XIV-45 East Bering Sea: LME #1

M.C. Aquarone and S. Adams

The East Bering Sea LME is characterised by an extremely wide, gradually sloping shelf, and by a seasonal ice cover that in March extends over most of this LME. The LME is bounded by the Bering Strait to the North, by the Alaskan Peninsula and Aleutian Island chain to the South, and by a coastline to the east that is thousands of miles in length. The surface area is about 1.4 million km^2, of which 0.87% is protected. It contains 0.07% of the world's sea mounts. This LME receives freshwater discharge from major rivers including the Yukon and Kuskokwim (Sea Around Us 2007). Book chapters and articles pertaining to this LME include Incze & Schumacher (1986), Carleton Ray & Hayden (1993), Livingston *et al*. (1999) and Schumacher *et al*. (2003).

I. Productivity

Temperature, currents and seasonal oscillations influence the productivity of this LME. For information on oceanographic and climate forcing in the East Bering Sea ecosystem, and the recruitment responses of many Bering Sea fish and crabs linked to decadal scale patterns of climate variability, see EPA (2004) and PICES (2005). The East Bering Sea LME is a Class II, moderately high productivity ecosystem (150-300 $gCm^{-2}yr^{-1}$). This LME is undergoing a climate driven change in species dominance and species abundance in some ecological groups (PICES 2005). On the temporal variability of the physical environment over the LME, see Stabeno et al., 2001. There is much to understand about its carrying capacity during the present period of climate change. For example, there have been nearly ice-free conditions in the mid shelf from January to May in 2000-2004. Accompanying this change are shifts in the trophic structure with walrus populations moving northward with the ice, and Alaska pollock moving east.

Oceanic fronts: Five major fronts can be found over the East Bering shelf and slope (Belkin et al., 2003; Belkin & Cornillon 2005; Belkin et al., 2009). The Coastal Front consists of three segments, the Bristol Bay Front (BBF), the Kuskokwim Bay Front (KBF), and the Shpanberg Strait Front (SSF), all extending approximately parallel to the Alaskan Coast at a depth of 10 to 20 meters (Figure XIV-45.1). Farther offshore, the Inner Shelf Front (ISF) is located at a depth of 20 to 40 meters while the Mid-Shelf Front (MSF) is found at 40 to 60 meters. These two fronts are also approximately isobathic. The most distant offshore fronts, the Outer Shelf Front (OSF; 60-100-m depth) and the Shelf-Slope Front (SSF; 100-200-m depth within this LME) are not isobathic. They extend from relatively shallow depths in the east, off Bristol Bay, to significantly greater depths in the west, where the SSF crosses the shelf break and slope to continue over the deep basin as it leaves the East Bering Sea LME and enters the West Bering Sea LME.

East Bering Sea SST (Belkin 2009)(Figure XIV-45.2)
Linear SST trend since 1957: 0.46°C.
Linear SST trend since 1982: 0.27°C.

The annual mean SST averaged over the East Bering Sea increased by 0.46°C between 1957 and 2006. The 50-year warming was not uniform: instead, the time span included two periods with opposite SST trends. In 1957 the average Bering Sea SST reached a maximum that has not been surpassed until recently (Niebauer et al., 1999). From 1957 to 1971, the SST decreased by 1.3°C. The SST drop was especially abrupt in the late 1960s-early 1970s; in 1969-71 SST decreased from 5°C to 4°C. The cold spell lasted through 1976. In the winter of 1976-77, the East Bering Sea underwent an abrupt regime shift to warm conditions, with the SST rising by 1°C in a single year and remaining relatively high through 2006. The 1°C SST jump from 4.1°C to 5.1°C between 1976-77 was a regional manifestation of a trans-North Pacific "regime shift" that occurred during the winter of 1976-77, caused by a major shift of the North Pacific atmospheric pressure pattern captured in three indexes, ENSO, PDO, and the Aleutian Low index (Mantua et al., 1997; Hare and Mantua, 2000). This has helped species such as salmon stocks rebound from previous low years of abundance. The atmosphere-ocean system shift was followed by an ecosystem shift around and across the entire North Pacific. For some species, the effects of this ecosystem shift were beneficial, for others they were detrimental. The most recent cold episode, in 1999, was short-lived. The East Bering Sea has returned to warm conditions.

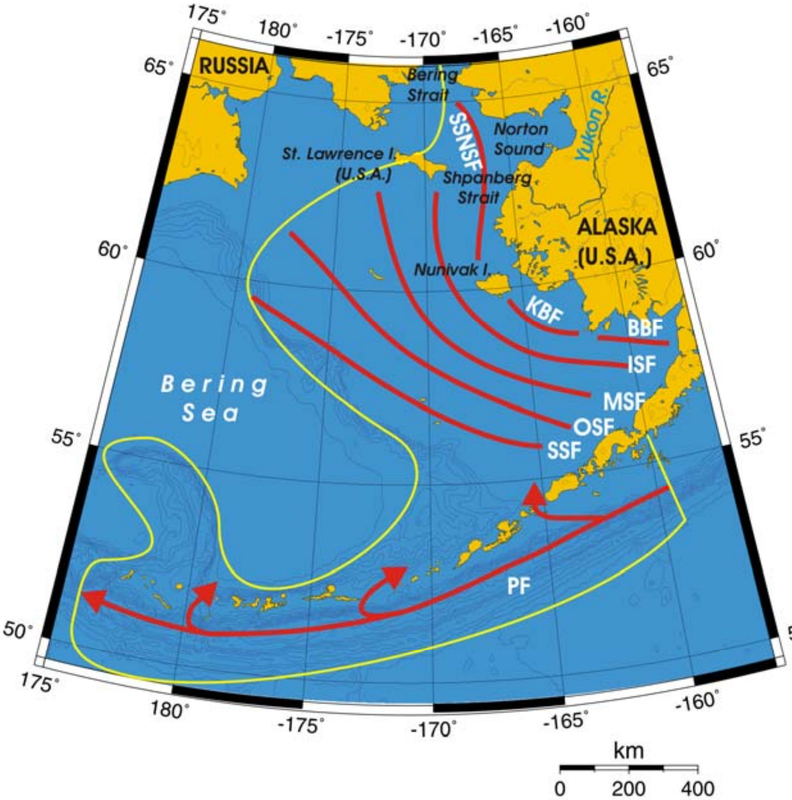

Figure XIV-45.1. Fronts of the East Bering Sea LME. BBF, Bristol Bay Front; ISF, Inner Shelf Front; KBF, Kuskokwim Bay Front; MSF, Mid-Shelf Front; OSF, Outer Shelf Front; PF, Polar Front; SSF, Shelf-Slope Front; SSNSF, Shpanberg Strait-Norton Sound Front. Yellow line, LME boundary. After Belkin *et al.* (2009).

The bathymetry of this LME is critically important while analyzing the area-averaged SST time series. The most important feature is the presence of two different oceanographic regimes within this LME, namely an extremely wide, nearly horizontal continental shelf and a deep-sea basin. This co-existence of shallow shelf and deep sea might explain the observed discrepancy between the LME-averaged SST time series and the SST observations over the East Bering Sea Shelf alone. Indeed, the most recent observations over the southeastern Bering Sea Shelf revealed a dramatic summertime warming by 3°C in the 2000s, likely caused by a synergy of several mechanisms, including (a) persistent northward winds since 2000; (b) a later fall transition combined with an earlier spring transition that resulted in a shorter sea ice season; (c) an increased flux of warm waters from the Gulf of Alaska LME through Unimak Pass; and (d) the feedback mechanism between warm summertime oceanic temperatures and the wintertime southward advection of sea ice (Stabeno et al., 2007).

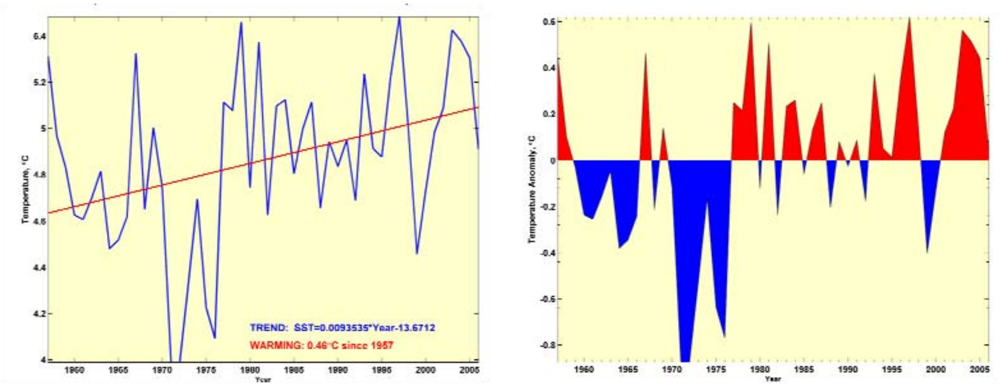

Figure XIV-45.2. East Bering Sea LME annual mean SST (left) and annual SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

East Bering Sea LME Chlorophyll and Primary Productivity: The East Bering Sea LME is a Class II, moderately high productivity ecosystem (150 – 300 $gCm^{-2}yr^{-1}$)(Figure XIV-45.3).

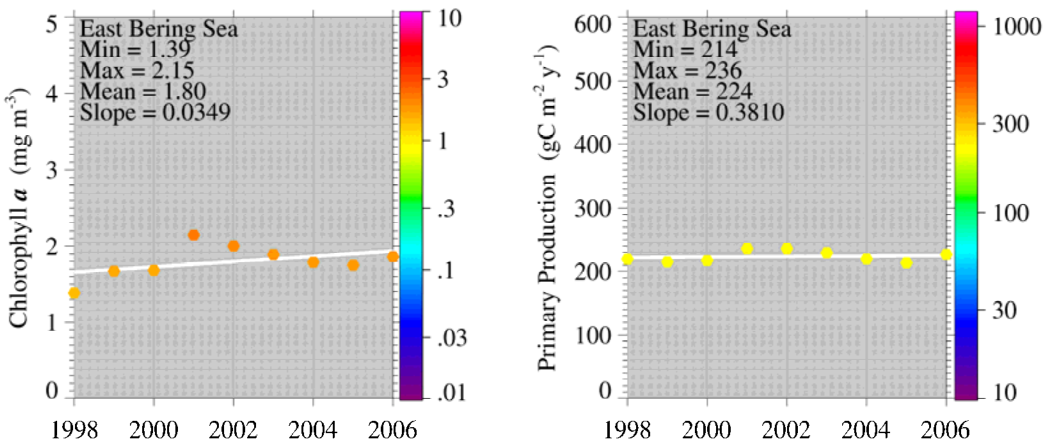

Figure XIV-45.3. East Bering Sea LME trends in chlorophyll-*a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

The LME's thousands of miles of coastline support populations of five species of salmon (pink, sockeye, chum, Coho and Chinook). The high abundance of salmon is due to a number of factors including favourable ocean conditions that promote high survival rates of juveniles, hatchery production, and reduction of bycatch (EPA 2004). Sockeye salmon (in Bristol Bay, Alaska Peninsula and Aleutian Islands) is the most valuable of the salmon species but has had recent declines, along with chum salmon. In some years, significant numbers of chum salmon are caught as bycatch in fisheries that target pollock and other groundfish. Despite relatively stable Chinook stocks there is concern over abundance trends. A quota under the provisions of the Pacific Salmon Treaty regulates the Chinook salmon harvest in this LME. Coho salmon is the most popular recreational species. Salmon bycatch in US groundfish fisheries continues to be a problem in fisheries management (NMFS 2009). Groundfish (Pacific halibut, Walleye pollock, Pacific cod, flatfish, sablefish, and Atka mackerel) are the most abundant fisheries resource off the East Bering Sea LME. The dominant species harvested are pollock and cod. Catch quotas have been capped at 2 million tons for groundfish in the fishery management plan for the East Bering Sea and Aleutian Islands. Reported annual landings of Alaska pollock (*Theragra chalcogramma*), the largest catch of any species harvested in the US EEZ, now range between 1.0 and 1.5 million tonnes, a level thought to be sustainable. Pollock has fluctuated in the past decades as a result of variable year classes. Other commercially valuable species include herring, rockfish, skate, Greenland turbot, sole, plaice and crab. The centers of abundance for pelagic herring are in northern Bristol Bay and Norton Sound (EPA 2004). This fishery occurs within state waters and is managed by the Alaska Department of Fish and Game. From catch records it is clear that herring biomass fluctuates widely due to the influence of strong and weak year-classes. Species such as herring, pollock and Pacific cod show interannual variability in recruitment that might be related to climate variability (EPA 2004). Herring biomass fluctuates widely due to strong and weak year classes. Years of strong onshore transport, typical of warm years in the East Bering Sea, correspond with strong recruitment of Pollock (NMFS 2009). Annual summaries of pollock catches and other groundfish, flatfish and invertebrates in the Eastern Bering Sea from 1954 to 1998 are presented in Schumacher *et al*. (2003).

Major shellfish fisheries in the LME are king and snow crab. King and Tanner crab fisheries are managed by the state of Alaska with advice from federal fisheries. Crab resources are fully utilized. Catches are restricted by quotas, seasons, size and sex limits. Shrimp are also managed by the state of Alaska. For biomass trends of crab species from 1979 to 1993, and for finfish fishery exploitation rates compared with crab recruitment in this LME, see Livingston *et al*. (1999). Nearshore fishery resources are those coastal and estuarine species found in the 0-3 nautical mile zone of coastal state waters. Pollock is targeted in the 'Donut Hole' that exists in the high seas area outside of the U.S. and Russian EEZs.

Historical catches in this area were very high and unsustainable. Since 1999, however, there has been evidence of increased abundance of Alaska pollock in the Donut Hole, coincident with the reduction of annual sea-ice cover (Overland *et al*. 2005). Another species that appears to be increasing in abundance in response to warming conditions in this LME is pink salmon (Overland *et al*. 2002 and 2005, Overland & Stabeno 2004), whose catches were about 100 thousand tonnes in 2003 and 2004. Patterns of production for salmon are inversely related to those in the California Current LME.

Total reported landings experienced a historic high of over 2.5 million tonnes between 1995 and 1990 (Figure XIV-45.4), with Alaska pollock dominating. In that period, the ex-vessel value of the catches from the East Bering Sea LME was US$2.5 billion (Figure XIV-45.5). The value of the salmon catch has declined due to a number of complex worldwide factors (see IV. Socioeconomic Conditions).

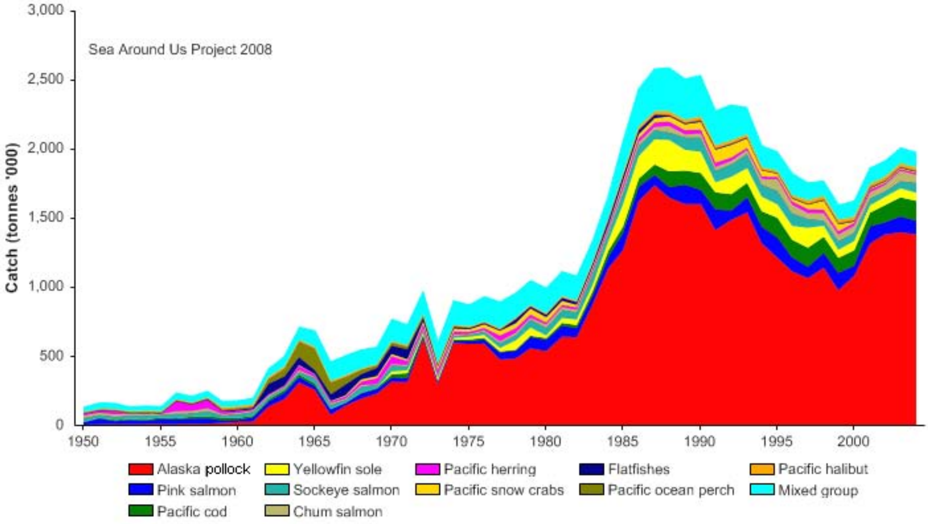

Figure XIV-45.4. Total reported landings in the East Bering Sea LME by species (Sea Around Us 2007).

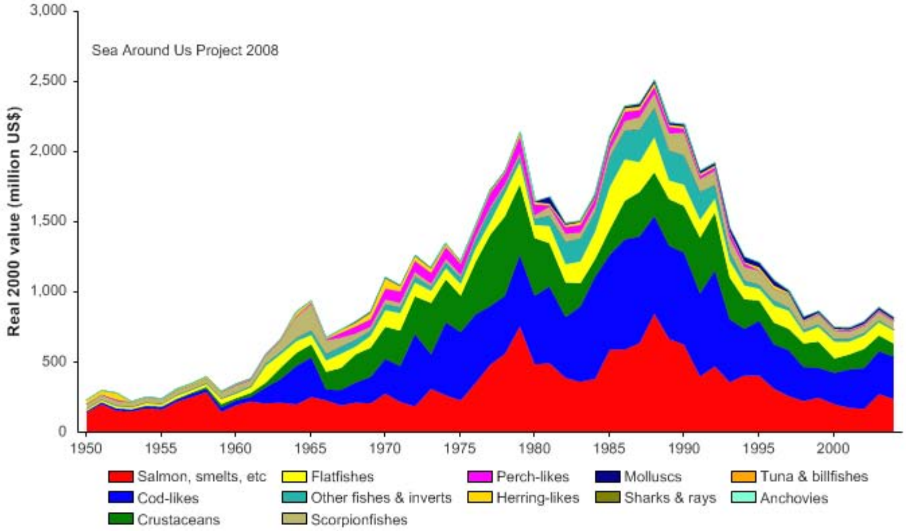

Figure XIV-45.5 Value of reported landings in the Eastern Bering Sea LME by commercial groups (Sea Around Us 2007)

The primary production required (PPR) (Pauly & Christensen 1995) to sustain the reported landings in this LME exceeded 45% of observed primary production in the late 1980s, and has remained around 40% in recent years (Figure XIV-45.6). The USA has the largest share of the ecological footprint in this LME. The mean trophic level of the reported landings (i.e., the MTI, Pauly & Watson 2005) declined from the 1950s to the early 1970s, but has since leveled off at around 3.5 due to the high catch of Alaska pollock. (Figure XIV-45.7, top). The geographic expansion which led to this dominance of Alaska pollock is represented by the increase of the FiB index from the mid 1970s to the mid-1980s (Figure XIV-45.7 bottom). The system appears sustainable according to these two indices, although it must be stressed that such an interpretation is based on the overwhelming effect of a single species.

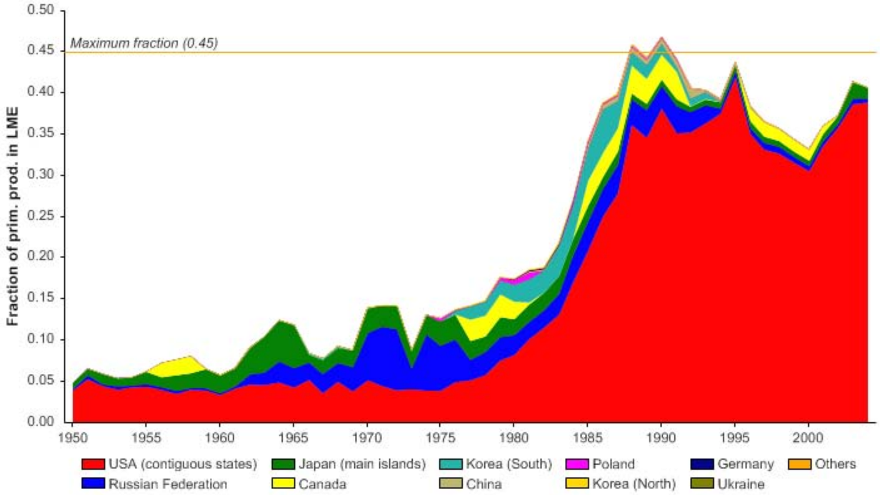

Figure XIV-45.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the East Bering LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

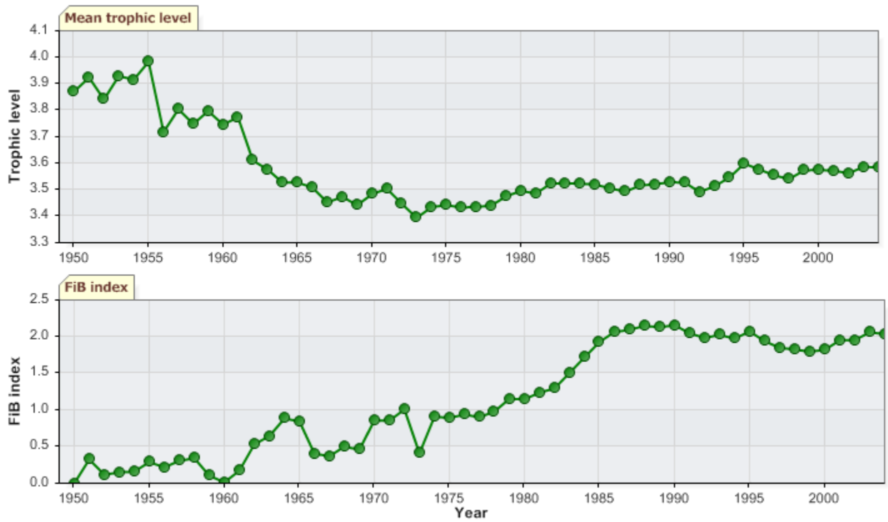

Figure XIV-45.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the East Bering Sea LME (Sea Around Us 2007)

The Stock-Catch Status Plots indicate that over 70% of the commercially exploited stocks are now generating catches of 10% less than the historic maximum, corresponding to the 'collapsed' status in Figure XIV-45.8 (top). This is in line with the findings of Armstrong *et al.* (1998), who reported, for an area immediately adjacent to the one considered here, on serial depletion of the (frequently small) stocks of commercial invertebrates. However, the overwhelming bulk of the reported landings for this LME is supplied by fully exploited stocks of Alaska pollock (Figure XIV-45.8, bottom). The US National Marine Fisheries Service (NMFS) includes "overfished" but not "collapsed" in its stock status categories. All five species of Alaska salmon are fully utilized, and stocks in the LME have rebuilt to near or beyond previous high levels. There is concern for some salmon stocks (especially Chinook and chum salmon) along the East Bering Sea LME, due to overfishing, incidental take of salmon as bycatch in other fisheries, and loss of freshwater spawning and rearing habitats. There is however growing evidence of population increases of pink salmon in Norton Sound and Kotzebue Sound, due perhaps to climatic changes. The halibut fishery is not subject to overfishing. A Pacific halibut cap constrains these fisheries. The Walleye Pollock stock in the LME is considered fully utilized and is well managed for bycatch and other issues which include minimizing impacts on Steller sea lion populations. Flatfish species are underutilized. The sablefish stock is fully utilized and is harvested under an IFQ system. Skates and squids are underutilized. Alaska crab resources are fully utilized (NMFS 2009). The difference between the two panels of Figure XIV-45.8 is the greatest of all LMEs included in this volume. It illustrates the contrast between the effect of prudent management in a few abundant stocks (bottom), combined with serial depletion of what might be seen as minor stocks (top).

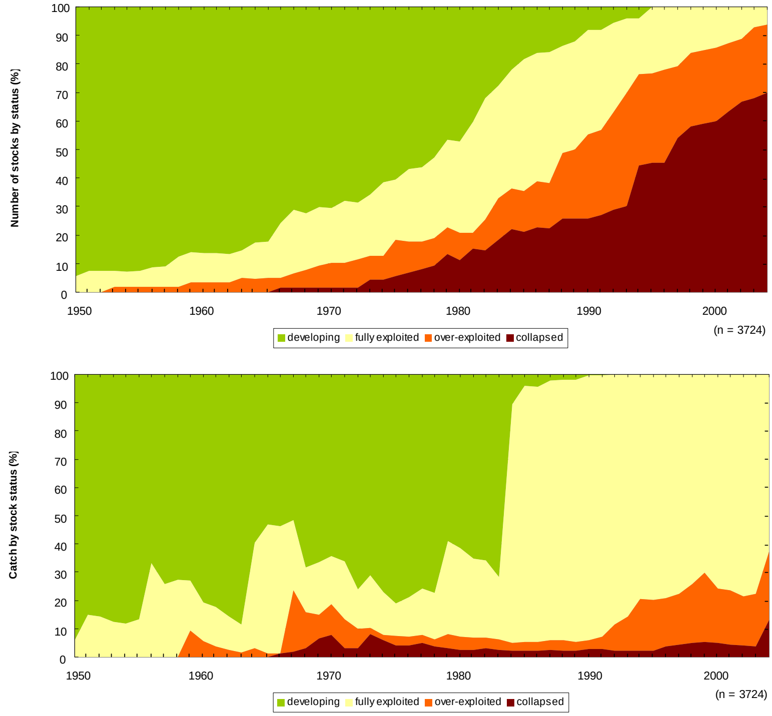

Figure XIV-45.8. Stock-Catch Status Plots for the East Bering Sea LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of 'stocks', i.e., individual landings time series, only include taxonomic entities at species, genus or family level, i.e., higher and pooled groups have been excluded (see Pauly *et al*, this vol. for definitions).

The management regime annually updates fishing quotas based on biomass estimates, including those for Alaska pollock. Because of the Steller sea lion interaction with pollock, research is underway to study the dynamics and distribution of Steller sea lion prey and predators, and to evaluate the connection with commercial fishing (www.etl.noaa.gov/). An ecosystem approach is being implemented for the assessment and management of fisheries biomass yields in the East Bering Sea LME. The basic ecosystem consideration is a precautionary approach. All groundfish stocks are considered healthy, providing sustained yields of approximately 2 mmt annually. Actions are taken by the North Pacific Fisheries Management Council to annually cap a total groundfish TAC based on NOAA-Fisheries survey operations (Witherell et al. 2000).

III. Pollution and Ecosystem Health

The coastal resources in this LME are generally in pristine condition. Coastal habitats are favourable to, for instance, the high abundance of salmon and with minimal impact from extensive development. Salmon being anadromous depend on freshwater streams, rivers and lakes. Their health is directly influenced by land management practices. The conservation of the region's salmon resource requires the conservation of the thousands of miles of riparian habitat that support salmon production. Competing uses for this habitat include logging, mining, oil and gas development, and industrial and urban development. Contaminant levels are consistently below the EPA's level of concern (EPA 2001 and 2004). Hypotheses concerned with the growing impacts of pollution, overexploitation and environmental changes on sustained biomass yields are under investigation. Concerns for the health of this LME focus on petroleum hydrocarbons found in the tissue of marine mammals, and the effects of the growing industrialisation of the region. Population levels of marine mammals in the coastal areas are low compared to other shallow seas. For statistics concerning the harbour seal, Beluga whale and harbor porpoise, see NOAA (1999, p. 231). Current regulations restrict the Aleutian Islands pollock quota due to concerns over food competition with Steller sea lions in this area, which contains critical habitat for the species. Marine mammal interactions with fish and fisheries are a major concern in fishery resource management in this LME. Fisheries compete for prey items that marine mammals and seabirds depend on for food and are a major factor in the decline of sea lion populations. The Steller sea lion is listed as threatened under the Endangered Species Act.

The East Bering Sea LME has low levels of toxic contaminants, but these have been rising over the last 50 years due to increased human activities (mining, fishing and oil exploration). This increase is linked to the long-range transport of contaminants through the ocean and atmosphere from other regions. Cold region ecosystems such as the East Bering Sea LME are more sensitive to the threat of contaminants than warmer regions because the loss and breakdown of these contaminants are delayed at low temperatures. Also, animals high in the food web with relatively large amounts of fat tend to accumulate organic contaminants such as pesticides and PCBs (EEA 2004). This causes concerns for human health in the region, particularly for Alaska natives, including the Aleut community, who rely on marine mammals and seabirds as food sources. The EPA and Indian Health Service contribute $20 million annually for water and sanitation projects now underway in rural Alaska so that 85% of all Alaska households will have access to safe water and basic sanitation (www.dced.state.ak.us.AEIS).

IV. Socioeconomic Conditions

The Alaskan coast east of the LME has a low population relative to its size and is distant from major urban or industrial areas. More than 65,000 Native Americans live on the shores of the East Bering Sea LME, with a long tradition of relying on salmon and other marine resources for economic, cultural and subsistence purposes. Pacific salmon plays an important and pivotal role, along with mining, timber, and furs, keystone natural resources that led to the settling and development of the US's 49th state by non-native peoples. Many Alaskans still depend heavily on salmon for recreation, food, and industry. Recent declines in chum and sockeye salmon runs have added to the hardships experienced by fishermen in Bristol Bay. The value of the salmon catch has declined over the past decade, along with a rising trend in total worldwide salmon production with the rapid growth of farmed salmon especially in Norway, Chile and the United Kingdom. Nearshore fishery resources provide important subsistence and recreational fishing opportunities for Alaskans of the East Bering Sea LME. Subsistence fishing is distributed all along the coastline of the LME. The East Bering Sea herring fishery began in the late 1920s, with a small salt-cure plant in Dutch Harbor in the Aleutian Islands. Commercial harvesting and processing, along with rapidly growing tourism and sport fishing, provide the region with big employment opportunities (NMFS 2009). According to statistics from the State of Alaska Department of Labor and Workforce Development in 2005, nearly 80% of the private sector population was engaged in fish harvesting or seafood processing in the Aleutian Islands. In the Bristol Bay Region, 75%, of which 40% were non-residents, were employed in the regional seafood industry (harvesting or processing). In the Yukon Delta Region, about 28%.were engaged in fish harvesting or seafood processing. Recreational fishing continues to grow due to an increase in guided fishing trips for visitors and tourists.

The East Bering Sea is home to a valuable offshore fishing industry. The interests of US factory trawlers differ markedly from those of small fisheries. Much of the groundfish catches are exported, particularly to Asia. This trade is a major source of revenue for US fishermen. For an article on the political economy of the walleye pollock fishery, see Criddle & Mackinko (2000). There are increasing demands from extractive industries to log and drill for oil and gas development. Climate change is having and is expected to have a profound influence on the socioeconomics of natural resources, goods and services of the East Bering Sea LME. The U.S. National Science Foundation supports studies of the physical, chemical and biological processes and human impacts to be expected by the reduction of sea ice in the East Bering Sea (BEST 2003).

V. Governance

The East Bering Sea LME is bordered by the USA (State of Alaska). The Alaska Board of Fisheries deals with the allocation of fish resources and quotas among various fisheries. The North Pacific Fishery Management Council (NPFMC) has primary responsibility for groundfish management within the US Exclusive Economic Zone (3 to 200 nautical miles) off the coasts of the East Bering Sea and Aleutian Islands, with the goal of maintaining stable yields by regulating harvest allocations among species. It is addressing the issue of salmon bycatch through time-area closures and bycatch limits set for different gear types in groundfish fisheries. The Alaska native populations benefit from individual fishing quotas or IFQs. There are also community development quotas (CDQs). Pelagic and salmon fisheries occurring within 3 miles are managed by the Alaska Department of Fish and Game. Improved management of the salmon fishery by state and federal agencies has contributed to the high abundance of Pacific salmon. High seas drift net fisheries by foreign nations for salmon has been eliminated through UN Resolution 46/215. The management of high seas salmon is under the North Pacific Anadromous Fish Commission. Initial signatories of the Commission are Canada, Japan, Russian Federation, Korea, and the United States. The Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean has eliminated a former high seas salmon fishery by Japan. An area involving salmon and negotiations with Canada concerns the stocks and fisheries of the 2,000 mile long Yukon River system. The agreement sets harvest quotas for Chinook and chum salmon stocks. The Magnuson-Stevens Fishery Conservation and Management Act extended federal fisheries management jurisdiction to 200 nautical miles and stimulated the growth of a domestic Alaskan groundfish fishery that rapidly replaced foreign fisheries. The former unregulated pollock fishery in the “Donut Hole” now comes under the Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea. The Convention has been signed by the Russian Federation, Japan, Poland, China, Korea, and the United States. A moratorium on pollock fishing was voluntarily imposed in 1993 (NMFS 2009). The Bureau of Indian Affairs has responsibility to protect and improve trust assets of Alaska natives. Alaska has a Department of Environmental Conservation (ADEC) responsible for assessing and controlling potential environmental degradation.

.

References

Armstrong, J., D. Armstrong and R. Hilborn 1998. Crustacean resources are vulnerable to serial depletion – the multifaceted decline of crab and shrimp fisheries in the Greater Gulf of Alaska. Reviews in Fish Biology and Fisheries. 8(2): 117-176.

Belkin, I.M. (2009) Rapid warming of Large Marine Ecosystems, Progress in Oceanography, in press.

Belkin, I.M. and Cornillon, P.C. (2005). Bering Sea thermal fronts from Pathfinder Data: Seasonal and interannual variability. Pacific Oceanography 3(1):6-20.

Belkin, I.M., Cornillon, P.C., and Sherman, K. (2009). Fronts in Large Marine Ecosystems. Progress in Oceanography, in press.

Belkin, I.M., P.C. Cornillon, and D. Ullman (2003). Ocean fronts around Alaska from satellite SST data, Proceedings of the Amer. Met. Soc. 7th Conf. on the Polar Meteorology and Oceanography, Hyannis, MA, Paper 12.7, 15 pp.

BEST (2003). Workshop agenda, 2003. Bering Sea Ecosystem Study. www.arcus.org/Bering /agenda.html

Carleton Ray, G. and Hayden. B.P. (1993). Marine biogeographic provinces of the Bering, Chukchi and Beaufort seas, p 175-184 in: Sherman, K., Alexander, L.M. and Gold, B.D. (eds), Large Marine Ecosystems: Stress, Mitigation and Sustainability. AAAS, Washington D.C., U.S.

Criddle, K.R. and Mackinko, S. (2000). Political economy and profit maximization in the Eastern Bering Sea fishery for walleye pollock. IIFET 2000 Proceedings. www.orst.edu/dept/IIFET/2000/papers/criddle.pdf

EEA (2004). Arctic environment European perspectives. Environmental Issue Report 38/2003. http://reports.eea.eu.int/environmental_issue_report_2004_38/en

EPA (2001). National Coastal Condition Report. EPA-620/R-01-005. Office of Research and Development/Office of Water, Washington D.C., U.S.

EPA (2004). National Coastal Condition Report 2. EPA-620/R-03-002. Office of Research and Development/Office of Water. Washington D.C., U.S.

ETL (NOAA, Earth System Research Laboratory , Marine Ecological Studies and Physical Sciences Division) at www.etl.noaa.gov/programs/marine/

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

Incze, L. and Schumacher, J.D. (1986). Variability of the environment and selected fisheries resources of the Eastern Bering Sea Ecosystem, in: Sherman, K. and Alexander, L.M. (eds), Variability and Management of Large Marine Ecosystems. AAAS Selected Symposium 99. Westview Press, Boulder, U.S.

Livingston, P.A., Low, L.L. and Marasco, R.J. (1999). Eastern Bering Sea Ecosystem trends, p 140-162 in: Sherman, K. and Tang, Q. (eds), Large Marine Ecosystems of the Pacific Rim: Assessment, Sustainability and Management. Blackwell Science, Malden, U.S.

Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis (1997) A Pacific decadal climate oscillation with impacts on salmon, Bulletin of the American Meteorological Society, 78(6), 1069-1079.

Niebauer, H.J., Bond, N.A. Yakunin, L.P. and Plotnikov V.V. (1999) An update on the climatology and sea ice of the Bering Sea, in *Dynamics of the Bering Sea,* edited by T.R. Loughlin and K. Ohtani, pp. 29–59, Alaska Sea Grant College Program, AK-SG-99-03, University of Alaska Fairbanks.

NMFS (2009). Our living oceans. Draft report on the status of U.S. living marine resources, 6th edition. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-80. 353 p.

NOAA (1999). Our living oceans. Report on the status of U.S. living marine resources. US Department of Commerce, Washington D.C., U.S.

Overland, J.E. and Stabeno, P.J. (2004). Is the climate of the Bering Sea warming and affecting the ecosystem? Transactions of the American Geophysical Union 85:309-310, 312.

Overland, J.E., Boldt, J. and Stabeno, P.J. (2005). Multiple indicators track major ecosystem shifts in the Bering Sea. ICES CM 2005/M:21.

Overland, J.E., Wang, M. and Bond, N.A. (2002). Recent temperature changes in the western Arctic during spring. Journal of Climate 15:1702-1716.

Pauly, D. and Christensen, V. (1995). Primary production required to sustain global fisheries. Nature 374: 255-257.

Pauly, D. and Watson, R. (2005). Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity. Philosophical Transactions of the Royal Society: Biological Sciences 360: 415-423.

PICES (2005). Fisheries and Ecosystem Response to Recent Regime Shifts. Report of the Study Group. North Pacific Marine Science Organisation. www.pices.int/publications/scientific_reports/Report28/Rep_28_default.aspx

Schumacher, J.D., Bond, N.A., Brodeur, R.D., Livington, P.A., Napp, J.M. and Stabeno, P.J. (2003). Climate change in the Southeastern Bering Sea and some consequences for its biota, p 17-40 in: Hempel, G. and Sherman, K. (eds), Large Marine Ecosystems of the World: Trends in Exploitation, Protection and Research. Elsevier Science, Amsterdam, The Netherlands.

Sea Around Us (2007). A Global Database on Marine Fisheries and Ecosystems. Fisheries Centre, University British Columbia, Vancouver, Canada. www.seaaroundus.org/lme/SummaryInfo.aspx?LME=1

Stabeno, P.J., Bond, N.A, Kachel, N.B., Salo, S.A. and Schumacher, J.D. (2001) On the temporal variability of the physical environment over the south-eastern Bering Sea, *Fisheries Oceanography,* **10**(1), 81–98.

Stabeno, P.J., N.A. Bond, S.A. Salo (2007) On the recent warming of the southeastern Bering Sea Shelf, *Progress in Oceanography*, accepted.

State of Alaska Department of Labor and Workforce Development at www.labor.state.ak.us/research/trends/nov07reg.pdf

Witherell, D., Pautzke, C. and Fluharty, D. (2000) An ecosystem-based approach for Alaska groundfish fisheries. ICES Journal of Marine Science 57:771-777.