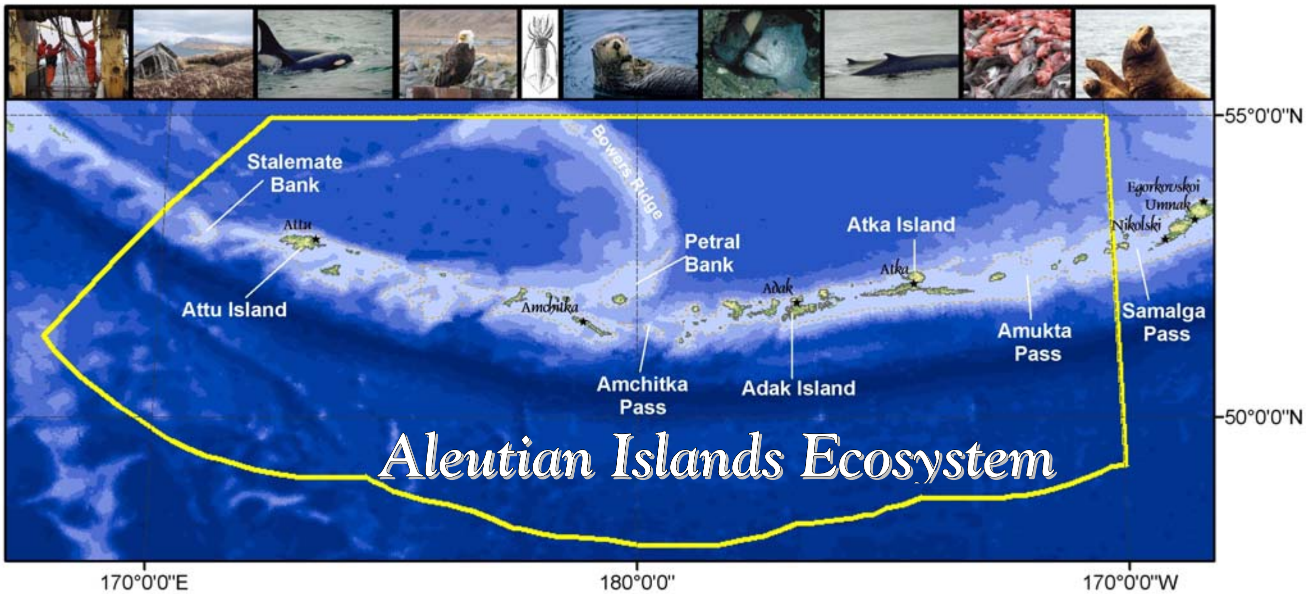
WORKING DRAFT

Aleutian Islands Fishery Ecosystem Plan



"Our creation story tells us that we dropped from the heavens above onto these islands that stretch across the stormy seas like a lifeline. Some say we walked across a land bridge… now why would we have walked when our iqyak and nigalax are among the best ocean going boats built by any people anywhere? An Aleut would have paddled, not walked."

by Allan Hayton, Alaska Initiative for Community Engagement
(http://www.alaskaice.org/material.php?matID=535)

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1 Introduction

1.1 Purpose and Need

The North Pacific Fishery Management Council (hereafter 'the Council') is faced with a growing national momentum to adopt an ecosystem approach to fisheries (EAF) management. While many of the Council's management actions reflect ecosystem considerations, such as conservative harvest levels and spatial and temporal closure areas to protect other species, there is still considerable progress to be made, especially at it pertains to the development of a formal process to integrate ecosystem considerations. After consideration of several possible approaches, much attention has focused on the concept of Fishery Ecosystem Plans (FEPs), and the Ecosystems Principles Advisory Panel (EPAP) touted FEPs as the way to move forward with ecosystem-based fishery management (NOAA 1999). Yet examples of FEPs or other types of fishery ecosystem management documents, both nationally and internationally, are few, and there is no template for their implementation, or a clear and direct relationship to fishery management plans (FMPs).

The Council believes that applying a more explicit ecosystem approach to fisheries management than is currently undertaken is the appropriate way to proceed. The purpose of an ecosystem approach to fisheries management is to "plan, develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from a full range of goods and services provided by marine ecosystems (FAO 2003, Garcia et al 2003). The management should thus be adaptive, specified geographically, take account of ecosystem knowledge and uncertainties, consider multiple external influences, and strive to balance diverse societal objectives (NOAA 2004).

The Council has drafted the following goal statement to capture its intent with the FEP:

> *The goal of this FEP is to provide enhanced scientific information and measurable indicators to evaluate and promote ecosystem health, sustainable fisheries, and vibrant communities in the Aleutian Islands region.*

Since 1995 the Council has prepared an Ecosystem Considerations chapter for the annual stock assessment and fishery evaluation reports. Over time, that document has evolved to include an annual ecosystem assessment in addition to tracking indicators and trends for the Alaska ecosystems. There is an ongoing need to improve the way these ecosystem considerations are included in the stock assessment process and the setting of fishing quotas, to reflect in a more holistic approach that addresses indirect and cumulative impacts. In this vein, the Council believes it is appropriate to develop and define a standard for Fishery Ecosystem Plans, starting with the Aleutian Islands as a test case.

The Aleutian Islands area has historically been a focus of measures to protect Steller sea lions, seabirds, benthic habitats that support coral and sponges, and other special resources of public interest (such as deep sea coral gardens). The Aleutian Islands have also been at the center of allocation issues related to the Aleutian Islands pollock and Pacific cod fisheries. Recent scientific evidence indicates a clear ecological difference between the eastern Bering Sea shelf ecosystem and the central and western Aleutian Islands archipelago west of Samalga Pass (Hunt and Stabeno 2005). Far less is understood about the ecological interactions in the Aleutians than in the eastern Bering Sea, yet the two areas are managed conjointly in all of the Federal fishery management plans. The Council recognizes that the Aleutian Islands contain unique and valuable ecological qualities that should be preserved, and wishes to build upon past actions by considering fishery interactions and cumulative impacts within this ecosystem more directly. Applying an ecosystem approach to fisheries management through the implementation of a FEP may promote this goal. For these reasons, the Aleutian Islands ecosystem area merits consideration as a candidate for area-specific management, and is an appropriate test case for the Council to develop a fishery ecosystem planning document.

The Council has captured their rationale in the following purpose statement:

> The Council recognizes that an explicit Ecosystem Approach to Fisheries is a desirable process for future management of the marine fishery resources in the Alaskan Exclusive Economic Zone (EEZ) and therefore is a concept that it wishes to pursue and further implement. A primary component of an EAF is the development of ecosystem-based fishery planning documents, and the Council intends to move forward with such development on a pilot basis. The Council recognizes that the Aleutian Islands ecosystem is a unique environment that supports diverse and abundant marine life, and a human presence that is closely tied to the environment and its resources. The Council believes that in light of these features, EAF could be a useful guide for future fishery management decisions in the Aleutian Islands area. Area-specific management associated with an EAF should specifically examine the aggregate effects of all fisheries within the Aleutian Islands ecosystem area, cumulatively with non-fishery inputs. Enhancing our current ecosystem approach to fisheries in the Aleutian Islands could allow the Council to better focus on the unique features of and interactions within the Aleutian Islands ecosystem area.

1.2 What is a Fishery Ecosystem Plan?

The purpose of a FEP was described in detail in the Ecosystems Principles Advisory Panel's Report to Congress in 1999. In brief, the FEP is intended to provide the mechanism to integrate ecosystem goals, principles, and policies into single species or species complex FMPs. According to NOAA (1999), the FEP is intended to:

- "provide Council members with a clear description and understanding of the fundamental physical, biological, and human/institutional context of ecosystems within which fisheries are managed;
- direct how that information should be used in the context of FMPs; and
- set policies by which management options would be developed and implemented," (NOAA 1999).

The scope of the FEP encompasses all Federal fisheries within the area, and considers the interactions of Federal and State fisheries with each other, and with other components of the ecosystem. The findings of an FEP may be used by the Council in managing Federal groundfish, king and tanner crab, scallop, and salmon FMPs. Figure 1-1illustrates a vision for the scope of the FEP, encompassing relationships among fisheries, prey and predators of target and non-target species, their habitat, the impacts of climate, and the cumulative impact on ecosystems from all fisheries and non-fishing impacts.

An FEP describes the ecosystem, including spatial boundaries, predator-prey interactions, habitat needs of the significant food web components, and current and historic states of the ecosystem. Indices of ecosystem health are used to assess all impacts, natural and anthropogenic. Goals and objectives are developed by the Council in the context of each fishery management plan. The FEP describes the interactions within the ecosystem, and the degree to which they are considered in conservation and management measures. Based on this broad perspective, the FEP evaluates implications of fishery management, including identifying areas of uncertainty and conflicting goals.

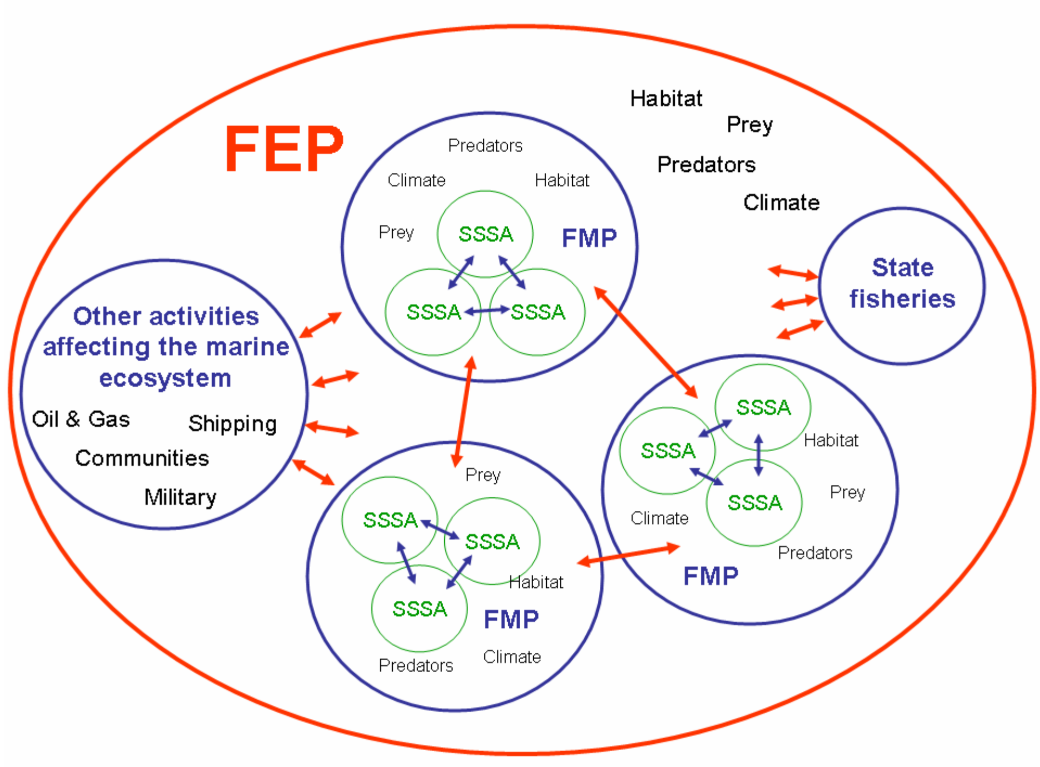

Figure 1-1 Illustration of the scope of the FEP.

Note: FMP = Federal Fishery Management Plan, SSSA = single species stock assessments

1.3 Role and Implementation of the FEP

The FEP will be used by the Council as a guidance document, and at this point does not constitute a policy documented as intended by the EPAP. It represents an additional tool for managing the fisheries under its jurisdiction. Under the Magnuson-Stevens Act, the FEP cannot authorize management measures. Only the FMPs can authorize regulations to implement management measures.

The role of the FEP, therefore, is to provide an understanding of the ecosystem context in which the FMPs operate. The FEP evaluates relationships among components of the ecosystem that may be managed separately, and may thus not always be considered in FMP analyses. The FEP may suggest implications for managers based on this geographic, ecosystem perspective, and based upon these, the Council may initiate focused FMP analyses that could result in changes to management measures in a particular fishery.

To be effective, implications brought forth in an FEP need to feed into the Council process on an annual basis at every level: stock assessment scientists, FMP teams, the Council's Scientific and Statistical Committee and Advisory Panel, and the Council itself (Figure 1-2). Integration and information-sharing are important at an early stage in the process of developing recommendations to come before the Council. The FEP document also needs to be a living document, in which ecosystem goals, indicator status, research priorities, and data gaps are updated on a 3-5 year schedule or more frequently as necessary. Updates to the FEP should be coordinated with programmatic reviews of the Council's FMPs. This FEP is being developed by the Aleutian Islands Ecosystem Team, appointed by the Council. The continuation of such a team might provide the appropriate vehicle to update the FEP as new information becomes available.

This Aleutian Islands FEP is being developed in two stages. The first version of the document is being prepared based on an evaluation and synthesis of existing information. Stakeholder participation and consultation with communities located in the Aleutian Islands ecosystem is being sought during this process. The first version of the FEP will indicate areas requiring more in-depth study and original research. Results from such studies will then be incorporated into the next version of the FEP. Such research may also allow a quantitative risk assessment ton be included in a future version of the FEP.

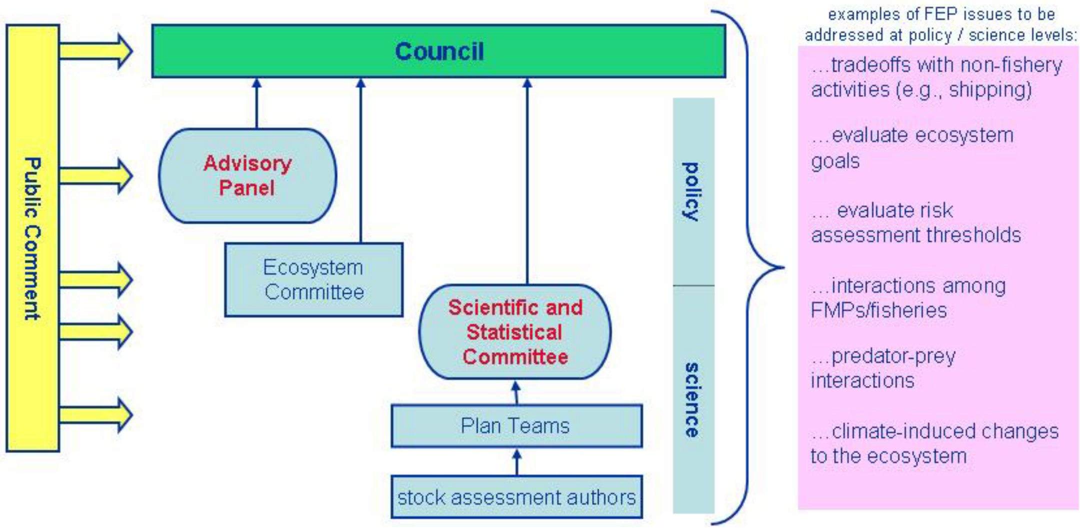

Figure 1-2 Schematic of how the FEP will interact with the Council process

Given the above, this document establishes an FEP for the federal fisheries in the Aleutian Islands. In particular, the FEP:

- describes and synthesizes the Aleutian Islands ecosystem processes and interactions,
- delineates the regulatory and bio-physical boundaries of the Aleutian Islands,
- identifies management objectives of the Aleutian Islands FEP,
- identifies ecological indicators appropriate to these management objectives,
- identifies knowledge gaps and research needs,
- provides a framework by which ecosystem considerations identified herein could be implemented within the current Council structure and management practice, and
- delineates a mechanism to assess whether the goals and objectives of the FEP are being met (to be developed further in a future version of the FEP).

2 Description of Aleutian Islands Ecosystem

Geographically, the Aleutian Islands archipelago ranges from Unimak Island to Attu Island, approximately from 165º W. to. 170º E. longitude, where it meets the Komandorski (Commander) Islands at the U.S.-Russian boundary (Figure 2-1). Numerous straits and passes through the Aleutian Islands connect the Bering Sea to the North Pacific Ocean. The islands are volcanic, with a narrow shelf descending to a steep dropoff. Rich in marine life, the Aleutian Islands are home to seabirds, marine mammals, sessile invertebrates, and fish stocks. The Aleut peoples have inhabited the islands for over 10,000 years and subsisted on the marine bounty.

For the purposes of this Fishery Ecosystem Plan, the Aleutian Islands ecosystem is defined as ranging from Samalga Pass (at 169ºW) to the western boundary of the exclusive economic zone, at 170ºE (Figure 2-2). Samalga Pass represents an ecological boundary with the neighboring Bering Sea and Gulf of Alaska ecosystems. There may in fact be more ecological boundaries throughout the Aleutian archipelago, within the area identified as the Aleutian Islands ecosystem. Spatial variation is high along the longitudinal axis of the islands (Ortiz 2007). The primary focus of this first iteration of the FEP, however, is to identify the unique characteristics and interactions of the identified area that cause it to be a significantly different system than its neighboring ecosystems.

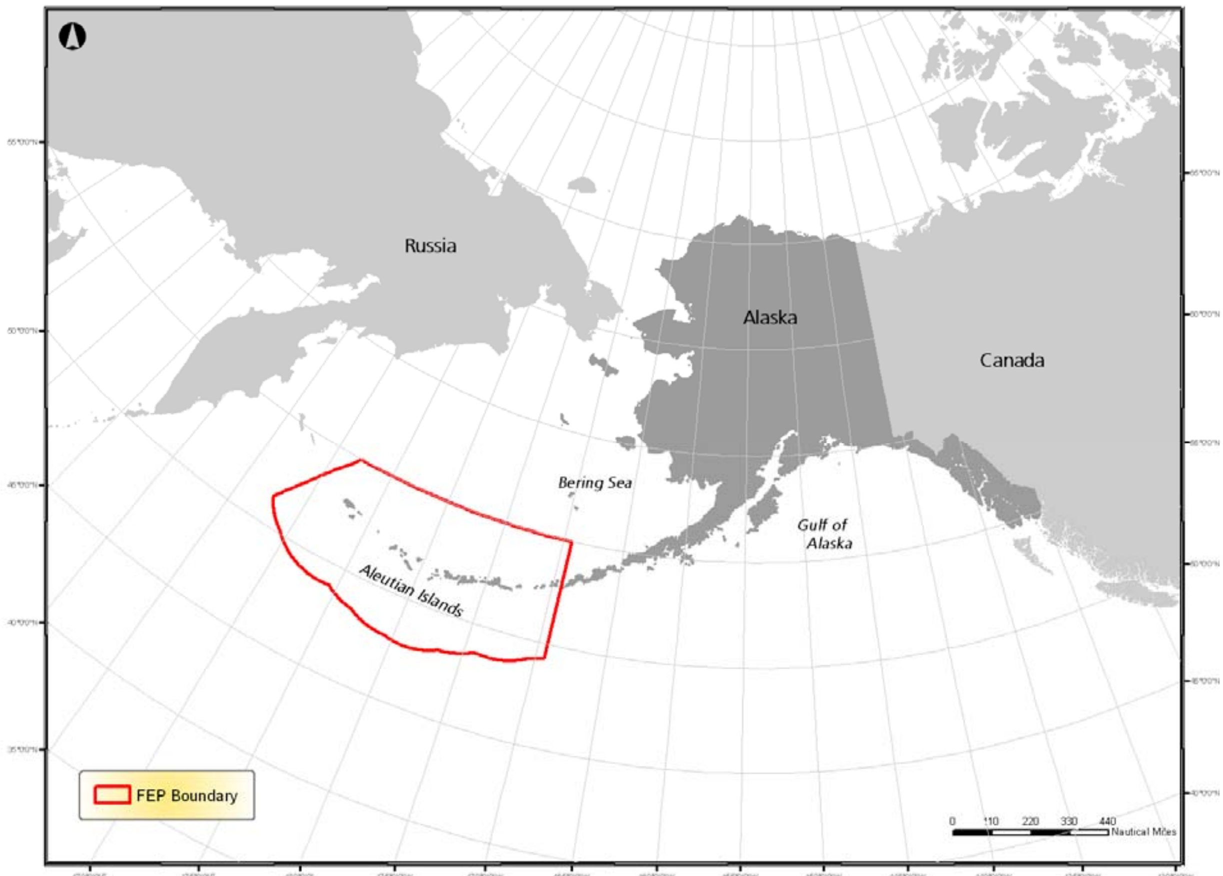

Figure 2-1 Boundary for the Aleutian Islands Fishery Ecosystem Plan

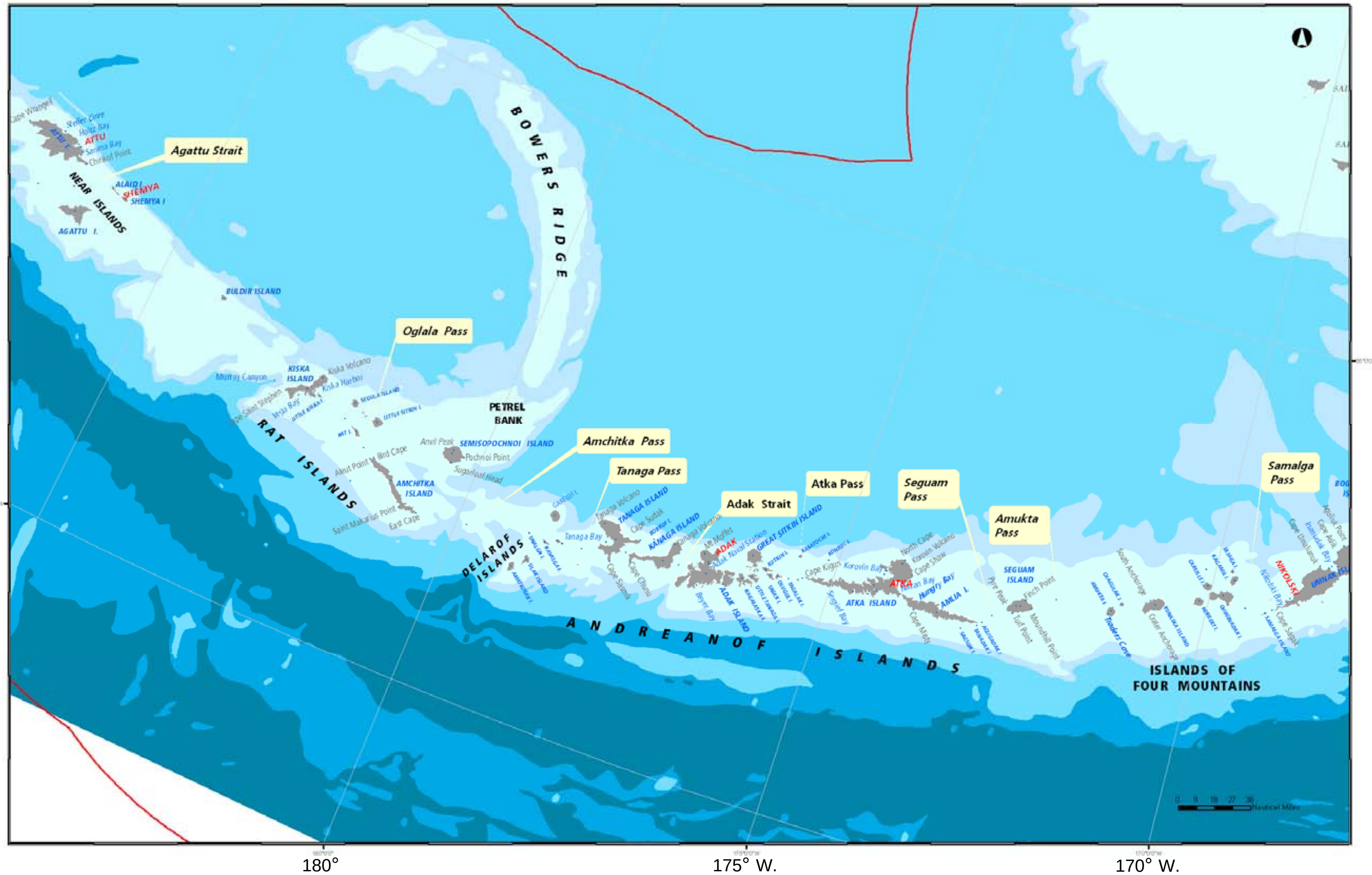

Figure 2-2 Map of the Aleutian Islands ecosystem

3 Understanding the Aleutian Islands Ecosystem

Understanding the Aleutian Islands ecosystem first requires an awareness of its history, which is summarized in Section 3.1. Sections 3.2, 3.3, and 3.4 describe the physical, biological, and social/economic relationships that define the ecosystem. The management boundaries that apply to activities within the ecosystem area are described in Section 0, as well as a brief description of fishery management in the Aleutians. Section 3.6 synthesizes the ecosystem interactions described in the previous sections.

3.1 Historical Perspectives

3.1.1 Aleutian Human Populations

Early Aleutian History

Both archaeological excavations and ethnographies of the Aleutian archipelago continue to challenge and refine theories of Aleutian prehistory. Standard perspectives for American scholars have maintained that humans entered the Aleutian Islands from the east, perhaps 8000 or 9000 years ago, traveling down through the Alaska Peninsula and spreading slowly to the far western islands (Laughlin 1963; McCartney 1984). Once established in the islands, these Paleo-Aleuts evolved in relative isolation, “where they were free to elaborate their own language and dialects and to evolve with a minimum of contamination from alien cultures and peoples” (Laughlin 1980:22). Essentially, researchers have maintained that Aleuts were buffered from contact with other groups until Russian traders arrived in the 18th century. Consequently, through lack of contact with other groups and existence in stable marine ecosystems, the assumption about ancient Aleutian peoples has been one of unchanging cultural traditions.

This assumption has been challenged by recent evidence. Following Russian scholars who have contextualized Aleut history within the greater Asian region, American scholars have also recently examined evidence of Aleuts engaging in a lengthy history of profound movement, contact, and integration for 10,000 years (Black 1984; 1983). Recent excavations, most notably the site at Margaret Bay that dates from 3000 – 6000 years ago, have provided “evidence of regular contact with other coastal areas of Alaska” (Knecht 2001:276). These findings suggest that “Aleutian prehistory is complex and dynamic, as one would expect in a similarly well-populated region with a rich resource base” (Knecht 2001: 279).

Knowledge of pre-contact Aleut culture depends on a mixture of archaeological data, ethnographic material, and records of early settlers such as Ivan Veniaminov, the Russian Orthodox priest who lived in Unalaska during the early 19th century. Eighty years after Veniaminov’s work and around forty years before modern research began, Lithuanian Waldemar Jochelson conducted ethnographic research that remains an important window on Aleut life and history. Drawing from these varied sources, a picture emerges of a dynamic culture with sophisticated technology adapted to a dependence on the sea “as the direct or indirect provider of virtually all basic necessities of life” (Veltre and Veltre 1980:12).

At the time of Russian contact in 1741, the population in the Aleutian Islands and Alaska Peninsula was estimated at 12,000 – 15,000 (McCartney 1984, Lantis 1984) although some evidence suggests it may have been higher. Most Aleuts lived on the larger eastern islands although settlements extended all the way to Attu, the island farthest west. Settlements were usually in defensible areas near natural resources – around coves and bays, rookeries, reef systems yielding subsistence resources at low tide, and near passes that channeled fish and sea mammals. Complex and flexible settlement patterns were critical to survival, as people often moved between permanent and seasonal settlements following fish or marine mammal migrations.

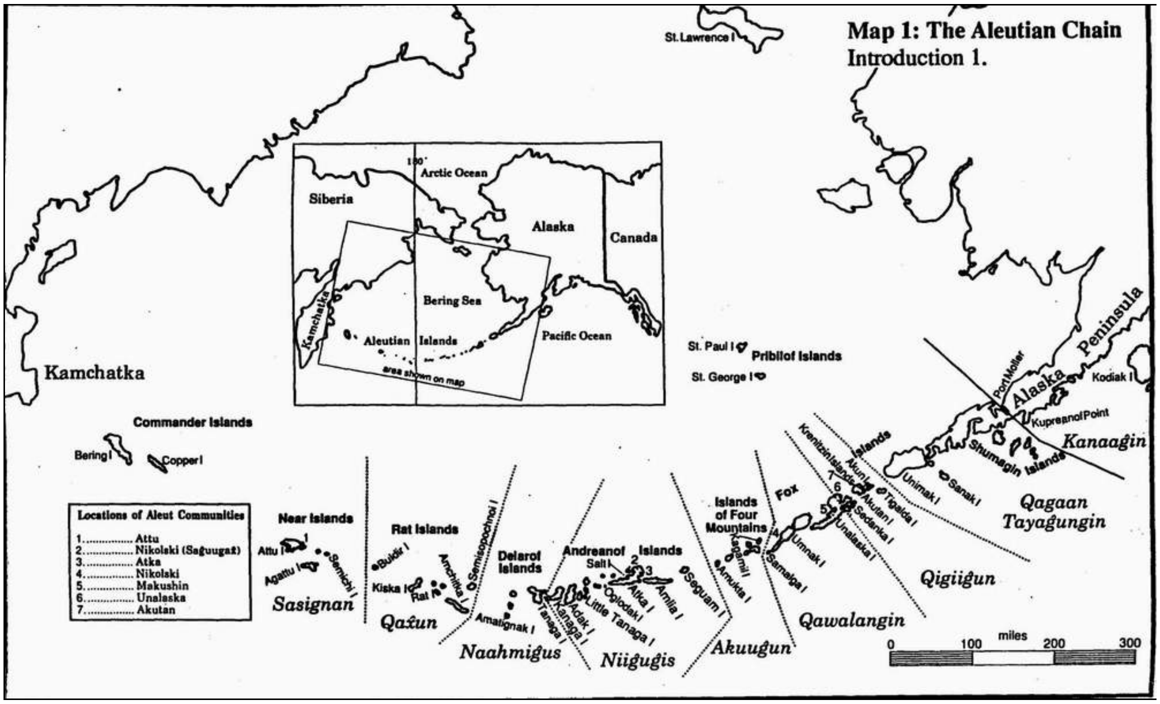

Figure 3-1 The Aleutian Chain, reprinted from Bergsland and Dirks (1990)[1].

Harbor seals and sea lions were the mammals of greatest importance to the Aleut diet and provided materials important for non-food uses such as clothing and construction. Whales, beached or hunted, were also an important resource that was surrounded with particular ceremonialism. Generally, although there were periods of hardship and starvation, the Aleuts maintained themselves for several millennia and were adept at exploiting every part of their environment.

Aleut stone-bone-wood technology was well adapted to harvesting marine resources. Sea vessels were constructed for hunting including kayaks, or baidarkas, and larger skin boats known as baidaras. Other hunting tools included numerous weapons, hooks, traps, and snares. Some iron was available from Japanese and Russian shipwrecks and Aleuts generally cold-hammered it into a desired shape – usually as knives. Aleuts also manufactured items for trade with other groups, particularly their rain shirts made of gut that were lightweight, durable, and considered luxury items.

The Aleut autonym (the name Aleut people call themselves) is Unangan, meaning 'the people.' 'Aleut' itself is a term that was applied by the Russians to all natives in the area, regardless of ethnicity or language. Consequently, although speaking mutually unintelligible languages, Koniag and other southern Eskimo's were grouped as Aleut, along with the eight or nine distinct island groups that collectively form the Unangan people (Lantis 1984:163, c.f. Bergland and Dirks 1990).

The Russian and American Colonial Periods

When the survivors of Vitus Bering's second (1741) expedition across the northern Pacific Ocean returned to Russia, they carried with them news of a "great land." More importantly, they bore hundreds

[1] http://www.alaskool.org/language/Aleut/Image/Use_map3.JPG

of valuable sea otter pelts that would soon prompt a “fur rush” through the Aleutian Islands, leading to a wave of Russian colonization and competition for land and resources with Spanish, British, and American rivals (Gibson 1976). The fur trade and Russian occupation of Aleutian territory drew the Aleut people into an international commercial market. The period shortly following Russian contact presented the Aleuts with profound social change. Impressed into work, relocated, and forcibly divested of pelts, Aleuts met the Russians with resistance, but their declining population was overwhelmed by the ever greater numbers of arriving Russians and a tremendous level of brutality. With a population estimated by some to be 16,000 at the time of Russian contact, Aleut numbers dwindled by at least 20% during the first 75 years of contact (Veltre and Veltre 1980:26). Much of this decline in population was due to epidemic, violent conflict with Russians and Tlingit, and forced resettlement and impressment into the labor force, especially to harvest fur seals in the previously unoccupied Pribilof Islands. (Black et al.1999).

The Russian-American Company gained control over Alaska’s commercial activity in 1799. With the formation of this company, some of the more oppressive practices towards Aleuts were halted, but not before Company officials relocated entire populations of Eastern Aleuts. Unlike the subsequent period of American colonization however, the Russian American Company maintained the political independence of Aleut polities and made it a policy to use and retain Aleut environmental knowledge and traditional skills in areas like watercraft construction, hunting, trapping, fishing, and architecture (Black et al.1999). Russian citizens were not permitted to take Native land or reside in Native communities although this was not always obeyed. Russian men married Native women, and some of these applied to the government for permission to remain in Alaska. The children of these unions, known as creoles, were “at home in Native communities, speaking both their own languages and Russian. Creoles were a bridge between two cultures and became agents of change. Through education, a Native middle class emerged, bound by kinship and sentiment both to Alaska and Russia. These men and women were the mainstay of Russian America” (Black 1999:7). The portion of today’s Aleutian residents who are their descendants often bear Russian family names, and maintain cultural and religious practices of both Russian and Native influence.

The United States purchased Alaska in 1867 from a beleaguered Russia whose navy, weakened by defeat in the Crimean Wars, could no longer secure its territory from British competition. The transfer of the territory meant drastic administrative changes that replaced a governmentally regulated economy with a *laissez-faire* capitalist system. For the first fifteen years of U.S. rule, Alaska was designated a “department” under military jurisdiction. Aleuts and other Native Alaskans were slotted into a highly racialized regime in which “social mobility of Natives and people of mixed origin became nearly impossible” and the only social services available were those offered by the Orthodox Church (Black 1999:16).

Not long after the purchase of Alaska, the vacancy left by the departure of the Russian-American Company was filled by the North America Commercial Company and the Alaska Commercial Company. The Eastern Aleutians were invaded by an influx of people seeking quick, easy wealth – an immigration unprecedented under Russian settlement restrictions. With an additional dismantling of Russian conservation restrictions, and additional pelagic sealing by Canadians and Japanese, the sea otter and fur seal populations were decimated by the end of the century. Local Aleut communities were able to profit from the sea otter industry, but the eventual monopolization of the fur industry by the Alaska Commercial Company limited their successful economic participation. The U.S. government later attempted to restrict sea otter hunting rights to natives or men married to native women. While some of the outsiders who married Aleuts became part of their communities, others married native women to make fortunes from the underpaid labor of the Aleut fur hunters that worked for them. Nearly extinct, sea otters were protected internationally by a complete ban on hunting in 1911 – “the first international convention aimed at conservation and protection of wildlife” (Black 1999, 17).

With the decrease in seal and sea-otter populations, fox farming became an important fur source in the Aleutians, with Unalaska serving as an important distribution location for pelts. However, the world market for fur was in rapid decline, and fox farm initiatives were largely abandoned by the end of the century. Alternately, commercial fishing for cod and salmon was developing as rapidly as the fur industry was declining, and by they early 1900s, commercial fishing became the largest source of employment in the Aleutians. Herring fisheries also began to emerge in the 1920s, leading to a cottage industry of salted herring. Canneries often employed local workers seasonally, but typically relied on imported labor, especially from China and Japan.

The educational system also changed dramatically with the sale of Alaska to the United States. Bilingual schools opened in the Russian period were entirely sustained by local Orthodox Church congregations between 1867 and 1884. In 1884 Dr. Sheldon Jackson, a Presbyterian missionary, became the General Agent for Education in Alaska. During that same year, the Organic Act “authorized the support of mission schools and the right of missions to claim up to 640 acres of land” (Black 1999, 20). Jackson partitioned Alaska into ‘spheres of influence,’ assigning different religious denominations to each area (excluding the Orthodox Church). The Aleutian area fell under the sphere of influence of the Methodist Church. For the most part, Aleut-led Orthodox Church community schools could not compete with this public school system, and eventually they closed down.

In 1924 Congress granted all Native Americans Citizenship. The citizenship status of Aleuts, however, remained ambiguous until 1936, when the Indian Reorganization Act of 1934 was applied to Alaska, granting native limited sovereignty to indigenous groups and establishing several Alaskan reservations (Black, 1999). It was also under the authority of the 1936 act that Aleut groups later organized into “tribes,” a legal term that denotes “Native American communities, which exercise powers of self-government” (Black, 19). Alaska has had a lengthy history of native participation in elections. Native candidates began to be elected routinely to the territorial legislature in1944.

Population and Villages since World War II

The modern population history of humans the Aleutian Islands is dominated by the continuing consolidation of villages and decline in the Native population due to the effects of World War II on the Aleut people. At the beginning of the war there were eight Aleut villages in the islands, but only four villages survived (Akutan, Atka, Nikolski, and Unalaska).

Unalaska was attacked by Japanese forces on June 3 and 4, 1942, due to the recently built up US military presence of over 50,000 personnel. A few days later, the Japanese took Attu Island, and brought all 42 Aleut villagers to prison camps in Japan where 16 died during three year’s internment. Aleut villages at Akutan, Biorka, Kashega and Makushin and Nikolski were all forcibly evacuated by the United States government on July 6, 1942. Atka was forcibly evacuated on June 14, 1942 and the village was burned to the ground by the US Navy. The Aleut residents of Unalaska were forcibly removed on July 22nd. All of the evacuations took place with little advance notice and few belongings permitted. Virtually everything not taken was destroyed or looted during the war. Along with the residents of the Pribilof Islands (also forcibly evacuated), the entire Aleut population of 820 men women and children were sent to internment camps in Southeast Alaska where they were kept under horrendous conditions for three years (Kohlhoff 1995).

Following the war, the government repatriated villagers to Akutan, Atka, Nikolski and Unalaska. Villagers from Biorka, Kashegan, and Makushin were compulsorily resettled in Unalaska, while villagers from Attu were compulsorily resettled at Atka. These regroupings were not easily absorbed in the social landscape (for example, Atkans and Attuans spoke different dialects and had longstanding rivalries) and village fidelity remains high to this day. Former evacuees visit their old village sites, considering them to be home. Malcolm (2006) tells of one Makushin evacuee who returns to stand and cross himself on the site of the Russian Orthodox Church, now covered with grass. He will be buried there. In 1988, the United States government apologized to the Aleut people and authorized financial reparations to survivors and communities.

In contrast to the loss of four village locations and numerous individuals (who died in the internment camps), World War II also brought a renewed population center to the island of Adak. The island had once had a large Native population, but had been depopulated during the Russian fur trade era, though it continued to be used for hunting and fishing. During the war it became an important military base. After the war, the Adak Naval Station remained active, with up to 6,000 personnel, until it was closed in 1997. Since that time, the Aleut Corporation has acquired the land and facilities and is promoting the location as a commercial center and fishing community. It is also the site of a recent national missile defense system installation.

The Aleutians again experienced a boom in population with the development and globalization of the fishing industry (Sepez et al. in press). First came the king crab boom in the late 1960s until 1982, followed by the Americanization of the deep sea fishing fleet under the Magnuson Act. Much of the industrial effect of these fisheries has been centered in Unalaska and Akutan.

3.1.2 Aleutian animal populations

Figure 3-2 provides an abbreviated overview of socio-ecological history the Aleutian Islands from 1740-2005. Total removals of marine species during this time are graphed, and significant impacts on Aleuts and species introductions and extinctions are entered on the timeline.

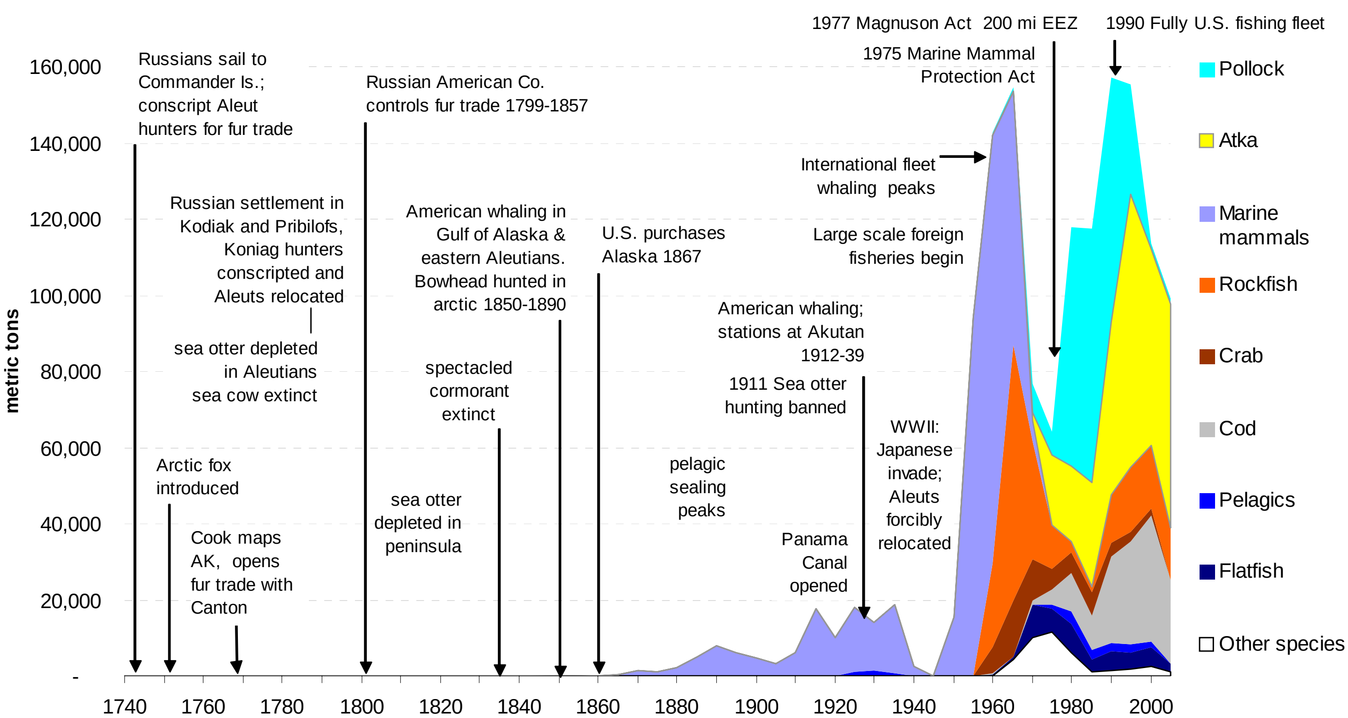

Figure 3-2 Aleutian Islands socio-ecological history (1740-2005): significant impacts on Aleuts, commercial exploitation with total tons removed, and species introductions and extinctions. Modified from Ortiz (2007).

Marine Mammals

Little is known about changes in mammal and bird populations prior the arrival of Russians in the region, although there is indication of changes in abundance of mammals and birds based on archeological material from Aleut midden sites (Causey et al. 2005). After Russian fur hunters arrived in the islands in the 1740s, some marine mammal populations declined due to hunting. By the beginning of the 20th century, Steller sea cow (*Hydrodamalis gigas*) was extinct (Stejneger 1887, Anonymous 1892), and sea otter and sea lion populations in the region were substantially reduced (Alekseev 1990, Bureau of Fisheries, 1906, REFS). Northern fur seals that moved through the Aleutians from breeding grounds in the Pribilof Islands were also reduced by pelagic sealing and harvest on the breeding areas (REF). Also, by the early 1900s whaling in the region was beginning to deplete whale stocks of some species (Starbuck 1878, Tønnessen and Johnsen 1982, Shelden et al. 2005, Mizroch and Rice 2006). As a result of these factors, historic populations of marine mammals in the region were substantially reduced between 1741 (Bering voyage) and the early 1940s (WWII).

Although not well documented, native animal populations were further stressed by habitat destruction and the presence of large numbers of troops during WWII on islands such as Atka, Adak, Amchitka, Kiska, Shemya, and Attu. Shipwrecks, cargo transfer, and fuel spills certainly had at least short-term negative impacts on animals populations.

Due to protective legislation for some of the marine mammals (e.g., Fur Seal Treaty, 1911) and changes in world markets (e.g., for fox fur and whales), marine mammal populations went through a period of recovery from 19th and early 20th century population lows. By the mid-1970s sea lion populations were at relatively high levels and sea otters had recovered over most of the Aleutians by the mid-1980s (Loughlin REF, Doroff et al. 2003). Although whaling ended in 1972, sperm whales and possibly other whale stocks in the Aleutians remain depleted (Shelden et al. 2005, Mizrock and Rice 2006); nevertheless, slow recovery may now be underway.

Although under the protection of the Marine Mammal Protection Act from 1972, Steller sea lions started declining in the mid 1970s throughout the eastern Aleutians. The decline extended to the central and western islands in the mid 1980s (Angliss and Lodge 2004), and its continuation resulted in their classification as “endangered” under the Endangered Species Act in 1997 (NOAA 2006). Northern fur seal (*Callorhinus ursinus*) pup production has declined in the Pribilof Islands since the mid-1970s, resulting in reduced populations passing through the Aleutians (REF). Harbor seals (*Phoca vitulina*) also showed a decline between the late 1970s and the late 1990s (Small et al. submitted). Furthermore, sea otters have been declining since the mid-1980s, and consequently were listed as “threatened” under the Endangered Species Act in August 2005.

Seabirds

After Russian fur hunters arrived in the islands in the 1740s, bird populations declined due to predation by foxes introduced for fur production. Some endemic birds, like Aleutian Cackling goose (*Branta hutchensii leucopareia*) and formerly common nearshore foraging short-tailed albatross (*Phoebastria albatrus*) – a species nearly extirpated by hunting for the feather trade on its breeding grounds in Japan (Tickell 2000), also were nearly extinct by 1930.

Special management of terrestrial systems in the Aleutians has resulted due to the establishment of the region originally as a wildlife reservation in 1913 and subsequently as part of the National Wildlife Refuge System (formerly the Aleutian Islands National Wildlife Refuge and now the largest unit of the Alaska Maritime National Wildlife Refuge). One of the primary objectives of the Refuge has been to try to restore native bird populations, including more than 20 species of seabirds by removing introduced foxes. Arctic foxes were the original target of the fur traders, and they moved foxes to the Aleutians from the Commander Islands as early as 1750 (Black, 2004). Most islands in the Aleutians were stocked during the heyday of fox farming between about 1913 to 1940 (Bailey 1993). Foxes depleted multiple seabird populations and other endemic taxa, extirpating some species from the larger islands (Byrd et al 2005). Ongoing eradication efforts started in 1949 and by 2002 only 6 islands still had non-native foxes (Ebbert 2000, Ebbert and Byrd 2002). Removal of foxes has allowed the restoration of most native birds through natural expansion (e.g., Byrd et al. 1994) or translocation (Byrd 1998). Aside from foxes, there have been a series of other introductions that have influenced seabird populations as well as the local flora. Norway rats were introduced in Rat Island after a Japanese shipwreck in 1780 (Black 1984) and have since become established on at least 11 additional islands larger than 500 ha and dozens of nearby satellite islands (Bailey 1993, Murie 1959). Rats are voracious predators with the potential to extirpate ground nesting seabirds such as Cassin’s auklets, storm petrels, tufted puffins (REF to cases elsewhere) and an effect on auklets on Buldir has already been documented (Major et al. REF – check). Ground squirrels were introduced at first by Native Alaskans and early Russians for clothing (parkas) and food (Ebbert and Byrd 2002). They were later introduced again by American ranchers as food for foxes after the seabirds had declined and the islands were running short on food supplies. Arctic ground squirrels are known to take passerine eggs, chicks and eggs of seabirds (Geist 1933; Sealy 1966). The impacts of both rats and squirrels extend to the local flora: they feed on stalks, stems, seeds and fruits, contribute to overgrazing and kill saplings, thereby modifying the plant communities and affecting the associated fauna (Courchamp et al. 2003, Bailey 1993, 2007 PSG presentation).

There do not appear to be any widespread declines in seabirds throughout the Aleutians, but there have been declines in the past 30 years for several species of nearshore feeders (cormorants, gulls, and pigeon guillemots), at least regionally (Byrd et al. 2005).

Fish

Little is known about fluctuations in marine fish populations until the start of the commercial fisheries in the early 1900s, and prior to that period, fish take consisted mainly of localized harvests (REF). A summary of the history of commercial exploitation is provided in Section 3.1.3, below. Figure 3-3 illustrates the stock assessment estimated biomass trends for species in the Aleutians from 1960-2005. Figure 3-4 shows survey biomass trends from the Aleutian Islands bottom trawl survey (1980-2005) for major fish species.

Fish and crab populations that have exhibited significant declines, at least in part due to fisheries, include Pacific Ocean perch and red king crab. The first was severely depleted in the 1960s by the foreign fishery and current estimates seem to indicate the stock has been consistently increasing since the 1990s (Spencer et al. 2004). In contrast, the American fleet obtained record catches of red king crab during the early 1960s both off Adak and Dutch Harbor and the stocks have not recovered, remaining at low levels and in some cases forcing the fishery to close (NPFMC 2005).

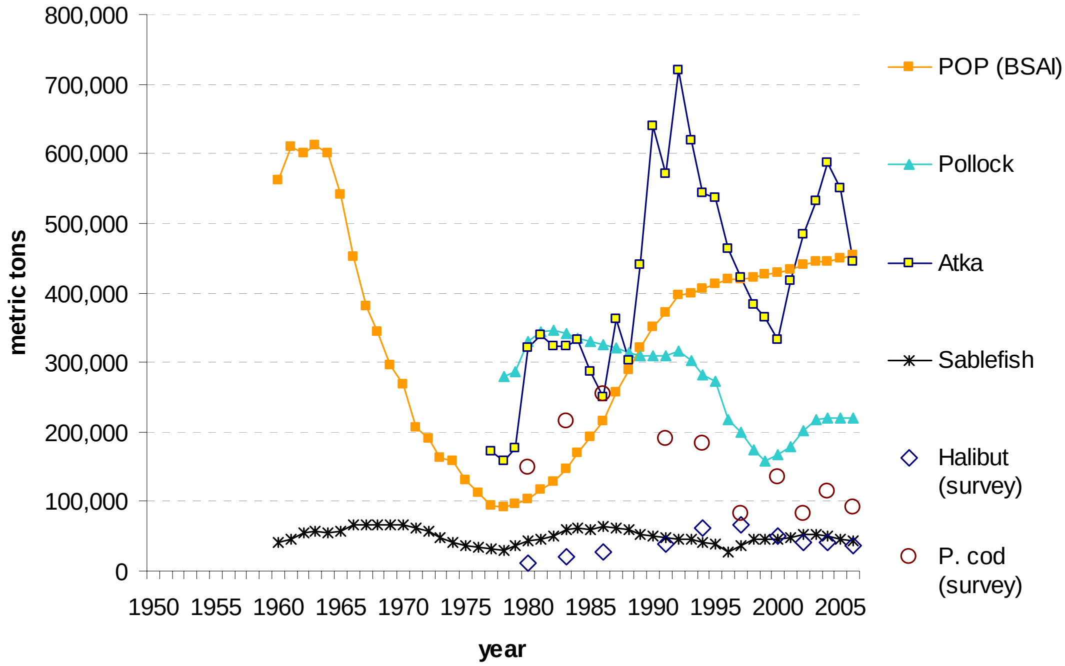

Figure 3-3 Stock assessment biomass trends for key commercial species in the Aleutian Islands, 1960-2005.

Note: Estimated biomass is from the stock assessment, where possible; for halibut and Pacific cod, which have no specific AI assessment, biomass figures are estimated from the AI bottom trawl survey.

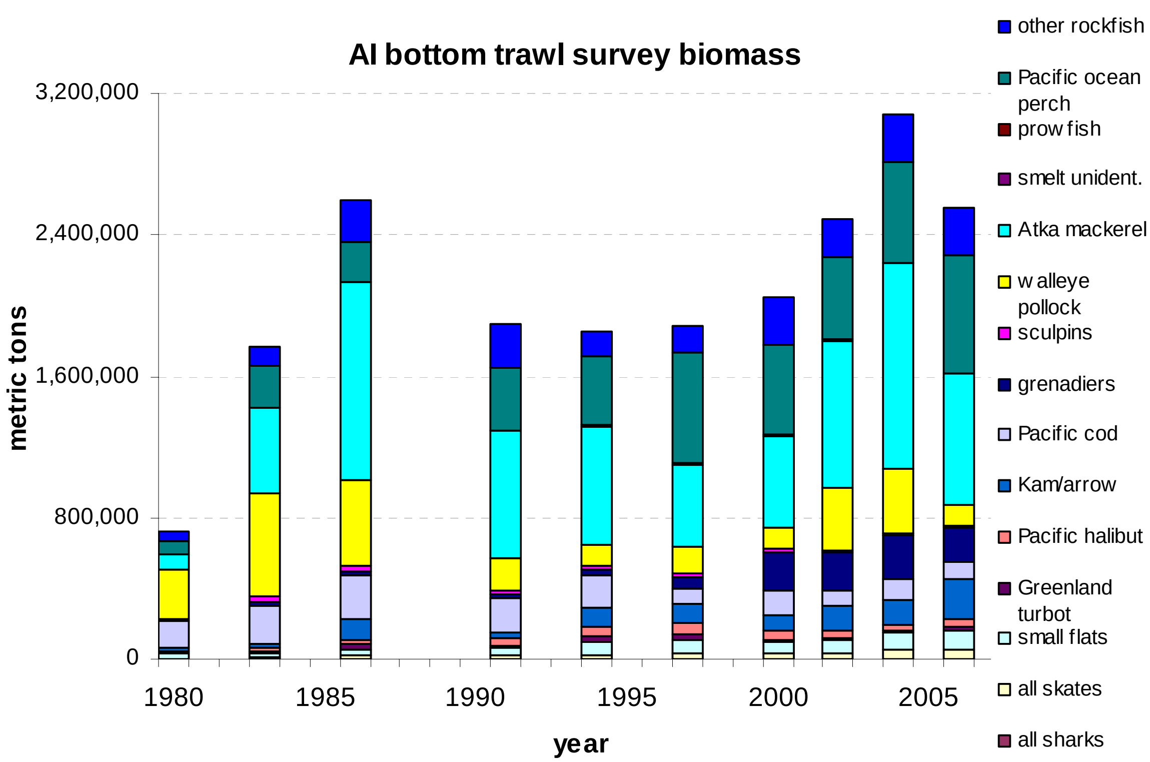

Figure 3-4 Survey biomass trends for major fish species, from the Aleutian Islands bottom trawl surveys, 1980-2006.

Historical Relationships illustrate connections across ecosystems and food webs

Perhaps the most widespread effect of depleted populations throughout the Aleutian archipelago is the islands' change in terrestrial landscape from grasslands to maritime tundra. The reduction of seabird's nutrient rich guano (resulting from population declines from introduced fox predation) to the plant communities favored less productive shrubs and forbs over more productive grasses and sedges. The marine derived nutrients delivered via guano reach beyond the plant community and are traceable to terrestrial mollusks, passerines, dipterans, and arachnids, illustrating the intricate nature of nutrient transport among ecosystems (Croll et al. 2005).

Within the marine environment, the extirpation of local sea otter populations had widespread consequences. Kelp is unevenly distributed throughout the islands but wherever they form forests, they support a marine community that includes multiple fishes, limpets, bryozoans, amphipods, tunicates, barnacles, mussels, asteroids, octopus, and other invertebrates (Simenstad et al. 1978, Isakson et al. 1971). The forest's extension is regulated through herbivory by sea urchins that in turn are controlled via predation by sea otters. At sites being recolonized by sea otters, sea urchin abundances have declined and kelp forests have increased as the sea otters increase; kelp and urchins have remained the same where sea otters populations have been stable (Estes and Duggin 1995). Kelp forests also incorporate nutrient inputs from offshore in the form of seabird's guano, exemplifying the importance of nutrient transport across habitats (Wainwright et al. 1998). The organic detritus originating from kelp support a variety of benthic suspension feeders, such as mysids, barnacles, and amphipods, enhancing secondary production in the nearshore areas (Duggins et al. 1989). The current contraction of kelp forests is a potential contributing factor in the decline of nearshore seabirds (Byrd et al. 2005).

As exemplified by seabirds and sea otters, changes in parts of the Aleutian Islands ecosystem can be linked to the cycling of nutrients and energy across environments, but the processes can unfortunately go easily unnoticed until broken or degraded. The changes in landscape were observed at local or small spatial scales, however the patterns behind them required studies over larger spatial scales, reaffirming Levin's (1992) proposition for studies at multiple scales. The influence of seabirds on vegetation and sea otters on kelp also show the usefulness of food webs to identify connections among species and understand how changes in abundances and distribution manifest themselves when processed through the food web. Large scale food webs can help us identify fundamental processes of nutrient cycling across areas, while local food webs and life history traits can help identify distinct ecological areas.

3.1.3 Commercial exploitation

Large scale exploitation began with the arrival of Russians in 1741 (Figure 3-2). In their quest for pelts, particularly of sea otters, Russian fur hunters and others associated with the fur trade had significant impacts on the local people including introduction of diseases, forced displacement, and servitude of the skilled Aleut hunters through violent coercion which included murdering some local people (Gibson 1996). The result was a significant decline in the population of Aleuts during the Russian colonial period (1741-1867). Other ecological changes included the reduction of sea otter populations and the introduction of arctic foxes to several large islands which drastically reduced native bird populations. Although there were significant social and ecological impacts associated with the Russian fur trade, the largest number of Russians ever in America at one time was a mere 823 (Haycox 2002). Further discussion of the Russian colonial period is presented in Appendix A.

Larger scale commercial fishing started in the early 1900s when cod stations were opened at Sanak and Unimak Island by various companies (Bureau of Fisheries 1907). Other fishing stations opened in 1916 throughout the eastern Aleutians, and one shore station opened at Attu (western Aleutians) where Atka mackerel and other greenling were caught. Salmon canneries opened in the eastern islands of Unalaska and Umnak, with limited success, as the total salmon catch from 1916 to 1939 was only 5,521 metric tons. A purse seine fishery for herring developed in the vicinity of Unalaska. Catches peaked in 1932 at about 2,800 metric tons and ranged between 1,000 and 2,000 metric tons until 1937. From then on herring catches declined until the fishery was abandoned in 1946 (INPFC 1979, Bakkala 1981). American vessels stayed in nearshore areas during the 1920s and 1930s. Through the first part of the 20th century, these fishing operations in the eastern Aleutians and fur seal harvesting jobs in the Pribilof Islands attracted people from Atka and Attu.

A shore whaling station was built in 1907 by a Norwegian company in Akutan (eastern Aleutians). The Akutan whaling station’s operations lasted from 1912 to 1939 (Tønnessen and Johnsen 1982). With the introduction of floating factories in the 1920s, Japan initiated pelagic whaling offshore of the Aleutians; however these catches were outside the 3 mile limit (the territorial water limit at that time), and hence there are no records of catches (Tønnessen and Johnsen 1982). In 1939, with the threat of World War, the facilities in Akutan were sold to the navy, and the shore-whaling industry came to an end in the Aleutians.

In 1913, the Aleutian Islands Reservation (later called the Aleutian Islands National Wildlife Refuge) was established and one of its functions was to administer the use of islands by fox trappers. Nearly every island was stocked with non-native arctic foxes and until the 1930s, trappers, often Aleuts from Attu, Atka, or eastern Aleut villages, spent winters on most of the islands.

World War II interrupted these activities, as the occupation of Attu and Kiska by Japanese soldiers brought WWII to the Aleutians (Figure 3-2). Aleut villages were forcibly evacuated by the United States government, and tens of thousands of troops occupied bases at Adak, Amchitka, Shemya and other islands. The era of fur farming was largely over after the war, but a few trappers continued to lease islands from the refuge until the late 1940s. Other commercial activities in the central and western Aleutian Islands, which had begun prior to the war (e.g., commercial fishing and whaling), continued. After World War II, whaling and fisheries by foreign fleets expanded to areas immediately outside the territorial waters (3 miles then) of the Aleutian Islands. Figure 3-5 summarizes commercial exploitation history in the Aleutian Islands from 1950-2005. Whaling was the first fishery to be reactivated in Aleutian waters, primarily by Japanese and Soviet Union fleets. Baleen whales were half or less of the catch, and sperm whales made up the rest of it. The whaling fleets operated offshore, seldom within 30 km of the coast until 1972 (Merrel 1971) when catches north of 50°N ceased, although globally stocks kept declining until a moratorium was set in 1982 (Tønnessen and Johnsen 1982, IWC 2006).

Japan began fishing off the Aleutian Islands waters in the early 1950s for salmon, and were later joined by other nations. The initial targets were Pacific Ocean perch (POP) and walleye pollock, but soon expanded to other groundfish species. Peak total groundfish harvest occurred in 1965 when almost 112,000 metric tons were taken. Most was Pacific Ocean perch, taken off the entire central and western Aleutians (Merrel 1971). Pacific Ocean perch remained the primary target until the 1970s when the stock declined and catches comprised only about a third or less of the total harvest in the region.

The American fleet started fishing for red king crab near Adak and Dutch Harbor in 1960 (NPFMC 2005). As the abundance of red king crab declined in the Aleutian Islands, fishers gradually transitioned to harvesting golden king crab and by 1982, golden king crab landings exceeded those for red king crab, although the total volume of golden king crab landed was never as high as for red king crab (Otto 1981). At its peak, the red king crab harvest in the Aleutian Islands exceeded 17,000 metric tons.

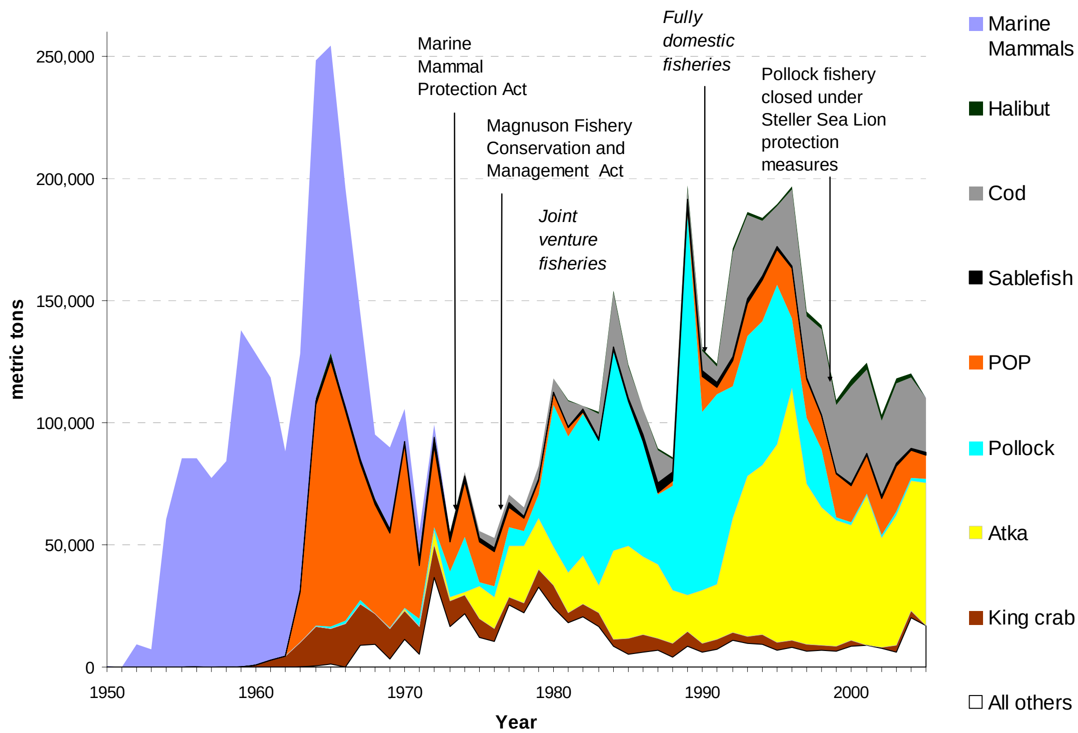

Figure 3-5 Aleutian Islands recent (1950-2005) commercial exploitation history with total tons removed, and significant management actions. Modified from Ortiz (2007).

In response to foreign high exploitation rates in waters adjacent to its 3 mile limit, the U.S. passed the Magnuson-Stevens Fishery Conservation and Management Act in 1976 which established the Fishery Conservation Zone (later the Exclusive Economic Zone) from 3 to 200 miles offshore. Foreign countries were allocated quotas based on their contribution to developing the domestic industry, and so the groundfish fisheries went through a period of joint ventures that lasted through the 1980s. Japan's new shipboard methods to produce surimi at sea allowed the pollock fishery to rapidly expand (Bakkala 1981), and pollock catches peaked in the Aleutians during the 1980s. By 1990 the fleets were domestic, and total catches remained in excess of 150,000 metric tons throughout the decade. In 1999 the pollock fishery was severely restricted due to concerns regarding the fishery's impact on Steller sea lions (Barbeaux 2004). Since then, total groundfish catches have averaged slightly above 100,000 metric tons and are roughly 50% Atka mackerel, 30% Pacific cod and 15% Pacific Ocean perch.

Military forces remained at Attu, Shemya, Amchitka, and Adak after WWII, and these supported military objectives through the Cold War era. Adak was the largest base with up to 6000 U.S. Navy and support personnel at its peak in the early 1990s. Following the fall of the Soviet Union, the Navy closed its base in 1997, and the land reverted to the Alaska Maritime National Wildlife Refuge, of which Adak is a part. The refuge traded the facilities associated with the base and lands nearby to the Aleut Corporation for corporation-selected lands elsewhere in the refuge, so that the corporation could foster the development of the current civilian community at the abandoned Navy base at Adak.

3.2 Physical relationships

Physical Description

The Aleutian Archipelago consists of hundreds of small, volcanic islands, separated by oceanic passes that connect the waters of the North Pacific with the Bering Sea. The island chain marks the tectonic subduction zone between the North American and Pacific Plates. Bathymetry changes dramatically in a very short distance, from the depths of the Aleutian Trench (> 7,000 m deep) to sea level to volcanoes (< 1,000 m high) in a distance of less than 150 km. The passes between the islands vary from narrow shallow passes in the east, to wider, deeper passes in the west (Figure 3-6). Th north-south width of the shelf also varies from east to west, with the greatest shelf-width (>80 km) occurring east of Samalga Pass (Stabeno et al. 2005).

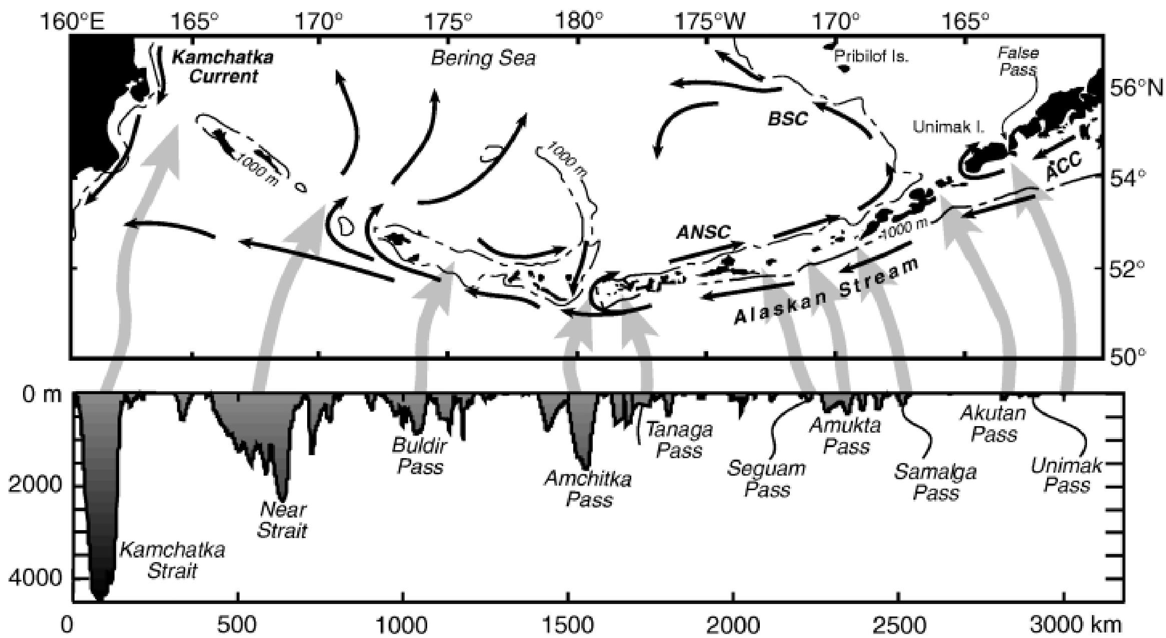

Figure 3-6 The mean circulation along the Aleutian Arc is shown together with geographic place names, The lower panel shows the depth of the passes in the Aleutian Arc. Reprinted from Stabeno et al. 2005.

Note: ANSC = Aleutian North Slope Current, ACC = Alaska Coastal Current, BSC = Bering Sea Current.

Benthic Habitat

The AI region has a complicated mixture of substrates, including a significant proportion of hard substrates (pebbles, cobbles, boulders, and rock). Two distinct zones are evident.East of Samalga Pass, the Aleutian Islands rise from shallow continental shelf covered by several sediment types deposited mainly during periods of glaciation. West of Samalga, steep rocky slopes to the north and south surround a mostly submerged mountain range resting on the Aleutian ridge (Hampton 1983). Cold-water corals and sponge communities are a dominant feature of benthic communities on the steep rocky slopes of the Aleutian Islands and likely provide important habitat for a variety of fish and invertebrate species (Heifetz et al 2005). The geographical split in substrate type at Samalga Pass is coincident with a shift in coral species diversity (with higher diversity to the west as well as shifts in surface water properties and populations of fish, invertebrates, seabirds, and marine mammals (Figure 3-7).

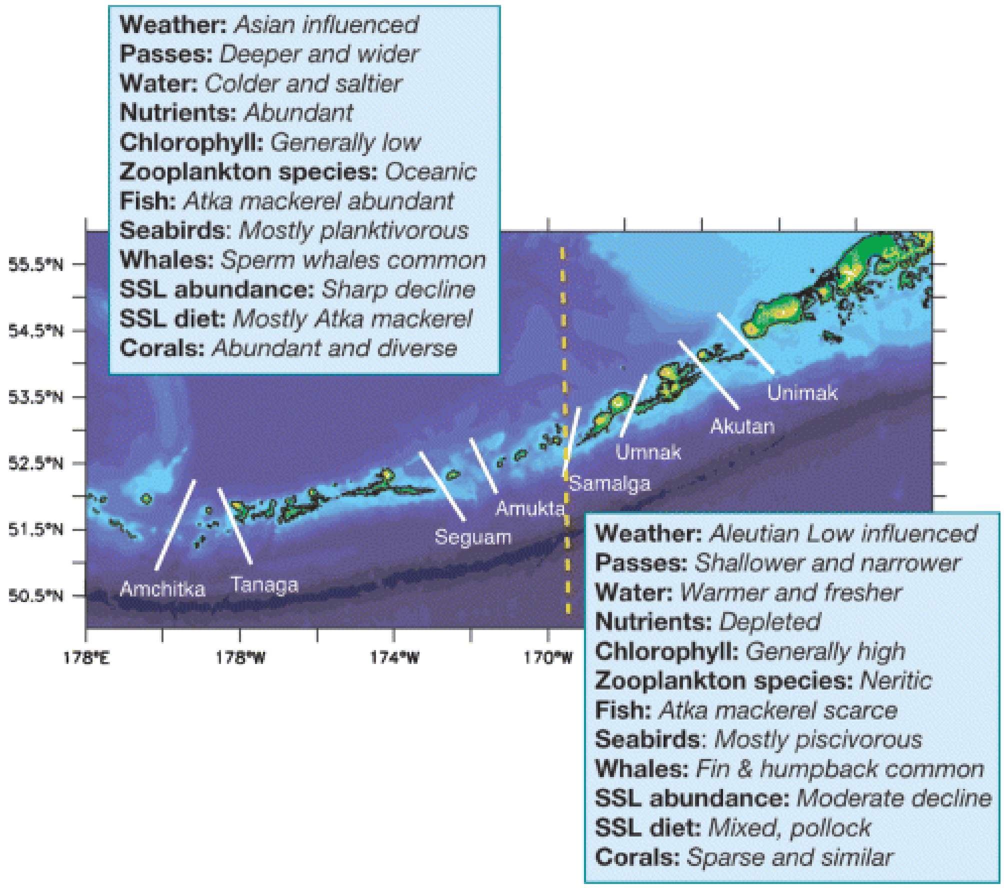

Figure 3-7 Many Aleutian environmental attributes change in the vicinity of Samalga Pass, suggesting that the marine ecosystem of the archipelago may be differentiated into multiple, ecologically distinct regions. Reprinted from Hunt and Stabeno 2005.

Oceanography (Pelagic Habitat)

The Aleutian Archipelago is influenced by three primary currents: the Aleutian North Slope Current (ANSC) in the Bering Sea, and the Alaska Coastal Current (ACC) and Alaskan Stream in the North Pacific (Favorite et al. 1976, Stabeno et al. 1999). East of Samalga Pass (170°W), the ACC flows southwestward along the southern side of the Aleutian Islands. This relatively fresh and shallow current hugs the shoreline and turns northward entering the Bering Sea through the eastern passes (Unimak, Akutan, Umnak, and Samalga; Ladd et al. 2005). West of Samalga Pass, the shelf south of the islands is much narrower. This narrow shelf allows the Alaskan Stream, the deep current that flows along the continental slope in the western Gulf of Alaska, to come close to the islands. The Alaskan Stream flows southwestward along the southern side of the islands, connecting the Gulf of Alaska to the Aleutian Islands region (Favorite et al. 1976). Waters from the Alaskan Stream flow northward through the central and western Aleutian Passes to feed the Aleutian North Slope Current, which flows northeastward along the northern side of the islands (Reed and Stabeno 1999; Figure 3-6).

While oscillating tidal currents are responsible for the extreme current speeds and mixing within the passes, the net northward transport of water from the Pacific to the Bering Sea plays a role in transport of nutrients and biota. There is evidence that transport in the Alaskan Stream influences transport in some passes. In particular, in the winter of 2001/2002 transport variations in the Alaskan Stream were shown to be related to transport variations through Amukta Pass (Stabeno et al. 2005). Large variations in transport in the Alaskan Stream may be related to the passage of mesoscale eddies (Okkonen 1996; Crawford et al.

2000) that move westward along the shelf-break from the GOA. Occurrence and persistence of these eddies is crucial for the understanding of productivity hotspots observed throughout the region (Batten et al 2006).

Due to the influence of the Alaska Coastal Current, the shallow, narrow passes east of Samalga Pass (170° W.) can be classified as a coastal environment with a strong influence of coastal freshwater discharge. These waters are warmer, fresher, more strongly stratified, and nitrate poor compared with the Aleutian waters west of Samalga Pass. West of Samalga Pass, the passes are deeper and wider. The marine environment can be classified as oceanic with primary influence from the Alaskan Stream (Ladd et al. 2005). The wider passes allow bidirectional currents with mean flow to the north (from the Pacific to the Bering) on the eastern side of the passes and to the south on the western side (Stabeno et al. 1999). However, the northward flow is generally stronger, more consistent, and occurs over most of the cross-section of the passes so, except in Kamchatka Strait far to the west, the net transport through the Aleutian Passes is northward from the Pacific Ocean to the Bering Sea.

Within the passes, fierce tidal currents, often exceeding 100 cm/s (Stabeno et al. 2005), present hazards to navigation and equipment. The tides result in substantial mixing within the passes. As the tidal current pushes water over the shallow sills of the passes, salt, nutrients, and plankton from deeper water can be mixed into the surface waters. The influence of tidal mixing on surface nutrient concentrations depends on the depth of the pass. Passes with depths between 120 and 200 m, such as Seguam and Tanaga Passes, are shallow enough to mix top to bottom but deep enough that the mixing can access the deep nutrient reservoir. Thus, these passes are most efficient at mixing nutrients into the euphotic zone. In contrast, nutrient concentrations at the bottom of shallower passes, such as Unimak and Akutan Passes, are lower so mixing does not result in substantially increased surface concentrations. In even deeper passes (>200m), such as Amukta and Amchitka Passes, the interaction of tidal currents and the bottom topography can not result in mixing that reaches the surface.

Although tidal mixing can result in high surface nutrients in the passes, it can hinder the development of phytoplankton blooms by mixing the phytoplankton out of the euphotic zone and reducing their access to light (Sverdrup 1953). Thus, blooms often occur north of the passes, away from the intense mixing in the passes, but utilizing the nutrients supplied by the mixing (Mordey et al. 2005). The vertical circulations created by interactions of tidal currents with steep and variable bathymetry can also result in surface convergences (i.e., fronts, eddies) creating regions of increased concentrations of prey for seabirds (Hunt et al. 1998) and other predators.

Climate (Terrestrial Habitat)

The windswept islands of the Aleutian Archipelago experience a wet and stormy maritime climate. Wind, fog, and rain are ubiquitous while sunny days are rare. The average temperature range during the summer is 7 – 14°C (45 – 57°F) and during the winter is -3 – 3°C (27 – 37°F). Temperature variability is determined by the Aleutian Low, a low pressure center that may be located east of 180°W or be split in two: one center located east of the Kamchatka peninsula, and the other in the Gulf of Alaska. Depending on the strength and location of the Aleutian Low, the dominant storm track can cross the Aleutians anywhere between 170°W and 150°W.

Precipitation is highly variable with annual averages ranging between 75 and 160 cm per year depending on the location. Wettest conditions normally occur during the winter[2]. The storms that frequently batter the Aleutian Islands typically originate east of Japan, moving northeastward along the Aleutian Chain

[2] Western Regional Climate Center, http://www.wrcc.dri.edu/summary/Climsmak.html

toward the Gulf of Alaska. These storms result in high winds, often in excess of 22 m/s (50 mph), during all but the summer months (Rodionov et al. 2005).

Regime shifts, in which the climate changes abruptly from one mean state to another, have had substantial impacts on the marine ecosystems of the North Pacific (Hare and Mantua 2000). East of 170°W, there is evidence that a regime shift towards a warmer climate occurred in 1977. The shift to a warmer physical environment was coincident with many biological changes including an increase in the Alaskan catch of many species of salmon (Hare and Mantua 2000). Although these regime shifts have had dramatic consequences for the Gulf of Alaska and the eastern Bering Sea, impacts on the Aleutian Islands weather have been insignificant (Rodionov et al 2005). Contrary to the warming signal elsewhere, the Aleutian Islands have experienced a long-term cooling trend between 1956 to 2002 with an associated increase in . surface air temperature variability (Rodionov et al. 2005).

How is the Aleutian Islands ecosystem different from the surrounding ecosystems?

The marine environment of the Aleutian Islands is very dynamic. The islands form a porous boundary between two ocean basins, the Bering Sea and the North Pacific. Thus, the islands are bathed by the warmer North Pacific on one side and the colder Bering Sea on the other. Bathymetry changes dramatically in a very short distance, from the depths of the Aleutian Trench (> 7,000 m deep) to sea level or above in a distance of less than 150 km, providing a huge variety of habitat and enabling tighter coupling between onshore, nearshore, and offshore systems. The eastern Bering Sea shelf, on the other hand, is more than 500 km wide. There, the nearshore environment has little or no connection with the outer shelf or slope environment (Figure 3-8). Due to the interaction of steep bathymetry with fierce tidal currents, mixing and convergences and divergences are ubiquitous in the Aleutian passes and variable on small spatial and temporal scales.

In most of the world's oceans (with the notable exceptions of the Arctic and Antarctic), boundaries are often oriented north/south. The Aleutian Archipelago is oriented east/west. This orientation could have profound implications in the face of large scale temperature changes. If a boundary is oriented north/south, as temperature changes, species that are dependent on the boundary can shift north or south along the boundary to remain in their preferred temperature range. If the boundary is oriented east/west, species would have to move away from the boundary to stay within their preferred temperature range. Thus species that are dependent on the environment of the Aleutian Islands may be less resilient or able to adapt to changes in temperature.

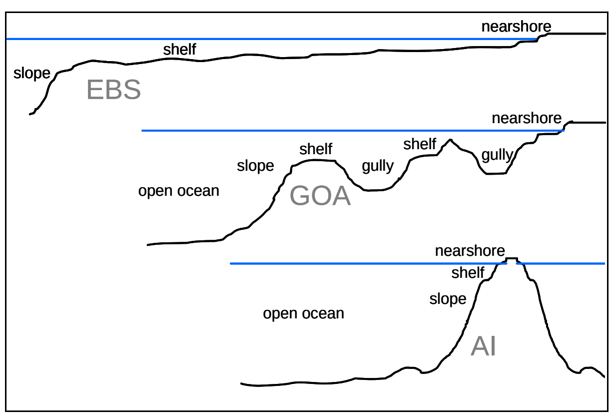

Figure 3-8 Aleutian Islands (AI) bathymetric profile and resulting oceanic-shelf-nearshore habitat proximity compared with other Alaskan ecosystems, to the Eastern Bering Sea (EBS) and the Gulf of Alaska (GOA).

3.3 Biological relationships

[PLACEHOLDER: insert discussion of food web model, why it is based on the early 1990s, built on stomach data from surveys so primarily summer diets, explain other characteristics]

Species distribution, richness, and diversity

In the Aleutian Islands, oceanography determines major physical attributes of the habitat. It also defines geographical boundaries for fish, playing a critical role in distributions of individual species, which in turn creates gradients of species richness (number of species), and species diversity (proportion of each species available within a unit of area). All of these processes operate at large scales, but can translate into smaller scale differences in biological relationships, which are observed as local habitat partitioning. We illustrate these relationships in general for the Aleutians here, and focus on more specific food web relationships for key species in the next section. We first describe longitudinal abundance trends along the sslands for fish, seabirds, and Steller sea lions, and then discuss how these trends translate into species richness and diversity in the ecosystem.

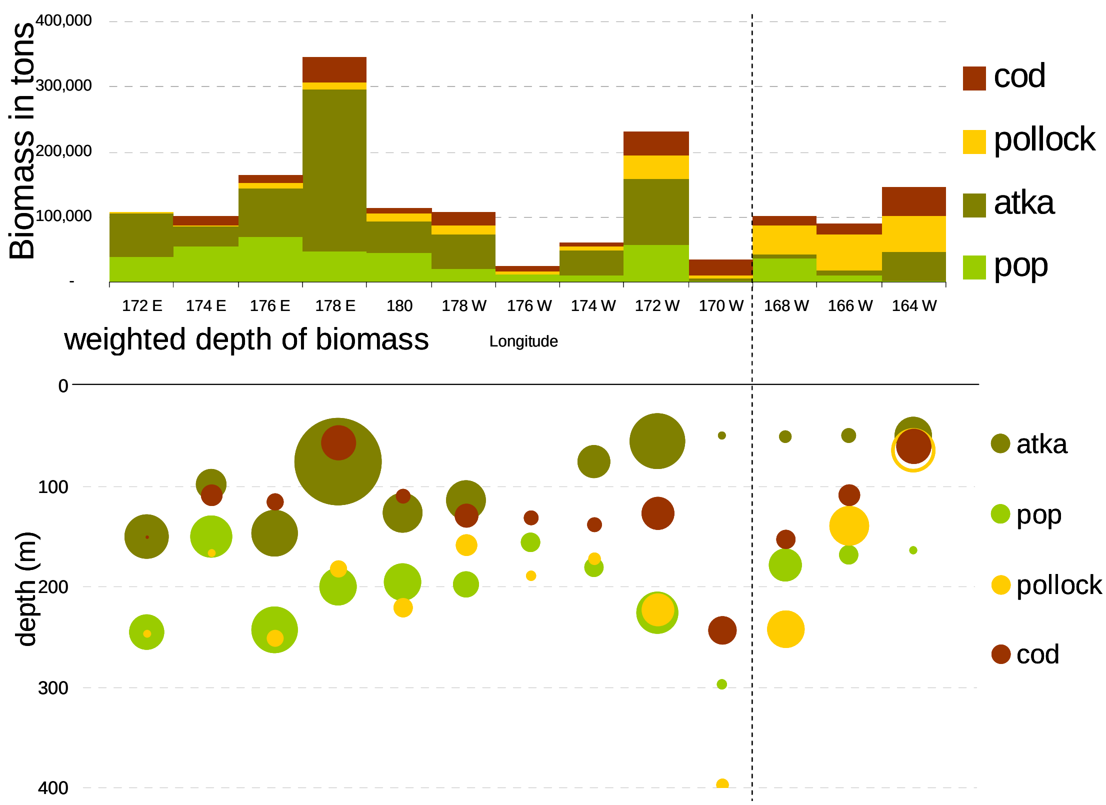

Figure 3-9 Longitudinal and depth biomass distribution (from trawl surveys) of major groundfish in the Aleutian Islands. Dashed vertical line represents the current management boundary between the AI and EBS, GOA management areas. Reprinted from Ortiz (2007).

The longitudinal trends in Aleutian Islands fish distribution can be illustrated as biomass densities per depth layer in two degree blocks (Figure 3-9). The first largest step increase in groundfish biomass from west to east is at area 172°W, the Yunaska/Amukta Passes. Atka mackerel and POP density increases significantly towards the west and they are split vertically, with the first inhabiting mostly above 200m depth and the second between 200-300m depth. In contrast, pollock and Pacific cod are found at all depths, but not at random. Pollock inhabit shallow waters (<200 m depth) east of area 170°W and deeper waters (>200 m) towards the west where it shares the 200-300 depth layer with POP. Pacific cod remains mostly within 100 to 200 m depth, in between Atka mackerel and pollock, but closer to whichever is more abundant (Ortiz 2007).

At a large scale, there is a correspondence in the longitudinal distribution of seabird and groundfish biomass in that fish in general constitute a larger portion of seabird diets east of area 172°W than towards the west (Figure 3-10). The longitudinal trend in the distribution of piscivorous and planktivorous seabirds has been observed and studied in previous seabird biogeography studies, and reflects the gradient of coastal to oceanic habitats found in the Aleutians (Ortiz 2007). The planktivorous seabirds in the western Aleutians are primarily auklets, several of which are known to be restricted to highly productive upwelling areas, and are absent in the warmer waters of the Gulf of Alaska (Stephensen and Irons 2003). Most seabirds along the Aleutians have breeding colonies in the western Bering Sea as well (Shuntov 1999), so the shift from piscivorous to planktivorous appears to reflect the overall lower abundance of shallow (<50m) small fish resources. The exception is area 174°E where both nearshore and offshore piscivorous seabird colonies dominate. Most seabirds throughout the archipelago are offshore diving feeders, other than northern fulmars which are primarily surface feeders and have their largest colonies near large passes, notably Samalga Pass and Buldir Pass (Byrd et al. 2005).

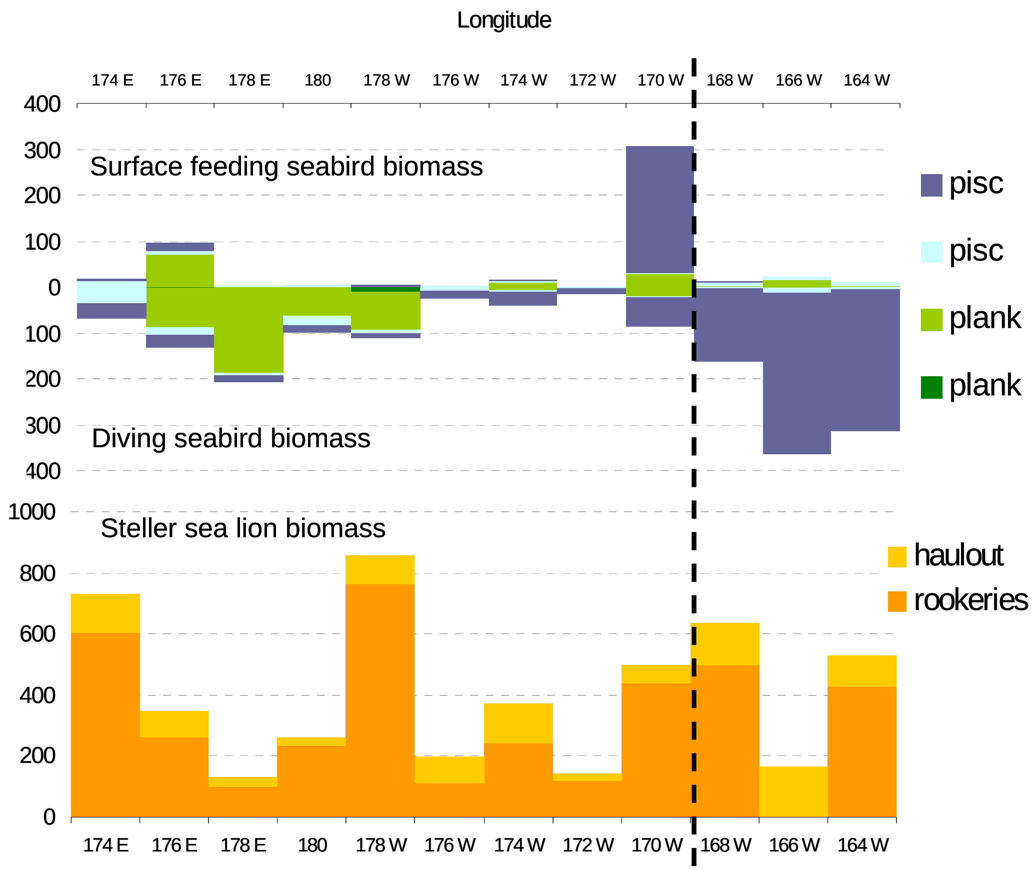

Figure 3-10 Longitudinal and depth biomass distribution of piscivorous (pisc) and planktivorous (plank) seabirds and Steller sea lions in the Aleutian Islands. Reprinted from Ortiz 2007.

Note: Dashed vertical line represents the current management boundary between the AI and EBS, GOA management areas.

In contrast with seabirds, Steller sea lion abundance shows no longitudinal pattern (Figure 3-10), but their highest abundances are all located near the largest passes, from east to west: area 168°W and 170°W (Samalga, Yunaska and Amukta Pass), area 178°W (Amchitka Pass), and 178°E (close to Buldir Pass). The lowest abundance of SSL is at area 178°E, coincident with the highest local density and biomass of Atka mackerel. This illustrates a habitat partitioning effect, examples of which are evident throughout the island chain. Habitat partitioning[3] is a multispecies interaction where the position of predators in space, with respect to each other, determines access to prey (Lehman and Tilman 1997, Pacala and Levin 1997). In this case, habitat partitioning regulates access to squid for Steller sea lions and Atka mackerel. Atka mackerel, distributed along the shelf breaks, consumes squid during its diel migrations. At low Atka mackerel densities, there is enough food at these locations for Atka mackerel and Steller sea lions. At high Atka mackerel densities, however, a major portion (~40%) of the squids' production is consumed by these predatory fish, as the squid comes to the surface. Atka mackerel thus out-compete Steller sea lions, which in this case have to cross the shelf and dive to access squid. The displacement of pollock by POP along the Aleutian chain (Figure 3-9) may illustrate another such competitive interactions, where competition for prey is mediated through space.

Species richness is simply a measure of the number of species in a given area; this measure is important from an apex predator or fishery perspective because it determines the variety of prey types available. The only study on fish species richness and community structure covering the entire Aleutian archipelago is that presented by Logerwell et al (2005). The study included 63 species of non-contiguous distribution along the Aleutian chain, and found there was a 28% decline in the number of demersal fish species (within 500 m depth) between Unimak/Samalga and Amukta Passes. The number of species remained relatively constant between Samalga and Amchitka and declined again (20%) west of Buldir Island.

Species diversity can be understood as the overlapping species biomass densities which determine the local proportion of each species present; species diversity, like species richness, affects energy flow in the ecosystem. Within food webs, there are a large number of species interactions, and also a wide range of interaction strengths (e.g., how much mortality a predator causes a prey, how dependent a predator is on a prey). Empirical work on natural food webs (Paine 1992, Power and Mills 1995, Wootton 1997) suggests that interaction strength tends to be skewed towards a few strong links and many weak ones. While it is tempting to assume that weak predator prey interactions are unimportant in the big picture of the food web (e.g., Pimm et al. 1991; Schoenly and Cohen 1991), in specific contexts weak links may be even more important than the strong links (Martinez and Dunne 1998).

A species and diversity gradient is apparent in local food webs along the Aleutian chain (Ortiz 2007, and discussed below). The food webs to the east of the deeper passes prominently feature forage fish and flatfish, while towards the west, coastal forage fish and flatfish are much less common and instead, demersal fish are more frequent. In the Aleutian Islands, interactions that are strong at only particular locations (and thus "weak" in the aggregated food web) are alternative energy pathways which keep the flow of energy from basal sources to higher levels of the food web uninterrupted, and thus makes the system more resilient (Ortiz 2007). This has important implications for the management of biodiversity; a locally common species may be only a small portion of the diet for a more widely distributed predator, but can represent a vital resource in a particular time and place. Therefore, at a large scale, a small set of key species may account for most of the energy flow in the food web, and impacts on these species are felt throughout the food web through the alteration of food-web wide energy pathways. At a small scale,

[3] Following Agostini's (2005) definition, habitat refers not only to physical structures but to the characteristics of the water column as well. In that respect, the species inhabiting the Aleutians move through a series of contracted and expanded habitats dependent on the amount of shelf and depth, as well as water column characteristics.

however, maintaining biological diversity ensures that local pathways remain connected, supporting the larger regional food web.

Key Species and energy flow in AI Food web

In this section, we aggregate the relationships described in the previous section to the ecosystem-wide spatial scale to examine the food web for the entire Aleutian Islands management area; once large scale relationships are identified, we will return to more local scales in the following sections.

A food web is a simple structure for visualizing energy flow relationships between species, one of the most basic types of ecosystem relationships – how does each group make a living? However, the complexity of the relationships in marine food webs can be overwhelming, so in this section we focus on key species from economic, biological, and social perspectives to illustrate relationships within the ecosystem. In recent years, the most economically important commercial species in the AI have been king crabs, Pacific halibut, Pacific cod, Atka mackerel, and (to a lesser extent) sablefish and Pacific ocean perch (see Section 3.4). Species groups with high biomass levels in the AI and which account for considerable energy flow within the pelagic portion of the AI food web include Atka mackerel, pollock, grenadiers, myctophids, and squids. Species that need special consideration due to special legislation[4], regulatory measures, or particular social interest include marine mammals (whales, seals, sea lions, and sea otters) and seabirds. Historically, most of these species were commercially important and heavily exploited in this ecosystem (Figure 3-2, Appendix A), but today most marine mammals and birds are protected from commercial exploitation. We note that our economic importance and high biomass groupings overlap: both Atka mackerel and pollock are now or historically were also commercially valuable species, and Pacific ocean perch has now recovered to a similarly high biomass level as these two species (Figure 3-6). Below, we give a brief overview of the most extensive food web we can describe with the available data, which we then aggregate to focus on these key groups.

The full food web of the Aleutian Islands is vastly complex, and even a relatively simplified quantitative representation still contains 149 groups, 134 of which are predator/prey groups and 15 are fisheries. A visual representation of the food web is shown in Figure 3-11, where box size is proportional to the estimated biomass in the ecosystem, the width of lines is proportional to estimated energy flow between boxes, and the vertical distribution of boxes in the figure represents trophic level. Groups are positioned so that benthic energy pathways originate on the left side of the figure (highlighted in blue) while pelagic energy pathways based on phytoplankton are to the right side of the figure (in green). Much of the pelagic energy flow in the AI food web moves through the key zooplankton groups of copepods and euphausiids (krill), which are discussed in detail below. The colors blend at higher trophic levels to the extent that the energy from benthic and pelagic sources blend. There are 1813 energy flow pathways between predators and prey, and 506 additional links when fisheries (pale orange boxes) are included.

[4] Species listed under the Endangered Species Act are listed in Appendix B.

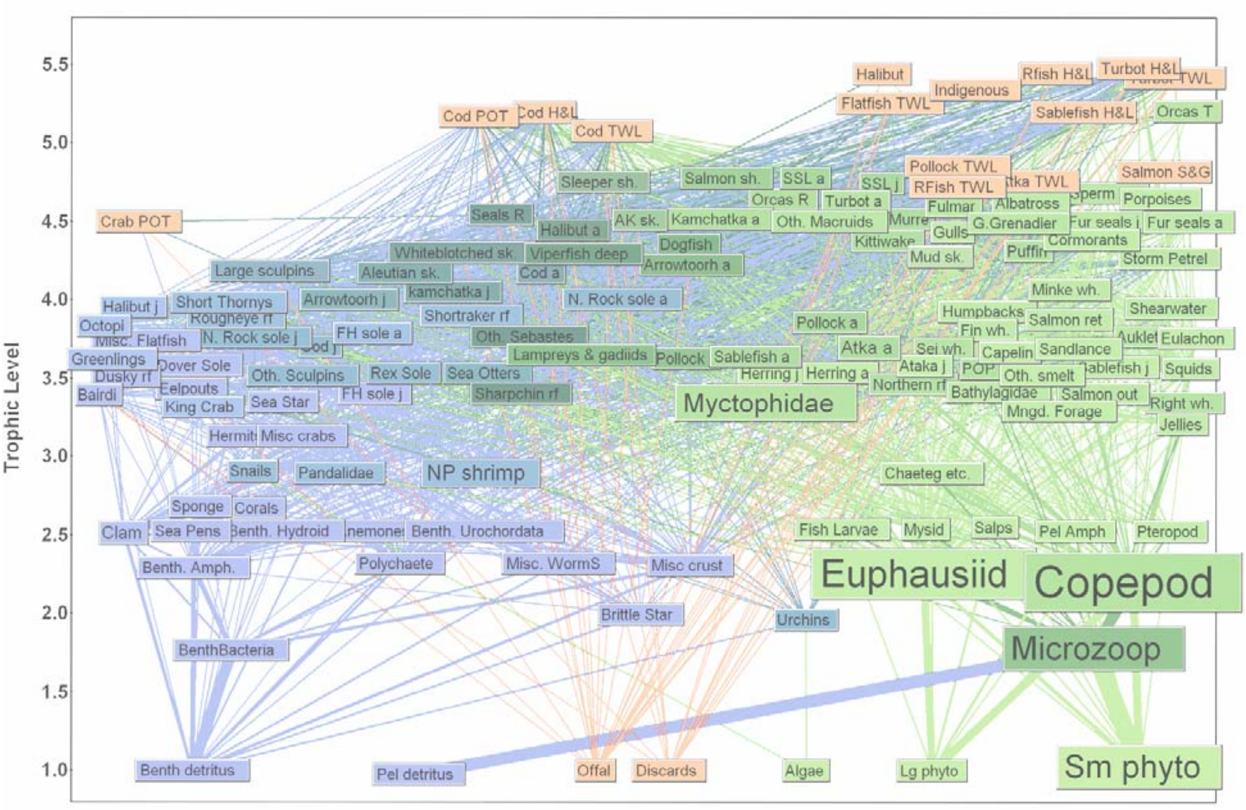

Figure 3-11 Visualization of the Aleutian Islands food web in the early 1990s. Reprinted from Ortiz (2007).

Note: Blue indicates benthic energy pathways; green indicates pelagic energy pathways based on phytoplankton. The colors blend at higher trophic levels to the extent that the energy from benthic and pelagic sources blend. Pale orange boxes represent fisheries.

When simplifying this food web to better portray the position of key species and the flows between them (Figure 3-12), several relationships emerge. Viewing the food web structure as a whole, it is apparent that humans are the highest trophic level predators in this ecosystem in the form of longline fisheries for Pacific halibut and Pacific cod, pot fisheries for Pacific cod, and subsistence fisheries. The socially protected species in pink share a trophic level with other fisheries such as the NMFS (groundfish) trawl fishery and ADF&G crab pot fishery, and are generally lower biomass, and mostly higher trophic level groups relative to the other key species highlighted in yellow and green. The high biomass groups in green (and yellow-green) cluster towards one side of the food web, the pelagic energy pathway, which is anchored on even larger biomass pools of zooplankton and phytoplankton. The high economic value groups in yellow (and yellow-green) share characteristics of both the high biomass groups and the protected species. Halibut and cod tend to be lower in biomass and higher in trophic level, sharing both pelagic and benthic energy pathways, while sablefish, Atka mackerel, and Pacific ocean perch occupy a lower trophic level and share the pelagic energy pathway with high biomass groups. King crabs are distinctive as an economically valuable group at a relatively low trophic level and entirely within the benthic energy flow pathway. Sea otters are distinctive as a protected species group entirely within the benthic energy flow pathway. Grenadiers are also distinctive as a high biomass group in the pelagic energy pathway, occupying a high trophic level comparable to the protected species.

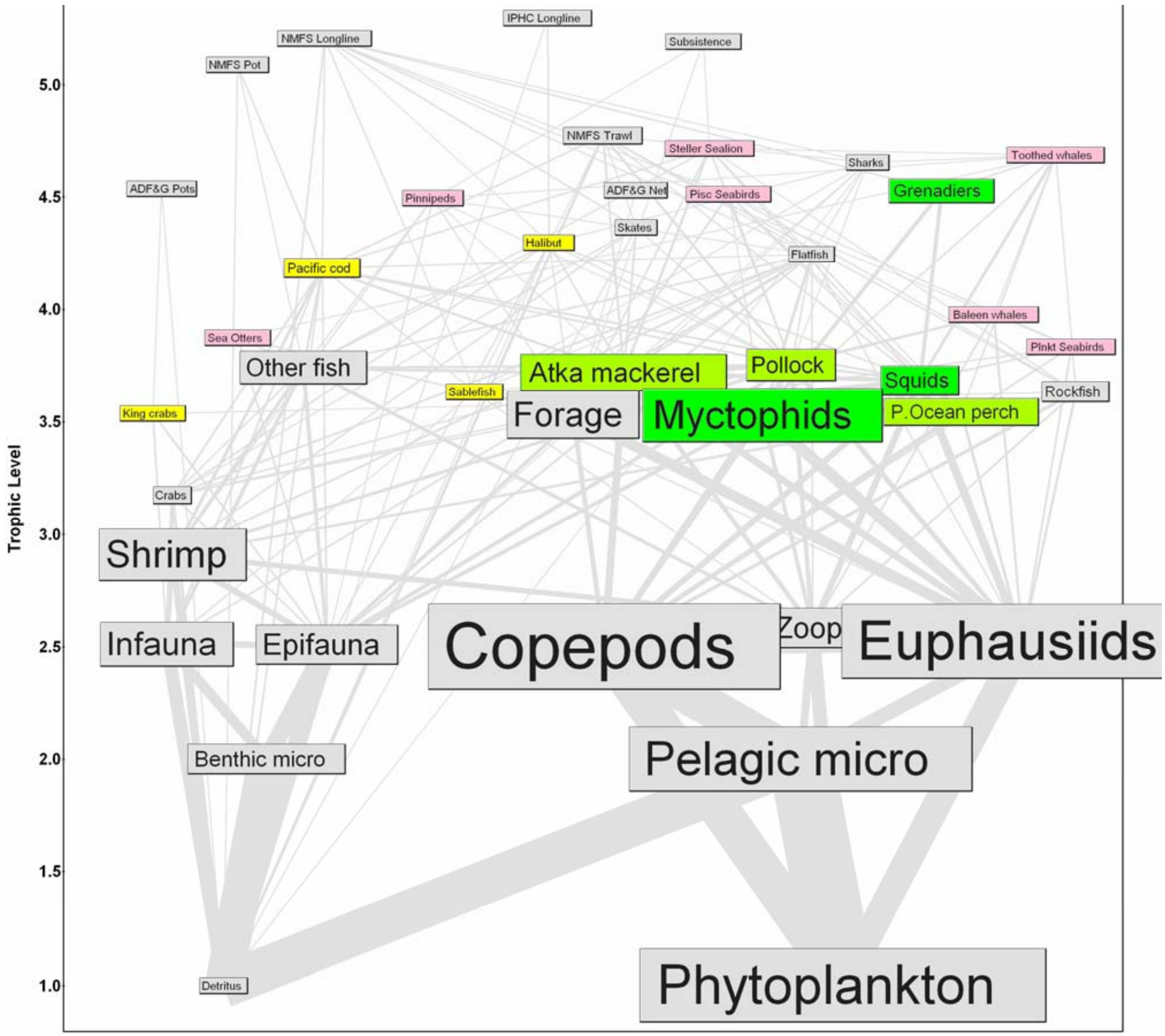

Figure 3-12 Visualization of the aggregated Aleutian Islands food web in the early 1990s.

NOTE: Key species are highlighted in green (high biomass), yellow (economic value), and pink (protected species). Blended yellow-green indicates overlap between high biomass and economic value groups. The size of the boxes represents relative biomass.

The high biomass of Atka mackerel, grenadiers, myctophids, and squids are unique to the AI ecosystem compared to the other Alaskan ecosystems (Aydin et al in review), as is the strong pelagic energy pathway which both economically important and protected species share with these high biomass groups (Figure 3-13). The difference in energy flow pathways is likely a result of the close proximity of oceanic habitat to shelf habitat in the AI, contrasted with the shelf-dominated EBS (see Figure 3-8). Therefore, while most of these key species are found in both the EBS and AI, and sometimes managed jointly between the two systems, the food web structure they depend on is distinctly different between the two regions.

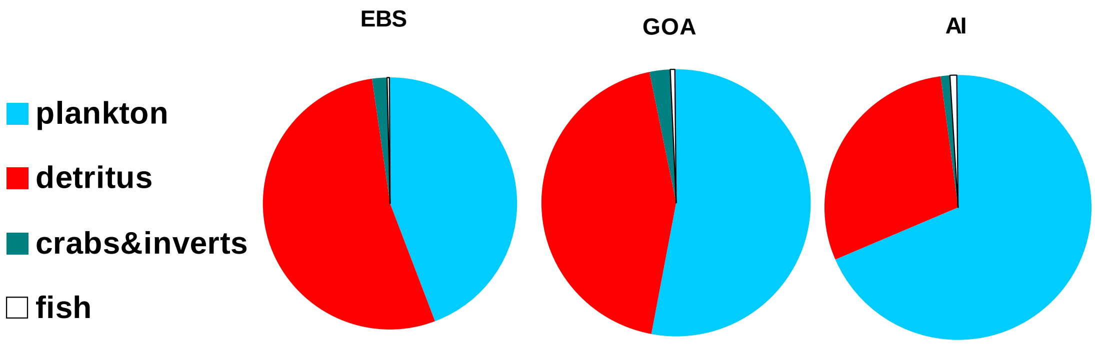

Figure 3-13 Comparison of energy flow between Alaskan ecosystems (reprinted from Aydin et al in review); the AI is a plankton / pelagic energy dominated system, the EBS is a detritus / benthic dominated system, and the GOA is intermediate.

Predator-prey relationships for key species

We present detailed relationships for key fish species/groups responsible for major energy flow within the ecosystem: Atka mackerel, Pacific ocean perch (POP) and lanternfish (myctophids). All three are high biomass planktivorous species, and two are economically important as well. Together, Atka mackerel and POP comprise 35% of the groundfish biomass and 33% of the total groundfish removals. Historically, they account for the largest catches in the Aleutian Islands ecosystem (Figure 2-1). Myctophids are an important prey item for many species including pollock and grendadier, and comprise 50% of the estimated forage fish biomass (including cephalopods); their mortality from fisheries (based on observer reports and survey data) is minimal (<0.0001%).

Atka mackerel, POP, and mytophids share a common zooplankton prey base along with pollock, squids and other forage fish (high biomass), sablefish and other rockfish (economic value), and baleen whales and planktonic seabirds (protected species; Figure 3-14). The production of the pelagic prey base, comprised of euphausiids, copepods, and other zooplankton, dominates the AI food web (Figure 3-12, Figure 3-13). Therefore, the processes maintaining this prey base also maintain many of our focal species at their current productivity levels. Given that there is little monitoring of these pelagic resources and limited understanding of physical factors affecting them in the AI at present, it may be difficult to fully understand key food web processes or to provide early warning of any changes to this important prey base for so many of our key species.

Several members of the zooplankton-feeding group (Atka mackerel, Pacific ocean perch, pollock, squids and other forage fish) are in turn part of the shared prey base of some fisheries, protected species, and other economically valuable species in the AI. Steller sea lions and other pinnipeds share this prey base with Pacific cod, halibut, skates, and the NMFS trawl fishery (Figure 3-14). Effectively, three other fisheries in the food web (NMFS longline, NMFS pot, and IPHC longline) also rely on this prey base because they specialize on Pacific cod and halibut. These relationships between major Aleutian Islands fisheries, key predators, and the shared prey base within the pelagic food web illustrate both the common oceanic energy source for fisheries, and the extent to which fisheries may compete with each other and with other predators for energy within the ecosystem. However, shared prey base alone does not necessarily imply competition. As discussed above, interaction strengths and spatial relationships greatly affect energy flow within this ecosystem. To clarify the relationships further, we first examine relative interaction strengths between predators and prey, and then the potential for habitat partitioning in space to mediate these relationships further. Interaction strengths for all key species are shown in Appendix C, Table 1 (fish) and Table 2 (protected species and fisheries), and are highlighted in detail for Atka mackerel Figure 3-15.

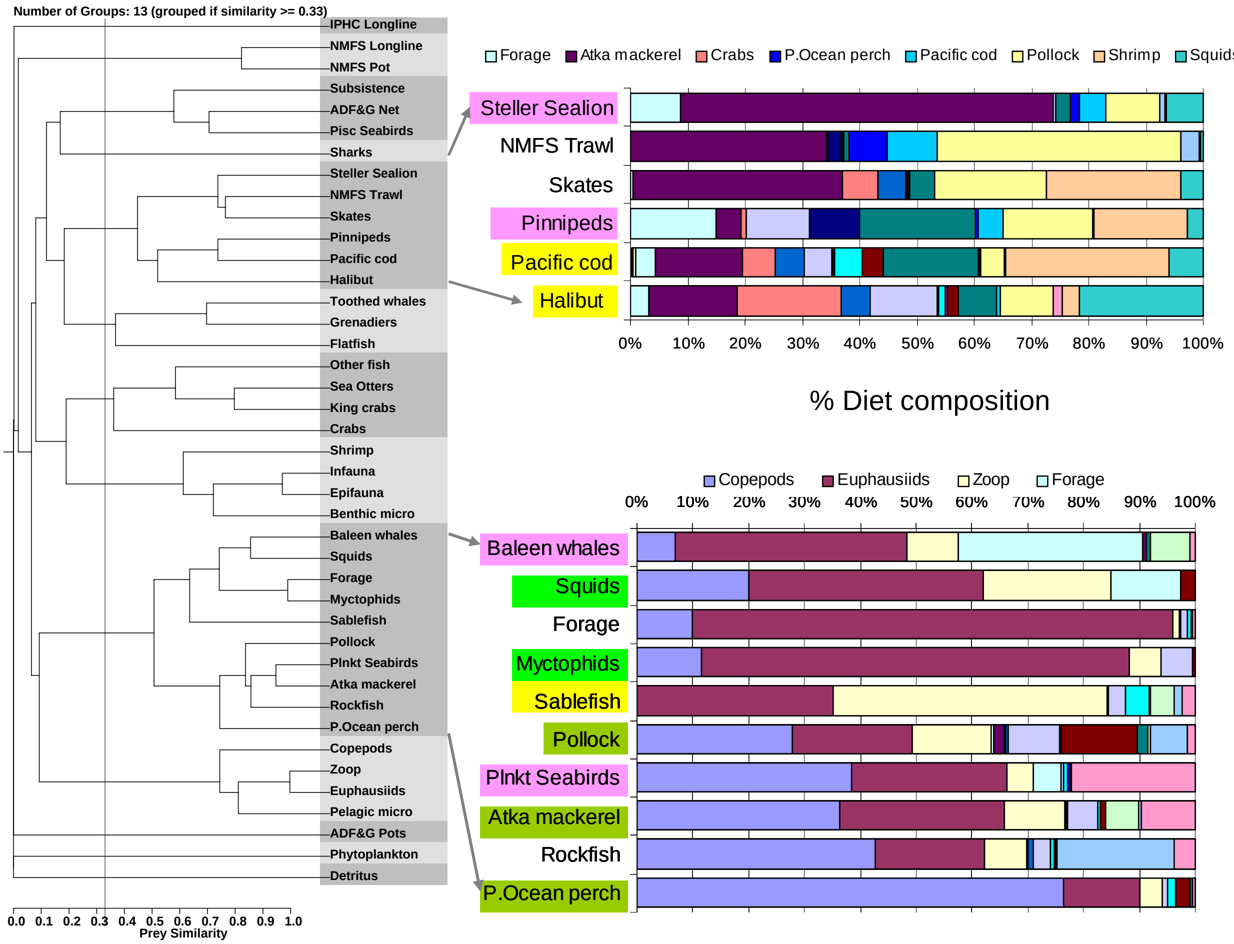

Figure 3-14 Shared prey base (at least 33% diet similarity) in the AI food web (organized in grey boxes): diet composition broken out for zooplankton feeders (lower) and Atka mackerel-pollock-squid feeders (upper).

Note: Bars for each species represent % diet composition, with major diet components labeled above each chart.

Role of Atka mackerel in the food web

Atka mackerel are commercially and energetically important in the AI, with food web connections to many other key species. Atka mackerel contributed 23% of the groundfish biomass and supported 28% of the total groundfish removals during the 1991-1994 period as the main groundfish target species by volume in the Aleutians since the early 1990s. Assuming the food web estimates are reliable, the production of Atka mackerel is almost entirely consumed within the ecosystem, and different predators rely on Atka mackerel as prey to different degrees (Figure 3-15). Juvenile Atka mackerel are consumed primarily by adult pollock (53%) and arrowtooth flounder (24%). As adults however, Pacific cod is their major predator (25% total mortality), along with pollock (7%), large flatfish and skates. Overall, groundfish predators cause 52% of combined adult and juvenile Atka mackerel mortality, juvenile and adult Steller sea lions account for 24%, and the directed fishery accounts for 17%. Of groundfish mortality, 20% is caused by Pacific cod predation on adult Atka mackerel and 18% by pollock predation on juvenile Atka mackerel. The extent to which each of these predators depends on Atka mackerel as prey differs substantially, however. Atka mackerel are only 5% of the overall pollock diet, and 15% of Pacific cod diet, whereas they represent 65% of the Steller sea lion diet and 34% of the early 1990s NMFS trawl fishery catch. (The proportion would be higher today, as the pollock fishery no longer contributes to the NMFS trawl fishery catch composition pictured in Figure 3-15). Therefore, while each of these predators is estimated to have a similar mortality effect on Atka mackerel, Atka mackerel energy has a very different affect on each of them.

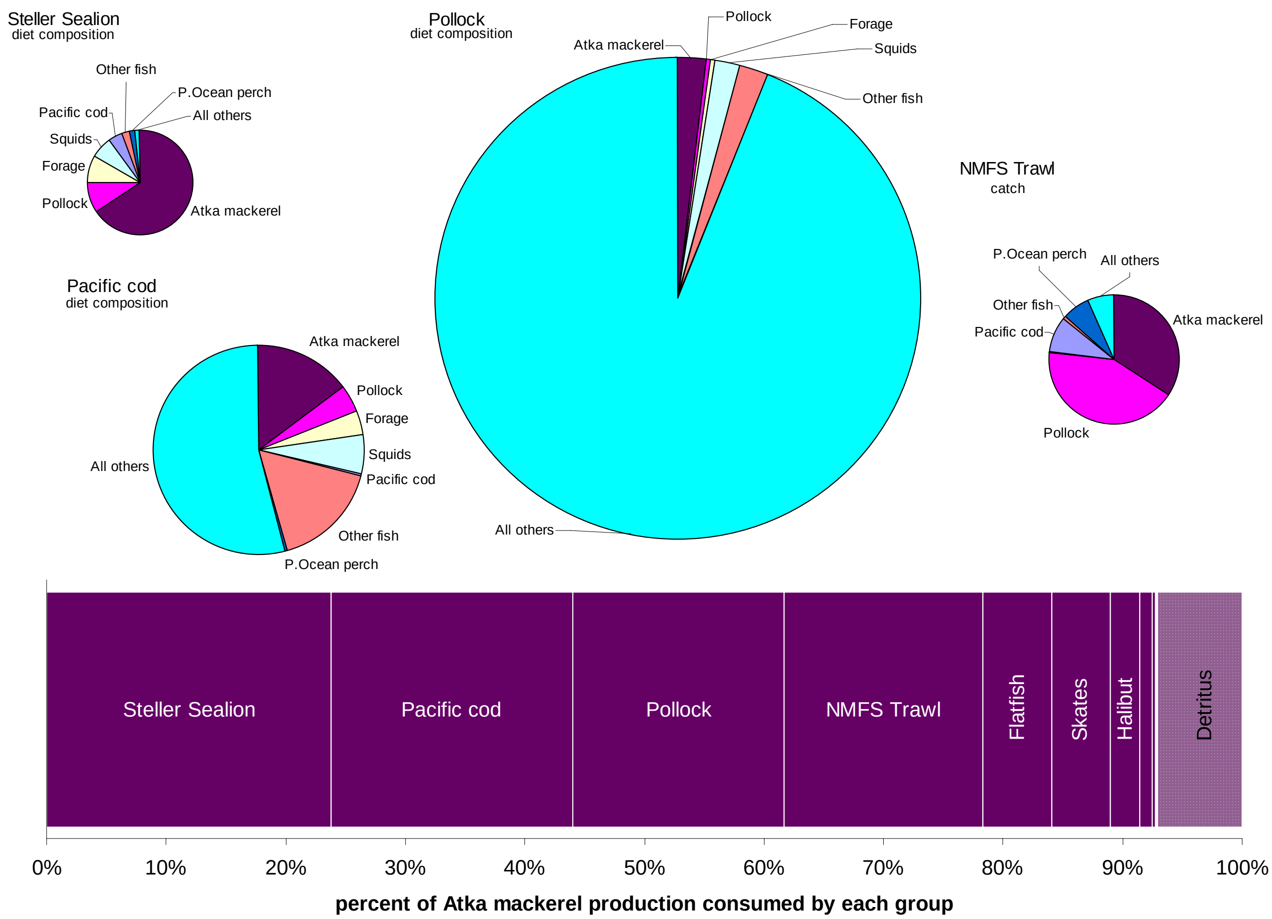

Figure 3-15 Atka mackerel food web relationships; lower bar represents total annual Atka mackerel production, labeled portions indicate the proportion consumed annually by each Atka mackerel predator. The pie charts above the bar show the proportion of Atka mackerel in the predator's overall diet.

Role of Pacific ocean perch in the food web

Pacific ocean perch (POP) supported the highest historical removals of any target species in the 1960s. Both total biomass and spawning biomass have increased monotonically since 1977 (Spencer et al 2005). The population is currently at around 66% of their estimated biomass in the early 1960s. Pacific ocean perch inhabit the outer continental shelf and upper slope. They are relatively small but long-lived fish with an estimated lifespan of 90 years (Spencer and Ianelli, 2003). The population is managed as a shared stock with the EBS, but the majority of the catches take place in the Aleutian Islands subarea where their abundance is estimated to be higher. In contrast to Atka mackerel, few predators in the ecosystem consume POP (Figure 3-16a). If we assume the structure of the food web is reliable, the main predators of POP are sperm whales (currently depleted), fulmars and Kamchatka flounder. The dominant role of POP in ecosystem energy flow is attributed to its large biomass and relevance as a species exploited commercially. Unlike the Northern California Current, where juvenile rockfish have been shown to play an important role in the productivity of diving piscivorous seabirds such as auklets and murres (Field et al. in review), no such trophic relationship has been observed at least for the western Aleutian Islands (Springer et al 1996).

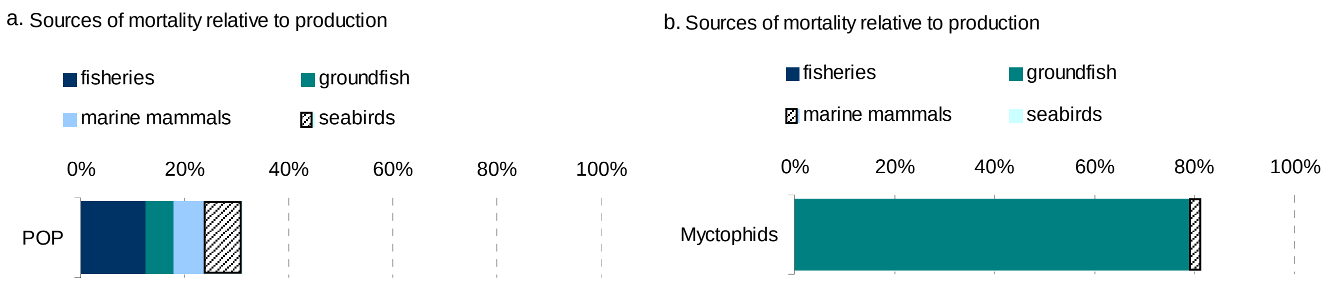

Figure 3-16 Mortality sources for (a) Pacific ocean perch (POP) and (b) Myctophids in the Aleutian Islands. Little information is available for Myctophids, so we assumed that 80% of their production is consumed by other species, comparable to pollock and Atka mackerel.

Role of myctophids in the food web

Myctophids are a composite taxonomic group containing all lanternfish members of this family in Alaska. Most myctophids are less than 10 cm long, but some reach up to 30 cm. They exhibit diel migration with peak abundances between 300 and 1200 m during daytime and between 10 and 100 m at night (Nelson 1994). Acoustic surveys show that the horizontal distribution of myctophids extends far off the shelf break but overlaps marginally with that of pollock near the shelf (Steven Barbeaux, pers. comm.). The vertical migration and overlap towards the shelf may make them available to groundfish predation (Figure 3-16b), in particular by pollock (responsible for 30% of their total mortality), giant grenadier (23% of total mortality), and Kamchatka flounder (6 % of total mortality). This dependence of pollock on myctophids as prey is unique to the Aleutian Islands among Alaskan ecosystems; Bering Sea and Gulf of Alaska pollock have almost no myctophids in their diets (Aydin et al in review). Provided that seabirds and killer whales consume forage fish in proportion to their abundance (as assumed in the model) then myctophids contribute substantially to the diet of killer whales, albatrosses and kittiwakes, making them a key prey item for fish and marine mammals in the Aleutian Islands, particularly towards the west. Spatial patterns in food webs are examined in more detail in the next section.

Spatial food web relationships in the Aleutians

Two main spatial patterns determine the structure of the food webs in the Aleutians. First, there is a longitudinal gradient from east to west along which the main prey supporting the food webs changes. Second, groundfish distribute vertically on the shelf at different depths. The longitudinal pattern is the result of large scale oceanographic processes which determine major physical attributes of the habitat and geographical boundaries for fish, playing a critical role in species richness (number of species) and species diversity (proportion of each species available within a unit of area). In contrast, the vertical pattern results from small scale factors: the amount of available shelf at depth and habitat partitioning. The relative position of the predators influences their access to prey. What the individuals eat most (strong links) is then the combination of what is available (through large scale processes) and what they can actually get to (local processes). The available resources are increased by spatial subsidies of myctophids and squids from adjacent pelagic oceanic waters and offal from fisheries. The result of these processes is an observed spatial difference in the diets of Atka mackerel and pollock (Figure 3-17) demonstrate the longitudinal variability in diet for major species.

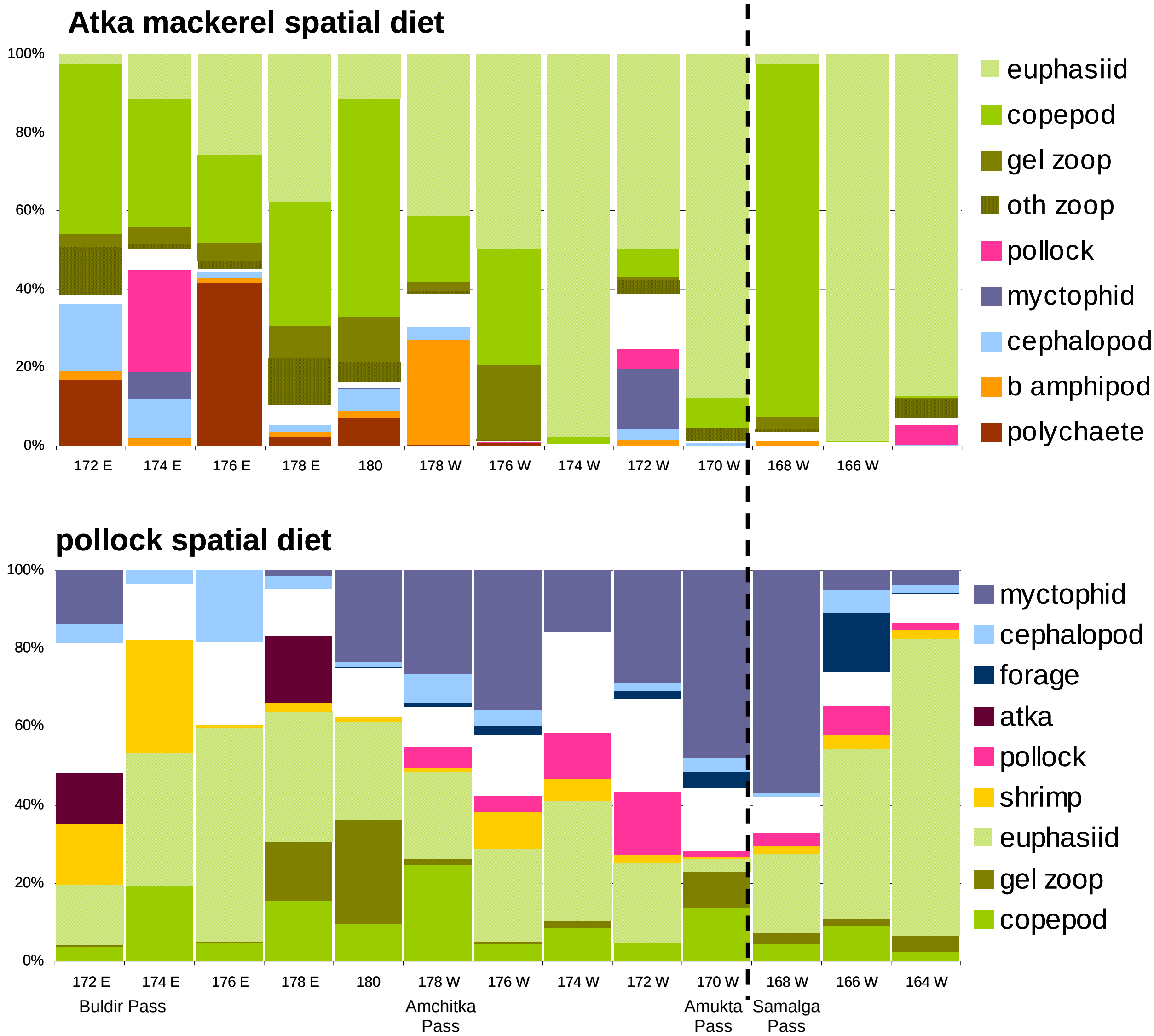

Figure 3-17 Spatial diet composition for Atka mackerel and pollock in the Aleutian Islands. Dashed vertical line represents the current management boundary between the AI and EBS, GOA management areas. Reprinted from Ortiz (2007).

The combined effect of large and local scale factors structures the food webs into one of three general types, where Amukta and Amchitka Pass mark the breakpoints where the food web structure changes (Figure 3-18). The first are food webs supported by pollock and various groundfish, with a gradually increasing proportion of myctophids and a decreasing proportion of euphasiids. The second are food webs supported by Atka mackerel, benthic invertebrates, myctophids and euphasiids. The third are food webs primarily supported by Atka mackerel, non decapod benthic invertebrates, copepods and euphasiids. Although all the main prey supporting the food webs are distributed throughout the archipelago, they are not of the same importance in each type of food web. Even greater diversity is observed among the weak links: flatfish and forage fish towards the east, demersal fish, polychates and amphipods towards the west.

As Berlow et al. (2004) point out, the relevance of any one given species lies in the particular configuration or structural organization of strong and weak links.

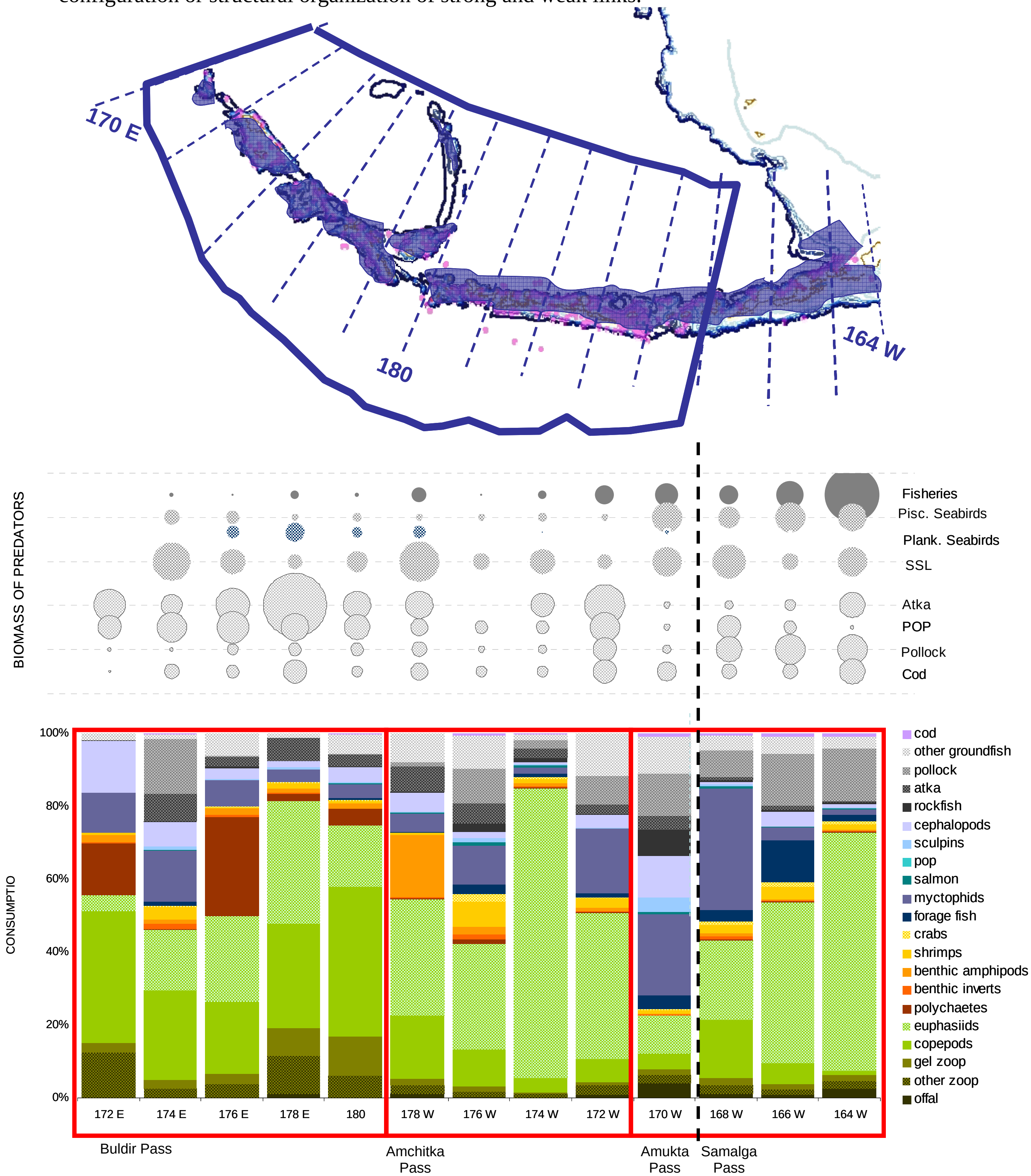

Figure 3-18 Spatial food webs in the Aleutian Islands. Dashed vertical line represents the current management boundary between the AI and EBS, GOA management areas.

Myctophids are common among the three food web structures. They are consumed all along the archipelago. Schools of myctophids and squids overlap the edge of the shelf and shelf break, and extend far off shore (Barbeaux et al 2005). As our food web models only include the shelf down to 500 m depth, it is unlikely that the myctophids and squids consumed come entirely from local communities. At least some level of spatial coupling occurs between these local communities and regional pools. If that is the case, then the archipelago receives a substantial subsidy from adjacent pelagic waters. The relevance of subsidies for local productivity depends on the permeability of the system and the potential for resource utilization. The ratio of perimeter to area, currents and upwelling all increase permeability or openness (Holt 2004, Witman et al. 2004). The islands, and archipelago [and shelf modeled here] as a whole, certainly have a large perimeter compared to its area characterized by tidal currents and passes. More than 20 groundfish have direct trophic connections with myctophids, 18 to squids (see chapter 2). This evidence points to the archipelago as a subsidized system where productivity on the shelf down to 500 m highly benefits from this process. A second source of subsidies is fisheries, which in some areas support an important portion of the local consumption. The risk of depending on subsidies is the expected low productivity when these resources are missing (Huxel et al. 2004).

Energy flow: leaky ecosystem boundaries

The Fishery Ecosystem Plan defines a boundary for the ecosystem (west from 169°W) based on ecological and management boundaries. However, the actual foraging and distributional ranges of marine species and humans that use and inhabit the ecosystem are neither uniform nor confined to these area, but have a strong relationship with areas outside of the defined boundary.

The primary marine currents that influence the marine waters near the central and western Aleutians originate outside the area. Although the Alaska Coastal current largely moves north into the Bering Sea between Unimak and Samalga Passes, the Alaska Stream continues west along the south side of the islands. The Aleutian North Slope Current apparently originates west of Attu and moves east along the north side of the islands (see Figure 3-6).

The primary atmospheric forcing is from the Aleutian Low Pressure system (REF). Cyclonic storms typically form southwest of the Aleutians and move to the east along the chain affecting not only weather in the Aleutians but also in the EBS and GOA and beyond.

Although the area of interest for this fishery ecosystem plan is the Aleutian Islands, management in this region potentially affects people and animals that are not resident in the area. For instance, several species of seabirds and marine mammals listed as threatened or endangered spend only a portion of the year in this area (Table 3-1). Oceanic seabirds including albatrosses and shearwaters feed near the Aleutians from distant breeding areas (central, eastern, or even south Pacific) or during their non-breeding seasons, but have historically been affected by fisheries in the area of interest (i.e., bycatch during long-lining or drift gill netting). Northern fur seals from breeding areas in the eastern Bering Sea migrate through the Aleutians and several species of whales spend summers in the region, but migrate out to the rest of the Pacific for the remainder of the year.

Table 3-1 Range of seabirds who spend some or all of the year in the Aleutian Islands ecosystem

Species	Seasonality in Aleutian Islands	Estimated population size	Notes
Short-tailed Albatross	Summer and fall foragers	Low hundreds	See Piatt et al.
Laysan Albatrosses	Oceanic, year around	Thousands	REF
Short-tailed Shearwater	Oceanic in summer	Hundreds of thousands	S. hemisphere breeders, Gibson and Byrd in press
Mottled Petrels	Oceanic in summer	Thousands	Gibson and Byrd in press
Marine Waterfowl	Winter	Tens of thousands	Gibson and Byrd in press
Through migrants birds	Spring and fall	Thousands	Gibson and Byrd in press

Current protection for marine mammals and recent advances in bycatch mitigation measures have substantially reduced the bycatch of seabirds and high-seas drift gill nets have now been banned from the EEZ. However, all these visiting species still depend upon healthy food webs in Aleutian waters (REFS) during their seasonal occupancy.

Marine waterfowl (i.e., swans, geese, sea ducks, loons, and grebes) congregate in nearshore waters and intertidal zones of the central and western Aleutians in winter from distant breeding areas. In fact, the Aleutians are the primary wintering area for emperor geese and harlequin ducks, and substantial numbers of species of sea ducks winter in the region.

[PLACEHOLDER need to talk about marine mammals; salmon from various stocks apparently spend a good portion of the year feeding with the Aleutian portion of the EEZ]

For some selected groundfish species, such as Pacific cod, Atka mackerel, pollock, and various rockfish species, the linkages with areas outside of the Aleutian Islands can be revealed from genetic patterns, tagging data, recruitment patterns, and other types of data. For Pacific cod, significant migration between and within the EBS, AI, and GOA has been demonstrated based on tagging studies (Shimada and Kimura 1994), and a study of allozymes failed to show significant stock structure between these areas (Grant et al.1987). The question of whether to manage EBS Pacific cod separately from AI Pacific cod is a current management issue, and additional genetic research using microsatellite DNA is underway at the Alaska Fisheries Science Center (M. Canino, AFSC, pers. comm.). Additionally, length and age frequency distributions, size at age data, and diet differ between the EBS and AI, but the degree to which these results reflect environmental differences, as opposed to spatial stock separation between the areas is not clear.

For Atka mackerel, examination of the linkage between the AI and the GOA has been examined with several types of data. Morphological and meristic studies suggests separate populations between these areas (Levanda 1979, Lee 1985), whereas an allozyme study showed no difference between the western GOA and three areas of the AI (Lowe et al. 1998). Ongoing work with microsatellite DNA did not show spatial structure with samples from the AI, GOA, and Japan, and examination of the temporal stability these results is currently being examined. The current genetic data indicates connectivity between the GOA and AI, perhaps due to high dispersal and/or recent population expansion. However, differences in population size, spatial distribution patterns, and recruitment patterns between the GOA and AI has motivated separate management of the AI and GOA populations.

For pollock, three stocks are recognized in the BSAI area: the EBS stock, an AI stock, and the central Bering Sea-Bogoslof Island stock, although these populations likely have interchange between them. Microsatellite data indicates weak differences among samples collected throughout the north Pacific; however, these weak differences were significant only at large geographical scales and conform to an isolation-by-distance pattern (O'Reilly et al. 2004; Canino et al. 2005). Separate stock assessments currently exist for AI and EBS pollock, but the stock assessment authors caution that interactions between AI pollock and EBS pollock do occur although the extent of these interactions are not known.

Tagging information does not exist for Alaskan rockfish, although genetic information is available for several rockfish species in the Aleutian Islands, including POP, northern rockfish, rougheye rockfish, and shortraker rockfish. For POP, microsatellite DNA was analyzed from 10 locations throughout the GOA, EBS, and AI, and the results indicate sub-population structure. Additionally, a pattern of isolation by distance was observed, in which the genetic difference between locations increased with the distance between locations. These results are consistent with research on British Columbia POP (Withler 2001), and suggest limited linkages between adjacent areas. Ongoing genetic research with POP is focusing on increasing the sample sizes and the number of collection sites for the microsatellite analysis in order to further refine our perception of stock structure.

For northern rockfish, a preliminary study revealed no evidence of population structure from either mtDNA or microsatellite analysis (Gharrett 2003). However, the sample sizes were small (20 fish from each of three locations), and only a portion of the mtDNA genome and a handful of microsatellite loci were examined. If subtle differences occur, much larger sample sizes would be required in order to identify stock structure. Additional northern rockfish genetic samples were collected from each of the four major areas in the 2004 Aleutian Islands survey (100 samples each), as well as 100 samples from the 2004 EBS slope survey, and a genetic analysis of these samples by Dr. Anthony Gharrett and his colleagues at the University of Alaska is currently in progress.

Population structure has also been observed for shortraker rockfish based upon microsatellite data, with the geographic scale roughly consistent with current management regions (i.e.,GOA, AI, and EBS) (Matala et al. 2004). The most efficient partitioning of the genetic variation into nonoverlapping sets of populations identified three groups: a southeast Alaska group, a group extending from southeast Alaska to Kodiak Island, and a group extending from Kodiak Island to the central Aleutians (the western limit of the samples). The available data are consistent with a neighborhood genetic model, suggesting that the expected dispersal of a particular specimen is much smaller than the species range. A parallel study with mitochondrial DNA revealed weaker stock structure than that observed with the microsatellite data. This study suggest some linkage between shortraker rockfish in the central and eastern AI and the GOA, although it is not known how shortrakers in the eastern Bering Sea or western Aleutians relate to the large population groups identified by Matala et al. (2004) due to a lack of samples from these areas.

Genetic analyses have revealed two species of rougheye rockfish motivates examination of stock, and rougheye in the Aleutian Islands consist predominately of "type I" rougheye. For these fish, four partitioning schemes were examined in which the samples were assigned to non-overlapping populations. Each of these four schemes indicates that significant divergence occurred between specimens from the central Aleutian Islands, the eastern Bering Sea and eastern Aleutian Islands. However, each of these four partitioning schemes show a linkage between GOA type I rougheye and either the AI rougheye or the EBS rougheye, thus suggesting some connectivity between rougheye rockfish in the BSAI area and the GOA.

How is the Aleutian Islands ecosystem different from the surrounding ecosystems?

The Aleutian Islands food web is dominated by oceanic processes, and is characterized by substantially higher pelagic energy flow than the Eastern Bering Sea or Gulf of Alaska ecosystems. Much of this pelagic energy could be considered an external "subsidy" for continental shelf and land based species inhabiting the Aleutian Islands (including humans). The gradient of depth defined habitats, species biomass, richness, and diversity across the Aleutian chain drives different food web interactions across space, where both regional and local scale interactions are combined to support ecosystem energy flow.

Groundfish relationships differ greatly between the Aleutian Islands and the Eastern Bering Sea, although the two ecosystems are often combined for management purposes. Atka mackerel dominate the Aleutian Islands food web, where they support economically important fish species, marine mammals, and directed fisheries simultaneously; however, Atka mackerel are only minor components of other Alaskan ecosystems. Commercially important groundfish species have different food web roles in the Aleutians than they do elsewhere in Alaska. Sablefish are zooplankton feeders here, whereas they feed on fish in the EBS and GOA; conversely, pollock rely on myctophids for a substantial portion of their diet in the AI, but are nearly exclusively zooplankton feeders in the other systems. Pacific cod interact strongly with Atka mackerel and sablefish in the Aleutians, whereas they interact mostly with crab species in the Eastern Bering Sea. Myctophids, squids, and grenadiers are prominent players in Aleutian Islands energy flow, but minor components of the Eastern Bering Sea and Gulf of Alaska food webs. This is primarily attributable to the proximity of pelagic oceanic habitats to shelf and nearshore habitats in the Aleutian Islands, which is nearly opposite in configuration to the Eastern Bering Sea shelf which has few connections to the open ocean.

3.4 Socioeconomic relationships in the Aleutian Islands Ecosystem

Unangam Tunuu

Language is one of the primary ways in which humans interact with and form concepts of the environment. Unangam Tunuu is the Aleut language, spoken for thousands of years in the Aleutian Islands Ecosystem. The language is very detailed in identification of marine species, reflecting the kind of meticulous environmental knowledge indigenous groups develop over many generations of observations in a particular ecosystem. Each term for a species or resource group is a linguistic marker for a much wider repository of traditional ecological knowledge about natural history, animal behavior, seasonal variation, cultural values, and spiritual interrelations.[5]

In Atka, the fish that bears the community's name in common English, the Atka mackerel (*Pleurogrammus monopterygius*) is called *tmadgi{* (*tavyi{* in Attuan). Some names are the same across the island chain, such as *haanu{* for the sockeye salmon (*Oncorhyncus nerka*). Others terms are distinct to each island, or reflect broader groupings of eastern and western, such as the Steller sea lion, known as *qawa{* from Atka east and *qava{* in Attu and the Commander Islands. Some words hint at the broader system of environmental knowledge of which they are a part, such as aligdusi-{, used in the eastern islands for jaegers (*Stercorarius parasiticus* and *S. longicaudus*). The name literally means "making vomit," a reference to the behavioral trait of forcing other birds to spit out fish they have just

[5] The examples of Unangam names for marine animals require the Unangam Tunuu font in order to see all the letters in the words correctly. The font is free and is easy to download at http://www.alaskool.org/LANGUAGE/fonts/unangam/unangam_font.htm. All examples are given in Atkan or Attuan dialects unless otherwise noted. A detailed pronunciation guide for the Atkan dialect may be found at http://www.ankn.uaf.edu:591/Atkan/Pronunciation.html.

caught. Other words retain traces of the region's colonial history, such as herring (*Clupea herengus*), which is called ungla-{, but may also be called sildi-{ from the Russian word *sel'd'* for herring.

There are also a huge number of Unangam names for places and geographic features in the islands. The terms on any contemporary map of the islands reflect Aleut, Russian, American, and scientific interests and influences in the islands. Understanding that the biotic, geographic, and oceanographic resources of the Aleutian Islands ecosystem are discursive objects in many different systems of meaning is a key to understanding that human history, along with a variety of human interpretations, human conflict, and human interests are an integral part of the ecosystem.

According to the US Census 2000, Unangam Tunuu, the Aleut language, is spoken in about ¼ of households in Atka and a much smaller percentage of households in Adak. The language is also taught in some of the area schools and at summer cultural camps. Although English is the predominate language of everyday discourse, Unangam names for places and common animals are more widely known and understood.

Communities in the Ecosystem Today

The Aleutian Island Fishery Ecosystem Plan boundaries contain four inhabited communities. Until recently, three of these (Adak, Attu and Shemya) were military locations, while only Atka was a civilian settlement. Atka is a Native village that has persisted for thousands of years, though its population is declining. The Aleut language is spoken in about ¼ of homes. When the base closed in Adak in 1997 the settlement lost most of its (predominantly military) population. However, there are still several hundred people there and it appears the location will remain a civilian population center. Both civilian communities (Atka and Adak) are highly dependent on commercial and subsistence fisheries in the Aleutian Islands ecosystem, though Adak has other economic development as well (see below).

Shemya and Attu

Shemya is the site of Eareckson Air Station, a U. S. Air Force base, which grew from an airfield first constructed during World War II. There are now about 1400 people at Shemya. It is largely a refueling stop for military aircraft. Shemya has Armed Forces supported radio and television, as well as a movie theater, a gym, and an enormous radar installation.

Attu hosts a Coast Guard Loran station manned by twenty active duty personnel that rotate yearly. It also receives Armed Forces supported radio and television.

Atka and Adak Demography

Populations in these communities have varied over time. The population of Atka has fallen consistently from the maximum of 132 listed for the 1880s and 1890s when Census records were first calculated, to 92 in the 2000 Census, and 90 in the state demographer's 2005 estimate. The population of Adak has fluctuated extensively over the years due to changing military activities. In 1944, there were more than 30,000 people in Adak, because of WWII action in the Aleutian Islands. A population was first recorded by the Census in 1970 at which time there were 2,249 inhabitants, but with the closing of the military base in 1997 the population decreased by about 2,000 persons. The 2000 Census recorded 316 people. By 2002, the population had reduced to 149 people, according to a state demographer, but has increased to 167 in 2005, largely due to efforts on the part of the Aleut Corporation to develop the location.

Table 3-2 Demographic data for Adak and Atka

U.S. Census 2000 Data	Adak	Atka
Population in year 2000	316	92
% Alaska Native	35.1%	80.4%
% White	49.7%	6.5%
% Asian	9.8%	1.1%
%Hawaiian Native or Pacific Islander	1.9%	1.1%
% Black	1.3%	0.0%
%Two or more races	2.2%	10.9%
% Hispanic ethnicity (supplementary to race)	5.1%	1.1%
Male/female ratio	65/35	50/50
Median age	35.2	35.5

The distribution of population by age and gender in Adak and Atka (Figure 3-19) show two distinct patterns found frequently in Alaskan communities. Atka's structure is most similar to the pyramidical "family shape" (Package and Sepez 2007), displaying a relatively even distribution between genders and a general decline by age. This structure is commonly found in Native villages, and often shows a reduction of 20-29 year olds out-migrating for educational opportunities. Adak's structure resembles the "labor shape" (Package and Sepez 2007), dominated by a bulge of working-age males, as is commonly observed for industrial towns, such as fish processing centers. The population structure of Adak is likely to change over time as the Aleut Corporation continues to actively seek to move Native families into the area.

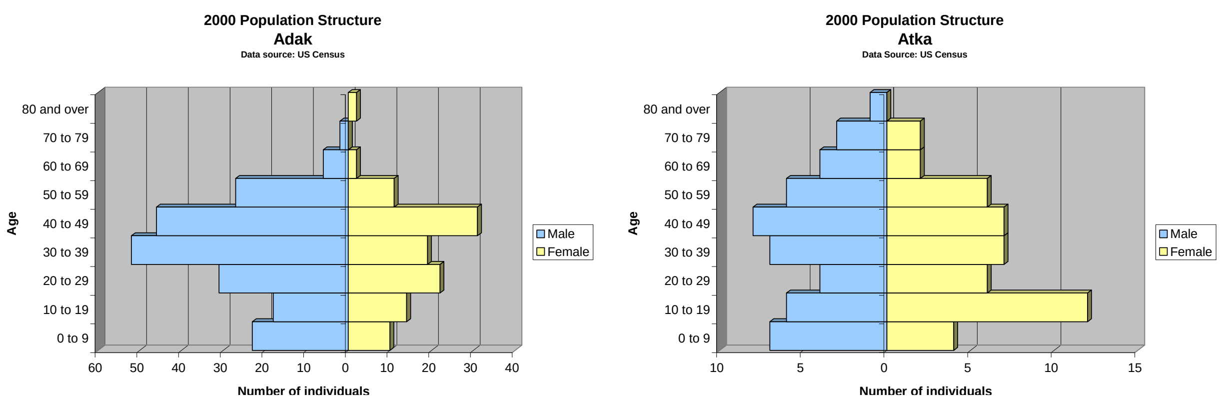

Figure 3-19 Distribution by age and gender of the 2000 Census populations in Adak and Atka.

Atka Economy and Infrastructure

The economy of Atka is predominantly based on subsistence living and commercial fishing. The median household income in 2000 was $30,938 and the per capita income was just over $17,000. Year-round income opportunities in the village are mostly limited to education and government related work. Some residents work off-island part of the year in order to make enough income to get by. Marine resources are abundant, and about 2,500 reindeer on the island and provide a source of fresh meat to local residents.

Atka was incorporated as an Alaska city in 1988. The city provides water, sanitation, and electricity (diesel powered). The Aleutian Pribilof Islands Association, Inc., a federally recognized, nonprofit, tribal organization provides public safety (Atka Village Public Safety Officers) and health programs (Atka Health Clinic). Atka is a member of the for-profit regional Aleut Corporation chartered under the Alaska Natives Claims Settlement Act (ANCSA). Atxam Corporation is the Native village corporation. The

Native Village of Atka is the federally-recognized tribe. Each of these governmental and quasi-governmental organizations plays a role in administering the community. Atka is within the Aleutian Region school district and one school on the island, with two teachers, serves 19 pupils ranging from grades K-12. The school gym is used widely for community gatherings including bingo nights. The St. Nicholas Russian Orthodox Church, rebuilt with reparation funds after being burned by the Navy in WWII, also serves as a focal point of village life.

Atka has a state-owned 3,200 foot lighted paved runway. Scheduled air services are available four times weekly from Unalaska and can also be chartered from Cold Bay. The cost of a roundtrip plane ticket from Atka to Anchorage is about $1,200 (based on fares searched for January 2007), which is about 7% of per capita income. Coastal Transportation provides freight services during the peak fishing season from May to October. A new dock and port facility, operated by the City, were recently completed 5 miles from town.

Adak Economy and Infrastructure

The economy of Adak is more varied than that of Atka, with shipping, military, and local commercial establishments as well as commercial and subsistence fishing. Its residents also have higher income levels than Atka. The median household income was $52,727 and the per capita income in 2000 for Adak was $31,747, nearly twice that of Atka.

The City of Adak incorporated in 2001 and provides police and fire services, electricity (from diesel fuel), water, and a sewer system. Adak Medical Clinic is operated by Eastern Aleutian Tribes. Although Adak was an Aleut village in earlier times, it was a military base during the latter half of the twentieth century. For that reason, it was not included in the Alaska Native Claims Settlement Act (ANCSA) and is not federally recognized as a Native village. Aleut Corporation has taken a very active role in the development of the city after the base closure, taking over responsibility for some services to the community, such as the landfill. Adak School, the only school present, teaches K-12th grade. The school had 18 students in 2000 and 3 teachers. There is a weight room and a racquetball court at the high school. At one time, there was an Olympic size swimming pool and a bowling alley associated with the military base, but these amenities have not been maintained. They are in a portion of the building that is no longer heated and they are deteriorating quickly. The St. Innocent Chapel of the Russian Orthodox Church was founded in 1996.

Adak has two 7,800 foot paved runways and Alaska Airlines operates passenger and cargo airline service to Adak on Tuesdays and Sundays. The approximate price to fly roundtrip from Adak to Anchorage is $1,302 (price given for dates in January 2007), which is about 4% of per capita income. There are three deep water docks and fueling facilities in Adak, originally built to handle naval ships. The city has about 16 miles of paved roads and also has other dirt and gravel roads.

Commercial Fisheries

The Aleutian Island Ecosystem provides fish that are eaten all over the world, and commercial fishing opportunities to residents of the ecosystem (in Atka and Adak) as well as to communities throughout Alaska and elsewhere. This section will examine commercial fisheries in two ways: commercial fisheries production in the ecosystem (for processors and vessels from anywhere) and commercial fisheries pursued by the communities (processors and resident-owned vessels) located in the ecosystem. Confidentiality requirements prevent a full disclosure of much of this data.

Commercial Fisheries Production in the Aleutian Islands Ecosystem

In 2005, the Aleutian Islands Fishery Ecosystem (defined for the purpose of this analysis as statistical areas 541, 542 and 543 combined, see Figure 3-20) produced 40.7 million pounds of fish, with an estimated ex-vessel value of $33,294,353.[6] Fish harvested over the last 5 years (2001-2005) was landed in 24 different ports in Alaska. Seventeen of these ports received AI Ecosystem fish in at least four of the last five years. The 16 onshore ports are Adak, Akutan, Atka, Dutch Harbor, Homer, King Cove, Kipnuk, Kodiak, Ninilchik, Nome, Nunivak Island, Saint Paul, Sand Point, Seward, Togiak, and Toksook Bay (Figure 3-21). The breadth of ports receiving Aleutian Island fish has been considerably widened by participation of communities in the Community Development Quota (CDQ) program, especially for halibut. The 17th "port" consists of all floating processors, catcher processors, motherships, and other off-shore sector participants, which account for 41% of the total landings from the ecosystem, although only 18% of ex-vessel value. Further information by community is difficult to provide because so many of these locations only have a single processor, making the data confidential.

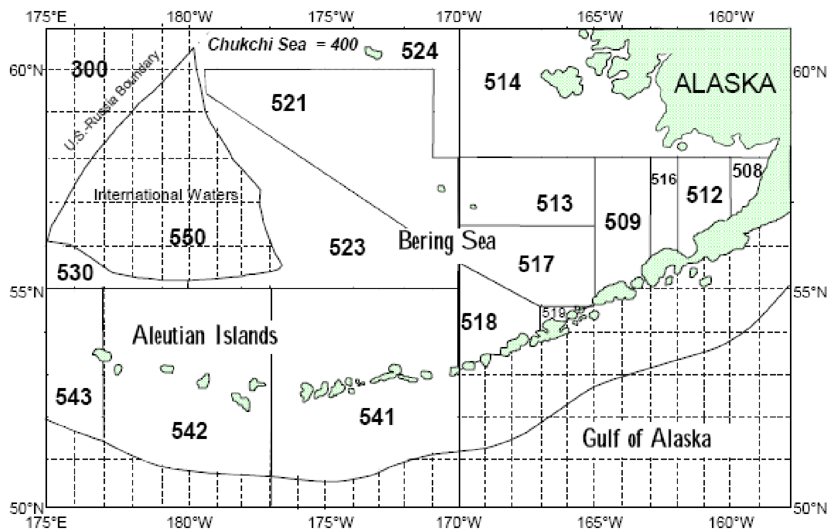

Figure 3-20 Management areas near the Aleutian Island Ecosystem, including 541, 542, and 543 (which extends further west to the limits of the EEZ).

[6] Areas for halibut and salmon fisheries do not exactly correspond to areas 541, 542 and 543. For these fisheries, reasonable approximations have been made to the Aleutian Islands Fishery Ecosystem Plan boundaries, but the associated data may not be as reliable as other fisheries.

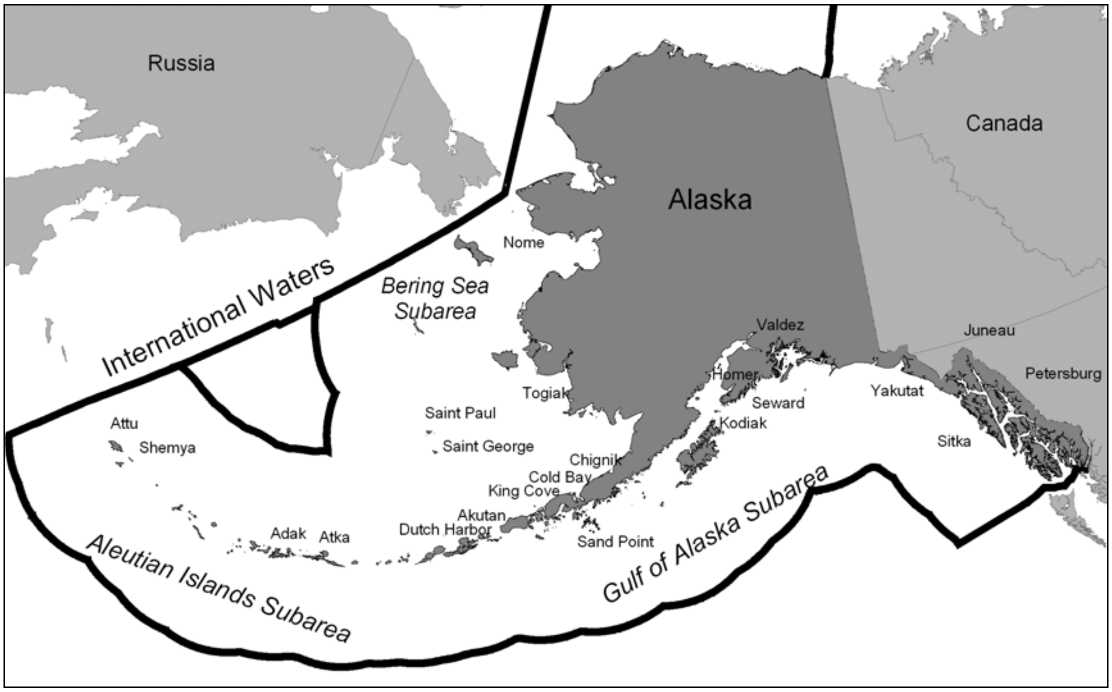

Figure 3-21 Major fishing communities in Alaska.

[PLACEHOLDER – find map that lists all of communities referenced]

The majority (by volume) of fishery resources harvested in the Aleutian Islands Fishery Ecosystem (again defined as Management Areas 541, 542, and 543 for the purpose of this analysis) in 2005 consisted of Atka mackerel (Figure 3-22). By value, Atka mackerel, Pacific cod, crab, and halibut together in similar proportions make up the majority of the value of fishery resources removed from the ecosystem (Figure 3-22).

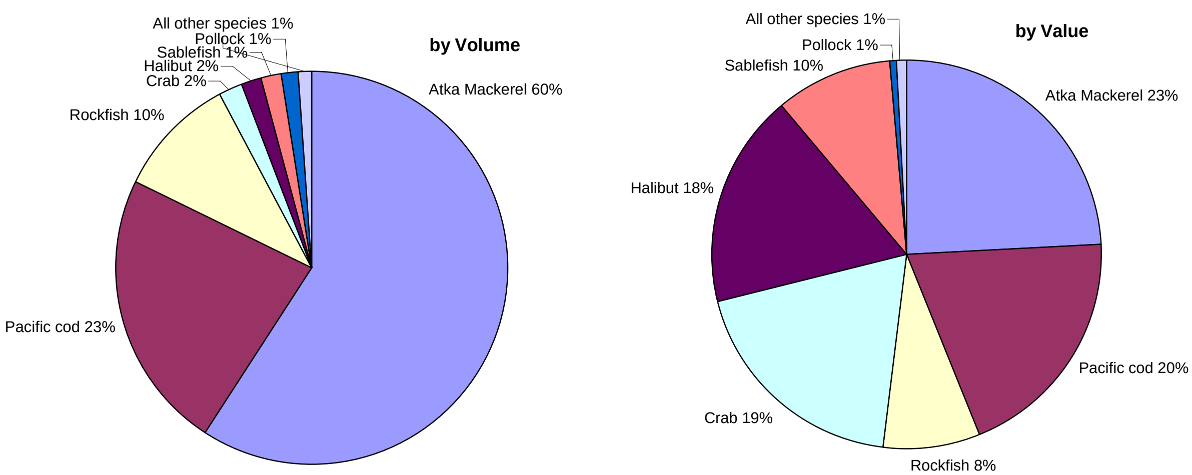

Figure 3-22 Fishery resources harvested in the Aleutian Islands Ecosystem (areas 541, 542, and 543) by volume and by value, in 2005.

A detailed description of the management of the fisheries is provided in Section 3.5.2.

Commercial Fishing in Atka

Commercial fishing is of great significance to the economy of Atka. According to APIA, the local fleet consists of 45 vessels. With the help of Atka's CDQ group, Aleutian Pribilof Island Community Development Association, the development of several facilities in the 1990s associated with the fishing industry has resulted in significant economic enhancement in the community (Obeso, 1994). The City of Atka collects a 2% raw fish tax on fish landed in the community. A small on-shore fish processor, Atka Pride Seafoods, services the local fleet. Because there is only one processor in the community, landings information must be kept confidential by law.

According to the Alaska Department of Fish and Game (ADF&G) and reported by Alaska Commercial Fisheries Entry Commission (ACFEC), 17 Commercial Fisheries Gear Operator Permits were held by 9 individuals in Atka in 2000. 10 of these were actively fished that year. There were 3 vessel owners in the federal fisheries, no vessel owners in the salmon fishery, and 19 licensed crew members with residence in Atka. A number of offshore fish processors carry out crew changes through Atka.

Permits for halibut issued in Atka for 2000 pertained to one hand troll (not fished), 7 longline vessels under 60 feet (6 fished), and one longline vessel over 60 feet. All permits designated for halibut for statewide waters. Permits for sablefish issued in 2000 pertained to four longline vessels under 60 feet for statewide waters (three fished). Additionally, one permit for a salmon set gillnet limited to the Atka/Amlia Islands and three permits for miscellaneous salt water finfish longline vessels under 60 feet for statewide waters were issued but not fished.

Commercial Fishing in Adak

Aleut Corporation has been working to recreate Adak as a commercial fishing hub for the area. In 2000, there were four commercial fishing permits issued. There was one community member who owned a vessel participating in federal commercial fisheries who was a resident of Adak, and according to the ACFEC there were two licensed crew members from Adak in 2000. Adak Fisheries Development Council is operating the local seafood processor in Adak which processes cod, crab, halibut and bottomfish. An allocation of pollock in 2005 to the Aleut Corporation and the implementation of state-waters Pacific cod and pollock fisheries in the central Aleutian Islands will contribute additional growth to this facility. Because there is only one processor in the community, landings information must be kept confidential by law. Adak Fisheries is also providing cold storage capacity in Adak.

All four commercial fishing permits issued to residents of the community were issued for the harvesting of groundfish. Specifically, one was issued for miscellaneous salt water finfish using a hand troll, one for miscellaneous salt water finfish using a mechanical jig, one for demersal shelf rockfish with a longline vessel under 60 feet in the southeast, and one permit was for demersal shelf rockfish using a mechanical jig in the southeast (not fished).

There were 49 vessels that delivered 'Other Groundfish' landings in Adak, 24 for sablefish, 32 for halibut, and 12 vessels that delivered Bering Sea and Aleutian Islands (BSAI) crab landings to the community. In accordance with confidentiality regulations, data for fish landings in the community cannot be revealed.

Globalization of Product and Labor Markets

Labor inputs in commercial fisheries, including crew and processing workers have a significant transnational component. Workers in the fisheries in Alaska come from all over the world. In the Aleutian Islands Ecosystem, transnational migratory laborers may be found in the processing plant in Adak, the off shore processor and catcher-processor fleet, and elsewhere. Laborers have come from the Philippines, Vietnam, and elsewhere in Asia, as well as Latin America and Africa. U.S. residents come from all 50 states to participate in Alaska fisheries as commercial fishing vessel crew and processing workers.

The processed fishery products of the Aleutian Islands are exported to countries around the globe. It is not possible to disentangle Aleutian harvests from other U.S. harvest locations in export records, but an examination of all Atka mackerel exported from the U.S. demonstrates just how globalized the market place is for fisheries products. Atka mackerel has been exported to 28 different countries over the last 7 years (1999-2005). Japan and Korea have consistently been the largest recipients of Atka mackerel (see Figure 3-23 for 2005 exports), but a geographically diverse group of nations are beginning to import the fish, including Bulgaria, Guatemala, Jamaica, Thailand, and Mexico. Records show this global market is continuing to develop, with just 2 nations importing $17 million worth of product in 1999 growing to 15 nations importing Atka mackerel worth an average of $52 million in 2005. It is likely that all of this product came from within the Aleutian Islands Fishery Ecosystem Plan boundaries.

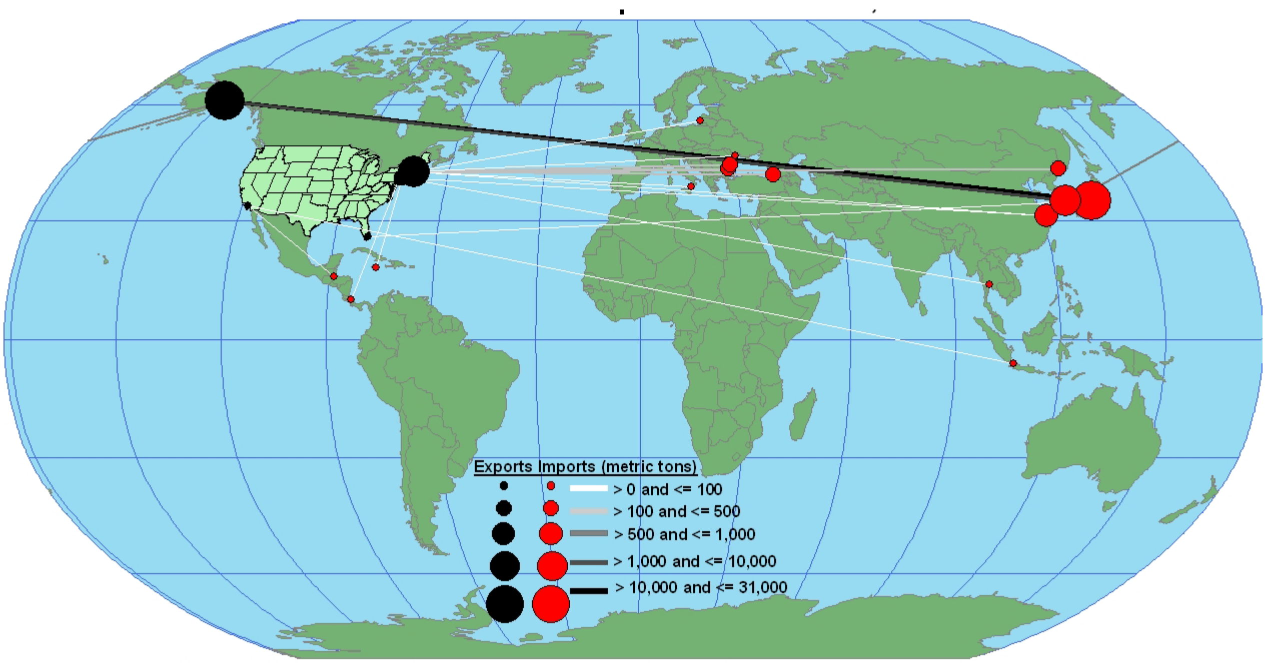

Figure 3-23 US Atka Mackerel Exports to the World, 2005.

Subsistence Fisheries

Subsistence harvests and related practices continue to provide Aleutian communities with important nutritional, economic, social, cultural, and spiritual requirements. The following information focuses on quantitative data, which may be used to track change over time in the ecosystem and its inhabitant's practices. However, the importance of subsistence goods in the social, cultural, and spiritual life of a community cannot be overstated. These values are repeatedly expressed by participants in many Alaska locations as core motivations and core rewards for engaging in subsistence harvesting and consumption. There are typically strong connections between commercial and subsistence fisheries with commercial vessels provisioning subsistence consumers with fish or opportunities to fish, and earnings from commercial fishing supporting subsistence gear and other expenses.

Subsistence management of marine mammals in the Aleutians is shared between the Department of Interior and several Alaska Native Organizations including the Alaska Sea Otter and Sea Lion Commission, the Alaska Native Harbor Seal Commission, and the Aleut Marine Mammal Commission. Management of subsistence fish and shellfish harvesting is conducted by the Alaska Department of Fish and Game in waters under state jurisdiction and by the federal Office of Subsistence Management in waters under federal jurisdiction. Management of the subsistence halibut fishery is conducted by the National Marine Fisheries Service

Subsistence Fishing in Atka

Every household in Atka participated in the use of subsistence resources in 1994, the year of the most recent ADF&G survey, including harvesting, sharing, and consuming resources.

Sea lions, salmon, and reindeer are the biggest contributors to the subsistence diet. Of the total population, 96.4% used salmon, 92.9% used non-salmon (cod, flounder, greenling, halibut, rockfish, sablefish, sculpin, char, and trout), 92.9% used marine mammals, and 85.7% marine invertebrates.

The total per capita harvest for the year was 439.28 lbs. The composition of the total subsistence harvest can be shown by the percentages of the resources which demonstrate the amount of each resource category used by the community relative to other resource categories. Salmon constituted 21.58% of the total subsistence harvest by weight while non-salmon fish made up 9.03%, land mammals 21%, marine mammals 34.3%, birds and eggs made up 1.81%, marine invertebrates were 1.19%, and vegetation made up 1.09%. The wild food harvest in Atka made up 284% of the recommended dietary allowance of protein in 1994 (corresponding to 49 g of protein per day or .424 lbs of wild food per day).

NOAA issued 19 Subsistence Halibut Registration Certificates (13 rural and 6 tribal) to residents of Atka between 2003 and 2005.

State subsistence permits and harvest reports for crab and salmon are not required in Atka. The most recent subsistence survey in Atka was conducted in 1994 and included 28 of 29 households. The 1994 subsistence salmon harvest in Atka was estimated to 2,504 salmon, comprised of 12 chinook, 431 sockeye, 567 coho, 1,387 pink and 107 chum salmon (Shaul and Dinnocenzo 1994). The magnitude of the subsistence king and Tanner crab harvest near Atka is unknown, but is believed to be relatively small.

Subsistence Fishing in Adak

Only limited information on subsistence fisheries in Adak is available. This information indicates that both salmon and halibut are important species harvested by local residents. Based on information about the remote environment of Adak, the heritage structure of the current population, and evidence from other Alaska locations, it is reasonable to assume that a host of other subsistence harvests, including other fish, shellfish, and marine mammals, are taking place around Adak.

Subsistence in Adak has been very unstable in the last decade because of the extreme fluctuations in population numbers and composition, the epic legal struggle between the state and federal government over subsistence management and the rural preference, and a change in Adak’s rural classification.

Prior to 1988, the non-commercial salmon net fishery at Adak was classified as a subsistence fishery. In 1988 it became a personal use fishery, but was reclassified as a subsistence fishery again in 1998. In 1999, all fresh water on Adak Island and all salt water within 100 yards of a stream terminus were closed to subsistence fishing for salmon because of the federal position on non-rural subsistence. In the Adak District in 1999 five subsistence salmon permits were issued in the area by the State and an estimated 164 sockeye and 4 chum salmon were harvested by those permit holders. Harvest increased to nearly 500 sockeye salmon taken by 17 permit holders in 2001, but decreased to 188 sockeye salmon taken by two permit holders in 2005 (Tschersich 2006). NOAA issued 15 Subsistence Halibut Registration Certificate (15 rural and 0 tribal) to residents of Adak between 2003 and 2005, and classified Adak as rural. In late 2006, the Federal Subsistence Board reclassified Adak as rural, which will re-open other federal areas near Adak to subsistence hunting and fishing for the 2007 harvest.

State subsistence permits and harvest reports for crab are not required in Adak and the magnitude of subsistence king and Tanner crab harvest near the island is unknown, but believed to be relatively small.

Recreational Fisheries

Recreational fisheries are not a significant factor in the Aleutian Islands ecosystem at this time. No recreational fishing licenses were sold in either Adak or Atka in the year 2000 (Sepez et al. 2005). Data have not yet been analyzed for later years. The recreational fishing situation was likely different when there was a large military population based on Adak.

A small amount of recreational fishing occurs in Shemya and Attu where military personnel are stationed, however licenses must be purchased elsewhere before deployment. The Coast Guard provides a fish smoker on Attu and notes an abundance of salmon (June through August) and Dolly Varden (year round) [http://www.uscg.mil/D17/loranattu/recreation.htm].

Other Human Activities in the Ecosystem

Tourism

Tourism is extremely limited in the Aleutian Islands Ecosystem. Birdwatching is probably the most significant tourist activity, as the Aleutians present an opportunity for North American birdwatchers to spot many Asian species that do not otherwise appear in the United States.

The Aleut Corporation is promoting tourism as one of the commercial developments that will benefit Adak. They have already attracted visitors from six cruise vessels. Car rentals are available at in Adak at Adak Car Rentals and Hotel Adak provides lodging. Both are run by Aleut Enterprise Corporation, a firm established by the Aleut Corporation to further commercial development of the island. The attractions promoted on the Adak website include hiking, bird watching, wildlife watching, sport fishing, caribou hunting, WWII installations, and purported nuclear weapons storage compounds. Some of these attractions may be in conflict with each other, such as hiking, which may require staying on established trails and roads to avoid unexploded WWII ordnance. It is expected that tourism will grow in Adak in the next few years. Because of the available facilities, recreational fishing has the potential to become a significant sector in Adak.

Tourism is essentially non-existent in Atka. There are short-term accommodations available and the city has a 10% accommodation tax.

Military

Military activities in the Aleutians have had a significant effect on the island ecosystem. Early Aleut history includes periods of war and peace that affected the places and types of resources used (West et al. in press). Russian military action (including massacres and enslavement) deeply changed the structure of Aleut society and local biotic resources.

More recently, World War II had significant local effects on the people (Kohlhoff 1995; Sepez et al. in press) and on the ecosystem wherever military personnel or actions were concentrated (notably Attu and Adak, as well as Unalaska). Gasoline and ammunition were dumped into the ocean, oil spills were numerous, spawning grounds were filled in or exploded, and terrestrial mammals were hunted in great numbers (so much so that the army had to initiate rules to stop it) (Malcolm 2006; Kohlhoff 2002).

The EPA has been performing Superfund clean-up and restoration of Adak because of the 40-year period that hazardous substances were disposed of on the island, including materials such as transformer oils containing PCBs, petroleum, chlorinated solvents, and batteries.

The military presence in the Aleutians has had additional social and environmental consequences. In 1965, 1969 and 1971, three underground nuclear tests were conducted on Amchitka Island, including the largest underground nuclear test ever conducted by the United States (Kohlhoff 2002). It is also widely believed (but neither confirmed nor denied by the Navy) that Adak was the site of nuclear depth charges and torpedoes, as well as nuclear weapons storage.

It was announced in April of 2003 that Adak was chosen as the site for a radar installation for the Missile Defense Agency. It is estimated that this facility will require approximately 75 to 95 people to operate the system. The sea-based X-band radar that identifies and tracks incoming missiles as part of the national missile defense system arrived at Adak in February, 2007.

Shipping

Unimak Pass is part of the “Great Circle” shipping route between the United States and Asia. As a result, a tremendous number of ships pass through the islands, particularly on the eastern end. Traffic is estimated to be 1600 container ships per year and 30-40 tankers, the majority of which are westbound, as well as smaller commercial traffic including tugs, barges and small commercial freighters for a total of 3000-3500 vessel transits per year through the Pass (APAWSA Workshop Report 2006). The vessels are flagged from all over the world and carry crews from many different countries.

Figure 3-24 The great circle shipping route through the Aleutians. Reprinted from *The Economist*, January 18, 2007.

The 2004 Seledang Ayu shipping disaster off the coast of Unalaska brought into sharp relief the vulnerability of the ecosystem, and particularly fishery resources, to impacts from shipping. Very large vessels are required to carry automatic identification system transmitters, but there are few receivers in the islands. Shipping traffic in the region is increasing as trade between Asia and North and South America increases. Oil development in the general area (Bristol Bay, Sakhalin Island) could further increase traffic and vulnerabilities.

A 2006 Aleutian Ports and Waterways Safety Assessment workshop, sponsored by the U.S. Coast Guard and the Alaska Department of Environmental Conservation noted that risk from shipping was concentrated in three areas: Dutch Harbor, Unimak Pass, and North of Akun Island (PAWSA Workshop Report 2006). On the western side, the shipping route passes through the Near Islands.

Oil and Gas Development

Oil and gas development in Alaska and elsewhere effects the Aleutian Islands ecosystem mostly through the indirect effect of shipping traffic, as discussed above.

The majority of the Aleutian Islands Ecosystem falls within the Aleutian Arc Planning Area of the Minerals Management Service's Outer Continental Shelf management system. Depending on the north latitude boundary, some of the ecosystem may be within the Bowers Basin Area. There is currently no oil and gas development in these areas, and none proposed for the upcoming 2007-2012 planning period.

The North Aleutian Basin Planning Area, which is roughly co-extensive with Bristol Bay is the nearest area with proposed development. It is currently withdrawn by presidential order from oil and gas leasing, however this protection is expected to end and the U.S. Minerals Management Service is preparing for leases in the area known as Sale 92 in 2010 (proposed sale 214) and in 2012 (proposed sale 223).

A large Russian oil terminal is scheduled to open on Sakhalin Island, which will increase eastbound tanker traffic (Anon. 2007).

Research

Research activity accounts for much of the non-fishery travel to the Aleutian Islands area, especially in summer months. The following is a brief overview of some of the ongoing research activity in the Aleutian marine waters.

Alaska Sea Grant Alaskan Regional Marine Research Plan

In 2006, SeaGrant began a five-year plan to identify the interdisciplinary (ecology, oceanography, fisheries, social, economic, engineering) research and information needs for the Aleutian Islands region. The following methodology will be used:

- Establish a Regional Coordination Group to oversee planning and implementation of the research and information strategy. The Group will work in concert with the Alaska Marine Ecosystem Forum, assisted by Alaska Sea Grant and the State of Alaska Ocean Policy Coordinator.
- Conduct a bottom-up interdisciplinary (ecology, oceanography, fisheries, social, economic, engineering) research and information needs assessment with broad user and stakeholder input.
- Develop an Aleutian Island Ecosystem Research Plan that prioritizes actions according to management critical needs.
- Develop coordination mechanisms to ensure the transfer of technology and information to the appropriate end users.
- Provide an ongoing platform for coordination, collaboration, and resource sharing among governmental and non-governmental coastal and marine resource management and research entities, stakeholders, user groups, coastal residents and other interested parties.

National Marine Fisheries Service Fishery Research

Resource assessment surveys have been conducted in the Aleutian Islands by the Alaska Fisheries Science Center (AFSC) with bottom trawls on a mostly triennially basis from 1980 to 1997, and biennially since 2000. The Aleutian Islands survey area which extends from Unimak Pass (165º W. longitude) to Statemate Bank (170º E. longitude), includes Petrel Bank and Petrel Spur, and covers the continental shelf and upper continental slope to 500 m. The objectives of the survey are to provide distribution and relative abundance data for the principal groundfish and commercially or ecologically important invertebrate species in the Aleutian Islands, and to collect data to estimate biological parameters such as growth rates, length-weight relationships, feeding habits, and size, sex, and age compositions. The most abundant groundfish species in the area are Atka mackerel, POP, northern rockfish, walleye pollock, Pacific cod, arrowtooth flounder, and giant grenadier. However, fish populations which extend into areas that are either untrawlable with the survey gear, such as several rockfish species, or extend further up in the water column, are not fully represented.

The Aleutian Islands has also been surveyed biennially by longline gear since 1996. Surveyed depths vary from 200 m to 1000 m. The objectives are to determine the relative abundance and age and size composition of sablefish. The survey also provides relative abundance and size composition information for shortspine thornyhead, rougheye and shortraker rockfish, Pacific cod, arrowtooth flounder, grenadiers, and Greenland turbot. The longline survey is also used as a platform to tag sablefish, shortspine thornyhead, and Greenland turbot to determine migration patterns.

In late 2000 the AFSC formed a Fishery Interaction Team (FIT) to investigate the effects of commercial fishing on top trophic level consumers. Members of the team conduct studies to determine whether commercial fishing operations are capable of impacting the foraging success of Steller sea lions, either through disturbance of prey schools or through direct competition for a common prey. The present research focus is on the three major groundfish prey of Steller sea lions: walleye pollock, Pacific cod and Atka mackerel.

FIT investigates the potential effects of commercial fishing on sea lion prey fields in two ways. First, by conducting field studies to directly examine the impact of fishing on sea lion prey fields and to evaluate the efficacy of trawl exclusion zones. Since 2000, Atka mackerel have been tagged, released and recovered at Seguam Pass, Tanaga Pass, Amchitka Island, and Kiska Island in the Aleutian Islands. The second way that FIT investigates the potential effects of commercial fishing on sea lion prey is by studying fish distribution, behavior and life history at spatial scales relevant to sea lion foraging (tens of nautical miles). Ongoing FIT research projects address the reproductive ecology, growth and food habits of Atka mackerel in the Aleutian Islands.

In 2006 the Aleutian Islands Cooperative Acoustic Survey Study was conducted to test the feasibility of using small (<30 m) commercial fishing vessels to conduct acoustic surveys in the Aleutian Islands. The project was successful; seven separate surveys were completed in a designated survey area and the data were determined to be of high enough quality for management purposes, verifying that commercial fishing vessels could be used as platforms for conducting scientifically valid acoustic surveys of pollock in the Aleutian Islands. For 2007 study expanded to a larger survey area in order to quantify the abundance of pollock in the region of the Central Aleutian Islands thought to be within small boat delivery distance of Adak Island.

[PLACEHOLDER for Auke Bay/gear effects on habitat research]

Alaska Department of Fish and Game Fishery Research

The Alaska Department of Fish and Game has conducted triennial golden king crab pot surveys in the waters near Yunaska Island and The Island of Four Mountains Since 1991 (Watson *in press*). The survey occurs over a one month period of time in July and August and is conducted by ADF&G biologists onboard a chartered commercial fishing vessel using research pots. This survey is not designed to produce abundance estimates, but does provide fishery managers with relative abundance trends, estimates of spatial and temporal migratory patterns and estimates of fishery removals from the survey area. Results from this survey are incorporated into the annual stock assessment and TAC setting process.

Surveys targeting red king crab in the Petrel Bank area were conducted by the Alaska Department of Fish and Game in January, February and November 2001 (Bowers et al. 2002) and again in November 2006 (Gish *in press*). The and 2001 pot surveys were approximately one month in duration and were conducted using commercial fishing vessels and provided relative abundance, distribution, size frequency and shell age data that were used to open commercial fisheries for red king crab on Petrel Bank in 2002 and 2003. Data from the 2006 survey will be utilized for stocks assessment and TAC setting in the fall of 2006 and another pot survey on Petrel Bank is planned for November 2007.

In November 2002 ADF&G used several commercial fishing vessels to conduct red king crab surveys in selected locations near Atka, Amlia and Adak Island. That survey yielded very low catches of red king crab and the department does not have current plans to repeat the survey (Granath 2003).

Seabird Research

Long-term seabird monitoring on Alaska Maritime National Wildlife Refuge includes several sites in the central and western Aleutians (Dragoo et al. 2006). Ongoing annual monitoring at breeding colonies includes population trends, patterns of reproductive success, and diets of a number of fish-eating and plankton-feeding species. Data for some of the sites span more than 30 years (mid-1970s to present--Buldir in the w. Aleutians and others span the past 15 years—Kasatochi in the central Aleutians). A number of other sites are surveyed less than annually. The objectives are to determine changes in seabird populations and provide time-series from which hypotheses about causes of change may be tested.

Seabird, marine mammal, oceanography coordinated investigations (SMMOCI) is a cooperative project with the National Marine Mammal Laboratory, the Institute of Marine Sciences at University of Alaska, and the US Geological Services (USGS), Biological Resources Division designed to describe physical and biological characteristics of nearshore marine ecosystems at annual seabird monitoring sites on Alaska Maritime NWR. Two of these sites are in the central and western Aleutains. Specific objectives include measuring on a series of transects within 40 km of selected islands, the sea temperature and salinity, biomass of prey in the water (including test fishing to evaluate relative abundance of species), and the distribution of birds and marine mammals at sea. Plankton tows also are conducted along with CTD casts (REFS).

Dr. Ian Jones of Memorial University, Canada, and his students have been studying plankton-feeding auklets in the central and western Aleutians for 15 years to document, among other things, changes in adult survival and diets relative to climate variation (REF)

Endangered short-tailed albatrosses and other albatrosses have been captured and fitted with satellite transmitters in Seguam Pass in the past several years to document movements relative to bycatch issues (Balogh REF).

Kittlitz's murrelet, a candidate species for listing under the ESA, and marbled murrelets have been surveyed at several sites in the central and western Aleutians since 2003 to document indices to abundance and distribution (REF). Furthermore, in 2005 and 2006 nesting pairs of Kittlitz's murrelets were discovered on Agattu Island providing a basis for future study of breeding ecology (R. Kahler unpubl. Data).

At sea observations of seabirds and marine mammals throughout the central and western Aleutians have been made opportunistically since 1988 from the USFWS ship the M/V Tiglax during primarily summer work conducted annually in the Aleutians (marine mammal observations are submitted to the NMFS ships of opportunity data base and seabird observations will be included in the Pelagic Seabird Database maintained by USGS Biological Resources Division and USFWS.

Marine Mammal Research

<u>Sea Otters</u>
The marine mammal management division of the USFWS has a monitoring plan in place for sea otter populations in the Aleutians including aerial survey of the entire area periodically and more frequent boat-based monitoring at selected sites (REF).

Also, research on sea otter ecology has been underway for years in the central and western Aleutians under the guidance of Dr. Jim Estes, USGS Biological Resources Division and this research continues with a recent extension to include the Commander Islands (REF).

<u>Steller sea lions</u>
[PLACEHOLDER for summary of sea lion studies]

<u>Northern Fur Seals</u>
[PLACEHOLDER for any relevant N. Fur seal research]

Harbor seals
The Alaska Department of Fish and Game (Dr. Bob Small), NMFS, and the refuge have collaborated on research to evaluate population change in Aleutian harbor seal populations over the past 25 years (Small et al. in review).

Restoration of Natural Biodiversity

Following removal of introduced foxes on a number of islands (Bailey 1993, Ebbert and Byrd 2002), research is being conducted to document the response of island ecosystems (Byrd et al. 1995; Croll et al. 2005). Studies are underway currently to evaluate the potential for removing introduced rats from islands (REF).

Archeology

A consortium of university researchers and USFWS archeologists are conducting archeological research in the western and central Aleutians. Studies by the Western Aleutians Archaeological and Paleobiological Project (WAAPP) have been conducted since 1991 supported by funding from the National Science Foundation and the Institut Français pour la Recherche et la Technologie Polaires. WAAPP has had a dual focus; first, to identify, document, and define the characteristics, and development of the distinctive western Aleut culture and second to document Holocene environmental processes and determine to what extent observed changes can be ascribed to natural and/or anthropogenic factors. Archaeological research is one of the few ways to obtain information on ecosystem function and process over hundreds or thousands of years (Corbett et al. in press).

[PLACEHOLDER: There has also been a good deal of geological research by Alaska Volcano Observatory and universities if we want to summarize that and there has been research on freshwater fish, and terrestrial birds (e.g., restoration of ptarmigan and Aleutian geese) if we want to go inland a bit.]

How is the Aleutian Islands ecosystem different from the surrounding ecosystems?

Socioeconomically, the Aleutian Islands differ from the surrounding ecosystem in several ways. First, the population of residents is dramatically lower than elsewhere. With only two civilian communities over thousands of miles, the remoteness and isolation of the islands is unrivaled in the coastal United States. Second, the competition and struggle over natural resources and territorial control among the great powers of North America and Asia and indigenous residents has had a greater influence on local history than other locations in Alaska due to the geographic extension of the archipelago between continents and the abundant resources available. From the modern influence of the Russian Orthodox Church, to the absence of villages refused resettlement after internment during World War II, to the nuclear legacy of Amchitka, these historical influences continue to shape communities in the ecosystem today.

3.5 Management Processes

3.5.1 Regulatory Boundaries

Geographically, the Aleutian Islands archipelago ranges from Attu Island to Unimak Island, approximately from 170º E. to 165º W. This Fishery Ecosystem Plan defines the Aleutian Islands ecosystem as ranging from Samalga Pass (approximately 165º W.) to the western boundary of the exclusive economic zone, at 170º E. For fishery management purposes, however, regulatory boundaries differ with respect to the species and agency (Figure 3-25).

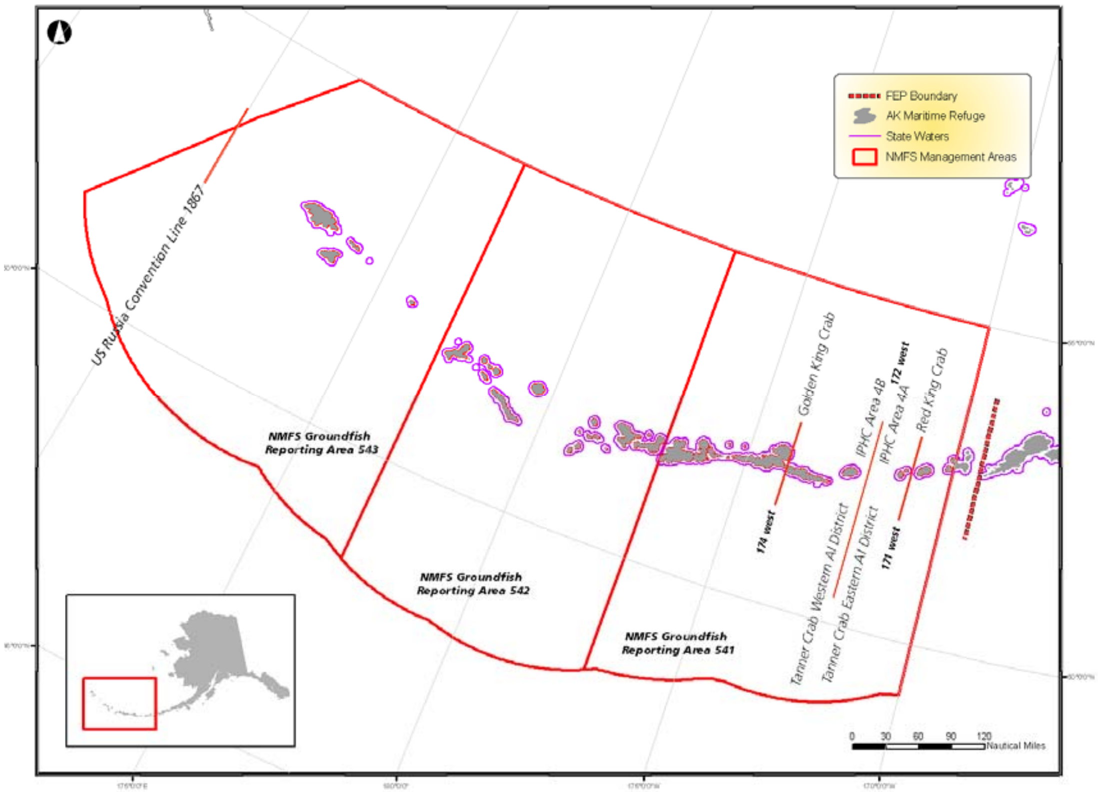

Figure 3-25 Management boundaries in the Aleutian Islands for groundfish, halibut, and crab fisheries.

Groundfish in Federal waters off the Aleutians are managed by the National Marine Fisheries Service and the North Pacific Fishery Management Council under the authority of the Bering Sea/Aleutian Islands fishery management plan. The BSAI FMP defines the Aleutian Islands subarea as that area of the exclusive economic zone (from 3-200 miles offshore) that is west of 170º W. and south of 55º N. (Figure 3-25, above; also see Figure 3-20 for extent of BSAI management area). This is the area that most closely approximates the Aleutian Islands ecosystem as identified in this FEP. The Aleutian Islands subarea represents approximately 44% of the BSAI management area, but accounts for only about 5% of total BSAI groundfish catch.

Some groundfish allocations may be harvested anywhere in the Bering Sea/Aleutian Islands management area; others are spatially restricted to as specific subarea. Allocations for Atka mackerel and Pacific ocean perch are further spatially divided between the three Aleutian Islands statistical areas, due to concerns about localized depletion and to minimize localized effects of Steller sea lion prey depletion resulting from competition from the fisheries.

Certain groundfish species may also be harvested in State of Alaska waters, within 3nm of shore. The State of Alaska is also responsible for managing golden and red king crab fisheries, and small Tanner crab fisheries, that take place in the area (Figure 3-25). Additionally, the State manages herring and salmon fisheries in the areas, which are prosecuted wholly within State waters. The State of Alaska uses its own grid of statistical areas to record catch and manage these fisheries.

The other regulatory areas within the Aleutian Islands are those of the International Pacific Halibut Commission (IPHC). Their areas consider the Aleutians Islands starting roughly at the tip of the Alaskan peninsula (164°W) and extending towards the west, with a split at 172°W. (Figure 3-25).

Inseason data are collected at many spatial levels, including Federal statistical areas, State of Alaska statistical areas and precise GPS haul locations for some directed fisheries.

Table 3-3 describes the regulatory responsibility of various international, Federal, State, and municipal agencies over the resources and people of the Aleutian Islands ecosystem.

Table 3-3 Regulatory responsibility in Aleutian Islands

Resource, Population	Agency	Responsibility
groundfish	NPFMC/NMFS ADFG	3-200nm; population abundance; setting harvest levels, fishery management, monitoring, and enforcement 0-3nm
halibut	IPHC NPMFC/NMFS	population abundance, setting harvest levels management of fishery
crab	NPFMC/NMFS ADFG	monitor overfishing levels, allocations harvest levels; fishery management, monitoring, enforcement
scallop	NPMFC/NMFS ADFG	monitor overfishing levels harvest levels, fishery management, monitoring, enforcement
salmon	ADFG NPFMC/NMFS	population abundance, harvest levels, fishery management retention prohibited 3-200nm
herring	ADFG	population abundance, harvest levels, fishery management
other fish	NMFS	advisory authority for habitat for all fish including fish in nearshore watersheds
marine mammals (except walrus and otters)	NMFS	population abundance, advisory authority, protection under the MMPA and ESA
walrus and otters	USFWS	population abundance, advisory authority, protection under the MMPA and ESA
birds	USFWS	population abundance, advisory authority, protection under the MBTA
citizens of Adak	City of Adak	municipal responsibility
citizens of Atka	City of Atka	municipal responsibility
land	USFWS BLM DNR DOD	protection of Alaska Maritime National Wildlife Refuge, including marine responsibility extending offshore (own some small parcels) (own some land parcels) Shemya, others?
shipping	DEC USCG	oversight of spill response ensure safety of vessels in US ports and waterways
oil and gas development	MMS DNR or DEC	3-200nm 0-3nm
military activity	Alaskan Command, Pacific Command	Shemya, floating barge
formerly used defense sites	AFCEE	cleanup
Amchitka	DOE	cleanup

KEY: ADFG – Alaska Department of Fish and Game; AFCEE – US Air Force Corps of Engineers; DEC – Alaska Department of Environmental Conservation; DNR – Alaska Department of Natural Resources; DOD – Department of Defense, DOE – Department of Energy, EPA – Environmental Protection Agency, MMS – Minerals Management Service, NMFS – National Marine Fisheries Service, NPFMC – North Pacific Fishery Management Council, USFWS – US Fish and Wildlife Service

3.5.2 Management of fisheries

Federal fisheries occur in the Aleutian Islands ecosystem for groundfish, halibut, scallop, and crab. The scallop and crab fisheries are managed by the state of Alaska under authority delegated in two federal FMPs. The State of Alaska manages parallel and state-water fisheries for Pacific cod, salmon, herring, pollock, sablefish and black rockfish. Subsistence fisheries also occur for many marine species, and recreational fishing effort is small in the area (see Section 3.4).

Federal Groundfish Fisheries

Table 3-4 lists the species managed under the BSAI Groundfish FMP, and the catch in 2005 for those species in the Aleutian Islands and Bering Sea subareas. Total catches in the AI subarea in recent years have been just over 100,000 mt annually, compared to over 1.8 million mt in the Bering Sea subarea. Total allowable catch for both the BS and AI subareas combined cannot exceed 2 million mt. Given that the sum of single species acceptable biological catches was approximately 3 million mt in 2007, this limit provides a buffer against the uncertainties of single species harvest targets. Other constraints are also built into the management program, including conservative harvest quotas that are spatially (see Table 3-4) and temporally apportioned for some species, bycatch limits, protected species and habitat area closures and restrictions, gear modifications to reduce bycatch, and a prohibition on directed forage fisheries.

Figure 3-26 illustrates year round fishery closures in the Aleutian Islands, which provide protection for Steller sea lions, essential fish habitat and habitat areas of particular concern. There are also partial year closures to protect Steller sea lions, which apply to the directed pollock, Pacific cod, and Atka mackerel trawl fisheries.

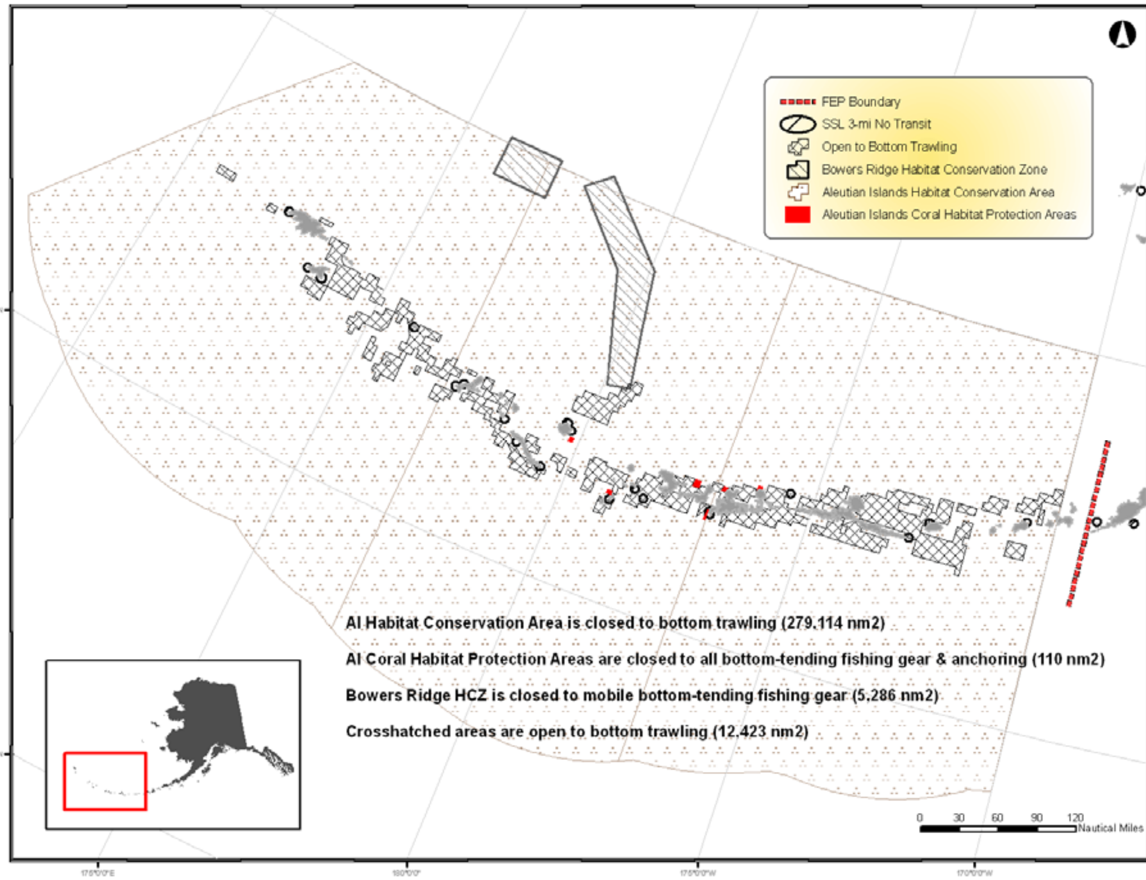

Figure 3-26 Year round fishery closures in the Aleutian Islands

Information on the relative AI and BS distribution of biomass of assessed fish stocks can be obtained from comparing the AI trawl survey estimates to the EBS slope and shelf survey biomass estimates, and the degree to which AI trawl survey information is used in stock assessments reflect these distributions. Some flatfish stocks (yellowfin sole, arrowtooth flounder, rock sole, and Alaska plaice) which occur nearly entirely on the EBS shelf and have low biomass levels in the Aleutian Islands do incorporate the AI survey estimates in their stock assessments. Many stock assessments include both Aleutian Islands and EBS survey information. For example, the EBS Pacific cod is modeled but expanded (based on the ratio of EBS to AI biomass estimates) to include AI cod. Sablefish is an Alaska-wide model, and uses a longline survey that covers the EBS, Gulf of Alaska, and Aleutian Islands. This longline survey is also used in the Greenland turbot assessment, where 31% of the stock is estimated to occur in the Aleutian Islands. For flathead sole, “other flatfish”, and “other rockfish”, both the EBS shelf survey and AI trawl survey are used to estimate the BSAI stock size. Several non-target species or species groups’ (skates, sharks, octopus, and sculpins) assessments are based on mean biomass from the trawl surveys on the EBS shelf, EBS slope, and AI. Finally, some stock assessments use the AI trawl survey exclusively and do not use the EBS surveys due to the stock distribution being predominantly concentrated in the Aleutian Islands (Atka mackerel) or because of the limited time series of EBS slope survey data (Pacific ocean perch, northern rockfish, shortraker rockfish, and rougheye), although the EBS slope survey is used to recommend area apportionments of catch for these rockfish.

Table 3-4 Catch, in mt, of groundfish FMP-managed species in the Aleutian Islands and the eastern Bering Sea, in 2005.

BSAI Groundfish FMP managed species	Aleutian Islands (AI)	Bering Sea (BS)	How total allowable catch is apportioned spatially
Pollock	1,621	1,483,279	separate BS and AI
Pacific cod	22,627	182,807	BSAI-wide
Sablefish	1,476	1,075	separate BS and AI
Atka mackerel	58,474 [4]	3,553 [4]	3 AI statistical areas [4]
Yellowfin sole	2	94,372	BSAI-wide
Greenland turbot	440	2,120	separate BS and AI
Rock sole	548	36,814	BSAI-wide
Arrowtooth flounder	828	13,405	BSAI-wide
Other flatfish [1]	59	20,642	BSAI-wide
Alaska plaice	0	11,175	BSAI-wide
Pacific ocean perch	9,548	879	BS and 3 AI statistical areas
Northern rockfish	3,852	112	BSAI-wide
Shortraker rockfish	61	108	BSAI-wide
Rougheye rockfish	78	12	BSAI-wide
Other rockfish [2]	286	178	separate BS and AI
Squid	17	1,168	BSAI-wide
Other species [3]	1,403	28,034	BSAI-wide

[1] Includes starry flounder, rex sole, longhead dab, butter sole, and all species of flatfish caught in the management area, other than flathead sole, Greenland turbot, rock sole, yellowfin sole, arrowtooth flounder, and Alaska plaice.

[2] Includes light dusky rockfish, shortspine thornyheads, and all species of Sebates and Sebastolobus caught in the management area, other than Pacific ocean perch, northern rockfish, rougheye rockfish, and shortraker rockfish.

[3] Includes sculpins, skates, sharks, and octopus.

[4] Atka mackerel for the combined Eastern Aleutian Islands district and Bering Sea subarea is reported under the Bering Sea.

Management of these Federal fisheries is complex given the size and geographic extent of the region, its distance from research and management facilities, and enforcement and safety concerns. The BSAI groundfish fisheries are managed under a single FMP, however Table 3-5 describes those FMP measures that are specific to the Aleutian Islands subarea, and those that apply to the BSAI management area as a whole.

Historically (year to year), groundfish fisheries prosecuted in the AI subarea have included Atka mackerel, Pacific cod, sablefish, flatfish, and rockfish. Prior to 1999, pollock were also harvested in this area. Pollock in the Aleutian Islands region is considered to be a separate stock from the eastern Bering Sea pollock, with a tentative boundary identified at 174º W. longitude, although there is some exchange between the stocks. From 1999 through 2004, the directed fishery was closed, although some pollock are harvested incidentally in other target fisheries (e.g., Atka mackerel, Pacific ocean perch); in 2003 pollock bycatch in other directed fisheries was 1,653 mt.

Beginning in 2005, the Council authorized allocation of pollock quota in a directed pollock fishery in the Aleutian Islands. The allocation is to the Aleut Corporation per recent Congressional action (PL 108-199). The annual quota for this fishery currently is set at no more than 19,000 mt, less the CDQ apportionment and incidental catch allowances for other directed groundfish fisheries. Historically, harvests in the AI subarea pollock fishery have occurred in several areas of concentration, including areas north of Atka Island, northwest of Adak Island, and east of Attu Island and north of Shemya Island.

Table 3-5 Current management measures in Bering Sea/ Aleutian Islands (BSAI) groundfish fisheries that apply across the management area, and those that are AI subarea-specific

Issue	FMP measures that apply BSAI-wide	FMP measures that apply to the Aleutian Islands only
Allocation	Total allowable catch (TAC) for the AI + BS subareas must be ≤ 2 million metric tons AI Fisheries with BSAI TAC: • Directed: Pacific cod • Incidental: Northern, shortaker and rougheye rockfish, flatfish, squid, other species	AI Fisheries with AI subarea TAC: • Directed: Pollock, Pacific ocean perch (by district), Atka mackerel (by district, jig 1% in Eastern AI/BS district), sablefish (trawl 25%, fixed gear 75%), Greenland turbot • Incidental: 'other rockfish'
Permit	BSAI license • certain vessels exempted: vessels fishing only in State waters, vessels less than 32' length overall, or jig gear vessels less than 60' length overall with specific effort restrictions.	Must have AI subarea endorsement
Closures/gear restrictions	Steller sea lions: • 3 nm no-transit zones around rookeries, no trawling for pollock, Pacific cod, or Atka mackerel within 20 nm of rookeries and haulouts during some or all seasons Prohibited species • Attainment of prohibited species catch limits for crab, salmon, and herring closes areas Gear: • Non-pelagic trawl gear prohibited in directed pollock fishery	Steller sea lions • Many of the rookeries and haulouts in the AI Essential Fish Habitat (EFH)and Habitat Areas of Particular Concern (HAPC): • Council has designated various AI EFH and HAPC areas with protections such as no bottom-trawling Prohibited species: • One closure area in the AI: Chinook Salmon Savings Area 1.
Prohibited species and bycatch	Halibut, herring, salmon, king crab, and tanner crab are prohibited species. • BSAI-wide halibut prohibited species catch limit for trawl fisheries (3,675 mt)	• Prohibited species catch limit for Chinook salmon in AI pollock trawl fisheries
Share-based programs	• Fixed-gear sablefish fishery is an individual fishing quota program. • BSAI Pacific cod sector allocations • some community development quota (CDQ) allocations BSAI-wide	• Directed pollock fishery in the AI subarea is fully allocated to the Aleut Corporation. • Sector allocations and cooperative program for POP, Atka mackerel fisheries • AI subarea-specific CDQ fisheries for pollock, POP, Atka mackerel, sablefish, Greenland turbot, rockfish;
Monitoring and Reporting	• 100%/30%/0% on vessels greater than 125'/60-124'/<60' length overall • Fish tickets, catcher/processor and processor reports	• 200% observer coverage on some vessels harvesting AI pollock, and on the head & gut trawl catcher/processor fleet

The Pacific cod fishery is managed under a quota apportioned to the entire BSAI management area. Pacific cod catch statistics for the AI subarea for the period 2001-2005 showed harvests declining from 34,207 in 2001 to 22,627 mt in 2005 (Thompson et al 2006). This fishery has historically (year to year) occurred around Adak and Atka islands. Since 1999, when the AI subarea was closed to a directed pollock fishery, the Pacific cod fishery has been prosecuted under Steller sea lion protection measures that allow Pacific cod fishing to occur closer to shore than a directed pollock fishery would be allowed. During 2001-2005, the AI subarea accounted for an average of about 15% of the BSAI Pacific cod catch.

The Atka mackerel fishery harvested 58,474 mt in 2005. The center of abundance of Atka mackerel is in the Aleutian Islands, although their distribution ranges from the Kamchatka peninsula to the Gulf of

Alaska. The harvest quota has been distributed among the AI subarea districts since 1992, to minimize the risk of localized depletion. Although the fishery takes place primarily in the AI subarea, the fishery also occurs north of Akutan Island in the Bering Sea subarea. Areas of harvest concentration in the AI subarea in 2003 were south of Amukta and Tanaga passes, east of Attu Island, and scattered in the Rat Islands area (Lowe et al. 2006).

The sablefish fishery in 2005 harvested 1,476 mt, almost all of which was from longline and pot fisheries (Hanselman et al. 2006). The population is considered to be a single stock throughout Alaska and northern British Columbia. The directed fishery is entirely under an IFQ management system and is prosecuted with fixed gear; a small amount is taken incidentally in some trawl fisheries (35 mt in 2003). The locations of the sablefish harvests from 1995-2003 suggest most of the fishing effort in the AI subarea occurs within 100 nm of Adak and Atka. This fishery is not under special restrictions for SSL protection, and occurs in waters within 20 nm of shore in the AI subarea.

The AI subarea rockfish fisheries include Pacific ocean perch, northern rockfish, shortraker and rougheye rockfish, and other rockfish. Rockfish harvested in the AI subarea in 2005 totaled 13,825 mt. The only directed AI rockfish fishery is for POP. Due to small harvest quotas, the other rockfish species' harvest quotas are taken as bycatch, primarily in the Atka mackerel and POP fisheries. Ninety percent of the BSAI northern rockfish caught are taken incidentally in the Atka mackerel fishery (Spencer and Ianelli 2006). The Pacific ocean perch stock is spatially distributed within the AI subarea, where approximately 84% of the population is concentrated, according to survey data (Spencer and Ianelli 2005). The fishery historically (year to year) has occurred throughout the AI subarea with some concentration of harvests between Kiska and Agattu islands, around Amchitka Island and Petrel Bank, north of Atka Island, and in Amukta Pass. Shortraker and rougheye rockfish are caught incidentally in a variety of target fisheries (such as rockfish and Atka mackerel trawl, and Pacific cod, halibut, and sablefish longline fisheries; Spencer and Reuter 2006). The majority of 'other rockfish' catch is dusky rockfish and shortspine thornyheads. Dusky rockfish are mainly caught incidentally in the Atka mackerel trawl fishery, and shortspine thornyheads are mainly caught in sablefish, grenadier or skate longline hauls or the POP trawl fishery. Dusky rockfish bycatch in recent years has been high near Seguam Pass and Petrel Bank, and in the AI survey they have been caught at the eastern tip of Amchitka Islands. 'Other rockfish' are also distributed in the Bering Sea subarea, north of Unalaska and Akutan Islands and at the southern tip of Zhemchug canyon (Reuter and Spencer 2006).

Most flatfish species are concentrated on the continental shelf of the Bering Sea, and have low abundance in the AI subarea. The only target flatfish fishery in the AI subarea is for Greenland turbot. About 25% of the Greenland turbot biomass is located in the area, however, juveniles are absent in the AI, suggesting that the population in the Aleutians originates from the EBS or elsewhere (Ianelli et al. 2006). In 2005, the harvest total was 440 mt, mainly by hook and line gear. The fishery occurs primarily within 100 nm of Adak and Atka islands (Ianelli et al. 2006).

Squid and other species (sculpins, skates, sharks, and octopi) are caught incidentally in other directed fisheries. Squid are caught primarily in the pollock trawl fishery. Skates represent the majority of the other species catch (over 22,982 mt for the BSAI in 2005), and are caught in the hook-and-line Pacific cod fishery (Matta et al. 2006).

CDQ fisheries occur in the AI subarea for sablefish, Atka mackerel, Greenland turbot, Pacific ocean perch, northern rockfish, shortraker and rougheye rockfish, and other rockfish. CDQ groups partner with commercial fishing corporations to harvest these allocations. Most of the CDQ groups have ownership interest in the partner corporations.

Spatial Distribution of Aleutian Island Ecosystem Fisheries by Gear Group

Bottom Trawl
The bottom trawl effort in the Aleutian Islands Ecosystem focuses on Atka mackerel, Pacific cod, and rockfish. The highest concentrations of effort occur along the east of Atka, in Tanaga Pass, on the Petrel Bank, northwest of Kiska Island.

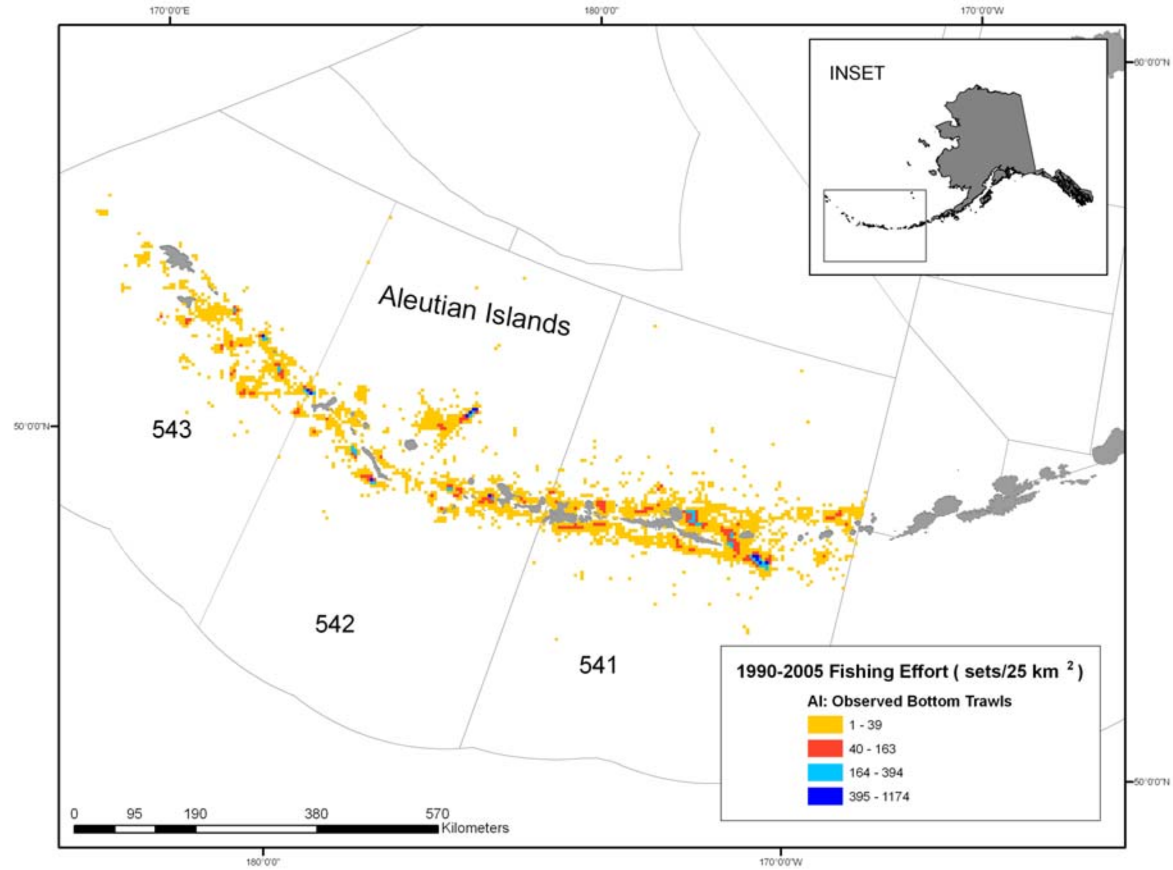

Figure 3-27 Location and density of bottom trawl effort in the Aleutian Islands, 1990-2005 (from Coon 2006).

Hook and Line
The commercial hook and line fishery uses catcher vessels and freezer longliners and harvests mainly Pacific cod, Greenland turbot, and sablefish (Coon 2006). Highest concentrations of effort occur around Atka Island, with pockets around Amchitka, Kiska, and Semichi Islands (Figure 3-28).

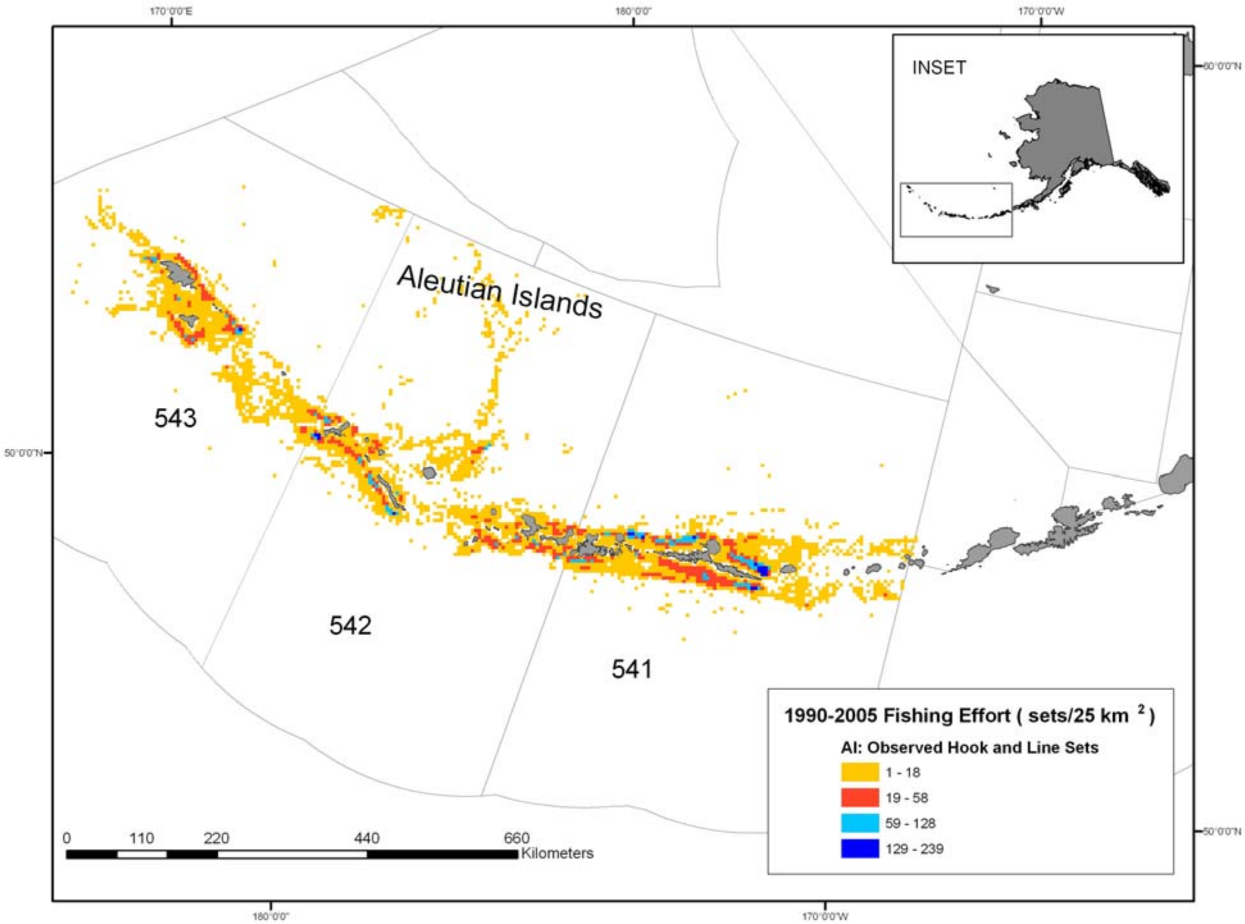

Figure 3-28 Spatial location and density of hook & line effort in the Aleutian Islands, 1990-2005 (from Coon 2006).

Halibut Fishery

The Aleutian Islands halibut fishery is managed by the International Pacific Halibut Commission. Two of the IPHC statistical areas for the halibut fishery encompass portions of the Aleutian Islands, Areas 4A and 4B (Figure 3-25). Over the last five years, approximately 8,028,000 lb annually, or 14% of the Alaska halibut quota, have been allocated to these areas. Halibut allocations in Alaska are managed under an individual fishing quota program and a community development quota program.

Scallop Fishery

The Federal weathervane scallop fishery is managed by the State of Alaska under authority of a federal scallop management plan. The Aleutian Islands scallop fishery is split into two registration areas at 171° W. longitude. Registration Area O extends from Scotch Cap Light (164º 44' W. longitude) to 171° W. longitude and Registration Area R extends from 171° W. longitude to the Maritime Boundary Agreement Line that separates U.S. and Russian waters, and encompasses both State and Federal waters. Scallop fishing in Area O generally occurs near Umnak Island. Area O was closed in 2000 due to management concerns over localized depletion. In 2002, the area was reopened with a reduced guideline harvest range of 0-10,000 pounds of shucked meats, of which 61% was harvested. Area O represents approximately 1.5% of the statewide guideline harvest range for scallops. The scallop fishery in Area R is opened annually with a guideline harvest range of 0-75,000 pounds of shucked meats. Weathervane scallops have been harvested in Area R only in 1979, 1992 and 1995 (Barnhart 2006). Petrel Bank is closed to commercial fishing for scallops to prevent red king crab bycatch and protect red king crab habitat.

King and Tanner Crab Fishery

The Federal king and Tanner crab fishery is also managed by the State of Alaska under authority of a federal king and Tanner crab fishery management plan. In the Aleutian Islands, king crab fisheries are managed within registration Area O (Figure 3-25). The primary crab fishery that occurs in the region is the Aleutian Islands golden (brown) king crab fishery. Separate total allowable catch levels (TAC), are established for the fishery east and west of 174º W. Stock assessment is performed using relative abundance indicators and other biological indicators of stock health such as size frequency, fecundity and shell age. These data are obtained from both fishery-dependant and independent sources. Harvest limits for this fishery are typically around 3.0 million pounds for the area east of 174° W. and 2.7 million pounds for the area west of 174° W. Compared to other BSAI crab fisheries the Aleutian Islands golden king crab fishery has exhibited less harvest variability and has never closed due to low stock abundance.

Table 3-6 State management measures

Management measure	State-waters groundfish	Parallel groundfish	Crab/scallops	Salmon/herring
Closed waters	Generally follow federal SSL and habitat closures	Federal SSL and habitat closures in effect	Federal SSL and habitat closures in effect	Area specific to protect spawning stocks
Vessel registration/ permitting	State CFEC permit and vessel registration with ADF&G	State CFEC permit and vessel registration with ADF&G. Potential federal requirements as well.	State CFEC permit and vessel registration with ADF&G. Potential federal permits required as well.	State CFEC permit and vessel registration with ADF&G
Reporting	Inseason and fish tickets	Fish tickets	Inseason and fish tickets	Inseason and fish tickects
Observer coverage	None	Federal coverage levels	100% for scallops and red king crab, 50% for golden king crab	None
Season dates	Set by ABOF	Based on federal seasons	Set by ABOF around biogically acceptable time periods	Set by ABOF around biogically acceptable time periods
VMS requirement	None	Based on federal requirements	Rationalized crab only	None
Bycatch management	Generally no retainable bycatch or limits	Based on federal requirements	Retainable bycatch limits for certain species, other bycatch prohibited	No bycatch retention or limits

Since the mid-1990s harvests of golden king crab in the area east of 174° W. have averaged 3.07 million pounds with nearly 16 vessels participating annually (ADF&G *in prep*.). With the implementation of the crab rationalization program in 2005, effort has dropped to about seven vessels per year and 10% of the total allowable catch has been allocated to the community development quota program. Most of the harvest east of 174° W. longitude occurs between the Islands of Four Mountains and Seguam Pass.

In the area west of 174° W. harvests have averaged 2.55 million pounds since the mid-1990s and an average of eight vessels have participate annually. Since 2005, effort has dropped to less than five vessels per year and 10% of the TAC has been allocated to the community of Adak. Harvest in the area west of

174° W. is more geographically dispersed than to the east and occurs primarily between the Delarof Islands and Attu Island.

The Aleutian Islands golden king crab stock is considered to be stable and is above FMP overfishing levels.

There is also an Aleutian Islands red king crab fishery in Area O. The eastern portion of the red king crab fishery has been closed since 1983, and the western portion, which operates primarily in the Petrel Bank area, has opened sporadically in recent years with the most recent harvest occurring in 2002 and 2003. The fishery did not open in 2005 or 2006. Red king crab abundance is believed to be very low in the Aleutian Islands. Future openings in the area will be based on survey results.

Small Tanner crab fisheries in the Aleutian Islands are managed in registration Area J (Figure 3-25). Tanner crab populations in this area are believed to limited by available habitat and have been managed primarily as incidental harvest during the red or golden king crab fisheries. The largest Tanner crab stock in the Aleutian Islands occurs east of 170° W. Directed fisheries for Tanner crabs in the Aleutian Islands west of 170° W. are unlikely to occur in the near future (ADF&G *in prep*.)

State Managed or Parallel Fisheries

Within state waters of the Aleutian Islands, groundfish fisheries occur as both actively managed state-waters fisheries and passively managed parallel fisheries.

In February 2006 the commissioner of the Alaska Department of Fish and Game enacted emergency regulations for a state-waters Pacific cod fishery occurring in waters of the Aleutian Islands west of 170° W. longitude. In October 2006 the Alaska Board of Fisheries modified the management plan adopted under emergency regulation and made it permanent in state regulations. The state-waters guideline harvest level is based on 3% of the federal BSAI Pacific cod ABC and the fishery opens four days after the federal trawl catcher vessel “A” season closure. Up to 70% of the state-waters guideline harvest level is available prior to June 10. The remainder of the state-waters guideline harvest level is available after June 10. The Board of Fisheries adopted maximum vessel overall length restrictions of 125 feet for pot vessels, 58 feet for jig and longline vessels and 100 feet for trawl vessels. The management plan specifies trip limits of 150,000 pounds and requires daily catch reporting to the department. Federal Steller sea lion and habitat protection measures are in effect, however vessel monitoring system is not required.

In 2006, 26 vessels participated in the initial state-waters fishery opening and harvested over 90% of the guideline harvest level in nine days. Over half of the participants were trawl vessels and most of the harvest occurred within 75 miles of Adak Island. Very little of the remaining guideline harvest level was taken during the September state-waters opening and the majority of the available guideline harvest level was returned to NMFS for reallocation in the federal/parallel fisheries.

The state of Alaska manages a state-waters sablefish fishery in waters of the Aleutian Islands and waters adjacent to the western portion of the Alaska Peninsula. The fishery began in 1995 and the guideline harvest level is based on approximately five percent of the federal BSAI sablefish total allowable catch. The state-waters fishery occurs from May 15 until November 15 and typically 20 to 40 vessels participate. Both federal IFQ holders and non-IFQ holders participate in the fishery and most of the harvest in the Aleutian Islands occurs on the north side of the Aleutian Islands between the Delarof Islands and Atka Island. Harvest in the state-waters fishery peaked at approximately 477,000 pounds in 2002, but has been less than 300,000 pounds in recent years (Rounds and Milani *in press*). Federal Steller sea lion and habitat protection measures are in effect, however a vessel monitoring system is not required.

In October 2006 the Alaska Board of Fisheries established a pollock fishery in state-waters of the Aleutian Islands between 174° W. and 178° W. The guideline harvest level for the state waters fishery is 3,000 metric tons and is reduced by the amount of pollock authorized for harvest inside Steller sea lion critical habitat under terms of a federal exempted fishing permit. In 2007, the state-waters guideline harvest level was zero pounds. The fishery opens seven days after the beginning of fishing operations allowed by the federal exempted fishing permit and closes on June 10, or earlier if the guideline harvest level is taken. Vessels participating in the state-waters fishery are limited to 58 feet or less in overall length and all state-waters, with the exception of the northwest side of Kanaga Island, within 20 miles of Stellar sea lion rookeries and three miles of Steller sea lion haul outs are closed to commercial fishing. A vessel monitoring system is not required in the state-waters pollock fishery.

Parallel fisheries are passively managed by the State of Alaska and occur concurrently with the Federal groundfish fisheries, mirroring the Federal closures and harvest restrictions. Parallel fisheries are opened annually by emergency order and allow for orderly prosecution of groundfish fisheries in state-waters that are not actively managed by the state. Currently, the major parallel fishery in the Aleutian Islands targets Pacific cod, although other species are taken incidentally (Rounds and Milani *in press*).

Commercial fisheries for salmon and herring are very limited in the Aleutian Islands outside of the immediate vicinity of Unalaska and Akutan Islands. Commercial harvests of salmon occurred in the Atka-Amlia Islands area in 1992, 1993 and 1994. Nearly 90% of the harvest in those years was comprised of pink salmon and total harvest exceeded 1,000 salmon only in 1992. Chum salmon were next most common species in the catch. Permit holders in the Atka-Amlia Islands fishery used set gillnet gear (Tschersich 2006). An experimental commercial food and bait herring fishery near Adak Island was recently established, however there has been very little fishing effort and no harvest in the fishery.

With increases in human populations in the Aleutian Islands that may accompany military, port, and community development, there may be additional participation and expanded harvest opportunity in the existing fisheries and perhaps other, new State fisheries may be developed.

3.6 Interactions

An ecosystem approach to fisheries management should consider the interactions among the fisheries and their target species as well as, their direct (e.g. bycatch) and indirect (e.g. habitat) impact on other species and this influence on other target fisheries, as well as broader ecosystem interactions such as climate, predator-prey relationships and other socio-economic activities. For the purpose of this FEP, an ‘interaction’ is defined as a component (or group of components) that has an impact on another component (or group of components). Interactions important to the FEP area fall within five general categories:

- Climate/Physical Interactions
- Predator-Prey Interactions
- Endangered Species Interactions
- Fishery Interactions
- Socioeconomic Activities Interactions

In addition, there are interactions among these higher level categories, e.g, climate and fisheries, community development and fisheries, predator-prey interactions and fisheries, and climate and predator-prey interactions. These higher level interactions are discussed within the individual interactions described below.

Below we characterize and highlight some of the important ecological (biological, chemical and physical), human and institutional interactions occurring within the Aleutian Islands FEP Area that could have implications for fisheries management.

Climate/Physical Interactions

Interaction: Changes in water temperature may impact ecosystem processes

Changes in water temperature have already been recorded over the last decade, and trends in global temperatures attributable to 'global warming' are already being noted, particularly in the Arctic and Antarctic (REF). While warming of the ocean temperatures is occurring on a global scale and the effects are likely to be greater at higher latitudes, there are potential ecosystem-level impacts for the Aleutian Islands. It is important to note that temperature change can occur for many reasons, not just global warming. Regime shifts and shifts in currents can also affect ocean temperatures (REF).

Temperature regulates all biological rates (growth, feeding, etc.), and has proven direct impacts on primary productivity and thus the forage base. Given this strong direct (exotherms and their habitat) and indirect (shift in distribution and abundance of prey base) dependency on water temperature, it is clear that changes in water temperature may greatly impact ecosystem processes.

Examples of ecosystem impacts due to temperature changes include shifts in species composition in shallow inshore areas and potential shifts in seabird and marine mammal populations in response. Also, deepwater corals may be sensitive to changes in water temperature (their shallow water hard coral counterparts have already been noted to be sensitive to small changes in water temperature). Other impacts to the human component of the ecosystem may include the loss of some salmon fisheries and the potential loss of some near shore fisheries such as Pacific cod and Atka mackerel.

Interaction: Increased acidification of the ocean may impact ecosystem processes

Ocean acidification, due to increasing atmospheric carbon dioxide concentrations, is documented to be occurring (The Royal Society 2005), and is likely to continue and increase given current trends in anthropogenic carbon emissions and projected release of deep water methane. The surface ocean is currently saturated with respect to calcium carbonate, but increasing carbon dioxide concentrations are reducing ocean pH and the level of calcium carbonate saturation. Experimental evidence suggests that, if these trends continue, some of the calcareous species will have difficulty maintaining their external calcium carbonate skeletons. Species groups such as pteropods, corals, foraminifera, and coccolithophorids would be especially impacted (Orr, et al. 2005) and this could lead to strong impacts throughout the ecosystem. For example, shelled pteropods contribute to the diets of many fish, including salmon. Increased acidification may also cause the dissolution of corals in the Aleutians which would have habitat implications for many species including commercial fish species. In summary, this interaction could impact primary production and the carrying capacity of the AI ecosystem.

Interaction: Changes in nutrient transport through the passes and changes in the predominant current patterns that drive primary production may impact ecosystem processes

The vertical mixing of nutrients from the deep waters into the surface waters in the passes is primarily accomplished through tidal currents (which are not likely to change) and their interaction with the steeply varying bathymetry. Net transport of newly mixed nutrients into the Bering Sea is due to mean northward currents. The slowly varying currents are dependent on large scale gyres in the North Pacific and Bering Sea which could change. Mixing in the passes (vertical transport of nutrients) is not likely to change, but if the northward horizontal transport of the newly mixed water changes, it could have implications for nutrients north of the passes. Changes in nutrient transport could impact the location and intensity of primary production and also pelagic habitat.

Interaction: Changing weather patterns may impact ecosystem processes

The influence of global climate change on local weather patterns is uncertain. The weather of the Aleutian Islands is highly variable and the AI ecosystem is likely fairly resilient to variable weather patterns. It is not clear that changing weather patterns will be strong enough on short enough timescales to impact the ecosystem. However, increased storminess could affect production at low trophic levels, and local shifts in abundance and species composition could occur as a response to changing weather patterns. A potentially long-term impact associated with global warming is a change in the frequency of storms. Other potential long-term impacts include changes in atmospheric circulation which could affect the transport of eggs, larvae and plankton, altering recruitment and or foraging patterns for higher trophic level consumers. Impacts to the human component include the ability of the fisheries to operate safely and efficiently in response to changing weather patterns.

Interaction: Impacts of seismic activity and volcanism on human and marine populations

Volcanic eruptions and earthquakes are common in the Aleutian Islands. Local impacts include direct displacement of benthic habitat which affects living substrate, and the destruction of rookeries for seabirds and pinnipeds. However, volcanic activity may also contribute to the creation of new habitat for seabirds and marine mammals. A large tsunami occurring during the breeding season could substantially impact some local seabird and marine mammal populations. Local human communities could be impacted by increased atmospheric acidity and ash clouds which could affect local weather conditions. Fisheries could be impacted if major changes were to occur in important fishing grounds, for example for Atka mackerel or Pacific cod. Volcanic activity can also impact transcontinental plane traffic.

Predator-Prey Interactions

Interaction: Changes in groundfish biomass attributable to fishing, impacts multiple species due to direct predation interactions

The main commercial species (by value) targeted in the AI are Pacific cod, Atka mackerel, king crab, halibut, sablefish, Pacific ocean perch, and pollock. For several of these species, direct predation among each other occurs. Changes in the level of fishing will have the highest impact on those predator-prey interactions which are strongest, e.g. the pollock and Atka mackerel interaction, the combined halibut and Pacific cod impact on sablefish, and the Pacific cod and Atka mackerel interaction. Other important interactions include halibut dependence on Atka mackerel and pollock, and pollock and Atka mackerel.

Pollock and Atka mackerel are both estimated to cause high mortality on each other despite being a small proportion of each other's diet. The high mortality is a result of the relatively large biomass of each species estimated to be in the ecosystem, combined with their consumption rates. Therefore, small changes in the biomass of either could result in large changes in the amount of mortality caused by predation. Given spatial differences in food webs across the AI and the importance of both pollock and Atka mackerel as prey to fish, mammal, and bird predators, this potentially high impact interaction is highlighted.

Another potentially high impact interaction is the combined effect of Pacific cod and halibut predation on sablefish. Although sablefish are less than 1% of each of these species diets in the AI, their combined effect is equivalent to the sablefish longline fishery. Changes in the combined cod and halibut biomass might impact sablefish populations, and increased sablefish fishing mortality might have stronger population effects than estimated due to this predation mortality.

Interaction: Competition for same prey base – changes in biomass of important prey species for which predators compete may impact ecosystem production and sustainable fisheries

For the purposes of this FEP we assume that species with greater than 10% of prey overlap in their diet, as well as exhibiting a dependence on that prey (i.e., it represents greater than 10% of their diet), are potential competitors. Competition implies that the prey resource is limited, but high levels of prey overlap may also be a reflection of the high prevalence of that prey.

The highest impacts of this interaction would result from changes in biomass of those species that form the prey base for most commercial and protected species. Specifically, these are the euphausiid prey base (shared by all forage fish, myctophids, baleen whales, squids, sablefish, Atka mackerel, seabirds, pollock, rockfish and POP); the copepod prey base (shared by euphausiids and most of the above species); the squid prey base (shared by toothed whales, grenadiers, seabirds, halibut, and Atka mackerel); and the myctophid prey base (shared by flatfish, grenadiers, and pollock). King crab and sea otters are the exception, as they compete for benthic invertebrates with other fish, crabs and shrimp. Pollock are the shared major prey of skates, pinnipeds, and Steller sea lions, and in the early 90s they were the major shared prey of the AI pollock trawl fishery. Atka mackerel are the shared major prey of Steller sea lions, skates, the Atka mackerel fishery, halibut and Pacific cod. Much attention has already been focused on the potential competition between Steller sea lions and the Federal trawl fisheries with respect to Atka mackerel, Pacific cod, and pollock. It is important to note that the potential competition between grenadiers and pollock for the myctophid prey base is not observed in any other Alaskan ecosystem, and the classification of sablefish with other zooplankton feeders is also unique to the AI. We highlight the importance of euphausiids and copepods as they are shared prey for a wide range of commercial and protected species in the AI.

Interaction: Changes in populations of unexploited apex predators (through fishery impacts or direct predation between predators) may impact system productivity and ecosystem functions

Unexploited apex predators in the Aleutian Islands include seabirds, marine mammals, sharks, and skates. The fisheries impact sharks, skates, and birds. While the fisheries interaction may have population consequences for these apex predators, it is unclear whether this bycatch mortality has an ecosystem-level effect. Marine mammals interact through predation on baleen whales, pinnipeds, sea otters, toothed whales, Steller sea lions, sharks and skates. There is also a seabird predation impact on seabirds, as piscivorous birds cause some mortality on themselves and planktivorous birds. This predation may have seabird population impacts, but it is also unclear whether this mortality has ecosystem-level impacts. On the other hand, large baleen whale populations have recovered substantially and there is concern that their energy demands will compete with commercial fisheries or other species of interest, and have the potential to restructure the ecosystem (REF).

Endangered Species Interactions

Interaction: Changes in the population status of ESA-listed seabirds impact fisheries through specific regulatory constraints

The BSAI groundfish fisheries interact with short-tailed albatross. The introduction of gear modifications to reduce seabird incidental catch in the BSAI longline fisheries have been very effective and has reduced bycatch of all seabirds significantly, and no short-tailed albatross have been incidentally caught in the BSAI groundfish fisheries since 1998. However, population increases of short tailed albatross may increase the probability of fishery interactions which means that mitigative measures will become increasingly important. Current regulations require a shut down of the fisheries if two or more short-tailed albatross are caught. Steller's eiders also occur in the ecosystem area, but take in the fisheries is believed to be minimal.

Interaction: Changes in the population status of ESA-listed marine mammals impact fisheries through specific regulatory constraints

Regulatory constraints impact fisheries through changes in spatial and temporal fishing patterns and harvest level reductions. Steller sea lion mitigation measures have already impacted fisheries, (in particular the pollock, Pacific cod, and Atka mackerel fisheries), and fisheries will continue to be affected by population changes (declines or recovery) of sea lions. The ESA-listed whales (see Appendix B) are not currently impacting fisheries. Sea otters are currently listed as threatened, but restrictive measures to decrease interactions with fisheries have not so far been identified.

Fishing Effects Interactions

Interaction: Total removals from the ecosystem due to fishing may impact ecosystem productivity

Fishing removals by definition impact the ecosystem, but total removals are considered to be well managed under the current system in an effort to ensure ecosystem productivity. However, there is much greater uncertainty associated with the levels of removals of many non target species (some of which are not subject to any monitoring) relative to target species, contributing uncertainty to the level of total removals. Another contributing factor to the uncertainty in the level of total removals from the Aleutian Islands ecosystem is the management system by which the Council and NMFS limit total removals from the BSAI as a whole, and not specifically from the AI subarea. Of the 18 managed groundfish categories, only 6 species or species groups (pollock, Pacific cod, sablefish, Greenland turbot, POP, other rockfish, and Atka mackerel) have Aleutian Islands area specific quotas. The interactions of marine food webs are not fully understood, and this combined with the uncertainty associated with the level of total removals in the Aleutian Islands ecosystem leads to uncertainty about impacts.

Interaction: Interaction of one fishery on another through habitat impacts

The process by which fisheries interact through habitat, is the disturbance and or destruction of essential fish habitat. Of particular concern are fisheries that disturb spawning habitat, nursery or rearing areas, or juvenile habitat of other fished species, although the effects are uncertain or undocumented.

Interaction: Interaction of one fishery on another through bycatch impacts

The Pacific cod and Atka mackerel fisheries in the Aleutian Islands interact through the bycatch of rockfish species. Bycatch of some rockfish species could impact the ability of the Pacific cod or Atka mackerel fisheries to harvest their quotas if bycatch levels approach rockfish overfishing levels.

Interaction: Commercial and subsistence fisheries may compete

Subsistence use in the AI is very important to the users but is conducted at a much lower level compared to the overall commercial harvest. Changes in subsistence use and the potential for increased interaction with commercial fisheries may occur if the community of Adak expands.

Interaction: Limited entry and allocation of harvest quota impact the flexibility of fishers to react to changing ecosystem conditions

The Council/NMFS have continuously moved from open access harvest systems towards allocating harvest quotas to sectors, cooperatives, and individuals. While there are options to allow flexibility built in to these programs, they limit the flexibility of fishers to respond to changing ecosystem conditions. Limited entry restricts the ability of fishers to change fisheries. However, other associated factors limit those changes as well, primarily economic. The expense to purchase new gear or vessels inhibits entry into other fisheries, even if they are open entry fisheries.

Other Socioeconomic Activity Interactions

Interaction: Changes in the level of military activity in the area may impact communities

The military has scaled down its AI operations considerably since the Cold War, has closed many installations, and is conducting cleanup of those sites. In a reversal of this trend, however, a missile defense radar installation is slated to be based in Adak aboard an oceangoing platform. This installation may add stability to the community of Adak by diversifying its economy supporting the military presence. This in turn may contribute to Adak's ability to function as a fishery hub in the Aleutian Islands. To the degree that nearshore development results in habitat loss, there may be localized effects on recreational and subsistence fisheries. These latter may also be affected by an increased number of people supporting the defense installations.

Interaction: Changes in fishery activities impact the stability of AI communities

Fishery activities are an important part of the economic base of Atka and Adak. These activities are economically important both to the people of the communities and to the fisheries they support. The Aleut Corporation is actively trying to develop the community of Adak, and expand its economy in order to improve the stability of the community. If the community of Adak expands and becomes a stable community, the amount of marine activity occurring in the area is likely to increase. An increase in the Adak community, particularly if it is through development, is likely to affect the prosperity of the community.

Interaction: Oil and gas development may impact ecosystem productivity

Development is being discussed for the North Aleutian Basin, just north of the Alaska Peninsula. There is a probability of oil spills occurring from the development and associated increased vessel traffic through the ecosystem area. The risk of oil spills from the North Aleutian Basin development is less important for the Aleutian Islands ecosystem area because current patterns are likely to disperse oil spills into other parts of the Bering Sea. However, increased vessel traffic has a potential to increase the likelihood of accidents, which may directly affect habitat, fish, marine mammals, and seabird species in the area of the accident.

Interaction: Vessel traffic on the great circle route, and risk of vessel grounding and spillage, may impact ecosystem productivity

Shipping on the great circle route passes through the AI ecosystem on the western end, as vessels transit between the North Pacific and the Bering Sea. As vessel traffic increases, so does the probability of accidents. There is the potential for significant impacts to the ecosystem if the grounding or spill occurs at key locations within the ecosystem area. Oil spills and the introduction of rats are of critical concern.

Interaction: The establishment of an onshore processor at Adak impacts the community and Aleutian Islands fisheries

Adak is working to build up an onshore processor capable of operating year-round in Adak; an onshore processor is likely a pre-requisite for developing a small boat fishery in Adak, and is part of the Aleut Corporation efforts to develop the community of Adak. The community of Adak currently relies on fish processing as a main economic basis. The ability to sustain a small vessel fleet is likely to add to the stability of the community of Adak. The establishment of an onshore processor will impact the Aleutian Island fishers who are able to deliver closer to the fishing grounds.

Interaction: Research activity may impact fisheries

Research vessels represent a considerable proportion of the vessel activity in the AI and they have the potential to impact commercial fishing activities. The presence of research vessels may result in gear conflicts between research and fishing vessels. A higher presence of vessels increases the threat of accidents, potentially resulting in oil spills, as discussed above. From a broader perspective, it is to be hoped that research activity conducted on the vessels will benefit the ecosystem and fisheries by elucidating ecosystem processes, and so allowing managers to more effectively maintain ecologically sustainable fisheries in the long term.

[PLACEHOLDER: Need to discuss value of including ‘upper-level’ interactions (climate vs. fisheries, community development vs. fisheries, fisheries vs. predator prey, climate vs. predator prey) independently. Most of these interaction categories are actually covered in the specific interactions cited above. But need to make sure that we’re not missing a ‘big picture’ perspective. These categories may also be useful to discuss categories of things that the Council can manage for, versus those things that we can only monitor and try to mitigate.]

4 Ecosystem Assessment

4.1 Risk Assessment

The objective of this section is to identify those parameters and ecosystem interactions that the Council may wish to monitor in order to avoid changes towards other, potentially undesired, ecosystem states. Most biological processes are not linear and most systems have boundary conditions that determine certain threshold levels that lead to what has been referred to as “regime shifts”. Passing a threshold in one direction may require little extra change close to this boundary, but returning to the previous state may not be as simple as reversing or halting the particular impact that lead to the change (Figure 4-1). For example, the changes in ecosystem structure and function in state 2 that will result in a switch to state 1 may be less than those required to bring the system back up into the second state. Processes of this kind may explain certain fishery collapses and their lack of their recovery despite a partial or total reduction of the fishery.

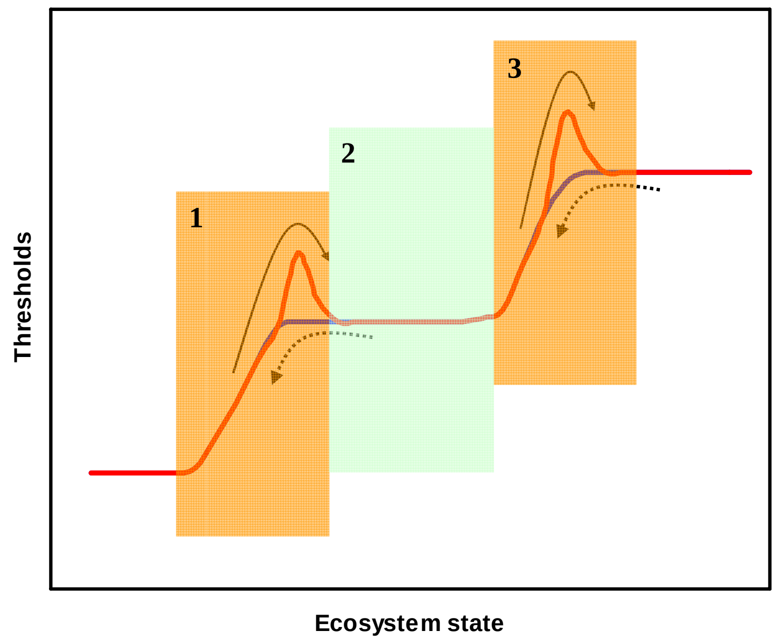

Figure 4-1 Conceptual visualization of non-linear changes between different ecosystem states within the same ecosystem.

Clearly some processes and interactions are more critical in determining or indicating ecosystem status than others, and not all are controllable through management actions. It is, therefore, of important to first define relevant ecosystem interactions (as in Section 3.6) and then determine their probability of occurrence, as well as the nature of level of impacts or harm (where harm is defined as a ‘cost’; in this case a change in biological structure or function that may or may not lead to economic cost) on the current ecosystem state, measured as the risk of pushing the current system closer to one of the thresholds that lead to a new ecosystem state.

Defining these interactions and their importance aids in the establishment of a risk assessment framework which ultimately identifies preferred actions with respect to one or more management objectives. It is the goal of such an assessment to provide managers with a tool to either make choices between different risks or to take actions to avoid, buffer or mitigate the risk all together through appropriate management actions.

Ecological risk assessment is defined as a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. A risk does not exist unless (1) the stressor has the inherent ability to cause one or more adverse effects and (2) it co-occurs with or contacts an ecological component (i.e., organisms, populations, communities, or ecosystems) long enough and at a sufficient intensity to elicit the identified adverse effect. Ecological risk assessment may evaluate one or many stressors and ecological components (EPA 1992).

4.1.1 Methodology

Ecological risk may be expressed in a variety of ways. While some ecological risk assessments may provide true probabilistic estimates of both the adverse effect and exposure elements, others may be deterministic or even qualitative in nature. In these cases, the likelihood of adverse effects is expressed through a semiquantitative or qualitative comparison of effects and exposure (EPA 1992).

For this first version of the FEP, it is not feasible (due to time constraints) to conduct a quantitative risk assessment analysis of the interactions defined in Section 3.6. Our process still follows the classic risk assessment framework defined elsewhere (NRC 1983, EPA 1992), but is qualitative in nature and relies on expert opinion and the building of consensus. It also makes use of a recent approach to determine critical ecosystem interactions via cognitive maps (Prigent et al. *in review*). In our approach, each Ecosystem Team member individually rated the interactions identified in Section 3.6. Ratings were then averaged across members. All scoring was based on the personal knowledge of each team member and augmented with a written rationale for each rating. Team members abstained from scoring particular interactions if they felt they did not have the expertise to do so. A written summary of the interaction assessment was compiled and circulated among Team members to achieve consensus.

The use of such a qualitative approach is appropriate at this stage of the FEP, because the results of the risk assessment are only intended to provide general guidance to the Council about the interactions on which to focus further research or Council attention. This risk assessment is not intended to serve as a decisionmaking tool for the Council to evaluate management measure tradeoffs. For future versions of the FEP, or in work that stems from the FEP, the Council may wish to utilize an Analytic Hierarchy Process, or a loss function decision tool such as is being developed for fishery management by Thompson and Goodman (REF).

Ratings were defined as follows:

> *Probability/risk*, defined as the probability of an interaction (or result of an interaction) occurring was scored as high, medium, or low.
>
> *Impact* was defined as the degree of consequence or importance of this interaction or change. Both ecological and economic impacts were identified, and scored as high, medium, or low. To show the combined impact, the average economic and ecological impact scores were multiplied and plotted against probability. The time scale of the impact (short-term or long-term) was considered, and also the geographic scale of the impact (local, regional, national, global).

4.1.2 Summary of risk assessment findings

The interactions defined in Section 3.6 describe a conceptual model of some of the major interactions in the ecosystem that go beyond single species assessment and which should be taken into account when making management decisions. The inter-relationship between these interactions is displayed qualitatively in a cognitive map, in which the direction and strength of the interaction can be indicated (Figure 4-2). In addition, the importance of these interactions for the ecosystem and subsequently for management can also be shown as probability versus impact plots, based on the average qualitative scores of the Ecosystem Team members (Figure 4-3, Figure 4-4).

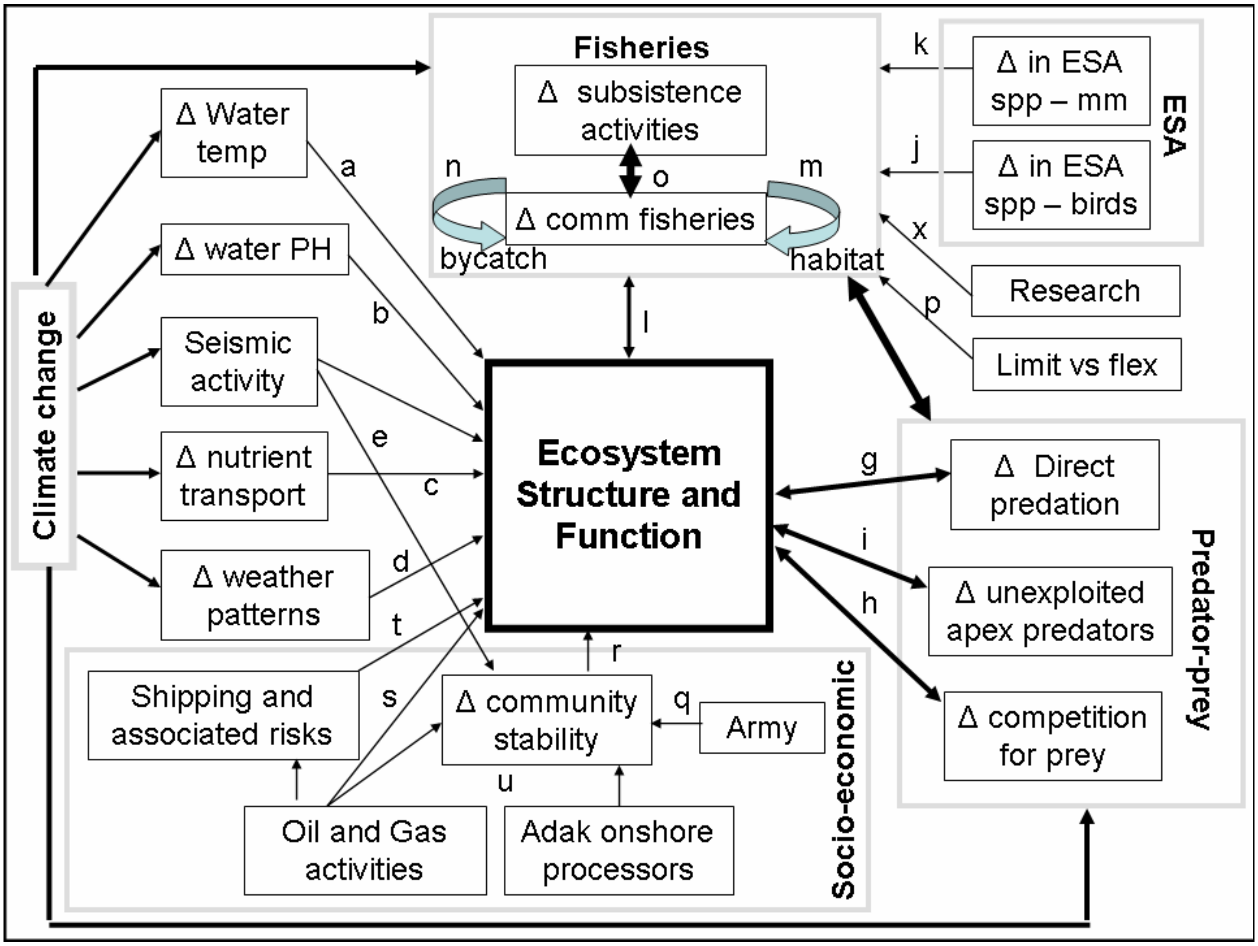

Figure 4-2 Map of ecosystem interactions

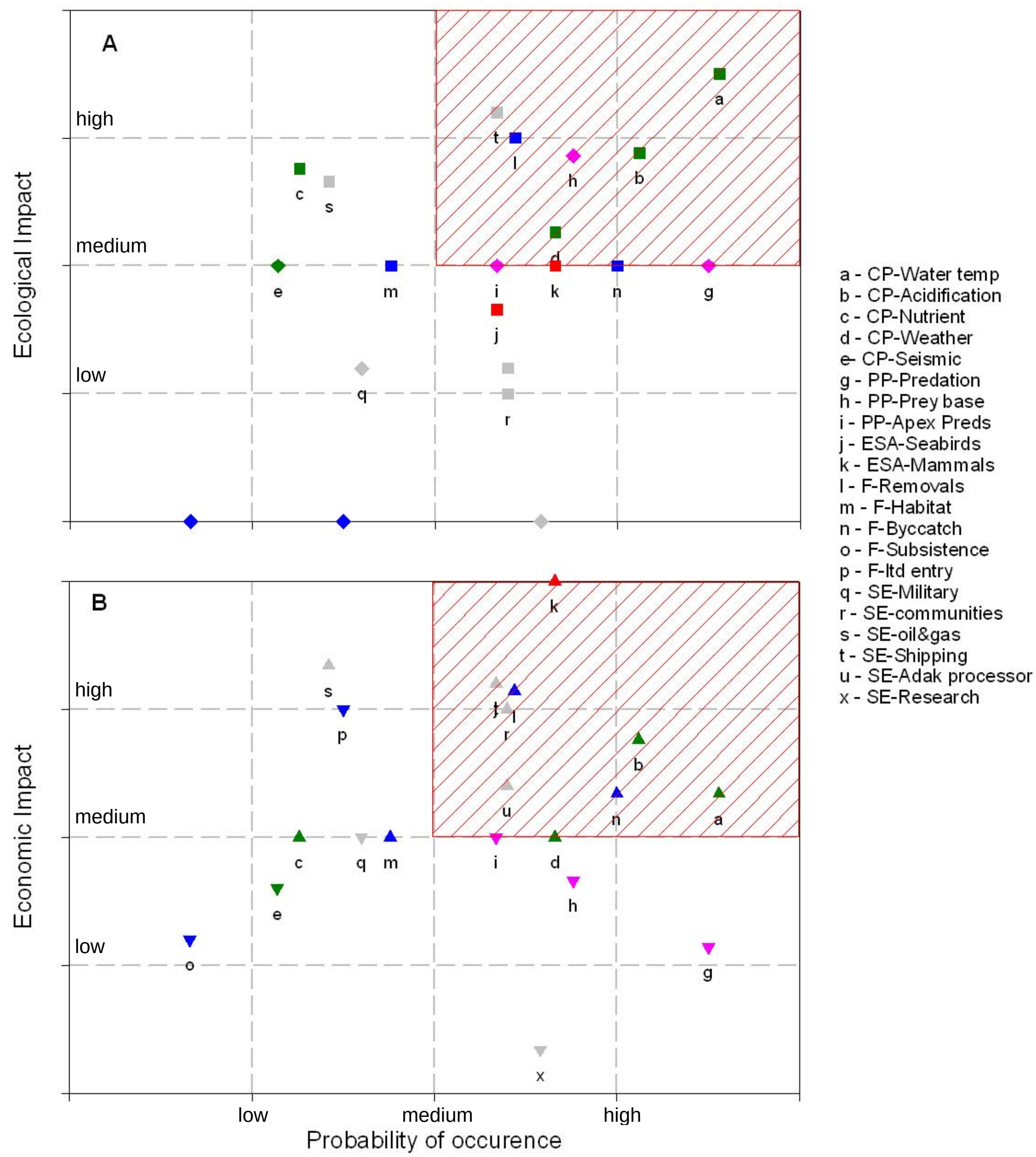

Figure 4-3 Probability of occurrence and (A) ecological and (B) economic impact assessment of interactions. Shaded area in upper right quadrant highlights those interactions with a medium to high probability of occurring and likely impact.

Note: Colors represent the interaction category. CP = Climate/Physical = green; PP = Predator-Prey = Pink; ESA = Endangered Species Action = red; FE = Fishing Effects = blue; SE = Socioeconomic Activities = grey; UL = Upper Level = black. Squares and down-triangles represent long-term impacts, and diamonds and up-turned triangles represent short-term impacts.

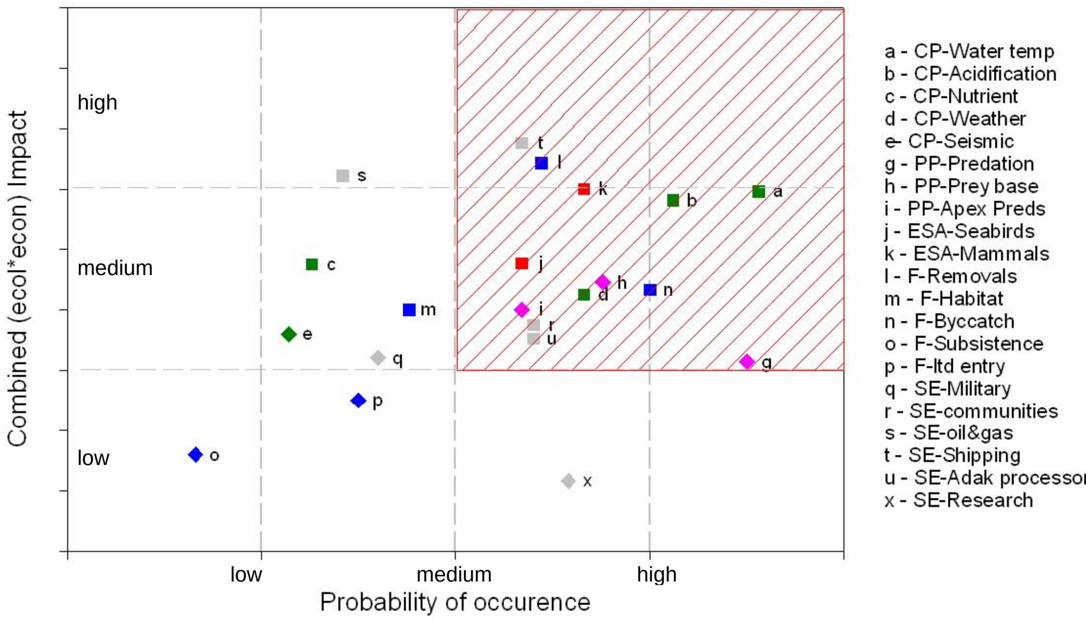

Figure 4-4 Characterization of interactions in terms of probability of occurrence and a combined ecological multiplied by economic impact. Shaded area in upper right quadrant highlights those interactions with a medium to high probability of occurring and likely impact.

Note: Colors represent the interaction category. CP = Climate/Physical = green; PP = Predator-Prey = Pink; ESA = Endangered Species Action = red; FE = Fishing Effects = blue; SE = Socioeconomic Activities = grey; UL = Upper Level = black. Squares and down-triangles represent long-term impacts, and diamonds and up-turned triangles represent short-term impacts.

4.1.3 Interpretation of Interaction Scores

Climate/physical Interactions

Interaction: Changes in water temperature may impact ecosystem processes

Summary Ratings: Probability – high, Ecosystem impact – high, Economic impact – medium
Geographic scale – global, Time scale – long-term

Probability: Changes in water temperature have already been recorded over the last decade and climate projections support a high probability of continued changes.

Ecological impact: Temperature regulates all biological rates (growth, feeding, etc.) and has direct proven impacts on primary productivity and thus the forage base. A re-organization of species composition and dominance due to temperature effects has been thoroughly documented (e.g. in relationship to the 1976/77 regime shift, recent changes in *Calanus* species composition, etc.), favoring some species and not others. Given this strong direct (exotherms and their habitat) or indirect (shift in distribution and abundance of prey base) dependency on water temperature, the impact of changes in water temperature on ecosystem processes and function is high. The effect on the AI ecosystem will probably be less than at higher latitude areas. Species residing in shallow inshore areas, seabird and marine mammal populations, deepwater corals, and any animals unable to move to stay within a temperature range, are particularly likely to be affected.

Economic impact: Economic impacts will include loss of some salmon fisheries (small in comparison to other areas in Alaska) and potential loss of some near shore fisheries such as Pacific cod and Atka mackerel. Also, there has already been a clear northward shift in the center of distributions of several commercial fish species (e.g. pollock, halibut); to the extent this affects AI fisheries, or AI communities, it could result in longer, farther fishing trips entailing higher costs. Some economic gain could be felt if the cooling trend in the Aleutians is reversed, due to increased tourism. Rise in sea level could negatively impact villages, but steep topography of islands would preclude significant loss of habitable areas.

Geographic scale: The impact of changes in water temperatures in this region may be felt from a local to a global scale if it affects prices of commercial species which go into the global market (e.g. Atka mackerel, crabs) or if there is species loss, which is a global loss in biodiversity.

Time scale: Changes in water temperature are already occurring and are projected to continue. Some of these effects may be observed and felt immediately but may last for several decades, others tend to occur gradually (strong presence of invasive species or changes in habitat structure).

Interaction: Increased acidification of the ocean may impact ecosystem processes

Summary Ratings: Probability – high, Ecosystem impact – medium, Economic impact – medium
Geographic scale – global, Time scale – long-term

Probability: Ocean acidification is documented to be occurring, and is likely to continue and increase given current trends in anthropogenic carbon emissions and projected release of deep water methane.

Ecological Impact: The AI is an oceanic food web, in which oceanic/planktonic energy is very important. Consequences of small changes in PH can be severe for calcifying organisms, such as shelled pteropods, corals, foraminifera, coccolithophors. We cannot predict which species will die out and which will adapt, but the impacts to the food web could be very severe if many species of plankton (or a few key species) are affected. The dissolution of corals in the Aleutians would have habitat implications for many species, and shelled pteropods contribute to the diets of many fish, including salmon. Effects could include significant declines in primary production and carrying capacity of the AI ecosystem.

Economic Impact: Depending on the impact of these predicted changes in zooplankton communities on commercial fish species, the economic impact is projected to be medium to high.

Geographic Scale: Ocean acidification is occurring globally, and as stated above, if ecosystem changes observed in the AI affect globally important species or ecosystem processes then the scale at which the impact of ocean acidification in this region is felt is global

Time Scale: Ocean acidification is occurring now and is projected to continue. Some of the consequences are short term, such as loss of critical species such as pteropods; others are long term (habitat changes due to coral loss).

Interaction: Changes in nutrient transport through the passes and changes in the predominant current patterns that drive primary production impact ecosystem processes

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – medium
Geographic scale – regional, Time scale – long-term

Probability: The vertical mixing of nutrients into the surface waters in the passes is primarily accomplished through the interaction of tidal currents and steep bathymetry, which are not likely to change. The net transport of nutrients from the Pacific into the Bering is due to the net northward flow, which could change (as opposed to tides).

Ecological impact: If there were a change in nutrient transport, the impact could be substantial. There could be substantial change of primary production and possibly changing pelagic habitat if current directions of magnitudes change. Change in the net transport from the Pacific into the Bering could change the locations and intensity of blooms.

Economic impact: If this drove a change in primary productivity the economic impact could also be significant.

Geographic scale: The impact would be on a regional level, but many of the smaller passes are affected by local conditions so there may be variation throughout the AI with respect to how changes affect different areas.

Time scale: Annual to decadal.

Interaction: Changing weather patterns impact ecosystem processes

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – medium
Geographic scale – regional, Time scale – long-term

Probability: Changing weather patterns are likely. For example, increased storm intensity globally is one mechanism the planet has for distributing heat from equator to poles. But climate change predictions in general are uncertain, and are unknown for the Aleutian Islands specifically.

Ecological impact: Changing weather patterns may not be strong enough to impact the ecosystem. The ecosystems in this part of the world have evolved in a highly variable system in terms of weather and are probably pretty resilient to changing weather patterns. Increased storminess could affect lower trophic levels productivity. Any longer term changes in atmospheric circulation could affect transport of eggs and larvae and plankton towards or away from their current locations, altering recruitment and or foraging patterns.

Economic impact: Changes may alter the ability of fisheries to operate the way they have before, in terms of seasonality, or safety, and there is cost associated with change.

Geographic scale: Changes in weather patterns are likely to be at a regional to global scale. Local shifts in abundance and species composition may occur, as a response to variable climate and weather patterns.

Time scale: Short term variability in weather is already apparent. Potential long-term impacts may be associated with global warming, which is predicted to change the frequency of storms and may affect the position of the Aleutian Low, which affects mixed layer depth and thus primary and secondary productivity. It is unclear how quickly ecosystem impacts may be reversed if weather patterns return to previous conditions.

Interaction: Impacts of seismic activity and volcanism on human and marine populations

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – medium
Geographic scale – regional, Time scale – short-term

Probability: Volcanic eruptions and earthquakes are common in the Al. Seismic and volcanic activity happens more in the AI than nearly anywhere else on the planet, so the probability of an eruption occurring is high, although the probability of an eruption occurring that would impact the ecosystem is less so. There is no reason to think volcanic activity or earthquakes will be changing from past frequency, so it is "natural" background.

Ecological impact: Impacts of minor eruptions and earthquakes are negligible on the AI ecosystem. Local impacts to ocean ecosystems could happen through direct displacement of benthic habitat which affects living substrate more than fish, who may just swim to a new place. Local impacts may include destruction of rookeries for seabirds and pinnipeds, but would likely be minor for marine organisms. Large volcanic events and earthquakes are rare but would similarly likely have little impact. Positive effects of volcanisms may be the creation of new habitat for seabirds and marine mammals.

Economic impact: Two volcanoes are active now (http://www.avo.alaska.edu/), one close to the village of Atka, so the potential for impact on the few human populations is high. Ash clouds might affect local weather conditions or acidity; it is uncertain the degree or length of such an impact, and whether this might in turn affect ocean communities. There is a potential to have an economic impact if a major change occurs in a local area that is a major fishing area, for example for Atka mackerel.

Geographic scale: A large tsunami during breeding season could substantially impact some local seabird and marine mammal populations, but would likely not be an ecosystem wide effect. Volcanic activity in the AI affects transcontinental plane traffic so the impact to humans is beyond local scale.

Time scale: An eruption impact on benthic living substrate may linger for decades to centuries; ash plume impact may dissipate in less than a year.

Predator-prey Interactions

Interaction: Changes in biomass attributable to fishing impact multiple species due to direct predation interactions

Summary Ratings: Probability – high, Ecosystem impact – medium, Economic impact – medium
Geographic scale – regional, Time scale – short-term

Probability: The main commercial species (by value) targeted in the AI are Pacific cod, Atka mackerel, king crab, halibut, sablefish, Pacific ocean perch, and pollock. Based on diet information for several of these species, direct predation among each other occurs. Diet and mortality information from the Aleutian Islands food web model is provided in **Error! Reference source not found.**.

Ecological impact: Changes in the level of fishing will have the highest impact where predation interactions are strongest, such as with the pollock and Atka mackerel interaction, the halibut and Pacific cod impact on sablefish, and the Pacific cod and Atka mackerel interaction. Halibut dependence on Atka mackerel and pollock is a medium strength interaction, and the interaction of king crabs and Pacific ocean perch with other species is low. Pollock and Atka mackerel are both estimated to cause high mortality on each other despite being a small proportion of each other's diet. The high mortality is a result of the relatively large biomass of each species estimated to be in the ecosystem, combined with their consumption rates. Therefore, small changes in the biomass of either could result in large changes in the amount of mortality caused by predation (assuming the diet and consumption rates remain the same). For example, if fishing reduces the biomass of Atka mackerel, they will cause less mortality on pollock, potentially releasing pollock to cause even more mortality on Atka, which is a positive feedback reducing Atka mackerel biomass further. The feedback could be even stronger if fishing reduces the biomass of pollock; however, Atka mackerel and pollock are distributed differently across the AI, so spatial interactions complicate this picture. Given spatial differences in food webs across the AI and the importance of both these species as prey to fish, mammal, and bird predators, this potentially high impact interaction should be monitored as fishing for each species continues.

A different impact is the effect of Pacific cod and halibut predation on sablefish. Sablefish are less than 1% of each of these species diets in the AI, but halibut are estimated to cause 17% and cod 18% of sablefish mortality; their combined effect is equivalent to the longline fishery. Changes in the combined cod and halibut biomass might impact sablefish populations, and increased sablefish fishing mortality might have stronger population effects than estimated due to this predation mortality. However, a change in sablefish biomass may not affect cod or halibut as sablefish is a small portion of the overall diet.

The interaction between Pacific cod and Atka mackerel is discussed in the annual Atka mackerel stock assessment. No adjustments are made to either the Pacific cod or Atka mackerel TACs in consideration of this interaction.

Economic impact: A high economic impact results where predation interactions result in tradeoffs between different fisheries. There is little economic impact for weakly interacting species.

Geographic scale: Local to regional. There may also be a global scale economic impact, to the extent Atka mackerel and crab go to global markets.

Time scale: Annual to decadal based on recovery of species, generation time, and passing of ecosystem thresholds and re-organization of ecosystem structure

Interaction: Changes in biomass of important prey species for which predators compete impact ecosystem production and sustainable fisheries

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – medium
Geographic scale – regional, Time scale – short-term

Probability: Direct competition is hard to analyze. This assessment assumes that species with greater than 10% of prey overlap in their diet, as well as exhibiting a dependence on that prey (i.e., it represents greater than 10% of their diet), are potential competitors. Competition implies that the prey resource is limited, and prey overlap may just be a reflection of the high prevalence of the prey. Several fishery species, and many other species share a prey base. **Error! Reference source not found.** illustrates prey groupings for AI species.

Ecological impact: The highest impact would result from depletion of those species that form the prey base for most commercial and protected species. Specifically, these are the euphausiid prey base (shared by all forage fish, myctophids, baleen whales, squids, sablefish, Atka mackerel, seabirds, pollock, rockfish and POP); the copepod prey base (shared by euphausiids and most of the above species); the squid prey base (shared by toothed whales, grenadiers, seabirds, halibut, and atka); and the myctophid prey base (shared by flatfish, grenadiers, and pollock). King crab and sea otters are the exception, as they compete for benthic invertebrates with other fish, crabs and shrimp. Pollock are the shared major prey of the Federal trawl fishery (in the early 90s), as well as skates, pinnipeds, and Steller sea lions. Atka mackerelare shared major prey of Steller sea lions, skates, the fishery, halibut and Pacific cod. Much attention has already been focused on the potential competition between Steller sea lions and the Federal trawl fisheries with respect to Atka mackerel, Pacific cod and pollock. It is important to note that the potential competition between grenadiers and pollock for myctophid prey is not observed in any other Alaskan ecosystem, and the classification of sablefish with other zooplankton feeders is also unique to the AI. If competition for a prey base and/or overall ecosystem productivity is of concern, the importance of euphausiids and copepods as prey for a wide range of commercial and protected species in the AI suggests that production of these important zooplankton groups might be monitored, especially under future climate change. Direct exploitation of euphausiids has been prohibited since 1998.

Economic impact: The highest economic impacts would result from the depletion of euphausiids; pollock and Atka mackerel, as they are prey shared by both commercial and protected predators and fisheries; and shrimp which are shared by cod, skate, rockfish, other fish, pinnipeds, and flatfish.

Geographic scale: Regional.

Time scale: Annual to decadal

Interaction: Changes in populations of unexploited apex predators (through fishery impacts or direct predation between predators) may impact system productivity and ecosystem functions

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – medium
Geographic scale – regional, Time scale – short-term

Probability: Unexploited apex predators in the Aleutian Islands include seabirds, marine mammals, sharks, and skates. There is a high probability of a fishery impact on sharks, skates, and a probability of a medium impact on birds. There is a probability of a medium marine mammal predation impact on baleen whales, pinnipeds, sea otters, toothed whales, Steller sea lions, sharks, skates, and a probability of a medium bird predation impact on birds.

Ecological impact: Fisheries cause more mortality for non-target sharks (79%) and skates (56%) than for any target species aside from king crabs. These species are not intended to be exploited, but effectively are as bycatch. While this may have large population consequences, it is unclear whether this bycatch mortality has an ecosystem-level effect. Fisheries were estimated to cause 3-6% of bird group mortality in the early 1990s, again potentially with consequences to bird populations but unclear ecosystem consequences. Fisheries cause negligible direct mortality on marine mammals (other than subsistence on pinnipeds).

Toothed whales are estimated to cause predation mortality (10-24%) on baleen whales, pinnipeds, sea otters, and lower estimated amounts (4-8%) on other toothed whales sharks, skates, and Steller sea lions. While some theorize that toothed whale (transient killer whale) predation might account for declines in pinniped and sea otter populations (and thus changes in community composition of apex predators), it is unclear what their diet preferences and even population size are to make credible quantitative estimates of their impacts to other mammal populations. To clarify this, directed research on transient killer whale population size, movements, and food habits should be continued, and this apex predator population monitored to the extent possible. Piscivorous birds cause some mortality on themselves (25%) and planktivorous birds (13%), which is the majority of explained bird mortality in the models, but a minority of total mortality (most is unexplained by predation or fishing). This predation may have seabird population impacts, but has unclear ecosystem impacts.

Economic impact: Economic impacts of population changes in unexploited apex predators may result from their increased competition for fishery species as prey when population levels are high. Population changes of listed species such as the Steller sea lion have an impact due to regulatory constraints on the fisheries, as described below.

Geographic scale: Local to regional.

Time scale: Annual to decadal.

Endangered species Interactions

Interaction: Changes in the population status of ESA-listed seabirds impact fisheries through specific regulatory constraints

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – high
Geographic scale – regional, Time scale – long-term

Probability: The probability of short-tailed albatross bycatch in the BSAI groundfish fisheries is medium. The introduction of gear modifications to reduce seabird incidental catch in the longline fisheries have been very effective and has reduced bycatch of all seabirds significantly. Population increases of short tailed albatross, however, may increase the probability of interactions which means that mitigative measures will become increasingly important. No short-tailed albatross have been incidentally caught in the BSAI groundfish fisheries since 1998. Steller's eiders also occur in the ecosystem area, but take in the fisheries is believed to be minimal.

Ecological impact: Relatively moderate impacts on the ecosystem as a whole from these rare species, although their population status is an indicator response to ecosystem change.

Economic impact: As the population of short-tailed albatross increases, interactions with fisheries will increase, but if prevention measures are effective, the impact may not be nearly as great as it would have been prior to recent advances in fishing methods to reduce bycatch. However, current regulations may lead to a shut down of the fisheries if two or more short-tailed albatross are caught, causing a huge economic impact.

Geographic scale: Bycatch of a short-tailed albatross in any BSAI groundfish fishery has regulatory ramifications for all groundfish fisheries, including those occurring in the Aleutian Islands. If fishery closures occur, then the geographical scope of the impacts may be felt globally due to markets, but certainly regionally.

Time scale: Short-tailed albatross are not likely to be delisted from ESA in the short term and thus this is a long-term consideration. Impacts on the fisheries and mitigative measures may be in the order of a season to several years.

Interaction: Changes in the population status of ESA-listed marine mammals impact fisheries through specific regulatory constraints

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – high
Geographic scale – regional, Time scale – long-term

Probability: Steller sea lion mitigation measures have already impacted fisheries, and fisheries will continue to be affected by population changes (declines or recovery) of sea lions. ESA-listed whales are not currently impacting fisheries. Sea otters are listed as threatened, but restrictive measures to control interactions with fisheries have not so far been identified.

Ecological impact: It is uncertain whether the Steller sea lion mitigation measures have had any impact on the ecosystem except by creating de facto marine protected areas around rookeries and haulouts. The extirpation of Steller sea lions from the ecosystem altogether would likely have significant local effects on species composition. It would likely release some prey items from predation but whether another predator would take advantage of this is unknown. Changes in otter populations significantly cascade through near shore habitat (see Estes, et al.). Otter populations have significantly declined from historic levels.

Economic impact: The sea lion mitigation measures have already had significant economic impact on the fisheries, changing spatial and temporal fishing patterns and reducing harvest levels. If Steller sea lions recover, there may also be economic impacts as their prey base becomes limited and affects fishery levels. To the extent that subsistence harvests of sea otters occur, the listing of the species could have a high impact on local communities.

Geographic scale: Local to regional.

Time scale: Effects from the Steller sea lion mitigation measures will likely continue for at least several decades and effects due to the listing of otters are still uncertain but will also likely impact fisheries for several years.

Fishing Effects Interactions

Interaction: Total removals from the ecosystem due to fishing impact ecosystem productivity

Summary Ratings: Probability – medium, Ecosystem impact – high, Economic impact – high
Geographic scale – regional, Time scale – long-term

Probability: While fishing removals from the ecosystem occur, total removals are considered to be well managed under the current system in an effort to ensure ecosystem productivity. For groundfish removals, however, the Council/NMFS limit total removals from the BSAI as a whole, and not specifically from the AI subarea. Although many species have AI-specific TACs, not all do, so there is a potential that total removals from the AI ecosystem may fluctuate.
Ecological impact: The interactions of marine food webs are not fully understood, so if total removals in the Aleutian Islands ecosystem increased substantially, there would potentially be increased uncertainty about impacts. Also, if total fishery removals in the AI ecosystem are coming from a localized area, impacts would potentially be high. There is much greater uncertainty associated with the levels of removals of many non target species (some of which are not subject to any monitoring) relative to target species, contributing uncertainty to the level of total removals. Another contributing factor to the uncertainty in the level of total removals from the Aleutian Islands ecosystem is the management system by which the Council and NMFS limit total removals from the BSAI as a whole, and not specifically from the AI subarea. Of the 18 managed groundfish categories, only 6 species or species groups (pollock, Pacific cod, sablefish, Greenland turbot, POP, other rockfish, and Atka mackerel) have Aleutian Islands area specific quotas.
Economic impact: To the extent that total removals affect the biomass levels of fishery species, the economic impact could be high.
Geographic scale: Local to regional.
Time scale: Annual to decadal.

Interaction: Impact of one fishery on another through fishing impacts on habitat

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – medium
Geographic scale – regional, Time scale – long-term

Probability: The bottom trawl fishery is now constrained to historic fishing areas in the Aleutians. Particularly sensitive areas such as deep coral gardens have been closed to bottom-tending fishing gear.
Ecological impact: If 'the first pass is the worst pass' is correct, the majority of the habitat damage should be done at this point. Geography limits the amount of area that can be impacted by mobile fishing gear at the current level of technology. Golden king crab fishing (longline pots) has the potential to continue disturbing sensitive coral habitat, but the footprint of this fishery is small.
Economic impact: Long-term economic effects may be apparent if fishing damage limits available habitat for juvenile fish, but the effects are uncertain.
Geographic scale: Local to regional.
Time scale: Effects are long term, as bottom habitat will likely recover on at least a decadal scale.

Interaction: Impact of one fishery on another through fishery bycatch

Summary Ratings: Probability – high, Ecosystem impact – medium, Economic impact – medium
Geographic scale – regional, Time scale – long-term

Probability: Management measures are in place to limit fishery bycatch impacts (prohibited species catch limits, required gear modifications, maximum retention allowances). Still, incidental species continue to be caught and often discarded in target fisheries.
Ecological impact: Management measures limit the overall bycatch of any species on which there is a directed fishery. Where bycatch mortality is unaccounted for, ecological impacts may occur.
Economic impact: Bycatch of some rockfish species could impact the ability to harvest other more abundant target species such as Pacific cod or Atka mackerel, by closing the directed fishery.

Geographic scale: Local to regional.
Time scale: The effects are long- or short-term depending on the lifespan of the bycatch species.

Interaction: Commercial fishery and subsistence uses may compete

Summary Ratings: Probability – low, Ecosystem impact – low, Economic impact – medium
Geographic scale – local, Time scale – short-term

Probability: Subsistence use in the AI is very important to the users but is at a low level compared to the overall commercial harvest. The particular interactions of note are 1) between subsistence and commercial uses of the same fishery resource, 2) between commercial and subsistence uses of different fishery resources (through bycatch or predator/prey dynamics and 3) between commercial fisheries and marine mammals. Changes in subsistence use may occur if the community of Adak expands. It should be noted that some small scale commercial fisheries in which local residents participate, such as the halibut fishery, interact synergistically with subsistence fish consumption.

Ecological impact: There would be no ecological impacts of an even tradeoff between subsistence and commercial fishery allocations. Subsistence uses may be impacted through increased or decreased prey species abundance via direct or indirect interactions. While these ecological changes are likely to be very important to local subsistence users and might affect local species compostions, they are not likely to have a large impact on the overall ecosystem.

Economic impact: The total population of Atka and Adak is a little over 400 people. Total per capita annual consumption of subsistence fish is high (about 440 lbs in Atka with 100 percent of households participating). While the subsistence harvest volume compared to commercial catch is low, the economic importance to those families dependent on subsistence resources is high.

Geographic scale: Subsistence is engaged in by local community members in local places close to Adak and Atka. Some subsistence harvesting takes place farther away in conjunction with commercial harvests (e.g. halibut).

Time scale: Short term.

Interaction: Limited entry and allocation of harvest quota impact the flexibility of fishers to react to changing ecosystem conditions

Summary Ratings: Probability – medium, Ecosystem impact – low, Economic impact – high
Geographic scale – regional, Time scale – short-term

Probability: The Council/NMFS have continuously moved from open access harvest systems towards allocating harvest quota to sectors, cooperatives, and individuals. While there are options to allow flexibility built in to these programs, they limit the flexibility of fishers to respond to changing ecosystem conditions by entering new fisheries.

Ecological impact: Quota systems keep fishing harvest steady in proportion to stocks, while open access tends to cluster effort in those fisheries which are “hot.” The social impacts of limited entry include are largely distributional (winners and losers in initial allocation or market-based redistribution of rights or in event of major prey abundance shifts).

Economic impact: Limited entry restricts the ability of fishers to change fisheries. However, other factors limit those changes as well, primarily economic. The expense of purchasing new gear or vessels inhibits entry into other fisheries, even if they are open entry fisheries. Limited entry simply adds the expense of a permit or quota to the other expenses of pursuing additional fisheries. Economic benefit accrues to the quota or permit holder.

Geographic scale: Allocation programs are regional in scope.

Time scale: Harvest quota limits are allocated for the long-term, although the Council always preserves the ability to reconsider allocation programs.

Other socioeconomic activity Interactions

Interaction: Changes in the level of military activity in the area may impact communities.

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – medium
Geographic scale – local, Time scale – short-term

Probability: The military has scaled down its AI operations considerably since the Cold War, has closed many installations, and as appropriate, is conducting cleanup of those sites. In a reversal of this trend, however, a missile defense radar installation has been installed near Adak aboard an oceangoing platform.
Ecological impact: To the extent that the installation requires nearshore development, or that other expansions of military activity in the Aleutians involve marine testing or maneuvers, there may be localized impacts to habitat, or sensitive marine populations. It is unlikely that there would be an ecosystem level impact from such expansion, however. To the degree that nearshore development results in habitat loss, there may be localized effects on recreational and subsistence fisheries. These latter may also be affected by an increased number of people supporting the defense installations.
Economic impact: This installation may add stability to the community of Adak by diversifying its economy supporting the military presence. This in turn may contribute to its ability to act as a fishery hub in the area.
Geographic scale: Local, as above.
Time scale: Effects are likely to be short-term for development activity, and potentially long-term for the stability of the community.

Interaction: Changes in fishery activities impact the stability of AI communities.

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – high
Geographic scale – local, Time scale – long-term

Probability: Fishery activity is an important part of the economic base of Atka and Adak. Also, the Aleut Corporation is actively trying to develop the community of Adak, and expand its economy, in order to improve the stability of the community.
Ecological impact: Changes in fishing activities could lead to substantial changes in human populations in the ecosystem. In particular, climate change effects could impact the types and abundances of commercial fish within viable distance of the hub port at Adak, causing the population to expand or contract in response.
Economic impact: Fishery support at Adak and Atka is important economically both to the people of the communities and to the fisheries they support. Economic effects will be high on those communities which experience instability. If the community of Adak expands, the amount of marine activity occurring in the area is likely to increase. This may result in some localized impact to subsistence and fishery resources in the immediate vicinity of Adak.
Geographic scale: Local communities.
Time scale: Population trends and fishery activity in the communities are long-term.

Interaction: Oil and gas development may impact ecosystem productivity.

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – high
Geographic scale – national, Time scale – long-term

Probability: Development is being discussed for the North Aleutian Basin, just north of the Alaska Peninsula. There is a reasonable probability of oil spills occurring from the development. Also, the development will undoubtedly lead to increased vessel traffic through the ecosystem area. The probability that these very likely activities will cause ecosystem system impacts is medium.

Ecological impact: Impacts from offshore structures or pipelines themselves are generally seen although their footprint is small. The ecological impacts in the AI FEP ecosystem from potential oil spills from the North Aleutian Basin development is likely small because current patterns are likely to disperse oil spills into other parts of the Bering Sea. With certain increased vessel traffic comes an increase the likelihood of accidents which may directly affect habitat, fish, marine mammal, and seabird species in the area of the accident. Depending on the location, ecological impacts will range from medium to high (see shipping below)

Economic impact: Economic impact will be twofold. With the onset of oil and gas development more resources and potential capital will flow into the area close to the development and some may spill over into the FEP area. Such an impact would be positive. On the other hand, oil spills or vessel accidents that might occur due to this development would certainly have negative and potentially high economic implications, especially if subsistence and commercial harvests are affected.

Geographic scale: The scale of impact of the development in the Aleutians is local to regional; the scale of an ecosystem or economic impact, if it occurs due to a North Aleutian Basin oil spill is national and potentially even global if it were to affect commercial values or global importance.

Time scale: Oil and gas activities would be carried out for many years. Local impacts would therefore be on that time scale. Impacts from oil spills or a vessel accident are also likely to be long-term.

Interaction: Vessel traffic on the great circle route, and risk of vessel grounding and spillage, may impact ecosystem productivity.

Summary Ratings: Probability – medium, Ecosystem impact – high, Economic impact – high
Geographic scale – regional, Time scale – long-term

Probability: Shipping on the great circle route passes through the AI ecosystem on the western end, as vessels transit between the North Pacific and the Bering Sea (see Figure 3-24). As vessel traffic increases, so does the probability of an accident.

Ecological impact: The potential for an adverse ecosystem impact is high if a vessel grounding or oil spill occurs at key locations within ecosystem area. Oil spills and introduction of exotic species are of critical concern.

Economic impact: As above, if the grounding or spill occurred in key areas within the ecosystem, the economic impact could be high.

Geographic scale: Effects could be localized or regional, depending on the location of the accident.

Time scale: Impacts from a vessel accident are likely to be long-term.

Interaction: The establishment of an onshore processor at Adak impacts the community and AI fisheries.

Summary Ratings: Probability – medium, Ecosystem impact – medium, Economic impact – medium
Geographic scale – regional, Time scale – long-term

Probability: Adak is working to build up an onshore processor operating year-round in Adak; an onshore processor is likely a pre-requisite for developing a small boat fishery in Adak, and is part of the Aleut Corporation efforts to develop the community of Adak.
Ecological impact: The increase in small vessels is not likely to adversely affect the ecosystem, as quotas will continue to be set at sustainable levels. Discharge from the processor may have a localized impact on water quality.
Economic impact: The economic impact is probably fairly large to the community, which currently relies on fish processing as a main economic basis. The ability to sustain a small vessel fleet is likely to add to the stability of the community of Adak.
Geographic scale: The scale of impact is local to regional, affecting the community of Adak, but also fishers in the Aleutians who are able to deliver closer to the fishing grounds.
Time scale: The establishment of an onshore processor in Adak is likely to be a long-term fixture and thus its associated impacts would operate on that scale.

Interaction: Research activity may impact fisheries

Summary Ratings: Probability – medium, Ecosystem impact – low, Economic impact – low
Geographic scale – local, Time scale – short-term

Probability: Research vessels represent a considerable proportion of the vessel activity in the AI. The probability that they will interact with fishing is medium.
Ecological impact: A higher presence of vessels increases the threat of accident, potentially resulting in an oil spill, as discussed above. From a broader perspective, it is to be hoped that research activity conducted on the vessels will benefit the ecosystem and fisheries by elucidating ecosystem processes, and so allowing managers to more effectively maintain ecologically sustainable fisheries in the long term.
Economic impact: The presence of research vessels and/or moored researched instrumentation may result in gear conflicts with fishing vessels, however such conflicts would be relatively easy to resolve and should be of short duration only. This could be more of a problem in the future if a small vessel fleet develops, fishing out of Adak in summer months, which is also when research vessels are likely to be present.
Geographic scale: Effects are primarily local.
Time scale: Potential impacts due to gear conflict would be of short duration; effects of a vessel accident could be long-term.

4.2 Tracking critical interactions

Ecosystem indicators may be used to track the critical interactions defined above. Indicators as determined for this FEP have two main objectives: (1) to help assess the status of the ecosystem/interaction, and (2) to monitor how well a fishery is managed in relation to an objective. Ideally, each indicator would need to be associated with reference points as well as with thresholds, the passing of which would indicate a large undesired shift (e.g., Figure 4-1), and consequently trigger a management action (Link 2005). Ultimately, in a quantitative model the indicators would trigger management actions in relation to different reference points in a control function, and an audit function would provide an assessment of the effectiveness of the management actions that were triggered

The tables below show a list of candidate indicators to be used to track the critical interactions previously identified. These indicators are divided into two categories: currently available (based on information currently being provided through the SAFE Ecosystem Considerations chapter) and ideal. The identification of ideal indicators can be further used to guide future research efforts in this field.

Much research is still needed to determine critical threshold levels for most of these indicators as well as to determine what the appropriate associated management actions should be.

Indicators of success of single species management

INDICATOR from chapter	Use indicator as is, or modify	Ideal indicator
BSAI groundfish stock status	yes, to extent can for AI stocks	Aleutian specific status for all AI stocks
Crab stock status - BSAI	plot on same index as groundfish	Aleutian specific status for all AI stocks

Indicators of potential shifts in system – anomalies

INDICATOR from chapter	Use indicator as is, or modify	Ideal indicator
NMFS bottom trawl survey – AI (anomalies)	rephrase as need to examine survey for anomalous catches; presence/absence, frequency of occurrence in tows (then perhaps cross-reference with fishery observer data) - perhaps index would look at some specific species, and then also try to look at anomalies too e.g. jellyfish, myctophids, grenadiers	potential good indicator – satellite data on chlorophyll/sea whip indicator of food base, should be able to get on monthly average perhaps? (also in NPRB RFP)
Non-specified species bycatch	combine with trawl survey data to look at key 3 spp for AI	
Seabird breeding chronology	yes	
Seabird productivity	yes	
Population trends	yes – perhaps choose a few representative species (include examples of resident versus migratory)	
NEW hot spots		distribution of feeding aggregations 'hot spots' of mammals and birds - physical models show where fronts are likely to occur, where hotspots likely to be?
NEW seabird survival rates	time series of survival rates for auklets - also index of die-offs	
NEW new fisheries	if new commercial fish is sold from AI subarea, need to take note	
NEW fish disease	-- measure: fish condition factors, levels of mercury and other toxins -- Track occurance of: harmful algal blooms, deformities	

Climate/physical change interactions

Interaction	INDICATOR from chapter	Use indicator as is, or modify	Ideal indicator
Changes in water temperature	AI summer bottom temperature	Temperature generally is useful.	Would prefer year-round indicator. Looking for change outside natural variation (?static, trend?)

Interaction	INDICATOR from chapter	Use indicator as is, or modify	Ideal indicator
	Seabird breeding chronology	yes	
	Combined standardized indices of groundfish recruitment	yes – pull out specifically for AI species	
	Combined standardized indices of groundfish survival	yes – pull out specifically for AI species	
Ocean acidification	**NEW** acidification		-- aragonite and calcite saturation horizon depths -- pH -- some measure of coral health (are they dissolving away?)
Change in nutrient transport though passes and predominant current patterns	**NEW** nutrient transport	use Amukta moorings for index on transport through the pass -- use Buck Stockhausen model for index of transport	data from moorings in Amukta Pass – would be nice if they have nutrient sensors too -- also nice to have more moorings in AI -- monitor transport & direction of Alaskan Stream (moorings & drifters) -- monitor occurrence of eddies (with altimetry) that might deflect or contribute to transport through the passes -- Stockhausen model needs improvement because based on Hermann model; possible area for focus of improvement -- also need better bathymetry – critical for models
	Combined standardized indices of groundfish recruitment **[DUPLICATE]**	yes – pull out specifically for AI species	
	Combined standardized indices of groundfish survival **[DUPLICATE]**	yes – pull out specifically for AI species	
Changing weather patterns	**NEW** change in weather patterns	need annual map showing frequency of storms (perhaps number of days per pixel that have weather considered stormy)	
	Combined standardized indices of groundfish recruitment **[DUPLICATE]**	yes – pull out specifically for AI species	
	Combined standardized indices of groundfish survival **[DUPLICATE]**	yes – pull out specifically for AI species	

Interaction	INDICATOR from chapter	Use indicator as is, or modify	Ideal indicator
Impacts of seismic activity (earthquakes) and volcanism on populations	**NEW** AVO seismic activity tracker		

Predator-prey interactions

Interaction	INDICATOR from chapter	Use indicator as is, or modify	Ideal indicator
fishing affects multiple species due to predation interactions	Trophic level catch EBS and AI	yes capture trophic level of what we're fishing and intensity over time (in SAFE chapter now – continue) Tim Essington - survey and fishery trophic level graphs	
Competing for same prey base affects ecosystem and fisheries	Forage biomass indices from AI bottom trawl survey	no. use forage estimates from diets - need to clarify what we mean by forage – one category is Council's forage fish category; also zooplankton category; also juveniles of commercial fish category (AM, cod, pollock) - seabirds and/or mammals as an indicator of forage biomass	- surveys of forage fish species - need diet data over time (only have snapshot right now) - need to coordinate between seabird, fish, mammal food habits databases - need biomass estimates (or index) for each prey species of commercial species
Population changes of unexploited apex predators affect ecosystem	Alaskan sea lion western stock non-pup counts	yes – but specifically for AI subarea - add index for pup counts in AI - SSL mortality by category (fishing, etc.)	combine into indicator of apex predators (show annual anomalies)
	Seabird breeding chronology **[DUPLICATE]**	yes	
	Seabird productivity **[DUPLICATE]**	yes	
	Population trends **[DUPLICATE]**	yes – perhaps choose a few representative species (include examples of resident versus migratory)	

Endangered species interactions

Interaction	INDICATOR from chapter	Use indicator as is, or modify	Ideal indicator
ESA-listed seabirds population status affects fisheries	Seabird bycatch	no – except for measuring ESA species bycatch and sightings	

Interaction	INDICATOR from chapter	Use indicator as is, or modify	Ideal indicator
ESA-listed marine mammals population status affects fisheries	Alaskan sea lion western stock non-pup counts **[DUPLICATE]**	yes – but specifically for AI subarea - add index for pup counts in AI - SSL mortality by category (fishing, etc.)	combine into indicator of apex predators (show annual anomalies)
	NEW otters: indicator of nearshore predator abundance – use also to determine whether connections between nearshore and shelf **[DUPLICATE]**	use otter surveys in the west to show nearshore predator abundance	

Fishing effect interactions

Interaction	INDICATOR from chapter	Use indicator as is, or modify	Ideal indicator
Total removals from ecosystem	Total groundfish catch AI	Potentially. Use catch relative to biomass, or catch relative to consumption? Use single species catch/biomass by trophic level? Also crab, halibut fisheries	looking for exploitation rate for the ecosystem, maybe catch relative to an ecosystem process more relevant; where is fishery relative to consumption in the ecosystem
	Total biomass EBS/AI	see above	AI specific biomass
	Trophic level catch EBS and AI **[DUPLICATE]**	yes capture trophic level of what we're fishing and intensity over time (in SAFE chapter now – continue) Tim Essington - survey and fishery trophic level graphs	AI specific
	NEW food web diversity indices		potentially important, but need to think about what do you want diversity index to measure, what is meaningful -- habitat diversity might give us the same answer – if we knew about benthic habitats -- acknowledge spatial gradient of diversity generally in AI (FO volume, Loggerwell article p 93)
Impact of one fishery on another through habitat impacts	Groundfish bottom trawling effort in AI	yes	area swept by gear type over particular habitat type
	Longline effort in AI	yes, also add pot	same as trawl

Interaction	INDICATOR from chapter	Use indicator as is, or modify	Ideal indicator
	Living substrate bycatch in EBS/AI groundfish fisheries	Potentially. Combine with frequency of tows with occurrence of living substrate	- impact rates - recovery rates
	living substate biomass indices in the AI bottom trawl survey	Potentially. Combine with frequency of tows with occurrence of living substrate	
	NEW food web diversity indices **[DUPLICATE]**		potentially important, but need to think about what do you want diversity index to measure, what is meaningful -- habitat diversity might give us the same answer – if we knew about benthic habitats -- acknowledge spatial gradient of diversity generally in AI (FO volume, Loggerwell article p 93)
Impact of one fishery on another through bycatch impacts	NMFS bottom trawl survey – AI (anomalies) **[DUPLICATE]**	rephrase as need to examine survey for anomalous catches; presence/absence, frequency of occurrence in tows (then perhaps cross-reference with fishery observer data) - perhaps index would look at some specific species, and then also try to look at anomalies too e.g. jellyfish, myctophids, grenadiers	potential good indicator – satellite data on chlorophyll/sea whip indicator of food base, should be able to get on monthly average perhaps? (also in NPRB RFP)
	Non-specified species bycatch **[DUPLICATE]**	combine with trawl survey data to look at key 3 spp for AI	
Subsistence and commercial fisheries competing	**NEW** commercial fishery: monitor for major changes	volume and value	regional economic model
	NEW recreational: monitor for major changes		work with AMNWR permits to figure out
	NEW subsistence	subsistence halibut permit	regular subsistence survey
Harvest quota privileges impede flexibility	**NEW** limits vs flexibility	description of entry level opportunities	

Socioeconomic activities

Interaction	INDICATOR from chapter	Use indicator as is, or modify	Ideal indicator
Military activity changes affect communities	NEW military activity		facility placement, use of low and medium sonar, other testing
Fishery activities affect the stability of communities	population in AI communities	yes (shows population growth/declines)	also include people on Shemya and Attu - also need to talk about seasonal shifts in populations in these areas
Oil and gas development impacts ecosystem	NEW oil and gas	DEC: history of development related spills	
Vessel traffic on great circle route affects ecosystem	NEW shipping route	port and waterways assessment; possibly information in contingency planning -- find out from DEC history of shipping related spills	count of vessels by type ?and cargo passing through route
Onshore processor at Adak affects community and fisheries	NEW processing jobs: indicator of onshore processing activities and habitat impacts	number of processing jobs	
Research activities impact fisheries	NEW research activities	fish resource permit from ADFG for research in State waters; EFH permits through NMFS	

5 Management Objectives

Decision makers are faced with uncertainty – uncertainty about the structure and dynamics of integrated physical, biological, economic, and sociocultural systems, uncertainty about how the systems will respond to the actions taken, and uncertainty about the merits of alternative outcomes. Decision making under these conditions entails risk to ecological systems, risk to socioeconomic systems and institutions, and risk that implementation of management actions will lead to unanticipated or undesired consequences. Actions taken to minimize one aspect of risk often increase the level of risk in other dimensions. When the consequences of management actions are uncertain, good decision making involves balancing risks and benefits (NRC 2004).

Multiple objectives may be balanced through political processes or formally examined using multiple criteria decision analysis methods (e.g., Keeney and Raiffa, 1976; Saaty, 1990). These methods have been used to address a variety of fishery management issues (e.g., Hilborn and Walters, 1977; Bain, 1987; Walker et al., 1983; Healey, 1984; Mackett, 1985; Merritt and Criddle, 1993). Solutions that emerge from the application of multiple criteria decision analysis often favor compromises that minimize maximum losses or maximize minimum benefits. Multiple criteria decision analyses that incorporate multiple stakeholders with overlapping objectives often select management options that enjoy broad support and limited objection (NRC 2004).

The Council recommends management measures on the basis of the ten MSA National Standards and the policy statement included in each of its FMPs. The Council's policy and objectives should guide the Council in prioritizing and addressing the risks that have been qualitatively identified through the risk assessment process in the previous chapter. This sction summarizes the management policy for the Council's FMPs and also the State of Alaska's management policy for the crab fishery. It also identifies audit indicators that can be used to measure the Council's progress in achieving its management objectives.

5.1 Management policies for groundfish and crab fisheries

BSAI Groundfish FMP

The BSAI Groundfish FMP was revised by the Council in April 2004 following a programmatic review of the BSAI and GOA groundfish fisheries. The new policy captures the Council's ecosystem approach to management, and contains a number of specific objectives that the Council is in the process of fully implementing. The following summarizes the management approach, and the goal statements under which the objectives fall.

> The fishery management goal is to provide sound conservation of the living marine resources; provide socially and economically viable fisheries for the well-being of fishing communities; minimize human-caused threats to protected species; maintain a healthy marine resource habitat; and incorporate ecosystem-based considerations into management decisions.
>
> This management approach recognizes the need to balance many competing uses of marine resources and different social and economic goals for sustainable fishery management, including protection of the long-term health of the resource and the optimization of yield. This policy will use and improve upon the Council's existing open and transparent process of public involvement in decision-making.

- Prevent Overfishing
- Promote Sustainable Fisheries and Communities
- Preserve Food Web
- Manage Incidental Catch and Reduce Bycatch and Waste
- Avoid Impacts to Seabirds and Marine Mammals
- Reduce and Avoid Impacts to Habitat
- Promote Equitable and Efficient Use of Fishery Resources
- Increase Alaska Native Consultation
- Improve Data Quality, Monitoring and Enforcement

BSAI King and Tanner Crab FMP

The BSAI King and Tanner Crab FMP includes a management goal and management objectives. The following is a summary of the FMP language:

> The management goal is to maximize the overall long-term benefit to the nation of BS/AI stocks of king and Tanner crabs by coordinated Federal and State management, consistent with responsible stewardship for conservation of the crab resources and their habitats.

- Ensure the long-term reproductive viability of king and Tanner crab populations.
- Maximize economic and social benefits to the nation over time.
- Minimize gear conflict among fisheries.
- Preserve the quality and extent of suitable habitat.
- Provide public access to the regulatory process for vessel safety considerations.
- Ensure that access to the regulatory process and opportunity for redress are available to all interested parties.
- Provide fisheries research, data collection, and analysis to ensure a sound information base for management decisions.

State of Alaska King and Tanner Crab Management Policy

In addition to the National Standards specified in the Magnuson-Stevens Fishery Management and Conservation Act, Aleutian Islands king and Tanner crab fisheries managed by the state of Alaska are managed in accordance with the Alaska Board of Fisheries Policy on King and Tanner Crab Resource Management (#90-04-FB, March 23, 1990).

This policy is summarized as follows:

> It is the goal of the Alaska Board of Fisheries and Alaska Department of Fish and Game to manage king and Tanner crab stocks in a manner that will protect, maintain, improve, and extend these resources for the greatest overall benefit to Alaska and the nation. Achievement of these goals is necessarily constrained by the requirements to minimize: (1) risks of irreversible adverse effects on reproducti9ve potential; (2) harvest during biologically sensitive periods of the life cycle; (3) adverse interactions with other fish and shellfish stocks and fisheries.
>
> Management of these fisheries for the purpose of achieving this goal will result in a variety of benefits which include, but are not limited to the following:
>
> (1) maintaining healthy stocks of king and Tanner crabs of sufficient abundance to insure their continued reproductive viability and maintenance of their role in the ecosystem;

(2) providing a sustained and reliable supply of high quality product to the industry and consumers which will provide sustainable and stable employment in all sectors of the economy relating to these fisheries; and
(3) providing opportunities for subsistence and personal use fisheries on these stocks.

The Alaska Board of Fisheries also recognizes the benefits of managing for the highest socio-economic benefit when such action does not conflict with biological constraints.

The state of Alaska does not take the National Standards into consideration when managing parallel or state-waters groundfish fisheries, however the Alaska Board of Fisheries has adopted a set of guiding principles for groundfish fishery management in state-waters. These guiding principles were adopted in 1997 (5 AAC 28.089) and are as follows:

> With state groundfish management expanding to cover the groundfish resources in the waters of Alaska, the Board of Fisheries (board) will be receiving regulatory proposals for these fisheries. The board will, to the extent practicable, consider the following guiding principles when taking actions associated with the adoption, amendment, or repeal of regulations regarding groundfish fisheries:
>
> 1. conservation of the groundfish resource to ensure sustained yield, which requires that the allowable catch in any fishery be based upon the biological abundance of the stock;
> 2. minimization of bycatch of other associated fish and shellfish and prevention of the localized depletion of stocks;
> 3. protection of the habitat and other associated fish and shellfish species from non-sustainable fishing practices;
> 4. maintenance of slower harvest rates by methods and means and time and area restrictions to ensure the adequate reporting and analysis necessary for management of the fishery;
> 5. extension of the length of fishing seasons by methods and means and time and area restrictions to provide for the maximum benefit to the state and to regions and local areas of the state;
> 6. harvest of the resource in a manner that emphasizes the quality and value of the fishery product;
> 7. use of the best available information presented to the board; and
> 8. cooperation with the North Pacific Fisheries Management Council (NPFMC) and other federal agencies associated with groundfish fisheries.

5.2 Meeting and monitoring management objectives

The tables below identify the indicators that may be used to quantify how well management objectives are being met and where there is conflict between different objectives across FMPs as well as in the broader ecosystem context. The eventual goal is to link the indicators to associated reference points or thresholds, however more research is necessary before this can be fully developed.

Indicators of success of single species management

- AI groundfish stock status relative to overfishing and overfished
- AI Crab stock status relative to overfishing and overfished

[PLACEHOLDER: This section would serve to help the Council cycle between indicators and interactions and assess whether we successfully managing what we think we are managing, and thus meeting our ecosystem management objectives. To include the audit function indicators identified above, and others. This section would also need to discuss conflicts between ecosystem objectives and individual FMP objectives identified above. These should become clear through the interactions identified in chapter 4.]

6 Implications for Human Use of Ecosystem

[PLACEHOLDER]

- identify areas of uncertainty, areas where management strategy evaluation would be helpful
- take indicators and provide method for Council to interpret them (e.g., when 5 of these show warning sign, take some action)
- map indicator table to where in process action should be taken (Plan Team level, single species issue, SSC issue, policy/Council issue)
- one recommendation: need assessment for each of the prey species of the main commercial species

7 Priorities

[PLACEHOLDER]

- identify specific areas for future management analyses/attention
- identify research needs
- categorize by required time frame, cost, and importance
- discuss follow-on issues for future versions of FEP

8 Recommendations for Council

[PLACEHOLDER]

9 What is the 'value added' of this FEP process?

[PLACEHOLDER]

- need to look at the recommendations in other FEPs, and show which we also do (e.g., Chesapeake Bay recommends figuring out what eats what

10 References and Preparers

10.1 References

[ADF&G] Alaska Department of Fish and Game. In prep. Annual Management Report for the Commercial and Subsistence Shellfish Fisheries of the Aleutian Islands, Bering Sea and the Westward Region's *Shellfish* Observer Program, 2005. Alaska Department of Fish and Game, Fishery Management Report No. YY-XX, *Anchorage*.

[APAWSA] Aleutians Ports and Waterways Safety Assessment Workshop. 2006. Workshop summary posted at URL: http://www.dec.state.ak.us/SPAR/perp/ai_risk/aleutian_islands_finalrpt.pdf. Accessed December 26, 2006.

Angliss, R.P. and K.L Lodge. 2004. Alaska Marine Mammal Stock Assessments. NOAA Technichal Memorandum NMFS-AFSC-144. 230 p.

[Anon.] Anonymous. 2007. A Cold Coming We Had of it: Shipwrecks in the Aleutians. *The Economist.* January 18, 2007. Barnhart, J.P. 2006. Annual management report for the commercial weathervane scallop fisheries in Alaska's westward region, 2003/04. Alaska Department of Fish and Game, Fishery Management Report No. 06-11, Anchorage.

Araujo, M. A. 2002. Biodiversity hot spots and zones of ecological transition. Conservation Biology 16:1662-1663.

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday, in review. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA Tech Memo, 277 pp.

Bakkala, R.G. 1981. History of the Bering Sea groundfish fishery. *In*: Reducing the incidental catch of prohibited species by foreign groundfish fisheries in the Bering Sea. NPFMC. Council Document No. 13, Anchorage, AK p.49-56.

Barbeaux, S. Ianelli, J. and E. Brown. 2004. Stock assessment of the Aleutian Islands region pollock. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/ Aleutian Islands regions. North Pacific Fishery Management Council, Anchorage, Alaska. November 2004.

Barbeaux, S. Ianelli, J. and E. Brown. 2005. Stock assessment of Aleutian Islands region pollock for 2005. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/ Aleutian Islands regions. North Pacific Fishery Management Council, Anchorage, Alaska. November 2005.

Batten, S. D., K. David Hyrenbach, W. J. Sydeman, K. H. Morgan, M. F. Henry, P. P. Y. Yen, and D. W. Welch (2006), Characterising meso-marine ecosystems of the North Pacific, *Deep Sea Res. II*, *53*, 270-290.

Bergsland, K. and M.L. Dirks. 1990. Unangam Ungiikangin kauyx Tunusangin/Unangum Uniikangis ama Tunuzangis: Aleut Tales and Narratives. Alaska Native Language Center, University of Alaska Fairbanks. http://eric.ed.gov/ERICWebPortal/Home.portal?_nfpb=true&_pageLabel=RecordDetails&ERICExtSearch_SearchValue_0=ED395464&ERICExtSearch_SearchType_0=eric_accno&objectId=0900000b80142e73

Berkh, V. 1823. The Chronological History of the Discovery of the Aleutian Islands or the Exploits of the Russian Merchants with Supplement of Historical Data on Fur Trade. San Petersburg, Bergsland, Knut and Moses L. Dirks, (eds.). 1990. *Unangam Ungiikangin kayux Tunusangin: Unangam Uniikangis ama Tunuzangis: Aleut Tales and Narratives*. Collected 1909-1910 by Waldemar Jochelson. Alaska Native Language Center. University of Alaska, Farbanks.

Black, L. 1981. Volcanism as a factor in human ecology: the Aleutian Case. Ethnohistory 28:313-340.

Black, Lydia. 1983. "Some problems in interpretation of Aleut prehistory," *Arctic Anthropology* 20(1): 49-69.Bowers, F.R., W. Donaldson and D. Pengilly. 2002. Analysis of the January-February and November 2001 Petrel Bank red king crab commissioner's-permit surveys. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K02-11

Black, Lydia T. 1984. *Atka: An Ethnohistory of the Western Aleutians.* Ontario: Limestone Press.

Black, Lydia. 1999. "Russian America: A place to start," *Alaska Geographic* 26(4):4-16.

Black, Lydia T.; McGowan, Sarah; Jacka, Jerry; Taksami, Natalia; Wright, Miranda. 1999. *The History and Ethnohistory of the Aleutians East Borough.* Richard Pierce, Katherine Arndt, and Sarah McGowan (eds.). Fairbanks: The Limestone Press.

Byrd, G.V. Renner, H.M. and M. Renner. 2005. Distribution patterns and population trends of breeding seabirds in the Aleutian Islands, Fisheries Oceanography 14 (Suppl. 1):139-159.

Causey, D., D.G. Corbett, C. Lefvre, D.L. West, A.B. Savinetsky, N.K. Kiseleva, and B.f. Khassanov. 2005. The paleoenvironment of humans and marine birds of the Aleutian Islands: three millennia of change. Fish. Oceanogr. 14 (Suppl. 1): 259-276.

Coon, Cathy. 2006. Hook and Line (Longline) and groundfish bottom trawl fishing effort in the Gulf of Alaska, Bering, Sea and Aleutian Islands. *In* Ecosystem Considerations for 2007. North Pacific Fishery Management Council. Anchorage, AK. November 2006.

Coyle, K. O. (2005), Zooplankton distribution, abundance and biomass relative to water masses in eastern and central Aleutian Island passes,

Fish. Oceanogr., 14, 77-92.Crawford, W. R., J. Y. Cherniawsky, and M. G. G. Foreman (2000), Multi-year meanders and eddies in the Alaskan Stream as observed by TOPEX/Poseidon altimeter, *Geophys. Res. Lett*., **27**, 1025-1028.

Croll, D.A., Maron, J.L., Estes, J.A., Danner, E.M., G.V. Byrd. 2005. Introduced predators transform islands from grasslands to tundra. Science 307:1959-1961.

Duggins, D.O., Simenstad, C.A. and J.A. Estes. 1989. Magnification of secondary production by kelp detritus in coastal marine ecosystems. Science 245:170-173.

Estes, J.A. and Duggins, D.O. 1995. Sea otters and kelp forests in Alaska: Generality and variation in a community ecological paradigm. Ecological Monographs 65:75-100.

Failor-Rounds, B. and K. Milani. In press. Bering Sea-Aleutian Islands Area state-waters groundfish fisheries and groundfish harvest from parallel seasons in 2005. Alaska Department of Fish and Game, Fishery Management Report No. 07-XX, Anchorage.

[FAO] Food and Agriculture Organization. 2003. Fisheries Management: 2. The ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2. Food and Agriculture Organization, Rome.

Favorite, F., Dodimead, A.J., Nasu, K., 1976. Oceanography of the subarctic Pacific region, 1960-71. International North Pacific Fisheries Commission, Bulletin 33, Vancouver, Canada, p. 187.

Garcia S.M., Zerbi A., Aliaume C., Do Chi T. and Lasserre G. 2003. The ecosystem approach to fisheries: Issues, terminology, principles, institutional foundations, implementation and outlook. FAO Fisheries Technical Paper 443. Food and Agriculture Organization, Rome.

Gibson, J.R. 1996. Russian dependence on the Natives of Alaska. Pp 21-42 in Haycox, SW. and M.C. Mangusso eds. An Alaska Anthology: Interpreting the Past. Seattle: University of Washington Press, 447 pp.

Gish, R.K. in press. The 2006 Petrel Bank red king crab survey. Alaska Department of Fish and Game, Fishery Management Report No. 07-XX, Anchorage.

Granath, K. 2003. Analysis of the November 2002 Adak, Atka and Amlia Islands red king crab commissioner's permit survey. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K03-33.

Hampton, M.A. (1983) Geology of the Kodiak Shelf, Alaska: environmental considerations for resource development. Cont. Shelf Res., 1, 253-281.

Hanselman, D.H., C.R. Lunsford, J.F. Fujioka, and C.J. Rodgveller. 2006. Alaska Sablefish ssessment for 2007. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. NPFMC, Anchorage, AK.

Hare, S.R., Mantua, N.J., 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47 (2-4), 103-145.

Haycox, S. 2002. Alaska, an American Colony. Seattle: University of Washington Press, 372 pp.

Heifetz, J., B. L. Wing, R. P. Stone, P. W. Malecha, and D. L. Courtney (2005), Corals of the Aleutian Islands, Fish. Oceanogr., 14, 131-138.

Holt, R.D. 2004. Implications of System Openness for local community structure and ecosystem function. *In:* Food Webs at the Landscape Level. G.A. Polis, M.E. Power and G.R. Huxel (eds.). The University of Chicago Press, p. 96-114.

Hunt, G.L. Jr., and P.J. Stabeno. 2005. Oceanography and ecology of the Aleutian Archipelago: spatial and temporal variation. Fisheries Oceanography 14 (Suppl. 1):292-306.

Hunt, G.L., Jr., Russell, R.W., Coyle, K.O., Weingartner, T., 1998. Comparative foraging ecology of planktivorous auklets in relation to ocean physics and prey availability. Marine Ecology-Progress Series 167, 241-259.

Huxel, G.R., Polis, G.A. and Holt, R.D. 2004. At the frontier of the integration of food web ecology and landscape ecology. *In:* Food Webs at the Landscape Level. G.A. Polis, M.E. Power and G.R. Huxel (eds.). The University of Chicago Press, p. 434-451

Ianelli, J., T. Wilderbuer, and D. Nichol. 2006. Assessment of Greenland Turbot in the Eastern Bering Sea and Aleutian Islands. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. NPFMC, Anchorage, AK.

[INPFC] International North Pacific Fisheries Council.1979. Historical Catch Statistics for Salmon of the North Pacific Ocean. International North Pacific Fisheries Council No 39. Vancouver, Canada.

Isakson, J.S., Simenstad, C.A., and R.L. Burgner, 1971. Fish communities and food chains in the Amchitka Area. BioScience 21:666-670.

[IWC] International Whaling Commission. 2006. International Whaling Commission website. http://www.iwcoffice.org/.

Knecht, R.A., and R.S. David. 2001. “A prehistoric sequence for the Eastern Aleutians” *University of Oregon Anthropological Papers* 58: 269-288.

Kolhoff, D.W. 2002. *Amchitka and the Bomb.* University of Washington Press, Seattle.

Kohlhoff, D. 1995. *When The Wind Was a River: Aleut Evacuation in World War II.* Seattle: University of Washington Press.

Ladd, C., Hunt, G.L., Jr., Mordy, C.W., Salo, S.A., Stabeno, P.J., 2005. Marine environment of the eastern and central Aleutian Islands. Fisheries Oceanography 14 (Suppl. 1), 22-38.

Lantis, M. 1984. Aleut. pp. 161-184 in *Handbook of North American Indians, Volume 5: Arctic,* David Damas (volume editor). Washington, DC: Smithsonian Institution.

Laughlin, W.S. 1963. The earliest Aleuts. *Anthropological Papers of the University of Alaska* 10(2):73-91.

Laughlin W.S. 1975. Aleuts: ecosystem, Holocene history, and Siberian origin. Science 189:507-515.

Laughlin, William S. 1980. *Aleuts: Survivors of the Bering Land Bridge.* New York: Holt, Rinehart, and Winston.

Levin, S.A. 1992. The problem of pattern and scale in ecology. Ecology, 73:1943-1967.

Levin, L.A., Boesch, D.L. Covich, A., Dahm, C. Erséus,C., Ewel, K.C., Kneib, R.T., Moldenke, A., Palmer,M.A., Snelgrove, P., Strayer, D., and Weslawski, J.M. 2001. The function of marine criticat transition zones and the importance of sediment biodiversity. Ecosystems 4: 430-451.

Logerwell, E.A., Aydin, K., Barbeaux, S., Brown, E, Conners, M.E., Lowe, S., Orr, J.W., Ortiz, I., Reuter, R. and P. Spencer. 2005. Geographic patterns in demersal ichthyofauna of the Aleutian Islands. Fisheries Oceanography 14 (Suppl 1):93-112.

Lowe, M. 2002. Socioecological Change in the Aleutian Islands. Unpublished progress report to the National Marine Fisheries Service. On file at the Alaska Fisheries Science Center.

Lowe, S., J. Ianelli, M. Wilkins, K. Aydin, R. Lauth, and I. Spies. 2006. Stock Assessment of Aleutian Islands Atka Mackerel. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Bering Sea/Aleutian Islands Regions. NPFMC, Anchorage, AK.

Malcolm, Patty, 2005. *Involuntary Resettlement: Lessons from the Aleut Relocation and Internment.* Master’s Thesis. Western Washington University, Bellingham.

McCartney, Allen P. 1984. “Prehistory of the Aleutian Region,” pp. 119-135 in *Handbook of North American Indians, Volume 5: Arctic,* David Damas (volume editor). Washington, DC: Smithsonian Institution.

Merrel, T.R. 1971. Marine fishery resources in the vicinity of Amchitka Islands Alaska. BioScience 21:610-614.

Mordy, C.W., Stabeno, P.J., Ladd, C., Zeeman, S., Wisegarver, D.P., Hunt Jr., G.L., 2005. Nutrients and primary production along the eastern Aleutian Island Archipelago. Fisheries Oceanography 14 (Suppl. 1), 55-76.

[NOAA] National Oceanic and Atmospheric Administration. 1999. Ecosystem-based Fishery Management: A Report to Congress by the Ecosystem Principles Advisory Panel. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. April 1999.

NOAA. 2004. New Priorities for the 21st Century – NOAA's Strategic Plan Updated for FY 2005-2010.

NOAA. 2006. Draft Steller Sea Lion Recovery Plan: Eastern and Western Distinct Population Segments (*Eumetopias jubatus*). First Revision; Original Approval: December 1992. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources. May 2006. 294 pp.

[NPFMC] North Pacific Fishery Management Council. 2005. Stock Assessment and Fishery Evaluation Report for the King and Crab Fisheries of the Bering Sea and Aleutian Islands Region 2005 Crab SAFE. NPFMC, Anchorage, Alaska. Downloaded 07/2006 from http://www.fakr.noaa.gov/npfmc/membership/plan_teams/CPT/CrabSafe05.pdf

[NRC] National Research Council. 1983. Risk Assessment in the Federal Government: Managing the Process. National Academy Press, Washington, DC, 191 p.

NRC 2004. Non-native Oysters in the Chesapeake Bay. National Academy Press. Washington DC. 325 p.

Obeso, Vera. 1994. Atka changing, striving for economic stability. *Dutch Harbor Fisherman*, May 9, 1994.

Okkonen, S. R. (1996), The influence of an Alaskan Stream eddy on flow through Amchitka Pass, *J. Geophys. Res. - Oceans*, **101**, 8839-8851.

Orr, J. C., V. J. Fabry, O. Aumont, L. Bopp, S. C. Doney, R. A. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, F. Joos, R. M. Key, K. Lindsay, E. Maier-Reimer, R. Matear, P. Monfray, A. Mouchet, R. G. Najjar, G.-K. Plattner, K. B. Rodgers, C. L. Sabine, J. L. Sarmiento, R. Schlitzer, R. D. Slater, I. J. Totterdell, M.-F. Weirig, Y. Yamanaka, and A. Yool (2005), Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms, *Nature*, **437**, 681-686.

Ortiz, I. 2007. Ecosystem Dynamics of the Aleutian Islands. Ph.D. Thesis. University of Washington, Seattle.

Otto, R.S. 1981. Eastern Bering Sea Crab Fisheries. *In*: D.W. Hood and J.A. Calder (eds.) The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. 2. Office of Marine Pollution Assessment. Juneau, Alaska pp. 1037-1068.

Package, C. and Sepez, J. 2007. "Alaska Communities Most Involved in Commercial Fisheries." Poster for Society for Applied Anthropology Meetings, March 2007, Tampa, FL. Available as pdf file from Alaska Fisheries Science Center.

Reed, R.K., Stabeno, P.J., 1999. The Aleutian North Slope Current. In: Loughlin, T.R., Ohtani, K. (Eds.), Dynamics of the Bering Sea. University of Alaska Sea Grant, Fairbanks, pp. 177-191.

Reuter, R.F. and P.D. Spencer. 2006. 2006 BSAI Other Rockfish. In: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. NPFMC, Anchorage, AK.

Rodionov, S.N., Overland, J.E., Bond, N.A., 2005. Spatial and temporal variability of the Aleutian climate. Fisheries Oceanography 14 (s1), 3-21.

Schumacher, J.D. and G.H. Kruse. 2005. Toward sustainable ecosysytem services from the Aleutian Archipelago. Fisheries Oceanography 14 (Suppl 1):277-291.

Sepez, J. A., B. Tilt, C. Package, H. Lazarus, and I. Vaccaro. 2005. *Community Profiles for North Pacific Fisheries - Alaska.* U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-160, 552 p.

Sepez, J., C. Package, P. Malcolm and A. Poole. In press. Unalaska, Alaska: Memory and Denial in the Globalization of the Aleutian Landscape. *Polar Geography* Volume/issue tba.

Shaul, A. R., and J. J. Dinnocenzo. 2004. Aleutian islands and Atka-Amlia Islands Management Areas Annual report, 2003. Alaska Department of Fish and Game Division of Commercial Fisheries, Regional Information Report 404-37, Kodiak.

Shields, E. 2001. Salt of the Sea: the Pacific Coast Cod Fishery and the Last days of Sail. Lopez Island, WA. Pacific Heritage Press. 238 p.

Sinclair, E.H., Moore, S.E., Friday, N.A., Zeppelin, T.K., and Waite, J.M. 2005. Do patterns of Steller sea lion (*Eumetopias jubatus*) diet, population trend and cetacean occurrence reflect oceanographic domains from the Alaska Peninsula to the central Aleutian Islands? Fisherie Oceanography, 14 Suppl. 1:223-242.

Simenstad, C.A., Estes, J.A. and K.W. Kenyon. 1978. Aleuts, sea otters, and alternate stable-states communities. Science 200:403-411.

Spencer, P. and J.N. Ianelli. 2005. Pacific Ocean Perch. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Management Area. North Pacific Fishery Management Council. November 2005.

Spencer P.D., and J.N. Ianelli. 2006. Northern Rockfish. In: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. NPFMC, Anchorage, AK.

Spencer P.D., and R.F. Reuter. 2006. Shortraker and Rougheye Rockfish. In: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. NPFMC, Anchorage, AK.

Springer, A.M, Piatt, J.F., Van Vliet, G. 1996. Seabirds as proxies of marine habitats and food webs in the western Aleutian Arc.Fish. Oceanogr. 5:45-55.

Stabeno, P.J., Schumacher, J.D., Ohtani, K., 1999. The physical oceanography of the Bering Sea. In: Loughlin, T.R., Ohtani, K. (Eds.), Dynamics of the Bering Sea. UNIV ALASKA SEA GRANT, Fairbanks, pp. 1-28.

Stabeno, P.J., Kachel, D.G., Kachel, N.B., Sullivan, M.E., 2005. Observations from moorings in the Aleutian Passes: temperature, salinity and transport. Fisheries Oceanography 14 (Suppl. 1), 39-54.

Stephensen, S.W. and Irons, D.B. 2003. Comparison of colonial breeding seabirds in the eastern Bering Sea and Gulf f Alaska. Marine Ornithology 31:167-173.

Straley et al. 2002.

Sverdrup, H.U., 1953. On conditions for the vernal blooming of phytoplankton. J. Conseil Exp. Mer 18, 287-295.

The Royal Society. 2005. Ocean acidification due to increasing atmospheric carbon dioxide. Policy document 12/05. The Royal Society, Science Policy Section. London, UK. June 2005.

Thompson, G.G. and M.W. Dorn. 2006. Assessment of the pacific cod stock in the eastern Bering Sea and the Aleutian Islands Area. In: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. NPFMC, Anchorage, AK.

Tønnessen, J.N. and A.O. Johnsen. 1982. The History of Modern Whaling, University of California Press. Berkely, USA.

Tschersich, P. 2006. Aleutian Islands and Atka-Amlia Islands Management Areas salmon management report, 2005. Alaska Department of Fish and Game, Fishery Management Report No. 06-04, Anchorage

Veltre, Douglas, and Mary Veltre. 1980. *Resource Utilization in Unalaska, Aleutian Islands, Alaska.* Technical Paper 58. Alaska Department of Fish and Game.

Wainright, S.C., J.C. Haney, C. Kerr, A.N. Golovkin, A.N. and M.V. Flint, 1998. Utilization of nitrogen derived from seabird guano by terrestrial and marine plants at St. Paul, Pribilof Islands, Bering Sea, Alaska. Marine Biology 131:63-71

Watson, L.J. in press. The 2006 triennial Aleutian Islands golden king crab survey. Alaska Department of Fish and Game, Fishery Management Report No. 07-XX, Anchorage.

West, Dixie, Michael Crawford, Arkady B. Savinetsky. In press. Genetics, Prehistory and the Colonization of the Aleutians. In *Holocene Environmental Change: Lessons from Small Oceanic Islands.* Edinburgh: Transactions of the Royal Society of Edinburgh.

Witman, J.D., Ellis, J.C. and Anderson, W.B. 2004. The influence of physical processes, organisms, and permeability on cross-ecosystem fluxes. *In:* Food Webs at the Landscape Level. G.A. Polis, M.E. Power and G.R. Huxel (eds.). The University of Chicago Press, p. 335-358

10.2 Acronyms and Abbreviations

[PLACEHOLDER]

10.3 Preparers

The Council created an Aleutian Islands Ecosystem Team, who wrote the FEP. Members of the team are:

Kerim Aydin, National Marine Fisheries Service, Alaska Fisheries Science Center
Steve Barbeaux, National Marine Fisheries Service, Alaska Fisheries Science Center
Forrest Bowers, Alaska Department of Fish and Game
Vernon Byrd, United States Fish and Wildlife Service, Alaska Region
Diana Evans, North Pacific Fishery Management Council
Sarah Gaichas, National Marine Fisheries Service, Alaska Fisheries Science Center
Carol Ladd, National Oceanic & Atmospheric Administration, Pacific Marine Environmental Laboratory
Sandra Lowe, National Marine Fisheries Service, Alaska Fisheries Science Center
John Olson, National Marine Fisheries Service, Alaska Regional Office
Jennifer Sepez, National Marine Fisheries Service, Alaska Fisheries Science Center
Paul Spencer, National Marine Fisheries Service, Alaska Fisheries Science Center
Francis Wiese, North Pacific Research Board

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Amanda Poole, University of Washington
Terry Hiatt, AFSC
Michael Dalton, AFSC
Dave Fraser, Adak Fisheries

Appendix A History of Natural Resource Exploitation

History of Exploitation

The Aleutian archipelago has been occupied by humans for nearly 9,000 years (Laughlin 1975). Prior to the arrival of the Russians, the Aleut population numbered about 16,000 inhabitants with 6,000 in the western and central islands and the rest distributed from eastern islands to Port Moeller. Each group of islands was occupied by independent polities with varying degrees of contact with each other as well as the mainland. Their culture was based on marine resources, with particular reliance on marine mammals such as sea otters and fur seals. Common uses, besides food, included fur for clothing, covers and bedding (e.g. sea lion and hair seal skins were used to sit on, sleep in, or cover objects with; guts were used for waterproof garments and utensils). Fox furs were also utilized in the eastern islands, and skins of various land and seabirds supplemented the Aleuts' needs. Down and feathers from seabirds were used for clothing and decoration, bones for needles and nose sticks, beaks for jinglets and rattles, wings for fetishistic purposes. Nets and seines were known to the Aleuts, yet they were not common or universal (Hrdlicka, 1945, Ransom 1946). Living in the islands with little additional resources other than those available locally, the Aleuts kept close track of abundance, distribution and even behavioral changes of animals in their surroundings. Although Aleut populations were not evenly distributed throughout the islands, their population density with respect to the marine exploitation area was uniform over the three regions (eastern, central and western) (Laughlin 1975). Close observation of spatial changes in the amount of resources and their even exploitation was lost after the Aleuts lost control over the marine resources. The level of resource use switched from subsistence requirements to maximization of short term profits –regardless of local changes in abundance or distribution of the resources. This profits-oriented ethic remained mostly unaltered for the next 250 years.

Russian colonial exploitation, 1741-1867

The most significant feature of the Russian colonial period of Alaskan history from an ecological and economic standpoint is the fur trade, a series of exploitative waves which removed sea otters, fur seals, and other mammals from the Gulf of Alaska, Aleutian Islands, and Eastern Bering Sea ecosystems in unprecedented numbers (Figure 1.2-2), while generating wealth for Russian, British, and American corporations, and fashion for European and Chinese markets. The wealth was substantial: "By 1867, the year of the Alaska purchase, Russia had exported Alaskan furs worth over six times what she accepted for the vast territory herself (Matthiessen 1987)." But associated with the Russian fur trade are equally significant social impacts; the displacement and forced servitude of many Aleuts and Pacific Eskimos of the Gulf of Alaska, whose hunting skills and free labor, gained by violent coercion, became essential to the Russian traders' business (Gibson 1996). Ecological impacts were not measured at the time, but we do have information on the separate population impacts to sea otters and fur seals, which are detailed below, and viewing the entire exploitation history reconstructed here suggests hypothesized ecological impacts to test with modeling (chapter 2).

Vitus Bering is posthumously credited with "discovering" the fur resources of the Aleutian Islands for Russia after his officially mandated exploratory expedition returned to Siberia in 1742 without him, but with the recorded observations of the naturalist Georg Steller, and with 900 sea otter pelts (Wickersham 1927, Lensink 1960). Soon Russian vessels were sailing westward along the Aleutian chain, more intent on "soft gold" exploitation than exploration: "Once at sea, the Russians navigated more on the principle that the Aleutian Islands were close together and hard to miss, [rather] than on mathematical calculations (Mohr 1977)." The fur traders operated independently of the Russian government; this invasion was purely economic and funded by private investors, and therefore subject to no regulation (Haycox 2002). By 1760, sea otters were already depleted in the western Aleutian Islands, driving the fur traders further east to the Alaska Peninsula, Kodiak, Prince William Sound and Southeast Alaska (Wickersham 1927, Mohr 1977). Kodiak was where Gregori Shelekhov established the first permanent Russian settlement in 1783, and soon after in 1784 the first Russian salmon fishery was established at the Karluk River in Kodiak to supply local needs (Mohr 1977, Browning 1980). By this time, the native Aleut population had also been reduced by violence and disease to the point where Russian traders faced a shortage of hunting expertise and began conscripting Koniag sea otter hunters as well (Gibson 1996).

By 1775, sea otters in the Aleutian Islands had declined so much that the Russians developed renewed interest in fur seals, which had less valuable pelts than sea otters because guard hairs had to be laboriously plucked (Sulzer 1912, Mohr 1977), but these animals had been taken only occasionally in the water. The Russians again depended on Aleut ecological expertise to surmise that fur seals must breed north of the Aleutian Islands in the Bering Sea, based on reported migration patterns through Aleutian passes in the spring and fall. Active searches ensued to the north, where in 1786 Gerasim (or Gavriil, historians disagree on his first name) Pribilof found the islands used by the fur seals as their major rookeries (Sulzer 1912). He left a small party on the islands for a year, who managed to nearly extirpate the local sea otters as well as collecting 40,000 seal skins and 15,000 lbs of walrus tusks before Pribilof returned in 1787 (Sulzer 1912). That year, the Pribilof Islands' sea otter population was hunted to extinction (Matthiessen 1987). Aleuts were forcibly relocated to the formerly uninhabited and newly named Pribilof Islands to conduct the seal hunt (Gibson 1996), and their descendants remain there to this day. By 1799, the chaotic free exploitation by nearly 40 different Russian investment companies (and associated inefficiencies) were ended when the Russian government granted a monopoly to the Russian American Company to conduct the fur trade, by then predominantly in fur seals (Haycox 2002). While the fur seal hunts took place on rookeries in the Eastern Bering Sea, fur seals forage in the Gulf of Alaska and throughout the

Pacific during the winter (Reeves et al 1992); therefore the intense exploitation of this apex predator on its breeding grounds between 1786 and 1867 (and later at sea in the Gulf of Alaska itself) represents a potentially important historical ecosystem impact throughout the North Pacific.

The Russians apparently never intended to occupy Alaska to establish a self-sufficient colony for the homeland, or even to learn to hunt sea mammals for themselves; “their chief objective was the exploitation of the available resources, mostly furs, on the least costly terms possible. Reflective of their concept of colonization in Alaska, the largest number of Russians ever in America at one time was a mere 823 (Haycox 2002).” Russian colonialism in American was actually an emergent property of exploitation by individual economic interests, as opposed to a government-sponsored and centrally controlled occupation (Haycox 2002). The exploitation benefited the government, however; between 1745 and 1823, a minimum of 123 boats came back to Siberia from North Pacific expeditions with 2.8 million declared sea otter, fox, and fur seal pelts (Mohr 1977). Given the economic incentives not to declare every pelt (ie, taxes), we may assume this is a minimal Russian take. But the Russians were not alone in exploiting marine mammals during the Russian colonial period; the British and American fur trade was well established in the Gulf of Alaska by 1792, peaking by 1812 (Mohr 1977). The period 1785-1825 had 300 fur trading ships recorded on the Northwest coast. Relationships between the fur trading colonial powers were altered over time by both external and internal events. In the competition for the North Pacific-China fur trade, Americans eventually dominated because the British were occupied with the Napoleanic wars in Europe. Russian and American traders initially cooperated; for example, Russian-enslaved Aleut hunters were provided to American vessels for the mutual profit of Americans and Russians, but eventually the Americans provided furs direct to China by sea, undercutting Russian prices (Mohr 1977). The Americans also undermined the Russian “relationship” with the Tlingits of Southeast Alaska by providing the essentials of “liquor, arms, and munitions” in trade for pelts so that again Russians had to pay natives more (Mohr 1977, Gibson 1996). Eventually, with fur stocks dwindling and profits eroding, the colonial nations switched to ride a new wave of exploitation: whaling.

In 1835 a whaler observed “abundant sperm and right whales” off Kodiak in the Gulf of Alaska, during the first Yankee exploration of the North Pacific (Morgan 1978). Whalers from the North Atlantic were exploring the Pacific whale stocks after nearly extirpating more local whales (Ellis 1991), largely uninterested in the fact that the Russians were already there. In contrast to the whalers in search of oil and baleen to supply European lighting and fashion markets, the Russians on Kodiak were just trying to eat, so they hired natives to kill a few whales for them in the early 1800s, and also had established a fishing industry of sorts to supply local needs. Right whales (so called because they were large, docile, and floated when killed, making them the “right” whale to hunt) from the Gulf of Alaska were the main target of first pelagic whaling wave in the Gulf of Alaska, and were heavily exploited from 1835 until 1848 (Scarff 2001, Shelden et al 2005). Just as the right whales were obviously severely depleted, bowhead whales were “discovered” in the Bering Sea (Bockstoce 1978). The next gold (or oil) rush was on, and the bowheads were pursued all the way up to their final summer refuge, feeding grounds in the Mackenzie River delta of the Beaufort Sea. During this hunt, the population of Pacific walrus was reduced to a quarter its original size; idle whalers hunted the walrus for ivory while they waited for ice to break up or bowheads to migrate by (Haycox 2002b). Bowhead whales were saved from full extinction by a combination of economic and social forces. First, there was a directed Civil war attack on the Yankee whaling fleet in which the Confederate vessel Shenandoah cruised 58 thousand miles between 1864-65 to destroy 29 whaling vessels and capture 38 more (Mohr 1977). Then, there was the discovery of petroleum oil and associated invention of plastics—diminishing the need for whale oil to light the lamps of Europe and America—and a final bad Arctic ice year (after many between 1871 and 1897) that crushed a significant portion of the active whaling vessels. It finally cost too much to catch the remaining bowhead whales for the companies to make any money on the products (Bockstoce 1978). For the Russian American Co., whaling never really got off the ground; they finally got 6 ships out in 1851 but the whaling was not profitable enough, and then the Crimean war with France and England removed financial backing entirely by 1854 (Mohr 1977). Eventually, declining profits in the fur trade, combined with evidence from the Crimean war of the limited capability of the Russian Navy to defend the colony from takeover, led Russia to sell its occupied territory in 1867 to a willing buyer (and the most likely invader), the United States of America (Haycox 2002).

History of Commercial Exploitation in the Aleutians

A bridge between Asia and North America, the Aleutian Islands boast a rich marine biodiversity that has evolved to withstand the strong winds, earthquakes, volcanic eruptions and tsunamis typical of the region. Despite the harsh conditions and sparsely scattered of settlements throughout the Aleutian chain, the history of the large scale exploitation of its natural resources has been almost uninterrupted for the past 250 years (Table 1). From fur trading to whaling and fisheries, the commercial ventures in the archipelago have a complex history of exhaustive exploitation followed by reactive conservation measures. Thus the islands' current wealth of resources is the combined result of environmental conditions (e.g., productive seas) and cumulative exploitation/ conservation actions. The archipelago is divided at Amchitka Pass by the 180˚ meridian, so about half of the island chain, closes to Asia, is in the Eastern Hemisphere, and the half closest to North America is in the Western Hemisphere. This location generates economic and environmental driving forces from opposite ends that meet in an alternating/simultaneous manner in time and space. The interplay of these forces shapes the marine environment in a longitudinal gradient of predominantly Asian/oceanic nature in the Eastern Hemisphere and North American/coastal in the Western Hemisphere. It has also divided the history of the islands into exploitation waves coming from Russia and Japan (reflected in the name "Near Islands" identifying the westernmost group closest to Asia), and those coming mostly from America, but also Britain/Canada. Fisheries exploitation from the eastern nations came to an end with the passage of the Magnuson-Stevens Fisheries Conservation and Management Act (MSA) which extended U.S. jurisdiction to 200 mi. offshore. Since then, domestic fishing activities have been based off the Alaska Peninsula and Dutch Harbor, in the eastern Aleutians.

Table 0-1 Key historical events in the Aleutian Islands and timeline of exploitation of natural resources, 1740-2005. Modified from Ortiz (2007).

	Natural Resource Exploitation	Key Historic Events	
1745-64	First Russian/European exploration of the Aleutians	Bering arrives to Commander Islands	1741
1750	Arctic fox introduced in Attu; sea otter extinct in Kamchatka		
1768	Sea cow extinct	First wintering at Kodiak	1763
1784	Permanent settlements at Kodiak & Unalaska	Cooks's third voyage California-Bering Strait	1776
1786	Discovery Pribilof Islands	Ships from Flanders, France, Spain, England and California reach Alaska and Aleutians	1785-87
1792	Sea otters extinct at Kodiak-Kenai Bay; new settlement at Chugatsk Bay	English sell sea otters at Canton	1788
1796	Sea otters extinct at Chugatsk Bay; new settlement at Yakutat	Beginning of Russian American Company	1799
1802	800,000 fur seal skins spoiled in storage	Fur prices drop in China	1803
1804	Fur seal hunting ban		
1808	Ban removed		
1810-13	700,000 skins burned in Unalaska	Second charter of Russian American Co.	1819
1812	New settlement Ross in California	15 permanent settlements in Alaska	1820
1820	Sea otters extinct at Yakutat, Icy Bay, Cape St Elias	English trade throughout AK, except near Russian colonies	1825
1828	Fox introduced to Andreanof/ Rat Islands; only 300 sea otters furs at Atka; trade minimal	Native trade for Russian American Co. in Yukon-North Slope	1826

	Natural Resource Exploitation	Key Historic Events	
1828-50	Moved people from Amchitka to Adak and Atka to let sea otters at Rat Islands rest	Panic of 1837 (economic depression)	1837
1835	First whale killed at Kodiak by Yankee whalers		1840-50
1840	700 whaling, fishing and fur hunting American vessels active I North Pacific	Third charter of RA company begins	1844
1848	Arctic whaling begins, Dutch Harbor main stocking station	Sea otter fur prices decline	1845
1867	American whaling in AK; pelagic sealing	Gold Rush in California	1848
1880	First steam whaler returns from Arctic	Russian-American Co losses fur monopoly	1857
		Oil well discovered in Pennsylvania	1859
		Sale of Alaska to the United States/ Independence of Canada	1867
		US transcontinental railroad completed	1869
		Fashion for wide skirts crinolin made of baleen	
		Gold rush at Nome	1899
1905	Steller sea lions scarce		1903
1912	Shore whaling station at Akutan	North Pacific Fur Seal Convention	1911
1920	Peak cod fishery	Alaska becomes territory	1912
1939	Akutan shore whaling station closes	Aleutian Chain Reservation established	
1913-40	Fox farming	WWI	1914-18
1950-72	Modern whaling	International Pacific Halibut Convention	1923
1952	High seas salmon fishery	Great Depression	1929
		Aleut internment?	1943
1960	Foreign crab & groundfish fisheries begin	WWII	1944
1962	POP *6336c2 f5sher5es start	International Whaling Convention	1948
		International North Pacific Fishery Commission	1953
1963	Sablefish and Greenland Turbot fisher5es start	Foreign fleets restricted to west of 175°W	
1970	Flatfish fishery beg5ns	Alaska and Hawaii become states	1959
1972	Atka mackerel fishery beg5ns	Marine Mammal Protection Act	1972
1980	Joint ventures begin	Endangered Species Act	1973
1990	Groundfish fleet fully domestic	Fisheries Management Conservation Act	1977
1997	Steller sea lion listed endangered under ESA	200 mi EEZ worlwide	1982
2000	Pollock fishery almost closed		

Commercial Exploitation

During the early Russian period (1741-1799), discovery and intense exploitation went hand in hand. Lack of involvement and direction from the Russian government allowed the traders to hunt on land, unrestrained, and investments on exploration were secured by maximizing the number of furs obtained per trip. The discovery of the entire Aleutian region spanned some 20 years (Haycox, 1997) (Figure 0-1). Along the way Aleuts were encountered and used as hunters and arctic foxes were introduced to islands formerly devoid of them (Black 2004). The extirpation of sea otters from the Kamchatka Peninsula and their decline along the western Aleutians pressed the fur traders to the east, arriving on the Alaska Peninsula in 1760 (Smith 2003). An earthquake had reportedly scared the sea otters away from the Kuriles in 1780, and there were subsequent declines in the sea otter populations along the Aleutian archipelago that directed exploration towards southeast Alaska (Berkh 1823, Tikhmenev 1861, Black 2004). The fur traders continued to exploit and explore Alaska until 1799. In all, the independent traders brought to Russia an estimated 1,120,000 furs: roughly 76% from fur seals, 12.5% from sea otter, and 11.5% from various types of foxes, not counting furs in storage houses or from land mammals other than foxes (Berkh 1823). These first 50 years of exploitation by independent fur traders yielded more sea otters furs than the subsequent 65 years under the auspice of the Russian American Company.

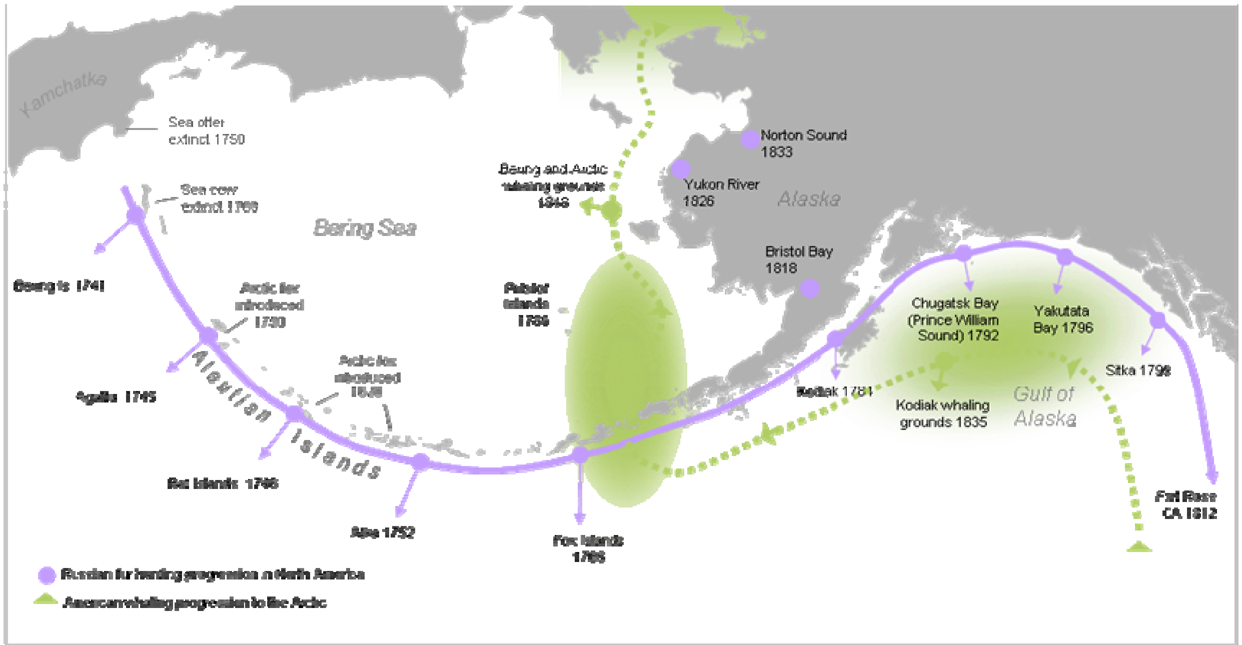

Figure 0-1 Initial advance of Russian fur hunters and American whalers during the Russian period 1741-1867. Reprinted from Ortiz (2007).

In 1798 Shelikov formed the Russian American company and was awarded the fur trade monopoly in 1799 (Berkh 1823, Tikhmenev 1861, Black 2004).The Russian American Company was modeled after the Hudson Bay Company and the British East Indian Company as a private enterprise in charge of trade, and served as the de facto local government. However, unlike the independent fur hunters who had no competition at the beginning, the company faced the established American and British trade, and its monopoly on fur trade was only within Russia. Under the freedom of the seas doctrine, waters more than 3 miles from the coast were considered international waters. James Cook's maps of the northwest coast were widely distributed (Hayes 2002), and the stories of the high prices obtained by his crew in exchange for sea otter furs at the port of Canton were highly publicized (Haycox et al. 1997). In the late 1780s, Alaskan waters were visited by Spain, the United States, England and France (Black 2004). British and American ships had continued sailing along the Northwest coast trading with the natives for furs (Malloy, 1998), eventually flooding the Chinese market with cheaper furs and causing prices to fall (Gibson 1992, Black 2004).

The Russians reacted by increasing the number of settlements, but had difficulty supporting those settlements without relying on international traders (Okun 1951, Black 2004). The company thus had gained domain over the land in Alaska, but at sea the independent American whalers and traders prevailed. The first right whale killed at Kodiak (Gulf of Alaska) in 1835 marked the beginning of American commercial whaling in Alaska (Starbuck, 1878). Hunting grounds extended east to the nearby Fox Islands (eastern Aleutian Islands) where right whales were commonly seen (Shelden et al. 2005). After only five years (1840) there were at least 250 American vessels whaling, fishing, and fur hunting in seas which fell under the jurisdiction of the Russian American Company (Alekseev 1990). Ten years later, in 1845, catches deteriorated markedly (Bockstoce 1986) but the discovery of bowhead whales in the Arctic and Bering Sea grounds gave rise to a second whaling surge farther north.

The Russian American Company operated from 1799 to 1864, and shipped to Russia a total of 1,678,000 fur seal skins, 117,000 sea otter pelts, and 128,000 fox furs, all of them largely obtained during its first of its three charters. Overall, catches declined steadily during the company’s lifetime. Aggravating these circumstances was Russia’s lack of means to defend the colonies in the event of war, and so in 1867 the American colonies were sold to the United States in the Alaska purchase (Berkh 1823, Tikhmenev 1861, Okun, 1951, Black 2004). The U.S.-Russia Convention Line of 1867 delimits the Aleutian Islands east and west of 170°E, so the Commander Islands (easternmost portion of the Aleutian Archipelago) remained under Russian jurisdiction.

Disregarding the Russian experience, American fur seal hunting was unrestrained between 1867 and 1868, when 140,000 animals were killed. The U.S. Treasury Department intervened, leased the hunting rights on the island to a private company and imposed the Russian practice of selecting individuals by sex and age (Riley 1967). Just like its predecessor, the U.S. did not have control over the offshore waters and as whaling vessels took on fur trading to offset declining catches, fur seal hunting shifted from land-based to pelagic operations. The pelagic hunting extended from around the Pribilof Islands to the Aleutian passes and the waters of the Gulf of Alaska (Bockstoce 1977, Jordan 1898).

Whaling ships eventually participated in pelagic sealing as well when whale populations declined. Bowhead whales had been depleted very quickly, but whaleships had taken walruses from 1859 to 1878 to make the trip worthwhile (Bockstoce 1986). By the time whale catches in Kodiak were rare, the Aleutian Islands were visited frequently as ships had to enter the Bering Sea through the passes and get provisions (Starks 1923, Tønnessen and Johnsen 1982). Whale oil prices declined, but those of whalebone for the fashion industry and multiple other purposes consistently increased. This, combined with cheaper shipping costs, allowed whaling to continue (Bockstoce 1977). American whaling profits were substantial despite the losses. From 1835 until after the Alaska Purchase, the northwest coast whaling grounds produced 60 percent of all the oil secured by the American whaling fleet (Kushner 1972). In 1880 offshore whaling had a third boost with the inception of steam whaling and later a final boost with the entrance of schooners to the fleet. Dutch Harbor became a frequented port, as passing steam whalers would get coal, supplies, and catch and salt cod (Bockstoce, 1977). It is in this last phase that fur trade became an additional incentive for the schooners, when furs offset the losses from the declining baleen catches (Bockstoce 1977). Whaling in the western Arctic ended in 1907 but by then pelagic sealing had long become a worthwhile pursuit on Alaskan waters.

By 1889, pelagic sealing was taking around 30,000 seals per year, one fourth of the total catch. In the 1890s pelagic sealing increased to 40,000 and 60,000 seals (86 percent of the catch) despite the Fur Seal Arbitration Tribunal banning pelagic sealing within 60 miles from the Pribilof Islands and the Act of Congress in 1897 banning pelagic sealing to all American vessels and citizens (Anonymous, 1907). This simply re-distributed effort south, towards the Aleutian passes and Gulf of Alaska, where fur seals herds could be found on their way to the Pribilofs. Pelagic sealers came from east and west as Canadians and Japanese continued to take seals in the water. The stock declined from an estimated 1,000,000 in 1891 to 185,000 in the early 1900s (Anonymous 1907). Scientific opinion was split as to the cause of the decline, some blaming the land based practices and others the pelagic catch; the issue became a highly publicized international affair. After multiple negotiations, Japan, Russia, the United States and Great Britain (for Canada) accepted the North Pacific Fur Seal Convention of 1911. Pressed by environmentalists, the United States issued a complete sealing moratorium in 1913. The moratorium lasted 5 years, the scientific debate was unresolved, and the recovery of the herd was and is still considered one of the biggest victories of conservation efforts and management (Fur Seal Investigations 1896, Hornaday 1920, Jordan 1913, 1920, Riley 1967).

An amendment to the North Pacific Fur Seal Convention also ended the international hunting of the nearly extinct sea otter, which had been recognized on the brink of extinction as early as 1895 (Dall 1896). The Act of 1910 had approved protection of the seal fisheries, sea otters, and fur bearing mammals in Alaska. The sea otter hunting had increased concurrently with pelagic sealing (Bureau of Fisheries 1906), and by the time the Convention was signed, the total number of sea otters was estimated between 1,000 and 2,000. Although both sea lion and walrus were also reported nearly extinct at this time, no direct law was issued to protect either one specifically. Whaling (the industry behind walrus hunting) had ended and sea lions were hunted by native Alaskans only. The Pribilof Islands had been named a Reservation in 1869, but this did little to prevent walrus hunting during the whaling era. Similar to the Russian's observation on the impact of whaling on native Alaskans (Alekseev 1990), the U.S. Bureau of Fisheries (1906) noted they were the most affected by the depletion of sea lions, as the native Alaskans' dependence on this particular resource was heightened by the scarcity of other once abundant marine mammals.

Subsequent commercial activities in the Aleutians in the first half of the twentieth century focused on fox farming, shore-based whaling and nearshore fisheries. Little information exists as to the furs produced by fox farming, except that introductions were restarted and the activity peaked from 1913 to 1940. The farming of foxes was encouraged despite an early warning by Turner (1886) in the 1870s about the decline of seabirds due to foxes. To top it off, ground squirrels were introduced to serve as food for foxes. All this happened after the Aleutian Islands (including Unimak and Sanak) had been declared a Reservation in 1913 to preserve breeding ground for native birds, promote propagation of reindeers and fur bearing animals, and encourage the development of fisheries. The same year saw a bill passed in which the take of fish and whales by non-US citizens were prohibited in Alaskan territorial waters, at the time defined as three miles from shore. Alaska had just become a territory of the United States and the bill's purpose was to take official claim of the marine resources in the adjacent waters.

A shore whaling station built in 1907 by a Norwegian company in Akutan (eastern Aleutians) was directly affected by the US claim of marine resources, as the whaling boats had to be registered in the U.S. and fly the American flag. The Akutan whaling station's operations lasted from 1912 to 1939 (Tønnessen and Johnsen, 1982). Only 1913 and 1921 reported no activity. During its operations some 10,181 whales were processed at Akutan, mostly those with neritic (coastal) affinities: 37% humpbacks, 37% fin whales, 13% blue, 9% sperm, and 0.5% sei whales; 3% were beluga whales caught in Cook Inlet. Gray and right whales, once abundant, were rarely taken (US Fisheries Bureau 1912-1939). Blue whales vanished from the east and western Pacific and only the waters south of the Aleutians sustained an average annual catch of 50 animals up until 1930. With the introduction of floating factories in the 1920s, Japan initiated pelagic whaling off the Aleutians; however these catches were outside the 3 mile limit and hence there are no records of catches (Tønnessen and Johnsen, 1982). In 1939, with the threat of World War, the facilities in Akutan were sold to the navy, and the shore-whaling industry came to an end in the Aleutians.

Formal commercial exploitation of fish stocks in the eastern Aleutians region started in 1906 when cod stations were opened at Sanak and Unimak Island by various companies (Bureau of Fisheries 1907). Vessels moved to the Alaska Banks of the Bering Sea, to south of Unimak Island, and around the Shumagin Islands to offset the end of cod fishing off the Russian coast after the 1909 season. Cod were to be found almost everywhere in the banks with less than 100 fathoms of water. The fishery operated from the permanent shore stations and was based primarily in harbors (Shields 2001). Overall, the Pacific cod fishery peaked during WWI when estimated annual catches ranged from 12,000 to 14,000 metric tons. Later, in 1915, there was an unexplained change in the migration pattern of cod, the fish began to disappear from harbors and a portion of the fishery moved outside the harbors (Shields 2001). The inshore winter fishery gradually declined after 1920 and ended in 1930. The rest of the fishery declined later due partly to cod deliveries by Japanese vessels and poor quality processing, which made the end product inferior to that of the East Coast. The fishery was terminated in 1950 (Dall 1896, INPFC 1979, Bakkala 1981, Shields 2001).

Other fishing stations opened in 1916 throughout the eastern Aleutians, and one shore station opened at Attu (western Aleutians) where Atka mackerel and greenling was caught. Salmon canneries opened in the eastern islands of Unalaska and Umnak, with limited success. The total salmon catch from 1916 to 1939 was only 5,521 metric tons with a peak in 1924 of 1,803 metric tons (Bureau of Fisheries 1906-1939). The halibut fishery had extended to Dutch Harbor after successive depletion from Banks all the way from Oregon to the Gulf of Alaska, but catches in the Aleutians were minor (Adams 1935, Fiedler 1940, Russell 1943). The Convention for the Preservation of the Halibut Fishery of the Northern Pacific Ocean was signed on March 2, 1923. Later, in 1953, Regulatory areas were established however it was not until 1966 that the Aleutians were included in an explicit regulatory area. A purse seine fishery for herring developed in the vicinity of Unalaska. Catches peaked in 1932 at 2,277 metric tons and ranged between 1,000 and 2,000 metric tons until 1937. From then on catches declined until the fishery was abandoned in 1946 (INPFC 1979, Bakkala 1981).

While the American vessels stayed in nearshore/eastern areas during the 1920's and 30's, foreign fishing fleets exploited the offshore/eastern grounds. Japan had developed a self sufficient fleet of motherships, and had the capacity to fish salmon and halibut in the high seas (i.e. outside territorial waters). However, in order to avoid conflicts with the United States over the catch of salmon or halibut (the main U.S. Alaska fisheries at the time), Japanese confined their catches to crab and fish meal in which the U.S. fishing industry had no interest (Barnes 1936, Fielder 1940). From 1933 to 1939 crab was caught north of Umnak and the fleet worked its way eastward along the north coast of the Alaska Peninsula (Parker 1974). An eventual Japan-U.S. conflict over salmon raised controversy over the "ownership" of salmon stocks and access rights. Alaska was the primary supplier of manufactured fishery products and catches in Bristol Bay were higher than those at Japan's fishing zones. The conflict was characterized as one between conservation (on the U.S. side) and advancing techniques (Japan's motherships). The fact that Japan restricted motherships from fishing off Kamchatka for fear of damaging their own shore-fishing operations (Barnes 1938) did little to appease concerns with regards to the future of Alaska fisheries. The onset of World War II brought a temporary halt to Japan's fishing fleet expansion, but the controversy between conservation and advancing techniques would resurface later. During World War II the Supreme Command Allied Powers limited fishing to coastal waters. Furthermore, Attu and Kiska were occupied by Japan, to be recovered by the U.S. in 1943. Overall, pelagic fishing during World War II was restricted to a minimum in the Aleutian Islands (Mathieson 1958).

After World War II, whaling and fisheries by foreign fleets expanded to areas immediately outside the territorial waters of the Aleutian Islands and catches exceeded historic high levels. Whaling was the first fishery to be reactivated in Aleutian waters. The International Convention for the Regulation of Whaling of 1946 was signed by the U.S., Canada and the U.S.S.R. among others. Japan joined in 1951 (IWC 2006) when it planned on extending its whaling grounds eastwards in the North Pacific. The signatories agreed on the establishment of the International Whaling Commission (IWC) to regulate catches. In the early 1950s Japanese factory ships expanded catches to the south coast of the western Aleutians. The total catches in the Aleutians increased steadily from a couple hundred whales in the early 1950s to over 4,000 by the end of the decade. Soviets subsequently increased effort in the North Pacific, and by 1963 had a fleet of 37 vessels. Baleen whales were half or less of the catch, and sperm whales made up the rest of it. Japanese and Soviet Union fleets operated freely in the North Pacific until their increased effort and the decline of Antarctic catches caught the attention of the IWC. By this time, global regulation was needed for both shore and pelagic whaling. The Scientific Committee requested limits on humpback and blue whales catches in 1965 and asked for their complete protection in 1966. This restriction, however, had little effect on the whaling activities around the Aleutians because the catch of humpbacks and blue whales rarely exceeded 200 individuals and comprised less than 10 percent of the catch throughout the archipelago. Nevertheless, sperm whale, followed by fin and sei whale continued to be caught in the central and western Aleutians while fin whales prevailed in the eastern islands. The whaling fleets operated offshore, seldom within 30 km of the coast until 1972 (Merrel 1971) when catches north of 50°N ceased, although globally stocks kept declining until a moratorium was set in 1982 (Tønnessen and Johnsen 1982, IWC 2006). Failure of international agreements to restrain whale catches pushed the implementation of one of the most comprehensive conservation laws in the United States: the Marine Mammal Protection Act (1972). The far reaching umbrella of this law established the legal grounds for many of the conservation and management actions of fishery-related resources in place today (Bean 1983).

Following the trend in whaling activities, foreign fleets expanded their operations to waters right outside the territorial limit of the U.S, encroaching into the eastern Bering Sea and the western Aleutians. Japanese fleets had started fishing for salmon near the Aleutians in 1952. The International North Pacific Fisheries Convention was signed by Canada, the U.S. and Japan in 1953. By 1955 the Japanese had 12 independent flotillas operating in the Aleutian area (Mathieson 1958). Meanwhile the U.S. fleet operated west of Unimak Pass. Pink salmon was the primary species (>90 percent) caught in the Aleutian Islands area and were taken almost exclusively in the bays of Unalaska (INPFC 1979). Alaska had gained statehood in 1959, and this transferred government of the coastal fisheries from the federal to the state government. The 1953 Convention established the division between Japan and Canada/U.S. areas of fishery and fisheries conservation with Japan restricted from activities east of 175°W. Towards the west, fishing activities were regulated by a Treaty between with the U.S.S.R. and Japan. This left fisheries beyond the 3 mile limit in the central and western Aleutians effectively outside U.S. jurisdiction and open to Japanese, Russian and other foreign fishing fleets (Merrel 1971).

In 1960 the Japanese and Soviet fishing fleets were operating at full force in the Aleutian Islands. They were later joined by Korea (1967), Taiwan (1974) and Poland (1979) (Bakkala 1981). The initial targets were Pacific Ocean perch and walleye Pollock, but soon expanded to sablefish and Greenland turbot (1963), Pacific cod (1964) flatfish (1970), and Atka mackerel (1972). Peak total groundfish harvest occurred in 1965 when almost 112,000 metric tons were taken. Most was Pacific Ocean perch, taken off the entire central and western Aleutians (Merrel 1971). Pacific Ocean perch remained the primary target until the 1970s when the stock declined and catches comprised only about a third or less of the total harvest in the region. Between 1973 and 1977 total catches were below 50,000 metric tons (Bakkala 1981).

The American fleet started fishing for Red king crab near Adak and Dutch Harbor in 1960 (NPFMC 2005). In 1964, the U.S. ratified the Convention of the Continental Shelf and designated both king and tanner crabs as shelf creatures; bilateral agreements were concluded with Japan and the USSR. The Soviets remained in the fishery until 1971 and the Japanese until 1974. Meanwhile the U.S. crab fishery developed rapidly during the 1960s and was receiving half of the total harvest by the early 1970s. Foreign fleets were excluded from the fishery by 1975, however this did not necessarily result in better management of crab stocks. As the abundance of red king crab declined in the Aleutian Islands, fishers gradually transitioned to harvesting golden king crab and by 1982, golden king crab landings exceeded those for red king crab, although the total volume of golden king crab landed was never as high as for red king crab (Otto 1981). At its peak, the red king crab harvest in the Aleutian Islands exceeded 17,000 metric tons.

In response to foreign high exploitation rates in waters adjacent to its 3 miles limit, the U.S. passed the Magnuson-Stevens Fishery Conservation and Management Act in 1976 (MSFMCA) which established the Fishery Conservation Zone (FCZ) from 3 to 200 miles offshore. Its objective was to rebuild depleted groundfish stocks, achieve and maintain an optimum yield for the various fisheries and “Americanize” the fleets. Foreign countries were allocated quotas based on their contribution to developing the domestic industry, and so the groundfish fisheries went through a period of joint ventures that lasted through the 1980s. These ventures transitioned foreign involvement in the fisheries from active fishing to investment in U.S. harvesting and processing capacity and destination markets.

During the 1980s groundfish catches increased back to over 100,000 metric tons as joint ventures successfully developed U.S. fisheries. U.S. vessels fishing for pollock, cod and yellowfin went into joint ventures with the USSR and Korea; and Japan's new shipboard methods to produce surimi at sea allowed the pollock fishery to rapidly expand (Bakkala 1981). Pollock catches peaked in the Aleutians during the 1980s. By 1990 the fleets were domestic, and total catches remained in excess of 150,000 metric tons throughout the decade. In 1999 the pollock fishery was severely restricted due to concerns regarding the fishery's impact on Steller sea lions (Barbeaux 2004). Since then, total groundfish catches have averaged slightly above 100,000 metric tons and are roughly 50% Atka mackerel, 30% Pacific cod and 15% Pacific Ocean perch.

Were not Japanese high seas drift nets still used near the western Aleutians until the mid-late 1980s? Wasn't there a big deal about banning them? Should be mentioned.

Appendix B Species listed under the Endangered Species Act

Due to declines based on past exploitation or because of other, often poorly understood, factors, a number of marine mammals occurring in the Aleutians are listed as endangered or threatened under the Endangered Species Act. The table below summarizes those species.

Endangered Species Act-listed marine mammal and seabird species that range in the Aleutian Islands

Common Name	Scientific Name	ESA Status
Steller Sea Lion (Western Population)	*Eumetopias jubatus*	Endangered
Blue Whale	*Balaenoptera musculus*	Endangered
Bowhead Whale	*Balaena mysticetus*	Endangered
Fin Whale	*Balaenoptera physalus*	Endangered
Humpback Whale	*Megaptera novaeangliae*	Endangered
Right Whale	*Balaena glacialis*	Endangered
Sei Whale	*Balaenoptera borealis*	Endangered
Sperm Whale	*Physeter macrocephalus*	Endangered
Northern Sea Otter[1]	*Enhydra lutris*	Threatened
Short-tailed Albatross	*Phoebaotria albatrus*	Endangered
Steller's Eider	*Polysticta stelleri*	Threatened
Spectacled Eider	*Somateria fishcheri*	Threatened
Kittlitz Murrelet	*Brachyramphus brevirostris*	Candidate

Appendix C Interaction Strength Tables

Table 1 Interaction strengths for key species in the Aleutian Islands food web.

Table 2 Interaction strengths for protected species and fisheries

High interaction strength arises from combined diet and mortality impacts between species; in general, more than 10% in diet or 10% mortality caused could be strong interactions.

Table 1 Interaction strengths for key species in the Aleutian Islands food web.

High interaction strength arises from combined diet and mortality impacts between species; in general, more than 10% in diet or 10% mortality caused could be strong interactions.

NOTE: blank cells mean no interaction reported, 0% cells are trace (less than 0.5%)

Consumer (row) causes this % of Prey mortality / Prey (column) is this % of Consumer diet	*Focus species as Prey*																		
	Atka mackerel		Halibut		King crabs		P.Ocean perch		Pacific cod		Sablefish		Pollock		Grenadiers		Myctophids		
Focus species as Consumer																			Diet from focus species
Atka mackerel			1%	0%									52%	6%			3%	1%	7%
Halibut	2%	16%	0%	0%	3%	0%			0%	1%	17%	2%	1%	9%			0%	2%	29%
King crabs																			
P.Ocean perch													0%	0%	0%	0%	1%	3%	3%
Pacific cod	20%	15%			1%	0%	1%	0%	1%	0%	18%	0%	4%	4%	0%	0%	1%	4%	24%
Sablefish													0%	4%			0%	0%	4%
Pollock	18%	2%			0%	0%							2%	0%			30%	14%	16%
Grenadiers																	23%	47%	47%
Myctophids																	2%	0%	0%
Mort explained by focus spp	40%		1%		5%		1%		2%		35%		58%		0%		61%		
Other Consumers of Focus species																			
ADF&G Pots					62%														
Baleen whales	0%												2%						
Detritus (unexplained mortality)	7%		57%		14%		69%		50%		7%		19%		83%		20%		
Flatfish	6%		1%		0%		4%		0%		19%		2%				8%		
Forage													0%						
IPHC Longline			34%																
NMFS Longline	0%		3%		0%		0%		17%		31%		0%		11%				
NMFS Pot	0%		0%		0%		0%		4%		0%		0%		0%				
NMFS Trawl	17%		3%		0%		12%		18%		3%		13%		1%		0%		
Other fish	1%				1%								0%				0%		
Pinnipeds	0%		0%		0%		0%		0%		0%		0%				0%		
Pisc Seabirds	0%						7%		0%				1%				0%		
Plnkt Seabirds	0%						0%		0%				0%						
Rockfish	0%				16%								0%				0%		
Sharks			1%		0%		0%		0%		5%		0%						
Skates	5%				2%								2%		0%		0%		
Squids																	10%		
Steller Sealion	24%				0%		2%		7%				2%						
Toothed whales			0%				4%		2%		0%		0%		5%		1%		
Zoop													0%				0%		
Total Mortality	100%		100%		100%		100%		100%		100%		100%		100%		100%		

Table 1 continued. Remainder of diets for focus species.

Consumer (row) causes this % of Prey mortality	Prey (column) is this % of Consumer diet	*Other prey of focus species*														
		Copepods	Crabs	Detritus	Epifauna	uphausiids	Flatfish	Forage	Infauna	Other fish	lagic micro	Rockfish	Shrimp	Squids	Zoop	Total Diet
Focus species as Consumer																
Atka mackerel		36%	0%	0%	6%	29%	0%	0%	1%	0%			0%	10%	11%	100%
Halibut			18%	5%	12%	0%	0%	3%	1%	7%			3%	22%	0%	100%
King crabs			4%		56%				40%							100%
P.Ocean perch		76%			1%	14%		0%	2%	0%	0%		0%	0%	4%	100%
Pacific cod		0%	6%	5%	5%	0%	0%	4%	5%	16%			28%	6%	0%	100%
Sablefish			0%	0%	3%	35%			4%	0%	0%	0%	1%	2%	49%	100%
Pollock		28%	0%	0%	9%	21%		0%	0%	2%			7%	1%	14%	100%
Grenadiers					2%	0%		1%						45%	6%	100%
Myctophids		12%			6%	77%									6%	100%

Table 2 Interaction strengths for protected species and fisheries.

% of Prey mortality caused by consumer	% of Prey in each consumer's diet	*prey groups*																		
ConsGroup	Consumer	Forage	Forage	Squids	Squids	P.Ocean	P.Ocean	Pollock	Pollock	Rockfish	Rockfish	Myctoph	Myctoph	Copepoc	Copepoc	Epifauna	Epifauna	Euphaus	Euphaus	Atka ma
Birds	Pisc Seabirds	3%	45%	1%	25%	7%	8%	1%	6%	14%	5%	0%	3%	0%	3%	0%	2%	0%	2%	0%
	Plnkt Seabirds	0%	5%	1%	22%	0%	0%	0%	0%	1%	0%		0%	0%	38%	0%	0%	0%	28%	0%
Mammals	Pinnipeds	0%	15%	0%	3%	0%	0%	0%	16%	0%	0%	0%	0%			0%	11%			0%
	Sea Otters	0%	11%													0%	62%			
	Steller Sealion	1%	9%	1%	6%	2%	2%	2%	10%	5%	1%					0%	0%			24%
	Baleen whales	5%	33%	0%	1%			2%	7%					0%	7%			0%	42%	0%
	Toothed whales	1%	3%	11%	87%	4%	2%	0%	0%	7%	1%	1%	5%							
Fishery	Subsistence	0%	42%																	
	ADF&G Net	0%	100%																	
	IPHC Longline			0%	0%															
	ADF&G Pots																			
	NMFS Pot			0%	0%	0%	0%	0%	0%	0%	0%					0%	4%			0%
	NMFS Longline	0%	0%	0%	0%	0%	0%	0%	0%	3%	3%					0%	0%			0%
	NMFS Trawl	0%	0%	0%	0%	12%	7%	13%	42%	22%	3%	0%	0%			0%	0%			17%

		Prey																		
	ConsGroup	Forage	Forage	Squids	Squids	P.Ocean	P.Ocean	Pollock	Pollock		Rockfish		Myctophids		Copepods		Epifauna		Euphausiids	
	Birds Total	4%	22%	2%	23%	7%	4%	1%	3%	15%	2%	0%	1%	0%	23%	0%	1%	0%	17%	0%
	Mammals Total	7%	14%	12%	36%	6%	1%	4%	5%	12%	1%	1%	2%	0%	2%	0%	4%	0%	12%	24%
	Fishery Total	0%	0%	0%	0%	13%	5%	13%	34%	25%	3%	0%	0%			0%	0%			17%
Mort not explained by these groups		90%		86%		74%		82%		49%		99%		100%		100%		100%		59%

Table 2 continued. Interaction strengths for protected species and fisheries.

% of Prey mortality caused by consumer	% of Prey in each consumer's diet																			
ConsGroup	Consumer	Infauna	Infauna	Detritus	Detritus	Pisc Sea	Pisc Sea	Plnkt Se	Plnkt Se	Pacific c	Pacific c	Shrimp	Shrimp	Other fis	Other fis	Crabs	Crabs	Grenadie	Grenadie	Flatfish
Birds	Pisc Seabirds	0%	0%	0%	0%	25%	0%	13%	0%	0%	0%									
	Plnkt Seabirds	0%	1%							0%	0%									
Mammals	Pinnipeds									0%	4%	0%	16%	0%	20%	0%	1%			1%
	Sea Otters	0%	4%									0%	3%	3%	19%	0%	0%			
	Steller Sealion			0%	0%					7%	4%	0%	0%	1%	3%	0%	0%			
	Baleen whales													1%	1%					
	Toothed whales									2%	1%			0%	0%			5%	1%	0%
Fishery	Subsistence																			
	ADF&G Net																			
	IPHC Longline																			
	ADF&G Pots																			
	NMFS Pot					0%	0%	0%	0%	4%	88%			0%	8%	0%	0%	0%	0%	0%
	NMFS Longline					5%	0%	3%	0%	17%	51%	0%	0%	0%	3%	0%	0%	11%	21%	4%
	NMFS Trawl					1%	0%	0%	0%	18%	9%	0%	0%	1%	1%	0%	0%	1%	0%	10%
	ConsGroup		Infauna		Detritus		Pisc Seabirds		Plnkt Seabirds		Pacific cod		Shrimp		Other fish		Crabs		Grenadiers	
	Birds Total	0%	0%	0%	0%	25%	0%	13%	0%	0%	0%									
	Mammals Total	0%	0%	0%	0%					9%	1%	0%	0%	6%	3%	0%	0%	5%	0%	1%
	Fishery Total					6%	0%	3%	0%	39%	16%	0%	0%	1%	1%	0%	0%	12%	3%	14%
Mort not explained by these groups		100%		100%		68%		83%		52%		100%		93%		100%		83%		85%

Table 2 continued. Interaction strengths for protected species and fisheries.

% of Prey mortality caused by consumer	% of Prey in each consumer's diet																			
ConsGroup	Consumer	Halibut	Halibut	King cral	King cral	Sablefisl	Sablefisl	Skates	Skates	Baleen v	Baleen v	Toothed	Toothed	Steller S	Steller S	Sharks	Sharks	Sea Otte	Sea Otte	Pinniped
Birds	Pisc Seabirds																			
	Plnkt Seabirds																			
Mammals	Pinnipeds	0%	0%	0%	0%	0%	0%													
	Sea Otters																			
	Steller Sealion			0%	0%			2%	0%							0%	0%			
	Baleen whales																			
	Toothed whales	0%	0%			0%	0%	4%	0%	24%	0%	7%	0%	8%	0%	6%	0%	10%	0%	14%
Fishery	Subsistence													1%	45%					11%
	ADF&G Net																			
	IPHC Longline	34%	100%																	
	ADF&G Pots			62%	100%													0%	0%	0%
	NMFS Pot	0%	0%	0%	0%	0%	0%	0%	0%											
	NMFS Longline	3%	1%	0%	0%	31%	6%	45%	7%							62%	0%			
	NMFS Trawl	3%	0%	0%	0%	3%	0%	12%	0%			0%	0%	0%	0%	17%	0%			

	ConsGroup		Halibut		King crabs		Sablefish		Skates		Baleen whales		Toothed whales		Steller Sealion		Sharks		Sea Otters	
	Birds Total																			
	Mammals Total	0%	0%	0%	0%	0%	0%	6%	0%	24%	0%	7%	0%	8%	0%	6%	0%	10%	0%	14%
	Fishery Total	40%	2%	62%	2%	34%	1%	56%	1%			0%	0%	1%	0%	79%	0%	0%	0%	11%
Mort not explained by these groups		60%		38%		66%		38%		76%		93%		91%		15%		90%		75%

Appendix D FEP Area Indicator Data

PLACEHOLDER

- pull data from Ecosystem Considerations chapter where possible, otherwise find other relevant data sets
- this will be like a draft EConsiderations chapter based on our desired indicators…