XIV-46 Gulf of Alaska: LME #2

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The Gulf of Alaska LME lies off the southern coast of Alaska and the western coast of Canada. It is separated from the East Bering Sea LME by the Alaska Peninsula. The cold Subarctic Current, as it bifurcates towards the south, serves as the boundary between the Gulf of Alaska and the California Current LME. For a description of the Gulf of Alaska's major currents, see www.pmel.noaa.gov/np/. The LME has a sub-Arctic climate and is subject to interannual and interdecadal climate variations (Brodeur *et al*. 1999). The area of this LME is about 1.5 million km², of which 1.50% is protected, and includes 0.52% of the world's sea mounts (as defined in Sea Around Us 2007 and Kitchingman et al. 2007). There are 14 estuaries and river systems, including the Stikine River, Copper River, and Chatham Sound (Skeena River). A book chapter pertaining to this LME is by Brodeur *et al*. (1999).

I. Productivity

The Gulf of Alaska LME is considered a Class II, moderately productive ecosystem (150-300 $gCm^{-2}yr^{-1}$). The LME's cold, nutrient-rich waters support a biologically diverse ecosystem. Large-scale atmospheric and oceanographic conditions affect the productivity of this LME. Changes in zooplankton biomass have been observed in both the Gulf of Alaska LME and the adjacent California Current LME. These biomass changes appear to be inversely related to each other (Brodeur *et al*. 1999). A well-documented climatic regime shift occurring in the late 1970s caused the Alaska gyre to be centred more to the east (Lagerloef 1995, Anderson & Piatt 1999). Brodeur and his co-authors suggested a possibility of increases in the future production of salmon as a consequence of long-term oceanographic shifts resulting in increases in plankton biomass in the last decade. More information is available on climate variability and its effect on the abundance and production of marine organisms in this LME (Hollowed *et al*. 1998). For more information on the production dynamics of Alaska salmon in relation to oscillating periods of 'warm' and 'cool' regimes, see Francis (1993), Francis & Hare (1994), and Hare & Francis (1995).

Oceanic Fronts (Belkin et al. 2009): The Polar Front (PF) exists year-round in the western part of the Gulf (Belkin *et al*. 2002) (Figure XIV-46.1). This front is associated with the Subarctic Current that crosses the North Pacific from Hokkaido to the Gulf of Alaska where it retroflects and flows along the Aleutian Island Chain, branching first into the Eastern Bering Sea, then into the Western Bering Sea. Several fronts develop in summer over the Alaskan Shelf (Belkin & Cornillon 2003, Belkin *et al*. 2003). The conspicuous Kodiak Front (KF) is observed east and south of Kodiak Island, where its quasi-stable location is controlled by local topography. The Inner Passage Front (IPF) is located in a strait between the Queen Charlotte Islands and the British Columbia coast.

Gulf of Alaska LME SST (Belkin 2009)(Figure XIV-46.2)
Linear SST trend since 1957: 0.38°C.
Linear SST trend since 1982: 0.37°C.

Temporal SST variability in the Gulf of Alaska (GOA) LME is strong (Figure XIV-46.2). In 1957-2006, three successive regimes were: (1) rapid cooling by nearly 2°C from the sharp peak of 1958 until 1971; (2) a cold spell in 1971-1976; (3) a warm epoch, from 1977 to the present. These epochs are best defined in the central GOA and off the Queen Charlotte Islands (Mendelssohn et al., 2003, and Bograd et al., 2005). The

transition from the cold spell to the present warm epoch occurred during the North Pacific regime shift of 1976-77 (see East Bering Sea LME). In general, the SST history of the GOA is very similar to the East Bering Sea (EBS). In particular, SST swings in 1996-2006 were synchronic, from the absolute maximum in 1997 to a 1.4°C drop in 1999, to a maximum in 2003-2005, followed by a drop in 2006. The observed synchronicity between the GOA and EBS is suggestive of large-scale forcing that spans the eastern North Pacific.

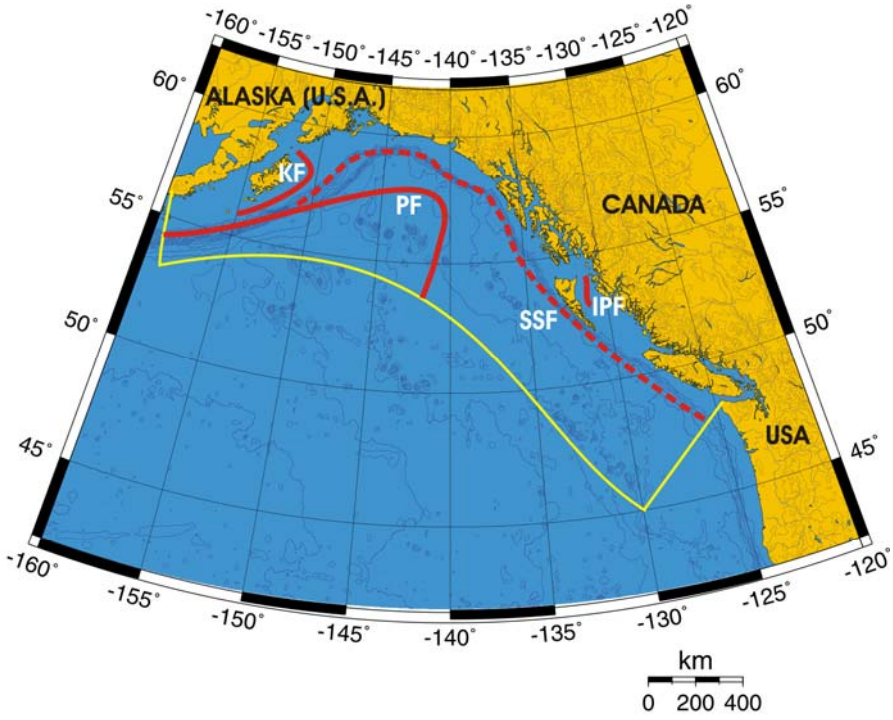

Figure XIV-46.1. Fronts of the Gulf of Alaska LME. IPF, Inner Passage Front; KF, Kodiak Front; PF, Polar Front; SSF, Shelf-Slope (most probable location). Yellow line, LME boundary. After Belkin et al. (2009).

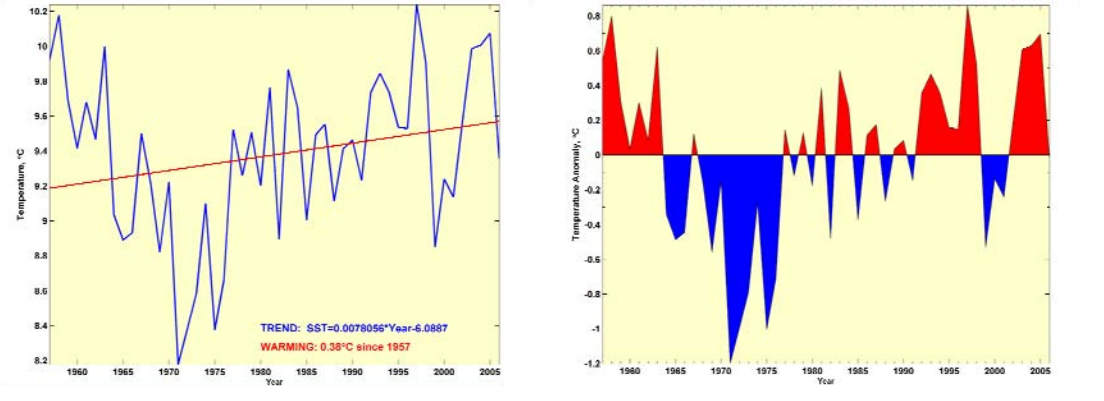

Figure XIV-46.2. Gulf of Alaska LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

Gulf of Alaska LME Chlorophyll and Primary Productivity: The Gulf of Alaska LME is a Class II, moderately productive ecosystem (150-300 $gCm^{-2}yr^{-1}$)(Figure XIV-46.3).

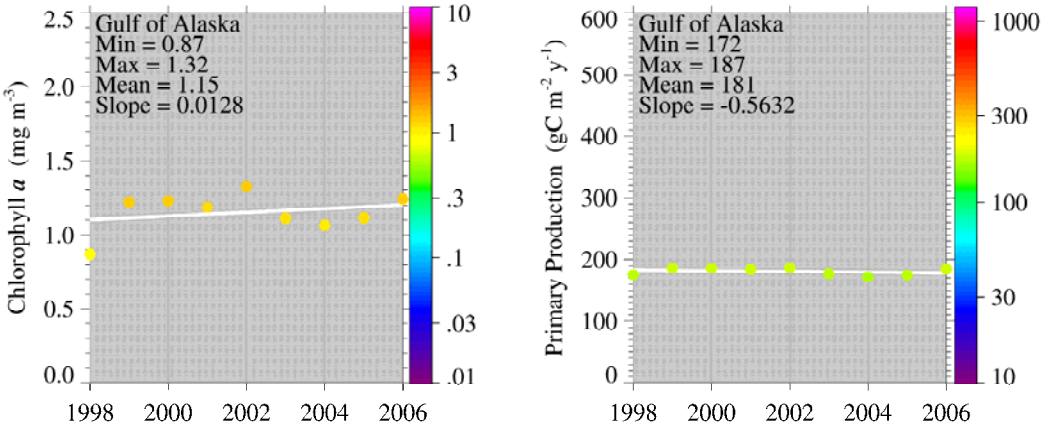

Figure XIV-46.3. Trends in Gulf of Alaska LME chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

This LME supports a number of commercially important fisheries for crab, shrimp, scallops, walleye pollock, Pacific cod, rockfishes, sockeye salmon, pink salmon and halibut. For information on salmon, pelagic, groundfish, shellfish and nearshore fisheries in Alaska, see NMFS (1999). The largest fisheries for sockeye salmon, the salmon species of highest commercial value in the US portion of the LME, occur in Cook Inlet, Kodiak Island, and Prince William Sound. Chum salmon hatcheries produce a significant portion of the catch. A quota, under the provisions of the Pacific Salmon Treaty between Canada and the US, regulates the Chinook salmon harvest in this LME. Pacific herring is the major pelagic species harvested in the LME. In Alaska, spawning fish concentrate in Prince William Sound and around the Kodiak Island-Cook Inlet area (EPA 2004). The groundfish complex (walleye pollock, Pacific cod, flatfish, sablefish, rockfish, and Atka mackerel) is an abundant fisheries resource in the Gulf of Alaska LME but less so than in the neighboring East Bering Sea LME. The extreme variation in pollock abundance is primarily the result of environmental forcing. For information on abundance of larval pollock, see Duffy-Anderson et al., 2002. Pollock are carefully managed due to concerns about the impact of fisheries on endangered Steller sea lions for which pollock is a major prey. Sea lion protection measures include closed areas and determinations of the acceptable biological catch. The western part of the Gulf (Kodiak Island and along the Alaska Peninsula) is a major area of operation for the shrimp fishery. Shrimp landings rose and are now declining. King crab catches peaked in the mid 1960s. Almost all Gulf of Alaska king crab fisheries have been closed since 1983. Dungeness crabs are harvested in the Yakutat and Kodial areas of the Gulf of Alaska. Most nearshore fisheries take place in the Gulf of Alaska LME near population centers (NMFS 2009). Current information regarding US fisheries in the GOA is available from the NMFS Alaska Region (www.fakr.noaa.gov), the Alaska Fisheries Science Center (www.afsc.noaa.gov), and the Alaska Department of Fish and Game (www.cf.adfg.state.ak.us). Current information regarding Canadian fisheries is available from Fisheries and Oceans, Canada, Pacific Region (www.pac.dfo-mpo.gc.ca).

The total of reported landings in this LME is in the order of 600 to 700 thousand tonnes, with a peak of 800 thousand tonnes in 1993 (Figure XIV-46.4). The value of the reported landings peaked in 1988 at nearly US$1.2 billion (calculated in 2000 US dollars) but has since declined to about US$500 million in 2004 (Figure XIV-46.5).

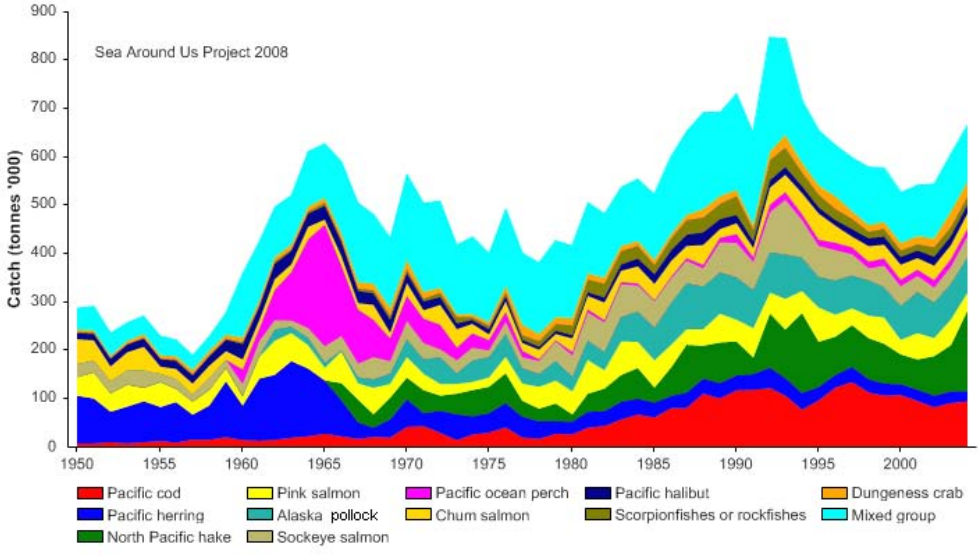

Figure XIV-46.4. Total reported landings in the Gulf of Alaska Sea LME by species (Sea Around Us 2007)

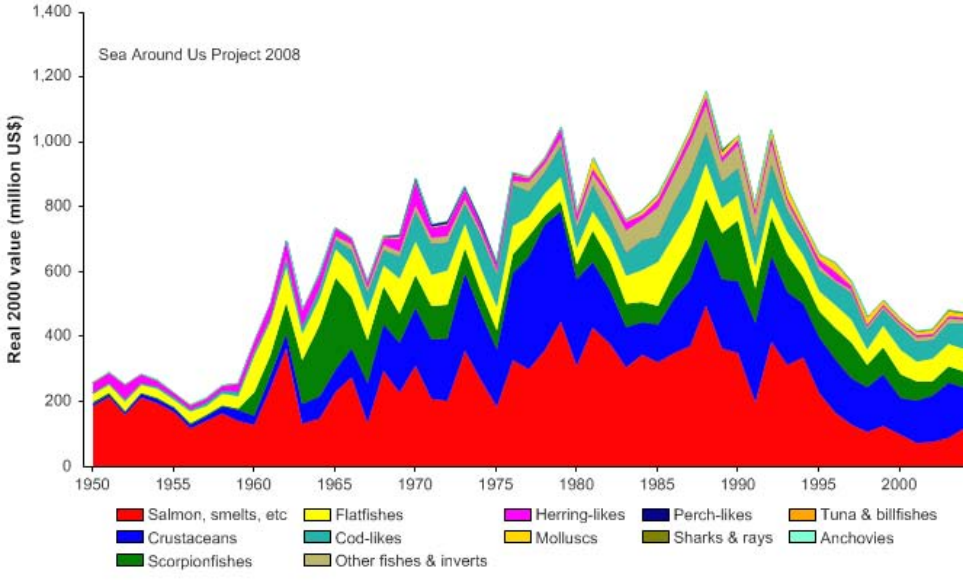

Figure XIV-46.5. Value of reported landings in the Gulf of Alaska LME by commercial groups (Sea Around Us 2007)

The primary production required (PPR) (Pauly & Christensen 1995) to sustain the reported landings in this LME reached over 25% of the observed primary production in

the late 1980s, but leveled off at around 20% in recent years (Figure XIV-46.6). The USA and Canada now account for all landings (i.e. ecological footprint) in this LME.

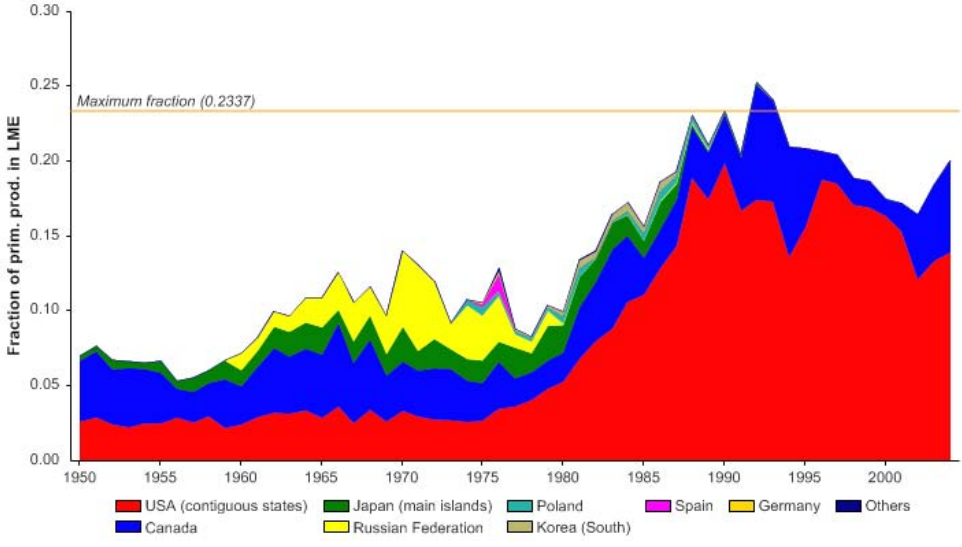

Figure XIV-46.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Gulf of Alaska LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of the fisheries landings (MTI) (Pauly & Watson 2005) is rather high, especially in recent years (Figure XIV-46.7 top), while the increase in the Fishing-in-Balance index in the early 1980s reflects the increased landings reported during that period (Figure XIV-46.7 bottom).

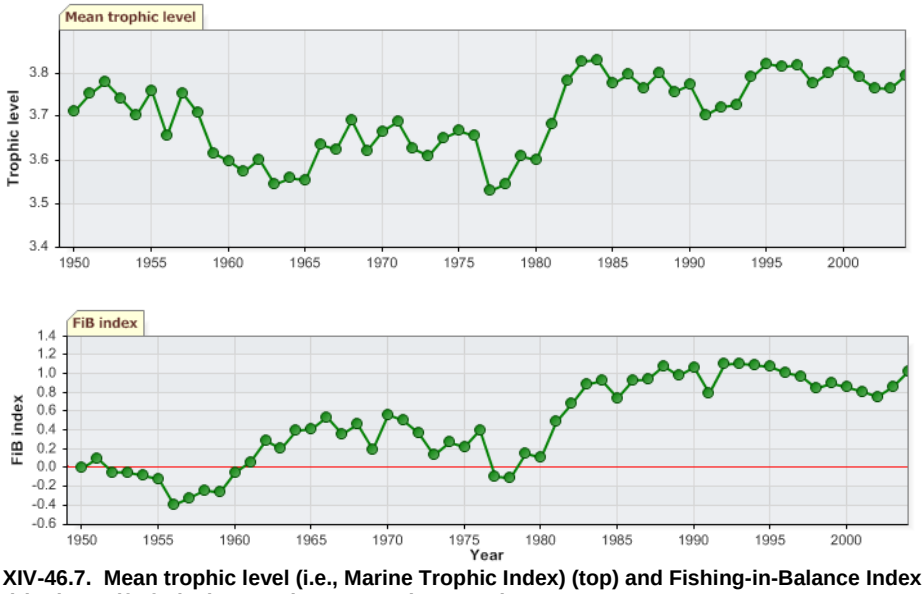

Figure XIV-46.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Gulf of Alaska LME (Sea Around Us 2007).

The Stock-Catch Status Plots indicate that over 30% of the commercially exploited stocks are now generating catches of 10% or less than the historic maximum, corresponding to

the ‘collapsed’ status (Figure XIV-46.8, top). Another 40% are generating catches from 50 to 10%, corresponding to the ‘overexploited ’ status (see Pauly et al. this vol.). This is explained by Armstrong *et al.* (1998), who reported on the serial depletion of (frequently small) stocks of commercial invertebrates. However, 80% (in bulk) of the reported landings in the Gulf of Alaska LME are contributed by fully exploited (i.e., not overexploited) stocks. (Figure XIV-46.8, bottom), thus confirming the positive assessment also suggested by Figure XIV-46.7. The US National Marine Fisheries service (NMFS) includes “overfished” but not “collapsed” in its stock status categories. NMFS 2009 lists no overfished species. Several groundfish are presently underutilized and cannot be fully harvested without exceeding the bycatch limits for Pacific halibut. Gulf of Alaska groundfish stocks in the US are considered to be in a healthy condition as a result of ecosystem-based management actions by the North Pacific Fishery Management Council, which include public participation, reliance on scientific assessments, conservative catch quotas built around annually determined overall fisheries biomass yield catch, and total allowable catch levels for key species with the objective of long term sustainability of fisheries stocks (Witherell et al, 2000; North Pacific Management Council, 2002).

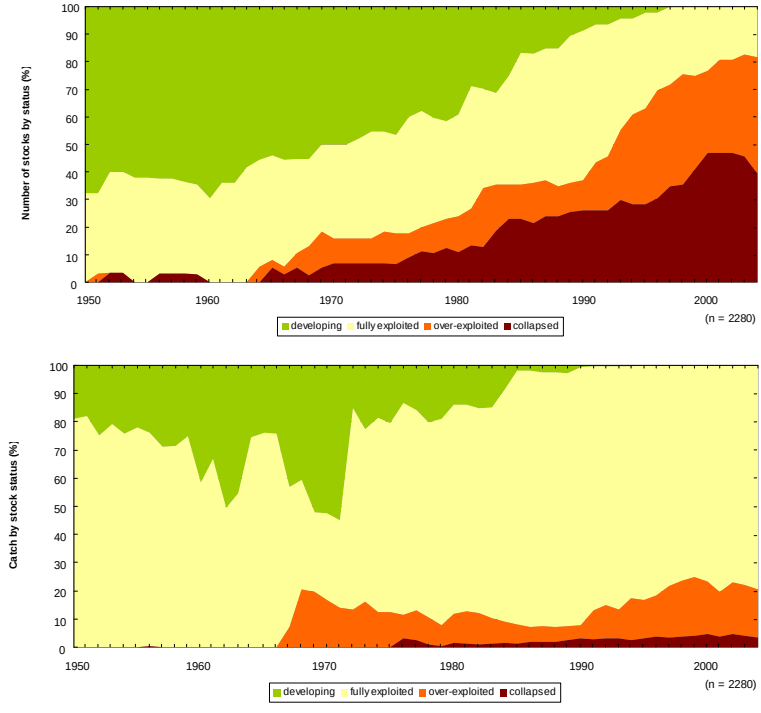

Figure XIV-46.8. Stock-Catch Status Plots for the Gulf of Alaska LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of ‘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).

III. Pollution and Ecosystem Health

Because salmon are anadromous and spend a portion of their lives in freshwater streams, rivers, and lakes, the health of salmon populations in this LME is directly influenced by land management practices in both countries and by the loss of freshwater spawning and rearing habitats. Competing uses for the salmon habitat include logging,

mining, oil and gas development, and industrial and urban development. Prince William Sound is an area of concern where large returns of hatchery pink salmon mix with lower numbers of wild fish. The Gulf of Alaska Ecosystem Monitoring and Research Program is a long-term effort to gather information about the physical and biological components of the marine ecosystem, the cooperation of agencies, public involvement and access to informative data. For pollution issues, see <www.evostc.state.ak.us/>. For information on coastal condition for all of Alaska, see EPA 2001 and 2004. A sampling survey of the ecological condition of Alaska's estuarine resources in the south-central region of the state of Alaska was completed in 2002 (EPA 2004), with data collected from 55 sites. Prince William Sound and Cook Inlet are major estuaries. The total allowable catch for pollock in the Alaska is apportioned to accommodate Steller sea lion concerns, as pollock are the major prey of Steller sea lions in the Gulf of Alaska. For information on clean water assessments in Alaska, see EPA (2004). For statistics on harbour seals and harbour porpoises in this LME, see NMFS (1999). Audubon red listed Alaskan seabirds include Steller's eider, Spectacled eider, Sooty grouse, Laysan albatross, Black-footed albatross, Short-tailed albatross, Pink-footed shearwater, Eskimo curlew, Rock sandpiper, Buff-breasted sandpiper, Ivory gull, and murrelet.

Problems affecting the LME include predation by invasive species, discharges of oil products, and industrial and agricultural contaminants that enter the LME through a variety of pathways (ocean currents, prevailing winds). Prince William Sound is routinely crossed by large oil tankers. In 1989, the *Exxon Valdez* spilled 11 million gallons of North Slope crude oil off the Port of Valdez, the terminal of the Trans-Alaskan Pipeline. This was the largest tanker oil spill in U.S. history and it contaminated over 2,000 km of the Gulf of Alaska's coastline. The livelihood of 70,000 full-time residents living in the area was directly affected by the Exxon Valdez oil spill. They had to overcome the effects of the oil-related fish mortalities. Others using the area seasonally for work or recreation were also seriously affected. There remain concerns about the lingering effects of the oil spill and the pockets of residual oil in the environment, especially in the Western portion of Prince William Sound. The effects of the oil spill interact with the effects of other kinds of changes and perturbations in the marine ecosystem. More common than spills, however, are smaller discharges of refined oil products, crude oil and hazardous substances.

IV. Socioeconomic Conditions

The LME coastal population is low relative to the length of the coastline, with the exception of the city area of Vancouver in the Canadian province of British Columbia. Native peoples have a long and rich tradition of relying on salmon for economic, cultural, and subsistence purposes. The coastal native communities rely for their subsistence largely on hunting and the harvesting of marine resources. The economy of the coastal communities is based on commercial fishing of pink and red salmon, fish processing, timber, minerals, agriculture and tourism. Pacific salmon has played a pivotal role in the history of the region. Although commercial salmon harvests are at high levels, the value of the catch has declined due to a number of world wide reasons, one of which is a rising trend in salmon farmed production in Norway, Chile, and the United Kingdom. Alaska's herring industry began in the late 19th century and expanded rapidly, with markets shifting from salt-cured herring to reduction products for fishmeal and oil (NMFS 2009). Shellfish fisheries developed in the 1960s in the Gulf of Alaska (NMFS 1999). US groundfish catches are exported to Asia and constitute a major source of revenue for US fishermen. The estuarine resources of Prince William Sound and Cook Inlet in Alaska are of major importance for the local and state economy. Conflicts have emerged between coastal and offshore interests. In addition to jobs in fishing and fish processing, people in Gulf of Alaska communities work in government, military (Kodiak U.S. Coast Guard base), logging, mining and tourism. In 1998, there was an increase of visitors to over 1 million a

year in Alaska. Colt et al. (2007) estimate summer 2005 revenue from nature-based tourism activities in Chichagof Island alone at $15.5 million.

V. Governance

The Gulf of Alaska LME is bordered by the U.S. and Canada, each with separate government actions and management plans. In 2004, Amendment #66 to the Halibut and Sablefish program became a law that allowed eligible coastal communities in Alaska to purchase halibut and sablefish quota shares. The North Pacific Fishery Management Council, in conjunction with NOAA, produces a Gulf of Alaska Groundfish Fishery Management Plan for Alaska. The Gulf of Alaska Coastal Communities Coalition has identified 42 communities within Alaska eligible to participate in a program to form a CQE (Community Quota Entity), a non-profit corporation for the purchasing of quota shares (www.goac3.org). The program helps compensate for the negative impacts of Individual Fishing Quotas (IFQs) on subsistence fishers. The transboundary management of Pacific salmon (sockeye, chum, pink, chinook, coho and steelhead salmon) is conducted under the Pacific Salmon Treaty (www.oceanlaw.net), signed in 1985 by Canada and the US. The Treaty is intended to facilitate the management of these salmon stocks by preventing overfishing and providing for optimum production and equitable sharing of the salmon catch. Catch quota levels since 1999 are subject to fluctuations of salmon abundance from year to year. Major transboundary concerns between the two countries are: Chinook salmon catches in southeastern Alaska where Canadian salmon are caught along with other non-Alaska US stocks; fisheries in the Dixon Entrance where each country catches salmon originating in the other nation; transboundary river stocks associated primarily with the Taku and Stikine Rivers; Canadian fisheries off the west coast of Vancouver Island; and Strait of Juan de Fuca fisheries for salmon bound for the Fraser River in Canada (NMFS 2009). The North Pacific Anadromous Fish Commission (NPAFC) manages the salmon harvest in the high seas. Signatories are Canada, Japan, Russian Federation, United States and Korea. The Convention prohibits high seas salmon fishing and trafficking of illegally caught salmon. United Nations Resolution 46/215 bans large scale pelagic driftnet fishing in the world's oceans. The Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean seeks to control the interception and incidental take of the LME's salmon resources. Pacific Halibut is also a target of transboundary management. The resource is managed by a bilateral treaty between the US and Canada, with recommendations coming from the International Pacific Halibut Commission. Both Canada and Alaska have moved to regulating halibut fisheries subareas through catch quotas, time-area restrictions, and by individual fishing quotas (IFQs). Under the IFQ system there has been a decline in the overall size of the fishing fleet.

In the aftermath of the Exxon Valdez oil spill, the US Congress crafted the Oil Pollution Act of 1990 (OPA 90). Under OPA 90, two Regional Citizen Advisory Councils were created, one for Prince William Sound, and one for Cook Inlet (EPA 2004). In the US, 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 the foreign fisheries. Pacific ocean perch was intensively exploited by foreign fleets in the 1960s. Inshore groundfish resources are managed by the Alaska Department of Fish and Game.

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