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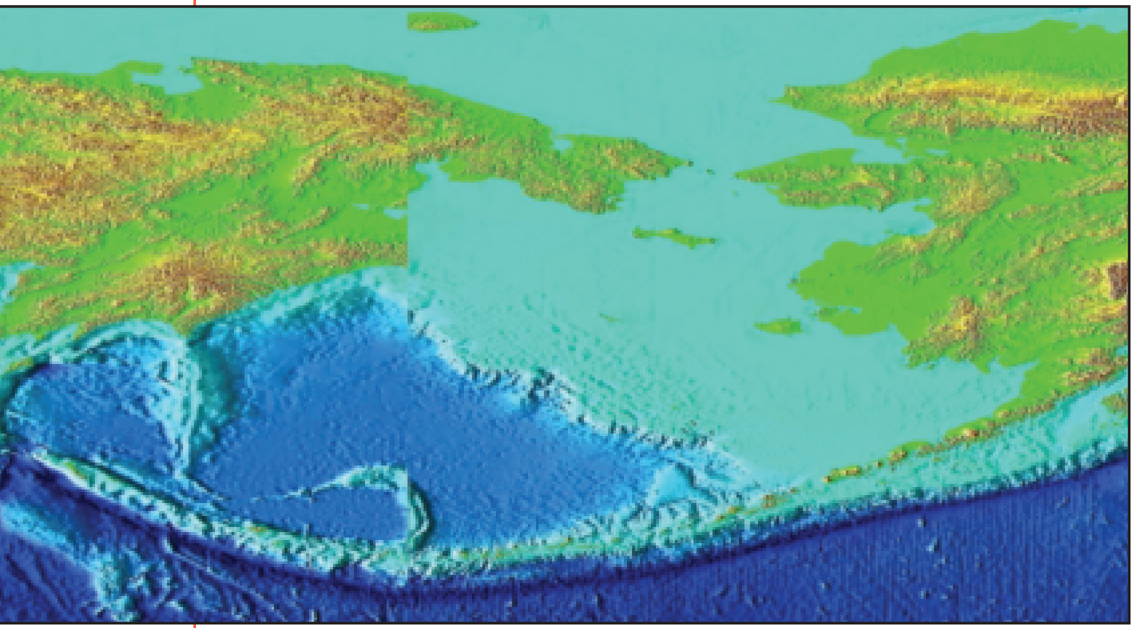
Bering Sea

highlights



- Oceanographic and ecosystem dynamics are dominated by sea ice (annual extent, duration, timing), which is sensitive to climate variations. Seawater temperatures on the eastern shelf have been warmer in winter in recent years, coinciding with a conspicuous absence of winter sea ice.
- The Bering Sea is known for high biological productivity that is strongly seasonal. Some of the largest fisheries in the U.S. occur in the eastern Bering Sea.
- The eastern part of the Bering Sea has experienced unusual blooms of both phytoplankton and zooplankton. Coccolithophore blooms, which first appeared during the 1997/1998 El Niño, failed to reappear in the summers of 2001 and 2002. Large jellyfish became increasingly abundant through the 1990s, but have subsequently declined to low levels.
- Shifts in abundance of fish and invertebrate populations occurred over the past 20 years although recently, groundfish populations appear to have stabilized while some crab stocks are at low levels. Catches of some Pacific salmon stocks returning to the Yukon River are depressed while most Bristol Bay sockeye stocks have been moderate to strong in the last decade. Kamchatka runs of pink salmon have been in good condition since 1989 and chum salmon catches have been stable in the west.
- There are concerns about declines in Steller sea lions and northern fur seal populations, and unusual distributions of endangered whales. Reproductive success of piscivorous seabirds has been above average while planktivorous species showed little change in recent years.
- Significant issues for this region include the effects of climate warming, novel phytoplankton and zooplankton blooms, interactions of commercial fishing with bottom habitats, and marine mammals.

background*

The Bering Sea is a semi-enclosed high-latitude sea with a deep basin (3,500 m), and shallow (<200 m) continental shelves. The broad shelf in the east contrasts with a narrow shelf in the west.[219]

In summer on the eastern shelf, coastal, middle, and outer domains can be distinguished by their hydrography and circulation patterns. The domains are separated by fronts that constrain cross-shelf exchange and are important locations for ecosystem interactions. Similar frontal zones exist in the western part, but they are less stable and depend on the position and intensity of the Kamchatka Current.[220] There are large seasonal differences in solar radiation, wind forcing, and sea ice. The Bering Sea is connected to the North Pacific through the Aleutian archipelago and there is a shallow connection with the Arctic Ocean through the Bering Strait. The region can be considered as a continuation of the North Pacific subarctic gyre. The Alaska Stream flows into the eastern Bering Sea, moving counter-clockwise around the basin, and exiting through Kamchatka Strait.[221] The average temperature of eastern Bering Sea shelf water in summer is 2.4°C at the bottom and 6.6°C at the surface.

The region has high biological productivity that is strongly seasonal. Over 266 species in 8 taxonomic classes of marine phytoplankton have been identified in the Bering Sea community.[222] Rates of primary productivity up to 225 gC m^{-2} y^{-1} have been reported from the most productive areas.[223] There are over 300 species of zooplankton; copepods, coelenterates, and amphipods are the most abundant taxa. Zooplankton biomass production is strongly seasonal but varies regionally, with estimates up to 64 gC m^{-2} y^{-1} from the shelf edge to 4 gC m^{-2} y^{-1} for the coastal domain.[222] The region includes more than 450 species of fish and invertebrates, of which about 25 are commercially important.

Forage fishes such as capelin (*Mallotus villosus*), eulachon (*Thalichthys pacificus*), deep sea smelts (Bathylagidae), myctophids, Pacific sand lance (*Ammodytes hexapterus*), and Atka mackerel (*Pleurogrammus monopterygius*) and juvenile cephalopods can be locally abundant. These are prey items of larger cephalopods, fishes, marine mammals and seabirds.[222] The most important commercial species are the groundfishes such as walleye pollock, flatfishes, and several species of crabs and Pacific salmon. With such high primary and secondary production in the Bering Sea, some commercially important species can reach very high abundances. In 2001, catches from the eastern Bering Sea region accounted for about 40% of all fish landings in the United States. Since the 1970s, when the period of recent observations began, most commercial populations of fishes and crabs have exhibited cyclic changes in abundance.

The high biological productivity of the region supports 38 species of seabirds and 25 species of marine mammals.[222] These species tend to have low reproductive rates and longer life spans. Changes in seabird population trends have been attributed to a combination of changes in productivity as well as changes in survival, for those species studied to date. Over the past 30 years, dramatic changes in the abundance of salmon, crabs, and groundfishes have occurred, declines in marine bird and pinniped abundances have lead to fishery closures, and unusual distributions of whales and blooms of unusual phytoplankton and zooplankton have been noted.

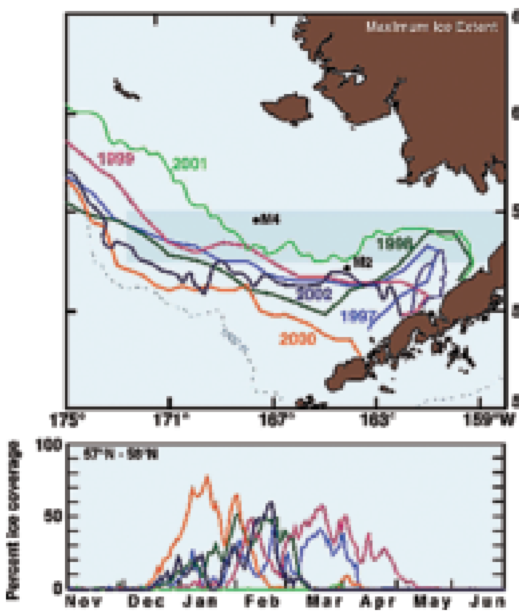
* At present, most of the information in this section pertains to the eastern Bering Sea. Additional information from the western Bering Sea will be added future editions.

Status and Trends

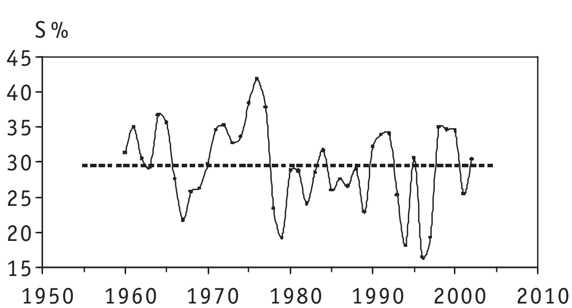
Hydrography

Sea ice in the Bering Sea has shown decadal-scale variability. There was less ice and warmer temperatures after the late 1970s, although the amount of sea ice has been increasing during the 1990s. Unusually low sea ice occurred in 2001 (Figure 94), mostly due to strong southerly winds that kept the ice north of 60°N.[232] Sea ice also disappeared earlier in the springs of 2000 and 2001. Beginning in 1998, an increase in ice cover in the Bering Sea was observed that was synchronous with the Okhotsk Sea (Figure 95).[22]

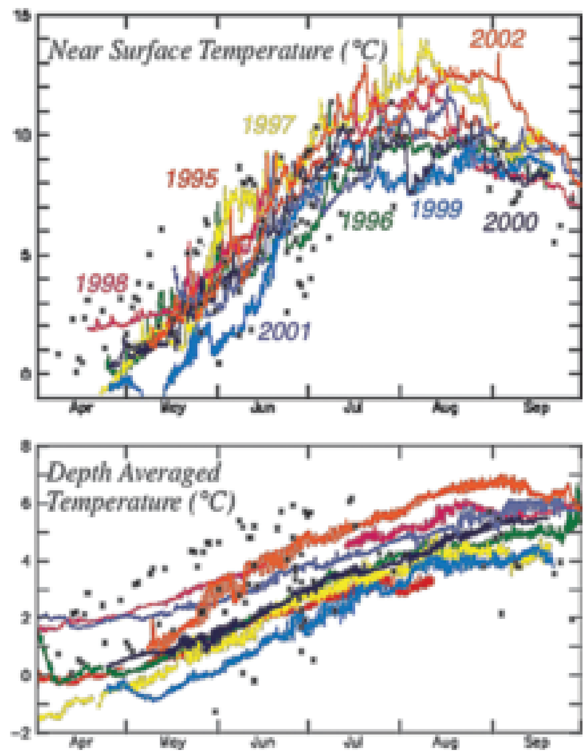
Temperatures in August/September in the southeastern middle shelf region are higher than historical values. Summer bottom temperatures in the whole southeastern shelf region from 2000 through 2002 have been increasing relative to the recent historical low observed in 1999 (Figure 96). In the western Bering Sea, a sharp decrease in temperature of near-bottom water was noted on the shelf from 1997 to 1999.



[Figure 94] The extent (upper panel) and timing (lower panel) of ice cover in the eastern Bering Sea in recent years. M2 denotes the location of mooring site 2. Colour/years in the lower panel match those in the upper panel.



[Figure 95] Changes in winter (January-April) ice cover area (% from the total sea area) in the Bering Sea.



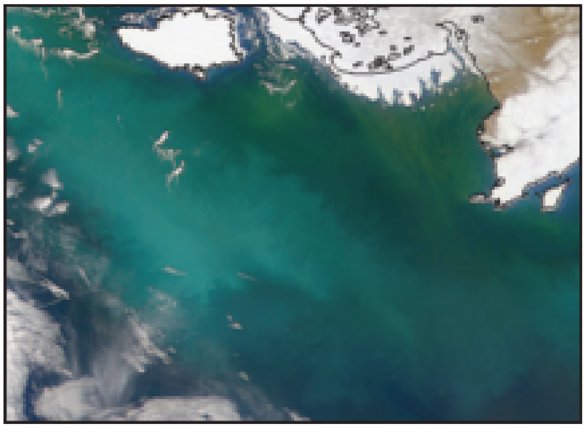
[Figure 96] Daily near surface (upper panel) and depth-averaged (lower panel) water temperatures of the SE Bering Sea Shelf, 1995-2002, measured at mooring Site 2. (X's are historical data back to 1965.)[225]

Chemistry

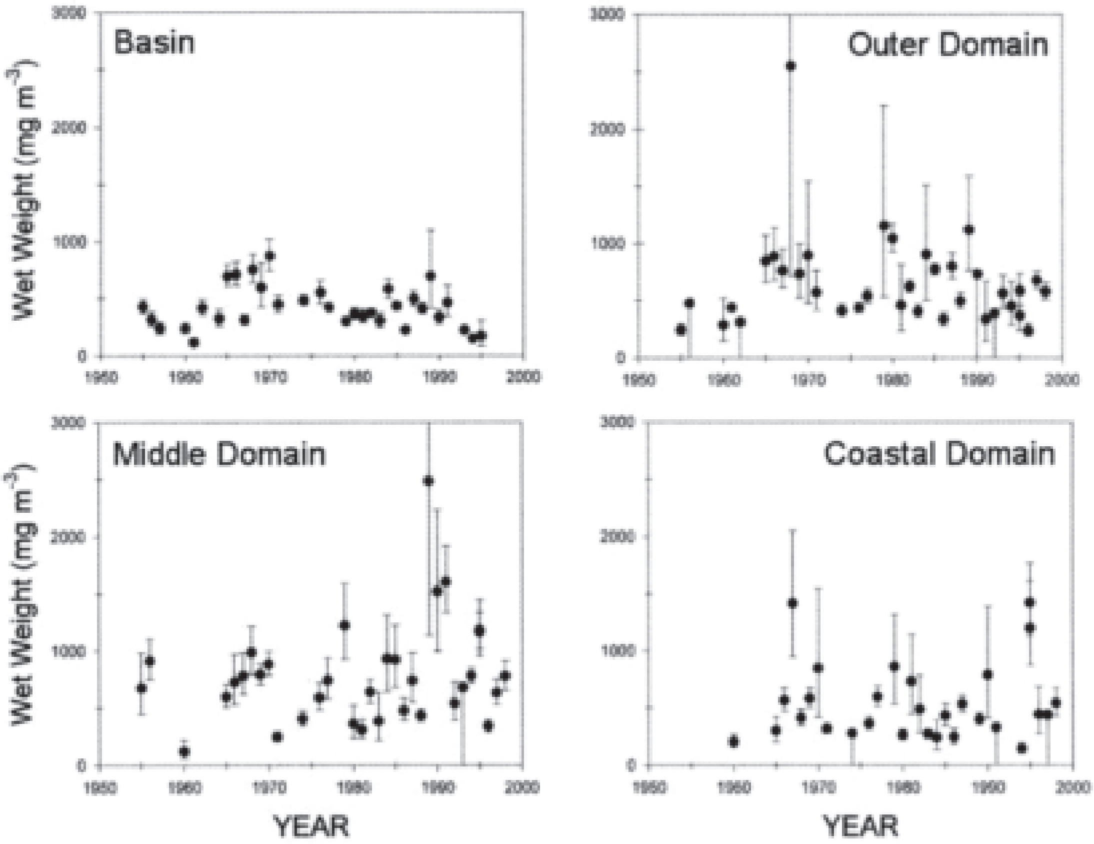
No data

Plankton

The spring phytoplankton bloom occurred late in spring in 2000 through 2002 due to the early retreat of ice from the eastern Bering Sea. Unusual, and sometimes very large, coccolithophore blooms have been observed on the eastern Bering Sea shelf beginning in 1997 through 2000 (Figure 97) but have not been present in 2001 and 2002.



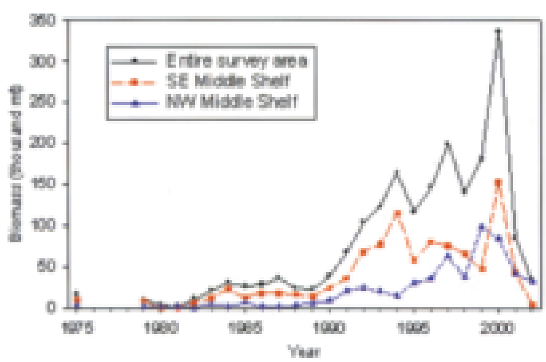
[Figure 97] Satellite image of a coccolithophore bloom in SE Bering Sea in 2000.



[Figure 98] Changes in summer zooplankton biomass (means with standard errors) in the southeastern Bering Sea. [226]

Demonstrating an effect of climate on lower-trophic levels in the eastern Bering Sea has proven to be very difficult. Zooplankton biomass data for each domain of the eastern Bering Sea from the T/S *Oshoru Maru* (Hokkaido University) does not show any trend with El Niño or longer term climate signals (Figure 98). However, a "wave" of predatory zooplankton, consisting mostly of chaetognaths, came through the western Bering Sea in the 1990s. An inverse relation between copepod and euphausiid biomass has also been seen.[227]

The most striking changes in zooplankton were associated with the huge increases and sudden decline in the biomass of gelatinous zooplankton (jellyfish) since 1989 on the eastern shelf (Figure 98). Most of this increase was due to the large scyphomedusa, *Chrysaora melanaster.*[228] The catch of jellyfish during the summer survey in 2000 was the highest recorded, with an estimate for the area surveyed of 336,673 t, although the densities were highly variable on local spatial scales. Abundance has dropped dramatically in the most recent years.



[Figure 99] Biomass index (thousand metric tons) of jellyfish caught in bottom-trawl surveys on the eastern Bering Sea shelf during 1975 and from 1979 to 2002. Also shown are the totals for the SE middle shelf and NW middle shelf only.

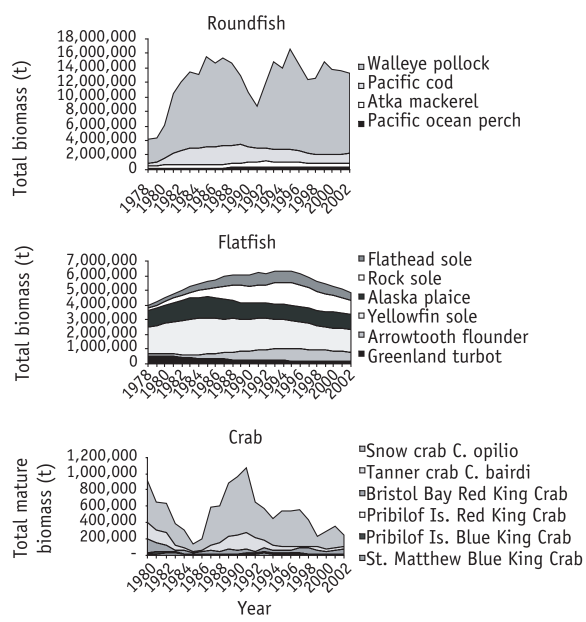
Fish and Invertebrates

Shifts in demersal fish and benthic invertebrates on the eastern shelf began around 1980.[229] There were strong increases in the biomass of walleye pollock, Pacific cod, Pacific ocean perch and Atka mackerel. Rock sole, flathead sole and arrowtooth flounder increased in abundance while Greenland turbot and other flatfish declined. Biomass of commercially important crab species on the eastern shelf had strong peaks around 1980 and 1990, mainly due to increases in snow crab abundance.

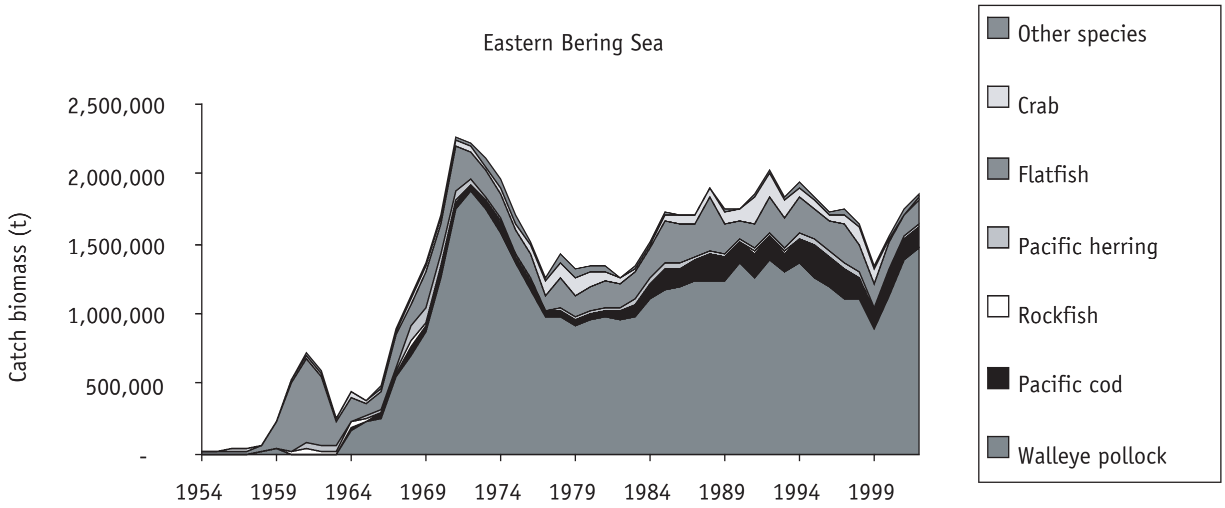
Since 1992, the total estimated biomass of dominant commercial groundfish species has ranged between 18 and 20 million t, with walleye pollock dominant. The total annual biomass of groundfish caught in the eastern Bering Sea during that period has also been relatively stable, averaging about 1.6 million t, also with walleye pollock dominant. Groundfish and shellfish fishery catches in the eastern Bering Sea have been relatively stable over the last 20 years with total catch approaching two million t (Figure 101). Generally, groundfish recruitment relative to spawning biomass declined from high levels observed in the late 1970s.[229]

Flatfish are lightly exploited for a number of reasons, including bycatch restrictions in the groundfish fisheries in the eastern Bering Sea. Although crabs comprise a small proportion of the catch, they are the highest in value. The trophic level of the catch has been high and stable over the last 20 years, with no "fishing down the food web" effect.

Recruitment for most Bristol Bay sockeye salmon stocks other than Kvichak has been moderate to strong in the last decade. Some weak runs due to poor recruitment events have been observed for Yukon and Kuskokwim River chinook and chum salmon. Pink salmon catches have been moderate to high in most regions over the last 20 years. Coho catches have been moderate to high in all regions.



[Figure 100] Time series of fish[230] and invertebrate[231] resource abundance in the southeastern Bering Sea.



[Figure 101] Total catch biomass of fish (excluding salmon) and shellfish in the eastern Bering Sea.[232]

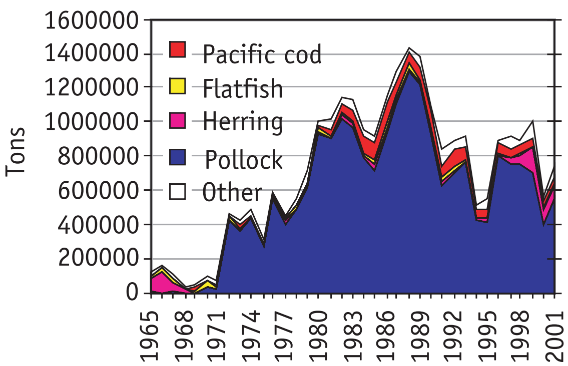
In the western Bering Sea (Figure 102), cooling of shelf waters during the 1990s has resulted in unfavorable conditions for walleye pollock.[233] Pacific cod abundance declined from an estimated 766,000 t in 1989 to 172,000 t in 2000.[234] Yellowfin sole biomass is estimated at 78,000 t on the southwestern shelf, much lower than on the eastern shelf, due to the narrow area of the western shelf. Greenland turbot are not abundant in the western Bering Sea and abundance was higher in the northern part of the Bering Sea in the 1990s compared with the 1980s. However, the total biomass and overall distribution of this flatfish decreased in the western Bering Sea as in the eastern region.

Since 1989, runs of pink salmon to the eastern Kamchatka coast have been in good condition during odd years. The average pink salmon catch (38,390 t) for 1989-2001 is more than twice the level calculated for 1952-1993 (15,996 t). Similarly, chum salmon catches were also stable at 11,000-12,000 t in 2000-2001 compared to 5,250 t for 1952-1993.[235]

Walleye pollock catches in the northwest shelf region declined due to poor stock condition and fishery management changes. Total pollock catch in the Russian EEZ declined from 1,327,000 t in 1988 to 393,180 t in 2000. Cod harvest peaked at 117,650 t in 1986 and has since declined due to decreases in cod abundance. The flatfish fishery did not exist in the northwestern region until the 1990s.

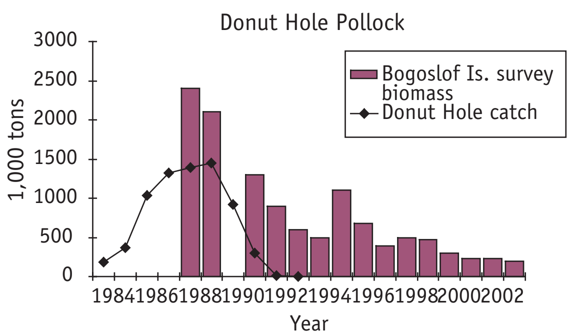
Capelin aggregations along the northwestern coast exhibit a stable distribution during the warm season. Biomass was estimated at 200,000 t on the western Bering shelf in 1986-1990. Polar/Arctic cod (*Boreogadus saida*) extended their summertime range southward on the shelf in the western Bering Sea during 1999-2000.

Snow crab and Tanner crab fisheries were not conducted in the western Bering Sea in 2000-2001. Research surveys indicated some improvement in stock condition allowing a small commercial fishery in 2002.



[Figure 102] Commercial fishery catches in the western Bering Sea.

The Bering Sea basin region has been the site of a walleye pollock fishery in international waters (the Donut Hole) beyond Russian and United States EEZs. High catches occurred during the 1980s but no fishery is presently allowed (Figure 103). Basin pollock are thought to originate from the Bogoslof Is. spawning population, which has been at low levels the last few years.

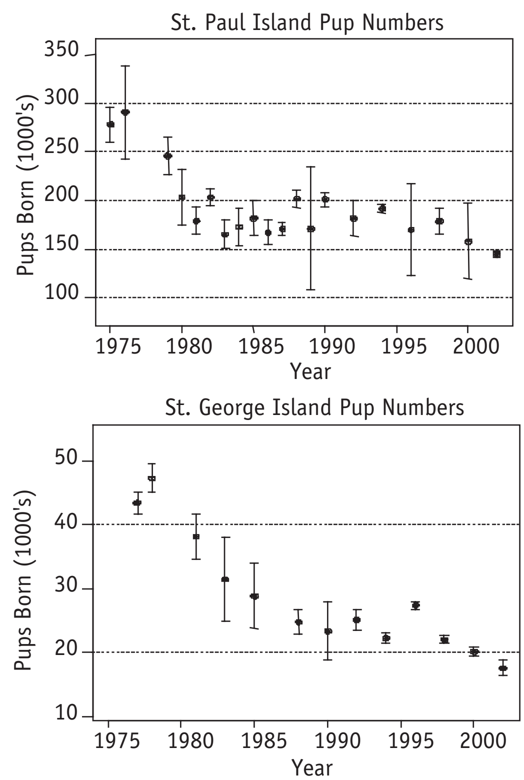


[Figure 103] Bogoslof Is. spawning biomass of walleye pollock and donut hole catch.

Marine Birds and Mammals

Seabirds It is estimated that 40-50 million seabirds live in the eastern Bering Sea, and summer migrants add another 30 million. In 2000, seabirds began nesting earlier than average, in contrast to 1999 when nesting began later. The reproductive success of piscivorous birds was generally better than average in 2000 whereas it was about the same in 2000 as in 1999 for planktivorous birds.

Pinnipeds Steller sea lions live predominantly along the Aleutian island archipelago, but some also occur in the Bering Sea. Through the 1990s the abundance of this species has been declining by 2-8% per year, and the cause is the subject of intense investigation. Northern fur seals (*Callorhinus ursinus*) are found throughout the northern North Pacific but breed mainly at the Commander and Pribilof Islands. Seventy-four percent of the world population breeds on the Pribilof Islands. The number of northern fur seal pups has been declining since 1975 (Figure 104).



[Figure 104] Counts (mean and standard error) of northern fur seal pups at rookeries on St. Paul (upper panel) and St. George (lower panel) Islands, Pribilof Islands[236]. Note rapid declines between 1976 and 1984

Cetaceans Unusual distributions of endangered North Pacific right whales (*Eubalaena japonica*) have been identified over the past 5 years, with a shift to shallower waters on the shelf and different prey species[237].

critical factors causing change

Sea ice and fishing are the most significant proximate causes of change in marine ecosystems of the eastern Bering Sea. The annual extent and duration of sea ice is central to the functioning of the ecosystem. It affects the timing, amount, and fate of primary production. It affects temperature and salinity properties, the strength of vertical stratification, and the spatial distributions of marine predators and prey. Cold regimes may have less coupling between the timing of phytoplankton and zooplankton production and subsequent survival of larval/juvenile fish, while warm regimes may promote increases in piscivorous fish populations.

If ice is present in mid-March or later it will trigger a strong phytoplankton bloom. If not, the bloom will occur later (e.g. in May) once the water column has stratified. The edge of the sea ice also has important influences on local phytoplankton production. In turn, sea ice is sensitive to variations in meteorological conditions, such that small variations in wind velocity and direction can greatly affect the extent, timing, and duration of ice. The locations of the Arctic High and Aleutian Low pressure regions govern the paths and intensities of the storms that impact the Bering Sea, particularly in winter. This region is therefore quite sensitive to low-frequency climate variations and change. Large-scale climate processes that influence the Bering Sea include those that are indexed by the Arctic Oscillation (AO) and the Pacific North America (PNA) pattern.

The predominant direct human forcing on the eastern Bering Sea is fishing. The amount of fishing effort (measured as bottom-trawling time) was lower in 1999 to 2001 than levels seen in the 1990's, and the total number of vessels fishing peaked in 1994 and subsequently decreased. A number of trawl closures have been put in place over the years, amounting to about 20% of the fishable area of the eastern Bering Sea. There was more bottom area closed to trawling in 2000 than in 1999. Areas of high trawling effort are north of Unimak Island and the edge of the southeastern shelf region.[316t]

issues

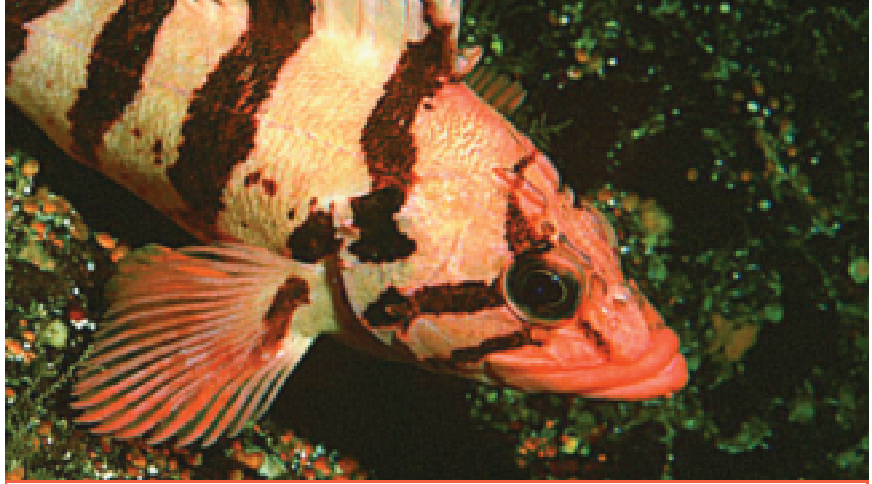
How will this system respond to global warming? Changes forecast for the Bering Sea include decreasing numbers of storms (less ocean mixing), leading to reduced nutrient levels, less sea ice, and higher sea temperatures. Ecosystem changes observed over the past 5 years include major coccolithophore blooms, high mortality of shearwaters in 1997, some reductions in salmon runs, and unusual whale distributions.[238]

The coccolithophore blooms have occurred for several years beginning in 1997, whereas they had not been observed prior to 1997. The cause(s) of the blooms are unknown but they alter the carbonate chemistry of the water and may increase dimethylsulfate production.[238] They may also replace the small flagellates that are normally dominant in summer. Since these blooms are readily observed by satellite, they affect light penetration in the ocean, decreasing light for primary production and visual foragers, with unknown consequences for other organisms.

The abundance of gelatinous zooplankton increased substantially after 1989. The dominant species are both predators on, and competitors with, juvenile stages of commercial fishes such as walleye pollock. These medusae can have an effect on zooplankton abundance that is potentially greater than that of age-0 walleye pollock. Competition with jellyfish for food may have a negative impact on the biomass of walleye pollock. The increase in jellyfish abundance is hypothesized by some to be due in part to a release from competition by planktivorous forage fishes.[239] After peaking in 2000, substantial reductions in jellyfish abundance have been observed.

An ecosystem-based approach to the management of groundfish fisheries which interact with other benthic species is being adopted in Alaska.[239] This includes closing areas of critical habitat of endangered species to fishing, and careful monitoring of the effectiveness of these closures and the impacts of displacing effort to other locations.

The decline of Steller sea lions in Alaska is presently the subject of intense investigation, in particular to identify any potential negative impacts of fishing for walleye pollock, an important prey species of the sea lions. Unusual distributions of endangered North Pacific right whales (*Eubalaena japonica*) have been identified over the past 5 years, with a shift to shallower waters on the shelf and different prey species. This may make such endangered species more susceptible to ecosystem changes.



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