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Beaufort Sea Fish and their Trophic Linkages: Literature Search and Synthesis

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Table of Contents

List of Tables

List of Figures

List of Appendices

Introduction

The Beaufort Sea borders the coast of northern Alaska from the Chukchi Sea, east to the Mackenzie River Delta and Amundsen Gulf of the Canadian Arctic (Figure 1). The Beaufort Sea Shelf is relatively narrow, ranging from about 90 km in the west to 50 km in the east (MMS 2003). A network of barrier islands and lagoons separate the nearshore (< 20 m depth) and offshore regions (BOEMRE 2010-048; Lowry and Frost 1981). The Beaufort Sea is ice covered for 9-10 months each year (Barnes et al. 1984).

Past studies of fish in the US Beaufort Sea (USBS) include the Outer Continental Shelf Environmental Assessment Program (OCSEAP) during the 1970s, a joint effort between the US Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) formerly Minerals Management Service (MMS) and the National Oceanic and Atmospheric Administration (NOAA). This body of work provides the first comprehensive assessment of marine and anadromous fishes in the region (Barnes et al. 1984). Regular fishery resource surveys have not been conducted in the Beaufort Sea. However, recent surveys of the nearshore (Johnson et al. 2010) and the offshore (BOEMRE 2010-048) regions by NOAA Fisheries provide an updated perspective on fish and their abundance and distribution (Appendix 1 and 2).

A synthesis of studies can present an overarching view of trophic relationships among individual species. A synthesis of trophic linkages for marine and anadromous fishes will provide necessary information to assess and manage the potential environmental effects of offshore developments to the Beaufort Sea ecosystem. The objective of this review was to perform a literature search and synthesis of Beaufort Sea higher trophic linkages, focusing on fish as prey, the diet of these fishes, and potential trophic competitors, to demonstrate where fish fit into the Beaufort Sea ecosystem.

This review has the following tasks: 1) synthesize existing literature linking fish as prey to a variety of predators in the USBS; 2) develop and present an overarching view of the many higher tropic linkages involving fish and their prey; 3) show the relative importance of a particular prey species among the diverse groups of predators and competitors, including marine mammals, birds, and fish; 4) construct and illustrate the tropic food web for the USBS, including specific fish species preyed upon by higher trophic level predators, the prey of the fish, and their potential competitors. The final product, a synthesis report and literature citations, will support BOEMRE

analysts currently conducting Environmental Impact Statements (EIS) under the National Environmental Policy Act (NEPA) for the Alaskan Arctic region.

Methods

Seven fish species were the focus of this review, including Arctic cod (*Boreogadus saida*), saffron cod (*Elginus gracilis*), capelin (*Mallotus villosus*), Pacific sand lance (*Amodytes hexapterous*), Pacific herring (*Clupea pallasi*), Arctic cisco (*Coregonus autumnalis*), and least cisco (*C. sardinella*). These fishes were chosen due to high local abundance, importance as prey to higher trophic level predators, and role as predators and trophic competitors with other key species in Beaufort Sea ecosystem.

We conducted a literature search to synthesize existing information for fish in the US Beaufort Sea (USBS) using bibliographic citation databases of scientific and technical journals, abstracts, and agency reports. The US Exclusive Economic Zone and Alaskan Arctic territorial waters were the focus of this synthesis for Task-1, to accomplish Tasks-2-4. As Beaufort Sea food web structure is likely similar to the adjacent Chukchi Sea and the Canadian Beaufort Sea, information from these areas was added to support the development of likely food web structure for the USBS. When information for the USBS or the Alaskan Arctic was not available, information from other Arctic regions was incorporated for species that occur in the Beaufort Sea.

Results and Discussion

This section presents information on the life history, distribution, and trophic interactions for the focal fish species. Trophic interactions are based on current knowledge of diet, predators, and potential trophic competitors in the USBS, and supplemented with information from regions outside of the Alaskan Arctic. Arctic and least ciscoes were combined for this synthesis. Fish species are cross referenced by prey items and predators with literature references in Tables 1 and 2. Food web diagrams illustrate trophic linkages between fish and their prey, predators, and competitors in the Alaskan Arctic (Figure 2-7).

The food webs presented are based on existing literature to convey the status of knowledge for these species in the Beaufort Sea ecosystem. Of the seven focal species investigated, the most complete understanding of food web structure and trophic pathways exists for Arctic cod. The food webs presented for other species are probably far more complex than indicated in this summary because these species are not well-studied in Beaufort Sea and the Alaskan Arctic.

Arctic Cod

Arctic cod are integral in the trophic pathways of Arctic marine food webs (Bradstreet et al. 1986; Craig and Haldorson 1981 OCSEAP; Schmidt et al. 1983 OCSEAP; Welch et al. 1992). Arctic cod are an important secondary consumer of zooplankton in the nearshore and offshore regions of the USBS (Frost and Lowry 1984). Higher trophic linkages between Arctic cod and predators are demonstrated through diet studies that use a variety of tools including, stomach content analysis (e.g., Divoky 1984), stable isotope analysis (e.g., Dehn et al. 2007), and most recently, fatty-acid signature analysis (e.g., Loseto et al. 2009). Several marine mammals and birds depend on Arctic cod as a primary prey item in the US Arctic.

Life History

Arctic cod are small, short-lived gadids that rarely exceed 300 mm in length, mature at age-2-3, and live to a maximum of 7 years (Bradstreet et al. 1986). In addition to their smaller maximum size, shorter life span, and early maturation, Arctic cod, unlike other marine gadids in northern environments, are believed to spawn only once (Craig et al. 1982b OCSEAP). Spawning in the Beaufort Sea occurs under ice during winter (Craig and Haldorson 1981). Arctic cod occur throughout the water column in nearshore and offshore locations (Lowry and Frost 1981) and often associate with ice (Welch et al. 1993). Arctic cod use fast ice and pack ice year round as foraging habitat and for protection from potential predators (Gradinger and Bluhm 2004). However, few studies have focused on the under-ice ecology of Arctic cod.

Distribution

Arctic cod have a circumpolar Arctic distribution (Welch et al. 1993). In the North American Arctic, Arctic cod occur from the northern Bering Sea north and east to the Beaufort

Sea, among the Arctic islands of Canada, and south to the Labrador Sea and northwest Atlantic (Bradstreet et al. 1986). In addition, they are broadly distributed throughout the Barents Sea and the Russian Arctic (Bradstreet et al. 1986). Arctic cod are abundant offshore in the northeastern Chukchi Sea and in the nearshore and offshore regions of the Beaufort Sea (Lowry and Frost 1981).

Several nearshore and shore-based sampling efforts have targeted Arctic cod and other fishes in the Alaskan Beaufort region. Arctic cod occur near barrier islands and in coastal lagoons as the dominant species during summer months (Craig et al. 1982b OCSEAP; Craig and Haldorson 1981 OCSEAP; Jarvela and Thorsteinson 1999). Young-of-the-year (YOY) and immature cod are common in coastal lagoons and adults move into these areas when water temperatures decrease (Craig et al. 1982a). Coastal lagoons in the Beaufort Sea region are important to Arctic cod, and several other fishes, as summer foraging areas when food in the marine environment is abundant (Craig and Haldorson 1981 OCSEAP). Arctic cod distribution and abundance varies annually in nearshore locations (Craig et al. 1982b OCSEAP; Craig and Haldorson 1981 OCSEAP; Johnson et al. 2010).

Offshore surveys in the USBS have been infrequent. Consequently, Arctic cod life history, distribution, and abundance in offshore areas are not well documented. Arctic cod were the most abundant fish captured by trawl sampling in the late 1970s-early 1980s at locations 50-150 km offshore during summer (Lowry and Frost 1981) and 175 km offshore during winter (Craig et al. 1982b OCSEAP). The most recent offshore survey in the US Beaufort Sea during summer 2008 was conceived and funded by BOEMRE and documented Arctic cod as the most abundant demersal and pelagic species captured from depths of 20-500 m using mid-water and bottom trawl sampling gear (Appendix 2). Peak density estimates for adult cod in the survey area were 150,000 fish·ha^{-1} at bottom depths of 100-350 m, and 160,000 fish·ha^{-1} for YOY cod at depths of 20-75 m (BOEMRE 2010-048).

Prey

Arctic cod consume a variety of prey, including benthic fauna, pelagic zooplankton, and organisms associated with the undersurface of ice such (Table 1 and Figure 2). Arctic cod are estimated to consume 6% of their body weight·day^{-1} during the short, productive Arctic summer (Craig and Haldorson 1981 OCSEAP). Copepods may be the most important diet component for

Arctic cod. Consumption of copepods in the Beaufort Sea has been estimated to be on the order of 1 million mt·year^{-1} (Frost and Lowry 1984).

Arctic cod diet varies with fish size or life stage. While YOY cod consume copepod early life stages almost exclusively, juveniles and adult cod consume adult copepods and a variety of other prey items. The diets of larval Arctic cod primarily consists of copepod nauplii (74% total items) and eggs (16%) (Michaud et al. 1996). Copepods, including nauplii and copepodites, are also the principal prey (86-99% total items) of YOY Arctic cod from 0-600 m depth during summer in the Canadian Arctic (Bradstreet et al. 1986). Similarly, the main prey items of YOY Arctic cod in the Beaufort Sea are copepod eggs and nauplii (64% total items) and calanoid copepods (26%) (Bradstreet et al. 1986). In general, juvenile and adult Arctic cod consume larger prey items such as adult copepods, amphipods, mysids and small fish, with smaller contributions from larvaceans, cumaceans, chaetognaths, and pteropods (Craig et al. 1982a; Craig et al. 1982b OCSEAP; Lowry and Frost 1981). Most studies that list fish as a diet component do not list species consumed (e.g., Craig et al. 1982a). However, Arctic cod consume smaller Arctic cod in shallow, nearshore locations in the Beaufort Sea (Frost and Lowry 1984) and consume capelin in the northern Bering Sea (Lowry and Frost 1981) and Barents Sea (Dolgov 2002).

Diets of Arctic cod vary by depth, season, and sample year. During summer in offshore waters of the northeastern Chukchi and Beaufort seas (40-400 m), Arctic cod consume primarily calanoid copepods (*C. hyperboreus* and *C. glacialis*) and the gammarid amphipod *Apherusa glacialis*, in addition to hyperiid amphipods (*Parathemisto spp.*), mysids, chaetognaths, euphausiids, and shrimps (Lowry and Frost 1981, Frost and Lowry 1984). Similar summer diets are reported for Arctic Canada (Bradstreet et al. 1986). Mysids, followed by amphipods and copepods, are the main diet component in the nearshore environment of the Alaskan Beaufort Sea, including barrier-island lagoons, during all seasons (Craig and Haldorson 1981 OCSEAP, Craig et al. 1982a, Craig et al. 1982b OCSEAP). Fatty acid signature analysis suggests that Arctic cod foraging offshore are more dependent on calanoid copepods than cod in the nearshore environment (Loseto et al. 2009). Copepods and fish are the main prey items in offshore under the ice during winter, while mysids are most important nearshore (Craig et al. 1982a). In the nearshore region, relative importance of different prey in the diet of Arctic cod varies annually, suggesting that the proportions of prey items may be based on availability (Craig et al. 1982a).

Predators

Studies of feeding ecology of vertebrate predators, including marine mammals and birds, confirm the widespread distribution of Arctic cod in the USBS and throughout the Arctic. In the Canadian Arctic, feeding aggregations of large numbers of marine mammal and bird predators targeting Arctic cod are almost always observed in late August-September, a period when cod concentrate in nearshore waters and in open water channels between ice (Bradstreet et al. 1986, Welch et al. 1993). This schooling pattern is also observed in nearshore areas of the Alaskan Beaufort Sea (Craig et al. 1982a). Several vertebrate predators are dependent on Arctic cod for food and for many predators there is no adequate replacement in terms of availability and energy value (Bradstreet et al. 1986). Arctic cod are the major link in the transfer of energy from lower to higher trophic levels in the Arctic (Bradstreet et al. 1986) for ice-associated and pelagic food webs (Bluhm and Gradinger 2008). Arctic cod are also important in the Alaskan Arctic ecosystem, specifically the Beaufort Sea, where the estimated amount of Arctic cod consumed by predators in is approximately 28,630 $mt \cdot yr^{-1}$ (Frost and Lowry 1984) .

Marine Mammals

Marine mammal predators of Arctic cod include beluga whale (*Delphinapterus leucas*), narwhal (*Monodon monoceros*), ringed seal (*Phoca hispida*), bearded seal (*Erignathus barbatus*), spotted seal (*Phoca largha*), ribbon seal (*Histriophoca fasciata*), harp seal (*Phoca groenlandicus*), and occasionally walrus (*Odobenus rosmarus*) (Frost and Lowry 1984, Bradstreet et al. 1986, Welch et al. 1993) (Table 2, Table 3, and Figure 2).

Ringed seals are present in the Beaufort Sea throughout the year where their local distribution and abundance is closely tied to ice conditions and prey distribution (Lowry et al. 1980, Frost and Lowry 1984). They forage on Arctic cod throughout the year (Bradstreet et al. 1986), but their reliance on Arctic cod as a primary food source varies seasonally. During the open water season, ringed seals forage continuously and their diet includes Arctic cod in addition to euphausiids, mysids, pelagic amphipods (*Parathemisto libellula*), benthic amphipods, and shrimps (Lowry et al. 1980, Frost and Lowry 1984, Bradstreet et al. 1986, Welch et al. 1993, Dehn et al. 2007). During late April-June they consume primarily benthic crustaceans (mysids, shrimp, amphipods), while diets are dominated by pelagic crustaceans (euphausiids, and

amphipods) during August-September, and by Arctic cod from November-early April, when estimated feeding rates are 8.4% of their body weight·day^{-1} (Lowry et al. 1980, Frost and Lowry 1984). Adult ringed seas in the Alaskan and Canadian Arctic have sexually heterogeneous diets, with male adult ringed seals consuming more zooplankton and females consuming more fish, mainly Arctic cod, as inferred from stable isotope analysis (Dehn et al. 2007). Consumption of Arctic cod by ringed seals in the Beaufort Sea also increases with predator age (Dehn et al. 2007). Ringed seals consume more Arctic cod than all other marine mammals and seabirds combined during the open water season in the Canadian Arctic (Bradstreet et al. 1986) and are the principal marine food for polar bears (*Ursus maritimus*) and Arctic foxes (*Alopex lagopus*) (Lowry et al. 1980; Thiemann et al. 2008). Because of the importance of Arctic cod in the diet of ringed seals, Arctic cod forms a major pathway from lower tropic levels to higher order vertebrate predators.

The relative importance of Arctic cod in the diets of other phocids varies by species and location. Spotted seals primarily consume teleost fishes, including Arctic cod in the northern Bering Sea (Dehn et al. 2007). Bearded seals are primarily benthic feeders of crustaceans and mollusks (Dehn et al. 2007) and will sometimes forage heavily on Arctic cod (Bradstreet et al. 1986, Welch et al. 1993). Ribbon seals in the northern Bering Sea consume Arctic cod (Dehn et al. 2007). Harp seals do not occur in the Alaskan Arctic. However, harp seals are primary consumers of Arctic cod throughout their range and forage on Arctic cod almost exclusively during summer in the Canadian Arctic (Bradstreet et al. 1986, Welch et al. 1993).

Beluga whales forage primarily on Arctic cod in the Beaufort Sea. Belugas migrate along the Northern Alaska coast during spring, arriving in the eastern Beaufort Sea in late May-early June, and appearing in the Mackenzie River estuary in late June-early July (Frost and Lowry 1984). Some whales remain in the estuary and others occupy the eastern Beaufort Sea during July and August (Frost and Lowry 1984). Belugas are estimated to consume 5.1% of their total body weight·day^{-1} while foraging in the Beaufort Sea, with 80% of their diet consisting of Arctic cod and 20% of other fishes, cephalopods, and shrimps (Frost and Lowry 1984). Fatty-acid signature analysis of blubber from belugas foraging in the Beaufort Sea demonstrates that Arctic cod are the most important summer food source for belugas in this region (Loseto et al. 2009). This study identifies spatially explicit size-related differences in foraging habitat with larger-sized individuals foraging on offshore Arctic cod and smaller individuals foraging on Arctic cod in

nearshore waters (Loseto et al. 2009). Belugas in the Barents Sea near Svalbard forage heavily on Arctic cod and capelin, as inferred from fatty-acid signature analysis (Dahl et al. 2000). Arctic cod are likely important in the summer diet of belugas throughout their range.

Narwhal forage heavily on Arctic cod along ice edges during the spring and summer, often observed in feeding aggregations with belugas and harp seals in waters of the Canadian Arctic and Greenland (Bradstreet et al. 1986; Laidre and Heide-Jorgensen 2005; Welch et al. 1993). Since narwhals are only incidentally found offshore in the Alaskan Arctic (Rice 1998), they are likely not major predators of Arctic cod in the Beaufort Sea.

Marine Birds

Several species of marine birds commonly forage in the Beaufort Sea on organisms connected to the pelagic food web, including Arctic cod (Frost & Lowry 1984). Large schools of Arctic cod in open channels between ice and in the nearshore environment are particularly vulnerable to avian predators (Welch et al. 1993). Most marine birds that prey on Arctic cod in this region are migratory and are only present during the open water season (Divoky 1984). Although, the pelagic region of the Beaufort Sea has the lowest bird densities of any sea adjacent to Alaska, this location is an important summering area for non-breeding birds, post-breeding staging area, and migratory pathway (Divoky 1984).

Avian predators of Arctic cod in the Beaufort Sea, including percent total, offshore, and nearshore composition of cod in the diet when available, are the following: thick-billed murre (*Uria lomvia*) (90-100% total); common murre (*Uria aalge*); black guillemot (*Cepphus grylle*) (80-100% total); black-legged kittiwake (*Rissa tridactyla*) (90% total, 90% offshore, 27% nearshore); northern fulmar (*Fulmarus glacialis*); Arctic tern (*Sterna paradisaea*) (40% total, 78% offshore, 21% nearshore); glaucous gull (*Larus hyperboreus*) (50% total, 56% offshore, 33% nearshore); Sabine's gull (*Xema sabini*) (10% total, 67% offshore, 3% nearshore); ivory gull (*Pagophila euburnea*) (80% total); Ross's gull (*Rhodostethia rosea*) (40% total), jaegers (*Stercorarius spp.*) (40% total); and loons (*Gavia spp.*) (50% total) (Divoky 1984, Frost and Lowry 1984, Bradstreet et al. 1986, Welch et al. 1993) (Table 2, Table 3, and Figure 2).

The feeding habits and large-scale distributions of the more numerous marine birds that occupy the Beaufort Sea during summer are presented by Divoky (1984). Data are collected from at-sea census and stomach contents during early August-mid September in 1971-72 and

1976-78. Species are separated based on foraging strategy, including surface-foragers and divers.

Surface-foragers that prey on Arctic cod include Arctic tern, black-legged kittiwake, glaucous gull, Sabine's gull, Ross's gull, and parasitic (*Stercorarius parasiticus*) and pomarine jaegers (*S. pomarinus*) (Divoky 1984). Glaucous gull accounted for 50% of the biomass of surface foragers observed. Arctic terns, jaegers, glaucous and Sabine's gulls over-winter in the tropics and forage in the Beaufort Sea after breeding inland on the tundra. Black-legged kittiwakes winter in the subarctic. Ross's gull forage in the Beaufort Sea after breeding in Siberia.

Diving birds that prey on Arctic cod are Arctic loon (*Gavia arctica*) and red-throated loon (*G. stellate*), thick-billed murre, and black guillemot (Divoky 1984). Loons nest in freshwater habitats inland and forage in the Beaufort Sea along the Alaska coast with their young after fledging. The red-throated loon is classified as a Bird of Conservation Concern by the USFWS (2008) due to declining numbers on Alaskan nesting grounds. Thick-billed murre that forage in the Beaufort during summer are non-breeders from colonies to the east in Canada and south in the Bering Sea in Alaska. Black guillemots breed in coastal debris in colonies along the Beaufort coast and feed their young almost exclusively Arctic cod. These diving species reside in the subarctic and north temperate waters during the winter.

Diets of marine birds foraging in nearshore and offshore locations in the Beaufort Sea are compared by Divoky (1984). Nearshore stomach samples contain a greater variety of prey items, whereas Arctic cod are the primary prey item of seabirds sampled offshore. Kittiwakes are more common in nearshore samples where amphipods and other zooplankton are their main prey items. However, kittiwakes primarily consume Arctic cod offshore. Jaegers foraging offshore obtain arctic cod by kleptoparasitism from glaucous gulls and kittiwakes. Arctic cod are the primary prey of Arctic terns and Sabine's gull in the offshore environment where both species also consume zooplankton.

Competitors

Bowhead whales (*Balena mysticetus*), ringed seals, and Arctic cod are trophic competitors for zooplankton prey in the US Arctic (Frost and Lowry 1984; Lowry and Burns 1980; Lowry et al. 1980) (Figure 2). Bowhead whales use the Beaufort Sea as a summer and early autumn

foraging area (Lowry and Burns 1980) and ringed seals are present throughout the year (Lowry et al. 1980). The dominant food items consumed by bowhead whales (91-99% of contents) are copepods (*Calanus hyperboreus*) and euphausiids (*Thysanoessa raschii*), and additional items include mysids, pelagic amphipods, shrimp, and small fish (Lowry and Burns 1980). The primary zooplankton prey of ringed seals are euphausiids, pelagic amphipods, and mysids (Frost and Lowry 1984; Lowry et al. 1980; Lowry and Burns 1978). The consumption rate of bowhead whales in the USBS is estimated as 3% of their total body weight·day^{-1} (Frost and Lowry 1984). Mean annual consumption rate of ringed seals in the USBS is 6% of their total body weight·day^{-1} ±1% SE (Frost and Lowry 1984). The daily food consumption rate of Arctic cod is approximately 6% of their total body weight·day^{-1} (Frost and Lowry 1984).

Other marine species are potential competitors with Arctic cod. Several marine birds that depend heavily on copepods, amphipods, euphausiids and other zooplankton prey may compete with Arctic cod in the nearshore environment, including gulls, Arctic terns, oldsquaw, and eiders (Divoky 1984; Frost and Lowry 1984). Capelin and Arctic cod may compete for copepods where their range and diet overlap in areas of the Alaskan Arctic, as suggested for the Barents Sea (Orlova et al. 2009). Arctic cod may compete with other zooplanktivorous fishes in the Beaufort Sea, including saffron cod, Pacific herring, and Pacific sand lance.

Saffron Cod

Life History

Saffron cod move nearshore to spawn during winter along the Beaufort Sea coast (Schmidt et al. 1983 OCSEAP), including the mouth of the Colville River (Craig and Haldorson 1981 OCSEAP). Age at maturity is not reported for the Beaufort Sea, but is 2-3 years in Siberian waters (Morrow 1980). Saffron cod in the Beaufort Sea move offshore to feeding areas during summer (Schmidt et al. 1983 OCSEAP). Saffron cod are utilized as food by northern indigenous peoples (Frost and Lowry 1981).

Distribution

The Beaufort Sea is the northern limit to the distribution of saffron cod (Craig and Haldorson 1981 OCSEAP). Although saffron cod are widely distributed along the Alaskan Beaufort Sea

coast, this species is not abundant in the region (Craig and Haldorson 1981 OCSEAP; Schmidt et al. 1983 OCSEAP). Saffron cod occur in nearshore lagoons during winter (Craig 1984; Craig and Haldorson 1981 OCSEAP). Saffron cod are abundant during the summer months in the northern Bering and southern Chukchi seas (Fechhelm et al. 1984; Lowry and Frost 1981).

Prey

Diet information for saffron cod is not available for the Beaufort Sea. Diet for this species can be inferred from other locations (Table 1 and Figure 3). Craig and Haldorson (1981 OCSEAP) examined samples captured from under the ice in Kotzebue Sound in November and found the stomachs to contain by weight 68% fish, 18% mysids, and 13% decapods. In Siberian waters saffron cod consume fish, mysids, amphipods, and polychaetes (Morrow 1980).

Predators

Ringed seals consume saffron cod in the Beaufort Sea (Dehn et al. 2007; Lowry et al. 1980; Lowry and Burns 1978) with significant seasonal and regional differences in diet based on stomachs collected at eight locations along the Alaskan coast (Lowry et al. 1980). Saffron cod were the most important food item during the summer in the nearshore environment of the northeastern Bering and southeastern Chukchi Seas (Lowry et al. 1980). Female ringed seals in the Bering sea ate more saffron cod than males (Lowry et al. 1980). The autumn diet of ringed seals in Norton Sound is mainly saffron cod (Lowry et al. 1980).

Belugas consume saffron cod in the Alaskan Arctic (Dahl et al. 2000), including the Beaufort Sea (Frost and Lowry 1984). Saffron cod are a major diet component of belugas, ringed seals, and spotted seals in the northern Bering and southern Chukchi Seas (Frost and Lowry 1981). Black-legged kittiwakes, and thick-billed and common murres consume saffron cod in the Chukchi Sea near Cape Lisborne and Cape Thompson (Springer and Roseneau 1978). Red-throated loons provision their chicks with saffron cod in the Beaufort Sea near the Colville River Delta and near Point Lay in the Chukchi Sea (Rizzolo and Schmutz 2010). Predators of saffron cod are listed in Table 2 and illustrated in Figure 3.

Competitors

Saffron cod is one of many species that consumes zooplankton in the Beaufort Sea. The diet and distribution of saffron cod in the Beaufort Sea overlaps with ringed seals, bowhead whales, and Arctic cod (Frost and Lowry 1984; Lowry and Burns 1980; Lowry et al. 1980) (Figure 3). Depending on population size and energy demands of saffron cod in this region, these species could be trophic competitors.

Capelin

Life History

Capelin are important to Arctic food webs as a main consumer of zooplankton and major prey item for marine mammals, birds, and fish (Dolgov 2002; Yndestad and Stene 2002). Capelin migrate to shallow nearshore locations of the Beaufort Sea to spawn in mid-to late summer (Craig and Haldorson 1981 OCSEAP). Spawning occurs near Point Barrow during July and August (Schmidt and McMillan 1983). Spawning occurs earlier, during May-July, in Prince William Sound, south central Alaska (Brown 2002). Age at maturity is one year and maximum age is generally three years (Hart 1973). Capelin are semelparous spawners (Murua and Saborido-Rey 2003).

Distribution

Capelin have a northern circumpolar distribution that includes the Arctic (Fishbase 2011; Yndestad and Stene 2002). Capelin are one of the most abundant epipelagic fishes in the coastal region of the Alaskan Beaufort Sea during late summer (BOEMRE 92-0011; Jarvela and Thorsteinson 1999; Johnson et al. 2010; Thorsteinson et al. 1990). Capelin are distributed over the continental shelf for most of the year and concentrate nearshore during summer (Brown 2002). Nearshore habitats are particularly important for capelin and other forage fish species, such as Pacific sand lance, and Pacific herring (Brown 2002; Norcross et al. 2001; Robards et al. 1999).

Prey

Capelin consume zooplankton, including calanoid copepods (*Calanus spp.*), hyperiid

amphipods (*Themisto spp.*), and euphausiids (*Thysanoessa spp.*) (Dalpadado et al. 2001; Hart 1973; Orlova et al. 2009; Yndestad and Stene 2002). Capelin are one of the most efficient grazers of zooplankton in the Barents Sea (Hassel et al. 1991). Infrequent studies of capelin in the Alaskan Arctic identify prey items as mysids, calanoid copepods, harpacticoid copepods, euphausiids, hyperiid amphipods, crustacean larvae, fish larvae, and fish eggs (Craig and Schmidt 1985; Fechhelm et al. 1984) (Table 1 and Figure 4).

Predators

Capelin are an important prey resource for marine mammals, birds, and fish throughout their range (Table 2 and Figure 4). Spotted seal consume plankton in the northern Bering Sea region, and the presence of capelin in the diet increases with age (Dehn et al. 2007). Capelin are a primary prey item of harp seal, and to a lesser extent ringed and bearded seals, in the Barents Sea (Dolgov 2002). Fatty acid signature analysis of blubber from belugas foraging near Svalbard suggests that this population forages heavily on capelin and Arctic cod (Dahl et al. 2000). Black-legged kittiwake consume capelin in the Gulf of Alaska (Ainley et al. 2003). Kittiwakes consume capelin in the Barents Sea, as do murres and guillemot (Dolgov 2002). Arctic cod consume capelin nearshore in the Beaufort and Barents seas, though capelin are not a primary prey item of Arctic cod (Lowry and Frost 1981, Dolgov 2002). Population dynamics of major predators in the Barents Sea, Canadian Arctic, and North Atlantic, including Atlantic cod (*Gadus morhua*) and Atlantic herring (*Clupea harengus*) (Hjermann et al. 2010; Orlova et al. 2009) are linked to interannual variability in capelin populations (Carscadden et al. 2002; Dolgov 2002). Population fluctuations of capelin and other forage fishes likely influence higher order trophic interactions in the Alaskan Arctic.

Competitors

Capelin may compete with other zooplanktivorous fishes in the Alaskan Arctic, including Arctic cod, Pacific herring, and Pacific sand lance. These fishes may compete for calanoid copepods, amphipods, and mysids in particular. Birds that consume zooplankton are also potential competitors with capelin.

Pacific Sand Lance

Life history

Pacific sand lance are a schooling and semi-demersal fish that bury in sand and gravel substrates. Sand lance are an important forage fish for marine mammals, birds, and fish. Sand lance form dense aggregations during spawning events in shallow, nearshore locations (Robards et al. 1999; Thedinga et al. 2008). Sand lance mature at age-2 and spawn intertidally in fine gravel or sand in late spring or early fall in Alaska (Robards et al. 1999). Spawning location is highly selective, related to substrate grain size (Robards et al. 1999).

Distribution

Pacific sand lance have a circumpolar boreal-Arctic distribution, including Arctic Alaska and the North Pacific (Fishbase 2011; Love et al. 2005). In Alaska, sand lance are abundant in shallow, nearshore sand and gravel habitats in the Gulf of Alaska, Bering Sea, and Aleutian Islands (Robards et al. 1999; Thedinga et al. 2008). The distribution of sand lance in the Beaufort Sea is not documented.

Prey

Pacific sand lance consume zooplankton (Fishbase 2011) (Table 1 and Figure 5).

Predators

Pacific sand lance are the third most frequently consumed fish in the diet of ringed seals in the Beaufort Sea, after Arctic and saffron cod (Dehn et al. 2007). Spotted seal consume sand lance in the northern Bering Sea (Dehn et al. 2007). Arctic terns consume sand lance in the Beaufort Sea (Divoky 1984). However, sand lance predation by marine birds is not well-documented in the Alaskan Artic. Black-legged kittiwakes consume sand lance in nearshore areas of the Gulf of Alaska (Ainley et al. 2003). Sand lance and herring are the primary prey of kittiwakes in Prince William Sound, Alaska (Suryan et al. 2002) and constitute 80% of the diet fed to chicks (Ailey et al. 2003). Predators of Pacific sand lance are listed in Table 2 and illustrated in Figure 5.

Competitors

Sand lance eat zooplankton, and may compete with other forage fishes in the Alaskan Arctic that have diet and range overlap, including Arctic cod, Pacific herring, and capelin.

Pacific Herring

Life History

Pacific herring are a long-lived forage fish with a maximum reported age of 19 years (Fishbase 2011). Pacific herring inhabit continental shelf regions and aggregate in coastal locations to spawn (Carlson 1980; Tanasichuk et al. 1993). Herring are iteroparous and spawn in the late spring in the Canadian Beaufort Sea (Tanasichuk et al. 1993), Prince William Sound Alaska (Norcross et al. 2001), and Lynn Canal in southeast Alaska (Carlson 1980). Herring are an important forage fish in northern waters, transferring energy from oceanic food webs to coastal areas (Prokopchuk 2009).

Distribution

Pacific herring inhabit the continental shelf and coastal regions of the Arctic, including the Beaufort Sea, and the North Pacific (Fishbase 2011). Herring aggregate and spawn in coastal areas near the Mackenzie River in the Canadian Beaufort Sea (Tanasichuk et al. 1993). Coastal habitat use in the Alaskan Beaufort Sea is not documented.

Prey

Pacific herring mainly eat zooplankton (Table 1 and Figure 6). Fatty acid signature analysis of herring from the Canadian Beaufort Sea suggests dependency on a copepod-based foodweb (Loseto et al. 2009). Herring in the Beaufort Sea consume mainly copepods, benthic infauna, and benthic organisms (Lawrence et al. 1984; Shields 1985). Studies in Prince William Sound, Alaska report a diverse diet, containing copepods (*Neocalanus cristatus* and *Calanus spp*), fish eggs, barnacle nauplii, larvacean, mysid, and euphausiid (Norcross et al. 2001). Diet of Atlantic herring (*Clupea harengus*) in the Barents Sea and northern Norwegian waters is also diverse, including hyperiid amphipods, calanoid copepods (*C. finmarchius*), euphausiids, larvaceans, cladocerans, and larval bivalves (Prokopchuk 2009). Atlantic herring are the main consumer of

plankton among pelagic fishes in the Barents Sea ecosystem (Dommasnes et al. 2004) and also consume small fishes, including capelin (Dolgov 2002). Diet variability is a function of seasonal and annual prey availability in the Gulf of Alaska and Barents Sea (Norcross et al. 2001, Prokopchuk 2009).

Predators

Pacific herring are frequently consumed by spotted seals in the northern Bering Sea, followed by gadids, capelin and sand lance (Dehn et al. 2007). Belugas consume Atlantic herring in the Barents Sea (Frost and Lowry 1984; Dahl et al. 2000), and are likely predators of herring in the Beaufort Sea. Herring and sand lance are the primary prey of kittiwakes in Prince William Sound, south central Alaska (Suryan et al. 2002) and constitute 80% of the diet fed to chicks at colonies in this location (Ainley et al. 2003). Avian predators of herring are not documented in the Alaskan Arctic, but species that consume herring at other locations, including kittiwake, are likely predators in the Beaufort Sea. Inconnu (*Stenodus leucithys*) are predators of herring when range overlap occurs near the Mackenzie River delta in the Canadian Beaufort Sea (Lawrence et al. 1984; Shields 1985). Predators of Pacific herring are listed in Table 2 and illustrated in Figure 6.

Competitors

Forage fishes that consume zooplankton, such as Arctic cod, capelin, and sand lance, are potential competitors of Pacific herring. Arctic cod are the most likely competitor of herring in the Beaufort Sea due to their high abundance in nearshore and offshore areas.

Arctic Cisco and Least Cisco

Life History

Ciscoes are anadromous fishes that inhabit the river deltas and coastal environment of the Beaufort Sea. Arctic cisco in the Alaskan Beaufort Sea originate from the Mackenzie River in Canada (Colonell and Gallaway 1997; Gallaway et al. 1983). YOY Arctic cisco are transported downstream during breakup and flooding events. Young fish that enter the marine environment are transported west along the coast into Alaskan waters. Coastal transport is driven by the

strength and direction of the prevailing winds, affecting recruitment strength of cisco to the Colville River system (BOEMRE 2007-042; Fechhelm and Griffiths 1990). Fish that reach the Colville or the Sagavanirktok rivers in Alaska overwinter in these locations (Moulton 1989). Adults and older juveniles enter the nearshore environment following breakup to forage on marine organisms, a behavior that replenishes energy reserves for spawning and the subsequent winter (Craig and Haldorson 1981 OCSEAP; Moulton et al. 1986). Fish remain in brackish and nearshore areas during summer and are not caught offshore (Craig and Haldorson 1981 OCSEAP). Arctic cisco that reach the Colville River remain in this system until sexual maturity around age 6-8 when mature adults migrate back to the Mackenzie River to spawn (Craig and Haldorson 1981 OCSEAP; Colonell and Gallaway 1997).

Resident populations of least cisco occur in the Colville River and in numerous streams to the west along the Alaska coast (Schmidt et al. 1983 OCSEAP). Least cisco overwinter in the Colville River, but not other Alaska rivers (Craig 1989; Craig and Haldorson 1981 OCSEAP). Similar to Arctic cisco, least cisco overwinter in brackish river deltas along the coast and enter the nearshore environment of the Beaufort Sea after breakup to forage on marine organisms (Schmidt et al. 1983 OCSEAP). The spring migration of least cisco is not as extensive as Arctic cisco (Schmidt et al. 1983 OCSEAP).

Ciscoes make annual upstream migrations to spawn multiple times in their adult life. Arctic cisco that return to the Mackenzie River to spawn remain in that system to spawn in subsequent years (Bond and Erickson 1997). Least cisco spawn in the Colville River, Alaska, and the Mackenzie and upper Yukon rivers in Canada (Craig and Haldorson 1981 OCSEAP; Craig 1989; Fishbase 2011). Ciscoes reach maximum age at 10-14 years, with some individuals living as many as 19 years (Craig and Haldorson 1981 OCSEAP; Craig 1989).

Distribution

Arctic cisco are distributed along the coast of the western North American Arctic, and the Arctic coast of Europe and Russia (Schmidt et al. 1983 OCSEAP; Fishbase 2011). Least cisco are distributed across the Canadian Arctic to Bristol Bay, Alaska (Fishbase 2011). Least cisco are more widely distributed than Arctic cisco in northern Europe and Russia, with spawning populations in several river systems (Fishbase 2011).

Prey

The diet of ciscoes depends upon life stage and seasonal distribution in marine or freshwater environments (Table 1 and Figure 7). Ciscoes consume mainly mysids and amphipods during summer in the nearshore environment (Schell et al. 1982 OCSEAP). Mysids account for 70-87% of the marine diet of Arctic cisco and 66-69% for least cisco (Craig and Haldorson 1981 OCSEAP). Ciscoes overwintering in river deltas along the Beaufort Sea coast consume mainly amphipods in brackish waters (Craig and Haldorson 1981 OCSEAP) and chironomid insect larvae further upstream (Schell et al. 1982 OSCEAP). Arctic and least cisco also consume copepods, polychaetes, insects, and larval fish (Schmidt et al. 1983 OCSEAP). Ciscoes from the Colville River system sampled in nearshore lagoons are almost entirely dependent upon the marine ecosystem for their nutrients during summer (Schell et al. 1982 OCSEAP). After ciscoes enter the Colville River in the fall, their food habitats shift to dependence on freshwater, detrital peat food webs as they forage on insect larvae and other freshwater invertebrates (Schell et al. 1982 OCSEAP).

Predators

Cisco predators are not well documented. Red-throated loons consume least cisco when foraging in the Colville River Delta (Rizzolo and Schmutz 2010) (Table 2 and Figure 7). Beluga whales and ringed seals likely consume ciscoes, because they are major predators of other nearshore fishes in the Alaskan Arctic (Table 2 and Figure 7). Inconnu and other piscivorous fishes may consume cisco in brackish river deltas and freshwater rearing and spawning habitat (Vanessa von Biella, US Geological Survey, personal communication) (Table 2 and Figure 7).

Competitors

Trophic competitors of ciscoes may include other zooplanktivorous fishes and birds that inhabit brackish river deltas and the nearshore marine environment during summer.

Table 1. Prey of focal fish species. Literature references are listed as letters. References from locations outside of the Alaskan Arctic are italicized and the location is provided. General prey items are indicated when more specific information is not available.

Fish Predator	Arctic cod	Saffron cod	Capelin	Pacific Sand lance	Pacific Herring	Arctic and Least Cisco
Prey						
Zooplankton			*m*, *x*	j		
Bivalve						
Larvae					*t*	
Pteropod	c, d, p					
Cladoceran					*t*	
Insect						v
Chironomid						
Larvae					n, u	u
Crustacean						d
Larvae			e, i			
Decapod		b				
Copepod	b, k		*l*		n, u	d, v
Calanoid	a, c, d, *f*, o, p		e, h, *s*		o, t	
Harpacticoid			e, i			
Nauplii	*r*					
Eggs	*r*					
Cumacean	c, d, p					
Amphipod	b	*q*	e, h, *l*			b, d, t
Gammarid	c, d, p					

Table 1. Continued.

Fish Predator	Arctic cod	Saffron cod	Capelin	Pacific Sand lance	Pacific Herring	Arctic and Least Cisco
Prey						
Hyperiid	d, p		*g*		*t*	
Mysid	b, c, d, p	b, *q*	e, i			b, d, u
Euphausiid	p		e, i, *l*		*t*	
Shrimp	p					
Chaetognath	c, d, p					
Marine worms			*l*			
Nematode					n, u	
Polychaete	*q*					v
Larvacean	c, d, p				*t*	
Fish	c, d, *h*, p	b, *q*	*l*		*h*	d
Larvae			e, i			v
Eggs			e, i			
Arctic cod	k					

Referenced literature, including location when outside of the Alaskan Arctic: a) (Bradstreet et al. 1986); b) (Craig and Haldorson 1981 OCSEAP); c) (Craig et al. 1982a); d) (Craig et al. 1982b OCSEAP); e) (Craig and Schmidt 1985); f) (Dahl et al. 2000) Barents Sea; g) (Dalpadado et al. 2001) Barents Sea; h) (Dolgov 2002) Barents Sea; i) (Fechhelm et al. 1984); j) (Fishbase); k) (Frost and Lowry 1984); l) (Hart 1973) British Columbia Canada; m) (Hassel et al. 1991) Barents Sea; n) (Lawrence et al. 1984); o) (Loseto et al. 2009); p) (Lowry and Frost 1981); q) (Morrow 1980) Russian Arctic; r) (Michaud et al. 1996) Greenland; s) (Orlova et al. 2009) Barents Sea; t) (Prokopchuk 2009); u) (Schell et al. 1982 OCSEAP); v) (Schmidt et al. 1983 OCSEAP); w) (Shields 1985); x) (Yndestad and Stene 2002) Barents Sea.

Table 2. Predators of focal fish species. Literature references are listed as letters. References from locations outside of the Alaskan Arctic are italicized and the location is provided. Likely predators of ciscoes in the Alaskan Arctic region are indicated (X).

Fish Prey	Arctic cod	Saffron cod	Capelin	Pacific Sand lance	Pacific Herring	Arctic and Least Cisco
Predator						
Marine Mammal						
Ringed seal *Phoca hispida*	b, d, h, m, r	d, g, m	*f*	d		X
Spotted Seal *P. largha*	d	g	d	d	d	
Harp seal *P. groenlandicus*	*b, s*		*f*			
Bearded seal *Erignathus barbatus*	b, d, s		*f*			
Ribbon Seal *Histriophoca fasciata*	d					
Beluga whale *Delphinapterus leucas*	b, *c*, h, l, s	*c*, g	*c*		*c*, h	X
Narwhal *Monodon monoceros*	*b, j, s*					
Marine Bird						
Thick-billed murre *Uria lomvia*	b, e, h	q	*f*			
Common murre *U. aalge*	b, e, h	q	*f*			

Table 2. Continued.

Fish Prey	Arctic cod	Saffron cod	Capelin	Pacific Sand lance	Pacific Herring	Arctic and Least Cisco
Predator						
Marine Bird						
Black guillemot *Cepphus grille*	b, e, *t*		*f*			
Northern fulmar *Fulmarus glacialis*	b, e, s, *t*					
Black-legged kittiwake *Rissa tridactyla*	b, e, h, s, *t*	q	a, *f*	a, s	a, s	
Arctic tern *Sterna paradisaea*	b, e, h, s, *t*			e		
Glaucous gull *Larus hyperboreus*	b, e, h, s, *t*					
Ivory gull *Pagophila euburnea*	b, e, h					
Sabine's gull *Xema sabini*	b, e, h					
Ross's gull *Rhodostethia rosea*	b, e, h					
Arctic loon *Gavia arctica*	e, h					
Red-throated loon *G. stellate*	e, h	o				o

Table 2. Continued.

Fish Prey	Arctic cod	Saffron cod	Capelin	Pacific Sand lance	Pacific Herring	Arctic and Least Cisco
Predator						
Marine Bird						
Parasitic Jaeger *Stercorarius parasiticus*	e, h					
Pomarine Jaeger *S. pomarinus*	e, h					
Fish						
Arctic cod *Boreogadus saida*	g		*f*, g			
Atlantic cod *Gadus morhua*			*f, i, n*			
Atlantic herring *Clupea harengus*			*f, i*			
Inconnu *Stenodus leucichthys*					k, p	X

Referenced literature, including location when outside of the Alaskan Arctic: a) (Ainley et al. 2003) Prince William Sound, Alaska; b) (Bradstreet et al. 1986) Alaskan and Canadian Beaufort Sea; c) (Dahl et al. 2000) Barents Sea; d) (Dehn et al. 2007) Alaskan and Canadian Beaufort Sea; e) (Divoky 1984); f) (Dolgov 2002) Barents Sea; g) (Frost and Lowry 1981); h) (Frost and Lowry 1984); i) (Hjermann et al. 2010); j) (Laidre and Heide-Jorgensen 2005) Canadian Arctic and Greenland; k) (Lawrence et al. 1984); l) (Loseto et al. 2009) Canadian Beaufort Sea; m) (Lowry et al. 1980); n) (Orlova et al. 2009); o) (Rizzolo and Schmutz 2010); p) (Shields 1985); q) (Springer and Roseneau 1978); r) (Suryan et al. 2002) Prince William Sound, Alaska; s) (Welch et al. 1993) Canadian Arctic; t) (Weslawski et al. 1994) Russian Arctic.

Table 3. Proportion of Arctic Cod in the diet of marine mammal and avian predators. Literature references are listed as letters.

Predator	Proportion	Reference(s)
Beluga Whale	80%	a,d,e
Ringed Seal*	up to *100%*	a,b,d,e,f
Thick-billed murre	90-100%	a,c,d,f
Black guillemot	80-100%	a,c,d,f
Black-legged kittiwake	90%	a,c,d,f
Arctic tern	40%	a,c,d,f
Glaucous gull	50%	a,c,d,f
Sabine's gull	10%	a,c,d,f
Ivory gull	80%	a,c,d,f
Ross's gull	40%	a,c,d,f
Jaegers	40%	a,c,d,f
Loons	50%	a,c,d,f

* Proportion of Arctic cod in the diet of ringed seals is estimated from the literature.

Referenced literature: a) Bradstreet et al. 1986; b) Dehn et al. 2007; c) Divoky 1984; d) Frost and Lowry 1984; e) Lowry et al. 1980; f) Welch et al. 1993.

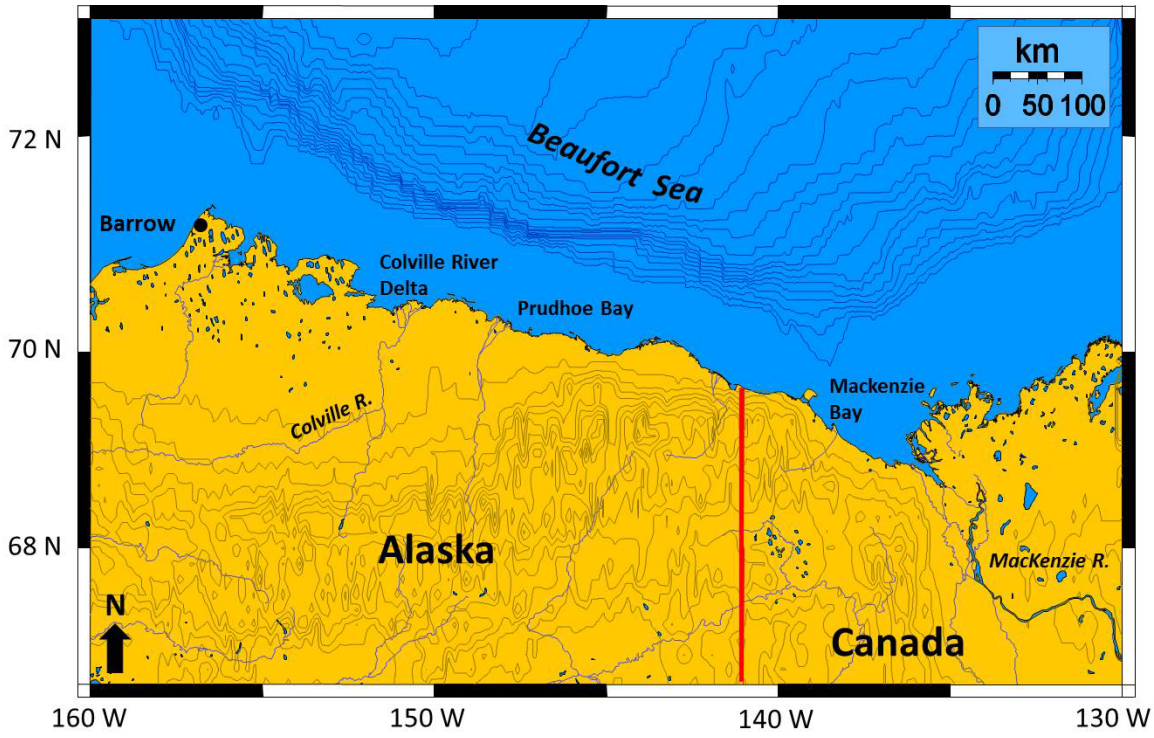

Figure 1. Map of the Beaufort Sea

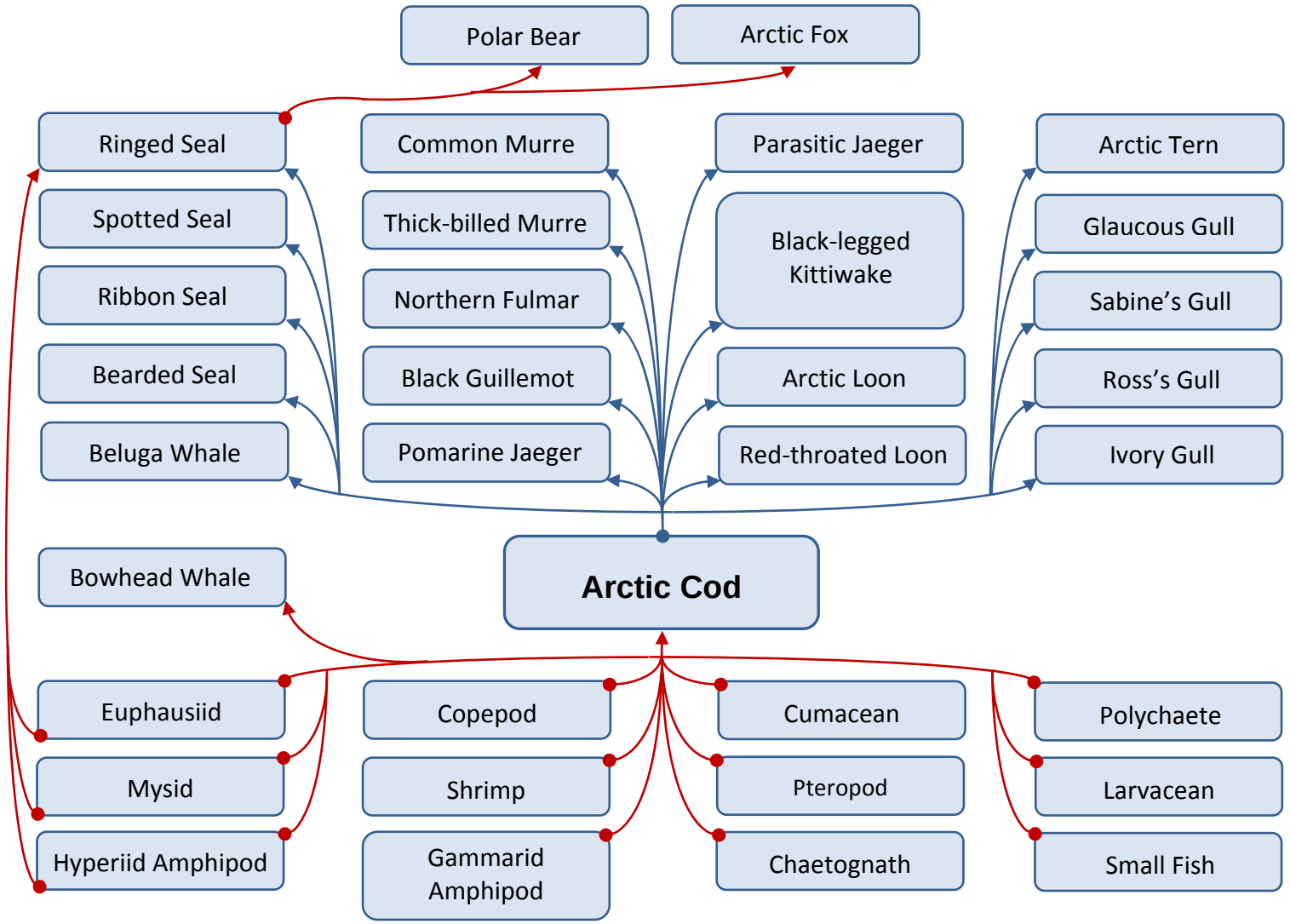

Figure 2. Trophic linkages of Arctic cod in an Alaskan Arctic food web. Predators and Arctic cod are linked by blue lines. Arctic cod prey and main trophic competitors are linked by red lines. Small fish as prey include Arctic cod and larval capelin (Table 1).

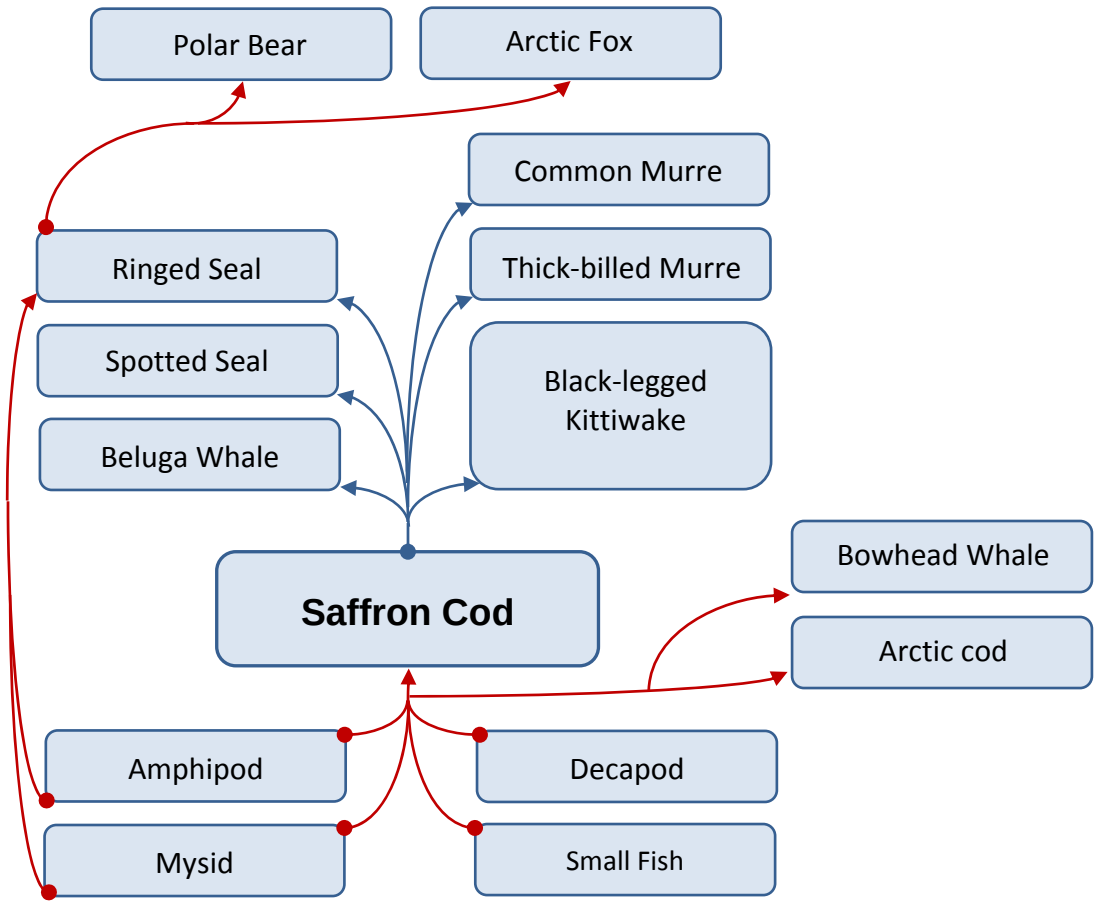

Figure 3. Trophic linkages of saffron cod in an Alaskan Arctic food web. Predators and saffron cod are linked by blue lines. Saffron cod prey and main trophic competitors are linked by red lines. Small fish as prey are not specifically referenced (Table 1).

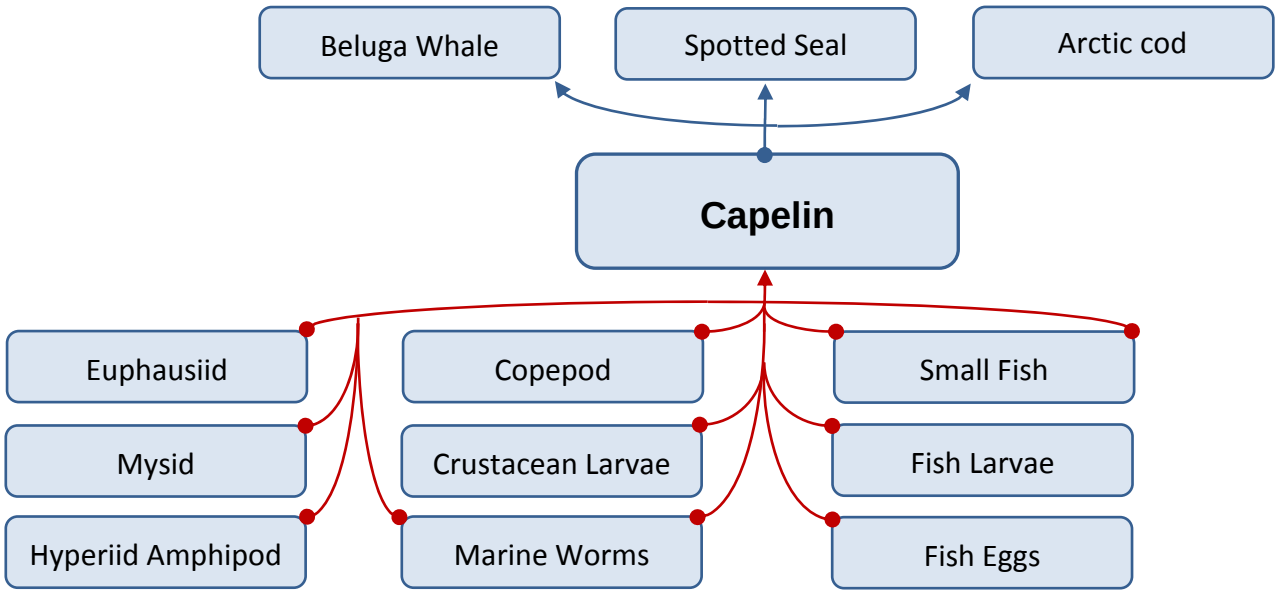

Figure 4. Trophic linkages of capelin in an Alaskan Arctic food web. Predators and capelin are linked by blue lines. Capelin prey are linked by red lines. Small fish as prey are not specifically referenced (Table 1).

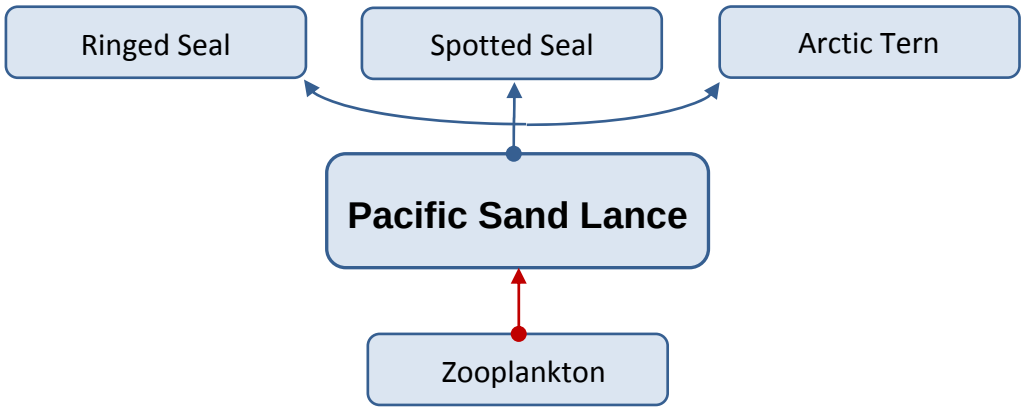

Figure 5. Trophic linkages of Pacific sand lance in an Alaskan Arctic food web. Predators and sand lance are linked by blue lines. A red line links sand lance prey.

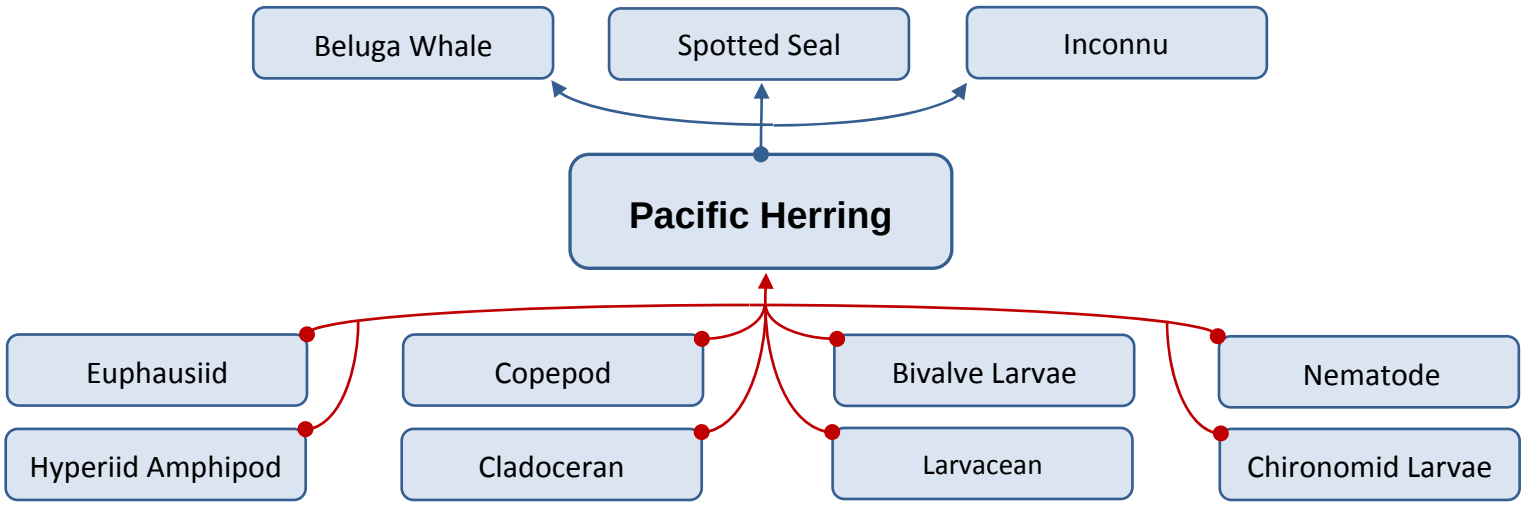

Figure 6. Trophic linkages of Pacific herring in an Alaskan Arctic food web. Predators and herring are linked by blue lines. Herring prey are linked by red lines.

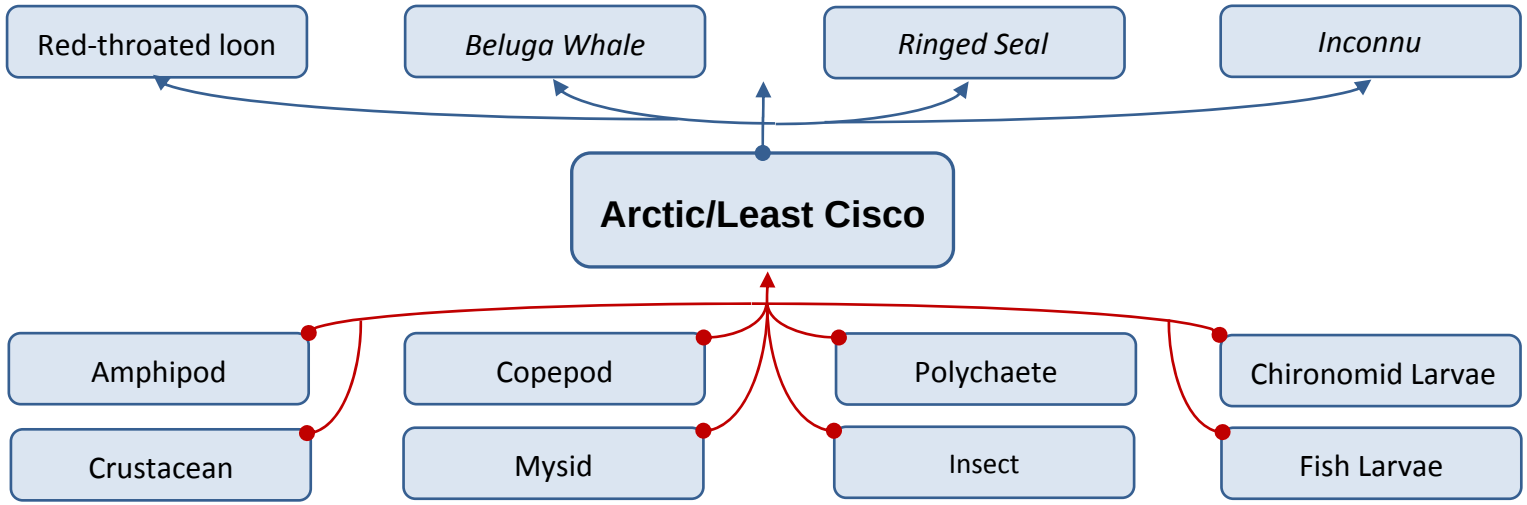

Figure 7. Trophic linkages of Arctic and least cisco in an Alaskan Arctic food web. Predators and ciscoes are linked by blue lines. Red-throated loons consume least cisco (Rizzolo and Schmutz 2010). Other likely predators are suggested. Cisco prey are linked by red lines. Larval fish as prey are not specifically referenced (Table 1).

Appendix 1. Fish taxa captured by beach seine in August 2004-2007 and September 2009 from the nearshore region of the Beaufort Sea, Alaska near Cooper Island and Elson Lagoon with total catch among years (Adapted from NOAA AFSC-210).

Scientific Name	Common Name	Total Catch
Mallotus villosus	capelin	936
Boreogadus saida	Arctic cod	356
Stichaeidae	juvenile prickleback	48
Cottidae	juvenile sculpin	42
Coregonus sardinella	least cisco	38
Division Teleostei	unidentified larvae	34
Ammodytes hexapterus	Pacific sand lance	29
Lumpenus fabricii	slender eelblenny	26
Eleginus gracilis	saffron cod	24
Gadidae	juvenile cod	7
Coregonus species	unidentified cisco	5
Agonidae	juvenile poacher	4
Pungitius pungitius	ninespine stickleback	4
Myoxocephalus scorpioides	Arctic sculpin	3
Myoxocephalus quadricornis	fourhorn sculpin	3
Myoxocephalus quadricornis	longhead dab	3
Podothecus veternus	veteran poacher	2
Liparidae	juvenile snailfish	1
Liparis tunicatus	kelp snailfish	1
Limanda aspera	yellowfin sole	1

Appendix 2. Fish taxa captured by bottom trawl during 2008 in the offshore region of the US Beaufort Sea with total numbers extrapolated from subsampling the total catch (Adapted from BOEMRE 2010-048).

Scientific Name	Common Name	Total Numbers
Boreogadus saida	Arctic cod	66,278
Lycodes raridens	marbled eelpout	1,642
Theragra chalcogramma	walleye pollock	1,082
Lycodes polaris	Canadian eelpout	772
Triglops pingeli	ribbed sculpin	219
Hippoglossoides robustus	Bering flounder	231
Reinhardtius hippoglossoides	Greenland turbot	221
Liparis fabricii	gelatinous seasnail	165
Artediellus scaber	hamecon	154
Lumpenus medius	stout eelblenny	136
Aspidophoroides olriki	Arctic alligatorfish	134
Liparis gibbus	variegated snailfish	132
Cottidae	sculpin family	79
Gymnocanthus tricuspis	Arctic staghorn sculpin	77
Lycodes sp.	unid. eelpout	72
Triglops nybelini	bigeye sculpin	71
Myoxocephalus verrucosus	warty sculpin	67
Lycodes rossi	threespot eelpout	66
Careproctus sp. cf. rastrinus (Orr et al.)	salmon snailfish	59
Lumpenus fabricii	slender eelblenny	41
Lumpenus maculatus	daubed shanny	40
Liparis sp.	unid. snailfish	36
Lumpenus sp.	unid. eelblenny	21
Icelus spatula	spatulate sculpin	20
Lycodes mucosus	saddled eelpout	18
Mallotus villosus	capelin	9

Appendix 2. Continued.

Scientific Name	Common Name	Total Numbers
Eumicrotremus derjugini	leatherfin lumpsucker	6
Gadus macrocephalus	Pacific cod	5
Eleginus gracilis	saffron cod	4
Eumesogrammus praecisus	fourline snakeblenny	3
Gymnelus viridis	fish doctor	3
Liparis marmoratus	festive snailfish	2
Enophrys diceraus	antlered sculpin	1
Nautichthys pribilovius	eyeshade sculpin	1

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.