Appendix C

Ecosystem Considerations for 2012

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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
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Eastern Bering Sea Report Card

- The North Pacific atmosphere-ocean system reflected a typical response to La Niña. The atmosphere during **summer 2011 was unusually cold**. If these conditions persist into fall, they would promote the relatively early development of sea ice during the **winter of 2011-12**, which **is predicted to be a neutral to a weak-moderate La Niña**.
- **Sea ice maximum extent was neutral in 2011**.
- The ***Calanus* spp. and euphausiid time series** show significant increases in concentration of large crustacean zooplankton since the recent 2001-2005 warm period. Both time series **showed a small decline in 2010 relative to 2009**, but concentrations remained well above the 2001-2005 levels. This suggests that prey availability for planktivorous fish, seabirds, and mammals continued to be high during the summer of 2010.
- **Thick-billed murre reproductive success on St. George Island was near record low in 2011**, continuing a declining trend since 2009. Most of the loss occured during the egg stage resulting in the lowest hatching success recorded, 0.26 chicks hatched per egg laid.
- **Northern fur seal pup production for St. Paul Island continues a downward trend**. The 2010 pup production estimates for St. Paul and St. George Islands were 8.8% and 1.0% less than the 2008 estimates. In 1916, the northern fur seal population was increasing at approximately 8% per year, while pup production on both islands is currently estimated to be decreasing at 5% per year
- The **area of seafloor habitat disturbed by bottom trawling decreased in 2010** from the previous year. The estimate of 63,249 km^2 was approximately 11% lower than the estimate from 2009.

Foraging guild biomasses were not updated in 2011, but the following summarizes their state through 2010:

- 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.
- 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.
- 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.

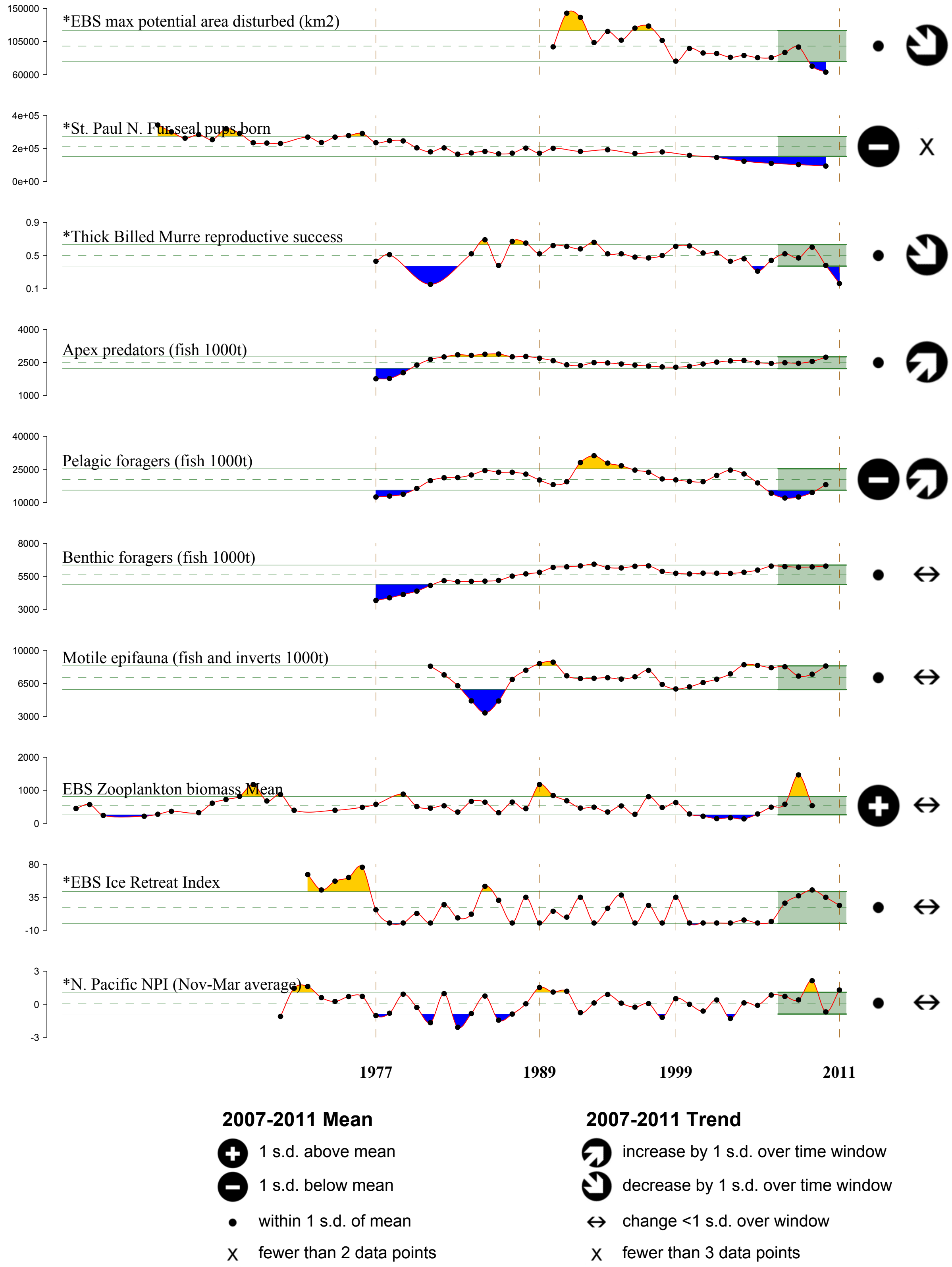

Figure 1: Eastern Bering Sea ecosystem assessment indicators; see text for descriptions. * indicates time series updated in 2011.

Aleutian Islands Report Card

- In 2010/2011, the winter North Pacific Index was positive by more than one standard deviation implying a **weaker Aleutian Low pressure system and less storminess** in the region than average. This is **expected to continue into the winter 2011/2012** due in part to projected la Niña conditions.
- There is an **overall decreasing trend in Pacific cod biomass**, which contributes the largest proportion to the fish apex predator foraging guild. **Arrowtooth flounder, Kamchatka flounder and skates all show an increasing trend**.
- There are several species showing longitudinal trends in the fish pelagic foragers foraging guild: the **biomass of walleye pollock increases towards the east**, whereas that of **northern rockfish and Pacific ocean perch increases towards the west**.
- **Fishing patterns have recently changed throughout the system**, largely in response to increased protection for Steller sea lions, although the final impacts to individual fishing sectors are currently unknown.
- In general, **school enrollment numbers** in the Aleutian Islands region have been **on the decline in the small village schools**, possibly indicating that communities with year-round residents that experience direct interactions with the ecosystem through residential and subsistence activites are faring poorly.

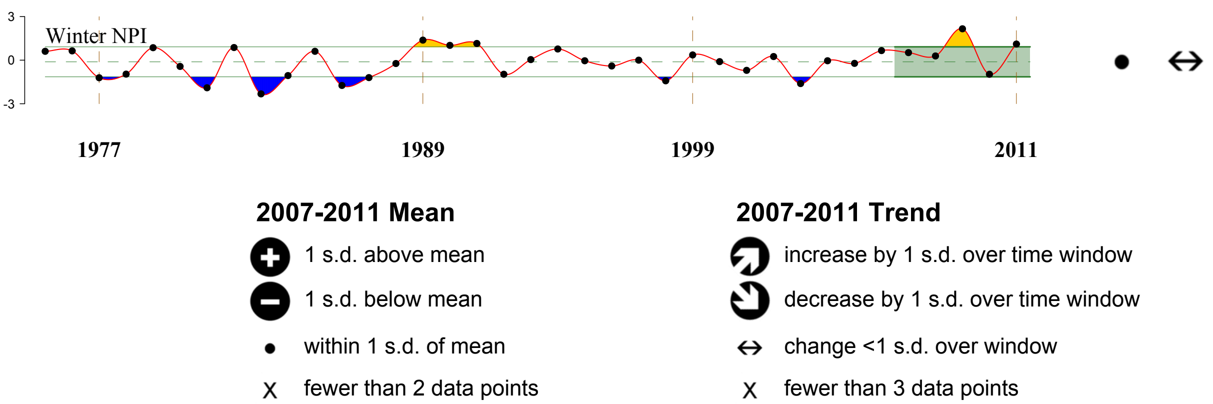

Figure 2: The winter North Pacific Index time series.

Western Ecoregion

- **Reproductive success of planktivorous auklets have been higher than average** for the past five years. Given the negative correlation between the strength of the Aleutian Low and planktivorous seabird productivity, we **anticipate continued favorable conditions** for auklets in this ecoregion.

- The **increase in the fish apex predators foraging guild** apparent in the 2010 trawl survey is driven by Pacific cod, reversing the declining trend in this foraging guild since 2000.
- The **pelagic fish foraging guild biomass has increased** since the last survey in 2006. Pollock, Pacific Ocean perch, northern rockfish, and Atka mackerel all contributed to this trend.
- Recent counts of **otters show no trend**, in contrast to the steep decline during the early 2000s.
- Steller **sea lions continue their decades-long decline** in this ecoregion. Between 1991 and 2008, non-pup counts declined 81%, or at a rate of -10% per year.
- The **amount of area trawled declined dramatically** this year due to recent measures aiming at increasing protection for Steller sea lions.

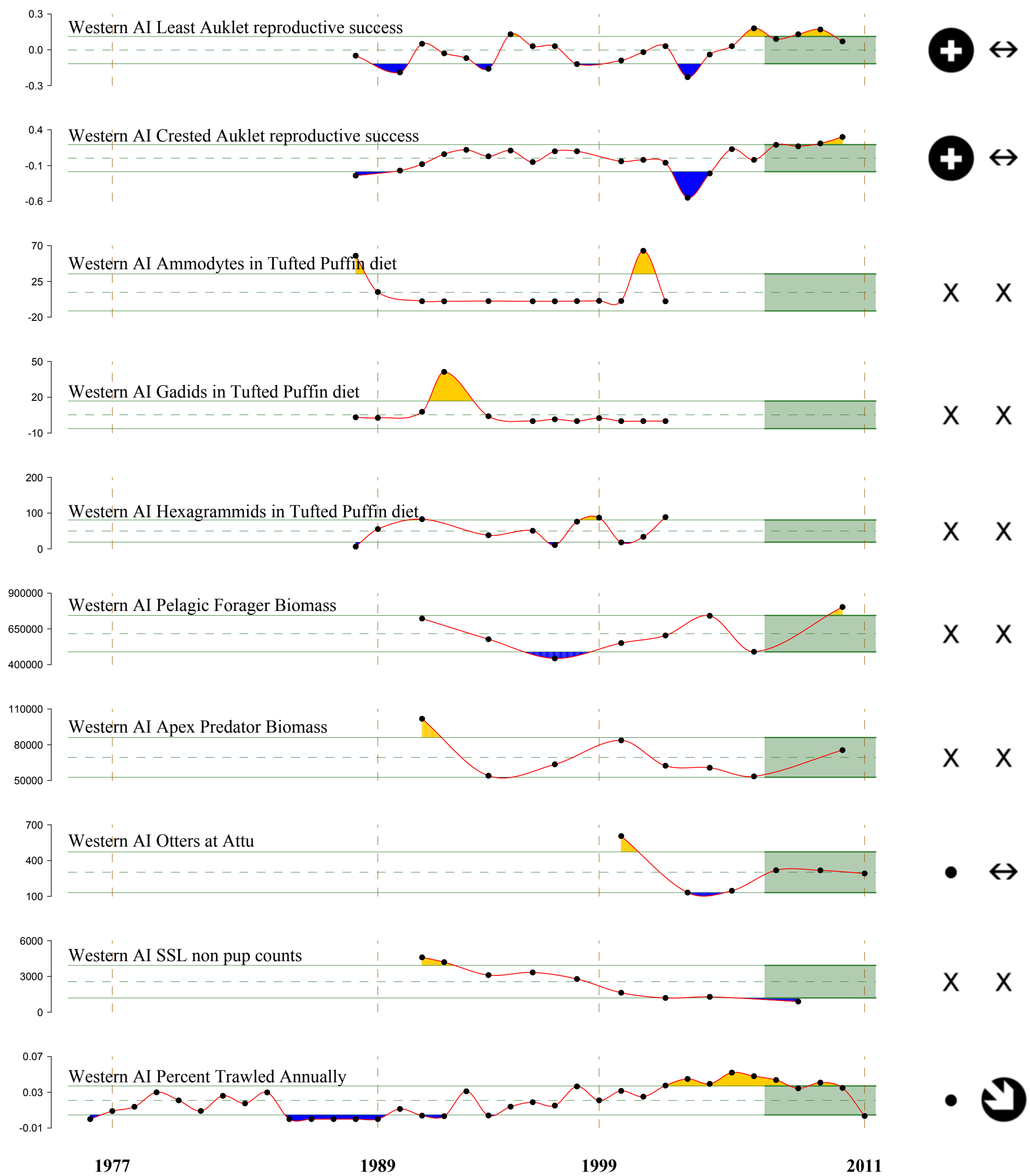

Figure 3: Western Aleutian Islands ecoregion indicators. See Figure 20 for legend.

Central Ecoregion

- Recent trends in auklet reproductive success are unknown but the **predicted continued positive state of the NPI indicates favorable foraging conditions for planktivorous auklets**.
- The **declining fish apex predator trend** is largely driven by Pacific cod. Kamchatka flounder contributes the second largest biomass.
- The **pelagic fish foraging guild biomass declined** since the last survey in 2006, although Pacific ocean perch biomass increased.
- Recent counts of sea **otters continue to decline**.
- **Counts of non-pup Steller sea lions declined** 33% overall between 1991 and 2008, a rate of -2% per year.
- **School enrollment has shown no trend** in recent years, following a decline since peak enrollment in 2000.

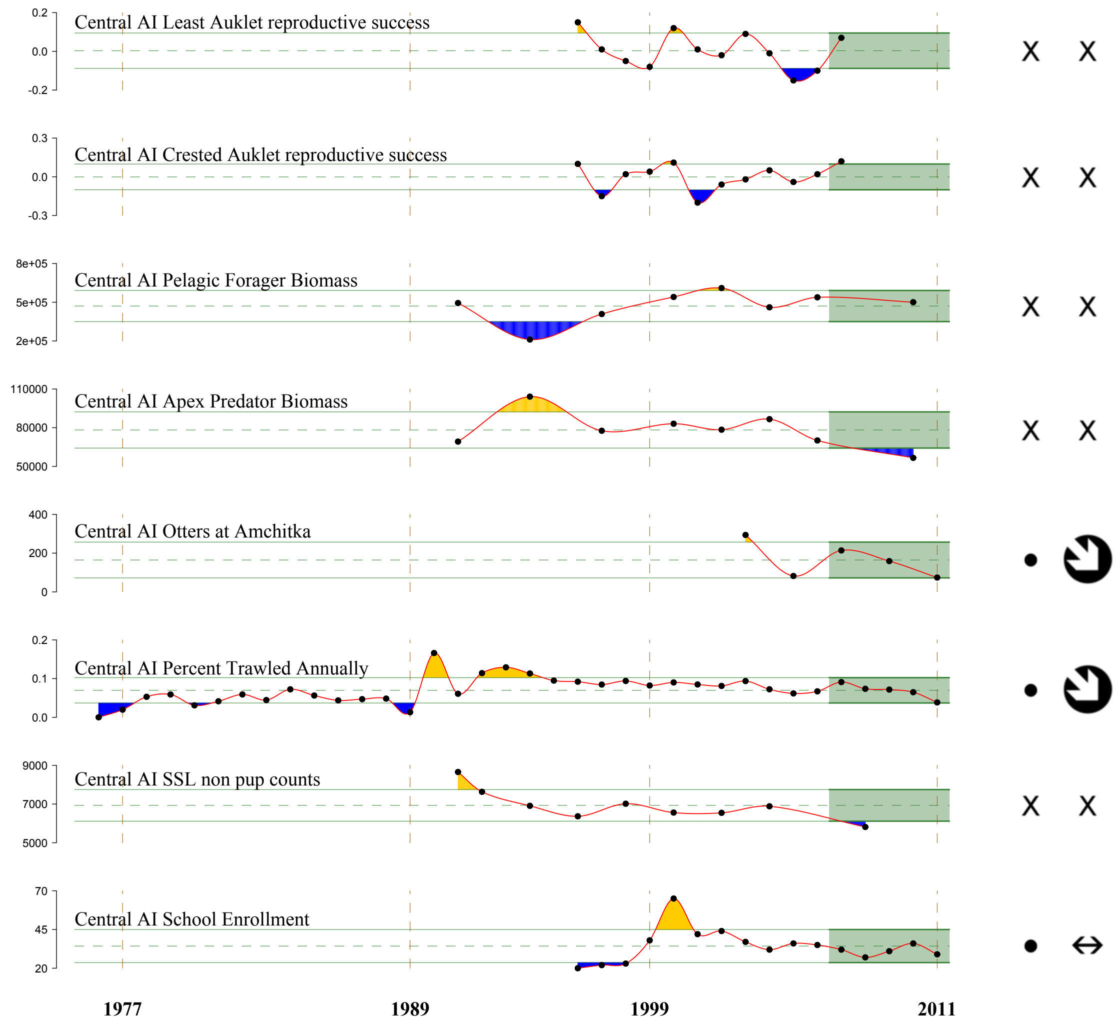

Figure 4: Central Aleutian Islands ecoregion indicators. See Figure 20 for legend.

Eastern Ecoregion

- Although **recent forage fish data are not currently available**, puffins have shown opposite trends in relative abundances of gadids and *Ammodytes* in prey brought back to feed chicks. These patterns suggest puffins are responding to changes in forage fish availability.
- **Fish apex predator biomass declined** relative to past surveys. This trend is driven by arrowtooth flounder jointly, which alternates with Pacific cod as the largest biomass in the area.
- The **fish pelagic forager biomass increased**, but remained below the peak value in 2004. Pollock, Atka mackerel, and Pacific ocean perch all contributed to this trend, but only on the northern side of the islands for Atka mackerel.
- In contrast to the other ecoregions, **non-pup counts of Steller sea lions increased** 21% overall between 1991 and 2008. Counts were largely stable through the 1990s, but increased at a rate of 3% per year between 2000 and 2008.
- **School enrollment has fluctuated** in this ecoregion, but has shown no overall trend in the past five years.

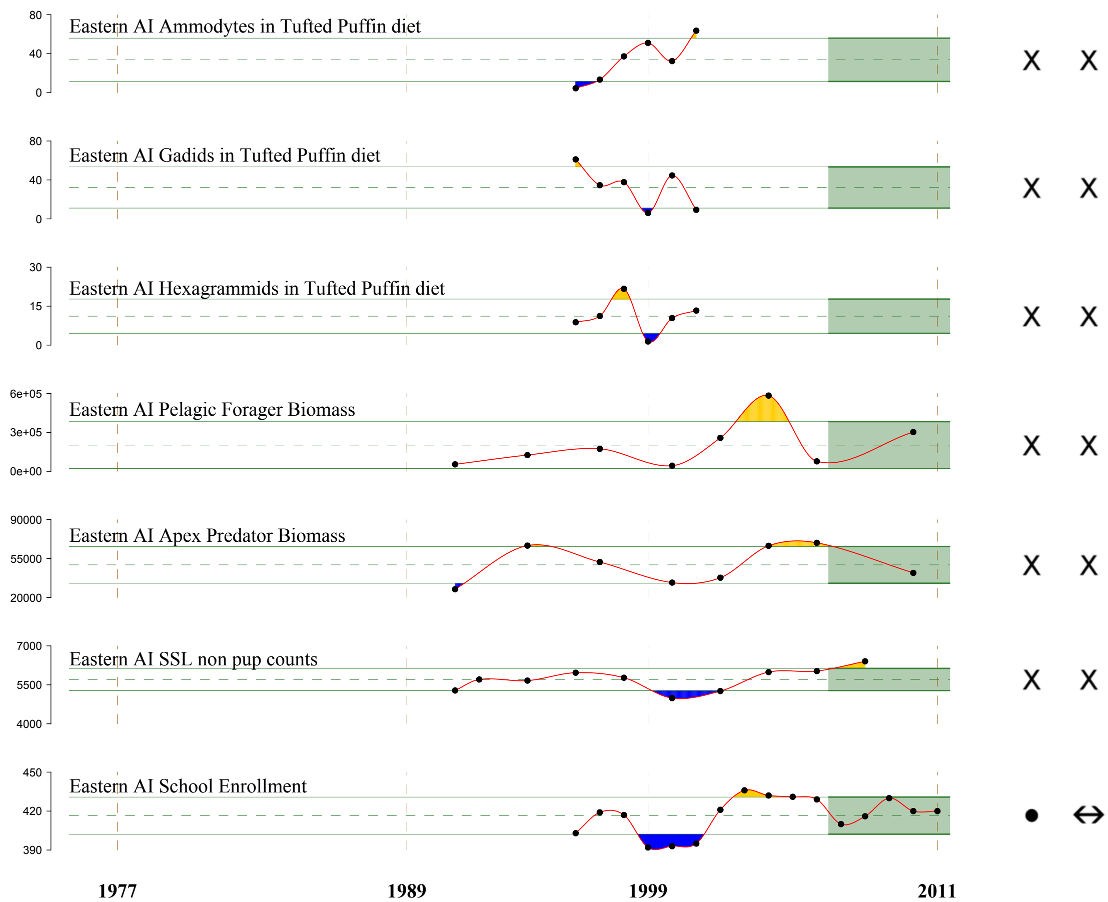

Figure 5: Eastern Aleutian Islands ecoregion indicators. See Figure 20 for legend.

Executive Summary of Recent Trends

Physical and Environmental Trends

- The state of the North Pacific atmosphere-ocean system during 2010-2011 reflected the typical response to La Niña. The Aleutian low was much weaker than usual in the winter of 2010-11, and the sea level pressure was higher than normal in the eastern portion of the basin for the year as a whole (p. 101)
- Cooler than normal upper ocean temperatures prevailed in the eastern portion of the North Pacific and warmer than normal temperatures occurred in the west-central and then central portion of the basin. This pattern reflects a negative sense to the Pacific Decadal Oscillation (PDO) (p. 101)
- Near-normal conditions are present in the tropical Pacific at the current time; the models used to forecast ENSO are indicating outcomes for the winter of 2011-12 ranging from a neutral to a weak-moderate La Niña state (p. 101).

Arctic

- The tendency for reduced sea ice cover in the Arctic during the summer has continued into 2011. The areal coverage in July 2011 was even less than in July 2007, and hence the lowest in the historical record (p. 101).
- It has become clear that the reduced ice cover at the end of the melt season tends to delay the development of ice in marginal seas such as the Bering Sea during the following cold season (p. 101).

Bering Sea

- The Bering Sea shelf experienced another relatively heavy ice year, but not as extreme as those of 2008-09 and 2009-10 (p. 101).
- The average bottom temperature during summer was nearly a degree warmer than 2010 and equal to the grand mean from 1982 to 2011. However, the surface temperature continued to be much lower than the long term mean, reflecting the unusually cold atmospheric conditions during July and August (p. 113).
- Maximum sea ice extent was neutral (p. 109).
- The most important aspects of the physical environment in the eastern Bering Sea during 2011, despite the relatively neutral weather and sea ice conditions during winter and spring, was that cool fall 2010 temperatures and a newly seen cold summer did not allow the multi-year sequential continuation of cold ocean temperatures to come to an end(p. 109).
- The summer of 2011 was relatively cold and stormy (p. 101, 109).
- If cold upper ocean conditions persist into fall, they would promote the relatively early development of sea ice during the winter of 2011-12 (p. 101).

Gulf of Alaska

- The poleward branch of the Alaska Current in the southeastern portion of the Gulf declined considerably over the last 18 months since its peak in the winter of 2009-10. This change is presumably due, at least in part, to the anomalous northerly and northwesterly winds over the interval (p. 101).
- The mixed layer depths in the Gulf have been near their seasonal norms (p. 101).
- Eddy Kinetic Energy (EKE) levels were very low in both NGOA and off Kodiak in 2009 and higher 2010. EKE in both regions was approximately average for the first six months of 2011 (p. 116).
- The pattern in water temperatures was generally similar to the pattern seen during the 2009 survey. East of 160W, the water column was stratified with relatively warm near-surface waters and temperatures rapidly dropping to 6 C or less in the upper 50 meters. West of 160W, near surface temperatures (<50 m) were much cooler and deeper waters were generally warmer than further east with a prominent inversion pattern noted at most stations.
- Phytoplankton biomass was probably more tightly confined to the shelf during 2009 due to the absence of eddies, while in 2007 and 2010, phytoplankton biomass likely extended farther off the shelf (p. 116).
- 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. 116).
- PAPA trajectory index trajectories fan out northeastwardly toward the North American continent except for the 2010 trajectory, which resulted in the westernmost trajectory endpoint for the entire set of model runs (1902-2011) (p. 119).

Alaska Peninsula and Aleutian Islands

- Westerly wind anomalies have prevailed in this region during the past year, except during spring 2011. These anomalies have served to suppress the northward transport through Unimak Pass and perhaps also the Aleutian North Slope Current (p. 101).
- The wind anomalies during spring 2011 were weak, but since they were easterly they would have acted to enhance upwelling during that season along the north side of the Alaska Peninsula and Aleutian Islands (p. 101).
- Particularly strong eddies were observed south of Amukta Pass in 1997/1998, 1999, 2004, 2006/2007, and 2009/2010. Eddy energy in the region has been low from the spring of 2010 through the first 6 months of 2011 (p. 123).
- 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 since spring of 2010 (p. 123).

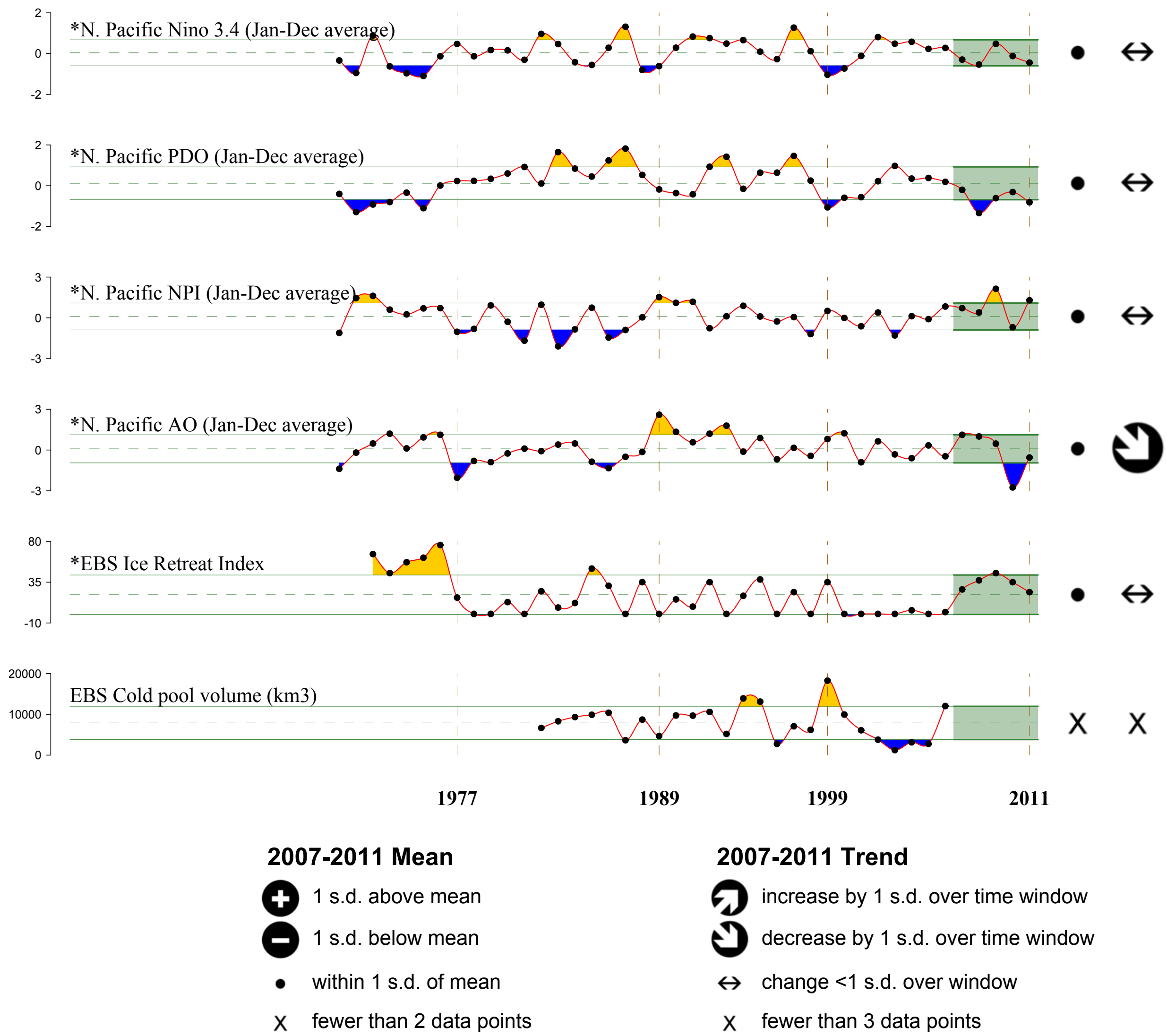

Figure 6: North Pacific and Eastern Bering Sea climate indices. *Time series updated in 2011.

Ecosystem Trends

Bering Sea

- EBS trawl survey structural epifauna showed variable trends: sea anemones may be increasing, while sponges and seapens were higher than in 2010 (p. 128).
- During 2003-2009, highest phytoplankton biomass was observed in the Outer shelf near the Pribilof Islands, and in the south Inner shelf. Lowest biomass was observed in the north Bering and SE Middle shelf (in a region of high stability). Larger phytoplankton were seen on the Inner shelf and near the Pribilofs. Smaller phytoplankton were seen on the SE Middle shelf (an area of lower total chla), and in the Outer shelf (an area of higher total chla) (p. 133).
- In the south Bering Sea, phytoplankton biomass and mean size of assemblages were higher in warm (03-05) than in cold (06-09) years on the Middle shelf. This trend was not observed in the north Bering Sea (p. 133).
- Both large copepod and euphausiid time series show a large increase since 2001-2005 ("warm years") , with the copepod increase lagging that for euphausiids. Both series showed a smaller decline in 2010 but remained well above 2001-2005 levels (p. 59).
- In warm years, the large copepod, *Calanus marshallae*, was in lower abundance than in cold years (p. 137).
- North-south variations in large zooplankton were also observed, with more Cnidaria present in the northern Bering and more polychaeta (in warm years) and pteropods in the southern Bering Sea (p. 137).
- 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 relative CPUE increased slightly in 2010 and 2011, and capelin relative CPUE remained relatively low. 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. 146).
- Reductions in temperature change index values from 2008 to 2011 suggest that conditions have continued to improve for the overwintering survival of pollock and cod from age-0 to age-1 in the Bering Sea. The 2011 temperature change index value and cold year models predict 48,094 million age-1 pollock and 785 million age-1 cod for 2011 (p. 167).
- Walleye pollock has dominated observed fluctuations in total groundfish biomass, particularly the decreased biomass in recent years(p. 160).
- 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. 160).
- The north-northeast wind drift pattern for 2011 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. 165).
- Jellyfish relative CPUE during summer 2011 was nearly doubled that of 2009 and 2010 (p. **??**).
- During 2010, combined jellyfish species biomass nearly doubled compared to the previous highs of 2004 and 2005. The prominent species, *C. melanaster* continued to increase in 2010, tripling its WPUE compared to 2009. During 2006-2009, biomass of all other species remained low in comparison to previous levels in 2004 and 2005, suggesting the trend for the area has shifted from multiple species to a single species dominant catch (p. 174).

- Eelpouts, poachers, and sea stars show broadly similar time trends in trawl survey CPUE, but no outstanding changes for 2011 (p. 176).
- Species richness and diversity on the Eastern Bering Sea shelf have undergone significant variations from 1982 to 2010. Richness (the average number of species per haul) increased by one to two species from 1995 to 2004 and has remained relatively high since then. 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 (p. 197).
- Total trawl survey CPUE in the EBS shows an apparent long-term increase from 1982-2005, followed by a decrease from 2005 to 2009 and an increase in 2010. 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. 200).
- A new multivariate seabird index based on 5 seabird species breeding on the Pribilof Islands from 1996-2010 explained 65.6% of the variance in reproductive data. Time series analysis indicate that both prey supply (as measured by age-1 pollock CPUE and recruitment) and bottom temperatures may influence seabird reproductive activity, although the effects may not been seen until the following 1-2 years (p. 189).
- Northern fur seal (listed as depleted under the MMPA) pup production on both Pribilof Islands is estimated to be decreasing at approximately 5% per year (p. 187).

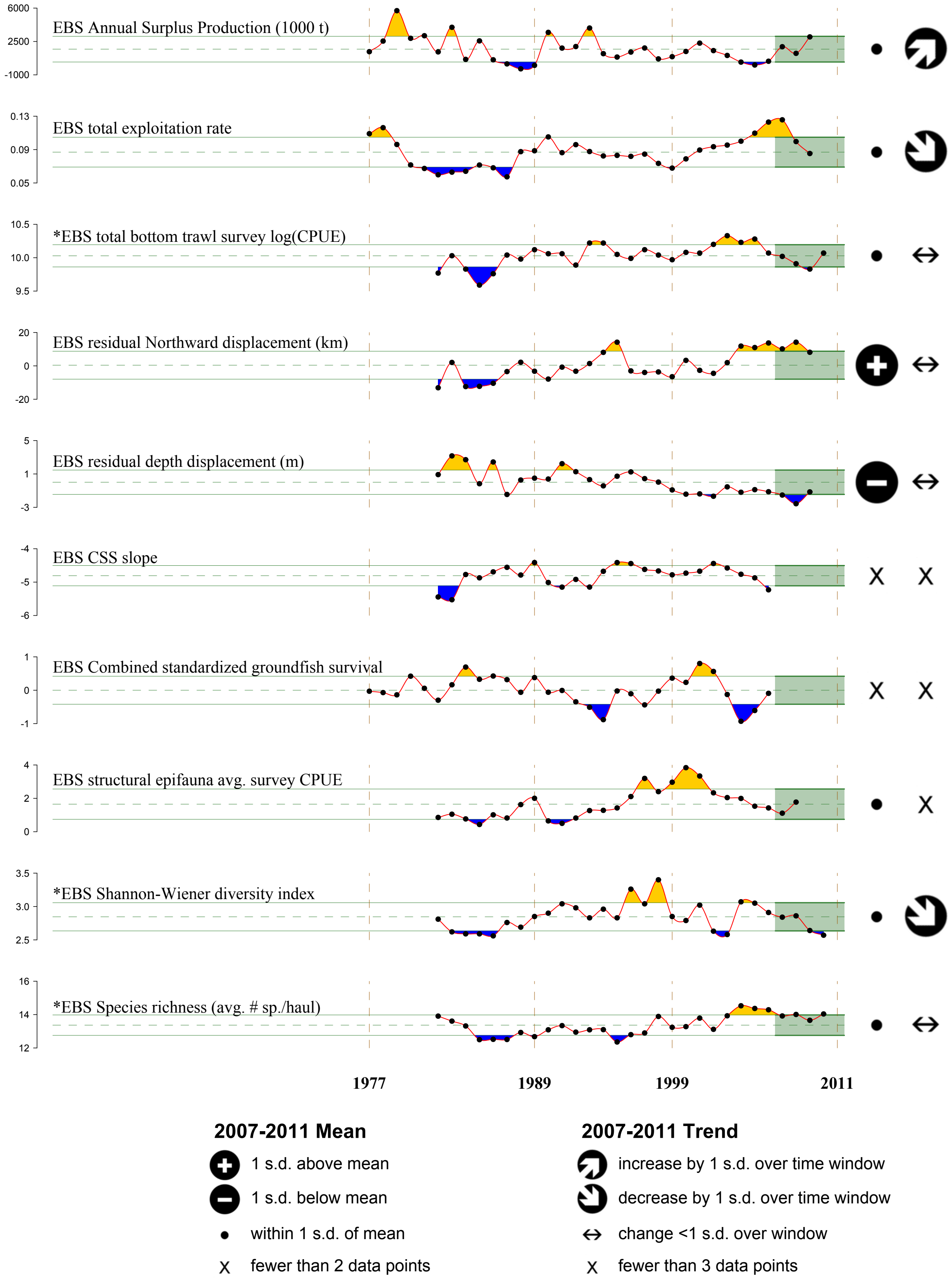

Figure 7: Eastern Bering Sea ecosystem indices. *Time series updated in 2011.

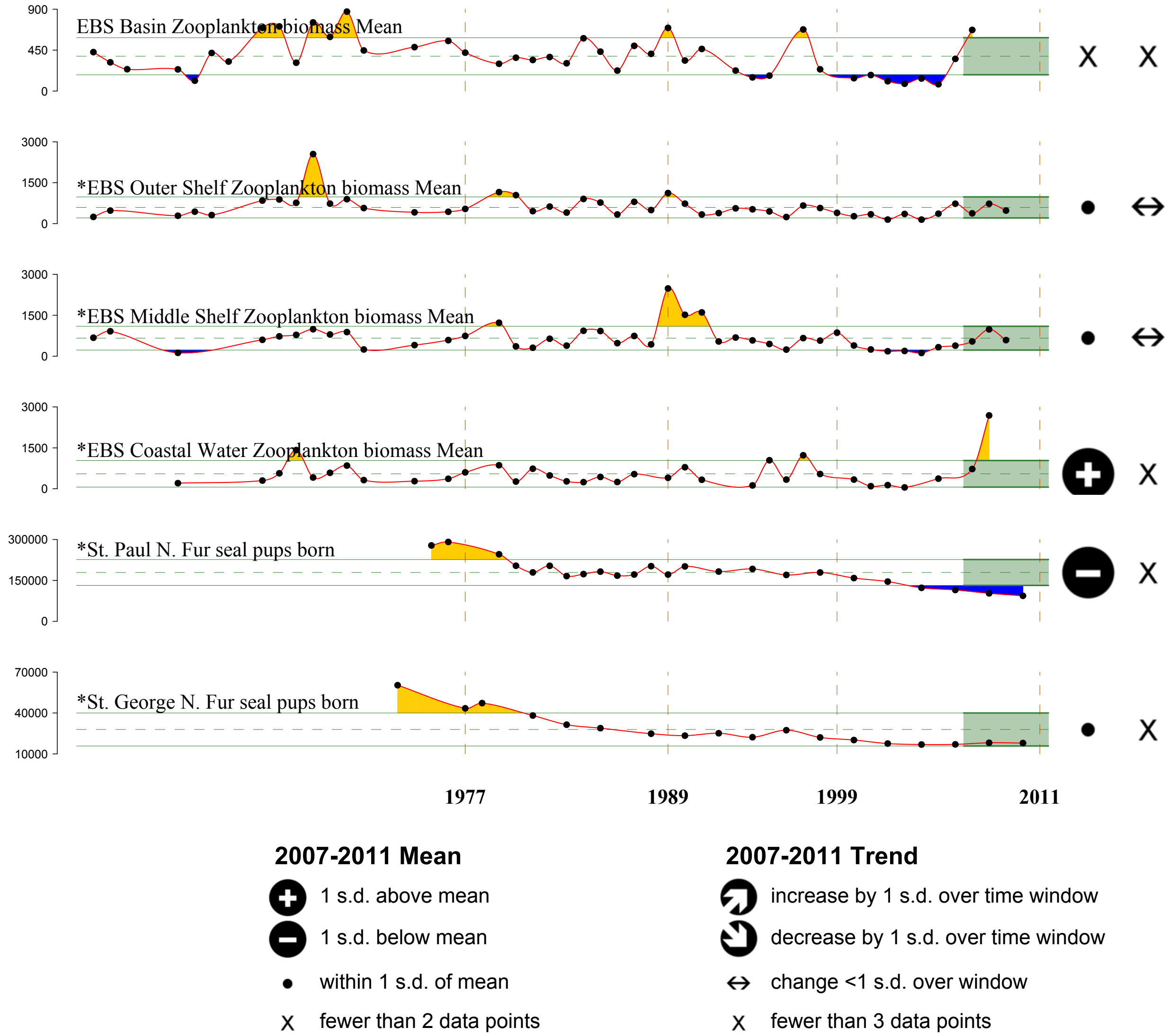

Figure 8: Eastern Bering Sea ecosystem indices. *Time series updated in 2011.

Gulf of Alaska

- Eddy kinetic energy (EKE) levels were very low in both regions in 2009 and higher 2010. EKE in both regions was approximately average for the first six months of 2011(p. 116)
- Within year spatial patterns in chlorophyll a were apparent during a new annual survey off the Alexander Archipelago in 2010. Elevated concentrations of chla were found north of Cross Sound in spring and summer, and north of the entrance to Chatham Strait during summer (p. 136).
- The seasonal cycle of mesozooplankton biomass in the eastern North Pacific during 2010 was average in terms of timing and duration of season. Mesozooplankton community analysis identified transition years: 2003 transitioning from cold to warm, 2006 transitioning from warm to cold, and neutral years in 2009 and 2010 (p. 143).

- 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. 160).
- 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. 160).
- Arrowtooth flounder, flathead sole, and other flatfish continue to dominate the catches in the ADF&G Kodiak trawl survey. A decrease in overall biomass is apparent from 2007 to 2008 from years of record high catches seen from 2002 to 2005. In 2010, above average anomaly values were recorded for both inshore and offshore skates, and Tanner crabs, while arrowtooth flounder, flathead sole, and Pacific cod have decreased to below average values (p. 177).
- Forage species catch rates in small mesh surveys remain at low levels, one to two orders of magnitude lower than peak values observed in the 1970s and early 1980s. The exception to this trend is eulachon. In recent years including 2010, it has had the highest catch rates of the time series (p. 180).
- 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. 200).

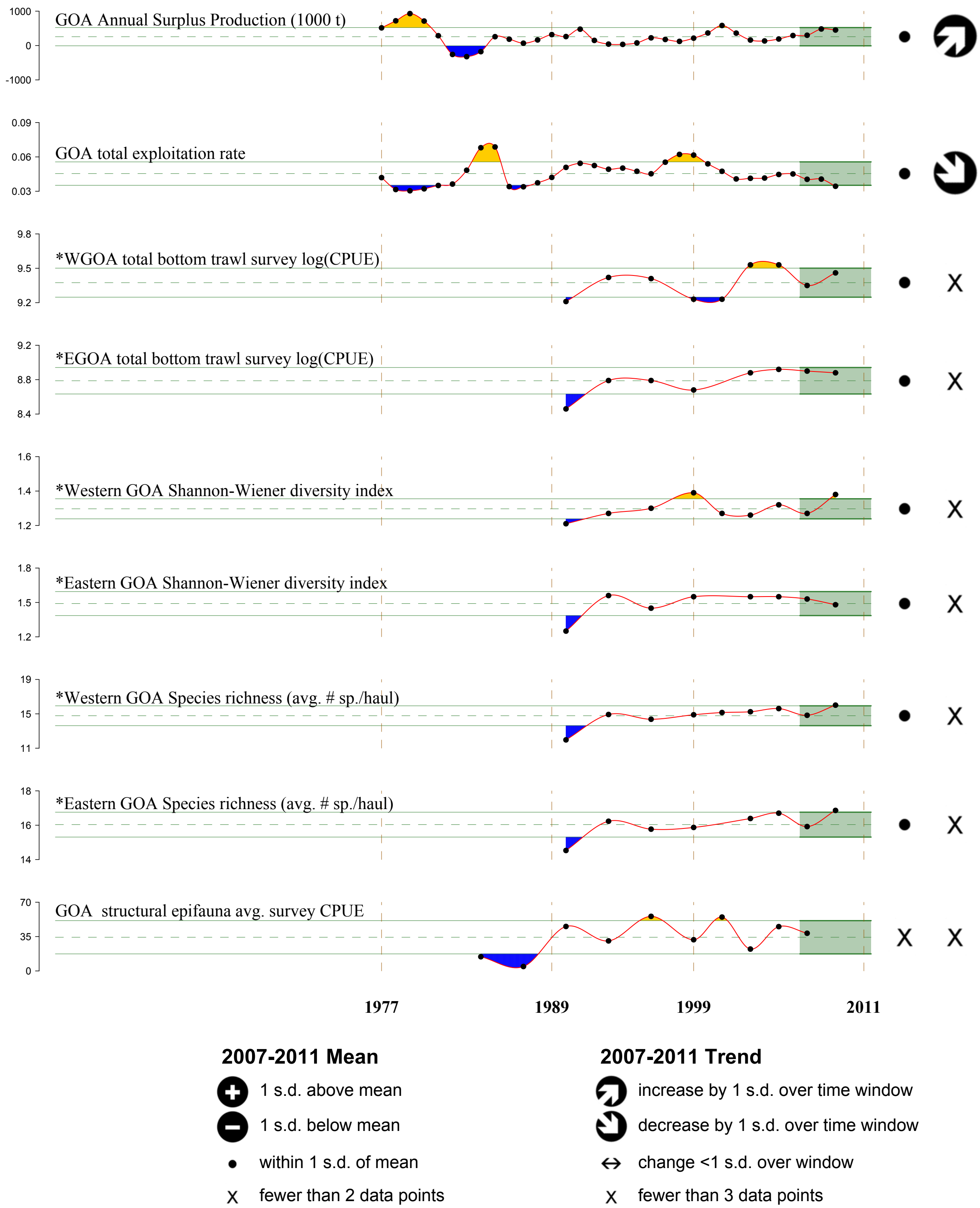

Figure 9: Gulf of Alaska ecosystem indices. *Time series updated in 2011.

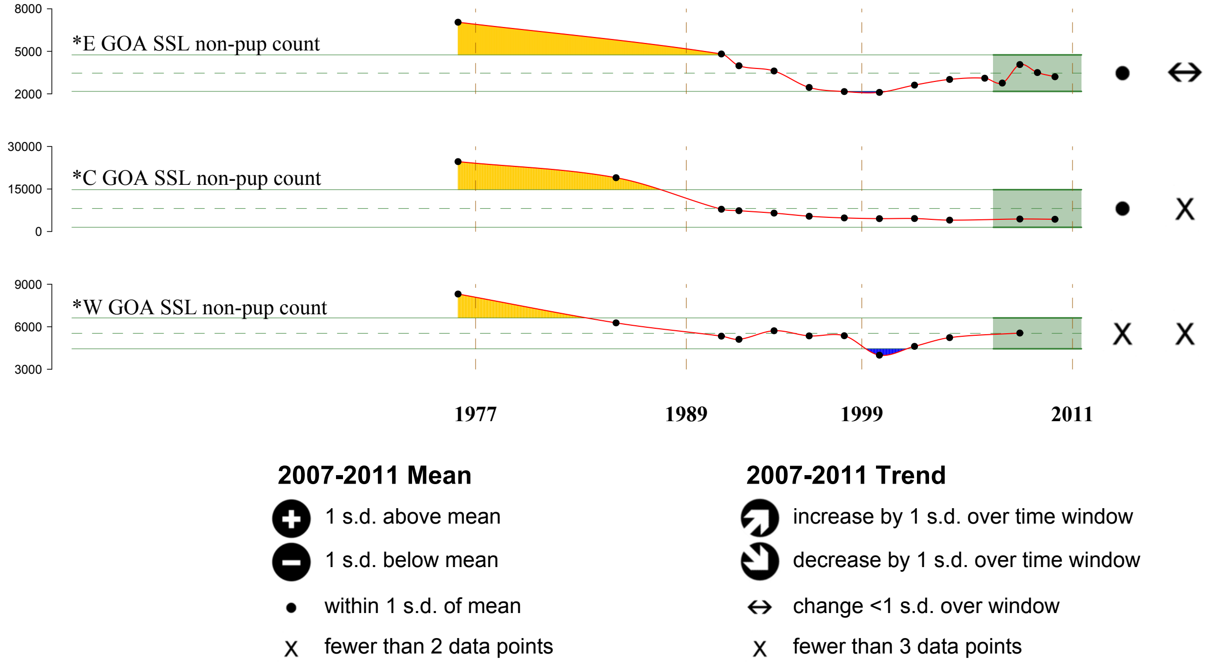

Figure 10: Gulf of Alaska ecosystem indices. *Time series updated in 2011.

Aleutian Islands

- There is an overall decreasing trend in Pacific cod biomass, which contributes the largest proportion to the fish apex predator foraging guild. Arrowtooth flounder, Kamchatka flounder and skates all show an increasing trend.
- There are several species showing longitudinal trends in the fish pelagic foragers foraging guild: the biomass of walleye pollock increases towards the east, whereas that of northern rockfish and Pacific ocean perch increases towards the west.
- In the Western ecoregion, reproductive success of planktivorous auklets have been higher than average for the past five years. The increase in the fish apex predators foraging guild apparent in the 2010 trawl survey is driven by Pacific cod, reversing the declining trend in this foraging guild since 2000. Recent counts of otters show no trend, in contrast to the steep decline during the early 2000s. Steller sea lions continue their decades-long decline in this ecoregion. Between 1991 and 2008, non-pup counts declined 81%, or at a rate of -10% per year (p. 65).
- In the Central ecoregion, the fish apex predator trend is also largely driven by Pacific cod. Kamchatka flounder contributes the second largest biomass. Atka mackerel and Pacific ocean perch drive the biomass trend, making up 80% of the pelagic foragers biomass, with the remaining split between walleye pollock and northern rockfish. Recent counts of sea otters continue to decline. Counts of non-pup Steller sea lions in the central Aleutians declined 33% overall between 1991 and 2008, a rate of -2% per year (p. 65).
- In the Eastern ecoregion, fish apex predator biomass declined relative to past surveys. This trend is driven by Pacific cod and Arrowtooth flounder jointly, which alternate as the largest biomass in the area. More than half the fish pelagic forager biomass is commonly contributed by walleye pollock and Atka mackerel. Atka mackerel show an increasing trend, but only in the data from the northern

portion of the islands. In contrast to the other ecoregions, non-pup counts of Steller sea lions increased 21% overall between 1991 and 2008. Counts were largely stable through the 1990s, but increased at a rate of 3% per year between 2000 and 2008 (p. 65).

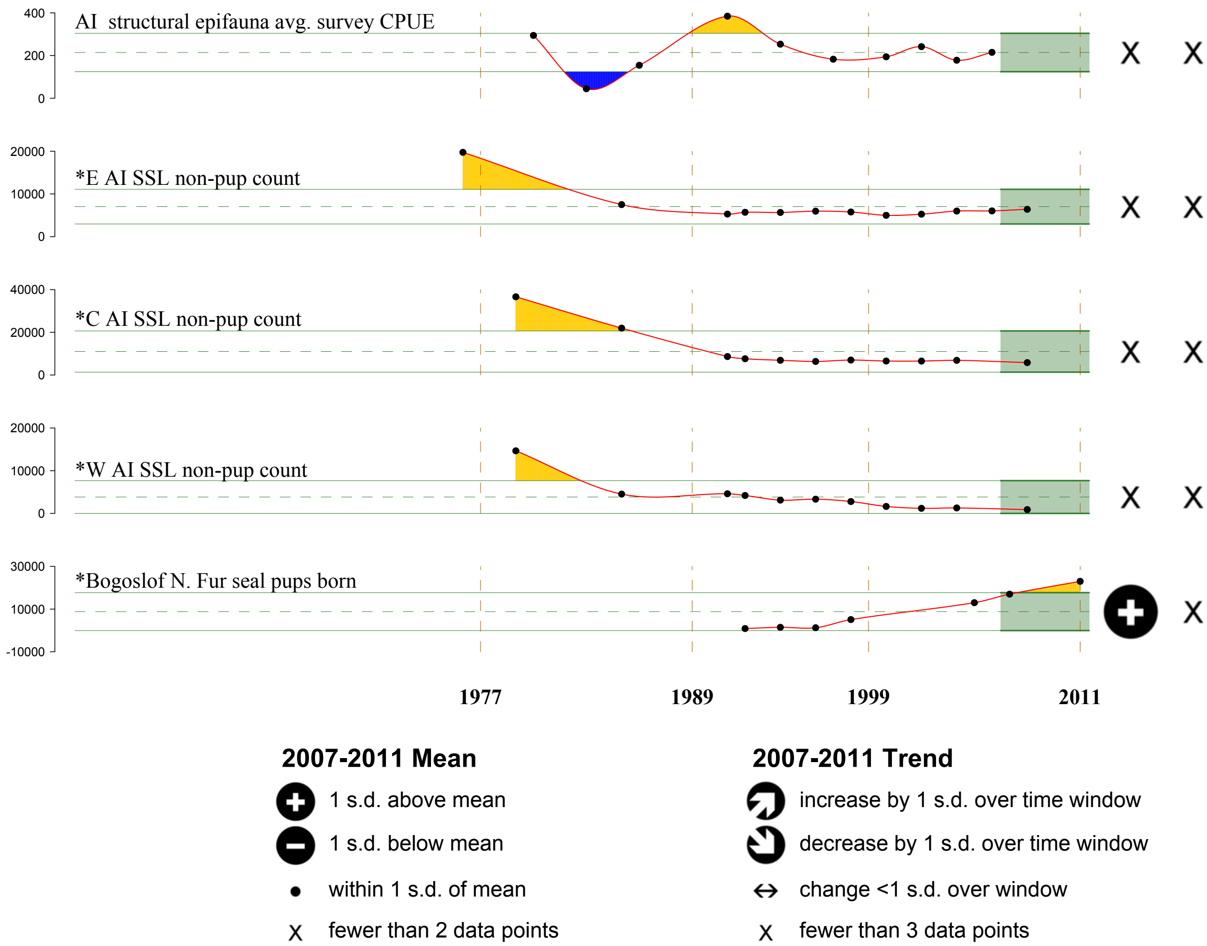

Figure 11: Aleutian Islands ecosystem indices. *Time series updated in 2011.

Fishing and Fisheries Trends

Bering Sea

- At present, 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. Stocks that are considered overfished are Pribilof Island blue king crab and BSAI tanner crab. Currently there is no directed fishing for snow crab, and the majority of blue king crab habitat is closed to bottom trawling (p. 230).
- Fishing effort has been stable in recent years, although pelagic trawl fishing effort has declined (p. 210, 226, 215, 221).
- The catch of non-specified species appears to have decreased overall since the late 1990s. The 2008-2009 increase in non-specified catch was driven by jellyfish. HAPC biota catch has generally decreased since 2004. 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. (p. 204).
- The maximum potential area of seafloor disturbed by trawling had increased slightly in 2007-2008 but continued to decrease in 2010 to below the low point in the time series estimated for 1999 (p. 125).

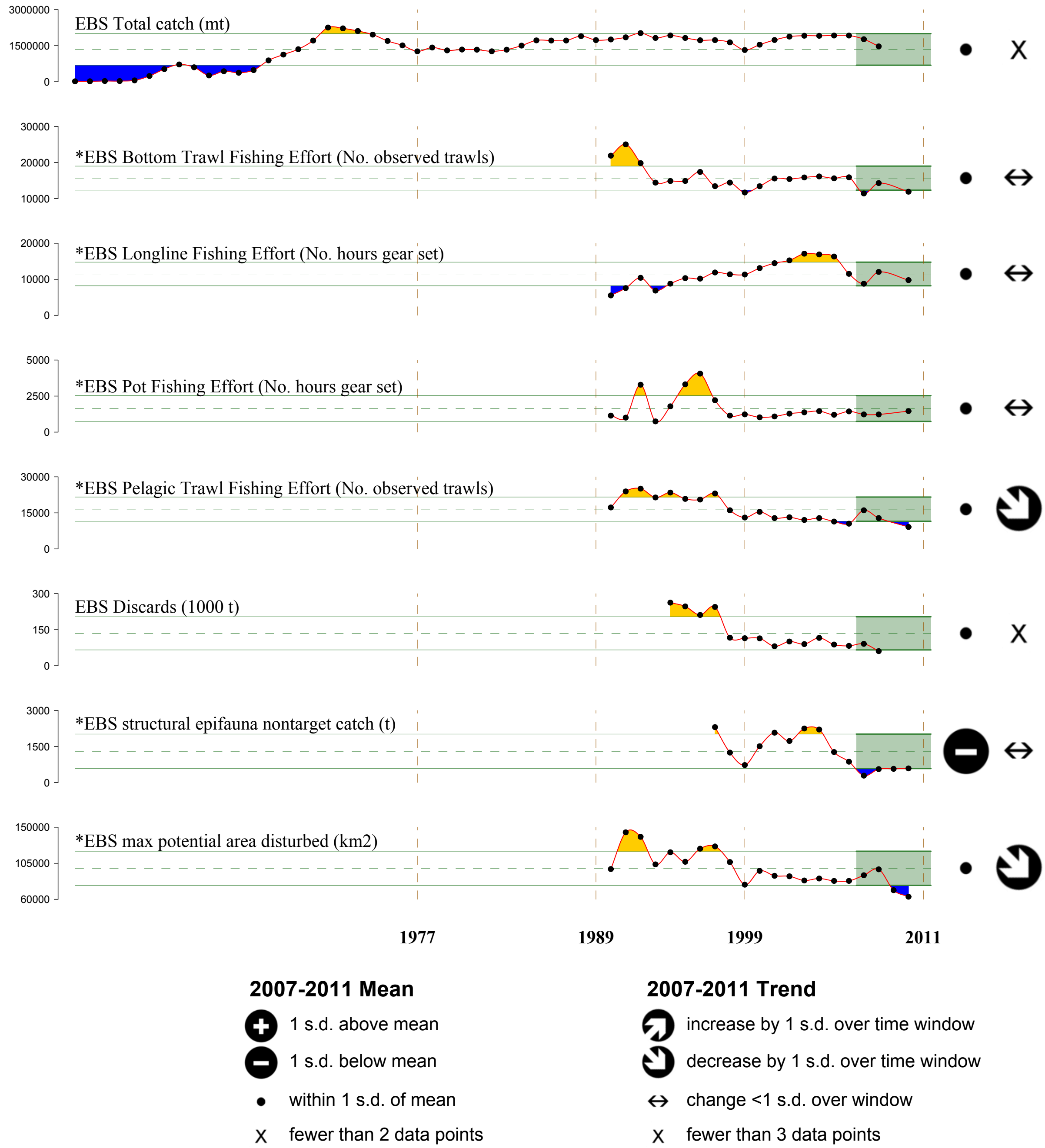

Figure 12: Eastern Bering Sea fisheries indices. *Time series updated in 2011.

Gulf of Alaska

- Bottom and pelagic trawl fishing has remained below the long term mean. Fishing effort with pot gear has declined recently; longline effort is increasing (p. 210, 226, 215, 221).
- Discarded tons of groundfish decreased in 2010, while the discard rate decreased to 10% (p. 204).

- 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. The catch of forage species has undergone large variations, peaking in 2005 and 2008 and decreasing in 2006-2007 and 2009-2010. (p. 204).

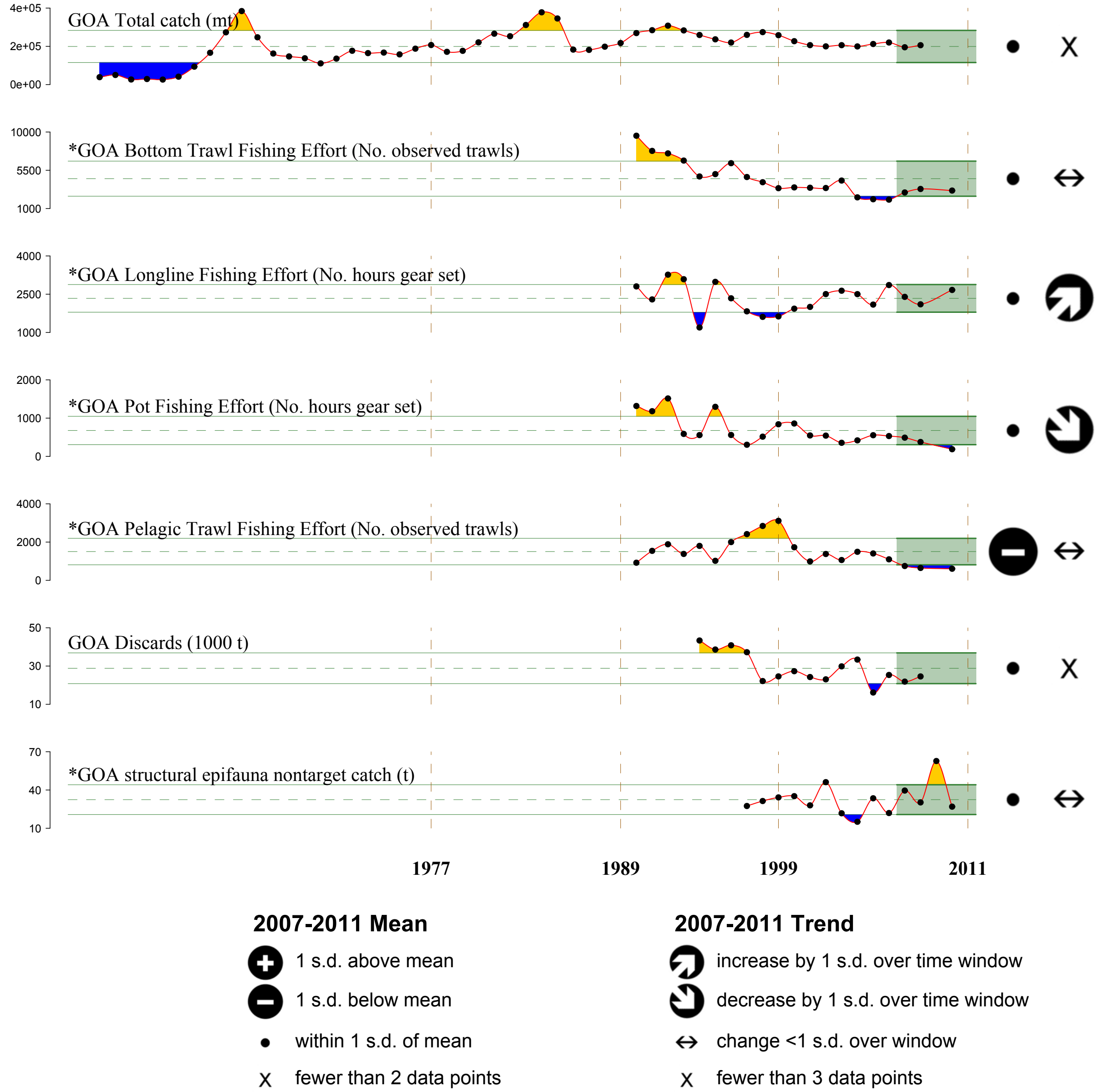

Figure 13: Gulf of Alaska fisheries indices. *Time series updated in 2011.

Aleutian Islands

- Fishing effort by gear type has been stable in recent years, although there was a increase in longline effort (p. 210, 226, 215, 221).

- Discard rates have declined over the past 7 years. Discards and discard rates are much lower now than they were in 1996. (p. 204).
- Catch of non-specified species (primarily grendadiers) shows little trend over time, although the highest catches were recorded in 2009-2010. HAPC 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. (p. 204).

Figure 14: Aleutian Islands fisheries indices. *Time series updated in 2011.

Contents

* indicates contribution updated in 2011
† indicates new contribution

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

December 2011 SSC Comments

Kerim Aydin (NMFS-AFSC) presented updates for the Ecosystem Considerations report to the SSC. The SSC commends the Ecosystem editors and contributors for continued improvement and for their responsiveness to SSC comments. The Eastern Bering Sea Report Card is a particularly useful addition. Regarding other sections, the Ecosystem Trends succinctly put recent trends in context of long-term trends and environmental conditions, and the section on gaps and needs for future EBS assessments identified potential analyses or research goals. New indices include the use of late summer and fall large zooplankton abundance in EBS, fall YOY condition index for age-1 EBS pollock recruitment, a combined juvenile salmon growth and temperature change index for GOA and EBS groundfish. To the extent that predictive models are being developed, they should be moved into each species' assessment.

Thank you. Due to the positive review of the EBS Report Card, we have developed one for the Aleutian Islands which is included here. This Report Card differs in that is is presented in several sections to represent the spatial variability in the system, which was the structuring theme around which the assessment was developed. Our intention is to adapt these Report Cards in future Ecosystem Considerations reports as we further refine the content and format based on feedback from readers.

Some key Plan Team findings include: 1) Bering Sea ecosystem indices for pollock recruitment are up, (ie, copepods, euphausiids, forage fish are all up, predation by arrowtooth flounder is low); 2) AI 2010 surveys indicated ecosystem shifts since 2006 (P. cod and Atka mackerel in particular); 3) the GOA team is looking forward to a synthesis workshop, and the team has identified three hot topics: Chinook salmon bycatch, Cook Inlet Belugas, and the listing of the southern Distinct Population Segment of eulachon (British Columbia to California).

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 Aleutian Islands included in this report. This assessment is the outcome of a workshop that took place on September 28th, during which hot topics were discussed. Due to scheduling changes, the GOA synthesis workshop is planned for winter 2012, during which the suggested hot topics will be evaluated.

For ecosystem indicators, the SSC finds the format helpful with 1) the description of the index, 2) description of the trends, 3) possible explanations of the trend and 4) their implications. However, not all sections conformed to the format, (e.g., the marine mammal section combined 2-4 and did not discuss sections 3 and 4). The figures with time series of indicators are particularly helpful and the legends of the 5 year mean s.d. and trend is appreciated. However, it may be useful to also highlight the historical trend, which often is orthogonal to the 5 year trend, so as not to lose sight of major historical changes

Greater effort was made this year to format all of the ecosystem indicator contributions similarly. Information about the historical trend is implied in the plus or minus icon in the time series figures. These icons compare the most recent 5 year mean to the long term mean. We highlighted the long-term trends more explicitly in the text bullets in the executive summary this year.

The Early Warnings and Hot Topics sections highlight interesting changes and could ultimately be quite useful. The early warning section could be improved by linking the observation to potential management implications. For example, the apparent incursion of GOA skates and spiny dogfish into the Bering Sea was reported but not examined further. In the Hot Topics section the text clearly refers only to the Eastern Bering Sea, but this is not clear in the table of contents; it would be helpful to mention that the Western Aleutian area is the area of major decline for Steller sea lions.

The hot topics in last year's report were developed during the eastern Bering Sea assessment workshops and therefore focused only on the EBS. This year we have included hot topics from all three ecosystems. The hot topics from the Aleutian Islands were chosen by the Aleutian Islands Ecosystem Synthesis Team during the September 28th workshop. In addition, we have included hot topics from the Gulf of Alaska chosen by the editor and from the eastern Bering Sea as suggested by Eastern Bering Sea Ecosystem Synthesis Team members.

The SSC looks forward to the planned spatial investigation of key indices and how distributions of prey species might affect central place foragers such as birds and mammals. The suggested development of these indices by shelf domain is also encouraged.

We did not fully update the eastern Bering Sea assessment this year, but we hope to have a spatial component in the next update. The new Aleutian Islands assessment contained in this report has a spatial component.

The selected indicators are often unique for different regions, but it may be useful to identify a few indicators that are common to all regions (e.g. temperature) that will allow cross-region comparisons. That being said, each region also has distinct features, and some region-specific indicators, e.g. freshwater influx in GOA, would be useful and should be included if possible. A 2009 request from the SSC was that indices be tied to thresholds that might indicate regime shifts. Towards this end, the editors plan a workshop in Spring 2011 to address such links. The SSC encourages the establishment of an Ecosystem Synthesis Team for each of the three major regions

(AI, BS, GOA). The SSC also recommends that the team make an effort to diversify and include more expert opinions in the workshops.

Anne Hollowed, Stephani Zador and others held a workshop in April 2011 that addressed indicators specific to groundfish and crab stocks. During this workshop, discussion focused on methods to incorporate environmental indicators into assessments and specifying which physical, biological or derived indicators could be used in particular assessments. Follow-up work to initiate research identified as highest-priority is in progress. These research projects should aid in the establishment of environmentally-induced thresholds. In terms of regime shifts, this report includes a new contribution that updates Hare and Mantua (2000) to provide indicators of recent community-level variability following climate regime shifts in Alaskan ecosystems. The editor organized an Aleutian Island assessment meeting, which included the establishment of the Aleutians Ecosystem Synthesis Team. Effort was made to increase the diversity of experts on the Team relative to the EBS team by inviting representatives from academia and the non-profit and private sector.

In the Summary Statement section, the SSC encourages a guild approach for seabirds, similar to fish guilds. For seabirds, the authors rely on a diving species and a surface foraging species, but both are primarily piscivorous, and inclusion of a planktivorous guild could be informative. The number of seabird indicators under 'Ecosystem Status and Management Indices (p.172), might, however, be reduced or altered. For example, planktivores are represented by least auklets and northern fulmars, but the latter are not primarily planktivorous nor are they regularly monitored. The proposed addition of sea ducks would contribute a benthic foraging bird guild. On p.61, the authors suggest that for seabirds it would be ideal to have a single multivariate index representing all birds. Any such analysis should consider that piscivores and planktivore seabird species often show opposite trends and a single value might be misleading.

This year, the report will include a new contribution on multivarite seabird indices for the EBS, which incorporates divers, surface-foragers, and a near-shore foraging species. The study authors found similar trends across species and colonies, which indicated that they were good candidates for inclusion in an integrated index. The two simplified indices used for time series analysis investigating relationships with select environmental variables at up to 3 year lags. The new indices are included in the EBS assessment update in this report and to move them into the EBS report card next year to replace the thick-billed murre indicator, pending favorable review by the EBS ecosystem team and council. The inclusion of sea ducks into a benthic foraging guild would be a useful addition. Time series data summarizing trends are not currently available. However, this is an area of active research and will hopefully be available in a book chapter in a couple years.

The sections on Steller sea lions and Pribilof Island seabirds are informative and thorough, but other sections on seabirds and marine mammals are still lacking recent indices beyond 2008; in particular, the section on seabird incidental take was last updated in 2006. This gap is not due to lack of data and should be rectified. Similarly, the time trend in incidental take of prohibited species under Ecosystem Goal: Maintain Diversity (p.189) was last updated in 2007.

Updated seabird incidental take rates have been recently estimated and are included as a new contribution this year. The authors of the contribution on time trends in incidental take of prohibited species are no longer able to update this contribution in this format.

Some guilds used as EBS indicators are dominated by a single species and should probably be split. For example, the pelagic foragers guild is dominated by walleye pollock, primarily because it is the only species with reliable data and with time series data. The forage fish, salmon, and squid lumped into this guild become inconsequential and conclusions could be misleading for the data-poor species. If a major component is ¿x (i.e., 40%), run the index with and without that species to test for sensitivity to the dominant species. Similarly, guilds like the mobile benthic epifauna, are dominated by non-target fish and invertebrates. The SSC again suggests that Ecosystem Teams strive to be consistent in fish foraging guilds in the GOA and EBS.

Due to staff loss, the Ecosystem Team was unable to complete any guild analysis for this report. Analysis for the 2012 report will explore these suggestions.

The section on Fishing and Fisheries Trends was a nice summary of key issues. Related to the trawl data, it might be useful to have a measure of HAPC biota caught as a function of the length of time since that exact location was last trawled, in order to get a sense of regeneration rates.

This comment was passed along to the author. She agrees that it would be useful to have this information, but it is not currently possible to calculate. The observer database records the end location of trawls, and sometimes the start location, but not the trackline. Determining regeration rates would require this information or controlled experiments at specific areas.

In several sections, and particularly for forage species, the authors note that indices are of limited value to managers because sampling is inadequate, and they look towards the GOA Integrated Ecosystem Research Program (IERP) to improve these abundance estimates. However, the authors also acknowledge the high variance in indices of forage abundance, and the GOA-IERP will be limited to two field seasons. The GOA-IERP and related studies will ideally lead to improved long-term monitoring of forage species. Where indicator data are acknowledged to be unreliable, that conclusion is often buried at the end of the species' section. The SSC suggests that deficiencies in data be stated up front or consolidated into a single section. Many indicators have not been updated for several years, and if there are no plans to update a specific indicator, perhaps it should be dropped from the main text body and incorporated into a table that lists indicators that are out of date. The SSC recognizes that the chapter editors depend on people to contribute to the updates, and there may not be any data available. Where data are available, the editors need to remind contributors that these updates are critical to incorporating all components into the Ecosystem Assessment. The SSC recognizes that the Stock Assessment Reports (SARs) for Alaska marine mammals are updated on a schedule, except for endangered species, which are updated annually. Perhaps a sentence or two about this system would be helpful in explaining the lack of updates for marine mammals.

Greater effort has been and will continue to be made to edit the language contained in this report to clarify the utility of data. Contributions that have not been updated for several years, or that will not be updated, have been deleted from the report. All past contributions will remain available on the website at `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`. This report includes an updated contribution on fur seals. A description and reference to the marine mammal stock assessments has included in the marine mammal section. We plan to include a summary of the marine mammal stock assessment with information relevent to this report next year, but were unable to do so this year.

The SSC requests that the authors be clear about what the data say and what the interpretation is of those data. For example, the authors state that 'predation is low' for pollock, but further discussion revealed that this conclusion was not based on diet data, but rather on low spatial overlap of adults and young Pollock.

We have paid special attention to editing for precision and will continue to do so in future drafts.

The northern fur seal (NFS) pup number time series is the longest term continuing data set for pinnipeds in the EBS, however, it may not be an appropriate index of pinniped status in the EBS. The rationale for choosing this measure is that females on St. Paul feed primarily on the shelf, but that is during lactation when the pup is on the breeding beaches at St. Paul. Although lack of food early in gestation might reduce the number of pups born the following year, food and condition during the winter and spring when they are not feeding on the EBS shelf may be the causative factor. The SSC suggests that authors investigate a recent study showing a significant relationship between the number of arrowtooth flounder and number of NFS pups the following year.

We appreciate this type of feedback on the indicators. We plan to revisit the suite of indicators chosen for the ecosystem assessments every few years. For the Bering Sea this year, we updated the indicators chosen last year and evaluated last year's predictions. Until the next full assessment, we will continue to research alternate indicators, as is currently occuring with the multivariate seabird indicator and copepod-euphausiid time series. We plan to address this comment on fur seals in the next full assessment.

In general, the report could be improved by consolidating key statements or reducing repetitions, such as the repeated statement that the usefulness (or lack thereof) of data for a species for management applications is limited. Throughout, there are also comments about planned changes or ideas for new analyses. These could be consolidated into one section, perhaps as a preface.

Some statements require clarification, such as: What is meant by easterly winds (p. 4)? From the east or to the east? Different disciplines designate direction differently.

We have attempted to increase precision in our editing. In the example above, the definition of easterly is from the east. This has been clarified in the text.

Area disturbed by bottom trawls (p. 63): What is considered a bottom trawl? Only true bottom trawls, or also mid-water trawls that come up with crabs?

We passed this question along to the contribution authors. The analysis referred to all trawl fishing gear. The current contribution clarifies this in both the title and text.

The variability in the miscellaneous category is dismissed as an artifact of standardized survey sampling methodology, but such patterns are accepted elsewhere in the document.

We have edited the text to agree with other contributions that describe trends in species from surveys not specifically designed to sample those species. We believe that the standard survey methodology produces trends worthy of reporting.

Are the trends in fish numbers (p. 154) caused by differences in production or movements and resulting distributions? What are the time lags between primary production and availability of food for fish?

This comment was passed along to the contribution author. The author agrees that these are good questions. However, the trawl survey offers a one-time snap shot each year of abundance and distribution and isn't designed to answer those questions.

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.

We initiated a regional approach to ecosystem assessments last year and presented a new ecosystem assessment for the eastern Bering Sea. This year we followed the same approach and present a new assessment for the Aleutian Islands based upon a similar format to that of the eastern Bering Sea. The entire assessment is now organized into six sections. In the first "Hot topics" section we present a succinct overview of potential concerns for fishery management, including endangered species issues, for each of the three ecosystems. 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. The fifth section addresses indicators common to all ecosystems, and the final section summarizes conclusions based upon all regions.

While all sections follow the DPSIR approach in general, the eastern Bering Sea and new Aleutian Islands assessments are based on additional refinements contributed by Ecosystem Synthesis Teams. For these assessments, the teams focused on a subset of broad, community-level indicators to determine the current state and likely future trends of ecosystem productivity in the EBS and ecosystem variability in the Aleutian Islands. The teams 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 ecosystem trends. Future assessments will address additional ecosystem objectives identified above. We expect to apply a team synthesis approach to the GOA ecosystem in 2012.

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 short-tailed albatross bycatch

A short-tailed albatross was incidentally caught and killed on a longline fishing hook in the Bering Sea in late October this year. The event occurred along the EBS shelf (Figure 15) on a longline vessel fishing for Paific cod. This was the first recored death of this species by a U.S. commercial fishing vessel this year and follows the two deaths recorded in the same fishery last year. Previous to 2010, the last recorded death in a U.S. commercial fishery was in 1998.

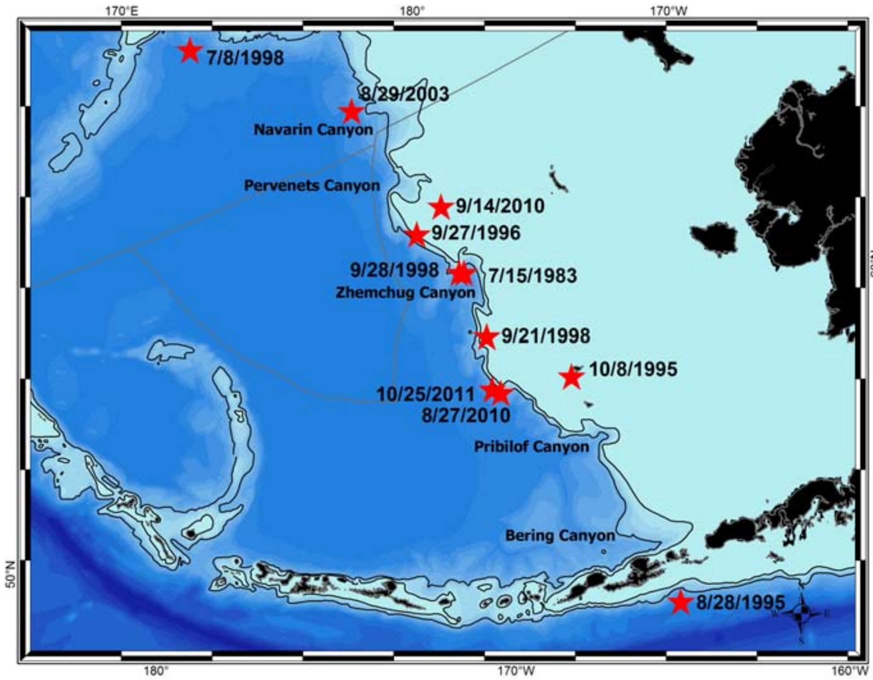

Figure 15: Locations and dates of short-tailed albatross bycatch. Figure courtesy Rob Suryan, OSU.

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 ($\geq$54%) and high adult and juvenile survival ($\geq$95% and $\geq$91%, respectively) (Zador et al., 2008*b*). These high survival rates suggest that fishery-related mortality currently appears to be a low risk for this population. However, given that the short-tailed albatross population is expanding rapidly ($\sim$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.

Recent increases in jellyfish

Time series of jellyfish catch-per-unit-effort are collected in the eastern Bering Sea during the summer NOAA bottom trawl surveys (p. 174) and during the autumn BASIS surface trawl surveys (p. 174). The summer time series dates back to 1982, whereas the autumn survey began in 2004. The species composition in both surveys has been dominated by *Chrysaora melanaster*. The autumn survey in particular has demonstrated a decline in other jellyfish species caught since 2004, suggesting that the trend has shifted to a single species-dominant catch.

Trends in the summer time series through 2004 were analyzed by Brodeur et al. (2008). They described the steep increase in jellyfish biomass throughout the 1990s that ended with peak biomass in 2000. Following that, biomass declined precipitously, stabilizing at a moderate level after 2001. The authors suggest that the onsets of the outburst and decline coincided with transitions between climatic regimes. Specifically, 1989 marked the beginning of a period of moderate temperatures in the eastern Bering Sea, after the warm conditions of the late 1970s, through the 1980s. Very warm conditions came to the eastern Bering Sea after 2000, as evidenced by decreased ice cover in winter and increased total heat content and surface water temperatures in summer. Ice cover, sea-surface temperature in spring and summer, and wind mixing were found to influence jellyfish biomass. In addition, the importance of juvenile pollock biomass and zooplankton biomass suggested that jellyfish biomass is sensitive to the availability of prey.

At the time of this study, most climate models suggest continued warming was likely in the Bering Sea, so Brodeur et al. (2008) predicted that the jellyfish populations would remain at moderate levels there but will likely shift northward into the Arctic Ocean. However, following this analysis, the eastern Bering Sea experienced cool conditions. In fact, 2006 was the beginning of an ongoing cycle of cool conditions. There was no change in jellyfish CPUE until a notable increase in 2009 and 2010. CPUE in 2011 was nearly double that of the previous two years and nearly the same as the peak value in 2000. The autumn survey also showed a dramatic increase, but not until 2010. Cieciel et al. (p. 174, this report) state that the cause for these shifts in biomass and distribution does not seem to rely solely on physical ocean factors (temperature and salinity). These shifts could also be a result of environmental forcing earlier in the growing season or during an earlier life history stage (polyp), which may influence large medusae biomasses and abundances (Purcell et al., 2009).

Current conditions in the eastern Bering Sea appear favorable overall for jellyfish, particularly *Chrysaora melanaster*. These significant increases in jellyfish biomass may redirect energy pathways in the food web through their predation on zooplankton and small fish.

Hot Topics: Gulf of Alaska

"Mushy" Halibut Syndrome

This condition has been observed with varying frequency for over 5 years, mostly in smaller halibut of 15-20 lbs in the Cook Inlet area. There have been only been 2 recorded reports from outside Cook Inlet - one from Kodiak, and one from Yakutat. In 2011 sport fishers noticed increasing numbers of affected fish. Alaska Department of Fish and Game (ADFG) describes the typical condition consisting of fish having large areas of body muscle that is abnormally opaque and flaccid or jelly-like. The overall body condition of these fish is usually poor and often they are released because of the potential inferior meat quality. No infectious agents of parasites have been detected in affected fish, therefore, transmission between fish is not likely.

The leading hypothosis is that a nutritional deficiency is the cause. According to ADFS, the Cook Inlet and Homer/Seward areas are nursery grounds for large numbers of young halibut that feed primarily on forage fish that have recently declined in numbers. Stomach contents of smaller halibut now contain mostly small crab species. Whether this forage is deficient, either in quantity or in essential nutrients is not known. However, mushy halibut syndrome is similar to that described for other animals with nutritional deficiencies in vitamin E and selenium. This muscle atrophy would further limit the ability of halibut to capture prey possibly leading to further malnutrition and increased severity of the primary nutritional deficiency. Recent field and lab research led by Brad Harris of Alaska Pacific University tested the hypothesis that parasite *Icthyophonus* was related to mushy halibut syndrome. Although the parasite was found in approximately 8 - 40% of halibut tested, only 1 of 14 halibut with mushy flesh was positive for *Ichthyophonus*. As of September 7th, ADFG reports that captures of mushy halibut are declining.

Infectious salmon anemia

Two of 48 British Columbia wild sockeye salmon smolts have tested positive for infectious salmon anemia (`http://www.nytimes.com/2011/10/18/science/18salmon.html`). This is the first incidence of this virus on the West Coast of North America. Researchers suggest that the virus may have spread from salmon farms, which import eggs from Europe, though at present local salmon farms have not tested positive for the virus. Infected salmon farms in Chile and Scotland have lost up to $\geq$ 70% of their stock. Transmission occurs by contact with infected fish, their secretions, and contact with humans and equipment that have handled infected fish. Sea lice have been shown to carry the virus on their surface and digestive tract, although transmission to salmon by this route has not been confirmed. Efforts are underway to determine the impacts of the virus on West Coast salmon farms and wild populations.

Hot Topics: Aleutian Islands

Fishery changes in the western and central AI ecoregions in 2011

In 2011, increased protection for endangered Steller sea lions was implemented, which resulted in changes to fishery management in the western and central AI ecoregions. Atka mackerel and Pacific cod can no longer be retained in the western AI ecoregion. The Atka mackerel and Pacific cod fisheries were also curtailed within critical habitat in the central AI ecoregion, and an overall limit on Pacific cod catch in the central AI was instituted. The analysis implementing the regulatory amendment estimated that all sectors (trawl and fixed gear, catcher vessels and catcher processors) would respond by trying to shift their harvest of Pacific cod to the Bering Sea, with mixed success across sectors. Atka mackerel quota allocated to the NMFS reporting area 543 (the western AI ecoregion) is foregone under these measures. Individual sectors' response to the new measures is not yet apparent. In the Central AI ecoregion, after many years of changing ownership, the processing plant in Adak was bought by Icicle Fisheries, and opened for processing in the fall of 2011 for AI golden king crab.

Aleutian Islands risk assessment released

The Aleutian Island Risk Assessment was released in August 2011. This risk assessment evaluates the impact of oil spills and shipping traffic in the Aleutian Islands. The Marine Accident Risk Calculation System (MARCS) tool was used to estimate spill frequency, spill size by Vessel Type, spill origination by geographical location, and establish baseline spill scenarios for the base year (2008/2009) and the predicted future year (2034). There are differing implications for the ecoregions. The greatest accident frequencies are predicted for the Eastern ecoregion, specifically the area through Unimak Pass, Akutan Pass and the approach to Dutch Harbor. The semi-quantitative traffic study included three elements: (1) summarization of vessel traffic patterns in the study area during the base year (2008/2009), including the types of vessels, frequency of transit, routes, and cargo; (2) prediction of anticipated changes in the vessel traffic patterns based on changes in trade, vessel characteristics, and regulations; and (3) forecast of changes in the fleet expected over a 25-year period (2009 - 2034). The largest increase in traffic for any vessel category was for chemical carriers and container ships (>4,500 TEU) transits, which are forecasted to more than double in the next 25 years. Oil spills are relevant to fisheries management because (1) spills may result in fishing closures, and (2) fishing boats may be diverted to assist in clean up.

Eastern Bering Sea Ecosystem Assessment for 2012

Contributed by Todd TenBrink[1], Stephani Zador[1], and 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[1]

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Editor's note: This year, we present an update to the full eastern Bering Sea assessement based on *the ten ecosystem indicators chosen in 2010 (Figure 1). For details about the selection and definition of the indicators see Zador and Gaichas (2010). New this year we also present an evaluation of predictions from last year's assessment.*

Summary

Conditions in the eastern Bering Sea over the last 4 - 5 years through 2010 have been favorable for lower trophic level production with extensive sea ice, early spring blooms, and moderately high concentrations of euphasiids and large copepods for planktivorous feeders. These conditions appear to be persisting, although moderating, through 2011 given the current state of North Pacific atmosphere-ocean system and observations from the Bering Sea. The winter of 2010-2011 reflected a typical oceanographic response to La Niña. The Aleutian low was much weaker than usual in the winter of 2010-11. The weather during early winter was quite cold, but the late winter and spring showed near neutral temperatures. The maximum sea ice extent and the cold pool were both less extensive than in the previous four years. The average bottom temperature during summer was nearly a degree warmer than 2010 and equal to the grand mean from 1982 to 2011. However, the surface temperature continued to be much lower than the long term mean, reflecting the unusually cold atmospheric conditions during July and August. If these conditions persist into fall, they would promote the relatively early development of sea ice during the winter of 2011-12. The most important aspects of the physical environment in the eastern Bering Sea during 2011, despite the relatively neutral weather and sea ice conditions during winter and spring, were that cool fall 2010 temperatures and a newly seen cold summer did not allow the multi-year sequential continuation of cold ocean temperatures to come to an end.

The persistent cool environment may be related to increased abundance in year class strength for fishes. For juvenile pollock (age-0 and age-1) conditions have continued to be favorable for the overwintering survival of pollock and cod in the Bering Sea based on moderate to low sea surface temperatures. It has been shown that pollock may be more sensitive to thermal processes important for overwintering survival during periods of warmer seas. Zooplankton biomass indices for both euphasiids and large copepods (*Calanus* spp.) remained relatively high in 2010, providing evidence that juvenile pollock prey was still abundant. Zooplankton indices for 2011 are currently unknown.

The increase in jellyfish catch rates, primarily *Chrysaora melanaster*, first seen during the summer trawl survey in 2009 and the fall surface trawl survey in 2010, persisted through summer 2010 and doubled in summer 2011. An earlier increasing jellyfish biomass trend in the eastern Bering Sea was linked to a period of climatic transition from warm to moderate conditions, with a sharp decline in biomass at the transition back to a period of very warm conditions. The moderate winter of 2010/2011 can be interpreted as the beginning of a transition out of the cold pattern seen for the past 4 - 5 years, although the unusually cold summer did not allow these conditions to persist. Jellyfish biomass has also been linked to prey availability. Increased jellyfish abundance may indicate an increased source of mortality on their zooplankton and small fish prey.

Biomass estimates of four fish foraging guilds (apex predators, pelagic foragers, benthic foragers, and motile epifauna) were not updated this year due to staff loss, so current trends are unknown. In early years, the apex predator and pelagic forager 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. Reductions in the extent of the cold pool, as occurred during summer 2011, may facilitate their expansion onto the shelf as seen during the warm years of 2003-2005.

Northern fur seals and seabirds breeding on the Pribilof Islands are representative of the air-breathing central place piscivorous foragers in the eastern Bering Sea. Northern fur seal pup production in the Pribilof Islands continued their overall decline in 2010, the last year they were counted. The breeding populations of the western stock of Steller sea lions, meanwhile, continue to respond differently despite the fact that both fur seals and sea lions forage extensively in the southeast Bering Sea. Pup counts at rookery sites have either declined or have stabilized in the western and central Aleutian Islands but have shown an increase in the eastern Aleutian Islands (see Aleutian Islands ecosystem assessment for more detail, p. 65).

The reproductive success of thick billed murres at St. George has been in decline following a peak in 2009, highlighted by very low breeding success this year. Most of this loss occurred early in the breeding season during the egg stage (∼July), unusual enough that hatching success was at a record low and suggesting that sufficient prey were not available before or during this time. A multivariate index representing black- and red-legged kittiwake productivity at the Pribilofs reached a minimum this year in a 16-year time series for these surface-feeders, despite the moderate estimates of age-1 pollock in 2010. This represented a different pattern than seen in previous years, when estimates of age-1 pollock were positively correlated with kittiwake productivity in the following year. A second multivariate index representing seabird phenology and murre productivity at the Pribilofs was neutral, which represented a decline from 2010.

Evaluation of 2010 predictions

In this section we provide an evaluation of predictions from the 2010 eastern Bering Sea assessment. A strong La Niña formed on the equator during summer 2010 as reflected in the downward trend in the NPI. The prediction for the Bering Sea was for above average sea-ice extent and duration in winter and spring 2011. The state of the North Pacific atmosphere-ocean system during 2010-2011 reflected the typical response to La Niña. The Aleutian Low was much weaker than usual in the winter of 2010-11, and the sea level pressure was higher than normal in the eastern portion of the basin for the year as a whole. Cooler than normal upper ocean temperatures prevailed in the eastern portion of the North Pacific and warmer than normal temperatures occurred in the west-central and then central portion of the basin. This pattern reflects a negative sense to the Pacific Decadal Oscillation (PDO). However, the prediction of above average sea-ice extent and duration through the winter of 2011 along the eastern Bering Sea shelf did not hold true. Sea ice conditions were neutral both in duration as indicated by the average Ice Retreat Index value and in extent as indicated by the maximum ice extent. The weather during early winter was quite cold, but the late winter was a bit warmer than normal; the winds during the spring did not feature the same northerlies that delayed the retreat of the ice in 2010. The most important aspects of the physical environmental in the eastern Bering Sea during 2011, despite the relatively neutral weather and sea ice conditions during winter and spring, were that cool fall temperatures and a newly seen cold summer did not allow the multi-year sequential continuation of cold ocean temperatures to come to an end. Consequently, the mechanism for the cold year was different than in the previous four years.

Overall food availability for planktivorous species was considered to be high in 2010 based on the euphausiid biomass index and thus the survival of this year classes of fishes was predicted to be potentially better than average. Although a full evaluation of this prediction is not currently possible, there is some indication that this may hold true. In evaluating sea temperatures to determine year class strength for groundfishes, conditions suggest continued improvement for the overwintering survival of pollock and cod from age-0 to age-1 in the Bering Sea. The 2011 temperature change index value and cold year models predict 48,094 million age-1 pollock and 785 million age-1 cod for 2011.

The numbers of northern fur seal pups born at St. Paul Island in 2010 was estimated to drop by approximately 8.8% from 2008 estimates. This is consistent with the declining trend observed since the mid-1990s. By contrast, the 2010 pup production estimate for St. George Island is 1.0% less than the estimate in 2008. The overall decrease in pup production for St. Paul and St. George Islands combined from 2008 to 2010 is approximately 7.6%. Since 1998, St. Paul Island has declined at an annual rate of 5.5% and on both Pribilof Islands at an annual rate of 4.9%, down from the 6% annual decrease anticipated during last year's assessment which had incorporated available data through 2008.

The prediction of an extention of cold conditions in the Bering led to a prediction that conditions would be favorable for thick-billed murre reproduction on St. George Island. The low level of reproductive success recorded for St. George thick-billed murres in 2011 (0.16) continues an unexpected downward trend from 2010. Although predicted continued cold conditions were thought likely to lead to favorable conditions for thick-billed murres nesting on St. George, the warmer than expected spring and cold summer may have influenced their reproductive failure. According to mean bottom temperature data from the 2011 Eastern Bering Sea groundfish survey, the cold pool during the late spring and early summer sampling period was significantly reduced in size. Most of the variation in murre reproductive success occurred during the egg period rather than the chick period and so may have been driven by conditions set up very early in the year or even the previous year's reproductive effort.

Additional EBS indicators

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 (Figure 16) 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 as shown in the Report Card (Figure 1). In future assessments we plan to replace the T/S Oshoro Maru time series in the Report Card with a combined euphausiid and copepod time series. In this section we describe the *Calanus* spp. and euphausiid time series (Figure 17).

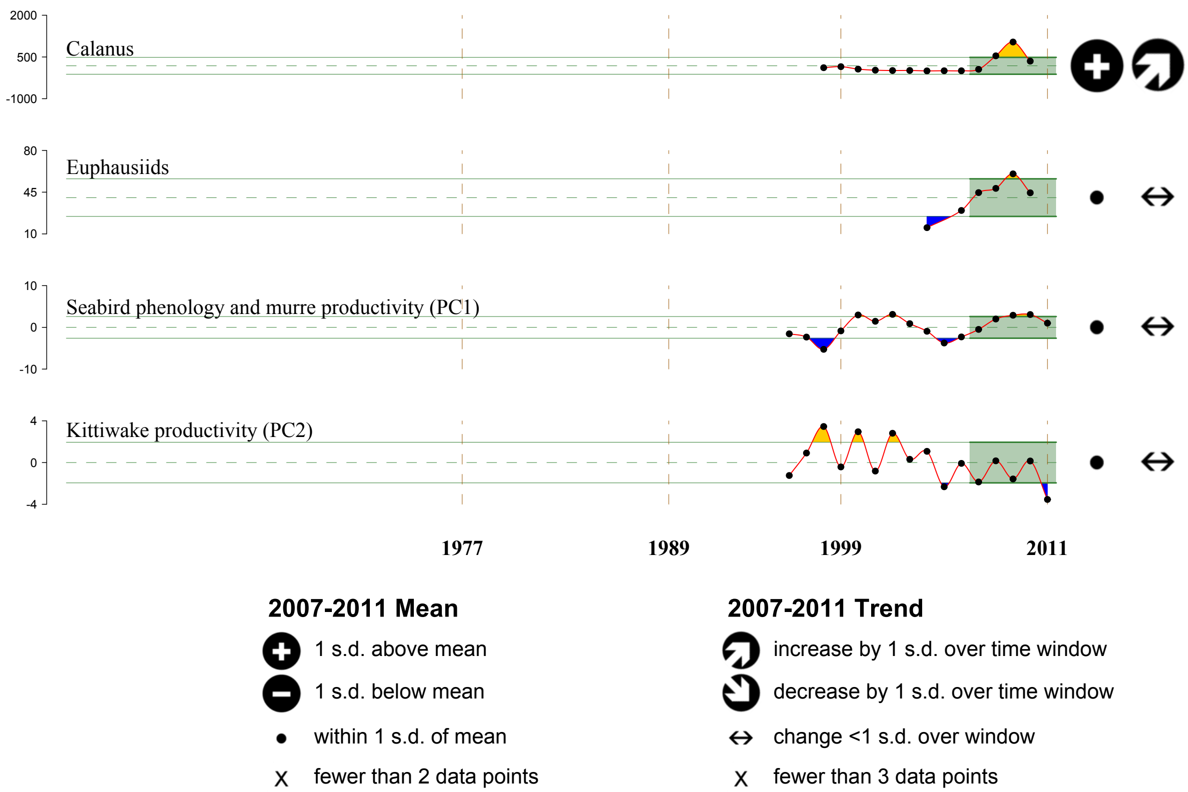

Figure 16: Additional eastern Bering Sea indicator time series.

Methods: Ressler et al. (accepted) computed abundance and biomass of adult and juvenile euphausiids on the middle and outer shelf of the eastern Bering Sea, using acoustic and Methot trawl data from 2004-2010 surveys of midwater pollock (Honkalehto et al. 2010). Estimated euphausiid density (no. m3) along acoustic survey transects was averaged over the water column and then across the surveyed area to produce the mean estimates shown in the plot for each year. Error bars are 95% confidence intervals computed from geostatistical estimates of relative estimation error (Petitgas 1993).

Stabeno et al. (accepted) computed the abundance of *Calanus* spp. (all copepodite stages) on the middle shelf of the eastern Bering Sea from summer net tows on multiple vessels (1981; PROBES,

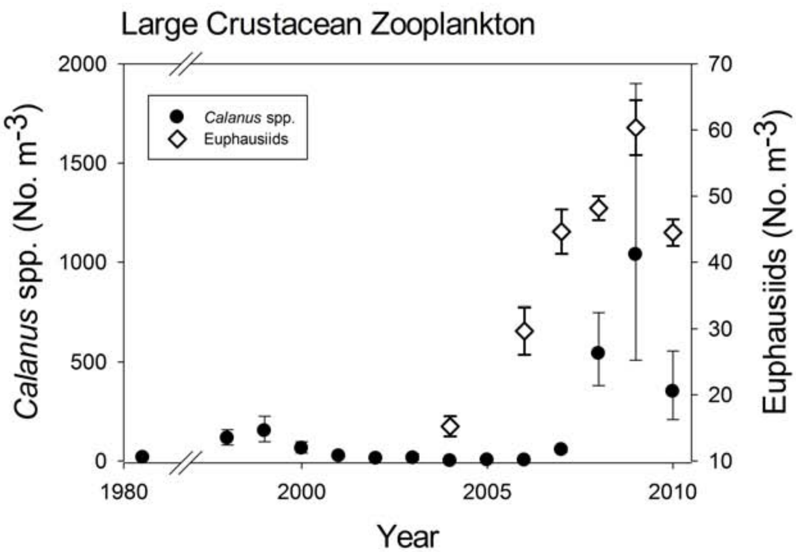

Figure 17: *Calanus* spp. and euphausiid time series.

1998 - 2008; T/S Oshoro Maru and 2009-2010; AFSC RACE Groundfish Assessment cruises). Shown are the mean and standard error. Raw data were fourth root transformed before calculation of the summary statistics and then back transformed before plotting.

Status and Trends: Both series show a large increase since 2001-2005 ("warm years" according to Stabeno et al., accepted), with the copepod increase lagging that for euphausiids. Both series showed a smaller decline in 2010 but remained well above 2001-2005 levels. The areas of the Bering Sea shelf sampled for copepods and euphausiids were not exactly the same, but we assume that the interannual variability in mean density indicated in the plot is correctly represented for both groups of animals, and that these groups are reasonable proxies for the trend in density of all large copepods and euphausiids on the Bering Sea shelf. These two main groups of large crustacean zooplankton are important in the Bering Sea ecosystem and in the diet of many predators. For example, ecosystem modeling indicates that the biomass densities of euphausiids and copepods in the Bering Sea are of the same order (Aydin et al. 2007a, p. 77; Aydin and Mueter, 2007, Fig. 3) and that they are of comparable importance in the diet of walleye pollock (Aydin et al. 2007a, p. 51).

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 from 2008 to 2010 are encouraging and suggest that overall food availability for planktivorous species 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.

Seabird indices During the initial meetings in 2010, the Team decided that 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. In the absence of this, they elected to choose a single sentinel species to represent seabird productivity on the Bering Sea shelf, thick-billed murres nesting on St George. Zador and TenBrink developed new multivariate seabird indicators representing all species nesting on the Pribilofs using a principal components analysis to combine annual hatch dates and reproductive success values. Further information can be found in this document on p.189. Strong and distinct trends were noted in the first two principal components. The first captured mainly the hatch dates and murre productivity trends; the second captured kittiwake productivity trends. The loadings on the two principal components followed the same patterns when 2011 data was added to produce index values for this year and indicated poorer productivity for both indices (Figure 18). These two indices may therefore serve as useful indicators to follow to capture more comprehensive seabird trends. Although a single index would be preferable, the analysis suggests that the two divergent patterns in the data could not be captured in a single index.

Gaps and needs for future EBS assessments

This section is unchanged from the 2010 assessment

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

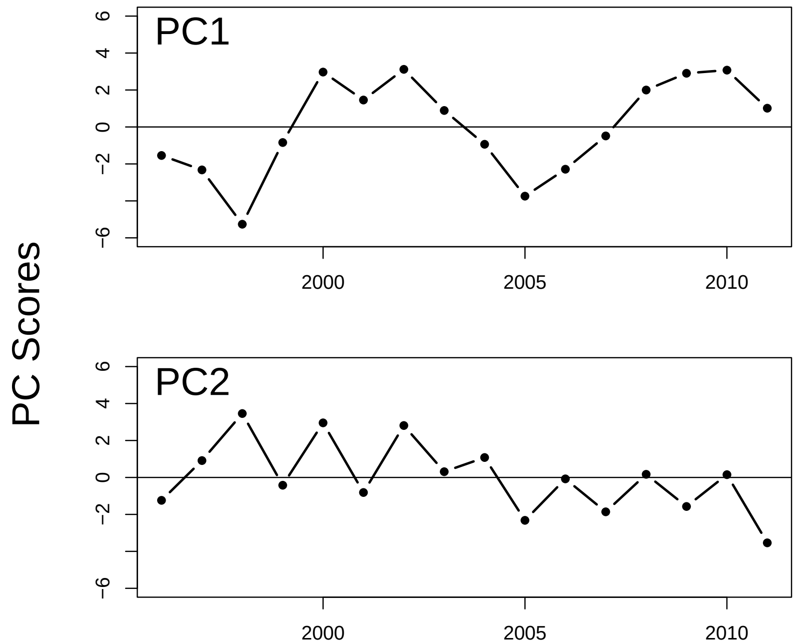

Figure 18: Time series of the first two leading principal components for combined seabird productivity and mean hatch date extended through 2011. For PC1, a more positive value indicates higher murre and cormorant productivity and earlier mean hatch dates. For PC2, higher values indicate increased kittiwake productivity. See contribution on p.

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. 203). 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 2). 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.

Gulf of Alaska

This report does not include a current ecosystem assessment of the Gulf of Alaska. A workshop is scheduled for winter 2012, during which a new Gulf of Alaska Ecosystem Assessment team will develop an assessment following the procedure and format of the EBS and AI assessments.

Aleutian Islands Ecosystem Assessment for 2012

Contributed by the Aleutian Islands Ecosystem Assessment Team: Stephani Zador[1], Kerim Aydin[1], Steve Barbeaux[1], Nick Bond[2], Jim Estes[3], Diana Evans[4], Dave Fraser[5], Lowell Fritz[6], Stephen

Table 2: 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	Zador and Gaichas (2010)
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	

Jewett[7], Carol Ladd[8], Elizabeth Logerwell[1], Sandra Lowe[1], John Olson[9], Ivonne Ortiz[1], John Piatt[10], Chris Rooper[11], Paul Wade[6], Jon Warrenchuk[12], Francis Weise[13], Jeff Williams[14] Additional data provided by Michael Martin[11]

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[6]National Marine Mammal Lab, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
[7]University of Alaska Fairbanks
[8]Pacific Marine Environmental Lab, NOAA
[9]Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
[10]Alaska Biological Science Center, USGS
[11]Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
[12]Oceana
[13]North Pacific Research Board
[14]Alaska Maritime National Wildlife Refuge, USFWS

Summary

We present this summary of the Aleutian Islands ecosystem by three ecoregions. These are briefly defined here and in more detail later in the document (Figure 19). The Western Aleutian Islands ecoregion spans 170° to 177°E. These are the same boundaries as the North Pacific Fishery Council fishery management unit 543. The Central Aleutian Islands ecoregion spans 177°E to 170°W. This area encompasses the North Pacific Fishery Council fishery management units 542 and 541. The Eastern Aleutian Islands ecoregion spans 170°W near Samalga Pass to False Pass at 164°W.

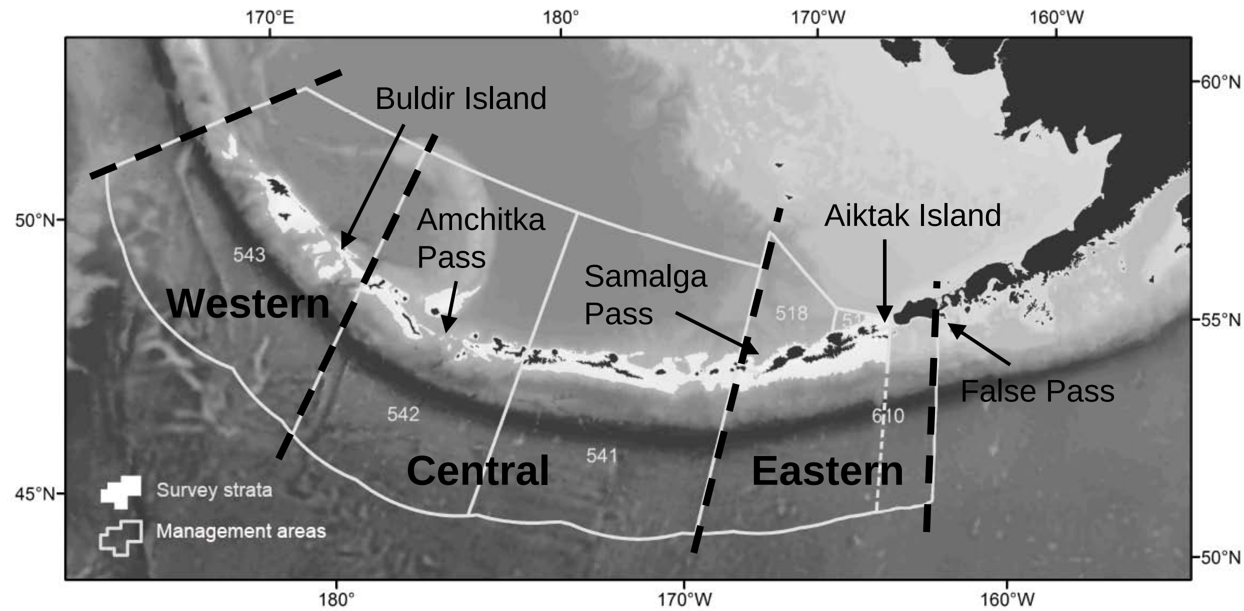


Figure 19: The three Aleutian Islands assessment ecoregions. Seabird monitoring islands are indicated by arrows.

Most of what we can say about the Aleutians Islands ecosystem is based upon biological trends. There are large gaps in knowledge about the local physical processes and, as a result, their impact on biological processes. These gaps are largely due to geographic reality. For example, persistent cloudiness precludes obtaining comprehensive satellite-derived data. Also, the sheer distances involved in surveying the island chain make comparing west-east trends in indicators such as bottom temperature difficult because of the difference in timing of oceanographic surveys across the region. Differences in survey timing may also affect detection of biological patterns, but biological indicators such as fish or sea lion abundances are more integrative indicators than a specific physical indicator such as bottom temperature that they may be responding to and thus are less sensitive to survey timing. Also, the extensive nearshore component of the ecosystem, narrow shelf relative to the entire ecosystem, as well as strong oceanographic input mean that some metrics commonly used as ecosystem indicators in other systems may not be as informative in the Aleutians. Therefore, our synthesis of ecosystem indicators will by necessity include speculation.

The Aleutian Islands ecosystem is currently experiencing a general state of less storminess and average bottom temperatures. The North Pacific Index, used as a measure of the intensity of the Aleutian Low, was positive from 2006-2009, implying a weaker Aleutian Low pressure system and less storminess in the region than average. Although the 2010 winter NPI was negative, the 2011 winter NPI was positive by more than one standard deviation implying a reversion to a weaker Aleutian Low pressure system and less storminess. This is expected to continue into the winter 2011/2012, due in part to projected La Niña conditions.

There is an overall decreasing trend in Pacific cod biomass, which contributes the largest proportion to the fish apex predator foraging guild across ecoregions. Arrowtooth flounder, Kamchatka flounder and skates, all show an increasing trend. It is possible that species that are faring poorly are those that are strictly tied to the shelf area due to limited depth range, such as Pacific cod, and/or are influenced by nearshore processes compared to midwater species that reside on the shelf and slope that are doing well, such as arrowtooth flounder and skates. However, this is an open area for research. Overall, the fish pelagic foragers increase in biomass towards the west, but Pacific ocean perch are increasing across all ecoregions. There are several species showing longitudinal trends in this group: the biomass of walleye pollock increases towards the east, whereas that of northern rockfish and Pacific ocean perch increases toward west. Fishing patterns have recently changed throughout the system, largely in response to increased protection for Steller sea lions, although the final impacts to individual fishing sectors are currently unknown. In general, school enrollments numbers in the Aleutian Islands region have been on the decline, possibly indicating that communities with year-round residents that experience direct interactions with the ecosystem through residential and subsistence activites are faring poorly. Rural communities in Alaska are suffering losses as Alaska Natives increasingly leave villages for the cities.

Western Ecoregion In the Western ecoregion specifically, reproductive success of planktivorous auklets, serving as indicators of zooplankton production, have been higher than average for the past five years. Given the negative correlation between the strength of the Aleutian Low and planktivorous seabird productivity (Bond et al., 2011), we anticipate continued favorable conditions for planktivores. Trends in forage fish as indicated in puffin chick diets are currently unknown; data have been collected since 2002 but not yet summarized. We anticipate these data will be included in the next assessment produced in 2012. Variable patterns in puffin chick diet from 1988-2001, specifically in proportions of hexagrammids, suggest that puffins are responding to changes in prey availability. Aggregate biomass of fish apex predator and pelagic foragers have increased since the previous trawl survey in 2006. The increase in the fish apex predators foraging guild apparent in the 2010 trawl survey is driven by Pacific cod, reversing the declining trend in this foraging guild since 2000. Atka mackerel and Pacific ocean perch drive the increasing biomass trend of pelagic foragers, surpassing the previous peak in 2004. Recent counts of otters show no trend, in contrast to the steep decline during the early 2000s, possibly indicating stability for this keystone species of the nearshore environment. Steller sea lions continue their decades-long decline in this ecoregion. Between 1991 and 2008, non-pup counts declined 81%, or at a rate of -10% per year. The population appears to be continuing to fare poorly as one major rookery that produced almost 400 pups in the early 1990s produced a singe pup in 2010. Causes for the declining trend are topics of active research on these apex piscivores wohse diet consists primarily of commercially-fished species. The amount of area trawled declined dramatically this year due to recent measures aiming at increasing protection for Steller sea lions.

Central Ecoregion Recent trends in auklet reproductive success are unknown but the predicted continued positive state of the NPI indicates favorable foraging conditions for planktivores. Forage fish trends as captured by puffins are not available from this ecoregion because puffins are not as numerous and nests are not monitored regularly. Fish apex predator and pelagic foraging guild biomasses have declined since the previous trawl survey in 2006, in contrast to the trend in the Western ecoregion. The decline apex predators is largely driven by Pacific cod, although Kamchatka flounder has increased. Atka mackerel and Pacific ocean perch make up 80% of the pelagic foraging guild biomass. The recent decline is largely driven by Atka mackerel, as Pacific ocean perch biomass has increased. Recent counts of sea otters continue to decline, possibly indicated poor conditions in the nearshore environment for this species. Counts of non-pup Steller sea lions in the central Aleutians declined 33% overall between 1991 and 2008, a rate of -2% per year. While this decline is occuring at a lower rate compared to that in the Western ecoregion, there is a still concern for these apex piscivores. School enrollment has shown no trend in recent years, following a decline since peak enrollment in 2000.

Eastern Ecoregion Planktivorous auklets are not as numerous in the Eastern ecoregion as in the Central and Western ecoregion and are not monitored in the Eastern ecoregion. Relative abundances of gadids and *Ammodytes* in prey brought back to feed puffin chicks have shown opposite trends, although recent data are not yet available. Hexagrammids comprise a lower proportion of chick diets relative to those in the Western ecoregion. Although recent data are not currently available, chick-provisioning patterns suggest puffins are responding to changes in forage fish availability. Fish apex predator biomass declined relative to past surveys. The long-term trends in this foraging guild is driven by Pacific cod and arrowtooth flounder jointly, which alternate as the largest biomass in the area. The recent decline is largely driven by arrowtooth flounder, as Pacific cod biomass has increased. More than half the fish pelagic forager biomass is commonly contributed by walleye pollock and Atka mackerel. Pollock, Atka mackerel, and Pacific ocean perch all contributed to this trend, but only on the northern portion of the islands for Atka mackerel. All fish groups fluctuate widely in this area, which has the lowest total biomass of pelagic foragers relative to the other ecoregions. In contrast to the other ecoregions, non-pup counts of Steller sea lions increased 21% overall between 1991 and 2008. Counts were largely stable through the 1990s, but increased at a rate of 3% per year between 2000 and 2008, indicating favorable conditions for these piscivores. School enrollment has fluctuated in this ecoregion, but has shown no overall trend in the past five years.

Objectives, selection and evaluation of key Aleutian Islands indicators

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

The Aleutian Islands Ecosystem Assessment Team met in September 2011 to begin the development of a structuring theme and selection of key indicators for the Aleutian Islands ecosystem. Following presentations and review of existing physical and biological data, the team concluded that the significant variability in the island chain ecosystem warranted structuring the assessment by three ecoregions: Western, Central, and Eastern. Accordingly, the suite of indicators chosen should be those for which there are data across all ecoregions and characterize a global attribute with local behavior. However, the final selection reflected the limitations of available data sets for this region.

The ecoregions were defined based upon evidence of significant ecosystem distinction from the neighboring ecoregions. The team also concluded that developing an assessment of the ecosystem at this regional level would emphasize the variability inherent in this large area, which stretches 1900 km from the Alaska Peninsula in the east to the Commander Islands in the west. For the purposes of this assessment, however, the western boundary is considered the U.S. - Russia border at 170°E.

The three Aleutian Islands ecoregions are defined from west to east as follows (Figure 19). The Western Aleutian Islands ecoregion spans 170° to 177°E. These are the same boundaries as the North Pacific Fishery Council fishery management area 543. This ecoregion was considered to be distinct from the neighboring region to the east by primarily northward flow of the Alaska Stream through wide and deep passes (Ladd, pers. comm.), with fewer islands relative to the other ecoregions.

The Central Aleutian Islands ecoregion spans 177°E to 170°W. This area encompasses the North Pacific Fishery Council fishery management areas 542 and 541. There was consensus among the group that the eastern boundary of this ecoregion occurs at Samalga Pass, which is at 169.5°W, but for easier translation to fishery management area, it was agreed that 170°W was a close approximation. The geometry of the passes between islands differs to the east and west of Samalga Pass (at least until Amchitka Pass). In the Central ecoregion the passes are wide, deep and short. The Alaska Stream, a shelf-break current, is the predominant source of water. There is more vertical mixing as well as bidirectional flow in the passes. This delineation also aligns with studies suggesting there is a biological boundary at this point based on differences in chlorophyll, zooplankton, fish, seabirds, and marine mammals (Hunt and Stabeno, 2005).

The Eastern Aleutian Islands ecoregion spans 170°W to False Pass at 164°W. The passes in this ecoregion are characteristically narrow, shallow and long, with lateral mixing of water and northward flow. The prominent source is from the Alaska Coastal Current, with a strong freshwater component.

The team was tasked with choosing a suite of indicators that together provide a comprehensive view of the Aleutian Island ecosystem reflecting across trophic levels from the physical environment to top predators and humans, as well as both the nearshore and offshore. In addition to providing the "vital signs" for the AI, the preliminarily chosen indicators needed to be updatable on a regular basis, preferably annually; however, the team recognized that many of the surveys that collect data for some indicators do not occur every year. Numerous gaps in available time series were noted and discussed. See the Gaps and Needs section below. Although a single suite of indicators were chosen for the entire ecosystem, not all are available or applicable in each of the three ecoregions.

The following indicators were selected for the Aleutian Island ecosystem assessment:

1. Winter North Pacific Index

2. Reproductive anomalies of planktivorous least auklet and crested auklets as indicators of zooplankton productivity

3. Proportions of hexagrammids, gadids, and *Ammodytes* in tufted puffin chick diets

4. Apex predator and pelagic forager fish biomass indices

5. Sea otter counts

6. Steller sea lion non pup counts (juveniles and adults)

7. Percent of shelf <500m deep trawled

8. K-12 enrollment in Aleutian Islands schools

The team also discussed a spring North Pacific Index (NPI), mean groundfish trawl survey bottom temperature, and the value of groundfish catch. The spring index, defined as the average NPI for April through June, was thought to best represent conditions that may be important during the spring bloom given that the quality of satellite-derived chlorophyll data is compromised due to persistent cloudiness. However, this index was ultimately excluded due to lack of science that relates this index to the ecosystem. The mean bottom water temperature recorded during NOAA survey trawls was initially included for each ecoregion as an index of habitat characteristic for commercially-fished groundfish. However, this index was ultimately excluded due to little evidence of temperature influencing groundfish trends. Finally, the ex-vessel value of the groundfish fishery catch was discussed as a measure of the health of the Aleutians fisheries, acknowledging the inclusion of humans as part of the ecosystem. This index was ultimately considered more appropriate for an economic analysis, for which the Team did not have expertise. Also, the inclusion of the indices for the percent of the shelf <500 m trawled and Aleutian Islands school enrollment were considered together to well represent both the physical impact of humans in the ecosystem and the health of the in-situ human components of the ecosystem.

In the sections below, we give a brief rationale for each indicator's selection, describe the indicator, the appropriate ecoregion, its status and trends, and provide a statement of its individual implications for fishery management. The summary section above provides a synthetic assessment based on all of the indicators available in each ecoregion. Time series of all indicators are presented in Figures 20, 21, 22, and 23.

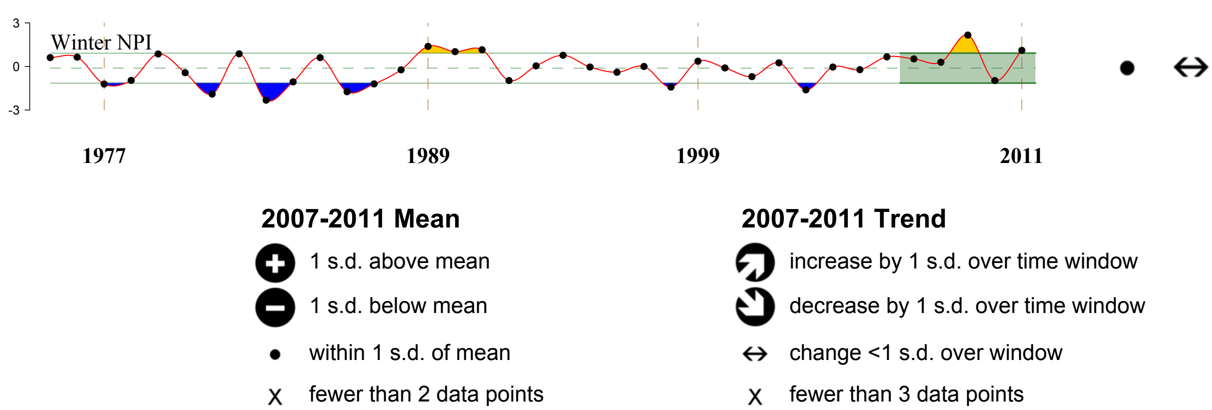


Figure 20: The winter North Pacific Index time series.

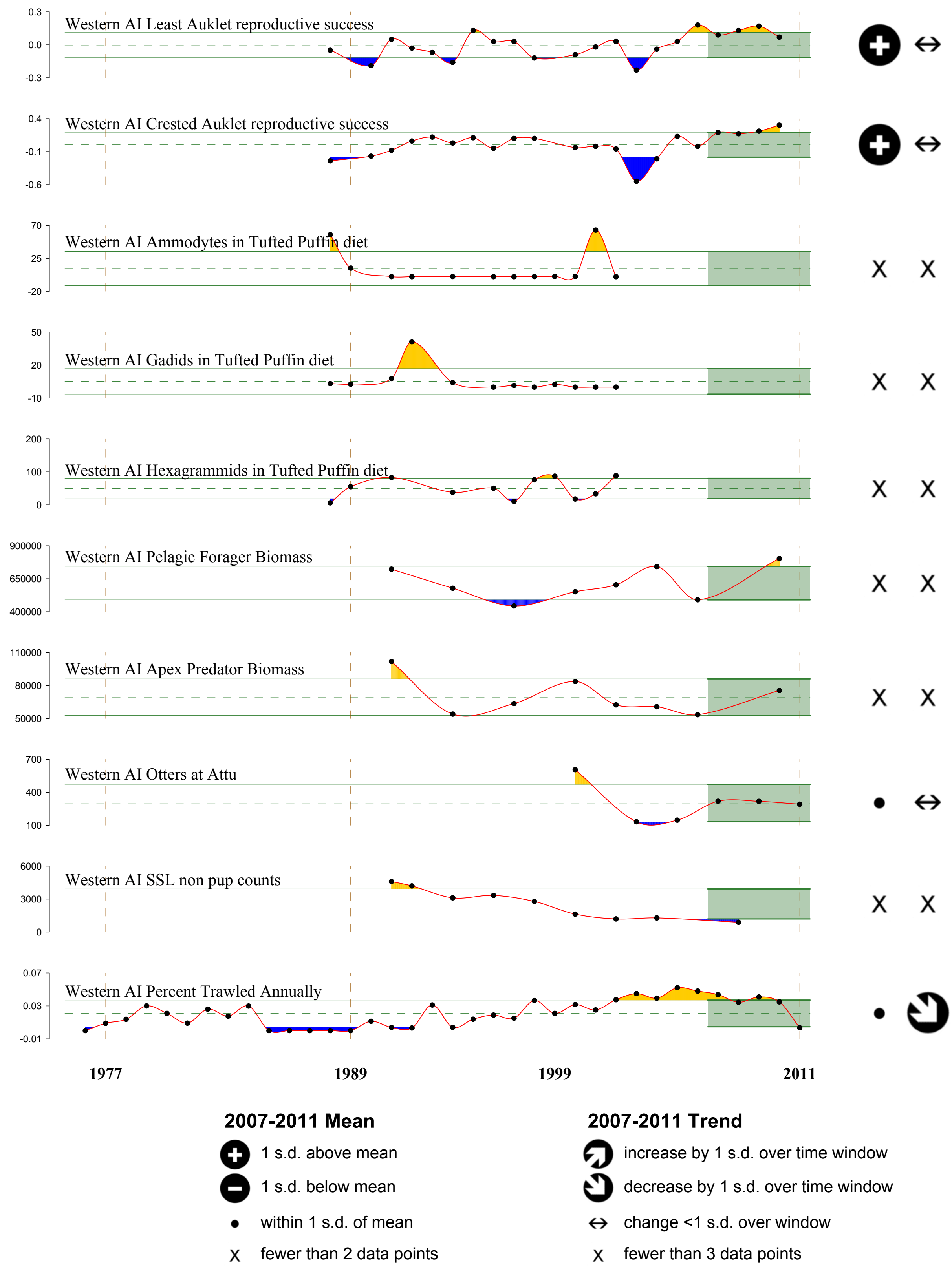


Figure 21: Aleutian Islands Western ecoregion indicators.

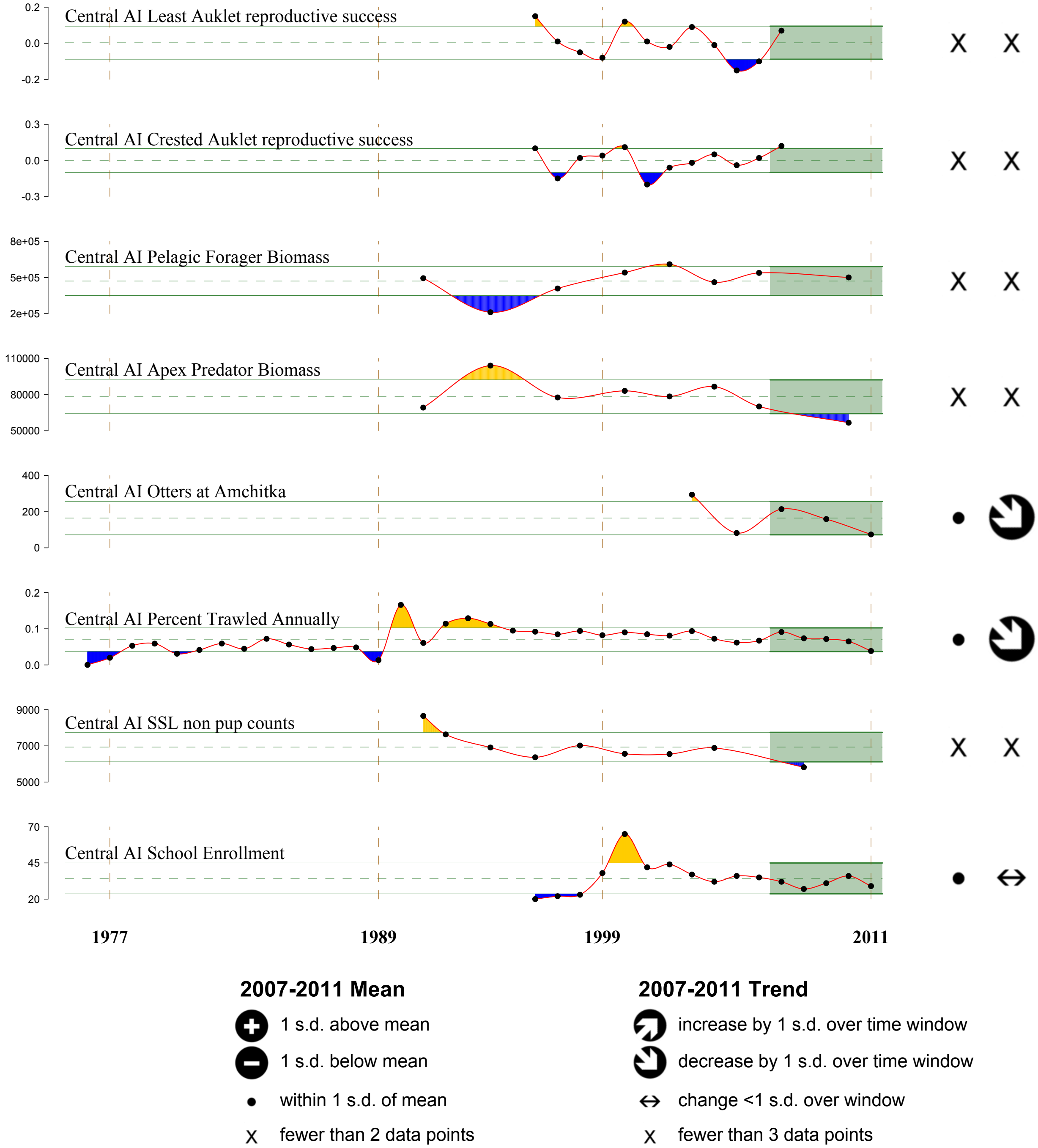


Figure 22: Aleutian Islands Central ecoregion indicators.

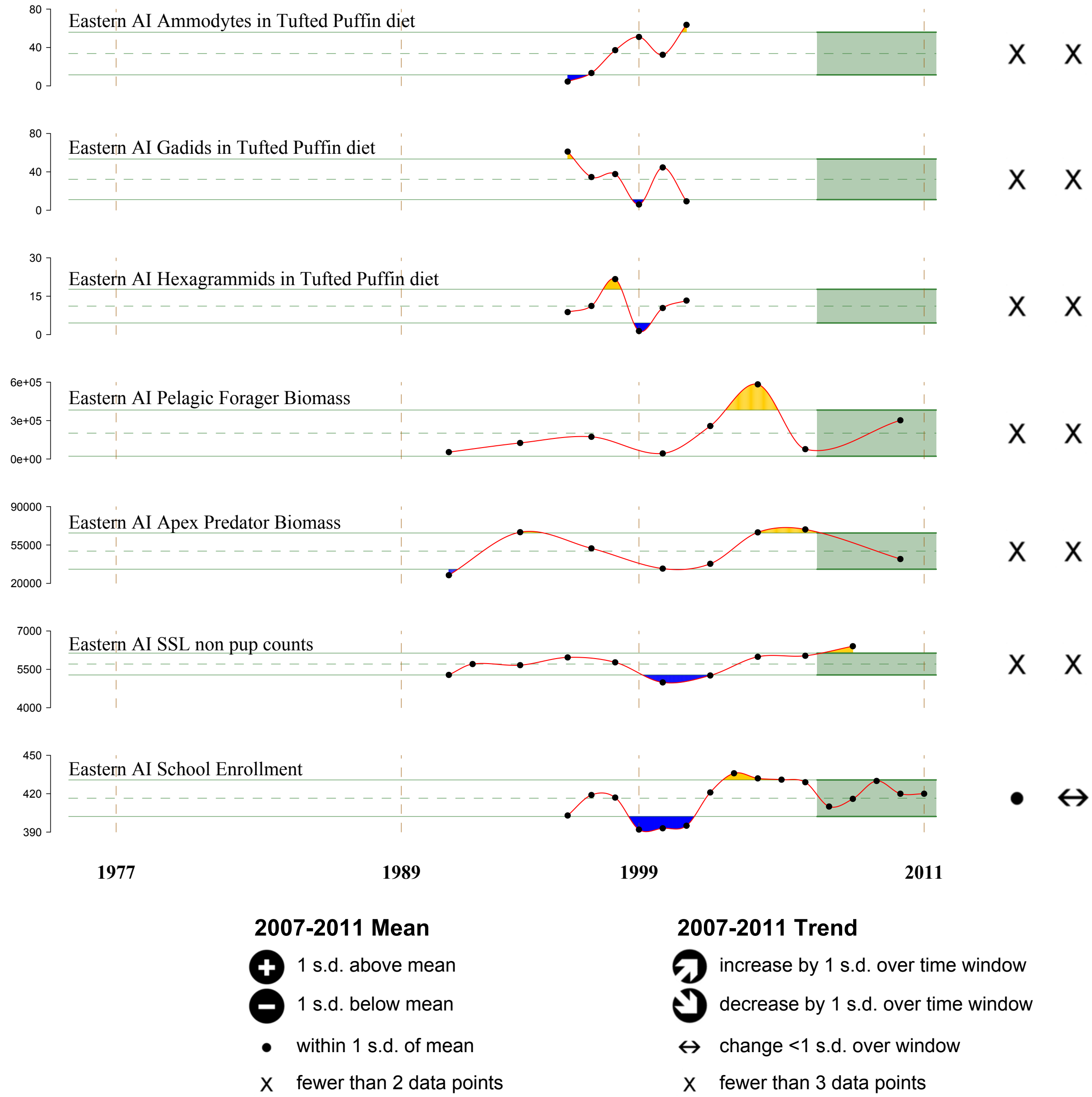


Figure 23: Aleutian Islands Eastern ecoregion indicators.

Winter North Pacific Index The North Pacific Index (Trenberth and Hurrell, 1994), the area weighted mean sea level pressure over the region 30° - 65°N, 160°E - 140°W, is a widely used measure of the intensity of the Aleutian Low. A negative winter (November - March) NPI anomaly implies a strong Aleutian Low and generally stormier conditions. It has been suggested that correlations between a strong Aleutian Low and decreased seabird productivity in the Aleutian Islands may be due to decreased prey (zooplankton) availability (Bond et al., 2011). The winter index is the average NPI from November through March (year of January), and the anomalies are normalized by the mean (8.65) and standard deviation (2.23) for 1961-2000.

The winter NPI was near-average or negative through most of the 1990s through 2005 (Figure 20). Since 2005, the index has been positive every year except 2010. In 2011, the winter NPI index (November 2010 - March 2011) was positive by more than one standard deviation implying a weaker Aleutian Low pressure system and less storminess in the region than average. This is expected to continue into the winter 2011/2012, due in part to projected La Niña conditions (see p. 101).

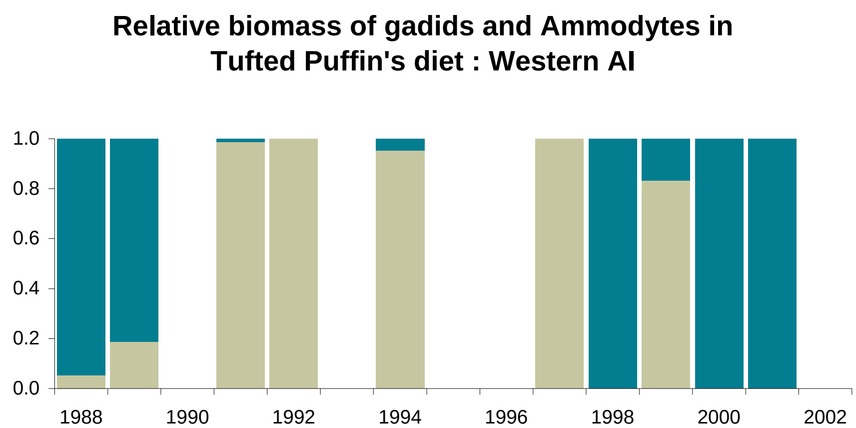
Reproductive anomalies of planktivorous least auklet and crested auklets Least auklets (*Aethia pusilla*) and crested auklets (*A. cristatella*) are small, abundant seabirds that nest in the Aleutian Islands. The USFWS stations field biologists to monitor auklet chick diets and reproductive success annually at Buldir Island and less frequently at other islands on which they occur. Both species are planktivorous and dive to capture their prey. Least auklet chick diets are mainly composed of *Neocalanus cristatus*, *N. plumchrus*, and *N. flemingeri*. Crested auklet chick diets consist of mainly Euphausiacea and *N. cristatus*. Due to the lack of time series of direct measurements of zooplankton in the Aleutian Islands, the team selected reproductive anomalies of least and crested auklets as indicators of copepod and euphausiid abundance, respectively. Reproductive anomalies were selected as the metric of interest instead of chick diets because reproductive success is an integrative indictor of ecosystem productivity and forage for planktivorous commercially-fished species.

Reproductive success is defined as the ratio of number of nest sites with a fledged chick to the number of nest sites with eggs. In the Western ecoregion, reproductive success of least and crested auklets were recorded annually at Buldir Island from 1988-2010 with the exception of 1989 and 1999. In the Central ecoregion, reproductive success was monitored annually at Kasatochi Island from 1996-2007. In 2008 a volcanic eruption covered the monitored colony in ash, disrupting breeding. It is unknown when auklets will nest there again and if so, whether observations will continue. Data were extracted from reports produced by the Alaska Maritime National Wildlife Refuge.

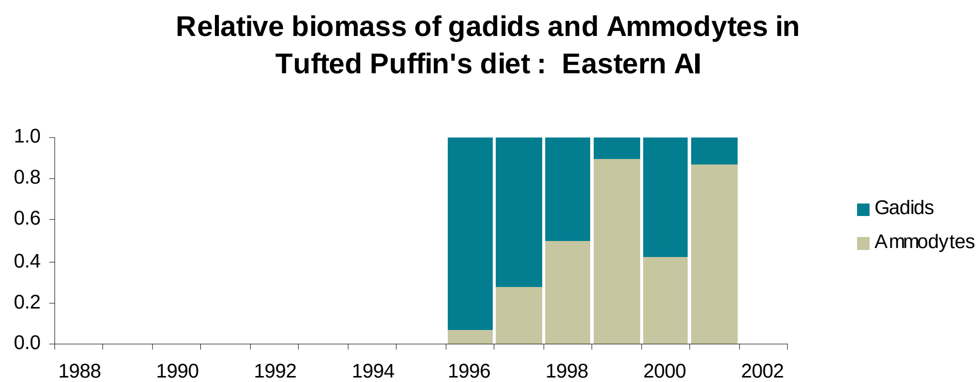
In the Western ecoregion, reproductive success trends differed between the auklet species in earlier years, but have trended similarly in recent years (Figure 21). Crested auklets trends were near the mean throughout most of the 1990s. From 2000 onward reproductive success has trended similarly. Both species fared poorly in 2003, but reproductive success have been higher than average for the past five years. In the Central ecoregion, auklet reproductive success trends differed between the species, with exceptionally poor years in 1997 and 2001 for crested auklets and in 2005 for least auklets. Recent trends are unknown (see above)(Figure 22).

Proportions of hexagrammids, gadids, and *Ammodytes* in tufted puffin chick diets Tufted puffins (*Fratercula cirrhata*) are medium-sized seabirds that nest in varying densities throughout the Aleutians. The USFWS stations field biologists to monitor puffin chick diets annually at Buldir and Aiktak Islands (Figure 19) and less frequently at other Aleutian islands on which they occur. Puffins carry multiple prey items in their bills when they return to their colonies to feed their chicks. Forage fish and squid comprise most of puffin chick diets. In the absence of direct measures of forage fish abundance, time series of percent biomass of hexagrammids, gadids, and *Ammodytes* in puffin chick meals were selected as indicators of forage fish recruitment and system-wide productivity.

Relative percent biomass of prey in diets of tufted puffin chicks have been collected most years since 1988 at Buldir Island in the Western ecoregion and since 1996 at Aiktak Island in the Eastern ecoregion (Figure 24). Data are not currently available for samples collected after 2002 on Buldir and 2001 on Aiktak Islands, but are expected to be available in the near future. Data included here were extracted from reports produced by the Alaska Maritime National Wildlife Refuge. Earlier data may be available from other studies.



(a)



(b)

Figure 24: Relative biomass of gadids and *Ammodytes* in tufted puffin chick diets at Buldir Island in the Western ecoregion and Aiktak Island in the Eastern ecoregion.

Apex predator and pelagic forager fish biomass indices We present two foraging guilds to indicate the status and trends for fish in the Aleutian Islands: apex predators and pelagic foragers. Each is described in detail below. This guild analysis was based on the time series available as part of the NOAA summer bottom trawl survey for the Aleutian Islands (Western and Central ecoregions) and the Aleutian Islands and Gulf of Alaska combined (Eastern ecoregion). These two guilds are based on the aggregation of Aleutian species by trophic role, habitat and physiological status. The species included in each guild are listed in Table 3.

Time series for the Western and Central ecoregions are based on data collected from the AI bottom trawl survey. The Eastern ecoregion time series is a composite of the Aleutian Islands survey,

Table 3: Species included in foraging guild-based fish biomass indices for the Aleutian Islands

Fish Apex Predators	**Pelagic Fish Foragers**
Pacfic cod	Atka mackerel
Pacific halibut	Northern Rockfish
Arrowtooth flounder	Pacific ocean perch
Kamchatka flounder	Walleye pollock
Rougheye rockfish	
Blackspotted rockfish	
Large sculpins	
Skates	

which samples the northern portion of the islands, and the Gulf of Alaska survey, which samples the southern portion. Since surveys in these two areas are conducted in different years, the biomass estimates represent the closest pair of years pooled together to get a total biomass estimate for the shelf region (0-500m). This time series excludes deep-water species such as sablefish and grenadiers, as most are found deeper than the trawl survey samples. The Team acknowledges that these would be good to include, but that the trawl survey does not sample them well.

Fish apex predators aggregate biomass There is an overall decreasing trend in Pacific cod biomass, which contributes the largest proportion to this guild across regions (Figure 25). Arrowtooth flounder, Kamchatka flounder and skates, all show an increasing trend.

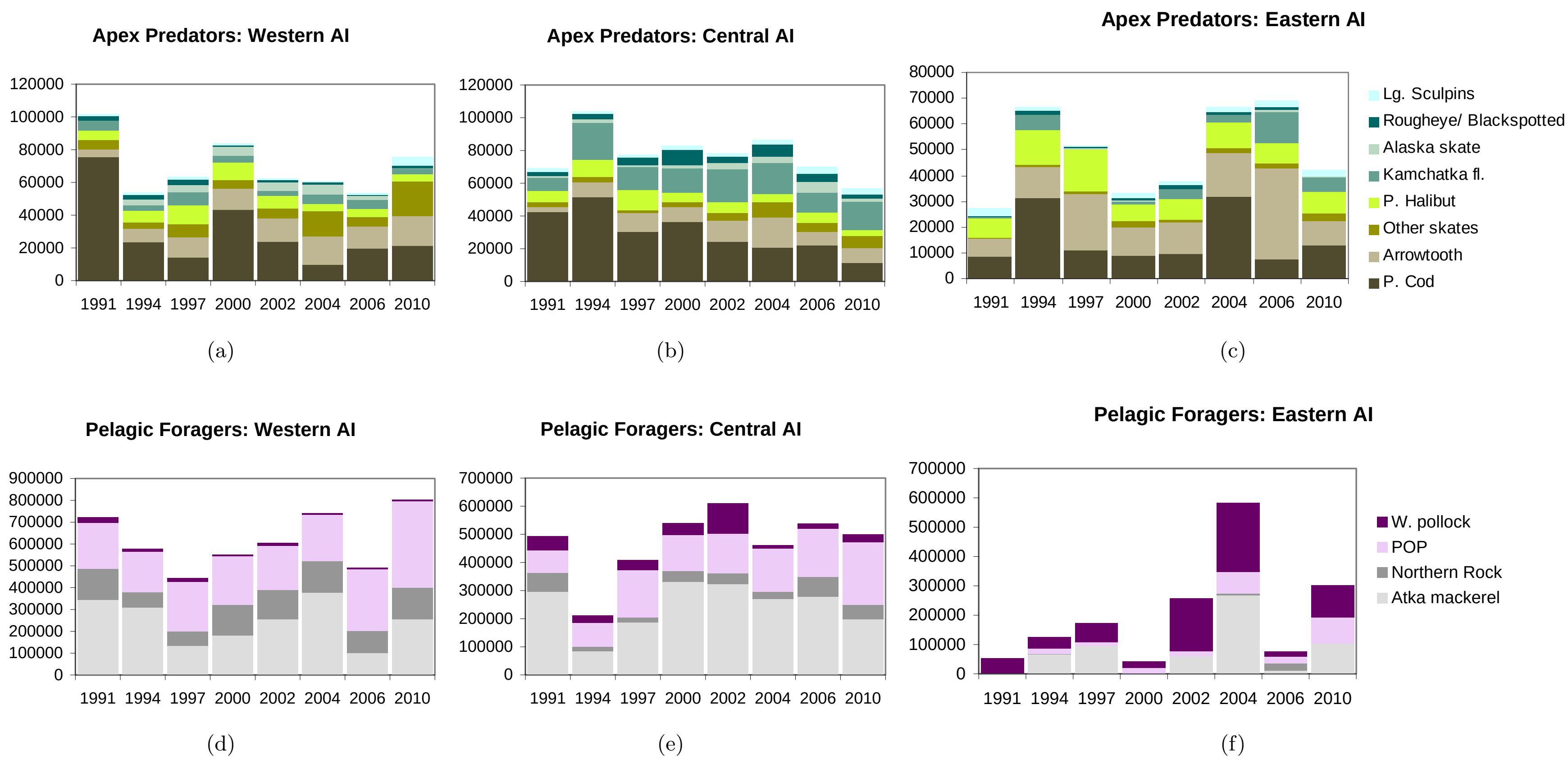


Figure 25: Composition in fish apex predator and pelagic fish foraging guilds by Aleutian Islands ecoregion.

In the Western ecoregion, the trend is largely driven by Pacific cod with second largest biomasses comprising skates and arrowtooth flounder. In the Central ecoregion, the trend is also largely driven by Pacific cod. In contrast to the Western ecoregion, Kamchatka flounder contributes the second largest biomass. In the Eastern ecoregion, the biomass trend is driven by Pacific cod and Arrowtooth flounder jointly, which alternate as the largest biomass in the area.

Fish pelagic foragers aggregate biomass Pacific ocean perch is increasing in all areas (Figure 25). There are several species showing longitudinal trends in this group: the biomass of walleye pollock increases towards the east, whereas that of northern rockfish and Pacific ocean perch increases toward west. Both walleye pollock and northern rockfish comprise a very low proportion of the total pelagic foragers at the lower end of their distribution. Overall pelagic foragers increase towards the west while benthic foragers increase towards the east (benthic foragers not shown due to limited reliable time series).

In the Western ecoregion, Atka mackerel and Pacific ocean perch drive the biomass trend and on average make up 80% of the pelagic foragers biomass with rest comprised mostly of northern rockfish. In the Central ecoregion, Atka mackerel and Pacific ocean perch also drive the biomass trend, making up 80% of the pelagic foragers biomass, with the remaining split between walleye pollock and northern rockfish. In the Eastern ecoregion, more than half the biomass is commonly contributed by walleye pollock and Atka mackerel. Atka mackerel show an increasing trend in the Eastern ecoregion, but only on the data from the northern portion of the islands. All groups fluctuate largely in this area, which has the lowest total biomass of pelagic foragers. There is almost no northern rockfish in this area.

Sea otter counts Sea otters (*Enhydra lutris*) counts were selected as a representative of the nearshore Aleutian environment. The >300 islands which make up the Aleutian chain provide extensive nearshore habitat. Sea otters are an integral component of the coastal ecosystems in which they occur. Sea otter predation limits the distribution and abundance of their benthic invertebrate prey, in particular herbivorous sea urchins. Otter-induced urchin declines increase the distribution and abundance of kelp in Alaska (Estes and Duggins, 1995) and in other areas of their range (Breen et al., 1982; Kvitek et al., 1998). This trophic cascade initiated by sea otters has indirect effects on other species and processes. Kelp forests are more productive than habitat without kelp (a.k.a. "sea urchin barrens"), fixing 3-4 times more organic carbon through photosynthesis (Duggins et al., 1989). This increased primary production results in increased growth and population size of consumers such as mussels and barnacles (Duggins et al., 1989). Rock greenling (*Hexagrammos lagocephalus*), a common fish of the kelp forests of the Aleutian Islands, are an order of magnitude more abundant in kelp forests than in sea urchin barrens (Reisewitz et al., 2006). Kelp forests likely function as nearshore habitat for other Aleutian Islands fish, such as the related Atka mackerel (*Hexamgrammos monopterygius*). Sea otter impacts on kelp forests also influence the behavior and foraging ecology of other coastal species such as Glaucous Winged Gulls (Irons et al., 1986) and Bald Eagles (Anthony et al., 2008).

Sea otter survey methods are detailed in Doroff et al. Doroff et al. (2003). Skiff-based surveys of sea otters were conducted several times during 2003, 2005, 2007, 2009 and 2011 at Amchitka Island, Kiska and Little Kiska Islands, Attu Island, Agattu Island, Rat Island and the Semichi Islands when viewing conditions were good to excellent (Beaufort sea state of 1-2, and .1 km of clear visibility at sea level). Full surveys were not conducted in 2011 at Kiska and Little Kiska

Islands, in 2003 at Rat Island, and in 2005 and 2011 at the Semichi Islands. Two or more observers counted sea otters from a 5.2-m skiff as it was run parallel to shore along the outer margins of kelp (*Alaria fistulosa*) beds at 15-22 km/h. Sea otters were counted with the unaided eye, using binoculars to confirm sightings or to count animals in large groups. The shoreline of each island was divided into contiguous segments, each 3-10 km in length and separated by distinctive topographic features (e.g., prominent points of land). Counts were recorded separately for each section. To maximize the time series available for this assessment, only counts of otters at Attu are presented for the Western ecoregion and counts at Amchitka for the Central ecoregion.

In the Western ecoregion, recent otter counts have shown no trend. In contrast, in the Central region, counts have declined recently. Sea otter populations were depleted by hunting at the turn of the 20th century but began to recover after the cessation of commercial hunting in 1911. Otter colonies in the Aleutian Islands continued to increase through the 1980s but then declined in the 1990s. The population declined to a uniformly low density throughout the islands, suggesting a common and widespread cause. A plausible hypothesis is that the decline was a result of increased predation by killer whales (Doroff et al., 2003) and possibly disease and contaminants (Kuker and Barrett-Lennard, 2010).

Steller sea lion non pup counts Counts of adult and juvenile Steller sea lions (*Eumetopias jubatus*) are used in the Aleutian Island ecosystem assessment to represent the status of an apex piscivorous predator whose diet consists primarily of commercially-fished species. The Steller sea lion inhabits coastal regions of the North Pacific Ocean, breeding in summer on terrestrial rookeries located from California north throughout the Gulf of Alaska, the eastern Bering Sea, the Aleutian Islands, Kamchatka Peninsula, Sea of Okhotsk, and the Kuril Islands (NMFS, 2010). The Steller sea lion is the world's largest member of the Otariidae family of pinnipeds. On average, Steller sea lions consume 6-10% of their body weight per day, but during lactation, energy intake by adult females may increase by as much as 3-fold (Keyes, 1968; Winship et al., 2002; Williams, 2005). Steller sea lions are generalist predators and consume a wide variety of fish and cephalopods in habitats ranging from nearshore demersal to offshore epi-pelagic, with local diets reflecting the species composition of the local fish community (Pitcher and Fay, 1982; Riemer and Brown, 1997; Sinclair and Zeppelin, 2002; Waite and Burkanov, 2006; Trites et al., 2007; McKenzie and Wynne, 2008; Fritz and Stinchcomb, 2005). In the Aleutian Islands, the diet consists largely of Atka mackerel, followed by salmon, cephalopods, Pacific cod, sculpins and walleye pollock (Sinclair and Zeppelin, 2002). Unlike phocid pinnipeds, otariids do not have large blubber (energy) stores, and as a consequence, require reliable access to predictable, local prey aggregations to thrive (Williams, 2005; Sigler et al., 2009).

Status and trend of Steller sea lion populations in Alaska are assessed using aerial photographic surveys of a series of 'trend' terrestrial haul-outs and rookeries that have been consistently surveyed each summer breeding season, when the proportion of animals hauled out is the highest during the year (Sease and York, 2003). Since 2004, NMFS has used high-resolution vertical photography (computer-controlled camera mounted in the belly of the plane) in its sea lion surveys in Alaska. This replaced the oblique, hand-held photographic techniques used from the first surveys in the 1960s and 1970s through 2002. Counts from vertical high resolution photographs were found to be 3.6% higher than those from oblique photos, necessitating the use of a correction factor to correctly compare recent counts with the rest of the time series (Fritz and Stinchcomb, 2005). Trend sites include the vast majority (>90%) of animals observed in each survey. Adults and juvenile (non-pup) numbers used for population trend assessment are sums of counts at trend sites within sub-areas or across the range of the western DPS in Alaska (NMFS, 2010). Replicate surveys conducted in the summers of 1992 and 1994 indicated that sub-area trend site counts of non-pups are stable within each breeding season (coefficients of variation of ∼5%; NMFS, unpublished data).

Steller sea lions inhabiting the Aleutian Islands are part of the western distinct population segment (DPS) currently listed as 'endangered' under the US Endangered Species Act due to a steep decline in abundance in the 1980s (-15%/y) and a continued, but slower decline in the 1990s (-5%/y) (NMFS 2010). Since 2000, the western DPS overall has increased slowly (∼1-2%/y), but there has been considerable regional variability in its response to changing management and environmental conditions: sea lion populations are stable or increasing in the 2000s throughout the Gulf of Alaska and in the Aleutian Islands as far west as Tanaga Pass (178°W) in the central Aleutian Islands, but continue to decline in the Delarof Islands (178-180°W; -2%/y), Rat Islands (177-180E; -4%/y) and Near Islands (172-177°E; -7%/y) (NMFS, 2010).

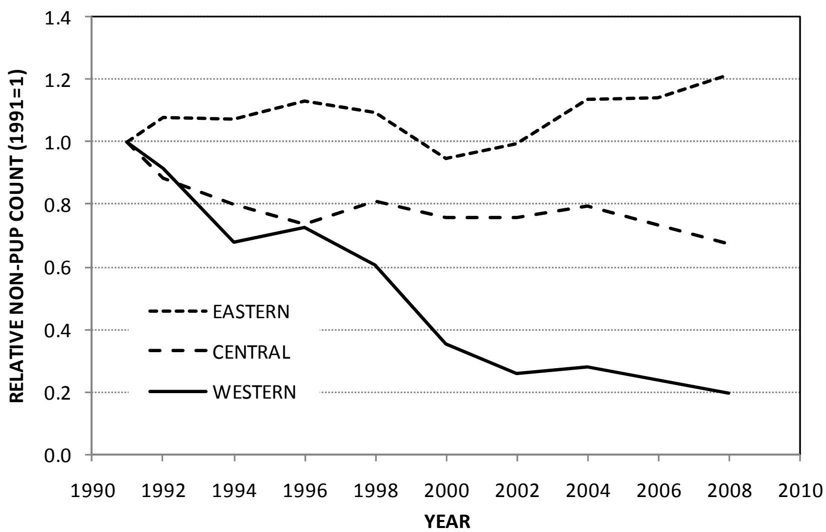


Figure 26: Relative change in counts of adult and juvenile (non-pup) Steller sea lions in the western, central and eastern Aleutian Island sub-areas, 1991-2008.

In our Aleutian Island ecosystem assessment, counts of adult and juvenile Steller sea lions at trend sites are used to indicate of the 'health' of apex piscivores whose diet consists primarily of commercially-fished species. The survey sites used in the assessment are:

- Western (172-177°E; 10 sites in the Near Island group and Buldir west of Kiska),
- Central (177E to ∼170°W; 62 sites in the Rat, Delarof, and Andreanof Island groups, plus the Islands of Four Mountains), and
- Eastern ecoregions (163-170°W; 30 sites in the Fox and Krenitzen Islands, on Unimak Island, and on and near Amak Island in the southeastern Bering Sea)

There is a strong west-east gradient in Steller sea lion population trends over the last 20 years in the Aleutian Islands (Figure 26). Between 1991 and 2008, non-pup counts declined 81% in the western Aleutians, or at a rate of -10%/y (P<0.001). One major rookery that produced almost 400 pups per year in the early 1990s (Buldir Island) produced only a single pup in 2010 (NMFS, unpublished). Sea lion population trends improve to the east. While counts of non-pups in the central Aleutians declined 33% overall between 1991 and 2008 (-2%/y, P=0.011), the trend was much less steep than in the western sub-area. In the eastern Aleutians, non-pup counts increased 21% overall between 1991 and 2008: counts were largely stable through the 1990s, but increased at a rate of 3%/y (P=0.008) between 2000 and 2008.

Percent of shelf <500m trawled The annual and cumulative percentage of AFSC RACE 5 km x 5 km survey cells with observed commercial trawling, was developed from the North Pacific Observer Program foreign and domestic database in the Aleutian Islands region in waters with a bottom depth shallower than 500 meters (Figure 27). For the annual index, a cell is counted as trawled if there is a single trawl in the cell for that year. For the cumulative index, a cell is counted as trawled if there is a single observed trawl end position in the cell for the entire time series in each period: 1977-1989, 1990-1999, 2000-2010. Periods were chosen based on significant policy changes: 1990 marks the start of the domestic fisheries, while in 1999 and 2000 the US government issued emergency interim rules to further protect Steller sea lions. These rules expanded the number of seasonal and year-round pollock trawl exclusion zones around important rookeries and haulouts, implemented measures to disperse pollock fishing effort spatially and tempoarlly, and closed the Aleutian Islands to pollock trawling; additional restrictions were placed on the Atka mackerel fishery in the AI. New extensive protection measures for Steller sea lion were implemented in 2011 which significantly expand closures.

The time series begins in 1977 for both indices. These indices measure the annual and cumulative impacts of trawling on AI shelf habitat within each eco-region, allowing for an evaluation of changes in these indices. Increases in the cumulative index are thought to indicate an expansion of the trawl fisheries into previously untrawled areas. Caution should be taken in the interpretation of these indices because only observed effort is included and changes in the indices may be influenced by changes in observer coverage. For example, a large increase in the annual and cumulative indices can be seen in 1991, when the domestic fishery observer program was implemented. Further, the implication of these indices is that the impact of a single trawl is the same as multiple trawls in an area, this is a gross simplification. Future work should concentrate on assessing the appropriate weighting of trawl impacts on different habitat types and defining habitat types in the Aleutian Islands region.

K-12 enrollment in Aleutian Islands schools The number of children enrolled in schools was selected as an indicator of vibrant, sustainable communities in the Aleutian Islands ecosystem. Community residents are closely tied to the ecosystem through sense of place and daily experience and activity. Enrollment statistics for kindergarten through twelfth (K-12) grades by school and region were compiled for the years 1996 through 2011 (`http://www.eed.state.ak.us/stats/`). School enrollment numbers fluctuate widely and serve to highlight the difficulties in maintaining sustainable communities within the Aleutian Islands ecosystem.

The Western ecoregion does not have any schools. The Central Aleutian ecoregion contains two communities with schools: Adak school and Yakov E. Netsvetov School in Atka. The Eastern Aleutian ecoregion has five schools within the region: Nikolski, Akutan, and False Pass Schools,

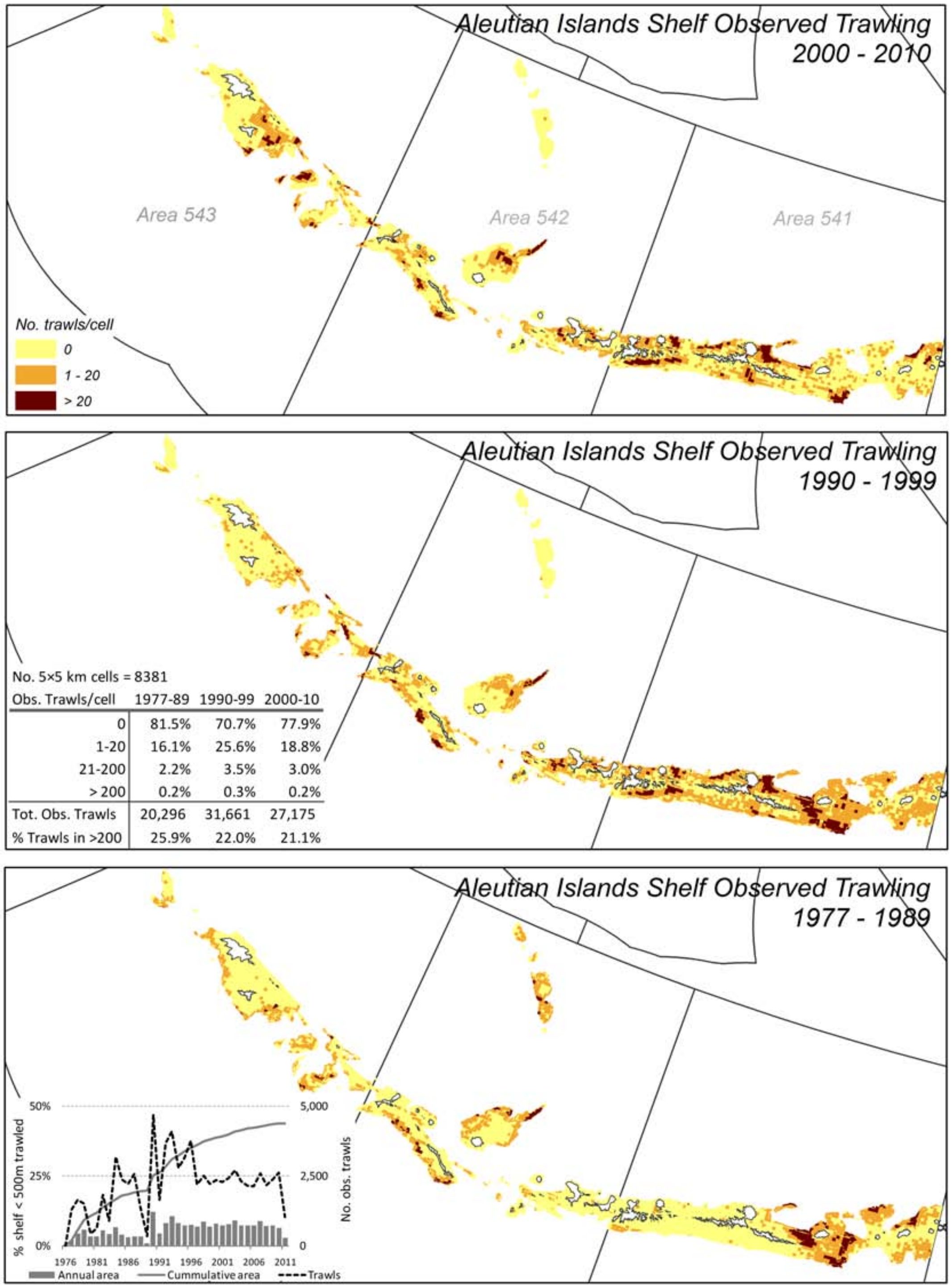


Figure 27: The annual and cumulative percentage of AFSC RACE 5 km5 km survey cells with observed trawling by decade.

two schools in Dutch Harbor (Unalaska Elementary and Unalaska Junior/Senior High School), and an Aleutians East Correspondence School.

Table 4: Number of children enrolled in kindergarten to twelfth grades by school in the Aleutian Islands ecosystem, 1996-2011. Source: `http://www.eed.state.ak.us/stats/`.

Region	Central		Western					
Year	Adak	Y.Netsvetov	Nikolski	Akutan	Aleutian E.	False Pass	Unalaska Elem.	Unalaska Jr/Sr High
1996		20		23		27	229	124
1997		22		23		21	218	157
1998		23		24		13	280	100
1999	19	19	13	20		11	248	100
2000	45	20	10	15		16	241	111
2001	23	19	15	15		13	207	145
2002	23	21	13	16	2	16	210	164
2003	18	19	15	18	1	12	164	226
2004	15	17	11	11	1	12	171	226
2005	19	17	10	14		10	161	236
2006	19	16	10	10		11	193	205
2007	19	13	10	10		5	193	192
2008	14	13	11	13		5	225	162
2009	17	14	8	7		11	228	176
2010	21	15	0	10		5	211	194
2011	19	10	0	8		6	208	198

In general, school enrollments numbers in the Aleutian Islands region have been on the decline in the small village schools, although the overall recent trends are stable (Table 4). Rural communities in Alaska are suffering losses as Alaska Natives increasingly leave villages for the cities. Young women in particular, have departed, and birth rates which were once disproportionately higher in villages, have dropped leading to a decline in rural Alaska schools.

Adak (formerly Adak Station), is the westernmost municipality in the United States and the southernmost city in Alaska. After World War II, Adak was developed as a naval air station and served as a key submarine surveillance center during the Cold War. After the Cold War ended, the base was downsized and both family housing and schools were closed by 1994. The station officially closed on March 31, 1997. The Aleut Corporation purchased Adak's facilities through a land transfer agreement with the Department of the Interior and the U.S. Navy/Department of Defense. Families with children relocated to Adak after the purchase agreement, and in 1998, the former high school reopened as a K-12 school. (`http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm?Comm_Boro_Name=Adak&Data_Type=generalOverview&submit2=Get+Data`). Peak enrollment for Adak school was in the 1999-2000 school year with 45 students. However, by 2003, six years after the closure of the station, many of the facilities developed by the Navy and Coast Guard closed, enrollment numbers declined and have since fluctuated between 14 and 21 students. Aleut Fisheries and Western Star Seafoods, a subsidiary of Icicle Seafoods finalized a lease of Adak's seafood processing facility in spring of 2011. The goal is to have the plant resume operations and become fully functional for the 2012 Pacific cod season. The resumption of the processing plant in Adak will have an impact on the local community and may have downstream effects on school enrollment numbers.

False Pass is located on the eastern end of Unimak Pass at the westernmost tip of the mainland Alaska Peninsula. The community has traditionally depended on commercial fishing. Fishing, fish processing and subsistence activities are the mainstays of the lifestyle. The local economy is driven by commercial salmon fishing and fishing services. False Pass is an important refueling stop for the Bristol Bay and Bering Sea fishing fleets. Bering Pacific and Peter Pan Seafoods process the commercial catch. False Pass is another example of a school and community struggling to sustain itself. Enrollment numbers have been on a general decline since 1996 and most recently were down to 5-6 children enrolled for the 2010 and 2011 school years.

The Nikolski School which serves grades K-12, was built by the Bureau of Indian Affairs in 1939 and is now in danger of extinction (Yardley 2009). The school had one live-in teacher that occupied a small home owned by the school district adjacent to the school building purpose-built for teachers and their family. Schools in rural Alaska must have at least 10 students to retain funding from the state. For the 2009-2010 school year, however, the Nikolski School had only eight enrolled students. This school is now closed and the fate of the village is uncertain. (`http://video.nytimes.com/video/2009/11/25/us/1247465851581/an-alaskan-village-in-crisis.html`).

Schools are closely linked to the heart of communities and reflect the health and sustainability of the communities they serve. The sustainability of these communities are not driven solely by economics such as fishery or processing plant closures, but also by ecosystem health as experienced through direct interactions with the ecosystem, such as subsistence fishing.

Gaps and Needs

1. Physical indices While it is widely assumed that variability in the physical environment influences Aleutian ecosystems, little is known about the mechanisms by which this influence occurs. It is plausible that the variability in temperatures, currents, mixing, storminess and cloudiness can all influence this ecosystem, but the relative importance of these factors is unknown. Many of the processes expected to be important here occur on small spatial scales, and it is likely that their importance differs in the eastern versus western portion of the domain. This situation is exacerbated by the immense size of the region and its remoteness, and the dearth of direct data on both the physical environment and its linkages to the biology. Moreover, the pervasive cloud cover limits the availability of satellite-based ocean color and sea surface temperature data. The team noted this lack of knowledge, especially during the evaluation of physical indicators important for the ecosystem. The team recommends more studies linking physical forcing to biological responses as well as more oceanographic studies, particularly west of Amchitka Pass.

2. Nearshore untrawlable habitat Nearshore untrawlable habitat is not currently monitored, nor are time series of data available. The Team discussed including the results of EMAP monitoring of benthic nearshore habitat. This project has had its baseline year, but continuation is contingent upon funding. If continued, results would be included in future assessments.

3. Regional analysis of stock exploitation rates A region by region analysis of spatial stock exploitation rates would be informative, as would an evaluation of spatial exploitatio rates as as a function of the area trawled. The data and models exist to accomplish this, but not in the time frame of this first assessment. This is under discussion for inclusion in the next version in fall 2012.

4. Myctophids/squids This is one of the most important pieces of the ecosystem in which we are lacking data. There are currently no direct estimates of small pelagics.

5. Corals Beginning in FY12 (and continuing through FY14) the NMFS Deep Sea Coral Research and Technology Program (DSCRTP) will be sponsoring a significant field research program in the Alaska region which will provide important information for use in future Aleutian Islands ecosystem assessments. The DSCRTP was established under the reauthorized MSA to improve the understanding, conservation and management of deep-sea coral and sponge ecosystems. The DSCRTP is funding rotating three year field initiatives in each fishery management council area, beginning with the Southeast United States in 2009. This was followed by a west coast of the United States initiative beginning in 2010 and the three year rotation to the Alaska region will begin in 2012.

In anticipation of the upcoming fieldwork a workshop was held in September 2010 in Anchorage, Alaska to identify important research priorities for the region. These priorities were largely derived from ongoing research needs and objectives identified by the DSCRTP, the North Pacific Fishery Management Council and EFH-EIS process. The research priorities included: (1) determining the distribution, abundance and diversity of sponge and coral in Alaska (and its distribution relative to fishing activity), (2) compiling and interpreting habitat and substrate maps for the Alaska region, (3) determining coral and sponge associations with FMP species (especially juveniles) and the continuing contribution of these ecosystems to fisheries production, (4) determining impacts of fishing by gear type and testing gear modifications to limit any impacts, (5) determining recovery rates of deep-water coral and sponge communities in Alaska from disturbance or mortality, and (6) establishing long-term monitoring programs that can be used to determine the effects of climate change and ocean acidification on deep-coral and sponge ecosystems.

Another outgrowth of this workshop was the formation of a planning team to guide the FY12-14 field research. Through on-going planning team discussions culminating in an August 2011 meeting, a series of specific research objectives to be addressed and corresponding research projects were identified. These projects were translated into specific field efforts that will begin in the summer of 2012. The field research will be led by scientists from the NMFS - Alaska Fisheries Science Center, the NOS - National Centers for Coastal Ocean Science, DSCRTP, NMFS - Alaska Regional Office, and the University of Alaska, Fairbanks. Most of these projects will be carried out in each of the three years of the DSCRTP funding and will result in completed research products and recommendations in early 2015.

Indicators common to all ecosystems

Objective: Maintain predator prey relationships and energy flow

Indicator: Discards and discard rates

See 2011 contribution by Terry Hiatt (p. 204, this document)

Index Estimates of discards for 1994-2002 come from NMFS Alaska Region's blend data; estimates for 2003-10 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). Discards in the Gulf of Alaska increased somewhat between 1998 and 2003, declined in 2004 and 2005, increased in 2006-2009, and declined again in 2010. 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 seven 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 2010 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.

Implications 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.

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 2011 contribution by Todd Tenbrink (p. 230, 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 (Tables 11 and 12). There are also 28 non-FSSI stocks in Alaska. There are 230 FSSI stocks in the U.S., with a maximum possible score of 920.

Status and trends As of June 30, 2011, 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. Stocks that are considered overfished are Pribilof Island blue king crab and BSAI tanner crab. The Pribilof Island blue king crab is on a continuing rebuilding plan (year 8 of 10-year plan) while the management required for the tanner crab stock is to develop a rebuilding plan. The BS snow crab stock is also on a continuing rebuilding plan (year 11 of 10-year plan). For this stock, the NPFMC is revising the rebuilding plan, which will extend the rebuilding target date. In the meantime, there is no directed fishing for snow crab, and the majority of blue king crab habitat is closed to bottom trawling.

The current overall Alaska FSSI for FSSI stocks is 119 of a possible 140 score, based on updates through June 2011. The overall Bering Sea/Aleutian Islands score is 76 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 25 of a possible score of 36. The Gulf of Alaska groundfish score is 43 of a maximum possible 48.

Factors causing trends The stocks that had low FSSI scores (1.5) in the GOA are shortspine thornyhead rockfish (indicator species for thornyhead rockfish complex) and yelloweye rockfish (indicator species for demersal shelf rockfish complex). The reasons for these low scores are: 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.

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

Indicator: Number of endangered or threatened species

See 2010 contributions by Lowell Fritz, Marcia Muto, 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

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	

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 20^{th} 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. 187). 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. 192). 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 in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`.

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, 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 2011 contribution by John Olson (p. 209, 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. For additional background on fishery closures in the U.S. EEZ off Alaska, see Witherell and Woodby (2005).

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) of 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 nm^2 to the area closed to bottom trawling year round.

In 2010, the Council adopted area closures for Tanner crab east and northeast Kodiak. Federal waters in Marmot Bay are closed year round to vessels fishing with nonpelagic trawl. In two other designated areas, Chiniak Gully and ADF&G statistical area 525702, vessels with nonpelagic trawl gear can only fish if they have 100% observer coverage. To fish in any of the three areas, vessels fishing with pot gear must have minimum 30% observer coverage.

Substantial parts of the Aleutian Islands were closed to trawling for Atka mackerel and Pacific cod (the predominant target species in those areas) in early 2011 as part of mitigation measures for Steller sea lions. Management area 543 and the western half of 542 are included in this closure.

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 2011 contributions by John Olson (p. 210, 215, 221, and 226, this document)

Index Fishing effort is an indicator of damage to or removal of structural epifauna, 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 In general, observed bottom trawl effort in the Gulf of Alaska and Aleutian Islands has declined as pollock and Pacific cod TACs have been reduced. Effort in the Bering Sea remained relatively stable between 1993 and 2010. In 2010, observed AI hook and line effort increased from the year before and was higher than the 13-year averge; decreased from 2009 in the EBS and remained below average, and was above average in the GOA. Pelagic trawl effort in the EBS declined to become lower than the 13-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 2010 was below the 13-year average. The observed pot fishing effort was similar to that seen in the last decade 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 strutural epifauna 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, structural epifauna, 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 structural epifauna 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. structural epifauna 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 structural epifauna.

Objective: Incorporate and/or monitor effects of climate change

Indicator: North Pacific climate indices

See 2011 contribution by Nick Bond and Lisa Guy (p. 106, this document)

Index To examine potential effects of climate on groundfish distribution, recruitment and survival, indices of climate conditions are assessed. The focus here is on five 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 three atmospheric indices, the North Pacific Index (NPI), North Pacific Gyre Oscillation (NPGO) and Arctic Oscillation (AO). The time series of these indices from 2001 through early 2011 are plotted in Figure 30.

Status, trends, and factors causing trends The state of the North Pacific atmosphere-ocean system reflected the influences of ENSO during 2010-11. The Aleutian Low tends to be weaker during La Niña winters, and 2010-11 was no exception, as evidenced by the strongly positive SLP anomalies shown in Figure 29b. It is worth noting that the degree of activity in the ENSO cycle varies on multi-year time scales. The ENSO cycle was relatively weak during the first half of the 2000s while it was in a predominantly positive phase; the fluctuations between significantly positive (El Niño) and negative values (La Niña) have been more prominent during the past 5-6 years. The projections of the dynamical and statistical models used to forecast ENSO are discussed in the last section of this overview.

The PDO became negative during spring of 2010 and reached a minimum of about -1.3 in early fall 2010. It exhibited an increasing trend from late 2010 through the spring of 2011. This trend reversed again in summer 2011. It is an open question whether this latest tendency will continue, or whether the PDO will return to a more neutral state. The PDO is related to ENSO through the effects of the latter on the atmospheric circulation over the North Pacific and hence air-sea interactions, and ultimately, SST patterns. The potential predictability of the PDO appears to be largely associated with its connection to ENSO.

The NPI is a commonly used measure of the strength of the Aleutian Low. The NPI has undergone large swings from positive to negative and then back to positive over the last three years. Note the negative correspondence with the NINO3.4 index in general; over the last few years this relationship appears to have been especially tight.

The climate community has been paying increasing attention to another mode of variability in the North Pacific termed the North Pacific Gyre Oscillation (NPGO). It has been shown to relate to chemical and biological properties in the Gulf of Alaska and the CalCOFI survey area (Di Lorenzo et al., 2008). It underwent a significant transition from strongly negative in the early 1990s to strongly positive in the early 2000s in concert with the so-called "Victoria" pattern in SST (Bond et al., 2003). It has been in a positive state since 2007, which projects on stronger than normal flows in both the Alaska Current portion of the Subarctic Gyre and the California Current.

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^o N. It has a weakly positive correlation with sea ice extent in the Bering Sea. During periods of positive AO, cold air outbreaks to mid-latitudes are suppressed. The AO had a record negative value during the winter of 2009-10; it was also strongly negative during the early portion of the winter of 2010-11 and then switched to positive during the early portion of 2011. It became weakly negative during late spring 2011. 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.

Implications The state of the North Pacific atmosphere-ocean system during 2010-2011 reflected the typical response to La Niña. The Aleutian low was much weaker than usual in the winter of 2010-11, and the sea level pressure was higher than normal in the eastern portion of the basin for the year as a whole. Cooler than normal upper ocean temperatures prevailed in the eastern portion of the North Pacific and warmer than normal temperatures occurred in the west-central and then central portion of the basin. This pattern reflects a negative sense to the Pacific Decadal Oscillation (PDO). Near-normal conditions are present in the tropical Pacific at the current time; the models used to forecast ENSO are indicating outcomes for the winter of 2011-12 ranging from a neutral to a weak-moderate La Niña state.

Indicator: Combined standardized indices of groundfish recruitment and survival

See 2010 contribution by Franz Mueter in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`.

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 (CSI_R) and survival (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 CSI_R and 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. La Niña conditions developed again in the summer of 2011, following on the heels of the same pattern last year. This is liable to bring about relatively cool 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 2006-2010, 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 structural epifauna. 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 structural epifauna as habitat for different species and life stages of fish, estimates of structural epifauna 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 structural epifauna.

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.

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.

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. Older contributions that are not maintained were excluded from this report. Please see archived versions available at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Physical Environment

North Pacific Climate Overview

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Summary: The state of the North Pacific atmosphere-ocean system during 2010-2011 reflected the typical response to La Niña. The Aleutian low was much weaker than usual in the winter of 2010-11, and the sea level pressure was higher than normal in the eastern portion of the basin for the year as a whole. Cooler than normal upper ocean temperatures prevailed in the eastern portion of the North Pacific and warmer than normal temperatures occurred in the west-central and then central portion of the basin. This pattern reflects a negative sense to the Pacific Decadal Oscillation (PDO). Near-normal conditions are present in the tropical Pacific at the current time; the models used to forecast ENSO are indicating outcomes for the winter of 2011-12 ranging from a neutral to a weak-moderate La Niña state.

Regional Highlights:

West Coast of Lower 48 This region experienced a typical response to La Niña during 2010-11. The waters near the coast tended to be cool, with varying salinity, relative to normal. The cooler waters were accompanied by a greater preponderance of sub-arctic than sub-tropical zooplankton than usual (B. Peterson, NOAA/NWFSC). With regards to the winds, the winter of 2010-11 brought anomalous upwelling off of Washington and Oregon and near-normal wind forcing along California. This pattern reversed for the spring and early summer 2011 during which upwelling was somewhat stronger than normal off California and weaker than normal to the north. The copious precipitation along the west coast during the winter and spring produced anomalously high freshwater discharges. More details on the state of the California Current system are available at `www.pacoos.org`.

Gulf of Alaska The data from Argo profiling floats, available at `http://www.pac.dfo-mpo.gc.ca/science/oceans/Argo/Alaska-Argo-eng.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 declined considerably over the last 18 months since its peak in the winter of 2009-10. This change is presumably due, at least in part, to the anomalous northerly and northwesterly winds over the interval. The mixed layer depths in the Gulf have been near their seasonal norms.

Alaska Peninsula and Aleutian Islands Westerly wind anomalies have prevailed in this region during the past year, except during spring 2011. These anomalies have served to suppress the northward transport through Unimak Pass and perhaps also the Aleutian North Slope Current. The wind anomalies during spring 2011 were weak, but since they were easterly they would have acted to enhance upwelling during that season along the north side of the Alaska Peninsula and Aleutian Islands.

Bering Sea The Bering Sea shelf experienced another relatively heavy ice year, but not as extreme as those of 2008-09 and 2009-10. The weather during early winter was quite cold, but the late winter was a bit warmer than normal and the winds during the spring did not feature the same northerlies that delayed the retreat of the ice in 2010. As noted above, the summer of 2011 has been relatively stormy. The upper ocean is also relatively cold in the eastern Bering Sea and if these conditions persist into fall, they would promote the relatively early development of sea ice during the winter of 2011-12. A confounding factor is the state of the Arctic, which is summarized briefly below.

Arctic The tendency for reduced sea ice cover in the Arctic during the summer has continued into 2011. The areal coverage in July 2011 was even less than in July 2007, and hence the lowest in the historical record. The idea that reduced sea ice cover in the fall may have systematic impacts on the hemispheric atmospheric circulation during early winter is consistent with the strongly negative AO state that occurred in December 2010. It has become clear that the reduced ice cover at the end of the melt season tends to delay the development of ice in marginal seas such as the Bering Sea during the following cold season. Nevertheless, it is unclear how much the maximum ice extent in these marginal seas depends on previous conditions in the central Arctic.

Sea Surface Temperature and Sea Level Pressure Anomalies

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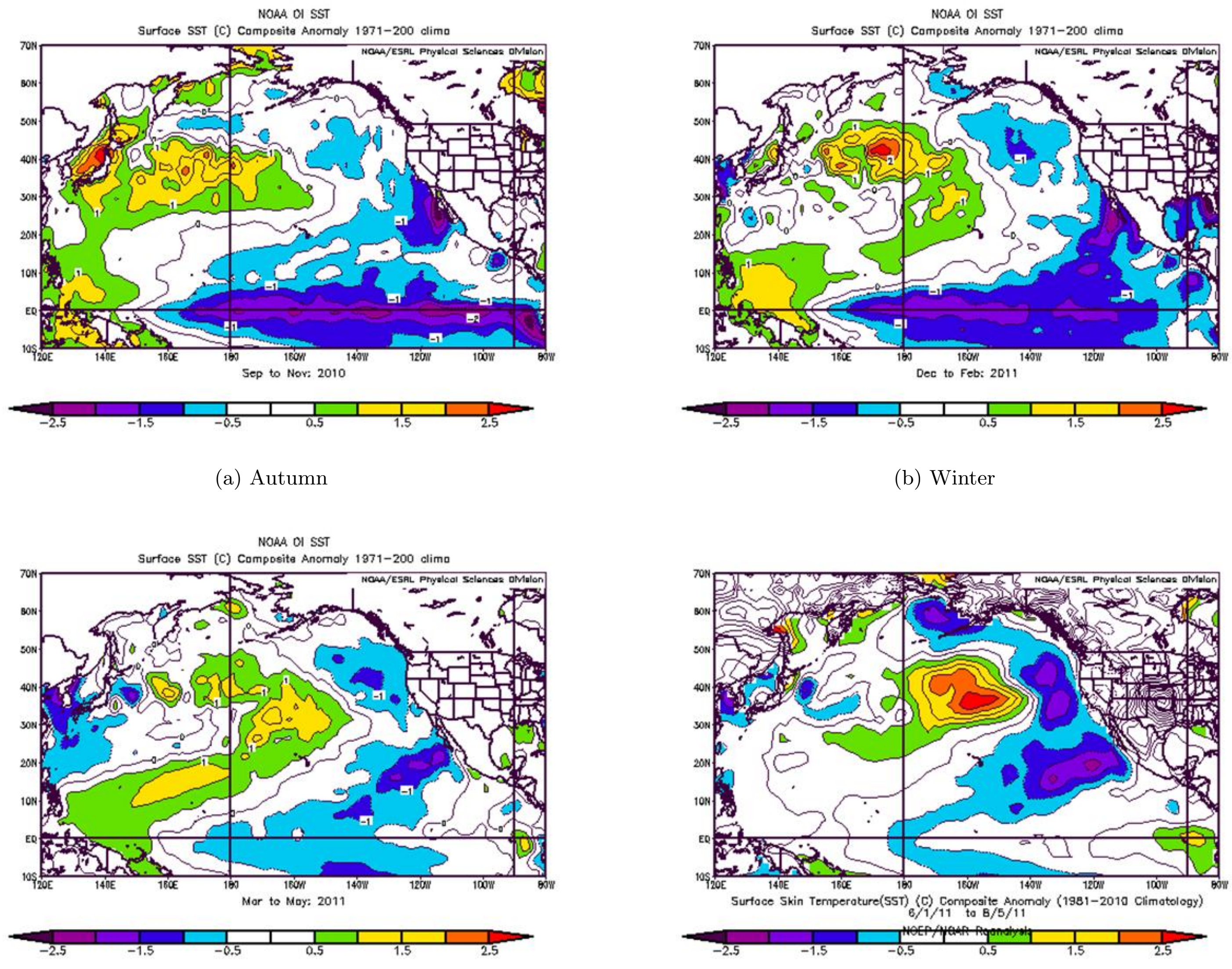
Description of indices: The state of the North Pacific from autumn 2010 through summer 2011 is summarized in terms of seasonal mean sea surface temperature (SST) and sea level pressure (SLP) anomaly maps. The SST and SLP anomalies are relative to mean conditions over the periods of 1971-2000 and 1981-2010, respectively. The SST data are from NOAA's Optimal Interpolation (OI) analysis; the SLP data are 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`.

Status and trends: In an overall sense, the climate forcing of the North Pacific during the year of 2010-11 was dominated by the response to La Niña. The autumn (Sep-Nov) of 2010 included weak to moderate negative SST anomalies in the northern and eastern North Pacific, and moderate to strong positive SST anomalies in the central and western North Pacific. Much cooler than normal SSTs occurred in the central and eastern tropical Pacific in association with La Niña (Figure 28a). The corresponding pattern of anomalous SLP included negative anomalies in the Gulf of Alaska and weaker positive anomalies in the eastern sub-tropical and tropical Pacific (Figure 29a). This pattern corresponds with westerly wind anomalies from roughly 30^o to 50^{o}N across the eastern North Pacific, and hence anomalous equatorward Ekman transports.



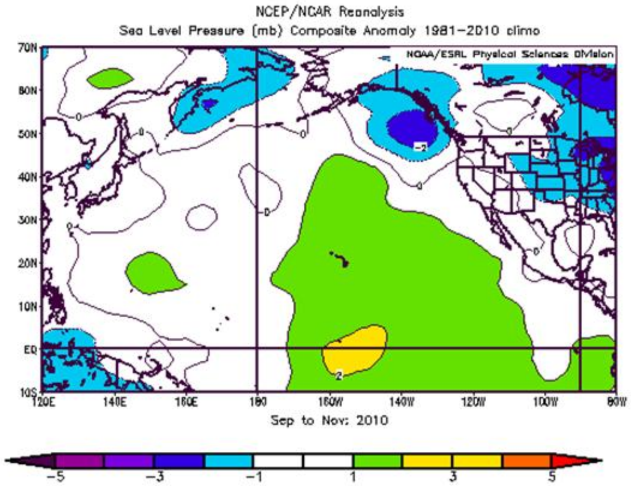
(a) Autumn

(b) Winter

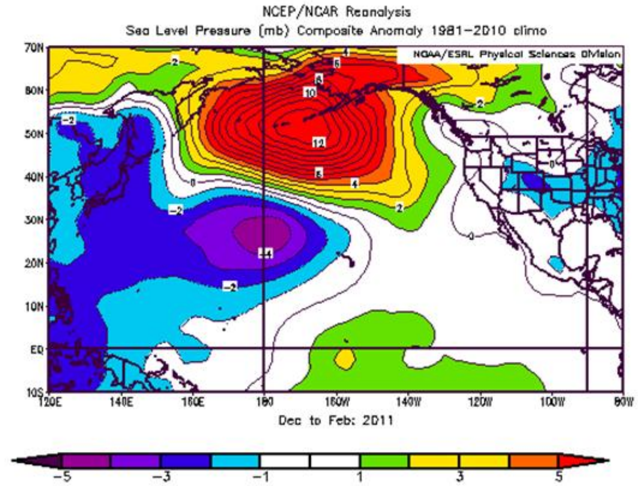
(c) Spring

(d) Summer

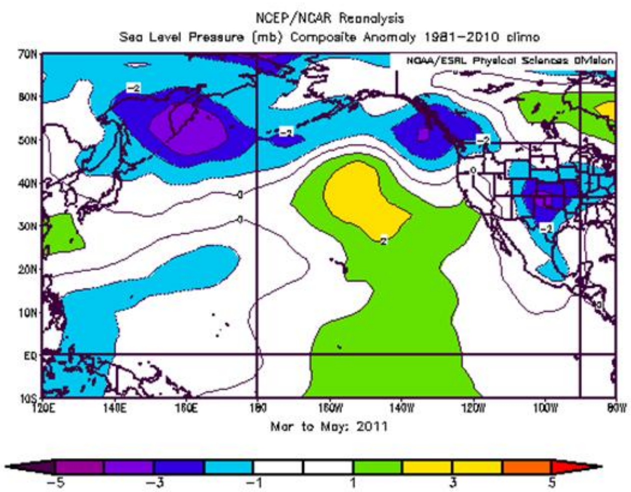
Figure 28: SST anomolies for autumn (September-November 2010), winter (December 2010 -February 2011), spring (March - May 2011), and summer (June - August 2011).



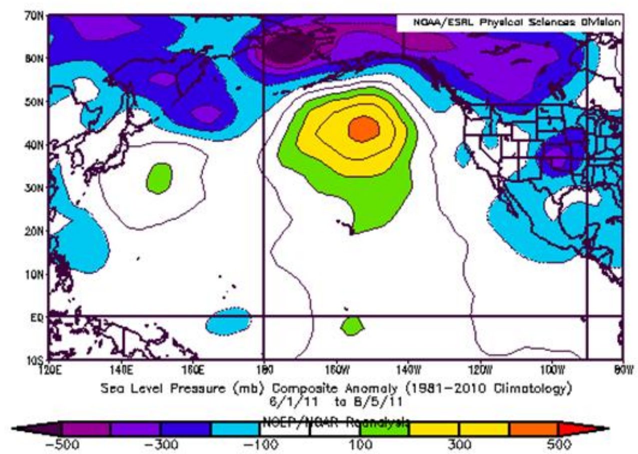
(a) Autumn



(b) Winter



(c) Spring



(d) Summer

Figure 29: SLP anomolies for autumn (September-November 2010), winter (December 2010 -February 2011), spring (March - May 2011), and summer (June - August 2011).

The pattern of anomalous SST during winter (Dec-Feb) of 2010-11 (Figure 28b) resembled its counterpart during the previous fall. There was some modest cooling, relative to seasonal norms, in the eastern Bering Sea, and continuation of La Niña in the tropical Pacific. The anomalous SLP during winter 2010-11 was dominated by a large and intense high (>12 mb) centered near 50° N, 165° W (Figure 29b). The seasonal average SLP near the center of this positive anomaly was the greatest since the winter of 1955-56 (which also featured La Niña). It is worth noting that the eastern North Pacific experienced SLP anomalies of comparable magnitude, but opposite sign, during the winter of 2009-10. This swing can be attributed, at least in part, to the transition from El Niño in 2009-10 to La Niña in 2010-11. The anomalous SLP pattern shown in Figure 29b indicates anomalous northwesterlies in the mean for the Gulf of Alaska and anomalous upwelling along the coast of North America from the Gulf of Alaska to California. The SLP pattern implies a suppression of storminess in the Aleutians and southwesterly wind anomalies across much of the Bering Sea. This is not a relatively warm pattern for the Bering Sea, since a weaker than normal Aleutian low means lesser than usual incursions of mild air of maritime origin.

The distribution of SST in spring (Mar-May) of 2011 (Figure 28c) indicates a continuation of colder than normal temperatures in the eastern basin of the North Pacific and anomalous warmth in the central North Pacific. There was a marked decline in La Niña in the tropical Pacific. The concomitant SLP anomaly map (Figure 29c) indicates a low-amplitude pattern with relatively low pressure extending from eastern Siberia across the northern Pacific into western and central North America, and high pressure in the eastern North Pacific. This pattern served to support anomalous easterlies for the Bering Sea shelf during the spring of 2011, and hence warming of this region relative to seasonal norms after a cold winter.

The pattern of anomalous SST in summer (Jun-Aug) 2011 (Figure 28d) featured the development of substantial negative values in the eastern Bering Sea, a strengthening of cold temperatures off the west coast of the lower 48 states and in the eastern sub-tropical Pacific, and continued cool conditions in the eastern Bering Sea. There was also a strengthening of warm SST anomalies to north of the Hawaiian Islands. The overall pattern projects rather strongly on the negative phase of the Pacific Decadal Oscillation (PDO). Near-neutral ENSO conditions prevailed in the tropical Pacific. The distribution of anomalous SLP (Figure 29d) included strongly negative and positive centers in the northern Bering Sea and southern Gulf of Alaska, respectively. The former anomaly helped cause the anomalous cooling of the Bering Sea due to enhanced storminess and westerly winds (equatorward Ekman transports). The circulation around the anomalous high in the southern Gulf of Alaska produced stronger than normal northwesterlies over much of the far eastern North Pacific.

Climate Indices

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Last updated: August 2011

Description of 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. The focus here is on five 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 three atmospheric indices, the North Pacific Index (NPI), North Pacific Gyre Oscillation (NPGO) and Arctic Oscillation (AO). The time series of these indices from 2001 through early 2011 are plotted in Figure 30.

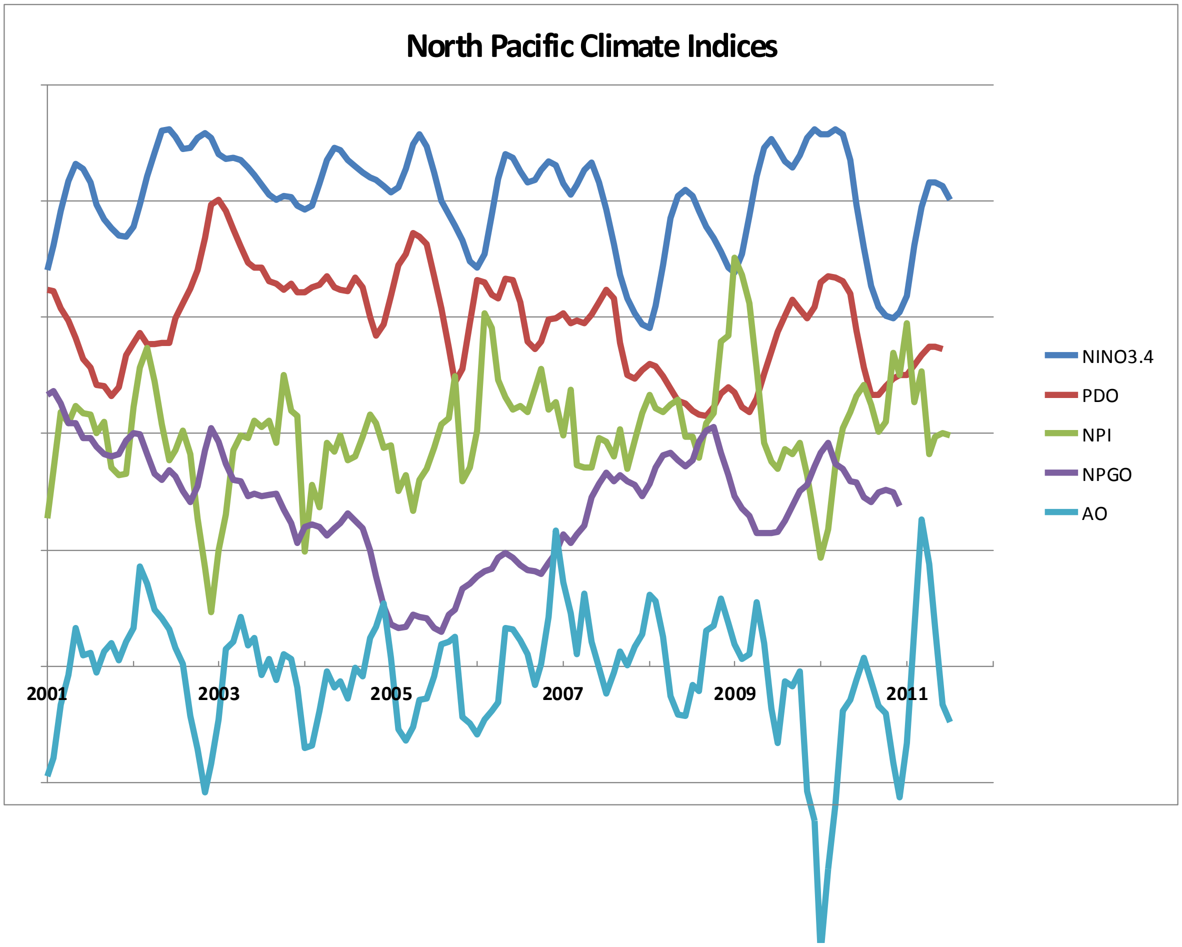

Figure 30: Time series of the NINO3.4 (blue), PDO (red), NPI (green), NPGO (purple), and AO (turquoise) indices. Each time series represents monthly values that are normalized and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 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.

Status and trends: The state of the North Pacific atmosphere-ocean system reflected the influences of ENSO during 2010-11. The Aleutian Low tends to be weaker during La Niña winters, and 2010-11 was no exception, as evidenced by the strongly positive SLP anomalies shown in Figure 29b. It is worth noting that the degree of activity in the ENSO cycle varies on multi-year time scales. The ENSO cycle was relatively weak during the first half of the 2000s while it was in a predominantly positive phase; the fluctuations between significantly positive (El Niño) and negative values (La Niña) have been more prominent during the past 5-6 years. The projections of the dynamical and statistical models used to forecast ENSO are discussed in the last section of this overview.

The PDO became negative during spring of 2010 and reached a minimum of about -1.3 in early fall 2010. It exhibited an increasing trend from late 2010 through the spring of 2011. This trend reversed again in summer 2011. It is an open question whether this latest tendency will continue, or whether the PDO will return to a more neutral state. The PDO is related to ENSO through the effects of the latter on the atmospheric circulation over the North Pacific and hence air-sea interactions, and ultimately, SST patterns. The potential predictability of the PDO appears to be largely associated with its connection to ENSO.

The NPI is a commonly used measure of the strength of the Aleutian Low. The NPI has undergone large swings from positive to negative and then back to positive over the last three years. Note the negative correspondence with the NINO3.4 index in general; over the last few years this relationship appears to have been especially tight.

The climate community has been paying increasing attention to another mode of variability in the North Pacific termed the North Pacific Gyre Oscillation (NPGO). It has been shown to relate to chemical and biological properties in the Gulf of Alaska and the CalCOFI survey area (Di Lorenzo et al., 2008). It underwent a significant transition from strongly negative in the early 1990s to strongly positive in the early 2000s in concert with the so-called "Victoria" pattern in SST (Bond et al., 2003). It has been in a positive state since 2007, which projects on stronger than normal flows in both the Alaska Current portion of the Subarctic Gyre and the California Current.

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 has a weakly positive correlation with sea ice extent in the Bering Sea. During periods of positive AO, cold air outbreaks to mid-latitudes are suppressed. The AO had a record negative value during the winter of 2009-10; it was also strongly negative during the early portion of the winter of 2010-11 and then switched to positive during the early portion of 2011. It became weakly negative during late spring 2011. 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.

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

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Last updated: August 2011

Description of index: Seasonal projections from the NCEP coupled atmosphere-ocean forecast system model (CFS) for SST are shown in Figure 31.

Status and Trends: On the hemispheric scale, these projections resemble those made a year ago. Of special note is the prediction of relatively cold SSTs in the tropical Pacific of a magnitude commensurate with a weak-moderate La Niña. Earlier predictions by the CFS model (made before June 2011), and many of the current predictions from the other statistical and numerical models used for ENSO forecasts, were indicating a near-neutral state for ENSO during the winter of 2011-12. Present conditions in the tropical Pacific support the possibility of the development of La Niña, but it is too early to make any reliable predictions for the upcoming winter except that the probability of El Niño is lower than usual. If the CFS model projections are correct, and this model does have a reasonably good track record over the last 5 years or so, the Aleutian low will be weaker than normal (not shown). If this comes to pass, the relatively cold upper ocean temperatures in the northeastern Pacific that stretch from the Bering Sea through the Gulf of Alaska to off the coast of California, and a negative sense to the PDO, can be anticipated to persist well into 2012, as shown in the SST projections of Figure 31.

Eastern Bering Sea

Eastern Bering Sea Climate - FOCI

Contributed by J. Overland, P. Stabeno, C. Ladd, S. Salo, M. Wang, and N. Bond (NOAA/PMEL)
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Last updated: October 2011

Summary *After an unusual sequence of six years of warm temperatures (2000-2005) and four years of cold temperatures (2007-2010), the question for 2011 was whether there would be a continuation of the cold sequence. These previous extremes were related to winter and springtime weather. In 2011 the atmosphere was neutral to warm in winter and spring (except April), but was unusually cold in summer. Given that the Bering Sea ocean temperatures started cold in fall of 2010 as shown by the M2 mooring, combined with a cold atmosphere in summer, by September 2011 Bering Sea ocean temperatures remained on the cold side, warmer than summer 2009 and 2010 but similar to 2007 and 2008. Sea ice maximum extent was neutral, less than the previous four years, but more than the warm years, and a cold pool was present. The mechanism for producing the cold conditions was different from the last four cold year sequence. The only multi-year temperature events comparable to the first decade of the 2000s in the 95-year meteorological record are a cold event in 1971-1976 followed by a warm event in 1978-1983. Evidence reinforces the idea that a red-noise model of climate variability is appropriate for the southeastern Bering Sea. Thus, in the past and the future we can expect large positive and negative climatic excursions from the mean that can last for multiple years, but there is little regularity (oscillations) or predictability for their timing and duration.*

Surface air temperatures are easily measured and provide an available long term measure of the state of the climate. Winter and spring surface air temperatures on St. Paul Island were neutral in 2011 following a sequence of warm and cold years (Figure 32). Spatially, winter and spring during 2011 was near neutral temperatures in the SE Bering Sea (Figure 33), while the northern Bering Sea is part a continued Arctic warming that has lasted a decade. The large meteorological event of the year was the relatively cold conditions in July and August (Figure 34). Winter Bering Sea in 2011 did not have the higher than normal sea level pressure (SLP) of previous cold years that indicated weaker or fewer storm systems entering the Bering Sea with east-west trending SLP contours suggesting the presence of cold Arctic air masses over the central Bering Sea. The

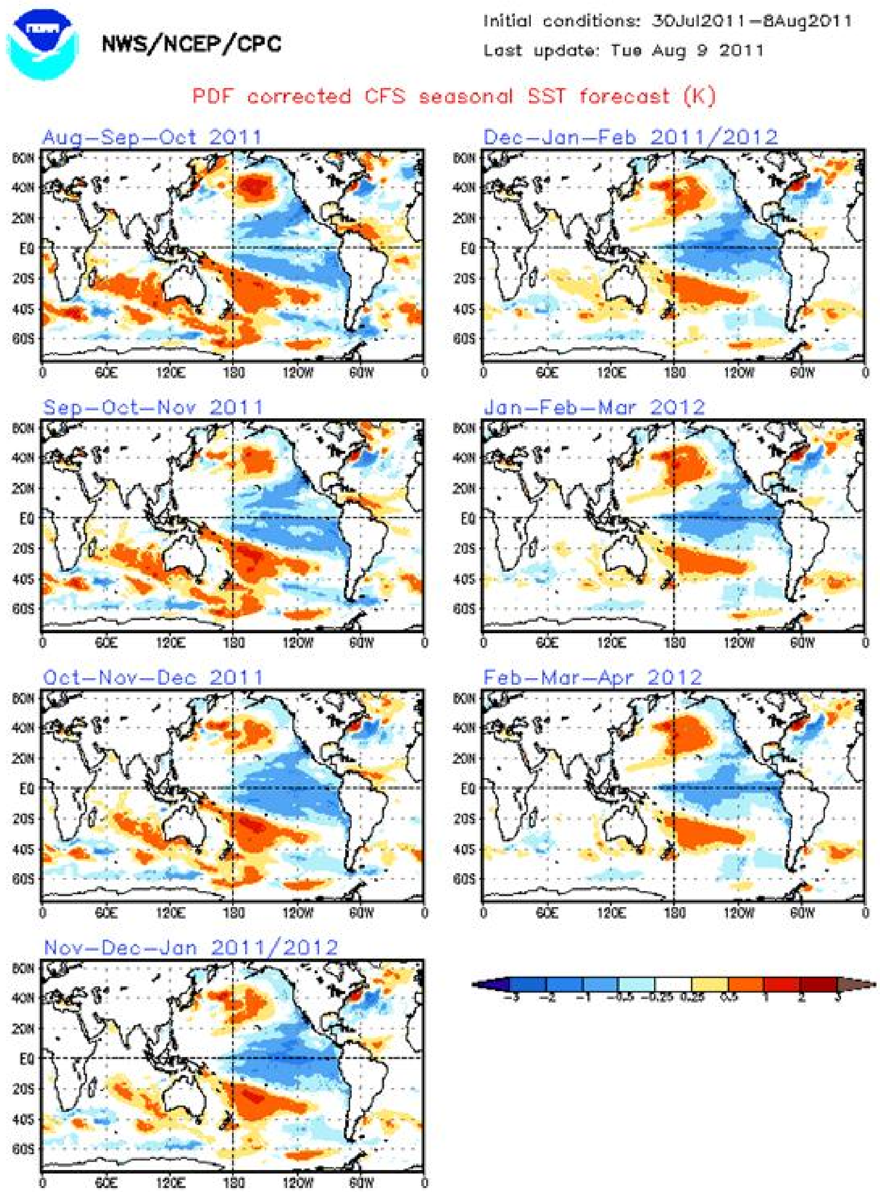

Figure 31: Seasonal forecast of SST anomalies from the NCEP coupled forecast system model for August 2011 through April 2012.

unusual summer weather conditions are shown in the SLP chart in Figure 35. The strong north-south pressure gradient kept warm southerly winds out of the southeastern Bering Sea during summer.

The meteorology and oceanography of the northern North Pacific has been recently dominated by a multi-year warm event (2000-2005) followed by a multi-year cold event (2007-2010) with many monthly anomalies exceeding plus/minus 4.0°C. The only multi-year temperature event comparable to the first decade of the 2000s in the 95 year meteorological record are a cold event in 1971-1976

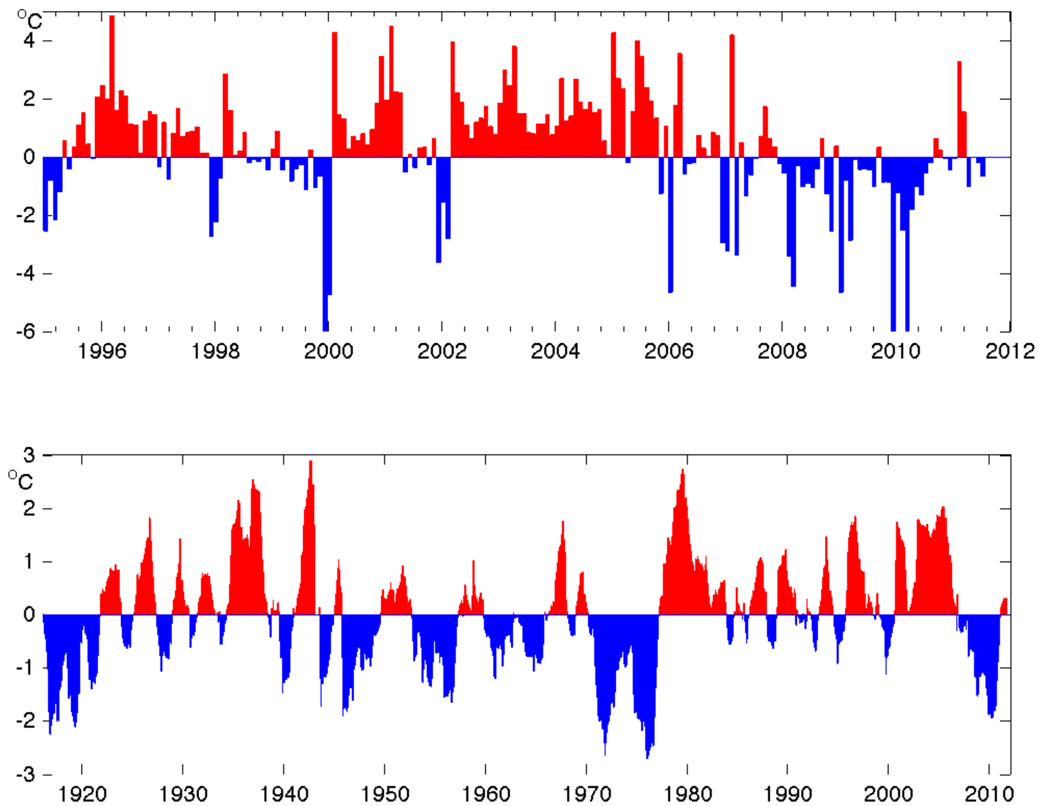

Figure 32: Mean monthly surface air temperatures anomalies in St. Paul, Pribilof Islands, a) unsmoothed, January 1995 through July 2011, and b) smoothed by 13-month running averages, January 1916 through July 2011. The base period for calculating anomalies is 1961-2000.

followed by a warm event in 1978-1983. While there are theoretical arguments for some physical memory processes in the North Pacific climate system, we cannot rule out that the recent warm and cold events are of a random nature: they are rare in the temperature record, they are dominated by North Pacific-wide sea level pressure events rather than local processes, and they are consistent with a red noise model of climate variability. We emphasizes the importance of these sub-decadal events with rapid beginning and ending transitions for the North Pacific and discount the importance of multi-decadal patterns of variability often associated with the Pacific Decadal Oscillation (PDO) that has dominated much of the scientific literature in recent years. Evidence provided by the meteorological record reinforces the idea that a red-noise model of climate variability is appropriate for the northern North Pacific and southeastern Bering Sea. Thus, in the past and the future we can expect large positive and negative climatic excursions in the region that can last for multiple years, but there is little regularity (oscillations) or predictability for their timing and duration.

Seasonal sea ice is a defining characteristic of the Bering Sea shelf. The presence of sea ice influences the timing of the spring bloom and bottom temperatures throughout the year. Sea ice extent in 2007 through 2010, (Figure 36) was close to record extents, not seen since the early 1970s, and contrast to the warm years of 2000-2005 (except 2002). The year 2011 (dashed brown line)shows

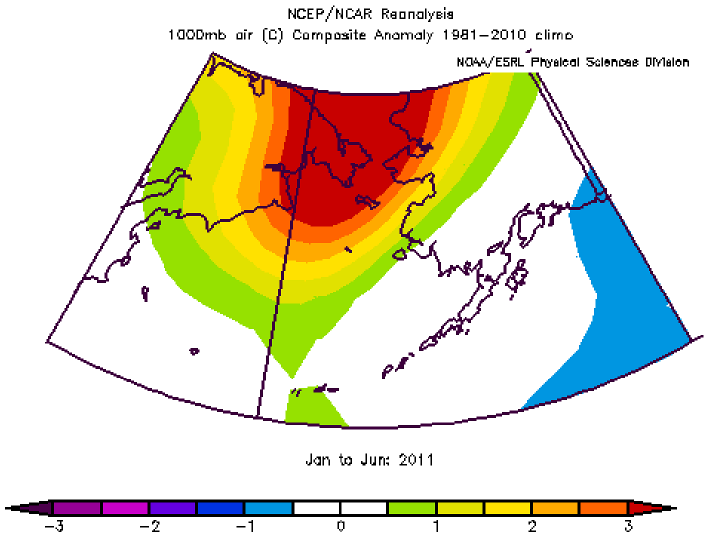

Figure 33: Surface air temperature anomaly over the greater Bering Sea region for winter-Spring 2011. Temperatures are near normal in the SE Bering Sea with warm anomalies to the northwest, which are part of the overall Arctic warming. All individual months resemble the composite except April which had a negative anomaly of 1 C in the SE Bering Sea.

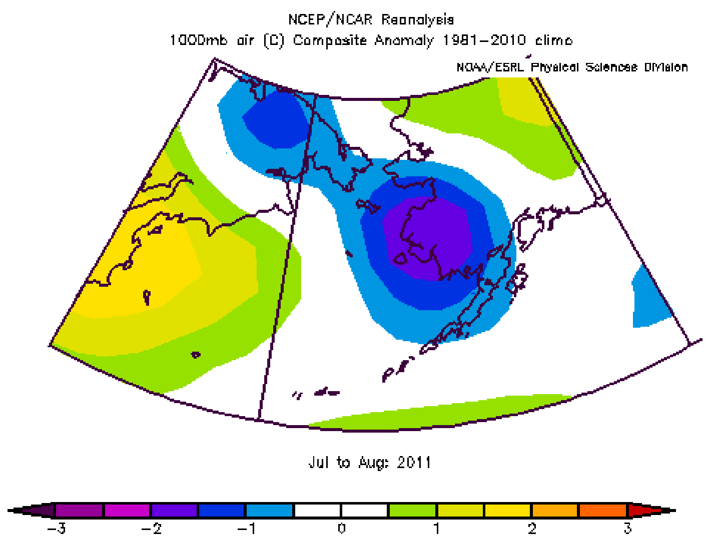

Figure 34: Surface air temperature anomaly conditions over the greater Bering Sea region during summer.

neutral conditions with less sea ice extent than the previous four years but more extent than the warm years of the earlier 2000 decade.

Along with cold air temperatures and extensive sea ice, ocean temperatures at the M2 mooring site were sharply lower in winter 2006 through winter 2010 compared with 2000-2005 (Figure 37). Ocean temperatures in 2011 were below normal, warmer than 2009 and 2010 but similar to 2007

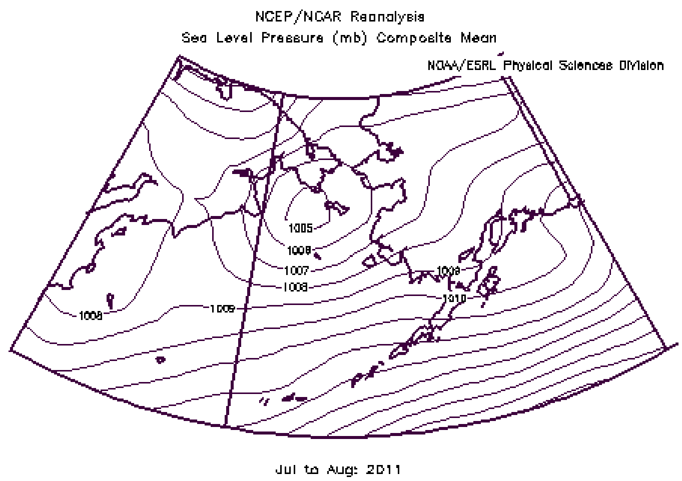

Figure 35: Sea level pressure (SLP) for July and August 2011. The strong north south pressure gradient kept warm southerly winds out of the southeastern Bering Sea during summer.

and 2008. The cold pool (Figure 38), defined by bottom temperatures <2°C, influences not only near-bottom biological habitat, but also the overall thermal stratification and ultimately the mixing of nutrient-rich water from depth into the euphotic zone during summer. The cold pool was present for summer 2011 but was less prominent than 2007 through 2010 similar to sea ice conditions. The most important aspects of the physical environmental in the eastern Bering Sea during 2011, despite the relatively neutral weather and sea ice conditions during winter and spring, was that cool fall temperatures and a newly seen cold summer did not allow the multi-year sequential continuation of cold ocean temperatures to come to an end. However the mechanism for the cold year was different than in the previous four years.

Summer Bottom and Surface Temperatures - Eastern Bering Sea

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Last updated: October 2011

Description of index: The annual AFSC bottom trawl survey for 2011 started on 1 June and finished on 5 August.

Status and trends: The average surface temperature, 5.0°C, was slightly lower (0.1°C) than 2010 and still much lower than the long-term mean of 6.4°C (Figure 39). The average bottom temperature in 2011 was 2.5°C nearly a degree warmer than 2010 and equal to the grand mean from 1982 to 2011. 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 40).

Factors causing observed trends: Warm and cold years are the result of interannual variability

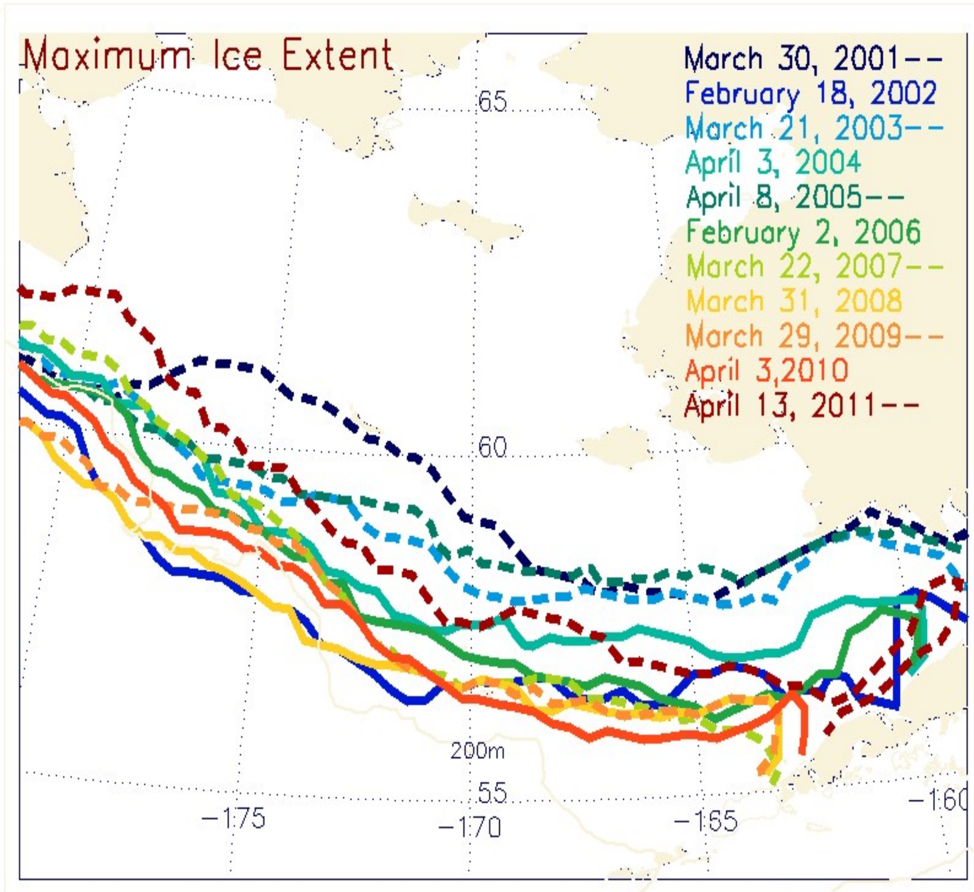

Figure 36: Recent springtime ice extents in the Bering Sea. Ice extent in 2006 through 2010 exceed the minimums of the early 2000s (except for 2002).

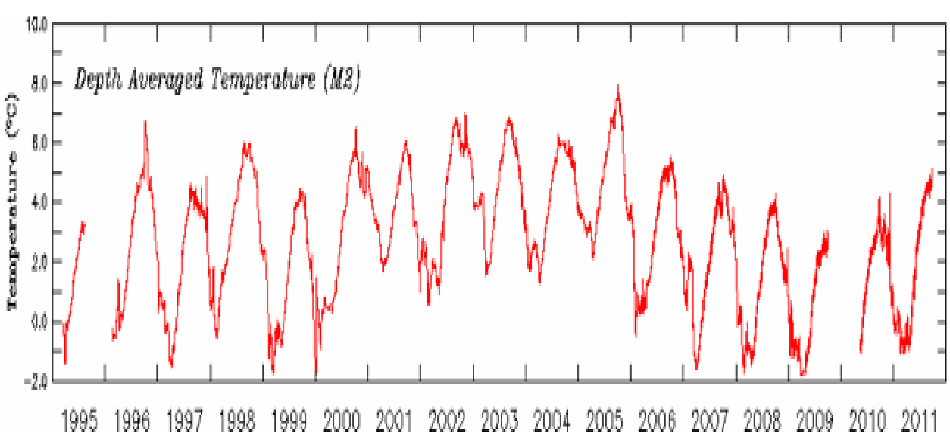

Figure 37: Depth averaged temperature measured at Mooring 2, 1995-2011 in the southeast Bering Sea (°C).

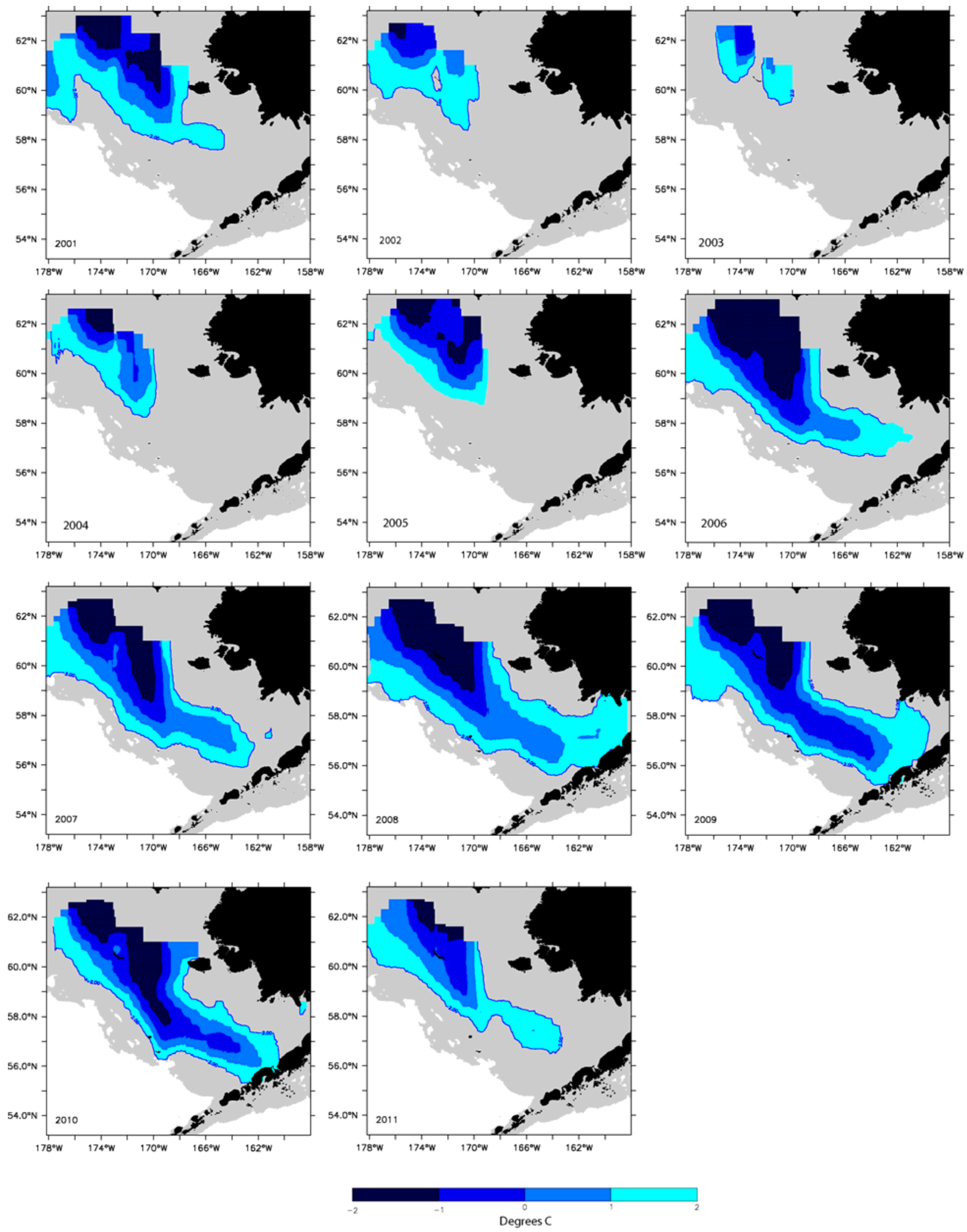

Figure 38: Cold Pool locations in southeast Bering Sea from 2001 to 2011. 2009 represents the maximum southeastward extent of the cold pool of the decade.

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.

Implications: 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

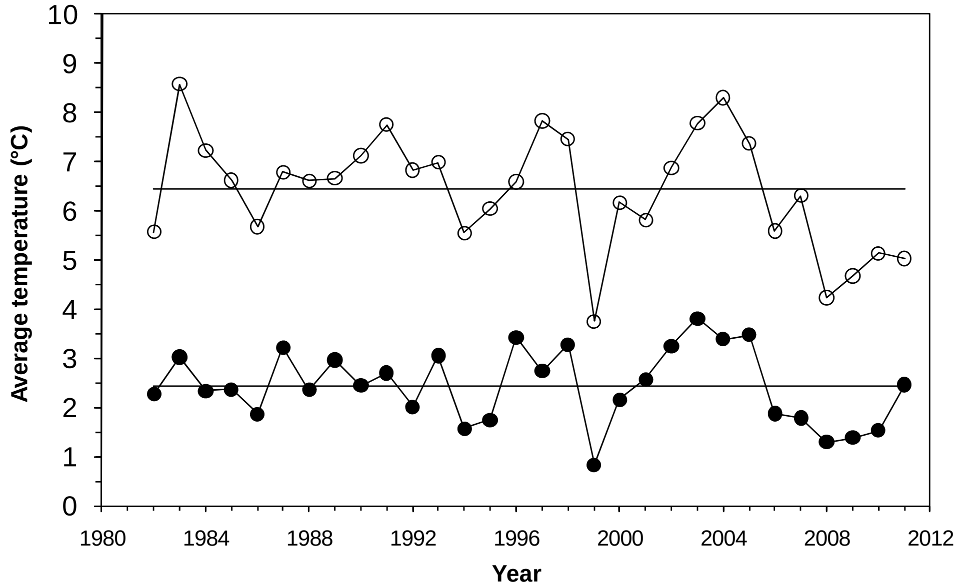

Figure 39: Average summer surface (open circles) and bottom temperatures (solid circles) (°C) of the eastern Bering Sea shelf collected during the standard bottom trawl surveys from 1982-2011. Survey water temperatures for each year were weighted by the proportion of their assigned stratum area.

juvenile fishes as well as the energy flow in the system (Hunt et al., 2002).

Gulf of Alaska

Eddies in the Gulf of Alaska - FOCI

Contributed by Carol Ladd, NOAA/PMEL
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Last updated: August 2011

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., 2010), 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 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

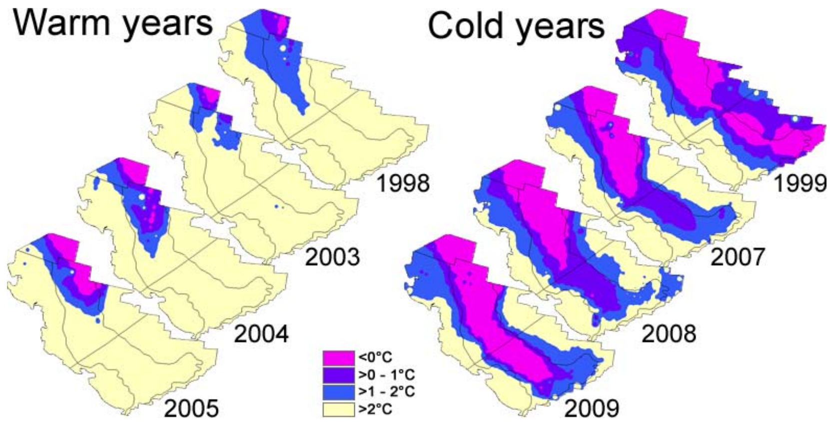

Figure 40: Temperature plots of average bottom temperature from the eastern Bering Sea shelf bottom trawl survey comparing the extent of the cold pool (<2C) during years warmer and colder than the 1982-2009 grand mean..

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 41). 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 41). By averaging EKE over regions c and d (see boxes in Figure 41), we obtain an index of energy associated with eddies in these regions (Figure 42).

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, 2007 and 2010. 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 2010. EKE in both regions was approximately average for the first six months of 2011.

Factors causing trends: The causes of variability in EKE are currently unclear and a subject of ongoing research.

Implications: Variations in EKE may have implications for the ecosystem. Phytoplankton

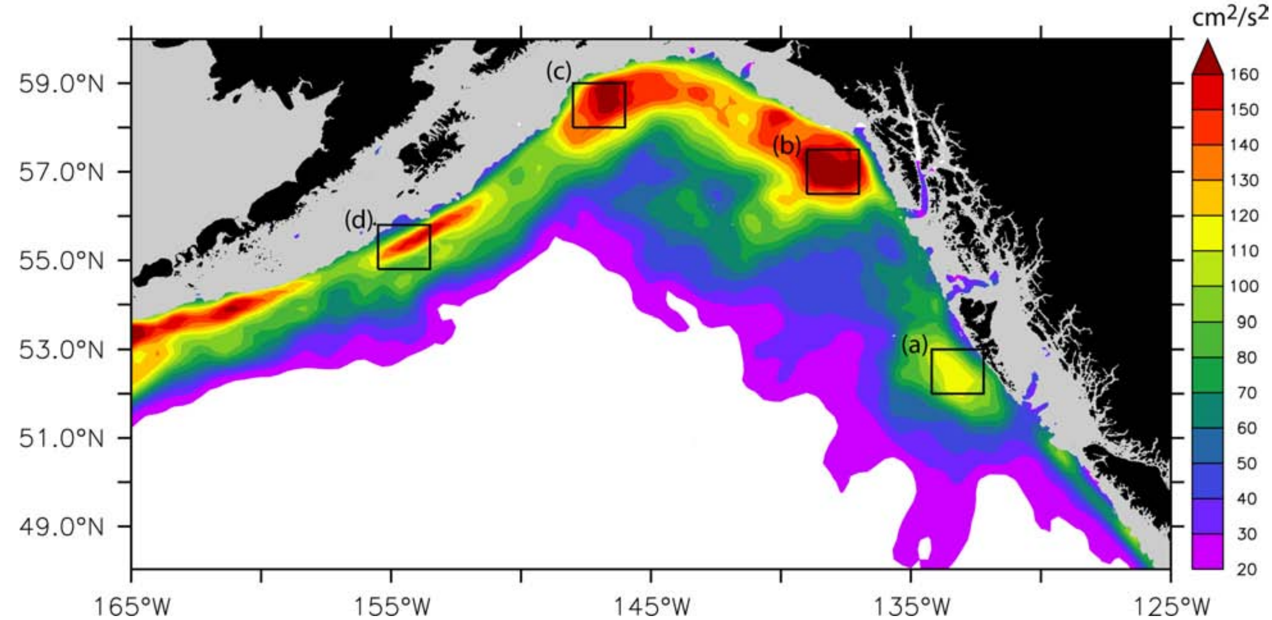

Figure 41: Eddy Kinetic Energy averaged over October 1993-October 2010 calculated from satellite altimetry. Regions (c) and (d) denote regions over which EKE was averaged for Figure 42.

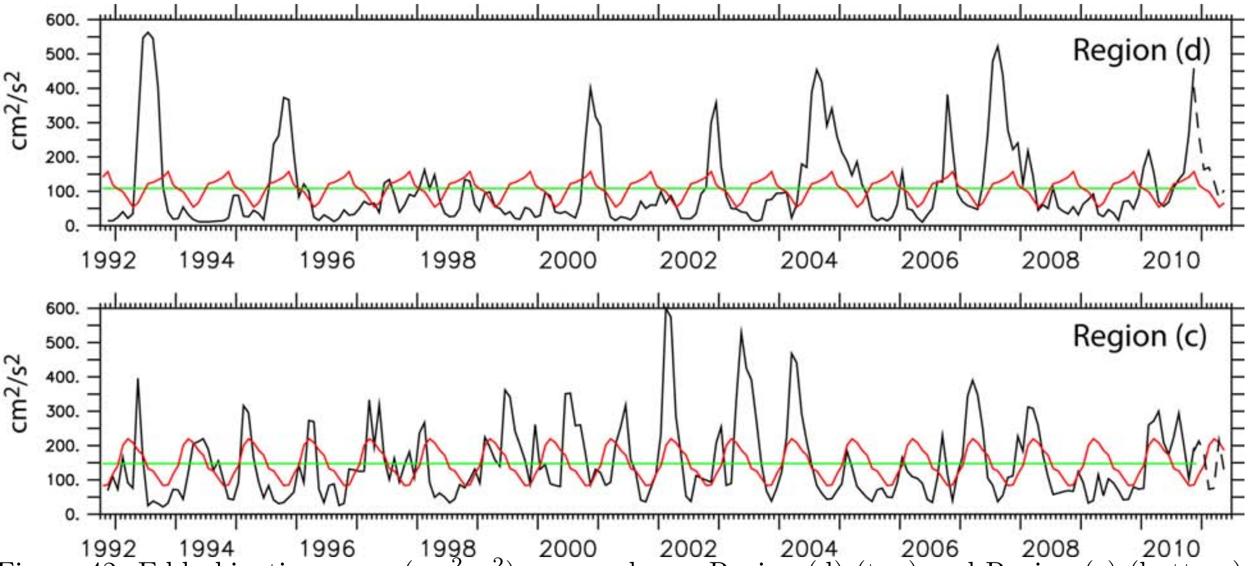

Figure 42: Eddy kinetic energy (cm^2 s^{-2}) averaged over Region (d) (top) and Region (c) (bottom) shown in Figure 41. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product), Red: seasonal cycle. Green (straight line): mean over entire time series.

biomass was probably more tightly confined to the shelf during 2009 due to the absence of eddies, while in 2007 and 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). Eddies sampled in 2002-2004 were found to contain different ichthyoplankton assemblages than surrounding slope and basin waters indicating that eddies along the slope may influence the distribution and survival of fish (Atwood et al., 2010). In addition, carbon isotope values suggest that cross-shelf exchange due to eddies may be important to the marine survival rate of pink salmon (Kline, 2010). 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 2011

Description of index: The year-to-year variability in near-surface water movements in the North Pacific Ocean has been shown to have important effects on the survival of walleye pollock (*Theragra chalcogramma*) by affecting its spatial overlap with predators (Wespestad et al., 2000), as well as to influence recruitment success of winter spawning flatfish in the eastern Bering Sea (EBS; Wilderbuer et al. (2002)). The PAPA Trajectory Index (PTI) provides an annual index of this variability, based on the trajectory of a simulated surface drifter released at Ocean Station PAPA (50° N, 145° W; Figure 43) . The simulation for each year is conducted using the "Ocean Surface CURrent Simulator" (OSCURS; `http://las.pfeg.noaa.gov/oscurs`). Using daily gridded atmospheric pressure fields, OSCURS calculates the speed and direction of water movement at the ocean's surface at the location of a simulated surface drifter. It uses this information to update the position of the simulated drifter on a daily basis over a specified time period. For the index presented here, OSCURS was run for 90 days to simulate a surface drifter released at Ocean Station PAPA on December 1 for each year from 1901 to 2010.

Status and trends: In general, the trajectories fan out northeastwardly toward the North American continent (Figure 43) except for the 2010 trajectory, which resulted in the westernmost trajectory endpoint for the entire set of model runs (1902-2011). This trajectoy is, however, consistent with the atmospheric conditions that existed during the winter of 2009-2010 (N. Bond, pers. comm.). Under the influence of contemporaneous El Niño conditions, the Aleutian Low in the winter of 2009-2010 was anomalously deep and displaced to the southeast of its usual position in winter (Bond and Guy, 2010), resulting in anomalously high easterly (blowing west) wind anomalies north of Ocean Station PAPA.

The PTI time series (Figure 44, black dotted line and points) indicates high interannual variation in the north/south component of drifter trajectories, with an average between-year change of ∼4° and a maximum change of greater than 13° (between 1931-1932). Using a 5-year running mean boxcar filter to smooth the raw PTI reveals multidecadal-scale oscillations in the north/south component of the drift trajectories (Figure 44, red line and squares), with amplitudes over 7° latitude. Over the past century, the filtered PTI has undergone four complete oscillations with distinct crossings of the mean, although the durations of the oscillations are not identical: 26 years (1904-1930), 17 years (1930-1947), 17 years (1947-1964), and 41 years (1964-2005). The filtered index indicates that a shift occurred in the mid 2000s to predominantly southerly anomalous flow following a 20+ year period of predominantly northerly anomalous flow. This indicates a return to conditions (at

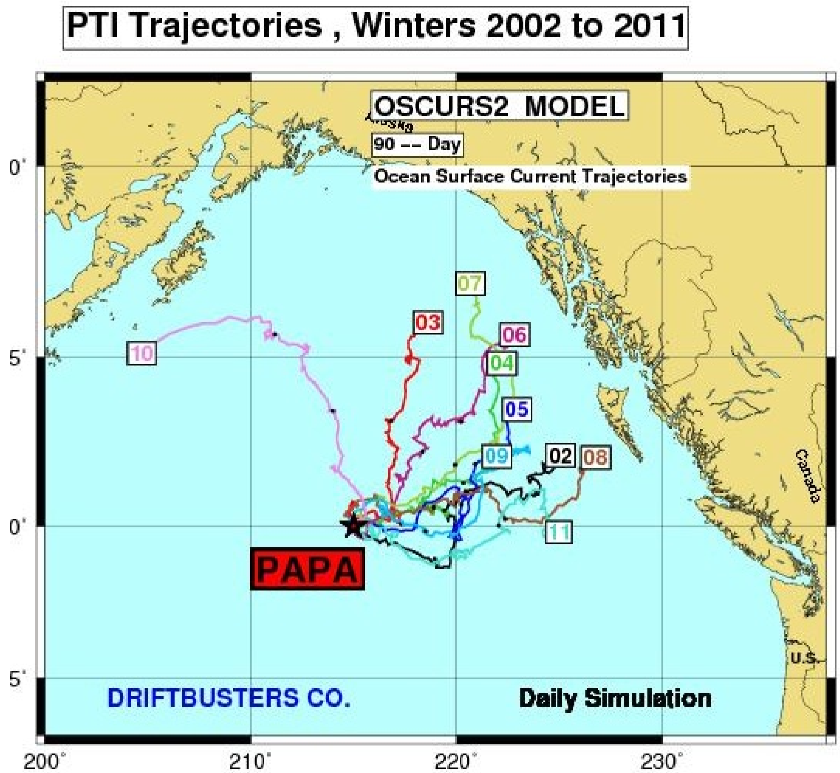

Figure 43: Simulated surface drifter trajectories for winters 2002-2011. Boxes indicate end points of 90-day trajectories for simulated surface drifters released on Dec. 1 at Ocean Weather Station PAPA (50° N, 145° W).

least in terms of surface drift) similar to those prior to the 1977 environmental regime shift.

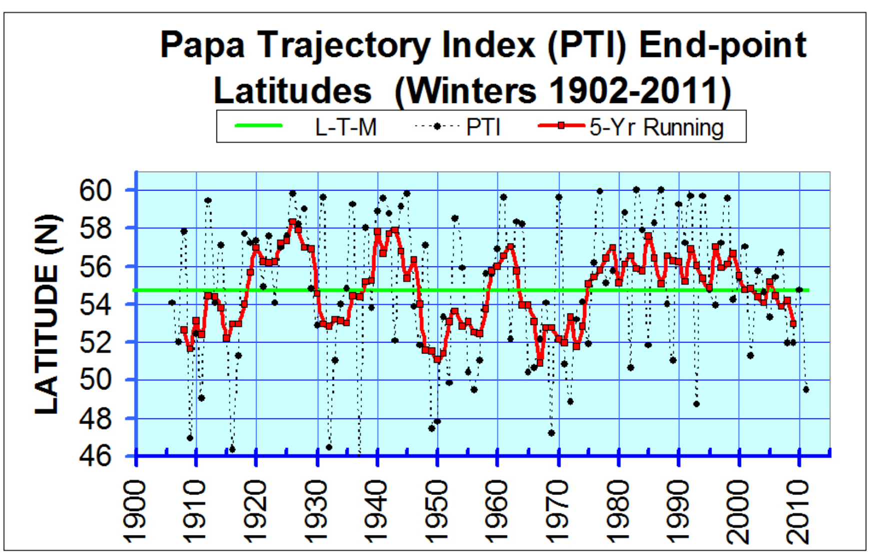

Figure 44: Annual, long-term mean (green line) and 5-year running mean (red line and squares) of the PAPA Trajectory Index time-series (dotted black line and points) for 1902-2011.

Factors causing observed trends: Filtered PTI values greater than the long-term mean are indicative of increased transport and/or a northerly shift in the Alaska Current, which transports warm water northward along the west coast of Canada and southeast Alaska from the south and consequently plays a major role in the Gulf of Alaska's heat budget. Interdecadal changes in the PTI reflect changes in ocean climate that appear to have widespread impacts on biological variability at multiple trophic levels (King, 2005). There is strong evidence that the productivity and possibly the carrying capacity of the Alaska Gyre and of the continental shelf were enhanced during the recent “war” regime that began in 1977. Zooplankton production was positively affected after the 1977 regime shift (Brodeur and Ware, 1992). Recruitment and survival of salmon and demersal fish species also improved after 1977. Recruitment of rockfish (Pacific ocean perch) and flatfish (arrowtooth flounder, halibut, and flathead sole) increased. However, shrimp and forage fish such as capelin were negatively affected by the 1977 shift (Anderson, 2003). The reduced availability of forage fish may have been related to the decline in marine mammal and seabird populations observed after the 1977 shift (Piatt and Anderson, 1996).

Implications: Interdecadal changes in the PTI reflect changes in ocean climate that appear to have widespread impacts on biological variability at multiple trophic levels (King, 2005). There is strong evidence that the productivity and possibly the carrying capacity of the Alaska Gyre and of the continental shelf were enhanced during the recent “war” regime that began in 1977. Zooplankton production was positively affected after the 1977 regime shift (Brodeur and Ware, 1992). Recruitment and survival of salmon and demersal fish species also improved after 1977. Recruitment of rockfish (Pacific ocean perch) and flatfish (arrowtooth flounder, halibut, and flathead sole) increased. However, shrimp and forage fish such as capelin were negatively affected by the 1977 shift (Anderson, 2003). The reduced availability of forage fish may have been related to the decline in marine mammal and seabird populations observed after the 1977 shift (Piatt and Anderson, 1996). The current trend of the PTI is consistent with a return to conditions associated with the preceding ”cold” regime and may thus be a harbinger of a decadal-scale reduction in regional productivity.

Gulf of Alaska Survey Bottom Temperature Analysis

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Last updated: October 2011

Description of index: Ocean circulation in the Gulf of Alaska (GOA) is dominated by two current systems, the Alaska Current and the Alaska Coastal Current (Stabeno et al., 2004). The Alaska Current is driven by the West Wind Drift of the subarctic gyre in the North Pacific basin and flows to the north-northwest from the survey boundary at Dixon Entrance. It is characterized by numerous eddies and meanders until forced to the southwest around Prince William Sound, forming the origins of the Alaska Coastal Current. The majority of this water flows through Shelikof Strait, with the remainder passing to the south of Kodiak Island, forming the origins of the Alaska Stream which continues to flow to the west along the Aleutian Islands (Stabeno et al., 1995; **?**). In addition, tidal forces dominate circulation in some local areas, particularly around Cook Inlet and in and around many of the bays along the Alaska Peninsula.

Water column temperature data have been routinely collected on bottom trawl hauls in the Gulf of Alaska Bottom Trawl Survey using bathythermographs attached to the headrope of the net since 1993. In earlier years, temperature data were often collected near trawl haul sites using expendable bathythermographs; however these earlier data were not considered in this analysis. The beginning date of the survey over the period included in the analysis has ranged from the middle of May to the first week in June, while the last day of the survey has ranged from the third week in July to the first week of September. In addition, the area and depth ranges covered by the survey have not been consistent from year to year. 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 depths less than 200 m throughout the GOA survey area. In order to account for these problems 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 for most GOA surveys (July 10). This was achieved by using generalized additive modeling techniques to model the effects of latitude, longitude, depth, and day of year on temperature. This model accounted for approximately 81% of the total deviance. The model was then used to estimate the temperature at an approximate median day of the year for survey tows (July 10), and the residuals from the original model were added to the prediction for the final temperature estimate. In order to facilitate visualization of the estimated temperatures, the data were binned into 0.5 degree latitude and multiple depth increments and a mean temperature in each increment was calculated. Depth increments were much finer at shallower depths to capture the rapid changes in water temperatures often seen in these depths.

Status and trends: The pattern in water temperatures was generally similar to the pattern seen during the 2009 survey (Figure 45). East of 160W, the water column was stratified with relatively warm near-surface waters and temperatures rapidly dropping to 6 C or less in the upper 50 meters. West of 160W, near surface temperatures (<50 m) were much cooler and deeper waters were generally warmer than further east with a prominent inversion pattern noted at most stations. In this area, water temperatures were generally warmer than in 2009, particularly at depths greater than 50 m.

Factors causing observed trends: The data represent a snapshot of water temperatures collected during bottom trawl surveys in the Gulf of Alaska. 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 events such as storm events, tidal currents, and changes in freshwater discharge. More persistent phenomena including mesoscale eddies, seasonal changes in solar heat flux, ENSO events, and changes in the Alaska Coastal Current also play an important role in mediating water column temperatures. The strength and persistence of eddies is believed to play a major role in the transport of both heat and nutrients across the continental shelf in the Gulf of Alaska (Ladd, 2007).

Implications: Water column temperatures influence the species assemblage, abundance, and growth rates of phytoplankton and zooplankton species. Ichthyoplankton distribution and growth has also been shown to be related to location in relation to the warm core eddies that are a prominent feature of the central GOA (Atwood et al., 2010). The implications of year to year differences in water column temperatures and the possible effect on fish populations in the GOA is not well understood.

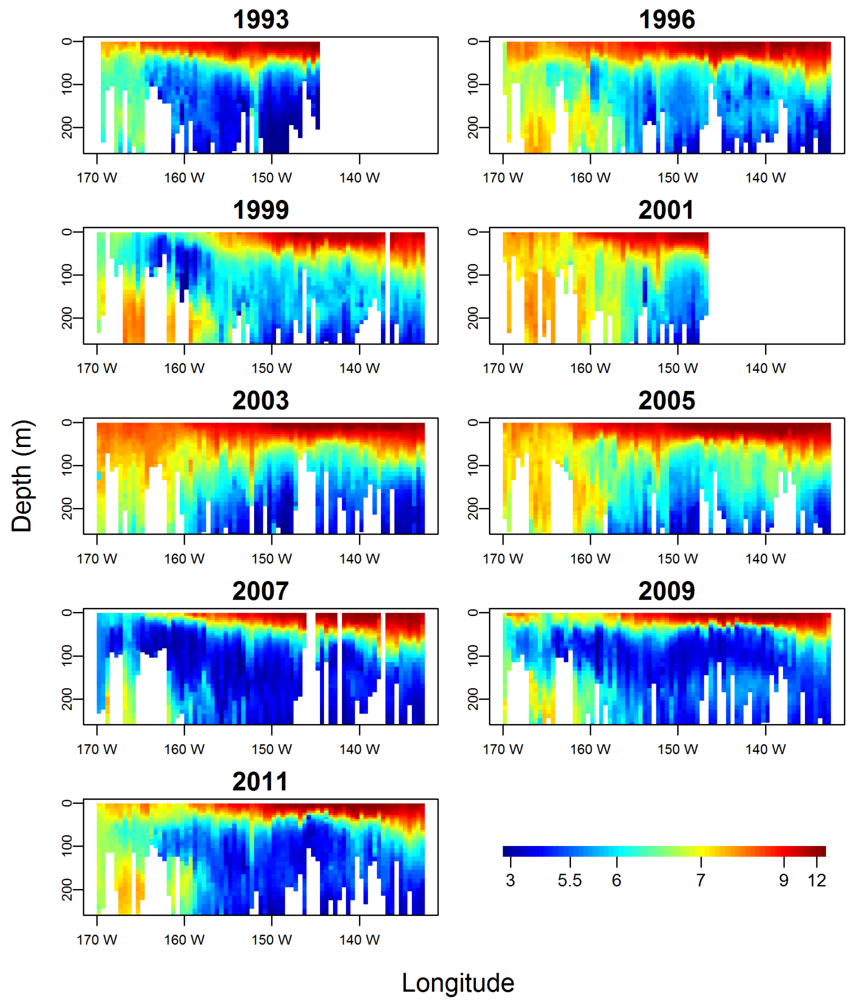

Figure 45: Date adjusted temperature profiles by $\frac{1}{2}$degree longitude intervals for years 1994-2011.

Aleutian Islands

Eddies in the Aleutian Islands - FOCI

Contributed by Carol Ladd, NOAA/PMEL
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Last updated: August 2011

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 46) 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 47) 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).

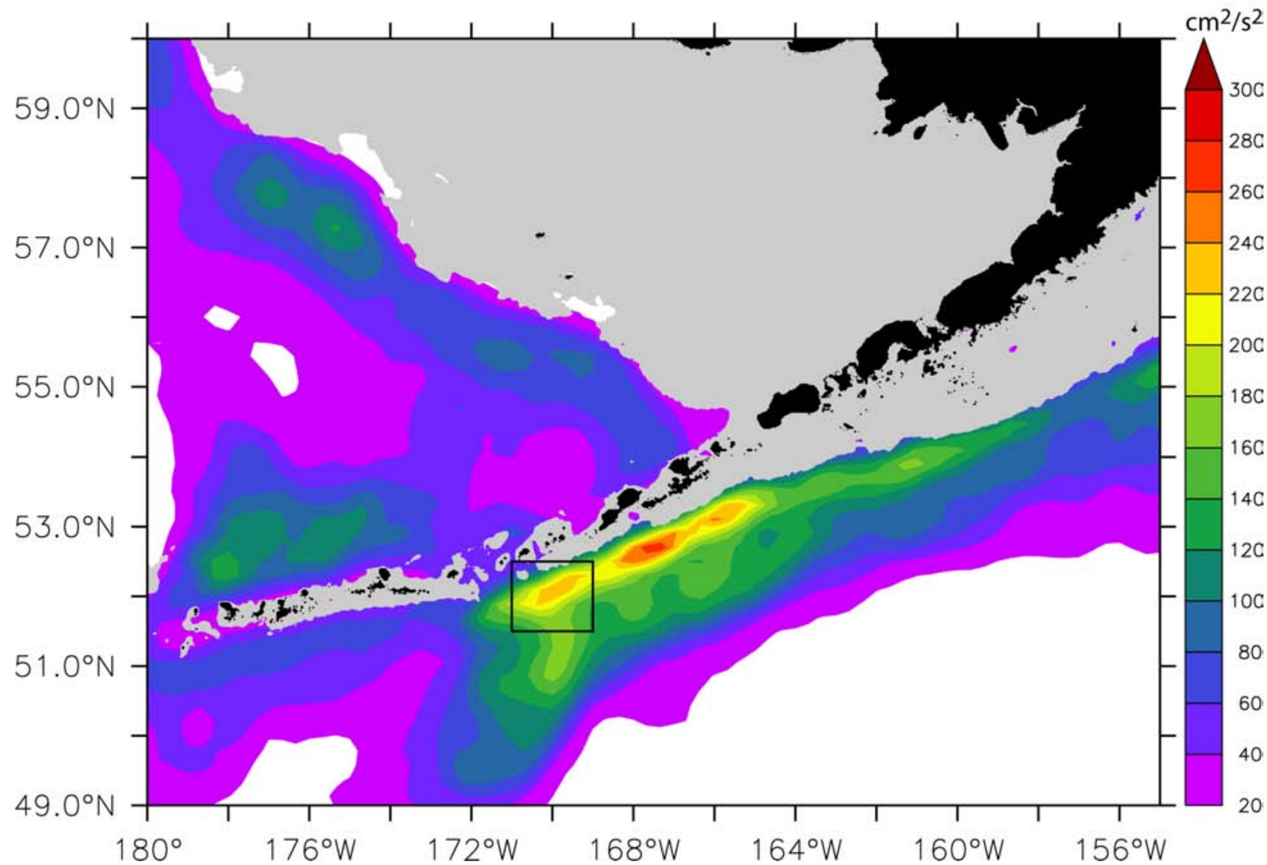

Figure 46: Eddy Kinetic Energy averaged over October 1993 - October 2010 calculated from satellite altimetry. Square denotes region over which EKE was averaged for Figure 47.

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 has been low from the spring of 2010 through the first 6 months of 2011.

Factors causing trends: The causes of variability in EKE are currently unclear and a subject of ongoing research.

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,

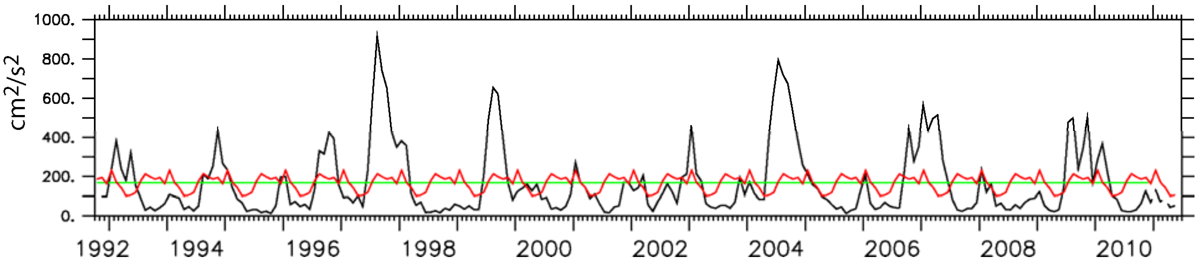

Figure 47: Eddy kinetic energy (cm^2 s^{-2}) averaged over region shown in Figure 46. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product). Red: seasonal cycle. Green (straight line): mean over entire time series.

2006/2007, and 2009/2010 while these fluxes may be reduced since spring of 2010.

Water Temperature Data Collections - Aleutian Islands Trawl Surveys

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Last updated: October 2010

Aleutian Islands surveys are conducted in alternate even years. For most recent data, see the 2010 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Habitat

Area Disturbed by Trawl Fishing Gear in the Eastern Bering Sea

Contributed by Angie Greig, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
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Last updated: June 2011

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 1990-2010. The duration of every 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`). Table B.2-4 in the EIS document lists the adjustment factor for each gear type and vessel class. 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 227 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 48a). 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 48b).

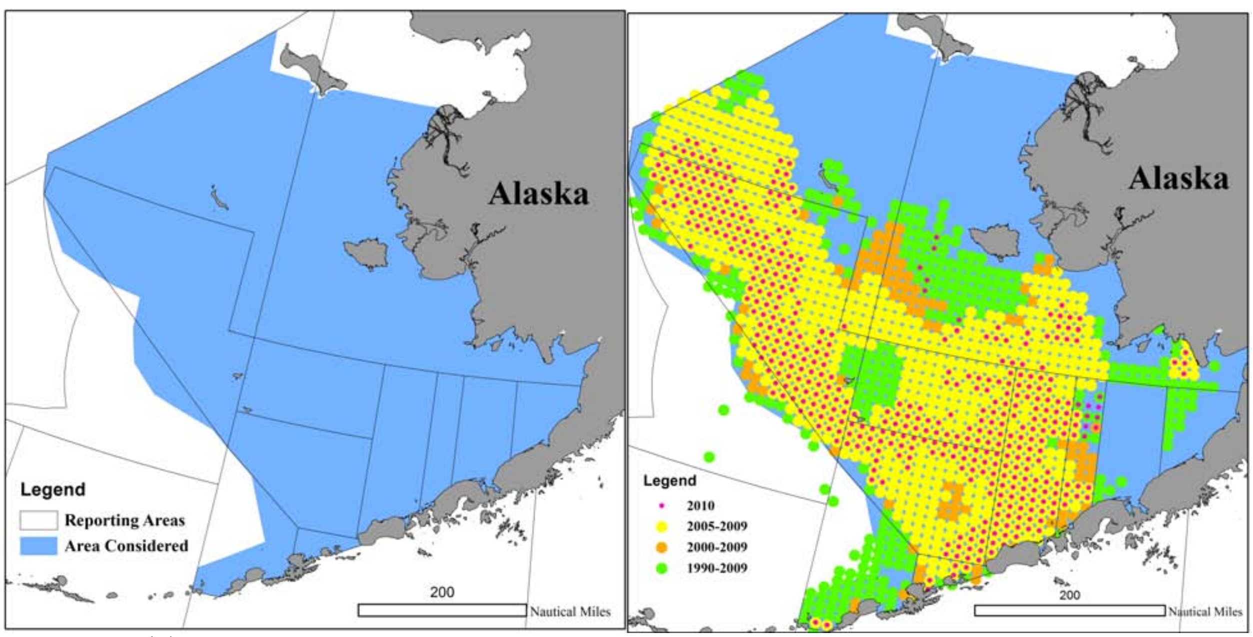

Figure 48: (a) Map of Eastern Bering Sea area considered when estimating percent area potentially disturbed by trawl fishing gear. (b) Map of 400 square kilometer cells with some trawling in cumulative time periods. Cells with fewer than 3 vessels are not shown

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 49).

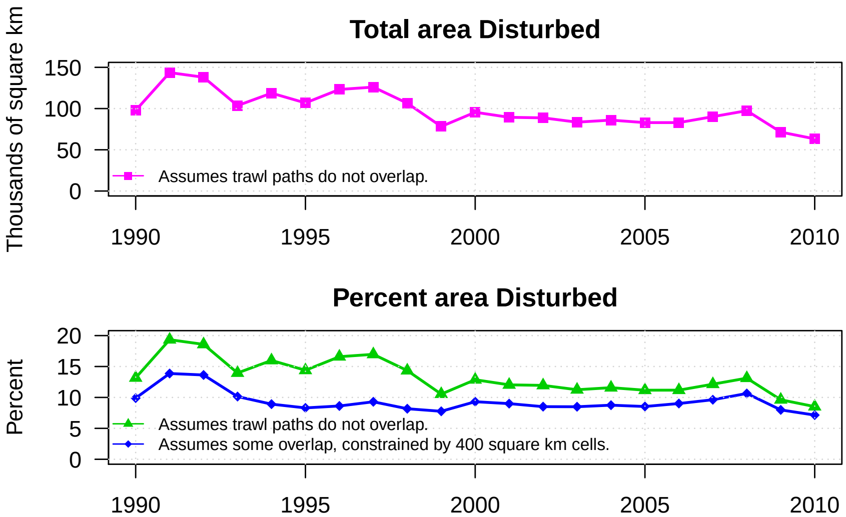

Figure 49: Total maximum potential area disturbed (assuming no spatial overlap of trawls), and the percent area disturbed. The green line, representing percent area disturbed, sums the area disturbed assuming no spatial overlap of trawl hauls in a year, thus providing an upper limit to the estimate of 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.

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 structural epifauna biota in the areas fished, and management changes that result in spatial changes in fishing effort.

Structural Epifauna Bering Sea

Contributed by Robert Lauth and Jerry Hoff, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
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Last updated: October 2011

Description of index: Groups considered to be structural epifauna 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 1982-2011. 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 structural epifauna groups in the Bering Sea shelf from the RACE bottom trawl survey results because there is taxonomic uncertainty within the 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 50).

Factors causing observed trends: Further research in several areas would benefit the interpretation of structural epifauna 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.

Implications: Changes in structural epifauna CPUE may indicate changes in habitat, but at present no research has demonstrated definitive links.

Structural Epifauna Gulf of Alaska

Contributed by Michael Martin, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: Michael.Martin@noaa.gov
Last updated: October 2011

Description of index: Structural epifauna groups include seapens/seawhips, corals, anemones, and sponges. The biennial survey in the Gulf of Alaska (GOA) does not sample any of these groups 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 limited in these areas as a result. 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 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 were quite different from the survey gear used 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 collection of structural epifauna species and it is likely that this increased emphasis influenced the results

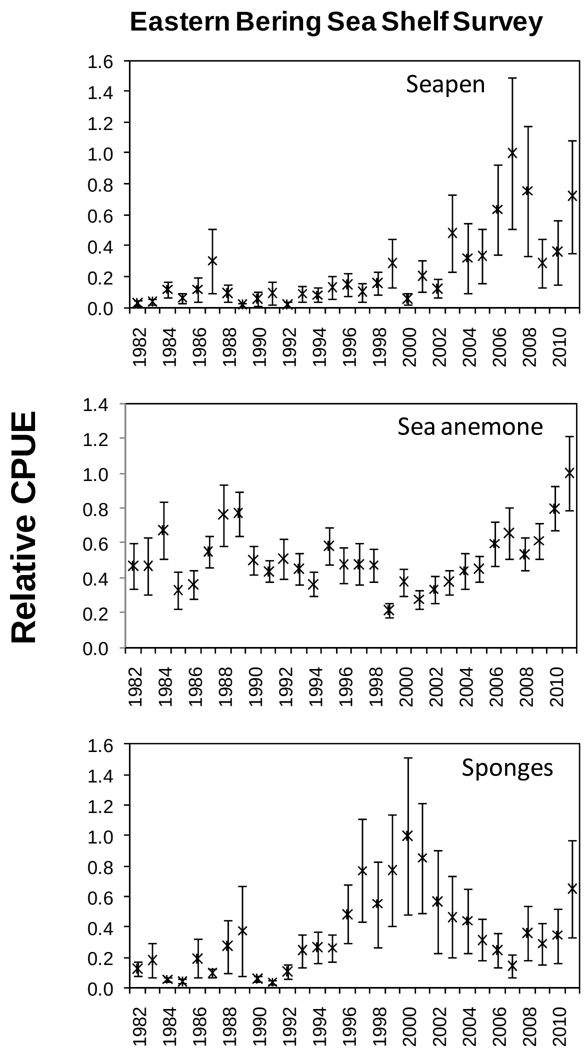

Figure 50: Relative CPUE trends of structural epifauna from the RACE bottom trawl survey of the eastern Bering Sea shelf, 1982-2011. Data points are shown with standard error bars.

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.

Status and trends: A few general patterns are clearly discernible. Sponge abundance generally decreases from west to east across the GOA (Figure 51). Sea anemones appear to be much more abundant in the Western and Central GOA than in the Eastern GOA in the areas sampled. The frequency of occurrence for both of these groups seems to have increased over time in all areas. Gorgonians seem to be most abundant in the eastern GOA. Sea pen and soft coral frequency of occurrence rates are also very low and no abundance trends are discernible from this limited information. Stony corals appear to be much more abundant in the areas sampled in the Western GOA, and are also captured more frequently in this area, although the highest CPUE in the 2011 survey came from the central GOA, due primarily to a single relatively large catch.

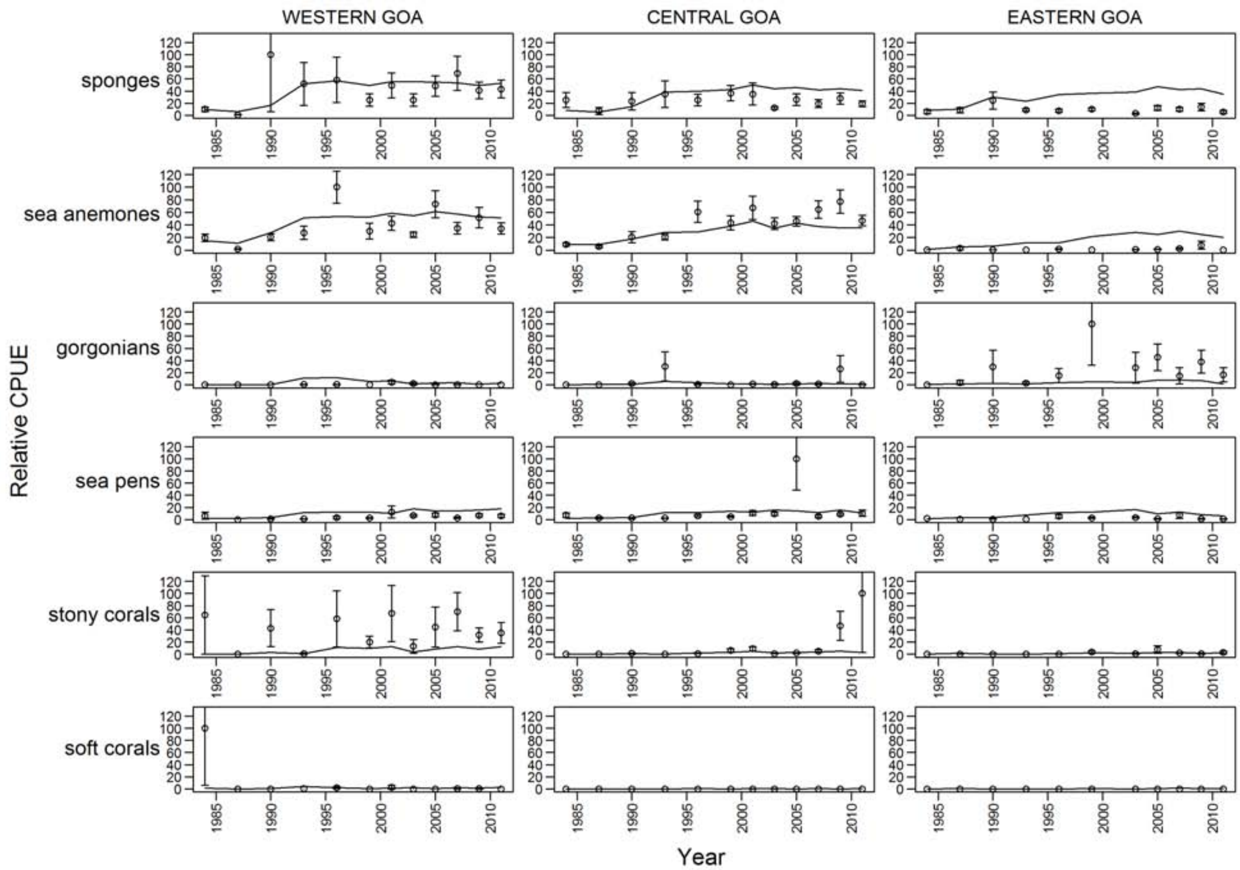

Figure 51: Mean CPUE of structural epifauna species groups by area from RACE bottom trawl surveys in the Gulf of Alaska from 1983 through 2011. Error bars represent standard errors. The solid lines represent the percentage of non-zero catches.

Factors causing observed trends: Unknown

Implications: Changes in structural epifauna CPUE may indicate changes in habitat, but at present no research has demonstrated definitive links.

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

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Last updated: October 2011

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 have been two statistically significant depth-related trends over the time series, as the distribution of both northern rockfish and shortspine thornyhead has been shallower in the most recent surveys of the Aleutian Islands (Figure 52). Northern rockfish have also shown a significant trend in their mean-weighted distribution towards the western Aleutians. There were no significant trends in mean-weighted temperature distributions for any species and all species were found within about 1°C over the entire time series, although since 2000 the mean-weighted temperature distributions have decreased 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.

The depth distribution of rockfish in the Gulf of Alaska has remained constant for each species over time with the exception of shortraker rockfish (Figure 53). Changes in rockfish distribution with temperature have occurred over the time series, most notably since 2007 where there has been a constriction of the range of mean-weighted temperatures for rockfish. In past contributions, a shift in the distribution of rockfish to the eastern and SE areas of the Gulf of Alaska was noted; however, in the 2011 bottom trawl survey data this trend was ameliorated.

Factors causing observed trends: The observed changes in depth and spatial distributions for northern rockfish, shortraker rockfish and shortspine thornyhead in the GOA and AI are probably related to changes in overall abundance. Although it is interesting to note that in the cases of shortspine thornyhead and shortraker rockfish their depth range has become shallower while the temperatures occupied by the species have not changed in recent surveys.

It is unclear why the shift in rockfish distribution towards the eastern GOA and SE Alaska was not found in the 2011 survey data. It may also be related to increased 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 and temperature distributions of rockfish.

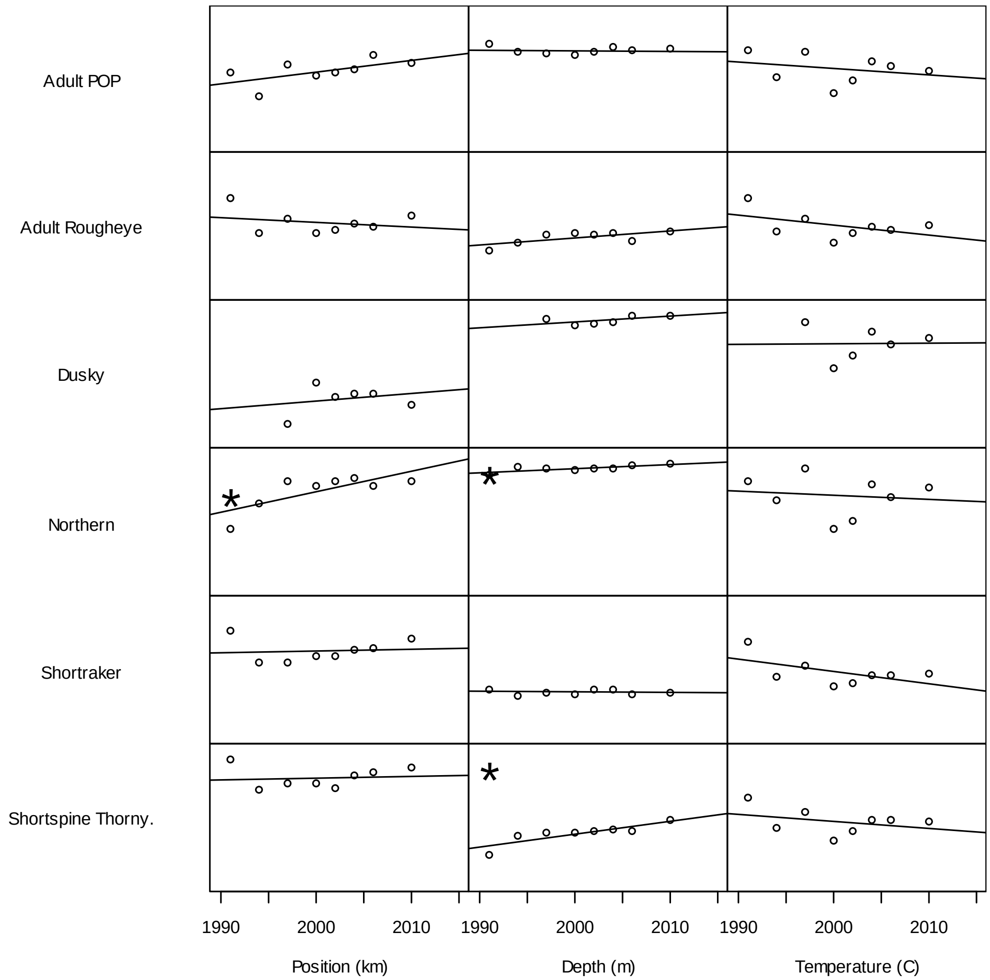

Figure 52: Plots of mean weighted (by catch per unit effort) distributions of six rockfish species-groups along three environmental variables in the Aleutian Islands. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance from Hinchinbrook Island, Alaska, with positive values west of this central point in the trawl surveys and negative values in southeastward. Asterisk indicates significant trend over the time series.

Structural Epifauna Aleutian Islands

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Last updated: October 2010

Aleutian Islands surveys are conducted in alternate even years. For most recent data, see the 2010 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

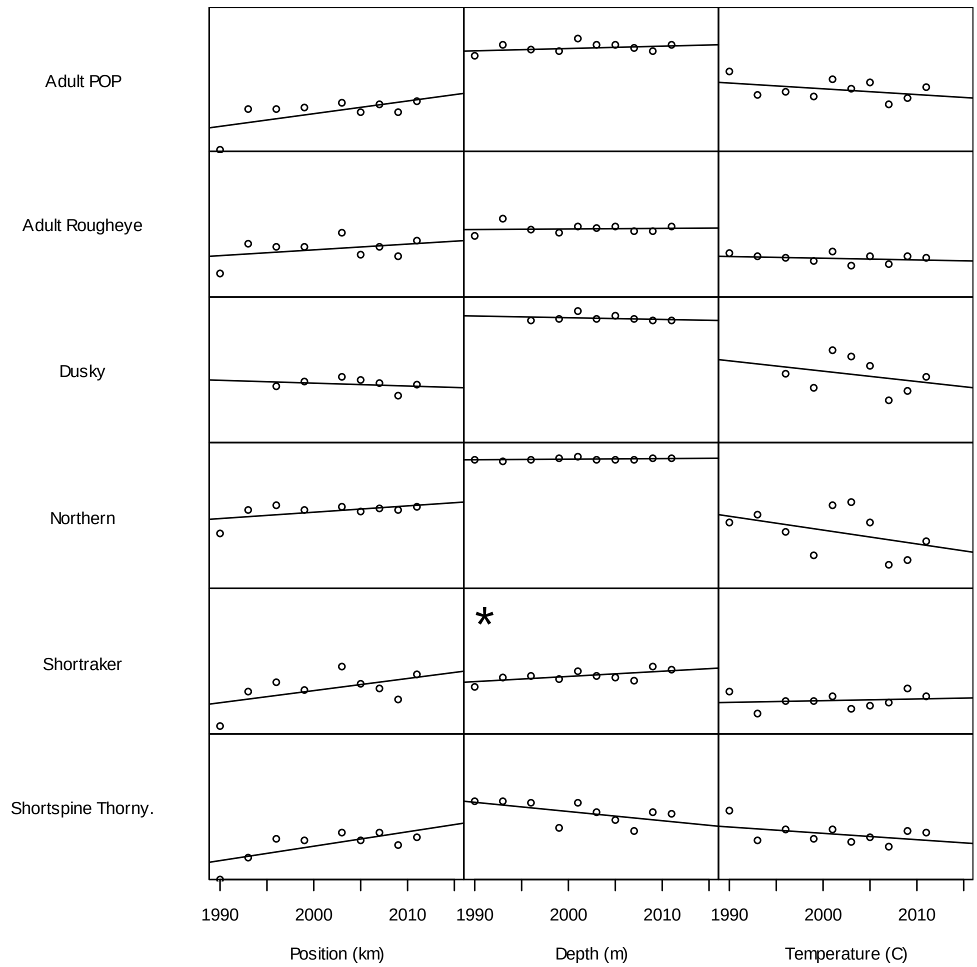

Figure 53: Plots of mean weighted (by catch per unit effort) distributions of six rockfish species-groups along three environmental variables in the Gulf of Alaska. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance from Hinchinbrook Island, Alaska, with positive values west of this central point in the trawl surveys and negative values in southeastward. Asterisk indicates significant trend over the time series.

Nutrients and Productivity

Phytoplankton biomass and size structure during late summer to early fall in the eastern Bering Sea

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Last updated: August 2011

Table 7: Anomalies (calculated for 2003-2009) for the south Bering Sea Middle shelf for mean water column T, wind events (number of times wind speed cubed exceeded a threshold value), stability, chla and ratio of large to total chla from BASIS data (Aug-Sept), and wind speed from NCEP data (Jun-Sept). Positive indicates above average and negative below average values

	2003	2004	2005	2006	2007	2008	2009
Water column T	0.8	0.6	0.8	0	-0.7	-0.6	-1
Wind speed	-0.3	-1	0.8	-0.2	0.7	-0.2	0.3
Wind events	-1	0.2	0.9	-0.6	0.5		
Stability	-0.7	-0.3	-0.2	-0.6	1	0.6	0.2
Chla	0.2	0.4	1	-0.4	-0.5	-0.7	0
Large chla	0.4	0.4	1	-0.4	-0.6	-0.7	0

Description of Index: BASIS conducted fisheries oceanography surveys in the eastern Bering Sea, mid-August to late September, for three warm (2003-2005) followed by four cold (2006-2009) years. Variations in chlorophyll a (chla) were used to evaluate spatial and interannual variations in total phytoplankton biomass and size structure (an indication of phytoplankton species). The percent large phytoplankton (>10 μm / total chla) were determined from discrete water samples collected with Niskin bottles and filtered through GFF and 10 μm filters. Integrated and mean chla values were estimated from CTD fluorescence profiles, calibrated with discrete chla samples. Chla data were averaged over the top 50 m of the water column or to the bottom for shallower stations. Water column stability was estimated over the top 70 m or to the bottom for shallower stations (Simpson et al., 1978). Spatial variations are shown for integrated chla, mean chla, ratio of large assemblages to total (>10 μm/total chla) and stability for 2003-2009 combined (Figure 54). Interannual variations in size structure are shown for the north and south Bering Sea Middle shelf (50-100 m station depths) (Figure 55). Anomalies of temperature, wind, stability, mean chla and size fraction ratios are shown for the south Bering Sea Middle shelf for summer to early fall 2003-2009 (Table 7).

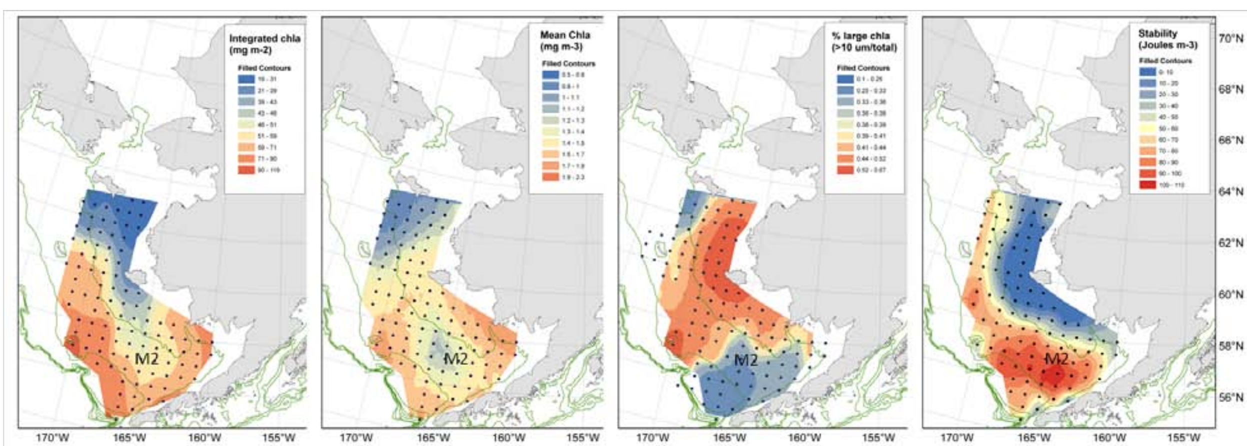

Figure 54: Spatial variations for integrated chla (mg m-2), mean chla (mg m-3), ratio of large assemblages to total (>10 μm /total chla) averaged over top 50 m, and stability (J m-3) averaged over top 70 m for 2003-2009 combined.

Status and Trends: Highest phytoplankton biomass was observed in the Outer shelf near the

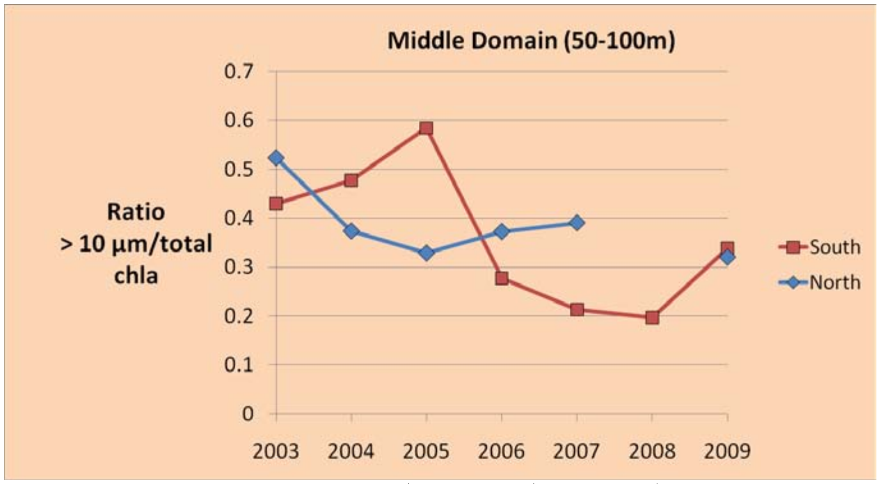

Figure 55: Ratio of large assemblages to total (>10 μm /total chla) in Middle Domain in the north (60 - 63 °N) and south (54.5 - 59.5 °N) Bering Sea for 2003-2009.

Pribilof Islands, and in the south Inner shelf. Lowest biomass was observed in the north Bering and SE Middle shelf (in a region of high stability). Larger phytoplankton were seen on the Inner shelf and near the Pribilofs. Smaller phytoplankton were seen on the SE Middle shelf (an area of lower total chla), and in the Outer shelf (an area of higher total chla). In the south Bering Sea, phytoplankton biomass and mean size of assemblages were higher in warm (03-05) than in cold (06-09) years on the Middle shelf. This trend was not observed in the north Bering Sea.

Factors Causing the Trend: Water column stability, wind and temperature may influence interannual and spatial variations in phytoplankton biomass. Deep nutrient-rich waters can be mixed to the surface to fuel production of large assemblages during periods of high winds and low water column stability. And phytoplankton growth may be enhanced at higher temperatures, depending on species. For example, the highest chla and largest size fractions were seen in 2005, during a period with high winds, average stability and high water column temperature (Table 7). While, the lowest chla and smallest size fractions were seen in 2008, during a period with low winds, high stability and low water column temperature. Spatially, low chla and small phytoplankton assemblages were seen in the area of highest stability, in the SE Middle shelf near mooring M2.

The greater variation in size structure in the south compared to the north may be related to the greater interannual variation in winter ice extent and subsequent effects on ecosystem dynamics in spring and summer (Stabeno et al., In press).

Implications: Phytoplankton dynamics determine the amount and quality of food available to zooplankton and higher trophic levels, and are thus important to ecosystem function. For example, larger phytoplankton assemblages may lead to shorter food webs and a more efficient transfer of energy to sea birds, fish and marine mammals. Data will be used to characterize interannual and spatial variation in primary production and ecosystem processes during the critical late summer/ fall period prior to the over-wintering of key forage fish (e.g. juvenile pollock, cod, salmon).

Gulf of Alaska Chlorophyll a Concentration off the Alexander Archipelago

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Last updated: August 2011

Description of index: Surface chlorophyll a concentrations (chla) were calculated for Gulf of Alaska (GOA) waters off the Alexander Archipelago as part of a pilot survey for the Gulf of Alaska Integrated Ecosystem Program (GOA Project) during the spring bloom (April) and summer (July) 2010. In coming years (2011-2013), seasonal chla concentrations will be calculated for both the southeastern and central regions of the GOA and used to estimate variations in total phytoplankton biomass. Chla is proportional to the amount of phytoplankton in the water column, which is controlled by light, temperature, water stratification, and nutrients. These values can be used as an index of primary productivity. Water samples were obtained at depth with Niskin bottles and filtered through GFF filters at five discrete depths (0, 10, 20, 30, 40, and 50 meters).

Bloom timing and intensity influences micro and macro zooplankton populations, which are the base of the food web supporting fish, marine mammals, and seabirds. Fluctuations in primary production cascade to upper trophic levels (zooplankton) (Cooney, 1986), which directly affect the abundance and quality of forage for commercially harvested fish (Mueter et al., 2011). Documenting interannual changes in primary productivity and understanding the underlying causes of these changes can improve our understanding on how biophysical process influence fish and fisheries.

Status and trends: Data reported in 2010 is the first installment of an impending time series, and thus there are no interannual trends to report at present. However, within year spatial patterns were apparent, with elevated concentrations of chla were north of Cross Sound in spring and summer (Figures 56 and 57), and north of the entrance to Chatham Strait during summer (Figure 57).

Factors causing observed trends: Increased chla concentrations north of Cross Sound are likely due to the along-shelf flow of tidally mixed waters exiting the sound (P. Stabeno, personal communication). Elevated concentrations north of the entrance to Chatham Strait during summer may be due to tidally mixed water exiting the entrance.

Implications: Chla is an indicator of primary productivity, but we don't have a time series to report at this time.

Zooplankton

Bering Sea Zooplankton

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Last updated: October 2010

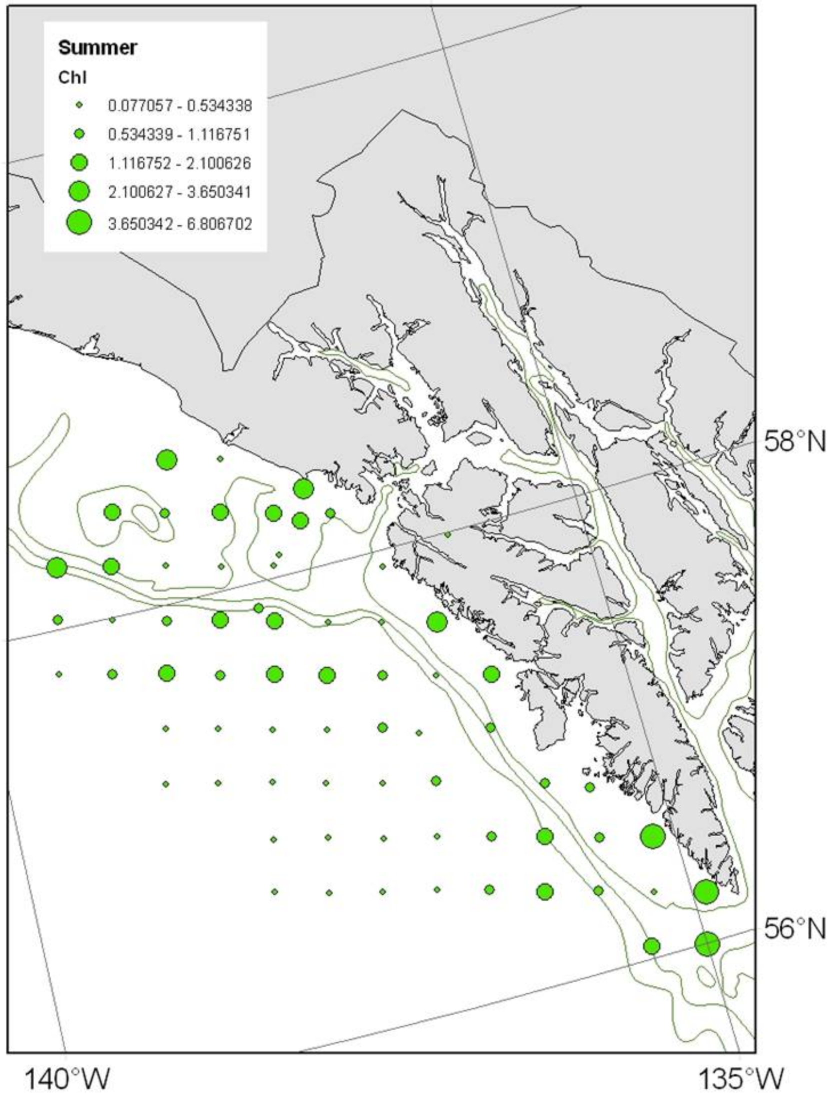

Figure 56: Chlorophyll a concentration in the southeastern Gulf of Alaska during April 2010.

See the 2010 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

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

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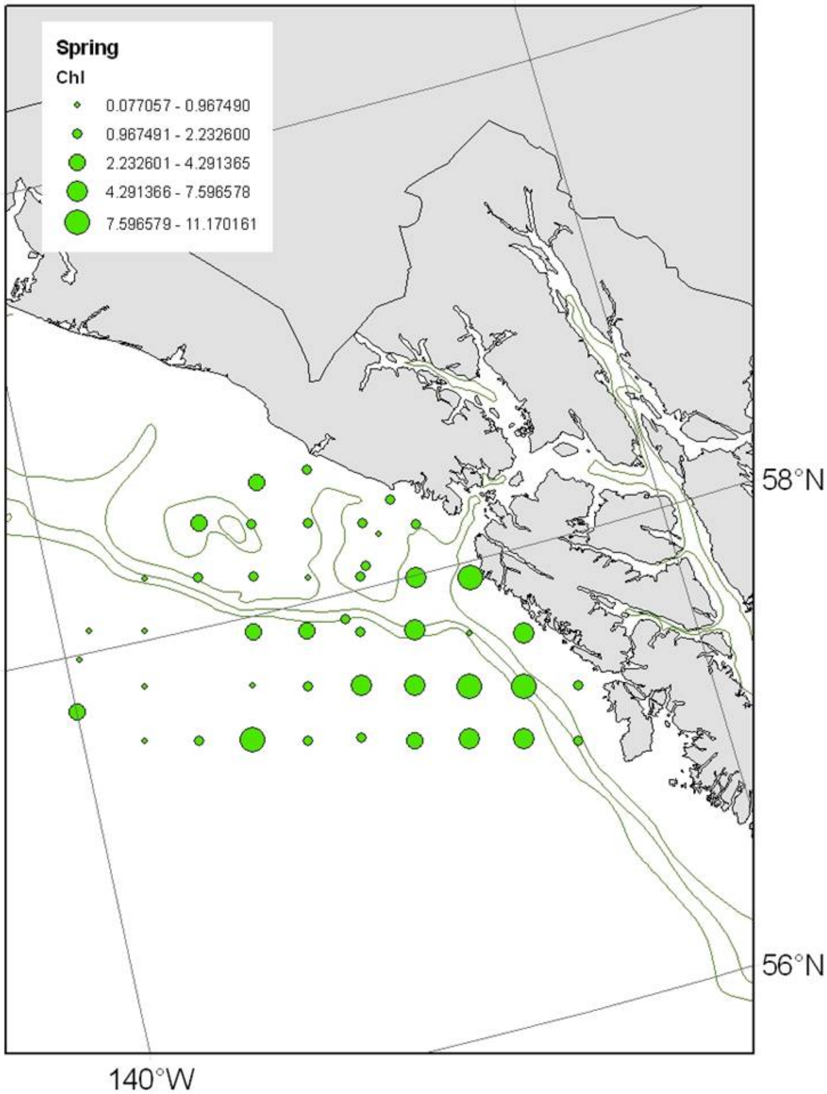

Figure 57: Chlorophyll a concentration in the southeastern Gulf of Alaska during July 2010.

Last updated: August 2011

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, 2003-2009. 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, by the University of Alaska Fairbanks for 2005-2008, and by Auke Bay Laboratories for 2009 following procedures outlined in Coyle et al. (2008). Mean abundances (number per m^3) by year of large zooplankton are shown for the northern (60-63.75°N) and southern (55-59.75°N) Bering Sea for warm (2003-2005) and cold (2006-2009) years (Figure 58).

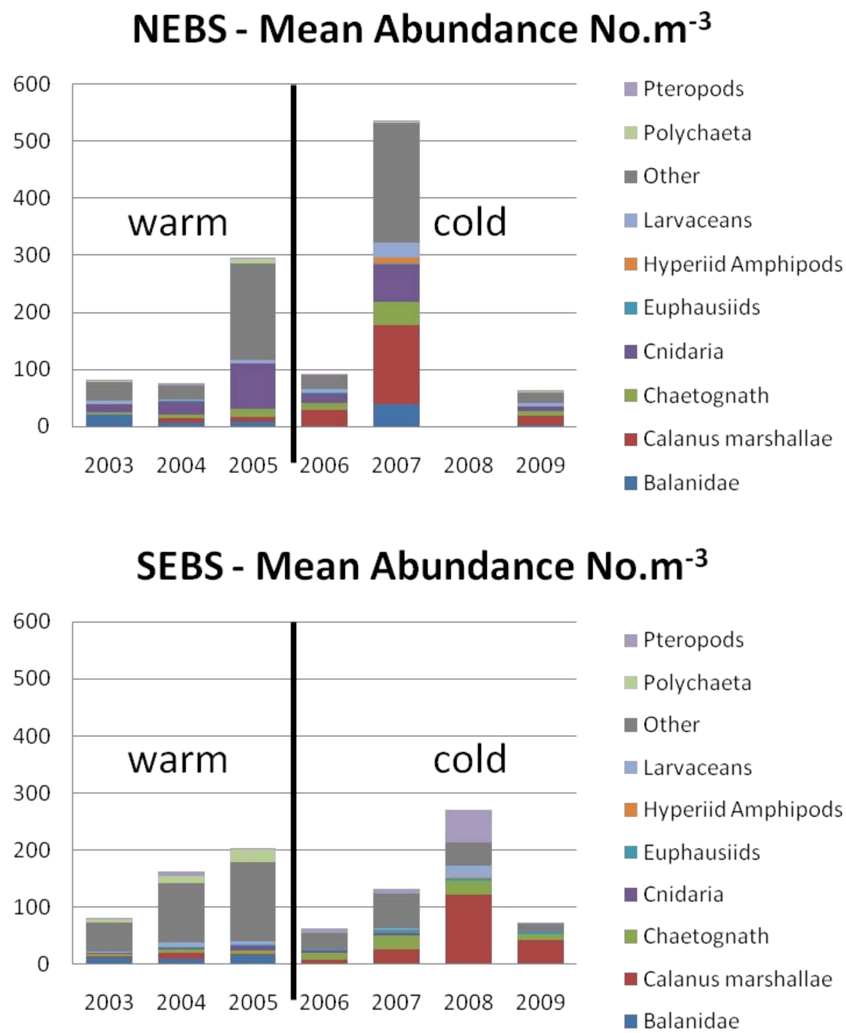

Figure 58: Mean abundance of large zooplankton collected with oblique bongo tows (505 μm mesh) on the Bering Sea shelf (<100 m) during BASIS surveys in the northern (top panel) and southern (bottom panel) Bering Sea.

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 58). When available, *C. marshalla* 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., 2011). Although not depicted here, euphausiids also increased in abundance in the Middle Domain in cold years (2008 and 2009) compared to warm years (2004)(Coyle et al., 2011; Hunt et al., 2011). Increases in energy density of age-0 pollock during cold years (Heintz et al., 2010) 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 Cnidaria present in the northern Bering and more polychaeta (in warm years) and pteropods in the southern Bering Sea (Figure 58). Salmon diets reflect these spatial variations in zooplankton with Cnidaria important in juvenile chum salmon diets in the northern Bering Sea.

Factors causing observed 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. marshalle* were concentrated in the Middle Domain in regions where the cold pool was observed (BASIS unpublished data).

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., 2010). 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., 2011). 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.

Long-term Zooplankton Trends in Icy Strait, Southeast Alaska

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Last updated: September 2011

Description of Index: The Southeast Coastal Monitoring (SECM) project of Auke Bay Laboratories, AFSC, has collected zooplankton data during fisheries oceanography surveys annually since 1997 (Orsi et al. (2011); `http://www.afsc.noaa.gov/abl/msi/msi_secm.htm`). The SECM project primarily samples eight stations in the vicinity of Icy Strait in the northern region of southeastern Alaska (SEAK), including monthly oceanographic sampling in May-August and surface trawling for juvenile salmon and associated epipelagic ichthyofauna in June-August. The primary goal of this research is to increase understanding of the early marine ecology of salmon (*Oncorhynchus* spp.), salmon relationships to co-occurring fishes, and how climate change may affect recruitment and survival. Another important goal is to develop an annual forecast of the adult pink salmon (*O. gorbuscha*) anticipated to return the following year (Orsi et al. 2009). The forecast relies on biophysical parameters such as zooplankton standing stock and temperature, as well as juvenile pink salmon abundance data. Detailed information on zooplankton density and species composition are collected from 333-μm bongo net samples ($\leq$ 200 m depth) preserved from four core stations, to complement data on juvenile salmon abundance, condition, and feeding (Orsi et al., 2011). The zooplankton laboratory methodology is reported in Park et al. (2004).

Status and trends: Monthly anomalies for total zooplankton density were computed against the longterm monthly means from the 14-yr time series. The longterm monthly mean densities of total zooplankton for May, June, July, and August were 1682, 1747, 1187, and 830 organisms/m3, respectively (Figure 59). From 1997-2005, a trend for strongly negative density anomalies was observed, followed in 2006-2009 by a trend for strongly positive density anomalies. A shift occurred in 2010, however, when monthly densities were near the longterm mean except in May, when densities were higher than average.

A new annual index of monthly zooplankton percentage composition anomalies for four principal

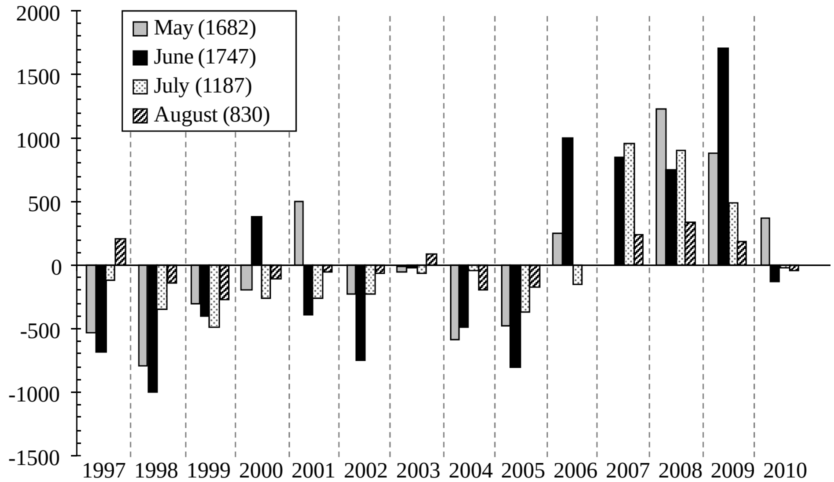

Figure 59: Zooplankton total density anomalies across the 14-yr time series from Icy Strait in the northern region of southeastern Alaska, 1997-2010. Data (shaded bars) are deviations from longterm monthly mean density (numbers/m^3) indicated by the 0-line; longterm monthly mean values are indicated in the key. Monthly samples (n = 4) were collected using a 333-$/mu/$m mesh bongo net deployed to a maximum depth of 200 m and retrieved using a double oblique trajectory. No samples were collected in August 2006, and the May 2007 nighttime values were omitted because high densities did not represent the standard daytime sampling protocol

taxonomic groups was also computed against the 14-yr monthly mean percentages, and indicated distinctly different taxonomic patterns for 2010 (Figure 60). Strongly negative anomalies were observed for percentages of large ($>$ 2.5 mm Total length, TL) and small ($\leq$ 2.5 mm TL) calanoid copepods, and strongly positive anomalies were observed for percentages of euphausiid larvae and larvaceans, particularly in May. The negative calanoid anomalies also occurred in synchrony, in contrast to most other years, when they were opposite. Overall, calanoids contributed less than the longterm average of 81-90% of zooplankters each month, whereas euphausiid larvae and larvaceans each contributed more than their longterm averages of $\leq$6% per month. No composition anomalies were observed for the total remaining taxa (decapod larvae, pteropods, amphipods, and miscellaneous others), which comprised $\leq$7% (data not shown). These changes indicate differences in the 2010 abundance, composition, and timing of zooplankton prey fields, including taxa that are seasonally prominent in diets of juvenile salmon and other planktivores (Coyle and Paul, 1992; Sturdevant et al., 2004, 2011).

Factors causing observed trend: Our research in SEAK over the past 14 years describes annual trends in prey fields and other biophysical factors for juvenile salmon. The 2010 prey field anomalies may reflect persistent effects of the seasonally early warm weather on surface temperatures, salinities, and mixed layer depths in the strait habitat transited by juvenile salmon approaching the Gulf of Alaska, and may have contributed to the negative size anomalies observed for juvenile salmon in 2010 (Orsi et al., 2011).

Implications: Although links between climate and plankton have been documented in Alaskan waters, mechanisms are poorly understood. In the Bering Sea, the magnitude and timing of production of the large copepod, *Calanus marshallae*, varied among years, reflecting interannual ocean-

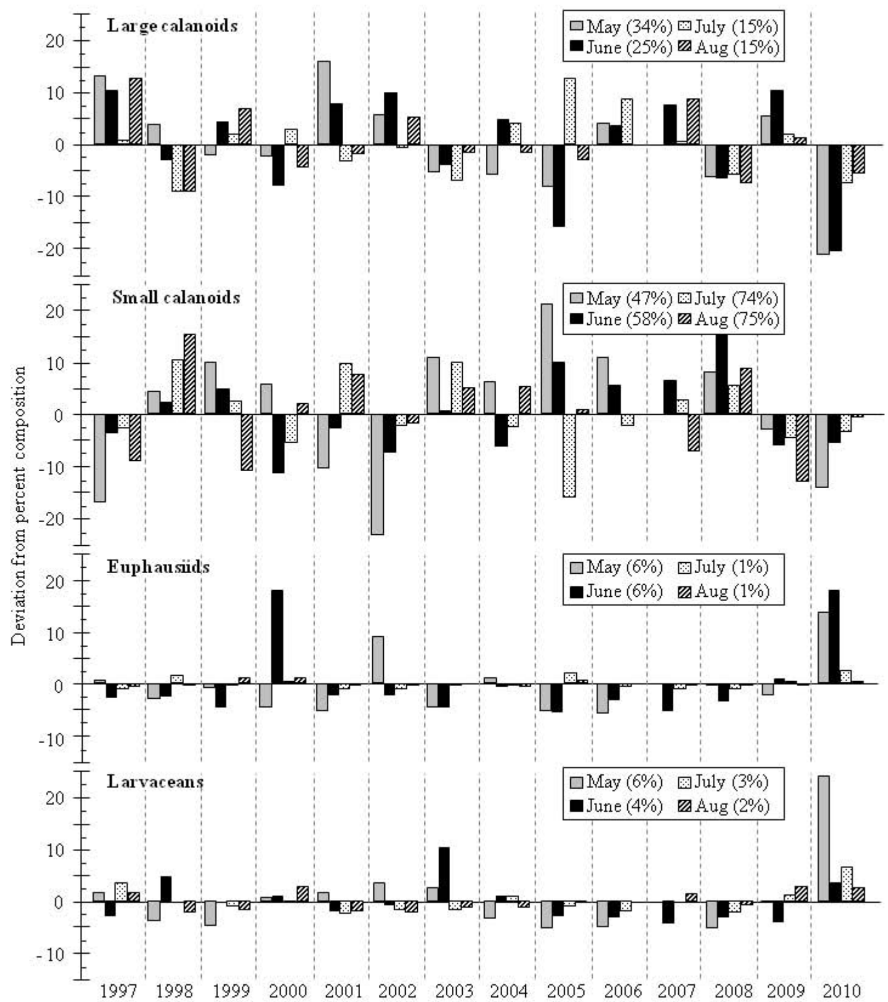

Figure 60: Zooplankton composition anomalies across the 14-yr time series from Icy Strait in the northern region of southeastern Alaska, 1997-2010. Data (shaded bars) are deviations from longterm mean percent of total density (percent number/m^3), indicated by the 0-line; longterm mean monthly values are indicated in the key. Data are from 333-μm mesh bongo net samples as described in Figure 59

atmosphere conditions (Baier and Napp, 2003), and in Southeast Alaska, large copepods with long life spans were thought to be more sensitive to climate fluctuation than small copepods (Park et al., 2004). Fish diets change on diel, seasonal, and interannual time scales (Coyle and Paul, 1992; Sturdevant et al., 2004, 2011) as well as spatial scales (Brodeur et al., 2007), with diet quality impacting survival (Armstrong et al., 2008). Thus, establishing links between longterm seasonal trends in prey field abundance, composition, and timing, environmental conditions, and the diet and condition of outmigrating juvenile salmon may improve understanding of marine mechanisms that influence recruitment (Downton and Miller, 1998; Francis et al., 1998).

Continuous Plankton Recorder data from the Northeast Pacific

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Last updated: August 2011

Description of Indices: Continuous Plankton Recorders (CPR) have been deployed in the North Pacific routinely since 2000. Two transects are sampled seasonally, both originating in the Strait of Juan de Fuca, one sampled monthly (approximately 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. Several indicators are now routinely derived from the CPR data and updated annually. They include indicators of mesozooplankton (1) biomass, (2) community, and (3) phenology (timing).

Mesozooplankton biomass and community composition are estimated for several regions. The eastern-most region has the best sampling resolution as both transects intersect here. This region has been sampled up to 9 times per year with some months sampled twice. Regions to the west are sampled only 3 times per year. Regions to the north are sampled 5-6 times per year, although there were some mechanical failures which reduced the number of samples for Cook Inlet and its associated shelf in 2010.

The calanoid copepod *Neocalanus plumchrus* is a dominant component of the spring mesozooplankton in the subarctic North Pacific and Bering Sea. 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 (offshore BC region in 61) is sampled by both transects giving sufficient sampling resolution to determine the timing of the peak of *Neocalanus plumchrus*. Further information on these indices can be found in Batten and Mackas (2009).

Summer samples were used for community composition analysis for two reasons: (a) they allowed us to use the pilot transect data from 1997, which is a useful comparative dataset because that was the start of a strong El Niño, 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.

Status and trends: Monthly mesozooplankton biomass estimates from several regions are shown in Figure 61, with 2010 data overlaid for comparison with previous years. The spring biomass in Cook Inlet was as high as previously recorded. In the adjacent shelf, it was lower than average in May but much higher than average in July, suggesting that the spring peak was later than normal here. The Bering Sea values were close to previous maxima and minima and again suggest a strong and relatively late spring peak. The Aleutian shelf samples were few in number and although the data suggest summer values were low, not too much emphasis should be placed on this. Values for the well-sampled offshore BC region were within the range previously found but consistently lower than average, culminating in the lowest annual biomass anomaly of the time series for this region.

Time series of the day of the year when peak biomass is projected to have occurred and the length of the season (defined as the number of days between the 25th and 75th percentile of cumulative biomass) are shown in Figure 62. Note that the date could not be calculated for 2008 as sampling did not begin until May, when the copepodites were too advanced. 2010 was an average year in

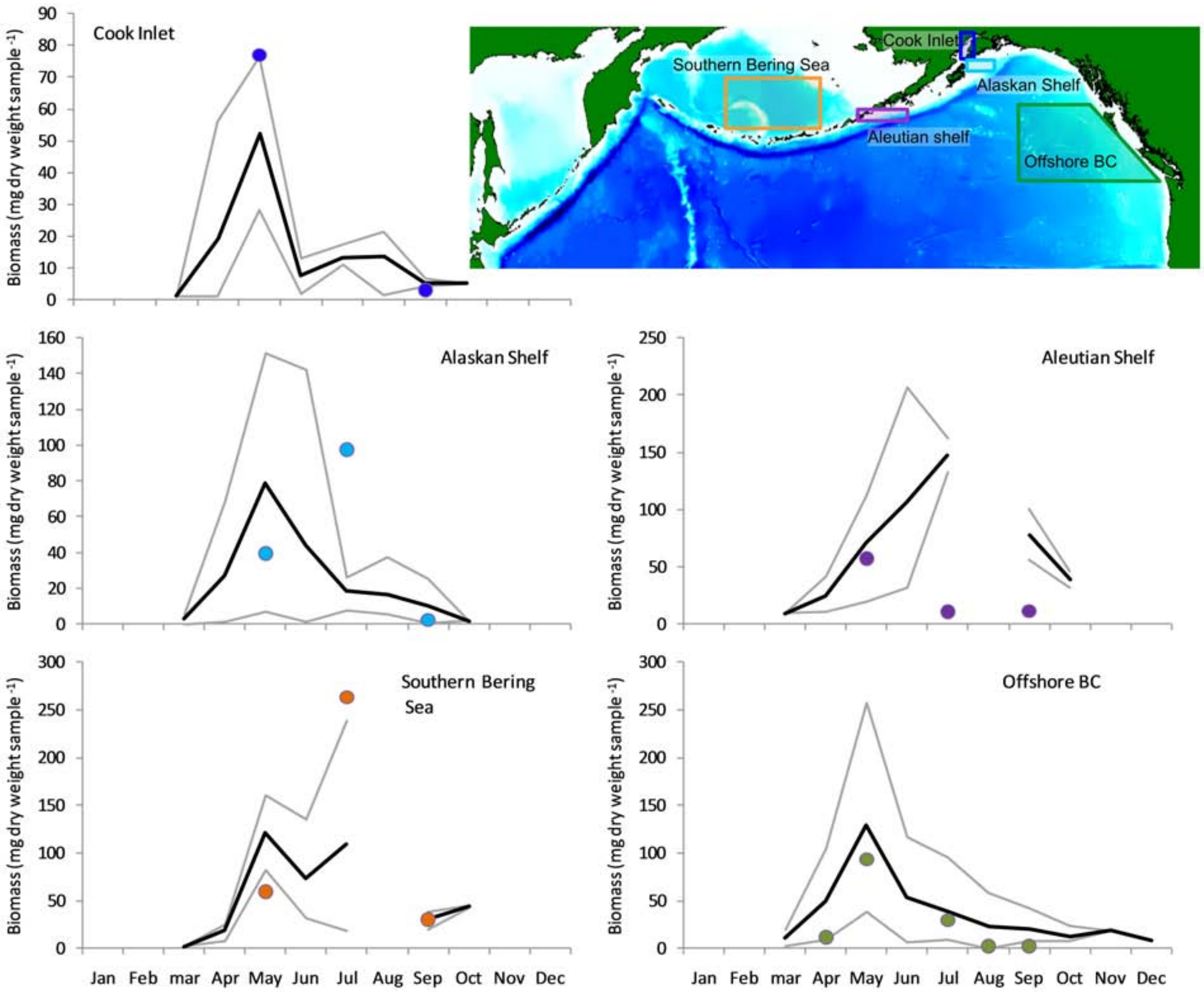

Figure 61: Mean (black lines), minimum and maximum (grey lines) monthly mesozooplankton biomass for the NE Pacific CPR sampling of the regions shown above right (2000 to 2009 except Cook Inlet and Alaskan Shelf regions where time series extends from 2004 to 2009), together with monthly data for 2010 overlaid as points

terms of timing and duration of season.

Non-metric Multidimensional Scaling (NMDS) analysis of log-transformed abundance data for individual mesozooplankton taxa shows a clear gradient in community composition with the warmest years at the top and left of the plot and coldest years plotting at the bottom (Figure 63). Transition years (2003 transitioning from cold to warm, 2006 transitioning from warm to cold, and neutral years 2009 and 2010) plot in the centre. 1997 and 2007 stand out as unusual years. Overall, the community in summer 2010 was very similar to that in 2009.

Factors causing observed trends: Changes in ocean climate can affect each of these indicators. 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). Community composition analyses

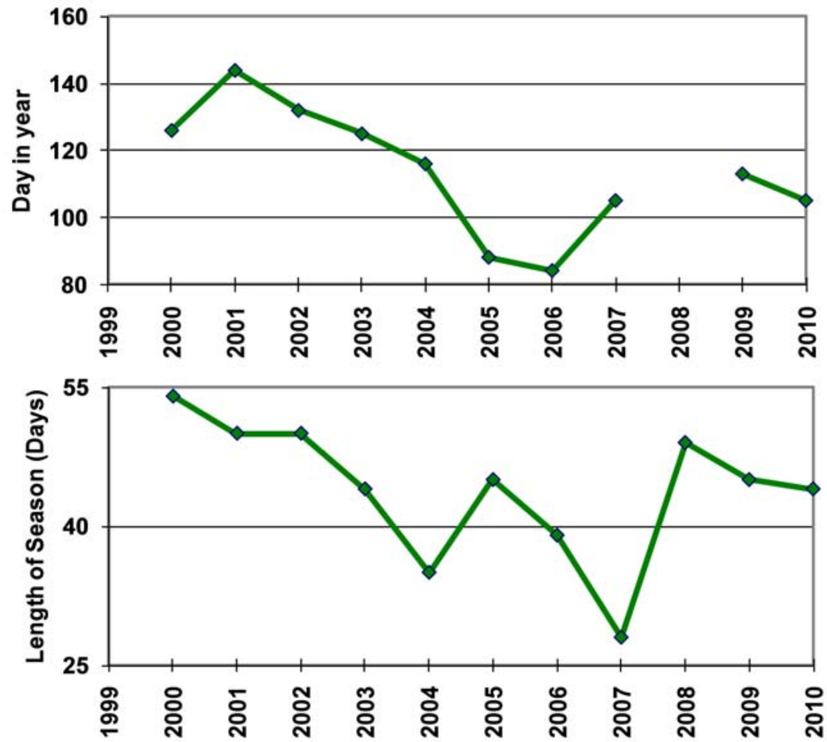

Figure 62: Day of the year when peak biomass of *Neoclanus plumchrus* occurred (based on stage composition, when 50% population was at copepodite stage 5), upper panel. Lower panel shows the length of the season calculated as the number of days between the 25^{th} and 75^{th} percentile of cumulative biomass.

of summer samples from the same eastern North Pacific region show a clear relationship between temperature and community composition. The unusual community composition score in 1997 was influenced by the strong El Niño, but there is currently no explanation for the unusual score for 2007.

Implications: Each of these variables is important to the way that productivity is passed through zooplankton to higher trophic levels. Changes in community composition may reflect changes in the nutritional quality of the zooplankton to their predators. Changes in ocean climate can affect the availability of zooplankton to their predators.

Forage Fish

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

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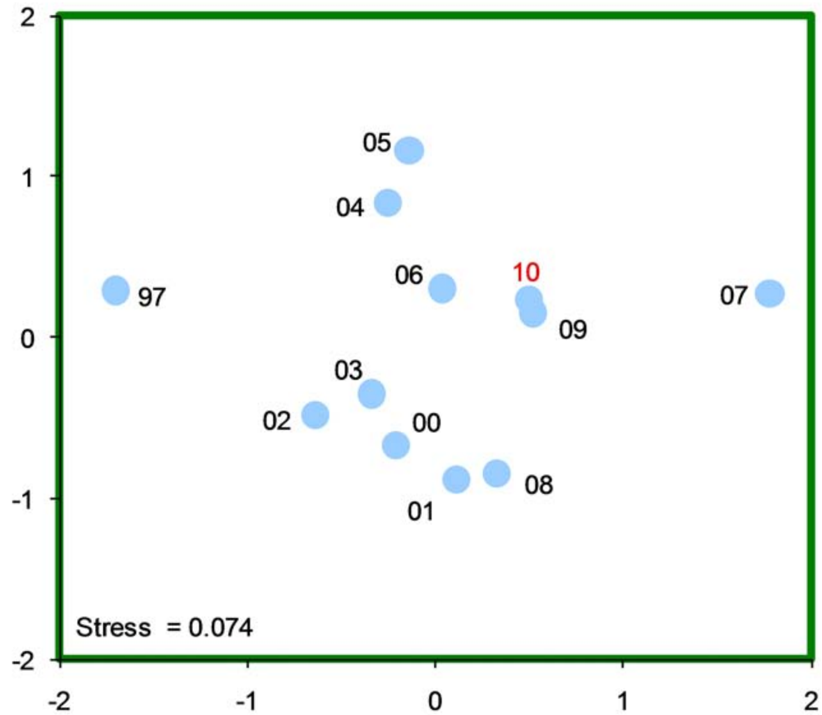

Figure 63: Non-metric MDS plot of log (x+1) transformed mean annual (from June 28th-August 31st) abundance data for each mesozooplankton taxon

See the 2010 report 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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Last updated: August 2008

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 2011

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. 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. Relative CPUE was calculated and plotted for each species or species group by year for 1982-2011. 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 65)

Status and trends: Sandfish were generally in low abundance in the trawl surveys (Figure 64) 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 increased slightly in 2010 and 2011 and capelin (*Mallotus villosus*) relative CPUE remained relatively low, with the exception of one year (1993; Figure 64). 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 ($<2^{o}$C) down the middle shelf during the cold years.

Factors causing observed trends: The high CPUE of Arctic cod during cold years is probably because of its association with the southern intrusion of the Arctic cold pool ($<2^{o}$C) down the middle shelf during the those years.

Implications: 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.

Forage Species - Gulf of Alaska

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Last updated: October 2011

Description of index: The North Pacific Fishery Management Council has defined several groups as forage species for management purposes in the Gulf of Alaska (GOA). 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 Gulf of Alaska. The survey is

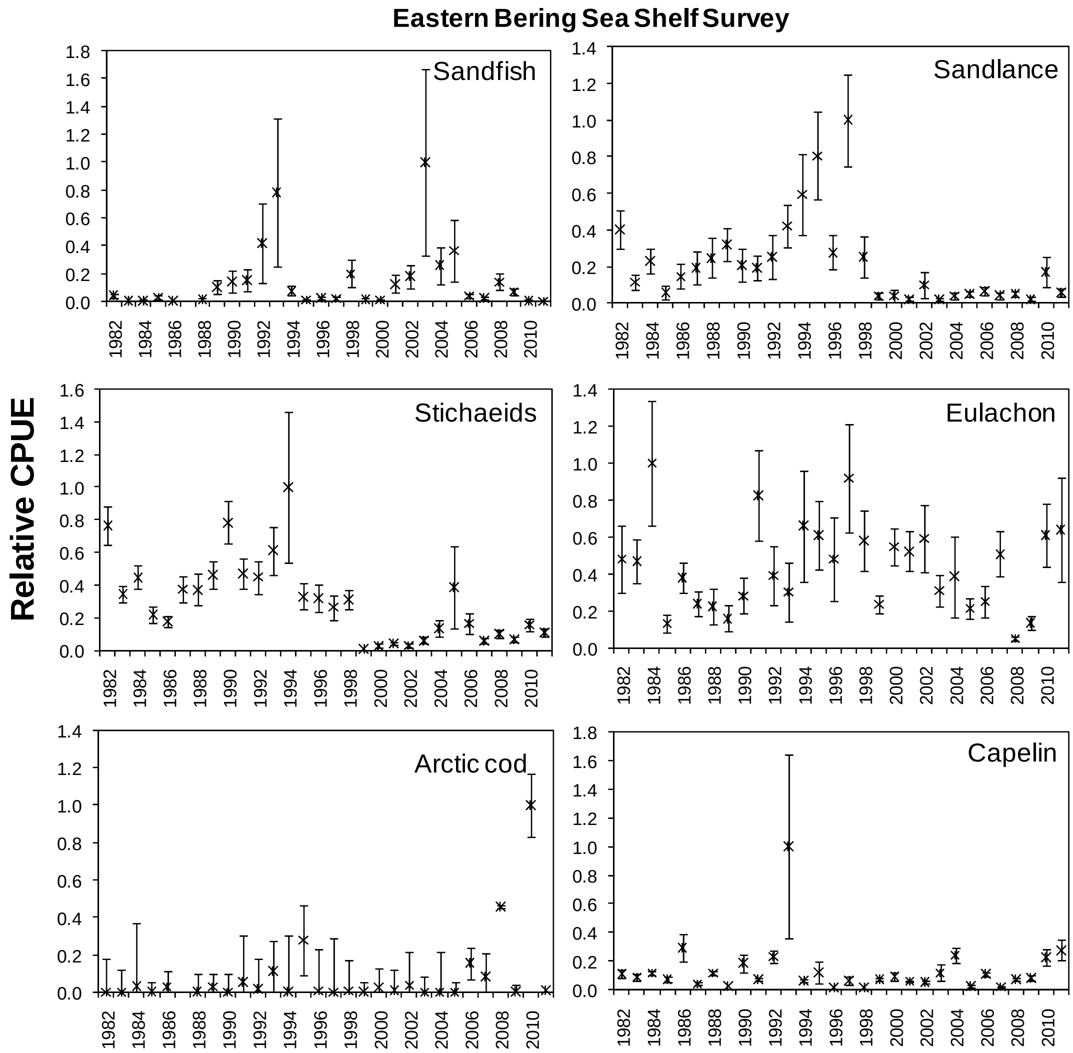
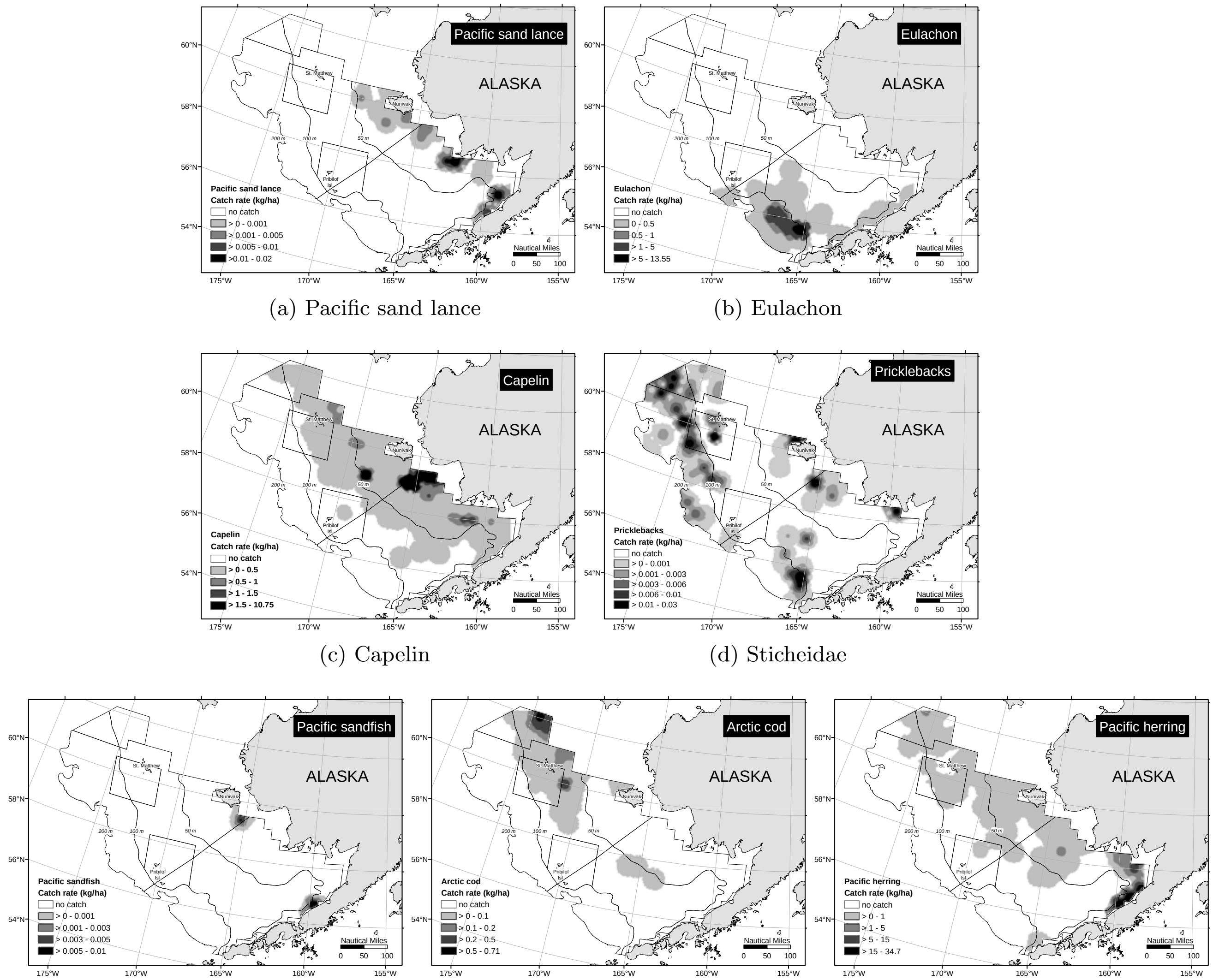


Figure 64: Relative CPUE of several forage fish groups from the eastern Bering Sea summer bottom trawl survey 1982-2011. Data points are shown with standard error bars.

not designed to assess these species and the survey gear mesh size is too large to efficiently capture these species. With the exception of eulachon, these species are rarely encountered during the survey and therefore trends in abundance are considered to be unreliable. Eulachon are generally captured in a relatively large number of tows, and although they are not sampled well by the gear, it is possible that trends in abundance may be discernible from the survey data. 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.

Status and trends: Eulachon appear to be most abundant in the Central GOA, particularly in Shelikof Strait, south of the Kenai Peninsula and Prince William Sound (Figure 66). However, eulachon are observed more frequently in survey tows in the Eastern GOA, although catches are generally smaller than in the Central GOA. Eulachon have generally been much more abundant since 2001, particularly in the Central GOA. In 2011, capelin appeared to be most abundant on



(a) Pacific sand lance (b) Eulachon

(c) Capelin (d) Sticheidae

(e) Pacific sandfish (f) Arctic Cod (g) Pacific herring

Figure 65: Distribution and relative abundance of forage species for the 2011 eastern Bering Sea bottom trawl survey.

the south side of Kodiak Island and around Portlock Bank. Pacific sand lance were caught in only 10 tows, with the largest catches occurring south of Kodiak Island. Pacific sandfish were also relatively rare in survey catches, with the largest catches centered around the Copper River delta. Pricklebacks were most abundant in Chiniak Bay and in inshore areas of Shelikof Strait. Maps showing the locations of forage fish catches are included (Figures 67, 68, 69, 70, 71).

Factors causing observed trends: Unknown.

Implications: 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.

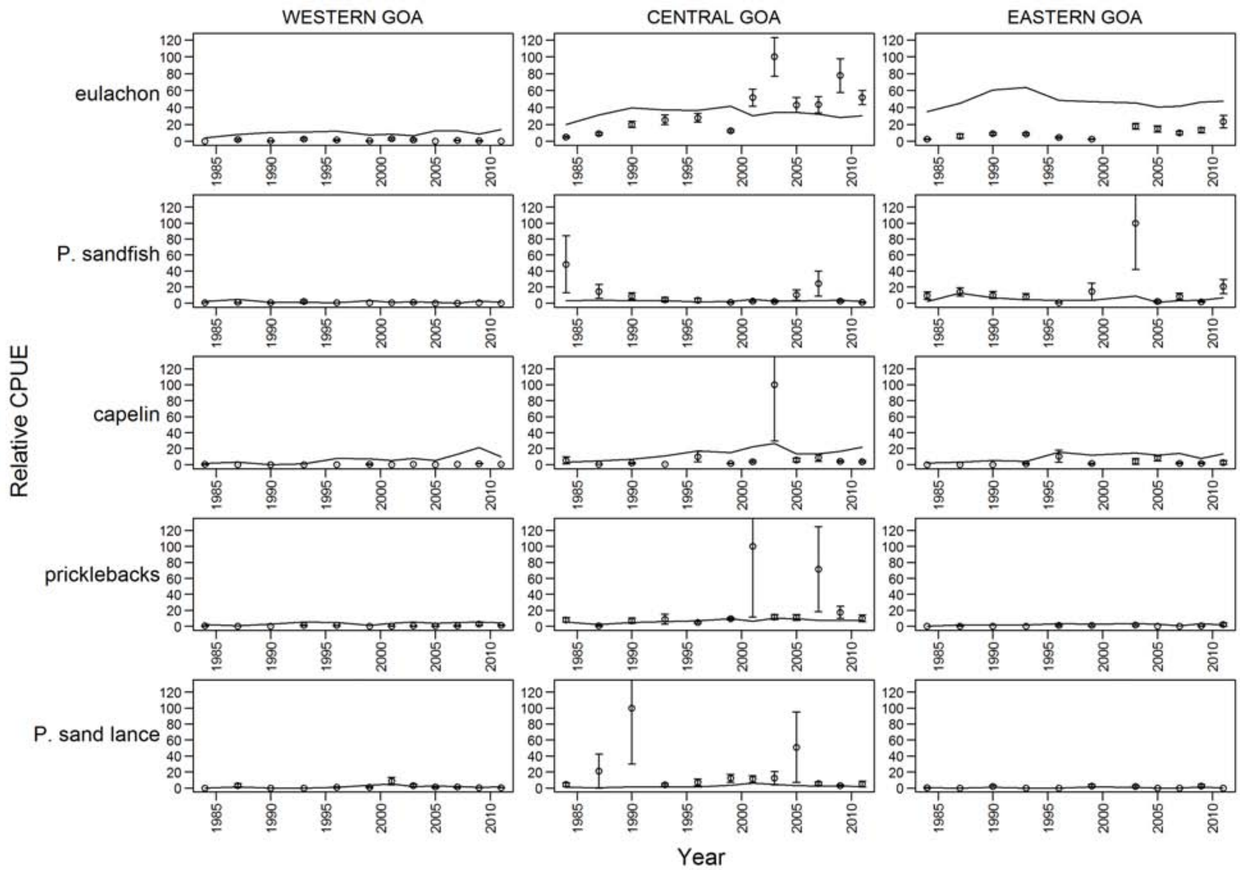


Figure 66: Relative mean CPUE of forage fish by area from RACE bottom trawl surveys in the Gulf of Alaska from 1983 through 2011. Error bars represent standard errors. The solid lines represent the percentage of non-zero catches.

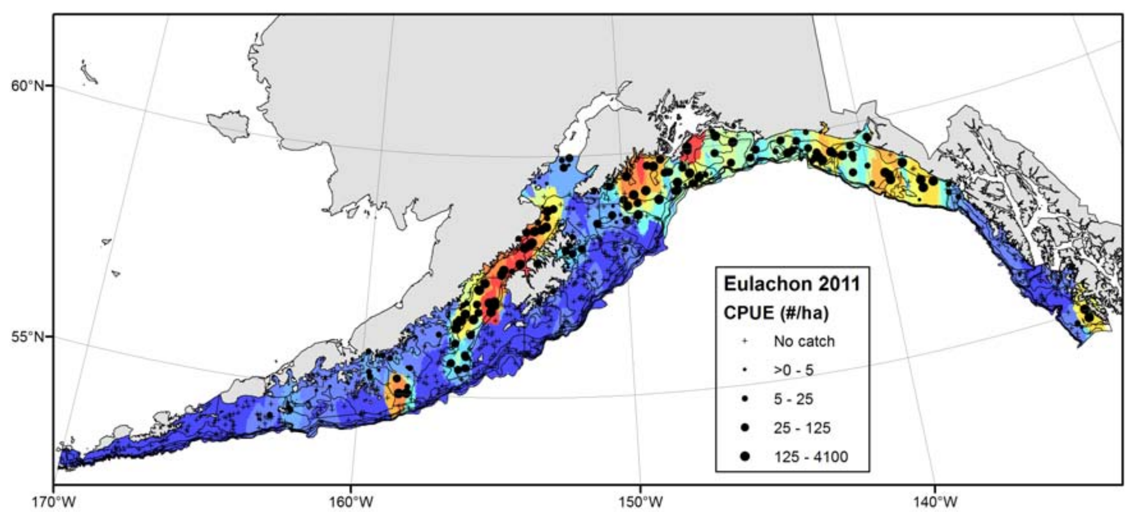


Figure 67: Catch per unit effort for eulachon during the 2011 Gulf of Alaska Groundfish Survey.

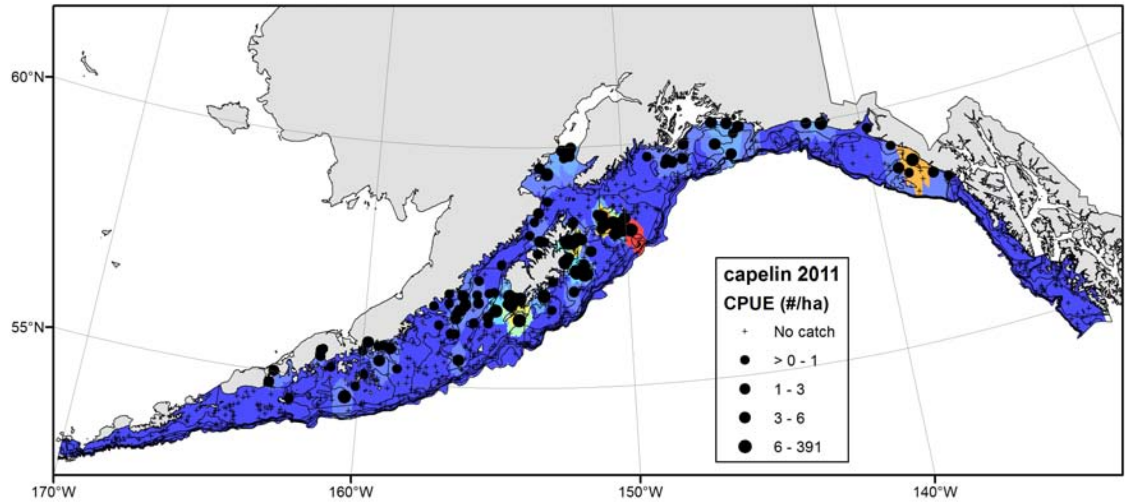


Figure 68: Catch per unit effort for capelin during the 2011 Gulf of Alaska Groundfish Survey.

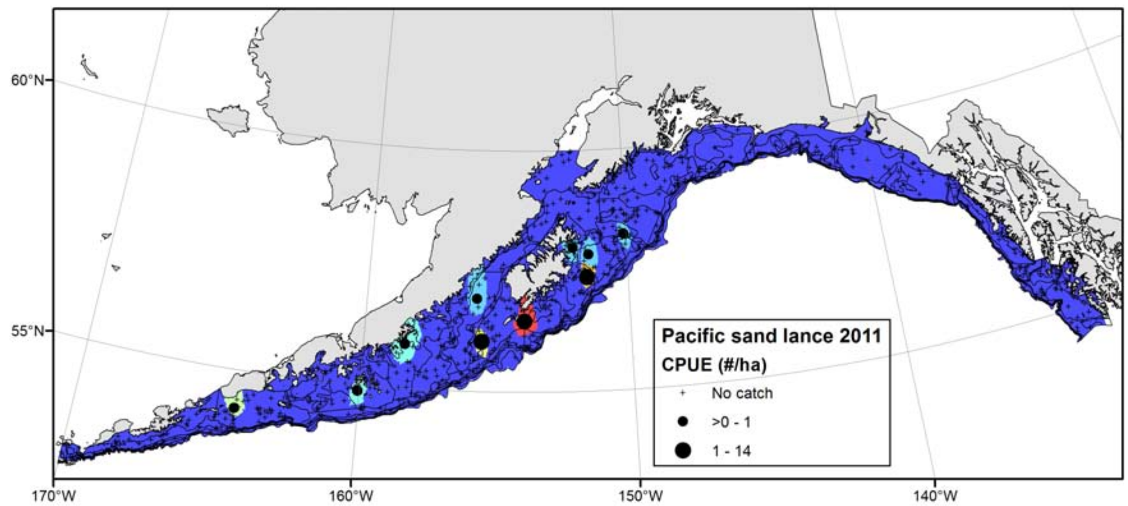


Figure 69: Catch per unit effort for Pacific sand lance during the 2011 Gulf of Alaska Groundfish Survey.

Forage Species - Aleutian Islands

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Last updated: October 2010

Gulf of Alaska surveys are conducted in alternate even years. For most recent data, see the 2010 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

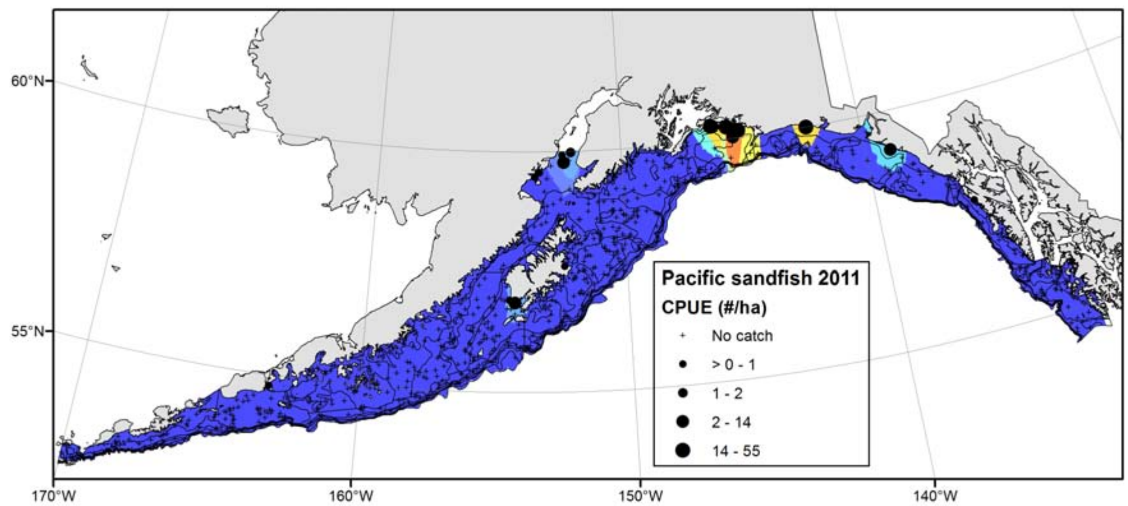

Figure 70: Catch per unit effort for Pacific sandfish during the 2011 Gulf of Alaska Groundfish Survey.

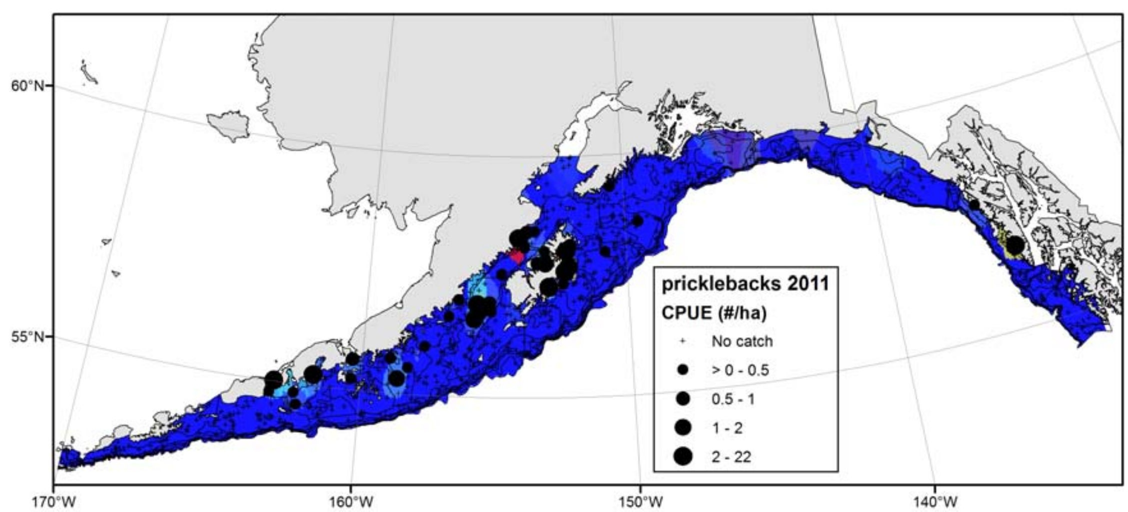

Figure 71: Catch per unit effort for pricklebacks during the 2011 Gulf of Alaska Groundfish Survey.

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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Last updated: August 2010

See the 2010 report at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Togiak Herring Population Trends

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Last updated: October 2011

Description of index: The biomass of Pacific herring occurring in the Togiak District of Bristol Bay has been tracked through aerial surveys since the late 1970s using methods described by Lebida and Whitmore (1985). An age-structured analysis (ASA) model is used to forecast biomass (Funk et al., 1992; Zheng et al., 1993). This model uses age composition information collected from the fishery. While we don't believe that herring are fully recruited into the fishery until around age-8, the model takes this into account and provides an estimate of all age classes back through age-4 (Figure 72). While we believe that this estimate of age-4 abundance is a reasonably valid picture of recruitment trends in this population, we also believe that the model has a tendency to over hindcast recruitment in the early 1980s due to factors that include limited data from that period.

Status and trends: The largest biomass observed in Togiak District of Bristol Bay occurred in 1979 when 239,022 tons was estimated while the minimum biomass occurred in 1980 with 68,686 tons (Figure 72). In 2010 we observed 146,913 tons which is 105% of the most recent 10-year average and 104% of the 20-year average.

An active sac roe fishery is conducted on this population, primarily with gillnet and purse seine gear. A small spawn on kelp quota is allowed but has not been utilized in recent years. The sac roe fishery harvested 26,355 tons in 2010 which is 132% of the 10-year average and 126% of the 20-year average.

Factors causing observed trends: Pacific herring recruitment is both highly variable and cyclic with large recruitment events occurring roughly every 8 to 10 years in this population. Williams and Quinn (2000) demonstrate that Pacific herring populations in the North Pacific are closely linked to environmental conditions particularly water temperature. We believe that closer examination of environmental conditions such as sea surface temperature, air temperature, and Bering Sea ice cover specific to the Bristol Bay area may increase our understanding of the recruitment process at play in this population.

Implications: Herring are an important forage fish for piscivorous fish, seabirds, and marine mammals as well as the basis for a roe fishery. The cyclic nature of the population trends influences availability to predators and the fishery. Recent estimates indicate that the population remains

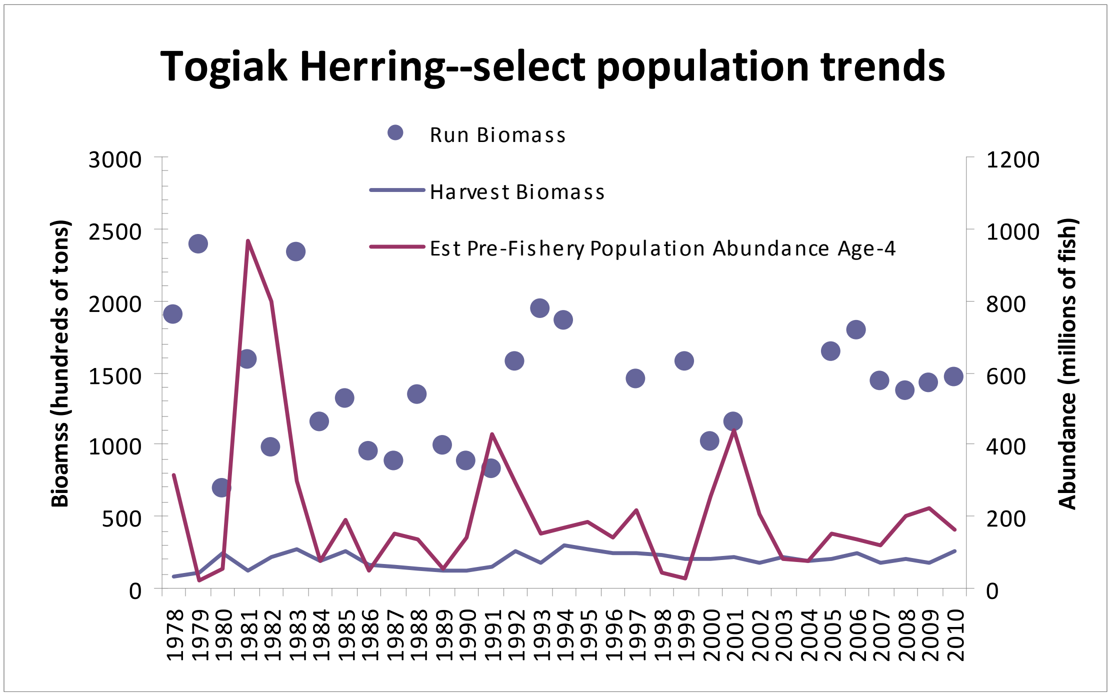

Figure 72: Observed total run and harvest biomass (hundreds of tons) with estimated abundance of age 4+ herring (millions of fish), for Pacific herring in Togiak District of Bristol Bay, Alaska 1978 - 2010.

relatively robust, although a strong recruitment event has not been observed since 2001.

Salmon

Historical and Current Alaska Salmon Trends

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Last updated: October 2011

Description of index: This represents the first update to this contribution since November 2006 and summarizes available information from current Alaska Department of Fish and Game (ADFG) agency reports (e.g. Eggers and Carroll (2011)). This contribution provides catch information for the Bering Sea and Gulf of Alaska and takes a closer look at two stocks that could be informative from an ecosystem perspective, Bristol Bay sockeye salmon and Prince William Sound hatchery pink salmon.

Pacific salmon in Alaska are managed in four regions based on freshwater drainage basins, Southeast, Central (encompassing Prince William Sound, Cook Inlet, and Bristol Bay), Arctic-Yukon-

Kuskokwim, and Westward (Kodiak, Chignik, and Alaska peninsula (`http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmonareas`). ADFG prepares harvest projections for all areas rather than conducting run size forecasts for each salmon run.

Status and trends: Catches from directed fisheries on the five salmon species have generally fluctuated over the last 35-40 years (Figure 73). According to ADFG, total salmon commercial harvests from 2010 totaled 171.2 million fish, approximately 33.9 million greater than the preseason forecast of 137.3 million. ADFG is forecasting an increase in 2011 total commercial catch due to the increase in the number of pink salmon. Projections for 2012 will not be available until February 2012.

Bering Sea Chinook salmon production for many stocks in the Yukon River has been declining in recent years; Chinook harvest for 2010 for this management region was considerably below average. Bristol Bay Chinook harvest was only 48% of the average harvest from the last 20 years, 1990-2009. Sockeye salmon runs in Bristol Bay in 2010 were above average based on the last 20 years. The coho catch in Bristol Bay was 7% above the recent 20 year average, with the majority of the catch in the Nushagak District. Chum salmon catches in Bristol Bay, depending on the district, have been above or below the 20 year average. In the past, chum salmon in the Yukon River have been classified as stocks of concern (Eggers, 2003).

Recruitment for most Bristol Bay sockeye salmon stocks was moderate to strong in the 1980s to the mid-1990s. The levels of recruitment observed for weak stocks during the recent period are not unprecedented. Similar levels of returns per spawner were observed for Bristol Bay sockeye during the 1960 to early 1970s. Beginning with the 1973 brood year (>1979 return year) of Bristol Bay sockeye salmon, the number of returning adults produced from each spawner showed a dramatic increase across most stocks (Fair, 2003). Poor returns in 1996-98, however, suggested a return to a level of productivity similar to the pre-1978 period. Fish from the 1996-98 return years reared in the ocean when temperatures were above average, whereas, cooler than average ocean temperatures characterized the pre-1978 period. Baywide forecasts have been fairly accurate in recent years, although forecasts to individual rivers have been less accurate. Historically, total runs to Bristol Bay have been highly variable, but in recent years, 2006-2010, sockeye salmon runs have been well above the long term mean (Figure 74). The 2011 forecast predicted the 8th consecutive year where total run is close to or exceeds 40 million sockeye salmon. There is uncertainty on how long this current trend will continue (ADFG, 2011 Bristol Bay Sockeye Salmon Forecast, 11/12/2010).

Gulf of Alaska In southeast Alaska and the Yakutat region, 2010 harvests totaled 37.2 million, were just below the long-term average since 1962. In the Central region, the Prince William Sound fishing area harvests the majority of the total catch. Purse seine fishing makes up the bulk of pink salmon harvests, which was approximately 90% of the total Prince William Sound salmon harvest. This was the highest harvest on record, 97% of which are hatchery fish. Historically, pink salmon catches increased in the late 1970s to the mid-1990s and have generally remained high in all regions in the last decade. Commercial chinook salmon fisheries occur in Copper River and the Southeast Alaska troll fishery. Catches in this fishery have declined in the late 1990s. Coho fisheries in Central and Western Alaska are not fully developed, but the harvest in 2010 was equal to the recent 10 year average. Directed chum salmon fisheries occur on hatchery runs in Prince William Sound and Southeast Alaska. The 2010 harvest of chum salmon in Southeast Alaska was above the average (1962-2009) and equivalent to the most recent 10 year average.

Historically, marine survival of Prince William Sound hatchery pink salmon appeared to increase

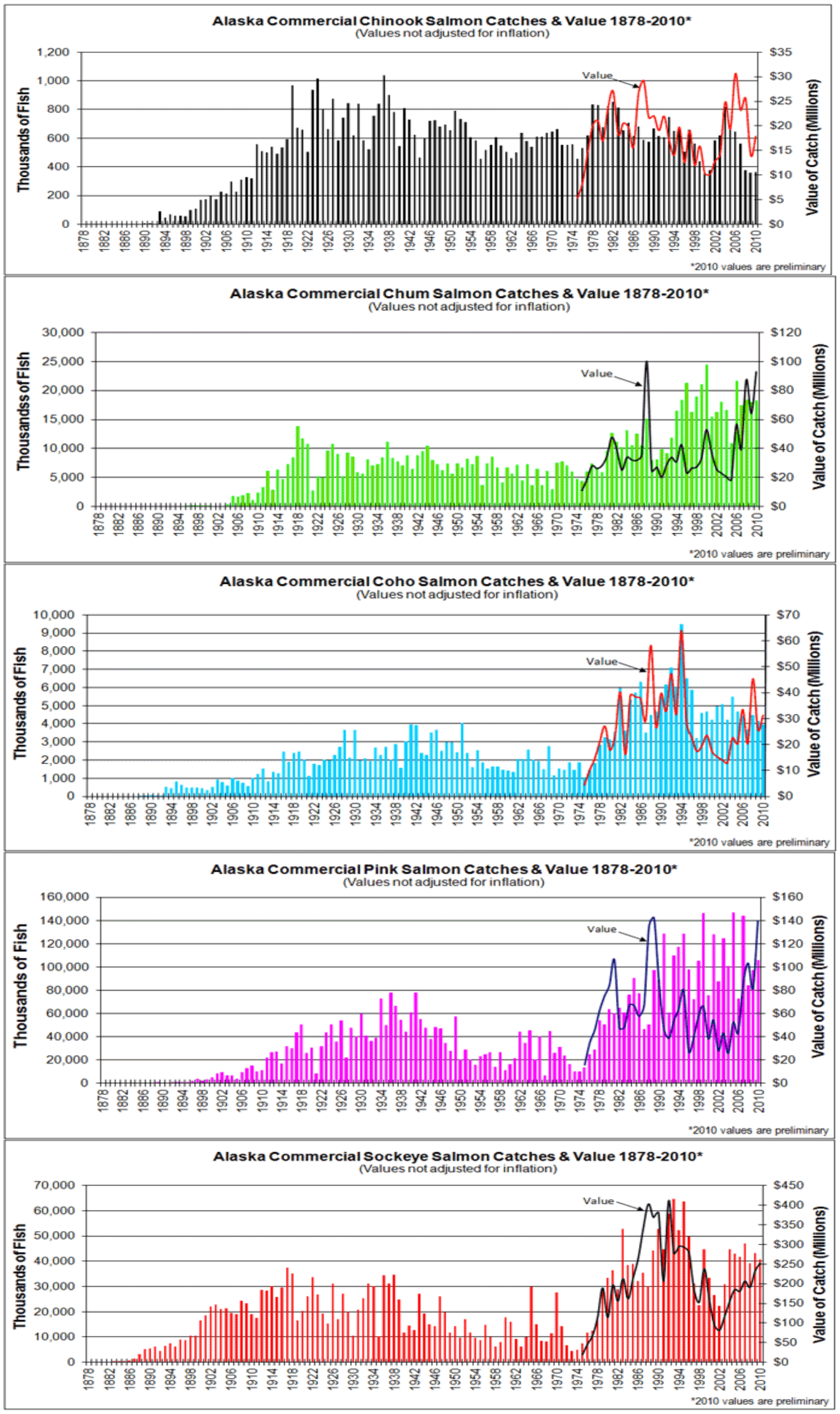

Figure 73: Commercial salmon catches and ex-vessel values. (Source: ADFG).

after 1977, but does not appear to have shifted after the 1988/89 or the 1998/99 climate regime shifts. Hatchery pink salmon marine survival in 2003 was the second highest recorded during the 1977-2004 time period, and was below average in 2004 (2002 brood year). Data through 2011 (2009

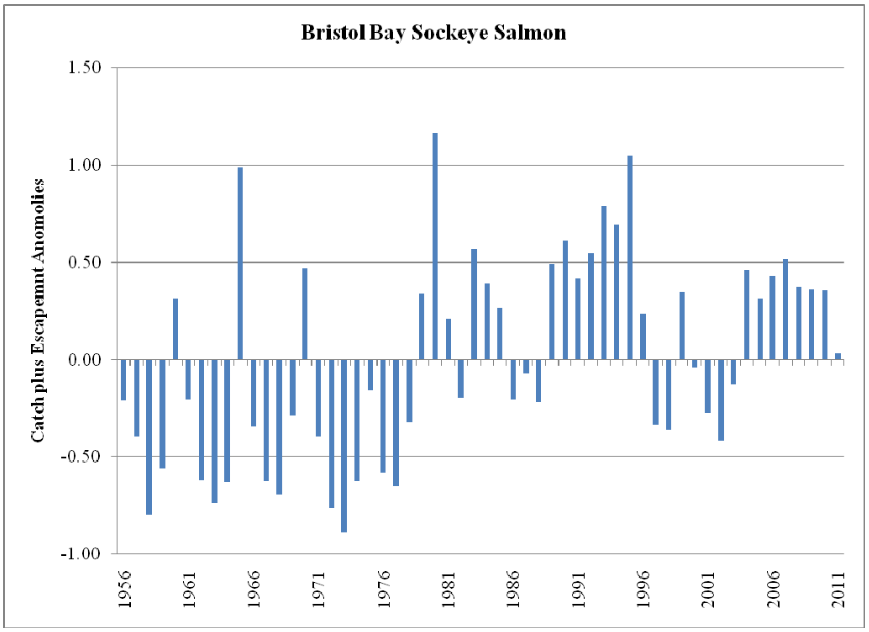

Figure 74: Historical catch plus escpapement anomalies of Bristol Bay sockeye salmon, 1956-2011. Data provided by Tim Baker (ADFG).

brood year) indicates a slight decrease below historical averages, but an all-time high from the 2008 brood year suggests that the population has done well recently (Figure 75).

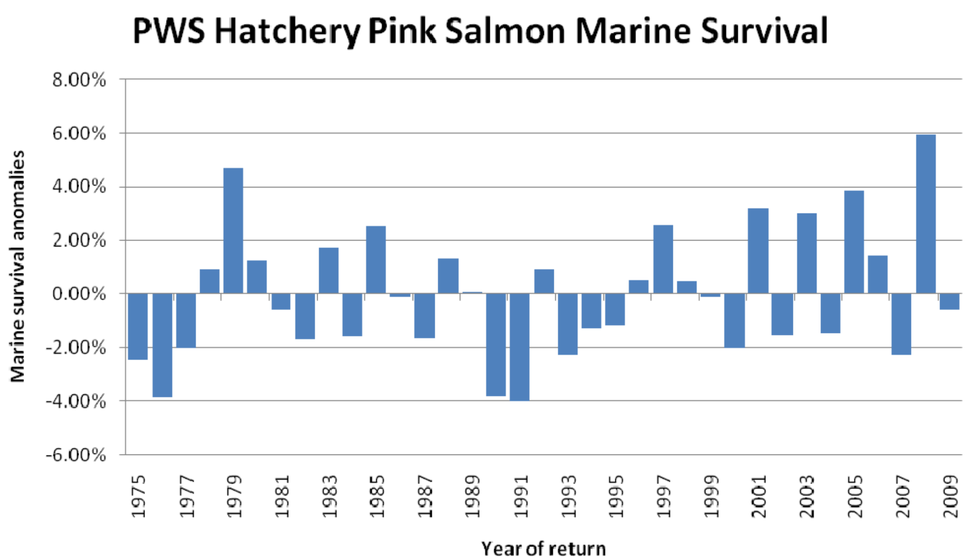

Figure 75: Marine survival of Prince William Sound hatchery pink salmon by year of return (brood year plus 2 years). Data provided by Bert Lewis (ADFG). Note: data from 2007-2009 are preliminary and may change slightly.

Factors causing observed trends: Bering Sea chum salmon are generally caught incidentally to other species and catches may not be good indicators of abundance. Directed commercial chinook salmon fisheries occur in the Yukon River and Nushagak management District in Bristol Bay. In all other areas chinook are taken incidentally and mainly in the early portions of the sockeye salmon fisheries.

Bristol Bay sockeye salmon display a variety of life history types. For example, their spawning habitat is highly variable and demonstrates the adaptive and diverse nature of sockeye salmon in this area (Hilborn et al., 2003). Therefore, productivity within these various habitats variable may be affected differently depending upon climate conditions, for example, so more diverse sets of populations provide greater overall stability (Schindler et al., 2010).

Pink salmon is the most abundant Pacific salmonid species. While both natural and hatchery populations return to Prince William Sound, a large majority of the returning fish are hatchery fish, upwards of up to one half billion are released from four hatcheries (Kline et al., 2008). Pink salmon have an abbreviated life cycle, consisting of three phases 1) brood year, 2) early marine year, and 3) return year (Kline et al., 2008).

Prince William Sound pink salmon run strength is established during early marine residence (Cooney and Willette, 1997). Diet and food availability may be factors that influence growth rates during this early marine residence period. Willette and Cooney (1991) found that productivity of pink salmon in southeast Alaska are sensitive to fry-year spring time temperatures.

Implications: Directed salmon fisheries are economically important for the state of Alaska. Salmon have important influences on Alaskan marine ecosystem through their predatory impacts and as sources of prey for species such as Steller sea lions.

Forecasting Pink Salmon Harvest in Southeast Alaska

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Last updated: August 2011

Description of index: Pink salmon (*Oncorhynchus gorbuscha*) returns are notoriously difficult to forecast because their 2-year life history cycle only involves one ocean winter and precludes the use of younger returning age classes to predict cohort abundance. Moreover, as a result of dynamic ocean conditions, year-class success varies widely with harvests ranging from 3 to 78 million fish annually in Southeast Alaska (SEAK) since 1960.

Understanding how ocean conditions impact salmon year class strength is an objective of the Auke Bay Laboratories (ABL) Southeast Alaska Coastal Monitoring (SECM) project. The SECM project has collected a time series of indexes that include juvenile salmon and their associated biophysical data in coastal SEAK since 1997 (`http://www.afsc.noaa.gov/abl/msi/msi_secm.htm`).

Researchers from ABL of the Alaska Fisheries Science Center (AFSC) have provided forecasting information to stakeholders of the pink salmon resource of SEAK since 2004. The forecasting parameters used by ABL are derived from an ongoing time series of data collected by the SECM project. The SECM project primarily samples eight stations in the vicinity of Icy Strait. This

Table 8: SECM pink salmon forecast models

SECM forecast models	Adj. R^2	AIC_c	P	Prediction for 2011
(1-parameter) Peak CPUE	82%	99.1	<0.001	56.2 M (47-62)
(2-parameter) Peak CPUE+May20m temp	92%	91.7	<0.001	45.0 M (35-54)

annual research consists of monthly oceanographic sampling in May, June, July, and August, with surface trawling for juvenile salmon in the latter three months.

The SECM pink salmon forecasts enable stakeholders to anticipate the harvest with more certainty than previous forecasting methods have allowed. In six of the seven past years, these forecast estimates have deviated from the actual harvests by an average of only 8% (Figure 76). Data from juvenile pink salmon catches are also shared with the Alaska Department of Fish and Game (ADFG) to help refine their SEAK pink salmon harvest forecast (`http://www.afsc.noaa.gov/abl/msi/msi_sae_psf.htm`).

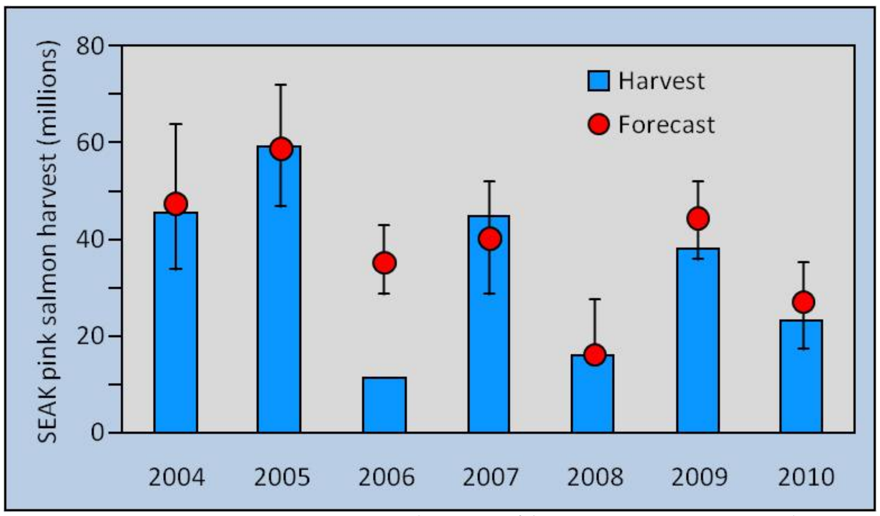
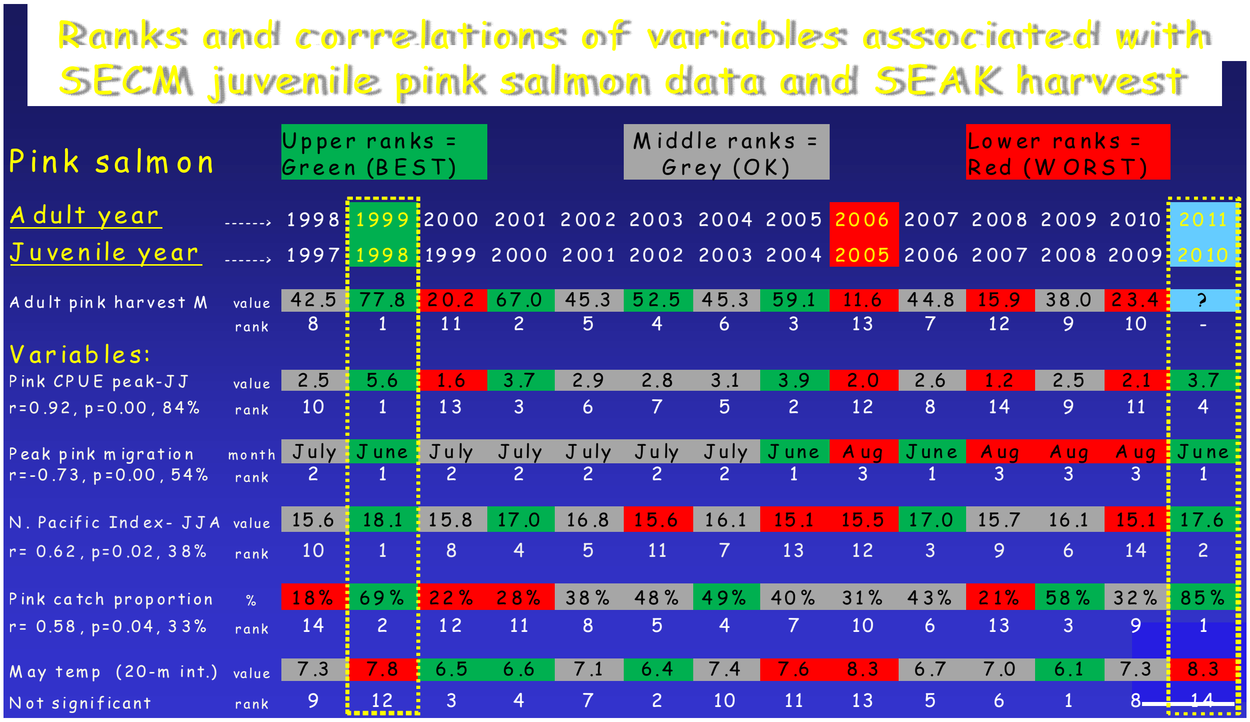


Figure 76: Previous forecast model predictions (with 80% confidence intervals) and actual harvests.

Status and trends: Table 8 indicates the two best SECM forecast models for the 2011 SEAK pink salmon harvest, with 80% confidence intervals shown in parentheses. The 2-parameter model is the best fit of the 13-year time series of SECM data parameters and subsequent SEAK pink salmon harvests from 1998 to 2010. However, our preferred model for 2011 is the 1-parameter model because the high May temperature anomaly in 2010 did not track a normal seasonal trajectory, unlike in 2005, when the forecast greatly overestimated the harvest.

Factors causing observed trends: Additional evidence from SECM research suggests a promising pink harvest in 2011. The strongest sign is that the 2010 peak juvenile pink CPUE was the fourth highest on record. Other encouraging signs include an early peak seaward migration (June), a high North Pacific Index, and that pink salmon comprised a high percent (85%) of the juvenile catch (Figure 77). All of these parameters were significantly correlated to harvest and point to an above average harvest in 2011. Finally, in 2010 we observed two first-time occurrences of adult pink salmon preying on juvenile pink salmon, which further suggests high juvenile pink salmon abundance in 2010 (`http://www.afsc.noaa.gov/ABL/MSI/pdf/PinkForecast2011.pdf`).

Implications: SECM research suggests a promising pink salmon harvest in 2011.



Adult year	------>	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Juvenile year	------>	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Adult pink harvest M	value	42.5	77.8	20.2	67.0	45.3	52.5	45.3	59.1	11.6	44.8	15.9	38.0	23.4	?
	rank	8	1	11	2	5	4	6	3	13	7	12	9	10	-
Variables:															
Pink CPUE peak-JJ	value	2.5	5.6	1.6	3.7	2.9	2.8	3.1	3.9	2.0	2.6	1.2	2.5	2.1	3.7
r=0.92, p=0.00, 84%	rank	10	1	13	3	6	7	5	2	12	8	14	9	11	4
Peak pink migration	month	July	June	July	July	July	July	July	June	Aug	June	Aug	Aug	Aug	June
r=-0.73, p=0.00, 54%	rank	2	1	2	2	2	2	2	1	3	1	3	3	3	1
N. Pacific Index-JJA	value	15.6	18.1	15.8	17.0	16.8	15.6	16.1	15.1	15.5	17.0	15.7	16.1	15.1	17.6
r= 0.62, p=0.02, 38%	rank	10	1	8	4	5	11	7	13	12	3	9	6	14	2
Pink catch proportion	%	18%	69%	22%	28%	38%	48%	49%	40%	31%	43%	21%	58%	32%	85%
r= 0.58, p=0.04, 33%	rank	14	2	12	11	8	5	4	7	10	6	13	3	9	1
May temp (20-m int.)	value	7.3	7.8	6.5	6.6	7.1	6.4	7.4	7.6	8.3	6.7	7.0	6.1	7.3	8.3
Not significant	rank	9	12	3	4	7	2	10	11	13	5	6	1	8	14

Figure 77: Ranks and correlations of variables associated with SECM juvenile pink salmon data and SEAK harvest.

Groundfish

Trends in Groundfish Biomass and Recruits per Spawning Biomass

Contributed by Jennifer Boldt[1], Todd TenBrink[2], Steven Hare[3], and the Alaska Fisheries Science Center Stock Assessment Staff
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Last updated: October 2011

Description of 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 (2010 a, b) and 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, 2009-2011). 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 (STARS)(Rodionov and Overland, 2005) 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 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. 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 (Figure 78).

Gulf of Alaska groundfish biomass trends (Figure 78) 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. BSAI catch trends are dominated by pollock catches, which decreased during 2004-2008 and increased slightly in 2009.

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 79, 80,81 and Table 9).

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

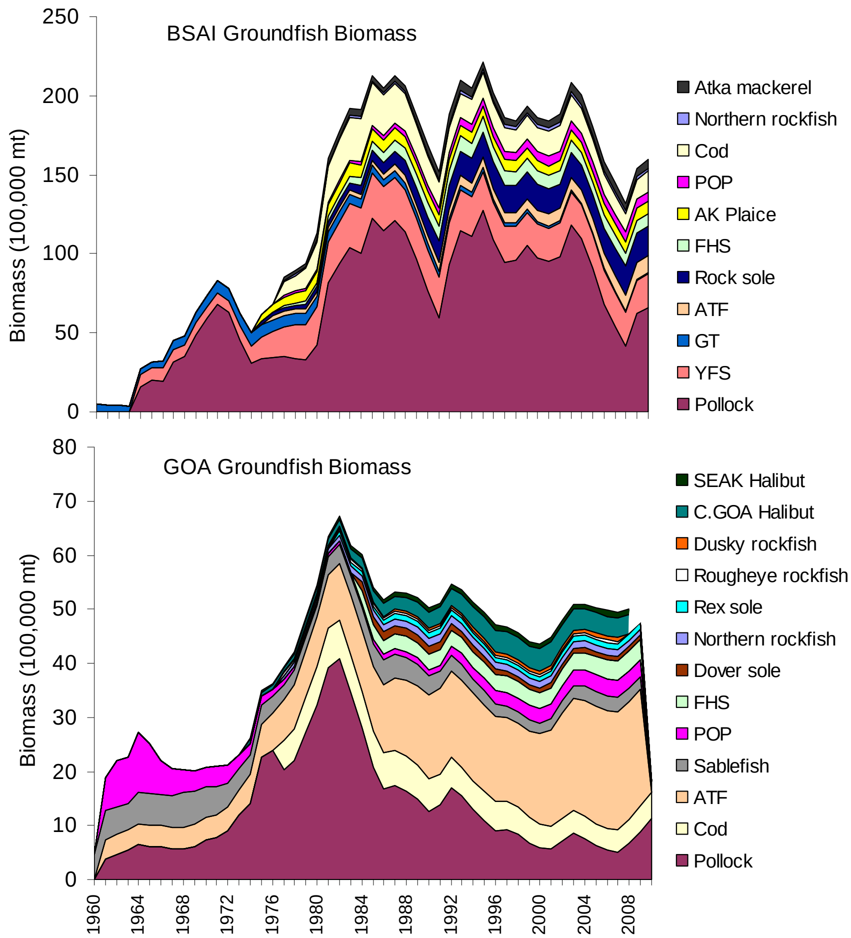
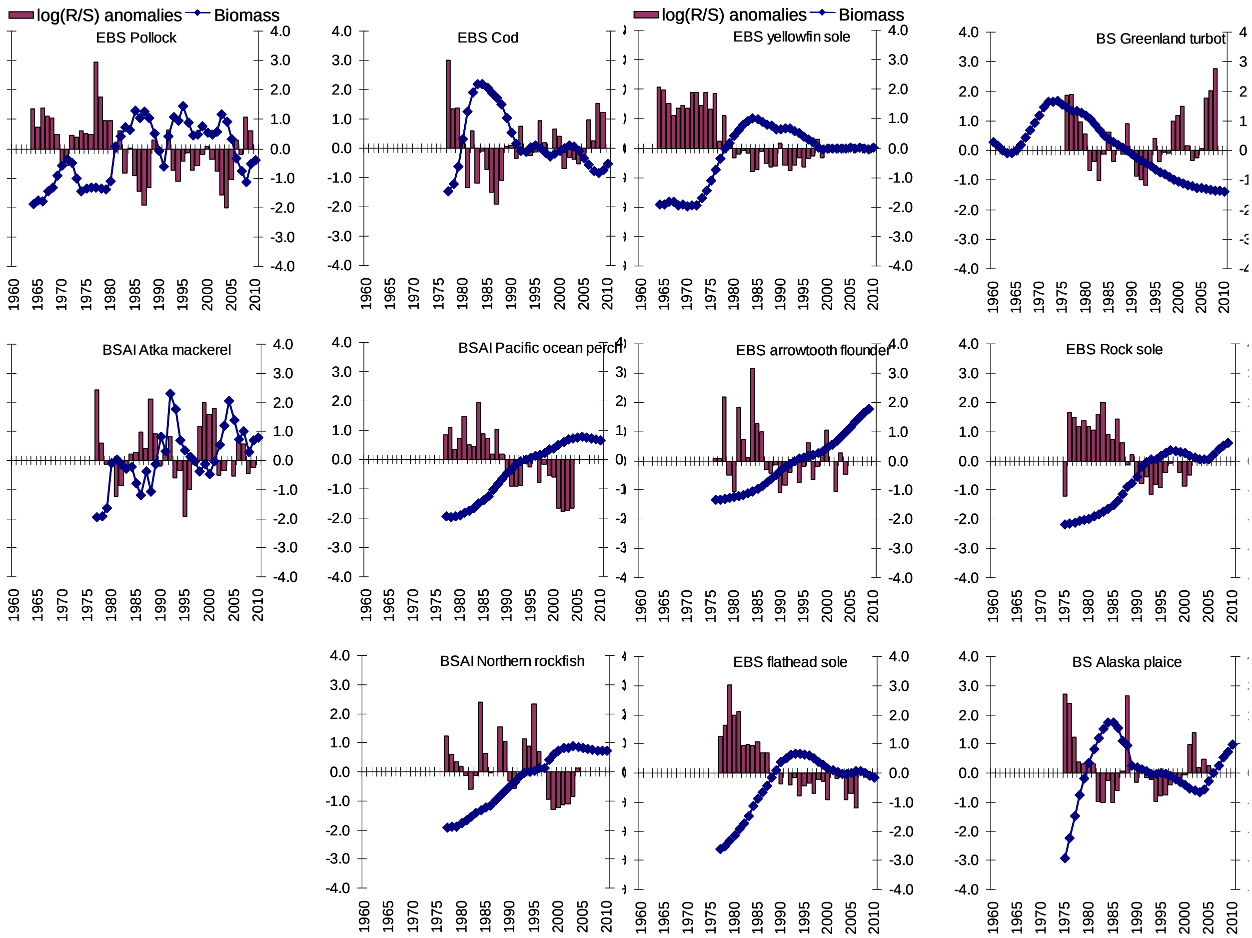


Figure 78: Groundfish biomass trends (metric tons) in the BSAI (1960-2010) and GOA (1960-2010), as determined from age-structured models of the Alaska Fisheries Science Center reported by NPFMCNPFMC (2010),**?**). GOA Pacific halibut, Dusky rockfish, and rougheye rockfish were not updated in this graph.

average survival after the early 1980s (Figures 79, 80). Negative shifts were observed in the early and mid-1980s (sablefish, BS pollock, and BS cod), and positive shifts were observed in 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 79 and Table 9). Most shifts for these species have been negative except for Alaska plaice, which showed decreased survival in 1982, but increased in 2001, and Greenland turbot, which showed an increase in survival in 1999.

There were positive shifts in GOA flatfish survival mid- late 1990s (Figure 80). 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.



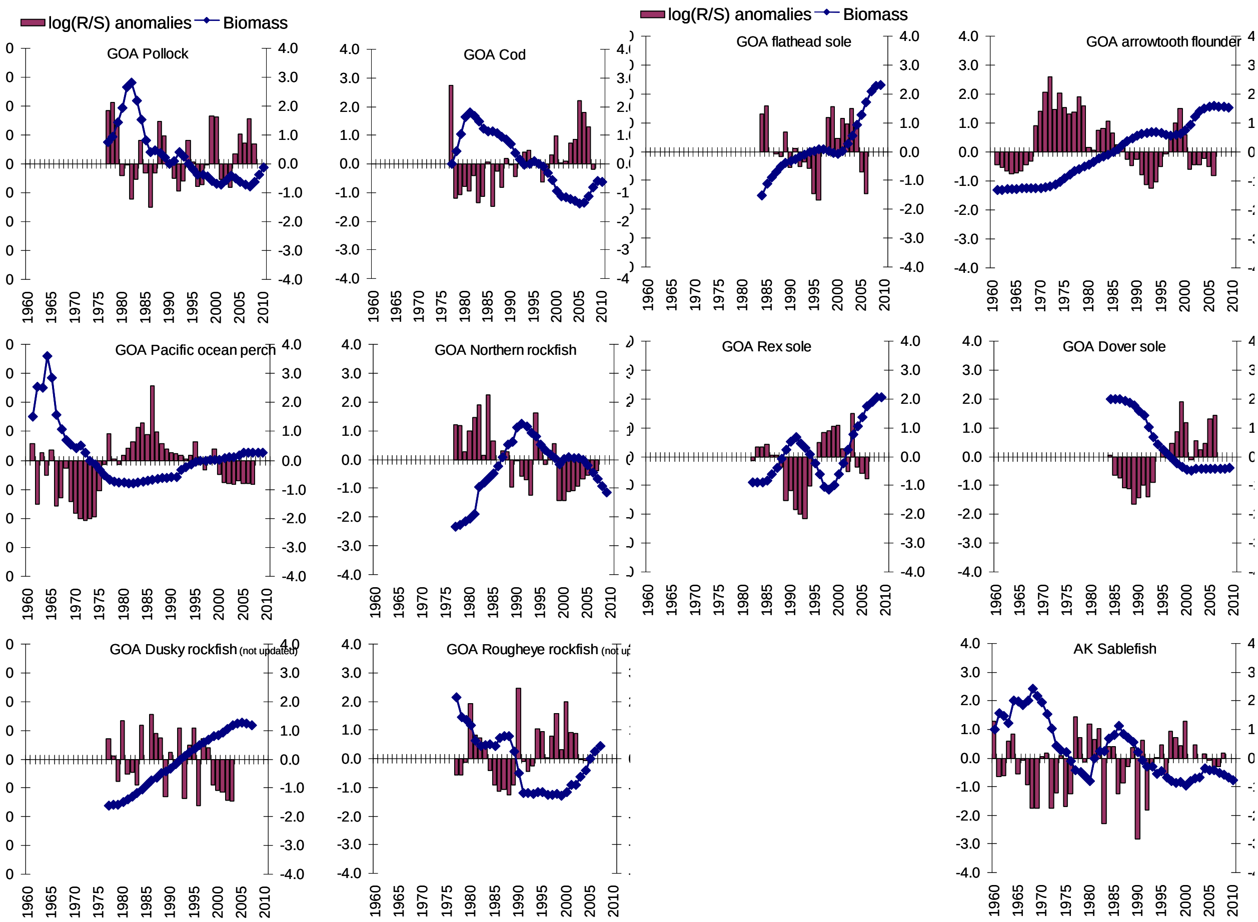
(a) Roundfish (b) Flatfish

Figure 79: Median log recruit per spawning biomass and biomass anomalies for BSAI groundfish species assessed with age- or size-structured models, 1960-2010. EBS = Eastern Bering Sea, BS = Bering Sea, AI = Aleutian Islands.

Pacific ocean perch showed positive shifts in 1976 in both the BSAI and GOA (Table 9; pre-1977 data for EBS Pacific ocean perch not included in this analysis). After the mid-1980s, there was a decreasing trend in log(R/S) anomalies in both the BSAI and GOA (Figures 79, fig.rsanomsGOA). BS POP also showed a negative shift in 1989, whereas, GOA POP showed a negative shift in 1969 and 2000 (Figures 79, 80 and Table 9).

Factors causing observed 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. 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



(a) Roundfish (b) Flatfish

Figure 80: Median log recruit per spawning biomass and biomass anomalies for GOA groundfish species assessed with age- or size-structured models, 1960-2009 or 2010. GOA = Gulf of Alaska.

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 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, 165).

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

Table 9: 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.

BSAI	Significant changes	GOA	Significant changes
EBS Pollock	(1983), 2006	GOA Pollock	2005
BSAI Pacific cod	(1983), 1992, 2006	GOA Pacifc cod	1989, 2005
BSAI Yellowfin sole	(1977)	GOA Arrowtooth flounder	1969, (1980), (1989)
BSAI Arrowtooth flounder	(1987)	GOA Rex sole	1996, (2004)
BSAI Alaska plaice	(1982)	GOA Flathead sole	1998
BSAI Flathead sole	(1986), (2004)	GOA Dover sole	1994, 2005
BSAI Greenland turbot	(1981), 1999, 2006	GOA Pacific ocean perch	(1969), 1976, (2000)
BSAI Northern rock sole	(1987)	GOA Northern rockfish	(1986), (1999)
BSAI Northern rockfish	(1998)	GOA Dusky rockfish	(1999)
BSAI Pacific ocean perch	(1989), (2001)	GOA Rougheye rockfish	1994, (2003)
BSAI Atka mackerel	none	Alaska Sablefish	1977, (1986), 1997

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/ecoweb/index.cfm`

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

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Last updated: August 2011

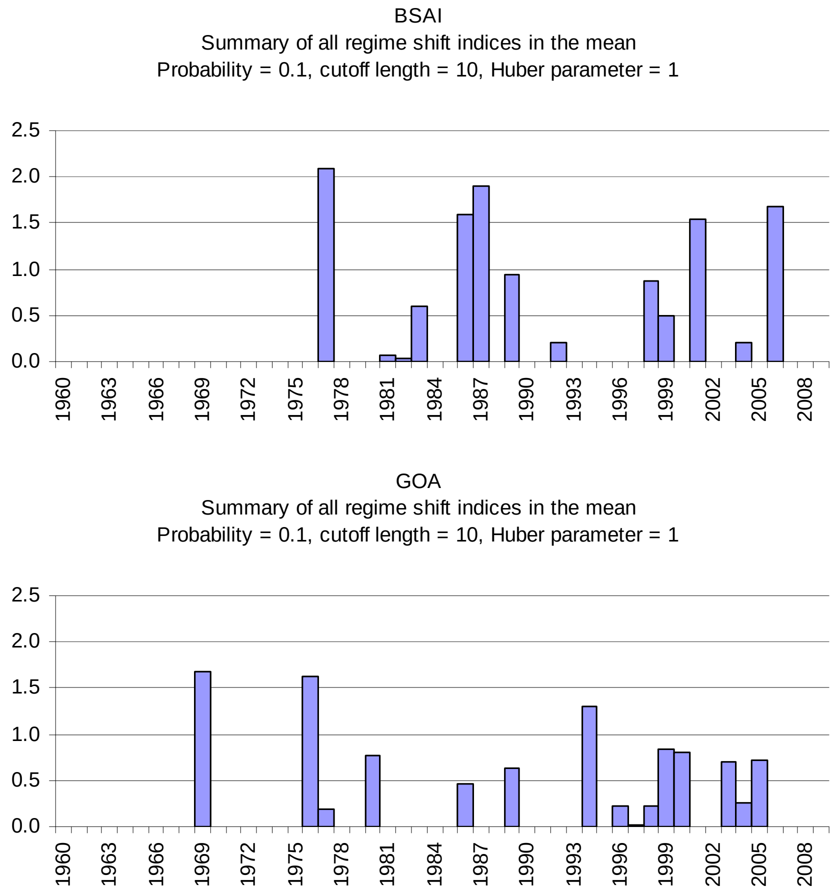

Figure 81: Summed regime shift index (RSI) values from the STARS (Rodionov and Overland, 2005) analysis (absolute values that indicate strength of step change) on log recruit per spawning biomass anomalies in each year for the BSAI and GOA. Pacific halibut were not included.

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. Favorable springtime winds were present again in the early 2000s which also corresponded with improved recruitment. The time series is updated through 2011 (Figure 82).

Status and trends: Five out of nine OSCURS runs for 2003-2011 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 83). For arrowtooth flounder and flathead sole, the corre-

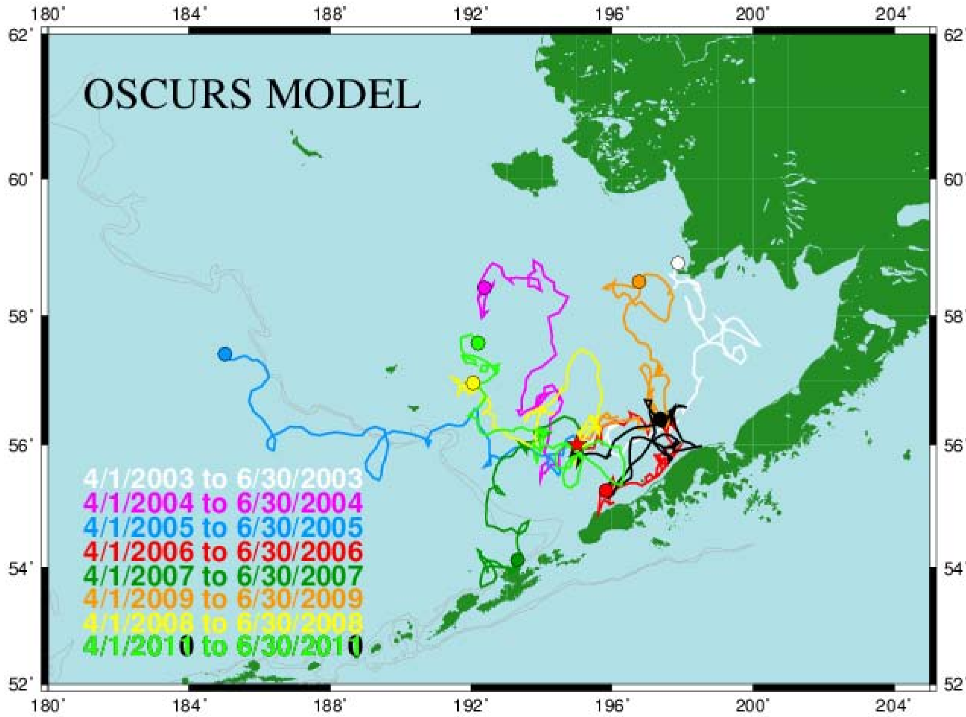

Figure 82: OSCURS (Ocean Surface Current Simulation Model) trajectories from starting point 56°N, 164°W from April 1-June 30 for three periods: 1980-89, 1990-97, and 2002-2010.

spondence 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 timing for spawning and larval occurrence than northern rock role. In the case of flathead sole, the 2001 and 2003 year-classes appear stronger than the weak recruitment that has persisted since the 1990s.

Implications: The drift patterns in 2010 and 2011 are less clear in terms of classification relative to other years. In 2010 there were strong northerly winds for part of the spring which would suggest increased larval dispersal to Unimak Island and the Alaska Peninsula. In 2011 the pattern was more across-shelf in a northerly direction, opposite of 2010.

Temperature Change index as a predictor for the abundance of age-1 pollock and age-1 cod in the Bering Sea

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Last updated: June 2011

Description of index: Sea temperatures may play a role in determining the year class strength of groundfish in the eastern Bering Sea. In the eastern Bering Sea, a cool late summer period

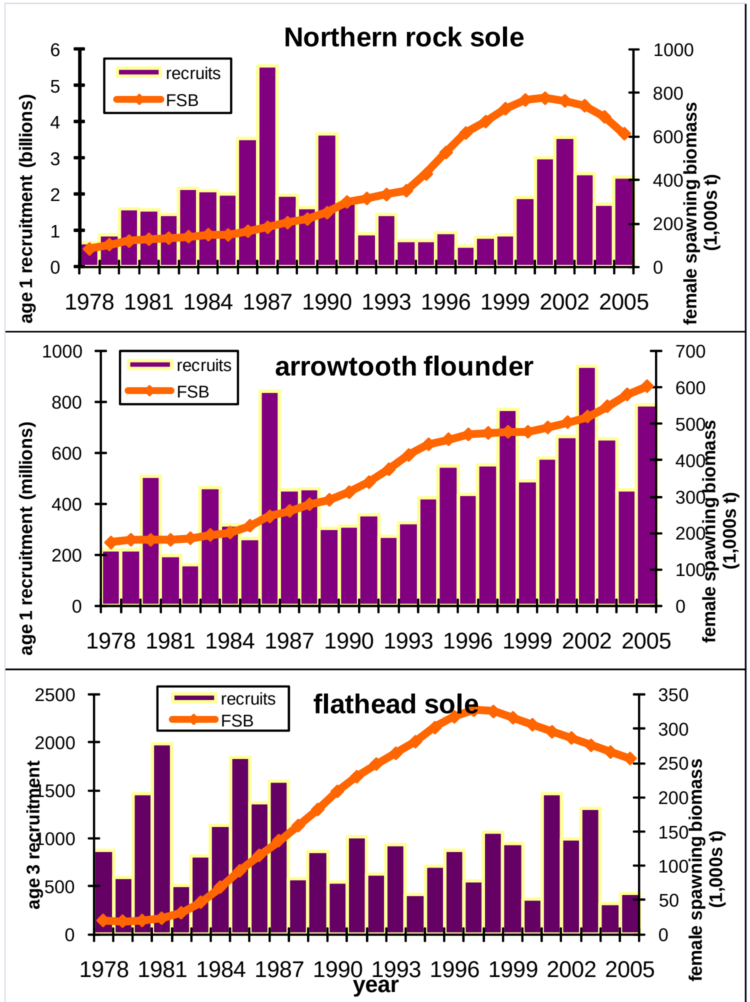

Figure 83: Recruitment of northern rock sole (1974-2003), flathead sole (1974-2004), and arrowtooth flounder (1974-2004) in the Bering Sea

is associated with reduced metabolic demand, higher energy prey (such as larger zooplankton), and higher energy reserves in the fish that improve the over-wintering survival of age-0 pollock (*Theragra chalcogramma*) (Andrews et al., 2009; Moss et al., 2009; Coyle et al., 2011; Hunt et al., 2011). Warm sea temperatures in the spring lead to an earlier ice retreat and a later thermal stratification induced spring bloom at an optimal time for feeding for pelagic fish such as age-0 and age-1 pollock (Stabeno and Hunt, 2002).

A temperature change index was developed to encompass pre- and post- winter sea temperature conditions experienced by age-0 and age-1 fish in the southern eastern Bering Sea (Figure 84). The index is calculated as the average sea temperature for June in year t minus the average sea temperature for August in year t-1. Less negative TC values represent a cool late summer followed by a warm spring, conditions favorable for overwintering survival to age-1, while more negative values represent warm late summer followed by a cool spring conditions not favorable for overwintering survival to age-1. The TC index provides an early estimate of the number of age-1 pollock in the eastern Bering Sea and possibly year class strength.

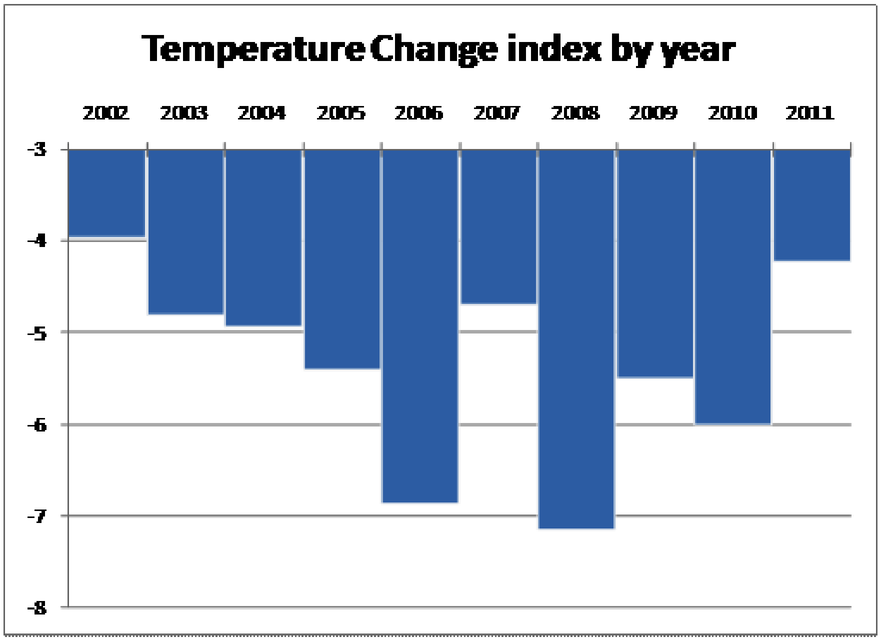

Figure 84: Time series of the Temperature Change index for recent warm years 2002-2005 and cold years 2006-2011 (Martinson et al., in review).

Time series of average monthly sea surface temperatures (SST) were obtained from the NOAA Earth System Research Laboratory Physical Sciences Division website. Sea surface temperatures were based on NCEP/NCAR gridded reanalysis data (Kalnay et al. (1996), data obtained from `http://www.esrl.noaa.gov/psd/cgi-bin/data/timeseries/timeseries1.pl`). The North Pacific groundfish stock assessment and fishery evaluation reports were the source of abundance estimates for age-1 pollock (Table 1.21 in Ianelli et al. (2010)), age-1 pollock estimated from the mid-water acoustic trawl survey (Table 1.14 in Ianelli et al. (2010)), and age-1 cod (*Gadus macrocephalus*)(Table 2.2.26 in Thompson et al. (2010)).

Status and trends: The 2011 TC index value -4.23 is based on a cool late summer in 2010 (8.34°C) followed by a normal spring in 2011 (4.11°C). For the 2002 to 2011 year period, the less negative TC index suggests events of cool late summers followed by warm springs in 2002, 2007, and 2011, ocean conditions favorable for the abundances of age-1 in 2002, 2007, and 2011.

Factors causing observed trends: The linear regression models show differences the relationship between the TC index and age-1 pollock during cold and warm years. In comparison to cold year models, the lower intercept of the warm year model indicate that pollock may be more sensitive to thermal processes important for overwintering survival during periods of warmer seas.

Implications: Reductions in the TC values from 2008 to 2011 suggest that conditions have continued to improve for the overwintering survival of pollock and cod from age-0 to age-1 in the Bering Sea. The 2011 TC index value and cold year models predict 48,094 million age-1 pollock and 785 million age-1 cod for 2011 (black x) (Figure 85). For the acoustic trawl estimates of pollock, the current model and the 2011 TC index value -4.23 predicts 7,198 million age-1 pollock for 2011 (black x) (Figure 86). The TC index provides an early estimate of the expected number of age-1 pollock and age-1 cod in the eastern Bering Sea.

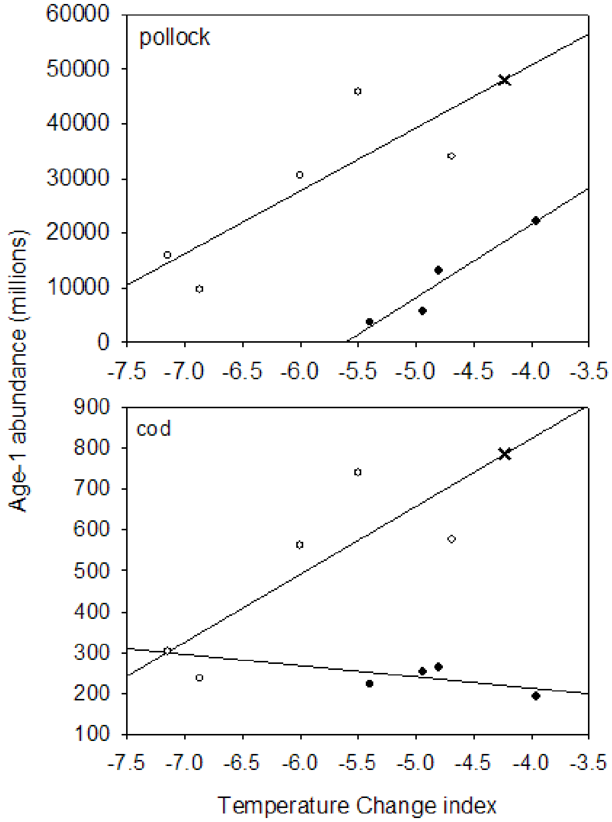

Figure 85: The estimated abundance (millions) of age-1 pollock and age-1 cod in the eastern Bering Sea in relation to the Temperature Change index for pollock ($R^2 = 0.919$, $P = 0.041$) and cod ($R^2 = 0.268$, $P = 0.482$) in recent warm years 2002-05 (block dots) and for pollock ($R^2 = 0.637$, $P = 0.106$) and cod ($R^2 = 0.641$, $P = 0.104$) in cold years 2006-10 (white dots). The cold year models and the 2011 TC value -4.23 predicts 48,094 million age-1 pollock and 785 million age-1 cod for 2011 (black x).

Benthic Communities and Non-target Fish Species

Biodiversity (Evenness) of the Groundfish and Invertebrate Community for the Eastern Bering Sea Slope

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Last updated: July 2011

Description of index: The Hills modified ratio index (Ludwig and Reynolds, 1988; Hill, 1973; Alatalo, 1981; Hoff, 2006) was used as a species evenness index to track the diversity and stability in the ecosystem community of the eastern Bering Sea upper continental slope over a 32 year period. The values for the evenness index range between one and zero, where one indicates complete biomass evenness amongst all species and zero indicates that a single species dominates the ecosystem. The

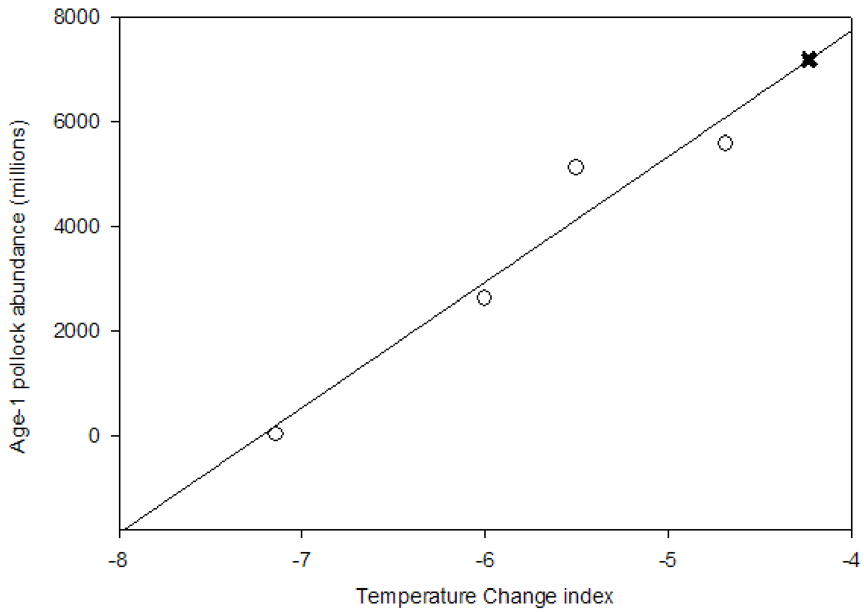

Figure 86: The NMFS summer mid-water acoustic-trawl survey estimates of the abundances (millions) of age-1 pollock in the Bering Sea in relation to the Temperature Change index for cold years 2007-2010 ($R^2 = 0.931$, $P = 0.035$). The current model and the 2011 TC index value -4.23 predicts 7,198 million age-1 pollock for 2011 (black x).

evenness index can be estimated in various ways with many biases and pitfalls depending on data sets and the intended purpose (see Alatalo (1981)). The Hills index is robust because it is not dependent on species richness, nor sensitive to rare species, and therefore it minimizes the biases from sampling limitations and species recognition in survey data.

Data for this index was gathered from the eastern Bering Sea upper continental slope bottom trawl survey (200-1200m) conducted between 1979 and 2010 by the RACE Division of the Alaska Fisheries Science Center. The survey was conducted triennially between 1979 and 1991, and with the exception of 2006, biennially from 2000-2010. The survey design is random and stratified by geographic area and depth with sampling effort being proportional to the estimated size of each stratum. Catch Per Unit Effort (CPUE in kg/ha) was used as a measure of species abundance and was pooled for a species or species group for each survey year across all area and depth strata. For this analysis there were 11 individual fish species, 13 fish species groups, and 13 invertebrate groups. Fishes were either classified as a single species if they were easily identified (e.g., Pacific halibut) or pooled into groups where species were not identified consistently throughout the survey years (e.g., arrowtooth and Kamchatka flounders). All invertebrates species were grouped into major taxonomic groups (i.e. crabs, seastars, hermit crabs, mollusks etc) due to the extreme diversity and identification uncertainty for similar species within the groups.

Status and trends: In fish species there has been a dramatic decrease in evenness between early survey years (1979-1991) and later years (2000-2010) (Figure 87). The trend in the evenness index indicates that the slope community was dominated by 5-7 ($\sim$80% of the total survey biomass) species during the 70's and 80's decreasing to approximately 3 species from 2000 to 2010 (Figure 88). The evenness index reflects the dramatic increase in the abundance of grenadier species such as the giant grenadier, *Albatrossia pectoralis* and the popeye grenadier *Coryphaenoides cinereus*; and by the moderate increases in Pacific ocean perch, *Sebastes alutus*, and the complex of arrowtooth (*Atheresthes stomias*) and Kamchatka (*A. evermanni*) flounders. There likewise has been a notable drop in species such as Greenland turbot, *Reinhardtius hippoglossoides*, sablefish, *Anoplopoma fimbria*, and walleye pollock, *Theragra chalcogramma* through the time series.

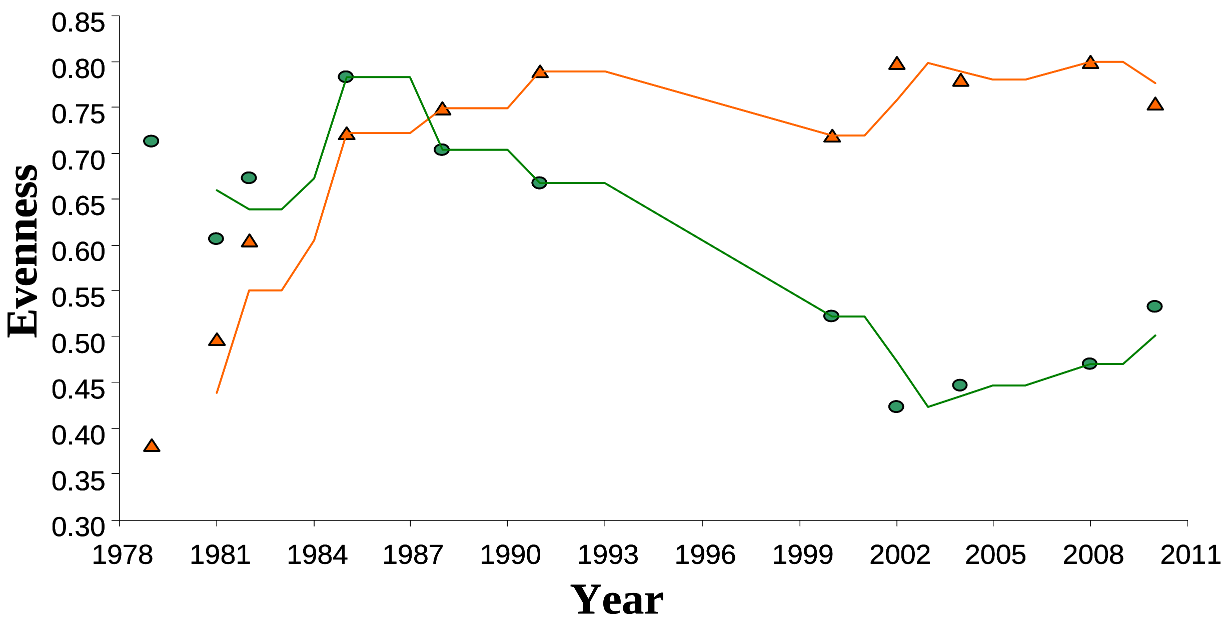

Figure 87: Evenness indices for the fish fauna (green circle) and invertebrate fauna (orange triangle) from the eastern Bering Sea upper continental slope survey conducted by the AFSC groundfish division from 1976 to 2010.

For invertebrates the opposite trend from fish is evident with a moderate increase in the evenness index (Figure 87) indicating a more even distribution of the biomass between species. Surveys from 1979 to 1985 indicate the ecosystem was dominated by few species groups such as crabs and octopus/squid (Figure 88). Beginning with the 1988 survey this trend had changed to a much more even distribution with the system dominated by 3 to 7 species. Recent surveys (2000-2010) indicated a diverse group of species with a relative even biomass distribution between 6-7 species. The most notable changes have been the decrease in Chionoecetes crab and octopus/squid dominated systems to one of more demersal sessile or benthic fauna of seastars, sea cucumbers and sea anemones which along with crab comprise 80% of the estimated invertebrate biomass of the slope.

Factors causing observed trends: The limitation of the data sets used for deriving this index is the lack of standardized methods used in conducting the older bottom trawl surveys (1979-1991) compared to a high level of standardization in the most recent surveys (2000-2010). Vast improvements have been made in net mensuration, taxonomic identification and survey standardization in the newer time series making direct comparisons between the two time series uncertain. However, the estimates of fish abundance are believed to be more sound than the estimates of invertebrates due to consistent identifications and catchabilities, and if either trend was to be used, fish would hold more credence. The consistency of the renewed time series (beginning in year 2000) provides confidence that trends evident between 2000 and 2010 reflect broad ecosystem changes.

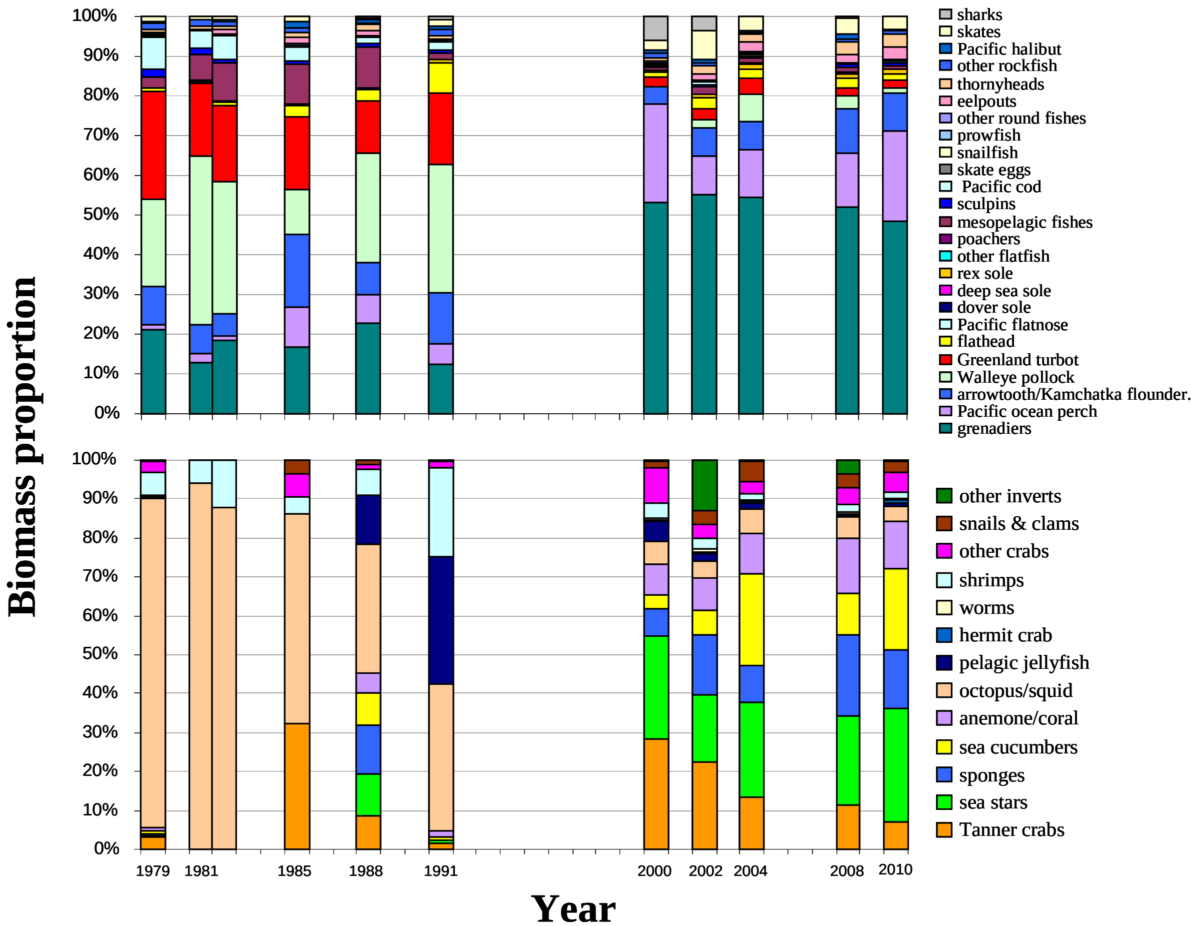

Figure 88: Biomass proportion estimates for the fish (top) and invertebrate (bottom) communities from the eastern Bering Sea upper continental slope from groundfish surveys conducted by the AFSC from 1976 to 2010

Implications: The evenness index can be interpreted as an indicator of the stability of an ecosystem by estimating the level of diversity of the key species driving the predator-prey relationships or competing for other key resources.

Bering Sea/Aleutian Islands King and Tanner Crab stocks

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See the 2010 report at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Jellyfish Eastern Bering Sea

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Description of index: The time series of jellyfish (principally *Chrysaora melanaster*) was updated for 2011 (Figure 89). 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.

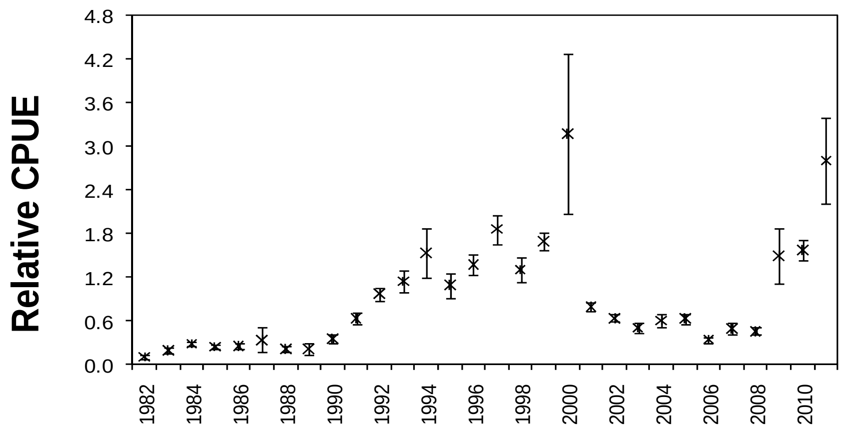

Figure 89: AFSC eastern Bering Sea bottom trawl survey relative CPUE for jellyfish during the May to August time period from 1982-2011.

Status and trends: Jellyfish relative CPUE in 2011 was nearly doubled that of 2009 and 2010. 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 2009-2011.

Factors causing observed trends: Ice cover, sea-surface temperature in spring and summer, and wind mixing all have been shown to influence jellyfish biomass (Brodeur et al., 2008). In addition, the importance of juvenile pollock biomass and zooplankton biomass suggest that jellyfish biomass is sensitive to the availability of prey.

Implications: 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 2011

Description of index: Jellyfish sampling was incorporated aboard the BASIS (Bering Aleutian Salmon International Surveys) vessels beginning in 2004 and will continue through 2012. All 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*. Biomass is calculated for each species and compared across species, and oceanographic domains (Inner Domain <50m, Middle Domain 50m-100m, Outer Domain ≥100m) Yearly distributions throughout the sample grid for all species have been patchy. Despite uneven distributions throughout oceanographic domains, highest concentrations of all species were found to occur in the Middle Shelf Domain. Of the six species sampled, Chrysaora melanaster had the highest weight per unit effort (kg) for all years.

Status and trends: During 2010, combined jellyfish species biomass nearly doubled compared to the previous highs of 2004 and 2005 (Figure 90). Notable declines in jellyfish biomass were observed for all taxa except *C. melanaster* during 2006-2010 (Figure 91. In 2008 our station grid was significantly reduced. However, comparisions with past years using the same survey area as 2008 indicate similar trends in species composition and distribution patterns. The prominent species, *C. melanaster* continued to increase in 2010, tripling its WPUE compared to 2009. During 2006-2009, biomass of all other species remained low in comparison to previous levels in 2004 and 2005, suggesting the trend for the area has shifted from multiple species to a single species dominant catch.

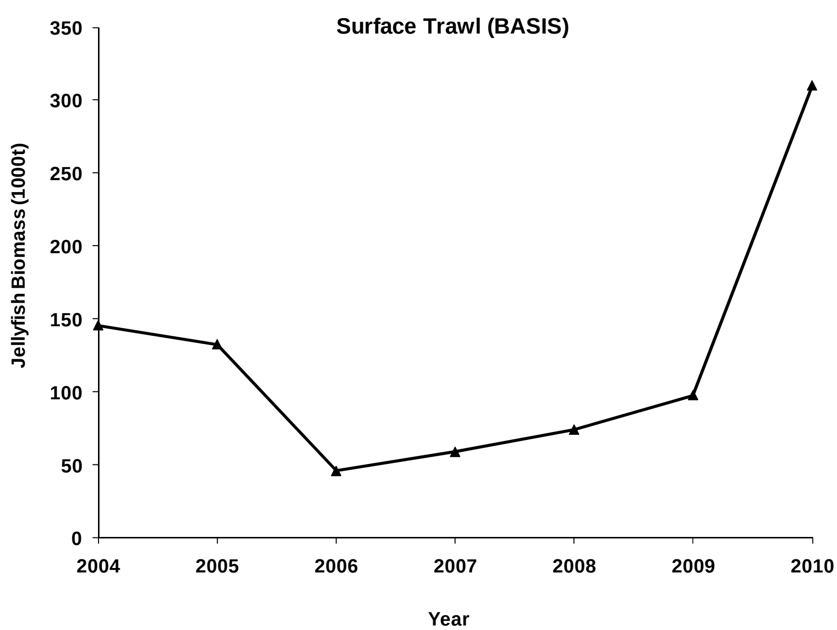

Figure 90: Total jellyfish biomass (1000 t) by year. Includes combined species caught in surface trawls in the Eastern Bering Sea during August-October. Biomass was calculated using average effort per survey area in km^2 by year.

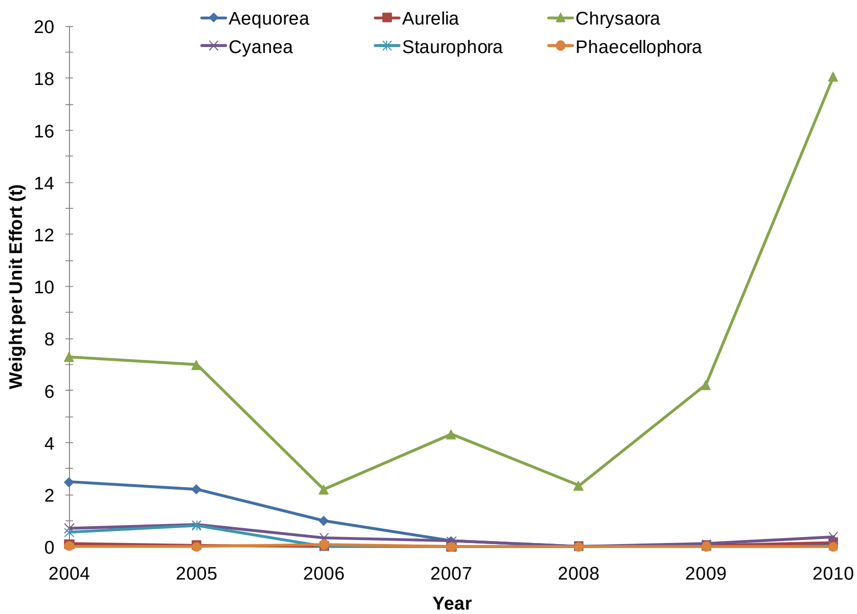

Figure 91: Total jellyfish biomass (1000 t) by year. Includes combined species caught in surface trawls in the Eastern Bering Sea during August-October. Biomass was calculated using average effort per survey area in km^2 by year.

Factors causing observed trends: The cause for these shifts in biomass and distribution do not seem to rely solely on physical ocean factors (temperature and salinity). These shifts could also be a result of environmental forcing earlier in the growing season or during an earlier life history stage (polyp), which may influence large medusae biomasses and abundances (Purcell et al., 2009).

Implications: Significant increases in jellyfish biomass may redirect energy pathways in the eastern Bering Sea foodweb through predation on zooplankton and small fish.

Miscellaneous Species Eastern Bering Sea

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Last updated: October 2011

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 1982-2011. 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 92).

Factors causing observed trends: 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: Eelpouts have important roles in the energy flow in benthic communities. For example, eelpouts are a common prey item of arrowtooth flounder. However, it is not known at present whether these changes in CPUE are related to changes in energy flow.

ADF&G Gulf of Alaska Trawl Survey

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Last updated: August 2011

Description of index: The Alaska Department of Fish and Game conducts an annual trawl survey for crab and groundfish in Gulf of Alaska targeting areas of crab habitat around Kodiak Island, the Alaska Peninsula, and the Eastern Aleutian Islands (Spalinger, 2010). 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 93) 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. 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 (arrowtooth flounder, flathead sole, Tanner crab, Pacific cod, and skates) using the method described by Link et al. (2002) (Figure 94). Bottom temperatures for each haul have been consistently recorded since 1990 (Figure 95).

Status and trends: Arrowtooth flounder, 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.

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 (Blackburn, 1977). Today, the Ugak Bay species composition is markedly different than in 1976. Red king crabs *Paralithodes camtschaticus* were the main component of the catch in 1976-1977, but now are nearly non-existent. Flathead sole *Hippoglosoides elassodon*, skate, and gadid catch rates have all increased roughly 10-fold, and while Pacific cod *Gadus macrocephalus* made up 88% and walleye pollock *Theragra chalcogramma* 10% of the gadid catch in 1976-1977, catch compositions have reversed in 2010 with Pacific cod making up 11% of catch and walleye pollock 89%. Overall catches have slightly increased in 2010 (Figure 96

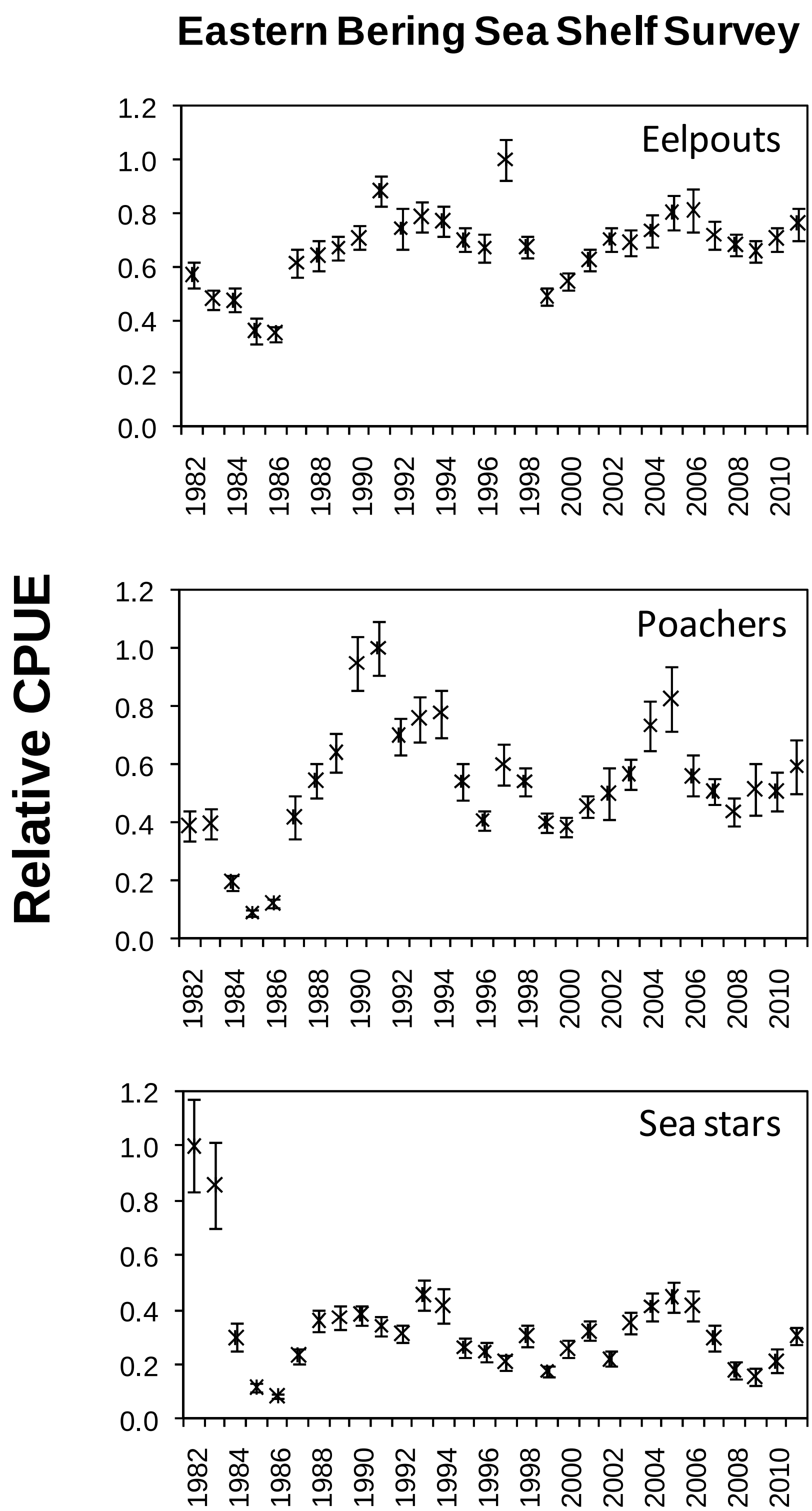

Figure 92: Relative CPUE of miscellaneous species caught in the eastern Bering Sea summer bottom trawl survey, 1982-2011. Data points are shown with standard error bars.

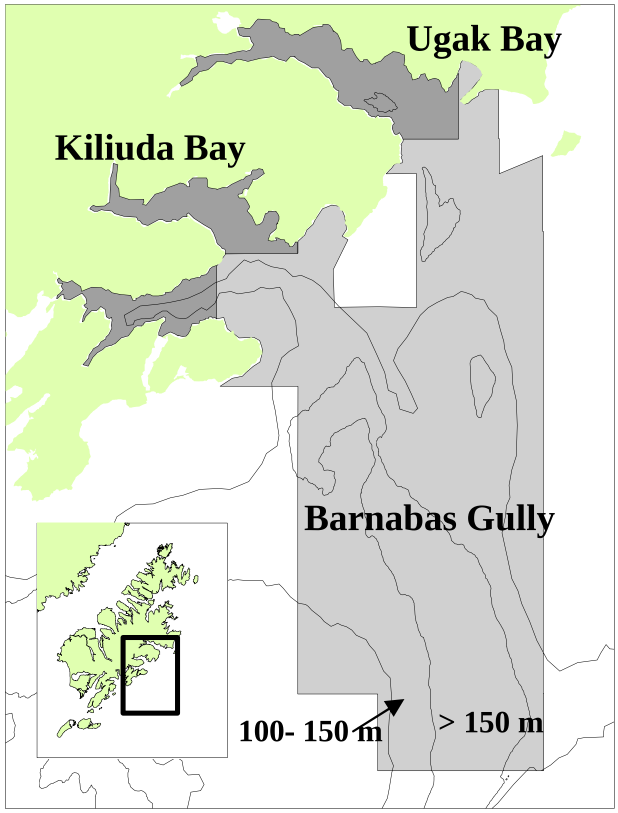

Figure 93: Adjoining survey areas on the east side of Kodiak Island used to characterize inshore (dark gray, 14 stations) and offshore (light gray, 33 stations) trawl survey results.

with arrowtooth flounder *Atheresthes stomias*, flathead sole, and Tanner crab *Chionoecetes bairdi* predominating the catch for both inshore and offshore areas (Figure 96).

The increased catches have contributed to the wide distribution of positive values for the standardized anomalies in the recent past. In 2010, above average anomaly values were recorded for both inshore and offshore skates, and Tanner crabs, while arrowtooth flounder, flathead sole, and Pacific cod have decreased to below average values.

Temperature anomalies for both inshore, Kiliuda and Ugak Bays and offshore stations, Barnabas Gully, from 1990 to 2010, show similar oscillations with periods of above average temperatures corresponding to the strong El Niño years (1997-1998; Figure 95;`http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html`).

Factors causing observed trends: The lower overall catch from 1993 to 1999 (Fig. 3) may be a reflection of the greater frequency of El Niño events on overall production while the period of less frequent El Niño events, 2000 to 2006, corresponds to years of greatest production and corresponding catches. The lower than average temperatures that have been recorded in both 2007 and 2008 along with decreasing overall abundances may indicate a response lag to environmental conditions or other factors maybe influencing this trend that are not yet apparent. It appears that significant changes in volume and composition of the catches on the east side of Kodiak are occurring, but it is unknown if predation, environmental changes, or fishing effort are contributing

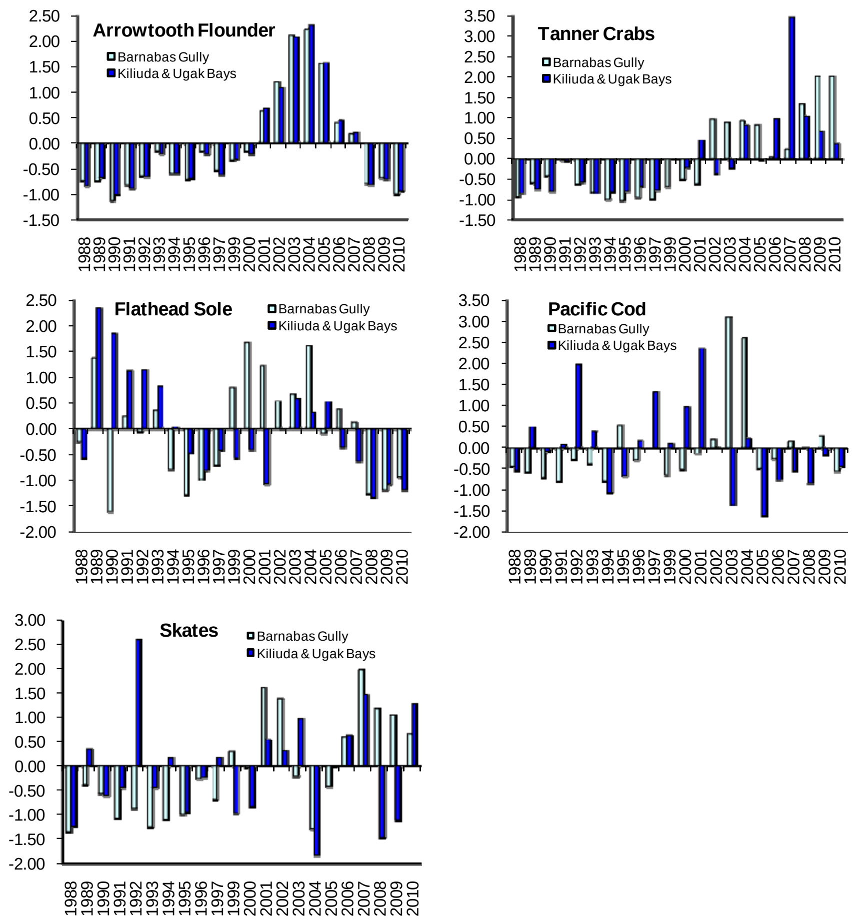

Figure 94: A comparison of standardized anomaly values for selected species caught from 1988-2010 in Kiliuda and Ugak Bays and Barnabas Gully during the ADF&G trawl surveys.

to these changes.

Implications: Although trends in abundance in the trawl survey appear to be influenced by major oceanographic events such as El Niño, local environmental changes, predation, movements, 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. The survey data is used directly 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 2011

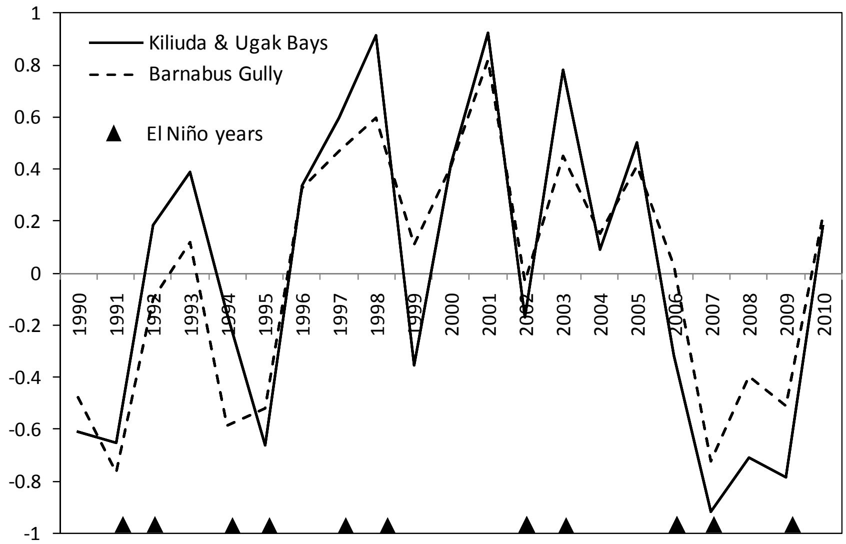

Figure 95: Bottom temperature anomalies recorded from the ADF&G trawl survey for Barnabas Gully and Kiliuda and Ugak Bays from 1990 to 2010, with corresponding El Niño years represented.

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 = 13,088 hauls). The most recent survey occurred between September 29 and October 29, 2010 (n = 160 hauls) around Kodiak Island (Chiniak and Marmot Bays and the Shelikof Strait), and along the Alaska Peninsula from Wide Bay to Mozhovoi Bay including Pavlof Bay.

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 (≤ 20 cm) *Theragra chalcogramma*, eulachon *Thaleichthys pacificu*, 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 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, available at: `www.beringclimate.noaa.gov/regimes/index.html`, Rodionov and Overland (2005)) was used to test for statistically significant shifts

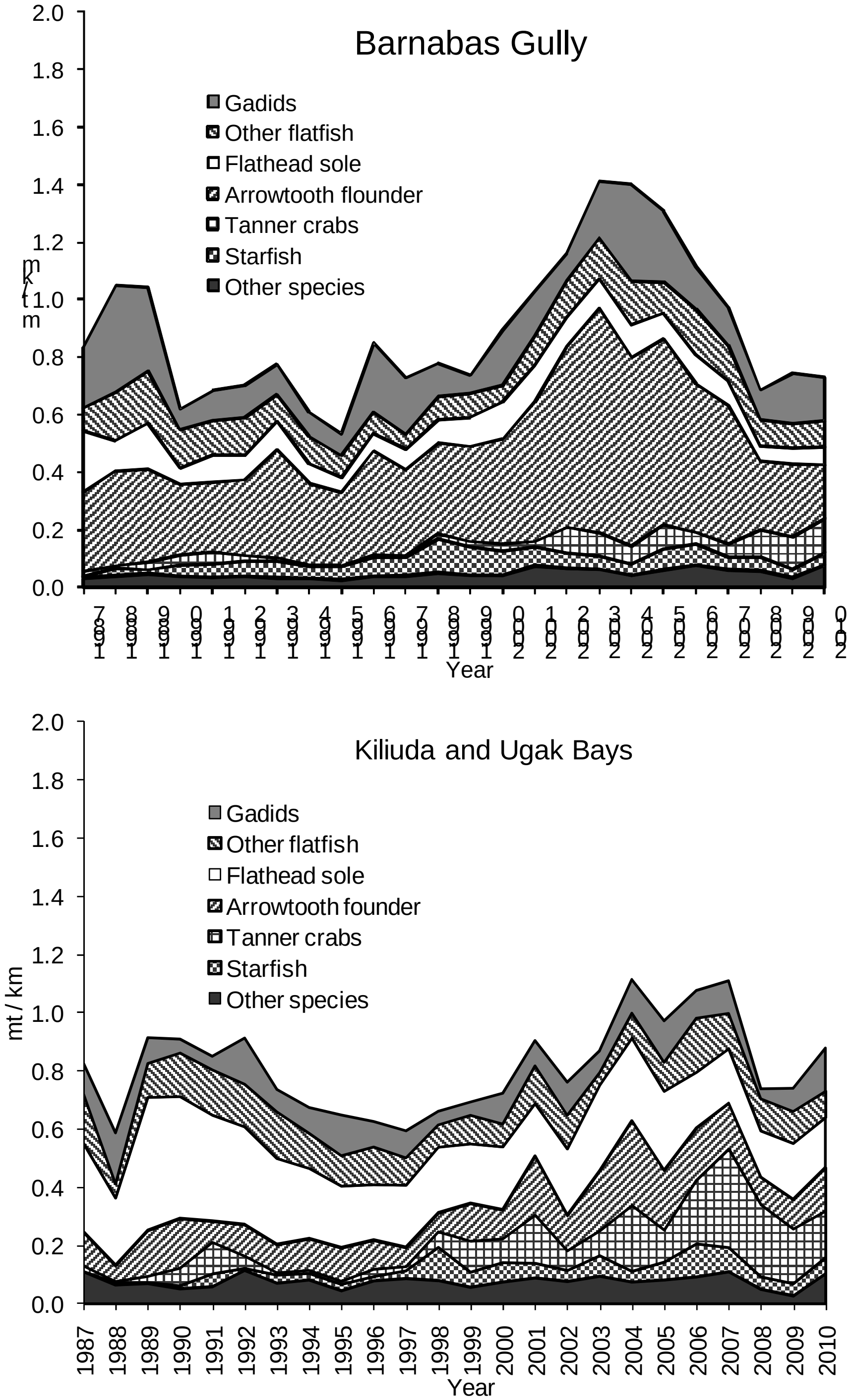

Figure 96: Total catch per km towed (mt/km) during the ADF&G trawl survey from adjacent areas off the east side of Kodiak Island, 1987 to 2010.

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 97). 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.

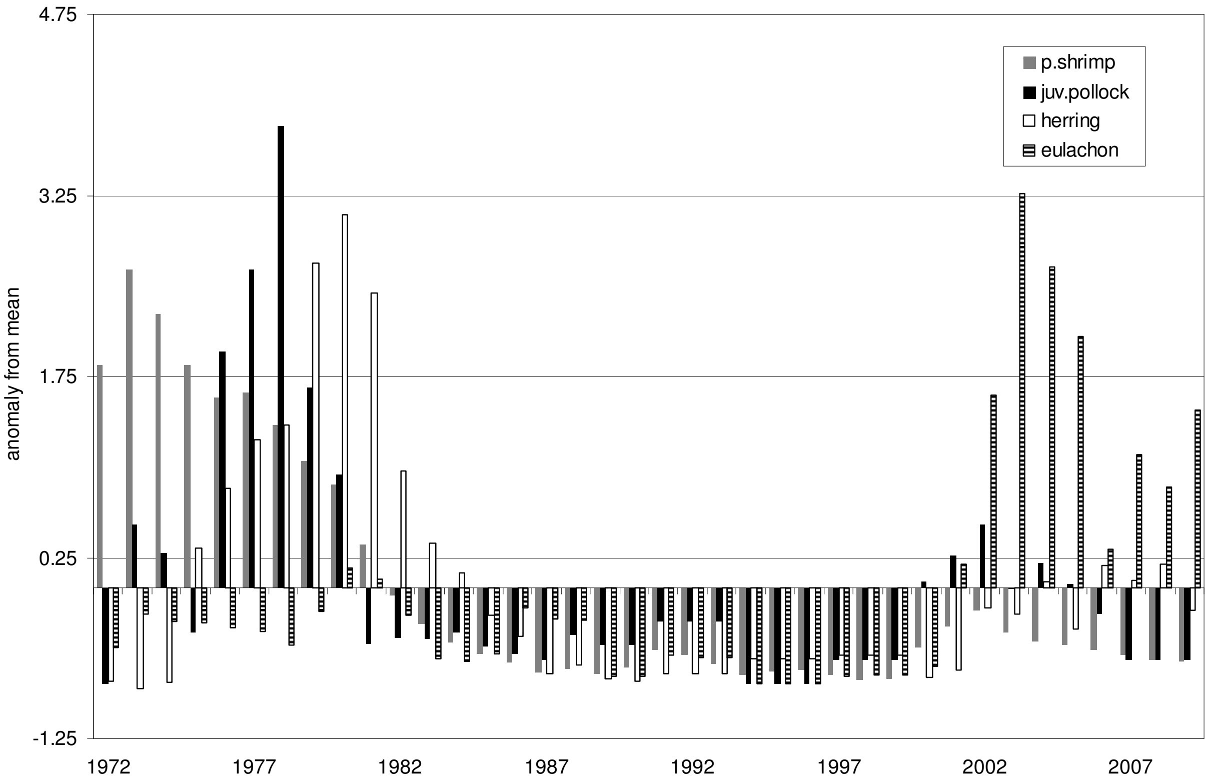

Figure 97: Anomalies of forage species CPUE (kg km^{-1}) in the Gulf of Alaska, 1972-2009. Data are taken from the smallmesh survey conducted jointly by the National Marine Fisheries Service and the Alaska Department of Fish and Game.

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 five more data points from recent surveys to Fig. 1a of Litzow et al. (2008) did not reveal any impending alternate state (Figure 98).

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 97 but are less clear for the 1998 shift. In any case, phase transitions (Duffy-Anderson et al., 2005) are not uniform within a

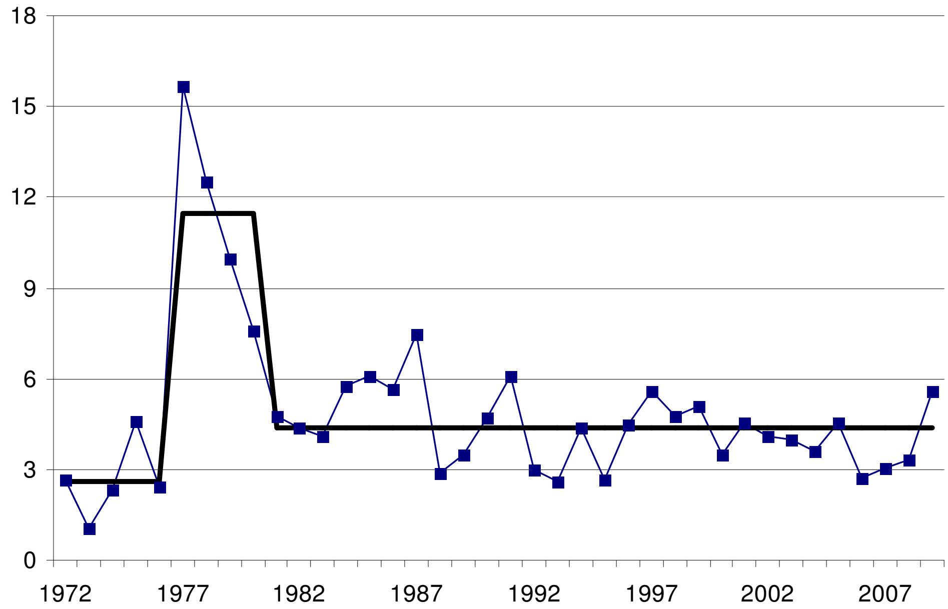

Figure 98: Time series of spatial variance in the cod:prey ratio (log + 10) in Pavlof Bay (line and squares) as adapted from Litzow et al. (2008). Heavy line indicates distinct states in the times series as defined by sequential t tests for analysis of regime shifts (STARS, $p = 0.03$, l = 5, H = 2).

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.

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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Last updated: October 2011

Description of index: RACE bottom trawl surveys in the Gulf of Alaska (GOA) 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. 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 GOA. The fishing gear used aboard the Japanese vessels that participated in all GOA surveys prior to 1990 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.

Status and trends: A few general patterns of abundance are discernible from the data (Figure 99). The abundance of jellyfish has generally been higher in the central and eastern GOA than in the western GOA, although jellyfish abundance was quite low in 2011 across all areas compared to previous survey years. By far the highest jellyfish abundance seen in the GOA time series was in 1990, particularly in the central and eastern GOA. Echinoderm abundances have generally been highest in the central GOA and their mean catch per unit effort (CPUE) in this areas has increased dramatically in this area since 1997. The percentage of hauls with echinoderms has also increased over time, leveling off in recent years at a very high percentage of tows in all areas, in a pattern remarkably similar to that found in the Aleutian Islands.

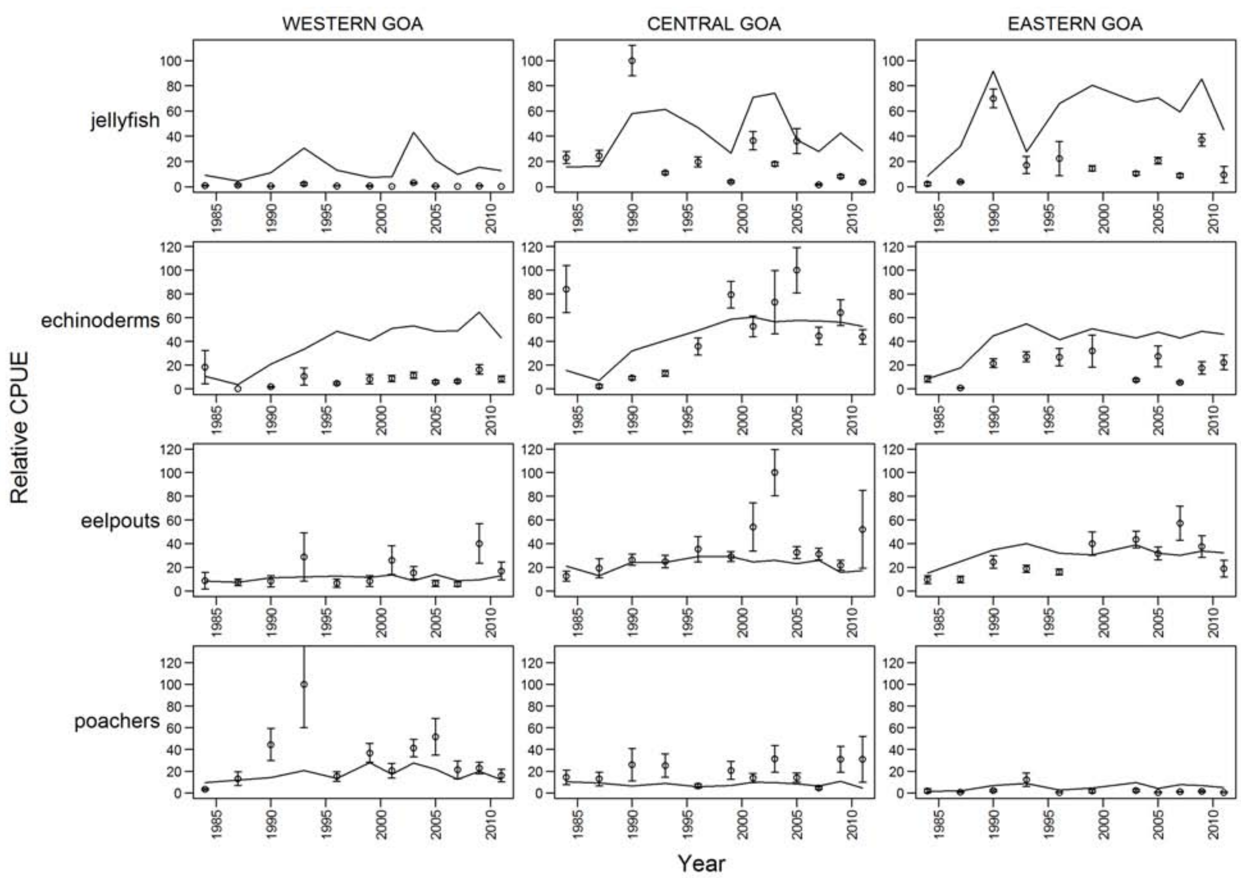

Figure 99: Relative mean CPUE of miscellaneous species by area from RACE bottom trawl surveys in the Aleutian Islands from 1980 through 2010. Error bars represent standard errors. The solid lines represent the percentage of non-zero catches.

Eelpout mean CPUE has consistently increased over time, particularly in the eastern GOA. Both poacher mean CPUE and rates of capture seems to consistently increase from east to west.

Factors causing observed trends: Abundance trends are difficult to ascertain definitely due to high variance and uncertain catchability.

Implications: Eelpouts and echinoderms have important roles in the energy flow in benthic communities. For example, eelpouts are a common prey item of arrowtooth flounder. However, it is not known at present whether these changes in CPUE are related to changes in energy flow.

Lingcod Catches in the Gulf of Alaska

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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`

Miscellaneous Species Aleutian Islands

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See the 2010 report at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Marine Mammals

The Marine Mammal Protection Act requires stock assessment reports to be reviewed annually for stocks designated as strategic, annually for stocks where there are significant new information available, and at least once every 3 years for all other stocks. Each stock assessment includes, when available, a description of the stocks geographic range, a minimum population estimate, current population trends, current and maximum net productivity rates, optimum sustainable population levels and allowable removal levels, and estimates of annual human-caused mortality and serious injury through interactions with commercial fisheries and subsistence hunters. The most recent Alaska Marine Mammal stock assessment was released in May 2011 and can be downloaded at `http://www.nmfs.noaa.gov/pr/pdfs/sars/ak2010.pdf`.

Steller sea lion (*Eumetopias jubatus*)

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See the 2010 report at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Northern fur seal (*Callorhinus ursinus*)

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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 declined to less than 50% of levels observed in the late 1950s, with no compelling evidence that carrying capacity had changed NMFS (1993, 2007). 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 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, 2007).

Description of index: Pup production of northern fur seals on Bogoslof and Pribilof Islands is estimated by NMML biennially using a mark-recapture method (shear-sampling) on 1-2 month old pups. The most recent pup production estimate for the Pribilof Islands is August 2010; pup production on Bogoslof was assessed in August 2011.

Status and trends, Factors causing observed trends, and Implications: NMML estimated that northern fur seal pup production on the Pribilof Islands in 2010 totaled 111,600, a decrease of ˜7.6% from 2008: 93,627 (SE = 1,034) pups were born on St. Paul Island and 17,973 (SE = 323) pups were born on St. George Island. The 2010 pup production estimates for St. Paul and St George Islands were 8.8% and 1.0% less, respectively than the 2008 estimates (Figure 100). Estimated pup production on both Pribilof Islands in 2010 was similar to the level observed in 1916; however the population trend almost 100 years ago was much different than it is now. 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 2010), pup production on both

Pribilof Islands is estimated to be decreasing at 5%/y (SE = 0.36).

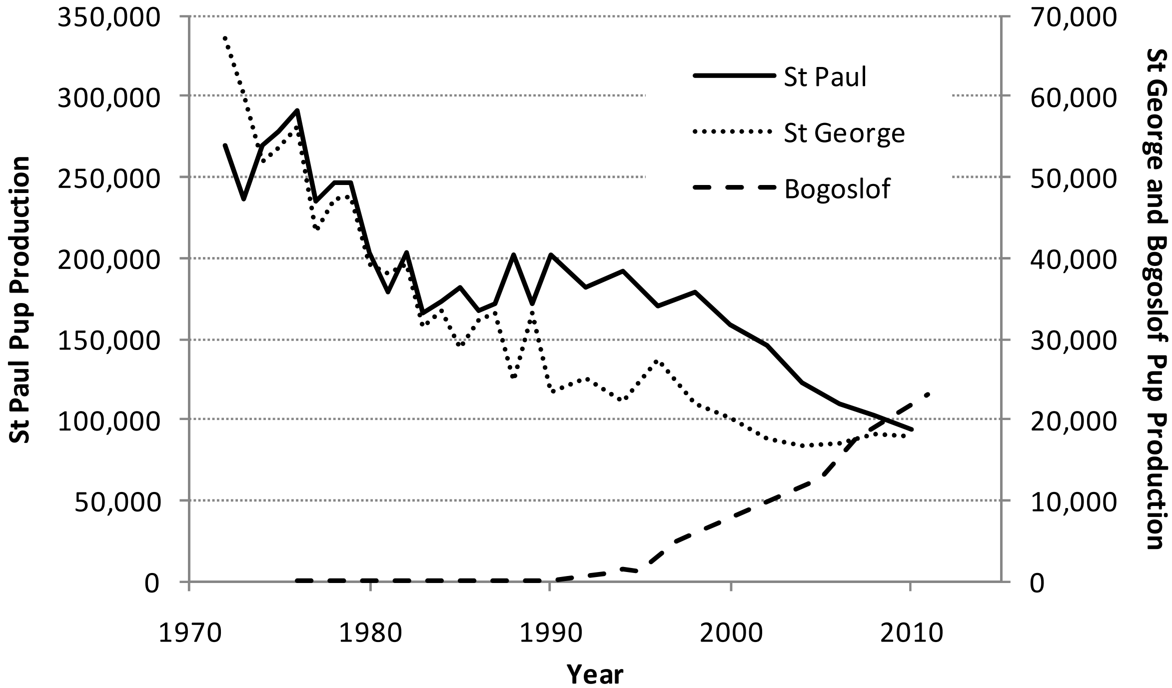

Figure 100: fur seal pup production estimates for the Pribilof Islands (St Paul and St George Islands) and Bogoslof Island, 1972-2011 (2011 Bogoslof estimate is preliminary).

The preliminary estimate of northern fur seal pup production in 2011 on Bogoslof Island is approximately 23,000. The recent trend in pup production on Bogoslof Island has been opposite to that on the Pribilofs (Figure 100). Pup production increased at approximately 24% per year on Bogoslof Island between 1990 and 2011 (using the preliminary estimate). This rate is faster than what could be expected from a completely closed population of fur seals, indicating that at least some of the increase 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 largely shelf-foraging Pribilof fur seals and the 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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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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Seabirds

A Multivariate Seabird Index for the Eastern Bering Sea

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Description of index: We investigated the utility of multivariate statistical techniques as a tool for developing an index of seabird trends in the eastern Bering Sea by integrating existing reproductive effort data from common murre *Uria aalge*, thick-billed murre *U. lomvia*, black-legged kittiwake *Rissa tridactyla*, red-legged kittiwake *R. brevirostris*, and red-faced cormorants *Phalacrocorax urile* breeding on the Pribilof Islands.

Mean hatch date and reproductive success data were standardized (mean of zero and unit variance) to assure equal weighting, and Principal Components Analysis (PCA) was performed using the correlation matrix. The two leading principal components (PC1 and PC2) were considered successful candidates for the index if they explained a sufficient level of the variance in the datasets. Inspection of the loadings of individual breeding parameters on PC1 and PC2 enabled interpretation of the biological meaning of their temporal trends.

We used time series analysis to test for significant relationships between the leading PCs and select environmental variables at lags of ≤3 years. Two measures of prey supply were used: the mean catch rates of age-1 pollock during summer trawl surveys within 200 km of the islands, and the estimated age-1 pollock recruitment from the pollock stock assessment (Ianelli et al., 2010). Three physical indices were also examined: the ice retreat index, the North Pacific Index, and mean bottom temperature. The ice retreat index is the number of days past March 15 when sea ice coverage is >10% across a section of the southeast Bering Sea (56.5-57.5 °N, 165-163 °W). The North Pacific Index measures the strength of the Aleutian Low, an indicator for potential climate forcing of the Bering Sea. These two indices were chosen from the eastern Bering Sea ecosystem assessment list of indicators. Mean bottom temperature was chosen to represent dynamics of the cold pool of bottom water that forms annually (Stabeno et al., 2001) and has been shown to be influential in the structure and function of the eastern Bering Sea ecosystem (Kotwicki et al., 2005; Mueter and Litzow, 2008; Spencer, 2008).

Status and trends: The PCA on the 15 yr annual time series (1996-2010) explained 65.6% of the variance in the data in the first two components. The loadings of all seabird phenology and all but kittwake productivity were strongly positive (≥0.4) on PC1, which explained 45.5% of the overall variance (Figure 101). The loadings of kittiwake productivity were all strongly positive (≥0.8; all other loadings were <0.4) on PC2, which explained 20% of the remaining variance.

We conducted a time series analysis of PC1 and PC2 scores to allow for testing of significant relationships with environmental variables at lags up to 3 years. The analysis of the PCs against the mean CPUE of age-1 pollock within 200km showed a strongly significant 1 year lag with PC2, indicating that more age-1 pollock in the survey, the higher kittiwake productivity the following year ($R = 0.80$, $P < 0.001$). The analysis with age-1 pollock recruitment showed that although not quite significant ($R = 0.50$, $P = 0.06$), higher pollock recruitment was positively correlated with PC1, indicating better conditions for most seabirds that year. The analysis of the PCs against the ice retreat index showed a significant -3 year lag with PC2, indicating that kittiwake productivity leads ice retreat by 3 years. This was deemed spurious, possibly because the area where the ice retreat index is calculated by not be the best measure of ice influence for Pribilof birds. No significant correlations were found between either PC and the North Pacific Index. However strong negative correlations at 1 and 2 years lags between PC1 and mean bottom temperature indicate that the warmer in year x, the later and less productive seabirds were in year x+1, x+2 (Figures 102 and 103).

Factors causing observed trends: Results indicate that both prey supply (as measured by age-1 pollock CPUE and recruitment) and bottom temperatures may influence seabird reproductive activity, although the effects may not been seen until the following 1-2 years.

Implications: This index presents a simplified and more comprehensive measure of seabird reproductive activity than the current seabird indicator contained in the EBS ecosystem assessment, which is composed solely of the reproductive success of thick-billed murres on St. George Island. Our original intent was to also incorporate northern fur seal *Callorhinus ursinus* pup count and weight data to examine a broader top predator index for the eastern Bering Sea. The available fur seal biennial datasets when matched with the existing annual seabird time series did not show any definitive signal; therefore, their overall contribution to the analysis was minimal. Our analysis sug-

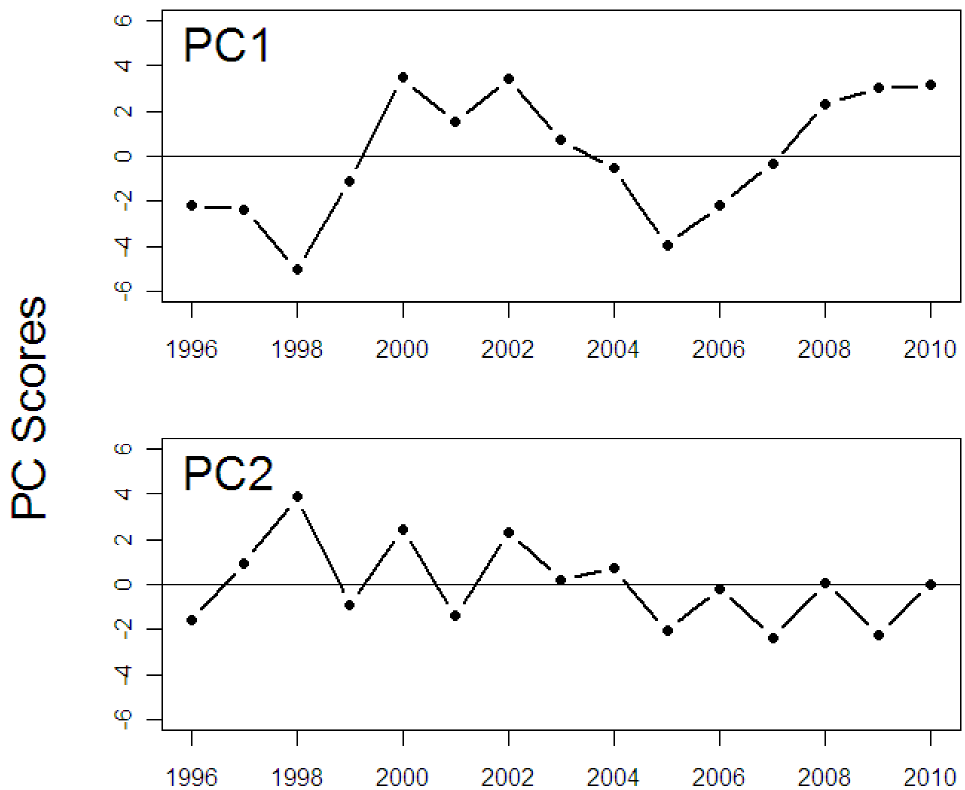

Figure 101: Time series of the first two leading principal components for combined seabird productivity and mean hatch date. For PC1, a more positive value indicates higher murre and cormorant productivity and earlier mean hatch dates. For PC2, higher values indicate increased kittiwake productivity.

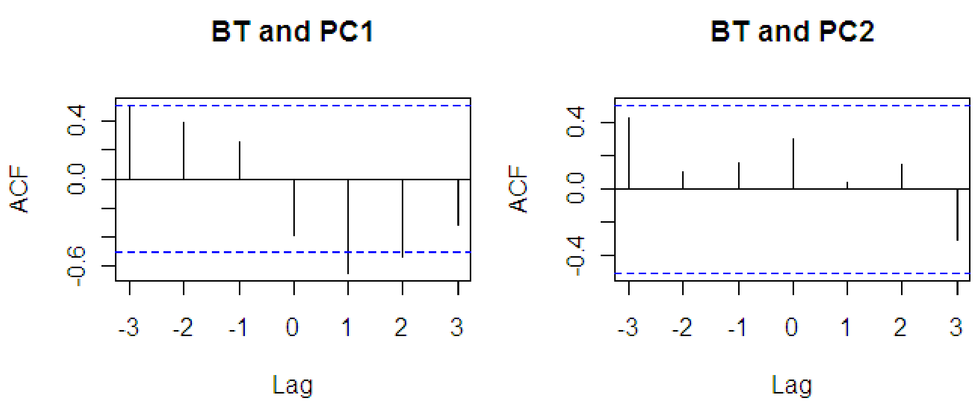

Figure 102: Time series analysis of seabird PC1 and PC2 against the eastern Bering Sea mean bottom temperature (BT). The auto-correlation function (ACF) describes the strength of the relationships between different points in the series. Significant lagged relationships are indicated by the vertical lines meeting or exceeding the dotted blue lines.

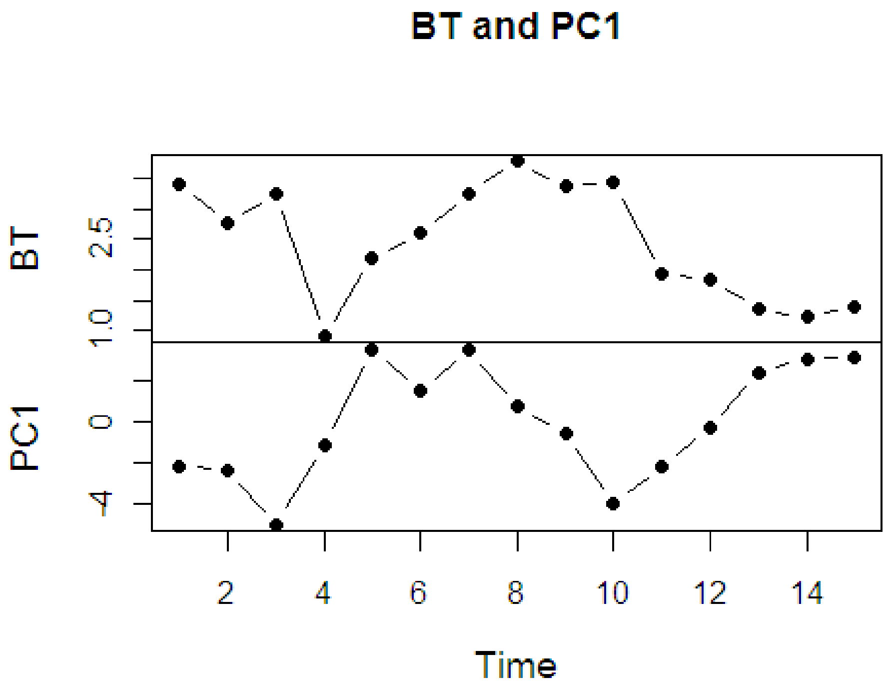

Figure 103: Time series of eastern Bering Sea mean bottom temperature (BT) displayed above the seabird PC1 scores, depicting significant negative correlations at 1-2 year lags.

gests that the use of multivariate statistics (i.e. PCA) to create a top predator index in the eastern Bering Sea is more successful as a seabird index due to data availability issues when avoiding large scale imputation of existing datasets. The analysis is robust to adding fur seal information but as a biennial index, but precludes investigating lagged effects when correlating with environmental indices.

Pribilof Islands Seabird Trends

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See the 2010 report at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Seabird Bycatch Estimates for Alaskan Groundfish Fisheries, 1993-2010

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Description of index: This report provides preliminary estimates of seabirds caught as bycatch in commercial groundfish fisheries in Alaska operating in federal waters of the U.S. Exclusive Economic Zone for the years 2007 through 2010, updating the previously reported estimates from 1993 to 2006 (Fitzgerald et al., 2008). Gear types represented are demersal longline, pot, pelagic trawl, and non-pelagic trawl. These numbers do not apply to gillnet, seine, troll, or halibut longline fisheries.

Estimates are based on two sources of information, (1) data provided by NMFS-certified Fishery Observers deployed to vessels and floating or shoreside processing plants, and (2) catch estimates provided by the NMFS Alaska Regional Office Catch Accounting System. The 2007 - 2010 bycatch estimates presented here are produced from the NMFS Alaska Regional Office Catch Accounting System (Cahalan et al., 2010). This is the third approach used to generate estimates of seabird bycatch in these fisheries. The first approach was carried out by the USFWS and covered the years 1993 through 1997 (Stehn et al., 2001). The second approach was completed within the AFSC, in the National Marine Mammal Laboratory, and covered the years 1993 through 2006 (Fitzgerald et al., 2008). Detailed methodology is available from Shannon Fitzgerald.

Status and trends: While all three approaches used the same two primary data sources, each approach is slightly different and produces slightly different results, although the results shown in years of overlap for the demersal longline fleet (Figure 104) show good agreement. Bycatch in this fishery showed a marked decline between 2000 and 2002. Since then, annual bycatch has remained below 10,000 birds, with the 2010 bycatch (3,704 birds) the lowest estimated in this fishery.

Total estimated seabird bycatch in all Alaskan groundfish fisheries are shown in Table 10. Northern fulmar *Fulmaris glacialis* are the most commonly caught in each year. Gulls and shearwaters, both combined species groups, were the second and third most commonly caught. Albatross bycatch varied annually. Greatest numbers of albatross were caught in 2008, but the endangered short-tailed albatross bycatch estimates were estimated above zero only in 2010, when 2 birds were incidentally hooked (see Hot Topics in Zador and Gaichas (2010)).

Factors influencing observed trends: The marked decline in overall numbers of birds caught as depicted in Figure 104 reflects the increased use of seabird mitigation devices. There are many factors that may influence annual variation in bycatch rates, including seabird distribution, population trends, prey supply, and fisheries activities. No specific factors influencing the annual trends depicted in Table 10 are known at present.

Implications: Development of this new method to estimate seabird bycatch allows the extension of the bycatch time series. Although the methodology has changed, the similarity in estimates calculated for three overlapping years provides some confidence in comparability. It is anticipated that bycatch estimates will be updated on an annual basis in future years, providing timely information to scientists and managers.

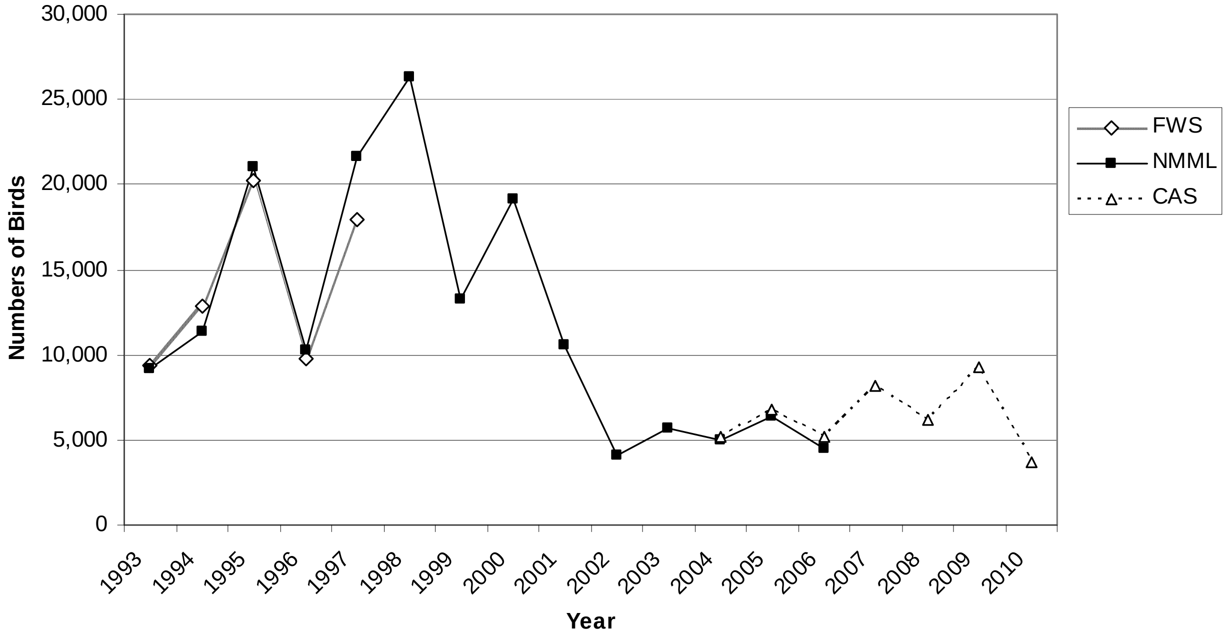

Figure 104: Total estimated seabird bycatch by year in the Alaskan demersal longline fishery derived by employing three methods: the Fish and Wildlife Service (Stehn et al., 2001), the National Marine Mammal Laboratory (Fitzgerald et al., 2008), and this preliminary report, using the Alaska Regional Office Catch Accounting System (Cahalan et al., 2010).

Ecosystem or Community Indicators

Combined Standardized Indices of recruitment and survival rate

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See the 2010 report at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Indicators of Alaska-wide community regime shifts

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Last updated: July 2011

Table 10: Total estimated seabird bycatch in Alaskan groundfish fisheries, all gear types and regions combined, 2007 through 2010.

Species/Species Group	2007	2008	2009	2010
Unidentified Albatross	16	0	0	0
Short-tailed Albatross	0	0	0	15
Laysan Albatross	17	420	114	267
Black-footed Albatross	176	290	52	44
Northern Fulmar	4,581	3,426	7,921	2,357
Shearwater	3,602	1,214	622	647
Storm Petrel	1	44	0	0
Gull	1,309	1,472	1,296	1,141
Kittiwake	10	0	16	0
Murre	7	5	13	102
Puffin	0	0	0	5
Auklet	0	3	0	0
Other Alcid	0	0	105	0
Other Bird	0	0	136	0
Unidentified	509	40	166	18
Total	10,226	6,914	10,440	4,595

Description of indices: Leading principal component (PC) scores for a set of diverse populations in the northeast Pacific showed abrupt, basin-scale change following climate regime shifts in 1976/77 and 1988/89 (Hare and Mantua, 2000). We updated 36 Alaskan biology time series from the Hare and Mantua study for the years 1965-2007 to provide indicators of recent community-level variability in Alaskan ecosystems. These time series come from the Eastern Bering Sea ($n = 16$) and the Gulf of Alaska ($n = 20$), and are comprised of assessment model-derived recruitment estimates for groundfish ($n = 15$) and herring ($n = 3$) populations, log-transformed and lagged to cohort year; commercial salmon catches ($n = 15$), log-transformed and lagged to year of ocean entry; measures of invertebrate abundance ($n = 2$); and a measure of seabird reproductive success ($n = 1$, not included in original study). Missing values were estimated prior to PC analysis using Bayesian linear regression techniques implemented in the MICE package in R (Van Buuren and Oudshoorn, 1999); too many time series were missing after 2007 for PC scores to be estimated. PC1 explained 34% of total variance in the times series, and PC2 explained 11%. Time series loading most strongly on each PC score (loading strength > 0.2) are illustrated in Figure 105. The sign of PC scores is arbitrary, and PC1 in our analysis shows an opposite sign from PC1 of biology time series from Hare and Mantua (2000).

Status and trends: Community changes following the 1976/77 and 1988/89 climate regime shifts, as documented by Hare and Mantua (2000), are evident in the updated time series. Using sequential t-test analysis for regime shifts [STARS] adjusted for first-order autocorrelation, we detected a 1977/78 shift in PC1 ($P = 0.03$) and a 1993/94 shift in PC2 ($P = 0.005$, Figure 105). PC2 scores showed a sharp increase in 2000/01 (Figure 105), but this change was not long-lived, and STARS showed no evidence of persistent shifts in either PC score in recent years ($P > 0.05$).

Factors causing trends: PC1 reflects changes to commercially exploited populations (i.e., declining crustaceans, increasing salmon) that are generally associated with the effects of the 1970s

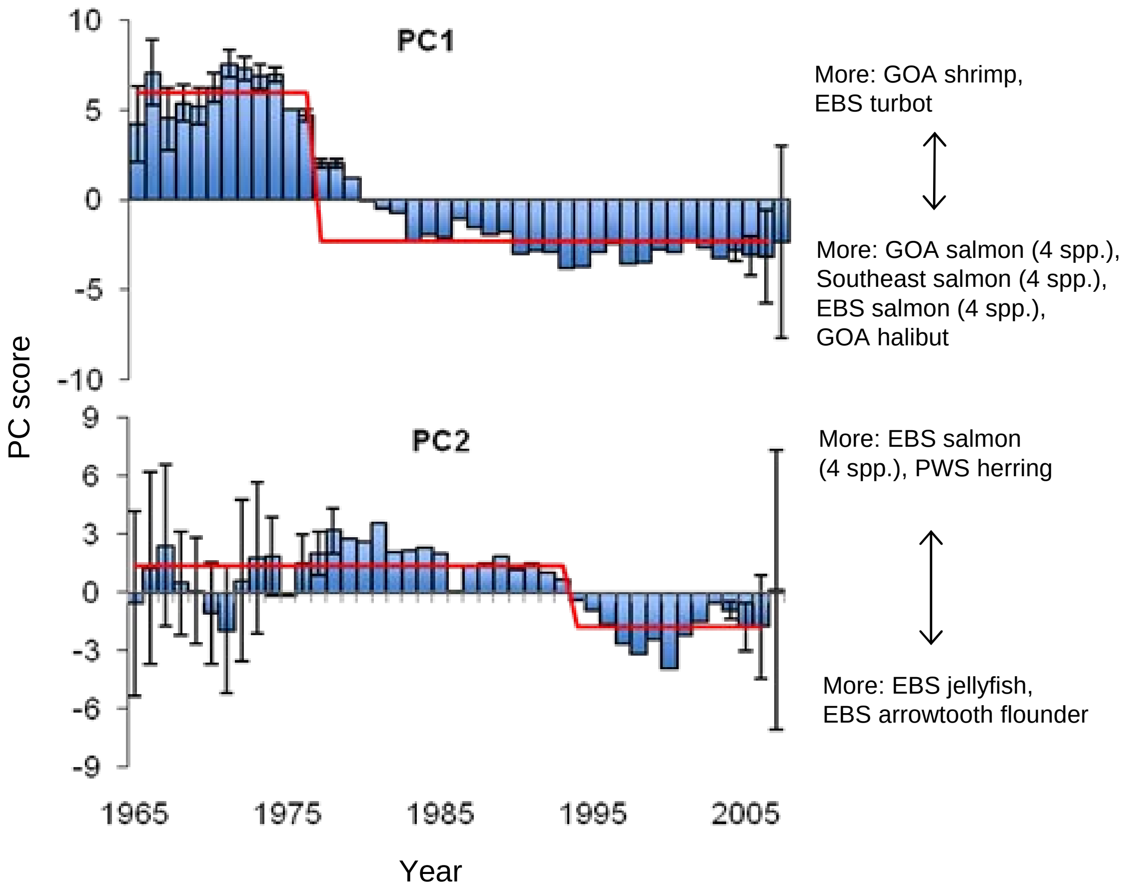

Figure 105: Time series of first two principal component (PC) scores for 36 Alaskan biology time series. Error bars = 95% CI associated with uncertainty through estimation of missing time series values; columns with no error bars indicate years with no missing values. Individual populations listed to the right of panels are time series showing strongest loading (≥ 0.2) on each PC score. Red lines indicate shifts detected by sequential t-test analysis for regime shifts adjusted for first-order autocorrelation ($P \leq 0.03$).

PDO regime shift (Anderson and Piatt, 1999; Hare and Mantua, 2000). PC1 has shown little variability since the early 1990s (Figure 105), and the PDO has also shown reduced amplitude and autocorrelation since the 1988/89 climate regime shift (Bond et al., 2003). So while PC1 apparently captured community variability associated with the last PDO regime shift, this PC score appears to be less important for describing community variability over the last ~20 years. This interpretation is supported by changes in the strength of association between PC1 and individual time series. We measured the relative importance of the PC scores by calculating the mean Pearson's correlation coefficient between individual time series and each PC score, since too many values were missing for valid PC loadings to be calculated separately before and after the 1988/89 shift. Prior to the 1988/89 shift (i.e., 1965-1988), the average absolute value of Pearson's correlation coefficients between individual time series and PC1 was 0.56 ± 0.05 (SE), but during 1989-2007 the mean declined to 0.20 0.03 (paired $t^{35} = 7.25$, $P < 0.0001$, Figure 106). Strength of association between PC2 and individual time series stayed constant across the 1988/89 event (Figure 106). The 1993/94 shift in PC2 (Figure 105) was approximately two years later than the shift in PC2 score for all northeast Pacific (i.e., Alaska and West Coast) biology time series in Hare and Mantua (2000). We interpret this shift as a delayed biological response to the 1988/89 climate shift, but a rigorous test of causality is very difficult with these sorts of observational data. The sharp increase in PC2 values in 2000/2001 (Figure 105) was coincident with a decline in recruitment and survival for a variety of Gulf of Alaska groundfish ((Mueter et al., 2007), updated in 2010 SAFE report), providing independent confirmation that the shift in PC2 scores reflected a broad change in ecosystem conditions. However, that shift has not shown the decadal-scale persistence associated with regime shifts.

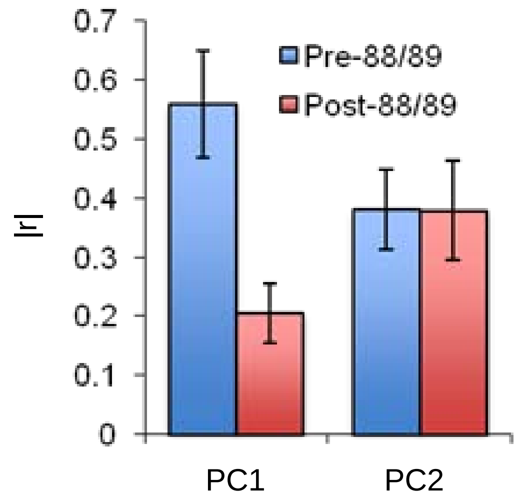

Figure 106: Strength of association (mean correlation coefficient) between leading PC scores and 36 Alaskan biology time series before and after 1988/89 climate regime shift. Error bars = 95% CI.

Implications: Simultaneous change across many populations at large spatial scales led to recognition of the ecological role played by the PDO and other climate indices showing "regime shift" dynamics. These shifts have historically been more evident in biology time series, which show high autocorrelation and coherent change at large spatial scales, than in noisier climate time series (Hare and Mantua, 2000). PC1 and PC2 of the updated time series (Figure 105) show no evidence of regime shift effects in Alaskan ecosystems beyond those documented by Hare and Mantua (2000). Change in the relative importance of these two PC scores, in terms of correlation strength with individual time series (Figure 106) may reflect a change in the leading axis of community variability in response to decline in the importance of the PDO as a driver of ecosystem variability.

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), western Gulf of Alaska (wGOA), and eastern Gulf of Alaska (eGOA). 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 for the EBS were based on 45 fish and invertebrate taxa that were consistently identified throughout all surveys since 1982 (Table 1 in Mueter and Litzow (2008)), excluding Arctic cod because of unreliable identification in early years). Indices for the Gulf of Alaska were based on 79 fish and invertebrate taxa that have been consistently identified since the early 1990s. Indices 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 with confidence intervals across the survey area using a Generalized Additive Model that accounted for the effects of variability in geographic location (latitude/longitude), depth, date of sampling, and area swept (Bering Sea only). In addition to trends in the indices over time, we mapped average spatial patterns for each index across the survey region.

Status and trends: Species richness and diversity on the Eastern Bering Sea shelf have undergone significant variations from 1982 to 2010 (Figure 107). The average number of species per haul increased by one to two species from 1995 to 2004 and has remained relatively high since then. 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. Richness and diversity in the Gulf of Alaska increased between 1990 and 1993 and has remained relatively stable since then with some interannual variability (Figure 108). In both the eGOA and wGOA, average species richness decreased in 2007, but increased again in 2009.

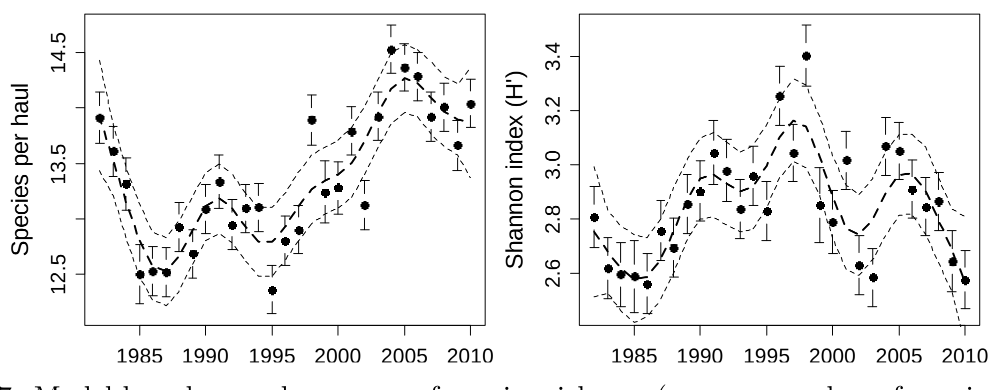

Figure 107: Model-based annual averages of species richness (average number of species per haul, dots), and species diversity (Shannon index) in the Eastern Bering Sea, 1982-2010, based on 45 fish and invertebrate taxa collected by standard bottom trawl surveys with pointwise 95% confidence intervals (bars) and loess smoother with 95% confidence band (dashed/dotted lines). Model means were adjusted for differences in area swept, depth, date of sampling, and geographic location.

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

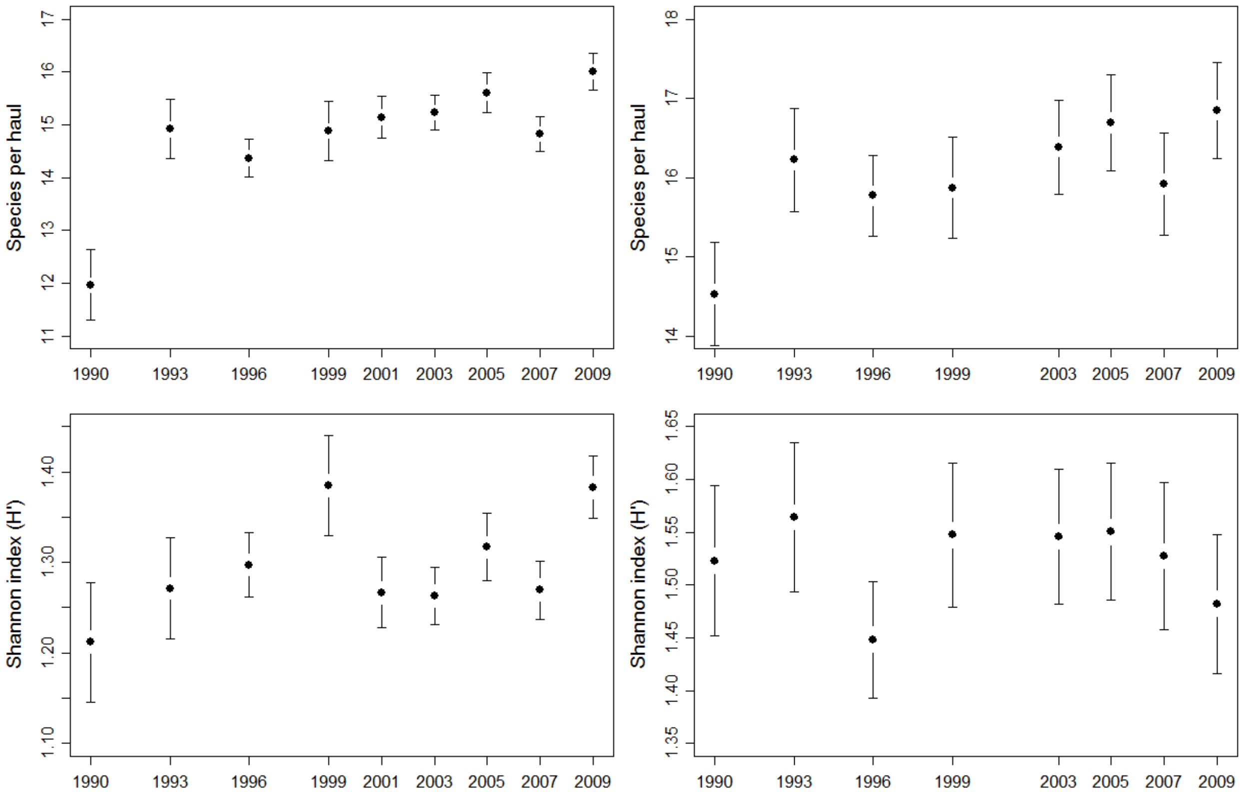

Figure 108: Model-based annual averages of species richness (average number of species per haul, dots, top panels) and species diversity (Shannon index, bottom panels), 1990-2009, for the Western (left) and Eastern (right) Gulf of Alaska based on 79 fish and invertebrate taxa collected by standard bottom trawl surveys with 95% pointwise confidence intervals. Model means were adjusted for differences in depth, date of sampling, and geographic location.

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 (Figures 107 and 108) and spatial patterns in species diversity (Figures 109 and 110) differed markedly from those in species richness. For example, low species diversity in 2003 in the EBS 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 in the EBS, 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 decreased from 1982 to 2005 (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 in the EBS, whereas species diversity is highest on the middle shelf because the middle shelf region is less dominated by a few abundant species. In the GOA, highest species richness tends to occur around the Shumagins and Kodiak Island, off the Kenai Peninsula, and along the slope in SE

Alaska. Spatial patterns in diversity were similar in the wGOA but a region of high diversity on the inner shelf between Prince William Sound (146 °W) and Yakutat (140 °W) was not evident in species richness. This is a region of relatively low biomass and the observed high diversity may be due to a more even abundance across species. The average number of species in both the eGOA and wGOA was significantly lower in 1990, which may be due to some species not being identified correctly prior to the early 1990s.

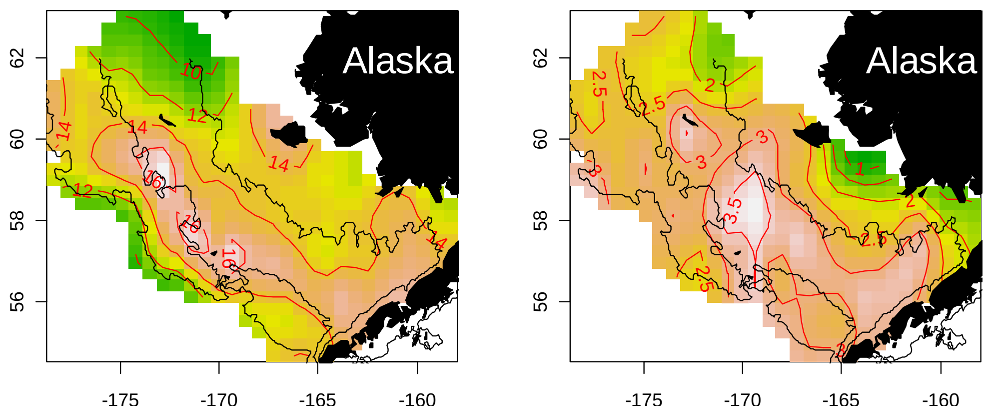

Figure 109: Average spatial patterns in local species richness (left, number of taxa per haul) and Shannon diversity in the Eastern Bering Sea. The 50m, 100m, and 200 m depth contours are shown as black lines.

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. In the EBS, 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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Last updated: July 2011

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, 1982-2010) 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

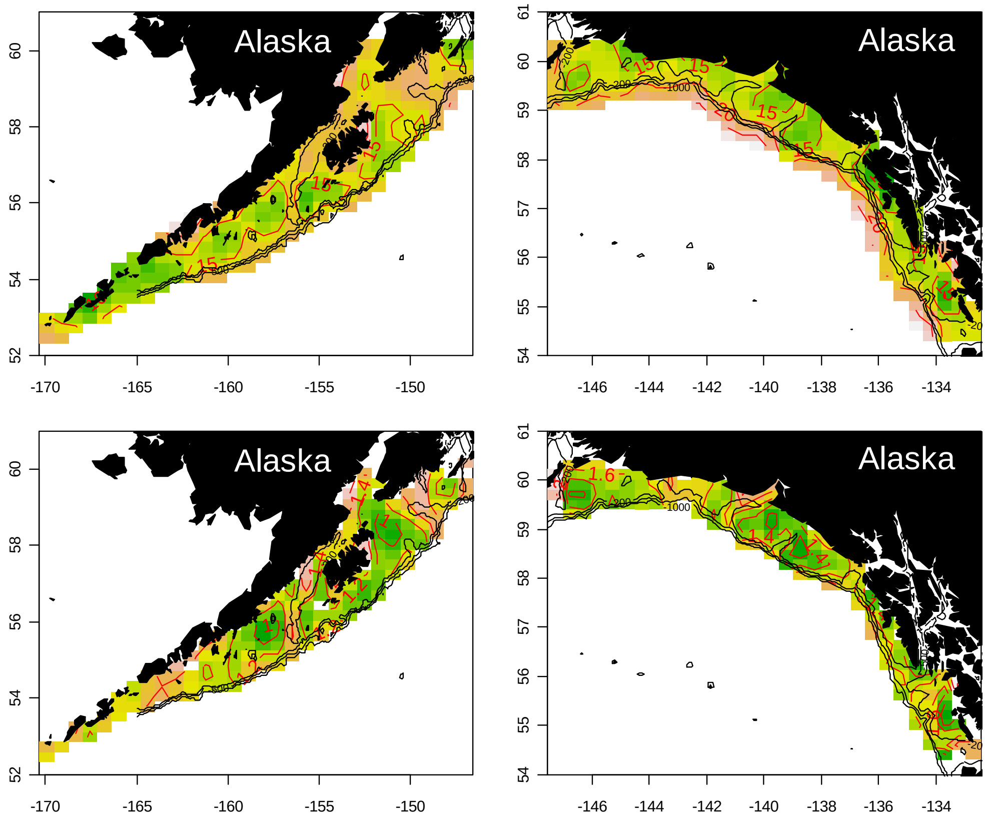

Figure 110: Average spatial patterns in local species richness (species per haul, top panels) and Shannon diversity (bottom panels) for the Western (left) and Eastern (right) Gulf of Alaska. The 200m, 500m, and 1000 m depth contours are shown as black lines.

total CPUE (N = 10796, 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.

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 111). 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 from 2005 to 2009 and an increase in 2010 (Figure 112). 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).

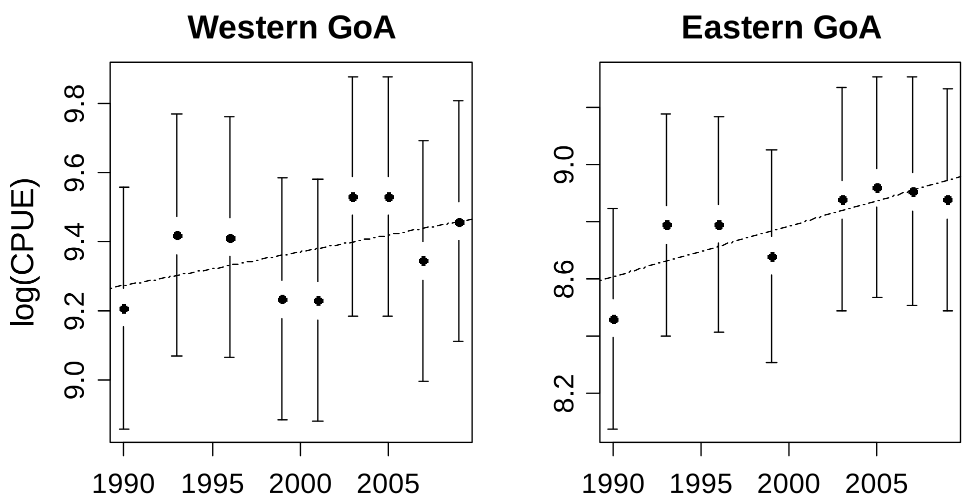

Figure 111: Model-based estimates of total log(CPUE) for major fish and invertebrate taxa captured in bottom trawl surveys from in the western Gulf of Alaska (west of 147° W) by survey year with approximate 95% confidence intervals. Estimates were adjusted for differences in depth and sampling locations (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: $t = 3.43$, $p = 0.019$).

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 2006-2009 are largely a result of decreases in walleye pollock abundance. Increases in pollock and Pacific cod biomass in 2010 resulted in the observed increase in log(CPUE). 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.

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

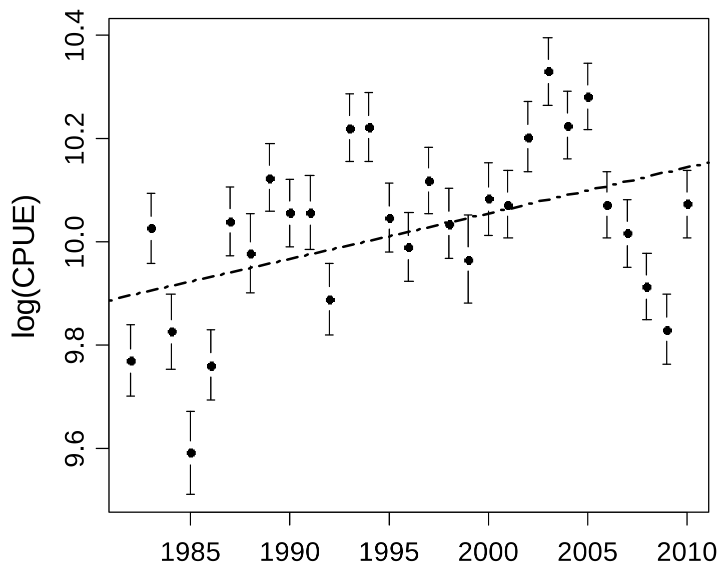

Figure 112: Model-based estimates of total log(CPUE) for major fish and invertebrate taxa captured in bottom trawl surveys from 1982 to 2010 in the Bering Sea with approximate pointwise 95% confidence intervals and linear time trend. Estimates were adjusted for differences in depth, day of sampling, 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 = 1.437, p = 0.162).

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

See the 2010 report at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

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 Groundfish Discards

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Last updated: October 2011

Description of index: Estimates of discards for 1994-2002 come from NMFS Alaska Region's blend data; estimates for 2003-10 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 113). Discards in the Gulf of Alaska increased somewhat between 1998 and 2003, declined in 2004 and 2005, increased in 2006-2009, and declined again in 2010. 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 seven 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 2010 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.

Implications: 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.

Time Trends in Non-Target Species Catch

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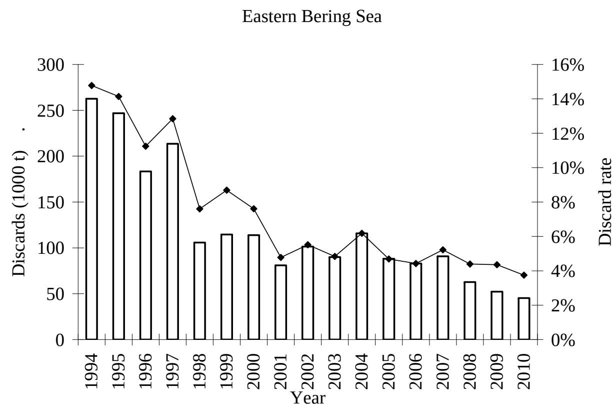
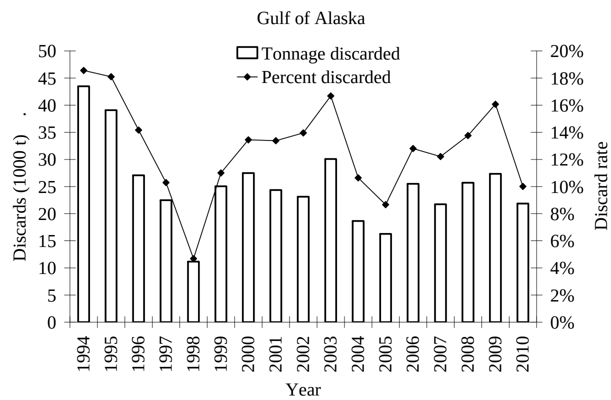
Last updated: July 2010

Description of index: We monitor the catch of non-target species in groundfish fisheries in the Eastern Bering Sea (EBS), Gulf of Alaska (GOA) and Aleutian Islands (AI) ecosystems (Figure 114). There are three 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), and 3.) non-specified species (grenadiers, crabs, starfish, jellyfish, unidentified invertebrates, benthic invertebrates, echinoderms, other fish, birds, shrimp). Stock assessments have been developed for all groups in the other species (sculpins, unidentified sharks, salmon sharks, dogfish, sleeper sharks, skates, octopus, squid) 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`).

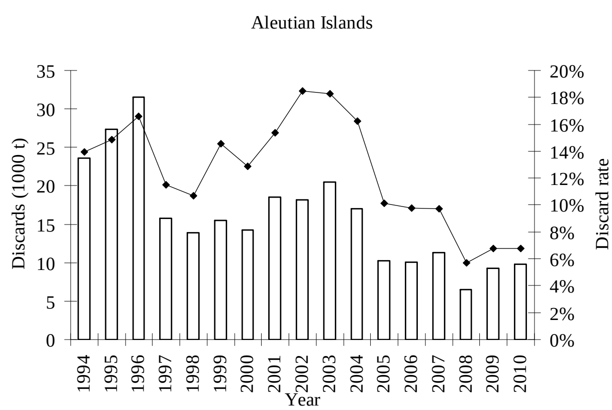
Total catch of nontarget species is estimated from observer species composition samples taken at sea during fishing operations, scaled up to reflect the total catch by both observed and unobserved hauls and vessels operating in all FMP areas. From 1997-2002, these estimates were made at the AFSC using 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.



(a) EBS



(b) GOA



(c) AI

Figure 113: 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)

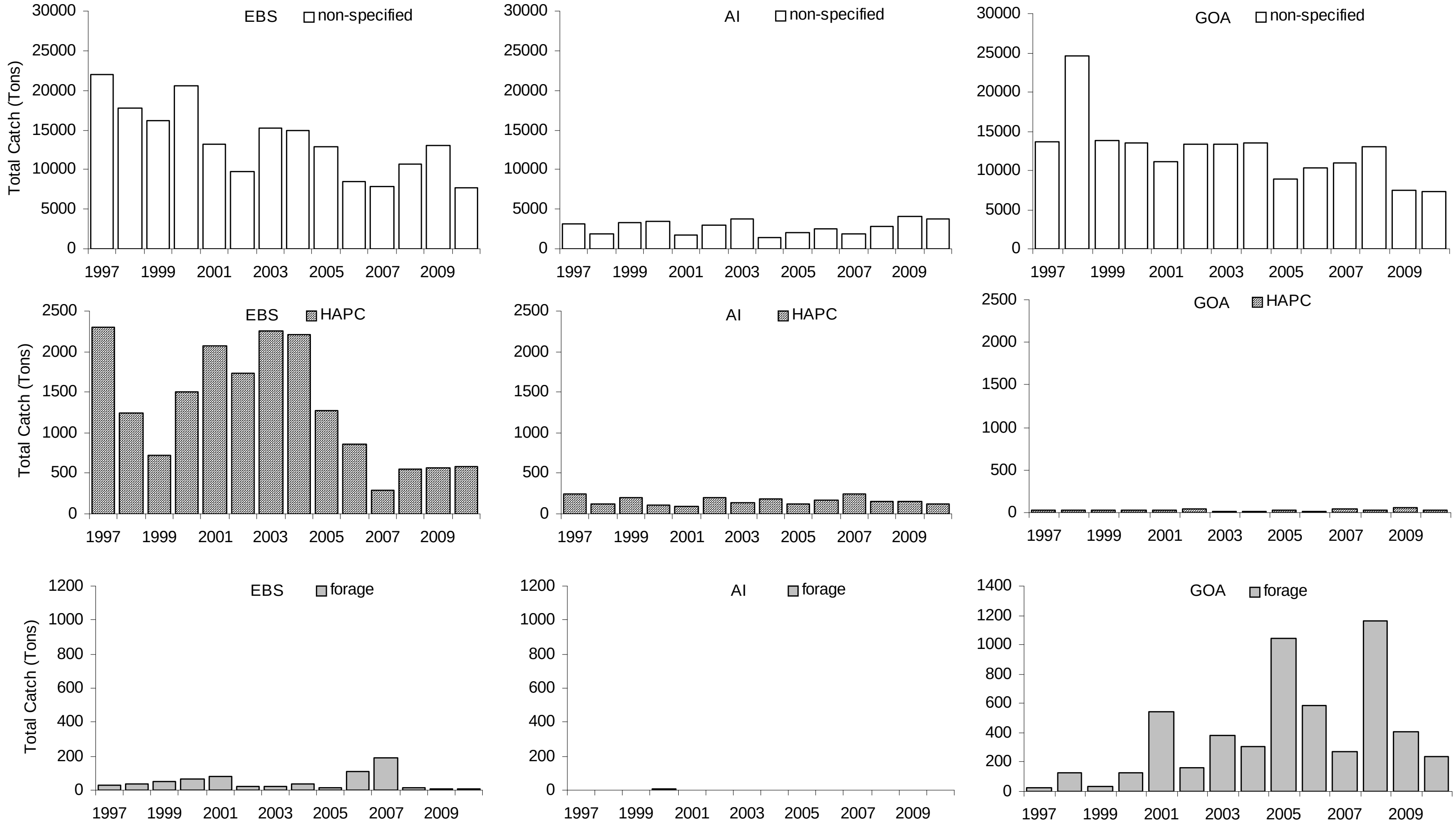


Figure 114: Total catch of non-target species (tons) in the EBS, AI, and GOA groundfish fisheries. Note: Incomplete 2011 data are not shown.

Status and trends: In all three ecosystems, non-specified catch comprised the majority of non-target catch during 1997-2007 (Figure 114). Non-specified 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.

In the EBS, the catch of non-specified species appears to have decreased overall since the late 1990s. Scyphozoan jellyfish, grenadiers and sea stars comprise the majority of the non-specified catches in the EBS. The 2008-2009 increase in non-specified catch was 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 2009-2010, when sponges and sea anemones increased in importance. 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 catches were recorded in 2009-2010. Grenadiers comprise the majority of AI non-specified species catch and are taken in flatfish and sablefish fisheries. HAPC 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. 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 2009-2010. The main species of forage fish caught are eulachon and they are primarily caught in the pollock fishery.

Factors causing observed 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 be 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 2011

Description of index: Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut)(Figure 115). 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. For additional background on fishery closures in the U.S. EEZ off Alaska, see Witherell and Woodby (2005).

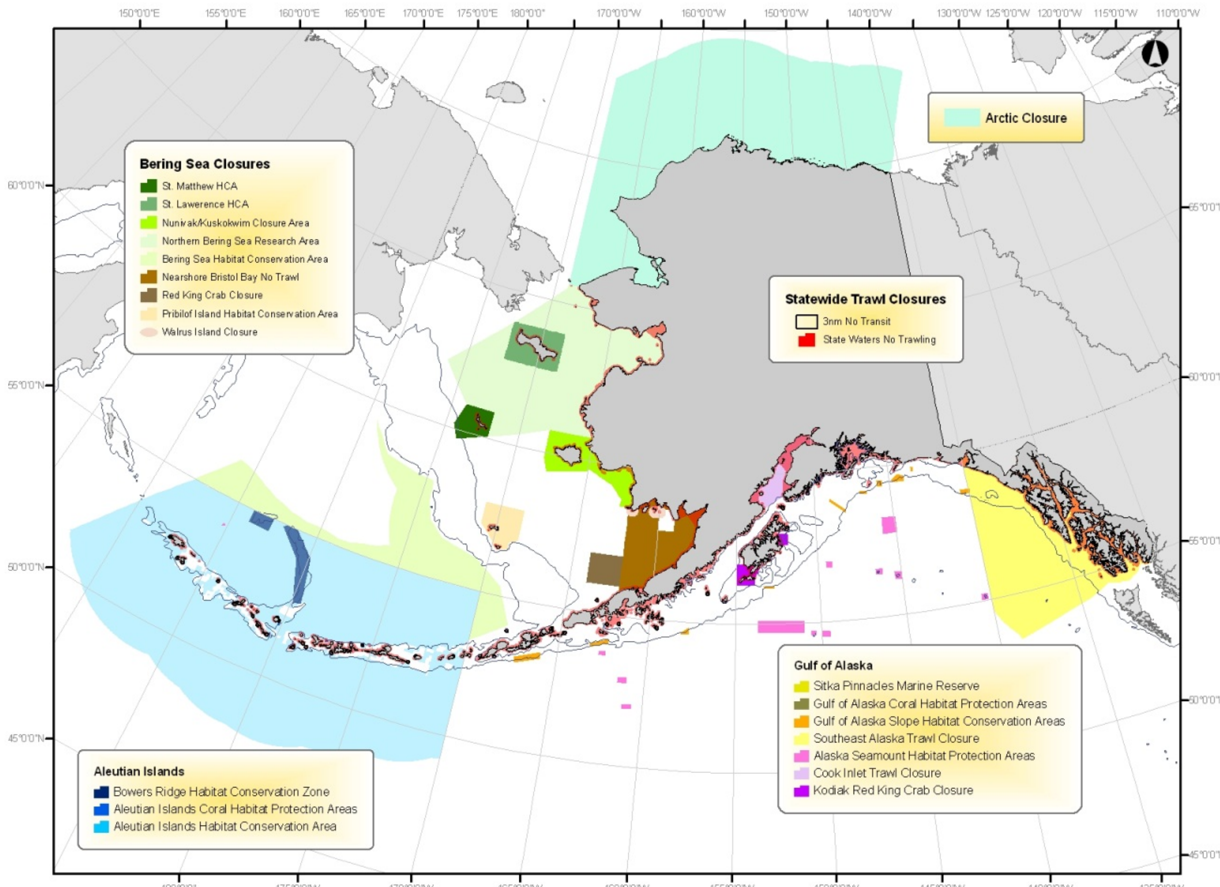

Figure 115: Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska, excluding most SSL closures.

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) of 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 nm^2 to the area closed to bottom trawling year round.

In 2010, the Council adopted area closures for Tanner crab east and northeast Kodiak. Federal waters in Marmot Bay are closed year round to vessels fishing with nonpelagic trawl. In two other designated areas, Chiniak Gully and ADF&G statistical area 525702, vessels with nonpelagic trawl gear can only fish if they have 100% observer coverage. To fish in any of the three areas, vessels fishing with pot gear must have minimum 30% observer coverage.

Substantial parts of the Aleutian Islands were closed to trawling for Atka mackerel and Pacific cod (the predominant target species in those areas) in early 2011 as part of mitigation measures for Steller sea lions. Management area 543 and the western half of 542 are included in this closure.

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

Steller Sea Lion closure maps are available here:

`http://www.fakr.noaa.gov/sustainablefisheries/sslpm/atka_pollock.pdf`

`http://www.fakr.noaa.gov/sustainablefisheries/sslpm/pcod_nontrawl.pdf`

`http://www.fakr.noaa.gov/sustainablefisheries/sslpm/cod_trawl.pdf`

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

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Last updated: October 2011

Description of index: Observed fishing effort (as measured by the number of longline sets fished) is used as an indicator of total fishing effort. It should be noted, however, that many vessels are catcher vessels either under 60' or between 60'-125', which do not require 100% observer coverage. These vessels either do not require an observer present (less than 60') or only on 30% of the fishing days (60'-125').The amount of effort in hook and line fisheries can be used as a proxy for habitat effects. 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. Changes in fishing effort are shown in anomaly plots that look at current effort relative to historical effort.

Status and trends: Effort in the hook and line fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 116.

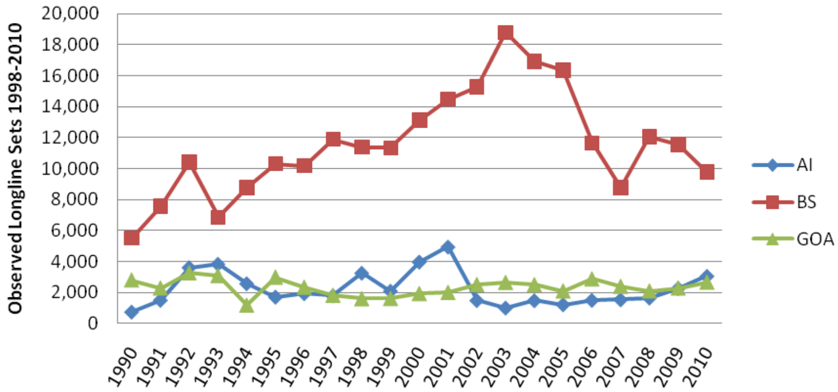

Figure 116: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of longline sets, 1990-2010.

Bering Sea. For the period 1998-2010, there were a total of 171,422 observed longline sets in the Bering Sea fisheries. Spatial patterns of fishing effort were summarized on a 10 km^2 grid (Figure 117). During 2010, the amount of observed longline effort was 9,766 sets, which represents a decrease from 2009 and is substantially lower than the 13-year average of 13,186. 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 2010, 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 118).

Aleutian Islands. For the period 1998-2010 there were 29,638 observed hook and line sets in the Aleutian Islands. During 2010, the amount of observed longline effort was 3,067 sets, considerably higher than both 2009 and the 13-year average. The spatial pattern of this effort was dispersed over a wide area. Patterns of high fishing effort were dispersed along the shelf edge (Figure 119). 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 2010, fishing effort anomaly showed increases south of Agattu Island, around Kiska Island, and to the south of Amlia Island. (Figure 120).

Gulf of Alaska. For the period 1998-2010 there were 29,275 observed hook and line sets in the Gulf of Alaska. During 20, the amount of observed longline effort was 2,667 sets, which is above the 13-year average. Patterns of high fishing effort were dispersed along the shelf (Figure 121). 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 and halibut have been IFQ fisheries 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 2010, fishing effort anomalies were varied throughout the region, with most of the increase occurring near the Shumagin Islands. (Figure 122).

Factors causing observed 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. Hook and line effort in both the Bering Sea and Aleutian Islands occurs mainly for Pacific cod, Greenland turbot, halibut and sablefish. The predominant hook and line fisheries in the Gulf of Alaska are composed of halibut, 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 and halibut have been an IFQ fishery since 1995, which has reduced the number of vessels, crowding, gear conflicts and gear loss, and increased efficiency.

Implications: The effects of changes in fishing effort on habitat are largely unknown. It is possible that increases in hook and line and pot fisheries could result in increased habitat loss/degradation due to fishing gear effects on benthic habitat and other species 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 living substrates in the areas fished, and management changes that result in spatial redistribution of fishing effort (NMFS, 2007)(`http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm`).

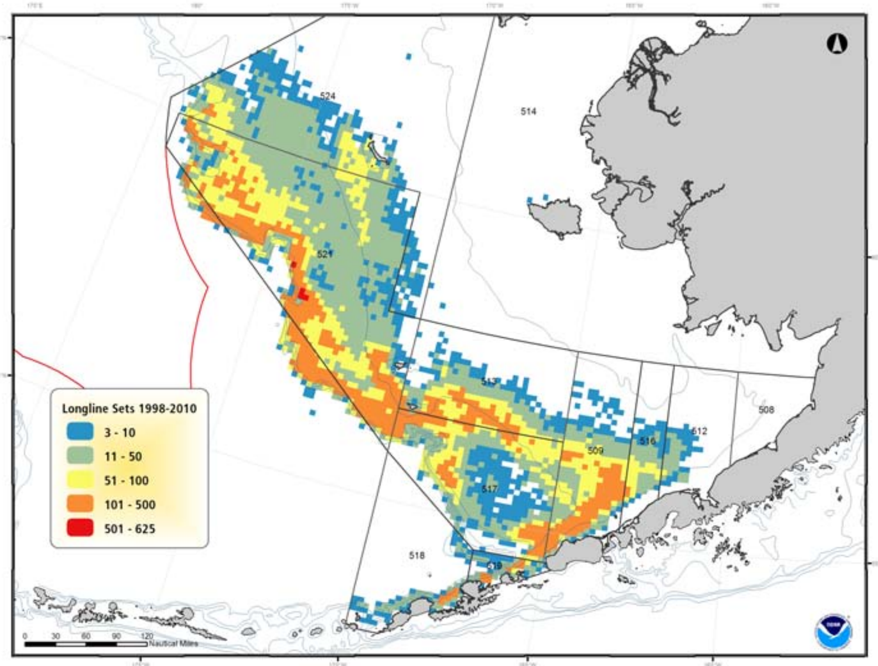

Figure 117: Longline effort (sets) in the Bering Sea 1998-2010.

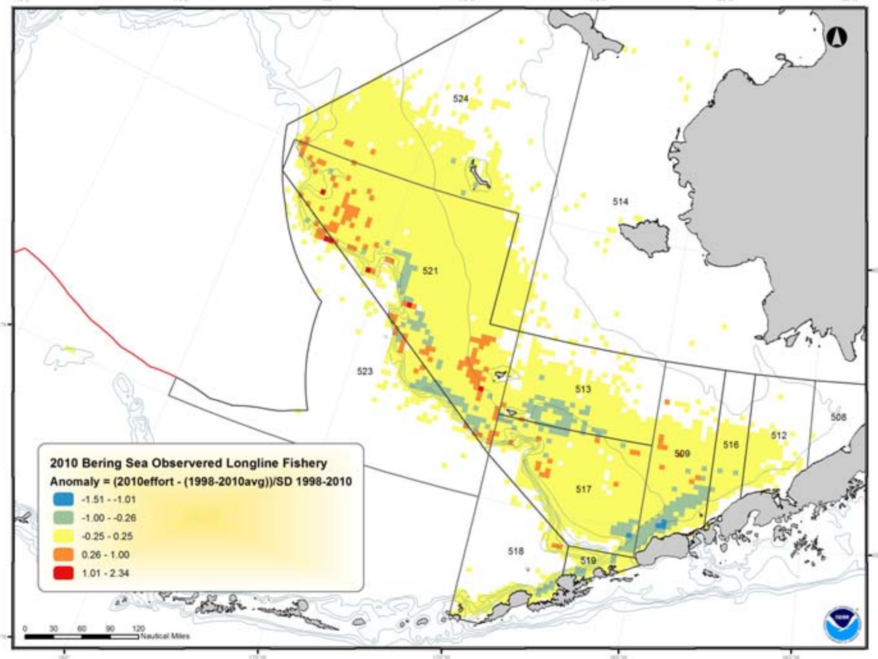

Figure 118: Observed hook and line fishing effort in 2010 relative to the 1998-2010 average in the Bering Sea. Anomalies calculated as (estimated effort for 2010 - average effort from 1998-2010)/stdev(effort from 1998-2010).

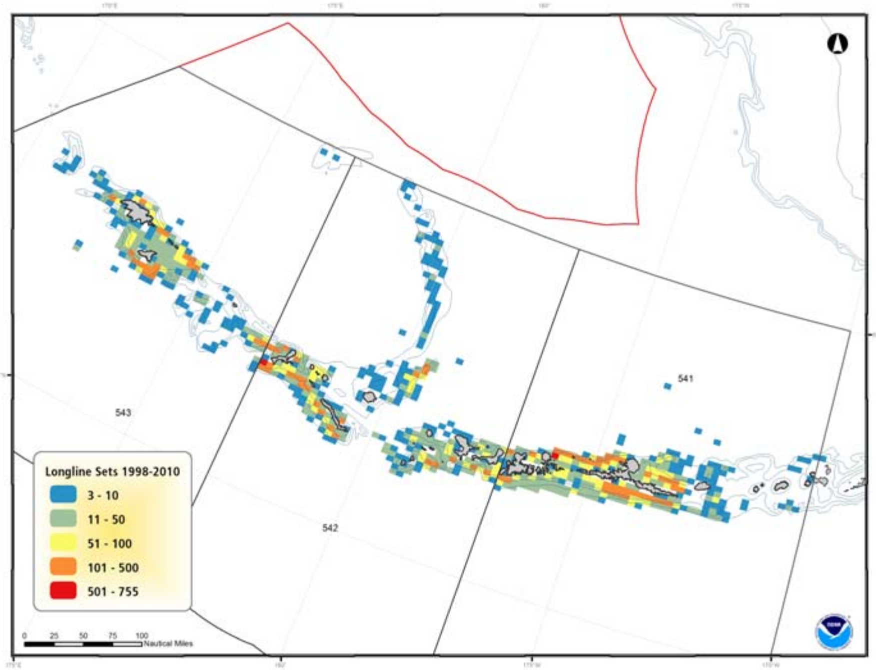

Figure 119: Longline effort (sets) in the Aleutian Islands, 1998-2010.

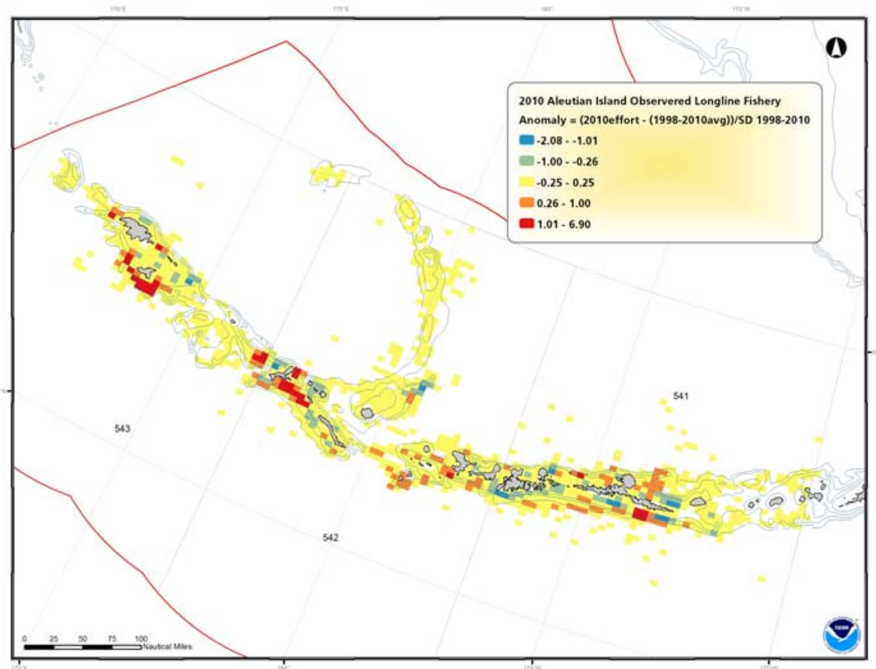

Figure 120: Observed hook and line fishing effort in 2010 relative to the 1998-2010 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2010 - average effort from 1998-2010)/stdev(effort from 1998-2010).

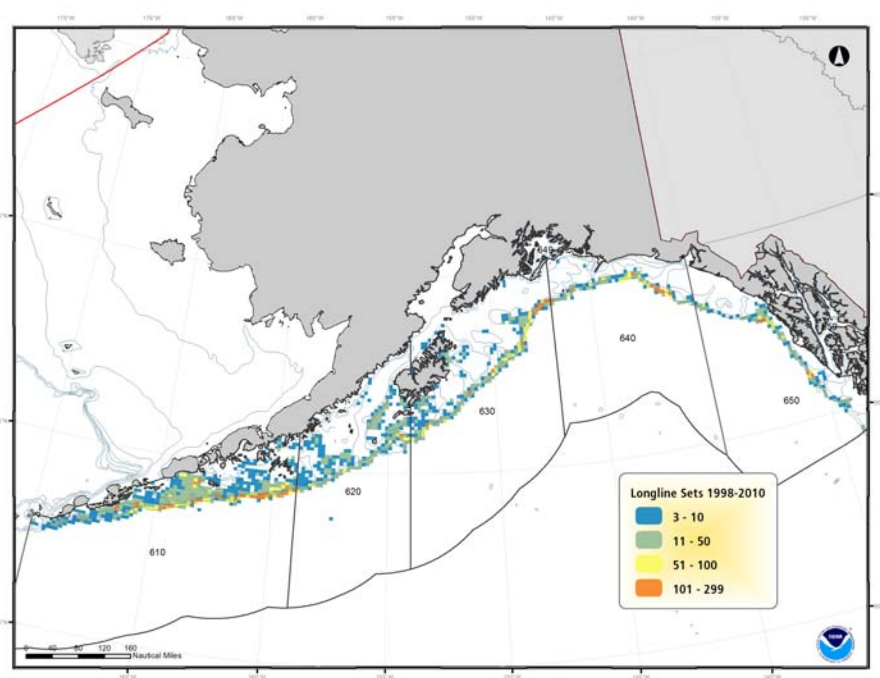

Figure 121: Longline effort (sets) in the Gulf of Alaska, 1998-2010.

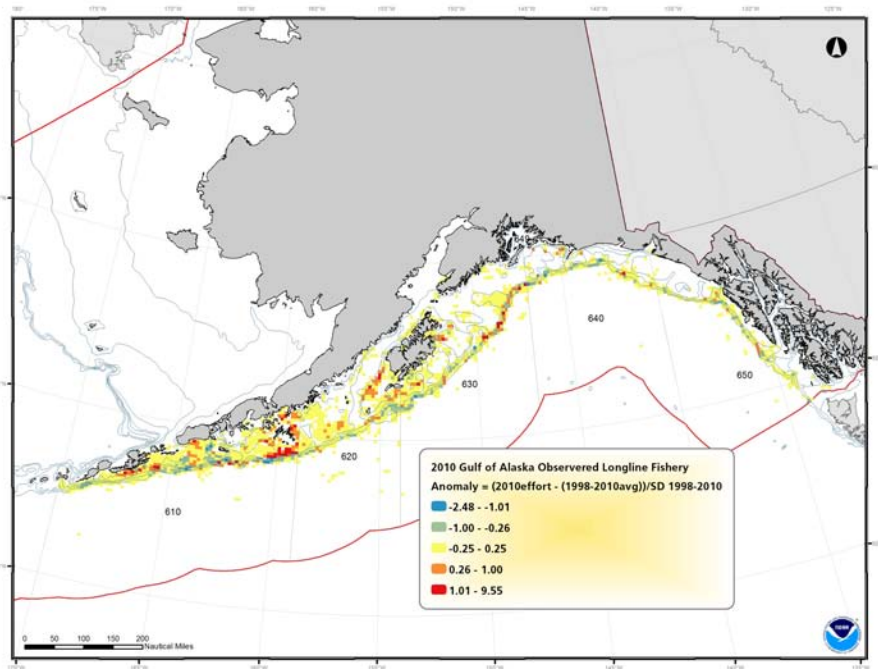

Figure 122: Observed hook and line fishing effort in 2010 relative to the 1998-2010 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2010 - average effort from 1998-2010)/stdev(effort from 1998-2010).

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

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
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Last updated: October 2011

Description of index: Bottom trawl and hook and line effort are measured as the number of tows fished. Observed fishing effort is used as an indicator of total fishing effort. It should be noted, however, that many vessels are catcher vessels either under 60' or between 60'-125', which do not require 100% observer coverage. These vessels either do not require an observer present (less than 60') or only on 30% of the fishing days (60'-125'). The amount of effort (as measured by the number of tows) in bottom trawl (non-pelagic trawl) fisheries can be used as proxy for the effects of trawling on habitat. The locations where bottom trawls have been used are of interest for understanding habitat effects.

Status and trends: 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 123). Effort in the Bering Sea remained relatively stable between 1993 and 2010. 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 cod and pollock. As of 1999, only pelagic trawls can be used in the Bering Sea pollock fisheries.

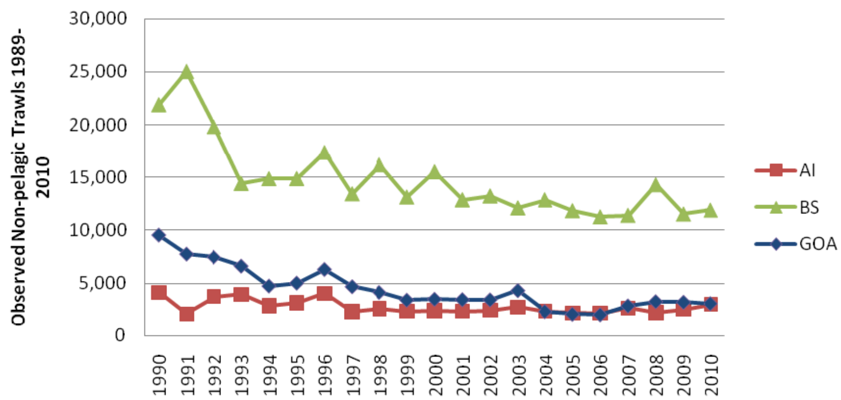

Figure 123: Gulf of Alaska, Bering Sea, and Aleutian Islands non-pelagic trawl effort (number of observed tows), 1990-2010.

Bering Sea. For the period 1998-2010, there were a total of 168,149 observed bottom trawl tows in the Bering Sea fisheries. During 2010, observed bottom trawl effort consisted of 11,896 tows, which was below average compared to the 13-year average. Spatial patterns of fishing effort were summarized on a 10 km2 grid (Figure 124). 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 2010, fishing effort was lower than average north of Unimak Island as well as some in the central Bering Sea (Figure 125). Higher fishing effort occurred in portions of 509, 513 and 516, as well as to the northwest of the Pribilof Islands in 521.

Aleutian Islands. For the period 1998-2010 there were 32,259 observed bottom trawl tows in the Aleutian Islands. During 2010, the amount of observed bottom trawl effort was 3,014 tows, which was above average for the 13-year period. Patterns of high fishing effort were dispersed along the shelf edge (Figure 126). 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 2010, areas of anomalous fishing effort were scattered throughout the region and catch was comprised of Atka mackerel, Pacific cod and rockfish (Figure 127). One area of much higher catch was north of Yunaska Island in area 541. 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. New management measures for the cod and mackerel fisheries in 542 and 543 will likely greatly change effort distribution in 2011.

Gulf of Alaska. For the period 1998-2010 there were 41,529 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 2010, the amount of trawl effort was 3,113 tows, which was approximately average for the 13-year period. Patterns of high fishing effort were dispersed along the shelf edge with high pockets of effort near Chirkoff, Cape Barnabus, Cape Chiniak and Marmot Flats (Figure 128). 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 2010, areas of higher than average fishing effort were scattered to the east side of Kodiak to the shelf break. (Figure 129).

Factors causing observed trends: 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. 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 cod and pollock.

Implications: Fishing effort is an indicator of damage to or removal of both living and nonliving bottom substrates, damage to small epifauna and infauna, and reduction in benthic biodiversity by mobile (trawl) or fixed (longline, pot) 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. These changes in effort can be observed by examining effort for the current year relative to the average effort in prior years of fishing

The effects of changes in fishing effort on habitat 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 and other species. 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 living substrates in the areas fished, and management changes that result in spatial redistribution of fishing effort (NMFS, 2007)(`http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm`).

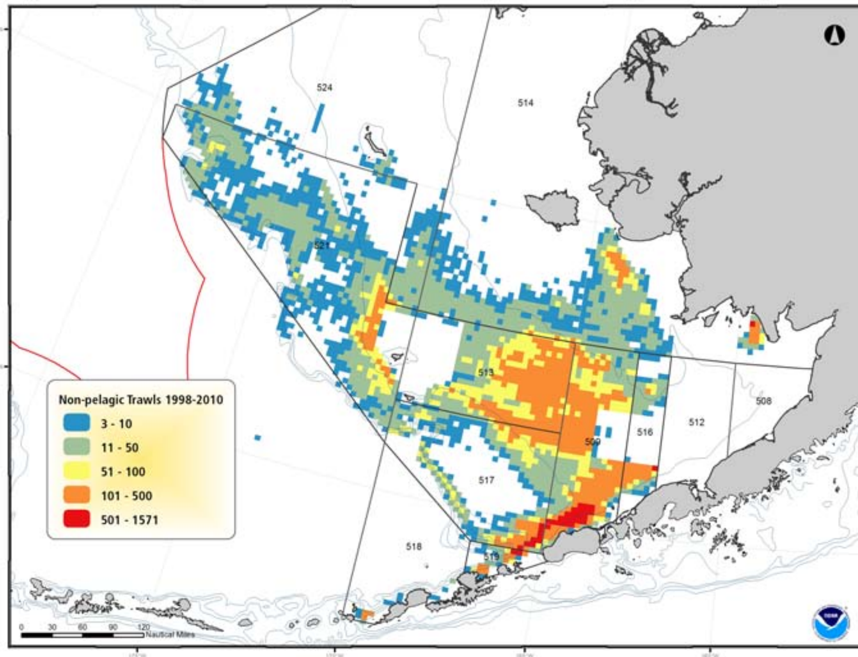

Figure 124: Spatial location and density of non-pelagic trawling in the Bering Sea, 1998-2010.

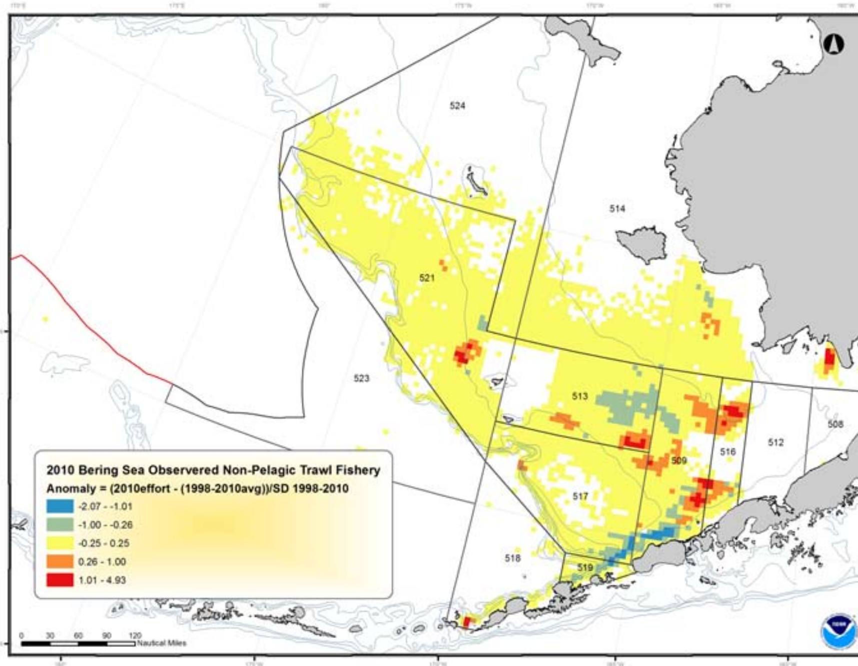

Figure 125: Observed non-pelagic trawl fishing effort in 2010 relative to the 1998-2010 average in the Bering Sea. Anomalies calculated as (estimated effort for 2010 - average effort from 1998-2010)/stdev(effort from 1998-2010).

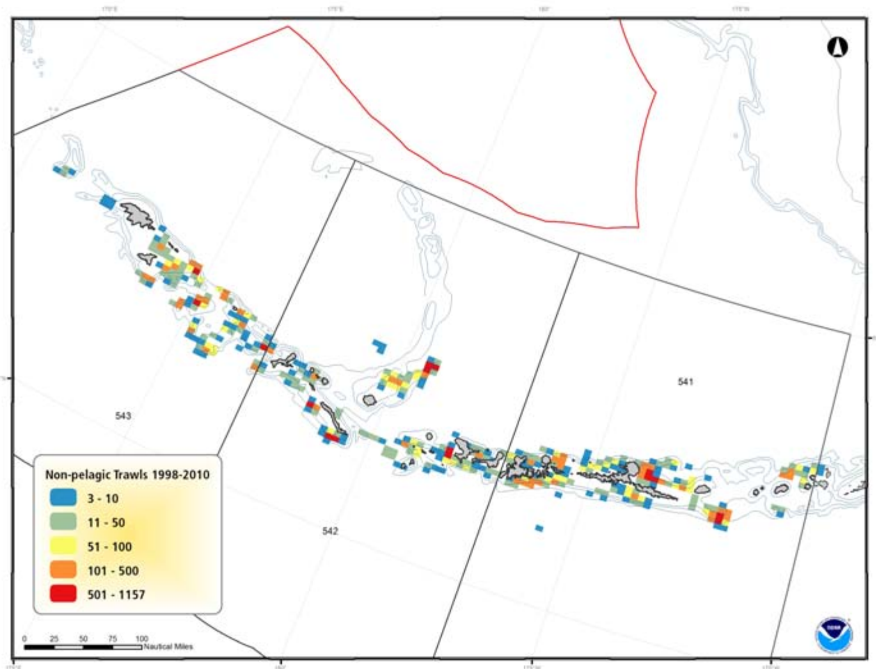

Figure 126: Spatial location and density of bottom trawl effort in the Aleutian Islands, 1998-2010.

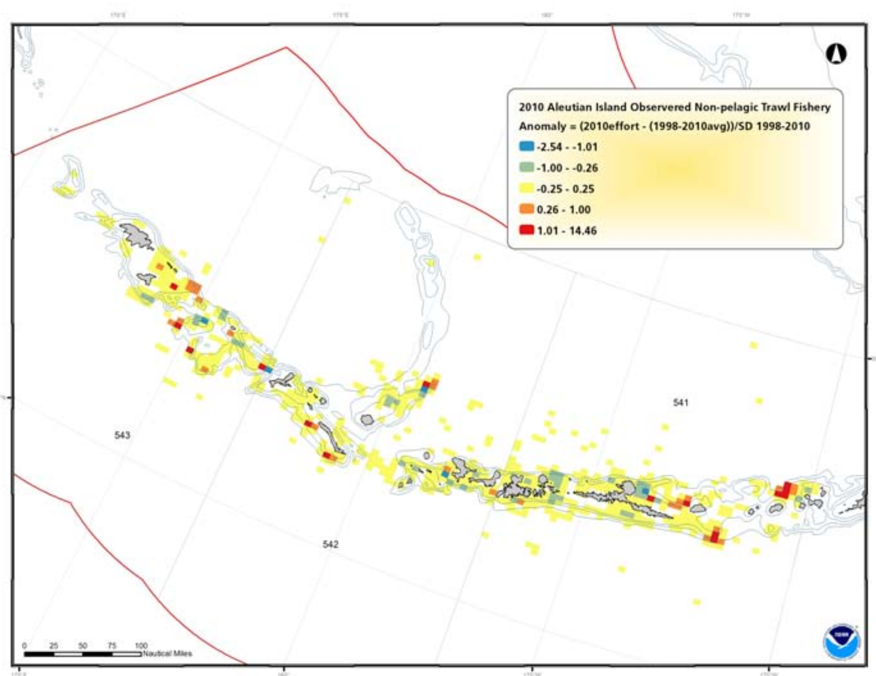

Figure 127: Observed non-pelagic trawl fishing effort in 2010 relative to the 1998-2010 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2010 - average effort from 1998-2010)/stdev(effort from 1998-2010).

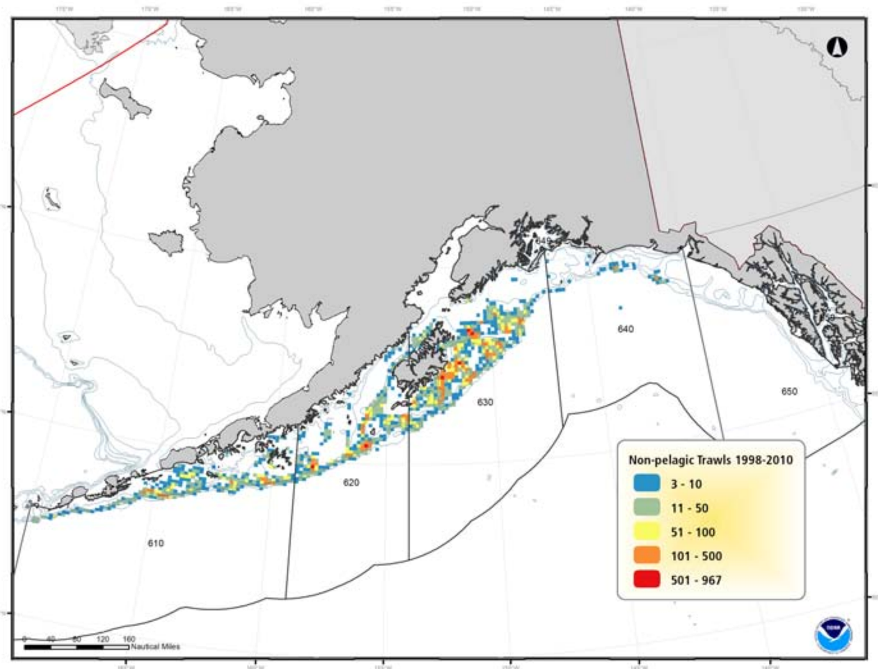

Figure 128: Spatial location and density of bottom trawl effort in the Gulf of Alaska, 1998-2010.

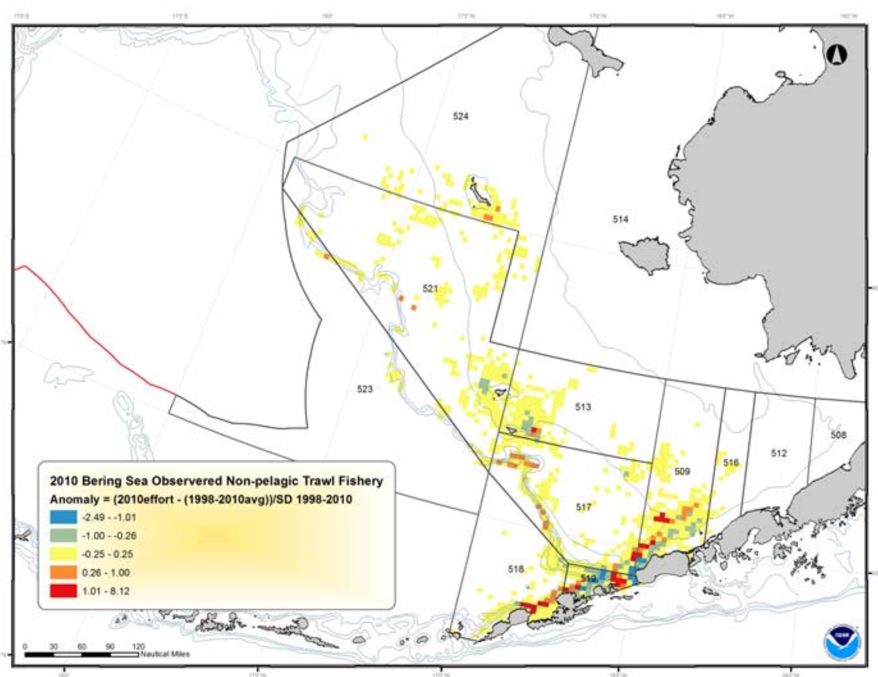

Figure 129: Observed non-pelagic trawl fishing effort in 2010 relative to the 1998-2010 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2010 - average effort from 1998-2010)/stdev(effort from 1998-2010).

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

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
Contact: john.v.olson@noaa.gov
Last updated: October 2011

Description of index: Pelagic trawl effort is measured as the number of tows fished. Observed fishing effort is used as an indicator of total fishing effort. It should be noted, however, that many vessels are catcher vessels either under 60' or between 60'-125', which do not require 100% observer coverage. These vessels either do not require an observer present (less than 60') or only on 30% of the fishing days (60'-125').

Status and trends: Effort in the pelagic trawl fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 130. 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 96-100 show the spatial patterns and intensity of pelagic trawl effort by region, based on observed data.

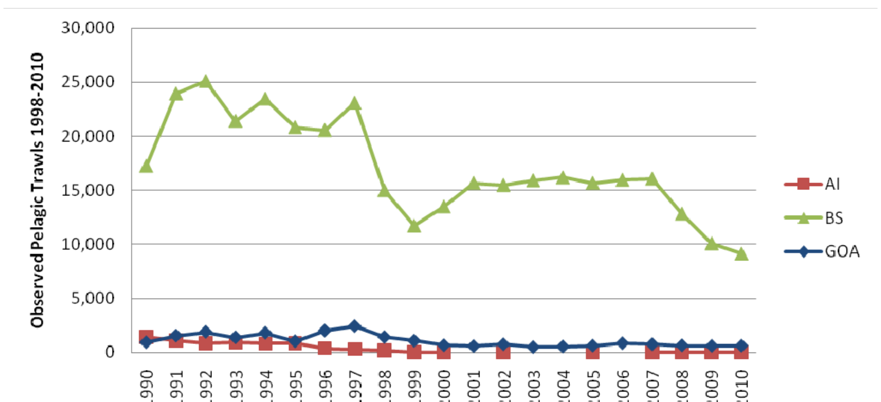

Figure 130: Gulf of Alaska, Bering Sea, and Aleutian Islands pelagic trawl effort (number of observed tows), 1990-2010.

Bering Sea. For the period 1998-2010 there were 183,283 observed pelagic trawl tows in the Bering Sea (Figure 131). There were 9,143 observed tows in 2010, which is significantly lower than the 13-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 occur on the sea bottom, the midwater and up to the surface. Most catch of pollock is taken at 50-300m. In 2010, as in 2009, fishing effort was anomalously low north of Unimak Island, an area of normally high fishing effort. Increased fishing effort occurred along the shelf break to the west and north of the Pribilof Islands in Area 521 (Figure 132). 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.

Aleutian Islands. For the period 1998-2010 there were 297 observed bottom trawl tows in the Aleutian Islands. In 2001, 2003, 3004, and 2006 there were no observed pelagic trawl tows. There were only 11 observed tows in 2010. Patterns of high fishing effort were historically dispersed along the shelf edge. As only 11 tows were recorded in the Aleutian Islands in 2010, maps of effort and anomaly are not included.

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 1998-2010 there were 9,495 observed pelagic trawl tows in the Gulf of Alaska (Figure 133). The spatial pattern of this effort centers on Kodiak, specifically Chiniak Gully and Marmot Bay, with limited fishing on the shelf break to the east and west. During 2010, the amount of trawl effort was 607 tows, which was below the 13-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 2010 was variable, but most effort was centered in areas 620-630 (Figure 134).

Factors causing observed 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 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.

In 1990, concerns about bycatch and seafloor habitats affected by the large Bering Sea pelagic trawl 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. Bering Sea chinook and chum bycatch led to NPFMC action limiting the total bycatch of these species. More information is available at `http://www.fakr.noaa.gov/npfmc/bycatch-controls/BSChinookBycatch.html`.

Management measurements have affected the pelagic trawl 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 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.

Implications: Fishing effort is an indicator of damage to or removal of both living and nonliving bottom substrates, damage to small epifauna and infauna, and reduction in benthic biodiversity by mobile (trawl) or fixed (longline, pot) 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. These changes in effort can be observed by examining effort for the current year relative to the average effort in prior years of fishing

The effects of changes in fishing effort on habitat 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 and other species. 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 living substrates in the areas fished, and management changes that result in spatial redistribution of fishing effort (NMFS, 2007)(`http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm`).

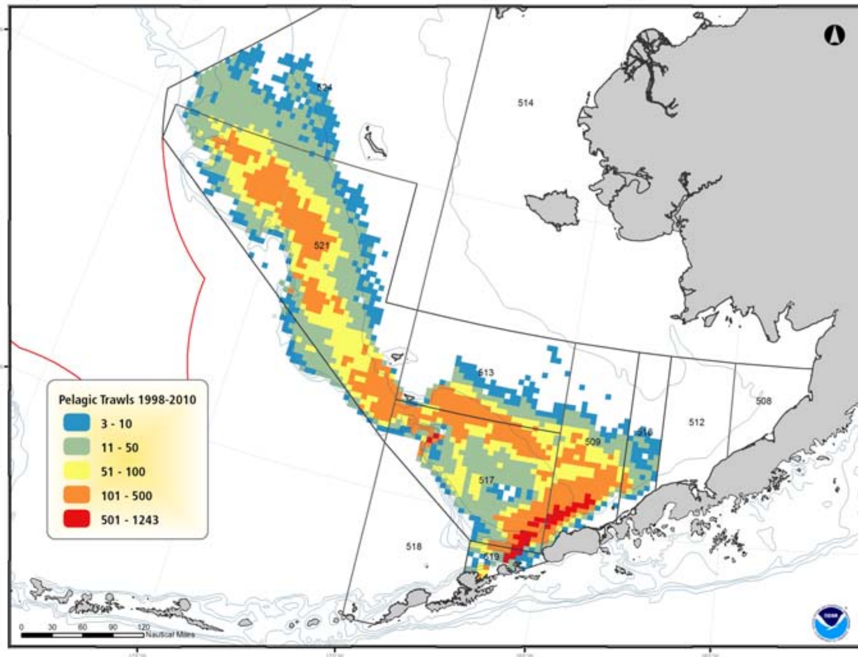

Figure 131: Spatial location and density of pelagic trawling in the Bering Sea, 1998-2010.

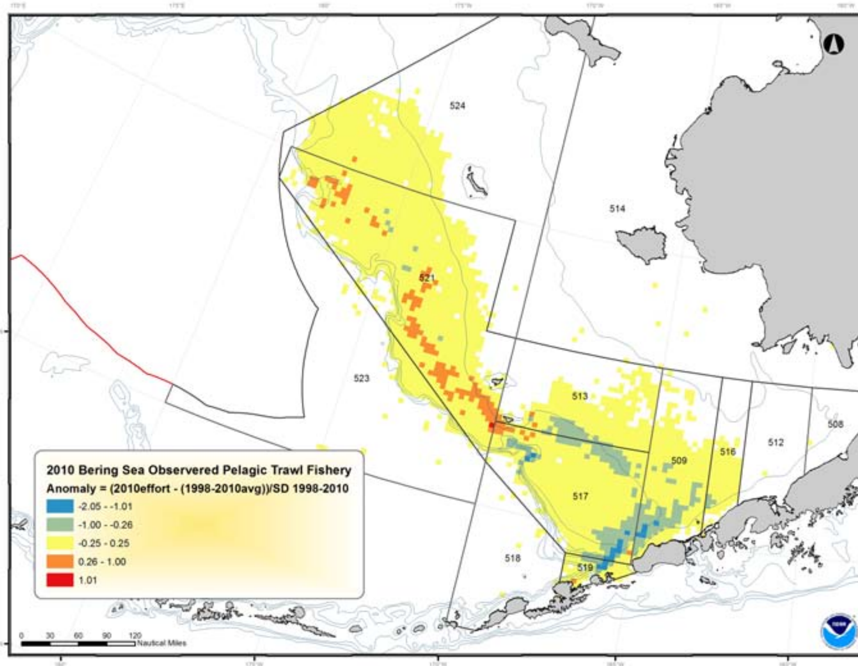

Figure 132: Observed pelagic trawl fishing effort in 2010 relative to the 1998-2010 average in the Bering Sea. Anomalies calculated as (estimated effort for 2010 - average effort from 1998-2010)/stdev(effort from 1998-2010).

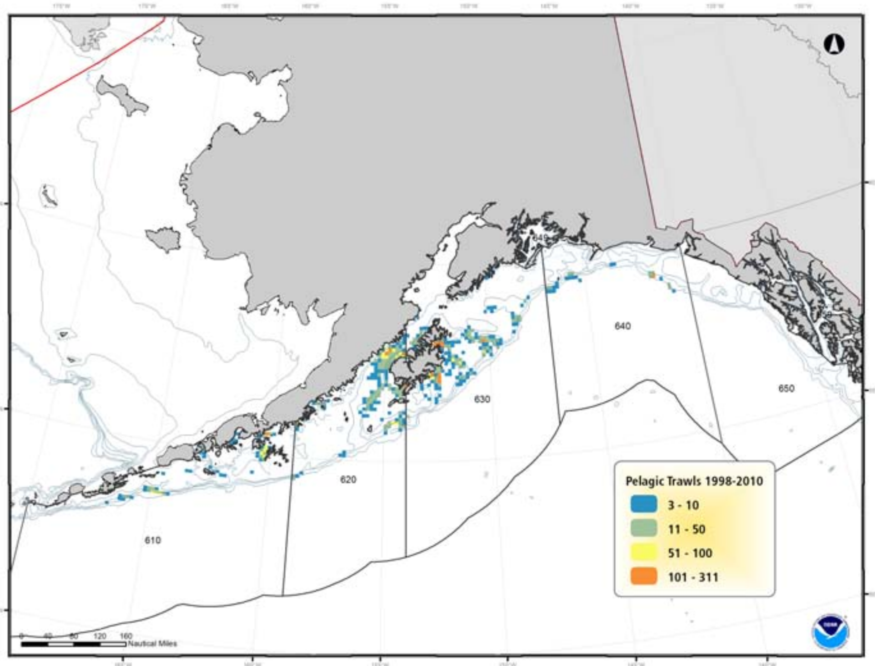

Figure 133: Spatial location and density of bottom trawl effort in the Gulf of Alaska, 1998-2010.

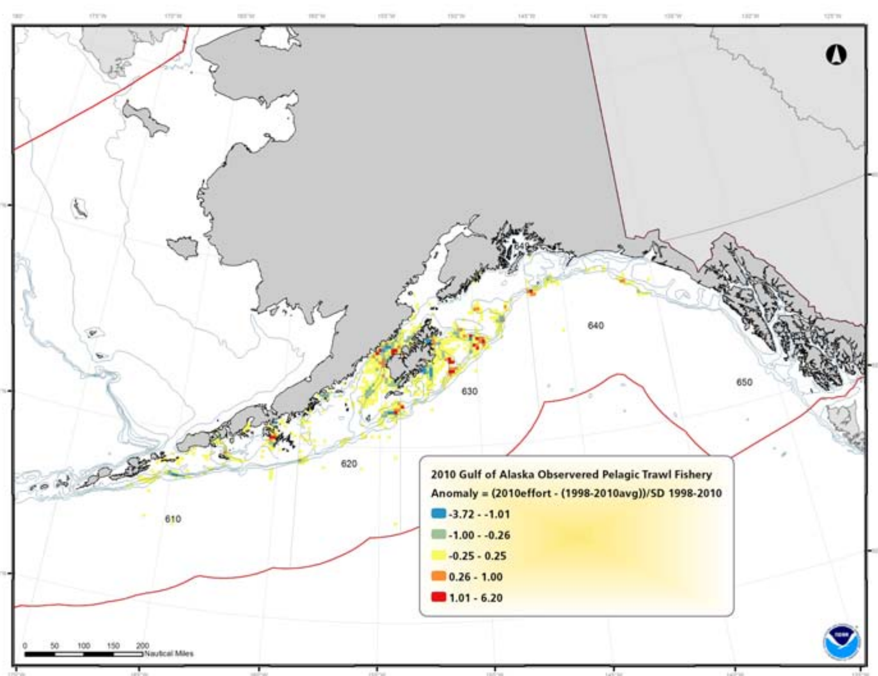

Figure 134: Observed pelagic trawl fishing effort in 2010 relative to the 1998-2010 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2010 - average effort from 1998-2010)/stdev(effort from 1998-2010).

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

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
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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. Observed fishing effort is used as an indicator of total fishing effort. It should be noted, however, that many vessels are catcher vessels either under 60' or between 60'-125', which do not require 100% observer coverage. These vessels either do not require an observer present (less than 60') or only on 30% of the fishing days (60'-125').

Status and trends: The observed pot fishing effort was similar to that seen in the last decade in all regions. Effort in the pot fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 135.

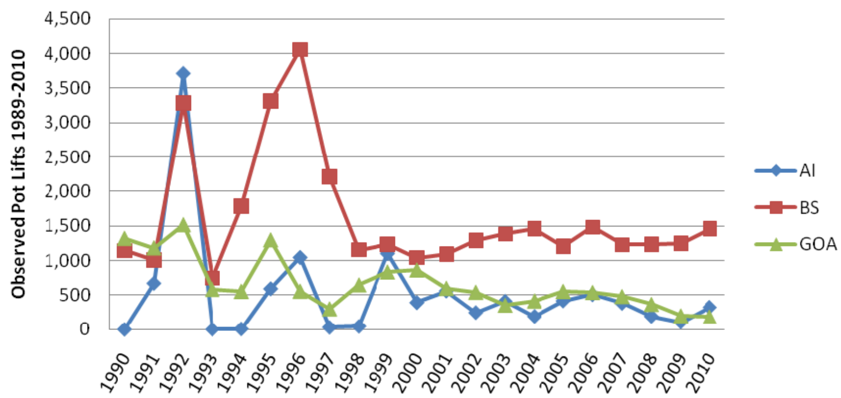

Figure 135: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of pot lifts, 1990-2010.

Bering Sea. For the period 1998-2010, there were a total of 16,518 observed pot lifts in the Bering Sea fisheries. During 2010, the amount of observed pot effort was 1,458 lifts, which is relatively consistent with the 13-year average of 1,255. Spatial patterns of fishing effort were summarized on a 10 km2 grid (Figure 136). 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 137). 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 1998-2010 there were 4,893 observed pot lifts in the Aleutian Islands. During 2010, the amount of observed pot effort was 325 lifts, which represents a steep increase from 2009 but is below the 13-year average of 376. High fishing effort was dispersed along the shelf edge with highest historic effort near Seguam Island (Figure 138). In 2010, the fishing anomaly was highest around Kiska and Adak Islands, with decreases to the east near Seguam Pass (Figure 139).

Gulf of Alaska. For the period 1998-2010 there were 6,614 observed pot lifts in the Gulf of Alaska. During 2010, the amount of observed pot effort was 188 lifts, which represents a decline from 2009 and also well below the 13-year average of 509. Patterns of higher fishing effort were dispersed along the shelf around Kodiak Island (Figure 140). Fishing effort in 2010 was varied in areas 610 and 630, with areas of both above and below long term averages (Figure 141). 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.

Factors causing observed trends: Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures, crab and habitat closures) as well as changes in markets and increased bycatch rates of non-target species. 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.

Implications: The effects of changes in fishing effort on habitat 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 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 living substrates in the areas fished, and management changes that result in spatial redistribution of fishing effort (NMFS, 2007)(`http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm`).

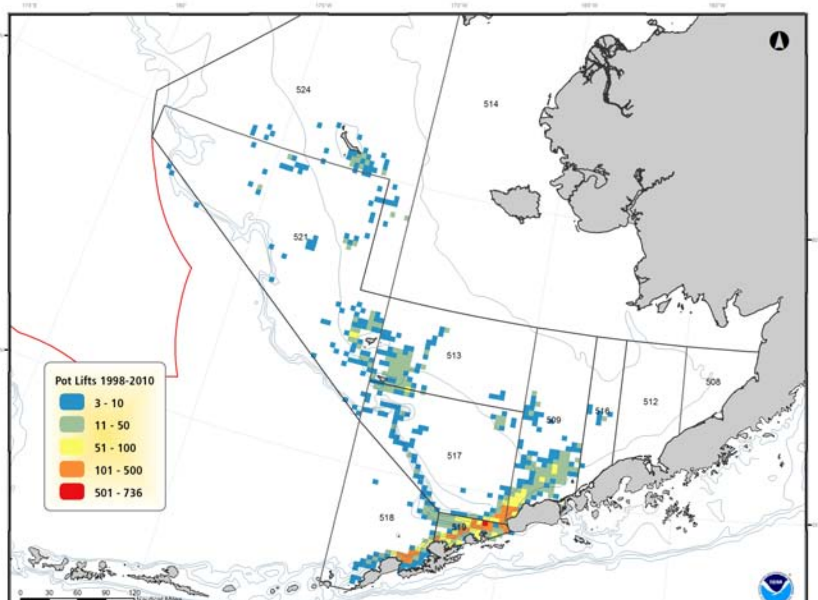

Figure 136: Spatial location and density of observed pot effort (observed number of pot lifts) in the Aleutian Islands, 1998-2010.

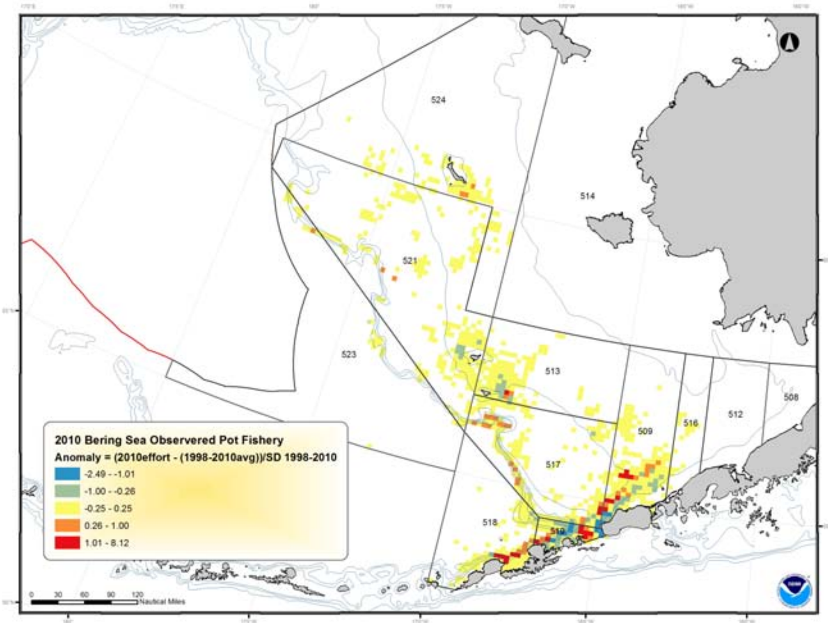

Figure 137: Observed pot fishing effort in 2010 relative to the 1998-2010 average in the Bering Sea. Anomalies calculated as (estimated effort for 2010 - average effort from 1998-2010)/stdev(effort from 1998-2010).

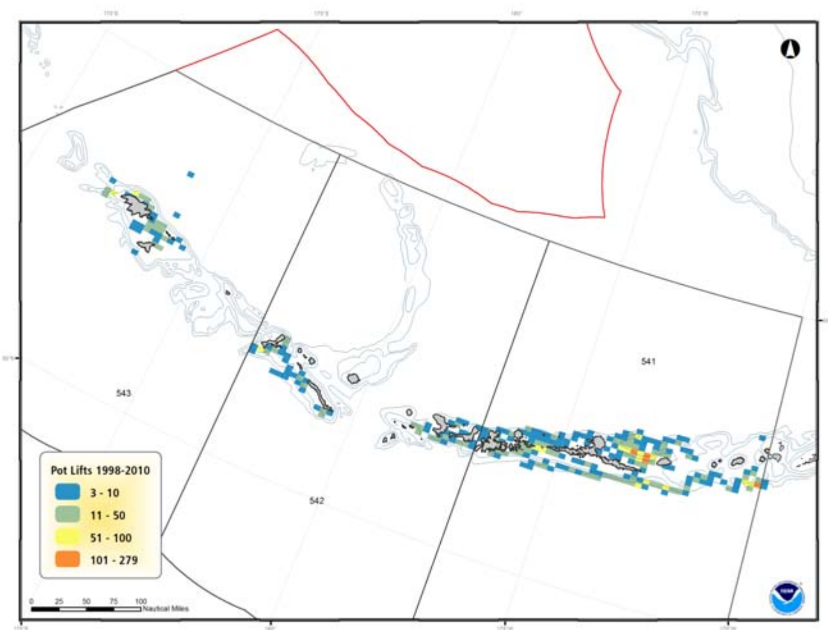

Figure 138: Spatial location and density of observed pot effort (observed number of pot lifts) in the Bering Sea, 1998-2010.

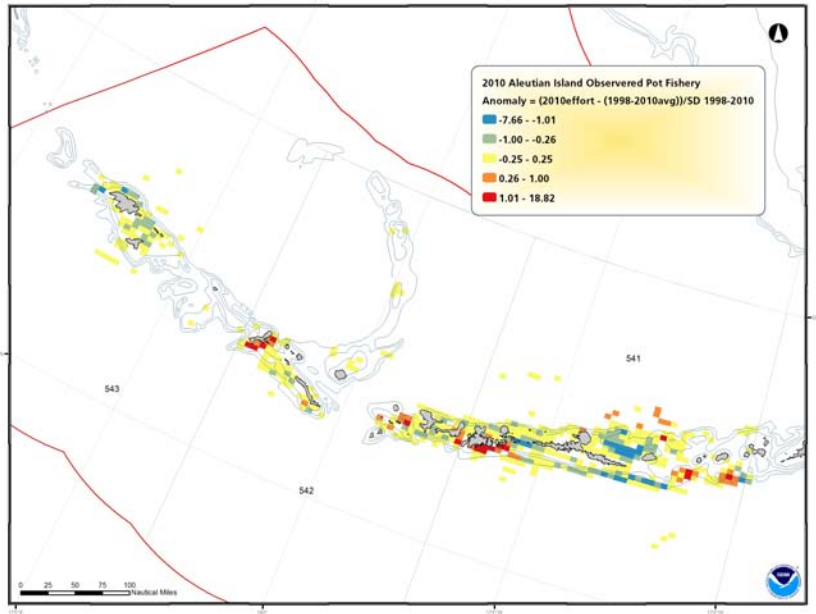

Figure 139: Observed pot fishing effort in 2010 relative to the 1998-2010 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2010 - average effort from 1998-2010)/stdev(effort from 1998-2010).

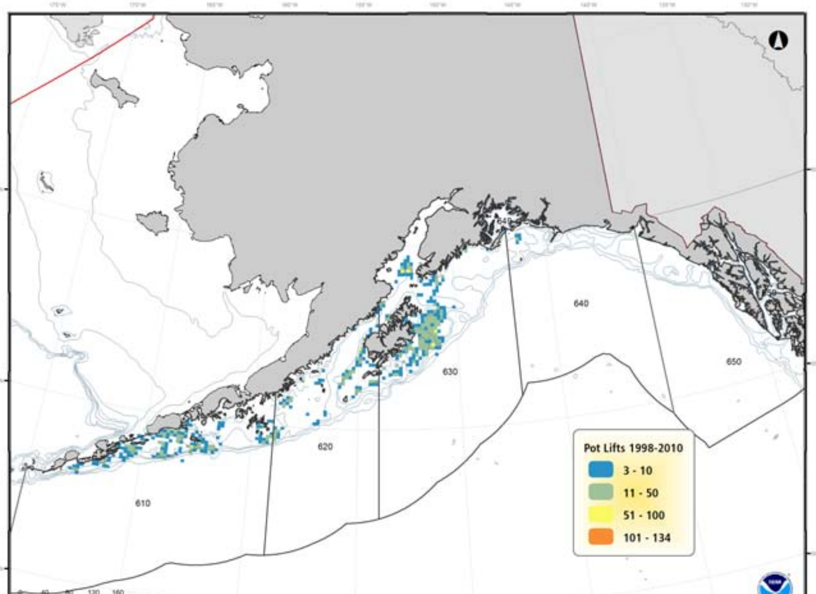

Figure 140: Spatial location and density of observed pot (observed number of pot lifts) effort in the Gulf of Alaska, 1998-2010.

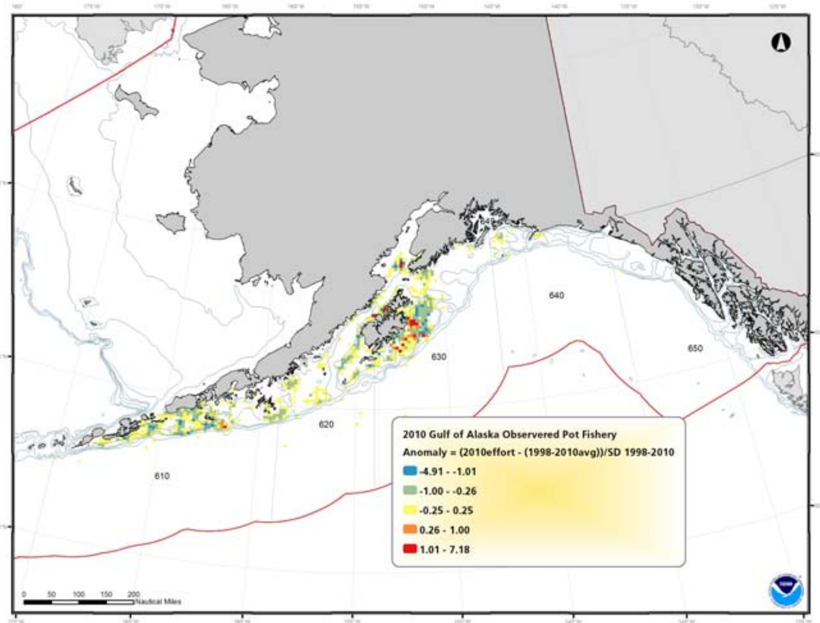

Figure 141: Observed pot fishing effort in 2010 relative to the 1998-2010 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2010 - average effort from 1998-2010)/stdev(effort from 1998-2010).

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

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

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Last updated: August 2011

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

Table 11: 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	2	29	0	4	0
NPFMC and IPHC	NonFSSI	35	0	21	7	7	0	4	4	27	0
	Total	70	0	56	7	7	2	33	4	31	0

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 11 and 12). There are also 28 non-FSSI stocks in Alaska (Tables 11 and 13). 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. In this current report, groups previously reported in the larger "Other Species" complex, have been separated out into their respective assemblage units (e.g. Sculpin complex).

Status and trends: As of June 30, 2011, 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 11 and 12). Stocks that are considered overfished are Pribilof Island blue king crab and BSAI tanner crab. The Pribilof Island blue king crab is on a continuing rebuilding plan (year 8 of 10-year plan) while the management required for the tanner crab stock is to develop a rebuilding plan. The BS snow crab stock is also on a continuing rebuilding plan (year 11 of 10-year plan). For this stock, the NPFMC is revising the rebuilding plan, which will extend the rebuilding target date. In the meantime, there is no directed fishing for snow crab, and the majority of blue king crab habitat is closed to bottom trawling.

The current overall Alaska FSSI for FSSI stocks is 119 of a possible 140 score, based on updates through June 2011 (Table 12). The overall Bering Sea/Aleutian Islands score is 76 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 25 of a possible score of 36. The Gulf of Alaska groundfish score is 43 of a maximum possible 48.

Factors causing trends: The stocks that had low FSSI scores (1.5) in the GOA are shortspine thornyhead rockfish (indicator species for thornyhead rockfish complex) and yelloweye rockfish (indicator species for demersal shelf rockfish complex). The reasons for these low scores are: 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.

Table 12: FSSI stocks under NPFMC jurisdiction updated August 2011, 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 8 of 10	0.07	2
Blue King Crab-St. Matthews Is.	No[a]	No	No	N/A	N/A	2.23	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	1.33	4
Red King Crab-Norton Sound	No	No	No	N/A	N/A	1.74	4
Red King Crab-Pribilof Is.	No[a]	No	N/A	N/	N/A	0.65	3
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 11 of 10[b]	0.77	3
Southern Tanner Crab-Bering Sea	No	Yes	N/A	Dev. rebuilding[c]	Dev. rebuilding[c]	0.31	2
BSAI Alaska plaice	No	No	No	N/A	N/A	1.93	4
Atka Mackerel-Aleutian Is.	No	No	No	N/A	N/A	1.6	4
BSAI Arrowtooth Flounder Complex[d]	No	No	No	N/A	N/A	3.16	4
BSAI Blackspotted/Rougyeye Rockfish[e]	No	No	No	N/A	N/A	0.9	4
BSAI Flathead Sole Complex[f]	No	No	No	NA/	N/A	2.05	4
BSAI Rock Sole Complex[g]	No	No	No	N/A	N/A	2.06	4
BSAI Greenland halibut	No	No	No	N/A	N/A	2.26	4
BSAI Northern rockfish	No	No	No	N/A	N/A	1.63	4
BSAI Pacific cod	No	No	No	N/A	N/A	0.91	4
BSAI Pacific ocean perch	No	No	No	N/A	N/A	1.66	4
Walleye pollock-Aleutian Is.	No	No	No	N/A	N/A	0.84	4
Walleye pollock-EBS	No	No	No	N/A	N/A	0.62	3
BSAI Yellowfin sole	No	No	No	N/A	N/A	1.75	4
BSAI GOA Sablefish[h]	No	No	No	N/A	N/A	1.1	4

Table 12: FSSI stocks under NPFMC jurisdiction updated August 2011, 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	2.99	4
GOA Flathead sole	No	No	No	N/A	N/A	2.82	4
GOA Blackspotted/Rougheye Rockfish[e]	No	No	No	N/A	N/A	1.53	4
GOA Deepwater Flatfish Complex[i]	No	No	No	N/A	N/A	2.58	4
GOA Demersal Shelf Rockfish Complex[j]	No	Undef	Unk	N/A	N/A	Not estimated	1.5
GOA Pelagic Shelf Rockfish Complex[k]	No	No	No	N/A	N/A	1.54	4
GOA Thornyhead Rockfish Complex[l]	No	Undef	Unk	N/A	N/A	Not estimated	1.5
Northern rockfish-West/Cent GOA	No	No	No	N/A	N/A	1.62	4
GOA Pacific cod	No	No	No	N/A	N/A	1.37	4
GOA Pacific ocean perch	No	No	No	N/A	N/A	1.35	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	0.82	4

[a] Fishery in the EEZ is closed; therefore, fishing mortality is very low. [b] The NPFMC is revising the rebuilding plan for snow crab, which will extend the rebuilding target date. In the meantime, there is no directed fishing for snow crab, and the majority of blue king crab habitat is closed to bottom trawling [c] The NPFMC was notified by the Alaska Regional Office on October 1, 2010 that Southern tanner crab is overfished. The NPFMC has 2 years from this date to implement a rebuilding plan for Souther Tanner crab-Bering Sea [d] 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. [e] 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. [f] 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. [g] 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. [h] 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. [i] 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. [j] 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. [k] 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. [l] 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

See the 2010 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

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

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

Ecosystem Goal: Humans are part of ecosystems

Fishing Overcapacity Programs

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Groundfish Fleet Composition

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Table 13: Non-FSSI stocks updated October 2010, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`. See website for definition of stocks and stock complexes.

Stock	Jurisdiction	Overfishing?	Overfished?	Approaching?
Golden King Crab-Pribilof Is.	NPFMC	No	Undef	Unk
BSAI Octopus Complex	NPFMC	Unk	Undef	Unk
BSAI Other Flatfish Complex	NPFMC	No	Undef	Unk
BSAI Other Rockfish Complex	NPFMC	No	Undef	Unk
BSAI Sculpin Complex	NPFMC	Unk	Undef	Unk
BSAI Shark Complex	NPFMC	Unk	Undef	Unk
BSAI Skate Complex	NPFMC	No	No	Unk
BSAI Squid Complex	NPFMC	No	Undef	Unk
BSAI Kamchatka Flounder	NPFMC	Undef	Undef	Unk
BSAI Shortraker Rockfish	NPFMC	No	Undef	Unk
Walleye Pollock - Bogoslof	NPFMC	No	Und	Unk
GOA Atka mackerel - Gulf of Alaska	NPFMC	No	Undef	Unk
GOA Big skate - Gulf of Alaska	NPFMC	No	Undef	Unk
GOA Octopus Complex	NPFMC	Unk	Undef	Unk
GOA Other Slope Rockfish Complex	NPFMC	No	Undef	Unk
GOA Other Skulpin Complex	NPFMC	Unk	Undef	Unk
GOA Shallow Water Flatfish Complex	NPFMC	No	Undef	Unk
GOA Shark Complex	NPFMC	Unk	Undef	Unk
GOA Alaska Skate Complex	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	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	Unk	N/A
Saffron cod	NPFMC	No	Unk	N/A
Snow crab	NPFMC	No	Unk	N/A
Pacific halibut-Pac. NW/Alaska	IPHC/NPFMC/PFMC	Undef	No	No

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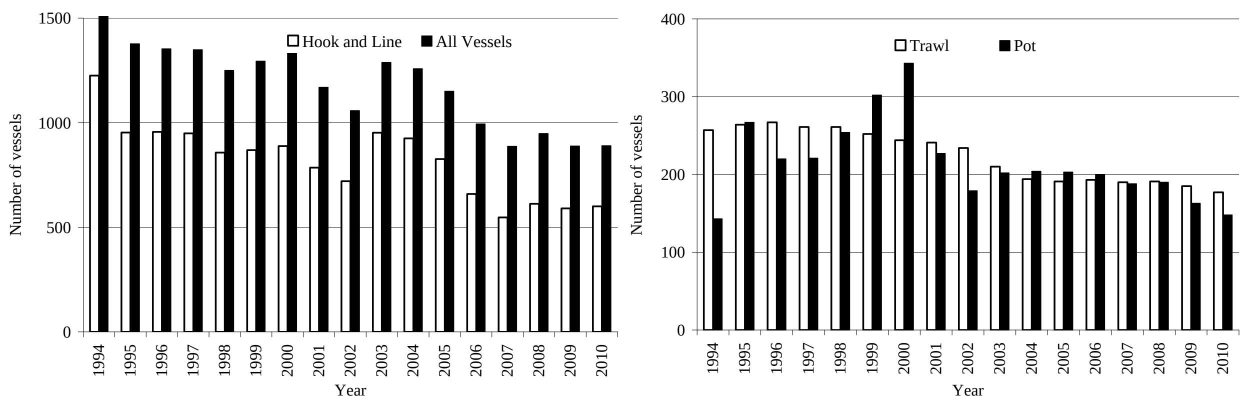
Description of index: Fishing vessels participating in federally-managed groundfish fisheries off Alaska principally use trawl, hook and line, and pot gear. Vessel counts in these tables were compiled from blend and Catch-Accounting System estimates and from fish ticket and observer data.

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 890 in 2010, the most recent year for which we have complete data (Figure 142). Hook and line vessels accounted for about 1,225 and 600 of these vessels in 1994 and 2010, respectively. The number of vessels using trawl gear decreased from 257 in 1994 to 177 in 2010. During the same period, the number of vessels using pot gear peaked in 2000 at 343 and decreased to 148 in 2010.



(a) Hook and Line, All vessels (b) Trawl, Pot

Figure 142: 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 2010 was mostly in the Pacific cod fisheries and possibly reflects lower ex-vessel prices for P. cod in 2009 and 2010, most likely due to reduced global market demand for cod and to the general economic downturn that began at the end of 2008.

Implications: 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.

Table 14: Bering Sea and Aleutian Island fishing community populations

	1920	1990	2009	% change 1990-2009
Alaska	55,036	538,347	692,314	28.6
BSAI fishing communities	6,215	45,394	45,940	1.2
% Alaskan pop in BSAI fishing communities	11.3%	8.4%	6.6%	

Distribution and Abundance Trends in the Human Population of the Bering Sea/Aleutian Islands

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Description of the index: Human population is a significant factor in Bering Sea/Aleutian Island (BSAI) groundfish fishery management given the reliance of many communities in the region on fisheries to support their economies and historical subsistence needs. This report describes the distribution and abundance over time of human populations in BSAI fishing communities. Population was calculated by aggregating community level demographic data for selected Bering Sea communities for 1990 and 2000 (data from U.S. Census Bureau), and yearly between 2001 and 2009 (data from the Alaska Department of Labor and Workforce Development). This approach is concordant with research on arctic communities that uses crude population growth or loss as a general index of community viability (Aarsaether and Baerenholdt, 2004).

The 91 Bering Sea and 8 Aleutian Islands fishing communities selected for use in this report comprise most of the population that lives along the coast of the Bering Sea and Aleutian Islands. Communities were selected if they were within 25 miles of the coast, and/or based on their historical involvement in BSAI subsistence or industrial fisheries. In addition, all Community Development Quota (CDQ) communities were included.

Status and trends: The overall population of BSAI fishing communities in 2009 was almost seven times larger than its 1920 population - growing from 6,215 to 45,940 - and seven and a half times larger than in 2009 - growing by an addition 418 people. Overall population in the region grew 1.2% between 1990 and 2009. However, the proportion of people living in BSAI fishing communities relative to the total Alaskan population has declined from 11.3% in 1920 to 8.4% in 1990 and to 6.6% in 2009 (Table 14).

Nearly all of Alaska's rural areas, including BSAI, have had a positive average annual population growth rate since 1990; however, in the past decade these upward trends have been slowing. Seventy-six BSAI fishing communities (or 83.5%, not including seasonal use areas) have had a positive average annual percent change during the period between 1990 and 2009. Fifteen communities showed less than one percent average annual change over the same time period and 26 had a negative average annual percent change. Communities with a negative annual percent change during this time period appear to be concentrated in Aleutians East and West along with Lake and Peninsula and Bristol Bay Boroughs. The sharp decrease in the Aleutians East and West area is largely due to the military base closure in Adak in 1997.

Overall, Alaska has one of the highest intra and interstate migration levels of any US state (Williams, 2004*b*). However, these figures differ dramatically across BSAI communities. Based on ADLWD 2004 statistics, Lake and Peninsula and Aleutians East and West exhibit some of the highest gross migration rates in Alaska (21 to 30% of the population) compared to the lowest rates of gross migration (9.5 - 11.9%) in Nome, Wade Hampton, and Bethel (Williams, 2004*b*). In Aleutians West, which includes the region's major fishing hub in Unalaska/Dutch Harbor, only 25% of the residents were born in Alaska, compared to 94.1% in Wade Hampton.

Alaska has the highest share of indigenous Americans of any US state (20%), and Alaska Natives made up 82% of the population in remote rural census areas, 90% when excluding regional hubs (Goldsmith et al. 2004). In the BSAI, the percent Native population is lowest among the Aleutians East (38.6%) and Aleutians West (22.5%) and highest in Wade Hampton (94.9%) and Bethel (85.5%), though there is significant variation between communities. In 2009, Alaska Natives made up 78.8% (34,379 people) of the total population of the BSAI.

Factors causing trends: The overall population growth in the BSAI region since 1920 reflects state and national trends, although the BSAI growth rate lags behind both. The two key factors affecting population growth rates are natural increase (birthrates subtracting mortality), and migration. Both factors affect the BSAI region.

High birth rates among Alaska Natives (50% higher than that of non-Natives) account for steady natural increase (births minus deaths) in many BSAI area populations (particularly Wade Hampton and Bethel), which serves to off-set out-migration from these areas. The Alaska version of the Todaro Paradox (Huskey et al., 2004) describes the out-migration of young Alaska Natives to urban centers for education and work opportunities, and the return migration to remote rural areas despite the high levels of unemployment there. This return migration is partly due to the social benefit of family networks, and the sustenance and income from subsistence activities which are most successful in natal villages where traditional environmental knowledge is an asset (Huskey et al., 2004).

Swift and dramatic changes in residency and migration patterns account for some of the region's population trends and anomalies. The military base closure in Adak accounts for Aleutians West population decline between 1992 and 1994. Historically, the gold mining industry accounted for community growth, decline, and in some cases abandonment (e.g., Council and Mary's Igloo) in the Nome area, while the fishing industry accounts for similar boom-bust dynamics in the Aleutians and Bethel, Dillingham, and Lake and Peninsula areas. An acute drop in ex-vessel prices for salmon has been the most significant driver of negative population growth in the latter two Census Areas in the last decade. Unlike many other parts of the state, the oil and gas industry has not been a direct factor in BSAI population dynamics.

Implications for fisheries management: Given that many Alaska Natives are traditionally dependent on harvesting marine resources for subsistence purposes and the high percentage of the BSAI population that considers themselves Alaska Native, it is not surprising that roughly 61% of salmon, 43% of non-salmon, 95% of walrus, and 86% of beluga whales taken for subsistence purposes in the state of Alaska are harvested by BSAI residents (ABWC, in press; ADFG, 2011). The regions reliance on the subsistence harvest of salmon is crucial as fisheries managers consider regulations for commercial groundfish fishing, especially given recent tensions surrounding bycatch of chum and Chinook salmon in commercial fisheries in the Bering Sea. In addition, over a third of BSAI fishing communities are highly dependent on the subsistence harvest of ice seals. As the Alaska Native population in this region expands, contracts and shifts around the Bering Sea, individual communities' reliance on salmon and other marine resources for subsistence will play heavily into the overall fishing pressure on all species harvested in the Bering Sea, including the commercial groundfish fishery.

Population decline or growth can affect community and regional specific pressures on fisheries resources. As populations throughout the BSAI expand and contract, so will pressures on groundfish resources. In 2009, 197 groundfish license limitation program (LLP) permits were held by BSAI residents, representing 17% of all these permits issued to Alaska residents. In addition, approximately 852.5 million pounds or 75% of all groundfish were landed in BSAI communities, thus contributing almost $15 million to the BSAI economy or 45% of the value of all groundfish landings at shore-based processors in the state (CFEC 2011). Based on how population across BSAI communities changes, changes in groundfish management could have implications for the stability of both regional and individual community economies. Timeseries data relating to changes in BSAI communities' participation in the Alaskan groundfish fishery are currently being compiled and will be provided in a future update to this report. This timeseries data will be able to shed light on changes in BSAI community participation in groundfish fisheries as they compare to changes in population in the region and the state as a whole, and how fisheries management decisions might affect the economies of individual communities throughout the region.

Finally, population decline or growth in small communities can factor into health care provision, education, land use, environmental impacts, transportation, and other social services (Williams, 2004*a*). Over 36% of federal dollars allocated to Alaska depend in some way on population, State programs attach many services to population, and CDQ quota shares are also provisioned in relation to population numbers. As an example, the CDQ entities distribute revenue from leasing and harvesting CDQ quota shares and provide CDQ funded programs and services to the 65 CDQ communities in Western Alaska. Any changes to fisheries management programs that affect the overall revenue gained through the CDQ program could drastically affect the welfare of the population of those communities.

Distribution and Abundance Trends in the Human Population of the Gulf of Alaska

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Last updated: July 2011

Description of the index: Human population is a significant factor in Gulf of Alaska (GOA) groundfish fishery management given the reliance of many communities in the region on fisheries to support their economies and historical subsistence needs. This report describes the distribution and abundance over time of human populations in the GOA (including Southeast Alaska, Cook Inlet, and Prince William Sound). Population in the region was calculated by aggregating community level demographic data for 1990 and 2000 (data from U.S. Census Bureau) and yearly between

Table 15: Gulf of Alaska (GOA) fishing community populations

	1920	1990	2009	% change 1990-2009
Alaska	55,036	538,347	692,314	28.6
Anchorage	na	226,338	290,588	28.4
GOA fishing communtities (incl. Anchorage)	18,533	345,230	443,912	28.6
GOA fishing communtities (excl. Anchorage)	na	118,892	234,324	97

2001 and 2009 (data from the Alaska Department of Labor and Workforce Development). This approach is concordant with research on arctic communities that uses crude population growth or loss as a general index of community viability (Aarsaether and Baerenholdt, 2004).

The 104 GOA fishing communities selected for use in this report comprise most of the population that lives along the coast of the Gulf of Alaska. Communities were selected if they were within 25 miles of the coast, and/or based on their historical involvement in Gulf of Alaska subsistence or industrial fisheries, or if they were included in one of the North Pacific Fishery Management Council's GOA fishery programs, such as the Community Quota Entity program.

Status and trends: The proportion of people living in GOA fishing communities relative to the total Alaskan population has increased from around 34% in 1920 to 64.1% in 2009 (Table 15). The vast majority of the growth occurred in the city of Anchorage after 1950. Between 1990 and 2009, its population grew by 28.4%.

The overall population of GOA fishing communities in 2009 was 24 times larger than its 1920 population (Table 15). However, 57% of the communities experienced an average annual decline between 2000 and 2009, compared to only 44% of communities between 1990 and 2007. Populations decreased to zero or near zero in 2009 for Whitestone logging camp, Cube Cove, Hobart Bay, and Ivanof Bay on the Alaska Peninsula.

Alaska currently has the highest share of indigenous Americans of any US state (20%). Alaska Natives made up 82% of the population of the remote rural Census Areas, 90% when excluding regional hubs (Goldsmith et al. 2004). In 2009, Alaska Natives made up 22.9% of the total population in the GOA, when excluding the population of Anchorage.

Alaska has one of the highest population concentrations in the United States with 42% of its population currently concentrated in Anchorage. New York and Hawaii have the most similar population concentrations with 42.9% in New York City and 28.9% in Honolulu. With respect to distance from the nearest major American city, Anchorage (1432 miles to Seattle) is second only to Honolulu (2554 miles to Los Angeles).

Factors causing trends: The overall population growth in the GOA region from 1990 to 2009 reflects state and national trends. The GOA population growth rate (28.6%) lags slightly behind state trends (25.9%) and is ahead of national trends (23.4%). The two key factors affecting these population growth rates are natural increase (births minus deaths) and migration. Except for the Matanuska-Susitna Borough, every area with positive population growth saw their natural increase outstrip their net migration between 2000 and 2004 (**?**). Birth rates in the state were lowest in the Aleutian chain and in Southeast Alaska between 2000 and 2004.

Changes in patterns of natural resource extraction and military presence explain many of the recent population trends in the GOA. Cut-backs in the Coast Guard account for Kodiak's population decline in the 1990s (?). The fishing industry accounted for community growth, decline, and in some cases abandonment in the Aleutians, Lake and Peninsula, and Kodiak areas. The Aleutians East gained population at this time because of the movement of a substantial amount of groundfish processing on shore (Williams, 2004*b*), while the population in Pelican declined 55% in part due to the closure of a processing plant. Other fishing communities, specifically those most dependent on salmon, were impacted by a sharp decline in ex-vessel prices. A loss of timber harvesting and wood processing jobs in the 1990s led to major population decreases in some Southeast communities, including Whitestone Logging Camp, which declined from 164 to 0 between 1990 and 2006, but has since increased to a population of 9 in 2009. Historically, the sharp increase in Anchorage's population began with the military buildup during and after WWII, but it was oil development beginning in the late 1970s that fueled unprecedented growth.

Implications: Population decline or growth can affect community and regional specific pressures on fisheries resources. As populations throughout the GOA expand and contract, so will pressures on groundfish resources. In 2009, 764 groundfish license limitation program (LLP) permits were held by GOA residents, representing 68% of all these permits issued to Alaska residents. In addition, approximately 277 million pounds of groundfish were landed in GOA communities, thus contributing almost $34 million to the GOA economy or 50% of the value of all groundfish landings at shore-based processors in the state. Based on how population across GOA communities changes, changes in groundfish management could have implications for the stability of both regional and individual community economies. Time series data relating to changes in GOA communities' participation in the Alaskan groundfish fishery are currently being compiled and will be provided in a future update to this report. This time series data will be able to shed light on changes in GOA community participation in groundfish fisheries as they compare to changes in population in the region and the state as a whole, and how fisheries management decisions might affect the economies of individual communities throughout the region.

Furthermore, the concentration of a state's population in a single city, Anchorage, concentrates goods, services, trade, and travel routes in one place. The concentrated population also allows for services (e.g., medical treatment, business and technology support, entertainment) that would not otherwise be sustainable in the state and attracts people to the area due to increased employment and education opportunities. The population growth and concentration in Anchorage has also had negative impacts on the surrounding area through sprawl into the Matanuska-Susitna valley, increased regional hunting and fishing pressures and lower take allowed per capita, increased recreation demand, and loss of agricultural land due to high speculative land values (Fischer, 1976).

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