FISH RESOURCES OF THE CHUKCHI SEA: STATUS OF EXISTING INFORMATION AND FIELD PROGRAM DESIGN

by

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ABSTRACT

Existing data sources describing fish resources in the Chukchi Sea are reviewed and annotated. The purpose of this review is to evaluate (rather than summarize) the status of available fisheries data in terms of the kinds of information needed to assess environmental impacts. Although a moderate amount of fisheries research has been conducted in southern regions of the Chukchi Sea, few data are available for northern regions, particularly the 'Barrow Arch Sale No. 85' oil and gas lease sale area. While it is tempting to draw upon the relatively greater data bases available for coastal regions adjacent to the 'Sale No. 85' area, there are reasons to suspect that such biological extrapolation may not be valid. These include differences in oceanography, fish populations and presumed fish use of coastal habitats. Several testable hypotheses regarding fish use of the 'Sale No. 85' area are discussed and a field research plan is formulated.

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INTRODUCTION

The forthcoming oil and gas lease sale in the northeast Chukchi Sea (Barrow Arch Sale No. 85) has prompted a review of the fisheries information currently available for this region. In recent overviews of biological resources of the northeaster Chukchi Sea, Moulton and Bowden (1981) and Morris (1981) found that marine fishes have been the subject of only a few studies, and anadromous fish are even more poorly known. Both of these reports list a variety of fisheries and habitat data gaps for this region. The present report examines the status of available literature in detail and formulates a research program to address data deficiencies. This report is not intended to serve as a resource document describing the environmental setting for Chukchi fish resources, since this would be a duplication of the existing reviews.

The specific objectives of the present study are to:

1. compile, evaluate and annotate a bibliography and analyze the state of knowledge of nearshore fish resources of the Chukchi Sea, particularly in the 'Sale No. 85' region,

2. evaluate the usefulness of fisheries data obtained in conjunction with subsistence fisheries, and

3. design a preliminary interdisciplinary research program to investigate the composition, movements and trophic relationships of nearshore anadromous and marine forage fishes.

The area covered by this study includes the Chukchi Sea with emphasis on the Alaskan coastal zone between Point Hope and Barrow (Fig. 1). In addition, Alaskan streams which flow into the Chukchi Sea have been included since they are used by anadromous fishes, and some streams play an important role in local fisheries.

Background Information

Although fisheries data are limited for the Chukchi Sea in general, and the lease sale area in particular, the available information has been recently summarized by Morris (1981), Moulton and Bowden (1981) and Bowden and Moulton (1981). The following brief introduction to the fish resources of the northeastern Chukchi Sea is from Morris (1981],

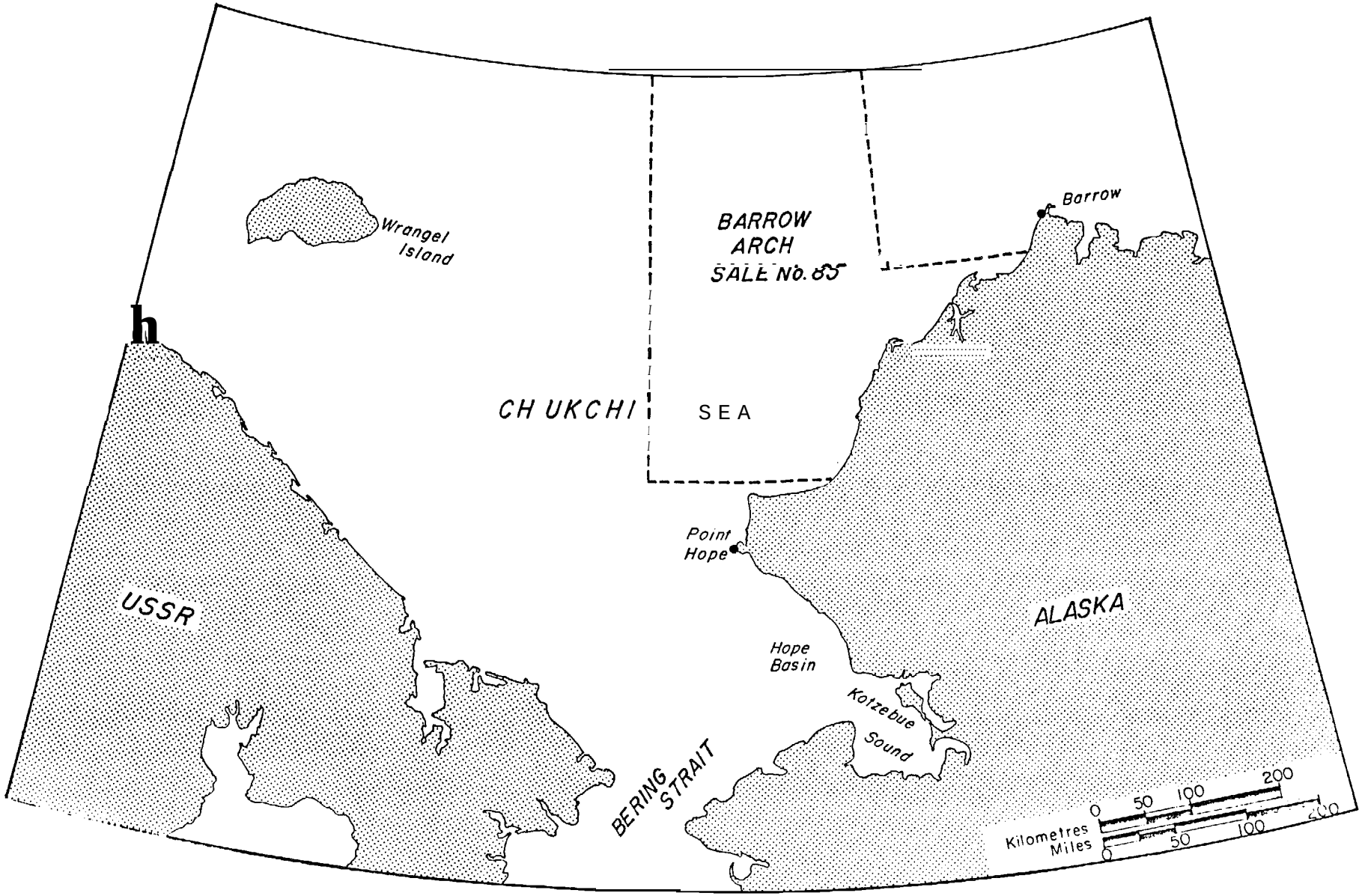


Figure 1. Location of the 'Barrow Arch Sale No. 85' area in relation to the primary study area between Barrow and Point Hope.

In terms of both species diversity and abundance, the fish fauna of the Chukchi Sea is sparse compared to that in the Bering Sea but greater than that in the Beaufort Sea. Based on limited sampling, the species composition in the Chukchi Sea consists of 41 marine species and 13 anadromous species. Abundant marine species are arctic cod, starry flounder, Pacific halibut, saffron cod, Pacific herring, capelin and sculpins. The majority of the marine fish fauna are demersal as adults; relatively few marine species are pelagic (arctic cod, Pacific herring, smelt, capelin and sand lance). Many of the marine fish in the Chukchi are believed to maintain their populations by recruitment of eggs and larvae transported north from the Bering Sea (Pruter and Alverson 1962). Fish that probably maintain their populations by resident breeding stocks include arctic and saffron cod, sand lance, capelin and some flounders (Walters 1955). Marine fishes are important prey of marine mammals and seabirds along the Chukchi coast.

Important anadromous species include pink and chum salmon, arctic char, ciscoes, whitefishes and smelt. Small runs of salmon occur in the larger rivers along the northeast coast: Kugrua, Utukok, Kokolik, Kukpowruk, and Pitmegea rivers. Sockeye and king salmon are also caught in coastal waters but they reach their northern spawning limit at Cape Lisburne. Larger runs of salmon occur in rivers along the southeast coast, especially near Kotzebue. There are no commercial fisheries for salmon north of Kotzebue Sound. Available data indicate that population densities of commercially valuable fish resources in the northeastern Chukchi Sea are low, but subsistence fishing, especially for salmon, whitefish and smelt, is important to some residents of villages along the coastline.

METHODS

It was recognized at the outset of this study that few fisheries studies had been conducted in the northeastern Chukchi Sea, and the data base for the 'Sale No. 85' region would likely be limited. Thus, our search for information was broadened to include the entire Chukchi Sea. Most information was obtained through a standard literature search as described below. In addition, we conducted interviews with agency personnel and subsistence users in the study area to insure that potential data sources were not overlooked.

Literature Search

Efforts were made to collect all pertinent information, including published reports, unpublished government file data and subsistence information. Foreign sources (Russian and Japanese) were also reviewed. Initial efforts to locate information began at the University of Alaska, Fairbanks, with a computer search of three data files maintained by Dialog Information Services, Inc. These were:

1. aquatic sciences and fisheries abstracts (1978, the starting date, to November 1981),
2. BIOSIS previews (1969 to November 1981), and
3. aquiculture (1970 to November 1981).

Russian translations of the key words used in these searches were included.

To insure coverage of unpublished information and reports with limited circulation, libraries at the North Slope Borough (Barrow), University?' of Alaska (Fairbanks), Arctic Project Office NOAA/OCSEAP (Fairbanks), Arctic Environmental Information and Data Center (Anchorage), University of Washington (Seattle), and National Marine Fisheries Service (Seattle) were searched.

The individuals contacted during the course of this study are listed in the Acknowledgments.

All sources of data gathered during this study were evaluated and pertinent information annotated and included in Appendix 1. We wish to emphasize that only information describing Chukchi fishes was annotated. Pertinent reports that were not obtained in time to be annotated are also listed in Appendix 1.

Subsistence Survey

Because information about subsistence fishing can often be obtained only by discussions with the fishermen themselves, we visited the coastal villages of Point Hope, Point Lay, Wainwright and Barrow during 19-29 March 1982. A primary objective was to gain insight about winter fish distributations through location and timing of the subsistence fishery and to document the extent of winter fishing. Where possible, fish samples were purchased to confirm species identification, and retained for future life history analyses.

RESULTS

The following material examines the status of available fisheries information. This includes an identification of data sources and an evaluation of the scope of the available data base which was annotated in Appendix 1. Available information was evaluated in relation to four basic questions.

1. To what extent does the total data base provide geographical coverage of the study area?
2. Have fish populations and their habitat uses been examined over an annual cycle?
3. Is the biology of important fish species reasonably well known?
4. Are subsistence fisheries adequately documented?

Status of Information

Data Sources

Research funded by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) has provided the majority of information for the eastern Chukchi Sea (Barton 1977; Spring and Roseneau 1977, 1978; Feder and Jewett 1978; Wolotira *et* aZ. 1979; Jewett 1981). However, while it is true that these reports are a substantial source of information, there are few studies whose primary purpose was collecting fishery data in the area from Point Hope *to* Point Barrow. Many of the above reports provide fishery data which were gathered incidentally or in conjunction with studies of marine mammals, birds or invertebrates. Barton (1977) and Wolotira *et CZZ.* (1979) describe fisheries investigations south of the area of interest.

Fisheries libraries at the University of Washington (Seattle) and National Marine Fisheries Service (Seattle) are outstanding sources of information, but they did not contain any additional information on the Chukchi Sea in general or the area covered by the 'Barrow Arch Sale No. 85' than was available from the University of Alaska library.

The Alaska Department of Fish and Game (ADF&G) has performed many studies in the Chukchi Sea, most of which deal with commercially valuable species in the area from Bering Strait to Point Hope (Geiger 1966; Winslow 1969; Lebida 1970; Hurd 1971; Yanagawa 1971; Alt 1971, 1973, 1979; Bendock

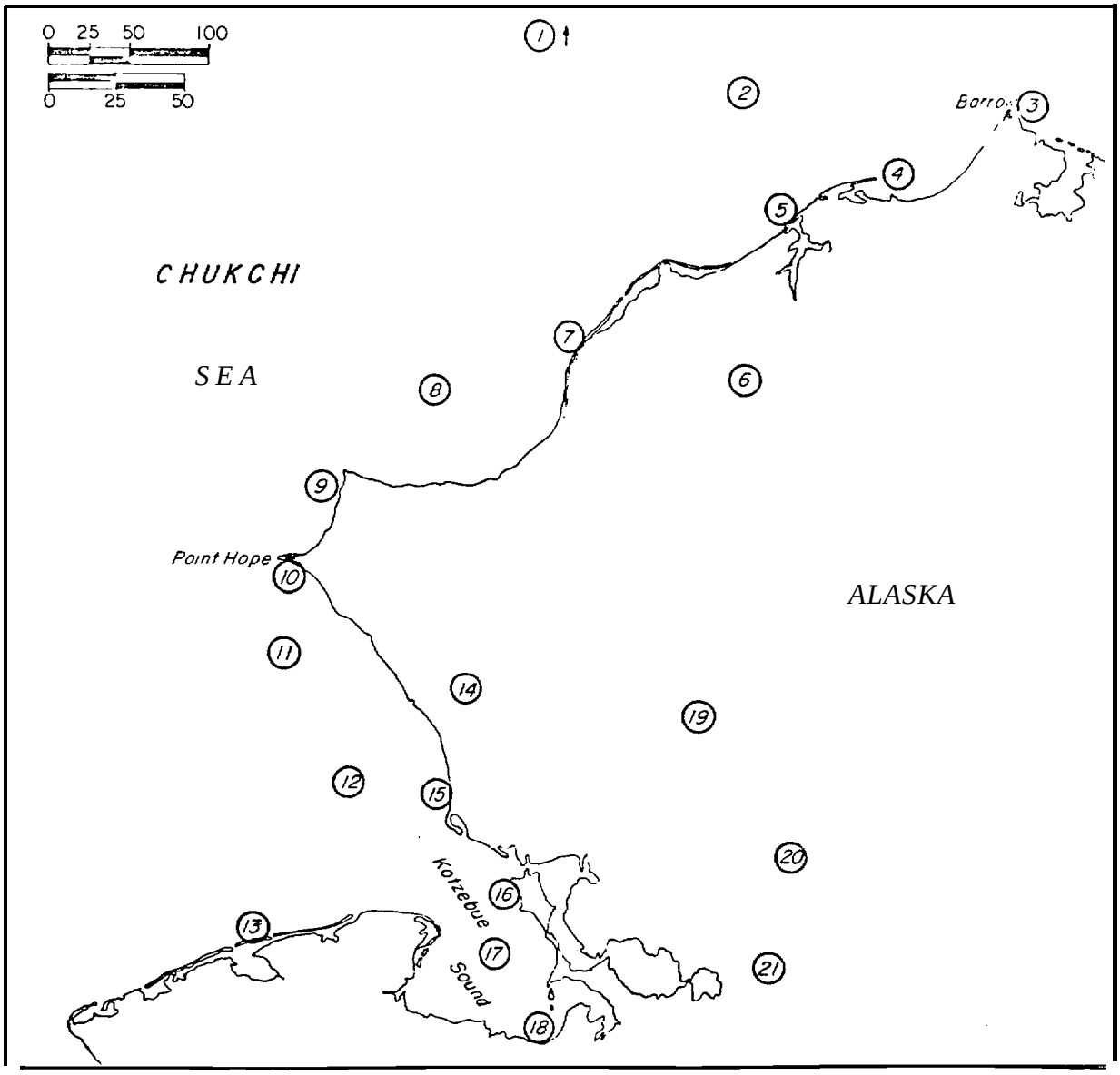
1979; Bendock and Burr 1980). Results of these studies are obtainable from ADF&G offices. These reports are often presented as annual progress reports of field work.

An important objective of the computer literature search was to locate Soviet and Japanese literature. It had been suggested that a substantial amount of information about fishes of the Chukchi Sea was available from these sources. However, it was found that Soviet literature pertaining to the study area is not abundant and what does exist is frequently 25-50 years old. Soviet literature is further limited because of its generalities. For example, older papers frequently discuss fish life histories using common non-specific names such as "cod" (which may be an artifact of translation from the Russian to English language) so that the particular species being referred to is not known (e.g., Moiseev 1953)*. The main value of the Russian literature is that it provides comparisons of life-history information for species common to both sides of the Chukchi Sea (e.g., Andriyashev 1954); for the most part, these reports are not included in Appendix 1. Pertinent Japanese information also appears to be limited. Only two reports describing cruises of Japanese research vessels in the Chukchi Sea were identified but not received in time for inclusion in this report (FFHU 1967, 1968).

Geographic Coverage

An initial view of geographic locations where studies have been conducted suggests a rather broad coverage for the eastern Chukchi Sea (Fig. 2). However, the impression is deceptive because of the limited fisheries content of many studies, particularly those in the region of the 'Barrow Arch Sale No. 85'. Without question, the region south of Point Hope has received the most study. A summary of the regional data coverage is as follows:

* Moiseev, P. 1953. Cod and flounders of far eastern waters. Fish. Res. Board Can., Translation Ser. No. 119.



1 Walters 1961 (winter fish 400 km NW Barrow)

2 Frost et al. 1978; Frost & Lowry 1981; Lowry & Frost 1981: Frost 1981 (offshore cod)

3 Murdoch 1884, 1885 MacGinitie 1955; Willmovsky 1956; Pedersen et al. 1979; Skvorc 1982 (subsistence general) Cohen 1954; Wohlschlag 1956 (whitefish ecol.) McPhail 1966 (cisco taxonomy)

4 Mohr et al, 1957 (kelp bed fishes)

5 Ivle & Schneider 1979 (subsistence) Craig & Schmidt 1982 (survey, subsistence)

6 Bendock 1979; Hablett 1979 (stream & lake survey) Bendock & Burr 1980

7 Schneider & Bennett 1979 (subsistence Craig & Schmidt 1982 (survey, subsistence)

8 Quast 1972, 1974 (offshore survey)

9 Swartz 1966; Springer & Roseneau 1978, 1979, Springer et al 1982 (seabird diets)

10 Pedersen 1979 Skvorc 1982 (subsistence) Lowry et al. 1980 (seal dieta) Seaman & Burns 1960 (belukha diets)

11 Pruter & Alverson 1962 (flounder ecology) Alverson & Willmovsky 1966 (marine fish)

12 Pereyra et al. 1977; Wolotira et al. 1979 (marine fish) Feder & Jewett 1978; Jewett & Feder 1980 (flounder ecology)

13 Raleigh 1958; Mattson 1962 (salmon)

14 Saarlo & Kessel 1966 (subsistence) Winslow 1969; Roguski & Winslow 1970; Alt 1978 (salmon)

15 Smith et al. 1966 (salmon)

16 Craig & Haldorson 1981 (saffron cod, subsis.) Geiger 1966 (salmon)

17 Labida 1970; Hurd 1971 Yanagawa 1971; Barton 1977 (salmon, whitefish)

16 Cunningham 1976 (salmon)

19 AEIDC 1975a (inventory)

20 Alt 1971, 1973, 1979 (whitefish, subsistence)

21 AEIDC 1975b (Inventory)

Figure 2. Approximate locations of fisheries-related studies conducted in the eastern Chukchi Sea.

Zone	Fish species	Relative fisheries coverage: south of Pt. Hope	Relative fisheries coverage: North of Pt. Hope
Offshore	marine	high	low
Coastal	anadromous, marine	high	low
Inland	anadromous	moderate	low

Salmon and offshore fishes south of Point Hope in Kotzebue Sound have been the subject of several sizable research programs: Project Chariot near Cape Thompson (Pruter and Alverson 1962; Alverson and Wilmovsky 1.966; Smith *et al.* 1966), ADF&G (Lebida 1970; Hurd 1971; Yanagawa 1971; Alt 1971, 1973, 1979; Cunningham 1976) and OCSEAP (Barton 1977; Pereyra *et al.* 1977; Feder and Jewett 1978; Springer and Roseneau 1978, 1979; Wolotira *et al.* 1979; Jewett and Feder 1980; Springer *et* aZ. 1982). Additional information has been gathered by USF&W (Raleigh 1957; Mattson 1962) and AEIDC (1975a, b). These studies provide considerable background information for both offshore and coastal fish populations and, because of interest in the commercial salmon fisheries, the major rivers have been surveyed from Cape Prince of Wales to Point Hope.

Fisheries data north of Point Hope are sparse. The data base for offshore waters is limited to trawl surveys in Ledyard Bay (Alverson and Wilmovsky 1966; Quast 1972, 1974) and near Barrow (Frost *et* aZ. 1978). Coastal information consists of species caught at Wainwright and Point Lay (Craig and Schmidt 1982) and in a kelp bed at Peard Bay (Mohr 1957). Similarly, information on anadromous fishes in rivers flowing into the northern Chukchi Sea is limited to brief surveys (Hablett 1979; Bendock 1979: Bendock and Burr 1980). Incidental fisheries data are available for the Barrow region (Murdoch 1884, 1885; Cohen 1954; MacGinitie 1955; Wohlschlag 1956; McPhail 1966) and an under-ice location 400 km northwest of Barrow (Walters 1961). Additional information can be derived from papers describing subsistence fishing patterns at coastal villages (Wilmovsky 1956; Ivie and Schneider 1979; Schneider and Bennett 1979; Pedersen 1979; Pedersen *et aZ.* 1979) and the feeding habits of seabirds at Cape Lisburne (Schwartz 1966; Springer and Roseneau 1978, 1979; Springer *et* aZ. 1982).

Seasonal Coverage

Virtually all fisheries data available for the Chukchi Sea have been gathered during the open-water season. The exceptions arc winter data collected in 1959-1960 at a floating ice station located 400 km northwest of Barrow (Walters 1961) and a pot pourri of information about subsistence fishing, including some winter information (Murdoch 1884, 1885; Wilimovsky 1956; Saario and Kessel 1966; Ivie and Schneider 1979; Schneider and Bennett 1979; Craig and Haldorson 1981; Craig and Schmidt 1982).

Biological Information

Because of the greater sampling effort in the southeast Chukchi Sea, there is a useful body of information describing the fish fauna of this region. Studies in offshore waters (e.g., Alverson and Wilimovsky 1966; Wolotira *et al.* 1979) and an interest in salmon and whitefish resources in Kotzebue Sound have provided some basic information regarding species composition, distribution, abundance and life history characteristics.

In contrast, the northeast region of the Chukchi Sea has received relatively little study and, consequent}', a potential understanding of fish communities in this area is largely based on extrapolation of data gathered elsewhere, principally from Kotzebue Sound, Beaufort Sea and Russian arctic waters (e.g., Andriyashev 1954).

The status of biological information for anadromous and marine fishes specifically in the 'Barrow Arch Sale No. 85' region has recently been reviewed by Morris (1981). We concur with his evaluation of the existing data base which follows in summary form (not a direct quotation):

1. Anadromous Fish. Knowledge of the anadromous fish resource is poor. Among the 13 anadromous species reported in these waters are arctic char, whitefish, ciscoes and salmon. The coastal distribution and abundance of these species between Point Hope and Barrow is largely undefined, and little is known of the location of their spawning areas in rivers along the northeast Chukchi coast.
2. Marine Fish. The marine fishes of the northeastern Chukchi Sea have received little attention in the past. From data provided by limited trawl surveys, the number of marine fishes reported for the Chukchi Sea is 41 species, but very little is known about the life history, population dynamics, or ecological relationships of most of these species. Even information about the relative abundance of marine fishes is derived mainly from south of Point

Hope. Little is known about forage species (arctic cod, sand lance, capelin, herring) which are important prey of marine mammals and seabirds in this area.

Subsistence Information

Subsistence fishing has been an important activity to the people living in villages along the Chukchi coastline. Some historical information describing past fishing practices is available (e. g., Murdoch 1884; Wilimovsky 1956), and more recent reports provide an adequate basis for understanding the general use of fish resources at each coastal village (Saario and Kessel 1976; Pedersen 1979; Pedersen *et al.* 1979; Schneider and Bennett 1979; Craig and Schmidt 1982; Skvorc 1982). Within the northern portion of the study area, it appears that residents of Wainwright and Point Hope are presently most active in subsistence fishing. Subsistence patterns are changing as villagers adopt a cash-based economy (Skvorc 1982); however, quantitative information regarding fish harvests is lacking. Consequently such changes, or changes resulting from future developments in *the* 'Sale No. 85' area, cannot be precisely determined.

Summary

Although a moderate amount of fisheries research has been conducted in the Chukchi Sea, it is apparent that most attention to date has been directed towards fishes in Hope Basin and Kotzebue Sound. Little information exists for the 520 km coastal region north of Point Hope and, consequently, little is known about marine or anadromous fish distribution, habitat dependencies, life histories or trophic interactions with other organisms in the 'Sale No. 85' area. Fish are known, however, to occupy an important position in foodwebs of this region. Marine fish are a vital component in the diets of many marine mammals and seabirds. Marine and anadromous fish are important to residents of the area since they are harvested in subsistence fisheries at or adjacent to several coastal villages.

The present situation is in direct contrast *to* that existing at the time of oil and gas lease sales in the Beaufort Sea. A feature common to both Chukchi and Beaufort lease areas is that very little was known about coastal resources or sensitivities prior to interest in offshore exploration. However, by the time the Beaufort Sea Joint State/Federal lease sale occurred

(December 1979), over four years of biological research had been conducted. Studies included both broad-scale surveys of marine organisms and an extensive process-oriented research program in coastal waters adjacent to the lease area. Consequently, the numerous scientists, agency personnel and industry representatives involved in Beaufort Sea studies were able to convene their first interdisciplinary workshop two years prior to the lease sale in order to:

1. provide a synthesis of existing knowledge about the Beaufort Sea as it related to the proposed leasing of the outer continental shelf,
2. assess likely impacts of petroleum developments, and
3. review the adequacy of on-going projects.

In addition, subsequent field research programs provided the basis for additional synthesis meetings and a re-evaluation of Federal/State Lease Sale Stipulations prior to the lease sale.

It is already too late to meet an equivalent timetable for environmental input into the Chukchi Sea 'Sale No. 85', since it is scheduled for January 1985. A substantial research effort is needed immediately to provide the fundamentals of biological understanding which scientists had already processed at the time of the first Beaufort Sea synthesis.

FIELD PROGRAM DESIGN

Rationale for New Studies

Recent reviews of fish resources in the northeast Chukchi Sea indicate that anadromous species play an important role in subsistence fisheries of several coastal communities and that marine species are an integral component of marine food webs in this region (Bowden and Moulton 1981; Morris 1981; Moulton and Bowden 1981). Despite this trophic linkage, it is apparent from the first section of this report that very few data describing fish resources in the study area currently exist. It is, therefore, tempting to draw upon the relatively greater data bases available for coastal regions adjacent to the study area. As previously described, knowledge of Chukchi Sea fish resources south of Point Hope is considerably better than for north of Point Hope. Similarly, years of fisheries research in the Beaufort Sea near Prudhoe Bay have produced a reasonable level of insight into fish use of coastal waters. While some cautious extrapolation of information from one area to another is not unreasonable, there are reasons to suggest that such extrapolation should not extend beyond the stage of establishing preliminary hypotheses to test with field studies in the study area. Several lines of reasoning, which point to the distinctiveness of the northeast Chukchi Sea, are discussed below.

Distinctiveness of the NE Chukchi Sea

While the coastal environment of the NE Chukchi Sea shares many physical and biological characteristics with both the SE Chukchi and Beaufort seas, there are also notable dissimilarities in oceanography, fish populations and presumed fish use of coastal habitats.

Comparisons with SE Chukchi Sea

The biological productivity of the SE Chukchi Sea, and the rivers which flow into it, appears to be considerably greater than *that of* the NE Chukchi Sea. For example, there are much larger runs of anadromous fish in the rivers to the south. Many thousands of pink and chum salmon from the Noatak and Kobuk rivers and arctic char from the Wulik and Kivilina rivers enter coastal waters and support extensive subsistence harvests and a commercial

fishery. The Noatak and Kobuk rivers are, in fact, the most northerly streams supporting major salmon runs. It has been hypothesized that water temperatures in more northern streams are prohibitively cold for the freshwater stages of some salmon species (Salonius 1973).

Two hydrologic features contribute to the apparent productivity of the SE Chukchi Sea. First, the water mass is more directly influenced by the relatively warm marine waters which flow northward from the Bering Sea. Pruter and Alverson (1962) have suggested that stocks of some marine species in the southern Chukchi Sea are maintained by recruitment from the Bering Sea. Second, there is a large freshwater input from several rivers flowing into Hope Basin and Kotzebue Sound. Consequently, the SE Chukchi Sea, particularly Kotzebue Sound, is warmer (Fig. 3), less saline and perhaps less nutrient limited than waters north of Point Hope.

Comparisons with the Beaufort Sea

There are fundamental oceanographic differences between the Chukchi and Beaufort seas. They differ in depth, productivity, circulation patterns and source of water. The Chukchi Sea is a relatively shallow basin which is heavily influenced by the northward flow of warm waters from the Bering Sea. In comparison, the Beaufort Sea is deeper and its coastal waters are part of the colder, westward-flowing Beaufort Sea gyre in the Arctic Ocean. The progressive cooling of waters from south to north is illustrated in Figure 3.

Such basic differences between these two water masses are reflected in their fish communities. The Chukchi Sea supports a more diverse fish fauna which includes salmon and forage species such as arctic and saffron cod, sand lance and herring which occur in vast numbers. These fish in turn support large populations of fish-eating seabirds and marine mammals, several coastal subsistence fisheries, and a commercial fishery in southern waters. On all of these accounts, there are smaller harvests of fish populations in the Beaufort Sea.

Fish use of coastal habitats in the two seas may likewise be very different. In Beaufort Sea coastal waters, studies have shown that the distribution of important anadromous species (char, ciscoes, whitefishes) is associated with a narrow band of relatively warm and brackish water which

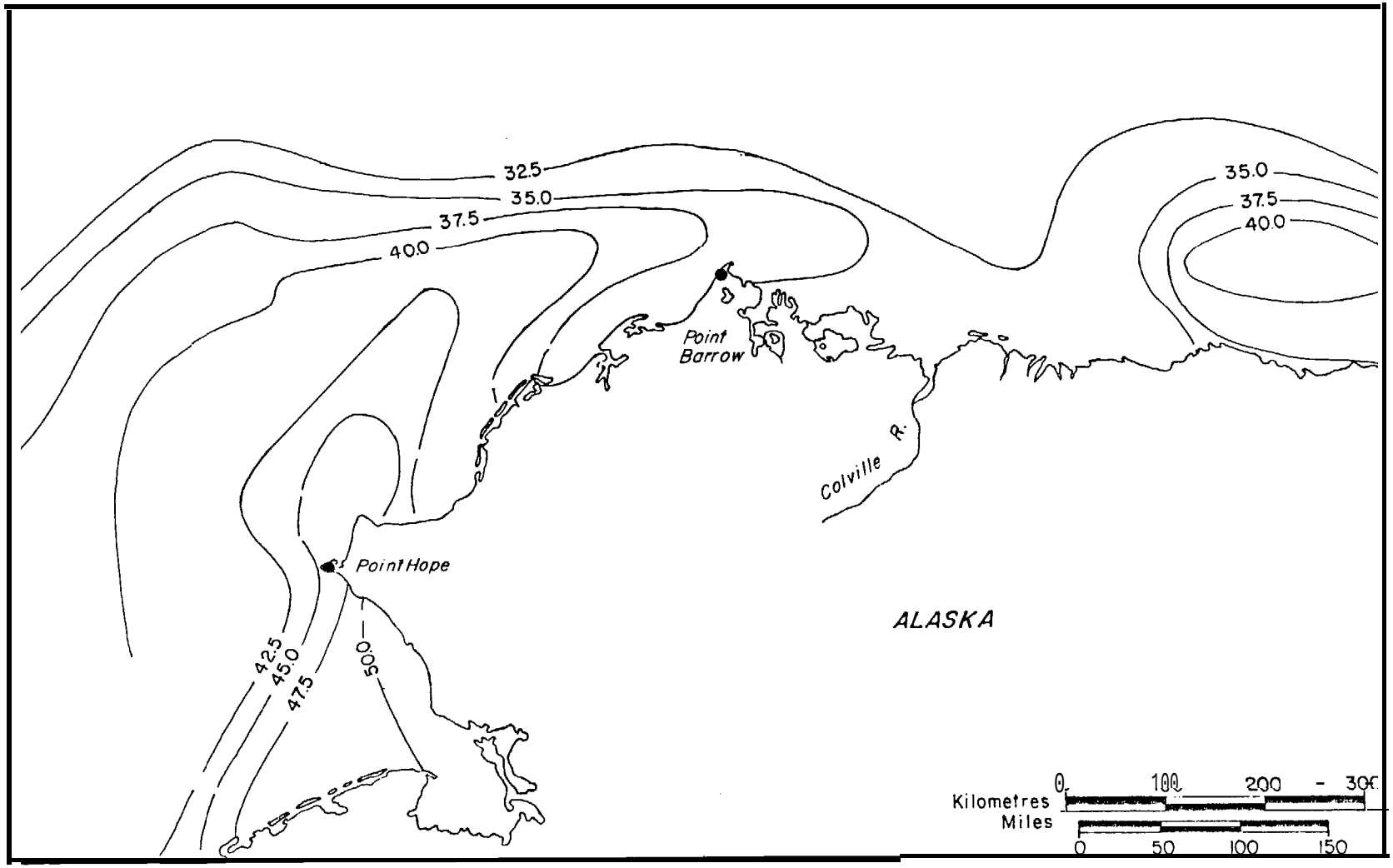


Figure 3. Average surface temperatures ("Fin August) for the Chukchi and Beaufort seas. Source: U.S. Navy Hydrographic Office, 1958 (reprint 1968); Oceanographic Atlas of the Polar Seas. Part II Arctic.

flows along the coast with prevailing westward currents. The width of this band of water is usually 1-4 km depending on coastal features such as barrier islands and freshwater plumes of the larger North Slope rivers. In comparison to offshore ocean waters of the Beaufort Sea, the nearshore waters are warm, periodically attaining temperatures up to 10 to 12°C as compared to levels generally well below 5°C in offshore waters. Recent OCSEAP research indicates that there are physiological advantages, and probably requirements, for anadromous species to remain in these nearshore waters (Fechhelm *et aZ.* 1982)*.

The situation in the Chukchi may not be analogous to that in the Beaufort. Based on very limited data, there does not appear to be a similar, characteristic band of warmer and brackish water along the northeast Chukchi coastline. This may be due to a combination of meteorological, hydrological and topographical features. Surface waters of the Chukchi Sea are warmer than in the Beaufort Sea due to the northward-moving current of warmer water from southern regions. At the same time, nearshore currents or the discharge of fresh water from streams along the northeast coast may be inadequate to establish a narrow and significantly distinct body of even warmer and brackish water along the shoreline, except in enclosed areas such as Wainwright Inlet or Kasegaluk Lagoon (Fig. 4). Consequently, we might predict one of *two* very different patterns of fish distribution and habitat use in the 'Sale No. 85' area.

1. Anadromous fish may range farther offshore (as occurs with salmon) since temperature and/or salinity gradients between nearshore and offshore waters are not great. It has already been hypothesizes that arctic char may range offshore in the Chukchi Sea (Alt, pers. comm. 1981, cited in Bowden and Moulton 1981).
2. Anadromous fish may congregate in the few protected coastal areas where coastal waters are warmest and brackish (i.e., Wainwright Inlet and Kasegaluk Lagoon).

Distinguishing between these two hypotheses is essential because each leads to a very different concept of the sensitivities of coastal habitats in the northeast Chukchi Sea.

*Fechhelm, R., W. Neill and B. Gallaway. 1982. Temperature preference of arctic cisco, *Coregonus autumnalis*. Rep. by LGL Ecological Research Associates (Bryan, Texas) for BLM/NOAA/OCSEAP, Arctic Project Office.

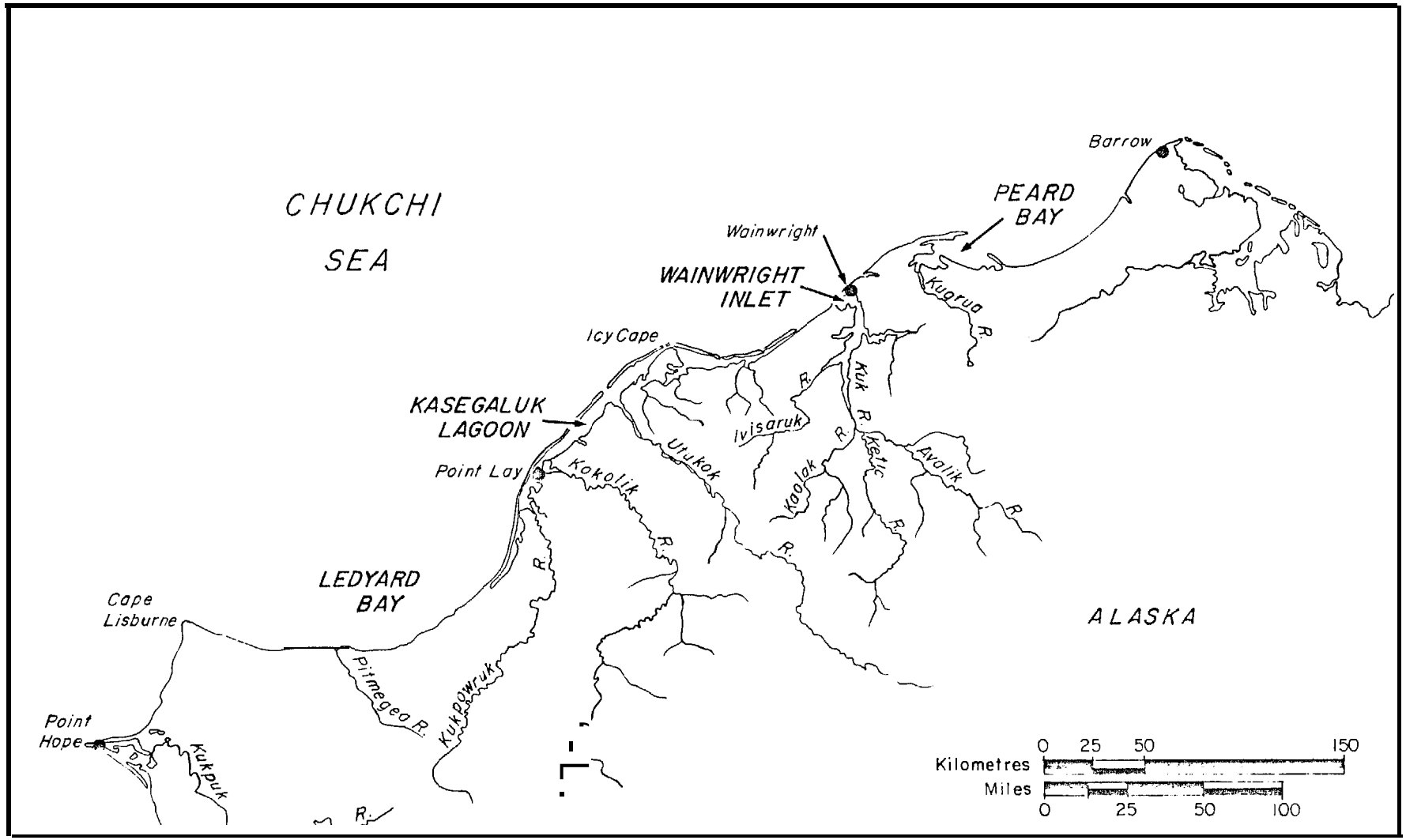


Figure 4. Major coastal features of the northeast Chukchi coast.

Other Distinctive Features

Kasegaluk Lagoon is a prominent feature of the study area that is unparalleled in size by the smaller lagoons along the Beaufort Sea coast. Kasegaluk Lagoon is a long and shallow body of water which extends along 180 km (110 mi) of coastline, forming an enclosed estuarine habitat. As previously described, the brackish waters of this lagoon may provide an important feeding area for anadromous and marine fishes. The lagoon is also an important subsistence hunting area for belukha.

Two sites of marine upwelling in the 'Sale No. 85' area may also affect aquatic productivity and distribution of fish. Morris (1981) states that a weak but apparently persistent anticyclonic gyre occurs northeast of Cape Lisburne, resulting in local upwelling and an increase in biological productivity in this area. Another anticyclonic eddy reportedly occurs near Peard Bay where Mohr *et al.* (1957) found the unusual occurrence of a kelp community on a rocky substrate.

Finally, results of the literature and information analyses suggest that the rivers which flow into the northeast Chukchi Sea appear to be less, not more, productive than Beaufort Sea drainages. Anadromous and resident freshwater fish in streams of the study area are extremely sparse in both species and numbers of fish. An ecological explanation for the paucity of anadromous fishes will be an important objective of this fisheries study. Population sizes of North Slope (Beaufort) fishes are considered to be limited by the extent of available overwintering habitat, not by food. This finding has had important ramifications for the oil industry, as regulatory agencies have consistently required protection of overwintering stream habitats. Possibly, the extent of overwintering areas along the Chukchi Sea coast is even more severely limiting to anadromous fish populations than in the Beaufort, as has been hypothesized by state fisheries biologists. Should this be the case, the apparently abundant anadromous fish in coastal waters of the northeast Chukchi Sea (compared *to* the Beaufort Sea) may well be a result of northward immigration of fishes originating from streams draining into the southern Chukchi Sea.

Agency Recommendations

Responses of state and federal regulatory agencies to the need for baseline information for the lease sale area have been direct. The Alaska Department of Fish and Game identified the following issues requiring additional information (Moulton and Bowden 1981):

> "Knowledge of the offshore and coastal circulation patterns in the Chukchi Basin is presently inadequate to develop an oil spill trajectory model for all seasons. Similarly, aside from a few critical habitats, there is a paucity of data relating to shoreline sensitivity. These issues should be addressed prior to the lease sale . . . . The importance of the nearshore region, Kasegaluk Lagoon in particular, to anadromous fish should be investigated prior to leasing; there is a significant lack of information on this species group."

Study recommendations from the National Marine Fisheries Service are similar. The fisheries portion of their list is as follows (Morris 1981):

> "3. Prior to the exploration phase, *studies* should be conducted and completed in sufficient detail to provide information on the following subjects:
>
> (b) The location of *critical habitats* and the key ecological parameters that characterize these habitats in the northeast Chukchi Sea for:
>
> 4. Winter under-ice habitat utilization by fish and invertebrates, especially in relation to the life history of key prey species such as Arctic cod, saffron cod, and shrimp.
>
> 5. Locations of concentration areas and movements of anadromous fish along the coast, in bays, lagoons, and river mouths, in both summer and winter seasons.
>
> (d) Offshore demersal *fish and shellfish* resource *surveys* similar to NMFS surveys conducted in Hope Basin should extend northward to improve on the very inadequate resource information that presently exists for the northeast Chukchi Sea."

Study Plan

The following material describes a basic research program to examine fish resources in the northeast Chukchi Sea prior to the scheduled 'Barrow Arch Sale No. 85' in January 1985. The initial phase of an intensive two-year fisheries study is outlined. It is anticipated that the results obtained during the first summer and winter will determine the objectives of further work.

Objectives

The objectives of the fisheries investigations are to:

1. assess fish population dynamics during open-water and winter periods, habitat dependencies and trophic relationships in the northeast Chukchi Sea.. Emphasis shall be placed upon subsistence-harvested and tropically important forage fishes in the coastal region between Point Hope and Barrow,
2. compare patterns of fish habitat use in the northern Chukchi Sea with those occurring in nearshore and offshore regions of the Beaufort Sea and southern Chukchi Sea,
3. analyze the degree to which physical and biological parameters are limiting determinants of the northern Chukchi Sea ichthyofauna, and
4. estimate harvest of subsistence-caught fish.

Methods

Approach

The general approach of first year studies should combine elements of both survey- and hypothesis-oriented studies. Some survey efforts are desirable because fish resources of the study area are so poorly known. In areas where fish resources are better known, research can progress to the stage where important hypotheses are generated and tested with field studies. Clearly the hypothesis-oriented approach is preferred, but to be productive it requires that there is already a basic understanding of the resources in the area to be examined. We are not yet at that point in the Chukchi program.

For the first year in the Chukchi program, we do not recommend sampling the entire coastline at frequent intervals since an inventory approach frequently results in little more than species distribution maps. Nor do we recommend concentrating all efforts at one location because we would not know whether these findings are applicable to different coastal areas. Rather, it seems prudent to sample several of the considerably different habitat types which occur along the northeastern Chukchi coastline, and at each of these sites conduct studies sufficiently intensive to allow general comparisons of habit use by fishes in the various segments of the Chukchi coastline. Results from the first year of study would also provide some

evidence to support or reject several of the hypotheses about fish use of the Chukchi Sea previously alluded to in this report . These include:

1. Fish use of nearshore and offshore waters in the Chukchi Sea is not analogous to that occurring in the Beaufort Sea; anadromous fish range farther offshore in the Chukchi Sea.
2. Kasegaluk Lagoon and Wainwright Inlet are of exceptional importance to anadromous fish.
3. The standing crop of fish food items (principally epibenthic invertebrates) is low in Kasegaluk Lagoon and Wainwright Inlet due to a limited water exchange with offshore marine waters.

Additional hypotheses for subsequent research are:

4. Subsistence-caught fish at villages within the study area are largely derived from streams south of Point Hope.
5. The low productivity of stream draining into the northeast Chukchi Sea is due to the limited availability of overwintering sites.
6. The productivity of ichthyofauna in the Chukchi Sea depends directly on the immigration of fish eggs, larvae and juveniles from the Bering Sea.

Study Area

The study area is the eastern Chukchi Sea with particular reference to the northern region between Point Hope and Point Barrow. This region appears to be a geographically distinct entity and it encompasses the 'Barrow Arch Sale No. 85' area (Fig. 1). The proposed area is defined as north of 69°N latitude, and south and west of a line that starts at a point where 71°N latitude intersects the coastline west of Barrow, thence west to 162°W longitude, thence north; the western boundary is at about 169°W at the U.S.-U.S.S.R. 1967 Convention Line (Morris 1981). This area encompasses approximately 28 million acres.

During the first year of study, emphasis should be directed towards the nearshore zone for several reasons. Subsistence fisheries are located in nearshore waters, and migratory pathways and feeding areas of important anadromous species are presumed to be located primarily in the nearshore zone. Also, it is likely that the petroleum industry will be technologically restricted to the nearshore zone during initial phases of exploration and development. The nearshore zone is broadly defined as coastal areas extending from the lower reaches of rivers to several miles offshore. This would

include the variety of aquatic habitats known to be important to anadromous fish species for various life functions (e.g., feeding, overwintering) during different stages of their life cycle.

Although the northeastern Chukchi coastline is long (550 km, 340mi) and varied, the study area can be divided into four coastal components, each of which may be characterized by distinctive patterns of fish usage. The four areas are:

Peard Bay
Wainwright Inlet
Kasegaluk Lagoon
Ledyard Bay

By coincidence, these locations are distributed evenly across the study area, thus providing some measure of geographic representation (Fig. 3).

Peard Bay is located in the northeast sector of the study area near Barrow where the Chukchi and Beaufort water masses mix. The general area includes an exposed coastline as well as Peard Bay proper which is a large body of water protected from direct ocean exposure by Point Franklin. As previously mentioned, upwelling of marine water may occur in this area, and the unusual occurrence of a kelp community on a rocky substrate has been reported. The region may, therefore, harbor (1) a presumed increase in biological productivity associated with coastal upwelling and a community of fishes associated with the kelp habitat, and (2) an assemblage of fishes associated with the northernmost extension of Chukchi waters and the mixture of these waters with the Beaufort Sea.

Wainwright Inlet is a large, inland body of brackish water utilized by anadromous fishes year-round. It is a summer feeding area and migratory pathway for a variety of species during the open-water season, and in winter it supports an important and well-known subsistence fishery for boreal smelt.

Kasegaluk Lagoon has been identified as a unique feature of the study area. This long and enclosed body of brackish water is distinctly different from adjacent aquatic habitats, and it may provide an important feeding area for anadromous and marine fishes.

Ledyard Bay forms the southern portion of the primary study area. Available biological evidence for the importance of Ledyard Bay is primarily related to the heavy use of the area by fish-eating seabirds and marine mammals. This in turn provides indirect evidence for the existence of large

populations of forage fish. The physical processes that contribute to the biological productivity of Ledyard Bay are probably related to the northward movement of the Alaska coastal water mass, a body of water that moves north from the Bering Sea and promotes a large clockwise gyre in Ledyard Bay. The resultant upwelling is presumably a factor contributing to the productivity of the area.

Key Species

Field studies will focus on fish species which are harvested in local subsistence fisheries or are tropically important forage fish in this region. At present, six anadromous fish species or species groups and four marine species fall within these categories:

Fish	Subsistence harvest	Important forage fish
Anadromous species		
Chum salmon	x	
Pink salmon	x	
Arctic char	x	
Whitefishes	x	
Ciscoes	x	
Boreal smelt	x	
Marine species		
Arctic cod	x	x
Saffron cod	x	x
Pacific herring		x
Sand lance		x

This list will likely be refined after field studies document the relative abundance and harvest of these species.

Data Collection

Fish will be sampled during open-water *and winter periods in* each of four regions: Peard Bay, Wainwright Inlet, Kasegaluk Lagoon and Ledyard Bay. In each region, the primary objective will be to determine fish utilization of major habitat types (exposed coast, bay, lagoon, offshore, etc.). The sampling design will facilitate comparisons of fish use (1) among habitat

types within -a region, (z) among the four Chukchi regions, and also (3) between habitats in the Chukchi and Beaufort seas. Sampling gear will include gill nets, seines and fyke nets for capture of representative samples and for catch-per-unit-effort comparisons, and plankton nets for capture of larval stages. Concurrent with biological collections, useful physical and chemical data (surface-to-bottom profiles of water temperature, salinity, turbidity, etc.) will be collected.

Winter sampling will require under-ice gill and fyke nets. Because of difficulties in collecting fish in ice-covered waters, it is worthwhile to investigate whether co-ordination with winter subsistence fisheries is possible.

Fish will be collected for life history analyses and diet studies. Arctic and Bering cisco, which are similar in appearance, will be distinguished taxonomically since the study area is a region where these two species overlap in distribution.

Timing, extent and amount of subsistence harvests will be documented in greater detail than presently available. Although general subsistence patterns have already been described, additional quantitative information may be warranted.

Scheduling

In order to provide useful and timely input to the regulatory processes prior to the 'Barrow Arch Sale No. 85', the fisheries field program should be initiated as soon as possible. A biologically convenient schedule is to begin with the open-water phase (i.e., summer 1983), to identify important species and areas, and then to proceed with winter studies. However, due to the lateness of the program (in terms of the lease sale schedule), serious consideration should be given to a winter 1982-83 start-up whereby field sampling would begin in late winter (March 1983) prior to the summer program. The advantages of this schedule are that:

1. the distribution of free (unfrozen) water and fish overwintering sites (or potential sites) could be determined when winter ice had reached its maximum thickness,
2. liaison with Chukchi coastal villagers and subsistence fishermen could be initiated, and
3. the study team and sampling gear would be assembled at an early date to insure that sampling during the biologically active period in summer would not be jeopardized by delays.

Co-ordination with Other Programs

While this program focuses on fish resources, we recognize that an important reason for initiating fisheries investigations is the trophic significance of fish in the Chukchi food web. For example, a major source of mortality for several juvenile and adult marine fishes (arctic cod, sand lance, herring) is predation by marine mammals and seabirds. Swartz (1966) estimated that as many as 250 million arctic cod are consumed annually by bird populations at Cape Thompson. The proposed fisheries program must, for completeness, draw upon such interdisciplinary information, some of which may best be obtained through co-ordination with studies being conducted by other government agencies. The interdisciplinary information needed to meet the fisheries objectives is listed in Table 1.

It is strongly recommended that a pre-field season organization and logistics meeting be held at the earliest possible date to co-ordinate all studies scheduled for Chukchi waters. Interdisciplinary exchange and co-ordination will greatly enhance the quality of research conducted in the study area.

Table 1. Interdisciplinary information needed to meet fisheries objectives.

Subject	Information needed
Coastal processes	nearshore circulation and temperature/ salinity patterns. seasonal dynamics and influence of water from the Bering Sea on biological processes in study area. historical warming trend of Chukchi waters. flushing rate of Kasegaluk Lagoon.
Food sources	distribution in time and space of fish food organisms (mysids, amphipods, etc.) is the ultimate source of fish food marine primary production or terrestrially derived energy (modern or peat)?
Fish predation	seasonal distributions and predation rates by marine mammals and seabirds.
Subsistence fisheries	locations, seasons and harvests by coastal communities.

APPENDIX 1

Fisheries information for the Chukchi Sea: an annotated bibliography

AEIDC (Arctic Environmental Information and Data Center). 1975a. Anadromous fish inventory, Noatak National Arctic Range, Alaska, and associated area of ecological concern. Report by AEIDC, Univ. Alaska (Anchorage) for U.S. Fish Wildl. Serv. Vol. 6. 37 p. + 9 maps.

This is part of a 10-volume set of reports which inventories streams and lakes important to anadromous fish in Alaska. Volume 6 describes the Noatak National Arctic Range which includes portions of the Noatak and Kobuk drainages and contains a list of anadromous and coastal-marine fishes of the locale.

Brief descriptions of subsistence, commercial and sport fisheries are provided. The extent and locations of habitat used by anadromous fishes are indicated for parts of the Noatuk and Kobuk rivers. Escapements, subsistence catches and commercial harvest are listed for the period 1963-1974. Chum salmon, followed by arctic char and inconnu, comprise most of subsistence and commercial catches.

This report identifies three requirements for further study: (1) a more thorough study of the upper Kobuk River, (2) more information about spawning areas for chum salmon, and (3) sport harvest data are needed in greater detail.

AEIDC (Arctic Environmental Information and Data Center). 1975b. Anadromous fish inventory, Selawik National Wildlife Refuge, Alaska, and associated area of ecological concern. Report by AEIDC, Univ. Alaska (Anchorage) for U.S. Fish Wildl. Serv. Vol. 7. 42p. + 6 maps.

This is volume seven of a 10-volume set of reports which inventories streams and lakes important to anadromous fish in Alaska. This volume describes the area of the Selawik National Wildlife Refuge, which includes streams that drain into the Chukchi Sea in Kotzebue Sound. The major river of importance to salmon migration in this region is the Kobuk River.

Brief descriptions of subsistence, commercial and sport fisheries are provided. The extent and locations of habitat used by anadromous fishes are indicated. Escapements, subsistence catches and commercial harvests are listed for the period 1963-1974. A variety of species are caught but chum salmon are a major portion of the harvest.

This report identifies two data gaps: (1) a more thorough study of the upper Kobuk is required, and (2) sport harvest data are needed in greater detail.

AEIDC (Arctic Environmental Information and Data Center). 1975c. Chukchi Sea: Bering Strait-Icy Cape; physical and biological character of Alaskan coastal zone and marine environment. AEIDC Publication A75, Sea Grant No. 75-10. 63 p. + 31 maps.

This report consists of a 60-page bibliography and 31 maps which summarize known information (up to 197S) about physical and biological features of the region between the Bering Strait and Icy Cape. Each map contains a descriptive section based on data sources included in this report.

AEIDC (Arctic Environmental Information and Data Center). 1976. Profiles of the physical, biological and human environments of the Alaskan outer continental shelf lease areas. Unpubl. Rep. 54 p.

This report provides a state-wide overview (as of 1976) of Alaskan outer continental shelf oil and gas lease areas. The oceanography and biotic resources of the Chukchi Sea are summarized.

AEIDC (Arctic Environmental Information and Data Center). 1977. Bibliography of the environmental and engineering studies on the arctic coast and Beaufort and Chukchi Seas. Report by AEIDC, Univ. of Alaska (Anchorage) .

This bibliography of 130 citations dealing with arctic coastal environmental and engineering studies was used in the present selection of annotated reports.

Alt, K. 1971. A life history study of sheefish and whitefish in Alaska. Alaska Dep. Fish and Game 12:1-31.

This report describes a variety of topics related to sheefish collected at various locations in Alaska. Sport and subsistence utilization in the Kobuk-Selawik area is briefly mentioned. During aerial surveys in 1968-1970, approximately 3000-5000 sheefish spawners were counted in the Kobuk River. The 1970 subsistence catch of sheefish in the Kobuk River was about 9000 fish. Additional sheefish were also caught in the Selawik drainage and Hotham Inlet in Kotzebue Sound.

Alt, K. 1973. Age and growth of the inconnu (*Stenodus leucichthys*) in Alaska. J. Fish. Res. Board Can. 30:457-459.

Age and growth characteristics are described for inconnu from several Alaskan drainages, including the Kobuk-Selawik rivers which flow into Kotzebue Sound. Inconnu from the Kobuk-Selawik system grew slower and lived longer than the other inconnu populations examined.

Alt, K. 1978. Inventory and cataloging of sport fish and sport fish waters of western Alaska - Wulik-Kivalina rivers study. Annual Report, Alaska Dep. Fish and Game 19:61-76.

The author's abstract follows:

> Information collected on various life history aspects of Wulik River and Kivalina River Arctic char, *Salvelinus alpinus* (Linnaeus), is presented. Major spawning grounds on both the Kivalina and Wulik rivers have been located and delineated. Overwintering areas are generally described. Information on migrations, size and structure of the spawning population, number and location of spawners, spawning behavior, and location of char fry is also presented. Approximately 3,200 Arctic char spawn in the Wulik-Kivalina system, with 60% spawning in the Kivalina River system. The sex ratio at spawning is approximately three females per male. Grayling Creek is the most important spawning area. The main utilization of these char is for subsistence with a few taken by sport anglers.

Alt, K.T. 1979. Contributions to the life history of the humpback whitefish in Alaska. Trans. Am. Fish. Sot. 108:156-160.

Life history aspects are described for humpback whitefish (*Coregonus pidschian*) from various areas throughout Alaska, including one Chukchi drainage (Kobuk River). The author states that test setting and observation of subsistence catches in the Kobuk River in 1967 indicate that, after overwintering in Hotham Inlet in Kotzebue Sound and in the lower reaches of the Kobuk River, the fish move upstream to feed and later to spawn. After spawning the fish move rapidly downstream.

Surveys in 1971 indicated residents of the five villages along the Kobuk River took 50,000 whitefish, of which over 60% were humpback whitefish.

Alverson, D. L., N.J. Wilimovsky and F. Wilke. 1960. Marine invest igations of the Chukchi Sea. U.S. Atomic Energy Commission. Rep. PNE-479. 3 p.

This is a preliminary report on the first year (1959) of studies on Project Chariot (Alverson and Wilimovsky 1966). information contained in this report is presented in greater detail by Alverson and Wilimovsky (1966).

Alverson, D.L. and N.J. Wilimovsky. 1966. Fishery investigations of the southeastern Chukchi Sea. Vol. 2, Chap. 31, Pages 843-860. *In*: N.J. Wilimovsky and J.N. Wolfe (eds.). Environment of the Cape Thompson Region, Alaska. U.S. Atomic Energy Commission, U.S. Dep. Commerce, Springfield, VA.

This report is part of Project Chariot, a comprehensive environmental study conducted in August 1959 in the Chukchi Sea, primarily south of Point Hope. The authors describe fishes caught in offshore waters by trawl, gill net and seine at 74 stations, only six of which were located north of Cape Lisburne.

Over 7000 fish of 52 species were collected. Although the species list was dominated by far northern types, the collection contained 12 fishes not previously known to occur north of the Bering Strait. For some species, distribution appeared related to water temperature and salinity.

Commercially important species were salmon, char, flatfish, herring and smelt. However, the authors note that these species were not found in sufficient abundance nor of an acceptable size to warrant a commercial interest.

Andriyashev, A.P. 1954. Ryby severnykh morei SSSR (Fish of northern Soviet Seas). Izdatel' stuo AN SSSR, Moscow. (Transl. by Israel Sci. Transl., 1964, 617 p., avail. U.S. Dep. Commerce, Nat. Tech. Inform. Serv., Springfield, VA, OTS63-11160).

This reference book contains extensive taxonomic, distributional and life history information for fishes of the northern seas of the Soviet Union.

Barton, L.H. 1977. Finfish resource surveys in Norton Sound and Kotzebue Sound. Pages 113-194. *In*: Environ. Assess. Alaskan Cont. Shelf, Ann. Rep. Prin. Invest. Vol. 7. BLM/NOAA, OCSEAP, Boulder, Colo.

This report contains considerable information on Pacific herring in the Bering Sea and the southeastern Chukchi Sea. Most information for the Chukchi portion of the study is confined to the area around Shishmaref. Herring are an important subsistence item to villagers at Shishmaref with the major fisheries effort completed by mid-August. At the villages of Deering, Buckland and Point Hope, dependence upon herring is lower because marine mammals are more important in filling subsistence needs.

Gillnetting conducted in the southern Chukchi Sea in fall (27 September through 9 October 1976) showed Pacific herring to be the most abundant species. Other species also taken included: king and pink salmon, and arctic char. Gill nets set near shorelines produced considerably greater catches than offshore sets.

Bendock, T.N. 1979. Inventory and cataloging of arctic area waters. Alaska Dep. Fish and Game, Sport Fish Division. Annual Performance Report, Study No. G-I. 20:1-64.

Although this report emphasizes fisheries information from the Colville River, the report includes data for three rivers which drain into the Chukchi Sea, the Kukpowruk, Kokolik and Utukok rivers. Surveys of the upper and middle reaches of these rivers were conducted 5-20 July 1978. Each river was sampled at 4-7 sites by seine and gill net (the level of effort was not specified).

All three rivers support small runs of pink salmon. Only single specimens of other anadromous species (chum salmon, arctic char and arctic cisco) were caught. Freshwater species present in low to moderate numbers were grayling, slimy sculpin and ninespine sticklebacks. [Additional information on fishes in the lower Kokolik is presented by Craig and Schmidt (1982)].

Bendock, T. and J. Burr. 1980. Index to North Slope stream and lake surveys. Rep. by Alaska Dep. Fish and Game (Fairbanks). 11 p.

This report is a list of fishes caught in North Slope streams and lakes, including several in the current study area. Accompanying text, specific sample locations and most data sources other than Alaska Department Fish and Game and U.S. Fish and Wildlife Service are not presented.

Bowden, C., and L. Moulton. 1981. Resource report for the proposed Hope Basin OCS oil and gas lease sale #86. Rep. by Alaska Dep. Fish and Game, Marine/Coastal Habitat Management. Anchorage, Alaska. 121 p.

This report provides a useful summary of the available information for marine and anadromous fishes in the Hope Basin lease sale #86 area. A comprehensive bibliography relevant to the southeastern Chukchi Sea is also provided.

Butorin, D.A. 1965. Areas of polar cod in the Arctic. Ryb. Khoz. 10(8).

(not seen)

Cohen, D.M. 1954. Age and growth studies on two species of whitefishes from Pt. Barrow, Alaska. Nat. Hist. Mus., Stanford Univ., Stanford Ichthyological Bull. Vol. 4(3):168-187.

This paper describes the age and growth characteristics of least cisco and broad whitefish near Barrow. Samples were collected in Ikroavik Lake and Elson Lagoon. Various growth patterns of least cisco were evident. The author concludes that fish in this region are few and slow growing. The possibility of a major commercial fishery seems improbable.

Craig, P.C. and L. Haldorson. 1981. Beaufort Sea barrier island-lagoon ecological process studies: Final report, Simpson Lagoon. Part 4. Fish. Pages 384-678. Res. Unit 467. *In:* Environ. Assess. Alaskan Cont. Shelf, OCS Biol. Sci. Final Rep. Prin. Invest. Vol. 7. BLM/NOM, OCSEAP, Boulder, Colo.

Although this report describes Beaufort Sea fishes, incidental information is presented about a sample of saffron cod (*Eleginus gracilis*) collected in the Chukchi Sea. The authors state that these fish were part of a subsistence catch of "tomcod" jigged through the ice *just* offshore from the village of Kotzebue, southeast Chukchi Sea, on 15-30 November 1978.

The sample (n=33) consisted almost entirely of large, mature fish that were approaching a spawning condition. The average fork length was 238 mm and all but one of each sex were mature. Most were females (79%); egg diameters averaged 0.9 mm. Only three fish had empty stomachs; the rest had eaten fish (68% wet weight), mysids (18%) and decapods (13%).

Craig, P.C. and D. Schmidt. 1982. Fisheries surveys at potential dredging sites at North Slope villages: Wainwright, Point Lay, Atkasook, Nuiqsut and Kaktovik. Rep. by LGL Ltd. (Sidney) for the North Slope Borough, Barrow, Alaska.

The purpose of this investigation was to document the fisheries importance of potential dredging sites at five North Slope villages. The study includes some subsistence information and surveys of several coastal locations around two Chukchi communities, Wainwright and Point Lay. Fish were sampled by gill net and seine during 22-30 July 1981.

Sites sampled and species recorded at Wainwright were: Wainwright Inlet (least *cisco,* boreal smelt, arctic flounder, fourhorn sculpin), lower Sinaruruk River (fourhorn sculpin) and two nearby lakes (nil). Subsistence fishing along the village shoreline caught pink, chum and king salmon and fourhorn sculpin. Most subsistence fishing occurs at that location in summer and in Wainwright Inlet in winter.

Sites sampled and species recorded at Point Lay were: Kasegaluk Lagoon between the new and old village sites (pink salmon, arctic char, arctic and Bering cisco, boreal smelt, saffron cod, arctic flounder and fourhorn sculpin, lower Kokolik River (Pacific herring, boreal smelt, fourhorn sculpin), and several unnamed lakes (ninespine sticklebacks). A brackish water intrusion (170/0.) from the lagoon extended 4 km into the Kokolik River at the time of sampling. Most subsistence fishing in summer occurs on both the ocean and lagoon sides of the barrier island at the old village site.

Cunningham, P. 1976. Deering experimental commercial salmon fishery. Alaska Dep. Fish and Game Spec. Rep. No. 9. 25 p.

This report discusses an experimental commercial salmon fishery in the Deering area of Kotzebue sound in 1974 and 1975. Results of this three year study indicate that the local stocks of pink and chum salmon in the vicinity of Deering are very limited and not capable of supporting harvests in excess of present subsistence needs. Furthermore, the Deering commercial fishery was dependent upon the interception of chum salmon bound for the Kotzebue/ Noatak River area. For these reasons, continuation of the commercial fishery at Deering was not warranted.

Derjugin, K.M. 1937. Introduction to the investigations of the Chukchi and Bering seas. Issledovannia Morei SSSR 25:5-9. (In Russian and German, Translated from German by P. Skvorc.)

This is a preliminary report about the initiation of studies in the Bering and Chukchi seas by the new communist government. No scientific data are presented. Rather, the report extolls the virtues of the Red Army and its associated bureaucracies. The author describes the great strides in science that have been made since the revolution, and suggests that the economic reconstruction is being advanced by the scientists at the State Institute of Hydrology.

Derjugin, K.M. and A. Ivanov. 1937. Preliminary survey of studies on the benthos of the Bering and Chukchi seas. Issled. Morei. SSSR Vol. 25: 246-259.

No Chukchi data are presented in this preliminary report.

Feder, H.M., D.G. Shaw and A.S. Naidu. 1976. The arctic coastal environment of Alaska. Volume II: A compilation and review of scientific literature of the arctic marine environment. Univ. Alaska (Fairbanks), Instit. Mar. Sci. Rep. R76-5. 201 p.

This report provides a comprehensive bibliography of published literature and unpublished reports (up to 1976) on fish resources of arctic Alaska and Canada. Brief annotations are provided for each entry. The paucity of bibliographic entries for the Chukchi Sea region emphasizes the lack of information available for this area.

Feder, H. and S. Jewett. 1978. Survey of epifaunal invertebrates of Norton Sound, southeastern Chukchi Sea and Kotzebue Sound. Univ. Alaska (Fairbanks] , Instit. Mar. Sci. Rep. R78-1. 124 p.

This report describes benthic invertebrates from the northeastern Bering Sea and southeastern Chukchi Sea. Information about starry flounders is also included (see Jewett and Feder 1980).

FFHU (Faculty of Fisheries, Hokkaido University). 1967. 1966 cruise of the 'Oshoro Maru' to the Bering and Chukchi seas. *in:* Data Record of Oceanographic Observations and Explorations Fish. Hokkaido Univ., Hakodate, Hokkaido, Japan. 10:126-215.

(not seen)

FFHU (Faculty of Fisheries, Hokkaido University). 1968. 1967 cruise of the 'Osmoro Maru' to the Chukchi Sea. *In:* Data Record of Oceanographic Observations and Explorations Fish. Hokkaido Univ., Hakodate, Hokkaido, Japan. 11:78-105.

(not seen)

Frost, K.J. 1981. Descriptive key to the otoliths of gadid fishes of the Bering, Chukchi and Beaufort seas. Arctic 34:55-59.

This report provides an illustrated key to the otoliths of fishes that are common food items of marine mammals of the northern seas, including the Chukchi Sea.

Frost, K.J. and L.F. Lowry. 1981. Trophic importance of some marine gadids in northern Alaska and their body-otolith size relationships. Fish. Bull. 79(1) :187-192.

Marine fishes are important in the diets of marine mammals, seabirds and other fish. This report examines relationships between otolith length and fish length for three marine fishes in northern waters: walleye pollock, saffron cod, arctic cod. By using these relationships, it is possible to determine sizes of fish consumed by predators based on sizes of otoliths remaining in predator stomachs.

Frost, K.J., L.F. Lowry and J.J. Burns. 1978. Offshore demersal fishes and epibenthic invertebrates of the northeastern Chukchi and western Beaufort Seas. Pages 231-365. *In*: Environ. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. , Vol. 1. BLM/NOAA, OCSEAP, Boulder, Colo.

This study provides some information on the abundance, distribution and life history characteristics of offshore demersal fishes in the northeastern Chukchi Sea. Ten otter trawl samples were collected between 2 August and 3 September 1977 in water depths ranging from 40 to 102 m. Ten species (or species groups) were identified, with the majority belonging to three families: Gadidae (cod), Cottidae (sculpin) and Zoarcidae (eel-blennies) . In terms of both numbers and biomass, the arctic cod (*Boreogadus saida*) was the most abundant species collected. Information regarding the distribution, food habits and life history of abundant species is presented: arctic cod, Canadian eelpout (*Lycodes polaris*), fish doctor (*Gymmelis viridis*), arctic alligatorfish (*Aspidophorcides olriki*) and spatulate sculpin (*Icelus* spatula).

Geiger, M. 1966. Kotzebue chum salmon tagging project. Pages 78-98. *In*: Ayk area 1966 annual management report. Div. of Comm. Fish., Anchorage, AK.

This report provides limited data on the magnitude and timing of chum salmon runs in the Noatak and Kobuk rivers. It also provides limited data on subsistence and commercial catches in the area from 1962 through 1966.

Hablett, T. 1979. Fish inventories conducted within the National Petroleum Reserve on the North Slope of Alaska, 1977-78. Chap. 10, Pages 337-406. *In*: Studies of selected wildlife and fish and their use of habitats on and adjacent to NPRA 1977-1978, Vol. 2

The pertinent fisheries information in this report is the same as that provided by Bendock (1979).

Hurd, C. 1971. Kotzebue Sound sheefish invest igations, 1971. Alaska Dep. Fish and Game, Arctic-Yukon-Kuskokwin Region. 17 p.

This report is a continuation of that by Lebida (1970) and provides limited age and length data for sheefish in the Kotzebue Sound area.

Ivie, P. and W. Schneider. 1979. Wainwright synopsis. pages 75-87. *In:* Native livelihood and dependence. A study of land use values through time. U.S. Dep. Interior, National *Petroleum* Reserve in Alaska, 105(c) Field Study No. 1.

This report describes land use patterns by villagers at Wainwright. The study is based on interviews with Wainwright residents, and a brief amount of fisheries information is presented as it pertains to domestic fisheries.

Gill nets are set out in front of the village for salmon, "trout" and whitefish beginning in July and August. In fall, migrating fish are caught at camps along the Vtukok and Kuk rivers, and in winter smelt are caught in Wainwright Lagoon.

Jewett, S.C. and H.M. Feder. 1980. Autumn food of adult starry flounders, *Platichthys stellatus*, from the northeastern Bering Sea and the southeastern Chukchi Sea. J. Cons. Int. Explor. Mer 39(1):7-14.

Data describing starry flounder in this report were gathered during a larger study of benthic invertebrates described by Feder and Jewett [1978). This trawl survey was conducted 2-13 September 1976 in the northern Bering Sea and southern Chukchi Sea. Only 10% of the total fish sample were from the Chukchi Sea proper, and these sampling stations were located approximately 90 km north of Cape Prince of Wales. Dominant food items of the flounders included the brittle star, *Diamphiodia craterocmeta* and the protobranch clam, *Yoldia hyperborea*. The authors suggest that the northern movement of starry flounders may be restricted by temperature.

Lebida, R. 1970. Kotzebue Sound sheefish investigations, 1970. Alaska Dep. Fish and Game, Arctic-Yukon-Kuskokwin Region. 12 p.

This report, part of a several year management investigation of sheefish in the Kotzebue Sound area, presents tagging data from 1966 to 1970. Relative abundance and spawning dates for sheefish in the Kobuk River are also given.

Lindberg, G. 1937. On the classification and distribution of sand lances genus. East Branch Acad. Sci. USSR. Bull. 27:85-93.

(not seen)

Lowry, F.L., K.J. Frost and J.J. Burns. 1980. Variability in the diet of ringed seals, *Phoca hispida*, in Alaska. Can. J. Fish. Aquat. Sci. 37:2254-2261.

This report examines the diet of ringed seals which are the most abundant and widespread phocid in the northern hemisphere. Samples were collected in the Bering and Chukchi seas.

Fish are an important dietary item for ringed seals. Arctic cod were by far the major food eaten during winter months. The authors suggest that the abundance and distribution of ringed seals is directly related to the distribution of two marine fishes, arctic and saffron cod. A similar relationship has been described between ringed seals and arctic cod in some areas of the Siberian Arctic (Chapskii 1940*).

Lowry, L.F. and K.J. Frost. 1981. Distribution, growth and foods of Arctic cod (*Boreogadus saida*) in the Bering, Chukchi and Beaufort Seas. Canadian Field-Naturalist 95(2) :186-191.

This study is based on a collection of fish in offshore arctic waters of the Beaufort, Chukchi and Bering seas. Bottom samples of fish were collected by otter trawl, 10 of which were located in the present study area. These samples were collected in the northeaster Chukchi Sea west of Pt. Barrow during late summer (2 August-3 September 1977). Although the Chukchi data are limited, this report nonetheless represents a significant portion of the fisheries data available for fish in the Chukchi Sea north of Pt. Hope.

Only one fish species, the arctic cod, is described in this report. It was presumably a dominant species in the trawl samples but the relative abundance of other species is not presented in this report. [A complete list of catch results is presented in another report by Frost *et al.* (1978).]

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*Chapskii, K.K. 1940. The ringed seal of western seas of the Soviet Arctic. Proc. Arctic Sci. Res. Inst., Leningrad, USSR. 145:1-72. (Transl. from Russian by Fish. Res. Board Can. Transl. Ser. No. 1665, 1971)

The author's abstract follows:

> Arctic Cod (*Boreogadus saida*) are abundant and ecologically important in arctic and subarctic marine ecosystems. Based on otter trawl collections made in the northern Bering and northeastern Chukchi and Beaufort seas, Arctic Cod were most abundant in the northeastern Bhukchi and western Beaufort seas. There was no relationship between water depth and abundance; however, in the Chukchi and Beaufort seas, small fishes were more common in water less than 100 m deep. Annual growth increments appear to be quite variable, which complicates interpretation of size at age data. Arctic Cod less than 4 yr were larger at a given age in the Bering Sea. In the Bering Sea gammarid amphipods were the main food with mysids, shrimps and hyperiid amphipods also eaten. In the northeastern Chukchi and Beaufort seas, calanoid copepods were by far the predominant prey with other crustaceans eaten much less frequently. Arctic Cod appear to be a very adaptable species, which may explain their overwhelming success in arctic marine waters.

MacGinitie, G.E. 1955. Distribution and ecology of the marine invertebrates of Point Barrow, Alaska. Smithsonian Misc. Coil. Vol. 128. No. 9.

Although fish were not within the scope of this project, the report provides a brief description of the fish fauna encountered during an invertebrate sampling program conducted in the Point Barrow area. The major species reported were: arctic cod, capelin and fourhorn sculpin.

Makarov, V.V. 1937. Data on the quantitative calculation of benthic fauna of the northern Bering Sea and the southern Chukchi Sea. Issled. Morei. USSR Vol. 25:260-291.

This report deals primarily with benthic invertebrates rather than fish.

Mattson, C.R. 1962. Chum salmon resources of Alaska from Bristol Bay to Point Hope. U.S. Fish Wildl. Serv., Special Scientific Rep. Fisheries No. 425. 22 p.

The author's abstract follows:

> A literature survey was conducted to determine the importance and utilization of chum salmon, *Oncorhynchus keta*, from Bristol Bay to Point Hope, Alaska. This species is the most abundant and economically important to the welfare of the local residents within this vast area, except for the Bristol Bay area where sockeye salmon, *Oncorhynchus nerka*, far outnumber chum salmon. The Yukon River system produces the greatest number of chum salmon of all the areas covered here, with catches ranging from 500,000 to nearly 1,000,000 fish annually. The Kuskokwim River system follows, with annual catches averaging over 500,000.

Ranking third in production is the Bristol Bay area where commercial catches range as high as 400,000. The rivers and streams entering Kotzebue Sound from the base of Seward Peninsula northwest to Point Hope rank fourth in importance, annual catches being estimated in excess of 264,000.

McPhail, J.D. *1966. The Coregonus autumnalis* complex in Alaska and northwestern Canada. J. Fish. Res. Board Can. 23:141-148.

Whitefish common to the study area pose taxonomic uncertainties with some regularity. The relevance of this taxonomic study lies mainly in that some samples were obtained from areas of interest to this bibliography. This report indicates that the Chukchi Sea is an area of dist,ributional overlap for arctic and Bering ciscoes. Since both the high gill raker form (arctic cisco) and low gill raker form (Bering cisco) occur along the arctic coast without intergrading, they are considered separate species.

Mohr, J.L., N.J. Wilimovsky and E.V. Dawson. 1957. An arctic Alaskan kelp bed. Arctic 10:45-52.

This paper reports the occurrence of a kelp bed near Peard Bay (70°51'30"N, 158°08'30"W) , southwest of Barrow. The authors suggest that northern Alaska is poor in marine algae and such algal beds are not common in arctic waters. [This suggestion is supported by OCSEAP studies in the Beaufort Sea which located only a few such kelp beds on rocky substrates (i.e., the Boulder Patch in Stefansson Sound)]. Six species of fish were collected from this kelp bed: arctic cod (*Boreogadus saida*), *an* eelpout (*Gymnelis viridis*), and four species of sculpin (*Gymnocanthus tricuspis, Myoxocephalus scorpius, Artediellus scaber beringianus, Enophrys diceraus*). *The* arctic cod had eaten gammarid amphipods and numerous copepods. The sculpin (species combined) had eaten mainly gammarid and caprellid amphipods, with small amounts of crab, shrimp, polychaete, pteropod and plant material.

Morris, B. 1981. Living marine resources of the Chukchi Sea: A resource report for the Chukchi Sea oil and gas lease sale #85. Rep. by Nat. Mar. Fish. Serv. for Bureau of Land Management (Anchorage). 117 p.

In this synthesis, the author presents an overview of northeast Chukchi fishes, although he concludes that marine fishes of this region have received little attention in the past and knowledge of anadromous fish is poor.

From limited sampling in other studies, the number of marine fishes reported in the Chukchi Sea is 41 species representing 11 families. The Chukchi Sea has lower species diversity and biomass than the northern Bering Sea but greater than that in the Beaufort Sea. Dominant marine species are arctic cod, starry flounder, Pacific halibut, saffron cod, Pacific herring, sculpins and capelin. Of the 13 anadromous fishes reported in the Chukchi, the most abundant are pink and chum salmon, arctic char, ciscoes, whitefish and smelt. Along the northeast coast, the larger drainages support small runs of salmon. Population sizes of commercially valuable fish resources in the Chukchi Sea are low, but villages along the coastline rely heavily on subsistence hunting and fishing for food.

Moulton, L.L. and S. Bowden. 1981. Resource report for the proposed Chukchi Basin OCS oil and gas lease sale #85. Unpubl. Rep. by Alaska Dep. Fish and Game, Marine/Coastal Habitat Management. Anchorage, Alaska. 38 p.

This report summarizes available information and identifies major data gaps in the knowldge of anadromous and marine species in the Chukchi Basin lease sale #85 area located in the northeaster Chukchi Sea, Two resource maps provide some information on habitat use of abundant marine fishes (arctic cod , Pacific sand lance and capelin) and anadromous fishes (arctic char, ciscoes, pink and chum salmon). The report also contains a comprehensive bibliography relevant to the Chukchi Sea lease area.

Murdoch, J. 1884. Fish and fishing at Point Barrow, arctic Alaska. Trans. Am. Fish. Sot. 13:111-115.

Murdoch presents an interesting account of the fish and fishing practices of the "Esquimaux" at Point Barrow in 1882. Whitefish, burbot, arctic cod, and occasionally pink salmon and arctic char were the species of primary importance. Capelin and *smelt* were also present since the author relates that in the summer of 1882 he caught thousands of capelin, but local residents did not utilize them because they lacked nets small enough to catch them. Gill-netting and jigging through the ice were the primary means of fishing observed. It is also noted that *while it was usually* only the women and children wrho fish, many people were involved in fishing activities when seal hunting was poor and during times of low food supplies.

Murdoch, J. 1885. Fishes. Pages 129-132. *In*: P. Ray (cd.) Report on the International Polar Expedition to Pt. Barrow, Alaska 1882-3. Part 4, sec. 3. U.S. Gov. Printing Office (Washington, D.C.).

This report provides interesting comments regarding 18 fish species caught in the Barrow area during 1881-1883. Of particular interest arc the life history observations on the distribution of arctic cod. The importance of boreal smelt in Wainwright Inlet is also noted.

Namvedt, T., S. Parrish, N. Friese and W. Quirk. 1974. Pages 252-268. *In*: Alaska arctic coast-a background study of overall knowledge. Prep. for Dep. of the Army, Alaska Dist. Corps of Eng. Alaska Office.

[not seen)

Pedersen, S. 1979. Point Hope synopsis. Pages 141-149. *In*: Native livelihood and dependence, A study of land use values through time. U.S. Dep. Interior, National Petroleum Reserve in Alaska, 105(c) Field Study No. 1.

This report describes land use patterns by villagers at Point Hope. A brief amount of fisheries information is presented as it pertains to subsistence fishing. Marine and freshwater fish are listed as a primary subsistence resource. Ocean fishing occurs almost year round and freshwater fishing on the Kukpuk River occurs in late fall and winter.

Pedersen, S., D. Libbey, W. Schneider and C. Dementieff. 1979. Barrow-Atgasuk (Atkasook) synopsis. Pages 49-74. *In*: Native livelihood and dependence. A study of land use values through time. U.S. Dep. Interior, National Petroleum Reserve in Alaska, 105(c) Field Study No. 1.

This report describes land use patterns by villagers at Barrow and Atkasook. A brief amount of fisheries information is presented as it pertains to domestic fisheries. In the area of current interest, some fishing for salmon, char and whitefish occurs along the Chukchi coastline between Point Barrow and Ualiqpaa, located about 35 km to the southwest. There is also jigging for tomcod in winter although this resource "does not receive much attention these days".

Pereyra, W. T., R.J. Wolotira, Jr., T.M. Sample and M. Morin, Jr. 1977. Baseline studies of fish and shellfish resources of Norton Sound and the southeastern Chukchi Sea. Pages 229-287. *In*: Environ. Assess. Alaskan Cont. Shelf. Ann. Rep. Prin. Invest. Vol. 8. BLM/NOAA, OCSEAP, Boulder, Colo.

This study summarizes existing literature about fish resources of the southeastern Chukchi Sea and presents new data collected during September-October 1976. Gillnet samples and pelagic trawl hauls for near-surface fish were generally unproductive, with toothed smelt (*Osmerus mordax dentex*) and Pacific herring (*Clupea harengus pallasi*) being most common. Inshore sets usually caught more than those made in offshore waters.

otter trawl catches of demersal fish were small. Fish commonly caught by this method were: Gadidae (arctic and saffron cod), Pleuronectidae [Alaska plaice), Osmeridae (rainbow smelt), Clupeidae (Pacific herring) and Cottidae (plain sculpin, shorthorn sculpin).

In a comparison of day/night otter trawl catches, most species were more abundant during the day.

Pfeifer, W.E. 1977. An annotated bibliography of the fishes of the Beaufort Sea and adjacent regions. Univ. Alaska, (Fairbanks), Biol. Pap. No. 17. 81 p.

This report is a useful compilation of approximately 500 references that describe fishes of the Beaufort Sea and adjacent regions. Coastal streams are also included because they are used by anadromous fishes of the study area. Several Russian references are included. Many of the references are briefly annotated.

Ponomarenko, V.P. 1968. Some data on the distribution and migration of polar cod in the seas of the Soviet Arctic. Rapp. Proc. Perm. Cons. Int. Explor. Mer 158:131-134.

The polar cod referred to in the title is *Boreogadus saida*. Very little of the information on distribution and life history was obtained from the Chukchi Sea. Because of the circumpolar distribution of *B. saida* and similarities in natural history between various stocks, the information from the western Soviet seas is helpful.

It is suggested that *B. saida* overwinters in the southern Chukchi and northern Bering seas and summers to the north and west. It is associated

with the ice-edge and spawns in January and February. It may be locally abundant at any time along any part of its distribution. The author states that during late fall storms, 'one may see heaps 50-100 cm wide and 30-50 cm deep extending over hundreds of kilometers along the waters edge'.

Pruter, A., and D. Alverson. 1962. Abundance, distribution, and growth of flounders in the south-eastern Chukchi Sea. J. Cons. Perm. Int. Explor. Mer 27:81-99.

This report concentrates on the flounders collected during the August 1959 'Project Chariot' studies reported by Alverson and Wilimovsky (1966). Demersal fish were collected by otter trawl throughout the southeast Chukchi Sea and southern Ledyard Bay.

A total of 289 pleuronectids composed of six species was collected; most were *Hippoglossoides robustus*. Population densities were extremely low and sizes of all flounder species were smaller than accepted in commercial markets.

An important contribution of this paper is the discussion regarding physical properties of the Chukchi Sea which dictate the population dynamics of flounders found there. Recruitment is apparently dependent upon the transport of eggs, larvae and young fish into the Chukchi Sea by waters originating south in the Bering Sea. The authors hypothesize that population levels of these fish are kept low due to harsh winter mortalities.

Quast, J.C. 1972. Preliminary report on the fish collected on WEBSEC-70. Pages 203-206. *In:* WEBSEC-70, an ecological survey in the eastern Chukchi Sea. U.S. Coast Guard, Oceanographic Rep. No. 50. 206 p.

This data report consists of tables which list species of fish collected during the WEBSEC-70 cruise in Ledyard Bay. Twenty-six species were caught by trawl at 21 offshore stations during the period 25 September to 17 October 1970. The most widespread species caught were arctic cod and sand lance.

Quast, J.C. 1974. Density distribution of juvenile arctic coil, *Boreogadus saida*, in the eastern Chukchi Sea in the fall of 1970. Fish. Bull. 72:1094-1105.

This study presents information about the biomass and distribution of juvenile arctic cod (*Boreogadus saida*) in the Chukchi Sea. Samples were collected during September and October 1970 at 20 stations in Ledyard Bay. An Isaacs-Kidd mid-water trawl was used to collect fish at depths of 2-45 m in water that was 22-54 m deep.

The two most abundant species collected were arctic cod and Pacific sand lance (*Ammodytes hexapterus*). The average concentration of arctic cod juveniles was 28/1,000 m^3 and their average biomass was 0.7 metric ton/km^2 of ocean surface. Numbers of arctic cod increased with depth, and concentrations at different depths appeared to be negatively related to sunlight. The author suggests that the arctic cod *originated* in the northwestern Bering Sea off Siberia or within the Chukchi Sea.

Raleigh, R.J. 1957. Reconnaissance of salmon fisheries between Cape Newenham and Point Hope, Alaska, 1957. U.S. Dep. Commerce, NMFS Biological Lab., Auke Bay, Alaska. 27 p.

This report deals almost exclusively with the subsistence use of salmon by the people along the Bering Sea and southern Chukchi Sea coastlines. Historical data regarding people:dog ratios and the quantity of fish used for dog food are presented.

Roguski, E. and P. Winslow. 1970. Monitoring and evaluation of arctic waters with emphasis on the North Slope drainages. Annu. Rep. No. 15-C. Alaska Dep. Fish and Game 11:279-301.

This report is primarily concerned about Beaufort Sea drainages but presents incidental information about the Wulik River subsistence catch. The total catch of all fish caught by Kivalina villagers in the spring of 1969 was 8400 arctic char weighing 19,000 pounds. Age and maturity data are presented for 24 arctic char.

Romanov, V.V. 1959. Bibliographe of literature relating to fish of the Far East 1923-1956. Akad. Sci. Moscow 1959. 290 p.

(translated copy not seen)

Saario, D.J. and B. Kessel. 1966. Human ecological investigations at Kivalina. Vol. 2, Chap. 35, Pages 969-1040. *In*: N.J. Wilimovsky and J.N. Wolfe (eds.) Environment of the Cape Thompson Region, Alaska. U.S. Atomic Energy Commission, U.S. Dep. Commerce, Springfield, VA.

This chapter documents subsistence patterns in the coastal village of Kivalina in the southern Chukchi Sea. The authors found that "fish play a vital part in the subsistence economy of the Kivalina people". The major portion of the catch consisted of Dolly Varden (*Salvelinus malma*) [currently called arctic char, S. *alpinus*], but whitefish and arctic cod were also taken. Seasonal fishing patterns, locations and methods are described. Most fishing occurred in the Wulik River in fall and Kivalina lagoon in winter. Fall catches totalled 98,000 lb in 1959 and 124,000 lb in 1960.

Salonius, P. 1973. Barriers to range extensions of Atlantic and Pacific salmon in arctic North America. Arctic 26:112-122.

This report suggests that the long arctic coastline between Alaskan salmon rivers and the Mackenzie River in Canada is a major barrier to the range extension of salmon because the rivers on these coastlines are not suitable for colonization. Salmon, particularly the juvenile life stages, have a marked intolerance to the low water temperatures (compared with other salmonids) occurring in these northern streams. The author suggests that this is the reason that chinook, sockeye and coho salmon are encountered only sporadically north of Norton Sound. Pink and chum salmon may have been able to colonize streams farther north because of their relative independence from freshwater life stages.

Schneider, h'. and R. Bemett. 1979. Point Lay synopsis. Pages 107-119. -In: Native livelihood and dependence. A study of land use values through time. U.S. Dep. Interior, National Petroleum Reserve in Alaska, 105(c) Field Study No. 1.

This report describes land use patterns by villagers at Point Lay. A brief amount of fisheries information is presented as it pertains to domestic fisheries. Gill nets are set, from early July through late September, at many places around Point Lay (i.e., river mouths, the lagoon, and the sea). Species caught include chum, pink and king salmon, flounder, smelt, herring, whitefish, sculpin and grayling. In late fall and winter, fishing in the Kukpowruk River yields large catches of grayling.

Seaman, G. andJ. Burns. 1980. Preliminary results of recent studies on belukhas in Alaskan waters. Unpubl. Rep. by Alaska Dep. Fish and Game (Fairbanks). 31 p.

This report describes the trophic importance of marine fishes in the diet of white whales in Chukchi coastal waters:

> Belukhas taken during spring migration in the Chukchi Sea had eaten arctic cod, (*Boreogadus saida*), shrimps, and octopus. During late spring and summer, in the coastal zone, important prey included saffron cod (*Eleginus gracilis*), sculpins, herring, smelt, capelin, salmon, char (*Salvelinus malma*), shrimps, and octopus. In Norton Sound and southeastern Kotzebue Sound, saffron cod were the primary prey. It was presumed that arctic cod are the most important prey in more northerly regions.

Sekerak, A. 1982. Summary of the natural history and ecology of the arctic cod (*Boreogadus saida*). Species Account Report by LGL Limited for BLM/NOAA OCSEAP. 10 p.

This report provides a review of the world-wide distribution and life history information for arctic cod, a species of prime trophic importance for seabirds and marine mammals in the Arctic. The report is useful for comparative purposes since arctic cod are abundant in the Chukchi Sea.

Skvorc, P.A. 1982. Winter subsistence fishing at villages along the northeast Chukchi coastline. Unpubl. Field Rep. by LGL Limited.

This report describes winter subsistence fishing at the villages of Barrow, Wainwright, Point Lay and Point nope. It is based upon conversations with villagers conducted during March 19-29, 1982, which were held in order to evaluate the extent that subsistence fisheries could serve as a source of fisheries data relevant to the 'Barrow Arch Sale No. 85' for oil and gas leases. The subsistence information gathered corroborates that related in previous reports (Ivie and Schneider 1979; Pedersen 1979; Pedersen *et aZ. 1979;* Schneider and Bemett 1979; Craig and Schmidt 1982).

There appears to be a general reduction in the level of winter fishing efforts as villagers adopt a cash-based economy. Time spent at a job is increasing as the villagers now pay for electric household appliances and electric heat. However, subsistence fishing remains important to the people of the villages along the Chukchi Sea coast, particularly at Wainwright. The fish caught here are often sent to Barrow and Point Lay through friends, relatives or barter. There is some winter fishing in Barrow and Point Hope and the people that participate rely on this source of food. In Point Lay, the fall fishing trip to the Kukpowruk River is an important social and subsistence activity.

Smith, H.D., A.H. Seymour and L.R. Donaldson. 1966. The salmon resource. Vol. 2, Chap. 31, pages 861-871. *In:* N.J. Wilimovsky and J.N. Wolfe (eds.). Environment of the Cape Thompson Region, Alaska. U.S. Atomic Energy Commission, U.S. Dep. Commerce, Springfield, VA.

This report describes salmon resources in Kotzebue Sound during 1959-1961. Data were gathered by coastal sampling near Cape Thompson, stream surveys, and discussions with local residents at Kotzebue, Kivalina and Point Hope.

The authors conclude that pink and chum salmon are the abundant species in this region, although all five salmon species range as far north as Cape Thompson. The number of salmon and their importance to the economy of the region dwindle north of Kotzebue Sound. Large catches of salmon are made in subsistence fisheries at Kotzebue, but very few salmon are taken at Point Hope and Kivalina. Some morphometric and meristic data are presented for salmon in the Kotzebue Sound region.

Springer, A.M. and D.G. Roseneau. 1978. Ecological studies of colonial seabirds at Cape Thompson and Cape Lisburne, Alaska. Pages 839-960. *In*: Environ. Assess. Alaskan Cont. Shelf. Annu. Rep. Prin. Invest. Vol. 2. BLM/NOAA, OCSEAP, Boulder, Colo.

This report concentrates on seabird studies, but also presents useful information about forage fishes in terms of the birds' feeding ecology. Information about the general distribution of fishes is derived from bird foraging patterns and fishes eaten. Principal fish species eaten by murres at Cape Thompson and Cape Lisburne were: arctic and saffron cod, sand lance, and sculpin. Yearly charges in seabird feeding patterns are discussed in terms of fish population dynamics.

Springer, A.M. and D.G. Roseneau. 1979. Ecological studies of colonial sea birds at Cape Thompson and Cape Lisburne, Alaska. Pages 517-574. *In*: Environ. Assess. Alaskan Cont. Shelf. Annu. Rep. Prin. Invest. Vol. 2. BLM/NOAA, OCSEAP, Boulder, Colo.

This report is similar *to an* earlier report by Springer and Roseneau (1978) and represents the data collection and analysis for 1978. More attention is given to feeding, flight patterns and feeding sites than previously, and less attention to stomach content analysis. It is noted that at Cape Thompson, murres and kittiwakes exploited Pacific herring, which had been absent from their diets in previous years. A major reason for fluctuations in bird distributions appears to be changes in prey (fish and zooplankton) abundance and diversity. The authors state:

> One of the most critical elements of kittiwake biology in the region appears to be sandlance. In certain years the fish school in dense shoals in shallow, nearshore waters and are easy prey for most seabirds, especially kittiwakes which are restricted to feeding in waters less than about one meter in depth. Sandlance have been seen to fluctuate in their abundance and in the time when they arrive near the bird colonies, fluctuations which have coincided with major changes in kittiwake reproductive success. Therefore, we believe that studies should be undertaken which would address questions concerning the natural history of sandlance. If sandlance populations were jeopardized by effects of resource development, the results might be disastrous to kittiwake populations in the eastern Chukchi Sea.
>
> Sandlance, however, are not the only food resources upon which seabirds depend. Murre food habits data suggest that other fish -- cod and sculpins -- and invertebrates are also important to the population. Our data also suggest that different food groups may be more abundant at some times during the summer than others. The success of the murre population, therefore, may depend upon a well-timed

sequence of events which assures" that adequate food of some type will be available to the birds throughout the summer. Loss of any component could threaten the population.

Springer, A.M., E.C. Murphy, D.G. Roseneau, and M.I. Springer. 1982. Population status, reproductive ecology and trophic relationships of seabirds in northwestern Alaska. *In:* Environ. Assess. Alaskan Cont. Shelf. BLM/NOAA, OCSEAP, Boulder, Colo. 470 p. (in press)

(not seen)

Swartz, L.G. 1966. Sea cliff birds. Bol. 2, Chap. 23, Pages 611-678. *In*: N.J. Wilimovsky and J.N. Wolfe (eds.). Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Commission, U.S. Dep. Commerce, Springfield, VA.

This chapter of the Project Chariot report concentrates on seabirds, but contains useful information about fish of the area as a function of bird diets. The author suggests that the birds in the Cape Thompson region consume approximately 13. million kg of fish per 139 day breeding season, indicating that there is a very substantial population of forage fish in the area. Most of this biomass is made up of arctic cod, sand lance and fourhorn sculpin .

Walters, V. 1955. Fishes of western arctic America and eastern arctic Siberia. Bull. Am. Mus. Nat. Hist. 106:255-368.

This report provides a taxonomic key and annotated list of arctic fishes, and an extensive discussion of zoogeographic patterns of fishes since the last period of glaciation. While the breadth of information presented is considerable, almost 30 years' worth of more recent information has accumulated.

Walters, V. 1961. Winter abundance of *Arctogadus glacialis* in the Polar Basin. Copeia 2:236-237.

In recognizing the sparsity of fisheries information available for the Polar Basin, the author briefly presents some data regarding fishes caught in 1959-1960 by seismic blasting and dredging from Station Charlie, a floating ice station northwest of Barrow. The polar cod, *Arctogadus glacialis*, was the principal species caught in the vicinity of 77°12'N lat., 168°12'W long.

The author suggests that, since these cod were only obtained in winter and only when the ice station was in the vicinity of the Chukchi Rise, that the fish were not following the ice in its movement, but rather that the ice passed over aggregations of fish. Dredge samples also yielded the greatest number of otoliths in the area of the Chukchi Rise. The author suggests that schools of polar cod undertake migrations across the shallow waters of the Chukchi Rise in mid-winter.

Single specimens of *Lycodes frigidus* and *Careproctus reinhardti* were also caught.

Wigutoff, N.B. and C.J. Carlson. 1950. A survey of the commercial fisheries possibilities of the Seward Peninsula area, Kotzebue Sound and certain inland rivers and lakes in Alaska. U.S. Fish Wildl. Serv. Fishery Leaflet 375. 24 p.

(not seen)

Wilimovsky, N.J. 1956. The utilization of fishery resources by the arctic Alaskan Eskimo. Nat. Hist. Mus. Stanford Univ., Occas. Pap. No. 2. 8 p.

This paper describes the utilization of arctic fish resources by North Slope communities from Point Hope, Alaska to Herschel Island, Canada. An attempt is made to compare the extent of utilization in the early 1950's with that in earlier periods in the history of these people. The data were gathered during the course of other studies, and include some 27 interviews with Eskimos and an examination of the literature pertaining to the fisheries.

The author first notes that, although arctic fish stocks are less numerous than those in more southern waters, local residents use a higher percent of the species present. In the 1950's, freshwater catches of grayling, whitefish, sheefish, trout and burbot were of economic value to the Eskimos. Marine species (salmon, smelt, cod and flounders) were exploited only slightly.

The author suggests that fish resources were under-utilized because:

> Fishing was, and is, not a highly regarded art, so many of its labors fell to women. There have never been rituals connected with it, as there were for practically all forms of hunting . . . . The reasons for this slight utilization of an otherwise valued economic resource may be traced in part to the social customs of these coastal people as well as to their economic needs. hey are gregarious and inter/intra-family ties were and still are strong. It was not desirable for a part of the family to be away, more or less isolated from any settlement, as fishing

at inland camps required. With an abundance of such marine mammals as seals, walrus and whale, there was no incentive to develop sea-fishing techniques to any degree.

There is an interesting note that salmon fishing in the Point Hope area "is carried out much more extensively today than in earlier times, if the limited finds of salmon spears in archeological sites can be taken as a true indication of fishing intensity . ..." Wilimovsky suggests that "perhaps this may be due to the general warming of the Arctic and the extension of salmon ranges to the north." [This appears to be a precursor to hypotheses like Nieman's (1963) "that annual fluctuations of water temperature, rather than availability of food, may be the determining factor responsible for the maximum northerly distribution of many benthophagic species" (cited in Feder and Jewett 1980)],

Wilimovsky summarizes:

> To the Arctic Alaskan Eskimo, fishing in general was never a highly important or significant occupation. Utilization of fish was secondary to exploitation of other animals . . . . Those Eskimos whose culture is built around a sea-mammal economy rely little on fish as food . . . . However, the few Eskimos living along the coast east of Barrow have come to use their fishery resource to a greater extent than in the past. It is quite clear that as long as the stock of sea mammals is abundant there is very little possibility that the Arctic Alaskan Eskimo (with the exception of the Anaktuvuk people) will come to exploit fishing to a greater extent.

Winslow, P. 1969. Investigation and cataloging of sport fish and sport fish waters in interior Alaska - char in northwestern Alaska. Annu. Rep. No. 15-A. Alaska Dep. Fish and Game 10:319-3321.

Portions of the author's abstract follow.

> This report presents the results of a study on anadromous Arctic char, *Salvelinus alpinus*, from the Wulik and Kivalina rivers . . . . Emphasis was placed on collecting life history, subsistence and sport history information . . . . An aerial count of char in the Wulik and Kivalina rivers revealed an estimated 46,000 char in the Kivalina and 180,500 to 225,600 char in the Wul . . . . Native fishermen took an estimated 120,000 pounds of char (49,500 fish) from the Wulik River with seines during the autumn of 1968. An estimated 50-60 sport fishermen trips were made to the Wulik River in 1968.

Winslow, P.C. 1969. Comments on the proposed Wulik River commercial fishery with recommendations. Alaska Dep. Fish and Game, Sport Fish Div., Admin. Rep. 11 p.

(not seen)

Wolotira, R.J., T.M. Sample and M. Morin. 1979. Baseline studies of fish and shellfish resources of Norton Sound and the southern Chukchi Sea. Pages 258-572. *In*: Environ. Assess. Alaskan Cont. Shelf, OCS Environ. Assess. Prog. Final Rep. Prin. Invest. Vol. 6. BLM/NOAA, OCSEAP, Boulder, Colo.

This report presents a comprehensive examination of fish and shellfish resources of the marine environment from Norton Sound northward through the Bering Strait and into the southeastern Chukchi Sea. The authors also review the commercial and subsistence fisheries of the area from 1962 to 1976.

There are 15 families represented by 87 fish species found in Norton Sound and the southeastern Chukchi Sea. Of these, seven families composed of 78 species make up 85% of the total fish fauna. Benthic species make up 74% of the total fish fauna of the area. The fish fauna of the area are characterized by three groups: (1) cold water groups indigenous to arctic marine waters including arctic cod, longhead dab, arctic flounder, and a number of cottid and blennoid species; (2) a subarctic boreal group which includes saffron cod, yellowfin sole, Alaska plaice, starry flounder and Pacific herring, whose distribution is centered south of the study area in the Bering Sea of regions of the eastern and western Pacific; and (3) an anadromous freshwater group with several forms such as char, whitefish and smelt, whose marine distribution occurs only in estuarine and other nearshore environments.

Substantial morphometric, distributional and catch-per-unit effort data are presented in this report. There are no other reports of this scope or magnitude with the exception of the 'Project Chariot' studies near Cape Thompson (Alverson and Wilimovsky 1966; Smith *et al.* 1966).

The authors' summary of several major findings pertaining to fish follows:

(1) Results of the 1976 BLM/OCS demersal survey of Norton Sound, the southeastern Chukchi Sea, and adjacent waters indicate that highest relative abundance for nearly all fish and invertebrates occurred south of Bering Strait, especially in Norton Sound.

(2) Gadidae (cods) and Pleuronectidae (flounders] were the dominant fish families encountered during the survey and had a combined estimated biomass of over 33,000 [metric tons]. This amount accounted for 70% of the total fish biomass estimated for the survey area. Cottidae (sculpin), Osmeridae (smelts), and Clupeidae (herring) accounted for an additional 25% of the total fish biomass.

(3) The eight most abundant fish species in the survey region, by rank order of estimated biomass were: saffron cod, starry flounder, shorthorn sculpin, Pacific herring, toothed smelt, Alaska plaice, yellowfin sole, and arctic cod.

(4) Most of the dominant fish species were found in highest relative abundance in areas south of Bering Strait and where bottom waters were warmer than 4°C and shallower than 30 m...

(5) Arctic cod was an exception to relative abundance trends for the dominant fish species. Relatively high abundance of this species occurred at nearly all bottom temperatures and at depths greater than 20 m.

(6) Almost no fish species were encountered in either sufficient size or quantity to be considered as potential for commercial harvest. Pacific herring is the only non-salmonid species presently taken in a commercial fishery in the survey region. Recent harvests have been very small and attempts to greatly expand harvest levels do not appear likely.

(7) Survey information on age-length and length-weight relationships indicate age and growth differences north and south of the Bering Strait for several fish species. Pacific herring, toothed smelt, yellowfin sole, and Alaska plaice all displayed greater lengths-at-age and maximum sizes south of Bering Strait than to the north, while saffron cod data suggested the opposite - largest size and lengths-at-age in the north. Definite reasons for growth differences were identified and seem to suggest some stock segregation within the survey region.

(8) Little is known about spawning and nursery areas in the survey region. An examination of catch rates by stratum for the youngest two age groups of each dominant fish species provides some insight as to possible locations of spawning areas and nursery grounds. Highest relative abundance for young saffron cod, Pacific herring, starry flounder, Alaska plaice, and yellowfin sole was found in Norton Sound. For species with more arctic distributions, arctic cod and toothed smelt, either cold-deep waters or regions north of Bering Strait provided the areas of highest density of young fish.

(9) About 2/3 of the area surveyed during the 1959 AEC work in the southeastern Chukchi Sea coincided with portions of our 1976 survey region (primarily stratum 1N). A general comparison of species composition and relative species abundances between the 1959 and 1976 data for this overlapping region suggests that no major changes have occurred in the fish community of the southeastern Chukchi Sea since that earlier stud?-.

Wohlschlag, D.E. 1956. Information from studies of marked fishes in the Alaskan Arctic. Copeia 4:237-242.

This report discusses technical aspects of mark-and-recapture studies of fishes in coastal waters near Barrow, Alaska. Some information on the distribution of least cisco and fourhorn sculpin in Elson Lagoon is also provided. Data indicate that least cisco use the area during the open-water season but move up to the Meade River by way of Admiralty Bay to spawn in the fall.

Yanagawa, C. 1971. Kotzebue chum salmon tagging project, 1966-1968. Alaska Dep. Fish and Game, Arctic-Yukon-Kuskokwim Region. Fish. Bull. No. 7.

(not seen)