Chapter 3: Affected environment

This chapter describes environmental components of the eastern Bering Sea and Aleutian Islands (BSAI) as they pertain to the fishery management plan (FMP) for BSAI king and Tanner crab. Components include physical and oceanographic features, major living marine resources (biology, habitat, and current status) as well as social and economic conditions associated with commercial crab fisheries. The BSAI area is a vast and complex region that contains parts of two major marine zoogeographic provinces (Figure 3.0-1) that broadly define the marine ecosystems that are most relevant to king and Tanner crabs. Here we are primarily concerned with the continental shelf and slope to depths of approximately 1,000 meters (m). The dynamics of eastern BSAI marine ecosystems are influenced by local climatic and oceanographic factors as well as broader conditions pertaining to the North Pacific and surrounding continental land masses.

The BSAI region has been studied over many years and a number of reports on both abiotic and biotic components of BSAI ecosystems have been published. Despite the considerable volume of research in the region, many mechanisms remain mysterious and many aspects of its marine ecosystems remain unstudied. This is largely due to the region's remoteness, low human population density, and inclement or hostile weather conditions during much of the year. This chapter provides an overview of the BSAI environment with references to scientific literature and traditional knowledge.

Section 3.1 describes the BSAI ecosystem and identifies relationships between crab populations and ecosystem components, highlighting components that may influence crab abundance. This section discusses historic trends in crab abundance related to ecosystem components, such as climate and currents, to the extent scientific information is available and identifies when scientific information is inconclusive or not available. A section on regime shifts provides insight about the long-term dynamics of the physical environment. Climatic regime shifts occurring in the North Pacific Ocean environment seem to have affected the dynamics of living marine resources in the BSAI region.

Section 3.2 describes the life history of each crab species, identifying the biological and environmental requirements at each life stage, to the extent scientific information is available. This section provides available detail on ecosystem relationships of crab species at each life stage, including habitat requirements and predator/prey relationships.

Section 3.3 presents information on the biology of the other species in the BSAI that could potentially be affected by the alternatives, including benthic species, marine mammals, and seabirds. A complete description of these species in the BSAI is contained in the Alaska Groundfish Fisheries Final Programmatic Supplemental Environmental Impact Statement (PSEIS) (NMFS 2004).

Section 3.4 describes social and economic conditions associated with BSAI crab fisheries. This section also includes discussion of the history of BSAI crab fisheries and the history of the FMP. It presents a profile of the BSAI crab industry, including harvesters, processors, captains, and crews. Also, this section describes the community development quota program for crab and existing conditions in the affected coastal communities.

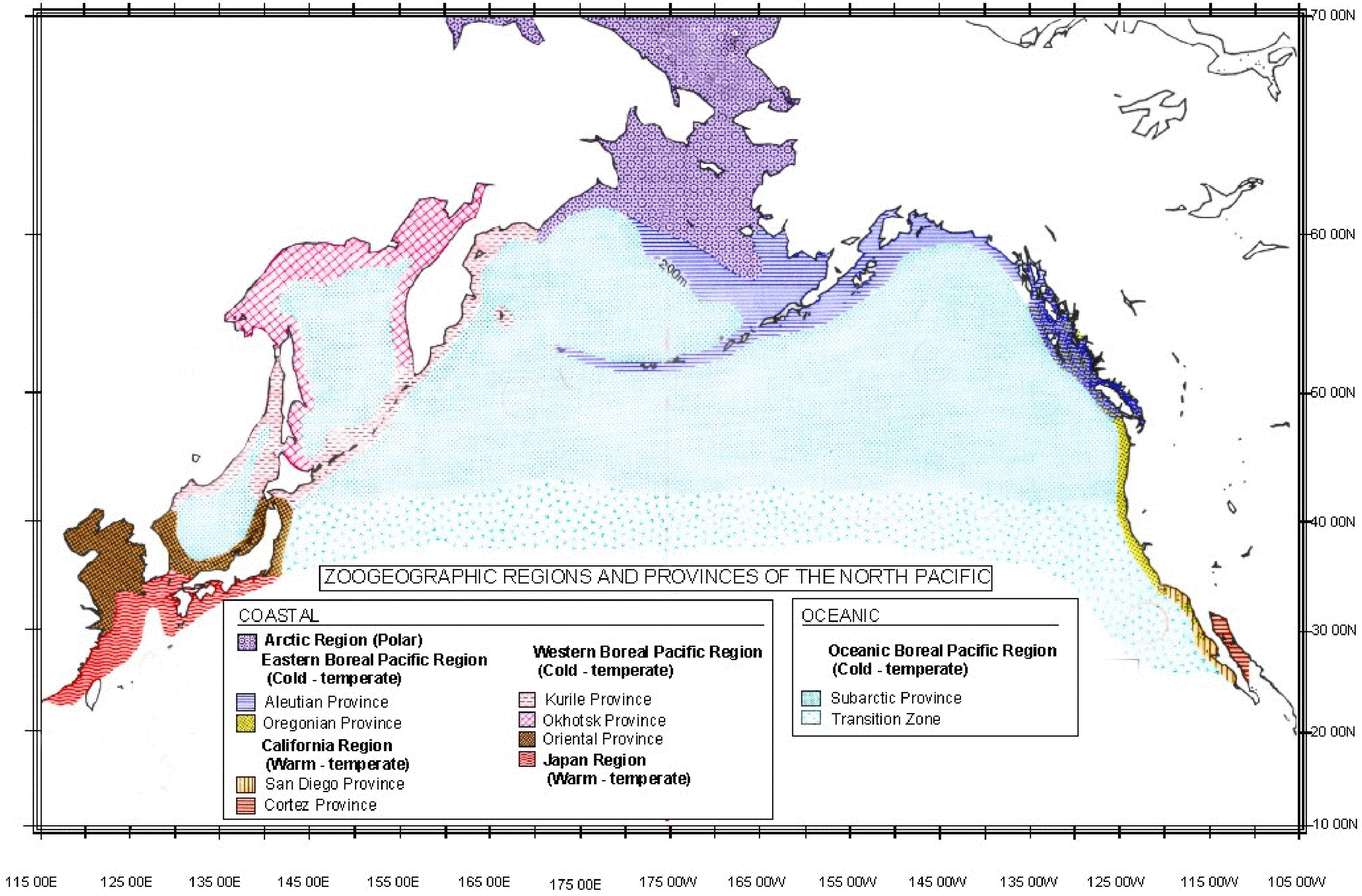


Figure 3.0-1 Zoogeographic regions and provinces of the North Pacific (Allen and Smith 1988). Note that the eastern Bering Sea shelf is an ecotone between the Arctic Region and the Aleutian Provence of the Eastern Boreal Pacific Region.

3.1 Bering Sea and Aleutian Islands ecosystems

The BSAI ecosystem is a complex mix of physical, chemical, and biological processes that shape species' life history and ecology. Processes are understood to varying degrees but knowledge is often scant as to how factors interplay over time and space to influence distribution and abundance of single species and broader communities in which they live. This section intends to distill the knowledge of the substantial complexity of processes and links within the system to a focused subset that directly influence crab biology, which is covered in greater detail in Section 3.2. Important summaries of BSAI information have been compiled in recent years: "The Bering Sea Ecosystem" (National Research Council 1996), "Dynamics of the Bering Sea" (a collection of papers in a PICES symposium; Loughlin and Ohtani, eds. 1999, published by Alaska Sea Grant), Chapter 3, "Affected Environment," from the Alaska Groundfish Fisheries Draft Programmatic SEIS (NMFS 2003b), various papers in "Climate change and northern fish populations" (Beamish, ed. 1995), and comprehensive theses such as "Recruitment variability in southeastern Bering Sea red king crab" (Loher 2001).

This overview of the BSAI ecosystem attempts to describe the world as experienced by the dominate crab species inhabiting the shelf and shelf-break areas of the BSAI managed and fished by the United States (U.S.). It is important to reduce the scope of coverage from the entire Bering Sea (Figure 3.1-1) that covers 2.3 million square kilometers (km^2), including 43 percent in deep-water basins where commercial crab do not occur. Of interest in this environmental impact statement (EIS) is the extensive area of continental shelf (44 percent) and a small portion of shelf-break (abrupt slope from the broad shelf to abyssal depths at thousands of meters) where substantial populations of king crab (*Paralithodes and lithodes*) and Tanner crab (*Chionoecetes spp*.) reside. This description of crab habitat is most concerned with the eastern Bering Sea encompassing the extensive shelf of Bristol Bay along the Alaska Peninsula, north to St. Matthew Island, seaward to the shelf-break that runs from southeast to northwest (Figure 3.1-1). This is because crab resources are usually much smaller and information less available in the Aleutian Islands.

3.1.1 Structure and classification of the eastern Bering Sea

The broad eastern Bering Sea shelf is not covered by a homogeneous water mass, but rather is composed of three water mass domains distributed over several hundred kilometers from shore to the shelf break (200 m), roughly delineated at boundaries (fronts) of summer to fall water masses (Figure 3.1-2). The inner front, at about 0-50 m depth, bounds the Coastal Domain which is a generally well mixed water column from surface to bottom (Figure 3.1-3). The Middle Domain occurs from about 50-100 m depth and is a two-layered water column for much of the year, especially in spring and summer when crab larvae are in the column (see "Larvae" below). Water in the upper layer tends to become warmer and that in the lower layer down to the seafloor can remain very cold (Figure 3.1-3). The Outer Domain extends from about 100 m to the shelf edge at 200 m depth. This water column may have three or more layers created by stratified layers of coastal-shelf waters near-surface, mid-layer, and oceanic waters at the bottom. In a broad 2-dimensional sense across the domains from shore to shelf edge (Figure 3.1-2), and when viewed vertically through the water column at any point (Figure 3.1-3), there are frequently very different physical properties (temperature, salinity, current direction, and strength) and biological communities including food and predators affecting crab.

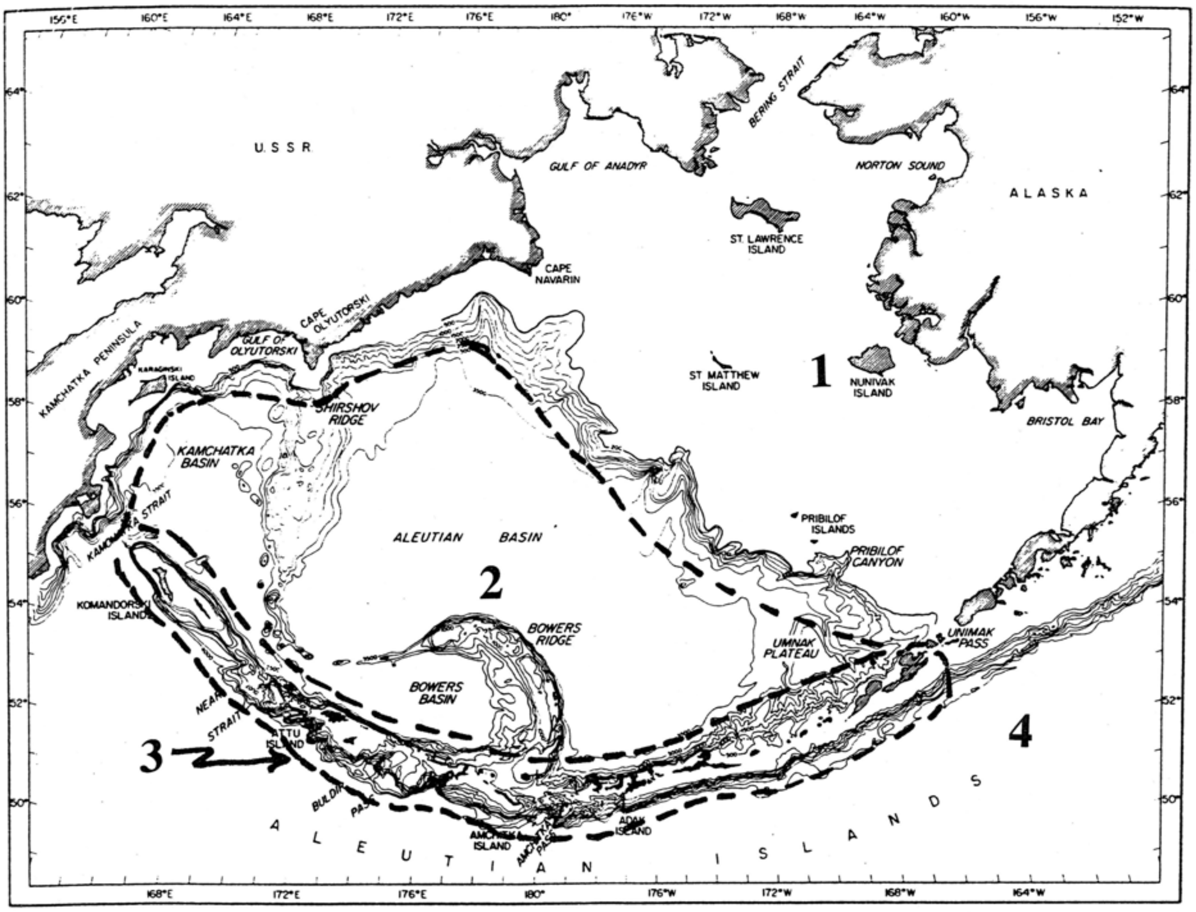


Figure 3.1-1 Bering Sea Map including the main Aleutian Basin and the extensive eastern Bering Sea shelf (National Research Council 1996).

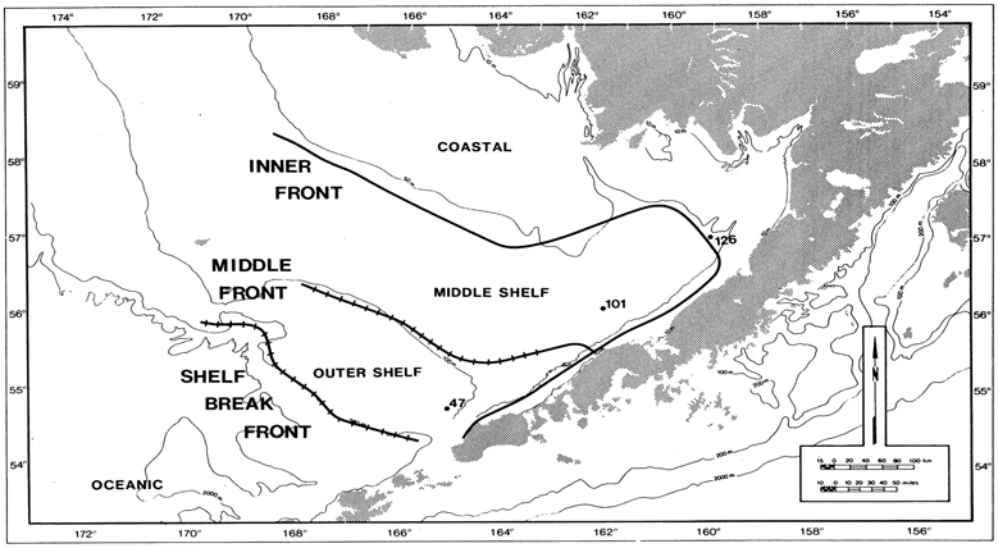


Figure 3.1-2 Three Oceanographic "Domains" of the eastern Bering Sea shelf marked by fronts as boundaries between water masses of very different properties (Kinder and Schumacher 1981; Schumacher and Reed 1983).

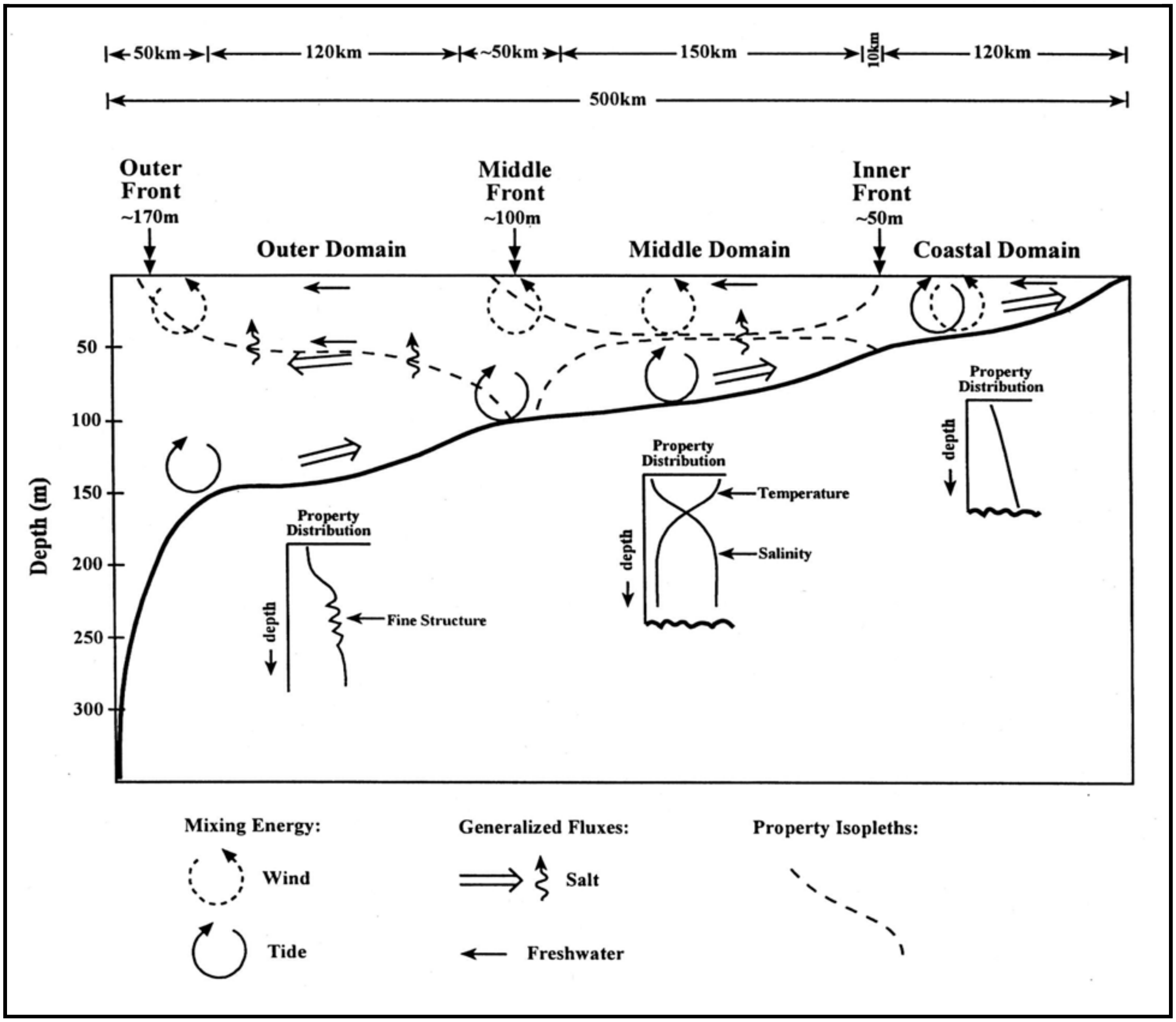


Figure 3.1-3 Cross-Section of the water column and its major features spanning the three domains (Kinder and Schumacher 1981).

3.1.2 Crab life history influenced by the ecosystem

Several significant aspects of king and Tanner crab life histories are central to understanding the ecosystem's role and impacts to crab ecology and population dynamics (Sections 3.2.1 and 3.2.2). Significant changes in relative abundance of crab species over time are obvious in National Oceanic and Atmospheric Administration, National Marine Fisheries Service, (NOAA Fisheries) trawl surveys and fishery data. Such significant changes in abundance may reflect effects of ecosystem processes that control different life history stages and, ultimately, commercial fisheries for these species. How does this happen? What leads to high or low abundance? What state of high or low is normal? There is wide opinion among scientists as to underlying causes, but highlighting crab life-history stages can help explain the impacts of physical and biological processes that shape populations over time.

Larvae

Eggs hatching, usually April to June, is followed by a series of planktonic larval stages that float/swim in the water column (the pelagic zone) (see Figure 3.2-7 for schematic of the life cycle for snow and Tanner crab). Zoea and megalops larvae are weak swimmers that tend to react to stimuli such as increased light and lower pressure which put them near the surface of the ocean. Their rate of development is controlled by temperature and may take 70-90+ days before they are ready to settle to the ocean bottom (the benthos). During these long periods of floating in the water column, they are carried variable distances by currents generated by winds, tides, and other differences in properties between water masses (temperature and salinity). Larvae have very limited behavioral ability to control where they go (for instance, they can be high or low in the water column in accord with tides and wind direction), they are generally passive and are carried with prevailing currents. In some years, conditions may make the currents stronger over longer periods and so larvae are transported farther, and vice versa (this is a very simplified portrayal and other factors such as location and timing of hatch also affect direction and distance of transport). By the time larvae are ready to settle to the seafloor bottom, they may be in areas of good or poor habitat relative to features of the substrate, type and amount of food, and degree of protection from predators. In many years, it is possible that most crab larvae of several species are transported away from parental grounds, are swept over the edge of the shelf, or settle to encounter high abundance of predators—all of which can lead to poor survival.

Because individuals of king, snow, and Tanner crab species are long-lived (10-20+ years; see Sections 3.2.1 and 3.2.2), it is not imperative that good larval survival occur every year. In contrast to cold-water crab species of the eastern Bering Sea, species of tropical shrimp, for example, frequently mature at age 1 and die by age 2; so each year's production of larvae is important in determining the next year's adult population. Over time, eastern Bering Sea crab can likely sustain several years of low larval survival without large changes in the adult population. Therefore, physical processes that sometimes adversely affect survival of this early larval stage are not necessarily detrimental to the adult reproducing population. Physical processes that directly (e.g., currents, temperature) or indirectly (e.g., timing of ice melt, supply of nutrients that promote food supply, vertical structure of the water column that enhances or diminishes feeding opportunity) affect larvae are operative weeks to a few months each year during the larval stage. In this sense, strength of a larval year class (the year in which a crab cohort hatches from eggs carried by females) may be determined over a relatively short period of time in spring to early summer.

Longer periods of several years in which physical processes are either favorable or adverse to good larval survival, can markedly change overall abundance and spatial distribution of juvenile and adult population segments over large areas of the eastern Bering Sea shelf (Wooster and Hollowed 1995; National Research Council 1996; Niebauer et al. 1999). There is strong evidence for environmental phases over time called regimes in which sets of characteristics such as water temperature, direction of prevailing winds, extent of annual ice cover are in one state (e.g., warm, from the south, little ice cover, and early ice melt), then shift (regime shift) to a different state that may be colder, driven by winds from the north off the continent, extensive ice cover for longer time each year, and larger resultant pools of very cold bottom-water. The attributes of either regime drive a complex web of other species (Wyllie-Echeverria and Wooster 1998; Wyllie-Echeverria and Ohtani 1999) that affect crab populations as food or predators. For example, if Tanner crab larvae are adversely affected by cold water temperatures below 4 degrees Celsius (°C) (slow rate of growth or no growth, low metabolism), then even if they are broadly distributed by currents across the eastern Bering Sea, settlement and survival will occur in a limited area where temperatures are favorable. If such a condition persists for several years during a cold regime, then there will effectively be no re-population over some adult areas otherwise inhabited during warmer regimes. As a consequence, there should eventually be some contraction of juvenile and adult distribution toward the Alaska Peninsula and shelf edge where waters are generally warmer than farther north and in the cold, Central Domain of the eastern Bering Sea shelf. In a warmer regime, larval survival and settlement should increase over a broader area to the north, and such long-term patterns of contraction and expansion in species distributions are seen in the NOAA Fisheries trawl survey time-series.

Juveniles

When larvae settle to the seafloor, they metamorphosis into small juvenile crabs of 2-4 millimeter (mm) carapace width (CW). At this small size, they are easy prey for a number of fish species as well as crab and other invertebrates. The degree of survival is dependent on two primary features: 1) the extent to which larvae settle into protective substrate that reduces predation, and 2) the abundance of predators in the vicinity. Juvenile red king crab, *Paralithodes camtschaticus*, are dependent on nearshore habitat along the Alaskan Peninsula to the far end of Bristol Bay and have requirements for complex structure such as cobble, empty bivalves shells, and living biogenic habitat such as algae, sponges, seastars and hydroids that provide 3-dimensional configurations in which they hide. (McMurray et al. 1984; Loher and Armstrong 2000; Loher 2001). Juvenile blue king crab, *Paralithodes platypus,* are very restricted to shell and biogenic habitat close to islands such as the Pribilofs Islands and St. Matthews Island (Armstrong et al. 1985; Palacios et al. 1985). In both cases, the spatial extent of such habitat is relatively limited across the eastern Bering Sea, and larvae may be hatched in areas and transported long or short distances in ways that increase or decrease the likelihood of settling to such benthic refuge. Both snow crab, *Chionoecetes opilio*, and Tanner crab, *C. bairdi*, juveniles survive in/on a sand-mud substrate. Survival is probably most dependent on proximity and abundance of fish predators whose distribution and abundance over time is generally controlled by the nature of physical processes and resultant biotic community in different regimes of conditions.

Adults

Abundance of adults is the result of egg, larval, and juvenile survival over time and space. Adult stages may move in response to adverse or beneficial conditions within and across regimes over time, and domains over space. For example, adult female snow crab appear to move through their lives as regular occurrence from shallower to deeper water across the shelf (Jose Orensanz, Billy Ernst and David Armstrong, University of Washington, Seattle; unpublished data; see Section 3.2.2). Following a regime of relatively cold conditions in the early 1970's, the mature female population contracted (perhaps due to lower larval recruitment or higher predation) and/or moved father northwest (NW) during a warmer regime (Figure 3.1-4). Adult female red king crab seem to have redistributed beginning in the early 1970's from areas north of the Alaskan Peninsula to areas as far southwest (SW) as Unimak Pass. Adults may have been avoiding extremely cold midshelf areas that were prevalent from 1971-1976. Prior to 1971, adult females were found mostly to the north or east of Amak Island (ca 163°W. longitude), then centered north of Unimak Islands in 1972, 1974, and 1975, and then centering back to the eastern areas in the late 1970's. It is possible that some of the crab found in North Unimak Pass resulted from larvae originating in the Gulf of Alaska (GOA) and drifting west or north with the Alaska coastal current system.

As a result of large-scale changes in benthic adult distribution, eggs are carried and larvae hatched in different geographic areas across decades. Spatial location of females when eggs hatch may have great consequence for direction and extent of larval transport, the amount and nature of food available in the water column during development (Incze et al. 1987), and where larvae eventually settle (good or bad refuge substrate) (see Sections 3.2.1 and 3.2.2). As noted above, adults of these species are fairly long-lived. Female king crabs have 5-10+ years of mature reproductive life to produce successful larval broods (Jensen and Armstrong 1989), but snow and Tanner crab females may have only two or three primary reproductive years. Still, it is possible to have several failed larval year classes that will not curtail overall adult abundance since long-lived species may eventually produce one strong year class in their lifetime.

3.1.3 Currents and circulation

Patterns and nature of currents and circulation are well described (Niebauer et al. 1999), and a generalized depiction is shown in Figure 3.1-6. The Alaskan Coastal Current enters the eastern Bering Sea through Unimak Pass and several major passes along the Aleutian Islands (Reed and Stabeno 1999), and moves east onto the eastern Bering Sea shelf as a cyclonic (counterclockwise) gyre (Figure 3.1-6). Much of the Alaska Coastal Current that enters through Unimak Pass flows either northwest along the eastern Bering Sea shelf slope (Bering Slope Current), or continues in a slow counterclockwise direction nearshore within the Coastal Domain along the north side of the Alaska Peninsula to the end of Bristol Bay, then west-northwest. Recent genetic studies (Alaska Department of Fish and Game [ADF&G] unpublished data) indicate that red king crab from Kodiak to Bristol Bay are homogeneous, suggesting that there may be a metapopulation connection between the GOA and eastern Bering Sea red king crab populations. This is a possibility for Tanner crab as well. Long-term averaged speeds are relatively fast within the Bering Slope Current (5-20 centimeters per second [cm/s]), are slower nearshore along the Peninsula (1-5 cm/s), and very weak within the Central Domain (Figure 3.1-6) where there is virtually no net directional flow (Figure 3.1-7). Sources of energy that cause water to move as currents include tides, winds, and differences in properties across adjacent water masses (baroclinic currents, e.g., warmer, less saline water on one side; colder, saltier water on the other).

The importance of currents in the life history of eastern Bering Sea crab relates to larval stages, and the net direction and distance larvae may be transported from point of hatch. As noted, location of females plays a role since the larvae of one parent spawning near the shelf break edge or on the slope may be transported northwest at relatively fast speeds, while larvae from a female hatching in the Middle Domain may effectively remain in the immediate locale for their entire developmental period (see Figure 3.1-7 for sense of direction and speed of currents that might transport larvae of the same species hatched in very different regions). Loher (2001) constructed a model of wind and currents to study potential direction and distance red king crab larvae would be transported in the eastern Bering Sea (Figure 3.1-8). Those hatched nearshore within the Inner Domain, and those entrained in the Bering Slope Current may be carried 100-175 km, while those hatched within the Middle Domain travel less than 1 km during pelagic development that may last 2 to 3 months. Given such potential distances, it would seem difficult for larvae of some species of restricted adult distribution to ever settle back to parental grounds. Blue king crab are closely tied to the Pribilof Islands, for example, and general northwest circulation would seem to move larvae away from those islands. However, small-scale eddies and local tidal currents with little net displacement are operative around islands and other bathymetric features (Stabeno et al. 1999) (Figure 3.1-9). Drifters deployed to measure direction and speed of currents around such islands are often entrained in clockwise circulation close to shore in repeated rotations, which suggests that larvae could remain in close proximity during pelagic development and settle nearshore around such islands.

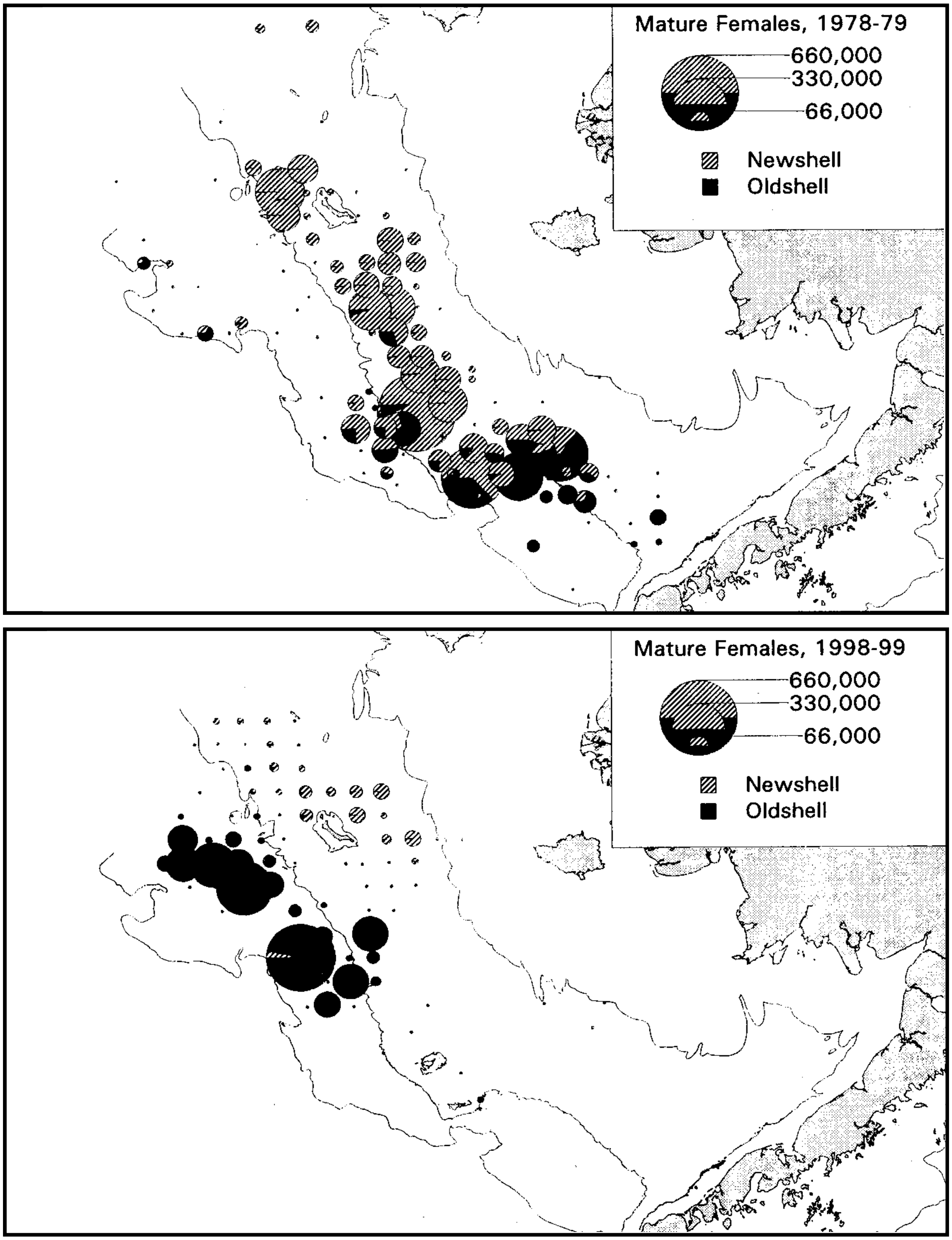


Figure 3.1-4 Change in distribution of mature female snow crab from a period following a cold regime in the later 1970's (Top) to a warm regime in the late 1990's (Lower) (Zheng et al. 2001).

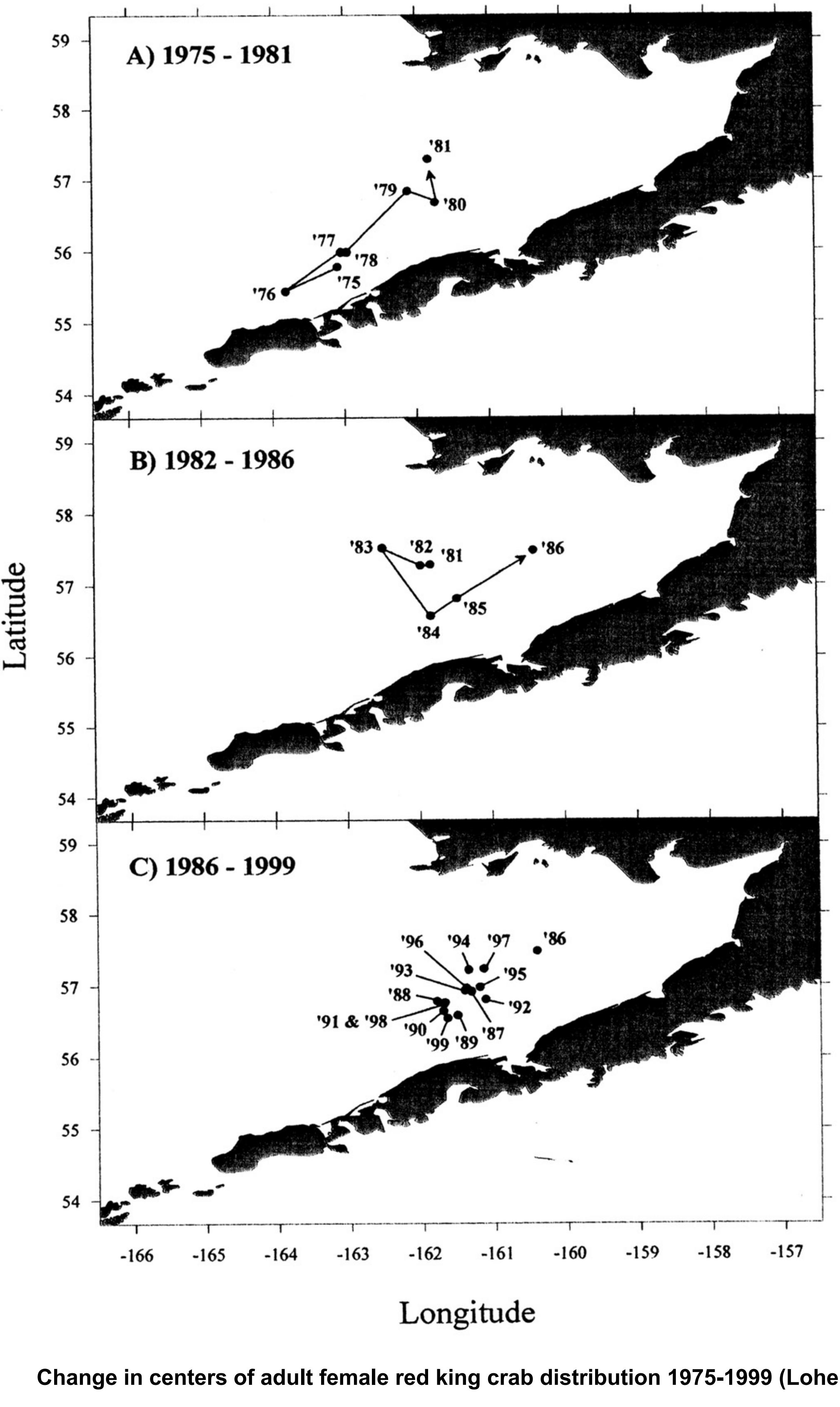


Figure 3.1-5 Change in centers of adult female red king crab distribution 1975-1999 (Loher 2001).

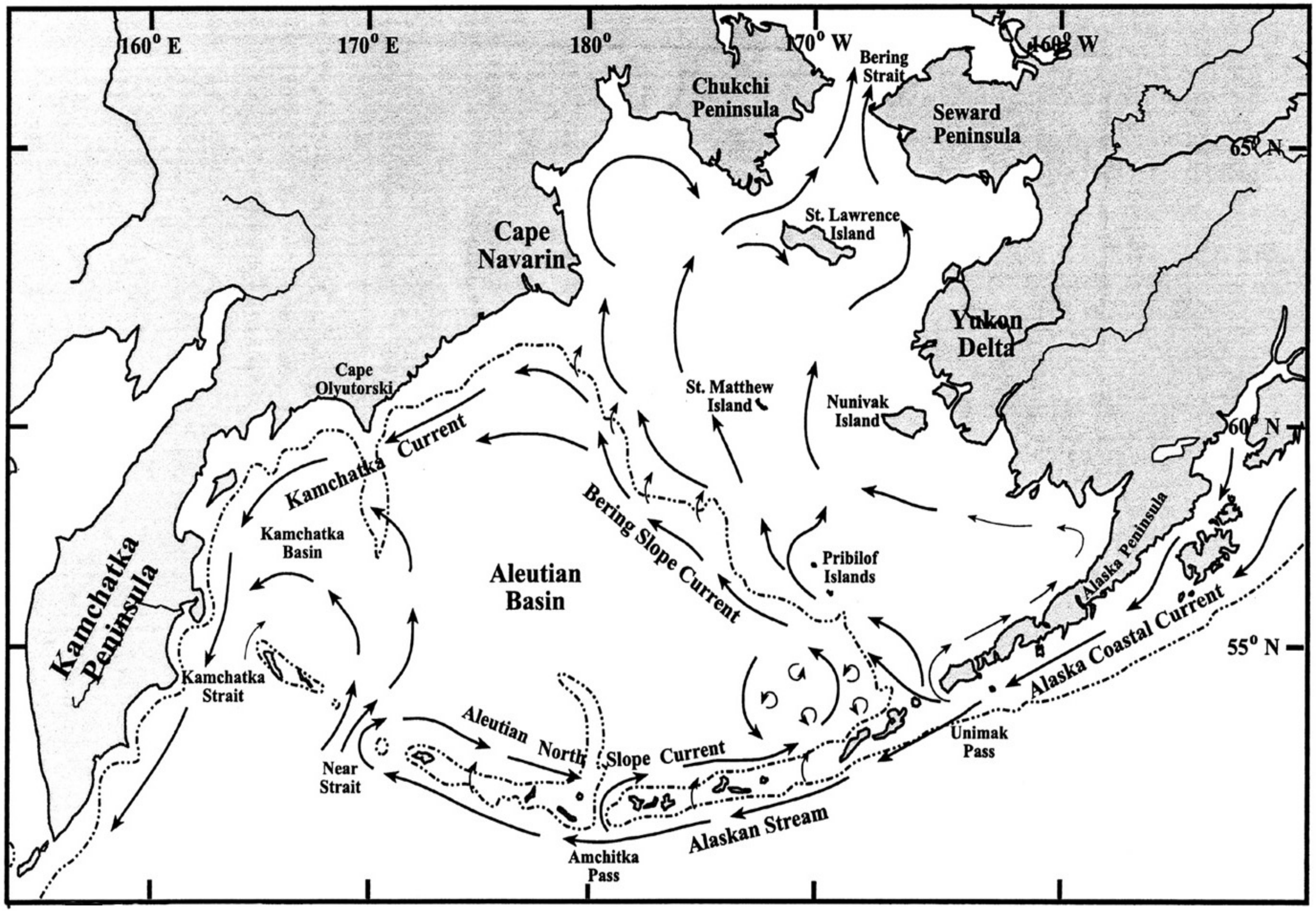


Figure 3.1-6 Major currents and direction of water flow throughout the Bering Sea (Loher 2001).

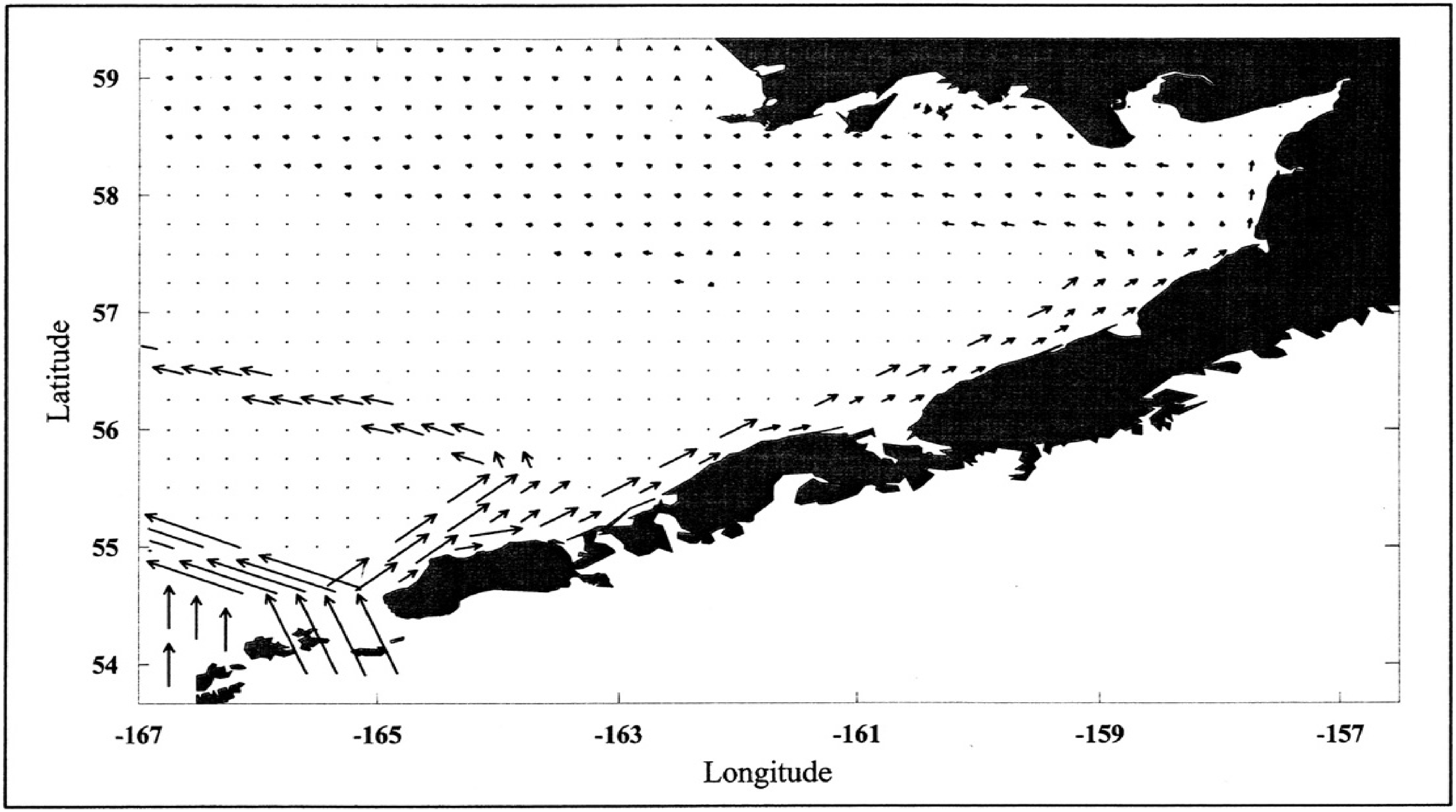


Figure 3.1-7 Relative direction and speed of currents over part of the eastern Bering Sea Shelf Based on Long-term Averages (Loher 2001).

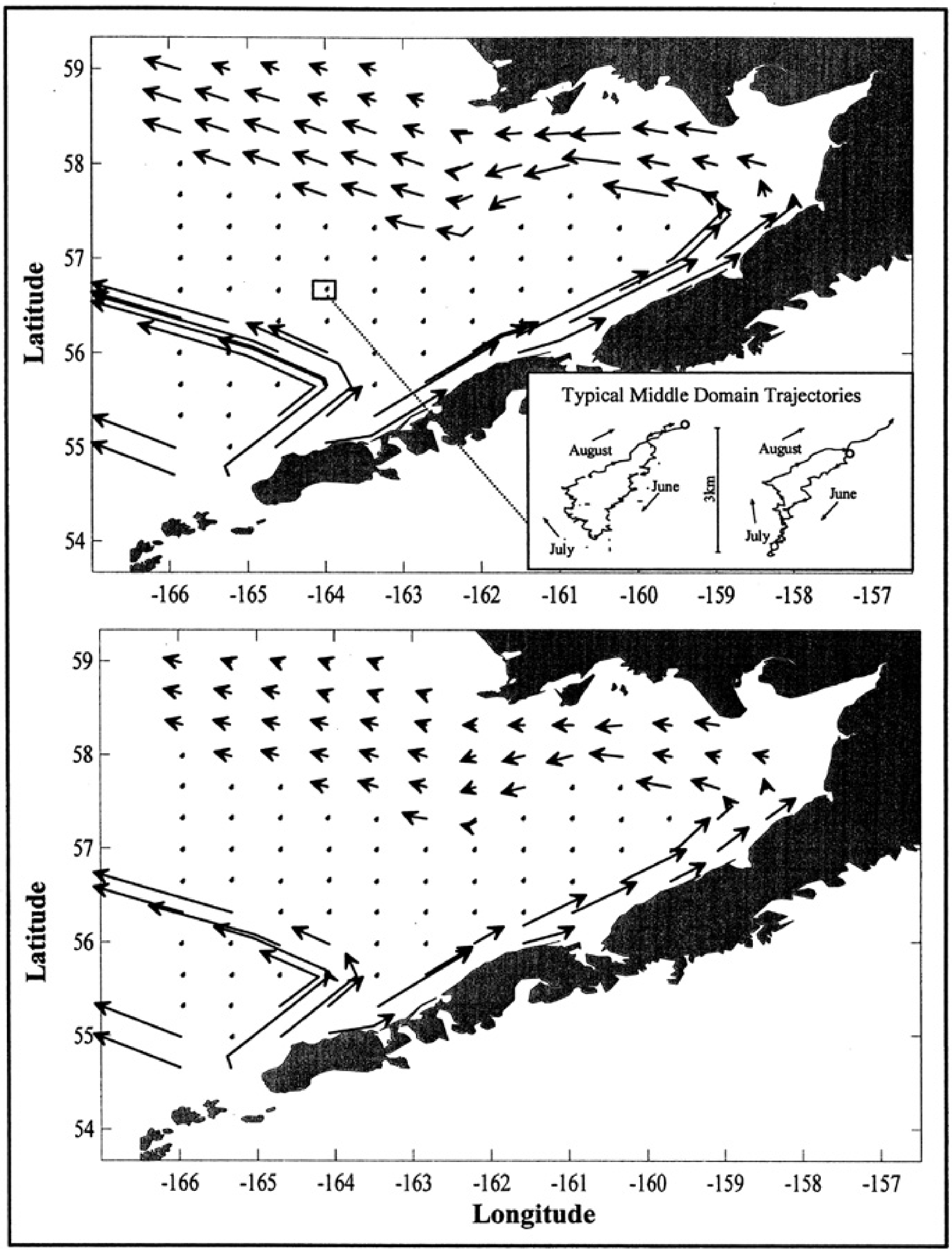


Figure 3.1-8 Model estimates of direction and distance red king crab larvae would be transported in the water column by currents during development (Loher 2001).

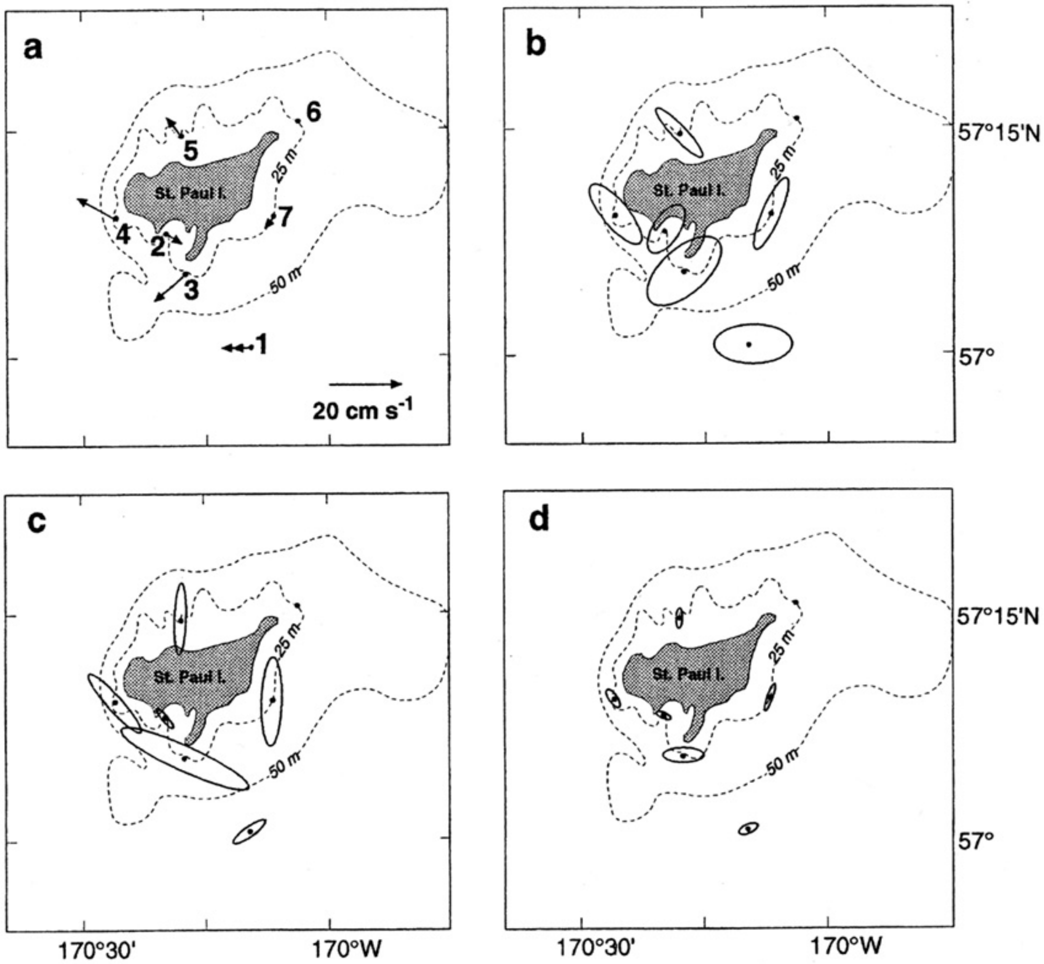


Figure 3.1-9 Relative speed of currents and tidal displacement around St. Paul Island (Stabeno et al. 1999).

Tidal currents are predictable in time and space across years and account for a majority of circulation and mixing in the Outer and Middle Domains (Coachman 1986; Schumacher and Stabeno 1998), yet likely do not account for high interannual variability in relative distance larvae are transported. But currents derived from winds or sharp gradients (baroclinic) in properties across adjacent water masses can vary tremendously from one year to the next, and result in stronger or weaker currents, and more or less larval transport. The magnitude of currents based on these properties is determined by weather to a large degree.

3.1.4 Weather

Weather patterns strongly influence and determine many dominant features of eastern Bering Sea domains that, in turn, drive abundance and distribution of species. Some aspects of these weather patterns originate many thousands of km away in the tropical Pacific (e.g., the Southern Oscillation-El Nino phenomenon, which ultimately may drive weather patterns in the upper atmosphere in the northern hemisphere), or more locally based on position and strength of the Aleutian Low pressure system that determines direction and strength of winds and, in turn, extent and duration of sea ice and water temperature (Stabeno et al. 1999, Niebauer et al. 1999; Schumacher and Alexander 1999). During winter, a low-pressure system establishes along the Aleutian Chain (the Aleutian Low) that normally draws cold arctic air from the northeast (NE) continental landmass across the eastern Bering Sea (NE to SW flow). This cold air drives the formation and pushes the southern extension of sea ice, a major and pervasive feature of the eastern Bering Sea. The winter storm-track pattern that results from the Aleutian Low is from west to east. Several indices have been developed to characterize attributes of this winter event (National Research Council 1996, Niebauer et al. 1999) that reflect various features of sea-level pressure, water temperature and height or elevation (water can stack up against or away from coastlines based on wind direction); all measures of change in conditions caused by weather. Based on an Aleutian Low Pressure Index (ALPI), storms are more frequent and/or more intense when the ALPI intensifies, or winters are less severe when the ALPI declines. The position (more east or west) of the Aleutian Low can affect strength and frequency of storms and weather: a more easterly position allows southerly, warm air to blow south to north in winter, which reduces ice cover and results in warmer water temperatures, and a westerly position results in the opposite (i.e., colder conditions).

3.1.5 Ice and water temperature

Up to 75 percent of the eastern Bering Sea shelf water is covered by ice in late fall-early spring. The advance and retreat of Bering Sea ice averages about 1,700 km north-south and is the most extensive such process in Arctic regions (Niebauer et al. 1999). Most striking about the annual cycle of ice formation and melt is the substantial variability in the extent of coverage over the shelf from one year to the next, determined in large measure by weather patterns noted above. Relative to the Bering Strait as a reference point, long-term average winter weather conditions cause ice to form about 900 km father south-southeast of the Bering Strait. In warm years ice extends only 700 km, and in cold years more than 1,100 km south of the Bering Strait (Figure 3.1-10; Niebauer 1981; Niebauer et al. 1999). Periods of several years of greater or lesser extent of ice coverage are evident during cold and warm regimes (Figure 3.1-11; Niebauer et al. 1999). A cold regime persisted until about 1976, during which time winter winds were out of the north off Asia-Siberian landmasses, air temperatures were cold, ice formation began early and extended far south into the eastern Bering Sea over much of the shelf. After 1976, the Aleutian Low intensified, warmer maritime winds blew from the south to north and limited ice to the upper portion of the eastern Bering Sea shelf (Figures 3.1-10 and 3.1-11). An informative series of relationships were given by Wyllie-Echeverria and Wooster (1998) (Figure 3.1-12) that shows how far south ice occurs in years when winter winds were either off land from the north and cold, or maritime from the south and warmer.

Extent and duration of sea ice affects important properties of the water including temperature, salinity (a huge freshwater input when surface freshwater ice begins to melt over salt water), extent of mixing of the water column, and timing and amount of nutrients that drive primary production of phytoplankton and secondary production including crab larvae (see several reviews in Loughlin and Ohtani 1999). As ice melts in spring, the less saline water floats over higher salinity marine water, and this upper layer is heated, which results in stratification of the water column; warmer less dense water in the upper layer, colder denser water in the bottom layer (Figure 3.1-3). Crab larvae develop in the upper portion of the pelagic zone where higher temperature and greater food production benefit growth rate. But the stratified water column also traps an extensive cold pool layer (water <2°C) down to the seafloor over a large area of the eastern Bering Sea. In summer this cold pool averages 200 km north to south and 500 km east to west, but following very cold winters the E-W axis of the cold pool may extend 1,300 km across most of Bristol Bay in the eastern Bering Sea (Figure 3.1-13). Following a warm winter, there may be virtually no cold pool over the eastern Bering Sea-Bristol Bay region (e.g., 1979), or the cold pool may cover most of this region following a cold winter such as in 1995 (Figure 3.1-14).

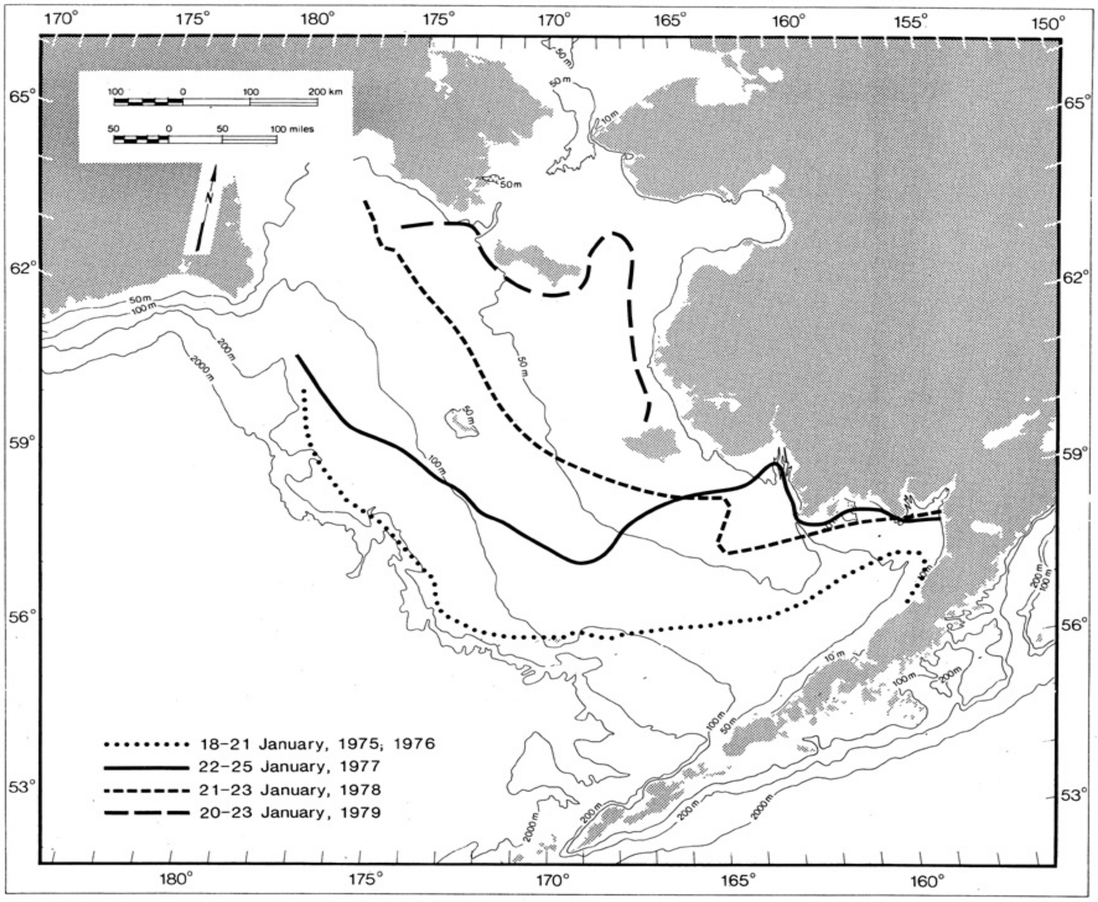


Figure 3.1-10 Position of the winter ice edge farther south in cold years (around 1975), but much farther north in warmer years (beginning about 1978) (Niebauer 1981; Niebauer et al.1999).

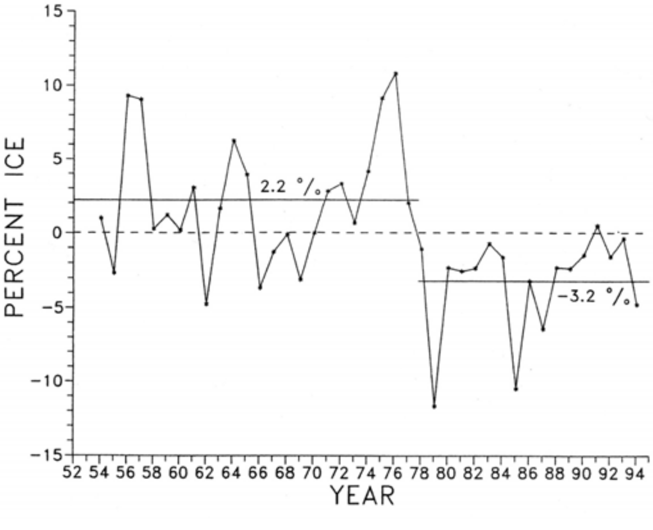
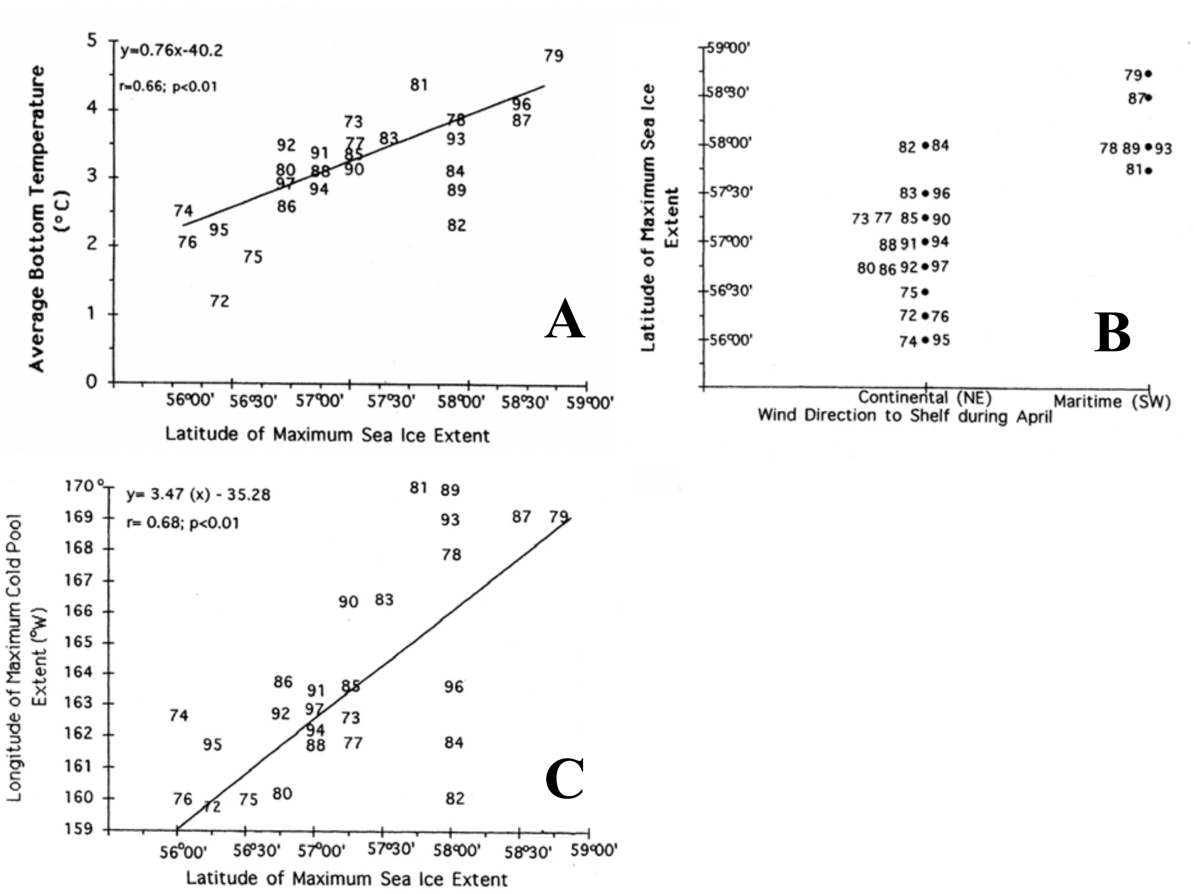


Figure 3.1-11 Index of relatively more ice cover over the eastern Bering Sea during the early 1970's, but less coverage during a warmer period after 1976 (Niebauer et al. 1999).

Figure 3.1-12 Relationships between spatial coverage of winter sea ice and water temperature over the eastern Bering Sea relative to latitude (A), wind direction (B), and longitude (C) (Wyllie-Echeverria and Wooster 1998).



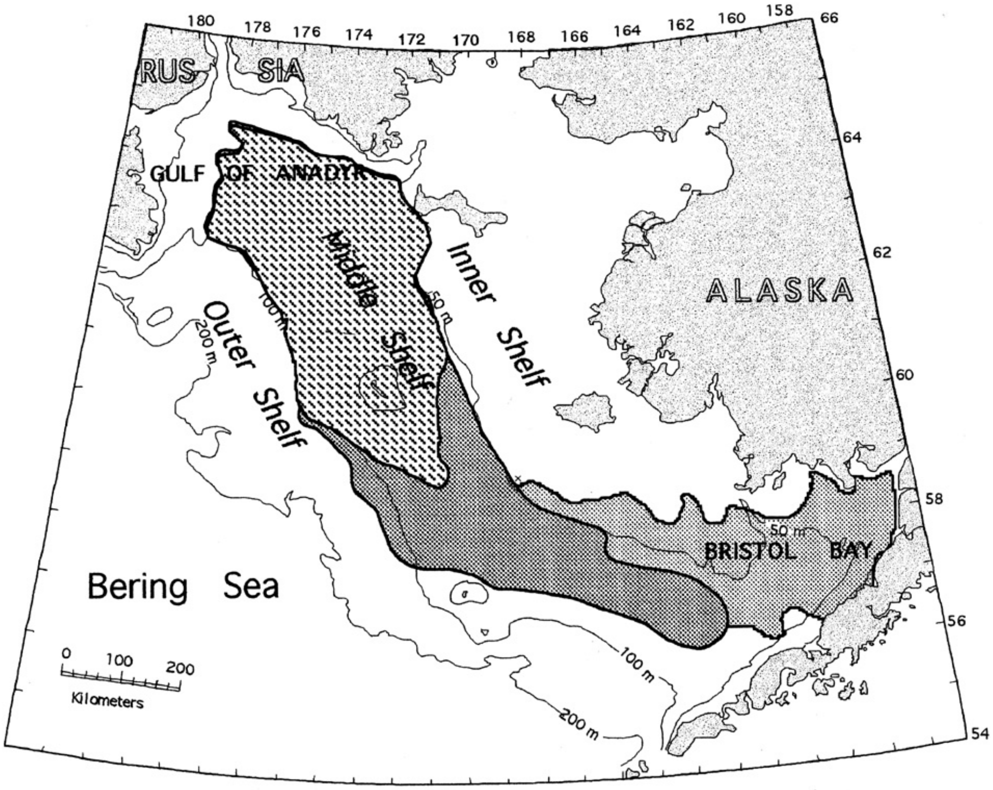


Figure 3.1-13 Extent of the cold pool of bottom water over the eastern Bering Sea shelf in warm compared to cold years (Wyllie-Echeverria and Wooster 1998).

3.1.6 Substrate

The eastern Bering Sea sediments are a mixture of the major grades representing the full range of potential grain sizes of mud (subgrades clay and silt), sand, and gravel. The relative composition of such constituents determines the type of sediment at any one location (Smith and McConnaughey 1999). Sand and silt are the primary components over most of the seafloor, with sand predominating the sediment in waters with a depth less than 60 m. Overall, there is often a tendency of the fraction of finer-grade sediments to increase (and average grain size to decrease) with increasing depth and distance from shore. This grading is particularly noticeable on the southeastern Bering Sea continental shelf in Bristol Bay and immediately westward. The condition occurs because settling velocity of particles decreases with particle size (Stokes Law), as does the minimum energy necessary to resuspend or tumble them. Since the kinetic energy of sea waves reaching the bottom decreases with increasing depth, terrigenous grains entering coastal shallows drift with water movement until they are deposited, according to size, at the depth at which water speed can no longer transport them. However, there is considerable fine-scale deviation from the graded pattern, especially in shallower coastal waters and offshore of major rivers, due to local variations in the effects of waves, currents, and river input (Johnson 1983).

The distribution of benthic sediment types in the eastern Bering Sea shelf is related to depth. Considerable local variability is indicated in areas along the shore of Bristol Bay and the north coast of the Alaska Peninsula, as well as west and north of Bristol Bay, especially near the Pribilof Islands. Nonetheless, there is a general pattern whereby nearshore sediments in the east and southeast on the inner shelf (0 to 50 m depth) often are sandy gravel and gravelly sand. These give way to plain sand farther offshore and west. On the middle shelf (50 to 100 m), sand gives way to muddy sand and sandy mud, which continue over much of the outer shelf (100 to 200 m) to the start of the continental slope. Sediments on the central and northeastern shelf (including Norton Sound) have not been so extensively sampled, but Sharma (1979) reports that, while sand is dominant in places here, as it is in the southeast, there are concentrations of silt both in shallow nearshore waters and in deep areas near the shelf slope. In addition, there are areas of exposed relic gravel, possibly resulting from glacial deposits. These departures from a classic seaward decrease in grain size are attributed to the large input of fluvial silt from the Yukon River and to flushing and scouring of sediment through the Bering Strait by the net northerly current.

McConnaughey and Smith (2000) and Smith and McConnaughey (1999) describe the available sediment data for the Bering Sea shelf. These data were used to describe four habitat types. The first, situated around the shallow eastern and southern perimeter and near the Pribilof Islands, has primarily sand substrates with a little gravel. The second, across the central shelf out to the 100-m contour, has mixtures of sand and mud. A third, west of a line between St. Matthew and St. Lawrence Islands, has primarily mud (silt) substrates, with some mixing with sand. Finally, the areas north and east of St. Lawrence Island, including Norton Sound, have a complex mixture of substrates.

The Aleutian Islands have complicated mixes of substrates, including a significant proportion of hard substrates (pebbles, cobbles, boulders, and rock), but data are not available to describe the spatial distribution of these substrates.

3.1.7 Change in other species within the ecosystem

The cold pool may persist over larger or smaller areas of the eastern Bering Sea for several consecutive years (a property that changes with regime shifts; Figure 3.1-15), and the degree of spatial coverage has strong influence on the abundance and distribution of benthic (bottom-dwelling) species of fishes and invertebrates including crab. Red king crab and Tanner crab likely avoid such cold bottom water while snow crab can tolerate it. Several major predators of crab, or dominant consumers within the community, shift their distribution as well in response to relative extent of the cold pool. Adult pollock, Pacific cod, thorny sculpin, and Greenland turbot have more extensive distribution over the eastern Bering Sea shelf during warm regimes compared to cold; arctic cod show the converse (Figure 3.1-16). Adult pollock during a warm year such as 1984 were distributed north to 61°N latitude, but did not occur north of 58°N latitude in 1976, a cold year (a difference of over 300 km) (Wyllie-Echeverria and Wooster 1998). Arctic cod were 120 miles farther south in the cold year. Many species of flatfish, sculpin, and cod that are common in the eastern Bering Sea prey on small juvenile stages of *Chionoecetes* spp. crab (Mito et al. 1999), and changes in abundance mirror cold-warm periods after regime shifts from one state to the other. Following regime shifts from cold to warm in the mid-1970's, abundance (measured as biomass) of several major species of benthic flatfish increased four to six fold in the eastern Bering Sea (Figure 3.1-17).

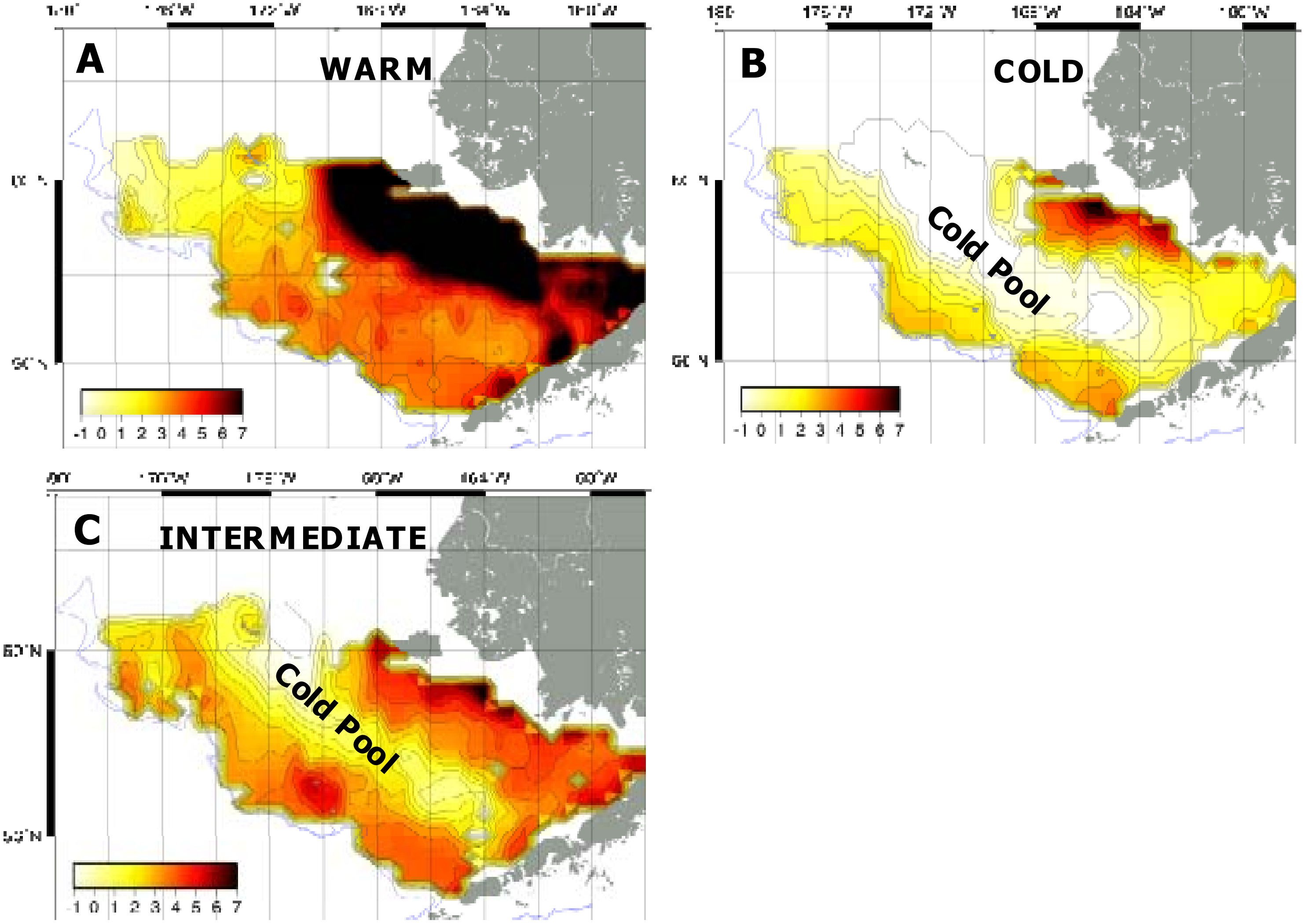


Figure 3.1-14 **Summer bottom water temperatures over the eastern Bering Sea showing extent of the cold pool in warm compared to cold years (Ernst, Orensanz, and Armstrong unpublished data).**

Figure 3.1-15 **Average summer bottom water temperatures over the eastern Bering Sea Bristol Bay NOAA Fisheries survey area from about 1970 to 1999 (Loher 2001).**

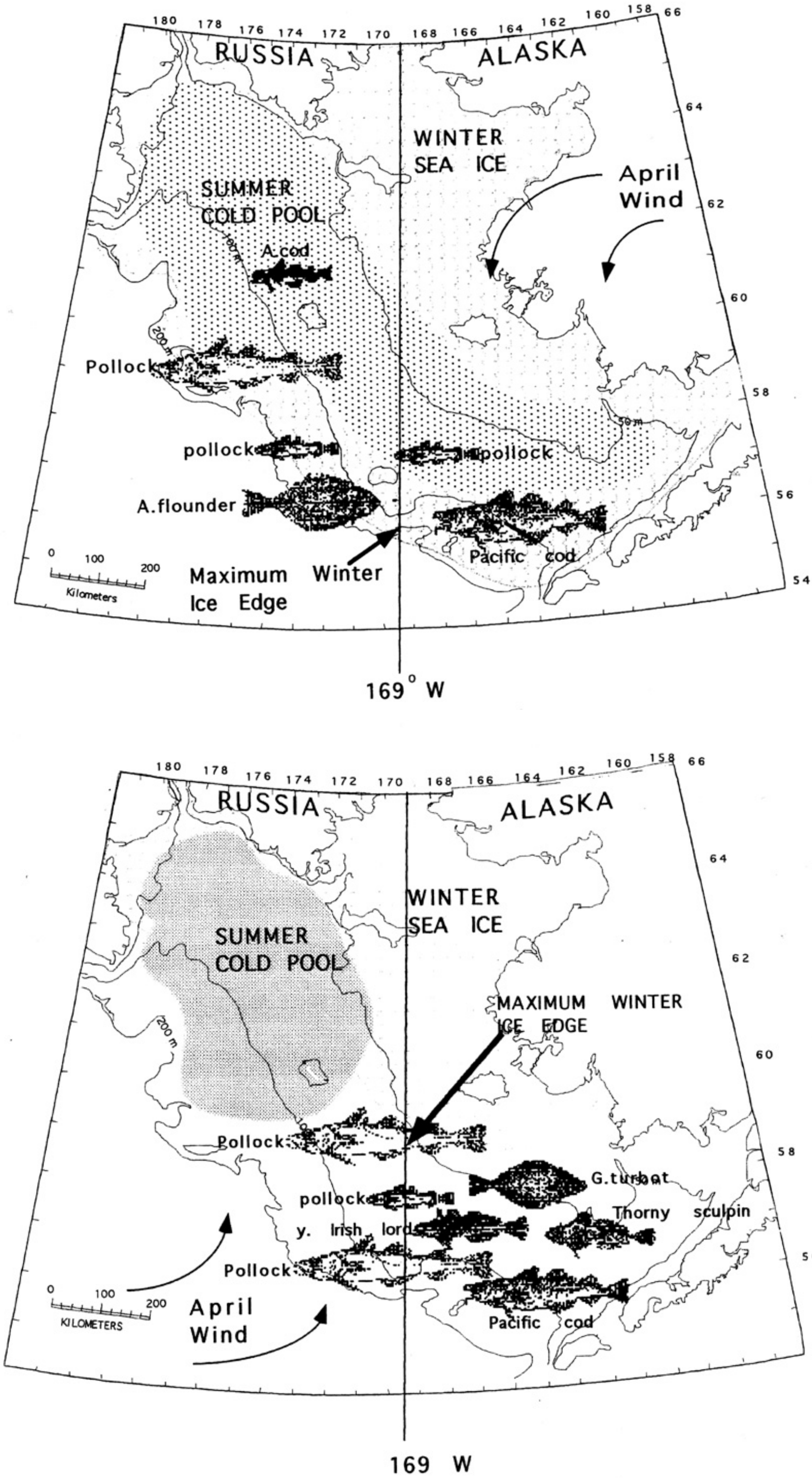


Figure 3.1-16 Generalized distribution of several species of fishes over the eastern Bering Sea during cold (Top Panel) compared to warm (Bottom Panel) regimes (Wyllie-Echeverria and Wooster 1999).

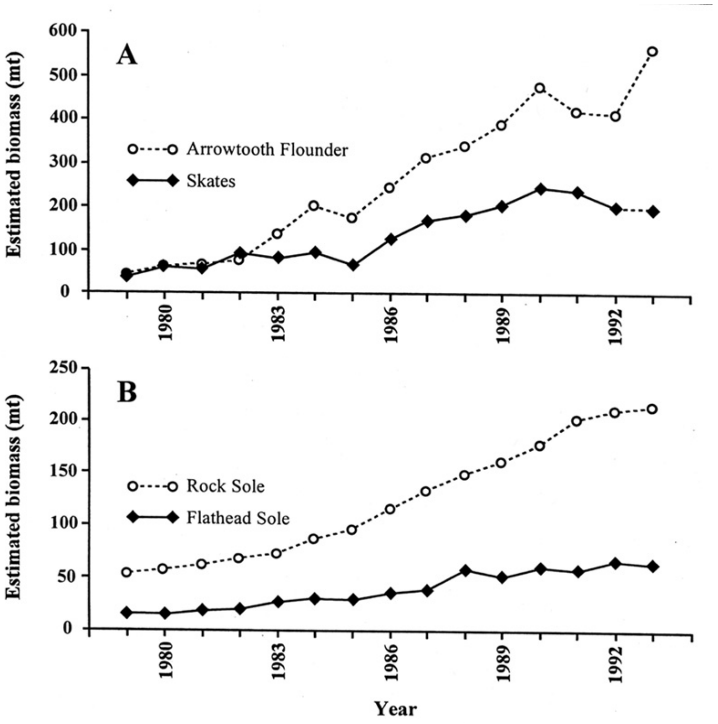


Figure 3.1-17 Trends in abundance of flatfish in the eastern Bering Sea from 1975-1993 (Loher 2001).

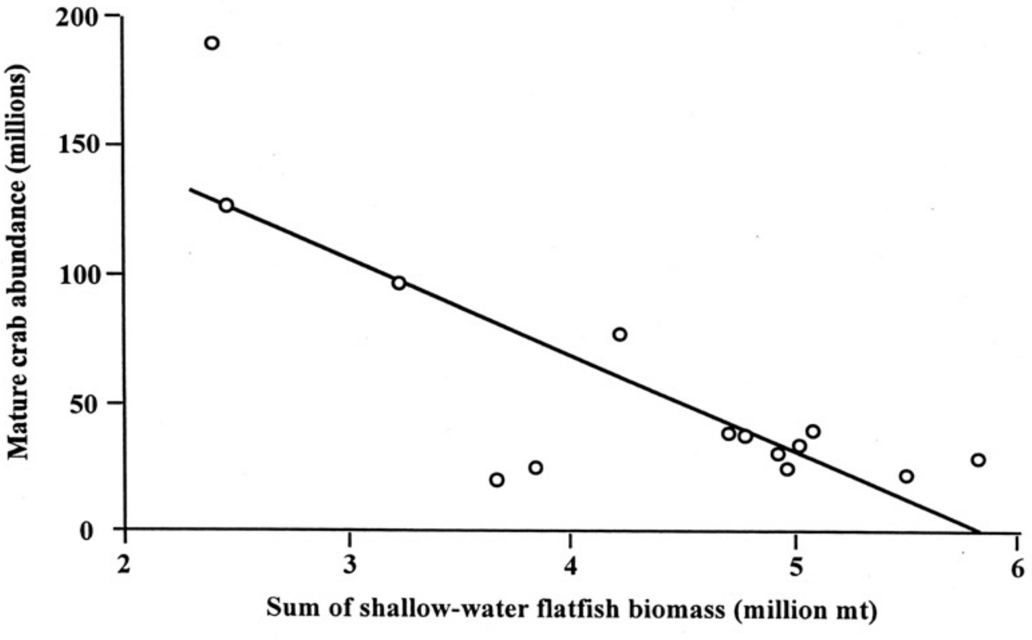


Figure 3.1-18 Relationship between number of fish predators and abundance of king crab in the eastern Bering Sea (Otto, NOAA, Kodiak, Alaska).

There is evidence of negative effects of increased number of fish predators on abundance of king crab in the eastern Bering Sea (Figure 3.1-18), which may hold true for other crab species as well. The mechanisms through which the meteorological regime shift is proposed to have acted on the adult stock are disease and increased groundfish predation by yellowfin sole (*Limanda aspera*) and Pacific cod (*Gadus macrocephalus*). For example, cod fish eat king crab during the molting period, that cod fish biomass rose sharply while Bristol Bay red king crab was declining rapidly and that there is a strong negative correlation (1979-2000, $r= -0.68$, $r^2 = 0.46$, 19 df, $P<0.01$) between assessed Pacific cod biomass and Bristol Bay red king crab spawning stock biomass. While we cannot definitely say that cod fish cause the Bristol Bay red king crab stock to decline, it may have been a factor. Similarly, if we lag the biomass of yellowfin sole, as a larval predator, by four years to earliest king crab maturity the correlation is again strong (1979-2000, $r = - 0.71$, $r^2 = 0.84$, df = 19, $P < 0.01$). If we combine these two ideas into a simple variable regression with interaction, the resulting equation accounts for over 96 percent of the variation in red king crab abundance over the same period.

However, the theory that groundfish predation caused the decline in crab abundance is controversial and was rejected by Kruse and Zheng (1999). Existing data indicate that yellowfin sole eat only the larvae of red king crab (Haflinger and McRoy 1983). Bakkala (1981) cited several food-habit studies showing that 50 different taxa were found in yellowfin sole stomachs throughout a broad area of the eastern Bering Sea, with no mention of red king crab as a prey item. Haflinger and McRoy (1983) characterized their yellowfin sole stomach-content data as "uncertain" because the estimated consumption of red king crab larvae was extrapolated largely from a single yellowfin sole (of 1,239 examined) that had eaten an extraordinary number of larval red king crab. Using Haflinger and McRoy's data, Jewett and Onuf (1988) calculated that the extrapolated number of red king crab larvae consumed by all the yellowfin sole in the southeastern Bering Sea may have represented 5% of the larvae available that year. If we account for the low reproductive value of an individual larva in terms of the estimated number of offspring it will likely contribute to the next generation, the population-level impact of larval losses on the order of 5-10% is negligible (e.g., Slobodkin 1970). Similarly, extensive data on the food habits of Pacific cod in the eastern Bering Sea demonstrate that cod predation, which accounted for an estimated loss to the mature female red king crab population of 1-4% during 1981-85 (Livingston 1989), was not a significant factor in the mature-female decline of 85-90% during the same 1981-85 time period. Moreover, Livingston (1989) found that Bering Sea cod ate less red king crab as the abundance of crab declined, a density-dependent pattern common among predators with a wide spectrum of prey species. Thus, the mortality arising from cod predation on red king crab is compensatory. Unlike the depensatory effect of predation in a single-prey system, compensatory predation tends to stabilize a prey population, not drive it toward extinction (e. g., Whittaker 1975).

3.2 Crab life history approach (physical and biological)

This section discusses in detail the life history of the crab species managed under the FMP and presents the reader with the life history of each crab species, identifying the biology and environmental requirements at each life stage, to the extent scientific information is currently available. This first section provides a general overview of crab life history, distribution, and the current status of the stocks. Sections 3.2.1 and 3.2.2 focus on the life history of king and Tanner crabs, respectively. In addition, this section provides more detail on the ecosystem relationships of the crab species at each life stage, including habitat requirements and predator/prey relationships. Best available information is presented for each species although the level of detail varies greatly because the level of scientific knowledge for the different species varies greatly.

Commercially important crab species in the BSAI are: red king crab (*Paralithodes camtschaticus*), blue king crab (*P. platypus*), golden or brown king crab (*Lithodes aequispinus*), Tanner crab (*Chionoecetes bairdi*), and snow crab *(C. opilio*). Scarlet king crab (*L. couesi*), grooved Tanner crab *(C. tanneri*), and triangle Tanner crab *(C. angulatus*) are also found in the BSAI, but their abundance is considered too low to support continuous commercial fisheries. Annual trawl surveys for crab stock assessments are conducted by NOAA Fisheries in the BSAI. A length-based analysis, developed by ADF&G, incorporates survey and commercial catch and observer data into more precise abundance estimates (Zheng et al. 1998; Zheng et al. 1995b). Various research efforts of foreign governments (Rodin 1990) and related to oil exploration have also added to our knowledge of crabs and their habitat in the BSAI area (Hood and Calder 1981). The publications of the International North Pacific Fisheries Commission are also a rich source of information (Jackson and Royce 1986).

Overview of crab life history

King, Tanner, and snow crabs share similar life cycles, although particular life cycle traits are distinct for each species. After males and females mate, the female carries eggs for approximately one year until they hatch into free swimming larvae. After drifting with the currents and tides, and undergoing several development changes, the larvae settle to the ocean bottom and molt into juveniles, which look very much like miniature adult crab. Juvenile crab settle on preferred habitat, where they continue to molt and grow for several years until they become sexually mature. Each life stage for stocks of BSAI crab is concentrated at some combination of depth, habitat, geographic area, and time of year.

In the trophic structure, crab are members of the inshore benthic infauna consumers guild (North Pacific Fishery Management Council [NPFMC] 1994a). During each life stage, crab consume different prey and are consumed by different predators. Planktonic larval crab consume phytoplankton and zooplankton and are prey for pelagic fish, such as pollock, salmon, and herring. Post-settlement juveniles feed on diatoms, protozoa, hydroids, crab, and other benthic organisms. Food eaten by king crab varies with their size, depth inhabited, and species, but includes a wide assortment of worms, clams, mussels, snails, brittle stars, sea stars, sea urchins, sand dollars, barnacles, fish parts, and algae. King crab fall prey to a wide variety of species including Pacific cod, rock sole, yellowfin sole, pollock, octopus, and sculpins (Livingston 1993). Snow and Tanner crab feed on an extensive variety of benthic organisms including bivalves, brittle stars, other crustaceans, polychaetes and other worms, gastropods, and fish (Lovrich and Sainte-Marie 1997). In turn, they are consumed by a wide variety of predators including groundfish, bearded seals, sea otters, octopus, Pacific cod, halibut and other flatfish, eel pouts, and sculpins (Tyler and Kruse 1997). Snow crab comprise a large portion of the diet of many species of skates (Orlov 1998).

Crab depend on specific benthic habitat types throughout their juvenile and adult life stages. Settlement on habitat with adequate shelter, food, and temperature is imperative to the survival of first-settling crab. Young of the year red and blue king crab require nearshore shallow habitat with significant protective cover (e.g., sea stars, anemones, micro algae, shell hash, cobble, and shale) (Stevens and Kittaka 1998). Early juvenile-stage Tanner and snow crab also occupy shallow waters and are found on mud habitat (Tyler and Kruse 1997).

Overview of surveys

NOAA Fisheries has conducted annual trawl surveys of the eastern Bering Sea to collect data on abundance, distribution and biology on five species of crabs and over ten species of groundfish. This is the major research program from which assessment data, species associations and habitat areas are derived. The area surveyed encompasses the adult distributions of most commercial species, but frequently does not cover an entire species' range. For example, immature king crab, less than three years, are typically found inshore on rocky grounds or other untrawled shallow areas. The eastern Bering Sea survey takes place annually during late May, June, July, and August in an attempt to avoid the spring crab molting periods. Over the period 1979-1994, the area covered, sampling density, and timing of the survey have been similar. The habitat of Bristol Bay red king crab has been well covered since 1968, and there is some data available from the 1950's. Abundance indices are calculated by an area-swept technique (Alverson and Pereyra 1969; Hoopes and Greenough 1970). Abundance indices are relative rather than absolute since there are very little data on catchability of juvenile crabs in the trawl or their actual availability to the survey. For management purposes, it is usually assumed that virtually all commercial-sized crab in the trawl's path are captured. Smaller males and females are probably less vulnerable than commercial-sized males. A detailed report (e.g., Stevens et al. 2002) is published each year and is also available online (http://www.afsc.noaa.gov/ kodiak/). Survey data are primarily used in stock assessment models (e.g., Zheng et al. 1998; Zheng et al. 1995b) to obtain estimates of abundance that are actually used to set quotas. Most crab-oriented survey data from the Aleutian Islands is obtained from ADF&G pot surveys (Blau et al. 1996). The ADF&G also conducts pot surveys near St. Matthew Island and a trawl survey in Norton Sound.

Overview of status of annually surveyed crab stocks

Table 3.2-1 provides summary information on the basic elements of stock condition for the six stocks that are surveyed annually by NOAA Fisheries. The Federal requirements for determining the status of the stocks are the minimum stock size threshold (MSST) and the maximum fishing mortality threshold (MFMT). These requirements are contained in the FMP and outlined in section 2.1. The MSST is 50% of the mean total spawning biomass (SB = total biomass of mature males and females, also known as TMB = total mature biomass) for the period 1983-1997, upon which the maximum sustainable yield (MSY) was based. A stock is overfished if the SB is below the MSST. The MFMT is represented by the sustainable yield (SY) in a given year, which is the MSY rule applied to the current SB (the MSY control rule is $F = 0.2$ for king crabs, and $F = 0.3$ for Tanner and snow crabs). Overfishing occurs if the harvest level exceeds the SY in one year. Guideline Harvest Levels (GHL) are developed from joint NOAA Fisheries and ADF&G assessment of stock conditions based on harvest strategies developed by ADF&G.

As well as the Federal requirements, survey results for five stocks (Pribilof blue king crab, St. Matthew blue king crab, Bristol Bay red king crab, eastern Bering Sea Tanner crab, and eastern Bering Sea snow crab) are compared to thresholds established in State of Alaska harvest strategies and regulations. ADF&G uses these thresholds to determine if a fishery should be opened and to calculate the GHL.

Table 3.2-1 MSST, 2003 spawning biomass (SB), sustained yield (SY), and 2003/2004 guideline harvest level (GHL) estimates for BSAI king and Tanner crab stocks. Estimated values are in millions of pounds.

Stock	MSST	2003 SB	2003 SY	2003/2004 GHL
Bristol Bay red king	44.8	178.1	35.7	15.7
Pribilof Islands red king	3.3	14.5	2.9	0
Pribilof Islands blue king	6.6	4.1	.8	0
St Matthew blue king	11.0	12.8	2.6	0
Eastern Bering Sea Tanner	94.8	100.8	30.2	0
Eastern Bering Sea snow	460.8	306.2	91.9	20.8

Stock status for the following stocks is unknown due to no survey biomass estimates: Pribilof Islands golden king crab; Saint Lawrence Island blue king crab; Northern District golden king crab; Western Aleutian Tanner crab; Aleutian Islands scarlet king crab; Bering Sea triangle Tanner crab; Eastern Aleutian Islands triangle Tanner crab; Eastern Aleutian Islands grooved Tanner crabs; Western Aleutian Islands grooved Tanner crabs and Bering Sea grooved Tanner crabs. The fisheries for the these species are by ADF&G commissioner's permit only with observer requirements. Estimation of MSST for these stocks is not possible at this time because of insufficient data on the basic stock abundance. The ADF&G Gulf of Alaska Marine Resource Assessment Survey is a triennial trawl survey east of 170°W that provides some information on Eastern Aleutian Islands red king crab and Eastern Aleutian Islands Tanner crab.

Section 3.4.1, History of the BSAI crab fisheries, contains more information of the status of the stocks and crab fisheries over time.

Red king crab

Red king crab are widely distributed throughout the BSAI, GOA, Sea of Okhotsk, and along the Kamchatka shelf up to depths of 250 m. Red king crab are found from eastern Korea around the Pacific rim to northern British Columbia and as far north as Point Barrow (Figure 3.2-1). Red king crab in the BSAI is managed as four separate fisheries: Bristol Bay, Pribilof Islands, Aleutian Islands, and Norton Sound.

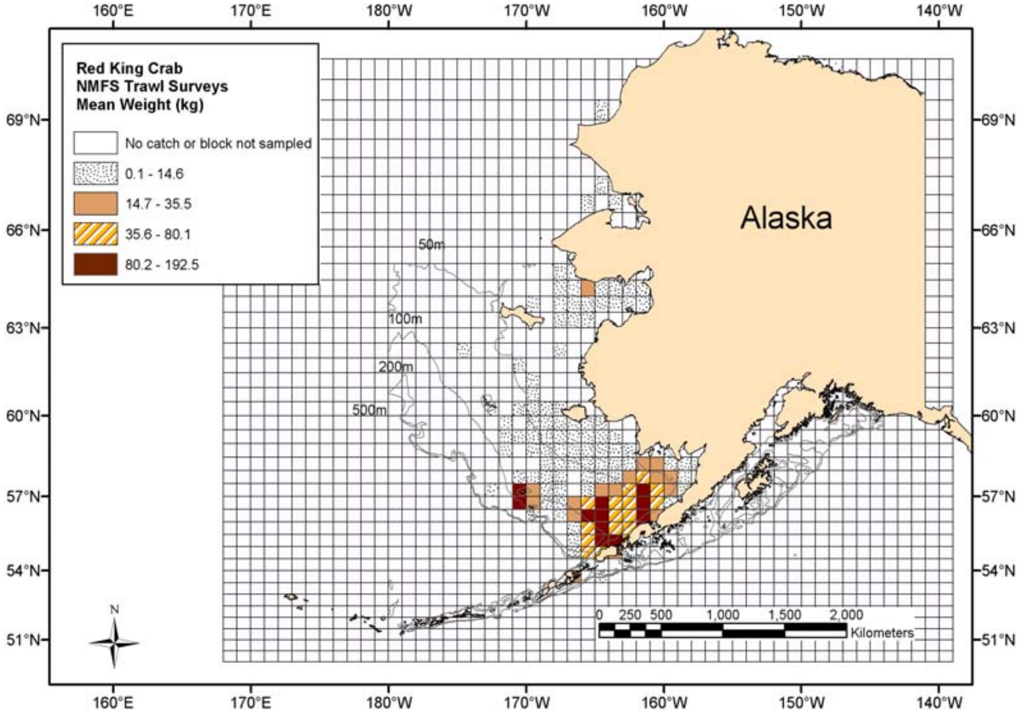


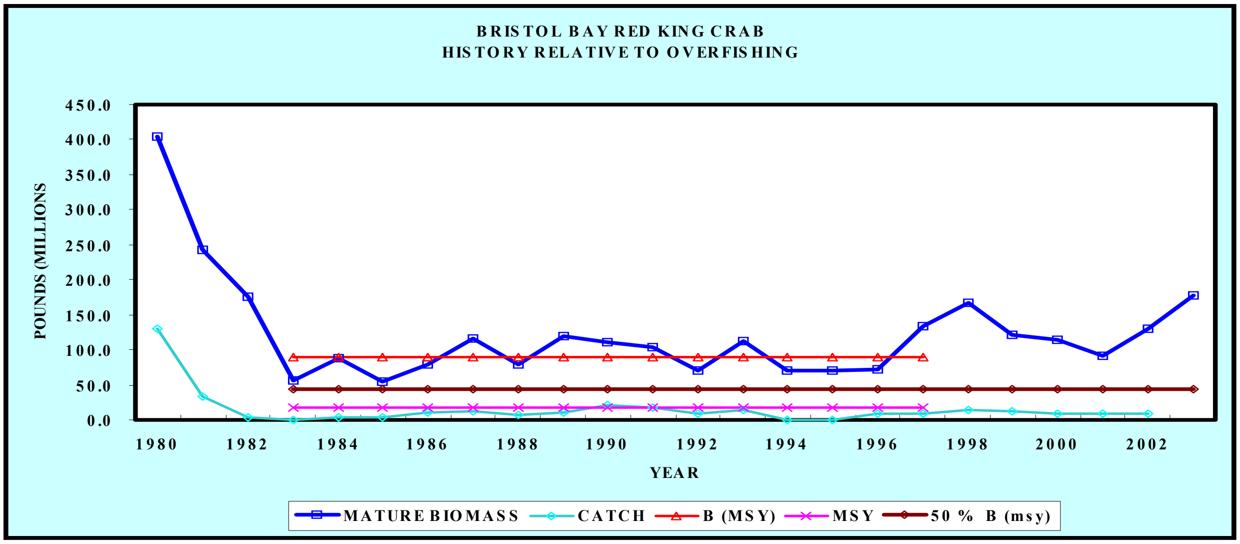
Figure 3.2-1 **Red king crab distribution in the Bering Sea, from the NOAA Fishery trawl survey (NMFS, AFSC Kodiak Lab).**

Bristol Bay: Estimated Bristol Bay red king crab SB for 2003 (178.1 million pounds) increased from the 2002 estimate of 129.9 million pounds, and increased over 50% from the 2001 estimate (88.0 million pounds) (Figure 3.2-2). Estimated SB for 2003 is over 50% higher than the B_{MSY} stock level defined in the FMP (89.6 million pounds). Hence there are no expectations for this stock to approach its MSST of 44.8 million pounds in the near future.

The 2003 mature female abundance is estimated to be 29.69 million female crabs >89 mm CL and effective spawning biomass (ESB) estimated at 60.70 million pounds. Therefore, this stock was estimated to be above the threshold for a fishery opening of 8.4 million female crabs >89 mm CL and 14.5 million pounds ESB. Length-based analysis (LBA) estimates indicate that the abundance of the mature portion of the stock has been essentially stable relative to 2001. Based on the 2003 LBA data, the ESB increased by 27% between 2002 and 2003. Mature male abundance increased 16% over the 2002 estimate and legal male abundance increased by 26%.

Indications from the 2002 survey data of future recruitment to the mature female size class and to the mature male size class continues to be evident in the 2003 survey data. That indication is given by the large mode for both males and females between 85 and 90 mm CL in the 2003 data. The mode of juvenile-sized females seen in the 2002 data has apparently contributed to the abundance of mature-sized females in 2003. That mode should continue to provide new recruitment to mature-sized females in 2004. For males, that mode may begin to provide some new recruitment to the mature male size class in 2004 and should provide increased recruitment to mature-sized males in 2005.

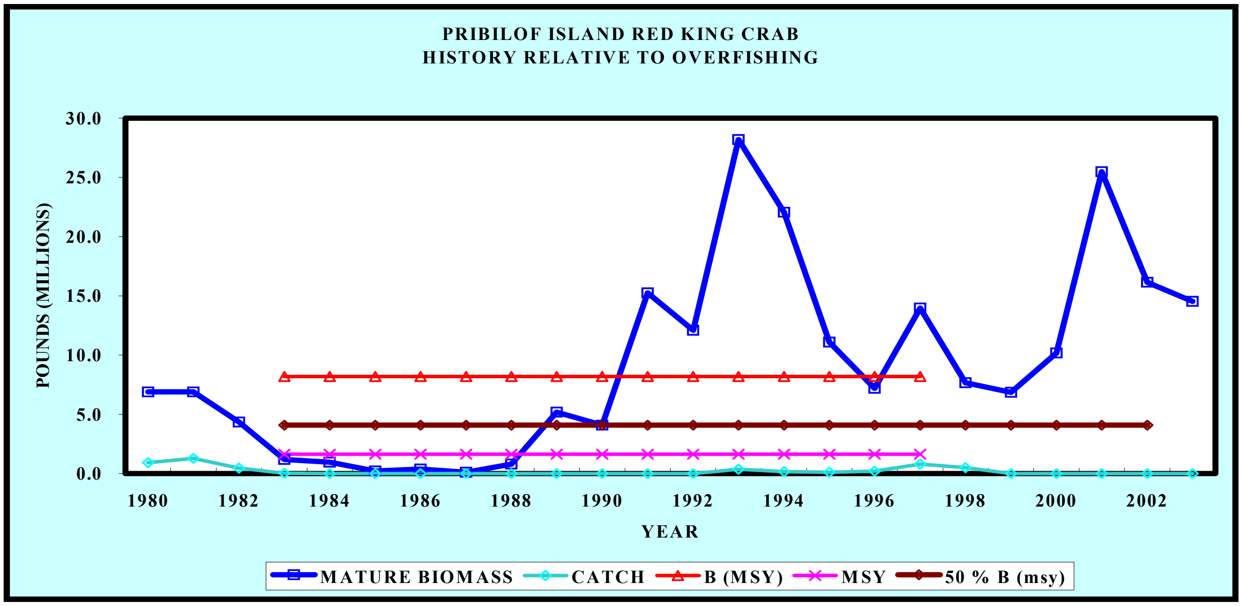
Figure 3.2-2 Bristol Bay Red king crab abundance and catch, from the NOAA Fishery trawl survey (NMFS, AFSC Kodiak Lab).



Pribilof Islands: The 2003 SB estimate for the Pribilof Islands red king crab from the survey was 14.5 million pounds, a continuing decrease from the 2002 estimate of 18.1 million pounds, and the 2001 survey SB estimate of 25.5 million pounds (Figure 3.2-3). This stock, however, presents particular problems to the NOAA Fisheries trawl survey in providing reliable levels of precision in stock estimates. Abundance estimates for the Pribilof red king crab stock have fluctuated widely and unpredictably since the early 1990's, but precision of estimates is so poor that this stock can only be considered stable within the limits of the precision afforded by the assessment data. If the stock is stable, the actual level at which it is stable is unknown. NOAA Fisheries estimates for total mature biomass in 2003 place this stock well above the MSST defined in the FMP (3.3 million pounds of spawning biomass). There are questions, however, whether the MSST defined for this stock is appropriate for "prevailing ecological conditions".

ADF&G, Catch-Survey Analysis (CSA) and NOAA Fisheries area-swept estimates for mature-sized males in 2003 are slightly lower than for 2002 (1.755 million crabs in 2002 as compared to 1.545 million in 2003 for the CSA estimates; 1.816 million in 2002 as compared to 1.298 million in 2003 for the area-swept estimates). The low precision for these estimates, however, precludes any conclusion on trend in abundance of mature males. The CSA estimate for legal males in 2003 (1.433 million) is comparable to that for 2002 (1.371 million). The NOAA Fisheries area swept estimate for legal males in 2003 (1.251 million) is lower than for 2002 (1.799 million), but the 95% confidence interval of +/- 130% disallows any meaningful conclusions on trend. What is noteworthy in the 2003 data is that few sublegal males were captured during the 2003 survey; the NOAA Fisheries area-swept estimate for sublegal males in 2003 is 0.047 million, as compared to an estimate of 1.251 million legal males. Poor representation of sublegal males in the 2003 and 2002 surveys provide low expectations for recruitment to the legal or mature male stock in the near future. The 2003 survey data, coupled with results from 2002, suggests that the two-fold increase in mature stock in the area-swept estimates between 2000 and 2001 was likely due to survey error in 2001. CSA point estimates of mature male abundance show an increasing trend from 1.021 million males since 1997 to, perhaps, a leveling out at approximately 1.5 million in 2002-2003. However, the 95% confidence interval for the 2003 mature male CSA estimate (0.709 million to 2.381 million) includes each of the point estimates for mature male abundance in 1991-2002. Such poor precision in abundance estimates makes it impossible to draw any conclusions on the reality of apparent trends or on the current status of the stock. At the level of precision that abundance is estimated, the mature male stock can be considered stable during 1999-2003. However, given the poor indications for recruitment, mature male abundance would be expected to decline with or without a fishery over the next several years; that decline may have already began between 2002 and 2003.

Figure 3.2-3 Pribilof Islands red king crab abundance and catch, from the NOAA Fishery trawl survey (NMFS, AFSC Kodiak Lab).



The Pribilof red king crab fishery is prosecuted concurrent with the Pribilof blue king crab. No formal harvest strategy has been developed for this stock. The stock has been closed to fishing since 1999 due to imprecision of abundance estimates and concerns about bycatch of blue king crab.

This fishery will remain closed for the 2003 season due to concerns about bycatch effects on blue king crab and the poor precision of red king crab abundance estimates. The Pribilof District blue king crab stock is below threshold for a fishery opening and the estimate of total mature biomass for the Pribilof blue king crab stock provided by NOAA Fisheries is below the MSST defining an "overfished" condition. The Magnuson-Stevens-Act is clear in its direction to managers of federal FMP fisheries to protect "overfished" stocks from fishing mortality that can impair stock rebuilding. There is no observer data available to estimate bycatch rates for blue king crab in a directed red king crab fishery. The timing and area covered by the NOAA Fisheries eastern Bering Sea trawl survey is not sufficient to determine potential distributional overlap of blue and red king crab during the commercial season. However, fish ticket data from past Pribilof king crab fisheries indicate the potential for bycatch of blue king crab during a directed fishery on the Pribilof red king crab stock. Uncertainty on stock abundance and trends for Pribilof blue king crab is so great and past fishery performance has been so poor that managers and analysts cannot determine a GHL for Pribilof red king crab that could be achieved without the risk of a prolonged season that would increase the potential for blue king crab bycatch. Aside from the concerns for blue king crab bycatch, the lack of a formal harvest strategy for Pribilof red king crab, the uncertainty on stock conditions, and poor fishery performance in past fisheries also raises concerns for the Pribilof red king crab stock when attempting to determine an appropriate GHL.

Aleutian Islands red king crab: western Aleutian Islands (Adak or Petrel Bank) and eastern Aleutian Islands (Dutch Harbor). The GHL for the eastern portion is based on the results of surveys performed by ADF&G on a triennial basis; the most recent survey was performed in 2003. Few red king crabs have been caught in surveys of the eastern Aleutians since 1995. The eastern portion has been closed since 1983. Historically, the GHL for the western portion has been based on the most recent fishery performance. The western portion was closed for the 1996/97 and 1997/98 seasons due to poor performance and poor signs of recruitment during the 1995/96 season. The western portion was reopened for limited exploratory fishing in some areas in 1998/99. Based on the results of the 1998/99 season, the fishery in the western portion was closed in 1999/2000. In 1999, the Crab Plan Team identified the need for standardized surveys in areas of historical production prior to reopening the fishery in the western portion; prior to that meeting, the western portion had not been surveyed since 1977. A cooperative ADF&G-Industry pot survey was performed in the Petrel Bank-Semisopochnoi Island area under the provisions of a permit fishery in January-February and November of 2001. Results of those surveys show high densities of legal crabs within limited portions of the surveyed area. Survey catches of females and prerecruit sized males were not as strong. Based on results of the 2001 surveys and recommendations from ADF&G and the public, the Alaska Board of Fisheries adopted pot limits, and modified the season opening date. A GHL of 0.5 million pounds was set for the 2002-03 season in the Petrel Bank area. Because only relative abundance information is available, ADF&G monitored the fishery utilizing inseason catch per unit effort (CPUE) . The management goal is to maintain a fishery CPUE of at least 10-legal crabs per pot. The 2002-03 fishery in the Petrel Bank area of the western Aleutian Islands harvested 505,000 pounds. The fishing CPUE was 18. Based on fishery performance, ADF&G has announced a 0.5 million pound GHL for the 2003-04 fishery.

In order to assess red king crab in other portions of the western Aleutian Islands, during November 2002, a survey was conducted between 172° W longitude, and 179° W longitude (area around Adak, Atka, and Amila Islands). The survey of these waters yielded very few red king crab. That area will remain closed until further notice.

Norton Sound red king crab: The Norton Sound red king crab legal male abundance is estimated from the triennial trawl survey. The 2002 ADF&G trawl survey estimated 2.3 million pounds of legal crab, a decrease from the 1999 survey estimate of 4.3 million pounds of legal male crab. This decrease in abundance was the result of weak recruitment over the previous three years. Recruitment is anticipated to be stronger over the next three years. Only the trawl survey conducted in 1996 produced a smaller biomass estimate. The Norton

Sound crab fishery operates in the summer and in the winter. The legal male abundance remained in a range that allowed a harvest rate of 8% to be applied to the 2002 legal biomass estimate. The 2003 GHL was 253,000 lbs. based on the triennial trawl survey stock abundance estimates. The open access fishery was open July 1 by regulation and was closed by emergency order on August 13, 2003. The open access goal was 234,000 lbs., and the harvest was 253,284 lbs. The CDQ portion opened June 15, 2003 and closed June 28, 2003. Because the open access harvest exceeded their allocation, the CDQ fishery reopened on August 15, 2003, after the readjusting their allocation. The CDQ fishery closed for the second time on August 24, 2003. Total harvest for the CDQ fisheries was 13,923 pounds. ADF&G never set a GHL for the winter fishery which ran Nov 15, 2002 until May 15, 2003.

Blue king crab

Blue king crab have a discontinuous distribution throughout their range (Hokkaido, Japan to southeast Alaska). In the Bering Sea, discrete populations exist around the Pribilof Islands, St. Matthew Island, St. Lawrence Island, and the Diomede Islands (Figure 3.2-4). Smaller populations have been found around Nunivak and King Island. Blue king crab is managed as two fisheries, Pribilof Islands and St. Matthew.

Pribilof Islands: The 2003 survey estimate of SB was 4.1 million pounds, a decrease from the 2002 SB estimate of 4.5 million pounds, and the 2001 survey estimate of 7.0 million pounds (Figure 3.2-5). This stock remains below the MSST of 6.6 million pounds. Hence, NOAA Fisheries declared the stock overfished. The North Pacific Fisheries Management Council (the Council) is developing a rebuilding plan for this stock. Although poor precision in abundance estimates makes year-to-year comparisons difficult, the trend in estimates since the mid-1990's indicates that this stock remains depressed and below MSST in 2003. Estimates of abundance for all male classes are low there is no indication that stock conditions are improving.

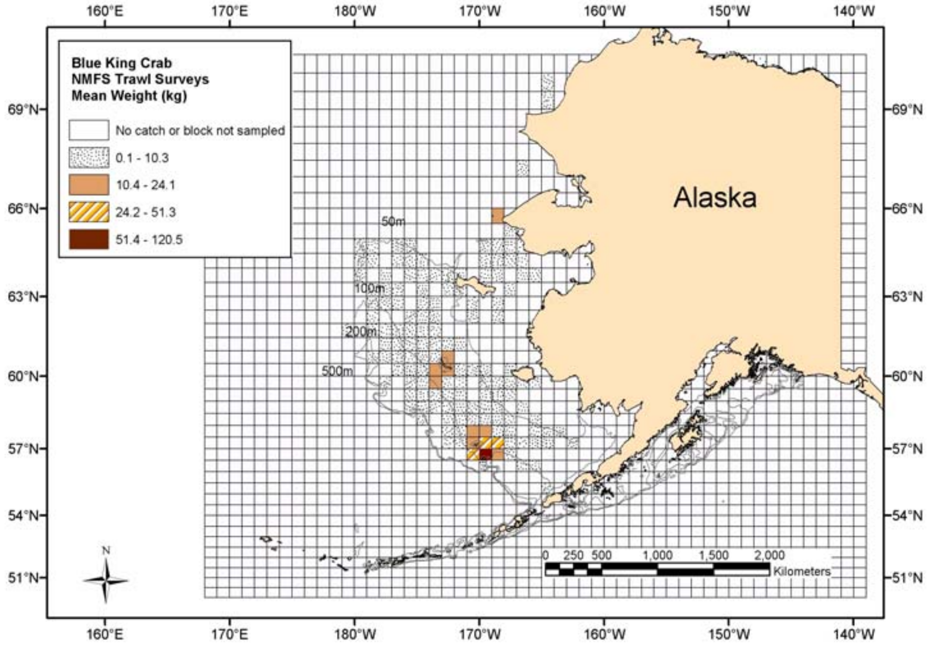


Figure 3.2-4 Blue king crab distribution in the Bering Sea, from the NOAA Fishery trawl survey (NMFS, AFSC Kodiak Lab).

Under the existing harvest strategy developed for the Pribilof blue king crabs, fisheries are not opened unless the stocks exceed a threshold level of abundance (Pengilly and Schmidt 1995). The thresholds established for Pribilof Islands blue king crab is 0.77 million males > 119 mm CL. Mature male abundance for 2003 is estimated at 0.291 million. The fishery has been closed since 1999 because the stock did not exceed the threshold level of abundance. Therefore, this population is declining in the absence of directed fishing pressure and in the absence of any bycatch during the Pribilof red king crab fishery; the Pribilof red king crab fishery has also remained closed since 1999. It is also worth noting that bycatch in trawl fisheries has not occurred due to the Pribilof trawl closure area. There is no evidence from this year's survey results that recruitment to the mature or legal male stock will occur in the near future.

St. Matthew: The 2003 SB estimate from the survey was 12.8 million pounds, an increase of over 50% from the 2002 estimate (4.7 million pounds), and value above the MSST. This stock is above the MSST (11.0 million pounds of SB) for the first time in five years. Estimated SB increased from 5.2 million pounds in 2000 to 9.0 million pounds in 2001, but dropped to 4.7 million pounds in 2002. Such erratic trends for this stock may reflect the low precision of the spawning biomass estimate. Low precision in estimation is due to the low number of tows that blue king crab are captured in during the trawl survey in the St. Matthew Island area; in that situation, only a few tows can have a large influence on the point estimate. Estimation of SB is particularly sensitive to the survey catch of mature females.

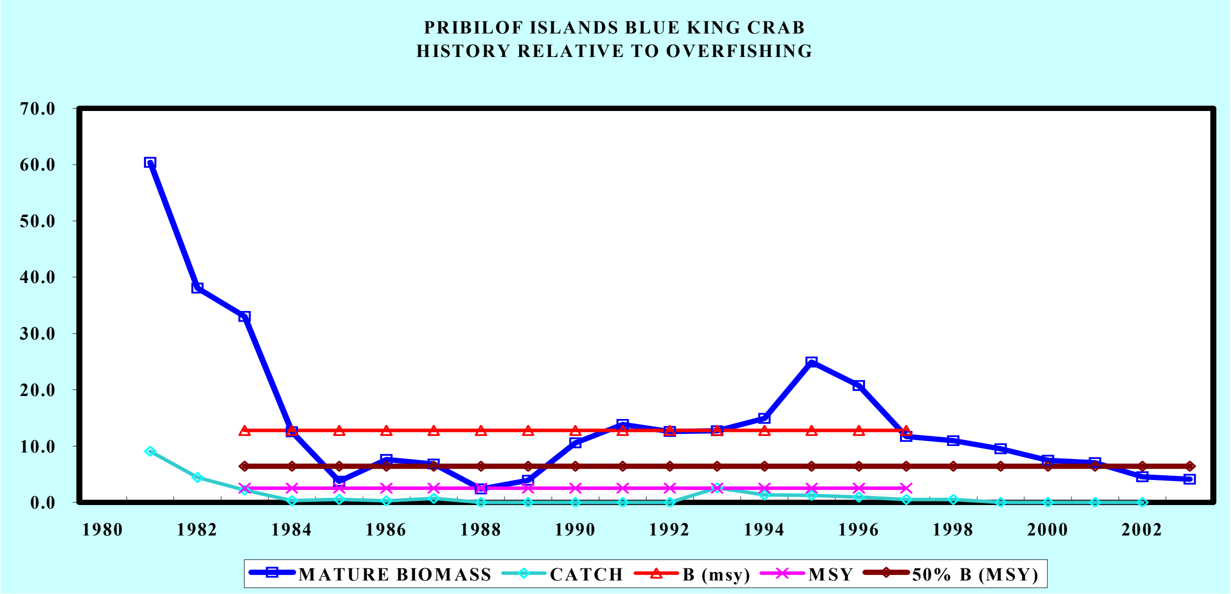


Figure 3.2-5 **Pribilof Islands blue king crab abundance and catch, from the NOAA Fishery trawl survey (NMFS, AFSC Kodiak Lab).**

Total mature biomass would need to double from the 2003 estimate to 22.0 million pounds for the stock to be considered “rebuilt”; data from the 2003 survey do not provide any expectations for such an increase in the near-term future. This stock remains at a depressed level comparable to that seen in the mid-1980's. The low catch of blue king crab during each of the 1999-2002 trawl surveys makes it unlikely that the estimated stock condition is attributable to survey error; instead, it supports the hypothesis that natural mortality was higher than normal between the 1998 and 1999 surveys. The 1999-2003 CSA estimates of mature male abundance suggests some stability at this low level. However, given the low precision of estimates, no definitive statements on stock trends can be made.

There is a small indication that stock conditions are improving is that at least some small crabs were taken during the 2003 survey. The NOAA Fisheries area-swept estimate for number of males <105 mm CL in 2003 (1.387 million) exceeds that for mature-sized (≥105 mm CL) in 2003 (0.824 million) by nearly 70%. Nonetheless, the low precision of estimates (95% confidence interval for the estimate of males < 105 mm CL is +/- 142 of the point estimate) suggests that we should adopt a “wait-and-see” attitude on this hopeful sign.

The fishery has been closed since 1999 and will remain closed in 2003. Although the stock is above the threshold for a fishery opening, the GHL of 0.685 million pounds computed according to the fishery harvest strategy is far below the minimum GHL of 2.5 million pounds that is considered manageable.

Golden king crab

Golden king crab, also called brown king crab, range from Japan to British Columbia. In the BSAI, golden king crab are found at depths from 200 m to 1,000 m, generally in high-relief habitat such as inter-island

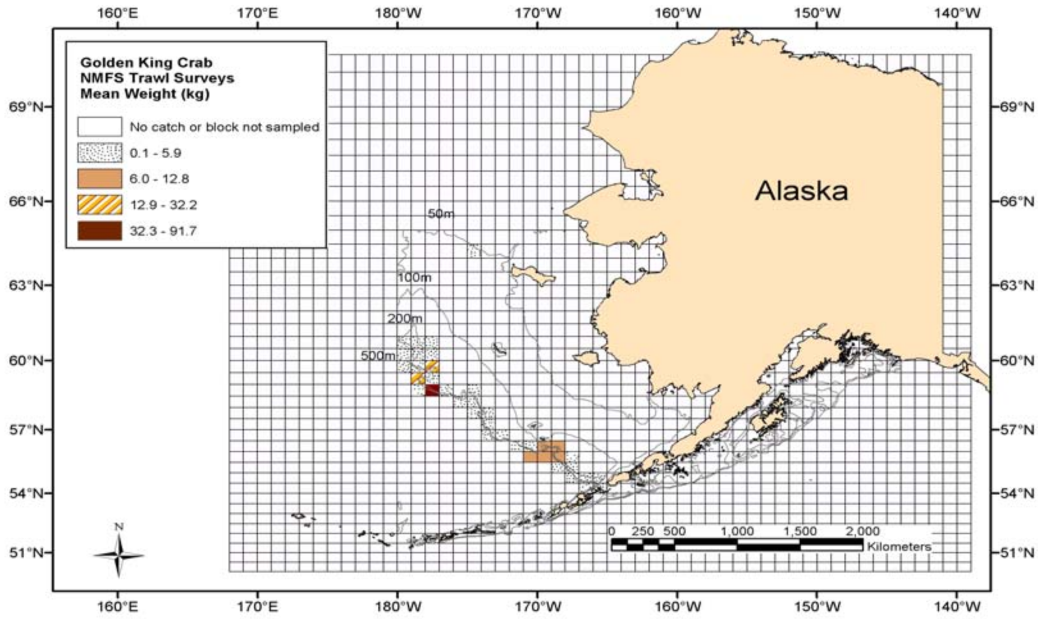


Figure 3.2-6 Golden king crab distribution in the Bering Sea, from the NOAA Fishery trawl survey (NMFS, AFSC Kodiak Lab).

passes (Figure 3.2-6). Golden king crab is managed as three separate fisheries, eastern Aleutian Islands, western Aleutian Islands, and Bering Sea.

Aleutian Islands golden king crab (eastern Aleutian Islands and western Aleutian Islands golden king crab stocks): A standardized triennial pot survey for golden king crab in a portion of the eastern Aleutian Islands (in the vicinity of Amukta, Chagulak, and Yunaska Islands) was initiated in 1997. Results from the 2002 survey of that area indicate that catch per unit effort (CPUE) of legal male crabs has dropped by roughly one-third from the 1997 CPUE, whereas female and pre-recruit male CPUEs remained roughly stable at their 1997 levels. Analysis of 1996-2002 golden king crab fishery performance and observer data from the entire area east of 174º W longitude, on the other hand, indicate that the golden king crab stock has remained stable in that larger area. The 2003-04 GHL for the Aleutian Islands has again been set at 5.7 million pounds, with 2.7 million pounds for the area west of 174°W, and 3.0 million pounds for the area east of 174°W. The pot survey was again conducted in July 2003, but information is not yet available.

Tanner crab

Tanner crab are distributed on the continental shelf of the North Pacific Ocean and Bering Sea from Hokkaido to Oregon. Tanner crab are concentrated around the Pribilof Islands and immediately north of the Alaska Peninsula, and are found in lower abundance in the GOA (Figure 3.2-7). After molting many times as juveniles, Tanner crab reach sexual maturity at about age six with an average CW of 110-115 mm for males and 80-110 mm CW for females (Tyler and Kruse 1997). At maturity, females undergo a terminal molt, it is unknown if males also undergo terminal molt; however, current stock assessment models assume some male crab may molt after maturity (Zheng et al. 1998). Male Tanner crab reach a maximum size of 190 mm CW and live up to 14 years (Donaldson et al. 1981). Males of commercial size usually range between seven and 11 years old and vary in weight 1 to 2 kilograms (kg) (Adams 1979). Natural mortality rate of adult Tanner crab is estimated at 0.3. Tanner crab females are known to form high-density mating aggregations, or pods, consisting of hundreds of crabs per mound. These mounds may provide protection from predators and also attract males for mating. Research shows female Tanner crab prefer mating with large, old shell males (Paul and Paul 1996b; Paul et al. 1995). Mating occurs from January through June. Some females can retain viable sperm in spermathecae for up to two years. Females carry clutches of 50,000 to 400,000 eggs for one year after fertilization. Hatching occurs between April and June (Tyler and Kruse 1997).

Figure 3.2-7 Tanner crab distribution in the Bering Sea, from the NOAA Fishery trawl survey (NMFS, AFSC Kodiak Lab).

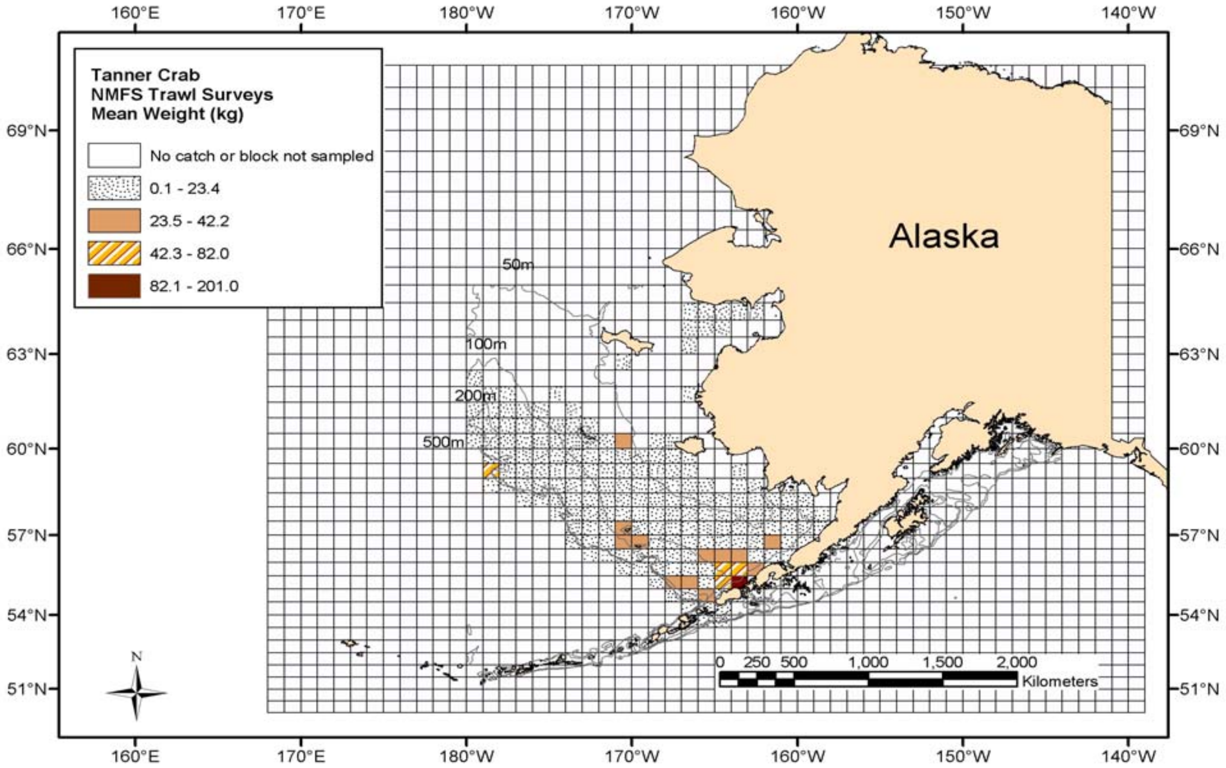
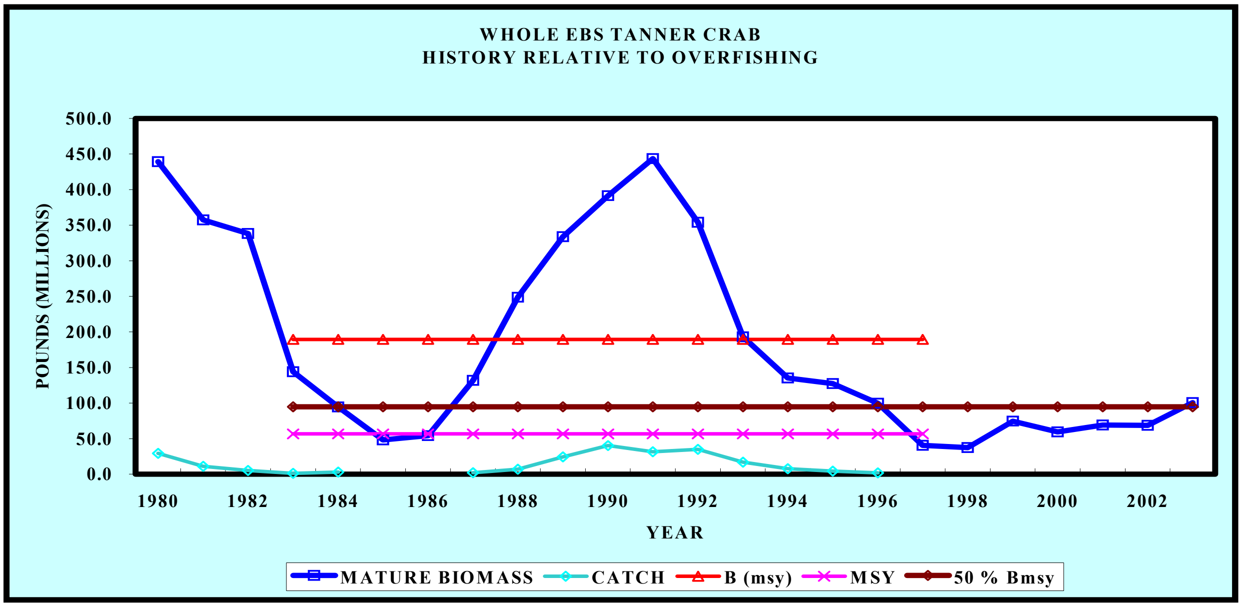


Figure 3.2-8 Tanner crab abundance and catch, from the NOAA Fishery trawl survey (NMFS, AFSC Kodiak Lab).



Bering Sea: The 2003 survey estimate of spawning biomass increased to 100.8 million pounds from the 2002 estimate of 69.4 million pounds, which was essentially unchanged from the 2001 estimate (67.7 million pounds) (Figure 3.2-8). In 2003, this stock increased above the MSST (94.8 million pounds spawning biomass) for the first time in six years.

The fishery was closed in 1997 due to near-record low stock abundance in the 1997 NOAA Fisheries survey and extremely poor performance in the 1996 fishery. The Council adopted a rebuilding plan for this stock in October 1999. NOAA Fisheries approved the rebuilding plan in June 2000 (65 FR 38216). The fishery has remained closed under the rebuilding harvest strategy since 1999. ADF&G will reopen the fishery when the female biomass is above the threshold and the fishery GHL is above the minimum identified in the rebuilding harvest strategy. Given the 2003 survey data, this stock is not expected to be above the "rebuilt" level (MSY biomass, defined in the FMP as 189.6 million pounds of total mature biomass) in 2004.

Estimated abundance in 2003 of molting mature males is 10.3 million animals (71% greater than the estimate for 2002). Estimates for abundance of mature-sized males and mature-sized females also show increases from 2002 to 2003; 44% greater than the 2002 estimate for mature-sized males and 52% greater than the 2002 estimate for mature-sized females. Abundance of exploitable legal males is, at 3.1 million animals, only slightly above the point estimate for 2002, however.

Although a sign of recruitment of males and females in the 1999 survey (a size-frequency mode at 80 to 90 mm CW) disappeared in the 2000 and 2001 surveys, the two size modes indicating juveniles recruiting to the stock in the 2001 survey track well into the 2002 data. These two juvenile size modes that first appeared in earlier survey data have continued to track well into the 2003 data. The 2001 survey data showed a new, large mode representing small (30 mm CW) juveniles that tracked to a mode at roughly 40 mm CW in the 2002 data and has apparently tracked to a mode of approximately 60 mm CW in the 2003 data. A mode of small

(30 mm CW) juveniles that appeared in the 1999 survey tracked through to a mode at roughly 60-65 mm CW in 2002. That mode has apparently tracked to a mode at approximately 75-80 mm CW in the 2003 data; in the case of females, this mode has begun to contribute to the mature-sized female component in 2003. That these modes have tracked well for the last 3 years provides some confidence that there has been recruitment to the surveyed population. The amplitude of the modes tends to decrease with successive years, and it remains to be seen how much these modes will contribute to stock rebuilding as they grow into the mature- and legal-size classes.

Eastern Aleutian Islands: The fishery has been closed since 1995 due to declining stock size estimated from surveys and poor fishery performance. In the 2000 survey, pre-recruit and recruit sized Tanner crabs declined from the 1999 survey in the Eastern Aleutians District. Tanner crab abundance in the eastern Aleutian Islands remains below levels observed in the early 1990's. The Alaska Board of Fisheries recently implemented individual and overall fishery pot limits. In 2003 ADF&G and industry conducted a pot survey of limited portions of the Eastern Aleutians District, results are pending. A decision on the 2004 fishing is expected in November 2003.

Snow crab

Snow crab are distributed on the continental shelf of the Bering Sea, the Arctic Ocean, the sea of Japan, and in the western Atlantic Ocean, as far south as Maine. Snow crab are not present in the GOA. In the Bering Sea, snow crab are common at depths of ≤200 m (Figure 3.2-9). The eastern Bering Sea population within U.S. waters is managed as a single stock; however, the distribution of the population extends into Russian waters to an unknown degree. Snow crab reach sexual maturity at age five to eight, with an average CW of 83 mm for males and 49 mm CW for females. The mean size of mature females varies from year to year over a range of 63-72 mm CW. Females cease growing with a terminal molt upon reaching maturity, and rarely exceed 80 mm CW. Males similarly cease growing upon reaching a terminal molt when they acquire the large claw characteristic of maturity. Male snow crab reach a maximum size of 150 mm CW and live up to 14 years. Large, old-shelled males (more than one year from molting) out compete adolescent, small adults and large, new-shell males (less than one year from molting) in mating with females (Sainte-Marie et al. 1997). Males of commercial size usually range between eight to nine years old and vary in weight from 0.5 to 1 kg (Adams 1979). Female snow crab are able to store spermatophores in seminal vesicles and fertilize subsequent egg clutches without mating. At least two groups of eggs can be fertilized from stored spermatophores, but the frequency of this occurring in nature is not known (Sainte-Marie et al. 1997).

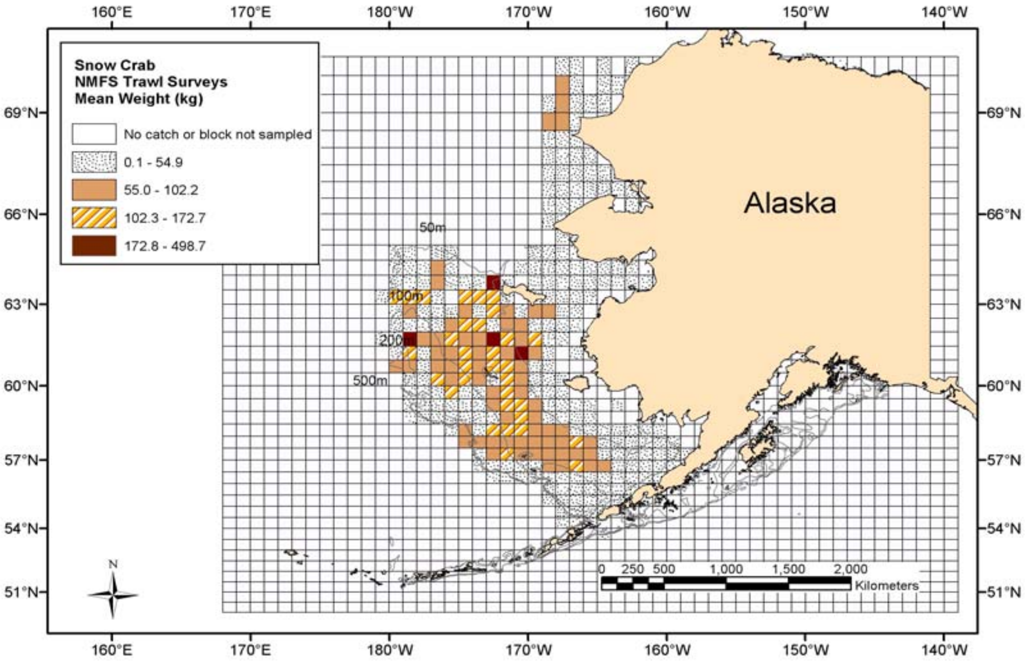


Figure 3.2-9 Snow crab distribution in the Bering Sea, from the NOAA Fishery trawl survey (NMFS, AFSC Kodiak Lab).

Snow crab spawning biomass in 2003 is estimated to be 306.2 million pounds. This stock is below the MSST of 406.8 million pounds, with an estimated SB that is the fourth lowest on record; estimated SB for 2003 exceeds only the estimates for 1985, 1986, and 1999. The SB estimated for 2003 (306.2 million pounds) is comparable to SB estimated in 2002 (313.3 million pounds), but is only 54% of the 571 million pounds that was estimated for SB in 2001. SB estimated for 2003 is only slightly higher than the estimate for 1999 (283.3 million pounds) that resulted in the "overfished" declaration. Estimated mature male biomass decreased to 82% of that estimated for 2002 (222.7 million pounds) and to 61% of that estimated 2001 (302 million pounds). This stock remains in a depressed condition and is unlikely to be estimated above the currently defined B_{MSY} in the next year; it is uncertain if it will be estimated above the thresholds that would allow for a commercial harvest in the 2005 season under the current FMP and harvest strategy.

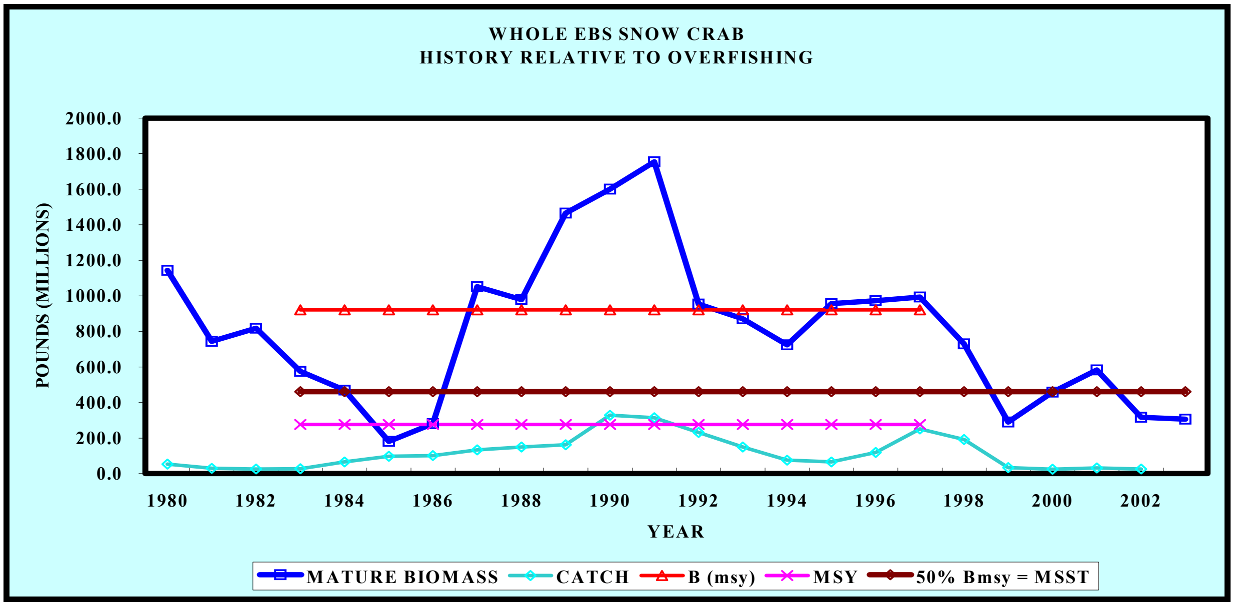
Size frequency distributions from the 2003 survey show modes representing new-shell males and females centered at 40-50 mm CW that indicate some recruitment to the stock not apparent in the 2002 survey or the 1999 survey. However, similar signs of recruitment to the stock in the 2000 and 2001 proved ephemeral, disappearing in the 2002 survey and not reappearing in the 2003 survey. A size-based assessment model for eastern Bering Sea snow crab estimates recruitment to the stock in 2003 to be high relative to that during 1995-2002, but low relative to that for the period 1979-1994.

The estimated abundance of males ≥ 4 in. CW in 2003 (65 million animals) has also declined from an estimated 78 million animals in 2001 and an estimated 76 million animals in 2002. Fifty-four percent of the estimated males ≥ 4 in. CW were from the western Subdistrict. The percentage of new-shell males ≥ 4 in.

CW from the 2003 survey (approximately 70%) is comparable to the 2002 estimate but higher than that for the 1999-2001 (Figure 3.2-10).

The GHL of 20.831 million pounds of retained catch in the 2004 season represents 6.8% of the estimated SB and 11.4% of the estimated mature male biomass in 2003. Total catch, including discards, would be a higher portion of the SB. At an average of 1.27 pounds per crab, the 20.831 million pound harvest would represent 16.403 million males. A harvest of 16.403 million males corresponds to 5% of the estimated mature male abundance (368 million animals), 36% of the abundance of new-shell males ≥ 4 in. CW, and 25% of the abundance of all males ≥ 4 in. CW estimated from the 2003 survey. The percentage of males ≥ 4 in. CW that are in new-shell condition in this year's survey has no impact on the determination of the 2004 GHL under the harvest strategy.

Figure 3.2-10 Snow crab abundance and catch, from the NOAA Fishery trawl survey (NMFS, AFSC Kodiak Lab).



3.2.1 King crab life history and environmental requirements

King crabs (*Lithodes* and *Paralithodes spp*., Family Lithodidae) are anomurans and differ from most commercial crab species (brachyurans) in that females must molt in order to mate and extrude a fertilized clutch. As suggested by their name they are much larger than most crabs and males frequently attain weights in excess of 4 kg; with maximum weights in excess of 10 kg in some GOA stocks. In general, the size at maturity in king crabs varies inversely with latitude and probably with average temperature. For example, red king crab (*Paralithodes camtschaticus*) females in Norton Sound mature at an average size of 71 mm CL while those from Bristol Bay mature at an average size of 89 mm CL (Otto et al. 1989).

Four species of king crabs support fisheries in the BSAI Region. They differ in their life history characteristics although they frequently co-occur in a given management area or district (Section 3.4). For example, red king crab, blue king crab (*P. Platypus*), and golden king crab (*Lithodes aequispinus*) all inhabit the Pribilof Islands area and are recognized as separate stocks in the FMP. The Bristol Bay red king crab fishery is the oldest most important king crab fishery in the BSAI. Red and golden king crabs also inhabit the Aleutian Island areas and are targeted by separate fisheries. Most red and blue king crab fisheries occur at depths from 50-200 m, but red king crab fisheries in the Aleutian Islands sometimes extend to 300 m. Golden king crab fisheries, most prominently in the Aleutian Islands region, take place at depths in excess of 300 m. Fisheries for the scarlet king crab (*L. couesi*) have been largely experimental and the species is mostly taken as bycatch in exploratory fisheries for deep water Tanner crabs. The scarlet king crab usually occurs at depths of 700 m or more.

The life history and environmental requirements presented below focus on red king crab because the majority of scientific research has been conducted on this species. When possible, life history differences for blue king crab and golden king crab are noted.

Red king crab overview

Red king crab are economically the most important of the king crabs. Commercial fisheries for them were pioneered by the Japanese in the early 1900's and fishing for this species soon developed into a major commercial enterprise. Cahn (1948) reviewed the development of the Japanese fishery. The economic importance of red king crab coupled with an ongoing interest in marine biology displayed by the Japanese royal family lead to a number of classic crab studies, such as that of Marukawa (1933). A special study of red king crab in Alaska was conducted in 1940-1941, this was both instrumental in stimulating fishery development and provided initial detailed biological information (Wallace et al. 1949, Harrison et al. 1942).

Red king crab is native to waters of 300 m or less extending from eastern Korea, the northern coast of the Japan Sea, Hokkaido, the Sea of Okhotsk, through the eastern Kamchatkan Peninsula, the Aleutian Islands, the Bering Sea, the GOA, and the Pacific Coast of North America as far south as Alice Arm in British Columbia. They are not found north of the Kamchatkan Peninsula on the Asian Pacific Coast. In North America red king crab range includes commercial fisheries in Norton Sound and sparse populations extending through the Bering Straits as far east as Barrow on the northern coast of Alaska. Red king crab have been acclimated to Atlantic Ocean waters in Russia and northern Norway. In the Bering Sea, red king crab are found near the Pribilof Islands and east through Bristol Bay; but north of Bristol Bay (58 degrees 39 minutes) they are associated with the mainland of Alaska and do not extend to offshore islands such as St. Matthew or St. Laurence Islands (Figure 3.2-1).

Red king crabs seem to follow a basic life history pattern where adults occur up current from juvenile nursery grounds and juveniles show a migration to the adult habitat (Vinogradov 1945; Rodin 1985 and 1990). This life history pattern is similar to those described by Jones (1968) for a wide variety of marine fishes and seems to be true of many major eastern Bering Sea crab stocks. Positioning of females at the time of egg hatching relative to long-shore currents appears important for king crabs as well as Tanner crabs. Adult king crab have a seasonal pattern of offshore-onshore migration that is apparently mediated by temperature and photoperiod. The life history pattern of Bristol Bay red king crab appears similar to that of the West Kamchatkan stock, except that there is currently only one area or sub-population of adults (Rodin 1990). In both populations, the spatial structure of adults appears to be important and the critical juvenile habitat appears to be limited to areas located downstream from adult habitats. Selection of benthic habitat by glaucothoe (= megalopae) appears to be an important mechanism leading to increased probability of larvae settling on an appropriate substrate (Stevens and Kittaka 1998). Such substrates appear to be largely rock or cobble bottoms, mussel beds or other areas with a variety of epifauna such as hydroids or epiflora such as kelp hold fasts. The largest collection of one to two year old juvenile red king crab ever collected was gleaned from kelp hold fasts and other debris caught up in Japanese tangle nets (Fisheries Agency of Japan 1958).

King crab molt several times per year through age three, after which molting is annual. At larger sizes, male king crab may skip molt as growth slows. Adult females grow more slowly and do not get as large as males. In Bristol Bay, males attain sexual maturity at 100-105 millimeter (mm) carapace length (CL) and females are mature at 90 mm CL (about seven years). Adult males may not mate until they reach larger sized 110-120 mm CL. Mean age at recruitment into the fishery is 8-9 years. Natural mortality rate of adult king crab is estimated at 0.2. Red king crab in the Norton Sound area mature at smaller sizes and do not attain the maximum sizes found in other areas. In Bristol Bay, red king crab mate when they enter shallow waters (less than 50 m deep), generally beginning in January and continuing through June. Red king crab are annual spawners with high fecundity and small sized (ca. 1.0 mm) eggs. Males grasp females just prior to female molting, after which the eggs (43,000 to 500,000 eggs) are fertilized and extruded on the female's abdomen. The females carry the eggs for 11 months before they hatch, generally in April. Red king crab spend about two months in larval stages before settling to the benthic life stage. Young of the year crab occur at depths less than 50 m. They are solitary and need high relief, spatially complex habitat or coarse substrate such as boulders, cobble, shell hash, and living substrates such as bryozoans and stalked ascidians (Stevens and Kittaka 1998). At 1.5 to 2 years, crab form pods consisting of thousands of crab and migrate to deeper water. Podding generally continues until four years (about 65 mm CL). In the spring, adults migrate to shallow water for spawning and migrate in the summer-fall to deep water for feeding. Adult male and female red king crab generally inhabit separate grounds during feeding, with males migrating farther. A spring spawning migration occurs during the molting and mating season.

Throughout most of the GOA and eastern Aleutian Islands, red king crab populations declined from the late 1960's until the fisheries were closed in 1983. Populations have been at low levels and fisheries closed since 1983. Populations declined soon after the now recognized regime shift of the late 1970's (Benson and Trites 2002). This decline was severe and much more sudden in Bristol Bay as well but there has been better recovery of red king crab in Bristol Bay than in the GOA or Aleutian Islands waters. On a world wide basis, over the past 20-30 years it appears that southern stocks of red king crab (Japan Sea, Hokkaido, Adak, and GOA) have not fared as well as more northerly stocks (eastern Bering Sea, West Kamchatka, and East Kamchatka). This pattern has lead to some speculation that declines might be related to long-term temperature increases such as global warming, but declines may also be explained by cyclic climatological phenomena and associated faunal changes. The failure of GOA red king crab stocks to recover despite nearly 20 years of commercial crab fishery closures, strict control of subsistence or personal use fisheries, and numerous areas protected from bottom trawling bespeaks the importance of climatic and ecological factors in regulating red king crab abundance. Serial depletion by overfishing has also been invoked as a causal mechanism (Orensanz et al. 1998), but this fails to account for the lack of rebuilding with closed fisheries and other protective measures. The introduction and apparent acclimation of red king crab to northern European waters gives evidence that recovery of red king crab populations is possible under favorable conditions.

Blue king crab overview

Blue king crab are similar in size and morphology to red king crab. In general they are a more northerly or cold-adapted species than red king crab. Blue king crab are not known from the Japan sea and are rare in Hokkaido waters. They are common in the Okhotsk Sea and several discrete stocks are found from the Tartar Straits to its northern portions. On the Asian Pacific Coast, they are common from the northern part of the eastern Kamchatkan Peninsula, Cape Olyutorsky, the Koryak Coast, and Cape Navarin but not common north of there. They are subject to subsistence fisheries at Little Diomede Island in the Bering Strait and also known from outer Kotzebue Sound and Point Hope. On the North American Bering Sea shelf blue king crab are found near offshore islands well within or on the edge of the cold mid-shelf regime (King Island, St. Lawrence Island, St. Matthew Island, and the Pribilof Islands) and occasionally on the offshore side of Nunavak Island (Figure 3.2-4). Blue king crab are not known from the Alaska Peninsula west of Black Hills, or the Aleutian Islands. From the northern side of the Alaska Peninsula (Herrendeen Bay) and south through Kodiak (Olga Bay), Prince William Sound (College Fjords), and various localities in Southeast Alaska blue king crab are found in bays or fjords, and sometimes in association with glaciers. They are not found in British Columbia. Throughout their range they have a tendency to form discrete populations along rocky coasts or islands (Okhotsk Sea, Bering Sea) or in fjord - like areas where larvae may be conserved and which may be buffered from high temperatures by two layered systems or glaciers. Somerton (1985) discusses the possibility that GOA populations are post glacial remnant populations.

Adult male blue king crab occur at an average depth of 70 m and an average water temperature of 0.6°C. Blue king crab molt multiple times as juveniles. Skip molting occurs with increasing probability for those males larger than 100 mm CL. In the Pribilof Islands area, it is estimated that 50 percent of males attain maturity at 108 mm CL and 50 percent of females attain maturity at 96 mm CL (about five years) (Somerton and MacIntosh 1983). Blue king crab in the St. Matthew Island area mature at smaller sizes (50 percent maturity at 77 mm CL for males and 81 mm CL for females) and do not get as large overall. Blue king crab differ from red king crab in that they usually are biennial spawners with lesser fecundity and somewhat larger sized (ca. 1.2 mm) eggs (Somerton and Macintosh 1983; Jensen and Armstrong 1989; Selin and Fedotov 1996). Blue king crab have a biennial ovarian cycle and a 14-month embryonic period before hatching in late spring. Juveniles require cobble habitat with shell hash. These habitat areas have been found at depths of 40-60 m around the Pribilof Islands. Blue king crab have larger larvae (Hoffman 1967) than red king crab and these may have better swimming ability. Unlike red king crab, juvenile blue king crab do not form pods, instead they rely on cryptic coloration for protection from predators.

Ecologically, red king crab and blue king crab apparently are very similar. The lower reproductive potential of blue king crab is interesting from an oceanographic perspective, since blue king crab populations form concentrations around offshore islands in the eastern Bering Sea. Presumably, either localized transport mechanisms or demersal larval behavior might be involved in maintaining these populations of blue king crab. The larger size of blue king crab larvae (Hoffman 1967) may enhance their swimming ability relative to red king crab and hypothetically help them to maintain their position relative to preferred habitat.

Oceanographic data from these near-shore, island areas has been insufficiently described and larval surveys, mostly for relative abundance within a specific survey design, have been sporadic.

The disjunct, insular distribution of blue king crab relative to the more broadly distributed red king crab is likely the result of post-glacial period increases in water temperature that have limited the distribution of this cold-water adapted species (Somerton 1985). Factors that may be directly responsible for limiting the distribution include the physiological requirements for reproduction, competition with the more warm-water adapted red king crab, exclusion by warm-water predators, or habitat requirements for settlement of larvae (Somerton 1985; Armstrong et al 1985 and 1987).

In general, blue king crab stocks are small and localized and support small fisheries. For example, combined landings from the Pribilof and St. Matthew Island areas have seldom exceeded 5,000 tons. Size at maturity in the St. Matthew Island stock is lower than that of the Pribilof Islands stock (Somerton and Macintosh 1983). This suggests an inverse relationship of size with latitude, as is seen for red king crab.

Golden king crab overview

Golden, or brown king crab occur from the Japan Sea to the northern Bering Sea (ca. 61° N latitude), around the Aleutian Islands, on various sea mounts, and as far south as northern British Columbia (Alice Arm) (Jewett et al. 1985). They are typically found on the continental slope at depths of 300-1,000 m on extremely rough bottom. They are frequently found on coral bottom. Their fisheries are relatively recent developments in most areas and frequently have developed after shallower-water king crab fisheries became fully developed or had declined (Somerton and Otto 1986; Orensanz et al. 1998). Golden king crab have much larger eggs (ca. 2.3 mm) than those of blue or red king crabs (Otto and Cummiskey 1985; Somerton and Otto 1986) and also tend to spawn throughout the year rather than in the late winter and spring (Hiramoto 1985; Hiramoto and Sato 1970; Otto and Cummiskey 1985; Klitin and Nizyayev 1999; Somerton and Otto 1986). Golden king crab eggs have about 12 times the volume of red king crab eggs. Large eggs tend to be characteristic of the genus Lithodes, and scarlet king crab also have relatively large eggs. A seasonal spawning occurs because larvae in this species are capable of lecithotrophic development, which means the larvae live by consuming egg yolk leftover after hatching (Shirley and Zhou 1997). There are few records of golden king crab larvae in upper water plankton tows and it is possible that these larvae are demersal. In southeastern Alaska and British Columbia, isolated golden king crab populations are frequently found in deep-water fjords or other long narrow sounds (Jewett et al. 1985). Populations in some of these confined areas seem to show an elevated incidence of parasitism (Sloan 1984; Sloan et al. 1984). In many areas of the GOA and northern British Columbian coastal waters, populations of golden king crab may spend their entire life span in such bays or fjords.

Size at sexual maturity depends on latitude, with crabs in the northern areas maturing at smaller sizes (Sommerton and Otto 1986). In the St. Matthew Island area, it is estimated that 50 percent of males attain maturity at 92 mm CL and females at 98 mm CL. In the Pribilof and western Aleutian Islands area, it is estimated that 50 percent of males attain maturity at 107 mm CL and females at 100 mm CL. Further south, in the eastern Aleutian Islands, it is estimated that 50 percent of males attain maturity at 130 mm CL and females at 111 mm CL. ADF&G and NOAA Fisheries do not make annual abundance estimates for Bering Sea golden king crab and commercial harvest is allowed by ADF&G permit (Morrison et al. 1998).

3.2.1.1 Embryonic stages

Embryonic development

Development of the fertilized embryos occurs in the egg cases attached to the pleopods beneath the abdomen of the female crab. This process requires variable amounts of time, depending upon whether or not the female is primiparous or multiparous. Primiparous means the female has not mated previously, and multiparous means she has mated previously. Adolescent females may undergo their molt to maturity and first mating anytime from late summer to early winter. However, the clutch of eggs must hatch prior to their second adult molting and mating, in the spring of the following year. So primiparous females may require 12 to 15 months for their embryos to develop while attached to their abdomen, whereas multiparous females require 11 to 13 months. In laboratory studies (Stevens unpublished data) primiparous females extruded their first clutch approximately two months earlier than multiparous crabs, with median dates of 27 January and 26 March, respectively.

Development time for invertebrates (including crabs) is often expressed using the concept of "degree-days", or heat budgets. For example, if 100 degree days are required for development from larval stage 1 to larval stage 2, such development would occur in 25 days at 4°C, in 20 days at 5°C, or in 10 days at 10°C (Kurata 1960). However, such relationships are typically not linear, and increases in temperature above 15°C result in longer development times than predicted by this simple equation, and often result in low survival (Stevens, 1990b; Stevens and Munk, 1990).

The time required for the embryos to develop (from fertilization to hatching) is longer for primiparous crabs than for multiparous crabs. A primiparous crab of 110 mm CW required about 360 days or 2,585 degree-days for development, whereas a multiparous crab of equal size would require only 327 days, or 2,450 degree-days, i.e. about 6 percent less time (Stevens unpublished data). Although primiparous crabs extrude their eggs up to two months earlier than multiparous crabs do, their eggs take longer to develop, so the difference in hatching time is only about 11 days. When hatching begins, individual crabs require an average of 27 days to release all their larvae, regardless of whether they are primiparous or multiparous (Stevens unpublished data).

During the development of fertilized embryos, they pass through developmental stages called nauplius and metanauplius. After hatching, the first larval stage is called a zoea (Nakanishi 1987). Nakanishi defined 53 stages of embryonic development for red king crab. Eggs range from 0.8 to 1.2 mm in length, decreasing slightly as they develop, then increasing again before hatching. Table 3.2-2 shows the number of days after fertilization required to reach a specific developmental stage.

Table 3.2-1 Number of days after fertilization required to reach a specific developmental stage.

Stage	Description	Days
4	Cell division	4
8	8-cell stage	8
12	64-cell stage	12
15	Morula	15
22	Gastrula	39
28	Blastopore	71
30	Nauplius/Blastodisk	92
32	Metanauplius	109
36	Maxilliped rudiments	154
42	Eye pigments appear	201
43	Proto-zoeal	211
45	Eyestalks appear	251
50	Further development	285
53	Pre-hatching	331

Environmental influences on embryonic development

Much of the following information comes from research conducted by T. Nakanishi on techniques for mass culture of red king crab (Nakanishi 1981; Nakanishi and Naryu, 1981; Nakanishi, 1987; Nakanishi, 1988). He attempted to determine the optimum conditions, and range of tolerance, to a variety of culture conditions, by measuring growth, survival, and behavior. All stages of early life history of red king crab were studied, including embryos, larvae, and juvenile crabs.

Oxygen consumption increases about 10-fold from during development from fertilization (0.05 microliters/hour [ul/hr]/embryo) to hatching (0.5 ul/hr), over a period of 330 days, at 3°C. At 13°C (i.e., a 10°C increase), oxygen consumption increases by a factor of about two. Newly fertilized eggs do not use all the oxygen available to them. Therefore, as oxygen levels decrease (as they do with depth in the ocean), oxygen consumption rates do not change, until a level of 50 percent oxygen saturation is reached. However, just prior to hatching, eggs use all the oxygen they can get, and their consumption declines if saturation decreases. The entire egg clutch of an ovigerous female uses about as much oxygen as the female crab does herself.

The rate of embryonic development increases as the temperature increases, from -1.8°C to 18°C. However, mortality also increases with temperature. At 258 days after extrusion, survival was about 75 percent at 3°C, 10 percent at 8°C, and 0 at 13°C. Survival decreases rapidly above 12°C , and all embryos died after two weeks at 18°C. Best survival was achieved at 3°C or less, but development rates at these cold temperatures were extremely slow.

The salinity of full strength seawater is about 33-35 parts per thousand (ppt). Developing embryos of red king crab are not usually subject to low salinity, but exposure to extremely low salinities can cause reduced survival. Over a range of temperature from -1.8 to 18°C, 50 percent of embryos survived a 24 hour exposure to salinity between 24 and 48 ppt. However, they can tolerate higher salinity (up to 60 ppt) at 8°C, and lower (down to 6 ppt) at 13°C. Embryos had 100 percent survival at salinities from 29 to 40 ppt, which is well within the range of normal seawater in Alaska nearshore areas.

Behavior

Embryos develop a heart beat late in their development. At least six weeks prior to hatching, heartbeat rates are 120-140 beats per minute (bpm), increasing to 160 bpm just prior to hatching (Stevens unpublished data). Heart rates for first stage larvae are also 160 bpm (Nakanishi 1987). Embryos may move slightly within their egg cases during the weeks prior to hatching.

Other biological factors

In addition to the effects of physical environmental factors, embryos are subject to a variety of biological influences. Egg masses of king crabs are often infested by a variety of symbionts and predators. These include small crustaceans (amphipods), flatworms, and roundworms. Of particular importance is the nemertean worm, *Carcinonemertes regicides*, (which, incidentally, means "king killing crab worm"). These worms have been observed in egg masses of king crabs in multiple locations of Alaska (Kuris et al. 1991). Prevalence of worms (the proportion of crabs infested with worms) was 100 percent in crabs collected from Southeastern Alaska, Cook Inlet, and many Kodiak sites, but worms were essentially absent from crabs collected in the Bering Sea. In crabs collected from Kachemak Bay, near Homer, Alaska, in 1983-1984, almost 100 percent of eggs were killed by worm predation. This predator may be responsible for severely limiting recruitment of crab populations in southcentral Alaska waters, but it is apparently not a major factor in the Bering Sea.

Embryonic development in other king crabs

Blue king crab. Embryonic development in other species of king crabs has not been well studied. However, blue king crab (*P. platypus*) have a two-year reproductive cycle, i.e. they spawn every other year, and development of embryos is hypothesized to require 14-15 months (Somerton and MacIntosh 1985). Blue king crab differ from red king crab in that they usually are biennial spawners with lesser fecundity and somewhat larger sized (ca. 1.2 mm) eggs (Somerton and Macintosh 1983; Jensen and Armstrong 1989; Selin and Fedotov 1996). Presumably, their environmental tolerances and requirements are similar to those of red king crabs.

Golden king crab. Golden king crab live at deeper depths (200-600 m), and colder temperatures than red king crabs. They also have eggs that are twice the size of red king crab eggs, and appear to have extended development, and perhaps asynchronous, year-round spawning behavior (Somerton and Otto 1986). These differences are probably adaptations to life in deeper waters.

Conclusions

There appears to be a threshold temperature between 3 and 8°C. At colder temperatures, embryos have high survival but poor development rates, whereas above that level they have lower survival but faster development. Complete development requires about 2,500 degree-days. Oxygen demands are low initially, but high in later stages, requiring water that is completely saturated with oxygen. Survival is high in salinities from 24 to 48 ppt.

Development of embryonic stages would not be impaired in seawater normally occupied by adult red king crab. Negative effects on development would only occur if adult females with eggs were subjected to extreme environmental conditions of high temperature, reduced salinity, or low oxygen. Such conditions might only exist in small bays with reduced inflows, or in bays where fish processing waste is discarded. Most crabs would probably leave such areas unless they were trapped by shallow sills at the mouth of the bays. Crabs in the Bering Sea would not be subject to such conditions.

3.2.1.2 Larval Stages

Development of king crab larvae

Larvae occasionally hatch out as a pre-zoea stage in the laboratory (Marukawa 1933), but this may be a laboratory artifact, and not a normal developmental stage. The pre-zoea stage may last only a few minutes to several hours. Hatching occurs within a few hours just after dusk, and individual female crabs may release some larvae daily over a period of three weeks (Stevens unpublished data). After hatching, the larvae pass through four zoeal stages (or instars), labeled Z1 to ZIV, by molting (Marukawa 1933). Detailed descriptions of the zoeal stages are available elsewhere (Sato 1945, 1949a, and 1949b). The first zoea is approximately 1.10 mm in length, and weighs 0.37 milligrams (mg). Stage ZIV larvae are 1.50 mm, and 0.89 mg (Nakanishi 1987). Zoeal stages have an extended tail, and swim using appendages that later become their mouthparts; they do not have walking legs or claws. Larvae molt from stage ZIV to a stage called the glaucothoe, which is transitional between larval and juvenile forms; it retains the extended tail and is a very capable swimmer, yet it also has fully formed walking legs and claws (chelipeds).

Environmental influences on king crab larvae

Zoea stage larvae consume more oxygen than embryos; their consumption ranges from 0.6 micrograms/hour (ug/hr) at 3°C to 1.2 ug/hr at 18°C (Nakanishi 1987). Consumption doubles from stage ZI to stage ZIV, then drops by 50 percent at the glaucothoe stage. Unlike the embryos, zoea larvae cannot tolerate low oxygen levels; their consumption rate declines linearly with decreasing saturation. Overall oxygen consumption was lowest at 8°C and 13°C.

The effects of water conditions on survival of the larvae are difficult to separate from the effects of nutrition. Nakanishi raised red king crab larvae solely on a diet of brine shrimp (*Artemia*) larvae, which is an inadequate diet (Kittaka et al. in press). Therefore, all of his survival rates were affected by poor nutrition. Nevertheless, survival to the first crab stage (C1) was best (25 percent) at 8°C, and less (8 percent) at 13°C; none survived at -1.8, 3, or 18°C.

Temperature has dramatic effects on growth of zoea larvae (Kurata 1960). Each larval stage requires a constant number of degree-days. Development of red king crab larvae from the first zoeal stage (termed Z1) to the first juvenile crab stage (termed C1) requires 376 degree-days at 8°C (Nakanishi 1987), to 429 degree-days at 13°C (Nakanishi and Naryu 1981). Kurata (1960) estimated complete development to require 460 degree-days. Nakanishi (1987) found that a total of 290 degree-days were required for complete development from ZI to glaucothoe at 8°C (i.e., 36.25 days at 8°C), whereas, 350 degree-days were required at any other temperature. He concluded that the optimal temperature for larval growth was 8°C. Stevens and Kittaka (1998) raised zoea larvae at 8°C and glaucothoe at 10.6°C, for a total of 396 degree-days (i.e., about 40 days at 10°C), of which glaucothoe development required 180 degree-days.

Tolerance to environmental stress is often assessed by exposing animals to some influence for a period of 96 hours (i.e. from noon Monday to noon Friday), and determining the resulting survival or mortality. The first stage zoea (Z1) has the widest range of salinity tolerance. The 96-hour survival of this stage exceeds 85 percent in salinities > 20 ppt, and temperature from 0-12°C (Shirley and Shirley 1989c). Survival is extremely poor above 18°C, or below 15 ppt. Thus, this stage can survive easily in nearshore waters typical of Southeastern Alaska, where the adult crabs are located. In a stratified or layered water column, typical of nearshore areas, Z1 larvae descend through the lower salinity upper layers until reaching a salinity of 27.5 ppt. Second stage larvae (ZII) have similar salinity tolerances, but lower temperature tolerance; survival exceeds 75 percent above > 20 ppt and <6°C. It prefers a salinity of 29.5 ppt. Larvae do not show any particular temperature preference. Rather, their responses to light and salinity induce them to move in particular directions, regardless of temperature (see below). Nakanishi (1987) reported similar results for all larval stages. Optimal salinity ranges for survival were greatest at 3-8°C, but vitality was best at 3°C; the optimal salinity in most cases was normal seawater (33.5 ppt).

At pH values from 6.5 to 8.0, survival of all zoeal stages is 100 percent (Nakanishi 1987). Survival is very poor at pH values below 6. However, seawater typically has a pH of 7.6-7.8, and is highly buffered, so pH never drops below about 7.0. Therefore, in natural waters, acidity is not a potential source of mortality.

Light levels are measured in lux (daylight is about 20,000 lux; average room light is 300-1,000). Constant light levels above 5,000 lux resulted in complete mortality of stage ZI to ZIV larvae and glaucothoe, but at 2,000 lux, 50 percent were still alive after 30 days (Nakanishi 1987). Stage ZIV and glaucothoe were less sensitive, and survived a few days longer at any light level than earlier stages. At 1,000 lux, constant illumination did not have any effect on survival. Light levels in the top meter of ocean water may be 1,000-2,000 lux, but decrease rapidly with depth, to about 100 lux at 10 m. Therefore, light levels would probably not affect survival of larvae in their natural environment.

Food quality and quantity is extremely important for zoea stage larvae. Stage I zoea larvae must find food within 60 hours; starvation reduces their ability to capture prey (Paul and Paul 1980). In nature, zoea larvae probably consume zooplankton such as copepod larvae, and phytoplankton (diatoms). In the laboratory, they are usually fed with brine shrimp (*Artemia*) larvae, with or without diatoms and other supplements. With some exceptions, food intake increases with both temperature and developmental stage. At 8°C, food intake increases from 20 *Artemia*/day stage, for stage ZI larvae, to 60 *Artemia*/day at stage ZIV (Nakanishi 1987). Stage ZI larvae required a prey concentration of at least 80 copepods/liter (L) before they could consistently capture one per day (Paul et al. 1979); the number consumed increased with prey concentration, so that zoeae consumed 7.6 copepods/day when the concentration was 160/L. However, natural concentrations rarely exceed 40/L in the ocean (Paul et al. 1989), so copepod larvae are probably not a major food source for stage ZI red king crab larvae.

Survival of zoea larvae in the laboratory can be increased by supplementing their diet with the chain-forming diatom *Thallasiosira nordenskioldii* (Kittaka et al. in press). In addition, enhancement of *Artemia* and diatoms with certain essential fatty acids, most notably eicosapentaenoic acid and docosahexaenoic acid (DHA), can improve survival of cultivated larvae significantly (Kittaka et al. in Press). Paul et al. (1989)

found that 100 percent of stage ZI larvae molted to stage ZII on a diet of *Thallasiosira* alone, at a concentration of 4,000 cells/milliliter (ml) or more. Natural concentrations can exceed 20,000 cells/ml during spring blooms, so this diatom could theoretically provide all the nutrition needed by ZI larvae. Other diatoms are not as nutritious; only 35 percent molted to stage ZII on a diet of *Skeletonema,* and 5 percent molted to ZII when fed with *Chaetoceros*, at concentrations near the extremes observed in nature.

Density of crab larvae, the number per liter, also affects survival. Increasing density from 35 to 750/L had little effect on survival of red king crab larvae. However, at the same densities, survival of larvae was greater in smaller batches (e.g. 35 zoea in 200 ml water) than in larger batches (e.g. 140 zoea in 800 ml). Survival rates were similar in 1 L or 30-l containers, but highly variable in 500-l tanks. Also, survival decreased with each successive zoeal stage; in a 30-l tank, survival remained above 80 percent at densities below 100, 50, and 30/L for stages Z1, Z2, and Z3 respectively. Therefore, each successive zoeal stage requires lower density of cultivation to maintain high survival. Cannibalism was common among stage ZI larvae held at a concentration of 50/L, even when fed abundant quantities of diatoms (Paul et al. 1989).

Tolerances of red king crab larvae for other characteristics of sea water such as ammonia, nitrates, or carbon dioxide levels is unknown. However, in the open ocean, these parameters are highly buffered, relatively constant, and rarely reach levels that would affect survival or behavior of larvae.

Behavior of larvae

Most planktonic organisms are nocturnal; they feed in the surface layers at night, then descend to deeper water in the daytime, to avoid visually-oriented predators such as fish. However, king crab larvae conduct this migration in reverse fashion. After hatching, king crab zoeae swim up in the water column and feed at depths of 5-10 m during the daytime; at night, they descend to depths below 30 m (Shirley and Shirley 1987; Shirley and Shirley 1989a). This strategy may minimize predation during the larval period. The depth of active feeding corresponds with the maximum density for both phytoplankton and copepod nauplii larvae, both of which are potential food sources. Larvae are sensitive to light, gravity, and currents. They swim towards light (i.e. they are positively phototactic) at high light levels, but swim away from dim lighting (i.e. they are negatively phototactic at low light levels); this “shadow response” may function as a mechanism for predator avoidance or as a cue to begin migrating downward at night. Zoea larvae can swim horizontally at speeds of 1.7 to 2.4 cm/s, and vertically at 1.6 cm/s; they sink at a rate of 0.7 cm/s (Shirley and Shirley 1988). They swim into water currents, i.e., are positively rheotactic, and can maintain their position in currents up to 1.4 cm/s. They are negatively geotactic, i.e. move up in a water column, but this response may be overcome by phototaxis.

Other biological factors

In the ocean, survival of larvae requires a balance between their ability to obtain adequate nutrition and to avoid predators. Hatching generally occurs during the spring, when phytoplankton and zooplankton populations are beginning to bloom. This match between hatching of larvae and growth of their food supplies has long been considered crucial to the survival and recruitment of marine species, and is termed the “match-mismatch” hypothesis (Hjort 1914; Cushing 1990). According to this hypothesis, larvae that hatch during periods of abundant food will have high survival and those that hatch too early or too late will have lower survival. Because embryonic development of king crabs is controlled by temperature, cold years tend to result in later hatching. For example, Shirley et al. (1989) reported a 25 percent decrease in laboratory incubation time at 6°C (241 days) vs. 3°C (321 days). If phyto- and zoo plankton blooms are similarly affected by temperature, no mismatch should occur, but phytoplankton blooms are typically more responsive to light levels, nutrient availability, and windstorms. Furthermore, studies in Southeast Alaska over a four-year period have shown that despite large variations in the timing of larval crab abundance relative to phytoplankton blooms, little variation in larval survival occurred (Shirley and Shirley 1989b). However, the availability of specific diatom species, such as *Thallasiosira*, may be critical to survival of red king crab larvae. Thus, it is likely that the community composition and relative abundance of various phytoplankton species has a greater influence on survival of red king crab larvae, than the overall abundance of phyto- or zooplankton communities as a whole.

Larvae are also subject to predation by many species. Limited evidence suggests that walleye pollock *(Theragra chalcogramma*), Pacific herring (*Clupea pallasi*), and sockeye salmon (*Oncorhynchus nerka*) all prey on red king crab larvae at some point in their lives (Loher 2001). During summer, juvenile pollock, herring, and sockeye salmon smolts are abundant in the nearshore waters of Bristol Bay, Alaska, where red king crab larvae are present. It is possible that increases in the abundance of pollock and salmon since 1980 may have played a role in limiting survival of red king crab larvae (Loher 2001). The abundance of large jellyfish also increased after 1980 (Brodeur et al. 2002). Although jellyfish may capture and consume crab larvae, it is more likely that their consumption of planktivorous fish larvae would have a positive influence on the abundance of larval crabs, by removing predators of crab larvae.

Larval development of other king crabs

Blue king crab. The requirements and effects of environmental influences on larvae other species of king crabs are poorly known. Both blue king crab and golden king crab usually have only three zoeal stages. Complete development of the zoeal stages in blue king crab requires 30 days at 8 °C (240 degree days), but only 21 days at 11°C (231 degree-days) (Kittaka et al. 2001). In the ocean, blue king crab larvae occur in waters with temperatures from 0-4°C, principally overlying the areas of adult female abundance (see below) (Armstrong et al. 1985).

Golden king crab. Golden king crab occasionally skip stage 3 and have an extra, fourth stage, molting from ZII to ZIV, prior to becoming a glaucothoe (Shirley and Zhou 1997). Unlike blue king crab and red king crab, the zoeal stages of golden king crab are lecithotrophic, i.e. they utilize nutritional supplies stored internally, rather than relying on external food sources (Shirley and Zhou 1997). Survival of unfed larvae was better than that of larvae fed with brine shrimp (*Artemia*) larvae. Complete larval development is a function of temperature, and requires from 23 days at 9°C, to 56 days at 3°C (Paul and Paul 1999). Lecithotrophic larval development (in golden king crab) probably arose as a response to lack of planktonic food sources at the depths where they live (200-600 m).

Conclusions: Environmental influences on larval development

The optimal conditions for survival of red king crab zoeae are: temperature 8°C; salinity of 34-35 ppt, pH of 7.5, oxygen at full saturation; constant illumination of 1,000-2,000 lux; density of 40 zoea per liter, and feeding rate of 50 *Artemia* nauplii per day. In these conditions, survival rates from stage ZI to C1 can exceed 20 percent in the laboratory. Larvae can survive solely on a diet of the diatom *Thallasiosira*, and other diatoms may supplement their diet but are not as nutritious. However, a mixed diet of zooplankton and phytoplankton is probably optimal for growth and survival. Densities of larvae in the ocean are much lower than those tolerated in culture. Requirements for pH, ammonia and nitrates are unknown, but probably never reach limiting concentrations in the ocean. Predation by planktivorous fishes may be a limiting factor in some years and seasons, but its overall effect on recruitment is unknown.

3.2.1.3 Transitional (glaucothoe) stage

Development of glaucothoe

Until recently, the glaucothoe stage was poorly studied. Its behavior and environmental requirements were presumed to be similar to those of the larval stages (Tyler and Kruse 1995). However, recent research has made it clear that the glaucothoe stage is unique, and plays a critical role in the life cycle of the king crab. Glaucothoe are 1.5 mm long, and weigh 1.30 mg. They look very much like small king crabs, except for the extended abdomen with pleopods, that it uses for swimming.

Environmental requirements of glaucothoe

Oxygen consumption of glaucothoe is similar to the larval stages; they consume 0.6 ul/hr of oxygen at 8°C and 18°C, but only 0.3 ul/hr at 13°C (Nakanishi 1987).

The length of the glaucothoe varies from 32 days at 13°C, to 43 days at 8°C (from 344 to 416 degree-days) (Nakanishi 1987). Other researchers found that the glaucothoe stage lasted only 24 days at 8°C (Kittaka et al. 2001), and only 16 days at 10°C (Stevens and Kittaka 1998), i.e. from 160 to 192 degree-days. Survival of glaucothoe was highest at 8°C, less at 13°C, and negligible at 3 or 18°C (Nakanishi 1987).

Glaucothoe have greater 48-hour salinity tolerance at 3°C than at 8°C (Nakanishi 1987). Best survival occurs at 7°C, and 37.9 ppt. At 8°C, 100 percent survived in salinities from 27 to 40 ppt. Nakanishi concluded that "vitality" was greatest at 3°C and 33.5 ppt. Heart-beat rate decreases from 160 bpm to 55 bpm at 20 ppt salinity, but the larvae recover after 24 hours. No effect occurred at 26.8 ppt, but salinities of 13.4 ppt and below resulted in complete mortality over 24 hours.

Exposure to high light levels is fatal to glaucothoe;100 percent died after 20 hour exposure to 5,000 lux, after 15 hours at 10,000 lux, and after four hours at 15,000 lux.

Nakanishi reported that glaucothoe appeared to consume very small numbers of *Artemia* larvae, if any. However, more recent work has shown that they do not feed at all. Both red king crab and blue king crab are unique in their development because they undergo a non-feeding glaucothoe stage (Abrunhosa and Kittaka 1997b; Abrunhosa and Kittaka 1997a). During the metamorphosis from the zoea to the glaucothoe, substantial morphological alterations occur, so that the mouthparts and stomach transform to non-feeding structures. The mandibles become reduced and lack grinding teeth. The maxillae also lack setae. Stomach components become reduced and atrophied, indicating that food processing does not occur in the glaucothoe. Upon metamorphosis to the first stage juvenile crab, however, the mouthparts become fully functional, and the stomach becomes highly complex with well developed gastric mill as in the adult form (Abrunhosa and Kittaka 1997a). Laboratory studies also demonstrate that glaucothoe do not feed. Those that were fed daily with *Artemia* had identical survival (73 percent) to those that were not fed (Stevens, unpublished data).

Unlike the larvae, which live in a fluid environment, the glaucothoe live attached to substrates (see below). Therefore, determination of density (numbers per unit area or volume) is difficult, and no studies have been conducted on its effects (see section below on juvenile crab density).

Behavior of glaucothoe

The glaucothoe stage is transitional in both form and habitat. It must make the change from a free swimming larva to a benthic juvenile. In order to do so, it must choose a suitable habitat in which to settle. This is a critical process in the life of the crab. While the larvae live freely in a large volume of water, and can be transported over long ocean distances, the juveniles are restricted to specific localized substrates, which form a bottleneck in the king crabs life cycle.

Red king crab glaucothoe settle readily on various types of artificial collectors (Donaldson et al. 1991). The most efficient collector consists of loose monofilament gillnet stuffed inside an onion bag (Blau et al. 1990). Glaucothoe prefer to settle on structurally complex substrata they can grip, with many small interstitial spaces in which to hide. They preferred plastic mesh filter material, but also settled in lower number on less complex substrata like gravel (Stevens and Kittaka 1998). Glaucothoe prefer both hydroids and red algae over calcareous tube worm colonies, which provide much more hard surface area for attachment, but have less interstitial space (Stevens in press). Their preference for hydroids is probably what attracts them to artificial collectors, which are typically covered by hydroid colonies. When placed in aquaria with suitable substrates on the day of metamorphosis from stage ZIV, the majority of glaucothoe will settle immediately. They grip the substrate with their claws, and remain immobile for most of the glaucothoe stage, which may last from 15 to 24 days. However, they refuse to settle on sand. If sand is the only substrate available, they will continue swimming until they undergo metamorphosis to stage C1 and can no longer swim (Stevens and Kittaka 1998). Sand is a poor substratum because it is easily disturbed, and king crabs do not bury into it.

Preference for complex substrata (such as highly branched organisms) may be an adaptive response to high predation levels, allowing red king crab glaucothoe to locate scarce shelters (Stevens and Kittaka 1998). Another advantage is that preferred habitats often reduced the required developmental time (time-to-metamorphosis [TTM]) for many invertebrate larvae, including decapod crustaceans. Red king crab glaucothoe that settled on plastic mesh material underwent metamorphosis to stage C1 one day earlier than those that settled on other substrates (Stevens and Kittaka 1998). Because glaucothoe do not feed, they are not restricted to any specific type of habitat, and do not respond to food cues, which could be very misleading.

Glaucothoe are capable swimmers, and will swim continuously during the daytime. At night, they stop swimming, and settle to the bottom of the tank, immobile (Stevens and Kittaka 1998). This suggests that their “modus operandi” during the glaucothoe phase is to swim during the daytime, and test out various substrates, but remain motionless at night in order to avoid predation (Stevens and Kittaka 1998).

Other biological factors

Like the larvae, glaucothoe are subject to predation by fish and other predators. However, because they take up a bottom-dwelling lifestyle almost immediately upon metamorphosis to this stage, glaucothoe are probably more susceptible to bottom-feeding predators than to pelagic fish. Such predators include sculpins and flounders, but a large proportion of mortality may be due to cannibalism by older king crabs (NMFS unpublished data). Haflinger and McRoy (1983) found yellowfin sole and rock sole consume glaucothoe.

Because they require specific types of habitat with complex structure, the options for settlement of a red king crab glaucothoe are limited. Such structure may occur only in a few isolated parts of the Bering Sea (Loher 2001). Furthermore, these habitats are highly susceptible to disturbance, destruction, or removal by fishing activities (Loher, 2001). While many parts of the Bering Sea are presently closed to on-bottom trawling, activities prior to the advent of closures may have affected the distribution or abundance of such habitats.

Glaucothoe of other king crab species

Blue king crab. Development of glaucothoe of blue king crab requires from 17 to 26 days (Kittaka et al. 2001).

Golden king crab. Golden king crab glaucothoe require 52-93 days at 3 to 9°C, respectively. Neither species feeds during this stage.

Conclusions: Requirements of glaucothoe development

Glaucothoe require high levels of oxygen, and have best survival at a temperature of 8°C. Their salinity requirements are unknown but probably similar to the zoea larvae, with an optimum near 35 ppt. They require moderate light levels (<1,000 lux), as high levels are fatal. Glaucothoe are not capable of feeding. Their most important requirement is for suitable substratum on which to settle. Such substrata include highly complex structures such as hydroids, algae, bryozoans, worm colonies, and gravel, but any complex substratum may suffice. Their sedentary bottom-dwelling life style makes them highly susceptible to predation and habitat disturbance.

3.2.1.4 Juvenile stages

Early benthic phase (EBP) juveniles are age 0-1 (= postlarval or young of the year) pre-podding, benthic instars that display a cryptic, solitary existence that is behaviorally distinct from older, podding individuals (Loher 2001). After metamorphosis from the glaucothoe, the juvenile crab stages, or instars, are numbered as C1, C2, C3, etc.

Environmental requirements of early benthic phase juvenile king crabs

Oxygen consumption of juveniles increases as they grow, from 0.78 ul/hr for stage C1 to 28.3 ul/hr for stage C7 (Nakanishi 1987). However, the weight specific consumption rates decrease over that range of instars, from 165 ul/ug-hr to 85 ul/ug-hr (Nakanishi 1987). Oxygen consumption is directly proportional to wet weight:

$$O^2 \text{ (ul/hr)} = 0.555 \text{ (Wt)}^{0.66} \qquad \text{(R)} = 0.837)$$

At 8°C, 100 percent of juvenile red king crab survived a 48-hour exposure of 27 to 54 ppt salinity (Nakanishi 1987). Optimal survival occurred at 8°C, and 33.5 ppt. Light and pH requirements of juvenile king crabs are poorly studied, and thus unknown.

Based on stomach-content analysis, juvenile crabs consume diatoms, foraminifera, algae, sponge spicules, bryozoans, polychaetes, copepods, and sediment; detritus may also be a major component of their diet (Feder et al. 1980). At age 1+, crabs will eat many different foods, including bivalves, worms, seastars, and other crustaceans. In the laboratory, their maximum consumption rate is approximately 10 percent of body weight per feeding, when fed twice weekly (Stevens unpublished data). Consumption rates of two-year old crabs increase with temperature, from 1 percent of body weight at 5°C to 3 percent at 20°C (Rice et al. 1985). Consumption rate decreases with size; crabs with body weights from 200 to 1,000 gram (g) consumed from 6 to 4 percent of body weight per feeding (Zhou et al. 1998).

As noted before, cannibalism of recently molted king crabs is common. Survival rates of first-stage crabs decline rapidly regardless of rearing density, primarily due to cannibalism. However, because young crab stages cling to substrate materials, density must be determined on an areal rather than volumetric basis. Juvenile crabs are randomly distributed, though they tend to concentrate at boundaries such as tank walls. Nakanishi recommended an optimal density of 1,000 stage C1 crabs per square meter (m^2) (Nakanishi 1987). The extent to which cannibalism occurs in nature is unknown. No cannibalism has been observed during underwater, in situ observation in various bays around Kodiak, Alaska (e. g., Dew 1990, Dew 1991; Dew et al. 1992). Some scientists speculate that it is likely that the high rates of cannibalism observed in laboratory enclosures is an artifact not replicated in nature.

Ecology of young of the year juveniles

After the EBP, juvenile crab develop into young of the year. Young of the year red king crab naturally occur on hard substrata with a cover of abundant live organisms (epifauna), indicating that they probably settle and metamorphose on these substrata. They have been found on hydroids attached to tangle nets in the Bering Sea (Kawasaki 1959). In Kachemak Bay, Alaska, most occurred on course substrata (pebbles, cobble, boulders, or shell debris) covered with sponges, hydroids, and bryozoans, suggesting that the abundance of epifauna influences the distribution of juvenile red king crab (Sundberg and Clausen 1977). In the Bering Sea, young of the year red king crab have been found almost exclusively among epifauna (hydroids, bryozoa, polychaete, and mussel colonies) associated with erect, stalked tunicates (*Boltenia* sp.), attached to dispersed hard substrata such as gravel or shell debris (McMurray et al. 1986; Stevens and MacIntosh 1991). In Kodiak, young of the year red king crab are found commonly on pilings covered with sponge, bryozoans, hydroids, and tunicates, in concentrations greater than on the surrounding substratum (Stevens et al. 2001b), and they settle abundantly on artificial collectors covered with hydroids (Blau et al. 1990; Donaldson et al. 1991). In their second year, at sizes > 10 mm, red king crab are commonly observed in contact with sea stars (Dew 1990). In southeast Alaska, juvenile red king crab have been found among shale cobble in the intertidal zone, but rarely among hydroids attached to floating docks (T. Shirley, University of Alaska, Juneau, AK, personal communication to B. Stevens, NOAA Fisheries, AFCS Kodiak Lab, August 2000). Settlement of young of the year red king crab was three times higher in rocky cobble than in shell hash, and no glaucothoe or early stage crabs were found in silty mud (Loher and Armstrong 2000). This distribution was the result of post-settlement processes rather than the result of larval supply, because post-larval settlement onto artificial collectors (Donaldson et al. 1991), was highest over the silty mud habitat. They concluded that "...substratum rich in available crevice space that is scaled to the body size of the crab instars appeared to be the primary determinant of the value of nursery habitat...".

In Kodiak, red king crab up to1.5 years of age are commonly found on wooden pilings covered with all of these fauna as biological structure (personal observation, B. Stevens, NOAA Fisheries, AFCS Kodiak Lab). Biological structure is scarce in the Bering Sea, yet is typically the only location where one year old red king crab are found. This suggests that the distribution of early stage red king crab arises due to either (1) indiscriminate settlement, followed by high mortality of those which settle in open habitats, or (2) selective settlement in structured habitats. The limited availability and discontinuous nature of structurally complex habitat presents a "bottleneck" which may limit survival and recruitment to the adult phase (Loher 2001). As settlement begins, habitats may become rapidly "saturated" with glaucothoe or stage C1 crabs, after which additional settlers are forced out to marginal habitats where predation risk from fish or other crabs is much higher.

Ecology of podding juveniles

As mentioned above, early stage crabs seek out biological cover in which to hide. At about age one (10 mm) they start appearing in contact with seastars. After they reach a size exceeding 25 mm CL, red king crab start to exhibit aggregative (podding) behavior (Powell and Nickerson 1965b; Dew 1990). Pods consist of similar sized crabs of both sexes, and may contain hundreds to thousands of crab. Juvenile crabs appear to form pods during the daytime, but dispersed at night for feeding. This behavior was more common in winter when activity and feeding were diminished, and was less common in summer when feeding was common throughout the day and (short) nighttime. Pod formation may also be a function of density; few pods have been observed in Kodiak since 1990, while king crabs have been very scarce (P. Cummiskey, NOAA Fisheries Kodiak Lab, personal communication to B. Stevens, NOAA Fisheries Kodiak Lab June 2001). However, the major pod studies at Kodiak, i.e., the studies that produced publishable results, were conducted from 1988-96. The largest pod of adult RKC ever documented (some 20,000 RKC age 5-12) was followed (and photographed) for several months during the late summer and fall of 1993. The frequency of pod sightings is inextricably bound up with the effective search hours spent underwater, which declined sharply after 1996.

A question that has been long debated is whether or not podding behavior continues into adulthood. Podding may becomes less common after the crabs reach maturity, but females may collect into loose aggregations during the mating period (Stone et al. 1993). Podding intensifies as separate, year-class pods combine into single aggregations at age 3-4 (Dew 1992). An informal consensus has developed over the years that only juveniles are podding crab and that podding behavior ceases after the crab attain a size of 60-65 mm CL at age four (e. g., Powell and Nickerson 1965b; Incze et al. 1986; Otto 1986; Armstrong et al. 1993; Witherell 1998; Ackley and Witherell 1999). Field studies at Kodiak, based on in-situ observations of sonic-tagged aggregations tracked for several years, show that pods initially form in the second year of life and are composed of a single year class. At age 3-4 these single-cohort pods combine with other older crab in the area to form very large, multiple-age pods (Dew 1992).

Podding may be a behavioral response to reduce predation. Predators searching for individual crabs would have difficulty recognizing a pod as a group of individuals. Some predators, such as Pacific cod, would probably have difficulty isolating or removing single crabs from the pod. However, sea otters, *Enhydra lutris*, have been observed to remove crabs from pods and feed on them at will (P. Cummiskey, NOAA Fisheries Kodiak Lab, personal communication to B. Stevens, NOAA Fisheries Kodiak Lab).

In the only study to observe the transition from the EBP to the podding phase, the inception of podding was in late September of the second year of life when the crab were about 1.5 years old and at a mean size of 24 mm (17-34 mm) (Dew 1990). Two different pods were monitored for 196 days (November 1987-June 1988) and 148 days (October 1988-February 1989), and the concepts of organized nocturnal foraging, homing behavior, and night-only molting were established. Now it could be understood that the typical dome-shaped pod reported on over the years (e. g., Powell and Nickerson 1965b; Bright 1967) was simply the daytime resting phase for crab that would be actively foraging throughout the night. Pods most often began foraging by moving into the oncoming current. Individual crab that were going to molt that night moved in the opposite direction, downcurrent and away from the foraging aggregation, to seek a relatively sheltered place to molt. Newly molted crab appeared to rejoin the pod within a day or two. Unlike reports from the laboratory (e. g., Stevens 2002), no molting was observed to occur in daytime and no incidents of molt-related cannibalism were observed in the wild.

Podding represents a sharp discontinuity in the behavioral ecology of juvenile red king crab. Podding juveniles are no longer cryptic and solitary, relying on complex habitat to provide individual niches for protection. Although pre-podding crab waited until after sunset to begin foraging and were not observed foraging during the day, podding crab quickly expanded their spring-summer foraging time to include daylight hours. Moreover, podding crab expanded their spring-summer foraging space by moving away from the complex habitat of nearshore waters, where temperatures were increasing, to deeper, relatively featureless silt bottoms where water temperatures were 3-5°C lower (Dew 1990; 1991; Dew et al. 1992). In 25 laboratory tests, Moles and Stone (2002) found that individual, age-two, red king crab never ventured onto mud substrates. Conversely, in nature, age zero to one pre-podding red king crab were found on the mud-silt substrates of Womens Bay 4 percent of the time and age two to four podding crab spent 86 percent of their time there (Dew 1991). It may be impractical to duplicate podding behavior in the laboratory; but experiments that fail to do so are likely to be unrepresentative of red king crab behavior in the wild.

Because podding concentrates a great many crab in a relatively small area, and because podding crab forage primarily at night and molt only at night, podding would not be an effective strategy to reduce predation except in the case of randomly searching, daytime-active predators such as cod or halibut. Podding would not be effective in countering the predation of otters and other relatively intelligent predators, which have the ability to follow or to nonrandomly relocate a pod (Dew 1990). Consistent with this hypothesis are in-situ observations made while tracking sonic-tagged red king crab aggregations in Womens Bay, which show that the two greatest sources of mortality for podding crab were otter predation and ghost-fishing by derelict crab pots. After two years of increasing otter predation in Womens Bay during 1994-1995, a sonic-tagged aggregation of about 1,000 crab tracked for several months abruptly reverted to cryptic behavior and began burying in the mud during the day, similar to red king crab behavior observed in other waters (e.g., Prince William Sound) where otters were abundant (B. Dew, NOAA Fisheries, AFSC, unpublished data).

Based on dozens of food-habit studies, most of which are cited in Jewett and Onuf (1988), it is reasonable to conclude that red king crab are omnivorous, eating a wide variety of microscopic and macroscopic plants and animals. There appear to be no particular food items that are critical to the survival of juvenile red king crab. The stomachs of red king crab from shallow (<20 m) waters around Kodiak during May-June 1978-1979 contained 53 different prey taxa, including bivalves, barnacles, polychaetes, snails, Tanner crab, echinoids, and hydroids (Feder and Jewett 1981). According to Jewett and Onuf (1988), stomach-content analysis tends to overstate the importance of prey such as mollusks and barnacles that contain hard parts. Alternatively, a list of food items observed being eaten in situ by age one to two crab in Womans Bay, Alaska, includes (in order of decreasing frequency): sea stars (primarily *Evasterias troschelii*), kelp (*Laminaria* sp.), sea lettuce (*Ulva* sp.), red king crab molt exuvia, littleneck clams (*Protothaca staminea*), mussels (*Mytilus edulis*), nudibranch egg masses, and barnacles (Dew 1990). Large pieces of kelp and *Ulva* were purposefully taken up and devoured, indicating that macrophytes were not simply ingested as incidental detritus while foraging. Small crab (30-50 mm) were observed cooperatively dismembering relatively large prey. Whole sea stars that were preyed upon ranged in diameter from approximately 50-200 mm, and chunks of still-living sea stars were often found in the vicinity of juvenile aggregations.

Juvenile and subadult red king crab may remain in nearshore waters for several years before moving to deeper, offshore waters to pursue a fully adult lifestyle. Almost continuous tracking of sonic-tagged aggregations at Kodiak enabled divers to follow cohorts (year classes) of crab for several years. In this way it was determined that members of the 1987 and 1988 year classes that appeared as age zero to one crab in Womens Bay remained there until October 1993. That is, they remained on or near their nursery grounds for 6.5 to 7.5 years until they were age 5.5 and 6.5. A question that has been long debated is whether or not podding behavior continues into adulthood. An informal consensus has developed over the years that only juveniles are podding crab and that podding behavior ceases after the crab attain a size of 60-65 mm CL at age four (e.g. Powell and Nickerson 1965b; Incze et al. 1986; Otto 1986; Armstrong et al. 1993; Witherell 1998; Ackley and Witherell 1999). Field studies at Kodiak, based on in-situ observations of sonic-tagged aggregations tracked for several years, show that pods initially form in the second year of life and are composed of a single year class. At age three to four these single-cohort pods combine with other older crab in the area to form very large, multiple-age pods (Dew et al. 1992). One such aggregation of 20,000 to 30,000 crab was studied for several months before it left Womens Bay and disappeared into the deep water (100-400 feet) off Kalsin Bay in October of 1993. Most were estimated to be age 5.5-6.5 crab from the 1987 and 1988 year classes. Upon leaving Womens Bay, the mean CL of the males was 110 mm (79-165 mm), that of the females was 96 mm (60-131 mm), and 12 percent of the females were carrying six to seven month-old egg clutches (Dew and McConnaughey 2003). This observed evolution, from multiple, separate cohorts of age one crab to a single very large aggregation of several age groups ranging from approximately age four to age 12, suggests that the intensity of podding tends to increase rather than decrease with age and that adult crab are podding crab.

Other biotic factors

Soon after settlement and metamorphosis to the first crab stage, juvenile red king crab are considered to be in their “early benthic phase” (Wahle and Steneck 1991; Loher 2001). Such EBP crabs, as they are known, are highly susceptible to predation. This period of their life is probably the most dangerous, and has the highest mortality, of any other period, because they are too small to escape large predators. In the southeast Bering Sea, major predators of early benthic phase crabs include Pacific cod (*Gadus macrocephalus*), Pacific halibut (*Hippoglossus stenolepis*), Alaska plaice (*Pleuronectes quadrituberculatus*), yellowfin sole (*Limanda aspera*), flathead sole (*Hippoglossoides elassodon*), and arrowtooth flounder (*Atheresthes stomias*) (Livingston et al. 1993). Predation by these commercially important fish is well documented; however, major predation also occurs by non-commercially valuable species though it is less well documented. Those species include sculpins (*Myoxocephalus* sp), Irish lords (*Hemilepidotus* sp), snailfish (*Liparis* sp.), and skates (*Raja* sp.).

Another major predator, and perhaps one of the most significant, are larger crabs. Up to age one, juvenile red king crab are found on the same type of structurally rally complex habitat that is preferred by the settling stages. The presence of one-year old crabs in such habitats could be a major limitation to successful recruitment. Preliminary laboratory studies have shown that age 1+ red king crab can consume 20- 25 glaucothoe or C1 crabs in a 24 hour period (Dew 1990). Larger, age 2+ crabs can consume 15-20 glaucothoe in 24 hours, even though their larger chelipeds make it much more difficult to handle small food items. Cannibalism may have a much larger impact on settling year classes than previously expected. This is especially true if recruitment to settlement habitats was higher than normal in the previous year, such that age 1+ crabs are more numerous than usual.

Juvenile red king crab that molt in laboratory tanks are usually preyed upon by other crabs in the tanks. However, this usually occurs during molting, when the crab is soft and vulnerable. If so, then how do crabs avoid cannibalism in the natural environment? Several mechanisms may function to reduce natural cannibalism levels. First, crabs preparing to molt often leave the pod or aggregation and move off by themselves (NMFS unpublished data). In laboratory tanks, the chemical odors produced by molting crabs are probably detectable by all crabs in the tank, whereas in the ocean, dilution probably makes them undetectable over short distances. Second, red king crab of the same age tend to molt synchronously. Observations in the lab and field show that most crabs in a cohort will molt over a period of several days (for recently settled stage C1-C4 crabs) to several weeks (for crabs up to age 2+). In addition, they do not feed for a week or more before and after molting (NMFS unpublished data). Synchronous molting and reduced appetites probably aid significantly in the reduction of cannibalism. Thirdly, diet may have a significant impact on cannibalism (Broderson et al., 1989). Crabs fed on mussels exhibited twice the growth rate and significantly less mortality due to cannibalism than those fed with shrimp. Thus, it is apparent that a varied diet of wild foods provides juvenile crabs with appropriate nutrition, lack of which may stimulate them to supplement their diet by consuming their cohorts.

As crabs grow older, they begin to exceed the mouth gape of these predators, and thus reach a "refuge in size". However, some large crab fall prey to large fish such as halibut or Pacific cod. However, nearly all such observations involved predation on soft-shelled female crabs that had recently molted (Livingston et al. 1993).

Juvenile development of other species of king crabs

Blue king crab. Compared to red king crab, blue king crab live in relatively small populations in isolated locations. Populations exist near the Pribilof Islands and St. Matthew Island in the Bering Sea, in Herendeen Bay on the Alaska Peninsula, Olga Bay on Kodiak Island, and in some bays and fjords of Southeast Alaska. These isolated groups may be relicts of a once more widely distributed population. Juvenile blue king crabs occur primarily on substratum of gravel and/or cobble overlaid with "shell hash", a mixture of broken bivalve and gastropod shells (Armstrong et al. 1985). This habitat occurs in limited areas around St. Paul Island in the Pribilofs, and indicates "a strong dependence of juveniles on substrate that affords refuge from predators"(Palacios et al. 1985). That association suggests a habitat requirement for juvenile blue king crab in the Bering Sea that is limiting to the species' distribution. Survival is linked to the abundance of shells of certain mollusk species, including mussels *(Modiolus modiolus),* scallops *(Chlamys sp.),* rock oysters *(Pododesmus macrochisma),* and hairy tritons *(Fusitriton oregonensis)* (Palacios et al., 1985). Such material is scarce in offshore, sandy environments. Over 80 percent of juveniles live at depths < 50 m, and >90 percent live between 0-1°C (data from Armstrong et al., 1985; Stevens et al. 2001a).

Armstrong et al. (1985 and 1987) suggested that shell hash habitat was important to juveniles as a refuge from predators; juvenile blue king crab lack the long spines present on juvenile red king crabs and may have a greater requirement for the cover afforded by shell hash to avoid predators. Blue king crab juveniles in their first year of life often have white carapaces that blend in with shell hash. Later juvenile stages have a mottled color pattern that blends into the background epifauna. Unlike red king crab juveniles, blue king crabs are not known to form pods.

Golden king crab. Juvenile golden king crab occur primarily at depths exceeding 600 m in the Aleutian Islands (Blau et al. 1996). On GOA seamounts they occur primarily in a narrow band from 580 to 630 m, and 90 percent were associated with cobble or rock (NMFS unpublished data).

Conclusions: Requirements of juvenile crabs

Early juvenile crabs (< 1 year) require high oxygen levels, temperatures between 2 and 10°C, salinity above 27 ppt. Highest survival occurs at 8°C and 34 ppt. Juveniles are voracious feeders and will eat almost any organic or biological material, but prefer small crustaceans, polychaetes, and bivalves. Feeding rates range from 1 percent to 10 percent of body weight per day, and increase with temperature, but decrease with size. First stage crabs can tolerate densities as high as 1,000/m^2, but probably rarely reach that concentration in nature. Cannibalism by other king crabs is a significant source of mortality. An important requirement for juveniles is the presence of complex substrata in which to hide from predators and other crabs. Substrata that meet these criteria change with size of the crab; first stage crabs prefer hydroids and algae, one-year old crabs occur on sea stars. Above 25 mm CW, crabs begin aggregating into pods with crabs of similar size and age. Such behavior may help reduce predation by large fish.

3.2.1.5 Adult stages

Female king crabs typically reach sexual maturity at approximately five years of age, and sizes of 85-95 mm CL. Males may reach maturity one year later, at six years of age, and sizes of 100-115 mm CL. Prior to this age, they spend much of their time in large aggregations which frequently coalesce into dense pods of similarly sized animals, with both sexes present (Powell and Nickerson 1965b; Dew 1990). However, after reaching sexual maturity, the sexes segregate into different groups. In the southeast Bering Sea females remain in relatively shallow nearshore waters most of the year, whereas males move offshore into deeper water during the summer and fall, and return to shallower water for breeding in the winter and early spring (Loher 2001). In southeast Alaska bays, females spend the summer and fall in deep water (>60 m). Males and females return to shallower water for molting and mating in the spring, then move offshore as the water temperature increases (Stone et al. 1992).

Although the juvenile crabs tend to live in highly heterogeneous habitats, adult crabs tend to live in habitats that are sandy to muddy, with very little structure. Adult red king crab live in depth ranges from 10 to 100 m in the Bering Sea, but >75 percent live between 50-75 m. 50 percent of adults, and >70 percent of juveniles live at temperatures >4°C, the remainder live between 2-3°C (data from Stevens et al. 2001a). Salinity of bottom waters in the region of greatest abundance ranges from 31.4 to 32.8. Adult red king crab occur primarily in habitats that are characterized as sand or muddy sand, with phi values ranging from 1.5-3.5 (0.4-0.1 mm) (Smith and McConnaughey 1999).

Adult king crabs are occasionally observed partly buried in the mud, especially in winter, when their metabolic rate is lower (B. Stevens, NOAA Fisheries Kodiak Lab, personal observation; Stone et al. 1993). While adult red king crab do not often form aggregations in open habitats, they occasionally aggregate against erratic structures such as rock outcrops, old tires, or derelict crab pots (B. Stevens, NOAA Fisheries Kodiak Lab, personal observation). In the southeast Bering Sea, they may also aggregate at locations where there is a sudden change in topography, such as the base of submarine slopes (NMFS unpublished data).

Because crabs have a hard outer shell, or exoskeleton, they do not grow in a linear fashion like most other animals. In order to grow, they must shed their shells in a process called molting. This is a complex physiological process. A month prior to molting, the crab secretes enzymes which help to separate the epidermis from the exoskeleton. Over the next few weeks, the crab gradually retracts all of its body parts from the outer shell be a few mm, while it begins to secrete a new shell beneath the old one. About 24 hours before the crab molts, it starts absorbing water, which causes it to swell up and burst out of its shell. In less than 10 minutes, it backs out of the shell, leaving behind all of its legs, mouthparts, antenae, eyestalks, the pharynx and stomach lining, and gill coverings. Molting takes place about 15-20 times in the life of a crab. A king crab may molt six times in its first year, four in its second, two or three times in its third, and after that, perhaps only once a year. After sexual maturity, the females continue to molt annually, while intermolt periods become continuously longer for males, so that they only molt once every few years.

Crabs molt in close synchrony to reduce the likely hood of being eaten. After molting the crabs are very soft and vulnerable. They cannot move much and they cannot eat for a week or two afterwards. Scientists predict that a physiological signal tells crab that its shell is too full and its time to molt. In addition, scientist predict that crabs molt based on an environmental signal and/or chemical communication between crabs.

Mating and reproduction

Prior to mating, female king crabs must shed their old shells and produce a new one (a process called molting). Immature females with ripe ovaries that are ready to mate for the first time are referred to as pubescent or adolescent, and must molt to the mature form. As they prepare to undergo the molting process, they release pheromones (biochemical hormones) into the water, that are detectable by male crabs up to several weeks before they actually molt. The male is probably attracted to the female by these pheromones, as seems true in some brachyuran (Gleeson 1980).

When a male locates a female, he grasps her first pair of legs (the ones with claws) in his claws and holds her facing him for several days. This behavior is called “hand-holding” or grasping. Soon, she begins to molt; her old shell separates, and in about 15 minutes, she wriggles out of her old shell, and is covered with a new, softer shell. At the same time, she absorbs lots of water, and swells up, thus growing in size. After she has molted, the male places her beneath him, and inserts himself between her abdomen and body. Males extrude strings of sperm packets (spermatophores), from the opening at the base of their small 5th pair of legs; using the brushy tip of this leg, he spreads them onto the abdominal appendages (pleopods) and abdomen of the female. This may require several attempts over a period of hours, and usually occurs at night. After copulation, the male releases the female, and has no more interest in her.

Females extrude their eggs from an opening on the underside of their bodies. Upon exposure to seawater, a sac forms around each egg, which attaches itself to small hairs on the pleopods. During this process, the eggs are fertilized by sperm from the spermatophores. Female crabs cannot store sperm. Therefore, they must mate annually to produce a clutch of fertile eggs. If a female with ripe ovaries is not fertilized by a male, she may reabsorb the eggs inside her body cavity, and not extrude them (Paul and Paul, 1997). The success rate of fertilization depends on male size and mating history: in laboratory studies, the proportion of eggs fertilized by small males (<90 mm CL) declined from 68 percent on their first mating to 12 percent for their third, whereas legal sized males (>135 mm CL) can fertilize up to four females with 100 percent success (Paul and Paul 1990; Paul and Paul 1997). Field studies at Kodiak showed that males <110 mm CL were incapable of sustained, continuous grasping over several days. In laboratory enclosures females were unable to leave the small male even when grasping was interrupted; in nature they would likely separate and mating would not occur. Males of the size that were grasping in the natural environment (≥123 mm) were relatively scarce, and yet it was this group of males that was mating rather than the smaller males (63-100 mm), which were abundant (Powell et al. 1973).

Females producing their first clutch of eggs, immediately after reaching sexual maturity, are called primiparous (first-time breeders). Those producing their second or later clutch (two or more years after reaching sexual maturity) are called multiparous. The number of eggs produced by each female (fecundity), increases with size of the female. The relationship between size and fecundity can be defined by the equation:

$$\text{Eggs} = 2{,}779(\text{CL}) - 193{,}422 \qquad \text{(Otto et al. 1989).}$$

A typical primiparous female of 105 mm CL would produce 98,352 eggs; whereas, a larger multiparous female of 120 mm CL could produce 140,034 eggs.

Other king crab species

Blue king crab. Adult female blue king crab prefer substratum of sandy mud (in 95 percent of samples) with gastropod shells, at depths of 40-80 m (Armstrong et al. 1985). Over 90 percent of legal males and mature females live at depths >50 m (data from Armstrong et al. 1985; Stevens et al. 2001a). 65 percent of adults live between 2-3°C, the remainder live at temperatures <2°C. Sea water conditions required by larvae, juveniles, and adults are unknown, but are presumably 31-33 ppt, and fully saturated with oxygen.

Female size at 50 percent maturity for blue king crab is estimated at 96 mm CL and size at maturity for males, as estimated from size of chela relative to CL, is estimated at 108 mm CL (Somerton and MacIntosh 1983). Those estimates of size at maturity for blue king crab in the Pribilof stock compare with estimates of 81 mm CL for females and 77 mm CL for males in blue king crab from the St. Matthew Island stock (Somerton and MacIntosh 1983). The biennial reproductive cycle of blue king crab females has been attributed to a prolonged (greater than one year) embryonic period; estimated at 19 months (Sasakawa 1975) and at 14-15 months (Somerton and MacIntosh 1985). Armstrong et al. (1985 and 1987), however, estimated the embryonic period for Pribilof blue king crab at 11-12 months, regardless of previous reproductive history.

The 11-12 months estimated for the embryonic period indicates that it is the inability to produce a full ovary in one year, rather than a prolonged embryonic period, that is responsible for the biennial reproductive cycle of large female blue king crab (Jensen and Armstrong 1989). It may not be possible for large female blue king crabs to support the energy requirements for annual ovary development, growth, and egg extrusion due to limitations imposed by their habitat, such as poor quality or low abundance of food or reduced feeding activity due to cold water (Armstrong et al. 1987; Jensen and Armstrong 1989). Both the large size reached by Pribilof Islands blue king crab and the generally high productivity of the Pribilof area, however, argue against such environmental constraints. Here it is pertinent to note that red king crab in the Pribilof District are larger than their Bristol Bay counterparts and have a size at maturity similar to that found in Kodiak waters. Fecundity of female blue king crab varies with size, from approximately 100,000 embryos for a 100-110 mm CL female to approximately 200,000 for a female >140-mm CL (Somerton and MacIntosh 1985). The egg mass produced by a female blue king crab is 20-30 percent greater than that produced by a comparably sized red king crab (Jensen and Armstrong 1989). However, the blue king crab females require two years to produce an egg mass 20-30 percent greater in size of that which a red king crab female produces in one year. Pribilof blue king crab molt, mate, and extrude their clutches in late March through mid April (Armstrong et al. 1987). The larval stage is estimated to last for three and a half months to four months and larvae metamorphose and settle during August through early September (Armstrong et al. 1987).

Adult blue king crabs in the Pribilof Islands do not show the same restrictions to the nearshore habitat as juveniles (Palacios et al. 1985; Armstrong et al. 1987). Instead, adults show a seasonal distribution, with a high density in the nearshore areas to the east of St. Paul Island in spring and a more dispersed distribution in the offshore areas in the summer (Armstrong et al. 1987). The occurrence of nearshore aggregations of adults in the spring indicate a shoreward migration for egg hatching and mating and suggest the importance of the nearshore habitat around St. Paul Island for those purposes. Release of larvae in the nearshore areas and local current patterns and eddies may increase the chances for settlement and metamorphosis of megalopae in the nearshore shell hash habitat. However, conditions that would transport larvae away from the nearshore habitat probably occur at least occasionally, and such events would be expected to drastically reduce post-settlement survivorship (Armstrong et al. 1987).

Golden king crab. In the Aleutian Islands, legal male golden king crab occurred primarily at depths of 150-725 m, and adult females occurred primarily between 275 and 550 m (Blau et al. 1996). Adults of both sexes ranged from 150 to 640 m on GOA seamounts (NMFS unpublished data). About 45 percent of golden king crab of all sizes were associated with sponges, 25 percent with echinoderms (primarily brittle stars or crinoids), and 15 percent with anemones or corals (NMFS unpublished data). Water temperatures occupied by adults range from 3.4-4.1°C. No data is available on salinity, pH, or oxygen conditions required by golden king crab. In the Aleutians and GOA seamounts, salinity of sea water is typically >32 ppt near surface, and increases to >34 ppt at 1,500 m. However oxygen saturation decreases with depth, from 300 micromoles oxygen/kg at the surface, to 50 micromoles oxygen/kg at 400 m (where adults live). At depths occupied by juveniles (600-700 m) oxygen saturation may be <10 percent of surface values.

Conclusion

After reaching sexual maturity, adult king crabs live in locations that are specific to each species. Habitat type is less important than temperature ranges, and they may move from shallow inshore to deeper offshore water seasonally, or for breeding purposes. Light, subsurface oxygen, salinity, and other water conditions are not normally limiting, and do not affect the location or survival of adult populations.

3.2.2 Snow and Tanner crab life history and environmental requirements

3.2.2.1 Overview

Biology and life history of crab in this group are inextricably tied to the ecosystem in which they have evolved. As noted in Section 3.1, there are suites of physical, chemical, and biological features that define the nature of the aquatic world in which these crab are so abundant. Extreme conditions in variables like temperature, ice cover, directions and strength of currents, nature and amount of food, and level of predation profoundly affect the distribution and abundance of crab long-term, and may account for significant variation over shorter time intervals of months to years. The following sections link the biology and life history of the snow and Tanner crab to dominate processes operative seasonally over vast areas of the eastern Bering Sea shelf. The intent is that the reader understands how the species' biology reflects the very dynamic processes that drive abundance and distribution, and how long-term shifts in physical properties may force (physical forcing) populations to new levels of high or low abundance. As a geographic point of clarification regarding terms for the regions discussed, we note the following names for areas as defined:

- BSAI system. While this is the primary phrase used in other sections of this EIS, "Bering Sea" is too broad in the context of focus on the U.S. snow and Tanner crab populations since it does not include the western Bering Sea.

- Eastern Bering Sea that encompasses Bristol Bay (southeastern Bering Sea) and the shelf area north towards Norton Sound. Eastern Bering Sea is the preferred inclusive term for the region of the snow and Tanner crab populations highlighted in this section. NOAA Fisheries does an annual trawl survey over a historic grid (Figure 3.2-11) that provides long-term data on abundance and distribution of crab and other invertebrate and fish species.

The genus *Chionoecetes* contains five species (including snow and Tanner crabs[1]), and is distributed from the Arctic in the North Pacific west into the Sea of Japan, and east through the eastern Bering Sea region, down the GOA coast, through British Columbia south to the shelf off Oregon, both on the shelf (from shoreline to about 200 m or 100 fathoms), and along the shelf slope to depths of several 100 fathoms (Kon and Sinoda 1992). One of the species (snow crab) also occurs in shelf areas of the northwest Atlantic in eastern Canada. *Chionoecetes* pp. share many of the following traits throughout their life cycles (Figure 3.2-12):

- *Chionoecetes* are long-lived compared to warm-water crab and shrimp. Snow and Tanner crabs of eastern Bering Sea may not reach adulthood until six to seven years of age, and may live more than ten years.

- Females are very fecund and may produce several 10,000s-100,000s of eggs per year.

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[1] Here we use the common names "snow crab" and "Tanner crab" for, respectively, *Chionoecetes opilio* and *C. bairdi*, in conformance with American Fisheries Society accepted common names. The name Tanner crab is also used by some authors in a more generic sense to refer to species of *Chionoecetes* in general.

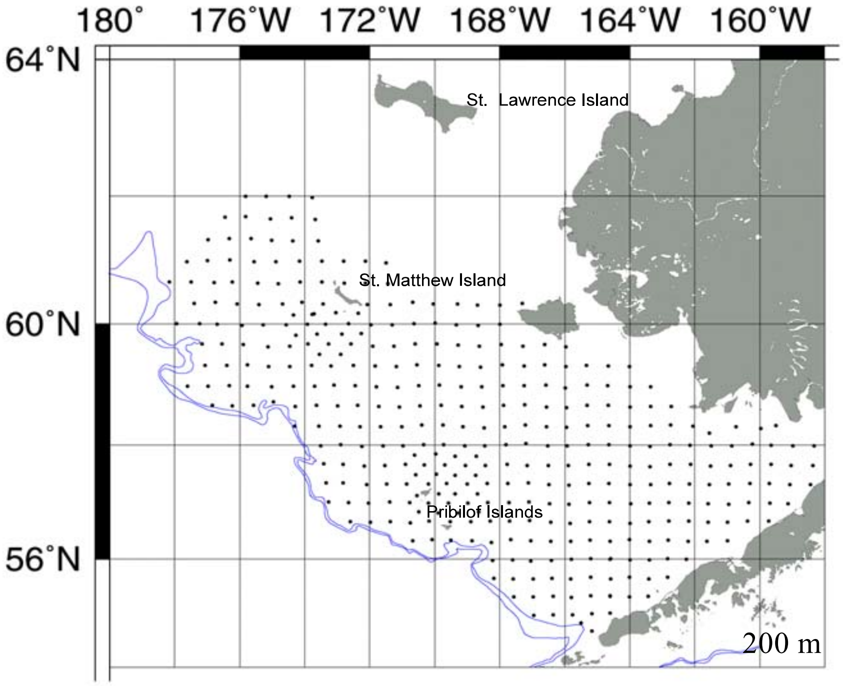


Figure 3.2-11 NOAA Fishery trawl survey grid in the eastern Bering Sea sampled annually since the mid-1970's.

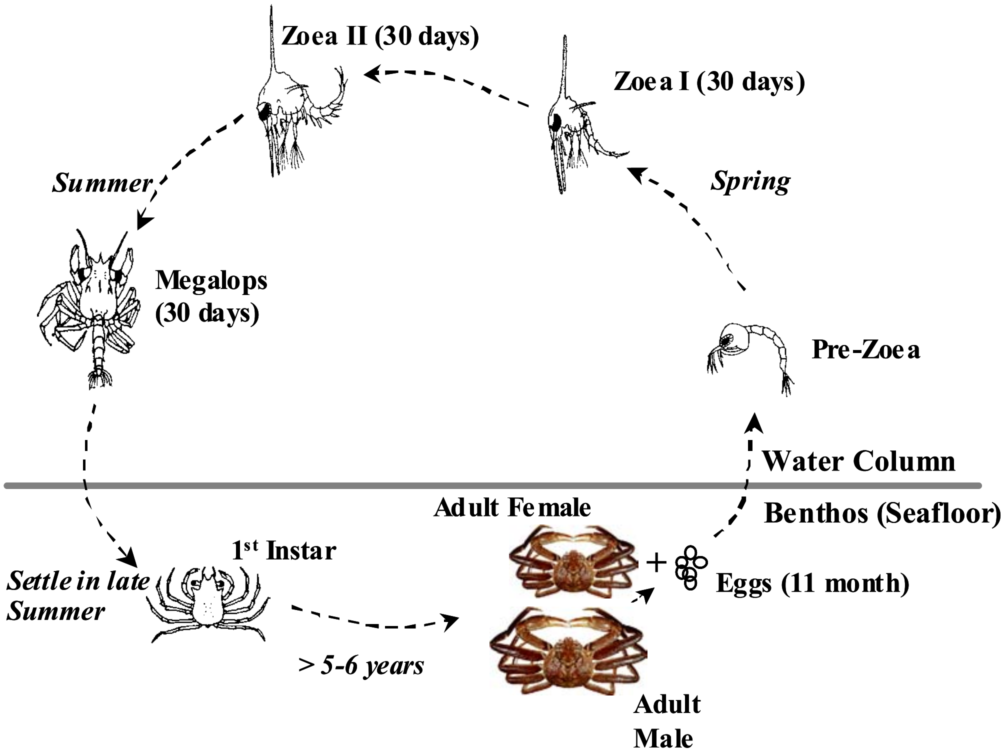


Figure 3.2-12 Schematic life cycle of snow and Tanner crab in the eastern Bering Sea (modified from Kon and Sinoda 1992).

- Eggs hatch into a larval stage that develops in the water column and may require two to three months depending on temperature. Larval stages include two zoea that are very weak swimmers but have some behavioral capability to detect water properties (depth, pressure, temperature, and salinity) that might place them in favorable currents. A final, more advanced megalops stage is a stronger swimmer and eventually explores the seafloor bed (benthos) in attempts to settle in a desirable habitat.

- During such a long time in the water column, larvae (plural of larva) may be carried by currents distances of several hundred kilometers or more.

- Survival of larvae is very low; most are consumed by predators within the plankton, starve due to little food supply in certain combinations of time and space, or are carried by currents well beyond the eastern Bering Sea Shelf and so lost to the population.

- The last larval megalops stage settles to the seafloor in mid-summer each year and metamorphosis into a juvenile, true crab stage, but at tiny size of only a few mm in width. Survival of such numerous, small juveniles is also very low since a variety of fish and crab predators (evidence of cannibalism in this group) consume this small stage.

- Like other crustaceans, *Chionoecetes* spp. grow by molting when they shed their old exoskeleton and then grow tissue to fill each new, larger exoskeleton. When small and young, several molts per year may occur, but when larger only one molt per year is typical.

- There is a terminal molt of both females and males at puberty from subadult to mature adult. Although an individual may live several more years after this terminal molt, it will no longer increase in size, and slowly becomes encrusted and fouled with other marine organisms that settle on the exoskeleton.

Snow crab occurs from the Bering Sea northward to the Chukchi Sea and even farther north into the Arctic Ocean (Beaufort and Barents Seas), along the coasts of the northwestern Atlantic (south to Maine) and the northwestern Pacific (south to the Japan Sea). The species is primarily restricted to waters shallower than 300 m, with temperatures ranging from –2°C to 4°C (Bailey and Elner 1989; Otto 1998). The upper temperature limit is set by bioenergetic requirements (Foyle et al. 1989) which reflects the amount of food needed by an individual to grow and respire relative to food supply and temperature that influences rates of growth and respiration (both processes slow at colder temperatures and accelerate at warmer temperatures). In the eastern Bering Sea, immature and adult snow crab are restricted to the mid- and outer-shelf domains, although their abundance is very low towards the southeastern end of the combined domains.

Tanner crabs occur along the northeastern Pacific shelf from Oregon (Hosie and Gaumer 1974) northward into the eastern Bering Sea, and from the southern Kuril Islands and western Kamchatka (Slizkin 1990) south to Hokkaido, Japan (Kon 1996). As with snow crab, Tanner crab are restricted to relatively shallow water less than 200 m on the shelf. The geographic range of the two species overlap in shelf areas of the eastern Bering Sea, where the southern limit of the range of snow crab and the northern limit of the range of Tanner crab in the northeastern Pacific occur (Figure 3.2-13). Broad patterns of distribution of both species in the eastern Bering Sea were attributed

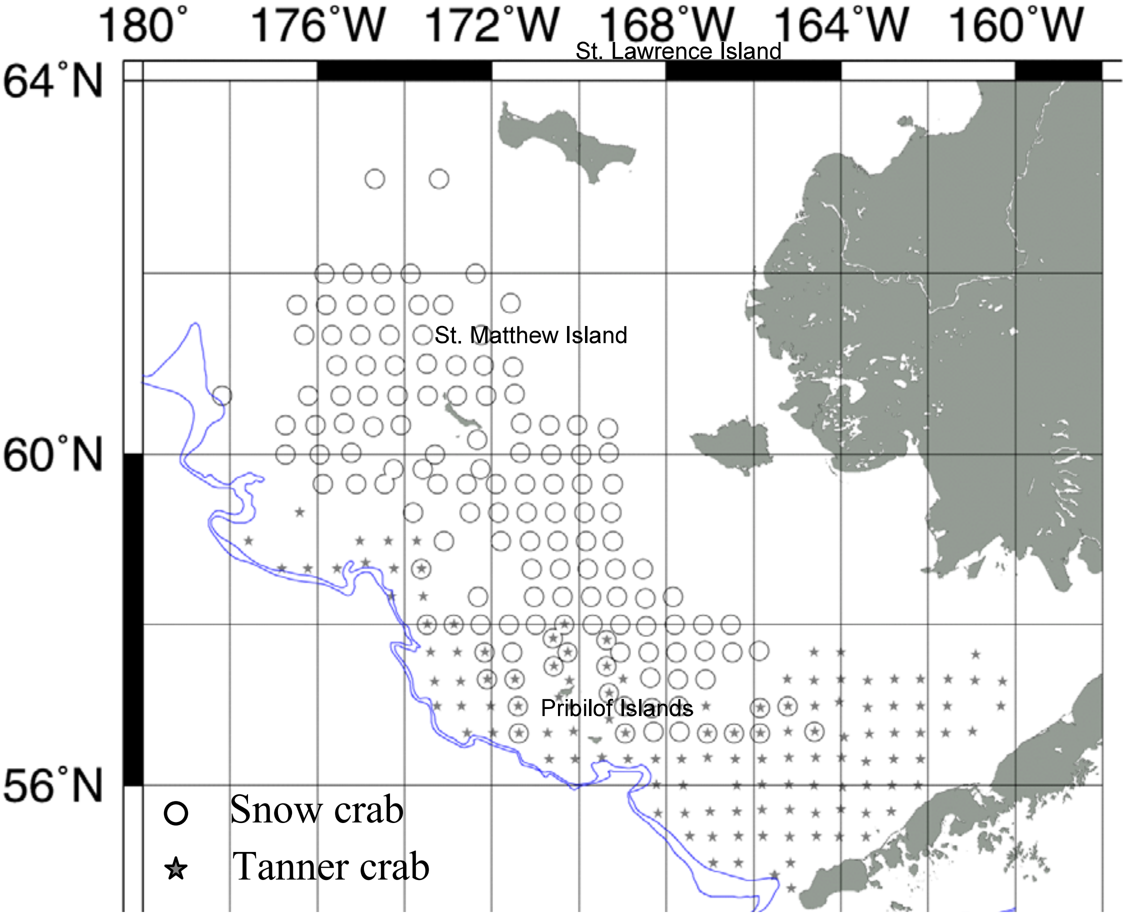


Figure 3.2-13 **General distribution of snow and Tanner crab in the eastern Bering Sea based on trawl surveys over 20 years.**

by Somerton (1981a) to temperature gradients; in general the snow crab distributed more north in regions of colder bottom water temperature, and Tanner crab to the south in warmer water. Along the interface of distribution, the two species hybridize, although there is not evidence that their offspring reproduce subsequent generations. There are not distinct areas of high abundance of hybrids in the eastern Bering Sea. Rather, they occur in relatively low abundance throughout the region where the ranges of the two species overlap (Somerton 1981a).

Many aspects of the reproductive biology, ecology, and population dynamics of these species are poorly known in the eastern Bering Sea, but have been intensively studied in other regions, mostly in eastern Canada, but also in Japan and the GOA. Reference is made to those studies whenever considered opportune in view of filling information gaps, or for comparative purposes. Eastern Bering Sea data used directly in portions of this section or as bases of analyses contained in other literature come from the annual NOAA Fisheries trawl surveys in the eastern Bering Sea (Figure 3.2-11). In many respects, this is the most comprehensive body of crab data and is essential in portraying some aspects of life history. The reader should understand, however, that there are otherwise very limited studies on specific life history stages and their ecology, but these will be show-cased as much as possible throughout this EIS.

3.2.2.2 Mating and reproduction

The mating process and behavior of snow and Tanner crabs are highly complex, and have received considerable attention in recent years (see Elner and Beninger 1995 for reviews). Two types of mating partners occur in each sex:

- Females can mate after their terminal puberty molt while still in a soft-shell condition (Shell Condition 1=SC 1; a code assigned to each crab captured annually during eastern Bering Sea trawl surveys by NOAA Fisheries. SC 1-2 are newly molted, clean shell individuals; SC 3-4 are older crab with increasing amounts of fouling on the shells), or in subsequent years while already in hard shell condition (SC 3 and higher). Females that first mate while soft just after the terminal molt are called primiparous (first-time), and females that mate in later years while hard are termed multiparous.

- Males can mate when physiologically mature yet still in the Morphologically Immature (MI) condition (certain appendages of their body still reflect juvenile characteristics), or after reaching the morphologically mature (MM) condition.

Reproductive organs and sperm storage by the females

In recent years there has been considerable interest in the study of reproductive organs of snow and Tanner crab, largely motivated by the need to understand the significance of sperm storage by females. This feature relates to the issue of male distribution and abundance since its possible that after first mating, an individual female may not need to mate again and can continue to fertilize eggs in subsequent years until death. Females store sperm in paired pouches inside their bodies known as spermathecae (Elner and Beninger 1992; Beninger et al. 1993; Sainte-Marie and Sainte-Marie 1998). Eggs are fertilized as they pass from the ovary by the sperm storage organ, and then are extruded externally on the females' body (the process is called oviposition). Surplus stored sperm are retained for use in future reproductive seasons (Watson 1970; Adams and Paul 1983; Paul and Paul 1992; Beninger et al.1988), but the supply dwindles with time (Paul 1984). At least two consecutive egg fertilization events can follow a single copulation in both snow (Sainte-Marie and Carriere 1995) and Tanner crab (Paul 1982; Adams and Paul 1983), but viability of the eggs decreases with time and age of stored sperm (Paul 1984): 97 percent, 71 percent, and 0 percent of test females produced viable clutches after one, two, and three years without re-mating. Many Tanner crab primiparous females (first-time spawners) do not receive enough sperm to fertilize a second clutch (Paul and Paul 1992). Interestingly, Tanner crab females collected from Kodiak had very low quantities of stored sperm (Stevens et al. 1996). By contrast, snow crab primiparous females usually store enough sperm to fertilize at least a second clutch (Sainte-Marie and Lovrich 1994).

Gamete production

The reproductive cycles of snow and Tanner crabs are generally annual, with the possible exception of primiparous females, that would develop their ovaries over a period longer than one year (up to 18 months). There is agreement about the reproductive cycle being annual in Tanner crab (Adams 1979; unpublished). In this case, an individual female that hatches eggs in spring of one year has developed a mature ovary over the preceding year, with new eggs to be extruded that same spring. In the case of snow crab however, some field studies in Japan and eastern Canada indicate that the reproductive cycle is biannual in many populations (Kanno 1987; Comeau et al. 1999), as conclusively shown by Sainte-Marie (1993) for Baie Sainte-Marguerite, Gulf of St. Lawrence. The usual habitat for snow crab in the Gulf is a layer of intermediate water, which remains in the range of -1°C to 1°C throughout the year. Some females, however, move into shallower, warmer water during spring, before hatching eggs, mating and oviposition. Unpublished observations (NMFS Survey of 1993) indicate that female snow crab have a biannual reproductive cycle at the northern end of the survey area, and annual in the rest (south of St. Matthew Island). The annual/biannual pattern is presumably controlled by temperature. This hypothesis is consistent with fluctuations (apparently temperature-related) between patterns in the Gulf of St. Lawrence (Sainte-Marie and Gilbert 1998; cited by Comeau et al. 1999).

Under the combination of a biannual reproductive cycle, ~five to six years maximum adult lifespan, senescence in females older than four years past terminal molt, and significant natural mortality, most females would have only two effective reproductive cycles in their life (Sainte-Marie 1993). Even in the case of an annual cycle, most of the reproductive contribution would come from primiparous and first-time multiparous females

Sequence of reproductive events

A female's reproductive cycle includes the following sequence of events:

- Mate location: including mate attraction, perhaps based on detection of chemical cues called pheromones, pairing, and pre-copulatory mate guarding.

- Molting in the case of primiparous females that are transforming from the last juvenile stage through the pubescent, terminal molt to adult body form, or after eggs of the previous year hatch in the case of multiparous females.

- Mating and copulation by insertion of the male's gonopod (a special appendage through which sperm are essentially injected into the female reproductive tract) and insemination.

- Oviposition or extrusion of eggs out of the gonopore on the underside of a female's abdomen where eggs are immediately attached to a network of hundreds of small hair-like stalks called setae on special appendages called pleopods.

- Incubation of the brood under the abdominal flap of the female for about 10-12 months (or up to 24 months in very northern stocks).

- Hatching of the eggs in early spring-summer.

- Cleansing of the pleopods (post-hatching stage).

Mating behavior appears to be similar in both species. Males locate females and guard their prospective mate for up to two weeks (Sainte-Marie et al. 1999). Pre-pubescent females molt (puberty molt) with help from their male partners (Watson 1970 and 1972; Donaldson and Adams 1989; Sainte-Marie and Hazel 1992). The actual copulation is relatively prolonged (35-45 minutes), and is shortly followed by egg extrusion or spawning (oviposition) (Watson 1972; Adams 1982; Sainte-Marie and Lovrich 1994). In the case of Tanner crab, the fertile period lasts 1-28 days after molting (Paul and Adams 1984). Multiparous females that are already beyond their terminal molt and in hard shell condition may copulate after cleansing their pleopods, and before eggs are next extruded. In Tanner crabs, receptive period for mating partner is one to seven days after cleansing the pleopods (Paul and Adams 1984).

Seasonality of mating and egg extrusion

There is no direct research on timing of such events among snow crab in the eastern Bering Sea system, but data from other locations can help estimate times. The puberty molt occurs in winter (February-April) in eastern Canada (Sainte-Marie and Hazel 1992; Sainte-Marie 1993; Sainte-Marie et al. 1995), but in the Sea of Japan it occurs during the summer (July-August) (Kon and Honma 1970) or early fall (September-October) (Ito 1967). In eastern Canada hatching of old eggs, copulation, and extrusion of new eggs occurs in April-June, after the corresponding reproductive events in the primiparous population (Taylor et al. 1985; Conan and Comeau 1986; Hooper 1986; Ennis et al. 1988 and 1990; Comeau et al. 1991, 1998b, and 1999; Sainte-Marie 1993). In Japan multiparous reproductive events occur earlier (February-April) (Ito 1967; Kon and Honma 1970).

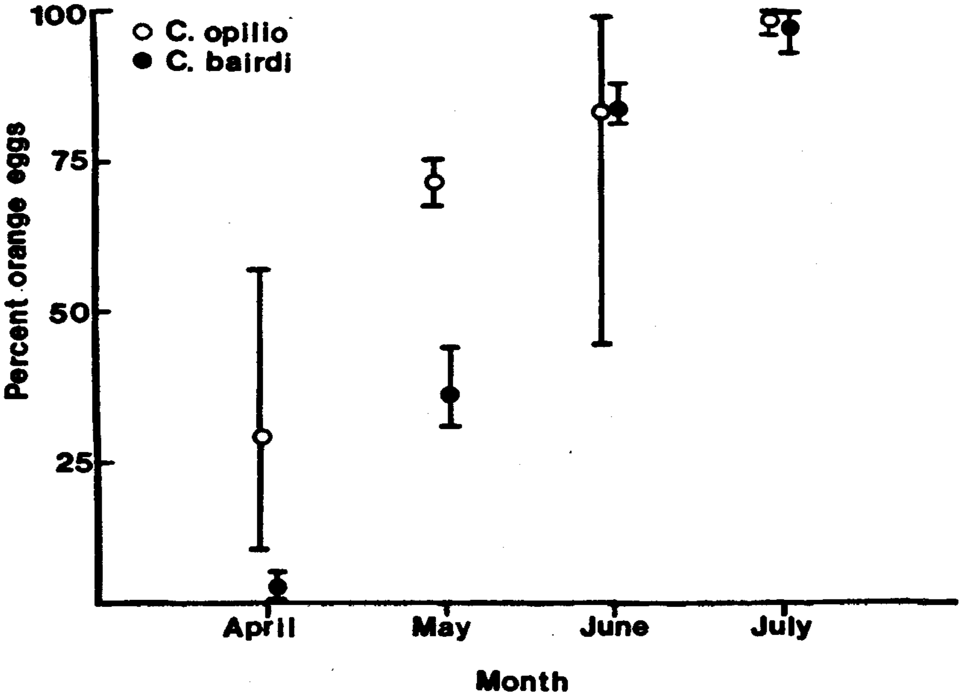
Among Tanner crab from the GOA and Prince William Sound, puberty, terminal molt, and reproductive events occur during the winter and spring (mid January to mid July), while comparative multiparous events occur later in the spring (mid April to early June) (Hilsinger 1976; Munk et al. 1996; Stevens 2000). By contrast, in the Sea of Japan puberty molts peak during the summer (July-September) and winter-spring (January-May), and multiparous reproductive events occur in winter-spring (January-May) (Watanabe 1992).

In the eastern Bering Sea Somerton (1981a) used the proportion of newly extruded eggs (bright orange) carried by multiparous females (SC 3 and higher) between April and May, 1976, in order to estimate the approximate time of egg hatching and extrusion of new ones (Figure 3.2-14). Egg extrusion starts earlier in snow crab (March) and later in Tanner (April) crab, with a lag of approximately one month, and is completed in both species by July. Seasonality is likely to show great regional variation, even within the eastern Bering Sea. These inferred seasons are comparable to those observed more directly in eastern Canada for snow crab, and in the GOA for Tanner crab.

Brooding

In general, female snow and Tanner crab extrude 10,000s of eggs that are attached to fibers on the underside of the abdomen and protected under a large flap of exoskeleton. Eggs begin to divide and embryos develop over a period of about 10-11 months. During the brooding period, egg color changes from yellow/orange when newly extruded, to dark brown/purple before hatching. Change in color indicates depletion of initial yolk material that is used in development of the embryo which eventually shows distinct eye spots, a beating heart, body segments, and an array of appendages by date of hatch. There are several systems to classify egg developmental stages. A simple two-color category system is used in NOAA Fisheries Surveys wherein the egg mass of each female is essentially categorized as newly extruded, or as very advanced embryos near time of hatch.

Figure 3.2-14 Monthly percent of new orange eggs on female snow and Tanner crab in the eastern Bering Sea (Somerton 1981a).



Egg hatching appears to be fairly synchronous in a population, perhaps in response to cues such as change in period of daylight signaling close of winter and beginning of spring and higher food production. In snow crab it is triggered by sinking detrital material from phytoplankton blooms (Starr et al. 1994; Conan et al. 1996), with obvious advantages of placing larval crab in the water column at the same time as their potential food supply. In Tanner crab, Stevens (2000) claimed that it is coincidental with the new moon. Stevens (2000) advanced the hypothesis that during new moon hatching would be synchronized with periods of high tidal current flow which, combined with mound-like reproductive aggregates of crabs (discussed later in the text), would provide larval launching pads facilitating escape of larvae from silty bottom sediments and the turbid water layer just above. Fairly good data on timing of new larvae in the water column as indication of hatching period were provided by Incze et al. (1987) for both snow and Tanner crab in the eastern Bering Sea region. In 1978, stage I larval zoeae (Z1) of snow and Tanner crab were most abundant in the water column of the eastern Bering Sea during April and May, respectively, but peak abundance was about a month later for each species in 1980-1981 which were colder years.

Forms of male maturity

Just as there are two stages or versions of mature females, there are also two forms of mature males, which further complicates the description of their mating system. It also suggests the diversity of strategies contained within a population likely provides alternatives to some degree if certain elements of these adult male-female combinations are missing or are in low abundance in various regions in certain years. Maturity of males can be defined on the basis of physiological, morphological, or behavioral criteria (Conan et al. 1988; Elner and Beninger 1989).

Physiological maturity

Male maturity can be assessed by the presence of spermatophores (packets of mature sperm) in the vas deferens. The proportion of physiologically mature males as related to size can be represented by a sigmoid curve (Comeau and Conan 1992). Commonly, 50 percent is taken as a measure of size or age of individuals that characterize the population showing some sort of trait. In the case of male snow crab, 50 percent maturity based on presence of spermatophores is about 34-38 mm CW, the size across the carapace that may be equated to age, in eastern Canadian populations (Comeau and Conan 1992; Sainte-Marie et al. 1995). Size at physiological maturity tends to decrease at higher, colder latitudes where growth is slower; e.g., in the Chukchi Sea just above the eastern Bering Sea system, mature males are only 20-30 mm CW (Paul et al. 1997). Physiological maturity of male Tanner crab is reached over the size range of 51-80 mm CW in various regions of Alaskan waters (Adams and Paul 1983; Paul 1992; Paul et al. 1995), but males are somewhat larger at maturity at about 75 mm CW in South Hokkaido (Watanabe 1992).

Although both male snow and Tanner crab in this category are physiologically mature, they are still MI based on retention of certain body traits of juvenile stages. As a consequence, they are limited in terms of females they are able to breed. Observation of snow crab held in tanks show that adolescent MI males do not develop pre-copulatory behavior when present with multiparous females, irrespective of their size (Comeau and Conan 1992). Small MI males that are presumably physiologically mature can mate with primiparous females, but cannot fertilize their eggs (Paul and Paul 1990b).

Morphological (or Morphometric) maturity

As males approach adulthood they experience a sudden change in the relative size of their claws because the propodus (large lower portion of a claw that contains edible meat) becomes proportionally larger and globose in shape (Figure 3.2-15). This happens in the course of a single molting episode. Since allometric changes (relative growth of a one body part compared to others) in the claws of male crab are generally associated with sexual maturity, males with proportionally large claws are usually known as morphologically mature, large clawed or MM, as opposed to small clawed, MI stages. When the height of the propodus is plotted versus CW in a log-log scale (Figure 3.2-15), the points corresponding to MI and MM males fall in two clusters implying that the size increment in claw size is proportional to body size.

Earlier studies on snow and Tanner crab (Watson 1970; Adams 1979; Somerton 1981a, 1981b, and 1982b; Kon and Sinoda 1992) assumed that MM large-claw males continue to grow and have no terminal molt. But Conan and Comeau (1986) reviewed existing information and contended that males stop growing after a terminal molt when they become MM, which is the universal case within the Family Majidae (the family to which the genus *Chionoecetes* belongs) (Elner and Beninger 1992). There is now substantial evidence supporting a terminal molt hypothesis for both male snow and Tanner crab (Yamasaki and Kuwahara 1991; Sainte-Marie and Hazel 1992; Stevens et al. 1993; Conan et al. 1996; Otto 1998; Cormier et al. 1999).

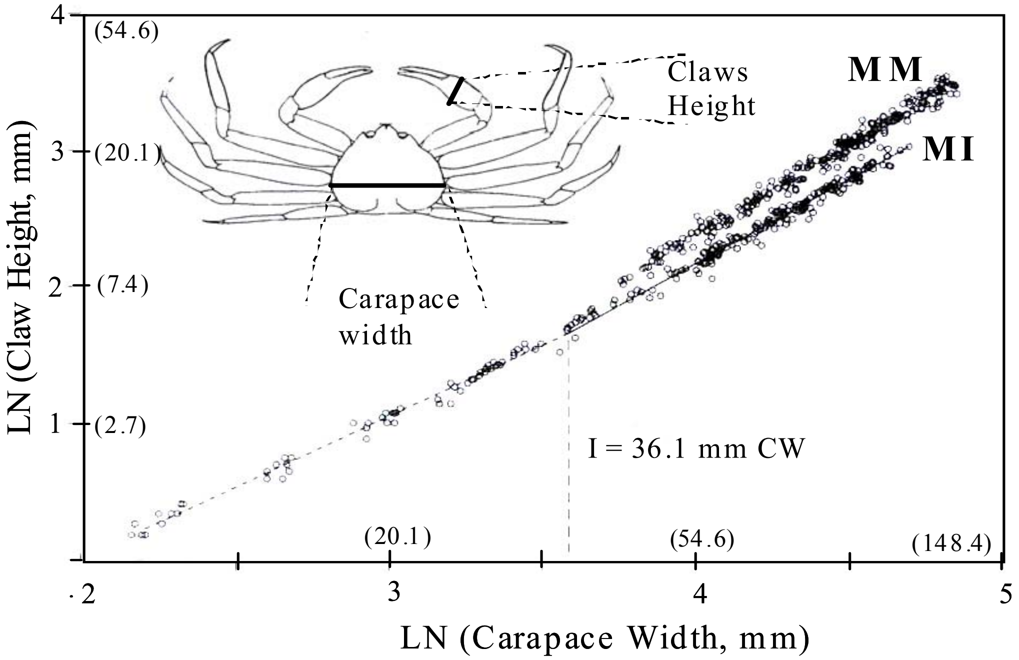


Figure 3.2-15 **Schematic of a morphologically mature male crab and relationship of size of claw to body width (Sainte-Marie et al. 1995; Conan and Comeau 1986).**

An important distinction between MI and MM males is that the latter can mate with a greater portion of the female population. The relevant question is: what triggers MI males to molt into the MM form? Several hypotheses generally relate to the sex-size composition and density of the overall population and extent of potential reproductive competition (Comeau et al. 1991; Elner and Beninger 1995). The biological interpretation reflects the advantages of either (1) rush to become MM even if small, or (2) wait to be large before molting one last time to the MM form. Otto (1998) observed that during a six-year period size at maturity was delayed for a very strong year class, whose recruitment drove total biomass upwards. Comeau et al. (1998b) (consistent with Hypothesis 2) speculated that the low number of small males reaching terminal molt between 1985 and 1987 in Bonne Bay, Newfoundland might have triggered successful molt to maturity by small adolescent males.

Mating system

Based on field observations of Tanner crab in the GOA, Somerton (1982a) proposed the bipartite mating hypothesis: primiparous females mate with adolescent MI males in shallow water (as observed by Brown and Powell 1972; Donaldson et al. 1981; Stevens et al. 1993), and multiparous females mate with large MM males in deeper regions. This behavior was attributed to habitat segregation of primi- and multiparous females by Stevens et al. (1994), and is consistent with bathymetric segregation by depth and sexual maturity stages reported for snow crab from eastern Canada (Comeau et al.1991; Sainte-Marie and Hazel 1992) and Japan (Yamasaki and Kuwahara 1993).

Long-term and extensive observations of snow crab mating in tanks, conducted in eastern Canada, show that MI males are able to mate with primiparous, but not with multiparous females, while MM males can mate with both primi- and multiparous females (Moriyasu et al. 1987; Moriyasu and Conan 1988; Conan et al.1990). These findings for snow crab are consistent with Somerton's bipartite mating hypothesis, based on field observations for Tanner crab. The MM male phase may be related to the fact that during precopulatory guarding, the male holds the female's pereiopods (long walking legs) with one claw (Comeau and Conan 1992). The grasp is strong enough to leave characteristic mating marks on the multiparous female pereiopods, which last for the rest of the female's life.

The potential for polygyny is well established; a single male can mate with more than one female in a breeding season. Up to ten female Tanner crab can be inseminated by one male in a single mating season based on laboratory experiments (Paul 1984). Experiments conducted with snow crab showed that a male can copulate up to five times in 14-33 days, whether the MI or MM form (Sainte-Marie and Lovrich 1994), with no decrease in the amount of sperm ejaculated between copulations. Among males collected in the field, however, there was evidence that in large MM males there is depletion of the sperm accumulated in the vas deferens (Conan and Comeau 1986; Comeau and Conan 1992; Sainte-Marie et al. 1995).

Male-male antagonism

Competition for access to females can be strong. Aggressive male-male antagonism during the spring breeding season has been documented for both species (Hooper 1986; Donaldson and Adams 1989). Size (everything else being equal) provides a competitive edge in both species (Paul and Paul 1996b; Sainte-Marie et al. 1997). Individuals that have reached MM and have an old, hard shell, and possess complete claws and/or legs have a competitive edge when competitors are equal size but lacking these traits (Paul et al. 1995; Paul and Paul 1996b; Sainte-Marie et al. 1997 and 1999). In laboratory experiments, large Tanner crab males (CW > 140 mm) commonly crush their opponent's limbs and break their exoskeletons during combat, and many of the wounded males die (Paul and Paul 1996b).

Fecundity

NOAA Fisheries annual trawl surveys collect data on a subjective clutch size index, a vague indicator of relative fecundity (the number of eggs carried by a female of a certain size). Other detailed studies have collected actual fecundity data (number of eggs per clutch = brood), mostly in relation to size. In snow crab, number of eggs per female ranges as high as 128,000 in eastern Canada (Comeau et al. 1999; Elner and Beninger 1992), but is lower in the small-sized females from the Chukchi Sea (10,000 to 40,000) (Jewett 1981). In Tanner crab from the eastern Bering Sea, Prince William Sound (Figure 3.2-16) and Hokkaido, fecundity per female ranges up to 400,000 (Somerton and Meyers 1983; Hilsinger 1976; Armstrong et al. 1995; Watanabe 1992).

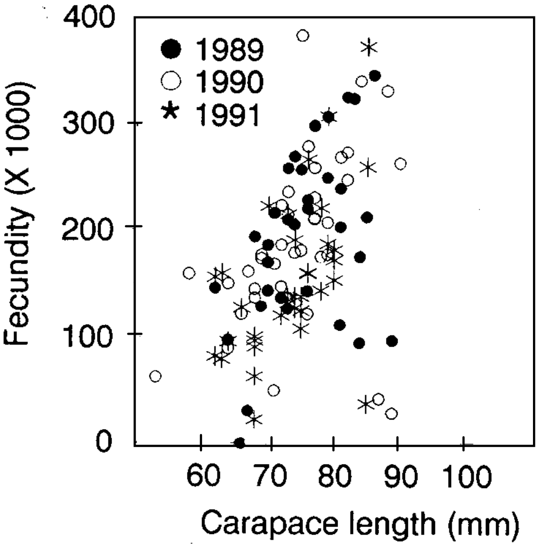


Figure 3.2-16 Number of eggs carried by females relative to their body size (Armstrong et al. 1995).

Fecundity can be affected by a number of factors:

- *Size of female*, as shown in all the studies listed above.
- *Size of the male partner*, although in Tanner crab, clutch size or stored sperm remaining in spermathecae are not related to partner size (Adams and Paul 1983).
- *Primi- vs. multiparous-condition,* first time spawners compared to older, multiple-time spawners (Somerton and Meyers 1983) showed that primiparous Tanner crab females from the eastern Bering Sea carried approximately 30 percent fewer eggs compared to equal-sized multiparous. Sainte-Marie (1993) observed the same pattern in snow crab from eastern Canada.
- *Insemination history,* (Paul 1984; Paul and Paul 1992) has a female been inseminated in later years after the molt to maturity, or is she using only stored sperm from that first copulation?
- *Senescence.* Senescent females often carry small clutches or no eggs at all in the eastern Bering Sea. Females would be classified as SC 4 and be heavily encrusted with fouling organisms.
- *Egg mortality*, from extrusion to larval hatching appears to be higher in larger females (Kon 1974; Elner and Beninger 1992). This is estimated by comparing egg counts just after extrusion and months later when close to hatching for a given range of female size. Estimated egg survival figures are 79 percent for snow crab from Newfoundland (Comeau et al. 1999), 60 percent for snow crab from Japan (Kon 1974), 79 percent for Tanner crab from Prince William Sound and the GOA (Hilsinger 1976) and 64 percent for Tanner crab from Japan (Watanabe 1992).

Factors involved in egg mortality include abrasion while carried on the abdomen of the female, unfertilized eggs, developmental failure and egg parasites within the clutch. Among the latter, the nemertean worm

Carcinonemertes has been observed in Tanner crab from the GOA (Hilsinger 1976; Wickham and Kuris 1990); but is apparently absent in the eastern Bering Sea. This worm can reach high population levels in the clutch of crab and consume thousands of eggs during development over 10-11 months.

3.2.2.3 Development and ecology of snow and Tanner crab early larval stages (Zoea)

Larvae hatch from eggs as a pre-zoea that lasts only an hour, and then develop through two zoeal stages, (ZI and ZII) by molting (Motoh 1982) (Figure 3.2-11). Hatching begins in the spring, appears to be somewhat synchronous, and larvae are generally released over a period of 30-40 days by the entire *Chionoecetes* spp. population in the Bering Sea (Armstrong et al. 1981). Duration of each zoeal stage is approximately 30 days (Incze et al. 1982). Descriptions of the zoeal stages are used to separate snow and Tanner crab collected in the field (Wencker et al. 1982) in eastern Bering Sea where their distributions overlap. The first zoea, ZI, is approximately 4-5 mm in length and ZII larvae are 5.5-7 mm (Wencker et al. 1982). Zoeae are planktonic, photopositive (they swim toward light and so tend to be located near the surface), and free swimming. Larvae molt from stage ZII to a stage called the megalopa (similar to the glaucothoe of the king crabs). This last larval stage is a fairly strong swimmer, and eventually moves toward the bottom and settles after about one month of development.

Environmental influences on snow and Tanner larvae

Temperature has a marked effect on larval growth rates and inter-molt periods of time between different stages. Growth experiments done on snow crab zoeae from the Japan Sea by Kon (1970) showed that best survival (54 percent) from ZI to ZII occurred at 9.6°C, and was less at 5, 13, 16, and 18°C; none survived at 19°C. Incze et al. (1987) studied population dynamics of snow and Tanner crab larvae in the eastern Bering Sea over a four year period, 1978-1981, which included two relatively warm years (1978 and 1981) (sea surface temperature about 3.1°C in April) and one cold year (1980; sea surface temperature about 1.2°C). Larvae of both crab species were far more abundant in both the warm years and earlier in the survey period (April) compared to the cold year (June). This indicates the effect of temperature both on the rate of egg development, time of hatch of larvae into the water column, and their subsequent rate of development.

Another measure of larval response to temperature is the rate at which they respire oxygen from the water. Respiration rate is often considered a reflection of metabolic rate in cold-blooded (exothermic) animals. Crabs tend to breathe at lower rates as the temperature drops and at accelerated rates as temperatures warm to some upper limit above which temperature becomes stressful. Work aboard ships in the Bering Sea showed that Tanner crab larvae are far more sensitive to lower temperatures than snow crab larvae (Armstrong, unpublished data). Over a temperature range of about 8°C down to 2°C, respiration of snow crab larvae declines very little, but Tanner crab metabolism declines about 50 percent, which indicates that overall developmental rate would decline as well. This suggests several differences: 1) Tanner crab larvae would typically not do well in early spring if hatched in the more northerly portions of the eastern Bering Sea system; 2) the broader distribution of snow crab throughout the eastern Bering Sea and far to the north reflects larval tolerance of low spring water temperatures; and 3) differences between years in timing and magnitude of water temperatures may play a major role in survival of various larval year classes.

Salinity and pH tolerance values for *Chionoecetes* spp. zoea have not been published. Tolerances of Tanner and snow crab zoea for other characteristics of seawater such as ammonia, nitrates, or CO_2 levels is also unknown. In the open ocean, these parameters are highly buffered, relatively constant, and rarely reach levels that would affect survival or behavior of zoeae. Studies on survival at differing light levels have not been published.

Wind can affect larvae directly and indirectly in a variety of ways. Northeast winds were found to enhance offshore Ekman transport (water moves about 90° to the right of surface winds) of surface water, which, in turn, increases coastal upwelling of colder water from deeper depths. This process promotes primary and secondary production, thus effecting the production of food (small copepod crustaceans like *Pseudocalanus*) for crab larvae (Incze et al. 1987; Rosenkranz et al. 1998). Wind speed and duration can also affect the mixed layer depth which describes the depth to which water is mixed from the surface down to some layer that is resistant to deeper mixing. In the eastern Bering Sea, Incze et al. (1987) found that this mixed layer depth was shallower in 1978-1979 and much deeper in 1980-1981, in some correspondence to higher density of potential larval crab prey including the copepod *Pseudocalanus* spp.

Current regimes over the eastern Bering Sea shelf were described by Schumacher and Kinder (1983) who noted insignificant/weak mean flow, kinetic energy and oceanic forcing within the mid-shelf domain (50-100 m depth). Thus, larvae released at these depths over the mid-shelf may have a better chance of larval retention and being situated over appropriate settlement habitat. Bands on either side of the mid-shelf domain occur with significant northwest flows (1-10 cm/s in the Outer-shelf in water depths >100 m, and 1-6 cm/s in the Inner-shelf domain at depths < 50 m). Larvae released at these depths have a greater chance at being transported great distances during the duration of their planktonic life (three to four months) and advected to the northwest beyond the area of most adult distribution.

Behavior of Tanner and snow crab larvae

Snow and Tanner crab larvae do not conduct extensive diel (24-hour day-night cycle) vertical migrations (Armstrong et al. 1981). After hatching, ZI zoeae swim up in the water column and remain at shallow depths of 0-20 m during the day and night (Incze et al. 1987) (Figure 3.2-17) for most of larval development. On average, 80 percent of crab zoeae are found in the upper 20 m of the water column near the chlorophyll maximum layer (measure of phytoplankton plant life that may provide some food for crab larvae), and more than 93 percent of larvae are in the upper 40 m (Figure 3.2-17). These larvae are generally sensitive to light (positively phototactic), gravity, and currents. Larvae tend to swim into and against water currents (positively rheotactic) and can maintain their position in slow currents. They are negatively geotactic (move up in a water column and avoid sinking in response to greater pressure at deeper depths). Thus over three to four months of larval development (ZI through megalops and metamorphosis to first benthic crab), larvae may be carried a substantial distance from their initial point of origin by wind and tidal currents.

Other biological factors

As discussed earlier in the case of larval red king crab, survival of larval snow and Tanner crab depends on both adequate feeding and avoiding predation. Hatching occurs during early spring, coincident with phytoplankton and zooplankton population blooms. The match-mismatch hypothesis (Hjort 1914; Cushing 1990) has been proposed to account for differing levels of larval survival. According to this hypothesis,

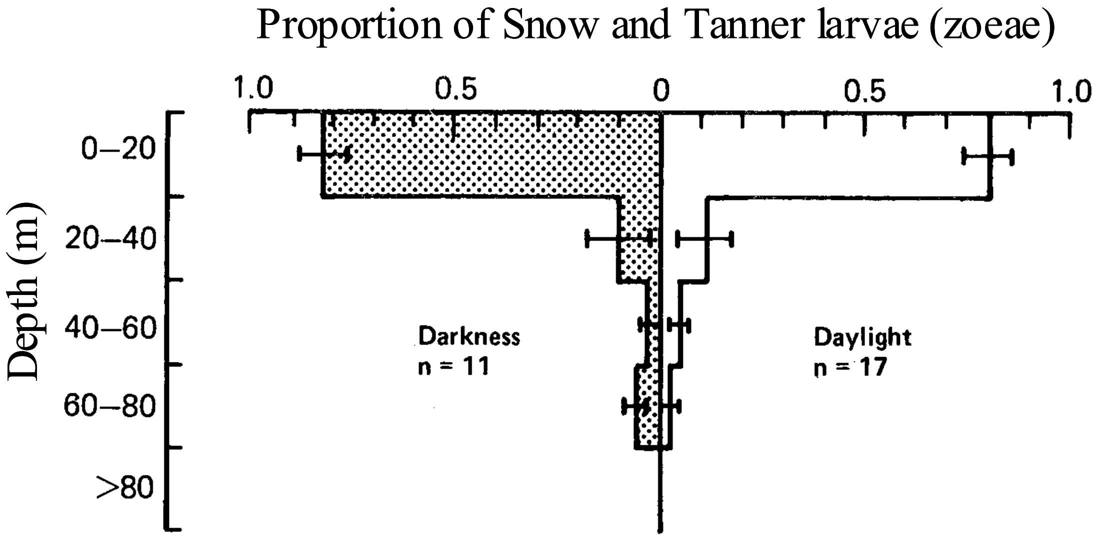


Figure 3.2-17 **Depth distribution of snow and Tanner crab larvae in the eastern Bering Sea (Incze et al. 1987).**

larvae that hatch during periods of abundant food will have high survival while those that hatch too early or too late will have lower survival. Comeau et al. (1991) hypothesized that the trigger to begin hatching of snow crabs eggs and release of larvae in Bonne Bay, Canada, was linked to the phytoplankton bloom and rain of organic particulate matter that follows. Food availability and thus distribution and abundance of snow and Tanner crab larvae in the eastern Bering Sea may be more closely linked to sea ice cover, shelf oceanography, and abundance of adult females (Somerton 1982c; Incze 1983; Incze et al. 1987). In addition Rosenkranz et al. (1998) hypothesized that northeastern winds in May and June are important for larval retention and recruitment success for eastern Bering Sea Tanner crabs.

Somerton (1982c) examined the link between sea ice coverage over the Bering Sea shelf and larval distribution and recruitment success of both snow and Tanner crab larvae. Survival of snow crab zoeae may be linked to a spring bloom of phytoplankton that is initiated by salinity changes during sea ice melting and subsequent stabilization of the water column. The southern boundary of female snow crab distribution has been found to be coincident with the mean southern extent of sea ice in April in the eastern Bering Sea. Snow crab zoeae are released in early to mid-April and take advantage of an early spring bloom that accompanies melting and receding of the ice. Conversely, female Tanner crab that are distributed in a more southerly area along the north Aleutian Shelf reside in ice free waters where the only spring bloom occurs later when a seasonal thermocline (boundary between two layers of water marked by an abrupt change in temperature) is established. Tanner crab release their larvae in May (about one month later than zoea of snow crab) to coincide with this later spring bloom.

Food quality and quantity is extremely important for larval crab. ZI larvae must find food within 72 hours or they will starve. In nature, crab larvae consume small zooplankton such as copepod larvae, and phytoplankton (diatoms). In the laboratory, they are usually fed brine shrimp (*Artemia*) larvae, with or without diatoms and other supplements. Paul et al. (1979) fed ZI Tanner crabs larval and adult copepods at prey concentration of at least 20-40 copepods per liter of water in order for crab larvae to consistently capture prey. Since natural concentrations of zooplankton prey are rarely at this density, consumption of copepod larvae is probably supplemented by diatoms in a natural diet. Incze and Paul (1983) demonstrated that Tanner crab zoea are omnivorous. ZI crab larvae grazing on phytoplankton alone were not able to meet more than 15 percent of their total energy demands but required zooplankton for a complete diet.

Incze et al. (1987) examined factors in the eastern Bering Sea influencing recruitment of *Chionoecetes* spp. larvae 1978-1981. In two of three geographic areas he found that a sharp decline in larval abundance after 1979 was related to a decline in adult female abundance. In the other area, he surmised that low larval abundance was linked to low food availability and low water column stability resulting in larval mortality.

While predation on juvenile and adult crab of the genus *Chionoecetes* in the Bering Sea is well documented, little is known about predation on larval snow and Tanner crab (Jewett 1982). Both stages of zoeal larvae and megalops in the upper 20 m of the water column would be vulnerable to predation by many planktivorous fish species in the eastern Bering Sea. Jewett (1982) lists juvenile walleye pollock (*Theragra chalcogramma*), Pacific tomcod (*Microgadus proximus*), starry flounder (*Platichthys stellatus*), and yellowfin sole (*Limanda aspera*) as predators of megalops *Chionoecetes* spp. The major prey of walleye pollock in Cook Inlet, Alaska in spring was documented to be Tanner crab megalopa (Blackburn et al. 1980 in Kim and Gunderson 1988). Chum, pink, and sockeye salmon have been observed to consume *Chionoecetes* spp. crab larvae in Alaskan waters (J. Armstrong, personal communication). Rosenkranz et al. (2001) discounted predator abundance (of sockeye salmon and cod) as being a determinant of year class success, but concluded that bottom temperatures during crab gonadal development and egg incubation are much more important.

Conclusions: Environmental influences on larval development

Studies to determine the optimal conditions for survival of Bering Sea snow and Tanner crab zoeae in the lab have not been conducted. Highest laboratory survival rates (54 percent at 9.6°C) of snow crab larvae from ZI to ZII were reported by Kon (1970) from the Japan Sea. A mixed diet of zooplankton and phytoplankton is probably optimal for growth and survival of these omnivorous larvae. More important to successful larval survival and recruitment may be an adaptation the two crab species have evolved with respect to egg hatch timing, location of larval release and phytoplankton blooms. Snow crab adult female distribution tends to mirror the mean southern ice edge extent in April in the eastern Bering Sea. Snow crab larvae are released earlier (in April) than Tanner crab larvae to coincide with a melting/retreating ice edge-instigated plankton bloom. Tanner crab adult females reside in generally ice-free regions and release their larvae somewhat later (in May) to coincide with the seasonal thermocline-induced spring bloom. Larval released by females at water depths between 50-100 m over the mid-shelf domain may favor retention of larvae over appropriate settlement habitat. Recruitment success may also be correlated to strength of northeastern winds during May-June which promote retention and later larval settlement in appropriate mud-sandy mid-shelf region. Predation by planktivorous fishes may be significant in some years and seasons, but their overall effect on recruitment is unknown.

3.2.2.4 Development of megalops larvae and metamorphosis to benthic juvenile crab

The ZII stage molts to the megalops stage, which is a very capable swimmer, and serves as the intermediate form between planktonic larvae in the water column and first true benthic juvenile crab. Megalopae are 2 mm CW, have the elongated abdomen of larvae but developed appendages with which they swim, as well as claws. The megalops stage lasts about 30-40 days as the larval crab continues to feed and searches for appropriate habitat on which to settle and molt to the first benthic (bottom-dwelling) instar crab (instar is borrowed from insect nomenclature to mean sequential stages of juveniles, then adults following each molt). They tend to begin settlement in the mid-summer to early fall. Newly settled megalopae molt to a very small first stage benthic instar. First instar juveniles are about 3 mm CW for both snow and Tanner crab (Comeau et al. 1998b; Donaldson et al. 1981).

Environmental influences on snow and Tanner crab megalopae

Chionoecetes spp. megalopae in the Bering Sea have not been as extensively studied as king crab glaucothoe. Temperature has a marked effect on growth rates and inter-molt periods. Kon (1970) raised snow crab megalopa from the Japan Sea and found that temperatures of 10-15°C were necessary for successful molting of ZII to the megalopa stage in the laboratory. Such high temperatures are clearly not necessary in the eastern Bering Sea since surface waters typically range from 2-10°C in regions and months when snow and Tanner megalopae develop.

Wind and tidal currents affect megalopal transport and dispersion, as is the case for earlier zoeal stages. While there is little information on the settlement habitat preferences of snow and Tanner crab in the eastern Bering Sea, crabs <20 mm CW are generally found on silt, fine sand, and mud substrates into which they can bury for protection from predators (Paul 1982). Thus crab megalopae need to be retained in the mid-and outer-shelf regions where these substrates predominate in order to have a better chance of survival upon settlement (Rosenkranz et al. 1998). Southeastern winds that promote advection inshore would carry the settlers to unsuitable areas of rocky to cobble substrates whereas northeastern winds in May and June assist in retention within the appropriate domain. As discussed previously for zoeal larvae, currents over the mid-shelf domain (50-100 m depths) are weak compared to those in areas on either side; thereby, favoring retention within that middle domain.

Megalopae are generally found in the upper 40 m of the water column (Armstrong et al. 1981). Timing of settlement has not been well established in the eastern Bering Sea for either snow or Tanner crab. Settlement in the Bering Sea may begin by August but there are still Tanner crab megalopae in the water by October (Incze 1983). Settlement of snow crab megalopae and metamorphosis to first instar crab began by early September 1981 as measured by yellowfin sole stomach contents (Livingston 1989). In Prince William Sound, Tanner crab settle during mid-summer (Donaldson et al. 1981; Armstrong et al. 1995). Exposure to low temperatures may tend to increase inter-molt period and delay settlement. How protracted a period over which megalopae settle is not known for the Bering Sea, although up to six months has been recorded for snow crab in Japanese waters. In Newfoundland, settlement of snow crab megalopae was inferred to occur in early fall based on the time of hatching (May) and the duration of the larval stage (three to five months) (Comeau et al. 1998b). Consistent with that time estimate, Sainte-Marie et al. (1995) reported abundance of Instar I juvenile crab in October, indicative of settlement peaking during September-October.

Other biological factors

Since newly settled first stage instars are so small, they are never captured in routine NOAA Fisheries trawl surveys, and there is virtually no direct measure of distribution and abundance. A surrogate measure of distribution of immature snow and Tanner crab in the eastern Bering Sea is based on stomach contents of Pacific cod (Livingston 1989). Data from three years (1981, 1984, and 1985) suggest that the geographic distribution of snow crab in cod stomach contents is related to the maximum extent of winter ice cover (Livingston *op.cit.*) (Figure 3.2-18); in years when ice cover moves farther south, snow crab larvae tend to settle farther south as reflected in fish stomach contents. During annual NOAA Fisheries trawl surveys, immature male and female snow crab have been found almost exclusively in the mid-shelf domain (NMFS Surveys; Zheng et al. 2001). Brêthes et al. (1987) found bottom water temperature under 3°C to be the most significant limiting factor governing the spatial distribution of immature crab (CW < 40 mm). Little is known about settlement habitat preferences for snow or Tanner crab megalopae in the eastern Bering Sea. Early benthic stage crabs are found on silt, fine sand, and mud substrates (Paul 1982; Rosenkranz et al. 2001), which may be preferred by settling megalopae.

Megalopa in the upper 20-40 m of the water column likely feed on small zooplankton, although there is no direct data on prey in the wild. Megalopae at this shallow depth would be vulnerable to predation by many planktivorous fish species in the eastern Bering Sea. Jewett (1982) lists walleye pollock, starry flounder, and yellowfin sole as predators of *Chionoecetes* spp. megalopae. In addition to sockeye and other young salmon, herring, jellyfish, and chaetognaths are predators on Bristol Bay Tanner crab (Tyler and Kruse 1997). The major prey of walleye pollock in Cook Inlet, Alaska, in spring is Tanner crab megalopae (Blackburn et al. 1980 in Kim and Gunderson 1988). Chum, pink, coho, chinook, and sockeye salmon have been observed to consume *Chionoecetes* crab larvae and megalopae in Alaska waters.

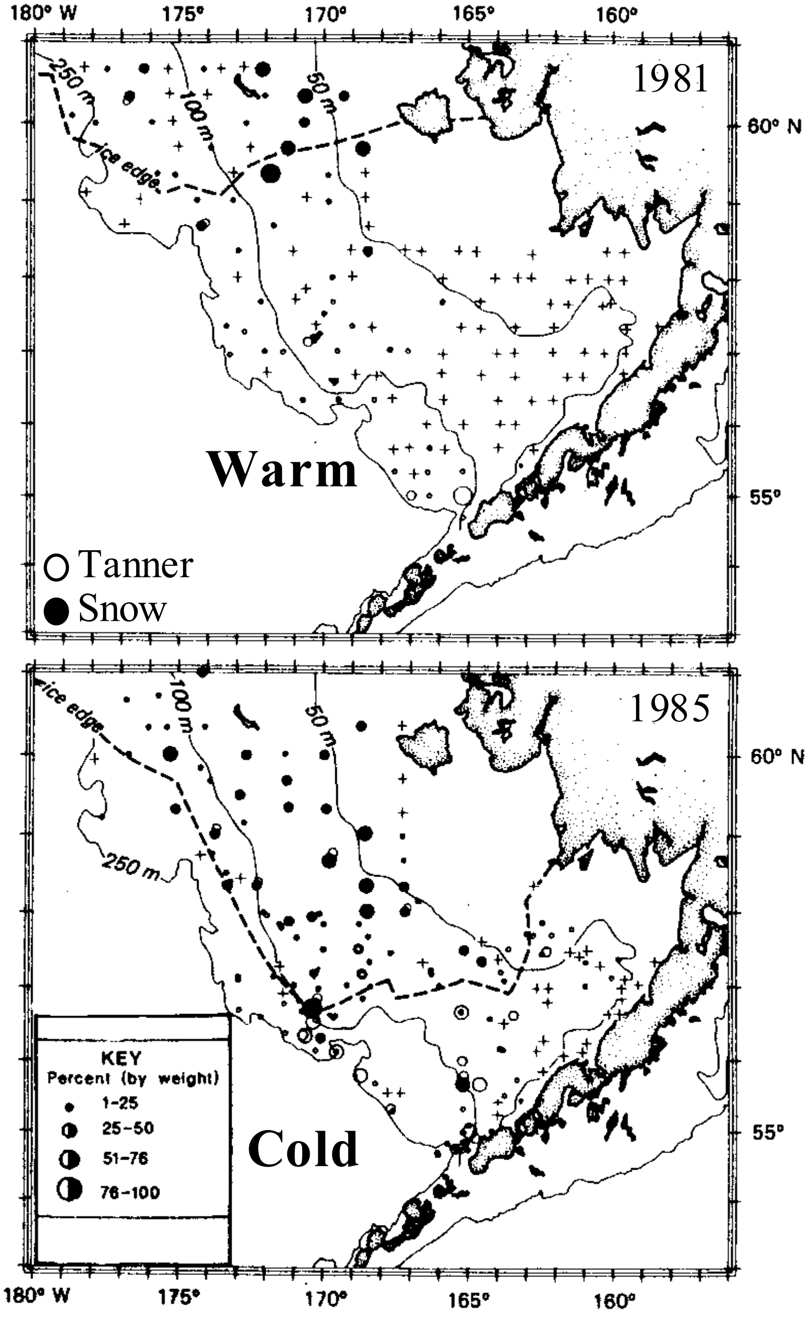


Figure 3.2-18 **Range of newly settled juvenile snow crab from cod stomachs in a warm and cold year (Livingston 1989).**

3.2.2.5 Immature and adolescent stages

Habitat preferences for immature snow and Tanner crab in the eastern Bering Sea have not been fully studied. In eastern Canada, small snow crab (CW < 30-50 mm) were found in substrates ranging from gravel (Coulombe et al. 1985) to mud (Brêthes et al. 1987; Robichaud et al. 1989). In Bonne Bay, Newfoundland, Comeau et al. (1998b) observed that settlement takes place in shallow rocky areas, from which juveniles migrate to deeper, muddy bottoms as they reach Instar V. Juveniles were observed from a mini-submarine in a wide variety of habitats (Conan et al. 1996), but they escape to hide under small rocks when disturbed. Immature Tanner crab (< 20 mm CW) are found on silt, fine sand, and mud substrates (Paul 1982; Rosenkranz et al. 2001), which tend to occur offshore in Bristal Bay.

Benthic life-history stages

The post-larval life history of snow and Tanner crabs are rather complex in comparison to other brachyuran (true) crabs. Throughout the text, terms like immature, adolescent, mature, and adult are used for specific life-history stages (largely following Comeau and Conan 1992; Sainte-Marie et al. 1995; Alunno-Bruscia and Sainte-Marie 1998):

- Immature: sexually immature crab, whether male or female.
- Adolescent (= juvenile in the sense of Comeau and Conan 1992): males that are physiologically mature but MI.
- Pre-pubescent: females in the instar prior to their puberty or terminal molt, which leads to adulthood.
- Mature: sexually mature males (whether MI or MM) and post-puberty females that, in both sexes, produce viable sperm and eggs.
- Adult: used equivalently with MM in the case of males.

Different authors have used juvenile as equivalent to either immature, immature + adolescent or adolescent, and MI male as equivalent to adolescent. These equivalences are avoided in this discussion because of their ambiguity.

Females stop growing after the puberty molt when they reach adulthood. There is overwhelming evidence indicating that male snow and Tanner crabs stop growing once they reach MM (see previous discussion on forms of male maturity; but some disagreement exists as to whether male Tanner crab actually have a terminal molt) and become adults (in the restricted sense indicated above). Thus, growth is primarily an aspect of the immature and adolescent life history stages. Snow and Tanner crabs, like other crustaceans, grow by discrete increments as size jumps from instar to instar that take place at the time of molting when an old, smaller exoskeleton is shed and a new, larger one emerges. Growth of one individual can be separated into two components: the size it becomes at each instar with new exoskeleton, and the frequency of molting (weekly, monthly, annually) which depends on temperature, season, age, and life-history stage.

Growth: Size increments at molt

Like other crustaceans, *Chionoecetes* spp. lack hard permanent structures such as otoliths in fish (that have a new layer added each year), or shells of clams (that also have a new boundary added each year) that are useful in estimating age. Growth and age studies of snow and Tanner crab make use of three types of data: analysis of size frequency data, individual size increments at molt of captive crab, and tagging.

Size Frequency Data (SFD). Each time a crab molts, it becomes a new instar numbered I, II, III, etc., until it no longer molts. When crab are young, they may molt several times each year and so several different instar groups can be the same age. For instance, if a snow crab megalops settles in April and another in July, by October they will both be within their first year of life, but might be Instar IV and Instar II, respectively. Among immature Tanner crab from Prince William Sound a typical year class (the year in which larvae hatch and settle to juvenile stages on the seafloor; e.g., those hatched in 2002 are thereafter termed the 2002 year class) is largely composed of two (sometimes three) instars (Armstrong et al. 1995). Each instar of snow and Tanner crab are fairly well defined in size at each instar stage (Figure 3.2-19).

Individual size-increments at molt of captive crab. Growth can also be studied by measuring the size of individual crab before and after molting (Miller and Watson 1976; Donaldson et al. 1981; McBride 1982; Taylor and Hoenig 1990; Hoenig et al. 1994; Sainte-Marie et al. 1995).

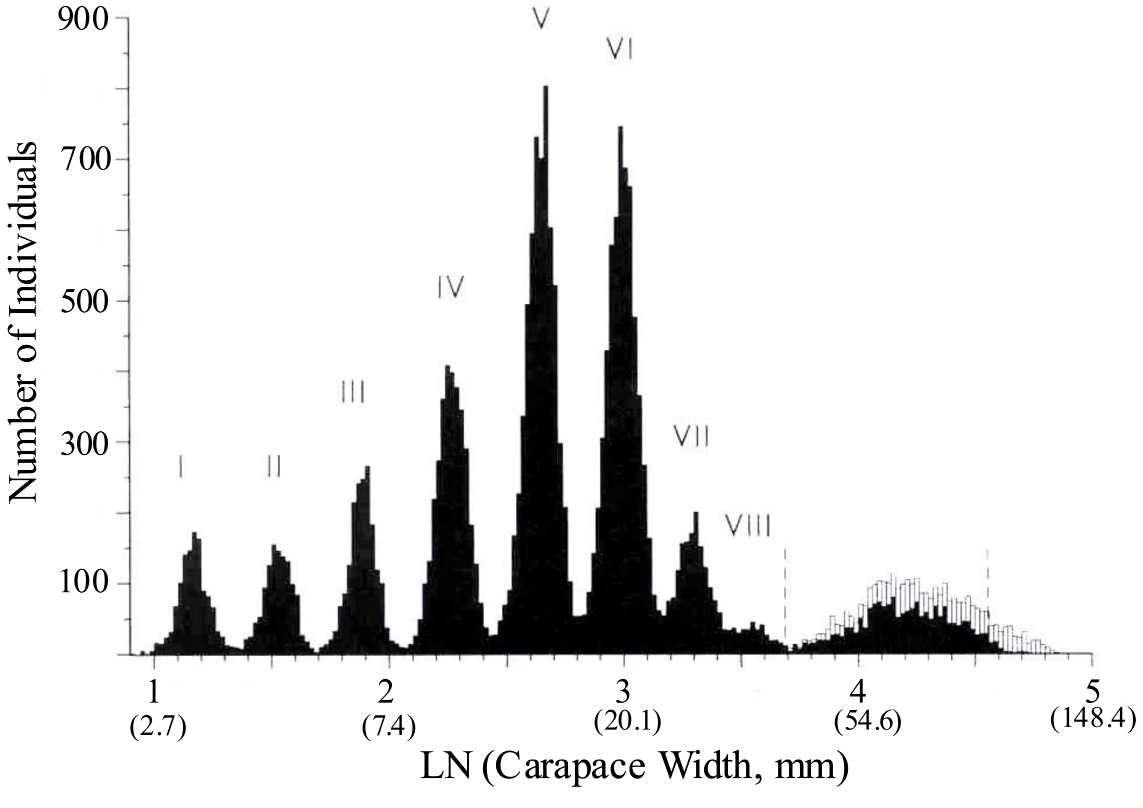


Figure 3.2-19 Pattern of size groups in juvenile and adult snow crab (Sainte-Marie et al. 1995).

Tagging

Tagging is accomplished with devices that are retained across molting events (Taylor and Hoenig 1990; Hurley et al. 1990), e.g., coded wire tags (Dufour and Bailey 1990). Estimation of the number of molts by tagged crab that are recovered was discussed by Warren (1994).

Growth: Frequency of molting and intermolt periods

Since each instar is a predictable size, growth rate is governed primarily by the frequency of molting, which in crabs tends to be governed by temperature. Frequency of crab molting has not been well studied in the eastern Bering Sea, and growth of snow and Tanner crabs is poorly documented. Two studies conducted in eastern Canada provide a detailed description of growth of male and female snow crab in that region. Over the life of crab from settlement, mean age at recruitment to commercial size (95 mm CW) is virtually the same in both cases: 8.7 year + in the Gulf of St. Lawrence, and 9 year+ (Instar XII) in Newfoundland. These are comparable to an age of about 9.5 year (Instar XIII) estimated by Watson (1969), also for eastern Canada. Comparison of results from different regions in Japan and eastern Canada suggest that, as expected, there is great variation in the frequency of molting (Comeau et al. 1998b). Biologists from the AFSC in Seattle tentatively separate age classes using size cuts; males are assumed to reach commercial size at six+ years of age post-settlement (Reeves, in Livingston 1989), which may be an underestimate.

Growth of small Tanner crab in Prince William Sound and adjacent regions of the GOA was studied by Donaldson et al. (1981) and Armstrong et al. (1995) (Figure 3.2-20). Patterns inferred are similar. Settlement of megalopae takes place in mid-summer, and juvenile molt several times to approximately 14 mm CW (Instar VI) at the age of one year. Males grow through 16, at most 17 instars, reaching legal size (140 mm CW) at approximately 7.5 years post-settlement. Most of the commercial catch apparently corresponds to Instar XVI (Donaldson et al. 1981; Orensanz et al. 1998). According to AFSC biologists, males reach commercial size in the eastern Bering Sea at five to six years of post-settlement age (Reeves, in Livingston 1989).

Natural mortality

Livingston (1989) and Livingston et al. (1993) documented consumption of snow and Tanner crab in the eastern Bering Sea by several fishes, most notably Pacific cod (*Gadus macrocephalus*), which accounted for 64 percent of the aggregate total finfish predation on snow crab. Most of the crab eaten were in the size range 20-60 mm CW. Livingston (1989) calculated that up to 84-95 percent of age one snow crab, and 27-57 percent age one Tanner crab could be consumed by Pacific cod. These figures are very tentative, but give an idea of the possible magnitude of predation based on what is known about cod and immature crab abundance, and estimated cod consumption rates. The other predators are three species of flatfish: yellowfin sole, rock sole, and flathead sole (Table 3.2-3). Among marine mammals, walrus and bearded seal consume snow crab (Feder and Jewett 1981). Snow crab are cannibalistic and larger crab (> 40 mm CW) consume more conspecifics (same species) than small crab (<40 mm CW) (Feder and Jewett 1981). Small Tanner crab (CW < 30 mm) are also consumed by Pacific cod, Pacific halibut, and tom cod in the GOA (Donaldson et al. 1981).

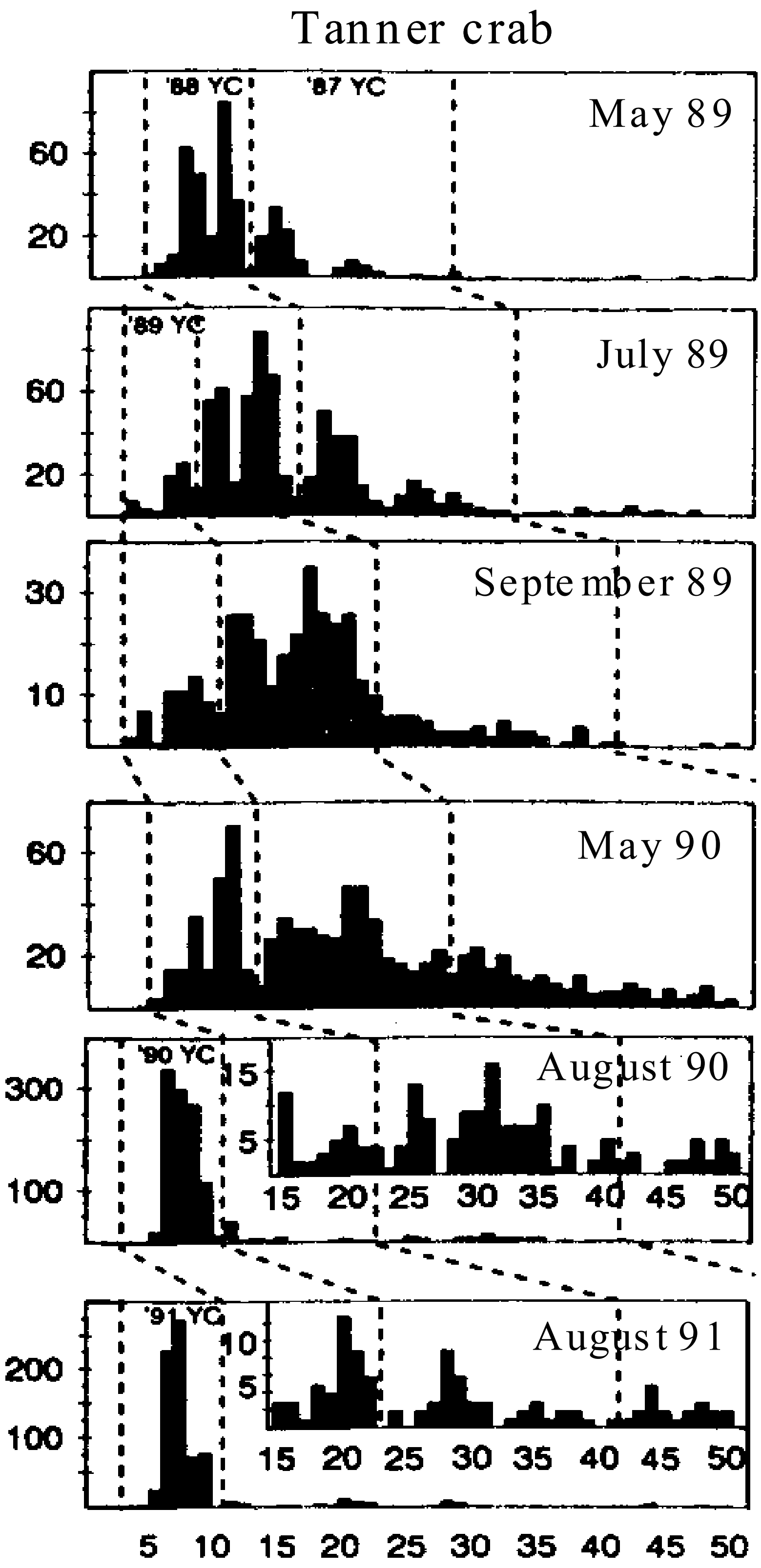


Figure 3.2-20 Change in size of juvenile Tanner crab over time in Prince William Sound (Armstrong et al. 1995).

3.2.2.6 Adult stage

Longevity after terminal molt

Molting ceases (anecdysis) once females reach maturity, and males molt to MM. After terminal molt, condition of the shell changes as time passes due to wear and colonization by a variety of marine organisms (epibionts) such as barnacles, worms, sponges, and algae. Subjective SC indices have been devised as a rough correlate of age since terminal molt (newly molted, clean shell SC2; progressively older crab have SC3, 4, 4+).

Several methods have been used to calibrate SC indices and estimate shell-age of individuals since their terminal molt:

- *Tagging:* Taylor et al. (1989) tagged soft-shell snow crab (SC1) in Newfoundland and recovered them during the ensuing fishing season. Hardening of the shell was estimated to take two to three months. Tagging results from the Gulf of Saint Lawrence indicate a maximum longevity of five to six years after the terminal molt (anecdysis) (Sainte-Marie unpublished cited by Sainte-Marie et al. 1996).

- *Radiometric:* results indicate that maximum age after the terminal molt is about five years in the Gulf of St. Lawrence (Conan et al. unpublished, results cited by Conan et al. 1996 and 1998), and six to seven years in the eastern Bering Sea (Nevisi et al. 1996 and unpublished data). Results from Conan et al. (*op. cit.*) were consistent with tracking of a strong year class.

- *Transition in identifiable year-classes:* best illustrated by transition between shell condition categories of female Tanner crab that entered the mature population of the eastern Bering Sea in 1969, and were tracked by Somerton (1982b) through 1972.

These results indicate that the maximum duration of the terminal anecdysis is five to six years, and that it tends to be rather conservative for the species. In the case of female Tanner crab, Donaldson et al. (1981) inferred a maximum age of six years after the terminal anecdysis. However, as indicated in Section 3.2.2.2, an individual female has only about two active spawning years before senescence.

Female size and age at maturity

When females molt from pubescence to adulthood (puberty molt) there is a dramatic, readily recognizable change in the relative width of the abdominal flap under which the eggs are carried. Because the molt to maturity is terminal, the best depiction of size at maturity is the size-frequency-distribution of mature females (Somerton 1981b). Mean CW of mature female snow crab was estimated by Otto (1998) at 56 mm for the eastern Bering Sea (data from 1989-1994 NMFS Surveys). Most females are in the range of 35-80 mm CW (exceptionally down to 26 mm or up to 89 mm). For comparison, size range of adult females is 39-85 mm CW (exceptionally up to 95 mm) in the Gulf of St. Lawrence (Sainte-Marie and Hazel 1992) and 40-54 mm CW in the Chukchi Sea (Jewett 1981). Instar number corresponding to maturity have not been identified in the eastern Bering Sea, but in eastern Canada females reach maturity at two or three specific instars: Instars X-XI (Comeau et al. 1998b) and mostly Instars IX-X (few at Instar VIII) (Alunno-Bruscia and Sainte-Marie 1998). Mature females at these instar stages are about four and a half to six and a half years post-settlement age (Alunno-Bruscia and Sainte-Marie 1998) in the Gulf of St. Lawrence, and at seven to eight years in Bonne Bay, Newfoundland (Conan et al. 1998). It is interesting to note that minimum adult female size shows little geographic variation (i.e., may be genetically size-determined), while the instars at which most females mature tend to be higher at lower latitudes (i.e., may be environmentally determined, perhaps by temperature), resulting in latitudinal gradients of mean adult female size.

Table 3.2-2 Predators of snow and Tanner crab in the Bering Sea.

Scientific Name	Common Name	Source
Raja parmifera	Alaska Skate	Mito 1974
Raja interrupta	Bering Skate	ibid
Gadus macrocephalus	Pacific cod	Jewett & Feder 1980
Myoxocephalus spp	sculpins	Jewett & Feder 1980
Malacottus zonarus	sculpin	Mito 1974
Hemilepidotus jordani	yellow Irish lord	Mito 1974
Dasycottus setiger	spinyhead sculpin	ibid
Hippoglossoides elassodon	flathead sole	ibid
Hippoglossus stenolepis	Pacific halibut	ibid
Pleuronectes bilineata	rock sole	ibid
Pleuronectes aspera	yellowfin sole	ibid
Glyptocephalus zachirus	rex sole	ibid
Lycodes palearis	wattled eelpout	Jewett 1982
Liparis cyclostigma	Polka-dot snailfish	ibid
Paralithodes camtschaticus	king crab	ibid
Asterias amurensis	sea star	ibid
Erignathus barbatus	bearded seal	Lowry et al. 1980

Sources: Robichaud 1987; Jewett 1982.

Female Tanner crab become adult over a size range of 55-80 mm in the GOA/Prince William Sound (50 percent adult by 68 mm CW, ~Instar XII) (Donaldson et al. 1981). Observed size (CW) range of adult females was 60 to 115 mm in the eastern Bering Sea, and 80 to 110 mm (50 percent adult by 83 mm, ~Instar XIII) in Prince William Sound and the GOA (Donaldson et al. 1981). Age at maturity (counting from settlement) has been estimated to range from four to six years (Donaldson et al. 1981; Rosenkranz et al. 1998; 2001).

Published SFDs of mature female snow and Tanner crab from the eastern Bering Sea show two major modes (Somerton, 1981b, Figure 2), which most likely correspond to different instars since: 1) females can reach maturity at different instars, and 2) size-at-instar tends to be rather conservative in snow crab (as discussed above). The two modes illustrated by Somerton (1981b, Figure 2) may correspond to instars IX and X, or X and XI, implying that in the eastern Bering Sea, most females grow through seven to nine immature instars and the pre-pubescent instar.

The mean size of mature females varies geographically in the eastern Bering Sea. Somerton (1981a, based on data from the 1979 NMFS Survey) explored latitudinal and longitudinal gradients, finding that mean size decreases northward in snow crab, and westward in Tanner crab. Mean size of female snow crab decreases from about 70 mm CW at 55° to only 40 mm at 63°, and mature female Tanner crab decline in size from about 100 mm at 159° to 80 mm at 177°W. Findings on snow crab by Otto (1998, based on 1989-1994 NMFS Survey data) and Zheng et al. (2001, based on 1978-1999 NMFS Survey data) showed the same basic pattern. A clinal (gradient of physiological or morphological changes within a species) reduction in size extends farther north, into the northeast Bering and Chukchi Seas (Stevens and MacIntosh 1986; Paul et al. 1997). Analyses of the same time series of NFMS trawl survey data clearly show that mature female snow crab are smaller and comprised by one instar in the northern portion of the NOAA Fishery survey range (Figure 3.2-11 for the survey area), and larger in the southern portions of the eastern Bering Sea.

Two general hypotheses have been advanced to explain clinal variation in size at maturity.

Environmental control. Somerton (1981a; 1981b) interpreted clinal size variation as an effect of bottom water temperature gradients. According to Zheng et al. (2001) smaller size at maturity towards colder regions could be attributed to (I) lower molting probability or (ii) smaller size increments per molt.

Genetic determination. Somerton (1981b) was puzzled by the modes in SFDs of female size at maturity, given that there are not abrupt changes in environmental gradients. This led him to speculate on the hypothetical existence of distinct populations in which size at maturity would be genetically determined. However, there is little genetic variation in snow crab throughout the eastern Bering Sea (Merkouris et al. 1997).

Data from the NOAA Fishery trawl surveys reveal significant fluctuations in the average size of adult females, which has implications for total egg and larval production over time. Since fecundity is a function of size, more or less production will occur when the mean size of females is large and small, respectively.

The estimated mean CW of MM male snow crab in the eastern Bering Sea is 88.5 mm (Otto 1998; data from 1989-1994 NMFS surveys). Smallest and largest size of MM males are around 30 mm and 146 mm, respectively, but MM males smaller than 40 mm or MI males larger than 80 mm are rare. The lower boundary agrees reasonably well with that reported for Sainte Marguerite Bay in eastern Canada (40.4 mm; Sainte-Marie and Hazel 1992). A substantial fraction of the MM male population does not reach commercial size. Average male size at maturity for snow crab varies over space and fluctuates from year to year in the eastern Bering Sea (Otto 1998). Average size at MM of Tanner crab from the GOA was estimated to be 112 mm CW, which corresponds to a pre-molt size of 90 mm CW (Somerton 1980b; Donaldson et al. 1981). Snow crab males reach MM over a range of six instars, IX-XIV, in eastern Canada (Sainte Marie et al. 1996; Comeau et al. 1998b). There are no comparable analyses for the eastern Bering Sea, but the pattern is probably similar considering the size range of adult males. Snow crab in eastern Canada reach maturity over a wide range of individual ages (at least five year), with an approximate average of eight years (Conan et al. 1996). Tanner crab are assumed to reach adulthood five to seven years after settlement in the eastern Bering Sea and GOA (Donaldson et al. 1981; Rosenkranz et al. 1998, 2001).

Seasonality of male terminal molt. Timing of terminal molt among male snow crab in the eastern Bering Sea is not known, but in eastern Canada terminal molt was observed to occur in aquaria in winter to early spring (February-late April; Conan et al. 1990), and was inferred to peak during spring (March-May) in the field, before ice breakup (Sainte-Marie et al. 1995, for references; Conan et al. 1996). Terminal molt of large adolescent Tanner crab (Somerton 1982b) peaks by late June-early July in the eastern Bering Sea (Somerton 1982b) and during the fall in Kodiak, with lesser numbers molting through winter and spring.

Natural mortality rate. Comeau et al. (1998b) estimated a life expectancy of male and female snow crab from Newfoundland of 13 and 19 years, respectively. There have been no comparable estimates for either species in the eastern Bering Sea, but age in excess of ten years is probably common. The terminal molt phenomenon presents a very special situation for the analysis of mortality rates in MM crab, since SC indices can be used to assign relative age. After correcting for fishing mortality, Otto (1998) estimated annual natural mortality to be about 30-35 percent, which is fairly high in the eastern Bering Sea. This low survival is consistent with radiometric results cited above. Yamasaki et al. (1990; 1992) used the ratio of MM/MI to estimate annual adult male mortality; his estimates were about 65 percent for the first year, and 50 percent for subsequent years.

Known sources of natural mortality include some diseases and predators, although the latter are more significant in the case of immatures. Well documented diseases (Sparks and Morado 1997) include black mat syndrome, which is a fungal infection caused by the ascomycete *Trichomaris invadens* (Hibbits et al. 1981; Kon 1996), and bitter crab disease caused by *Hematodinium* spp., a parasitic dinoflagellate that affects mostly Tanner crab in southeastern Alaska but is also detected in the two species in the eastern Bering Sea (Meyers et al. 1990, 1996; Love et al. 1996). Necrotic bacterial infections developing from carapace wounds are also common (Benhalima et al. 1998).

3.2.2.7 Segregation of life history stages and migrations

General patterns in the eastern Bering Sea

The benthic life history stages described in previous sections follow distinctive patterns of geographic distribution within the eastern Bering Sea. Somerton (1981a) already observed that there are some areas that contain many immatures but few adults, and other areas that contain many adults but few immatures. The annual NOAA Fishery trawl surveys show some striking patterns for the snow crab. Immature males and females are circumscribed to the mid-shelf Domain, suggesting that settlement takes place there. Newly molted primiparous mature females (SC2) are also circumscribed to the mid-shelf Domain, but older multiparous females (SC3 and higher) appear displaced to the outer-shelf Domain, suggesting a large-scale ontogenetic migration with a northeast to southwest vector of movement (Zheng et al. 2001, Figure 1) (Figure 3.2-21). Patterns of spatial distribution have been studied in Bonne Bay by Conan et al. (1996), who found consistent segregation by age, sex, and degree of sexual differentiation. In the case of Tanner crab, by contrast, immatures and adults co-occur everywhere within the species' range (Somerton 1981a).

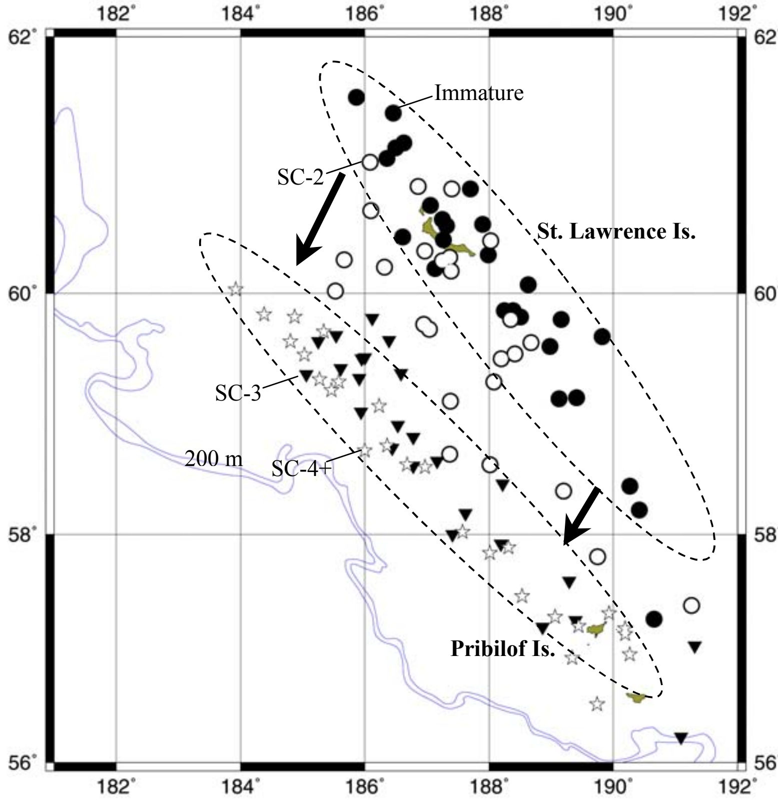


Figure 3.2-21 Ontogenetic movement of female snow crab on the eastern Bering Sea shelf from the northeast as immatures to the southwest as old-shell adults (Ernst, Orensanz, and Armstrong unpublished data).

Seasonal (short-term) migrations and aggregations

It has been traditionally held that snow and Tanner crab migrations in the eastern Bering Sea are negligible, if present at all:

> "There is no indication that either species undertakes large seasonal migrations in this region" (Incze et al. 1987).
>
> "Short-term changes due to crab migration also appear not to be important" (Somerton 1981b).

This view is supported by tagging results on Tanner crab obtained by Donaldson (1983) in the GOA, in which tagged males were at liberty for up to three years. However, seasonal mating aggregations have been documented for Tanner crab in the GOA. Stevens et al. (1994) studied a very large aggregation off Kodiak from a submersible in April 1991, at a depth of 150 m. The aggregation of up to 100,000 crab consisted primarily of old-shell ultiparous females, which formed mounds up to 1-2 m in diameter, 0.5-l m high, and spaced at intervals of 1-2 m. Males were found at the periphery of the aggregation in a ratio of one male to 10-100 females. The phenomenon re-occurred at the same location during subsequent years, always between mid-April and early June (Stevens 2000), related to reproductive events including hatch of eggs and mating thereafter. Besides these aggregations involving adult, non-molting crab, Stone (1999) reported a spring migration of MI males to a shallow cove in southeast Alaska, where they molted. The phenomenon was observed during two consecutive years.

In the case of snow crab, seasonal offshore-onshore migrations and aggregations have been well documented in eastern Canada. Immature/adolescent male and female crab migrate to shallower, warmer waters during the spring in both the Gulf of Saint Lawrence (Sainte-Marie et al. 1988; Sainte-Marie and Hazel 1992; Mallet et al. 1993; Lovrich et al. 1995) and Newfoundland (Taylor et al. 1985; Hooper 1986; Ennis et al. 1990; Comeau et al. 1991 and 1998b; Conan et al. 1996). Mating aggregations, including heaps (pods) of females were observed during mini-submarine dives in shallow water at the vicinity of the summer thermocline (Conan unpublished results cited by Conan et al. 1996), and appear to reoccur at the same location year after year. The conditions that elicit spring aggregation at those sites are unknown; they have been variously interpreted as the result of a directed reproductive migration (Hooper 1986), or, more generally, as tracking of temperature gradients (Sainte-Marie and Hazel 1992). After aggregations disassemble, males move offshore, apparently tracking bottom water temperature gradients (Maynard 1991 cited by Conan et al. 1996). Males apparently need to remain in colder water (-1 to 1°C) due to metabolic constraints. Radio-telemetry showed that after mating, females remained in shallow water, while males moved offshore (Conan and Maynard unpublished results cited by Conan et al. 1996); if disturbed, MM males can move several miles in a few days. These observations are consistent with the hypothesis that recruitment of large males to deep coastal fishing grounds occurs following a down-slope movement of recently molted males (Coulombe et al. 1985; Bouchard et al. 1986; Sainte-Marie and Hazel 1992).

Ontogenetic (long-term) migrations

Whether short-term, seasonal migrations exist or not in the eastern Bering Sea, there is growing evidence of an extensive ontogenetic (over the course of a species' life-time) migration of both male and female snow crab in the eastern Bering Sea, from shallower to deeper waters (Otto 1998), with a predominant northeast-southwest direction (Zheng et al. 2001) (Figure 3.2-21). This can be inferred from the spatial shifts in the distribution of shell-condition categories, whether cohorts are pooled or not. Otto (1998) was able to track a strong year class, identifiable because of its small MM size, as it vanished from shallow areas (< 80 m depth) after 1990, and was then detected in deeper water a year later. Large male snow crab in Bristol Bay, where immatures do not occur, presumably immigrate from the north (Zheng et al. 2001). Tagging experiments conducted in the eastern Bering Sea between 1978 and 1982 showed an average displacement of 75 km for male snow crab (McBride 1982). This figure is commensurate with the ontogenetic migration inferred from NOAA Fisheries Survey data.

Such pronounced seasonal migrations and re-distributions indicate complex behavior that tracks environmental changes to which the species must cue for a variety of reproductive and mating activities. Crab are by no means static in time and space as shown in examples above. Interannual changes in onset and magnitude of such cues (e.g., ice cover, temperature gradients, photoperiod—relative proportions of day-night/24 hour) likely exert strong influence on year class strength and overall population abundance and distribution. Migrations over longer periods of life suggest changes in needs of different life history stages. For example, type of prey differ considerably between small immature stages and larger adults, and such prey may be more/less abundant across the shelf domains as reflection of sediment types, temperature, and abundance of other competing predators for the same prey.

3.2.2.8 Fluctuations in abundance

The long history of annual NOAA Fisheries trawl surveys of the eastern Bering Sea provide an important record of changes in population abundance and distribution in the cases of both snow and Tanner crab (Figure 3.2-22). Over two decades of data show significant changes in abundance of large male snow crab that fluctuate from about 50-70 million crab in the late 1970's-early 1980's, to peaks over 500 and 300 million in 1991 and 1997, respectively (Figure 3.2-22). Similar fluctuations occur among Tanner crab in which large, legal males ranged from peaks of about 100 million in the later 1970's and 40 million in the early 1990's, to less than 5 million in the mid-1980's and later 1990's (Figure 3.2-22).

Variability of recruitment

Recruitment of both species in the eastern Bering Sea is characterized by sporadic strong year classes. A strong year class is first detected in NOAA Fisheries trawl surveys several years after larvae settle to the seafloor when juveniles have grown to a size that is captured in the survey nets; perhaps at three to four years of age. Given all of the vagaries in individual growth rates in time and space, a single strong year class will likely recruit to commercial fisheries over several years as well. Strong year-classes are the result of sporadic pulses of recruitment. Documented pulses of snow crab recruitment are summarized in Table 3.2-4. Only one consistent pulse of recruitment to the mature population (spread over two years) appears to be present in the 11-year period 1969-1979, judging from data illustrated by Somerton (1981a, Figure 10), although it must be stressed that the region covered by his study was marginal for snow crab. Data from the NOAA Fisheries Surveys presented by Zheng et al. (2001) show only three pulses of recruitment to the large male and mature female populations during the 21-year period from1978-1999. Recruitment of a strong year-class to a size of 45 mm CW (males) or maturity (females) can be spread over one to three years, leading to high catches one to four years later. Only five such pulses have been documented in the 32-year period from 1969-2001 of eastern Bering Sea surveys (Table 3.2-4).

In Baie Sainte Marguerite (Gulf of St. Lawrence) recruitment patterns have followed an ~ eight-year cycle over a 25-year period (Sainte-Marie et al. 1996). This results from episodes of ~ five strong year classes interspersed with two to three year periods of low recruitment. Such periodicity in strong/weak recruitment could be a widespread pattern in snow crab populations. Conan et al. (1996), for example, showed that in Bonne Bay, Newfoundland series of three to four successive years of good recruitment are interspersed with series of five to six years of poor recruitment.

Table 3.2-3 Evidence of periodic strong snow crab year classes in the eastern Bering Sea based on several analyses of various intervals of the NOAA Fishery trawl survey data sets.

Study period	Years of pulse[2]	Duration in years	Associated pulse in the fishery	Data sources
Before 1969	Mature females already recruited in 1969	?	Males recruited to commercial size in 1972-1973	Somerton 1981a[1]
1969-1979 (11 year)	1975 → 1976	2		Somerton 1981a[1]
1978-1999 (21 year)	1979 → 1980	1		Zheng et al. 2001
1978-1999 (21year) 1989-1994 (6 year)	1986/1987 → 1987/1988	2	1987-1991	Zheng et al. 2001 Otto 1998 [check]
1978-1999 (21 year)	1992/1994 → 1993/1995	3	1997-1999	Zheng et al. 2001

Notes: [1] The area studied by Somerton (1981b) was a rectangle delimited by 163°W, 167°W, 57°30'N and the coast of the Alaska Peninsula. This region is marginal for snow crab.

[2] The period in which high abundance in the survey was actually measured, not the year of origin of the particular year class (e.g., a strong pulse in 1975-1976 may have been four to six years old by then when large enough in size to be caught in the survey nets).

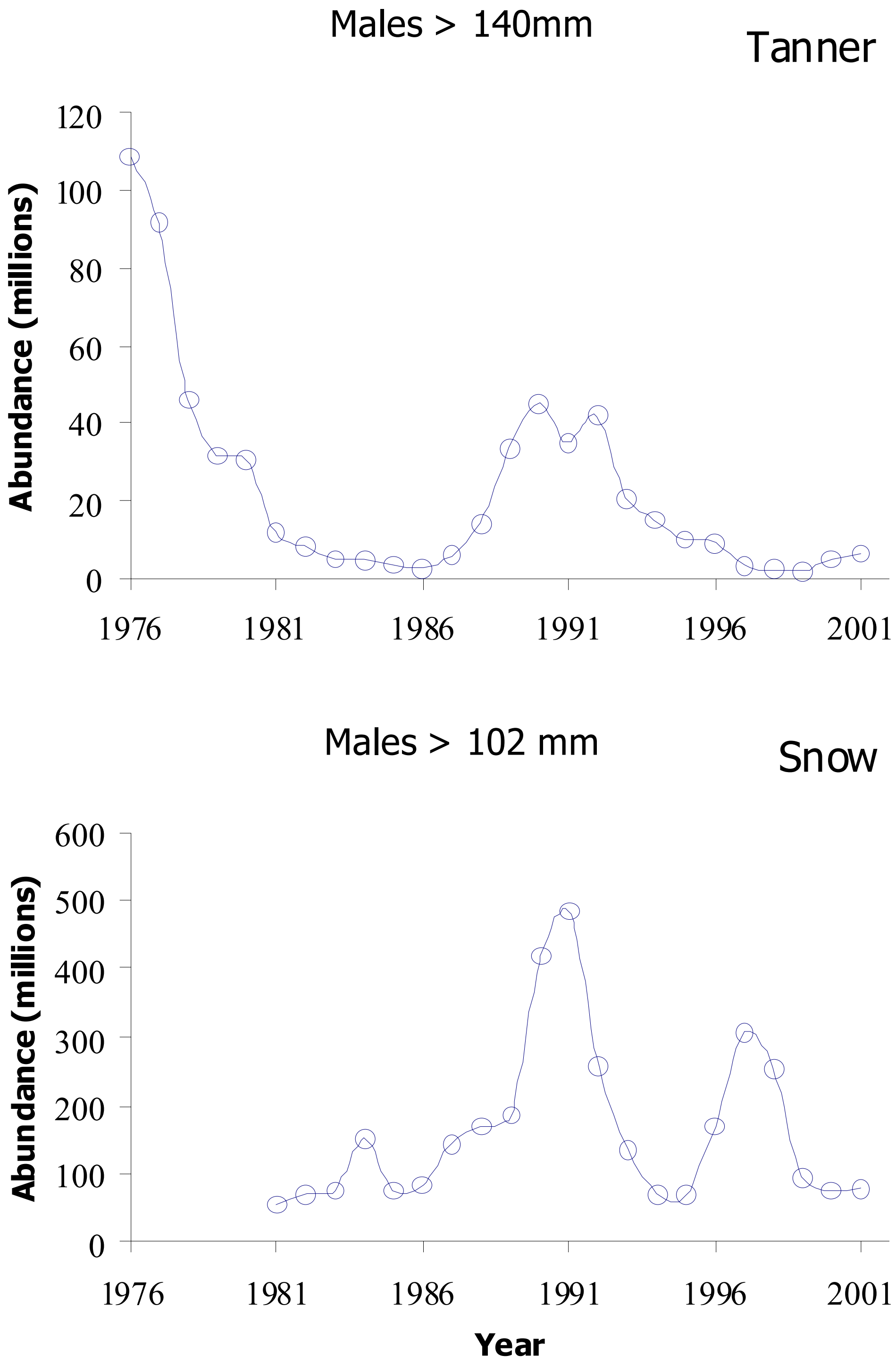


Figure 3.2-22 NOAA Fishery survey trends in abundance of male snow and Tanner crab over the last 20+ years in the eastern Bering Sea.

Factors governing recruitment

Several factors may be involved in governing year-class strength and fluctuations of snow and Tanner crab populations:

Size of the reproductive female stock. Postulated by Incze et al. (1987) and implied in the ascending branch of stock-recruitment relations (e.g., Zheng and Kruse 1998; stock-recruitment relationships essentially indicate some correspondence between the size of adult female populations—the stock of spawners, and juvenile recruits). Sainte-Marie et al. (1996) noticed that the failure of two year classes (1993-1994) in Baie Ste. Marguerite, Gulf of St. Lawrence) coincided with the lowest female spawning stock recorded over a 16 year period. The reproductive contribution of females could be affected by availability of suitable male mates (poor operational sex ratios for primi- and multiparous females), which in turn could be determined by alternation of strong and weak year classes, or removal of large males by the fishery.

External forcing operating during the period of larval development. In spite of considerable scrutiny, evidence of association between snow and Tanner crab recruitment and environmental variables in the eastern Bering Sea (e.g., Zheng and Kruse 2000a) is weak, and often contradictory. Hypotheses explored largely emphasized environmental forcing (physical features such as direction and strength of currents, ice cover, temperature, and biological variables such as food and predators) operative during the larval stage. Reconstructed time series of year-class strength of Tanner crab from Bristol Bay and snow crab from the eastern Bering Sea are not cross-correlated (Zheng et al. 2000, Table 3). Relative abundance of neither species was associated with the strength of the Aleutian Low (Section 3.1) nor with cod predation on immatures (Zheng and Kruse 2000a), two hypotheses often considered. Rosenkranz et al. (1998 and 2001) found that year-class strength of Tanner crab from Bristol Bay is positively correlated with northeastern winds during the spring-summer larval period, and with higher bottom temperature during gonadal development. These two factors accounted for about half of the variability in a year class strength index estimated with a length-based method that used data from NOAA Fisheries Surveys and from the commercial catch (Zheng et al. 1998). Anomalously cold bottom temperatures may adversely affect the Tanner crab reproductive cycle, and northeastern winds may promote coastal upwelling while advecting larvae to regions of fine sediments favorable for post-settlement survival (Rosenkranz et al. 1998).

Endogenous regulation. Beyond larval supply, Conan et al. (1996) and others have hypothesized that recruitment can be controlled by density-dependent mechanisms, e.g., cannibalism by older, larger crab on new settlers (Sainte-Marie and Dufour 1994 cited by Sainte-Marie et al. 1995; Conan et al. 1996). Cannibalism has been observed in snow crab, both in the wild and in the laboratory. The most common perspective of cannibalism in crabs is predation on very small stages by larger ones. In lab experiments Instar I crab were cannibalized by males 8-50 mm CW (Lovrich and Sainte-Marie 1997). Stomach content analyses of wild crab over a wide size range conducted in the Gulf of St. Lawrence showed that Instar I appears in about 7 percent of wild caught, mostly adult crab (Lovrich and Sainte-Marie 1997). Conspecific prey ranged from about 4 to 50 mm CW, but most were immature crab, Instars V-VII (15-30 mm CW). Lovrich and Sainte-Marie (1997) concluded that intraspecific predation might reduce cohort strength over the first four years following settlement.

Predation. Predation mostly by cod (*Gadus* spp.) on immature stages. As discussed earlier, cod can have a significant impact on immature snow crab in the eastern Bering Sea (Livingston 1989). Cod predation was hypothesized to control snow crab abundance in the Gulf of St. Lawrence (Bailey 1982), but later studies failed to find population fluctuations consistent with that hypothesis (Elner and Bailey 1986).

Temperature-dependent growth rate of benthic stages. Environmental forcing could also affect post-settlement stages. Since temperature can affect the rate of growth, recruitment to legal, commercial size may depend on the region where larvae settle and immatures grow. Zheng et al. (2001) observed that pulses of recruitment to the adolescent male population (45 mm CW) in 1985-1987 were centered towards the southeast, but during 1991-1994 such abundance was centered towards the northwest, which led to relatively low and high recruitment to the fishery, respectively. Delays of two to three years in the molting of adolescent crab (skipmolting) has been reported for eastern Canada (Comeau et al. 1991; Sainte-Marie et al. 1995), but its cause remains unexplained. Taylor et al. (1993) attributed the 1982-1985 collapse of the Avalon Peninsula fishery (Newfoundland) to a reduction in recruitment to legal size due to cold water that inhibited molting of the sublegal size group over several consecutive years. Alternatively, other authors have proposed that skipmolting could result from competitive interactions between large resident males and prospective recruits.

Year-class strength appears to be established before the second year of benthic life in different regions (Sainte Marie et al. 1996; data presented by Zheng et al. 2001), either before, at, or shortly after settlement. This rules out Hypothesis (5) as a main regulatory process. There appears to be good evidence supporting endogenous regulation (Hypothesis 3), but broad geographic coherence of recruitment (either high or low over large regions in the same time periods) seems to point to factors with a larger operating scale, some type of environmental forcing working at the level of an entire region (Conan et al. 1996; Sainte-Marie et al. 1996). It is obvious that female abundance when very low should affect recruitment (Hypothesis 1), but this could be non-apparent in the case of open populations. Populations of snow and Tanner crab, as is the case of other benthic invertebrates with long-lived pelagic larvae, are spatially structured as metapopulations (Orensanz et al. 1998). In this case of crab metapopulations, benthic adults that typically do not move 100s km may yet be connected over long distances by transport of larvae that results in an interconnection. Connectivity between population units (mediated by larval dispersal) may be complex and asymmetrical, but is poorly understood. Some of the populations that have been well studied in eastern Canada (e.g. Bonne Bay, Newfoundland) are small and confined to semi-closed basins. These can probably be regarded as unit stocks. Stocks from the eastern Bering Sea and the GOA, by contrast, are spread over vast expanses of shelf area. A study of haplotypes in mDNA of Tanner crab from the GOA suggests the possibility that larvae are transported preponderantly from east to west by westwardly flowing currents (Bunch et al. 1998). Declining stocks in western management areas could be the result of population fluctuations in eastern, upstream populations. The population of southeast Alaska appears to be genetically isolated, with one predominant haplotype. The issue of factors controlling snow and Tanner crab recruitment in different systems remains open.

Trends in geographic distribution

The centers of distribution of mature females and large males of snow crab in the eastern Bering Sea have moved gradually from southeast to northwest since the late 1970's (Zheng et al. 2001) (Figure 3.2-23 and Figure 3.2-24) over five year intervals beginning in the late 1970's. In the case of female snow crab, centers of distribution in the late1970's were about 56° latitude from the shelf break east towards Unimak Island (Figure 3.2-23). By 2000, distribution was centered over 200 nautical miles northwest. Such shift has important implications relative to larval production and whether weak or strong probability that a new year class settles on the shelf and over a large area of historic distribution. Spatial change in centers of spawning mature females from southeast to northwest may reduce the supply of larvae back to southerly areas of the eastern Bering Sea shelf given the general northwest direction of currents along the shelf margin (Section 3.1). A possible cause for such spatial shift in distribution may be the regime shift that occurred in 1976-

1977. The intensity of the Aleutian Low (a measure of the shift) generally intensified from 1977 to 1998 (Zheng and Kruse 2000a). During this period of intensification, seawater temperatures were generally warmer, which could cause snow crab to concentrate in the colder northern area (Zheng et al. 2001).

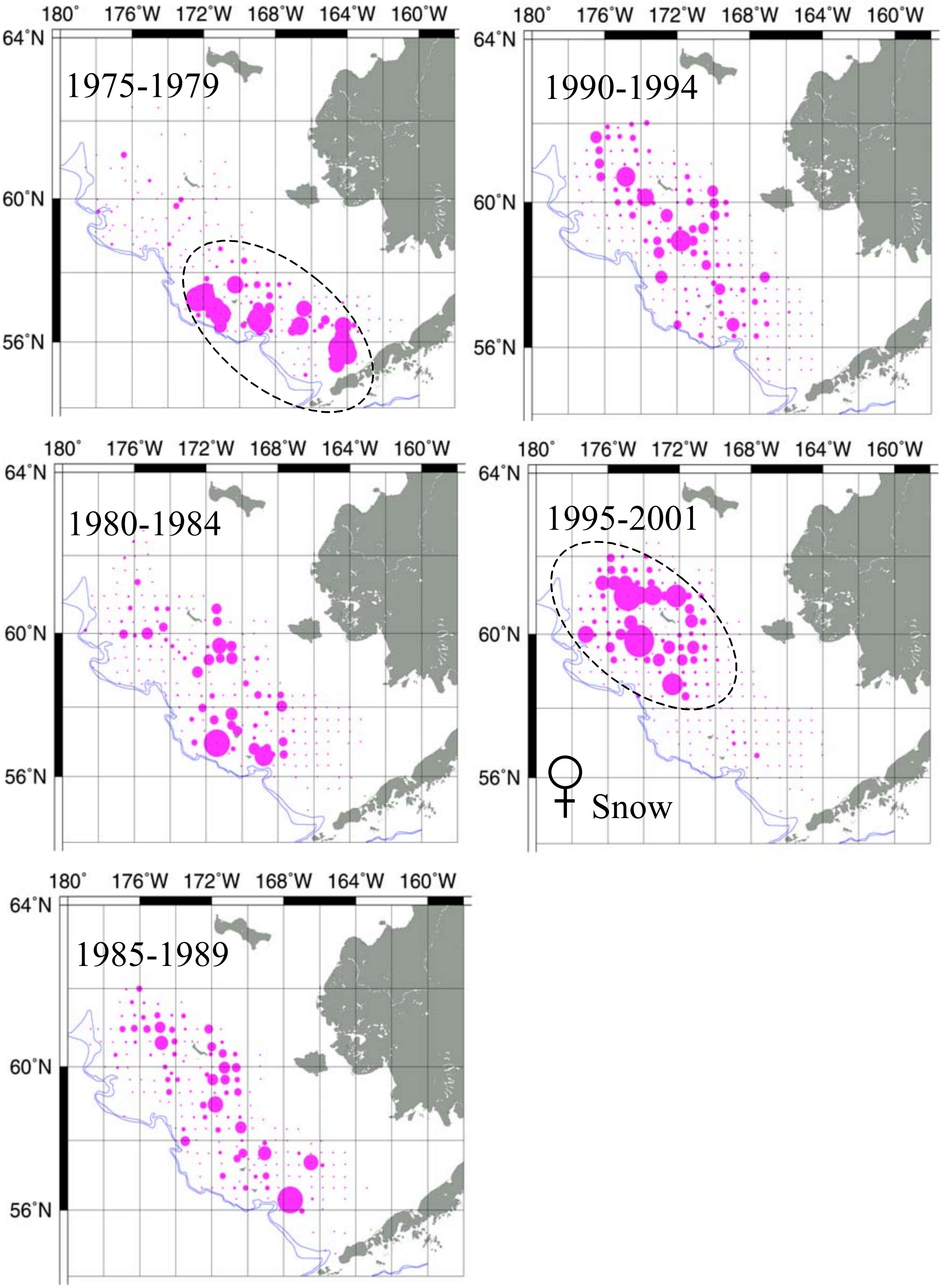


Figure 3.2-23 **Spatial distribution of adult female snow crab in the eastern Bering Sea over five year intervals beginning in the late 1970's (Ernst, Orensanz, and Armstrong unpublished data).**

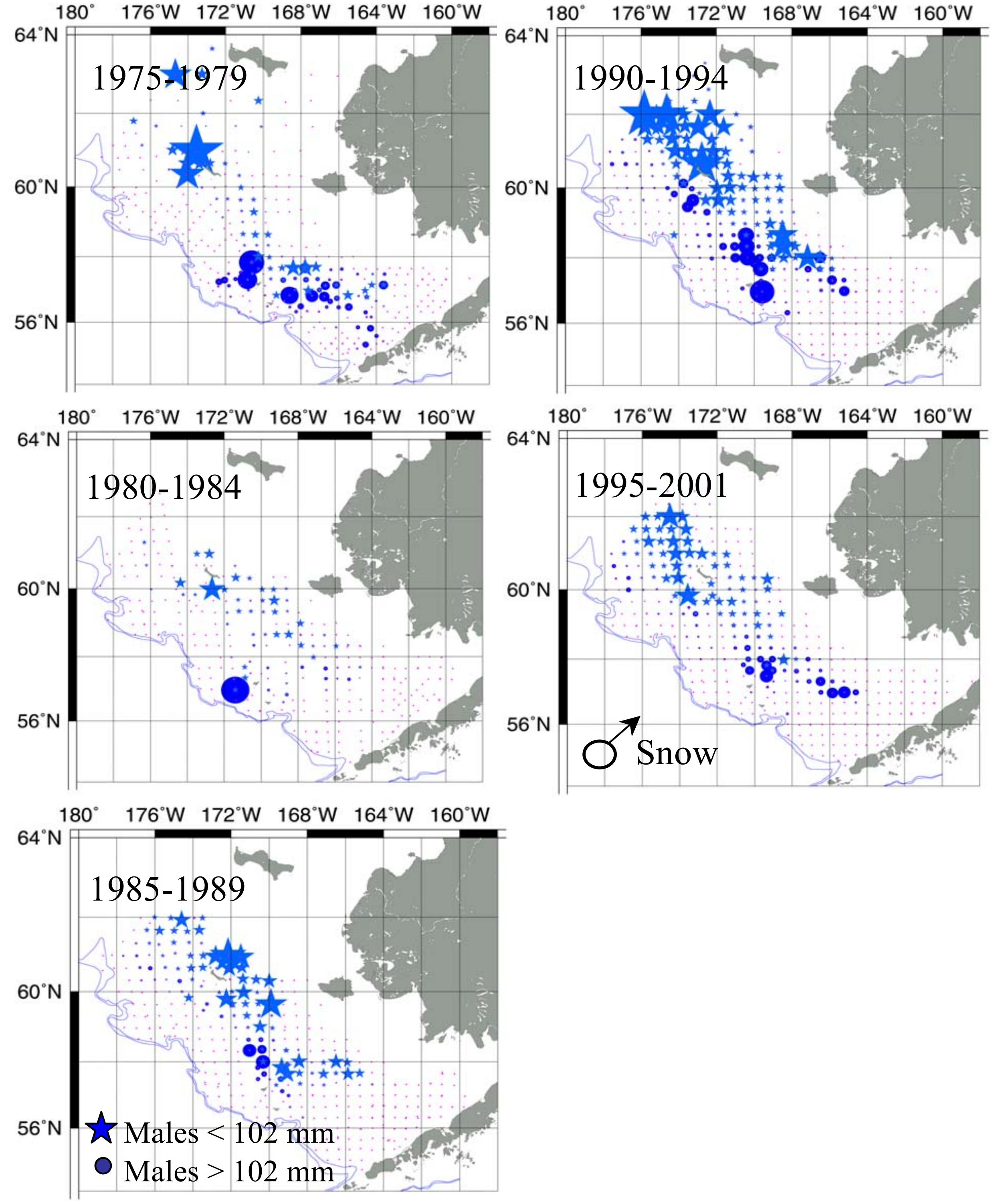


Figure 3.2-24 **Spatial distribution of adult male snow crab in the eastern Bering Sea over five year intervals beginning in the late 1970's (Ernst, Orensanz, and Armstrong unpublished data).**

3.3 Other biological resources

This section discusses other biological resources in the BSAI that are impacted by the BSAI crab fisheries. Section 3.3.1 describes the benthic species and habitat located in the BSAI that interact with crab and the crab fisheries.

3.3.1 Benthic species and habitat

An estimated 70 percent of the invertebrate epifaunal biomass in the eastern Bering Sea consists of red king crab (*Paralithodes camtschatica*), blue king crab (*P. platypus*), golden king crab (*Lithodes aequispina*), scarlet king crab (*L. couesi*), snow crab (*Chionoecetes opilio)*, Tanner crab *(C. bairdi)*, grooved Tanner crab *(C. tanneri),* triangle Tanner crab *(C. angulatus*), and four species of sea stars. The mean invertebrate epifaunal biomass in the southeastern Bering Sea is 4.1 grams per square meter (g/sq. m). In the southeastern Bering Sea, echinoderms, especially *Asteria amurensis*, represent 84.4 percent (1.6 g/sq. m) of the epifauna biomass in water less than 40 m deep. In 40 to 100 m of water, *A. amurensis* represents 12.7 percent (0.6 g/sq. m), the largest component of the biomass with the exception of red king crab and snow crab. The largest component of the invertebrate epifaunal biomass in water deeper than 100 m in the southeastern Bering Sea other than crabs of the genus *Chionoecetes* or *Paralithodes* is a basket star, *Gorgonocephalus caryi*, representing 7.3 percent (0.4 g/sq. m) (Jewett and Feder 1981). In the trophic structure, crabs are members of the inshore benthic infauna consumers guild (NPFMC 1994a). Section 3.1.6 contains a description of the substrate for the BSAI.

3.3.1.1 Crab habitat

Summaries and assessments of habitat information for the BSAI crab species are provided in Essential Fish Habitat (EFH) Assessment Report (NPFMC 1998d). Stocks of BSAI crabs have widely varying levels of information available. Some stocks have only limited fishery data while Bristol Bay red king and Tanner crabs have been studied intensely. The type and level of information available for most BSAI crabs' life stage is minimal. The type of habitat information available for almost all crab species is spatial distribution over depth and broad geographic areas as collected from survey and fishery samples that have limited linkage with habitat characteristics. Coupled with traditional knowledge these data demonstrate that geographic distribution of crab contracts and expands due to a variety of factors including, but not limited to, temperature changes, current patterns, changes in population size, and changes in predator and prey distribution.

Specific data are lacking to precisely define localized habitat for each life stage of crab because surveys are cost prohibitive to document the expanse of king and Tanner crab habitat along the coast line of the BSAI and on the continental shelf and slope. Consequently, the oceanographic (temperature, salinity, nutrient, and current), trophic (presence/absence of food and predators), and physical (depth, substrate, latitude, and longitude) characteristics of crab habitat are restricted for most crab species and life stages to broad general associations. Types of data used to describe habitat association of BSAI king and Tanner crabs include: AFSC trawl surveys; the Outer Continental Shelf Environmental Assessment Program (OCSEAP) survey, NMFS and ADF&G tagging surveys, ADF&G pot surveys; ADF&G shellfish observer program; ADF&G harvest records, and Japanese and Russian surveys.

King and Tanner crabs share a similar life cycle, although particular life cycle traits are distinct for each species. After males and females mate, the female carries the eggs for approximately one year, at which time the eggs hatch into free-swimming larvae. After drifting with the currents and tides and undergoing several development changes, the larvae settle to the ocean bottom and molt into nonswimmers, looking very much like miniature adult crabs. The juvenile crabs settle on preferred habitat, where they continue to molt and grow for several years until they become sexually mature. Each life stage for BSAI crab stocks is concentrated at some combination of depth, habitat, geographic area, and time of year.

During each life stage, crab consume different prey and are consumed by different predators. Food eaten by king crabs varies with size, depth inhabited, and species, but includes a wide assortment of worms, clams, mussels, snails, brittle stars, sea stars, sea urchins, sand dollars, barnacles, fish parts, and algae. King crabs fall prey to a wide variety of species, including Pacific cod, rock sole, yellowfin sole, pollock, octopus, and other king crab (Livingston et al. 1993). Snow and Tanner crab feed on an extensive variety of benthic organisms, including bivalves, brittle stars, other crustaceans, polychaetes and other worms, gastropods, and fish (Lovrich and Sainte-Marie 1997). In turn, they are consumed by a wide variety of predators, including groundfish, bearded seals, sea otters, octopus, Pacific cod, halibut and other flatfish, eelpouts, and sculpins (Tyler and Kruse 1997). Snow crab comprise a large portion of the diet of many skate species (Orlov 1998).

Life history stages of king and Tanner crabs were defined according to accepted habitat usage: eggs, larvae, early juveniles, late juveniles, and mature crabs (Tyler and Kruse 1996, 1997). This information is presented in general for king and Tanner crab and then specific information is provided for each species. More detailed information on the interactions between the crab life stages and habitat are in Section 3.2.1 for king crabs and Section 3.2.2 for snow and Tanner crabs.

Egg Stage: Female king and Tanner crab extrude eggs, carry and nurture them outside the maternal body. The number of eggs developed by the female increases with body size and is linked to nutrition at favorable temperatures. Planktonic larval crab consume phytoplankton and zooplankton and are prey for pelagic fish, such as salmon and herring. Information on egg bearing females is used to define habitat for the egg stage of crabs. The egg stage is discussed below along with the mature stage.

Larval Stage: Larvae are planktonic. Successful hatch of king and Tanner crab larvae is a function of temperature and concentration of diatoms so presence of larvae in the water column can vary accordingly. Larvae are minute forms and their sustained horizontal swimming is inconsequential compared to horizontal advection by oceanographic conditions. Larvae vertically migrate within the water column to feed. Diel vertical migration may be a retention mechanism to transport larvae inshore. Post-settlement juveniles feed on diatoms, protozoa, hydroids, crabs, and other benthic organisms.

Early Juvenile Stage: The early juvenile stage includes crabs first settling on the bottom (glacothoe and megalops), young of the year crabs, and crabs up to a size approximating age two. Habitat relief is obligatory for red and blue king crabs of this life stage. Individuals are typically less than 20 mm CL distributed in nearshore waters among niches provided by sea star arms, anemones, shell hash, rocks, and other bottom relief. Early juvenile Tanner crab settle on mud and are known to occur there during summer but are not easily found in this habitat in winter.

Late Juvenile Stage: The late juvenile stage for crab is defined as the size at about age two to the first size of functional maturity. Late juvenile crabs are typically found further offshore in cooler water than early juvenile crabs. Smaller red king crabs of this life stage form pods during day that break apart during the night when the crabs forage and molt. As these crabs increase in size, podding behavior declines and the animals are found to forage throughout the day.

Mature Stage: Mature crabs are defined as those crabs of a size that are functionally mature. Functional maturity is based on size observed in mating pairs of crabs. This maturity definition differs from morphometric maturity based on chela height and physiological maturity when sperm or eggs can be produced. The mature stage includes crabs from the first size of functional maturity to senescence.

Red king crab

Larvae: Red king crab larvae spend two to three months in pelagic larval stages before settling to the benthic life stage. Reverse diel migration and feeding patterns of larvae coincide with the distribution of food sources.

Early Juvenile: Crabs in their first one to two years of life generally occur at depths of less than 50 m on grounds characterized by cobble, rock, shell hash, and extensive epifaunal growth in the form of mussels, sponges, compound tunicates, and hydroids. Early juvenile stage red king crabs are solitary and need high relief habitat or coarse substrate such as boulders, cobble, shell hash, and living substrates such as bryozoans, stalked ascidians, sea stars, and urchins.

Late Juvenile: Late juvenile stage red king crabs of the ages of two and four years exhibit decreasing reliance on habitat and a tendency for the crab to form pods consisting of thousands of crabs. Podding generally continues until four years of age (about 6.5 cm), when the crab move to deeper water and join adults in the spring migration to shallow water for molting and mating.

Mature: Mature red king crabs exhibit seasonal migration to shallow waters for reproduction. The remainder of the year red king crabs are found in deep waters. In Bristol Bay, red king crabs mate when they enter shallower waters (<50 m), generally beginning in January and continuing through June. Males grasp females just prior to female molting, after which the eggs (43,000 to 500,000 eggs) are fertilized and extruded on the female's abdomen. The female red king crab carries the eggs for 11 months before they hatch, generally in April.

Blue king crab

Larvae: Blue king crab larvae spend three and a half to four months in pelagic larval stages before settling to the benthic life stage. Larvae are found in waters of depths between 40 to 60 m.

Early Juvenile: Early juvenile blue king crabs require refuge substrate characterized by gravel and cobble overlaid with shell hash, and sponge, hydroid and barnacle assemblages. These habitat areas have been found at 40-60 m around the Pribilof Islands.

Late Juvenile: Late juvenile blue king crab require nearshore rocky habitat with shell hash.

Mature: Mature blue king crabs occur most often between 45-75 m depth on mud-sand substrate adjacent to gravel rocky bottom. Female crabs are found in a habitat with a high percentage of shell hash. Mating occurs in mid-spring. Larger older females reproduce biennially while small females tend to reproduce annually. Fecundity of females range from 50,000 to 200,000 eggs per female. It has been suggested that spawning may depend on availability of nearshore rocky-cobble substrate for protection of females. Larger older crabs disperse farther offshore and are thought to migrate inshore for molting and mating.

Golden king crab

Larvae: Information on golden king crab larvae is not available.

Early Juvenile: Information on habitat of early juvenile golden king crabs is not available.

Late Juvenile: Late juvenile golden king crabs are found throughout the depth range of the species. Abundance of late juvenile crab increases with depth and these crab are most abundant at depths >548 m.

Mature: Mature golden king crabs occur at all depths within their distribution. Males tend to congregate in somewhat shallower waters than females, and this segregation appears to be maintained throughout the year. Legal male crabs are most abundant between 274 m and 639 m. Abundance of sub-legal male increases at depth >364 m. Female abundance is greatest at intermediate depths between 274 m and 364 m.

Scarlet king crab

Scarlet king crab are associated with steep rocky outcrops and narrow ledges. Strong currents are prevalent. Mature scarlet king crabs are caught incidentally in the golden king crab and *C. tanneri* fisheries. Information is not available to define habitat for eggs, larvae, or juvenile stages of scarlet king crab.

Tanner crab

Larvae: Larvae of *C. bairdi* Tanner crabs are typically found in BSAI water column from 0 – 100 m in early summer. They are strong swimmers and perform diel migrations in the water column (down at night). They usually stay near the depth of the chlorophyll maximum during the day. The last larval stage settles onto the bottom mud.

Early Juvenile: Early juvenile *C. bairdi* Tanner crabs occur at depths of 10 - 20 m in mud habitat in summer and are known to borough or associate with many types of cover. Early juvenile *C. bairdi* Tanner crabs are not easily found in winter.

Late Juvenile: The preferred habitat for late juvenile *C. bairdi* Tanner crabs is mud. Late juvenile Tanner crab migrate offshore of their early juvenile nursery habitat.

Mature: Mature *C. bairdi* Tanner crabs migrate inshore and mating is known to occur February through June. Mature female *C. bairdi* Tanner crabs have been observed in high density mating aggregations, or pods, consisting of hundreds of crabs per mound. These mounds may provide protection from predators and also attract males for mating. Mating need not occur every year, as female *C. bairdi* Tanner crabs can retain viable sperm in spermathecae up to two years or more. Females carry clutches of 50,000 to 400,000 eggs and nurture the embryos for one year after fertilization. Primiparous females may carry the fertilized eggs for as long as one and a half years. Brooding occurs in 100-150 m depths.

Snow crab

Larvae: Larvae of *C. opilio* snow crab are found in early summer and exhibit diel migration. The last of three larval stages settles onto bottom in nursery areas.

Early Juvenile: Shallow water areas of the eastern Bering Sea are considered nursery areas for *C. opilio* snow crabs and are confined to the mid-shelf area due to the thermal limits of early and late juvenile life stages.

Late Juvenile: A geographic cline in size of *C. opilio* snow crabs indicates a large number of morphometrically immature crabs occur in shallow waters less than 80 m.

Mature: Female *C. opilio* snow crabs are acknowledged to attain terminal molt status at maturity. Primiparous female snow crabs mate January through June and may exhibit longer egg development period and lower fecundity than multiperous female crabs. Multiparous female snow crabs are able to store spermatophores in seminal vesicles and fertilize subsequent egg clutches without mating. At least two clutches can be fertilized from stored spermatophores, but the frequency of this occurring in nature is not known. Females carry clutches of approximately 36,000 eggs and nurture the embryos for approximately one year after fertilization. However, fecundity may decrease up to 50 percent between the time of egg extrusion and hatching presumably due to predation, parasitism, abrasion or decay of unfertilized eggs. Brooding probably occurs in depths greater than 50 m. Changes in proportion of morphometrically mature crabs by CW have been related to an interaction between cohort size and depth.

Grooved Tanner crab

In the eastern North Pacific Ocean the grooved Tanner crab ranges from northern Mexico to Kamchatka. Little information is available on the biology of the grooved Tanner crab. This species occurs in deep water and not common at depth <300 m. Male and female crabs are found at similar depths. Male and female grooved Tanner crab generally reach maturity at 11.9 centimeters (cm) and 7.9 cm CW, respectively. Information is not available to define habitat for eggs, larvae, or juvenile stages for grooved Tanner crab.

Triangle Tanner crab

In the eastern North Pacific Ocean the distribution of triangle Tanner crab ranges from Oregon to the Sea of Okhotsk. This species occurs on the continental slope in waters >300 m and has been reported as deep as 2,974 m in the eastern Bering Sea. A survey limited in depth found mature male crabs inhabit depths around 647 m shallower than the mean depth of 748 m for female crabs. Size at 50 percent maturity for male triangle Tanner crabs is 9.1 cm CW and 5.8 cm for females.

3.3.1.2 Habitat types where crab fisheries occur

This section describes the habitat types where the BSAI crab fisheries occur. Maps on the distribution of the BSAI crab fisheries are in Section 3.4.6. In general, the majority of the crab fisheries occur on sandy and sand/silt bottom types in waters greater than100 feet deep.

Bristol Bay Red King Crab Fishery: Bristol Bay red king crab are considered a distinct genetic stock and are managed as a single unit. Area boundaries are established to accomplish this. Red king crabs are mostly taken in areas consisting of sandy and silty bottoms at depths of 20 to 80 fathoms (120 to 480 feet). This bottom is typically low relief, without marked features or steep slopes. Occasionally red king crab may be taken on shell hash, gravel, or cobble bottoms. They frequently feed on sand dollars, starfish, clams, scallops, and various marine worms in these areas. The commercial fishery tends to concentrate on mature stocks that have segregated themselves by size and sex. The fishery seasons avoids mating and molting periods, when males and females are found together.

Norton Sound Red King Crab Fishery: Norton Sound red king crabs are taken primarily in areas consisting of sandy and silty bottoms at depths of 25 fathoms or less.

Pribilof Islands Red and Blue King Crab Fishery: Red king crabs are taken in areas consisting of sandy and silty bottoms at depths of 15 to 60 fathoms (90 to 360 feet). Blue king crabs are generally taken in similar depths, but are more likely found on harder bottom, including cobble, gravel, and occasional rock ledges. Red and blue king crab in the Pribilof Islands are each considered to be a unique genetic stock.

St. Matthew Blue King Crab Fishery: Blue king crabs are taken at depths of 15 to 60 fathoms (90 to 360 feet) on hard bottom, including cobble, gravel, and occasional rock ledges nearshore, and softer bottom offshore. Blue king crab in the St. Matthew Island fishery are considered to be a unique genetic stock. The early life history of this blue king crab is expected to be similar to the Pribilof Islands blue king crab.

Aleutian Islands Red King Crab Fishery: Red king crabs are taken in areas of all sediment types at depths of 20 to 100 fathoms (120 to 600 feet).

Aleutian Islands Golden King Crab Fishery: Golden king crabs are taken in areas consisting of rough, uneven bottom and in compacted sand-cobble sediments at depths of 100 to 400 fathoms (600 to 2,400 feet). Fishery effort is concentrated at the entrances to passes between the islands, particularly in the eastern district. In the western district, the fishery occurs in steep rocky terrain, near passes between islands, and on moderately sloping mud/sand sediments in basins.

Aleutian Islands Tanner Crab Fishery: Tanner crabs are taken in areas of soft sediment types (silt and mud) at depths of 30 to 110 fathoms (180 to 660 feet).

Bering Sea Tanner Crab Fishery: Tanner crabs are taken in areas of soft sediment types (silt and mud) at depths of 30 to 110 fathoms (180 to 660 feet). Tanner crabs tend to inhabit the warmer waters of the Bering Sea where summer bottom temperatures exceed 4º C. These occur in western Bristol Bay, the Pribilof Islands, and along the shelf edge.

Bering Sea Snow Crab Fishery: Snow crabs are taken in areas of soft sediment types (silt and mud) at depths of 40 to 110 fathoms (240 to 660 feet). They are generally found in colder areas of the Bering Sea where summer bottom temperatures are less than 4º C. These areas occur in the mid-shelf region of the central portion of the eastern Bering Sea shelf. In areas of overlap with Tanner crab stocks, hybridization occurs.

3.3.1.3 Benthic species impacted by pot gear

Crab fishing impacts benthic species that live where the crab fisheries occur. These benthic species include fish, gastropods (snails), coral, echinoderms (stars and sea urchin), non-FMP crab, and other invertebrates (sponges, octopus, anemone, and jelly fish). The crab fisheries catch these species as bycatch and pot gear impacts these species in the setting a retrieval of the pots from the sea floor. The impacts of pot fishing are analyzed in Section 4.3.

Fish

Fish, including a number of crab predators, especially Pacific cod, halibut, yellowfin sole, and sculpin (*Myoxocephalus* spp.) account for the greatest proportion of estimated crab pot bycatch. These species are widely distributed and highly abundant representatives of the greater groundfish community. The Alaska Groundfish Fisheries Draft Programmatic SEIS contains a complete description of the life history, habitat, and stock status for these species (NMFS 2003b), and is incorporated by reference.

Corals

Corals are a diverse group of invertebrates within the phylum Cnidaria. Five major taxonomic groups of corals occur in Alaska waters (Cimberg et al. 1981): Gorgonacea ("hard corals," such as horny corals, sea fans, tree corals, and bamboo corals), Alcyonacea (soft corals), Scleractinia (cup corals or stony corals), Stylasterina (hydrocorals), and Antipatharia (black corals). Approximately 80 species of coral have been reported from Alaska waters (Wing and Barnard, in prep., A Field Guide to Alaskan Corals).

Coral is a living substrate that may serve as fish habitat for some species. The habitat formed by corals supports communities with high biodiversity and may provide shelter for fish (Risk et al. 1998; Fossa et al. 1999). Although scientists have a limited understanding of its importance as fish habitat, deep-water corals clearly provide vertical structure that fish use for protection and cover. Corals have been associated with some rockfish species in Alaska during submersible dives (Krieger and Wing 2000).

Hard corals belong to several diverse orders within the phylum Cnidaria (Barnes 1980). The horny, or fan corals, are members of the order Gorgonacea and comprise all of the corals (with the exception of the soft coral *Gersemia*) that have been identified on the NMFS southeast Bering Sea survey (http://www.afsc.noaa.gov/groundfish/HAPC/EBScontents.htm). Horny corals are rare near the edge of the southeast Bering Sea shelf and slope. In the majority of horny corals, growth resembles that of a plant, with a short main trunk fastened to the substrate and lateral branching stems that may be in the same plane. The living tissues are composed of polyps, each with a mouth surrounded by tentacles. Some species are composed of a single polyp while others are colonies of many polyps (Cimberg et al. 1981). Fertilized eggs develop within the female polyps into planula larvae. Planula larvae of most corals are not usually dispersed very far from parent colonies. In colonial species, asexual reproduction also occurs through budding of the primary polyp. Growth of most corals is slow and they may require over 100 years to reach maximum size (Cimberg et al. 1981). Horny corals are suspension feeders, taking their food from the water column. Coral predators include snails, fish, polychaetes, sea stars, and nudibranchs (Cimberg et al. 1981).

Some species of sea fans (such as *Muriceides*) have been reported from the Aleutian Islands and lower Bering Sea along the continental slope and in southeast Alaska. Sea fans were observed, but not identified, in southeast Alaska during submersible dives as part of NOAA's project Sub-Sea. These corals were found at depths of 10 to 2,000 m.

In Alaska, hard corals, particularly gorgonian corals of the genera *Paragorgia* spp and *Primnoa* spp. (red tree coral), may be especially valuable as fish habitat due to the longevity and large size of colonies (Witherell and Coon 2001). *Paragorgia arborea* (Kamchatka coral) is uncommon north of the Alaska Peninsula (Kessler 1985; Heifetz 2002), although recent submersible surveys indicate that it is common on the north sides of the central Aleutian Islands (Stone, R., NOAA Fisheries, Auke Bay Laboratory, personal communication). This species ranges from the BSAI to California in depths from 30 to 2,000 m. Kamchatka coral forms large branched colonies (up to 2 m in height). *Primnoa willeyi*, or red tree coral, is rare north of the Alaska Peninsula, but is common in the GOA (Cimberg et al. 1981; Kessler 1985; Heifetz 2002). Red tree coral has been reported from depths of 10 to 800 m and is likely found in greatest abundance between 50 and 250 m. The colonies may survive more than 100 years (Andrews et al. 2002; Risk et al. 2002). Red tree coral colonies may reach 3 m high and 7 m wide.

Fishermen have reported bamboo corals (*Lepsedisis* and *Keratoisis*) from the inside passages of southeast Alaska and in the southeast GOA. These corals have not been reported from the northern portion of the Bering Sea (above 58º N), or from the Chukchi or Beaufort Seas. Bamboo corals have the deepest distribution (300 to 3,500 m) of the Alaska corals. Their northern distribution in the Bering Sea and occurrence in deep waters indicate that these corals can live at temperatures less than 3º C. Their distribution also suggests that these corals have a low tolerance for sediments.

Soft corals (*Alcyonacea*) have the widest geographic range of all Alaska corals and have been reported from the GOA to the Beaufort Sea. These corals are found on cobble and larger substrates, from 10 to 800 m, in areas where temperatures range from -1º C to above 9º C. This species has the widest distributional range, temperature range, and substrate preference of all Alaska corals.

Cup corals (*Balanophyllia* and *Caryophyllia*) differ in geographic range and habitat. *Balanophyllia* has only been reported from southeast Alaska, whereas *Caryophyllia* has been reported from southeast Alaska and Prince William Sound. Neither has been reported in the Bering, Chukchi, or Beaufort Seas. Cup corals are predicted to occur in additional regions of the GOA and southeast Alaska, from 0 to 12 m for *Balanophyllia* and from 12 to 400 m for *Caryophyllia*. Since these corals do not appear to tolerate temperatures below 4.5º C, their distribution west of Kodiak Island should be infrequent. Cup corals are not expected to occur in the Bering Sea beyond the Aleutian Islands or in the Chukchi or Beaufort Seas.

Hydrocorals (*Stylasterina*) commonly occur on cobble and larger rocky substrates. Their distribution in the Aleutian Islands suggest that hydrocorals can tolerate temperatures less than 3º C. They can, therefore, be expected to occur in additional regions of the GOA as well as the Aleutian Islands.

Black corals (*Antipatharia*) are found at depths of 400 m and deeper, typically ranging from 500 to 1,000 m deep. They have been reported throughout the GOA and extending out the Aleutian Island chain (Wing, B., June 5, 2003, personal communication).

Sponges

Some information in the paragraph below is adapted from http://www.afsc.noaa.gov/groundfish/HAPC/EBScontents.htm. Sponges (*Phylum Porifera*) are multicellular organisms containing a system of chambers and passageways that allows water to circulate constantly through the body. In many species, body size and shape can vary highly and are strongly influenced by currents and other environmental parameters (Bell and Barnes 2000; Bell et al. 2002). Many sponges have a skeleton consisting of calcium carbonate, silicon dioxide, collagen fibers, or a combination of these substances (Barnes 1980). Sponges reproduce both sexually and asexually. During sexual reproduction, a parenchymella larva develops and swims freely for a short time before settling to the substrate (O'Clair and O'Clair 1998). Sponges are suspension feeders, creating currents that draw in plankton and organic detritus from the water column.

Four species commonly occur in the southeast Bering Sea. *Halichondria panicea*, or barrel sponge, is common north of the Alaska Peninsula. The barrel sponge is a large, thick-walled colony that is highly variable in shape, but may reach a maximum height of 30 cm (Kessler 1985). *Aphrocallistes vastus* is an upright sponge commonly captured during Bering Sea trawl surveys (Malecha et al. unpublished), which grows to 30 cm in height (Kessler 1985). The hermit sponge, *Suberites ficus*, is a small (less than 15 cm) sponge that is common north of the Alaska Peninsula. This sponge species grows over snail shells, which it eventually dissolves, and thus is not attached to any substrate. The shell/sponge is utilized by a hermit crab, hence its common name (Kessler 1985). The tree sponge, *Mycale loveni*, is also common north of the Alaska Peninsula. The tree sponge forms a hard, tree-like skeleton surrounded by soft sponge and attains a maximum height of 25 cm (Kessler 1985). The distribution of sponges off Alaska is described by Malecha et al. (unpublished). Sponges are patchily distributed across the Bering Sea shelf, with low catches relative to other Alaska waters, although high catches are observed near St. George Island (Malecha et al. unpublished). In the western Bering Sea, a diverse assemblage of sponges, bryozoans, and hydroids are prime habitat for young of the year red king crab, *Paralithodes camtschaticus* (Tsalkina 1969). Sponges are most commonly associated with rockfish and Atka mackerel in NMFS trawl survey data from Alaska (Malecha et al. unpublished).

Bryozoans

Information in the paragraphs below is adapted from http://www.afsc.noaa.gov/groundfish/HAPC/EBScontents.htm. Bryozoans are small colonial animals that are common on hard substrates in the southeast Bering Sea. They can easily be confused with hydroids and corals. Each individual (called a zooid) in a bryozoan colony is interconnected. Some species produce a non-feeding larva with a brief, free-swimming period, while some larva persist for several months (Barnes 1980). Only the largest, most conspicuous species have been identified from the NMFS southeast Bering Sea trawl survey, although none are routinely identified. About 90 species of bryozoans have been identified in the southeast Bering Sea, but intensive collecting might double that number. Roughly two-thirds of the area's known species are low-profile encrusting forms. Rock, live and dead bivalve and gastropod shells, and crab shells are common substrates for attachment. Age and growth rates of bryozoans vary, but many species in the southeast Bering Sea probably mature in one to three years.

In lower Cook Inlet, Alaska, the bryozoans *Flustrella* sp. and *Dendrobeania* spp. were associated with the largest catches of juvenile red king crab (*Paralithodes camtschatica*) (Sundberg and Clausen 1977). Bryozoans were a common component of young of the year red king crab habitat on the west Kamchatka Shelf (Tsalkina 1969), and they were the substrate of choice in laboratory experiments with young of the year and two to three year old red king crab (Babcock et al. 1988).

Other sessile epifuana

Other sessile epifuana include hydroids, sea raspberries, sea pens, anemones, sea onions, and sea peaches. Information on these species is adapted from the AFSC website (http://www.afsc.noaa.gov/groundfish/HAPC/EBScontents.htm).

Hydroids are small, mostly colonial, cnidarians in the class Hydrozoa. Approximately 200 species have been identified in Alaska (O'Clair and O'Clair 1998). Many species encountered on the NMFS trawl survey have yet to be identified. Most species are erect and tree-like, while others are prostrate encrustations on mollusk shells, rock, and other hard surfaces. The erect species generally grow no taller than 15 cm. Some hydroids have alternating benthic and pelagic generations. The pelagic medusae are jellyfish (sizes range from less than 3 mm to more than 250 mm in diameter). Reproduction in the group is varied and complex, with many species having a free-swimming planula larva that spends hours to days in the water column before settling to the bottom (Barnes 1980).

On the west Kamchatka Shelf, a rich assemblage dominated by hydroids, bryozoans, and sponges was the favored habitat of young of the year red king crab (*Paralithodes camtschaticus*), and hydroids were considered to be their main food. On stations where young crab were caught, hydroids averaged more than 50 percent of the total biomass (Tsalkina 1969). Such strong linkage is not suspected in the southeast Bering Sea, although hydroids are part of the sessile invertebrate communities where young of the year red king crab occur (McMurray et al. 1984, Stevens and MacIntosh 1991). In the southeast Bering Sea, the hermit crab *Labidochirus splendescens* (splendid hermit) is typically found in a moon snail shell encrusted with the velvet textured hydroid *Hydractinia* sp. (Kessler 1985).

Sea raspberries, *Gersemia* sp., is a colonial soft coral in the class Anthozoa, which also includes the sea anemones, sea pens, and other corals. Soft corals of this genus are found worldwide from the Arctic to the Antarctic. Two species of sea raspberries are found in the southeast Bering Sea: *Gersemia rubiformis* and *G. fruticosa*. These species are distributed in the north Atlantic and in the Pacific from the Bering Sea south to California (Koltun 1955, Gotshall 1994). Within Alaska, *Gersemia* sp. has the widest distributional, temperature, and substrate preference range of all Alaska corals (Cimberg et al. 1981). Kessler (1985) reports it common north of the Alaska Peninsula. When inflated, groups of small polyps form thick, soft, red lobes in colonies that can reach a height of about 25 cm (Koltun 1955). When contracted, the colony has a brain-like appearance and is considerably smaller. Colonies are found attached to stones or shells. *Gersemia* is thought to be a plankton feeder (O'Clair and O'Clair 1998).

Sea whips and sea pens (order Pennatulacea) are colonial octocorals supported by internal skeletal structures and adapted to living as sedentary animals partially buried in fine sediments on the sea floor (Barnes 1980). Spawning may be annual (seasonal) or continual (Eckelbarger et al. 1998). Gametes are released into the water column, where fertilization occurs. Planula larvae settle to the bottom after about seven days if favorable substratum is available (Chia and Crawford 1973). In Puget Sound, the sea pen, *Ptilosarcus gurneyi,* is preyed upon by starfish and nudibranchs (Birkeland 1974). Stands of sea whips provide shelter and food for Pacific ocean perch, *Sebastes alutus* (Brodeur 2001). The family Halipteridae has near-cosmopolitan distribution and occurs from 36 to 1,950 m deep (Williams 1999).

One species of sea whip, *Halipteris willemoesi*, has a patchy distribution in the southeast Bering Sea, but is commonly found on the outer shelf in the NMFS southeast Bering Sea trawl survey (Malecha et al. unpublished). A single sea whip is a colony of animals. The base of the colony, or peduncle, anchors the colony to the sea floor by means of peristaltic contractions and hydrostatic pressure. The exposed portion of the colony can reach 2.5 m in height and supports fleshy secondary polyps that cover the hard shaft, or axial rod. Feeding polyps capture small animals. Fish eggs were present in one eastern Bering Sea specimen. Examination of the axial rod reveals more than 100 growth rings that may be annuli. Definitive aging is currently underway.

Sea anemones are members of the Cnidarian order Actiniaria. They attach to hard substrates, including rock and shell. Sea anemones are solitary animals, but they can form dense concentrations. *Metridium* sp. reproduces sexually and eggs are fertilized in the water column, producing planula larvae that eventually settle on suitable substrate. This species also reproduces asexually by splitting into two pieces in a process called pedal laceration (Wahl 1985). The anemone *Urticina crassicornis* is reported to live at least 60 to 80 years (O'Clair and O'Clair 1998). Some members of the genus *Metridium* reach a height of 51 cm or more (Barr and Barr 1983), but most southeast Bering Sea anemones are less than 10 cm in height. *Metridium senile* is capable of restricted locomotion and may also reattach itself after it is detached from the substrate (Wahl 1985). *Metridium* sp. is a suspension feeder, its tentacles selectively trapping zooplankton, eggs, and detritus (O'Clair and O'Clair 1998). Anemones are preyed upon by nudibranchs and sea stars (O'Clair and O'Clair 1998).

Ascidians include members of the genus *Boltenia* (sea onions), *Styela* (sea potato), and *Halocynthia* (sea peach). Two species of *Boltenia* are commonly found in Alaska waters. *Boltenia ovifera*, a stalked, solitary ascidian, is widely distributed in the north Atlantic and north Pacific, including Alaska (Malecha et al. unpublished). *Boltenia ovifera* is locally abundant north of the Alaska Peninsula (Kessler 1985). This species is found in the Okhotsk and Bering Seas, mainly at depths of 25 to 100 m, usually together with sponges and hydroids (Ushakov 1955). Sexual reproduction results in the formation of a tadpole larva that is free-swimming for only hours before it settles on a hard substrate and begins its metamorphosis to the adult form. In the Bay of Fundy, the tadpole larvae appeared in the plankton in January and February, far preceding the appearance of any other plankton (Lacalli 1981). The adult sea onion has a white or pinkish bulb-like body that floats in the water column and is tethered to the bottom by a stalk that terminates in a root-like holdfast or hapteron. The stalk is usually two to three times the length of the bulbous body, with the entire animal reaching 30 cm or more in length (Kessler 1985). Compound ascidians like *Molgula* sp, bryozoans, and hydroids are frequently attached to the stems and holdfasts of sea onions. Sea onions and associated attached invertebrates are known to provide habitat to small juvenile red king crab (*Paralithodes camtschaticus*) (McMurray et al. 1984, Stevens and Kittaka 1998).

Sea potatoes, *Styela rustica*, grow in clumps and are permanently attached to snail or clam shells, or to other invertebrates such as mussels. They are abundant north of the Alaska Peninsula and are relatively common in the 40 to 100 m depth range. The sea potato is so named due to its dark brown coloration and potato-shaped body, which can reach a maximum size of 10 cm (Kessler 1985).

The sea peach, *Halocynthia aurantium*, occurs from the Arctic, throughout the Bering Sea, and south to Puget Sound (Ushakov 1955, Gotshall 1994). The sea peach is common north of the Alaska Peninsula (Kessler 1985). It is most common in depths of 40 to 100 m in the southeast Bering, northeast Bering, and southeast Chukchi Seas (Jewett and Feder 1981). The sea peach has a barrel-shaped body that is directly attached to the substrate. The red-to-orange outer covering is smooth or wrinkled and has two large siphons on top. It grows up to 18 cm (Kessler 1985). This large, solitary ascidian is often found in groups (Ushakov 1955). In the western Bering Sea, *Halocynthia* is preyed upon by the crabs *Chionoecetes opilio* and *C. bairdi* (Ivanov 1993). It is also preyed upon by the sea star *Evasterias troschelii* (Barr and Barr 1983).

Octopi

Octopi are members of the molluscan class Cephalopoda, along with squid, cuttlefish, and nautiloids. In the BSAI and GOA, the most commonly encountered octopods are the shelf demersal species *Enteroctopus dofleini*, and the bathypelagic species *Vampyroteuthis infernalis*. Octopods, like other cephalopods, are dioeceous, with fertilization of eggs requiring transfer of spermatophores during copulation. Octopods usually do not live longer than two to four years. *E. dofleini*, the giant octopus, is distributed in the southern boreal region from Japan and Korea, through the Aleutian Islands, GOA, and south along the Pacific coast of North America to California. This species inhabits the sublittoral to upper slope regions. Mating for this species likely occurs in late fall and winter, but oviposition occurs the following spring. *V. infernalis* lives at depths well below the thermocline and is most commonly found at 700 to 1,500 m depth. This species is found throughout the oceans of the world. Little is known of their food habits, longevity, or abundance.

3.3.2 Physical environment in vicinity of crab processors

Alaskan crab processing occurs primarily in the Pribilof Islands, Norton Sound, Unalaska Bay, Akutan Harbor, Kodiak, King Cove, and at-sea in the Bering Sea and GOA. This section provides a brief description of the location and environment and the crab processor discharges for each crab processing community.

The discharge of waste products and the potential effect of that discharge on water quality, benthic habitat, and marine life is the major environmental concern connected with seafood processing. Crab is such a high-value and low-volume product; however, that a small amount of shell and other waste solids is discharged in comparison with other seafoods (notably, pollock, cod, and salmon). Furthermore, the majority of the crab processing is conducted so as to either recover the waste solids as secondary byproduct that is commingled with pollock offal in the shore-based production of fishmeal, or to discharge the waste solids from vessels underway offshore in deep water. In the early 1990's, water quality plans were developed by the Environmental Protection Agency (EPA) for seafood processing plants in Unalaska Bay and other harbors.

Location and oceanography

A brief description of the environment around the major crab processing plants, emphasizing factors relevant to water quality issues is provided for each community below. For a more thorough discussion of the physical environment of the BSAI, refer to the Alaska Groundfish Fisheries Draft Programmatic SEIS (NMFS 2003b). Coastal and insular Alaska is characterized by a maritime climate and is well-known for adverse, often extreme weather conditions. Normal summer air temperatures range from 50 to 60°F, while winter temperatures range from 25 to 35°F. Low-lying fog, overcast skies, rain, and drizzle are prevalent. Average annual precipitation, including snow precipitation, ranges from 30 to 60 inches. Low cloud cover is common, as is windy weather. Winds in winter and during storms are usually strong throughout the eastern Aleutian Islands.

Water quality issues

Sources of pollution. Crab processor discharges affect water quality in these waterbodies in two ways: mass loadings of biochemical oxygen demand (BOD) and accumulations of processing wastes, consisting of total settleable solids (TSS). BOD loading leads to reduced dissolved oxygen concentrations as the wastes decompose. Reductions in dissolved oxygen may negatively affect aquatic life, particularly benthic fish and invertebrates that require specific concentrations of dissolved oxygen. However, this is most often a problem in environments that have minimal circulation and mixing. Accumulations of processing wastes physically alter habitat and may bury or smother benthic epifauna and infauna. Depending on their size, particulates may settle rapidly or remain suspended for extended periods of time.

Crab processing, unless circulation is poor, entails only a nominal problem with consumption of dissolved oxygen. However, discharge of wastes from crab processing can result in the accumulation of settleable solids in the area around outfalls.

Crab processor discharges. Historic waste piles consist of a combination of crab and finfish. In 1985, the bulk of the waste came from crab processing, but most wastage since the mid-1980's has come from pollock production.

Across the State, there are an estimated ten acres of currently discharged crab waste on the ocean floor. Royal Aleutian Seafoods-Unalaska Bay, Westward Seafoods-Captains Bay, Peter PanSeafoods-King Cove, and Trident-Akutan each have about an acre of waste primarily from crab processing, and the other six acres are accounted for by the other onshore processors and at-sea processors. About 15 additional acres of historical crab processing waste piles are no longer receiving new deposits and are decomposing. In general, they are largely composed of hard, semi-aggregated material comparable to windrows of broken shells.

Crab processors handle their wastes in different ways. Some processors have reduction plants where crab and fish waste is commingled and turned into fishmeal. Others discharge their wastes at the end of outfall pipes in accordance with their permits.

The EPA has not been able to evaluate the deep-water crab discharge from at-sea processors but believes for the most part that the scattered discharge is assimilated by the ocean within months if not weeks of discharge.

Pollution control strategy. The basic approach taken to water quality problems caused by seafood processing in the area focuses on the National Pollutant Discharge Elimination System (NPDES) permits for the shore-based seafood processing facilities. In Alaska, NPDES permit program is administered by the EPA. These permits involve effluent, or end-of-pipe, limitations for Alaska seafood processors, which have changed since the issuance of the first permits in 1975.

In the late 1970's, the EPA required seafood processors to relocate their outfalls from Iliuliuk Harbor, Iliuliuk Bay, and Dutch Harbor to south Unalaska Bay and to Iliuliuk Bay outside of the Dutch Harbor spit and Iliuliuk-Dutch Harbor sill. Effluents derived primarily from crab processing were redirected to receiving waters having year-round circulation throughout the water column, at considerable expense to the industry.

With the development of the pollock fisheries, NPDES permits were issued in 1991 and 1996 to require one mm screening of fish wastes and reduction of those wastes to fish meal. This represented a significant reduction in the amount of solids discharged from these facilities. The 1991 NPDES permits also provided technology-based effluent limitations for finfish and fish meal processing in greater Unalaska Bay, and required annual surveys of dissolved oxygen and waste piles in the receiving water. The EPA required that the permitted facilities would either conduct or contribute support to a circulation study of greater Unalaska Bay. The resulting “Circulation study of Unalaska Bay and contiguous inshore marine waters” (CH2M-Hill 1994) in turn aided in the EPA water quality assessment and determination of total maximum daily wasteload allocations. These permits expired in May 2001 and are in the process of being reissued. In some cases, the NPDES permits have been supplemented with Total Maximum Daily Load (TMDL) plans and explicit limits of the wasteloads of BOD and settleable solid waste residues. A TMDL identifies levels of pollution control needed to achieve water quality standards. The TMDL needs to consider all sources, point, nonpoint, and background, in determining the loading capacity of a waterbody. The plan identifies preventative and remedial actions which will reduce pollutant loads to water quality-limited waterbodies.

Unalaska Bay

Greater Unalaska Bay, on the north side of Unalaska Island, is the foremost safe harbor and anchorage in the eastern Aleutian Islands and shelters both fishing and cargo vessels. Greater Unalaska Bay lies at roughly 54°N and 166.5°W. It is about 790 air miles southwest of Anchorage, and supports a national airport along its limited coastal bench. The bay is approximately 87 square nautical miles in area and has roughly 50 nautical miles of shoreline. It provides shelter and food for juvenile life stages of many fish and invertebrate species, such as king crab, cod, and salmon. The bay is also a protected setting which supports the most productive commercial seafood port in the U.S., as well as sport and subsistence fishing.

The topography of its complex shoreline and islands divides greater Unalaska Bay into a number of continuous bodies of water. These consist of smaller bays or fjords, which are deep and steep-sided, with shallow sills (i.e., elevations in the seafloor) across their entrances. The bay's topography includes five such sills and four water basins. Circulation in these basins is seasonally restricted due to a stratified water column and the absence of appreciable currents in the bottom layer. These deep basins may act as traps for settleable solids and nutrients and may experience seasonal oxygen depletion. Iliuliuk Bay and Dutch Harbor constitute a single basin within the bay, bordered by a sill extending from the Dutch Harbor spit east to Unalaska Island on its north side and by the convergence of Amaknak Island and Unalaska Island and the shallower Iliuliuk Harbor to the south. Captains Bay is a deep indentation in the southern shore of the bay.

Within Unalaska Bay, water temperatures range from 3 to 10°C near the surface and from 3 to 7°C near the seafloor. Vertical gradients of temperature and salinity which cause stratification of marine and estuarine waters are strongly seasonal, forming in May and June and becoming more pronounced in July through middle to late September.

Tides in Unalaska Bay are relatively small; the mean tidal amplitude is approximately 1 m, and the maximum tidal amplitude is about 3 m. A circulation study of greater Unalaska Bay (CH2M-Hill 1994) indicated that more than 90 percent of the water circulation within the bay is driven by winds; tides are only a secondary factor. This results in strongly seasonal currents which change direction from summer to winter in many sections of the bay. The study suggests that the flushing time required for 95 percent of the water at a given location in the bay to be replaced by ocean water from outside of the bay ranges from 20 days in central Unalaska Bay to 70 days at the head of Captains Bay.

The deeper sections of Captains Bay and Iliuliuk Bay–Dutch Harbor are the exceptions to these generalizations on flushing time. Captains Bay has a deep 113 m basin below a 29 m deep sill, which is only flushed intermittently during strong, persistent winds or storms from the north. Similar processes renew Iliuliuk Bay-Dutch Harbor. In the deep water basins below such sills water is replaced intermittently throughout the year when very specific combinations of wind, air temperature and hydrography occur; residence times in these deep basins may last as long as six months.

Three large freshwater streams enter greater Unalaska Bay: the Makushin River of Broad Bay, the Shaishnikof River at the head of Captains Bay, and Iliuliuk Creek which drains Unalaska Lake east of Iliuliuk Harbor. All three streams are utilized by salmon for spawning. At least five other streams flow into Unalaska Bay year-round, and more than thirty other streams seasonally flow into the bay.

Four shore-based seafood processing plants are located within greater Unalaska Bay, including UniSea, Alyeska Seafoods, Royal Aleutian Seafoods, and Westward Seafoods. In addition, several vessels may anchor in northwest Unalaska Bay for processing crab. The primary species processed at these facilities are pollock and crab; cod, salmon, halibut, and herring are also processed to a lesser degree.

Crab processing discharges. Of the four shore-based seafood processors in Unalaska, the largest processor of crabs is Westward Seafoods, whose peak daily crab production is 555,000 lbs. for snow crabs, or 700,000 lbs. for king crabs. Crab recovery rate is approximately 65 percent; 30–40 percent of the crab waste is made into fishmeal. The remaining crab waste is ground up and discharged into the bay. No crab waste gets barged out of the bay; only stick water is barged to an offshore area (Personal communication August 1, 2002, Ken Dorris, Westward plant manager, to Rance Morrison, NOAA Fisheries fisheries biologist). Westward is located in Captains Bay, a semi-enclosed waterbody with a sill that rises from the bottom to 36 feet below the surface. The discharged waste is sent through an outfall pipe to an 85 foot depth. Westward is the only processor with authorization to deposit wastes across a two-acre area. This area has the most constrained circulation of any seafloor area used for waste deposit in Alaska. The offal solids are discharged below the level of the sill and settle on the bottom to rot. The decomposing waste matter competes with living organisms for limited oxygen in the deep water, which is replenished very slowly (the water column turns over about twice a year). By contrast, South Unalaska Bay's circulation pattern frequently replenishes the oxygen supply (Section 3.3.6.2).

Royal Aleutian Seafoods can process approximately 350,000 lbs. of snow crabs per day but the plant has done as much as 450,000 lbs. in one day. Such high production can only occur under ideal conditions, with uniform size, high quality crabs and loads large enough to extend the offload over an entire 24-hour period. When processing king crabs, the capacity of this facility is approximately 250,000 lbs. per day. Smaller production levels when processing king crabs is due to a reduced processing crew on staff during the short king crab season. The plant has no meal production, so 100 percent of the crab waste is ground to <1/4 inches and discharged into the bay. Royal Aleutians is not required by the EPA to screen, but the plant is limited to a total annual discharge of 10,800,000 lbs. of settleable solid seafood processing waste residues. It has a one-acre deposit zone, and estimates that it uses about 60 percent of that area (Pers. comm, Aug. 1, 2002, Gary Loncon of Royal Aleutian Seafoods to Rance Morrison, NOAA Fisheries).

Alyeska Seafood's peak crab production is 200,000 lbs. for snow crabs, or 300,000 lbs. for king crabs. All crab waste goes into a reduction plant where it is turned into fishmeal. UniSea can produce between 100,000 and 200,000 lbs. a day for snow crabs and 200,000-300,000 lbs. a day for king crabs. All of its crab waste goes to fishmeal (Personal communication August 1, 2002. Al Mendoza and Don Graves of Alyeska Seafoods to Rance Morrison, NOAA Fisheries).

Icicle seafood owns two floating processors which process crab in the area. The BERING STAR processes snow crab in season with a daily processing capacity of 125,000 pounds live weight. The ARCTIC STAR processes red king crab in season and has a daily processing capacity of 250, 000 pounds live weight. The two floaters operate under the general NPDES permit. The waste in ground and discharged at an appropriate site, The most recent survey showed an accumulation of waste covering 0.23 acre to a maximum depth of 2-3 inches (Public comment from John Garner, North Pacific Crab Association, complete public comment contained in Chapter 8.).

Akutan Harbor

Akutan Harbor is on the east side of Akutan Island in the Fox Islands group of the eastern Aleutian Islands. It lies at roughly 54.1°N, 165.5°W. The harbor is a glacially-formed fjord with an area of approximately 4.5

square miles, or 3,800 acres. The head of the fjord is a flat valley with a gradually increasing slope as it curves around to a high ridge to the northeast. It is about 710 miles southwest of Anchorage.

The waters of Akutan Harbor transition from estuarine at its head to marine at its mouth. Salinities are generally typical of coastal Alaskan waters except at the surface of the head of the harbor. The harbor waters are predominantly unstratified throughout most of the year, but becomes progressively stratified from May through early September and then rapidly returns to an unstratified condition in October.

Tidal currents are weak and drive a relatively minor portion, less than 10 percent, of the harbor's hydrodynamics. Intermittent winds are the primary forces generating currents in Akutan Harbor. These winds vary in both direction and velocity. Circulation and current velocities decrease and turnover or replacement time increases from the outer to the inner harbor.

The subsurface topography is relatively simple. The submarine slopes along the sides of the harbor are steep, with water depths of 60 feet reached within 480 feet from shore. The seafloor is relatively flat, gradually deepening from 88 feet at the head of the harbor to 200 feet at its mouth. The harbor has a slight sill at its mouth which rises approximately 20 feet above the outer harbor basin before descending to depths of greater than 300 feet. As a depositional basin, the seafloor is predominantly a silty habitat which has an increasing component of sand, gravel, and rocks near shore.

Several small streams discharge freshwater to Akutan Harbor. Three streams are known to support runs of anadromous salmonids: two at the head of the harbor and one along its southeast margin. A number of streams on the northern slopes of the fjord are impounded and/or diverted for domestic use and seafood processing.

Trident Seafoods owns and operates the Trident-Akutan processing plant, a large facility which houses pollock fillet and surimi and crab processing lines, a meal reduction facility, product warehouses, residential buildings, a tank farm, and docks (EPA 2001). Trident Seafoods also anchors and operates a fish processing vessel (P/V Arctic Enterprise) and a meal reduction motorized barge (M/B Arctic V), in the outer harbor.

Crab processing discharges. The Trident Seafoods plant in Akutan harbor is capable of processing approximately 250,000 lbs. of snow crabs or 300,000 lbs. of king crabs a day. It's effluent screening treatment was installed in the early 1990's in order to capture crab offal and finfish waste for reduction to meal; thereby, both producing a marketable byproduct and affecting the amount of dissolved oxygen, suspended solids, settleable solid seafood residues, and floating process residues in Akutan Harbor. The screen system was upgraded to a finer mesh in the mid-1990's. This treatment system commingles most crab and fish waste and reduces it to fishmeal. However, a special provision in their permit allows the plant to discharge small amounts of ground crab wastes directly through its outfall pipe. Trident has contracted with vessels for the conveyance and at-sea disposal of stickwater, surimi wastewater, and crab wastes in order to meet its effluent limits during high-volume summer fisheries. Circulation studies of Akutan Harbor (Jones and Stokes 1992; EPA 1993) indicate that Trident Seafood's onshore plant discharges through its bottom outfall into very low current speeds (annual average current velocity ~1 cm/s).

King Cove

King Cove is adjacent to the City of King Cove, in the Aleutians East Borough near the west tip of the Alaska Peninsula, at about 55°N, 162.19°W. King Cove is approximately 1.5 square miles in area.

A large, shallow lagoon lake drains into the cove and receives tidal exchanges from the cove. The watershed includes the small community of the City of King Cove, the Peter Pan Seafoods processing facility, a commercial and recreational boat harbor, and several large tributary streams.

The Peter Pan Seafoods facility in King Cove is the only shore-based seafood processor in King Cove. It houses finfish processing lines, a cannery and a meal reduction facility, and a small crab processing house on a dock over the water.

Crab processing discharges. Currently, Peter Pan Seafoods converts all waste to fish meal. In the past, crab waste was discharged directly through a pipe into King Cove. King Cove was identified in the 1998 ADEC list of water quality-limited water bodies, due to its exceeding settleable solid residues from seafood processing. The Alaska Water Quality Standards state that residues in marine waters "May not...cause a sludge, solid, or emulsion to be deposited beneath or upon the surface of the water, within the water column, on the bottom, or upon adjoining shorelines" (AAC Sec. 18.70.020[b][2]). Peter Pan had created a waste pile deposit of settleable solid residues measuring 11 acres in area and averaging three feet thick in King Cove (Enviro-Tech Diving 1998). This wastepile exceeded the standard for residues.

By way of mitigation, Peter Pan Seafoods proposed dispersing a large portion of the existing waste pile, which included some crab waste, by having a bottom dredge pulled through the processing residues to break them up during outgoing tides in the spring and/or fall seasons. The plant received approval to conduct this operation during the winter months to optimize dispersal and did it in a two-year period, from 1998-1999. The 11-acre wastepile is reported to have been reduced to an acre of accretion of crab and bony fish skeleton.

Pribilof Islands

The Pribilof Islands are a group of volcanic islands located in the northwest portion of the southeastern Bering Sea shelf near the 100 m isobath. The islands are treeless and covered with grasses, dwarf willows, lichens, mosses, and numerous varieties of flowering plants. There are no natural harbors on the islands and only a few freshwater streams on St. George (EPA 1998a).

The southeastern Bering Sea is covered by a broad, shallow shelf, with the shelf break located in approximately 170 m of water. Significant seasonal variation in water temperature and density structure occur, influenced by the seasonal advance and retreat of ice cover in winter and spring.

Shore-based facilities are located in St. Paul and St. George; additionally, floating processors anchor in near-shore seas where they find some shelter from the strong winds and rough seas. Crab processing accounts for up to 90-99 percent of the annual processing activity (raw product weight) and 99 percent of the annual discharge (by weight) in the Pribilof Islands area. Activity is concentrated in the first three months of the year, with lower activity during a few days in September and November/December.

Crab processing discharges. The processors at St. Paul and St. George discharge their seafood processing waste directly through the outfall pipes. The Pribilofs have extremely strong wind-driven and tidal currents which disperse waste quickly. A series of dive surveys have shown no accumulation at any location (Enviro-Tech Diving, Inc. series of reports from 1995-1997). In its environmental assessment for a general NPDES permit for seafood processors in the Pribilofs (EPA 1998a), the EPA concluded, "Because of the dispersive nature of the receiving environment, seafood wastes are not accumulating, sediment character and infaunal community in the vicinity of the outfalls are similar to appropriate reference areas, and water quality is not significantly affected."

Kodiak Island

Kodiak Island is located in the GOA approximately 225 air miles southwest of Anchorage and approximately 550 miles northeast of Dutch Harbor. The City of Kodiak has three fish processing companies that currently purchase king and snow crabs from the Bering Sea: Ocean Beauty Seafoods, Alaska Fresh Seafoods, and Alaska Pacific Seafoods. Processing of crabs from the Bering Sea at Kodiak normally takes place at the conclusion of the season, when vessels that home port in Kodiak transport their final load of crabs to processors in Kodiak. The processors in Kodiak provide price incentives which make delivering crabs from the Bering Sea to Kodiak economically viable.

Crab processing discharges. Since 1986, all seafood processing facilities in Kodiak have been required to treat seafood processing wastes by screening the effluent, to recover the waste solids, and then sending the waste solids to byproduct reduction facilities. Therefore, all three processing plants in Kodiak which purchase king and snow crabs from the Bering Sea fisheries reduce 100 percent of their crab waste to fishmeal. Of the three processors, Ocean Beauty Seafoods is the largest, with a daily processing capacity of 180,000 lbs. for king and 150,000 lbs. for snow crabs (Personal communication August 22, 2002, Rance Morrison, NOAA Fisheries). Alaska Fresh Seafoods (Personal communication August 22, 2002, Dave Woodriff of Ocean Beauty Seafoods to Rance Morrison, NOAA Fisheries) is second in size with a daily crab production capacity of 150,000 lbs. for king and 70,000 lbs. for snow crabs. Alaska Pacific Seafoods is capable of processing 120,000 lbs. of king and 70,000 lbs. of snow crabs (Personal communication August 22, 2002, Jim Major of Alaska Pacific Seafoods to Rance Morrison, NOAA Fisheries).

3.3.3 Endangered species act listed species present in action area

Twenty-four species occurring in the BSAI crab management area are currently listed as endangered or threatened under the Endangered Species Act (ESA) (Table 3.3-1). The group includes seven great whales, one pinniped, twelve Pacific salmon, two seabirds, one albatross, and one sea turtle. This section describes these listed species because they occur in the action area and therefore may be affected by the proposed action. The purpose of this section is to establish context to evaluate the effects of the proposed action on these species.

Table 3.3–1 Species currently listed as endangered or threatened under the Endangered Species Act and occurring in the Bering Sea or Aleutian Islands crab management areas.

Common Name	Scientific Name	ESA Status
Northern Right Whale	*Balaena glacialis*	Endangered
Bowhead Whale[1]	*Balaena mysticetus*	Endangered
Sei Whale	*Balaenoptera borealis*	Endangered
Blue Whale	*Balaenoptera musculus*	Endangered
Fin Whale	*Balaenoptera physalus*	Endangered
Humpback Whale	*Megaptera novaeangliae*	Endangered
Sperm Whale	*Physeter macrocephalus*	Endangered
Steller Sea Lion	*Eumetopias jubatus*	Endangered
Snake River Sockeye Salmon	*Onchorynchus nerka*	Endangered
Snake River Fall Chinook Salmon	*Onchorynchus tshawytscha*	Threatened
Snake River Spring/Summer Chinook Salmon	*Onchorynchus tshawytscha*	Threatened
Puget Sound Chinook Salmon	*Onchorynchus tshawytscha*	Threatened
Lower Columbia River Chinook Salmon	*Onchorynchus tshawytscha*	Threatened
Upper Willamette River Chinook Salmon	*Onchorynchus tshawytscha*	Threatened
Upper Columbia River Spring Chinook Salmon	*Onchorynchus tshawytscha*	Endangered
Upper Columbia River Steelhead	*Onchorynchus mykiss*	Endangered
Snake River Basin Steelhead	*Onchorynchus mykiss*	Threatened
Lower Columbia River Steelhead	*Onchorynchus mykiss*	Threatened
Upper Willamette River Steelhead	*Onchorynchus mykiss*	Threatened
Middle Columbia River Steelhead	*Onchorynchus mykiss*	Threatened
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Short-tailed Albatross	*Phoebaotria albatrus*	Endangered
Spectacled Eider	*Somateria fishcheri*	Threatened
Steller Eider	*Polysticta stelleri*	Threatened

Notes: [1]The bowhead whale is present in the Bering Sea area only.

NOAA Fisheries is the expert agency for ESA listed marine mammals. The United States Fish & Wildlife Service (USFWS) is the expert agency for ESA listed seabirds. NOAA Fisheries consults on fisheries management actions that may affect marine mammals with NOAA Fisheries Protected Resources Division. For fisheries management actions that may affect seabirds, NOAA Fisheries consults with USFWS. NOAA Fisheries prepared biological assessments to assess the effects of the crab BSAI crab fisheries on these listed species (NMFS 2000; NMFS 2002a). From these assessments, NOAA Fisheries determined that the crab fisheries do not adversely affect listed species or destroy or modify their critical habitat. For marine mammals, salmon, and Leatherback sea turtles, NOAA Fisheries Protected Resources concurred with this determination, and determined a formal consultation is not required (NMFS 2001a). For seabirds, USFWS concurred with the NOAA Fisheries determination, and determined a formal consultation is not required (USFWS 2003).

NOAA Fisheries Sustainable Fisheries Alaska Region, with an addendum to the 2000 Biological Assessment (BA) for the king and Tanner crab FMP, included all listed species of salmon and Leatherback sea turtles in the informal Section 7 Consultation (NMFS 2001b). After reviewing the current status of the endangered and threatened species of salmon and the endangered Leatherback sea turtle, the environmental baseline for the action area, the effects of the crab fisheries prosecuted under the FMP, NOAA Fisheries Sustainable Fisheries Alaska Region concluded that the actions considered, as proposed, would not adversely impact listed salmon species or Leatherback sea turtles in the action area. Therefore, NOAA Fisheries Sustainable Fisheries believes formal consultation is not required. NOAA Fisheries Protected Resources concurred with this determination (NMFS 2001a). Since no evidence indicates a plausible interaction between the crab fisheries and these species, they will not be further discussed in this EIS.

Analysis of the potential effects of the alternatives on ESA species is in Chapter 4. NOAA Fisheries reinitiated consultation with USFWS and Protected Resources on the BSAI crab fisheries to include the Voluntary Three-pie Cooperative Program (NMFS 2004b, NMFS 2004c). On May 26, 2004, Protected Resources concurred with the determination that the Program is not likely to adversely affect listed species of marine mammals, salmon or leatherback sea turtles, or destroy or adversely modify Steller sea lion critical habitat (NMFS 2004c). On June 16, 2004, USFWS concurred with the determination that the Program is not likely to adversely affect listed species of seabirds or destroy or adversely modify critical habitat (USFWS 2004).

3.3.4 Marine mammals

The BSAI support one of the richest assemblages of marine mammals in the world. Twenty-six species are present from the orders Pinnipedia (seals, sea lion, and walrus), Carnivora (sea otter and polar bear), and Cetacea (whales, dolphins, and porpoises). Most species are resident throughout the year, while others seasonally migrate into or out of the management areas. Marine mammals occur in diverse habitats, including deep oceanic waters, the continental slope, and the continental shelf (Lowry et al. 1982). The Alaska Groundfish Fisheries Final Programmatic SEIS (NMFS 2004a) provides descriptions of the range, habitat, diet, abundance, and population status for these marine mammals. These descriptions are incorporated by reference.

Endangered Species Act listed marine mammals

The marine mammal species listed as endangered or threatened under the ESA (Table 3.3-1) are the northern right whale, the bowhead whale, the blue whale, the fin whale, the sei whale, the humpback whale, the sperm whale, and the western and eastern populations of Steller sea lions. NOAA Fisheries prepared a biological assessment for the BSAI crab FMP that assesses the effects of the crab fisheries on these species of marine mammals and their critical habitat (NMFS 2000). The biological assessment reviews the current status of the endangered species of marine mammals, the critical habitat designated for Steller sea lions, the environmental baseline for the action area, and the effects of the crab fisheries prosecuted under the FMP. The research presented in the biological assessment indicates that crab do not interact with any of the listed species of marine mammals. Crab do not comprise a measurable portion of the diet of any of the listed marine mammals. Furthermore, the crab species targeted by the crab fishery live in deep waters far from shore.

Limited direct interactions between the crab fisheries and marine mammals have been reported. This is most likely due to the nature of pot gear, the time of the crab fisheries (in the fall and winter), and the location of the fisheries (far from shore). NOAA Fisheries Sustainable Fisheries concluded that the actions considered in the BA, as proposed, are not likely to (1) result in the direct take or compete for the prey of the seven large protected whale species or the western and eastern population of Steller sea lions, or (2) destroy or adversely modify designated Steller sea lion critical habitat. Therefore, this BA is incorporated by reference and it is not necessary to repeat the information in the BA in this EIS.

Non-Endangered Species Act marine mammals

Of the marine mammals not listed under the ESA, the bearded seals (*Erignathus barbatus*) are the only marine mammals potentially impacted by the crab fisheries because crab are a measurable portion of the diet of these species. For all other marine mammals, the interactions between the crab fisheries and these species are negligible. Therefore, the effects of the crab fisheries on marine mammals other than bearded seals will not be analyzed in this EIS.

Bearded seals are circumpolar in their distribution, extending from the Arctic Ocean south to Hokkaido in the western Pacific. In Alaskan waters, bearded seals occur on the continental shelves of the Bering, Chukchi, and Beaufort Seas (Burns 1981a; Johnson et al. 1966; Ognev 1935). Only the Alaska bearded seal stock is recognized in United States waters.

Bearded seals usually are solitary animals. They make seasonal migrations as they follow the movement of sea ice. The density of animals in a given area varies widely. In late winter, when ice occupies a large area of the northern seas, bearded seals are widely dispersed. During their northward spring migration through the constricted waters of the Bering Strait and during late summer when sea ice has receded to the Arctic Ocean they are more concentrated. Adult bearded seals are almost always associated with ice, but young seals sometimes remain in ice-free areas where they frequent bays and estuaries.

Bearded seals feed on the benthos; therefore, their distribution appears to be strongly dictated by the occurrence of shallow water and high prey biomass. They appear to be limited to feeding depths of less than 150–200 m (Burns 1981a; Kosygin 1966) preferring depths of 25–50 m (Kingsley et al. 1985; Stirling et al. 1982). Decapod crustaceans and mollusks make up most of their diet, although prey include a wide variety of invertebrates and fish (Burns and Frost 1983; Lowry et al. 1979; Lowry et al. 1980a; Lowry et al. 1981a; Lowry et al. 1981b; Smith 1981). Major prey in the Bering, Chukchi, and Beaufort Seas include snow crab, clams, shrimps, and Arctic cod (Kosygin 1966; Kosygin 1971; Lowry et al. 1981a; Lowry et al. 1981b). There appears to be a seasonal preference in prey items: clams are consumed during the summer (May through September; Burns 1967; Lowry et al. 1980a), and shrimp and crabs, although consumed throughout the year, are represented in higher proportions in the diet in October-April (Lowry et al. 1980a). In the Beaufort Sea, crabs and shrimp appear to be primary prey items, though clams are important prey species in August, and arctic cod is a primary prey species in November and February (Burns and Frost 1983). In the Bering Sea, the estimated percentage composition of the bearded seal diet is 23 percent fish and 77 percent invertebrates. This information (based on data in Kenyon 1962; Kosygin 1966 and 1971; and Lowry et al. 1980a, 1981a, and 1982), accounts for the relative seasonal abundance of the bearded seal population in the eastern Bering Sea (Perez 1990; Perez and McAlister 1993). The total estimated annual food consumption by the population in this area is 265.2×10^3 metric tons (mt), of which 61.0×10^3 mt is fish that comprise 23 percent of their diet, assuming a population of 5,000 bearded seals in summer and 150,000 in winter (Perez and McAlister 1993).

Early estimates of the Bering-Chukchi Sea population range from 250,000 to 300,000 (Burns 1981a; Burns 1981b; Burns et al. 1981; Popov 1976). Until additional surveys are conducted, reliable estimates of abundance are considered unavailable. Reliable data on trends in population abundance are likewise unavailable.

3.3.5 Seabirds

Seabirds spend the majority of their life at sea rather than on land. The group includes albatrosses, shearwaters, petrels (*Procellariiformes*), cormorants (*Pelecaniformes*), and two families of *Charadriiformes*, gulls (*Laridae*), and auks (*Alcidae*), such as puffins, murres, auklets, and murrelets. Thirty-eight species of seabirds breed in Alaska. More than 1,600 colonies have been documented, ranging in size from a few pairs to 3.5 million birds. Breeding populations are estimated to contain 36 million individual birds in the Bering Sea; total population size (including subadults and nonbreeders) is estimated to be approximately 30 percent higher. Five additional species that occur in Alaskan waters during the summer months contribute another 30 million birds.

Several groups of marine-oriented birds inhabit the BSAI nearshore or offshore areas. These groups include four loons (*Gavidae)*,two grebes (*Podicipedidae*), and two phalaropes (*Phalaropodidae*). These species seldom interact with crab fisheries, and therefore will not be further discussed.

Several species of sea ducks (*Merganini*) also spend much of their lives in marine waters. The major sea ducks in this region include four species of eiders, harlequin ducks (*Histrionicus histrionicus*), oldsquaws (*Clangula hyemalis*), black scoters (*Melanitta nigra*), surf scoters (*M. perspicillata*) and white-winged scoters (*M. fusca*). Of these sea ducks, eiders are of special interest because of recent population declines and because large portions of eider populations occur in areas potentially affected by the crab fisheries.

The Alaska Groundfish Fisheries Final Programmatic SEIS (NMFS 2004a) provides life history, population biology and foraging ecology for these marine birds. These descriptions are incorporated by reference. From this information, it is possible to conclude that the crab species under the FMP have very limited interactions with these seabirds.

Endangered Species Act listed seabirds

The seabird species listed as endangered under the ESA are short-tailed albatross, spectacled eider, and Steller's eider. USFWS designated critical habitat for spectacled eider and Steller's eider. NOAA Fisheries prepared a BA for the BSAI crab FMP that assesses the effects of the crab fisheries on these seabirds and their critical habitat (NMFS 2002a). The BA identified how BSAI crab fisheries may affect, directly or indirectly, seabird populations and critical habitat. This BA identifies that the only plausible biological interaction between the crab fisheries and threatened and endangered species is vessel strikes by seabirds. While such interactions are possible, the available evidence is not sufficient to argue persuasively that these interactions do occur in today's fisheries to an extent that limits the recovery of listed species occurring in the action area. The BA recommends enhanced observer reporting procedures to better document when strikes occur or do not occur. After reviewing the current status of the short-tailed albatross, the spectacled eider, and Steller's eider, the critical habitat designated for the spectacled eider and Steller's eider and the potential effects of the crab fisheries prosecuted under the FMP, NOAA Fisheries concluded that the actions considered in the BA are not likely to (1) adversely affect the listed seabirds, or (2) destroy or adversely modify designated critical habitat. Additionally, NOAA Fisheries determined that the changes to the management of the fisheries as a result of Voluntary Three-pie Cooperative Program are not likely to (1) adversely affect the listed seabirds, or (2) destroy or adversely modify designated critical habitat.

Non-Endangered Species Act seabirds

From the information presented in the Alaska Groundfish Fisheries Final Programmatic SEIS (NMFS 2004a), it is possible to conclude that the crab species under the FMP have very limited interactions with seabirds. And, that the interactions that do occur do not impact any species of seabird on a population level. Commercial crab species do not comprise a measurable portion of seabird prey.

Limited direct interactions between the crab fisheries and seabirds is most likely due to the nature of pot gear, the time of the crab fisheries (fall and winter), and the location of the majority of fishing (far from shore). (NMFS 2002a). The crab fisheries do not discharge offal that would attract seabirds. Pot gear is set in winter when fewer birds would be present and bait is hard to see in the water due to seasonal darkness. Seabirds are attracted to fishing bait, but pot gear does not attract seabirds to the same extent as that of longline and trawl bait/gear. Crab bait is enclosed in a wire cage and is fairly inaccessible to diving seabirds. Groundfish and crab pot gear account for less than one percent of the total average annual seabird incidental catch in GOA and BSAI, while the remaining 99 percent is attributed to longline and trawl gear (NPFMC 2002). Bycatch in groundfish and crab pot fisheries is estimated at approximately 100 birds per year consisting of primarily northern fulmars (NMFS 2004a). A full list of species taken by groundfish and crab pot gear for the years 1993 to 1999 can be found in the Alaska Groundfish Fisheries Final Programmatic SEIS (NMFS 2004a). Seabird mortality due to groundfish and crab pot bycatch is estimated at 0.00012 percent of the total estimated Alaska summer seabird population (NMFS 2004a).

Seabird mortality due to vessel strikes is highly dependent on time of day, weather, vessel rigging, vessel lighting, and proximity to seabird colonies during the breeding season (NPFMC 2002). Most bird-vessel interactions occur at night, in stormy and foggy weather, and when bright deck lights are on. Many bird strikes occur in the vessel's rigging, specifically on the "third wire" of a trawl vessel. Crab vessels do not have extensive rigging or a third wire. The bright lights of a crab vessel would only be a cause for collision in conjunction with foul weather, which is an unpredictable factor for vessel strikes. Non-ESA listed seabird vessel strikes do occur in the crab fisheries, however, these strikes are very limited and have not been shown to impact the population levels of non-ESA listed seabirds. A full discussion of vessel strikes is in Section 4.3.4.

Vessel pollution caused specifically by crab vessels cannot be determined. Total vessel pollution from all fishing vessels is minimal, and the total number of crab vessels is a small proportion of the total number of fishing vessels in the BSAI. No evidence indicates that the crab fisheries would fundamentally change the marine ecosystem to the extent that seabirds would be impacted. No adverse effect on seabird habitat is expected, due to the very limited interaction between the commercial crab fishery and seabird habitat. Existing information suggests that the BSAI crab fisheries do not have a significant effect on the populations of any seabird species. Therefore, since no evidence indicates substantial interactions between crab gear and seabirds, it will not be discussed further in this EIS.

3.4 Features of the human environment

This section details the features of the human environment pertaining to the BSAI crab fisheries. Section 3.4.1 details the history of the BSAI crab fisheries, including information on harvest levels, stock abundance, and fishing effort over time. Section 3.4.2 provides a history of the fishery management plans for the crab fisheries in the BSAI and contains a description of all of the FMP amendments adopted by NOAA Fisheries. Section 3.4.3 is a profile and description of the BSAI crab industry, including both the harvesting sector and the processing sector. This section also contains information on the existing relationship between harvesters and processors and ex-vessel pricing. Section 3.4.4 describes the community and social existing conditions for the communities impacted by the BSAI crab fisheries. Section 3.4.5 describes the CDQ program for BSAI crab. Section 3.4.6 provides maps to illustrate the distribution of the fisheries and the crab stocks that are covered in the NOAA Fisheries eastern Bering Sea trawl survey.

3.4.1 History of the BSAI crab fisheries

This section describes the history of the BSAI crab fisheries and their management by the State of Alaska (State). This history is summarized from the 2001 Annual Management Report for the Shellfish Fisheries of the BSAI (ADF&G 2001).

Introduction[1]

The domestic deepwater crab industry in the U.S. EEZ off Alaska is only about 55 years old. The crab fisheries developed later than the groundfish fisheries because of their distance from markets and their capital requirements: large vessels, expensive gear, and sophisticated freezing equipment or live-holding tanks. Pioneers in the industry, however, quickly recognized the high value of the resource.

The State of Alaska has actively managed the crab fisheries from their inception. This is true even though the commercial crab fisheries in the BSAI are located in federal waters. The State continued to manage the crab fisheries after the establishment of Federal fisheries management with the passage of the Magnuson-Stevens Act in 1976. Currently, the State's management authority is derived from the 1989 cooperative FMP, which reserves to the Council the right to carry out major changes such as those contemplated in this EIS, but enables the State to carry out primary management through ADF&G.

Four species of king crabs support fisheries in the BSAI Region: red king crab, blue king crab, golden king crab, and scarlet king crab. They differ in their life history characteristics although they frequently co-occur in a given management area or district. For example, red king crab, blue king crab, and golden king crab all inhabit the Pribilof Islands area and are recognized as separate stocks in the FMP. Most red and blue king crab fisheries occur at depths from 50 to 200 m but red king crab fisheries in the Aleutian Islands sometimes extend to 300 m. Golden king crab fisheries take place at depths in excess of 300 m. The scarlet king crab fisheries usually occurs at depths 700 m or more. All species of king crabs have finely flavored meat that is easily extracted from their large shells. Technically, only members of the genus *Paralithodes* may be sold as "king crab" under FDA regulations. Landings of king crabs have been much more stable in Asian than

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[1] Section 3.4.1 relies heavily on the 2001 Annual Management Report for the Shellfish Fisheries of the BSAI (ADF&G 2001). Parts of this introduction excerpted from Alaska's Crab Fisheries: Management by individual transfer quotas (Mollett 1997).

in North American waters (Otto and Jamieson 2001) and much of the king crab now on the U.S. market comes from Russian waters. The economic importance of king crabs stems from the fact that they are sold at the highest prices of any crabs in U.S. fisheries. Due to the long-term economic importance of king crabs and significance in international trade, the history of BSAI king crab fisheries is central to the development of all U.S. fisheries in the BSAI region.

The Bristol Bay red king crab fishery has been the oldest most important king crab fishery in the BSAI. A Japanese ship was the first to harvest red king crabs in the Bering Sea, processing about one million crabs in 1930. No harvest occurred in 1931, but one or two Japanese factory trawlers operated each year from 1932 to 1939 and caught about 7.6 million crabs altogether (Otto 1981). Canned crab was popular in the U.S. in the pre-World War II years; the U.S. imported about ten million lbs. per year from Japan and the Soviet Union. The Bristol Bay red king crab fishery largely remained a foreign fishery until the 1970's. Prior to this time, U.S. fishermen were occupied with the development of red king crab fisheries in the GOA and Aleutian Islands.

During World War II, the trading stopped, and a domestic fleet filled the gap. Salmon fishermen had begun exploratory trawling for king crab in 1936. Congress authorized a one-year study in 1941 to locate crab stocks and to develop equipment suitable for harvesting and canning; the resulting expedition mapped the major stocks in the Bering Sea and smaller stocks around Kodiak Island in Pavlof and Canoe Bays, concluding that the fishery had the potential to supplement the salmon industry (Browning 1980). Japanese fishermen began exploiting the Bristol Bay red king crab fishery heavily when they returned to the area in 1953, and in 1959 the Soviet Union began fishing for crab in Bristol Bay as well. Meanwhile, the domestic king crab fishery was growing in importance. It was concentrated at first in the eastern Bering Sea, but shifted to the Kodiak area in 1954.

Small-scale domestic processing started up in the same period. Pacific Fishing and Trading, Inc., the first sizable processor, owned a factory ship that began purchasing and processing king crab in 1938, but the operation lost money. In 1946 Lowell Wakefield, whose family was canning king crab on Raspberry Island near Kodiak, built the first American ship intended solely as a crab catcher and processor. By 1955, Wakefield was processing 85 percent of the domestic king crab catch, and most of the other families and companies which later became prominent in the Alaska crab fisheries had already become involved (Browning 1980). However, over the past two decades, processing companies have increasingly come under the ownership of foreign companies. Unisea, Peter Pan, and Westward Seafoods are owned entirely by Japanese companies. Alyeska and Stellar are partially owned (56 percent and 25 percent, respectively) by Japanese companies as well. In all other cases, foreign ownership is thought to be less than 5 percent (NPFMC 2002).

The Aleutian Islands fishery near Adak Island was particularly important in the 1960's as was that near Unalaska Island from the mid-1960's through 1980. In general, blue king crab stocks are small and localized and support small fisheries near the Pribilof Islands and St. Matthews Island. Pribilof Islands blue king crab are among the largest in the world and the average size of landed crab has exceeded 3.5 kg in many years. Blue king crab in the St. Matthew Island area are smaller and fishery average weight seldom exceeds 2.2 kg. Blue king crab fisheries near the Pribilof Islands were first developed by the Japanese in the mid-1960's and then taken over by U.S. fishermen who later developed fisheries near St Matthew Island in the late 1970's. Golden king crab fisheries, most prominently in the Aleutian Islands region, were the last to be developed, entirely by U.S. fishermen and in part because of economic forces brought to bear by low abundances of almost all BSAI crab stocks in the early 1980's. Fisheries for the scarlet king crab have been largely experimental and the species is mostly taken as bycatch in exploratory fisheries for deep water Tanner crabs.

Within the genus *Chionoecetes*, landings of snow crab (*Chionoecetes opilio*) have been most important, followed by Tanner crab *(C*. bairdi) and recently, small, exploratory fisheries for deep water species *(C*. tanneri, C. angulatus) that are generally found at depths exceeding 400 m. Tanner crab fisheries were developed earlier than snow crab fisheries and had their origins as bycatch in various king crab fisheries. The snow crab fishery is confined to the eastern Bering Sea and had its origin as bycatch in the Tanner crab fishery, generally becoming more important as fleets developed and Tanner crab populations declined. The eastern Bering Sea snow crab fishery has been particularly significant over the past 15 years and has been subject to large fluctuations in landings. Fisheries for the other two species, grooved Tanner crab *(C*. tanneri) and angled Tanner crab *(C*. angulatus), have been exploratory and only limited harvest of these two minor species in North America (Jamieson 1990; Jamieson et al. 1990; Phillips and Lauzier 1997; Boutillier et al. 1998). The Tanner crab is the largest of the genus and the average size of males landed in the commercial fishery is 1.0 to 1.2 kg, while the other species are generally about half this size.

In 1964, the U.S. ratified the International Convention of the Continental Shelf, and declared that king, Tanner and snow crab belonged to the U. S. continental shelf. Then through separate bilateral agreements, the U.S. gradually displaced the Japanese and Soviet fleets. The accords restricted harvest to hardshell males with a minimum carapace size of 158 mm, and set catch quota and area restrictions. Foreign harvests began decreasing annually starting in 1966 as a result of these agreements, and the reduction was compounded by stock declines in traditional fishing areas. The Soviet fleet had exited entirely by 1972 and the Japanese fleet by 1975 (Fukuhara 1985).

In the early years, crabbers used trawls and tangle nets, which are large-mesh bottom gillnets. However, it was difficult to return females and sub-legal males to the sea uninjured after catching them in tangle nets, and the equipment was also expensive to maintain (Browning 1980). Crab pots proved to be more efficient. The Japanese started using them in 1968, and pots had mostly replaced the nets by 1971 (Otto 1981).

Currently, Alaska crabs are taken almost exclusively with pots. King crab posts are about five to eight feet square and two to four feet deep, and weigh 400-700 lbs. Snow and Tanner crab pots are usually smaller, but some areas use modified Tanner pots for king crab (Johnson 1990).

The widely fluctuating character of the resource became apparent through two collapses, the first in Kodiak in 1969, the second in Bristol Bay in 1982. At its peak in 1965/1966 the Kodiak fishery harvested 94 million lbs., close to 70 percent of the total domestic Alaska king crab harvest of 138 million lbs. The Kodiak catch then began its decline. By 1969, when the total Alaska king crab harvest was 55 million lbs., the Kodiak contribution amounted to only 12 million lbs.

Despite the collapse of the fishery, the Kodiak fleet survived; some converted to halibut or other species, while the bulk of the fleet moved westward to Bristol Bay.

3.4.1.1 Bristol Bay red king crab

The Bristol Bay red king crab fishery has been the dominant king crab fishery since the Kodiak fishery's collapse. Bristol Bay King Crab Registration Area T was defined by the Alaska Board of Fisheries (BOF) in 1980 as including all waters north of the latitude of Cape Sarichef (54°36'N), east of 168°W and south of the latitude of Cape Newenham (58°39'N); all waters of Bristol Bay are included. The area is designated as an exclusive registration area. During any king crab registration year (June 28 through June 27), vessels registering for and fishing in this area are prohibited from fishing in any other exclusive or superexclusive king crab registration areas. Only non-exclusive areas (the Bering Sea Area Q and or Aleutians Area O) can subsequently be fished once a vessel is registered in Area T.

The GHL for the Bristol Bay red king crab fishery is set annually based on NOAA Fisheries eastern Bering Sea crab and groundfish trawl abundance index surveys, which were initiated in 1968. The survey is conducted during the summer months, and the resulting area-swept estimates of abundance are published annually. Since 1995, ADF&G has used a length-based model to estimate abundance from the survey data, also incorporating other sources of data, including dockside sampling and data collected by observers. These abundance estimates are compared to regulatory harvest strategy thresholds, which must be met for the fishery to open. The MSST are set at 8.4 million mature females and 14.5 million lbs. of effective spawning biomass. If these numbers are met, an exploitation rate is applied, based on the effective spawning biomass.

The Bristol Bay harvest increased rapidly through the 1970's, peaking at 130 million lbs. in 1980–when a record total of 189 million lbs. of king crab was caught in Alaska. During this period, the crab industry flourished, and made national news because of the profits that could be raked in by crew members and owners in the course of a six-week session (Gay 1991). In 1980, the ex-vessel value of the king crab harvest was $175 million and the Alaska shellfish harvest was valued at $265 million, greater than the salmon harvest that year (Johnson 1990).

Over the next few seasons, numbers of legal male red king crabs in Bristol Bay decreased far more sharply than anticipated. Landings of Alaska king crab overall decreased 55 percent from 1980 to 1981. The Bristol Bay fishery plunged 91 percent further the following year (1982), to three million lbs. The 1983 NOAA Fisheries trawl survey of the Bering Sea indicated a record low number of legal male crabs and the lowest total king crab population ever recorded. Small female crabs carrying fewer eggs and high predator abundance was also noted. Consequently, the fishery was closed for the 1983 season. The fishery has fluctuated at depressed levels since then, never again approaching the peak levels in 1979-1980 (Table 3.4-1).

The causes of the Alaska red king crab collapse have been disputed for many years among biologists. Some emphasize large-scale changes in the ecosystem of the Bering Sea, including major climactic changes and alterations in the mixture of species. According to this explanation, the fishery was a factor in the decline of the mature population level, and also a factor in preventing the stocks from recovering, but was not responsible for the primary decline in production (Otto in Witherell and Harrington 1996). Others are less willing to let managers off the hook, noting evidence of a rapid decline in brood strength in the late 1970's, prior to the decrease in mature stock biomass, and the fact that juvenile populations were not being monitored and that fishing pressure continued unabated during the brood stock decline (Personal interview, Oct. 22, 1997, Al Tyler, Fisheries Science Professor, University of Alaska with N. Mollett). In addition, some hypothesize that the increasing amount of bottom trawling effort since 1977 in areas known for high concentrations of females caused the collapse of the Bristol Bay red king crab and is the reason the population remains below abundance levels observed prior to 1980 (Dew and McConnaughey 2003).

Table 3.4-1 Abundance of legal males (millions of crab from LBA model), pre-season guideline harvest level (in millions of lbs.), and total catches (millions of lbs., includes deadloss, but not community development quota) of Bristol Bay red king crab, 1980-2001.

Year	Abundance	Guideline Harvest Level	Catch
1980	44.2	70.0 - 120	129.9
1981	9.5	70.0 - 100	35.1
1982	2.9	10.0 - 20	3.0
1983	2.5	0	0
1984	2.3	2.5 - 6.0	4.2
1985	1.8	3.0 - 5.0	4.2
1986	4.3	6.0 - 13.0	11.4
1987	6.7	8.5 - 17.7	12.3
1988	8.3	7.5	7.4
1989	9.7	16.5	10.3
1990	10.1	17.1	20.4
1991	8.5	18.0	17.2
1992	6.6	10.3	8.0
1993	5.9	16.8	14.6
1994	4.8	0	0
1995	6.1	0	0
1996	7.0	5.0	8.4
1997	7.2	7.0	8.8
1998	7.4	15.8	14.2
1999	8.6	10.1	11.1
2000	8.0	7.7	7.5
2001	7.2	6.6	7.8

The fishery reopened in 1984 and catches slowly increased to over 20.3 million lbs. in 1990. An onboard observer program for catcher/processors was initiated in 1988 to enable ADF&G to better monitor catches. Fishing effort increased dramatically from 89 vessels in 1984 to over 300 vessels in 1991. The number of pots being fished by the fleet also increased, from just under 22,000 pots registered in 1984 to almost 90,000 pots registered for the 1991 fishery.

The BOF established a pot limit in 1992 intended to improve its ability to manage the fishery by extending the length of the season, and to reduce the potential for pot loss. The initial 250-pot limit for all vessels was repealed by NOAA Fisheries after the first season because it was considered inconsistent with the FMP, which mandated a nondiscriminatory application of pot limits. Under new pot limits set the following spring, vessels 125 feet or less were allowed a maximum of 200 pots, while the 250-pot limit continued to apply for vessels more than 125 feet long. These pot limits were administered through a buoy tag program from the

Dutch Harbor and Kodiak ADF&G offices. Also in 1993, ADF&G began requesting voluntary daily vessel reports via single side band radio and marine telex, which have been used since then in calculating catch per unit effort (CPUE), defined as number of crab caught per pot lift, and daily harvest.

King crab stocks in the eastern Bering Sea again declined in the mid-1990's. The Bristol Bay red king crab fishery was closed in 1994 and 1995 due to declines in all size classes of both male and female red king crabs. In 1994, the abundance index of large females (>89 mm CL) was estimated at 7.5 million crabs, below the minimum threshold of 8.4 million necessary to allow a fishery. The BOF adopted a revised harvest strategy at their March 1996 meeting to promote stock rebuilding. One of the most significant changes to the harvest strategy was to reduce the exploitation rate of mature male crabs from 20 percent down to 10 percent, when the effective spawning biomass is below levels where the stock is considered rebuilt (55 million lbs.).

Increased abundance was seen in the 1996 NOAA Fisheries survey in all size classes of males and females (Zheng et al. 1996a). The number of large females increased to 10.2 million crabs, well above the threshold level needed to reopen the fishery. The 1996 GHL was set at 5 million lbs. The 1996 fishery lasted four days and a total of 8.4 million lbs. were harvested – 68 percent over the GHL.

Because the fishery ran so far over its GHL and ADF&G seemed unable to adequately manage it at these low levels, the BOF held a special meeting in August of 1997. A number of new regulations were adopted, including new pot limits based on vessel overall length, the pre-season GHL, and the number of vessels which pre-registered for the fishery.[2]

All components of the Bristol Bay red king crab stocks increased over the following two years (Zheng et al. 1997a; Stevens et al. 1998). In 1997, using a 10 percent exploitation rate for mature males, the GHL was set at 7 million lbs., which was exceeded by 24 percent, largely due to extremely high fishery performance in the final hours of the fishery. The harvest rate was increased to 15 percent in 1998, and the GHL for the open access fishery was set at 15.8 million lbs. Total harvest in the 1998 fishery, which lasted five days, was 14.3 million lbs.

At its March 1999 meeting, the BOF passed anti-prospecting regulations, prohibiting vessels (with certain exceptions for the directed pollock fishery) from participating in the Bristol Bay king crab fishery if they had operated pot, longline, or trawl gear in that portion of Registration Area T north of 55° 30'N and east of 164° W during the 30 days prior to the king crab season. The BOF also moved up the opening date of the commercial red king crab fishery in Bristol Bay from November 1 to October 15, to mesh better with the Bering Sea king crab fisheries, which open on September 15.

1999-2001 fishery and survey results[3]

Over the years 1999 and 2000, most size classes of Bristol Bay red king crab stocks decreased in abundance. Pre-recruit males decreased by 43 percent, and large females by 49 percent over the two-year period. The decrease in abundance of the larger-sized crabs was attributed to fishery removals, as well as natural mortality (Zheng and Kruse 2000b). Management returned to a mature male exploitation rate of 10 percent.

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[2] Specific information on pot limits, based on GHL and the number of vessels participating in the Bristol Bay fishery, are found under 5 AAC 34.825 of the 2000-2002 Commercial Shellfish Fishing Regulations.

[3] Information on 2001 red king crab fishery from ADF&G memorandum "2001 Bristol Bay king crab fishery summary," by Forrest Bowers, December 21, 2001.

In 2000, the open-access GHL was set at 7.72 million lbs. A pot limit of 100 was established for vessels less than or equal to 125 feet in overall length and 125 for vessels over 125 feet overall length. A total of 239 catcher-only vessels and seven catcher/processors participated in the fishery, which lasted 4.3 days and caught 7.55 million lbs. of king crabs which was valued at $36 million, roughly half the 1999 fishery value. The ex-vessel price of red king crabs harvested in the 2000 fishery was $4.81 per lb. in Dutch Harbor and on the one floating processor that operated during the fishery. Processors in Kodiak paid $5.00 per lb. These prices were a decrease from the $6.26 per lb. paid in 1999, but still among the highest paid in the history of this fishery.

For the 2000 Bristol Bay red king crab fishery, observer coverage on approximately 8 percent of catcher-only vessels, including American Fisheries Act (AFA) boats, was implemented for the first time. This coverage, employing both contract observers and state biologists, is required by revisions to the State's shellfish observer program adopted by the BOF in 1999. Some of the funding for the observers came from the annual cost recovery program, designed to conduct research on Bering Sea shellfish. The program, conducted prior to the open-access fishery by ADF&G, harvested and sold 86,200 lbs. of red king crabs in 2000, worth $500,000.

The 2001 NOAA Fisheries' annual trawl survey and analysis indicated about 5.1 million legal sized male crabs, a 41 percent decrease from the previous year; 4.3 million pre-recruits, a 41 percent decrease, and 21.2 million large females, a 22 percent increase. The decline in abundance of mature, legal males, which is at approximately 68 percent of the previous 20-year average, was attributed to mortality, fishery removals, and poor recruitment.

The total mature biomass was above the MSST, allowing a 10 percent exploitation rate. The effective spawning biomass, estimated at 40.6 million lbs., and total mature biomass levels were comparable to levels in 2000. The 2001 GHL was set at 7.15 million lbs. Pot limits remained the same as the previous year.

A total of 242 vessels participated in the fishery, including six catcher/processors and one floating processor. Based on post-season production reports, 8.42 million lbs. of red king crab was harvested in the 80 hours that the fishery was open. Twenty-three catcher vessels were selected to carry onboard observers. Components of the 2001 fishery and effort are summarized in Table 3.4-2.

Table 3.4-2 2001 fishery and effort.

	Guideline Harvest Level (lbs)	Harvest (lbs)	Number of Vessels
General Fishery	6.61 million	7.1 million	201
American Fisheries Act capped vessels		0.7 million	31
Community Development Quota Fishery	0.62 million	0.62 million	10
Total	7.23 million	8.42 million	242

Thirty-one of the catcher-only vessels participated under AFA sideboards. The AFA, passed in 1998 by Congress, gives pollock fishermen exclusive fishing privileges in the BSAI pollock fishery. To protect the interests of fishermen not directly benefitting from the AFA, sideboards were established for AFA boats qualified to participate in BSAI crab fisheries. In order to implement these sideboards, the BOF developed a management plan specifying that a harvest cap would be applied to AFA vessels, to be equally apportioned, or through a cooperative, if all AFA participants agreed to the cooperative. This AFA harvest cap was implemented for the first time in the 2000 Bristol Bay red king crab fishery. In the 2001 season, the AFA vessels fished in a cooperative with a pre-specified harvest cap of slightly over 10 percent of the open access GHL, or 725,000 lbs. According to the AFA cooperative agreement, when AFA vessels reached 80 percent of their cap, each AFA vessel would be given an equal limit on the number of crabs that it could keep. Based on in-season reports, AFA vessels reached their 80 percent cap by noon on October 18. At that time, each vessel was given an individual limit of 600 harvestable crabs. Twenty-four of the AFA vessels were constrained by this limit and stopped fishing prior to the closure – by contrast, in 2000 only two AFA vessels were able to catch their 872-crab limit before the closure. Post-season production reports show that AFA vessels harvested approximately 704,000 lbs., or 97 percent of their cap, in 2001.

Although the 2001 season is the shortest on record, lasting only 80 hours, it had the highest seasonal catch rate since 1980. The fleet pulled approximately 63,000 pots, harvesting 7.79 million lbs. The CPUE was 19 legal crabs per pot lifted. Landed king crabs averaged 6.5 lbs. per crab, the same average weight observed during the 2000 season. Fishermen were paid an average price of $4.81 per lb. by shore plants in Dutch Harbor, Akutan, King Cove, Adak, and Kodiak. In addition, one floating processor and two catcher/processors purchased crabs after the season. The 2001 Bristol Bay red king crab fishery had an ex-vessel value of $37.2 million, a slight increase from the 2000 fishery's ex-vessel value of $36 million.

ADF&G personnel or observers contacted approximately 75 percent of Bristol Bay red king crab vessel operators for post-season interviews. Biological data were collected from most of these deliveries. The Department of Public Safety stationed personnel in all ports where Bristol Bay red king crab were landed and cited five vessel operators for possession of undersized crab. Very poor weather conditions on October 17 resulted in the death of one fisheman, injury to several others and damage to several vessels.

3.4.1.2 Bering Sea red and blue king crab

The Bering Sea king crab registration, Area Q, is divided into the Pribilof District, which includes waters south of Cape Newenham, and the Northern District, which incorporates all waters north of Cape Newenham. The Northern District is further subdivided into three sections: the Saint Matthew Island Section, the Norton Sound Section, which includes all waters north of Cape Romanzof, and the Saint Lawrence Island Section, which encompasses all remaining waters of the district.

Pribilof District

The king crab fishery in the Pribilof District started in 1973, when vessels targeted blue king crabs, *(Paralithodes platypus)* in the vicinity of St. George and St. Paul Islands. The first reported catch in this area was 1.2 million lbs. taken by eight vessels between July 1973 and October 1974. The average weight of crabs harvested was 7.3 lbs. and CPUE was 26 (crabs per pot pulled). By the 1980/1981 season, the fishing effort had increased to 110 vessels, which harvested 11 million lbs., the highest catch on record (Table 3.4-3). However, by then the fishery was depleted as elsewhere in the State, the CPUE had dropped to nine, and it continued declining to a low of two crabs per pot pulled by the end of the 1986/1987 season. The harvest that year was only 260,000 lbs., taken by 16 vessels. Due to this six-year decline in harvest and concurrently low annual population estimates, the blue king crab fishery was closed beginning with the 1988/1989 season and remained closed until 1995.

In 1993, the NOAA Fisheries summer trawl survey of the Bering Sea indicated a marked increase in the abundance of red king crabs around the Pribilof Islands. No threshold abundance level had been established for the area, but survey results indicated a harvestable surplus of male crabs. Consequently, a red king crab fishery in the Pribilof District opened for the first time in September 1993. Pot limits were established at 50 for vessels over 125 feet and 40 for vessels 125 feet or less, and a GHL of 3.4 million lbs. was set. A harvest of 2.6 million lbs. was taken in 1993, and roughly half that amount was taken the following year.

In 1995, an increase in blue king crab abundance and a continued harvestable surplus of red king crabs resulted in a combined red and blue king crab GHL of 2.5 million lbs. Subsequent declines in red and blue king crab abundance over the next three years led to a combined GHL for 1998 of 1.25 million lbs. Annual harvests fell below the fishery GHL during this period. In 1999, red and blue king crab abundance continued to decline and the Pribilof fishery was closed. It has remained closed since then, due both to the continued decline and to significant uncertainty surrounding estimated red king crab abundance.

The economic value of the Pribilof District red king crab fishery peaked at $13 million in 1993 with an ex-vessel price of $4.98 per lb. The value of the Pribilof District blue king crab fishery peaked at $13.6 million in 1981/1982, with an ex-vessel price of $1.50 per lb. Since 1995, the ex-vessel price of red or blue king crabs has not exceeded $3.37 per lb. Total value of the fishery declined from $6.8 million in 1995 to $2.4 million in 1998. The average historical weight of red king crabs in the Pribilof District is 7.8 lbs., slightly larger than the average weight of 7.5 lbs. for blue king crabs.

2001 stock status

Red king crab abundance appears to be increasing. The legal red king crab abundance index for 2001 was 1.8 million crabs, a 54 percent increase from 2000; pre-recruits were at 2.5 million crabs, a 587 percent increase; and large females at 4 million crabs, a 549 percent increase. The fishery nonetheless remained closed along with the blue king crab fishery, partly to avoid bycatch of blue king crab, and partly because the localized, highly concentrated population of crabs results in an index with very low precision. Females in particular are considered to be poorly estimated. (Rugolo et al. 2001).

The population of blue king crabs in the Pribilof District showed no detectable trend from 2000, when it hit its lowest level since 1989. Estimates from the 2001 NOAA Fisheries trawl survey showed 0.4 million legal males, a 16 percent decrease from 2000; 0.1 million pre-recruits, a 48 percent decrease; and 1.6 million large females, a 17 percent increase. The male population, at 42 percent of the previous 20-year average, is notably below the fishery threshold definition. Overall, the population remains low and appears to be in a long-term decline (Stevens et al. 2001a; Rugolo et al. 2001).

Table 3.4-3 Abundance of legal males (millions of crab), pre-season guideline harvest levels (in millions of lbs.), and total catches (millions of lbs., including deadloss) of Pribilof District blue king crab, 1980-2000.

Year	Abundance	Guideline Harvest Levels[1]	Catch
1980	4.2	5.0 - 8.0	11.0
1981	4.2	5.0 - 8.0	9.1
1982	2.2	5.0 - 8.0	4.4
1983	1.3	4.0	2.2
1984	0.6	0.5 - 1.0	0.3
1985	0.3	0.3 - 0.8	0.5
1986	0.4	0.3 - 0.8	0.3
1987	0.7	0.3 - 1.7	0.7
1988	0.2	0	0
1989	0.2	0	0
1990	0.4	0	0
1991	1.0	0	0
1992	1.0	0	0
1993	1.0	0	0
1994	0.8	0	0
1995	2.0	2.5	1.3
1996	1.2	1.8	1.1
1997	0.8	1.5	0.7
1998	0.8	1.25	1.03
1999	0.5	0	0
2000	0.5	0	0
2001	0.4	0	0

Notes: [1] Since 1995, GHL includes both red and blue king crab combined.

3.4.1.3 St. Matthew Island blue king crab fishery

The commercial blue king crab fishery in the St. Matthew Island Section of the Northern District was first exploited in 1977, resulting in a commercial harvest of 1.2 million lbs. In 1978, the catch increased to almost 2 million lbs. Catches decreased in 1979 and 1980 due to lack of effort. In 1981, several vessels returned to the St. Matthew Island Section during the Norton Sound Section fishery. Catches were good, and after the Norton Sound Section closed, additional vessels moved into the St. Matthew Section, taking 4.6 million lbs. of blue king crabs (Table 3.4-4). Catch and effort increased to a peak harvest of 9.5 million lbs. in 1983, when 164 vessels participated. In subsequent seasons, catches remained at or below 5 million lbs.

NOAA Fisheries trawl surveys between 1983 and 1999 in the St. Matthew Island Section of the Northern District indicated a harvestable surplus of blue king crabs ranging from 1.7 to 8 million lbs. In 1993, the BOF moved the opening date of the St. Matthew king crab fishery from September 1 to September 15, concurrent with the king crab fishery in the Pribilof District. This action was taken to improve effort distribution between the Pribilof and St. Matthew areas; thereby, reducing the number of vessels participating in each fishery. Differential pot limits, established in 1993 for the St. Matthew Island Section, limited vessels over 125 feet to a maximum of 75 pots and vessels 125 feet or less to 60 pots.

In 1998, the annual NOAA Fisheries trawl survey indicated that legal male abundance had decreased by 21 percent. The GHL was set at 4 million lbs. The 1998 season lasted 11 days, the second longest season on record, but closed before the GHL was attained due to poor fishery performance and observer information indicating a relatively high incidental capture rate of sublegal males and female crabs. The 1998 harvest was 2.9 million lbs. and the CPUE was seven crabs per pot lift, the second lowest CPUE on record for the area. From 1999 to 2001, the St. Matthew Fishery was closed due to a continued decline in male and female crab abundance as seen in the NOAA Fisheries survey results.

Stock status and rebuilding plan

Analysis of the 2001 NOAA Fisheries survey data produced an estimated legal male abundance of 1.1 million crabs, a 16 percent increase from 2000, but still well below the 20-year average of 2.4 million crabs. Pre-recruit male crab abundance, at 0.1 million crabs, decreased 48 percent from 1999, while the abundance of mature female crabs was estimated at 1.6 million crabs (Rugolo et al. 2001). Spawning biomass in 2001 was estimated at 6 percent above the MSST of 11 million lbs. established for this stock. As defined by the FMP and the Magnuson-Stevens Fishery Conservation Management Act (Magnuson-Stevens Act), this fishery is considered overfished and a rebuilding plan has been adopted including a harvest strategy, bycatch control measures, and habitat protection measures.

The harvest strategy includes four components: (1) a minimum stock threshold of 2.9 million lbs. of mature male biomass, (2) a minimum GHL of 2.5 million lbs., (3) variable mature male harvest rates based on the mature male biomass level, and (4) a 40 percent cap on the legal male harvest rate (Zheng and Kruse 2000b). To reduce mortality associated with crab bycatch, gear modification measures were adopted requiring each pot to be fitted with either 5.8-inch diameter escape rings or 8-inch stretch mesh on at least one-third of one vertical surface of the pot. To further reduce bycatch of females, the BOF also closed fishing in the areas around St. Matthew Island, Hall Island, and Pinnacles Island, where egg-bearing females have historically been found during pre-season pot surveys and in observer pot samples. In addition, the BOF directed that in consultations on any proposed non-fishing activities, the importance of blue king crab EFH in maintaining stock productivity will be emphasized, and to the extent practicable, this area would be protected from adverse impacts. Because it has been declared an overfished stock, all habitats used by St. Matthew blue king crabs will be treated as EFH. The projected rebuilding time-period is six years (NPFMC 2000a).

Table 3.4-4 **Abundance of legal males (millions of crab from catch-survey estimates), pre-season guideline harvest levels (in millions of lbs.), and total catches (millions of lbs., including deadloss) of St. Matthew District blue king crab, 1980-2001.**

Year	Abundance	Guideline Harvest Levels	Catch
1980	2.5	Not Available	Not Available
1981	3.1	1.5 - 3.0	4.6
1982	6.8	5.6	8.8
1983	3.5	8.0	9.5
1984	1.6	2.0 - 4.0	3.8
1985	1.1	0.9 - 1.9	2.4
1986	04	0.2 - 0.5	1.0
1987	0.7	0.6 - 1.3	1.1
1988	0.8	0.7 - 1.5	1.3
1989	1.5	1.7	1.2
1990	1.7	1.9	1.7
1991	2.2	3.2	3.4
1992	2.3	3.1	2.5
1993	3.6	4.4	3.0
1994	2.5	3.0	3.8
1995	1.9	2.4	3.2
1996	3.4	2.4	3.1
1997	3.9	5.0	4.6
1998	3.1	4.0	2.9
1999	0.6	0	0
2000	0.8	0	0
2001	1.1	0	0

3.4.1.4 Bering Sea golden king crab

The golden king crab (*Lithodes aequispinus*) fishery in the Bering Sea is managed using in-season catch reports provided by processors and vessel logbooks issued with the commissioner's permit. The logbooks provide location of fishing operations, effort and estimates of bycatch. Primary bycatch species include non-retained golden king crabs, halibut, Pacific cod, and snow crabs. Beginning January 1, 2001, observers were placed on each vessel registered for the fishery in order to provide fishery and biological data that has not previously been available.

The golden king crab population in the Bering Sea is not currently surveyed and no estimate of abundance has been made. There are currently no plans to survey this population, nor has a harvest strategy been developed. Future deep water trawl surveys conducted by NOAA may provide some information regarding the status of this stock. Population size is believed to be limited by the amount of available habitat in the Bering Sea. BSAI golden king crab catches are summarized in Table 3.4-5.

Pribilof District

Golden king crab (*Lithodes aequispina)* in the Bering Sea District (Registration Area Q) are found in only a few deep canyons and have never sustained large harvests when compared to other Bering Sea king crab fisheries. As with many other crab fisheries in the Bering Sea, the fishery for golden king crabs was pioneered by foreign fishing fleets.

The first domestic harvest of golden king crabs in the Bering Sea occurred in June of 1982 when two vessels fished in the Pribilof District. Ten vessels fished during the following season, harvesting nearly 70,000 lbs. The size limit for golden king crabs in the Pribilof District was reduced from 6.5 inches to 5.5 inches in 1983. Effort in the Pribilof District peaked during the 1983/1984 season, when 50 vessels harvested 856,475 lbs. of golden king crab. Since then, no more than seven vessels have registered for this fishery in a given year and harvest has not exceeded 350,000 lbs. annually. The Pribilof District golden king crab fishery reached a maximum ex-vessel value of just over $1 million in 1995. During the last 15 years in the Pribilof District fishery, an average of three vessels have harvested an average of 147,000 lbs. annually. CPUE has averaged five legal crabs per pot lift, with average weight of 4 lbs. Most harvest in the Pribilof District has occurred in the area immediately to the south of the Pribilof Islands.

The 1999 season's Bering Sea golden king crab fishery was substantially different from previous seasons because increased sustained effort produced record catch rates. The season opened April 2, with three vessels registered; but the first landings did not occur until April 22. Initial catches were relatively large, averaging 25,000 lbs. per week with a CPUE of nearly 20 legal crabs per pot lift. Over one month after the first landing, catch rates were still well above the historic average at 14 legal crabs per pot lift.

These stronger than expected catches prompted ADF&G to develop an in-season GHL for the Pribilof District. A GHL of 200,000 lbs. was established, based on historic catch data and provisions of the FMP for the king and Tanner crab fisheries of the BSAI (NPFMC 1998a).

The fleet was notified of the newly created GHL on June 4. In-season reports from processors indicated that the GHL would be reached by June 10 and an emergency order was issued closing the fishery at noon on June 10. Harvest was 177,108 lbs. from nine landings. CPUE was 15 legal crabs per pot lift, and the average weight of retained crabs was 4 lbs.

Table 3.4-5 Total catches, in thousands of lbs. (includes deadloss), of Bering Sea and Aleutian Islands golden king crab, by management area, 1980-2000.

Year	Dutch Harbor	Adak District	Pribilof District	Saint Matthew
1980	Not available	59	0	Not available
1981	116	1,194	8	Not available
1982	1,185	8,006	70	Not available
1983	1,811	8,128	856	194
1984	1,521	3,180	0	0
1985	1,968	11,125	trace	0
1986	1,869	12,798	4	0
1987	1,383	8,001	26	424
1988	1,545	9,080	3	160
1989	1,852	10,162	7	4
1990	1,719	5,251	0	0
1991	1,448	6,254	6	0
1992	1,357	4,916	3	trace
1993	915	4,636	67	0
1994	1,750	6,378	89	13
1995	1,994	4,897	342	1
Aleutians Area O				
	East	**West**		
1996	3,263	2,592	329	conf.
1997	3,501	2,444	179	0
1998	3,248	1,691	36	0
1999	3,070	2,769	177	0
2000			127	0

Source: 2001 SAFE report.

The 2000 Pribilof District golden king crab fishery opened on January 1 with a GHL of 150,000 lbs. Three vessels began fishing in February; but most effort occurred in April and May after the Bering Sea snow crab fishery closed. Additional fishing occurred in August and September. A total of six vessels participated in the directed fishery and a seventh vessel registered to retain golden king crab bycatch during directed fishing efforts for grooved Tanner crabs (*Chionoecetes tanneri)*. The fleet harvested 127,217 lbs. Because the GHL was not reached, the fishery remained open until December 31, 2000. Catch rates ranged from five to eight legal crabs per pot lift and averaged five crabs per pot lift, a substantial decrease from the 1999 CPUE of 15 legal crabs per pot lift. Landed crabs averaged 4.4 lbs. per crab, a 10 percent increase from the 1999 average weight of 4 lbs. per crab. Nearly all of the 2000 harvest occurred in two statistical areas immediately to the south and southeast of St. George Island. Four shore-based plants in Dutch Harbor paid the fleet an average of $3.22 per lb. for live crabs. The 2000 Pribilof District golden king crab fishery had an ex-vessel value of $392,000.

Northern District golden king crab

A domestic fishery for golden king crabs in the St. Matthew Island Section of the Northern District also began in the 1982/1983 season. Effort and harvest in the Northern District has been sporadic. Since the initial fishery, harvest has only been documented during seven seasons. Harvest peaked during the 1987 season when 11 vessels harvested 424,394 lbs. Most of the golden king crab harvest in the Northern District occurred west of St. Matthew Island and no harvest has occurred since 1996. No harvest of golden king crabs has been documented from either the St. Lawrence Island or Norton Sound Sections.

Current pot limits in the Pribilof District are 40 pots for vessels 125 feet or less in length and 50 pots for vessels greater than 125 feet in length. In the Northern District, pot limits were set at 60 pots for vessels 125 feet or less in length and 75 pots for vessels greater than 125 feet in length. These pot limits are significantly lower than the average number of pots fished per vessel in the Aleutian Islands golden king crab fishery, which has no pot limits in place. The Northern District fishery has never been closed by emergency order.

3.4.1.5 Aleutian Islands red king crab

The Aleutian Islands king crab registration area, Area O, has an eastern boundary at the longitude of Scotch Cap Light (164°44'W), western boundary at the U.S.-Russia Convention line of 1867, and a northern boundary a line from the latitude of Cape Sarichef (54°36'N) to 171°W, north to 55°30'N and west to the U.S.-Russia Convention line of 1867.

Until the mid-1960's, red king crabs in the Aleutian Islands were harvested in two registration areas, Adak and Dutch Harbor, divided at the 171°W line. A third registration area, Area S, was established in 1967 for the waters around Amchitka Island and the Petrel Banks, but it was merged into Area R in 1978. At its March 1996 meeting, the BOF combined the Dutch Harbor and Adak Registration Areas into the Aleutian Islands king crab registration Area (Area O). This change was intended to improve management of increasingly important golden king crab stocks in the Aleutian Islands. It was not expected to affect management of red king crabs in the Aleutian Islands.

Domestic fisheries for red king crabs in both the Adak and Dutch Harbor Registration Areas started up in 1961. Effort and harvest increased rapidly. The Adak Area reached a peak harvest of 21 million lbs. in 1964/1965, and the peak in the Dutch Harbor Area was reached two years later with a harvest of 33 million lbs. Fluctuating harvest levels from one year to the next characterized these fisheries. By the 1982/1983 season, the Dutch Harbor fishery had declined to a harvest of 430,000 lbs. Commercial fishing for red king crabs in the Dutch Harbor Area was closed on an annual basis thereafter. The Adak fishery remained open until the 1995/1996 season, when only 39,000 lbs. were harvested.

Since the 1995/1996 season, commercial fishing for red king crabs has been closed in the Aleutian Islands with the exception of the 1998/1999 season, when ADF&G opened the area for a test fishery for stock assessment purposes. All crabs not harvested had to be tagged and released, vessel operators were required to document all red king crab fishing activities in a pilot house logbook, and observers were required on all participating vessels. The GHLs were set using historic catch information: east of 179°W, a GHL of 5,000 lbs. was established and west of 179°E, a GHL of 10,000 lbs. was set. Three vessels registered to harvest red king crabs, but only one recorded any landings. The GHL was not reached in either open area, and the fishery was closed by emergency order on July 31, 1999.

Besides commercial fisheries, longstanding subsistence and sport fisheries have targeted red king crabs in the vicinity of Unalaska Island. In order to address conservation concerns for the eastern Aleutian Islands red king crab stock, the BOF closed the sport fishery and reduced the daily bag limit of subsistence king crabs from six to one crabs per day, in the area between 168° and 164°44'W.

In 1999, ADF&G staff in Dutch Harbor issued 179 subsistence permits and harvest logsheets, of which 80 were returned. Estimates generated from the logsheets indicate that approximately 1,434 king crabs were taken, with harvest ranging from 0 to 131 king crab per permit. The majority of subsistence-caught king crabs were taken in Illiuliuk and Captain's Bays and most of the harvest occurred prior to the end of July. These harvest figures are substantially less than estimates generated by a 1994 survey of 15.1 percent of households in Unalaska, where 6,892 king crab were estimated to have been taken (ADF&G 1999b).

The commercial fishery for red king crabs in the Aleutian Islands did not open during the 1999/2000 or 2000/2001 season due to low stock abundance.

Fishery management and stock status

Recent harvest goals have been based on historic catch data, although in the late 1970's, a blend of pot survey results and fisheries data was used to set GHL ranges. Western Aleutian Islands pot surveys conducted from 1975 to 1977 provided CPUE, fecundity, and relative abundance information (ADF&G 1978). Pot surveys were conducted on an annual basis in the Dutch Harbor area until 1990, when trawl surveys were implemented to survey larger areas in a more timely fashion.

Most shellfish research in the Aleutian Islands has been directed at crab stocks inhabiting the eastern Aleutian Islands. Bottom trawl surveys of the waters around Unalaska Island were conducted in 1991, 1994, 1995, and 1999. Recent bottom trawl surveys have not captured large numbers of king crabs. In 1995, only two red king crabs were caught; thus no population estimate could be generated. During the 1999 survey, 72 red king crabs were caught, one of which was a legal male. All others were pre-recruit males and small females captured in a single tow made in Kalekta Bay (Worton 2000). This catch, while encouraging, does not appear to constitute a rebuilding event. The eastern Aleutian Islands were again surveyed by bottom trawl during the summer of 2000 and a single red king crab was captured (Worton in press), indicating that the red king crab population in the eastern Aleutian Islands remains severely depressed.

When red and golden king crab seasons are open concurrently, red king crabs may be retained from longlined brown king crab pots, provided the pots are fished in waters deeper than 100 fathoms. Otherwise, red king crabs may only be taken from red king crab pots fished in a single-line fashion. There is no pot limit for king crab fisheries in the Aleutian Islands. Observers have been required on all crab catcher/processor vessels since 1988 and on catcher vessels targeting red and golden king crabs in the Aleutian Islands since 1995. Observer coverage on golden king crab vessels provides red king crab bycatch data from that fishery, although such bycatch is minimal due to the limited overlap in distribution of the two species.

Most data available for red king crabs in the western Aleutian Islands do not indicate that stocks are recovering in that area. In order to address concerns for red king crab abundance in the Petrel Banks area, a combination fishery/survey was opened during the 2000/2001 season on the Petrel Banks. The survey specified stations to be fished, soak times, and effort levels. The fishery was limited by number of pot lifts per station and fishermen were permitted to retain all legal red king crab landed. Results of that fishery/survey will be used to address future management measures for red king crab in the western Aleutian Islands.

Given limited stock status information, future effort will be directed towards obtaining abundance data and developing a conservative rebuilding and management plan through the BOF and Crab Plan Team process. A decision to open the western Aleutian Islands red king crab fishery for the 2001/2002 season awaits review of the 2000/2001 fishery/survey results. Prior to reopening a full commercial fishery, ADF&G intends to develop a management plan for western Aleutian Islands red king crabs.

3.4.1.6 Aleutian Islands golden king crab

The golden king crab *(Lithodes aequispinus)* fishery in the Aleutian Islands is unique among Westward Region king crab fisheries in that it has never failed to open due to low stock abundance. Also, golden king crabs inhabit depths greater than where other commercially exploited king crabs are typically found (Blau et al. 1996). The depths and steep bottom topography in the inter-island passes inhabited by golden king crabs necessitates the use of longlined rather than single pot gear. There are no other major king crab fisheries in Alaska where longlined pot gear is the only legal gear type.

Historically, golden king crabs were taken as incidental bycatch in the Adak (west of 171°W) and Dutch Harbor (east of 171°W) Registration Areas. Directed fishing for golden king crabs began in the 1981/1982 season; until the 1996/1997 season, golden king crabs in the Aleutian Islands were harvested in two directed fisheries occurring in the Adak (Area R) and Dutch Harbor (Area O) Registration Areas (ADF&G 1984).

During the 1981/1982 season, 14 vessels landed 1.2 million lbs. of golden king crabs in 76 deliveries from the Adak Area. By the following season, harvest had reached 8 million lbs., with 99 vessels participating. Between 1981 and 1995, an average of 49 vessels participated in the Adak golden king crab fishery, harvesting an average of 6.9 million lbs. annually. Peak harvest in the Adak fishery occurred during the 1986/1987 season when 12.8 million lbs. of golden king crabs were harvested, for an ex-vessel value of $37.6 million. No stock assessment of the golden king crab population was performed in the Adak area, and initially the fishery was managed based on size, sex, and season restrictions. Catches were monitored in-season (ADF&G 1999b) and after the initial fishery, harvest levels were set based on harvest expectations generated from catch in prior seasons (ADF&G 1983b). The majority of golden king crabs harvested in the Adak Area were taken in the North Amlia and Petrel Banks Districts. The western Aleutian District was also productive.

From 1981/1982 to 1995/1996, the average weight of golden king crabs harvested in the Adak area fishery declined from 5.1 to 4.2 lbs. and CPUE declined from 17 to five legal crabs per pot pulled. In July 1985, the BOF adopted a regulation reducing the minimum legal size for golden king crabs from 6.5 to 6 inches CW. The expected decrease in average weight of legal crabs harvested occurred, and catch and CPUE increased over the 1985/1986 and 1986/1987 seasons. This regulation change did not, however, reverse the trend of slowly declining catch rates in the area west of 171°W.

Initial catches of golden king crabs in the Dutch Harbor Area were similar to those observed in the Adak Area fishery (ADF&G 1984). Harvest was incidental to the red king crab fishery and effort in the fishery increased only as red king crab stocks decreased in abundance. Six vessels harvested approximately 116,000 lbs. of golden king crabs during the 1981/1982 Dutch Harbor red king crab season. By the following season, 49 vessels were participating in the directed golden king crab fishery, accounting for a harvest of 1.2 million lbs. of golden king crabs. Between 1981 and 1995, an average of 18 vessels harvested approximately 1.5 million lbs. of golden king crabs annually. Peak golden king crab harvest in the Dutch Harbor area occurred during the 1995/1996 season when 2 million lbs. were harvested, for an ex-vessel value of $5.2 million. The Dutch Harbor stock was harvested primarily in the Islands of Four Mountains and Yunaska Island area.

In general, the average weight of golden king crabs harvested in the Dutch Harbor Area declined during the period from 1981 to 1995, ranging from a high of 7.6 lbs. in the 1983/1984 season to 4.1 lbs. during the 1992/1993 season. CPUE has slowly declined throughout the history of this fishery, reaching a peak of 14 legal crabs per pot during the 1984/1985 season and declining to six crabs during the 1994/1995 season. The golden king crab stock in the Dutch Harbor area was not surveyed for abundance prior to 1991 and the fishery was managed based on a historical average catch of 1.5 million lbs. (ADF&G 1999b). In 1984, the BOF adopted an ADF&G staff proposal to lower the legal size for golden king crab in the Dutch Harbor Area from 6.5 inches to 6 inches CW and to establish the area as a permit fishery.

At its March 1996 meeting, the BOF restructured its management of king crabs in the Aleutian Islands. With the decline of red king crab fisheries in the Aleutian Islands during the 1970's and 1980's and increasing importance of the golden king crab fishery, the BOF felt that king crab management areas in the Aleutian Islands should be redesignated to more accurately reflect current golden king crab stock distribution and patterns in fishing effort. After considering some alternative proposals, the BOF elected to eliminate the Adak and Dutch Harbor Areas entirely. In addition, the BOF directed ADF&G to manage the golden king crab stocks of the Aleutian Islands east and west of 174°W as two distinct stocks. The majority of fishing effort historically was directed at the more productive eastern stock in the vicinity of the Island of Four Mountains, Yunaska Island, and Amukta and Seguam Passes. The BOF directed the department to manage the eastern stock at a lower exploitation rate. A conservative management plan was initiated, and all vessels registered for the fishery were required to carry an onboard observer during all fishing activities.

The initial golden king crab fishery in the new Area O king crab Registration Area occurred in 1996/1997. GHLs of 3.2 million lbs. and 2.7 million lbs., respectively, were established for the areas east and west of 174°W. Compared to prior combined Adak and Dutch Harbor Area fisheries, effort and harvest were lower. Eighteen vessels harvested 5.9 million lbs., down from 28 vessels taking 6.9 million lbs. in 1995/1996. This reduction in effort is likely due to the departure of vessels for the Bristol Bay red king crab season, which reopened to commercial fishing in 1996 for the first time since 1993.

In the Aleutian Islands golden king crab fishery, the long-term trend in fishing effort is a decline in the number of vessels registered per season with increasing number of pots registered per vessel. With the legalization of longline gear in 1986, vessels became more specialized in fishing for golden king crabs and were able to more efficiently operate gear. The longline vessels tended to fish in the Aleutian Islands almost exclusively and forego some Bering Sea crab fisheries (ADF&G 1987). Effort and harvest have remained relatively stable in the Aleutian Islands east of 174°W, while the fishery west of 174°W has experienced greater variability in catch and effort.

2000-2001 fishery

The 2000/2001 Aleutian Islands (Area O) golden king crab fishery opened by regulation at 12:00 PM August 15. The opening date was moved to August 15 from September 1 by the BOF in July 1999 to accommodate golden king crab fishermen that also participate in the Bristol Bay red king crab fishery. The Bristol Bay red king crab fishery opening date had been moved from November 1 to October 15; thereby, reducing the amount of fishing time available to the golden king crab fleet prior to the Bristol Bay opening.

The 2000/2001 Aleutian Islands golden king crab fishery GHL of 5.7 million lbs. was allocated, as it had been the previous year, into eastern (3 million lbs.) and western (2.7 million lbs.) portions. Fifteen vessels participated in the eastern fishery and deployed 10,648 pots, an average of 710 pots per vessel. The fleet harvested approximately 393,000 lbs. per week with an average CPUE of ten legal crabs per pot lift, a slight increase from the prior year. The fishery closed on September 24 after 3.14 million lbs. had been taken. High demand for golden king crab resulted in an average ex-vessel price of $3.55 per lb. and a total fishery value of $11 million. This was $7 million less than the previous season, but it was still the highest value golden king crab fishery and second most valuable king crab fishery in the State.

Fishery management and stock status

The Aleutian Islands golden king crab fishery is managed using two sources of in-season fishery data: processors' weekly reports of landed catch; and vessel observers' reports of average weight and catch rate.

ADF&G surveyed a small portion of the golden king crab habitat in the Aleutian Islands during the summer of 1997. Prior to that, the department had performed the only survey of this area in 1991 (Blau and Pengilly 1994). Mark-recapture data from the 1997 survey suggested that the commercial fishery was annually removing a minimum of 20 percent of the legal male crabs present in the area surveyed. The FMP specifies that the golden king crab stock in the Aleutian Islands is considered overfished when F (the instantaneous fishing mortality rate) exceeds 0.2 (NPFMC 1998c). A fishing rate of F=0.2 corresponds to a mature male removal rate of approximately 18 percent.

The stations surveyed in 1997 were again surveyed in 2000. Tag recovery and harvest rate information from the 2000/2001 commercial fishery is currently unavailable; however, approximately the same number of crabs were tagged in 2000 as in 1997. Analysis of this survey and catch data will help the department to further refine harvest goals for the eastern Aleutian Islands golden king crab fishery.

Despite harvest rates that are at or near the allowable maximum in some areas, the Aleutian Islands golden king crab population is believed to be healthy since much recruitment occurs at depths greater than those fished. Additionally, the area recently surveyed receives more fishing pressure than many other areas in the Aleutian Islands, so golden king crabs in other less heavily fished locales are likely being harvested at rates lower than those reported here. In order to operate their gear more efficiently, fishermen tend to utilize the shallowest waters where crabs may be found in abundance. Distribution of legal males extends to depths greater than those fished, so the entire population of legal males is probably not fully exploited. The fishery data also indicates that the stock is healthy. Average size of crabs harvested has remained constant at 147 mm CL for the last three seasons. Average weight has declined 0.2 lbs. in the last three seasons; however, this could be due to both the removal of older and larger animals and zero recruitment. CPUE has also been stable and has been above the ten year average during the last two seasons. Currently, the department intends to survey the area around Amukta and Yunaska Islands every three years, with the next survey scheduled for the summer of 2003.

3.4.1.7 Bering Sea Tanner crab

The Bering Sea District of Tanner crab Registration Area J includes all waters of the Bering Sea north of Cape Sarichef at 54°36'N and east of the U.S.-Russia Convention Line of 1867. This district is divided into the Eastern and Western Subdistricts by a line at 173°W. The Eastern Subdistrict is further divided at the latitude of Cape Romanzof and 168°W into the Norton Sound Section to the east and the General Section to the west.

The first reported catches of Tanner crabs (*Chionoecetes bairdi)* occurred in 1968, incidental to the harvest of red king crabs in Bristol Bay. In 1974, a directed Tanner crab fishery began. Harvest peaked at 66.6 million lbs. during the 1977/1978 season. In the fall of 1978, NOAA Fisheries predicted sharp declines in Tanner crab abundance. By 1984, the commercial harvest had fallen to 1.2 million lbs. (Table 3.4-6). Further stock declines led to a fishery closure during the 1986 and 1987 seasons.

In 1992, in order to slow the harvest rate to improve in-season management, regulations were adopted that limited vessels fishing for Tanner crabs to no more than 250 pots. As happened with king crabs, these regulations were in conflict with federal law regarding nondiscriminatory application of pot limits. In 1993, the regulations were changed. Vessels 125 feet or under in overall length were limited to a maximum of 200 pots, while vessels longer than 125 feet in overall length were limited to a maximum of 250 pots.

In 1993, the BOF also adopted regulations which opened and closed part of the Eastern Subdistrict east of 168°W to Tanner crab fishing concurrently with the Bristol Bay red king crab season. The Eastern Subdistrict between 163° and 173°W for the directed Tanner crab fishery was mandated to reopen ten days after the closure of the Bristol Bay red king crab fishery or, if the Bristol Bay red king crab fishery failed to open, on November 1. These actions were intended to avoid excessive female king crab bycatch, and were based on observer data indicating that most female king crab bycatch in the Bristol Bay red king crab and Bering Sea Tanner crab fisheries came from waters east of 163°W.

As described earlier, the Bristol Bay red king crab fishery did not open in 1994 and 1995 due to low stock abundance. As a result, the Tanner crab fishery opened on November 1 in the Eastern Subdistrict, west of 163°W. The commercial Tanner crab harvest in 1994 was 7.8 million lbs., in 1995 the harvest declined to 4.2 million lbs. The decline intensified the following year. The GHL for the 1996 Tanner crab fishery was 8.4 million lbs., but the fishery was closed before that level was reached due to poor performance, a total of 1.8 million lbs. was harvested.

Based on the 1997 NOAA Fisheries surveys, which showed significant declines for both years in most segments of the Tanner crab population, the Bering Sea Tanner crab fishery was closed for the 1997 season (Table 3.4-7). Abundance of large male and female Tanner crabs continued to decline and reached the lowest level in the history of the survey in 1998 (Stevens et al. 1998). The stock remained below fishery threshold levels and the area remained closed to fishing from 1999 through 2001 (Table 3.4-7).

At the March 1999 BOF meeting, a revised harvest strategy was adopted as part of a comprehensive Bering Sea Tanner crab rebuilding plan. The harvest strategy for the Eastern Subdistrict specifies a threshold of 21 million lbs. of mature female biomass. No directed crab fishery is prosecuted when female biomass is below that threshold. When the mature female biomass is between 21 million and 45 million lbs., a maximum harvest rate of 10 percent is applied to molting mature males, or those mature male crabs likely to continue to grow, defined as 100 percent of new-shell and 15 percent of old-shell males greater than 112 mm CW.

When the mature female biomass is above 45 million lbs., the harvest rate is set at a maximum of 20 percent of molting mature males. When establishing a GHL, no more than 50 percent of the exploitable legal-size male abundance may be harvested. Separate GHLs are calculated for the areas east and west of 166°W. The minimum harvest threshold for opening the fishery is 4 million lbs.

Table 3.4-6 Abundance of legal males (≥5.5") (millions of crab), pre-season guideline harvest levels (millions of lbs.), and total catches (millions of lbs., including deadloss) of Bering Sea Tanner crab, 1980-2001.

Year	Abundance	Guideline Harvest Level	Catch
1980	26.2	28 - 36	36.6
1981	12.0	28 - 36	29.6
1982	8.2	12 - 16	11.0
1983	5.1	5.6	5.3
1984	4.7	7.1	1.2
1985	3.9	3.0	3.1
1986	2.6	0	0
1987	5.9	0	0
1988	14.3	5.6	2.2
1989	33.6	13.5	7.0
1990	45.1	72.3	64.6
1991	35.1	32.8	31.8
1992	41.8	39.2	35.1
1993	20.6	19.8	16.9
1994	15.4	7.5	7.8
1995	10.0	5.5	4.2
1996	9.2	6.2	1.8
1997	3.4	0	0
1998	2.2	0	0
1999	2.0	0	0
2000	4.9	0	0
2001	6.3	0	0

Source: NOAA Fisheries trawl survey data.

Table 3.4-7 Catch (includes deadloss), effort, and economic data from the Bering Sea Tanner crab fishery, 1989-2001.

Year	Catch	Number of Vessels	Number of Days	Number of pots	Price Per Pound	Total Value
1989	7.0	109	110	43,600	2.90	20,300,000
1990	64.6	179	89	46,400	1.50	90,000,000
1991	31.8	255	126	75,400	1.50	47,300,000
1992	35.1	294	137	85,400	1.69	58,800,000
1993	16.9	296	42	53,700	1.90	31,600,000
1994	7.8	183	20	38,600	3.75	28,500,000
1995	4.2	196	15	40,800	2.80	11,700,000
1996	1.8	135	12	30,000	2.50	4,500,000
1997	No Commercial Fishery					
1998	No Commercial Fishery					
1999	No Commercial Fishery					
2000	No Commercial Fishery					
2001	No Commercial Fishery					

Source: 2001 SAFE report.

2001 stock status

Continued low stock abundance resulted in continued closure for the Eastern District Tanner crab fishery in 2001. The NOAA Fisheries survey estimated 6.3 legal male crabs, a 28 percent increase from 2000; 17.3 million pre-recruits, a 4 percent decrease, and 13.2 million large females, also a 4 percent decrease. The legal male population increased from the previous year, but remained 86 percent lower than in 1990, and has essentially not changed for five years. Total mature biomass is below the minimum stock threshold. The decrease in pre-recruits reverses a perceived trend of moderate recruitment that had been observed over the previous few years (Rugolo et al. 2001; Stevens et al. 2000).

3.4.1.8 Eastern Aleutian Tanner crab

The eastern Aleutian Tanner crab management district encompasses all waters of Registration Area J between the longitude of Scotch Cap light at 164°44'W, west to 172°W, and south of the latitude of Cape Sarichef at 54°36'N.

The eastern Aleutian District has not supported harvests of Tanner crabs as large as those recorded in other districts of Area J (Table 3.4-8). Tanner crabs are found only in a few major bays and inlets of the eastern Aleutian Islands, and the directed fishery for them was relatively small in volume and geographically limited until the late 1970's. The fishery began in Akutan and Unalaska Bays and subsequently expanded to include all areas of known Tanner crab distribution in the eastern Aleutian District. Harvest of Tanner crabs over the last 26 years has typically remained under 1 million lbs. per year, exceeding that figure however in three consecutive seasons from 1976/1977 to 1978/1979, when it reached a peak of 2.5 million lbs. Vessel participation reached a high of 31 in 1982 when the fishery was in decline. Five vessels fished in 1991, when the harvest reached a low of 50,038 lbs. The eastern Aleutian Islands Tanner crab fishery reached a maximum ex-vessel value of approximately $950,000 in 1977/1978 and 1989. Commercial fishing for Tanner crabs has not been permitted in the eastern Aleutian District since 1994 due to low stock abundance.

Subsistence harvest limit reductions applied to the eastern Aleutian Islands red king crab fishery in 1999 were not applied to Tanner crabs. However, the permit and reporting requirements for subsistence harvest were reinstated. Between 1988 and 1994, an average of 15 subsistence permits per year were returned and accounted for approximately 121 Tanner crabs annually. A survey of 15.1 percent of Unalaska households in 1994 generated an estimated total subsistence Tanner crab harvest of 10,957 crabs (ADF&G 1999a). ADF&G staff in Dutch Harbor issued 179 subsistence permits in 1999, of which 80 were returned. Returned permits accounted for a Tanner crab harvest of 1,430 crabs and the estimated total harvest was 2,937 crabs. The majority of Tanner crab harvest occurred in Illiuliuk and Captain's Bays. Tanner crab harvest peaked in early July and continued until the permits expired on January 31.

Table 3.4-8 Total harvest (thousands of lbs.) of Tanner crab from the Aleutian Islands area, 1980-2000.

Year	Western	Eastern
1980	221	886
1981	839	655
1982	488	740
1983	384	548
1984	163	240
1985	207	166
1986	43	167
1987	141	160
1988	149	310
1989	49	326
1990	15	172
1991	8	50
1992	conf.	99
1993	0	119
1994	0	167
1995	0	0
1996	conf.	0
1997	0	0
1998	0	0
1999	0	0
2000	0	0

Fishery management and stock status

Prior to 1990, sporadic pot surveys were utilized to generate a Tanner crab abundance index in the eastern Aleutian Islands (Urban 1992). The pot surveys were not utilized to generate a GHL; instead they were used to monitor trends in abundance and recruitment. Pot surveys and fishery data yielded harvest levels of 0 to 250,000 lbs. (ADF&G 1983a). Since 1990, trawl surveys have been used to estimate abundance and are used in conjunction with fishery data for management.

Trawl surveys in 1990 and 1991 indicated that a surplus of 100,000 lbs. of Tanner crabs was available for harvest. Commercial fisheries that opened in 1991 and 1992 based on those surveys resulted in legal male harvest rates of approximately 33 percent. A 1994 trawl survey of the same location revealed that Tanner crab abundance had decreased by 87 percent since 1991. Results of the 1994 survey prompted the department to issue an emergency preventing the opening of the 1995 season (ADF&G 1999b). The 1995 survey found an increase in juvenile male and immature female crabs, but the abundance of legal male crabs was still very low (Urban 1996), thus the fishery closure was extended.

A trawl survey conducted in 1999 indicated that the biomass of Tanner crabs in the eastern Aleutian Islands had increased. Abundance increases were recorded for all size classes, with females and large males showing the greatest change. Female abundance had more than doubled from the 1995 survey estimate to 2.2 million crabs, and male crab abundance had increased nearly fourfold to just over 4 million crabs, of which approximately 0.4 million were legal size. The majority of the recruitment was observed in Akutan, Unalaska, and Makushin Bays (Worton 2000).

Because encouraging signs of recruitment were noted during the 1999 trawl survey, the department surveyed the eastern Aleutian Islands again in 2000. Much of the recruitment observed in Akutan Bay in 1999 was not encountered in 2000; thus, Tanner crab abundance declined (Worton, *in press*). The next trawl survey of the eastern Aleutian Islands is planned for the summer of 2003.

3.4.1.9 Triangle Tanner crab

Surveys of population abundance are not conducted for triangle Tanner crabs; thus the status of this stock is unknown. Because of the paucity of population level data for this species and the history of the fishery, additional fishing for triangle Tanner crabs in the eastern Aleutian District will be limited to bycatch during the grooved Tanner crab fishery. Vessels registered to fish for grooved Tanner crabs will be permitted to harvest triangle Tanner crabs at up to 50 percent of the weight of the target species as bycatch. This harvest level is consistent with the historical development of the fishery and allows retention of a deepwater species that is believed to be subject to high bycatch mortality.

3.4.1.10 Western Aleutian Tanner crab

The western Aleutian District of Registration Area J includes all waters west of 172°W, east of the U.S.-Russia Convention Line of 1867, and south of 54°36’N.

Harvest of Tanner crabs from the western Aleutian District has, in general, been incidental to the directed red king crab fishery in that area. Commercial harvest has ranged from a high of over 800,000 lbs. during the 1981/1982 season to less than 8,000 lbs. in 1991/1992. No commercial harvest of Tanner crabs has occurred in the western Aleutian District since 1995/1996. The western Aleutian District Tanner crab fishery reached a maximum value of just over $1 million in the 1981/1982 season. Tanner crab abundance in the western

Aleutian District is probably limited by available habitat. Most of the historical harvest occurred within a few bays in the vicinity of Adak and Atka Islands.

The western Aleutian District Tanner crab fishery has a regulatory opening date of November 1; however, the fishery was closed during the 2000/2001 season. The fishery was not opened because there is no BOF approved management plan in place, nor has sufficient population data been collected to develop a GHL.

Fishery management and stock status

No stock assessment surveys are conducted for Tanner crabs in the western Aleutian District; thus, no population estimates are available. Stock status is currently unknown. Historical fisheries were managed using GHLs set from commercial catch data (ADF&G 1985).

3.4.1.11 Bering Sea snow crab

Just as the first landings of Tanner crabs in 1968 were incidental to the catch of red king crabs, the first commercial landings of snow crabs *(Chionoecetes opilio)* from the Bering Sea, recorded in 1977, were incidental to the harvest of Tanner crabs. The reduced Tanner crab harvest in 1981 led to an increased snow crab harvest of 52.8 million lbs. in 1981, which initially fell, but in 1984 began to rise steadily. The harvest total was 98 million lbs. in 1986, and reached a peak of 328.6 million lbs. in 1991. Although stocks then began to decline, the snow crab harvest remained over 100 million lbs. through the 1994 season. In 1996, the catch declined to 65.7 million lbs., the lowest of the preceding 11 seasons (Table 3.4-9). The GHL more than doubled in 1997 to 117 million lbs. and the fleet harvested 119.5 million lbs. In the 1998 open access fishery, 229 vessels harvested 243.3 million lbs. Twenty-one vessels in the CDQ fishery, first implemented in 1998, harvested an additional 8.9 million lbs. of snow crab.

In 1999, the surveyed stock was 60 percent of the MSST, defined in the FMP as half the long-term average mature biomass. In response to significant stock declines, and in accordance with NOAA Fisheries guidelines for stock rebuilding, the harvest rate was reduced from its normal 58 percent to 22 percent. This reduction in the exploitation rate resulted in a GHL of 28.5 million lbs. for the 2000 season.

The 2000 snow crab fishery was originally scheduled to open at noon on January 15. However, by early January, a significant portion of the fishing grounds were covered with ice. Because of concerns over potential gear conflicts and gear loss in the limited fishing area available because of the sea ice, as well as the potential for increased handling mortality and loss of limbs of captured crabs, ADF&G, after consultation with industry, delayed opening the fishery until April 1.

The 2000 open-access fishery opened at noon on April 1 and closed at noon on April 8. A total of 229 vessels, including nine catcher/processors, made 287 landings and harvested 30.8 million lbs. in the 2000 fishery, approximately 17 percent over the GHL. Thirteen vessels in the CDQ fishery, which occurred after the open access fishery, harvested an additional 2.5 million lbs.

The ex-vessel price for snow crabs harvested in the 2000 fishery was two-tiered due to concerns for higher than normal old-shell crabs expected in the catch. Fishermen were offered $1.85 per lb. for clean, new-shell crabs and $1.00 per lb. for old shell, dirty, or dark crabs. Fishermen reported encountering high percentages of old-shell crabs in the first two days of the fishery, but thereafter located areas which contained predominantly new-shell animals. Based on an overall ex-vessel price of $1.81 per lb., the 2000 snow crab fishery was worth $55.1 million. This compares to an ex-vessel value of $0.88 per lb. and an overall fishery value in excess of $161 million in 1999.

Table 3.4-9 **Abundance of large males (millions of crab ≥4.0" from previous year's NOAA Fisheries trawl survey), pre-season guideline harvest levels (millions of lbs.), and total catches (millions of lbs., includes deadloss, but not CDQ) of Bering Sea snow crab, 1980-2002. Data from SAFE report.**

Year	Abundance	Guideline Harvest Levels	Catch
1980	Not available	Not available	39.6
1981	Not available	39.5 - 91.0	52.8
1982	Not available	16.0 - 22.0	29.4
1983	Not available	15.8	26.1
1984	Not available	49.0	26.8
1985	153	98.0	66.0
1986	75	57.0	98.0
1987	83	56.4	101.9
1988	151	110.7	134.0
1989	171	132.0	149.5
1990	187	139.8	161.8
1991	420	315.0	328.6
1992	484	333.0	315.3
1993	256	207.2	230.8
1994	135	105.8	149.8
1995	72	73.6	75.3
1996	69	50.7	65.7
1997	172	117.0	119.5
1998	306	234	239.9
1999	255	186.2	243.3
2000	94	26.4	30.8
2001	76	25.3	23.4
2002	78	25.6	30.3

2001 fishery[4]

In the spring of 2000, the BOF adopted a harvest strategy which reduced the exploitation rate on mature male crabs to a stepped rate depending on the effective spawning biomass. This rebuilding plan stipulates an exploitation rate of 16.875 percent of the mature male biomass when the spawning biomass is between 460.8

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[4] BAS ADF&G 2001 Bering Sea snow crab *(C. opilio)* Fishery Summary, HED on http://www.cf.adfg.state.ak.us/region4/shellfsh/crabs/catchval/01snow_c/op_sum01.htm

and 921.6 million lbs. The resulting GHL for the 2001 season was 25.3 million lbs. for the open access fishery and 2 million lbs. for the CDQ fishery.

The 2001 Bering Sea snow crab fishery opened by regulation at noon on January 15 and closed by emergency order at 11:59 PM on February 14. Preliminary processor reports indicated a harvest of 23 million lbs., or 91 percent of the GHL. A total of 207 vessels, including seven catcher/processors, participated in the 2001 fishery. Three floating processors also registered and purchased crabs on the grounds during and after the fishery. A total of five shore-based processors in Dutch Harbor, two in St. Paul, one in King Cove, and two in Kodiak also purchased and processed snow crabs.

Due to a price dispute, all catcher vessels remained in port until 4:00 PM on February 1, and agreed to wait 48 hours, or until 4:00 PM on February 3, before setting pots. As a result, harvest for the first 18 days of the season, 2.2 million lbs., was taken by the catcher/processor fleet of seven vessels. In-season catch projections indicated a daily harvest ranging from less than 60,000 lbs. on the first day of gear operations on January 17, to over 2.7 million lbs. harvested on February 12 and February 14. Although it appeared that the 25.3 million lb. GHL would be reached by the close, a weather forecast of hurricane force winds on the fishing grounds immediately after the closure caused many vessels to head for port a full 12 hours before the closure, so that the total catch fell short of the GHL.

Fishery performance, in numbers of crabs per pot pulled, increased steadily from 101 crabs per pot on January 17 to 201 crabs per pot on January 27 and then steadily declined throughout the remainder of the fishery. Daily CPUE remained below 100 crabs per pot in the final ten days of the fishery, partly because many smaller vessels fished east of the Pribilof Islands in areas which proved to be relatively unproductive. The overall projected fleet CPUE for the 2001 fishery, which lasted a total of 29 days (only 11 days of which all vessels were participating) was 85. This compares to a CPUE of 137 for the seven day long 2000 season.

The preliminary estimated average weight of crabs landed during the 2001 fishery, derived from observer samples and dockside interviews, is 1.4 lbs., one-tenth of a lb. higher than the average for the preceding two years. The higher average weight estimate for 2001 may be due in part to a large percentage of post-recruit crabs present in the population. Preliminary data indicates that crabs harvested from waters east of the Pribilof Islands weighed approximately 1.45 lbs., and crabs harvested west of the Pribilof Islands averaged about 1.35 lbs.

The ex-vessel value for snow crabs initially offered by processors on the day of tank inspections was $1.37 per lb. This offer was rejected by fishermen, who were hoping to obtain a higher price. Fishermen met almost daily to consider price offers by processors, which by January 26 had increased to $1.50 per lb., which fishermen rejected. On February 1, fishermen accepted $1.55 per lb. At that time fishermen agreed to wait 48 hours before setting any gear. This stand down period was intended to provide time for vessels in Dutch Harbor and King Cove to transit to the fishing grounds to ensure a fair start for all vessels. Based on an ex-vessel price of $1.55 per lb., the estimated 2001 snow crab fishery value is $35.9 million, compared to over $55 million in 2000.

Most vessels delivered to floating processors on the grounds, or to shore processors in the Pribilof Islands, Akutan, or Dutch Harbor. However, twenty vessels checked out to the port of King Cove and four to processors in Kodiak. Processing operations were completed at AFA processors by February 22; but non-AFA processors did not complete operations until February 26. No AFA processors reported reaching their processing caps in 2001.

Weather conditions in the Bering Sea throughout the 2001 fishery were extremely harsh. A number of storms, some generating hurricane force winds, combined with some of the largest tides of the year to produce extremely dangerous sea conditions. A number of vessels had wheelhouse windows blown out and other structural damaged caused by large waves. However, no vessels or lives were lost during the 2001 fishery. Sea ice was not a concern in 2001, and the main ice pack remained north of St. Matthew Island throughout the fishery.

2001 stock status

Analysis of the 2001 NOAA Fisheries summer trawl survey indicated the abundance index of large males at 77.5 million crabs, essentially unchanged from the previous year; pre-recruits at 281.1 million crabs, a 114 percent increase, and large females at 1,524 million crabs, close to the 2000 estimate. The abundance of legal males was at 46 percent of the previous 20-year average. The population is experiencing recruitment of crabs to smaller size groups, which may yield legal males in several years, conditional on losses to mortality and the fishery. The total mature biomass is above the minimum stock threshold, but significantly below the rebuilt threshold (Rugolo et al. 2001).

3.4.2 History of the BSAI crab fishery management plans

Pursuant to the Magnuson-Stevens Act, the Council has responsibility for preparing FMPs and amendments to FMPs for conservation and management of fisheries in the exclusive economic zone (EEZ) of Alaska. Prior to the Magnuson-Stevens Act, and through development of Federal fisheries management, the State of Alaska managed the commercial crab fisheries in the BSAI. On December 7, 1984, the Council adopted findings regarding fishery management policy which address the need for federal management of fisheries off Alaska. The Council found that the history of variation in the abundance of king and Tanner crab off Alaska, and the interstate nature of the crab fleet and heavy capitalization in crab fisheries, particularly in the Bering Sea, create a situation which demands the Federal management oversight contemplated by the Magnuson-Stevens Act. Prior to the

In January 1977, the Secretary of Commerce (Secretary) adopted and implemented a preliminary FMP for the foreign king and Tanner crab fisheries in the eastern Bering Sea. Under this plan, no foreign fishing for king crab was allowed and restrictions were continued on the foreign Tanner crab fishery.

After this initial action, the decision was made to coordinate federal management of crab fisheries with the State. This decision was based on a desire to optimize the use of limited State and federal resources and prevent duplication of effort by making use of the existing State management regime. The State has managed king crab fisheries inside and outside State waters since statehood in 1959. It also managed domestic Tanner crab fisheries since their inception in the Bering Sea in 1968, and in the Aleutian Islands in 1973. The State had an extensive existing management regime, under which it still manages crab today. The BOF is responsible for regulating and establishing policy for management of the crab fisheries for vessels regulated under the laws of the State. The State's regulatory system provides for extensive public input, ensures necessary annual revisions, is flexible enough to accommodate changes in resource abundance and resource utilization patterns, and is familiar to crab fishermen and processors. The State has made a substantial investment in facilities, communications, information systems, vessels, equipment, experienced personnel capable of carrying out extensive crab management, research, and enforcement programs.

From December 6, 1978, until November 1, 1986, the Council and the State jointly managed the Tanner crab fishery in the BSAI area and GOA, in accordance with the FMP for Commercial Tanner Crab Fishery off the Coast of Alaska. The Tanner crab FMP was approved by the Secretary and published in the Federal Register on May 16, 1978, (43 FR 21170) under the authority of the Magnuson-Stevens Act. Final implementing regulations applicable to vessels of the U.S. were published on December 6, 1978 (43 FR 57149). Final implementing regulations applicable to vessels of foreign nations were published on December 19, 1978 (43 FR 59075, 43 FR 59292). The Tanner crab FMP was amended nine times. To achieve its conservation and management objectives and to coordinate management effectively with the State, the FMP adopted many of the management measures employed by the State.

In October 1981, the Council and the State adopted a joint statement of principles for the management of domestic king crab fisheries in the BSAI area. This agreement formed the basis for interim management during the development of the BSAI king crab FMP. A final rule implementing the FMP was published on November 14, 1984 (49 FR 44998). Although the federal regulations implementing framework provisions of the FMP were effective, actual implementation of the management measures under the FMP was deferred pending acceptance of the delegation of authority of the Governor of Alaska. In a letter dated June 20, 1986, the Governor declined the delegation of authority. His principle objections to the delegation were: excessive

Federal oversight, uncertainties in the regulatory process, unnecessary governmental duplication, and concerns for the degree to which discretionary authority of the BOF would be constrained.

At the March 1986 meeting, the Council voted to suspend the implementing regulation for the Tanner crab FMP because it did not provide for management based on the best available scientific information, provide for timely coordination of management with the State, or conform to several of the Magnuson-Stevens Act's National Standards. Following the March meeting, the Council published management alternatives for public comment. Three major alternatives were: 1) State management with no federal FMP; 2) an FMP that delegates management to the State; or 3) an FMP with direct federal management. Three overriding concerns were evident in the public comments reviewed by the Council in September. Any management arrangement must provide efficient and effective management, conservation of the crab stocks, and fair access by all user groups to management's decision-making. The Council, at its September 1986 meeting, appointed a workgroup of both industry representatives and Council members to develop a comprehensive management approach for crab fisheries off Alaska that would address these concerns.

On November 1, 1986, NOAA Fisheries promulgated an emergency interim rule, at the request of the Council, to repeal the regulations implementing the Tanner crab FMP (51 FR 40027). On November 20, 1986, the Council workgroup met and recommended repeal of the Tanner crab FMP and its implementing regulations. The workgroup recommended that the Council's crab plan team draft a new FMP that includes both king and Tanner crabs, limit its scope to the BSAI area, and defer management to the State to the maximum extent possible.

At the December 1986 meeting, the Council accepted the recommendation of the Council workgroup to begin preparation of a new king and Tanner crab FMP that would replace both previous FMPs for the BSAI area, but not address king and Tanner crab fisheries in the GOA. The Council requested the Secretary to prepare and implement a Secretarial amendment repealing the Tanner crab FMP and its implementing regulations, to allow time for preparation, approval, and implementation of a new FMP for king and Tanner crabs in the BSAI area, and to prevent reinstitution of the Tanner crab FMP implementing regulations which did not conform to the Magnuson-Stevens Act national standards. A final rule was published on May 11, 1987, (52 FR 17577) implementing the Secretarial Amendment repealing the Tanner crab FMP.

The FMP for the Commercial King and Tanner Crab Fisheries in the BSAI was approved by the Secretary on June 2, 1989. The FMP was written as a cooperative FMP in an attempt to avoid problems that were encountered in the previous king and Tanner crab FMPs. It contains a general management goal with seven management objectives identified, and relevant management measures required to meet the objectives that are presented. Several management measures may contribute to more than one objective, and several objectives may mesh in any given decision on a case-by-case basis.

The management measures in the FMP are ones that have been used in managing the king and Tanner crab fisheries of the BSAI areas and have evolved over the history of the fishery. Additional analysis is encouraged in the FMP to determine if alternative management measures may be more appropriate. This FMP attempts to avoid unnecessary duplication of effort. It defers much of the management to the State, while the most controversial measures are fixed in the FMP and require FMP amendment changes. Federal management oversight to determine if an action is consistent with this FMP, the Magnuson-Stevens Act, and other applicable federal laws is also provided in the form of a review and appeals procedure for both State preseason and in-season actions and through formation of a Council Crab Interim Action Committee.

The Council has not developed an FMP for the GOA crab stocks because of the limited crab fisheries in federal waters. In years when there is a crab fishery in federal waters, the fishery is managed by the State along with the portion of the fishery in State waters.

In 1998, the Council revised and updated the FMP, and changed the title to FMP for BSAI King and Tanner Crabs (NPFMC 1998c). The Secretary approved the revised FMP on March 3, 1999 (64 FR 11390). The revised version of the FMP incorporates: six FMP amendments; catch data and other scientific information from the past ten years; and changes due to amendments to the Magnuson-Stevens Act and other laws, a Russian/U.S. boundary agreement, and a federal/State Action Plan. The revised FMP included Amendment 7 to specify criteria for identifying overfishing and when a crab stock is overfished.

Since the FMP was revised, NOAA Fisheries has approved Amendment 8 to establish EFH; Amendment 9, to extend the moratorium program; Amendment 10, to establish recency criteria for the crab license limitation program; Amendment 11, to implement a rebuilding plan for Tanner crab; Amendment 14, to implement a rebuilding plan for snow crab; Amendment 15, to implement a rebuilding plan for St. Matthew blue king crab; Amendment 13, to implement AFA sideboards; and Amendment 17 to implement a rebuilding plan for Pribilof Islands blue king crab. The Council is developing Amendment 12 to establish habitat areas of particular concern. Alternative 1, status quo, encompasses all of these FMP amendments. Each FMP amendment is described as follows:

BSAI Crab FMP Amendment 1 - Overfishing Definitions

Dates. Amendment 1 was adopted by the Council in September 1990. NOAA Fisheries published a notice of availability on November 30, 1990 (55 FR 49673). The notice of approval was published on March 4, 1991 (56 FR 8985). Effective date was February 26, 1991.

Purpose and need. In 1989, NOAA Fisheries issued revised guidelines for FMPs based on national standards (the 602 guidelines: 50 CFR Part 602). The 602 guidelines required that "Each FMP must specify, to the maximum extent possible, an objective and measurable definition of overfishing for each stock or stock complex covered by that FMP, and provide an analysis of how the definition was determined and how it relates to reproductive potential."

Regulation summary. Overfishing is defined for each king and Tanner crab stock in the BSAI area. For which sufficient data exist, overfishing is defined as the level of commercial harvest from directed (pot) and non-directed (trawl and pot) fisheries resulting in a fishing mortality rate (F) value that exceeds the fishing mortality rate that would yield the MSY known as F_{msy}.

Analysis. An environmental assessment (EA) analysis (final draft dated November 20, 1990) was prepared for this amendment. Four alternatives, including the status quo, were considered. The alternative chosen defined overfishing as a constant rate of fishing mortality in excess of F_{msy}. The other alternatives considered included a variable fishing rate, or a constant fishing mortality rate with a MSST set at 10 percent of the long-term average biomass. The variable rate alternative was not chosen due to data limitations, the extensive analysis required, and the development of new harvest strategies by the State. The threshold alternative was not chosen because it could not be determined if the 10 percent biomass could be estimated for most stocks, and whether this level of reserve would be a conservative measure.

Results. Since the amendment was approved, the fisheries for major BSAI crab stocks have fluctuated. Revised overfishing definitions were adopted under Amendment 7 in 1998. Amendment 7 implemented overfishing based on variable fishing mortality rates relative to biomass, and incorporated MSST. Some stocks are currently deemed overfished because their stock size is below thresholds established in Amendment 7.

BSAI Crab FMP Amendment 2 - Norton Sound superexclusive

Dates. Amendment 2 was adopted by the Council in January 1994. NOAA Fisheries published a proposed rule for Amendment 2 on March 4, 1994 (59 FR 10365). The final rule was published on June 1, 1994 (59 FR 28276). Effective date of implementation was June 27, 1994.

Purpose and need. The Norton Sound summer king crab fishery was established by the BOF in 1977 at the request of local residents, who wanted more employment and economic opportunities. The fishery had generally been prosecuted at low levels of participation. In 1993, a combination of factors lead to high participation which was expected to continue into the future. These factors are based primarily on the overcapitalized crab fleet and on participants' efforts to establish catch histories in the event individual fishing quotas were to be instituted.

Prior to the 1993 season, the BOF instituted numerous management measures to conserve the resource and allow fair harvest sharing opportunities. These included area closures, pot limits, and season adjustments. More recent management changes further restrict pot limits to 50 for vessels over 125 feet and 40 for vessels under 125 feet, change the season opening date to July 1 from August 1, and designate the fishery as superexclusive. This latter measure was rejected by the Secretary after the season began.

The intent of this measure was to allow for a slower paced fishery, full attainment of guideline harvest levels, longer seasons, and reduced administrative and enforcement costs. It also provided consistency between the FMP and State regulations.

Regulation summary. The FMP contains three categories of management measures: 1) specific federal management measures that require an FMP to change; 2) framework type management measures, with criteria set out in the FMP that the State must follow when implementing changes in State regulations; and 3) measures that may be freely modified by the State, subject to an appeals process or other Federal laws. This amendment added the Norton Sound superexclusive designation as a category one measure. The effect of superexclusive registration would be that vessels participating in this fishery could not participate in any of the other king crab fisheries managed under the federal crab FMP. Additionally, vessels fishing for king crab in Norton Sound could not fish in any other king crab fisheries of the State.

Analysis. An EA/Regulatory Impact Review/Initial Regulatory Flexibility Analysis (RIR/IRFA) analysis (final draft dated January 20, 1994) was prepared for this Amendment. Two management alternatives to the status quo were considered to remedy the aforementioned problems for this unique area: superexclusive registration and exclusive registration. Prior to this amendment the fishery was nonexclusive and any vessel could participate in it regardless of participation in other crab fisheries. Designation of superexclusive registration was chosen as the preferred alternative in that it would effectively limit participation by the most highly mobile large crab vessels resulting in a fishery consisting of smaller, less mobile vessels. Choosing the other alternative, exclusive registration, would prevent vessels from participating in other exclusive king crab fisheries such as Bristol Bay, but would not eliminate vessels from participating in nonexclusive fisheries such as Adak and the Bering Sea.

Results. Since the amendment was approved, the Norton Sound fishery has been prosecuted as a superexclusive fishery and remains a small boat fishery.

BSAI Crab FMP Amendment 3 - Research Plan

Dates. Crab FMP Amendment 3 (also groundfish FMP amendments 27/30) was adopted by the Council in June 1992, then reconsidered and adopted as revised in December 1993. NOAA Fisheries published a proposed rule on May 6, 1994 (59 FR 23664) and a final rule on September 6, 1994 (59 FR 46126). Effective date of implementation was October 6, 1994. Amendment 1 (which delayed implementation until 1997) to the research plan was announced on December 26, 1995 (60 FR 66755).

Purpose and need. The State crab observer program required that owners and operators of catcher/processor vessels and shoreside processing facilities participating in the crab fishery arrange for and pay for the cost of placing observers aboard their vessels and at their shoreside processing facilities. Each vessel or processor required to have observer coverage is responsible for the cost of obtaining the required observers from a certified contractor. The cost averaged between $5,800 and $7,100 per observer month in 1991. There were three problems identified for this method of paying for observer coverage. It was not an equitable system in that some operations payed for 100 percent coverage and others did not pay anything, and it may have resulted in a conflict of interest that could reduce the credibility of observer data. It also based observer coverage levels on a simple vessel length criterion, which likely does not result in the most efficient, appropriate coverage across all fisheries. The Research Plan was designed to address these problems. Industry support for such a change is demonstrated by the willingness and ability of the industry to convince Congress to amend the Act to allow the North Pacific Fisheries Research Plan to be established and paid for by a broad-based system of user fees. The proposed plan was to be applicable to the groundfish, halibut, and BSAI crab fisheries.

Regulation summary. The Magnuson-Stevens Act authorized the Council and the Secretary to establish a North Pacific Fisheries Research Plan which: 1) requires that observers be stationed on fishing vessels and at fish processing facilities, and 2) establishes a system of fees to pay for the cost of implementing the research plan. The Research Plan, as adopted under this amendment, contained four objectives and elements that included observer employment and contracts, observer duties, data collection and transmission, annual determination of coverage levels by fishery, in-season changes to coverage levels, establishment of an observer oversight committee, coordination between the NOAA Fisheries groundfish and ADF&G shellfish observer programs, a fee assessment (up to 2 percent of ex-vessel value of harvested fish), and details on fee collection and contingency plans in case of funding shortfalls.

Analysis. An EA/RIR (final draft dated March 22, 1994), together with an appendix section, was prepared for this amendment. Three alternatives including the status quo were considered. Under the status quo alternative, the authority to establish a research plan would not be used, existing observer coverage requirements and contracting arrangements would be used, and no observer program would be implemented for the halibut fishery. The alternative adopted provided for a research plan, and attendant fee on landings, to address problems identified with the existing observer program.

Results. Though the amendment was approved, it was never fully implemented. Instead, implementation was delayed one year, then replaced with a modified pay-as-you-go system for groundfish fisheries and status quo for crab fisheries. Start-up fees were collected by NOAA Fisheries in the first year of implementation (1995), but the Council repealed the Research Plan due to various concerns, including the possibility that the fee would not cover all necessary coverage levels. Fees were refunded following the repeal of the plan. Since that time, the Council has requested redevelopment of fee plan alternatives and will evaluate possible options through 2000 and 2001.

BSAI Crab FMP Amendment 4 - Moratorium

Dates. The final version of BSAI Crab FMP Amendment 4 was adopted by the Council in December 1994. NOAA Fisheries published a proposed rule for BSAI Groundfish FMP Amendment 23 and GOA Groundfish FMP Amendment 28, and Crab FMP Amendment 5 on May 12, 1995 (60 FR 25677). The final rule was published on August 10, 1995 (60 FR 40763). Effective date of implementation for most sections of the amendment was September 11, 1995.

Purpose and need. In 1987, concerned with excess harvesting capacity in the groundfish, crab, and halibut fisheries of the BSAI and GOA, the Council established a committee to examine the problem of overcapitalization. Upon concluding that allocation conflicts and overcapitalization would worsen under the current open access system, the committee recommended a limited access management approach for these three fisheries. Concerned with the potential for speculative entry into the fisheries during discussions of management alternatives, NOAA Fisheries published a control date notice of February 9, 1992. Anyone not having previously participated in the fisheries before that date would not be assured future access to the fisheries should a limited access system be adopted.

The purpose of this amendment was to provide for an interim measure to slow significant increases in the harvesting capacity of the groundfish and crab fishing fleets until a Comprehensive Rationalization Plan (CRP) could be implemented. The CRP, which continues to be developed by the Council, is intended to resolve the overall issue of overcapitalization on a long-term basis, and transition the fisheries from an open access management system to a more market-based, limited access system. Without the regulatory ability to institute a moratorium, the Council feared that potentially unlimited new entry into the fishery would exacerbate overcapitalization and hinder the ultimate development of a successful CRP. The anticipated short-term effects of the amendment included increasing economic benefits to fishermen and reducing the risk of overfishing.

Regulation summary. After several proposed moratoriums, the final rule required a moratorium permit for vessels within specific vessel categories that harvest groundfish and BSAI crab resources off Alaska. Generally, a vessel qualified for a moratorium permit if it made a legal landing of any moratorium species during the qualifying period of January 1, 1988 through February 9, 1992. In addition, a vessel that made a legal landing during the qualifying period, in either a groundfish or crab fishery, but not both, can cross over as a new vessel in the fishery in which it did not make a legal landing in the qualifying period provided: 1) it uses the same gear type in the new fishery as it used to qualify for the moratorium in the other fishery; or 2) it made a legal landing in the crossover fishery during the qualifying period and it uses only the same gear type it used in that period.

Analysis. A supplemental analysis (final draft dated February 1995) was prepared for the final resubmittal of the proposed moratorium for these amendments, which were originally approved by the Council in 1992. The supplemental analysis outlined the changes from the original moratorium proposal: revision of the qualification period, halibut and sablefish qualification, consideration of current participation, crossovers, and the appeals process. The analysis also indicated that the revised moratorium would allow 4,144 unique vessels in the crab and groundfish fisheries, about 1,800 more than the current participant fleet but significantly less than the 15,709 unique vessels that participated in the fisheries since 1978 that had the potential to re-enter if no action was taken.

Results. Since the amendment was approved, the Council has implemented the license limitation program (LLP) to limit entry into the groundfish and crab fisheries off Alaska. As anticipated, the LLP (Amendment 60 to the BSAI FMP/Amendment 58 to the GOA FMP/Amendment 10 to the BSAI Crab FMP) replaced the vessel moratorium established in these amendments starting in the 2000 fishing season. For general licenses, the base qualifying period established was January 1, 1988, through June 27, 1992, approximately four months longer than the moratorium qualification period, in order to be consistent with the Council's published cutoff date for qualification under the CRP. The LLP also required an area endorsement for the BSAI or the GOA, to provide for present participation in the fisheries (the qualifying period being January 1, 1992 through June 17, 1995). The moratorium established by Amendments 23 and 28 limited speculative entry into the fisheries while the LLP was being developed and approved, and kept the overcapitalization situation from worsening during development of the long-term CRP. In addition, the moratorium qualifications could be transferred to other vessels (provided that the length of the new vessel was the same or less than the original), and so helped provide a basis for the LLP transfer process.

BSAI Crab FMP Amendment 5 - License Limitation Program

Dates. NOAA Fisheries published a proposed rule for Crab FMP Amendment 5 on August 15, 1997 (62 FR 43866). The amendment was adopted with Amendment 39 to the BSAI Groundfish FMP and Amendment 41 to the GOA FMP. NOAA Fisheries published the final rule on October 1, 1998 (63 FR 52642). Effective date of implementation was January 1, 1999, except for some parts effective January 1, 2000.

Purpose and need. In 1992, the Council committed to rationalize the groundfish and crab fisheries and begin development of a CRP. The CRP was prompted by concerns that expansion of the domestic harvesting fleet, in excess of that needed to efficiently harvest the optimum yield, was burdening compliance with the Magnuson-Stevens Act and severely deteriorating the economic benefits derived from the crab and groundfish fisheries. The Council examined several management alternatives including, license limitation, individual fishing quota (IFQs), and more traditional measures, and determined that a limited entry program had the most potential to address the immediate overcapitalization problems of the industry. As a result, the Council approved the LLP in 1995, recognizing the need for further rationalization in the future.

The overall purpose of the LLP is to help resolve the competing, and oftentimes, conflicting needs of the domestic fisheries that developed under open access and to close the gap between fishing capacity and the available fishery resource. The LLP limits the number, size, and specific operation of vessels fishing crab and groundfish in the BSAI and GOA based on historical participation. During the design and refinement of the LLP, the Vessel Moratorium Program (VMP) was implemented to provide industry stability and curtail interim increases in fishing capacity. The intent was for the LLP to replace the VMP upon implementation.

The LLP Amendments also expanded the CDQ program by including in CDQ allocations a percentage of the total allowable catch (TAC) of groundfish and crab species in the BSAI that was not previously included in the existing CDQ programs for pollock, halibut, and sablefish.

Regulation summary. The final rule limited access to the commercial groundfish fisheries in the BSAI and GOA and commercial crab fisheries in the BSAI, except for demersal shelf rockfish east of 140°W and sablefish managed under the IFQ program. The rule provided for the following: issuance of a single type of groundfish license; LLP is not applicable to waters of the State; licenses would be issued to current owners (as of 6/17/95) of qualified vessels; licenses would be designated as catcher vessel or catcher/processor and with one of three vessel length classes; the crab and groundfish base qualifying period is January 1, 1988 through June 27, 1992 and the groundfish area endorsement qualifying period is January 1, 1992 through June 17, 1995; endorsement areas are defined as Aleutian Islands, Bering Sea, western GOA, central GOA, and Southeast Outside, or State waters shoreward of those endorsement areas; landing requirements for general license and area endorsement qualifications by vessel class; and additional provisions addressing crossover vessels, transfers, and vessel linkages. The rule also included in CDQ allocations 7.5 percent of the TAC of groundfish and crab in the BSAI that was not originally included in the CDQ programs for pollock, halibut, and sablefish.

Analysis. A final EA/RIR (dated September 1997) and several supplemental analyses considered the status quo and a general license limitation alternative. Out of a comprehensive list of elements and options the Council considered during the debates on LLP, the analysis identified one option for each component of a LLP to create the preferred alternative described above in the final rule. A supporting document also analyzed the differences between the vessel moratorium program and the LLP passed by the Council. The vessel moratorium was more liberal in terms of qualification criteria and the areas a vessel could fish. Under the moratorium, a vessel was only required to make one landing of a qualifying species between January 1, 1988 and February 9, 1992, and having met that criteria, the moratorium permit holders could fish groundfish in any federal waters off Alaska. Therefore, because the LLP had dual qualification criteria, many fewer vessels were expected to qualify than did for the moratorium.

Results. The LLP went into effect on January 1, 2000; thus, an evaluation of the program and the final number of license holders is not yet available. The LLP continues to be refined through subsequent amendments. The Council recently approved BSAI Amendment 60, GOA Amendment 58, and BSAI Crab Amendment 10 which amended the LLP to include: a crab recency requirement of one landing during January 1, 1996 through February 7, 1998 in addition to the general license and area endorsement qualifications; a requirement that the vessel name is included on the license; license designations for the type of gear authorized to harvest LLP groundfish as either trawl or non-trawl gear (or both); and a requirement that the vessel itself would be a specific characteristic of the license and could not be severed (i.e., the license could not be used on any other vessel). In addition, Amendment 67 to the BSAI FMP was approved by the Council in April 2000. This amendment requires a Pacific cod species and gear endorsement to fish in the BSAI fixed gear Pacific cod fishery, including recent participation criteria for the period 1995 to 1999, in addition to the general license and area endorsement qualifications.

BSAI Crab FMP Amendment 6 - Third Party Observer Program

WITHDRAWN - At the December 1997 meeting, the Council was scheduled to take action approving an alternative observer program structure - a Joint Partnership Agreement between NOAA and the Pacific States

Marine Fisheries Commission (PSMFC), which would have established PSMFC as a third party procurement point for observers. This was being considered as a replacement for the repealed Research Plan (crab FMP Amendment 3, and groundfish FMP Amendments 27/30), in an effort to address conflict of interest and other issues in the existing pay-as-you-go program structure. Due to legal concerns of PSMFC, this amendment was not approved by the Council and was never forwarded for Secretarial review. Instead, the existing pay-as-you-go program was extended for an additional time period, through the year 2000.

BSAI Crab FMP Amendment 7 - Revised Overfishing Definitions

Dates. Amendment 7 was adopted by the Council in June 1998. The notice of availability was published on December 1, 1998 (63 FR 66112) and notice of approval was published on March 9, 1999 (64 FR 11390). Effective date was March 3, 1999.

Purpose and need. The 1996 amendments to the Magnuson-Stevens Act defined the terms overfishing and overfished to mean a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the MSY on a continuing basis. Additionally, it requires that all FMPs specify objective and measurable criteria for identifying when the fishery is overfished and, in the case of a fishery which is approaching an overfished condition or is overfished, contain conservation and management measures to prevent overfishing and rebuild the fishery. The Magnuson-Stevens Act further required regional fishery management councils to submit amendments, by October 11, 1998, that would bring FMPs into compliance.

Regulation summary. MSY represents the average of sustainable yield over a suitable period of time, where sustainable yield is a fraction the total mature biomass (male and female) for a given year. The BSAI Crab Plan Team estimated MSY from the best scientific information available. However, the scientific information required to determine MSY was not available for several BSAI crab stocks. In these cases, proxy stocks have been used to estimate MSY. The MSY control rule for king and Tanner crabs is the mature biomass of a stock, or proxy thereof, exploited at a fishing mortality rate equal to a conservative estimate of natural mortality, M, which is M=0.2 for all king crab species and M=0.3 for all Tanner crab species. For BSAI crab, the MSY stock size is the average mature biomass observed over the past 15 years, from 1983 to 1997. Overfishing is defined for king and Tanner crab stocks in the BSAI as any rate of fishing mortality in excess of the maximum fishing morality threshold for a period of one year or more. Maximum fishing morality threshold, defined by the MSY control rule, is expressed as the MSY fishing mortality rate, F_{msy}=M. MSST is specified as one-half of the MSY stock size. If stock abundance falls below MSST, the stock is considered overfished and the guidelines specify that a rebuilding plan must be prepared for the stock.

Analysis. An EA (final draft dated February 1, 1999) was prepared for this amendment. Two alternatives including the status quo were considered. The alternative chosen was more conservative in that it consistently treats MSY as a limit rather than a target and, it is based on the best available scientific information.

Results. Several stocks of crabs are considered overfished because the stocks are below MSST. Rebuilding plans, as FMP amendments, have been developed for these species.

BSAI Crab FMP Amendment 8 - Essential Fish Habitat

Dates. NOAA Fisheries published EFH guidelines as interim final rule on December 19, 1997 (62 FR 66531). Crab FMP Amendment 8 was adopted by the Council in June 1998 along with EFH amendments for other FMPs (groundfish, salmon, scallops, and crab). NOAA Fisheries approved the amendment on January 20, 1999. The notice of approval was published on April 26, 1999 (64 FR 20216).

Purpose and need. The Magnuson-Stevens Act was amended in 1996 by the Sustainable Fisheries Act. The new act mandated that any FMP must include a provision to describe and identify EFH for the fishery, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat. EFH has been broadly defined by the act to include "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity"(see Figure 3.4-6). All eight regional councils are required to amend their fishery management plans by October 1998 to:

- identify and describe EFH for species managed under an FMP;
- describe adverse impacts to that habitat from fishing activities and non-fishing activities;
- recommend conservation and enhancement measures necessary to help minimize impacts, protect, and restore that habitat; and
- include conservation and enhancement measures necessary to minimize to the extent practicable, adverse impacts from fishing on EFH.

The purpose of this amendment is to provide for improved long-term productivity of the fisheries, to allow NOAA Fisheries and the Council to be more proactive in protecting habitat areas, and by alerting other federal and state agencies about areas of concern. Federal agencies engaging in activities that may adversely affect EFH must consult with NOAA Fisheries regarding those activities. NOAA Fisheries must, and the Council may, make suggestions on how to mitigate any potential habitat damage. The Council will be required to comment on any project that may adversely affect salmon habitat or habitat of any other anadromous fish (smelt, steelhead, etc.).

Regulation summary. The alternative adopted and approved, defined EFH as all habitat within a general distribution for a species life stage, for all information levels and under all stock conditions. A general distribution area is a subset of a species range. For any species listed under the ESA, EFH includes all areas identified as critical habitat. EFH was described in text, tables, and maps. Habitat areas of particular concern were identified as living substrates in shallow and deep waters, and freshwater habitats used by anadromous fish.

Analysis. An EA (final draft dated January 1999) and a background assessment report were prepared for this amendment. Three alternatives including the status quo were considered. The other alternative that was not chosen would have defined EFH only as areas of high concentration for each life stage. The alternative chosen was more conservative in that defining a larger area may offer more protection.

Results. Since the amendment was approved, NOAA Fisheries has been sued by a coalition of plaintiffs (Earthjustice Legal Defense Fund, Center for Marine Conservation, National Audubon Society, and other groups) who allege that the EFH amendment failed to meet statutory requirements (did not analyze the effects of fishing on habitat, and did not impose practicable measures to minimize impacts of fishing gear) and violated National Environmental Policy Act (NEPA).

BSAI Crab FMP Amendment 9 - Moratorium Extension

Dates. On November 13, 1998, NOAA Fisheries published the proposed rule for Amendment 9 to the crab FMP, Amendment 59 to the FMP for the groundfish of the BSAI, Amendment 57 to the FMP for groundfish of the GOA (63 FR 63442). Amendments 9, 59, and 57 were approved jointly by the Council in June 1998. The final rule was published on January 25, 1999 (64 FR 3651). Effective date of implementation was January 19, 1999.

Purpose and need. In 1987, concerned with excess harvesting capacity in the groundfish, crab, and halibut fisheries of the BSAI and GOA, the Council established a committee to examine the problem of overcapitalization. Upon conclusion that allocation conflicts and overcapitalization would worsen under the current open access system, the committee recommended a limited access management approach for these three fisheries. Concerned with the potential for speculative entry into the fisheries during discussions of management alternatives, the Council adopted crab FMP Amendment 4, Amendment 23 to the BSAI FMP, and Amendment 28 to the GOA FMP, which required a moratorium permit for vessels within specific vessel categories that harvest groundfish and BSAI crab resources off Alaska. Generally, a vessel qualified for a moratorium permit if it made a legal landing of any moratorium species during the qualifying period of January 1, 1988 through February 9, 1992.

The purpose of the original moratorium amendments was to provide for an interim measure to slow significant increases in the harvesting capacity of the groundfish and crab fishing fleets until additional measures, such as the LLP could be implemented. The LLP is part of a developing CRP intended to resolve the overall issue of overcapitalization on a long-term basis, and transition the fisheries from an open access management system to a more market-based, limited access system. Without a moratorium, the Council feared that potentially unlimited new entry into the fishery would exacerbate overcapitalization and hinder the ultimate development of a successful CRP.

The original amendments instituting the VMP were scheduled to expire on December 31, 1998. The LLP, intended to replace the VMP, would not be in effect until January 1, 2000. Therefore, regulatory action was necessary to extend the moratorium in order to eliminate the one-year lag time between the expiration of the moratorium and the beginning of the LLP.

Regulation summary. The final rule simply extended the VMP and the existing moratorium permits through December 31, 1999. The regulation also provided that no person could apply for a new moratorium permit after the original moratorium program expiration date of December 31, 1998, unless the application was based on a moratorium qualification that was used as a basis for obtaining a moratorium permit issued on or before that date.

Analysis. An RIR (final draft dated August 1998) was prepared for Amendments 59, 57, and 9. Two alternatives were considered: 1) allowing the VMP to expire (no action alternative), and 2) extending the program for one year. The analysis determined that although all of the impacts of a one-year lapse between the moratorium program and the LLP were not known, one potentially significant impact could be speculative entry into the affected fisheries by persons who would not qualify to fish under the moratorium program or the LLP. Because allowing new entry would exacerbate overcapitalization and the race for fish, the analysis determined that the no action alternative was inconsistent with the overall intent of comprehensive rationalization. The preferred alternative extended the moratorium for one year, allowing time for NOAA Fisheries to complete the design and implementation of the LLP.

Results. As anticipated, the LLP to limit entry into the groundfish and crab fisheries off of Alaska went into effect January 1, 2000, effectively replacing the VMP (the authorization for the LLP is contained in BSAI Amendment 60/GOA Amendment 58/BSAI Crab Amendment 10). For general licenses, the base qualifying period established was January 1, 1988, through June 27, 1992, approximately four months longer than the moratorium qualification period, in order to be consistent with the Council's published cutoff date for qualification under the CRP. The LLP also required an area endorsement for the BSAI or the GOA, to provide for present participation in the fisheries (the qualifying period being January 1, 1992 through June 17, 1995). The moratorium established by Amendments 23 and 28 and extended by Amendments 59, 57, and 9 limited speculative entry into the fisheries while the LLP was being developed and approved, and kept the overcapitalization situation from worsening.

BSAI Crab FMP Amendment 10 - License Limitation Changes

Dates. Amendment 10 was approved by the Council in October 1998, together with BSAI groundfish FMP Amendment 60 and GOA groundfish FMP Amendment 58. The Secretary issued implementing regulations for this amendment on September 24, 2001 (66 FR 48813).

Purpose and need. Following the approval of the original LLP program, industry members requested that the Council revise several of the provisions and qualification criteria, including adding a recent participation criteria for crab. BSAI Amendment 60, GOA Amendment 58, and BSAI Crab Amendment 10 encompass a package of changes focusing primarily on further capacity reductions and transferability restrictions, to tighten up the LLP before implementation.

Regulation summary. Five changes were adopted and approved under these amendments: 1) a requirement that the vessel itself would be a specific characteristic of the license and could not be severed (i.e., the license could not be used on any other vessel); 2) license designations for the type of gear authorized to harvest LLP groundfish as either trawl or non-trawl gear (or both); 3) rescission of the CDQ exemption and thus the requirement that CDQ vessels hold a crab or groundfish license; 4) the addition of a crab recency requirement which requires one landing during January 1, 1996 to February 7, 1998 in addition to the general license and area endorsement qualifications; and 5) allowance of limited processing (1 mt) for vessels <60 feet length overall with catcher vessel designations. The most significant addition under these amendments was the recent participation requirement of at least one landing in the king and Tanner crab fisheries between January 1, 1996 and February 7, 1998, which applied only to the base qualifying period under the crab LLP.

Analysis. An EA/RIR/IRFA (final draft dated July 1999) was prepared for these amendments. Six proposed actions were analyzed along with the status quo for each alternative, and the five changes outlined above were adopted. The change that was not approved would have clarified the Council's intent that catch history transfers be recognized, except those occurring after June 17, 1995, and where the owner of the vessel at that time was unable to document a vessel under Chapter 121, Title 46, United States Code (U.S.C.) NOAA-GC advised the Council that this action may violate foreign reciprocity agreements listed in the Magnuson-Stevens Act; therefore, the Council decided not to proceed with this proposed action.

Results. Amendment 10 reduced the number of licenses that can be used to participate in the overcapitalized crab fisheries; thus, providing further capacity restriction.

BSAI Crab FMP Amendment 11 - Tanner crab (C. bairdi) Rebuilding Plan

Dates. Amendment 11 was approved by the Council in October 1999. A notice of availability for this amendment was published on March 7, 2000 (65 FR 11973). The amendment was approved on June 8 and a notice as published on June 20, 2000 (65 FR 38216).

Purpose and need. NOAA Fisheries declared the Bering Sea stock of Tanner crab overfished on March 3, 1999, because the spawning stock biomass was below the MSST defined in Amendment 7 to the FMP (64 FR 11390). Amendment 7 specified objective and measurable criteria for identifying when all of the crab fisheries covered by the FMP are overfished or when overfishing is occurring. NOAA Fisheries notified the Council once NOAA Fisheries determined that the stock was overfished (64 FR 15308). The Council then took action to develop a rebuilding plan within one year. Amendment 11, the rebuilding plan, is an FMP amendment that accomplishes the purposes outlined in the national standard guidelines to rebuild the overfished stock. Furthermore, Amendment 11 specifies a time period for rebuilding the stock that satisfies the Magnuson-Stevens Act.

Regulation summary. The rebuilding plan approved by the Council in October 1999 contains the following three components to improve the status of this stock: a harvest strategy, bycatch control measures, and habitat protection measures. The rebuilding plan is estimated to allow the Bering Sea Tanner crab stock to rebuild, with a 50 percent probability, in ten years. The stock will be considered rebuilt when the stock reaches the MSY stock size level for two consecutive years. The revised harvest strategy should result in more spawning biomass, because more larger male crab would be conserved and fewer juveniles and females would die due to discarding. This higher spawning biomass would be expected to produce good year-classes when environmental conditions are favorable. Protection of habitat and reduction of bycatch will reduce mortality on juvenile crabs; thus, allowing a higher percentage of each year-class to contribute to spawning (and future landings).

Analysis. The Council prepared an EA for Amendment 11 (final draft date June 1, 2000) that describes the management background, the purpose and need for action, the management alternatives, and the environmental and the socioeconomic impacts of the alternatives. There was only one primary alternative examined in addition to the status quo. However this alternative (a rebuilding plan) contained numerous options for harvest strategies, bycatch controls, and habitat protection. The analysis suggested that the most important component of the rebuilding plan was the harvest strategy, and the option adopted included lower harvest rates at low biomass levels, and incorporated a threshold female biomass. The analysis did not indicate that further reducing bycatch or adding additional trawl closure areas would help to rebuild the population much faster.

Results. The Tanner crab stock remains below threshold, and no fishery has occurred since the fishery closure in 1997. However, signs of good recruitment are showing up in the surveys, so the stock is rebuilding, and a fishery is quite likely in the near future.

BSAI Crab FMP Amendment 13 - American Fisheries Act Implementation

Dates. BSAI Crab FMP Amendment 13, together with BSAI and GOA groundfish FMP Amendments 61/61 was approved by the Council in June 1999, and implemented by NOAA Fisheries via two emergency rules: 1) AFA permit requirements published on January 5, 2000, with an effective date of December 30, 1999, and 2) all other provisions of the AFA published on January 28, 2000 with an effective date of January 21, 2000. A permanent rulemaking to implement the provisions of the AFA, for 2001 and beyond, is expected to be implemented in the fall of 2000, following completion of an EIS.

Purpose and need. In October 1998 the U.S. Congress passed the AFA to achieve the following primary objectives: 1) remove excess capacity in the offshore pollock sector through the retirement of nine factory trawlers (through a combination of appropriated funding and a loan to the onshore sector); 2) establish U.S. ownership requirements for the harvest sector vessels; 3) establish specific allocations of the BSAI pollock quota as follows - 10 percent to the western Alaska CDQ program, with the remainder allocated 50 percent to the onshore sector, 40 percent to the offshore sector, and 10 percent to the mothership sector; 4) identify the specific vessels and processors eligible to participate in the BSAI pollock fisheries; 5) establish the authority and mechanisms by which the pollock fleet can form fishery cooperatives; and, 6) establish specific measures to protect the non-AFA (non-pollock) fisheries from adverse impacts resulting from the AFA or pollock fishery cooperatives. In addition, the AFA included provisions for the Council to enact measures as necessary to further protect non-AFA fisheries from adverse impacts resulting from the AFA and pollock fishery cooperatives. In addition to implementing the prescribed portions of the AFA, these Amendments contain various specific protective measures developed by the Council which limit the pollock industry's participation in other fisheries - these are referred to as sideboards.

Regulation summary. Regulations establish the sector allocations of pollock, define the eligible vessels and processors, define the vessel/processor co-op linkages (which vessels are eligible for which co-ops), make allocations of the pollock TAC among each of the co-ops, and define the sideboard amounts of crab and non-pollock groundfish (based on historical share) that can be harvested and processed by the AFA operators, in both the BSAI and the GOA.

Analysis. The original analysis for these Amendments, upon which the emergency rules are based, is 320 pages plus several appendices. That analysis focuses on alternatives for establishing sideboard limits for the AFA harvesters and processors, and also examines alternatives for the structure of inshore sector co-ops (the relationship between harvest vessels and the shore plants to which they deliver pollock). Primarily, the alternatives analyzed cover a wide range of options for determining the amount of the sideboard limits for each sector, whether such sideboards are applied at the sector level vs. individual vessel/plant level, and whether and to what extent there may be exemptions from the sideboards. The analysis also examines the ownership structure of the pollock industry to determine the entities and companies to which sideboards will be applied. Implementation and monitoring aspects of the various alternatives are also considered. The EIS further examined these issues as well as the prescribed measures of the AFA, including the specific sector allocations and limited entry aspects of the AFA.

Results. Under regulations implementing the AFA, a vessel is ineligible to participate in any BSAI crab fishery unless that specific vessel participated in a specific crab fishery during certain qualifying years. The AFA was fully implemented in 2000 via the emergency rules, with permanent implementing regulations (through at least 2004) expected in the fall of 2000. Several issues continue to consume a significant amount of NOAA Fisheries and Council resources, with various changes and regulatory amendments in the pipeline. Included are further consideration of the issues of inshore co-op structure, processing sideboards for crab and groundfish, recalculation of sideboard amounts, and consideration of further exemptions from sideboards. One indirect impact of the AFA is that other industry sectors are now pushing for co-op style management in their fisheries, through either Congressional mandate or through the Council process.

BSAI Crab FMP Amendment 14 - Snow Crab Rebuilding Plan

Dates. Amendment 14 was approved by the Council in June 2000. The Secretary approved this amendment in January 2001 (66 FR 742).

Purpose and need. NOAA Fisheries declared the Bering Sea stock of snow crab overfished on September 24, 1999, because the spawning stock biomass was below the MSST defined in Amendment 7 to the FMP (64 FR 11390). Amendment 7 specified objective and measurable criteria for identifying when all of the crab fisheries covered by the FMP are overfished or when overfishing is occurring. NOAA Fisheries notified the Council once NOAA Fisheries determined that the stock was overfished (64 FR 15308). The Council then took action to develop a rebuilding plan within one year. Amendment 14, the rebuilding plan, is an FMP amendment that accomplishes the purposes outlined in the national standard guidelines to rebuild the overfished stock. Furthermore, Amendment 14 specifies a time period for rebuilding the stock that satisfies the Magnuson-Stevens Act.

Regulation summary. The rebuilding plan approved by the Council in June 2000 contains the following three components to improve the status of this stock: a harvest strategy, bycatch control measures, and habitat protection measures. The rebuilding plan is estimated to allow the Bering Sea snow crab stock to rebuild to the B_{msy} level, with a 50 percent probability, in seven to ten years. The stock will be considered rebuilt when the stock reaches the MSY stock size level. The revised harvest strategy should result in more spawning biomass, because more larger male crab would be conserved and fewer juveniles and females would die due to discarding. This higher spawning biomass would be expected to produce good year-classes when environmental conditions are favorable. Protection of habitat and reduction of bycatch will reduce mortality on juvenile crabs, thus allowing a higher percentage of each year-class to contribute to spawning (and future landings).

Analysis. The Council prepared an EA for Amendment 14 (draft date June 19, 2000) that describes the management background, the purpose and need for action, the management alternatives, and the environmental and the socio-economic impacts of the alternatives. There was only one primary alternative examined in addition to the status quo. However this alternative (a rebuilding plan) contained numerous options for harvest strategies, bycatch controls, and habitat protection. The analysis suggested that the most important component of the rebuilding plan was the harvest strategy, and the option adopted included lower harvest rates at low biomass levels, and incorporated a threshold female biomass. The analysis did not indicate that further reducing bycatch or adding additional trawl closure areas would help to rebuild the population much faster.

Results. The snow crab stock remains low, but a reduced fishery has occurred every year. However, there are few signs of recruitment in the surveys, so the stock is expected to remain low in the near term.

BSAI Crab FMP Amendment 15 - St. Matthew Blue King Crab Rebuilding Plan

Dates. Amendment 15 was approved by the Council in June 2000. A notice of availability for this amendment was published on August 29, 2000 (65 FR 52405). The Secretary approved this amendment in December 2000 (65 FR 76175).

Purpose and need. NOAA Fisheries declared the St. Matthew blue king crab overfished on September 24, 1999, because the spawning stock biomass was below the MSST defined in Amendment 7 to the FMP (64 FR 11390). Amendment 7 specified objective and measurable criteria for identifying when all of the crab fisheries covered by the FMP are overfished or when overfishing is occurring. NOAA Fisheries notified the Council once the stock was determined to be overfished (64 FR 15308). The Council then took action to develop a rebuilding plan within one year. Amendment 15, the rebuilding plan, is an FMP amendment that accomplishes the purposes outlined in the national standard guidelines to rebuild the overfished stock. Furthermore, Amendment 15 specifies a time period for rebuilding the stock that satisfies the Magnuson-Stevens Act.

Regulation summary. The rebuilding plan approved by the Council in June 2000 contains the following three components to improve the status of this stock: a harvest strategy, bycatch control measures, and habitat protection measures. The rebuilding plan is estimated to allow the St. Matthew blue king crab stock to rebuild to the B_{msy} level, with a 50 percent probability, in about six years. The stock will be considered rebuilt when the stock reaches the MSY stock size level for two consecutive years. The revised harvest strategy should result in more spawning biomass, because more larger male crab would be conserved and fewer juveniles and females would die due to discarding. This higher spawning biomass would be expected to produce good year-classes when environmental conditions are favorable. Protection of nearshore habitat for egg bearing females was accomplished through a prohibition of crab fishing within three miles of St. Matthew Island, Hall Island, and Pinnacle Island. Reduction of bycatch will reduce mortality on juvenile crabs; thus, allowing a higher percentage of each year-class to contribute to spawning (and future landings).

Analysis. An EA was prepared for Amendment 15 (draft date July 31, 2000) that describes the management background, the purpose and need for action, the management alternatives, and the environmental and socio-economic impacts of the alternatives. There was only one primary alternative examined in addition to the status quo. However this alternative (a rebuilding plan) contained numerous options for harvest strategies, bycatch controls, and habitat protection. The analysis suggested that the most important component of the rebuilding plan was the harvest strategy, and the option adopted included lower harvest rates at low biomass levels, and incorporated a threshold female biomass. The analysis did not indicate that further reducing bycatch would help to rebuild the population much faster.

Results. The St. Matthew blue king crab stock remains at low levels, and the fishery remains closed. However, there are few signs of recruitment in the surveys, so the stock is expected to remain at low levels in the near future.

BSAI Crab FMP Amendment 17 - Pribilof Blue King Crab Rebuilding Plan

Dates. Amendment 17 was approved by the Council in October 2003. A notice of availability for this amendment was published on December 18, 2003 (68 FR 70484). The Secretary approved this amendment on March 18, 2004 (69 FR 17651).

Purpose and need. On September 23, 2002, NOAA Fisheries declared the Pribilof Islands stock of blue king crab overfished because the 2002 abundance estimate of 4.5 million pounds of spawning biomass was below the MSST of 6.6 million pounds (67 FR 62212). NOAA Fisheries notified the Council once the stock was determined to be overfished. The Council then took action to develop a rebuilding plan within one year. Amendment 17, the rebuilding plan, is an FMP amendment that accomplishes the purposes outlined in the national standard guidelines to rebuild the overfished stock. Furthermore, Amendment 17 specifies a time period for rebuilding the stock that satisfies the Magnuson-Stevens Act.

Regulation summary. The rebuilding plan approved by the Council in October 2003 contains a harvest strategy to improve the status of this stock. The rebuilding plan is estimated to allow the Pribilof blue king crab stock to rebuild to the B_{msy} level, with a 50 percent probability, in about nine years. The stock will be considered rebuilt when the stock reaches the MSY stock size level for two consecutive years. The revised harvest strategy should result in more spawning biomass, because more larger male crab would be conserved and fewer juveniles and females would die due to discarding. This higher spawning biomass would be expected to produce good year-classes when environmental conditions are favorable.

Analysis. An EA was prepared for Amendment 17 that describes the management background, the purpose and need for action, the management alternatives, and the environmental and socio-economic impacts of the alternatives. This stock is somewhat unique in that it is already protected by the following Council, State of Alaska, and NMFS management measures:

- The Pribilof blue king crab fishery has been closed since 1999;
- The Pribilof habitat conservation area protects blue king crab habitat from trawl gear; and
- No bycatch of Pribilof blue king crab occurs in other fisheries.

The Council, working with the State and NMFS, developed three alternative rebuilding strategies. These strategies included Alternative 1, the status quo management of this fishery, Alternative 2, a rebuilding plan which allows for some directed harvest prior to the stock being rebuilt, and Alternative 3, a rebuilding plan which allows for no directed harvest prior to the stock being rebuilt. Options under each alternative include a range of thresholds for opening the fishery, a range of harvest strategies for the directed fishery, and conservative time periods above the designated threshold for opening the fishery. The analysis suggested that the most important component of the rebuilding plan was the harvest strategy, and the option adopted included lower harvest rates at low biomass levels, and incorporated a threshold female biomass. The analysis did not indicate that further reducing bycatch would help to rebuild the population much faster.

Results. The Pribilof blue king crab stock remains at low levels, and the fishery remains closed. However, there are few signs of recruitment in the surveys, so the stock is expected to remain at low levels in the near future.

3.4.3 Profile/description of the BSAI crab industry

Complete profiles and descriptions of the BSAI crab industry are contained in the RIR/IRFA in Appendix 1. The information contained below is a summary of that information.

3.4.3.1 Harvesting sector

Description of fleet

License Limitation Program. Fishing under the crab LLP began in January 2000. Interim licenses were issued if any part of a person's claim is contested. Interim licenses are temporary and the total number of licenses will decrease as interim licenses are denied or licenses are granted and made permanent. The number of LLP licenses provides an indication of the maximum possible number of participants in the BSAI crab fisheries. The LLP license includes the mode of operation and the maximum length overall of the vessel on which the license may be used.

As of December 2001, there were a total of 442 crab LLP licenses, 338 of which were permanent and 104 of which were interim. Of the 442 crab LLP licenses, 428 (approximately 93 percent) allow operation as a catcher vessel, while the remaining 33 (approximately 7 percent) allow operation as a catcher/processor.

Each crab LLP licenses carries one or more area/species endorsements. Approximately 80 percent of the crab LLP licenses carry an endorsement for the Bering Sea *C. opilio* and *C. bairdi* fisheries. Approximately 80 percent of crab LLP licenses also carry endorsements for the Bristol Bay red king crab fishery. Almost 50 percent of the crab LLP licenses are endorsed for St. Matthew Island blue king crab, 36 percent are endorsed for Pribilof Islands king crab, and less than 20 percent of the licenses are endorsed for the Norton Sound king, Aleutian Island red king, and Aleutian Island golden king crab fisheries.

Participation and harvests

This section provides general background information concerning the participation patterns of vessels harvesting crab in the BSAI fisheries from 1991 to 2000. The analysis examines both the participation and division of harvests between vessels that qualified for an LLP license with an endorsement in the appropriate fishery and vessels that do not meet the qualification for an LLP license in the fishery. In addition, a discussion of the ex-vessel gross revenues is included for each fishery.[1]

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[1] The estimated ex-vessel gross revenues include an amount that is the estimated to account for catcher/processor harvests. It should be noted that catcher/processors do not generate an ex-vessel revenue. The amount included as a proxy for the catcher/processor harvests is equal to the average price paid to catcher vessels times catcher/processor harvests. Since catcher/processors do not purchase or sell crab, instead they harvest and process the crab onboard to a first wholesale level, this amount is only an estimate of the value of unprocessed crab harvested by catcher/processors and is included only to provide an estimate of the total fishery. This report includes this proxy for catcher/processor harvests, in part, to maintain consistency with the Annual Management Report of ADF&G, which includes those estimated revenues of catcher/processor harvests in the estimated gross revenues from each fishery.

Table 3.4-10 LLP licenses in the Bering Sea and Aleutian Islands crab fisheries.

Aleutian Island Brown king endorsement: 41 licenses

	Non-Interim C/P	Non-Interim CV	Non-Interim Total	Interim C/P	Interim CV	Interim Total
MLOA < 60	0	0	0	0	0	0
MLOA >=60 & <125	0	13	13	0	7	7
MLOA >= 125	6	8	14	2	5	7
Total	6	21	27	2	12	14

Aleutian Island Red king endorsement 46 licenses

	Non-Interim C/P	Non-Interim CV	Non-Interim Total	Interim C/P	Interim CV	Interim Total
MLOA < 60	0	0	0	0	2	2
MLOA >=60 & <125	0	17	17	0	13	13
MLOA >= 125	3	4	7	1	6	7
Total	3	21	24	1	21	22

BSAI *Opilio/Bairdi* Tanner endorsement: 353 licenses

	Non-Interim C/P	Non-Interim CV	Non-Interim Total	Interim C/P	Interim CV	Interim Total
MLOA < 60	0	5	5	0	9	9
MLOA >=60 & <125	1	161	162	1	55	56
MLOA >= 125	26	67	93	5	23	28
Total	27	233	260	6	87	93

BSAI Bristol Bay red king endorsement 349 licenses

	Non-Interim C/P	Non-Interim CV	Non-Interim Total	Interim C/P	Interim CV	Interim Total
MLOA < 60	0	2	2	0	3	3
MLOA >=60 & <125	1	165	166	1	57	58
MLOA >= 125	25	67	92	5	23	28
Total	26	234	260	6	83	89

Norton Sound red/blue king endorsement: 64 licenses

	Non-Interim C/P	Non-Interim CV	Non-Interim Total	Interim C/P	Interim CV	Interim Total
MLOA < 60	0	57	57	0	3	3
MLOA >=60 & <125	0	2	2	0	2	2
MLOA >= 125	0	0	0	0	0	0
Total	0	59	59	0	5	5

Pribilof red/blue king endorsement: 158 licenses

	Non-Interim C/P	Non-Interim CV	Non-Interim Total	Interim C/P	Interim CV	Interim Total
MLOA < 60	0	9	9	0	4	4
MLOA >=60 & <125	0	74	74	0	31	31
MLOA >= 125	2	25	27	0	13	13
Total	2	108	110	0	48	48

St. Matthew blue king endorsement: 213 licenses

	Non-Interim C/P	Non-Interim CV	Non-Interim Total	Interim C/P	Interim CV	Interim Total
MLOA < 60	0	0	0	0	0	0
MLOA >=60 & <125	1	91	92	1	37	38
MLOA >= 125	13	49	62	2	19	21
Total	14	140	154	3	56	59

Notes: C/P - catcher/processor
CV - catcher vessel
MLOA - maximum length overall

Bering Sea C. opilio

The number of qualified and non-qualified vessels in the Bering Sea *C. opilio* fishery has remained fairly constant throughout the 1990's. The number of qualified vessels increased slightly during the first half of the decade to a high of 231 in 1994, followed by a gradual decline to 205 vessels in the latter half of the decade. The number of non-qualified vessels was 34 in 1991 and 23 in 2000. The fleet composition is primarily catcher vessels. In 1991 there were 174 qualified catcher vessels and 17 qualified catcher/processors. Ten years later there were 197 catcher vessels and eight catcher/processors. Non-qualified catcher vessels and catcher/processors numbered 27 and nine during the 1991 season, while in 2000 there were 22 catcher vessels and one catcher/processor. Over the ten seasons, the percent of qualified to non-qualified vessels increased from 85 to 90 percent.

The fishery during the last ten years has seen a gradual decline in harvest and gross revenues punctuated by a short and dramatic increase in 1996 and 1997 followed by a dramatic decline in the years following. In 1991, qualified vessels harvested 277 million lbs. and non-qualified vessels harvested 48 million lbs. Ten years later, 27 million lbs. and three million lbs. were harvested by qualified and non-qualified vessels, respectively. In 1991, ex-vessel gross revenues of qualified vessels were $140 million and ex-vessel revenues of non-qualified were $24 million. Ten years later, ex-vessel revenues of qualified vessels were $51 million and ex-vessel revenues of non-qualified vessels was $5 million.

Over the past ten years, the percent of pounds harvested by qualified vessels in relation to non-qualified vessels has increased moderately. During the 1991 season, 85 percent of the total pounds harvested was by qualified vessels. Ten years later, the harvest by qualified vessels increased to 90 percent.

Bristol Bay red king crab

With the exception of the 1996 season, the number of qualified and non-qualified vessels in the Bristol Bay red king crab fishery has remained fairly constant throughout the 1990's. The fishery was closed during the 1994 and 1995 season. In 1991, there were 244 qualified vessels and 54 non-qualified vessels. Following the reopening of the fishery in 1996, the number of qualified vessels dropped to 179, while non-qualified vessels declined to 15. In the years following the 1996 season, the number of qualified and non-qualified vessels increased to levels seen before the closure. In the last three years, the number of qualified vessels has declined slightly from 241 in 1998 to 213 in 2000, while non-qualified vessels declined from 33 to 31. The majority of vessels in the Bristol Bay red king crab fishery are catcher vessels. In 1991, there were 232 qualified catcher vessels and 41 non-qualified catcher vessels. During the same season, there were 12 qualified and 13 non-qualified catcher/processors. However, unlike the catcher vessels which show only slight variation, the number of catcher/processors over the years has declined dramatically. During the 2000 season, there were only six qualified catcher/processors and there were no non-qualified catcher/processors.

The Bristol Bay red king crab fishery from 1991 to 2000 has been marked with fluctuating harvests with no discernable trend. During this period, total harvest ranged between 7 million to16 million lbs. In 1991, qualified vessels harvested 14 million lbs., while non-qualified vessels harvested 2.6 million lbs. In 2000, 7 million lbs. and 0.8 million lbs. were harvested by qualified and non-qualified vessels, respectively. In the most recent three years, total harvest declined from 14 million lbs. to 7.5 million lbs. Earnings also show no discernable trend. During the 1991 season, ex-vessel revenues of qualified vessels were $46 million and ex-vessel revenues of non-qualified vessels were $9 million. Ten years later, ex-vessel revenues of qualified vessels were $32 million and ex-vessel revenues of non-qualified vessels were $3 million.

Over the past ten years, the percent of pounds harvested by qualified vessels in relation to non-qualified vessels has increased very moderately. During the 1991 season, 84 percent of the total pounds harvested was by qualified vessels. Ten years later, the harvest by qualified vessels increased to 90 percent.

Bering Sea C. bairdi Tanner crab

The Bering Sea *C. bairdi* Tanner crab fishery can be characterized as having two different participation patterns for qualified and non-qualified vessels during the 1991 to 1996 time period. From the 1991-1992 to 1993-1994 seasons, qualified vessel participation was between 234 to 249, while non-qualified participation was between 45 and 51. After the 1993-1994 season, qualified vessel participation was between 171 and 186, while non-qualified vessels was between 10 to 15. The fishery is composed mostly of catcher vessels. During the 1991-1992 season, there were 222 qualified and 37 non-qualified catcher vessels. During that same period, there were 14 qualified and 15 non-qualified catcher/processors. In 1996, the last year the fishery was open, there were 177 qualified and 15 non-qualified catcher vessels and four qualified and no non-qualified catcher/processors. Over the six seasons, the percent of qualified to non-qualified vessels increased from 82 to 92 percent.

The Bering Sea *C. bairdi* fleet has seen a dramatic decline in harvest and earnings during the 1992 to 1996 time period. The best season during the six year period was 1992-1993 where 30 million lbs. was harvested by qualified vessels. During that same period, non-qualified vessels harvested 4 million lbs. Just four seasons later, 1.7 million lbs. and 0.1 million lbs. were harvested by qualified and non-qualified vessels, respectively. Fleet earnings faired no better. During the 1992-1993 season, ex-vessel revenues of qualified vessels were $50 million, while ex-vessel revenues of non-qualified vessels were $7 million. In 1996, total ex-vessel revenues of qualified vessels were $4 million, while ex-vessel revenues of non-qualified vessels were $0.3 million.

Over the period of six seasons, the percent of pounds harvested by qualified vessels in relation to non-qualified vessels has increased. During the 1991-1992 season, 82 percent of the total pounds harvested was by qualified vessels. Four years later, the harvest by qualified vessels increased to 94 percent.

Pribilof red king crab

During the 1993 to 1998 period, the Pribilof red king crab fishery has experienced a decline in the number of qualified vessels, while non-qualified participants has remained near the same level. The fishery was closed during the 1999 and 2000 seasons. During the five years the fishery was open, qualified vessels declined from a high of 93 in 1993 to 41 in 1998. Non-qualified vessel participation peaked in 1995 at 41, but during subsequent years, vessel participation ranged between 16 to 21. The percent of qualified vessels to non-qualified vessels increased over the five year period. In 1993, 80 percent of the total vessels were qualified vessels, while in 1998 qualified vessels had decreased to 72 percent. The fishery is composed almost entirely of catcher vessels, with only two qualified catcher/processors participating in the 1993 fishery. There were no non-qualified catcher/processors during the 1993 to 1998 period.

Harvest and earnings during the 1993 to 1998 time period has steadily declined. In 1993, qualified harvest was 2 million lbs. and non-qualified harvest was 0.3 million lbs. Six years later harvest had declined to 0.4 million for qualified vessels and 0.1 million lbs. for non-qualified vessels. Ex-vessel gross revenues declined rapidly from a high of nine million dollars in 1995 to one million dollars in 1998 for qualified vessels, while ex-vessel revenues of non-qualified vessels dropped from one million dollars to $0.3 million. The share of qualified to non-qualified pounds declined from 89 percent in 1993 to 74 percent in 1998.

Pribilof blue king crab

The Pribilof blue king crab (*P. platypus*) can be characterized as a fishery with declining participants during the 1995 to 1998 period. The fishery was closed during the 1993 and 1994 seasons and again during the 1999 and 2000 seasons. During the four years the fishery was open, qualified vessels declined from a high of 76 in 1995 to 35 in 1997. Non-qualified vessels declined from a high of 42 in 1995 to 16 in 1998. The percent of qualified vessels to non-qualified vessels remained fairly constant during the four seasons at roughly a 70/30 split. The fishery is composed almost entirely of catcher vessels, with only one qualified catcher/processor having participated in the 1995 fishing season. There were no non-qualified catcher/processors during the 1995 to 1998 time period.

Harvest and earnings during the 1995 to 1998 time period has steadily declined. In 1995, qualified vessels harvested 0.9 million lbs. and non-qualified vessels harvested 0.3 million lbs. Four years later, 0.3 million and 0.1 million lbs. were harvested by qualified and non-qualified vessels, respectively. Ex-vessel revenues declined from $2.3 million in 1995 to $0.7 million in 1998 for qualified vessels, while ex-vessel revenues of non-qualified vessels declined from $0.6 million to $0.3 million. The share of qualified to non-qualified pounds remained relatively constant during the four years. In 1995, 79 percent of the harvest was from qualified vessels, while four years later it decreased to 71 percent.

St. Matthew blue king crab

The St. Matthew blue king crab fishery has experienced an increase in the number of qualified and non-qualified vessels during the 1991 to 1998 period. The fishery was closed during the 1999 and 2000 season. Over the eight year period, qualified vessels increased from a low of 51 in 1991 to 101 in 1998. In 1992, the fishery experienced an unusual increase in the number of qualified vessels (when 154 qualified vessels participated), but the participation rate returned to levels more consistent with the trend the following year. Non-qualified vessel participation declined during the first four seasons from 17 in 1991 to only five vessels in 1994, but subsequently increased over the remaining four years to a high of 30 in 1998. The percent of qualified vessels to non-qualified vessels increased during the first four years from 75 percent to 94 percent, but declined to a low of 77 percent in 1998.

The majority of the St. Matthew blue king crab fleet during the eight year period was catcher vessels. During this period, qualified and non-qualified catcher/processors participation declined, while qualified and non-qualified catcher vessels participation increased. In 1991, there were five qualified and four non-qualified catcher/processors, while in 1998 there was one qualified and one non-qualified catcher/processor that participated in the fishery. Qualified catcher vessel participation increased from 46 in 1991 to 100 in 1998. As noted above, the 1992 season experienced a sharp increase in the number of qualified vessels, all of which were catcher vessels. Non-qualified catcher vessel participation increased from 13 in 1991 to 29 in 1998.

Harvest and earnings has remained relatively stable over the eight years. In 1991, qualified harvest was 2.3 million lbs. and non-qualified harvest was 0.8 million lbs. Eight years later, the harvest was 2.1 million lbs. for qualified vessels and 0.7 million lbs. non-qualified vessels, respectively. Ex-vessel revenues during this period fluctuated from a high of $13.8 million in 1994 to a low of $4.2 million dollars in 1998 for qualified vessels, and from a high of $2.1 million in 1991 to a low of $0.7 million in 1994 for non-qualified vessels. The share of qualified to non-qualified pounds increased during the first four years from 75 percent to 94 percent, but subsequent years declined to previous levels.

Eastern Aleutian Islands (Dutch Harbor) golden king crab

The eastern Aleutian Islands (Dutch Harbor) golden king crab (*L. aequispina*) has relatively few participating vessels and has remained somewhat constant from 1991 to 2001. The number of qualified vessels has ranged between eight and 13, while the number of non-qualified vessels has ranged between four and eight with the exception of the 1993-1994 season when only one non-qualified vessel participated in the fishery. The fleet is composed mostly of catcher vessels, while at the same time the number of qualified and non-qualified catcher/processors has diminished over the ten year period. In the 1991-1992 season, there were two qualified and four non-qualified catcher/processors, while during the 1999-2000 season there was only one catcher/processor who participated in the fishery and it was a qualified vessel.

The relative percent of qualified vessels to non-qualified vessels showed no discernable trend during the 1991 to 2001 time period. During the 1991-1992 season, 53 percent of the total vessels qualified. Immediately following the 1991-1992 season, the percent of qualified vessels to non-qualified vessels increased substantially where it peaked during the 1993-1994 season at 90 percent. In the subsequent years, the relative percent of qualified to non-qualified vessels followed a more typical pattern of roughly a 70/30 split with the exception of the 1996-1997 season where the number of qualified and non-qualified vessels were equal.

With the exception of the 1994-1995 and 1995-1996 seasons, harvest by qualified vessels has remained relatively constant at approximately 2 million lbs. During the 1994-1995 and 1995-1996 season, harvest increased to 3.3 million and 3.4 million lbs., respectively. Harvest by non-qualified vessels declined from a high of 2.4 million lbs. during the 1991-1992 and 1992-1993 seasons to approximately 0.7 million lbs. in the 1999-2000 season. Ex-vessel revenues followed a similar trend with non-qualified vessels surpassing qualified vessels during the 1991-1992 and 1992-1993 seasons. Since the 1992-1993 season, ex-vessel revenues of non-qualified vessels declined in relation to qualified vessels.

Qualified vessel ex-vessel revenues peaked during the 1994-1995 season at $11 million and then subsequently declined to between $5 million and $7 million between the 1996-1997 and 1999-2000 seasons. Non-qualified vessels harvested more golden king crab during the first years, then quickly declined as a percent of qualified harvest in the subsequent years. During this period, the percent of pounds harvested by qualified vessels in relation to non-qualified vessels increased moderately from 45 percent in the 1991-1992 season to 68 percent in the 2000-2001 season.

Western Aleutian Islands (Adak) golden king crab

The western Aleutian Islands golden king crab fishery has experienced shifting trends in vessel participation over the 1991 to 2001 time period. During the first seasons years, the number of qualified vessels increased from nine to 16. This was followed by five years of declining participation until the 1998-1999 season when only one qualified vessel fished in this fishery. In the remaining two years, participation of qualified vessels increased to nine and ten. Non-qualified vessel participation followed a similar pattern. With the exception of the 1993-1994 season, participation increased over the first four years, peaking at 13 vessels during the 1994-1995 season. Participation declined over the next five years to only two vessels during the 1998-1999 season. This was followed by a slight increase during the remaining two years.

The percent of qualified vessels to non-qualified vessels during the 1991 to 2001 period showed no discernable trend. During the 1991-1992 season, 73 percent of the total vessels participating in the crab fishery were qualified vessels, while during the 2000-2001 season 75 percent were qualified vessels. However, during the 1998-1999 season, only 33 percent of the total participants were qualified vessels.

The composition of the western Aleutian Islands (Adak) golden king crab fleet has undergone some change during the 1991 to 2001 time period. Catcher/processor participation declined during the ten years, while catcher vessel participation increased during the early years, and followed a slow decline in subsequent years. In the 1991-1992 season, there were four qualified and three non-qualified catcher/processors, while in 2000-2001 there was only one qualified and no non-qualified catcher/processors. Qualified catcher vessel participation increased from four in 1991-1992 to 16 in 1993-1994, followed by a decline to eight in 2000-2001. Non-qualified catcher vessel participation increased from none in 1991-1992 to 12 in 1994-1995 and then declined to three in 2000-2001. Unfortunately, the extent of the confidential data precludes any real trend analysis for qualified and non-qualified vessels.

Western Aleutian Islands (Adak) red king crab

The Adak red king crab fishery has very few participants. The limited number of participants in this fishery precludes the release of harvest data to the public. With the exception of the 1995-1996 season, the western Aleutian Islands red king crab fishery has experienced an increase in qualified vessel participation from seven in 1991-1992 to 19 in 1994-1995, while non-qualified participation declined during this period from three to one vessel. The fishery has been closed since 1997. During the 1995-1996 season, qualified vessel participation declined to three. The percent of qualified vessels to non-qualified vessels increased during the first four seasons the fishery was open from 70 to 95 percent, but then declined to 75 percent during the 1995-1996 season. The qualified fleet was composed mostly of catcher vessels, which showed an increase during the first four of the five years from five to 17 vessels, but then declined the last year the fishery was open to three. Catcher/processor numbers fluctuated between one and two vessels. Non-qualified catcher vessels declined from three to one participant and catcher/processors declined from one to no participants during the five years.

3.4.3.2 Processor participation

This section summarizes processor participation in the different BSAI crab fisheries. For each fishery, the number of processors participating, the region of participation, and pounds of delivered are presented and discussed. To the extent permitted by rules intended to protect confidentiality, these figures are reported for qualified and unqualified processors (as defined by the rationalization program options) and for each region (as defined under the regionalization program options). In addition, the RIR/IRFA, Appendix 1, contains a brief summary of first wholesale prices received by processors of BSAI crab for products produced from these fisheries.

Bering Sea C. opilio fishery

Deliveries of Bering Sea *C. opilio* to processors have declined significantly since 1991. With the exception of a few years, the largest portion of deliveries were to the southern region. Processing by catcher/processors has gradually declined over the period. In 1991, 37 percent of deliveries were to the southern region, 21 percent were to catcher/processors, 7 percent were to the northern region, while 35 percent were to floating processors in locations that could not be identified for this report. Ten years later, 67 percent of the total pounds processed were processed in the southern region, 18 percent were to the northern region, 6 percent were processed by catcher/processors, and the remaining 26 percent were split between the northern processors and processors the location of which could not be established.

The number of qualified processors in the Bering Sea *C. opilio* fishery has remained relatively constant, while the number of unqualified processors has declined throughout the 1990's. In 1991, approximately 67 percent of the total pounds processed were processed by 37 qualified processors and 32 percent of pounds processed were processed by 35 non-qualified processors. Since 1998, all processing has been by qualified processors. Since 1998, the number of qualified processors receiving deliveries declined from 47 to 30.

Bristol Bay red king crab fishery

Total deliveries of Bristol Bay red king crab from 1991 to 2000 have fluctuated between 7 million to 17 million pounds showing no discernable trend. There was no fishing during the 1994 and 1995 seasons. The largest share of deliveries during this period was made to the southern region. Processing by catcher/processors has gradually declined over this period as has the number of pounds processed by floating processors that could not be categorized by region. In 1991, 60 percent of total pounds processed were processed in the southern region, while 16 percent were processed by catcher/processors. The remaining share of the fishery was processed by a single processor in the north and floating processors, the location of which could not be established. Ten years later, 96 percent of the total deliveries were to the southern region, while the remaining 4 percent went to catcher/processors, processors in the north and floating processors that could not be categorized by region.

The number of qualified processors in the Bristol Bay red king crab fishery has remained relatively constant, while the number of unqualified processors declined throughout the 1990's. In 1991, approximately 71 percent of the total deliveries were to 29 qualified processors, while the remaining 29 percent were delivered to 27 non-qualified processors. Only three unqualified processors participated in the fishery in 2000.

Bering Sea C. bairdi fishery

During the 1990 to 1996 period, deliveries of Bering Sea *C. bairdi* to processors has increased during the first two years followed by a dramatic decline during the last four years the fishery was open. During this period, deliveries to processors in the southern region increased as a percent of the total. In 1991, 51 percent of pounds were processed by processors in the southern region, 12 percent were processed by catcher/processors, and the remaining 37 percent was split between processors in the north and floating processors the region of which could not be categorized. In 1996, 96 percent of the total deliveries were to the southern region.

The number of qualified processors in the Bering Sea *C. bairdi* fishery increased slightly during the first few years and then declined the remaining three years, while the number of non-qualified processors has declined throughout the 1990's. In 1991, approximately 69 percent of the total deliveries were to 33 qualified processors and the remaining 31 percent of deliveries were to 30 non-qualified processors. In 1996, 98 percent of the deliveries were to qualified processors.

Pribilof blue king crab fishery

Between the 1995 and 1998 period, deliveries of Pribilof blue king crab to processors has declined. Over these four seasons, 50 percent of deliveries were to the northern region, while deliveries to the southern region were slightly lower. The Pribilof blue king crab fishery was closed during the 1993 and 1994 seasons, and again during the 1999 and 2000 seasons. Due to the limited number of processors in the fishery, details on regional deliveries cannot be reported.

The number of qualified processors in the Pribilof blue king crab fishery has remained relatively constant, between 11 to 15 over the fours years, while there was only one non-qualified processor during the first two years, but then subsequently dropped out the last two years. Almost all processing was by qualified processors in this fishery, with 100 percent of processing by qualified processors in 1997 and 1998.

Pribilof red king crab fishery

Between 1993 and 1998, processing of Pribilof red king crab has declined. The limited number of processors in the fishery have created confidentiality problems for disclosing data making general statements concerning the regional distribution of processing difficult. Generally speaking, deliveries to floaters that cannot be regionally categorized and catcher/processor processing has been minor during the six year period. Catcher/processors have not participated in the processing sector of this fishery since the 1993 season. The fishery was closed during the 1999 and 2000 seasons.

Between 1993 and 1998, the number of qualified processors in the Pribilof blue king crab fishery has ranged from 11 to 14, while the number of non-qualified processors has declined from five during the first three years to none during the last three years. The majority of crab was processed by qualified processors during the five year period. In 1993, 71 percent of crab was processed by 12 qualified processors and the remaining 29 percent was processed by five non-qualified processors. In 1996 and continuing through 1998, 100 percent was processed by qualified processors.

St. Matthew blue king crab fishery

During the 1991 to 1998 period, the distribution of processing in the St. Matthew blue king crab has remained relatively constant. During the first two years floaters at unknown locations captured the largest portion of deliveries. However, in the following years, the northern region captured the largest portion of deliveries. Deliveries to floaters and catcher/processors declined during the entire period. The fishery was closed in 1999 and 2000.

The number of qualified processors in the St. Matthew blue king crab fishery has increased from seven in 1991 to 14 in 1998, while the number of non-qualified processors has declined from eight to zero. During the first two years, processing was fairly evenly divided between qualified and non-qualified processors, but in subsequent years processing by qualified processors surpassed non-qualified processors. In 1991, 51 percent of processing was by seven qualified processors and the remaining 49 percent was by eight non-qualified processors.

Western Aleutian Islands (Adak) golden king crab fishery

During the 1990 to 2001 period, the distribution of processing of Adak brown king crab has remained relatively constant. During the 1991-1992 and 1992-1993 seasons, catcher/processors processed the majority of the crab in this fishery. In subsequent years, the processing distribution could not be shown because of confidentiality. No processing occurred in the northern region during the period.

The number of qualified processors in the Adak brown king crab fishery has remained relatively constant during the 11 year period, while the number of non-qualified processors has declined from three to zero.

Eastern Aleutian Islands (Dutch Harbor) golden king crab fishery

During the 1990 to 2001 period, the southern region has processed an increasing amount of crab from the eastern Aleutian Islands (Dutch Harbor) golden king crab fishery. No deliveries were made to northern region processors during this period. Due to the limited number of processors, little more on the distribution of processing can be reported.

The number of qualified processors has remained relatively constant, while the number of non-qualified processors has declined in this fishery. The majority of processing was by qualified processors during the ten year period, with all processing since the 1996-1997 season, being by qualified processors.

Western Aleutian Islands (Adak) red king crab fishery

Between the 1990 and 1996 period, processing of western Aleutian Islands (Adak) red king crab increased rapidly and then declined rapidly. Due to the limited number of processors in the fishery little can be said about the regional distribution of processing.

The number of qualified processors in the Adak red king crab fishery increased from two in the 1990-1991 season to nine during the 1994-1995 season, followed by a decline to four in the 1995-1996 season, the last season the fishery was open. The number of non-qualified processors has declined during the six years from a high of five during the 1991-1992 season to none in the 1995-1996 season.

3.4.3.3 The relationship between harvesters and processors

Harvesters and processors in the crab fisheries are related on several levels ranging from common ownership to simply repeated transactions in the buying and selling of crab. Since the relationships are often manifold, their dynamics are also quite complicated. Understanding these relationships, however, is critical to understanding the applicability of a rationalization program in a fishery. A cooperative program may exploit strong ties and close working relationships between processors and vessels to the benefit of all parties. A system of cooperatives, however, may constrain participants in a fishery, if relationships between harvesters and processors are transitory and fluid. This section describes the various relationships between harvesters and processors. This material is used later in the analysis to develop an understanding of the practicability of the different rationalization alternatives and to assess the market power between harvesters and processors under the different alternatives.

Common ownership of harvesters and processors

Common ownership of vessels and processors will have a strong influence on the relationship between harvesters and processors and the coordination of activities in the two sectors. Common ownership will also affect the nature of transactions between the sectors and the dependence of one sector on the other. In a fishery with expansive common ownership of the harvesting and processing sectors, participants in either sector that are not vertically integrated will have a different position in the market from those participants that are vertically integrated.

A portion of the crab industry is vertically integrated (either a processor owns an interest in a vessel or a vessel owner owns an interest in a processor). Representatives of the major processors in the fisheries provided the analysts with a list of vessels owned by processors that participate in the BSAI crab fisheries. Table 3.4-11 shows the number of vessels that a processor or a processor subsidiary or affiliate owns at least 10 percent[2] of and the harvest histories of those vessels in the fisheries under consideration for rationalization between 1991 and 2000. The table includes only harvests of vessels (including catcher/processors) that are affiliated with shoreside processors.

Table 3.4-11 Participation of shoreside processor affiliated vessels in BSAI crab fisheries, 1991-2000.

Fishery	Processor with affiliated vessels	Vessels affliliated with processors	Pounds Caught by Vertically Integrated Vessels (in thousands)	Total Pounds (in thousands)
WAI (Adak) golden king crab	2	6	*	26,998.9
WAI (Adak) red king crab	1	1	*	3,326.7
Bristol Bay red king crab	6	37	11,564.5	88,761.2
Bering Sea C. opilio	6	30	212,759.2	1,724,107.9
Bering Sea C. bairdi	6	36	12,908.0	112,158.0
EAI (Dutch Harbor) golden king crab	2	3	*	38,481.1
Pribilof blue king crab	3	8	*	3,098.2
Pribilof red king crab	4	12	*	6,212.9
St. Matthew blue king crab	6	21	1,844.8	25,751.8

* Withheld to protect confidentiality.
Includes all harvests (including those by unqualified vessels) from seasons which began between January 1, 1991 and January 31, 2000, and harvests from the Aleutian Islands golden king crab fishery from the 2000-2001 season.
Sources: Summarized from the NPFMC Bering Sea Crab Data Base (2001 Version 1) using vessel list provided by processor representatives.

The amount of vertical integration varies by fishery. In several of the fisheries, harvests could not be revealed because of confidentiality protections. In the Bristol Bay red king crab, the Bering Sea *C. opilio*, and the Bering Sea *C. bairdi* fisheries, processor affiliated vessels have caught between 11 and 13 percent of the total catch in the seasons considered. In the St. Matthew blue king crab fishery processor affiliated vessels harvested 7 percent of the total fleet harvests.

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[2] This level of ownership and the ownership of affiliates is intended to capture all relationships and influences and was used for determining ownership under the AFA.

Support relationships between harvesters and processors

Harvesters and processors also have support relationships that are important to both sectors. Some processors sell bait, fuel, and food to vessels (often on credit) and store gear for vessels during the offseason. At times, vessel owners with large debts to processors will give the lending processor a lien on their vessels. Whether a lien is taken is dependent on the relationship between the vessel owner and the processor. Because of confidentiality, the number of these liens and whether and the extent to which they are used to exert pressure on vessel operators is not known. Vessel owners also enter contracts to tender salmon and herring for processors outside of the crab season. Both vessel owners and processors contend that tendering relationships are important to their businesses. The extent to which either side exploits the other based on these tendering contracts is also not known.

Harvest delivery patterns and processor purchasing patterns

Patterns of harvest deliveries and processor purchases can influence the applicability of different rationalization programs to a fishery. Fisheries in which fishermen consistently delivery harvests to a single processor, both during and across seasons, show a strong harvester/processor relationship that can benefit from the coordination of AFA style cooperative management. Fisheries in which harvesters deliver to several processors in the course of a season and change processors across seasons might be more suitable for a system of individual quotas or a cooperative program that provides greater flexibility in delivery patterns than AFA style cooperatives.

3.4.3.4 Ex-vessel pricing

The interaction between harvesters and processors is critical to the distribution of rents in a fishery. This section describes the current methods by which ex-vessel prices are determined in the BSAI crab fisheries. The discussion is intended to describe the general procedures used to establish ex-vessel prices. If known, exceptions to these general procedures are discussed.

Pricing practices

Pricing practices differ somewhat between fisheries with relatively short seasons and a relatively high number of participants (such as the Bristol Bay red king crab and the Bering Sea *C. opilio* fisheries) and fisheries with fewer participants and longer seasons (such as the Aleutian Islands golden king crab fisheries). Pricing practices in these different fisheries are therefore discussed separately.

Pricing in the Bristol Bay red king crab and Bering Sea C. Opilio fisheries

In recent years, harvesters in the BSAI crab fisheries have coordinated most price negotiations. Since the early 1990's, the Alaska Marketing Association (AMA) has represented a substantial share of harvesters in price negotiations in the largest BSAI fisheries–the Bristol Bay red king crab, the Bering Sea *C. opilio*, and the Bering Sea *C. bairdi* fisheries. Informal discussions have indicated that AMA membership has ranged from 25 percent to 95 percent of crab vessel owners.

Approximately one month prior to each season opening, AMA representatives meet with each of the major crab processors informally to discuss the markets for crab products. Based on this information and information gathered through its own market research, the AMA determines an expected price for crab, which it communicates to the processors. The AMA then solicits price offers from each processor, which it submits to its members for a vote. This process of soliciting prices continues until a price offer acceptable to AMA members is received. Receipt of an acceptable offer from a single processor has typically driven pricing of all processors. In the current fisheries, with unrestricted deliveries, processors have matched the accepted offer to maintain market share[3]. Prices generally remain constant in the current, short season fisheries. To create an incentive for higher offers, in the 2001 Bristol Bay red king crab fishery, AMA members informally agreed to reward the processor that offered the accepted price with additional deliveries. This was the first time AMA members had offered such an arrangement. A similar arrangement was offered in the 2002 Bering Sea *C. opilio* fishery.

If an acceptable price is not received prior to the season opening, catcher vessels will not begin fishing. In the 2000 and 2001 Bering Sea *C. opilio* season harvesters did not begin fishing until several days after the announced opening because an acceptable price offer was not received from a processor. Although not all vessel owners are members of the AMA, in recent years all catcher vessels have remained at port after season openings until an acceptable price has been received by the AMA. Catcher/processors, on the other hand, have not abided by these “stand downs” but have begun fishing at the opening of the season. Since catcher/processors do not sell unprocessed crab they are not directly affected by the price negotiations. Fishing by catcher/processors may weaken the negotiating position of catcher vessels that may delay fishing since their harvests will reduce the amount of catch remaining after a price agreement is reached.

The pricing process typically establishes two prices– the main price applies to higher value new shell crab (grade 1) and a secondary, lower price for lower value, old shell crab (grade 2). These different grades bring different prices in ex-vessel, wholesale, and consumer markets. The price variation between grades can vary greatly between processors. The price difference averages approximately 25 percent of the grade 1 price ($1.00 per lb. for red king crab and $0.25 for *C. opilio*) but difference in practices among processors can be extreme, defying generalization. The grade 2 price is important to harvesters, but the grade 1 price negotiation is paramount.

Although this informal system establishes a single price for each grade of crab, price competition exists on a minor scale. Occasionally, processors offer small bonuses (e.g., $0.05 per lb.) to attract additional vessels. Processors also use different grading practices to attract vessels. Some harvesters will select processors based on grading practices to realize better returns on harvests. In addition, a few harvesters continue to handle their own price negotiations (separate from the AMA negotiations).

Pricing also varies regionally among processors in the crab fisheries. Regional price differences have several sources. In fisheries where vessels make several deliveries, the availability of goods and services in a location can be important to harvesters. Food, bait, fuel, and good port facilities can make a processor more attractive to vessels wishing to offload harvests. Processors in locations that offer fewer goods and services may pay price premiums to induce harvesters to sell their harvests. Processors that are distant from grounds may also need to pay a premium price to compensate harvesters for time away from the grounds while making deliveries. Proximity to consumer markets can also influence ex-vessel prices. Processors with less access to consumer markets may pay slightly less for crab inputs than processors closer to end markets since they must bear the cost of delivering the crab to the market.

Generalizations concerning the spatial distribution of ex-vessel prices may be difficult to make. Dutch Harbor, where the most processors are located can be used as the basis for determining prices. The prices in

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[3] Not all processors participate in the AMA pricing activities. Although some harvesters believe that the AFA has reduced participation of AFA processors, in the most recent *C. opilio* fishery an AFA processor made the price offer accepted by the harvesters.

Kodiak are higher (approximately $0.20 in the recent Bristol Bay red king crab fishery) because of the longer distance to the fishing grounds and the proximity to consumer markets. The St. Paul processors are thought to pay slightly less for crab ($0.05 less than the Dutch Harbor price for *C. opilio*) possibly as a result of the close proximity of the port to the fishing grounds. These minor price differences between ports are thought to have little effect on the competitiveness of vessels that deliver to the facilities at the different ports, when the other costs are considered.

Pricing in the Aleutian Islands golden king crab fisheries

The Aleutian Islands golden king crab fisheries have fewer participants than the Bristol Bay red king crab and Bering Sea *C. opilio* fisheries. Seasons in these golden king crab fisheries also last several months, in contrast to seasons shorter than one month in the Bristol Bay red king and Bering Sea *C. opilio* fisheries. As a result, ex-vessel pricing practices differ substantially in the Aleutian Islands golden king crab fisheries.

Traditionally, participants in the Aleutian Islands golden king crab fisheries have negotiated prices independently. Only recently have harvesters in the Aleutian Islands golden king crab fisheries used collective action to negotiate ex-vessel prices for the fleet. Notwithstanding these efforts, some harvesters continue to negotiate prices for their harvests independent of any collective negotiations. Longer seasons in the Aleutian Islands golden king crab fisheries allow for substantial in-season price fluctuations, which are uncommon in the short season fisheries. The long seasons with fluctuating prices have also complicated organizing collective action in the fishery.

Other influences on prices

To an unknown extent, price negotiations and delivery patterns are influenced by relationships between harvesters and processors. Some harvesters tender salmon and herring for processors. Maintaining this contract might require the harvester to continue to deliver crab to the processor. Similarly, some harvesters receive financial support from processors. Whether formalized or not, some of these harvesters have a perceived obligation to deliver crab harvests to the processor with whom they have the financial relationship. The extent of the impact of these relationships and obligations on prices and delivery patterns is not known.

Estimated ex-vessel prices

Ex-vessel prices for the fisheries and years under consideration are reported in the RIR/IRFA in Appendix 1. Catch and value data from catcher/processor harvests and fish tickets reported by catcher/sellers are excluded. Those fish tickets were excluded because they do not generate a true ex-vessel price. Details of the ex-vessel price calculations and data included or excluded are also provided in the RIR/IRFA. The RIR/IRFA also contains a discussion of the methods and assumptions that were used to generate these ex-vessel prices.

3.4.4 Community and social existing conditions

Community and social existing conditions are discussed in this section and in an appendix to this volume (Appendix 3: Social Impact Assessment, Overview and Community Profiles). These two discussions, taken together, comprise the Social Impact Assessment (SIA) for this EIS. These two discussions provide separate perspectives on the community and social context for the potential differential distribution of impacts associated with alternative management approaches being analyzed in this EIS.

In this section, information from quantitative fisheries data sources for harvesting and processing is presented where those data can meaningfully be attributed to communities or regions. As discussed below, there are fundamental problems with sector-based community discussions for a number of the sectors, based upon data confidentiality considerations. Within the constraints imposed by the data, this section focuses on the pattern of engagement of the crab fishery sectors across communities and regions, with the purpose of allowing a subsequent analysis of how alternative associated changes within a given sector would result in a differential distribution of impacts between communities and regions. In this section, the frame of reference or unit of analysis is the fishery sector (harvester, catcher/processor, and processor) and the human geographies associated with each sector.

Within the quantitative data, assignment of a region or community of ownership for harvest vessels and catcher/processors is based on the vessel ownership and address information as listed in CFEC vessel registration files or NOAA Fisheries federal permit data. As a result, some caution in the interpretation of this information is warranted. It is not unusual for vessels to have complex ownership structures involving more than one entity in more than one region (or for some of the vessels from the Pacific Northwest that spend a great deal of time in Alaska ports to hire at least a few crew members from these ports), but the region or community of ownership provides a rough indicator of the direction or nature of ownership ties (and associated employment and economic activity) when patterns are viewed at the sector or vessel class level. For shoreplant and floating processing entities, regional or community designation was based on the location of the plant or floater itself (rather than ownership address) in order to provide a relative indicator of the local volume of fishery related economic activity, which can also serve as a rough proxy for the relative level of associated employment and local government revenues.

Appendix 3 takes a different approach and contains community-specific information to provide a detailed context for the community and SIA. The frame of reference or unit of analysis in the appendix is the community or region. Within that frame, the attributes of the locally occurring crab fishery sectors and associated support sectors are detailed and put in a local social and economic context to allow a subsequent assessment of how the proposed management alternatives for the crab fisheries are likely to impact the social and economic base of the relevant communities. This appendix also contains an overview of community experience with previous fishery rationalization programs and provides a summary of community level impacts of those programs likely to be useful as analogs for anticipating impacts associated with the proposed rationalization alternatives. In detailing the localized nature and intensity of engagement with and dependency on the crab fishery, the community profiles also contain an analysis of the direction and magnitude of the social impacts likely to result from the proposed alternatives. In addition to covering a broad range of social impact issues for directly engaged communities, the appendix also features a discussion of CDQ region existing conditions and social impacts to supplement the summary CDQ discussions in Sections 3.4.5 and 4.6.8, respectively.

The SIA thus utilizes a two-pronged approach to understanding the nature and distribution of potential impacts. This section focuses on quantitative sector-related data. Appendix 3 focuses more on narrative descriptions of community and regional socioeconomics using both qualitative and quantitative information. Additional information specific to the characterization of minority populations and low-income populations engaged in the fishery may also be found in Section 4.7.

In terms of organization, this section contains a series of discussions and tables that cover harvest vessel (catcher vessel plus catcher/processor), catcher/processor, and processing (shore plant, floater) sector information. Each of these, and their ties to particular communities as shown through quantitative data, are presented in turn. Harvest vessels are much more numerous than are processors, so that confidentiality concerns are much less problematic for harvest vessels than for processors. As a result, the quantitative tables that were produced are more comprehensive for the harvesting sector than the processing sector.

3.4.4.1 Harvest sector existing conditions

This section presents a series of tables that show different attributes and patterns of distribution of vessels and harvest volume and values for the crab harvesting sector. The first series of tables focuses on crab vessels and their participation in the individual crab fisheries as well as in other non-crab fisheries.

Table 3.4-12 provides summary information on the distribution by community of BSAI crab catcher vessels (including catcher/processors) over the period 1991-2000 on an annual average basis. Not all of the listed fisheries were open each year, and the average number of vessels for the relevant individual fisheries was calculated in this table using years open during 1991-2000. For volume and value tables that appear in this section, figures for 1991-2000 are annualized on a ten-year basis, no matter how many years each fishery was actually open. The intent of this approach is to approximate the "worth" or "benefit" of each fishery to the relevant communities or regions on a comparable basis over the 1991-2000 period. The time span 1991-2000 was chosen for analysis because this encompasses the entirety of the available data. For readers interested in trends of change within the 1991-2000 decade (and there were fundamentally important changes in individual fisheries) or for specific subsets of years, such as those corresponding to various qualifying periods, detailed data tables are presented in an attachment to Appendix 3 (SIA Attachment 3) of this document.

As with other summary tables in this section, Table 3.4-12 provides individual species information for only the three largest BSAI crab fisheries (Bristol Bay red king crab, Bering Sea opilio crab, and Bering Sea Tanner crab), a combined total for those three fisheries, a combined total for the "other six" relevant BSAI crab fisheries, and a combined total of all nine BSAI crab fisheries included in the proposed management alternatives analyzed in this EIS.[1] This lumping of the quantitative information from smaller

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[1] In this section, "PMA crab" is used in data tables as an abbreviated reference to relevant BSAI crab species that are being considered for inclusion in the proposed management alternatives in this EIS (the rationalization alternatives, along with the status quo alternative). Crab species and stocks included in the proposed management alternatives include Adak (western Aleutian Island) brown (golden) king crab (*Lithodes aequispina*), Adak (western Aleutian Island) red king crab (*Paralithodes camtschaticus*), Bristol Bay red king crab (*P. camtschaticus*), Bering Sea opilio (snow) crab (*Chionoecetes opilio*), Bering Sea Tanner (C. *bairdi*), Dutch Harbor (eastern Aleutian Island) brown (golden) king crab (*L. aequispina*), Pribilof blue king crab (*P. platypus*), Pribilof red king crab (*P. camtschaticus*), and St. Matthew blue king crab (*P. platypus*). Three additional species or stocks were originally proposed for inclusion in the rationalization program but were later excluded (and do not appear in the quantitative data tables in this section) due to low levels of harvest and/or recent multi-year closures: Dutch Harbor (eastern Aleutian Island) red king crab (*P. camtschaticus*), eastern Aleutian Island Tanner *(C. bairdi*), and western Aleutian Island Tanner *(C. bairdi*). The rationalization program includes Adak red king crab west of 179° W Longitude and excludes it east of this line, but the tables in this section include data for this species/stock from both sides of the line. In the tables, the "non-PMA" crab designation includes all crab species not covered by the proposed management alternatives including, among others, species covered by the BSAI crab FMP but managed under state discretion via an ADF&G commissioner's permit (e.g., Aleutian Island scarlet king crab [*L. couesi*]), BSAI federal waters fishery crab managed by the state and not included in the FMP (e.g., Korean hair crab [*Erimacrus isenbeckii*]), low-volume primarily state water fisheries (e.g., Aleutian District Dungeness [*Cancer magister*]), or non-BSAI FMP area federal fisheries (e.g., multiple

volume/participation fisheries is due primarily to confidentiality considerations. Information for each of the fisheries by species or group of species is presented for the entire fishery category, lumping together landings that would be "qualified" and "non-qualified" with respect to the rationalization alternatives. To provide some context on the distinction between non-qualified vessels and landings, Table 3.4-12 provides separate rows displaying the number of vessels with non-qualified landings and the number of "overlap" vessels with qualified landings in at least one relevant crab fishery and non-qualified landings in at least one other relevant crab fishery. (Analogous rows do not appear in subsequent harvest volume or value tables, yet again due primarily to confidentiality considerations). The table row labeled "All fisheries other than Proposed Management Alternatives (PMA) Crab" provides a measure of participation of crab vessels in other fisheries. In other words, this row provides a look at "dependency" of crab vessels on crab compared to other fisheries in which they are engaged. For readers interested in analogous detailed breakouts on the same fisheries categories, tables displaying the full annual time series data appear at the end of the community profile document (Appendix 3, SIA Attachment 3).

Due to confidentiality restrictions, availability of information by community is somewhat limited. For Alaska, data are sufficient to provide information on a community basis in this table series for Anchorage, Homer, King Cove/Sand Point, Kodiak, and a residual category "other Alaska." For Washington, the Seattle-Tacoma Coastal Management Service Area (CMSA) is used as the unit of analysis for the greater Seattle area, and an "other Washington" residual category is also used. For Oregon, data for Newport and "other Oregon" are displayed. Due to confidentiality restrictions, data from vessels from states other than Alaska, Washington, and Oregon are not displayed. By examining Table 3.4-12, the relative distribution of the fleet by place of ownership can be determined. Table 3.4-13 shows these same data as a percentage of the individual species or species group. This table shows, for example, that within the Bristol Bay red king crab fishery, of the total vessels in the fishery, 56.8 percent of the vessels were owned by residents of the Seattle-Tacoma CMSA, 17.2 percent were owned in Kodiak, 3.6 percent were owned by residents of Newport, and so on. The clear dominance of Seattle within the overall harvest sector and of Kodiak within the portion of the fleet owned by Alaska residents is readily apparent for each of the fisheries listed.

Tables 3.4-14 through 3.4-16 provide information on the absolute and relative average annual value of harvest by these same fishery and community categories. Table 3.4-14 provides information on the value of the summary fishery categories by community on an average annual basis in terms of dollars. Table 3.4-15 provides information on harvest value as a percentage of the total species listed for an individual community or community group in order to provide a quick means of gauging the importance of each individual fishery for that community relative to the other fisheries listed. For example, for Kodiak, Bristol Bay red king crab accounted for 12.2 percent of the average annual value of the combined relevant species harvested by vessels owned in the community, while Bering Sea opilio accounted for 46.7 percent, and so on. In each case the percentages for the community or place columns total 100 percent. This table can also be used to show the relative dependence of local crab vessels on crab itself. For example, crab vessels from King Cove and Sand Point derive 31.7 percent of their annual harvest value from fisheries other than the relevant BSAI crab fisheries. No other local Alaska crab fleet derives more than 20 percent of harvest value from non-BSAI crab species. Crab vessels from Anchorage and Homer are more dependent on the relevant BSAI crab species (94 and 89 percent of annual average harvest value, respectively) than other Alaska communities or areas shown (ranging from 68 to 82 percent). Dependency ranged from 71 to 90 percent for Pacific Northwest BSAI crab vessels, but it is important to note that BSAI crab vessels from the Pacific Northwest may also fish outside of Alaska EEZ or Alaska state waters, and that activity would not show up in these data.

GOA crab fisheries).

Table 3.4-16 provides information on the harvest value from locally owned vessels for each place as a percentage of the total value for that fishery. In other words, in this table the fishery rows (not the place columns) total to 100 percent. This information allows an at-a-glance comparison of the distribution of harvest value for each species by place. For example, for Bristol Bay red king crab, 2.3 percent of total value for the species on an annual average basis is harvested by vessels owned by residents of Anchorage, 3.3 percent by residents of Homer, 2.2 percent by residents of King Cove and Sand Point, and so on. The relative dominance of Seattle-Tacoma and Kodiak is again clear, but the importance of Newport, Oregon, is also apparent as the third largest "BSAI crab port" in terms of vessel harvests.

Table 3.4-12 Average number of relevant BSAI species crab vessels in various fisheries categories, by fisheries category and community of vessel owner – Alaska, Washington, and Oregon, 1991-2000.

	Alaska					Washington		Oregon		
Fishery Category	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	Grand Total
Bristol Bay Red King Crab	5.8	9.3	7.0	44.3	15.9	145.9	13.1	9.3	6.4	256.8
Bering Sea Opilio Crab	5.7	8.1	5.3	37.8	14.7	138.4	12.1	8.4	5.3	235.8
Bering Sea Tanner Crab	4.8	9.3	6.3	43.7	13.3	139.3	11.8	8.5	6.7	243.8
BBR/BSO/BST Crab group	6.5	9.6	7.3	45.8	18.1	162.0	14.4	10.4	6.8	280.9
Other 6 PMA Crab group	3.9	6.0	10.5	25.9	11.4	81.6	8.8	5.8	3.6	149.4
All 9 PMA Crab group	6.7	9.6	11.4	48.1	19.1	163.2	14.8	11.1	6.8	290.8
Non-Qualified PMA Crab (all 9)	1.2	1.3	5.1	11.3	6.7	26.1	5.8	2.3	2.3	62.1
"Overlap" Vessels, all 9 PMA Crab	0.6	0.0	1.1	1.8	2.1	9.7	2.0	1.8	0.7	19.8
All Fisheries other than PMA Crab	3.5	8.1	8.4	34.4	10.9	80.5	7.3	7.5	4.8	165.4

Notes: PMA crab fishery and group vessel counts are not mutually exclusive and therefore do not sum to column totals, as some vessels fish several fisheries.
PMA crab fishery and group vessel counts include all landings (qualified and non-qualified).
Average vessel counts for individual fisheries are computed using years open during 1991-2000.
Average vessel counts for grouped fishery categories used all ten years (unweighted), except for years with zero participation in all fisheries in the group for a given community.
Vessels fishing multiple fisheries have been counted only once in combined categories.
Non-qualified and “overlap” vessels do not appear in subsequent harvest or value tables due to confidentiality concerns.
“Overlap” vessels have both qualified and non-qualified PMA crab fisheries landings but are counted only once in combined groups.
“All Fisheries other than PMA Crab” represents that subset of PMA crab vessels that also fish other fisheries.
Data from vessels owned by residents of states other than Alaska, Washington, and Oregon have been deleted due to confidentiality concerns.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-13 **Average number of relevant BSAI species crab vessels in various fisheries categories, by fisheries category and community of vessel owner, by percent of total vessels in the fishery – Alaska, Washington, and Oregon, 1991-2000.**

Data	Alaska					Washington		Oregon		Grand Total
	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	
Bristol Bay Red King Crab	2.2%	3.6%	2.7%	17.2%	6.2%	56.8%	5.1%	3.6%	2.5%	100.0%
Bering Sea Opilio Crab	2.4%	3.4%	2.2%	16.0%	6.2%	58.7%	5.1%	3.6%	2.2%	100.0%
Bering Sea Tanner Crab	2.0%	3.8%	2.6%	17.9%	5.5%	57.1%	4.9%	3.5%	2.7%	100.0%
BBR/BSO/BST Crab group	2.3%	3.4%	2.6%	16.3%	6.4%	57.7%	5.1%	3.7%	2.4%	100.0%
Other 6 PMA Crab group	2.6%	3.2%	5.6%	17.3%	6.1%	54.6%	4.7%	3.9%	1.7%	100.0%
All 9 PMA Crab group	2.3%	3.3%	3.9%	16.5%	6.6%	56.1%	5.1%	3.8%	2.3%	100.0%
Non-Qualified PMA Crab (all 9)	1.9%	2.1%	8.2%	18.2%	10.8%	42.0%	9.3%	3.7%	3.7%	100.0%
"Overlap" Vessels, all 9 PMA Crab	3.0%	0.0%	5.6%	9.1%	10.6%	49.0%	10.1%	9.1%	3.5%	100.0%
All fisheries other than PMA Crab	2.1%	4.9%	5.1%	20.8%	6.6%	48.7%	4.4%	4.5%	2.9%	100.0%

Notes: PMA crab fishery and group vessel counts are not mutually exclusive, and therefore do not sum to column totals, as some vessels fish several fisheries.
PMA crab fishery and group vessel counts include all landings (qualified and non-qualified).
Average vessel counts for individual fisheries are computed using years open during 1991-2000.
Average vessel counts for grouped fishery categories used all ten years (unweighted), except for years with zero participation in all fisheries in the group for a given community.
Vessels fishing multiple fisheries have been counted only once in combined categories.
Non-qualified and “overlap” vessels do not appear in subsequent harvest or value tables due to confidentiality concerns.
“Overlap” vessels have both qualified and non-qualified PMA crab fisheries landings but are counted only once in combined groups.
“All Fisheries other than PMA Crab” represents that subset of PMA crab vessels that also fish other fisheries.
Data from vessels owned by residents of states other than Alaska, Washington, and Oregon have been deleted due to confidentiality concerns.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-14 Average annual value of harvest for relevant BSAI species crab vessels in various fisheries categories, by fisheries category and community of vessel owner – Alaska, Washington, and Oregon, 1991-2000.

	Alaska					Washington		Oregon		
Data	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	Grand Total
Bristol Bay Red King Crab	$827,311	$1,167,033	$782,112	$5,240,622	$1,589,774	$21,857,948	$1,557,482	$1,466,012	$775,679	$35,263,972
Bering Sea Opilio Crab	$2,539,097	$3,725,622	$2,705,133	$20,081,371	$6,158,292	$89,969,977	$6,426,721	$5,151,151	$2,636,270	$139,393,635
Bering Sea Tanner Crab	$216,299	$615,159	$429,111	$3,593,507	$685,572	$13,163,108	$765,462	$740,503	$512,954	$20,721,675
BBR/BSO/BST Crab group	$3,582,707	$5,507,813	$3,916,357	$28,915,500	$8,433,638	$124,991,034	$8,749,665	$7,357,666	$3,924,903	$195,379,282
Other 6 PMA Crab group	$730,890	$302,773	$537,166	$5,390,614	$761,770	$16,168,524	$831,041	$3,798,493	$205,249	$28,726,520
All 9 PMA Crab group	$4,313,597	$5,810,586	$4,453,523	$34,306,113	$9,195,408	$141,159,558	$9,580,705	$11,156,159	$4,130,153	$224,105,802
All fisheries other than PMA Crab	$260,445	$742,913	$2,064,507	$8,711,223	$2,030,719	$31,632,523	$1,032,300	$4,529,452	$1,581,269	$52,585,352
Total All Fisheries	$4,574,041	$6,553,499	$6,518,030	$43,017,337	$11,226,127	$172,792,081	$10,613,005	$15,685,611	$5,711,421	$276,691,153

Notes: “Fisheries other than PMA crab” includes both Alaska EEZ (federal) and Alaska state waters fisheries.
PMA crab fishery and group harvest values include all landings (qualified and non-qualified).
Average annual community harvest values are computed using 1991-2000 (that is, including years various fisheries were closed).
“All Fisheries other than PMA Crab” represents the value of non-PMA crab harvests by PMA crab vessels (that is, the other fisheries in which they participate).
“Other States” have been deleted due to confidentiality concerns.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-15 Average annual value of harvest for relevant BSAI species crab vessels in various fisheries categories, by fisheries category and community of vessel owner – Alaska, Washington, and Oregon as percent of total harvest value of community crab vessels, 1991-2000.

	Alaska					Washington		Oregon		
Data	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	Grand Total
Bristol Bay Red King Crab	18.1%	17.8%	12.0%	12.2%	14.2%	12.6%	14.7%	9.3%	13.6%	12.7%
Bering Sea Opilio Crab	55.5%	56.8%	41.5%	46.7%	54.9%	52.1%	60.6%	32.8%	46.2%	50.4%
Bering Sea Tanner Crab	4.7%	9.4%	6.6%	8.4%	6.1%	7.6%	7.2%	4.7%	9.0%	7.5%
BBR/BSO/BST Crab group	78.3%	84.0%	60.1%	67.2%	75.1%	72.3%	82.4%	46.9%	68.7%	70.6%
Other 6 PMA Crab group	16.0%	4.6%	8.2%	12.5%	6.8%	9.4%	7.8%	24.2%	3.6%	10.4%
All 9 PMA Crab group	94.3%	88.7%	68.3%	79.7%	81.9%	81.7%	90.3%	71.1%	72.3%	81.0%
All fisheries other than PMA Crab	5.7%	11.3%	31.7%	20.3%	18.1%	18.3%	9.7%	28.9%	27.7%	19.0%
Total All Fisheries	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Notes: “Fisheries other than PMA crab” includes both Alaska EEZ (federal) and Alaska state waters fisheries.
PMA crab fishery and group harvest values include all landings (qualified and non-qualified).
Average annual community harvest values are computed using 1991-2000 (that is, including years various fisheries were closed).
“All Fisheries other than PMA Crab” represents the value of non-PMA crab harvests by PMA crab vessels (that is, the other fisheries in which they participate).
“Other States” have been deleted due to confidentiality concerns.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-16 Average annual value of harvest for relevant BSAI species crab vessels in various fisheries categories, by fisheries category and community of vessel owner as percent of total fishery harvest value for crab vessels from Alaska, Washington, and Oregon, 1991-2000.

	Alaska					Washington		Oregon		
Data	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	Grand Total
Bristol Bay Red King Crab	2.3%	3.3%	2.2%	14.9%	4.5%	62.0%	4.4%	4.2%	2.2%	100.0%
Bering Sea Opilio Crab	1.8%	2.7%	1.9%	14.4%	4.4%	64.5%	4.6%	3.7%	1.9%	100.0%
Bering Sea Tanner Crab	1.0%	3.0%	2.1%	17.3%	3.3%	63.5%	3.7%	3.6%	2.5%	100.0%
BBR/BSO/BST Crab group	1.8%	2.8%	2.0%	14.8%	4.3%	64.0%	4.5%	3.8%	2.0%	100.0%
Other 6 PMA Crab group	2.5%	1.1%	1.9%	18.8%	2.7%	56.3%	2.9%	13.2%	0.7%	100.0%
All 9 PMA Crab group	1.9%	2.6%	2.0%	15.3%	4.1%	63.0%	4.3%	5.0%	1.8%	100.0%
All fisheries other than PMA Crab	0.5%	1.4%	3.9%	16.6%	3.9%	60.2%	2.0%	8.6%	3.0%	100.0%
Total All Fisheries	1.7%	2.4%	2.4%	15.5%	4.1%	62.4%	3.8%	5.7%	2.1%	100.0%

Notes: “Fisheries other than PMA crab” includes both Alaska EEZ (federal) and Alaska state waters fisheries.
PMA crab fishery and group harvest values include all landings (qualified and non-qualified).
Average annual community harvest values are computed using 1991-2000 (that is, including years various fisheries were closed).
“All Fisheries other than PMA Crab” represents the value of non-PMA crab harvests by PMA crab vessels (that is, the other fisheries in which they participate).
“Other States” have been deleted due to confidentiality concerns.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

The next series of tables presents information on the total locally owned harvest vessel fleet, not just crab vessels as was the case in the previous table series. This "total local fleet" information allows an assessment of the relative "worth" or "benefit" of the relevant BSAI crab fisheries compared to all other fisheries pursued by the local fleet. This is a more accurate reflection of the importance of crab from a community level perspective, in terms of engagement in and dependence upon the BSAI crab fisheries.

Table 3.4-17 provides information on the total harvester fleet by community for the period 1991-2000. Table 3.4-18 provides this information in the form of percentages, which allows an at-a-glance look at the relative participation of the overall local fleet in the BSAI crab fisheries in comparison to other fisheries. Table 3.4-19 also provides percentage information, but in this case as a function of the overall participation in the individual fisheries, allowing an at-a-glance look at the relative participation in individual fisheries by the fleets from different communities.

Table 3.4-20 provides information on the value in dollars of crab and non-crab species harvested by catcher vessels owned by residents of the relevant communities for the period 1991-2000. The fisheries listed are PMA crab, non-PMA crab, pollock, Pacific cod, other groundfish, salmon, "non-vessel"[2] fisheries, and other fisheries. This information can be used to gauge the relative dependence of the community fleet (both crab and non-crab vessels) on any particular species group. Table 3.4-21 provides parallel information for harvest volume.

Table 3.4-22 provides the same information as in Table 3.4-20, but in percentage of value for the overall fishery for each species or species group rather than in absolute dollars. This display allows an easy comparison of distribution of harvested value, by community, for the individual fishery. For example, in terms of value for the combined relevant BSAI crab fisheries, Kodiak-owned vessels harvested 15.1 percent of the grand total value of these fisheries over the years shown, while vessels owned in the Seattle-Tacoma CMSA accounted for 62.1 percent of these same fisheries, with the species group rows in this table summing to 100 percent. The "Total Community Value" row allows a quick comparison of the combined value of all fisheries listed for each community relative to all of the other communities listed. Table 3.4-23 provides analogous percentage of total fishery information by harvest volume by community of vessel owner rather than by value. Volume figures are useful for comparing effort within fisheries, but not particularly useful for summing across fisheries, given the sharp differences in both volume and value per unit in the different fisheries.

Table 3.4-24 provides the same information as in Table 3.4-22, but in percentage of value in terms of the overall fisheries for each place rather than for each fishery. In this table, the community columns sum to 100 percent, rather than the species row. This allows for a quick comparison of the patterns of dependency by community catcher vessel fleets across the various fisheries. This table indicates, for example, that relevant BSAI crab species account for 35.5 percent of the total value harvested by the combined Kodiak fleet. As shown, although Kodiak has a large and diversified fleet, the Kodiak community fleet is relatively more dependent on the relevant BSAI crab species (by far) than any other local Alaskan Fleet. It should be

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[2] "Non-vessel" fisheries are included in local harvest totals for the sake of completeness. Non-vessel harvests are harvests that appear in the Fish Ticket database and are assigned a location but have no associated vessel information. The vast majority of this harvest is salmon and derives from non-vessel gear (e.g., beach set nets). Some of these fisheries may, in fact, involve vessels (such as skiffs), but no information on these vessels appears in the harvest data set. These "non-vessel" landings may be more or less important to the total value of landings by residents of a given community and are provided to better place relevant crab landings in a context of total landings by community residents.

clearly noted, however, that these dependency figures are for Alaska water fisheries (Alaska EEZ plus Alaska state waters) and thus mean different things for the fleets from Alaska versus those from other states. Presumably, a very high percentage of Alaska-owned vessels direct their effort exclusively toward fisheries off of Alaska. For Washington-owned vessels, on the other hand, there is presumed to be a greater likelihood that, among the total vessels in any given community, there would be greater additional effort directed toward non-Alaska waters fisheries than is the case for Alaska-owned vessels. In other words, these dependency figures apply to the universe of vessels that participate in the Alaska fisheries, and for Alaska communities this is assumed to approximate the total community fleet, but for specific Pacific Northwest communities the total local fleet is likely to include vessels that fish other waters as well. Table 3.4-25 provides similar catcher vessel fleet relative dependency information, but by volume rather than value. Again, however, the utility of this information is limited compared to the value figures.

Table 3.4-17 Average annual number of vessels participating in commercial fisheries in Alaskan waters, by community and fishery category, 1991-2000.

Fishery	Alaska					Washington		Oregon		Other States	Grand Total
	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon		
PMA Crab	6.7	9.6	11.6	48.1	18.9	163.2	14.8	11.1	6.8	5.9	296.7
non-PMA Crab	4.1*	30.5	0.8*	55.8	380.7	31.0	35.1	1.9*	4.1	16.3	560.3
Salmon	277.1	267.5	138.5*	209.5	3,290.7	628.5	801.4	3.4*	219.4	1,055.0	6,891.0
Pollock	2.0*	9.3	14.6*	53.0	25.6	69.8	15.3	16.2	10.7	5.0	221.5
Pacific Cod	28.4	94.4	62.3	161.9	466.0	140.2	52.0	20.8	25.6	19.3	1,070.9
Other Groundfish	40.5	105.6	23.9	134.8	843.6	159.4	100.6	18.1	45.7	24.1	1,496.3
Other Fisheries	136.4	208.0	79.5	263.9	2,779.9	231.7	312.3	10.4	84.4	127.1	4,233.6
Total Community Fleet	361.1	354.1	161.4	417.3	4,816.4	919.9	956.0	30.2	262.9	1,160.1	9,439.4

Notes: Offshore harvest (and value) not included, which affects mainly groundfish and Seattle-Tacoma CMSA (but also some other communities).
Database as provided combines all PMA fisheries.
"PMA Crab" includes both qualified and non-qualified vessels.
"Non-PMA Crab" includes all crab (federal and state waters) other than PMA crab.
Counts by fishery within individual communities are not mutually exclusive as some vessels participate in more than one listed fishery.
"Total Community Fleet" represents unique vessels.
Cells with values marked * are suppressed in subsequent harvest value and volume tables to protect confidentiality.
Vessel numbers are not identical to those shown in Table 3.4-12 due to slightly different data sets, so should be used to examine relative levels of participation rather than absolute or comparative measurements.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-18 Percentage of community-owned vessels participating in commercial fisheries in Alaskan waters, by fishery category, 1991-2000.

	Alaska					Washington		Oregon			
Fishery	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	Other States	Grand Total
PMA Crab	1.9%	2.7%	7.2%	11.5%	0.4%	17.7%	1.5%	36.8%	2.6%	0.5%	3.1%
non-PMA Crab	1.1%	8.6%	0.5%	13.4%	7.9%	3.4%	3.7%	6.3%	1.6%	1.4%	5.9%
Salmon	76.7%	75.5%	85.8%	50.2%	68.3%	68.3%	83.8%	11.3%	83.5%	90.9%	73.0%
Pollock	0.6%	2.6%	9.0%	12.7%	0.5%	7.6%	1.6%	53.6%	4.1%	0.4%	2.3%
Pacific Cod	7.9%	26.7%	38.6%	38.8%	9.7%	15.2%	5.4%	68.9%	9.7%	1.7%	11.3%
Other Groundfish	11.0%	29.8%	14.8%	32.3%	17.5%	17.3%	10.5%	59.9%	17.4%	2.1%	15.9%
Other Fisheries	37.8%	58.7%	49.3%	63.2%	57.7%	25.2%	32.7%	34.4%	32.1%	11.0%	44.9%
Total Community Fleet	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Notes: Offshore harvest (and value) not included, which affects mainly groundfish and Seattle-Tacoma CMSA (but also some other communities).
Database as provided combines all PMA fisheries.
“PMA Crab” includes both qualified and non-qualified vessels.
“Non-PMA Crab” includes all crab (federal and state waters) other than PMA crab.
Counts by fishery within individual communities are not mutually exclusive as some vessels participate in more than one listed fishery.
“Total Community Fleet” represents unique vessels.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-19 Percentage of vessels participating in selected commercial fisheries in Alaskan waters, by community of ownership, 1991-2000.

	Alaska					Washington		Oregon			
Fishery	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	Other States	Grand Total
PMA Crab	2.3%	3.2%	3.9%	16.2%	6.4%	55.0%	5.0%	3.7%	2.3%	2.0%	100.0%
non-PMA Crab	0.7%	5.4%	0.1%	10.0%	67.9%	5.5%	6.3%	0.3%	0.7%	2.9%	100.0%
Salmon	4.0%	3.9%	2.0%	3.0%	47.8%	9.1%	11.6%	0.0%	3.2%	15.3%	100.0%
Pollock	0.9%	4.2%	6.6%	23.9%	11.6%	31.5%	6.9%	7.3%	4.8%	2.3%	100.0%
Pacific Cod	2.7%	8.8%	5.8%	15.1%	43.5%	13.1%	4.9%	1.9%	2.4%	1.8%	100.0%
Other Groundfish	2.7%	7.1%	1.6%	9.0%	56.4%	10.7%	6.7%	1.2%	3.1%	1.6%	100.0%
Other Fisheries	3.2%	4.9%	1.9%	6.2%	65.7%	5.5%	7.4%	0.2%	2.0%	3.0%	100.0%
Total Community Fleet	3.8%	3.8%	1.7%	4.4%	51.0%	9.7%	10.1%	0.3%	2.8%	12.3%	100.0%

Notes: Offshore harvest (and value) not included, which affects mainly groundfish and Seattle-Tacoma CMSA (but also some other communities).
Database as provided combines all PMA fisheries.
“PMA Crab” includes both qualified and non-qualified vessels.
“Non-PMA Crab” includes all crab (federal and state waters) other than PMA crab.
Counts by fishery within individual communities are not mutually exclusive as some vessels participate in more than one listed fishery.
“Total Community Fleet” represents unique vessels.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-20 Average annual value (in dollars) of commercial fisheries harvest from Alaskan waters, by community and fishery category, 1991-2000.

	Alaska					Washington		Oregon			
Fishery	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	Other States	Grand Total
PMA Crab	$4,313,597	$5,810,586	$4,587,926	$34,306,113	$9,061,006	$141,159,558	$9,580,706	$11,156,159	$4,130,153	$3,224,107	$227,329,909
non-PMA Crab	*	$276,040	*	$1,879,682	$11,468,042	$3,428,402	$1,438,342	*	$156,602	$287,643	$19,220,047
Salmon	$14,727,345	$14,723,836	*	$15,815,247	$128,672,683	$47,636,036	$52,557,339	*	$10,921,412	$22,893,700	$320,808,279
Pollock	*	$107,704	*	$6,005,876	$791,729	$53,995,031	$10,665,645	$6,745,705	$3,242,185	$4,453,312	$87,302,404
Pacific Cod	$340,576	$1,827,514	$4,982,291	$10,308,203	$3,932,386	$13,419,197	$3,050,236	$5,001,739	$2,430,722	$921,241	$46,214,104
Other Groundfish	$868,950	$2,057,026	$235,271	$7,144,549	$31,966,447	$15,267,487	$6,883,516	$531,274	$2,700,291	$1,699,582	$69,354,393
Other Fisheries	$2,692,853	$8,228,277	$1,780,749	$17,398,694	$45,216,286	$11,681,963	$9,156,290	$1,017,593	$3,047,420	$4,255,919	$104,476,043
"Non-vessel" Fisheries	$6,328,785	$1,278,131	$636,580	$3,779,779	$33,774,137	$2,696,724	$4,403,224	$11,001	$1,713,504	$5,215,035	$59,836,898
Total Community Value	$29,510,744	$34,309,114	$26,099,302	$96,638,141	$264,882,716	$289,284,397	$97,735,297	$24,789,538	$28,342,289	$42,950,539	$934,542,077

Notes: Offshore harvest (and value) not included, which affects mainly groundfish and Seattle-Tacoma CMSA (but also some other communities).
Database as provided combines all PMA fisheries.
“PMA Crab” includes both qualified and non-qualified vessels.
“Non-PMA Crab” includes all crab (federal and state waters) other than PMA crab.
“Other Fisheries” include all harvests associated with vessels attributed to a community, including halibut, exclusive of crab, salmon, pollock, Pacific cod, and other groundfish.
“Non-vessel” fisheries represent fish ticket landings attributable to residents of a community, but that do not have an associated vessel record (see text).
Average annual community harvest values are computed using 1991-2000 (that is, including years various fisheries were closed).

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-21 Average annual volume (in pounds) of commercial fisheries harvest from Alaskan waters, by community and fishery category, 1991-2000.

	Alaska					Washington		Oregon			
Fishery	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	Other States	Grand Total
PMA Crab	3,292,360	5,062,135	4,012,913	30,146,663	8,307,660	128,940,296	8,399,699	8,207,446	3,523,907	2,832,604	202,725,683
non-PMA Crab	*	143,737	*	1,097,065	5,971,964	1,770,543	967,223	*	112,621	186,822	10,412,633
Salmon	24,022,264	24,258,110	*	40,266,848	256,476,193	112,129,986	105,528,064	*	14,762,643	36,222,593	647,369,850
Pollock	*	1,313,831	*	68,321,595	8,757,773	623,965,654	119,922,540	76,889,832	37,769,105	49,953,114	1,002,378,430
Pacific Cod	1,445,915	7,136,265	26,630,638	45,586,871	15,913,174	71,605,318	15,603,709	26,852,414	11,898,341	4,841,239	227,513,883
Other Groundfish	1,067,436	1,769,931	608,592	19,240,712	22,092,178	22,527,337	8,797,458	2,918,791	6,261,156	1,749,690	87,033,281
Other Fisheries	5,280,218	13,595,750	2,829,117	19,511,615	66,595,299	16,103,408	18,904,012	699,378	2,826,116	4,021,936	150,366,849
"Non-vessel" Fisheries	7,217,411	1,491,641	*	6,536,465	41,437,616	3,180,870	5,330,636	13,006	2,049,978	6,160,106	74,298,811
Total Community Volume	42,325,604	54,771,399	67,605,059	230,707,832	425,551,856	980,223,412	283,453,340	115,747,211	79,203,867	105,968,106	2,402,099,419

Notes: Offshore harvest (and value) not included, which affects mainly groundfish and Seattle-Tacoma CMSA (but also some other communities).
Database as provided combines all PMA fisheries.
"PMA Crab" includes both qualified and non-qualified vessels.
"Non-PMA Crab" includes all crab (federal and state waters) other than PMA crab.
"Other Fisheries" include all harvests associated with vessels attributed to a community, including halibut, exclusive of crab, salmon, pollock, Pacific cod, and other groundfish.
"Non-vessel" fisheries represent fish ticket landings attributable to residents of a community, but that do not have an associated vessel record (see text).
Average annual community harvest values are computed using 1991-2000 (that is, including years various fisheries were closed).

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-22 Total value of commercial fisheries harvest from Alaskan waters, by community and fishery category, 1991-2000 as percent of total fishery value.

Fishery	Alaska					Washington		Oregon		Other States	Grand Total
	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle- Tacoma CMSA	Other Washington	Newport	Other Oregon		
PMA Crab	1.9%	2.6%	2.0%	15.1%	4.0%	62.1%	4.2%	4.9%	1.8%	1.4%	100.0%
non-PMA Crab	*	1.4%	*	9.8%	59.7%	17.8%	7.5%	*	0.8%	1.5%	100.0%
Salmon	4.6%	4.6%	0	4.9%	40.1%	14.8%	16.4%	*	3.4%	7.1%	100.0%
Pollock	*	0.1%	*	6.9%	0.9%	61.8%	12.2%	7.7%	3.7%	5.1%	100.0%
Pacific Cod	0.7%	4.0%	10.8%	22.3%	8.5%	29.0%	6.6%	10.8%	5.3%	2.0%	100.0%
Other Groundfish	1.3%	3.0%	0.3%	10.3%	46.1%	22.0%	9.9%	0.8%	3.9%	2.5%	100.0%
Other Fisheries	2.6%	7.9%	1.7%	16.7%	43.3%	11.2%	8.8%	1.0%	2.9%	4.1%	100.0%
"Non-vessel" Fisheries	10.6%	2.1%	1.1%	6.3%	56.4%	4.5%	7.4%	0.0%	2.9%	8.7%	100.0%
Total Community Value	3.2%	3.7%	2.8%	10.3%	28.3%	31.0%	10.5%	2.7%	3.0%	4.6%	100.0%

Notes: Offshore harvest (and value) not included, which affects mainly groundfish and Seattle-Tacoma CMSA (but also some other communities).
Database as provided combines all PMA fisheries.
"PMA Crab" includes both qualified and non-qualified vessels.
"Non-PMA Crab" includes all crab (federal and state waters) other than PMA crab.
"Other Fisheries" include all harvests associated with vessels attributed to a community, including halibut, exclusive of crab, salmon, pollock, Pacific cod, and other groundfish.
"Non-vessel" fisheries represent fish ticket landings attributable to residents of a community, but that do not have an associated vessel record (see text).
Average annual community harvest values are computed using 1991-2000 (that is, including years various fisheries were closed).

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-23 Total volume of commercial fisheries harvest from Alaskan waters, by community and fishery category, 1991-2000 as percent of total fishery harvest.

	Alaska					Washington		Oregon			
Fishery	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	Other States	Grand Total
PMA Crab	1.6%	2.5%	2.0%	14.9%	4.1%	63.6%	4.1%	4.0%	1.7%	1.4%	100.0%
non-PMA Crab	*	1.4%	*	10.5%	57.4%	17.0%	9.3%	*	1.1%	1.8%	100.0%
Salmon	3.7%	3.7%	*	6.2%	39.6%	17.3%	16.3%	*	2.3%	5.6%	100.0%
Pollock	*	0.1%	*	6.8%	0.9%	62.2%	12.0%	7.7%	3.8%	5.0%	100.0%
Pacific Cod	0.6%	3.1%	11.7%	20.0%	7.0%	31.5%	6.9%	11.8%	5.2%	2.1%	100.0%
Other Groundfish	1.2%	2.0%	0.7%	22.1%	25.4%	25.9%	10.1%	3.4%	7.2%	2.0%	100.0%
Other Fisheries	3.5%	9.0%	1.9%	13.0%	44.3%	10.7%	12.6%	0.5%	1.9%	2.7%	100.0%
"Non-vessel" Fisheries	9.7%	2.0%	1.2%	8.8%	55.8%	4.3%	7.2%	0.0%	2.8%	8.3%	100.0%
Total Community Volume	1.8%	2.3%	2.8%	9.6%	17.7%	40.8%	11.8%	4.8%	3.3%	4.4%	100.0%

Notes: Offshore harvest (and value) not included, which affects mainly groundfish and Seattle-Tacoma CMSA (but also some other communities).
Database as provided combines all PMA fisheries.
“PMA Crab” includes both qualified and non-qualified vessels.
“Non-PMA Crab” includes all crab (federal and state waters) other than PMA crab.
“Other Fisheries” include all harvests associated with vessels attributed to a community, including halibut, exclusive of crab, salmon, pollock, Pacific cod, and other groundfish.
“Non-vessel” fisheries represent fish ticket landings attributable to residents of a community, but that do not have an associated vessel record (see text).
Average annual community harvest values are computed using 1991-2000 (that is, including years various fisheries were closed).

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-24 Total value of commercial fisheries harvest from Alaskan waters, by community and fishery category, 1991-2000 as percent of total value of fish harvested in Alaskan water fisheries by vessels owned by community residents.

	Alaska					Washington		Oregon			
Fishery	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	Other States	Grand Total
PMA Crab	14.6%	16.9%	17.6%	35.5%	3.4%	48.8%	9.8%	45.0%	14.6%	7.5%	24.3%
non-PMA Crab	*	0.8%	*	1.9%	4.3%	1.2%	1.5%	*	0.6%	0.7%	2.1%
Salmon	49.9%	42.9%	*	16.4%	48.6%	16.5%	53.8%	*	38.5%	53.3%	34.3%
Pollock	*	0.3%	*	6.2%	0.3%	18.7%	10.9%	27.2%	11.4%	10.4%	9.3%
Pacific Cod	1.2%	5.3%	19.1%	10.7%	1.5%	4.6%	3.1%	20.2%	8.6%	2.1%	4.9%
Other Groundfish	2.9%	6.0%	0.9%	7.4%	12.1%	5.3%	7.0%	2.1%	9.5%	4.0%	7.4%
Other Fisheries	9.1%	24.0%	6.8%	18.0%	17.1%	4.0%	9.4%	4.1%	10.8%	9.9%	11.2%
"Non-vessel" Fisheries	21.4%	3.7%	2.4%	3.9%	12.8%	0.9%	4.5%	0.0%	6.0%	12.1%	6.4%
Total Community Value	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Notes: Offshore harvest (and value) not included, which affects mainly groundfish and Seattle-Tacoma CMSA (but also some other communities).
Database as provided combines all PMA fisheries.
“PMA Crab” includes both qualified and non-qualified vessels.
“Non-PMA Crab” includes all crab (federal and state waters) other than PMA crab.
“Other Fisheries” include all harvests associated with vessels attributed to a community, including halibut, exclusive of crab, salmon, pollock, Pacific cod, and other groundfish.
“Non-vessel” fisheries represent fish ticket landings attributable to residents of a community, but that do not have an associated vessel record (see text).
Average annual community harvest values are computed using 1991-2000 (that is, including years various fisheries were closed).

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-25 Total volume of commercial fisheries harvest from Alaskan waters, by community and fishery category, 1991-2000 as percent of total value of fish harvested in Alaskan water fisheries by vessels owned by community residents.

	Alaska					Washington		Oregon			
Fishery	Anchorage	Homer	King Cove/ Sand Point	Kodiak	Other Alaska	Seattle-Tacoma CMSA	Other Washington	Newport	Other Oregon	Other States	Grand Total
PMA Crab	7.8%	9.2%	5.9%	13.1%	2.0%	13.2%	3.0%	7.1%	4.4%	2.7%	8.4%
non-PMA Crab	*	0.3%	*	0.5%	1.4%	0.2%	0.3%	*	0.1%	0.2%	0.4%
Salmon	56.8%	44.3%	*	17.5%	60.3%	11.4%	37.2%	*	18.6%	34.2%	27.0%
Pollock	*	2.4%	*	29.6%	2.1%	63.7%	42.3%	66.4%	47.7%	47.1%	41.7%
Pacific Cod	3.4%	13.0%	39.4%	19.8%	3.7%	7.3%	5.5%	23.2%	15.0%	4.6%	9.5%
Other Groundfish	2.5%	3.2%	0.9%	8.3%	5.2%	2.3%	3.1%	2.5%	7.9%	1.7%	3.6%
Other Fisheries	12.5%	24.8%	4.2%	8.5%	15.6%	1.6%	6.7%	0.6%	3.6%	3.8%	6.3%
"Non-vessel" Fisheries	17.1%	2.7%	1.1%	2.8%	9.7%	0.3%	1.9%	0.0%	2.6%	5.8%	3.1%
Total Community Volume	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Notes: Offshore harvest (and value) not included, which affects mainly groundfish and Seattle-Tacoma CMSA (but also some other communities).
Database as provided combines all PMA fisheries.
"PMA Crab" includes both qualified and non-qualified vessels.
"Non-PMA Crab" includes all crab (federal and state waters) other than PMA crab.
"Other Fisheries" include all harvests associated with vessels attributed to a community, including halibut, exclusive of crab, salmon, pollock, Pacific cod, and other groundfish.
"Non-vessel" fisheries represent fish ticket landings attributable to residents of a community, but that do not have an associated vessel record (see text).
Average annual community harvest values are computed using 1991-2000 (that is, including years various fisheries were closed).

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

3.4.4.2 Catcher/processor sector existing conditions

This section provides information on BSAI crab catcher/processors. This sector has far fewer entities than seen in the harvest sector, and a very different distribution pattern by community and region than seen in the harvest sector.

Table 3.4-26 provides an annual average number of catcher/processors by fishery and community of ownership for the period 1991-2000. This table provides an at-a-glance summary of the distribution of the catcher/processor fleet. As shown, the fleet is highly concentrated in the Seattle-Tacoma CMSA, such that potential social or community impacts associated with this fleet under the various alternatives would accrue in large part to the greater Seattle area.

Table 3.4-26 Annual average number of qualified catcher/processors by relevant Bering Sea and Aleutian Islands crab fishery and location of owner of vessel, 1991-2000.

	Alaska		Washington	Oregon	
Data	Anchorage	Kodiak	Seattle-Tacoma CMSA	Newport	Grand Total
Bering Sea Opilio	0.1	1.1	8.6	0.0	9.9
Bering Sea Tanner	0.0	0.7	6.7	0.0	7.3
Bristol Bay Red	0.0	0.9	6.0	0.0	6.9
St. Matthew Blue	0.0	0.5	1.4	0.0	1.9
Adak Brown	0.0	1.0	0.2	0.0	1.2
Adak Red	0.0	0.8	0.3	0.0	1.2
Dutch Harbor Brown	0.0	0.1	0.0	0.0	0.1
Pribilof Blue	0.0	0.0	0.3	0.0	0.3
Pribilof Red	0.0	0.0	0.3	0.0	0.3
Total Non-Qualified (all 9 PMA Crab)	0.0	0.1	9.1	0.2	9.4
"Overlap" Vessels (all 9 PMA Crab)	0.0	0.1	0.3	0.0	0.4

Notes: Includes all catcher/processors, locations with zero excluded.
Annual averages based on the participation in open years for each fishery.
Over the 1991-2000 span a total number of unique qualified catcher/processors from each community for any and all years were:
Anchorage, 1; Kodiak, 2; Seattle-Tacoma CMSA, 8; Newport, 0 (Grand Total, 11).
Non-qualified were: Anchorage, 0; Kodiak, 0; Seattle-Tacoma CMSA, 25; Newport, 2 (Grand Total, 27).
Geographical ownership of some vessels changed over time, accounting for Anchorage and S-T CMSA opilio numbers.
“Overlap” vessels have both qualified and non-qualified PMA crab fisheries landings.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

3.4.4.3 Processing sector existing conditions

The amount of community-specific information that can be shown for the processing sector is very limited due to confidentiality restrictions. For example, because other Alaskan communities have fewer than four processing entities, only Kodiak and Unalaska/Dutch Harbor can be discussed in stand-alone terms. Tables 3.4-27 through 3.4-33 provide information on the BSAI crab processing sector by community or region.

Table 3.4-27 provides a count of processing entities by community, on an average annual basis for the period 1991-2000, for Kodiak processors, Unalaska/Dutch Harbor processors, other South region processors, total

South region processors, and North region processors.[3] Catcher/processor and some floating processor information does not have the same type of geographically referenced data as for the shore processors, so the direct applicability of this information in terms of community impact assessment of processing activity is limited. (These data appear under "Processing Activity without Area Designation" in the following table series.) As shown, even within these highly aggregated community and region categories, there are few processing entities for many of the cells. While count information is not confidential, value and volume data for entities in the low-count cells must be suppressed due to confidentiality concerns.

Table 3.4-28 provides processing volume information (in pounds) for the sectors, communities, and species shown in Table 3.4-27. This table provides a quick reference for the relative level of processing effort for the different fisheries by location, as measured by the volume of harvest. Table 3.4-29 shows this same information, but expressed as a percentage of each fishery by location. In other words, the fishery columns sum to 100 percent, allowing an at-a-glance perspective on the relative harvest volume within each fishery by place. For example, for the Bering Sea opilio fishery, 29.7 percent of the total fishery volume is processed in Unalaska, 39.2 percent in all locations within the south region combined, 26.8 percent in the north region, and so on. Table 3.4-30 also presents the information in terms of percentage, but in this case the place rows sum (rather than the fishery columns), allowing an easy reference for examining the relative processing volumes of the different BSAI crab fisheries for any given location. For example, Adak brown king crab comprises 1.7 percent of all the BSAI crab processed in Unalaska, Bristol Bay red king crab comprises 5.9 percent of the total BSAI crab processed in the community, the local volume dominance of opilio is seen in the fact that it makes up 79.8 percent of local BSAI crab processing, and so on.

Table 3.4-31 provides processing value information (in dollars) for the sectors, communities, and species shown in Table 3.4-27. This table provides a quick reference for the relative level of processing value for the different BSAI crab fisheries by location. Table 3.4-32 provides this same information as a percentage of the total processing value for each fishery (i.e., the fishery columns sum to 100 percent, in the way that volumes do in Table 3.4-29). This table is useful for determining how much of the total processing value of each BSAI crab species accrues to the individual locations listed. In Table 3.4-33, value information is presented in terms of individual species as percent of total BSAI crab processing value by location (i.e., the sector/location rows sum to 100 percent, in the way that volumes do in Table 3.4-30). Using this table, the value of individual crab species relative to all BSAI crab processed in that same location can be easily determined.

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[3] Where location information is available for floating processors, these processors are lumped with shore processors in relevant community totals.

Table 3.4-27 Annual average number of processors, 1991-2000, by city/port category and BSAI crab fishery.

	Processing Activity with Area Designation					Processing Activity without Area Designation		
	South Region							
Species	Kodiak	Unalaska	Other South	Total South	North Region	Catcher Processors	Undesignated Floaters	Grand Total
Adak Brown	0.0*	4.2	0.8*	5.0*	0.0*	2.5*	0.4*	7.9
Adak Red	0.5*	3.5*	1.3*	5.3*	0.2*	1.7*	0.5*	7.7
Bristol Bay Red	3.4*	7.1	4.3*	14.8	0.9*	10.8	3.4*	29.8
Bering Sea Opilio	3.0*	9.1	4.5*	16.6	6.6	16.0	5.1	44.3
Bering Sea Tanner	6.2	8.5	5.3	20.0	2.0*	15.7	7.0*	44.7
Dutch Harbor Brown	0.0*	4.7	0.6*	5.3*	0.0*	1.6*	0.4*	7.3
Pribilof Blue	1.0*	3.8*	2.5*	7.3*	4.0*	0.3*	1.0*	12.5
Pribilof Red	1.3*	4.5	2.5*	8.3*	3.5*	0.3*	1.2*	13.3
St. Matthew Blue	0.3*	4.0	1.0*	5.3*	3.6*	4.0	1.8*	14.6

Notes: Catcher processor data do not have area designations.
"Undesignated Floaters" are mobile processors that could not be assigned city or port locations.
"Other South" includes all southern locations except Kodiak and Unalaska.
"North Region" includes St. George, St. Matthew, and St. Paul.
Averages are computed using years that each fishery was actually open 1991-2000.
Cells with values marked * are suppressed in subsequent volume and value tables due to confidentiality.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-28 Annual average of pounds processed, 1991-2000, by city/port category and BSAI crab fishery.

	Processing Activity with Area Designation					Processing Activity without Area Designation		
	South Region				North Region	Catcher Processors	Undesignated Floaters	Grand Total
Species	Kodiak	Unalaska	Other South	Total South				
Adak Brown	*	1,078,931	*	*	*	*	*	26,998,930
Adak Red	*	*	*	*	*	*	*	3,326,722
Bristol Bay Red	*	3,762,629	*	6,892,088	*	821,212	*	88,761,237
Bering Sea Opilio	*	51,229,673	*	67,607,801	46,192,962	24,732,733	33,877,297	1,724,107,927
Bering Sea Tanner	561,414	3,986,754	2,570,940	7,119,107	*	1,614,029	*	112,158,020
Dutch Harbor Brown	*	3,372,344	*	*	*	*	*	38,481,064
Pribilof Blue	*	*	*	*	*	*	*	3,098,193
Pribilof Red	*	175,223	*	*	*	*	*	6,212,922
St. Matthew Blue	*	437,785	*	*	*	231,041	*	25,751,808
Grand Total	1,516,279	64,210,611	21,649,062	87,375,952	48,733,900	29,226,286	37,553,545	2,028,896,823

Notes: Catcher processor data do not have area designations.
"Undesignated Floaters" are mobile processors that could not be assigned city or port locations.
"Other South" includes all southern locations except Kodiak and Unalaska.
"North Region" includes St. George, St. Matthew, and St. Paul.
Annual average obtained by dividing decade total by ten (i.e., for all years, not just open years) to provide for comparability across all fisheries and all years for the communities and regions.
* = cells must be suppressed due to confidentiality due to individual or a combination of cell characteristics.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-29 Volume processed, 1991-2000, by city/port category as percentage of individual BSAI crab fishery.

	Processing Activity with Area Designation					Processing Activity without Area Designation		
	South Region							
Species	Kodiak	Unalaska	Other South	Total South	North Region	Catcher Processors	Undesignated Floaters	Grand Total
Adak Brown	0.0%	40.0%	*	*	0.0%	*	*	100.0%
Adak Red	*	*	*	*	*	*	*	100.0%
Bristol Bay Red	*	42.4%	*	77.6%	*	9.3%	*	100.0%
Bering Sea Opilio	*	29.7%	*	39.2%	26.8%	14.3%	19.6%	100.0%
Bering Sea Tanner	5.0%	35.5%	22.9%	63.5%	*	14.4%	*	100.0%
Dutch Harbor Brown	0.0%	87.6%	*	*	0.0%	*	*	100.0%
Pribilof Blue	*	*	*	*	*	*	*	100.0%
Pribilof Red	*	28.2%	*	*	*	*	*	100.0%
St. Matthew Blue	*	17.0%	*	*	*	9.0%	*	100.0%
Grand Total	0.7%	31.6%	10.7%	43.1%	24.0%	14.4%	18.5%	100.0%

Notes: Catcher/processor data do not have area designations.
"Undesignated Floaters" are mobile processors that could not be assigned city or port locations.
"Other South" includes all southern locations except Kodiak and Unalaska.
"North Region" includes St. George, St. Matthew, and St. Paul.
Annual average obtained by dividing decade total by 10 (i.e., for all years, not just open years) to provide for comparability across all fisheries and all years for the communities and regions.
* = cells must be suppressed due to confidentiality due to individual or a combination of cell characteristics.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-30 Volume processed, 1991-2000, by city/port category as a percentage of total BSAI crab fisheries.

	Processing Activity with Area Designation					Processing Activity without Area Designation		
	South Region							
Species	Kodiak	Unalaska	Other South	Total South	North Region	Catcher Processors	Undesignated Floaters	Grand Total
Adak Brown	0.0%	1.7%	*	*	0.0%	*	*	1.3%
Adak Red	*	*	*	*	*	*	*	0.2%
Bristol Bay Red	*	5.9%	*	7.9%	*	2.8%	*	4.4%
Bering Sea Opilio	*	79.8%	*	77.4%	94.8%	84.6%	90.2%	85.0%
Bering Sea Tanner	37.0%	6.2%	11.9%	8.1%	*	5.5%	*	5.5%
Dutch Harbor Brown	0.0%	5.3%	*	*	0.0%	*	*	1.9%
Pribilof Blue	*	*	*	*	*	*	*	0.2%
Pribilof Red	*	0.3%	*	*	*	*	*	0.3%
St. Matthew Blue	*	0.7%	*	*	*	0.0%	*	1.3%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Notes: Catcher/processor data do not have area designations.
“Undesignated Floaters” are mobile processors that could not be assigned city or port locations.
“Other South” includes all southern locations except Kodiak and Unalaska.
“North Region” includes St. George, St. Matthew, and St. Paul.
Annual average obtained by dividing decade total by 10 (i.e., for all years, not just open years) to provide for comparability across all fisheries and all years for the communities and regions.
* = cells must be suppressed due to confidentiality due to individual or a combination of cell characteristics.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-31 Annual average of value in dollars of crab processed, 1991-2000, by city/port category and BSAI crab fishery.

	Processing Activity with Area Designation					Processing Activity without Area Designation		
	South Region							
Species	Kodiak	Unalaska	Other South	Total South	North Region	Catcher Processors	Undesignated Floaters	Grand Total
Adak Brown	*	$2,648,595	*	*	*	*	*	$6,837,538
Adak Red	*	*	*	*	*	*	*	$1,349,400
Bristol Bay Red	*	$15,069,715	*	$28,088,680	*	$3,191,166	*	$35,781,442
Bering Sea Opilio	*	$40,233,123	*	$54,415,414	$44,504,637	$19,174,922	$23,619,793	$141,714,765
Bering Sea Tanner	$1,170,659	$7,589,340	$5,279,072	$14,039,070	*	$2,778,785	*	$20,922,829
Dutch Harbor Brown	*	$8,902,323	*	*	*	*	*	$10,215,680
Pribilof Blue	*	*	*	*	*	*	*	$747,600
Pribilof Red	*	$764,114	*	*	*	*	*	$2,690,481
St. Matthew Blue	*	$1,205,264	*	*	*	$638,736	*	$7,070,174
Grand Total	$3,542,039	$76,942,759	$31,857,603	$112,342,401	$51,582,835	$30,541,540	$32,863,133	$227,329,909

Notes: Catcher/processor data do not have area designations.
"Undesignated Floaters" are mobile processors that could not be assigned city or port locations.
"Other South" includes all southern locations except Kodiak and Unalaska.
"North Region" includes St. George, St. Matthew, and St. Paul.
Annual average obtained by dividing decade total by 10 (i.e., for all years, not just open years) to provide for comparability across all fisheries and all years for the communities and regions.
* = cells must be suppressed due to confidentiality due to individual or a combination of cell characteristics.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-32 Value of crab processed, 1991-2000, by city/port category as percentage of individual BSAI crab fishery.

Species	Processing Activity with Area Designation					Processing Activity without Area Designation		Grand Total
	South Region				North Region	Catcher Processors	Undesignated Floaters	
	Kodiak	Unalaska	Other South	Total South				
Adak Brown	0.0%	38.7%	*	*	0.0%	*	*	100.0%
Adak Red	*	*	*	*	*	*	*	100.0%
Bristol Bay Red	*	42.1%	*	78.5%	*	8.9%	*	100.0%
Bering Sea Opilio	*	28.4%	*	38.4%	31.4%	13.5%	*	100.0%
Bering Sea Tanner	5.6%	36.3%	25.2%	67.1%	*	13.3%	16.7%	100.0%
Dutch Harbor Brown	0.0%	87.1%	*	*	0.0%	*	*	100.0%
Pribilof Blue	*	*	*	*	*	*	*	100.0%
Pribilof Red	*	28.4%	*	*	*	*	*	100.0%
St. Matthew Blue	*	17.0%	*	*	*	9.0%	*	100.0%
Grand Total	1.6%	33.8%	14.0%	49.4%	22.7%	13.4%	14.5%	100.0%

Notes: Catcher/processor data do not have area designations.
"Undesignated Floaters" are mobile processors that could not be assigned city or port locations.
"Other South" includes all southern locations except Kodiak and Unalaska.
"North Region" includes St. George, St. Matthew, and St. Paul.
Annual average obtained by dividing decade total by 10 (i.e., for all years, not just open years) to provide for comparability across all fisheries and all years for the communities and regions.
* = cells must be suppressed due to confidentiality due to individual or a combination of cell characteristics.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-33 Value of crab processed, 1991-2000, by city/port category as a percentage of total BSAI crab fisheries.

	Processing Activity with Area Designation					Processing Activity without Area Designation		
	South Region							
Species	Kodiak	Unalaska	Other South	Total South	North Region	Catcher Processors	Undesignated Floaters	Grand Total
Adak Brown	0.0%	3.4%	*	*	0.0%	*	*	3.0%
Adak Red	*	*	*	*	*	*	*	0.6%
Bristol Bay Red	*	19.6%	*	25.0%	*	10.4%	*	15.7%
Bering Sea Opilio	*	52.3%	*	48.4%	86.3%	62.8%	71.9%	62.3%
Bering Sea Tanner	33.1%	9.9%	16.6%	12.5%	*	9.1%	*	9.2%
Dutch Harbor Brown	0.0%	11.6%	*	*	0.0%	*	*	4.5%
Pribilof Blue	*	*	*	*	*	*	*	0.3%
Pribilof Red	*	1.0%	*	*	*	*	*	1.2%
St. Matthew Blue	*	1.6%	*	*	*	2.1%	*	3.1%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Notes: Catcher/processor data do not have area designations.
“Undesignated Floaters” are mobile processors that could not be assigned city or port locations.
“Other South” includes all southern locations except Kodiak and Unalaska.
“North Region” includes St. George, St. Matthew, and St. Paul.
Annual average obtained by dividing decade total by 10 (i.e., for all years, not just open years) to provide for comparability across all fisheries and all years for the communities and regions.
* = cells must be suppressed due to confidentiality due to individual or a combination of cell characteristics.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

The next series of tables (Tables 3.4-34 through 3.4-36) represents an attempt to characterize "processor dependency" on the relevant BSAI crab species encompassed in the proposed management alternatives relative to other fisheries. To support this effort, NPFMC staff prepared a data file containing all fish ticket information for all processors (not only those that process at least some volume of the relevant crab species[4]), and linked this to a file containing specific processor attribute information. However, information on the location of processing proved difficult to determine for more than a few processors and was especially problematic for a number of floating processors.[5] Further, catcher/processors do not have areas of operation analogous to shore based processors, or even floaters, meaning that a significant amount of processing effort cannot be geographically referenced in a way useful for community or SIA.

Because of these locational problems, it was thought desirable to check the extent to which the database adequately represents the processing activity of any given community in order to be able to interpret the apparent results of the dependency analysis. The most readily available (and most relevant) processing information with which to make this test is the BSAI crab database itself. This database contains geographic reference information for approximately 93 percent of BSAI crab processed and was constructed by NPFMC staff in order to analyze the regionalization aspects of the proposed alternatives. Both databases contain the same amount of crab in terms of pounds and value; however, the BSAI crab-only database is much more complete in terms of attributing location to the processing. This is largely due to the complexity of designing a database that can organize information on an entity (i.e., floater or catcher/processor) that can potentially process many different species in many different areas. Not surprisingly, locational information for communities with a preponderance of shoreplants (Kodiak and Unalaska) are those for which information for the two databases is most nearly the same – a 100 percent match for Kodiak and about a 78 to 82 percent correspondence for Unalaska as well as the "Other South" category (i.e., the residual south region exclusive of Kodiak and Unalaska). This contrasts sharply with the northern region, where most processors are floaters or catcher/processors, and the two databases only have about a 32 percent correspondence. In practical terms, this means that it is reasonable to use these data to discuss dependency for Kodiak, Unalaska, and "Other South," but not for other areas.

Another important caveat is that the data correspondence test was performed only for BSAI crab, and different fisheries could exhibit different patterns. (It does, however, make intuitive sense that shoreplants, and locations where they are concentrated, may be better documented in terms of location of processing than are more mobile operations.) It is also important to note that given these and other known limitations of the data, the "dependency figures" shown in the tables are, at best, rough approximations. Further, it is important to bear in mind that these data cover the full spectrum of processing operations in a given locality, and not

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[4] In the harvest vessel discussion in Section 3.4.4.1, diversity or dependency for local fleets was discussed both in terms of community crab fleets and community total (crab and non-crab) fleets. This processing discussion only covers community total processing and not community crab processors. A discussion of diversity or dependency for only crab processors in specific locations was not practical with the available data, as data by entity included facilities in multiple communities and regions.

[5] Tables 3.4-34 through 3.4-36 are based on a different data set than Tables 3.4-27 through 3.4-33, which also cover processing by location. Tables in the latter series cover crab species only, while tables in the former series cover many commercial fisheries. A directed effort was made for this analysis to specifically clean up location information for crab processing in the data set focused on crab species (i.e., the data that underlies Tables 3.4-27 through 3.4-33). As a result, location information for crab differs between the two data sets, with the crab-specific distribution tables containing fewer "unknown" records than the multi-fisheries data set. As a result, more crab processing is assigned, for example, to Unalaska and Other South in Tables 3.4-27 through 3.4-33 than in 3.4-34 through 3.4-36 (where there is more crab in the "Other/Unknown" category). This being the case, these table series should be used independently and for comparison purposes internal to each table set, avoiding apparent inconsistencies between the two sets.

only those that process BSAI crab. It thus represents community dependence on BSAI crab at a relatively high level of abstraction and may not reflect any specific operation in the community, and the data may represent more in the way of collective entity dependency rather than community dependency. Community dependency specifically for Unalaska and Kodiak is discussed in the relevant community profiles in Appendix 3, but confidentiality restrictions prevent parallel discussions for other communities. Data for the northern region, catcher/processors, floating processors without a geographic designation, and other processors that lacked a geographic reference in the database are lumped into the "Other/Unknown" category in the tables.

Table 3.4-34 presents annual average value data for the various species run by BSAI crab processors over the period 1991-2000. Table 3.4-35 provides this information expressed in terms of percentage of total value by place, and the rows of this table provide a quick look at the relative value by species for the geographic locations specified. As shown, Unalaska crab processors are heavily dependent on BSAI crab and pollock, with Pacific cod and salmon in (quite distant) third and fourth places. "Other South" locations are very dependent (nearly 59 percent of total value) on salmon but also process a significant amount of BSAI crab, pollock, Pacific cod, and halibut (in order of descending percentage of total value processed). Kodiak processors also relied more on salmon than on any other species during this period, but at only about half of the percentage of "Other South" processors. Kodiak processors demonstrated somewhat more diversified and balanced operations dependent on Pacific cod, halibut, pollock, sablefish, and crab. Time series information is presented in the data appendix and is also summarized in the community profiles and possible dynamics (and their significance) are discussed there. Table 3.4-36 provides the same type of information, but expressed as a percentage of the individual fisheries distributed by community. In this case, the columns in the table provide a useful summary of the distribution of processing of any given species or species group. For example, for the relevant BSAI crab species, about 2 percent is processed in Kodiak, 28 percent in Unalaska, and 12 percent in "Other South," and 59 percent falls into the residual "Other/Unknown" category. For most categories, the "unknown" locational category comprises a large part of the data.

Although quantitative processing dependency information for the north region is not well developed and would be confidential in any case, it is common knowledge that the relevant BSAI crab species (and especially opilio crab) and halibut are the two most important fisheries for communities in that region. The former is a fundamental part of the tax base of regional communities through the raw fish tax, and the latter is a fishery in which local fishermen are significantly engaged. More detailed qualitative information is provided in the community profiles for St. Paul and St. George in Appendix 3.

Table 3.4-34 Annual average value of processing by species by place, 1991-2000.

City	PMA Crab	Non-PMA Crab	Salmon	Halibut*	Sablefish	Pollock	Pacific Cod	Other Groundfish	All Other Fisheries	Non-Commercial	TOTAL all Fisheries
Kodiak	$3,542,040	$2,512,134	$26,575,772	$14,220,043	$7,292,082	$10,204,100	$14,357,799	$3,287,010	$2,168,172	$634,245	$84,793,396
Unalaska	$62,852,299	$2,158,182	$6,585,749	$4,631,533	$2,446,047	$55,274,719	$9,079,646	$1,032,549	$855,197	$1,438,979	$146,354,900
Other South	$26,255,324	$948,210	$138,004,815	$12,441,264	$6,054,635	$25,413,947	$17,815,591	$481,978	$5,325,998	$2,729,178	$235,470,941
Other/Unknown	$134,680,283	$14,628,485	$209,186,010	$42,712,902	$46,120,675	$717,195	$4,881,809	$2,614,089	$30,524,351	$18,330,793	$504,396,591
Grand Total	$227,329,946	$20,247,010	$380,352,346	$74,005,742	$61,913,439	$91,609,960	$46,134,845	$7,415,627	$38,873,718	$23,133,195	$971,015,828

Notes: "Non-commercial" includes forfeited bycatch, test fisheries, CDQ, etc.
"Other/Unknown" includes Northern Region, catcher/processors, floaters without a geographic designation, or any processing entity without a geographic reference in the database.
* Note 2000 halibut data missing from the database; therefore, halibut values are understated.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-35 Annual average value of processing by species as a percentage of total by place, 1991-2000.

City	PMA Crab	Non-PMA Crab	Salmon	Halibut*	Sablefish	Pollock	Pacific Cod	Other Groundfish	All Other Fisheries	Non-Commercial	TOTAL all Fisheries
Kodiak	4.2%	3.0%	31.3%	16.8%	8.6%	12.0%	16.9%	3.9%	2.6%	0.7%	100.0%
Unalaska	42.9%	1.5%	4.5%	3.2%	1.7%	37.8%	6.2%	0.7%	0.6%	1.0%	100.0%
Other South	11.2%	0.4%	58.6%	5.3%	2.6%	10.8%	7.6%	0.2%	2.3%	1.2%	100.0%
Other/Unknown	26.7%	2.9%	41.5%	8.5%	9.1%	0.1%	1.0%	0.5%	6.1%	3.6%	100.0%
Grand Total	23.4%	2.1%	39.2%	7.6%	6.4%	9.4%	4.8%	0.8%	4.0%	2.4%	100.0%

Notes: "Non-commercial" includes forfeited bycatch, test fisheries, CDQ, etc.
"Other/Unknown" includes Northern Region, catcher/processors, floaters without a geographic designation, or any processing entity without a geographic reference in the database.
* Note 2000 halibut data missing from the database; therefore, halibut values are understated.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

Table 3.4-36 Annual average value of processing by place as a percentage of total by species, 1991-2000.

City	PMA Crab	Non-PMA Crab	Salmon	Halibut*	Sablefish	Pollock	Pacific Cod	Other Groundfish	All Other Fisheries	Non-Commercial	TOTAL all Fisheries
Kodiak	1.6%	12.4%	7.0%	19.2%	11.8%	11.1%	31.1%	44.3%	5.6%	2.7%	8.7%
Unalaska	27.6%	10.7%	1.7%	6.3%	4.0%	60.3%	19.7%	13.9%	2.2%	6.2%	15.1%
Other South	11.5%	4.7%	36.3%	16.8%	9.8%	27.7%	38.6%	6.5%	13.7%	11.8%	24.2%
Other/Unknown	59.2%	72.3%	55.0%	57.7%	74.5%	0.8%	10.6%	35.3%	78.5%	79.2%	51.9%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Notes: “Non-commercial” includes forfeited bycatch, test fisheries, CDQ, etc.

“Other/Unknown” includes Northern Region, catcher/processors, floaters without a geographic designation, or any processing entity without a geographic reference in the database.

* Note 2000 halibut data missing from the database; therefore, halibut values are understated.

Source: Summarized from the NPFMC Bering Sea Crab Data Base / 2001_1

3.4.4.4 Detailed community existing conditions

Community profiles for Unalaska/Dutch Harbor, Akutan, King Cove, Sand Point, Adak, St. Paul, St. George, Kodiak, and Seattle may be found in Appendix 3. These profiles contain detailed descriptions of the existing conditions in these communities, as well as overview treatments of potential social impact issues relative to BSAI crab management alternatives for the particular communities.

3.4.5 Community development quota program for BSAI crab fisheries

The Magnuson-Stevens Act mandated that the Council and NOAA Fisheries establish a CDQ program under which a percentage of the total allowable catch of BSAI crab fisheries is allocated to the program (16 USC 1855[i][1][A]). The goals and purpose of the CDQ program are to allocate CDQ to eligible western Alaska communities to provide the means for starting or supporting commercial fishery activities that will result in ongoing, regionally based, commercial fishery or related businesses. The CDQ program extends the economic opportunities of the developing fisheries in the BSAI to small, rural communities which had otherwise not benefitted from their proximity to these valuable living marine resources. The CDQ program began in 1992 with the pollock CDQ fishery, and expanded to include halibut, sablefish, all BSAI groundfish, and BSAI crab. According to the Alaska Department of Community and Economic Development, since 1992, approximately 9,000 jobs have been created for western Alaska residents with wages totaling more than $60 million. The CDQ program has contributed to fisheries infrastructure development in western Alaska, as well as providing vessel loan programs, education, training, and other CDQ related benefits.

The communities which are currently eligible to participate in the CDQ program include 65 coastal Alaska villages with a total population of about 27,000. The CDQ-qualifying communities have organized themselves into six non-profit groups (with between 1 and 20 villages in each group). The CDQ-villages are geographically dispersed, extending from Atka, on the Aleutian chain, along the Bering coast, to the village of Wales, near the Arctic Circle. The six CDQ organizations have been in existence since late 1992. The groups are the Aleutian Pribilof Island Community Development Association, Bristol Bay Economic Development Corporation, Central Bering Sea Fishermen's Association, Coastal Villages Regional Fund, Norton Sound Economic Development Corporation, and Yukon Delta Fisheries Development Association. More detailed information on the CDQ program is available in the SIA: BSAI Crab Rationalization Overview and Community Profiles, which is Appendix 3.

The CDQ groups are non-profit entities, which may have for-profit subsidiaries. Each group submits comprehensive plans on the intended use of the CDQ funds. These uses vary widely between groups, but most are fishing-related investments, scholarships, training, employment services and other projects which are intended to benefit the communities and regions the CDQ groups represent. The groups are buying equity in fishing vessels which will harvest crab in both CDQ and open access fisheries.

In early 1998, NOAA Fisheries created the crab CDQ reserve and accompanying regulations. The crab CDQ species include all king and Tanner crab species in the BSAI that have a GHL specified by the State, which are Bristol Bay red king crab, Pribilof Islands red and blue king crab, St. Matthew blue king crab, snow crab, Norton Sound red king crab, and Tanner crab. The CDQ allocation is based on the total harvest of each of these crab species. Crab CDQ fisheries began in 1998. In establishing the crab CDQ program, the Magnuson-Stevens Act phased in the crab CDQ reserves. The crab CDQ groups received 3.5 percent of the CDQ crab species harvested in 1998, 5.0 percent in 1999 and 7.5 percent in 2000 and beyond. In 1998, the CDQ groups harvested snow crab, St. Matthew blue king crab, Pribilof red and blue king crab, and Bristol Bay red king crab. No CDQ fishery for Tanner crab occurred. In 1999, the State closed the fisheries for Pribilof red and blue king crab and St. Matthews blue king crab. Since 1999, CDQ groups have only harvested snow crab and Bristol Bay red king crab.

NOAA Fisheries implements the crab CDQ program by establishing the crab CDQ reserve and authorizing the State to manage crab harvesting activity of the BSAI CDQ groups. The State also recommends the annual percentage allocations of crab among the CDQ groups. NOAA Fisheries reviews these recommendations and approves them if they comply with 50 CFR part 679 and all other applicable federal laws. The State submits to NOAA Fisheries its recommendations for approval of Community Development Plans (CDPs) and allocation of the crab CDQ reserve among CDQ groups.

The percent allocation to each group is determined by a percentage set forth for each CDQ group by the Alaska Department of Community and Economic Development, and reviewed and approved by NOAA Fisheries. Table 3.4-37 shows the CDQ allocation to each CDQ group for 2001-2002.

Table 3.4-37 Community development quota allocation for 2001- 2002.

Crab species	APICDA	BBEDC	CBSFA	CVRF	NSEDC	YDFDA
Bristol Bay red king crab	18%	18%	10%	18%	18%	18%
Norton Sound red king crab	0%	0%	0%	0%	50%	50%
Pribilof red and blue king crab	0%	0%	100%	0%	0%	0%
St. Matthew blue king crab	50%	12%	0%	12%	14%	12%
Snow crab	10%	19%	19%	17%	18%	17%
Tanner crab	10%	19%	19%	17%	18%	17%

Notes: APICDA - Aleutian Pribilof Island Community Development Association
BBEDC - Bristol Bay Economic Development Corporation
CBSFA - Central Bering Sea Fishermen's Association
CVRF - Coastal Villages Relief Fund
NSEDC - Norton Sound Economic Development Corporation
YDFDA -Yukon Delta Fisheries Development Association

The State is responsible for monitoring and enforcing the crab CDQs under authority contained in the crab FMP. The FMP authorizes the State to manage crab harvesting activity of the BSAI CDQ groups (§8.1.4.2 of the BSAI crab FMP). The State manages the BSAI crab CDQ program according to regulations at 5 AAC 39.690. In 1997, the BOF adopted the BSAI king and Tanner Crab CDQ FMP. In the regulations implementing the State's plan, the BOF authorized the Commissioner of ADF&G to open and manage the CDQ crab fisheries by issuing permits to CDQ groups. ADF&G requires the CDQ groups to submit fishery plans prior to each fishery. Plans include names of participating vessels and operators, vessel information regarding safety and communications, intended processor and location, method of attaining but not exceeding the allocation, and if a cooperative effort, the method of dealing with deadloss and overages.

The CDQ groups harvest crab using a vessel owned in whole or in part by the CDQ group or the CDQ group contracts with a crab vessel to harvest its allocation. For small crab fisheries, the CDQ groups also pool their allocation and harvest it with one or two vessels. In 2002, CDQ groups have ownership in approximately 13 crab fishing vessels. According to the Alaska Department of Community and Economic Development, the CDQ groups that contract with vessels to harvest crab receive an estimated 20 to 30 percent of the ex-vessel price due to the costs of harvesting the crab. The revenues the CDQ groups receive from crab is substantial. In 2000 and 2001, CDQ groups earned approximately $5.7 million in royalties from the harvest of Bristol Bay red king crab and snow crab.

All CDQ crab fisheries have occurred subsequent to the open access fisheries, and all CDQ vessels participated in the prior open access fishery. Before vessels are allowed to register for the CDQ fishery, the offload of crab harvested in the open access fishery had to be complete. Fishermen were required to obtain buoy tags for all gear fished, and if required, an onboard observer. At the time of registration all gear onboard the vessel had to be tagged with CDQ pot tags; all gear in the water had to be CDQ tagged before being deployed in the fishery.

The following CDQ fishery information provides details for each CDQ fishery each year since 1998, when the program started. The Norton Sound CDQ fishery is discussed separately at the end of this section. Additional information on the CDQ crab fisheries is provided in the Annual Management Report for the Commercial and Subsistence Shellfish Fisheries of the Bering Sea 2002/2003 (ADF&G 2003).

1998

The allocation for 1998 was 3.5 percent of the total harvest of red king crab, blue king crab, and snow crab. All six CDQ groups participated in those fisheries during the year; however, not all groups participated in each individual fishery. A total of 20 vessels harvested 9.5 million lbs. of red king crab, blue king crab, and snow crab. The fishery value for all CDQ crab fisheries was approximately $6.2 million. Four shorebased processing plants, two shorebased live crab shippers, and one floater-processor operated during the CDQ fisheries.

No Tanner crab fishery occurred due to low stock abundance.

Onboard observers were required during all fishing operations. Observers documented fishing practices and collected biological data during periods outside of the normal fishery seasons. The onboard observers provided data in fisheries where at-sea sampling was minimal. Data obtained from observers deployed during CDQ king crab fisheries indicated no appreciable difference in fishing strategy as compared to the open access fishery. The industry-preferred minimum size is 4.0 inches for snow crab. A high discard rate of crabs over 4 inches was observed during the CDQ snow crab fishery, which indicated a possible change in fishing strategy.

Regulations pertaining to the CDQ fisheries authorize a harvest prior to the open access fishery. ADF&G did not allow a CDQ harvest before the open access fishery during the first year. A full understanding of the impact of these new fisheries and adequate staff to handle the increased management burden was needed before allowing CDQ fisheries to occur prior to the open access fisheries. The intent was to allow CDQ groups to harvest part of their allocation before the open access fishery during the second and subsequent years of the program. This would have allowed CDQ groups to harvest part of their 1999 allocation of snow crab in the fall of 1998. NOAA Fisheries determined that their CDQ crab regulation language did not allow for a harvest of the allocation outside of the calendar year to which it was assigned. The intent of NOAA Fisheries was not to impede ADF&G management of the CDQ crab fisheries. The federal CDQ regulations were revised; however, not in time for any harvest of the 1999 allocation of snow crab to occur in the fall of 1998.

1999

The CDQ allocation for 1999 was 5 percent of the total harvest of BSAI crab. Bering Sea snow crab and Bristol Bay red king crab were the only CDQ fisheries to occur. No commercial harvest of St. Matthew blue king crab, Tanner crab, or Pribilof red or blue king crab occurred in the Bering Sea during 1999 due to low stock abundance. A total of 25 vessels harvested 10.25 million lbs. of red king crab and snow crab. The total CDQ fishery value was $11.5 million. Four shorebased processing plants and one floater-processor operated during the CDQ fisheries.

The BOF agreed to address an agenda change request at the March 1999 meeting to consider a proposal to prohibit any CDQ harvest prior to the open access fishery. Representatives of processors and non-CDQ fishermen contended that CDQ crab on the market prior to the open access fishery would be detrimental to value of the latter fishery. The BOF directed the CDQ, non-CDQ and processor representatives to reach a compromise, and put the results into regulation. The new regulations allow a CDQ king or Tanner crab fishery prior to the open access fishery only when the GHL is 50 million lbs. or more, and a maximum of 30 percent of the CDQ allocation may be harvested.

Six CDQ groups participated in the Bering Sea snow crab fishery. The observer coverage was reduced in the CDQ snow crab fishery from one observer per vessel to one per CDQ group. This level of coverage, based on the number of vessels in the 1998 fishery, was considered adequate to obtain biological sampling goals set forth by ADF&G.

ADF&G changed permitting procedures after the allocation was exceeded in the snow crab fishery for two consecutive years. Permits for CDQ fisheries were previously issued only to vessels fishing for the groups. These permits were issued before the actual allocation was established, and therefore did not reference the CDQ group's harvest allocation. Permits were henceforth to be issued to each CDQ group, initially stating the group allocation percentage and followed by an addendum with the actual allocation in pounds. The vessels were to be issued a permit that referred to the group permit and the associated allocation.

Ten vessels fished for the five CDQ groups eligible to participate in the Bristol Bay CDQ red king crab fishery. Observer coverage remained at one observer per vessel. This level of coverage was due to the anticipated short duration of the fishery; therefore, the inability for observers to attain the goal one sampling trip on each vessel during the fishery.

Data obtained from observers deployed during CDQ king crab fisheries indicated no noteworthy difference in fishing strategy as compared to the open access fishery. The high discard rate of crabs over four inches was observed during the 1998 CDQ snow crab fishery was also observed during the 1999 fishery. Data collected by observers and dockside samplers in the open access fishery and by observers during the 1999 CDQ fishery showed no substantial difference in average CW of harvested snow crab. Fish ticket data show no appreciable difference in average weight. Observer debriefings and analysis of logbook data from unobserved effort show that the discard of four-inch and larger crab in the CDQ fishery is primarily due to the high occurrence of epibionts. This fishery follows the open access fishery, thus fewer marketable crabs are available for harvest.

2000

The CDQ allocation for 2000 was 7.5 percent of the total harvest of Bristol Bay red king crab and Bering Sea snow crab. All CDQ fishing activity occurred subsequent to the open access fishery. All CDQ vessels participated in the open access fishery, and all permit and registration requirements previously stated were still in effect. No commercial harvest of St. Matthew blue king crab, Tanner crab, or Pribilof red or blue king crab, CDQ or open access, occurred in the Bering Sea during 2000 due to low stock abundance.

Six CDQ groups participated in the Bering Sea snow crab fishery in 2000. Five CDQ groups participated in the Bristol Bay red king crab fishery. A total of 15 vessels harvested 3.1 million lbs. of red king crab and snow crab for a total CDQ fisheries value of $7.2 million. The CDQ group portion is estimated to be 20 to 30 percent of the fishery value. In 2000, the CDQ groups received estimated royalties of $3.2 million.

In 2000 the observer coverage was increased in the CDQ snow crab fishery from one observer per group to two per group. This level of coverage was necessary to obtain the biological sampling goals set forth by ADF&G. Observer coverage remained at one observer per vessel for the Bristol Bay red king crab fishery. Observers continued to collect biological data and documented fishing practices of the CDQ fleet.

Data obtained from observers deployed during CDQ red king crab fishery indicated no appreciable difference in fishing strategy as compared to the open access fishery. A high discard rate of crabs over four inches was observed during the CDQ snow crab fishery. Data collected by observers and dockside samplers in the open access fishery and by observers in the CDQ fishery show no substantial difference in average CW of harvested snow crab. The average width was 111.3 mm in the open access fishery compared to 111.1 mm in the CDQ fishery. Fish ticket data show a slight increase in average weight, 1.39 lbs. in the CDQ fishery, and 1.32 lbs. in the open access fishery. Information obtained during observer debriefings indicates that the discard of four-inch and larger crab in the CDQ fishery is primarily due to the high occurrence of epibionts. This fishery follows the open access fishery, thus fewer marketable are available for harvest.

Bering Sea snow crab. The allocation for the 2000 Bering Sea snow crab fishery was 2,518,760 lbs. All six CDQ groups participated in the fishery; the percent allocated to each group varied from 10 to 19 percent. Thirteen vessels participated in the fishery. The first vessel to start gear retrieval did so on April 15, and the last delivery occurred on May 12.

Catch per unit effort (or pot pull) (CPUE) varied from 69 to 200 crabs and averaged 144 crabs. CPUE in the open access fishery was estimated to be 129 crabs. The higher CPUE in the CDQ fishery may be attributed to longer soak times. Average soak time, from onboard observer data, was 37 hours in the CDQ fishery compared to 30 hours in the open access fishery. Average weight of crabs in the CDQ fishery was 1.4 lbs., which compares to 1.3 lbs. observed in the open access fishery.

Major fishing effort was spread out in 2000; it occurred southeast, northwest and just west of the Pribilof Islands. In 1999 most of the fishing effort was centered just to the west of the islands.

Observer deployment was delayed at the start on the CDQ fishery. This delay caused some vessels to reschedule the start of fishing operations, and for others to make an extra trip only to retag and set their gear in order to be in compliance with the closure regulations of the open access fishery. Those regulations require all gear to be in legal storage within ten days of the close of the fishery (or be converted to legal gear for another fishery). The delay was due in part to the slightly protracted processing period of the open access fishery due to AFA processing caps, and to the failure of contractors to provide these CDQ vessels with observers in a timely manner. The level of coverage allowed for all but one trip to be observed.

Bristol Bay CDQ fishery. The 2000 Bristol Bay CDQ red king crab fishery allocation, based on inseason processor reports and hailed weights from the open access fishery, was 610,265 lbs. Eleven vessels fished for the five CDQ groups eligible to participate.

A commissioner's permit was issued to each CDQ group on October 20 at the close of the open access fishery. The permit stated the percentage of the species-specific CDQ allocation the group may harvest; the percentage is set forth for each CDQ group, by fishery, in federal regulations. The permit listed the vessel(s) requested by the group and authorized by ADF&G to participate in the fishery, and stated that those vessels must comply with requirements such as dates of operation, pot limits, buoy tags, observer coverage, etc. The 72-hour period was sufficient to allow ADF&G to obtain the open access harvest and establish CDQ harvest levels. A longer period may be appropriate if smaller allocations, an increase in participating vessels, or a delay in reporting from the open access fishery occurs.

CDQ vessels fished for an average of 4.7 days, approximately one-half a day longer than in the open access fishery. One of the groups used one vessel to harvest their allocation; this vessel fished for seven days, which compares to just over four days in the open access fishery. The CDQ fishery started on October 25. Most CDQ fishing operations were completed by October 31; all CDQ operations were finished on November 8.

Average weight of crabs in the 2000 CDQ fishery was 6.7 lbs., the same as in 1999 but below the average weight of 7 lbs. observed in the 1998 fishery. The 2000 open access fishery average weight was 6.4 lbs. per crab. The CDQ vessels operated in an area where larger crabs were harvested in the open access fishery. The catch per pot pull varied from five to over 22, and averaged almost 20 crabs. The CPUE in the 1999 CDQ fishery was 29 crabs, while it was 23 crabs per pot pull in 1998. Average soak time for the CDQ fishery was 25 hours, somewhat less than the 36 hours observed during the 1999 fishery. The 2000 open access fishery CPUE was 12 crabs.

2001

The CDQ allocation for 2001 was 7.5 percent of the total harvest of Bristol Bay red king crab and Bering Sea snow crab. All CDQ fishing activity occurred subsequent to the open access fishery. All CDQ vessels participated in the open access fishery, and all permit and registration requirements previously stated were still in effect. No commercial harvest of St. Matthew blue king crab, Tanner crab, or Pribilof red or blue king crab, CDQ or open access, occurred in the Bering Sea during 2001 due to low stock abundance. In 2001, the CDQ groups earned estimated royalties of $2.4 million for Bristol Bay red king crab and snow crab.

Bering Sea snow crab. The CDQ allocation for this fishery was 1,878,070 lbs. All six CDQ groups participated in this fishery. Eleven vessels participated in the fishery; all vessels had fished in the regular commercial fishery. Vessels started fishing February 18 and the last delivery was on March 29.

The 2001 fishery progressed slowly due to a decrease in the number of participating vessels and a lower CPUE than in previous years. The CPUE varied from 31 to 158 crabs and averaged 98 crabs. The CPUE in the 2001 regular commercial snow crab fishery was estimated to be 85 crabs. Soak times in the CDQ fishery was greater than in the regular commercial fishery, which may account for the higher CPUE in the

CDQ fishery. Average weight of the crabs in the CDQ fishery was 1.3 lbs., the same as the 2000 CDQ fishery, but down from the 1.4 average obtained in the 2001 regular commercial fishery.

Observer coverage in the 2001 fishery was two for each group, the same as in the 2000 fishery. This level of coverage allowed for all trips to be observed.

Bristol Bay CDQ fishery. The 2001 Bristol Bay red king crab CDQ fishery occurred subsequent to the general fishery. Based on inseason processor reports and hailed weights from the general fishery, the allocation was 617,623 lbs. Ten vessels fished for the six CDQ groups eligible to participate.

The average number of legal male CPUE was 29, higher than the CPUE of 19 for the general fishery, and higher than the 2000 CDQ fishery which had a CPUE of 20. The average soak time during the CDQ fishery was 37 hours compared to a soak of 23 hours during the general fishery. This probably accounts for the higher CPUE. Average weight of crabs in the CDQ fishery was 6.8 lbs., higher than the average weight of 6.5 for the general fishery. Possible reasons for the higher average weight could be due to fishing locations or high grading. Catches were landed at two shorebased processors, one in Dutch Harbor, and one in Akutan. No floater/processors operated during the CDQ fishery.

In previous years, all CDQ vessels for this fishery were required to carry on-board observers. During the 2001 season, only one observer was required per CDQ group. With this year's level of coverage, four vessels were without an observer. Observers collected biological data, provided inseason harvest rates to ADF&G, and documented fishing practices of the CDQ fleet. Biological samples show that 91 percent of the crabs sampled from CDQ vessels were new shell crabs, compared to 79 percent new shell crabs for the general fishery.

2002

Bering Sea snow crab. The 2002 Bering Sea CDQ snow crab fishery occurred subsequent to the general snow crab fishery. The 2002 CDQ allocation was 7.5 percent of the total snow crab commercial harvest. Based on inseason processor reports and hailed weights from the general fishery, the CDQ allocation was 2,458,565 lbs. All six CDQ groups participated in the fishery.

Eleven vessels fished for the six CDQ groups. Original data from fish tickets show that those vessels made 33 deliveries for a harvest of 2,394,095 lbs. Fish tickets were edited for the deadloss reported by on-board observers which brings the actual harvest to 2,399,716 lbs., approximately 98 percent of the allocation.

Permits were issued to each CDQ group prior to the closure of the general fishery on February 8. The permit stated the group's allocation, listed the vessel(s) requested by the group and authorized by ADF&G to participate in the fishery, and stated that those vessels must comply with requirements such as dates of operation, pot limits, buoy tags, observer coverage, etc. Vessel registration could begin noon February 11, 72 hours after the closure of the general fishery. The preliminary allocation made to the CDQ groups on February 11 was based on hailed weights from the general fishery. The 72-hours allows ADF&G sufficient time to obtain harvest estimates from the general fishery and announce the initial allocation for each CDQ group. The final allocation was announced February 25. During the fishery, the allocations for five of the groups changed due to poundage transfers. Three groups requested to transfer part of their allocation to two other groups. Reasons for these transfers include a group being unable to harvest their entire allocation prior to the end of the season or vessels not fishing to the end of the season. Transfers were approved through the Alaska Department of Community and Economic Development.

The first vessel registered on February 15, and the last registered April 24. Deliveries began March 1, and the final delivery was made June 5. The biological closure for the 2002 season was May 15. ADF&G received a request from one group to extend the season by two weeks. The group claimed that due to poor weather and sea ice conditions at the beginning of the CDQ fishery, and the fact that they were fishing with one vessel, they would not be able to harvest their allocation prior to May 15. ADF&G approved the request to extend the season to midnight, May 31, 2002; however, if ADF&G observers began to notice a high proportion of molting crabs or the numbers of molting crab increased significantly, the season could have closed prior to May 31.

Average ex-vessel price per pound in the 2002 CDQ snow crab fishery was $1.33, less than in the general fishery where the price per pound was $1.49. The fishery value to the fleet was approximately $3.1 million, and the estimated value to the CDQ groups was 20 to 30 percent of the CDQ fleet fishery value.

The average number of legal male CPUE was 99, higher than the CPUE of 76 for the general fishery, but was consistent with the 2001 CDQ fishery which had a CPUE of 98. The average soak time during the CDQ fishery was 51 hours compared to a soak of 38 hours during the general fishery, which probably accounts for the higher CPUE. Average weight of crabs in the CDQ fishery was 1.3 lbs., the same as the general fishery. Catches were landed at three shorebased processors, one in Dutch Harbor, one in Akutan and one in St. Paul. No floater/processors operated during the CDQ fishery.

Observer coverage in the 2002 fishery was two for each group, the same coverage since 2000. With this year's level of coverage, all but one vessel had continuous observer coverage. One group utilized three vessels. One of these vessels which was carrying an observer dropped out of the fishery, and that observer transferred to the group's third vessel. Observers collected biological data, provided inseason harvest rates to ADF&G, and documented fishing practices of the CDQ fleet. This season, observers on six of the vessels were instructed to take brailer weights instead of biological data during the offload. Brailer data from one vessel recorded 446 lbs. of crab over what the fish ticket reflected, and data from a second vessel recorded 2,204 lbs. of crab less than what the fish ticket reflected; however, that could have been due to a missed brailer. There were no significant weight differences from the other vessels where only brailer weights were taken.

Bristol Bay Red King Crab. The 2002 Bristol Bay CDQ red king crab fishery allocation based on inseason processor reports and hailed weights from the general fishery, was 714,239 pounds. All six CDQ groups participated in this fishery. Overall harvest and value for this fishery is confidential because only two processors purchased the CDQ harvest.

The average number of legal male crab per pot pull (CPUE) was 99, higher that the CPUE of 76 for the general fishery, but was consistent with the 2001 CDQ fishery, which had a CPUE of 98. The average soak time during the CDQ fishery was 51 hours compared to a soak time of 38 hours during the general fishery, which probably accounts for the higher CPUE. Average weights of crabs in the CDQ fishery was 1.3 pounds, the same as the general fishery. Catcher were landed at three shorebased processors. Observer coverage in the 2002 fishery was two for each group. With this level if coverage, all but one vessel had continuous observer coverage.

Norton Sound CDQ fishery

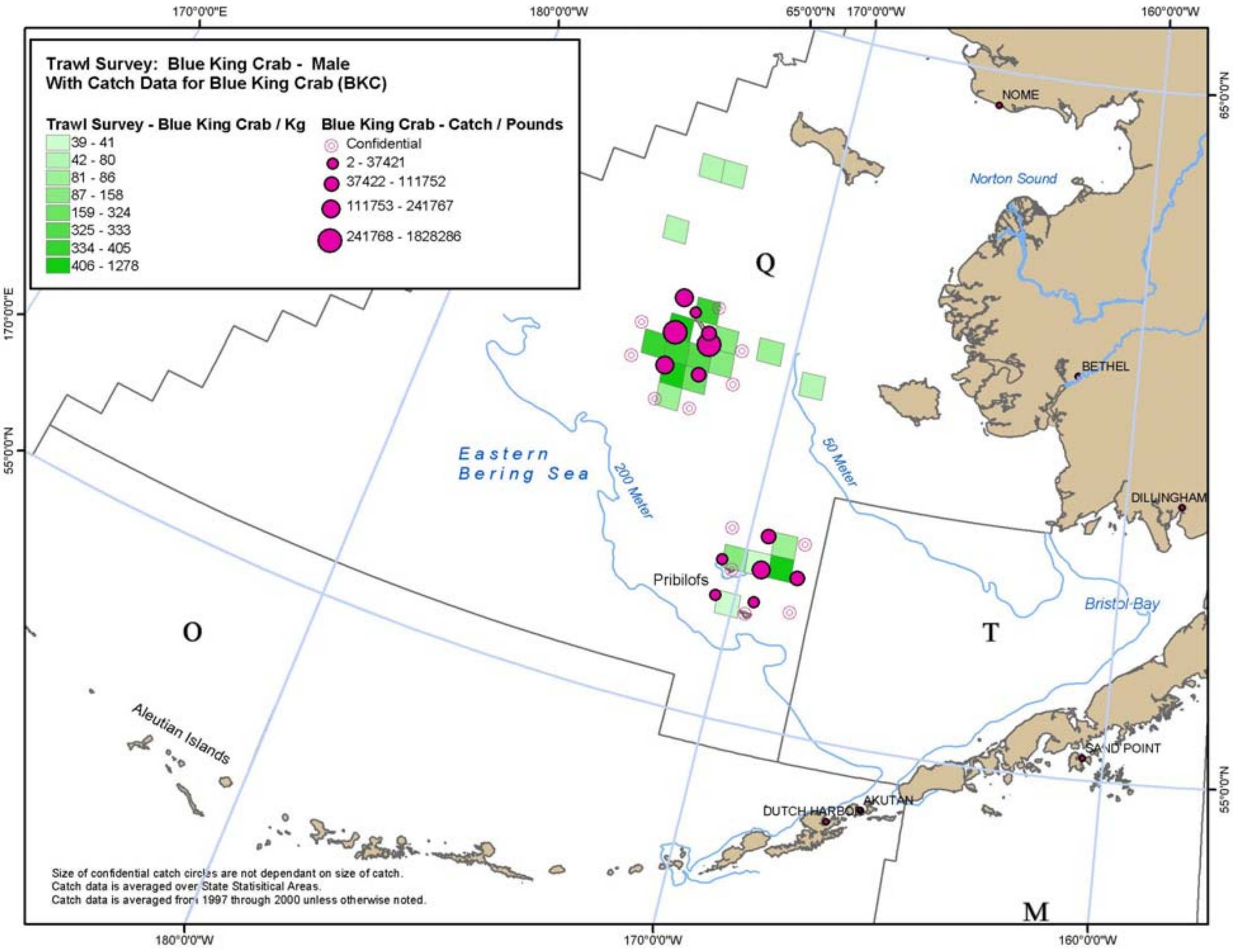
The Norton Sound CDQ fishery for red king crab has only been prosecuted in 2000 and 2002. In previous years, the two CDQ groups that received allocation chose not to prosecute this fishery. In Norton Sound, the season of open water with no ice is so short, the current CDQ fishery often has difficulties reaching their quota.

The 2000 CDQ fishery opened by emergency order on September 1 and closed on September 30. The allocation was 24,750 lbs. Five permit holders on four vessels made 16 landings. A little more than half the allocation was harvested. Average weight was 2.75 lbs. per crab. Only fishermen from the Norton Sound Economic Development Corporation CDQ group participated. The Yukon Delta CDQ group had come to an agreement with Norton Sound Economic Development Corporation to allow them to harvest their half of the allocation.

The 2002 CDQ fishery was opened by emergency order on June 15 and closed on June 28. ADF&G may reopen the CDQ fishery once the open access fishery is complete because the CDQ fishery has not caught all of its quota allocation of 18,600 lbs. Seventeen permit holders in 16 vessels made 30 landings. A total of 10,051 lbs. were harvested. The average weight was 2.73 lbs. per crab. There were three Yukon Delta Fisheries Development Association CDQ permit holders and 14 Norton Sound Economic Development Corporation CDQ permit holders.

3.4.6 Distribution of the BSAI crab stocks and fisheries

Figures 3.4-1 through 3.4-8 show the distribution of the BSAI crab fisheries compared to NOAA Fisheries trawl survey information on crab stock abundance and distribution for the stocks covered in the survey (blue king crab, red king crab, snow crab, and Tanner crab). These maps illustrate the spatial extent of the crab fisheries, degree of fishing effort, and spatial extent of the crab stocks. For each species, there are two maps. One shows the fishery retained catch and the trawl survey data for males. The survey data includes all sizes of crabs captured in the survey, however, these maps only provide the reasonable coverage of the distributions of larger crabs. Trawl survey data for females and juveniles depends on the catchability of female crabs and late juvenile crabs in survey gear. The second map shows the fishery catch of male crabs and the trawl survey data for females. The fishery harvests and retains males only.



Size of confidential catch circles are not dependant on size of catch.
Catch data is averaged over State Statisitical Areas.
Catch data is averaged from 1997 through 2000 unless otherwise noted.

Figure 3.4-1 **Blue king crab male abundance from trawl survey data and blue king crab catch data, by State of Alaska statistical area.**

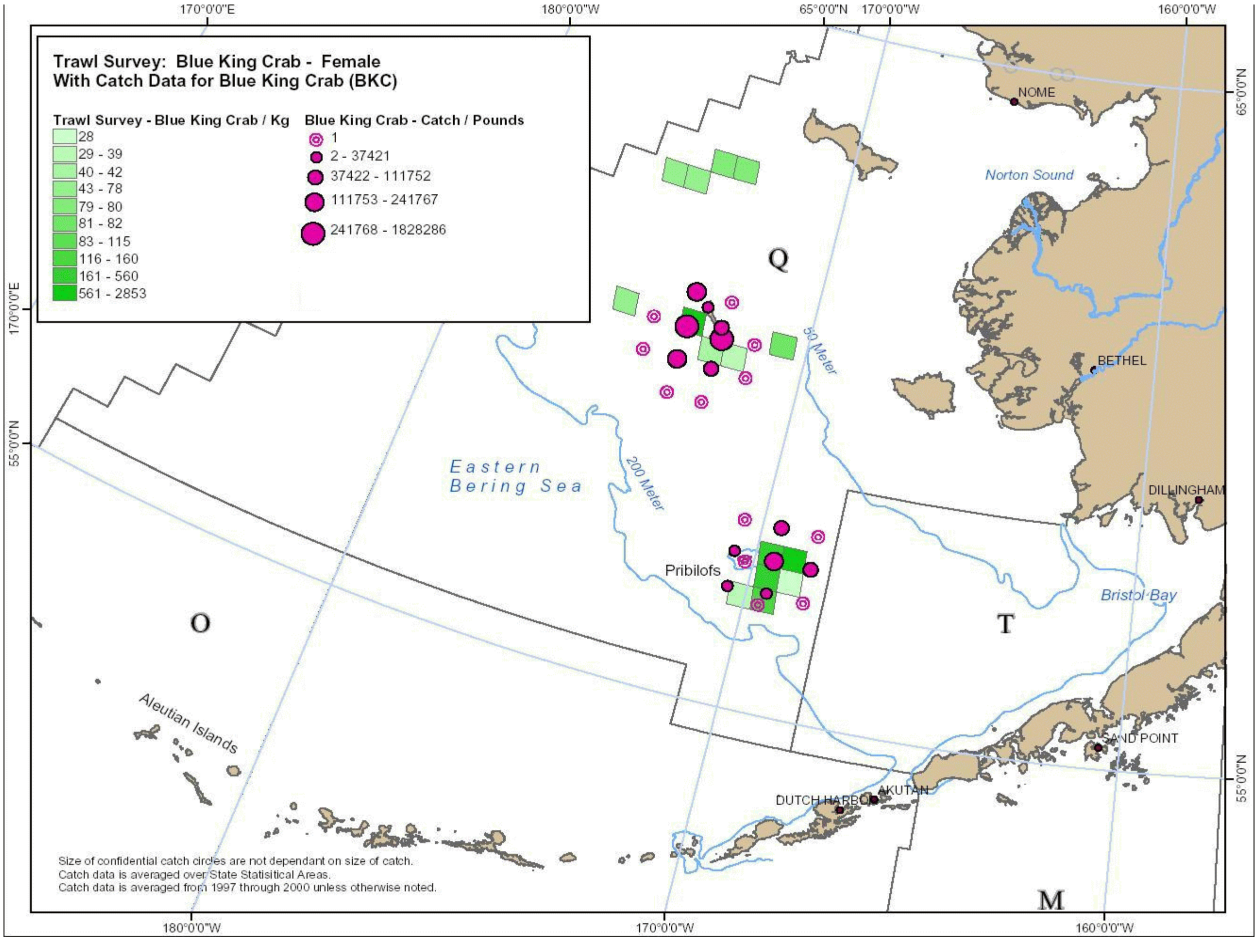


Figure 3.4-2 Blue king crab female abundance from trawl survey data and blue king crab catch data, by State of Alaska statistical area.

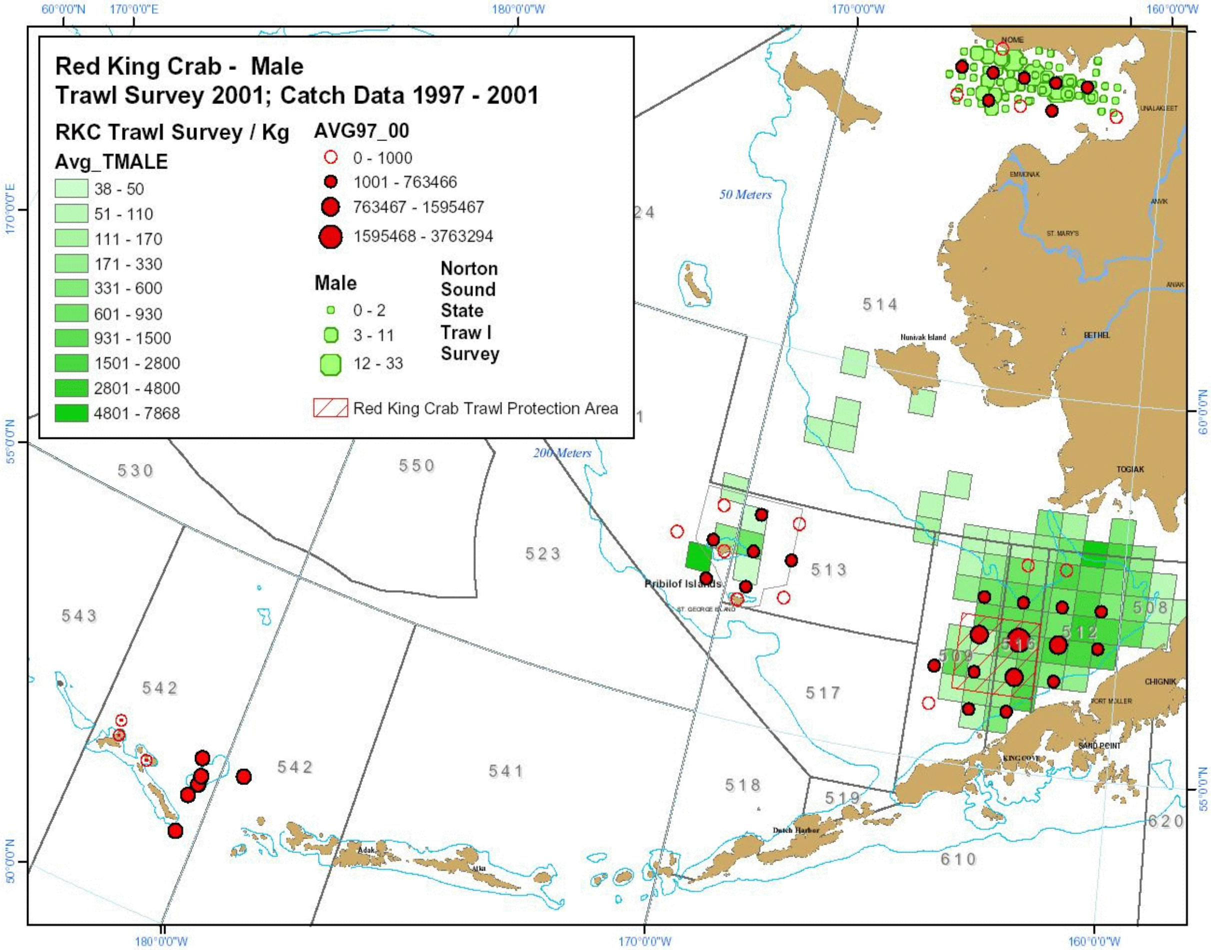


Figure 3.4-3 Red king crab male abundance from trawl survey data and red king crab catch data, by State of Alaska statistical area.

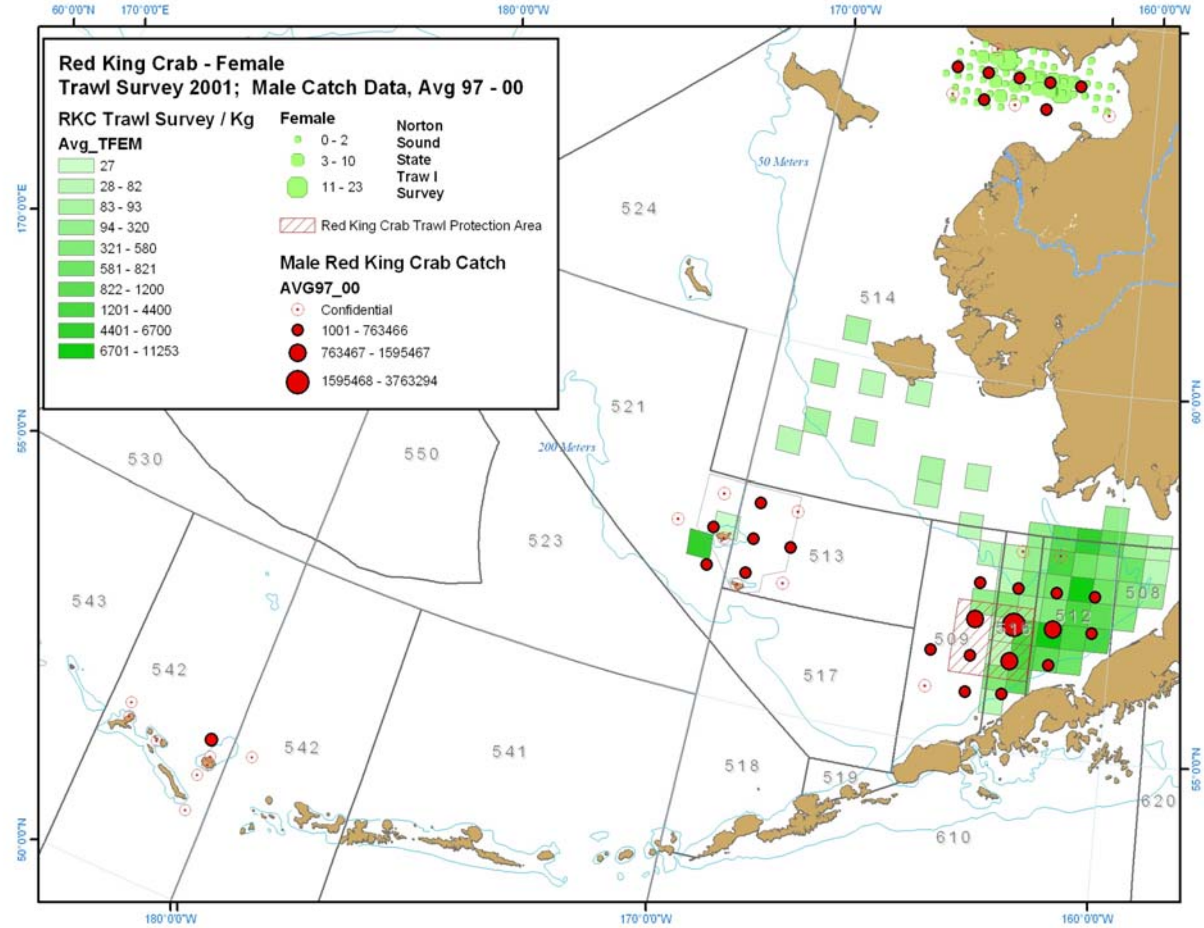


Figure 3.4-4 Red king crab female abundance from trawl survey data and red king crab catch data, by State of Alaska statistical area.

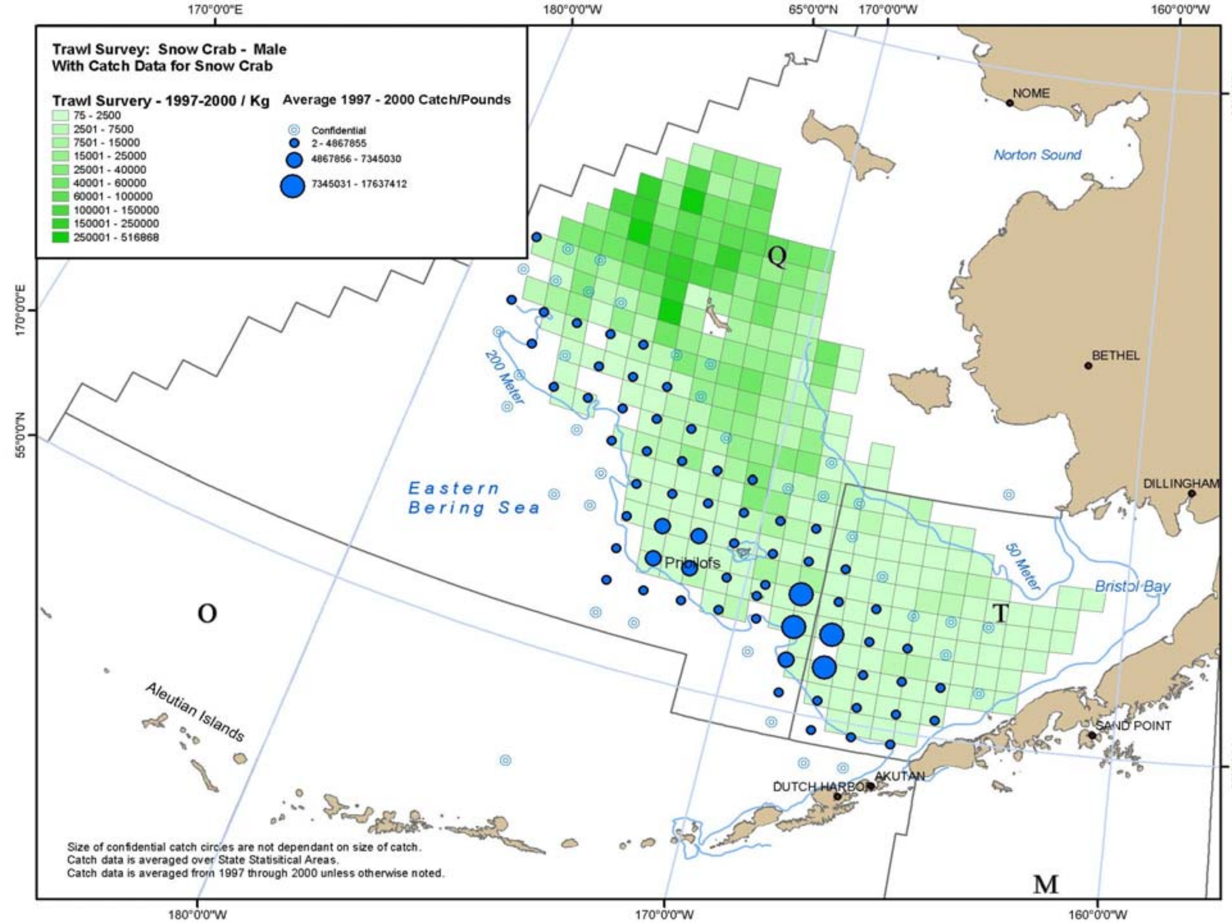


Figure 3.4-5 **Snow crab male abundance from trawl survey data and snow crab catch data, by State of Alaska statistical area.**

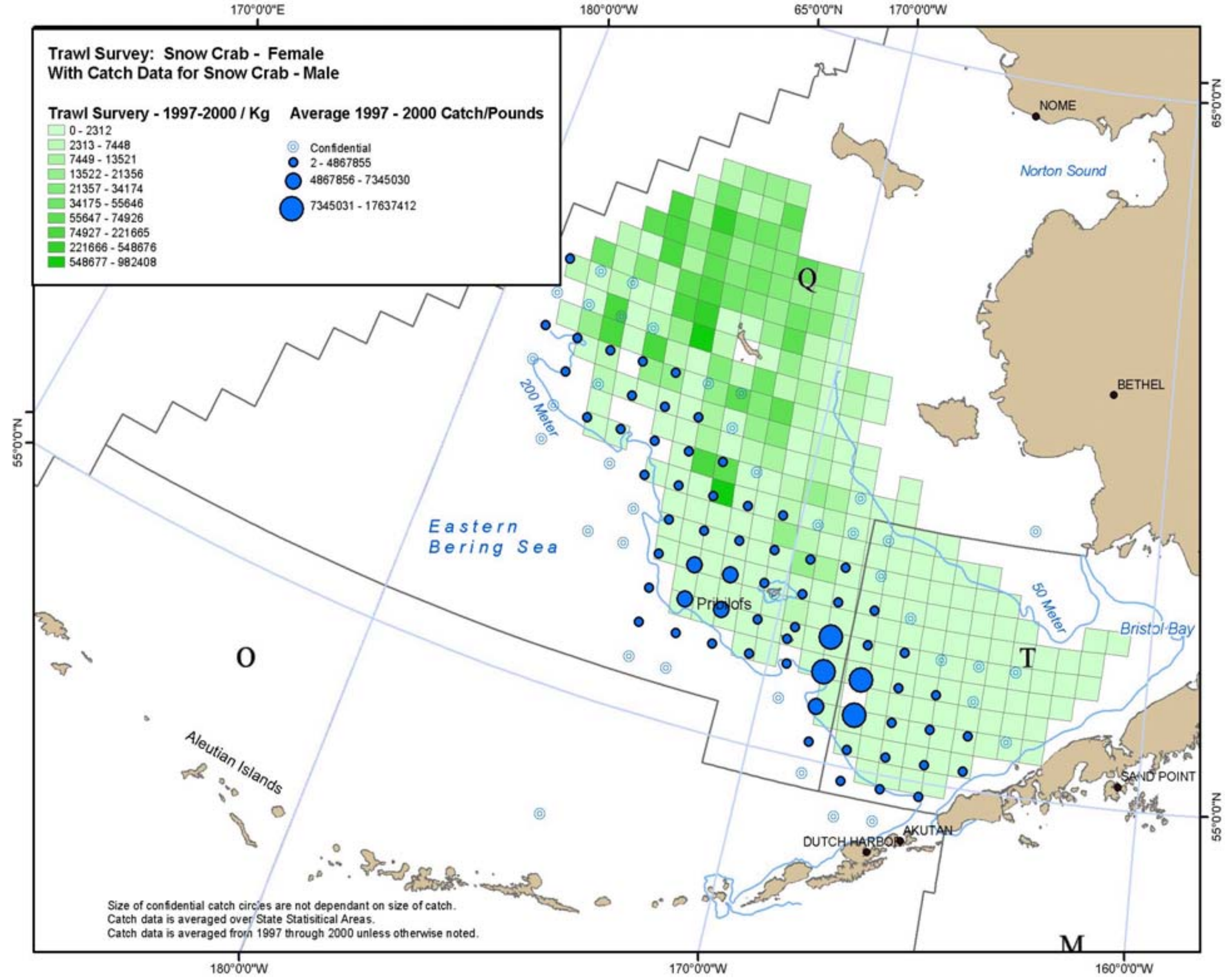


Figure 3.4-6 Snow crab female abundance from trawl survey data and snow crab catch data, by State of Alaska statistical area.

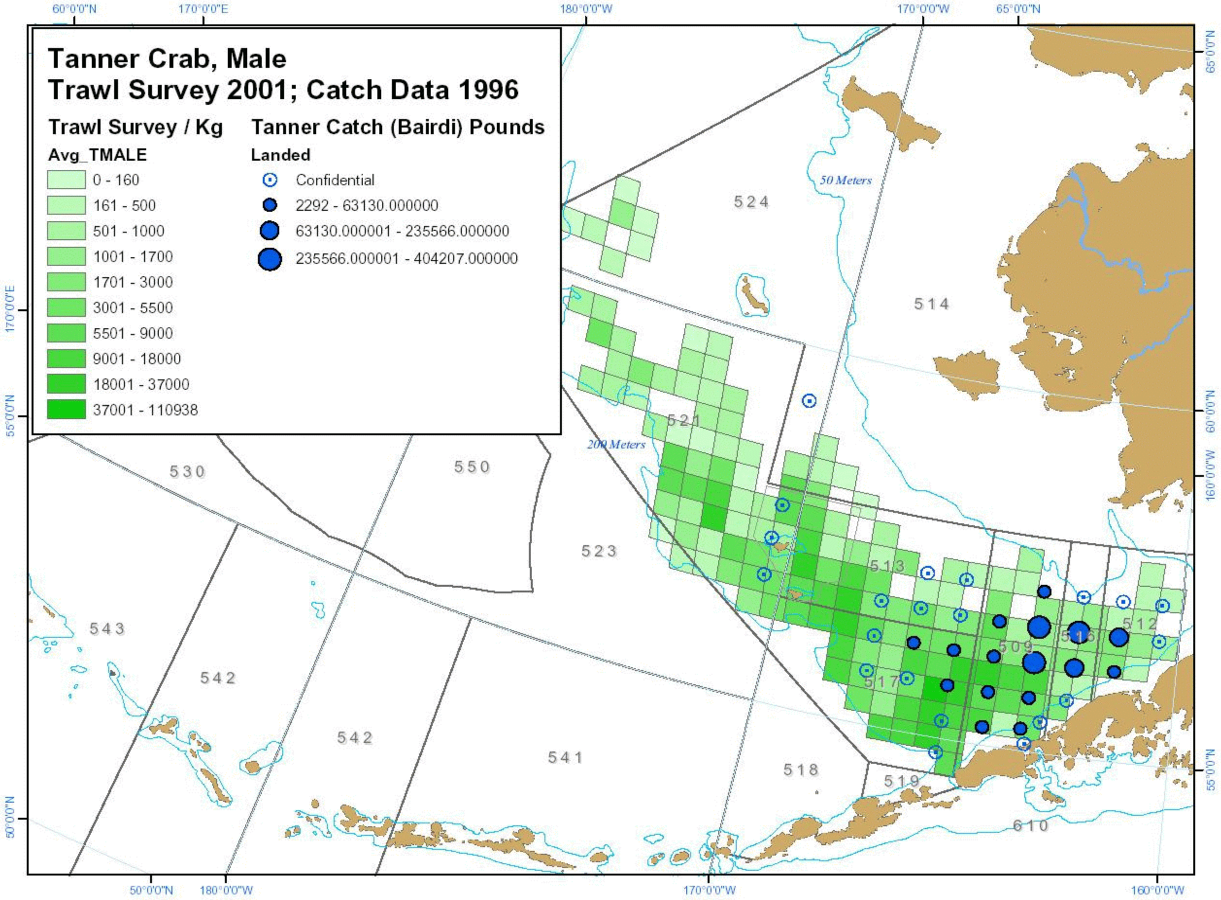


Figure 3.4-7 Tanner crab male abundance from trawl survey data and Tanner crab catch data, by State of Alaska statistical area.

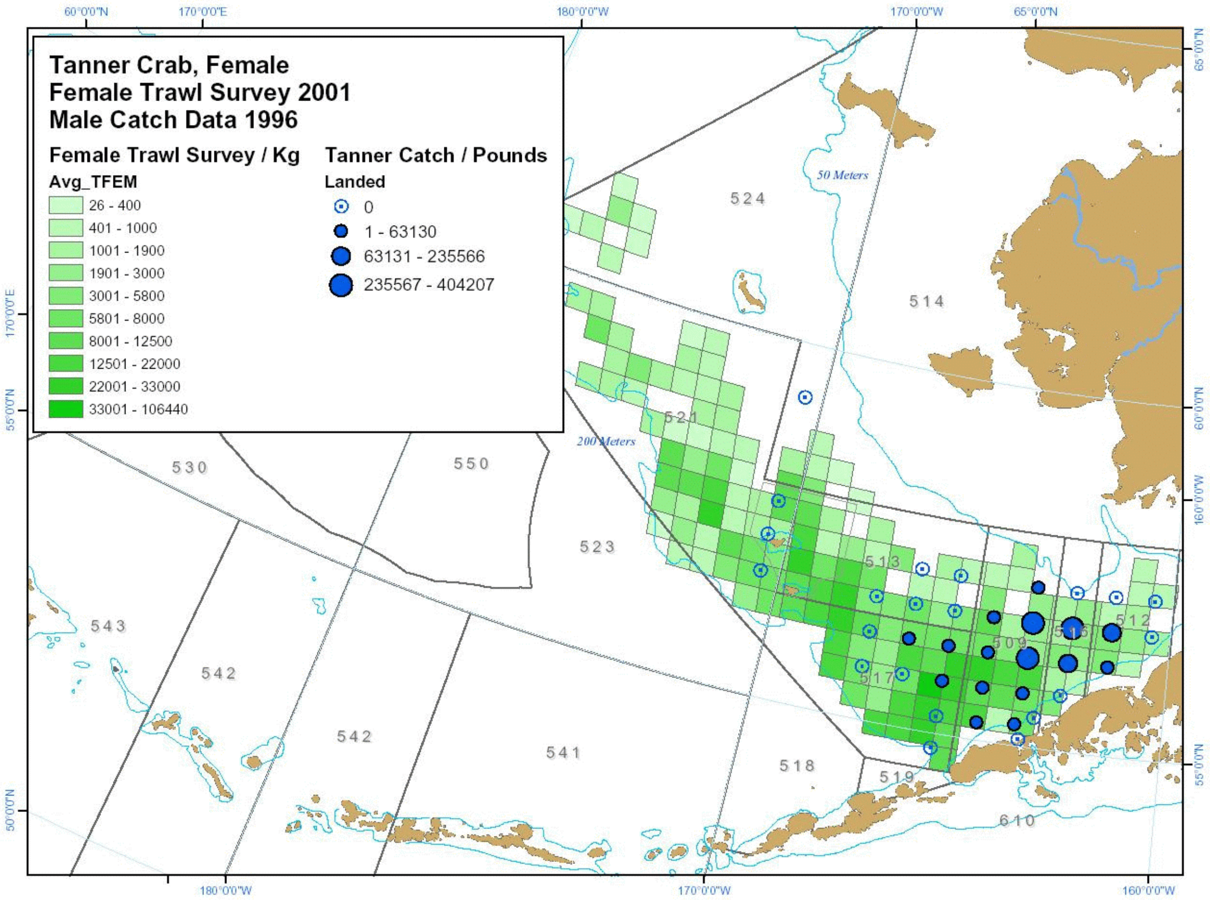


Figure 3.4-8 **Tanner crab female abundance from trawl survey data and Tanner crab catch data, by State of Alaska statistical area.**

3.5 Past/present effects and comparative baseline

The current status of any given resource is based on natural and human events over time. Consequently, this section includes the past and present analysis components of the cumulative effects analyses. The past/present analyses in this section focus on the synergy of crab fisheries management policies with other external events that have potentially affected the physical, biological, and socio-economic resource components.

Comparative baseline information is also summarized in this section, incorporating the more detailed information on the existing environment in Sections 3.1 through 3.4. This information will be carried forward for use in the alternative direct and indirect effects analyses and cumulative effects analyses in Chapter 4 of this EIS. An important goal of this EIS is to provide an integrative view of crab fishery management policy in a broad context; the cumulative effects analysis provides the means to accomplish this goal. The concept behind cumulative effects analysis is to capture the total effects of many actions over time that would be missed by evaluating each action individually. Cumulative effects are defined by federal regulation as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions."

To be reliable, any cumulative effects analysis must use a procedure that is logical, methodical, transparent, and reproducible. The analysis must combine three components:

- A scope that sets boundaries in location and time;

- Past, present, and predicted actions, internal and external to the management of crab fisheries that have shaped the existing environment and have a bearing on potential environmental consequences; and

- Past, present, and predicted environmental effects of the actions.

The methods described below pertain to the past/present effects analyses conducted in this section. These methods comply with guidance set forth by the CEQ for scoping and organizing processes associated with cumulative effects analysis (CEQ 1997), as well as EPA guidance for the consideration of cumulative effects (EPA 1999). The reader should refer to the methods described in Section 4.9.1 for a comprehensive description of how these analyses feed into the cumulative effects analyses. This section will focus primarily on the past/present effects of the following resource categories:

- crab;
- seabirds;
- marine mammals;
- ecosystem;
- physical environment;
- benthic species and habitat; and
- socio-economics (industry sector, regional/community, CDQ, and subsistence characteristics).

3.5.1 Scope of analysis

NEPA scoping defines the issues, actions, and boundaries (geographic and time-frame) for the past/present effects analyses. Scoping activities conducted to define the issues and actions were as follows:

- Review of public and agency comments;
- Identification of issues/events connected with the crab fisheries since its implementation;
- Identification of human controlled and natural issues/events external to the crab fisheries;
- Identification of management actions external to the FMP process and their the potential effects; and
- Identification of internal FMP management actions and their potential effects.

The overall geographic scope was defined to include the BSAI Crab FMP management area. When the overall geographic scope is not applicable to a given resource, a relevant geographic subarea within the overall area is defined in the analysis.

The environmental reference point in time for the start of the past/present effects was defined as 1953, the beginning of the post-WWII crab fisheries. The overall time-frame for the past/present effects analyses was defined as 1953 to 2002. The environmental reference point of 1953 is a logical starting point because the post-WWII crab fisheries began during this year, and foreign groundfish fisheries were also starting to expand.

3.5.2 Organization and consolidation of issues

The organizing step characterizes and consolidates the issues and actions defined during the scoping process. Organization activities during the scoping process included:

- Identification of relevant physical, biological, and socio-economic resources presented in Sections 3.1 through 3.4;

- Literature review, personal communication with resource specialists, and documentation of available information on identified resources (i.e., descriptive, trend, and impact information);

- Identification of direct and indirect effects that could cause population and/or ecosystem level effects to occur (e.g., mortality, nutritional stress, disruption of spawning/nesting habitat, distribution of benefits between harvesting and processing sectors, community revenue generated from fish taxes, etc.);

- Conducting a past/present effects analyses; and

- Defining a baseline condition for identified resources.

3.5.2.1 Identification of effects, events, and actions

A cumulative effects analysis takes into account the incremental impact of the proposed action when added to other past, present, and reasonablely foreseeable future actions (40 CFR 1508.7). For the purposes of this EIS, the definition of other actions includes human controlled, natural, and climatic events. Effects are analyzed separately for each resource sub-category (ie. species or economic sector). The predicted contribution of the crab fisheries to that effect is considered in the context of all the other reasonably foreseeable human and natural events that contribute to the effect. In both text and table formats in the cumulative effects analysis, the information is presented in the following order: direct/indirect effects of the crab fisheries and their significance, persistent past effects, reasonably foreseeable future external events, and the cumulative condition of the resource with the significance rating for the incremental contribution of the proposed action to the cumulative condition.

Direct and indirect effects. Direct and indirect effects are specific to each resource category and are present in the past/present effects analysis for each resource.

Past/present external events and actions. Examples of the human controlled, natural, and climatic events relevant to the past/present effects analysis include, but are not limited to, the following:

- Foreign fisheries direct crab catch inside the U.S. EEZ from 1953 to 1975;
- Groundfish fisheries bycatch of crab including pre- and post-Magnuson-Stevens Act foreign fleets inside the U.S. EEZ;
- Bycatch of crab in other federal and state commercial fisheries (trawl, pot, and other bottom-gear fisheries);
- Habitat impacts from bottom gear used in groundfish fisheries.
- Management measures for BSAI fisheries that impact the crab fisheries or the crab stocks.
- Economic development activities in regions and communities participating in the crab fisheries;
- Natural and climatic events including long- and short-term climatic changes (regime shift).

Internal events and actions. These include state and federal fishery management actions under the BSAI Crab FMP and associated amendments.

3.5.2.2 Past/present effects tables

A table structure is used in conjunction with discussions in text to organize information in the past/present effects that shape the comparative baseline. The tables are used to summarize external effects that are presented in written discussions. This method helps to assure that the analyses are orderly and systematic.

The tables organize information from the past/present effects analyses used in defining baseline conditions for the topic being discussed. The baseline information then feeds into the second tier, the cumulative effects table, which is located in Section 4.9. The reader should refer to Chapter 4 for a detailed discussion of the cumulative effects table. The first tier past/effects analysis table is explained below.

The main column headings in the past/present effects analysis table are as follows:

- **Effect on particular resource.** Effects are identified that have the potential to cause population-level effects.

- **Past/present events that could have caused the effect.** Events that produce or have the potential to produce the identified direct and indirect effects are listed. The table lists internal and/or external events.

  – **Internal.** Events and actions directly associated with the BSAI crab fisheries are listed.
  – **External.** Natural, climatic, and human controlled events and actions not directly associated with the BSAI crab fisheries are listed.

3.5.3 Past/present external events and comparative baseline

3.5.3.1 Crab

Events are described as activities or occurrences that have or have had the potential to induce one or more of the following direct and/or indirect effects on crab populations in the BSAI:

- Direct mortality;
- Change in reproductive success; and
- Changes in habitat suitability.

Events can either be internal or external to the crab fisheries. Internal events are the actions or methods of harvesting crabs, while external events are actions outside of the crab fisheries. Therefore, external events can either be human controlled (e.g., fisheries, pollution) or natural (e.g., climate change). As shown below in Table 3.5-1, the following events have occurred both internally and externally to the managed crab fisheries. These events have had effects on crab populations and are discussed in detail following the table.

Direct Catch

The State manages the crab fisheries through the Federal BSAI Crab FMP and sets GHLs for these fisheries based on available stock assessment information. Therefore, impacts of direct removals of crab in the BSAI crab fisheries are accounted for in the setting of GHLs.

Bycatch

A major avenue for direct mortality of crab is bycatch in the pre- and post-Magnuson-Stevens Act fisheries, subsistence fisheries, present-day groundfish fisheries, and scallop fisheries. For example, Table 3.5-2 provides a summary of the number of crab taken as bycatch in 2001 in the federally-managed groundfish fisheries in the BSAI.

Table 3.5-1 Past/present events and effects on crab populations.

Effect on crab populations	Internal events that could have caused the effect	External events that could have caused the effect
Direct mortality	• Direct catch of crab in the crab fisheries. • Bycatch of other species of crab in a given crab fishery.	• Bycatch of crab in other fisheries, such as pre- and post-MSA foreign fisheries, JV fisheries, present-day commercial groundfish fisheries, and scallop fisheries. • State and subsistence fisheries (minor contributors). • Climate variability. • Changes in oceanographic conditions.
Change in reproductive success	• Direct catch of adult males. • Bycatch, particularly of gravid females.	• Disproportionate bycatch of adult males, sub-adult males and gravid females in the other fisheries resulting in changes to sex ratio of population. • Climate variability. • Changes in oceanographic conditions. • Predation of eggs and larvae. • Infestation of eggs and larvae by symbionts and /or predators.
Change in habitat suitability	• Effects of crab pots on the benthic environment.	• Degradation of crab habitat from trawl, hook and line, dredge, and pot fisheries. • Climate variability. • Changes in oceanographic conditions.

Crab bycatch in the trawl fisheries are categorized as red king crab, other king crab (including blue, golden, and scarlet king crab), Tanner crab and other Tanner crab (including grooved Tanner, hybrid Tanner and triangle Tanner crab). As shown on Table 3.5-2, while red king crab are caught in the Pacific cod pot, and hook and line fisheries (19,000 individuals total), more red king crab are caught in the yellowfin (31,700 individuals) and rock sole (21,600 individuals) trawl fisheries. Other king crab are taken in the Pacific cod fixed gear fisheries and, to a lesser extent in the flatfish and rockfish trawl fisheries. The pelagic trawl pollock fishery in the BSAI also catches other king crabs. Large numbers of Tanner crab are caught in the BSAI trawl fisheries, namely the yellowfin fishery (324,700 individuals), the flathead sole fishery (293,000 individuals), and the rock sole fishery (264,000 individuals). The hook and line, and pot fishery for Pacific cod also catches Tanner crabs, nearly 80,000 individuals for the two fisheries combined in 2001. Snow crabs and other Tanner crab are taken in the largest numbers in the yellowfin trawl fishery (over 1 million crabs in 2001), flathead sole (nearly 500,000 individuals), and rock sole (261,500 individuals) fisheries. The Pacific cod fisheries (both fixed gear and trawl) also bycatch a number of these crabs.

Table 3.5-2 also shows the PSC seasonal allowances for bycatch of crabs from the groundfish fisheries in the BSAI. As seen on the table, the total number of red king crabs taken by trawl gear in Zone 1 cannot exceed 97,000 individuals. The limits for taking Tanner crab in Zones 1 and 2 total nearly 4 million individuals, and 4,350,000 snow crab and other Tanner crab can be taken in the *C. opilio* Bycatch Limitation Zone. In summary, Table 3.5-2 shows that the BSAI fixed gear fisheries (mainly those for Pacific cod), caught approximately 335,000 crabs in 2001. The trawl gear fisheries caught nearly 3 million individuals. Groundfish trawl fisheries catching the most crab include yellowfin sole (over 1.3 million crabs), flathead sole (nearly 800,000 crabs), rock sole (over 550,000 individuals), and Pacific cod (nearly 100,000 individuals). However, the levels of crab bycatch in these trawl fisheries for 2001 do not exceed the established PSC limits for these species. These PSC limits are conservative and based on annual estimates of spawning biomass for each stock.

Table 3.5-3 compares bycatch in all groundfish fisheries over the period 1996-2001. The table shows that while total catch of crabs in the BSAI hook and line fisheries has not changed much over the period (fluctuating between 113,00 and 160,000 individuals), catch of red king crab in these fisheries more than doubled in 2001. The BSAI pot fisheries had greatly fluctuating catches of red king crab, with 1,000 individuals caught in 2000 and 35,000 caught in 2001. Totals of other king crabs caught in the pot fisheries increased in 1998 and 1999, but decreased and held steady at 12,000 individuals in 2000 and 2001. Overall, the total number of crab caught in the pot fisheries has decreased on average over the period 1999-2001 as compared to 1996-1998.

BSAI trawl fisheries catch the largest numbers of crabs of all species (see Table 3.5-3). Numbers of other king crabs caught in the fisheries over the 1996-2001 period have remained relatively stable, while red king crab numbers have ranged from 31,000 to 85,000 over the same period. Catch of Tanner crabs has remained relatively consistent over the period 1999-2001, and has decreased on average as compared to the period of 1996-1998. Average catch of all crabs in the BSAI trawl fisheries has also decreased on average over the last three years when compared to the 1996-1998 period.

A summary of annual crab bycatch in the BSAI weathervane scallop fisheries from 1993-2002 is presented in Table 3.5-3. In addition to area closures for scallop dredging and bycatch limits set forth by ADF&G, scallop vessel owners formed a cooperative before the 2000 fishing season and are developing measures to further reduce crab bycatch and habitat degradation. In considering the small number of vessels fishing for scallops outside of the Cook Inlet region (approximately 3), crab bycatch levels in this fishery over the past few years in the BSAI, and additional bycatch limits for individual vessels set forth by the cooperative, it is presumed that crab bycatch associated with scallop fishing is minor when compared to bycatch rates observed in groundfish trawl fisheries in the same region.

Table 3.5-2 BSAI crab bycatch rates and recommended allowances by species, gear, and groundfish target fishery 2001 (number of Individuals).

Gear/Target Fishery	Red King Crab			Other King Crab			Tanner Crab			Other Tanner Crab		
	2000 bycatch	2001 bycatch	2002 PSC allowance (zone 1)	2000 bycatch	2001 bycatch	2002 PSC allowance	2000 bycatch	2001 bycatch	2002 PSC allowance (zones 1 and 2)	2000 bycatch	2001 bycatch	2002 PSC allowance (Opilio - COBLZ)
Pot												
Sablefish	0	0	n/a	6,200	1,000	n/a	0	0	n/a	300	300	n/a
Pacific Cod	34,500	1,100	n/a	5,000	10,700	n/a	132,800	65,100	n/a	161,400	127,000	n/a
Hook and line												
Sablefish	0	0	n/a	1,100	600	n/a	0	0	n/a	100	100	n/a
Pacific Cod	4,800	17,700	n/a	3,600	8,400	n/a	7,900	14,800	n/a	107,800	87,700	n/a
Rockfish	0	0	n/a	100	0	n/a	0	0	n/a	0		
Turbot		0	n/a	1,800	300	n/a	0	0	n/a	900	500	n/a
Fixed gear subtotal	*39,300*	*18,800*		*17,800*	*21,000*		*140,700*	*79,900*		*270,500*	*215,600*	
Trawl												
Pollock (bottom)	0	900	1,615	0	0	n/a	5,300	15,700	44,697	13,400	25,200	72,428
Pollock (pelagic)	0	0	n/a	100	5,100	n/a	200	100	inc. with bottom	2,900	2,200	inc. with bottom
Sablefish	0	0	n/a	0	100	n/a	0	700	n/a	0	500	inc. with arrowtooth
Pacific Cod	5,700	2,300	11,664	900	300	n/a	81,800	65,500	507,288	122,800	29,800	124,736
Arrowtooth founder	0	100	n/a	1,400	1,500	n/a	8,600	20,000	n/a	5,300	11,600	40,238
Flathead sole	100	400	inc. with rock sole	3,600	1,800	n/a	203,000	293,200	inc. with rock sole	297,800	475,700	inc. with rock sole
Rock sole	54,000	26,600	59,782	600	1,500	n/a	209,200	269,000	961,474	192,000	261,500	969,130
Turbot	100	0	n/a	4,800	600	n/a	1,100	2,100	n/a	2,900	8,000	n/a
Yellowfin	15,700	31,700	16,664	2,700	400	n/a	482,100	324,700	2,129,303	2,353,900	1,010,200	2,776,981
Other flatfish	0	100	inc. with rock sole	1,600	1,300	n/a	9,200	6,600	inc. with rock sole	23,500	27,000	inc. with rock sole
Atka mackerel	0	0	n/a	0	0	n/a	0	2,100	inc. with pollock	0	0	inc. with pollock
Rockfish	1,000	0	n/a	2,400	4,700	n/a	0	0	10,988	0	100	40,237
CDQ fisheries	nr	nr	7,275	nr	nr	n/a	nr	nr	296,250	nr	nr	326,250
Trawl gear subtotal	*76,600*	*62,100*		*18,100*	*17,300*		*1,000,500*	*999,700*		*3,014,500*	*1,851,800*	
BSAI all gear total	**115,900**	**80,900**	**97,000**	**35,900**	**38,300**	**n/a**	**1,141,200**	**1,079,600**	**3,950,000**	**3,285,000**	**2,067,400**	**4,350,000**

Sources: Hiatt et al. 2002, NPFMC 2002

Note: "0" indicates <100 individuals n/a - no limit set

nr - not reported separately inc - included

Table 3.5-3 **Crab bycatch in the BSAI groundfish fishery by species and gear type, 1996-2001 (number of individuals) and crab bycatch in the BSAI weathervane scallop fisheries, 1993-2002 (number of individuals).**

Year	Red king	Other king	*C. baird*i Tanner	Other Tanner	Total crabs caught
BSAI hook and line					
1996	2,000	3,000	18,000	90,000	113,000
1997	5,000	3,000	11,000	141,000	160,000
1998	3,000	6,000	6,000	156,000	273,000
1999	8,000	4,000	3,000	92,000	107,000
2000	5,000	7,000	8,000	109,000	129,000
2001	18,000	9,000	15,000	88,000	130,000
BSAI pot					
1996	74,000	5,000	262,000	177,000	518,000
1997	21,000	1,000	39,000	413,000	474,000
1998	4,000	21,000	41,000	403,000	469,000
1999	1,000	45,000	41,000	179,000	266,000
2000	35,000	12,000	133,000	162,000	342,000
2001	1,000	12,000	65,000	127,000	205,000
BSAI trawl					
1996	31,000	13,000	1,836,000	3,643,000	5,523,000
1997	51,000	24,000	1,918,000	5,276,000	5,352,918
1998	37,000	15,000	1,447,000	4,047,000	5,546,000
1999	85,000	18,000	872,000	1,342,000	2,317,000
2000	77,000	18,000	1,001,000	3,014,000	4,110,000
2001	62,000	17,000	1,000,000	1,852,000	2,931,000
Weathervane scallop fishery					
	Snow[1]	**Tanner**	**King**	**Dungeness**	**Tanner crab mortality (%)**
Alaska Peninsula					
1993/94	NA	180,319	25	0	35
1994/95	NA	25,287	0	73	29
1995/96	Season Closed				
1996/97	NA	19,045	0	4	32
1997/98	NA	21,971	0	0	21
1998/99	NA	47,780	0	140	20
1999/2000	NA	28,160	1	2,349	32
2000/01	NA	2,636	1	0	28
2001/02	Season Closed				
Bering Sea					
1993/94	15,000	290,913	207	0	12
1994/95	34,867	220,710	22	0	24
1995/96	Season Closed				
1996/97	106,935	16,642	0	0	16
1997/98	195,345	28,446	0	0	53

Table 3.5-3 (Cont.) **Crab bycatch in the BSAI groundfish fishery by species and gear type, 1996-2001 (number of individuals) and crab bycatch in the BSAI weathervane scallop fisheries, 1993-2002 (number of individuals)**.

	Snow[1]	Tanner	King	Dungeness	Tanner crab mortality (%)
1998/99	232,911	39,363	46	12	44
1999/2000	159,656	62,268	2	0	22
2000/01	103,350	52,505	2	0	30
2001/02	68,458	48,718	2	0	41
Dutch Harbor					
1993/94	NA	69,354	35	0	50
1994/95	NA	757	7	0	54
1995/96	Confidential				
1996/97	No Fishing				
1997/98	NA	12,582	1	0	44
1998/99	NA	6,479	0	23	8
1999/2000	NA	4,274	0	0	47
2000/01	Season Closed				
2001/02	Season Closed				
Adak fishery closed since 1997					

[1] Snow crab and hybrids combined.
Sources: (Hiatt et al. 2001, 2002), (Barnhart and Rosenkranz 2003)

Climate variability and oceanographic conditions

Changes to both water temperature and currents could have had positive or negative effects on direct mortality and reproductive success. Section 3.2 provides a discussion of the life history stages of each of the commercially important crab species, and the environmental factors potentially impacting each of these stages. These discussions include information regarding the importance of physical factors such as water temperature, and current regimes to egg and larval crab survival.

Predation of adults, eggs and larvae and infestation of eggs and larvae

Predation and infestation can occur at all stages of crab development, having a direct effect on crab survival or an indirect effect on reproductive success. Section 3.2 provides a discussion of the environmental factors affecting each stage of crab development.

Changes to habitat suitability

Information on preferred crab habitat by life history stage is provided in Section 3.3.1.1. A discussion of the impacts of crab fishing gear on habitat (internal effects) is provided in Section 3.3.1. Any type of fishing gear that is towed, dragged, or dropped on the seabed will disturb the sediment and the resident community to varying degrees, regardless of the organism targeted in the fishery. The intensity of disturbance is dependent on the type of gear, sediment type, and frequency of disturbance. Heavy gears such as the shellfish dredge and the flatfish beam trawl disturb the seabed intensely. Lighter gears also cause disturbance mostly due to the trawl doors and foot ropes. Limited information exists regarding the effects of longlining on benthic habitat. The principal longline components that can produce seabed effects are the anchors, weights, hooks, and mainline (ICES 2000). It is postulated that due to the very light weight of the lines used with longline gear, effects on substrate and benthic organisms would be limited to the impact of anchors and weights (Craig Rose, draft white paper prepared 2002). These make up less than 1/500th of the total length of the gear so effects on soft bottoms should be very small. However, effects in hard bottom areas could be realized through snagging on smaller boulder piles and other emergent structures. Although there has been little research conducted to document the impacts to physical structure from pot gear, it is likely that benthic structures (both living and non-living) could be impacted as the pots are dropped or dragged along the bottom. Section 3.3.1.3 provides a description of the benthic species potentially impacted by pot gear.

Scallop fishing, using shellfish dredges, does occur in areas of the BSAI that overlap with king and Tanner crab populations. However, specific areas in the Bristol Bay region and Pribilof Islands have been closed to protect king crab stocks (see Table 3.5-4). In addition to area closures for scallop dredging, scallop vessel owners formed a cooperative before the 2000 fishing season and are developing measures to further reduce crab bycatch and habitat degradation. These measures are in addition to the State crab bycatch limits already in place. When a scallop vessel encounters areas of high abundance for crab, this information is shared among other vessels in the fleet and the area is then avoided (Barnhart 2001). Mandatory 100 percent onboard observer coverage is required on all scallop vessels. Data is collected on crab bycatch, catch composition, location, area, and depth fished, retained scallop catch, discarded scallop catch, and CPUE (Barnhart and Rosenkranz 2000).

Table 3.5-4 Chronology of closures and restrictions intended to protect crab and crab habitat in the BSAI.

Closure Area	Year	Closure Type	Closure Purpose	Major Gear Restricted	Main Species Protected	Direct Intent of Closure	Habitats Protected (living and non- living)
Red king crab saving Area 512 (middle Bristol Bay)	1987	year-round	species habitat	all trawl gear scallop dredge gear	Red king crab juveniles and adults	Closure to protect high densities of red king crab adults and juvenile rearing habitats.	epifauna infauna sand shelf
Red king crab savings Area 516 (outer Bristol Bay)	1987	seasonal March 15 to June 15	species	bottom trawl gear scallop dredge gear	Red king crab adults	Closure to protect high densities of red king crab adults and halibut.	epifauna infauna sand/mud shelf
Pribilof Islands habitat conservation area	1995	year-round	habitat	all trawl gear scallop dredge gear	Blue king crab juveniles	Closure to protect important areas for juvenile blue king crab survival.	shell hash slope shelf
Zones 1 and 2	1995	Inseason PSC Cap	Tanner crab	trawl gear	Tanner crab	Closure to limit bycatch of Tanner crabs in specified groundfish fisheries. Fisheries are closed when crab bycatch trigger is reached.	emergent epifauna shelf
Adak scallop closure area	1995	year-round	habitat	scallop dredging	Scallops, groundfish, crab	Closure to prevent scallop dredging in biologically critical areas: reduce high bycatch of other species (i.e., crabs); avoid nursery for groundfish and shellfish; avoid sensitive habitats.	sand mud
Dutch Harbor scallop closure area	1995	year-round	habitat	scallop dredging	Scallops, groundfish, crab	Closure to prevent scallop dredging in biologically critical areas: reduce high bycatch of other species (i.e., crabs); avoid nursery for groundfish and shellfish; avoid sensitive habitats.	sand mud
Bering Sea scallop closure areas	1995	year-round	habitat	scallop dredging	Scallops, groundfish, crab	Closure to prevent scallop dredging in biologically critical areas: reduce high bycatch of other species (i.e., crabs); avoid nursery for groundfish and shellfish; avoid sensitive habitats.	sand mud

Table 3.5-4 (Cont.) Chronology of closures and restrictions intended to protect crab and crab habitat in the BSAI.

Closure Area	Year	Closure Type	Closure Purpose	Major Gear Restricted	Main Species Protected	Direct Intent of Closure	Habitats Protected (living and non- living)
Bristol Bay nearshore closure	1997	year-round	habitat	all trawl scallop dredge gear	Red king crab juveniles	Closure to protect juvenile red king crab and rearing habitats. Expanded Area 512 closure (see below).	emergent epifauna shell hash HAPC shallows sand slope
C. opilio bycatch limitation zones (COBLZ)	1997	Inseason PSC Cap	species	trawl gear	Tanner crab adults Snow crab adults	Closed to specified groundfish fisheries when crab bycatch trigger is reached in order to reduce mortalities to crab and egg-laden mature crabs.	emergent epifauna shelf
State of Alaska nearshore waters closure	2000	year-round	habitat	all bottom trawl gear	Nearshore adult and juvenile salmon, crab, shellfish, and groundfish	Close all State waters (0-3 nm) to commercial bottom trawling to protect nearshore habitats and species.	nearshore nursery and adult areas HAPC slope
State of Alaska St. Matthew nearshore waters closure	2000	year-round	habitat	all gear	Blue king crab	Close all State waters (0-3 nm) around St. Matthew, Hall, and Pinnacle Islands to protect habitat of egg-bearing female blue king crab from all fisheries.	rocky

Comparative baseline

The comparative baseline status and past/present major population-level effects for each stock are summarized in the sections to follow.

Red king crab

There are three main stocks of red king crab in the BSAI region: Bristol Bay; Norton Sound; and Aleutian Islands. Red king crab are also distributed throughout the Pribilof Islands, St. Matthew and St. Lawrence Islands, but are managed in conjunction with blue king crab fisheries in those areas.

Bristol Bay red king crab stocks have experienced fluctuations in abundance and harvest since the 1960's. Peak harvests occurred between 1977 and 1980, but was followed by a collapse in 1981 and 1982 and complete closure in 1983. The fishery continued at reduced levels until 1993 and the fishery was once again closed during the 1994 and 1995 seasons. The 2002 length-based analyses show mature female crab abundance has decreased slightly from the 2001 level; however, legal males show a slight increase and pre-recruit males have decreased in abundance. Legal male abundance in Bristol Bay increased from 7.5 million crab in 1997 to 9.4 million crab in 1999, decreased to 8.3 million crab in 2001, then increased slightly to 8.6 million crab in 2002 (NPFMC 2002). Mature females (>89 mm) declined from 28.2 million crab in 1997 to 18.9 million crab in 2000, increased slightly in 2001 to 21.8 million crab, then declined to 18.6 million crab in 2002. Due to the decrease in abundance of mature females, ADF&G decreased the 1999 GHL from a 15 percent to a 10 percent exploitation rate; this rate was also used for the 2001 and 2002 fishery (NPFMC 2002). The GHL was increased to 15 percent for the 2003 fishing season based on increasing abundance estimates of mature females.

Survey estimates of Pribilof Islands red king crab have been highly variable over the last 10 years and have a high degree of uncertainty due to the patchy distribution of the animals. Model estimates of mature male abundance show a decline from about 2 million in 1992 to 1 million in 1997, and then an increase to about 1.7 million in 2002. Legal male abundance was estimated at 1.36 million in 2002 (NPFMC 2002). The Pribilof red king crab fishery has been closed since 1999 due to uncertainty with the abundance estimates and concern for bycatch of blue king crab. Concerns for the Pribilof blue king crab stock focus on decreased abundance and poor fishery performance. These trends complicate the establishment of a GHL for Pribilof red king crab since it is difficult to determine an optimal GHL for red king crab that will not result in increased bycatch of blue king crab (NPFMC 2002, executive summary). A small Aleutian Island red king crab fishery occurs, with a 2002 GHL of 0.5 million pounds. Norton Sound also supports a small summer red king crab fishery (Bowers *et al.* 2001).

Blue king crab

Populations of blue king crab exist around the Pribilof Islands, St. Matthew Island, and St. Lawrence Island. Commercial fisheries in the Pribilof Islands and St. Matthew Island are actively managed by ADF&G, but no commercial fishery exists near St. Lawrence Island. In addition, no survey biomass estimates currently exist for the St. Lawrence Island blue king crab stock.

The blue king crab population in the Pribilof Islands is low, and population trends are not easily detectable (NMFS 1998b). Blue king crab female abundance is considered imprecise because trawling does a poor job of sampling the inshore, rocky substrate preferred by females (Morrison *et al.* 1998). Based on the 2002

NMFS annual bottom trawl survey estimate, the Pribilof Islands stock has fallen below MSST (6.6 million pounds) and is considered "overfished". This fishery has been closed since 1999 due to the stock being below the threshold level of abundance to allow a fishery opening. According to the 2002 SAFE report for BSAI king and Tanner crab fisheries (NPFMC 2002), this population is declining. The Pribilof red and blue king crab fisheries have been closed since 1999 and bycatch in trawl fisheries has been eliminated through the establishment of the Pribilof Islands Area Habitat Conservation Zone. A rebuilding plan for the Pribilof blue king crab stock has been developed.

Blue king crab in the St. Matthew Island area have increased from 0.8 million crab in 2000 to 1.1 million crab in 2001. However, spawning biomass is still estimated to be below the MSST (Bowers *et al.* 2001). It is hypothesized that natural mortality was higher than normal between 1998 and 1999 based on the low catch levels of blue king crab in each of the annual trawl surveys from 1999-2002 (NPFMC 2002). The St. Matthew Island blue king crab stock was declared overfished and the fishery was closed in 1999 and continues to be closed. A rebuilding plan was developed for the St. Matthew Island stock and adopted as BSAI Crab FMP Amendment 15 on November 29, 2000. Although the stock is above the threshold for a fishery opening, the GHL determined by the rebuilding harvest strategy is well below the minimum GHL (2.5 million pounds) set forth by ADF&G and is not considered manageable due to the current size of the fishing fleet.

Golden king crab

Golden king crab are found near the Aleutian Islands, Pribilof Islands, and St. Matthew Island, at depths between 200 and 1,000 m in high-relief habitat such as inter-island passes on rough bottom strata. This type of habitat is not suitable for trawl surveys and it can be presumed that minimal commercial trawl fishing effort occur in these areas. ADF&G conducts the Aleutian Islands golden king crab pot survey; however, there are no absolute estimates of abundance. Based on fishery performance and observer data from 1996 to present, the golden king crab stock in the Aleutian Islands is considered stable for the area east of 174° W. A GHL has been set for areas east and west of 174° W.

ADF&G and NOAA Fisheries do not make annual abundance estimates for Bering Sea golden king crab, and commercial harvest is allowed by ADF&G permit (Morrison *et al.* 1998). Catches have declined from the early years of the fishery, as the initial stock was exploited and recruitment was unable to sustain the fishery at its initial harvest levels (Morrison *et al.* 1998). Small fisheries for golden king crab exist in the Pribilof Island area and in the Northern District of St. Matthew Island (Bowers *et al.* 2001). However, stock status is unknown for golden king crab in these areas.

Tanner crab

There are three distinct stocks of Tanner crab including: eastern Bering Sea, eastern Aleutian Islands, and western Aleutian Islands. The Tanner crab fishery has been closed since 1997 due to low abundance. During the 1997 survey, 95 percent of legal males encountered were old-shelled and not expected to molt again, and few young males in the 50 to 115 mm CW range were surveyed. In the 1998 survey, most legal males encountered were in the eastern district, with the highest abundance in central Bristol Bay. The cohort which began recruiting into the fishery in 1988 to 1992 has declined as a result of natural mortality and fishery removals.. The 2001 survey abundance estimates for large males (135 mm CW) and large females have decreased from the 2000 estimates (Bowers *et al.* 2001). Currently, the eastern Bering Sea stock remains below MSST, a trend that has continued over the past six years. NPFMC considers the stock overfished and its crab plan team has developed a rebuilding plan (NMFS 1999). The Tanner crab rebuilding plan was adopted as BSAI Crab FMP Amendment 11 on June 8, 2000. Eastern and western Aleutian Islands Tanner fisheries are closed due to declining stock size and poor fishery performance. ADF&G will continue to conduct stock assessments in this area to determine if future openings are possible.

Snow crab

Snow crab are common at depths less than 200 m in the Bering Sea. The eastern Bering Sea population is managed as a single stock but extends into Russian waters. Large male snow crab were estimated at 94 million crab in 1999, a decline of 63 percent from 1998. The mature biomass declined below the MSST of 460 million lbs, and the stock was declared overfished on September 24, 1999 (NMFS 1999). A rebuilding plan was developed by NPFMC's crab plan team. This rebuilding plan was adopted as BSAI Crab FMP Amendment 14 on December 28, 2000. The 2001 NOAA Fisheries survey estimated 77.5 million crab, 2 percent above the 2000 estimate. The 2002 Bering Sea snow crab GHL was established at 31 million pounds (Bowers *et al.* 2001). In 2002, this stock was below MSST, characterized by the fourth lowest spawning biomass estimate on record (NPFMC 2002). This spawning biomass represents an overall decreasing trend since 1991 and all sex-size classes, mature and immature, are at depressed levels. Despite these decreases in abundance, the GHL was set at 25.6 million pounds for the 2003 fishing season (NPFMC 2002).

Historical catch trends from 1980 through 1998 show that the GHL for Bering Sea snow crab is consistently surpassed over time. With the exception of 1992, catch of Bering Sea snow crab exceeded established GHLs every year from 1986 through 1998 (NPFMC 1999). The risk of over-exploiting mature males increases as this trend continues year after year. In addition, bycatch of sublegal and female crab is presumed to occur in conjunction with overharvesting of legal males which may exert population-level impacts over time. The *C. opilio* Bycatch Limitation Zone was established, via BSAI Groundfish FMP Amendment 40, and provides for a closure to specific trawl fisheries in the event that the PSC limit is reached for this crab stock. Scallop fisheries also experience bycatch of snow crab and ADF&G implements bycatch limits annually per region that trigger closure of the scallop fishery in the event that these limits are reached.

King and Tanner crab cumulative effects analysis status

All crab species mentioned here will be carried forth for cumulative effects analyses. Analyses of cumulative effects must take into account declining or fluctuating stock status and/or lack of information regarding current population status of particular BSAI stocks.

3.5.3.2 Seabirds

The following information has been summarized from the species accounts presented in the Alaska Groundfish Fisheries Draft Programmatic SEIS (NMFS 2003b) and the BA for the BSAI king and Tanner crab fisheries (NMFS 2002b). The BSAI king and Tanner crab fisheries potentially affect seabird species in several ways (Table 3.5-5). The direct and indirect effects of the crab fisheries are discussed in Chapter 4 and the contribution of other anthropogenic activities and natural events to these effects are described in the cumulative effects analyses in Section 4.9.3. The following summaries provide a baseline description for the status of each species that will be used as the starting point for the analyses of direct, indirect, and cumulative effects in Chapter 4.

Table 3.5-5 Past/present events and effects on ESA seabirds.

Effect on ESA seabirds	Event(s) that could have caused the effect
Mortality	• Incidental take in fisheries throughout range of species. • Collisions with fishing vessels and gear. • Commercial, sport, and subsistence hunting.
Changes in prey availability	• Catch and bycatch of seabird prey in various fisheries. • Climatic fluctuations affecting primary productivity. • Oceanographic changes affecting prey distribution. • Regime shifts.
Changes in benthic habitat	• Degradation of critical habitat by trawl, longline, and pot fisheries. • Disturbance of habitat by gray whales and walrus.
Oil/toxic waste pollution	• Terrestrial and marine pollution from multiple sources. • Acute and chronic effects on species reproduction and survival.

Comparative baseline

The comparative baseline status and past/present major effects for each species are summarized in the sections to follow.

Short-tailed albatross

Short-tailed albatross were nearly exterminated by commercial hunting about 100 years ago but are making a comeback. The population appears to be increasing at a near-maximum rate of three to four percent per year. They are still one of the rarest species on earth with an estimated population of only 1600 to 1700 birds and are listed as endangered under the ESA. The need to protect this species from all sources of human-induced mortality has driven a great deal of research and regulation of seabird/fisheries interactions in the BSAI/GOA area, especially for fisheries using longline gear. NOAA Fisheries and USFWS are currently researching the potential threat to short-tailed albatross from collisions with trawl vessels. The USFWS has concluded that interactions between short-tailed albatross and the BSAI crab fisheries are minimal and that the crab fisheries do not pose a significant threat to the continued existence or recovery of short-tailed albatross (USFWS 2003).

Spectacled eiders

Spectacled eiders were listed as threatened under the ESA in 1993 due to major declines in their Alaska breeding populations. The breeding population of spectacled eiders on the Yukon-Kuskokwim Delta appears to be increasing in recent years. The current worldwide population estimate is 360,000 birds, including non-breeding birds. Although there appears to be almost no spatial/temporal overlap with commercial fisheries operating in the U.S. EEZ and marine waters used by spectacled eiders, the potential effects of trawling and other bottom-contact fishing gear on the benthic habitat of eider prey has been cited as one of several possible reasons for the declining population. Specific evidence of adverse impacts from the commercial fisheries have not been demonstrated. Spatial overlap of spectacled eider designated critical habitat with the king and Tanner crab fisheries has been limited to small areas of Norton Sound and St. Matthew Island waters (NMFS 2002).

The USFWS has concluded that interactions between spectacled eiders and the BSAI crab fisheries are minimal and that the crab fisheries do not pose a significant threat to the continued existence or recovery of spectacled eiders (USFWS 2003).

Steller's eiders

No reliable overall population estimates are available but there appear to be over 100,000 Steller's eiders nesting in Russia. Steller's eiders were listed as threatened under the ESA in 1997 due to major declines in their Alaska breeding populations. Although there appears to be no direct competition for prey and very little spatial/temporal overlap with commercial fisheries operating in the U.S. EEZ and marine waters used by Steller's eiders, the contribution of the fisheries to changes in the marine environment has been cited as one of several possible reasons for the declining population. Specific evidence of adverse impacts from commercial fisheries have not been demonstrated. Spatial overlap of Steller's eider designated critical habitat with the king and Tanner crab fisheries has been limited to a small area of Nelson Lagoon (NMFS 2002). The USFWS has concluded that interactions between Steller's eiders and the BSAI crab fisheries are minimal and that the crab fisheries do not pose a significant threat to the continued existence or recovery of Steller's eiders (USFWS 2003).

3.5.3.3 Marine mammals

The following information has been summarized from the species accounts presented in the Alaska Groundfish Fisheries Draft Programmatic SEIS (NMFS 2003b) and the BA for the BSAI king and Tanner crab fisheries (NMFS 2000). The BSAI king and Tanner crab fisheries potentially affect these species in several ways (Table 3.5-6). The direct and indirect effects of the crab fisheries, and the contribution of other anthropogenic activities and natural events to these effects are described in the cumulative effects analysis in Chapter 4. The following summaries provide a baseline description for the status of each species that will be used as the starting point for the analyses of direct, indirect, and cumulative effects in Chapter 4.

Table 3.5-6 Past/present events and effects on ESA marine mammals.

Effect on ESA marine mammals	Event(s) that could have caused the effect
Mortality	• Incidental take in fisheries throughout range of species. • Commercial and subsistence hunting. • Intentional shooting by fishermen.
Competition for food	• Catch and bycatch of marine mammal prey in various fisheries, especially groundfish. • Climatic fluctuations affecting primary productivity. • Oceanographic changes affecting prey distribution. • Regime shifts.
Disturbance	• Disturbance by fishing and marine transport vessels. • Disturbance by subsistence hunting. • Disturbance by resource development activities.

Comparative baseline

The comparative baseline status and past/present major effects for each species are summarized in the sections to follow.

Steller sea lions

Steller sea lions were classified into two separate stocks in 1997 based on several factors, including major differences in their population trends. The western stock consists of the animals west of Cape Suckling, including animals of the BSAI, and was listed as endangered under the ESA in 1997. The western stock was estimated to be approximately 185,000 sea lions in the late 1970's but declined precipitously to an estimated 34,595 animals in 2001. Surveys in 2002 indicated the first region-wide increase in population in over 20 years but it remains to be seen whether this positive trend will continue. Current estimates of incidental take from all commercial fisheries (29) and subsistence harvest (198) exceeds the PBR (208) for this stock. While research continues on the causes(s) for the decline of the western stock, fishery management efforts have focused on trying to minimize the spatial and temporal competition between the fisheries and sea lions, which have almost a complete overlap of preferred prey with species taken in the groundfish fisheries. NOAA Fisheries has concluded that interactions between Steller sea lions and the BSAI crab fisheries are minimal and that the crab fisheries do not pose a significant threat to the continued existence or recovery of Steller sea lions (NMFS 2001a).

ESA-listed cetaceans

These species include the northern right whale, bowhead whale, blue whale, fin whale, sei whale, humpback whale, and sperm whale. All of these species have been depleted by commercial hunting in the last century and are listed as endangered. The IWC outlawed commercial whaling for these species at different times over the past 50 years.

Population trends and current status of the North Pacific stock of northern right whales are unknown although the population is believed to be very small based on the infrequency of sightings. Diets of North Pacific right whales do not overlap with species taken by commercial fisheries in the U.S. EEZ and they do not appear to interact with fishing vessels on a regular basis. No incidental takes of right whales have been reported in North Pacific fisheries. Ship collisions and entanglement in fishing gear are important sources of mortality in the Atlantic stock of northern right whales, but their rarity in the Pacific has made it impossible to assess the susceptibility of the North Pacific stock to vessel collisions.

Bowhead whale populations have been increasing in the Bering Sea since commercial whaling was stopped in the early 1900's. From 1978 to 1993, the western Arctic stock increased from approximately 5,000 to 8,000 whales, and the most recent estimate, derived from spring 2001 surveys, was about 9,860 bowheads. They are an important subsistence resource for northern Alaska Inupiat. The IWC has authorized Alaska Natives to strike up to 67 bowheads per year since 1978, but actual strikes have been less than the quota. The calculated PBR for this stock is 77 animals per year. Diets of bowheads do not overlap with species taken by commercial fisheries. Interaction with fishing gear is rare, however, whales with ropes caught in their baleen and with scarring caused by rope entanglement have been reported. No incidental takes of bowheads due to entanglement in commercial fishing gear or vessel collisions have been reported in U.S. waters.

The number of blue whales that actually live in waters affected by the BSAI crab fisheries is unknown. A minimum abundance estimate of 3,300 has been proposed for the North Pacific as a whole, including about 2,000 whales that breed in California waters. However, recent surveys conducted in previous commercial hunting areas in Alaska and Russia failed to find any blue whales. Their diet does not overlap with species taken by commercial fisheries and they do not appear to interact with fishing vessels on a regular basis.

Pre-whaling estimates for the northeast Pacific stock of fin whales range from 42,000 to 45,000 whales and post-whaling estimates range from 14,620 to 18,630 whales. However, these estimates are not considered reliable. One recent survey yielded a regional estimate of abundance of 4,951 fin whales for the central Bering Sea shelf in the summer of 1999. Prey includes planktonic crustaceans (euphausiids and copepods), squid, fish (herring, cod, mackerel, pollock, and capelin), and cephalopods. Diets of fin whales overlap to a small extent with species targeted or taken as bycatch by the groundfish and crab fisheries but they do not appear to interact with fishing vessels on a regular basis.

Early estimates suggested that the North Pacific population of sei whales declined from about 42,000 to 8,600 between 1963 and 1974. Current abundance or population trends are not known. Diets of sei whales do not overlap with species taken by commercial fisheries and they do not appear to interact with fishing vessels on a regular basis. No incidental take from commercial fisheries have been reported.

The North Pacific population of humpback whales has been estimated at 15,000 animals before commercial whaling began in the late 1800's. By the time whaling was prohibited in 1966, there may have been only 1000 animals left. Recent population estimates for the eastern and central North Pacific stocks of humpback whales are 394 and 4,005 respectively. Trends for the western stock are unknown. The central stock is thought to be increasing but at an unknown rate. Humpback whales in the North Pacific and Bering Sea prey on euphausiids, mackerel, capelin, sand lance, pollock, and herring. There have been numerous cases of incidental take related to commercial fisheries in the past ten years, including two observed mortalities from

BSAI groundfish trawls since 1998. Ship collisions and interactions with vessels unrelated to fishing have also accounted for humpback mortality. In the central North Pacific stock, four ship collisions were recorded between 1995-1999 for an average of 0.8 humpback mortalities per year.

Sperm whales are divided into several stocks in U.S. waters, including the North Pacific stock that regularly inhabits Alaskan waters, but population estimates are considered unreliable. No incidental take of sperm whales has been observed or reported in commercial fisheries although there have been reports of fishermen trying to deter sperm whales from their longline catches in the GOA. Sperm whale diets overlap with commercial fisheries harvests more than any other species of toothed whales, but the degree of overlap is at least partly because of direct interactions with longline gear. In addition to consuming primarily medium- to large-sized squids, sperm whales also consume some fish and have been observed feeding off longline gear targeting sablefish and halibut in the GOA. The interactions with commercial longline gear do not appear to have an adverse impact on sperm whales, although the whales appear to have become more attracted to these vessels in recent years. NOAA Fisheries has concluded that interactions between listed cetaceans and the BSAI crab fisheries are minimal and that the crab fisheries do not pose a significant threat to the continued existence or recovery of listed cetaceans (NMFS 2001a).

Bearded seals

Early estimates of the Bering-Chukchi Sea population of bearded seals range from 250,000 to 300,000 seals. Although these estimates are not considered scientifically reliable, they appear to be abundant and are believed to be stable. Bearded seals eat a variety of fish and invertebrates, including various crab species, and have a partial overlap of prey with species caught in the groundfish and crab fisheries. Incidental take in the groundfish fisheries has been documented but appears to be a rare occurrence. The species is an important subsistence resource for Alaska Natives. ADF&G estimates the average number of bearded seals currently taken by Alaska Natives for subsistence is approximately 6,800 seals per year.

3.5.3.4 Ecosystem

The status of the BSAI ecosystems with respect to king and Tanner crabs has been summarized in Section 3.1 from a variety of cited sources. For the analytical purposes of NEPA documents, such a summary serves as a baseline description from which to compare the direct, indirect, and cumulative effects of the EIS alternatives in Chapter 4. The BSAI king and Tanner crab fisheries potentially affect ecosystem processes through several mechanisms (Table 3.5-7). The direct and indirect effects of the crab fisheries, and the contribution of other anthropogenic activities and natural events to these effects are described in the cumulative effects analysis in Chapter 4.

Table 3.5-7 Past/present events and effects on the BSAI ecosystem.

Effect on BSAI ecosystem	Event(s) that could have caused the effect
Changes in predator/prey relationships	• Removal of target species by groundfish, crab, and scallop fisheries such that predator/prey balance shifts. • Removal of predators by hunting. • Competition for food with cascade effects on predators and prey. • Introduction of non-native species.
Changes in energy flow and balance	• Harvest and bycatch of all fish and shellfish. • Commercial and subsistence hunting of marine mammals. • Energy/biomass redirection through offal and fishery discards. • Climate variability. • Oceanographic fluctuations, regime shifts.
Changes in biological diversity	• Differential loss of long-lived benthic species from bottom fishing. • Overfishing of target stocks. • Commercial hunting of whales and seabirds. • Alteration of trophic diversity through regime change.

Describing an ecosystem is akin to describing the view from a kaleidoscope. The key elements and their relationships to each other are always moving and changing, a situation that does not lend itself to a static description. Ecosystems are more complicated, however, because any description will depend greatly on the perspective from which it is written. The same ecosystem looks very different from the point of view of zooplankton or crabs or whales. Recent trends in fishery management are to try to incorporate an ecosystem perspective into target stock management plans. The goal is no longer to assess just the abundance, distribution, and allowable harvest of a given species, all of which are difficult tasks in themselves, but to also assess the broader implications of the target fishery on other fisheries, other natural resources, and the shared habitats that support them all. This requires a background knowledge of many different scientific disciplines and access to ongoing research data. While there are many important gaps in our knowledge about the composition and dynamics of the BSAI ecosystems, a great deal of information and analyses are already available. The real challenge lies in integrating all of this information into a comprehendible format where management options can be assessed, and clear implications can be drawn for management decisions.

NOAA Fisheries has developed a framework for adding ecosystem considerations into their annual stock assessments for commercially harvested groundfish species. Although different crab species are included in these groundfish analyses, and crab biologists certainly consider many environmental variables in their stock predictions, no similar framework has been developed for crab stock assessments. Still, the groundfish example provides a useful format for organizing the relevant information for crab. Since ecosystem management is a rather new concept, the format for presenting the information is still being developed and refined. For groundfish, this type of information is presented in an "Ecosystem Considerations" appendix to the annual SAFE report (NPFMC 2002). Currently, stock assessment biologists are asked to look at several types of interactions that clearly affect and are affected by their fishery.

Comparative baseline

The comparative baseline status and past/present major effects on the ecosystem are summarized in the sections to follow.

Predator/prey relationships

King and Tanner crabs prey on a variety of organisms in different parts of their ranges and in different seasons and life stages. They also serve as prey for many large predatory fish and mammals, including humans. Crab population trends may thus be influenced by changes in foraging success and mortality rates from the "bottom up" and/or from the "top down". Different types of fisheries affect these relationships by disturbing or destroying habitat that supports crab prey (i.e. bottom trawling and scallop dredging), or by removing crab predators through targeted or incidental take. Many other human activities, like commercial whaling and release of toxic pollution, may also have contributed to past changes in either predator or prey dynamics. Many physical and oceanographic processes, such as water currents, seasonal variations in temperature and primary productivity, can have major influences on predator/prey relationships. In fact, many scientists are convinced that such natural factors are much more responsible for the state of the ecosystem than any anthropogenic factors. The "regime shift" theory is based on the idea that subtle shifts in climate and oceanography can produce dramatic changes in species compositions, which may destroy or greatly enhance the potential for commercial fisheries. However, the role humans have played in climate change is still being investigated and debated, so it is difficult to declare such changes to be completely "natural". While there has been a great deal of research on relevant subjects, assigning causal relationships to ecosystem level changes has been very difficult or impossible, given our present level of understanding.

Energy flow and balance

Energy, in the form of biomass, moves through an ecosystem from one trophic level to another. Most species are limited in the size/type of prey species that they can eat so energy flows to and from any one species are usually fairly limited. Depictions of energy flows from many sectors at once constitute the classic "food web" diagrams that can be exceedingly complex and difficult to decipher. While these types of trophic descriptions are of considerable academic interest, fishery managers are more concerned with maintaining a sufficient prey base for their target species and regulating the amount of mortality on the stock so that harvests can continue without depleting overall biomass.

Biological diversity

A basic tenet of ecological theory is that highly diverse systems are more resilient to perturbations and less susceptible to sudden changes than simpler systems. Since fishery managers are interested in long-term sustainability of their fisheries, maintaining species and trophic diversity within the ecosystem is an important goal. Many natural resource laws, including the MSA, support or mandate this goal. Genetic diversity of the managed stocks is also an important consideration and there is an increasing amount of research on basic genetic variability of stocks and the potential effects of selective fishing pressure.

3.5.3.5 Physical environment in the vicinity of crab processors

The history and status of water quality and benthic substrate issues in the vicinity of crab processors have been summarized in Section 3.3.6. This summary serves as a baseline description from which to compare the direct, indirect, and cumulative effects of the EIS alternatives in Chapter 4. The direct and indirect effects of the crab fisheries (Table 3.5-8), and the contribution of other anthropogenic activities and natural events to these effects are described in the cumulative effects analysis in Chapter 4.

Table 3.5-8 Past/present events and effects on the physical environment in the vicinity of crab processors.

Effect on physical environment in the vicinity of crab processors	Event(s) that could have caused or mitigated the effect
Accumulation of benthic waste piles	• Multiple species fish processing. • Multiple species crab processing. • Dredging for port maintenance. • EPA and ADEC regulatory oversight. • Oceanographic factors concerning flushing.
Biological oxygen demand	• Multiple species fish processing. • Multiple species crab processing. • EPA and ADEC regulatory oversight. • Oceanographic factors concerning flushing.
Suspended solids	• Multiple species fish processing. • Multiple species crab processing. • Dredging for port maintenance. • EPA and ADEC regulatory oversight. • Oceanographic factors concerning flushing.

Comparative baseline

The Clean Water Act (1972) established national standards for the discharge of waste into natural bodies of water. Concerns for water quality in the BSAI and GOA have centered on localized areas where fish and crab processing have occurred, especially shore-based processing. The EPA is charged with regulating and monitoring pollution sources through NPDES permits. The ADEC also has regulatory authority and monitoring obligations for discharge into state waters. Federal and state regulations limit several aspects of waste discharge that may affect the biological, chemical, and aesthetic characteristics of a water body and benthic substrate. For fish and crab processing operations, these include the composition, volume, and particle size of suspended solids, the concentration of BOD, and the accumulation of organic and inorganic wastes on the sea floor.

Since the effects of fish-processing wastes range from beneficial (to scavenging species), to benign (when diluted), to adverse (leading to anaerobic conditions), regulatory measures have focused on adequate flushing and dilution. The capacity of marine waters to disperse fish processing effluents depends on the volume and speed of current flow through the affected area. Major shore-based facilities that process BSAI crab are located in Dutch Harbor, Akutan, King Cove, the Pribilof Islands, and Kodiak. Discharge permits require mitigation measures customized to the water flushing characteristics of each locality and are designed to prevent the development of detrimental conditions. The EPA and ADEC are responsible for enforcing compliance with individual discharge permits and monitoring for cumulative effects within designated water bodies.

3.5.3.6 Benthic species and habitat

Benthic species and the types of habitat that are potentially affected by the BSAI crab fisheries are described in Section 3.3.1. The direct and indirect effects of the crab fisheries (Table 3.5-9), and the contribution of other anthropogenic activities and natural events to these effects are described in the cumulative effects analysis in Chapter 4. This summary serves as a baseline description from which to compare the direct, indirect, and cumulative effects of the EIS alternatives in Chapter 4.

Table 3.5-9 Past/present events and effects on benthic species and habitat.

Effect on benthic species and habitat	Event(s) that could have caused the effect
Mortality	• Bycatch in groundfish, crab, and scallop fisheries. • Injury by contact with trawls, pots, dredges, longline gear, or anchors. • Mortality in lost fishing gear. • Smothering under fish processing waste. • Environmental contamination.
Changes in species diversity within the benthic community	• Concentration of targeted fisheries on unique geographic stocks. • Differential loss of highly susceptible species in heavily fished areas. • Cumulative loss of long-lived species over time. • Loss of living habitat that supports many other species in different ways.
Changes in habitat	• Physical disruption of benthic substrate from trawl, dredge, longline, and pot fisheries. • Physical disruption of benthic substrate by port dredging. • Mortality and injury of species that form living habitat.

Comparative baseline

Benthic species that occur in areas fished by the BSAI king and Tanner crab fisheries, other than the targeted crab, include fish, sea stars, urchins, corals, sponges, anemones, macroalgae, molluscs, octopi, snails, other crab, bryozoans, hydroids, stalked ascidians, sea onions, and other sessile invertebrates. Many of the sessile species provide physical and functional habitat to many other species within the benthic community, including economically important crab and groundfish species. In addition, benthic species serve as an integral part of the overall marine food web. The Bering Sea shelf, where the majority of crab and groundfish fisheries take place, is a relatively shallow (< 80 fathoms or 480 ft), low-relief plain that consists mostly of silty mud, sand, shell hash, and gravels with some scattered boulders and small rocks. Benthic communities in the Bering Sea consist of numerous infauna and epifauna taxa such as sea stars, sponges, soft corals, anemones, marine worms, and bryozoans. The Aleutian Islands are volcanic in origin with numerous high relief rock and gravel passes, canyons, trenches, and vertical rock wall ledges. The shelf break occurs much closer to shore in the Aleutians than in the Bering Sea. Benthic communities are very diverse and contain high concentrations of long-lived gorgonian corals, sponges, and anemones.

Essentially all areas of the Bering Sea shelf have been subjected to fishing pressure of one kind or another over the past 70 years. However, some areas have been fished much more intensively than others. Bottom trawling for pollock, Pacific cod, Greenland turbot, and yellowfin sole has been particularly heavy along the shelf edge, along the Alaska Peninsula near Unimak Island, and in Togiak Bay (Fritz *et al.* 1998). Fishing effort in the Aleutian Islands has been less intense and more restricted spatially but has included substantial bottom trawling for Atka mackerel, Pacific ocean perch, and rockfish along the shelf edge and upper slope. The type of gear used, species targeted, and intensity of fishing effort have varied greatly over time and space with changing markets, stock abundances, and fishery management regulations. The potential effects of fisheries on benthic habitat include direct mortality and injury of organisms that leads to changes in species abundance, diversity, and spatial distribution, changes in prey availability, and physical disruption of the substrate that causes changes in water quality (suspended sediments). Of particular concern are effects on sessile epifauna that are important living habitats for commercial crab and groundfish species.

Analyses of fishing impacts have focused on the length of time it would take an area to recover from a disturbance and the total area affected by a fishery (its “footprint”) relative to the amount of habitat available. Recovery times depend on the physical characteristics of the substrate, life history parameters of the affected species, frequency of disturbance, and the type of fishing gear used. While NOAA Fisheries has recently begun to use underwater cameras and submersibles to research the direct effects of fishing gear on benthic habitat, many variables that potentially affect recovery times have not been investigated. Investigations to date indicate that soft bodied epifauna that can bend out of the way fare better than inflexible epifauna (Eno *et al.* 2001) although soft shelled molluscs and sea stars are more susceptible to damage than hard shelled species (Rumohr and Krost 1991). Animals that can move, swim, or retract below the surface suffer less damage than sessile or reef-building epifauna (Freese *et al.* 1999, Hall 1999). Since soft bodied sessile species and mobile species are often associated with sandy/silty substrates, fishery impacts on these habitat types are considered less intense and shorter in duration than they are for rocky substrates that often have hard bodied sessile species. Gorgonian corals are especially vulnerable to fishing impacts and may take over 100 years to recover.

Bottom trawls have the largest footprint of any gear type because they have several parts that may contact the substrate, including the trawl doors, sweeps, footrope, and netting, and they are intentionally towed across the bottom. Although longline and pot gear is sometimes dragged across the bottom during setting and retrieval or by currents and storm waves, the surface area of these gear types that is normally in contact with the bottom is much less than trawl gear. Dredging certainly disrupts benthic habitat but the Alaska scallop fisheries have been rather limited in scope so their overall footprint is relatively small. On a cumulative basis, the amount of area affected by bottom trawl gear used for groundfish is much greater than pots, longlines, or dredging gear used for any other fisheries.

While the impacts of fishing gear on benthic habitat have been studied in a few specific sites, many questions remain about the effects of particular fisheries and the overall effects of all fisheries on the structure and dynamics of benthic communities. This is partly due to the fact that there is very limited baseline information on the population trends of non-commercial benthic species. The extent to which observed or potential changes in benthic species diversity or abundance affects the carrying capacity of the benthic habitat for commercially harvested species or any other taxon is unknown.

Research and conservation efforts are presently focused on trying to identify EFH and HAPC that are high in biotic value, highly susceptible to degradation from fishery impacts, and likely to recover very slowly if and when impacts occur. The NPFMC is considering a range of fishery management options to protect these important habitats, including the designation of no-fishing reserves. Other NPFMC and State fishery management actions that may afford some protection of benthic species and communities include the designation of MPAs, trawl and dredge closure areas, Steller sea lion critical habitat restrictions, and in-season fishery closures triggered by PSC limits.

For most areas of the BSAI, baseline information on the abundance, distribution, population trends, and trophic relationships of non-commercial benthic species and their associated communities is not available. Ongoing research investigating the effects of fishing on benthic species and habitat should improve this situation as more areas are sampled over time. The establishment of restricted or prohibited fishing areas will facilitate the study of various fishing impacts on benthic species in relation to non-fished conditions. An improved understanding of the trophic structure and interactions within the BSAI ecosystem may enable further assessment of short-term and long-term effects of anthropogenic activities and natural events which can then be implemented into fishery management decisions.

3.5.3.7 Fishing industry, region and community socio-economic characteristics

Events and management actions internal to BSAI crab fisheries, and external events and management actions associated with other Federal and State fisheries, have been the predominant factors in shaping the comparative socio-economic baseline. The primary internal and external events are the same for many of the indicators used to measure potential effects on the harvesting sector, processing sector, and regions and communities. A summary of external factors is presented in Table 3.5-10.

Harvesting sector past and present effects

The collapse of the Kodiak red king crab fishery in the late 1970's and the decline in Bristol Bay red king crab stocks in the 1980's led to a diversification of species harvested to include snow crab, Tanner, and other king crab species. Low stock levels, combined with excess capacity in the fisheries and subsequent closures, coupled with overcapitalization in the harvesting sector, led to the establishment of the LLP and other management measures (such as establishing pot limits and AFA sideboard measures) to reduce harvest capacity and to limit entry in the crab fisheries. The reservation of a certain percent of the crab GHL for CDQ groups to increase fishing related benefits to western Alaska communities has also affected the fisheries. Given the current level of participation in the fisheries, current technology, and existing GHLs, fishing seasons are relatively short, with GHLs reached or surpassed in less than a month in some fisheries. The development of a crab catcher/processor fleet has influenced setting prices for delivered crab. These internal events have had a bearing on efficiency, capitalization, distribution of benefits, the ability to enter the fishery, and concentrations in ownership. For more information on the historic and current crab fishery, please refer to Section 3.4.1 through 3.4.3.

The transition of fisheries in the EEZ from foreign to domestic, and management actions within the crab fishery related to stock levels have resulted in an evolution in the harvesting vessels and gear currently used to fish crab. Given short fishing seasons and reduced GHL over past years, some vessels now participate in other fisheries besides crab. However, changes in these other fisheries, such as the limits to entry into various fisheries, spatial and temporal closures of the groundfish fishery related to conservation and habitat concerns, and trends in management of groundfish fisheries limit opportunities for participation in these other fisheries, and amplify the potential effects of management actions taken in the crab fisheries. Other events and factors, such as the price collapse for salmon and implications for participants in those fisheries, and rising fuel costs, also affect decisions on participation in specific fisheries.

Other external factors have affected harvest sector participation in the crab fisheries. Changes in foreign fisheries, such as the decline in Russian red king crab stocks, and development of a Canadian snow crab fishery, and decline in Asian demand for crab associated with their economic downturn, have affected demand and prices. Harbor and marine service infrastructure improvements have increased Alaska regional and community capacity to service resident and transient crab vessels, and facilitate participation in other fisheries.

Harvesting sector comparative baseline

Sections 3.4.2 and 3.4.3 summarize harvesting sector participation on the crab fisheries and related socio-economic characteristics, and can be referred to for more detail.

While the LLP limits entry into the crab fisheries, quota share is not assigned. The number of vessels that have been fishing for crab in recent years are less than those currently eligible to fish under the LLP (see Table 4.1.1). Approximately 225 vessels participated in crab fisheries in the year 2000. Given excess capacity and technological improvements, in combination with conservative GHLs, the crab fisheries remain a "race for fish", where harvest in most fisheries occurs during a very short period until the GHL is reached. This resulted in harvest inefficiencies, and increased gear loss and safety concerns. Because excess capacity, and in some cases depressed demand, currently exists in other fisheries where crab harvesters participate, inefficiency in the harvesting sector is accentuated.

With regard to distribution of benefits between the harvesting and processing sectors, the LLP determines who may fish for crab, but does not assign share to harvesters. Because there are no limits on processors that can enter the crab fisheries, processors must compete to purchase a portion of the harvest. The price paid for crab landed, and hence distribution of benefits, is balanced by processor competition for landings and the short season and limited delivery window because crab must be processed live. Prices are negotiated collectively in some fisheries. Strikes have occurred when harvesters have disputed the prices offered by processors.

New participants can enter the crab fishery through purchase of an existing LLP license, which require use of a vessel and gear. Harvesters have successively found entry to other fisheries limited by limited entry programs. Effects of these programs on entry vary with management type (e.g., IFQ programs or licensing program) and the circumstances and capital requirements of the fishery.

Acquisition of excessive shares, as discouraged by the Magnuson-Stevens Act, does not apply to the comparative baseline because the current fishery does not allocate harvest or processing shares.

Processing sector past and present effects

Many of the key internal events affecting the harvesting sector have also affected the processing sector (i.e. fisheries open and closed, GHLs, length of season). Other internal events include: the development of the domestic C/P industry and allocation of LLP licenses to C/P vessels; increases in utilization and reductions in waste discharges (which have affected operation practices and costs of crab processors in Dutch Harbor and Akutan in the early 1990's), and changes in fishing trends and stock levels.

Key external factors for processing are also similar to the harvesting sector. These include: diversification of processors into multiple species and fisheries and changes that have occurred in those fisheries; competition from other fisheries; changes in Asian demand; and improvements in marine infrastructure that support delivery and product shipment.

Processing sector comparative baseline

Sections 3.4.2 and 3.4.3 summarize processing sector participation on the crab fisheries and related socio-economic characteristics, and can be referred to for more detail.

Processor entry into the crab fisheries is not limited; however, as with the harvesting sector, processing must accommodate the race for fish, resulting in inefficiency and overcapacity. The processing sector has consolidated in recent years, and to the extent possible processing labor and equipment lines are scheduled to accommodate multiple fisheries. Trends in management of other fisheries have included rationalization and the establishment of cooperatives, where the harvesting and processing sectors associate. These measures mitigate inefficiency and excess capacity in the processing sector to some degree.

Should a new processor decide to enter the fishery, operation expertise and purchase of additional facilities and equipment would likely be required, with no guarantee of the amount of crab that could be purchased. Given the short fishing season, a new processing entrant would likely need to participate in other fisheries, most of which are fully capitalized.

Acquisition of excessive shares, as discouraged by the Magnuson-Stevens Act, does not apply to the comparative baseline because the current fishery does not allocated harvest or processing shares.

Regional and community past and present effects

Past and present internal crab fishery events and actions that have shaped regional and community participation in the crab fishery are similar to those for the harvesting and processing sector. Prior to the Americanization of the offshore fisheries, regional and community fishery participation revolved around harvesting and processing coastal fisheries such as salmon and halibut, and providing services to the foreign fishery. The rise of the crab fisheries in the 1960's and 1970's led to growth in local harvesting and processing activities, setting a precedent for Americanization of other fisheries. The crab fishery collapses that occurred in Kodiak and Bristol Bay were difficult for many communities that had become economically and fiscally dependent on these fisheries. As crab fisheries have diversified and management measures have been instituted affecting entry into crab fisheries, a variety of regions and communities now support harvesting and processing of various crab fisheries (see Section 3.4.4).

External events affecting regions and communities that participate in the crab fisheries include: changes in management and economic conditions in other fisheries; diversification into multiple fisheries (groundfish, halibut, and salmon); changes in other economic activities (military activity, shipping, and tourism); development of marine infrastructure and services that support the crab fleet; and reductions in state and federal revenue sharing. The transition of fisheries in the EEZ from foreign to domestic have resulted in the development of regional/community based fishing fleets, onshore processors, and economic support activities, which generate a significant amount of state and local tax revenue. The fishery closures, competition, and demand/price developments affecting the fishing industry have had economic effects on regions and communities. As regions and communities have become more dependent on fishing, changes in other economic activities that have developed employment and revenue have occurred. Military expenditures associated with bases and clean-up activity have decreased significantly, as have local infrastructure development projects. Some activities, such as tourism, have increased but are not enough to offset declines in fisheries and other economic activities. Finally, revenue to municipalities from federal, state, and local sources have been decreasing over the last five years, affecting the ability of local government to provide services and employment opportunities.

Regional and community comparative baseline

Section 3.4.4 and the SIA in Appendix 3 summarize regional and community participation on the crab fisheries and related socio-economic characteristics, and can be referred to for more detail.

The regions and communities that currently participate in the crab fisheries include coastal areas of Alaska, and specific areas within Washington and Oregon. Over the period of 1991-2000, Washington-based vessels showed the greatest participation in crab fisheries, with Kodiak a distant second. The majority of C/P vessels are also based out of Washington. Shore-based crab processors are concentrated in the Kodiak, Alaska Peninsula/Aleutian Islands, and Bering Sea regions. While the size of the Washington-and Oregon-based fishing industry and their dependence on Alaska fisheries are substantial, regional economies in those states are dominated by sectors other than fishing. The same can be said for crab harvesting and processing participants based out of Anchorage. However, for other coastal regions and communities in Alaska, particularly the Kodiak, Alaska Peninsula/Aleutian Islands, and Bering Sea regions, local economies are more dependent on fishing, including the crab fisheries. Fishing contributions are significant to regional and local economies including direct and indirect employment, economic support services, and generation of state and municipal revenue.

Changes in fisheries as a whole, such as the price collapse in salmon, crab closures, conservation/habitat related closures, and management measures such as limited entry and rationalization, have had profound economic effects on many communities. Effects in one fishery are more likely to have repercussions in other fisheries. Coupled with external factors such as decreases in revenue sharing and capital project funding, decreases in other economic activities, and high transportation and energy costs, coastal communities in Alaska are vulnerable to changes in how fisheries are managed.

Table 3.5-10 Summary of external factors for harvesting and processing sectors, and communities and regions.

	Harvest sector	Processing sector	Communities and regions
External factors	• Changes in foreign crab fisheries. • Changes in economic conditions in other fisheries, diversification into multiple fisheries (groundfish, halibut, and salmon). • Changes in technology and operating costs. • Development of marine infrastructure and services that support the crab fleet. • Management actions in state and federal fisheries other than crab.	• Changes in foreign crab fisheries. • Changes in economic conditions in other fisheries, diversification into multiple fisheries (groundfish, halibut, and salmon). • Changes in technology and operating costs. • Development of marine infrastructure and services that support the crab fleet. • Management actions in state and federal fisheries other than crab.	• Changes in economic conditions in other fisheries, diversification into multiple fisheries (groundfish, halibut, and salmon). • Changes in other economic activities (military activity, shipping, tourism). • Development of marine infrastructure and services that support the crab fleet. • Management actions in state and federal fisheries other than crab. • Reductions in state and federal revenue sharing.