Appendix C

Ecosystem Considerations for 2011

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Reviewed by:
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Bering Sea, Aleutian Islands, and Gulf of Alaska

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North Pacific Fishery Management Council
605 W. 4th Avenue, Suite 306
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EBS Report Card

- **A strong la Niña** has formed on the equator as reflected in the recent **downward trend in NPI**. The prediction for the Bering Sea is **above average sea-ice extent** and duration in winter and spring 2011. This would result in a **fifth year of extensive ice** over the southern Bering Sea shelf.
- The euphausiid biomass index increased more than three fold from 2004 to 2009 and then decreased in 2010 by ca. 30%. Large copepod biomass increased 10 fold from very low values during the recent 2002-2005 warm period to 2009. This suggests that **overall food availability for planktivorous species is high**. Age-0 pollock and other planktivorous species may be dependent on the availability of sufficient prey to generate enough depot lipids to survive their first winter. Thus, **we predict that the survival of this particular year class of fishes might be better than average**.
- Current (2005-2010) mean biomass, catch, and exploitation rates of motile benthic epifauna and benthic foraging fish have been within ±one standard deviation of 1977-2010 levels. **No trend is apparent in recent years for these foraging guilds**.
- There is a **concern with two of the commercial crab stocks** in the mobile benthic epifauna guild which are overfished. However, this guild appears stable because the guild is dominated by non-target fish and invertebrate biomass.
- There are **no apparent trends in benthic forager catch and exploitation rate**. The benthic foragers guild appears stable and **may not require further management action**.
- Pelagic foragers have biomass below mean and exploitation rate above mean, but increasing trends in biomass and decreasing trends in catch and exploitation rates. The **pelagic foragers guild biomass has been at a historic low**, which has been a recent management concern. However, there are signs of recovery within the guild, as well as increased forage and positive physical conditions to support recovery. Continued caution with the management of species in this guild and continued monitoring may be necessary, **but the outlook is improved from last year**.
- The **recent increasing trend in the apex predator guild biomass** is driven largely by a decrease in Pacific cod biomass being offset by an increase in arrowtooth flounder biomass. The fish apex predators guild appears stable and **may not require additional management action**.
- Thick-billed murre reproductive success has increased during the past five years, concurrent with a colder Bering Sea, later ice retreat, and increased biomass of zooplankton on the outer shelf. Continued cold conditions in the Bering Sea will likely lead to **favorable conditions for thick-billed murres** nesting on St. George Island and a continued trend of higher reproductive success in 2011.
- Northern fur seal pup production on St Paul Island has been declining since the mid-1990s, while it has been relatively stable on St George since 2002. Estimated pup production on both Pribilof Islands in 2008 was similar to the level observed in 1916; however the population trends are different. In 1916, the northern fur seal population was increasing at approximately 8% per year following the cessation of extensive pelagic sealing, while currently (1998 through 2008), **northern fur seal pup production on both Pribilof Islands is decreasing** at approximately 6% per year.

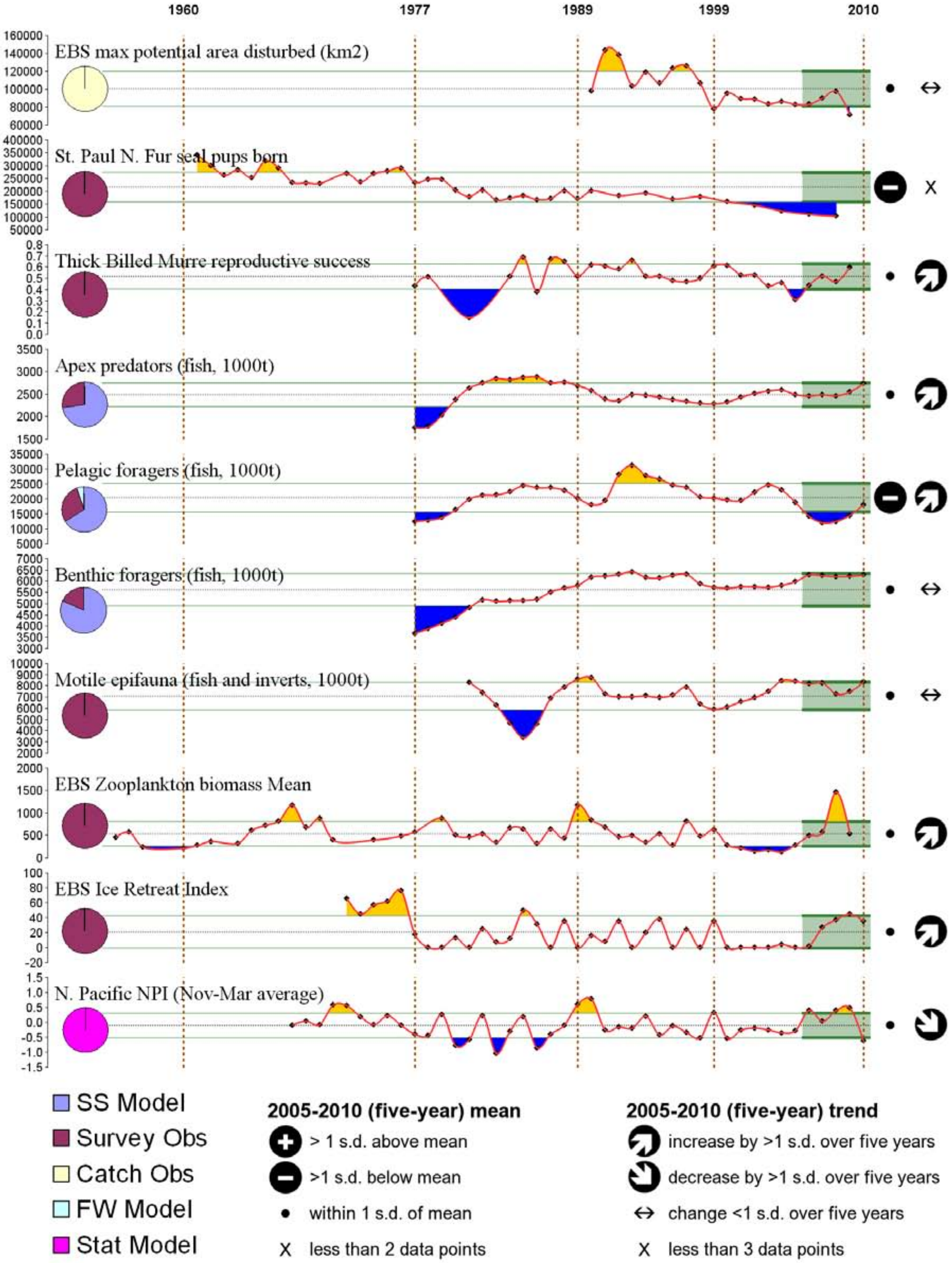

Figure 1: Eastern Bering Sea ecosystem assessment indicators; see text for descriptions.

Executive Summary of Recent Trends

Physical and Environmental Trends

- The North Pacific experienced mostly cooler than normal upper ocean temperatures in its eastern and northern portions from fall 2009 through summer 2010. These conditions can be attributed to the pre-existing state of the North Pacific and the basin-scale climate forcing during the past year (Figure 2). An El Niño occurred during the winter of 2009-10, and while the associated atmospheric circulation anomalies resembled those with past events, its effects do not appear to have persisted beyond spring 2010. La Niña began developing in the spring/summer of 2010 and is forecast to strengthen over the remainder of 2010. This should lead to a relatively weak Aleutian low, and a negative sense to the Pacific Decadal Oscillation (PDO) for the North Pacific atmosphere-ocean climate system into spring 2011 (p. 90).

Arctic

- The tendency for reduced sea ice cover in the Arctic during the summer has continued into 2010. The areal coverage in July 2010 was the second lowest in the historical record (the record low for July was in 2007) (p. 90).
- There is now very little multi-year ice in the Arctic (p. 90).

Bering Sea

- The Bering Sea shelf experienced a relatively heavy ice year in 2010. It is rare for this region to have greater than normal ice extent during El Niño years. The especially low heat content on the shelf going into the fall of 2009 is likely to have been an important contributing factor (p. 90).
- The summer of 2010 has generally been a bit stormier than usual (p. 90).
- EBS trawl survey average surface temperature (5.3°C) was higher than 2009 but still 1.2°C lower than the long-term mean (6.5°C). The average bottom temperature (1.40°C) was below the grand mean for the fifth consecutive year. The 'cold pool' extended down the middle shelf to the Alaska Peninsula and into Bristol Bay (p. 98).

Gulf of Alaska

- The poleward branch of the Alaska Current in the southeastern portion of the Gulf was considerably greater than normal in the winter of 2009-10; but the strength of this branch of the Alaska Current has since declined to about its mean over the last decade (p. 90).
- The mixed layer depths in the Gulf were relatively shallow during the winter, as might be expected with anomalously strong upward Ekman pumping. During the summer of 2010 they have been observed to be somewhat deeper than normal (p. 90).

- Eddy Kinetic Energy (EKE) was particularly low in the NGOA for 2009 indicating a reduced influence of eddies in the region. EKE levels were very low in both the NGOA and off Kodiak in 2009 and higher in the spring of 2010 (p. 99).
- Phytoplankton biomass was probably more tightly confined to the GOA shelf during 2009 due to the absence of eddies, while in 2007 and possibly 2010, phytoplankton biomass likely extended farther off the shelf (p. 99).
- Cross-shelf transport of heat, salinity and nutrients were likely to be smaller in 2009 than in 2007 and 2010 (or other years with large persistent eddies) (p. 99).

Alaska Peninsula and Aleutian Islands

- The winter of 2009-10 featured strong easterly wind anomalies, which probably promoted northward transport through Unimak Pass and enhanced the Aleutian North Slope Current (p. 90).
- The sense of the wind anomalies switched to anomalous westerly during the spring and summer of 2010 for the Alaska Peninsula and eastern Aleutian Islands. This would tend to produce suppressed upwelling on their north sides and enhanced upwelling to their south (p. 90).
- Particularly strong eddies were observed south of Amukta Pass in 2009/2010. Eddy energy in the region appeared to be returning to low levels in the spring of 2010 (p. 103).
- These trends indicate that higher than average volume, heat, salt, and nutrient fluxes to the Bering Sea through Amukta Pass may have occurred in 2009/2010 while these fluxes may have been reduced in the spring of 2010 (p. 103).
- AI trawl survey water temperatures were warmest in 1997 amd 2004, and coolest in 2000. Water temperatures in 2010 appeared to be intermediate to these extremes as evidenced by the warmer surface temperatures in the eastern and western ends of the survey area, cooler water around Seguam Island, and generally warmer than normal temperatures below 100 m west of 180°. This is the same general pattern noted during the 2006 survey (p. 104).

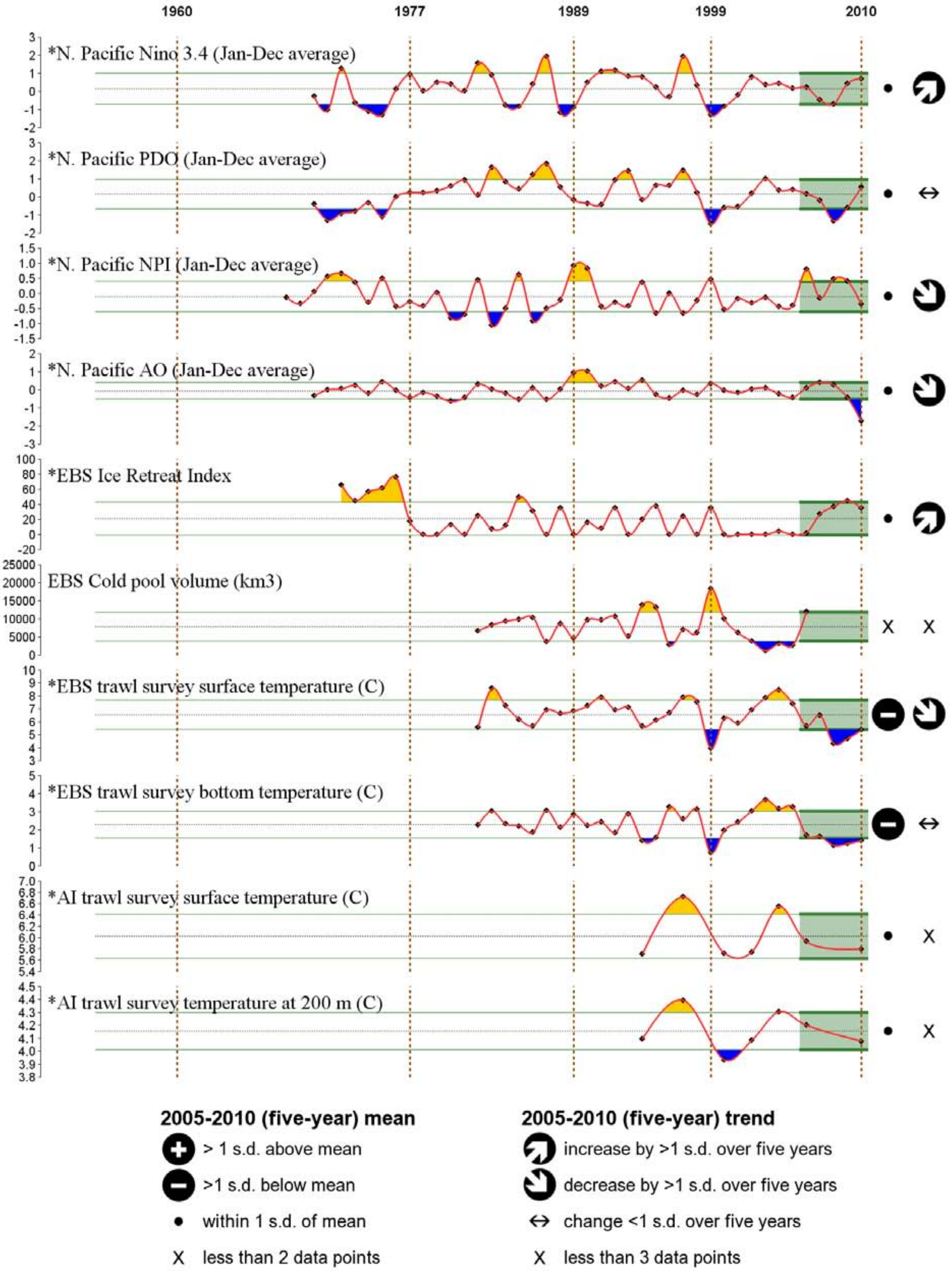

Figure 2: North Pacific and Eastern Bering Sea climate indices. *Time series updated in 2010.

Ecosystem Trends

Bering Sea

- EBS trawl survey HAPC biota showed variable trends: sea anemones may be increasing, while sponges and seapens remained similar to 2009 (p. 109).
- Zooplankton biomass has increased since 2004/2005 in all EBS domains. In warm years (2003-2005), the large copepod, *Calanus marshallae*, was in lower abundance than in cold years (2006-2008). Increases were observed first in the northern Bering Sea in 2006 and in the southern Bering Sea in 2007. When available, *C. marshallae* is an important prey item for age-0 pollock. Euphausiids also increased in abundance in the Middle Domain in cold years (2008 and 2009) compared to warm years (2004) (p. 117 and 119).
- North-south variations in large zooplankton were also observed, with more Cnidera present in the northern Bering and more polychaetes (in warm years) and *Limacina* spp. in the southern Bering Sea (p. 119).
- Average energy content of 2009 age-0 pollock suggest recruitment to age-1 may be relatively high. Recruitment may be strong so long as summer conditions remain cold. A return to warm conditions in the Bering Sea may result in reduced recruitment of pollock (p. 124). Increases in energy density of age-0 pollock during cold years may be associated with increases in *C. marshallae* and euphausiids on the eastern Bering Sea shelf (p. 119).
- Sandfish were generally in low abundance in EBS trawl surveys, and typically caught in only a few shallow stations. The relative CPUEs of sandlance and Stichaeids was higher prior to 1999. Eulachon and capelin relative CPUE changed little over the past four years. Arctic cod relative abundance was higher in cold years (1999-2000, 2006-2010) compared to warm years (1996-98, 2002-2005) because of its association with the cold pool on the middle shelf (p. 127).
- An experimental combined annual index of juvenile Naknek river sockeye salmon growth and temperature change may be a predictor of recruitment strength in pollock and cod (p. 135).
- Walleye pollock has dominated observed fluctuations in total groundfish biomass, particularly the decreased biomass in recent years. BSAI catch trends are dominated by pollock catches, which decreased during 2004-2008 and increased slightly in 2009. (p. 139).
- Several stocks experienced step-changes in survival in the late 1970s and 1980s; however, in general, there was no indication of uniform step changes in all stocks in either time period for the BSAI (p. 139).
- The north-northeast wind drift pattern for 2003-2004, 2006, and 2008 suggests that winter spawning flatfish larvae may have been advected to favorable nursery areas in Bristol Bay. Rock sole recruitment estimates in recent years remain consistent with this larval drift hypothesis. For arrowtooth flounder and flathead sole, the relationship has weakened since the 1990s, suggesting that these species may have different settlement preferences than northern rock role (p. 144).
- Commercial crabs show variable trends: EBS red king crab have declined for the last three years but remain in the range of 20-50,000 t. Tanner crabs increased until 2007 but there was a substantial decrease to 27,949 t in 2010. Snow crabs have gradually increased to the 2010 adult male biomass of 107,131 t (p. 146).
- Jellyfish trawl survey CPUE in 2010 was similar to 2009, which was a substantial increase over the previous 8 years (p. 149). The 2009 increase was observed only on the middle shelf in the BASIS survey, but was comparable to 2005-2005 biomass. *Chrysaora melanaster* dominates the community (p. 149).
- Eelpouts, poachers, and sea stars show broadly similar time trends in trawl survey CPUE, but no outstanding changes for 2010 (p. 152).

- Survival and recruitment of demersal species in the BSAI were below-average during most of the 1990s and above-average across stocks in the late 1990s/early 2000s (Figure 3). In the eastern Bering Sea there was no strong indication of below average recruitment across multiple stocks until 2004, when all 7 stocks with recruitment estimates had below average recruitment and stock-recruit indices (p. 179).
- Species richness and diversity on the EBS shelf have undergone significant variations from 1982 to 2009 (Figure 3). Richness (the average number of species per haul) has increased by one to two species since 1995, but decreased in 2009. The Shannon Diversity Index increased from 1985 through 1998 and decreased sharply in 1999. Diversity was low in 2002/03, increased substantially in 2005 and has been decreasing since then (p. 181).
- Total trawl survey CPUE in the EBS shows an apparent long-term increase from 1982-2005, followed by a decrease during the recent cold years (2006-2009). Recent changes in CPUE in the EBS have been most pronounced on the middle-shelf, which is occupied by the cold pool during cold years. Higher CPUEs on the middle shelf during the 2001-2005 warm period appeared to be related to the increasing colonization of this area by subarctic demersal species (p. 183).
- Both the latitudinal and depth distribution of the demersal community on the EBS shelf show strong directional trends over the last three decades, indicating significant distributional shifts to the North and into shallower waters (p. 186).
- Pribilof Island seabird hatch dates have trended earlier since 2005. Reproductive success has been variable and recently increasing for kittiwakes on St. Paul and murres on St. George (p. 172).
- Northern fur seal (listed as depleted under the MMPA) pup production on both Pribilof Islands is estimated to be decreasing at approximately 6% per year (p. 165, Figure 5).
- Several Pribilof Island seabird counts show long term declines from 1977 levels, although kittiwakes and thick billed Murres on St. George have increased since the 1990s back to 1977 levels (p. 172, Figure 5).

Gulf of Alaska

- The seasonal cycle of mesozooplankton biomass in the eastern North Pacific was close to average in 2009 and indications are that spring 2010 was also close to average. Peak biomass and season length for the dominant *Neocalanus plumchrus* were close to average, showing that 2009 was an unexceptional year. Mesozooplankton community analysis identified transition years: 2003 transitioning from cold to warm, 2006 transitioning from warm to cold and, tentatively, 2009 cold to warm again or neutral (p. 121).
- Southeast Alaska herring 2008 and 2009 estimates of spawning biomass were the two highest in the 25-year time series. For most spawning areas, the recent phenomenon of high or increasing abundance despite low or very low levels of mature age-3 herring, has continued through 2009. There has been recruitment to spawning stocks at ages older than 3, and age-structured modeling of some stocks suggest that there has been a change in the maturation schedule (p. 132).
- An experimental combined annual index of juvenile Fish Creek chum salmon growth and temperature change may be a predictor of recruitment strength in sablefish. A similar index using Karluk River sockeye salmon and temperature change shows promise for pollock (p. 135).
- Shelf-spawning species (flathead sole, southern rock sole, and starry flounder) were all found to be negatively impacted by strong eddy activity along the shelf break off Kodiak, so the Eddy kinetic energy indicator above suggests that the biomass of these species may have been smaller in 2007 relative to 2009 (p. 99).

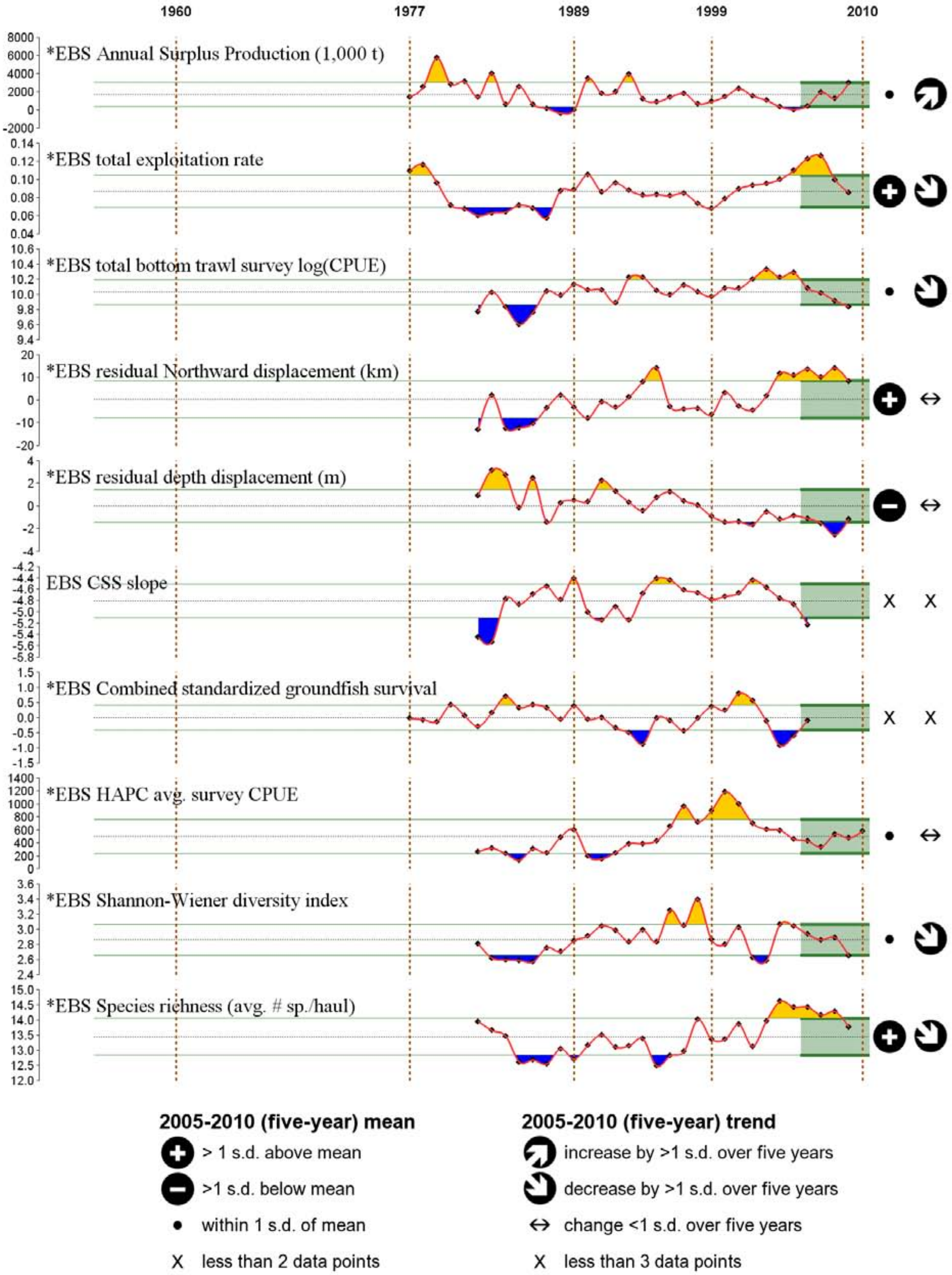

Figure 3: Eastern Bering Sea ecosystem indices. *Time series updated in 2010.

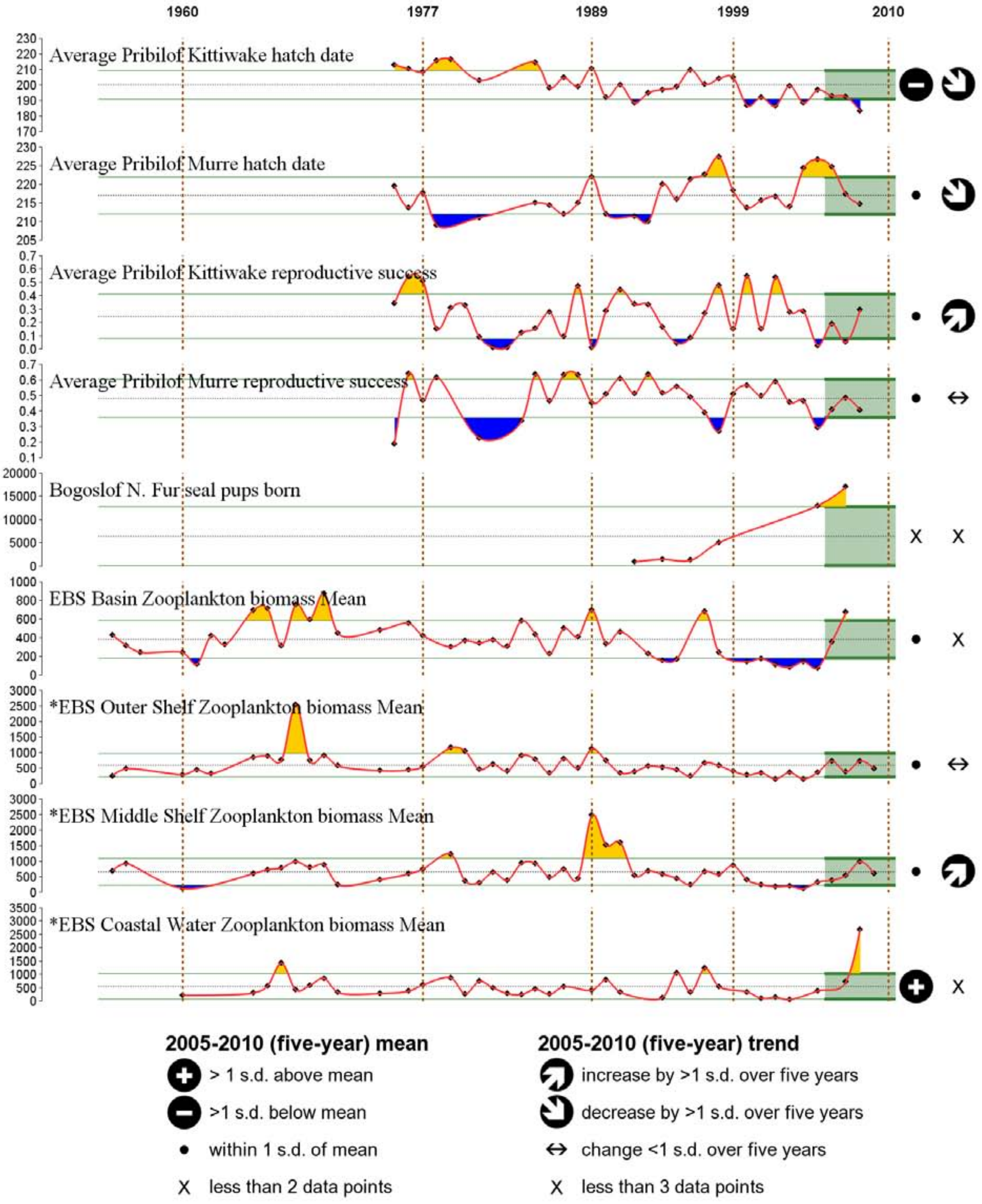

Figure 4: Eastern Bering Sea ecosystem indices. *Time series updated in 2010.

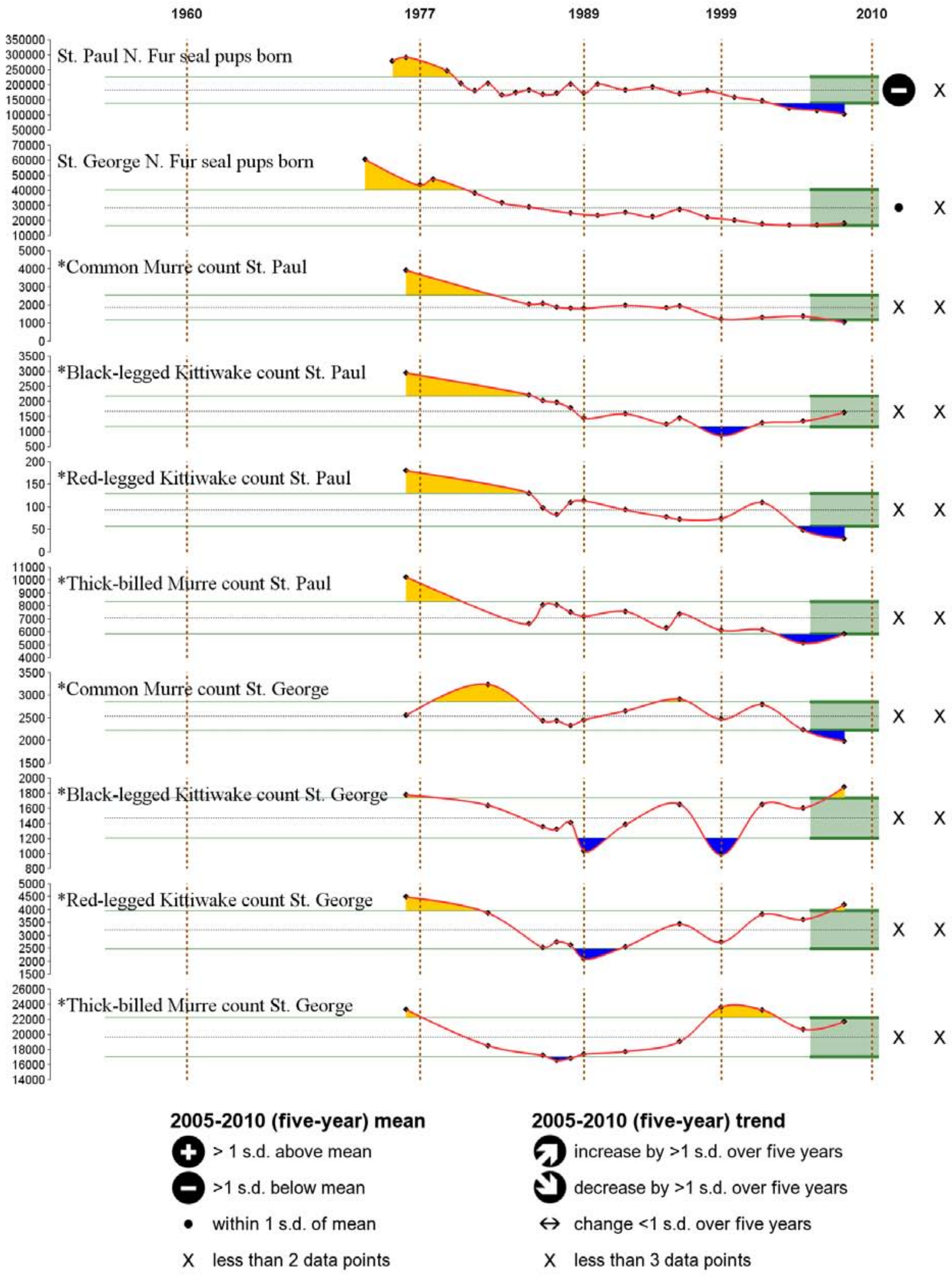

Figure 5: Eastern Bering Sea ecosystem indices. *Time series updated in 2010.

- GOA groundfish biomass declined after peaking in 1982 at over 6 million metric tons, primarily due to changes in walleye pollock biomass. Pollock were the dominant groundfish species prior to 1986 but arrowtooth flounder has increased in biomass and is now dominant. Pacific halibut biomass increased from 1978 to 1996, and declined slightly during 2001-2004 (p. 139).
- Several stocks experienced step-changes in survival in the late 1970s and 1980s; however, in general, there was no indication of uniform step changes in all stocks in either time period for the GOA (p. 139).
- ADF&G Kodiak trawl survey catches slightly increased in 2009. Arrowtooth flounder remains the main component in most of the offshore catches, while flathead sole and Tanner crab were the largest components inshore. Standardized anomalies show significant recent changes in volume and composition of the catches on the east side of Kodiak for arrowtooth flounder, flathead sole, Tanner crabs, and offshore skates and Pacific cod (p. 152).
- Most forage species catch rates in small mesh surveys remain at one to two orders of magnitude lower than peak values observed in the 1970s and early 1980s, except for Eulachon, which has recently had the highest catch rates of the time series. Forage species catch rates varied widely both between bays and within bays (p. 156).
- Survival and recruitment of demersal species in the GOA were below-average during the early 1990s and above-average across stocks in the late 1990s/early 2000s (Figure 6). There is strong indication for above-average survival and recruitment in the GOA from 1994-2000 (with the exception of 1996, which had very low indices) and below- or near-average survival / recruitment since 2001 (p. 179).
- Total trawl survey CPUE in the western GOA varied over time with a decrease between 2005 and 2007. The eastern GOA shows a similar patterns with a significantly increasing trend (p. 183).
- There is considerable variation between sub-areas in Steller sea lion trends estimated in the 2000s: sub-area population trends improved to the east through the western Gulf of Alaska, where the annual trend was approximately +4% per year; the central Gulf of Alaska population was stable in the 2000s, while the eastern Gulf of Alaska increased at approximately 5% per year. Regional trends in pup production are similar to trends in non-pup counts, with stability in the central Gulf of Alaska and improvement in the western and eastern Gulf of Alaska. (p. 162, Figure 6).

Aleutian Islands

- AI trawl survey HAPC biota showed variable distributions: Sponges are caught in most tows in the AI west of the southern Bering Sea. Stony corals are commonly captured outside of the southern Bering Sea and their abundance appears highest in the central and eastern AI. Sea anemones are common in survey catches but abundance trends are not clear. Sea pens are most likely to be encountered in the southern Bering Sea and eastern AI (p. 112).
- In contrast to the GOA, there were no definitive trends in rockfish distribution for geographic position or depth in the AI. Mean-weighted temperature distributions for all species were stable within about 1°C over the entire time series, although since 2000 the mean-weighted temperature distributions have increased for most species (0.1 - 0.5°C)(p. 110).
- AI trawl survey forage fish catch is episodic; maps and timeseries are reviewed (p. 129).
- Jellyfish were generally more abundant in the 2004 AI trawl survey and had the highest level of CPUE for all survey years in 2006. This change in abundance pattern is quite different from the eastern Bering Sea where peak abundances occurred in 2000 and 2009 (p. 160).
- The western AI Steller sea lion adult population decreased rapidly at approximately -7% per year and sub-area population trends improved to the east through the western Gulf of Alaska, where the annual trend was approximately +4% per year. Regional trends in pup production are similar to trends in non-pup counts, with continued relatively steep declines in the western AI, a less steep decline in the central AI, and improvement in the eastern AI (p. 162, Figure 7).

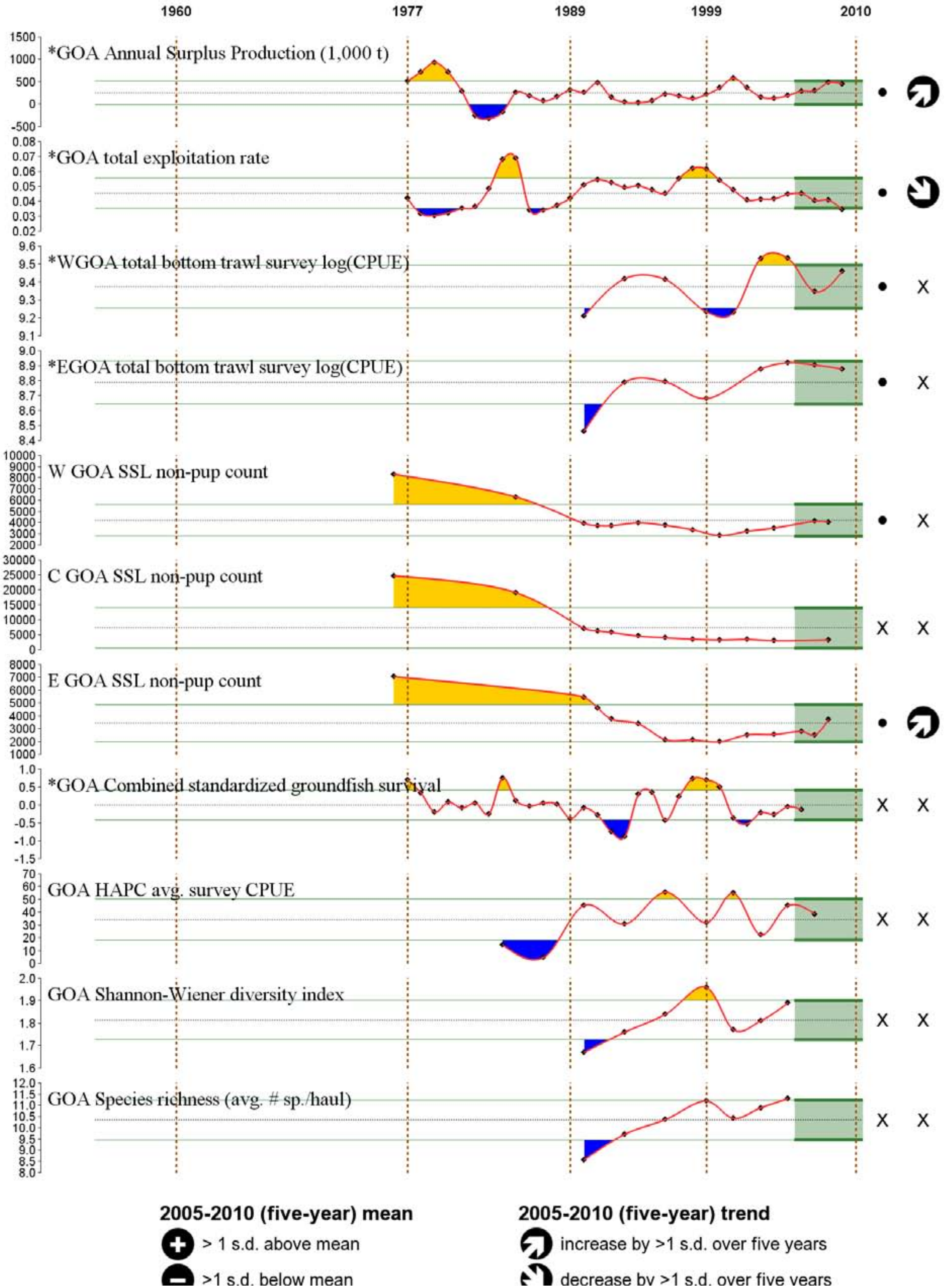

Figure 6: Gulf of Alaska ecosystem indices. *Time series updated in 2010.

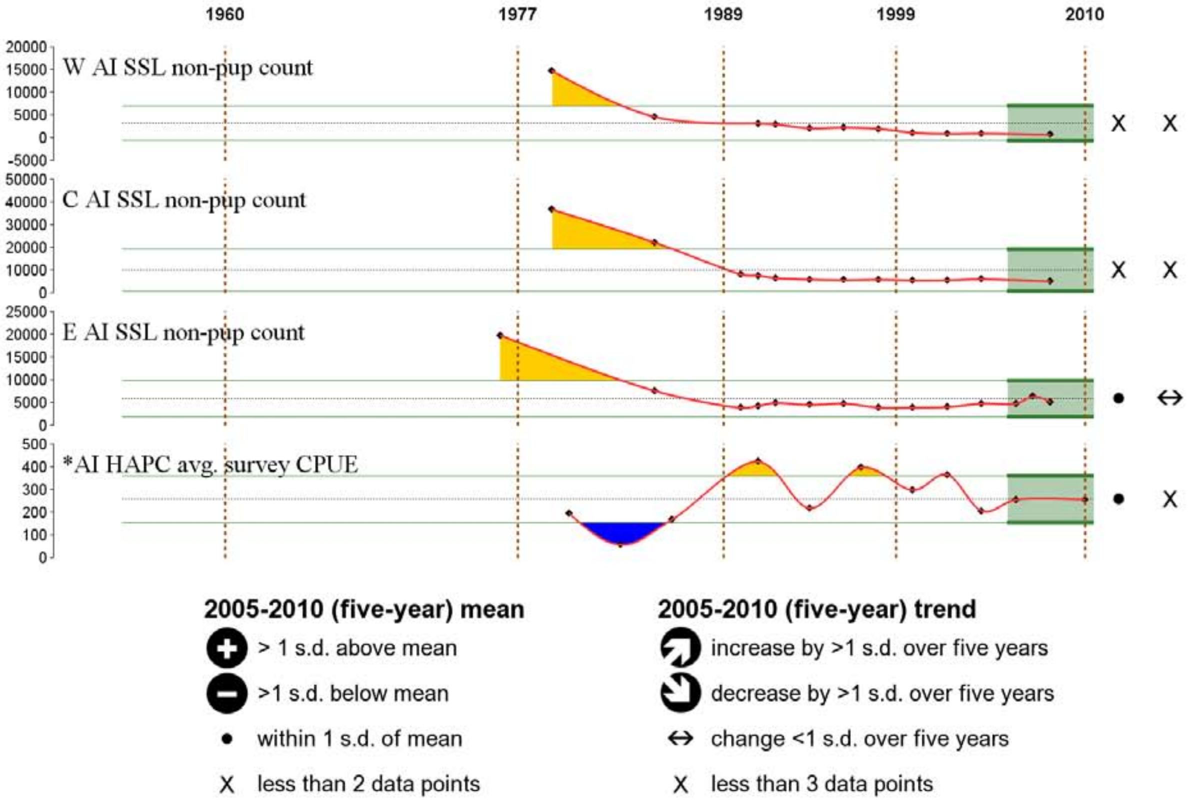

Figure 7: Aleutian Islands ecosystem indices. *Time series updated in 2010.

Fishing and Fisheries Trends

Bering Sea

- Snow crab was declared overfished in 1999 and is under a rebuilding plan. The Pribilof Islands blue king crab was declared overfished in 2002 and remains at a low overfished biomass. St. Matthew blue king crab was declared overfished in 1999, was officially considered rebuilt in 2009, and supported a commercial fishery in 2009. The southern Tanner crab stock is now overfished based on the 2009 survey estimates and 2009/2010 catch data (p. 146).
- The Trophic Level of the Catch and the FIB (Fisheries in Balance) indices for the EBS have been stable and close to their long-term means since the 1970s (p. 204, Figure 8). Total catch was stable throughout the 2000s but has decreased recently.
- Fixed gear fishing effort has likewise been stable in recent years, although longline hours set have declined since 2005 (p. 193, 202). There was a decrease in bottom trawl and an increase in pelagic trawl fishing effort in 2007 driving recent trends (p. 195, 198).
- Target groundfish surplus production in the eastern Bering Sea is highly variable and has decreased between 1977 and 2007; however there is an increasing trend from 2005-2009 (Figure 3 and p. 214).
- The overall target groundfish exploitation rate in the EBS reached a low of 6.9% in 1999, increased to 12% by 2006, and decreased in 2008/2009 due to a reduction in walleye pollock harvest rates (Figure 3 and p. 214).
- Discarded tons of groundfish decreased in 2009, while the discard rate remained stable around 4% (p. 189).
- Catch of HAPC biota in 2009 EBS fisheries remained similar to recent years and among the lowest since 1997. The catch of non-specified species decreased 2003-2007 but increased again in 2008-2009, primarily due to jellyfish catch. The catch of forage species in the EBS increased in 2006-2007 and was comprised mainly of eulachon that was caught primarily in the pollock fishery; however, forage catch decreased in 2008-2010 (p. 190).
- The maximum potential area of seafloor disturbed by trawling had increased slightly in 2007-2008 but decreased again in 2009 to approximately the low point in the time series estimated for 1999 (p. 107).

Gulf of Alaska

- Total catch, the Trophic Level of the Catch, and the FIB (Fisheries in Balance) indices for the GOA have been stable and close to their long-term means since 1999 (p. 204, Figure 9).
- Fishing effort for all but bottom trawl gear has declined recently; bottom trawl effort is increasing from a low point in the 2005 (p. 193, 202, 195, 198).
- Annual target groundfish surplus production in the GOA did not show a significant trend between 1977 and 2009; however there is an increasing trend from 2005-2009 (Figure 6 and p. 214).
- The overall target groundfish exploitation rate in the Gulf of Alaska has generally been less than 6% except in 1984/85, and has declined since 2005 (Figure 6 and p. 214).
- Discarded tons of groundfish decreased in 2009, while the discard rate increased slightly to 15% (p. 189).
- HAPC biota catch in the GOA is extremely low overall and widely variable. Catch of non-specified species (primarily grenadiers) declined in 2009. The catch of forage species has undergone large variations, peaking in 2005 and 2008 and decreasing in 2006-2007 and 2009. The main species of forage fish caught are eulachon in the pollock fishery (p. 190).

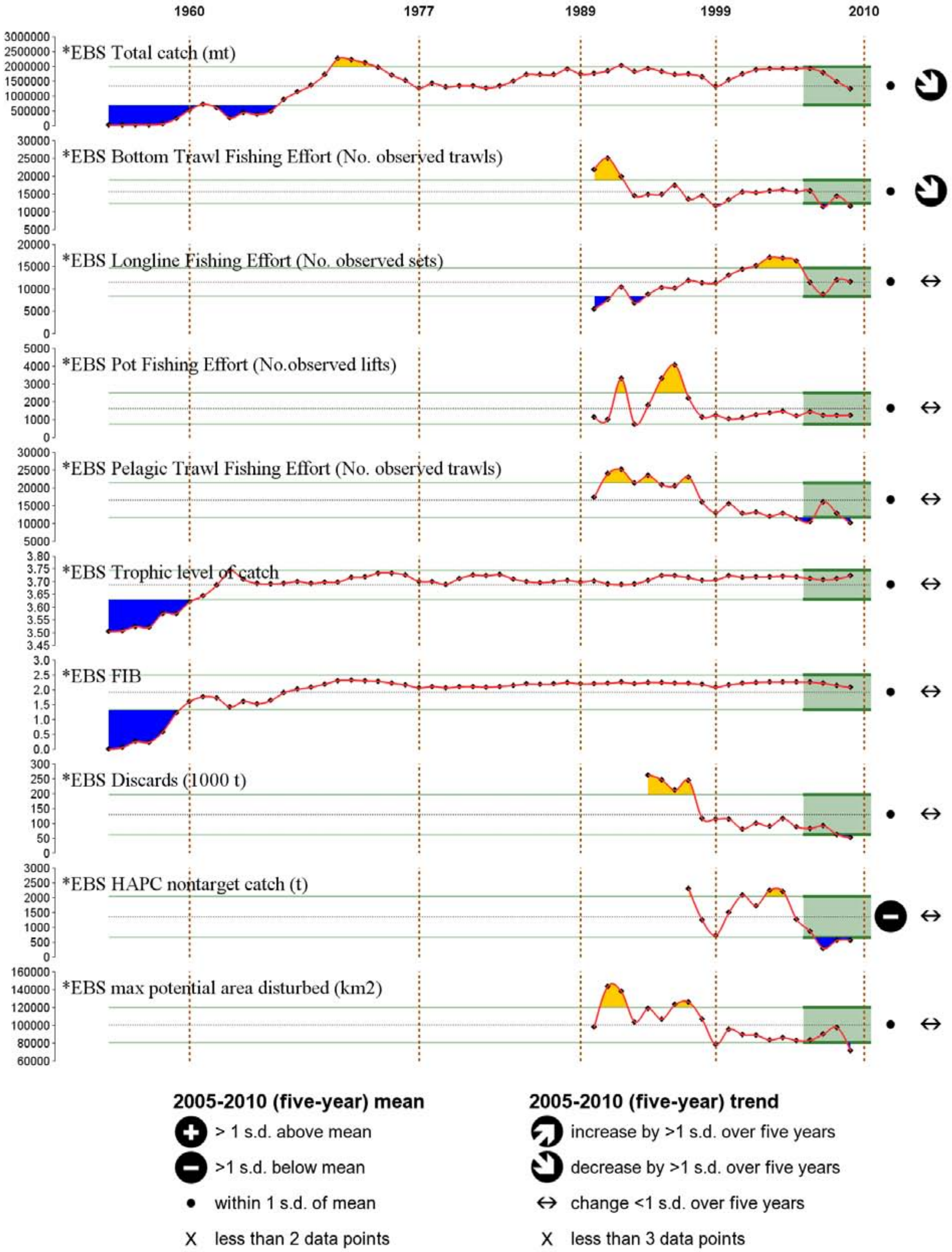

Figure 8: Eastern Bering Sea fisheries indices. *Time series updated in 2010.

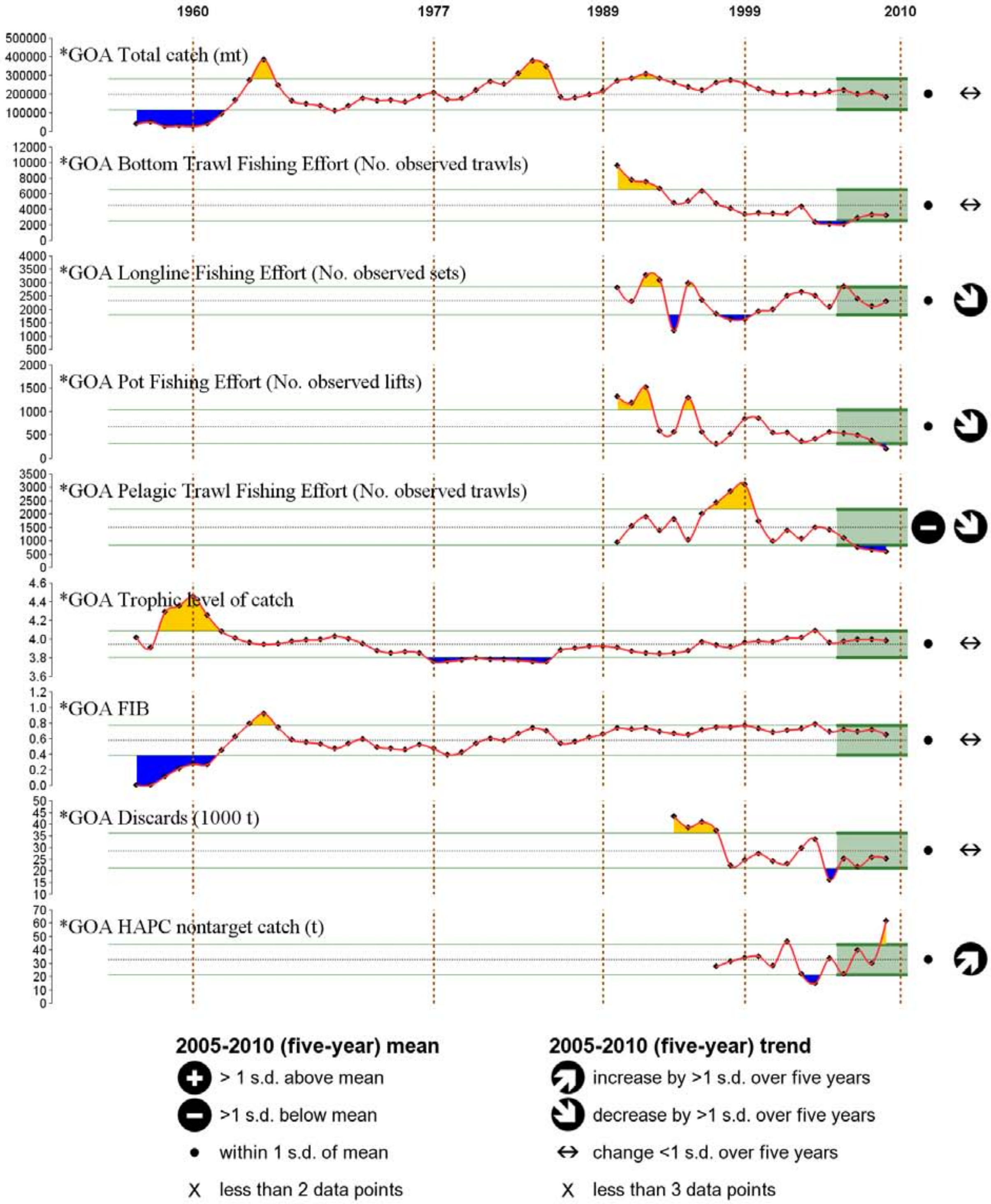

Figure 9: Gulf of Alaska fisheries indices. *Time series updated in 2010.

Aleutian Islands

- Total catch, the Trophic Level of the Catch, and the FIB (Fisheries in Balance) indices for the AI have been stable and close to their long-term means since 1999 (p. 204, Figure 10).
- Fishing effort by gear type has likewise been stable in recent years, although there was a small increase in bottom trawl fishing effort in 2007 (p. 193, 202, 195, 198).
- Discarded tons of groundfish increased in 2009, and the discard rate increased slightly to 7% (p. 189).
- HAPC catch has been variable over time in the AI, and is driven primarily by sponges caught in the Atka mackerel, rockfish and cod fisheries. Non-specified species catch (primarily grenadiers) shows little trend over time, although the highest catch was recorded in 2009. Forage fish catches in the AI are minimal, amounting to less than 1 ton per year (p. 190).

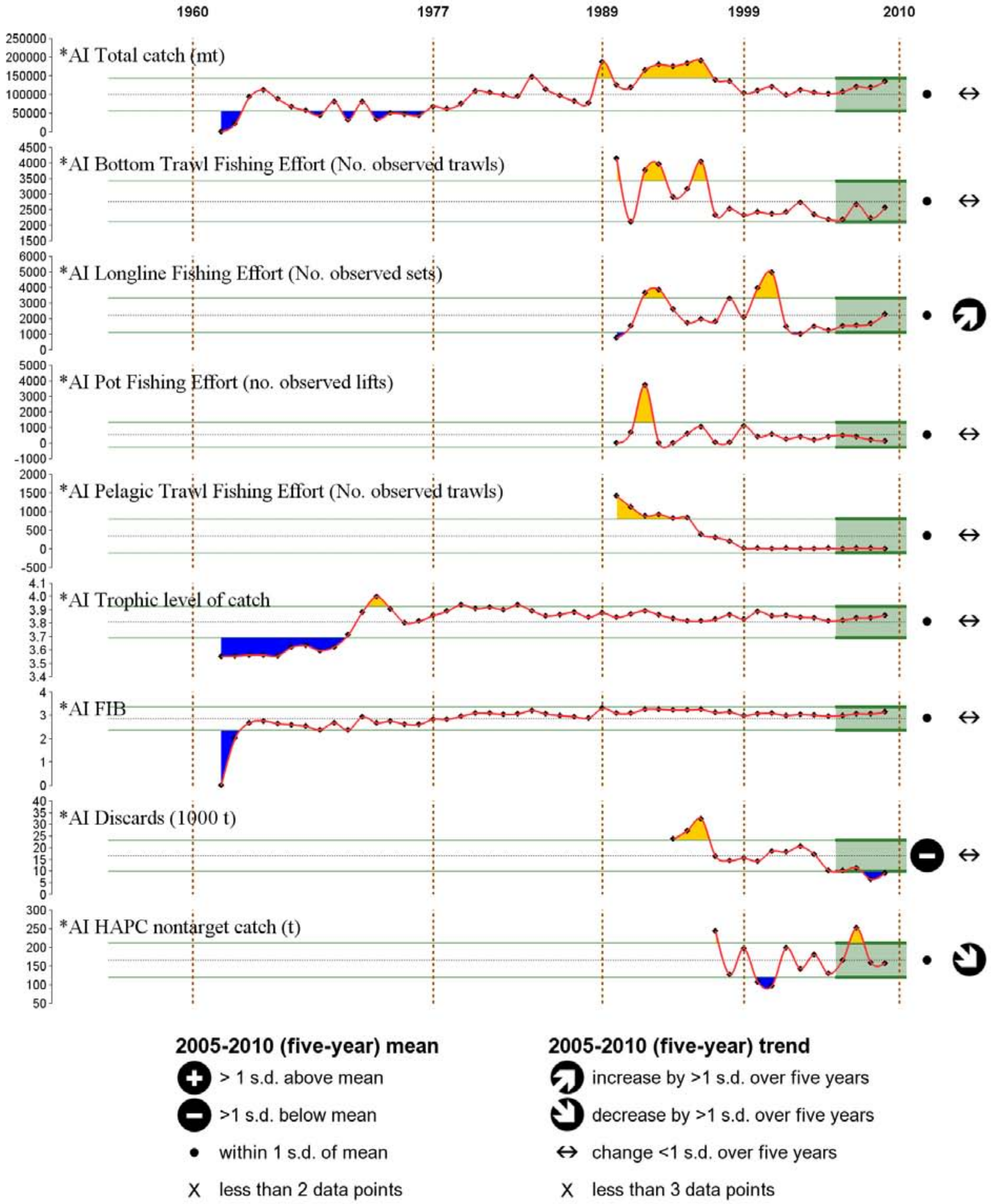

Figure 10: Aleutian Islands fisheries indices. *Time series updated in 2010.

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* indicates contribution updated in 2010
† indicates new contribution

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Responses to Comments from the Science and Statistical Committee (SSC)

October 2010 SSC Comments

The new Ecosystems Considerations Chapter of the Groundfish SAFE reflects adoption of many of the changes suggested by the SSC in 2009, and has the potential to be of considerable value. A significant deficiency of the current draft is the absence of updates on most of the marine mammal and seabird issues. Of the sections listed, two were last updated in 2009, two in 2008, three in 2007 and five were last updated in 2006. Many of these involve endangered species (SSL last updated in 2007; seabird bycatch in 2006, reported in 2008, and declines in marine mammals in 2006). The lack of this information on seabirds and marine mammals is a serious deficiency. This information is critical to managers and industry because interactions between fisheries and these species could result in the shutdown of a segment or segments of the fishery.

We continue to adopt the changes suggested by the SSC in this draft, including the addition of a new synthetic Ecosystem Assessment section for the Eastern Bering Sea (beginning on p. 52). Also in this draft are 2010 updates for marine mammal and seabird issues, with particular attention to those involving endangered species. Please see the updated contributions for Steller sea lions (p. 162), northern fur seals (p. 165), and Pribilof seabirds (p. 172). Please see also the new "Hot topics" section on p. 49 which emphasizes endangered species information critical to managers and industry.

December 2009 SSC Comments

1. *This chapter and associated analyses continues to provide useful insight into the status and trends of BSAI and GOA ecosystems. The chapter has gone from collecting some of the early papers on ecosystem-based management and a collection of time series data to analyses of which indices are meaningful and how indicators can inform fishery management. The new format and associated models and projections are interesting and appear well-developed enough to be brought before the SSC in detail. As noted in the Plan Team minutes, the goal is to develop an ecosystem report card that concisely represents the state of the ecosystem and provides key information that sets an ecosystem context for ABC recommendations discussed at the December council meetings. A workshop on this topic has been proposed for the February 2010 SSC meeting and the SSC agreed*

that this was a priority topic to cover if there is sufficient time in the SSC agenda.

A workshop was held in Portland, OR, on February 10, 2010. Stephani Zador, Kerim Aydin, and Sarah Gaichas gave an overview of the current Ecosystem Chapter, including their ideas for changes in format, content and orientation. They sought SSC feedback on what to synthesize, when and how to present it, and how to represent uncertainty. The SSC supported the overall proposed new organization of the ecosystem chapter into a 3-5 page highly focused executive summary, a 20-page synthesis, and a body of text with ecological indicators and management indices. The SSC also supported the general approach for the ecosystem-level synthesis to include global to regional indices, use of guild indices, etc. The SSC suggested that consideration could be given to a brief description of the level of uncertainty associated with each indicator in the summary section of each indicator, following the brief description of the index, but advised against cluttering figures with measures of uncertainty. For a detailed review of the workshop, see `http://www.fakr.noaa.gov/npfmc/minutes/SSC210.pdf`

2. *In response to an SSC comment, authors described the importance of an index to groundfish management, implications of index trends on the ecosystem or ecosystem components, and how the information can be used to inform management decisions. The SSC suggests three next steps aimed at more directly using the information in management decisions. First, many of the indices are monitored for trends but no thresholds have been identified when the changes become worrisome and what change in management might be advised. For example, if evidence indicates a regime shift, biological indicators may need to be revised.*

At the February 2010 SSC meeting, we discussed the utility of gathering an Ecosystem Synthesis Team with diverse expertise in marine ecosystems to evaluate indicators, establish thresholds, and make recommendations for using ecosystem information in management decisions. We held an Ecosystem Synthesis scoping meeting August 3, 2010 jointly with Jeff Napp and Phyllis Stabeno of NOAA's North Pacific Climate Regimes and Ecosystem Productivity program (NPCREP). NPCREP has been contributing data, time series, and interpretation to the Chapter since the beginning of the program. NPCREP, as part of its mission, plans to be involved in providing synthesis, in addition to data and interpretation. Our goal this year was to assemble an Ecosystem Synthesis Team and conduct a workshop to prepare an initial synthesis for the eastern Bering Sea that would be ready for the November 2010 Plan Team meeting. The workshop was held October 14-15. Ideally, this will become an annual event with the goal to provide a more synthetic statement of ecosystem status by linking individual trends. It is viewed as an iterative learning process whereby each year the Synthesis Team will strive to increase the direct inclusion of ecosystem information into the management process. For this initial EBS Ecoystem Assessment, the team focused on a subset of 10 broad, community-level indicators to determine the current state and likely future trends of ecosystem productivity overall, including switches between major pathways (benthic/pelagic). The team also selected indicators thought to best guide managers on ensuring the needs of non-fishery apex predators and maintaining a sustainable species mix in the harvest, given the current state and likely future trends of overall productivity and the distribution/strength of pathways. Future assessments will address additional ecosystem objectives identified above. We expect to apply a team synthesis approach to the GOA and AI ecosystems in upcoming years.

3. *The second suggestion is that there should be more interaction between SAFE chapter and the ecosystem authors so that ideas brought forward in the Ecosystem Considerations section could be*

tested in stock assessments.

Stock assessment authors are almost always willing to incorporate more ecosystem forcing in their assessments but have substantial time constraints as do we; e.g. we have spent large amounts of time writing proposals, etc., for coordinated research (also, see next question). As a step toward increasing communication however, Stephani Zador gave a presentation to the stock assessment scientists on March 24, 2010, during their annual technical workshop. She presented an overview of the February workshop with the SSC, including the SSC request to increase interaction and communication. In terms of how to prioritize coordination with the assessment authors, it was suggested that those assessments that have weak to non-existent ecosystem sections should have higher priority for direct help from our group. Another assessment author suggested that we put together a powerpoint of products that our group can produce so that assessment authors can see the types of figures, etc., that are available and 'choose' ones they would like to include in their assessments. At the August 3, 2010 Ecosystem Synthesis scoping meeting, we also discussed developing species-specific ecosystem indicators and thresholds for use in stock assessments. The group decided that stock assessment ecosystem considerations would be most thoroughly addressed outside the fall stock assessment cycle. Therefore, the set of core Bering Sea ecosystem indicators that are identified in the October 2010 workshop (see above) will serve as a starting point to develop stock-specific indicators in a subsequent workshop with assessment authors, to be scheduled in spring 2011.

4. *Finally, explanations of observations such as the lack of strong year classes should be investigated in light of Ecosystem Considerations indices and data.*

We will strive to include more explanations of noteworthy observations in the new ecosystem assessment format, and have begun this process in the current ecosystem considerations report. Also, Anne Hollowed will be co-advising a coordinated research project for a new graduate student starting Fall quarter 2010 at the UW School of Aquatic and Fishery Sciences to conduct a retrospective analysis with a specific focus on the conditions during and leading up to the production of strong year classes. The project goal is to develop indices that reflect the amplitude and frequency of strong year classes in managed groundfish stocks that exhibit sporadic recruitment patterns and to use these indices to investigate the effects of fishing and regional-to-large scale environmental change/regime shifts on recruitment patterns. The indices will be complimentary to existing stock assessment methods, and if successful have the potential to be incorporated quantitatively into assessments. At the August 3, 2010 Ecosystem Synthesis scoping meeting, we also discussed developing species-specific ecosystem indicators and thresholds for use in stock assessments. The group decided that stock assessment ecosystem considerations would be most thoroughly addressed outside the fall stock assessment cycle. Therefore, the set of core Bering Sea ecosystem indicators that are identified in the October 2010 workshop (see above) will serve as a starting point to develop stock-specific indicators in a subsequent workshop with assessment authors, to be scheduled in spring 2011.

5. *Overall, this chapter has improved greatly over the years. However, it would be useful to link the various and disparate sections. Although there was some improvement in this, it remains unclear how the various sections are integrated. Perhaps a flow chart illustrating all sections showing main links would give the reader a visual template of what is available and how sections are related. Sections that need more recent information include pinnipeds, seabirds, and seabird bycatch.*

As mentioned above, we are working towards a more inclusive and synthetic ecosystem assessment to be included in the ecosystem considerations report. Although a flow chart illustrating all sections is a good idea, we decided against including one in this transitional document. Instead, we hope that the synthesis we have provided and the modified format we start in this document will clarify how the sections are related. New last year, we included seabird and marine mammal data in the executive summary. This year we continue to attempt to include more updated information on pinnipeds, seabirds, and seabird bycatch in the assessement and the individual contributions (p.165, p.162, p.172); however, recent data are not always available. For example, seabird bycatch records have not been updated since 2006.

6. *This year, the Ecosystem Considerations Chapter focused on the development and listing of indices, with the result that at times the big picture seemed obscured. It is important that not only the most recent environmental data be provided, but that its importance be emphasized by the synthesis of disparate fragments of data into interpretive reports. These connections should enhance understanding of processes that are of management importance or which have predictive power. Just because a phenomenon is measurable doesn't mean it is important. Five examples of reports that are lost in the indices and individual accounts are: 1. Flatfish recruitment hypothesis...2. Impact of Climate on Fish Distributions...3. Importance of predation on pollock by arrowtooth flounder... 4. What is the status of the crustacean zooplankton on the shelf, and what are the implications of recent changes?...5. The interaction of zooplankton abundance and cannibalism...The importance of the focus on stories of this sort are at least two-fold: in the first place, they help assessment authors put their assessments in an ecosystem context- are the age-0 pollock seen this year likely to show up next year, and secondly, when the importance of certain data types is linked directly to fisheries management issues, there is an increased likelihood that further research effort will de devoted toward determining if the apparent relationships can be relied upon for predictive purposes.*

New this year we have included a section on "hot topics" in the November 2010 ecosystem assessment. Based on the results of the October Bering Sea Ecosystem Synthesis workshop, we have showcased several topics in the EBS summary (p. 53) and conclusions sections (p. 87) of the assessment.

7. *The maximum disturbed area information is interesting but the SSC suggests that data on the amount of new area disturbed would also be of interest.*

This comment was passed along to the study author. She mapped areas trawled in the most recent year (2009) and comparing that to cumulative areas trawled in all years, the past 10 years, and the past 5 years (p. 107).

8. *In the GOA, the SSC recommends comparing survey bottom temperatures with temperature data from moorings. We know that wind events can affect bottom temperatures temporarily and mooring data could help with interpretation of the survey snapshot of bottom temperatures.*

This comment was passed along to the study author. He agrees that it seems like a good idea and plans to include this type of analysis in the 2011 ecosystem chapter. In fact, he had included a comparison with UAF's GAK1 data in previous years. He also wanted to point out that his water temperature analysis was for the entire water column, not just the bottom temperatures. We provided links to recent GAK1 data (up to 2009) and to the Alaska Ocean Observing System for the author.

9. *The Ecosystem Considerations appendix was originally envisioned to include tracking of regime shifts. An explicit statement about what indices are involved and what they mean relative to regime shifts would be helpful.*

The Ecosystem Synthesis team (see comment 2) was tasked with defining key thresholds for indicators in the Bering Sea ecosystem, as well as choosing indicators that according to team expertise are best suited to identify potential regime shifts. In its first iteration this year, the team discussed runs of years with certain conditions, but not regime shifts explicitly. We plan to move further in this direction during subsequent meetings of the this team and the teams convened for the other marine ecosystems.

10. *The indices are useful and an especially important part of the display of data are the pie graphs to show source of data. The SSC recommends including these pie charts with all of the indices (i.e, the Pribilof Island top predators and regional trends graphs).*

We have attempted to include pie charts or other indicators of data source with the indices in the November 2010 SAFE. However, as was discussed during the February SSC workshop, categorizing the data sources is not trivial. Very few of the indices represent true (raw observational) data. For this report, we consider statistical sampling model-based estimates such as survey biomass, catch weight, and groundfish diet composition as data, and we consider stock assessments model estimates, statistically-derived climate indices, and food web model estimates as model output.

11. *Although there is an apparent relationship between pollock year class strength and summer stratification, other factors may be involved. This index may be misleading if events earlier in the year determine the distribution and abundance of critical food resources for the pollock.*

We agree. This index was featured as what we would now call a hot topic but not meant to be presented as full and integrated research results. We plan to present this type of topical new research in the hot topics sections of the Ecosystem Assessment.

12. *The five year spans of the projection windows represent different proportions of the life span depending on species, making it difficult to interpret the importance of the projections.*

Initially we chose a five year span to ease comparisons among indices. The Ecosystem Synthesis team agreed to adjust some spans to better reflect attributes of the time series, such as longer spans for long-lived seabirds. However, we believe the appropriate time span depends on what the indicator is supposed to reflect. For example, population trends that reflect long term change are appropriate to show in longer time spans, whereas reproductive success trends that reflect shorter term changes in zooplankton are appropriate to summarize in shorter time spans.

13. *Many of the editor's responses to SSC comments were inadequate. Does 'okay' or 'comments were passed on to authors' mean that the authors agree, or that the requests were addressed in the*

respective sections? If they were or weren't addressed, a brief explanation would help the SSC review the progress of those sections.

We have attempted to make our responses more informative this year.

14. *It is not always clear what population or species group is being addressed (e.g., Page iv, bullet on seabird reproductive success at Pribilofs - 'half of the populations are within 1sd of their long-term mean' Were the authors referring to different species on the Pribilofs?*

We have edited our language for clarity. The above mentioned bullet refered to four monitored species on each island. We considered these 8 populations in total.

15. *Table 2 (p.8) is difficult to read or compare EBS to GOA biomass components. It may be necessary to split this into several tables and organize them to allow direct comparisons between EBS and GOA. In Table 2 /apex predators, it might be useful to combine seabird species by forage guild (i.e., piscivorous, planktivorous, or diver, surface-feeder) or families with similar diets and foraging behaviors (i.e., tubenoses, alcids, larids, seaducks). Seabird species are individually a relatively small part of the biomass, so lumping certain groups for the biomass presentation would be more useful; a separate list of species that occur in EBS and GOA could be provided. Also in Table 2, Benthic Foragers should include seaducks (eiders, scoters, long-tailed ducks). In particular, eiders should be included here because two species are listed under ESA, and scoter species are of concern.*

Thank you. We appreciate this type of feedback and commentary on the groupings. We have revised the table in the EBS assessement and will do the same for the GOA when the guild analysis is updated with the most recent information. We will work towards adding groups, especially if new time series data becomes available (i.e., sea ducks, for which we currently lack information).

16. *Pages 11-12: It appears that the final paragraphs in these first two sections have been exchanged.*

We believe these paragraphs were displayed as intended, although we agree that the presentation was confusing. The indicator Total Catch Levels is used to describe two ecosystem pressures: energy redirection and introduction of non-native species. We hope that with the new assessment format, the implications of this indicator will be more clear.

17. *Under 'Status and Trends' for seabirds (p.15), it is unclear what the source is for categorizing these as species of concern. The authors should re-check the current status for these species in Alaska (as opposed to other regions).*

We have rechecked the source for the status of these species in Alaska.

18. *Page 19: these 2 items do not have all the sections of the previous ones such as factors causing trends and implications. Section 2, Fishing Effort, is a confusing mix of observations, effort, and HAPC.*

We have edited these sections to conform with our new format as well as clarity.

19. *Page 24, Implications section of North Pacific climate and SST indices is more of a forecast for what to expect for El Nino and the PDO - not implications for groundfisheries management. The sentence "This could have a broad range of effects on Alaska marine ecosystems" is not adequate.*

The goal of the Ecosystem Synthesis Team workshops in September and October was to include implications of climate and SST indices for groundfish management that are more informative than last year (at least with respect to the Bering Sea ecosystem). Discussion of implications for groundfish management is contained in the Ecosystem Assessment, with references to the contribution.

20. *The SSC suggests providing distribution maps in the Forage Fish section (p.66-67), including forage species with indices available from acoustic surveys (i.e., euphausiids, capelin, juvenile pollock). Some mention, and distribution maps, should be made here or elsewhere for commercial species that are important prey as juveniles (i.e., pollock).*

During communication with the stock assessment authors, it was agreed that time series of forage fish distribution maps be added to the forage fish and walleye pollock assessments, whereas this report would have only the current year's forage fish distribution appended to the Bering Sea and Gulf of Alaska survey-based forage fish contributions. Requests for adding distribution maps were made to the forage fish contribution authors. See contributions on p. 127 and p. 129.

Introduction

The goal of the Ecosystem Considerations appendix is to provide stronger links between ecosystem research and fishery management and to spur new understanding of the connections between ecosystem components by bringing together many diverse research efforts into one document. There are three main sections:

- Executive Summary
- Ecosystem Assessment
- Ecosystem Status and Management Indicators

The purpose of the first section, the Executive Summary, is to provide a consise summary of the status of marine ecosystems in Alaska for stock assessment scientists, fishery managers, and the public. Time series of indicators are presented in figures formatted similarly to enable comparisons across indicators. Recent trends in climate and the physical environment, ecosystems, and fishing and fisheries are highlighted in bulleted lists.

The purpose of the second section, the Ecosystem Assessment, is to synthesize historical climate and fishing effects on the eastern Bering Sea/Aleutian Islands and Gulf of Alaska ecosystems using information from the Ecosystem Status and Management Indicators section and stock assessment reports. Notable trends, “hot topics”, that capture unique occurrences, changes in trend direction, or patterns across indicators are highlighted at the end. An ongoing goal is to produce an ecosystem assessment utilizing a blend of data analysis and modeling to clearly communicate the current status and possible future directions of ecosystems. In future drafts, the Ecosystem Assessment section will also provide an assessment of the possible future effects of climate and fishing on ecosystem structure and function.

The purpose of the third section, Ecosystem Status and Management Indicators, is to provide detailed information and updates on the status and trends of ecosystem components as well as to provide either early signals of direct human effects on ecosystem components that might warrant management intervention or to provide evidence of the efficacy of previous management actions. In the first instance, the indicators are likely to be ones that summarize information about the characteristics of the human influences (particularly those related to fishing, such as catch composition, amount, and location) that are influencing a particular ecosystem component.

Since 1995, the North Pacific Fishery Management Councils (NPFMC) Groundfish Plan Teams have prepared a separate Ecosystem Considerations appendix to the annual SAFE report. Each new Ecosystem Considerations appendix provides updates and new information to supplement the original appendix. The original 1995 appendix presented a compendium of general information on the Bering Sea, Aleutian Island, and Gulf of Alaska ecosystems as well as a general discussion of ecosystem-based management. The 1996 appendix provided additional information on biological features of the North Pacific, and highlighted the effects of bycatch and discards on the ecosystem. The 1997 appendix provided a review of ecosystem-based management literature and ongoing ecosystem research, and provided supplemental information on seabirds and marine mammals. The 1998 edition provided information on the precautionary approach, essential fish habitat, effects of fishing gear on habitat, El Nino, local knowledge, and other ecosystem information. The 1999 edition again gave updates on new trends in ecosystem-based management, essential fish habitat, research on effect of fishing gear on seafloor habitat, marine protected areas, seabirds and marine mammals, oceanographic changes in 1997/98, and local knowledge.

In 1999, a proposal came forward to enhance the Ecosystem Considerations appendix by including more information on ecosystem indicators of ecosystem status and trends and more ecosystem-based management performance measures. The purpose of this enhancement was to accomplish several goals:

1. Track ecosystem-based management efforts and their efficacy,
2. Track changes in the ecosystem that are not easily incorporated into single-species assessments,
3. Bring results from ecosystem research efforts to the attention of stock assessment scientists and fishery managers,
4. Provide a stronger link between ecosystem research and fishery management, and
5. Provide an assessment of the past, present, and future role of climate and humans in influencing ecosystem status and trends.

The 2000-2009 Ecosystem Considerations appendices included some new contributions in this regard and will continue be built upon. Evaluation of the meaning of the observed changes needs to be in the context of how the indicator relates to a particular ecosystem component. For example, particular oceanographic conditions such as bottom temperature increases might be favorable to some species but not for others. Evaluations should follow an analysis framework such as that provided in the draft Programmatic Groundfish Fishery Environmental Impact Statement that links indicators to particular effects on ecosystem components.

In 2002, stock assessment scientists began using indicators contained in this appendix to systematically assess ecosystem factors such as climate, predators, prey, and habitat that might affect a particular stock. Information regarding a particular fishery's catch, bycatch and temporal/spatial distribution can be used to assess possible impacts of that fishery on the ecosystem. Indicators of concern can be highlighted within each assessment and could be used by the Groundfish Plan Teams and the Council to justify modification of allowable biological catch recommendations or time/space allocations of catch.

In the past, contributors to the Ecosystem Considerations appendix were asked to provide a description of their contributed index/information, summarize the historical trends and current status of the index, and identify potential factors causing those trends. Beginning in 2009, contributors were also asked to describe why the index is important to groundfish fishery management and implications of index trends. In particular, contributors were asked to briefly address implications or impacts of the observed trends on the ecosystem or ecosystem components, what the trends mean and why are they important, and how the information can be used to inform groundfish management decisions. Answers to these types of questions will help provide a "heads-up" for developing management responses and research priorities.

It was requested that contributors to the ecosystem considerations appendix provide actual time series data or make it available electronically. Most of the time series data for contributions are now available on the web, with permission from the authors.

It is particularly important that more time is spent in the development of ecosystem-based management indices. Ecosystem-based management indices should be developed to track performance in meeting the stated ecosystem-based management goals of the NPFMC, which are:

1. Maintain biodiversity consistent with natural evolutionary and ecological processes, including dynamic change and variability
2. Maintain and restore habitats essential for fish and their prey
3. Maintain system sustainability and sustainable yields for human consumption and nonextractive uses
4. Maintain the concept that humans are components of the ecosystem

The Ecosystem Considerations appendix and data for many of the time series presented in the appendix are now available online at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Past reports and all groundfish stock assessments are available at: `http://www.afsc.noaa.gov/refm/stocks/assessments.htm`

If you wish to obtain a copy of an Ecosystem Considerations Appendix version prior to 2000, please contact the Council office (907) 271-2809.

Ecosystem Assessment

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Introduction

The primary intent of this assessment is to summarize and synthesize historical climate and fishing effects on the shelf and slope regions of the eastern Bering Sea, Aleutian Islands and Gulf of Alaska from an ecosystem perspective and to provide an assessment of the possible future effects of climate and fishing on ecosystem structure and function. The Ecosystem Considerations section of the Groundfish SAFE provides the historical perspective of status and trends of ecosystem components and ecosystem-level attributes using an indicator approach. For the purposes of management, this information must be synthesized to provide a coherent view of ecosystems effects in order to clearly recommend precautionary thresholds, if any, required to protect ecosystem integrity.

The eventual goal of the synthesis is to provide succinct indices of current ecosystem conditions reflecting these ecosystem properties. In order to perform this synthesis, a blend of data analysis and modeling will need to be employed to place measures of current ecosystem states in the context of history and past and future climate. In this assessment, we have provided a short list of key indicators to track in the EBS, AI, and GOA, using a stepwise framework, the DPSIR (Drivers, Pressure, Status, Indicators, Response) approach (Elliott, 2002).

In applying this framework we initially determined four objectives based, in part, on stated ecosystem-based management goals of the NPFMC: maintain predator-prey relationships, maintain diversity, maintain habitat, and incorporate/monitor effects of climate change. Drivers and pressures pertaining to those objectives were identified and a list of candidate indicators were selected that address each objective and candidate indicators were chosen based on qualities such as, availability, sensitivity, reliability, ease of interpretation, and pertinence for addressing the objectives (Table 1). In future drafts, we plan to more fully address the human responses (Response portion of the DPSIR approach) to changes in status and impacts. Use of this DPSIR approach will enable the Ecosystem Assessment to be in line with NOAAs vision of Integrated Ecosystem Assessments.

For each objective, driver and pressure identified, indicators are briefly described and the status and trends of the indicators are explained. Where possible, factors that caused those trends are discussed and the potential implications are described. Some gaps in knowledge are listed for each objective.

November 2010 Assessment: a regional, synthetic approach highlighting management concerns. We initiate a regional approach to ecosystem assessments this year and present an entirely new Ecosystem Assessment for the eastern Bering Sea. This assessment is now organized into five sections. In the first "Hot topics" section we present a succinct overview of potential concerns for fishery management, including endangered species issues. In the next three sections, we address objectives and indicators specific to the Bering Sea, the Gulf of Alaska, and the Aleutian Islands ecosystems, respectively. (Arctic ecosystems will be added in another assessment section as information becomes available). The final section addresses indicators common to all ecosystems.

While all sections follow the DPSIR approach in general, the new eastern Bering Sea assessment is based on additional refinements contributed by an Ecosystem Synthesis Team. For this initial EBS Ecoystem Assessment, the team focused on a subset of 10 broad, community-level indicators to determine the current state and likely future trends of ecosystem productivity overall, including switches between major pathways (benthic/pelagic). The team also selected indicators thought to best guide managers on ensuring the needs of non-fishery apex predators and maintaining a sustainable species mix in the harvest, given the current state and likely future trends of overall productivity and the distribution/strength of pathways. Future assessments will address additional ecosystem objectives identified above. We expect to apply a team synthesis approach to the GOA and AI ecosystems in upcoming years.

Table 1: Objectives, drivers, pressures and effects, significance thresholds and indicators for fishery and climate induced effects on ecosystem attributes. Indicators in italics are currently unavailable

Pressures/Effects	**Significance Threshold**	**Indicators**
Objective: Maintain predator-prey relationships and energy flow **Drivers: Need for fishing; per capita seafood demand**		
Availability, removal, or shift in ratio between critical functional guilds	Fishery induced changes outside the natural level of abundance or variability, taking into account ecosystem services and system-level characteristics and catch levels high enough to cause the biomass of one or more guilds to fall below minimum biologically acceptable limits. Long-term changes in system function outside the range of natural variability due to fishery discarding and offal production practices	• Trends in catch, bycatch, discards, and offal production by guild and for entire ecosystem • Trophic level of the catch • Sensitive species catch levels • *Population status and trends of each guild and within each guild* • *Production rates and between-guild production ratios (balance)* • *Scavenger population trends relative to discard and offal production levels* • Bottom gear effort (proxy for unobserved gear mortality on bottom organisms)
Energy redirection		• Discards and discard rates • Total catch levels
Spatial/temporal concentration of fishery impact on forage	Fishery concentration levels high enough to impair long term viability of ecologically important, nonresource species such as marine mammals and birds	• Degree of spatial/temporal concentration of fishery on pollock, Atka mackerel, herring, squid and forage species (qualitative)

Introduction of nonnative species	Fishery vessel ballast water and hull fouling organism exchange levels high enough to cause viable introduction of one or more nonnative species, invasive species	- Total catch levels - Invasive species observations
Objective: Maintain diversity **Drivers: Need for fishing; per capita seafood demand**		
Effects of fishing on diversity	Catch removals high enough to cause the biomass of one or more species (target, nontarget) to fall below or to be kept from recovering from levels below minimum biologically acceptable limits	- Species richness and diversity - Groundfish status - Number of ESA listed marine species - Trends for key protected species
Effects on functional (trophic, structural habitat) diversity	Catch removals high enough to cause a change in functional diversity outside the range of natural variability observed for the system	- Size diversity - Bottom gear effort (measure of benthic guild disturbance) - HAPC biota bycatch
Effects on genetic diversity	Catch removals high enough to cause a loss or change in one or more genetic components of a stock that would cause the stock biomass to fall below minimum biologically acceptable limits	- Size diversity - Degree of fishing on spawning aggregations or larger fish (qualitative) - Older age group abundances of target groundfish stocks
Objective: Maintain habitat **Drivers: Need for fishing; per capita seafood demand**		
Habitat loss/ degradation due to fishing gear effects on benthic habitat, HAPC biota, and other species	Catch removals high enough or damage caused by fishing gear high enough to cause a loss or change in HAPC biota that would cause a stock biomass to fall below minimum biologically acceptable limits.	- Areas closed to bottom trawling - Fishing effort (bottom trawl, longline, pot) - Area disturbed - HAPC biota catch - HAPC biota survey CPUE
Objective: Incorporate/ monitor effects of climate change **Drivers: Concern about climate change**		
Change in atmospheric forcing resulting in changes in the ocean temperatures, currents, ice extent and resulting effects on production and recruitment	Changes in climate that result in changes in productivity and/or recruitment of stocks	- North Pacific climate and SST indices (PDO, AO, NPI, and NINO 3.4) - Combined standardized indices of groundfish recruitment and survival - Ice indices (retreat index, extent) - Volume of cold pool - Summer zooplankton biomass in the EBS

Hot Topics: Eastern Bering Sea

Endangered species information critical to fishery management

Short Tailed Albatross Two short-tailed albatross were incidentally caught and killed on longline fishing hooks in the Bering Sea fishery this year. Both events occurred along the EBS shelf (Figure 11) on longline vessels fishing for cod. These were the first recorded deaths of these birds by U.S. commercial fishing vessels since 1998.

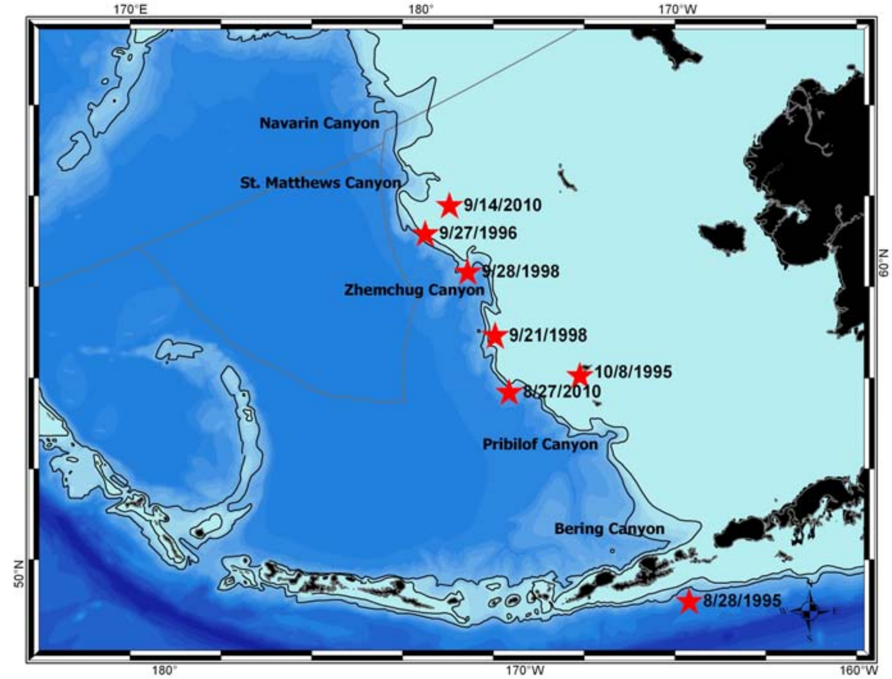

Figure 11: Locations and dates of short-tailed albatross bycatch. Figure courtesy Rob Suryan, OSU.

Short-tailed albatross were federally listed as endangered under the US Endangered Species Act in 2000. The current ESA biological opinion specifies that the expected take (bycatch) in the longline fishery is four in any 2-year period. In the event that a fifth bird is bycaught, an ESA Section 7 consultation involving the U.S. Fish and Wildlife Service and the National Marine Fisheries Service must be initiated. This process can lead to additional regulatory action on the fishery.

The short-tailed albatross were hunted to near extinction from the 1880s to the 1930s; by 1949 there were no known breeding colonies left. Since that time, the population has been increasing rapidly due to a combination of high annual breeding success (≥54%) and high adult and juvenile survival (≥95% and ≥91%, respectively) (Zador et al., 2008*b*). These high survival rates suggest that fishery-related mortality currently appears to be a low risk for this population. However, given that the short-tailed albatross population is expanding rapidly (7% annually; USFWS (2005), Zador et al. (2008*b*)) it has been suggested that their spatial and temporal overlap with the Alaskan commercial fisheries will become more extensive (Zador et al., 2008*a*). Specifically, increases in the cod quota may lead to more bycatch incidents. Recent actions by the Council to restructure the observer program and increase data quality may allow for more detailed monitoring and analysis of bycatch incidents.

Steller sea lions in the eastern Bering Sea Steller sea lions that feed within the eastern Bering Sea shelf ecosystem are largely thought to breed and give birth on rookeries in the eastern Aleutian Islands (163-170°W) and in the Pribilof Islands. It is also possible that some sea lions that breed on rookeries in the central and western Aleutian Islands (west of 170°W), particularly adult males, may inhabit the eastern Bering sea between breeding seasons, but this is not known. Non-breeding season surveys west of 170°W in the Aleutians have discovered that it is largely adult females and juveniles that overwinter in this area, indicating that adult males leave the Aleutians to overwinter elsewhere. Large numbers of adult males are observed in fall on St Lawrence Island (Gay Sheffield, ADFG, pers. Comm.), but it is not known where these animals were during the breeding season.

Steller sea lion populations that breed in the eastern Aleutians and the Pribilof Islands currently have different trends, with the eastern Aleutian population increasing while the Pribilof breeding population is disappearing.

Pribilof Islands: The breeding population of Steller sea lions on the Pribilof Islands has largely disappeared and is not currently considered in the trend analyses for the western stock. Elliott (1881) reported that approximately 10,000 to 12,000 animals were distributed at rookeries on both St. Paul and St. George Islands in the 1870s. Osgood et al. (1915) described the importance of Steller sea lions to the local community for both food and material for clothing and boats. The pups especially were favored for their meat. Between 1870 and 1890, at least 4,000 Steller sea lions were killed on St. Paul Island and by the early 1900s the local agent noted that the hunt should cease due to a reduced population (Osgood et al., 1915). In 1940, Scheffer counted 800-900 adults and 300-400 pups on St. Paul. He noted that the population was growing and that the Steller sea lions interfered with the management of the fur seal herd by competing for both food and space and "creating a nuisance to the men who drive and kill the seals" (Scheffer, 1946). This competition initiated a request to cull part of the population. The recommendation was to kill 50 pups a month during June, July, and August to assess the seasonal quality of the pelts.

The combination of hunting and culling in the late 1800s and early 1900s appears to have greatly reduced the size of the Pribilof Steller sea lion population. Loughlin et al. (1984) reported that the breeding rookeries on St. George Island were extirpated by 1916. No pups have been reported on St. George since that time. In the summer of 1960, 4,000 to 5,000 non-pups and 2,866 pups were counted on Walrus Island, just offshore of St. Paul (Kenyon, 1962). However, between the 1960s and 2005 numbers on Walrus Island declined over 90%, to only 322 non-pups in 2001 and 29 pups in 2005 (Figure 3.6 in NMFS (2008)). A count in 2010 yielded a minimum of only 14 pups on Walrus Island, but some (perhaps as many as 5) could have been missed since the count was made from an overlook on land and from a skiff rather than walking through the rookery.

Eastern Aleutian Islands: The Steller sea lion population in the eastern Aleutian Islands totaled at least 50,000 as recently as the late 1950s (when more than 44,000 were actually counted), and it was in this sub-area that the population decline was first detected in the mid-1970s (Braham et al., 1980; NMFS, 2008). In 1990 when the species was listed under the ESA, the non-pup count in the eastern Aleutians had declined to approximately 3,800, a decline of over 90%. Throughout the 1990s, the population was relatively stable, but since 2000 has been increasing at approximately 3% per year. NMML initiated a study in 2001 to estimate survival and reproductive rates at Ugamak Island, the largest rookery in the eastern Aleutians. Estimates of juvenile and young adult survival rates (through age 8; NMML unpublished) from sightings of animals marked as pups were greater than those from the central Gulf of Alaska in the late 1980s-early 1990s (Pendleton et al., 2006), suggesting that juvenile survivorship had improved during this period as the population stabilized and increased in size. This suggests that direct sources of mortality (e.g., illegal shooting, incidental catches in fisheries, predation by killer whales) are currently not threats to recovery, at least in this area. The breeding populations of sea lions in the eastern Aleutian Islands are responding differently (increasing at 3% per year) from those in Pribilof Islands despite the fact that both appear to forage extensively in the southeast Bering Sea.

Early warnings: potential future fishery management interest

Rare Species observed in the Bering Sea Although the eastern Bering Sea has a distinct fauna that is characteristic of the sub-arctic environment, it is open to movement of species from the Gulf of Alaska through the various passes along the Aleutian Island chain. It is unknown if these species are residents or seasonal transients to the Bering Sea, but movements may be influenced by changing environments. Four species that are common to the Gulf of Alaska that have been encountered in the eastern Bering Sea are the longnose skate *Raja rhina*, the big skate *Raja binoculata*, the spiny dogfish *Squalus acanthias*, and the Pacific Hake *Merluccius productus*. Increases in the incidence of the spiny dogfish is notable. Spiny dogfish have been encountered at least once in each of the last three survey years (2008-2010) and prior to that only 3 times in the previous 19 years (1989-2007). The big skate incidence went from no encounters in 2003 and steadily increased to 6 encounters in the most recent survey (2010). The first documented encounters in the eastern Bering sea since 1982 from the standard survey occurred in 2008 for the longnose skate and in 2010 for the Pacific hake. Although these species are rare, continued monitoring of encounters may indicate growing stocks or movement patterns into the eastern Bering Sea.

Eastern Bering Sea Ecosystem Assessment for 2011

Contributed by the Eastern Bering Sea Ecosystem Synthesis Team: Sarah Gaichas[1], Phyllis Stabeno[2], Jeff Napp[1], Lisa Guy[3], Kerim Aydin[1], Anne Hollowed[1], Patrick Ressler[4], Nick Bond[3], Troy Buckley[1], Jerry Hoff[4], Jim Ianelli[1], Tom Wilderbuer[1], Lowell Fritz[5], Diana Evans[6], Martin Dorn[1], Pat Livingston[1], Franz Mueter[7], Robert Foy[4], Ed Farley[8], Sue Moore[2], Stephani Zador[3]

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Editors' Note: The EBS Report Card was updated with new data from the stock assessments available after the EBS assessment was written.

Summary

The eastern Bering Sea experienced favorable conditions for lower trophic level production during 2010 with extensive sea ice, an early spring bloom, and moderately high concentrations of euphausiids and large copepods for planktivorous feeders. This was the 4th or 5th consecutive year with similar conditions potentially permitting the build up of overwintering populations of some of the large zooplankton species. The reproductive success of thick-billed murres matches the rise in our zooplankton indices and further supports the hypothesis that food concentrations are ample in cold years. With the anticipated development of La Niña conditions at the equator, and past correlations between sea ice extent and El Niño-La Niña cycles, we are expecting to see a continuation of late ice retrieval, early under ice spring phytoplankton bloom, and good availability of forage for planktivores. The anticipated availability of food for planktivores is likely to benefit different life history stages of planktivores such as age-0 walleye pollock from the 2011 year class.

The late sea ice retreat also creates an extensive cold pool over the southeastern shelf and tends to segregate species by their tolerance for cold water. For example, cod and pollock tend to remain offshore of the cold water. For the former this isolates them from their capelin prey, while for the latter it helps reduce the overlap between adult and juvenile pollock that results in cannibalism. During the warm years (2000 - 2005) recruitment by pelagic foragers was poor, and the total biomass of this guild decreased. The trend in recent years has been a very slow increase back to former levels. With the high levels of forage anticipated to be available and continued segregation of pollock life stages, we expect a continued, but slow recovery of the guild biomass, all other sources of mortality being equal.

The relationship between pelagic forager and benthic forager biomass is uncertain from the index time series. Initially the series seem to be correlated and in phase with each other. In later years, they may be correlated, but out of phase. It is hypothesized that cold conditions and high primary production could result in conditions that deliver food to both benthic and pelagic food webs. Unknown is whether or not top-down control (predation) will eventually occur once the biomass of these two guilds builds to a particular level (e.g. Oscillating Control Hypothesis).

Top-down control continues to be a concern in the ecosystem, particularly with the increase in arrowtooth flounder. Arrowtooth generally avoid areas with cold bottom temperatures during summer, with the result that their distribution and predatory impacts increase across the shelf during warm years. However, little is known about their winter distribution and behavior. Similarly, continued recover of protected marine mammal species could one day affect the availability of food for other plantivores creating a recruitment bottleneck among fish populations.

Northern fur seals breeding on the Pribilof Islands are representative of a group of air-breathing, central place piscivorous foragers (ABCPPF) in the eastern Bering Sea. Other members of the ABCPPF include piscivorous seabirds also breeding on the Pribilofs. There is some correlation between fluctuations in ABCPPF production and pelagic forage biomass over the last several decades: for instance, northern fur seal pup production on St Paul was highest at intermediate biomass of pelagic forage in the late 1970s, was relatively stable as pelagic forage biomass increased through the mid 1990s, and has declined at 6% per year since 1998 as pelagic forage biomass declined through at least 2008. By contrast, the biomass of fish apex predators (e.g., Pacific cod and arrowtooth flounder) has been relatively stable for almost 30 years. These patterns suggest a decoupling of energy flow to apex predators that have some restrictions (e.g., a pup or chick to feed at a terrestrial location for an extended period) on the spatial-temporal distribution of their foraging habitats. Further research into how changes in the distribution of prey caused by climate/environmental change, fisheries and other factors is necessary to determine how and if they affect apex predators differently.

Objectives, selection and evaluation of key EBS indicators

"What are the vital signs for the EBS, with an eye toward fishery management objectives?"

The Eastern Bering Sea Synthesis Team met in September 2010 to develop a list of approximately 10 synthetic ecosystem indicators for the eastern Bering Sea. The suite of indicators was selected to represent key ecosystem components by choosing the best available indicators related to 1. Atmosphere and upper-ocean physics, 2. Lower trophic levels and primary production, 3. Fish and shellfish distribution and abundance, 4. Fish and shellfish production, 5. Fisheries productivity, 6. Seabirds, 7. Pinnipeds, and 8. Whales.

For this initial EBS Ecoystem Assessment, we focused on broad, community-level indicators to determine the current state and likely future trends of ecosystem productivity overall, including switches between major pathways (benthic/pelagic), rather than focus on single species productivity (e.g., pollock). The team also selected indicators thought to best guide managers on ensuring the needs of non-fishery apex predators and maintaining a sustainable species mix in the harvest, given the current state and likely future trends of overall productivity and the distribution/strength of pathways.

The goal of this Ecosystem Assessment is to provide scientific advice for fisheries managers. We note that we are examining strategic rather than tactical objectives in this assessment, although further work on developing ecosystem level indicators and thresholds is planned. Single stock indicators will be discussed in a separate meeting in January or February when the group meets with the Plan Teams. More tactical management advice based on ecosystem considerations may come out of single species stock assessments integrating stock-specific ecosystem indicators.

The spatial boundaries of the ecosystem considered for the purposes of the Synthesis Team are the eastern Bering Sea shelf from Bristol Bay in the east to the continental slope in the west, and from the Alaskan Peninsula in the south to the southern boundary of the Northern Bering Sea Research Area (NBSRA;latitude of Nunivak Island) in the north. The northern and southern Bering Sea shelves are very different ecosystems, with the majority of fisheries in the south.

The following indicators were selected for the EBS Ecosystem Assessment for 2011 (Figure 12):

1. North Pacific Index
2. Eastern Bering Sea ice retreat
3. Zooplankton - euphausiid hydroacoustic data and copepod index
4. Motile epifauna aggregate biomass

5. Benthic foragers aggregate biomass
6. Pelagic foragers aggregate biomass
7. Fish apex predators aggregate biomass
8. St. Paul fur seal pup production
9. Thick-billed murre reproductive success on St. George
10. Maximum potential trawl area disturbed

In the sections below, we give a brief rationale for the indicator's selection, describe the indicator, its status and trends, and provide a statement of its individual implcations for fishery management. The summary section above provides a synthetic assessment based on all ten indicators.

1. The North Pacific Index (NPI): The NPI has been selected as the single most appropriate index for characterizing the climate forcing of the Bering Sea. The NPI is a measure of the strength of the Aleutian Low, specifically the area weighted sea level pressure (SLP) for the region of 30^o to 65^oN, 160^oE to 140^oW (Trenberth and Hurrell, 1994). It has been used in a number of North Pacific applications. It is relevant to the Bering Sea because the strength of the Aleutian Low relates to wintertime temperatures, with a deeper low (negative SLP anomalies) associated with a greater preponderance of maritime air masses and hence warmer conditions.

The advantageous aspects of the NPI for the present purpose include its systematic relationship to the primary causes of climate variability in the Northern Hemisphere, especially the El Niño-Southern Oscillation (ENSO) phenomenon, and to a lesser extent the Arctic Oscillation (AO). It may also respond to North Pacific SST and high-latitude snow and ice cover anomalies, but it is difficult to separate cause and effect. The NPI also has some drawbacks: (1) it is relevant mostly to the atmospheric forcing in winter, (2) it relates mainly to the strength of the Aleutian Low rather than its position, which has also been shown to be important to the seasonal weather of the Bering Sea (Rodionov et al., 2007), and (3) it is more appropriate for the North Pacific basin as a whole than for a specific region such as the Bering Sea shelf.

The NPI underwent a tremendous swing from about 3 positive standard deviations during the winter of 2008-09 to about negative 2 standard deviations during the winter of 2009-10. The magnitude of this transition has only been exceeded twice since 1968, with one of those instances being associated with the intense El Niño of 1982-83. The La Niña that is developing at the time of the writing of this overview suggests another sizable swing to a positive state for the NPI, as the trend in the index itself is demonstrating.

2. Eastern Bering Sea ice retreat index: Sea ice over the southern Bering Sea (south of $\tilde{5}9$N) varies greatly on all time scales (daily, annual, decadal), while the variability of northern Bering Sea shelf is much less. We use here an index of the number of days after March 15 in which areal sea ice concentration was greater than 10% in a 2^o x 1^o box (bounded by 56.5^oN to 57.5^o, 165^oW to 163^oW). We chose the spring, because it is spring sea ice that influences the timing spring phytoplankton bloom, determines the extent of the cold pool and strongly influences the surface ocean temperatures during summer.

Historically (1972 - 1999), sea ice extent over the southern Bering Sea shelf varied greatly on annual time scales. Beginning in 2000 we entered a 7-year period where there little sea ice in this southern

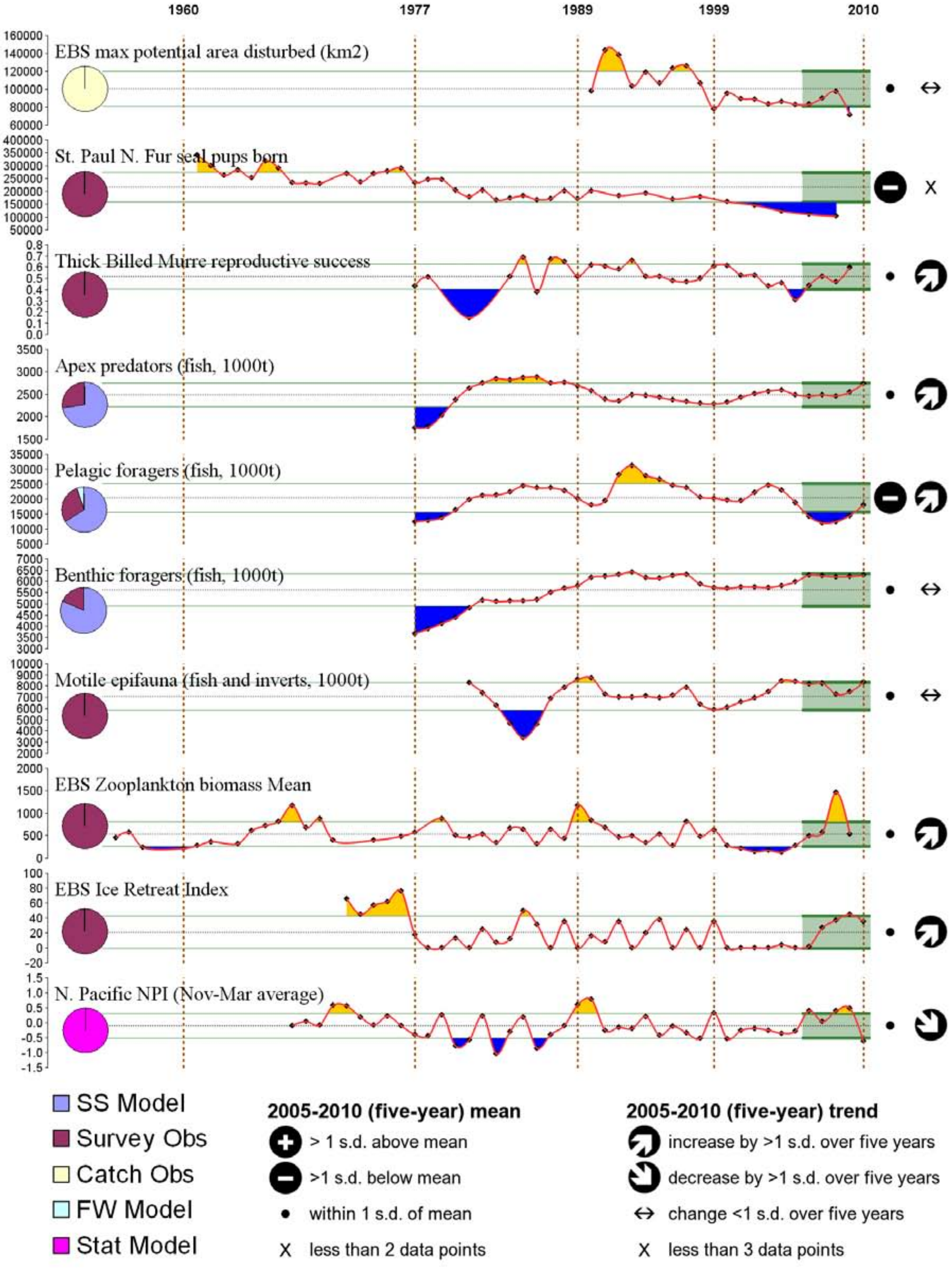

Figure 12: Eastern Bering Sea ecosystem assessment indicators; see text for descriptions.

region. That has followed with a 4-year period of very extensive ice in the spring over this region. While there have been other years with extensive ice in the spring, we need to go back to the early 1970s to find a series of 4-5 years with extensive spring ice. What was also unique was the period of 7 years with virtually no spring ice south of 57.5°N over the southern shelf.

A strong la Niña has formed on the equator (see the NPI index above). The prediction for the Bering Sea is above average sea-ice extent and duration in winter and spring 2011. This would result in a fifth year of extensive ice over the southern Bering Sea shelf.

3. Zooplankton biomass index: Macrozooplankton are intermediaries in the transfer of carbon from primary production to living marine resources (commercial fisheries and protected species). Understanding the mechanisms that control secondary production is an obvious goal toward building better ecosystem syntheses. In the absence of direct measurements of secondary production in the eastern Bering Sea we must rely on estimates of biomass. We have chosen to use and interpret estimates of summertime euphausiid and large copepod biomass for the eastern Bering Sea shelf as an index of the forage available to planktivorous fish, seabirds, and marine mammals. These time series are relatively short compared to those of climate and fisheries, however they appear to be in agreement with much longer time series of total zooplankton biomass from the T/S Oshoro Maru begun in 1954 (see contribution on p.117 and Figures 35 and 36).

Status and Trends: The euphausiid biomass index increased more than three fold from 2004 to 2009 and then decreased in 2010 by ca. 30%. Large copepod biomass (concentration of *Calanus* spp. in the Middle Shelf Domain) also increased 10 fold from very low values during the recent warm period (2002 to 2005) to 2009. Large copepod data are not yet available for 2010.

Interpretation and Implications: Standing stock of invertebrate forage is both a function of secondary production and consumption by planktivorous species. Euphausiids are a key zooplankton component of the Bering Sea food web (Aydin and Mueter, 2007) and euphausiids and large copepods are important dietary components of multiple life history stages of walleye pollock (Livingston, 1991; Lang et al., 2000; Brodeur et al., 2002; Ciannelli et al., 2004; Lang et al., 2005). These taxa are more numerous in cold as opposed to warm years (Baier and Napp, 2003; Coyle et al., 2008; Hunt et al., 2008). The relative contributions of production and predation to the standing stock are not yet known, however the high standing stocks in 2009 and 2010 are encouraging and suggest that overall food availability for planktivorous specie is high (ignoring mismatch in spatial distributions). Age-0 pollock, in particular, may be dependent on the availability of sufficient prey to generate enough depot lipids to survive their first winter. Thus, in the absence of compensatory predation on the early life history stages, we predict that the survival of this particular year class of fishes may be better than average. The same may be true for other planktivorous species.

4., 5., 6., 7. Description of the fish and invertebrate biomass indices: We present four guilds to indicate the status and trends for fish and invertebrates in the EBS: apex predators, pelagic foragers, benthic foragers, and motile epifauna. Each is described in detail below. The full guild analysis involved aggregating all EBS species included in a food web model (Aydin et al., 2007) into 18 guilds by trophic role, habitat, and physiological status (Table 2). For each guild, time trends of biomass are presented for 1977-2010. Catch and exploitation rate (catch/biomass) are presented for guilds with exploitation rates exceeding 0.0001. EBS biomass trends are summed stock assessment model estimates or scaled survey data, where available, for each species within the guild. If neither time series are available, the species is assumed to have a constant biomass equal to the mid-1990s mass balance level estimated in Aydin et al. (2007). Catch data was directly taken from the Catch Accounting System and/or stock assessments for historical reconstructions. Pie charts indicate the relative contribution of each data type to the average biomass within each guild (Figures 12 and 13). For 2011-2012 projections, the stock assessment authors' recommended catch and estimated biomass time series were used.

Table 2: Composition of foraging guilds in the eastern Bering Sea.

Motile epifauna	**Benthic foragers**	**Pelagic foragers**	**Fish apex predators**
Eelpouts	P. cod (juv)	W. pollock (juv)	P. cod
Octopuses	Arrowtooth (juv)	W. pollock	Arrowtooth
Tanner crab	P. halibut (juv)	P. herring (juv)	Kamchatka fl. (juv)
King crabs	Yellowfin sole (juv)	P. herring	Kamchatka fl.
Snow crab	Yellowfin sole	Gr. turbot (juv)	P. halibut
Sea stars	Flathead sole (juv)	Sablefish (juv)	Alaska skate
Brittle stars	Flathead sole	P. ocean perch	Large sculpins
Other echinoderms	N. rock sole (juv)	Sharpchin rockfish	
Snails	N. rock sole	Northern rockfish	
Hermit crabs	AK plaice	Dusky rockfish	
Misc. crabs	Dover sole	Other Sebastes	
	Rex sole	Atka mackerel (juv)	
	Misc. flatfish	Atka mackerel	
	Shortraker rockfish	Misc. fish shallow	
	Thornyhead rockfish	Squids	
	Greenlings	Salmon returning	
	Other sculpins	Salmon outgoing	
		Bathylagidae	
		Myctophidae	
		Capelin	
		Eulachon	
		Sandlance	
		Other pelagic smelts	
		Other managed forage	
		Scyphozoid jellies	

4. Motile epifauna (fish and benthic invertebrates): This guild includes both commercial and non-commercial crabs, sea stars, snails, octopuses, and other mobile benthic invertebrates. Information is based on bottom trawl survey data (for more information, see p. 146 and 152). There are ten commerical crab stocks in the current Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs; we include seven on the EBS shelf: two red king crab *Paralithodes camtschaticus* (Bristol Bay, Pribilof Islands), two blue king crab *Paralithodes platypus* (Pribilof District and St Matthew Island), one golden king crab *Lithodes aequispinus* (Pribilof Islands), and two Tanner crab stocks (southern Tanner crab *Chionoecetes bairdi* and snow crab *C. opilio*). The three dominant species comprising the eelpout group are marbled eelpout (*Lycodes raridens*), wattled eelpout (*L. palearis*) and shortfin eelpout (*L. brevipes*). The composition of sea stars in shelf trawl catches are dominated by the purple-orange sea star (*Asterias amurensis*), which is found primarily in the inner/middle shelf regions, and the common mud star (*Ctenodiscus crispatus*), which is primarily an inhabitant of the outer shelf. Stock assessments for crabs have not been included to date, but could be in the future.

Status and Trends: Current (2005-2010) mean biomass, catch, and exploitation rates have been within ±one standard deviation of 1977-2010 levels. No trend is apparent in recent years.

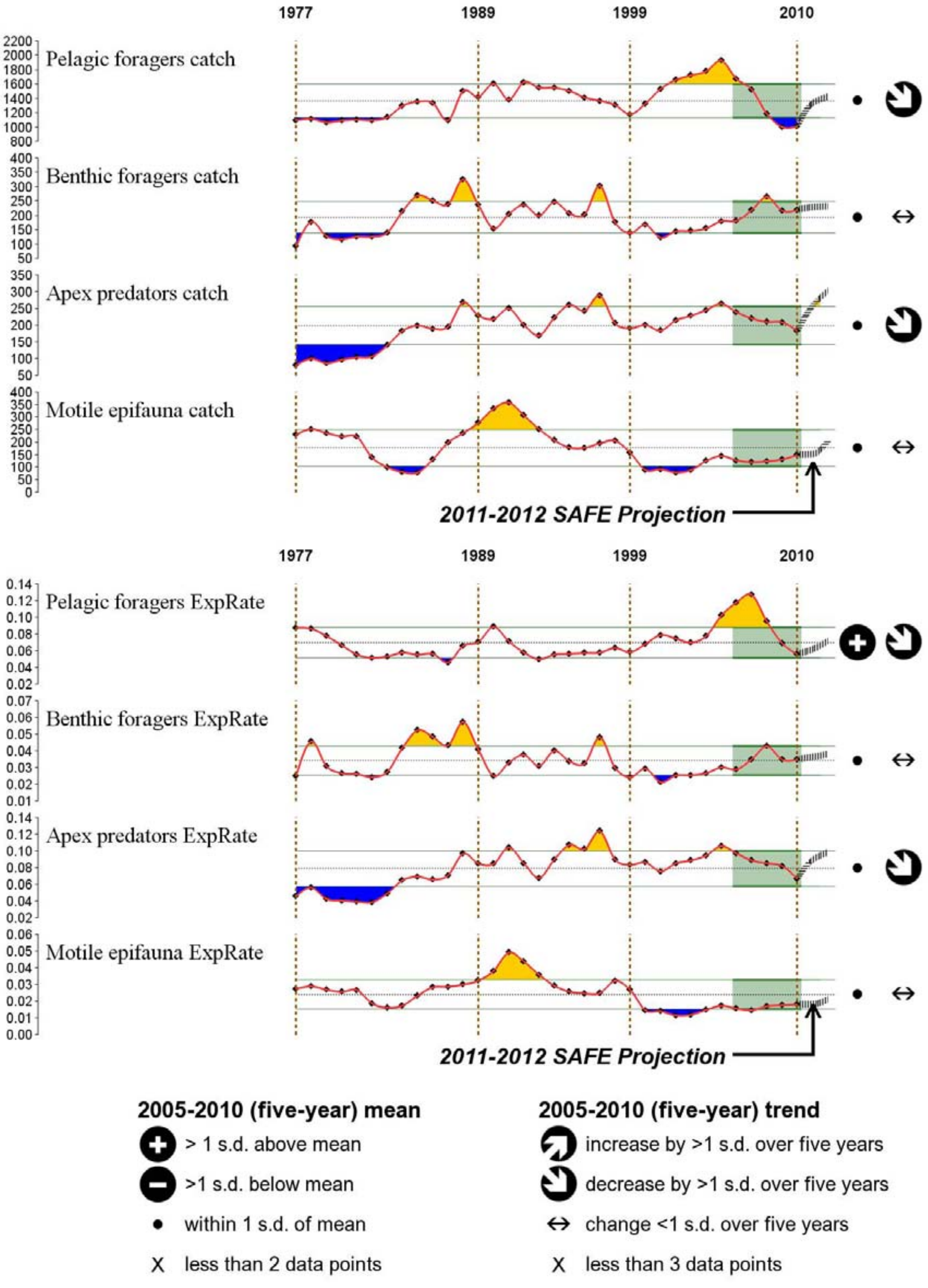

Figure 13: Guild-level catch and exploitation rates.

Factors causing trends: Fluctuations in commercial crab stocks have coincided with variable fishing pressure and changes in environmental conditions affecting benthic organisms in the eastern Bering Sea although no one cause has been identified to explain the wild fluctuations in some stocks and the precipitous decline from the 1970s and 1980s in other stocks. Bottom trawl survey data for the biomass dominants in this guild (eelpouts, brittle stars, sea stars and other echinoderms) has shown some similar patterns. With few exceptions, the trend in relative CPUE for all three species groups was very similar (Figure 60). Determining whether this trend represents a real response to environmental change or is simply an artifact of standardized survey sampling methodology will require more specific research on survey trawl gear selectivity and on the life history characteristics of these epibenthic species.

Implications: There is a concern with three of the commercial crab stocks in this guild which are overfished. However, the motile epifauna guild appears stable because the guild is dominated by non-target fish and invertebrate biomass.

5. Benthic foragers (fish only): The species which comprise the benthic foragers group are the Bering Sea shelf flatfish species, juvenile arrowtooth flounder and the sculpins. The major species of this group are surveyed annually and have abundances estimated by statistical models, therefore our confidence in their time-trend of abundance is high.

Status and Trends: The combined benthic foragers biomass trend indicate this group of species was at low levels in the late 1970s and then went through a period of increasing abundance which peaked in the early to mid 1990s after which they again declined moderately before increasing again to their present level of high biomass and stable biomass. Current (2005-2010) mean biomass, catch, and exploitation rates have been within ±one standard deviation of 1977-2010 levels. Increasing trends in benthic forager catch and exploitation rate reflect increased ABCs for flatfish species allowable under the 2 million metric ton OY cap with decreased pollock ABCs.

Factors causing trends: In general, the prey of the adults of these species includes bivalves, polychaetes, amphipods, mollusks and miscellaneous crustaceans. Information is not available to assess the abundance trends of the benthic infauna of the Bering Sea shelf. The original description of infaunal distribution and abundance by Haflinger (1981) resulted from sampling conducted in 1975 and 1976 and has not be re-sampled since. The large populations of benthic foragers which have occupied the middle shelf of the Bering Sea over the past thirty years for summertime feeding do not appear food-limited. These populations have fluctuated due to the variability in recruitment success which suggests that the primary infaunal food source has been at an adequate level to sustain their populations. Presence of these species in the stomachs of apex predators as adults is infrequent, although they are preyed upon as juveniles.

Implications: The benthic foragers guild appears stable and may not require further management action.

6. Pelagic foragers (fish and squid only): This guild includes adult and juvenile pollock, other forage fish such as herring, capelin, eulachon, and sandlance, pelagic rockfish, salmon, and squid. Information quality ranges from a sophisticated highly quantitative stock assessment for pollock (the biomass dominant in the guild) through relatively high variance EBS shelf survey data for forage fish, to no time series data for salmon and squid.

Status and Trends: Pelagic foragers have biomass below mean and exploitation rate above mean, and decreasing trends in biomass, catch, and exploitation rates.

Factors causing trends: The pelagic foragers guild is dominated by walleye pollock (77% of guild biomass in 2009), whose decrease with general declines in other forage species has brought the biomass of this group to overall low levels. Exploitation rate was over one standard deviation above the mean from 2004-2007, however the decreased catches in 2008 and 2009 have decreased the pelagic foragers exploitation rate back towards its long-term mean.

Implications: The pelagic foragers guild biomass is at a historic low, which has been a recent management concern. However, there are signs of recovery within the guild, as well as increased forage and positive physical conditions to support recovery (see Summary above). Continued caution with the management of species in this guild and continued monitoring may be necessary, but the outlook is improved from last year.

7. Apex predators (shelf fish only): This guild includes Pacific cod, arrowtooth flounder, Kamchatka flounder, Pacific halibut, Alaska skate, and large sculpins. Pacific cod and arrowtooth flounder time series are from stock assessments, and the remaining time series are from the annual EBS shelf bottom trawl survey.

Status and Trends: Current (2005-2010) mean biomass, catch, and exploitation rates have been within ± standard deviation of 1977-2010 levels.

Factors causing trends: The apex predator stability is driven largely by a decrease in Pacific cod biomass being offset by an increase in arrowtooth flounder biomass.

Implications: The fish apex predators guild appears stable and may not require further management action.

8. Thick-billed Murre Reproductive Success on St. George Island: The ideal indicator of seabird productivity in the Bering Sea would be a multivariate index representing all combinations of piscivores and planktivores, divers and surface feeders. The Synthesis Team will work toward this goal of a more synthetic seabird index in the future; however, for 2011 we have elected to choose a single sentinel species to represent seabird productivity on the Bering Sea shelf.

Our criteria for selection of a seabird indicator for 2011 were that the species should be a central-place forager during the nesting season and not migrate far outside of the Bering Sea during winter. We also wanted a species that forages in predominantly shelf waters. Seabirds nesting on the Pribilof Islands were the best fit within our geographic scope. Time series data collected by the USFWS -AMNWR on parameters such as reproductive success, breeding chronology (i.e. hatch date), and population counts are available for seabird species nesting on both St. Paul and St. George Islands (Shannon et al., 2010; McClintock et al., 2010).

Recent work on Pribilof murres and kittiwakes led by Kathy Kuletz, David Irons, and Daniel Roby as part of BEST-BSIERP provided more detailed information on foraging areas and behavior of murres and kittiwakes at sea which helped us to further refine our seabird indicator selection (`http://bsierp.nprb.org/results/progress.html`). St. Paul birds may forage more in middle shelf waters, but the population is so much larger on St. George Island that St. George Island birds that forage more on the outer shelf are probably a better choice to represent what is happening in the ecosystem. Thick-billed murres are a better choice to represent the Bering Sea ecosystem than common murres and black-legged kittiwakes because they stay in high latitudes all winter. Thick-billed murres are more closely tied to the colony during the breeding season while black-legged kittiwakes are more likely to travel off the shelf in search of food. Thick-billed murre reproductive success is relatively stable (usually about 50%) and would be better to look at long-term (decadal) trends in seabird productivity. Black-legged kittiwakes reproductive success is very sensitive and may have too much 'noise' to be as useful for detection of decadal-scale changes.

Thick-billed murres are central-place foragers of invertebrates and fish with relatively stable reproductive success and populations. Changes in their reproductive success on St. George Island where their population is large and stable could be a useful indicator of fundamental changes in prey availability in EBS shelf waters near the Pribilof Islands.

Status and Trends: Thick-billed murre reproductive success has increased during the past five years, concurrent with a colder Bering Sea, later ice retreat, and increased biomass of zooplankton on the outer shelf. Adult thick-billed murres have high proportions of invertebrates such as euphausiids, amphipods, and squid in their diets (Gaston and Hipfner, 2000), so would likely be more productive in conditions that favor planktivorous species than the more piscivorous common murres. Continued cold conditions in the Bering Sea will likely lead to favorable conditions for this species and a continued trend of higher reproductive success in 2011.

Implications: The population of thick-billed murres in Alaska is roughly 4.7 million in the Bering and Chukchi seas (Gaston and Jones, 1998). Potential threats to thick-billed murres nesting in the Bering Sea include climate change, fisheries bycatch, oiling, and introduced predators at nesting sites. Continued cold conditions in the Bering Sea will likely lead to favorable conditions for thick-billed murres nesting on St. George Island and a continued trend of higher reproductive success in 2011.

9. Fur seals pup production, St Paul: Pup production on St Paul was chosen as an index for pinnipeds on the eastern Bering Sea shelf because the foraging ranges of females that breed on this island are largely on the shelf, as opposed to St George which to a greater extent overlap with deep waters of the Basin and slope. Bogoslof females forage almost exclusively in pelagic habitats of the Basin and Bering Canyon and as such would not reflect foraging conditions on the shelf at all.

NMFS estimated that 120,800 pups were born on the Pribilof Islands in 2008: 102,674 (SE = 1,084) pups on St. Paul Island and 18,160 (SE = 288) on St. George Island. Pup production on St Paul Island has been declining since the mid-1990s (Figure 73; Towell et al. (2006)), while it has been relatively stable on St George since 2002. Estimated pup production on both Pribilof Islands in 2008 was similar to the level observed in 1916; however the population trend at the beginning of the 20th century was much different than at beginning of the 21st. In 1916, the northern fur seal population was increasing at approximately 8% per year following the cessation of extensive pelagic sealing, while currently (1998 through 2008), pup production on both Pribilof Islands is estimated to be decreasing at approximately 6% per year.

The recent trend in pup production on Bogoslof Island has been opposite of that observed on the Pribilofs (Figure 73). Pup production increased at approximately 20% per year on Bogoslof Island between 1995 and 2007. This rate is faster than what could be expected from a completely closed population of fur seals, indicating that at least some of it is due to females moving from the Pribilof Islands (presumably) to Bogoslof to give birth and breed. However, declines observed on the Pribilof Islands are much greater than the increase in numbers on Bogoslof, indicating that the decline on the Pribilofs cannot be due entirely to emigration. Differences in trends between the predominately shelf-foraging Pribilof fur seals and the predominately pelagic-foraging Bogoslof fur seals likely reflect differences in their summer foraging habitats, and are unlikely related to large-scale changes in the North Pacific Ocean (e.g., regime shifts, Pacific Decadal Oscillation), since these populations both occupy the same habitats in the North Pacific Ocean during the fall, winter and spring.

10. Area Disturbed by Bottom Trawls: Fishing gear can affect habitat used by a fish species for the processes of spawning, breeding, feeding, or growth to maturity. An estimate of the area of seafloor disturbed by trawl gear may provide an index of habitat disturbance. The area disturbed in the Eastern Bering Sea floor was calculated from observer trawl data each year from 1990-2009. An upper limit of the total area potentially disturbed by trawl hauls was estimated by assuming that no trawl hauls overlapped spatially. The percent of area disturbed was estimated in two ways: 1) with no spatial overlap of trawl hauls in a given year, providing an estimate of the maximum potential percent of area disturbed and 2) with spatial overlap of trawl hauls within 400 km^2 cells to limit the disturbance of trawls recorded in a cell to 400 km^2, providing an estimate of potential percent of area disturbed. The average distance of a haul based on recorded start and end locations is 14 km with a standard deviation of 10 km. The cell size was chosen to reflect this spatial resolution of the hauls.

Status and trends: The maximum total area of seafloor in the Eastern Bering Sea potentially disturbed by trawls varied around 120,000 km^2 in the 1990s and decreased in the late 1990s to approximately 90,000 km^2. The area disturbed remained relatively stable in the 2000s with a slight increase in the 2007-2008. The percent of total area disturbed varied between 10% and 15% in the 1990s and between 9% and 11% in the 2000s, however due to trawls overlapping the same area the more realistic area disturbed was less than 10% from the mid 1990s on. Reduction in hours fished in the 2000s indicates greater fishing efficiency.

Factors causing trends: Trends in seafloor area disturbed can be affected by numerous variables, such as individual fishery movements, fish abundance and distribution, management actions (e.g., closed areas), changes in the structure of the fisheries due to rationalization, increased fishing skills (e.g., increased ability to find fish), and changes in vessel horsepower and fishing gear. During 1993-1999, fishing effort was more concentrated in the southern area compared to 1990-1992 and 2000-2008, where effort was spread out spatially, particularly towards the northwest. This may, in part, explain the larger difference between the upper and lower estimates of percent area disturbed (with no overlap and with overlap within 400 km^2 cells, respectively) during 1993-1998 relative to other years. As of 1999 only pelagic trawls can be used in the Bering Sea pollock fisheries. To check to see if this affected the trends the graph was recalculated making no distinction between gears. The result showed no change to the trend. Short wiring was only identified in the database from 1995 onward, however short wiring accounts for only 2% of the total hauls and does not explain the early 1990 trends.

Implications: Without additional information, the decreasing trend in area disturbed is difficult to interpret as a fishing performance indicator for ecosystem-based fisheries management (see Gaps and needs, below).

Gaps and needs for future EBS assessments

Climate index development: We plan to develop a multivariate index of the climate forcing of the Bering Sea shelf in the near future. This index will likely have the NPI as one of its elements, but also incorporate variables related to the regional atmosphere including winds and temperatures. The primary application for this index, which has yet to be determined, will guide the selection of the exact variables, and the domains and seasons for which they will be considered. Three biologically significant avenues for climate index predictions include advection, setup for primary production, and partitioning of habitat with oceanographic fronts and temperature preferences.

Primary production time series: No suitable indicator for primary production is currently available. We are lacking direct measurements of primary production that could be assembled into a time series. We do, however, have indices of phytoplankton biomass. Our chlorophyll measurements are from M2, 70m isobath, and from satellites. Satellite (SeaWiFS) estimated chlorophyll (and productivity) go back to 1997 or 1998, but are spotty due to cloud cover. Continuous chlorophyll fluorescence measurements at M2 started in 1995. Stabeno is working on generating a fluorescence-to-chlorophyll conversion factor based on ground truth samples taken each year. These derived estimates will have a significant error, but satellites are no better because of data gaps due to cloud cover and surface-only data. Fluorescence at M2 was measured at 3 depths. The derived measurements may also allow us to estimate what percent of phytoplankton standing stock ends up on the seafloor.

In the future we would like to develop the ability to measure chlorophyll in sediments as is done for the Northern Bering Sea by Grebmeier and Cooper. It will be important to decide where such measurements should be taken. New production at M2 is thought to be low and may not be good for epibenthic fish. The location formerly occupied by M3 would have been good, but it was abandoned because boats kept running over the mooring there.

Some index of stratification may be a proxy for new production. We have stratification data for M2, but no primary production data to go with it.

Spatial scales for assessment: The team reviewed EBS bottom trawl survey data at the guild level to determine whether there were striking changes in distribution patterns over time. No patterns of immediate concern were detected; however, the team felt that including a thorough spatial investigation of key indices would be a high priority in upcoming assessments. For example, spatial distributions of zooplankton, benthos, and forage fish would be critical for predicting the foraging success of central place foragers such as seabirds and pinnipeds. It may be desirable to examine the selected indices by domain (e.g., outer, middle, and inner shelf) rather than EBS-wide. Distributional indices could be developed for foraging guilds, indicator species, and fisheries (see below) similar to some already presented in the Ecosystem Considerations SAFE (e.g. Mueter et al. on p. 186). In addition, an index of cold-pool species or other habitat specific groups could be developed and tracked. Spatially explicit indicators could be used to investigate observed patterns such as the relative success of commercial crabs in Bristol Bay versus further out on the EBS shelf.

Considerable work is already underway to address processes at different spatial scales, in particular for central place foragers. NMML has the following active fur seal research programs at the Pribilof Islands:

1. Bienniel pup production estimation at each rookery

2. Adult female summer foraging, physiology and energy transfer to pup with specific focus on differences by rookery and foraging habitat in the eastern Bering Sea
3. Adult female and pup over-winter satellite tracking to determine foraging and pelagic habitat differences by year and rookery
4. Pup and adult female tagging to determine fur seal survival and reproductive rates

These programs have been underway since the early 2000s, but particularly in the case of item 4 above, take many years (e.g., decades to determine reproductive rates of such a long-lived species) to produce results. NMML needs to continue this field work, and couple it with habitat and ecosystem models to help us understand the differences in fur seal population responses between Bogoslof and the Pribilof Islands, and differences in responses between air-breathing and fish apex predator responses over the last 20 years.

Differences in Steller sea lion population response between the Pribilofs and the eastern Aleutian Islands also requires further research, and may be related to spatial-temporal distribution and abundance of prey.

Fishery performance index needed: Several measures of the performance of current management relative to the goals and objectives of the NPFMC should be considered. An obvious candidate is an index of the catch relative to the TAC, ABC and OFL. The phase diagram showing the distribution of current biomass/Bmsy and catch / OFL provides a quick assessment of whether the stock is overfished or whether overfishing is occurring. However, for some stocks, the TAC is set well below the ABC and OFL. Therefore an assessment of whether the TAC is fully utilized may serve as a better indicator of the performance of the fishery relative to the predicted level of catch. Likewise, catch relative to TAC may be a useful indicator for the efficiency of pollock because the 2 million t cap constrains this fishery when the stock is in high abundance.

Other measures of net income or revenue might be considered as fishery performance indicators. For example, when stocks are low, the price may increase, this may compensate for longer search time. Thus, when pollock is at a high abundance, and search time is low, the price per pound may be lower than when pollock are scarce.

Integration with stock assessments: Ecosystem indicators specific to stocks and ABC decisions within single species stock assessments will be developed in a separate workshop, to be scheduled in early 2011. However, integration of the stock assessments and this ecosystem assessment will continue to be developed. The group noted that dominant species often dictate the time trend in aggregate indicators. Several times the group strayed into conversations that were focused on relationships between a select group of species. It is important that the synthesis chapter is dynamically linked to the single species ecosystem assessments so that specifics on how climate impacts dominant species, their prey, and their distribution can be readily obtained if a person wishes to drill down to the single species interactions underlying the guild responses provided.

The development of predictive models for single species or a small group of interacting species (e.g. multispecies stock assessments) is moving ahead at a rapid pace. Some stock assessments already include forecasts that incorporate climate forcing and efforts to address predation on natural mortality rate and prey availability on growth are currently underway. As noted above it will be important to provide a dynamic link between the description of these innovations to stock assessments and the synthesis chapters. We expect that description of the models will continue to appear in the stock assessment. This will allow a thorough review of the mathematical formulations used to depict the relationships between predators, prey, competition and environmental disturbance within the assessment.

Future use of ecosystem/climate models in development: Several reviews of the utility of ecosystem models are available. Hollowed et al (in press) examined which quantitative modeling tools were needed to support an Ecosystem Approach to Management (EAM) in the EBS. This review revealed that a diverse suite of models were utilized to support an EAM in the EBS (Table 3). Single-species stock assessment and projection models are the most commonly used tools employed to inform managers. Comprehensive assessments (e.g. Management Strategy Evaluation) are emerging as a new and potentially valuable modeling approach for use in assessing trade-offs of different strategic alternatives. In the case of management in the Eastern Bering Sea, end-to-end models and coupled biophysical models have been used primarily to advance scientific understanding, but have not been applied in a management context. In future synthesis attempts, we will add a section that brings forward predictions from different models to initiate an evaluation of the predictive skill of different assessment tools.

Table 3: Suite of models used for implementation of an ecosystem approach to management in the Bering Sea (From Hollowed et al. (In Press)).

Model	**Application**	**Issue**	**Example reference**
Stock assessment models	Tactical	Evaluate stock status	Ianelli (2005); Methot (2005)
Stock projection models	Tactical	Assessing overfished condition	Turnock and Rugolo (2009)
Management strategy evaluation	Strategic	Assessing the performance of a harvest strategy	A'mar et al. (2008); NOAA (2004)
Habitat assessment	Strategic	Evaluating the long-term impact of fishing on EFH	Fujioka (2005)
Multispecies Yield-per-recruit	Strategic	Assessing the implications of prohibited species caps	Spencer et al. (2002)
Multispecies technical interaction model	Strategic	Assessing the performance of harvest strategies on combined groundfish fisheries	NOAA (2004)
Coupled biophysical models	Research	Assessing processes controlling recruitment and larval drift	Hinckley et al. (2009)
Integrated Ecosystem Assessments	Strategic	Assessing ecosystem status	Boldt and Zador (2009)
Mass Balance models	Strategic	Describing the food-web	Aydin et al. (2007)
Dynamic food web models	Strategic	Describing trade-offs of different harvest strategies through food-web	Aydin et al. (2007)
FEAST	Strategic	End-to-end model	

Gulf of Alaska

Objective: Maintain predator prey relationships and energy flow

Indicator: Biomass, catch, and exploitation rates of ecological guilds

Contributed by Kerim Aydin and Sarah Gaichas

Index All species included in food web models (Aydin et al., 2007) were aggregated into 12 guilds by trophic role. The guilds span the trophic levels between phytoplankton and apex predators and include a separate pathway for pelagic and benthic components of the ecosystem (Table 4). For each guild, time trends of biomass are presented for 1977-2009. Catch and exploitation rate (catch/biomass) are presented for guilds with exploitation rates exceeding 0.0001. Differences in time series data availability led to different methods for EBS and GOA ecosystem guild analysis. Inconsistencies in the GOA trawl survey time series in depth and area surveyed made ecosystem model fits to trends more reasonable than summing scaled survey data. The GOA ecosystem model was forced by stock assessment model estimates where available for each species within the guild, and fit to survey time series, catch data, groundfish diet data, and the mid-1990s mass balance for all other species. In both regions, catch data was directly taken from the Catch Accounting System and/or stock assessments for historical reconstructions. Pie charts indicate the relative contribution of each data type to the average biomass within each guild (Figure 14). For 2010-2011 projections from the 2009 SAFE, the stock assessment authors recommended catch and estimated biomass time series were used in both regions.

Status and trends Current (2004-2009) mean biomass is more than one standard deviation above 1977-2009 mean levels for apex predators and benthic foragers, and trends for catch and exploitation rate are also increasing for these guilds. The apex predator guild is driven by the stock assessment-estimated increase in arrowtooth flounder, and to a lesser extent in Pacific halibut and Pacific cod, while the benthic forager guild is driven by a stock assessment-estimated increase in flathead sole and survey trends for increasing skates and flatfish. In contrast, pelagic foragers recent mean biomass is one standard deviation below the long term mean, driven by the stock assessment estimated decline in pollock. Catch and exploitation rates for pelagic foragers remain within one standard deviation of the long term mean (Figure 15). GOA shrimp are above long term mean biomass, a trend which agrees with trawl survey results. Based on assessment and survey results for the data rich guilds, current status of infauna is estimated to be below long term average; structural epifauna, mesozooplankton, and copepods are predicted to be above long term average; and pelagic primary production remains close to the long term average.

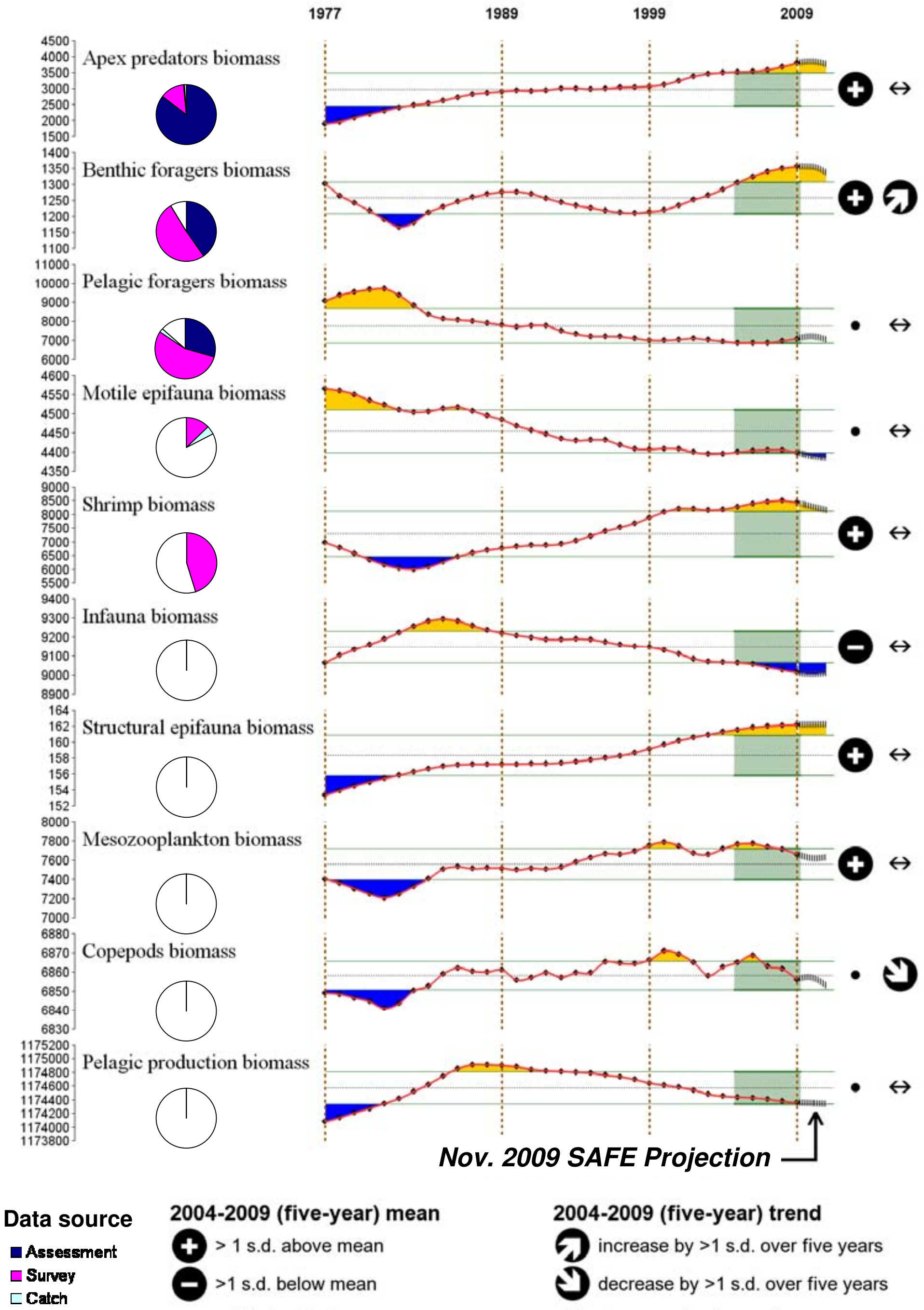

Figure 14: Gulf of Alaska trophic guild analysis, Nov 2009.

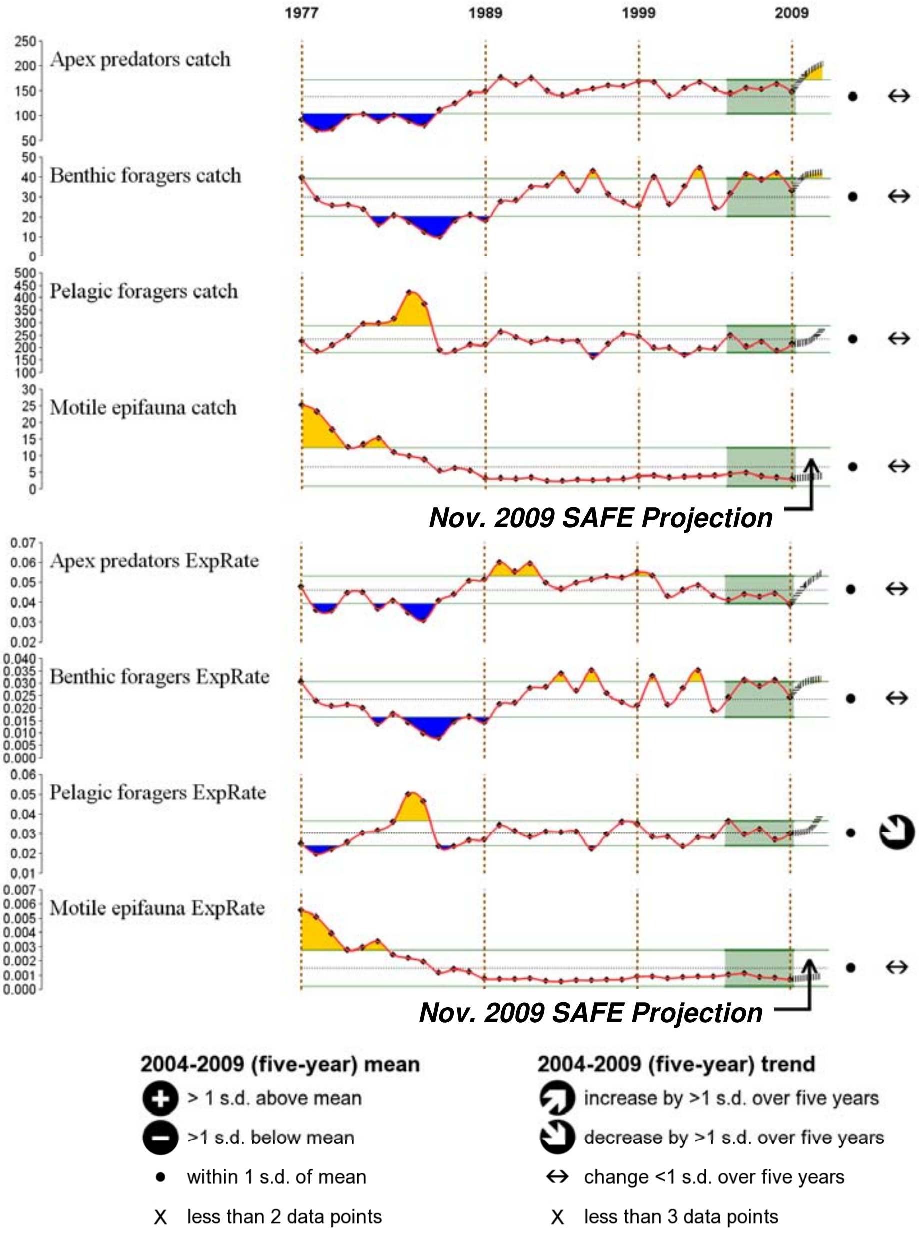

Figure 15: Gulf of Alaska trophic guild analysis, Nov 2009.

Table 4: Composition of GOA foraging guilds.

Apex predators	**Pelagic foragers**	**Benthic foragers**	**Shrimp**
Arrowtooth	Capelin	Other sculpins	Non-Pandalid shrimp
P. cod	Sandlance	Flathead sole	Pandalidae
P. halibut	Squids	Dover sole	
Grenadiers	Other managed forage	S. rock sole	**Structural epifauna**
Sablefish	Eulachon	Rex sole	Urochordata
Rougheye rockfish	P. ocean perch	Yellowfin sole	Hydroids
Large sculpins	Misc. fish shallow	N. rock sole	Sponges
Dogfish	W. pollock	Misc. flatfish	Anemones
Sperm whales	Salmon returning	P. cod (juv)	Corals
Longnose skate	Other pelagic smelt	Flathead sole (juv)	Sea Pens
Other skates	Myctophidae	Big skate	
Misc. fish deep	W. Pollock (juv)	Arrowtooth (juv)	**Infauna**
Salmon shark	Atka mackerel	Shortraker rockfish	Bivalves
Porpoises	Northern rockfish	Gray whale	Benthic amphipods
Sleeper shark	Sharpchin rockfish	Thornyhead rockfish	Polychaetes
N. fur seal	P. herring	Alaska plaice	Misc. worms
Steller sea lion	Fin whale	Greenlings	Misc. Crustaceans
Puffins	Herring (juv)	P. halibut (juv)	
Murres	Dusky rockfish	Thornyhead rockfish (juv)	**Copepods**
Sea otters	Humpback whale		
Resident seals	Atka mackerel (juv)	**Motile epifauna**	**Mesozooplankton**
Minke whales	Scyphozoid jellies	Brittle stars	Euphausiids
Resident killer whale	Other Sebastes	Hermit crabs	Pelagic amphipods
Kittiwakes	Bathylagidae	Misc. crabs	Gelatinous filter feeders
Fulmars	P. ocean perch (juv)	Other echinoderms	Pteropods
Gulls	Sei whale	Eelpouts	Chaetognaths
Cormorants	Salmon outgoing	Snails	Mysids
N. fur seal (juv)	Sablefish (juv)	Octopi	Fish larvae
Transient killer whale	Right whale	Tanner crab	
Shearwater	Auklets	Sea stars	**Pelagic production**
Storm petrels		King crabs	Small phytoplankton
Albatross and Jaegers			Large phytoplankton
Steller sea lion (juv)			Macroalgae

Objective: Maintain habitat

Indicator: HAPC biota catch

See 2010 contribution by Sarah Gaichas (p. 190, this document)

Index In addition to prohibited and target species catches, groundfish fisheries also catch non-target species. HAPC biota (seapens/whips, sponges, anemones, corals, tunicates) comprise a portion of the non-target species catches. HAPC biota are taxa which form living substrate, and are identified by NMFS as meeting the criteria for special consideration in resource management. HAPC biota are used by fish, including commercially important groundfish, as habitat. Bycatch of HAPC species in both trawl and longline gear is of concern. Concentrations of HAPC species often occur in nearshore shallow areas but also are found in offshore deep water areas with substrata of high microhabitat diversity. Trends in fishery catches of HAPC biota may be indicators of total HAPC biota removals. In addition to tracking removal of HAPC biota, fishery catches of HAPC biota may also reflect changes in management actions, fishing effort, the spatial distribution of the fishery, and/or in HAPC biota abundance; however, distinguishing between these is not possible and not the purpose of this index here. Catches are estimated based on visual observations by observers rather than from direct sampling; therefore, may be less accurate than target fish catch estimates.

Status and trends Among the three ecosystems, Catches of HAPC biota are highest in the EBS, intermediate in the AI and lowest in the GOA. Estimated GOA HAPC catches for 1997-2007 range from 15 to 62 t and shows no trends, although uncertainty in these numbers is currently not calculable and may be high. The highest estimated catch of 62 t was in 2009.

Factors causing trends Sea anemones comprise the majority of the variable but generally low HAPC biota catch in the GOA and they are caught primarily in the flatfish fishery. The catch of nontarget species may change if fisheries change, if ecosystems change, or both. Because nontarget species catch is unregulated and unintended, if there have been no large-scale changes in fishery management in a particular ecosystem, then large-scale signals in the nontarget catch at may indicate ecosystem changes. Catch trends may be driven by changes in biomass or changes in distribution (overlap with the fishery) or both.

Implications Overall, the catch of HAPC species in all three ecosystems is very low compared with the catch of target and non-specified species. Unless HAPC catch in the GOA is highly localized and/or drastically underestimated, it does not appear to pose a management concern at the regional scale.

Indicator: HAPC biota survey catch-per-unit-effort

See 2009 contribution by Michael Martin in the “Assessment Archives” at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Index HAPC biota are taxa that form living substrate which are used by fish, including commercially important groundfish, as habitat. HAPC biota include seapens/whips, sponges, anemones, corals, and tunicates. NMFS bottom trawl survey catches of HAPC biota provide one potential indicator of HAPC biota abundance trends. Sampling is done biennially in the GOA. This is, however, not the ideal indicator of abundance trends because the survey gear is not designed for efficient capture of all HAPC biota, it does not perform well in many of the areas where these groups are thought to be more prevalent and survey effort is quite limited in these areas as a result, catches are highly variable, and the survey gear and onboard sampling techniques have changed over time. Examination of the frequency of occurrence in hauls may address some of these issues (see HAPC biota for the three regions, this report).

Status and trends Despite the caveats, a few general patterns are clearly discernible. HAPC biota CPUE in the GOA have been relatively low and stable, with a slight decline during the last 4 survey years. The frequency of occurrence of sponge and sea anemones in the GOA, however, seems to have increased since 1984.

Factors causing trends Sea anemone and sponge CPUE drive trends observed in the GOA. Prior to 1990, Japanese vessels using large tire gear performed the majority of tows in the GOA. This allowed these vessels to sample in areas considered untrawlable with current survey gear, so damage to HAPC biota likely exceeded later years, even though catches were generally smaller. This gear difference is thought to largely account for the abrupt change in relative abundance patterns after 1987. There are also regional trends within the ecosystem (see HAPC biota for the three regions, this report).

Implications Survey catches of HAPC biota may not necessarily reflect population abundance trends; therefore, the implications of survey catch trends of HAPC biota are largely unknown. The population trends of HAPC biota are not necessarily represented by survey catches because surveys are currently unable to devote effort to sampling untrawlable areas that have the highest HAPC biota abundance.

Aleutian Islands

Objective: Maintain habitat

Indicator: HAPC biota catch

See 2010 contribution by Sarah Gaichas (p. 190, this document)

Index In addition to prohibited and target species catches, groundfish fisheries also catch non-target species. HAPC biota (seapens/whips, sponges, anemones, corals, tunicates) comprise a portion of the non-target species catches. HAPC biota are taxa which form living substrate, and are identified by NMFS as meeting the criteria for special consideration in resource management. HAPC biota are used by fish, including commercially important groundfish, as habitat. Bycatch of HAPC species in both trawl and longline gear is of concern. Concentrations of HAPC species often occur in nearshore shallow areas but also are found in offshore deep water areas with substrata of high microhabitat diversity. Trends in fishery catches of HAPC biota may be indicators of total HAPC biota removals. In addition to tracking removal of HAPC biota, fishery catches of HAPC biota may also reflect changes in management actions, fishing effort, the spatial distribution of the fishery, and/or in HAPC biota abundance; however, distinguishing between these is not possible and not the purpose of this index here. Catches are estimated based on visual observations by observers rather than from direct sampling; therefore, may be less accurate than target fish catch estimates.

Status and trends Among the three ecosystems, Catches of HAPC biota are highest in the EBS, intermediate in the AI and lowest in the GOA. Estimated AI HAPC catches for 1997-2007 range from 97 to 252 t and shows no trends, although uncertainty in these numbers is currently not calculable and may be high. The highest estimated catch of 252 t was in 2007.

Factors causing trends HAPC biota catch has been variable over time in the AI, and is driven primarily by sponges caught in the trawl fisheries for Atka mackerel, rockfish and cod. The catch of nontarget species may change if fisheries change, if ecosystems change, or both. Because nontarget species catch is unregulated and unintended, if there have been no large-scale changes in fishery management in a particular ecosystem, then large-scale signals in the nontarget catch at may indicate ecosystem changes. Catch trends may be driven by changes in biomass or changes in distribution (overlap with the fishery) or both.

Implications Overall, the catch of HAPC species in all three ecosystems is very low compared with the catch of target and non-specified species. Unless HAPC catch in the AI is highly localized and/or drastically underestimated, it does not appear to pose a management concern at the regional scale.

Indicator: HAPC biota survey catch-per-unit-effort

See 2010 contribution by Michael Martin (p. 112, this document)

Index HAPC biota are taxa that form living substrate which are used by fish, including commercially important groundfish, as habitat. HAPC biota include seapens/whips, sponges, anemones, corals, and tunicates. NMFS bottom trawl survey catches of HAPC biota provide one potential indicator of HAPC biota abundance trends. However, he biennial survey in the Aleutian Islands (AI) does not sample any of the HAPC fauna well. The survey gear does not perform well in many of the areas where these groups are likely to be more abundant and survey effort is quite limited in these areas. In tows where they are encountered, the standard survey gear is ill-suited for efficient capture of these groups. As a result, CPUE is often strongly influenced by a very small number of catches with a resulting high variance. In recent years, more emphasis has been placed on the collection of more detailed and accurate data on HAPC species and it is likely that this increased emphasis influenced the results presented here. Examination of the frequency of occurrence in hauls may address some of these issues (see HAPC biota for the three regions, this report).

Status and trends Despite the caveats, a few general patterns are clearly discernible (Figure 34). Sponges are caught in most tows in the Aleutians west of the southern Bering Sea. Interestingly, the frequency of occurrence of sponges in the southern Bering Sea is relatively high, but sponge abundance is much lower than other areas. The sponge estimates for the 1983 and 1986 surveys are much lower than other years, probably due to the use of different gear, including large tire gear that limited the catch of most sponges. Stony corals are commonly captured outside of the southern Bering Sea and their abundance appears to be highest in the central and eastern Aleutians. Soft corals are caught much less frequently and the survey likely does not provide a reliable estimate of soft coral abundance. Sea anemones are also common in survey catches but abundance trends are not clear for most areas. Sea pens are much more likely to be encountered in the southern Bering Sea and eastern AI than in areas further west. Abundance estimates are low across the survey area and large apparent increases in abundance, such as that seen in the eastern AI in 1997, are typically based on a single large catch.

Factors causing trends Prior to 1990, Japanese vessels using large tire gear performed the majority of tows in the AI. This allowed these vessels to sample in areas considered untrawlable with current survey gear. This gear difference is thought to largely account for the abrupt change in relative abundance patterns after 1987.

Implications Survey catches of HAPC biota may not necessarily reflect population abundance trends; therefore, the implications of survey catch trends of HAPC biota are largely unknown. The population trends of HAPC biota are not necessarily represented by survey catches because surveys are currently unable to devote effort to sampling untrawlable areas that have the highest HAPC biota abundance, especially in the AI.

Indicators common to all ecosystems

Objective: Maintain predator prey relationships and energy flow

Indicator: Trophic level of the catch

See 2010 contribution by Jennifer Boldt and Pat Livingston (p. 204, this document)

Index An index that has been suggested as a measure of overall top-down control of the ecosystem due to fishing is the trophic level of the fishery; in particular, the notion of fishing down the food web has been popularized in recent years. The trophic level of the catch and the Fishery in Balance (FIB) indices have been monitored in the BS, AI, and GOA ecosystems to determine if fisheries have been“fishing-down” the food web by removing top-level predators and subsequently targeting lower trophic level prey. The FIB index was developed by Pauly et al. (2000) to ascertain whether trophic level catch trends are a reflection of deliberate choice or of a fishing-down the food web effect. This index declines only when catches do not increase as expected when moving down the food web (i.e., lower trophic levels are more biologically productive), relative to an initial baseline year. The single metrics of TL or FIB indices, however, may hide details about fishing events.

Status and trends Although there has been a general increase in the amount of catch since the late 1960s in all three areas of Alaska, the trophic level of the catch has been high and relatively stable over the last 25 years.

Factors causing trends In general, it appears that fishing events on different species are episodic in the AI and GOA, while pollock steadily dominate catches in the BS throughout the period (Figure 109).

Implications Stability in the trophic level of the total fish and invertebrate catches and FIB indices in the EBS, AI, and GOA indicate that the "fishing-down" effect is not occurring in these regions. Further examination supports the idea that fishing-down the food web is not occurring in Alaska, and there does not appear to be a serial addition of lower-trophic-level fisheries in the EBS or GOA.

Indicator: Bycatch of sensitive top predators

See contributions by Elizabeth Sinclair and Shannon Fitzgerald in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Index Groundfish fishery bycatch of sensitive species such as marine mammals and seabirds provides an index of the total fishery removal of top predators in ecosystems.

Status and trends Incidental mortality of pinnipeds in groundfish fisheries was low from 1998-2005, and did not exceed PBRs, and are not expected to have a direct effect on the population status of pinnipeds (Sinclair et al., 2006). Between 1998 and 2005, an average of 24 harbor seals was taken annually in fisheries in both SEAK and the GOA, and an average of 1 was taken in the EBS (Sinclair et al., 2006). An annual average of 2.6 and 24.6 Steller sea lions were taken in the Eastern and Western Pacific (Sinclair et al., 2006). Sixteen Northern fur seals on average were taken in the East North Pacific annually (Sinclair et al., 2006).

Most seabird bycatch is taken with longline gear (65-94%), although some bycatch is taken with trawls (6-35%) or pots (1%). The average annual longline bycatch of seabirds is comprised of primarily fulmars, gulls, and some unidentified birds, albatross, and shearwaters. Of the total longline seabird bycatch in 2004, 94.3% was caught in the EBS, 2.5% in the AI, and 3.2% in the GOA. Pots catch primarily Northern fulmars, whereas trawl and longline fisheries catch a wider variety of seabirds. In 2002, total catch of seabirds was 4,694 in the EBS, 124 in the AI, and 161 in the GOA (Fitzgerald et al., 2006). Between 1993 and 2004 the average annual bycatch in the combined Alaskan longline fisheries was 13,144 birds (Fitzgerald et al., 2006). Over this period the average annual bycatch rates (birds per 1,000 hooks) were 0.065 in the AI and EBS areas and 0.021 in the GOA (Fitzgerald et al., 2006). Those rates have dropped in the last few years, with the running 5-year average now (2000-2004) at 0.035, 0.036, and 0.010 for the AI, EBS, and GOA regions respectively.

Catch of spiny dogfish in groundfish fisheries varies spatially and temporally. Catches of spiny dogfish were highest in 1998 and 2001 in many areas of the central and western GOA and Prince William Sound Courtney et al. (2004); Boldt (2003). Spiny dogfish catch in the EBS was low, but also peaked in 2001. Bycatch in the EBS is primarily from along the Alaska Peninsula and along the EBS shelf Courtney et al. (2004); Boldt (2003). There was no apparent temporal pattern in sleeper shark bycatch in the GOA or PWS Courtney et al. (2004); Boldt (2003). Bycatch in the EBS was lower and concentrated along the EBS shelf. EBS sleeper shark bycatch in 2001 was the highest since 1997 Courtney et al. (2005); Boldt (2003). Courtney et al. (2005) state that: "a 2% reduction in biomass per year due to fishing is likely less than natural mortality for Pacific sleeper sharks, unless they are extremely long lived. Based upon this risk criterion, Pacific sleeper sharks do not appear to be at risk of overfishing at current levels of incidental catch."

Factors causing trends Trends in bycatch may reflect changes in populations due to environmental and/or biological factors, but could also be due to changes in management and bycatch avoidance measures. Also, seabird mortality in Alaska groundfish fisheries represents only a portion of the fishing mortality that occurs, particularly with the albatrosses.

Indicator: Discards and discard rates

See 2010 contribution by Terry Hiatt (p. 189, this document)

Index Estimates of discards for 1994-2002 come from NMFS Alaska Region's blend data; estimates for 2003-09 come from the Alaska Region's catch-accounting system. It should be noted that although these sources provide the best available estimates of discards, the estimates are not necessarily accurate because they are based on visual observations by observers rather than data from direct sampling.

Status and trends In 1998, the amount of managed groundfish species discarded in federally-managed Alaskan groundfish fisheries dropped to less than 10% of the total groundfish catch in both the Eastern Bering Sea (EBS) and the Gulf of Alaska (GOA) (Figure 88). Discards in the Gulf of Alaska increased somewhat between 1998 and 2003, declined in 2004 and 2005, and have increased again during the last four years. Discard rates in the Aleutian Islands (AI) dropped significantly in 1997, trended generally upwards from 1998 through 2003, and have declined again over the last six years. As in the EBS and the GOA, both discards and discard rates in the AI are much lower now than they were in 1996.

Factors causing trends Discards in both the EBS and the GOA are much lower than the amounts observed in 1997, before implementation of improved-retention regulations. These decreases are explained by reductions in the discard rates of pollock and Pacific cod that resulted from regulations implemented in 1998 prohibiting discards of these two species. The decline in discards in both the AI and the EBS in 2008, which continued into 2009 in the EBS, is largely due to enactment of improved retention/utilization regulations by the NPFMC for the trawl head-and-gut fleet.

Indicator: Invasive species observations

Index Invasive species are those that are not native to Alaska and that could harm the environment, economics, and/or human health of the region (Fay, 2002). The main marine invasive species that are in Alaska or that could potentially be introduced to Alaska include: Atlantic salmon (*Salmo salar*), green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), oyster spat and associated fauna, bacteria, viruses, and parasites.

Status and trends Currently, Alaska has relatively few aquatic (including marine) invasive species. Natural spawning of escaped Atlantic salmon has been observed in British Columbian streams, indicating that this could also occur in Alaska. Chinese mitten crab, native to China, is now established in California and may have spread to the Columbia River (Fay, 2002). Uncertified oyster spat that is imported to Alaska for farming purposes can introduce not only oyster spat (although it is thought that Alaskan waters are too cold for oysters to reproduce), but also other invertebrate larvae, bacteria and viruses (Fay, 2002).

Factors causing trends The introduction of aquatic invasive species in Alaska can occur in a number of ways, such as those that (Fay, 2002) lists, including: "fish farms, the intentional movement of game or bait fish from one aquatic system to another, the movement of large ships and their ballast water from the United States West Coast and Asia, fishing vessels docking at Alaskas busy commercial fishing ports, construction equipment, trade of live seafood, aquaculture, and contaminated sport angler gear brought to Alaskas world-renowned fishing sites."

Implications The potential implications of introductions of non-native species to Alaska marine ecosystems are largely unknown. Fay (2002), however, states: "It is thought Atlantic salmon would most likely compete with native steelhead, cutthroat trout, Dolly Varden, and coho salmon, and may also adversely impact other species of Pacific salmon." The green crab, which is capable of surviving in Alaskan nearshore waters, could pose a competitive threat to Alaskan tanner and Dungeness crab stocks since they utilize the same nearshore areas as nurseries. Fay (2002) states: With a catadromous life history [the Chinese mitten crab] can move up rivers hundreds of miles where it may displace native fauna, and it is known to feed on salmonid eggs, which could affect salmon recruitment. Fay (2002) states: "Little is known about the threat of the movement of bacteria, viruses, and parasites within or to Alaska. Devastations from the Pacific herring virus in PWS is well known and documentedmovement of ballast water from one place to another within Alaska coastal waters could result in injury to other fisheries. Atlantic Ocean herring disease could also be introduced into Alaska through the import of frozen herring that are used as bait by Alaskan commercial fishers."

Gaps in predator-prey relationship knowledge common to all ecosystems

Information or indicators that would improve our understanding of predator-prey relationships in Alaska marine ecosystems includes:

1. a time series of zooplankton biomass in the GOA and AI

2. a time series of forage fish species in all areas
3. an indicator of the degree of spatial and temporal concentration of groundfish fisheries

Objective: Maintain diversity

Indicator: Groundfish status

See 2010 contribution by Jennifer Boldt (p. 209, this document)

Index The Fish Stock Sustainability Index (FSSI) is a performance measure for the sustainability of fish stocks selected for their importance to commercial and recreational fisheries (`http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`). The FSSI will increase as overfishing is ended and stocks rebuild to the level that provides maximum sustainable yield. The FSSI is calculated by assigning a score for each fish stock based on the following rules:

1. Stock has known status determinations:
    (a) overfishing 0.5
    (b) overfished 0.5
2. Fishing mortality rate is below the overfishing level defined for the stock 1.0
3. Biomass is above the overfished level defined for the stock 1.0
4. Biomass is at or above 80% of maximum sustainable yield (MSY) 1.0 (this point is in addition to the point awarded for being above the "overfished" level)

The maximum score for each stock is 4. The value of the FSSI is the sum of the individual stock scores. In the Alaska Region, there are 35 FSSI stocks and an overall FSSI of 140 would be achieved if every stock scored the maximum value, 4. There are also 25 non-FSSI stocks in Alaska. There are 230 FSSI stocks in the U.S., with a maximum possible score of 920.

Status and trends The current overall Alaska FSSI for FSSI stocks is 125 of a possible 140 score, based on updates through October 2010 (Table 14). The overall Bering Sea/Aleutian Islands score is 78 of a possible maximum score of 88. The BSAI groundfish score is 51 of a maximum possible 52 and BSAI king and tanner crabs score 27 of a possible score of 36. The Gulf of Alaska groundfish score is 43 of a maximum possible 48. The sablefish, which are managed as a BSAI/GOA complex, score is 4. For the entire U.S., the score is 582.5 of a possible maximum score of 920.

Table 5: Summary of status for FSSI and non-FSSI stocks managed under federal fishery management plans off Alaska, October 2010.

Jurisdiction	Stock Group	Number of Stocks	Overfishing				Overfished				Approaching Overfished Condition
			Yes	No	Unk	Undef	Yes	No	Unk	Undef	
NPFMC	FSSI	35	0	35	0	0	1	29	0	4	1
NPFMC and IPHC	NonFSSI	28	0	20	1	7	0	3	3	22	0
	Total	63	0	55	1	7	1	32	3	26	1

Factors causing trends As of October 2010, no BSAI or GOA groundfish stock or stock complex is overfished and no BSAI or GOA groundfish stock or stock complex is being subjected to overfishing (Table 5). One crab stock is considered overfished: Pribilof Island blue king crab. Two stocks of crabs are under continuing rebuilding plans: BS snow crab (year 10 of 10 year plan) and Pribilof Island blue king crab (year 7 of 10 year plan). The Bering Sea southern tanner crab stock is approaching an overfished condition. Halibut is a major stock (but a non-FSSI stock, since it is jointly managed by PFMC and NPFMC) that is not subject to overfishing, is not approaching an overfished condition, and is not considered overfished. The stocks that had low FSSI scores (1.5) are the GOA shortspine thornyhead rockfish complex, the GOA demersal shelf rockfish complex, the AI golden king crab, and Western AI red king crab. The reasons for these low scores are that it is undefined whether these species are overfished and unknown if they are approaching an overfished condition.

Implications The majority of Alaska groundfish fisheries appear to be sustainably managed.

Indicator: Number of endangered or threatened species

See 2010 contributions by Lowell Fritz (p. 162 and 165, this document), Marcia Muto (p. 168, this document), and by Shannon Fitzgerald, Kathy Kuletz, Elizabeth Sinclair, and Ward Testa in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Index Another measure of diversity in ecosystems in the number of species that are listed as threatened or endangered through the Endangered Species Act (ESA). The list of threatened and endangered species below was reported on the U.S. Fish and Wildlife service (`http://ecos.fws.gov/tess_public//pub/stateListingAndOccurrence.jsp?state=AK`, June 23, 2010) and on the NOAA Fisheries Office of Protected Resources (`http://www.nmfs.noaa.gov/pr/species/mammals/`, August 22, 2008) websites. To have a proactive approach to the conservation of species, we also list species of concern, which are those species about which NOAA's National Marine Fisheries Service (NMFS) has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the Endangered Species Act (ESA). Depleted stocks are those listed under the Marine Mammal Protection Act. Some species that may or may not be listed here have been officially proposed as either threatened or endangered in a Federal Register notice after the completion of a status review and consideration of other protective conservation measures (e.g., Cook Inlet beluga whales). Additionally, bearded, ribbon, ringed, and spotted seals are candidate species (i.e., being considered for listing as endangered or threatened under the ESA). Conservation status of seabirds are taken from the U.S. Fish & Wildlife Service (USFWS) Migratory Bird Management Nongame Program Alaska seabird information series(`http://alaska.fws.gov/mbsp/mbm/seabirds/pdf/asis_complete.pdf`; Denlinger (2006)).

Status and trends There are 9 species listed as endangered and 5 species that are listed as threatened in Alaska (Table 6). Three marine mammal species are considered depleted and three species of birds are considered highly imperiled. The USFWS considers three seabird species as highly imperiled in Alaska: black-footed albatross, red-legged kittiwakes, and Ancient murrelets. Also, the USFWS considers seven seabird species in Alaska of high concern: Laysan albatross, pelagic cormorants, red-faced cormorants, Arctic terns, marbled murrelets, Kittlitzs murrelets, and Cassins auklets. Ten seabird species in Alaska are of moderate concern: Northern fulmars, Leachs storm-petrels, black-legged kittiwakes, Aleutian terns, black guillemot, pigeon guillemot, Least auklets, whiskered auklets, crested auklets, and horned puffins. Low to moderate concern was identified for parasitic jaegers and herring gulls in Alaska. Low concern was identified for fork-tailed storm-petrels, Pomarine jaegers, Sabines gulls, common murres, Parakeet auklets, and Rhinoceros auklets in Alaska. Fourteen other seabird species in Alaska are not of concern or do not have a conservation status. Two endangered fish species that migrate to Alaskan waters include Lower Columbia River chinook salmon and upper Willamette River chinook salmon.

Factors causing trends Exploitation in the early part of the 20th century reduced populations of large whales, such as North Pacific right, blue, fine, sei, humpback, and sperm whales, and sea otters to the point of depletion. Relatively recent surveys suggest that humpback, fin, and minke whales were abundant in old whaling grounds (Zerbini et al., 2006). Currently, potential causes of declines in marine mammals include direct takes in fisheries, resource competition, indirect competition, and environmental change (see Steller sea lion section, p. 162). Reduced polar bear numbers have been attributed to climate change and the loss of sea ice, representing a loss of habitat, in the Arctic. Trends in seabird populations may be related to fishery mortality, climate variability, predation, nesting habitat destruction, prey availability, and/or food provisioning (see Seabirds, p. 172). Bycatch of salmon in Alaska has the potential to affect the endangered lower Columbia River and upper Willamette River chinook salmon, but is closely monitored.

Indicator: Steller sea lion non-pup counts and pup production

See 2010 contribution by Lowell Fritz (p. 162, this document)

Index The western stock of Steller sea lions, which occurs from 144W (approximately at Cape Suckling, just east of Prince William Sound, Alaska) westward to Russia and Japan, was listed as "endangered" in June 1997 (62 Federal Register 24345, May 5, 1997). The eastern stock, which occurs from Southeast Alaska southward to California, remained classified as threatened (since 1990). To elucidate trends in Steller sea lion stocks, non-pup counts and pup production are two indices that are monitored. Population assessment for Steller sea lions is currently achieved by aerial photographic surveys of non-pups (adults and juveniles at least 1 year-old) and pups,

Table 6: Species in Alaska that are listed as endangered or threatened, marine mammals listed as depleted, species of concern, and seabirds considered highly imperiled

Species	Endangered	Threatened	Depleted	Species of Concern	Highly imperiled
Steller sea lion (western stock)	X				
Steller sea lion (eastern stock)		X			
Northern fur seal			X		
Blue whale*	X				
Bowhead whale	X				
Humpback whale	X				
Fin whale	X				
Right whale (northern Pacific)*	X				
Sperm whale*	X				
Beluga whale (Cook Inlet)			X	X	
Killer whale (AT1 transient)			X		
Northern sea otter (southwest AK)		X			
Polar bear		X			
Leatherback sea turtle	X				
Short-tailed albatross	X				
Spectacled eiders		X			
Stellers eiders		X			
Black-footed albatross					X
Red-legged kittiwakes					X
Ancient murrelets					X
Lower Columbia R. Chinook salmon	X				
Upper Willamette R. Chinook salmon	X				
Pinto abalone (southeast AK)				X	

supplemented by on-land pup counts at selected rookeries each year. Trends in the non-pup western stock in Alaska are monitored by surveys at groups of trend sites (all rookeries and major haul-outs) that have been surveyed consistently since the mid-1970s (N=87 sites) or 1991 (N=161 sites). To investigate spatial differences in population trends, counts at trend sites within sub-areas of Alaska are monitored.

Status and trends Counts of adult and juvenile Steller sea lions at all trend sites within the range of the western stock in Alaska increased 14% between 2000 and 2008, and most of this increase occurred in the first four years (11% increase between 2000 and 2004). Additional non-pup surveys conducted in 2009 indicated that survey timing in 2008 may have affected the results with respect to distribution of sea lions east and west of the stock boundary at 144°W. Accounting for this seasonal movement in 2008 (based on the 2009 data) lowered the percentage change in non-pup counts between 2000 and 2008 from 14% to 12% (for an average annual growth rate of 1.5% with a 90% CI of -0.3% to +3.3% per year), and from 2004 to 2008 from 3% to 1%. There is considerable variation between sub-areas in non-pup count trends estimated in the 2000s: the western Aleutian Islands decreased rapidly at approximately -7% per year and sub-area population trends improved to the east through the western Gulf of Alaska, where the annual trend was approximately +4% per year; the central Gulf of Alaska population was stable in the 2000s, while the eastern Gulf of Alaska increased at approximately 5% per year. Winship and Trites (2006) also noted that significant differences in regional trends could affect the species' ability to occupy its present range in the future.

Regional trends in pup production are similar to trends in non-pup counts, with continued relatively steep declines in the western Aleutians, less steep decline in the central Aleutians, stability in the central Gulf of Alaska and improvement in the eastern Aleutians, and western and eastern Gulf of Alaska. Demographic modeling suggests that reproductive rates of adult females in the central Gulf of Alaska declined 36% between the mid-1970s and 2004 (Holmes et al., 2007). Ratios of pups to non-pups (an index of rates of natality) also declined in the western Gulf of Alaska and the eastern Aleutian Islands during this same period, suggesting that declines in natality rates may not be limited solely to the central Gulf sea lion population. Pup to non-pup ratios based on data collected in 2009 suggest that natality rates of western stock sea lions are lower than those in SE Alaska (eastern stock). At the two largest and oldest rookeries in SE Alaska (Forrester Complex and Hazy Island), the pup:non-pup ratio was 0.85 in 2009; Pitcher et al. (2007) reported a ratio of 0.75 in 2002. Rookery pup:non-pup ratios within the western stock in AK ranged from 0.44 to 0.63 by sub-area in 2009, and averaged 0.57, or 33% lower than in SE Alaska. While rookery pup:non-pup ratios are not direct estimates of female natality (since they include juveniles and males in the denominator), they do provide insight into the relative birth rates of females within each region since females dominate rookery populations.

Factors causing trends NMFS, along with its research partners in the North Pacific, is exploring several hypotheses to explain these trends, including climate or fisheries related changes in prey quality or quantity, and changes in the rate of predation by killer whales.

There is both direct and indirect overlap in the species and size of primary prey consumed by marine mammals and targeted in commercial fisheries. For example, adult and juvenile walleye pollock are both consumed by adult and juvenile Steller sea lions (Merrick and Calkins, 1996; Sinclair and Zeppelin, 2002; Zeppelin et al., 2004). The hypothesis is that either direct or indirect competition for food with commercial fisheries may limit the ability of apex predators to obtain sufficient prey for growth, reproduction, and survival (NRC, 1996). In the case of Steller sea lions, direct competition with fisheries may occur for walleye pollock, Atka mackerel, salmon, and Pacific cod (Sinclair and Zeppelin, 2002; Zeppelin et al., 2004). Competition may also exist where marine mammal foraging areas and commercial fishing zones overlap. More difficult to identify are the indirect effects of competition between marine mammals and fisheries for prey resources. Such interactions may limit foraging success through localized depletion (Lowe and Fritz, 1997), destabilization of prey assemblages (Freon et al., 1992; Nunnallee, 1991; Laevastu and Favorite, 1988), or disturbance of the predator itself.

There is considerable uncertainty on how and to what degree environmental factors, such as the 1976/77 regime shift (Benson and Trites, 2002), may have affected both fish and marine mammal populations. Some authors suggest that the regime shift changed the composition of the fish community resulting in reduction of prey diversity in marine mammal diets (Sinclair et al., 2008, 1994; Piatt and Anderson, 1996; Merrick and Calkins, 1996), while others caution against making conclusions about long-term trends in Steller sea lion diets based on small samples collected prior to 1975 (Fritz and Hinckley, 2005). Shima et al. (2000) hypothesized that the larger size and restricted foraging habitat of Steller sea lions, especially for juveniles that forage mostly in the upper water column close to land, may make them more vulnerable than other pinnipeds to changes in prey availability, and spatial and temporal changes in prey, especially during the critical winter time period. Determining the individual magnitudes of impacts that fisheries and climate changes have had on localized prey availability for foraging marine mammals is difficult.

Gaps in diversity knowledge common to all ecosystems

Information or indicators that would improve our understanding of diversity in Alaska marine ecosystems includes:

1. an index of guild diversity
2. trophic level of ecosystem
3. better understanding of diversity indices and what causes trends
4. ratio of target to nontarget fish catches

Objective: Maintain habitat

Indicator: Areas closed to bottom trawling in the eastern Bering Sea, Aleutian Islands and the Gulf of Alaska

See 2010 contribution by John Olson (p. 192, this document)

Index Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut). Some of the trawl closures are in effect year-round while others are seasonal. In general, year-round trawl closures have been implemented to protect vulnerable benthic habitat. Seasonal closures are used to reduce bycatch by closing areas where and when bycatch rates had historically been high.

Status and trends Additional measures to protect the declining western stocks of the Steller sea lion began in 1991 with some simple restrictions based on rookery and haulout locations; in 2000 and 2001 more specific fishery restrictions were implemented. In 2001, over 90,000 nm2 of the Exclusive Economic Zone (EEZ) off Alaska was closed to trawling year-round. Additionally, 40,000 nm2 were closed on a seasonal basis. State waters (0-3 nmi) are also closed to bottom trawling in most areas. A motion passed the North Pacific Management Council in February 2009 which closed all waters north of the Bering Strait to commercial fishing as part of the development of an Arctic Fishery management plan. This additional closure adds 148,300 nm2 to the area closed to bottom trawling year round.

Implications With the Arctic FMP closure included, almost 65% of the U.S. EEZ off Alaska is closed to bottom trawling.

Indicator: Fishing Effort

See 2010 contributions by John Olson (p. 193, 195, 198, and 202, this document)

Index Fishing effort is an indicator of damage to or removal of Habitat Areas of Particular Concern (HAPC) biota, modification of nonliving substrate, damage to small epifauna and infauna, and reduction in benthic biodiversity by trawl or fixed gear. Intensive fishing in an area can result in a change in species diversity by attracting opportunistic fish species which feed on animals that have been disturbed in the wake of the tow, or by reducing the suitability of habitat used by some species. Trends in fishing effort will reflect changes due to temporal, geographic, and market variability of fisheries as well as management actions. Bottom trawl and hook and line effort are measured as the number of observed days fished; whereas, pot fishing effort is measured as the number of observed pots fished. Observed fishing effort is used as an indicator of total fishing effort. It should be noted, however, that most of the vessels using pot gear are catcher vessels either under 60 or between 60-125. These vessels either do not require an observer present or only on 30% of the fishing days.

Status and trends Bottom trawl effort in the Gulf of Alaska, Bering Sea, and Aleutian Islands was near or below the 12-year average in 2009. In 2009, observed AI hook and line effort increased slightly but remained near average, decreased from 2008 in the EBS remained below the 12-year average, and was near average in the GOA. Pelagic trawl effort in the EBS declined to become significantly lower in 2009 than the 12-year average. There has been very little or no pelagic trawl effort in the AI in recent years. Pelagic trawl effort in the GOA in 200 was below the 12 year average. The observed pot fishing effort was similar to that seen in the last 8 or 9 years in all regions.

Factors causing trends Some of the reduction in bottom trawl effort in the Bering Sea after 1997 can be attributed to changes in the structure of the groundfish fisheries due to rationalization. As of 1999, only pelagic trawls can be used in the Bering Sea pollock fisheries. Fluctuations in bottom trawl effort track well with overall landings of primary bottom trawl target species, such as flatfish and to a lesser extent pollock and cod.

Hook and line effort in both the Bering Sea and Aleutian Islands occurs mainly for Pacific cod, Greenland turbot, and sablefish. The predominant hook and line fisheries in the Gulf of Alaska are composed of sablefish and Pacific cod. In southeast Alaska, there is a demersal rockfish fishery dominant species include yelloweye rockfish (90%), with lesser catches of quillback rockfish. Sablefish has been an IFQ fishery since 1995, which has reduced the number of vessels, crowding, gear conflicts and gear loss, and increased efficiency.

The pot fishery occurs mainly for Pacific cod which form dense spawning aggregations in the winter months. In the Bering Sea, fluctuations in the pot cod fishery may be dependent on the duration and timing of crab fisheries. There is also a state-managed fishery in State waters.

There are spatial variations in fishing effort in the EBS, GOA, and AI (see fishing effort contributions). Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures) as well as changes in markets and increased bycatch rates of non-target species.

Implications The effects of changes in fishing effort on habitat and HAPC biota are largely unknown. It is possible that the reduction in bottom trawl effort in all three ecosystems could result in decreased habitat loss/degradation due to fishing gear effects on benthic habitat, HAPC biota, and other species; whereas, increases in hook and line and pot fisheries could have the opposite effect. The footprint of habitat damage likely varies with gear (type, weight, towing speed, depth of penetration), the physical and biological characteristics of the areas fished, recovery rates of HAPC biota in the areas fished, and management changes that result in spatial changes in fishing effort (NMFS 2007;`http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm`).

Gaps in habitat knowledge common to all ecosystems

Information or indicators that would improve our understanding of habitat in Alaska marine ecosystems includes:

1. habitat disturbance as a function of fishing intensity
2. HAPC biota population abundance and distribution, particularly in areas currently untrawlable with standard survey gear.
3. the importance of HAPC biota as habitat for different species and life stages of fish
4. the relationship between physical factors such as sediment type, bathymetry, and oceanography and the abundance and distribution of HAPC biota.

Objective: Incorporate and/or monitor effects of climate change

Indicator: North Pacific climate and sea surface temperature indices

See 2010 contribution by Nick Bond and Lisa Guy (p. 90, this document)

Index To examine potential effects of climate on groundfish distribution, recruitment and survival, indices of climate conditions are assessed. Four indices of climate conditions that influence the north Pacific are: the NINO3.4 index to characterize the state of the El Nino/Southern Oscillation (ENSO) phenomenon, the Pacific Decadal Oscillation (PDO) index (the leading mode of North Pacific sea surface temperature (SST) variability), and two atmospheric indices, the North Pacific index (NPI) and Arctic Oscillation (AO). The NPI is one of several measures used to characterize the strength of the Aleutian low. The AO signifies the strength of the polar vortex, with positive values signifying anomalously low pressure over the Arctic and high pressure over the Pacific and Atlantic at a latitude of roughly 45° N, and hence anomalously westerly winds across the northern portion of the Pacific and Alaska. These indices, along with measures of sea surface temperature (SST) and sea level pressure (SLP) provide information on the climate conditions in the north Pacific.

Status, trends, and factors causing trends The North Pacific experienced mostly cooler than normal upper ocean temperatures in its eastern and northern portions from fall 2009 through summer 2010. These conditions can be attributed to the pre-existing state of the North Pacific and the basin-scale climate forcing during the past year. An El Niño occurred during the winter of 2009-10, and while the associated atmospheric circulation anomalies resembled those with past events, its effects do not appear to have persisted beyond spring 2010. La Niña began developing in the spring/summer of 2010 and is forecast to strengthen over the remainder of 2010. This should lead to a relatively weak Aleutian low, and a negative sense to the Pacific Decadal Oscillation (PDO) for the North Pacific atmosphere-ocean climate system into spring 2011.

Implications In light of the present conditions in the tropical Pacific, in particular the anomalously low vertically integrated heat content and the combination of easterly wind anomalies and suppressed deep cumulus convection in the central Pacific, it can be anticipated with a high degree of certainty that La Niña conditions will prevail through the remainder of 2010 into 2011. A La Niña generally brings a weaker Aleutian low than normal, and cool upper ocean conditions along the west coast of North America, and for Alaska waters.

Indicator: Combined standardized indices of groundfish recruitment and survival

See 2010 contribution by Franz Mueter (p. 179, this document)

Index Decadal scale variability in climate may affect groundfish survival and recruitment (Hollowed et al., 2001). Indices of recruitment and survival rate (adjusted for spawner abundance) across the major commercial groundfish species in the Eastern Bering Sea / Aleutian Islands (BSAI, 11 stocks) and Gulf of Alaska (GOA, 11 stocks) provide an index that can be examined for decadal-scale variability. Time series of recruitment and spawning biomass for demersal fish stocks were obtained from the 2007 SAFE reports to update results of Mueter et al. (2007). Only recruitment estimates for age classes that are largely or fully recruited to the fishery were included. Survival rate (SR) indices for each stock were computed as residuals from a spawner-recruit model. Each time series of log-transformed recruitment (logR) or SR indices was standardized to have a mean of 0 and a standard deviation of 1 (hence giving equal weight to each stock in the combined index, see below). A combined standardized index of recruitment ($\mathrm{CSI_R}$) and survival ($\mathrm{CSI_{SR}}$) was computed by simply averaging indices within a given year across stocks. Uncertainty in the stock-specific estimates of logR and SR indices was not accounted for; therefore the most recent estimates of the combined indices should be interpreted with caution.

Status and trends: The $\mathrm{CSI_R}$ and $\mathrm{CSI_{SR}}$ suggest that survival and recruitment of demersal species in the GOA and BSAI followed a similar pattern with below-average survival/recruitments during the early 1990s (GOA) or most of the 1990s (BSAI) and above-average indices across stocks in the late 1990s/early 2000s. Because estimates at the end of the series were based on only a few stocks and are highly uncertain, we show the index through 2006 only, the last year for which reasonable estimates for the majority of stocks were available in each region. There is strong indication for above-average survival and recruitment in the GOA from 1994-2000 (with the exception of 1996, which had very low indices) and below- or near-average survival / recruitment since 2001. In the eastern Bering Sea there was no strong indication of below average recruitment across multiple stocks until 2004, when all 7 stocks with recruitment estimates had below average recruitment and stock-recruit indices ($P < 0.001$).

Factors causing trends: Trends in recruitment are a function of both spawner biomass and environmental variability. Trends in survival rate indices, which are adjusted for differences in spawner biomass, are presumably driven by environmental variability, but are even more uncertain than recruitment trends. Typically, spawner biomass accounted for only a small proportion of the overall variability in estimated recruitment. The observed patterns in recruitment and survival since the 1976/77 regime shift suggest continuing decadal-scale variations in overall groundfish productivity across multiple stocks in the Gulf of Alaska and Bering Sea. Unlike earlier analyses including longer time series that spanned the 1976/77 regime shift, the recruitment and survival series are un-correlated between the two regions (CSI_R: $r = 0.014$; CSI_{SR}: $r = 0.165$). However, indices in the Bering Sea appear to lag the corresponding indices in the Gulf of Alaska by approximately 2 years with statistically significant correlations when adjusted for autocorrelation ($r = 0.487$, $p = 0.034$ and $r = 0.547$, $p = 0.019$ for CSI_R and CSI_{SR}, respectively). While longer time series of the indices (1970-2004) were positively correlated with the PDO, the post-regime shift indices were not significantly correlated with either the PDO or with regional SST indices.

Gaps in climate-related knowledge common to all ecosystems

Information or indicators that would improve our understanding of climate-related knowledge in Alaska marine ecosystems includes:

1. knowledge of the effects of increased climate variation on ecosystem components
2. indicators of ocean acidification and its effect on shell-building animals and their predators
3. indicators of harmful algal blooms and their effects on ecosystem components

Conclusions

Climate Monitoring climate variability is necessary to understanding changes that occur in the marine environment and may help predict potential effects on biota. El Nino conditions developed in the summer of 2009 and are likely to persist, and probably strengthen into 2010. This is liable to bring about a positive state for the PDO and relatively warm SSTs along the west coast of North America. This could have a broad range of effects on Alaska marine ecosystems. These large-scale climate factors determine the size and location of the cold pool in the Bering Sea. In the summers of 2006-2009, the extent of the cold pool increased from low values observed during 2000-2005. Changes in the cold pool size and location may affect the distribution of some fish species and may also affect stratification, production, and community dynamics in the Bering Sea. Observed changes in the physical environment in the Bering Sea may be, in part, responsible for the increased zooplankton biomass observed in the last two or three years. The increased zooplankton biomass may have positive effects on zooplanktivorous fish, such as juvenile walleye pollock, in the

Bering Sea. It is apparent that many components of the Alaskan ecosystems respond to variability in climate and ocean dynamics. Predicting changes in biological components of the ecosystem to climate changes, however, will be difficult until the mechanisms that cause the changes are understood (Minobe, 2000).

Habitat It is difficult to assess the effects of fishing on habitat and HAPC biota. Increased knowledge of habitat disturbance as a function of fishing intensity would improve our ability to assess this objective. Also, it would be beneficial to have improved knowledge of the importance of HAPC biota as habitat for different species and life stages of fish, estimates of HAPC biota population abundance and distribution, particularly in areas currently untrawlable with standard survey gear, the relationship between physical factors such as sediment type, bathymetry, and oceanography and the abundance and distribution of HAPC biota.

Diversity Measures of diversity are subject to bias and we do not know how much change in diversity is acceptable (Murawski, 2000). Furthermore, diversity may not be a sensitive indicator of fishing effects (Livingston et al., 1999; Jennings and Reynolds, 2000). We, therefore, attempted to look at a variety of indicators for the diversity objective. EBS species richness has increased since 1995 and this has been attributed to subarctic species spreading into the former cold pool area as the extent of the cold pool has decreased over recent decades (Mueter and Litzow, 2008). Species diversity in the EBS, however, has been relatively low in recent years, compared to the 1990s, which suggests that species remain patchily distributed such that a given haul may be dominated by one or a few species. With regards to size diversity of fish in the Bering Sea, unlike other marine ecosystems, there has not been a linear decreasing trend in groundfish size or abundance during 1982-2006 (Boldt et al., 2008). No groundfish species is overfished or subject to overfishing; however, Pribilof Island blue king crab are considered overfished. These indices, however, apply only to fish and invertebrate species. There are eight endangered and five threatened marine mammal and seabird species in Alaska. One of those endangered species is the western stock of Steller sea lions, of which, the adult females may be experiencing declines in reproductive rates since the early 1990s (Holmes and York, 2003; Holmes et al., 2007). The number of northern fur seal pups born on the Pribilof Islands and Bogoslof Island show opposite trends, which can not be explained by immigration/emigration, or large-scale spatio-temporal environmental changes in the North Pacific Ocean. Further research is needed to improve our understanding of diversity indices and what causes some of these trends.

Predator-prey relationships and energy flow The FIB index and the trophic level of the catch in the EBS, AI, and GOA have been relatively constant. Further examination supports the idea that fishing-down the food web is not occurring in Alaska, and there does not appear to be a serial addition of lower-trophic-level fisheries in the EBS or GOA. Most recent exploitation rates on biological guilds in the Bering Sea are within one standard deviation of long-term mean levels. An exception was for the forage species of the Bering Sea (dominated by walleye pollock) which had relatively high exploitation rates 2005-2007 as the stock declined. The 2008 and 2009-recommended catch levels were again within one standard deviation of the historical mean. This is a more direct measure of catch with respect to food-web structure than are trophic level metrics.

Gaps in knowledge There are gaps in understanding the system-level impacts of fishing and spatial/temporal effects of fishing on community structure and prey availability. Validation and improvements in system-level predator/prey models and indicators are needed along with research and models focused on understanding spatial processes. Improvements in the monitoring system should include better mapping of corals and other benthic organisms, development of a system for prioritizing non-target species bycatch information in groundfish fisheries, and identification of genetic subcomponents of stocks. In the face of this uncertainty, additional protection of sensitive or rare ecosystem components such as corals or local spawning aggregations should be considered. Improvements in understanding both the nature and direction of future climate variability and effects on biota are critical. An indicator of secondary production or zooplankton availability would improve our understanding of marine ecosystem dynamics and in prediction of groundfish recruitment and survival.

Overall conclusions and future research needs The EBS ecosystem assessment identified both hopeful signs and areas that may require further management action. While there are several indicators pointing to continued improvements in the recently low production regime for zooplankton and the fish and seabirds that that feed directly on them (in particular, young pollock), this improved production has yet to benefit central place foragers such as northern fur seals, whose pup production continues to decline. These indicators suggest changes in the EBS production regime, but it remains difficult to detect significant adverse impacts of fishing on the ecosystem relating to predator/prey interactions and energy flow/removal, diversity, or habitat. There are several cases where those impacts are unknown because of incomplete information on population abundance of certain species such as forage fish or HAPC biota that are not well-sampled by surveys, or of entire benthic energy flow pathways that support the currently depressed commercial crab stocks. Identification of fishery-related thresholds and limits through further analyses, research, and modeling is needed to identify impacts to the ecosystem and recommend alternative management actions for consideration.

Ecosystem Status and Management Indicators

Ecosystem Status Indicators

Indicators presented in this section are intended to provide detailed information and updates on the status and trends of ecosystem components.

Physical Environment

Ecosystem Indicators and Trends Used by FOCI

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Last updated: August 2009

See the 2009 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

North Pacific Climate Overview

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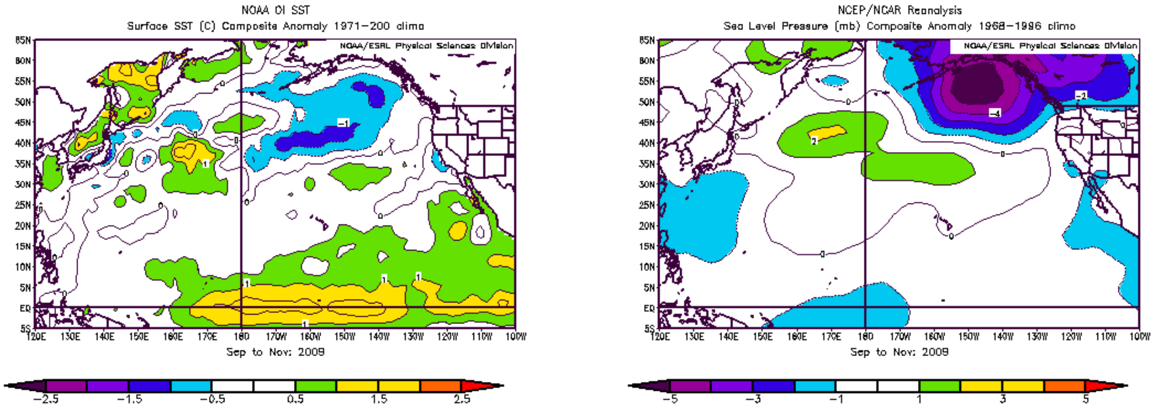
Summary *The North Pacific experienced mostly cooler than normal upper ocean temperatures in its eastern and northern portions from fall 2009 through summer 2010. These conditions can be attributed to the pre-existing state of the North Pacific and the basin-scale climate forcing during the past year. An El Niño occurred during the winter of 2009-10, and while the associated atmospheric circulation anomalies resembled those with past events, its effects do not appear to have persisted beyond spring 2010. La Niña began developing in the spring/summer of 2010 and is forecast to strengthen over the remainder of 2010. This should lead to a relatively weak Aleutian low, and a* *negative sense to the Pacific Decadal Oscillation (PDO) for the North Pacific atmosphere-ocean climate system into spring 2011.*

1. SST and SLP Anomalies

The state of the North Pacific from autumn 2009 through summer 2010 is summarized in terms of seasonal mean SST and sea level pressure (SLP) anomaly maps. The SST and SLP anomalies are relative to mean conditions over the periods of 1971-2000 and 1968-1986, respectively. The SST data is from NOAA's Optimal Interpolation (OI) analysis; the SLP data is from the NCEP/NCAR Reanalysis projects. Both data sets are made available by NOAA's Earth System Research Laboratory at: `http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl`. In an overall sense, the year of 2009-10 featured prominent signals in the climate forcing of the North Pacific. This forcing was apparently on short enough time scales to produce a largely muted response in upper ocean temperatures.

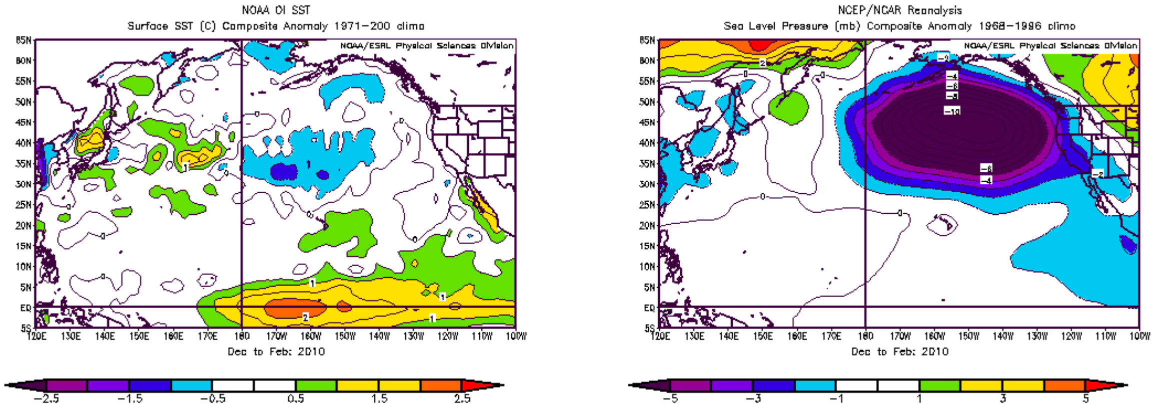
The autumn (SON) of 2009 included negative SST anomalies in the eastern North Pacific, with the largest amplitudes exceeding 1° magnitude. Mostly positive SST anomalies prevailed in the western North Pacific. Warmer than normal SSTs occurred in the central and eastern tropical Pacific in association with the development of El Niño (Figure 16a). The corresponding pattern of anomalous SLP included negative anomalies in the Gulf of Alaska and weaker positive anomalies stretching from eastern Siberia to north of the Hawaiian Islands (Figure 16b). This pattern corresponds with both northerly wind anomalies over the Bering Sea, and hence relatively cool air temperatures (not shown), and westerly wind anomalies from roughly 35° to 50° N across the eastern North Pacific, and hence anomalous equatorward Ekman transports.



(a) SST (b) SLP

Figure 16: Anomalies for September-November 2009.

The pattern of anomalous SST during winter (DJF) of 2009-10 was rather similar to that during the fall of 2009 (Figure 17a). There was some modest cooling, relative to seasonal norms, in the northern Bering Sea, and continued warming in the central North Pacific due to El Niño. It bears noting that this particular El Niño featured its strongest SST anomalies in the central Pacific, rather than the eastern Pacific. This has been a tendency of recent El Niños. The causes and effects of the two different types of warm events are receiving increasing attention from the climate community. The SLP during winter 2009-10 was dominated by a large and very deep anomalous low centered near 45° N, 150° W (Figure 17b). The location of this anomaly is almost identical to that which occurred during the winter of 2008-09 but of opposite sign. In both winters the SLP pattern was consistent with past ENSO events, but the magnitudes of the atmospheric responses were comparatively large, given both the La Niña of 2008-09 and the El Niño of 2009-10 were of no more than moderate intensity. The anomalous SLP pattern shown in Figure 17b indicates anomalous easterlies in the mean across the northern portion of the basin from southeast Alaska to the dateline, and anomalous downwelling along the coast of North America from California to the Alaska Peninsula. The SLP pattern implies northeasterly wind anomalies on the eastern Bering Sea shelf, which do not tend to be especially cold. It appears that the development of heavy ice on the Bering Sea shelf this winter into the following spring can be attributed in large part to the relatively low heat content of the water column going into the season (P. Stabeno, pers. comm.).

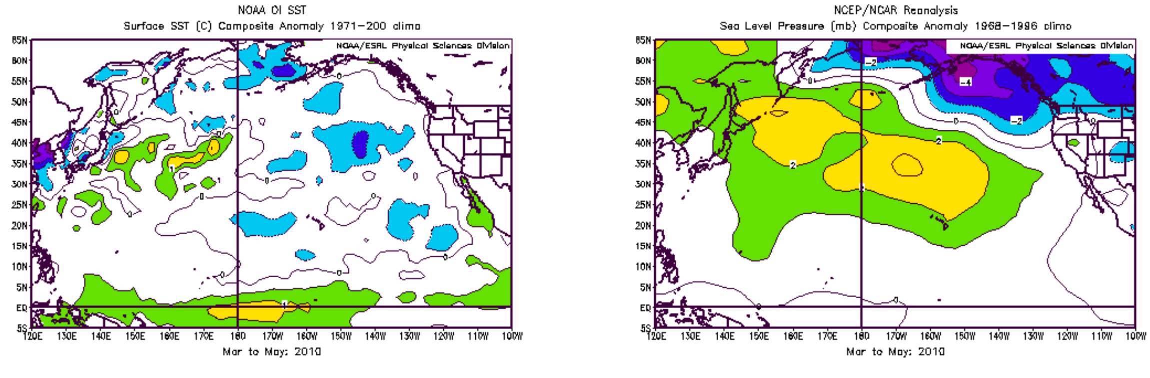


(a) SST (b) SLP

Figure 17: Anomalies for December 2009-February 2010.

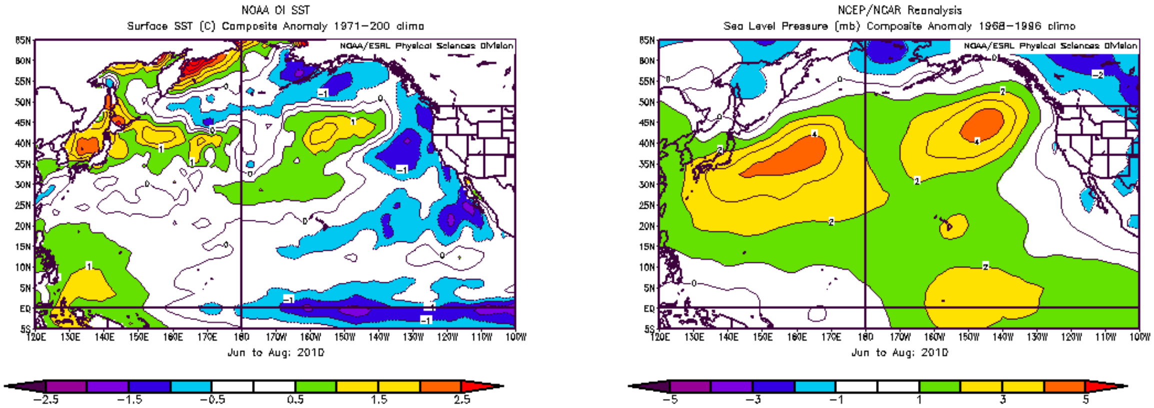
The distribution of SST in spring (MAM) of 2010 indicates a continuation of temperatures that are colder than normal in the eastern basin of the North Pacific and warmer than normal in the western basin, strengthening of the negative anomalies in the Bering Sea, and a weakening of the El Niño signal in the tropical Pacific (Figure 18a). The concomitant SLP anomaly map (Figure 18b) indicates relatively low pressure extending from far eastern Siberia into western Canada, and high pressure from the Sea of Okhotsk to north of the Hawaiian Islands. This pattern served to support the flow of relatively cold air off Siberia across the Bering Sea, and hence contributed to the extensive ice that occurred on the Bering Sea shelf during the spring of 2010.

The pattern of anomalous SST in summer (JJA) 2010 (Figure 19a) included the development of substantial negative values along much of the west coast of North America, and continued cool conditions in the eastern Bering Sea. Relatively warm SSTs developed north of the Hawaiian Islands. The overall pattern resembles that associated with the negative phase of the Pacific Decadal Oscillation (PDO). This is consistent with the rapid development of cool SSTs in the central and eastern tropical Pacific, i.e., La Niña. It is also consistent with the field of anomalous SLP (Figure 19b). The relatively high pressure in the northeastern portion of the basin supports anomalous upwelling along the entire coast of North America; the warming in the central part of the basin is consistent with suppressed cloudiness/enhanced insolation in the vicinity of the pressure center itself, and anomalous poleward Ekman transports on its southern and western flanks.



(a) SST (b) SLP

Figure 18: Anomalies for March-May 2010.



(a) SST (b) SLP

Figure 19: Anomalies for June-August 2010.

2. Climate Indices

There is a small set of climate indices that can provide useful context for the SST and SLP anomaly maps for the North Pacific presented above. The focus here is on four commonly used indices: the NINO3.4 index to characterize the state of the El Niño/Southern Oscillation (ENSO) phenomenon, the Pacific Decadal Oscillation (PDO) index (the leading mode of North Pacific SST variability), and two atmospheric indices, the North Pacific index (NPI) and Arctic Oscillation (AO). The time series of these indices from 2001 through the early summer of 2010 are plotted in Figure 20.

As mentioned above, ENSO appears to have had an important influence on the North Pacific climate during 2009-10. In particular, a deeper and southeastward displaced Aleutian low during winter tends to accompany El Niño, as was observed in 2009-10. The transition from El Niño to La Niña that occurred from spring into summer of 2010 was also accompanied by the development of typical SLP and wind anomalies. While most of the variability in ENSO is on temporal scales of a few years, it also exhibits some power on longer time scales. ENSO was predominantly positive during the first half of the 2000s and has oscillated between negative and positive during the past five years. The projections of the dynamical and statistical models used to forecast ENSO are discussed in the last section of this overview.

The PDO underwent a marked increase over the course of 2009 into early 2010 and since then, has trended negative. The PDO, to a significant extent, responds to ENSO (Newman et al., 2003); the correlation coefficient between the NINO3.4 and PDO indices is about 0.5 over the period of record. While ENSO has some predictability, it is important to recognize that the atmospheric circulation over the North Pacific has considerable variability from sources (intrinsic and perhaps forced) other than ENSO. In particular, it is presently not feasible to project the magnitude of the PDO, nor the details in the SST of the North Pacific on regional scales.

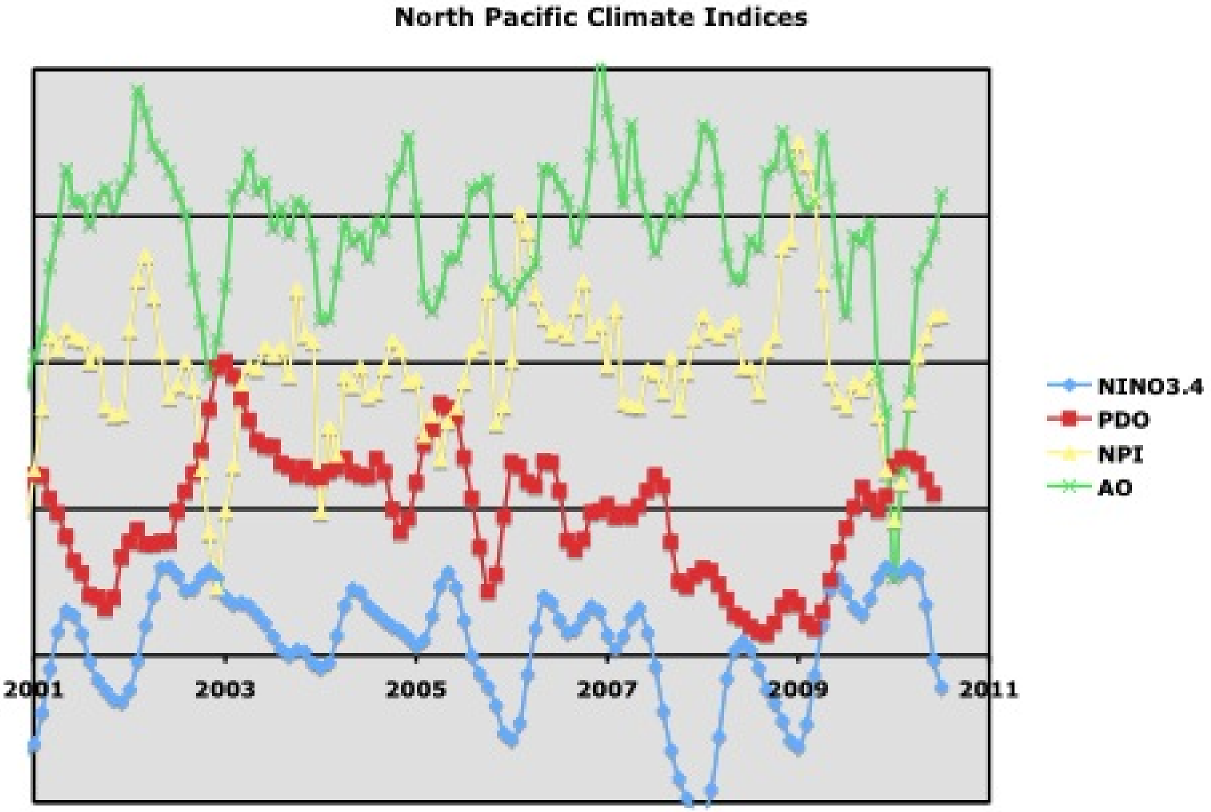


Figure 20: Time series of the NINO3.4 (blue), PDO (red), NPI (yellow), and AO (green) indices. Each time series represents monthly values that are normalized and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 2 standard deviations. More information on these indices is available from NOAA's Earth Systems Laboratory at `http://www.esrl.noaa.gov/psd/data/climateindices/`.

The NPI is an appropriate means for characterizing the strength of the Aleutian low. The NPI underwent a tremendous swing from about 3 positive standard deviations during the winter of 2008-09 to about negative 2 standard deviations during the winter of 2009-10 (Figure 20). The magnitude of this transition has only been exceeded twice since 1968, with one of those instances being associated with the intense El Niño of 1982-83. The La Niña that is developing at the time of the writing of this overview suggests another sizable swing to a positive state for the NPI, as the trend in the index itself is demonstrating.

The AO represents a measure of the strength of the polar vortex, with positive values signifying anomalously low pressure over the Arctic and high pressure over the Pacific and Atlantic, at a latitude of roughly 45° N. It is closely related to the North Atlantic Oscillation (NAO). The AO mostly decreased over the course of 2009, bottoming out in January 2010 with a record negative value of almost 5 standard deviations. The response of the atmospheric circulation in the North Pacific to ENSO tends to be enhanced during periods of a negative state and suppressed during periods of a positive state in the AO (Bond and Harrison, 2006). The unusually strong response in the Aleutian low, as reflected in the NPI, to the moderate El Niño of the winter of 2009-10 may reflect another instance of this interaction between ENSO and the AO in terms of the climate forcing of the North Pacific. There are no reliable forecast tools at present for seasonal prediction of the AO and so it is unknown how it may impact the North Pacific during the upcoming year.

3. Regional Highlights

West Coast of Lower 48 - This region appears to have experienced a relatively modest response to the El Niño of 2009-10. There was a period of highly anomalous southerly, downwelling-favorable, winds along the coast of Oregon and Washington during the winter, and a rather late spring transition to upwelling-favorable winds for the coast as a whole. Since the spring transition, upwelling has generally been stronger than normal. The climate forcing is reflected in the coastal SST, which was near normal during the winter and spring, but cooler than normal during the summer of 2010. The physical conditions are consistent with lower-trophic level species populations, which included low levels of krill and somewhat high numbers of sub-tropical copepods in spring 2010, but also a recent tendency towards typical values.

Gulf of Alaska -The data from Argo profiling floats, available at `http://www.pac.dfo-mpo.gc.ca/sci/osap/projects/argo/Gak_e.htm`, are useful for diagnosing the sub-surface physical properties of this region. Based on the gradient in dynamic height from Argo, the poleward branch of the Alaska Current in the southeastern portion of the Gulf was considerably greater than normal in the winter of 2009-10, presumably at least in part due to the anomalous southerly winds during this season. The strength of this branch of the Alaska Current has since declined to about its mean over the last decade. The mixed layer depths in the Gulf were relatively shallow during the winter, as might be expected with anomalously strong upward Ekman pumping. During the summer of 2010 they have been observed to be somewhat deeper than normal.

Alaska Peninsula and Aleutian Islands - The winds in this region impact the upwelling along the arc of the Alaska Peninsula and Aleutian Islands, and the flow of Pacific water through Unimak Pass into the Bering Sea (Stabeno et al., 2002). The winter of 2009-10 featured strong easterly wind anomalies, which probably promoted northward transport through Unimak Pass and enhanced the Aleutian North Slope Current. The sense of the wind anomalies switched to anomalous westerly during the spring and summer of 2010 for the Alaska Peninsula and eastern Aleutian Islands. This would tend to produce suppressed upwelling on their north sides and enhanced upwelling to their south.

Bering Sea - The Bering Sea shelf experienced a relatively heavy ice year in 2010. It is rare for this region to have greater than normal ice extent during El Niño years. The especially low heat content on the shelf going into the fall of 2009 is likely to have been an important contributing factor, as mentioned above. Two notable advances occurred in the ice cover due to episodic weather events, specifically a severe cold snap near the end of February into March, and a period of strong northerlies (but not unusually cold temperatures) from late April through the middle of May 2010. The summer of 2010 has generally been a bit stormier than usual.

Arctic - The tendency for reduced sea ice cover in the Arctic during the summer has continued into 2010. The areal coverage in July 2010 was the second lowest in the historical record (the record low for July was in 2007). There is now very little multi-year ice in the Arctic (R. Lindsay, pers. comm.). There is some tentative evidence that reduced sea ice cover in the fall, through its impacts on low-level air temperatures, may impact the hemispheric atmospheric circulation (Overland and Wang, 2010). In particular, low ice cover in fall tends to be followed by a negative sense to the AO in the following winter. Current research is investigating whether this mechanism represents a reliable source of predictability.

4. Seasonal Projections from the National Centers for Environmental Prediction (NCEP)

Seasonal projections from the NCEP coupled atmosphere-ocean forecast system model (CFS) for SST are shown in Figure 21. The SST anomaly maps indicate negative SST anomalies in the equatorial Pacific from fall 2010 into spring 2011, with the event's peak near the first of the year. This forecast is in agreement with the vast majority of the forecasts from other models run operationally and experimentally at a variety of US and international centers. As a group, the dynamical models such as CFS tend to indicate a stronger La Niña than their statistical/empirical model counterparts. In light of the present conditions in the tropical Pacific, in particular the anomalously low vertically integrated heat content and the combination of easterly wind anomalies and suppressed deep cumulus convection in the central Pacific, it can be anticipated with a high degree of certainty that La Niña conditions will prevail through the remainder of 2010 into 2011. A La Niña generally brings cool upper ocean conditions along the west coast of North America, and for Alaska waters. The CFS model is indicating the likelihood of a weaker Aleutian low than normal, as typically occurs during La Niña. The model has a good track record at predicting the broad patterns in the anomalous atmospheric circulation in winter. On the regional scale, however, the weather is more difficult to forecast reliably. For example, some of the individual runs of the ensemble of CFS simulations are indicating a storm track into the western Bering Sea that generally brings more mild air of maritime origin into the Bering Sea. Consequently, the evidence for continued cold in the Bering Sea, at least from this particular forecast model, is not that strong. The Bering Sea is one of the few regions that have been relatively cold in recent years, and it will be interesting to see if this La Niña will help keep it cold there, or whether it warms like much of the rest of the globe.

Arctic Sea Ice Cover - From the Arctic Report Card

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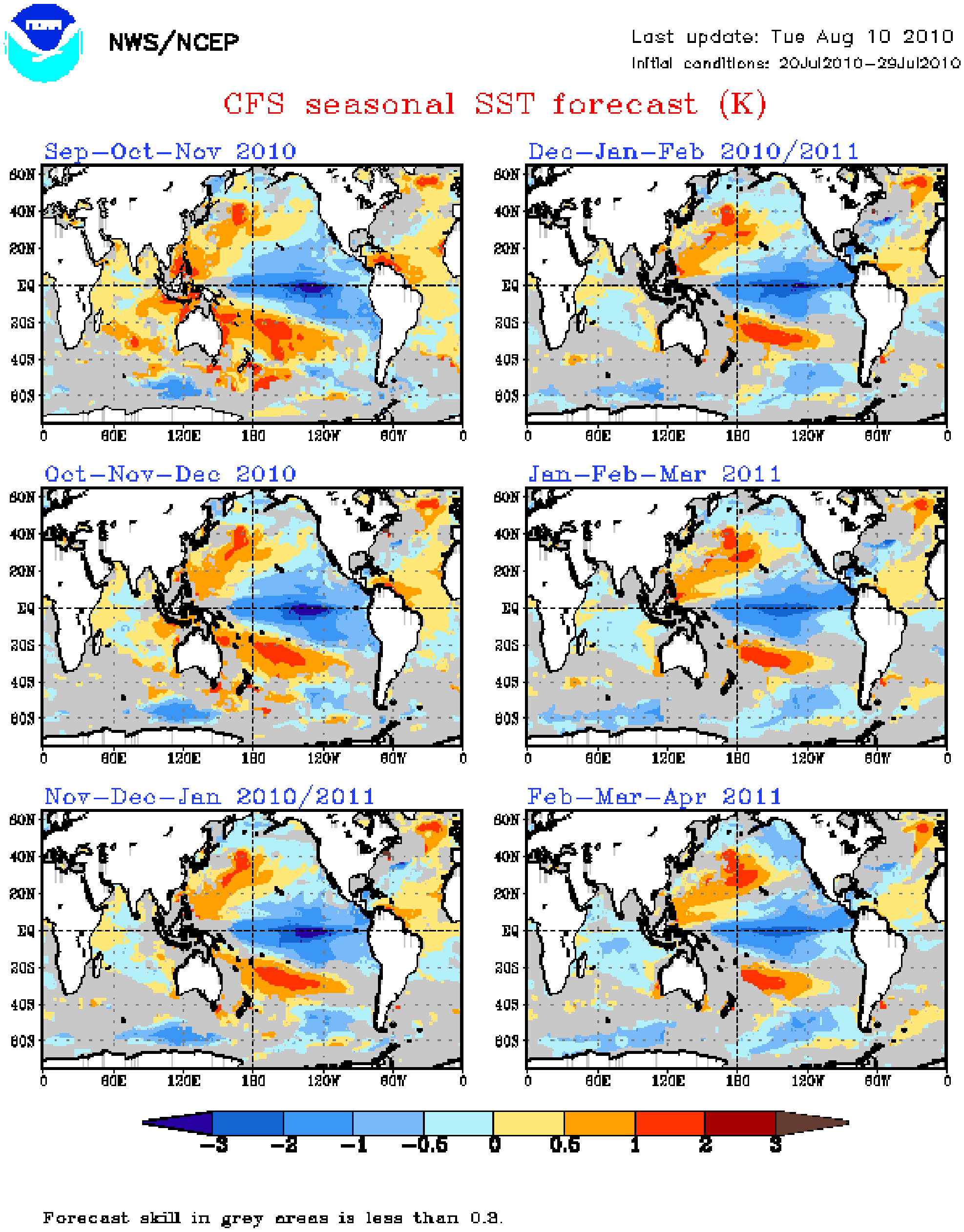

Figure 21: Seasonal forecast of SST anomalies from the NCEP coupled forecast system model.

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Last updated: October 2008

See the 2008 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Eastern Bering Sea

Eastern Bering Sea Climate - FOCI

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Last updated: September 2009

See the 2009 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Summer Bottom and Surface Temperatures - Eastern Bering Sea

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Last updated: October 2010

The annual AFSC bottom trawl survey for 2010 started on 3 June and finished on 4 August. The average surface temperature, 5.3°C, was slightly higher than 2009 but still 1.2°C lower than the long-term mean of 6.5°C (Figure 22). The average bottom temperature in 2010 was 1.40°C, which was below the grand mean for the fifth consecutive year. The 'cold pool', usually defined as an area with temperatures <2°C, extended down the middle shelf to the Alaska Peninsula and into Bristol Bay similar to other years when bottom temperatures were below the grand mean (Figure 23). Warm and cold years are the result of interannual variability in the extent, timing, and retreat of sea ice in the EBS shelf. During cold years, sea ice extent is further south and sea ice retreat occurs later. The relatively large interannual fluctuations in bottom temperature on the EBS shelf can influence the spatial and temporal distribution of groundfishes and the structure and ecology of the marine community (Kotwicki et al., 2005; Mueter and Litzow, 2008; Spencer, 2008). The timing of phytoplankton and subsequent zooplankton blooms are also affected by the extent of sea ice and timing of its retreat which in turn can affect survival and recruitment in larval and juvenile fishes as well as the energy flow in the system (Hunt et al., 2002).

Variations in Water Mass Properties During Fall 2000-2007 in the Eastern Bering Sea - BASIS

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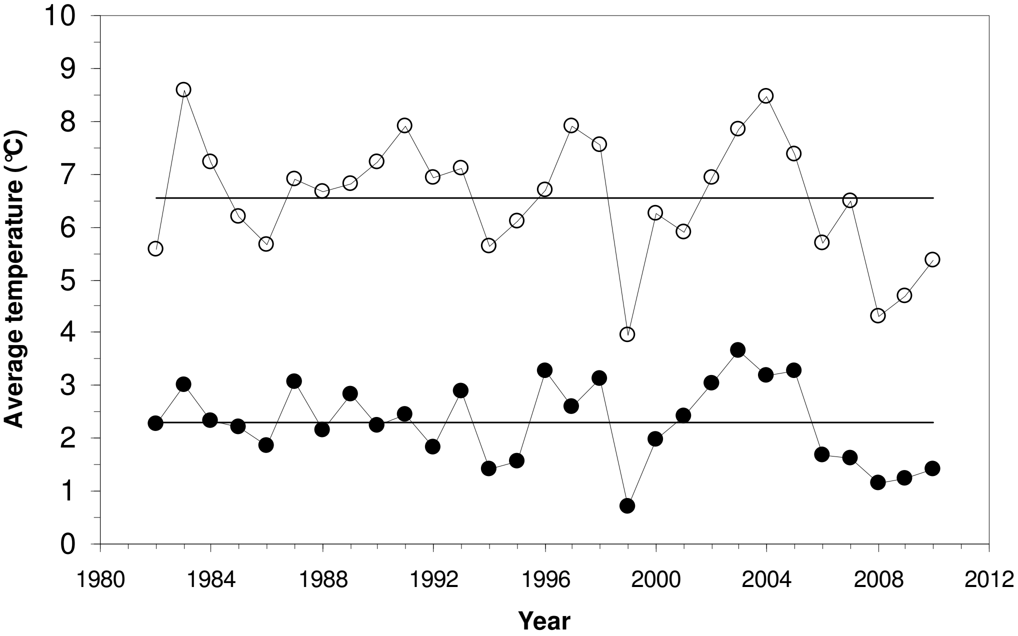

Figure 22: Average summer surface (open circles) and bottom temperatures (solid circles) (oC) of the eastern Bering Sea shelf collected during the standard bottom trawl surveys from1982-2010. Survey water temperatures for each year were weighted by the proportion of their assigned stratum area.

Last updated: August 2008

See the 2008 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Gulf of Alaska

Eddies in the Gulf of Alaska - FOCI

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Last updated: August 2010

Description of index: Eddies in the northern Gulf of Alaska have been shown to influence distributions of nutrients (Ladd et al., 2009, 2005, 2007), phytoplankton (Brickley and Thomas, 2004) and ichthyoplankton (Atwood et al., Accepted), and the foraging patterns of fur seals (Ream et al., 2005). Eddies propagating along the slope in the northern and western Gulf of Alaska are generally formed in the eastern Gulf in autumn or early winter (Okkonen et al., 2001). Using altimetry data from 1993 to 2001, Okkonen et al. (2003) found that strong, persistent eddies occur

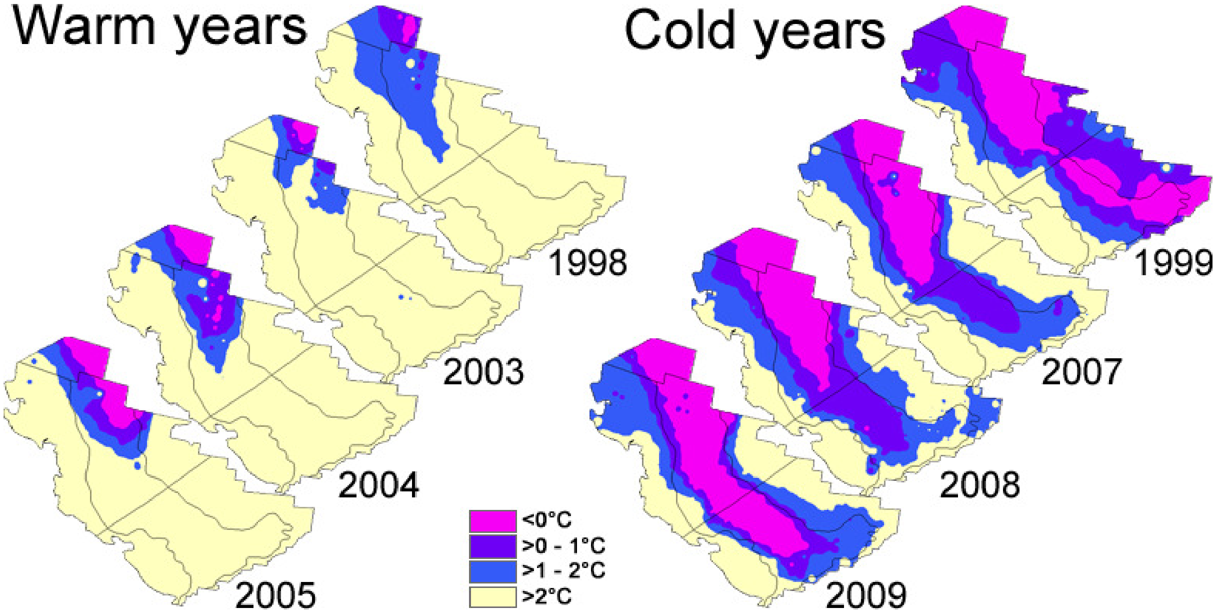

Figure 23: Temperature plots of average bottom temperature from the eastern Bering Sea shelf bottom trawl survey comparing the extent of the cold pool (<2C) during years warmer and colder than the 1982-2009 grand mean.

more often after 1997 than in the period from 1993 to 1997. Ladd (2007) extended that analysis and found that, in the region near Kodiak Island, eddy energy in the years 2002-2004 was the highest in the altimetry record (1993-2006).

Since 1992, the Topex/Poseidon/Jason/ERS satellite altimetry system has been monitoring sea surface height. Eddy kinetic energy (EKE) can be calculated from gridded altimetry data (merged TOPEX/Poseidon, ERS-1/2, Jason and Envisat; (Ducet et al., 2000). A map of eddy kinetic energy in the Gulf of Alaska averaged over the altimetry record (updated from Ladd (2007)) shows four regions with local maxima (labeled a, b, c and d in Figure 24). The first two regions are associated with the formation of Haida (a) and Sitka (b) eddies. Eddies that move along the shelf-break often feed into the third and fourth high EKE regions (c and d; Figure 24). By averaging EKE over regions c and d (see boxes in Figure 24), we obtain an index of energy associated with eddies in these regions (Figure 25).

Status and trends: The seasonal cycle of EKE averaged over the two regions (c and d) are out of phase with each other. Region (c) exhibits high EKE in the spring (March-May) and lower EKE in the autumn (September-November) while region (d) exhibits high EKE in the autumn and low EKE in the spring. EKE was particularly high in region (c) in 2002-2004 when three large persistent eddies passed through the region. In region (d), high EKE was observed in 1993, 1995, 2000, 2002, 2004, 2006 and 2007. Particularly low EKE values were observed in region (c) for 2005-2006 and 2009 indicating a reduced influence of eddies in the region. EKE levels were very low in both regions in 2009 and higher in the spring of 2010.

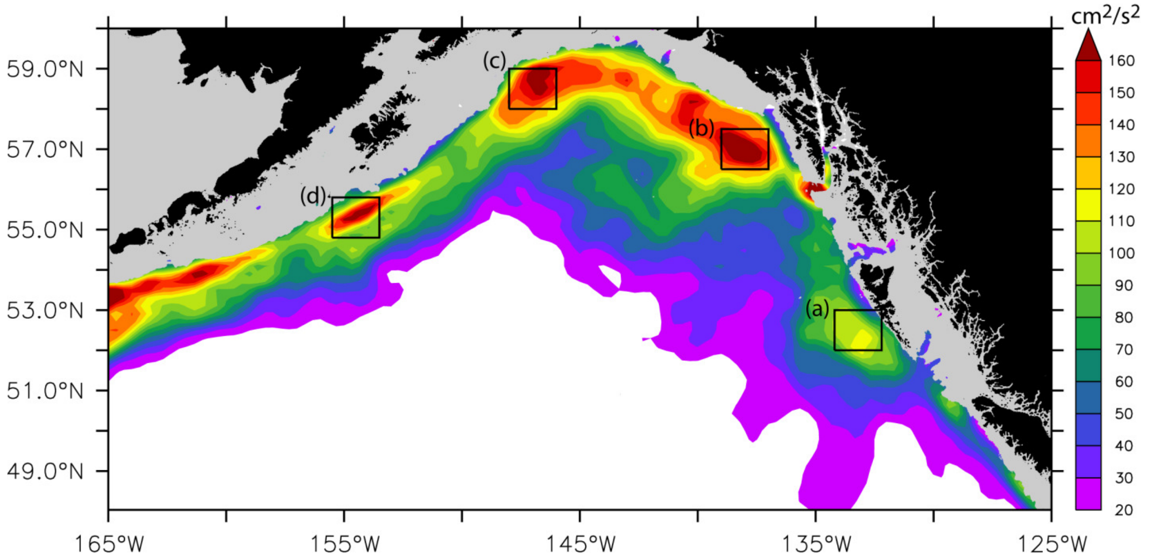

Figure 24: Eddy Kinetic Energy averaged over October 1993-October 2009 calculated from satellite altimetry. Regions (c) and (d) denote regions over which EKE was averaged for Figure 25.

Implications: This may have implications for the ecosystem. Phytoplankton biomass was probably more tightly confined to the shelf during 2009 due to the absence of eddies, while in 2007 and possibly 2010, phytoplankton biomass likely extended farther off the shelf. In addition, cross-shelf transport of heat, salinity and nutrients were likely to be smaller in 2009 than in 2007 and 2010 (or other years with large persistent eddies). Shelf-spawning species, flathead sole, southern rock sole, and starry flounder, were all found to be negatively impacted by strong eddy activity along the shelf break in region (d) (Atwood et al., Accepted), suggesting that the biomass of these species may have been smaller in 2007 relative to 2009. The altimeter products were produced by the CLS Space Oceanography Division (AVISO, 2008).

Ocean Surface Currents - Papa Trajectory Index

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Last updated: July 2009

See the 2009 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

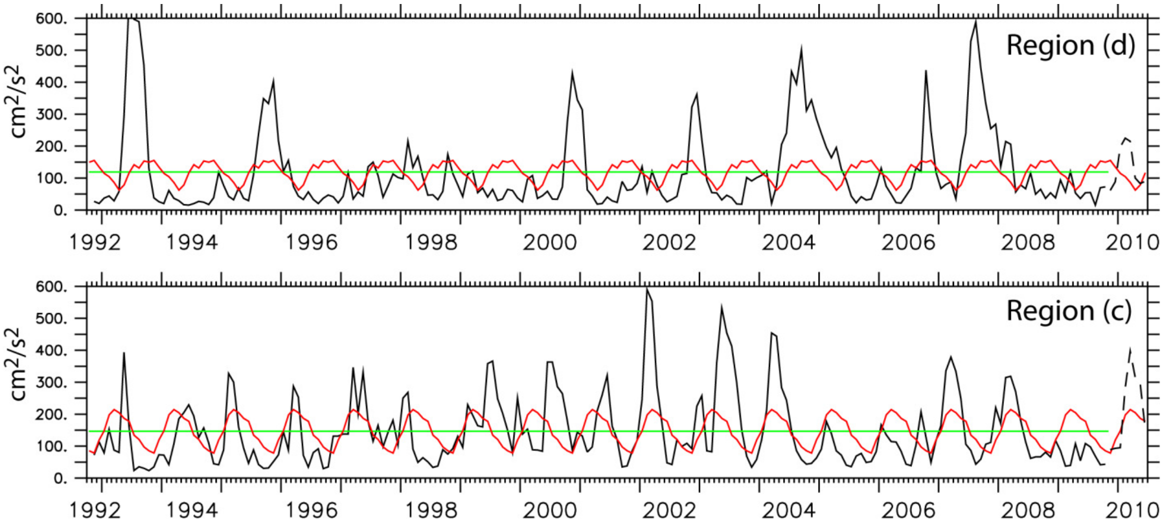

Figure 25: Eddy kinetic energy (cm^2 s^{-2}) averaged over Region (d) (top) and Region (c) (bottom) shown in Figure 24. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product), Red: seasonal cycle. Green (straight line): mean over entire time series.

Gulf of Alaska Survey Bottom Temperature Analysis

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Last updated: October 2009

Gulf of Alaska surveys are conducted in alternate odd years. For most recent data, see the 2009 report in the “Assessment Archives” at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Winter Mixed Layer Depths at GAK 1 in the Northern Gulf of Alaska

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Last updated: October 2007

See the 2007 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Pollock Survival Indices - EcoFOCI

Seasonal Rainfall at Kodiak

Wind Mixing at the Southwestern End of Shelikof Strait

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Last updated: August 2008

See the 2008 reports for these three indices in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`. Also see the GOA pollock stock assessment as these contributions will no longer be updated in the Ecosystem Considerations report.

Aleutian Islands

Eddies in the Aleutian Islands - FOCI

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Last updated: August 2010

Description of index: Eddies in the Alaskan Stream south of the Aleutian Islands have been shown to influence flow into the Bering Sea through the Aleutian Passes (Okkonen, 1996). By influencing flow through the passes, eddies could impact flow in the Aleutian North Slope Current and Bering Slope Current as well as influencing the transports of heat, salt and nutrients (Mordy et al., 2005; Stabeno et al., 2005) into the Bering Sea.

Since 1992, the Topex/Poseidon/Jason/ERS satellite altimetry system has been monitoring sea surface height. Eddy kinetic energy (EKE) can be calculated from gridded altimetry data (merged TOPEX/Poseidon, ERS-1/2, Jason and Envisat; (Ducet et al., 2000)). Eddy kinetic energy (EKE) calculated from gridded altimetry data (Ducet et al., 2000) is particularly high in the Alaskan Stream from Unimak Pass to Amukta Pass (Figure 26) indicating the occurrence of frequent, strong eddies in the region. The average EKE in the region 171°W-169°W, 51.5°-52.5°N (Figure 27) provides an index of eddy energy likely to influence the flow through Amukta Pass. Numerical models have suggested that eddies passing near Amukta Pass may result in increased flow from the Pacific to the Bering Sea (Maslowski et al., 2008). The altimeter products were produced by the CLS Space Oceanography Division (AVISO, 2008).

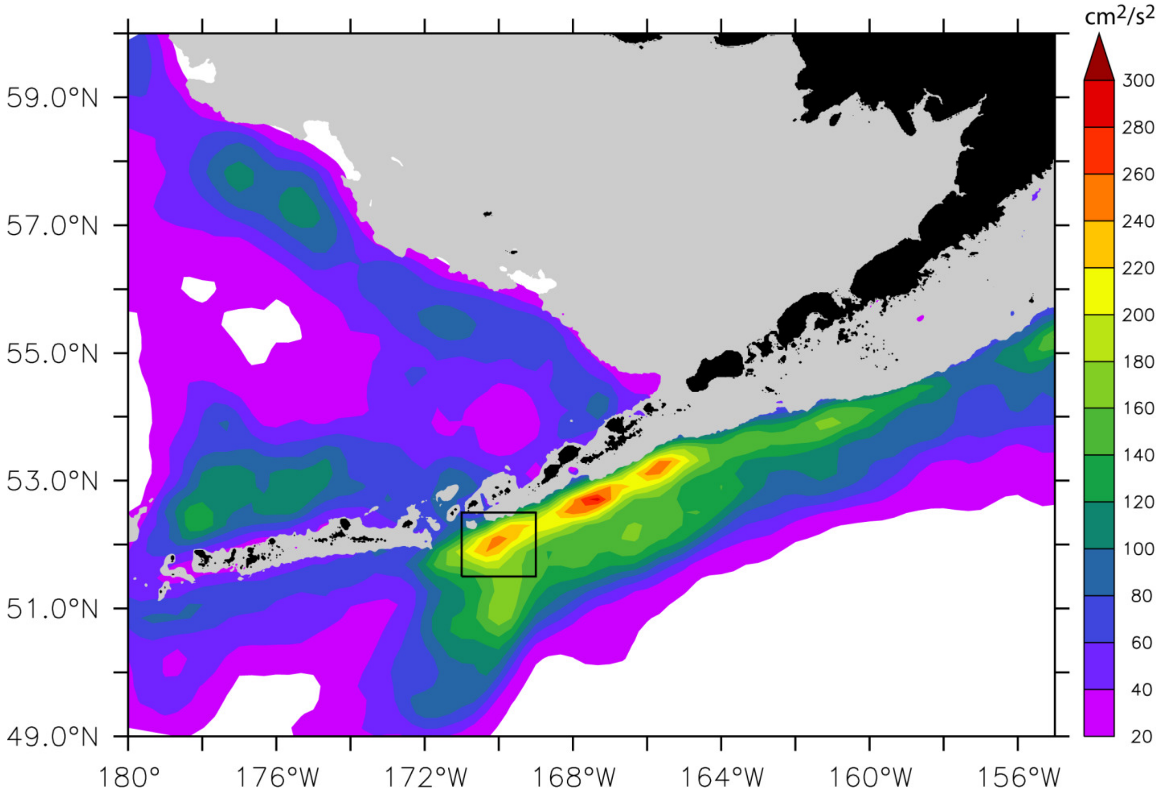

Figure 26: Eddy Kinetic Energy averaged over October 1993 - October 2009 calculated from satellite altimetry. Square denotes region over which EKE was averaged for Figure 27.

Status and trends: Particularly strong eddies were observed south of Amukta Pass in 1997/1998, 1999, 2004, 2006/2007, and 2009/2010. Eddy energy in the region appeared to be returning to low levels in the spring of 2010.

Implications: These trends indicate that higher than average volume, heat, salt, and nutrient fluxes to the Bering Sea through Amukta Pass may have occurred in 1997/1998, 1999, 2004, 2006/2007, and 2009/2010 while these fluxes may be reduced in the spring of 2010.

Water Temperature Data Collections - Aleutian Islands Trawl Surveys

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Last updated: October 2010

Description of index: The oceanography of the Aleutian Islands is shaped in large part by three major currents running along the archipelago and strong tidal forces in the passes between islands (Hunt and Stabeno, 2005). The Alaska Coastal Current (Schumacher and Reed, 1986; Reed, 1987)

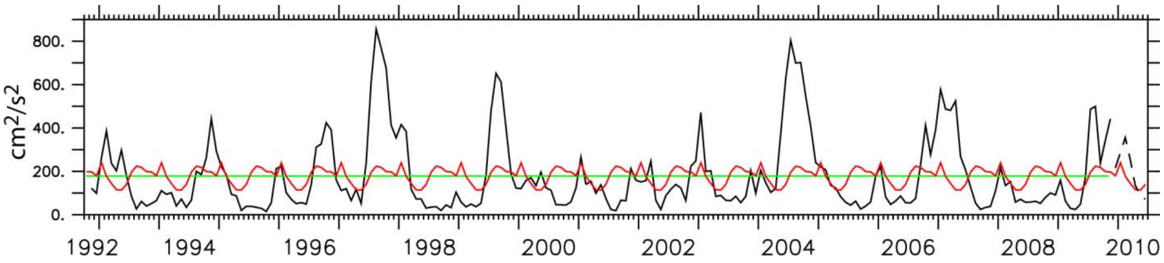

Figure 27: Eddy kinetic energy (cm^2 s^{-2}) averaged over region shown in Figure 26. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product). Red: seasonal cycle. Green (straight line): mean over entire time series.

flows westward along the south side of the Aleutians from the Gulf of Alaska to Samalga Pass. The Alaskan Current also flows westward along the southern shelf break of the Aleutians to Amchitka Pass where some of the water flows northward to serve as the source water for the Aleutian North Slope Current. The remainder of the Alaskan Current continues westward in a series of meanders and eddies to bathe the western Aleutians. The Alaska Coastal Current is warmer and fresher than the Alaskan Current and these differences contribute greatly to the chemical and physical properties of the water flowing through the passes of the Aleutian Islands. The Aleutian North Slope Current flows eastward along the north side of the Aleutians from Amchitka Pass.

Water temperature data have been routinely collected on NMFS survey bottom trawl hauls since 1994 using micro-bathythermographs attached to the headrope of the trawl. Prior to that, temperature data were routinely collected near trawl haul sites using expendable bathythermographs, although these earlier data were not used in this analysis. Groundfish assessment survey periods have ranged from early May to late September and sampling has usually progressed from east to west, but notable exceptions exist especially for the earliest three surveys involving Japanese vessels (1980, 1983, and 1986) and for the 2002 and 2006 surveys. These differences in sampling patterns in time and space complicate inter-annual comparison due to the strong relationship between date of collection and water temperature at all depths throughout the survey area.

Water temperature data during trawl descent (the period between when the doors were dropped until the center of the footrope touched the bottom) were used to estimate water temperatures at depth. Average Water temperature was estimated at each of several depths from 3 meters to the deepest depth of each tow. Depth increments were much finer at shallower depths to capture the rapid changes in water temperatures often seen in these depths. In order to account for the seasonal differences in water temperatures and make inter-annual comparisons more meaningful, an attempt was made to remove the effect of date of collection on water temperature, in effect standardizing temperatures to an approximate median date (July 10) for most AI surveys. This was achieved by using generalized additive modeling techniques to model the effects of date on temperature at each depth interval. The model was then used to estimate the temperature at the standard date (July 10) at the same depth and the residuals of the original model were added to the prediction for the final estimate. The estimated temperatures were binned into ½ degree longitude by depth increments and mean temperature in each increment was calculated. The results are shown in Figure 28.

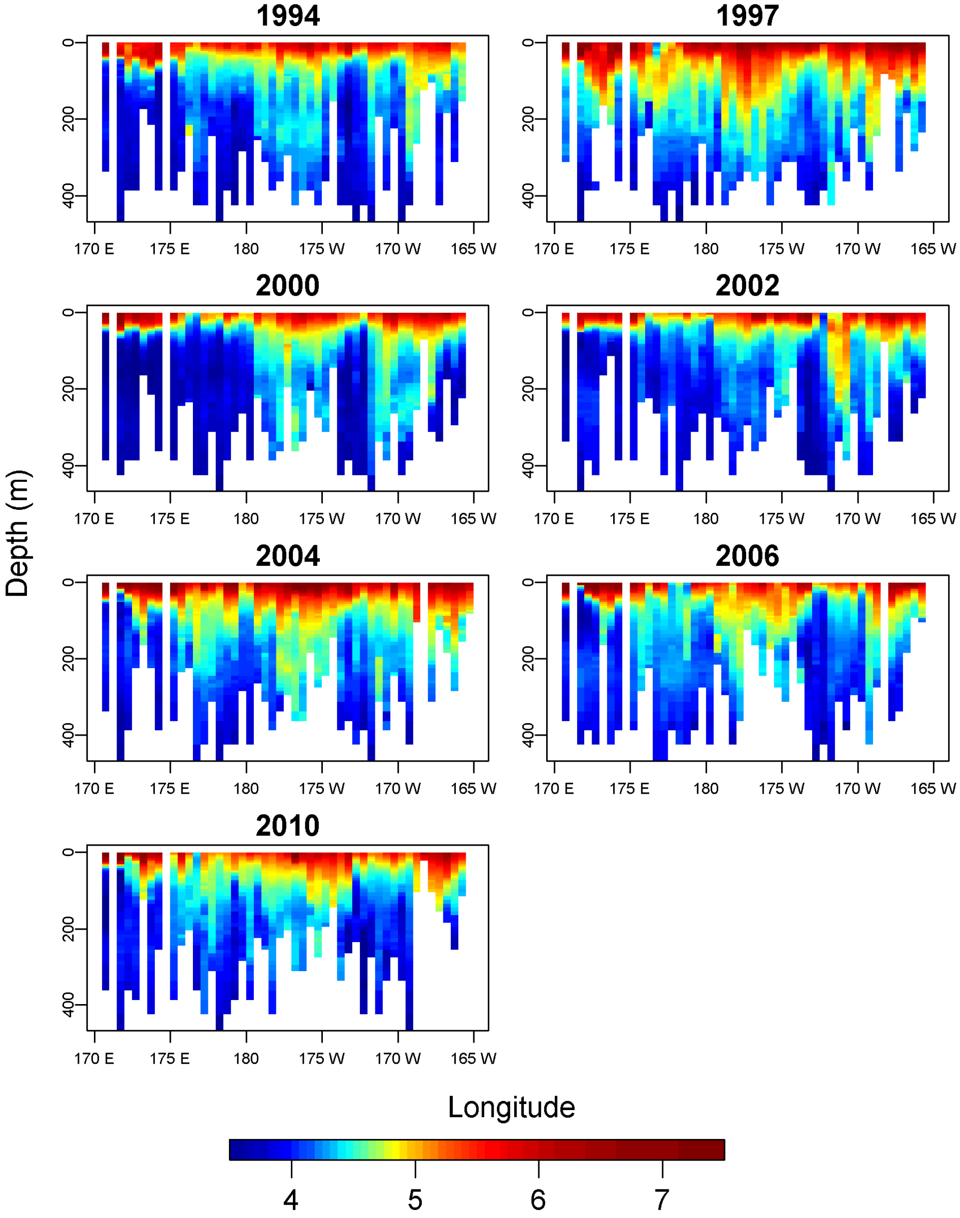

Figure 28: Date adjusted temperature profiles by ½ degree longitude intervals for years 1994-2010.

Status and Trends: Some common features are notable for all years, including warmer surface temperatures east of Amukta Pass (170 ° 30' W), between Seguam Pass (173° W) and Amchitka Pass (179° W) and west of Buldir Pass (175° E). The influence of these warmer surface temperatures generally extends to about 100 m, although in the warmest years it can reach 200 m. Cooler temperatures at depths greater than 100 m appear consistently around Seguam Island (172° 30' W), and this seems to be a particularly striking feature in colder than average years (e.g., 2000). Cooler temperatures at depths greater than 100 m are frequently a predominant feature west of 175° E, although in cooler years this area of cooler water extends as far east as Amchitka Pass.

Water temperatures were warmer in 1997 than in any other year in the time series. Not only were surface temperatures quite warm, but deeper waters were also consistently warmer than in other years. Temperatures in 2004 were also quite warm with a similar temperature pattern to 1997, although deeper waters in the extreme western Aleutians were cooler than in 1997. The coolest year in this series is 2000 when surface temperatures were generally cooler at the surface throughout the survey area, and waters deeper than 100 m were dominated by cooler water in the western Aleutians, particularly west of 180°. Water temperatures in 2010 appeared to be intermediate to these extremes as evidenced by the warmer surface temperatures in the eastern and western ends of the survey area, cooler water around Seguam Island, and generally warmer than normal temperatures below 100 m west of 180°. This is the same general pattern noted in 2006.

Factors causing the trend: The data presented here show a snapshot of water temperatures collected during bottom trawl surveys in the Aleutian Islands. Since each temperature bin represents data that were collected over a relatively short period as the vessels moved through the area, it is difficult to draw general conclusions as these temperatures are often greatly affected by short term phenomena such as storm events, tidal current velocity and/or direction and eddies.

Implications: The strength and persistence of eddies is believed to play a major role in mediating the transport of both heat and nutrients into the Bering Sea through the Aleutian passes (Maslowski et al., 2008) and this could have large impacts on both the Aleutian Islands and the Bering Sea ecosystems.

Habitat

Area Disturbed by Trawl Fishing Gear in the Eastern Bering Sea

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Last updated: June 2010

Description of index: Fishing gear can affect habitat used by a fish species for the processes of spawning, breeding, feeding, or growth to maturity. An estimate of the area of seafloor disturbed by trawl gear may provide an index of habitat disturbance. The area disturbed in the Eastern Bering Sea floor was calculated from observer trawl data each year from 1990-2009. The duration of each trawl haul was multiplied by a fishing effort adjustment as outlined in Appendix B of the January 2005 EFH EIS (`http://www.fakr.noaa.gov/habitat/seis/efheis.htm`). The adjustment converted trawl haul duration to area disturbed based on the type of trawl gear used (pelagic or bottom) and the vessel length. The adjustment also expanded smaller vessel fishing effort, which has 30% observer coverage, to simulate 100% coverage. Records missing trawl haul duration data and short wire hauls (hauls pulled in but not immediately brought on board) were assigned the average trawl haul duration over all years of 228 minutes (no more than 5% of hauls in any given year needed this adjustment).

An upper limit of the total area potentially disturbed by trawl hauls was estimated by assuming that no trawl hauls overlapped spatially. To find the percent disturbed, it was necessary to find the total area of the Eastern Bering Sea being considered (Figure 29a). NMFS reporting areas for the Bering Sea were used as a baseline; however, Norton Sound was excluded because it is beyond the range of many commercially fished groundfish species. The Bering Sea Habitat Conservation boundary was used to exclude areas beyond the shelf break. The resulting total area considered was 742,647 km^2. The percent of area disturbed was estimated in two ways: 1) with no spatial overlap of trawl hauls in a given year, providing an estimate of the maximum potential percent of area disturbed and 2) with spatial overlap of trawl hauls within 400 km^2 cells to limit the disturbance of trawls recorded in a cell to 400 km^2, providing an estimate of potential percent of area disturbed. The average distance of a haul based on recorded start and end locations is 14 km with a standard deviation of 10 km. The cell size was chosen to reflect this spatial resolution of the hauls. Though this cell size allows some overlap of hauls, it still may over estimate the percent area disturbed in a year. The map below shows in what areas trawling disturbances accumulated over various time intervals (Figure 29b).

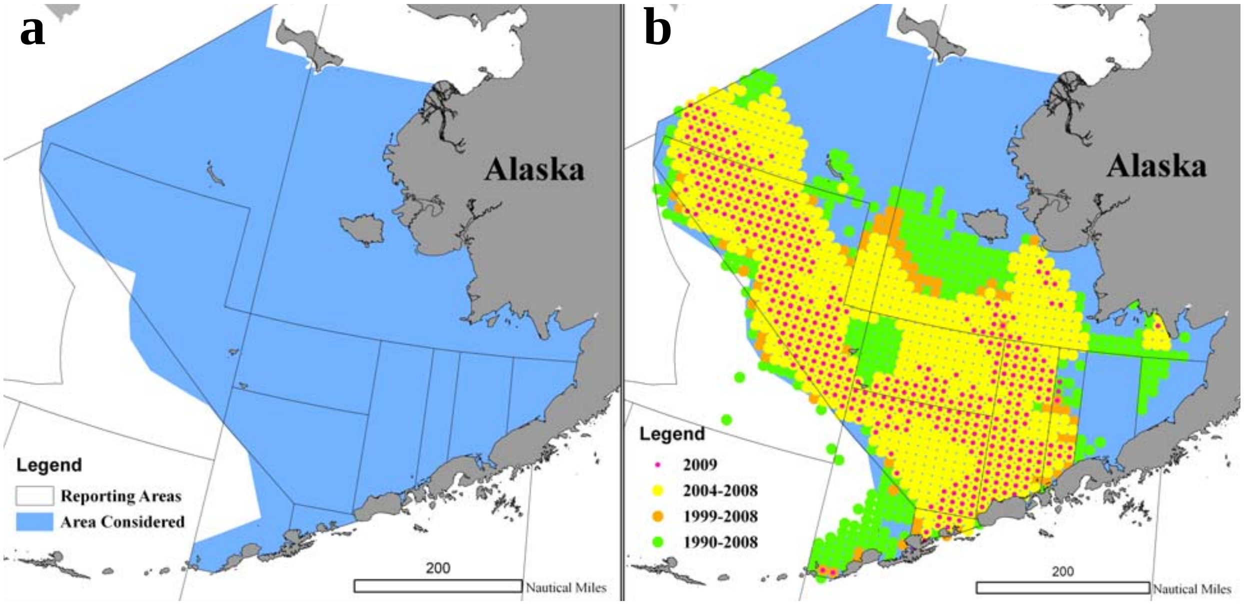

Figure 29: (a) Map of Eastern Bering Sea area considered when estimating percent area potentially disturbed by trawl fishing gear. (b) Map of 400 square kilometer cells with some trawling in cumulative time periods. Cells with fewer than 3 vessels are not shown

Status and Trends: The maximum total area of seafloor in the Eastern Bering Sea potentially disturbed by trawls varied around 120,000 km^2 in the 1990s and decreased in the late 1990s to approximately 90,000 km^2. The area disturbed remained relatively stable in the 2000s with a slight increase in the 2007-2008. The percent of total area disturbed varied between 10% and 15% in the 1990s and between 9% and 11% in the 2000s, however due to trawls overlapping the same area the more realistic area disturbed was less than 10% from the mid 1990s on. Reduction in hours fished in the 2000s indicates greater fishing efficiency.

Factors Causing Trends: Trends in seafloor area disturbed can be affected by numerous variables, such as individual fishery movements, fish abundance and distribution, management actions (e.g., closed areas), changes in the structure of the fisheries due to rationalization, increased fishing skills (e.g., increased ability to find fish), and changes in vessel horsepower and fishing gear.

During 1993-1999, fishing effort was more concentrated in the southern area compared to 1990-1992 and 2000-2008, where effort was spread out spatially, particularly towards the northwest. This may, in part, explain the larger difference between the upper and lower estimates of percent area disturbed (with no overlap and with overlap within 400 km^2 cells, respectively) during 1993-1998 relative to other years (Figure 30).

As of 1999 only pelagic trawls can be used in the Bering Sea pollock fisheries. To check to see if this affected the trends the graph was recalculated making no distinction between gears. The result showed no change to the trend. Short-wiring was only identified in the database from 1995 onward, however short-wiring accounts for only 2% of the total hauls and does not explain the early 1990 trends.

Implications: Habitat damage varies with the physical and biological characteristics of the areas fished, recovery rates of HAPC biota in the areas fished, and management changes that result in spatial changes in fishing effort.

HAPC Biota Bering Sea

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Last updated: October 2010

Description of index: Groups considered to be HAPC biota include: seapens/whips, corals, anemones, and sponges. Corals are rarely encountered on the Bering Sea shelf so they were not included here. Relative CPUE was calculated and plotted for each species group by year for 1982-2010. Relative CPUE was calculated by setting the largest biomass in the time series to a value of 1 and scaling other annual values proportionally. The standard error (± 1) was weighted proportionally to the CPUE to produce a relative standard error.

Status and Trends: It is difficult to detect trends of HAPC groups in the Bering Sea shelf from the RACE bottom trawl survey results because there is taxonomic uncertainty within the HAPC biota groups and because the quality and specificity of field identifications have varied over the course of the time series (Stevenson and Hoff, 2009). Moreover, relatively large variability in the relative CPUE values makes trend analysis difficult (Figure 31). Further research in several areas would benefit the interpretation of HAPC biota trends including systematics and taxonomy of Bering Sea shelf invertebrates; survey gear selectivity; and the life history characteristics of the epibenthic organisms captured by the survey trawl.

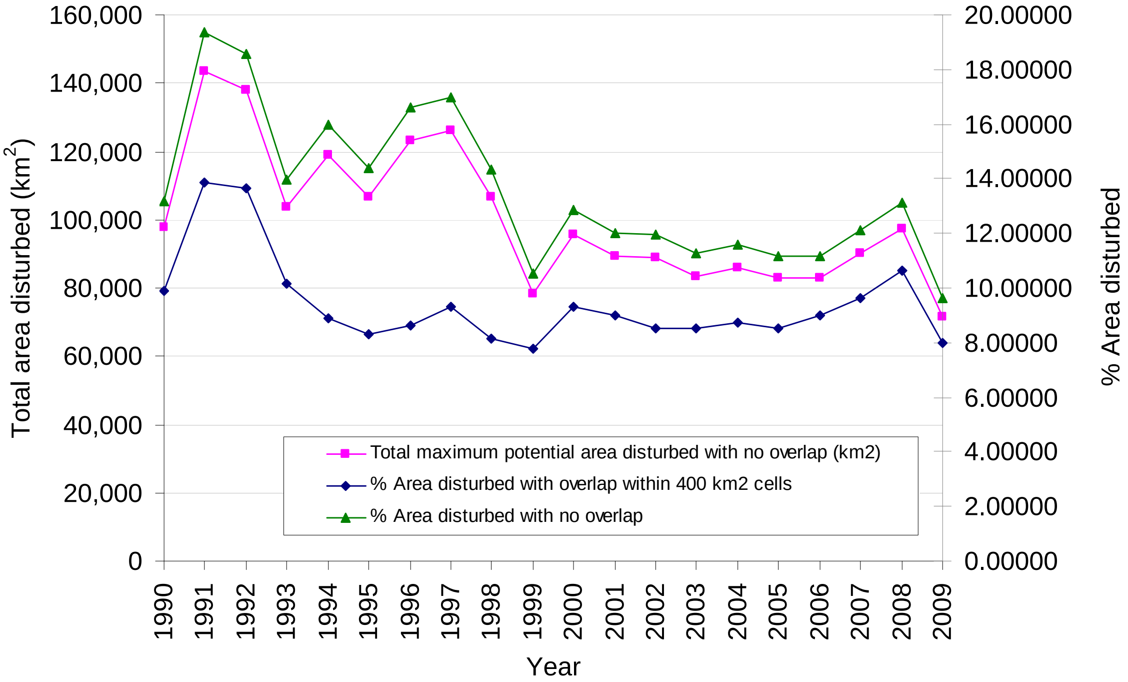

Figure 30: Total maximum potential area disturbed (assuming no spatial overlap of trawls), and the percent area disturbed. The green line, representing percent area disturbed, sums the area disturbed assuming no spatial overlap of trawl hauls in a year, thus providing an upper limit to the estimate of area disturbed. The blue line represents the percent area disturbed with spatial overlap of trawl hauls within 400 km^2 cells, thereby, limiting the disturbance of trawls recorded in a cell to 400 km^2.

HAPC Biota Gulf of Alaska

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Last updated: October 2009

Gulf of Alaska surveys are conducted in alternate odd years. For most recent data, see the 2009 report in the “Assessment Archives” at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Distribution of rockfish species along environmental gradients in Gulf of Alaska and Aleutian Islands bottom trawl surveys

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Last updated: October 2010

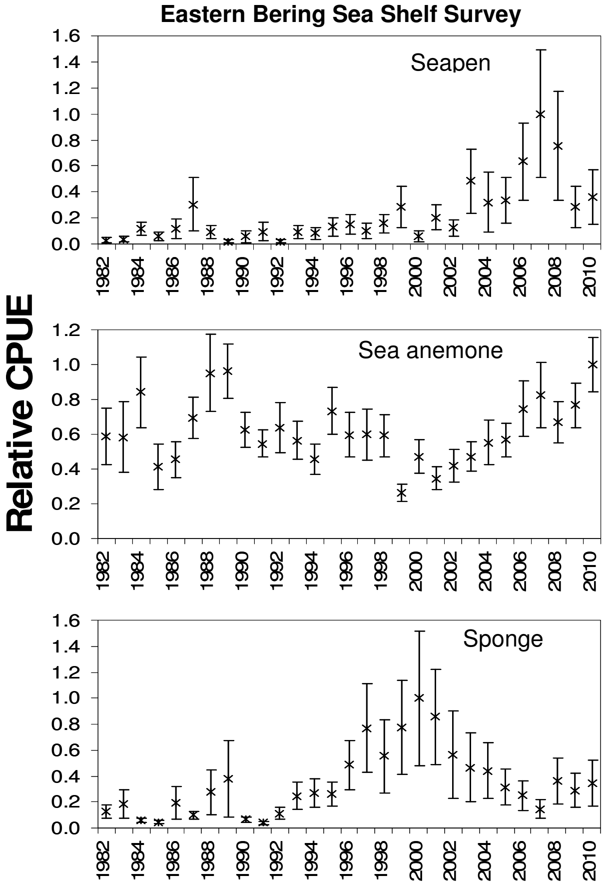

Figure 31: Relative CPUE trends of HAPC biota from the RACE bottom trawl survey of the Bering Sea shelf, 1982-2010. Data points are shown with standard error bars.

Description of index: In a previous analysis of rockfish from 14 bottom trawl surveys in the Gulf of Alaska and Aleutian Islands (Rooper, 2008), five species assemblages were defined based on similarities in their distributions along geographical position, depth, and temperature gradients. The 180 m and 275 m depth contours were major divisions between assemblages inhabiting the shelf, shelf break, and lower continental slope. Another noticeable division was between species centered in southeastern Alaska and those found in the northern Gulf of Alaska and Aleutian Islands.

In this time-series, the mean-weighted distributions of six rockfish (*Sebastes* spp.) species along the three environmental gradients (depth, temperature, and position) were calculated for the Gulf of Alaska and Aleutian Islands. A weighted mean value for each environmental variable was computed for each survey as:

$$Mean = \frac{\sum (f_i x_i)}{\sum f_i},$$

where f_i is the CPUE of each rockfish species group in tow i and x_i is the value of the environmental variable at tow i. The weighted standard error (SE) was then computed as:

$$SE = \frac{\sqrt{\frac{(\sum(f_i x_i^2)) - ((\sum f_i) * mean^2)}{(\sum f_i) - 1}}}{\sqrt{n}},$$

where n is the number of tows with positive catches. Details of the calculations and analyses can be found in Rooper (2008). These indices monitor the distributions of major components of the rockfish fisheries along these environmental gradients to detect changes or trends in rockfish distribution.

Status and trends: There were no definitive trends in distribution over the time series for position or depth in the Aleutian Islands (Figure 32). Mean-weighted temperature distributions for all species were within about 1°C over the entire time series, although since 2000 the mean-weighted temperature distributions have increased for most species (0.1 - 0.5°C). There was high variability in the mean-weighted variables in the 1991 Aleutian Islands survey, but since then the time series is remarkably stable. This is in contrast to the trends in rockfish distribution in the Gulf of Alaska. The depth distribution of rockfish in the Gulf of Alaska has remained constant for each species over time (Figure 33). Changes in rockfish distribution with temperature have occurred over the time series, most notably in 2007 and 2009 where there has been a constriction of the range of mean-weighted temperatures for rockfish. With the exception of northern rockfish, there has been a continued trend of the movement of the center of the rockfish distribution towards the eastern GOA and SE Alaska since 2003. Northern rockfish do not typically occur in high numbers in the eastern GOA, so their distribution has not changed.

Factors causing observed trends: The observed changes in temperature distributions for rockfish in the GOA and AI are probably related to changes in temperature at depth, since rockfish depth distributions have remained stable over the time series. It is unclear what is causing the shift in rockfish distribution towards the eastern GOA and SE Alaska, although this is probably related to changes in abundance of major rockfish species in the central and western GOA.

Implications: The trends in the mean-weighted distributions of rockfish should continue to be monitored, with special attention to potential causes of the shift in position of rockfish toward the eastern GOA.

HAPC Biota Aleutian Islands

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Last updated: October 2010

Description of index: Groups considered to be Habitat Area of Particular Concern (HAPC) biota include seapens/seawhips, corals, anemones, and sponges. The biennial survey in the Aleutian Islands (AI) does not sample any of the HAPC fauna well. The survey gear does not perform well in many of the areas where these groups are likely to be more abundant and survey effort is quite limited in these areas. In tows where they are encountered, the standard survey gear is ill-suited for efficient capture of these groups. As a result, CPUE is often strongly influenced by

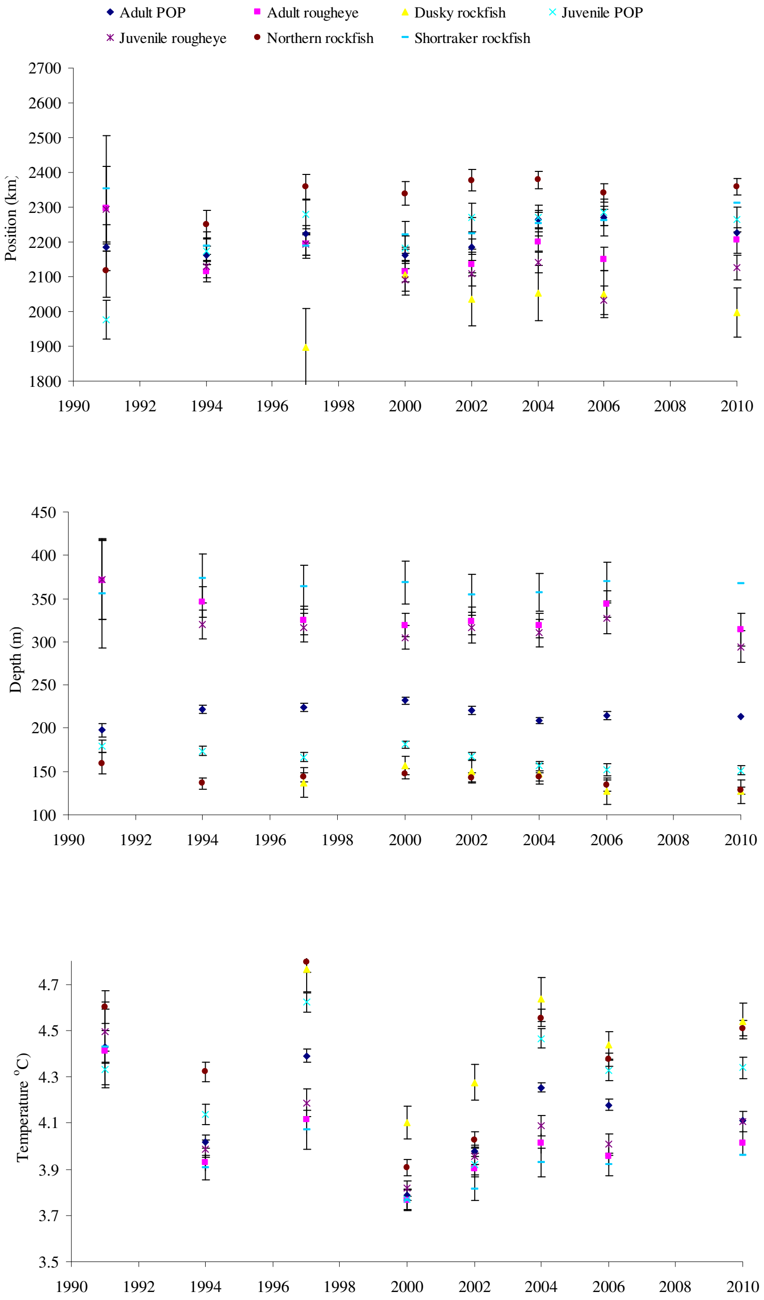

Figure 32: Plots of mean weighted (by catch per unit effort) distributions (and SEs) of seven rockfish species-groups along three environmental variables in the Aleutian Islands. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance from Hinchinbrook Island, Alaska, with positive values west of this central point in the trawl surveys and negative values in southeastward.

a very small number of catches with a resulting high variance. Another complicating factor in interpreting these results is that the gears used by the Japanese vessels in the surveys prior to 1991

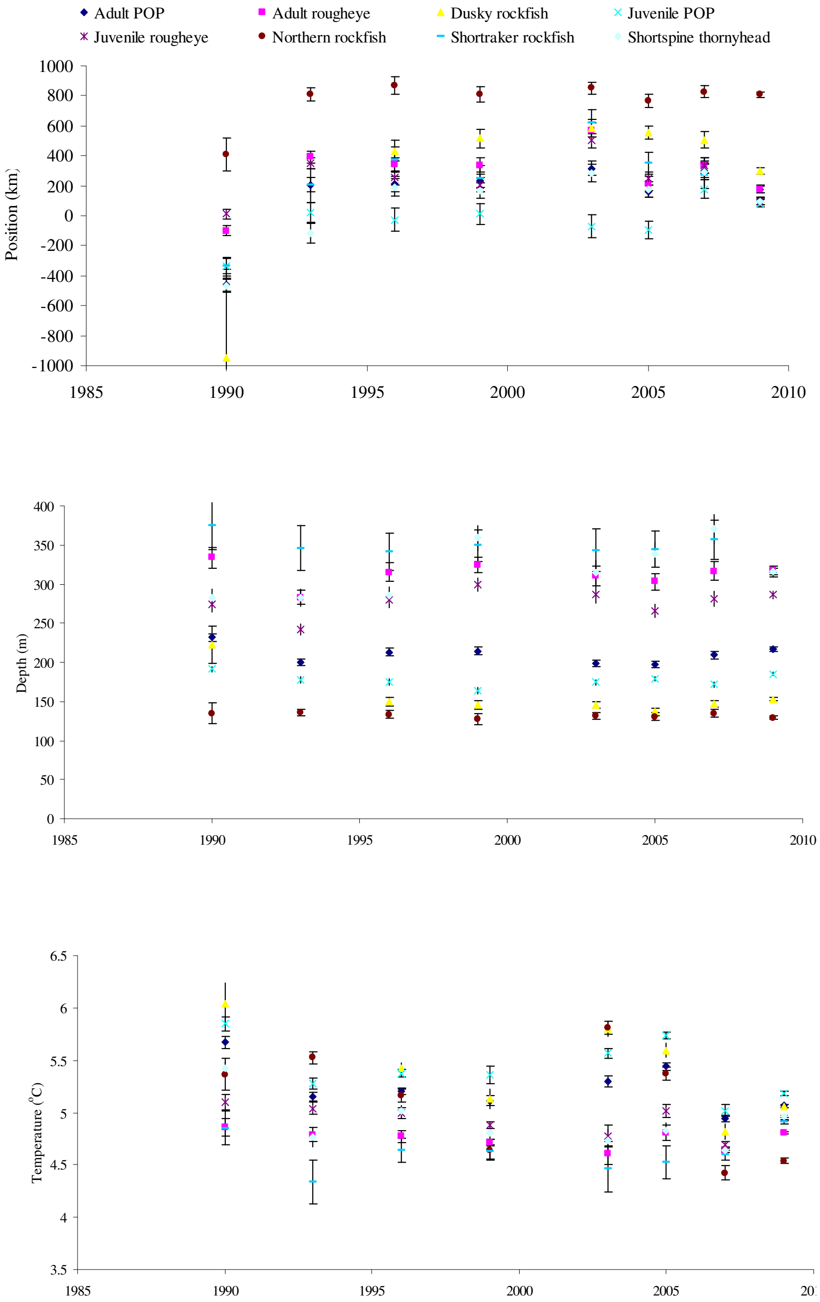

Figure 33: Plots of mean weighted (by catch per unit effort) distributions (and SEs) of seven rockfish species-groups along three environmental variables in the Gulf of Alaska. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance from Hinchinbrook Island, Alaska, with positive values west of this central point in the trawl surveys and negative values in southeastward.

were quite different from the survey gear used aboard American vessels in subsequent surveys and likely resulted in different catch rates for many of these groups. In recent years, more emphasis has been placed on the collection of more detailed and accurate data on HAPC species and it is likely that this increased emphasis influenced the results presented here. For each species group, the largest catch over the time series was arbitrarily scaled to a value of 100 and all other values were similarly scaled. The standard error (±1) was weighted proportionally to the CPUE to get a relative standard error.

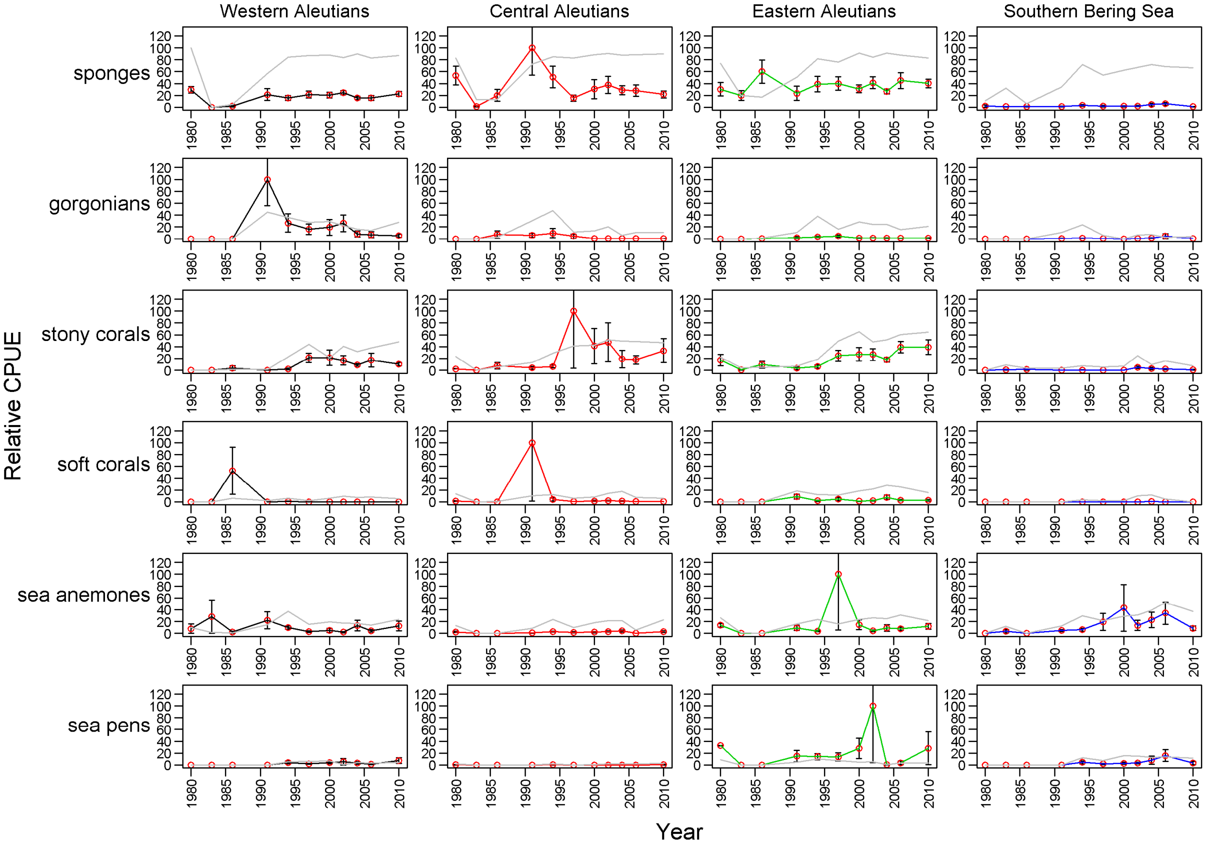

Figure 34: Mean CPUE of HAPC species groups by area from RACE bottom trawl surveys in the Aleutian Islands from 1980 through 2010. Error bars represent standard errors. The gray lines represent the percentage of non-zero catches.

Status and trends: A few general patterns are clearly discernible (Figure 34). Sponges are caught in most tows in the Aleutians west of the southern Bering Sea. Interestingly, the frequency of occurrence of sponges in the southern Bering Sea is relatively high, but sponge abundance is much lower than other areas. The sponge estimates for the 1983 and 1986 surveys are much lower than other years, probably due to the use of different gear, including large tire gear that limited the catch of most sponges. Stony corals are commonly captured outside of the southern Bering Sea and their abundance appears to be highest in the central and eastern Aleutians. Soft corals are caught much less frequently and the survey likely does not provide a reliable estimate of soft coral abundance. Sea anemones are also common in survey catches but abundance trends are not clear for most areas. Sea pens are much more likely to be encountered in the southern Bering Sea and eastern AI than in areas further west. Abundance estimates are low across the survey area and large apparent increases in abundance, such as that seen in the eastern AI in 1997, are typically based on a single large catch.

Implications: AI survey results provide limited information about abundance or abundance trends for these organisms due to problems in catchability and areas sampled relative to areas of greatest HAPC abundance as discussed above. Therefore the indices presented are likely of limited value to fisheries management.

Effects of Fishing Gear on Seafloor Habitat

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Last updated: November 2005

See the 2005 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Nutrients and Productivity

Nutrients and Productivity Processes in the southeastern Bering Sea

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Last updated: November 2005

See the 2005 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Variations in phytoplankton and nutrients during fall 2000-2006 in the eastern Bering Sea- BASIS

Contributed by Lisa Eisner, Kristen Cieciel, Ed Farley, and Jim Murphy, Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
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Last updated: August 2008

See the 2008 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Nutrient and Chlorophyll Processes on the Gulf of Alaska Shelf

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Last updated: November 2004

See the 2004 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Zooplankton

Bering Sea Zooplankton

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Description of Indices: Summer zooplankton biomass data are collected in the eastern Bering Sea by the Hokkaido University research vessel T/S Oshoru Maru. The cruises began in 1954 and continue today, although the ship was not able to sample the eastern Bering Sea shelf in 2010. The time series (up to 1998) was re-analyzed by Hunt et al. (2002) and Napp et al. (2002) who examined the data by oceanographic domain. Hunt et al. (2008) addressed recent (up to 2005) declines in summer zooplankton biomass in relation to a warming of the eastern Bering Sea (2001 - 2005). Figure 35 below updates the time series to 2009 extending the time series into a cold period in the eastern Bering Sea and presents the data as biomass (wet weight) over the time period sampled.

Summer concentrations of dominant species within the crustacean copepod community were also examined using samples obtained by the EcoFOCI Program at Alaska Fisheries Science Center on either the T/S Oshoro Maru or from boats chartered for the AFSC RACE Groundfish Bottom Trawl Surveys. The abundances of four species were examined for the Middle and Outer Shelf Domains (Figure 36): *Calanus marshallae* (all copepodite stages), *Neocalanus* spp (C2 to C6 *N. flemingeri* and *N. plumchrus*), *Pseudocalanus* spp. (all stages) and *Acartia* spp (C6 only).

Status and Trends: Up to 1998 there were no discernable trends in the time series for any of the four geographic domains (Napp et al., 2002). There was a strong decrease in biomass 2000 to 2004 or 2005 depending on the region. The increase in biomass after the end of the warm period appears to be real with 2009 values well above those during the warm period, albeit less than the previous year 2008 on the Middle and Outer Shelf Domains. Note that the number of observations in some of the regions (basin and coastal water) was very low. What is remarkable is that the trends appear to occur in all four domains although the initiation or time of the end of a trend

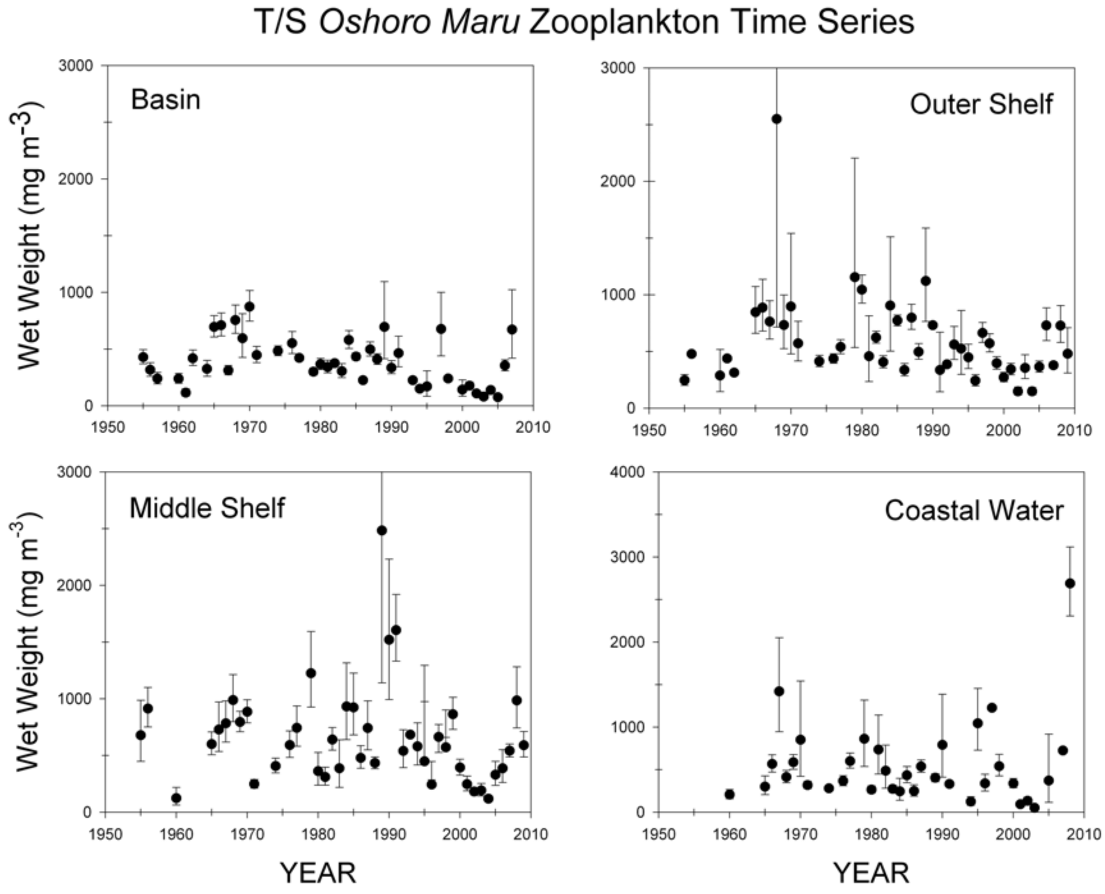

Figure 35: Zooplankton biomass at stations in regions of the deep basin of the Bering Sea and in the outer, middle and coastal domains of the southeastern Bering Sea shelf sampled during the T/S Oshoro Maru Summer Cruises. Data from 1977 to 1994 from Sugimoto and Tadokoro (1998). Data from 1995 to 2004 from Dr. N. Shiga. Data from 2005 to 2009 from Dr. A. Yamaguchi, all from the Graduate School of Fisheries, Hokkaido University, Japan.

may be slightly different (Figure 35). Part of the decrease in biomass over the middle shelf during the warm years was most likely due to decreases in the abundance of *Calanus marshallae*, the only "large" copepod found in that area and euphausiids (Coyle et al., 2008; Hunt et al., 2008). It is not clear what might be the cause of declines in other regions.

Recent increases in the abundance of large copepods (favored prey taxa of planktivorous seabirds, fishes, and marine mammals) were noted for 2008 and 2009. Concentrations of *C. marshallae* in the Middle Shelf Domain began to increase in 2007 and reached very high levels in 2009. *Neocalanus* spp concentrations in the Outer Shelf Domain may have been at high levels 2006, 2008 and 2009, although the number of samples available make it difficult to say this with any confidence. *Pseudocalanus* spp concentrations in the Middle Shelf Domain appear to be elevated in 2006 to 2009 although there is not as great of a difference between the values during the warm and cold periods as there was for *Calanus*. Concentrations of *Acartia* spp do not show any pattern.

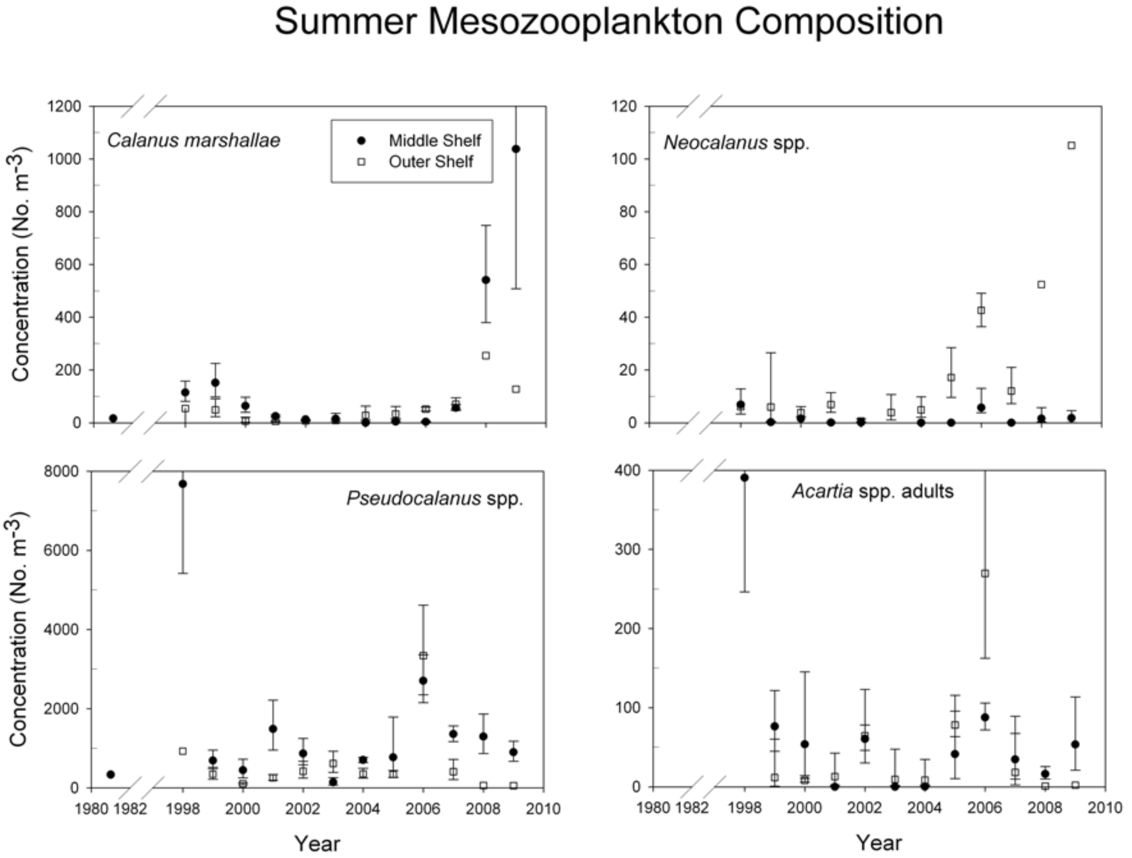

Figure 36: Zooplankton concentrations for four species from the deep basin of the Bering Sea and in the outer, middle and coastal domains of the southeastern Bering Sea shelf. Data from 1998 to present were collected by the EcoFOCI program of the Alaska Fisheries Science Center. Data from 1991 were from the PROBES (Processes and Resources of the Bering Sea Shelf) Program.

Late summer/fall abundances of large zooplankton in the eastern Bering Sea

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Description of Index: Abundances of large zooplankton were estimated for all BASIS stations in the Inner and Middle Domains (bottom depths <100 m) collected during mid-August - early October, 2003-2008. Zooplankton samples were collected during daylight hours with oblique bongo tows from near bottom to surface using a 505 μm mesh. Samples were preserved in 5% formalin and counted to lowest identifiable taxonomic level by the Morski Instytut Rybacki Plankton and

Identification Center (Szczecin, Poland) for 2003-2004 and by the University of Alaska for 2006-2008 following procedures outlined in Coyle et al. (2008). Average abundances (number per m^3) by year of large zooplankton (excluding euphausiids) are shown for the northern (60-63.5°N) and southern (55-59.5°N) Bering Sea for warm (2003-2005) and cold (2006-2008) years (Figure 37).

Status and Trends: In warm years, the large copepod, *Calanus marshallae*, was in lower abundance than in cold years. Increases were observed first in the northern Bering Sea in 2006 and in the southern Bering Sea in 2007 (Figure 37). When available, *C. marshallae* is an important prey item for age-0 pollock (Moss et al., 2009) and comprised an average of 40% by wet weight in 2008 in the southern Bering Sea (Coyle et al., Submitted). Euphausiids also increased in abundance in the Middle Domain in cold years (2008 and 2009) compared to warm years (2004) (Coyle et al., Submitted; Hunt et al., Submitted). Increases in energy density of age-0 pollock during cold years (Heintz et al., this document) may be associated with increases in *C. marshallae* and euphausiids on the eastern Bering Sea shelf.

North-south variations in large zooplankton were also observed, with more Cnidera present in the northern Bering and more polychaetes (in warm years) and *Limacina* spp. in the southern Bering Sea (Figure 37). Salmon diets reflect these spatial variations in zooplankton with Cnideria important in juvenile chum salmon diets in the northern Bering Sea.

Factors Causing the Trend: *C. marshallae* survival and growth of early life stages may be related to cold spring temperatures (Baier and Napp, 2003). Lower temperatures on the shelf during summer also may lower metabolic rates such that less food is required to sustain growth. During cold years, *C. marshallae* were concentrated in the Middle Domain in regions where the cold pool was observed (BASIS unpublished data). Advection of *C. marshallae* on to shelf is also important and may be related to ice extent and other climatic drivers.

Implications: Age-1 pollock recruitment was higher in two of the cold years, 2006 and 2008, suggesting that an increase in large zooplankton in the water column and diets of age-0 pollock may lead to increases in energy density and over-winter survival of pollock during their first winter (Heintz et al., this document p. 124). In addition, during cold years, large zooplankton may serve as alternative prey for larger predators, such as juvenile salmon, that would otherwise be focusing on age-0 pollock as their major prey source (Coyle et al., Submitted). Thus, potential reductions in the abundance of large zooplankton (*C. marshallae* and euphausiids) on the eastern Bering Sea shelf during warm years may lead to poor survival and reduced recruitment of age-1 pollock.

Gulf of Alaska Zooplankton

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See the 2006 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

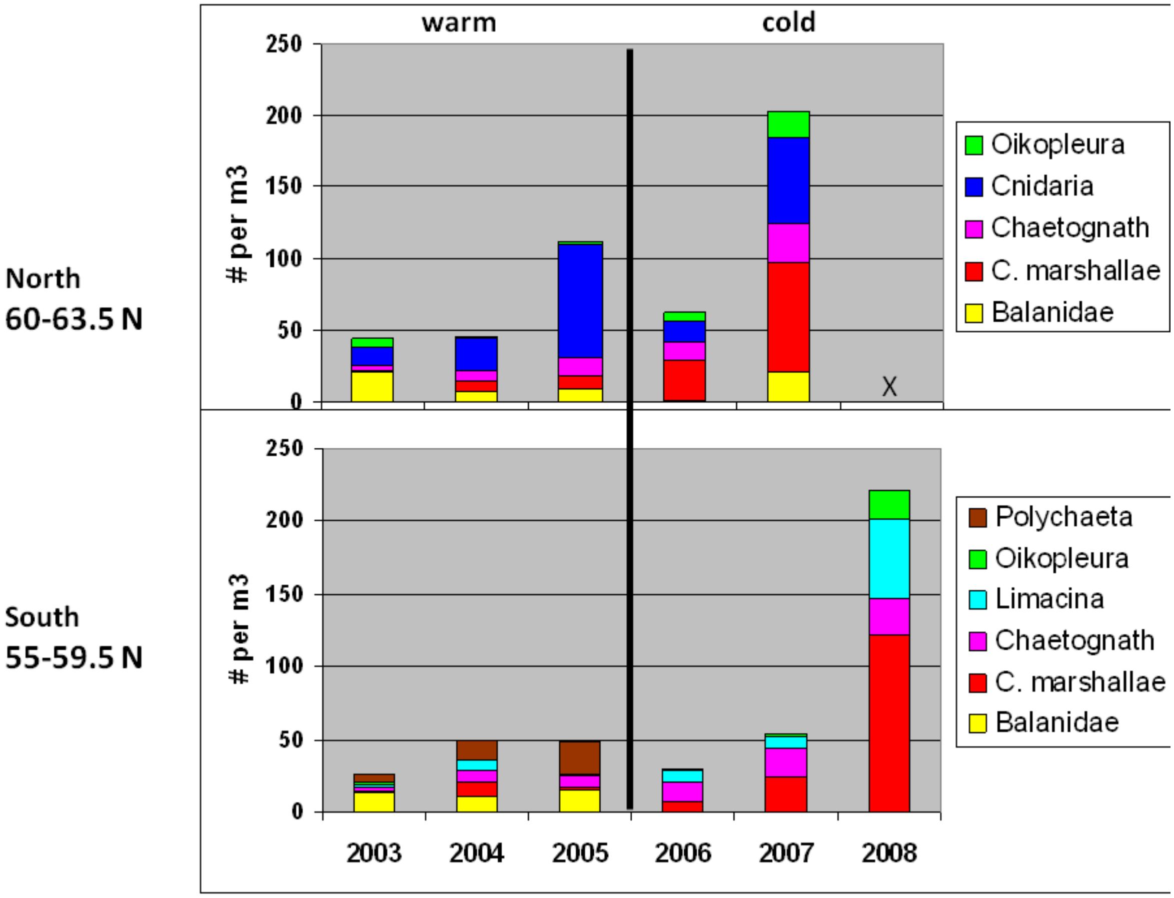

Figure 37: Mean abundance of large zooplankton (excluding euphausiids) collected with oblique bongo tows (505 μm mesh) on the Bering Sea shelf (<100 m) during BASIS surveys in the northern (top panel) and southern (bottom panel) Bering Sea.

Continuous Plankton Recorder data from the Northeast Pacific

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Description of Indices: Continuous Plankton Recorders (CPR) have been deployed in the North Pacific routinely since 2009. Two transects are sampled seasonally, both originating in the Strait of Juan de Fuca, one sampled monthly (Apr-Sept) which terminates in Cook inlet, the second sampled 3 times per year which follows a great circle route across the Pacific terminating in Japan. The region closer to the origin of both transects has the best sampling resolution and combined data from this region are described here (48°N to 55°N, shelf edge out to 145°W). Several indicators are now routinely derived from the CPR data and updated annually. They include indicators of zooplankton biomass, community composition and phenology (timing), each of which are important to the way that productivity is passed through zooplankton to higher trophic levels. Changes in ocean climate can affect each of these indicators and thus the availability of zooplankton to their predators.

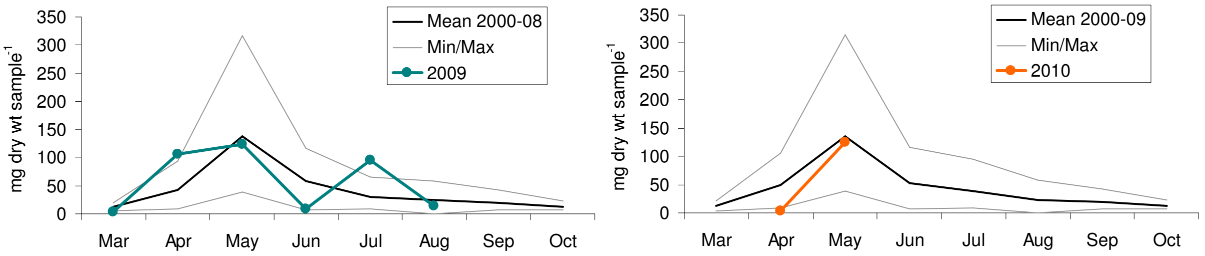

Figure 38: Mean, minimum and maximum monthly mesozooplankton biomass for the NE Pacific CPR timeseries, together with monthly data for 2009 and provisional spring 2010 data overlaid.

1. Mesozooplankton biomass trends, factors, and implications: Monthly mesozooplankton biomass data are shown in Figure 38, with 2009 and provisional spring 2010 data overlaid for comparison with previous years. The seasonal cycle in the eastern North Pacific was close to average in 2009 and early indications are that spring 2010 is also close to average. April 2009 biomass appears high but in fact the sampling dates were all in the second half of the month, with the highest values occurring on April 30th, so these late April and May values were close to the long term mean. July 2009 values were higher than previously recorded but not by much and again sampling occurred in the first few days of July and so would be expected to be higher than samples taken later in the month.

2. Neocalanus phenology trends, factors, and implications: The calanoid copepod *Neocalanus plumchrus* is a dominant component of the spring mesozooplankton in the subarctic North Pacific and Bering Sea. Previous studies have shown interdecadal and latitudinal variation in seasonal developmental timing with peak biomass occurring earlier in years and places with warmer upper ocean temperatures (Mackas et al., 1998; Batten et al., 2003; Mackas et al., 2007). Because *N. plumchrus* normally has a single dominant annual cohort, its seasonal timing can be indexed from measurements of total population biomass or by following progressive changes in stage composition. The eastern North Pacific is sampled by both transects giving sufficient sampling resolution to determine the timing of the peak of *Neocalanus plumchrus*. Figure 39 shows the time series of the day of the year when peak biomass is projected to have occurred (note that the date could not be calculated for 2008 as sampling did not begin until May and the copepodites were too advanced), together with the length of the season (defined as the number of days between the 25th and 75th percentile of cumulative biomass). Further information on these indices can be found in Batten and Mackas (2009).

These phenology indices show that 2009 was an unexceptional year. Although the date of peak biomass could not be calculated for 2008, the 50th percentile of cumulative biomass occurred earlier in 2009 than in 2008 by about 3 weeks, consistent with the somewhat warmer temperatures, but the peak was not as early as in the warmer years of 2005-2006. Cooler years tend to have a lengthier season, i.e. the copepodites grow and mature more slowly and are in surface waters for longer. However, the season length for 2009 was close to average, emphasising that 2009 was not an unusual year in our 10-year record.

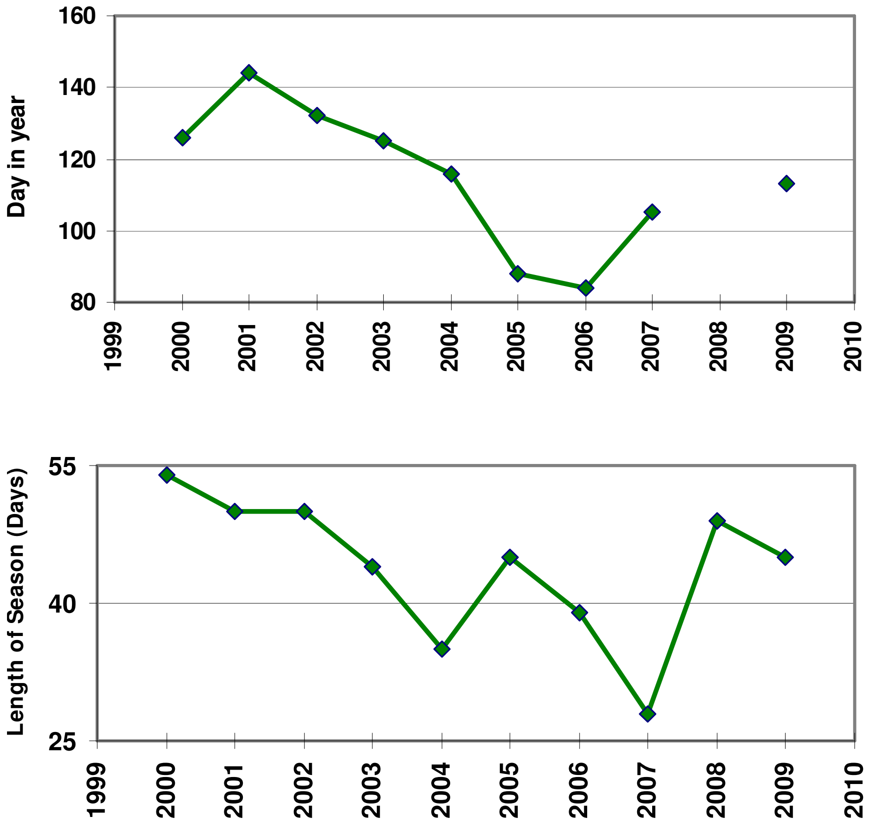

Figure 39: Day of the year when peak biomass of *Neoclanus plumchrus* occurred (based on stage composition, when 50% population was at copepodite stage 5), upper panel. Lower panel shows the length of the season calculated as the number of days between the 25th and 75th percentile of cumulative biomass.

3. Community composition trends, factors, and implications: Changes in community composition may reflect changes in the nutritional quality of the zooplankton to their predators. Community composition analyses of summer samples from the same eastern North Pacific region show a clear relationship between temperature and community composition (Figure 40). Summer samples were selected for two reasons: (a) it allowed us to use the pilot transect data from 1997, which because that was the start of a strong El Niño is a useful comparative dataset, and (b) summer community composition tends to be more diverse because the dominant spring copepods are mostly at depth and smaller zooplankton are more numerous. Non-metric Multidimensional Scaling (NMDS) analysis of log-transformed abundance data for individual mesozooplankton taxa shows a clear gradient with the warmest years at the top right of the plot and coldest years plotting at the bottom. Transition years (2003 transitioning from cold to warm, 2006 transitioning from warm to cold and, tentatively, 2009 cold to warm again or neutral) plot in the centre. 1997 stands out as an unusual year, influenced by the strong El Niño, as does 2007, although there is no explanation for that year as yet. The x-dimension is significantly ($p<0.05$) positively correlated with the Pacific Decadal Oscillation (PDO), and both x and y dimensions significantly ($p<0.05$) positively correlate with summer temperature indices from both coastal lighthouse observations and SST data from satellites.

Figure 40: Non-metric MDS plot of log (x+1) transformed mean annual (from June 28th-August 31st) abundance data for each mesozooplankton taxon

Forage Fish

Fall Condition of YOY Predicts Recruitment of Age-1 Walleye Pollock

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Last updated: August 2010

Description of Index: Average Energy Content (AEC) is the product of the average individual mass and energy density of YOY pollock collected from BASIS surveys. Average individual mass is estimated at sea from the mean individual mass of YOY pollock in each haul weighted by the percentage of the total YOY pollock catch in the haul. The average energy density of YOY pollock is estimated in the laboratory using fish collected at random from each haul and is weighted by relative YOY pollock catch to represent the relative contribution of each haul to total YOY pollock catch. The product of the two averages represents the total energy content of the average YOY pollock for a given year.

The analytical procedures for measuring energy density follow strict protocols. Fish are retained from each haul during the BASIS survey, frozen and shipped to Auke Bay for analysis. Catch records are examined to identify the number of fish to process from each haul so that a total of 50 fish is processed. Fish are dried, homogenized and combusted in our bomb calorimeter. Along with each batch of 15 samples we combust two samples of benzoic acid and a reference material to verify the accuracy of our methods. In addition, one of the samples is duplicated to verify that the precision of our estimates is within 3%.

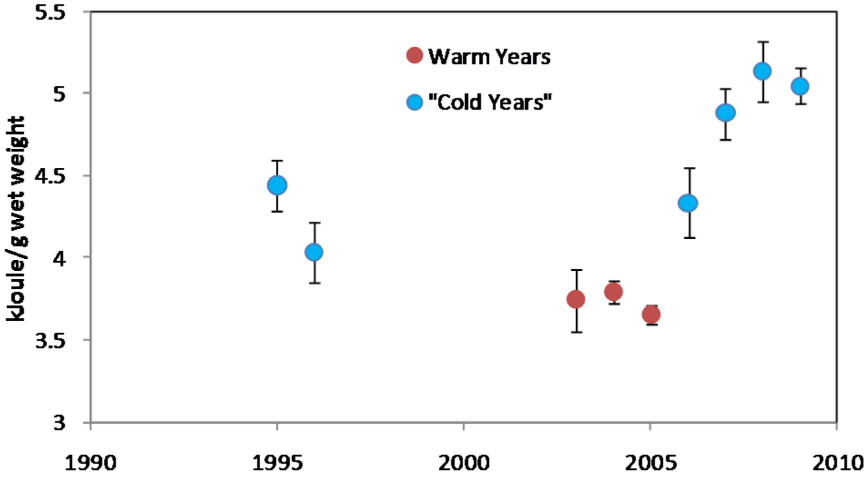

Figure 41: Annual changes in the average energy density of age-0 pollock sampled by BASIS surveys.

Status and Trends: In warm years YOY pollock have had lower energy density than pollock in cold years. We have been monitoring AEC since 2003 and have observed a striking pattern between the thermal regime in a given summer and the energy density of pollock collected on the subsequent BASIS survey (Figure 41). In contrast, thermal regime and size were not correlated between 2003 and 2009. Comparisons of size and energy density with recruitment revealed poor correlations, but combining size and energy density into AEC yielded a model that accounted for more than 70% of the variation in recruitment (Figure 42). Currently, we predict that recruitment of age-1 pollock from the 2009 year class should be relatively high as the energy densities observed in the surface trawls from 2009 were very high.

Factors Causing the Trend: Pollock are susceptible to size dependent mortality during their first winter (Heintz and Vollenweider, 2010). Among salmon, size dependent mortality during winter can be proportionally as high as mortality during the first 40 days at sea (Farley et al., 2007). Therefore, large size prior to winter should be a predictor of a high probability of surviving winter. However, the size that is good in one year may not the optimal size for another. Similarly, high energy density does not necessarily predict high survival because energy density is mass normalized and does not convey information about size. The total energy content of individual YOY pollock integrates information about size and energy density into a single index. YOY pollock have a relatively narrow window within which they can provision themselves prior to winter. Larval pollock allocate the majority of their ingested energy into developmental processes leaving little energy for somatic growth or sequestration of energy stores. They can only invest energy in growth and storage after they have successfully transitioned into fully developed juveniles. Their success at exploiting this window likely depends on water temperatures, prey quality and foraging costs. Cold years appear to be associated with greater densities of euphausiids, medium and large copepods in the middle domain (Hunt et al., Submitted).

Implications: The current data indicate that recruitment to age-1 should continue to be strong so long as summer conditions remain cold. A return to warm conditions in the Bering Sea is likely to result in reduced recruitment of pollock. While warm conditions apparently are good for pollock

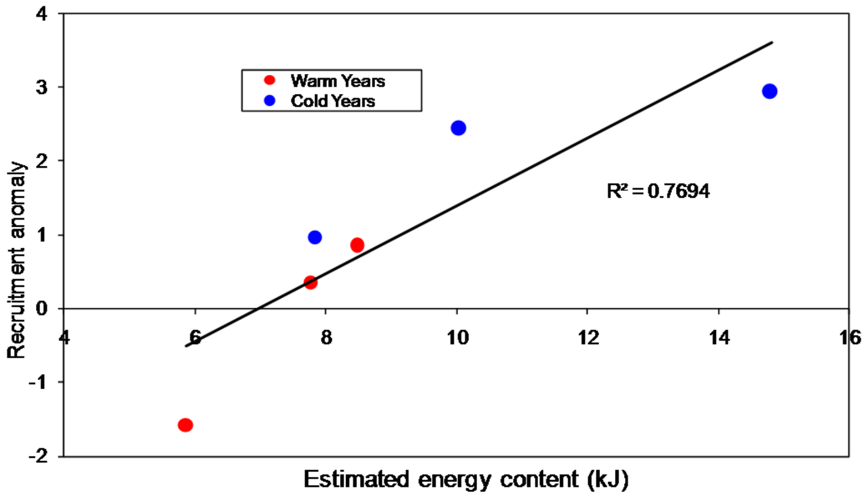

Figure 42: Relationship between average energy content (AEC) of individual age-0 pollock and their subsequent abundance in MACE surveys as age-1.

survival during the first few months of their lives, it may lead to poor provisioning for the oncoming winter.

Variations in distribution, abundance, energy density, and diet of age-0 walleye pollock, *Theragra chalcogramma*, in the eastern Bering Sea

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Last updated: August 2007

See the 2007 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Variations in juvenile salmon, age -0 pollock, and age-0 Pacific cod catch per unit effort and distributions during fall 2002-2007 in the eastern Bering Sea- BASIS

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See the 2008 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Forage Species - Eastern Bering Sea

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Last updated: October 2010

Description of Index: The North Pacific Fishery Management Council defined several groups as forage species for management purposes. These groups include: gunnels (Pholidae), lanternfish (Myctophidae), sandfish (*Trichodon trichodon*), sandlance (*Ammodytes hexapterus*), smelts (Osmeridae), stichaeids (Stichaeidae), and euphausiids. Forage fishes are important prey items for piscivorous fishes and marine birds and mammals. Changes in distribution and abundance of forage species can dramatically alter the community structure of the marine ecosystem and affect foraging success and survival of predators. Although the AFSC eastern Bering Sea shelf survey bottom trawl and procedures are not specifically designed to assess the abundance of these species, the survey time series may be useful for investigating coarse changes in distribution or relative abundance of these forage species over time (Figure 43). Relative CPUE was calculated and plotted for each species or species group by year for 1982-2010. Relative CPUE was calculated by setting the largest biomass in the time series to a value of 1 and scaling other annual values proportionally. The standard error (± 1) was weighted proportionally to the CPUE to produce a relative standard error. Maps showing the locations of forage fish catches are included (Figure 44).

Status and Trends: Sandfish were generally in low abundance in the trawl surveys (Figure 43) because they are typically caught in only a few stations at shallower depths. Stichaeids, which include the longsnout prickleback (*Lumpenella longirostris*), daubed shanny (*Lumpenus maculatus*) and snake prickleback (*L. sagitta*), are small benthic-dwelling fish. Their relative abundance was generally higher prior to 1999. Similar to stichaeids, the relative CPUEs of sandlance were generally higher prior to 1999. Eulachon (*Thaleichthys pacificus*) relative CPUE changed little over the past four years and capelin (*Mallotus villosus*) relative CPUE remained relatively low, with the exception of one year (1993; Figure 43). The relative CPUE of Arctic cod (*Boreogadus saida*), an Arctic fish species, was higher in cold years (1999-2000, 2006-2010) compared to warm years (1996-98, 2002-2005) probably because of its association with the southern intrusion of the Arctic cold pool ($<2^oC$) down the middle shelf during the cold years.

Exploring Links between Ichthyoplankton Dynamics and the Pelagic Environment in the Northwest Gulf of Alaska

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See the 2006 report in the “Assessment Archives” at: `http://access.afsc.noaa.gov/reem/`

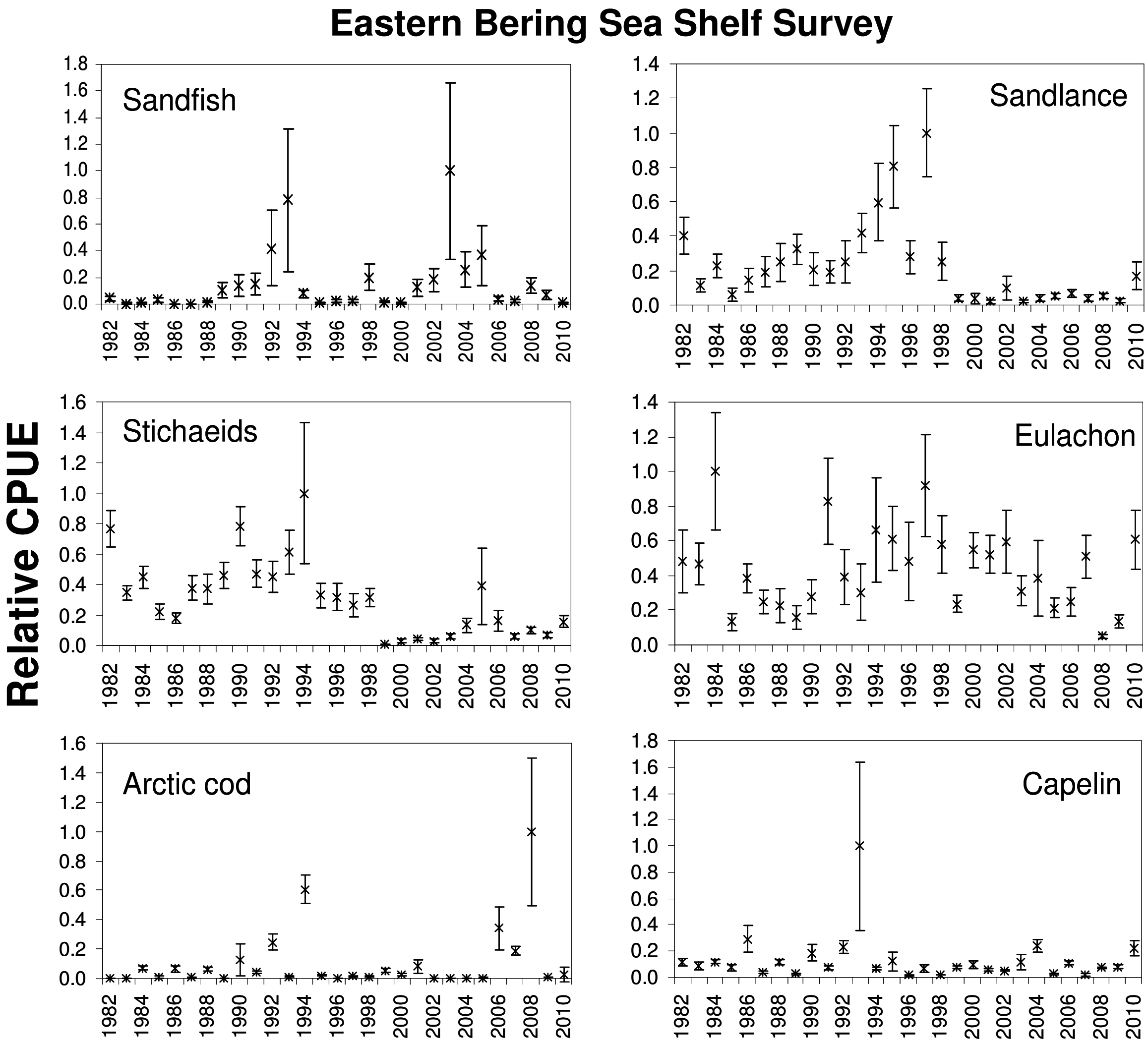

Figure 43: Relative CPUE of several forage fish groups from the eastern Bering Sea summer bottom trawl survey, 1982-2010. Data points are shown with standard error bars.

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Forage Species - Gulf of Alaska

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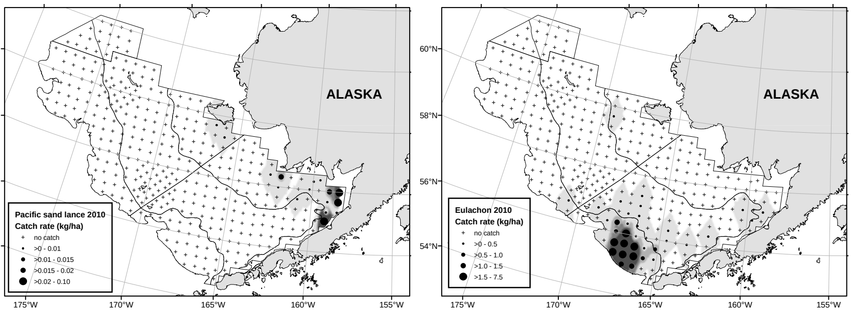
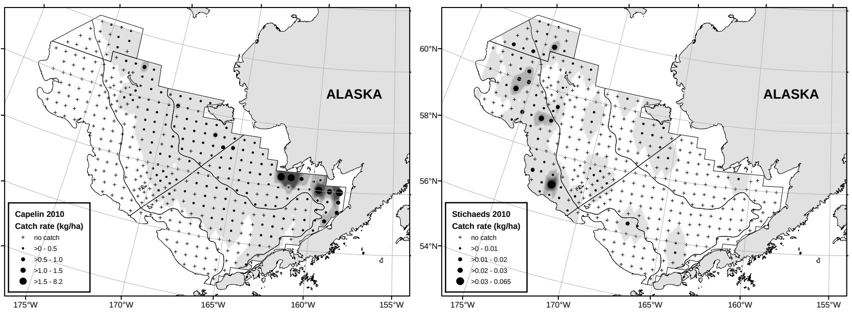
Last updated: October 2009

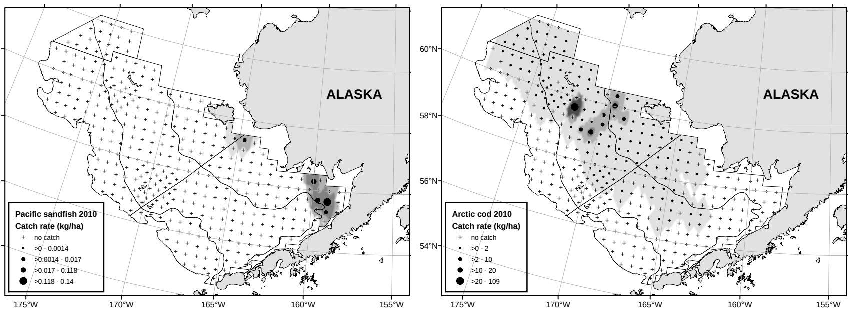
Gulf of Alaska surveys are conducted in alternate odd years. For most recent data, see the 2009



(a) Pacific sand lance (b) Eulachon



(c) Capelin (d) Sticheidae



(e) Pacific sandfish (f) Arctic Cod

Figure 44: Distribution and relative abundance of forage species for the 2010 eastern Bering Sea bottom trawl survey.

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Forage Species - Aleutian Islands

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Last updated: October 2010

Description of index: The North Pacific Fishery Management Council has defined several groups as forage species for management purposes in the Aleutian Islands (AI). These groups include gunnels, lanternfish, sandfish, sandlance, smelts, stichaeids, and euphausiids. Some of these groups are captured occasionally in the RACE bottom trawl survey of the Aleutian Islands. For each species group, the largest catch over the time series was arbitrarily scaled to a value of 100 and all other values were similarly scaled (Figure 45). The standard error (±1) was weighted proportionally to the CPUE to get a relative standard error. Maps showing the locations of forage fish catches are included (Figure 46).

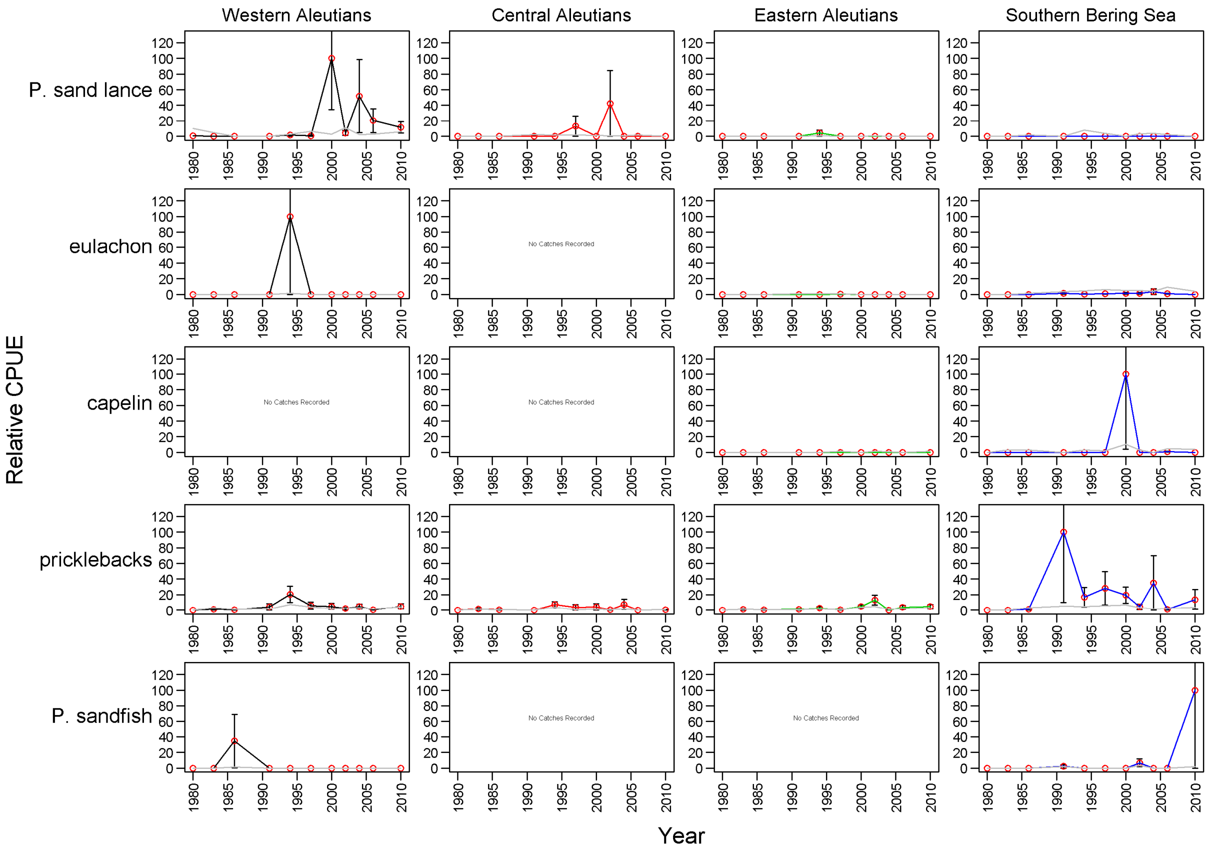
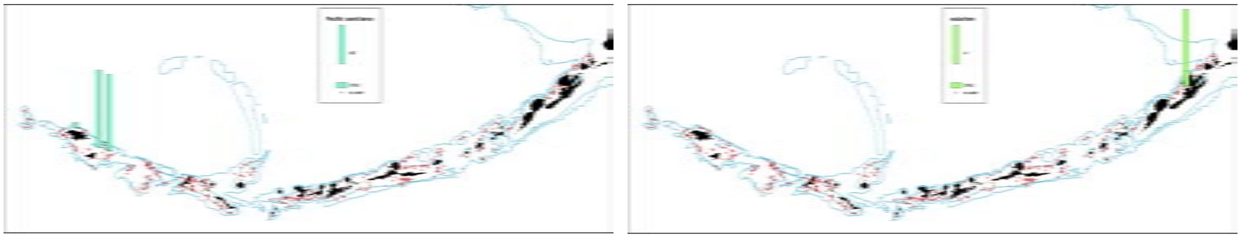


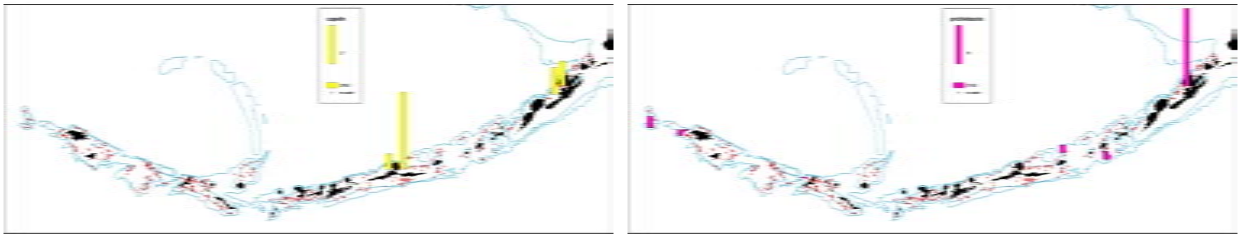
Figure 45: Relative mean CPUE of forage fish by area from RACE bottom trawl surveys in the Aleutian Islands from 1980 through 2010. Error bars represent standard errors. The gray lines without error bars represent the percentage of non-zero catches.

Status, trends and Factors causing the trends: The survey is not designed to assess these species and all of these species are rarely encountered during the survey. The relatively large mesh size allows most of these fish to escape when they are encountered by the gear. Therefore, trends in abundance are considered to be unreliable. For example, the apparent large increase of Pacific sandfish catch per unit effort (CPUE) seen in the western Aleutian Islands in 1986 is a result of only 4 individuals appearing in one catch, the only year that this species has been captured in the western Aleutians. Similarly, the highest catch rates for pricklebacks, eulachon and capelin are attributable to two to three catches. The large increase in pricklebacks seen in the western Aleutians in 1991 was attributable to only three catches, the largest being less than 8 kg. The high abundance of eulachon in the western Aleutians in 1994 was due to only two unusually large



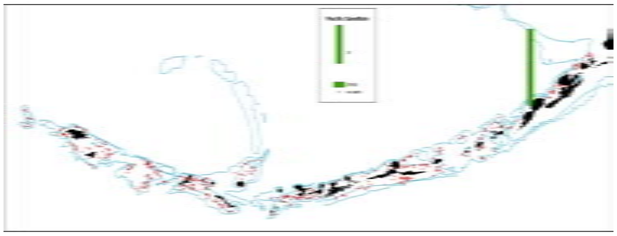
(a) Pacific sand lance

(b) Eulachon



(c) Capelin

(d) Pricklebacks



(e) Pacific sandfish

Figure 46: Catch per unit effort for forage species during the 2010 Aleutian Islands Groundfish Survey.

catches of 431 kg and 63 kg while the high CPUE of capelin in the southern Bering Sea in 2000 was the result of one very unusually large catch of 221 kg.

Implications: AI survey results provide limited information about abundance or abundance trends for these species due to problems in catchability. Therefore, the indices presented are of limited value to fisheries management.

Herring

Prince William Sound Pacific herring

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Last updated: October 2008

See the 2008 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Southeastern Alaska Herring

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Description of indices: Pacific herring (*Clupea pallasi*) populations in southeastern Alaska are monitored by the Alaska Department of Fish and Game. Populations are tracked using spawn indices. Stock assessments that combine spawn indices with age and size information have been conducted each fall by the Alaska Department of Fish and Game for nine spawning areas in southeastern Alaska for most years since 1980. The magnitude and regularity of spawning in these areas has warranted annual stock assessment surveys and potential commercial harvests at these locations during most of the last 30 years. Limited spawning occurs at other locales throughout southeastern Alaska. Little stock assessment activity occurs at these locations other than aerial surveys to document the miles of spawn along shoreline. Spawning at the nine primary sites for which regular assessments are conducted have probably accounted for 95-98% of the spawning biomass in southeastern Alaska in any given year.

Status and trends: Herring spawning biomass estimates in southeastern Alaska often change markedly from year to year, rarely exhibiting consistent, monotonic trends (Figure 47). Since 1980, most stocks show at least moderate increasing trend, with at least three of the nine primary locations (Sitka Sound, Hoonah Sound, Seymour Canal, and possibly Craig) exhibiting a pronounced trend of increasing biomass, and one area (Kah Shakes/Cat Island) exhibiting a pronounced downward trend. Since 1997, the southeastern Alaska spawning herring biomass estimate has been above the long-term (1980-2009) median of 86,525 tons. Although the long-term trends in most spawning areas are increasing, an apparent decrease in biomass was observed for all areas except Sitka and West Behm Canal between 2008 and 2009. Nevertheless, the 2008 and 2009 estimates of spawning biomass, combined for the entire region, were the two highest in the 25-year time series (Figure 48). Since 1980, herring biomass near Sitka has contributed between 37% and 69% (median: 55%) of the total estimated annual biomass among the nine spawning locations. Excluding the Sitka biomass from a combined estimate, southeastern Alaska herring biomass has been above the 25-year median of 40,954 tons in every year since 1997, except for 2000.

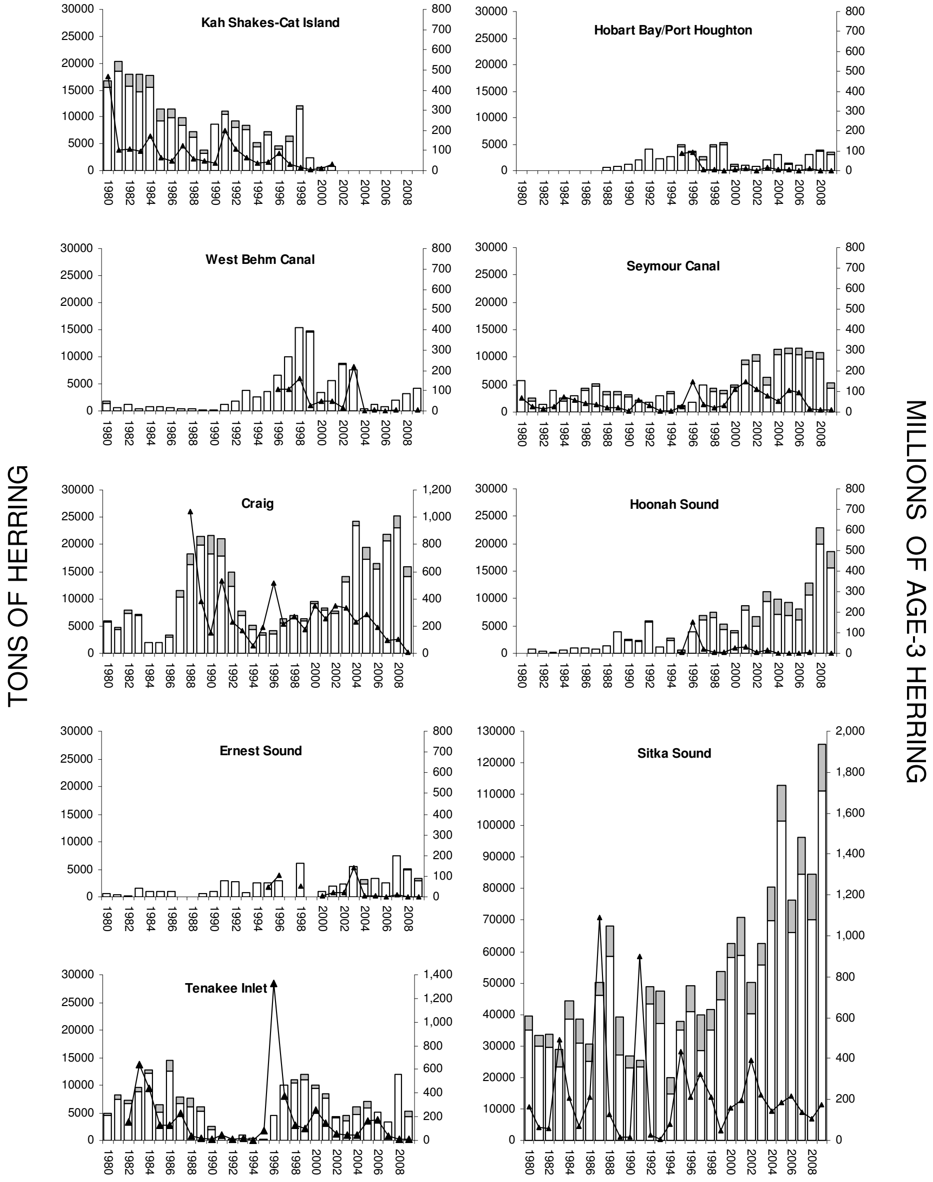

Figure 47: Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 recruitment to mature population (black line) at nine major spawning locations in southeastern Alaska, 1980-2009.

Estimated abundance of age-3 herring recruits to the mature population has varied greatly among and within stocks over time (Figure 47). The number of age-3 recruits has been estimated for Kah Shakes-Cat Island, Seymour Canal, Sitka, and Tenakee Inlet for most years since 1980; for Craig in every year since 1988; and for West Behm Canal, Ernest Sound, Hobart Bay-Port Houghton, and Hoonah Sound for most years since 1995. An oscillating recruitment pattern with strong recruit classes every three to five years is apparent for Kah Shakes/Cat Island, Craig, and Sitka Sound stocks prior to 1997. For Sitka Sound, the stock with the greatest annual recruit abundance, oscillating years of extremely high and low recruit abundance in the 1980s and early 1990s changed to more consistent, intermediate recruit abundances in the mid-1990s to early 2000s. All stocks exhibited low recruitment to the mature population in 2007, 2008, and 2009 relative to other years.

Factors causing trends: The generally increasing long-term trends observed for many herring stocks in southeastern Alaska, particularly over the past decade, are thought to be at least partially a result of higher survival rates among adult age classes. Age-structure analysis (ASA) modeling of several herring stocks in the region suggests that changes in survival during the late 1990s are partially responsible for the observed increasing and high herring abundance levels. Estimates of current survival rates range from 64% to 87%, depending on spawning area. Prior to the late 1990s, survival has been estimated to be in the range 38-60%. ASA modeling has also identified a change to older age-at-maturity in the early 2000s as a factor explaining the continued high abundance levels despite the low number of age-3 recruits to the mature population. Both changes in survival and age-at-maturity coincide with time periods of change in ocean conditions, as indexed by the Pacific Decadal Oscillation (PDO).

For most spawning areas, the recent phenomenon of high or increasing abundance despite low or very low levels of mature age-3 herring, has continued through 2009. Although mature age-3 herring abundance has been and is currently at low levels, there has been recruitment to spawning stocks at older ages. Age-structured modeling of the Sitka Sound and Seymour Canal stocks both suggest that there has been a change in the maturation schedule. There has been some speculation and debate about the extent to which commercial harvests may have contributed to marked declines in estimated abundance and/or localized changes in herring spawning sites in a few areas in southeastern Alaska, notably Revillagigedo Channel (Kah Shakes/Cat Island) and Lynn Canal. In the Revillagigedo Channel area, significant spawning and a fishery occur at Annette Island, a site outside the management jurisdiction of the State and from which limited data are gathered by the department. Although spawning activity at the Kah Shakes and Cat Island sites in Revillagigedo Channel has declined in recent years, this decline may be at least partially attributable to a shift of herring to spawning grounds within the Annette Island Reserve, bordering Revillagigedo Channel. In Lynn Canal spawning area reasons for the decline are unclear but may have been influenced by a number of factors including commercial harvest, increased predation by marine mammals, and development near spawning grounds.

Implications: The harvest rate policy in southeastern Alaska allows for harvest rates ranging from 10 to 20% of the forecasted spawning biomass when the forecast is above a minimum threshold biomass. The rate of harvest depends upon the ratio of forecast to threshold (the more the forecast exceeds the threshold, the higher the harvest rate). Consequently, catch, at most areas, has varied roughly in proportion to forecast biomass (Figure 47). The high abundance of mature herring observed at many spawning areas suggests that these stocks should remain above threshold in the near future and provide opportunities for commercial fisheries. However, natural fluctuations of stock levels, particularly of smaller-sized stocks, may potentially result in a forecast below threshold despite increasing, long-term population trends.

Togiak Herring Population Trends

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Figure 48: Estimated combined annual mature herring biomass (including and excluding Sitka) at major southeastern Alaska spawning areas, 1980-2009.

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See the 2008 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Salmon

Juvenile Salmon Growth and Temperature Change as Predictors of Subsequent Recruitment of Groundfish in the Gulf of Alaska and the Bering Sea

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Last updated: August 2010

Description of index: The marine growth of juvenile salmon and a new temperature change index were assessed as possible ecosystem indicators and forecast tools for predicting year class strength of groundfish - one year in advance. The concept was that juvenile salmon growth (SW1) on the continental shelf is a proxy for ocean productivity on the continental shelf in the Gulf of Alaska (GOA) and eastern Bering Sea (EBS)-an important rearing area for age-0 and age-1 groundfish (Martinson and Stokes, In Review). For the temperature change (TC) index, positive values represent cold summer (energy density hypothesis) and subsequent warm spring (oscillating control hypothesis) events that are favorable for groundfish recruitment, while negative values represent warm summer and subsequent cool spring events that are not favorable for groundfish recruitment. For juvenile salmon and age-0 pollock, attaining a larger and more energy dense body by fall improves the probability of surviving the winter, termed the energy density hypothesis in the Bering Sea and Gulf of Alaska (Beamish and Mahnken, 2001; Andrews et al., 2009; Moss et al., 2009). In the following spring, warmer sea temperatures lead to an earlier ice retreat and a later spring bloom, at an optimal timing for feeding for pelagic fish species such as age-0 pollock and juvenile salmon in the EBS called the oscillating control hypothesis (Hunt et al., 2002). Although not tested we also apply cold fall and warm spring hypothesis to the GOA groundfish stocks. In the GOA, warm spring temperatures leads to thermal water column stratification that helps initiate the spring bloom of phytoplankton.

Three salmon populations were chosen to match the rearing locations of young groundfish on the continental shelf of the EBS and GOA. March-May, juvenile sockeye salmon leave the Karluk River on Kodiak Island, enter Shelikof Strait and migrate west, an important rearing area for age-0 pollock. Juvenile chum salmon leaving Fish Creek in Portland Canal in February span the entire GOA shelf to overlap with the distribution of age-0 and age-1 sablefish in the summer. In the EBS, juvenile sockeye leave the Naknek River in the spring and enter into the Bristol Bay and the eastern Bering Sea in the summer. In the EBS, juvenile salmon and age-0 pollock and age-0 cod are captured together in surface trawl tows during the BASIS surveys in the EBS in August and September. Juvenile pink captured during the BASIS survey were also used in the analysis.

Four juvenile salmon growth SW1 time series were developed from measurements on scales collected from adult salmon and as the average length of pink salmon in the EBS. An average for SW1 was calculated for each year. The SW1 index derived from scales of adult age 2.2 sockeye salmon sampled at the Naknek River in Bristol Bay in western Alaska from 1980 to 2006 were used to predict EBS pollock and cod recruitment. SW1 index derived from scales sampled from age 0.3 chum salmon at Fish Creek near Hyder in southern southeast Alaska from 1972 to 2007 were used to predict age-2 GOA sablefish recruitment. SW1 index derived from scales sampled from age 2.2 sockeye salmon at the Karluk River on Kodiak Island Alaska from 1991 to 2001 were used to predict GOA pollock recruitment in years from 1988 to 1998. For 2003 to 2009, the average lengths of pink salmon from the EBS ocean survey were used to predict age-1 EBS pollock and cod abundance. SW1 was a negative predictor of subsequent groundfish recruitment in the EBS and a positive predictor in the GOA.

TC indices were developed for the EBS and GOA (Figure 49). For the EBS, the TC index was calculated as the difference in the average of the August (t-1) and June (t) Reynolds SST in the region 56.2° to 58.1° N and 166.9° to 161.2° W. For the GOA, TC index values are the difference in the summer and subsequent spring Pacific Decadal Oscillation index (PDO).

The hypothesis was that SW1 is a positive predictor of groundfish recruitment. The Quandt Likelihood statistic (Chapter 9 in Stokes (1997)) detected a change in the SW1-recruitment relationship

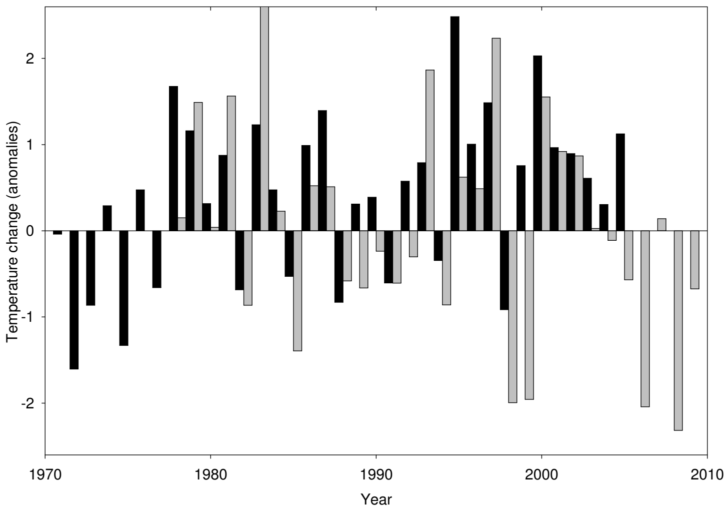

Figure 49: Temperature change index anomalies for the eastern Bering Sea (grey bars) and Gulf of Alaska (black bars), 1971-2010. Positive values represent cold summer and subsequent warm spring (+) and warm summer and subsequent cold spring (-)events.

during the late 1980s, possibly associated with a negative to positive shift in the mean winter Arctic Oscillation (Thompson and Wallace, 1998). For years 1989-2005, SW1 was a negative predictor and TC a positive predictor of groundfish recruitment in the EBS. For the GOA, SW1, but not TC, was a positive predictor of GOA groundfish for years 1991-2005.

Currently, negative TC values occurred in 4 of the last 5 years in the EBS. The cause of this trend is changes in marine sea temperatures, a relatively warm summer followed by a cool spring. Lower TC indices imply less favorable conditions for bioenergetics, overwintering survival, and first feeding in the spring and subsequently reduced recruitment of groundfish in the eastern Bering Sea. TC and SW1 may be significant predictors of early year class strength in groundfish. This information may be used to inform managers on the likelihood of good or poor recruitment of groundfish to age 1 and 2 (Figure 50). However, this requires more analysis.

Historical trends in Alaskan salmon

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Last updated: November 2006

See the 2006 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

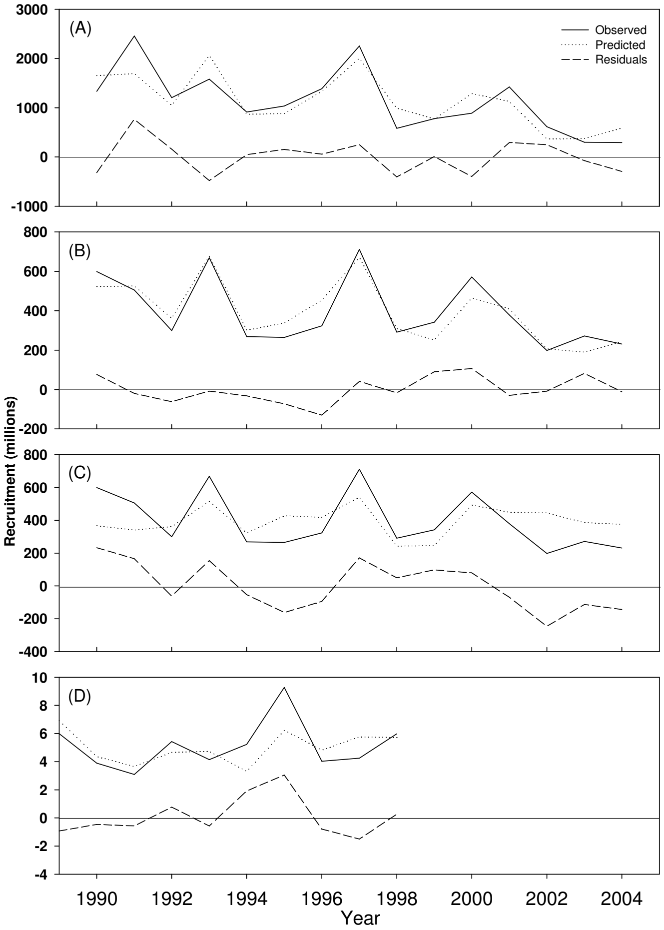

Figure 50: Multiple regression model output describing groundfish recruitment (t) as a function of juvenile salmon growth (t-1) and temperature changes index: age-1 pollock and age-1 cod recruitment in the eastern Bering Sea as a function of juvenile growth measured on scales of age 2.2 sockeye salmon from the Naknek River (a and b), age-2 sablefish recruitment in the Gulf of Alaska as a function of juvenile salmon growth measured on scales of age 0.3 chum salmon from Fish Creek (c), and the natural logarithm of age-1 pollock recruitment in the Gulf of Alaska as a function of juvenile salmon growth measured on scales of age 2.2 sockeye salmon from the Karluk River (d).

Western Alaska juvenile salmon ecology along the eastern Bering Sea shelf

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See the 2005 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Groundfish

Trends in Groundfish Biomass and Recruits per Spawning Biomass

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Last updated: October 2010

Description of the Indices: Groundfish biomass and an index of survival were examined for temporal trends. Median recruit per spawning biomass (log(R/S)) anomalies were calculated for groundfish, assessed with age- or size-structured models in the Bering Sea/Aleutian Islands (BSAI) and the Gulf of Alaska (GOA), to provide an index of survival. Biomass, spawner abundance, and recruitment information is available in the NPFMC stock assessment and fishery evaluation reports for 2009 on the web at: `http://www.afsc.noaa.gov/refm/stocks/assessments.htm`. Halibut information was provided by the International Pacific Halibut Commission (IPHC, S. Hare, personal communication; these time series were not updated in recent years, 2009-2010). In stocks that are abundant, the relationship between recruits and spawners will not be linear and density dependent factors may limit recruitment. Under these circumstances, the pattern of recruits per spawner will appear as an inverse of the pattern of spawning biomass as annual rates of production have leveled off. For this reason, it is important to also consider recruitment, as well as recruits per spawning biomass. Abundance of recruits for each species was lagged by the appropriate number of years to match the spawning biomass that produced them. For graphical display, the median of each time series was subtracted from the log-transformed recruit per spawning biomass ratios and expressed as a proportion of the median. A sequential t-test analysis of regime shifts (Rodionov, 2005; Rodionov and Overland, 2005, STARS;) was used to determine if there were significant shifts in the logged recruit per spawning biomass ratios. The STARS method sequentially tests whether each data point in a time series is significantly different from the mean of the data points representing the latest regime (Rodionov and Overland, 2005). The last data point in a time series may be identified as the beginning of a new regime; and, as more data is added to the time series, this is confirmed or rejected. At least two variables are needed for the STARS method: the cutoff value (minimum length of regimes) and the p-value (probability level). For this analysis, a cutoff value of 10 years and a p-value of 0.10 were chosen. A description of STARS and software is available at: `http://www.beringclimate.noaa.gov/index.html`. An analysis of recruitment is not included in this section; however, Mueter (see contribution on p. 179 and Mueter et al. (2007)) examined combined standardized indices of groundfish recruitment and survival rate. Mueter's indices of survival rate are calculated as residuals from stock-recruit relationships, thereby, accounting for density dependence and providing an alternative examination of groundfish survival.

Status and Trends: BIOMASS: Total biomass of BSAI groundfish was apparently low in the late 1970s but increased in the early 1980s to around 20 million metric tons (Figure 51). Walleye pollock, which is the dominant species in the BS throughout the time series, has influenced observed fluctuations in total biomass, particularly the decreased biomass in recent years. BSAI catch trends are dominated by pollock catches, which decreased during 2004-2008 and increased slightly in 2009.

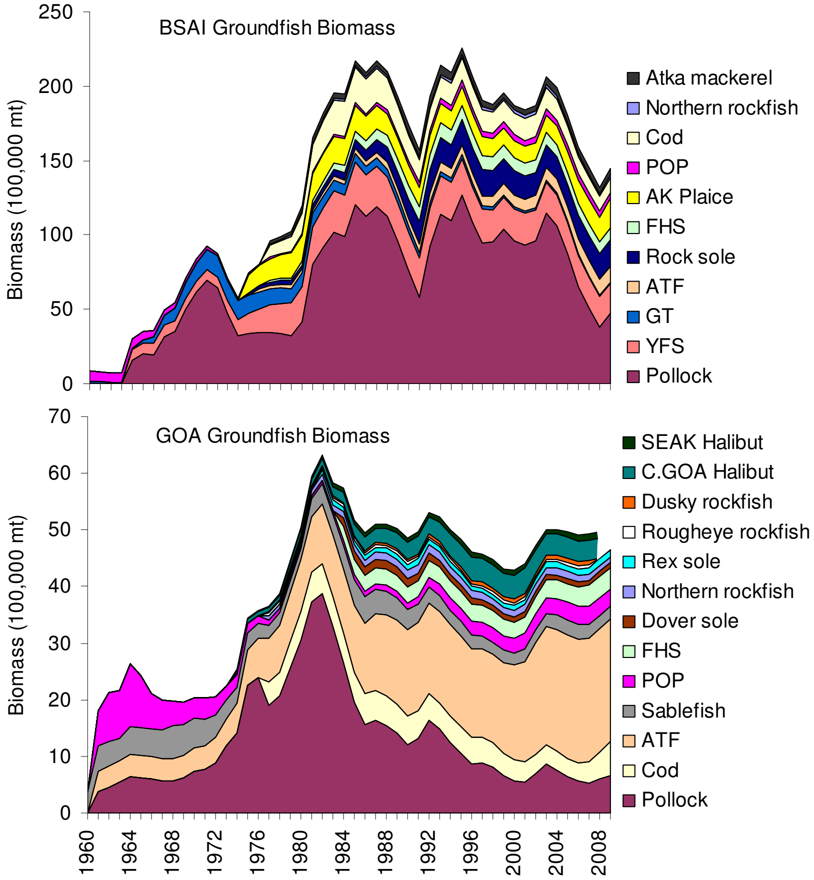
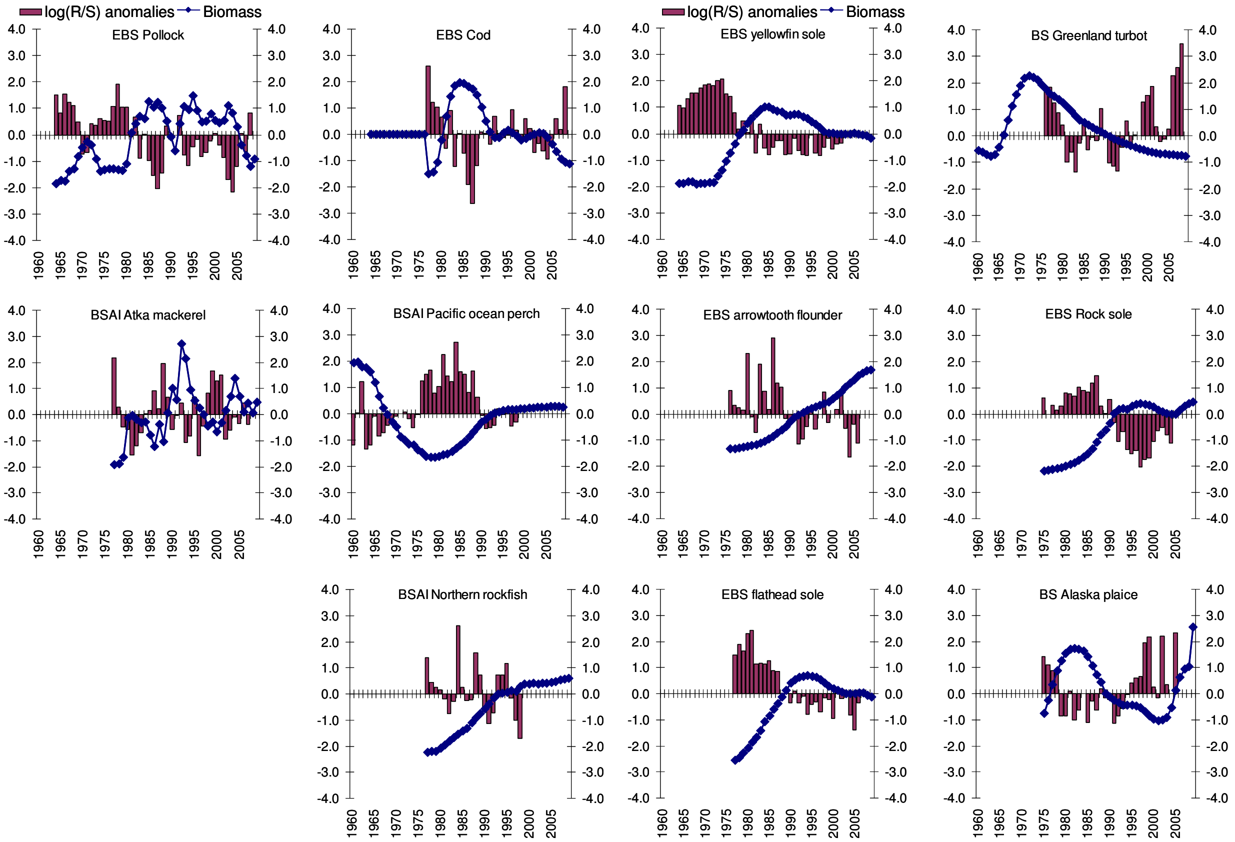


Figure 51: Groundfish biomass trends (metric tons) in the BSAI (1960-2009) and GOA (1960-2009), as determined from age-structured models of the Alaska Fisheries Science Center reported by NPFMC (2009 a, b). GOA Pacific halibut, Dusky rockfish, and rougheye rockfish were not updated in this graph.

Gulf of Alaska groundfish biomass trends (Figure 51) are different from those in the BSAI. Although biomass increased in the early 1980s, as also seen in the BSAI, GOA biomass declined after peaking in 1982 at over 6 million metric tons, primarily due to changes in walleye pollock biomass. Total biomass has been fairly stable since 1985, however the species composition has changed. Pollock were the dominant groundfish species prior to 1986 but arrowtooth flounder has increased in biomass and is now dominant. The 2007 IPHC stock assessment of halibut, ages 6 and older, for the GOA (areas 2C and 3A) indicates halibut biomass increased from 1978 to 1996, declined slightly during 2001-2004.

RECRUIT PER SPAWNING BIOMASS: Several stocks experienced step-changes in survival, as indicated by log(R/S), in the late 1970s and 1980s; however, in general, there was no indication of uniform step changes in all stocks in either time period (known periods of climate regime shifts) for the GOA or BSAI (Figures 52, 53, 54 and Table 7).

In general, roundfish, pollock, cod, and sablefish, showed above average survival prior to and below



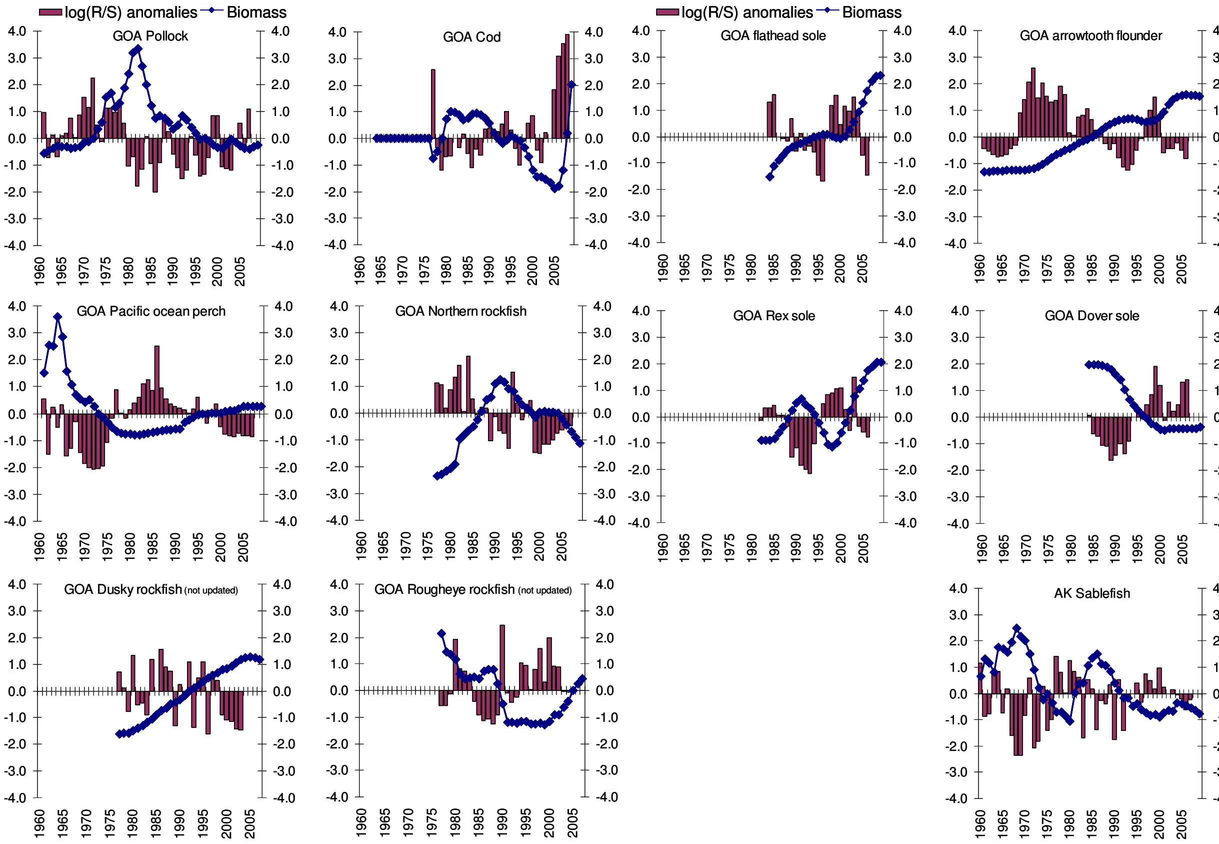
(a) Roundfish (b) Flatfish

Figure 52: Median log recruit per spawning biomass and biomass anomalies for BSAI groundfish species assessed with age- or size-structured models, 1960-2009. EBS = Eastern Bering Sea, BS = Bering Sea, AI = Aleutian Islands.

average survival after the early 1980s (Figures 52 and 53). Negative shifts were observed in the early and mid-1980s (GOA pollock, sablefish, BS pollock, and BS cod), and positive shifts were observed in 1970 (GOA pollock), 1977 (sablefish), the late 1980s and early 1990s (GOA cod, BS cod), and in the early 2000s (GOA pollock and GOA cod).

Several BSAI flatfish had high survival prior to and during the 1980s and lower survival during most of the 1990s, including arrowtooth flounder, northern rock sole, Greenland turbot, and flathead sole. Yellowfin sole showed high survival prior to the 1980s and low survival afterwards (Figure 52b and Table 7). All shifts for these species have been negative with the exception of a positive shift for Northern rock sole in 2001. Alaska plaice survival also decreased in 1981, but increased in 1997. Greenland turbot showed an increase in survival in 1998. There were positive shifts in GOA flatfish survival mid- late 1990s (Figure 53). GOA arrowtooth flounder had negative step-changes in survival in 1980 and 1989; however the total biomass of arrowtooth flounder has been increasing since the mid-1970s.

Pacific ocean perch showed positive shifts in 1976 in both the BSAI and GOA (Table 7). After the mid-1980s, there was a decreasing trend in log(R/S) anomalies in both the BSAI and GOA (Figures 52 and 53). BS POP also showed a negative shift in 1989, whereas, GOA POP showed a



(a) Roundfish (b) Flatfish

Figure 53: Median log recruit per spawning biomass and biomass anomalies for Gulf of Alaska (GOA) groundfish species assessed with age- or size-structured models, 1960-2008 or 2009.

negative shift in 1969 and 2000 (Figures 52 and 53 and Table 7). Other rockfish showed shifts in the mid- to late- 1990s, as well as some other years.

Factors Causing Trends: Several stocks experienced step-changes in survival in the late 1970s and 1980s; however, in general, there was no indication of uniform step changes in all stocks in either time period for the GOA or BSAI. Mueter et al. (2007) found, however, that when groundfish time series are combined, there does appear to be a system-wide shift in groundfish survival and recruitment within the BSAI and GOA in the late 1970s with mixed results in the late 1980s. This indicates that there may be some overall response to changes resulting from environmental forcing.

Examination of the average recruit per spawning biomass anomalies indicates gadids experience similar trends in survival within and between ecosystems. BS cod and pollock experience similar trends in survival, and BS and GOA pollock show similar trends in survival. This may be an indication that gadids respond in similar ways to large-scale climate changes.

Flatfish survival did appear to be related to known climate regime shifts, especially the late 1980s shift. In particular, the BSAI winter spawning flatfish (rock sole, flathead sole and arrowtooth flounder) showed a negative shift in survival in the late 1980s-early 1990s. Favorable recruitment was linked to wind-driven advection of winter-spawning flatfish larvae during spring (Wilderbuer

Table 7: Years of significant step-changes in log-recruit per spawning biomass anomalies in the Bering Sea/Aleutian Islands (BSAI) and the Gulf of Alaska (GOA). Regular font represent years of positive changes, parentheses represent years of negative changes, and italics represent a significant step-change in the final year of the time series (i.e., likely to change with the addition of newer data).

BSAI	**Significant changes**	**GOA**	**Significant changes**
EBS Pollock	(1983), *2008*	GOA Pollock	1970, (1980), 2004
BSAI Pacific cod	(1983), 1992, *2008*	GOA Pacifc cod7 1989, 2005	
BSAI Yellowfin sole	(1977), (1984), *2003*	GOA Arrowtooth flounder	1969, (1980), (1989)
BSAI Arrowtooth flounder	(1989), (2004)	GOA Rex sole	1996, (2004)
BSAI Alaska plaice	1995, *2005*	GOA Flathead sole	1998
BSAI Flathead sole	(1986), (2004)	GOA Dover sole	1994, 2005
BSAI Greenland turbot	1999, 2006	GOA Pacific ocean perch	(1969), 1976, (2000)
BSAI Northern rock sole	(1985)	GOA Northern rockfish	(1986), (1999)
BSAI Northern rockfish	(*1997*)	GOA Dusky rockfish	(1999)
BSAI Pacific ocean perch	1976, (1989)	GOA Rougheye rockfish	1994, (2003)
BSAI Atka mackerel	none	Alaska Sablefish	(1967), 1977, (1986)

et al., 2002). Years of consecutive strong recruitment for these species in the 1980s corresponds to years when wind-driven advection of larvae to favorable inshore nursery grounds in Bristol Bay prevailed. The pattern of springtime wind changed to an off-shore direction during the 1990s which coincided with below-average recruitment. This pattern is being examined further for northern rock sole (Wilderbuer, this report p. 144).

Pacific ocean perch survival also appears to be related to decadal-scale variability since it responded positively to the mid-1970s shift (BS and GOA) and negatively to the late 1980s shift (BS). The mechanism causing these shifts in survival is unknown. Recruit per spawning biomass ratios are autocorrelated in long-lived species, such as rockfish.

Implications: Large-scale climate changes may affect the survival of some groundfish stocks. Years of shifts in groundfish survival varies among individual species; however, combined groundfish survival does show a system-wide shift within the BSAI and GOA in the late 1970s with mixed results in the late 1980s.

Bering Sea Groundfish Condition

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Last updated: October 2008

See the 2008 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/`

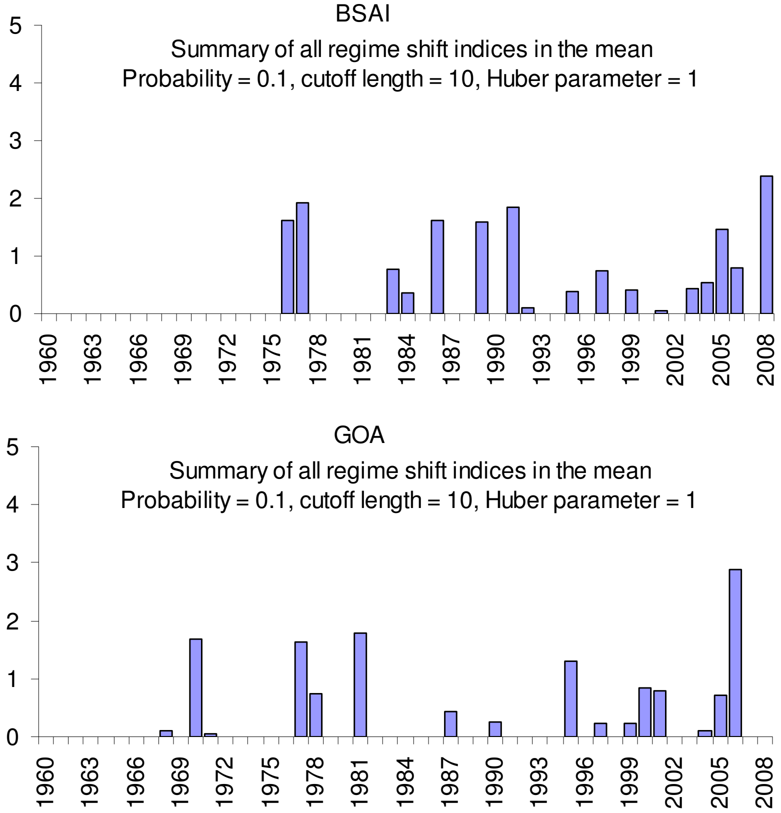

Figure 54: Summed regime shift index (RSI) values from the STARS (Rodionov, 2005; Rodionov and Overland, 2005) analysis (absolute values that indicate strength of step change) on log recruit per spawning biomass anomalies in each year for the BSAI and GOA. Pacific halibut were not included.

`ecoweb/index.cfm`

Update on eastern Bering Sea Winter Spawning Flatfish Recruitment and Wind Forcing

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Last updated: July 2010

Description of index: Wilderbuer et al. (2002) summarized a study examining the recruitment of winter-spawning flatfish in relation to decadal atmospheric forcing, linking favorable recruitment to the direction of wind forcing during spring. OSCURS model time series runs indicated in-shore advection to favorable nursery grounds in Bristol Bay during the 1980s. The pattern change to off-shore in the 1990-97 time series coincided with below-average recruitment for northern rock sole, arrowtooth flounder and flathead sole, relative to the 1980s. The time series is updated through 2008 (Figure 55).

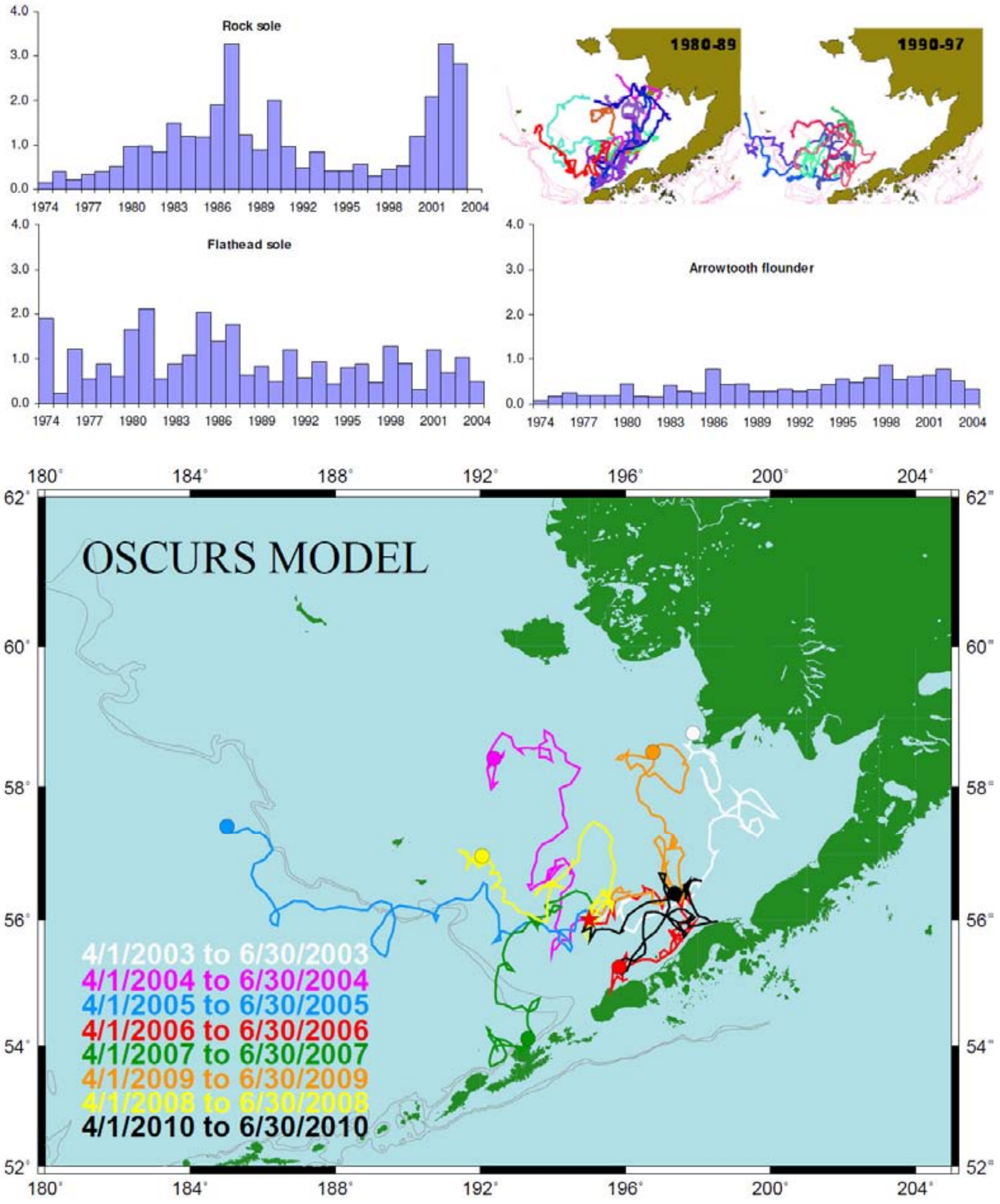

Figure 55: Recruitment of northern rock sole (1974-2003), flathead sole (1974-2004), and arrowtooth flounder (1974-2004) in the Bering Sea, with OSCURS (Ocean Surface Current Simulation Model) trajectories from starting point 56°N, 164°W from April 1-June 30 for three periods: 1980-89, 1990-97, and 2002-2010 (bottom).

Status and trends: Five out of eight OSCURS runs for 2003-2010 were consistent with those which produced above-average recruitment in the original analysis, 2005, 2007 and 2009 being the exceptions. The north-northeast drift pattern suggests that larvae may have been advected to favorable, near-shore areas of Bristol Bay by the time of their metamorphosis to a benthic form of juvenile flatfish. Preliminary estimates of rock sole recruitment in recent years are consistent with this larval drift hypothesis (Figure 55). For arrowtooth flounder and flathead sole, the correspondence between the springtime drift pattern from OSCURS and estimates of year class strength have weakened since the 1990s. Arrowtooth flounder produced year classes of average strength during some off-shore drift years, suggesting that this species may have different settlement preferences than northern rock role. In the case of flathead sole, weak recruitment has persisted since the 1990s with no apparent response to the surface wind advection pattern in the early 2000s.

Implications: The drift pattern in 2010 was less clear in terms of classification relative to other years. There were strong northerly winds for part of the spring which would suggest increased larval dispersal to Unimak Island and the Alaska Peninsula. To the extent that these areas are favorable nursery grounds for northern rock sole, this could have been a favorable wind-drift pattern.

Density-Independent and Density-Dependent Factors Affecting Spatial Distributions of Eastern Bering Sea Flatfish from 1982-2006

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Last updated: October 2009

See the 2009 report in the “Assessment Archives” at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Benthic Communities and Non-target Fish Species

Bering Sea/Aleutian Islands King and Tanner Crab stocks

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Last updated: October 2010

Description of the Indices: Eastern Bering Sea crab abundance indices are based on the annual National Marine Fisheries Service bottom trawl survey area swept estimates, Alaska Department of Fish and Game (ADF&G) trawl surveys, ADF&G pot surveys, and from commercial catch data. There are ten crab stocks in the current Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs: four red king crab *Paralithodes camtschaticus* (Bristol Bay, Pribilof Islands, Norton Sound, and Adak), two blue king crab *Paralithodes platypus* (Pribilof District and St Matthew Island), two golden king crab *Lithodes aequispinus* (Aleutian Islands and Pribilof

Islands), and two Tanner crab stocks (southern Tanner crab *Chionoecetes bairdi* and snow crab *C. opilio*).

Overfishing and overfished status of crab stocks are based on a five tier system where mature male biomass is currently used as a measure of the productive capacity of the stock (B). Snow crab and Bristol Bay red king crab are managed as Tier 3 stocks with length based models where proxy limit reference points are estimated based on life history information. Snow crab was declared overfished in 1999 and is under a rebuilding plan. Tanner crab, Pribilof Islands red and blue king crab, and St. Matthew blue king crab are Tier 4 stocks where data on life history and a spawner-recruit relationship are lacking. The Pribilof Islands blue king crab was declared overfished in 2002 and remains at a low overfished biomass. St. Matthew blue king crab was declared overfished in 1999, was officially considered rebuilt in 2009, and supported a commercial fishery in 2009. The southern Tanner crab stock is now overfished based on the 2009 survey estimates and 2009/2010 catch data. The remaining stocks are Tier 5 stocks with no reliable estimates of biomass or natural mortality and are managed on average catch data.

Status and trends: *Red king crab* Bristol Bay red king crab estimates of total survey biomass of adult males increased to 150,193 metric tons (t) in 1977 decreased sharply to a low of 9,582 t in 1983, and then remained steady between 20,000 and 50,000 t through 2010 (Figure 56). Recent above-average year classes have recruited into the fished population and there is no evidence any strong year classes recruiting. As a result both immature and mature biomass has declined in the last 3 years. Pribilof Islands red king crab were not prevalent in the Pribilof Islands until the early 1990s. The large male biomass peaked in the 1990s at 9,687 t and then declined to biomasses between 2,000 to 3,000 t between 1998 and 2010. Recruitment indices are not well understood for Pribilof red king crab largely due to the difficulty in catching the smaller crab in the nearshore habitat and due to their small numbers. There was a substantial decrease in abundance for all crab size groups in this stock in 2009 that leveled in 2010.

Norton Sound red king crab adult male abundance was highest during the 1970s at around 5,611 t, declined into the 1980s and 1990s to a low of 805 t, and since 1996 has gradually increased to 2,468 t in 2010. Juvenile male abundance has fluctuated over the time series but has increased gradually in recent years to over 400 t in 2009.

Adak red king crab estimates of biomass are not available for this stock. Fishery catches decreased from a 9,613 t peak in the 1960s to less than 3 t in the late 1990s. Since the end of the 2003/2004 fishing season the fishery has been closed due to poor recruitment indices from periodic pot surveys.

Blue king crab Pribilof Island blue king crab adult male biomass peaked in the late 1970s between 15,798 and 38,756 t before a precipitous decline to less than 752 t in 1989. Biomass estimates have remained low in this designated overfished stock with average estimates less than 50 t. Juvenile male blue king crab biomass in the Pribilof Islands fluctuated between 0 and 232 t in the last decade. Survey results from 2009 and 2010 showed a slight increase in adult males with no apparent incoming year classes.

St. Matthew blue king crab adult male biomass fluctuated between low and high biomass over three periods: 1978 to 1985, 1986 to 1999, and 2000 to current. Historical peaks in adult male biomass were 13,947 t in 1982 and 9,137 t in 1997. Currently the stock has increased from a low of 1,126 t in 2003 to the current 2010 biomass estimate of 8,141 t.

Tanner crab Tanner crab adult male biomass in the survey peaked in the 1970s around 149,948 t

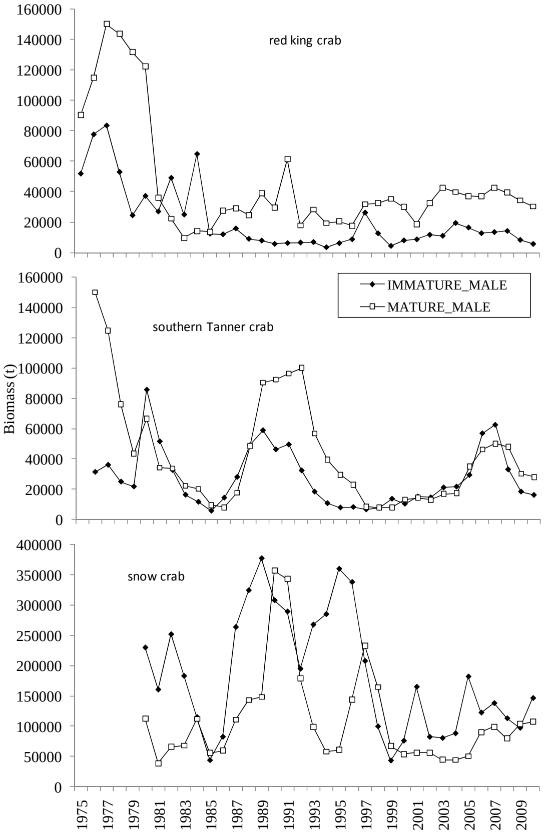

Figure 56: Eastern Bering Sea red king crab, southern Tanner crab, and snow crab survey biomass of immature and mature males.

and early 1990s at 99,991 t (Figure 56). From 1990s through 2007, adult male biomass increased to 50,149 t. However, in 2008 and 2009 there was a substantial decrease to 27,949 t in 2010. Juvenile male crab have fluctuated similarly with peaks of 85,825, 58,938, and 62,537 t in 1980, 1989, and 2007. Recent juvenile crab abundance estimates have declines to less than 150 million crab in 2009.

Snow crab Snow crab adult male survey biomass peaked in the mid to late 1970s and again at 356,511 t of adult male crab in 1990 and 144,022 t in 1996 (Figure 56). After a decline to 53,757 t in 2000 the adult male portion of the snow crab stock has gradually increased to the current adult male biomass of 107,131 t. Snow crab recruitment has varied substantially with peaks of 263,362 t and 359,485 t of juvenile males in 1987 and 1995 respectively. Recent juvenile male snow crab survey biomass estimates were between 97,000 t and 146,000 t.

Golden king crab Stock abundance estimates are not available for golden king crab stocks in the eastern Bering Sea/Aleutian Islands. Fluctuations in Aleutian Islands golden king crab and Pribilof Islands golden king crab fishery catch per unit effort have led to speculation about changes in recruitment. In the Pribilof Islands, commercial catches ranged from 16 to 155 t in the late 1990s and early 2000s and have dropped to 0 in recent years. In the Aleutian Islands, catches of golden king crab remain steady with average catches of 4,536 t in the 1980s and 2,722 t in the 1990s and 2000s.

Factors Influencing Trends: Fluctuations in crab stocks have coincided with variable fishing pressure and changes in environmental conditions affecting benthic organisms in the eastern Bering Sea although no one cause has been identified to explain the wild fluctuations in some stocks and the precipitous decline from the 1970s and 1980s in other stocks.

Stock-recruitment relationships for Bristol Bay red king crabs

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Last updated: October 2007

See the 2007 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Jellyfish Eastern Bering Sea

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Last updated: October 2010

Description of index: The time series of jellyfish (principally *Chrysaora melanaster*) was updated for 2010 (Figure 57). Relative CPUE was calculated by setting the largest biomass in the time series to a value of 1 and scaling other annual values proportionally. The standard error (± 1) was weighted proportionally to the CPUE to produce a relative standard error.

Status and trends: Jellyfish relative CPUE in 2010 was very similar to 2009. The increasing trend in jellyfish biomass throughout the 1990's was first reported by Brodeur et al. (1999). The peak in the year 2000 was followed by a precipitous decline and stabilization until an increase in 2009 and 2010. The ecological implications of increases in jellyfish biomass and links between jellyfish biomass and biophysical indices are discussed by Brodeur et al. (2002, 2008).

Trends in Jellyfish Bycatch from the Bering Aleutian Salmon International Survey (BASIS)

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Last updated: August 2010

Description of index: Jellyfish sampling was incorporated aboard the US BASIS (Bering Aleutian Salmon International Surveys) vessels beginning in 2004 and will continue through 2010. All

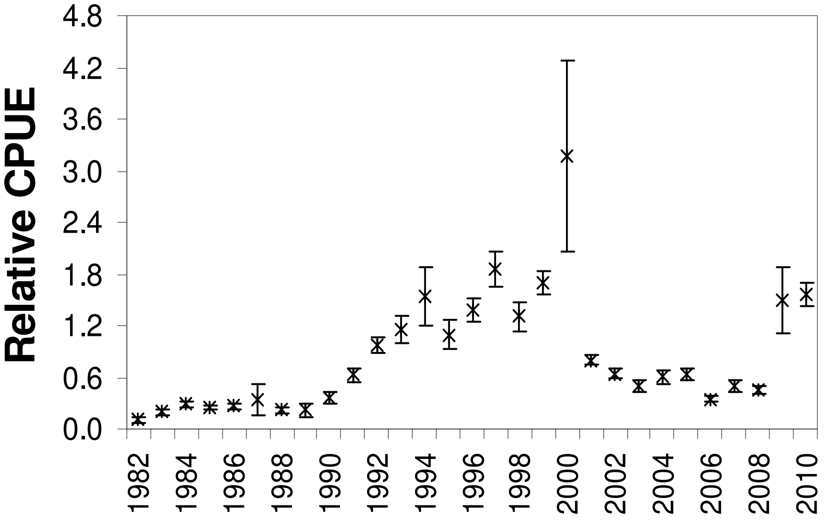

Figure 57: AFSC eastern Bering Sea bottom trawl survey relative CPUE for jellyfish during the May to August time period from 1982-2010.

jellyfish medusae caught in the surface trawl (top 18-20 m of the water column) are sorted by species and subsampled for bell diameter and wet weight. Six species are commonly caught with the surface trawl: *Aequorea* sp., *Chrysaora melanaster*, *Cyanea capillata*, *Aurelia labiata*, *Phacellocephora camtschatica*, and *Staurophora mertensi*. Distributions have been patchy for all species in the sampling grid for each year. Highest concentrations of all species combined were found to occur in the Middle Shelf Domain, although distributions throughout the domains were uneven for all years (Figure 58). Of the six species sampled, *Chrysaora melanaster* had the highest CPUE (catch per unit effort) for all years, followed by *Aequorea* sp.

Status and trends: Notable declines in jellyfish biomass for five of the species were observed in 2006 and 2007 compared to 2004 and 2005. Only *P. camtschatica* had a recorded increase in biomass in 2006. In 2007, *C. melanaster* biomass doubled compared to 2006 but was still far below the 2004 and 2005 year measurements. In 2008 our station grid was significantly reduced and is not included in Figure 58 or 59. However, comparisions with past years using the same areas from 2008 indicate similar trends in species composition and distribution patterns with the exception of *Aequorea* sp., which substantially decreases in abundance and biomass (Figure 59). 2009 shows decreases for all species compared to previous years except for *C. melanaster*, which shows increases but still not to levels of 2004 and 2005.

Factors causing trends: The cause for these shifts in biomass and distribution do not seem to rely on physical ocean factors (temperature and salinity) alone but possibly due to environmental forcing earlier in the growing season or during an earlier life history stage (polyp), which may influence large medusae biomass and abundances.

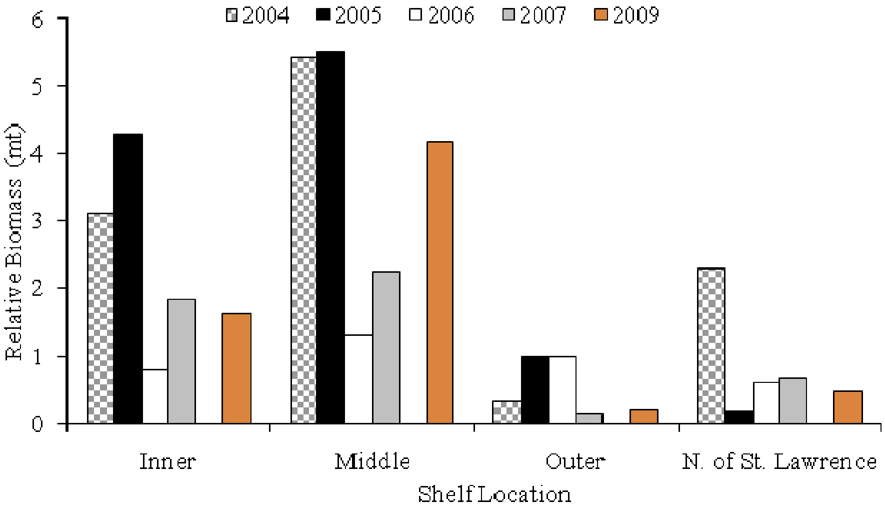

Figure 58: Relative Biomass by year for each shelf location in the Eastern Bering Sea. Relative biomass is defined as the total weight of large jellyfish species caught in a 30 minute trawl. Shelf locations (domains) are by depth, Inner 0-50m, Middle 50-100m, and Outer >100m. North of St. Lawrence is all stations sampled between 63-64.5° N latitude.

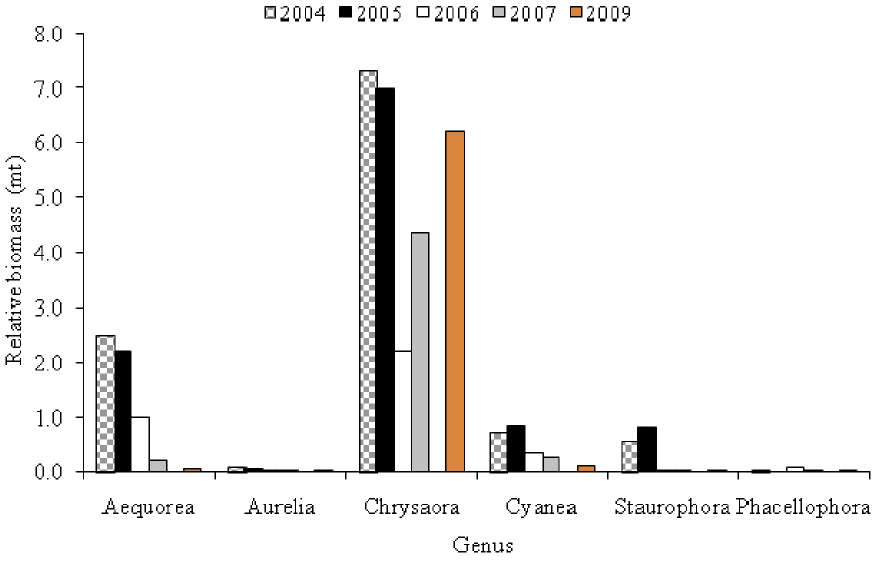

Figure 59: Relative biomass (mt) by genus for 2004-2007, and 2009 in the Eastern Bering Sea. Relative biomass is defined as the total weight of a particular genus in a 30 minute trawl.

Miscellaneous Species Eastern Bering Sea

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Last updated: October 2010

Description of index: "Miscellaneous" species fall into three groups: eelpouts (Zoarcidae), poachers (Agonidae) and sea stars (Asteroidea). The three dominant species comprising the eelpout group are marbled eelpout (*Lycodes raridens*), wattled eelpout (*L. palearis*) and shortfin eelpout (*L. brevipes*). The biomass of poachers is dominated by a single species, the sturgeon poacher (*Podothecus acipenserinus*) and to a lesser extend the sawback poacher (*Sarritor frenatus*). The composition of sea stars in shelf trawl catches are dominated by the purple-orange sea star (*Asterias amurensis*), which is found primarily in the inner/middle shelf regions, and the common mud star (*Ctenodiscus crispatus*), which is primarily an inhabitant of the outer shelf. Relative CPUE was calculated and plotted for each species or species group by year for 1982-2010. Relative CPUE was calculated by setting the largest biomass in the time series to a value of 1 and scaling other annual values proportionally. The standard error (± 1) was weighted proportionally to the CPUE to produce a relative standard error.

Status and trends: With few exceptions, the trend in relative CPUE for all three species groups was very similar (Figure 60). Determining whether this trend represents a real response to environmental change or is simply an artifact of standardized survey sampling methodology will require more specific research on survey trawl gear selectivity and on the life history characteristics of these epibenthic species.

ADF&G Gulf of Alaska Trawl Survey

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Last updated: August 2010

Description of index: The Alaska Department of Fish and Game continued its trawl survey for crab and groundfish in 2009. The 400 Eastern trawl net is targeted on areas of crab habitat around Kodiak Island, the Alaska Peninsula, and the Eastern Aleutian Islands. While the survey covers a large portion of the central and western Gulf of Alaska, results from Kiliuda and Ugak Bays (inshore) and the immediately contiguous Barnabas Gully (offshore) (Figure 61) are broadly representative of the survey results across the region. These areas have been surveyed annually since 1984, but the most consistent time series begins in 1988.

Status and trends: Prior to the start of our standard trawl survey in 1988, Ugak Bay was the subject of an intensive seasonal trawl survey in 1976-1977, also using a 400 Eastern trawl net (Blackburn, 1977). Today, the Ugak Bay species composition is markedly different than in 1976. Red king crabs were the main component of the catch in 1976-1977, but now are nearly non-existent. Flathead sole, skate, and gadid catch rates have all increased roughly 10-fold, and while Pacific cod

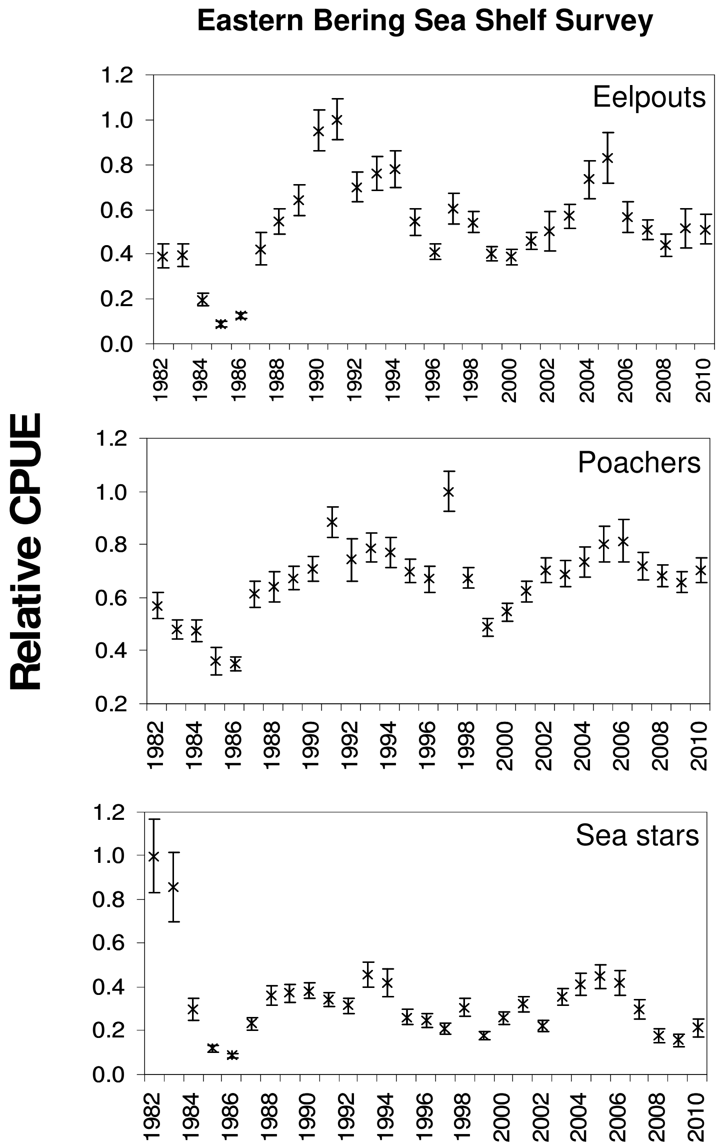

Figure 60: Relative CPUE of miscellaneous species caught in the eastern Bering Sea summer bottom trawl survey, 1982-2010. Data points are shown with standard error bars.

made up 88% and walleye pollock 10% of the gadid catch in 1976-1977, catch compositions have reversed in 2009 with Pacific cod making up 19% of catch and walleye pollock 78%. Arrowtooth flounder continues to be the main component in most of the offshore catches, while flathead sole and Tanner crab were the largest components inshore (Figure 62). Overall catches have slightly increased in 2009 (Figure 63). Arrowtooth, flathead sole, and gadid catches have contributed to overall increases both inshore and offshore, while Tanner crabs have shown increases only in the offshore areas (Figure 63).

Standardized anomalies, a measure of departure from the mean, for the survey catches from Kiliuda and Ugak Bays, and Barnabas Gully were calculated and plotted by year for selected species (ar-

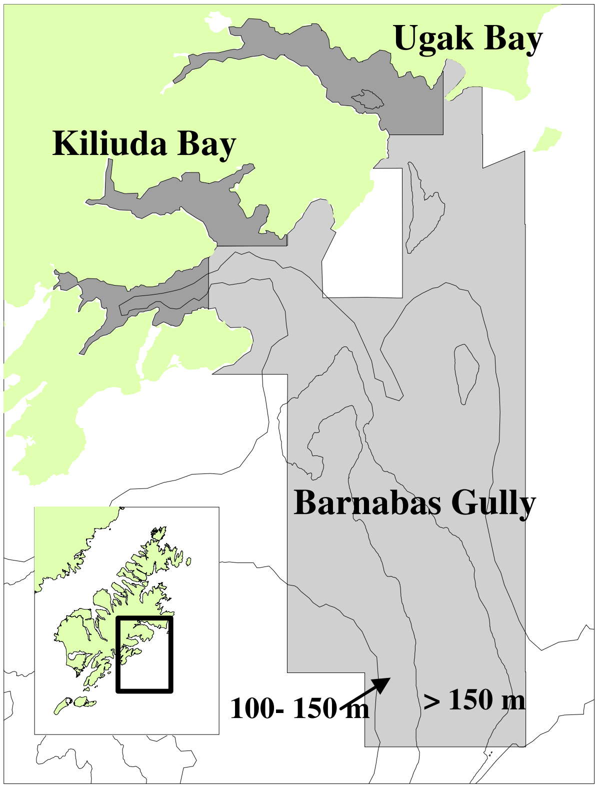

Figure 61: Adjoining survey areas on the east side of Kodiak Island used to characterize inshore (dark gray, 14 stations) and offshore (light gray, 33 stations) trawl survey results.

rowtooth flounder, flathead sole, Tanner crab, Pacific cod, and skates) using the method described by Link et al. (2002) (Figure 64). The increased catches have contributed to the wide distribution of positive values for the standardized anomalies in the recent past. In 2009, above average anomaly values were recorded for offshore skates, Pacific cod and both offshore and inshore Tanner crabs, while arrowtooth flounder and flathead sole have decreased to below average values. It appears that significant changes in volume and composition of the catches on the east side of Kodiak are occurring for these species, but it is unknown if predation, environmental changes, or fishing effort are contributing to these changes.

Factors causing trends: Bottom temperatures for each haul have been consistently recorded since 1990 (Figure 65). Temperature anomalies for both inshore, Kiliuda and Ugak Bays and offshore stations, Barnabas Gully, from 1990 to 2009, show similar oscillations with periods of above average temperatures corresponding to the strong El Niño years (1997-1998; Figure 65; `http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html`). The lower overall catch from 1993 to 1999 (Figure 3) may be a reflection of the greater frequency of El Niño events on overall production while the period of less frequenct El Niño events, 2000 to 2006, corresponds to years of greatest production and corresponding catches. Lower than average temperatures have been recorded in both 2007 and 2008 along with decreasing overall abundances. This may indicate a response lag to environmental conditions or other factors maybe influencing this trend that are not yet apparent.

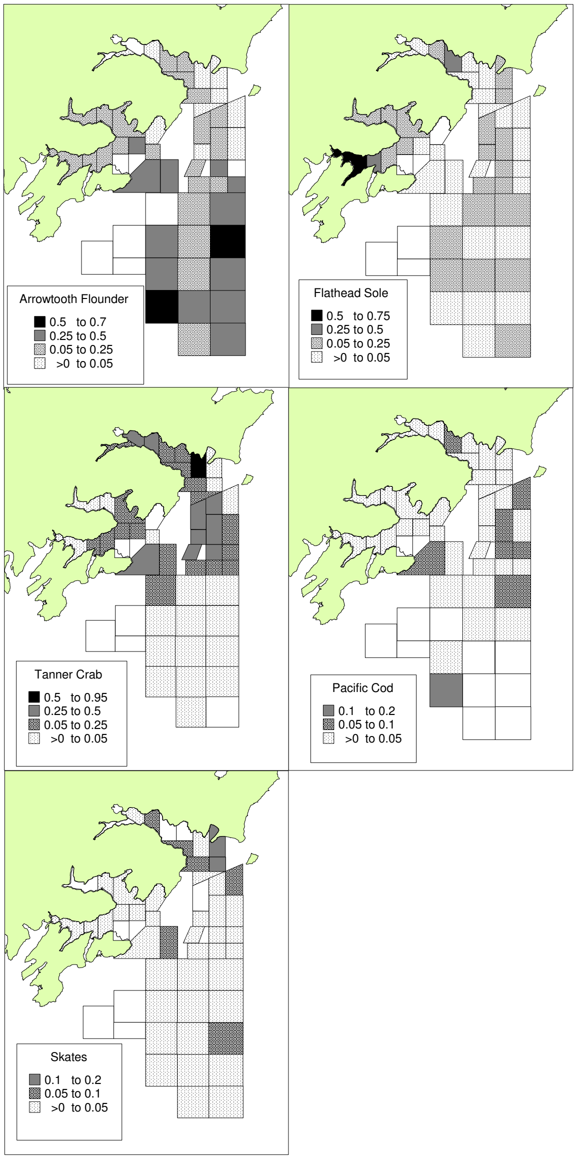

Figure 62: The catch in mt/km of selected species during the 2009 ADF&G trawl survey from Kiliuda and Ugak Bays and Barnabas Gully on the east side of Kodiak Island.

Although trends in abundance in the trawl survey appear to be affected by major oceanographic events such as El Niño, local environmental changes, predation, and fishery effects may influence species specific abundances and need to be studied further. Monitoring these trends is an important process used in establishing harvest levels for state water fisheries.

Implications: Arrowtooth, flathead sole, and other flatfish continue to dominate the catches in the ADF&G trawl survey. A decrease in overall biomass is apparent from 2007 to 2008 from years of record high catches seen from 2002 to 2005. These trends are likely influenced by large oceanographic events such as El Niño, although local environmental conditions, predation, and fishing effects may also play an important role in species abundance. The survey data is used directly

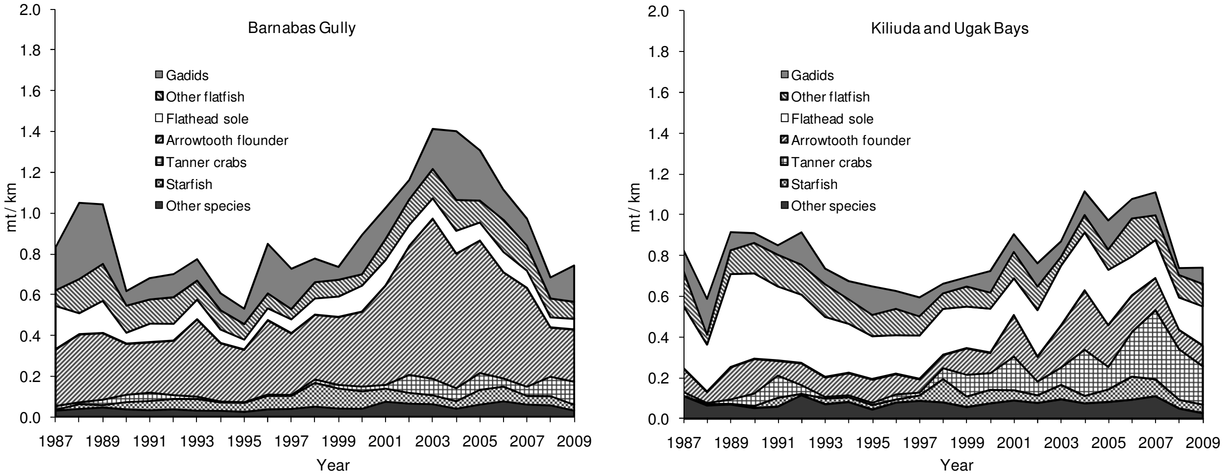

Figure 63: Total catch per km towed (mt/km) during the ADF&G trawl survey from adjacent areas off the east side of Kodiak Island, 1987 to 2009.

to establish guideline harvest levels of state managed fisheries and supply abundance estimates of the nearshore component of other groundfish species such as Pacific cod and pollock. Decreases in species abundance will most likely be reflected in decreased harvest guidelines.

Gulf of Alaska Small Mesh Trawl Survey Trends

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Last updated: August 2010

Description of index: Smallmesh trawl surveys of the nearshore Gulf of Alaska have been conducted by the Alaska Fisheries Science Center and Alaska Department of Fish and Game using standard methods since 1972 (n = 9,373 hauls). The most recent survey occurred between September 29 and October 29, 2009 (n = 134 hauls) around Kodiak Island (Chiniak, Marmot, Ugak, Kiliuda, Uganik, and Alitak Bays and Twoheaded Gully), and along the Alaska Peninsula (Kukak, Puale, Wide, Beaver, and Pavlof Bays).

The smallmesh survey results are presented here as a long-term time series of fish and invertebrate CPUEs (kilograms captured per kilometer towed ± SD). The CPUE time series was used to calculate two indices. First, Gulf-wide anomalies from the long-term mean of pink shrimp *Pandalus borealis*, juvenile pollock ($\leq$20 cm) *Theragra chalcogramma*, eulachon *Thaleichthys pacificus*, and Pacific herring *Clupea pallasi* are reported. These species are important prey items of commercial species so their abundance and distribution should be important to fishery managers. Because of the timing, location, and gear used, the smallmesh survey provides a unique opportunity to collect information on these forage species.

Second, increased spatial variance in the smallmesh catch of Pacific cod and their prey in Pavlof

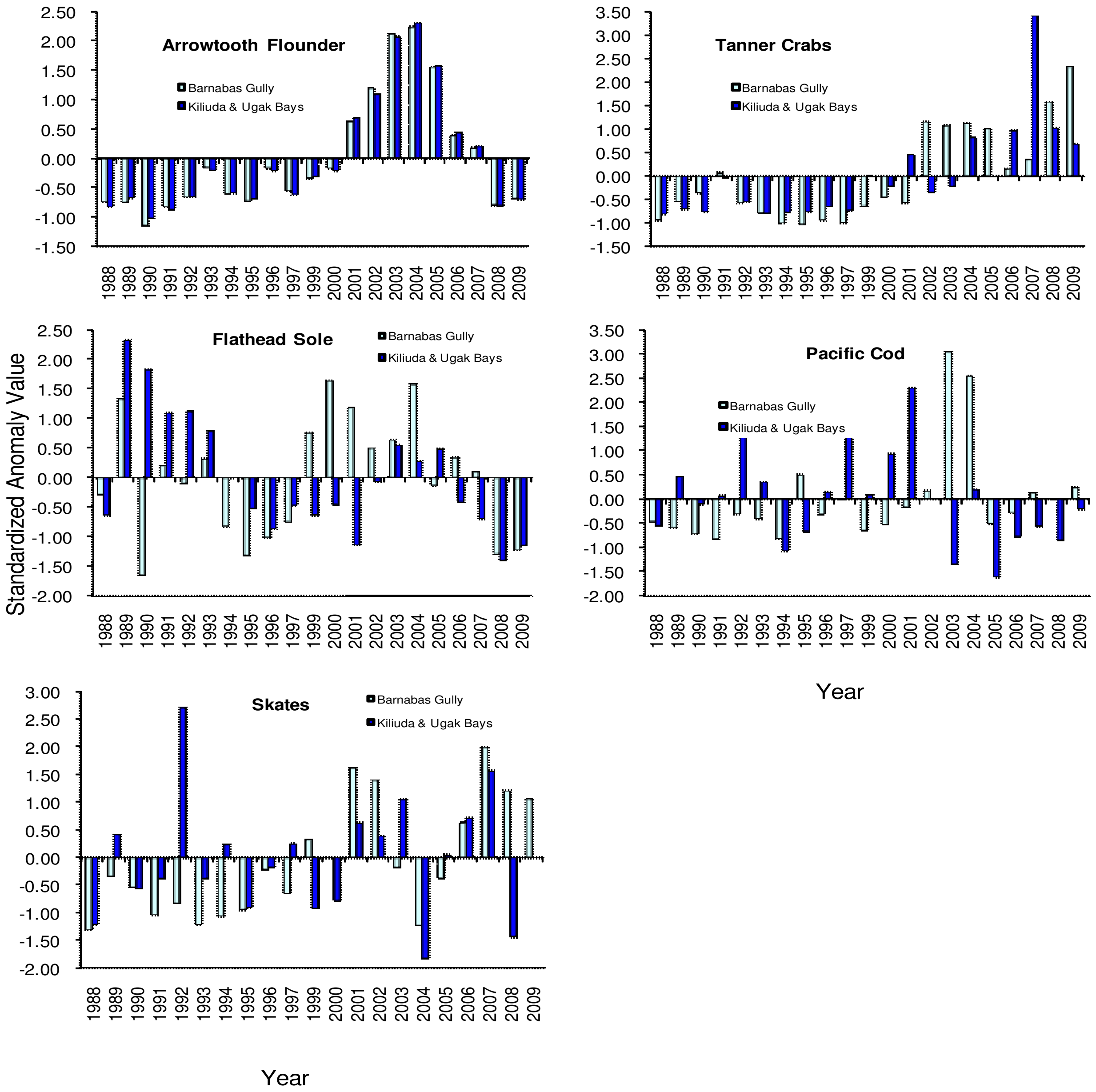

Figure 64: A comparison of standardized anomaly values for selected species caught from 1988-2009 in Kiliuda and Ugak Bays and Barnabas Gully during the ADF&G trawl surveys.

Bay has been shown to be a leading indicator of abrupt community reorganization (Litzow et al., 2008). Developing methods that would allow for the early detection of impending ecosystem transition could allow managers to take steps to help prevent ecosystem collapse (Peterson et al., 2003). The coefficient of variation of the log (cod:prey) CPUE ratio is used here as the measure of spatial variance following methods of Litzow et al. (2008). Prey species used include those that are vulnerable to top-down control by cod (capelin *Mallotus villosus*, pink shrimp, coonstripe shrimp *Pandalus hypsinotus*, humpy shrimp *P.goniurus*, and sidestripe shrimp *Pandalopsis dispar*). Sequential t tests for the analysis of regime shifts (STARS, Rodionov and Overland (2005), available at

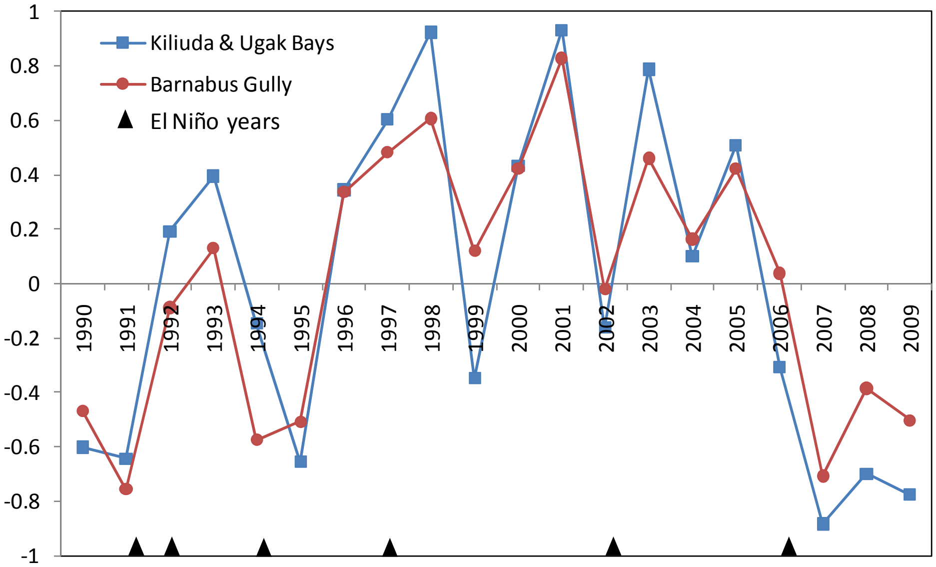

Figure 65: Bottom temperature anomalies recorded from the ADF&G trawl survey for Barnabas Gully and Kiliuda and Ugak Bays from 1990 to 2009, with corresponding El Niño years represented.

`www.beringclimate.noaa.gov/regimes/index.html`) was used to test for statistically significant shifts between alternate states.

Status and trends: Forage species catch rates remain at low levels, one to two orders of magnitude lower than peak values observed in the 1970s and early 1980s (Figure 66). The exception is eulachon which in recent years has had the highest catch rates of the time series. Forage species catch rates are not uniform across the region, however. For example, both pink shrimp and juvenile pollock were captured in all bays surveyed but catch rates varied widely both between bays and within bays. The 2009 catch rate for pink shrimp in Pavlof Bay was 4.1 ± 4.7 kg km^{-1}, while the catch rate in Wide Bay was 48.2 ± 40.2 kg km^{-1}. Juvenile pollock catch rates ranged from 9.08 ± 9.38 kg km^{-1} in Wide Bay (one haul catching nearly 30 kg km^{-1}) to <0.10 ± 0.09 kg km^{-1} in Chiniak Bay.

The STARS analysis of the cod:prey ratio in Pavlof Bay showed increased spatial variability surrounding the period of the well documented community reorganization of 1976/77 (Anderson and Piatt, 1999; Mueter and Norcross, 2000; Litzow et al., 2008) but the addition of four more data points from recent surveys to Fig. 1a of Litzow et al. (2008) did not reveal any impending alternate state (Figure 67).

Factors causing observed trends: Climate forcing on the marine community has often been implicated in explaining changes in community organizations. Climate changes reported in 1976/77 and 2001/02 (Overland et al., 2008) are qualitatively detectable in Figure 66 but are less clear for the 1998 shift. In any case, phase transitions (Duffy-Anderson et al., 2005) are not uniform within a community, as seen in recent eulachon abundance levels, and may involve different time lag periods for different species (Overland et al., 2008). Describing shifts in a marine community is difficult and so changes to use of the cod:prey ratio and input parameters to the STAR algorithm may be necessary to better capture phase transitions in the GOA that are weaker than the 1976/77 event.

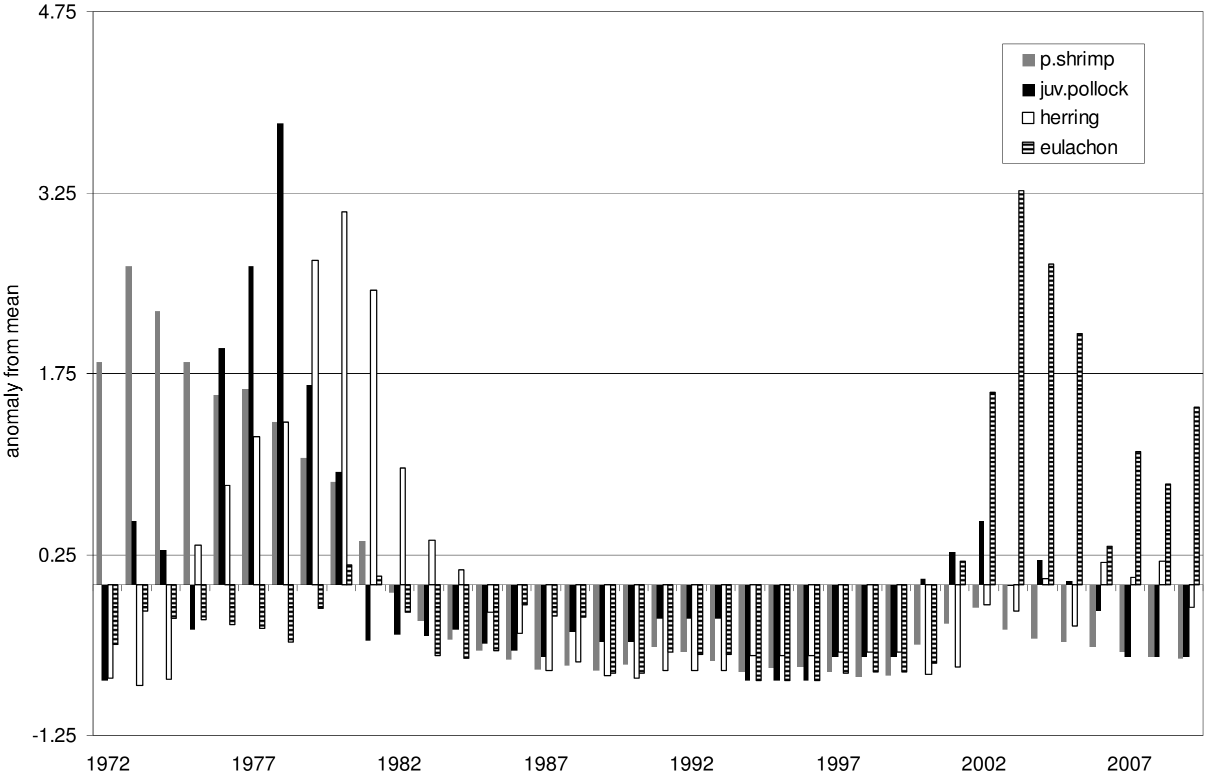

Figure 66: Anomalies of forage species CPUE (kg km^{-1}) in the Gulf of Alaska, 1972-2009. Data is taken from the smallmesh survey conducted jointly by the National Marine Fisheries Service and the Alaska Department of Fish and Game.

Implications: While the community changes in the marine ecosystem caused by the environmental changes of 1976/1977 appeared strong and widespread across the GOA, the Pacific Decadal Oscillation has not recently had as a dramatic effect (Bond et al., 2003; Litzow, 2006; Mueter et al., 2007), limiting its value as a predictive tool for groundfish managers. Linkages between ocean climate and the marine ecosystem are still important (Di Lorenzo et al., 2008) but improving our understanding of the changing ocean environment requires continued careful monitoring of the physical and biological systems.

Miscellaneous Species Gulf of Alaska

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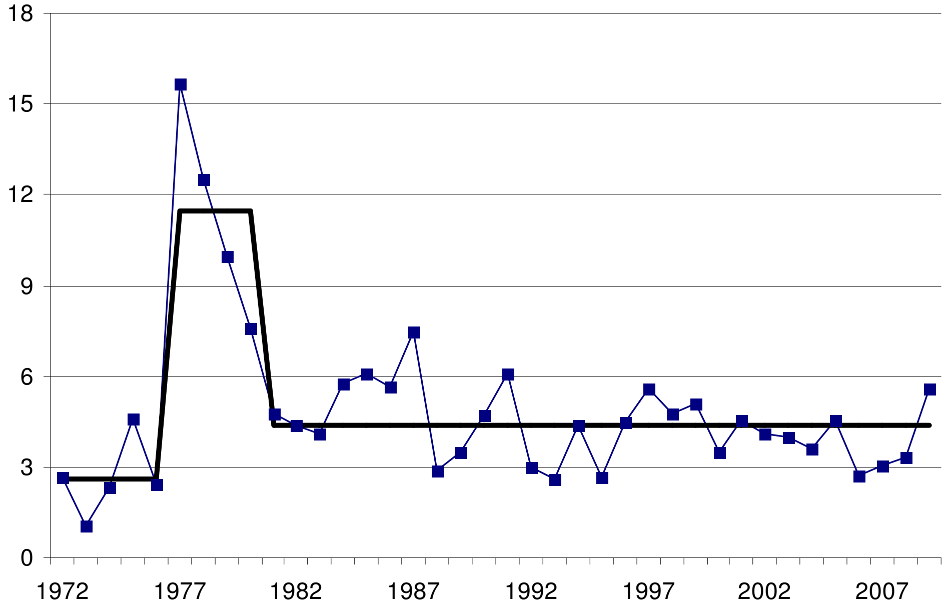

Figure 67: Time series of spatial variance in the cod:prey ratio (log + 10) in Pavlof Bay (line and squares) as adapted from Litzow et al. (2008). Heavy line indicates distinct states in the times series as defined by sequential ttests for analysis of regime shifts (STARS, p= 0.03, l = 5, H = 2).

Gulf of Alaska surveys are conducted in alternate odd years. For most recent data, see the 2007 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Lingcod Catches in the Gulf of Alaska

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See the 2009 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Miscellaneous Species Aleutian Islands

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Description of index: RACE bottom trawl surveys in the Aleutian Islands (AI) are designed primarily to assess populations of commercially important fish and invertebrates. However many other species are identified, weighed and counted during the course of these surveys and these data may provide a measure of relative abundance for some of these species. Apparent abundance trends for a few of these groups are shown in Figure 68. For each species group, the largest catch over the time series was arbitrarily scaled to a value of 100 and all other values were similarly scaled. The standard error (±1) was weighted proportionally to the CPUE to get a relative standard error.

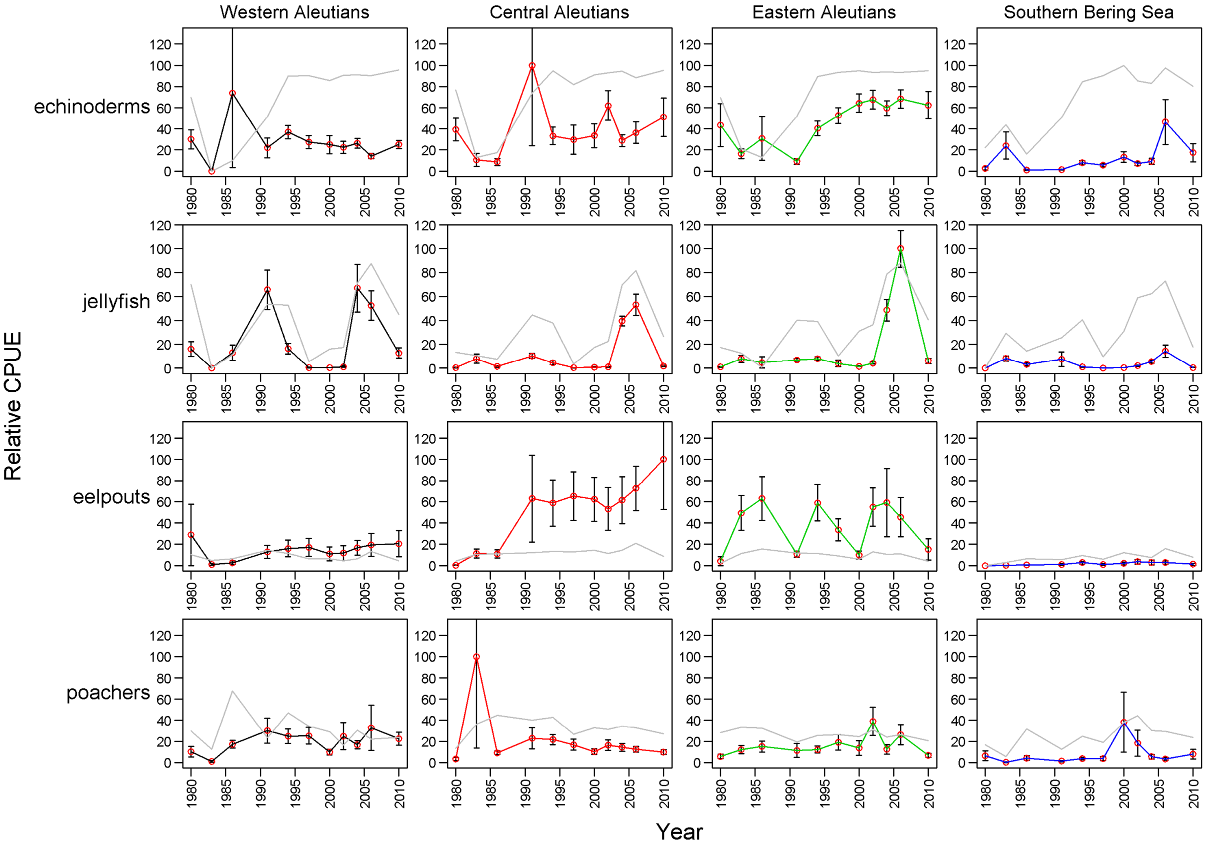

Figure 68: Relative mean CPUE of miscellaneous species by area from RACE bottom trawl surveys in the Aleutian Islands from 1980 through 2010. Error bars represent standard errors. The gray lines represent the percentage of non-zero catches.

Status and trends: Echinoderms are frequently captured in all areas of the AI surveys. Echinoderm mean catch per unit effort (CPUE) is typically higher in the central and eastern AI than in other areas, although frequency of occurrence in trawl catches is consistently high across all areas. The lowest echinoderm CPUE has usually been in the southern Bering Sea. Jellyfish were generally more abundant in 2004 and 2006 than in other years. The frequency of occurrence shows two distinct modes across all areas (1991-94 and 2004-06), although only in the western AI did this translate into higher abundance during the earlier period. The 2006 survey showed the highest level of jellyfish CPUE for all survey years, with a particularly large increase in the eastern AI. This change in abundance pattern is quite different from the eastern Bering Sea where peak abundances occurred in 2000 and 2009. Eelpout CPUEs have generally been highest in the central and eastern AI and have remained consistently high since 1991, the first survey that did not involve Japanese vessels with non-standard gear. Poachers occur in a relatively large number of tows across the AI survey area, but mean CPUE trends are unclear.

Factors causing trends: Many of these species are not sampled well by the gear or occur in areas that are not well sampled by the survey (hard, rough areas, mid-water etc.) and are therefore encountered in small numbers which may or may not reflect their true abundance in the AI. The fishing gear used aboard the Japanese vessels that participated in all AI surveys prior to 1991 was very different from the gear used by all vessels since. This gear difference almost certainly affected the catch rates for some of these species groups.

Implications: AI survey results provide limited information about abundance or abundance trends for these species due to problems in catchability. Therefore, the indices presented are likely of limited value to fisheries management.

Marine Mammals

Steller sea lion (*Eumetopias jubatus*)

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In November 1990, the NMFS listed Steller sea lions as "threatened" range-wide under the U.S. Endangered Species Act (55 Federal Register 49204, November 26, 1990) in response to a population decrease of 75% during the previous 15-year period in the core of their range in the Aleutian Islands and Gulf of Alaska. By 1997, two population stocks were identified, based largely on genetic differences, but also on regional differences in morphology and population trends (Bickham et al., 1996; Loughlin, 1997). The western stock, which breeds and gives birth on rookeries from 144 W (approximately at Cape Suckling, just east of Prince William Sound, Alaska) westward to Russia and Japan, was listed as "endangered" in June 1997 (62 Federal Register 24345, May 5, 1997) because of persistent 5% per year declines through the 1990s. The eastern stock, which occurs from Southeast Alaska southward to California, remained classified as threatened, but has been increasing at 3% per year since at least the mid-1970s (Pitcher et al., 2007). The Steller sea lion Recovery Plan (NMFS, 2008) contains recovery criteria for de-listing both stocks (removal from the list of threatened and endangered species) and down-listing the western stock from endangered to threatened. NMFS (2008) also assessed the threats to recovery for both stocks, and determined that there were no threats to recovery for the eastern stock (it is a candidate for de-listing), while for the western stock, nutritional stress resulting from competition with fisheries or environmental variability, and predation by killer whales were listed as potentially high threats to recovery, and effects of contaminants or pollutants was listed as a medium threat (largely due to significant data gaps).

Description of the index: Population assessment for Steller sea lions is currently achieved by

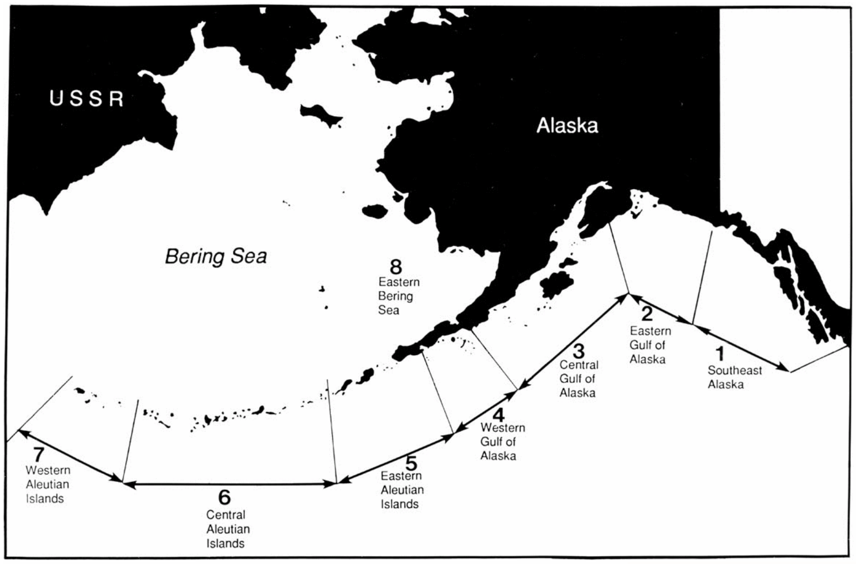

Figure 69: Map of Alaska showing sub-areas within the range of the Steller sea lion in Alaska. Sub-area 1 (SE Alaska) is part of the eastern stock of Steller sea lion, while sub-areas 2-8 are within the range of the western stock.

aerial photographic surveys of pups and non-pups (adults and juveniles at least 1 year-old). Trends in the non-pup western stock in Alaska are monitored by surveys at groups of 'trend sites' (all rookeries and major haul-outs) that have been surveyed consistently since the mid-1970s (N=87 sites) or 1991 (N=161 sites; Fritz et al. (2008)). To investigate spatial differences in population trends, counts at trend sites within sub-areas of Alaska are monitored (Figure 69).

Status and trends, factors causing trends, and implications: A. Adults and Juveniles The most recent complete aerial survey of non-pups in the endangered western Steller sea lion population in Alaska (from Cape St. Elias, 144°W to Attu Island, 172°E) was conducted by NMFS in June-July 2008. NMFS conducted a non-pup survey from Dixon Entrance (134°W) through the Delarof Islands (180°) in June-July 2010, but results were not available as of October 2010. Counts of adult and juvenile Steller sea lions at all trend sites within the range of the western stock in Alaska increased 14% between 2000 and 2008, and most of this increase occurred in the first four years (11% increase between 2000 and 2004; Table 8). Additional non-pup surveys conducted in 2009 indicated that survey timing in 2008 may have affected the results with respect to distribution of sea lions east and west of the stock boundary at 144°W: the 'early' 2008 survey found 3,000 fewer sea lions in SE Alaska (eastern stock) than the 'late' 2009 survey, while 800 more were counted in the Prince William Sound area (western stock). Accounting for this seasonal movement in 2008 (based on the 2009 data) lowered the percentage change in non-pup counts between 2000 and 2008 from 14% to 12% (for an average annual growth rate of 1.5% with a 90% CI of -0.3% to +3.3% per year), and from 2004 to 2008 from 3% to 1% (Figures 69 and 70). NMML is continuing to study the issue of trans-boundary seasonal movement and its effect on trend analyses in both the eastern and western DPS. In 2010, both 'early' and 'late' non-pup surveys were conducted in the eastern half of the Gulf of Alaska.

There is considerable variation between sub-areas in non-pup count trends estimated in the 2000s

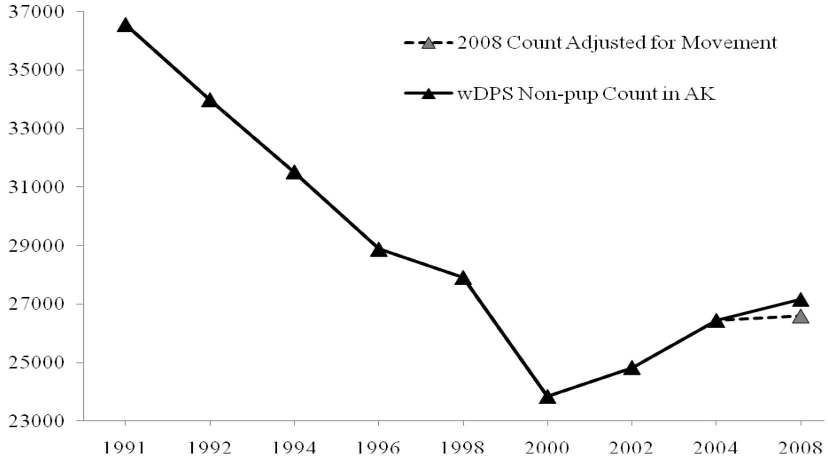

Figure 70: Total count of adult and juvenile Steller sea lions at trend sites within the range of the western stock in Alaska from 1991-2008. Non-pup count adjusted for movement of Steller sea lions primarily between southeast Alaska and the western DPS is shown in gray and with the dashed line.

(Table 9; Figure 71): the western Aleutian Islands decreased rapidly at approximately -7% per year and sub-area population trends improved to the east through the western Gulf of Alaska, where the annual trend was approximately +4% per year; the central Gulf of Alaska population was stable in the 2000s, while the eastern Gulf of Alaska increased at approximately 5% per year. Winship and Trites (2006) also noted that significant differences in regional trends could affect the species' ability to occupy its present range in the future.

B. Pups The most recent complete Steller sea lion pup production survey in Alaska was conducted in June-July 2009; pup production on the four western Aleutian Island rookeries was also assessed in 2010 (Table 10; Figure 72). Regional trends in pup production are similar to trends in non-pup counts, with continued relatively steep declines in the western Aleutians, less steep decline in the central Aleutians, stability in the central Gulf of Alaska and improvement in the eastern Aleutians, and western and eastern Gulf of Alaska. Demographic modeling suggests that reproductive rates of adult females in the central Gulf of Alaska declined 36% between the mid-1970s and 2004 (Holmes et al., 2007). Ratios of pups to non-pups (an index of rates of natality) also declined in the western Gulf of Alaska and the eastern Aleutian Islands during this same period, suggesting that declines in natality rates may not be limited solely to the central Gulf sea lion population. Pup to non-pup ratios based on data collected in 2009 suggest that natality rates of western stock sea lions are lower than those in SE Alaska (eastern stock). At the two largest and oldest rookeries in SE Alaska (Forrester Complex and Hazy Island), the pup:non-pup ratio was 0.85 in 2009; Pitcher et al. (2007) reported a ratio of 0.75 in 2002. Rookery pup:non-pup ratios within the western stock in AK ranged from 0.44 to 0.63 by sub-area in 2009, and averaged 0.57, or 33% lower than in SE Alaska. While rookery pup:non-pup ratios are not direct estimates of female natality (since they include juveniles and males in the denominator), they do provide insight into the relative birth rates of females within each region since females dominate rookery populations.

Table 8: Counts of adult and juvenile (non-pup) Steller sea lions observed at rookery and haulout trend sites surveyed consistently since 1991 (N=161) in six sub-areas of the Alaskan range of the western stock during June and July aerial surveys from 1991 to 2008. 2008*=counts in the eastern and central Gulf of Alaska in 2008 were adjusted to account for seasonal movement of sea lions between these two western stock sub-areas and SE Alaska, an eastern stock sub-area.

Year	**Gulf of Alaska (GOA)**			**Aleutian Islands (AI)**			**Western Stock in Alaska**
	Eastern	Central	Western	Eastern	Central	Western	
1991	4,812	7,872	5,338	5,283	8,656	4,601	36,562
1992	3,981	7,358	5,112	5,707	7,633	4,199	33,991
1994	3,612	6,505	5,718	5,664	6,909	3,114	31,522
1996	2,450	5,400	5,356	5,967	6,368	3,334	28,875
1998	2,158	4,806	5,367	5,774	7,017	2,786	27,908
2000	2,102	4,555	3,996	4,990	6,560	1,633	23,836
2002	2,615	4,594	4,617	5,261	6,547	1,196	24,829
2004	3,015	4,028	5,233	5,991	6,885	1,286	26,438
2006	3,101			5,973			
2007	2,760						
2008*	3,313	4,602	5,558	6,405	5,817	894	26,589

Table 9: Annual growth rates from 2000 to 2008 of non-pup sea lion populations by sub-area with 90% confidence intervals.

Sub-Area	**Growth rate**	**-90%**	**+90%**
Western AI	-7.19%	-11.63%	-2.52%
Central AI	-1.82%	-4.20%	0.62%
Eastern AI	3.22%	-1.72%	8.41%
Western GOA	4.30%	-0.69%	9.55%
Central GOA	-0.14%	-3.54%	3.39%
Eastern GOA	5.07%	0.04%	10.35%

Northern fur seal (*Callorhinus ursinus*)

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Last updated: October 2010

The northern fur seal ranges throughout the North Pacific Ocean from southern California north to the Bering Sea and west to the Okhotsk Sea and Honshu Island, Japan. Breeding in the US is restricted to only a few sites: the Pribilof Islands and Bogoslof Island in Alaska, and the Channel Islands off California (NMFS, 1993). Two separate stocks of northern fur seals are recognized within U.S. waters: an Eastern Pacific stock (Pribilofs and Bogoslof) and a San Miguel Island stock.

Northern fur seals were listed as depleted under the MMPA in 1988 because population levels had

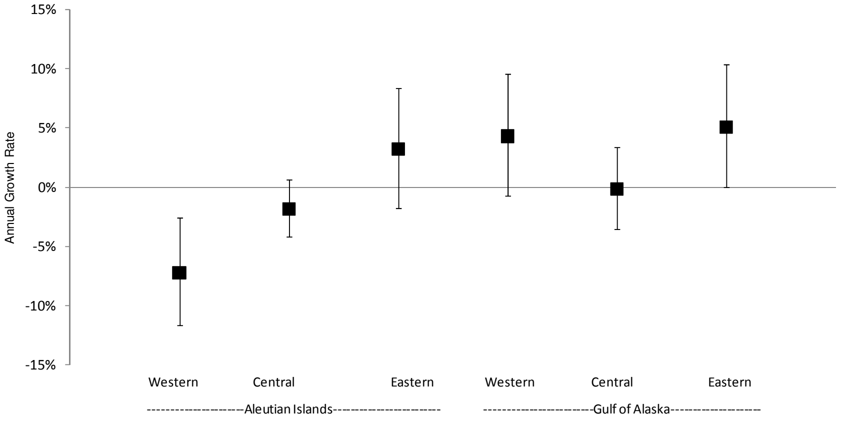

Figure 71: Annual growth rates (90% CI) of western Steller sea lions (non-pups) by sub-area in Alaska, 2000-2008.

declined to less than 50% of levels observed in the late 1950s, with no compelling evidence that carrying capacity had changed (NMFS, 1993). Fisheries regulations were implemented in 1994 (50 CFR 679.22(a) (6)) to create a Pribilof Islands Area Habitat Conservation Zone (no fishing with trawl permitted), in part, to protect the northern fur seals. Under the MMPA, this stock remains listed as "depleted" until population levels reach at least the lower limit of its optimum sustainable population (estimated at 60% of carrying capacity). A Conservation Plan for the northern fur seal was written to delineate reasonable actions to protect the species (NMFS, 1993)).

Description of the index: The population size and trends of northern fur seals on the Pribilof Islands are estimated by NMFS biennially using a mark-recapture method (shear-sampling) on pups of the year; pup production was estimated in August 2010 but the results were not available in October 2010.

Status and trends, factors causing trends, and implications: NMFS estimated that 120,800 pups were born on the Pribilof Islands in 2008: 102,674 (SE = 1,084) pups on St. Paul Island and 18,160 (SE = 288) on St. George Island. Pup production on St Paul Island has been declining since the mid-1990s (Figure 73; Towell et al. (2006)), while it has been relatively stable on St George since 2002. Estimated pup production on both Pribilof Islands in 2008 was similar to the level observed in 1916; however the population trend at the beginning of the 20th century was much different than at beginning of the 21st. In 1916, the northern fur seal population was increasing at approximately 8% per year following the cessation of extensive pelagic sealing, while currently (1998 through 2008), pup production on both Pribilof Islands is estimated to be decreasing at approximately 6% per year.

The recent trend in pup production on Bogoslof Island has been opposite of that observed on the Pribilofs (Figure 73). Pup production increased at approximately 20% per year on Bogoslof Island between 1995 and 2007. This rate is faster than what could be expected from a completely closed population of fur seals, indicating that at least some of it is due to females moving from the Pribilof Islands (presumably) to Bogoslof to give birth and breed. However, declines observed on the Pribilof Islands are much greater than the increase in numbers on Bogoslof, indicating that

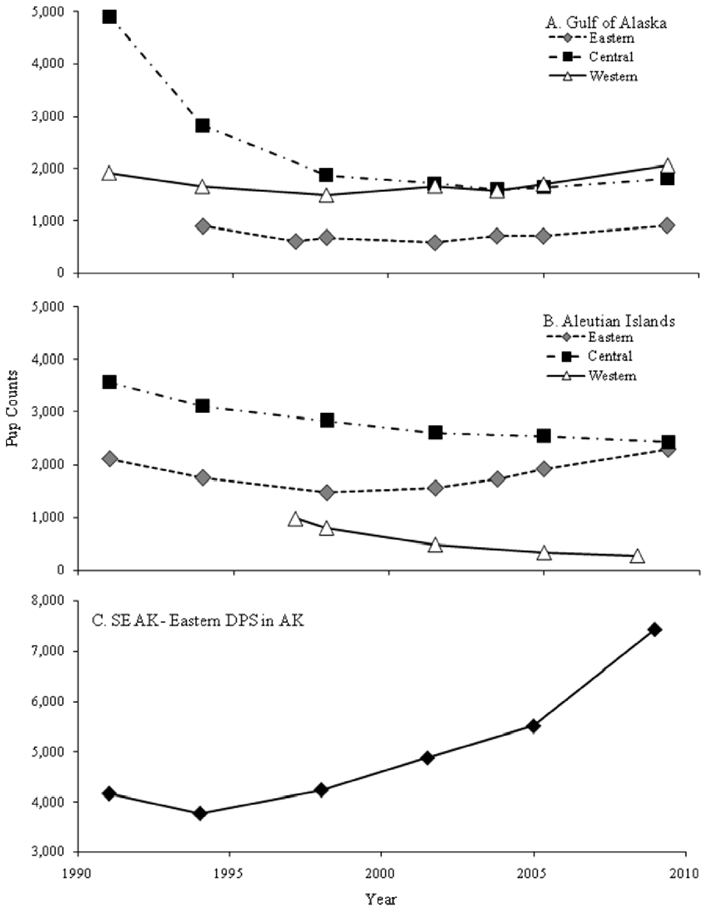

Figure 72: Steller sea lion pup counts at trend rookeries in the range of the western and eastern stocks in Alaska by region, 1991-2009 in the Gulf of Alaska (A), Aleutian Islands (B), and SE Alaska (C; eastern stock, or distinct population segment (DPS).

the decline on the Pribilofs cannot be due entirely to emigration. Differences in trends between the predominately shelf-foraging Pribilof fur seals and the predominately pelagic-foraging Bogoslof fur seals likely reflect differences in their summer foraging habitats, and are unlikely related to large-scale changes in the North Pacific Ocean (e.g., regime shifts, Pacific Decadal Oscillation), since these populations both occupy the same habitats in the North Pacific Ocean during the fall, winter and spring.

Harbor Seals (*Phoca vitulina*)

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Table 10: Counts of Steller sea lions pups at trend rookeries in the ranges of the western and eastern stocks in Alaska. Counts were conducted during both onshore surveys and high resolution aerial photographs in June-July 1978-1979, 1984-1989, 1990-1992, 1994, 1997, 1998, 2001-2002, 2003-2004, 2005, 2009, and 2010 (western Aleutians only). * 1984-89 CAI count does not include Amchitka/Column Rocks.

	Western Stock							**Eastern DPS**
	Gulf of Alaska			**Aleutian Islands**				
	Eastern	Central	Western	Eastern	Central	Western	Total	SE AK
N Rookeries	2	5	4	5	11*	4	31	5
Year								
1978-1979	574	18,893	9,351					2,219
1984-1989		10,254	5,879	4,778	9,382			
1990-1992		4,904	1,923	2,115	3,568			4,164
1994	903	2,831	1,662	1,756	3,109			3,770
1997	611					979		
1998	689	1,876	1,493	1,474	2,834	803	9,169	4,235
2001-2002	586	1,721	1,671	1,561	2,612	488	8,639	4,877
2003-2004	716	1,609	1,577	1,731				
2005	715	1,651	1,707	1,921	2,551	343	8,888	5,510
2009	918	1,820	2,062	2,299	2,431	279	9,809	7,444
2010						225		

See the 2007 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Arctic ice seals: Bearded seal, ribbon seal, ringed seal, spotted seal

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See the 2009 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Bowhead whale (*Balaena mysticetus*)

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All stocks of bowhead whales (*Balaena mysticetus*) were severely depleted by commercial whaling

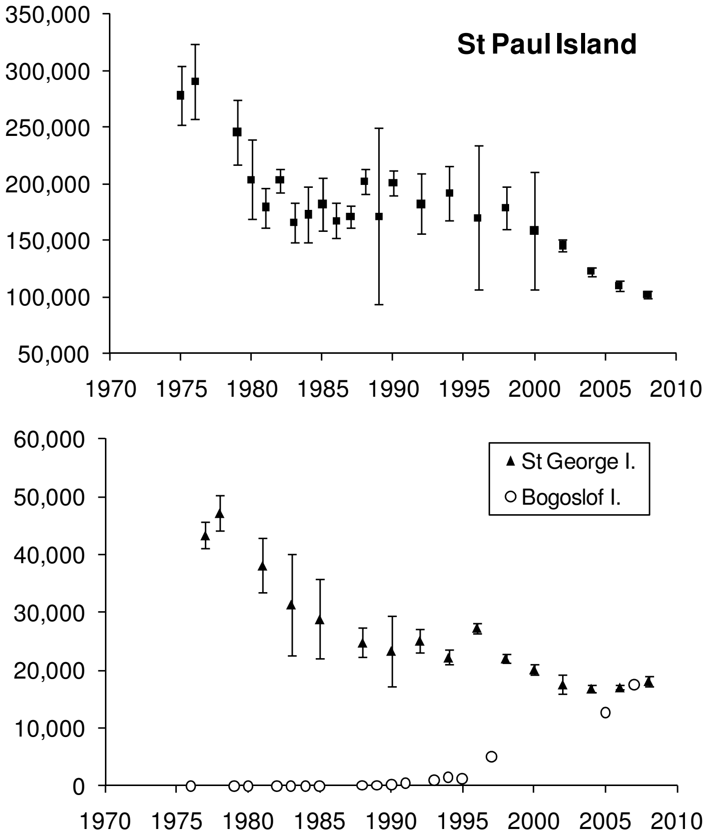

Figure 73: Northern fur seal pup production estimates for the Pribilof Islands (St Paul and St George Islands) and Bogoslof Island, 1975-2008. Error bars are approximate 95% confidence intervals.

(Woodby and Botkin, 1993) and were classified as protected by the International Whaling Commission (IWC) under the 1946 International Convention for the Regulation of Whaling. The IWC currently recognizes the Okhotsk Sea, Spitsbergen, Eastern Canada-West Greenland, and Western Arctic stocks of bowhead whales (IWC, 2007*b*). The Western Arctic stock, also known as the Bering Sea (Burns et al., 1993) or Bering-Chukchi-Beaufort Seas (Rugh et al., 2003) stock, is the only stock of bowheads in U.S. waters (Rugh et al., 2003; George et al., 2007; IWC, 2007*b*). In the U.S., this stock is classified as endangered under the Endangered Species Act (ESA) of 1973 and depleted under the Marine Mammal Protection Act of 1972; thus, it is also considered a strategic stock. However, the Western Arctic stock has been increasing in recent years (George et al., 2004; Koski et al., In Press) and may be approaching its carrying capacity (Brandon and Wade, 2006).

Western Arctic bowheads generally migrate between wintering areas in the Bering Sea and summering areas in the eastern Beaufort Sea (Braham et al., 1980; Moore and Reeves, 1993). Systematic ice-based visual counts during this migration have been conducted since 1978 (Krogman et al., 1989; George et al., 2004). A summary of the resulting abundance estimates, corrected for whales missed during the census (Zeh et al., 1993; Clark et al., 1996), is provided in Table 11 (Allen and

Angliss, 2010) and Figure 74 (George et al., 2004); however, these estimates have not been corrected for a small, unknown portion of the population that does not migrate past Point Barrow during the survey (Allen and Angliss, 2010). The most recent population abundance estimate in 2004 of 12,631 (CV=0.2442) whales in the Western Arctic stock (excluding calves) was calculated from aerial photographic surveys of bowhead whales in 2003, 2004, and 2005 (Koski et al., In Press). The rate of increase indicates a steady recovery of the stock (George et al., 2004; Brandon and Wade, 2006; Koski et al., In Press).

Table 11: (from Allen and Angliss (2010)). Summary of population abundance estimates for the Western Arctic stock of bowhead whales. The historical estimates were made by back-projecting using a simple recruitment model. All other estimates were developed by corrected ice-based census counts. Historical estimates are from Woodby and Botkin (1993); 1978-2001 estimates are from George et al. (2004) and Zeh and Punt (2004).

Year	**Abundance Estimate (CV)**
Historical estimate	10,400-23,000
End of commerical whaling	1,000-3,000
1978	4,765 (0.305)
1980	3,885 (0.343)
1981	4,467 (0.273)
1982	7,395 (0.281)
1983	6,573 (0.345)
1985	5,762 (0.253)
1986	8,917 (0.215)
1987	5,298 (0.327)
1988	6,928 (0.120)
1993	8,167 (0.017)
2001	10,545 (0.128)

There are no observer program records of bowhead whale mortality incidental to commercial fisheries in Alaska. Historically, however, some bowheads have had interactions with crab pot gear. More recent NMFS Alaska Region stranding records have reported bowhead whale entanglements, including a bowhead that was found dead in Bristol Bay in 2003, with line (of unknown origin) around its caudal peduncle and both flippers, and a bowhead that was observed near Point Barrow in 2004 with fishing net and line around its head (Allen and Angliss, 2010).

Alaska Natives living in villages along the migration route of the Western Arctic stock of bowheads have hunted these whales for at least 2,000 years (Marquette and Bockstoce, 1980; Stoker and Krupnik, 1993), and the IWC has regulated subsistence takes since 1977 (IWC, 1978). Alaska Native subsistence hunters landed 832 bowhead whales between 1974 and 2003 (Suydam and George, 2004), 37 in 2004 (Suydam et al., 2005, 2006), 55 in 2005 (Suydam et al., 2006), 31 in 2006 (Suydam et al., 2007), 41 in 2007 (Suydam et al., 2008), and 38 in 2008 (Suydam et al., 2009). Russian subsistence hunters harvested one bowhead whale in 1999 and one in 2000 (IWC, 2002), three in 2003 (Borodin, 2004), one in 2004 (Borodin, 2005), two in 2005 (IWC, 2007*b*), and two in 2008 (IWC, 2010). Canadian Natives also harvested one bowhead whale in 1991 and one in 1996 (Allen and Angliss, 2010). At its annual meeting in 2007, the IWC renewed the existing 5-year bowhead quota for the 5-year period from 2008 to 2012 (IWC, 2007*a*); the quota currently includes up to 280 whales landed, with no more than 67 whales struck in any year and up to 15 unused strikes

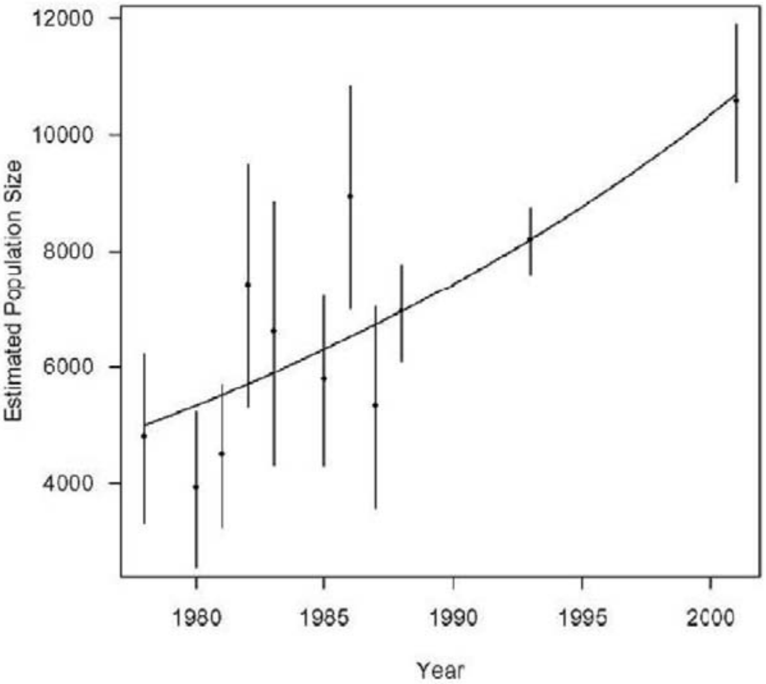

Figure 74: (George et al., 2004). Population abundance estimates for the Western Arctic stock of bowhead whales, 1977-2001, as computed from ice-based counts, acoustic locations, and aerial transect data collected during bowhead whale spring migrations past Barrow, Alaska. Error bars show +/- 1 standard error.

carried over each year.

Oil and gas development in the Arctic has the potential to impact bowheads through increased risks of exposure to pollution and to the sound produced by exploration, drilling operations, and increased vessel traffic in the area (Allen and Angliss, 2010). Past studies have indicated that bowheads are sensitive to sounds from seismic surveys and drilling operations (Richardson and Malme, 1993; Richardson, 1995; Davies, 1997) and will avoid the vicinity of active seismic operations (Miller et al., 1999), active drilling operations (Schick and Urban, 2000), and the resulting vessel traffic (Richardson et al., 2004). Each year since 1979, the U.S. Department of the Interior's Minerals Management Service (MMS) has funded and/or conducted aerial surveys of bowhead whales during their fall migration through the western Beaufort Sea in what is known as the Bowhead Whale Aerial Survey Project (BWASP). In 2007, as part of an Inter-Agency Agreement (IAA) between the MMS and NMFS, the National Marine Mammal Laboratory (NMML) took over the coordination of BWASP. Through a second IAA, the survey area has been expanded to include the northeastern Chukchi Sea as part of the Chukchi Offshore Monitoring in Drilling Area (COMIDA) project. To facilitate mitigation of future oil and gas development along the migration route of the Western Arctic stock of bowheads, the multi-year (2007-2012) Bowhead Whale Feeding Ecology Study (BOWFEST), administered by NMFS and funded by the MMS, will estimate relationships among bowhead whale prey, oceanographic conditions, and bowhead whale feeding behavior in the western Beaufort Sea (Rugh, 2009). Aerial survey daily reports for the

BWASP, COMIDA, and BOWFEST projects are available at `http://www.afsc.noaa.gov/nmml/cetacean/bwasp/index.php` and annual reports are available through NMML.

Potential Causes of Declines in Marine Mammals

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Last updated: November 2006

See the 2006 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Seabirds

Pribilof Islands Seabird Trends

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Last updated: October 2010

Description of indices: The seabird indicator species included in the Ecosystem Considerations Chapter for 2010 are black- and red-legged kittiwakes, common and thick-billed murres, red-faced cormorants, northern fulmars, and least auklets. All species are cliff-nesters with the exception of the crevice-nesting least auklets. Black- and red-legged kittiwakes are surface-feeding piscivores. Common murres, thick-billed murres, and red-faced cormorants are diving piscivores. Common and thick-billed murres also consume invertebrates such as amphipods, euphausiids, and squid, with the thick-billed murres consuming invertebrates to a greater extent than common murres (Decker and Hunt Jr., 1996). Northern fulmars are surface-feeding planktivores and least auklets are diving planktivores. The Alaska Maritime Wildlife Refuge conducts annual monitoring of these seabird species representing a variety of foraging guilds on both St. George and St. Paul Islands. All time-series data listed here are from the 2009 annual monitoring reports for the Pribilof Islands (McClintock et al., 2010; Shannon et al., 2010).

Reproductive success was measured by monitoring individual nests to determine the number of chicks fledged per nest within the breeding season. Hatch date, used to measure nesting chronology, was determined by calculating the mean hatch date from all eggs hatched in monitored nests for each species. Seabird populations were measured using counts of seabirds performed on index plots at breeding colonies. The same index plots for productivity and populations are used each year.

Status and Trends: Seabird species are grouped by island to account for localized effects on the indices. Reproductive success has recently significantly increased for common murres throughout the Pribilofs, thick-billed murres on St. George Island, and for red-legged kittiwakes and red-faced cormorants on St. Paul Island (Figure 75). In contrast, black legged kittiwakes on St. George have shown a recent decreasing trend (Figure 76). Red-legged kittiwakes on St. George Island and black-legged kittiwakes and thick-billed murres on St. Paul Island show no recent significant trends in reproductive success (Figures 75 and 76).

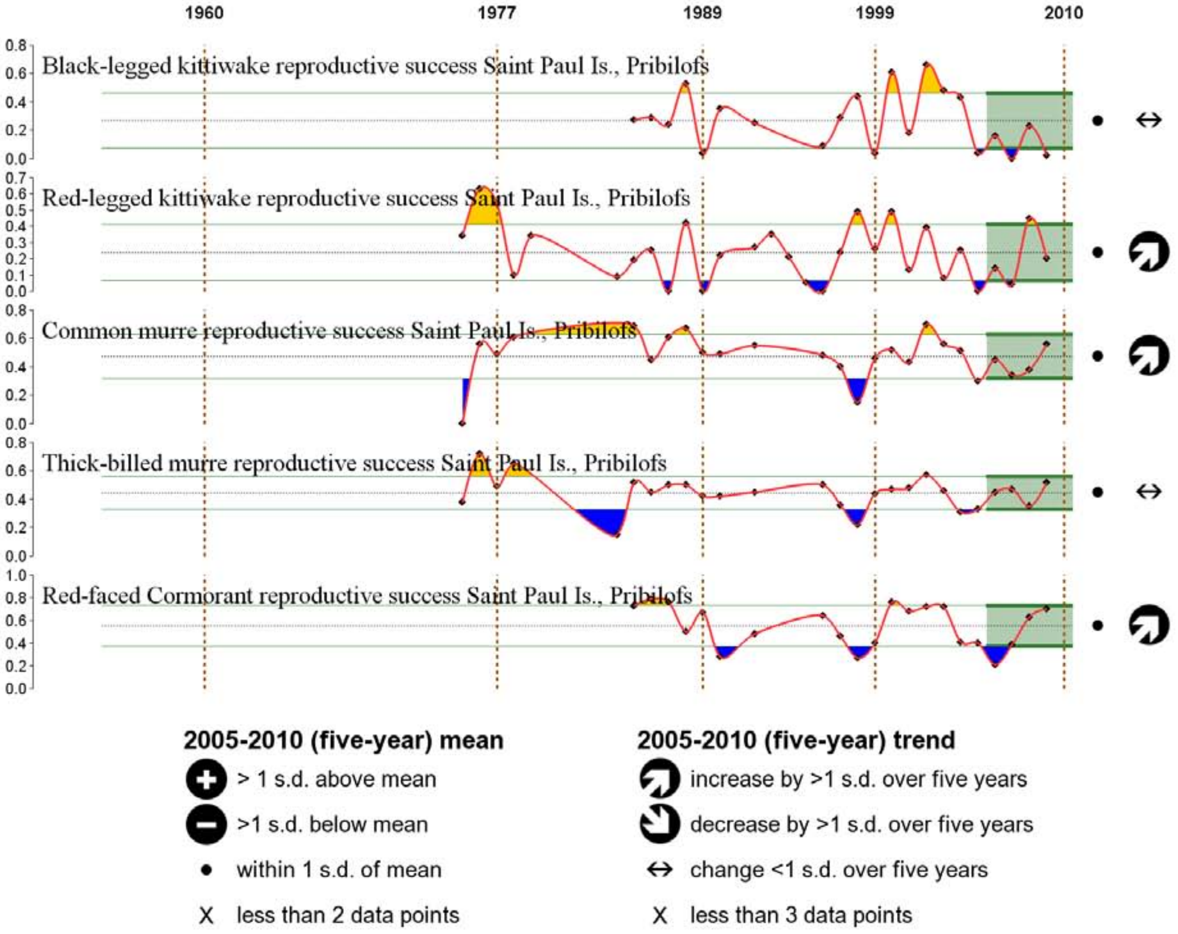

Figure 75: Seabird reproductive success on St. Paul Island, Pribilofs, Eastern Bering Sea.

Hatch dates have recently significantly decreased (become earlier in the year) for black-legged kittwakes, common murres, and thick billed murres on St. Paul Island (Figure 77), and for all species monitored on St. George Island (Figure 78). Only St. Paul red-legged kittiwakes and red-faced cormorants have no recent significant trend in hatch date.

Pribilof seabird population counts do not ocurr with enough frequency to determine recent (5 year) trends or status. Therefore, we evaluate population counts within the most recent 10 years. All

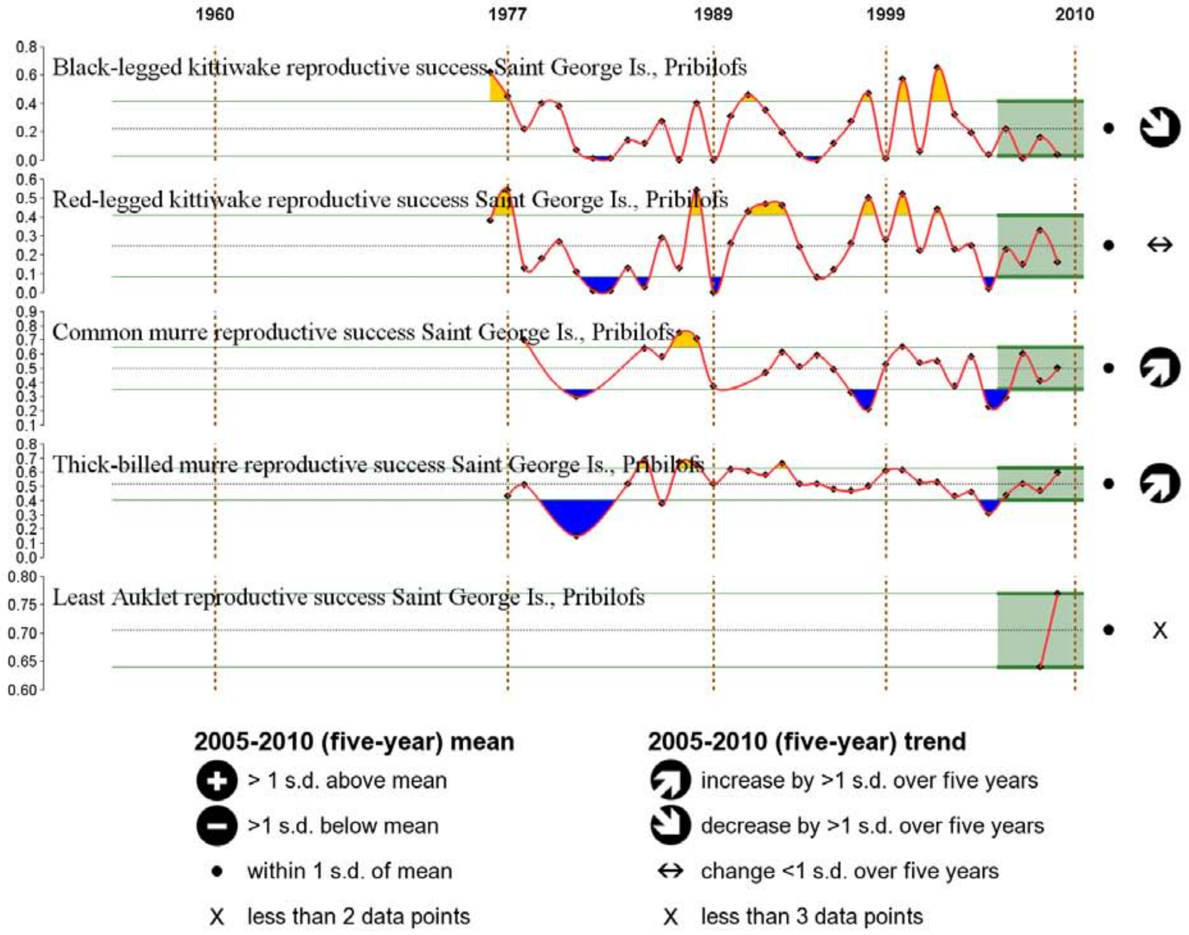

Figure 76: Seabird reproductive success on St. George Island, Pribilofs, Eastern Bering Sea.

Pribilof seabird counts have been within one standard deviation of the mean for the full time series except for thick-billed murres on St. Paul Island, which are below the mean in the most recent decade (Figures 79 and 80). No Pribilof seabirds show increasing counts over the past ten years; four show decreasing counts (St. Paul Island red-legged kittiwakes, St. George Island common murres, and northern fulmars on both islands), and the rest show no significant ten year trend.

Factors causing trends: Byrd et al. (2008) found that both red- and black-legged kittiwakes on the Pribilof Islands nested earlier and with higher breeding success when sea ice cover was greater in the eastern Bering Sea. The same study found no relationships between murre timing or productivity and sea ice cover; however, murres did have higher productivity in cooler summers. The factors causing the trends in hatch date and reproductive success observed for seabirds nesting on the Pribilof Islands are unknown, but likely include prey availability and abundance as affected by ocean conditions.

Implications: Seabirds nesting on the Pribilof Islands, such as murres and kittiwakes, which tend to have higher productivity in cold years will likely continue to have high productivity in 2011. Fu-

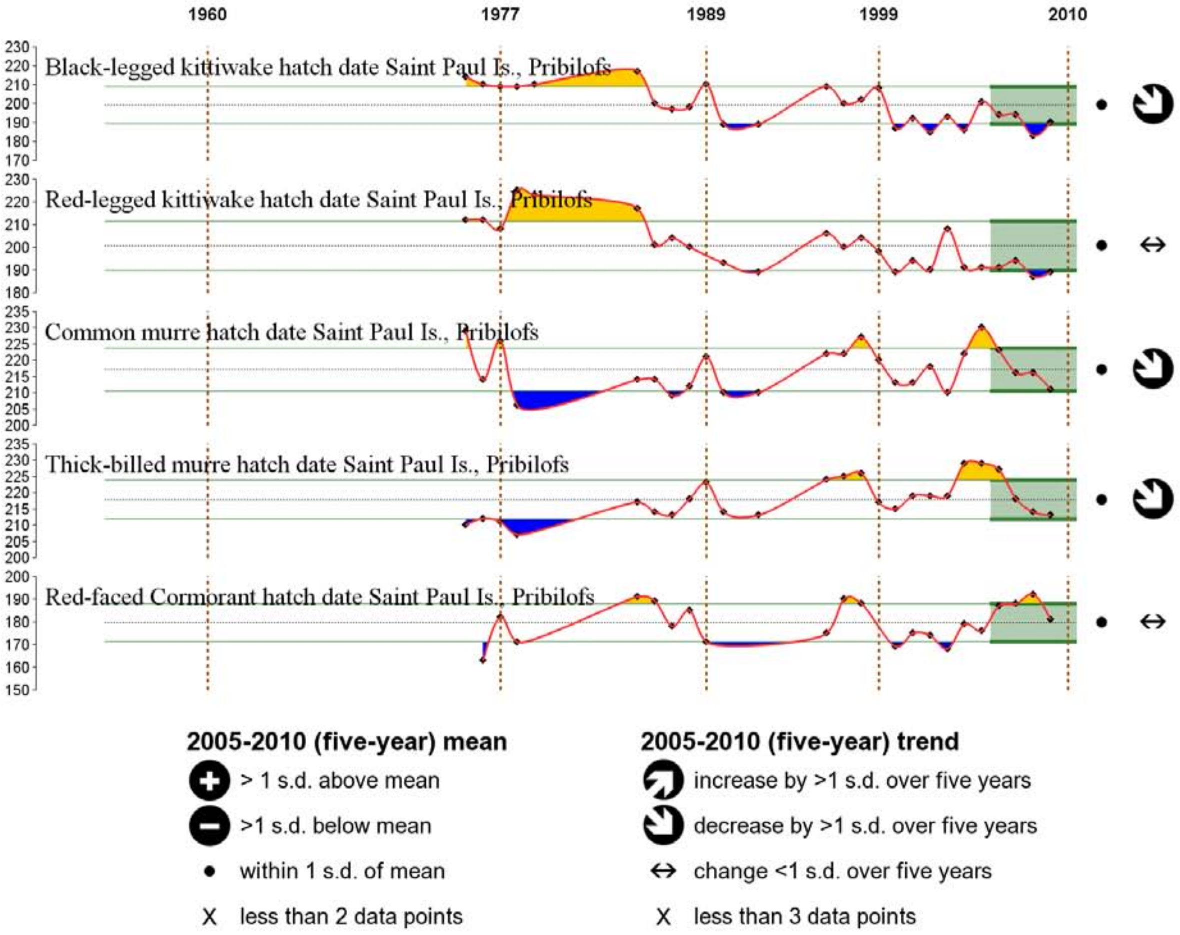

Figure 77: Seabird hatch dates on St. Paul Island, Pribilofs, Eastern Bering Sea.

ture changes in ocean conditions that lead to a warmer Bering Sea and lower productivity of forage fish and zooplankton could reverse this trend of earlier nesting and relatively high productivity for some seabird species.

Seabird distribution

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Last updated: August 2008

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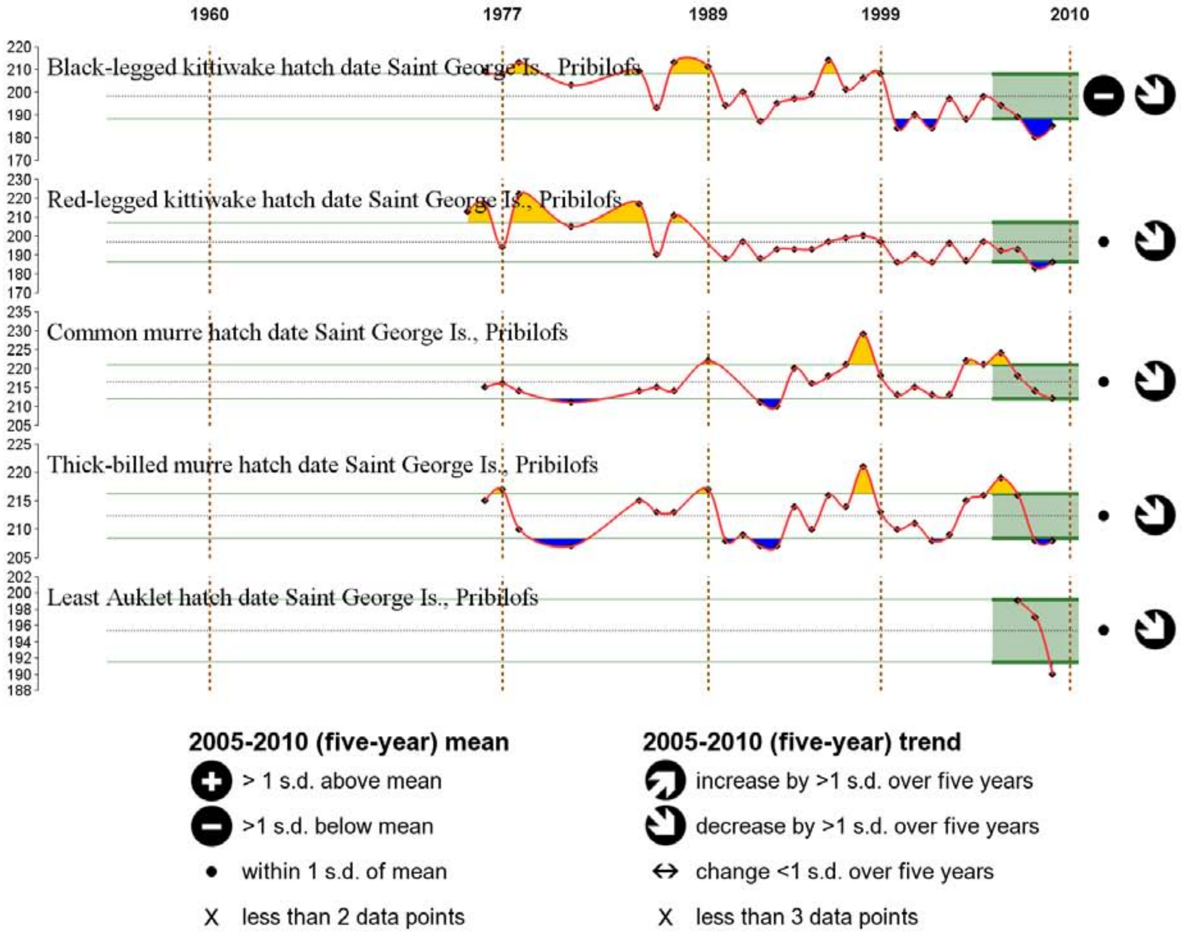

Figure 78: Seabird hatch dates on St. George Island, Pribilofs, Eastern Bering Sea.

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Trends in Abundance and Productivity

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Last updated: 2006

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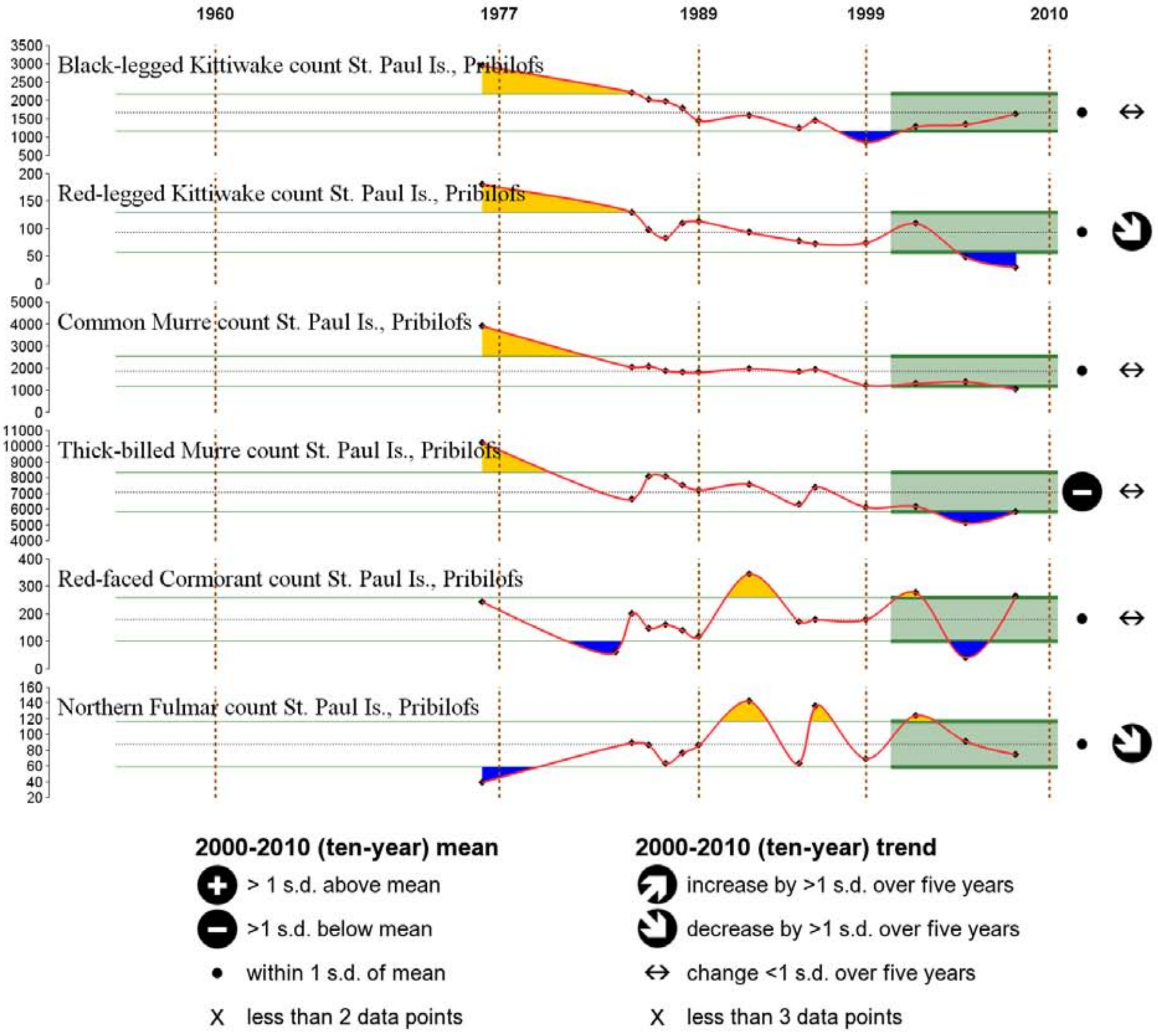

Figure 79: Seabird population counts on St. Paul Island, Pribilofs, Eastern Bering Sea.

Ecosystem Factors Affecting Seabirds

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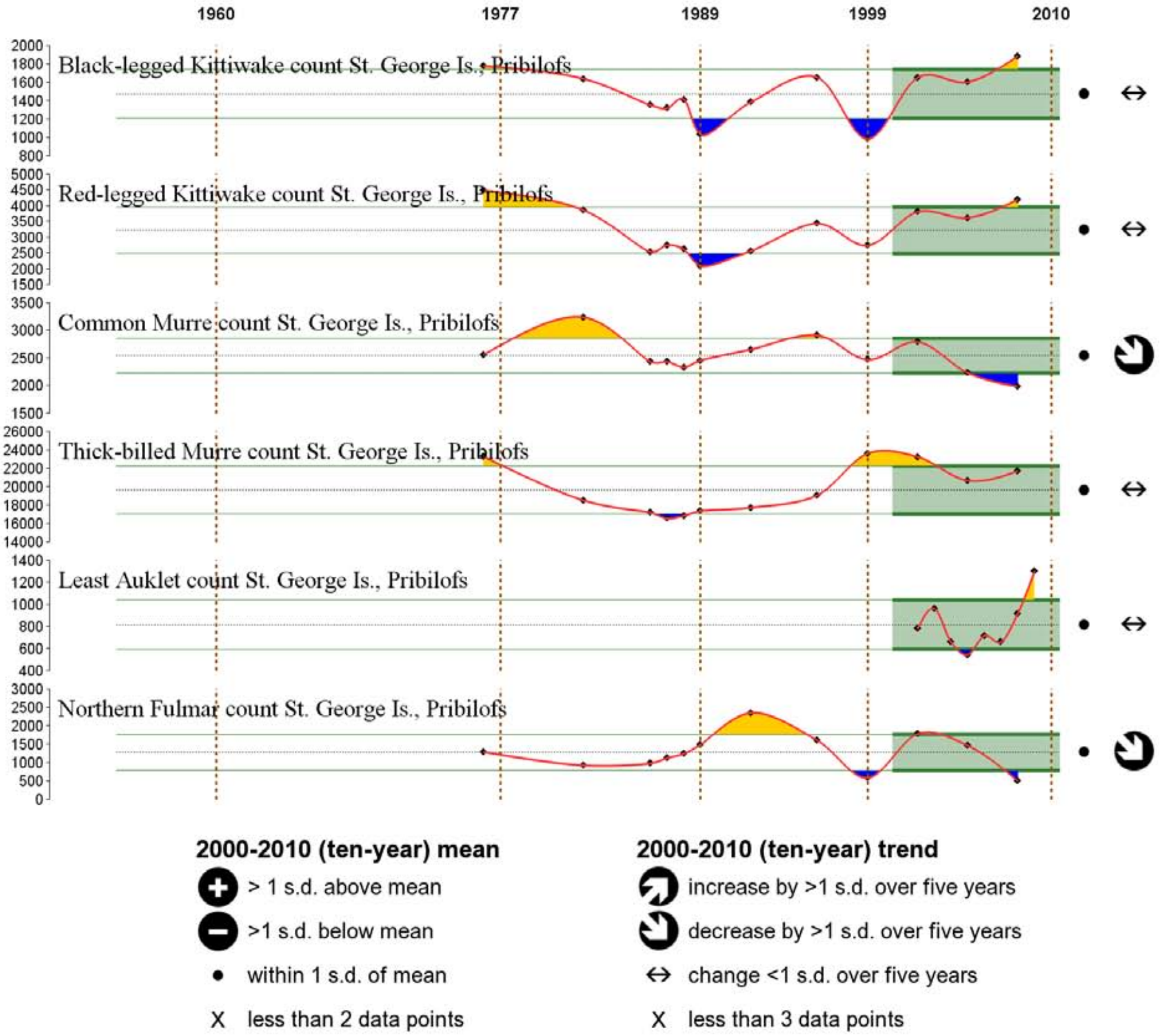

Figure 80: Seabird population counts on St. George Island, Pribilofs, Eastern Bering Sea.

Summary of Seabird Bycatch in Alaskan Groundfish Fisheries, 1993 through 2006

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Seabird Research Needs

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Ecosystem or Community Indicators

Alaska Native Traditional Environmental Knowledge of Climate Regimes

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See the 2005 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Combined Standardized Indices of recruitment and survival rate

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Last updated: August 2010

Description of indices: Indices of overall recruitment and survival rate (adjusted for spawner abundance) across the major commercial groundfish species in the Eastern Bering Sea (EBS, 8 stocks) and Gulf of Alaska (GOA, 11 stocks) are provided (Figure 81). Time series of recruitment and spawning biomass for demersal fish stocks were obtained from the 2009 SAFE reports to update results of Mueter et al. (2007). Only recruitment estimates for age classes that are largely or fully recruited to the fishery were included. Survival rate (SR) indices for each stock were computed as residuals from a spawner-recruit model. A Ricker and Beverton-Holt model (with or without first-order autocorrelated errors) were fit to each stock's recruitment and female spawning biomass data and the model with the best fit (based on the small-sample Akaike Information Criterion) was used to compute the SR index. Each time series of log-transformed recruitment (logR) or SR indices was standardized to have a mean of 0 and a standard deviation of 1 (hence giving equal weight to each stock in the combined index). Time series were lined up by year-class for the period 1977-2006, resulting in matrices of logR or SR indices by year with missing values at the beginning and end of some series. A combined standardized index of recruitment ($\mathrm{CSI_R}$) and survival ($\mathrm{CSI_{SR}}$) was computed by simply averaging indices within a given year across stocks. Prior to standardizing the series, missing values were estimated by imputation using additive regression, bootstrapping, and predictive mean matching as implemented in the "Hmisc" package for R (Frank Harrell, Univ. of Virginia, available at StatLib at `http://lib.stat.cmu.edu/`). Multiple imputations were obtained through bootstrap resampling to estimate the variability in the averaged index that results from filling in missing values. Because missing values are not missing at random, it is assumed that correlations between time series did not change over the period 1977-2006. Uncertainty in the stock-specific estimates of logR and SR indices was not accounted for; therefore the most recent estimates of the combined indices should be interpreted with caution.

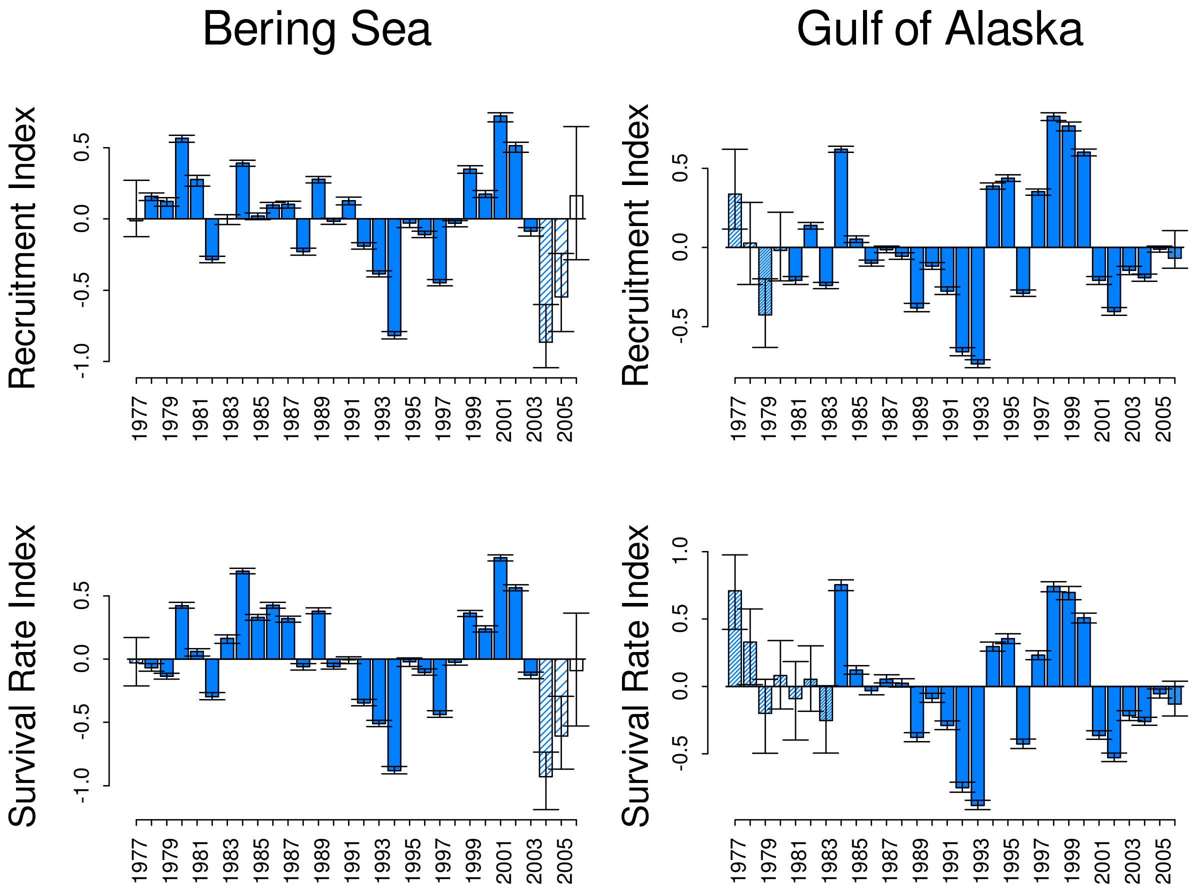

Figure 81: Combined Standardized Indices of recruitment (top) and survival rate (stock-recruit residuals, bottom) by year class across demersal stocks in the eastern Bering Sea (8 stocks) and in the Gulf of Alaska (11 stocks). Solid blue bars represent years with data for all stocks or stock groups. Lighter shading corresponds to years with more missing stocks. Series were truncated in 1970 and only years with data for at least 6 stocks were included. Bootstrap confidence intervals (95%) depict uncertainty resulting from filling in missing values, but assume that survival and recruitment are estimated without error.

Status and trends: The $\mathrm{CSI_R}$ and $\mathrm{CSIS_{SR}}$ suggest that survival and recruitment of demersal species in the GOA and BSAI followed a similar pattern with below-average survival / recruitments during the early 1990s (GOA) or most of the 1990s (BSAI) and above-average indices across stocks in the late 1990s / early 2000s. Because estimates at the end of the series were based on only a few stocks and are highly uncertain, we show the index through 2006 only, the last year for which reasonable estimates for the majority of stocks were available in each region. There is strong indication for above-average survival and recruitment in the GOA from 1994-2000 (with the exception of 1996, which had very low indices) and below- or near-average survival / recruitment since 2001. In the eastern Bering Sea there was no strong indication of below average recruitment across multiple stocks until 2004, when all 7 stocks with recruitment estimates had below average recruitment and stock-recruit indices ($P < 0.001$).

Factors causing trends: Trends in recruitment are a function of both spawner biomass and environmental variability. Trends in survival rate indices, which are adjusted for differences in spawner biomass, are presumably driven by environmental variability, but are even more uncertain than recruitment trends. Typically, spawner biomass accounted for only a small proportion of the overall variability in estimated recruitment. The observed patterns in recruitment and survival since the 1976/77 regime shift suggest continuing decadal-scale variations in overall groundfish productivity across multiple stocks in the Gulf of Alaska and Bering Sea. Unlike earlier analyses including longer time series that spanned the 1976/77 regime shift, the recruitment and survival series are un-correlated between the two regions ($\mathrm{CSI_R}$: $r = 0.014$; $\mathrm{CSI_{SR}}$: $r = 0.165$). However, indices in the Bering Sea appear to lag the corresponding indices in the Gulf of Alaska by approximately 2 years with statistically significant correlations when adjusted for autocorrelation ($r = 0.487$, $p = 0.034$ and $r = 0.547$, $p = 0.019$ for $\mathrm{CSI_R}$ and $\mathrm{CSI_{SR}}$, respectively). While longer time series of the indices (1970-2004) were positively correlated with the PDO, the post-regime shift indices were not significantly correlated with either the PDO or with regional SST indices.

Average Local Species Richness and Diversity of the Groundfish Community

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Description of indices: This section provides indices of local species richness and diversity based on standard bottom trawl surveys in the eastern Bering Sea (EBS). We computed the average number of fish and major invertebrate taxa per haul (richness) and the average Shannon index of diversity (Magurran, 1988) by haul based on CPUE (by weight) of each taxon. Indices were based on 45 taxa that were consistently identified throughout all surveys (Table 1 in (Mueter and Litzow, 2008), excluding Arctic cod because of unreliable identification in early years) and were computed following Mueter and Norcross (2002). Briefly, annual average indices of local richness and diversity were estimated by first computing each index on a per-haul basis, then estimating annual averages across the survey area using a Generalized Additive Model that accounted for the effects of variability in geographic location, depth, date of sampling, and area swept.

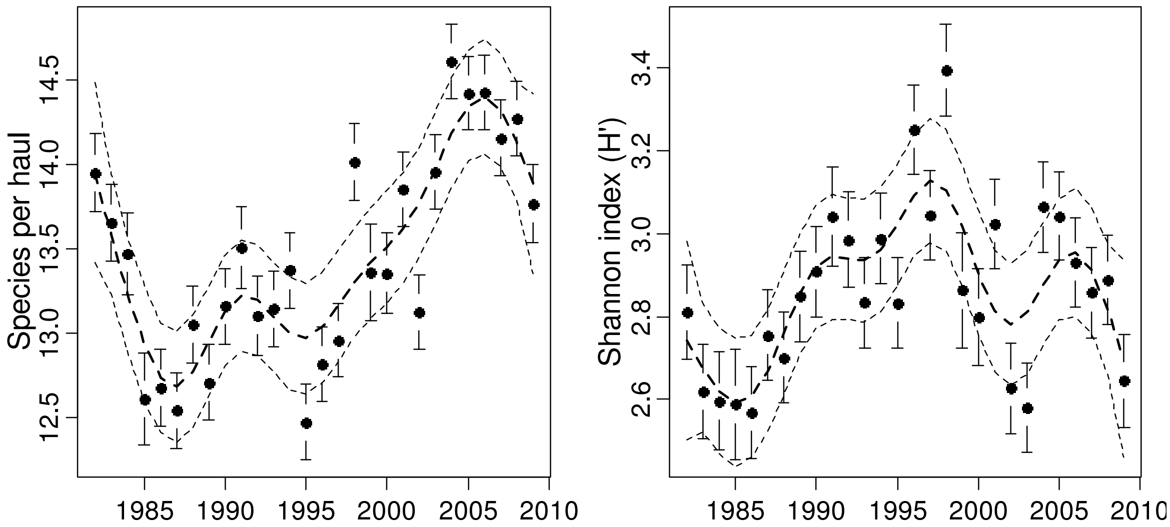

Figure 82: Model-based annual averages of species richness (average number of species per haul), and species diversity (Shannon index) in the Eastern Bering Sea, 1982-2008, based on 45 fish and invertebrate taxa collected by standard bottom trawl surveys with 95% confidence intervals. Model means were adjusted for differences in area swept, depth, date of sampling, and geographic location among years.

Status and trends: Species richness and diversity on the Eastern Bering Sea shelf have undergone significant variations from 1982 to 2009 (Figure 82). The average number of species per haul has increased by one to two species since 1995, but decreases in 2009. The Shannon Index increased from 1985 through 1998 and decreased sharply in 1999. Diversity was low in 2002/03, increased substantially in 2005 and has been decreasing since then.

Factors causing observed trends: The average number of species per haul depends on the spatial distribution of individual species (or taxa). If species are, on average, more widely distributed in the sampling area the number of species per haul increases. Spatial shifts in distribution from year to year can cause high variability in local species richness in certain areas, for example along the 100m contour in the Eastern Bering Sea. These shifts appear to be the primary drivers of changes in species richness. Local species diversity is a function of how many species are caught in a haul and how evenly CPUE is distributed among the species. Both time trends (Figure 82) and spatial patterns in species diversity (Figure 83) differed markedly from those in species richness. For example, low species diversity in 2003 occurred in spite of high average richness, primarily because of the high dominance of walleye pollock, which increased from an average of 18% of the catch per haul in 1995-98 to 30% in 2003, but decreased again to an average of 21% in 2004. The increase in species richness, which was particularly pronounced on the middle shelf, has been attributed to subarctic species spreading into the former cold pool area as the extent of the cold pool has decreased over recent decades (Mueter and Litzow, 2008). However, species diversity has been relatively low in recent years, compared to the 1990s, which suggests that species remain patchily distributed such that a given haul may be dominated by one or a few species. Spatially, species richness tends to be highest along the 100 m contour, whereas species diversity is highest on the middle shelf because the middle shelf region is less dominated by a few abundant species.

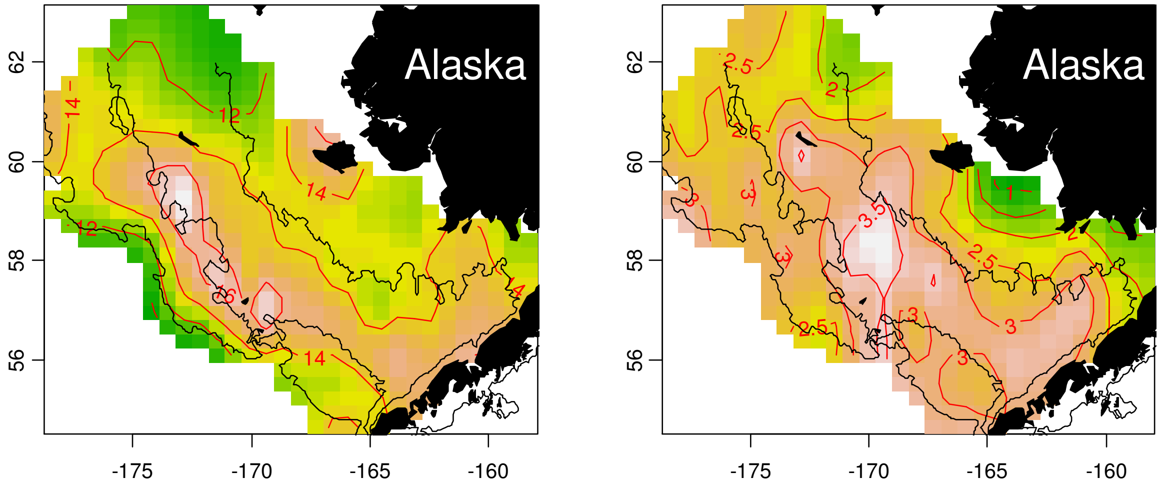

Figure 83: Average spatial patterns in local species richness (left, number of taxa per haul) and Shannon diversity in the Eastern Bering Sea. The 50m, 100m, and 200 m depth contours are shown as black lines.

Implications: The effect of fishing on species richness and diversity are poorly understood at present and this index likely reflects changes in spatial distribution and species composition that can only be interpreted in the context of environmental variability in the system. Local species richness may be particularly sensitive to long-term trends in bottom temperature as the cold pool extent changes (Mueter and Litzow, 2008) and may provide a useful index for monitoring responses of the groundfish community to projected climate warming.

Total Catch-Per-Unit-Effort of All Fish and Invertebrate Taxa in Bottom Trawl Surveys

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Description of index: The index provides a measure of the overall biomass of demersal and benthic fish and invertebrate species. We computed catch-per-unit-effort (CPUE in kg km^{-2}) of fish and major invertebrate taxa for each successful haul completed during standardized bottom trawl surveys on the eastern Bering Sea shelf (EBS, 1982-2009) and on the Gulf of Alaska shelf (GOA, 1990-2009). Total CPUE for each haul was estimated as the sum of the CPUEs of all fish taxa (except salmonidae) and major invertebrate taxa (crab, shrimp, squid, octopus, and starfish). To obtain an index of average CPUE by year across the survey region, we modeled log-transformed total CPUE ($N = 10386$, 5280, and 1388 hauls in the EBS, western GOA, and eastern GOA, respectively) as smooth functions of depth, net width, and location (latitude / longitude in the

EBS, alongshore distance and sampling stratum in the GOA) using Generalized Additive Models following Mueter and Norcross (2002). Although catches were standardized to account for the area swept by each haul we included net width in the model for the Bering Sea because of differences in catchability of certain taxa with changes in net width (von Szalay and Somerton, 2005) and because there was strong evidence that total CPUE tends to decrease with net width, all other factors being constant. The CPUE index does not account for gear or vessel differences, which are strongly confounded with interannual differences and may affect results prior to 1988 in the Bering Sea.

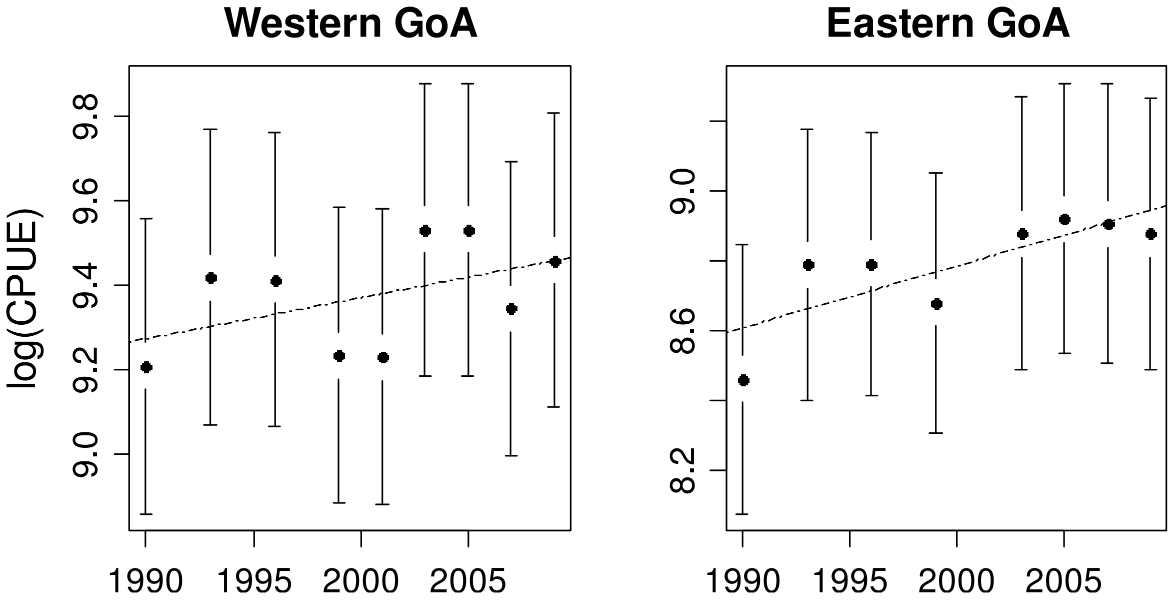

Figure 84: Model-based estimates of total log(CPUE) for major fish and invertebrate taxa captured in bottom trawl surveys from in the western Gulf of Alaska (west of 147^{o} W) by survey year with approximate 95% confidence intervals. Estimates were adjusted for differences in depth and sampling locations (alongshore distance) among years. Linear trends based on generalized least squares regression assuming 1st order auto-correlated residuals (West: $t = 0.846$, $p = 0.430$; East: $t = 3.43$, $p = 0.019$).

Status and trends: Total log(CPUE) in the western GOA varied over time with an increasing trend (not significant) and a decrease between 2005 and 2007 (Figure 84). The eastern GOA shows a similar patterns with a significantly increasing trend (p 0.013). The most notable difference was the lack of a decrease after 2005. Total log(CPUE) in the EBS shows an apparent long-term increase from 1982-2005, followed by a decrease during the recent cold years (2006-2009)(Figure 85). However, estimated means prior to 1988 may be biased due to unknown gear effects and because annual differences are confounded with changes in mean sampling date, which varied from as early as June 15 in 1999 to as late as July 16 in 1985. On average, sampling occurred about a week earlier in the 2000s compared to the 1980s. Recent changes in CPUE in the EBS have been most pronounced on the middle-shelf, which is occupied by the cold pool during cold years. Higher CPUEs on the middle shelf during the 2001-2005 warm period appeared to be related to the increasing colonization of this area by subarctic demersal species (Mueter and Litzow, 2008).

Factors causing observed trends: Commercially harvested species account for over 70% of survey catches. Fishing is expected to be a major factor determining trends in survey CPUE, but environmental variability is likely to account for a substantial proportion of the observed variability in CPUE through variations in recruitment, growth, and distribution. The increase in survey CPUE in the EBS in the early 2000s primarily resulted from increased abundances of walleye pollock and a number of flatfish species (arrowtooth flounder, yellowfin sole, rock sole, and Alaska plaice) due to strong recruitments in the 1990s. Decreases in recent years are largely a result of decreases in walleye pollock abundance. In addition, models including bottom temperature suggest that, in the EBS, CPUE is greatly reduced at low temperatures (<1°C) as evident in reduced CPUEs in 1999 and 2006-2009, when the cold pool covered a substantial portion of the shelf. At present, it is unclear whether this effect is primarily due to actual changes in abundance or temperature-dependent changes in catchability of certain species. A sharp increase in CPUE in the western GOA between 2001 and 2003 was largely due to a substantial increase in the abundance of arrowtooth flounder, which accounted for 43% of the total survey biomass in 2003. The significant increase in total CPUE in the eastern GOA was associated with increases in arrowtooth flounder (particularly 1990-93), several rockfish species, Pacific hake, and spriny dogfish.

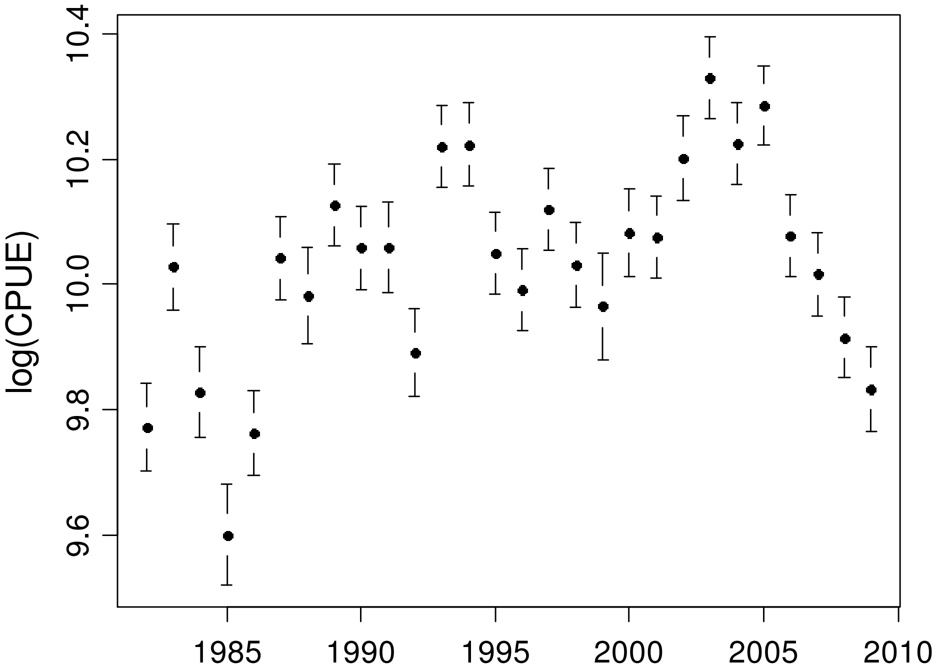

Figure 85: Model-based estimates of total log(CPUE) for major fish and invertebrate taxa captured in bottom trawl surveys from 1982 to 2004 in the Bering Sea with approximate pointwise 95% confidence intervals and long-term linear trend. Estimates were adjusted for differences in depth, day of sampling, net width and sampling location among years. Gear differences prior to 1988 were not accounted for. A linear time trend based on generalized least squares regression assuming 1st order auto-correlated residuals was not significant (t = 0.857, p = 0.400).

Implications: This indicator can help address concerns about maintaining adequate prey for upper trophic level species and other ecosystem components. Relatively stable or increasing trends in the total biomass of demersal fish and invertebrates, together with a relatively constant size composition of commercial species, suggest that the prey base has remained stable or has increased over recent decades. Decreasing CPUE in the eastern Bering Sea in recent years is a potential concern.

Spatial Distribution of Groundfish Stocks in the Bering Sea

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Last updated: July 2010

Description of indices: We provide indices of changes in the spatial distribution of groundfish on the eastern Bering Sea shelf. The first index provides a simple measure of the average North-South displacement of major fish and invertebrate taxa from their respective centers of gravity (e.g. Woillez et al. (2009)) based on AFSC-RACE bottom trawl surveys for the 1982-2009 period. Annual centers of gravity for each taxon were computed as the CPUE-weighted mean latitude across 285 standard survey stations that were sampled each year and an additional 58 stations sampled in 26 of the 27 survey years. Each station (N=343) was also weighted by the approximate area that it represents. Initially, we selected 46 taxa as in Table 1 of Mueter and Litzow (2008). Taxa that were not caught at any of the selected stations in one or more years were not included, resulting in a total of 39 taxa for analysis. In addition to quantifying N-S shifts in distribution, we computed CPUE and area-weighted averages of depth to quantify changes in depth distribution. Because much of the variability in distribution may be related to temperature variability, we removed linear relationships between changes in distribution and temperature by regressing distributional shifts on annual mean bottom temperatures. Residuals from these regressions are provided as an index of temperature-adjusted shifts in distribution.

Status and trends: Both the latitudinal and depth distribution of the demersal community on the eastern Bering Sea shelf show strong directional trends over the last three decades, indicating significant distributional shifts to the North and into shallower waters (Figure 86). Moreover, strong shifts in distribution over time remain evident even after adjusting for linear temperature effects (Figure 86). The average distribution shifted slightly south after the very warm years of 2004/05, with a delayed shift back to deeper waters in 2009. Average spatial displacements across all species by year suggest that most interannual shifts in distribution occur along a NW-SE axis (i.e. along the main shelf/slope axis), but that a pronounced shift to the Northeast and onto the shelf occurred between the 1990s and 2000s (Figure 87). On average, there was a gradual shift to the north from 2001 to 2005, which reversed as temperatures cooled after 2006. In 2009, the average center of gravity across species was similar to where it was in the early 1990s.

Factors causing trends: Many populations shift their distribution in response to temperature variability. Such shifts may be the most obvious response of animal populations to global warming (Parmesan and Yohe, 2003). However, distributional shifts of demersal populations in the Bering

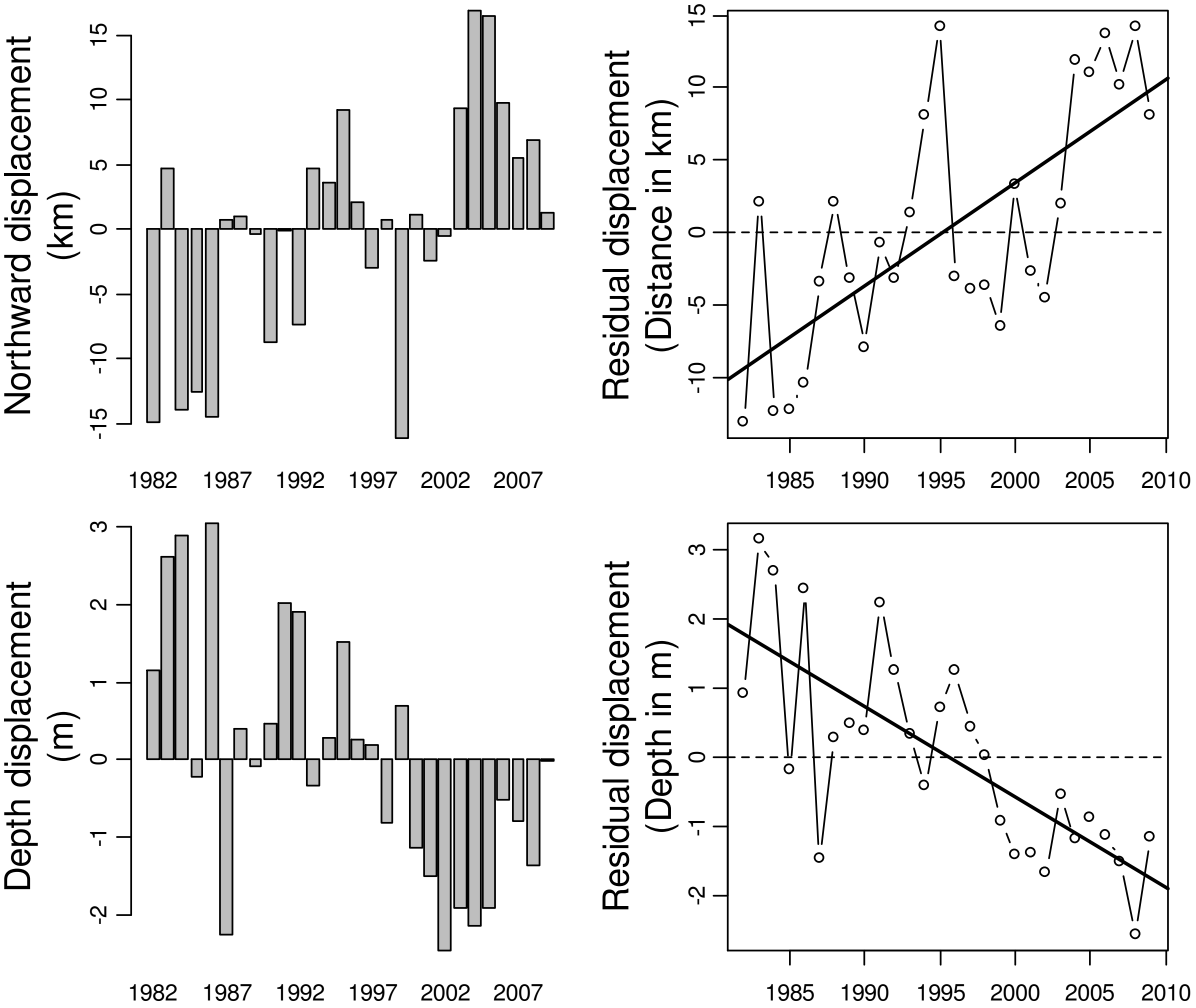

Figure 86: Left: Distributional shifts in latitude (average northward displacement in km from species-specific mean latitudes) and shifts in depth distribution (average vertical displacement in m from species-specific mean depth, positive indices indicate deeper distribution). Right: Residual displacement from species-specific mean latitude (top) and species-specific mean depth (bottom) after adjusting the indices on the left for linear effects of mean annual bottom temperature on distribution. Residuals were obtained by linear weighted least-squares regression on annual average temperature with first-order auto-correlated residuals over time (Northward displacement: $R^2 = 0.25$, $t = 3.72$, $p = 0.001$; depth displacement: $R^2 = 0.24$, $t = -3.37$, $p = 0.002$). Solid lines denote linear regressions of residual variability over time (top: $R^2 = 0.50$, $t = 3.39$, $p = 0.002$; bottom: $R^2 = 0.55$, $t = -5.67$, $p < 0.001$).

Sea are not a simple linear response to temperature variability (Mueter and Litzow, 2008), (Figure 86). The reasons for residual shifts in distribution that are not related to temperature changes remain unclear but could be related to density-dependent responses (Spencer, 2008) in combination with internal community dynamics (Mueter and Litzow, 2008). Unlike groundfish in the North

Sea, which shifted to deeper waters in response to warming (Dulvy et al., 2008), the Bering Sea groundfish community shifted to shallower waters during the recent warm period (Figure 86).

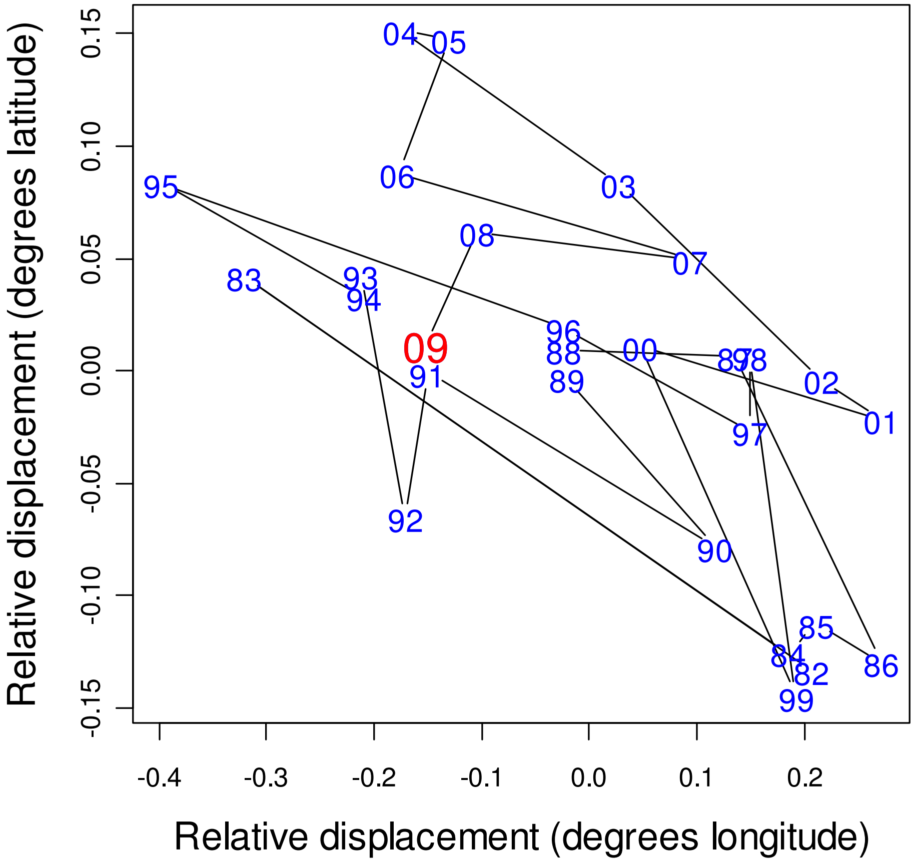

Figure 87: Average North-South and East-West displacement across 39 taxa on the eastern Bering Sea shelf relative to species-specific centers of distribution.

Implications: Changes in distribution have important implications for the entire demersal community, for other populations dependent on these communities, and for the fishing industry. The demersal community is affected because distributional shifts change the relative spatial overlap of different species, thereby affecting trophic interactions among species and, ultimately, the relative abundances of different species. Upper trophic level predators, for example fur seals and seabirds on the Pribilof Islands and at other fixed locations, are affected because the distribution and hence availability of their prey changes. Finally, fisheries are directly affected by changes in the distribution of commercial species, which alters the economics of harvesting because fishing success within established fishing grounds may decline and travel distances to new fishing grounds may increase. A better understanding of the observed trends and their causes is needed to evaluate the extent to which fishing may have contributed to these trends and to help management and fishers adapt to apparent directional changes in distribution that are likely to be further exacerbated by anticipated warming trends associated with increasing CO_2 concentrations.

Ecosystem-Based Management Indicators

Indicators presented in this section are intended to provide either early signals of direct human effects on ecosystem components that might warrant management intervention or to provide evidence of the efficacy of previous management actions. In the first instance, the indicators are likely to be ones that summarize information about the characteristics of the human influences (particularly those related to fishing, such as catch composition, amount, and location) that are influencing a particular ecosystem component.

Ecosystem Goal: Maintain Diversity

Time Trends in Bycatch of Prohibited Species

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See the 2007 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Time Trends in Groundfish Discards

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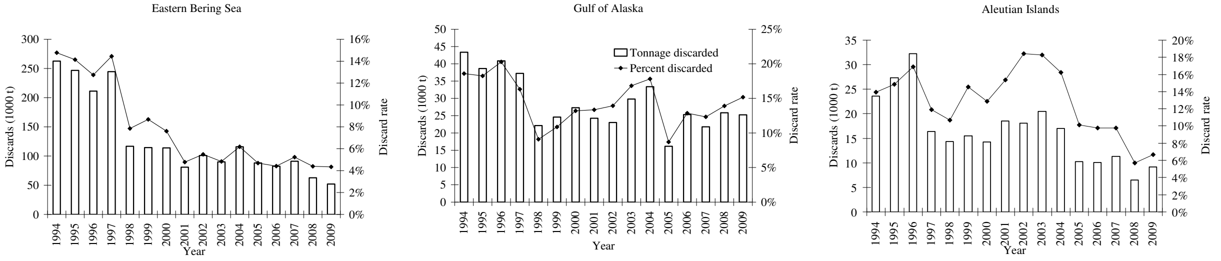
Last updated: July 2010

Description of index: Estimates of discards for 1994-2002 come from NMFS Alaska Region's blend data; estimates for 2003-09 come from the Alaska Region's catch-accounting system. It should be noted that although these sources provide the best available estimates of discards, the estimates are not necessarily accurate because they are based on visual observations by observers rather than data from direct sampling. The management of discards in commercial fisheries is important for the obvious reason that discards add to the total human impact on the biomass without providing a benefit to the Nation.

Status and Trends: In 1998, the amount of managed groundfish species discarded in federally-managed Alaskan groundfish fisheries dropped to less than 10% of the total groundfish catch in both the Eastern Bering Sea (EBS) and the Gulf of Alaska (GOA) (Figure 88). Discards in the Gulf of Alaska increased somewhat between 1998 and 2003, declined in 2004 and 2005, and have increased again during the last four years. Discard rates in the Aleutian Islands (AI) dropped significantly in 1997, trended generally upwards from 1998 through 2003, and have declined again over the last six years. As in the EBS and the GOA, both discards and discard rates in the AI are much lower now than they were in 1996.



(a) EBS (b) GOA (c) AI

Figure 88: Total biomass and percent of total catch biomass of managed groundfish discarded in the EBS, GOA, and AI areas, 1994-2009. (Includes only catch counted against federal TACS)

Factors Causing Trends: Discards in both the EBS and the GOA are much lower than the amounts observed in 1997, before implementation of improved-retention regulations. These decreases are explained by reductions in the discard rates of pollock and Pacific cod that resulted from regulations implemented in 1998 prohibiting discards of these two species. The decline in discards in both the AI and the EBS in 2008, which continued into 2009 in the EBS, is largely due to enactment of improved retention/utilization regulations by the North Pacific Fishery Council for the trawl head-and-gut fleet.

Time Trends in Non-Target Species Catch

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Last updated: July 2010

Description of index: We monitor the catch of non-target species in groundfish fisheries (Figure 89). There are four categories of non-target species: 1.) forage species (gunnels, sticheids, sandfish, smelts, lanternfish, sandlance), 2.) species associated with Habitat Areas of Particular Concern-HAPC species (seapens/whips, sponges, anemones, corals, tunicates), 3.) non-specified species (grenadiers, crabs, starfish, jellyfish, unidentified invertebrates, benthic invertebrates, echinoderms, other fish , birds, shrimp), and 4.) other species (sculpins, unidentified sharks, salmon sharks, dogfish, sleeper sharks, skates, octopus, squid). Stock assessments have been developed for all groups in the other species category, so we do not include trends for "other species" here (see AFSC stock assessment website at `http://www.afsc.noaa.gov/refm/stocks/assessments.htm`). Previously we reported the BSAI and GOA catches of non-target species, but this year we separate catches within the BSAI FMP area to examine catches in the Eastern Bering Sea (EBS) and Aleutian Islands (AI) ecosystems.

Total catch of nontarget species is estimated from observer species composition samples taken at sea during fishing operations, scaled up to reflect the total catch by both observed and unobserved hauls and vessels operating in all FMP areas. From 1997-2002, these estimates were made at the AFSC using data from the observer program and the NMFS Alaska Regional Office. Catch since 2003 has been estimated using the Alaska Region's new Catch Accounting system. These methods should be comparable. This sampling and estimation process does result in uncertainty in catches, which is greater when observer coverage is lower and for species encountered rarely in the catch. Until 2008, observer sample recording protocols prevented estimation of variance in catch; however, we are developing methods to estimate variance for 2008 on which will be presented in future reports.

Status and Trends: In all three ecosystems, non-specified species catch comprised the majority of non-target species catch during 1997-2007 (Figure 89). (If other species are included in non-targets, their catch would be the majority in the EBS, but non-specified is still highest in the AI and GOA.) Non-specified species catches are similar in the EBS and GOA, but are an order of magnitude lower in the AI. Catches of HAPC biota are highest in the EBS, intermediate in the AI and lowest in the GOA. The catch of forage fish is highest in the GOA, low in the EBS and very low in the AI.

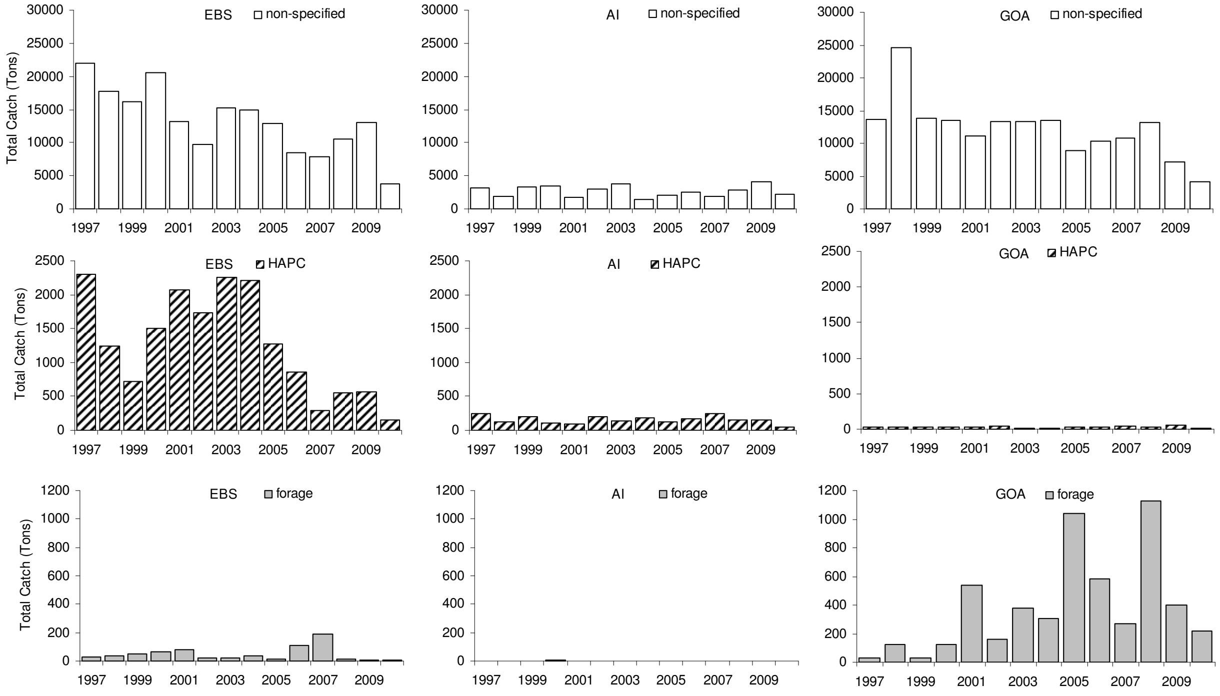

Figure 89: Total catch of non-target species (tons) in the EBS, AI, and GOA groundfish fisheries. Note: 2010 data are incomplete. We include information available as of July 6, 2010.

In the EBS, the catch of non-specified species decreased 2003-2007 but increased again in 2008-2009. Scyphozoan jellyfish, grenadiers and sea stars comprise the majority of the non-specified species catches in the EBS, and the recent increase in catch appears to be driven by jellyfish. Grenadiers (including the Giant grenadier) are caught in the flatfish, sablefish, and cod fisheries. Jellyfish are caught in the pollock fishery and sea stars are caught primarily in flatfish fisheries. HAPC biota catch has generally decreased since 2004. Benthic urochordata, caught mainly by the flatfish fishery, comprised the majority of HAPC biota catches in the EBS in all years except 2009, when sponges and sea anemones increased in importance (a trend continuing in the incomplete 2010 data). The catch of forage species in the EBS increased in 2006 and 2007 and was comprised mainly of eulachon that was caught primarily in the pollock fishery; however, forage catch decreased in 2008-2010.

In the AI, the catch of non-specified species shows little trend over time, although the highest catch was recorded in 2009. Grenadiers comprise the majority of AI non-specified species catch and are taken in flatfish and sablefish fisheries. HAPC biota catch has been similarly variable over time in the AI, and is driven primarily by sponges caught in the trawl fisheries for Atka mackerel, rockfish and cod. Forage fish catches in the AI are minimal, amounting to less than 1 ton per year, with the exception of 2000 when the catch estimate was 4 tons, driven by (perhaps anomalous) sandfish catch in the Atka mackerel fishery.

The catch of non-specified species in the GOA has been generally consistent aside from a peak in 1998 and lows in 2009 and 2010 (incomplete data). Grenadiers comprise the majority of non-specified catch and they are caught primarily in the sablefish fishery. Sea anemones comprise the majority of the variable but generally low HAPC biota catch in the GOA and they are caught primarily in the flatfish fishery. The catch of forage species has undergone large variations, peaking in 2005 and 2008 and decreasing in 2006-2007 and 2009. Preliminary data also suggest lower forage fish catches in 2010. The main species of forage fish caught are eulachon and they are primarily caught in the pollock fishery.

Factors Causing Trends: The catch of nontarget species may change if fisheries change, if ecosystems change, or both. Because nontarget species catch is unregulated and unintended, if there have been no large-scale changes in fishery management in a particular ecosystem, then large-scale signals in the nontarget catch at may indicate ecosystem changes. Catch trends may be driven by changes in biomass or changes in distribution (overlap with the fishery) or both.

Implications: Catch of non-specified species is highest in the non-target category and has remained stable or possibly recently declined in all three ecosystems. Overall, the catch of HAPC and forage species in all three ecosystems is very low compared with the catch of target and non-specified species. HAPC species may have become less available to the EBS fisheries (or the fisheries avoided them more effectively) during the late 2000s. Forage fish may have been more available to fisheries in the GOA during the 2000s.

Ecosystem Goal: Maintain and Restore Fish Habitats

Areas Closed to Bottom Trawling in the EBS/ AI and GOA

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Last updated: October 2010

Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut) (Table 12 and Figure 90). Some of the trawl closures are in effect year-round while others are seasonal. A review of trawl closures implemented since 1995 is provided in Table 12. In general, year-round trawl closures have been implemented to protect vulnerable benthic habitat. Seasonal closures are used to reduce bycatch by closing areas where and when bycatch rates had historically been high. Additional measures to protect the declining western stocks of the Steller sea lion began in 1991 with some simple restrictions based on rookery and haulout locations; in 2000 and 2001, more specific fishery restrictions were implemented. In 2001, over 90,000 nm^2 of the Exclusive Economic Zone (EEZ) off Alaska was closed to trawling year-round. Additionally, 40,000 nm^2 were closed on a seasonal basis. State waters (0-3 nmi) are also closed to bottom trawling in most areas.

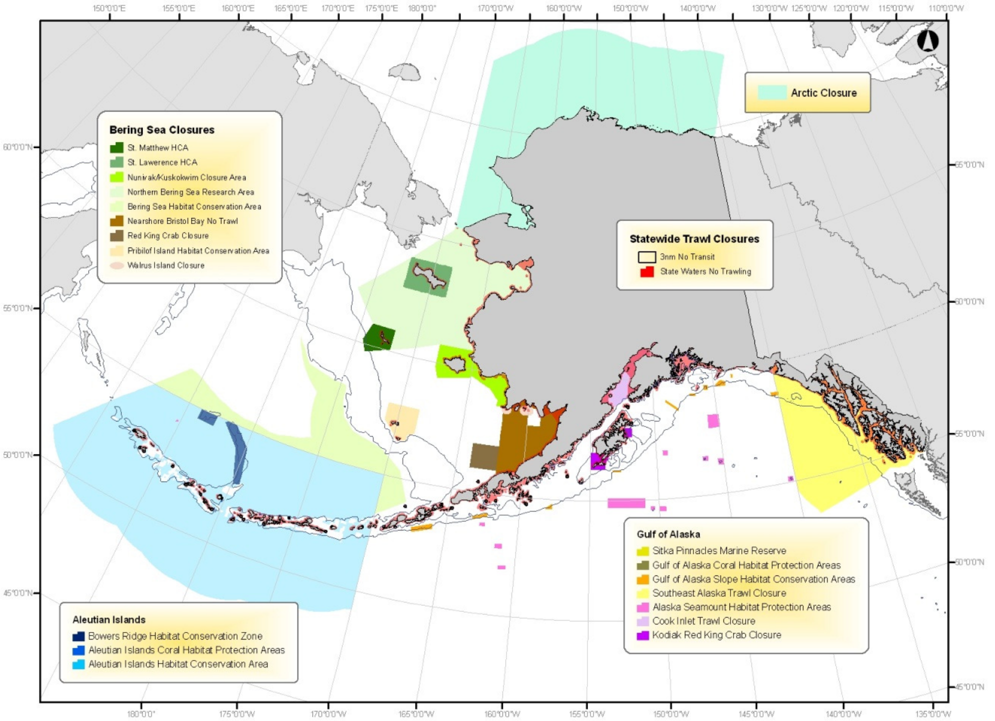

Figure 90: Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska.

A motion passed the North Pacific Management Council in February 2009 which would close all waters north of the Bering Strait to commercial fishing as part of the development of an Arctic Fishery management plan (Figure 90). This additional closure adds 148,300 nm^2 to the area closed to bottom trawling year round. By implementing this closure, almost 65% of the U.S. EEZ off Alaska would be closed to bottom trawling. For additional background on fishery closures in the U.S. EEZ off Alaska see Witherell and Woodby (2005).

Hook and Line (Longline) Fishing Effort in the Gulf of Alaska, Bering Sea and Aleutian Islands

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Last updated: October 2010

Description of Index: The amount of effort (as measured by the number of longline sets fished) in hook and line fisheries can be used as a proxy for habitat effects. Effort in the hook and line fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 91. This fishery is prosecuted with anchored lines onto which baited hooks are attached. Gear components which may interact with benthic habitat include the anchors, groundline, gangions, and hooks. The fishery is prosecuted with both catcher vessels and freezer longliners.

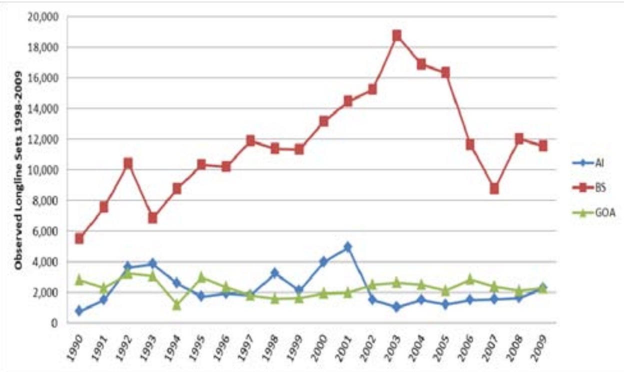


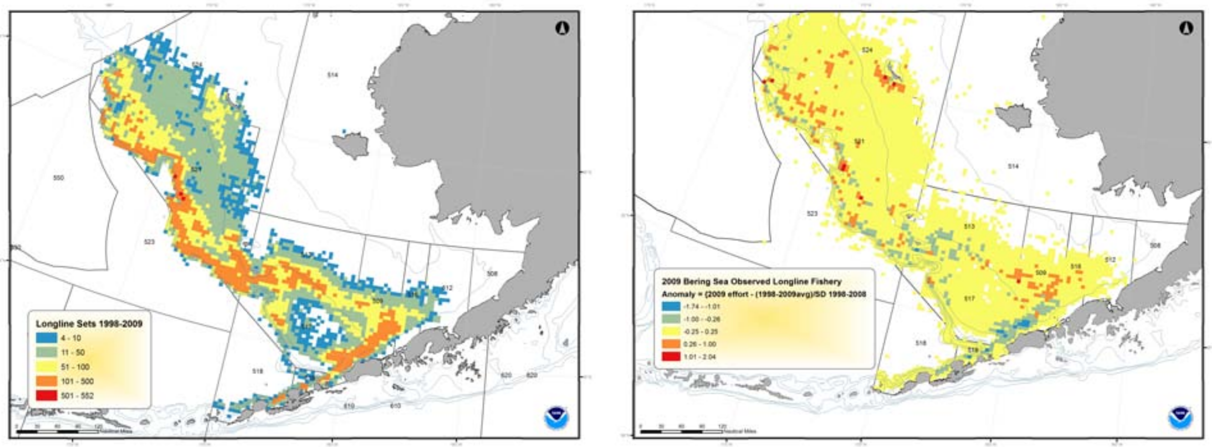
Figure 91: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of longline sets, 1998-2009.

Status and Trends: Figures 92-94 show the spatial patterns and intensity of longline effort, based on observed data as well as anomalies for 2009 based on the 1998-2009 average. Changes in fishing effort are shown in anomaly plots that look at current effort relative to historical effort.

Bering Sea For the period 1998-2009, there were a total of 161,656 observed longline sets in the Bering Sea fisheries. Spatial patterns of fishing effort were summarized on a 10 km^2 grid (Figure 92a). During 2009, the amount of observed longline effort was 11,551 sets, which represents a decrease from 2008 and is lower than the 12-year average. Areas of high fishing effort are north of False Pass (Unimak Island), the shelf edge represented by the boundary of report areas 513 and 517, as well as the outer boundaries of areas 521 and 517. This fishery occurs mainly for Pacific cod, Greenland turbot, and sablefish. In 2009, fishing effort was anomalously low north of Unimak Pass and of areas 509 and 517, with small localized increases throughout the rest of the Bering Sea (Figure 92b).

Aleutian Islands For the period 1998-2009 there were 26,571 observed hook and line sets in the Aleutian Islands. During 2009, the amount of observed longline effort was 2,281 sets, which is near the 12-year average but considerable higher than 2008. The spatial pattern of this effort was dispersed over a wide area. Patterns of high fishing effort were dispersed along the shelf edge (Figure 93a). This fishery occurs mainly on Pacific cod, Greenland turbot, and sablefish. The catcher vessel longline fishery occurs over mud bottoms. In the summer, the fish are found in shallow (150-250 ft) waters, but are deeper (300-800 ft) in the winter. Catcher-processors fish over more rocky bottoms in the Aleutian Islands. The sablefish/Greenland turbot fishery occurs over silt, mud, and gravel bottom at depths of 150 to 600 fm. In 2009, fishing effort anomaly showed no specific patterns, with some decreases occurring in the entire AI region with specific increases some local areas in each of the three management areas (Figure 93b).

Gulf of Alaska For the period 1998-2009 there were 26,608 observed hook and line sets in the Gulf of Alaska. During 2009, the amount of observed longline effort was 2,292 sets, which is near the



(a) 1998-2009 combined

(b) 2009 anomaly

Figure 92: a.) Longline effort (sets) in the Bering Sea 1998-2009. b.) Observed hook and line fishing effort in 2009 relative to the 1998-2009 average in the Bering Sea. Anomalies calculated as (estimated effort for 2009 - average effort from 1998-2009)/stdev(effort from 1998-2009).

12-year average. Patterns of high fishing effort were dispersed along the shelf (Figure 94a). The predominant hook and line fisheries in the Gulf of Alaska are composed of sablefish and Pacific cod. In southeast Alaska, there is a demersal rockfish fishery; dominant species include yelloweye rockfish (90%), with lesser catches of quillback rockfish. The demersal shelf rockfish fishery occurs over bedrock and rocky bottoms at depths of 75 m to >¿200 m. The sablefish longline fishery occurs over mud bottoms at depths of 400 to >¿1000 m. This fishery is often a mixed halibut/sablefish fishery, with shortraker, rougheye, and thornyhead rockfish also taken. Sablefish has been an IFQ fishery since 1995, which has reduced the number of vessels, crowding, gear conflicts and gear loss, and increased efficiency. The cod longline fishery generally occurs in the western and central Gulf of Alaska, opening on January 1st and lasting until early March. Halibut prohibited species catch sometimes curtails the fishery. The cod fishery occurs over gravel, cobble, mud, sand, and rocky bottom, in depths of 25 fathoms to 140 fathoms. In 2009, fishing effort anomalies were varied throughout the region, with no specific patterns (Figure 94b).

Factors Influencing Trends: Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures) as well as changes in markets and bycatch rates of non-target and prohibited species.

Groundfish Bottom Trawl Fishing Effort in the Gulf of Alaska, Bering Sea and Aleutian Islands

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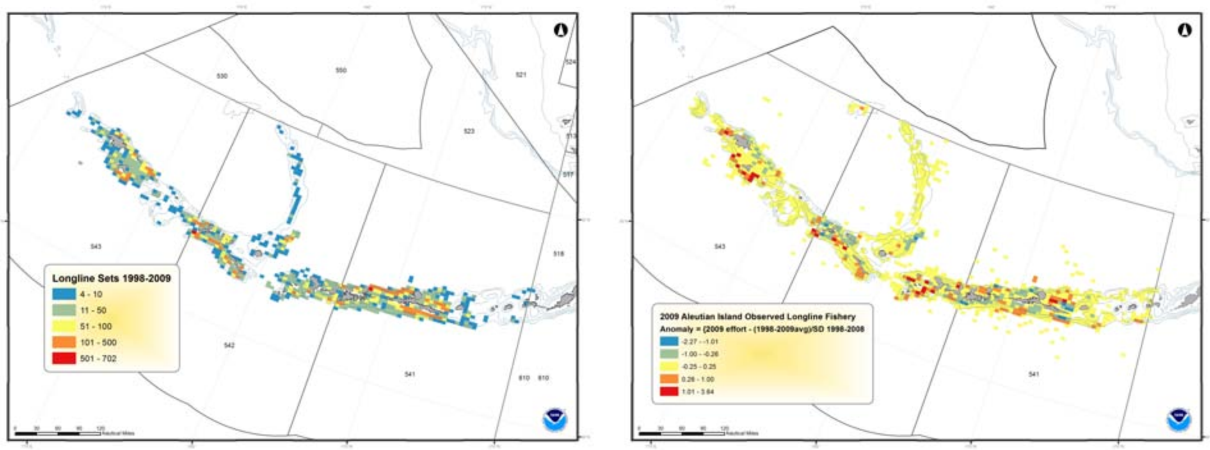
Last updated: October 2010

Description of Index: The amount of effort (as measured by the number of tows) in bottom



(a) 1998-2009 combined

(b) 2009 anomaly

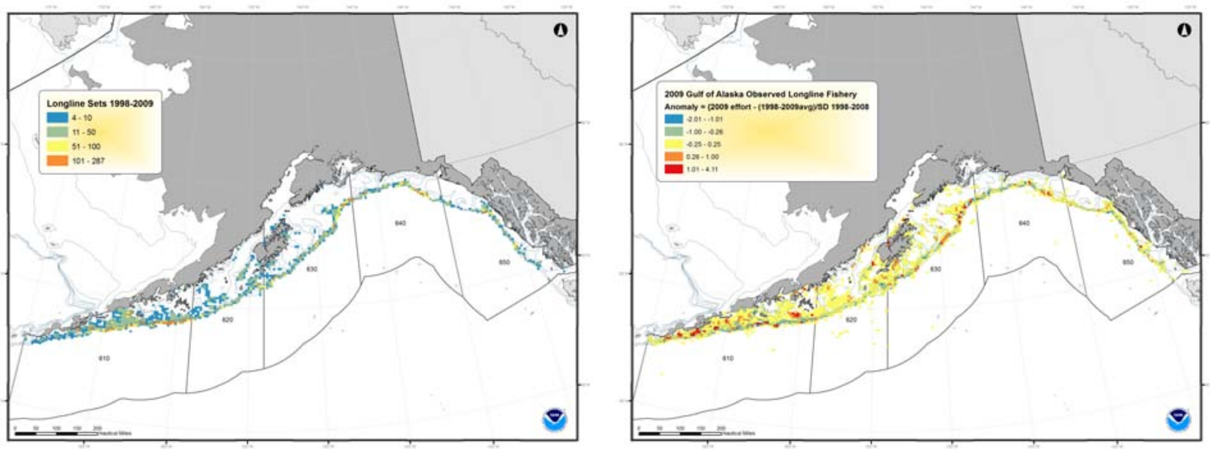
Figure 93: a.) Longline effort (sets) in the Aleutian Islands 1998-2009. b.) Observed hook and line fishing effort in 2009 relative to the 1998-2009 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2009 - average effort from 1998-2009)/stdev(effort from 1998-2009).

trawl (non-pelagic trawl) fisheries can be used as proxy for the effects of trawling on habitat. In general, bottom trawl effort in the Gulf of Alaska and Aleutian Islands has declined as pollock and Pacific cod TACs have been reduced (Figure 95). Effort in the Bering Sea remained relatively stable between 1993 and 2009 (Figure 95). The magnitude of the Bering Sea trawl fisheries is twice as large in terms of effort as the Aleutian Islands and Gulf of Alaska fisheries combined. Fluctuations in fishing effort track well with overall landings of primary bottom trawl target species, such as flatfish and to a lesser extent pollock and cod. As of 1999, only pelagic trawls can be used in the Bering Sea pollock fisheries.

Factors Influencing Trends: The locations where bottom trawls have been used are of interest for understanding habitat effects. The following figures show the spatial patterns and intensity of bottom trawl effort, based on observed data. Spatial changes in fisheries effort may in part be affected by many factors, including fishing closure areas (i.e., habitat closures, Steller sea lion protection measures) as well as changes in markets, environmental conditions, and/or increased bycatch rates of non-target species. These changes in effort can be observed by examining effort for the current year relative to the average effort in prior years of fishing (effort anomalies).

Bering Sea For the period 1998-2009, there were a total of 156,253 observed bottom trawl tows in the Bering Sea fisheries. During 2009, observed bottom trawl effort consisted of 11,527 tows, which was below average compared to the past 12 years. Spatial patterns of fishing effort were summarized on a 10 km^2 grid (Figure 96a). Areas of high fishing effort are north of False Pass (Unimak Island) as well as the shelf edge represented by the boundary of report areas 513 and 517 and the northeastern section of area 513. The primary catch in these areas was Pacific cod and yellowfin sole. In 2009, fishing effort was lower than average north of Unimak Island in the southern portion of areas 509 and 517 as well as some larger areas of the central Bering Sea (Figure 96b). Higher fishing effort occurred in portions of 509 and 513, as well as to the northwest of the Pribilof Islands in 521.

Aleutian Islands For the period 1998-2009 there were 29,245 observed bottom trawl tows in the



(a) 1998-2009 combined

(b) 2009 anomaly

Figure 94: a.) Longline effort (sets) in the Gulf of Alaska 1998-2009. b.) Observed hook and line fishing effort in 2009 relative to the 1998-2009 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2009 - average effort from 1998-2009)/stdev(effort from 1998-2009).

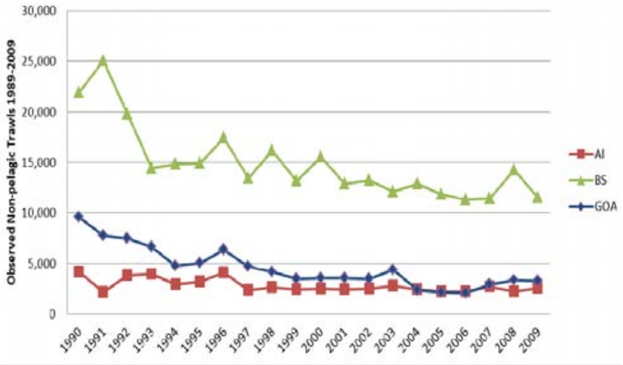
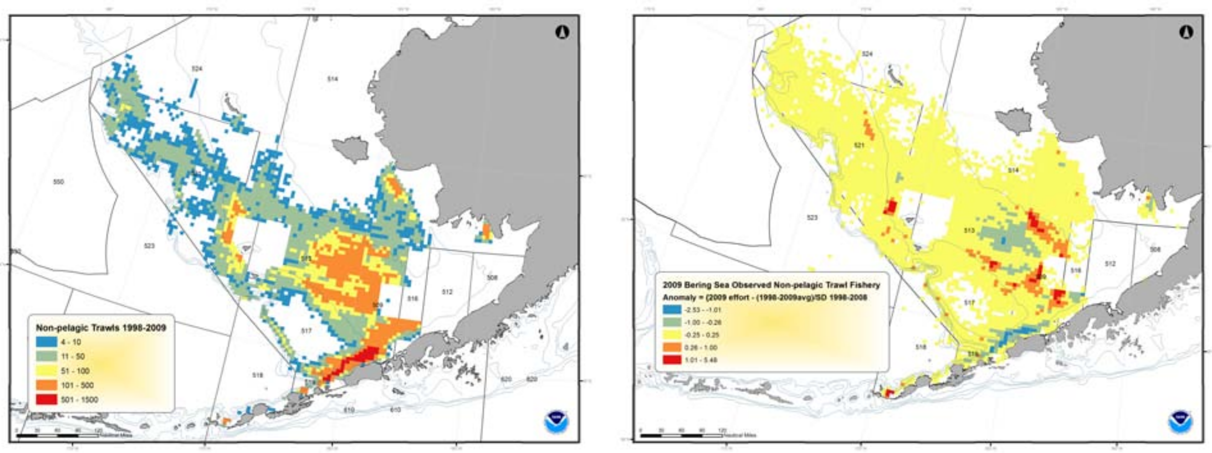


Figure 95: Gulf of Alaska, Bering Sea, and Aleutian Islands non-pelagic trawl effort (number of observed tows), 1998-2009.

Aleutian Islands. During 2009, the amount of observed bottom trawl effort was 2,566 tows, which was about average for the 12-year period. Patterns of high fishing effort were dispersed along the shelf edge (Figure 97a). The primary catches in these areas were Pacific cod and Atka mackerel. Catch of Pacific ocean perch by bottom trawls was also high in earlier years. In 2009, areas of anomalous fishing effort were scattered throughout the region and catch was comprised of Atka mackerel, Pacific cod and rockfish (Figure 97b). Some areas now have lower patterns of fishing effort which could be due to the implementation of new management measures. In 2006, the Aleutian Islands Habitat Conservation Area (AIHCA) closed approximately 279,114 nm^2 to bottom trawl fishing in the three AI management areas.

Gulf of Alaska For the period 1998-2009 there were 38,416 observed bottom trawl tows in the Gulf of Alaska. The spatial pattern of this effort was much more dispersed than in the Bering Sea region. During 2009, the amount of trawl effort was 3,240 tows, which was near the average for the 12-year period. Patterns of high fishing effort were dispersed along the shelf edge with high pockets of effort



(a) 1998-2009 combined

(b) 2009 anomaly

Figure 96: a.) Spatial location and density of non-pelagic trawling in the Bering Sea, 1998-2009. b.) Observed non-pelagic trawl fishing effort in 2009 relative to the 1998-2009 average in the Bering Sea. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2009)/stdev(effort from 1998-2009).

near Chirkoff, Cape Barnabus, Cape Chiniak and Marmot Flats (Figure 98a). Primary catches in these areas were Pacific cod, flatfish and rockfish. A larger portion of the trawl fleet in Kodiak is comprised of smaller catcher vessels that require 30% observer coverage, indicating that the actual amount of trawl effort would be much higher since a large portion is unobserved. In 2009, much like 2008, areas of higher and lower than average fishing effort were scattered throughout the Central and Western Gulf (Figure 98b).

Groundfish Pelagic Trawl Fishing Effort in the Gulf of Alaska, Bering Sea and Aleutian Islands

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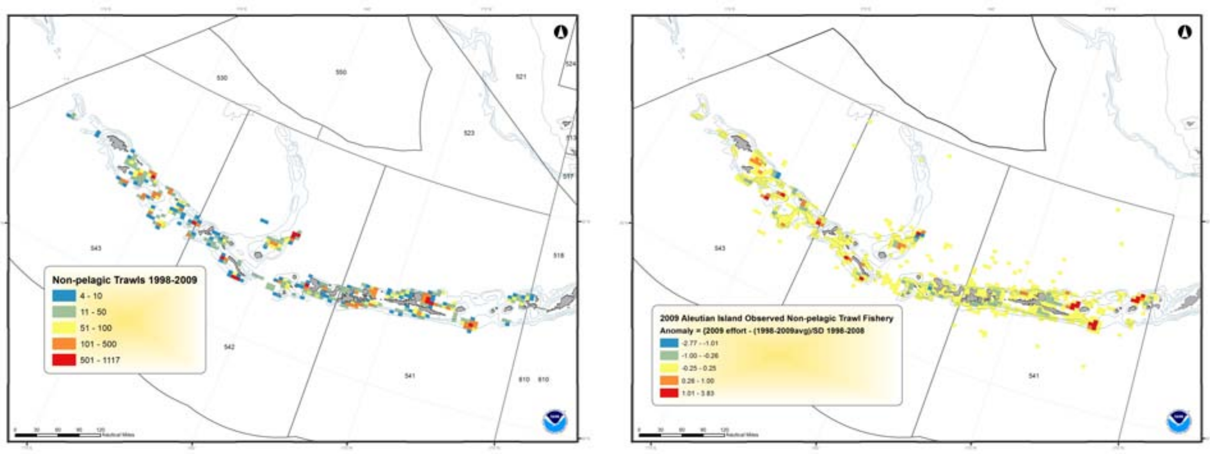
Last updated: October 2010

Description of Index: Effort in the pelagic trawl fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 99. The magnitude of the Bering Sea trawl fisheries effort is four times larger than effort in both the Aleutian Islands and Gulf of Alaska combined. While this fishery is much larger than in the other two regions, smaller vessels that only require 30% observer coverage occur in larger proportions in the GOA and AI resulting in less documented fishing effort. Figures 100-102 show the spatial patterns and intensity of pelagic trawl effort by region, based on observed data.

Status and Trends: Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures), changes in markets, changes in environmental conditions, and increased bycatch rates of non-target species. The Bering Sea pollock fishery is the



(a) 1998-2009 combined

(b) 2009 anomaly

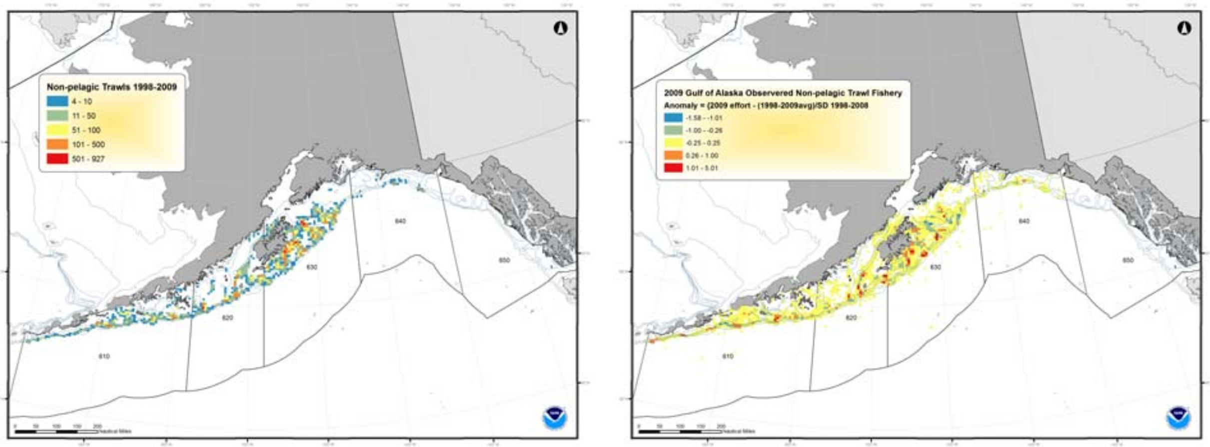
Figure 97: a.) Spatial location and density of non-pelagic trawling in the Aleutian Islands, 1998-2009. b.) Observed non-pelagic trawl fishing effort in 2009 relative to the 1998-2009 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2009)/stdev(effort from 1998-2009).

largest volume U.S. Fishery, and most pollock is harvested with pelagic trawl nets. Effort in the Bering Sea has remained relatively stable from 1995 through present, although the current levels of catch are somewhat below levels in recent years. Some of the consistency of effort can be attributed to changes in the structure of the groundfish fisheries due to rationalization. Effort in both the GOA and AI has trended downward in the last decade, in part due to restricted fishing from Steller sea lion protection measures.

Bering Sea For the period 1998-2009 there were 174,140 observed pelagic trawl tows in the Bering Sea (Figure 100a). There were 10,092 observed tows in 2009, which is significantly lower than the 12-year average. Areas of high fishing effort are north of Unimak Island along the shelf edge represented by the shelf edge connecting management areas 509, 517, and 519. Fishing was also focused near the Pribilof Islands, and northwest between the 100-200 meter contours. The predominant species harvested within the eastern Bering Sea is walleye pollock (*Theragra chalcogramma*). Pollock occur on the sea bottom, the midwater and up to the surface. Most catch of pollock is taken at 50-300m.

In 1990, concerns about bycatch and seafloor habitats affected by this large fishery led the North Pacific Fishery Management Council to apportion 88 percent of TAC to the pelagic trawl fishery and 12 percent to the non-pelagic trawl fishery (North Pacific Fishery Management Council, 1999). For practical purposes, non-pelagic trawl gear is defined as trawl gear that results in the vessel having 20 or more crabs (*Chionecetes bairdi*, *C. opilio*, and *Paralithodes camstschaticus*) larger than 1.5 inches carapace width on board at any time. Crabs were chosen as the standard because they live only on the seabed and they provide proof that the trawl has been in contact with the bottom.

Pollock fishermen formed fish harvesting cooperatives to ”rationalize” fishing activities, including resolving problems of overcapacity, promoting conservation and enhancing utilization of fishery resources. Under a co-op arrangement, fewer vessels are fishing and daily catch rates by participating vessels are significantly reduced since the ”race for fish” ended in 1999.



(a) 1998-2009 combined

(b) 2009 anomaly

Figure 98: a.) Spatial location and density of non-pelagic trawling in the Gulf of Alaska, 1998-2009. b.) Observed non-pelagic trawl fishing effort in 2009 relative to the 1998-2009 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2009)/stdev(effort from 1998-2009).

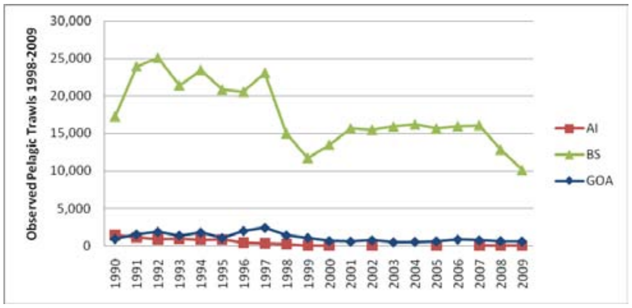
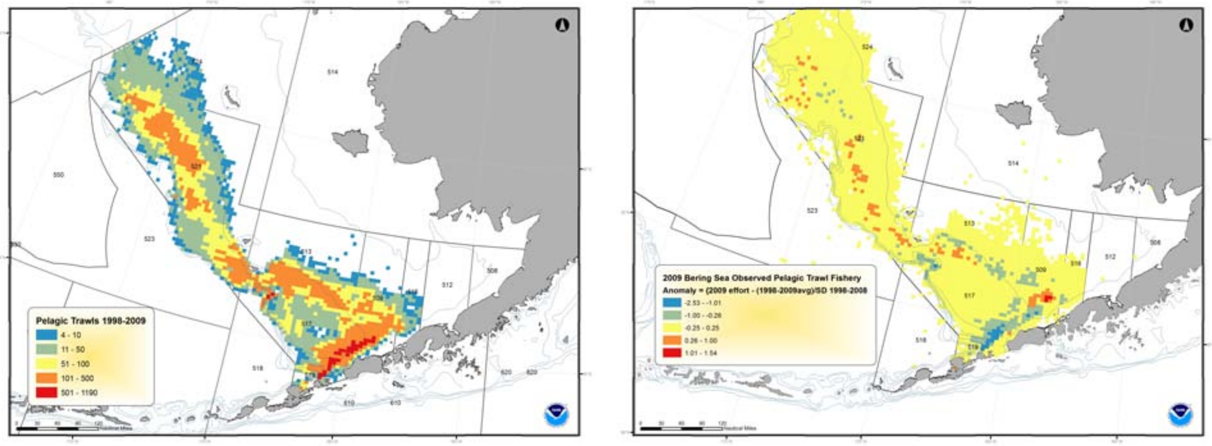


Figure 99: Gulf of Alaska, Aleutian Islands, and Bering Sea pelagic trawl effort (observed pelagic trawl tows), 1998-2009.

In 2009, fishing effort was anomalously low north of Unimak Island, an area of normally high fishing effort. Increased fishing effort occurred in the southern section of area 509 (Figure 100b). Some changes in fleet movement may be attributed to the AFA fishing coop structure and voluntary rolling hotspot closures to reduce the incidental take of Chinook and ”Other Salmon” bycatch; whereas, other changes in fishing effort might be attributed to changes in pollock distribution. Overall catch was down due to a decrease in the TAC.

Aleutian Islands For the period 1998-2009 there were 286 observed bottom trawl tows in the Aleutian Islands (Figure 101). In 2001, 2003, 3004, and 2006 there were no observed pelagic trawl tows. There were only 4 observed tows in 2009. Patterns of high fishing effort were historically dispersed along the shelf edge.

Management measurekims have affected the fishing effort in the Aleutian Islands. In recent years pollock fishing in the Aleutian Islands has been restricted by the Stellar Sea Lion Closures. The western distinct population segment of Steller sea lions occurs in the Aleutian Islands subarea and is listed as endangered under the Endangered Species Act (ESA). Critical habitat has been



(a) 1998-2009 combined

(b) 2009 anomaly

Figure 100: a.) Spatial location and density of pelagic trawl effort in the eastern Bering Sea, 1998-2009. b.) Observed pelagic trawl fishing effort in 2009 relative to the 1998-2009 average in the Bering Sea. Anomalies calculated as (estimated effort for 2009 - average effort from 1998-2009)/stdev(effort from 1998-2009).

designated for this area, including waters within 20 nautical miles (nm) of haulouts and rookeries. Pollock is a principal prey species of Steller sea lions.

Aleutian Islands pollock had been harvested primarily in Steller sea lion critical habitat in the past until the Aleutian Islands subarea was closed to pollock fishing in 1999. In 2003, the Aleutian Islands subarea was opened to pollock fishing outside of critical habitat under regulations implementing the current Steller sea lion protection measures. Part of the 2004 Consolidated Appropriations Act required that the directed fishing allowance of pollock in the Aleutian Islands subarea be allocated to the Aleut Corporation. The Aleut Corporation harvested only about 1 percent of its initial 2005 pollock allocation due, in part, to difficulty in finding pollock. To harvest the fish, the Aleut Corporation is allowed to contract only with vessels under 60 feet length overall or vessels listed under the American Fisheries Act. The smaller vessels do not require observer coverage.

Additionally, closures implemented in 2006 as part of protection for Essential Fish Habitat will limit the areas where bottom trawl fishing can occur. The Aleutian Islands Habitat Conservation Area (AIHCA) closed approximately 279,114 nm^2 to bottom trawl fishing in the three AI management areas.

Gulf of Alaska The primary target of the GOA pelagic trawl fishery is pollock. The fleet is comprised of trawl catcher vessels that deliver their catch onshore for processing. For the period 1998-2009 there were 8,888 observed pelagic trawl tows in the Gulf of Alaska (Figure 102a). The spatial pattern of this effort centers around Kodiak, specifically Chiniak Gully and Marmot Bay, with limited fishing on the shelf break to the east and west. During 2009, the amount of trawl effort was 591 tows, which was below the 12-year period. A large portion of the trawl fleet in Kodiak is comprised of smaller catcher vessels that require 30% observer coverage, indicating that the actual amount of trawl effort is likely much higher since a large portion is unobserved. The catch anomaly for 2009 was variable, but most effort was centered in areas 620-630 (Figure 102b).

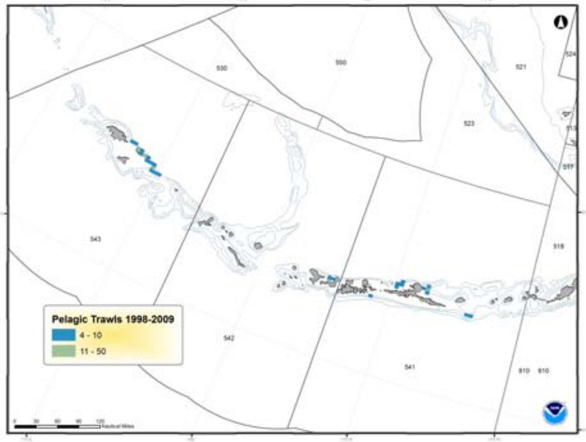


Figure 101: Spatial location and density of pelagic trawl effort in the Aleutian Islands, 1998-2009.

Pot Fishing Effort in the Gulf of Alaska, Bering Sea, and Aleutian Islands

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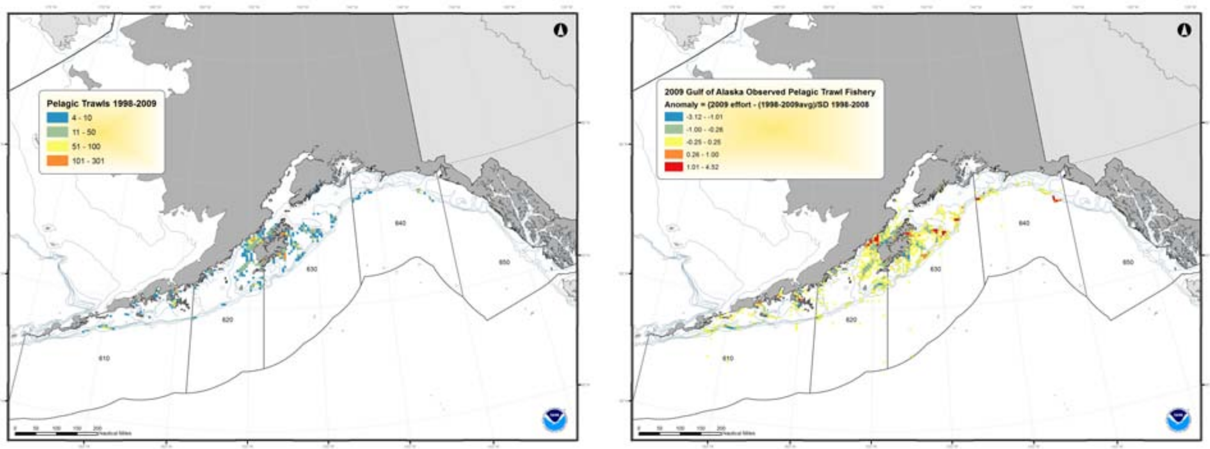
Last updated: October 2010

Description of Index: The amount of effort (as measured by observed pot lifts) in pot fisheries is used as a proxy for fishing effects on benthic habitat. Effort in the pot fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 103. The amount of pot effort fluctuates annually by region. However, annual observed estimates of pot lifts does not reflect the entire pot fishery. Most of the vessels using pot gear are catcher vessels either under 60' or between 60'-125'. These vessels either do not require an observer present or only on 30% of the fishing days. Fluctuations in the pot cod fishery may also be dependent on the duration and timing of the crab fisheries.

Status and Trends:

Bering Sea For the period 1998-2009, there were a total of 15,060 observed pot lifts in the Bering Sea fisheries (Figure 104a). During 2009, the amount of observed pot effort was 1,247 lifts, which is consistent with the 12-year average of 1,255. Spatial patterns of fishing effort were summarized on a 10 km^2 grid (Figure 102). Areas of high fishing effort are west of Unimak Island and to the north of Akutan. This fishery occurs mainly for Pacific cod which form dense aggregations for spawning in the winter months. Effort anomalies occurred mainly to the west of Unimak Island (lower effort) and in small areas throughout the Bering Sea (higher)(Figure 104b). Spatial and temporal changes to the fishery may have occurred in the past 10 years due to current Steller Sea Lion regulations.

Aleutian Islands For the period 1998-2009 there were 4,568 observed pot lifts in the Aleutian Islands. During 2009, the amount of observed pot effort was 108 lifts, which represents a decline from 2008 and also well below the 12-year average of 381. High fishing effort was dispersed along the shelf edge with high effort near Seguam Island (Figure 105a). In 2009, the fishing anomaly



(a) 1998-2009 combined (b) 2009 anomaly

Figure 102: a.) Spatial location and density of pelagic trawl effort in the Gulf of Alaska, 1998-2009. b.) Observed pelagic trawl fishing effort in 2009 relative to the 1998-2009 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2009 - average effort from 1998-2009)/stdev(effort from 1998-2009).

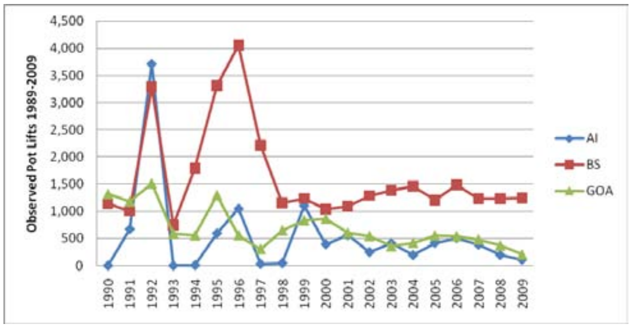
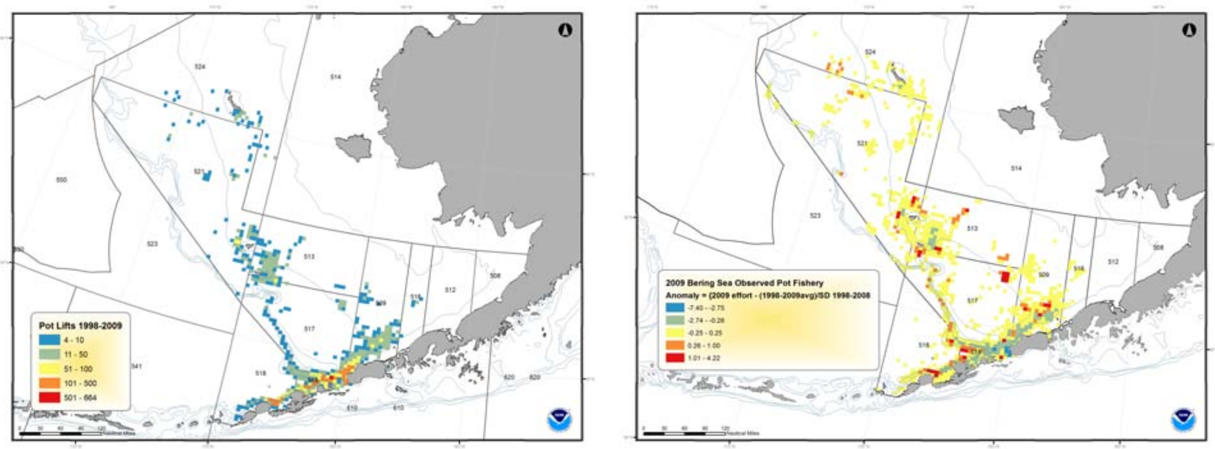


Figure 103: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of pot lifts, 1998-2009.

throughout the region was minimal (Figure 105b).

Gulf of Alaska For the period 1998-2009 there were 6,426 observed pot lifts in the Gulf of Alaska. During 2009, the amount of observed pot effort was 204 lifts, which represents a decline from 2008 and also well below the 12-year average of 536. Patterns of higher fishing effort were dispersed along the shelf around Kodiak Island (Figure 106a). Fishing effort in 2009 was varied in areas 610 and 630, with areas of both above and below long term averages (Figure 106b). Approximately 100 boats participate in this fishery. Vessels used in the inshore fishery are all catcher vessels of small (less than 60-foot LOA) and medium size (60- to 125-foot LOA). The offshore fishery includes some catcher-processors ranging from 90 to over 125 feet. The A season fishery begins on January 1st and concludes in early March. The B season fishery opens September 1 and can be expected to last 6 weeks or less. There is also a state-managed fishery in state waters.



(a) 1998-2009 combined

(b) 2009 anomaly

Figure 104: a.) Spatial location and density of observed pot effort (observed number of pot lifts) in the Bering Sea, 1998-2009. b.) Observed pot fishing effort in 2009 relative to the 1998-2009 average in the Bering Sea. Anomalies calculated as (estimated effort for 2009 - average effort from 1998-2009)/stdev(effort from 1998-2009).

Ecosystem Goal: Sustainability (for consumptive and non-consumptive uses)

Trophic Level of the Catch

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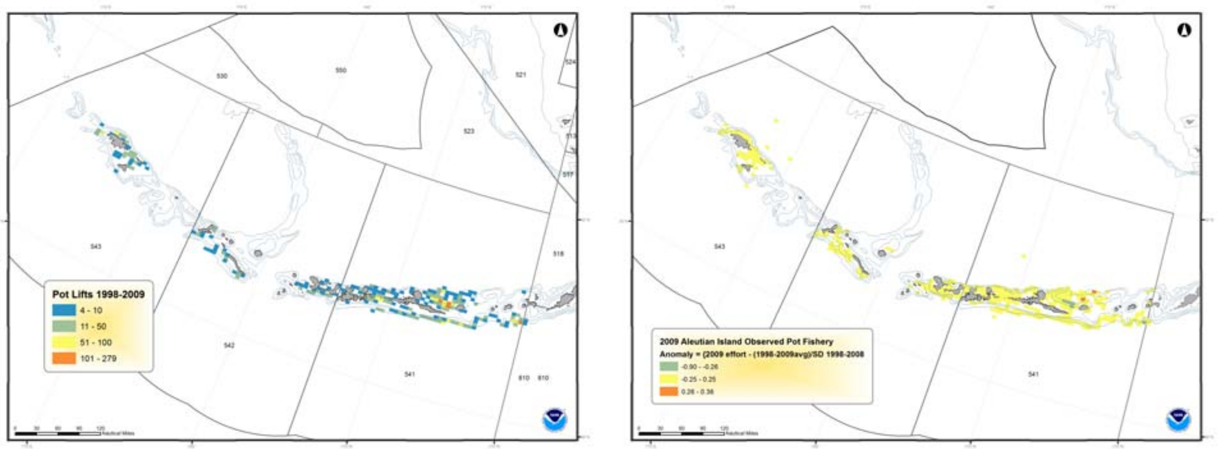
Last updated: October 2010

Description of indices: To determine whether North Pacific fisheries were"fishing-down" the food web, the total catch, trophic level of the catch, and the Pauly et al. (2000) Fishery In Balance (FIB) Index in the eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) areas were determined. To estimate the trophic level of the catch, the catch of each species in a given year was multiplied by the trophic level of that species; products were summed across all species in a given year and divided by the total catch in that year. To calculate the FIB index (Pauly et al., 2000):

$$FIB = log(Y_i \cdot \frac{1}{TE} TL_i) - log(Y_0 \cdot \frac{1}{TE} TL_0),$$

where Y_i is the catch in year i, TL_i the mean trophic level in the catch in year i, TE the transfer efficiency (assumed to be 0.1), and 0 refers to a year used as a baseline (first year in the time series).

Status and trends: Total catch levels and composition for the three regions show the dominance of walleye pollock in the catch from around the 1970s to at least the early 1990s (Figure 107).



(a) 1998-2009 combined

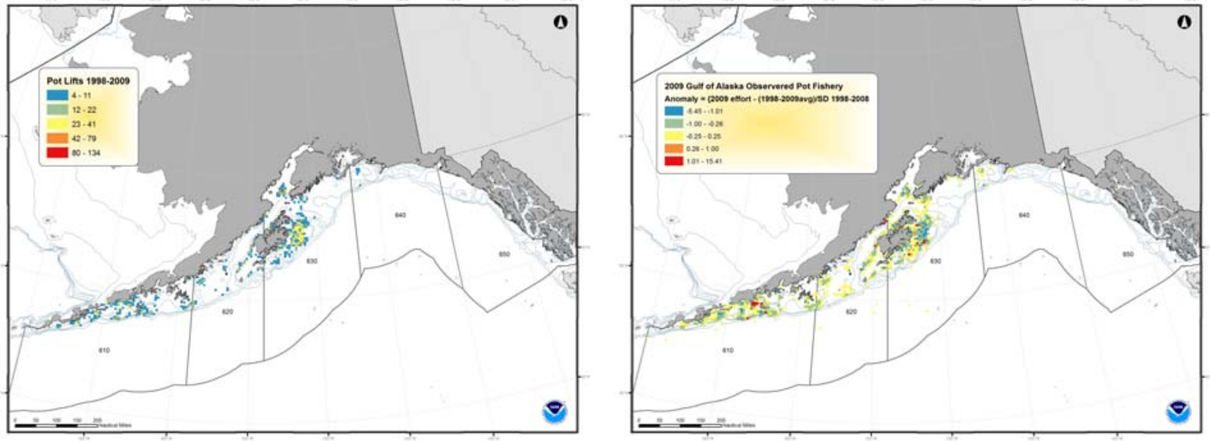
(b) 2009 anomaly

Figure 105: a.) Spatial location and density of observed pot effort (observed number of pot lifts) in the Aleutian Islands, 1998-2009. b.) Observed pot fishing effort in 2009 relative to the 1998-2009 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2009 - average effort from 1998-2009)/stdev(effort from 1998-2009).

Other dominant species groups in the catch were rockfish prior to the 1970s in the AI and the GOA and Atka mackerel in the 1990s in the AI. EBS catches decreased during 2007-2009 due to reduced walleye pollock catches.

Stability in the trophic level of the total fish and invertebrate catches in the EBS, AI, and GOA (Figure 108) indicate that the "fishing-down" effect is not occurring in these regions. Although there has been a general increase in the amount of catch since the late 1960s in all areas, the trophic level of the catch has been high and stable over the last 25 years. The overall trophic level of the catch did not decrease with time when pollock were excluded from the catches (Figure 108). Excluding pollock from EBS catches did result in more temporal variability in the trophic level of the catch.

Factors causing trends: The Fishery in Balance Index (FIB) of Pauly et al. (2000) was developed to ascertain whether trophic level catch trends are a reflection of deliberate choice or of a "fishing down the food web" effect. This index declines only when catches do not increase as expected when moving down the food web, relative to an initial baseline year. The FIB index for each Alaskan region was calculated (Figure 108) to allow an assessment of the ecological balance of the fisheries. Unlike other regions in which this index has been calculated, such as the Northwest Atlantic, catches and trophic level of the catch in the EBS, AI, and GOA have been relatively constant and suggest an ecological balance in the catch patterns. The EBS FIB index decreased during 2007-2008 due to decreased pollock catches. When pollock were excluded from EBS catches, the FIB index was lower, but still relatively stable, fluctuating around 1.7 for approximately the last 30 years (Figure 108). Pollock catch has had a 'stabilizing' effect on the trophic level and FIB index of the Eastern Bering Sea catch, since it comprised the majority of the catch since the late 1960s (Figure 108). Another species of interest is arrowtooth flounder because of recent population increases. Since this species comprises a small proportion of the catches, it has virtually no effect on the trophic level of the catch or the FIB index in the EBS or GOA.



(a) 1998-2009 combined

(b) 2009 anomaly

Figure 106: a.) Spatial location and density of observed pot effort (observed number of pot lifts) in the Gulf of Alaska, 1998-2009. b.) Observed pot fishing effort in 2009 relative to the 1998-2009 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2009 - average effort from 1998-2009)/stdev(effort from 1998-2009).

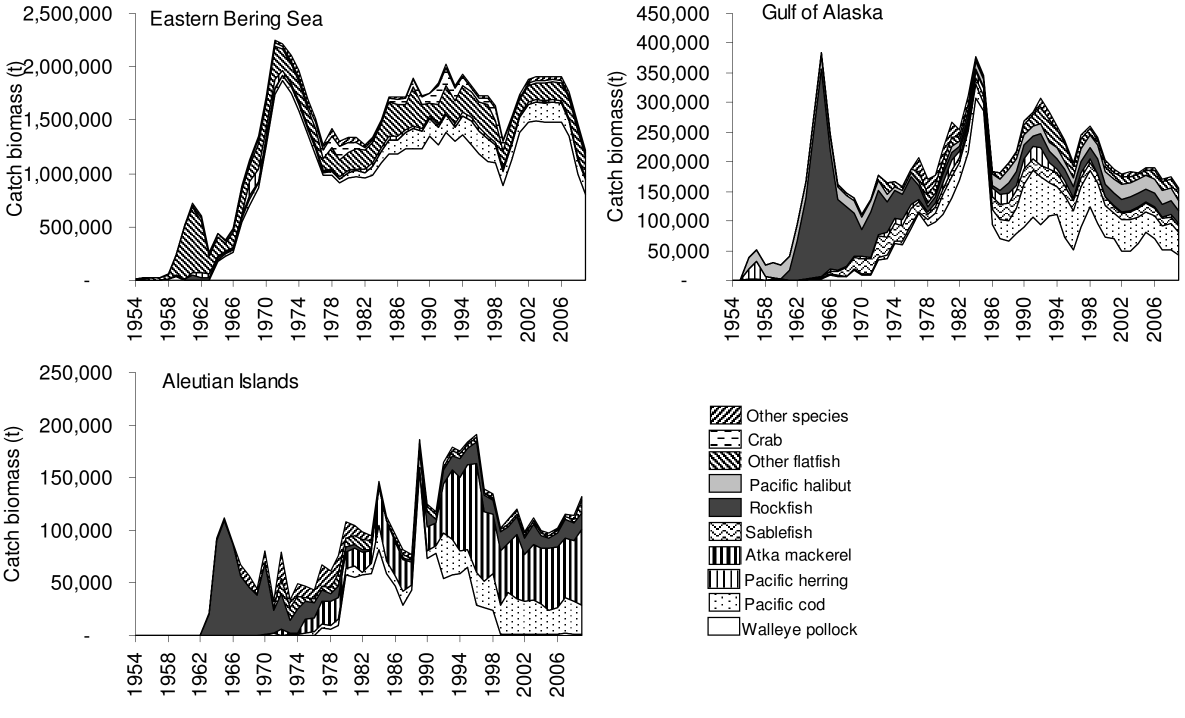


Figure 107: Total catch biomass (except salmon) in the EBS, GOA, and AI, 1954-2009. EBS 2009 crab catches were assumed to be equivalent to the average of 2007 and 2008 catches (catches were not available at the time of the writing of this contribution).

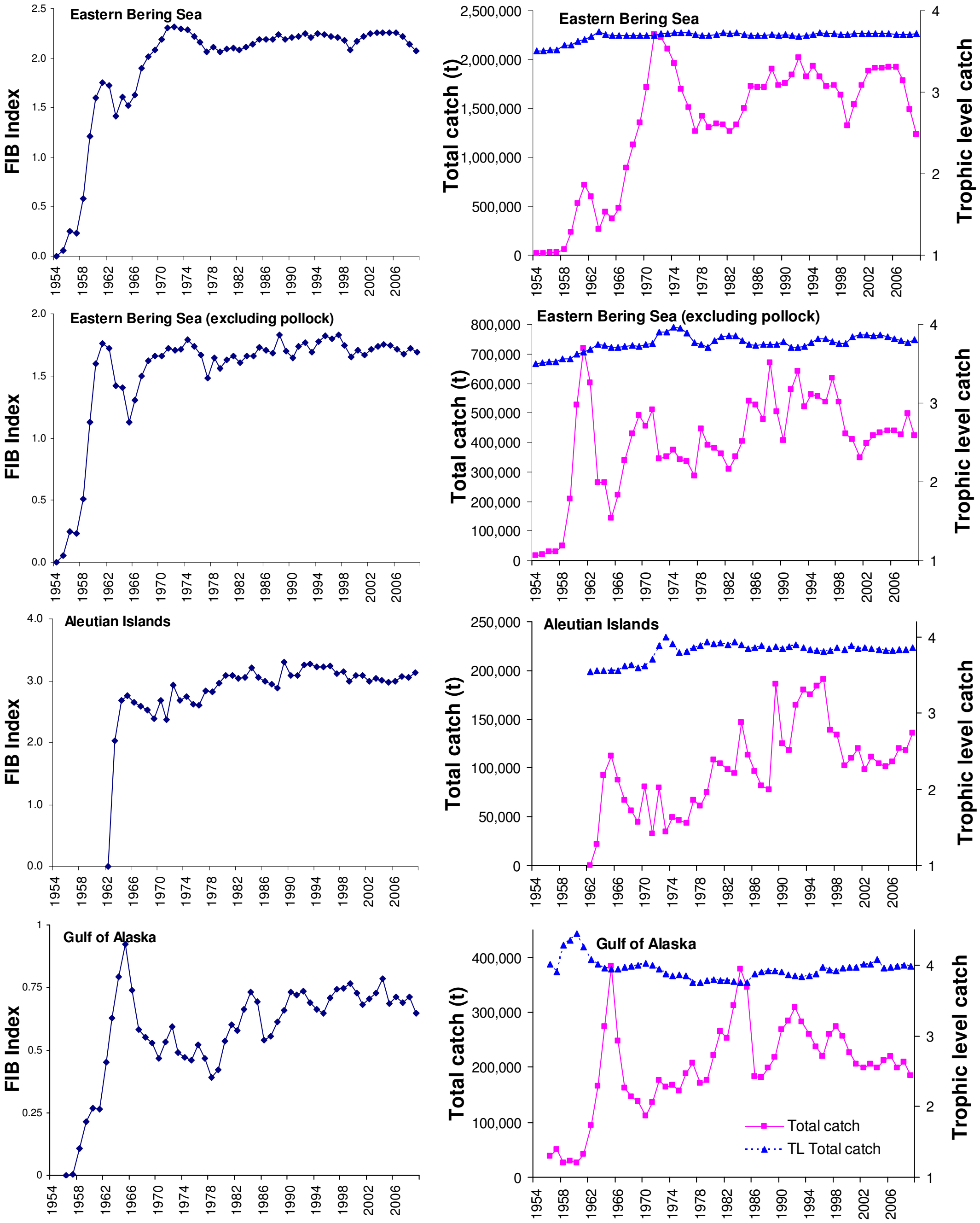


Figure 108: Total catch (groundfish, herring shellfish, and halibut) and trophic level of total catch in the EBS, EBS (excluding pollock), AI and GOA, 1954-2009 (right column). Left column shows FIB index values for the EBS, AI and GOA, 1954-2009. EBS 2009 crab catches were assumed to be equivalent to the average of 2007 and 2008 catches (catches were not available at the time of the writing of this contribution).

Graphs illustrating the total catch by trophic level increments, similar to those created by Essington et al. (2006), reveal patterns not easily seen in the total trophic level values or FIB index. This

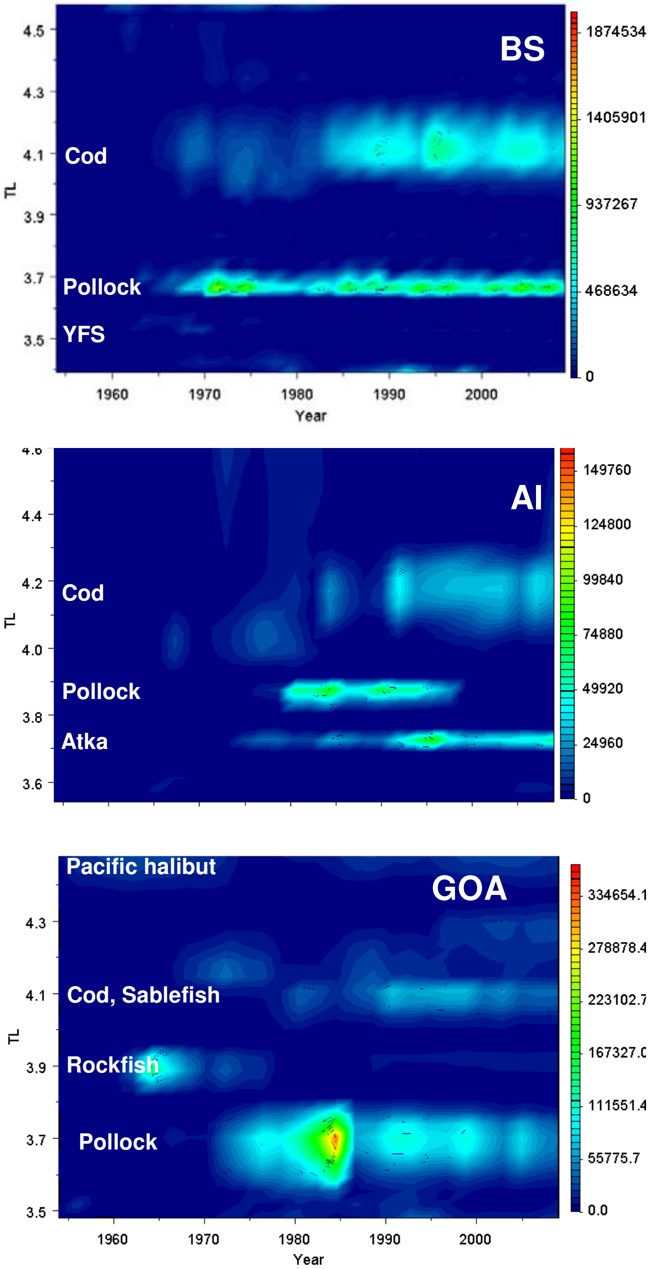


Figure 109: Total catch of all species plotted as colour contours by trophic level and year for the Bering Sea, Aleutian Islands, and Gulf of Alaska, 1954-2009. Note: Catch scales are different for each ecosystem. The species that comprise the majority of catches are labeled on the contour plots at the appropriate trophic levels.

further examination supports the idea that fishing-down the food web is not occurring in Alaska. In general, it appears that fishing events on different species are episodic in the AI and GOA, while pollock steadily dominate catches in the BS throughout the period (Figure 109).

Implications: Stability in the trophic level of the total fish and invertebrate catches and FIB indices in the EBS, AI, and GOA indicate that the "fishing-down" effect is not occurring in these regions.

Fish Stock Sustainability Index and Status of Groundfish, Crab, Salmon and Scallop Stocks

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Last updated: October 2010

Description of index: The Fish Stock Sustainability Index (FSSI) is a performance measure for the sustainability of fish stocks selected for their importance to commercial and recreational fisheries (`http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`). The FSSI will increase as overfishing is ended and stocks rebuild to the level that provides maximum sustainable yield. The FSSI is calculated by assigning a score for each fish stock based on the following rules: 1. Stock has known status determinations: a) overfishing 0.5 b) overfished 0.5 2. Fishing mortality rate is below the "overfishing" level defined for the stock 1.0 3. Biomass is above the "overfished" level defined for the stock 1.0 4. Biomass is at or above 80% of maximum sustainable yield (MSY) 1.0 (this point is in addition to the point awarded for being above the "overfished" level)

The maximum score for each stock is 4. The value of the FSSI is the sum of the individual stock scores. In the Alaska Region, there are 35 FSSI stocks and an overall FSSI of 140 would be achieved if every stock scored the maximum value, 4 (Tables 13 and 14). There are also 28 non-FSSI stocks in Alaska (Tables 13 and 15). There are 230 FSSI stocks in the U.S., with a maximum possible score of 920.

Many species in Alaska are monitored as part of a group or complex, but are considered individually for the purposes of the report. The overfishing determination for the individual species is listed as "unknown", but the species' complex is determined to be "not subject to overfishing" based on the abundance estimates for the entire complex. This determination is applicable for some sharks, skates, sculpins, octopus, and squid complexes in the Gulf of Alaska (GOA) Groundfish FMP. In the Bering Sea/Aleutian Islands (BSAI) Groundfish FMP, similar determinations are made for some stocks in the sharks, skates, sculpins, octopus, rockfish, and flatfish complexes.

Status and trends: As of October 2010, no BSAI or GOA groundfish stock or stock complex is overfished and no BSAI or GOA groundfish stock or stock complex is being subjected to overfishing (Tables 13 and 14). One crab stock is considered overfished: Pribilof Island blue king crab. Two stocks of crabs are under continuing rebuilding plans: BS snow crab (year 10 of 10 year plan) and Pribilof Island blue king crab (year 7 of 10 year plan). The Bering Sea southern tanner crab stock is approaching an overfished condition.

The current overall Alaska FSSI for FSSI stocks is 125 of a possible 140 score, based on updates through October 2010 (Table 14). The overall Bering Sea/Aleutian Islands score is 78 of a possible maximum score of 88. The BSAI groundfish score is 51 of a maximum possible 52 and BSAI king and tanner crabs score 27 of a possible score of 36. The Gulf of Alaska groundfish score is 43 of a maximum possible 48. The sablefish, which are managed as a BSAI/GOA complex, score is 4. For the entire U.S., the score is 582.5 of a possible maximum score of 920.

Factors causing trends: The stocks that had low FSSI scores (1.5) are the GOA shortspine thornyhead rockfish complex, the GOA demersal shelf rockfish complex, the AI golden king crab, and Western AI red king crab. The reasons for these low scores are: it is undefined whether these species are overfished and unknown if they are approaching an overfished condition.

Table 12: Groundfish trawl closure areas, 1995-2009. License Limitation Program (LLP); Habitat Conservation Area (HCA); Habitat conservation zone (HCZ).

Area	Year	Location	Season	Area Size	Notes
BSAI	1995	Area 512	year-round	8,000 nm^2	closure in place since 1987
		Area 516	3/15-6/15	4,000 nm^2	closure in place since 1987
		Chum Salmon Savings Area	8/1-8/31	5,000 nm^2	re-closed at 42,000 chum
		Chinook Salmon Savings Area	trigger	9,000 nm^2	closed at 48,000 Chinook
		Herring Savings Area	trigger	30,000 nm^2	trigger closure
		Zone 1	trigger	30,000 nm^2	trigger closure
		Zone 2	trigger	50,000 nm^2	trigger closure
		Pribilofs HCA	year-round	7,000 nm^2	
		Red King Crab Savings Area	year-round	4,000 nm^2	pelagic trawling allowed
		Walrus Islands	5/1-9/30	900 nm^2	12 mile no-fishing zones
		SSL Rookeries	seasonal extensions	5,100 nm^2	20 mile ext., 8 rookeries
	1996	Nearshore Bristol Bay Trawl Closure	year-round	19,000 nm^2	expanded area 512 closure
		C. opilio bycatch limitation zone	trigger	90,000 nm^2	trigger closure
	2000	Steller Sea Lion protections			
		Pollock trawl exclusions	* No trawl all year	11,900 nm^2	*haulout areas include GOA
			No trawl (Jan-June)*	14,800 nm^2	
		Atka Mackerel restrictions	No trawl	29,000 nm^2	
	2006	Essential Fish Habitat			
		AI Habitat Conservation Area	No bottom trawl all year	279,114 nm^2	
		AI Coral Habitat Protection Areas	No bottom contact gear	110 nm^2	all year
		Bowers Ridge HCZ	No mobile bottom tending fishing gear	5,286 nm^2	
	2008	Northern Bering Sea Research Area	No bottom trawl all year	66,000 nm^2	
		Bering Sea HCA	No bottom trawl all year	47,100 nm^2	
		St. Matthews HCA	No bottom trawl all year	4,000 nm^2	
		St. Lawrence HCA	No bottom trawl all year	7,000 nm^2	
		Nunivak/Kuskokwim Closure	No bottom trawl all year	9,700 nm^2	
Arctic	2009	Arctic Closure Area	No Commercial Fishing	148,393 nm^2	
GOA	1995	Kodiak King Crab Protection Zone Type 1	year-round	1,000 nm^2	red king crab closures, 1987
		Kodiak King Crab Protection Zone Type 2	2/15-6/15	500 nm^2	red king crab closures, 1987
		SSL Rookeries	year-round	3,000 nm^2	10 mile no-trawl zones
	1998	Southeast Trawl Closure	year-round	52,600 nm^2	adopted as part of the LLP
		Sitka Pinnacles Marine reserve	year-round	3.1 nm^2	
	2000	Pollock trawl exclusions	No trawl all year	11,900 nm^2*	*haulout areas include BSAI
			No trawl (Jan-June)	14,800 nm^2	
	2006	Essential Fish Habitat			
		GOA Slope Habitat Conservation Area	No bottom trawl all year	2,100 nm^2	
		GOA Coral Habiat Protection Measures	No bottom tending gear	13.5 nm^2	all year
		Alaska Seamount Habitat Protection Measures	No bottom tending gear	5,329 nm^2	all year

Table 13: Summary of status for FSSI and non-FSSI stocks managed under federal fishery management plans off Alaska, October 2010.

Jurisdiction	Stock Group	Number of Stocks	Overfishing				Overfished				Approaching Overfished Condition
			Yes	No	Unk	Undef	Yes	No	Unk	Undef	
NPFMC	FSSI	35	0	35	0	0	1	29	0	4	1
NPFMC and IPHC	NonFSSI	28	0	20	1	7	0	3	3	22	0
	Total	63	0	55	1	7	1	32	3	26	1

Table 14: FSSI stocks under NPFMC jurisdiction updated October 2010, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`.

Stock	Overfishing?	Overfished?	Approaching?	Action	Progress	B/BMSY	FSSI Score
Blue King Crab-Pribilof Is.	No[a]	Yes	N/A	Cont. rebuilding	Year 7 of 10	0.03	2
Blue King Crab-St. Matthews Is.	No[a]	No	No	N/A	N/A	1.34	4
Golden King Crab-Aleutian Is.	No	Undef	Unk	N/A	N/A	Not estimated	1.5
Red King Crab-Bristol Bay	No	No	No	N/A	N/A	1.28	4
Red King Crab-Norton Sound	No	No	No	N/A	N/A	1.89	4
Red King Crab-Pribilof Is.	No[a]	No	N/A	N/	N/A	1.25	4
Red King Crab-Western AI	No	Undef	Unk	N/A	N/A	Not estimated	1.5
Snow Crab-Bering Sea	No	No; Rebuilding	No	Cont. rebuilding	Year 10 of 10	0.74	3
Southern Tanner Crab-Bering Sea	No	No	Yes	N/A	N/A	0.62	3
BSAI Alaska plaice	No	No	No	N/A	N/A	2.45	4
Atka Mackerel-Aleutian Is.	No	No	No	N/A	N/A	1.37	4
BSAI Arrowtooth Flounder Complex[b]	No	No	No	N/A	N/A	3.08	4
BSAI Blackspotted/Rougyeye Rockfish[c]	No	No	No	N/A	N/A	1.11	4
BSAI Flathead Sole Complex[d]	No	No	No	NA/	N/A	2.02	4
BSAI Rock Sole Complex[e]	No	No	No	N/A	N/A	2.00	4
BSAI Greenland halibut	No	No	No	N/A	N/A	2.12	4
BSAI Northern rockfish	No	No	No	N/A	N/A	1.41	4
BSAI Pacific cod	No	No	No	N/A	N/A	1.04	4
BSAI Pacific ocean perch	No	No	No	N/A	N/A	1.24	4
Walleye pollock-Aleutian Is.	No	No	No	N/A	N/A	0.90	4
Walleye pollock-EBS	No	No	No	N/A	N/A	0.62	3
BSAI Yellowfin sole	No	No	No	N/A	N/A	1.82	4
BSAI GOA Sablefish[f]	No	No	No	N/A	N/A	1.04	4

Table 14: FSSI stocks under NPFMC jurisdiction updated October 2010, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`. (continued)

Stock	Overfishing?	Overfished?	Approaching?	Action	Progress	B/BMSY	FSSI Score
GOA Arrowtooth flounder	No	No	No	N/A	N/A	2.98	4
GOA Flathead sole	No	No	No	N/A	N/A	2.75	4
GOA Blackspotted/Rougheye Rockfish[c]	No	No	No	N/A	N/A	1.51	4
GOA Deepwater Flatfish Complex[g]	No	No	No	N/A	N/A	2.58	4
GOA Demersal Shelf Rockfish Complex[h]	No	Undef	Unk	N/A	N/A	Not estimated	1.5
GOA Pelagic Shelf Rockfish Complex[i]	No	No	No	N/A	N/A	1.56	4
GOA Thornyhead Rockfish Complex[j]	No	Undef	Unk	N/A	N/A	Not estimated	1.5
Northern rockfish-West/Cent GOA	No	No	No	N/A	N/A	1.65	4
GOA Pacific cod	No	No	No	N/A	N/A	1.12	4
GOA Pacific ocean perch	No	No	No	N/A	N/A	1.38	4
GOA Rex sole	No	No	No	N/A	N/A	2.69	4
Walleye pollock-West/Cent GOA	No	No	No	N/A	N/A	0.84	4

[a] Fishery in the EEZ is closed; therefore, fishing mortality is very low. [b] Arrowtooth Flounder and Kamchatka Flounder. Arrowtooth Flounder dominates the biomass and is the indicator species for the complex. The overfished and overfishing determinations are based on the combined abundance estimates for the two species. [c] Blackspotted Rockfish and Rougheye Rockfish. An assessment of the combined species provides the overfished determination, and the OFL is based on the combined-species assessment. [d] Flathead Sole and Bering Flounder. Flathead Sole dominates the biomass and is the indicator species for the complex. The overfished and overfishing determinations are based on the combined abundance estimates for the two species. [e] Northern Rock Sole and Southern Rock Sole (two distinct species). Northern Rock Sole dominates the biomass and is the indicator species for the complex. The overfished and overfishing determinations are based on the combined abundance estimates for the two species. [f] Although Sablefish is managed separately in the Gulf of Alaska, Bering Sea, and Aleutian Islands, separate assessments are not conducted for each of these three regions. Therefore status determination is reported for all Alaska. [g] Deepsea Sole, Dover Sole, and Greenland Turbot. The overfished determination is based on Dover Sole as an indicator species; the overfishing determination is based on the OFL, which is computed by using the dover sole assessment combined with abundance estimates for the remainder of the complex. [h] Canary Rockfish, China Rockfish, Copper Rockfish, Quillback Rockfish, Rosethorn Rockfish, Tiger Rockfish, and Yelloweye Rockfish. The overfishing determination is based on the OFL, which is computed by using estimates of Yelloweye Rockfish and then increased by 10% to account for the remaining members of the complex. [i] Dark Rockfish, Dusky Rockfish, Widow Rockfish, and Yellowtail Rockfish. The overfished determination is based on Dusky Rockfish as an indicator species; the overfishing determination is based on the OFL, which is computed by using the dusky rockfish assessment combined with abundance estimates for the remainder of the complex. [j] Longspine Thornyhead and Shortspine Thornyhead. The overfishing determination is based on the OFL, which is computed using abundance estimates of Shortspine Thornyhead.

Total Annual Surplus Production and Overall Exploitation Rate of Groundfish

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Last updated: July 2010

Description of indices: Total annual surplus production (ASP) of groundfish on the Eastern Bering Sea shelf (EBS) and on the Gulf of Alaska (GOA) shelf from 1977-2009 was estimated by summing annual production across major commercial groundfish stocks for which assessments were available (Table 16). These species represent at least 70-80% of the total catch in bottom trawl surveys. Annual surplus production in year t can be estimated as the change in total adult groundfish biomass across species from year t (Bt) to year t+1 ($Bt + 1$) plus total catches in year t (Ct):

$$ASPt = Bt + Ct = Bt + 1 - Bt + Ct$$

All estimates of B and C are based on 2009 stock assessments. An index of total exploitation rate within each region was obtained by dividing the total groundfish catch across the major commercial species by the estimated combined biomass at the beginning of the year:

$$ut = Ct/Bt$$

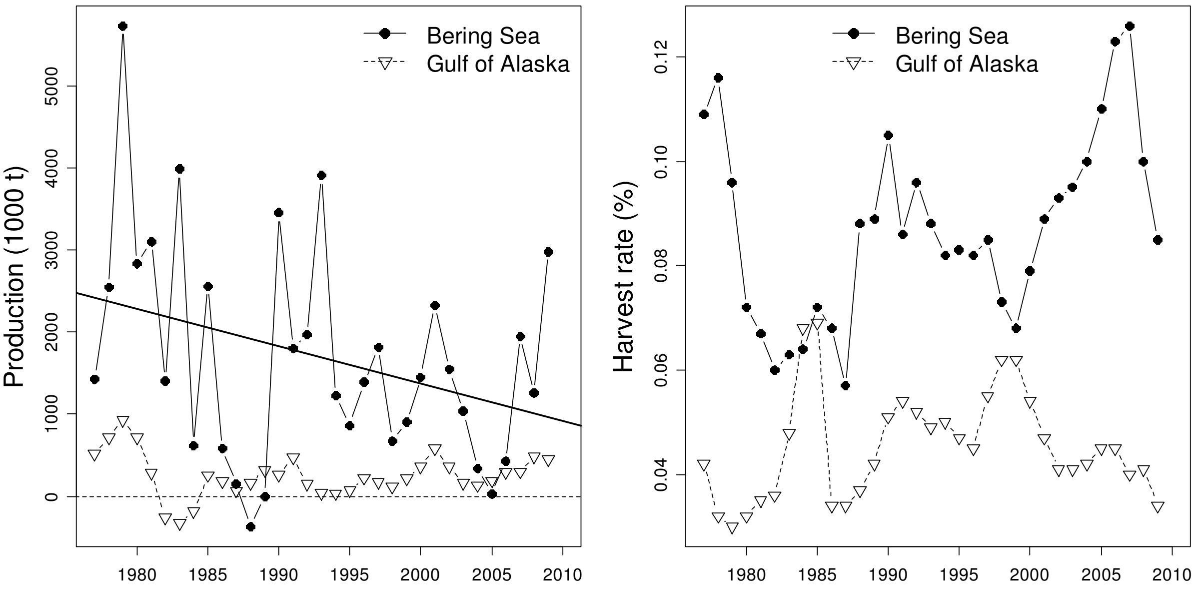

Figure 110: Total annual surplus production (change in biomass plus catch) across all major groundfish species in the Gulf of Alaska and Bering Sea with estimated linear trends and total harvest rate (total catch / beginning-of-year biomass) across all major groundfish species in the Gulf of Alaska and Bering Sea.

Table 15: Non-FSSI stocks updated October 2010, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`.

Stock	Jurisdiction	Overfishing?	Overfished?	Approaching?
Golden King Crab-Pribilof Is.	NPFMC	Unk	Undef	Unk
BSAI Other Flatfish Complex[a]	NPFMC	No	Undef	Unk
BSAI Other Rockfish Complex[b]	NPFMC	No	Undef	Unk
BSAI Other Species Complex[c]	NPFMC	No	Undef	Unk
BSAI Squid Complex[d]	NPFMC	No	Undef	Unk
BSAI Shortraker rockfish	NPFMC	No	Undef	Unk
Walleye pollock - Bogoslof	NPFMC	No	Undef	Unkn
GOA Atka mackerel - Gulf of Alaska	NPFMC	No	Undef	Unk
GOA Big skate - Gulf of Alaska	NPFMC	No	Undef	Unk
GOA Other Skates Complex[e]	NPFMC	No	Undef	Unk
GOA Other Slope Rockfish Complex[f]	NPFMC	No	Undef	Unk
GOA Other Species Complex[g]	NPFMC	Undef	Undef	Unk
GOA Shallow Water Flatfish Complex[h]	NPFMC	No	Undef	Unk
GOA Longnose skate	NPFMC	No	Undef	Unk
GOA Shortraker rockfish	NPFMC	No	Undef	Unk
Walleye pollock-Eastern GOA	NPFMC	No	Undef	Unk
Alaska Coho Salmon Assemblage[i]	NPFMC	No	No	No
Chinook salmon-ENP Far North	NPFMC	No	No	No
Bering scallop-Alaska	NPFMC	Undef	Undef	N/A
Giant rock scallop-Alaska	NPFMC	Undef	Undef	N/A
Reddish scallop-Alaska	NPFMC	Undef	Undef	N/A
Spiny scallop-Alaska	NPFMC	Undef	Undef	N/A
Weathervane scallop-Alaska	NPFMC	No	Undef	N/A
White scallop-Alaska	NPFMC	Undef	Undef	N/A
Arctic cod	NPFMC	No[j]	Unk	Unk
Saffron cod	NPFMC	No[j]	Unk	Unk
Snow crab	NPFMC	No[j]	Unk	Unk
Pacific halibut-Pac. NW/Alaska	IPHC/NPFMC/PFMC	Undef	No	No

[a] Arctic Flounder, Butter Sole, Curlfin Sole, Deepsea Sole, Dover Sole, English Sole, Longhead Dab, Pacific Sanddab, Petrale Sole, Rex Sole, Roughscale Sole, Sakhalin Sole, Sand Sole, Slender Sole, and Starry Flounder. The overfishing determination is based on the OFL, which is computed by using abundance estimates of the complex.

[b] Dark Rockfish, Dusky Rockfish, Harlequin Rockfish, Redbanded Rockfish, Redstripe Rockfish, Sharpchin Rockfish, Shortspine Thornyhead, and Yelloweye Rockfish. The overfishing determination is based on the OFL, which is computed by using abundance estimates of the complex.

[c] Antlered Sculpin, Arctic Staghorn Sculpin, Armorhead Sculpin, Banded Irish Lord, Bigmouth Sculpin, Blackfin Sculpin, Blacknose Sculpin, Blob Sculpin, Bride Sculpin, Broadfin Sculpin, Butterfly Sculpin, Crescent-tail Sculpin, Crested Sculpin, Darkfin Sculpin, Eyeshade Sculpin, Flabby Sculpin, Fourhorn Sculpin, Great Sculpin, Grunt Sculpin, Leister Sculpin, Longfin Irish Lord, Longfin Sculpin, Northern Sculpin, Pacific Hookear Sculpin, Pacific Staghorn Sculpin, Plain Sculpin, Purplegray Sculpin, Red Irish Lord, Ribbed Sculpin, Roughskin Sculpin, Roughspine Sculpin, Sailfin Sculpin, Scaled Sculpin, Scalybreasted Sculpin, Scissortail Sculpin, Slim Sculpin, Smoothcheek Sculpin, Spatulate Sculpin, Spectacled Sculpin, Spinyhead Sculpin, Sponge Sculpin, Tadpole Sculpin, Thorny Sculpin, Threaded Sculpin, Uncinate Sculpin, Warty Sculpin, Wide-eye Sculpin, Yellow Irish Lord, Flapjack Devilfish, Giant Pacific Octopus, Pelagic Octopus, Smoothskin Octopus, Octopus Benthoctopus oregonensis, Octopus Gld bifi, Octopus Bathypolypus arcticus, Pacific Sleeper Shark, Salmon Shark, Spiny Dogfish, Alaska Skate, Aleutian Skate, Bering Skate, Big Skate, Butterfly Skate, Commander Skate, Deepsea Skate, Mud Skate, Okhotsk Skate, Roughshoulder Skate, Roughtail Skate, Whiteblotched Skate, and Whitebrow Skate. The overfishing determination is based on the OFL, which is computed by using abundance estimates of skates and sculpins and average historical catch for sharks and octopus.

[d] Squid Belonella borealis, Squid Berryteuthis anonychus, Squid Berryteuthis magister, Squid Chiroteuthis calyx, Squid Cranchia scabra, Squid Eogonatus tinro, Squid Galiteuthis phyllura, Squid Gonatopsis borealis, Squid Gonatopsis makko, Squid Gonatus berryi, Squid Gonatus kamtschaticus, Squid Gonatus madokai, Squid Gonatus onyx, Squid Gonatus pyros, Squid Histioteuthis hoylei, Squid Moroteuthis robusta, and Squid Rossia pacifica. The overfishing determination is based on the OFL, which is equal to average historical catch.

[e] Alaska Skate, Aleutian Skate, Bering Skate, Deepsea Skate, Roughshoulder Skate, Routhtail Skate, and Whiteblotched Skate. The overfishing determination is based on the combined abundance estimates of these species.

[f] Blackgill Rockfish, Bocaccio, Chilipepper, Darkblotched Rockfish, Greenstriped Rockfish, Harlequin Rockfish, Northern Rockfish (Eastern GOA only), Pygmy Rockfish, Redbanded Rockfish, Redstripe Rockfish, Sharpchin Rockfish, Silvergray Rockfish, Splitnose Rockfish, Stripetail Rockfish, Vermilion Rockfish, and Yellowmouth Rockfish. The overfishing determination is based on the OFL, which is computed by using abundance estimates of the complex.

[g] Pacific Sleeper Shark, Salmon Shark, Spiny Dogfish, Antlered Sculpin, Armorhead Sculpin, Bigmouth Sculpin, Blackfin Sculpin, Blob Sculpin, Brightbelly Sculpin, Brown Irish Lord, Buffalo Sculpin, Crested Sculpin, Darkfin Sculpin, Dusky Sculpin, Eyeshade Sculpin, Fourhorn Sculpin, Frog Sculpin, Frogmouth Sculpin, Great Sculpin, Grunt Sculpin, Longfin Sculpin, Northern Sculpin, Pacific Staghorn Sculpin, Plain Sculpin, Red Irish Lord, Ribbed Sculpin, Roughspine Sculpin, Roughskin Sculpin, Sailfin Sculpin, Scissortail Sculpin, Silverspotted Sculpin, Slim Sculpin, Smoothcheek Sculpin, Smoothhead Sculpin, Spatulate Sculpin, Spectacled Sculpin, Spinyhead Sculpin, Sponge Sculpin, Spotfin Sculpin, Tadpole Sculpin, Thorny Sculpin, Threaded Sculpin, Threadfin Sculpin, Warty Sculpin, Yellow Irish Lord, Sculpin Artediellus sp., Sculpin Icelus euryops, Flapjack Devilfish, Giant Pacific Octopus, Pelagic Octopus, Red Octopus, Smoothskin Octopus, Vampire Squid, North Pacific Bigeye Octopus, Squid Berryteuthis anonychus, Squid Berryteuthis magister, Squid Chiroteuthis calyx, Squid Cranchia scabra, Squid Eogonatus tinro, Squid Galiteuthis phyllura, Squid Gonatopsis makko, Squid Gonatus berryi, Squid Gonatus kamtschaticus, Squid Gonatus madokai, Squid Gonatus onyx, Squid Gonatus pyros, Squid Histioteuthis hoylei, Squid Loligo opalescens, Squid Moroteuthis robusta, Squid Octopoteuthis deletron, and Squid Onychoteuthis borealijaponicus. There is no OFL specified for this complex. The TAC is set at an amount less than or equal to 5 percent of the combined TACs for the remainder of the groundfish fishery.

[h] Alaska Plaice, Butter Sole, C-O Sole, Curlfin Sole, English Sole, Northern Rock Sole, Pacific Sanddab, Petrale Sole, Sand Sole, Slender Sole, Southern Rock Sole, Speckled Sanddab, Starry Flounder, and Yellowfin Sole. The overfishing determination is based on the OFL, which is computed by using abundance estimates of the complex.

[i] Coho, sockeye, pink, and chum salmon throughout southeast Alaska. Four indicator stocks of coho salmon (Auke Creek, Berners River, Ford Arm Lake, and Hugh Smith Lake) are used to determine the status of the assemblage.

[j] There is no commercial fishing for this stock, including Alaska state waters and international fishing, so fishing mortality is expected to be zero.

Table 16: Species included in computing annual surplus production in the Bering Sea and Gulf of Alaska.

Bering Sea	**Gulf of Alaska**
walleye pollock (*Theragra chalcogramma*)	walleye pollock (*Theragra chalcogramma*)
Pacific cod (*Gadus macrocephalus*)	Pacific cod (*Gadus macrocephalus*)
yellowfin sole (*Limanda aspera*)	Sablefish (*Anoplopoma fimbria*)
Greenland turbot (*Reinhardtius hippoglossoides*)	Pacific halibut (*Hippoglossus stenolepis*)
arrowtooth flounder (*Atheresthes stomias*)	arrowtooth flounder (*Atheresthes stomias*)
Northern rock sole (*Lepidopsetta polyxystra*)	flathead sole (*Hippoglossoides spp.*)
flathead sole (*Hippoglossoides spp.*)	rex sole (*Glyptocephalus zachirus*)
Alaska plaice (*Pleuronectes quadrituberculatus*)	Dover sole (*Microstomus pacificus*)
	Pacific ocean perch (*Sebastes alutus*)
	Northern rockfish (*Sebastes polyspinus*)
	dusky rockfish (*Sebastes variabilis*)
	rougheye (*Sebastes aleutianus*)
	and blackspotted rockfish (*S. melanostictus*)

Status and trends: The resulting indices suggest high variability in groundfish production in the eastern Bering Sea (Figure 110) and a decrease in production between 1977 and 2007 (slope = -45,500 mt / year, t = -1.922, p = 0.064). Annual surplus production in the GOA was much lower on average, less variable, and did not show a significant trend over time (slope = - 1,508 mt/ year, t = -0.109, p = 0.914). Total exploitation rates for the groundfish complex are generally much higher in the EBS than in the GOA and were highest in the early part of the time series due to high exploitation rates of walleye pollock (Figure 110). The overall exploitation rate in the EBS reached a low of 6.9% in 1999, increased to 12% by 2006, and decreased in 2008/2009 due to a reduction in walleye pollock harvest rates. The overall exploitation rate in the Gulf of Alaska has generally been less than 6% except in 1984/85.

Because trends in annual surplus production in the Eastern Bering Sea are almost entirely driven by variability in walleye pollock, ASPt for the Bering Sea was also computed after excluding walleye pollock (Figure 111). The results suggest a pronounced decrease in aggregate surplus production of all non-pollock species from a high of over 1 million tons in 1979/1980, due to strong recruitment of a number of species, to lows of around 300,000 t in the late 1990s. In 2008, annual surplus production increased substantially due to an estimated increase in the biomass of Alaska plaice.

Factors causing trends: Annual Surplus Production is an estimate of the sum of new growth and recruitment minus deaths from natural mortality (i.e. mortality from all non-fishery sources) during a given year. It is highest during periods of increasing total biomass (e.g. 1991-92 in the EBS) and lowest during periods of decreasing biomass (e.g. 1982-1984 in the GOA and 2004-2007 in the EBS). In the absence of a long-term trend in total biomass, ASP is equal to the long-term average catch. Theory suggests that surplus production of a population will decrease as biomass increases much above BMSY, which has been the case for a number of flatfish species (e.g. rock sole, flathead sole) and rockfish species (Pacific ocean perch, northern rockfish). Exploitation rates are primarily determined by management and reflect a relatively precautionary management regime with rates that have averaged less than 10% across species in the EBS. Exploitation rates are much lower in the GOA because of the very limited exploitation of arrowtooth flounder, which currently make up the majority of the biomass in the GOA. If arrowtooth flounder are excluded, rates are comparable to those in the EBS.

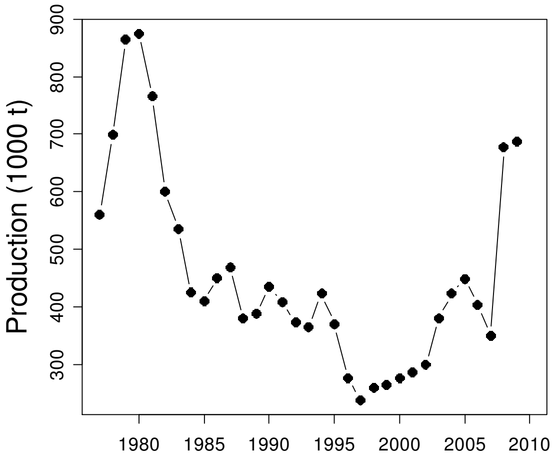

Figure 111: Total annual surplus production (change in biomass plus catch) in the Bering Sea across all major groundfish species, excluding walleye pollock.

Implications: Under certain assumptions, aggregate surplus production can provide an estimate of the long-term maximum sustainable yield of these groundfish complexes (Mueter and Megrey, 2006), (Figure 112). Although there is little contrast in total biomass over time, it appears that biomass was generally above the level that would be expected to yield maximum surplus production under a Graham-Schaefer model fit to aggregate ASP (Figure 112). The recent decrease in aggregate biomass in the EBS from 2004 through 2007 (largely due to decreases in walleye pollock abundance) to levels last seen in the late 1970s was associated with an increase in aggregate ASP, suggesting that compensatory mechanisms may be starting to increase production through increases in growth or reduced predation mortality. If projected increases in biomass materialize, aggregate ASP will increase further in 2010.

Community Size Spectrum of the Bottom Trawl-Caught Fish Community of the Eastern Bering Sea

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Last updated: August 2008

See the 2008 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

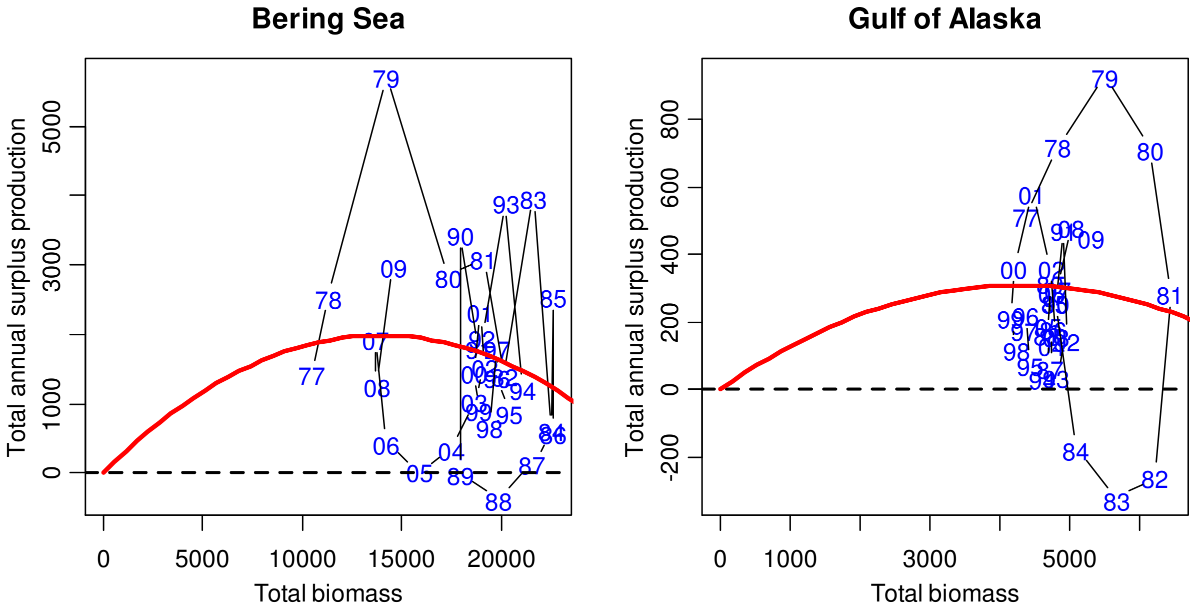

Figure 112: Estimated annual aggregated surplus production against total biomass of major commercial species with fitted Graham-Schaefer curve.

Ecosystem Goal: Humans are part of ecosystems

Fishing Overcapacity Programs

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Overview Overcapacity, defined here as an excessive level of investment or effort relative to the available fisheries resources, is considered a problem in fisheries throughout the world. The problem is often manifested in short fishing seasons, increased enforcement and safety problems, and reduced economic viability for vessel owners and crew-members. Overcapacity can, under certain conditions, have grave implications for conservation as well.

The North Pacific Fishery Management Council (Council) and Congress have developed numerous tools and programs to address overcapacity in the Alaskan fisheries. Moratorium programs were implemented in the crab scallop, and groundfish fisheries to limit the number of harvesting vessels that may be deployed off Alaska, and access has since been limited further by replacing the moratoria with license limitation programs (LLP). Capacity reduction ("buyback") programs have been used to permanently retire vessels, licenses, and participation histories through monetary compensation. However, rights-based management such as individual transferable quotas and dedicated allocations to cooperatives has increasingly being used to “rationalize” fisheries. And, “sideboard” measures prevent “spillover” effects due to imposition of right-based programs.

The first rights-based management program in Alaska was the Individual Fishing Quota (IFQ) program, which has been used to manage the halibut and fixed gear sablefish fisheries since 1995. Rather than explicitly limiting the number of harvesting vessels, this program grants quota holders the privilege of harvesting a specified percentage of the Total Allowable Catch (TAC) each year. A similar program developed by the Council, beginning in 2005, placed management of most crab fisheries of the Bering Sea and Aleutian Islands (BSAI) under a quota system, in which quota shares were issued to harvesters (including vessel captains) and processors. The program also includes community protection measures and provides for voluntary harvesting cooperatives. Some features of this crab program had to be authorized by Congressional action. As a prelude to a more complex GOA rationalization program, the National Marine Fisheries Service (NMFS), in response to a Congressional mandate and in consultation with the Council, developed a demonstration quota program for Central Gulf of Alaska rockfishes, since extended to five years. Most recently, in a program implemented under statutory authority, NMFS attached quota to LLP licenses for historic participants in the non-AFA catcher/processor sector (“Amendment 80”). The quota may be used annually to provide dedicated allocations to harvesting cooperatives or pooled in a limited access fishery.

Moratorium on New Vessels NMFS implemented a moratorium on new vessel entry into the federally managed groundfish and crab fisheries in 1996 and for scallops in 1997. The programs were considered place holders while more comprehensive management measures were developed. The owners of 1,864 groundfish and 653 crab vessels held moratorium fishing rights at the time the groundfish and crab program was sunsetted (December 31, 1999). In addition to limiting the number of vessels the moratorium also restricted the lengths of vessels that could be deployed under moratorium permits. Qualifying vessels that were less than 125’ in length overall received licenses that had a maximum length overall of 120 percent of the qualifying vessel’s length on June 24, 1992, or up to 125’, whichever is less; vessels that were 125’ or longer could not increase their length. The concern over increasing vessel length arises because such actions can increase harvesting capacity even though additional vessels are prohibited from entering a fishery, thus undermining the effectiveness of a moratorium.

License Limitation Program for Groundfish and Crab The LLP for groundfish and crab vessels was implemented on January 1, 2000 to replace the vessel moratorium. The original LLP, approved in 1995, was intended as the second step in fulfilling the Council’s commitment to develop a comprehensive and rational management program for fisheries off Alaska. Amendments to that program recommended by the Council in 1998 and April 2000 tightened the LLP program and included additional restrictions on crab vessel numbers and on fishery crossovers. The amendments also limited participation in the non-trawl BSAI Pacific cod fisheries. The LLP reduced the number of harvesting vessels eligible to participate in the BSAI crab fisheries by more than 50% relative to the vessel moratorium (down to about 347 licenses), of which for the fourth year under rationalization, 127 were licensed and 88 fished under rationalized fisheries, respectively. The number of current LLP groundfish licenses (1,824) is similar to the number that held moratorium permits and some of both types of licenses were or are not actively used. At present, only 1,468 groundfish LLP licenses name vessels. However, the groundfish LLP is more restrictive than that for the crab fisheries which indicate allowed fisheries. For groundfish, endorsements control areas in which a license holder can fish and the types of gear that may be deployed. Also important to note is that the vast majority of the vessels that can be deployed under the LLP are longline vessels less than 60' (and are eligible to participate only in Gulf of Alaska fisheries). These vessels have typically had relatively small catch histories in past years. The LLP Program was modified to accommodate changes implemented under the Crab Rationalization Program (CR Crab). In addition to crab endorsement changes resulting from new quota fisheries, some groundfish licenses were modified to incorporate "sideboard" restrictions, as they have become known, on GOA groundfish activities to avoid "spillover" effects of excess crab capital on groundfish fisheries.

In April, 2008 the Council recommended reducing "latent" capacity in trawl groundfish fisheries by creating a new "recent participation" requirement for licenses and endorsements. NMFS implemented the new requirements as Amendments 82 (GOA) and 92 (BSAI), under which harvesting privileges unused in specific management areas in recent years were forfeit. Vessels not actively fishing as a result of provisions of existing programs (such as AFA cooperatives) were exempt from these requirements. As recommended by the Council, NMFS added an Aleutian Islands area endorsement to some trawl groundfish licenses to provide sufficient harvesting capacity in that area, particularly for Pacific cod. This harvesting authority was not earned under original LLP eligibility rules due to absence of processors operating in the remote AI subarea in qualifying years.

To limit effort in the GOA Pacific cod fishery, at its April 2009 meeting, the Council recommended revising the LLP program by adding gear-specific (pot, hook-and-line, and jig) Pacific cod endorsements to Western and Central GOA fixed gear LLP licenses. If approved, vessels will be required to hold a Pacific cod endorsement to participate in the directed Pacific cod fisheries in the Western and Central GOA. Endorsements would be based on license participation. NMFS has published a proposed rule and draft implementing regulations for GOA Amendment 86 (75 FR 43118, July 23, 2010).

License Limitation Program for Scallops (LLPS) The LLPS was implemented in 2001 to replace a 1997 temporary vessel moratorium program for this fishery. Under the LLPS, nine persons were issued transferable licenses authorizing them to deploy vessels in the scallop fishery off Alaska. The licenses restrict the lengths of vessels and the size and amount of gear that may be used.

Bering Sea and Aleutian Islands Crab "Buyback" and Rationalization The North Pacific Fishery Management Council developed, and NMFS has implemented, a plan to rationalize the BSAI crab fishery.

A statutory change to the Magnuson-Stevens Fishery Conservation and Management Act (MS-FCMA) authorized an industry-funded buyback program for the crab fisheries. In late 1994, this program permanently retired the fishery endorsements of 25 vessels, and LLP crab licenses and vessel histories; as well as 15 limited entry licenses for groundfish (and some halibut quota share) associated with those histories. The program was approved by an industry referendum in which a majority of participants approved the proposed effort reduction and a debt retirement burden of $97.4 million.

The Council also developed, and NOAA Fisheries Service, has implemented, the Crab Rationalization Program (CR Crab). This program includes allocations to Community Development Quota Groups, an allocation of one species of king crab to the community of Adak, and a complex quota system for harvesters and processors called the "three-pie voluntary cooperative program". CR Crab program attempts to balance the interests of several identifiable groups that depend on these fisheries. Allocations of harvest shares are made to harvesters, including captains. Processors are allocated processing shares. Community protection measures are designed to help provide economic viability of fishery-dependent communities. Designated regions are allocated landings and processing activity to preserve their historic interests in the fisheries. Harvesters are permitted to form cooperatives to realize efficiencies through fleet coordination. The novelty of the program has compelled the Council to include several safeguards into the program, including a binding arbitration program for the resolution of price disputes and extensive economic data collection and review programs to assess the success of the rationalization program. These safeguards, together with the Council's continuing development of the program through a series of ongoing amendments and clarifications, demonstrate the Council's commitment to a fair and equitable rationalization program that protects the interests of those dependent on the BSAI crab fisheries.

As of July 2010, NOAA Fisheries Service has initially issued one or more types of quota to 511 persons, including harvesting quota issued to 490 distinct persons, and processing quota issued to 27 persons. For harvesters, NOAA Fisheries initially issued quota to 271 applicants who qualified based on holding a transferable LLP crab license; and to 231 individuals who qualified for "Captain" (also known as "crew") shares by virtue of both historic and recent participation in these crab fisheries. Fishing under Crab Rationalization began with two Aleutian Islands golden king crab fisheries, in August 2005. During the first year of the program, fishery managers determined that for conservation reasons, the Bering Sea Chionoecetes bairdi Tanner crab (BST) biomass should be managed in two separate fisheries. Just prior to the start of the second crab fishing year, NMFS issued all current holders of BST quota shares for both the new Eastern and Western Bering Sea C. bairdi fisheries. As of the end of the fifth (2009/10) crab fishing year under rationalization, 481 persons (whether or not initial issuees) were holding harvesting quota share (QS), and 30 were holding PQS. Of the persons holding harvesting QS, 291 held "owner" type, and 206 individual persons held "crew" type. Consolidation has occurred in the crab fisheries, due largely to widespread use of cooperatives and to some attrition of initial issuees out of the fisheries without total replacement by new entrants. During the first five years under rationalization, the numbers of vessels authorized to harvest crab decreased from 154 to 127, and the number that actually had landings decreased from 101 to 78, respectively. The Council has changed the rationalization program to address a number of issues, including those that relate to capacity in various sectors.

Starting with the fourth crab fishing year on July 1, 2008 NMFS implemented a change required by statute as part of crab FMP Amendment 25 (73 FR 29979, May 23, 2008). This change allows three corporations initially issued certain types of harvesting QS or processing PQS to annually combine the harvester and processor IFQ/IPQ held by them and their affiliates and change it into catcher processor IFQ for use in the north region. This program feature should preserve economic benefits from crab-related State tax revenues shared with northern communities while providing operational flexibility for program participants. One corporation has since sold its holdings and is no longer eligible for this benefit.

The Council recommended measures to both relieve some restrictions and create some new ones for holders and users of "crew" QS. Under FMP Amendment 26 "crew" quota share and IFQ are exempt from requirements for delivery to specific processors, delivery within specific geographic regions, and participation in an arbitration system to resolve price disputes, previously due to take effect in the fourth program year. NMFS published a final rule to implement Amendment 26 on June 20, 2008 (73 FR 35084). The Council also made recommendations at its April 2008 meeting on active participation criteria to ensure that persons obtaining, holding, and using "crew" QS and IFQ remain personally involved in crab harvesting activities. These provisions remain under regulatory development.

The Council recommended exemptions for custom processed crab from IPQ use caps. NMFS implemented regulations under crab FMP Amendment 27 (74 FR 25449, May 28, 2009) intended to protect crab revenues historically available to fishery-dependent economies while providing operational and business flexibility to processors.

NMFS greatly enhanced participant operational flexibility by introducing two new program features. First, Amendment 28 added a "post-delivery transfer" provision, under which IFQ and IPQ holders could make landings in excess of a permitted amount and "backfill" the account at a later time. Also, in many cases NMFS now offers real-time, entirely electronic transfers of IFQ between cooperatives and of IPQ between IPQ holders.

An Emergency Rule effective during the 2009/10 crab fishing year exempted IFQ and IPQ holders of Western Aleutian Islands golden king crab designated for delivery in the west-region from that regional requirement. This provision responds to a lack of significant processing capacity in the west region due primarily to the bankruptcy of a processor located in Adak and high costs of operating in that region for processors located elsewhere. A similar exemption is expected to be in effect until a more permanent management measure is implemented.

The Council received an 18-month status report on crab rationalization in April, 2007; a major 3-year program review in December, 2008; and will hear a five-year review in October, 2010. It is currently analyzing a number of proposed program changes that, among other actions, would amend the Right of First Refusal (which during quota transfers provides certain communities the opportunity to keep processing activity within their confines), provide an emergency exemption to regional delivery requirements, and that might affect capacity.

Sablefish and Halibut Individual Fishing Quotas The halibut and sablefish fisheries provide good examples of how the Council is working to control overcapacity in fisheries off Alaska. From 1975 to 1994 the Central Gulf of Alaska halibut fishing seasons decreased from approximately 125 days to single day openings, while catches increased. Faced with very short seasons and increasing fishing effort, the Council recommended an IFQ program for both the halibut and fixed gear sablefish fisheries. These programs were initiated in 1995. After implementation, the traditional short, pulse fisheries were extended to more than eight months long. Individual Fishing Quota has allowed participants to better match fishing capacity with the amount of fish they are allowed to harvest during a year, improving economic efficiency for harvesters and decreasing gear conflicts on fishing grounds, among other salutary effects. The program includes a means for non-profit representatives of small GOA communities to purchase quota for use by residents, protecting fishery-dependent revenue and employment. Since the start of the program, the numbers of vessels and QS holders have continued to decline, even as new persons entered the fisheries and the TACs increased. A total of 4,829 persons were initially issued halibut quota share (QS) and 1,054 were initially issued sablefish QS. At the end of 2009, 2,852 persons held halibut QS and 835 held sablefish QS. The number of vessels landing halibut in the IFQ fishery declined from 3,450 in 1994, just prior to the IFQ and CDQ halibut programs, to 1,090 at the end of 2009; the number landing sablefish in the IFQ fishery declined from 1,191 in 1994 to 363 in 2009. NMFS expects to soon publish a proposed rule to implement a Council recommendation to revoke "inactive QS". Inactive QS is that held by initial issuees who have not (a) fished their allocation, or (b) conducted any quota transfers. Such holders would be provided an opportunity to request in writing (at the appropriate time) that their

QS remain "active". Revocation of unused QS would reduce program costs and might increase fishery yield by reallocating TAC into the hands of active participants. The Council is considering additional amendments to further IFQ Program goals.

American Fisheries Act The American Fisheries Act (AFA), passed in late 1998, retired nine catcher-processors under a "buyback" program, limited entry of additional harvesting vessels, authorizes harvesting cooperatives to which a portion of the total allowable catch of BSAI pollock is granted, prevents pollock fishery participants from expanding historical activities to other fisheries, and stabilized deliveries to shoreside processors. Only harvesting and processing vessels that met specific requirements, based on their participation in the 1995-97 fisheries are eligible to harvest BSAI pollock. At the inception of the AFA, 21 catcher/processors and 112 catcher vessels qualified, or were specifically identified, as eligible to participate under the AFA guidelines. Nine other catcher/processors were bought out at a cost of $90 million.

Specific provisions in the AFA allow for the formation of cooperatives among catcher/processors, among the catcher vessels that deliver to the catcher-processors, among eligible motherships and catcher vessels in the mothership sector, and among the eligible catcher vessels in the inshore sector of the BSAI pollock fishery. Within each cooperative, each member company is then contractually allocated a percentage share of the total cooperative allocation based on its historical catch (or processing) levels. The catcher-processor cooperative is called the Pollock Conservation Cooperative (PCC) and is made up of eight companies that own 19 of the 20 catcher-processors currently eligible to fish in the pollock fishery (the fishing privileges of the 21st eligible vessel were purchased by the PCC in 2000, and one eligible vessel has not joined the PCC). The catcher vessel cooperative is called the High Seas Catchers' Cooperative (HSCC), and comprises seven catcher vessels authorized under the AFA to deliver to the eligible catcher/processors (these vessels had traditionally delivered the majority of their pollock to catcher/processors).

Under the AFA, the PCC is currently allocated 91.5% of the total offshore pollock allocation (the rest is allocated to members of the HSCC). When the new fishery cooperative structure was adopted in 1999, not all of the eligible catcher/processors fished during the 1999 late winter and early spring pollock seasons; four catcher/processors opted not to fish during the winter season and six chose not to fish during the summer season. This pattern continued in 2000 and 2001 when four and three catcher/processors were idle in the winter season, respectively. Five of the catcher/processors were idle in both 2000 and 2001 for the summer season. In 2002, three vessels were idle in the winter season and four were idle in the summer season. Two vessels were idle during the winter season in each of the six years from 2003 to 2008, and six vessels were idle during the 2009 winter season. During the summer season, three vessels were idle in 2006; four vessels were idle in 2003, 2004, 2005, and 2007; five vessels were idle in 2008; and seven were idle in 2009. The variations in vessel participation can probably be attributed to the variations in the pollock TAC.

The HSCC is allocated 8.5% of the offshore pollock allocation. However, since the formation of the cooperative, they have leased much of their TAC allocation for pollock to catcher/processors. In fact, since 1999, none of the seven HSCC vessels have engaged in directed fishing for pollock, choosing instead to lease their catch to the AFA catcher/processor fleet.

The AFA also authorizes three motherships to participate in the BSAI pollock fishery. In 1998, 31 vessels landed greater than 10 mt of pollock to be processed by offshore motherships. In 1999, this number decreased to 27. In 2000, the first year in which a cooperative was operating in the mothership sector, 19 of the 20 catcher vessels eligible to deliver pollock to these motherships actually did so. The same number of vessels made deliveries to motherships in 2001, dropped to 17 vessels annually in 2002 and 2003, increased to 18 in 2004, and dropped again to 17 annually for the five years 2005-2009.

In 1998 107 inshore catcher vessels each delivered more than 10 mt of pollock to inshore processors (including stationary floating processors). That number decreased slightly in 1999 (100 vessels), again decreased in the 2000 roe fishery (91 vessels), remained at that level in 2001, and dropped to 85 in 2002. The number of vessels delivering at least 10 mt of pollock to inshore processors remained at 85 vessels for the four years 2003-2006, fell to 83 for the years 2007-2008, and declined again to 81 vessels in 2009.

Finally, it should be noted that the AFA also restricts eligible vessels from shifting their effort into other fisheries. “Sideboard” measures prevent AFA eligible vessels from increasing their catch in other fisheries beyond their average 1995-97 levels. Sideboard restrictions reduce the likelihood that the fishing capacity of AFA eligible vessels will spill over and compete in other fisheries.

Two recent acts of Congress provided additional authority and guidance to the Council and NMFS for developing and implementing limited access privilege (LAP) programs. Under these authorities, the Rockfish Pilot Program, a BSAI groundfish capacity reduction (“buyback”) program, and Amendment 80 to the FMP for the BSAI are in various stages of development or implementation by the Council and/or NMFS.

Rockfish Pilot Program Congress granted NMFS specific statutory authority to manage Central GOA rockfish fisheries in Section 802 of the Consolidated Appropriations Act of 2004 (Pub. L. 108-199; Section 802). The North Pacific Fishery Management (Council) was required to establish the Rockfish Pilot Program, to provide exclusive harvesting and processing privileges for a specific set of rockfish species and for associated species harvested incidentally to those rockfish in the Central GOA, an area from 147 °W to 159 °W. The Program is intended to increase resource and improve economic efficiency for harvesters and processors who participate in the fishery. Initially for two years, later extended to the five year period through December, 2011, exclusive harvesting and processing privileges were allocated for three primary rockfish species and for five incidentally harvested secondary species in the Central GOA, with annual associated pounds. NMFS also allocated a portion of the total GOA halibut mortality limit to participants based on historic halibut mortality rates in the primary rockfish species fisheries.

Under the Rockfish Program NMFS: 1. Assigned quota share (QS) for primary rockfish species to an LLP license with a trawl gear designation in the Central GOA. 2. Established eligibility criteria for processors to have an exclusive privilege to receive and process primary rockfish species and secondary species allocated to harvesters in this Program. 3. Allows a person holding a LLP license with QS to form a rockfish cooperative with other persons (i.e., harvesters) on an annual basis. 4. Allows rockfish cooperatives to transfer all or part of their CFQ to other rockfish cooperatives, with some restrictions. 5. Provides an opportunity (annually) for a person not in a rockfish cooperative, but who holds an LLP license with QS, to fish in a limited access fishery. 6. Establishes a small entry level fishery for Central GOA rockfish for harvesters and processors not eligible to receive QS under this Program. 7. Allows holders of catcher/processor LLP licenses to opt-out of the Program annually, with certain limitations. 8. Limits the ability of processors to process catch outside the communities in which they have traditionally processed primary rockfish species and associated secondary species. 9. Establishes catch limits, commonly called ”sideboards”, to limit the ability of participants eligible for this Program to harvest fish in fisheries other than the Central GOA rockfish fisheries. 10. Created a monitoring and enforcement mechanism to ensure that harvesters maintain catches within their annual allocations and will not exceed sideboard limits.

In 2007, QS was initially awarded and attached to 62 distinct LLP licenses, 47 of which were catcher processor licenses and 15 of which were catcher vessel licenses. LLP holders formed 7 catcher vessel harvesting cooperatives in each year 2007, 8, and 9; and 8 cooperatives in 2010. Cooperatives may transfer primary species allocation to other cooperatives.

The authorizing statute will expire after 2011; following a Council recommendation, NMFS is developing implementing regulations for a successor program.

Capacity Reduction in Non-Pollock Groundfish Fisheries of the Bering Sea and Aleutian Islands Under the Consolidated Appropriations Act of 2005 (Public Law 108-447) and Consolidated Appropriations Act of 2004 (Public Law 108-199), NMFS implemented a capacity reduction program pursuant to applicable provisions of the MSA (15 U.S.C. 1861a(b-e)). The program reduced current and future effort in the non-pollock groundfish fisheries in the BSAI through a ”buyback” program to retire vessels, licenses, and vessel histories. The legislation provided for a total loan of up to $75 million and authorizes specific amounts for four subsectors in the fishery: longline catcher processors, AFA trawl catcher processors, non-AFA catcher processors, and pot catcher processors. A separate program will be developed for each subsector, with the first, for longline catcher processors, in effect. The objective of the program is to achieve a permanent reduction of capacity to: increase post-reduction harvester’s productivity, help financially stabilize the fishery, and help conserve and manage fishery resources

On September 29, 2006, NMFS published the final rule in the Federal Register (71 FR 57696) to implement this buyback program. On January 5, 2007, the Freezer Longline Conservation Cooperative (FLCC) submitted their Fishing Capacity Reduction Plan (Plan) to the NMFS Financial Services Division. The Plan included four (4) formal offers for catcher processor groundfish licenses that would be removed from the fishery, and that the FLCC members had selected. The 4 offers included three (3) active fishing licenses that were associated with 3 catcher processor vessels. The fourth offer was that of an inactive license, with no vessel associated with the license. The total amount of the government loan was $35 million, to be repaid over a thirty (30) year period using a percentage of future fish landings of BSAI Pacific cod.

On March 16, 2007 NMFS approved the FLCC’s plan. On March 21, 2007, NMFS issued ballots to the voting members of the FLCC to vote in a referendum to determine industry support of the fishing capacity reduction loans. On April 6, 2007, voting in the referendum was completed, with 87 percent participation in the referendum. Thirty-four (34) voters cast ballots, unanimously in favor of the reduction plan. Therefore, the referendum was successful, and the referendum voters approved the repayment fees for the $35 million fishing capacity reduction loan.

On April 26, 2007, NMFS issued a payment tender notice in the Federal Register (72 FR 20836), and provided thirty (30) days for public notice before tendering payment. On May 29, 2007, NMFS disbursed payments to the owners of the 4 fishing licenses that were being relinquished as part of the reduction capacity program. In exchange for payment, the owners relinquished their fishing licenses, reduction privilege vessels where appropriate, and fishing histories.

Amendment 80 The Council adopted Amendment 80 in June, 2006 to meet the broad goals of: (1) improving retention and utilization of fishery resources by the non-AFA trawl catcher/processor fleet by extending the groundfish retention standard (GRS) to non-AFA trawl catcher/processor vessels of all lengths; (2) allocating fishery resources among BSAI trawl harvesters in consideration of historic and present harvest patterns and future harvest needs; (3) authorizing the allocation of groundfish species to harvesting cooperatives and establishing a limited access privilege program (LAPP) for the non-AFA trawl catcher/processors to reduce potential GRS compliance costs, encourage fishing practices with lower discard rates, and improve the opportunity for increasing the value of harvested species; and (4) limiting the ability of non-AFA trawl catcher/processors to expand their harvesting capacity into other fisheries not managed under a LAPP.

In response to requirements of the Consolidated Appropriations Act of 2005 (Public Law 108-447) on September 14, 2007 NMFS published a Final Rule in the Federal Register with regulations to implement Amendment 80 to the FMP for the BSAI (72 FR 52668). Under this Amendment, vessels owned, and/or LLP licenses held, by eligible participants were allocated quota for target groundfish species, based on historic participation. Including combinations of allocated species and fishing areas, there are a total of 11 quota categories. Quota holders annually receive pound allocations based on quota holdings, and can elect to form harvesting cooperatives or participate in a limited access fishery. Cooperatives and the limited access fishery are each allocated amounts of bycatch of Pacific halibut and crab, which are prohibited species in groundfish fisheries; inter-cooperative allocation transfers are authorized. Caps limit the amounts of quota a person may hold at any time. Sideboard provisions limit "spillover" effects of this program on other fisheries and required reporting allows NMFS and the Council to monitor the efficacy of the program over time. Regulations list 28 vessels and LLP groundfish licenses that are be designated Amendment 80 vessels and licenses, respectively. The groundfish species in the BSAI directly affected by Amendment 80 include: o Atka mackerel o Aleutian Islands Pacific ocean perch o Flathead sole o Pacific cod o Rock sole o Yellowfin sole In addition, Amendment 80 modified the management of halibut and crab prohibited species catch (PSC) limits.

Amendment 85 At its April, 2006 meeting, the Council took final action to recommend Amendment 85 to the FMP for the BSAI, which would modify the current annual allocations of BSAI Pacific cod (after deductions for the CDQ fishery) among jig, trawl, and fixed gear (hook-and-line and pot) subsectors. The recommended allocations were determined based on a set of historic participation criteria, with consideration for small boats and coastal communities dependent on the Pacific cod resource. The Council also recommended seasonal apportionments for jig and trawl gear and a hierarchy for reallocating projected unused allocations among the various sectors. The number of eligible persons subject to this Amendment would be reduced to the extent that prior capacity reduction programs first reduce the size of the fleet. NMFS has implemented these changes starting in 2008.

Parallel Waters Fisheries At its June, 2009 meeting, the Council took final action on a regulatory amendment package that limits access by federally-permitted pot and hook-and-line catcher processor vessels to the BSAI Pacific cod parallel State waters fishery and precludes those vessels from fishing past the end of the sector closures. The Council's action complements the December 2008 action by the Alaska Board of Fisheries that limits the size of vessels using hook-and-line gear in the BSAI Pacific cod parallel State waters fishery to 58 ft LOA. NMFS is developing implementing regulations which also would require certain license endorsements to participate in these fisheries.

Arctic FMP The Council recommended a new Fishery Management Plan for Fish Resources of the Arctic Management Area (Arctic FMP) and Amendment 29 to the Fishery Management Plan for Bering Sea/ Aleutian Islands King and Tanner Crabs (Crab FMP). The Arctic FMP and Amendment 29 to the Crab FMP, if approved, would establish sustainable management of commercial fishing in the Arctic Management Area and move the northern boundary of the Crab FMP out of the Arctic Management Area south to Bering Strait. The new FMP was established in 2009.

Guided Sport Halibut On March 31, 2007 the Council recommended a moratorium on entry into the guided sport fishery for IPHC areas 2C and 3A, using a control date of December 9, 2005. NMFS published a proposed rule (74 FR 18179, April 21, 2009) with implementing regulations. This sector has been operating under a guideline harvest level (GHL) for several years. For both areas the GHL has been exceeded, in 2C by a substantial amount in the past few years, with future service demand expected to increase. Under the program, NMFS would issue Federal charter halibut permits (CHP) to individual U.S. citizens and to primarily U.S.-owned businesses with historical participation based on required State logbook reporting and State and USCG licensing. These Charter Halibut Permits with be required to be onboard charter vessels carrying halibut anglers in Areas 2C and 3A, starting February 1, 2011. Other program features include: 1. minimum participation tests to receive a license(s); 2. caps on the number of licenses that could be held by a person; 3. transferability of most permits, with a prohibition on permit leasing; 4. permit endorsements for numbers of clients; 5. special licenses to be issued to communities identified under IFQ Amendment 66; and 6. a military hardship provision.

At its October, 2008 meeting the Council adopted a final preferred alternative to replace the current guideline harvest level program for the charter halibut fisheries in Area 2C (Southeast) and Area 3A (Southcentral) with a "catch sharing plan" between the charter sector and commercial setline IFQ fisheries in each of those areas. The purpose of the plan is to establish a clear allocation, with sector accountability, between the charter and commercial setline sectors in each area. Under the plan the Council would request that the International Pacific halibut Commission (IPHC) annually set a combined charter and setline catch limit to which the allocation percentage for each area automatically would be applied to establish domestic harvest targets for each sector. This action also included a component for "guided angler fish" (GAF), under which holders of charter halibut permits could purchase annual IFQ halibut from the commercial fishery for use in individual accounts, to support halibut retention by their guided sport anglers. NMFS is currently drafting implementing draft regulations to implement the allocations and GAF components of the catch sharing plan.

Groundfish Fleet Composition

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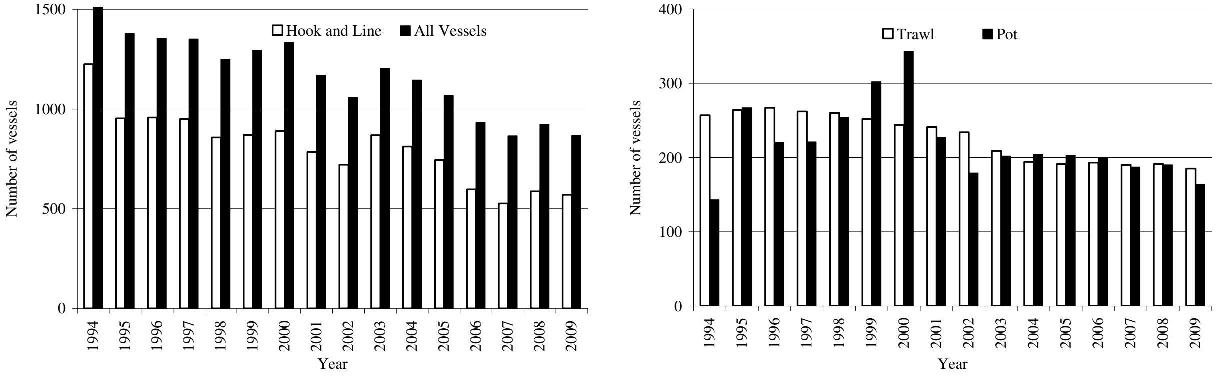
Description of index: Monitoring the numbers of fishing vessels is important to fisheries managers, because it provides big-picture views of both fishing effort and the potential magnitude of effects on industry stakeholders caused by management decisions. Fishing vessels participating in federally-managed groundfish fisheries off Alaska principally use trawl, hook and line, and pot gear. Vessel counts in these tables were compiled from blend and Catch-Accounting System estimates and from fish ticket and observer data.

Status and Trends: The pattern of changes in the total number of vessels harvesting groundfish and the number of vessels using hook and line gear have been very similar since 1994. They both were high in 1994 and then decreased annually through 1998 before increasing slightly in 1999 and 2000, and then declining again in 2001 and 2002. The total number of vessels was about 1,518 in 1994, decreased to 1,250 in 1998, and was 867 in 2009, the most recent year for which we have complete data (Figure 113). Hook and line vessels accounted for about 1,225 and 570 of these vessels in 1994 and 2009, respectively. The number of vessels using trawl gear decreased from 257 in 1994 to 185 in 2009. During the same period, the number of vessels using pot gear peaked in 2000 at 343, decreased to 179 in 2002, increased again to 204 in 2004, and then decreased to 164 in 2009.



(a) Hook and Line, All vessels

(b) Trawl, Pot

Figure 113: Number of vessels participating in the groundfish fisheries off Alaska by gear type, 1994-2009.

Factors Causing Trends: The increase, in 2003, in the number of hook-and-line vessels (and, consequently, also in the total number of vessels) results from replacement of the old blend system with the Catch-Accounting System (CAS) as the official estimates of ground fish catch. The new CAS data include the Federal Fisheries Permit numbers of catcher vessels delivering both to motherships and to shoreside processors, making possible a more complete count of participating vessels. The decline in the number of pot vessels between 2008 and 2009 was mostly in the Pacific cod fisheries and possibly reflects lower ex-vessel prices for P. cod in 2009, most likely due to reduced global market demand for cod and to the general economic downturn that began at the end of 2008.

Distribution and Abundance Trends in the Human Population of the Gulf of Alaska

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Distribution and Abundance Trends in the Human Population of the Bering Sea/Aleutian Islands

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