GEOLOGY, TOPOGRAPHY, TRACE METALS, CHEMICAL COMPOSITION, FISH, INVERTEBRATES, MAMMALS, BIRDS, MARINE. STUDY AREA JUST NORTH OF SANTA CRUZ. (UC BERKELEY - WATER RESOURCES CENTER ARCHIVES.)
44. BUCHANAN, D.V.; MILLEMAN, R.E.; STEWART, N.E. 1970. EFFECTS OF SEVIN ON VARIOUS STAGES OF THE DUNGENESS CRAB, CANCER MAGISTER. FISH RES BOARD CAN J 27(1): 93-104. WATER QUALITY, PESTICIDES, DUNGENESS CRAB, CANCER

MAGISTER, LIFE HISTORY, SE V IN, MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)

- 45* BURKE, R. T.; SCHULTZ, S.A. 1973. THE MARINE ENVIRONMENT IN THE VICINITY OF DIABLO COVE WITH SPECIAL REFERENCE TO ABALONES AND BONY FISHES. CALIF DEPT FISH GAME MARRES TECH REP NO 19. 433 P. MCR, OMAK FISH, INVERTEBRATES, LIFE HISTORY, DISTRIBUTION, ABUNDANCE, DIABLO COVE, ABALONE, MARINE-SUBTIDAL-AQUATIC BED, ESTUARINE. (CCCD GENERAL REFERENCE. (UC BERKELEY - BIOLOGY.)
46. BURT, W.H.; GROSSENHEIDER, R.P. 1976. A FIELD GUIDE TO THE MAMMALS. BOSTON. Houghton Mifflin Company. 289 P. MAMMALS, DISTRIBUTION.
47. CAILLIET, G.M.; LEA, K.N. 1977. ABUNDANCE OF THE 'RARE' ZOARCID, MAYNEA CALIFORNICA, GILBERT, 1915, IN THE MONTEREY CANYON, MONTEREY BAY, CALIFORNIA. CALIF FISH GAME 63(4): 253-261. OCRZ ALGAE, DISTRIBUTION, FISH, MAYNEA CALIFORNICA, MONTEREY BAY, MONTEREY CANYON, HABITATS, MACROCYSTIS PYRIFERA, ABUNDANCE, MARINE-SUBTIDAL-UNCON BOTTOM-MUD, MARINE-INTERTIDAL-AQUATIC BED-ALGAL. (STANFORD UNIVERSITY, CALIF. DEPT. OF FISH AND GAME, RESOURCES AGENCY LIBRARY, UC SANTA CRUZ.)
48. CALCOFISEE CALIFORNIA COOPERATIVE OCEANIC FISHERIES INVESTIGATIONS
49. CALDWELL, R.S.; ARMSTRONG, O.A.; BUCHANAN, D.V.; MALLON, M.H.; MILLMANN, R.E. 1978. TOXICITY OF THE FUNGICIDE CAPTAN TO THE DUNGENESS CRAB CANCER MAGISTER. MAR BIOL (BERL) 40: 11-17. PESTICIDES, WATER QUALITY, DUNGENESS CRAB, CANCER MAGISTER, TOXICITY, LIFE HISTORY, CAPTAN, MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
50. CALIFORNIA DEPT. OF FISH AND GAME. 1976. REPORT TO THE STATE WATER RESOURCES CONTROL BOARD ON THE IMPACT OF WATER DEVELOPMENT ON FISH AND WILDLIFE RESOURCES IN THE SACRAMENTO-SAN JOAQUIN ESTUARY. Cd. 124 P. FRA KING SALMON, CHINOOK SALMON, ENGRYHYNCHUS TSHAWYTSCHA, STRIPED BASS, RUCCUS SAXATILIS, MORONE SAXATILIS, STEELHEAD, STEELHEAD RAINBOW TROUT, SALMO GAIKONERI, SALMO GAIKONERI GAIKONERI, AMERICAN SHAD, ALUSA SAPIDISSIMA, NEOMYSIS, NEOMYSIS MERCEDIS, WHITE STURGEON, GREEN STURGEON, COROPHIUM, STREAM FLOW, LOW FLOW, SUISUN MARSH, DELTA, SACRAMENTO-SAN JOAQUIN DELTA, ESTUARINE-WATER COLUMN, ESTUARINE-SUBTIDAL, RIVERINE-TIDAL-UNCON BOTTOM-SAND, RIVERINE-TIDAL-UNCON BOTTOM-MUD, RIVERINE-TIDAL-UNCON BOTTOM-ORGANIC. RELATIONSHIPS BETWEEN FLOW, DIVERSION, AND FISH AND WILDLIFE RESOURCES. (CALIF. STATE WATER RESOURCES CONTROL BD., DIV. OF WATER RIGHTS.)
51. CALIFORNIA NATURAL AREAS COORDINATING COUNCIL, SONOMA, CA: HOLL, L. (ED.). 1975- INVENTORY OF CALIFORNIA NATURAL AREAS. VOLS. 1-11. SM1, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SIS, CAR, MUR, MAR, ANT, YNZ, ARG, DEEL, OARE, OBCO, OCRZ, OMAK HABITATS, ANIMALS, PLANTS, ENDANGERED SPECIES, HISTORICAL RESOURCES, BREEDING AREAS, COMMUNITIES (BIOLOGICAL), DISTURBANCE, FEEDING, NATURAL RESOURCES, BIOLOGICAL RESERVES, PARKS, NATURAL HISTORY. LOCSE-LEAF. (CALIFORNIA NATURAL AREAS COORDINATING COUNCIL, 1505 SUTHER VISTA DRIVE, SONOMA, CALIFORNIA 95476.)
- 52* CALIFORNIA STATE WATER QUALITY CONTROL BOARD. 1964A. AN INVESTIGATION OF THE EFFECTS OF DISCHARGED WASTES ON KELP. CALIF STATE WATER QUALITY CONTROL BOARD PUBLICATION NO. 26. 124 P* ALGAE, MACROCYSTIS PYRIFERA, KELP, TEMPERATURE--WATER, WIND, WATER QUALITY, IMPACTS, NUTRIENTS, THERMAL POLLUTION, WASTE WATER, MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (UC SANTA CRUZ, STANFORD UNIVERSITY, RESOURCES AGENCY LIBRARY.)
53. CALIFORNIA STATE WATER QUALITY CONTROL BOARD. 1964B. AN OCEANOGRAPHIC STUDY BETWEEN THE POINTS OF IRINICAC HEAD AND THE EEL RIVER. CALIF. STATE WATER QUALITY CONTROL BOARD, PUBLICATION NO. 25. 136 P. CEEL OCEANOGRAPHY, TEMPERATURE--WATER, SALINITY, DISSOLVED OXYGEN, BIOCHEMICAL OXYGEN DEMAND, NUTRIENTS, MARINE. (UC BERKELEY - WATER RESOURCES CENTER ARCHIVES.)
54. CAMERON, G.N. 1972. ANALYSIS OF INSECT TROPHIC DIVERSITY IN TWO SALT MARSH COMMUNITIES. ECLOGY 53(1): 58-73. FRA PRODUCTIVITY, FOOD WEBS, INSECTS, INTERRELATIONSHIPS, COMMUNITIES (BIOLOGICAL), ESTUARINE-INTERTIDAL-EMERGENT WETLAND. SEASONALITY AND PHYSICAL MICROENVIRONMENTAL FACTORS WERE ASSESSED FOR THEIR RELATIONSHIP TO TROPHIC DIVERSITY OF INSECT POPULATIONS IN SALT MARSH COMMUNITIES DOMINATED BY SALICORNIA PACIFICA AND SPARTINA FLORESCENS. (UC BERKELEY - BIOLOGY, MOST UNIV. LIBS.)

55. CARPFOOT, T. 1977. PACIFIC SEASHORES: A GUIDE TO INTERTIDAL ECOLOGY. SEATTLE. UNIVERSITY OF WASHINGTON PRESS. 208 P. MARINE BIOLOGY, MARINE-INTERTIDAL. (UNIVERSITY LIBS.)
56. CHAPMAN, V.J. 1950. SEAWEEDS AND THEIR USES. LONDON. METHUEN AND CO. 287 P. ALGAE, CHEMICAL COMPOSITION, COMMERCE AND INDUSTRY, KELP HARVESTING, MARINE-SUBTIDAL-AQUATIC BED-ALGAL.
- 57* CHAPMAN, V.J. (ED.). 1977. WEST COASTAL ECOSYSTEMS. NEW YORK. ELSEVIER SCIENTIFIC PUBLISHING COMPANY. 428 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, F L U S, SMN, LAG, FRA, GRE, L O I L, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG ANIMALS, BIRDS, COMMUNITIES (BIOLOGICAL), DISTRIBUTION, FOODWEBS, INSECTS, INVERTEBRATES, MAMMALS, MOLLUSCS, PLANTS, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. (UC BERKELEY - FJOL (IGY. I
58. CHEATHAM, N.H.; HALLER, J.R. 1975. AN ANNOTATED LIST OF CALIFORNIA HABITAT TYPES. BERKELEY, CA. UNIVERSITY OF CALIFORNIA NATURAL LAND AND WATER RESERVES SYSTEM. 6 P. + TABLES. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, HABITATS, TOPOGRAPHY, DISTRIBUTION, GRASSLANDS, COASTAL STRAND, SHRUBLANDS. CLASSIFICATION SYSTEM FOR CALIFORNIA HABITATS WITH ANNOTATIONS CONCERNING DISTRIBUTION, ECOLOGICAL FEATURES, VEGETATION STRUCTURE, AND CHARACTERISTIC SPECIES. (UC BERKELEY - BIOLOGY.)
59. CLARK, J.R. 1977. COASTAL ECOSYSTEM MANAGEMENT; A TECHNICAL MANUAL FOR THE CONSERVATION OF COASTAL ZONE RESOURCES. NEW YORK. JOHN WILEY & SONS. 928 P. + BARPIERS, BEACH PROCESSES, BEACH PROTECTION STRUCTURES, BEACH REPLENISHMENT PROGRAMS, ECOLOGY, EROSION, URBAN PLANNING. ANALYSIS OF COASTAL ENVIRONMENTS AND IDENTIFICATION OF MAJOR CONFLICTS WITH PROPOSED SOLUTIONS. DEVELOPS MANAGEMENT METHODOLOGY. (UNIVERSITY LIBS.)
60. CLEM, J.D. 1975. MANAGEMENT OF THE PARALYTIC SHELLFISH POISON PROBLEM IN THE UNITED STATES. IN LOCICERO, V.R. (ED.) THE FIRST INTERNATIONAL CONFERENCE ON TOXIC DINOFLAGELLATE BLOOMS. PROCEEDINGS. MASSACHUSETTS. THE MASSACHUSETTS SCIENCE AND TECHNOLOGY FOUNDATION. P. 459-471. DINOFLAGELLATES, PARALYTIC SHELLFISH POISON, MARINE.
61. CLENDENNING, K.A.; NORTH, W.J. 1960. EFFECTS OF WASTES ON THE GIANT KELP MACROLYSTIS PYRIFERA. IN PEARSON, E.A. (ED.) WASTE DISPOSAL IN THE MARINE ENVIRONMENT. PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE. NEW YORK. PERGAMON PRESS. P. 82-91. SPONSORED BY THE UNIVERSITY OF CALIFORNIA AND CALIFORNIA STATE WATER POLLUTION CONTROL BOARD. WATER QUALITY, MACROCYSTIS PYRIFERA, MARINE-SUBTIDAL-AQUATIC BED. (UC SANTA CRUZ, MOST UNIV. LIBS.)
62. COGSWELL, H.L. 1977. WATERBIRDS OF CALIFORNIA. CALIFORNIA NATURAL HISTORY GUIDES, 4C. BERKELEY. UNIVERSITY OF CALIFORNIA PRESS. 399 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, L A P, MOR, MAR, ANT, YNZ, ARG, DEEL, CARE, OBOC, OORZ, OMAR BIRDS, BREEDING AREAS, DISTRIBUTION, ENDANGERED SPECIES, FEEDING, HABITATS, LIFE HISTORY, OVERWINTERING, SHOREBIRDS, WATER BIRDS. GENERAL REFERENCE.
63. CONNELL, J.H.; SLATYER, R.O. 1977. MECHANISMS OF SUCCESSION IN NATURAL COMMUNITIES AND THEIR ROLE IN COMMUNITY STABILITY AND ORGANIZATION. THE AMERICAN NATURALIST. 111(982): 1111-1143. STABILITY (COMMUNITY), SUCCESSION, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
64. COOPER, W.S. 1967. COASTAL DUNES OF CALIFORNIA. GEOL SOC AM MEM 104. 131 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG GEOMORPHOLOGY, DISTRIBUTION, SUCCESSION, COASTAL FREDUNE COMPLEX, COASTAL DUNE SCRUB. GENERAL OVERVIEW OF CALIFORNIA DUNES, WITH SPECIFIC DISCUSSION OF 32 LOCALITIES FROM THE OREGON BORDER TO BAJA CALIFORNIA. INCLUDES HISTORICAL INFORMATION FOR SOME LOCALITIES, INCLUDING SAN FRANCISCO. (UC BERKELEY - EARTH SCIENCES.)
65. CUTTAM, C.; MUNRO, O. 1954. EELGRASS STATUS AND ENVIRONMENTAL RELATIONSHIPS. JOURNAL OF WILDLIFE MANAGEMENT. 18(4): 449-460. EELGRASS, ESTUARINE-INTERTIDAL-UNCON SHORE-VEG. (UC BERKELEY - BIOLOGY.)
66. COWAN, B. 1975. PROTECTING AND RESTORING NATIVE DUNE PLANTS. FREMONTIA 31(2): 3-7. SMI, KLA, MAD, MAT, NOY, SMN, LAG, GRE, LOR, SLS, CAR, MOR, ANT, ARG PLANTS, IMPACTS, MANAGEMENT RECOMMENDATIONS, COASTAL SCRUBLANDS, NORTH COASTAL BLUFF SCRUB. (UC BERKELEY - BIOLOGY.)

67. COWARDIN, L.M.; CARTER, V.; GOLET, F.C.; LARUE, E.T. 1979. CLASSIFICATION OF WETLANDS AND DEEP-WATER HABITATS OF THE UNITED STATES. PREPARED FOR U. S. FISH AND WILDLIFE SERVICE. 135 P. HABITATS, MARINE, ESTUARINE, RIVERINE, LACUSTRINE-PELAGIAL, PALUSTRINE. 4 PLOKE FINAL VERSION OF THIS WAS PUBLISHED IN DECEMBER 1979 AS FWS/OES-79/31.
68. CHY, J.L. 1976. SAMPLING VARIATION IN SANDY BEACH LITTORAL AND NEARSHORE MEIOFAUNA AND MACROFAUNA. PREPARED FOR U.S. ARMY CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER. TECHNICAL PAPER NO. 76-14. 74 P. ANIMALS, INVERTEBRATES, DISTRIBUTION, MARINE-SUBTIDAL-UNCONSOLIDATED BOTTOM.
69. CRAMPTON, B. 1974. GRASSES IN CALIFORNIA. BERKELEY. UNIVERSITY OF CALIFORNIA PRESS. 178 P. SMI, KIA, MAC, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, DISTRIBUTION, ECOLOGY, TAXONOMY, GRASSLANDS. DISTRIBUTION AND TAXONOMY OF GRASSES. (UC BERKELEY - BIOLOGY.)
70. CRISP, D.J.(ED.). 1962. GRAZING IN TERRESTRIAL AND MARINE ENVIRONMENTS. A SYMPOSIUM OF THE BRITISH ECOLOGICAL SOCIETY, BANGOR, 11-14 APRIL 1962. OXFORD, GREAT BRITAIN. BLACKWELL SCIENTIFIC PUBLICATIONS. 322 P. GRAZING/BROWSING PRESSURE, FEEDING, ECOLOGY, INTERRELATIONSHIPS, PLANKTON, ALGAE, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
71. CUSHING, D.H. 1975. MARINE ECOLOGY AND FISHERIES. NEW YORK. CAMBRIDGE UNIVERSITY PRESS. 278 P. ECOLOGY, FISH, UPWELLING, NUTRIENTS, PRODUCTIVITY, PLANKTON, MIGRATION, FOOD WEBS, MARINE.
72. DAHLSTROM, W.A. 1973B. THE STATUS OF THE MARKET CRAB RESOURCE AND ITS MANAGEMENT. CALIFORNIA FISH GAME MARKESOUR TECH REP NO. 8. 17 P. DEEL, OAKE, OBOD, OCRZ, OMAR FISHERIES, POPULATION DYNAMICS, MANAGEMENT RECOMMENDATIONS, CANCELMAGISTER, REGULATIONS, MARINE-SUBTIDAL-UNCONSOLIDATED BOTTOM-SAND. (UC SANTA CRUZ, MOST UNIV. LIBS.)
73. DAUBENMIRE, R. 1968B. PLANT COMMUNITIES: A TEXTBOOK OF PLANT SYNECOLOGY. NEW YORK. HAPPEL + ROW. 300 P. SMI, KIA, MAC, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, PALUSTRINE-MOSS WETLAND (IE BOGS + FENS), PALUSTRINE-EMERGENT WETLAND, PAL-SCRUB/SHRUB WETLAND (IE FRESHWATER SWAMP), PAL-FORESTED WETLAND (IE FRESHWATER SWAMP), ASSOCIATIONS (BIOLOGICAL), COMMUNITIES (BIOLOGICAL), SUCCESSION, ECOSYSTEMS. TEXTBOOK ON ANALYSIS AND CLASSIFICATION OF VEGETATION. (UC BERKELEY - FORESTRY.)
74. DAUBENMIRE, F. 1978. PLANT GEOGRAPHY: WITH SPECIAL REFERENCE TO NORTH AMERICA. NEW YORK. ACADEMIC PRESS. 338 P. PLANTS, ECOLOGY, DISTRIBUTION. TEXT ON THE DESCRIPTION AND INTERPRETATION OF REGIONAL PLANT DISTRIBUTIONS, INCLUDING THE DISTINCTION BETWEEN FLORISTIC AND ECOLOGIC PLANT GEOGRAPHY. (UC BERKELEY - BIOLOGY.)
75. DAUGHERTY, A.: CALIF. DEPT. OF FISH AND GAME. 1965. MARINE MAMMALS OF CALIFORNIA. 86 P. (EEL, OAKE, [(CC, OCRZ, OMAR MAMMALS, TAXONOMY, DISTRIBUTION, MARINE. (UC SANTA CRUZ, UC BERKELEY - BIOLOGY.)
76. DAVIDSON, E.D.; BARBOUR, M.C. 1977. GERMINATION, ESTABLISHMENT, AND DEMOGRAPHY OF COASTAL BUSH LUPINE (LUPINUS ARBOREUS) AT BODEGA HEAD, CALIFORNIA. ECOLOGY 58(3): 592-600. SMI, [(LA, MAC, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, REGENERATION, LUPINUS ARBOREUS, COASTAL DUNE SCRUB, SEED AVAILABILITY, PRODUCTIVITY. STUDY OF LUPINE REPRODUCTIVE ECOLOGY. (UC BERKELEY - BIOLOGY.)
77. DAWSON, E.Y. 1966B. SEASHORE PLANTS OF NORTHERN CALIFORNIA. BERKELEY. UNIVERSITY OF CALIFORNIA PRESS. 103 p. DEEL, OAKE, OBOD, OCRZ, OMAR ALGAE, MARINE-SUBTIDAL-AQUATIC BED, MARINE-INTERTIDAL-AQUATIC BED. GUIDE TO SEASHORE PLANTS OF NORTHERN CALIFORNIA. (MOST COLLEGE LIBS.)
78. DAYTON, P.K. 1973. DISPERSION, DISPERSAL? AND PERSISTENCE OF THE ANNUAL INTERTIDAL ALGA, POSTELSIA PALMAEFORMIS RUPRECHT. ECOLOGY 54(2): 433-439. ALGAE, POSTELSIA PALMAEFORMIS. (CALIF. STATE COLLEGE, SANTA CRUZ STATE UNIVERSITY LIB., MOST COLLEGE LIBS.)
79. DEAN, J.J. 1971. CANCELMAGISTER DANA (DUNGENESS CRAB). IN OREGON STATE UNIVERSITY. OCEANOGRAPHY OF THE NEARSHORE

COASTAL WATERS OF THE PACIFIC NORTHWEST RELATING TO POSSIBLE POLLUTION, VOL. 1, P. 255-258. PREPARED FOR WATER QUALITY OFFICE, ENVIRONMENTAL PROTECTION AGENCY UNDER GRANT NO. 16073EOK. LIFE HISTORY, REPRODUCTION, TEMPERATURE--WATER, SALINITY, MIGRATION, PREDATION, ECONOMICS, MARINE-SUBTIDAL-UNCONSOLIDATED BOTTOM-SAND. (UC SANTA CRUZ, SUPERINTENDENT OF DOCUMENTS, U. S. GOVERNMENT PRINTING OFFICE.)

80. DELAPP, J. 1960. (UNPUBLISHED MIMED REPORT). A PRELIMINARY GUIDE TO THE WILDLAND SOILS OF HUMBOLDT COUNTY. BERKELEY. U. S. FOREST SERVICE. 9 P. KLA, MAD, FEL, MAT SOILS, PLANTS, GEOLOGY, DISTRIBUTION, GRASSLAND, CHAPARRAL, BROAD-LEAVED EVERGREEN FORESTS, OAK WOODLANDS, COASTAL CONIFER FOREST, LOWER MONTANE CONIFER FOREST. DESCRIPTIONS OF SOIL CHARACTERISTICS AND ASSOCIATED VEGETATION. (UC BERKELEY - FORESTRY.)
81. DEWITT, J.H.; WELSH, J.P. 1977. CHAPTER IV. FISHERIES. IN WINZLER AND KELLY, CONSULTING ENGINEERS, EUREKA, CA. A SUMMARY OF KNOWLEDGE OF THE CENTRAL AND NORTHERN CALIFORNIA COASTAL ZONE AND OFFSHORE AREAS. VOLUME 2. BIOLOGICAL CONDITIONS. BOOK 2* P. VI-1 - VI-337. PREPARED FOR BUREAU OF LAND MANAGEMENT UNDER CONTRACT NO. AA550-C76-52. FISH, FISHERIES, BREEDING AREAS, DISTRIBUTION, ECOLOGY, ENDANGERED SPECIES, EPIPLAGIC, FEEDING, FOOD SOURCES, HABITATS, LIFE HISTORY, MESOPELAGIC, MIGRATION, NATURAL RESOURCES, OVERWINTERING, PREDATION, SPAWNING, BEHAVIOR, NICHES, CONSERVATION, MARINE-PELAGIC, MARINE-SUBTIDAL, INVERTEBRATES. SUMMARY OF MARINE AND ANADROMOUS FISHES, COMMERCIAL FISHERIES OF THE AREA. CA. 650 REFERENCES. (NTIS PB-274 213.)
82. DODGE, M. 1977. CHAPARRAL SOILS AND FIRE-VEGETATION INTERACTIONS. IN SYMPOSIUM ON THE ENVIRONMENTAL CONSEQUENCES OF FIRE AND FUEL MANAGEMENT IN MEDITERRANEAN ECOSYSTEMS, AUG. 1-5, 1977, PALO ALTO, CA. PROCEEDINGS. P. 374-377. U.S. FOREST SERVICE TECH REP WO-3. MAT, NOY, GUA, KUS, GRE, LGR, PAJ, ELK, SLS, CAR, MCR, MAR, ANT, YNZ, AFG FIRE, ECOLOGY, SOIL, EROSION, SUCCESSION, PLANTS, GRASSLAND, CHAPARRAL. DISCUSSION OF IMPACTS OF OVERGRAZING AND DECREASED FIRE FREQUENCY ON ESTABLISHMENT OF CHAPARRAL ON FLAMEP GRASSLAND SITES. (UC BERKELEY - FORESTRY.)
83. DOTY, M.S. 1946. CRITICAL TIDE FACTORS THAT ARE CORRELATED WITH THE VERTICAL DISTRIBUTION OF MARINE ALGAE AND OTHER ORGANISMS ALONG THE PACIFIC COAST. ECOLOGY 27: 315-328. FRA, CAR, ALGAL, ZONATION (BIOLOGICAL), TIDES, ESTUARINE-SUBTIDAL-UNCONSOLIDATED BOTTOM, ESTUARINE-INTERTIDAL-UNCONSHORE, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. (UC BERKELEY - BIOLOGY.)
84. EASTON, R. 1972. BLACK TIDE--THE SANTA BARBARA OIL SPILL AND ITS CONSEQUENCES. NEW YORK. DELACORTE PRESS. 336 P. OIL POLLUTION, OIL SPILLS, INVERTEBRATES, FISH, ALGAE, ECOLOGY, IMPACTS, WATER QUALITY.
85. EMERY, K.O.; STEVENSON, R.E. 1957. ESTUARIES AND LAGOONS. III. SEDIMENTATION IN ESTUARIES, TIDAL FLATS AND MARSHES. (IN HEDGPETH, J.W. (ED.) TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY 1. GEOLOGICAL SOCIETY (AMERICAN) MEMOR 67, P. 729-734. MIXING, SEDIMENTATION, SUSPENDED SOLIDS, ESTUARINE. SEDIMENTARY ENVIRONMENT OF COASTAL ESTUARIES IS DISCUSSED; INCLUDES SEDIMENT DISTRIBUTION AND SORTING, SOURCES OF SEDIMENTS AND SOME INFORMATION ON CHEMICAL CONSTITUENTS OF SURFACE DEPOSITS.
86. ENGINEERING-SCIENCE; MOSS LANDING MARINE LABORATORIES. 1979. PREDISCHARGE OCEANOGRAPHIC INVESTIGATIONS IN CENTRAL MONTEREY BAY: 1977. VOL. 1 DRAFT FINAL REPORT. PREPARED FOR MONTEREY PENINSULA WATER POLLUTION CONTROL AGENCY. CA. 130 P. OCPZ WATER QUALITY, SEDIMENT, PHYSICAL OCEANOGRAPHY, TEMPERATURE--WATER, CALIFORNIA CURRENT SYSTEM, CHEMICAL COMPOSITION, GEOLOGY, WIND, CURRENTS--OCEAN* FISH, INVERTEBRATES, ASSEMBLAGES, SALINITY, FOOD WEBS, ABUNDANCE, DISTRIBUTION, MARINE. (CALIFORNIA STATE WATER RESOURCES CONTROL BOARD.)
87. ERMAN, D.C.; NEWBLD, J.C.; ROBY, K.P. 1977. EVALUATION OF STREAMSIDE BUFFER STRIPS FOR PROTECTING AQUATIC ORGANISMS. U.C. DAVIS CALIFORNIA WATER RESOURCES CENTER CONTRIBUTION NO. 165. 44 P. SMI, I(LA, MAD, FEL, MAT, NOY INVERTEBRATES, INSECTS, EROSION, DISTURBANCE, LOGGING, SEDIMENTATION, WATERSHED MANAGEMENT, RIVERINE-UPPER PEREN-UNCON BOTTOM. BUFFER STRIPS GREATER THAN 4 N 30 METERS WIDE PREVENT CHANGES IN BENTHIC INVERTEBRATE COMMUNITY DUE TO LOGGING. (UC DAVIS.)
88. EVEREST, F.H.; CHAPMAN, D.W. 1972. HABITAT SELECTION AND SPATIAL INTERACTION BY JUVENILE CHINOOK SALMON AND STEELHEAD TROUT IN TWO IDAHO STREAMS. J FISH RES BOARD CAN 29: 91-100. LIFE HISTORY, CHINOOK SALMON, KING SALMON, ONCORHYNCHUS Tshawytscha, STEELHEAD, STEELHEAD RAINBOW TROUT, SALMO Gairdneri, SALMO Gairdneri CALIFNERI,

COMPETITION, INTERRELATIONSHIPS, RIVERINE-UPPER PERENNIAL. AGE 0 STEELHEAD FOUND OVER RUBBLE SUBSTRATE IN WATER DEPTHS LESS THAN 0.15M, AND VELOCITY LESS THAN 9.15 M/SEC.. AGE 0 CHINOOK FOUND OVER SILT SUBSTRATE IN WATER DEPTHS OF 0.15-0.33M, AND VELOCITY LESS THAN 0.15 M/SEC. AGE 1 STEELHEAD FOUND OVER RUBBLE SUBSTRATE. FISH MOVE TO DEEPER FASTER WATER AS THEY GET OLDER. (UC DAVIS, MAJOR UNIVERSITY LIBRARIES.)

89. FARMANFARMAIAN, A.; GIESE, A.C.; BOGUCOTIAN, R.A.; BENNET, J. 1959. ANNUAL REPRODUCTIVE CYCLES IN FOUR SPECIES OF WEST COAST STARFISHES. J EXP ZOO 138: 355-367. OCRZ LIFE HISTORY, SEA STARS, ECOLGY, PACIFIC COVE, PISASTER OCHRACEUS, PISASTER BREVISPINUS, PATIRIA MINIATA, PISASTER GIGANTEUS, MARINE-SUBTIDAL, LEPTASIFRIAS HEXACTIS. (UC SANTA CRUZ, MOST UNIV. LIBS.)
90. FAUCHALD, K. 1972. A SURVEY OF THE BENTHOS OFF SANTA BARBARA FOLLOWING THE JANUARY 1969 OIL SPILL. CALIF CLIP FISH INVEST REP 1(1): 125-129. BIOMASS, INVERTEBRATES, DIVERSITY (ECOSYSTEMS 1, STABILITY (ECOSYSTEMS), OIL POLLUTION, OIL SPILLS, DISTRIBUTION, ABUNDANCE, LITTOLOGOUS PELOIDS, ANIMALS, MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
91. FAUCHALD, K.; JUMARS, P. 1979. THE DIET OF WORMS: A STUDY OF POLYCHAETE FEEDING GUILDS. OCEANOGRAPHIC ANNU REV 17: 193-284. FEEDING, TROPHIC LEVELS, POLYCHAETA, WORMS, FOOD WEBS, MARINE. (UC SANTA CRUZ, MOSS LANDING MARINE LABORATORY, MOST UNIV. LIBS.)
92. FEDER, H.M.; TURNER, C.H.; LIMBAUGH, C. 1974. OBSERVATIONS ON FISHES ASSOCIATED WITH KELP BEDS IN SOUTHERN CALIFORNIA. CALIF CLIP FISH GAME FISH BULL 16'3. 144 P. ASSOCIATIONS (BIOLOGIC ALI, ALGAE, BEHAVIOR, DISTRIBUTION, ECOSYSTEMS, FISH, FOOD WEBS, FOOD SOURCES, HABITATS, LIFE HISTORY, KELP, PRECATION, SPAWNING, TROPHIC LEVELS, MARINE-SUBTIDAL-ROCK BOTTOM, MARINE-SUBTIDAL-AQUATIC BED-ALGAL, ESTUARINE-SUBTIDAL-AQUATIC BED. (MOSS LANDING MARINE LABORATORY, MOST UNIV. LIBS.)
93. FITCH, J.E.; LAVENBERG, R.J. 1968. DEEP-WATER TELEOSTEAN FISHES OF CALIFORNIA. LOS ANGELES. UNIVERSITY OF CALIFORNIA PRESS. 155 P. DEEL, CARE, OBOD, OCRZ, OMAR FISH, DISTRIBUTION, ABUNDANCE, TELEOSTEA, MARINE-PELAGIC LARVAE, TAXONOMY, ECOLOGY. (UCLA.)
94. FITCH, J.E.; LAVENBERG, R.J. 1971. MARINE FOOD AND GAME FISHES OF CALIFORNIA. BERKELEY. UNIVERSITY OF CALIFORNIA PRESS. 179 P. DEEL, CARE, OBOD, OCRZ, OMAR NATURAL HISTORY, FISH, FISHERIES, FISHING--SPORT, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
95. FLEMINGER, A. 1964. DISTRIBUTIONAL ATLAS OF CALANOID COPEPODS IN THE CALIFORNIA CURRENT REGION, PART 1. SPONSORED BY CALIF. MARINE RESEARCH COMMITTEE. CALIF COOP OCEANIC FISH INVEST ATLAS NO. 1. 2. 213 P. DEEL, CARE, OBOD, OCRZ, OMAR DISTRIBUTION, CALANOID COPEPODS, CALIFORNIA CURRENT, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
96. FLEMINGER, A. 1967. DISTRIBUTIONAL ATLAS OF CALANOID COPEPODS IN THE CALIFORNIA CURRENT REGION, PART 11. SPONSORED BY CALIF. MARINE RESEARCH COMMITTEE. CALIF COOP OCEANIC FISH INVEST ATLAS NO. 7. 213 P. DEEL, CARE, OBOD, OCRZ, OMAR DISTRIBUTION, CALANOID COPEPODS, CALIFORNIA CURRENT, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
97. FLEMINGER, A.; ISSACS, D.; WYLLIE, J.G. 1974. ZOOPLANKTON BIOMASS MEASUREMENTS FROM CALCOFI CRUISES OF JULY 1955 TO 1959 AND REMARKS ON COMPARISON WITH RESULTS FROM OCTOBER, JANUARY AND APRIL CRUISES OF 1955 TO 1959. SPONSORED BY CALIF. MARINE RESEARCH COMMITTEE. CALIF COOP OCEANIC FISH INVEST ATLAS NO. 21. 118 P. DEEL, CARE, OBOD, OCRZ, OMAR ZOOPLANKTON, DISTRIBUTION, CALIFORNIA CURRENT, BIOMASS, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
98. FLORENCE, R.G. 1965. DECLINE OF OLD-GROWTH REDWOOD FORESTS IN RELATION TO SOME SOIL MICROBIOLOGICAL PROCESSES. ECOLOGY 46(1): 52-64. SM, KLA, MAD, EEL, NOY, GUA, RUS, LAG, GPF, LCR, CAR, MCR PLANTS, ECOLOGY, COMPOSITION, NUTRIENTS, REGENERATION, ALLUVIAL REDWOOD FOREST, SLOPE REDWOOD FOREST. STUDY OF MICROBIAL ECOLOGY IN REDWOOD LITTER. (UC BERKELEY - BIOLOGY.)

99. FOLK, R.L. 1968. PETROLOGY OF SEDIMENTARY ROCKS. AUSTIN, TEXAS. THE UNIVERSITY OF TEXAS. 170 P. SEDIMENT, MINING, GEOLOGY, MARINE.
100. FOSTER, M.S. 1975A. ALGAL SUCCESSION IN A MACROCYSTIS PYRIFERA FOREST. MAR BIOL (BERL) 32: 312-329. ALGAE, SUCCESSION, MACROCYSTIS PYRIFERA, KELP, COMPETITION, ECOLOGY, LIGHT PENETRATION, PRODUCTIVITY, COMMUNITIES (BIOLOGICAL), GROWTH RATES, MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (UC SANTA CRUZ, STANFORD UNIVERSITY, MONT UNIV. LIBS.)
101. FOSTER, M.S.; AGEKIAN, C.R.; COWAN, R.K.; VAN WAGENEN, R.F.; ROSE, D.K.; HUXLEY, A.C. 1975. TOWARD AN UNDERSTANDING OF THE EFFECTS OF SEA OTTER FORAGING ON KELP FOREST COMMUNITIES IN CENTRAL CALIFORNIA. PREPARED FOR U.S. MARINE MAMMAL COMMISSION UNDER CONTRACT NO. MM7AC023. 60 P. OCRZ MOLLUSCS, SUCCESSION, INVERTEBRATES, KELP, ALGAE, MACROCYSTIS PYRIFERA, GRAZING/BROWSING PRESSURE, COMMUNITIES (BIOLOGICAL), DISTRIBUTION, MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (UC SANTA CRUZ, STANFORD, NTIS PB-293891.)
102. FOWELLS, H.A. (ED.). 1965. SILVICS OF FOREST TREES OF THE UNITED STATES. AGRICULTURE HANDBOOK NO. 271. WASHINGTON, D.C. USDA-FOREST SERVICE. 762 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, FUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, SILVICULTURE, DISTRIBUTION, BROAD-LEAVED FORESTS & WOODLANDS, CONIFER FORESTS. ECOLOGICAL REQUIREMENTS AND LIFE HISTORIES OF MAJOR CONIFER AND HARDWOOD TREE SPECIES. (UC BERKELEY - FORESTRY.)
103. FRANKLIN, J.F.; DYRNESS, C.T. 1973. NATURAL VEGETATION OF OREGON AND WASHINGTON. U.S. FOR SERV GEN TECH REP PNW-8. 417 P. SMI, KLA, MAD, EEL PLANTS, ECOLOGY, DISTRIBUTION, SUCCESSION, MIXED EVERGREEN FOREST, RED ALDER FOREST, COASTAL CONIFER FOREST, LOW MOUNTAIN CONIFER FOREST. DESCRIPTION OF PACIFIC NORTHWEST VEGETATION TYPES, SOME OF WHICH EXTEND SOUTH TO DEL NORTE AND HUMBOLDT COUNTIES, CALIFORNIA. (UC BERKELEY - FORESTRY.)
104. FREDRICKSON, L.H.; ANDERSON, J.M.; KLZLIK, F.M.; RYDER, R.A. 1977. AMERICAN COOT (FULICA AMERICANA). IN SANDERSON, S.C. (ED.). MANAGEMENT OF MIGRATORY SHORE AND UPLAND GAME BIRDS IN NORTH AMERICA. WASHINGTON, D.C. THE INTERNATIONAL ASSOCIATION OF FISH AND WILDLIFE AGENCIES. P. 122-147. BIRDS, STATUS, MANAGEMENT RECOMMENDATIONS, NATURAL HISTORY, COOT, AMERICAN COOT, FULICA AMERICANA, PAL-EM WET-PERS-PER MUIS (FRESHWATER).
105. FREY, H.W. 1971. CALIFORNIA'S LIVING MARINE RESOURCES AND THEIR UTILIZATION. SACRAMENTO. CALIFORNIA DEPARTMENT OF FISH AND GAME. 148 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, FUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG, DEEL, CARE, OBOD, OCRZ, OMAR FISH, LIFE HISTORY, INVERTEBRATES, FISHERIES, ALGAE, CONSERVATION, CRUSTACEA, ENDANGERED SPECIES, MOLLUSCS, MAMMALS, DISTRIBUTION, MARINE. MUCH USEFUL INFORMATION ON LIFE HISTORY AND FISHERIES OF IMPORTANT SPECIES. (UC BERKELEY - AGRICULTURE, UC SANTA CRUZ, STANFORD UNIVERSITY.)
106. FREY, H.W.; BASAN, P.B. 1978. COASTAL SALT MARSHES. IN DAVIS, R.A. JR. (ED.) COASTAL SEDIMENTARY ENVIRONMENTS. NEW YORK. SPRINGER-VERLAG. P. 121-169. ZONATION (BIOLOGICAL), SEDIMENTATION, HYDROLOGY, TIDES, ESTUARINE-INTERTIDAL-EPHEMERAL WETLAND.
107. GALLINER, F.W. [CALIF. DIVISION OF MINES AND GEOLOGY]. 1932. SEDIMENTS OF MONTEREY BAY, CALIFORNIA. MINING [IN CALIFORNIA]. 28TH REPORT OF THE STATE MINEROLOGIST. 28(1): 42-72. OCRZ SEDIMENT, PHYSICAL OCEANOGRAPHY, MARINE. (CALIF. STATE LIBRARY. J)
108. GATES, D.E.; FREY, H.W. 1974. DESIGNATED COMMON NAMES OF CERTAIN MARINE ORGANISMS OF CALIFORNIA. CALIF DEP FISH GAME FISH BULL 161: 55-90. DEEL, CARE, OBOD, OCRZ, OMAR NOMENCLATURE, FISH, MOLLUSCS, ECHINODERMS, ARTHROPODS. UPDATES DESIGNATED COMMON NAMES FOR MARINE ORGANISMS OF CALIFORNIA, INCLUDING NUMEROUS FISHES; HISTORY, RATIONALE, ANNOTATIONS ON COMMON NAMES; REFERENCES. (UC BERKELEY - WATER RESOURCES CENTER ARCHIVES.)
109. GERARD, V.A. 1976. SOME ASPECTS OF MATERIAL DYNAMICS AND ENERGY FLOW IN A KELP FOREST IN MONTEREY BAY, CALIFORNIA. DISSERTATION, UNIV. OF CALIF. SANTA CRUZ. 173 P. OCRZ MACROCYSTIS PYRIFERA, ECOLOGY, TEMPERATURE--WATER, ALGAE, PRODUCTIVITY, DETRITUS, GROWTH PATTERNS, INSOLATION, NUTRIENTS, KELP, POPULATION DYNAMICS, COMMUNITIES (BIOLOGICAL), MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (UC SANTA CRUZ, STANFORD UNIVERSITY.)

110. GERDES, G.L.: PRIMRS, E.R.J.: BROWNING, B.M. 1974. NATURAL RESOURCES OF MORRO BAY, THEIR STATUS AND FUTURE. PREPARED UNDER CONTRACT WITH CALIF. COASTAL ZONE CONSERVATION COMMISSION WITH FUNDS GRANTED BY THE NATIONAL OCEAN AND ATMOSPHERIC ADMINISTRATION. CALIF DEP FISH GAME COASTAL WETLAND SERIES #9. 103 P. MOR ANIMALS, BIRDS, COMMUNITIES (BIOLOGICAL), CRUSTACEA, ECOLOGY, FISH, FOOD WEBS, GEOMORPHOLOGY, HABITATS, INSECTS, INVERTEBRATES, MAMMALS, MOLLUSCS, NATURAL RESOURCES, PLANTS, POPULATION DYNAMICS, RECREATION, SHORE BIRDS, WATER BIRDS, WATER FOWL, ZONATION (BIOLOGICAL), TROPHIC LEVELS, ESTUARINE. (UC BERKELEY - WATER RESOURCES CENTER ARCHIVES.)
111. GHELARDI, R.J. 1971. 'SPECIES' STRUCTURE OF THE ANIMAL COMMUNITY THAT LIVES IN MACROCYSTIS PYRIFERA NODULASTS. IN NORTH, W.J. (ED.). THE BIOLOGY OF GIANT KELP BEDS (MACROCYSTIS) IN CALIFORNIA. NOVA HEDWIGIA 32. P. 381-420. ALGAE, KELP, COMMUNITIES (BIOLOGICAL), INVERTEBRATES, POPULATION DYNAMICS, MACROCYSTIS PYRIFERA, MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (UC SANTA CRUZ, STANFORD UNIVERSITY, MOST UNIV. LIBS.)
112. GILMARTIN, W.G.; DELONG, R.L.; SMITH, A.W.; SWEENEY, J.C.; DELAPPE, B.W.; RISEBROUGH, R.W.; GRINLE, L.A.; DAILEY, M.D.; PEAKALL, D.B. 1976. PREMATURE PARTURITION IN THE CALIFORNIA SEALION. JOURNAL OF WILDLIFE DISEASES 12: 104-115. CALIFORNIA SEALION, ZALOPHUS, LIFE HISTORY, MARINE.
113. GOSSFLINK, J.G.; TURNER, K.E. 1978. THE ROLE OF HYDROLOGY IN FRESHWATER WETLAND ECOSYSTEMS. IN GOOD, R.E. (ED.); WHIGHAM, O.F. (FO.): SIMPSON, R.L. (ED.). FRESHWATER WETLANDS: ECOLOGICAL PROCESSES AND MANAGEMENT POTENTIAL. NEW YORK. ACADEMIC PRESS. P. 63-78. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, HYDROLOGY, NUTRIENTS, DECOMPOSITION, PRODUCTIVITY, PALUSTRINE-MOSS WETLAND (IE BOGS + FENS), PALUSTRINE-EMERGENT WETLAND, PAL-SCRUB/SHRUB WETLAND (IE FRESHWATER SWAMP), PAL-FORESTED WETLAND (IE FRESHWATER SWAMP), MONTANE MEADOWS. DISCUSSION OF FRESHWATER WETLAND HYDROLOGY. (UC BERKELEY - BIOLOGY.)
114. GRASSLE, J.F.; GRASSLE, J.P. 1974. OPPORTUNISTIC LIFE HISTORIES AND GENETIC SYSTEMS IN MARINE BENTHIC POLYCHAETES. J MAR RES 32: 253-284. LIFE HISTORY, POLYCHAETA, WORMS, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
115. GRAY, J.S. 1974. ANIMAL-SEDIMENT RELATIONSHIPS. OCEANOGRAPHIC ANNALS REV 12: 223-261. ANIMALS, SEDIMENT, ECOLOGY, SUBSTRATUM, INVERTEBRATES, MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
116. GREVE, d.; PARSONS, T.R. 1977* PHOTOSYNTHESIS AND FISH PRODUCTION; HYPOTHETICAL EFFECTS OF CLIMATIC CHANGE AND POLLUTION. HELGOL WISS MEERESUNTERS 30: 666-672. FOOD WEBS, FISH, PRODUCTIVITY, PHYTOPLANKTON, MARINE, PHOTOSYNTHESIS. (UC SANTA CRUZ.)
117. GRIFFIN, J.R. 1964 ISOLATED PINUS PONDEROSA FORESTS ON SANDY SOILS NEAR SANTA CRUZ, CALIFORNIA. ECOLOGY 45(2): 419-412. LOR PLANTS, SOILS, FIRE, ECOLOGY, COAST RANGE PONDEROSA PINE FOREST. SOIL AND FIRE RELATIONS OF AN UNUSUAL LOW-ELEVATION OCCURRENCE OF PONDEROSA PINE. (UC BERKELEY - BIOLOGY.)
118. GRIFFIN, J.R. 1971. OAK REGENERATION IN THE UPPER CARMEL VALLEY, CALIFORNIA. ECOLOGY 52(5): 862-868. CAR PLANTS, HERBIVORY, REGENERATION, SEED AVAILABILITY, ECOLOGY, OAK WOODLANDS. OAK REGENERATION SUCCESS VARIED WITH ASPECT, GRASS DENSITY, AND HERBIVORE PRESSURE. (UC BERKELEY - BIOLOGY.)
119. GRIFFIN, J.R. 1973. XYLEM SAP TENSIC IN THREE WOODLAND OAKS OF CENTRAL CALIFORNIA. ECOLOGY 54: 152-155. NOY, GUA, RUS, SMN, LAG, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, DISTRIBUTION, PHYSIOLOGY, WATER BALANCE, OAK WOODLANDS. (UC BERKELEY - FORESTRY.)
120. GRIFFIN, J.R. 1976. REGENERATION IN QUERCUS LOBATA SAVANNAS, SANTA LUCIA MOUNTAINS, CALIFORNIA. AM MID NAT 95(2): 422-435. CAR, MOR PLANTS, REGENERATION, SUCCESSION, PREDATION, FIRE, DISTRIBUTION, BROAD-LEAVED EVERGREEN FORESTS, OAK WOODLANDS, LOWER MONTANE CONIFER FOREST. STUDY OF REGENERATION AND SUCCESSION IN VALLEY OAK WOODLANDS. (UC BERKELEY - BIOLOGY.)
121. GRIFFIN, J.R. 1977. OAK WOODLAND. IN BARBUR, M.G. (ED.): MAJOR, J. (ED.). TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILLY + SONS. P. 383-416. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, IPA, GFL, LOR, PAJ, ELK,

SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, DISTRIBUTION, SUCCESSION, SOILS, FIRE, OAK WOODLANDS. SURVEY OF PREVIOUS STUDIES ON OAK WOODLAND. (UC BERKELEY - FORESTRY.)

122. GRIFFIN, J.R. 1978. THE MARBLE-CONE FIRE TEN MONTHS LATER. FREMENTIA 6(2): 8-14. CAR, MOR FIRE, PLANTS, ECOLOGY, SUCCESSION, CHAPARRAL, BROAD-LEAVED EVERGREEN FORESTS, KNOBCONE PINE FOREST, SLOPERED WOOD FOREST, LOWER MONTANE CONIFER FOREST. DESCRIPTION OF FIRE EFFECTS AND VEGETATION RECOVERY AFTER 1977 FIRE IN SANTA LUCIA MTS., MONTEREY CO.. (UC BERKELEY - BIOLOGY.)
123. GRIFFITHS, C.L.; KING, J.A. 1979. ENERGY EXPENDED ON GROWTH AND GONADOTROPIN IN THE RIBBED MUSSEL AULACOMYA ATER. MAR BIOL (BERL) 53: 217-222. AULACOMYA ATER, GROWTH RATES, LIFE HISTORY, FEEDING, RIBBED MUSSEL, MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
124. GUNNISON, D.; U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, ENVIRONMENTAL LABORATORY, VICKSBURG, MS. 1978. MINERAL CYCLING IN SALT MARSH-ESTUARINE ECOSYSTEMS: ECOSYSTEM STRUCTURE, FUNCTION, AND GENERAL COMPARTMENTAL MODEL DESCRIBING MINERAL CYCLES. PREPARED FOR OFFICE, CHIEF OF ENGINEERS, U. S. ARMY, WASHINGTON, D. C. UNDER CMRP WORK UNIT NO. 2A05. TECHNICAL REPORT C-78-3. 150 P. NUTRIENTS, DREDGING, HEAVY METALS, ESTUARINE, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. EXISTING INFORMATION ON MINERAL CYCLING IN SALT MARSH-ESTUARINE ECOSYSTEMS IS SUMMARIZED; A COMPARTMENTAL MODEL WAS DEVELOPED.
125. GUNTER, G. 1957. CHAPTER 8, TEMPERATURE. IN HEDGPETH, J.W. (ED.). TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY. THE GEOLOGICAL SOCIETY OF AMERICA MEMOIR 67. P. 159-184. TEMPERATURE--WATER, IMPACTS, BEHAVIOR, DISTRIBUTION, ANIMALS, PERIODICITY, GROWTH RATES, MORPHOLOGY, ECOLOGY, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
126. HANES, T.L. 1977. CALIFORNIA CHAPARRAL, IN BARBOUR, M.G. (ED.); MAJOR, J. (ED.). TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK, JOHN WILEY + SONS. P. 417-469. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, SOIL, SUCCESSION, TOPOGRAPHY, FIRE, ALLELOPATHY, LIFE HISTORY, CHAPARRAL. DESCRIPTION OF TYPES OF CHAPARRAL VEGETATION, SUCCESSION, FIRE ECOLOGY, WATER RELATIONS, AND REPRODUCTION. (UC BERKELEY - BIOLOGY.)
127. HARDING, L.W.; BUTLER, J.H. 1979. THE STANDING STOCK AND PRODUCTION OF EELGRASS, ZOSTERA MARINA IN HUMPHREY HAY, CALIFORNIA. CALIF FISH GAME 65(3): 151-159. MAD ZOSTERA MARINA, EELGRASS, HUMPHREY HAY, PRODUCTIVITY, MARINE-SUBTIDAL-AQUATIC BED-ROOTED VAS, MARINE-INTERTIDAL-AQUATIC BED-ROOTED VAS, ESTUARINE-SUBTIDAL-AQUATIC BED-ROOTED VAS, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. (UC BERKELEY - BIOLOGY.)
128. HARDY, A. 1965. THE OPEN SEA: ITS NATURAL HISTORY. PART I: THE WORLD OF PLANKTON. BOSTON. HUGHSON MIFFLIN COMPANY. 322 P. PLANKTON, CURRENTS--OCEAN, PHYTOPLANKTON, SEASONAL VARIATION, ZOOPLANKTON, MIGRATION, FISHERIES, MARINE-PELAGIC. REFERENCE.
129. HARRISON, A.T.; SMALL, E.; MOONEY, H.A. 1971. DROUGHT RELATIONSHIPS AND DISTRIBUTION OF TWO MEDITERRANEAN-CLIMATE CALIFORNIA PLANT COMMUNITIES. ECOLOGY 52(5): 869-875. LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, DISTRIBUTION, SOILS, PHYSIOLOGY, PRODUCTIVITY, DROUGHT, SHRUBLANDS. DISCUSSION OF RELATIONSHIPS BETWEEN LEAF MORPHOLOGY, LEAF PHYSIOLOGY, PHOTOSYNTHETIC RATES, AND DISTRIBUTIONS OF CHAPARRAL AND COASTAL SCRUB SPECIES. (UC BERKELEY - BIOLOGY.)
130. HART, J.L. 1977. PACIFIC FISHES OF CANADA. FISH RES BOARD CAN BULL 180. 740 P. FISH, LIFE HISTORY, DISTRIBUTION, SPAWNING, HABITATS, FOOD SOURCES. ECOLOGY, BATHYPELAGIC, DEHYVIOG, BREEDING AREAS, EPIPELAGIC, FEEDING, FISHERIES. NATURAL RESOURCES, NICHES, PREDATION, TAXONOMY, MARINE. GENERAL REFERENCE ON PACIFIC COAST FISH, INCLUDES MANY SPECIES FOUND IN STUDY AREA. SPECIES ACCOUNTS FOR 325 MARINE, ANADROMOUS FISH. (UC BERKELEY - BIOLOGY, UC DAVIS.)
131. HARTMAN, G.F. 1965. THE ROLE OF BEHAVIOR IN THE ECOLOGY AND INTERACTION OF UNDERYEARLING COHO SALMON (ONCHOSALMONUS KISUTCH) AND STEELHEAD TROUT (SALMO GAIRONERI). J FISH RES BOARD CAN 22(4): 1035-1061. STEELHEAD, STEELHEAD RAINBOW TROUT, SALMO GAIRONERI, SALMO GAIRONERI GAIRONERI, COHO SALMON, SILVER SALMON, ONCHOSALMONUS KISUTCH,

BEHAVIOR, COMPETITION, RIVERINE-UPPER PERENNIAL-ROCK BOTTOM, RIVERINE-UPPER PERENNIAL-ROCK BOTTOM. COHO AND STEELHEAD SEGREGATED IN SPRING AND SUMMER, WHEN ECOLOGICAL DEMANDS FOR THE TWO SPECIES WERE SIMILAR; STEELHEAD DROVE COHO FROM RIFFLES INTO POOLS. THEY BOTH OCCUPIED SAME HABITAT (POOL) IN WINTER WHEN ECOLOGICAL DEMANDS WERE LOW. (UC DAVIS, MAJOR UNIV. LIBS.)

132. HARTMAN, G.F.; GILL, C.A. 1968. DISTRIBUTIONS OF JUVENILE STEELHEAD AND CUTTHROAT TROUT (SALMO GAIRONERI AND S. CLARKI) WITHIN STREAMS IN SOUTHWESTERN BRITISH COLUMBIA. J. FISH. RES. BOARD CAN. 25(1): 33-48. DISTRIBUTION, STEELHEAD, SALMO GAIRONERI, SALMO GAIRONERI, SALMO GAIRONERI, STEELHEAD RAINBOW TROUT, CUTTHROAT TROUT, COASTAL CUTTHROAT TROUT, SALMO CLARKI, SALMO CLARKI, ECOLOGY, INTERRELATIONSHIPS, RIVERINE-LOWER PERENNIAL-ROCK BOTTOM, RIVERINE-LOWER PERENNIAL-ROCK BOTTOM, RIVERINE-UPPER PERENNIAL-ROCK BOTTOM, RIVERINE-UPPER PERENNIAL-ROCK BOTTOM. CUTTHROAT FOUND IN SMALL STREAMS AND STREAMS OF LOW GRADIENT. STEELHEAD FOUND IN STEEPER, LARGER STREAMS. (UC DAVIS, MAJOR UNIV. LIBS.)
133. HARTMAN, G. 1963. SUBMARINE CANYONS OF SOUTHERN CALIFORNIA. PART II BIOLOGY. ALLAN HANCOCK PACIFIC EXPEDITIONS VOL. 27. LOS ANGELES. UNIVERSITY OF SOUTHERN CALIFORNIA PRESS. 424 P. SUBMARINE CANYONS, MARINE. (UC SANTA CRUZ.)
134. HASLER, A.D. (ED.). 1975. COUPLING OF LAND AND WATER SYSTEMS. ECOLOGICAL STUDIES; VOL. 1. NEW YORK. SPRINGER-VERLAG. 309 P. DECOMPOSITION, HYDROLOGY, PLANTS, ECOLOGY, SOIL, PALUSTRINE-MOSS WETLAND (IE PEGS + FENS), PALUSTRINE-EMERGENT WETLAND, PAL-SCRUB/SHRUB WET (IE FRESHWATER SWAMP), PAL-FORESTED WETLAND (IE FRESHWATER SWAMP), MEADOWS + SEEPS. COLLECTION OF ARTICLES ON HYDROLOGIC, NUTRIENT, AND TROPIC RELATIONS BETWEEN AQUATIC AND TERRESTRIAL ECOSYSTEMS. (UC BERKELEY - BIOLOGY.)
135. HEADY, H.F. 1977. VALLEY GRASSLAND. IN BARBOUR, M.G. (ED.): MAJOR, J. (ED.) TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILEY + SONS. P. 491-514. MAT, MOY, GUA, RUS, SMN, LAG, FRA, GRE, LCP, PAJ, ELK, SLS, CAP, MCR, MAR, ANT, VNZ, ARG. PLANTS, ECOLOGY, DISTRIBUTION, PRODUCTIVITY, SUCCESSION, GRASSLAND. SURVEY OF ECOLOGY AND COMPOSITION OF CALIF. GRASSLANDS. (UC BERKELEY - BIOLOGY.)
136. HEADY, H.F.; FOIN, T.C.; HEKNER, M.M.; TAYLOR, D.W.; BARBOUR, M.G.; BARRY, W.J. 1977. COASTAL PRAIRIE AND NORTHERN COASTAL SCRUB. IN BARBOUR, M.G. (ED.); MAJOR, J. (ED.). TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILEY + SONS. P. 733-760. SMI, KLA, MAD, EEL, MAT, NCY, GUA, PUS, SMN, LAG, FRA, GRE, LCP, PAJ, ELK, SLS, CAP, MCR. PLANTS, ECOLOGY, DISTRIBUTION, SUCCESSION, COASTAL PRAIRIE, NORTH COASTAL SCRUB, CENTRAL COASTAL SCRUB. SURVEY OF COASTAL PRAIRIE AND NORTHERN COASTAL SCRUB COMPOSITION, DISTRIBUTION, AND ECOLOGY. (UC BERKELEY - BIOLOGY.)
137. HEDGPETH, J.W. 1957B. CHAPTER 13. MARINE BIOGEOGRAPHY. IN HEDGPETH, J.W. (ED.) TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY VOL. 1, THE GEOLOGICAL SOCIETY OF AMERICA MEMOR. 67. P. 359-382. BIOGEOGRAPHY, ECOLOGY, COMMUNITIES (BIOLOGICAL), DISTRIBUTION, ANIMALS, PLANTS, PLANKTON, TEMPERATURE--WATER, MIGRATION, MARINE. (UC SANTA CRUZ.)
138. HESSLER, R.R.; JUMARS, P.A. 1974. ABYSSAL COMMUNITY ANALYSIS FROM REPLICATE BOX CORES IN THE CENTRAL NORTH PACIFIC. DEEP-SEA RES. 21: 185-209. COMMUNITIES (BIOLOGICAL), MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
139. HESSLER, R.R.; WILSON, G.F.J.; THISTLE, D. 1979. THE DEEP-SEA ISPODS: A BIOGEOGRAPHIC AND PHYLOGENETIC OVERVIEW. SARZIA 64: 67-75. ISPODS, TAXONOMY, ECOLOGY, MARINE. (MOSS LANDING MARINE LAB) CPALORY, UCSANTA CRUZ.)
140. HINDE, H.P. 1954. THE VERTICAL DISTRIBUTION OF SALT MARSH PHANEROGAMS IN RELATION TO TIDE LEVELS. ECOLOG. MONOGR. 24(2): 209-225. FRA. DISTRIBUTION, PLANTS, LIMITING FACTORS, TIDES, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. A QUANTITATIVE STUDY OF THE RELATIONSHIP BETWEEN TIDAL INFLUENCES AND SALT MARSH PLANT VERTICAL DISTRIBUTION. (UC BERKELEY - BIOLOGY., MOST UNIV. LIBS.)
141. HOLLAND, R.; JAIN, S. 1977. VERNAL POOLS. IN BARBOUR, M.G. (ED.): MAJOR, J. (ED.). TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILEY + SONS. P. 515-533. PLANTS, ECOLOGY, SOILS, DISTRIBUTION, PAL-EM WET-FERS-SEAS MOIS (IE VERNAL MAR), PALUSTRINE-EMERGENT WETLAND-NONPERSIS. DISCUSSION OF ORIGIN, ECOLOGY, AND BOTANICAL

COMPOSITION OF VERNAL POOLS. (UC BERKELEY - BIOLOGY.)

142. HOLLAND, R.F. 1976. THE VEGETATION OF VERNAL POOLS: A SURVEY. IN JAIN, S. (ED.). VERNAL POOLS: THEIR ECOLOGY AND CONSERVATION, A SYMPOSIUM. INSTITUTE OF ECOLOGY, UNIVERSITY OF CALIFORNIA, DAVIS. MAY 1-2, 1976. P. 11-15. INSTITUTE OF ECOLOGY PUBLICATION NO. 9. RUS, SMN, LAG, FRA, GRF, LOR, PAJ, ELK, SLS, CAR, MOR, MAP, ANI, YNZ, ARG PLANTS, ECOLOGY, TOPOGRAPHY, PAL-EM WET-PERS-SEAS MOIS (IE VERNAL MAR), PALUSTRINE-EMERGENT WETLAND-NOIPERSIS. SURVEY OF VERNAL POOL PLANT SPECIES AND A CLASSIFICATION SCHEME FOR VERNAL POOLS. (UC DAVIS.)
143. HOLLAND, V.L. 1974. A STUDY OF SOIL AND VEGETATION UNDER QUERCUS DOUGLASII H. & A. COMPARED TO OPEN GRASSLAND. DISSERTATION, UNIV. CALIF., BERKELEY. BERKELEY. UNIVERSITY OF CALIFORNIA PRESS. 349 P. CAR PLANTS, ECOLOGY, SOIL, NUTRIENTS, MICROCLIMATE, PRODUCTIVITY, GRASSLAND, OAK WOODLANDS. STUDY OF OAK TREE EFFECTS ON UNDERSTORY HERBACEOUS VEGETATION. (UC BERKELEY - BIOLOGY.)
144. HORN, H.S. 1974. THE ECOLOGY OF SECONDARY SUCCESSION. ANNU REV ECOL SYST 5: 25-37. SUCCESSION, PLANTS, ECOLOGY. (UC BERKELEY - BIOLOGY.)
145. HOWELL, J.T. 1970. MARIN FLORA: MANUAL OF THE FLOWERING PLANTS AND FERNS OF MARIN COUNTY, CALIFORNIA. BERKELEY. UNIVERSITY OF CALIFORNIA PRESS. 366 P. RUS, SMN, LAG PLANTS, ECOLOGY, DISTRIBUTION, PAL-EM WET-PERS-SEAS MOIS (IE VERNAL MAR), GRASSLANDS, COASTAL SCRUBLANDS, CHAPARRAL, BROAD-LEAVED EVERGREEN FORESTS, RIPARIAN FORESTS, OAK WOODLANDS, BISHOP PINE FOREST, DOUGLAS-FIR FOREST, ALLUVIAL REDWOOD FOREST, SLOPE REDWOOD FOREST. FLORA WITH DISCUSSION OF PLANT ASSOCIATIONS AND ENVIRONMENTAL FACTORS IN MARIN COUNTY. (UC BERKELEY - BIOLOGY.)
146. HYNES, H.B.N. 1970. THE ECOLOGY OF RUNNING WATERS. LIVERPOOL. LIVERPOOL UNIVERSITY PRESS. 555 P. ALGAE, CRUSTACEA, FISH, FISHERIES, PRODUCTIVITY, DETRITUS, ECOLOGY, FOOD WEBS, HABITATS, HYDROLOGY, INVERTEBRATES, INSECTS, MOLLUSCS, NUTRIENTS, STREAM FLOW, SUSPENDED SOLIDS, RIVERINE. TEXTBOOK. EMPHASIS ON BENTHIC INVERTEBRATES. CA. 1500 REFERENCES. (UC DAVIS, CALIF. STATE UNIVERSITY, SACRAMENTO, UC BERKELEY - BIOLOGY.)
147. INGLES, L.G. 1965. MAMMALS OF THE PACIFIC STATES. CALIFORNIA, OREGON, WASHINGTON. STANFORD, CA. STANFORD UNIVERSITY PRESS. 506 P. TAXONOMY, MAMMALS, DISTRIBUTION, LIFE HISTORY, FOOD SOURCES, HABITATS. TEXT INCLUDES CLASSIFICATION OF SPECIES, THEIR GEOLOGICAL HISTORY, THEIR RANGE AND DISTRIBUTION, THEIR HABITATS IN Biotic COMMUNITIES AND THEIR STATUS IN THE ECOSYSTEMS THEY INHABIT. (UC DAVIS, MOST UNIV. LIBS.)
148. ISSACS, J.D.; FLEMING, A.; MILLER, J.K. 1971*. DISTRIBUTIONAL ATLAS OF ZOOPLANKTON BICMASS IN THE CALIFORNIA CURRENT REGION: WINTER 1955-1959. SUPPORTED BY CALIF. MARINE RESEARCH COMMITTEE. CALIF COOP OCEANIC FISH INVEST ATLAS NO. 14. 122 P. GEL, CARE, OBOD, OCRZ, CMAR DISTRIBUTION, ZOOPLANKTON, BICMASS, CALIFORNIA CURRENT, ABUNDANCE, MIGRATION, AMPHIPODA, CHAETOGNATHA, CLADOCERA, COPEPODA, CRUSTACEA, CTENOPHORA, DECAPODA, EUPHAUSIACEA, HETEROPODA, LARVACEA, MEDUSAE, MYSIDACEA, OSTRACODA, PTEROPODA, RADIOLARIA, SIPHONOPHORA, THALASSEA, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
149. ISSACS, J.D.; TONT, S.L.; WICK, G.L. 1974. DEEP SCATTERING LAYERS: VERTICAL MIGRATION AS A TACTIC FOR FINDING FOOD. DEEP-SEA RES 21: 651-656. MIGRATION, FOOD SOURCES, FEEDING, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
150. JENNY, H.; ARKLEY, R.J.; SCHULTZ, A.M. 1969. THE PYGMY FOREST-PODSOL ECOSYSTEM AND ITS DUNE ASSOCIATES OF THE MENDOCINO COAST. MADRONO 20(2): 40-74. NOY PLANTS, SOIL, ECOLOGY, NUTRIENTS, PYGMY CONIFER FOREST. DISCUSSION OF SOIL-VEGETATION INTERACTIONS, POSITIVE FEEDBACK PROCESSES, AND PODSOL SOIL DEVELOPMENT. (UC BERKELEY - BIOLOGY.)
151. JOHNSGARD, P.H. 1979. A GUIDE TO NORTH AMERICAN WATERFOWL. BLOOMINGTON, INDIANA. INDIANA UNIVERSITY PRESS. 269 P. WATERFOWL, WATER BIRDS, BIRDS, POPULATION DYNAMICS, HABITATS, BREEDING AREAS, ABUNDANCE, REPRODUCTION, MIGRATION, DISTRIBUTION, FEEDING, SEASONAL VARIATION, ENDANGERED SPECIES.
152. JOHNSON, R.G. 1967. TEMPERATURE VARIATION IN THE INFAUNAL ENVIRONMENT [OF 4 SAND FLATS]. LIMNOLOGY AND OCEANOGRAPHY 12: 114-120. LAG TEMPERATURE, DIURNAL VARIATION, ZONATION (BIOLOGICAL), ESTUARINE-SUBTIDAL-UNCONGLOTTED-SAND,

ESTUARINE-INTERTIDAL-UNCON SHORE-SAND. (UC BERKELEY - B10L(,)GY.)

153. JONES, G.F. 1969. THE BENTHIC MACROFAUNA OF THE MAINLAND SHELF OF SOUTHERN CALIFORNIA. ALLAN HANCOCK MEMORIALS IN MARINE BIOLOGY NO. 4. 219 P. ASSOCIATIONS (BIOLOGICAL), ECOLOGY, INVERTEBRATES, ANIMALS, DIVERSITY (ASSOCIATION 1, MARINE-SUBTIDAL).
154. JUNSGARD, A. 1966. BIOLOGY OF THE NORTH ATLANTIC FIN WHALE BALAENOPTERA PHYSALUS (1): TAXONOMY, DISTRIBUTION, MIGRATION AND FOOD. HVALRADET SKR 49; 2-62. FIN WHALE, BALAENOPTERA PHYSALUS, LIFE HISTORY, FOOD SOURCE, TAXONOMY, DISTRIBUTION, MIGRATION, MARINE. (SCRIPPS INSTITUTION OF OCEANOGRAPHY (LACILLA).)
155. JUMARS, P.; FAUCHALD, K. 1970. FEEDING AND METABOLISM: BETWEEN-COMMUNITY CONTRASTS IN SUCCESSFUL POLYCHAETE FEEDING STRATEGIES. IN COULL, B. ECOLOGY OF MARINE BENTHOS. COLUMBIA, SOUTH CAROLINA. UNIVERSITY OF SOUTH CAROLINA PRESS. P. 1-20. FEEDING, POLYCHAETA, WORMS, TROPHIC LEVELS, SEDIMENT, ZONATION (BIOLOGICAL), MARINE, MARINE-SUBTIDAL. (UC SANTA CRUZ.)
156. KEEFE, C.D. 1972. MARSH PRODUCTION: A SUMMARY OF THE LITERATURE. CONTRIB MAR SCI 16; 163-181. PLANTS, PRODUCTIVITY, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. PROVIDES A SUMMARY (1) OF PRODUCTIVITY MEASUREMENTS FOR EAST COAST AND EUROPEAN SALT MARSH PLANTS, INCLUDING METHODS, AND FACTORS INFLUENCING PRODUCTION. (UC BERKELEY - BIOLOGY.)
157. KELLER, D.; HARRIS, S.W. 1966. THE GROWTH OF EELGRASS IN RELATION TO TIDAL DEPTH. J WILDL MANAGE 29(2); 280-285. MAR EELGRASS, ZOSTERA MARINA, LIFE HISTORY, ESTUARINE-SUBTIDAL-AQUATIC BED-ROCKEDVA, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. (UC BERKELEY - BIOLOGY.)
158. KINETIC LABORATORIES, INC., SANTA CRUZ, CA. 1976. BENTHIC BIOLOGICAL SURVEY WATSONVILLE WASTEWATER OUTFALL MONITORING, 1975. 26 P. CCRZ INVERTEBRATES, COMMUNITIES (BIOLOGICAL), WATSONVILLE, PAJARO RIVER, DISTRIBUTION, ABUNDANCE, MARINE-SUBTIDAL.
159. KINETIC LABORATORIES, INC., SANTA CRUZ, CA. 1977. RECEIVING WATER MONITORING PROGRAM, CARMEL BAY, CALIFORNIA, FINAL REPORT 1976 FOR THE PERIOD JUNE 1976 THROUGH MAY 1977. PREPARED FOR CARMEL SANITARY DISTRICT, CARMEL, CALIFORNIA. 200 P. CCRZ PHYSICAL OCEANOGRAPHY, TEMPERATURE--WATER, CHEMICAL COMPOSITION, INVERTEBRATES, WATER QUALITY, PESTICIDES, HEAVY METALS, ALGAE, DIOPATRA, MACROCYSTIS PYRIFERA, SALINITY, CARMEL BAY, MARINE-SUBTIDAL, KELP, COMMUNITIES (BIOLOGICAL), WASTEWATER, IMPACTS, MARINE-SUBTIDAL-ROCK BOTTOM, MARINE-SUBTIDAL-AQUATIC BED-ALGAL.
160. KINETIC LABORATORIES, INC., SANTA CRUZ, CA. 1978. BIOLOGICAL MONITORING PROGRAM CARMEL BAY, CALIFORNIA FINAL REPORT FOR PERIOD JUNE 1977 THROUGH DECEMBER 1977. PREPARED FOR CARMEL SANITARY DISTRICT CARMEL, CALIFORNIA. 137 P. CCRZ COMMUNITIES (BIOLOGICAL), POLYCHAETA, MARINE.
161. KINETIC LABORATORIES, INC., SANTA CRUZ, CA. 1979A. APPLICATION FOR MODIFICATION OF REQUIREMENTS OF SECONDARY TREATMENT. CITY OF SANTA CRUZ, CALIFORNIA. SEPTEMBER 13, 1979. PREPARED FOR CITY OF SANTA CRUZ. 650 P. CCRZ WATER QUALITY, INVERTEBRATES, DISTRIBUTION, ABUNDANCE, FISH, SANTA CRUZ, MARINE-SUBTIDAL.
162. KLUGH, A. 1924. FACTORS CONTROLLING THE BIOTA OF TIDE POOLS. ECOLOGY. 5(2); 192-196. MARINE-INTERTIDAL. (CALIF. STATE COLLEGE, SONOMA.)
163. KNAUER, G.A.; MARTIN, J.H. 1972. MERCURY IN A MARINE PELAGIC FOOD CHAIN. LIMNOL OCEANOGR VOL. 17; 868-876. MERCURY, FOOD WEBS, BIOACCUMULATION, MARINE-PELAGIC. (UC SANTA CRUZ, MUST UNIV. LIBS.)
164. KUMER, P.D. 1976. BEACH PROCESSES AND SEDIMENTATION. NEW JERSEY. PRENTICE-HALL. 429 P. WAVES (OCEAN), CURRENTS--OCEAN, TIDES, SEDIMENT, MARINE.
165. KRALIK, N.J.; SCHERWINE, J.E. 1977. THE ROLE OF TWO NORTHERN CALIFORNIA INTERMITTENT STREAMS IN THE LIFE HISTORY OF ANADROMOUS SALMONIDS. THESIS, HUMBOLDT STATE UNIV., ARCAFA, CA. 68 P. KLA, MAC STEEL HEAD, SALMON CAIRONERI,

STEELHEAD RAINBOW TROUT, SALMO GAIKNERI GAIKNERI, COHO SALMON, SILVER SALMON, ONCERHYNCHUS KISUTCH, MIGRATION, SPAWNING, PRODUCTIVITY, LACUSTRINE-LITTORAL-UNCON SHORE-VEG. SMALL INTERMITTENT (SEASONAL) STREAMS CAN BE IMPORTANT PRODUCERS OF COHO, STEELHEAD. STEELHEAD SPAWN HIGHER IN ELEVATION THAN COHO. SUCCESSFUL REPRODUCTION DEPENDS ON PRECIPITATION PATTERNS AND CONDITION OF WATERSHED. (HUMBOLDT STATE UNIV.)

166. KRAVITZ, M.J.; PEARCY, W.G.; GUIN, M.P. 1976. FOOD OF FIVE SPECIES OF CO-OCCURRING FLATFISHES ON CRESCENT CONTINENTAL SHELF. U S NATMAREFISH SERV FISH BULL 74(4): 584-995. FLATFISH, FOOD SOURCES, FEEDING, MARINE-SUBTICAL. [UC SANTA CRUZ, MOST UNIV. LIBS.]
167. KUCHLER, A.W. 1977. THE MAP OF THE NATURAL VEGETATION OF CALIFORNIA. IN BARBOUR, M.G. (ED.); MAJOR, J. (ED.). TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILEY & SONS. P. 909-938 PLUS MAP. SMI, KLA, MAD, EEL, PAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, DISTRIBUTION, COVER TYPES, GRASSLANDS, COASTAL STRAND, SHRUBLANDS, BROAD-LEAVED FORESTS & WOODLANDS, CONIFER FORESTS. (UC BERKELEY - ETIOLOGY.)
168. LAACKE, R.J. (ED.). 1979. CALIFORNIA FOREST SOILS: A GUIDE FOR PROFESSIONAL FORESTERS AND RESOURCE MANAGERS AND PLANNERS. BERKELEY, CA. UNIVERSITY OF CALIFORNIA, DIVISION OF AGRICULTURAL SCIENCES. 181 P. SMI, I(LA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG SOILS, FORESTRY, FIRE, NUTRIENTS, BROAD-LEAVED EVERGREEN FORESTS, OAK WOODLANDS, COASTAL CONIFER FOREST, LOWER MOUNTAIN CONIFER FOREST. GUIDE TO SOIL PROPERTIES AND FOREST SOILS IN CALIFORNIA. (UC BERKELEY - FORESTRY.)
169. LAEVASTU, R.; FISCUS, C. 1978. REVIEW OF CEPHALOPOD RESOURCES IN THE EASTERN NORTH PACIFIC. NORTHWEST AND ALASKA CENTER PROCESSED REPORT. 15 P. CEPHALOPOD, FISHERIES, MARINE-PELAGIC. NOT A PUBLICATION--A PROVISIONAL REPORT.
170. LANE, R.S. 1969. THE INSECT FAUNA OF A COASTAL SALT MARSH. THESIS, SAN FRANCISCO STATE COLLEGE, CALIFORNIA. 778 P. FRA INSECTS, TROPHIC LEVELS, FOOD WEBS, ESTUARINE-INTERTIDAL-EMERGENT WETLAND.
171. LAVENBERG, R.J.; ERELING, A.W. 1967. DISTRIBUTION OF MIDWATER FISHES AMONG DEEP-WATER BASINS OF THE SOUTHERN CALIFORNIA SHELF. IN PHILBRICK, R.M. (ED.) SYMPOSIUM ON THE BIOLOGY OF THE CALIFORNIA ISLANDS. PROCEEDINGS. SANTA BARBARA. SANTA BARBARA BOTANIC GARDEN, INC. P. 185-201. DEEL, CARE, GBD, CCRZ, CMAR FISH, DISTRIBUTION, MARINE-PELAGIC.
172. LEIGHTON, D.L. 1971. GRAZING ACTIVITIES OF BENTHIC INVERTEBRATES IN KELP BEDS. IN NORTH, W.J. (ED.). THE BIOLOGY OF GIANT KELP BEDS (MACROCYSTIS) IN CALIFORNIA. NOVA HEDWIGIA NO. 32. P. 421-453. CRAZING/GRUZZING PRESSURE, ALGAE, MACROCYSTIS PYRIFERA, KELP COMMUNITIES (BIOLOGICAL), INVERTEBRATES, FEEDING, FOOD SOURCES, MOLLUSCS, MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (UC SANTA CRUZ, STANFORD UNIVERSITY, MOST UNIV. LIBS.)
173. LINDER, J.L. 1977. TOXIC SUBSTANCES. IN CLARK, J.R. (ED.) COASTAL ECOSYSTEM MANAGEMENT. NEW YORK. WILEY-INTERSCIENCE. P. 740-752. PESTICIDES, CHLORINATED HYDROCARBONS, HEAVY METALS, FOOD WEBS, CHRONIC EFFECTS, WATER QUALITY, MARINE-SUBTIDAL. (UC SANTA CRUZ.)
174. LONGLEY, W.L.; JACKSON, P.; SNYDER, B. 1978. MANAGING OIL AND GAS ACTIVITIES IN COASTAL ENVIRONMENTS. PREPARED FOR U. S. FISH AND WILDLIFE SERVICE, OFFICE OF BIOLOGICAL SERVICES, NATIONAL COASTAL ECOSYSTEM TEAM. 56 P. ENVIRONMENTAL PLANNING, OIL DRILLING, OIL, MANAGEMENT RECOMMENDATIONS, ESTUARINE.
175. MACDONALD, K.B. 1969. QUANTITATIVE STUDIES OF SALT MARSH MOLLUSC FAUNAS FROM THE NORTH AMERICAN PACIFIC (PART 1). ECOL MONOGR 39: 33-60. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG INVERTEBRATES, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. (UC BERKELEY - BIOLOGY.)
176. MACDONALD, K.B. 1977. COASTAL SALT MARSH. IN BARBOUR, P.G. (ED.) AND MAJOR, J. (ED.). TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILEY & SONS. P. 263-294. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, ZONATION (BIOLOGICAL), DISTRIBUTION, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. (UC BERKELEY - BIOLOGY.)

177. MACDONALD, K.R.; BARBOUR, M.G. 1974. BEACH AND SALT MARSH VEGETATION OF THE NORTH AMERICAN PACIFIC COAST. P. 175-233 IN REIMOLD, R.J. (ED.): QUEEN, W.H. (ED.). ECOLOGY OF HALOPHYTES. NEW YORK. ACADEMIC PRESS. SMI, KLA, MAD, EEL, MAT, NGY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANI, YNZ, ARG. DISTRIBUTION, PLANTS, ESTUARINE-INTERSTITIAL-EMERGENT WETLAND, SUPRATIDAL BEACH. THE GEOGRAPHIC DISTRIBUTION OF BEACH AND SALT MARSH PLANTS ALONG THE PACIFIC COAST, DESCRIPTIVE AND QUANTITATIVE TREATMENT. (UC BERKELEY - BIOLOGY, MOST UNIV. LIBS.)
178. MACGINITIE, G.E. 1935. ECOLOGICAL ASPECTS OF A CALIFORNIA MARINE ESTUARY. 4M MIDNAT 16(5): 629-765. EEL, INVERTEBRATES, HABITATS, DISTRIBUTION, LIFE HISTORY, ESTUARINE. (UC BERKELEY - BIOLOGY.)
179. MACGINITIE, G.E.; MACGINITIE, N. 1968. NATURAL HISTORY OF MARINE ANIMALS, SECOND EDITION. NEW YORK. MCCRAW-HILL. 523 P. EEL, CARE, CRUD, OCRZ, OMAR. LIFE HISTORY, MARINE BIOLOGY, MARINE-INTERSTITIAL, ESTUARINE-INTERSTITIAL. BROAD EXAMINATION OF NATURAL HISTORY OF MOST PHyla RECOGNIZED IN MARINE ENVIRONMENTS.
180. MAHALL, B.E.; PARK, P.B. 1976. THE ECOTONE BETWEEN SPARTINA FOLIOSA TRIN. AND SALICORNIA VIRGINICA L. IN SALT MARSHES OF NORTHERN SAN FRANCISCO BAY: I. BIOMASS AND PRODUCTION. J ECOL 64: 421-419. FRA PLANTS, COMMUNITIES (BIOLOGICAL), ECOLOGY, SPARTINA FOLIOSA, SALICORNIA VIRGINICA, ESTUARINE-INTERSTITIAL-EMERGENT WETLAND. (UC BERKELEY - BIOLOGY.)
181. MAIS, K.F. 1974. PELAGIC FISH SURVEYS IN THE CALIFORNIA CURRENT. CALIF DEP FISH GAME FISH BULL 162. 79 P. CALIFORNIA CURRENT, FISH, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
182. MAJOR, J. 1951. A FUNCTIONAL, FACTORIAL APPROACH TO PLANT ECOLOGY. ECOLOGY 32(3): 392-412. ECOLOGY, PLANTS, SOILS, TOPOGRAPHY, MICROCLIMATE, CLIMATOLOGY. MAJOR'S ECOSYSTEM MODEL AND DISCUSSION OF DIFFERENCES BETWEEN REGIONAL CLIMATE, LOCAL CLIMATE, AND MICROCLIMATE. (UC BERKELEY - FORESTRY.)
183. MALL, R.E. 1969. SOIL-WATER-SALT RELATIONSHIPS OF WATERFOWL FOOD PLANTS IN THE SUISUN MARSH OF CALIFORNIA. CALIF DEP FISH GAME WILDL BULL NO. 1. 59 P. FRA PLANTS, SALINITY, SOIL, ESTUARINE-INTERSTITIAL-EMERGENT WETLAND. (UC BERKELEY - BIOLOGY.)
184. MALONE, I.C. 1971. THE RELATIVE IMPORTANCE OF NANNOPLANKTON AND NETPLANKTON AS PRIMARY PRODUCERS IN THE CALIFORNIA CURRENT SYSTEM. U S NAT MAR FISH SERV FISH BULL 69(4): 799-820. EEL, CARE, CRUD, OCRZ, OMAR. PRODUCTIVITY, PHYTOPLANKTON, CALIFORNIA CURRENT SYSTEM, UPWELLING, BIOMASS, FOOD WEBS, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
185. MARCUT, B.G. (ED.). 1979. CALIFORNIA WILDLIFE / HABITAT RELATIONSHIPS PROGRAM: NORTH COAST / CASCADES ZONE, INTRODUCTION. EUREKA, CALIFORNIA. U.S. FOREST SERVICE, SIX RIVERS NATIONAL FOREST. 132 P. SMI, KLA, MAD, EEL. ANIMALS, BIRDS, HERPTILES, ECOLOGY, HABITATS, MEADOWS + SEEPS, RIPARIAN FORESTS. INTRODUCTORY VOLUME TO WILDLIFE HABITAT NARRATIVES AND SPECIES/HABITATS MATRIX COMPILED FOR NATIONAL FORESTS OF NORTH COAST STATES.
186. MARGALEF, R. 1967. THE FOOD WEB IN THE PELAGIC ENVIRONMENT. HELGOLANDER WISSENSCHAFTLICHE MEERESUNTERSUCHUNGEN 15: 548-559. FOOD WEBS, PHYTOPLANKTON, FEEDING, SUCCESSION, MARINE-PELAGIC. (MOSS LANDING MARINE LABORATORY, MOST UNIV. LIBS.)
187. MARTIN, A.C.; ZIM, H.S.; NELSON, A.L. 1951. AMERICAN WILDLIFE AND PLANTS: A GUIDE TO WILDLIFE FOOD HABITS. NEW YORK. DOVER PUBLICATIONS. 500 P. SMI, KLA, MAD, EEL, MAT, NGY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANI, YNZ, ARG, EEL, CARE, CRUD, OCRZ, OMAR. FOOD SOURCES, MAMMALS, BIRDS, PLANTS. (UC BERKELEY - BIOLOGY.)
188. MARTIN, J.H.; ELLIOT, P.I.; ANDERLINI, V.C.; GIRVIN, O.; JACOBS, S.A.; RISEBROUGH, F.W.; DELONG, P.L.; GILMARTIN, W.G. 1976. MERCURY-SELENIUM-BROMINE IMBALANCE IN PREMATURE PARTURIENT CALIFORNIA SEA LIONS. PAR BUL (BERK) 35: 91-104. MERCURY, SELENIUM, BROMINE, CALIFORNIA SEA LION, LIFE HISTORY, ECOLOGY, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)

189. MARTIN, M.; STEVENSON, M. D.; MARTIN, J. F. 1977. COPPER TOXICITY EXPERIMENTS IN RELATION TO ABALONE DEATHS OBSERVED IN A POWER PLANT'S COOLING WATERS. CALIF FISH GAME 63(2): 95-100. OMAR ABALONE, HALIOTUS SPP., WATER QUALITY, DEATH RATES (ANIMALS), MARINE-SUB TIDAL-AQUATIC BED. (UC SANTA CRUZ, MOST UNIV. LIBS.)
190. MASON, H. L.; LANGENHEIM, J. H. 1957. LANGUAGE ANALYSIS AND THE CONCEPT OF ENVIRONMENT. ECOLOGY 38: 325-339. ECOLOGY, PLANTS. THEORETICAL DISCUSSION AND DEFINITION OF OPERATIONAL ENVIRONMENTS. (UC BERKELEY - BIOLOGY.)
- 191* MCBRIDE, J. R. 1974. PLANT SUCCESSION IN THE BERKELEY HILLS, CALIFORNIA. MADRONA 22(7): 317-329. NCY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR PLANTS, ECOLOGY, SUCCESSION? FIRE, GRAZING/BROWSING PRESSURE, COASTAL PRAIRIE, NORTH COASTAL SCRUB, MIXED EVERGREEN FOREST, CALIFORNIA BAY FOREST, COAST LIVE OAK FOREST. DISCUSSION OF SUCCESSIONAL RELATIONSHIPS BETWEEN COASTAL PRAIRIE, NORTHERN COASTAL SCRUB, COAST LIVE OAK FOREST, AND CALIF. BAY FOREST. (UC BERKELEY - BIOLOGY.)
192. MCCONNAUGHEY, B. H. 1974. INTRODUCTION TO MARINE BIOLOGY, SECOND EDITION. SAINT LOUIS, MISSOURI. C.V. MOSBY COMPANY. 544 P* MARINE BIOLOGY, MARINE. TEXT ON GENERAL MARINE BIOLOGY AND ECOLOGY. (CALIF. STATE COLLEGE, SONOMA STATE UNIV. LIB.)
193. MCGOWAN, J. A. 1967. DISTRIBUTIONAL ATLAS OF PELAGIC MOLLUSCS IN THE CALIFORNIA CURRENT REGION. SPONSORED BY CALIF. MARINE RESEARCH COMMITTEE. CALIF COOPOCEANIC FISH INVEST ATLAS NO. 4. 210 P. CEEL, DARE, DBOD, OCRZ, OMAR DISTRIBUTION, MOLLUSCS, CALIFORNIA CURRENT, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
194. MCLUSKY, D. S. 1971. ECOLOGY OF ESTUARIES. LONDON. HEINEMANN EDUCATIONAL BOOKS. 144 P* ANIMALS, COMMUNITIES (BIOLOGICAL), DISSOLVED OXYGEN, DIURNAL VARIATION, ECOLOGY, INVERTEBRATES, PLANTS, IJL)ES, NUTRIENTS, PHYSICAL OCEANOGRAPHY, ESTUARINE. (UC BERKELEY - WATER RESOURCES CENTER ARCHIVES.)
195. MEGLITSCH, P. A. 1972. INVERTEBRATE ZOOLOGY, SECOND EDITION. NEW YORK. OXFORD UNIVERSITY PRESS. 834 P. CEEL, DARE, DBOD, OCRZ, OMAR TAXONOMY, PROTOZOA, RADIATA, MOLLUSCA, CNIDARIA, ANNELIDA, ARTHROPODA, CRUSTACEA, ECHINODERMATA, GROWTH RATES, POPULATION DYNAMICS, LIFE HISTORY, INVERTEBRATES, MARINE-PELAGIC, MARINE-SUBTIDAL. TEXT. (UC SANTA CRUZ, MOST UNIV. LIBS.)
196. MERLINI, M. 1971. HEAVY-METAL CONTAMINATION. IN HODD, O. W. (ED.) IMPINGEMENT OF MAN ON THE OCEANS. NEW YORK. WILEY-INTERSCIENCE. P. 461-486. CEEL, DARE, DBOD, OCRZ, OMAR HEAVY METALS, POLLUTION, IMPACTS, TRACE METALS, WATER QUALITY, INVERTEBRATES; J310 ACCI JPL JLAT[ONS MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
197. MERRILL, R. J.; ROBSON, E. S. 1970. FIELD OBSERVATIONS OF DENDRASTER EXCENTRICUS, A SAND DOLLAR OF WESTERN NORTH AMERICA. AMMIO NAT 82(2): 595-624. MAO, EEL, MAT, NCY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG SAND DOLLAR, DENDRASTER EXCENTRICUS, LIFE HISTORY, DISTRIBUTION, ABUNDANCE, MARINE-SUBTIDAL-UNCON BOTTOM-SAND, MARINE-INTERTIDAL-UNCON SHORE-SAND, ESTUARINE-SUBTIDAL-UNCON BOTTOM-SAND, ESTUARINE-INTERTIDAL-STREAMBED-SAND. (UC BERKELEY - BIOLOGY.)
198. MILEIKOVSKY, S. A. 1970. THE INFLUENCE OF POLLUTION ON PELAGIC LARVAE OF BOTTOM INVERTEBRATES IN MARINE NEARSHORE AND ESTUARINE WATERS. MAR BIOL (BERL) 6: 350-356. LARVAE, WATER QUALITY, INVERTEBRATES, MARINE-PELAGIC, MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
199. MILLER, D. J.; GIBEL, J. J. 1973. SUMMARY OF BLUE ROCKFISH AND LINGCOD LIFE HISTORIES; A REEF ECOLOGY STUDY; AND GIANT KELP, MACROCYSTIS PYRIFERA, EXPERIMENTS IN MONTEREY BAY, CALIFORNIA. CALIF DEP FISH GAME FISH BULL 158. 137 P. OCRZ KELP CANOPY, KELP HARVESTING, MACROCYSTIS PYRIFERA, MONTEREY BAY, ALGAL, PRODUCTIVITY, ASSEMBLAGES, INVERTEBRATES, BLUE ROCKFISH, SEETASTES MYSTINUS, LINGCOD, GPHIOGNELONGATUS, LIFE HISTORY, ECOLOGY, BEHAVIOR, BREEDING AREAS, COMMUNITIES (BIOLOGICAL), COMPETITION, EPIPELAGIC, FISHERIES, FISH, ECOSYSTEMS, HABITATS, MIGRATION, NICHES, PREDATION, SPAWNING, MARINE-SUBTIDAL-ROCK BOTTOM-BEDROCK, MARINE-SUBTIDAL-UNCON BOTTOM-SAND, MARINE-SUBTIDAL-UNCON BOTTOM-MUD, MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (UC SANTA CRUZ, MUSS LANDING MARINE LABORATORY, MOST UNIV. LIBS.)

200. MILLER, D.J.; GEIDEL, J. J.; HOOK, J. 1974. RESULTS OF THE 1972 SKINDIVING ASSESSMENT SURVEY, PISMO BEACH TO CREGON. CALIF DEPT FISH GAME MARINE RESOURCES TECHNICAL REPORT NO. 23. 89 P. CEEL, OARE, CPOD, CCRZ, OMAF RECREATION, FISHING--SPORT, MOLLUSCS, HALSCNE, MARINE-SUBTIDAL-AQUATIC BED, PARKS/BEACHES. (UC SANTA CRUZ, STANFORD UNIVERSITY, CALIF. DEPT. OF FISH AND GAME, RESOURCES AGENCY LIBRARY, MOST UNIV. LIBS.)
201. MILLER, D.J.; LEA, R.N. 1972. GUIDE TO THE COASTAL MARINE FISHES OF CALIFORNIA. CALIF DEPT FISH GAME FISH BULL 157. 235 P. SMI, KLA, MAD, EEL, NAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAP, MOR, MAR, ANT, YNZ, ARG, CEEL, OARE, CPOD, CCRZ, OMAF FISH, DISTRIBUTION. KEY TO CALIFORNIA FISH, DISTRIBUTION AND MERISTICS. (UC BERKELEY - BIOLOGY.)
202. MILLER, D.J.; LEA, R.N. 1976. GUIDE TO THE COASTAL MARINE FISHES OF CALIFORNIA (AND ADDENDUM). UNIVERSITY OF CALIFORNIA DIVISION OF AGRICULTURAL SCIENCES SALES PUBL 4065. 249 P. CEEL, OARE, CPOD, CCRZ, OMAF FISH, NOMENCLATURE, DISTRIBUTION, TAXONOMY. CONSISTS OF REPRINT OF CALIF DEPT FISH GAME FISH BULL 157 PLUS ADDENDUM UPDATING IT. (UC BERKELEY - WATER RESOURCES CENTER ARCHIVES, UC BERKELEY - AGRICULTURE.)
203. MILLER, D.J.; SCHMIDTKE, J. 1956. REPORT ON THE DISTRIBUTION OF PACIFIC HERRING (CLUPEA PALLASII) ALONG THE COAST OF CENTRAL AND SOUTHERN CALIFORNIA. CALIF FISH GAME 42(3): 163-186. FRA, GRE, LCR, PAJ, ELK, SLS, CAP, MOR, MAR, ANT, YNZ, ARG PACIFIC HERRING, CLUPEA HARENGUS PALLASII, DISTRIBUTION, FISHERIES, LIFE HISTORY, TOMALES BAY, SAN FRANCISCO BAY, ESTUARINE-SUBTIDAL-ROCK BOTTOM, ESTUARINE-SUBTIDAL-AQUATIC BED, ESTUARINE-INTERTIDAL-ROCKY SHORE, ESTUARINE-INTERTIDAL-UNCON SHORE-VEG. LIFE HISTORY INFORMATION, SPAWNING AREAS FROM SAN FRANCISCO TO SAN DIEGO. (UC BERKELEY - BIOLOGY.)
204. MOE, R.L.; SILVA, P.C. 1979. PRELIMINARY REPORT ON THE ALGAE OF CORDELL BANK, CALIFORNIA. IN SCHMIDTKE ET AL. CORDELL BANK EXPEDITION 1977-78. FINAL REPORT FEBRUARY 28, 1979. P. 70-73. OBOO, CCRZ ALGAE, CORDELL BANK, MARINE-SUBTIDAL.
205. MOONEY, H.A. 1977C. SOUTHERN COASTAL SCRUB. IN BARBOUR, M.G. (ED.); MAJOR, J. (ED.). TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILEY & SONS. P. 471-489. MOR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, PHYSIOLOGY, SUCCESSION, ALLELOPATHY, CENTRAL COASTAL SCRUB COMMUNITIES (BIOLOGICAL), HABITATS, CHAPARRAL. SURVEY OF DISTRIBUTION, PHYSIOLOGY, AND SUCCESSION IN AREAS OF SOUTHERN COASTAL SCRUB. (UC BERKELEY - BIOLOGY.)
206. MOONEY, H.A. (ED.); CONRAD, C.E. (ED.). 1977. SYMPOSIUM ON THE ENVIRONMENTAL CONSEQUENCES OF FIRE AND FUEL MANAGEMENT IN MEDITERRANEAN ECOSYSTEMS, AUG. 1-5, 1977, PALO ALTO, CALIF. PROCEEDINGS. U.S. FOREST SERVICE GENERAL TECHNICAL REPORT WO-3. 498 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAP, MOR, MAR, ANT, YNZ, ARG PLANTS, FIRE, SOIL, ANIMALS, BIRDS, ECOLOGY, MANAGEMENT RECOMMENDATIONS, LIFE HISTORY, CHAPARRAL. COLLECTION OF ARTICLES ON ALL ASPECTS OF FIRE ECOLOGY AND VEGETATION MANAGEMENT IN CHAPARRAL ECOSYSTEMS. (UC BERKELEY - FORESTRY.)
207. MOREJOHN, G.V. 1977. MARINE MAMMALS. IN WINZLER AND KELLY CONSULTING ENGINEERS, EUREKA, CA. A SUMMARY OF KNOWLEDGE OF THE CENTRAL AND NORTHERN CALIFORNIA COASTAL ZONE AND OFFSHORE AREAS. VOLUME II CHAPTER V. SUPPORTED BY U.S. BUREAU OF LAND MANAGEMENT UNDER CONTRACT NO. A4550-CT6-52. CEEL, OARE, CPOD, CCRZ, OMAF LIFE HISTORY, DISTRIBUTION, ECOLOGY, SEA OTTER, CALIFORNIA SEALION, STELLAR SEALION, ELEPHANT SEAL, HARBOR SEAL, GUADALUPE FUR SEAL, SPERM WHALE, GRAY WHALE, BLUE WHALE, FIN WHALE, SEI WHALE, HUMPBACK WHALE, RIGHT WHALE, PINNIPEDIA, CETACEA, WATER QUALITY, MARINE MAMMALS, ECOLOGY, DISTRIBUTION, ABUNDANCE. SPECIES ACCOUNTS OF THE MARINE MAMMALS FOUND IN CENTRAL AND NORTHERN CALIFORNIA WATERS. (NTIS PB-274 213.)
208. MORGAN, M.H. 1961. ANNUAL ANGIOSPERM PRODUCTION ON A SALT MARSH. THESIS, UNIVERSITY OF DELAWARE. CALICJP. PLANTS, PRODUCTIVITY, ESTUARINE-INTERTIDAL-EMERGENT WETLAND.
209. MORING, J.R.; LANTZ, R.L. 1975. THE ALSEA WATERSHED STUDY: EFFECTS OF LOGGING ON THE AQUATIC RESOURCES OF THREE HEADWATER STREAMS OF THE ALSEA RIVER, OREGON. PART 1 - BIOLOGICAL STUDIES. OREGON DEPT. OF FISH AND WILDLIFE FISHERY RESEARCH REPORT NO. 9. 66 P. SILVICULTURE, SEDIMENTATION, COHO SALMON, SILVER SALMON, LUCIOPELICHUS KISUTCH, COASTAL CUTTHROAT TROUT, CUTTHROAT TROUT, SALMO CLARKI, SALMO CLARKI CLARKI, STEELHEAD, STEELHEAD RAINBOW

TROUT, SALMO GAIKNERI, SALMO GAIKNERI GAIKNERI, F I S H, RIVERINE-UPPER PEREN-ROCK BOTTOM-FIDDLE, RIVERINE-UPPER PEREN-UNCON BOTTOM-CORBLE, RIVER INE-UPPER PEREN-UNCON BOTTOM-SAND, RIVERINE-UPPER PEREN-UNCON BOTTOM-MUC. 14-YEAR STUDY OF EFFECTS; BUFFER STRIPS GOCC FOR MINIMIZING DEGRADATION. (GREGGON DEPT. OF FISH AND WILDLIFE.)

210. MOYLE, P.B. 1976. INLAND FISHES OF CALIFORNIA. BERKELEY. UNIVERSITY OF CALIFORNIA PRESS. 405 P. SMI, KLA, MAO, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG FISH, DISTRIBUTION, LIFE HISTORY, TAXONOMY, ESTUARINE, RIVERINE, FISHERIES. GOOD GENERAL REFERENCE; DEALS PRIMARILY WITH FRESHWATER FISH, BUT INCLUDES MANY CHARACTERISTIC ESTUARINE FISH. (UC BERKELEY - BIOLOGY.)
211. MUCHMORE, O.; EPEL, O. 1973. THE EFFECTS OF CHLORINATION OF WASTEWATER ON FERTILIZATION IN SOME MARINE INVERTEBRATES. MAR BIOL (BERL) 19: 93-95. CHLORINE, INVERTEBRATES, WATER QUALITY, LIFE HISTORY, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
212. MUELLER-DOMBOIS, D.; ELLENBERG, H. 1974. AIMS AND METHODS OF VEGETATION ECOLOGY. NEW YORK. JOHN WILEY & SONS. 547 P. PLANTS, ECOLOGY, CLASSIFICATION, ECOSYSTEMS. COMPREHENSIVE TEXT ON THEORY AND PRACTICE OF VEGETATION CLASSIFICATION, ANALYSIS, AND ECOLOGY. (UC BERKELEY - BIOLOGY, UC BERKELEY - FORESTRY.)
213. MUNZ, P.A.; KECK, D.D. 1949. CALIFORNIA PLANT COMMUNITIES. EL ALISO 2(1): 87-105. SMI, KLA, MAO, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, DISTRIBUTION, CLIMATOLOGY, COMMUNITIES (BIOLOGICAL), GRASSLANDS, COASTAL STRAND, SHRUBLANDS, BROAD-LEAVED FORESTS & WOODLANDS, CONIFER FORESTS. VEGETATION CLASSIFICATION SYSTEM FOR CALIFORNIA WITH ANNOTATIONS CONCERNING CLIMATE, TOPOGRAPHY, DISTRIBUTION, AND CHARACTERISTIC SPECIES. (UC BERKELEY - BIOLOGY.)
214. MUNZ, P.A.; KECK, D.D. 1973. A CALIFORNIA FLORA WITH SUPPLEMENT. BERKELEY. UNIVERSITY OF CALIFORNIA PRESS. 1681 + 224 P. SMI, KLA, MAO, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, TAXONOMY, DISTRIBUTION, PALUSTRINE-MOSS WETLAND (IE BOGS & FENS), PALUSTRINE-EMERGENT WETLAND, PAL-SCRUB/SHRUB WET (IE FRESHWATER SWAMP), PAL-FORESTED WETLAND (IE FRESHWATER SWAMP), GRASSLANDS, COASTAL STRAND, SHRUBLANDS, BROAD-LEAVED FORESTS & WOODLANDS, CONIFER FORESTS. DEFINITIVE TAXONOMIC TREATISE ON VASCULAR PLANTS OF CALIFORNIA. (UC BERKELEY - BIOLOGY.)
215. NATIONAL ACADEMY OF SCIENCES. 1975. ASSESSING POTENTIAL OCEAN POLLUTANTS. PREPARED FOR THE OCEAN AFFAIRS BOARD ON NATURAL RESOURCES NATIONAL RESEARCH COUNCIL. WASHINGTON, D.C. NATIONAL ACADEMY OF SCIENCES. 438 P. IMPACTS, ENVIRONMENTAL PLANNING, BIOACCUMULATION, RADIOACTIVITY, CHLORINATED HYDROCARBONS, HYDROCARBONS, HEAVY METALS, OCEAN DUMPING, SEWAGE TREATMENT, SOLID WASTE, SUSPENDED SOLIDS, WASTEWATER, WATER QUALITY, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
216. NEUSHUL, M. 1971. THE KELP COMMUNITY OF SE WEEDS. [NORTH, W.J. (ED.). THE BIOLOGY OF GIANT KELP BEDS (MACROCYSTIS) IN CALIFORNIA. NOVA HEDWIGIA 32, P. 265-267. MACROCYSTIS PYRIFERA, COMMUNITIES (BIOLOGICAL), ALGAE, MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (UC SANTA CRUZ, STANFORD UNIVERSITY, MOST UNIV. LIBS.)
217. NORTH, W.J. 1911. INTRODUCTION AND BACKGROUND. IN NORTH W.J. (ED.). THE BIOLOGY OF GIANT KELP BEDS (MACROCYSTIS) IN CALIFORNIA. NOVA HEDWIGIA 32, P. 1-97. MACROCYSTIS PYRIFERA, KELP, ALGAE, ECOLOGY, ZONATION (BIOLOGICAL), LIFE HISTORY, GROWTH RATES, HABITATS, LIGHT PENETRATION, POPULATION DYNAMICS, PRODUCTIVITY, COMMUNITIES (BIOLOGICAL), MARINE-SUBTIDAL-AQUATIC BED, MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (UC SANTA CRUZ, STANFORD UNIVERSITY, MOST UNIV. LIBS.)
218. NORTH, W.J. (ED.); HUBBS, C.L. (ED.). 1968. UTILIZATION OF KELP-BED RESOURCES IN SOUTHERN CALIFORNIA. CALIF DEPT FISH & GAME FISH BULL 139. 264 P. ALGAE, COMMUNITIES (BIOLOGICAL), KELP, FISH, FISHING--SPORT, MACROCYSTIS PYRIFERA, MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (UC SANTA CRUZ, STANFORD UNIVERSITY, CALIF. DEPT. OF FISH AND GAME, RESOURCES AGENCY LIBRARY, MOST UNIV. LIBS.)
219. NORTH, W.J.; PEARSE, J.S. 1970. SEA URCHIN POPULATION EXPLOSION IN SOUTHERN CALIFORNIA COASTAL WATERS. ST. [INCL. 167: 209. DEEL, GARE, OBOO, ORZ, OMAR ACANTHASTER PLACI, STRONGYLOCENTROTUS FRANCISCANUS, STRONGYLOCENTROTUS

PIRIPURATUS, SEA URCHIN, SEA STAR, SEA OTTER, MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)

220. NYBAKKEN, J.: CAILLIET, G.: BRZENKOW, W. 1977. ECOLOGIC AND HYDROGRAPHIC STUDIES OF ELKHORN SLOUGH, MUSS LANDING HARBOR AND NEARSHORE COASTAL WATERS- JULY 1974 TO JUNE 1976. MUSS LANDING, CALIFORNIA. MUSS LANDING MARINE LABORATORY. 465 P. ELK INVERTEBRATES, FISH, ZOOPLANKTON, LIFE HISTORY, ABUNDANCE, PHYSICAL GEOGRAPHY, ESTUARINE. GOOD SURVEY OF AREA.
221. ODUM, E.P. 1961. THE ROLE OF TIDAL MARSHES IN ESTUARINE PRODUCTION. NEW YORK STATE CONSERVATIONIST 15(6): 2-15. PLANTS, PRODUCTIVITY, ECOLOGY, ESTUARINE-INTERTIDAL-EMERGENT WETLAND.
222. ODUM, E.P. 1971. FUNDAMENTALS OF ECOLOGY. PHILADELPHIA. W.B. SAUNDERS. 574 P. ECOLOGY. COVER TOPICS SUCH AS ECOSYSTEM PRINCIPLES AND CONCEPTS, ENERGY, FOOD WEBS, BIOGEOCHEMICAL CYCLES, LIMITING FACTORS, COMMUNITY STRUCTURE, POPULATIONS, SPECIES CONCEPTS, ECOSYSTEM EVOLUTION, MATHEMATICAL MODELING, HABITAT ECOLOGY, POLLUTION, REMOTE SENSING, AND HUMAN ECOLOGY. (UC DAVIS, MOST UNIV. LIBS.)
223. OKUTANI, R.: MCCOMAN, J.A. 1969. SYSTEMATIC, DISTRIBUTION, AND ABUNDANCE OF THE EPIPLANKTONIC SQUID (CEPHALAPODA, DECAPODA) LARVAE ON THE CALIFORNIA CURRENT APRIL, 1954 - MARCH, 1957. BULLETIN OF SCRIPPS INSTITUTION OF OCEANOGRAPHY 14: 1-90. TAXONOMY, DISTRIBUTION, ABUNDANCE, SQUID, CEPHALAPODA, LARVAE, CALIFORNIA CURRENT, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
224. OLIVER, J.S.: SLATTERY, P.N. 1976. EFFECTS OF DREDGING AND DISPOSAL ON SOME BENTHIC AT MONTEREY BAY, CALIFORNIA. PREPARED FOR U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER. TECHNICAL PAPER NO. 76-15. 81 P. UCRZ INVERTEBRATES, POLYCHAETA, CRUSTACEA, WATER QUALITY, DREDGING, COMMUNITIES (BIOLOGICAL), IMPACTS, MARINE-SUBTIDAL. (MUSS LANDING MARINE LABORATORY)
225. OLIVER, J.S.: SLATTERY, P.N.: HULBERG, L.W.: NYBAKKEN, J.W. 1977. PATTERNS OF SUCCESSION IN BENTHIC INFAUNAL COMMUNITIES FOLLOWING DREDGING AND DREDGED MATERIAL DISPOSAL IN MONTEREY BAY. FINAL REPORT. U.S. ARMY ENGINEERS WATERWAY EXPERIMENT STATION DREDGED MATERIAL RESEARCH PROGRAM TECHNICAL REPORT D-77-27. PREPARED FOR OFFICE, CHIEF OF ENGINEERS, U.S. ARMY, WASHINGTON, D.C. UNDER CONTRACT NO. DACW39-74-C-0151. 186 P. UCRZ SUCCESSION, WATER QUALITY, ANIMALS, INVERTEBRATES, POLYCHAETA, DREDGING, COMMUNITIES (BIOLOGICAL), ECOLOGY, ASSOCIATIONS (BIOLOGICAL), ASSEMBLAGES, CRUSTACEA, SUBMARINE CANYONS, LIFE HISTORY, MARINE-SUBTIDAL-UNCONSOLIDATED BOTTOM. (MUSS LANDING MARINE LABORATORY)
226. USMAN, R.W. 1977. THE ESTABLISHMENT AND DEVELOPMENT OF A MARINE EPIFAUNAL COMMUNITY. ECOLOGICAL MONITORING 47: 37-63. DIVERSITY (COMMUNITY), SEASONAL VARIATION, SUCCESSION, INVERTEBRATES, LARVAE, COMPETITION, SUBSTRATUM, PREDATION, SALINITY, CURRENTS--OCEAN, ASSEMBLAGES, GROWTH RATES, MARINE-SUBTIDAL. MASSACHUSETTS. (UC SANTA CRUZ, MOST UNIV. LIBS.)
227. OWEN, R.D. 1974. DISTRIBUTION OF PRIMARY PRODUCTION, PLANT PIGMENTS AND SECCHIDEPTH IN THE CALIFORNIA CURRENT REGION, 1969. SUPPORTED BY CALIF. MARINE RESEARCH COMMITTEE. CALIF. COASTAL FISH INVESTIGATION. 20. CA. 24 P. DEFL, OARE, CHOD, OCRZ, OMAP PLANKTON, CALIFORNIA CURRENT, DISTRIBUTION, ECOLOGY, SUSPENDED SOLIDS, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
228. PAGE, G.: PEASLEE, S.C. 1977. NUMBERS 4 AND 0 HABITAT DESCRIPTION, PART II. IN STATUS OF THE SNOWY PLOVER ON THE NORTHERN CALIFORNIA COAST. CALIF. DEP. FISH & GAME NONGAME WILDL. INVEST. FINAL REPORT. SMI, KLA, MAC, FEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MUR, MAP, ANT, YNZ, ARG, LEEL, OARE, OCRZ, CCFZ, OMAP SNOWY PLOVER, CHADRIUS ALEXANDRINUS, HABITATS, ABUNDANCE, BIRDS, SHOREBIRDS, WATERBIRDS, BREEDING AREAS, COASTAL FOREDUNE COMPLEX. (CALIF. DEPT. OF FISH AND GAME-SAC.)
229. PAINE, R.T. 1976. SIZE LIMITED PREDATION: AN OBSERVATIONAL AND EXPERIMENTAL APPROACH WITH THE MYTILUS-PIASTER INTERACTION. ECOLOGY 57(51): 858-873. DEEL, OARE, OBOO, OCRZ, OMAP FOOD WEBS, LIMITING FACTORS, MARINE-SUBTIDAL-ROCK BOTTOM. (COLLEGE OF MARIN, MOST COLLEGE LIBS.)

230. PARKER, I.; MATIAS, W.J. 1978. CALVEG: VEGETATION CLASSIFICATION + MAPPING OF CALIFORNIA. SAN FRANCISCO. U.S. FOREST SERVICE REGION 5. 160 P. PLUS 30 MAP SHEETS. SMI, KLA, MAD, EEL, MAT, NGY, CUA, FUS, SMN, LAC, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG COVER TYPES, PLANTS, GRASSLAND, COASTAL SCRUBLANDS, CHAPARRAL, BROAD-LEAVED EVERGREEN FORESTS, OAK WOODLANDS, CLOSED-CONE CONIFER FOREST, COASTAL CONIFER FOREST, LOWER MONTANE CONIFER FOREST. CALVEG MANUAL DEFINING VEGETATION CLASSIFICATION UNITS AND SET OF 30 MAPS PORTRAYING THESE UNITS AS DELINEATED ON SATELLITE IMAGERY.
231. PARSONS, T.R.; TAKAHASHI, M.; HARGAVE, B. 1977. BIOLOGICAL OCEANOGRAPHIC PROCESSES. 2ND EDITION. NEW YORK. PERGAMON PRESS. 332 P. DEEL, DARE, OBOD, OCRZ, OMAR BIOLOGICAL OXYGEN DEMAND, PRODUCTIVITY, COMMUNITIES (BIOLOGICAL), DETRITUS, FOOD WEBS, NUTRIENTS, DISTRIBUTION, SEDIMENTATION, PLANKTON, INVERTEBRATES, PARTICULATES--WATER, TEMPERATURE--WATER, MARINE, ESTUARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
232. PATTERSON, C. 1971. LEAD. IN HOOD, D.W. (ED.) IMPINGEMENT OF MAN ON THE OCEANS. NEW YORK. WILEY-INTERSCIENCE. P. 245-258. DEEL, DARE, OBOD, OCRZ, OMAR LEAD, HEAVY METALS, IMPACTS, POLLUTION, BIOACCUMULATION, WATER QUALITY, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
233. PEARCY, W.G. 1965. SPECIES COMPOSITION AND DISTRIBUTION OF PELAGIC CEPHALOPODS FROM THE PACIFIC OCEAN OFF OREGON. PAC SCI 19: 261-266. DISTRIBUTION, CEPHALOPOD, ECOLOGY, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
234. PEARCY, W.G. 1972. DISTRIBUTION AND ECOLOGY OF OCEANIC ANIMALS OFF OREGON. IN PRUTER, A.I. (ED.); ALVERSON, D.L. (ED.) COLUMBIA RIVER ESTUARY AND ADJACENT OCEAN WATERS: BICENTENNIAL STUDIES. SEATTLE. UNIVERSITY OF WASHINGTON PRESS. P. 351-377. DISTRIBUTION? ECOLOGY, ANIMALS, FISH, PLANKTON, MIGRATION, FOOD WEBS, INVERTEBRATES, MARINE-PELAGIC.
235. PEARCY, W.G. 1979. DISTRIBUTION AND ABUNDANCE OF SMALL FLATFISHES AND OTHER DEMERSAL FISHES IN A REGION OF DIVERSE SEDIMENTS AND BATHYMETRY OFF OREGON. U.S. NAT. MAR. FISH. SERV. FISH. BULL. 76(3): 629-640. DISTRIBUTION, ABUNDANCE, FLATFISH, BATHYMETRY, SEDIMENT, ASSOCIATIONS (BIOLOGICAL), MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
236. PEARSE, J.S. 1975. CLASS ECHINOIDEA. IN SMITH, R.I. (ED.); CARLTON, J.T. (ED.) LIGHT'S MANUAL: INVERTIBAL INVERTEBRATES OF THE CENTRAL CALIFORNIA COAST. BERKELEY. UNIVERSITY OF CALIFORNIA PRESS. P. 221-222. INVERTEBRATES, TAXONOMY, DISTRIBUTION, ECHINOIDEA, MARINE-SUBTIDAL. (UC SANTA CRUZ, MESS LANDING MARINE LABORATORY, MOST UNIV. LIBS.)
231. PEARSE, J.S.; HINES, A.H. 1977. KELP FOREST ECOLOGY OF THE CENTRAL CALIFORNIA COAST. IN UNIVERSITY OF CALIFORNIA SEA GRANT COLLEGE PROGRAM ANNUAL REPORT 1976-77. SEA GRANT PUBLICATION NO. 61. P. 80-82. OCRZ ALGAE, ECOLOGY, INVERTEBRATES, PRODUCTIVITY, COMMUNITIES (BIOLOGICAL), KELP, MACROCYSTIS PYRIFERA, POPULATION DYNAMICS, MARINE-SUBTIDAL-AQUATIC RED-ALGAL. (UC SANTA CRUZ, STANFORD UNIVERSITY.)
238. PEARSON, T.H.; ROSENBERG, R. 1978. MACROBENTHIC SUCCESSION IN RELATION TO ORGANIC ENRICHMENT AND POLLUTION OF THE MARINE ENVIRONMENT. OCEANOGRAPHIC MAR. BIOL. ANNU. REV. 16: 229-311. SUCCESSION, INVERTEBRATES, ANIMALS, ALGAE, WATER QUALITY, MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
239. PEDDICORD, R.K.; MCFARLAND, V.A. 1978. EFFECTS OF SUSPENDED DREDGED MATERIAL ON AQUATIC ANIMALS. PREPARED FOR OFFICE, CHIEF OF ENGINEERS, U.S. ARMY, WASHINGTON, D.C. 192 P. FR4 SUSPENDED SOLIDS, INVERTEBRATES, FISH, DREDGING, ESTUARINE.
240. PEQUEGNAT, W.E. 1964. THE EPIFAUNA OF A CALIFORNIA SILTSTONE REEF. ECOLOGY 45: 272-283. ECOLOGY, INVERTEBRATES. (UC SANTA CRUZ, MOST UNIV. LIBS.)
241. PEREYA, W.T.; PEARCY, W.G.; CARVEY, F.E. 1969. SEBASTODES FLAVIUS, A SHELF ROCKFISH FEEDING ON MESOPELAGIC FAUNA, WITH A CONSIDERATION OF ECOLOGICAL IMPLICATIONS. FISH. RES. BOARD CAN. J. 26: 2211-2215. SEBASTODES FLAVIUS, ROCKFISH, FOOD SOURCES, ECOLOGY, MARINE-PELAGIC-OCEANIC. (USCC, MOST UNIV. LIBS.)

242. PESTRONG, R. 1965. THE DEVELOPMENT OF DRAINAGE PATTERNS ON TIDAL MARSHES. STANFORD UNIVERSITY PUBLICATION GEOLOGICAL SCIENCES 13: 1-87. FRA HYDROLOGY, SEDIMENTATION, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. (STANFORD UNIVERSITY.)
243. PESTRONG, R. 1967-9. TIDAL FLAT SEDIMENTATION AT COOLEYLANDING, S.W. SAN FRANCISCO BAY. A TECHNICAL REPORT UNDER THE OFFICE OF NAVAL RESEARCH, CONTRACT NCR-4433(30) WITH STANFORD UNIVERSITY. 55 P. FRA SEDIMENTATION, HYDROLOGY, ESTUARINE.
244. PHILLIPS, R.C. 1976. SEAGRASSES AND THE COASTAL MARINE ENVIRONMENT. OCEANUS. 21(3): 30-40. ECOSYSTEMS, PLANTS, ECOLOGY, FOOD CHAINS, SEDIMENT, SEAGRASSES.
245. PHLEGER, F.B.; PRADSHAW, J.S. 1966. SEDIMENTARY ENVIRONMENTS IN A MARINE MARSH. SCIENCE 154: 1551-1553. DIURNAL VARIATION, SALINITY, PH, DISSOLVED OXYGEN, TEMPERATURE--WATER, TIDES, SEASONAL VARIATION, ESTUARINE. DIURNAL AND SEASONAL VARIATION OF PH, OXYGEN, WATER TEMPERATURE AND SALINITY OF TIDAL FLOWS WERE MEASURED FOR A MISSION BAY, CALIFORNIA MARSH. (MOST UNIV. LIBS.)
246. PHLEGER, R. C. 1967. MARSH FORAMINIFERAL PATTERNS, PACIFIC COAST OF NORTH AMERICA. AN INST. BIOC. UNIV. CALIF. AUTON. MEX. SER. CIENC. MAR. LIMNOL. 38(1): 11-38. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG. INVERTEBRATES, DISTRIBUTION, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. (UC BERKELEY - BIOLOGY.)
247. PITT, M.; HEADY, H.F. 1978. RESPONSES OF ANNUAL VEGETATION TO TEMPERATURE AND RAINFALL PATTERNS IN NORTHERN CALIFORNIA. ECOLOGY 59(2): 336-350. MAT, NOY, GUA, RUS, SMN, LAG. PLANTS, ECOLOGY, PRECIPITATION, TEMPERATURE -- AIR, PRODUCTIVITY, VALLEY & FOOTHILL GRASSLAND. STUDY OF EFFECTS OF WEATHER PATTERNS OVER 18 YEARS ON STANDING CROP AND BOTANICAL COMPOSITION OF ANNUAL GRASSLAND. (UC BERKELEY - FORESTRY.)
248. RAMELEY, F. 1918. NOTES ON DUNE VEGETATION AT SAN FRANCISCO, CALIFORNIA. THE PLANT WORLD 21(8): 191-201. LAG, GRE. PLANTS, COMMUNITIES (BIOLOGICAL), HABITATS, COASTAL FOREDUNE COMPLEX. (UC BERKELEY - BIOLOGY.)
249. RANWELL, D.S. 1972. ECOLOGY OF SALT MARSHES AND SAND DUNES. LONDON. CHAPMAN AND HALL. 258 P. COMMUNITIES (BIOLOGICAL), PRODUCTIVITY, COMPETITION, DISTRIBUTION, ENVIRONMENTAL PLANNING, HABITATS, MANAGEMENT RECOMMENDATIONS, NUTRIENTS, PLANTS, SUCCESSION, ESTUARINE-INTERTIDAL-EMERGENT WETLAND, COASTAL FOREDUNE COMPLEX. STRUCTURE AND FUNCTION OF SALT MARSHES AND SAND DUNES ARE ANALYZED, PLANT AND ANIMAL RELATIONSHIPS AND THEIR INTERRELATIONSHIP WITH THE PHYSICAL ENVIRONMENT ARE REVIEWED, MANAGEMENT PRACTICES RECOMMENDED. (UC BERKELEY - BIOLOGY.)
250. RAUP, D.M. 1958. THE RELATIONSHIP BETWEEN WATER TEMPERATURE AND MORPHOLOGY IN DENDRASTER. JOURNAL OF GEOLOGY 66: 668-677. DENDRASTER, TEMPERATURE--WATER, MORPHOLOGY, MARINE-SUBTIDAL-UNCONSOLIDATED BOTTOM. (UC SANTA CRUZ, MOST UNIV. LIBS.)
- 251* RAVEN, P.H.; AXELROD, D.L. 1978. ORIGIN AND RELATIONSHIPS OF THE CALIFORNIA FLORA. UNIVERSITY OF CALIFORNIA PUBLICATIONS IN BOTANY VOLUME 72. BERKELEY. UNIV. OF CALIF. PRESS. 134 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG. PLANTS, EVOLUTION, SOIL, CLIMATOLOGY, GRASSLANDS, SHRUBLANDS, BROAD-LEAVED FORESTS & WOODLANDS, CONIFER FORESTS. DISCUSSION OF EVOLUTION OF CALIFORNIA PLANT SPECIES IN CONJUNCTION WITH CLIMATIC CHANGE: TOPICS INCLUDE ENDEMICISM, SERPENTINE, CALIFORNIA FLORESTIC PROVINCE. (UC BERKELEY - BIOLOGY.)
252. RECHER, H.F. 1966. SOME ASPECTS OF THE ECOLOGY OF MIGRANT SHORE BIRDS. ECOLOGY 47(3): 393-407. SHOEBIRDS, ECOLOGY, HABITATS. (UC BERKELEY - BIOLOGY.)
253. RECKSIEK, C.W.; FREY, H.W. 1978A. BACKGROUND OF MARKET SQUID RESEARCH PROGRAM, BASIC LIFE HISTORY, AND THE CALIFORNIA FISHERY. CALIFORNIA FISH GAME FISH BULL. NO. 169: 7-9. OCRZ, LOLLIGO OPAL ESCIFIS, MARKET SQUID, SQUID, CEPHALOPODA, MOLLUSCA, FISHERIES, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)

254. REED, P. 1969. CULTURE METHODS AND EFFECTS OF TEMPERATURE AND SALINITY ON SURVIVAL AND GROWTH OF DUNGENESS CRAB (CANCER MAGISTER) LARVAE IN THE LABORATORY. FISH RES BOARD CAN J 26(2): 386-397. DUNGENESS CRAB, MARKET CRAB, CANCER MAGISTER, TEMPERATURE--WATER, SALINITY, GROWTH RATES, LIFE HISTORY, LARVAE, LARVAL DEVELOPMENT, FOOD SOURCES, FEEDING, MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
255. REID, J.L.; RODEN, G.L.; WYLLIE, J.G. 1958. STUDIES OF THE CALIFORNIA CURRENT SYSTEM. CALIF OCEANIC FISH INVEST PROGRESS REP NO. 1; 29-56. DEEL, DARE, OBOD, OCR7, OMAR WIND, CURRENTS--OCEAN, TEMPERATURE--WATER, CHEMICAL COMPOSITION, SALINITY, PLANTS, ANIMALS, PLANKTON, CALIFORNIA CURRENT SYSTEM, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
256. REIMOLD, R. L.; GALLAGHER, J. L.; LINTHURST, R. A.; PLUMLEY, F. G. 1974. RESEARCH STUDY FOR DETERMINING THE PRODUCTION OF MINOR PLANT SPECIES AND THEIR SUBSTRATE SELECTIVE PROPERTIES. PREPARED FOR THE OFFICE OF DEPOSED MATERIALS RESEARCH, U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS, VICKSBURG, MISSISSIPPI, UNDER CONTRACT NO. DACW 39-73-C-0110. 51 P. PLANTS, PRODUCTIVITY, ESTUARINE-INTERTIDAL-EMERGENT WETLAND.
257. REVELLE, C.; REVELLE, P. 1974. SOURCEBOOK ON THE ENVIRONMENT; THE SCIENTIFIC PERSPECTIVE. BOSTON. HOLT RINEHART AND WILSON COMPANY. 332 P. AIR QUALITY, ECOLOGY, PESTICIDES, CARBON DIOXIDE, CARBON MONOXIDE, WATER QUALITY, CHLORINATED HYDROCARBONS, HEAVY METALS, ENERGY, MERCURY, RADIOACTIVITY, THERMAL POLLUTION, CONSERVATION, CIL POLLUTION, PARTICULATES. (UC SANTA CRUZ, MOST UNIV. LIBS.)
258. RICE, T. R.; WOLFE, Q. 1971. RADIOACTIVITY - CHEMICAL AND BIOLOGICAL ASPECTS. IN HODD, D. W. IMPINGEMENT OF MAN ON THE OCEANS. NEW YORK. WILEY-INTERSCIENCE. P. 325-380. RADIOACTIVITY, IMPACTS, WATER QUALITY, PHYTOPLANKTON, ZOOPLANKTON, MARINE. (UC SANTA CRUZ.)
259. RICHARDSON, S. L.; PEARCY, W. G. 1977. COASTAL AND OCEANIC FISH LARVAE IN AN AREA OF UPWELLING ON YAGUINABAY, OREGON. U S NAT MAR FISH SERV FISH BULL 75: 125-145. LARVAE, FISH, UPWELLING, DISTRIBUTION, ABUNDANCE, ECOLOGY, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
260. RICKETTS, E. F.; CALVIN, J. 1968. BETWEEN PACIFIC TIDES, FOURTH EDITION. STANFORD, CA. STANFORD UNIVERSITY PRESS. 614 P. DEEL, DARE, OBOD, OCR7, OMAR MARINE BIOLOGY, MARINE, ESTUARINE. TEXT ON MARINE BIOLOGY OF PACIFIC COAST: HODD, D. W. (ED.). (MOST COLLEGE LIBS.)
261. RIEDL, R. 1971. WATER MOVEMENT. IN KIANE, C. (ED.) MARINE ECOLOGY VOL. I ENVIRONMENTAL FACTORS PART 11. NEW YORK. WILEY-INTERSCIENCE. P. 1085-1156. CURRENTS--OCEAN, GEOLOGY, IMPACTS, MARINE. (UC SANTA CRUZ.)
262. RIGG, G. B. 1933. NOTES ON A SPHAGNUM BOG AT FORTERAGG, CALIFORNIA. SCIENCE 77(2005): 535-6. hcv PLANTS, ECOLOGY, HYDROLOGY, SOIL, PALUSTRINE-MOSS WETLAND (IE BOGS + FENS). DESCRIPTION OF FLORA AND ABIOTIC CHARACTERISTICS OF SPHAGNUM BOG. (UC BERKELEY - BIOLOGY.)
263. RISEBROUGH, R. W.; DAVIS, J. D.; ANDERSON, D. W. 1970. EFFECTS OF VARIOUS CHLORINATED HYDROCARBONS ON BIRDS. IN GILLET, J. W. (ED.) BIOLOGICAL IMPACT OF PESTICIDES IN THE ENVIRONMENT. P. 40-52. CORVALLIS. OREGON STATE UNIVERSITY PRESS. CHLORINATED HYDROCARBONS, BIRDS, PESTICIDES, FOOD WEBS, ECOLOGY, MARINE.
264. ROBERTS, W. G.; HOWE, J. G.; MAJOR, J. 1971. A SURVEY OF RIPARIAN FOREST FLORA AND FAUNA IN CALIFORNIA. IN SYMPOSIUM ON RIPARIAN FORESTS IN CALIFORNIA: THEIR ECOLOGY AND CONSERVATION, MAY 14, 1977, DAVIS, CA, PROCEEDINGS. SANDS, A. (ED.). SPONSORED BY INSTITUTE OF ECOLOGY AND DAVIS AUDUBON SOCIETY. INSTITUTE OF ECOLOGY PUBLICATION NO. 15. P. 3-19. SMI, KLA, MAD, EEL, MAT, NOV, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MGR, MAR, ANT, YNZ, ARG PLANTS, ECOLOGY, DISTRIBUTION, MAMMALS, INSECTS, RIPARIAN FORESTS. ECOLOGICAL, FLORAL, AND FAUNAL DESCRIPTION OF RIPARIAN FORESTS IN CALIFORNIA. (UC BERKELEY - BIOLOGY.)
265. ROEDEL, P. M. 1962. THE NAMES OF CERTAIN MARINE FISHES OF CALIFORNIA. CALIF FISH GAME 48(1): 19-34. DEEL, DARE, OBOD, OCR7, OMAR NOMENCLATURE, FISH. UPDATES STANDARD REFERENCE BY SAME AUTHOR ON COMMON NAMES OF MARINE FISHES OF CALIFORNIA. (UNIVERSITY LIBS.)

266. ROSENTHAL, R. J.; CLAPKE, W. U.; DAYTON, P.K. 1974* ECOLOGY AND NATURAL HISTORY OF A STAND OF GIANT KELP, *MACROCYSTIS PYRIFERA*, OFF DEL MAR, CALIFORNIA. U S NAT MAR FISH SERV FISH BULL 72: 670-684. *MACROCYSTIS PYRIFERA*, ECOLOGY, LIFE HISTORY, MARINE. [UC SANTA CRUZ, MOST UNIV. LIBS.]
267. ROY, D.F. 1966. SILVICAL CHARACTERISTICS OF REDWOOD (*SEQUOIA SEMPERVIRENS*). U S FOR SERV RES PAP PSW-28. 19 P. SMI, KLA, MAD, EEL, MAT, NIY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, CAR, MOR PLANTS, ECOLOGY, DISTRIBUTION, LIFE HISTORY, ALLUVIAL REDWOOD FOREST, SLOPE REDWOOD FOREST. DESCRIPTION OF ENVIRONMENTAL CONDITIONS AND LIFE HISTORY OF COAST REDWOOD. (UC BERKELEY - FORESTRY.)
268. RUBTZOFF, P. 1953. A PHYTOGEOGRAPHICAL ANALYSIS OF THE PITKIN MARSH. THE WASMANN JOURNAL OF BIOLOGY 11(2): 129-218. RUS TAXONOMY, PLANTS, DISTRIBUTION, PAL - EM WET-PERS-PER MOISTIE FRESHWATER. DESCRIPTION OF FLORA AT PITKIN MARSH NE AFFORESTVILLE. [UC BERKELEY - BIOLOGY.]
269. RUNDEL, P.W. 1977. WATER BALANCE IN MEDITERRANEAN SCLEROPHYLL Ecosystem. IN SYMPOSIUM ON THE ENVIRONMENTAL CONSEQUENCES OF FIRE AND FUEL MANAGEMENT IN MEDITERRANEAN ECOSYSTEMS, AUG. 1-5, 1977, PALO ALTO, CA. PROCEEDINGS. U.S. FOREST SERVICE GENERAL TECHNICAL REPORT WO-3. P. 95-136. SMI, KLA, MAD, EEL, MAT, NIY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SIS, CAR, MOR, MAR, ANT, VNZ, ARG PLANTS, ECOLOGY, GROWTH, WATER BALANCE, PHYSIOLOGY, TRANSPIRATION, FIRE, CHAPARRAL. DISCUSSION OF MORPHOLOGICAL AND PHYSIOLOGICAL ADAPTATIONS OF SCLEROPHYLL SHRUBS TO DROUGHT STRESS IN MEDITERRANEAN-TYPE ECOSYSTEMS. (UC BERKELEY - FORESTRY.)
270. RUTNER, F. 1953. FUNDAMENTALS OF LIMNOLOGY. LONDON. OXFORD UNIVERSITY PRESS. 242 P. ALGAL, CRUSTACEA, DETRITUS, INSECTS, MOLLUSCS, NITROGEN, NUTRIENTS, PRODUCTIVITY, ZOOPLANKTON, LACUSTRINE-PELAGIAL, PALUSTINE. LIMNOLOGY TEXT. (LJC DAVIS, MOST UNIV. LIBS.)
271. RYDER, R.A. (ED.); RYDER, A. (ED.). 1976. 29TH WINTER BIRD-POPULATION STUDY. AMERICAN BIRDS 30(6): 1040-1075. BIRDS, HABITATS, CHAPARRAL, BROAD-LEAVED EVERGREEN FORESTS. WINTER BIRD CENSUS IN WESTERN SYCAMORE-COAST LIVE OAK RIPARIAN WOODLAND-SANTA BARBARA CO. (PAGE 1063) AND COASTAL CHAPARRAL-LOS ANGELES CO. (PAGE 1065). (UC DAVIS, MOST UNIV. LIBS.)
272. RYTHER, J.H. 1963. GEOGRAPHIC VARIATIONS IN PRODUCTIVITY. IN HILL, M.N. (ED.). THE SEA: IDEAS AND OBSERVATIONS ON PROGRESS IN THE STUDY OF THE SEAS, VOL. 2, P. 347-389. NEW YORK. INTERSCIENCE PUBLISHERS. PRODUCTIVITY, GEOGRAPHY, PLANTS, LIMITING FACTORS, NUTRIENTS, UPWELLING, LIGHT PENETRATION, PHOTOSYNTHESIS, TEMPERATURE--WATER, MIXING, MARINE-PELAGIC, MARINE-SUBTIDAL. REFERENCE.
273. RYTHER, J.H. 1969. PHOTOSYNTHESIS AND FISH PRODUCTION IN THE SEA. SCIENCE 166: 72-76. PRODUCTIVITY, FOLD WEBS, FISH, PLANKTON, MARINE-PELAGIC. (UC SANTA CRUZ, MOST UNIV. LIBS.)
274. SANDERS, H.L.; HESSLER, R.R. 1969. ECOLOGY OF THE DEEP SEABENTHOS. SCIENCE 163(3874): 1418-1424. ECOLOGY, INVERTEBRATES, ANIMALS, MIPINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
275. SAWYER, J. (L.); THORNBURGH, D.A. 1977. MONTANE AND SUBALPINE Vegetation OF THE KLAMATH MOUNTAINS. IN BARBOUR, M.G. (ED.); MAJOR, J. (ED.). TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILEY & SONS. P. 699-732. SMI, KLA, MAD, EEL PLANTS, ECOLOGY, SOILS, FIRE, DISTRIBUTION, COAST RANGE MIXED CONIFER FOREST, COAST RANGE PINE FOREST. SURVEY OF MONTANE VEGETATION STUDIES. (UC BERKELEY - FORESTRY.)
276. SAWYER, J.D.; THORNBURGH, D.A.; GRIFFIN, J.R. 1977. MIXED EVERGREEN FOREST. IN BARBOUR, M.G. (ED.); MAJOR, J. (ED.). TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILEY & SONS. P. 359-381. SMI, KLA, MAD, EEL, MAT, NIY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SIS, CAR, MOR PLANTS, DISTRIBUTION, ECOLOGY, SUCCESSION, SOILS, BROAD-LEAVED EVERGREEN FORESTS, COASTAL CONIFER FOREST. DISCUSSION OF DISTRIBUTION AND ECOLOGY OF MIXED EVERGREEN FOREST. (UC BERKELEY - FORESTRY.)
277. SCHLINGER, E.I.; BARRY, W.J.; FRMAN, O.C.; BAKER, H.G.; KAWIN, R. 1977. BIOTIC COMMUNITIES. IN BARRY, W.J. (ED.); SCHLINGER, E.I. (ED.). INGLEDOUFFEN: A STUDY AND PLAN. SACRAMENTO, CALIFORNIA DEPARTMENT OF PARKS AND RECREATION.

p.52-81. NOY, LAG PLANTS, ECOLOGY, SUCCESSION, SOILS, HYDROLOGY, PALUSTRINE-MOSS WETLAND (ILBGS + FENS), PALUSTRINE-EMERGENT WETLAND, PAL-SCRUB/SHRUB WET (IE FRESHWATER SWAMP), PAL-FORRESTED W I LAND (IE FRESHWATER SWAMP), COASTAL PRAIRIE, C O A S T A L FOREDUNE COMPLEX, NORTH COASTAL SCRUB, BISHOP PINE FOREST, COASTAL CONIFER FOREST. STRUCTURE AND COMPOSITION OF ECOSYSTEMS IN AND AROUND INGLENOOK F E N . (UC BERKELEY - BIOLOGY.)

278. SCOFIELD, W.L. 1959. HISTORY OF KELP HARVESTING IN CALIFORNIA. CALIFFISH GAZE 45: 125-157. CORZ, CMAR ALGAE, KELP, MACROCYSTIS PYRIFERA, ECONOMICS, COMMERCE AND INDUSTRY, DISTRIBUTION, REGULATIONS, KELP HARVESTING, MARINE-SUBTIDAL-AQUATIC BED-ALGAL. (UC SANTA CRUZ, STANFORD UNIVERSITY, CALIF. DEPT. OF F I S H AND GAME, RESOURCES AGENCY LIBRARY, MOST UNIV. LIBS.)
279. SEAPY, R.R.; LITTLER, M.M. 1978. T H E DISTRIBUTION, ABUNDANCE, COMMUNITY STRUCTURE, AND PRIMARY PRODUCTIVITY OF MACROORGANISMS FROM TWO CENTRAL CALIFORNIA ROCKY INTERTIDAL HABITATS. PAC SCI 32(3): 293-314. MCR INVERTEBRATES, DISTRIBUTION, ABUNDANCE, CAYUCOS POINT, ESTUARINE-SUBTIDAL-ROCK BOTTOM, ESTUARINE-INTERTIDAL-ROCKY SHORE. COMPARISON OF SLIGHTLY EXPOSED AND PROTECTED HABITATS. (UC BERKELEY - BIOLOGY.)
280. SHAPOVALOV, L.; TAFT, A.C. 1954. T H E LIFE HISTORIES OF THE STEELHEAD RAINBOW TROUT (SALMO GAIRONERI GAIRONERI) AND SILVER SALMON (ONCORHYNCHUS KISUTCH) WITH SPECIAL REFERENCE TO WADDELL CREEK, CALIFORNIA, AND RECOMMENDATIONS REGARDING THEIR MANAGEMENT. CALIF OEP FISH GAME FISH HULL NO. 08. 375 P. LOR STEELHEAD RAINBOW TROUT, STEELHEAD, SALMO GAIRONERI GAIRONERI, SALMO GAIRONERI, LIFE HISTORY, FISH, FISHERIES, SILVER SALMON, COHO SALMON, ONCORHYNCHUS KISUTCH, WADDELL CREEK, SCOTT CREEK, SPAWNING, INVERTEBRATES, COTTUS ASPER, PRICKLY SCULPIN, ESTUARINE-WATER COLUMN, RIVERINE-TIDAL, RIVERINE-LOWER PERENNIAL, RIVERINE-UPPER PERENNIAL. EIGHT-YEAR DETAILED LIFE HISTORY STUDY OF STEELHEAD AND COHO. (CALIF. STATE LIBRARY, MAJOR UNIV. LIBS.)
281. SHEPARD, F.P. 1967. THE EARTH BENEATH THE SEA. BALTIMORE, MARYLAND. JOHN HOPKINS PRESS. 242 P. PHYSICAL OCEANOGRAPHY. SUBMARINE GEOLOGY. (MOST COLLEGE LIBRARIES.)
282. SKOGSBERG, T. 1936. HYDROGRAPHY OF MONTEREY BAY, CALIFORNIA, THERMAL CONDITIONS, 1929-1933. TRANS AM PHILS SOC 29: 1-152. CORZ CURRENTS--OCEAN, PHYSICAL OCEANOGRAPHY, MARINE. (MOST UNIV. LIBS.)
283. SMALL, A. 1974. THE BIRDS OF CALIFORNIA. NEW YORK. MACMILLAN. 310 P* BIRDS, ECOLOGY, HABITATS, DISTRIBUTION. TEXT INCLUDES INFORMATION (IN LAND REGIONS AND CLIMATE OF CALIFORNIA AS THEY RELATE TO ECOLOGY AND DISTRIBUTION OF BIRDS. A COMPLETE ANNOTATED LIST OF ALL BIRDS OCCURRING IN STATE FROM 1900 TO 1974, THEIR RANGE, SEASONALITY, HABITATS AND BREEDING STATUS. (UC DAVIS, MOST UNIV. LIBS.)
284. SMALLEY, A.E. 1959. T H E GROWTH CYCLE OF SPARTINA AND ITS RELATION TO THE INSECT POPULATIONS IN THE MARSH. IN PROCEEDINGS OF A SALTPANSH CONFERENCE, MARINE INSTITUTE, UNIVERSITY OF GEORGIA, SAPELO ISLAND, GEORGIA, P. 96-100. PLANTS, INSECTS, PRODUCTIVITY, SPARTINA, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. (UNIVERSITY OF GEORGIA, MARINE INSTITUTE, SAPELO ISLAND, GEORGIA 31327.)
285. SMITH, J.E. (EEI.). 1968. 'TORREY CANYON' POLLUTION AND MARINE LIFE. MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM. LONDON. CAMBRIDGE UNIVERSITY PRESS. 196 P. WATER QUALITY, OIL POLLUTION, MARINE. SURVEYS AND DISCUSSES EFFECTS OF OIL T I J (ILLUSTRATION ON MARINE LIFE. (UNIVERSITY LIBRARIES.)
286. SMITH, R.I. (FC.); CARLTON, J.T. (EU.) 1975. LIGHT'S MANUAL; INTERTIDAL INVERTEBRATES OF THE CENTRAL CALIFORNIA COAST, THIRD EDITION. BERKELEY. UNIVERSITY OF CALIFORNIA PRESS. 716 P. CEEL, GAZE, OBCD, CORZ, CMAR INVERTEBRATES, ALGAE, FISH, TAXONOMY, MAR [AE-INTERTIDAL, MARINE-SUBTIDAL. (UC BERKELEY - BIOLOGY, ECOLOGICAL & MARINE LAB. (UC), STANFORD UNIVERSITY, CALIF. STATE COLLEGE, SONOMA, MOST UNIV. LIBS.)
287. SOKOLOVA, M.N. 1972. TROPHIC STRUCTURE OF DEEP-SEA MACROBENTHOS. MARINE BIOLOGY 16(1): 1-12. CEEL, GAZE, OBCD, CORZ, CMAR BIOLOGICAL OXYGEN DEMAND, PRODUCTIVITY, CHEMICAL COMPOSITION, MIXING, DETRITUS, DECOMPOSITION, CURRENTS--OCEAN, OXIDATION, NUTRIENTS, DISSOLVED OXYGEN, SEDIMENTATION, TROPHIC LEVELS, MARINE-SUBTIDAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)

288. SPIES, R.B.; DAVIS, P.H.; STURMER, D.H. IN PRESS. ECOLOGY OF A SUBMARINE PETROLEUM SEEP. IN STUDIES IN MARINE ENVIRONMENTAL POLLUTION. NEW YORK. ELSEVIER NORTH HOLLAND. ECOLOGY, OIL POLLUTION, OIL SPILLS, WATER QUALITY, COMMUNITIES (BIOLOGICAL), IMPACTS, MARINE.
289. STALLCUP, R. 1976. PELAGIC BIRDS OF MONTEREY BAY. WESTERN BIRDS 7(4): 113-127. OCRZ BIRDS, BEHAVIOR, ENDANGERED SPECIES, LIFE HISTORY, WATER BIRDS, OCEANOGRAPHY, MONITORING, ASHY STORM-PETREL, PUFFINUS GRISEUS, SOOTY SHEARWATER, DIOMEDEA ALBATRUS, SHORT-TAILED ALBATROSS, MARINE.
290. STANDING, J.; BROWNING, O.; SPETH, J.W. 1975*. THE NATURAL RESOURCES OF BODEGA HARBOR. PREPARED IN COOPERATION WITH U.S. ARMY CORPS OF ENGINEERS AND UNDER CONTRACT WITH THE CALIFORNIA COASTAL ZONE CONSERVATION COMMISSION WITH FUNDS GRANTED BY THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION. CALIFORNIA FISH AND GAME COASTAL WETLANDS SERIES #11. 183 P. SMN ANIMALS, BIRDS, COMMUNITIES (BIOLOGICAL), CRUSTACEA, ECOLOGY, FISH, FOOD WEBS, GEOMORPHOLOGY, HABITATS, INSECTS, INVERTEBRATES, MAMMALS, MOLLUSCS, NATURAL RESOURCES, PLANTS, POPULATION DYNAMICS, RECREATION, SHOREBIRDS, WATER BIRDS, WATER FOWL, ZONATION (BIOLOGICAL), TROPHIC LEVELS, ESTUARINE, MARINE, PHYSICAL OCEANOGRAPHY, SALINITY, TEMPERATURE--WATER, SEDIMENTATION, WATER QUALITY. (UC BERKELEY - WATER RESOURCES CENTER ARCHIVES.)
291. STEBBINS, R.C. 1966. A FIELD GUIDE TO WESTERN REPTILES AND AMPHIBIANS. BOSTON, MASS. Houghton Mifflin Company. 279 P. TAXONOMY, HERPETOLOGY, DISTRIBUTION, HABITATS, FOOD SOURCES. A GUIDE FOR IDENTIFICATION OF REPTILES AND AMPHIBIANS. ALSO INCLUDED IS INFORMATION ON SPECIES RANGE, HABITAT TYPES, TIME OF ACTIVITY, HABITS, AND SUBSPECIES. DISTRIBUTION MAPS INCLUDED. (UC DAVIS, MOST UNIV. LIBS.)
292. STEPHENSON, T.A., STEPHENSON, A. 1972. LIFE BETWEEN TIDEMARKS ON ROCKY SHORES. SAN FRANCISCO. W.H. FREEMAN AND COMPANY. 423 P. ZONATION (BIOLOGICAL), INVERTEBRATES, TIDES, ECOLOGY, ALGAE, INTERRELATIONSHIPS, MARINE BIOLOGY, MARINE-SUBTIDAL-AQUATIC BED-ROOTED VAS. DESCRIPTION OF ROCKY INTERTIDAL ZONES AND VARIOUS SPECIES INHABITING THESE ZONES. TEXT COVERING INTERTIDAL REGION THROUGHOUT WORLD.
293. STONE, E.C. 1971. THE DYNAMICS OF VEGETATION CHANGE ALONG THE CARMEL RIVER. PREPARED FOR THE CALIFORNIA AMERICAN WATER COMPANY. BERKELEY. STONE AND ASSOCIATES. 54 P. CAP PLANTS, SUCCESSION, HYDROLOGY, DISTURBANCE, ECOLOGY, RIPARIAN FORESTS. ANALYSIS OF VEGETATION CHANGE INDUCED BY GROUNDWATER PUMPING. (UC BERKELEY - FORESTRY.)
294. STONE, E.C.; MCBRIDE, J.K. 1969. RESOURCE MANAGEMENT STUDY OF LAS LOMAS STATE PARK. PREPARED FOR CALIF. DEPT. OF PARKS AND RECREATION. BERKELEY. STONE AND ASSOCIATES. 62 P. CAP PLANTS, ECOLOGY, SUCCESSION, MONTEREY PINE FOREST. STUDY OF DUNE SUCCESSION ON MONTEREY PENINSULA. (UC BERKELEY - FORESTRY.)
295. STRAUGHAN, O. 1971*. BIOLOGICAL AND OCEANOGRAPHICAL SURVEY OF THE SANTA BARBARA CHANNEL OIL SPILL 1969-1970. VOLUME ONE. BIOLOGY AND BACTERIOLOGY. UNIVERSITY OF SOUTHERN CALIFORNIA. ALLAN HANCOCK FOUNDATION. 426 P. OIL SPILLS, MARINE. (UNIVERSITY LIBS.)
296. STROUD, L.M.; COOPER, A.H. 1969. COLOR INFRARED AERIAL PHOTOGRAPHIC INTERPRETATION AND NET PRIMARY PRODUCTIVITY OF A REGULARLY-FLOODED NORTH CAROLINA SALT MARSH. UNIV. OF NORTH CAROLINA. WATER RESOURCES RESEARCH INSTITUTE. REPORT 14. 86 P. PLANTS, PRODUCTIVITY, NORTH CAROLINA, ESTUARINE-INTERTIDAL-EMERGENT WETLAND.
297. SUDWORTH, J.B. 1967. FOREST TREES OF THE PACIFIC SLOPE. NEW YORK. DIVER PUBLICATIONS. 455 P. SMI, KLA, MAD, EEL, MAT, NDY, GUA, RUS, SAN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, AFG PLANTS, ECOLOGY, LIFE HISTORY, DISTRIBUTION, BROAD-LEAVED FORESTS + WOODLANDS, CONIFER FORESTS. LIFE HISTORY AND DISTRIBUTION DATA ON ALL PACIFIC COAST TREES. (UC BERKELEY - FORESTRY.)
298. SVERDRUP, H.U.; JOHNSON, M.W.; FLEMING, R.H. 1942. THE OCEANS: THEIR PHYSICS, CHEMISTRY, AND GENERAL BIOLOGY. NEW YORK. PRENTICE-HALL, INC. 1087 P. PHYSICAL OCEANOGRAPHY, TEMPERATURE--WATER, SALINITY, DISTRIBUTION, CHEMICAL COMPOSITION, PLANTS, ANIMALS, LIFE HISTORY, CURRENTS--OCEAN, HYDROLOGY, WAVES (OCEAN), TIDES, PRODUCTIVITY, FOOD WEBS, SEDIMENTATION, ASSOCIATIONS (BIOLOGICAL), MARINE-PELAGIC. (UC BERKELEY - BIOLOGY.)

299. SWEENEY, B.M. 1975. REDTIDES I HAVE KNOWN. IN LOCICERO, V.R. (ED.) THE FIRST INTERNATIONAL CONFERENCE ON TOXIC DINOFLLAGELLATE BLOOMS. PROCEEDINGS. MASSACHUSETTS SCIENCE AND TECHNOLOGY FOUNDATION. P. 225-248. DINOFLLAGELLATES, DISTRIBUTION, MARINE.
300. TEAL, J.M. 1962. ENERGY FLOW IN THE SALT MARSH ECOSYSTEM OF GEORGIA. ECOLOGY. 43: 614-624. PLANTS, ANIMALS, ENERGY, ECOLOGY, PRODUCTIVITY, ESTUARINE-INTERITIDAL-EMERGENT WETLAND. (UC BERKELEY - BIOLOGY.)
301. THORNE, R.F. 1976. THE VASCULAR PLANT COMMUNITIES OF CALIFORNIA. IN LATTING, J. (ED.) SYMPOSIUM PROCEEDINGS, PLANT COMMUNITIES OF SOUTHERN CALIFORNIA. CALIFORNIA NATIVE PLANT SOCIETY SPECIAL PUBLICATION NO. 2. P. 1-31. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, DISTRIBUTION, COVER TYPES. A PLANT COMMUNITY CLASSIFICATION SYSTEM. (UC BERKELEY - BIOLOGY.)
- 302* THORP, R.W. 1976. INSECT POLLINATION OF VERNAL PULL FLOWERS. IN JAIN, S. (ED.) VERNAL POLLS: THEIR ECOLOGY AND CONSERVATION, A SYMPOSIUM. INSTITUTE OF ECOLOGY, UNIVERSITY OF CALIFORNIA, DAVIS, MAY 12, 1976. P. 36-40. INSTITUTE OF ECOLOGY PUBLICATION NO. OF RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG PLANTS, INSECTS, EVOLUTION, ECOLOGY, PAL-EM WET-PERS-SEAS MOIST (IE VERNAL MAR), PALUSTRINE-EMERGENT WETLAND-CONPERSIS. DISCUSSION OF HOST-SPECIFIC BEE POLLINATORS OF VERNAL POOL PLANT SPECIES. (UC DAVIS.)
303. THORSON, G. 1957. CHAPTER 17. BOTTOM COMMUNITIES (SUBLITTORAL OR SHALLOW SHELF). IN HECCKETH, J.W. (ED.) TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY. VOL. 1 ECOLOGY. THE GEOLOGICAL SOCIETY OF AMERICA MEMOR. 67. P. 461-534. ANIMALS, ECOLOGY, DIVERSITY (ECOSYSTEM), STABILITY (ECOSYSTEM), INVERTEBRATES, HABITATS, COMMUNITIES (BIOLOGICAL), LARVAE, SUBSTRATUM, TROPHIC LEVELS, FOOD WEBS, BIOMASS, GROWTH RATES, LIFE HISTORY, PRODUCTIVITY, DISTRIBUTION, MARINE-SUBTICAL. (UC SANTA CRUZ, MOST UNIV. LIBS.)
304. TRASK, P.O. (EO.). 1955. RECENT MARINE SEDIMENTS: A SYMPOSIUM. PREPARED UNDER THE DIRECTION OF A SUBCOMMITTEE OF THE COMMITTEE ON SEDIMENTATION OF THE DIVISION OF GEOLOGY AND GEOGRAPHY OF THE NATIONAL RESEARCH COUNCIL. TULSA, OKLAHOMA. AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS. 736 P. EEL, OAK, CED, OCR, CMAR SEDIMENTATION, PHYSICAL OCEANOGRAPHY, MARINE-SUBTIDAL, MARINE-INTERITIDAL, ESTUARINE-SUBTIDAL, ESTUARINE-INTERITIDAL, RIVERINE, LACUSTRINE-LIMNETIC (IE LAKE BOTTOM), LACUSTRINE-LITTORAL (IE LAKE SHORE). DETAILED ANALYSIS OF ALL MARINE DEPOSITIONAL PROCESSES AND SEDIMENT CHARACTERISTICS. (UC BERKELEY - EARTH SCIENCES.)
305. U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, ENVIRONMENTAL LABORATORY, VICKSBURG, MS. 1978. PRELIMINARY GUIDE TO WETLANDS OF THE WEST COAST STATES: MAJOR ASSOCIATIONS AND COMMUNITIES IDENTIFIED. PREPARED FOR OFFICE, CHIEF OF ENGINEERS, U.S. ARMY, WASHINGTON, D. C. TECHNICAL REPORT Y-78-4. 95 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG COMMUNITIES (BIOLOGICAL), COVER TYPES, PLANTS, ESTUARINE-INTERITIDAL-EMERGENT WETLAND. WRITTEN TO ALL IN FIELD INVESTIGATIONS ASSOCIATED WITH THE IMPLEMENTATION OF SECTION 404 PERMIT PROGRAM, DESCRIPTIONS OF EIGHT WETLAND TYPES, OCCURRING WITHIN THE WEST COAST REGION, ARE PROVIDED. INCLUDES INFORMATION ON PHYSIOGNOMY, SPECIES COMPOSITION AND ENVIRONMENTAL CONDITIONS.
306. U. S. FISH AND WILDLIFE SERVICE. 1979A. CONCEPT PLAN FOR WATERFOWL WINTERING HABITAT PRESERVATION, CALIFORNIA COAST, PRIORITY CATEGORY 6. 122 P. WITH APPROX. 50 P. OF APPENDICES. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG WATERFOWL, MIGRATION, HABITATS, OVERWINTERING, ESTUARINE. DESCRIPTION OF WATERFOWL POPULATIONS AND WINTERING HABITATS ALONG THE CALIFORNIA COAST; DISCUSSION OF HABITAT THREATS, IMPACTS, AND PRESERVATION EFFORTS; PRESERVATION STRATEGIES AND OBJECTIVES. (U.S. FISH AND WILDLIFE SERVICE--PORTLAND, SUPERINTENDENT OF DOCUMENTS, U. S. GOVERNMENT PRINTING OFFICE.)
307. UCHUPI, E.; EMERY, K.C. 1963. THE CONTINENTAL SLOPE BETWEEN SAN FRANCISCO, CALIFORNIA AND CEDROS ISLAND, MEXICO. DEEP-SEA RESEARCH 10(4): 397-447. CONTINENTAL SLOPE, GEOLOGY, DETRITUS, SUBSTRATUM, SEDIMENTATION, BATHYMETRY, SEDIMENTATION, EROSION, SUBMARINE CANYONS, MARINE-PELAGIC, MARINE-SUBTIDAL. (UC SANTA CRUZ, UC BERKELEY - EARTH SCIENCES.)
308. USFWS SEE U. S. FISH AND WILDLIFE SERVICE

309. VAN VELDHUIZEN, H.D.; PHILLIPS, D.W. 1978. PREY CAPTURE BY PISASTER BREVISPINUS (ASTEROCIDEA: ECHINODERMATA) ON SOFT SUBSTRATE. MARINE BIOLOGY 48: 89-97. SEASTAR, PREDATION, TRESUS NUTTALLII, PISASTER BREVISPINUS, FEEDING, MARINE-SURTIDAL-UNCOLN BOTTOM-SANG. (MOST UNIV. LIBS., UCSC.)
310. VAN VELZEN, W.T. (ED.). 1971. THIRTY-FIFTH BREEDING-BIRD CENSUS. AMERICAN BIRDS 25(6): 460-1022. LAG, GRE BIRDS, HABITATS, GRASSLANDS, SHRUBLANDS, DOUGLAS-FIR FOREST. A CENSUS OF BREEDING BIRDS IN COASTAL CHAPARRAL- MARIN COUNTY (PAGE 1002), FOOTHILL GRASSLAND- SAN MATEO COUNTY (PAGE 1009) AND MATURE DOUGLAS-FIR FOREST- MARIN COUNTY (PAGE 987). (UC DAVIS, MOST UNIV. LIBS.)
311. VAN VELZEN, W.T. (ED.). 1972. THIRTY-SIXTH BREEDING-BIRD CENSUS. AMERICAN BIRDS 26(6): 937-1006. LAG, GRE BIRDS, HABITATS, SHRUBLANDS, BROAD-LEAVED EVERGREEN FORESTS, RIPARIAN FORESTS, MONTEREY PINE FOREST, BISHOP PINE FOREST, DOUGLAS-FIR FOREST. A CENSUS OF BREEDING BIRDS IN CALIF. BAY-BUCKEYE-MIXED FOREST- MARIN CO. (PAGE 981), BISHOP PINE FOREST- MARIN COUNTY (PAGE 985), LOGGED DOUGLAS-FIR-RESEEDED TO MONTEREY PINE- MARIN COUNTY (PAGE 983), COASTAL SCRUB- MARIN COUNTY (PAGE 987), RIPARIAN WILLOW WOODLAND- SAN MATEO COUNTY (PAGE 1002) AND MATURE DOUGLAS-FIR FOREST- MARIN COUNTY (PAGE 984). (UC DAVIS, MOST UNIV. LIBS.)
312. VAN VELZEN, W.T. (ED.). 1973. THIRTY-SEVENTH BREEDING-BIRD CENSUS. AMERICAN BIRDS 27(6): 955-1015. LAG BIRDS, HABITATS, SHRUBLANDS, BROAD-LEAVED EVERGREEN FORESTS, MONTEREY PINE FOREST, BISHOP PINE FOREST, DOUGLAS-FIR FOREST. A CENSUS OF BREEDING BIRDS IN OAK-CALIF. BAY-BUCKEYE-MIXED FOREST- MARIN CO. (PAGE 955), CALIF. BAY-BISHOP PINE-MIXED FOREST- MARIN CO. (PAGE 947), BISHOP PINE FOREST- MARIN CO. (PAGES 956-999), LOGGED DOUGLAS-FIR-RESEEDED WITH MONTEREY PINE- MARIN CO. (PAGE 1000), MATURE DOUGLAS-FIR FOREST- MARIN CO. (PAGE 1001) AND COASTAL SCRUB- MARIN CO. (PAGE 1004). (UC DAVIS, MOST UNIV. LIBS.)
313. VAN VELZEN, W.T. (ED.). 1974. THIRTY-EIGHTH BREEDING-BIRD CENSUS. AMERICAN BIRDS 28(6): 987-1054. LAG BIRDS, HABITATS, SHRUBLANDS, BROAD-LEAVED EVERGREEN FORESTS, MONTEREY PINE FOREST, BISHOP PINE FOREST, DOUGLAS-FIR FOREST. A CENSUS OF BREEDING BIRDS IN OAK-CALIF. BAY-BUCKEYE-MIXED FOREST- MARIN CO. (PAGE 1035), CALIF. BAY-BISHOP PINE-MIXED FOREST- MARIN CO. (PAGE 1037), BISHOP PINE FOREST- MARIN CO. (PAGE 1039), LOGGED DOUGLAS-FIR-RESEEDED WITH MONTEREY PINE- MARIN CO. (PAGE 1040), MATURE DOUGLAS-FIR FOREST- MARIN CO. (PAGE 1041) AND COASTAL SCRUB- MARIN CO. (PAGE 1042). (UC DAVIS, MOST UNIV. LIBS.)
314. VAN VELZEN, W.T. (ED.). 1975. THIRTY-NINTH BREEDING BIRD CENSUS. AMERICAN BIRDS 29(6): 1080-1145. LAG BIRDS, HABITATS, SHRUBLANDS, BROAD-LEAVED EVERGREEN FORESTS, MONTEREY PINE FOREST, BISHOP PINE FOREST, DOUGLAS-FIR FOREST. A CENSUS OF BREEDING BIRDS IN CALIF. BAY-BUCKEYE-MIXED FOREST- MARIN CO. (PAGE 1123), CALIF. BAY-BISHOP PINE-MIXED FOREST- MARIN CO. (PAGE 1125), BISHOP PINE FOREST- MARIN CO. (PAGES 1125-1127), LOGGED DOUGLAS-FIR-RESEEDED WITH MONTEREY PINE- MARIN CO. (PAGE 1127), MATURE DOUGLAS-FIR FOREST- MARIN CO. (PAGE 1128) AND COASTAL SCRUB- MARIN CO. (PAGE 1129). (UC DAVIS, MOST UNIV. LIBS.)
315. VAROUJEAN, D.H. 1979. SEABIRD COLONY CATALOG: WASHINGTON, OREGON, 4 N U CALIFORNIA. PREPARED FOR U. S. FISH AND WILDLIFE SERVICE. 456 P. SMI, KLA, MAD, FEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCP, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG BIRDS, MARINE.
316. VIERS, S.D. 1973. ECOLOGY OF COAST REDWOOD. IN OFFICE OF NATURAL SCIENCE ANNUAL REPORT FOR CALENDAR YEAR 1973. U.S. NATIONAL PARK SERVICE. P. 151-157. S'41, KLA, MAD, EEL, NOY, GUA, RUS, LAG, GRE, LUF PLANTS, ECOLOGY, REGENERATION, DISTURBANCE, ALLUVIAL REDWOOD FOREST, SLIPPERED WOOD FOREST. STUDY OF REDWOOD AGE-CLASS DISTRIBUTIONS AND REGENERATION RATES IN REDWOOD NATIONAL PARK. (UC BERKELEY - FORESTRY.)
317. VOGL, R.J. 1977. FIRE FREQUENCY AND SITE DEGRADATION. IN SYMPOSIUM ON THE ENVIRONMENTAL CONSEQUENCES OF FIRE AND FUEL MANAGEMENT IN MEDITERRANEAN ECOSYSTEMS, AUG. 1-5, 1977, PALM SPRING, CALIF. PROCEEDINGS. P. 193-221. U.S. FOR SER GEN TECH REP WO-3. SMI, KLA, MAD, EEL, NOY, GUA, RUS, SMN, LAG, IPA, GRE, LCP, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG FIRE, PLANTS, ECOLOGY, DISTURBANCE, CHAPARRAL. DISCUSSION OF RELATIONS OF FIRE FREQUENCY AND FIRE INTENSITY TO SITE DEGRADATION IN CHAPARRAL ECOSYSTEMS. (UC BERKELEY - FORESTRY.)
318. VOGL, R.J.; ARMSTRONG, W.P.; WHITE, K.L.; COLE, K.L. 1977. THE CLOSED-CONE PINE S AND CYPRESS. IN BARBOUR,

M.G.(ED.);MAJOR,J.(ED. I. TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILEY + SONS. P. 295-298. SMI, K L A , MAD, MAT, NOY, GUA, RUS, LAG, GRE, LOR, PAJ, C A R , MOR, ANT, YNZ, ARG PLANTS, FIRE, ECOLOGY, SOIL, DISTRIBUTION, LIFE HISTORY, CLOSED-CONE CONIFER FOREST. SURVEY OF CLOSED-CONE CONIFER ECOLOGY AND LIFE HISTORIES. (UC BERKELEY - BIOLOGY.)

319. WALDELICH, R. 1976. SEASONAL AND SPATIAL FLUCTUATIONS OF PHYTOPLANKTON IN MONTEREY BAY. THESIS CALIFORNIA STATE UNIVERSITY HAYWARD. 124 P. OCRZ PHYTOPLANKTON, MONTEREY BAY, BIOMASS, SEASONAL VARIATION, MARINE-PELAGIC. (MOSS LANDING MARINE LABORATORY.)
320. WARING, R.H.; FRANKLIN, J.F. 1979. EVERGREEN CONIFEROUS FORESTS OF THE PACIFIC NORTHWEST. SCIENCE 204: 1380-1386. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR EVOLUTION, PLANTS, PHYSIOLOGY, NUTRIENTS, ECOLOGY, PRODUCTIVITY, RED ALDER FOREST, COASTAL CONIFER FOREST. DISCUSSION OF EVOLUTION OF COASTAL CONIFER SPECIES AND THEIR ADVANTAGES RELATIVE TO DECIDUOUS HARDWOODS. (UC PERKLEY - BIOLOGY.)
321. WARING, R.H.; MAJOR, J. 1964. SOME VEGETATION OF THE CALIFORNIA COASTAL REDWOOD REGION IN RELATION TO GRADIENTS OF MOISTURE, NUTRIENTS, LIGHT, AND TEMPERATURE. ECOL MONOGR 34(2): 167-215. EEL, MAT, NOY PLANTS, ECOLOGY, SOILS, MICROCLIMATE, NUTRIENTS, DISTRIBUTION, GRASSLAND, CHAPARRAL, RIPARIAN FORESTS, NORTHERN OAK WOODLAND, COASTAL CONIFER FOREST, LOWER MONTANE CONIFER FOREST. STUDY OF DISTRIBUTIONS OF TEN HABITAT TYPES ON FOUR ENVIRONMENTAL GRADIENTS AT HUMBOLDT REDWOODS STATE PARK. (UC BERKELEY - FORESTRY.)
322. WARNE, J.E. 1971. PALEOECOLOGICAL ASPECTS OF A MODERN COASTAL LAGOON. UNIV CALIF PUB GEOL SCI 67. 131 P. SEDIMENTATION, PLANTS, ANIMALS, MUGILACEON, ZONATION (BIOLOGICAL), ESTUARINE. MAPS INCLUDED. (UC PERKLEY - EARTH SCIENCES.)
323. WATERS, T.F. 1969. INVERTEBRATE DRIFT-ECOLOGY AND SIGNIFICANCE TO STREAM FISHES. IN NORTH COLE, T.G.(ED.). SYMPOSIUM ON SALMON AND TROUT IN STREAMS. H.R. MACMILLAN LECTURES IN FISHERIES. VANCOUVER. UNIV. OF BRITISH COLUMBIA. P. 121-134. CRUSTACEA, DIURNAL VARIATION, ECOLOGY, FOOD SOURCES, FISH, INSECTS, INVERTEBRATES, STREAM FLOW, TEMPERATURE--WATER, RIVERINE-UPPER PERENNIAL. MOST INVERTEBRATES DRIFT IN DIEL PERIODICITY. MOST NIGHT-ACTIVE. SOME DAY-ACTIVE. DRIFT IMPORTANT FOOD SOURCE FOR FISHES. (CALIF. STATE LIBRARY, MAJOR UNIV. LIBS.)
324. WEAVER, A.M. 1977. ASPECTS OF THE EFFECTS OF PARTICULATE MATTER ON THE ECOLOGY OF A KELP FOREST (MACROCYSTIS PYRIFERA (L.) C.A. AGARDH) NEAR A SMALL DOMESTIC SEWER OUT FILL. DISSERTATION, STANFORD UNIVERSITY, STANFORD, CALIFORNIA. 174 P. OCRZ DEL MONTE BEACH, (SEDIMENT) SEDIMENTATION, WATER QUALITY, MACROCYSTIS PYRIFERA, ALGAE, INVERTEBRATES, TOPOGRAPHY, GEOLOGY, PARTICULATES--WATER, MARINE-SUBTIDAL. (STANFORD UNIVERSITY.)
325. WELDAY, E.E.; WILLIAMS, J.W. 1975. OFFSHORE SURFICIAL GEOLOGY OF CALIFORNIA. MAP SHEET 26. PREPARED FOR CALIF. DIVISION OF MINES AND GEOLOGY. 1 MAP SHEET. GEOLOGY, SEDIMENTATION. (CALIF. DIV. OF MINES + GEOLOGY--SAN FRANCISCO.)
326. WELLS, P.V. 1962. VEGETATION IN RELATION TO GEOLOGICAL SUBSTRATUM AND FIRE IN THE SAN JUAN CRISPO QUADRANGLE, CALIFORNIA. ECOL MONOGR 32(1): 19-103. MOR, MAR PLANTS, FIRE, SOILS, ECOLOGY, DISTRIBUTION, SUCCESSION, SEED AVAILABILITY, GRASSLAND, SHRUBLANDS, BROAD-LEAVED FORESTS 4 WOODLANDS, CLOSED-CONE CONIFER FOREST. VEGETATION STRUCTURE AND COMPOSITION DETERMINED BY INTERACTION OF FIRE AND SOIL PROPERTIES. (UC BERKELEY - BIOLOGY.)
327. WELLS, P.V. 1969. THE RELATION BETWEEN MODE OF REPRODUCTION AND EXTENT OF SPECIATION IN WOODY GENERACEAE. California CHAPARRAL. EVOLUTION 23: 264-261. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG EVOLUTION, PLANTS, ECOLOGY, REGENERATION, CHAPARRAL. DISCUSSION OF EVOLUTIONARY IMPLICATIONS OF SPROUTING AND NON-SPROUTING CHAPARRAL PLANT SPECIES.
328. WESTMAN, W.E. 1975. EDAPHIC CLIMAX PATTERN OF THE PYGMY FOREST REGION OF CALIFORNIA. ECOL MONOGR 45(2): 109-125.

NOY PLANTS, SOIL, ECOLOGY, FIRE, BISHOP PINE FOREST, PYGMY CONIFER FOREST, SLOPE REDWOOD FOREST. STUDY OF PLANT-SOIL RELATIONSHIPS IN MENDOCINO PYGMY FORESTS. (UC BERKELEY - BIOLOGY.)

329. WESTMAN, W.E.; WHITTAKER, R.H. 1975. THE PYGMY FOREST REGION OF NORTHERN CALIFORNIA; STUDIES ON BIOMASS AND PRIMARY PRODUCTIVITY. J ECOL 63: 493-520. EEL, NOY PLANTS, PRODUCTIVITY, ECOLOGY, SOILS, BISHOP PINE FOREST, PYGMY CONIFER FOREST, AL LUVIAL REDWOOD FOREST, SLOPE REDWOOD FOREST. STUDY OF PRODUCTIVITY AND BIOMASS IN THREE CALIFORNIA CONIFER FOREST TYPES. (UC BERKELEY - BIOLOGY.)
330. WETZEL, R.G. 1975. LIMNOLOGY. PHILADELPHIA. W.B. SAUNDERS. 743 P. LIMNOLOGY, ALGAE, LIMITING FACTORS, BIOACCUMULATION, CRUSTACEA, DETRITUS, INSECTS, INVERTEBRATES, MOLLUSCS, NUTRIENTS, PHYTOPLANKTON, PRODUCTIVITY, PREDATION, POPULATION DYNAMICS, RESERVOIRS, SUCCESSION, WATER TEMPERATURE, ZOOPLANKTON, LACUSTRINE-PELACIAL, PALUSTRINE. FRESHWATER ECOLOGY TEXT. [UC DAVIS, MOST UNIV. LIBS.]
331. WHITTAKER, R.H. 1953. A CONSIDERATION OF CLIMAX THEORY; THE CLIMAX AS A POPULATION PATTERN. ECOL MONOGR 23(1): 41-78. SUCCESSION, ECOLOGY, PLANTS. THE DEFINITIVE THEORETICAL TREATMENT OF SUCCESSION AND CLIMAX. (UC BERKELEY - BIOLOGY.)
332. WHITTAKER, R.H. 1960. VEGETATION OF THE SISKIYOU MOUNTAINS, OREGON AND CALIFORNIA. ECOL MONOGR 30(2): 279-338. SMI, KLA, MAO, FEL, MAT PLANTS, SOIL, TOPOGRAPHY, SUCCESSION, FIRE, MIXED CHAPARRAL, SERPENTINE CHAPARRAL, MIXED EVERGREEN FOREST, CANYON LIVE OAK FOREST, NORTHERN OAK WOODLAND, KNOB CONE PINE FOREST, CYPRESS FOREST, DOUGLAS-FIR FOREST, COAST RANGE MIXED CONIFER FOREST, COAST RANGE PINE FOREST. DESCRIPTION AND ANALYSIS OF VEGETATION PATTERN, SUCCESSION, CLASSIFICATION, IN RELATION TO ENVIRONMENTAL GRADIENTS OF MOISTURE, ELEVATION, PARENT MATERIAL IN SISKIYOU MOUNTAINS. (UC BERKELEY - BIOLOGY.)
333. WICKETT, W.P. 1967. EKMAN TRANSPORT AND ZOOPLANKTON CONCENTRATIONS IN THE NORTH PACIFIC OCEAN. J FISH RES BOARD CAN 24(3): 581-594. ZOOPLANKTON, DISTRIBUTION, MARINE. (UC SANTA CRUZ, MOST UNIV. LIBS.)
334. WILLARD, D.E. 1977. THE FEEDING ECOLOGY AND BEHAVIOR OF FIVE SPECIES OF HERONS IN SOUTHEASTERN NEW JERSEY. CONDOR 79: 462-470. HERONS, CICONIFORMES, WATER BIRDS, FEEDING, BEHAVIOR. (UC BERKELEY - BIOLOGY., UCD, MOST UNIV. LIBS.)
335. WILLIAMS, J. 1979*. INTRODUCTION TO MARINE POLLUTION CONTROL. NEW YORK. JOHN WILEY & SONS. 173 P. CURRENTS-OCEAN, MIXING, ENVIRONMENTAL PLANNING, RADIOACTIVITY, THERMAL POLLUTION, OIL POLLUTION, NUTRIENTS, SEDIMENT, WATER QUALITY, PESTICIDES, LEGISLATION, PHYSICAL OCEANOGRAPHY, MARINE. (UC SANTA CRUZ.)
336. WILLIAMS, W.I. 1974. SPECIES DYNAMISM IN THE COASTAL STRAND PLANT COMMUNITY AT MORRO BAY, CALIFORNIA. BULL TORREY BOT CLUB 101(7): 83-89. 173 P. MOR PLANTS, ECOLOGY, COMMUNITIES (BIOLOGICAL), SUCCESSION, COASTAL STRAND. (UC BERKELEY - BIOLOGY.)
337. WILLIAMS, W.I.; POTTER, J.R. 1972. THE COASTAL STRAND COMMUNITY AT MORRO BAY STATE PARK, CALIFORNIA. BULL TORREY BOT CLUB 99(4): 163-171. MOR PLANTS, COMMUNITIES (BIOLOGICAL), HABITATS, COASTAL STRAND. (UC BERKELEY - BIOLOGY.)
338. WINZLER AND KELLY CONSULTING ENGINEERS, EUREKA, CA. 1977A. A SUMMARY OF KNOWLEDGE OF THE CENTRAL AND NORTHERN CALIFORNIA COASTAL ZONE AND OFFSHORE AREAS. PREPARED FOR U.S. BUREAU OF LAND MANAGEMENT. VOLUME II, BIOLOGICAL CONDITIONS, BOOKS 1 AND 2. LA 10173 P. SMI, KLA, MAO, EEL, MAT, NOY, GUA, RUS, SMI, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAR, MGR, MAR, ANT, YAZ, ARG, CEEL, OAK, UOOD, OCRZ, OMAR ANIMALS, BIRDS, BREEDING AREAS, CRUSTACEA, JUVENILE OUTLUN, ENDANGERED SPECIES, FEEDING, FOOD WEBS, HABITATS, INVERTEBRATES, MAMMALS, REPRODUCTION, MOLLUSCS, NURSERY AREAS, POPULATION DYNAMICS, PREDATION, ROOKERIES, SHORE BIRDS, SPAWNING, WATER BIRDS, WATER FOWL, ABUNDANCE, PLANTS, MARINE. (NTIS.)
339. WINZLER AND KELLY CONSULTING ENGINEERS, EUREKA, CA. 1977B. A SUMMARY OF KNOWLEDGE OF THE CENTRAL AND NORTHERN CALIFORNIA COASTAL ZONE AND OFFSHORE AREAS. PREPARED FOR U.S. BUREAU OF LAND MANAGEMENT. VOLUME III,

SOCIOECONOMIC CONDITIONS, BOOKS 1 AND 2. SMI, KLA, MAD, EEL, MAT, NGY, GUA, RUS, SMN, LAG, FRA, GRE, L (F, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG. COASTAL PLANNING, EMPLOYMENT, DEMOGRAPHY, GIL DRILLING, LAND USE. LITERATURE SURVEY AND INTERPRETATION OF EXISTING INFORMATION RELATED TO SOCIOECONOMIC AND CULTURAL CONDITIONS OF COASTAL COUNTRIES FROM VENTURA CO. TO THE OREGON BORDER.

340. WU, R.S.; LEVINGS, C.D. 1979. ENERGY FLOW AND POPULATION DYNAMICS OF THE BARNACLE BALANUS GLANDULA. MAR BICL (BERL) 54: 83-89. POPULATION DYNAMICS, BALANUS GLANDULA, BARNACLE, ARTHROPODA, CRUSTACEA, FEEDING, PRODUCTIVITY, LIFE HISTORY, MARINE-SUBTIDAL. BRITISH COLUMBIA. (UC SANTA CRUZ, MOST UNIV. LIBS.)
- 341* YELLIN, M.B.; AGEGLIAN, C.P.; PEARSE, J.S. 1977. ECOLOGICAL BENCHMARKS IN THE SANTA CRUZ COUNTY (FLP FORESTS BEFORE THE RE-ESTABLISHMENT OF SEA OTTERS. PREPARED FOR THE U.S. MARINE MAMMAL COMMISSION IN FULFILLMENT OF CONTRACT MM6AC029; REPORT NO. MMC-76/04. UCSC CENTER FOR COASTAL MARINE STUDIES TECHNICAL REPORT NO. 6. 125 P. COPEZ COMMUNITIES (BIOLOGICAL), DISTRIBUTION, ECOLOGY, INVERTEBRATES, ALGAE, MACROCYSTIS, NEREGCYSTIS, SEA URCHINS, SEA OTTERS, MARINE-SUBTIDAL-AQUATIC BED. (UC SANTA CRUZ.)
342. YOUNG, D.R.; MEARNS, A.J. 1978. POLLUTANT FLOW THROUGH FOOD WEBS. IN BASCOM, W. (ED.). COASTAL WATER RESEARCH PROJECT ANNUAL REPORT FOR THE YEAR 1978. EL SEGUNDO, CALIFORNIA. SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT. P. 1315-202. INVERTEBRATES, SEDIMENTS, WATER QUALITY, PHYSICAL OCEANOGRAPHY, FOOD WEBS, PESTICIDES, HEAVY METALS, TROPHIC LEVELS, MARINE-SUBTIDAL, BIOACCUMULATION. (UC SANTA CRUZ, MOST UNIV. LIBS.)
343. ZEDLER, J.B. 1975. SALT MARSH COMMUNITY STRUCTURE IN THE TIJUANA ESTUARY, CALIFORNIA. SAN DIEGO STATE UNIV CENTER FOR MARINE STUDIES, CONTRIB 7. 32 P. PLANTS, PRODUCTIVITY, ESTUARINE-INTERTIDAL-EMERGENT WETLAND. (UC BERKELEY - BIOLOGY.)
344. ZEDLER, J.B.; WINFIELD, T.; MAURIELLO, D. 1978. PRIMARY PRODUCTIVITY IN A SO. CALIFORNIA ESTUARY. IN SYMPOSIUM ON TECHNICAL, ENVIRONMENTAL, SOCIOECONOMIC AND REGULATORY ASPECTS OF COASTAL ZONE MANAGEMENT, SAN FRANCISCO, CALIFORNIA MARCH 14-16, 1978. COASTAL ZONE '78. NEW YORK. AM SOCIETY OF CIVIL ENGINEERS. VOL. II. P. 649-662. ALGAE, PLANTS, PRODUCTIVITY, ESTUARINE-INTERTIDAL-EMERGENT WETLAND.
345. ZINKE, P.J. 1977. THE REDWOOD FOREST AND ASSOCIATED NORTH COAST FORESTS. IN BARBOUR, M.C. (ED.); MAJOR, J. (ED.). TERRESTRIAL VEGETATION OF CALIFORNIA. NEW YORK. JOHN WILEY & SONS. P. 679-698. SYE, KLA, MAD, EEL, MAT, NGY, GUA, RUS, SMN, LAG, FRA, GRE, LOK, PAJ, ELK, SLS, CAR, MOR. PLANTS, ECOLOGY, SUCCESSION, DISTRIBUTION, SOILS, FIRE, FLOOD, MIXED CHAPARRAL, RED ALDER FOREST, COASTAL CONIFER FOREST. SURVEY OF ECOLOGY AND SUCCESSION IN COASTAL CONIFER FORESTS. (UC BERKELEY - BIOLOGY.)