Ecosystem Considerations

2014

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Bering Sea, Aleutian Islands, and Gulf of Alaska

November 17, 2014
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Eastern Bering Sea 2014 Report Card

- The North Pacific atmosphere-ocean system during 2013-2014 featured **the development of strongly positive SST anomalies south of Alaska**. This warming was caused by unusually quiet weather conditions during the winter of 2013-14 in association with a weak Aleutian low (positive NPI), and abnormally high SLP off the coast of the Pacific Northwest.
- The **eastern Bering Sea experienced warmer air temperatures and less sea ice** that were related to the broader North Pacific conditions. Dates of sea ice retreat, summer surface and bottom temperatures, and the extent of the cold pool were **similar to those of the warm years of 2003-2005**.
- The summer **acoustically-determined time series of euphausiids continues to decrease** from its peak in 2009. This suggests that prey availability for planktivorous fish, seabirds, and mammals was low in 2014.
- **Survey biomass of motile epifauna** has been **above its long-term mean** since 2010, although the trend has stabilized. However, the trend of the last 30 years shows a **decrease in crustaceans** (especially commercial crabs) and a **long-term increase in echinoderms**, including brittle stars, sea stars, and sea urchins. It is not know the extent to which this reflects changes in survey methodology rather than actual trends.
- **Survey biomass of benthic foragers has remained stable** since 1982, with interannual variability driven by short-term fluctuations in yellowfin and rock sole abundance.
- **Survey biomass of pelagic foragers has increased steadily** since 2009 and is currently above its 30-year mean. While this is primarily driven by the **increase in walleye pollock** from its historical low in the survey in 2009, it is also a result of **increases in capelin from 2009-2013**, perhaps due to cold conditions prevalent in recent years.
- **Fish apex predator survey biomass is currently above its 30-year mean**, although the increasing trend seen in recent years has leveled off. **The increase since 2009** back towards the mean is driven primarily by the increase in Pacific cod from low levels in the early 2000s. **Arrowtooth flounder**, while still above its long-term mean, **has declined nearly 50% in the survey from early 2000s** highs, although this may be due to a distributional shift in response to colder water over the last few years, rather than a population decline.
- **The multivariate seabird breeding index is above the long term mean**, indicating that seabirds bred earlier and more successfully in 2014. This suggests that **foraging conditions were favorable for piscivorous seabirds**.
- **Northern fur seal pup production for St. Paul Island remained low** in 2014, with fewer pups produced than the last survey in 2012.

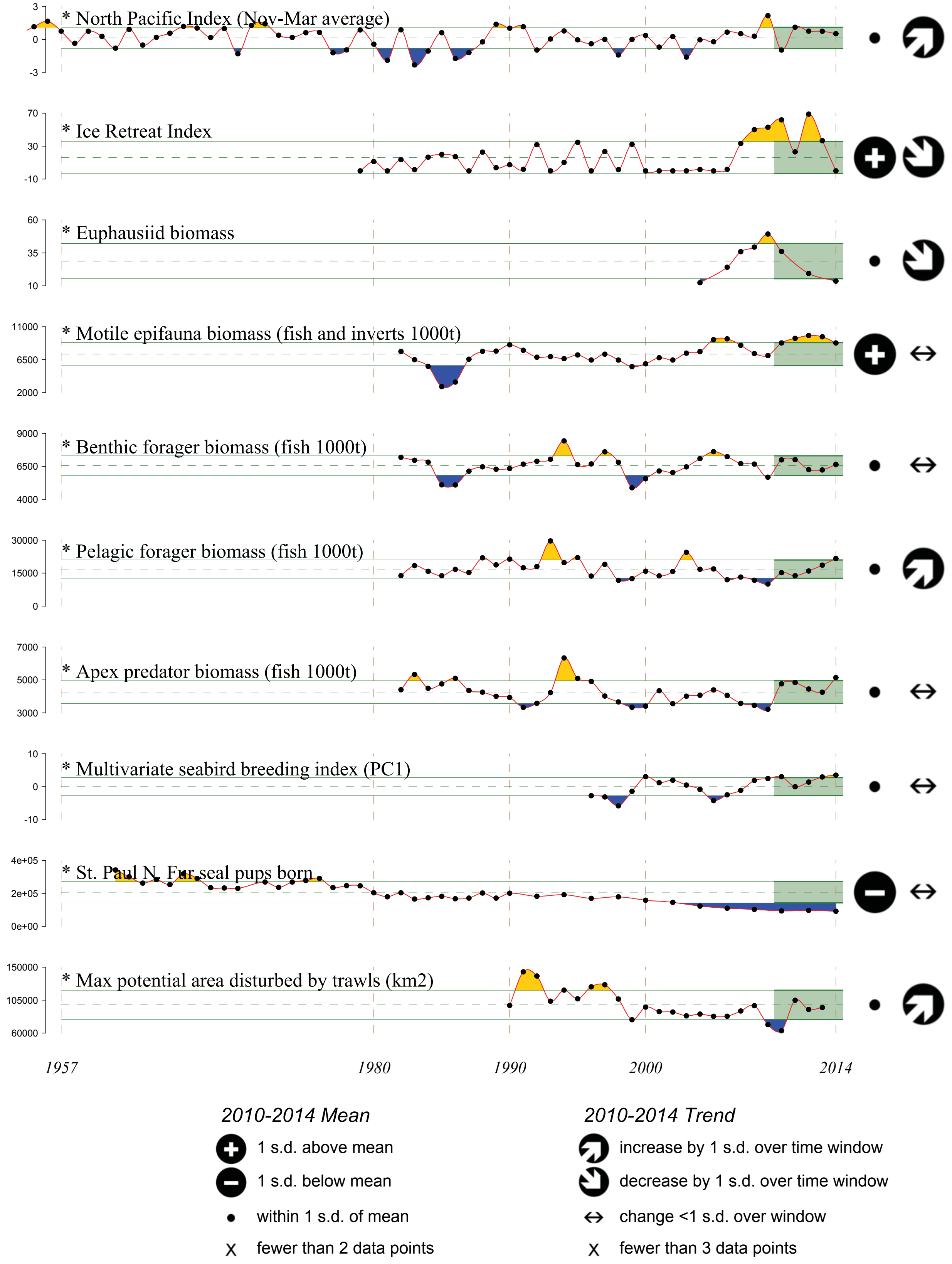

Figure 1: Eastern Bering Sea ecosystem assessment indicators; see text for descriptions. * indicates time series updated in 2014.

Aleutian Islands 2014 Report Card

Region-wide

- The North Pacific atmosphere-ocean system during 2013-2014 featured the development of **strongly positive SST anomalies south of Alaska**. Warm upper ocean conditions persisted through the summer of 2014.
- The winter NPI was positive, implying **a weak Aleutian Low and suppressed storminess**.
- The wind anomalies produced **reduced flow of Pacific water northward through Unimak Pass and a relatively broad and weak Alaskan Stream** over much of the last year, with spring 2014 being an exception.
- **Water column temperatures were the warmest** recorded during survey years since 1994.
- **Biomass of pelagic forager and apex fish predator foraging guilds increased across the region** between the 2012 and 2014 surveys, although patterns varied among species. The overall increase **may indicate a response to the warmer water, such as increased catchability or habitat shift, or reflect high variances commonly observed in estimated biomass among survey years**.
- Several species show 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 increase 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.
- The amount of **area with observed trawling has declined overall**, likely reflecting less fishing effort, particularly in the western ecoregion.
- In general, **schools in the Aleutian Islands have shown no recent trends in enrollment**, possibly indicating that communities with year-round residents that experience direct interactions with the ecosystem through residential and subsistence activites are stable.

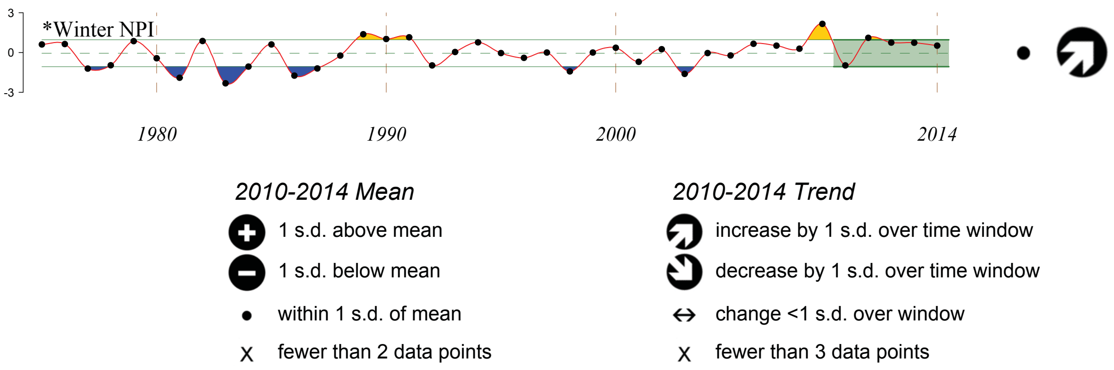

Figure 2: The winter North Pacific Index time series. * indicates time series updated in 2014.

Western Aleutian Islands Ecoregion

- While the reproductive success of planktivorous least auklets has remained stable, that of crested auklets has declined to levels not seen since the late 80's and 2003. Crested auklets rely more on euphausiids than the copepod-specialist least auklets, thus **we can speculate that euphausiid availability has declined**.
- Forage fish trends as indicated in tufted puffin chick meals have varied over the long term. In general, sand lance have been absent since 2010, and age-0 gadids uncommon. The **number of hexagrammids (likely age-0 Atka mackerel) has increased in the past two years, possibly indicating high recruitment**.
- The **pelagic fish foraging guild biomass increased** from 2012 to the highest value observed. All four species - pollock, Pacific ocean perch, northern rockfish, and Atka mackerel - contributed to this trend.
- Although the **overall biomass of the fish apex predator foraging guild declined from 2012**, Pacific cod and Kamchatka flounder biomasses increased.
- Steller **sea lions remain well below their long-term mean** in this ecoregion. The 2014 counts were the lowest in the time series.
- The **amount of area trawled increased in 2013** relative to the dramatic declines of the previous two years that were due to recent measures aiming at increasing protection for Steller sea lions.

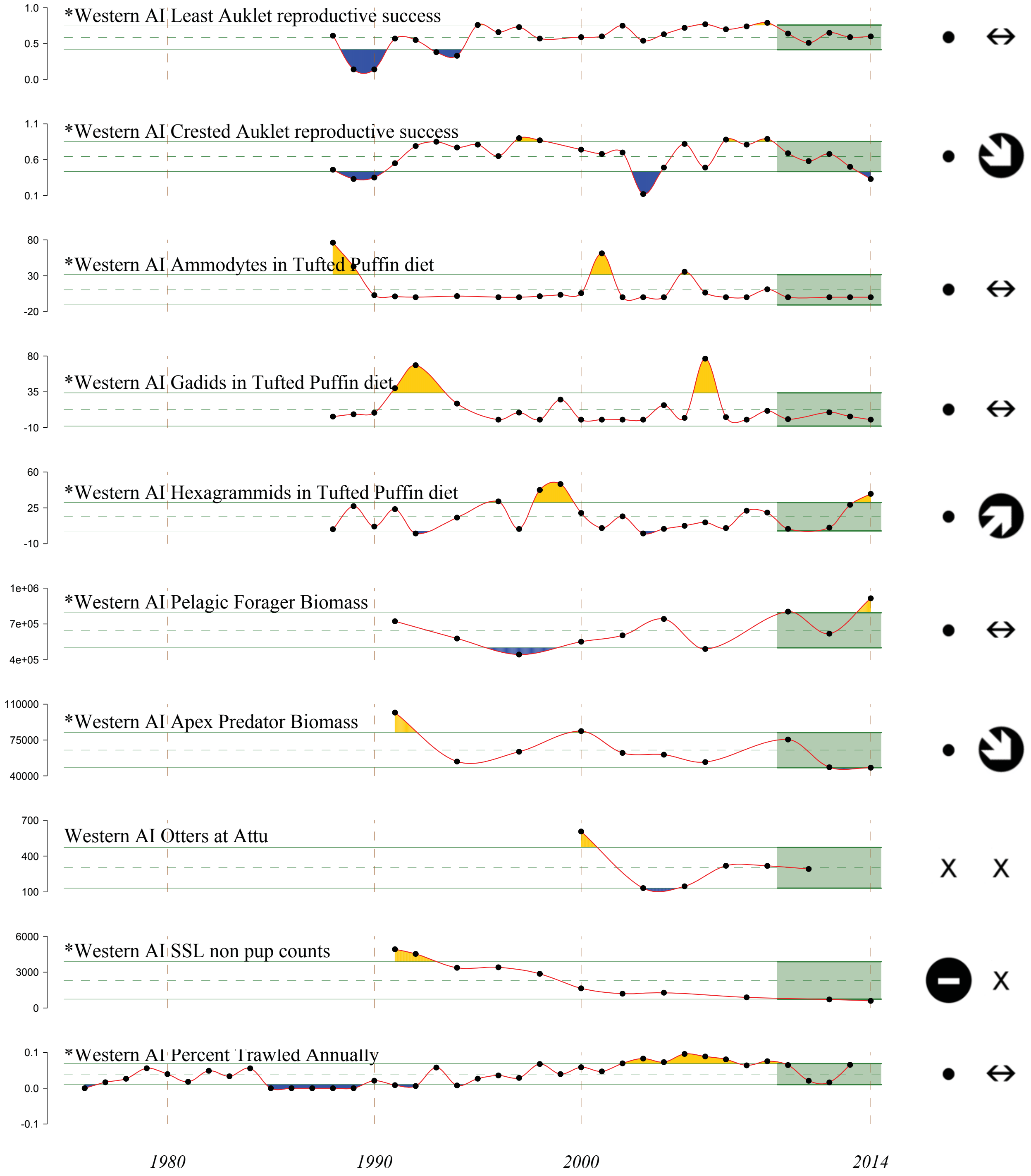

Figure 3: Western Aleutian Islands ecoregion indicators. * indicates time series updated in 2014. See Figure 2 for legend.

Central Aleutian Islands Ecoregion

- Recent trends in auklet reproductive success are unknown but the **continued positive state of the NPI indicates favorable foraging conditions for planktivorous auklets**.
- The **pelagic fish foraging guild biomass increased** overall from 2012 to 2014, nearly reaching the peak biomass observed in 2010. Increases were seen in all species but Pacific ocean perch.
- The **slight increase in the fish apex predator foraging guild biomass** from 2012 to 2014 was largely driven by Pacific cod, arrowtooth flounder and Kamchatka flounder.
- Neither otter or sea lion counts were available, although updated data should be available next year with 2014 surveys.
- **School enrollment has shown no trend** in recent years, following a decline since peak enrollment in 2000, and potentially indicating stability in the residential communities.
- The **amount of area trawled has been stable in the past few years**.

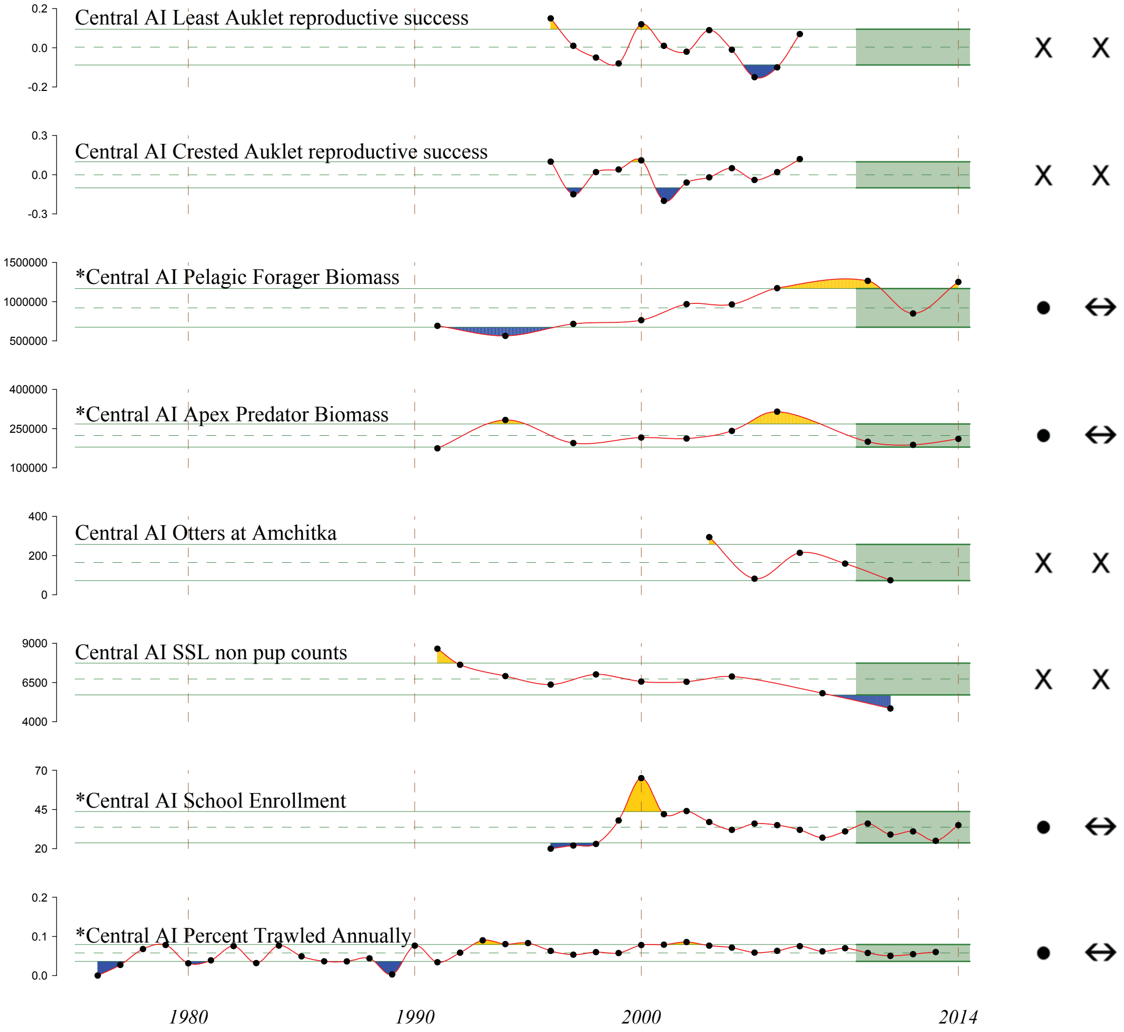

Figure 4: Central Aleutian Islands ecoregion indicators. * indicates time series updated in 2014. See Figure 2 for legend.

Eastern Aleutian Islands Ecoregion

- Relative abundances of **gadids and *Ammodytes*** in prey brought back to feed puffin chicks **have shown opposite trends, although both declined from 2013 to 2014**. Chick-provisioning patterns suggest puffins are responding to changes in forage fish availability.
- Pollock, Pacific ocean perch, and northern rockfish all contributed to the **increase in fish pelagic forager biomass** from 2012, although there has been an overall declining trend over the past 3 surveys.
- **Fish apex predator foraging guild biomass increased** from the low values in 2012. Pacific cod and arrowtooth flounder contributed most to the increase.
- **School enrollment has shown an overall increasing trend in the past five years**, although 2014 attendance declined slightly from the previous year. These numbers suggest a positive trend in community expansion in the eastern ecoregion communities.

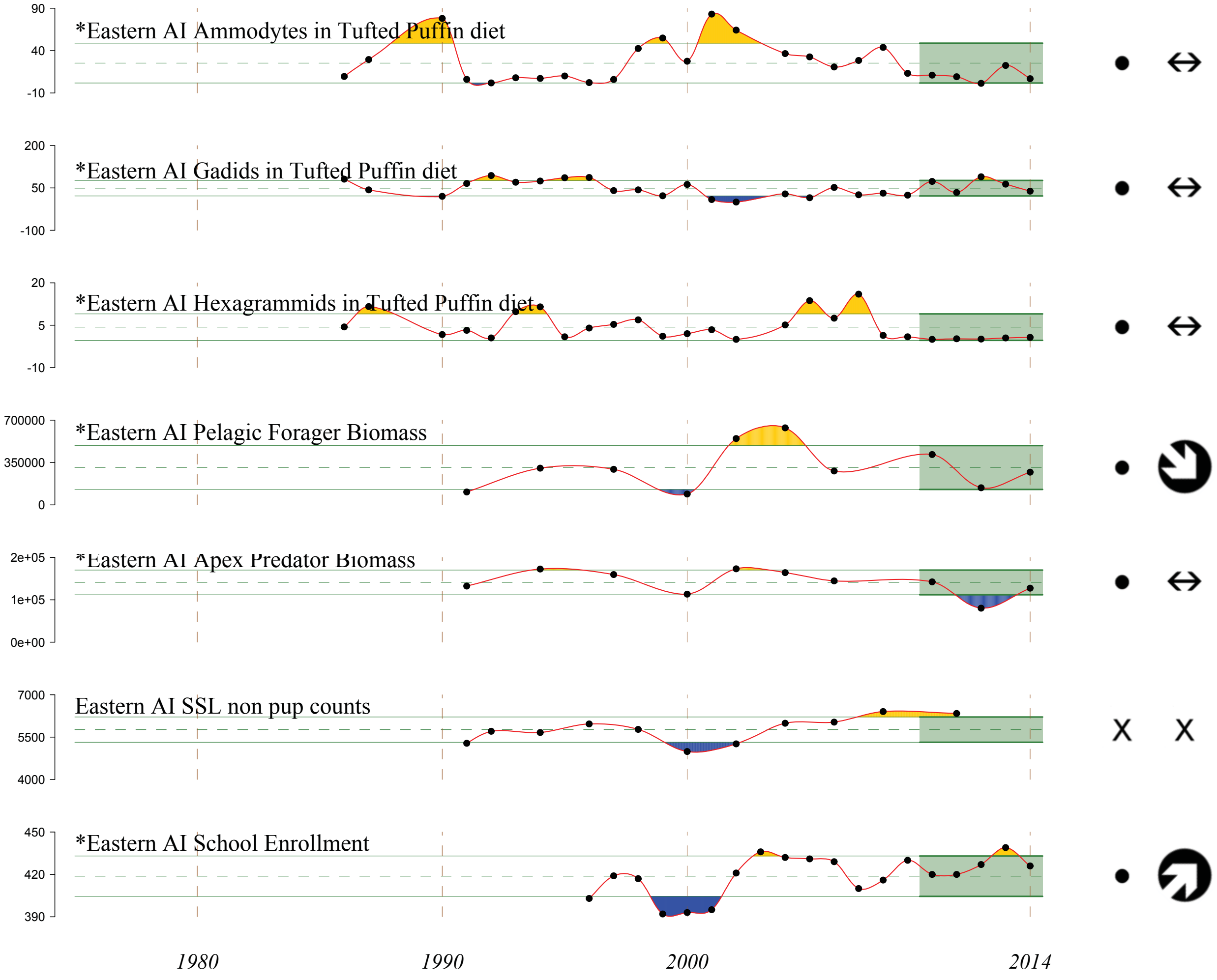

Figure 5: Eastern Aleutian Islands ecoregion indicators. * indicates time series updated in 2014. See Figure 2 for legend.

Executive Summary of Recent Trends

This section contains links to all new and updated information contained in this report. The links are organized by ecosystem within three sections: Physical and Environmental Trends, Ecosystem Trends, and Fishing and Fisheries Trends.

Physical and Environmental Trends

- The state of the North Pacific atmosphere-ocean system during 2013-2014 featured the development of strongly positive SST anomalies south of Alaska; the warm upper ocean conditions persisted through the summer of 2014 (p. 79).
- The unusual winter weather appears to be largely due to intrinsic variability rather than associated with leading modes of climate variability such as ENSO (p. 79).
- The Pacific Decadal Oscillation (PDO) underwent a transition from negative to positive during the past year (p. 84).
- The models used to forecast ENSO, as a group, are indicating weak-moderate El Niño conditions for the winter of 2014-15, which should serve to maintain a positive sense to the PDO (p. 86).

Arctic

- There was reduced sea ice cover in the Arctic during the summer of 2014 compared to seasonal norms, but not to the extent that occurred in 2011 and 2012 (p. 79).
- The average September Arctic sea ice extent for 2014 was the sixth lowest in the satellite record. The seasonal daily minimum ice extent of 5.02 million square kilometers was set on September 17th (p. 88).
- There was an earlier onset of ice on the Beaufort Sea shelf in fall 2013 than most previous years; the onset in the Chukchi Sea was more typical of the recent past (p. 79).

Eastern Bering Sea

- 2014 broke the unusual sequence of seven years with cold winter-spring temperatures (2007-2013), following the seven warm temperature years (2000-2006) (p. 88).
- Sea ice maximum extent was reduced (p. 79 and 88).
- Anomalous warming was particularly prominent during spring 2014 (p. 79.
- January-May 2014 near surface air temperature anomalies in the southeastern Bering Sea were +2C, in contrast to 2013 at -2.5°C and 2012 at -3°C (p. 88).

- The summer cold pool during 2014 was mostly restricted to north of 60°N.
- Summer 2014 continued warm conditions due to high sea level pressures and weak winds. There was less storminess than usual (p. 79 and 88).

Aleutian Islands

- The wind anomalies in this region were of the sense to produce reduced flow of Pacific water northward through Unimak Pass and a relatively broad and weak Alaskan Stream over much of the last year, with spring 2014 being an exception (p. 79).
- Eddy energy in the region was low from the fall 2012 through July 2014, indicating that average volume, heat, salt, and nutrient fluxes through Amukta Pass were likely smaller during the this time (p. 97).
- Sea surface temperature values warmed from near normal to above normal during the past year (p. 80).
- Temperatures from the 2014 NOAA bottom trawl survey appear to be the most broadly distributed (vertically and longitudinally) and warmest temperatures since 1994 (p. 99).

Gulf of Alaska

- The upper ocean in this region was fresher than usual with a relatively strong pycnocline (p. 79).
- The coastal winds were upwelling favorable in an anomalous sense, which helped maintain relatively normal SST along the coast as compared with the much warmer than normal water offshore (p. 79).
- The sub-arctic front was farther north than usual, which is consistent with the poleward surface currents shown in the Ocean Surface Currents - Papa Trajectory Index (p. 104).
- Eddy Kinetic Energy (EKE) levels in the western Gulf of Alaska were particularly weak in summer of 2014. Thus, phytoplankton biomass were likely more tightly confined to the shelf in those years and cross-shelf transport of heat, salinity and nutrients were probably weak (p. 102).
- In the northern Gulf, relatively high eddy kinetic energy was observed in the summer of 2014 (p. 102).
- It now appears the filtered PAPA Trajectory Index may shift back to northerly flow, which would indicate that the recent period of predominantly southern flow (mid-2000s to present) will have been the shortest and weakest in the time series (p. 104).

Ecosystem Trends

Bering Sea

- EBS trawl survey structural epifauna catch rates generally show increasing trends in anemones and sponges in recent years. Catch rates of seawhips have been variable (p. 107).
- During the BASIS surveys from 2003-2012, the highest phytoplankton biomass was observed in the Outer shelf inshore of Bering Canyon, near the Pribilof Islands, along the Aleutian Islands, north of St Lawrence, and in the south Inner shelf. Lowest biomass was observed in the north Bering and SE Middle shelf (in a region of high stability) (p. 111).
- 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. 111).

- In the south Bering Sea, the mean size of phytoplankton assemblages were higher in warm (2003-2005) than in cold (2006-2-12) years, and higher in 2003-2005 and 2011-2012 than in 2006-2010 in the north. Typically years with higher integrated chla had a greater fraction of large phytoplankton(p. 111).
- Late summer concentrations of surface silicate may serve as an indicator of nutrient availability, with higher concentrations seen during windy lower stratification years and low concentrations seen when storm activity is minimal and stratification is high (p. 116).
- Age-0 pollock weights and surface silicate concentrations are positively correlated (p. 116).
- Acoustic surveys of euphausiids on the middle and outer shelf indicate that summertime euphausiid density increased from 2004-2009, but subsequently declined in 2010 through 2014. Abundance in summer 2014 was only slightly greater than in 2004, the lowest estimate in the time series (p. 118).
- Continuous plankton recorder observations indicated that the 2013 copepod community size was anomalously low in the southern Bering Sea regions; however, mesozooplankton biomass was near average and large diatom abundance was above average (p. 132).
- Jellyfish relative CPUE in 2014 was down slightly from 2013, but remained relatively high when compared to the last 10 years. The recent peak abundance occurred in 2009 (p. 121).
- The fall 2013 survey of jellyfish occurred only north of 60°, where biomass was similar to previous years. The southern area, which had shown record biomass the previous year, was not surveyed (p. 122).
- The 2013 Bristol Bay sockeye salmon run of 23.0 million fish was 12% below the preseason forecast of 26.0 million, and was 36% below the recent 20-year average (1993-2012) of 36 million. Chinook salmon abundance in the Arctic-Yukon-Kuskokwim region has been declining since 2007 and no commercial periods targeting Chinook salmon were allowed in the Yukon Area during the 2013 summer season (p. 143.
- The 2012-2014 springtime drift patterns do not appear to be consistent with years of good recruitment for northern rock sole, arrowtooth flounder and flathead sole (p. 154).
- The 2011 Temperature Change (TC) index value was below the long term average, therefore slightly below average numbers of pollock are expected to survive to age-3 in 2014. In the future, the TC values in 2013 and 2014 indicate above average abundances of age-3 pollock in 2014 and 2015 (p. 156).
- Below average age-1 pollock recruitment is expected in 2014 based on 2013 and 2014 biophysical indices indicating average ocean productivity (chum salmon growth), warm spring sea temperatures (less favorable), and above average predator abundances (pink salmon) (p. 159).
- Groundfish length-weight residuals (a measure of fish condition) have varied over time for all species with a few notable patterns. Residuals for all species where there was data were negative in 1999, a cold year in the Bering Sea. There has been a distinct negative trend in Pacific cod since a peak value in 2003. Age 1 walleye pollock and older walleye pollock were not well correlated in most years. Residual patterns for all species except Pacific cod were positive in 2014. Spatial trends in residuals were also apparent for some species (p. 161)
- The trend in relative CPUE for poachers and sea stars groups during the bottom trawls was very similar to 2013, and eelpouts show a slight increase (p. 179).
- A multivariate seabird index indicates that 2014 was a generally successful year reproductively for Pribilof seabirds. The dominant temporal trend among kittiwake reproductive success data continues to be an alternating biennial pattern. Years of high pink salmon abundance, the odd-numbered years after 1997, correlate with poor kittiwake productivity (p. 186).
- The 2014 northern fur seal pup production estimate for St. Paul Island is 5.2% less than the estimate in 2012. Since 1998 pup production on the Pribilof Islands (St. Paul and St. George Islands combined) declined 45.0%, or at an annual rate of 3.7% (p. 190).

- The leading principal component of 16 biological time series from the EBS shows a transition to negative values around 2009, similar in sign but lower in magnitude than before the 1976/77 regime shift which resulted in highly disruptive changes to ecosystems and fisheries. Recent scores show a linear relationship with winter SST, thus reflecting a possible response to recent changes in climate (p. 193)

Aleutian Islands

- The Aleutian islands trawl survey of structural epifauna showed variable distributions: Sponges are caught in most tows in the AI west of the southern Bering Sea. Stony corals are commonly captured outside of the southern Bering Sea, and their abundance appears highest in the central and eastern AI. Sea anemones are common in survey catches but abundance trends are not clear. Sea pens are most likely to be encountered in the southern Bering Sea and eastern AI (p. 109).
- Jellyfish were generally more abundant in 2004 and 2006 than in other years and have been low since 2012. There appears to have been a slight uptick in 2014 (p. 179).
- Eelpout CPUEs have generally been highest in the central and eastern AI and have remained high since 1991 except for 2012 in the central AI. Poachers occur in a relatively large number of tows across the AI survey area, but mean CPUE trends are unclear (p. 179).
- Length-weight residuals (a measure of groundfish condition) for most species where there was data were negative from 2000 to 2006. Residuals were positive for all species but southern rock sole in 2010. In 2014 length-weight residuals were negative for all species. For northern rockfish, Pacific cod and Pacific ocean perch there has been a declining trend in residuals over the years covered by the survey. Species generally exhibited the worst condition in the Western Aleutians (p. 165
- The distributions of rougheye rockfish, shortspine thornyhead, and shortraker rockfish have been shallower in the most recent surveys of the Aleutian Islands (last surveyed in 2012). Northern rockfish have shown a significant trend in their mean-weighted distribution towards the Western Aleutians. Mean-weighted temperature distributions for all rockfish species were stable 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)(p. 173).

Gulf of Alaska

- The highest density of euphausiids was consistently observed in Barnabas Trough during acoustic surveys in 2003, 2005, 2011, and 2013. The highest overall abundance was observed in 2011, with lowest euphausiid abundance in 2003 (p. 124).
- Total Icy Strait zooplankton density was anomalously low for all months during the 2013 summer survey. Density anomalies were mostly negative from 1997-2005, positive in 2006-2009, and negative in 2010-2013 (p. 125).
- Icy Strait zooplankton were numerically dominated by calanoid copepods. In 2013, large calanoids and larvaceans were anomalously high while small calanoids were anomalously low (p. 125).
- In the Alaskan Shelf region sampled by the continuous plankton recorder, copepod community size and mesozooplankton biomass anomalies became negative in 2013 while large diatom abundance anomalies remained positive (p. 132).
- Overall catch rates of juvenile pollock in the 2013 smallmesh survey were the highest since 1979, although eulachon, herring, and pink shrimp catches remained low (p. 135).
- Temporal patterns in sand lance captured by puffins provisioning chicks show that sand lance were most prevalent from the mid 1990s to the mid 2000s in the central and western GOA. In contrast, sandlance were most prevalent in the mid-1990s and have been decreasing since then in the eastern GOA (p. 137)

- Although the estimated total mature herring biomass in southeastern Alaska has been above the long-term (1980-2013) median of 90,495 tons since 2003 through 2013, an apparent decrease in biomass has been observed since the peak in 2011. The most notable drop in biomass was observed in Hoonah Sound (p. 140).
- The total number of salmon harvested in 2013 was the largest going back to 1962. Marine survival of Prince William Sound hatchery pink salmon does not appear to have shifted after the 1988/89 or the 1998/99 climate regime shifts. Marine survival in 2010 (2008 brood year) was at an all-time high since 1977 but dropped in 2011 and 2012 (p. 143).
- Ecosystem indicators predict a low pink salmon harvest in 2014 of about 30 M fish (p. 148).
- A new Southeast Alaska Coastal Monitoring project Chinook salmon index is the abundance estimate of ocean age-1 fish sampled in Icy Strait, lagged two years later to their ocean year of recruitment as ocean age-3 fish, the age when most reach legal size. Based on this Chinook index, June 1-ocean abundance has been below average in 8 of the past ten years. Most recently, Chinook salmon fishery recruitment appears weak in 2014 and 2016, but strong in both 2013, and particularly in 2015 (p. 153).
- Ecosystem indicators predict below average recruitment events for age-2 sablefish in 2013 and 2015, and a slightly above-average recruitment event in 2014 (p. 173).
- Length-weight residuals for most groundfish species were positive in the first two years of the survey (1985-1987). The residuals have been mixed for all species since then, but generally smaller and varying from year to year. Most species were generally in better condition in the Kodiak area, especially southern rock sole. Fish condition was generally worse in the southeastern area than other areas of the GOA (p. 167
- ADF&G received no reports of “mushy” halibut during the 2014 fishing season (p. 172)
- The depth distribution of rockfish in the Gulf of Alaska has remained constant for each species over time with the exception of shortraker rockfish, which have moved toward shallower water. Since 2007, the range of mean-weighted temperatures where rockfish are found has narrowed. In past contributions, a shift in the distribution of rockfish from the eastern and SE areas of the Gulf of Alaska was noted; however, in the 2013 bottom trawl survey data this trend was not significant (p. 173).
- Arrowtooth flounder, flathead sole, and other flatfish continue to dominate the biomass in the ADF&G trawl survey. A decrease in overall biomass is apparent from 2007 to 2013 from years of record high estimates seen from 2002 to 2005 (p. 183).
- In 2013, overall gadid biomass in the ADF&G trawl survey has slightly increased in offshore area of Barnabus Gully, but decreased in the inshore areas of Kiliuda and Ugak Bays. Below average anomaly values for Tanner crabs, arrowtooth flounder, and flathead sole were recorded for both inshore and offshore areas, while Pacific cod were well above average. Skates and Pacific halibut were above average for offshore areas, while remaining below average inshore (p. 183).
- The leading principal component of 18 biological time series from the GOA shows a transition to lower-magnitude positive values around 2006. Recent scores show a linear relationship with winter SST, thus reflecting a possible response to recent changes in climate (p. 193)

Fishing and Fisheries Trends

Alaska-wide

- With the Arctic FMP closure included, almost 65% of the U.S. EEZ of Alaska is closed to bottom trawling (p. 208).

- At present, no BSAI or GOA groundfish stock or stock complex is subjected to overfishing, and no BSAI or GOA groundfish stock or stock complex is considered to be overfished or to be approaching an overfished condition. The only crab stock considered to be overfished is the Pribilof Islands blue king crab stock, which is in year 11 of a 10-year rebuilding plan. None of the non-FSSI stocks are subject to overfishing, known to be overfished, or known to be approaching an overfished condition (Table 14) (p. 237).
- The total catch of non-target species groups in commercial groundfish fisheries has been highest in the EBS, compared with the AI and GOA. Scyphozoan jelly catches in the GOA are an order of magnitude lower than the EBS and three orders of magnitude lower in the AI. Catches of HAPC biota are intermediate in the AI and lowest in the GOA. The catches of assorted invertebrates in the GOA are an order of magnitude lower than the EBS, and are lowest in the AI (p. 202).
- Catch of HAPC biota and assorted invertebrates in 2013 were the highest in the time series (p. 202).
- The 2013 estimated numbers of bycaught seabirds in groundfish fisheries are the lowest since bycatch estimates began in 1993 (p. 204).
- There seems to be a generally decreasing trend in seabird bycatch since the new estimation procedures began in 2007, indicating no immediate management concern other than continuing our goal of decreased seabird bycatch (p. 204).
- 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. Numbers have generally decreased since 1994 but have remained relatively stable in the last 5 years (2009-2013). The total number of vessels was 1,518 in 1994 and 936 in 2012. The number of vessels using trawl gear decreased from 257 in 1994 to 177 in 2012 (p. 245).

Bering Sea

- The maximum potential area of seafloor disturbed by trawling remained relatively stable in the 2000s, decreased in 2009-2010 but in 2012 returned to levels seen in the early 2000s. In 2013, the estimated area was 94,975 km^2 (p. 211).
- Since 1993, discard rates of managed groundfish species in federally-managed Alaskan groundfish fisheries have generally declined in the trawl pollock and non-pollock fisheries in the Bering Sea/Aleutian Islands (BSAI). Discard rates in the BSAI fixed gear sector fell from around 20% in 1993 to 12% in 1996, and since then have generally fluctuated between 10% and 14% (p. 199).
- Trends in total non-target catch in the groundfish fisheries have varied in the EBS. The catch of Scyphozoan jellyfish has fluctuated over the last ten years with peaks in 2009, 2011, and 2013. HAPC biota catch decreased from 2003 to 2007 and has been generally steady since. Sea anemones comprised the majority of the catch (p. 202).

Aleutian Islands

- Since 1993, discard rates of managed groundfish species in federally-managed Alaskan groundfish fisheries have generally declined in the trawl pollock and non-pollock fisheries in the Bering Sea/Aleutian Islands (BSAI). Discard rates in the BSAI fixed gear sector fell from around 20% in 1993 to 12% in 1996, and since then have generally fluctuated between 10% and 14% (p. 199).
- Trends in total non-target catch in the groundfish fisheries have varied in the AI. The catch of Scyphozoan jellyfish has been variable and shows no apparent trend over time. HAPC biota and assorted invertebrate catches reached new peaks in 2013 (p. 202).

Gulf of Alaska

- Discarded tons of groundfish have remained relatively stable in the past few years with the exception of fixed gear, in which discard rates jumped from 6% to to 21% in 2013. Improved observer coverage on vessels less than 60' long and on vessels targeting IFQ halibut may account for the increase (p. 199).
- Assorted invertebrates comprise the majority of non-target catch in groundfish fisheries in the GOA. Catches of Schyphozoan jellies have alternated annually between above and below-average since 2007. Catches of HAPC biota and assorted invertebrates have varied little since 2003 (p. 202).

Contents

* indicates contribution updated in 2014
† indicates new contribution

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

December 2013 SSC Comments

The SSC received a report on the Ecosystem Considerations Chapter from Stephani Zador (NMFS-AFSC). No public comments were offered. The editor and authors were responsive to past SSC comments, though in many cases the implementation of the suggestions was deferred due to time missed during the furlough.

The SSC recognizes the immense amount of effort put into the Ecosystem Considerations Chapter, and its steady improvement in readability and value. The evolving format and crisp editing have made this a much more useful document than it was ten years ago. The three Hot Topics sections were very informative, though the one for the potentially large 2013 pollock year class in the Gulf was a bit too detailed regarding the methods. The SSC commends the authors and editor on a job well done.

Thank you. We have decreased the detail provided in the Hot Topics this year.

The addition of an Editor's summary at the beginning of each trophic level (zooplankton, salmon etc) section would be very valuable for synthesizing different indices and reports. The SSC urges the Editor to implement this feature in 2014.

This year, we focused our efforts on updating and synthesizing all four regional ecosystem assessments. Within the preliminary and full assessments we summarizing the available information by trophic level and provided overall syntheses.

Likewise, throughout the chapters, the Implications sections were very useful and showed continued improvement. Continued development of these sections is warranted, and section authors should be urged to use these to guide the reader.

We continue to emphasize this section with contributors and assist with completion when needed.

The SSC looks forward to the development of the prediction evaluations planned for the future. The SSC will be especially interested in how the information from the two Integrated Ecosystem Studies (Bering Sea and Gulf of Alaska) can be used for informing our understanding and ability to predict ecosystem changes.

This year, the eastern Bering Sea ecosystem assessment highlights modeling efforts that are part of the Bering Sea IERP and that provides a preliminary 9 month forecast of environmental conditions in the eastern Bering Sea. We are in active discussions with scientists from both Integrated Ecosystem Studies about both development of indicators to include as contributions and risk assessments and management strategy evaluations to include in our ecosystem assessments. The latter is an integral part of our longer-term plan to align this report more closely with the NOAA-adopted Integrated Ecosystem Assessment (IEA) format and program.

The SSC appreciated the update to the Arctic section, despite the shutdown. The general ecosystem information section and the list of potential ecosystem indicators were most useful. The SSC urges the authors to continue pursuing efforts to improve the Arctic Section and to develop an Arctic Report Card similar to those available for the Bering Sea, Gulf of Alaska and the Aleutian Islands. A reference to the Marine Fish section of NOAA's Arctic Report Card would be a useful start (`http://www.arctic.noaa.gov/reportcard/marine_fish.html`).

An update to the Arctic assessment section is provided in this report.

The newly initiated Arctic Distributed Biological Observatory (DBO) may provide valuable information beyond that available from more traditional fisheries surveys. It would also be good to add some physical measurements, such as flow through Bering Strait, which is monitored by Dr. Rebecca Woodgate at the UW Applied Physics Laboratory. Flow rates in the period March through May may be particularly important in determining when and how much large lipid-rich zooplankton is advected to the Chukchi and Beaufort Seas. Monitoring the date of arrival of these zooplankton in Bering Strait could be valuable in predicting both seabird and fish prey availability north of Bering Strait.

This comment has been passed along to the lead author, who is actively pursuing the suggested physical measurements. We will continue to follow and reference the DBO.

When survey information is available, it would be useful to include in the Arctic Section information on fish length frequencies, growth and condition, in addition to biomass or an index of abundance. Likewise, it would be useful to include information on any subsistence harvesting of fish, because in the absence of regular fishery surveys, this might provide an early warning of changes in Arctic fish stocks. This could also provide information on the communities that harvest them.

This comment has been passed along to the lead author. The biggest challenge with reporting survey data is the lack of comparison possible between the few surveys that have taken place due to differences in spatial coverage and survey methodology.

In the eastern Bering Sea, several important trends were noted, including: 1) continued extensive sea ice and cold sea temperatures; 2) above average biomass of Calanoid copepods; 3) increases in pelagic foragers including pollock and capelin; 4) the first apparent increase in fur seal pup counts on St. Paul Island since 1998; the multivariate index of seabird reproductive performance showed that 2012 was a "good" year for these predators as well; and 6) In the northern Bering Sea, between 2002 and 2012, juvenile salmon were found in regions with high abundances of copepods. Other findings of note relative to commercially important fish stocks include:

1. *Despite the increase in Calanus copepods, the low water temperatures in 2012 apparently led to fewer and smaller age-0 pollock, possibly because temperatures were too low for early survival;*

2. *The small age-0 pollock had low total energy content in 2012, suggesting that recruitment to age-1 for this year class may be weak;*

3. *The biomass of euphausiids in 2012 was again down, as in 2010, despite cold waters and extensive sea ice.*

Conditions in the eastern Bering Sea during 2014 are proving to be quite different from 2013 and recent years. Ice broke out earlier and the cold pool is much reduced as described in Nick Bond's contributions on North Pacific Climate (p. 79). The eastern Bering Sea assessment includes a full recap of the environmental conditions and ecosystem state in 2013, a summary and synthesis of available information on the 2014 ecosystem state, and a preliminary forecast of environmental conditions in 2015 that predicts continued warmth.

Bycatch of seabirds in 2012 was 40% below the 5-year running mean, supporting the conclusion that the efforts by the longline fleet to reduce bycatch are paying off. It was suggested that there may be a connection between ocean conditions and the numbers of bycaught seabirds, with more seabirds caught in years with reduced prey availability.

This topic is being further explored by Stephani Zador for a presentation at the Pacific Seabird Group in February 2015 and will be summarized in the 2015 Ecosystem Considerations report.

The information on discard rates (page 172-176) might be more helpful if broken out by industry sector. The huge, very clean pollock catch may hide the impacts of the bottom-trawl fisheries. Knowledge of how each sector is progressing toward lowered bycatch could help to improve management in this area.

The contribution author has provided the data by sector this year. Discards in the sectors targeting pollock have remained low, while discards increased in 2013 in the fixed gear sector, particularly in the Gulf of Alaska. Improved observer coverage on vessels $<$ 60' long and on vessels targeting IFQ halibut may account for the increase.

In both the eastern Bering Sea and the Gulf of Alaska, there is evidence that arrowtooth flounder biomass on the shelves is down, and that pollock biomass is up. Continued effort to examine these relationships is warranted as future warming may mean a return to heavy predation on pollock by arrowtooth flounder.

Survey data from summer 2014 may help to inform this question as conditions have warmed considerably. With the increased temperatures, these relationships have likely changed. Specifically we would predict that arrowtooth density on the shelf areas would have increased, and thus there would be more overlap between the two species.

In the Gulf of Alaska, the shift in the Papa Trajectory Index to conditions similar to those pre-1977 is of considerable interest, as it may presage a new regime in the Gulf with very different fishery performance than is currently the case. It would be interesting to know if sea temperatures in the Gulf have made a similar shift. Likewise, the improved survival of sablefish juveniles in warmer water suggests that there may be a potential for developing a predictive index.

It now appears the filtered PAPA Trajectory Index may shift back to northerly flow, in contrast to the conclusion last year, which would indicate that the recent period of predominantly southern flow (mid-2000s to present) will have been the shortest and weakest in the time series (p. 104). Also, the Gulf of Alaska has experienced record warm anomalies this winter through summer (p. 79); the extent of biological response to this warming is still being determined. A sablefish recruitment prediction index is included in this report (p. 173). Based on sea temperature, chlorophyll a, and pink salmon productivity, the model predicts below average recruitment events for age-2 sablefish in 2013 and 2015, and a slightly above-average recruitment event is expected in 2014. This year, we also include a summary and synthesis of indicator states' in the ecosystem assessment that together suggest that there may have been a shift in the ecosystem state in the Gulf of Alaska in 2006.

The SSC supports the development of an acoustic index of euphausiid abundance and distribution in the Gulf similar to that available for the Bering Sea.

New this year we include a contribution on a newly developed euphausiid index for the GOA (p. 124).

There is now evidence of negative relationships between pink salmon abundance and the timing and size of sockeye salmon returning to Bristol Bay, the survival of sablefish juveniles in southeast Alaska (page 150), and the multivariate index of seabird reproductive performance at the Pribilof Islands. Is there evidence from anywhere that pink salmon interfere with survival or growth of juvenile Chinook salmon?

This report includes a new contribution titled Using Ecosystem Indicators to develop a Chinook Salmon Abundance Index for Southeast Alaska (p. 153). The authors state that contrary to many of the assumptions of negative impacts of pink salmon on other species, in the case of these two strong year classes of Chinook, they coincide with the same ocean entry years of the high juvenile pink salmon abundances in 2010 and 2012. This suggests that both juvenile Chinook and pink salmon mutually benefited from favorable ocean conditions in 2010 and 2012, or the smaller, more abundant juvenile pink salmon proved to be a predator buffer to the larger Chinook salmon juveniles. The upcoming 2015 Chinook salmon harvest and abundance of legal sized (age 3-ocean) will be a good test of this index.

It is unclear how a Climate Index for the Bering Sea would be used. Perhaps determination of its use should precede its development? Similarly, an index of primary production in spring, when there are massive blooms might only give a weak indication of the possible flux of detritus to the benthos. Conversely, an index of primary production between August and September might give an indication of the food available to the large crustacean zooplankton in the upper mixed layer, and hence their likelihood of remaining near the surface and available to planktivorous predators including age-0 pollock, seabirds and cetaceans.

This is a good suggestion and continues to be an area of active discussion.

In the discussion of HAPC biota bycatch and discards, it would seem possible that some species return to the bottom relatively unharmed, whereas others are destroyed. In trying to separate out the relative importance of factors impacting trends in bycaught benthos, it might be helpful to know what they eat and how the availability of their prey has been changing.

We agree.

The discussions of communities and subsistence were most valuable. It could be worth considering combining the sections on populations in the Bering Sea/Aleutian Islands and the Gulf of Alaska into a single section. Doing so should result in a decrease in redundancies, and the potential for *comparing and contrasting the various regions and their dependencies on commercial fishing and subsistence harvest.*

The contributions on human communities were separated by ecosystem to facilitate comparison among various ecosystem components within an ecosystem. We may rearrange how the contributions are organized, but not in this year's report as we don't anticipate any updated information.

Research Needs: Several recent findings suggest areas for research on the predictability of these relationships and their value for informing future management decisions:

1. *It could be useful to examine the role of energy content/density in age-1 pollock to see if their condition influences their survival. Use of weights at length from the survey catches, in addition to those from the fishery, might be useful;*

   We have separated age-1 pollock from age- 2+ in the eastern Bering Sea groundfish condition contribution, which may be useful for further exploration of this topic. New this year, we also include the same groundfish condition analysis for the Aleutian Islands and the Gulf of Alaska.

2. *The possibility that the decline in euphausiids was driven by increasing pollock biomass needs investigation, as top-down control would suggest that, in the future, predators specializing on euphausiids may be in competition for a limiting resource;*

   This is an area of active research.

3. *The hypothesis that seabird bycatch differs among years in response to natural prey availability should be tested rigorously, as it suggests that there may be limits imposed on the efficacy of bycatch reduction measures when birds are starving;*

   This is under investigation.

4. *The potential role of pink salmon as a predator and/or as a competitor of other commercially important species needs careful examination.*

   There is substantial literature on the role of pink salmon and competitors of other salmon, but less so for other species. This is an area of active research.

5. *To assess the importance of HAPC bycatch, research is needed to determine the post release survival of the different classes of organisms that are important components of the structural epifauna.*

We agree.

Introduction

The goal of the Ecosystem Considerations report 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 four main sections:

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

The purpose of the first section, the Report Cards, is to summarize the status of the top indicators selected by teams of ecosystem experts to best represent each ecosystem. 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 Executive Summary, is to provide a concise summary of the status of marine ecosystems in Alaska for stock assessment scientists, fishery managers, and the public. Page links to sections with more detail are provided.

The purpose of the third 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 beginning. An ongoing goal is to produce ecosystem assessments 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 fourth 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. Ecosystem-based management indicators should also 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

Since 1995, the North Pacific Fishery Management Councils (NPFMC) Groundfish Plan Teams have prepared a separate Ecosystem Considerations report within the annual SAFE report. Each new Ecosystem Considerations report provides updates and new information to supplement the original report. The original 1995 report 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 edition provided additional information on biological features of the North Pacific, and highlighted the effects of bycatch and discards on the ecosystem. The 1997 edition 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 Niño, 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 report 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.

Each year since then, the Ecosystem Considerations reports has included some new contributions in this regard and will continue to evolve as new information becomes available. Evaluation of the meaning of observed changes should be in the context of how each 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 report 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 report 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 report provide actual time series data or make it available electronically. Many of the time series data for contributions are available on the web, with permission from the authors. We are in the process of improving online access to indicators and plan to debut a new webpage in the near future.

The Ecosystem Considerations appendix and data for many of the time series presented in the appendix are 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 report version prior to 2000, please contact the Council office (907) 271-2809.

Ecosystem Assessment

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Last updated: October 2014

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, Gulf of Alaska, and the Arctic, 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 Stock Assessment and Fishery Evaluation (SAFE) report 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.

This assessment originally 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). Use of this DPSIR approach allows the Ecosystem Assessment to be in line with NOAAs vision of Integrated Ecosystem Assessments (IEA)(Figure 6).

We initiated a regional approach to ecosystem assessments in 2010 and presented a new ecosystem assessment for the eastern Bering Sea. In 2011 we followed the same approach and presented a new assessment for the Aleutian Islands based upon a similar format to that of the eastern Bering

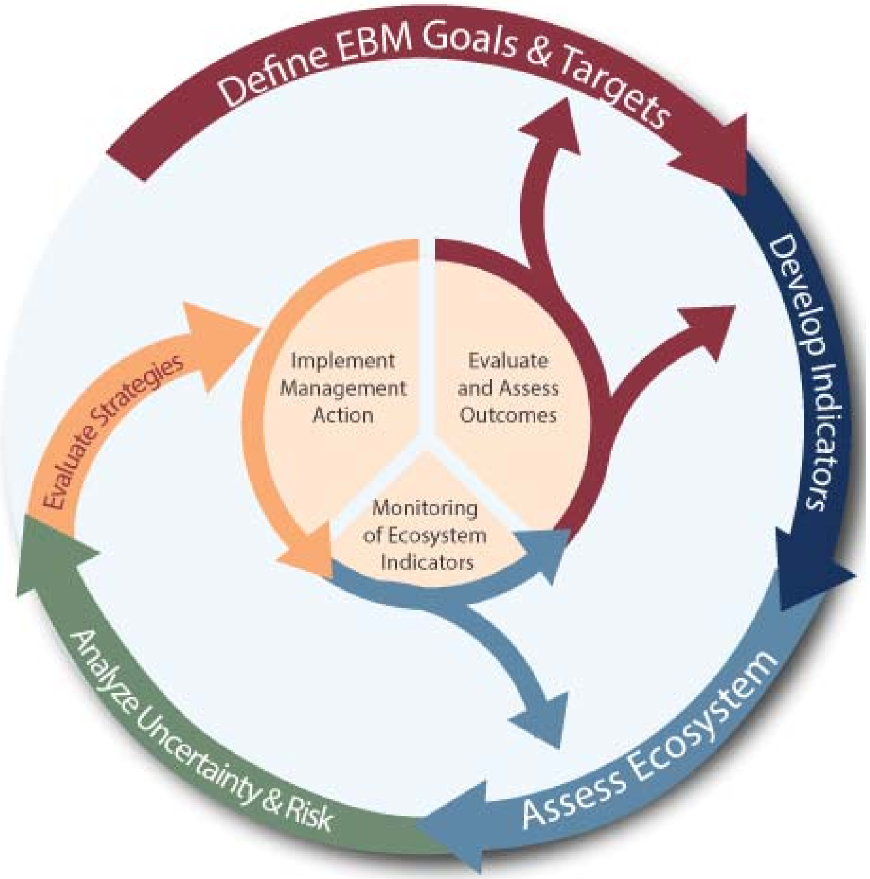

Figure 6: The IEA (integrated ecosystem assessment) process.

Sea. In 2012, we provided a preliminary ecosystem assessment on the Arctic. Our intent was to provide an overview of general Arctic ecosystem information that may form the basis for more comprehensive future Arctic ecosystem assessments. We are currently in the process of developing a new assessment for the Gulf of Alaska with a similar format to those of the eastern Bering Sea and Aleutian Islands.

While all sections follow the DPSIR approach in general, the eastern Bering Sea and 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 are currently in the process of surveying experts to select a list of top indicators for the Gulf of Alaska ecosystem with the goal of producing a report card and full assessment in 2015. We plan to do the same for the Arctic at a later time.

The entire ecosystem assessment is now organized into five sections. In the first "Hot topics" section we present succinct overviews of potential concerns for fishery management, including endangered species issues, for each of the four ecosystems. In the next sections, we present the region-specific ecosystem assessments. This year, we have included updated assessments for the Arctic, eastern Bering Sea (including the eastern Bering Sea Report Card), and the Aleutian Islands (including the Aleutian Islands Report Card). For the Gulf of Alaska, we include a summary of ecosystem state based on indicators contributed to the report.

This report now represents much of the first three steps in Alaska's IEA: defining ecosystem goals, developing indicators, and assessing the ecosystems. The primary stakeholders in this case are the North Pacific Fisheries Management Council. Research and development of risk analyses and management strategies is ongoing and will be referenced or included in this document as possible.

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

We present items that are either new or otherwise noteworthy and of potential interest to fisheries managers as Hot Topics.

Hot Topics: Arctic

Prolific phytoplankton bloom under Arctic sea ice

New research suggests primary production pathways may be changing in the Chukchi Sea. Primary production in the Arctic Ocean is seasonally limited by light and the presence of sea ice. Under the traditional view of primary production in the Arctic Ocean, photosynthesis in the water column beneath the sea ice is generally assumed to be of little importance, and the growing season is thought to begin in spring with an ice edge bloom shortly after the sea ice starts to break-up (Sakshaug 2004, Arrigo and van Dijken 2011). However, during the summer of 2011 a large phytoplankton bloom was observed beneath the sea ice in the northeastern Chukchi Sea, and extended for more than 100 km into the ice pack (Arrigo et al. 2012). Under the ice, phytoplankton production and biomass was high while in the surface layer of the adjacent open water, in the area of a typical ice-edge bloom, phytoplankton biomass was low and nutrient concentrations depleted (Arrigo et al. 2012). Arrigo et al. (2014) have suggested that in areas where such a prolific under-ice bloom occurs, that the depletion of nutrients in the surface layer by the under-ice bloom prior to ice break-up, may limit or prevent a traditional ice edge bloom from forming. In the newly opened water, instead of a productive surface layer associated with an ice-edge bloom, the bulk of phytoplankton biomass and primary production may now be focused in deeper sub-surface layers where nutrients are more plentiful (Arrigo et al. 2014).

It is unclear what effects these spatial and temporal changes in spring primary production may have on the food web. Herbivorous copepods are important consumers of Arctic phytoplankton and the timing of their reproductive events and growth is synchronized with the timing of Arctic primary production events (Runge and Ingram 1991, Sreide et al. 2010, Daase et al. 2013). More work is required to determine if under-ice blooms create a ”mismatch” with the timing of zooplankton growth and life history events, due to a change in the timing of the bloom or to a change in bloom location, now occurring in cold water under the sea ice (Arrigo et al. 2014, Palmer et al. 2014).

It is not yet known whether the under-ice blooms are a recent development and a product of thinning Arctic ice, or whether they have been a regular feature in the past and have just gone undetected until now (Arrigo et al. 2014). In a recent re-analysis of the satellite record from 2012 to 1998, Lowry et al. (2014) attempted to identify evidence of under-ice blooms on the Chukchi Sea from satellite data and found evidence of under-ice blooms in every year they examined. These results indicate that under-ice blooms have been regular features in the Chukchi Sea over the time period they examined. *Contributed by Andy Whitehouse*

Hot Topics: Eastern Bering Sea

Two short-tailed albatross confirmed takes in the eastern Bering Sea

The National Marine Fisheries Service (NMFS) confirmed the take of two endangered short-tailed albatross in the hook-and-line groundfish fishery of the Bering Sea/Aleutian Islands Management Area (BSAI). On September 16, 2014, NMFS reported the verified take of a STAL and the take of a second unidentified albatross in the same haul. US Fish & Wildlife Service seabird experts, Washington Sea Grant, and NMFS interviewed the observer, reviewed all available information of the incident, and concluded that the previously unidentified bird was also a short-tailed albatross. The birds were taken on September 7, 2014 at 58°47” 54’ N and 177°43” 36’ W in NMFS reporting area 521 (Figure 7). The last three documented short-tailed albatross takes in Alaska were in August 2010, September 2010, and October 2011.

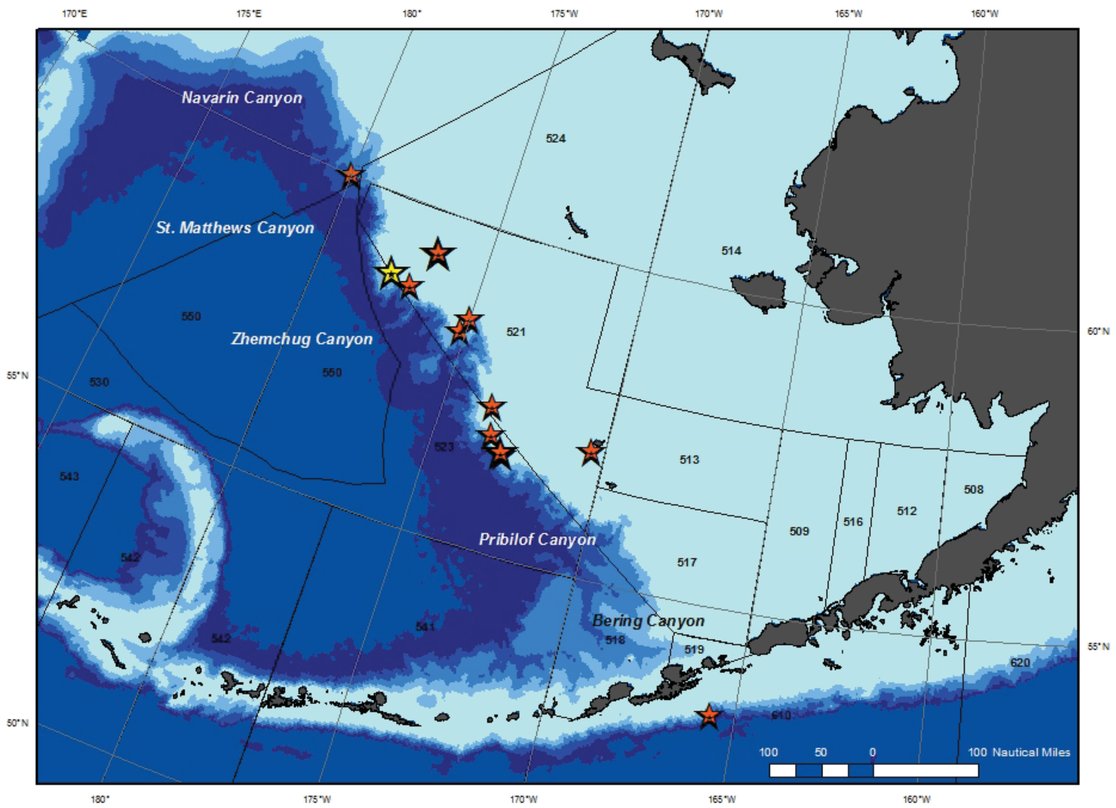

Figure 7: Observed locations of short-tailed albatross takes in Alaska groundfish fisheries since 1987 (red stars). Location of the latest confirmed takes on September 7, 2014 is shown with the yellow star.

Hot Topics: Gulf of Alaska

Gulf of Alaska "Warm Blob"

A warming event began in the central Gulf of Alaska in November 2013 and by early 2014 sea surface temperatures were 3°C above the long-term mean (Figure 8). The "blob" (as named by Nick Bond) persisted through the summer and was joined during the summer by additional warm areas in the eastern Bering Sea and off Baja California. The ecosystem impacts of this unusual warming are currently unknown but are being monitored. Possibly related ecosystem observations include: (1) fish species often associated with warm water, such as pomfret, ocean sunfish, blue shark and thresher shark observed during NOAA surveys in SE Alaska, and (2) high breeding success of seabirds in the Semidi Islands (see Hot Topic below, p. 45). As of fall 2014, the warm conditions have begun to dissipate.

Banner Year for Seabird Reproduction in the Western Gulf of Alaska

Seabird reproduction is monitored by the Alaska Maritime National Wildlife Refuge (USFWS) at Chowiet Island, which is part of the Semidi Islands archipelago. Refuge biologist Nora Rojek reported that during 2014 just about all seabird species monitored, except for cormorants, had good

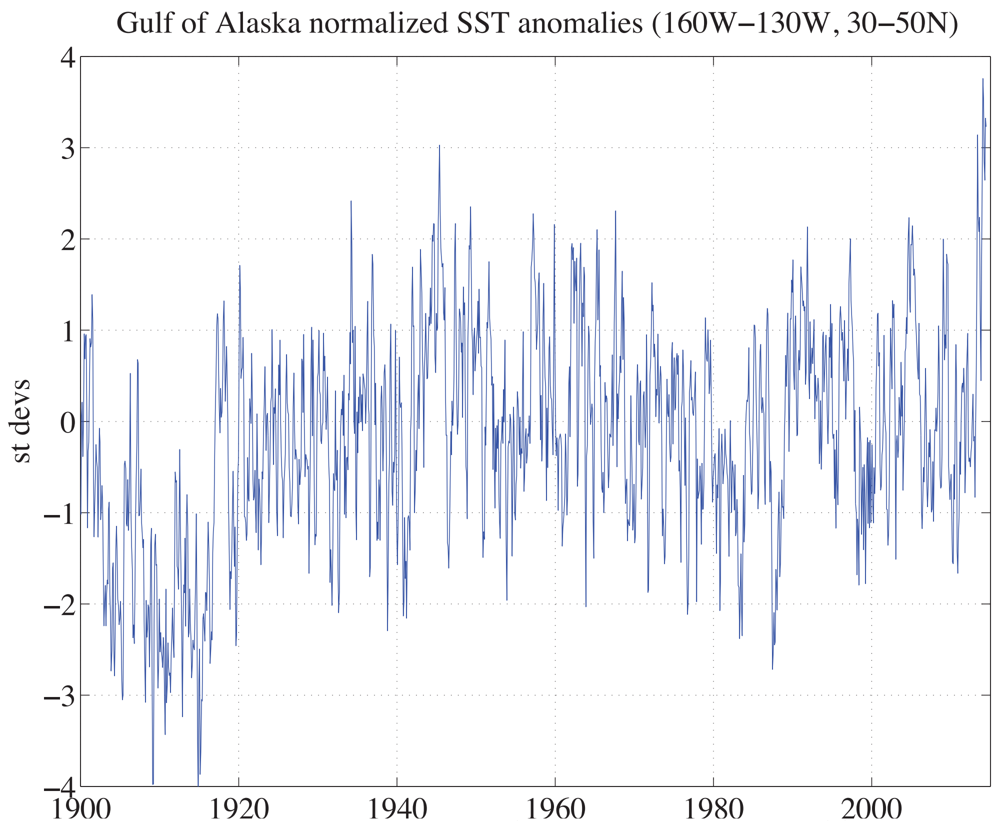

Figure 8: Gulf of Alaska normalized SST anomalies (160W to 130W, 30 to 50N)(credit: Nate Mantua, NOAA)

or above average productivity. In fact, for black-legged kittiwakes it was the highest productivity (51%) of all years except for 1981. Common murres had the highest productivity (61%) since 1980/1981. Thick-billed murre productivity was slightly above average. Parakeet auklet and horned puffin productivity were above average. Tufted puffin productivity was the highest since started monitoring began in 2005 (75% reproductive success), and hatching was the earliest recorded. Glaucous-winged gulls also had early hatching dates, high hatching success, and high fledgling counts. Northern fulmars had their highest mean and max chick counts since counts started in 2005. This widespread breeding success is in stark contrast to 2011, when most species failed or did poorly.

Preliminary Assessment of the Alaska Arctic

Andy Whitehouse[1] and Stephani Zador[2]

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Defining the Alaska Arctic assessment area

In 2012 preliminary assessment of the Alaska Arctic, we proposed the inclusion of the northern Bering Sea (>approx. 60°N) within the Alaska Arctic assessment area. The Alaska Arctic assessment area would then include the entire Arctic management area (NPFMC, 2009) and the northern Bering Sea (Figure 9). This suggestion was made in recognition of the growing body of scientific literature that indicates the northern Bering Sea is biologically and physically distinct from the southeastern Bering Sea (Grebmeier et al., 2006; Mueter and Litzow, 2008; Sigler et al., 2011; Stabeno et al., 2012; Stevenson and Lauth, 2012). The northern Bering Sea is not presently part of the assessed area in the eastern Bering Sea. Thus including the northern Bering Sea within the proposed Arctic area would create a continuum of assessed large marine ecosystems (LMEs) throughout Alaska. In the time since our preliminary assessment was published, the Arctic Council, an international forum of Arctic governments and indigenous communities (`http://www.arctic-council.org`), has published a revision to their boundaries for LMEs of the Arctic Area (PAME, 2013). In their revision they moved the southern boundary of the Chukchi LME further south into the northern Bering Sea. Previously their boundary was at the Bering Strait (∼66°N) but is now located south of St. Lawrence Island at 61.5°N. Similarly, the rationale for this revision was in recognition of the combined biological and physical properties linking the northern Bering Sea to the Chukchi Sea. As this Arctic section of the Ecosystem Considerations report progresses we will likely specify 61.5°N as the southern boundary of the Alaska Arctic assessed area, coincident with the LME boundary revisions made by the Arctic Council.

General ecosystem information

Most of the Alaska Arctic is covered by sea ice for some portion of the year and the seasonal presence and dynamics of sea ice has a strong influence on ecosystem structure and function. During years of low ice coverage, the most southerly portions of the northern Bering Sea may only be covered by sea-ice for a few weeks or not at all. The Chukchi and Beaufort seas are covered by sea ice for about 6 to 8 months of the year. During years of heavy summer ice coverage, portions of the northern Chukchi and Beaufort seas may retain their ice coverage throughout the year. However, Arctic sea ice cover has declined over recent decades, with the seven lowest annual sea ice minima over the satellite record (1979-present) occurring in the last 7 years, 2007-2013 (Comiso, 2012; Stroeve et al., 2012)(`http://nsidc.org`). A recent reconstruction of Arctic sea ice cover over the last 1,450 years has indicated that the observed declines in sea ice starting in the 1990's are the lowest over this time period, and fall outside the range of variability in previous observations (Kinnard et al., 2011). Regionally, some of the most pronounced declines of September ice extent in recent decades have been observed in the Chukchi and Beaufort seas (Meier et al., 2007).

The persistence of sea ice during the summer season has implications for the primary productivity regimes in these northern systems. Primary production during winter is limited by ice coverage

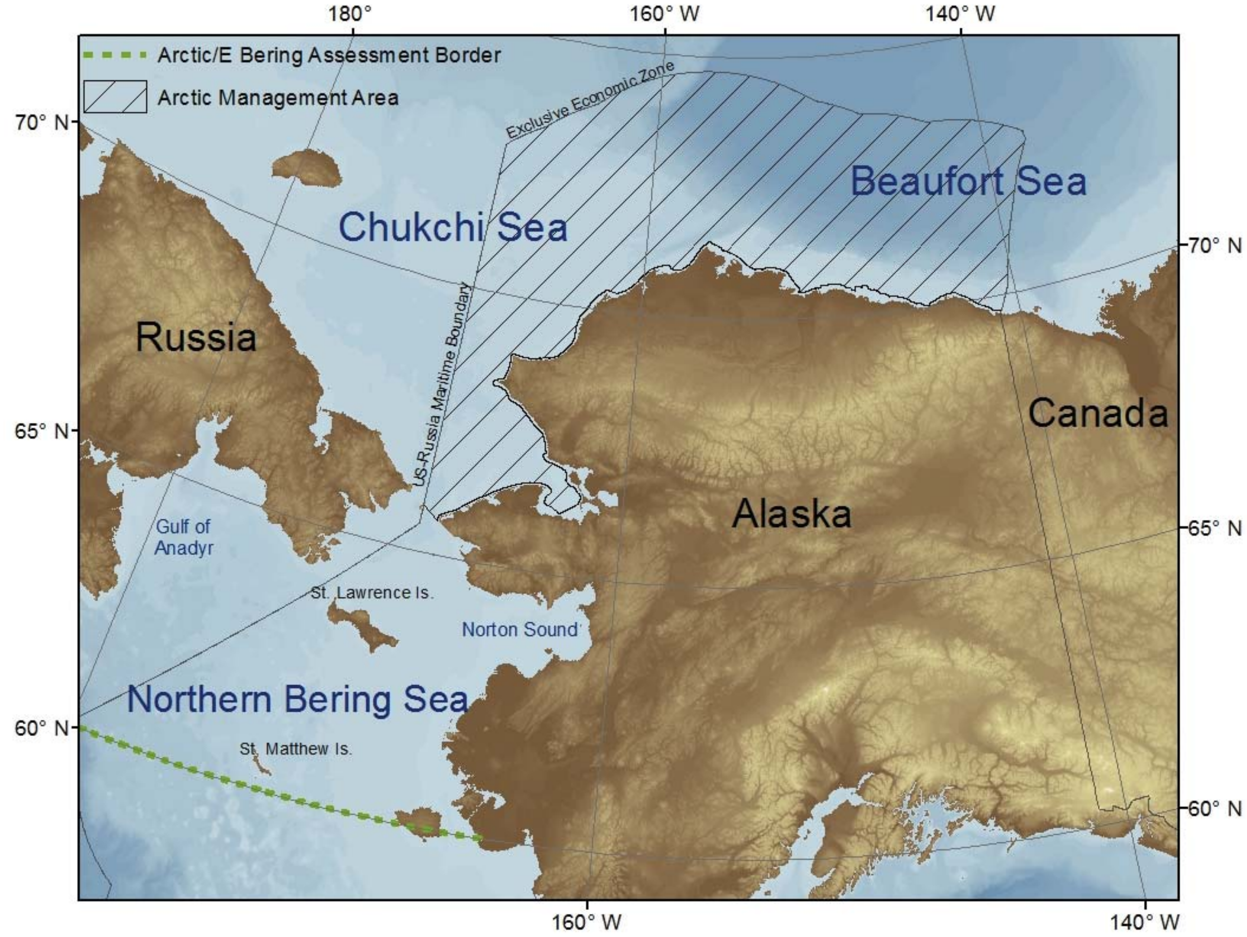

Figure 9: The proposed Arctic assessment area in Alaska, encompassing the northern Bering Sea, Chukchi Sea, and Beaufort Sea, within US territorial waters. The existing Arctic management area is filled with hatched lines.

and shortened day length, including periods of arctic night in the Chukchi and Beaufort seas. Phytoplankton growth begins in late winter with the return of daylight and an ice algae bloom that continues until the onset of ice melt (Cota, 1985; Cota and Smith, 1991)). At a time when food may be limited, the ice algae bloom provides early season forage for ice-associated invertebrates, which in turn are preyed upon by Arctic cod *Boreogadus saida*) (Bradstreet, 1982; Legendre et al., 1992; Gradinger and Bluhm, 2004). In seasonally ice covered areas, ice algae may contribute less than 5% to total annual primary production (water column and sea ice), while at the northern margins of the Chukchi and Beaufort seas, which may experience year-round ice coverage, ice algae can account for more than 50% of the annual primary production budget (Gosselin et al., 1997). Additionally, recent work in the northern Chukchi Sea has indicated that under-ice phytoplankton blooms, which had previously been unaccounted for, may contribute substantially to total primary production (Arrigo et al., 2012). Current estimates of primary production over Arctic continental shelves that do not take these under-ice blooms into account may be several times too low (Arrigo et al., 2012). The breaking-up and melting of sea ice in spring strengthens water column stratification, and when combined with increasing day-length, induces an ice edge phytoplankton bloom that follows the retreating ice edge northward (McRoy and Goering, 1974; Niebauer et al., 1981; Sakshaug, 2004).

Seasonal ice coverage cools the entire water column over the shallow shelves of the northern Bering and Chukchi seas to temperatures below 0°C. These cold temperatures limit the northern distribution of sub-Arctic populations of groundfish, such as walleye pollock and Pacific cod (Osuga and Feeney, 1978; Wyllie-Echeverria and Wooster, 1998; Mueter and Litzow, 2008; Stevenson and Lauth, 2012), and may constrain their growth (Pauly, 1980). During summer much of the zooplankton community occupying the northern Bering and Chukchi seas are of Pacific origin, and are advected into these Arctic waters through Bering Strait (Springer et al., 1989; Hopcroft et al., 2010; Matsuno et al., 2011). Here, the cold water temperatures may limit zooplankton growth and their grazing efficiency of phytoplankton (Coyle and Pinchuk, 2002; Matsuno et al., 2011). Cold-adapted Arctic zooplankton species are more prevalent in the northern portions of the Chukchi Sea, near the continental slope and canyons (Lane et al., 2008). In years of low ice coverage, an overall northward distribution shift in southern extent of Arctic species and the northern extent of Pacific species has been observed (Matsuno et al., 2011). Additionally, an increase in total zooplankton abundance and biomass has also been observed in years of low ice coverage, and this has been in part attributed to an increased influx of larger zooplankton species of Pacific origin and temperature effects on their growth (Matsuno et al., 2011).

The annual dynamics of sea ice also affects the distribution of marine mammals. Pacific walrus and ice seals utilize sea ice in the Bering Sea during winter to haulout, breed, and whelp. Ringed seals are present throughout the Alaska Arctic during winter and maintain breathing holes in the ice to keep access to the water (Lowry et al., 1980; Kelly, 1988). Ringed seals also construct resting lairs over breathing holes and beneath the snow cover, which provide protection from the elements and predators, and are used to raise pups (Burns, 1970; Smith et al., 1991; Kelly et al., 2010). Pinnipeds may also use sea ice as a form of transportation during ice retreat and as a platform to rest between foraging excursions. Polar bears utilize sea ice as platform to hunt from throughout the year. Pregnant female polar bears may also excavate maternity dens on sea ice in the fall, where they will give birth to cubs in winter (Lentfer and Hensel, 1980; Amstrup and Gardner, 1994; Fischbach et al., 2007). Belugas and bowhead whales spend the winter along the ice edge in the northern Bering Sea, and in the spring they follow regularly recurring leads and fractures in the ice that roughly follow the Alaska coast during migration toward their summering grounds in the Beaufort Sea (Frost and Lowry, 1983; Ljungblad et al., 1986; Moore et al., 1993; Quakenbush et al., 2010). Belugas also forage near the ice edge and in more dense ice coverage among leads and polynyas in both the Beaufort and Chukchi seas (Richard et al., 2001; Suydam, 2009). Seabirds may also concentrate near the ice-edge (Divoky, 1976; Bradstreet, 1982; Hunt, 1991), preying on ice-associated invertebrates and Arctic cod (Bradstreet, 1982).

Marine mammals have been important subsistence resources in Alaska for thousands of years and the continued subsistence harvests of marine mammals are important to the maintenance of cultural and community identities (Hovelsrud et al., 2008). The presence and dynamics of sea ice is an integral part of many subsistence harvests, including the hunting of bowhead whales (George et al., 2004), belugas (Huntington et al., 1999), Pacific walrus (Fay, 1982), and ice seals (Kenyon, 1962). Traditional knowledge of sea ice behavior, the effect of environmental conditions on sea ice stability, and how sea ice conditions relate to the seasonal presence and migratory habits of marine mammals has accumulated over time. The sharing of this knowledge helps maintain the successful and safe harvest of marine mammals (Huntington et al., 1999; George et al., 2004; Noongwook et al., 2007).

The net flow of water through the northern Bering and Chukchi seas is northward (Coachman et al., 1975; Walsh et al., 1989; Woodgate et al., 2005). High levels of primary production in the northern

Bering and southern Chukchi seas is maintained throughout the open water season by nutrient rich water advected from the Bering Sea continental slope and the Gulf of Anadyr (Springer and McRoy, 1993; Springer et al., 1996). During the open water season, primary production in the northern Chukchi Sea is focused in the vicinity of the ice edge (Wang et al., 2005) and Barrow Canyon where occasional flow reversals allow for upwelling of Arctic basin waters, which promote phytoplankton blooms (Aagaard and Roach, 1990; Hill and Cota, 2005; Woodgate et al., 2005). Primary production in the Beaufort Sea may be enhanced during summer when sea ice retreats beyond the shelf break allowing for phytoplankton blooms driven by upwelling along the shelf break (Pickart et al., 2009).

The northern Bering and Chukchi seas are benthic-dominated systems. Several ecological studies carried out over the last approximately 50 years have documented the abundant community of benthic invertebrates (Sparks and Pereyra, 1966; Feder and Jewett, 1978; Stoker, 1981; Grebmeier et al., 1988; Feder et al., 1994, 2005, 2007; Bluhm et al., 2009). Here, the combination of high primary production, shallow continental shelves (< 60 m), and cold water limiting the growth and grazing of zooplankton results in high delivery of organic matter to the benthos, where it supports an abundant benthic community (Grebmeier et al., 1988; Grebmeier and McRoy, 1989; Dunton et al., 2005; Lovvorn et al., 2005). The prominent benthos supports a community of benthic-foraging specialists, including gray whale (Highsmith and Coyle, 1992), Pacific walrus (Fay, 1982), bearded seals (Lowry et al., 1980), and diving ducks (eiders) (Lovvorn et al., 2003).

Species of commercial interest

Snow crabs are the basis of an economically important fishery in the eastern Bering Sea (NPFMC, 2011) and are a species of potential commercial importance in the Alaska Arctic (NPFMC, 2009). Snow crab are a dominant benthic species in the Chukchi and Beaufort seas. However, they are seldom found to grow to a commercially viable size, which is >78 mm carapace width (CW) (Frost and Lowry, 1983; Paul et al., 1997; Fair and Nelson, 1999; Bluhm et al., 2009). More recently, a trawl survey of the western Beaufort Sea in August 2008 (Rand and Logerwell, 2011) documented the first records of snow crab in the Beaufort Sea at sizes equal to, or greater than the minimum legal size in the eastern Bering Sea, finding males as large as 119 mm CW. Studies of snow crab reproduction biology have observed some flexibility in the size at maturation, indicating snow crabs in these colder Arctic waters may mature at a smaller size (Somerton, 1981; Paul et al., 1997; Orensanz et al., 2007). Snow crabs are also found throughout the northern Bering Sea.

Commercially important species of king crab have been sparsely encountered in the Chukchi Sea (Barber et al., 1994; Fair and Nelson, 1999; Feder et al., 2005) and were not encountered during the 2008 survey of the western Beaufort Sea (Rand and Logerwell, 2011). In the northern Bering Sea blue king crab are found near St. Matthew Island and north of St. Lawrence Island, and red king crab in Norton Sound (Lauth, 2011). The northern Bering Sea (as defined here) includes the northern half of the Alaska Dept. of Fish & Game management area for St. Matthew Island blue king crab. Following a ten year closure to rebuild the St. Matthew Island stock of blue king crab, the commercial fishery was reopened in 2009/10 (NPFMC, 2011). Red king crab presently support both, commercial and subsistence fisheries in Norton Sound (NPFMC, 2011).

The fish resources of the Alaska Arctic have not been as thoroughly sampled as in other large marine ecosystems in Alaska (e.g., eastern Bering Sea, Gulf of Alaska, Aleutian Islands), but a limited number of standardized demersal trawl surveys have been conducted in the region since the mid 1970's. The northern Bering and southeastern Chukchi seas were surveyed in 1976 (Wolotira et al. 1977), the northeastern Chukchi Sea in 1990 (Barber et al., 1994, 1997), the western Beaufort Sea in 2008 (Rand and Logerwell, 2011), the northern Bering Sea again in 2010 (Lauth, 2011),and the eastern Chukchi Seat in 2012 (Arctic EIS, https://web.sfos.uaf.edu/wordpress/arcticeis/). The catch data from these trawl surveys indicate that fish sizes are generally small and demersal fish biomass is low. Though fish have not been particularly abundant in survey catches, when present they have been dominated by cods, flatfishes, sculpins, and eelpouts (Wolotira et al., 1977; Barber et al., 1997; Lauth, 2011; Rand and Logerwell, 2011). In the Chukchi and Beaufort seas, Arctic cod has been consistently identified as the most abundant fish species (Alverson and Wilimovsky, 1966; Quast, 1974; Wolotira et al., 1977; Frost and Lowry, 1983; Barber et al., 1997; Rand and Logerwell, 2011). They occur in benthic and pelagic habitats in ice-free waters and are also found in association with sea-ice during ice covered periods (Bradstreet et al., 1986; Gradinger and Bluhm, 2004; Parker-Stetter et al., 2011). Arctic cod primarily prey on pelagic and ice-associated invertebrates and also form an important prey base for pelagic predators, including belugas, seabirds, and ice seals (Bradstreet, 1982; Frost and Lowry, 1984; Welch et al., 1992). Commercially important species of the eastern Bering Sea, such as walleye pollock and Pacific cod, have been infrequently encountered in the Chukchi and Beaufort seas (Frost and Lowry, 1983; Barber et al., 1997; Norcross et al., 2010; Rand and Logerwell, 2011).

Gaps and needs for future Arctic assessments

The intent of adding the Alaska Arctic to the regions assessed in the Ecosystem Considerations report is to provide information placed within a broad ecosystem context to fisheries managers that would be useful when making decisions on the authorization and management of new fisheries in the Alaska Arctic. We intend for future Arctic assessments to include indicators that directly address ecosystem-level processes and attributes that can inform fishery management advice. There is a continued need to convene Arctic experts to identify a list of indicators and corresponding time series data that best capture ecosystem components and trends that would be of value to fishery managers. Several biomass indices are presently used as indicators in assessments of the EBS, GOA, and AI. Time series data to support similar indices in the Alaska Arctic are lacking, but recent ongoing studies are accumulating data that may be of use as indicators.

Several data sets that may be of future use are being collected by the Distributed Biological Observatory (DBO,`http://www.arctic.noaa.gov/dbo/index.html`). The DBO is a coordinated effort by international members of the Pacific Arctic Group (PAG, `http://pag.arcticportal.org`) that has begun to collect scientific observations at selected locations (transects) over a latitudinal gradient from the northern Bering Sea to the western Beaufort Sea, in an effort to track ecosystem change over time (Figure 10)). As data accumulate, it is hoped that the sampling design of the DBO across a range of latitude will permit it to detect emergent patterns and trends. The data to be collected include oceanographic measurements (temperature, chlorophyll, etc.) and biological measurements, such as species composition, biomass, and the size and condition of selected key species (Grebmeier et al., 2010). Many of these metrics may be suitable for use as indicators in future Arctic assessments.

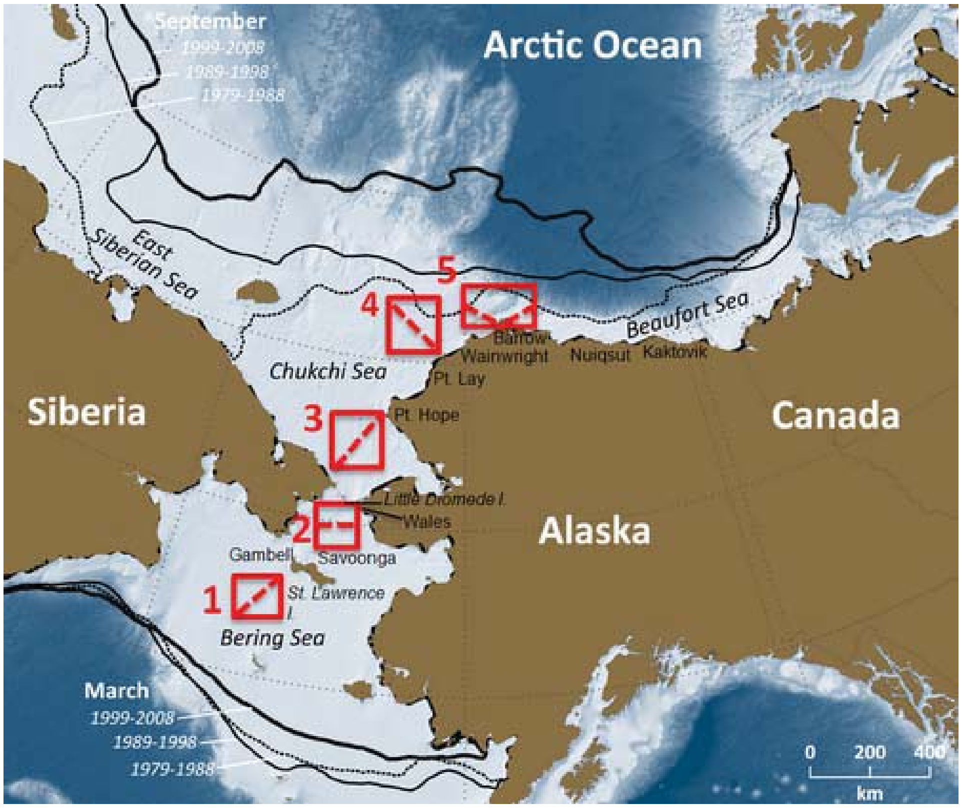

Figure 10: The Distributed Biological Observatory (DBO) in the Alaska Arctic. The red boxes are regional areas selected for observation and the dashed lines are the sampling transect lines. Figure from `http://www.arctic.noaa.gov/dbo/index.html`.

Potential indicators

In last year's preliminary Arctic assessment we suggested a short list of potential indicators as a starting point for indicator discussion and development. Here we hope to continue that discussion and present an expanded list that includes the indicators suggested in last year's document, some of which are presently available (both climate indicators), and some additional biological indicators that may be of value, but are not presently available. The compiled list of potential indicators includes:

Climate

- *Arctic Oscillation index* (`www.cpc.ncep.noaa.gov`). This index tracks large scale climate patterns in the Arctic and offers a limited capacity to predict the extent of Arctic sea ice (Rigor et al., 2002).
- *September sea ice index* (`http://nsidc.org/data/seaice_index/`) This index monitors the status and trends of September sea ice coverage for the entire Arctic over the satellite record (1979-present). The end of the sea ice melt season and the annual minimum in total Arctic sea ice extent occurs during September.

Plankton

- *A primary production time series.* Developing a primary production time series (remote sensing or in situ) would improve our ability to recognize changes in the primary production regime of the Alaska Arctic. Climate change and alterations to sea ice phenology are expected to effect the timing (Ji et al., 2013) and magnitude (Brown and Arrigo, 2012) of phytoplankton blooms. Such changes may have consequences for herbivorous zooplankton whose life history events are linked to the cycle of Arctic primary production events (Conover and Huntley, 1991; Conover and Siferd, 1993; Ji et al., 2012; Daase et al., 2013)

- *Zooplankton species composition and biomass.* Zooplankton species of Arctic and subarctic (Pacific) origin are present in the Chukchi Sea (Lane et al., 2008; Hopcroft et al., 2010; Matsuno et al., 2011). Species of Pacific origin are advected by the net northrward flow of water from the Bering Sea into the Chukchi Sea and influence the species composition and biomass of zooplankton in the Chukchi Sea (Hopcroft et al., 2010; Matsuno et al., 2011).

Fish

- *Fish biomass (or index of abundance).* Previous efforts to quantitatively sample fish resources of the Alaska Arctic have been separated in both space and time and often confounded by the use of different sampling methodologies, preventing the establishment of a baseline. Instead, the data provide a series of benchmarks presently unsuitable for the establishment of temporal biomass trends. Establishment of such a baseline would require quantitative sampling of fish biomass at regular interavals (e.g, every 1 to 3 years), such as from trawl surveys. Development of such a time series would permit the tracking of biomass and community composition over time and allow for the identifications of significant changes.Previous efforts to quantitatively sample fish resources of the Alaska Arctic have been separated in both space and time and often confounded by the use of different sampling methodologies, preventing the establishment of a baseline. Instead, the data provide a series of benchmarks presently unsuitable for the establishment of temporal biomass trends. Establishment of such a baseline would require quantitative sampling of fish biomass at regular interavals (e.g, every 1 to 3 years), such as from trawl surveys. Development of such a time series would permit the tracking of biomass and community composition over time and allow for the identifications of significant changes, such as what might be expected with climate change (Hollowed et al. 2013). Recent demersal trawl survey work has helped to describe current conditions in the Chukchi Sea (Goddard et al. 2013) but continued work will be necessary for development of biomass indicators. A summary of recent efforts to sample fish resources in Arctic Alaska is available at the marine fish section of NOAA's Arctic Report Card (`http://www.arctic.noaa.gov/reportcard/marine_fish.html`). Additionally, Logerwell et al. (in review) has synthesized data from recent fish surveys (2007-2012) in the Alaska Arctic from multiple habitat types across the Beaufort and Chukchi Seas to explore patterns in community composition, habitat use, and life history.

Seabirds

- *Black guillemot (Cepphus grylle) reproductive success.* Trends in the reproductive success of black guillemots on Cooper Island, AK may provide an indication of overall favorable or declining conditions for piscivorous sea ice associated seabirds.

- *Black guillemot food habits.* Changes in diet of black guillemots on Cooper Island, AK may affect growth, survival, and reproductive success, and may be a reflection of changing climatic conditions (e.g., loss of sea ice) and the availability of preferred prey.

Marine mammals

- *Marine mammal body condition.* Changes in body condition (e.g., body mass at age and season) may reflect changes in climate and/or changes in prey distribution and availability.
- *Marine mammal abundance/biomass.* Determining for which species time series data exists or initiating regular censuses for other species to track the overall health and persistence of marine mammal populations in the Alaska Arctic.

Humans

- *An index of subsistence hunting of marine mammals* intended to provide a gross measurement of human interaction with the marine environment. This index could be based on the number/mass of harvested animals and/or effort (CPUE), may be species specific or aggregate, or could be a measure of subsistence participation in aggregate or by community (number of people participating/permits). The success of any particular subsistence hunt may be subject to a multitude of factors including (but not limited to) effort, hunter experience, environmental factors, and prey abundance. An index of subsistence hunting would ideally be sufficiently broad in scope to minimize the effects of such confounding factors, but focused enough to provide an informative measure of direct human interaction with living marine resources.

Eastern Bering Sea Ecosystem Assessment

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Summary

Recap of the 2013 ecosystem state

Some of the ecosystem indicators that we follow are updated to the current year's state, while others can be updated only to the end of the previous calendar year or before due to the nature of the data collection, processing, or modelling. Thus some of the "new updates" in each Ecosystem Considerations report reflect information from the previous year. Below is an updated summary of last year (i.e., 2013) that includes 2013 information that we have received in 2014. Our goal is to provide a complete picture of 2013 based on the status of most of the indicators we follow. The next section will provide a summary of the 2014 ecosystem state based on indicators that are updated in the current year.

Conditions in the eastern Bering Sea in 2013 remained in the generally cold pattern seen since 2007 that is favorable for lower trophic level production with extensive sea ice, early spring blooms, and moderately high concentrations of euphausiids and large copepods for planktivorous feeders. These conditions moderated in 2011 with warmer bottom temperatures and less extensive maximum ice extent and cold pool. However, 2012 followed with the most extensive cold pool area of the recent decade and the latest ice retreat (along with 2009) in more than two decades. Dates of sea ice retreat, summer surface and bottom temperatures, and the extent of the cold pool in 2013 were very similar to those during 2007.

Anenomes and sponges had the highest mean CPUE in the bottom trawl survey time series, continuing a long-term increasing trend since 2001 for anenomes and 2007 for sponges. Sponges and jellyfish in the trawl survey show similar temporal trends; both increased to peaks in 2000, reached low values around 2007, and have increased since. It is unknown whether these correlations may be influenced by shared environmental sensitivities. The area potentially disturbed by trawls increased slightly in the non-pelagic gear sector in 2013 while continuing to decrease in the pelagic gear sector after a recent peak in 2011.

Jellyfish, primarily *Chrysaora melanaster*, remained abundant in the summer 2013 surveys, although CPUE was down slightly from 2012. The years 2009-2013 continue a trend of abundance, relative to the years 2001-2008 when catch rates of jellyfish remained low, and may indicate increased predatory pressure on the zooplankton and small fish that jellyfish consume.

The 2013 springtime drift patterns based on OSCURS model time series runs did not appear to be consistent with years of good recruitment for winter-spawning flatfish such as northern rock sole, arrowtooth flounder and flathead sole. However, groundfish length-weight residuals from the trawl surveys were positive for all but Pacific cod in 2013, indicating that foraging conditions and general ecosystem productivity were positive for groundfish in 2013.

The extremely cold conditions in 2012 led to a prediction of below median recruitment of age-0 pollock to age-1 in 2013, based on their low average energy content. The prediction was supported by the 2013 pollock stock assessment estimate of numbers of age-1 (18,523 millions of fish) relative to the median (19,467 millions of fish). Both the abundance and sac roe fishery for herring in the Togiak region were 113% and 134% of the recent 10-year average and thus considered healthy and sustainably harvested.

Survey biomass of motile epifauna has been above its long-term mean since 2010 and fairly stable since the early 1990s. However, the trend of the last 30 years shows a decrease in crustaceans (especially commercial crabs) and a long-term increase in echinoderms, including brittle stars, sea stars, and sea urchins. It is not know the extent to which this reflects changes in survey methodology rather than actual trends. Survey biomass of benthic foragers has remained stable since 1982, with interannual variability driven by short-term fluctuations in yellowfin and rock sole abundance. Survey biomass of pelagic foragers has increased steadily since 2009 and is currently above its 30-year mean. While this is primarily driven by the increase in walleye pollock from its historical low in the survey in 2009, it is also a result of increases in capelin from 2009-2013, perhaps due to cold conditions prevalent in recent years. Fish apex predator survey biomass is currently near its 30-year mean. The increase since 2009 back towards the mean is driven primarily by the increase in Pacific cod from low levels in the early 2000s. Arrowtooth flounder, while still above its long-term mean, has declined nearly 50% in the survey from early 2000s highs, although this may be due to a distributional shift relative to the summer survey in response to colder water over the last few years, rather than a population decline.

Chinook salmon continued to do poorly in the eastern Bering Sea. Chinook in the Arctic-Yukon-Kuskokwim region have been declining since 2007 and no commercial periods targeting Chinook salmon were allowed in the Yukon Area during the 2013 summer season. Abundance and harvest were also low in the Kuskokwim Area and Bristol Bay. In contrast, coho harvests were above average in these two areas. Chum salmon catches varied; in Bristol Bay were 10% below the 20 year average, while harvests were above average in the Arctic-Yukon-Kuskokwim region. The 2013 Bristol Bay sockeye salmon run was 36% below the recent 20-year average. Run size has decreased each year since 2010. Thus, only coho and some chum salmon returns were above average throughout the eastern Bering Sea.

The leading component of the multivariate seabird breeding index indicated that birds generally bred earlier in 2013 and diving birds such as murres were successful reproductively. In contrast, the dominant pattern in kittiwake reproductive success continued its annual trend reversal, showing poorer reproduction for kittiwakes in 2013. The biennial signal in kittiwake reproduction is negatively correlated with pink salmon trends, suggesting potential competition between these predators with overlapping diets and winter distributions.

Overall, indicators suggest a mixed signal in ecosystem state for the eastern Bering Sea in 2013, with some indicators suggesting increased productivity and some suggesting lower productivity.

Current conditions: 2014

The year 2014 broke the unusual sequence of seven years with cold winter-spring temperatures (2007-2013), following the seven warm temperature years (2000-2006)(Overland et al., p. 88. January-May 2014 near surface air temperature anomalies in the southeastern Bering Sea were

+2°C, in contrast to 2013 at -2.5°C and 2012 at -3°C; sea ice maximum extent was reduced. Warm temperatures related to weaker winds than normal and mild temperatures over the northern North Pacific. Summer 2014 continued warm conditions due to high sea level pressures and weak winds. Ocean temperatures reflected the shift to warmer conditions throughout the year. The cold pool extent for summer 2014 retreated in contrast to recent cold years. It is unknown whether the one year change will bring the beginning of a climate shift, but warmer ocean heat storage will persist into fall 2014.

Biota associated with bottom habitat, such as sea whips, anemones, and sponges, all showed light declines in survey catch rates compared with 2013, although these trends may be influenced by gear selectivity.

The 2014 springtime drift patterns based on OSCURS model time series runs did not appear to be consistent with years of good recruitment for winter-spawning flatfish such as northern rock sole, arrowtooth flounder and flathead sole. This is the third spring with drift pattern that are not consistent with good recruitment for these flatfish.

In the pelagic zone, preliminary euphausiid abundance as determined by acoustics continued a decline seen since a peak in abundance was observed in 2009. This suggests that foraging conditions for euphausiid predators were relatively more limited this year. However, concurrent estimates of copepod abundance are not currently available, thus it is unknown whether planktivorous predators experienced limited prey resources overall. Jellyfish catch rates were similar to those last year, continuing a decline since a peak in 2009.

Length-weight residuals, an indicator of fish condition, for planktivous age-1 pollock were strongly positive, similar to those during the warm years of 2002-2005, and indicative of good foraging conditions. Colder later summers during the age-0 phase followed by warmer spring temperatures during the age-1 phase, as occurred in 2013-2014, are assumed favorable for the survival of pollock from age-0 to age-1, further supporting that the 2013 pollock year class experienced favorable conditions in 2014. However a new multiple regression model incorporating biophysical indices from 2013 and 2014 indicated that the average ocean productivity (based on chum salmon growth), warm spring sea temperatures (less favorable), and above average predator abundances (as measured by pink salmon) would result in below average age-1 pollock recruitment in 2014.

Length-weight residuals for all analyzed groundfish species including age 2+ pollock were positive, with the exception of Pacific cod. Residuals for age-1 and older pollock are not well-correlated in most years. Residuals were negative for both age-classes in 1999 and 2012, both particularly cold years; similarly, residuals were positive in the warm years of 2003 and this year. However, the link with warm and cold years is not always simple as residuals were positive for both pollock age-classes in 2010, which was a cold year. However, this year appeard to favor both age-1 and older pollock, indicating favorable foraging conditions.

Survey biomass of motile epifauna has been above its long-term mean since 2010, although the recent increasing trend has stabilized. However, the trend of the last 30 years shows a decrease in crustaceans (especially commercial crabs) and a long-term increase in echinoderms, including brittle stars, sea stars, and sea urchins. It is not know the extent to which this reflects changes in survey methodology rather than actual trends. Survey biomass of benthic foragers has remained stable since 1982, with interannual variability driven by short-term fluctuations in yellowfin and rock sole abundance. Survey biomass of pelagic foragers has increased steadily since 2009 and is currently above its 30-year mean. While this is primarily driven by the increase in walleye pollock from its historical low in the survey in 2009, it is also a result of increases in capelin from 2009-2014, perhaps due to cold conditions prevalent in recent years. Fish apex predator survey biomass is currently near its 30-year mean, although the increasing trend seen in recent years has leveled off. The increase since 2009 back towards the mean is driven primarily by the increase in Pacific cod from low levels in the early 2000s. Arrowtooth flounder, while still above its long-term mean, has declined nearly 50% in the survey from early 2000s highs, although this may be due to a distributional shift relative to the summer survey in response to colder water over the last few years, rather than a population decline.

With the reduced cold pool seen this year, cold water-avoiding groundfish such as pollock and especially arrowtooth flounder likely expanded their range onto the shelf, increasing their predatory impact there. The cold pool potentially serves as a refuge for age-1 pollock, so it is possible that the reduction in the cold pool may have increased predation pressure on age-1 pollock by groundfish predators.

Seabirds breeding on the Pribilof Islands experienced overall early nesting and high reproductive success, indicating that foraging conditions were favorable for these piscivorous and planktivorous predators. Because environmental conditions have been shown to related to successful breeding at lagged scales, the breeding success this summer may have been influenced by favorable conditions experienced this summer and/or the past few seasons. In contrast, the number of fur seals pups born at the Pribilofs was 2.1% less than during the last count in 2012, indicating continued unfavorable conditions for fur seals breeding there. The larger rookery on St. Paul Island this year had 5.2% fewer pups born this year than during the last count, but the smaller rookery at St. George Island has 17% more pups born.

In general, the shift from sequential cold years to a warm year appeared to coincide with a surge in productivity for groundfish and seabirds as indicated by general biomass trends, groundfish condition, and seabird reproductive success. Some, such as overall pollock and arrowtooth flounder biomass, are likely influenced by the reduction in the cold pool, which expanded their preferred thermal habitat. Groundfish condition was positive most groundfish species and seabird reproductive success was high, indicating favorable conditions for these piscivorous and planktivorous predators. This was not the case for fur seals, which may be responding to a different suite of population pressures or a similar suite in a different way. This pattern of high productivity in years immediately following cold years is similar to that in 2003, which saw peak survey estimates of pollock biomass and increasing groundfish condition. It is unknown whether the overall decreasing trend in groundfish productivity in the subsequent warm years after 2003 will repeat in the case of continued warm years in the future.

Preliminary 9 month ecosystem forecast for the eastern Bering Sea

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In November 2013 and November 2014, AFSC and PMEL produced 9-month forecasts of ocean conditions in the eastern Bering Sea as part of the Alaska region's Integrated Ecosystem Assessment (IEA) program. Large-scale atmospheric and oceanic forecasts from the NOAA/NCEP Climate Forecast System (CFS) were applied as atmospheric surface forcing and oceanic boundary conditions to a fine-scale oceanic model of the region.

The CFS is a global, coupled atmosphere-ocean-land model, which uses a 3DVAR technique to assimilate both in-situ and satellite-based ocean and atmospheric data (Saha et al. 2010). The CFS resolves the global atmosphere at 200km resolution and the global ocean at 50km resolution. Monthly and daily averages of CFS output are available online, and include both hindcasts, from 1979-present and forecasts out to 9 months beyond present time. The CFS is currently being run operationally by NOAA/NCEP/CPC for seasonal weather prediction. Skill metrics for this system have been reported in Wen et al. (2012).

The regional model is based on the Regional Ocean Modeling System (ROMS) implemented at 10km resolution (Hermann et al., 2013), and includes an embedded Nutrient Phytoplankton Zooplankton (NPZ) model with euphausiids (Gibson and Spitz, 2011). The regional models were developed with funding from NOAA/NPCREP and the NSF/NPRB funded Bering Sea Project, and calibrated through repeated hindcasts of the region.

The forecast for January - July 2014 (from November 2013) predicted substantial warming in the Bering Sea throughout the winter and spring, including much lower sea ice in the winter and a reduced cold pool for summer 2014; this has been confirmed with 2014 winter ice cover and summer survey data.

The 2015 prediction suggests that the Bering Sea will stay warm over the next 9 months, with winter ice cover similar to 2014 and continued above-average temperatures into the summer.

Description of the Report Card indicators

Three of the Report Card indicators have been modified this year to reflect advances in recent research. In the sections below, we describe both original and new indicators and provide a brief rationale for their inclusion.

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

The advantageous aspects of the NPI for the present purpose include its systematic relationship to the primary causes of climate variability in the Northern Hemisphere, especially the El Niño-

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

2. Eastern Bering Sea ice retreat index: Sea ice over the southern Bering Sea (south of 5̃9^{o}N) varies greatly on all time scales (daily, annual, decadal), while the variability of northern Bering Sea shelf is much less. We use here an index of the number of days during March and April in which there was at least 20% ice cover in a 100 km box around the M2 mooring located in the southeastern portion of the shelf at 57^{o}N and 164^{o}W (Stabeno et al., 2012). As of this year, this calucation replaces the original ice retreat index, which was calculated as the number of days past March 15 when areal sea ice concentration was greater than 10% in a 2^o x 1^o box (bounded by 56.5^{o}N to 57.5^o, 165^{o}W to 163^{o}W). We chose the spring, because it is spring sea ice that influences the timing spring phytoplankton bloom, determines the extent of the cold pool and strongly influences the surface ocean temperatures during summer.

3. Euphausiid 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. For this year, we are using an estimate of euphausiid biomass as determined by acoustic trawls (see contribution on p.118).

4., 5., 6., 7. Description of the fish and invertebrate biomass indices: We present four guilds to indicate the status and trends for fish and invertebrates in the EBS: apex predators, pelagic foragers, benthic foragers, and motile epifauna. Each is described in detail below. The full guild analysis involved aggregating all EBS species included in a food web model (Aydin et al., 2007) into 18 guilds by trophic role, habitat, and physiological status (Table 2). For each guild, time trends of biomass are presented for 1977-2014. EBS biomass trends are summed stock assessment model estimates or scaled survey data, where available, for each species within the guild. If neither time series are available, the species is assumed to have a constant biomass equal to the mid-1990s mass balance level estimated in Aydin et al. (2007). Catch data was directly taken from the Catch Accounting System and/or stock assessments for historical reconstructions.

4. Motile epifauna (fish and benthic invertebrates): This guild includes both commercial and non-commercial crabs, sea stars, snails, octopuses, and other mobile benthic invertebrates. Information is based on bottom trawl survey data (for more information, see p. 178 and 179). There are ten commerical crab stocks in the current Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs; we include seven on the EBS shelf: two red king crab *Paralithodes camtschaticus* (Bristol Bay, Pribilof Islands), two blue king crab *Paralithodes platypus* (Pribilof District and St Matthew Island), one golden king crab *Lithodes aequispinus* (Pribilof Islands), and two Tanner crab stocks (southern Tanner crab *Chionoecetes bairdi* and snow crab *C. opilio*). The three dominant species comprising the eelpout group are marbled eelpout (*Lycodes raridens*), wattled eelpout (*L. palearis*) and shortfin eelpout (*L. brevipes*). The composition of sea stars in shelf trawl catches are dominated by the purple-orange sea star (*Asterias amurensis*), which is found primarily in the inner/middle shelf regions, and the common mud star (*Ctenodiscus crispatus*),

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

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

which is primarily an inhabitant of the outer shelf. Stock assessments for crabs have not been included to date, but could be in the future.

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

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

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

8. Multivariate seabird index: This index represents the dominant trend among 17 reproductive seabird data sets from the Pribilof Islands that include diving and surface-foraging seabirds. The trend of the leading principal component (PC1) represents all seabird hatch timing and the reproductive success of murres and cormorants. Thick-billed murre reproductive success on St.

George was initially selected as a sentinel seabird indicator in the absence of a multivariate index. As of this year, the PC1 of the multivariate index replaces the single species index. Further detail on the new index is reported on p. 186.

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

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

Gaps and needs for future EBS assessments

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

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

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

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

Spatial scales for assessment: The team reviewed EBS bottom trawl survey data at the guild level to determine whether there were striking changes in distribution patterns over time. No patterns of immediate concern were detected; however, the team felt that including a thorough spatial investigation of key indices would be a high priority in upcoming assessments. For example, spatial distributions of zooplankton, benthos, and forage fish would be critical for predicting the foraging success of central place foragers such as seabirds and pinnipeds. It may be desirable to examine the selected indices by domain (e.g., outer, middle, and inner shelf) rather than EBS-wide. Distributional indices could be developed for foraging guilds, indicator species, and fisheries (see below) similar to some already presented in the Ecosystem Considerations SAFE (e.g. Mueter et al. on p. 199). 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: Integration of the stock assessments and this ecosystem assessment is an ongoing goal. During the 2010 meeting, the assessment team noted that dominant species often dictate the time trend in aggregate indicators. Several times the team strayed into conversations that were focused on relationships between a select group of species. It is important that the synthesis chapter is dynamically linked to the single species ecosystem assessments so that specifics on how climate impacts dominant species, their prey, and their distribution can be readily obtained if a person wishes to drill down to the single species interactions underlying the guild responses provided.

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

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

Table 3: Suite of models used for implementation of an ecosystem approach to management in the Bering Sea (From Hollowed et al. (2011)).

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 Wilderbuer (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 (2006)
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	

Aleutian Islands Ecosystem Assessment

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[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

The Aleutian Islands ecosystem assessment area

The Aleutian Islands ecosystem assessment and Report Card are presented by three ecoregions. The ecoregions were defined based upon evidence of significant ecosystem distinction from the neighboring ecoregions. The ecosystem assessment 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^{o}E.

The three Aleutian Islands ecoregions are defined from west to east as follows (Figure 11). The Western Aleutian Islands ecoregion spans 170^o to 177^{o}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 (Figure 12). 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. This area encompasses the NPFMC fishery management areas 518, 517 (EBS) and the western half of 610 (GOA).

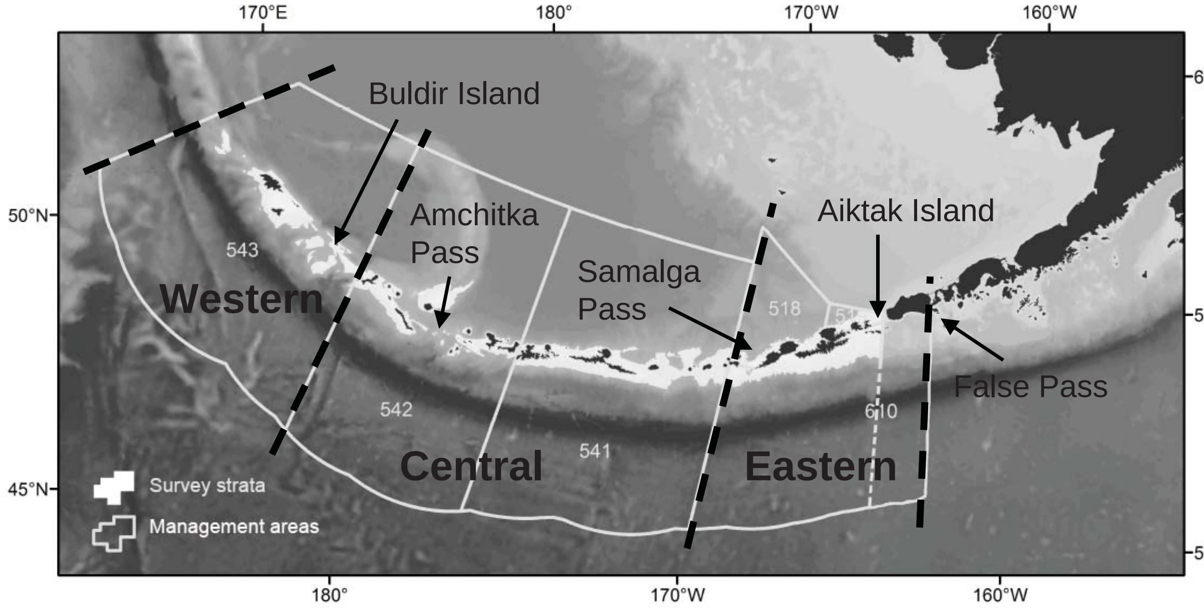

Figure 11: The three Aleutian Islands assessment ecoregions. Seabird monitoring islands are indicated by arrows.

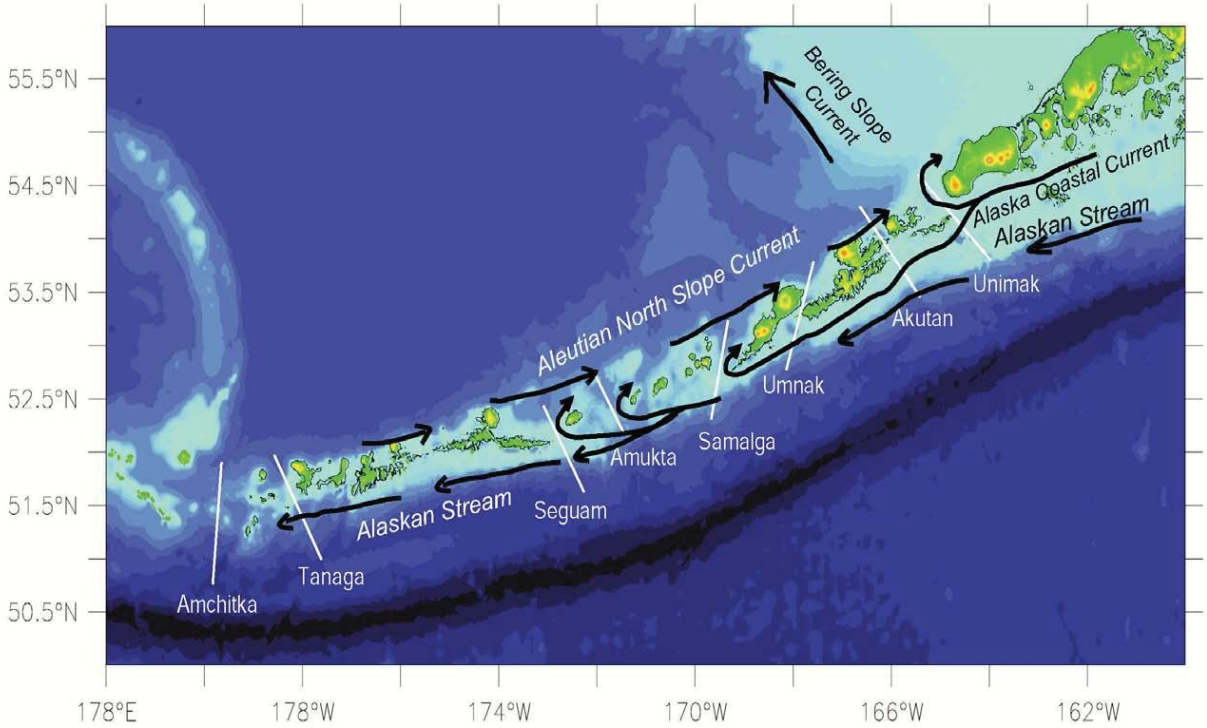

Figure 12: Ocean water circulation in the Aleutions. Currents are indicated with black lines. Passes are indicated with white lines. Image from Carol Ladd.

Summary

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 state of the North Pacific atmosphere-ocean system during 2013-2014 featured the development of strongly positive sea surface temperature anomalies south of Alaska. This warming was caused by unusually quiet weather conditions during the winter of 2013-14 in the region in association with a weak Aleutian low, as indicated by the positive NPI, and abnormally high sea level pressure off the coast of the Pacific Northwest. The result was much reduced seasonal cooling of the upper part of the water column. The warm upper ocean conditions persisted through the summer of 2014.

These patterns were reflected in the physical environment of the Aleutians region. The wind anomalies in general produced reduced flow of Pacific water northward through Unimak Pass and a relatively broad and weak Alaskan Stream over much of the last year, with spring 2014 being an exception. Eddy kinetic energy in the region was low from the fall 2012 through July 2014, indicating that average volume, heat, salt, and nutrient fluxes through Amukta Pass were likely smaller during this time. Temperatures from the 2014 NOAA bottom trawl survey appeared to be the most broadly distributed (vertically and longitudinally) and warmest since 1994 (see Figure 31 in Laman contribution p.contrib.AIsurveyTemp).

The year of the last NOAA survey, 2012, was a cold year that negatively impacted either availability to trawl survey gear and or biomass/recruitment for both fish apex predators and pelagic foragers. However, this year's warm temperatures have had the opposite effect, with all around increased biomasses for all species but particularly so for pelagic foragers. The spatial displacement of shallow pelagic foragers by rockfish combined with temperature responses of both pelagic foragers and apex predators will be of interest over the next years to the overall trophic interactions and energy flow in the Aleutians.

The largest total biomass of both fish apex predators and pelagic foragers is located in the central ecoregion, the region with the largest shelf area under 500m (Figure 13). Total apex predator biomass decreases towards the west whereas that of pelagic foragers decreases towards the east. This pattern has been constant since 1991, though individual species groups do not necessarily follow the same behavior. Both western and central ecoregions have a larger total biomass of pelagic foragers compared to that of apex predators, while in the eastern ecoregion the largest total biomass alternates between these guilds. The fish apex predator biomass is primarily driven by Pacific cod and arrowtooth flounder which show the highest net increase, followed by Pacific halibut, Kamchatka flounder and skates other than Alaska skates. Although total apex predators biomass is up from its all time low in 2012, it is still below previous values, and the increase holds for the eastern and central Aleutians only; total biomass in the Western Aleutians remained basically unchanged. Total pelagic foragers biomass increased across all ecoregions and is back up to over 2 million tons, primarily driven by Pacific ocean perch and Atka mackerel in the western and central ecoregions, and Pacific ocean perch and pollock in the eastern ecoregion. This is not the case across ecoregions. There seems to be a trend towards an overall gradual shift from shallow foragers (Atka and pollock mostly between 100-200 m) to rockfish (northern rockfish/POP, >300m). The most recent sea otter survey data we have is from 2011; thus, current trends are unknown for these nearshore foragers.

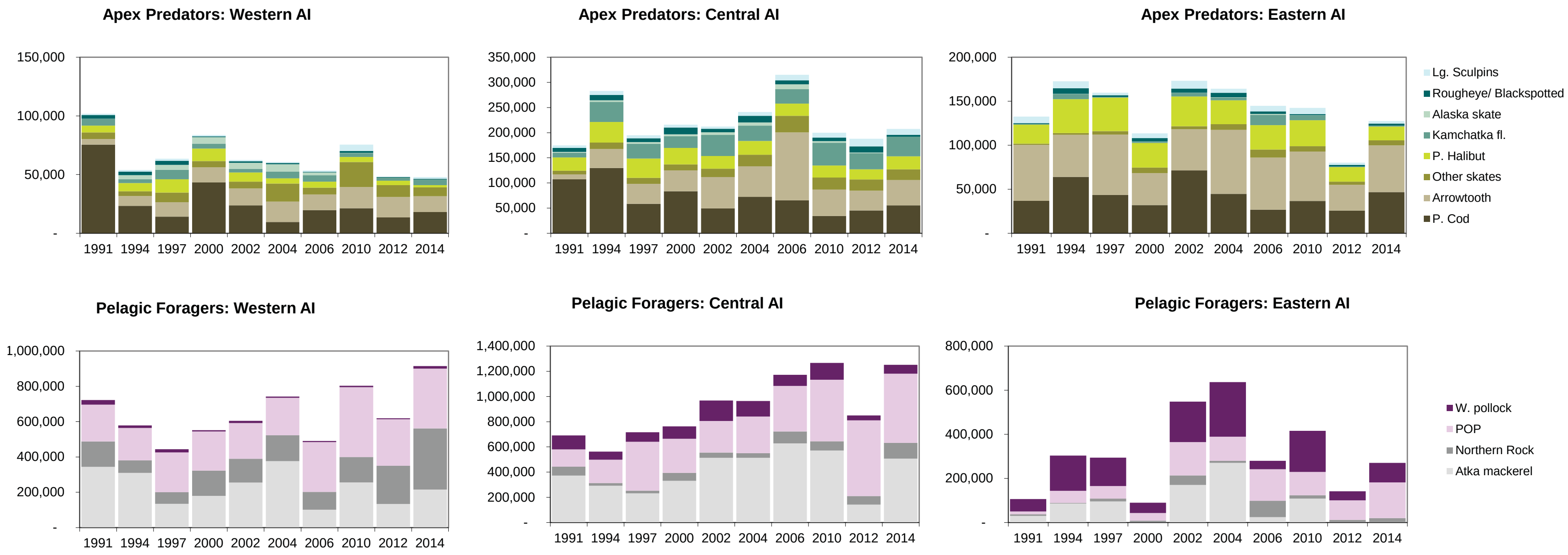

Figure 13: Estimated biomasses of fish apex predators and pelagic foraging guilds aggregated by Aleutian Islands ecoregions.

Western Ecoregion In the western ecoregion specifically, the reproductive success of planktivorous auklets, serving as indicators of zooplankton production, was stable or declining. The decline was seen in crested auklets, which feed their chicks mainly euphausiids and copepods compared with least auklets, which focus on copepods. Thus, we can speculate that euphausiids were less available to the crested auklets, reducing their reproductive success. Forage fish trends as indicated in tufted puffin chick meals have varied over the long term. In general, *Ammodytes* (sand lance) have been absent since 2010, and age-0 gadids (pollock and cod) uncommon. The number of hexagrammids (likely age-0) varied among years, but has increased in the past two years to numbers not seen since 1998-1999, possibly indicating high recruitment in Atka mackerel as 80% of the hexagrammids in 2013 and 100% in 2014 were Atka mackerel. Atka mackerel and POP drive the biomass trend and on average make up 80% of the pelagic foragers biomass with rest comprised mostly of northern rockfish. POP has been increasing (rebuilding) since 1991, and along with northern rockfish make up over 75% of the pelagic foragers biomass in the Western ecoregion since 2012. Steller sea lion non-pup counts from 2014 are the lowest in the time series. Causes for the declining trend are topics of active research on these apex piscivores wohse diet consists primarily of commercially-fished species. The area trawled increased in 2013 relative to the dramatic declines in fishing following the sea lion protection measures that took effect in 2011. Following the new 2014 Biological Opinion, looser limits to commercial fishing could start by Jan 2015. It should be noted that despite this loosened restriction, the separation of quotas between the AI and EBS for Pacific cod will result in an aportioned quota lower than that from previous years.

Central Ecoregion Recent trends in auklet reproductive success in the central ecoregion are unknown due to the disruption of the monitored colony in 2008, when the volcano on Kasatochi Island erupted and the seabird research field camp and the monitored colonies were covered with ash. 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. Both fish apex predator and pelagic foraging guild biomasses have increased since the previous trawl survey in 2012. Atka mackerel and POP drive the pelagic foragers biomass trend making up 80% of the total biomass, with the remaining split between walleye pollock and northern rockfish. Neither otter or sea lion counts were available, although updated data should be available next year with 2014 surveys. School enrollment has remained stable in the central ecoregion, potentially indicating stability in the residential communities. There has been no trend in the estimate of the trawlable area trawl in the past four years, possibly indicating similar extents of habitat distubance by trawls in each year. It is important to keep in mind that the trawlable shelf area in the Aleutians in a minor part of the sea floor landscape, as most is quite rocky and steep.

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 both declined from 2013 to 2014. Hexagrammids comprise a lower proportion of chick diets relative to those in the Western ecoregion. Chick-provisioning patterns suggest puffins are responding to changes in forage fish availability. Commonly more than half the biomass is contributed by walleye pollock and Atka mackerel. Atka mackerel show an increasing trend, 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. Both Atka mackerel and pollock used to be the dominant biomasses until 2004, but

POP has been gradually increasing and since 2006 has been either on a par or higher than either Atka mackerel or pollock. School enrollment has shown an overall increasing trend in the past five years, although 2014 attendance declined slightly from the previous year. These numbers suggest a positive trend in community expansion in the eastern ecoregion communities.

Indicators

The suite of indicators that form the basis for the assessment was selected to 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. Ideally, they could be regularly updatable across all ecoregions, thereby characterizing a global attribute with local conditions. 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 final selection reflected the limitations of available data sets for this region.

1. Winter North Pacific Index anomaly relative to the 1961-2000 mean
2. Reproductive anomalies of planktivorous least auklet and crested auklets as indicators of zooplankton productivity
3. Proportions of *Ammodytes*, gadids, and hexagrammids 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

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.

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.

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 11) 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.

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 4.

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, 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.

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

Table 4: 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	

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.

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 C, 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 C, 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).

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

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. 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 2014 (`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.

Gulf of Alaska Ecosystem Assessment Update

Stephani Zador

We are currently in the process of selecting a short (8-10) list of ecosystem indicators for the Gulf of Alaska that will form the basis of a Gulf of Alaska (GOA) Report Card and Ecosystem Assessment. The format of the new GOA Report Card and Ecosystem Assessment will be similar to those that have been produced in recent years for the eastern Bering Sea and Aleutian Islands. We broadened the expertise of the team developed to select the Aleutian Islands indicators relative to the eastern Bering Sea team based on comments from the Science and Statistical Committee of the North Pacific Fisheries Management Council. For the GOA, we hope to increase the group size and diversity in GOA expertise of the participants in the indicator selection process by soliciting information individually via an email survey. The main objective of the survey is to have participants rank the importance of indicators; the surveys will then be compiled to generate a list of top indicators. This process will be followed by a smaller in-person meeting to refine this list to form to basis of the new GOA Report Card. We hope that by surveying a greater number of individuals than were involved with indicator selection for the eastern Bering Sea and Aleutian Islands, the survey results will reflect broader expertise and an "equal voice" from all participants. We are currently in the process of obtaining approval for this survey through the Paperwork Reduction Act.

The GOA is characterized by topographical complexity, including: islands; deep sea mounts; continental shelf interrupted by large gullies; and varied and massive coastline features such as the Cook Inlet, Prince William Sound, Copper River, and Cross Sound, which bring both freshwater and nutrients into the GOA. The topographical complexity leads to ecological complexity, such that species richness and diversity differ from the western to eastern GOA. Thus, local effects of ecosystem drivers may swamp basin-wide signals. With this in mind, we hope to create a short list of ecosystem indicators that best reflect the complexity of the GOA. Although there are many more people living in both large and small communities throughout the GOA relative to the AI or EBS, we consider the GOA to be data-moderate relative to the AI (data-poor) and EBS (data-rich). We hope to be able to select indicators from those that we already monitor in this report as well as new sources of data.

Current environmental state The state of the North Pacific atmosphere-ocean system during 2013-2014 featured the development of strongly positive SST anomalies south of Alaska. This warming was caused by unusually quiet weather conditions during the winter of 2013-14 in the region in association with a weak Aleutian low, as indicated by the positive NPI, and abnormally high SLP off the coast of the Pacific Northwest. The result was much reduced seasonal cooling of the upper part of the water column. The warm upper ocean conditions persisted through the summer of 2014. The most striking oceanographic feature in the GOA was the development of the "warm blob" during early 2014, a persistent area of warm water with temperatures 3°C above the long-term mean (see Hot Topic, p. 45). The warm temperatures dissipated in fall. The extent of the ecosystem impacts of this event are currently unknown but will be of great interest as indicators are updated.

Was there a ecosystem shift in the GOA in 2006? A review of the indicators in this report suggests that 2006 was a year of changes in many of the ecosystem time-series. Pink salmon in southeast Alaska shifted to the strong odd/ low even year cycle in 2006, with record abundance in 2013. When the regime shift indicator of Litzow and Mueter (p. 193) includes only GOA data, the leading mode of variability shows a transition to a lower-magnitude positive state in 2006. A similar shift is also seen in sand lance trends in the western and central GOA (p. 137), but is seen one year earlier in southeast AK. 2006 and 2007 were also peak years of sand lance abundance in larval surveys centered in Shelikof straits (contribution not updated this year; see 2013 Ecosystem Considerations report). 2005 was the first year of a substantial jump in herring biomass in southeast Alaska (p. 140). At the time, it was the highest since 1980, although biomass was subsequently surpassed in 2009, 2010, 2011 and 2013. In addition, there has been a decrease in overall biomass of groundfish and crab in the ADF&G trawl survey. While pink salmon commerical catches are included in the regime shift indicator of Litzow and Mueter, and therefore not independent, sand lance, herring, and groundfish biomass datasets are not and thus may reflect a broader ecosystem shift.

Whether these coordinated changes are in response to bottom up environmental forcing is unknown. Notable shifts occurred in both the PDO and the NPGO climate indices near that time. The PDO shifted to a predominantly negative phase in 2007 that lasted until this year, while the NPGO rapidly shifted to negative in 2005 and climbed back to a positive state by 2007, where it remained until this year. The NPGO is significantly correlated with salinity and nutrients in the GOA (Di Lorenze et al, 2008). A negative sense of this index implies a reduced west wind drift and projects on weaker than normal flows in the Alaska Current (p. 84). Surface drift, as indicated by the PAPA trajectory index, switched from predominantly northern flow to southerly flow in the mid 2000's, similar to the predominant flow before the 1976/1977 regime shift. However, the pattern has shifted back to northerly flow this year, making the previous period the shortest and weakest flow pattern in the time series. Thus it is conceivable that broad scale changes in sea surface temperatures and subsurface flow into the GOA may have been of sufficient distinction to influence observable change in ecosystem components.

Ecosystem 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 have not been updated are 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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Last updated: September 2014

Summary: *The state of the North Pacific atmosphere-ocean system during 2013-2014 featured the development of strongly positive SST anomalies south of Alaska. This warming was caused by unusually quiet weather conditions during the winter of 2013-14 in the region in association with a weak Aleutian low, and abnormally high SLP off the coast of the Pacific Northwest. The result was much reduced seasonal cooling of the upper part of the water column. The warm upper ocean conditions persisted through the summer of 2014. The unusual winter weather appears to be largely due to intrinsic variability rather than associated with leading modes of climate variability such as ENSO. The Bering Sea experienced less sea ice than during past winters since 2007, perhaps marking the end of the recent cold spell. With the warming in the eastern portion of the basin, the Pacific Decadal Oscillation (PDO) underwent a transition from negative to positive during the past year. The models used to forecast ENSO, as a group, are indicating weak-moderate El Niño conditions for the winter of 2014-15, which should serve to maintain a positive sense to the PDO.*

Regional Highlights:

Arctic. There was an earlier onset of ice on the Beaufort Sea shelf in fall 2013 than most previous years; the onset in the Chukchi Sea was more typical of the recent past. The winter along the Arctic coast was relatively warm, with surface air temperature anomalies of 4° C. There is reduced sea ice cover in the Arctic during the summer of 2014 compared to seasonal norms, but not to the extent that occurred in 2011 and 2012.

Bering Sea. The Bering Sea shelf experienced a much lighter ice year than during the previous years of the recent cold period dating back to 2007. Anomalous warming was particularly prominent during spring 2014. The summer cold pool during 2014 was mostly restricted to north of 60°N. There was less storminess than usual during most of the year, especially for the eastern Bering Sea shelf.

Alaska Peninsula and Aleutian Islands. The wind anomalies in this region were of the sense to produce reduced flow of Pacific water northward through Unimak Pass and a relatively broad and weak Alaskan Stream over much of the last year, with spring 2014 being an exception. There is relatively little direct monitoring of the physical oceanography of this region, but SST values (based in large part on remote sensing from satellites) warmed from near normal to above normal during the past year.

Gulf of Alaska. The upper ocean in this region was fresher than usual with a relatively strong pycnocline. The sub-arctic front was farther north than usual, which is consistent with the poleward surface currents shown in the Ocean Surface Currents - Papa Trajectory Index section (Stockhausen and Ingraham). The coastal winds were upwelling favorable in an anomalous sense, which helped maintain relatively normal SST along the coast as compared with the much warmer than normal water offshore.

West Coast of Lower 48. This region experienced a very quiet winter, with less downwelling-favorable winds than normal, especially from northern California to the Canadian border. Spring included anomalous upwelling along the central and northern coast of California and downwelling farther north. The waters near the coast tended to be mostly cool, especially as compared with offshore, with some low oxygen concentrations observed at depth during summer 2014. Relatively high concentrations of sub-arctic versus sub-tropical zooplankton were observed in this region during 2011-2013; there are some indications of a reversal over the past couple of seasons. Additional information on the state of the California Current system is available at `www.pacoos.org` and `http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/bb-midyear-update.cfm`.

Sea Surface Temperature and Sea Level Pressure Anomalies

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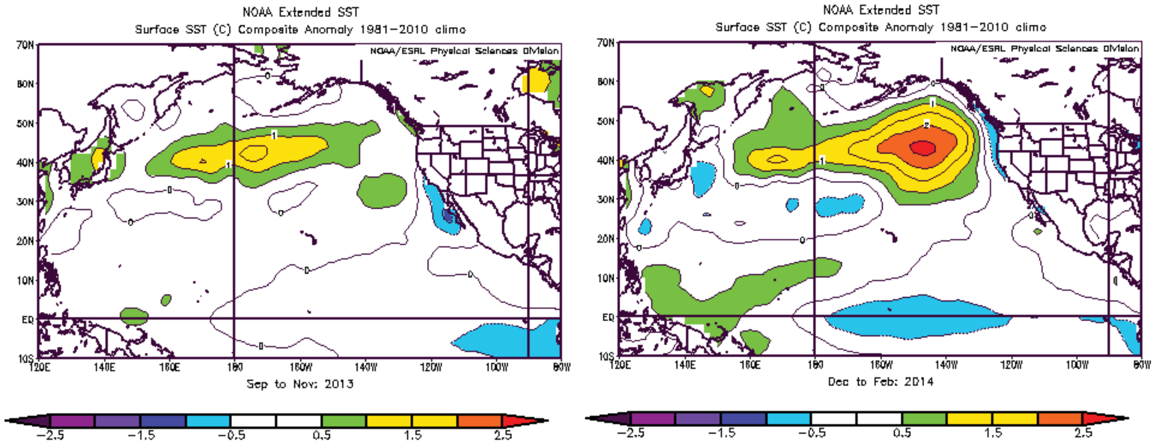
Last updated: August 2014

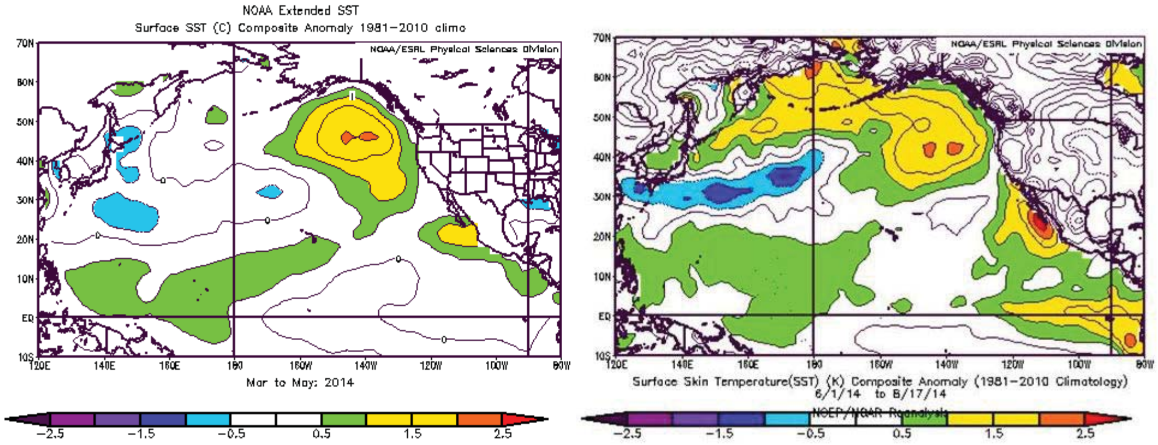
Description of indices: The state of the North Pacific from autumn 2012 through summer 2013 is summarized in terms of seasonal mean sea surface temperature (SST) and sea level pressure (SLP) anomaly maps. The SST and SLP anomalies are relative to mean conditions over the period of 1981-2010. The SST data are from NOAA's Extended Reconstructed SST analysis; the SLP data are from the NCEP/NCAR Reanalysis project. 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: The climate forcing of the North Pacific during the year beginning with the autumn of 2013 featured a transition from a negative to a positive state in the Pacific Decadal Oscillation (PDO). This transition was accompanied by a shift in tropical Pacific SST, specifically the NINO3.4 region, was slightly cooler than normal to warmer than normal. The tropical Pacific does not appear to have been a primary cause of the conditions that developed in the North Pacific, in that the tropical Pacific conditions were not too different from normal, and the patterns in the anomalies in the North Pacific little resembled those that have accompanied past changes in ENSO.

The SST anomalies in the North Pacific during the autumn (Sep-Nov) of (Figure 14a) were minimal over much of the basin, with the most prominent exception of an east-west oriented band of positive anomalies along 40^o centered near the dateline. The pattern of anomalous SLP during autumn 2013 featured strongly positive anomalies from roughly 40^o to 60^oN across virtually the entire North Pacific, with particularly large anomalies south of Alaska (Figure 15a). This pattern implies anomalous upwelling in the coastal waters extending from the south side of the Alaska Peninsula through the Gulf of Alaska (GOA) to the Pacific Northwest.

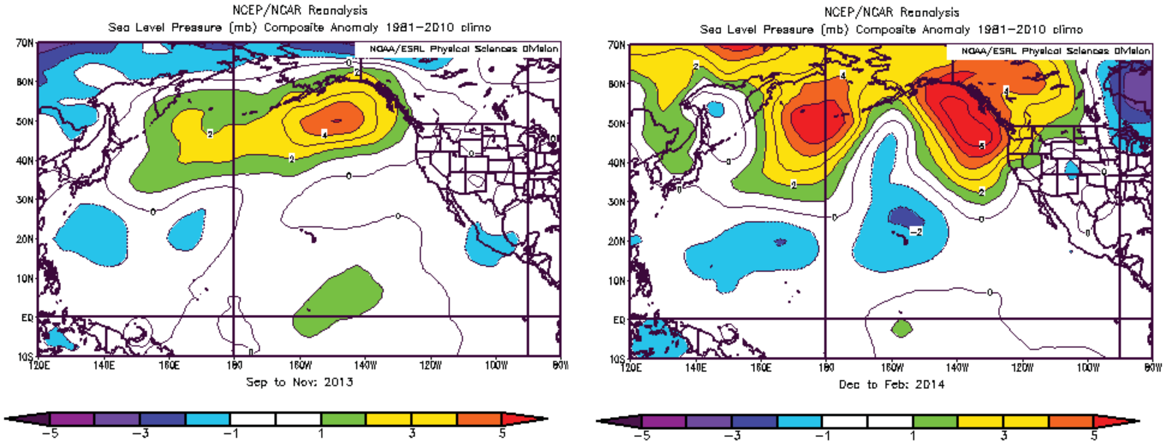


(a) Autumn (b) Winter



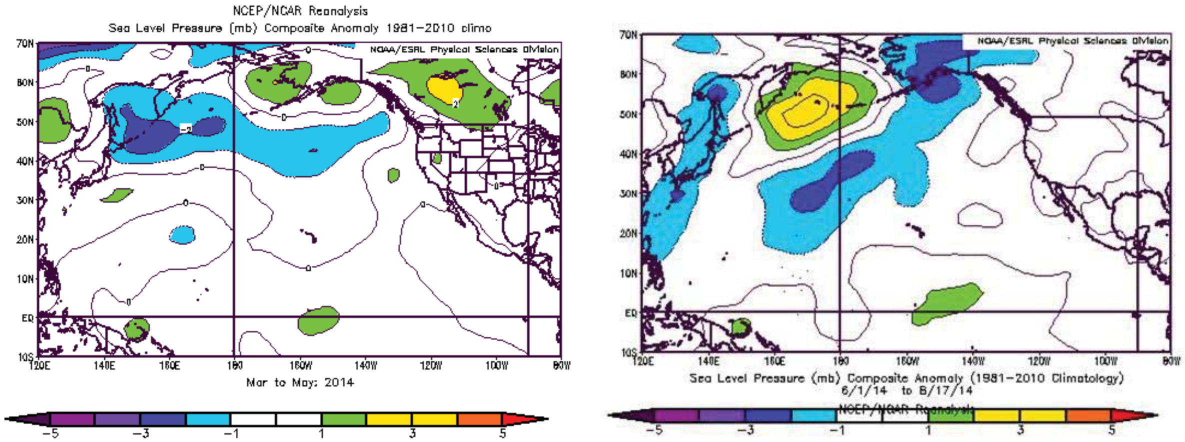
(c) Spring (d) Summer

Figure 14: SST anomolies for autumn (September-November 2013), winter (December 2013 -February 2014), spring (March - May 2014), and summer (June - August 2014).



(a) Autumn

(b) Winter



(c) Spring

(d) Summer

Figure 15: SLP anomolies for autumn (September-November 2013), winter (December 2013 -February 2014), spring (March - May 2014), and summer (June - August 2014).

Remarkably warm SST anomalies developed in the northeast Pacific during winter (Dec-Feb) of 2013-14 (Figure 14b). The maximum values of these anomalies exceeded 2.5°C. The anomalies for most of the rest of the basin were little changed from the previous season. The development of the positive SST anomalies off the west coast of North America can be attributed to the continuation of much higher than normal SLP in the northeast Pacific (Figure 15b). This region experienced an unusually strong and persistent ridge of high pressure or "block". This block resulted in fewer storms and hence abnormally low magnitude of heat loss from the upper ocean to the atmosphere and also less mixing of cool water from depth into the waters near the surface. It also implies easterly wind anomalies and hence poleward Ekman transport anomalies. Much higher than normal SLP was also present from east Siberia across the Bering Sea to south of the Aleutian Island. The overall pressure pattern favored fewer and weaker cold-air outbreaks than normal over the northern Bering Sea and mainland Alaska, leading to relatively warm surface air temperatures (not shown). Coastal winds from the GOA to California continued to be upwelling favorable in an anomalous sense.

The distribution of anomalous SST in the North Pacific during spring (Mar-May) of 2014 (Figure 14c) resembled that of the season before, with lessening of the positive anomalies off the coast of the Pacific Northwest. The SST anomalies in the tropical Pacific were weakly positive in the west and near neutral in the east. There was some warming, but the overall tropical Pacific atmosphere-ocean system remained in the near-neutral category. The SLP anomaly pattern (Figure 15c) for spring 2014 was substantially different than that for the previous winter. The most prominent feature was a region of negative anomalies extending from the southern portion of the Sea of Okhotsk to near 50°N and the dateline, with an extension of weaker negative anomalies stretching almost to Vancouver Island.

The SST in summer (Jun-Aug) 2014 (Figure 14d) indicated anomalous warmth across the northern portion of the Pacific bain from the Kamchatcka to nearly the west coast of North America. A much smaller band of relatively cool water was present west of the dateline along about 30°N. The tropical Pacific included substantial warming in its far eastern portion off the coast of South America. The overall distribution represented a positive expression of the PDO, with the most positive anomalies in the northeastern Pacific to the west of their location in the classic PDO pattern. The distribution of anomalous SLP (Figure 15d) during summer 2014 featured a dipole of higher than normal SLP over the western Aleutian Islands and lower than normal SLP to the south extending from 30° N and the dateline northeastward into the Gulf of Alaska and mainland Alaska. The SLP and associated wind anomalies were very weak over virtually the entire North Pacific east of about 150°W.

Climate Indices

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Last updated: August 2014

Description of indices: Climate indices provide a complementary perspective on the North Pacific atmosphere-ocean climate system to the SST and SLP anomaly maps presented above.

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, Pacific Decadal Oscillation (PDO) index (the leading mode of North Pacific SST variability), North Pacific Index (NPI), North Pacific Gyre Oscillation (NPGO) and Arctic Oscillation (AO). The time series of these indices from 2004 through early summer 2014 are plotted in Figure 16.

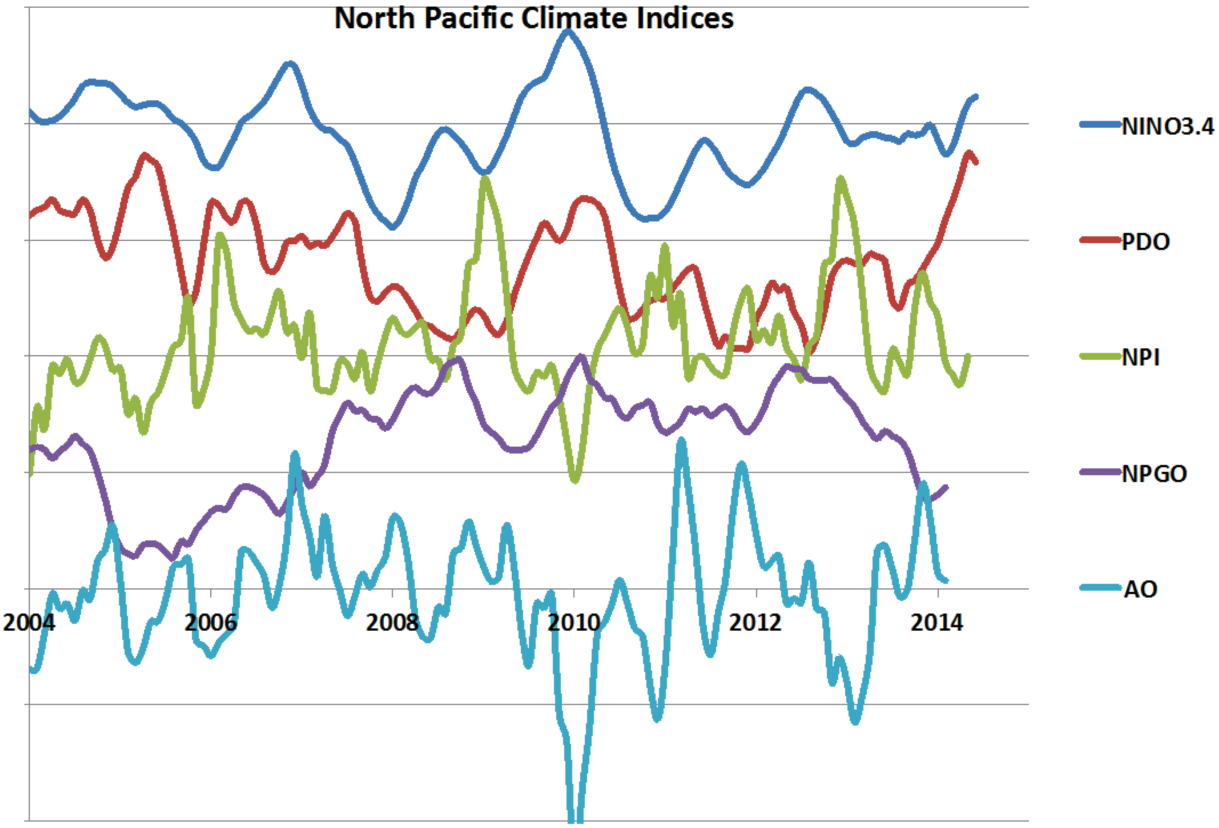

Figure 16: Time series of the NINO3.4 (blue), PDO (red), NPI (green), NPGO (purple), and AO (turquoise) indices. Each time series represents monthly values that are normalized and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 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 North Pacific atmosphere-ocean climate system underwent significant changes during 2013-14. These kinds of changes in previous years have often been associated with ENSO events. For the present case, however, ENSO has been in a near-neutral state over the past year, as indicated by the time series of the NINO3.4 index shown in Figure 5. The PDO became significantly positive during the past year in a continuation of a general increasing trend that began in autumn 2012. Changes in the PDO typically lag those in ENSO by a few months due to the North Pacific oceanic response to atmospheric teleconnection patterns emanating from the tropical Pacific, but the past year appears to represent an exception. The NPI was positive (implying a weak Aleutian Low) during the last few months of 2013. This often occurs in association with La Niña, but as discussed above, was not the case in this instance.

The North Pacific Gyre Oscillation (NPGO) represents the second leading mode of variability for the North Pacific, and has been shown to relate to chemical and biological properties in the northeastern Pacific, in particular the Gulf of Alaska. The NPGO has undergone a systematic decrease from a strongly positive state in 2012 to weakly negative in 2014. A negative sense of this index implies a reduced west wind drift and projects on weaker 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. The AO was positive late in 2013 and decreased to near-zero on average during the early part of 2014. It does not appear that the variations in the AO were strongly related to conditions in the vicinity of Alaska during the last year or so. The fluctuations in the AO during the last 5-10 years, and in particular the linkages between the AO and arctic sea ice, continue to be a subject of interest and controversy for the climate community.

Seasonal Projections from the National Multi-Model Ensemble (NMME)

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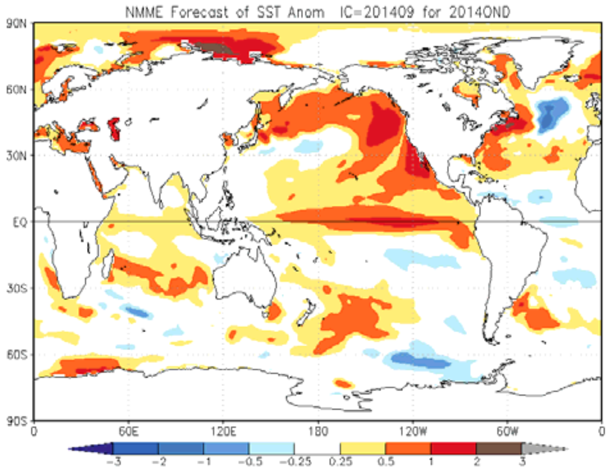
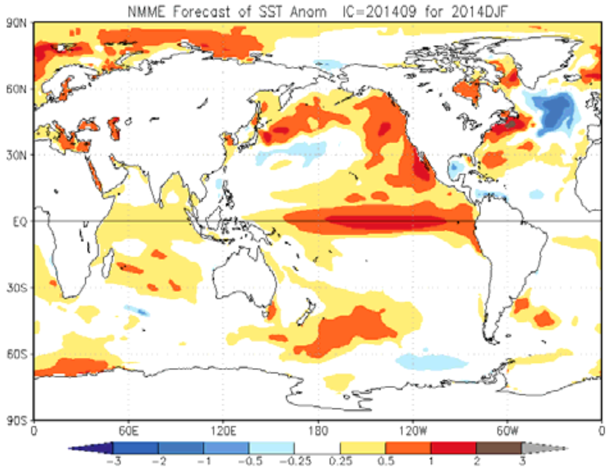
Last updated: September 2014

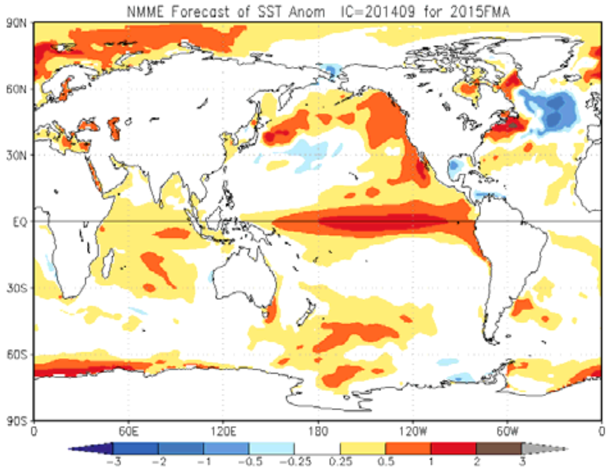
Description of index: Seasonal projections of SST from the National Multi-Model Ensemble (NMME) are shown in Figure 17. The uncertainties and errors in the predictions from any single climate model can be substantial. An ensemble approach incorporating different models is particularly appropriate for seasonal and longer term simulations; the NMME represents the average of 6 models. More detail on the NMME, and projections of other variables, are available at the following website: `http://www.cpc.ncep.noaa.gov/products/NMME/`.



(a) Months OND



(b) Months DJF



(c) Months FMA

Figure 17: Predicted SST anomalies from the NMME model for OND (1 month lead), DJF (3 month lead), and FMA (5 month lead) for the 2014-2015 season.

Status and trends: These NMME forecasts of 3-month average SST anomalies indicate a continuation of warm conditions in the northern and eastern portions of North Pacific between the Hawaiian Islands and Alaska through the end of the year (Oct-Nov 2014) with a smaller region of slightly cooler water than normal in the western North Pacific (Figure 17a). This overall pattern is maintained, with a slight weakening in magnitude, through the 3-month periods of December 2013 - February 2014 (Figure 17b) and February - April 2015 ((Figure 17c). These SST patterns project onto a positive sense for the PDO, which represents a marked contrast with the previous year. All three 3-month periods feature weak-moderate El Niño conditions in the tropical Pacific.

Implications At the time of this writing (late summer 2014) the probabilistic forecast provided by NOAA's Climate Prediction Center (CPC) in collaboration with the International Research Institute for Climate and Society (IRI) for the upcoming fall through spring is almost a 80% chance of El Niño and virtually no chance of La Niña. The skill in these projections is limited. For example, earlier this year there were indications that warming in the tropical Pacific would materialize by summer 2014, and would be of moderate or stronger amplitude but recent observations and model results suggest a much more modest event with presumably lesser effects on the global climate.

Arctic

Arctic Sea Ice Cover

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Last updated: October 2014

Description of index: The National Snow and Ice Data Center provides monthly (or more frequently) updates on Arctic sea ice conditions. The following is taken from the website (`http://nsidc.org/arcticseaicenews/`.

Status and trends: The seasonal daily minimum ice extent of 5.02 million square kilometers was set on September 17th (Figure 18). The average September sea ice extent for 2014 was the sixth lowest in the satellite record (Figure 19).

Eastern Bering Sea

Eastern Bering Sea Climate - FOCI

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Last updated: September 2014

Summary. The year 2014 broke the unusual sequence of seven years with cold winter-spring temperatures (2007-2013), following the seven warm temperature years (2000-2006). January-May

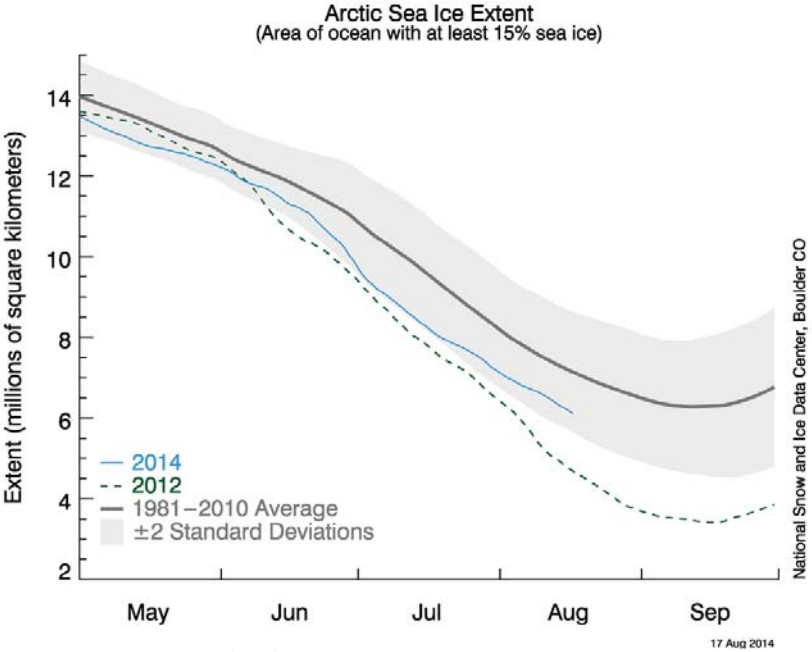

Figure 18: Arctic sea ice extent for September 2014 was 5.28 million square kilometers (2.04 million square miles). The magenta line shows the 1981 to 2010 median extent for that month. The black cross indicates the geographic North Pole Credit: National Snow and Ice Data Center

2014 near surface air temperature anomalies in the southeastern Bering Sea were +2°C, in contrast to 2013 at -2.5°C and 2012 at -3°C; sea ice maximum extent was reduced. Warm temperatures related to weaker winds than normal and mild temperatures over the northern North Pacific. Summer 2014 continued warm conditions due to high sea level pressures and weak winds. Ocean temperatures reflected the shift to warmer conditions throughout the year. The cold pool extent for summer 2014 retreated in contrast to recent cold years. It is unknown whether the one year change will bring the beginning of a climate shift, but warmer ocean heat storage will persist into fall 2014.

Possible Climate Shift for the Bering Sea? The clearest indicator of climate regimes for the Bering Sea is shown by the history of percent sea ice cover (Figure 20). After extensive sea ice in the mid-1970s, sea ice was variable through 1999. The year 2000 began the unusual persistence of warm years with less sea ice through 2006 followed by unusual cold years. The reasons for the shift from year to year variability to persistent warm and cold regimes is unknown, but random climate variability cannot be ruled out. Warm regimes are associated with stronger Aleutian Lows centered in the Aleutian chain, while cold regimes have the Aleutian Low shifted to the Gulf of Alaska with cold NE winds over the SE Bering Sea shelf; see previous year discussions. Warmer temperatures and less sea ice in 2014 appear to be associated with changes over the northern North Pacific. Whether 2014 is a one year event or the beginning of a change is also unknown.

Air temperatures and sea level pressure. Near surface air temperature anomalies for winter-spring in southwest Alaska and the southeastern Bering Sea were warmer than climatology with extreme temperatures further to the north (Figure 21). Temperature anomalies varied spatially across the southeastern Bering Sea during 2014 but were roughly +2°C in contrast to 2012 and 2013

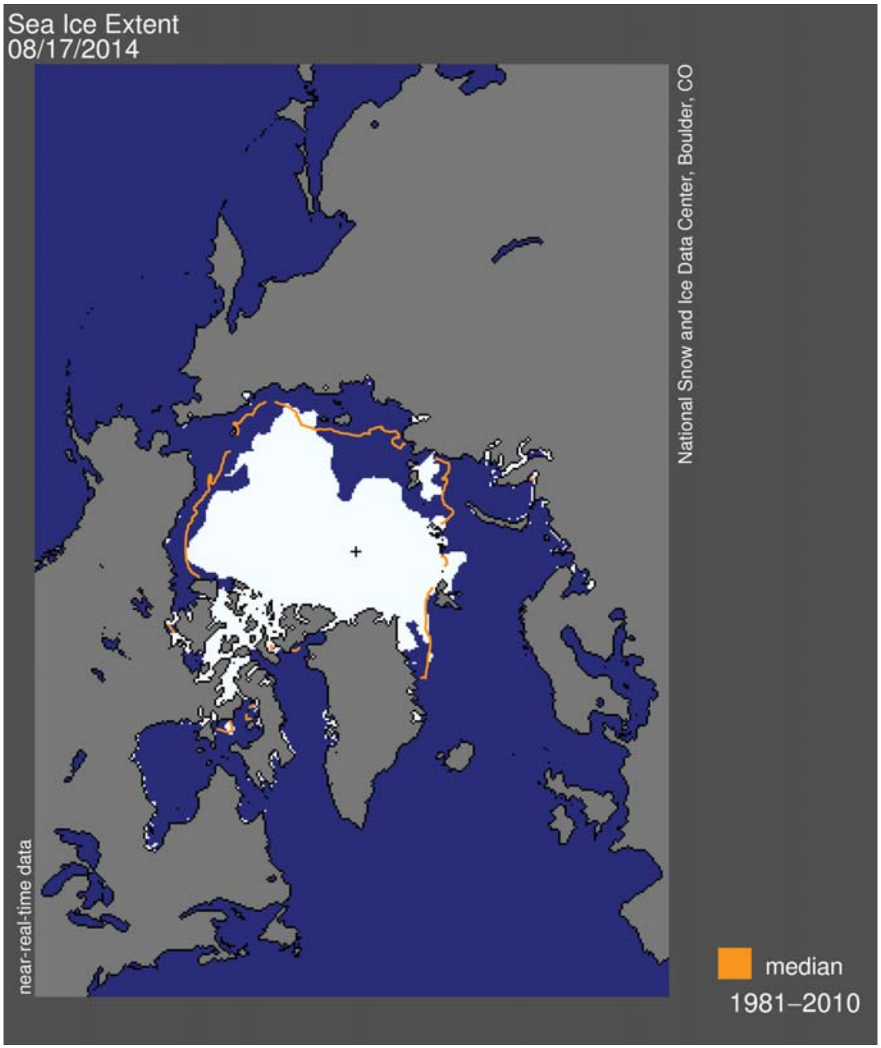

Figure 19: Arctic sea ice extent for September 2014 was 5.28 million square kilometers (2.04 million square miles). The magenta line shows the 1981 to 2010 median extent for that month. The black cross indicates the geographic North Pole. Credit: National Snow and Ice Data Center

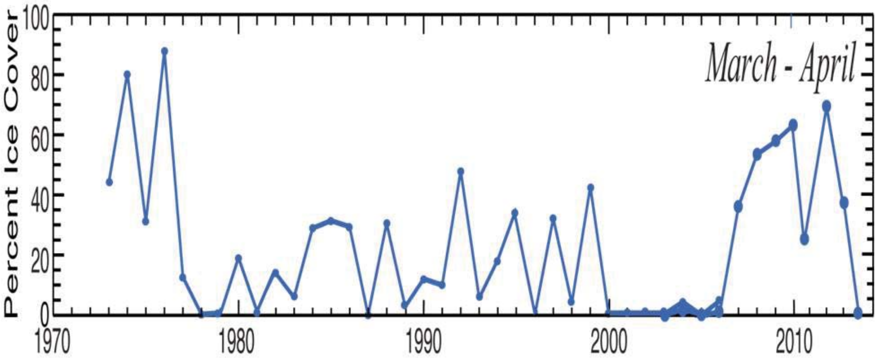

Figure 20: Long term record of percent sea ice cover for the southeastern Bering Sea shelf in spring.

at -3°C and -2.5°C. Patterns of temperature varied from month to month, with the southeastern Bering Sea particularly warm in January, April and May. Sea level pressure (SLP) in winter-spring 2014 had positive anomalies over the southern Bering Sea; see plots in the North Pacific Climate Summary. These anomalies were associated with weak winds and milder sea surface temperatures than normal. Thus Bering Sea conditions were part of a larger regional pattern of warm North Pacific SST anomalies, but not necessarily part of major climate index variations such as ENSO or the Pacific Decadal Oscillation (PDO). Summer continued above normal temperatures over the Bering Sea especially in August (Figure 22). Summer was characterized by high sea level pressure and weak westerly winds (Figure 23). Long-term surface air temperature measurements on St. Paul Island (Figure 24) also reflect the end of the cold sequence of years.

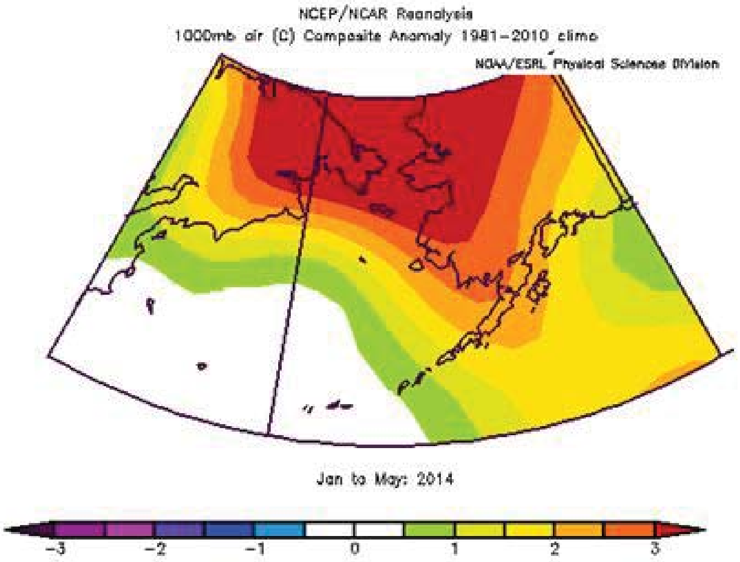

Figure 21: Surface air temperature anomaly over the greater Bering Sea region for Winter-Spring 2014.

Sea ice. 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 2008, 2010, 2012 and 2013 (Figure 25) are close to record maximum extents not seen since the early 1970s, and contrast to the warm years of 2000-2005 (except 2002). Spring 2014 had a return to less sea ice cover (solid brown line).

Ocean temperatures. Ocean temperatures at the M2 mooring site were returned to warm conditions with late summer surface temperatures of 14°C and vertically integrated temperatures near 7°C (Figure 26). The cold pool (Figure 27), 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 extent for summer 2014 retreated in area compared to the prominent sequence of recent cold years.

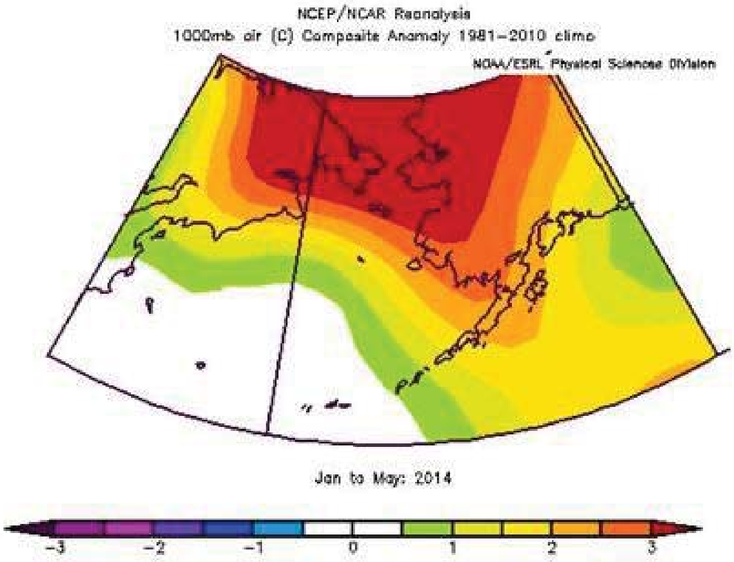

Figure 22: Surface air temperature anomaly over the greater Bering Sea region for June-August 2014.

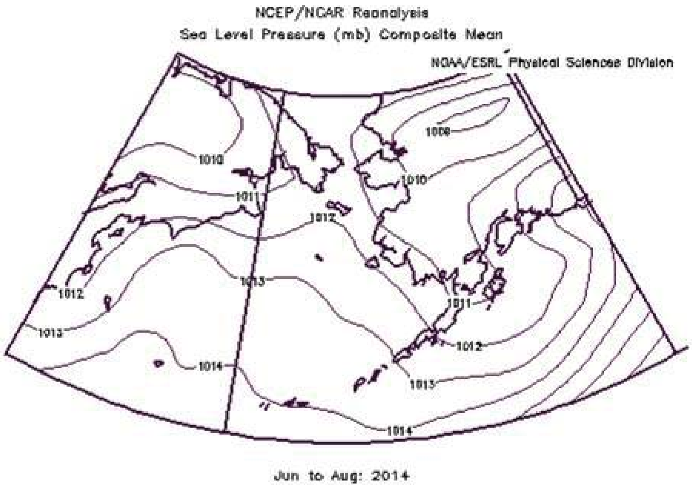

Figure 23: Summer sea level pressure. Note rather high pressures over the central Bering Sea

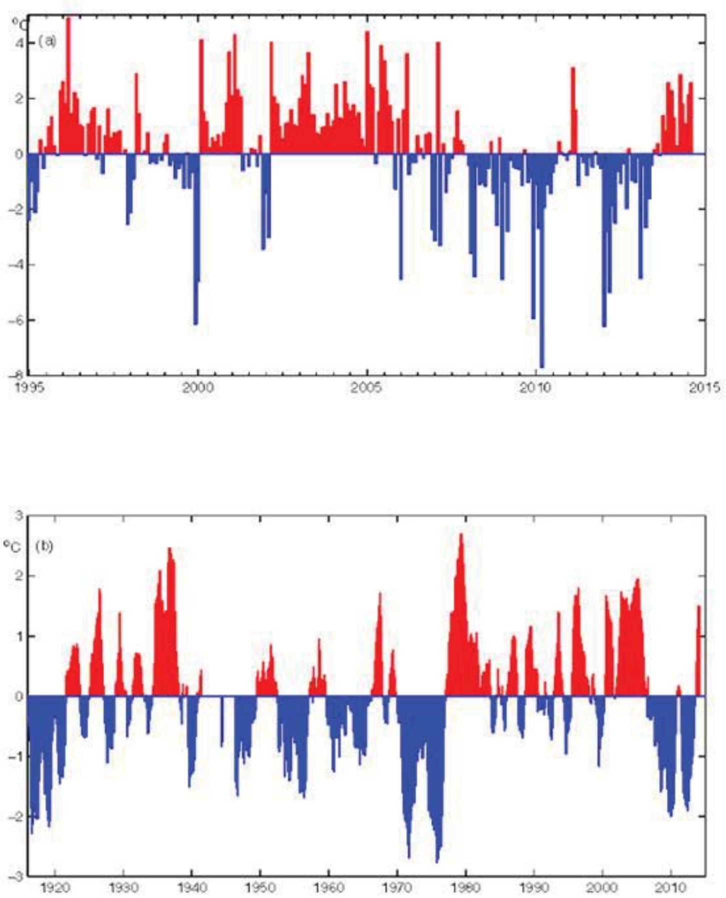

Figure 24: Mean monthly surface air temperatures anomalies in St. Paul, Pribilof Islands, a) unsmoothed, January 1995 through August 2014, and b) smoothed by 13-month running averages, January 1916 through June 2014. The base period for calculating anomalies is 1961-2000.

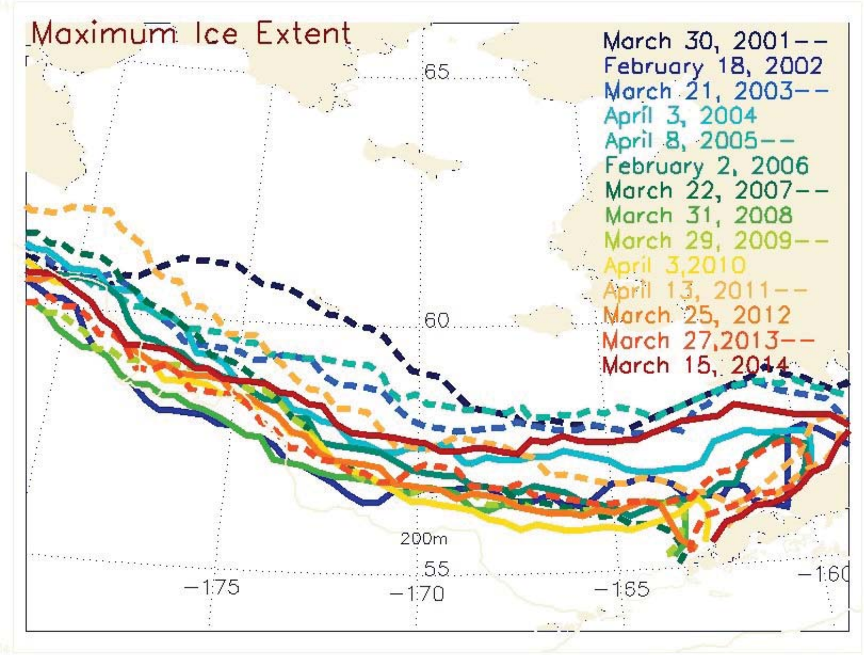

Figure 25: Recent springtime ice extents in the Bering Sea.

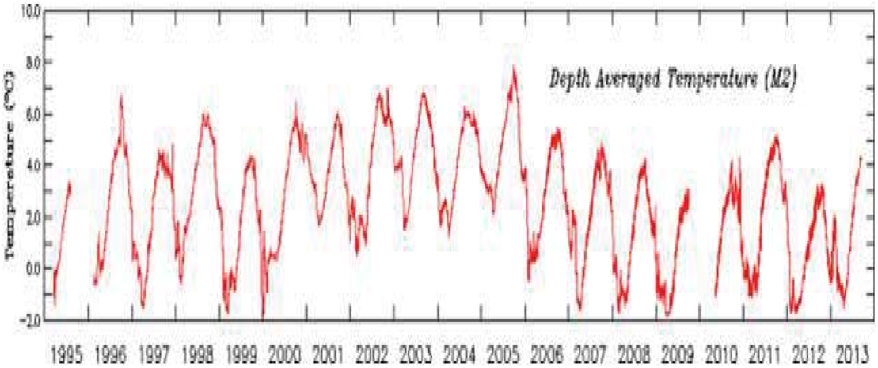

Figure 26: Depth averaged temperatures measured at Mooring 2, 1995-2013 in the southeast Bering Sea (°C). **Summer temperatures in late August 2014 are 7°C.**

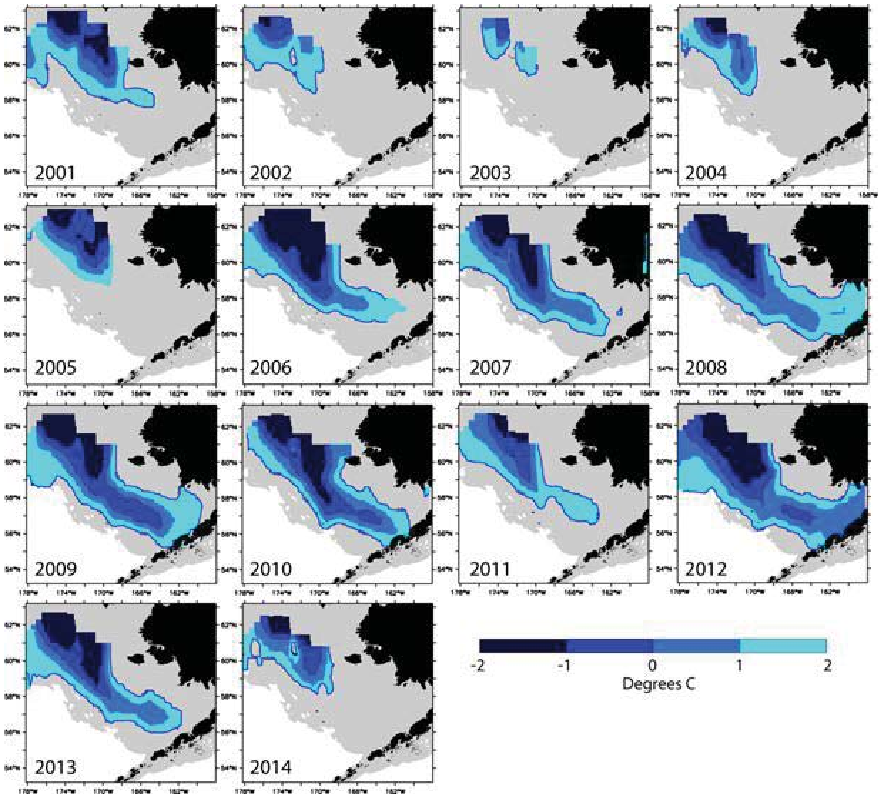

Figure 27: Cold Pool extent in southeast Bering Sea from 2001 to 2014. After an extensive sequence of cold years, the year 2014 more resembles earlier warm years.

Summer Bottom and Surface Temperatures - Eastern Bering Sea

Contributed by Robert Lauth and Gerald Hoff, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
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Last updated: October 2014

Description of index: The annual AFSC bottom trawl survey for 2013 started on 3 June and finished on 7 August.

Status and trends: Average surface and bottom temperatures in 2014 were the highest observed since the early 2000's (Figure 28). The 2014 average surface temperature was 8.2°C, which was well above the time-series mean (6.5°C) and the third highest in the 33-year time-series after 1983 (8.6°C) and 2004 (8.4°C) . The average bottom temperature in 2014 was 3.0°C, which was also above the long-term mean (2.2°C) and the ninth highest in the 33-year time-series. The 'cold pool', defined as an area with temperatures <2°C, was mostly confined to the northwestern shelf with only a small portion dipping into the southeastern middle shelf (Figure 28).

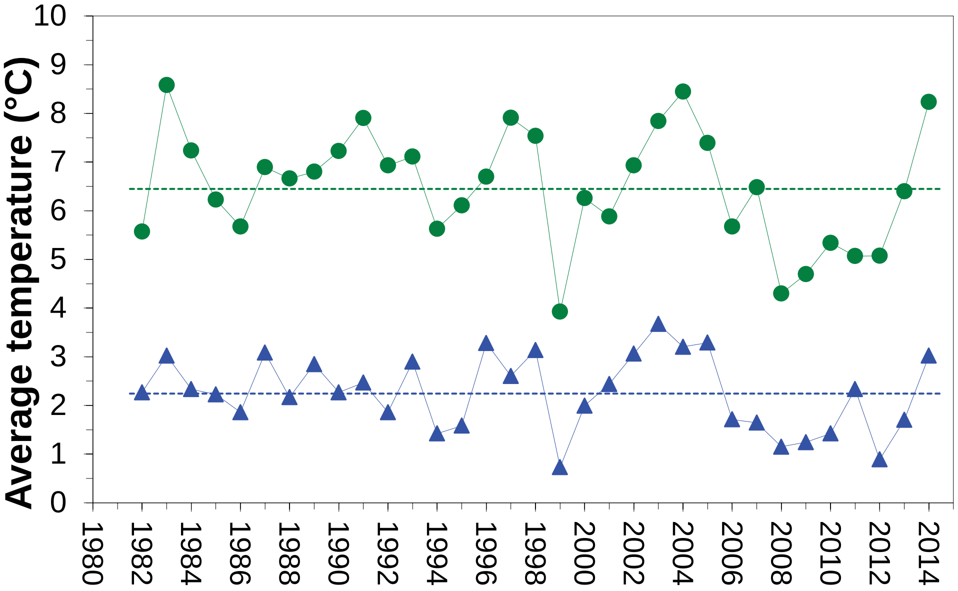

Figure 28: Average summer surface (green triangles) and bottom (blue dots) temperatures (°C) of the eastern Bering Sea shelf collected during the standard bottom trawl surveys from 1982-2014. Survey water temperatures for each year were weighted by the proportion of their assigned stratum area. Dotted line represents the time-series mean for 1982-2013.

Factors influencing observed trends: Warm and cold years are the result of interannual variability in the extent, timing, and retreat of sea ice on the EBS shelf. During warm years, sea ice generally does not extend as far down the shelf and retreats sooner.

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 juvenile fishes as well as the energy flow in the system (Hunt et al., 2002; Coyle et al., 2011).

Spatial patterns in near-bottom oceanographic variables collected during AFSC bottom trawl surveys on the EBS slope

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Last updated: October 2013

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

Regional Water Mass Characteristics in the Northern Bering Sea

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Last updated: July 2013

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

Aleutian Islands

Eddies in the Aleutian Islands - FOCI

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Last updated: September 2014

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 (Ducet et al., 2000). Eddy kinetic energy (EKE) calculated from gridded altimetry data is particularly high in the Alaskan Stream from Unimak Pass to Amukta Pass (Figure 29) 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 30) 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, 2012).

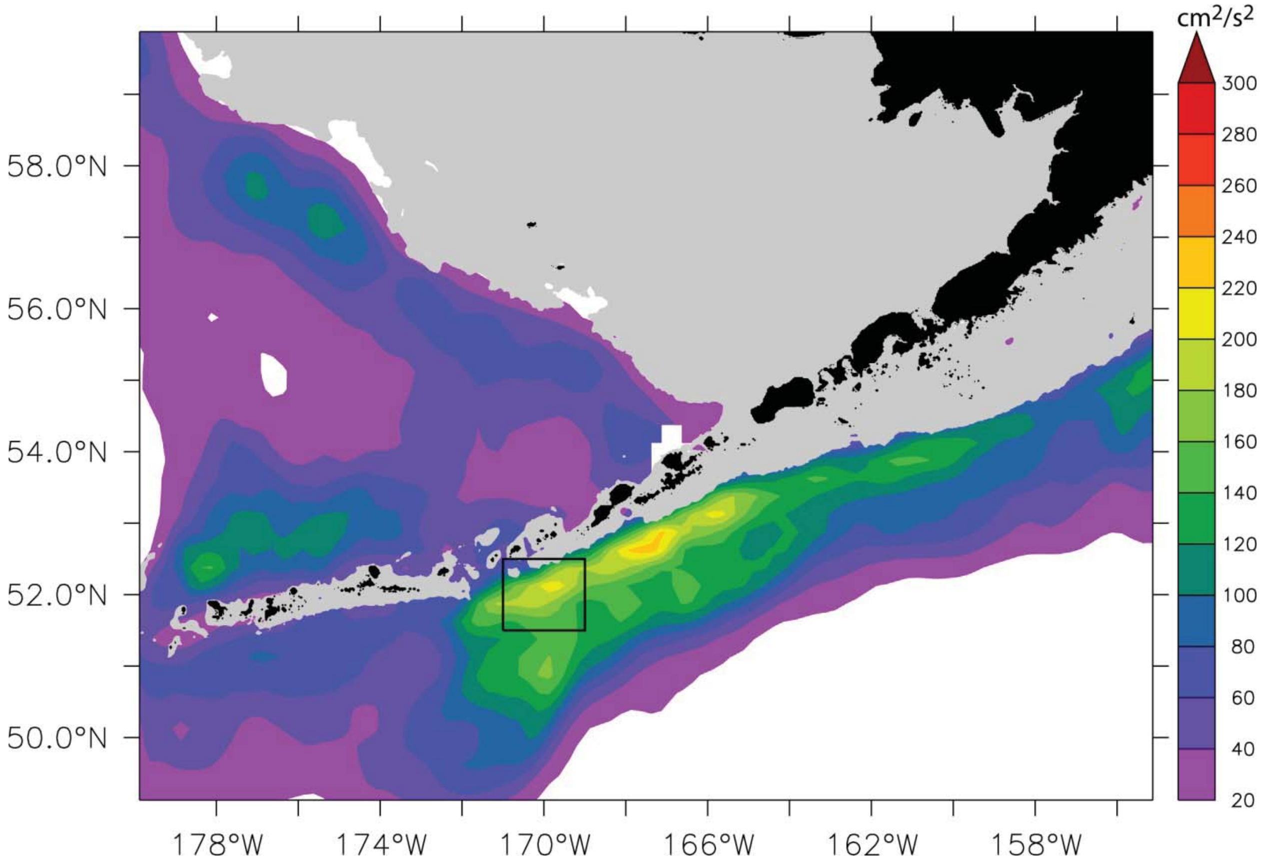

Figure 29: Eddy Kinetic Energy averaged over October 1993 - October 2013 calculated from satellite altimetry. Square denotes region over which EKE was averaged for Figure 30.

Status and trends: Particularly strong eddies were observed south of Amukta Pass in 1997/1998, 1999, 2004, 2006/2007, 2009/2010, and summer 2012. Eddy energy in the region has been low from the fall 2012 through July 2014.

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, 2006/2007, 2009/2010, and summer 2012. These fluxes were likely smaller during the period from fall 2012 until early 2014.

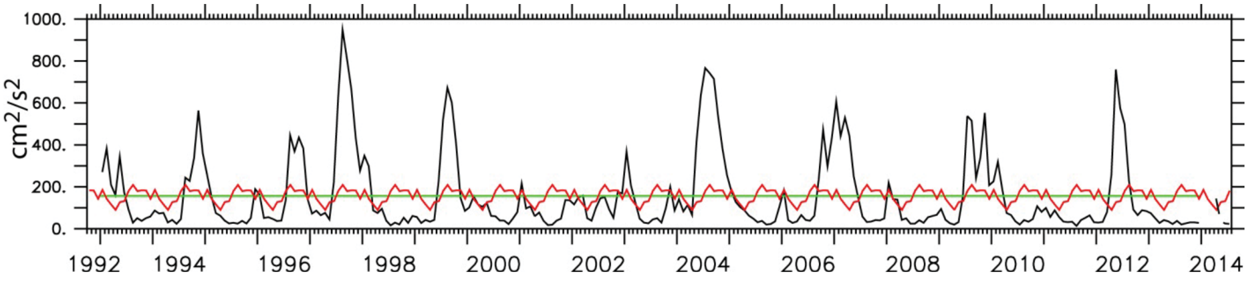

Figure 30: Eddy kinetic energy (cm^2 s^{-2}) averaged over region shown in Figure 29. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product). Red: seasonal cycle. Green (straight line): mean over entire time series.

Water Temperature Data Collections - Aleutian Islands Trawl Surveys

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Description of index: The oceanography of the Aleutian Islands (AI) is shaped by three major currents running along the archipelago and strong tidal forces in the passes between islands (Hunt and Stabeno, 2005). The Alaska Coastal Current (Schumacher and Reed, 1986; Reed, 1987) flows westward along the south side of the Aleutians from the Gulf of Alaska to Samalga Pass. The Alaskan Current also flows westward along the southern shelf break of the Aleutians to Amchitka Pass where some of the water flows northward to serve as source water for the Aleutian North Slope Current. The remainder of the Alaskan Current continues westward in a series of meanders and eddies to bathe the western Aleutians. The Alaska Coastal Current is warmer and fresher than the Alaskan Current and these differences contribute greatly to the chemical and physical properties of the water flowing through the passes of the Aleutian Islands. The Aleutian North Slope Current originates at Amchitka Pass and flows eastward along the north side of the Aleutians. The Aleutian passes are zones of strong vertical mixing (Ladd et al., 2005).

Water temperature data have been routinely collected during National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering Division (RACE) bottom trawl surveys since 1994 using micro-bathythermographs attached to the headrope of the net during each trawl haul. Groundfish assessment survey periods in the Aleutian Islands have ranged from early May to late September and sampling has usually progressed from east to west, but notable exceptions exist for the 2002 and 2006 surveys. These spatial and temporal differences in sampling patterns across the survey area complicate inter-annual comparison because of the strong relationship between collection date and water temperature at all depths.

Water temperature data collected from the trawl downcast (the period of time between when the trawl net is released to sink and the center of the footrope touches the bottom) were used to model water temperatures at depth. Average water temperatures were estimated at each of several depths from 3 m to the deepest depth of each tow. Finer depth increments were used in shallower depths to capture the rapid changes in water temperatures often seen in shallower waters; broader increments were used in deeper depths where changes are not as rapid. To account for the influence of changing day length on water temperatures over the course of the summer and to make inter-annual comparisons more meaningful, an attempt was made to remove the effect of collection date on water temperature. We standardized the data collection day to an approximate median date (July 10) from all of our summer surveys. This was achieved by using generalized additive modeling (GAM) to account for the effect of date on temperature at each depth interval. The resulting model was used to estimate the temperature at depth on the standard date and the residuals of the original model were added to the prediction to arrive at the final estimate. These estimated temperatures were binned into ½ degree longitude-by-depth increments and mean temperature of each bin was reported. To enhance the visual differences in Figure 31 the temperature range was truncated so that all temperatures ≥ 7.5°C are represented by the same color range. The same was done for all temperatures ≤ 3.5 °C.

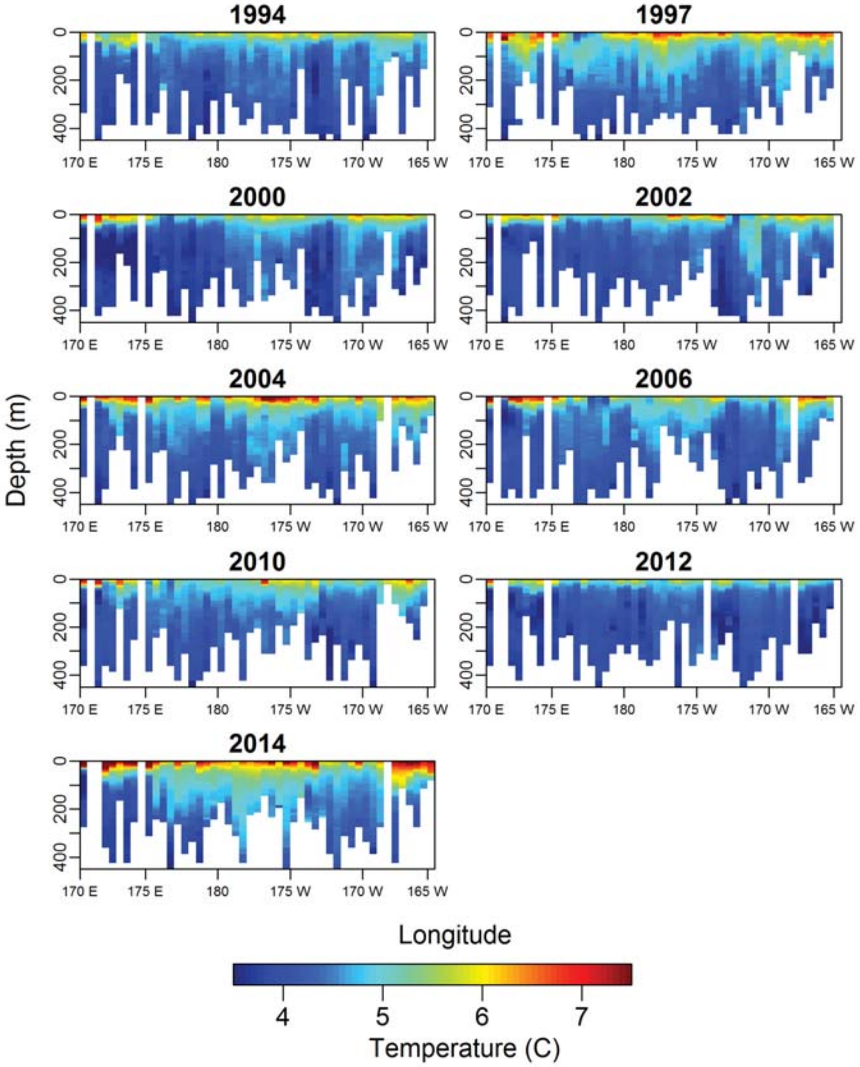

Figure 31: Date adjusted temperature profiles by ½ degree longitude intervals for years 1994-2014.

Status and trends: Water temperatures varied considerably during the nine survey years reported (Figure 31). Temperatures from the 2014 AI survey appear to be the most broadly distributed (vertically and longitudinally) and warmest temperatures we have encountered thus far. The 1997 and 2004 surveys are the next warmest in the series, but the warm waters in these years are not as broadly distributed nor do the surface waters extend to the depths observed in 2014. The 2012 AI survey was the coldest year since 1994. The dramatic difference between these two survey years serves to demonstrate the highly variable and dynamic nature of the oceanographic environment across the Aleutian archipelago.

Some common features are notable for all years, including warmer surface temperatures east of Amukta Pass (170 ^{o} 30' W), between Seguam Pass (173^o W) and Amchitka Pass (179^o W) and west of Buldir Pass (175^o E)(Figure 31)). The influence of these warmer surface temperatures generally extends to about 100 m, although in the warmest years it can reach 200 m. Cooler temperatures at depths greater than 100 m appear consistently around Seguam Island (172^o 30' W), and this seems to be a particularly striking feature in colder than average years (e.g., 2000). Cooler temperatures at depths greater than 100 m are frequently a predominant feature west of 175^o E, although in cooler years this area of cooler water extends as far east as Amchitka Pass.

Factors influencing observed trends: The water temperature data collected each year are a snapshot of water temperatures collected during RACE bottom trawl surveys in the Aleutian Islands. Since each temperature bin represents data that were collected over a relatively short period as the vessels moved through the area, drawing broad conclusions from temperatures that are greatly affected by short term phenomena such as storm events, tidal current velocity, and/or direction and persistence of eddies can be difficult. To make inter-annual comparisons of our thermal data more meaningful we standardized temperatures from each trawl haul to a median date in an attempt to account for the expected temporal trend of increasing temperatures over the duration of the summer survey. Due to these and other sources of variation that were not accounted for in the temperature model, caution should be exercised when interpreting these results.

Implications: The strength and persistence of eddies is believed to play a major role in mediating the transport of both heat and nutrients into the Bering Sea through the Aleutian passes (Maslowski et al., 2008). These phenomena likely have important impacts on both the Aleutian Islands and the Bering Sea ecosystems. The temperatures observed during the 2014 RACE AI bottom trawl survey suggest some of the most widely distributed and warmest waters seen since 1997.

There are no apparent trends across years when visually comparing AI survey water temperatures modeled here. However, increased thermal stratification and shallower mixed-layer-depths during warmer years (such as 2014) appear to form a relatively consistent pattern in our data series. Thermal regime and mixed-layer-depth differences are known to influence regional biological processes impacting the populations in this region (e.g., magnitude of primary production depends on mixed-layer-depth ((Mordy et al., 2005), ontogenesis of Atka mackerel eggs and larvae (Lauth et al., 2007), and pollock distribution ((Stevenson and Lauth, 2012)). Therefore, investigating differences in water temperatures and thermal stratification amongst years provides additional context to our annual resource surveys.

Gulf of Alaska

Eddies in the Gulf of Alaska - FOCI

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Last updated: September 2014

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 (Figure 32; Region c, eddy energy in the years 2002-2004 was the highest in the altimetry record.

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), giving a measure of the mesoscale energy in the system. 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 32). 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 32). By averaging EKE over regions c and d (see boxes in Figure 32), we obtain an index of energy associated with eddies in these regions (Figure 33). The altimeter products were produced by the CLS Space Oceanography Division (AVISO, 2012).

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, 2010, 2012, and 2013. Relatively high EKE was observed in the summer of 2014 in region (c) while EKE was particularly weak in region (d). The summer 2014 EKE is calculated from near-real-time altimetry data which has lower quality than the delayed time data and may be revised.

Factors causing observed trends: In the eastern Gulf of Alaska, interannual changes in surface winds (related to the Pacific Decadal Oscillation, El Niño), and the strength of the Aleutian Low modulate the development of eddies (Combes and Di Lorenzo 2007, Di Lorenzo et al., 2013). In the western Gulf of Alaska, variability is related both to the propagation of eddies from their formation regions in the east and to intrinsic variability.

Implications: EKE may have implications for the ecosystem. Phytoplankton biomass was probably more tightly confined to the shelf during 2009 due to the absence of eddies, while in 2007,

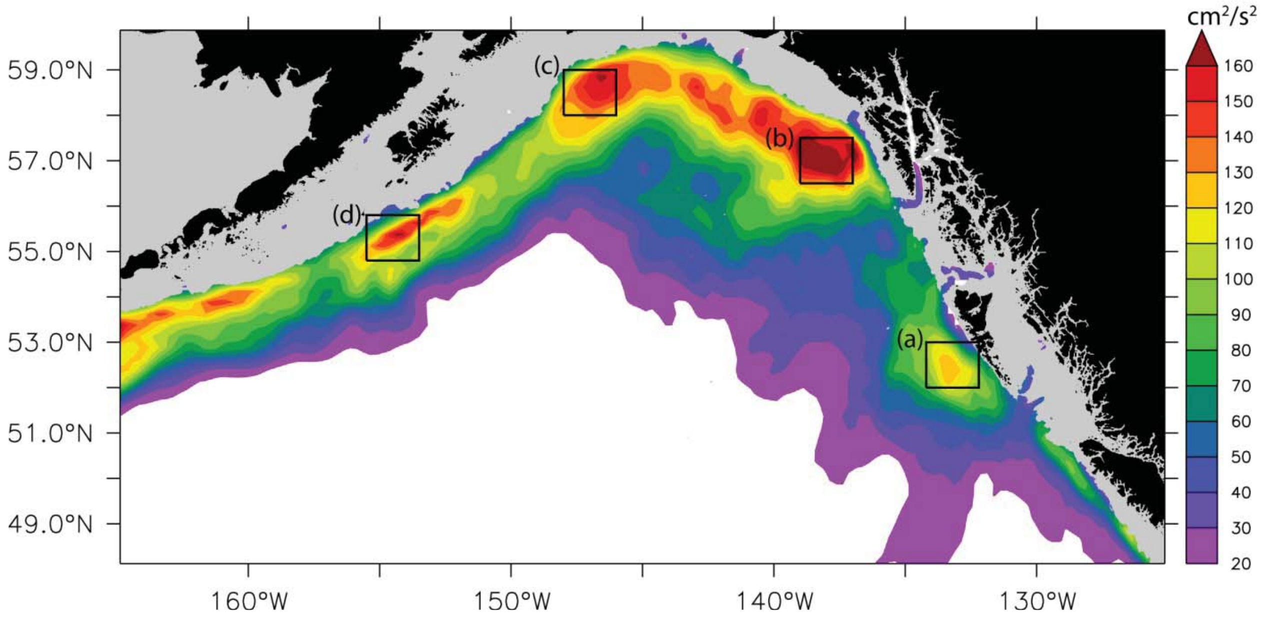

Figure 32: Eddy Kinetic Energy averaged over October 1993-October 2013 calculated from satellite altimetry. Regions (c) and (d) denote regions over which EKE was averaged for Figure 33.

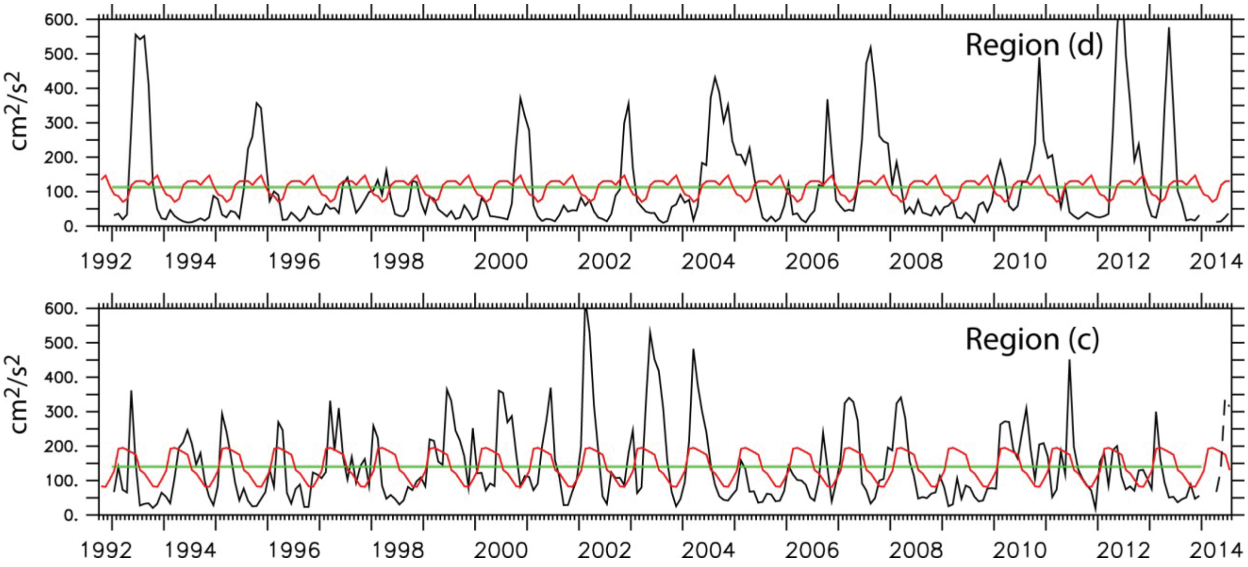

Figure 33: Eddy kinetic energy (cm^2 s^{-2}) averaged over Region (d) (top) and Region (c) (bottom) shown in Figure 32. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product), Red: seasonal cycle. Green (straight line): mean over entire time series.

2010, 2012 and 2013 (region (d)), phytoplankton biomass likely extended farther off the shelf. In addition, cross-shelf transport of heat, salinity and nutrients were probably weaker in 2009 than in 2007, 2010, 2012 and 2013 (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).

Ocean Surface Currents - Papa Trajectory Index

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Description of index: The PAPA Trajectory Index (PTI) provides an annual index of near-surface water movement variability, based on the trajectory of a simulated surface drifter released at Ocean Station PAPA (50°N, 145°W; Figure 34). 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 2013 (trajectory endpoints years 1902-2014).

Status and trends: In general, the trajectories fan out northeastwardly toward the North American continent (Figure 34). The 2009/2010 trajectory was an exception and resulted in the westernmost trajectory endpoint for the entire set of model runs (1902-2014). This trajectory 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 2011/2012 trajectory followed the general northeastwardly path of most drifters, but was notable because its ending latitude was the northernmost of all trajectories since 1994. The 2012/2013 trajectory was notable as ending up the furthest east among trajectories in recent years. However, the ending latitude was only somewhat southerly of the average ending latitude for all trajectories (Figure 35) and certainly not atypical. This is consistent with the northeast Pacific wind forcing, which featured very strong westerly anomalies. The 2013/14 trajectory was quite similar to the 2011/12 trajectory, although it did not reach as far north as the latter. The mean wind anomalies in the vicinity of the simulated drifter were from the southeast in December 2013, and from the south in January 2014, but then transitioned rapidly to out of the northeast in February 2014, with the latter period limiting the northward extent of the modeled trajectory.

The PTI time series (Figure 35, 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°

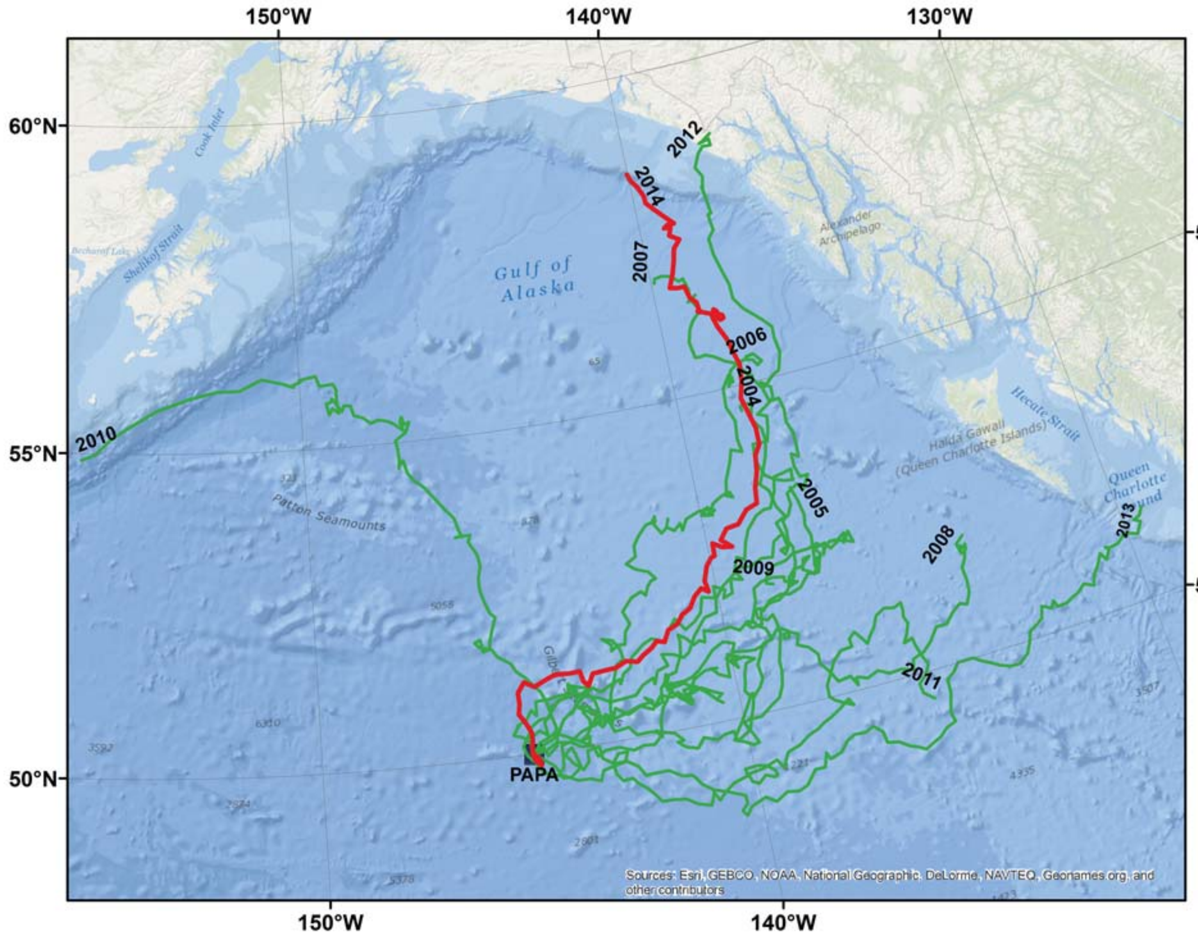

Figure 34: Simulated surface drifter trajectories for winters 2004-2014 (endpoint year). End points of 90-day trajectories for simulated surface drifters released on Dec. 1 of the previous year at Ocean Weather Station PAPA are labeled with the year of the endpoint (50°N, 145°W).

and a maximum change of greater than 13° (between 1931-1932). The change in the PTI between 2010/11 and 2011/12 was the largest since 1994, while the changes between 2011/12 and 2012/13, and between 2012/13 and 2013/14, represented reversals with slightly less, but diminishing, magnitude. However, such swings are not uncommon over the entire time series.

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 35), 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 was indicative of a return to conditions (at least in terms of surface drift) similar to those prior to the 1977 environmental regime shift. This part of the cycle may have ended rather quickly, however, as it now appears the filtered PTI is about to cross the mean in the opposite direction. If this occurs, the recent period of predominantly southern flow will have been the shortest and

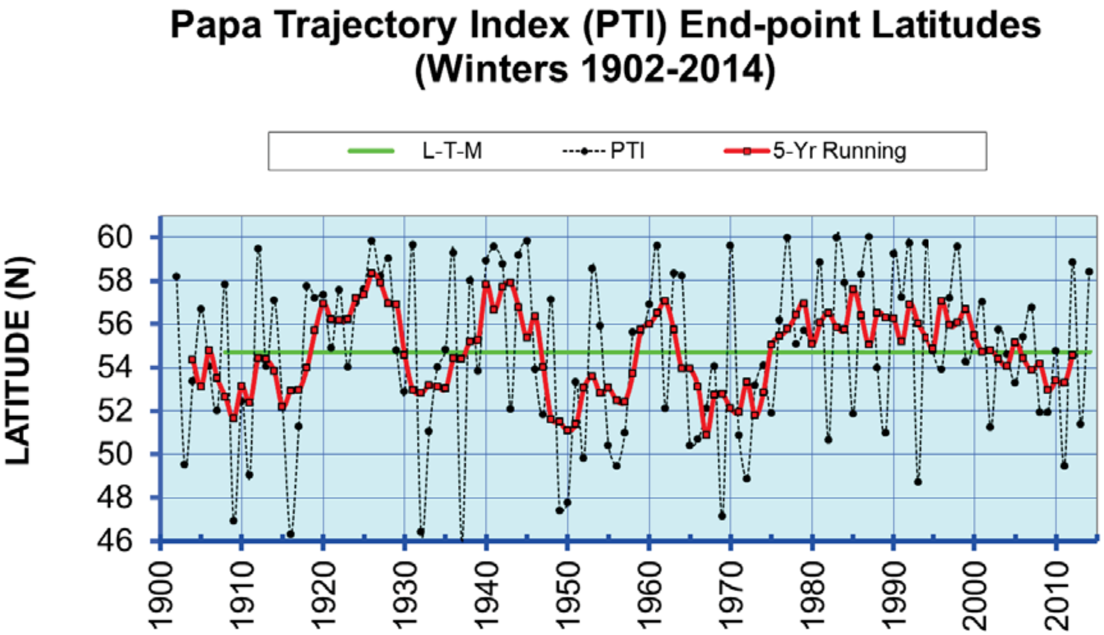

Figure 35: Annual, long-term mean (green line) and 5-year running mean (red line and squares) of the PAPA Trajectory Index time-series (dotted black line and points) for 1902-2014.

weakest in the time series.

Factors influencing 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. Individual trajectories also reflect interannual variability in regional (northeast Pacific) wind patterns.

Implications: 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 (*Gadus 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)). 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 "warm" 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).

Although the PTI was smaller than the mean in both 2010/11 and 2012/13, it was substantially larger than the mean in both 2011/12 and 2013/14. As such, its current (5-year averaged) trend appears to indicate a reversal from a return to conditions associated with the pre-1977 "cold" regime. It may thus **not** be a harbinger of a decadal-scale reduction in regional productivity (contrary to the suggestion in 2013). The trajectory for 2012/13 indicated the potential for southeast Alaska to have experienced an influx of open ocean type organisms at the lower trophic levels in 2013, as well as a southward shift in the "boundary" between sub-arctic and sub-tropical species. The trajectory for 2013/14 indicates a northward shift in the "boundary" between sub-arctic and sub-tropical species, as well as a relative absence of open ocean type organisms at the lower trophic levels in southeast Alaska.

Gulf of Alaska Survey Bottom Temperature Analysis

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Last updated: October 2013

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

Spatial patterns in near-bottom oceanographic variables collected during AFSC bottom trawl surveys in the Gulf of Alaska

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Last updated: October 2013

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

Habitat

Structural Epifauna (HAPC Biota) - Eastern Bering Sea

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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 1982-2014. 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 36). However, catch rates generally show increasing trends in anemones and sponges in recent years. Catch rates of seawhips have been variable.

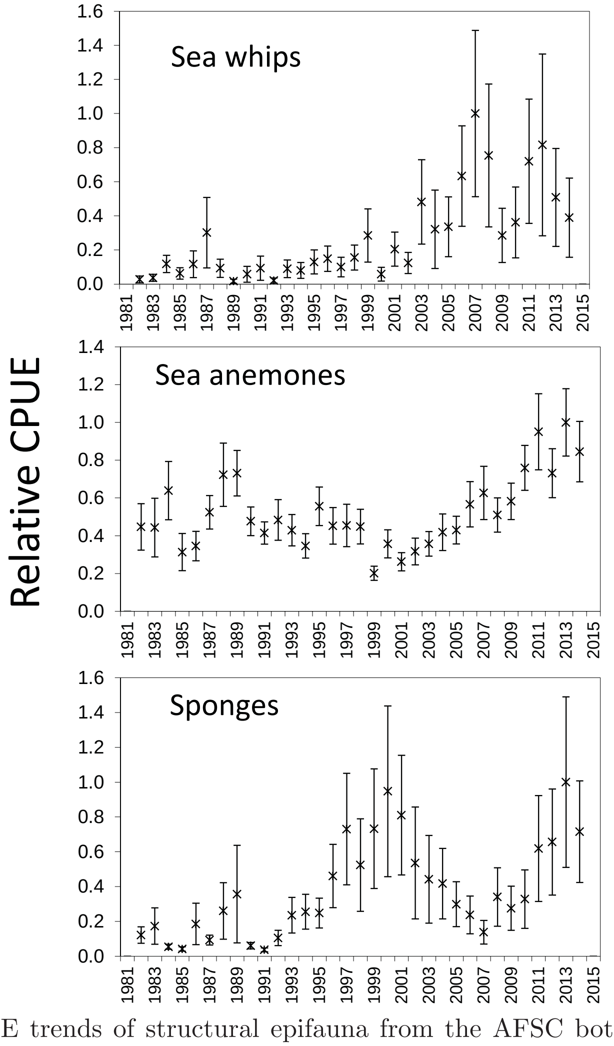

Figure 36: Relative CPUE trends of structural epifauna from the AFSC bottom trawl survey of the eastern Bering Sea shelf during the May to August time period from 1982-2014. Data points are shown with standard error bars.

Factors influencing 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 (HAPC Biota)- Aleutian Islands

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Description of index: Groups considered to be Habitat Area of Particular Concern (HAPC) biota include seapens/seawhips, corals, anemones, and sponges. The biennial survey in the Aleutian Islands (AI) does not sample any of the HAPC fauna well. The survey gear does not perform well in many of the areas where these groups are likely to be more abundant and survey effort is quite limited in these areas. In tows where they are encountered, the standard survey gear is ill-suited for efficient capture of these groups. As a result, CPUE is often strongly influenced by a very small number of catches with a resulting high variance. Another complicating factor in interpreting these results is that the gears used by the Japanese vessels in the surveys prior to 1991 were quite different from the survey gear used aboard U.S. vessels in subsequent surveys and likely resulted in different catch rates for many of these groups. In recent years, more emphasis has been placed on the collection of more detailed and accurate data on HAPC species and it is likely that this increased emphasis influenced the results presented here. For each species group, the largest catch over the time series was arbitrarily scaled to a value of 100 and all other values were similarly scaled. The standard error (±) was weighted proportionally to the CPUE to get a relative standard error.

Status and trends: A few general patterns are clearly discernible (Figure 37). Sponges are caught in most tows in the Aleutians west of the southern Bering Sea. Interestingly, the frequency of occurrence of sponges in the southern Bering Sea is relatively high, but sponge abundance is much lower than other areas. The sponge estimates for the 1983 and 1986 surveys are much lower than other years, probably due to the use of different gear, including large tire gear that limited the catch of most sponges. Stony corals are commonly captured outside of the southern Bering Sea and their abundance appears to be highest in the central Aleutians. Soft corals are caught much less frequently and the survey likely does not provide a reliable estimate of soft coral abundance. Sea anemones are also common in survey catches but abundance trends are not clear for most areas. Sea pens are much more likely to be encountered in the southern Bering Sea and eastern AI than in areas further west. Abundance estimates are low across the survey area and large apparent increases in abundance, such as that seen in the eastern AI in 1997, are typically based on a single large catch. There has been a decline in CPUE for sponges, stony corals, and anemones from the 2010 survey to the 2014 survey, but trends have been generally inconsistent or level since 2000 for most species and areas.

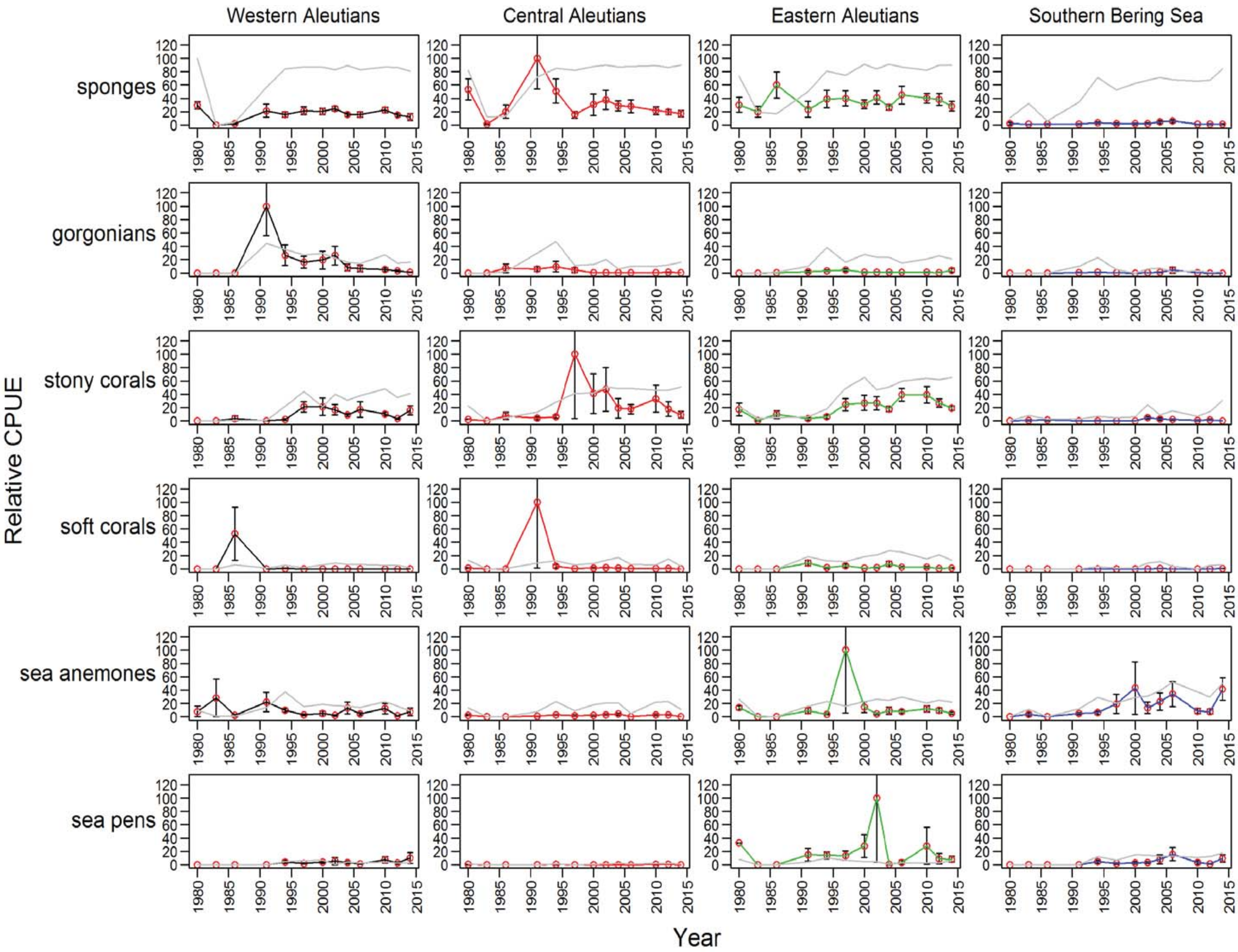

Figure 37: Mean CPUE of HAPC species groups by area from RACE bottom trawl surveys in the Aleutian Islands from 1980 through 2014. Error bars represent standard errors. The gray lines represent the percentage of non-zero catches. The Western, Central, and Eastern Aleutians correspond to management areas 543, 542, and 541, respectively. The Southern Bering Sea corresponds to management areas 519 and 518.

Factors influencing observed trends: Unknown

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

Structural Epifauna (HAPC Biota)- Gulf of Alaska

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Last updated: October 2013

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

Primary Production

Phytoplankton Biomass and Size Structure During Late Summer to Early Fall in the Eastern Bering Sea

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Description of index: BASIS conducted fisheries oceanography surveys in the eastern Bering Sea, mid-August to late September, for three warm years (2003-2005) followed by one average (2006) and six cold years (2007-2012). Variations in chlorophyll ^{a} (chla) were used to evaluate spatial and interannual differences in total phytoplankton biomass and size structure (an indication of phytoplankton species). Large (>10 μm) phytoplankton biomass and fraction of total biomass (>10 μm / total chla) were estimated from discrete water samples filtered through GFF and 10 μm filters. Integrated chla values were estimated from CTD fluorescence profiles, calibrated with discrete chla (GFF) samples. Chla data (total and >10 μm) 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). Friction velocity cubed (u^{*3}), a proxy for wind mixing, were obtained from NCEP reanalysis for PMEL mooring 2 (M2) (courtesy of Nick Bond).

Spatial variations for all years combined are shown for integrated chla (total and >10μm size fraction) for 2003-2012 and for stability for 2003-2009 (Figure 38). Interannual variations (2003-2012) in integrated chla and size structure are shown for the north and south Bering Sea Middle shelf (50-100 m station depths) (Figure 39). We evaluated the relationship between wind mixing 2-3 weeks prior to sampling (August u^{*3}) and integrated chla for the southeastern Middle shelf

(Figure 40). Anomalies of temperature, u^{*3}, stability, integrated chla and large size fraction chla are shown for the southeastern Bering Sea Middle shelf for 2003-2012 (Table 5).

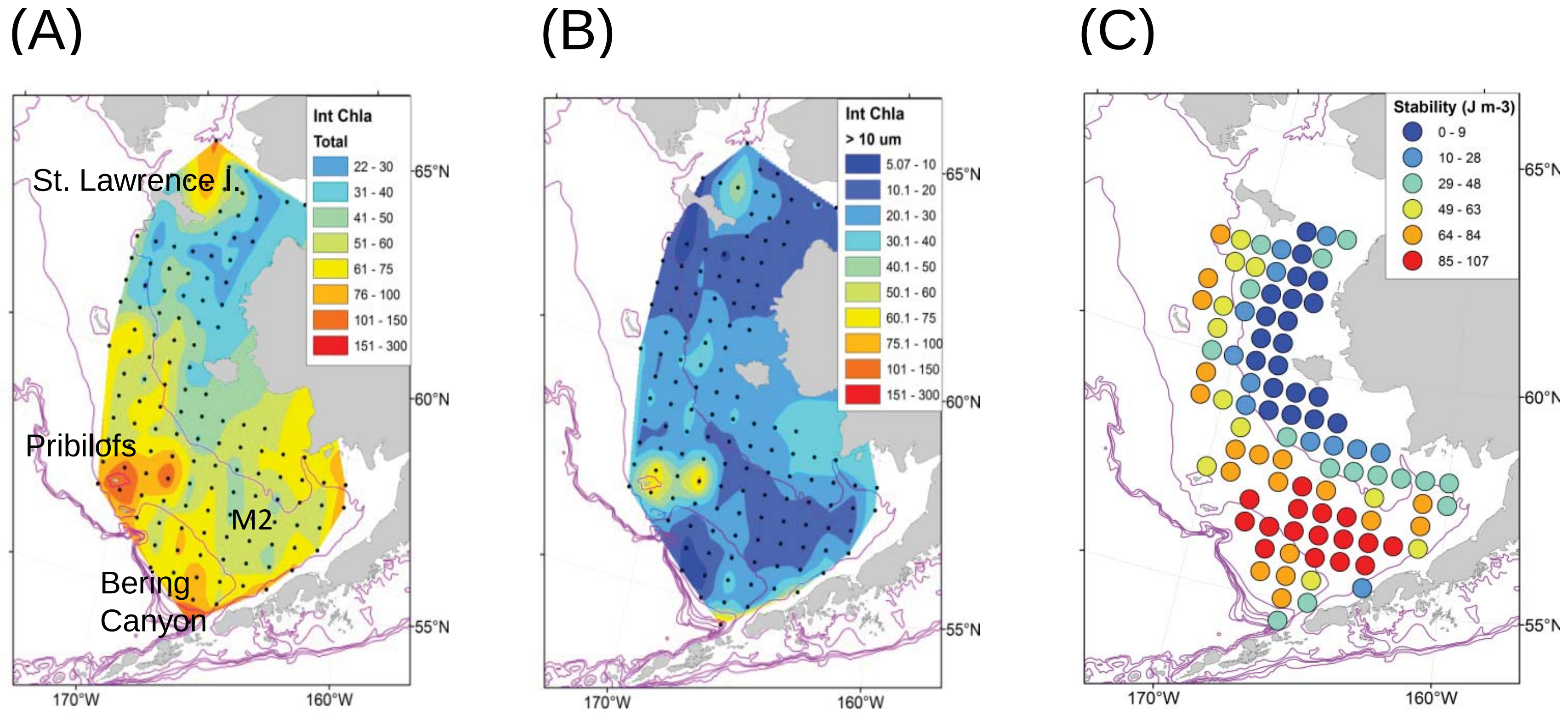

Figure 38: Contours of integrated total chla (mg m^{-2}) (A) and integrated $>10\mu$m chla (B) averaged over 2003-2012, and stability (C) averaged over 2003-2009. Bathymetry contours are shown for 50 m, 100 m and 200 m (shelf break).

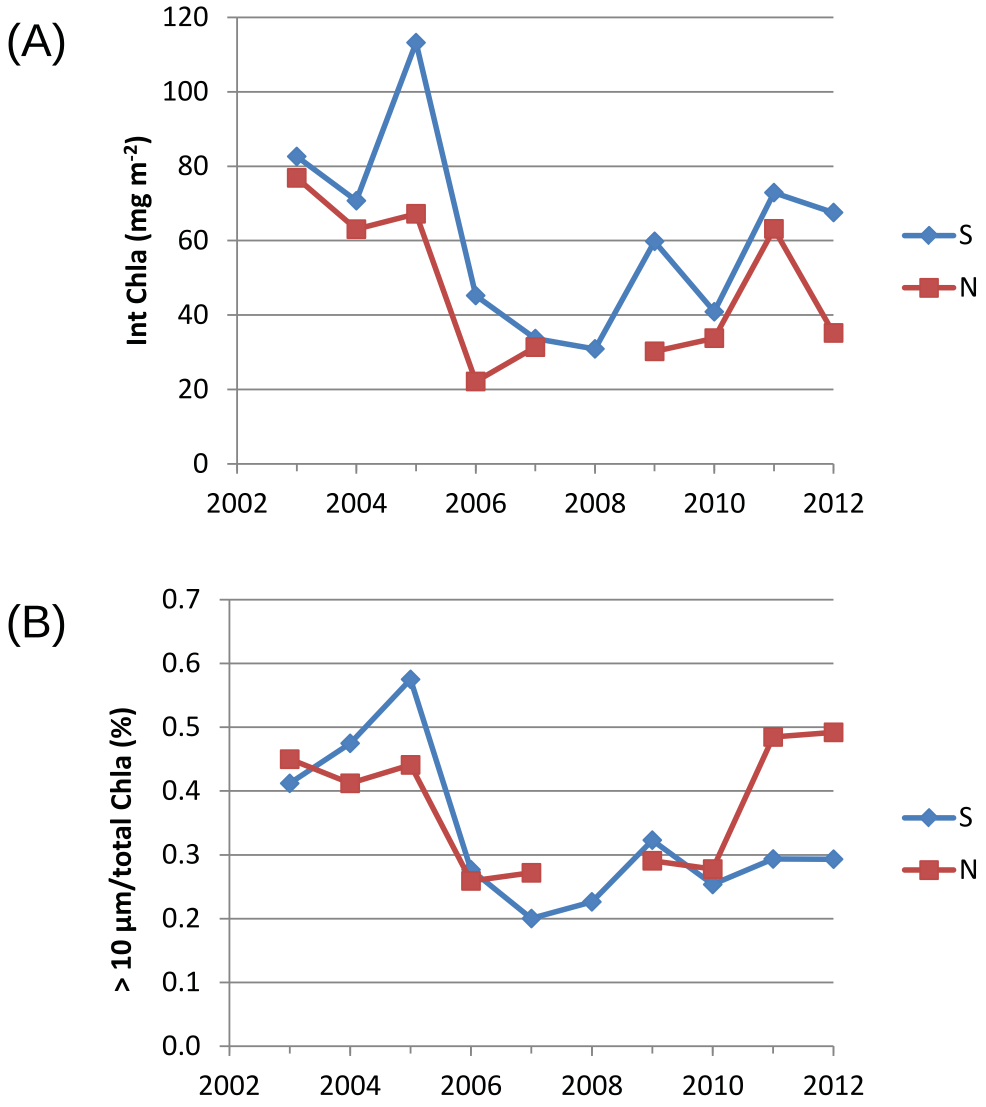

Figure 39: Integrated total chla (A) and ratio of large assemblages to total (>10μm /total chla) (B) in the Middle Domain in the south (54.5 to 59.5 °N, Bering project regions 3 and 6) and north (60 to 63 °N, Bering project regions 9 and 10) for 2003-2012.

Status and trends: Highest phytoplankton biomass was observed in the south Outer shelf (100-200 m) with highest values inshore of Bering Canyon, near the Pribilof Islands, along the Aleutian Islands, north of St. Lawrence Island and on the south Inner shelf (< 50 m). Lowest biomass was observed in the north Bering Sea and on the southeastern Middle shelf in a region of high stability, near M2. Larger phytoplankton were observed on the Inner shelf and near the Pribilof Islands. Smaller phytoplankton were observed on the south Middle shelf (an area of lower total chla) and on the Outer shelf (an area of higher total chla). On the Middle shelf, integrated chla varied 3-fold among years, with the highest values seen in 2005 in the south and 2003 in the north. The mean size of phytoplankton assemblages were higher in warm (2003-2005) than in cold (2006-2012) years in the south, and higher in 2003-2005 and 2011-2012 than in 2006-2010 in the north. Typically years with higher integrated chla had a greater fraction of large phytoplankton.

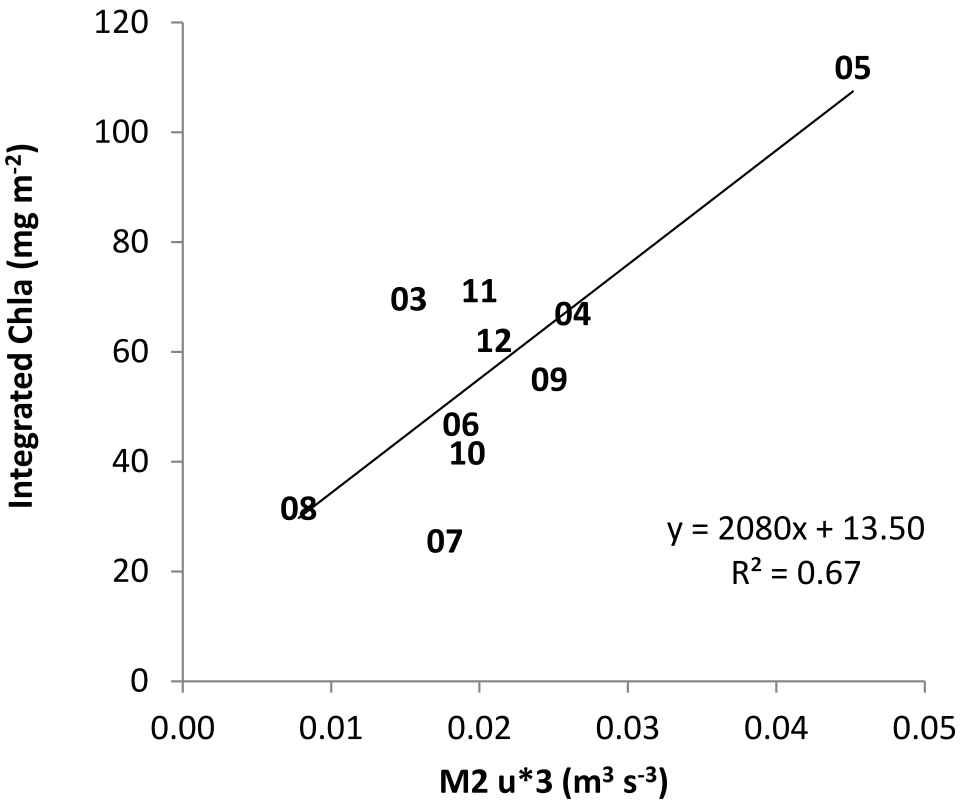

Figure 40: Linear regression between mean August u^{*3}, an indicator of wind mixing, at mooring M2 and integrated chla for the southeastern Bering Sea Middle shelf in Bering Project Region 3 (region around M2) for 2003-2012.

Factors influencing trends: Water column stability, wind and temperature can influence interannual and spatial variations in phytoplankton biomass. For the south Middle shelf, a positive association was observed between August wind mixing and integrated chla in the top 50 m (Figure 40). Deep nutrient-rich waters may be mixed to the surface to fuel production of large assemblages during periods of high winds and low water column stability. Phytoplankton growth may be enhanced at higher temperatures, depending on species. For example, the highest chla and largest size fractions were seen in 2005, a period with high August wind mixing, average stability and high water column temperature (Table 5). While, the lowest chla and smallest size fractions were observed in 2008, a period with low wind mixing, high stability and low water column temperature. Spatially, low chla and small phytoplankton assemblages were seen in the area of highest stability, in the southeastern Middle shelf near M2.

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 period prior to the over-wintering of key forage fish (e.g. juvenile pollock, cod, salmon).

Table 5: Normalized anomalies calculated for 2003 to 2012 or to 2009 (stability) for the south Bering Sea Middle shelf (Bering Project regions 3 and 6) for temperature (T) above and below the pycnocline, stability over top 70 m, integrated chla and ratio of large ($> 10\ \mu$m) to total chla over top 50 m data (August-September) from BASIS data, and friction velocity cubed (u^{*3}) near mooring M2 (August) from NCEP data. Data normalized to maximum anomaly for each variable.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
T above	0.7	1	0.5	0.1	0.1	-0.3	-0.6	-0.4	-0.4	-0.6
T below	0.8	0.6	1	-0.1	-0.3	-0.4	-0.3	-0.7	0.1	-0.7
u^{*3}	-0.3	0.2	1	-0.1	-0.2	-0.6	0.1	-0.1	-0.1	0
Stability	-0.7	-0.3	-0.2	-0.6	1	0.6	0.2			
Int chla	0.4	0.2	1	-0.3	-0.5	-0.6	0	-0.4	0.2	0.1
Large chla ratio	0.3	0.6	1	-0.2	-0.5	-0.4	0	-0.3	-0.2	-0.2

Surface silicate as a potential indicator of nutrient availability during summer/early fall in the eastern Bering Sea; implications for age-0 walleye pollock condition

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Last updated: August 2014

Description of index: Nitrogen (nitrate, nitrite or ammonium) is usually the principal limiting nutrient in the Eastern Bering Sea (EBS) for phytoplankton growth. It is often near detection limits during late summer/ early fall for stratified surface waters, so inter-annual variations in surface nitrogen cannot be measured. In contrast, surface silicate is found in higher concentrations than nitrogen and inter-annual variations are detectable. At the start of summer, surface silicate reflects the concentration remaining in the surface layer after draw down by spring diatom blooms. Silicate was observed during late summer/early fall, in conjunction with age-0 pollock weights and primary productivity to look for possible connections between nutrients, phytoplankton growth and fisheries.

Hydrographic data and surface water samples for surface chlorophyll (Chla) and nutrients (silicate, nitrate, ammonium and nitrite), and primary production experiments along with surface fish tows were collected on the south EBS shelf (south of 60°N) during mid-August through early October on Bering Arctic Sub-Arctic Integrated Survey (BASIS) cruises from 2006 to 2012.

Status and trends: Late summer primary productivity (uptake of carbon by phytoplankton), surface Chla, and surface silicate concentrations in the south EBS had significantly lower values during 2007 (Figure 41). Silicate concentrations were below 2 μM during late summer of 2007, a value observed in laboratory experiments to be a threshold, below which, diatom dominance is no longer possible (Egge and Aksnes, 1992). Age-0 pollock weights were also very low in 2007. In addition to 2007, 2012 had lowered silicate concentrations and age-0 pollock weights compared with other years (2006-2012). When age-0 weights and silicate concentrations are plotted together, a strong positive correlation is seen (Figure 42). The same inter-annual trend is not seen for surface total Chla (or primary productivity) and silicate concentrations.

Factors influencing observed trends: During summer, the strength and frequency of summer

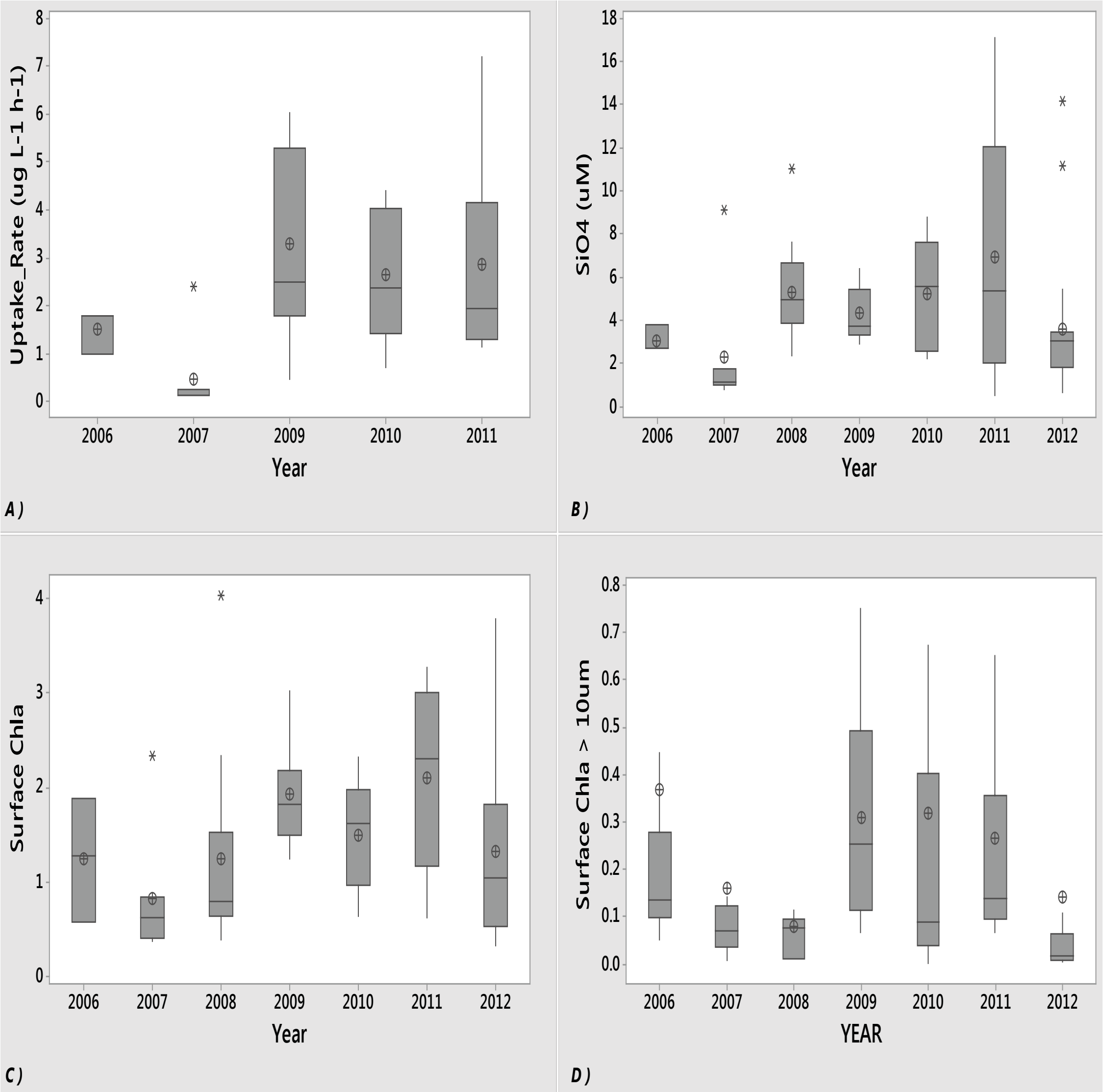

Figure 41: Box and whisker plots depicting the median (solid horizontal line), mean values (circle with cross), and extremes (whiskers) of surface; phytoplankton uptake (μg L^{-1}hr^{-1}) (A), silicate (Si(OH)4, μM) (B) Chla (mg m^{-3}) (C) and ¿10 μm size Chla (mg m^{-3}) (D). Data are from primary production station locations (inner and middle domains only) with the exception of 2008 and 2012, where data are from Region 3. Asterisks indicate outliers from 95% CI. Outliers (for the year 2007 only) in plots A, B, and C are from the same date and location (57.5°N, 168.77°W). Due to an excess of outliers, they are not shown for plot D.

storm events and water column stratification will influence how much silicate and other nutrients are brought to surface waters from depth. Therefore, late summer concentrations of surface silicate may serve as an indicator of nutrient availability, with higher concentrations seen during windy lower stratification years and low concentrations seen when storm activity is minimal and stratification is high. Lower production in the upper water column may directly affect food stores for higher trophic levels and lead to slowed growth of age-0 pollock.

Implications: The positive correlation silicate has with age-0 pollock weight, could mark its

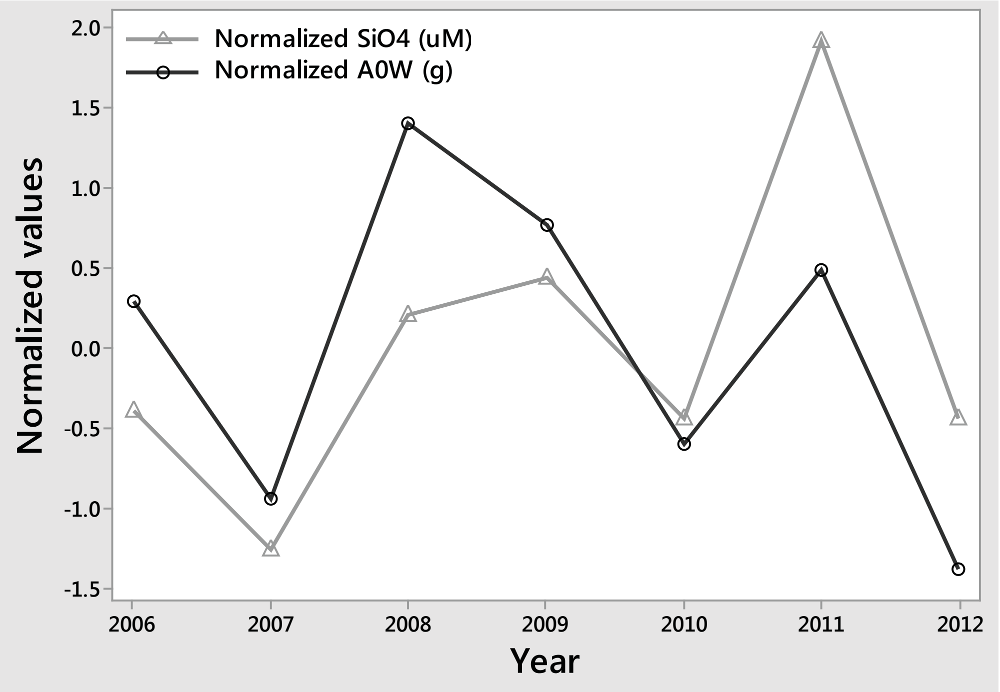

Figure 42: Inter-annual variability of normalized surface silicate ($Si(OH)_4$, from Region 3) and normalized mean weights of age-0 pollock (south of 60°N). Values were normalized by subtracting the mean from each value and dividing by the standard deviation.

potential as a variable for use in an age-1 pollock recruitment model. Future possibilities for this index may include the use of age-0 pollock energy content as well as silicate or other primary production variables to help predict the likelihood of over-winter survival during the first year at sea for pollock.

Gulf of Alaska Chlorophyll a Concentration off the Alexander Archipelago

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

Zooplankton

Bering Sea Zooplankton

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Last updated: September 2014

Description of index: Ressler et al. (2012) developed a method to estimate the abundance and biomass of euphausiids on the middle and outer shelf of the eastern Bering Sea, using acoustic and Methot trawl data from surveys of midwater pollock (*Gadus chalcogrammus*; Honkalehto et al. 2013). Euphausiid density (no. m^3) estimated using this approach was averaged over the water column and then across the surveyed area for each year between 2004 and 2014 (Figure 43). Because few net samples are available in the some years of the times series, the conversion from 120 kHz acoustic backscatter to number of euphausiids per m3 for this index is based on an average of length and species composition from net samples collected between 2004-2012 (euphausiid length and species composition from 2014 net samples are not yet available). Error bars are 95% confidence intervals computed from geostatistical estimates of relative estimation error due to sampling variability (Petitgas, 1993).

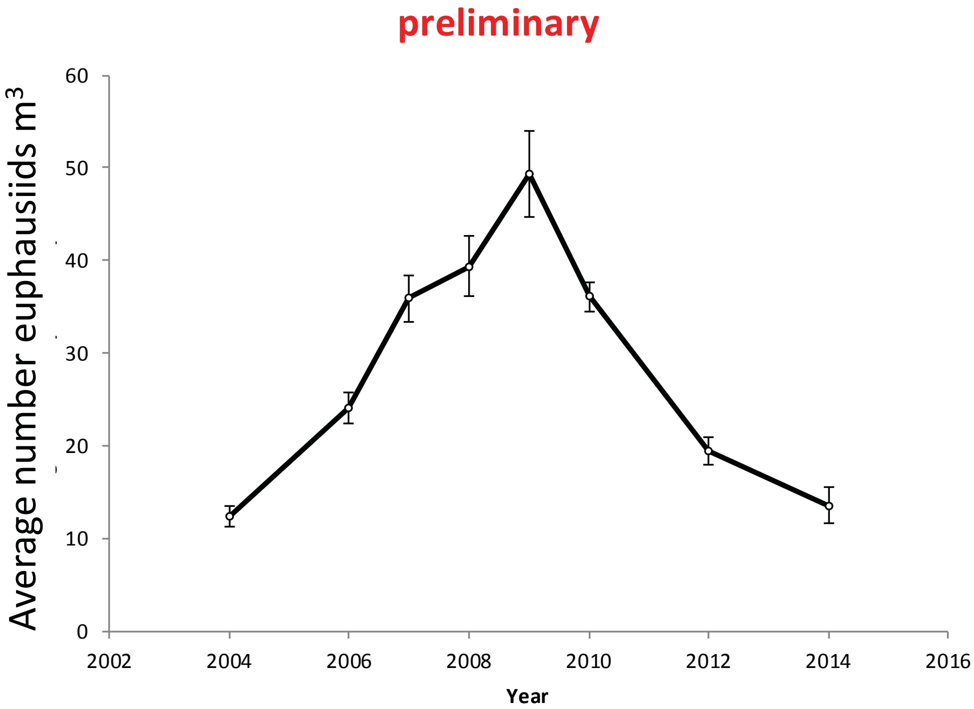

Figure 43: Acoustically-estimated euphausiid density from AFSC summer acoustic-trawl surveys (no. m^3). Error bars are approximate 95% confidence intervals computed from geostatistical estimates of relative estimation error (Petitgas, 1993).

Status and trends: Summertime euphausiid density increased from 2004-2009, but subsequently declined 2010 through 2014 (Figure 43). Abundance in summer 2014 was only slightly greater than in 2004, the lowest estimate in the time series. The spatial distribution of euphausiids in 2014 (Figure 44) indicates that high concentrations of euphausiids are patchy; a notable area of dense concentration is on the southeast continental shelf north of Unimak Pass. These results are preliminary at this time and are subject to change.

Since the last update to this index, 1) euphausiid backscatter observations from the 2014 acoustic-trawl survey of pollock and 2) length and species composition from net samples collected in 2010 and 2012 surveys were added to the analysis. The addition of these new data extended the time series and changed the absolute abundance shown in the plot from previous reports, but the temporal pattern remained very similar. Typically, the average length of euphausiids during summer in the eastern Bering Sea was between 18 and 20 mm; in terms of species, *Thysanoessa inermis* dominated on the outer shelf, while *T. raschii* dominated inshore. These observations are consistent with what is known from the literature (Smith et al., 1991; Coyle and Pinchuk, 2002). There is some indication that euphausiids were smaller on average in 2004-2009 than in more recent years (by 1-2 mm). Overall though, no large interannual changes in length composition nor species composition of euphausiid scattering layers have been indicated.

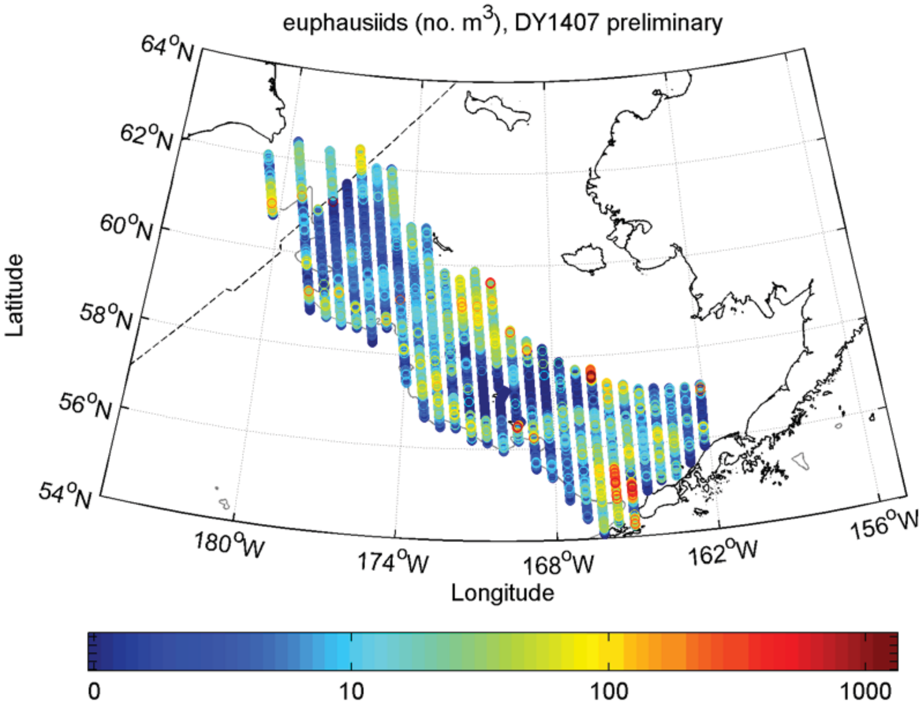

Figure 44: Spatial distribution of average euphausiid density (no. m^3) in summer 2014.

Factors influencing observed trends: The processes controlling variation in the standing stock of euphausiids are not well understood, but temperature conditions and predation have been proposed as important factors (Coyle et al., 2011; Hunt et al., 2011; Ressler et al., 2012). Ressler et al. (2014) used 2004-2010 survey data in multiple regression models to show that euphausiid abundance was better predicted by water temperatures during summer than by the abundance of walleye pollock, the single largest predator of euphausiids in the Bering Sea.

Implications: Euphausiids are food for many species of both ecological and commercial importance in the eastern Bering Sea, including walleye pollock (Aydin et al., 2007). These data suggest that euphausiid prey may have become less available in 2010-2014 compared to several recent summers.

Late Summer/Fall Abundances of Large Zooplankton in the Eastern Bering Sea

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

Jellyfish - Eastern Bering Sea

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Last updated: October 2014

Description of index: The time series of jellyfish (principally *Chrysaora melanaster*) was updated for 2014 (Figure 45). 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.

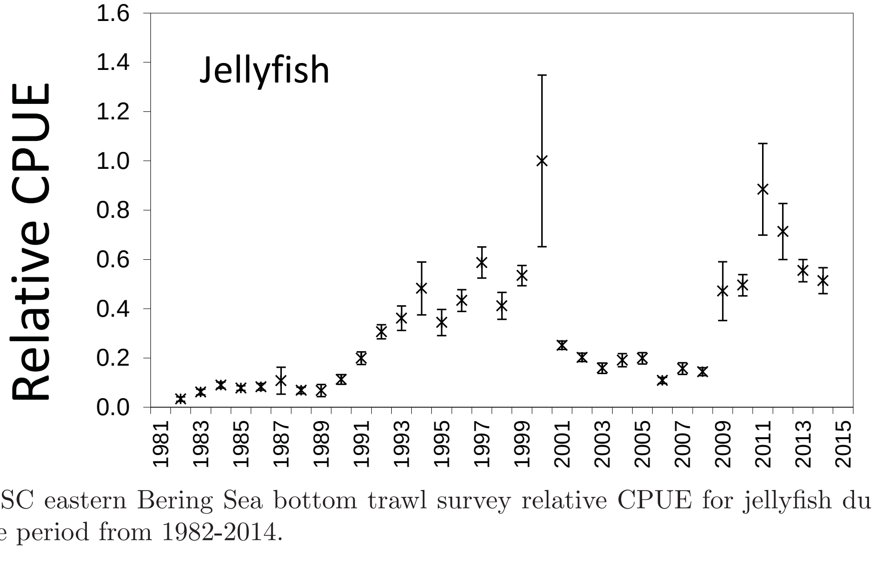

Figure 45: AFSC eastern Bering Sea bottom trawl survey relative CPUE for jellyfish during the May to August time period from 1982-2014.

Status and trends: Jellyfish relative CPUE in 2014 was down slightly from 2013, but remained relatively high when compared to the last 10 years. 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 2009-2014.

Factors influencing observed trends: The associations of fluctuations in jellyfish biomass and their impacts on forage fish, juvenile pollock and salmon in relation to other biophysical indices were investigated by Cieciel et al. (2009); Brodeur et al. (2002, 2008). 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: Jellyfish are an important predator and prey, and large blooms can impact survival of juvenile and forage fishes. Monitoring fluctuations in jellyfish abundance is important for understanding ecological impacts to fishes and higher trophic levels.

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

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Last updated: August 2014

Description of index: Jellyfish sampling was incorporated aboard the BASIS (Bering Aleutian Salmon International Surveys) vessels beginning in 2004 and continuing through 2014. 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 on the Bering Sea shelf.

Status and trends: The coverage for the 2013 survey did not include anything below 60°N. The biomass for the North remained relatively similar to previous years (Figure 46). The dominant species in terms of biomass and abundance was *C. melanaster*. The highest recorded biomass year occurred in 2012 for our survey. One station in the southern Bering Sea portion of our grid during that time was responsible for half the total catch of the entire survey. During 2010, another high biomass year, combined jellyfish species was double the previous high of 2004. Unlike in 2012, half the total catch did not come from a single station but was spread out over the entire sampling grid. 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 Domain. Of the six species sampled, *C. melanaster* had the highest CPUE (catch per unit effort) for all years.

Starting in 2007, notable declines in jellyfish species compostion were observed for all taxa except *C. melanaster* and continued through 2012 (Figure 47). The dominant species continues to be *C. melanaster*, nearly quadrupling its biomass in 2012 compared to 2004. During 2007-2012, biomass of all other species have remained low in comparison to 2004-2006, suggesting the trend for the region has shifted from multiple species to a single species dominant.

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

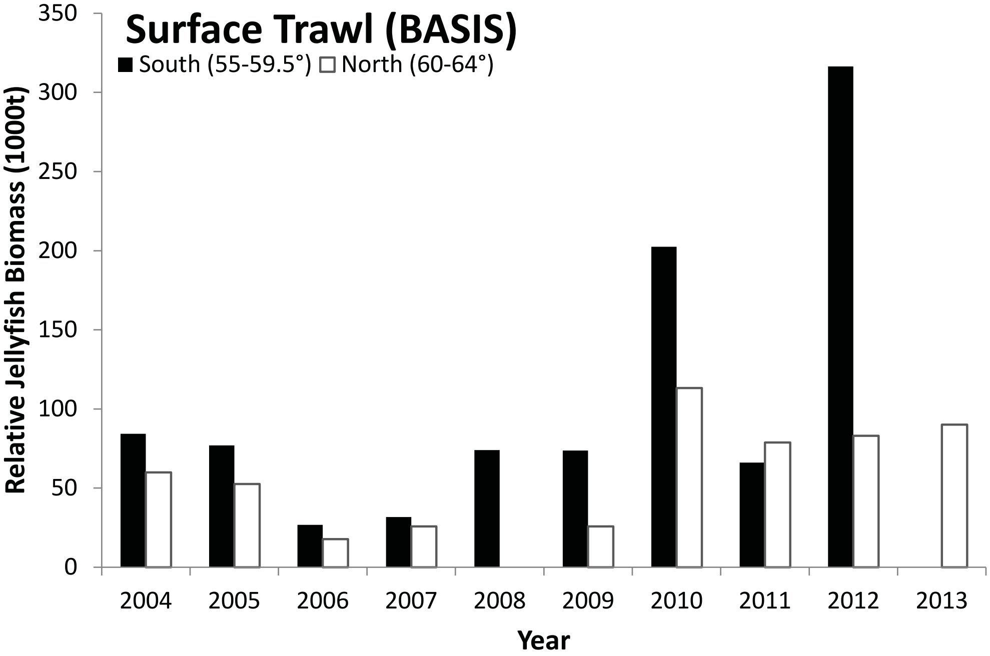

Figure 46: Total jellyfish biomass (1000 t) by year. Includes combined species caught in surface trawls in the Eastern Bering Sea during August-October. Biomass was calculated using average effort per survey area in km^2 by year.

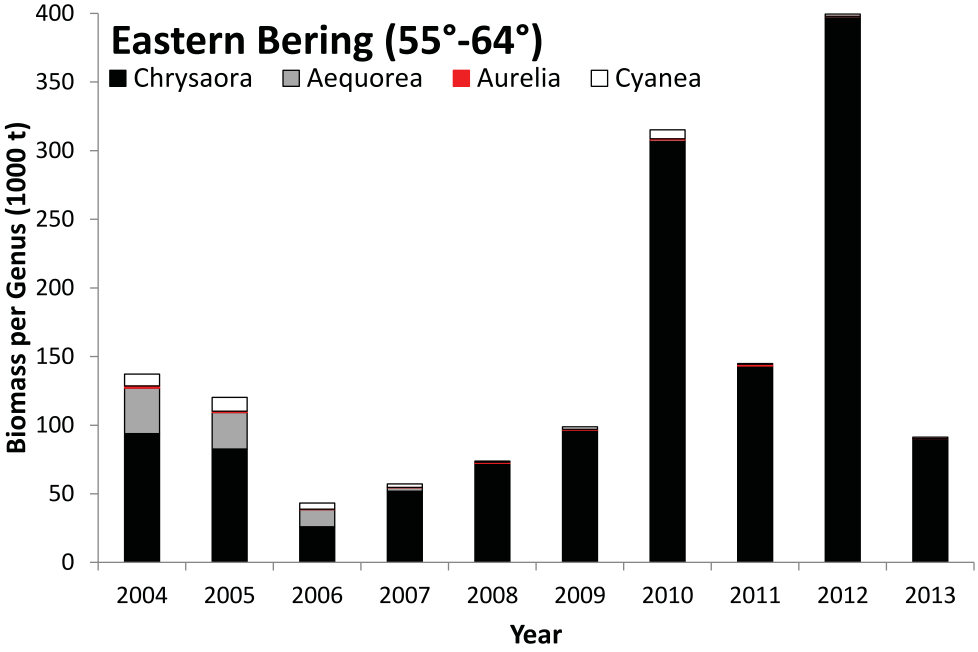

Figure 47: BASIS surface trawl Biomass (1000t) by genus for 2004-2013 in the Eastern Bering Sea during August -October. Biomass was calculated using average effort per survey area in km^2 by year.

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 jellyfish predation on zooplankton and larval fish, and could result in limiting carbon transfer to higher trophic levels (Condon et al., 2011).

Gulf of Alaska Euphausiids ("krill")

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Last updated: August 2014

Description of index: The Gulf of Alaska survey of the abundance and distribution of euphausiids ('krill', principally *Thysanoessa* spp.) is under development based on methods developed by Ressler et al. (2012) in the Bering Sea. The survey incorporates both acoustic and Methot trawl data from the summer Gulf of Alaska acoustic-trawl surveys for pollock conducted in 2003, 2005, 2011, and 2013 by NOAA-AFSC. Acoustic backscatter per unit area (s_A at 120 kHz, m^2 nmi^{-2}) classified as euphausiids was integrated over the water column and then across the surveyed area to produce an annual estimate of acoustic abundance (s_A * area, proportional to the total abundance of euphausiids). Approximate 95% confidence intervals on these estimates were computed from geostatistical estimates of relative estimation error (Petitgas, 1993). The index is limited to areas that were consistently sampled by the surveys (Figure 48). These data are preliminary and will change.

Status and trends: In all years euphausiid backscatter was detected throughout the survey area, but was patchy in distribution. The highest density of euphausiids was consistently observed in Barnabas Trough (Figure 48). Results indicate that highest abundance of euphausiids was observed in 2011, with lowest euphausiid abundance in 2003 (Figure 49).

Factors influencing observed trends: In 2005, euphausiid backscatter was more patchily distributed (Figure 1), leading to wider confidence bands on the estimate (Figure 49). Also, we suspect the 2005 value may be biased low because of increased mixing of euphausiids with other acoustically important organisms in 2005; this is currently under investigation. Finally, as in the Bering Sea, the physical and environmental factors that influence the abundance and distribution of euphausiids in the Gulf of Alaska are not well understood. There is some preliminary evidence that temperature and chlorophyll *a* may influence interannual differences.

Implications: Euphausiids are a key prey species for fish species of both ecological and economic importance in the Gulf of Alaska, including walleye pollock (*Gadus chalcogrammus*), Pacific Ocean perch (*Sebastes alutus*), arrowtooth flounder (*Atheresthes stomias*), capelin (*Mallotus villosus*), eulachon (*Thaleichthys pacificus*), and as well as many species of seabirds and marine mammals. These data indicate that 2011 saw the highest abundance of euphausiids, thus potentially providing an abundant prey source for many species during this time.

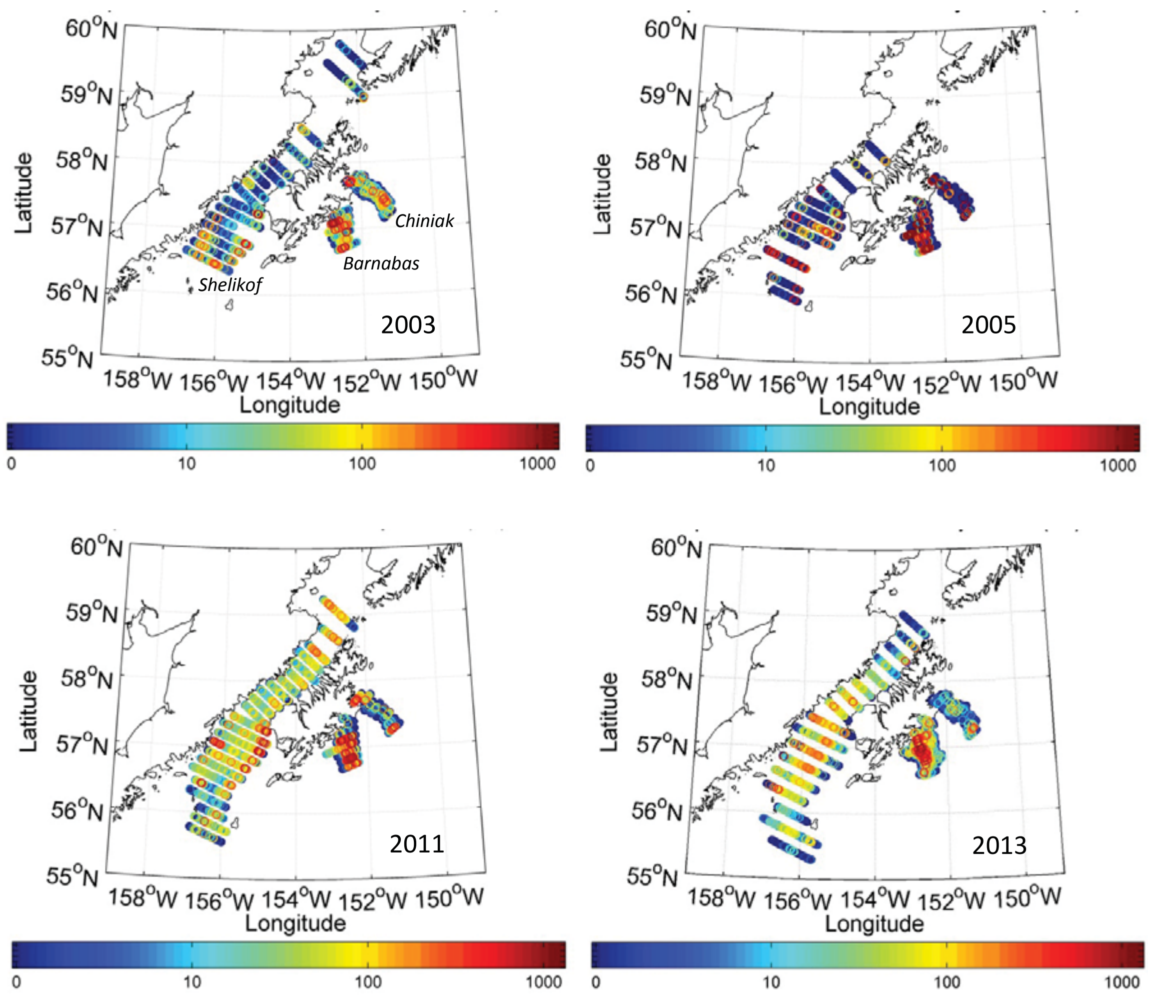

Figure 48: Spatial distribution of acoustic backscatter density (s_A at 120 kHz, m^2 nmi^{-2}) attributed to euphausiids in key areas around Kodiak Island (Shelikof Strait, Barnabas Trough, and Chiniak Trough, as labeled in upper left panel) during the 2003, 2005, 2011, and 2013 Gulf of Alaska summer acoustic-trawl surveys.

Long-term Zooplankton and Temperature Trends in Icy Strait, Southeast Alaska

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Last updated: August 2014

Description of index: The Southeast Coastal Monitoring (SECM) project of Auke Bay Laboratories, AFSC, has collected zooplankton and temperature data during fisheries oceanography surveys annually since 1997 (Orsi et al. 2012; `http://www.afsc.noaa.gov/abl/msi/msi_secm.htm`). The SECM project primarily samples 8 stations in the vicinity of Icy Strait in the northern region of southeastern Alaska (SEAK), including monthly sampling with CTDs and plankton nets in

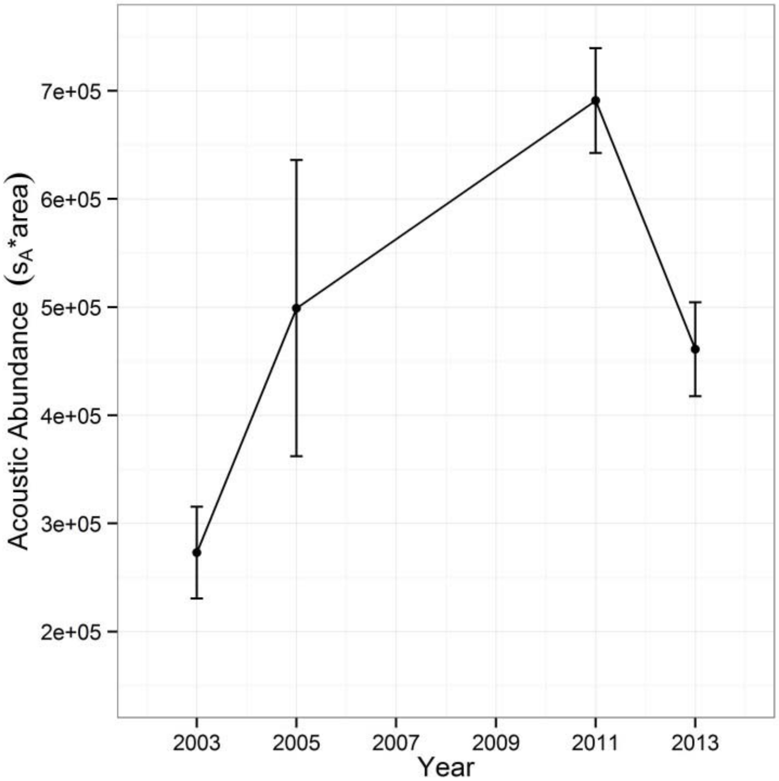

Figure 49: Acoustic backscatter estimate of euphausiid abundance from NOAA-AFSC Gulf of Alaska summer acoustic-trawl survey. Error bars are approximate 95% confidence intervals computed from geostatistical estimates of relative estimation error (Petitgas 1993).

May-August. Surface trawling for juvenile Pacific salmon (*Oncorhynchus* spp.), the most abundant forage species in local epipelagic waters in day time, and associated nekton is conducted in June-August. The primary goals of this research are to investigate how climate change may affect SEAK ecosystems, to increase understanding of the early marine ecology of salmon and their trophic linkages, and to develop an annual forecast of the adult pink salmon (*O. gorbuscha*) from stock assessments of juveniles in the prior year (Sturdevant et al., 2012; Fergusson et al., 2013; Orsi et al., 2013). Biophysical parameters representing temperature, zooplankton prey, and fish abundance and condition are used to characterize seasonal and interannual ecosystem conditions for inside waters of northern Southeast Alaska.

This report presents 2013 monthly temperature and zooplankton data measured in relation to long-term trends in Icy Strait. The Icy Strait Temperature Index (ISTI, °C) is computed from CTD data at 1-m increments over the 20-m upper water column ($\geq$160 observations per month each year). The ISTI is linked to a climate metric, the El Niño/La Niña-Southern Oscillation (ENSO) Multivariate ENSO Index (MEI) (Wolter, 2012; Sturdevant et al., 2012). We used the mean winter MEI (November to March) for the year prior to the sample year, to capture the lag effect of propagating ocean-atmospheric teleconnections from the equatorial Pacific Ocean (Orsi et al., 2013). Zooplankton total density (number per m^3) and percent composition were computed from 333-μm bongo net samples collected at 4 stations ($\leq$200 m depth) (Orsi et al., 2004; Park et al., 2004). Temperature and zooplankton anomalies were computed as deviations from the longterm

Table 6: Zooplankton long-term mean total density (numbers^{-3}) and taxonomic percent composition in Icy Strait, Southeast Alaska, 1997-2013. Data represent 4 stations sampled annually across the strait ($\leq$ 200 m depth) with a 0.6 m diameter 333-μm mesh Bongo net (double-oblique trajectory). Values are references for the 0-lines shown in Figures 51 and 52 interannual anomalies.

	Total organisms	% Large calanoids	% Small calanoids	% Euphausiid larvae	% Larvaceans	% Amphipods	% Decapod larvae	% Other
May	1634(142)	33(3)	49(4)	5(1)	6(2)	<1(0)	1(0)	7(1)
June	1645(187)	23(2)	57(2)	7(2)	5(1)	1(0)	<1(0)	7(0)
July	1204(106)	15(1)	74(2)	1(0)	2(1)	2(1)	<1(0)	4(0)
August	885(56)	15(2)	73(4)	1(0)	2(1)	2(0)	<(0)1	7(4)

monthly mean values. These indices may help to explain climate-related variation in prey fields for diverse fish communities (Sturdevant et al., 2012; Fergusson et al., 2013).

Status and trends: Overall, monthly mean temperatures ranged from approximately 7 °C to 10 °C and anomalies did not exceed ±1.5 °C (Figure 50, top). During 2013, temperatures were anomalously cool in May and June and warm in July and August. The ISTI was significantly correlated with the MEI (Figure 50, bottom), with 9 years warmer and 8 years colder than average (9.3 °C)); mean ISTI was average in 2013. Warm and cold years typically had positive and negative MEI values, respectively. In the most anomalous years, all 4 months were warm (2003 and 2005) or cold (2002, 2006, 2008, 2012; Figure 50, top), whereas moderately warm or cold years had unique months of temperature reversal. For example, the warm years of 2004 and 2010 were actually colder than average in June and July, respectively.

Overall, long-term mean zooplankton density peaked in May and June at ∼1,600 organisms per m^3, and declined ∼50% by August (Table 1). During 2013, total density was anomalously low for all months. Density anomalies were mostly negative from 1997-2005, positive in 2006-2009, and negative in 2010-2012 (Figures 51 and 52). Total density showed little correspondence with annual temperature trends, with both positive and negative monthly anomalies in both warm and cold years.

Overall, zooplankton was numerically dominated by calanoid copepods, including small species ($\leq$2.5 mm length; $\leq$74% composition; primarily *Pseudocalanus* spp.) and large species (>2.5 mm; $\leq$34% composition; primarily *Metridia* spp.) (Table 6). Four other taxa important in fish diets (Sturdevant et al. 2012; Fergusson et al. 2013) contributed small percentages (euphausiids, $\leq$7%; decapod larvae, $\leq$1%; amphipods, $\leq$2%; and larvaceans, $\leq$6%). For 2013, large calanoids and larvaceans were anomalously high while small calanoids were anomalously low. Small and large calanoids typically had inverse monthly composition anomalies that indicated different seasonality and temperature response (Figures 51 and 52). However, these anomalies varied from year to year, suggesting different innate timing cues. In some years, high percentages of euphausiid larvae (2000, 2002, 2010), larvaceans (2010), or pteropods (2012) contributed to monthly composition anomalies (Figures 51 and 52). Such shifts could lead to mismatched timing of prey fields for planktivorous fish.

Factors influencing observed trends: Our research in SEAK over the past 16 years described annual trends in temperature, prey fields, and other biophysical factors (Orsi et al., 2013). We documented a significant link between ISTI and a basin-scale climate index, with limited diet-climate

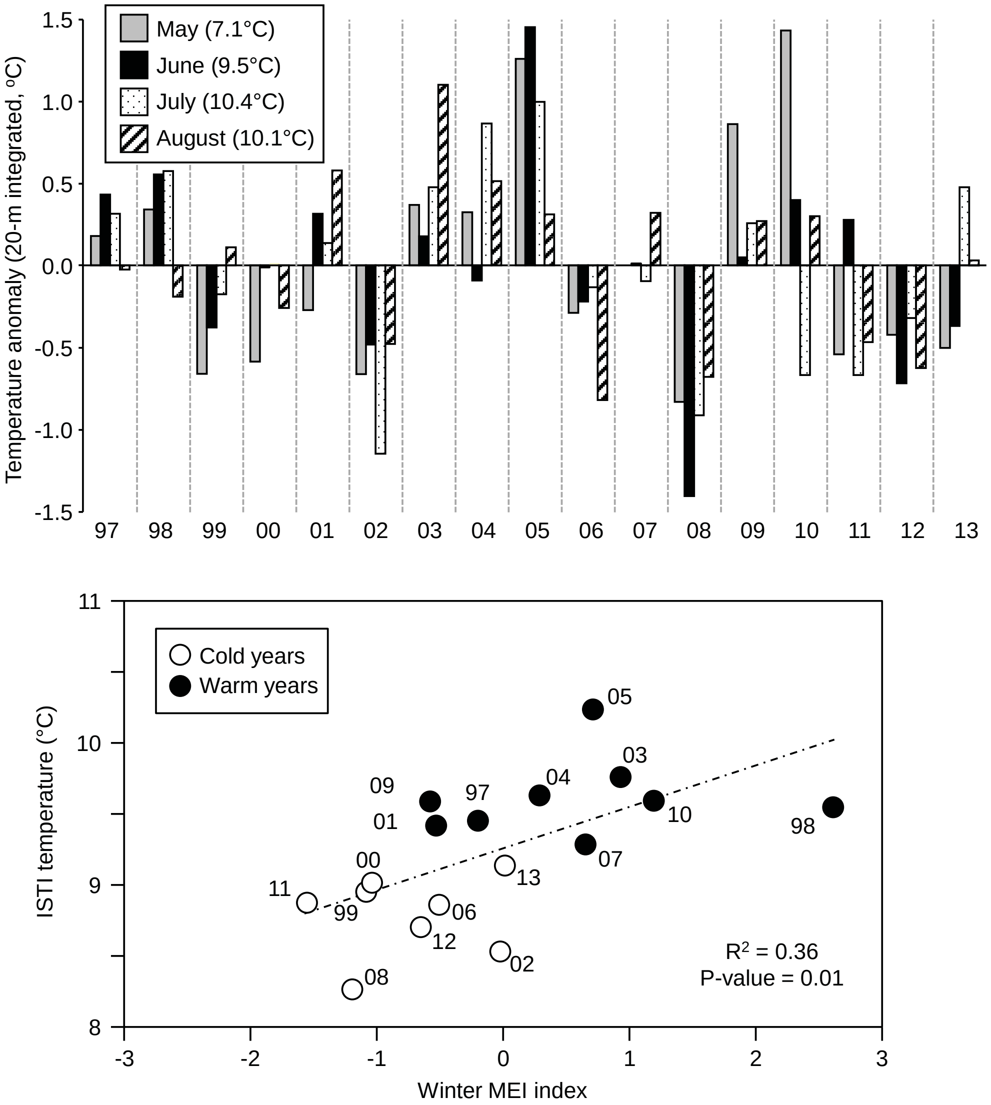

Figure 50: Marine climate relationships for the northern region of Southeast Alaska from the SECM 17-year time series, 1997-2013. Upper panel: mean monthly temperatures (°C, 20-m integrated water column) in Icy Strait; lower panel: correlation of mean annual temperature (°C, 20-m integrated water column) with the Multivariate ENSO Index (MEI), showing warm and cold years. Long-term mean temperatures are indicated in the top panel key by month.

relationships (Sturdevant et al., 2012, 2013; Fergusson et al., 2013). Although subarctic zooplankton typically follow seasonal cycles of abundance, responses to climate change may be species-specific based on life history, seasonal timing cues, physiology, and environmental parameters other than temperature (Mackas et al., 2012), and these responses could depend on the monthly timing, magnitude, and duration of temperature anomalies in warm or cold years. Therefore, the simple ISTI may not explain shifts in abundance and composition of these prey fields, particularly at broad taxonomic scales. Further analysis of specific target prey at a species specific level is planned to refine this index so it more accurately reflects critical trophic interactions with respect to climate change.

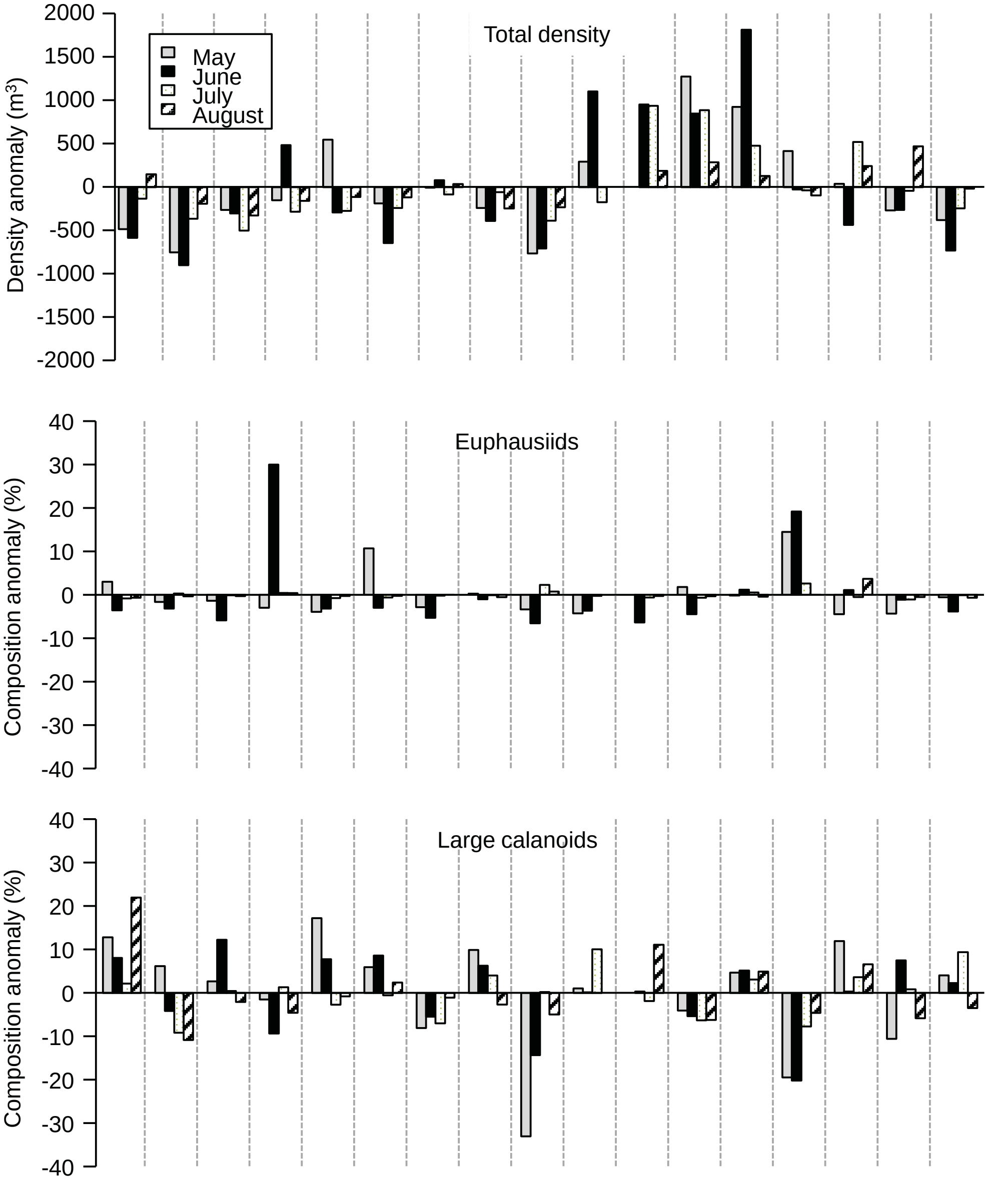

Figure 51: Total zooplankton, euphausiid and large Calanoid density and composition anomalies for the SECM 17-yr time series from Icy Strait, Southeast Alaska, 1997-2013. Long-term monthly means are indicated by the 0-line (values given in Table 6). Data (shaded bars) are deviations for total density (number/m^3; top left panel), and taxonomic percent composition.. No samples were available for August 2006 or May 2007. Warm years are indicated in boxes on the x-axis; see Figure 50.

Implications: Climate change can have broad impacts on key trophic linkages in marine ecosystems by changing relationships of the biophysical environment with seasonal abundance, composition, timing, and utilization of prey (Mackas et al., 2004, 2012; Coyle et al., 2011). 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-atmosphere conditions (Baier and Napp, 2003), and in SEAK, large copepods with long life spans were thought to be

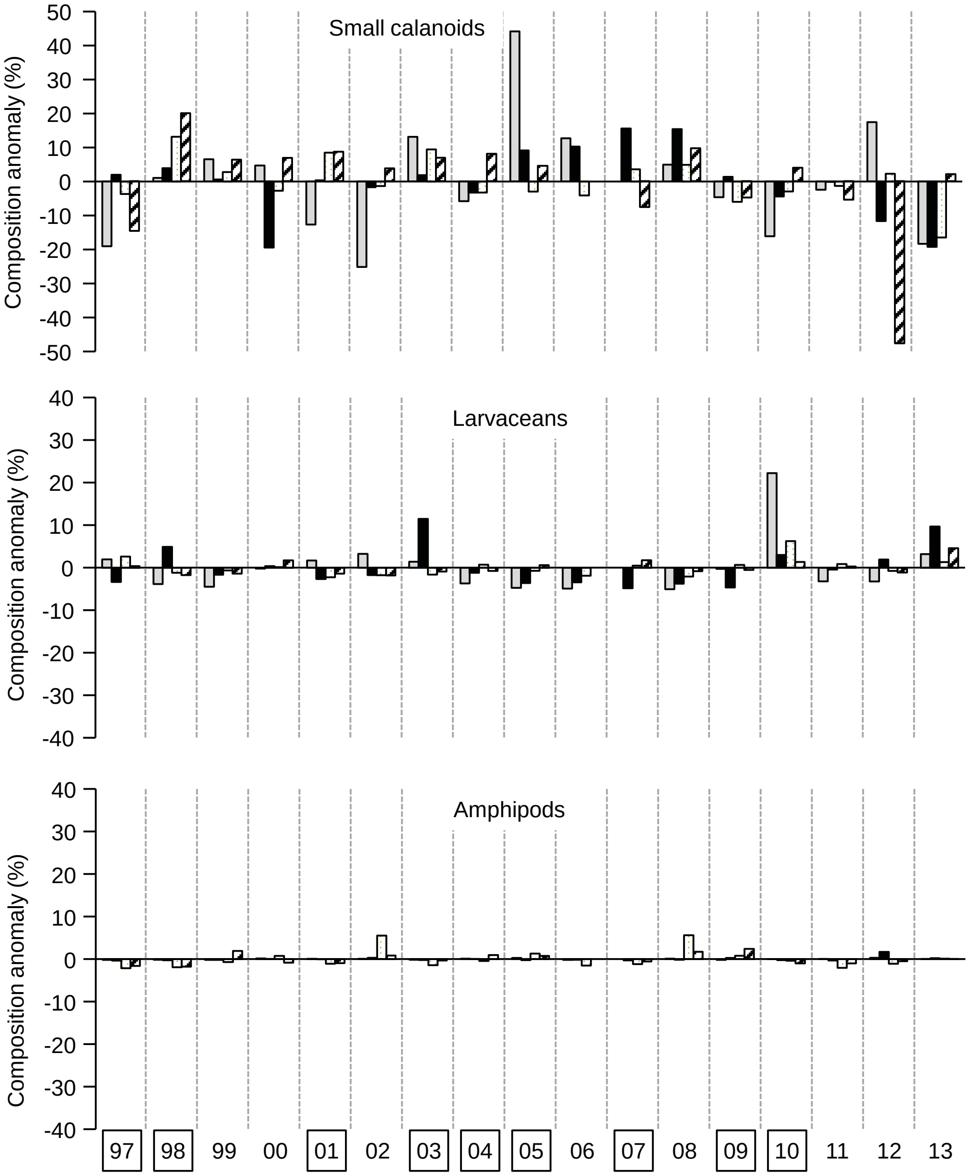

Figure 52: Small Calanoind, Larvacean and amphipod density and composition anomalies for the SECM 17-yr time series from Icy Strait, Southeast Alaska, 1997-2013. Long-term monthly means are indicated by the 0-line (values given in Table 6). Data (shaded bars) are deviations for total density (number/m^3; top left panel), and taxonomic percent composition. No samples were available for August 2006 or May 2007. Warm years are indicated in boxes on the x-axis; see Figure 50.

more sensitive to climate fluctuation than small copepods (Park et al., 2004). Temperature and other climate metrics may affect fish production and recruitment directly or indirectly, through prey resources (Beamish et al., 2004, 2012; Coyle et al., 2011). In dynamic ecosystems such as SEAK (Weingartner et al., 2009), the effects of climate variation on prey fields are likely to be complex, varied, and difficult to distinguish from natural variation, particularly if annual temperature changes are moderate. However, further analysis of the potentially more direct links between monthly temperature and zooplankton secondary production may lead to improved understanding of marine mechanisms that influence fish recruitment during periods of climate change (Downton and Miller, 1998; Francis et al., 1998).

Continuous Plankton Recorder Data from the Northeast Pacific

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Last updated: August 2014

Description of index: 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 (∼ 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. In this report we update three indices for three regions (Figure 53); large diatoms (the CPR only retains large, hard-shelled phytoplankton so while a large proportion of the community is not sampled, the data are internally consistent and may reveal trends), mesozooplankton biomass (estimated from taxon-specific abundance data) and mean copepod community size (Richardson et al., 2006) as an indicator of community composition. Anomaly time series of each index have been calculated as follows: A monthly mean value (geometric mean) for all sampled years was first calculated. Each sampled month was then compared to the mean of that month and an anomaly calculated (Log_{10}). The mean anomaly of all sampled months in each year was calculated to give an annual anomaly (Figure 54).

The indices are calculated for three regions; the oceanic North-East Pacific, the Alaskan shelf SE of Cook Inlet and the deep waters of the southern Bering Sea (Figure 53). The NE Pacific 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. The southern Bering Sea is sampled only 3 times per year by the east-west transect while the Alaskan shelf region is sampled 5-6 times per year by the north-south transect.

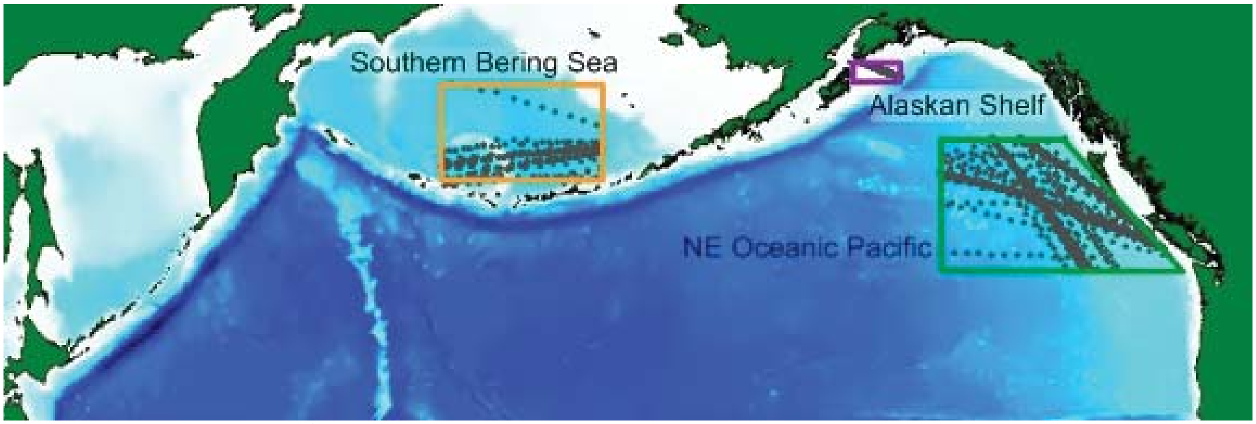

Figure 53: Boundaries of the three regions described in this report. Dots indicate actual sample positions (note that for the Alaskan Shelf region the multiple transects, more than 50, overlay each other almost entirely).

Status and trends: 2013 saw values of each these indices within the range seen before, in all 3 regions, so 2013 was not an unusual year. Large diatoms continued to show a positive anomaly on the Alaskan Shelf, increasing slightly in 2013. They continued to show a negative anomaly in the oceanic Pacific, though not especially low. The Southern Bering Sea region had a positive anomaly for diatoms, however, since this region is only sampled once in spring, and the timing varies from year to year, it is more difficult to detect trends here. Mesozooplankton biomass was down slightly on the Alaskan Shelf and oceanic NE Pacific. The copepod community was comprised of smaller organisms than in 2013 in the Southern Bering sea and most noticeably on the Alaskan shelf.

Factors influencing observed trends: An increase in warm water species was noted in the Alaskan shelf region in the latter part of 2013, and although copepods were not at all dominant, the warmth likely contributed to the negative size anomaly. Changes in ocean climate can affect each of these indicators. Cool conditions are generally favourable for the larger subarctic copepod species which have high individual biomass, consequently we can expect more positive anomalies of mesozooplankton biomass and average copepod community size during cool years, and the reverse in warm years.

Implications: Each of these variables is important to the way that ocean climate variability is passed though the phytoplankton to zooplankton and up to higher trophic levels. Changes in community composition (e.g. abundance of large diatoms, prey size as indexed by mean copepod community size) may reflect changes in the nutritional quality of the organism to their predators. Changes in abundance or biomass, together with size, influence availability of prey to predators.

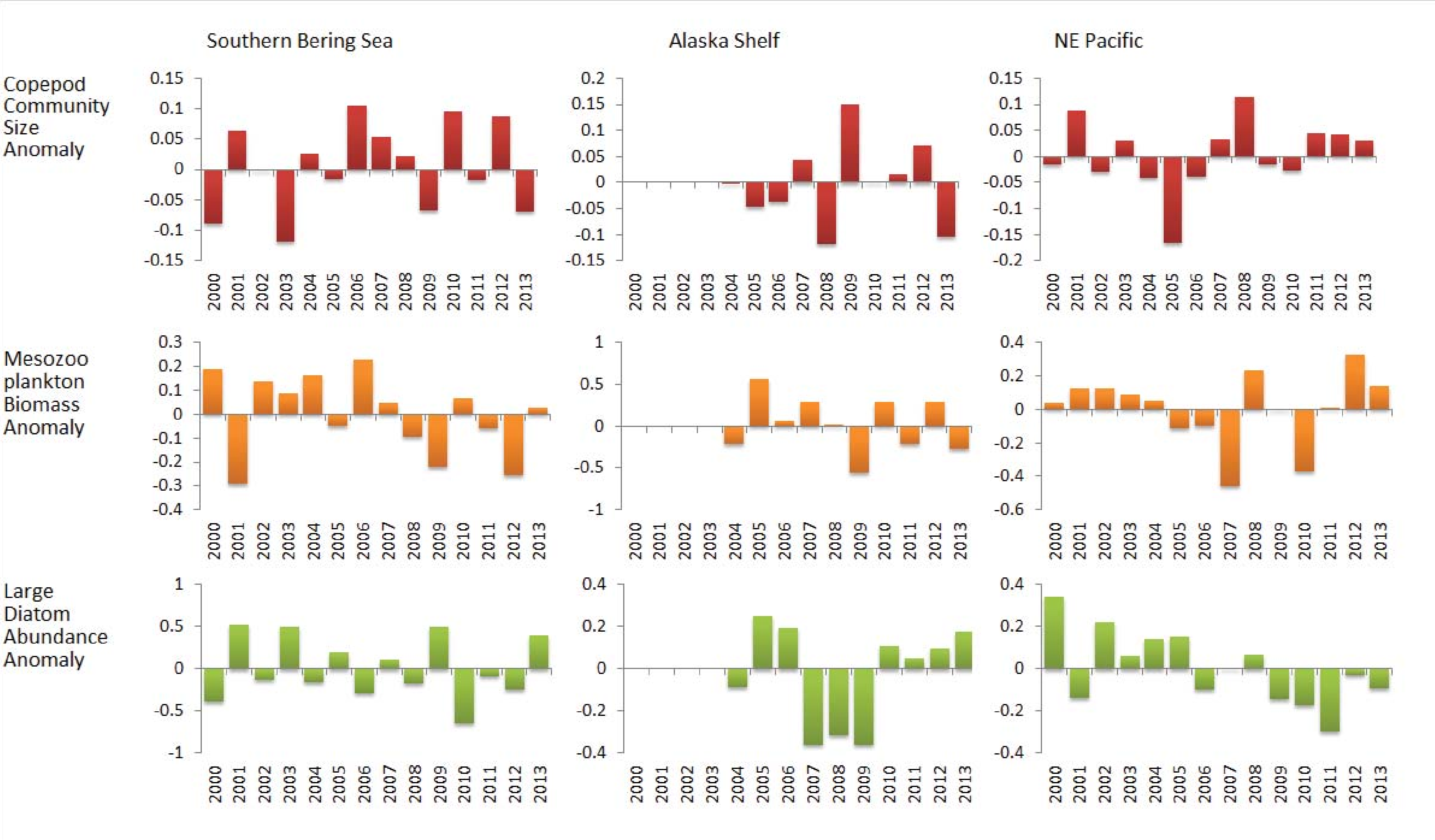

Figure 54: Annual anomalies of three indices of lower trophic levels (see text for description and derivation) for each region shown in (Figure 53). Note that sampling of this Alaskan Shelf region did not begin until 2004.

Forage Fish

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

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

Forage Fish CPUE - Bering Aleutian Salmon International Survey - BASIS

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Gulf of Alaska Smallmesh Trawl Survey Trends

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Last updated: August 2014

Description of index: Smallmesh trawl surveys of the nearshore Gulf of Alaska have been conducted jointly by the Alaska Fisheries Science Center and Alaska Department of Fish and Game using standard methods since 1972 (n = 13,477 hauls), making it one of the longest continuous marine survey time series in the North Pacific. The most recent survey occurred in September and October of 2013 (n = 106 hauls) in the bays on the in the bays around Kodiak Island, the Shelikof Strait, and Wide Bay and Pavlof Bay along the south side Alaska Peninsula. The smallmesh survey results are presented as fish and invertebrate CPUEs (kilograms captured per kilometer towed).

The CPUE time series was used to calculate gulf-wide anomalies from the long-term mean CPUE of pink shrimp *Pandalus eous*, juvenile pollock ($\leq$ 20 cm) *Gadus chalcogramma*, eulachon *Thaleichthys pacificus*, and Pacific herring *Clupea pallasi*. These species were selected because they are key prey items of many commercial species. The timing, location, and gear used on the smallmesh survey provides a unique opportunity to collect information on these forage species.

Status and trends: While herring and pink shrimp catches remain well below the rates of the 1970s and early 1980s (Figure 55) (Anderson and Piatt, 1999), the gulf-wide catch rate of juvenile pollock of 16.5 kg km^{-1} was the highest observed since 1979 (Figure 55). Both pink shrimp and juvenile pollock were widely distributed across the survey area but the catch rates were highly variable. Pink shrimp catches of over 100 kg km^{-1} were found in Wide, Uyak, and Izhut Bays. For juvenile pollock, catches of over 100 kg km^{-1} occurred in Pavlof, Wide, and Uyak Bays. In over 75% of stations, however, the catches of these species were less than 20 kg km^{-1}.

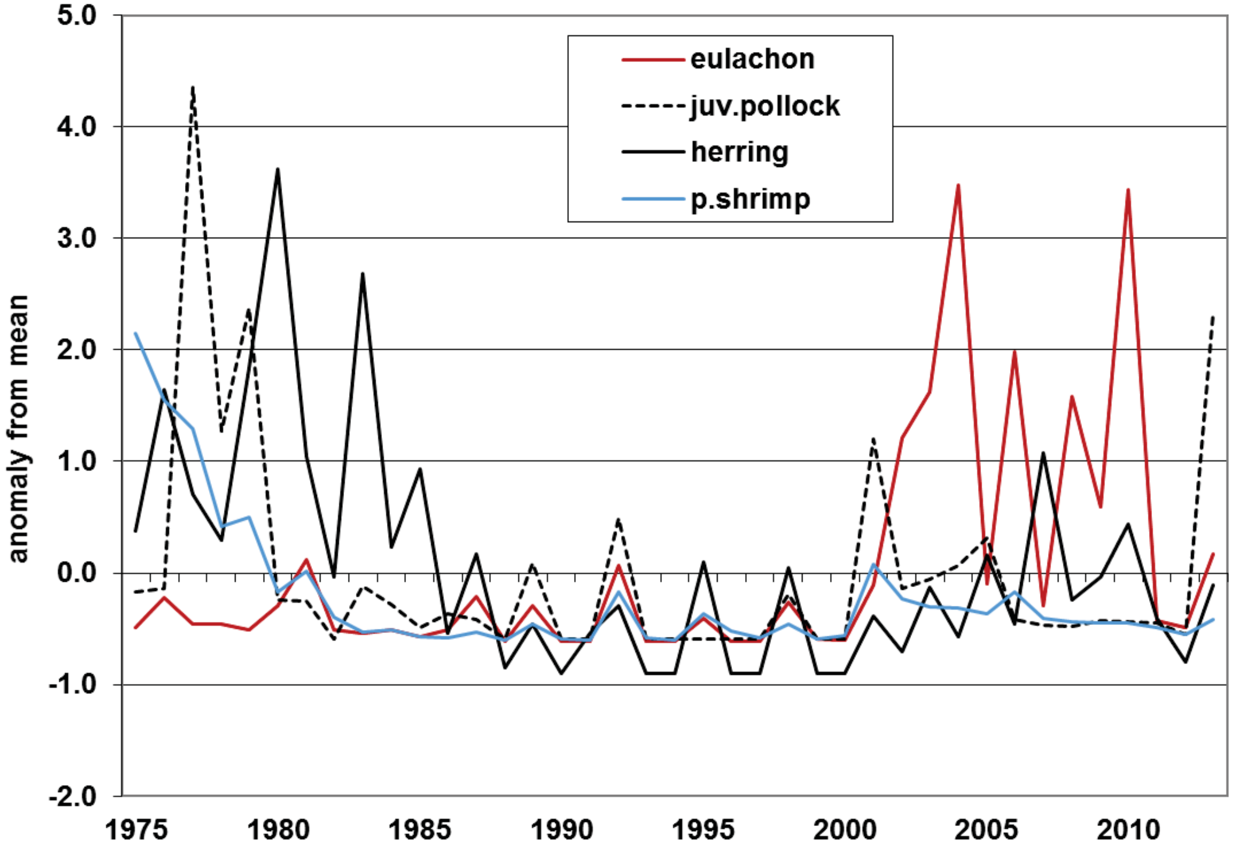

Figure 55: Anomalies from the long-term mean of forage species CPUE (kg km^{-1}) captured during the smallmesh survey in the Gulf of Alaska, 1972-2013.

Factors influencing observed trends: There is widespread evidence that climate change affects the population dynamics and production of fish stocks in the north Pacific Ocean (Noakes and Beamish 2009) but large scale community reorganizations are not necessarily uniform within the community (Duffy-Anderson et al. 2005), as seen in recent differences in forage fish abundance trends and may involve different time lag periods for different species (Overland et al. 2008).

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) so improving our understanding of the changing ocean environment requires continued careful monitoring of the physical and biological systems. While our understanding of the linkages between climate changes and the marine ecosystem have improved in the last 30 years, we still lack the ability to forecast trends in a way that is useful to fishery managers (Noakes and Beamish, 2009; Preikshot et al., 2013).

Temporal Variability in Pacific Sand Lance Revealed by Puffins in the Gulf of Alaska

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Description of index: Seabirds, as conspicuous, highly-mobile samplers of the forage nekton community, have been suggested for decades to be reliable indicators of marine "food supplies" (Cairns 1987, Hatch and Sanger 1992, Mills et al. 2007, Renner et al. 2012, Hatch 2013). In the Gulf of Alaska (GOA), dietary analysis of two species of puffin, tufted puffin (*Fratercula cirrhata*), and rhinoceros auklet (*Cerorhinca monocerata*), at three sites from the eastern GOA (St. Lazaria Island), to the central GOA (Middleton Island) to the western GOA (Aiktak Island) were collated and integrated (using multivariate statistical techniques) to investigate interannual and lower-frequency variability in sand lance availability. Here, we demonstrate that combining seabird diet composition across species and sites into multivariate indicators of forage fish availability is a promising approach to assessing temporal dynamics of this and perhaps other key forage species in remote marine environments.

The data used for this analysis were obtained from puffin diet sampling conducted from 1994 through 2012, and reflect multi-prey item "bill-loads" obtained from parent puffins bringing food back to their breeding colonies to provision offspring (Hatch and Sanger 1992). We summarized a subset of an Alaskan puffin diet database compiled with support from the North Pacific Research Board (Thompson et al. 2013). For the analysis here we included 8,491 bill-loads comprising 46,023 single prey items belonging to 51 species/taxonomic groups. We calculated the percent by number of sand lance per sample and then took the mean per year for each puffin species and site to develop a multivariate sand lance index. To develop this regional index, we used Principal Components Analysis (PCA). To fill in occasional empty cells (n = 5 site-years), we averaged the two years of data before and after missing values assuming monotonic changes in the sand lance availability and take. We retained the resulting leading and second principal components (e.g.,"$\mathrm{PC1}_{\text{sand lance}}$" and "$\mathrm{PC2}_{\text{sand lance}}$"). Last, we related our multivariate sand lance index to a regional PCA-derived index of environmental conditions, including annual values of sea surface temperature (SST) and sea level pressure (SLP; obtained from Hadley Met Office reconstructions; `http://www.metoffice.gov.uk/hadobs/`), and wind speed (data were obtained from iCOADS; `http://icoads.noaa.gov/`). Funding for this contribution was provided by the North Pacific Research Board. Puffin dietary data was contributed by the AMNWR, USGS, and Institute for Seabird Research and Conservation (ISRC).

Status and trends: $\mathrm{PC1}_{\text{sand lance}}$ explained 57% of the temporal variation in the percent of sand lance in puffin chick diets across species and islands, with another 25% explained by $\mathrm{PC2}_{\text{sand lance}}$. Sand lance time series from rhinocerous auklets at Middleton, tufted puffins at Middleton, and tufted puffins at Aiktak were associated with PC1$_{\text{sand lance}}$ (loadings = 0.62, 0.56, and 0.53 respectively). The time series from rhinoceros auklets at St. Lazaria loaded very strongly (0.96) onto PC2$_{\text{sand lance}}$; loadings for the other species-sites on PC2$_{\text{sand lance}}$ were <0.28 . Therefore, we interpret PC1$_{\text{sand lance}}$ as reflecting interannual variability in the western GOA (Aiktak and Middleton) and PC2$_{\text{sand lance}}$ as interannual variation in the eastern GOA (St. Lazaria) (Figure 56). Temporal patterns in PC trends show that sand lance were most prevalent from the mid 1990s to the mid 2000s in the central and western GOA. In contrast, sandlance were most prevalent in the mid-1990s and have been decreasing since then in the eastern GOA. PC1$_{\text{env}}$ mostly reflected annual variation in SST, and was positively correlated with PC1$_{\text{sand lance}}$ (n = 19, $\rho = 0.567$, p = 0.011; Figure 57).

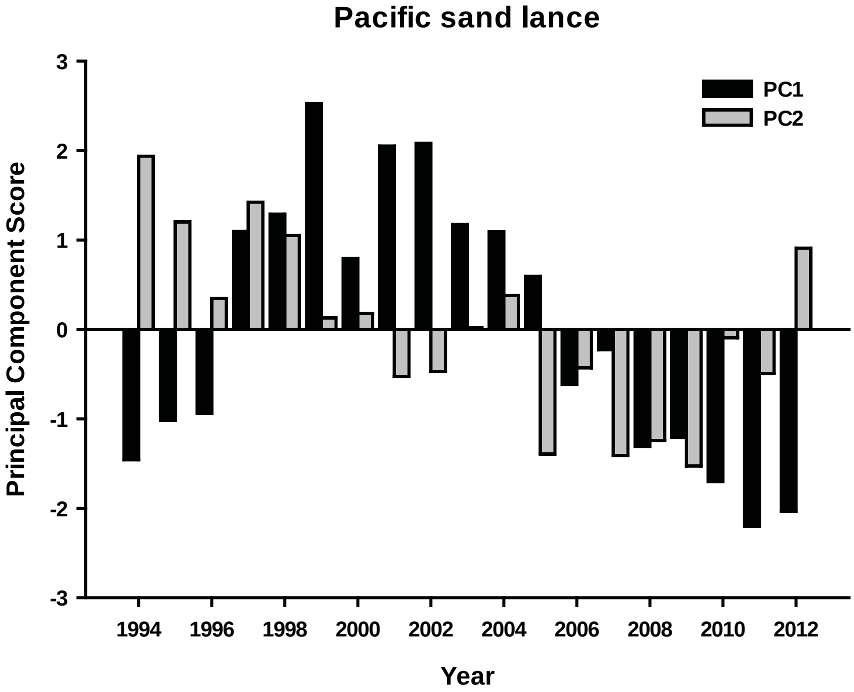

Figure 56: Time series (1994-2012) of first and second principal component scores for Pacific sand lance (black and gray, respectively).

Factors influencing observed trends: North Pacific marine ecosystems are characterized by temporal environmental variability at multiple time scales, which should have direct impacts on local food webs. Pacific sand lance is a key component of the local forage nekton communities, and an important prey item for seabirds, marine mammals, and commercially valuable fish. Differences in prey preference relative to availability may also influence trends in the species composition of fish captured and delivered to chicks. Our multivariate sand lance index shows that the relative availability of this species tracks the low-frequency environmental variability in the Gulf of Alaska Ecosystem, with higher values during the 1997-2005 warm period and low values thereafter. Both PC1$_{\text{sand lance}}$ (Middleton to Aiktak, central to western GOA) and PC2$_{\text{sand lance}}$ (St. Lazaria, eastern GOA) show this pattern, but the shifts in relative availability between these sites did not appear to be synchronous. Changes at St. Lazaria appeared to precede shifts at the other sites, a pattern which is not currently understood.

Implications: Understanding the spatial and temporal dynamics of forage fish is important for forecasting the status of upper trophic level consumers and overall health of marine ecosystems

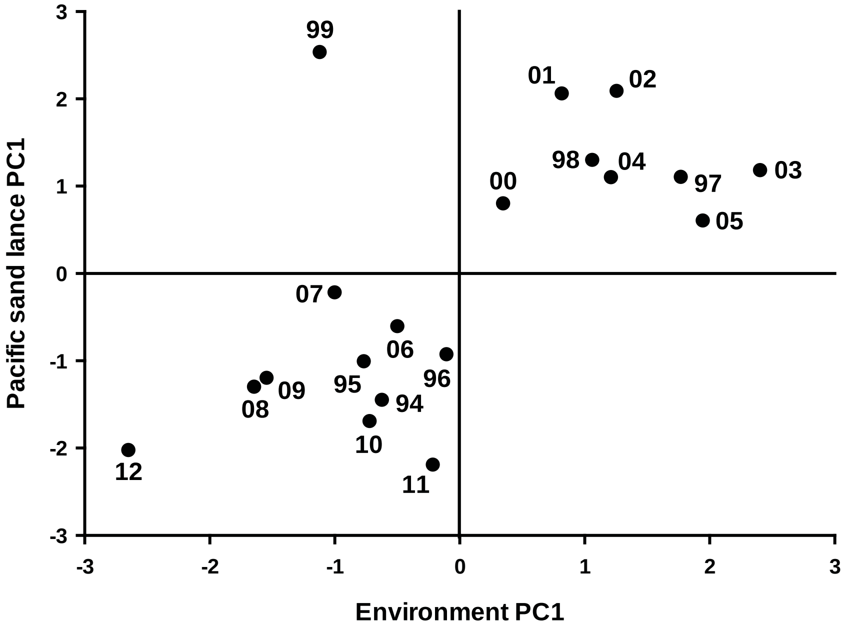

Figure 57: Relationship between PC1env and PC1sand lance. Years are indicated by a 2-digit value.

(Smith et al. 2011). In the Alaskan North Pacific, forage nekton of the families Ammodytidae (sand lance), Myctophidae (lanternfish), Osmeridae (capelin), Clupeidae (herring), Gadidae (age-0 and age-1 pollock and cods), Hexagrammidae (age-0 greenlings), Sebastidae (age-0 rockfish), and Salmonidae (age-0 salmon), as well as Euphausiacea (krill), and Teuthida (squids) are key prey for many upper trophic level fish, bird and mammal predators. Because these small forage taxa are only caught incidentally, if at all, in large-meshed research or commercial trawl nets, their distribution and abundance is poorly described except from small-scale studies employing small-mesh sampling gear (e.g., mid-water herring trawls or beach seines; this document, p. 135 and Anderson and Piatt 1999) and hydroacoustic surveys (e.g., Sigler et al. 2004, Abookire and Piatt 2005). As a result, forage community dynamics at regional ecosystem scales are mostly inferred from incidental catch in large-mesh trawl fisheries surveys that were not designed to sample this community. However, long-term studies of marine predator food habits may help to reveal large-scale temporal variability in these difficult to study forage nekton populations. Nonetheless, combining puffin diet composition across species and sites in the Gulf of Alaska into multivariate indicators of sand lance availability appears to be a promising approach to assessing temporal dynamics in this key forage species.

Regional Distribution of Juvenile Salmon and Age-0 Marine Fish in the Gulf of Alaska

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Last updated: August 2012

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

Herring

Togiak Herring Population Trends

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Last updated: October 2013

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

Prince William Sound Pacific Herring

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Last updated: October 2008

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

Southeastern Alaska Herring

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Last updated: August 2014

Description of index: Pacific herring (*Clupea pallasi*) populations in southeastern Alaska are monitored by the Alaska Department of Fish and Game. Populations are tracked using spawn indices. Stock assessments that combine spawn indices with age and size information have been conducted each fall by the Alaska Department of Fish and Game for nine spawning areas in southeastern Alaska for most years since 1980. The magnitude and regularity of spawning in these areas has warranted annual stock assessment surveys and potential commercial harvests at these locations during most of the last 30 years. Although spawning occurs at other locales throughout southeastern Alaska, little or no stock assessment activity occurs at these locations other than occassional aerial surveys to document the miles of spawn along shoreline. Spawning at the nine primary sites for which regular assessments are conducted probably accounts for the majority of the spawning biomass in southeastern Alaska in any given year.

Status and trends: Herring spawning biomass estimates in southeastern Alaska often change markedly from year to year, rarely exhibiting consistent, monotonic trends (Figures 58, 59). Over the period 1980 through 2013, some stocks have undergone increasing trends (Sitka Sound, Craig, Seymour Canal, Hoonah Sound), while others have declined (Kah Shakes/Cat Island, Lynn Canal not shown in figures), and yet others have exhibited no obvious trend (West Behm Canal, Hobart Bay/Port Houghton, Tenakee Inlet, Ernest Sound).

Although the estimated total mature herring biomass in southeastern Alaska has been above the long-term (1980-2013) median of 90,495 tons since 2003 through 2013, an apparent decrease in biomass has been observed since the peak in 2011 (Figure 60). The most notable drop in biomass has been observed in Hoonah Sound where the mature biomass dropped from 16,411 tons to 375 tons in just two years. Although it is apparent that the herring population in southeastern Alaska has come down a period of high productivity during about 2005-2011, most spawning areas rebounded in 2013 following lower spawning biomass in 2012 (Figure 1a). The herring biomass in Sitka Sound continues to be by far the highest in the region. Since 1980, herring biomass near Sitka has contributed between 37% and 72% (median of 57%) of the total estimated annual mature biomass among the nine surveyed spawning locations. Excluding the Sitka biomass from the combined estimate, southeastern Alaska herring biomass has been above the 34-year median of 41,073 tons in every year since 2003 (Figure 60).

In southeastern Alaska, the first potential age of recruitment to the mature population of herring is three years old. Estimated abundance of total age-3 herring (used to gauge recruitment) has varied greatly among and within stocks over time (Figures 58, 59). The number of age-3 herring has been estimated for Seymour Canal and Sitka for most years since 1980, for Craig in every year since 1988, for Tenakee Inlet every years since 1997, and for West Behm Canal, Ernest Sound, Hobart Bay-Port Houghton, and Hoonah Sound for most years since 1995. An oscillating recruitment pattern with strong recruit classes every three to five years was observed for Sitka Sound and Craig stocks prior to 1997. For Sitka Sound, the stock with the greatest annual recruit abundance, oscillating years of extremely high and low recruit abundance in the 1980s and early 1990s changed to more consistent, intermediate recruit abundances in the mid-1990s through 2013 (Figure 59).

Factors influencing observed trends: The generally increasing long-term trends of biomass observed for many herring stocks in southeastern Alaska, particularly over the last decade, are thought to be at least partially a result of higher survival rates among adult age classes. Age-structure analysis (ASA) modeling of several herring stocks in the region suggests that changes in survival during the late 1990s are partially responsible for the observed increasing and high herring abundance levels. For example, for the Sitka stock, during the period 1980-1998, survival has been estimated to be 57%, while for the period 1999-2013 survival is estimated at 78%. These shifts in survival coincide with time periods of change in ocean conditions, as indexed by the Pacific Decadal Oscillation (PDO) (predominately positive phase in the former and predominantly negative phase during the latter time periods).

There has been some speculation and debate about the extent to which commercial harvests may have contributed to marked declines in estimated abundance and/or localized changes in herring spawning sites in some areas of southeastern Alaska, notably Revillagigedo Channel (Kah Shakes/Cat Island) and Lynn Canal. In the Revillagigedo Channel area, significant spawning and a fishery occur at Annette Island, a site outside the management jurisdiction of the State and from which limited data are gathered by the department. Although spawning activity at the Kah Shakes and Cat Island sites in Revillagigedo Channel has declined in recent years, this decline may be at least partially attributable to a shift of herring spawning grounds within the Annette Island Reserve, bordering Revillagigedo Channel. Long-term surveys of spawning biomass have not been conducted In the Lynn Canal spawning area long-term surveys of spawning biomass have not been conducted. Reasons for the biomass decline in the area are unknown but possibilities include

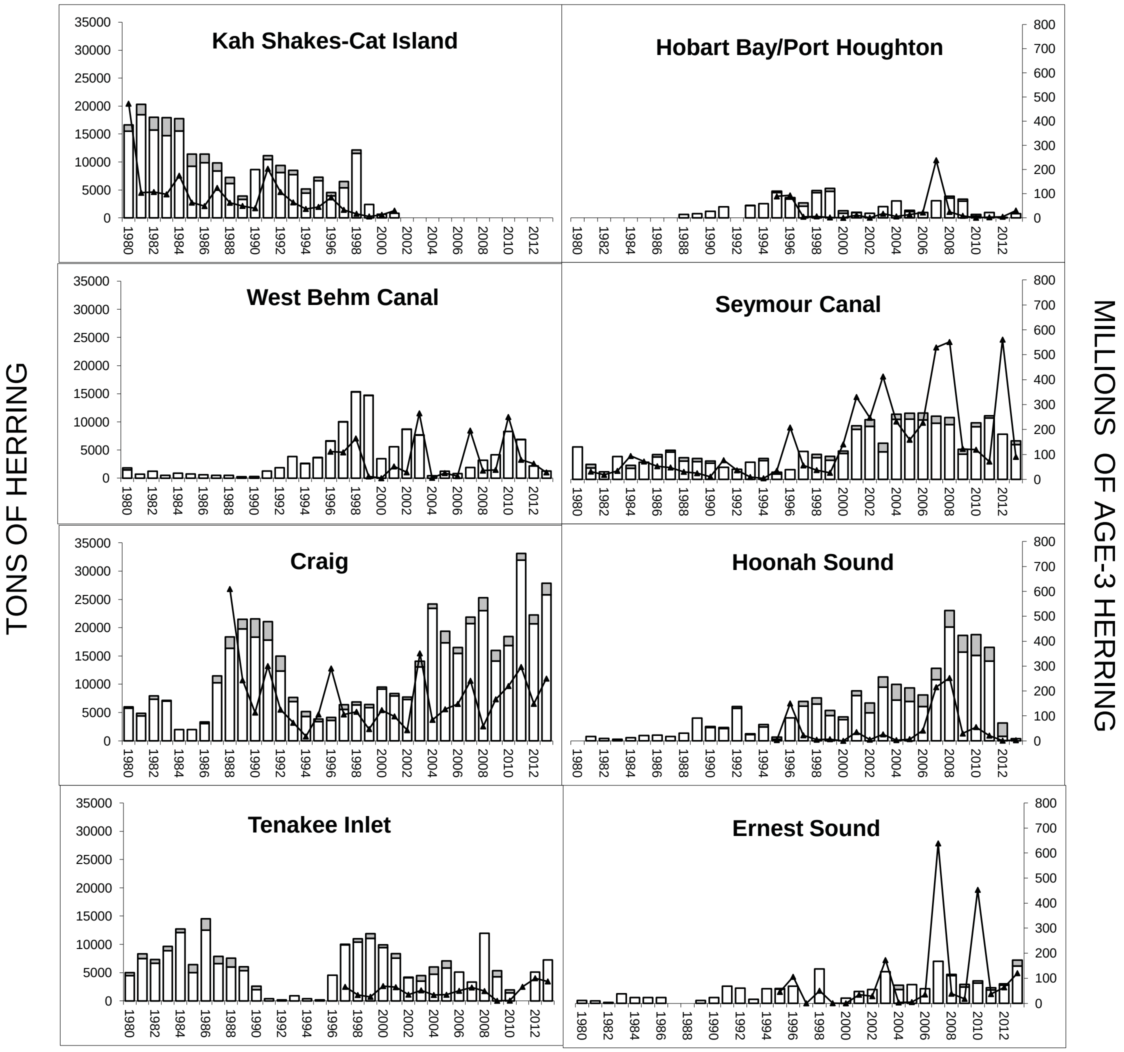

Figure 58: Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 abundance (black line) at eight major spawning locations in southeastern Alaska, 1980-2013. Estimates of age-3 abundance for Tenakee Inlet were unavailable by time of publication.

commercial harvest, increased predation by marine mammals and fish, and shoreline development on or near spawning grounds.

Implications: The harvest rate policy in southeastern Alaska allows for harvest rates ranging from 10 to 20% of the forecasted spawning biomass when the forecast is above a minimum threshold biomass. The rate of harvest depends upon the ratio of forecast to threshold (the more the forecast exceeds the threshold, the higher the harvest rate). Consequently, catch limits have varied in direct proportion to forecasted biomass (Figures 1a,1b). The lower abundance of mature herring observed at some spawning areas will likely reduce commercial harvest opportunity in the region due to lower guideline harvest levels. However, the short life-span of herring and the natural volatility of stock levels, particularly of smaller-sized stocks, make it difficult to speculate on long-term fishery implications. The relationship between PDO phase and herring survival suggests that survival may decline if the PDO shifts to a positive phase, however this is an area that requires further research.

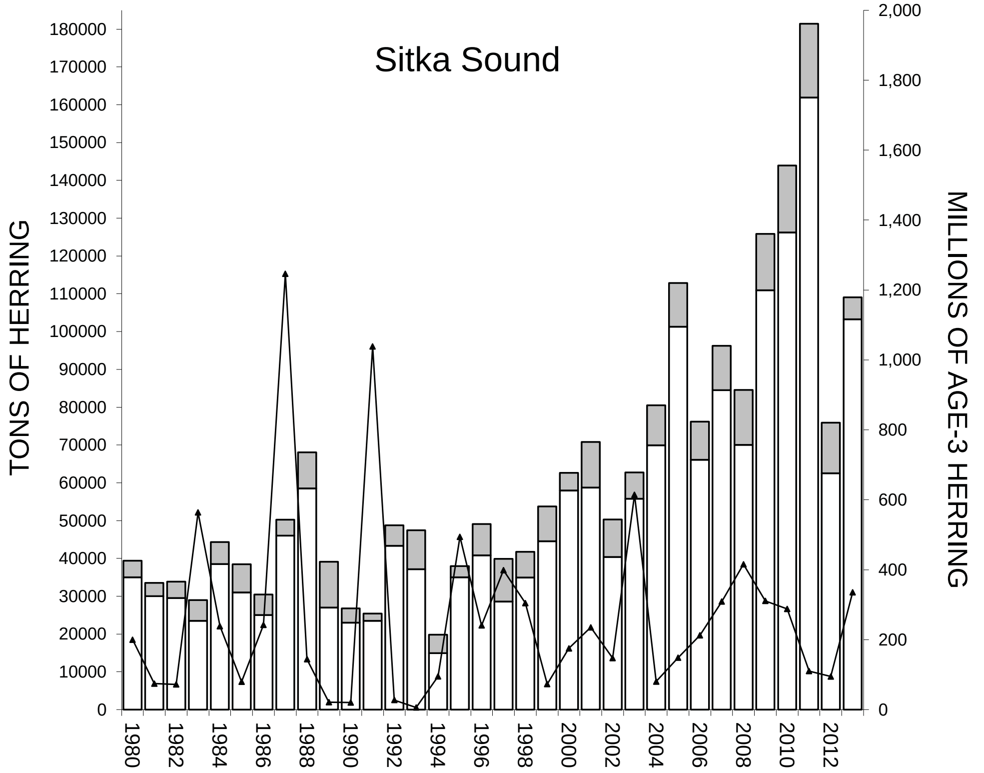

Figure 59: Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 abundance (black line) at Sitka Sound spawning location in southeastern Alaska, 1980-2013.

Salmon

Historical and Current Alaska Salmon Trends

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Last updated: September 2014

Description of index: This contribution provides historic and current catch information for salmon of 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. This contribution summarizes available information that is included in current Alaska Department of Fish and Game (ADF&G) agency reports (e.g., Munro and Tide (2014)).

Pacific salmon in Alaska are managed in four regions based on freshwater drainage basins (`http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmonareas`), Southeast/Yakutat, Central (encompassing Prince William Sound, Cook Inlet, and Bristol Bay), Arctic-Yukon-Kuskokwim, and Westward (Kodiak, Chignik, and Alaska peninsula). ADF&G prepares

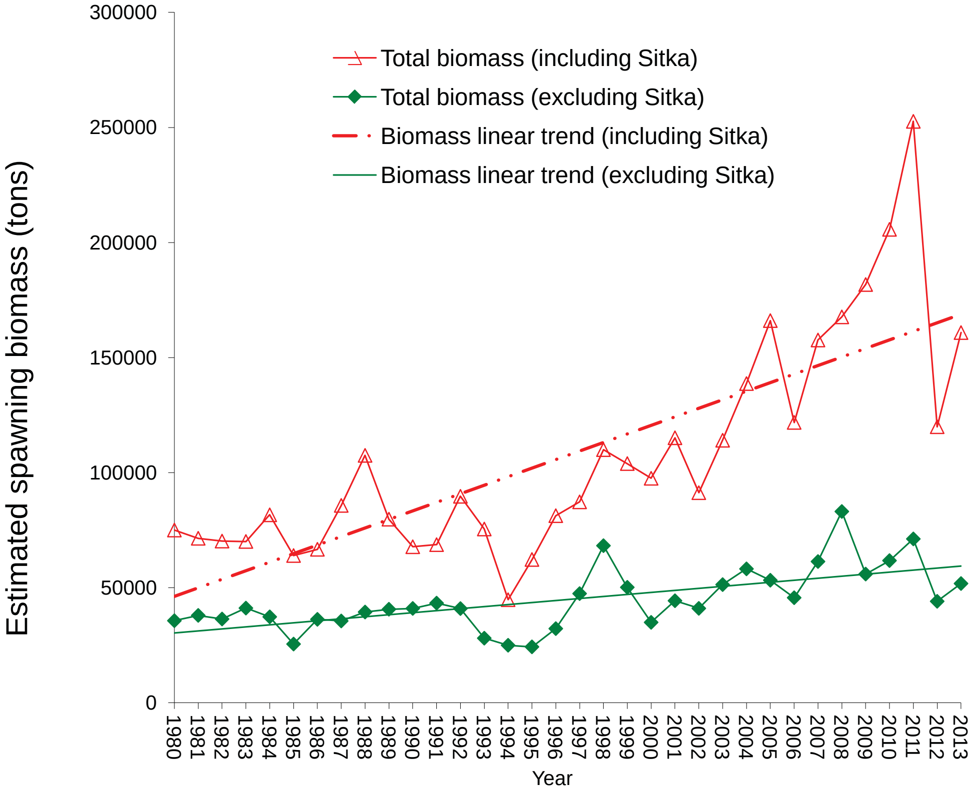

Figure 60: Estimated combined annual mature herring biomass (including and excluding Sitka) at major southeastern Alaska spawning areas, 1980-2013.

harvest projections for all areas rather than conducting run size forecasts for each salmon run. There are five Pacific salmon species with directed fisheries in Alaska; they are sockeye salmon (*Oncorhynchus nerka*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), Chinook salmon (*O. tshawytscha*), and coho salmon (*O. kisutch*).

Status and trends: Catches from directed fisheries on the five salmon species have fluctuated over the last 35-40 years (Figure 61) but in total have been generally strong. According to ADF&G, commercial salmon harvests from 2013 totaled 282.9 million fish, which was more than 100 million more than the preseason forecast of 178.8 million. The 2013 total salmon harvest is more than double the 2012 total harvest of 127.5 million. The elevated harvest in 2013 was bolstered by the catch of 226.3 million pink salmon. In 2014 ADF&G is forecasting a substantial decrease in the total commercial salmon catch to 132.6 million fish, due to an expected decrease in the number of pink salmon. Projections for 2015 are not yet available.

Bering Sea Chinook salmon abundance in the Arctic-Yukon-Kuskokwim region has been declining since 2007 and no commercial periods targeting Chinook salmon were allowed in the Yukon Area during the 2013 summer season. In the Kuskokwim Area, Chinook salmon abundance was poor and only 2 of 10 escapement goals were met. In Bristol Bay, Chinook salmon were primarily caught during directed sockeye periods. The total 2013 Chinook salmon harvest in Bristol Bay was about 19,000 and was approximately 71% below the average for the last 20 years.

The 2013 catch of coho salmon in Bristol Bay was 80% above the recent 20 year average (75,000).

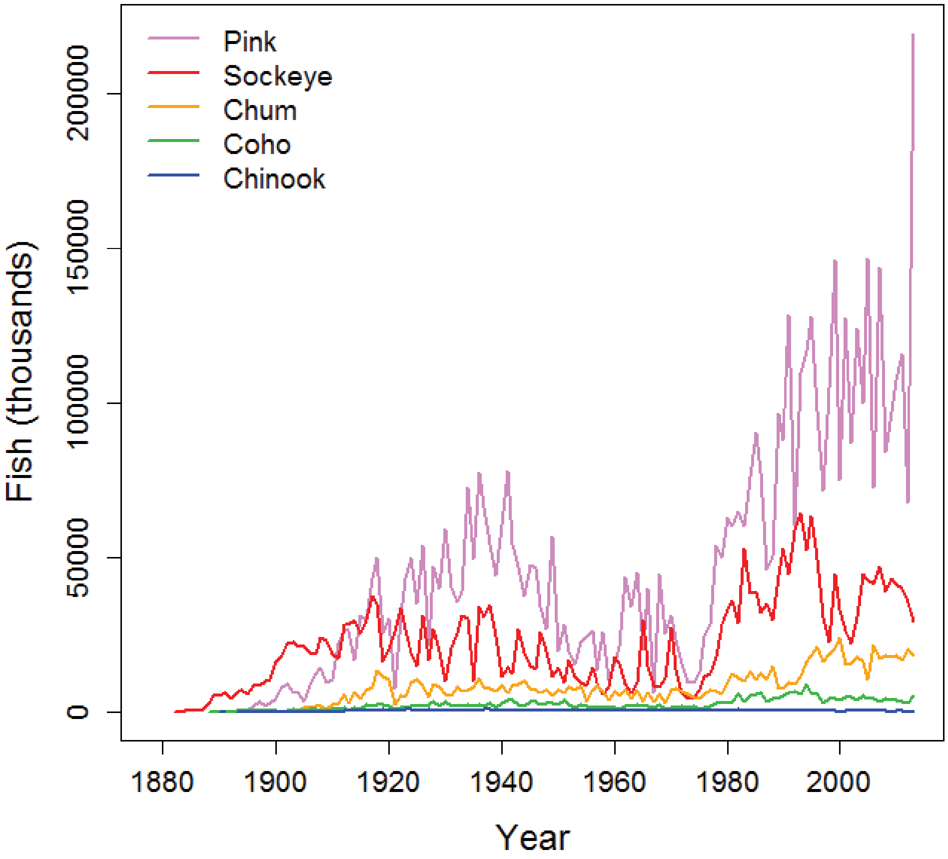

Figure 61: Alaskan historical commercial salmon catches. 2013 values are preliminary. (Source: ADF&G, `http://www.adfg.alaska.gov`. ADF&G not responsible for the reproduction of data.)

Coho salmon harvests were also above average in the Arctic-Yukon-Kuskokwim region. Chum salmon catches in Bristol Bay were 10% below the 20 year average, while harvests were above average in the Arctic-Yukon-Kuskokwim region.

The 2013 Bristol Bay sockeye salmon run of 23.0 million fish was 12% below the preseason forecast of 26.0 million, and was 36% below the recent 20-year average (1993-2012) of 36 million. Historically, total runs to Bristol Bay have been highly variable, but in recent years, 2004-2010, sockeye salmon runs have been well above the long term mean (Figure 61). Run size has decreased each year since 2010; the 2013 run was below the long-term historical average run size of 32.3 million fish. The forecast for 2014 Bristol Bay sockeye was for a run size similar to 2013 at 26.6 million. Preliminary information suggests that the 2014 forecast may have been low (Figure 62). Recruitment for most Bristol Bay sockeye salmon stocks was moderate to strong in the 1980s and into the mid-1990s. The number of returning adult sockeye salmon produced from each spawner increased dramatically for most Bristol Bay stocks, beginning with the 1973 brood year (>1979 return year) (Fair, 2003). Poor returns in 1996-98, however, suggested a return to a level of productivity similar to the pre-1978 period (Fair, 2003). 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.

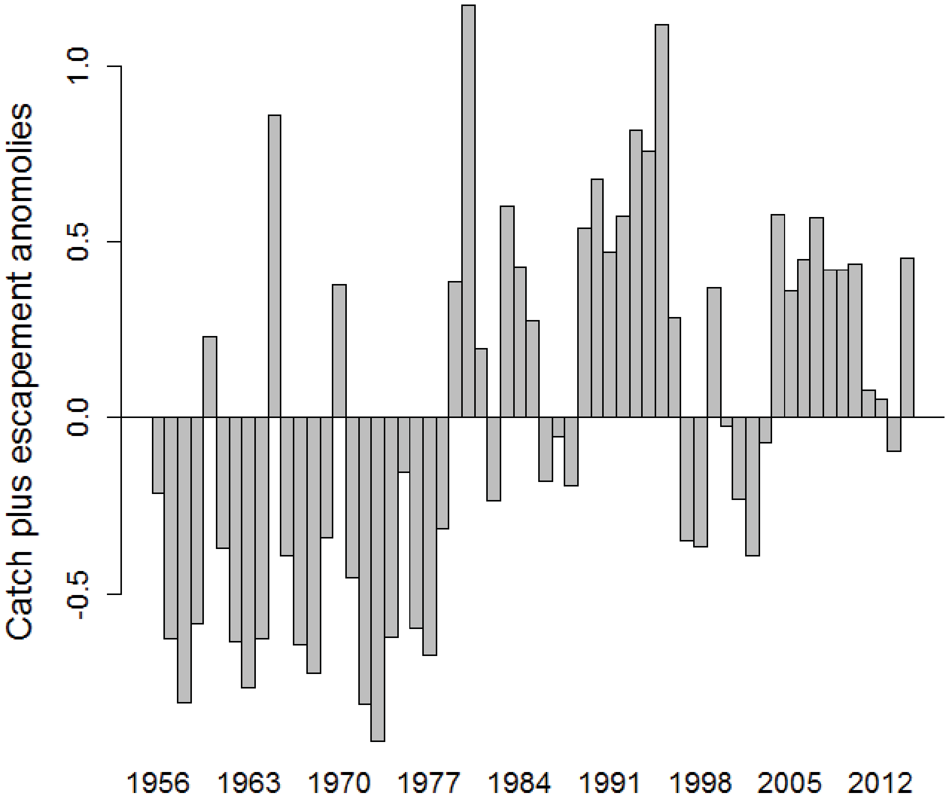

Figure 62: Historical catch plus escapement anomalies of Bristol Bay sockeye salmon, 1956-2014. Data provided by Charles Brazil (ADF&G). Note: the value for 2014 is preliminary and subject to revision.

Gulf of Alaska In the Southeast/Yakutat region, 2013 salmon harvests totaled 112.4 million, which far exceeded the 51.6 million average harvest over the most recent ten years and the long-term average (since 1962) of 39.2 million fish. The total number of salmon harvested in 2013 was the largest going back to 1962. Pink salmon comprised 84% of the total number of salmon harvested. Since 2006 pink salmon returns have followed a cycle of strong odd years and weak even years and that pattern continued in 2013. The 2013 pink salmon harvest in the Southeast region reached a record high of 94.8 million.

In the Southeast/Yakutat region, the harvest of 241,000 Chinook salmon was below the long-term average harvest of 299,000 fish, and much lower than the recent 10-year average harvest of 347,000. In contrast, the harvest of 3.9 million coho salmon was well above the long-term average harvest of 2.1 million and above the recent 10-year average of 2.5 million fish. The commercial harvest of 12.6 million chum salmon in the Southeast/Yakutat region was above the recent 10-year average harvest (10.3 million) and well above the long-term average harvest (5.6 million).

In the Prince William Sound Area of the Central region, the total salmon harvest was 99.5 million fish, of which 92.5 million were pink salmon. The catch of other salmon species in the Prince William Sound Area included 2.3 million sockeye, 4.1 million chum, 609,000 coho, and 10,900 Chinook. The purse seine harvest of 85.9 million pink salmon was the largest purse seine harvest of pink salmon on record in Prince William Sound. 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. Marine survival of Prince William Sound hatchery pink salmon does not appear to have shifted after the 1988/89 or the 1998/99 climate regime shifts (Figure 63). Marine survival of 11.17% in 2010 (2008 brood year) was an all-time high since 1977, but dropped to 4.34% in 2011 and 3.80% in 2012 (Sheridan et al. 2013).

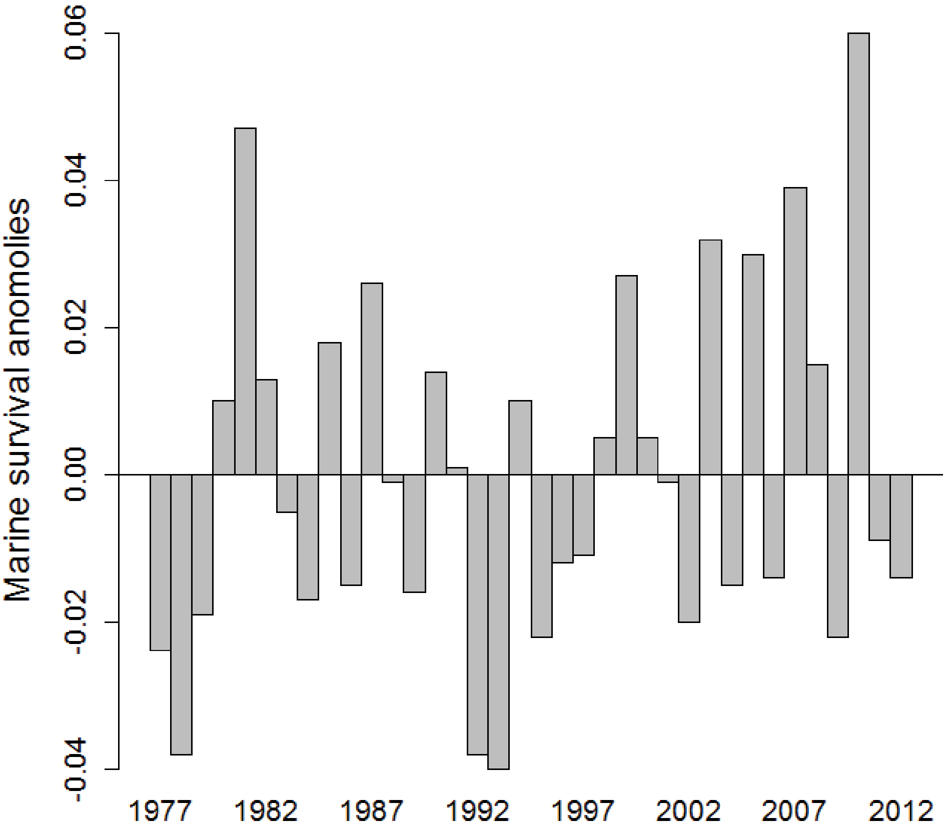

Figure 63: Marine survival of Prince William Sound hatchery pink salmon by year of return (brood year +2 years) from 1977 to 2012. Data reproduced from Sheridan et al.(2013).

Factors influencing observed trends: In the Bering Sea, chum salmon are generally caught incidental to other species and catches may not be good indicators of abundance. There were no directed openings for Chinook salmon in the Yukon Area due to low early season returns. In other areas of Bristol Bay, 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 may be affected differently depending upon varying conditions, such as climate (Mantua et al., 1997), so more diverse sets of populations provide greater overall stability (Schindler et al., 2010). The abundance of Bristol Bay sockeye salmon may also vary over centennial time scales, with brief periods of high abundance separated by extended periods of low abundance (Schindler et al., 2006).

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).

Pink salmon run strength is established during early marine residence and may be influenced by diet and food availability (Cooney and Willette, 1997). Survival rates of Alaska pink salmon are positively related to sea surface temperatures and may reflect increased availability of zooplankton prey during periods with warmer surface temperatures (Mueter and Norcross, 2002).

Implications: Salmon have important influences on Alaska marine ecosystems through interactions with marine food webs as predators on lower trophic levels and as prey for other species such as Steller sea lions. In years of great abundance, salmon may exploit prey resources more efficiently than their competitors. Springer and van Vliet (2014) recently demonstrated negative relationships between seabird reproductive activity and years of high pink salmon abundance. In addition, the dominant temporal pattern in kittiwakes reproductive success at the Pribilofs is negatively correlated with pink salmon abundance (this doc, p.186, and Zador et al. (2013)). Directed salmon fisheries are economically important for the state of Alaska. The trend in total salmon catch in recent decades has been for generally strong harvests, despite annual fluctuations.

Forecasting Pink Salmon Harvest in Southeast Alaska

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Last updated: August 2014

Description of index: Alaska stocks of pink salmon and Chinook salmon spend a large portion of their life history in marine waters within the U.S. Exclusive Economic Zone (EEZ) and beyond the 200-mile EEZ of the coastal States north of 33°N in international waters. However, year class strength of these salmon species is often set earlier, further inshore of the EEZ, during their seaward migration phase as juveniles or during the ensuing overwintering phase of immatures. Thus, the Alaska Fisheries Science Center (AFSC), Auke Bay Laboratories (ABL) initiated the Southeast Alaska Coastal Monitoring (SECM) project in 1997 to better understand the effects of climate and ocean conditions on year class strength of salmon and ecologically-related species.

The SECM project has collected a monthly time series of data of ecosystem metrics in coastal Southeast Alaska (SEAK) and in the Gulf of Alaska (GOA) annually using surface trawls and oceanographic instruments for nearly 18 years. The time series from this SECM research has allowed annual indexes to be constructed and applied to pre-season forecast models for SEAK pink salmon harvest since

The index is derived from ecosystem metrics obtained from stations sampled in the vicinity of Icy Strait (58°N, 135°W) by SECM researchers in coastal SEAK (Orsi et al., 2014*a*). This locality is the principal northern exit route for seaward migrating juvenile salmon through SEAK to the GOA. Based on salmon origin information from coded-wire tags and thermally induced ototlith marks, fish exiting this migration corridor are comprised of stocks originating predominately from SEAK. Temporally, oceanographic sampling occurs in May, June, July, and August, while surface trawling (0-20 m depth) for epipelagic fish species is conducted in the latter three months as fish move offshore. Pink salmon are the most abundant of the salmon species and rapidly migrate seaward as fry.

Pink salmon adult returns are notoriously difficult to forecast because their brief two-year life history includes only one ocean winter (age 1-ocean) thus precluding the use of younger returning sibling ages reflecting cohort abundance that are traditionally used for sibling or stock assessment models. Over the years, SECM ecosystem metrics associated with migrating pink salmon have helped assess year class strength of juveniles (age 0-ocean) after most of the early marine mortality has occurred. Thus, beginning in 2004, an SECM pink salmon pre-season forecast model was developed to: 1) help fishery managers maintain sustainable fisheries, 2) meet the pre-season planning needs of the resource stakeholders in the commercial fishing industry, and 3) gain a better understand of mechanisms related to salmon production in the GOA large marine ecosystem. These forecast models have been described in Wertheimer et al. (2013) and have been tested annually for ten years.

Status and trends: Since 1960 pink salmon year-class success has varied widely, with annual harvests ranging from 3 to 95 M fish in SEAK (ADFG 2013). Pink salmon are an ecologically and economically important resource in SEAK, and reached a record harvest (95 M) and value ($125 M) in 2013. These returns also show decadal abundance trends and alternating odd-even year brood line dominance patterns. This variability may result from dynamic ocean conditions or ecological interactions that affect juvenile salmon or overwintering adults above the transition domain in the North Pacific. Additionally, pink salmon production in SEAK is predominately derived from >97% wild stocks of varied run timings that originate from >2,000 anadromous streams throughout the region. Pink salmon in SEAK are a key stock group proposed for monitoring in the North Pacific (Orsi et al., 2014*b*). For pink salmon forecasting, SECM data is used with other regional and basin-scale data sources to construct an ecosystem matrix of input variables related to the response variable of SEAK harvest.

Forecasting information from SECM research has been provided to stakeholders of the pink salmon resource of SEAK since 2004 (Wertheimer et al., 2006). These forecasts have allowed stakeholders to anticipate the harvest with more certainty than previous forecasting methods. For example, in eight of the past ten years, SECM forecast estimates have only deviated from the actual harvests by an average of 7% (`http://www.afsc.noaa.gov/abl/msi/msi_sae_psf.htm`) (Figure 64). Data from juvenile pink salmon catches (CPUE) are also shared with the Alaska Department of Fish and Game (ADFG) to help refine their SEAK pink salmon harvest forecast that is developed by a different method.

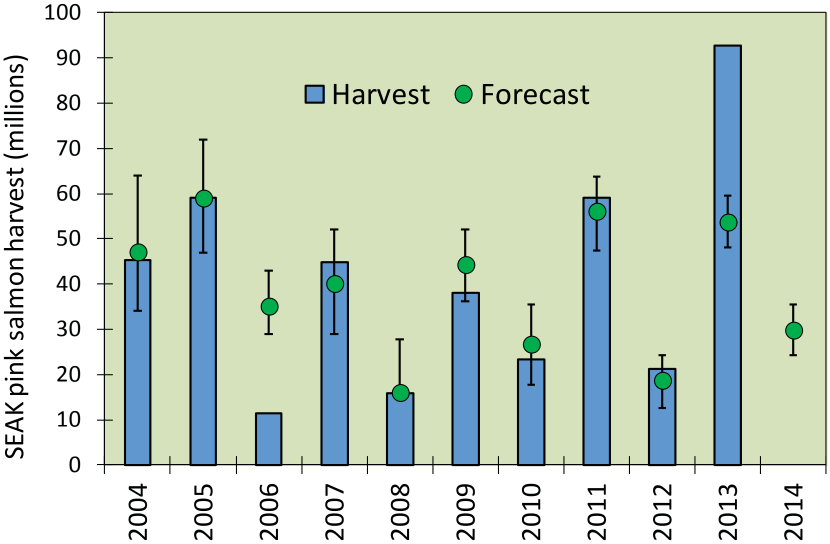


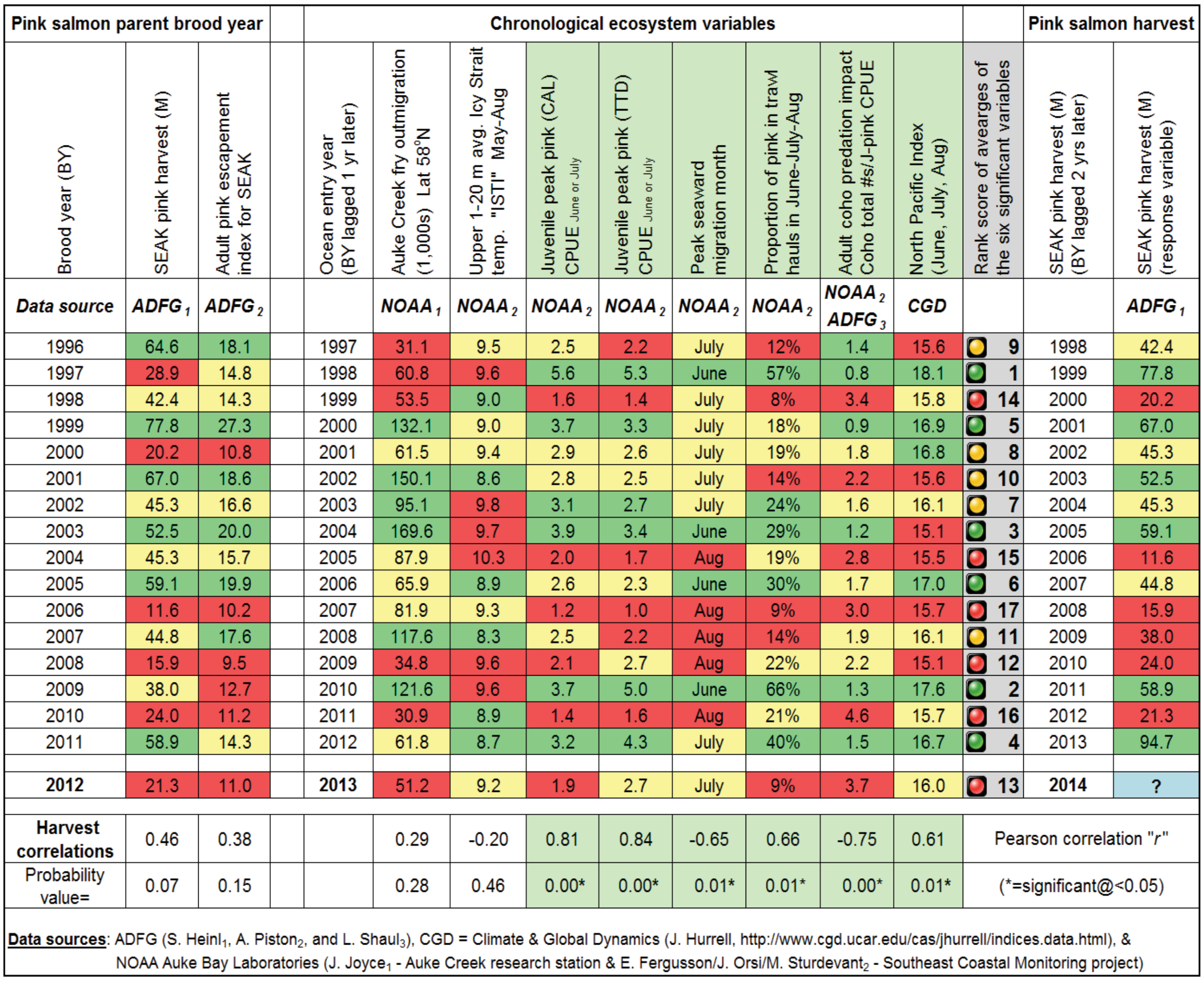
Figure 64: Previous SECM pink salmon pre-season forecast model predictions (with 80% confidence intervals) and actual SEAK harvests over the past decade. Harvest data from the SEAK pink salmon fishery still incomplete for 2014, and 2014 SECM surveys still ongoing for the 2015 forecast.

Factors influencing observed trends: Given the ecosystem conditions and SECM metrics sampled in 2013, the two best SECM forecast models for the 2014 SEAK pink salmon harvest are shown below in Table 3. Each forecast model value has an 80% bootstrap confidence interval shown in parentheses. The 2-parameter model is the best fit predictor for the relationship of the 17-year time series of SECM data parameters with subsequent SEAK pink salmon harvests from 1998 to 2013, based on the R^2 and AICc.

A chronological set of ecosystem metrics associated with SEAK adult pink harvest over the 17-year SECM time series are shown in Table 2 below. Note that in addition to CPUE, four other variables are significantly correlated with harvest (Peak migration month, %pink in June-July trawl hauls, the North Pacific Index, and Adult coho predation impact) and **these ecosystem indicators in concert suggest a low pink salmon harvest in 2014**. Additionally, this matrix shows that anomalously low (red: 2000, 2006, 2008, 2012) or high (green: 1999, 2001, 2005, 2011, 2013) return years always flag 3-5 ecosystem indicators of the respective color signal in each row. For the 2014 forecast, however, there were only "red" and "yellow" ecosystem indicator flags. The Icy Strait temperature index (ISTI) shown in the last column is not significantly correlated with harvest, but is an important secondary parameter to explain the error in the CPUE and harvest regression model.

Of all the large basin scale ecosystem metrics considered to influence SEAK pink salmon production, only the North Pacific Index (NPI, summer) has been significantly correlated with harvest over the time series.

Implications: Pink salmon returns to SEAK were the largest in history in 2013 and were a significant fish harvest component in the GOA ecosystem. In 2013, it was estimated that pink salmon represented 46% of the 643,779 metric tons of fish commercially harvested off Alaska in the GOA and adjacent coastal waters. Of these total fish landings in 2013, the commercial harvest component of SEAK pink salmon represented about 21%. Based on ecosystem metrics, the pink



Pink salmon parent brood year				Chronological ecosystem variables										Pink salmon harvest	
Brood year (BY)	SEAK pink harvest (M)	Adult pink escapement index for SEAK		Ocean entry year (BY lagged 1 yr later)	Auke Creek fry outmigration (1,000s) Lat 58°N	Upper 1-20 m avg. Icy Strait temp. "ISTI" May-Aug	Juvenile peak pink (CAL) CPUE June or July	Juvenile peak pink (TTD) CPUE June or July	Peak seaward migration month	Proportion of pink in trawl hauls in June-July-Aug	Adult coho predation impact Coho total #s/J-pink CPUE	North Pacific Index (June, July, Aug)	Rank score of averages of the six significant variables	SEAK pink harvest (M) (BY lagged 2 yrs later)	SEAK pink harvest (M) (response variable)
Data source	**ADFG$_1$**	**ADFG$_2$**			**NOAA$_1$**	**NOAA$_2$**	**NOAA$_2$**	**NOAA$_2$**	**NOAA$_2$**	**NOAA$_2$**	**NOAA$_2$** **ADFG$_3$**	**CGD**			**ADFG$_1$**
1996	64.6	18.1		1997	31.1	9.5	2.5	2.2	July	12%	1.4	15.6	🟡 **9**	1998	42.4
1997	28.9	14.8		1998	60.8	9.6	5.6	5.3	June	57%	0.8	18.1	🟢 **1**	1999	77.8
1998	42.4	14.3		1999	53.5	9.0	1.6	1.4	July	8%	3.4	15.8	🔴 **14**	2000	20.2
1999	77.8	27.3		2000	132.1	9.0	3.7	3.3	July	18%	0.9	16.9	🟢 **5**	2001	67.0
2000	20.2	10.8		2001	61.5	9.4	2.9	2.6	July	19%	1.8	16.8	🟡 **8**	2002	45.3
2001	67.0	18.6		2002	150.1	8.6	2.8	2.5	July	14%	2.2	15.6	🟡 **10**	2003	52.5
2002	45.3	16.6		2003	95.1	9.8	3.1	2.7	July	24%	1.6	16.1	🟡 **7**	2004	45.3
2003	52.5	20.0		2004	169.6	9.7	3.9	3.4	June	29%	1.2	15.1	🟢 **3**	2005	59.1
2004	45.3	15.7		2005	87.9	10.3	2.0	1.7	Aug	19%	2.8	15.5	🔴 **15**	2006	11.6
2005	59.1	19.9		2006	65.9	8.9	2.6	2.3	June	30%	1.7	17.0	🟢 **6**	2007	44.8
2006	11.6	10.2		2007	81.9	9.3	1.2	1.0	Aug	9%	3.0	15.7	🔴 **17**	2008	15.9
2007	44.8	17.6		2008	117.6	8.3	2.5	2.2	Aug	14%	1.9	16.1	🟡 **11**	2009	38.0
2008	15.9	9.5		2009	34.8	9.6	2.1	2.7	Aug	22%	2.2	15.1	🔴 **12**	2010	24.0
2009	38.0	12.7		2010	121.6	9.6	3.7	5.0	June	66%	1.3	17.6	🟢 **2**	2011	58.9
2010	24.0	11.2		2011	30.9	8.9	1.4	1.6	Aug	21%	4.6	15.7	🔴 **16**	2012	21.3
2011	58.9	14.3		2012	61.8	8.7	3.2	4.3	July	40%	1.5	16.7	🟢 **4**	2013	94.7
2012	21.3	11.0		**2013**	51.2	9.2	1.9	2.7	July	9%	3.7	16.0	🔴 **13**	**2014**	?
Harvest correlations	0.46	0.38			0.29	-0.20	0.81	0.84	-0.65	0.66	-0.75	0.61	Pearson correlation "*r*"		
Probability value=	0.07	0.15			0.28	0.46	0.00*	0.00*	0.01*	0.01*	0.00*	0.01*	(*=significant@<0.05)		

Data sources: ADFG (S. Heinl$_1$, A. Piston$_2$, and L. Shaul$_3$), CGD = Climate & Global Dynamics (J. Hurrell, http://www.cgd.ucar.edu/cas/jhurrell/indices.data.html), & NOAA Auke Bay Laboratories (J. Joyce$_1$ - Auke Creek research station & E. Fergusson/J. Orsi/M. Sturdevant$_2$ - Southeast Coastal Monitoring project)

Figure 65: Matrix of ecosystem metrics considered for pink salmon forecasting. The ranges of values below each metric are color-coded, with the highest values in green, intermediate values in yellow, and the lowest values in red. Metrics to the right of the response variable column for SEAK pink harvest are ordered by declining correlation and significance (increasing P-value = declining significance); the corresponding correlation coefficient r and P-value are shown below each metric. Data sources include: the Alaska Department of Fish and Game (A. Piston), NOAA (SECM/Auke Creek-J. Joyce), and Climate and Global Dynamics (J. Hurrell, `http://www.cgd.ucar.edu/cas/jhurrell/indices.data.html`).

salmon harvest to SEAK in 2014 is forecasted to be around 30 M fish, somewhat below the historical average, thus continuing a depressed even year cycle that began nearly a decade ago in 2006, off the poor ocean conditions in 2005 (Figure 65).

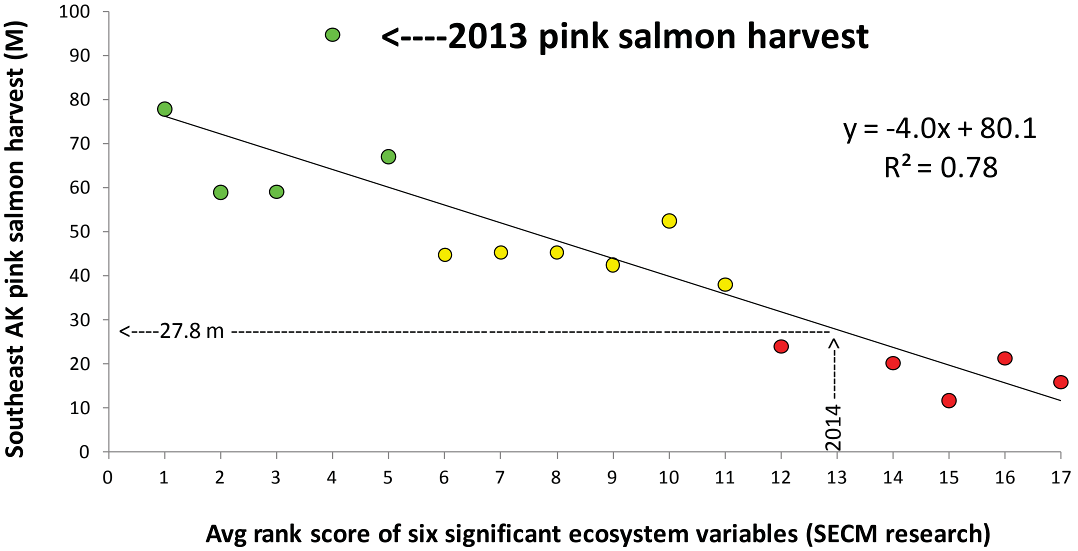


Figure 66: An alternate approach to forecasting pink salmon returns using a hind cast regression of the average ranks of the six significant ecosystem metrics (shaded green in Figure 65) and SEAK pink salmon harvest the ensuing year. The average rank in 2013 is 13th and projects a harvest in 2014 of about 28 M fish. This approach gives a similar harvest number to the 30 M predicted by the step-wise regression method.

Table 7: The two best SECM pink salmon forecast models for the 2013 SEAK harvest.

2013 SECM pink salmon forecast models	Adj. R^2	AICc	P	Prediction for 2014
(1-parameter) Peak CPUE	67%	135.8	<0.001	30.0 M (26-37)
(2-parameter) Peak CPUE+ISTi$_{\mathbf{20m\ temp}}$	77%	131.2	<0.001	**29.9 M (26-38)**

Using Ecosystem Indicators to develop a Chinook Salmon Abundance Index for Southeast Alaska

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Last updated: August 2014

Description of index: Alaska stocks of pink salmon (Oncorhynchus gorbuscha) and Chinook salmon (O. tshawytscha) spend a large portion of their life history in marine waters within the U.S. Exclusive Economic Zone (EEZ) and beyond the 200-mile EEZ of the coastal States north of 33°N in international waters. However, year class strength of these salmon species is often set earlier, further inshore of the EEZ, during their seaward migration phase as juveniles or during the ensuing overwintering phase of immatures. Thus, the Alaska Fisheries Science Center (AFSC), Auke Bay Laboratories (ABL) initiated the Southeast Alaska Coastal Monitoring (SECM) project in 1997 to better understand the effects of climate and ocean conditions on year class strength of salmon and ecologically-related species.

The SECM project has collected a monthly time series of data of ecosystem metrics in coastal Southeast Alaska (SEAK) and in the Gulf of Alaska (GOA) annually using surface trawls and oceanographic instruments for nearly 18 years. The SECM data have been used to develop a SEAK Chinook salmon abundance index beginning in 2013. The index is derived from ecosystem metrics obtained from stations sampled in the vicinity of Icy Strait (58°N, 135°W) in coastal SEAK (Orsi et al., 2014*a*). This locality is the principal northern exit route for seaward migrating juvenile salmon through SEAK to the GOA. Based on salmon origin information from coded-wire tags and thermally induced ototlith marks, fish exiting this migration corridor are comprised of stocks originating predominately from SEAK. Temporally, oceanographic sampling occurs in May, June, July, and August, while surface trawling (0-20 m depth) for epipelagic fish species is conducted in the latter three months as fish move offshore. Chinook salmon are the least abundant of the salmon species; Chinook salmon smolts have a more localized early marine residency pattern and often linger in Icy Strait as older immature fish.

Chinook salmon are harvested in commercial and sport fisheries in SEAK under annual quotas established by the Chinook Technical Committee of the U.S./Canada Pacific Salmon Treaty (**?**). Understanding the impact of climate versus bycatch on Chinook salmon abundance trends is important, as high catches of immature Chinook have the potential to trigger management actions in Alaska's groundfish fisheries. Chinook salmon stocks are harvested off SEAK as predominately immature fish and are comprised of mixed stocks from SEAK and further southward. The quotas are allocated based on the estimated abundance of index populations from SEAK to Oregon. Most Chinook salmon harvested in SEAK are caught in commercial troll and recreational fisheries in which the minimum size limit is 28 in. total length (71 cm). This allows information to be collected on fish typically aged two or more ocean winters old (ocean age-2 to ocean age-5 fish), but not on younger ocean age-1 and ocean age-0 fish. These younger fish are however sampled annually in SECM surveys, and are mostly comprised of immature ocean age-1 fish in early summer and some juvenile (ocean age-0) fish in fall. Abundance information on ocean age-1 fish in June has been significantly correlated to brood year survival of selected stocks of wild and hatchery Chinook salmon in SEAK (Orsi et al., 2013). A reporting of a SECM Chinook salmon index of ocean age-1 fish would provide managers and stakeholders in SEAK with a leading ecological indicator of year class strength a year or two prior to fishery recruitment.

Status and trends: Chinook salmon returns throughout Alaska have been in decline for about the past decade (**?**). Annual Chinook salmon harvests off SEAK are set by quotas under the Pacific Salmon Treaty through the Joint Chinook Technical Committee and are based on traditional harvest allocations and the catch composition and productivity of coast-wide stock groups. In SEAK, Chinook salmon are normally harvested in commercial, sport, and charter fisheries, and to a lesser extent in net fisheries such as gillnet and purse seine. The Chinook salmon harvest in 2013 was 0.15 M fish.

Chinook stock analysis of coded-wire tags recovered from fish sampled during SECM surveys in SEAK indicate they represent both wild and hatchery stocks from the northern region of SEAK. Nearly all these fish are immature and are represented by primarily ocean age-1 fish, mostly in June. Since there is a significant correlation between ocean age-1 abundance of Chinook salmon caught in SECM surveys in June and Chinook salmon brood year survival of selected wild and hatchery stocks (Orsi et al., 2013), a SECM Chinook index of ocean age-1 abundance in June would identify a future production trend for SEAK stocks (Figure 67).

The SECM Chinook salmon index is the abundance estimate of ocean age-1 fish sampled in Icy Strait, lagged two years later to their ocean year of recruitment as ocean age 3 fish, the age when most reach legal size. The 1997-2014 time series is based on a total of 293 surface trawl hauls, of about 20 minutes of duration each, and a total of 322 one-ocean Chinook sampled. Based on this SECM Chinook index, June 1-ocean abundance has been below average in 8 of the past ten years. Most recently, Chinook salmon fishery recruitment appears weak in 2014 and 2016, but strong in both 2013, and particularly in 2015.

Factors influencing observed trends:

Implications: As in most of Alaska, Chinook salmon returns to SEAK have been in decline for almost a decade. This trend is also apparent in the SECM Chinook salmon abundance index (Figure 68). Based on this index of age 1-ocean fish, there appears to be two strong Chinook salmon year classes emerging: one as age 3-ocean fish in 2103 and a stronger one appearing two years later in 2015. Contrary to many of the assumptions of negative impacts of pink salmon on other species, in the case of these two strong year classes of Chinook, they coincide with the same ocean entry years of the high juvenile pink salmon abundances in 2010 and 2012. This suggests that both juvenile Chinook and pink salmon mutually benefitted from favorable ocean conditions in 2010 and 2012, or the smaller, more abundant juvenile pink salmon proved to be a predator buffer to the larger Chinook salmon juveniles. The upcoming 2015 Chinook salmon harvest and abundance of legal sized (age 3-ocean) will be a good test of this index.

Groundfish

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

Contributed by Tom Wilderbuer, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA

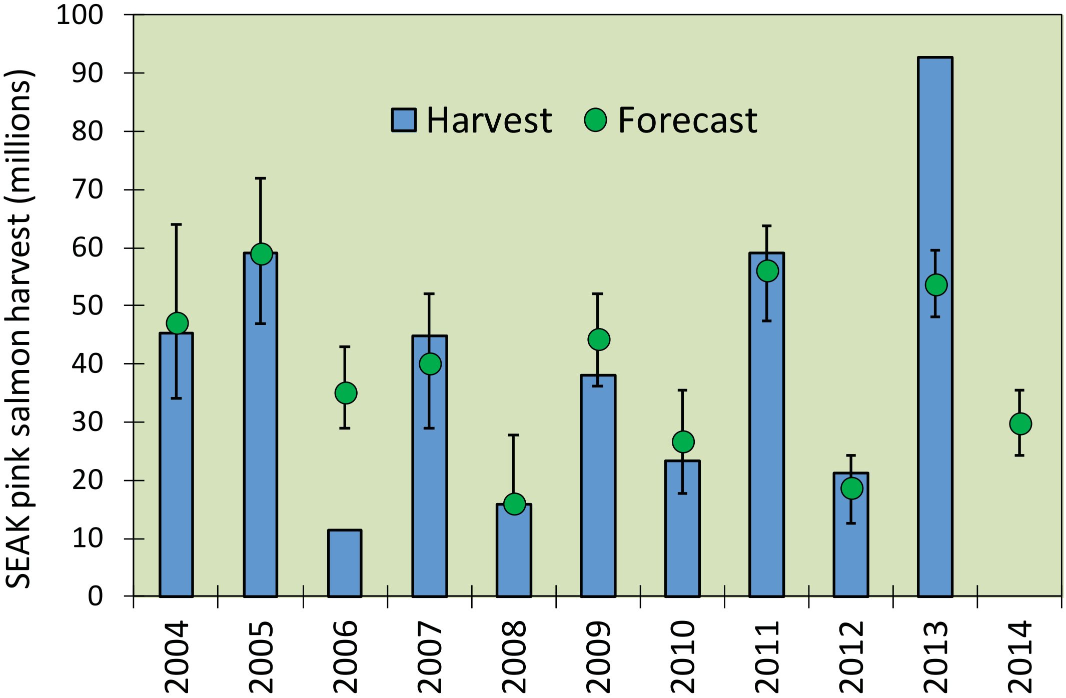

Figure 67: Monthly correlations of juvenile and immature ocean age-1 Chinook salmon catch per unit effort in SECM surveys in Icy Strait lagged to ocean entry year and subsequent brood year survivals of wild and hatchery Chinook salmon stocks in Southeast Alaska over the 1995-2005 brood years (1997-2007 ocean years). Note the significant positive correlations of CPUE of ocean age-1 fish in June and salmon survival of most stock groups.

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Last updated: August 2014

Description of index: Wilderbuer et al. (2002, 2013) 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 2014 and shown for 2006 through 2014 in (Figure 69).

Status and trends: The 2014 springtime drift patterns do not appear to be consistent with years of good recruitment for winter-spawning flatfish. Three out of nine OSCURS runs for 2006-2014 were consistent with those which produced above-average recruitment in the original analysis (2006, 2008, 2010). 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. For arrowtooth flounder and flathead sole, the correspondence between the springtime drift pattern from OSCURS and estimates of year class strength have weakened since

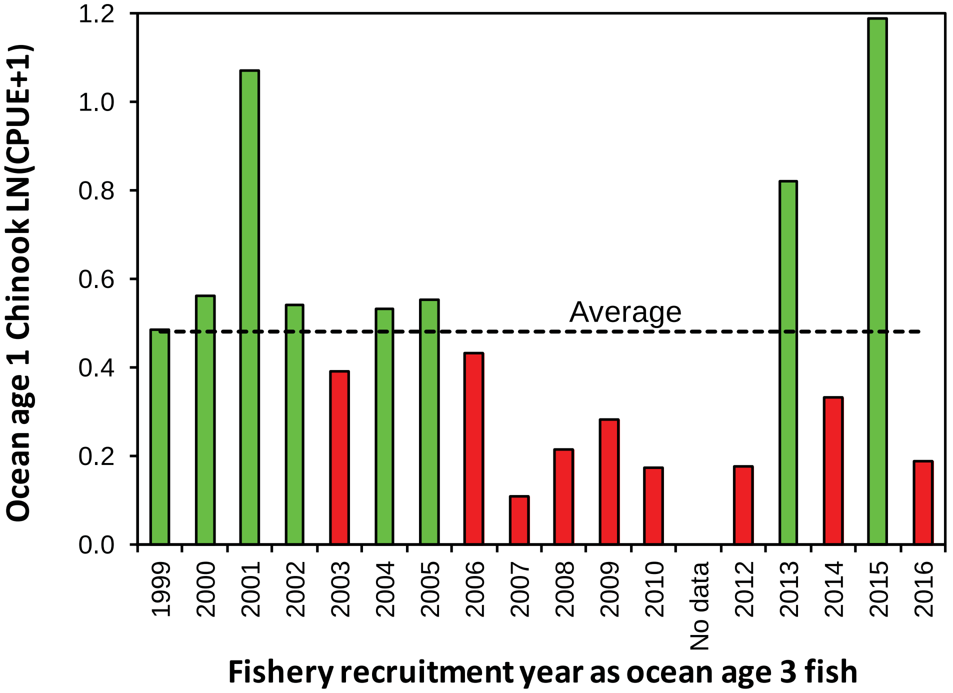

Figure 68: The SECM Chinook salmon index estimate of ocean age 1 fish sampled in Icy Strait in June, lagged two years later to potential recruitment of ocean age 3 fish, 1999-2016. No trawling was conducted in June of 2009, so the index was not available for 2011

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, larval occurrence and settlement preferences 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 2012-2014 springtime drift patterns do not appear to be consistent with years of good recruitment for northern rock sole, arrowtooth flounder and flathead sole. 2011 featured a mixture of wind direction as there were strong northerly winds for part of the spring but also southerly winds that would suggest increased larval dispersal to Unimak Island and the Alaska Peninsula. In 2012 and 2014 the pattern was more across-shelf in a northerly direction, opposite of 2011.

Pre- and Post-Winter Temperature Change Index and the Recruitment of Bering Sea Pollock

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Last updated: August 2014

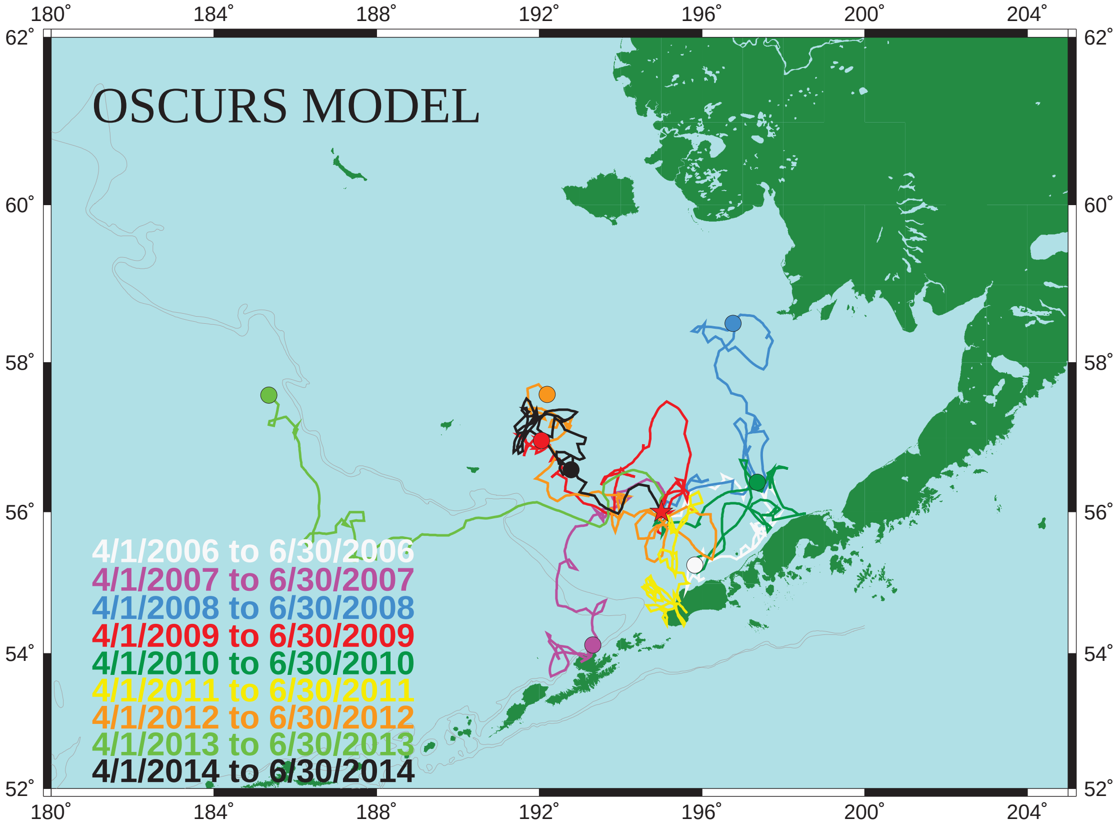

Figure 69: OSCURS (Ocean Surface Current Simulation Model) trajectories from starting point 56°N, 164°W from April 1-June 30 for 2006-2014.

Description of index: The temperature change (TC) index is a composite index for the pre- and post-winter thermal conditions experienced by pollock (*Gadus chalcogramma*) from age-0 to age-1 in the eastern Bering Sea (Martinson et al., 2012). The TC index (year t) is calculated as the difference in the average monthly sea surface temperature in June (t) and August (t-1) (Figure 70) in an area of the southern region of the eastern Bering Sea (56.2°N to 58.1°N latitude by 166.9°W to 161.2°W longitude). Time series of average monthly sea surface temperatures 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`). Less negative values represent a cool late summer during the age-0 phase followed by a warm spring during the age-1 phase for pollock.

Status and trends: The 2014 TC index value is -3.84, similar to the 2013 TC index value of -3.89. Both the late summer and the following spring sea temperature were warmer than average. The TC index is positively correlated with subsequent recruitment of pollock to age-1 through age-6 for based on abundance estimates from Table 1.21 in Ianelli et al. 2013 (Table 8). Over the longer period (1964-2013), the TC index was more statistically significant for the age-1, age-2, and age-3 pollock, than for the older pollock (Table 8). For years 1995-2013, this relationship was more statistically significant (p-values were lower) for the age-3, -4, -5 and -6 pollock, than for the age-1 and -2 pollock.

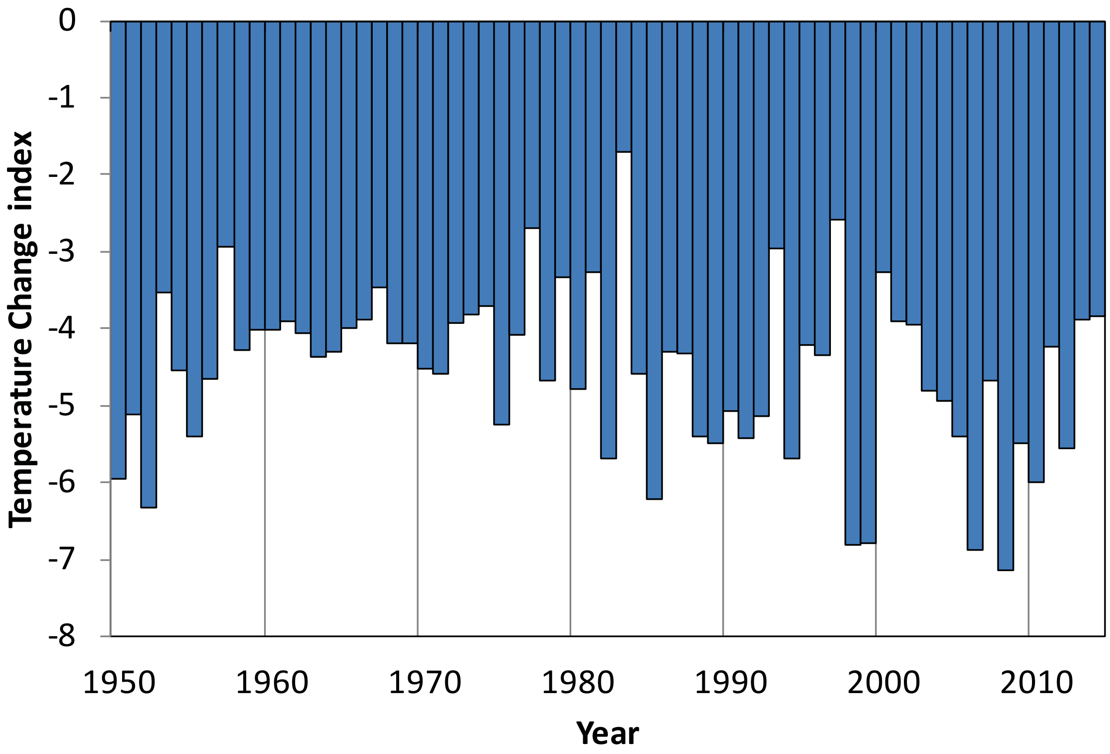

Figure 70: The Temperature Change index value from 1950-2014.

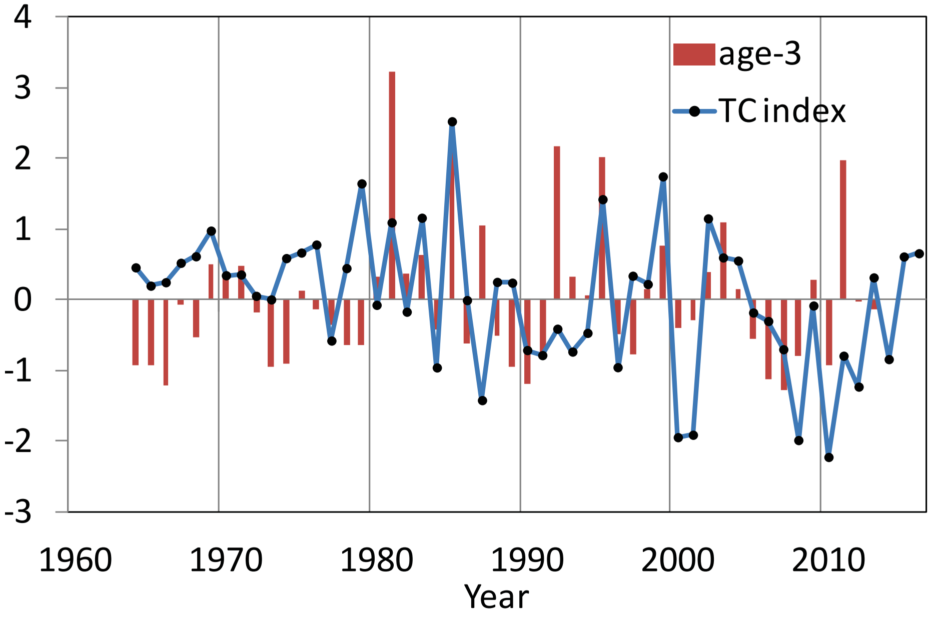

Figure 71: Normalized times series values of the temperature change index (t-2) and the estimated abundance of age-3 walleye pollock in the eastern Bering Sea (t)) from Table 1.21 in Ianelli et al. 2013.

Factors causing observed trends: Age-0 pollock are more energy-rich and have higher over-wintering survival to age-1 in a year with a cooler late summer (Coyle et al., 2011; Heintz et al.,

Table 8: Pearson's correlation coefficient relating the temperature change index to subsequent estimated year class strength of pollock (Age-x+1). Bold values are statistically significant ($p < 0.05$).

	Correlations					
TC Index Pollock	t Age-1	t+1 Age-2	t+2 Age-3	t+3 Age-4	t+4 Age-5	t+5 Age-6
1964-2013	**0.39**	**0.38**	**0.35**	**0.31**	**0.29**	**0.33**
1995-2013	0.40	0.42	**0.52**	**0.52**	**0.53**	**0.57**

2013). Warmer spring temperatures lead to an earlier ice retreat, a later oceanic and pelagic phytoplankton bloom, and more food in the pelagic waters at an optimal time for use by pelagic species (Hunt et al., 2002, 2011; Coyle et al., 2011). Colder later summers during the age-0 phase followed by warmer spring temperatures during the age-1 phase are assumed favorable for the survival of pollock from age-0 to age-1.

Implications: In 2012, the TC index value of -5.56 was below the long-term average of-4.57, therefore we expect slightly below average numbers of pollock to survive to age-3 in 2014 (Figure 70). In the future, the TC values in 2013 (TC=-3.89) and in 2014 (TC=-3.84) indicate above average abundances of age-3 pollock in 2015 and 2016 (Figure 71).

Salmon, Sea Temperature, and the Recruitment of Bering Sea Pollock

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Description of index: Chum salmon growth, pink salmon abundances, and sea temperature were used to predict the recruitment of pollock to age-1 in 2014 (Yasumiishi et al.,*in review*). Chum salmon are incidentally captured in the commercial fisheries for walleye pollock (*Gadus chalcogrammus*) in the Bering Sea (**?**). We used the intra-annual growth in body weight of these immature and maturing age-4 chum salmon from the pollock fishery as a proxy for ocean productivity experienced by age-0 pollock on the eastern Bering Sea shelf. Adult pink salmon are predators and competitors of age-0 pollock (Coyle et al., 2011). We modeled age-1 pollock recruitment estimates from 2001 to 2010 as a function of chum salmon growth, sea temperature, and total production of pink salmon in the Pacific Ocean and used the model parameters and biophysical indices from 2013 to predict age-1 pollock abundances in 2014. Estimates of age-1 pollock abundance were from (Ianelli et al., 2013).

Status and trends: Pollock recruitment was highly variable within the 10-year time series, 2001-2010 (Figure 72). A slight alternating year pattern was observed in the time series, with higher recruitment in odd-numbered years at age-1 that corresponds with higher age-0 recruitment in even-numbered years. The lower age-0 recruitment in odd-years may be associated with higher abundances of adult pink salmon (a predator and competitor) in odd-years.

In a multiple regression model, age-1 pollock recruitment was negatively related to spring sea temperatures during their age-1 stage and positively related to chum salmon growth during the pollock age-0 stage ($R^2 = 0.77$; p-value = 0.012). Model residuals had an alternating year pattern. Therefore, we added pink salmon abundances (harvest and escapement) from Asia and North America from (Ruggerone et al., 2010) to the model. The pink salmon abundance predictor variable had a significant negative coefficient and explained an additional 15% of the variation in age-1 pollock recruitment ($R^2 = 0.92$; p-value = 0.004) (Figure 72).

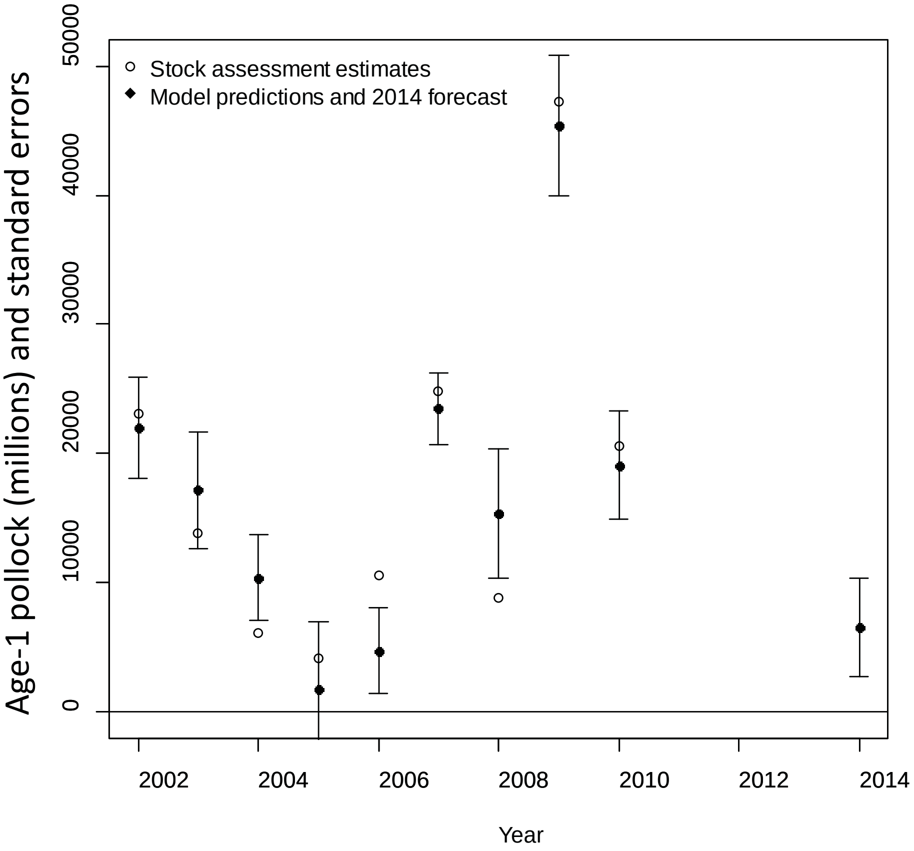

Figure 72: Age-1 pollock modeled as a function of the intra-annual growth in body weight of chum salmon during the age-0 stage (t-1), spring sea temperature during the age-1 stage (t), and adult pink salmon productivity during the age-0 stage (t-1).

Factors influencing observed trends: The model parameters (2001-2010) and biophysical indices (2013 and 2014) were used to predict the recruitment of Bering Sea pollock in 2014. The 2013 and 2014 biophysical indices (chum salmon growth = 0.969 kg, spring sea temperature = 3.95^o pink salmon = 493 million) produced a forecast of 6,569 million (3,837 standard error, c.v. = 0.22) age-1 pollock in 2014. The 2013 and 2014 biophysical indices indicated average ocean productivity (chum salmon growth), warm spring sea temperatures (less favorable), and above average predator abundances (pink salmon). These factors are expected to result in below average age-1 pollock recruitment in 2014.

Implications: Below average recruitment was forecasted for age-1 pollock in 2014.

Trends in Groundfish Biomass and Recruits per Spawning Biomass

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

Bering Sea Groundfish Condition

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Last updated: October 2014

Description of index: Length-weight residuals are an indicator of somatic growth (Brodeur et al., 2004) and, therefore, a measure of fish condition. Fish condition is an indicator of how heavy a fish is per unit body length, and may be an indicator of ecosystem productivity. Positive length-weight residuals indicate fish are in better condition (i.e., heavier per unit length); whereas, negative residuals indicate fish are in poorer condition (i.e., lighter per unit length). Fish condition may affect fish growth and subsequent survival (Paul et al., 1997; Boldt and Haldorson, 2004). The AFSC eastern Bering Sea shelf bottom trawl survey data was utilized to acquire lengths and weights of individual fish for walleye pollock, Pacific cod, arrowtooth flounder, yellowfin sole, flathead sole, northern rock sole, and Alaska plaice. Only summer standard survey strata and stations were included in analyses (no corner stations were included)(Figure 73). Survey strata 31 and 32 were combined as stratum 30; strata 61 and 62 were combined as stratum 60; strata 41, 42, and 43 were combined as stratum 40. Strata 82 and 90 were excluded from analyses because they are not standard survey strata. Length-weight relationships for each of the seven species were estimated with a linear regression of log-transformed values over all years where data was available (during 1982-2013). Predicted log-transformed weights were calculated and subtracted from measured log-transformed weights to calculate residuals for each fish. Length-weight residuals were averaged for the entire EBS and for the 6 strata sampled in the standard summer survey. Temporal and spatial patterns in residuals were examined.

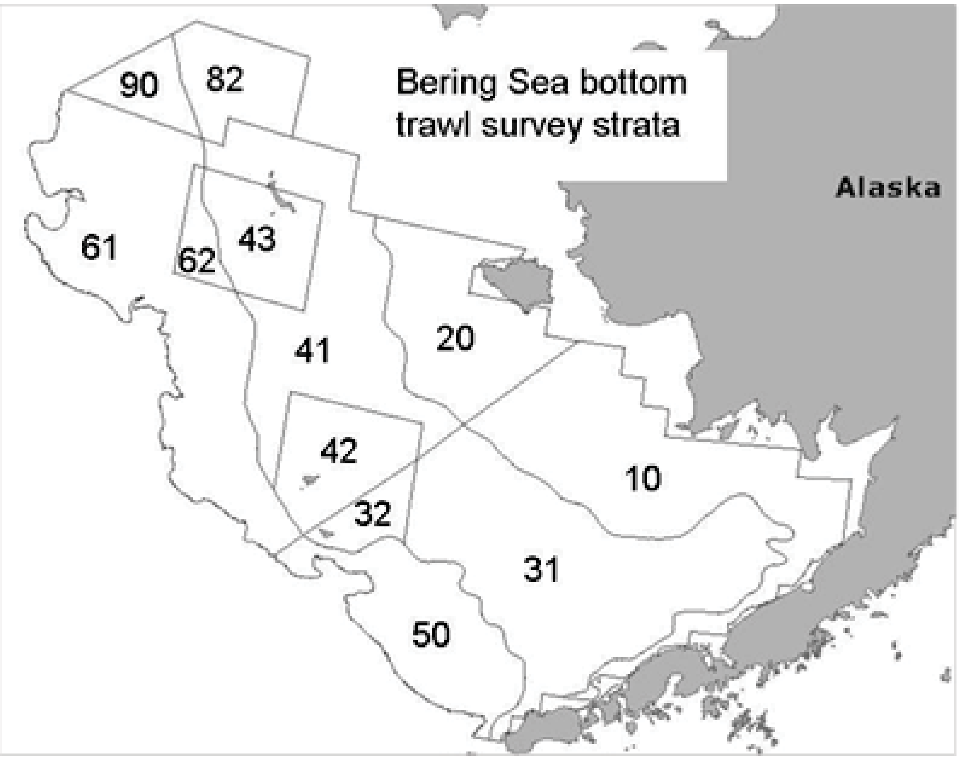

Figure 73: NMFS summer bottom trawl survey strata. Survey strata 31 and 32 were combined as stratum 30; strata 61 and 62 were combined as stratum 60; strata 41, 42, and 43 were combined as stratum 40. Strata 82 and 90 were excluded from analyses because they are not standard survey strata.

Status and trends: Length-weight residuals varied over time for all species with a few notable patterns (Figure 74). Residuals for all species where there was data were negative in 1999, a cold year in the Bering Sea. Residuals became positive or more positive in 2002 for five of the seven species examined. Flatfish residuals were generally positive from 2002 to 2004 or 2005 depending on species. Age 1 walleye pollock and Pacific cod residuals were positive from 2001 to 2004 or 2005. In 2008, all species except flathead sole and walleye pollock had negative residuals. There has been a distinct negative trend in Pacific cod since a peak value in 2003. Age 1 walleye pollock and older walleye pollock were not well correlated in most years. Residual patterns for all species except Pacific cod were positive in 2014.

Spatial trends in residuals were also apparent for some species (Figure 75). Generally, fish were in better condition on the outer shelf (strata 50 and 60). For all species except yellowfin sole (which did not occur in outer shelf strata), residuals were almost always positive on the northern outer shelf (stratum 60). For yellowfin sole, residuals were positive in the outermost shelf strata in which they occurred (stratum 40) except in 1999. In addition to having positive residuals on the outer shelf, gadids tended to have negative residuals on the inner shelf (Figure 75). Pollock residuals were generally positive in strata 50 and 60 and negative in strata 10, 20, and 40. Cod residuals were generally positive in stratum 60 and negative in strata 10 and 20. Spatial patterns in flatfish residuals were also apparent but varied among species. Alaska plaice residuals were almost always negative in stratum 40. Flathead sole residuals were often positive in strata 40 (Figure 75).

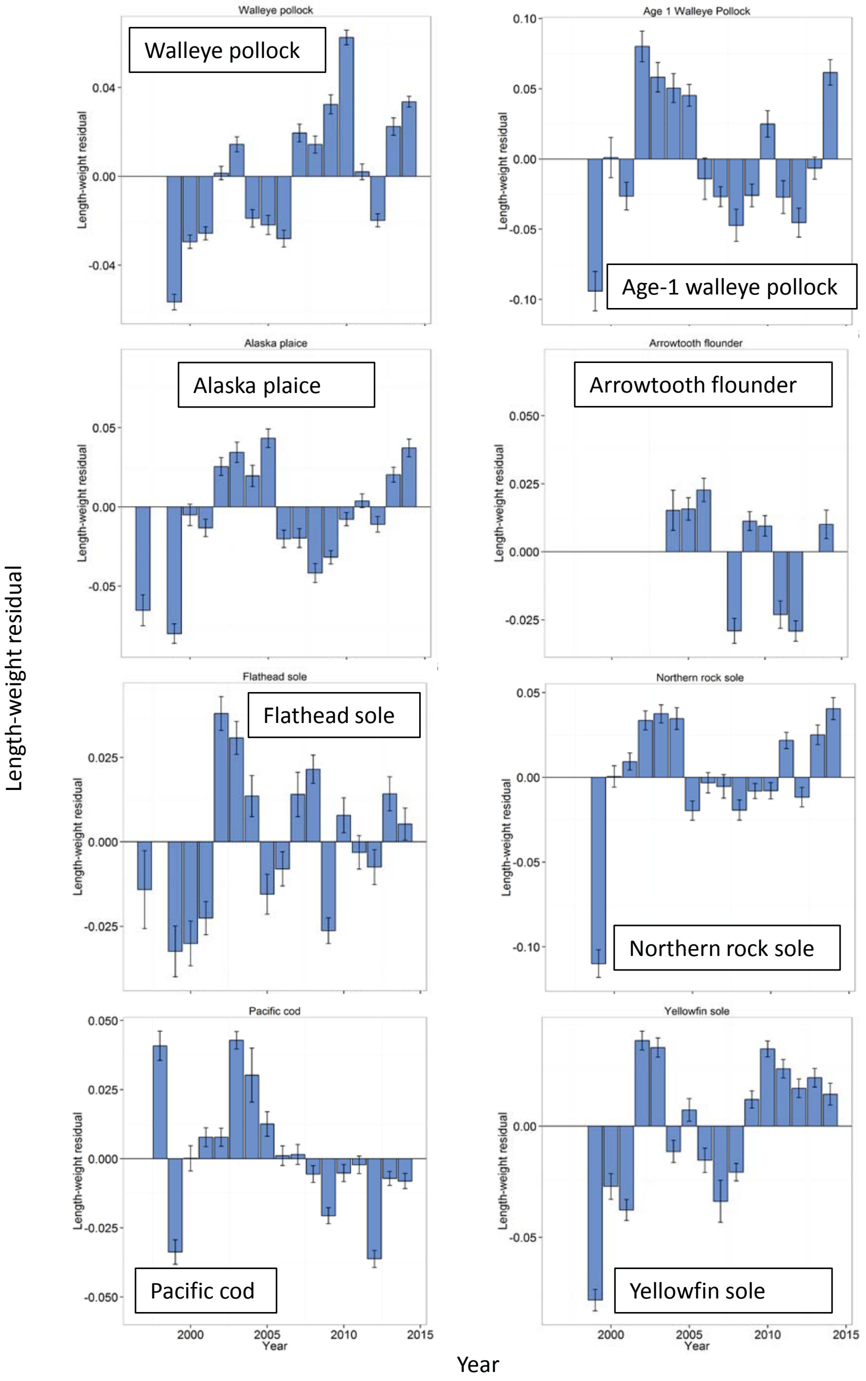

Figure 74: Length-weight residuals for seven Eastern Bering Sea groundfish sampled in the NMFS standard summer bottom trawl survey, 1997-2014.

Factors influencing observed trends: One potential factor causing the observed temporal variability in length-weight residuals is temperature. The year 1999 was a particularly cold year in the Bering Sea and also a year of negative length-weight residuals for all groundfish examined (where data existed). Despite the abundant large crustacean zooplankton and relatively high microzooplankton productivity present in 1999 (Hunt et al., 2008), the spatial distribution of some

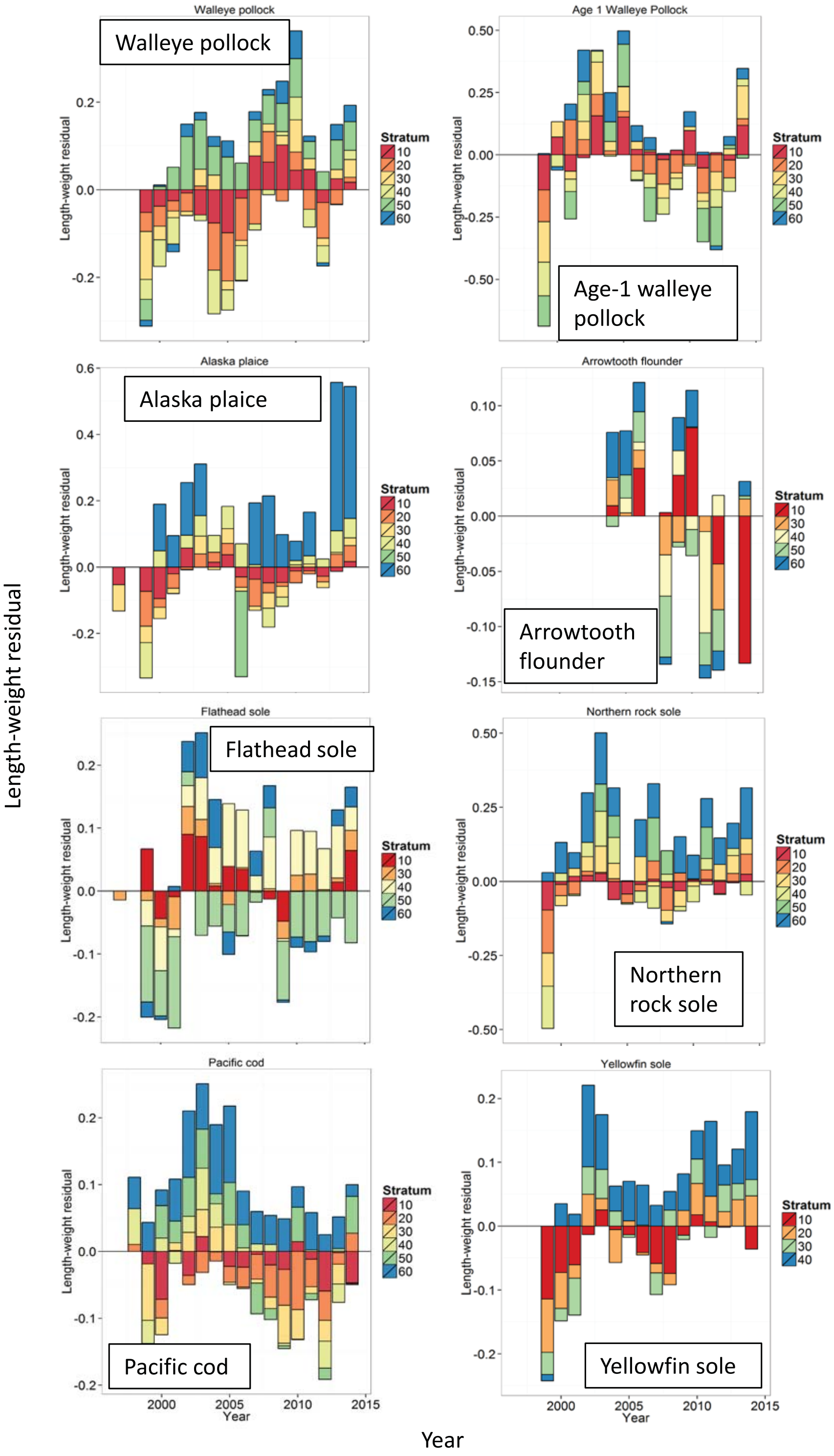

Figure 75: Length-weight residuals for seven Eastern Bering Sea groundfish sampled in the NMFS standard summer bottom trawl survey, 1997-2014, by survey strata (10 - 60).

groundfish species is affected by temperatures and a cold year may, therefore, have affected the spatial overlap of fish and their prey. Cold temperatures may have also affected fish energy requirements and prey productivity. Conversely, the warmer than normal 2014 temperatures across the Bering Sea shelf may have resulted in positive trends for length-weight residuals.

Other factors that could affect length-weight residuals include survey sampling timing and fish migration. The date of the first length-weight data collected annually varied from late May to early June (except 1998, where the first data available was collected in late July). Also, the bottom trawl survey is conducted throughout the summer months, and as the summer progresses, we would expect fish condition to improve. Since the survey begins on the inner shelf and progresses to the outer shelf, the higher fish condition observed on the outer shelf may be due to the fact that they are sampled later in the summer. We also expect that some fish will undergo seasonal and, for some species, ontogenetic migrations through the survey months. For example, seasonal migrations of pollock occur from overwintering areas along the outer shelf to shallow waters (90-140 m) for spawning (Witherell, 2000). Pacific cod concentrate on the shelf edge and upper slope (100-250 m) in the winter, and move to shallower waters (generally <100 m) in the summer (Witherell, 2000). Arrowtooth flounder are distributed throughout the continental shelf until age 4, then, at older ages, disperse to occupy both the shelf and the slope (Witherell, 2000). Flathead sole overwinter along the outer shelf, and move to shallower waters (20-180 m) in the spring (Witherell, 2000). Yellowfin sole concentrate on the outer shelf in the winter, and move to very shallow waters (<30 m) to spawn and feed in the summer (Witherell, 2000). How these migrations affect the length-weight residuals is unknown at this time.

Implications: A fish's condition may have implications for its survival. For example, in Prince William Sound, the condition of herring prior to the winter may in part determine their survival (Paul and Paul 1999). The condition of Bering Sea groundfish, may therefore partially contribute to their survival and recruitment. In the future, as years are added to the time series, the relationship between length-weight residuals and subsequent survival can be examined further. It is likely, however, that the relationship is more complex than a simple correlation. Also important to consider is the fact that condition of all sizes of fish were examined and used to predict survival. Perhaps, it would be better to examine the condition of juvenile fish, not yet recruited to the fishery, or the condition of adult fish and correlations with survival.

Aleutian Islands Groundfish Condition

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Last updated: October 2014

Description of index: Length-weight residuals are an indicator of somatic growth (Brodeur et al., 2004) and, therefore, a measure of fish condition. Fish condition is an indicator of how heavy a fish is per unit body length, and may be an indicator of ecosystem productivity. Positive length-weight residuals indicate fish are in better condition (i.e., heavier per unit length); whereas, negative residuals indicate fish are in poorer condition (i.e., lighter per unit length). Fish condition may affect fish growth and subsequent survival (Paul et al., 1997; Boldt and Haldorson, 2004).). The AFSC Aleutian Islands bottom trawl survey data was utilized to acquire lengths and weights of individual fish for walleye pollock, Pacific cod, arrowtooth flounder, southern rock sole, Atka mackerel, northern rockfish, and Pacific ocean perch. Only standard survey stations were included in analyses. Data were combined by INPFC area; Southern Bering sea, Eastern Aleutian Islands, Central Aleutian Islands, and Western Aleutian Islands.Length-weight relationships for each of the seven species were estimated with a linear regression of log-transformed values over all years where data was available (during 1984-2014). Additionally, length-weight relationships for age 1+ walleye pollock (length from 100-250 mm) were also calculated independent from the adult life history stage. Predicted log-transformed weights were calculated and subtracted from measured log-transformed weights to calculate residuals for each fish. Length-weight residuals were averaged for the entire AI and for the 3 INPFC areas sampled in the standard summer survey. Temporal and spatial patterns in residuals were examined.

Status and trends:: Length-weight residuals varied over time for all species with a few notable patterns (Figure 76). Residuals for most species where there was data were negative from 2000 to 2006. Residuals were positive for all species but southern rock sole in 2010. In 2014 length-weight residuals were negative for all species. For northern rockfish, Pacific cod and Pacific ocean perch there has been a declining trend in residuals over the years covered by the survey.

Spatial trends in residuals were also apparent for some species (Figure 77). Most species were generally in better condition in the southern Bering sea (with the exception of Pacific cod). Species generally exhibited the worst condition in the Western Aleutians (with the exception of Pacific cod) Even in years where length weight residuals were positive overall (such as the early years in the northern rockfish time series), length weight residuals were lower (although still positive) in the western Aleutian Islands relative to other areas.

Factors influencing observed trends: One potential factor causing the observed temporal variability in length-weight residuals may be population size. The species that appear to exhibit declining trends over the time series, have generally been increasing in abundance throughout the Aleutians (northern rockfish, Pacific Ocean perch and Pacific cod). In the western Aleutians, this may be especially magnified, due to the overall high level of population abundance in the area.

Other factors that could affect length-weight residuals include temperature, survey sampling timing and fish migration. The date of the first length-weight data collected is generally in the beginning of June and the bottom trawl survey is conducted sequentially throughout the summer months from east to west. Therefore, it is impossible to separate the in-season time trend from the spatial trend in this data.

Implications: A fish's condition may have implications for its survival. For example, in Prince William Sound, the condition of herring prior to the winter may in part determine their survival (Paul and Paul 1999). The condition of Aleutian Island groundfish, may therefore partially contribute to their survival and recruitment. In the future, as years are added to the time series, the relationship between length-weight residuals and subsequent survival can be examined further. It is likely, however, that the relationship is more complex than a simple correlation. Also important to consider is the fact that condition of all sizes of fish were examined and used to predict survival. Perhaps, it would be better to examine the condition of juvenile fish, not yet recruited to the fishery, or the condition of adult fish and correlations with survival.

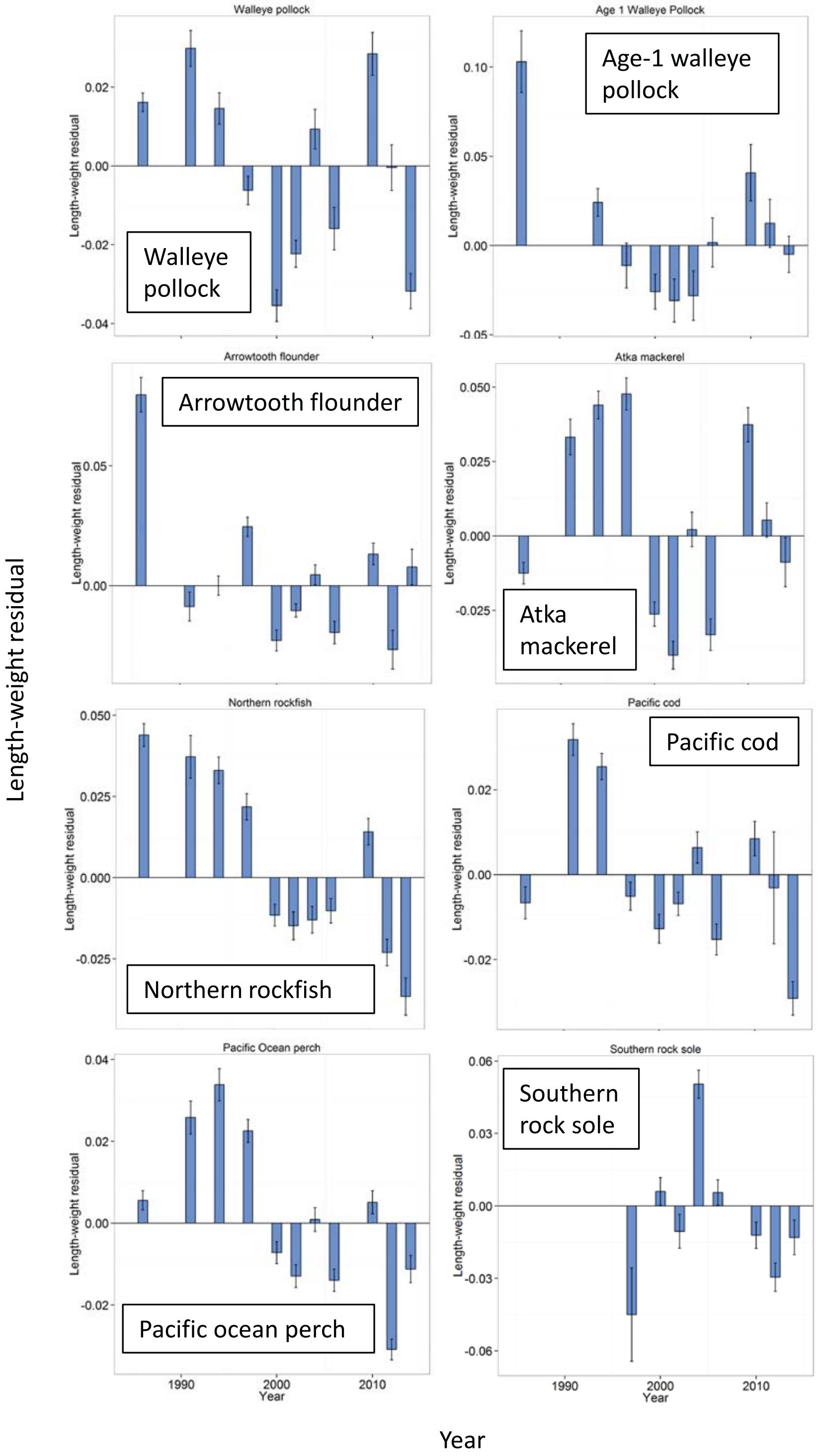

Figure 76: Length-weight residuals for seven Aleutian Islands groundfish sampled in the NMFS standard summer bottom trawl survey, 1984-2014.

Gulf of Alaska Groundfish Condition

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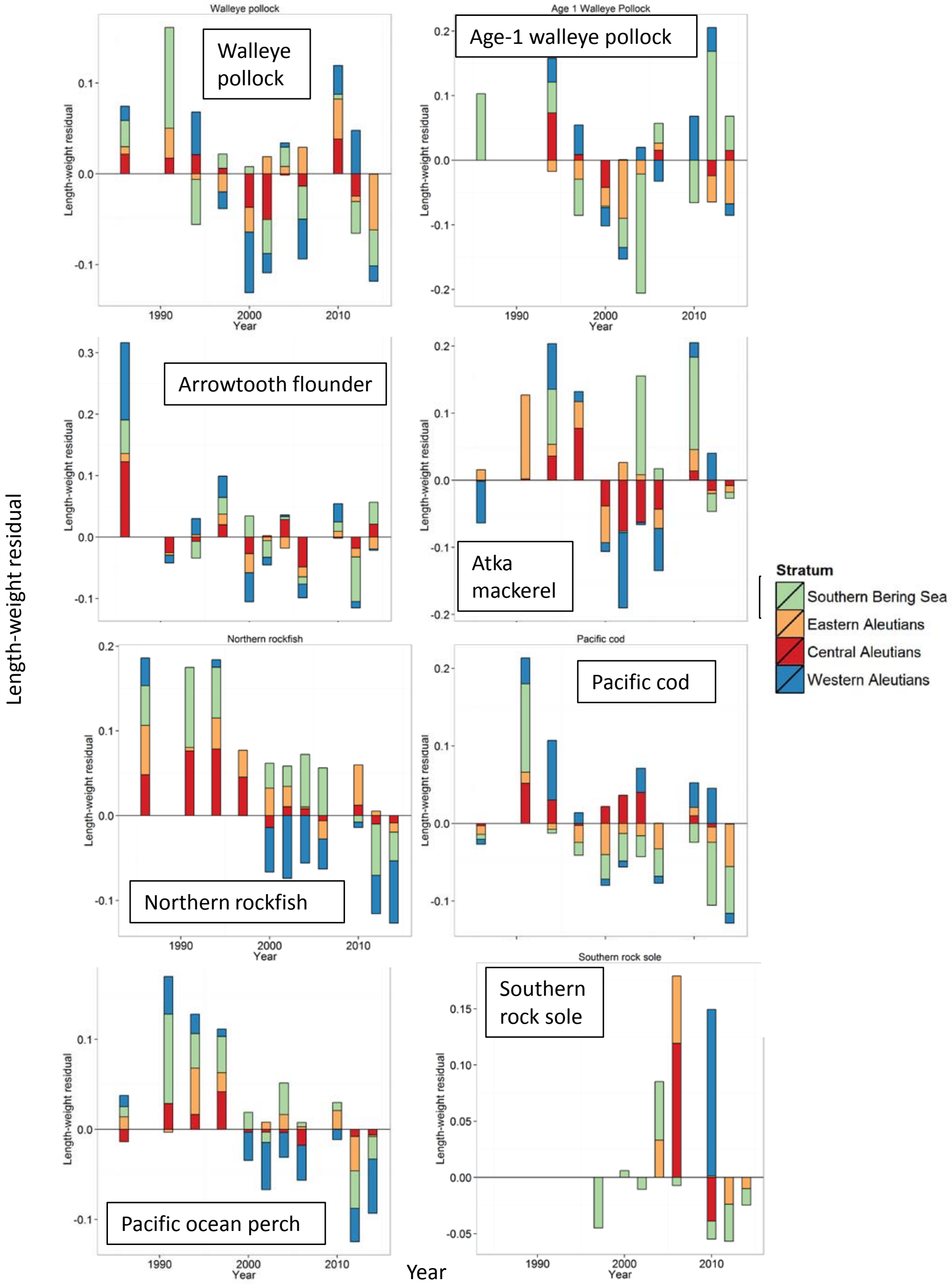

Figure 77: Length-weight residuals for seven Aleutian Islands groundfish sampled in the NMFS standard summer bottom trawl survey, 1984-2014, by INPFC area.

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Last updated: October 2014

Description of index: Length-weight residuals are an indicator of somatic growth (Brodeur et al., 2004) and, therefore, a measure of fish condition. Fish condition is an indicator of how heavy a fish is per unit body length, and may be an indicator of ecosystem productivity. Positive length-weight residuals indicate fish are in better condition (i.e., heavier per unit length); whereas, negative residuals indicate fish are in poorer condition (i.e., lighter per unit length). Fish condition may affect fish growth and subsequent survival (Paul et al., 1997; Boldt and Haldorson, 2004). The AFSC Gulf of Alaska bottom trawl survey data was utilized to acquire lengths and weights of individual fish for walleye pollock, Pacific cod, arrowtooth flounder, southern rock sole, dusky rockfish, northern rockfish, and Pacific ocean perch. Only standard survey stations were included in analyses. Data were combined by INPFC area; Shumagin, Chirikof, Kodiak, Yakutat and Southeastern. Length-weight relationships for each of the seven species were estimated with a linear regression of log-transformed values over all years where data was available (during 1984-2014). Additionally, length-weight relationships for age 1+ walleye pollock (length from 100-250 mm) were also calculated independent from the adult life history stage. Predicted log-transformed weights were calculated and subtracted from measured log-transformed weights to calculate residuals for each fish. Length-weight residuals were averaged for the entire GOA and for the 5 INPFC areas sampled in the standard summer survey. Temporal and spatial patterns in residuals were examined.

Status and trends: Length-weight residuals varied over time for all species with a few notable patterns (Figure 78). Residuals for most species where there was data were positive in the first two years of the survey (1985-1987). The residuals have been mixed for all species since then, generally smaller and varying from year to year. The exception might be for Pollock, where there has been a noticeable uptick of fish condition in 3 of the last 4 surveys.

Spatial trends in residuals were also apparent for some species (Figure 2). Most species were generally in better condition in the Kodiak area, especially southern rock sole. The southeastern area was an area where fish condition was generally worse than other areas of the GOA. For Pacific Ocean perch, the Kodiak and Shumagin areas generally had positive length-weight residuals. Arrowtooth flounder was the only species with consistently higher residuals in the Yakutat area.

Factors influencing observed trends: One potential factor causing the observed temporal variability in length-weight residuals may be temperature and local production. The lack of consistent trends in any of the species and any of the areas suggests that local conditions that vary from year to year might be driving condition trends in the Gulf of Alaska.

Other factors that could affect length-weight residuals include survey sampling timing and fish migration. The date of the first length-weight data collected is generally in the beginning of June and the bottom trawl survey is conducted sequentially throughout the summer months from west to east. Therefore, it is impossible to separate the in-season time trend from the spatial trend in this data.

Implications: A fish's condition may have implications for its survival. For example, in Prince William Sound, the condition of herring prior to the winter may in part determine their survival (Paul and Paul 1999). The condition of Gulf of Alaska groundfish, may therefore partially contribute to their survival and recruitment. In the future, as years are added to the time series, the relationship between length-weight residuals and subsequent survival can be examined further. It is likely, however, that the relationship is more complex than a simple correlation. Also important to consider is the fact that condition of all sizes of fish were examined and used to predict survival. Perhaps, it would be better to examine the condition of juvenile fish, not yet recruited to the fishery,

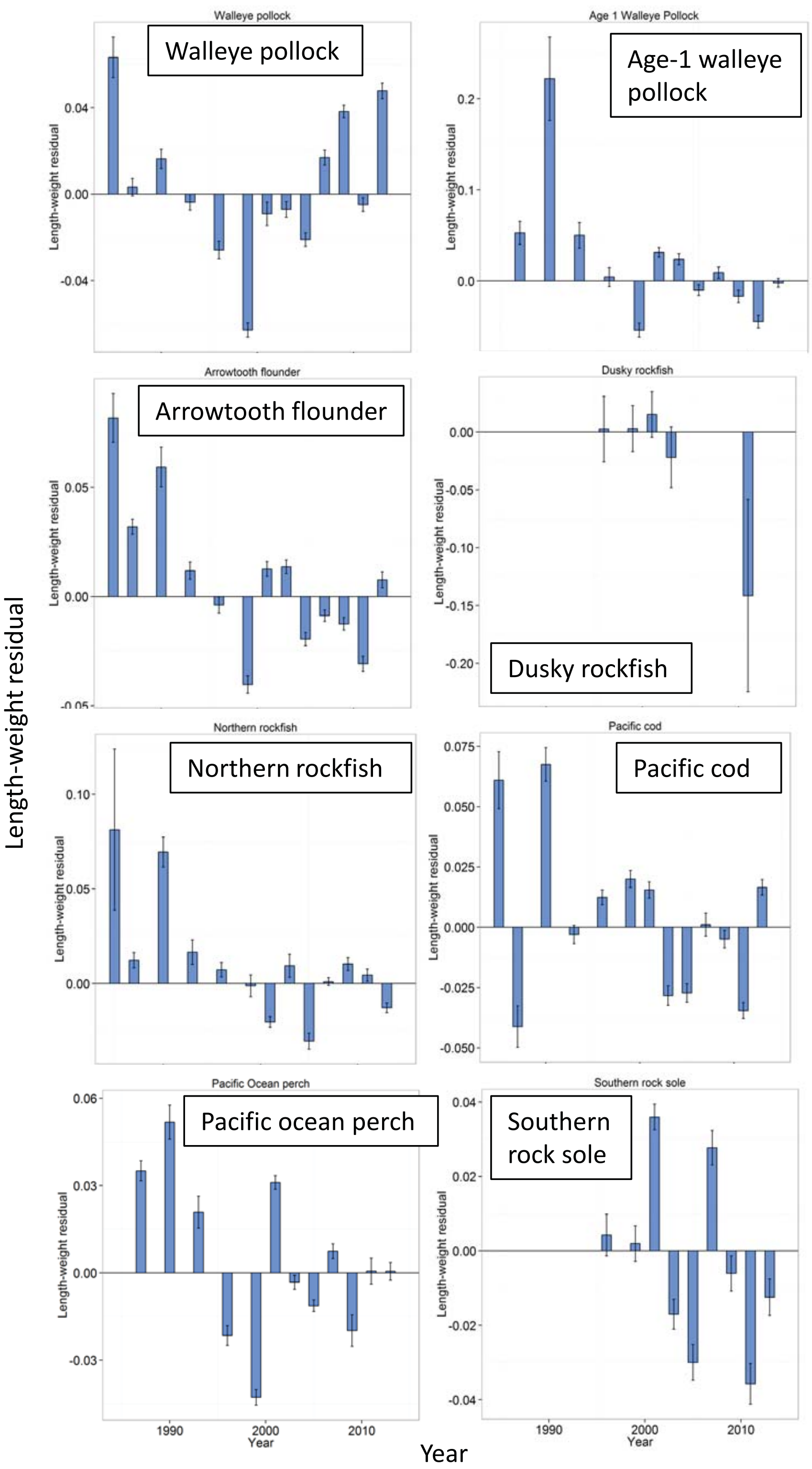

Figure 78: Length-weight residuals for Gulf of Alaska groundfish sampled in the NMFS standard summer bottom trawl survey, 1985-2013.

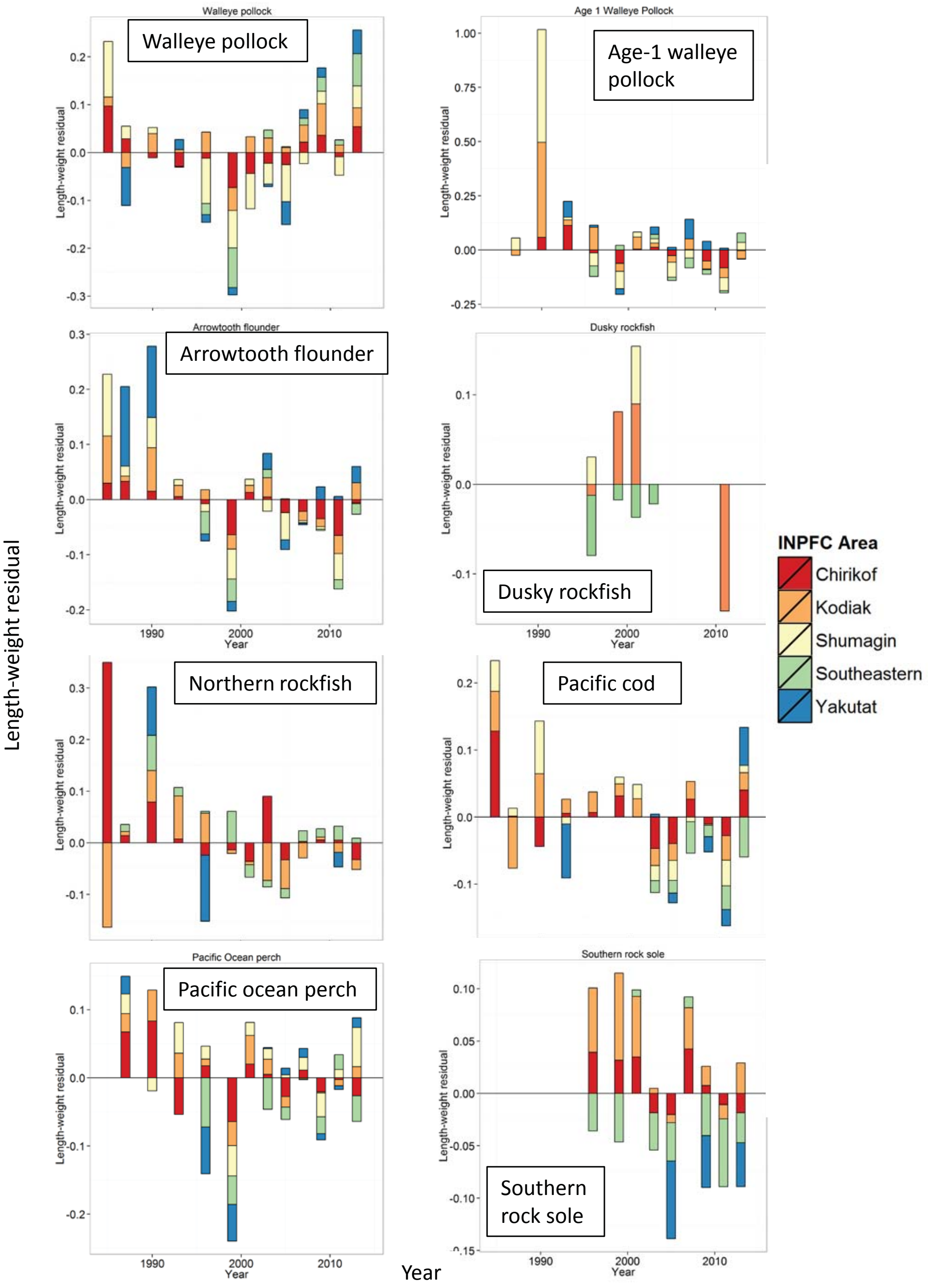

Figure 79: Length-weight residuals for Gulf of Alaska groundfish sampled in the NMFS standard summer bottom trawl survey, 1985-2013, by INPFC area.

or the condition of adult fish and correlations with survival.

“Mushy” Halibut Syndrome occurrence

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Last updated: September 2014

Description: The condition was first detected in Gulf of Alaska halibut in 1998. Increased prevalence occurred in 2005, 2011, and 2012. It is most often observed in smaller halibut of 15-20 lbs in the Cook Inlet area, but has also been noted in Kodiak, Seward, and Yakutat. Alaska Department of Fish and Game (ADF&G) describes the typical condition consisting of fish having large areas of body muscle that are 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.

Status and trends: ADF&G received no reports of “mushy” halibut during the 2014 fishing season (`http://www.alaskaoutdoorjournal.com/Reports/Adfg/homer.html`).

Factors influencing observed trends: The condition is considered a result of nutritional myopathy/deficiency, and thus may be indicative of poor prey conditions for halibut. According to ADF&G, 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.

Implications: The decrease in “mushy” halibut, particularly relative to 2011 and 2012, may indicate that foraging conditions for young halibut were favorable during the past year.

Gulf of Alaska Ichthyoplankton Abundance Indices 1981-20011

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

Southeast Coastal Monitoring Survey Indices and the Recruitment of Gulf of Alaska Sablefish

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Last updated: August 2014

Description of index: Biophysical indices from surveys and fisheries were used to predict the recruitment of sablefish to age-2 from 2013 to 2015 (Yasumiishi et al. in AFSC review). The southeast coastal monitoring project is an annual survey of oceanography and fish conducted in inside and outside waters of northern southeast Alaska (Orsi et al., 2012). Oceanographic sampling included, but was not limited to, sea temperature and chlorophyll *a*. These data are available from documents published through the North Pacific Anadromous Fish Commission website from 1999 to 2012 (`www.npafc.org`) and from Emily Fergusson. These oceanographic metrics may index sablefish recruitment because sablefish use these waters as rearing habitat early in life (late age-0 to age-2). Estimates of age-2 sablefish abundance are from **?**. We modeled age-2 sablefish recruitment estimates from 2001 to 2012 as a function of sea temperature, chlorophyll *a*, and pink salmon productivity in southeast Alaska.

Status and trends: Age-2 sablefish recruitment was described as a function of late August sea temperature, late August chlorophyll a, and juvenile pink salmon productivity index during the age-0 stage (based on adult salmon returns to southeast Alaska during the age-1 stage) in a multiple regression model (Figure 80; Table **??**). Chlorophyll *a* during the age-0 phase was most strongly correlated with sablefish recruitment ($R^2 = 0.80$; $p = 0.00003$) with a three-fold increases in chlorophyll *a* in 2000 and recruitment (age-2) in 2002. Sea temperature and pink salmon productivity explained an additional 15% of the variation in sablefish recruitment ($R^2 = 0.950$; $p = 0.00001$).

Factors influencing observed trends: Warmer sea temperatures were associated with high recruitment events in sablefish (**?**). Higher chlorophyll *a* content in sea water during late summer indicates higher primary productivity and a possible late summer phytoplankton bloom. Higher pink salmon productivity, a co-occurring species in near-shore waters, was a positive predictor for sablefish recruitment to age-2. These conditions are assumed more favorable for age-0 sablefish, overwintering survival from age-0 to age-1, and overall survival to age-2.

Implications: The model parameters (2001-2012) and biophyscial indices (2011-2013) were used to predict the recruitment of Gulf of Alaska sablefish (2013-2015). **Below average recruitment events for age-2 sablefish are expected in 2013 and 2015, and a slightly above-average recruitment event is expected in 2014** due to the high juvenile pink salmon productivity in 2013.

Distribution of Rockfish Species in Gulf of Alaska and Aleutian Islands Trawl Surveys

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Table 9: Sablefish estimates from **?**, predictor variables used in the model (2001-2012), model estimates and standard errors (2001-2012), and forecast estimates; SE = standard error; SST = sea surface temperature.

	SA	Model				
	Estimates	Fitted and forecasts		Predictor variables		
Year	Sablefish (t)	Estimates	SE	Chla(t-2)	SST(t-2)	Adult pink salmon (t-1)
2001	11.6	7.8	1.3	2.15	13.4	31,009,547
2002	42.39	43	2.6	6.08	12	85,654,226
2003	7.69	8.7	1	1.63	12.8	61,929,924
2004	14.43	13.8	1.6	2.64	10.7	72,431,623
2005	6.67	6.2	1.1	1.22	13.1	60,965,661
2006	10.73	10.9	2.1	1.05	14.5	79,033,917
2007	8.42	8.1	1.5	2.68	12.5	21,848,850
2008	9.54	8.7	1.6	2.15	10.8	62,435,599
2009	9.37	9.5	1.7	2.33	14.2	25,406,377
2010	20.75	18.4	1.2	3.59	11.7	50,695,114
2011	2.91	9.1	1.2	2.52	12.3	35,196,281
2012	2.62	2.9	1.6	0.55	12.7	73,123,947
2013		10.3	1.7	3.06	11.2	32320595
2014		18.8	2.7	1.58	12.7	119898191
2015		6.5	1.3	1.92	13.5	32000000

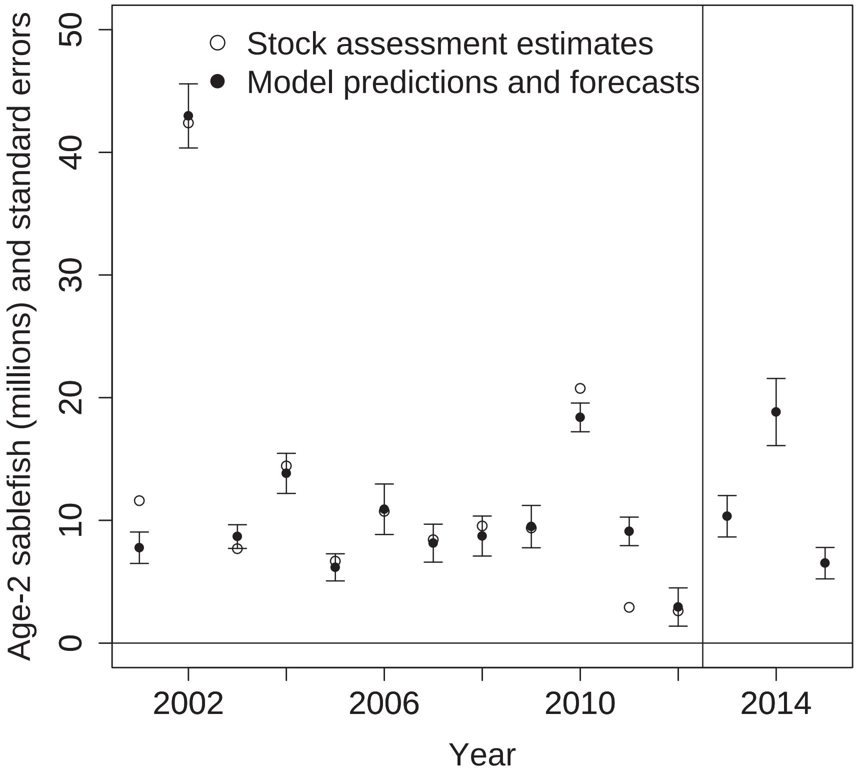

Figure 80: Age-2 sablefish modeled as a function of chlorophyll a during the age-0 stage (t-2), sea temperature during the age-0 stage (t-2), and juvenile pink salmon productivity during the age-0 stage and overwintering survival to age-1 (based on adult pink salmon in year t-1).

Last updated: October 2014

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 are two statistically significant depth-related trends over the time series that have continued over the last couple of surveys, as the distribution of both adult rougheye rockfish and shortspine thornyhead have been shallower in the most recent surveys of the Aleutian Islands (Figure 81). Northern rockfish have also shown a significant trend over the last few surveys 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 ($\sim$0.1 - 0.5C). 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 which have generally moved shallower (Figure 82). 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 from the eastern and SE areas of the Gulf of Alaska was noted; however, in the 2013 bottom trawl survey data this trend (although present for all species except dusky rockfish) was not significant.

Factors causing observed trends: The observed changes in depth and spatial distributions for adult rougheye rockfish, shortraker rockfish, northern 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 adult rougheye rockfish, shortspine thornyhead and shortraker rockfish their depth range has become shallower while the temperatures occupied by the species have not changed significantly in recent surveys.

It is unclear why the shift in rockfish distribution from the eastern GOA and SE Alaska was not found in the 2013 survey data. It may 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 depth and position distributions of rockfish, especially as they relate to changing temperatures.

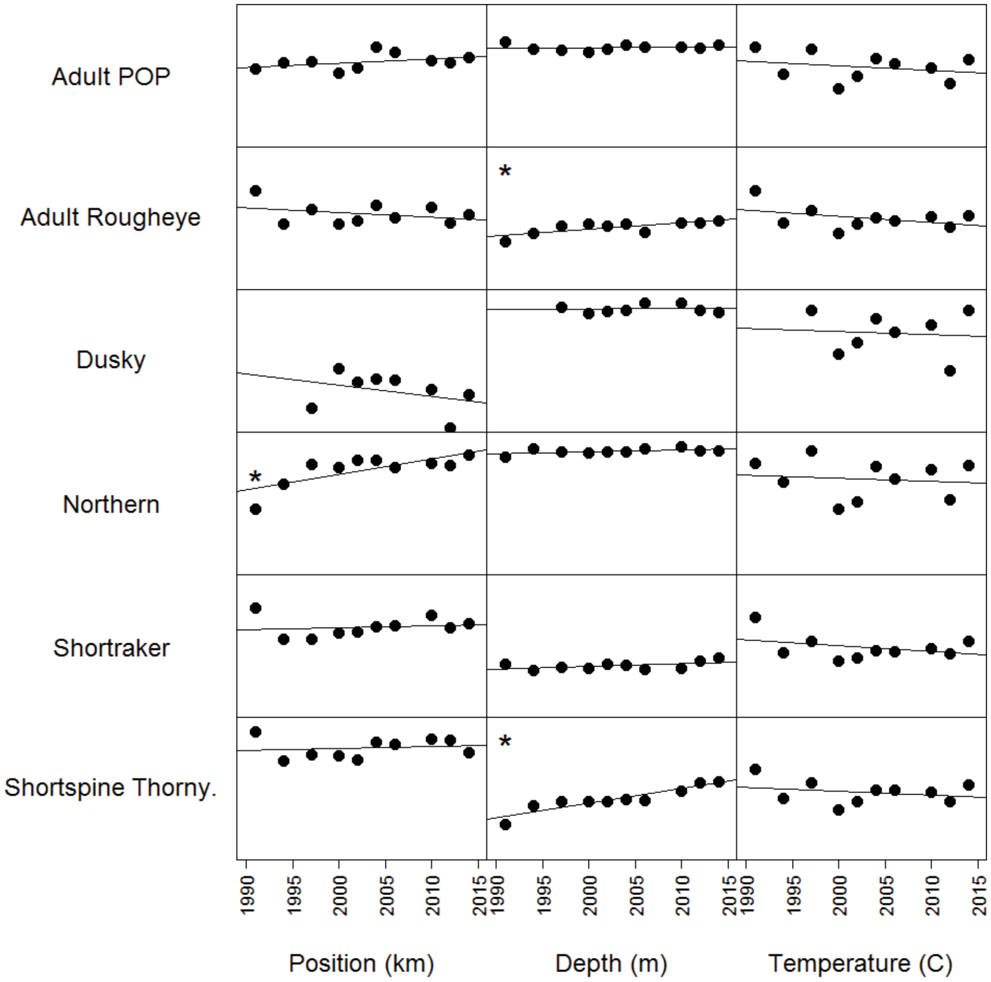

Figure 81: Plots of mean weighted (by catch per unit effort) distributions of six rockfish species-groups along three environmental variables in the Aleutian Islands. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance 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.

Benthic Communities and Non-target Fish Species

Spatial Variability of Catches in Bering Sea and Gulf of Alaska Crab Fisheries

Contributed by Mike Litzow[1,2], Franz Mueter[3], and Dan Urban[4]
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Last updated: January 2012

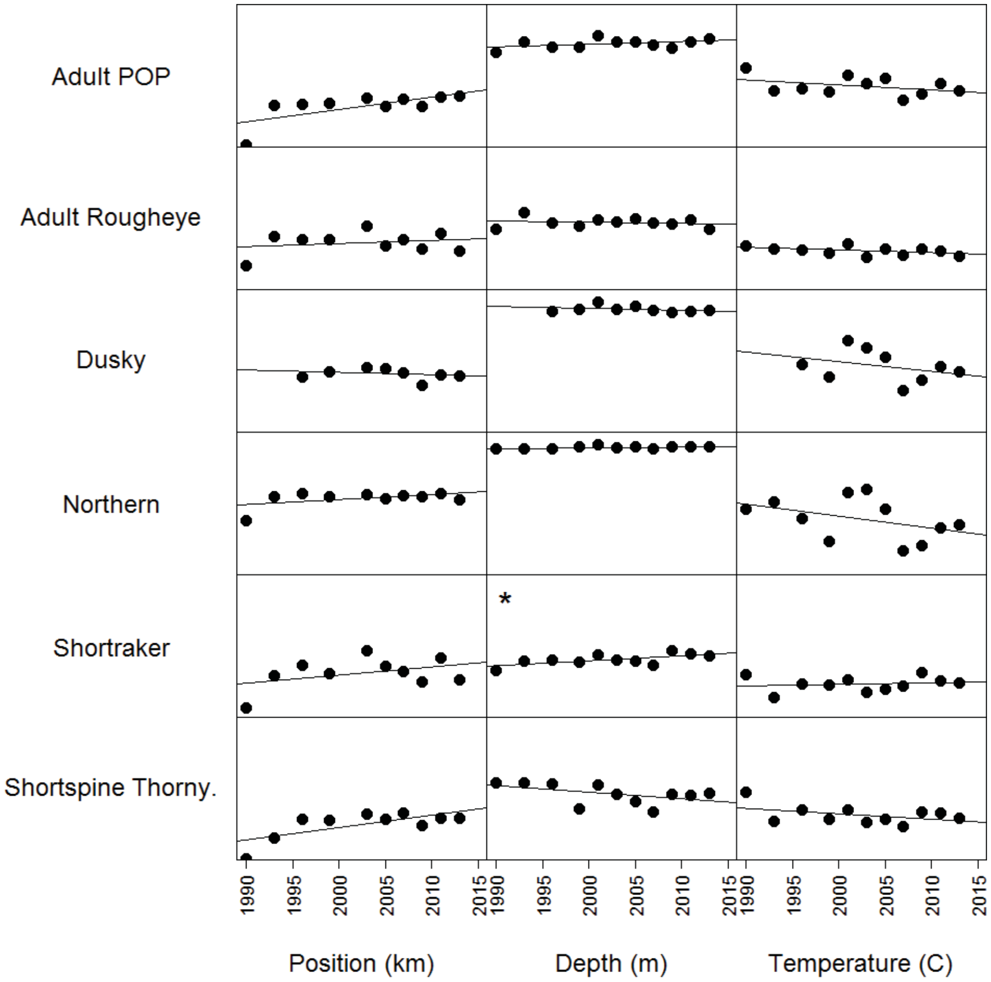

Figure 82: Plots of mean weighted (by catch per unit effort) distributions of six rockfish species-groups along three environmental variables in the Gulf of Alaska. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance 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.

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

Bering Sea/Aleutian Islands King and Tanner Crab Stocks

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Last updated: October 2010

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

Miscellaneous Species - Eastern Bering Sea

Contributed by Robert Lauth and Gerald Hoff, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
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Last updated: October 2014

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 1982-2014. 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: The trend in relative CPUE for poachers and sea stars groups was very similar to 2013, and eelpouts show a slight increase (Figure 83).

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.

Miscellaneous Species - Aleutian Islands

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Last updated: October 2014

Description of index: RACE bottom trawl surveys in the Aleutian Islands (AI) are designed primarily to assess populations of commercially important fish and invertebrates. However many other species are identified, weighed and counted during the course of these surveys and these data may provide a measure of relative abundance for some of these species. Many of these species are not sampled well by the gear or occur in areas that are not well sampled by the survey (hard, rough areas, mid-water etc.) and are therefore encountered in small numbers which may or may not reflect their true abundance in the AI. The fishing gear used aboard the Japanese vessels that participated

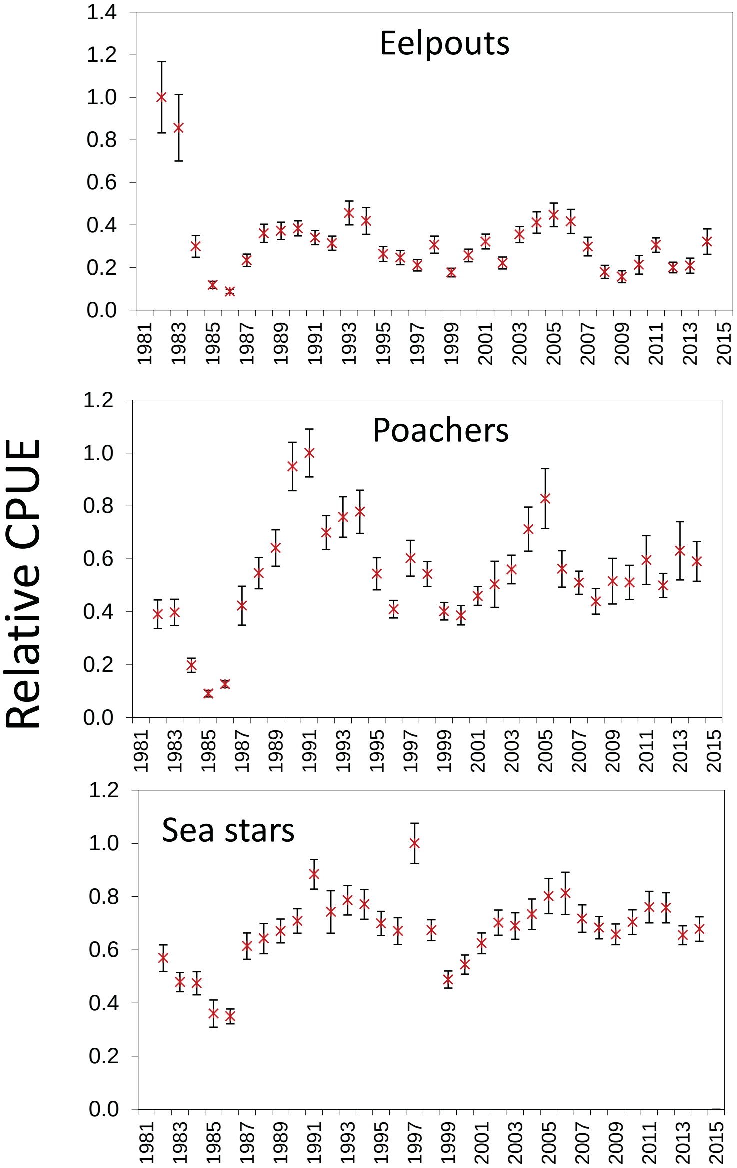

Figure 83: AFSC eastern Bering Sea bottom trawl survey relative CPUE for miscellaneous species during the May to August time period from 1982-2014.

in all AI surveys prior to 1991 was very different from the gear used by all vessels since. This gear difference almost certainly affected the catch rates for some of these species groups. Apparent abundance trends for a few of these groups are shown in Figure 84. 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: Echinoderms are frequently captured in all areas of the AI surveys. Echinoderm mean catch per unit effort (CPUE) is typically higher in the central and eastern AI than in other areas, although frequency of occurrence in trawl catches is consistently high across all areas.

The lowest echinoderm CPUE has usually been in the southern Bering Sea. Jellyfish were generally more abundant in 2004 and 2006 than in other years and increased slightly in 2014. The frequency of occurrence shows two distinct modes across all areas (1991-94 and 2004-06), although only in the western AI did this translate into higher abundance during the earlier period. There appears to have been an uptick in jellyfish frequency of occurrence in 2014. The 2006 survey showed the highest level of jellyfish CPUE for all survey years, with a particularly large increase in the eastern AI. This change in abundance pattern is quite different from the eastern Bering Sea where peak abundances occurred in 2000 and 2011. Eelpout CPUEs have generally been highest in the central and eastern AI and have remained high since 1991 except for 2012 in the central AI. Poachers occur in a relatively large number of tows across the AI survey area, but mean CPUE trends are unclear and abundance appears low.

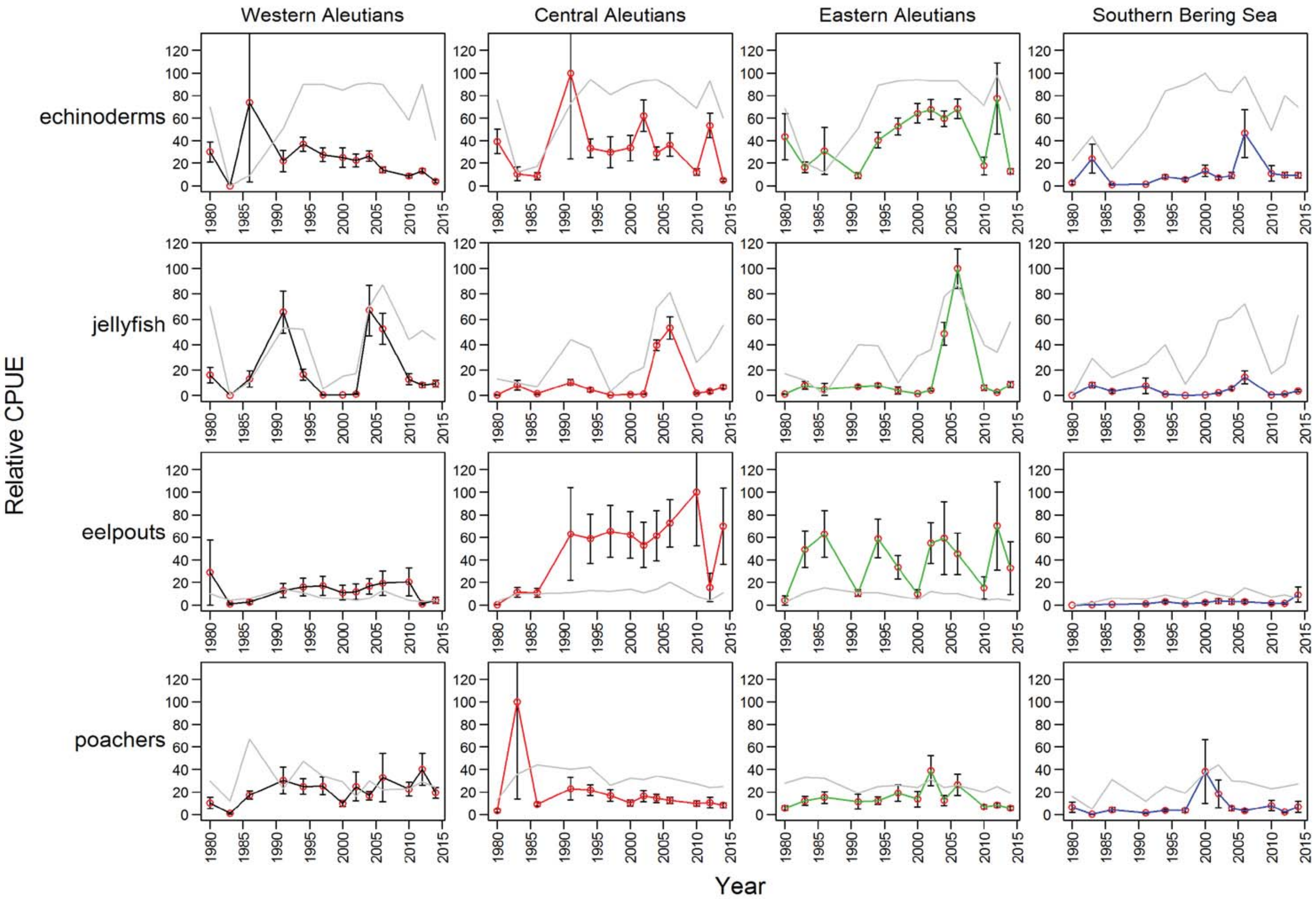

Figure 84: Relative mean CPUE of miscellaneous species by area from RACE bottom trawl surveys in the Aleutian Islands from 1980 through 2014. Error bars represent standard errors. The gray lines represent the percentage of non-zero catches. The Western, Central, and Eastern Aleutians correspond to management areas 543, 542, and 541, respectively. The Southern Bering Sea corresponds to management areas 519 and 518.

Factors influencing observed trends: Unknown

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

ADF&G Gulf of Alaska Trawl Survey

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Last updated: September 2014

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, 2013). 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 85) 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. In 2013, a total of 387 stations were sampled from June 13 through September 12. 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 *Atheresthes stomias*, flathead sole *Hippoglosoides elassodon*, Tanner crab *Chionoecetes bairdi*, Pacific cod *Gadus macrocephalus*, skates, and Pacific halibut *Hippoglossus stenolepis*) using the method described by Link et al. (2002) (Figure 86). Bottom temperatures for each haul have been recorded since 1990 (Figure 87).

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 2013 from years of record high catches seen from 2002 to 2005 (Figure 88).

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, skate, and gadid catch rates have all increased roughly 10-fold. While Pacific cod made up 88% and walleye pollock 10% of the gadid catch in 1976-1977, catch compositions have reversed in 2013 with Pacific cod making up 27% of catch and walleye pollock 72%.

In 2013, overall gadid catches have slightly increased in offshore area of Barnabus Gully, but decreased in the inshore areas of Kiliuda and Ugak Bays (Figure 88). In 2013, below average anomaly values for Tanner crabs, arrowtooth flounder, and flathead sole were recorded for both inshore and offshore areas, while Pacific cod were well above average (Figure 86). Skates and Pacific halibut were above average for offshore areas, while remaining below average inshore.

Temperature anomalies for both inshore, Kiliuda and Ugak Bays and offshore stations, Barnabas Gully, from 1990 to 2013, show similar oscillations with periods of above average temperatures

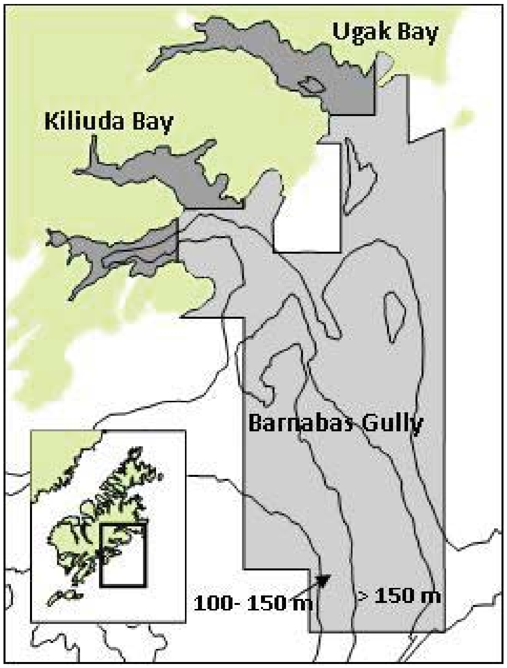

Figure 85: Kiliuda Bay, Ugak Bay, and Barnabus Gully survey areas used to characterize inshore (dark gray, 14 stations) and offshore (light gray, 33 stations) trawl survey results.

corresponding to the strong El Niño years (1997-1998; Figure 87; `http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html`). Cooler temperatures are apparent from 2011 to 2013.

Factors influencing observed trends: It appears that significant changes in volume and composition of the catches on the east side of Kodiak are occurring, but it is unknown to what extent predation, environmental changes, and fishing effort are contributing. The lower overall catch from 1993 to 1999 (Figure 88) 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. Lower than average temperatures have been recorded from 2007 to 2009 along with decreasing overall abundances. This may indicate a possible lag in response to changing environmental conditions or some other factors may be affecting abundance that are not yet apparent.

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. This survey data is used 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 guideline harvest levels.

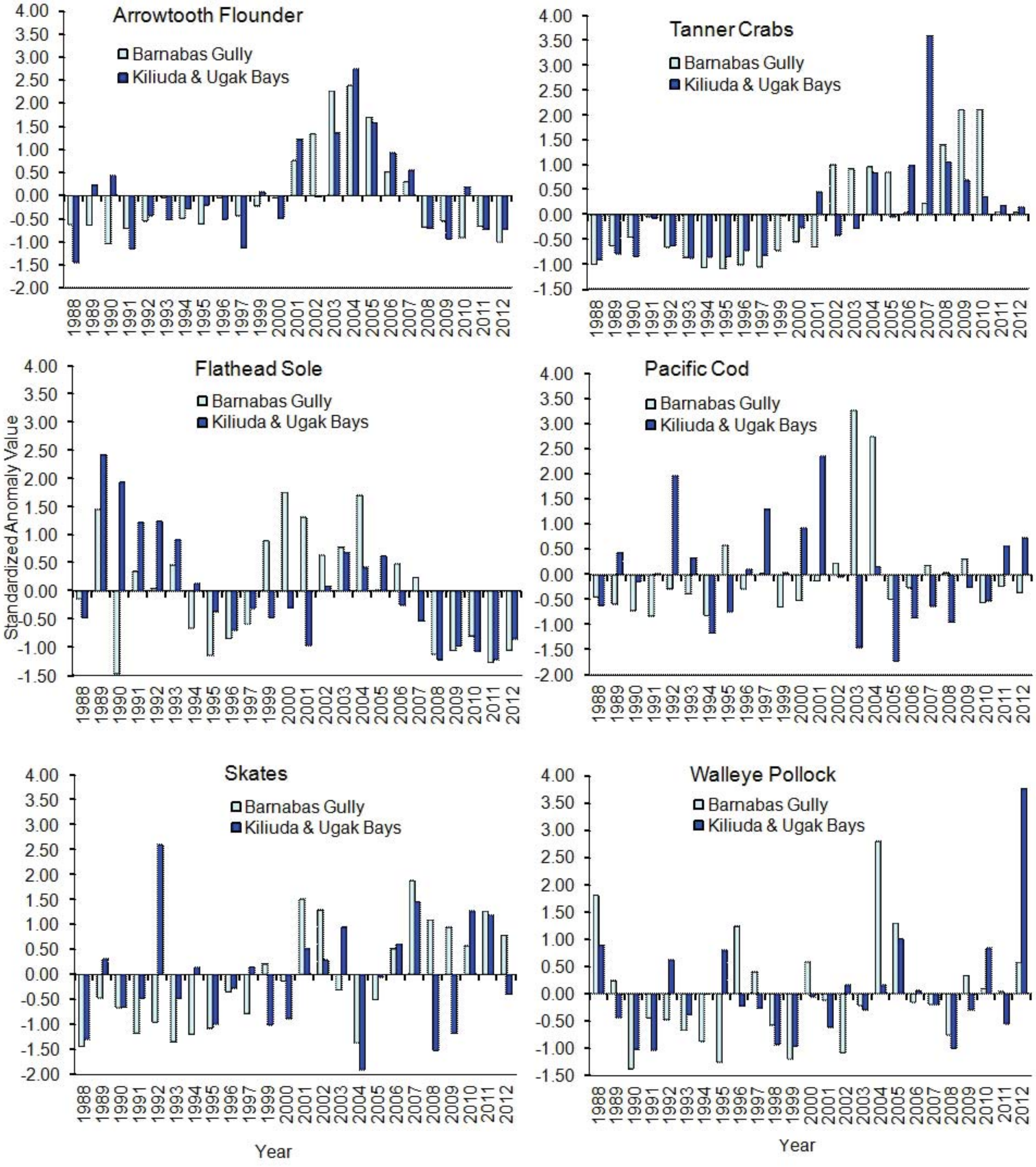

Figure 86: A comparison of standardized anomaly values for selected species caught from 1988-2013 in Barnabas Gully and Kiliuda and Ugak Bays during the ADF&G trawl survey.

Miscellaneous Species - Gulf of Alaska

Contributed by Chris Rooper, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA

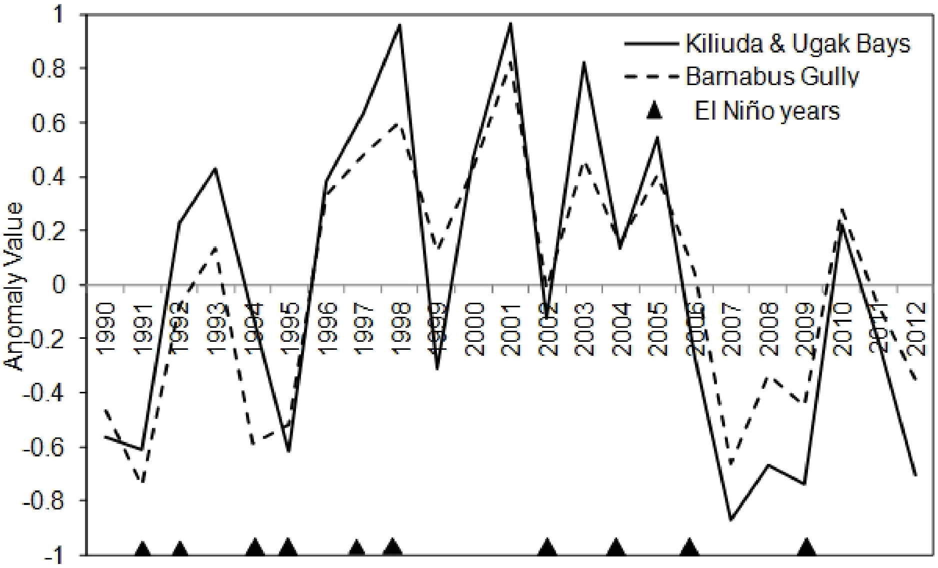

Figure 87: Bottom temperature anomalies recorded from the ADF&G trawl survey for Barnabas Gully and Kiliuda and Ugak Bays from 1990 to 2013, with corresponding El Niño years represented.

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Last updated: October 2013

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

Seabirds

Multivariate Seabird Indices for the Eastern Bering Sea

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Last updated: Oct 2014

Description of index: The index is derived from the first two principal components of a principal components analysis (PCA) that combines reproductive effort data (mean hatch date and reproductive success) 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. Data are collected by the USFWS Alaska Maritime National Wildlife Refuge. The most recent PCA includes 17 individual data sets spanning 1996 to 2014.

All data were standardized (mean of zero and variance of 1) to assure equal weighting. PCAs were

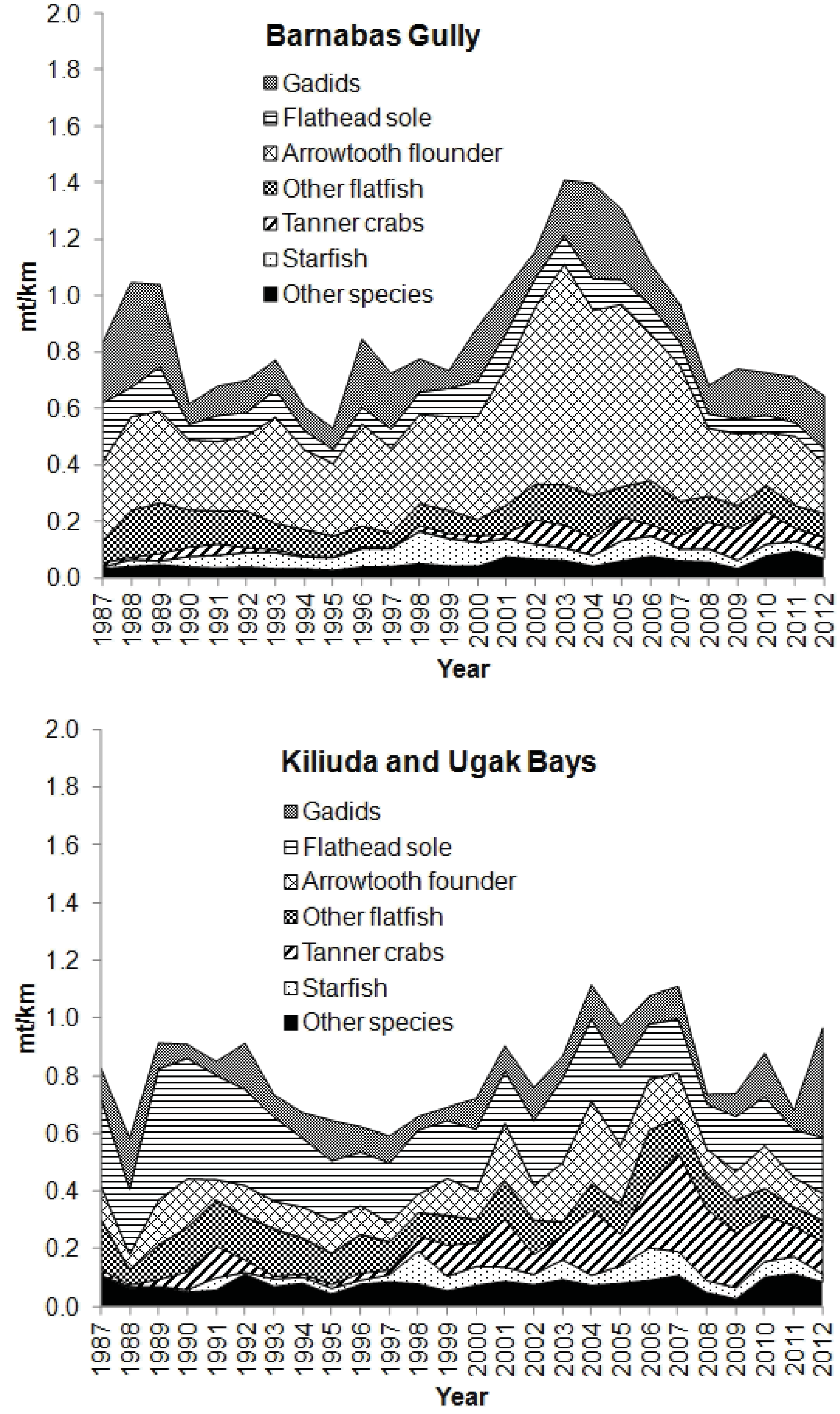

Figure 88: Total catch per km towed (mt/km) of selected species from Barnabus Gully and Kiliuda and Ugak Bay survey areas off the east side of Kodiak Island, 1987 to 2013.

performed using the `prcomp` function in R. We considered the 2 leading principal components (PC1 and PC2) successful candidates for combined seabird indices if they explained a sufficient level (>20% each) of the variance in the datasets. Inspection of the time series of breeding parameters loading most strongly on each PC (loading strength >0.2) enabled interpretation of the biological meaning of the indices. Methodogical detail can be found in Zador et al. (2013).

Status and trends: The PCA on the 19 yr annual time series (1996-2014) explained 65.8% of the variance in the data in the first two components. All seabird phenology and red-faced cormorant, common murre and St. Paul thick-billed murre reproductive success time series were associated (loadings >0.2) with PC1, which explained 44.2% of the total variance (Figure 89). All kittiwake reproductive success time series were strongly associated (loadings ≥ 0.3) with PC2, which explained 21.6% of the total variance. With the addition of 2014 data, St. Paul thick-billed murre reproductive success and St. Paul and St. George black-legged kittiwake hatch dates were also associated with PC2, although not as strongly as the kittiwake reproductive success time series (loadings = 0.28, 0.26, and 0.22, respectively). Also, St. George thick-billed murre reproductive success, which grouped with kittiwake reproductive success in PC2 in previous years, was not associated with either PC.

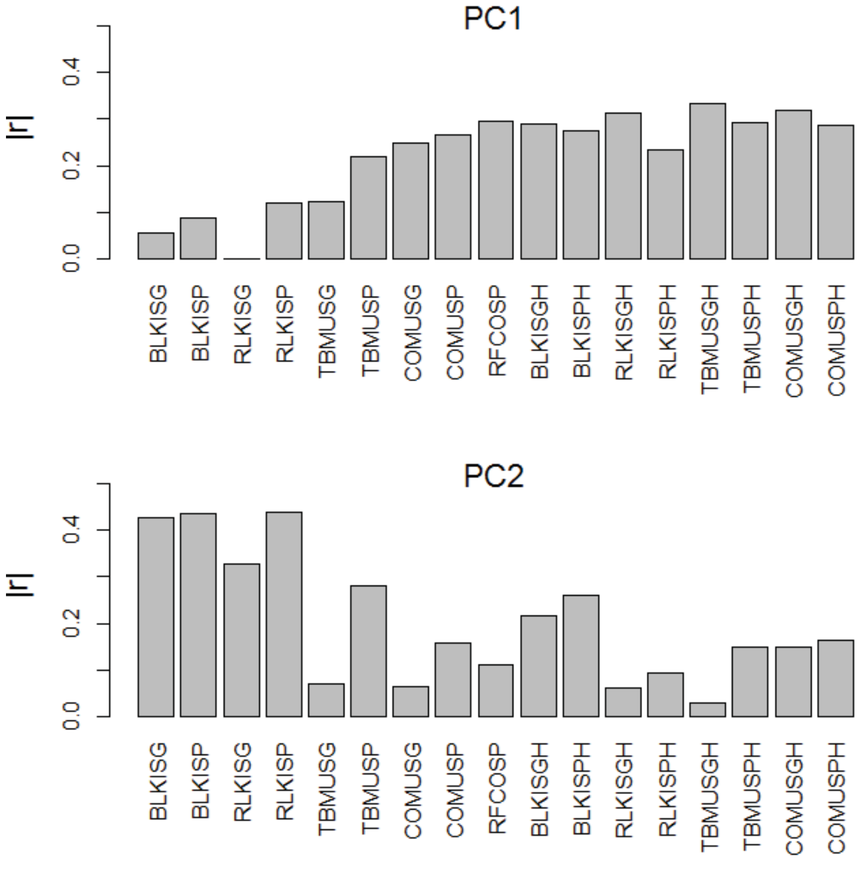

Figure 89: Loadings (absolute correlations) measuring the strength of association between individual time series and the first (PC1, top) and second (PC2, bottom) principal components. The datasets are labeled in order with a 4-letter bird species code following American Ornithological Union convention (e.g., BLKI: black-legged kittiwake), a 2-letter island code (SP: St. Paul; SG: St. George), and H if it is a hatch date time series.

The temporal trend in PC1 has continued to increase since 2011, indicating earlier hatch dates and higher reproductive success for cormorants, common murres and St. Paul thick-billed murres (Figure 90). The dominant temporal trend among kittiwake reproductive success data is an alternating biennial pattern. PC2 continued the nearly annual trend reversal with the 2014 value showing an increase from the previous year and indicating an increase in kittiwake reproductive success.

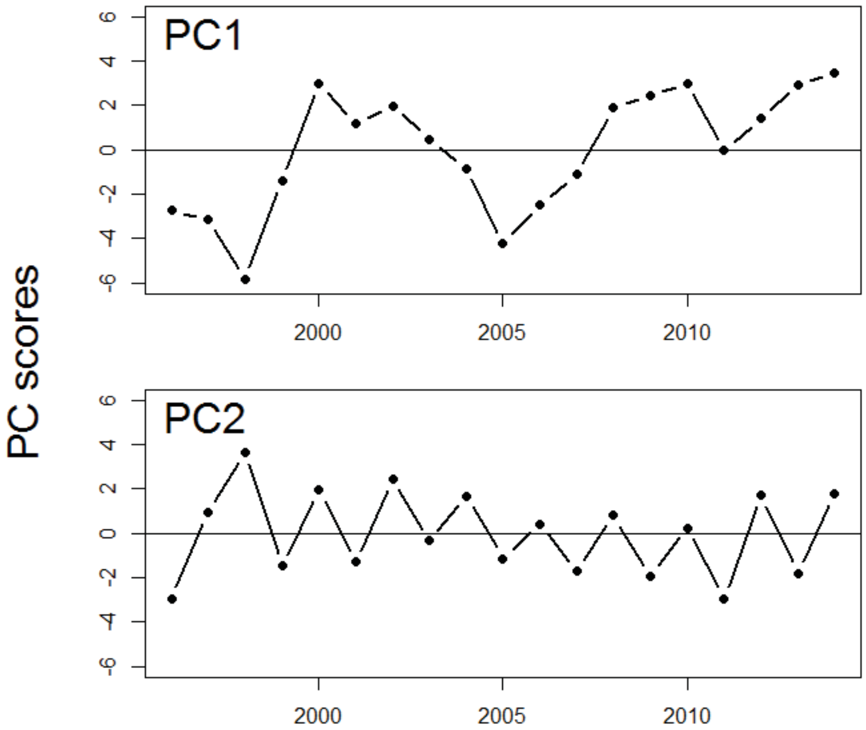

Figure 90: The value of PC1 (top) and PC2 (bottom) over time. Higher values of PC1 indicate earlier seabird hatch dates and higher cormorant and murre reproductive success (except for St. George thick-billed murres). Higher values of PC2 indicate higher kittiwake reproductive success, and to a lesser degree, St. Paul thick-billed murre reproductive success and St. Paul black-legged kittiwake hatch dates.

Factors influencing observed trends: Time series analysis of PC1 and PC2, calculated from 1996-2011 data, against selected environmental variables showed significant, but in most cases, lagged relationships between ocean conditions and seabird reproductive effort (Zador et al., 2013). Warmer bottom and surface temperatures, greater wind mixing and higher stratification correlated with delayed and lower productivity for most seabirds up to 2 years later. Later ice retreat was correlated with lower kittiwake productivity 2 years later, but higher local abundances of age-1 walleye pollock were linked to higher kittiwake productivity the following year. The biennial pattern in PC2 negatively correlates with pink salmon abundance using the reconstructed Kamchatka pink salmon run size through 2012 from (Springer and van Vliet, 2014))($t = 3.5$, $p = 0.003$).

Implications: These results indicate that 2014 was a generally successful year reproductively for Pribilof seabirds. Years of high pink salmon abundance, the odd-numbered years after 1997, correlates with poor kittiwake productivity. This correspondence may be a result of competition between abundant zooplanktivorous pink salmon and kittiwakes or related responses to environmental conditions. The winter distribution of kittiwakes overlaps with the pink salmon in the North Pacific, thus broad-scale environmental exposure may be similar.

These indices can provide fisheries managers with useful information through both their current state (most recent annual index values) and past relationships with environmental conditions. For example, a current index value indicating high reproductive success and/or early breeding that is assumed to be mediated through food supply could indicate better than average recruitment of year classes that seabirds feed on (e.g., age-0 pollock), or better than average supply of forage fish that commercially-fished species feed on (e.g., capelin eaten by both seabirds and Pacific cod). Also, better understanding of past relationships between the seabird indices and environmental conditions could help managers to anticipate ecosystem level effects of varying ecosystem states.

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 stock's 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 2012 and can be downloaded at `http://www.nmfs.noaa.gov/pr/sars/region.htm`.

Steller Sea Lions

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Last updated: October 2010

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

Northern Fur Seals

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Last updated: October 2014

Description of index: Numbers of northern fur seal, *Callorhinus ursinus*, pups were estimated using a mark-recapture method, shear-sampling, on the Pribilof Islands during August 2014. To minimize disturbance, dead pup counts were conducted at 4 sample rookeries on St. Paul Island and 3 sample rookeries on St. George Island. Since 2006 this dead pup counting procedure resulted in a ratio estimation protocol for the calculation of the estimate of the total number of pups born. Adult male northern fur seals on St. Paul and St. George Islands were counted over the period July 7 to 15, 2014.

Status and trends: We estimated 91,737 (SE = 769) pups were born on St. Paul Island and 18,937 (SE = 308,) pups were born on St. George Island. The observed pup mortality rates were 3.0% on St. Paul Island and 2.7% on St. George Island. Pup production was estimated on Sea Lion Rock, a small island approximately 500 m from St. Paul Island in 2014 resulting in an estimate of 5,250 (SE = 293) pups born. The 2014 Sea Lion Rock estimate was 22.1% lower than the previous estimate in 2008. The 2014 pup production estimate for St. Paul Island is 5.2% less than the estimate in 2012 (Figure 91). The 2014 pup production estimate for St. George Island is 17.0% greater than the estimate in 2012. Overall pup production for the Pribilof Islands decreased approximately 2.1% from 2012 to 2014. Since 1998 pup production on St. Paul Island declined 49.0%, or at an annual rate of 4.25% (SE = 0.48), while pup production on the Pribilof Islands (St. Paul and St. George Islands combined) declined 45.0%, or at an annual rate of 3.7% (SE = 0.48).

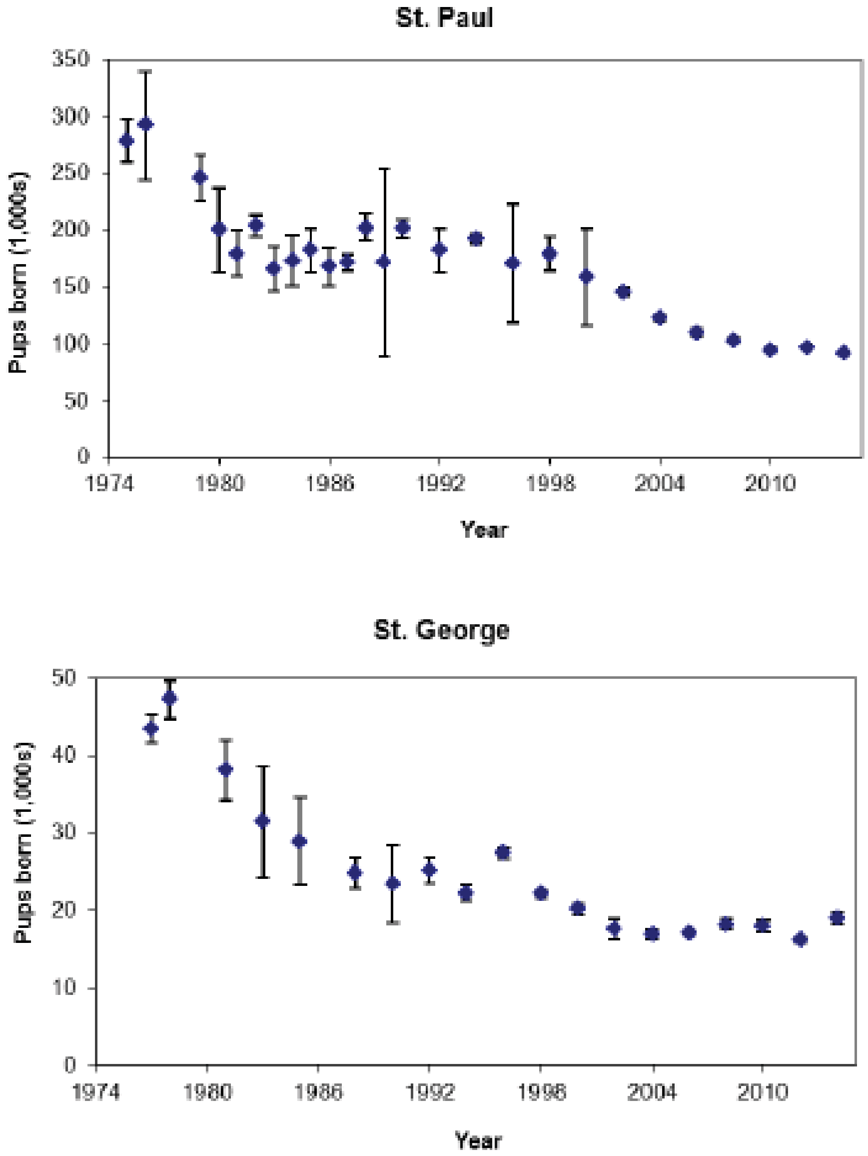

Figure 91: Northern fur seal pups born on the Pribilof Islands 1975-2014. Error bars are approximate 95% confidence intervals. Note that St. Paul Island estimates do not include pups born on Sea Lion Rock.

Counts of territorial males with females (class 3; "harem" males) on St. George Island decreased by 8.1% compared to 2013. Idle males (classes 2 and 5) on St. George Island increased in comparison to 2013 by 21.1%. On St. Paul Island the "harem" males decreased by 11.4% and the idle males decreased by 13.3%. Overall, the total number of adult males counted on the Pribilof Islands in 2014 decreased by 8.8% from 2013 to 8,850. The total number of "harem" males decreased by 10.7% on the Pribilof Islands.

Factors influencing observed trends:

Implications: U

Harbor Seals

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See the contribution archive 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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Bowhead Whales

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

Ecosystem or Community Indicators

Regime shift indicators for the Gulf of Alaska and eastern Bering Sea

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Description of index: The leading principal components (PCs) for 33 biology time series first published by Hare and Mantua (2000) allow community-wide biological variability to be monitored in the Gulf of Alaska and Bering Sea during the years 1965-2012. Too many time series values are missing to estimate PC scores in 2013-2014. In the eastern Bering Sea, the data include commercial catches for all five salmon species, recruitment estimates for ten groundfish species, and jellyfish abundance as measured by the AFSC trawl survey. In the Gulf of Alaska, the data include ten time series of commercial salmon catches (all five species, each divided between central and Southeast Alaska), recruitment estimates for seven groundfish species, and shrimp abundance as estimated by the ADF&G small-mesh survey. Salmon catches are log-transformed and lagged to year of ocean entry, and groundfish recruitment estimates are log-transformed and lagged to cohort year. In a change from previous contributions, the data are analyzed separately for the two ecosystems. In the Bering Sea, the first three PCs appear to summarize interpretable information (PC1 = 24% of total variance, PC2 = 18%, PC3 = 16%). In the Gulf of Alaska, only PC1 appears to be interpretable (47% of total variance).

Sequential t-test analysis of regime shifts (STARS, Rodionov 2006) was used to test for recent changes in time series of each PC score, with = 0.05, L (length of proposed regimes) = 15 years, H (Huber weight parameter) = 6 standard deviations and autocorrelation accounted for with the IP4N method (subsample length = 5 years). Climate state is indexed with winter (NDJFM) sea surface temperature (SST) data from the HadISST data set (`http://www.metoffice.gov.uk/hadobs/hadisst/`).

Status and trends: During 2006-2012, winter SST in each ecosystem reached low values not observed since before the 1976/77 Pacific Decadal Oscillation (PDO) shift (Figure 92). PC1 scores showed a transition to negative values in the Bering Sea around 2009 (Figure 93, $p < 0.0001$), and a transition to lower-magnitude positive values in the Gulf of Alaska around 2006 (Figure 94, $p = 0.03$). No persistent changes were observed during the last two decades in Bering Sea PC2-3. For a summary of the individual time series associated with PC scores, see Figures 93 and 94.

Factors influencing observed trends: Variability in PC1 (and possibly subsequent axes) appears to be related to climate variability and climate change (Hare and Mantua, 2000; **?**). Recent PC1 scores in both ecosystems show a linear relationship with winter SST (Figure 95). However, the community response to SST variability since the onset of cold temperatures around 2006 has been of a smaller magnitude than the non-linear response observed across the 1976/77 PDO shift. In other words, SST-PC1 relationships appear to follow time-dependent functions in both ecosystems (Figure 95).

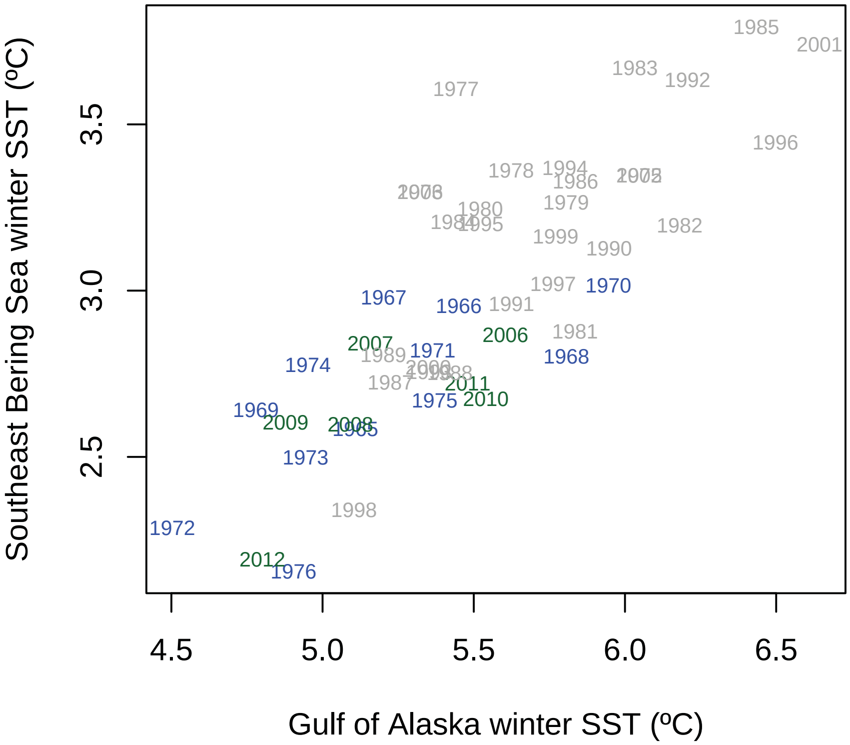

Figure 92: Winter (NDJFM) SST for the Gulf of Alaska and southeastern Bering Sea, 1965-2012. Recent years (2006-2012, green) and years prior to the 1976/77 PDO shift (1965-1976, blue) are highlighted for comparison.

Implications: Enough years of observation are now available following the onset of cold conditions around 2006 to make reasonably strong inferences about the nature of community response. While the leading axes of variability in Gulf of Alaska and Bering Sea communities appear to have responded to recent changes in climate, the magnitude of community response is much less than the highly disruptive changes to ecosystems and fisheries observed following 1976/77. The reasons for the apparently modest biological response to extremely cold conditions are unknown. Possibilities include resilience in the community state dominated by high-trophic level groundfish and salmon (**?**) and declining strength in correlations between SST and other ecologically important climate parameters (M. Litzow, unpublished results).

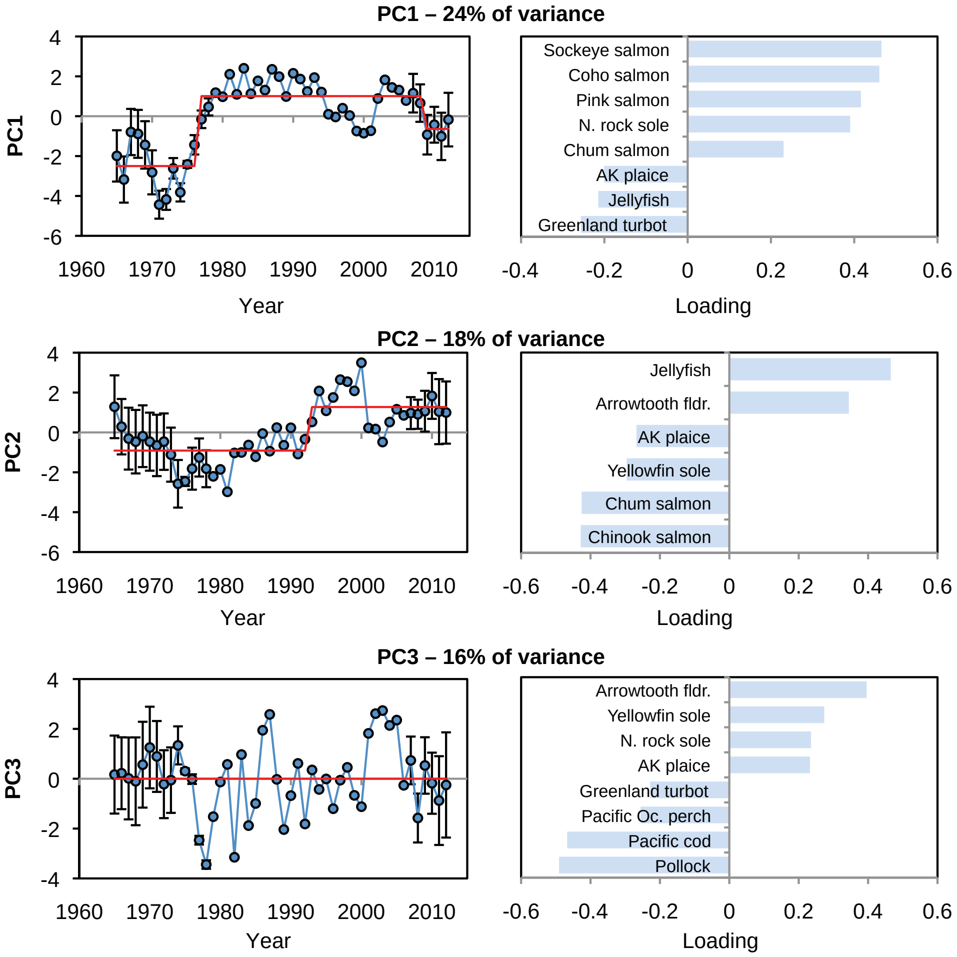

Figure 93: Time series and loadings for PC1-3 in southeast Bering Sea biological time series. Dots in left-hand panels indicate annual values, with error bars = 95% CI, reflecting uncertainty associated with estimating missing values. Red lines indicate mean values of regimes defined by STARS. Bars in right-hand columns indicate loadings for taxa most strongly associated with each PC (absolute values > 0.2).

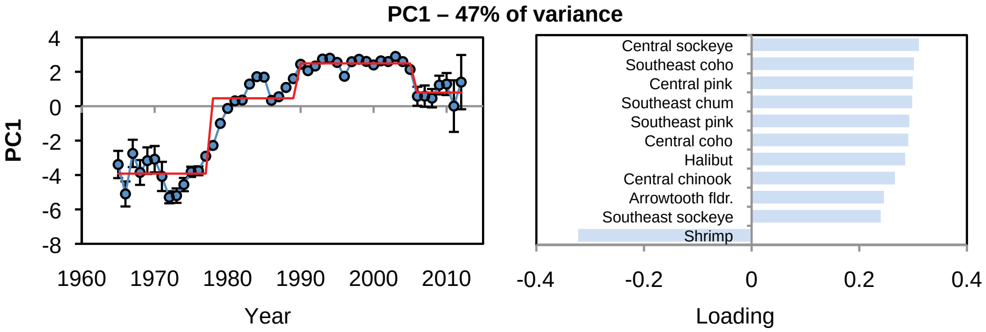

Figure 94: Time series and loadings for PC1 in Gulf of Alaska biological time series. Dots in left-hand panels indicate annual values, with error bars = 95% CI, reflecting uncertainty associated with estimating missing values. Red line indicates mean values of regimes defined by STARS. Bars in right-hand columns indicate loadings for taxa most strongly associated with PC1 (absolute values > 0.2).

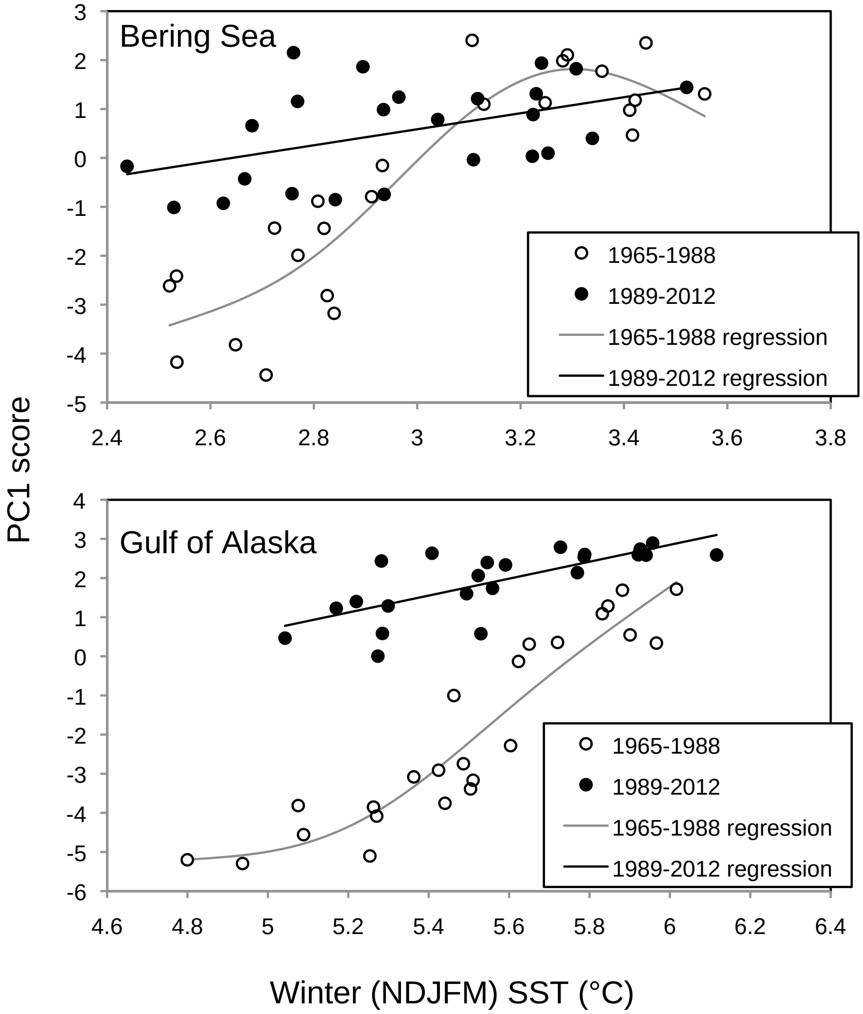

Figure 95: Time-dependent climate-biology relationships in the Bering Sea and Gulf of Alaska: SST-PC1 relationships before and after 1988/89 climate shift (Hare and Mantua, 2000). Regressions are best non-parametric models, with smoothing limited to ≤ 3 effective degrees of freedom. SST values are 3-yr running means.

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

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

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

Average Local Species Richness and Diversity of the Groundfish Community

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Combined Standardized Indices of Recruitment and Survival Rate

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Spatial Distribution of Groundfish Stocks in the Eastern Bering Sea

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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.

Maintaining Diversity: Discards and Non-Target Catch

Time Trends in Groundfish Discards

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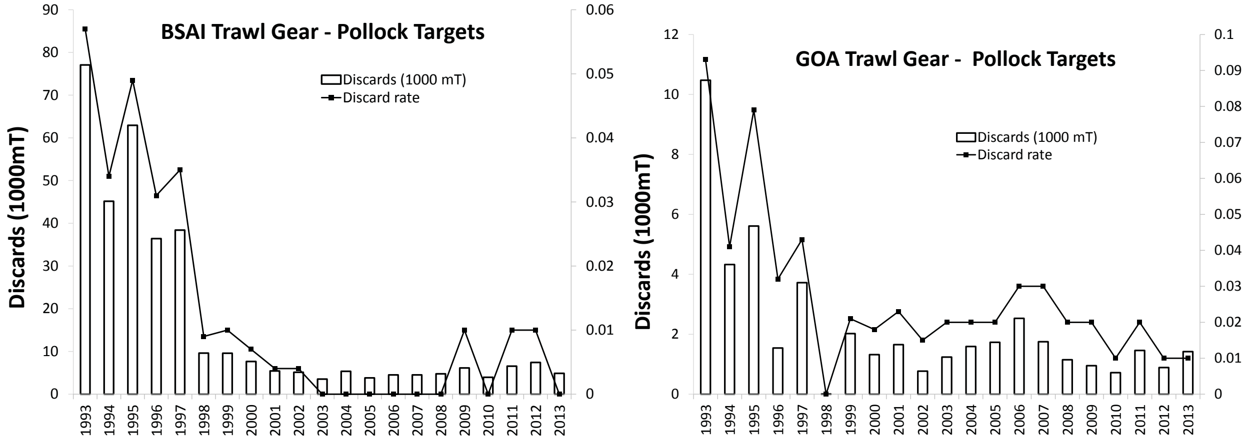
Description of index: Estimates of discards for 1994-2002 are sourced from NMFS Alaska Region's blend data, while estimates for 2003 and later come from the Alaska Region's catch-accounting system. Although these sources provide the best available estimates of discards, the estimates are not necessarily accurate because they are based on visual observations by observers rather than data from direct sampling. Beginning in 2013, the catch-accounting system includes estimates of groundfish discards in the fixed gear Pacific halibut fishery. As such, 2013 values are not directly comparable to values from prior years, particularly in the GOA fixed gear sector where the halibut fishery is primarily prosecuted.

Status and trends: Since 1993, discard rates of managed groundfish species in federally-managed Alaskan groundfish fisheries have generally declined in the trawl pollock fisheries in both the Bering

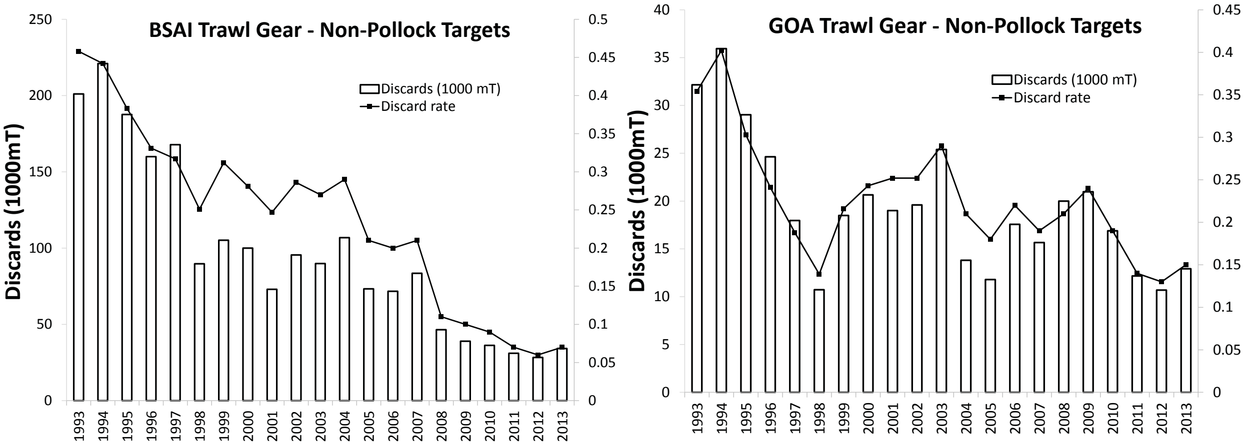
Sea/Aleutian Islands (BSAI) and the Gulf of Alaska (GOA), as well as in the BSAI non-pollock trawl sector (Figure 96). In the GOA non-pollock trawl sector, discard rates dropped from 40% in 1994 to less than 15% in 1998, trended upwards from 1998 to 2003, and have generally declined over the last ten years. Discard rates in the BSAI fixed gear sector fell from around 20% in 1993 to 12% in 1996, and since then have generally fluctuated between 10% and 14%. Rates in the GOA fixed gear sector over the most recent 20 years for which data are available have varied between a high of 15% in 1993 to a low of 1% in 1998.

Factors influencing observed trends: Improved-retention regulations implemented in 1998 prohibiting discards of pollock and Pacific cod help account for the sharp declines in discard rates in the GOA and BSAI trawl pollock fisheries after 1997. Discard rates in the BSAI non-pollock trawl sector had a similar decline in 2008 following implementation of a groundfish retention standard for the trawl head-and-gut fleet. Improved observer coverage on vessels less than 60' long and on vessels targeting IFQ halibut may account for the increase in the volume of discards in the GOA fixed gear sector in 2013.

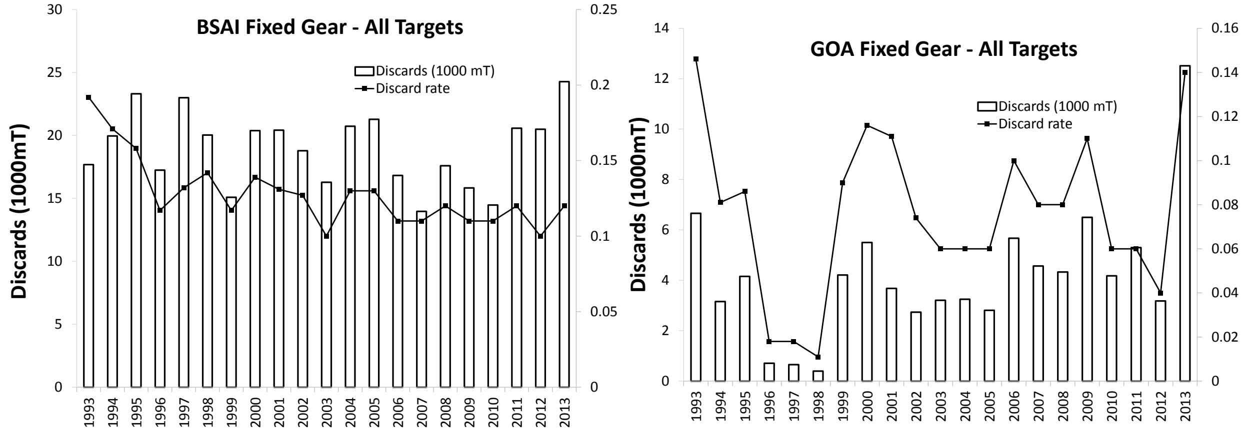
Implications: Discards add to the total human impact on the biomass without providing a benefit to the Nation.



(a) EBS (b) GOA



(c) EBS (d) GOA



(e) EBS (f) GOA

Figure 96: Total biomass and percent of total catch biomass of managed groundfish discarded in the BSAI and GOA fixed gear, pollock trawl, and non-pollock trawl sectors, 1993-2013. (Includes only catch counted against federal TACS)

Time Trends in Non-Target Species Catch

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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. In previous years we included the catch of "other" species, "non-specified" species, and forage fish in this contribution. However, stock assessments have now been developed or are under development for all groups in the "other species" category (sculpins, unidentified sharks, salmon sharks, dogfish, sleeper sharks, skates, octopus, squid), some of the species in the "non-specified" group (giant grenadier, other grenadiers), and forage fish (e.g., capelin, eulachon, Pacific sandlance, etc.), therefore we no longer include trends for these species/groups here (see AFSC stock assessment website at `http://www.afsc.noaa.gov/refm/stocks/assessments.htm`). Starting with the 2013 Ecosystem Considerations Report, the three categories of non-target species we continue to track here are:

1. Scyphozoan jellyfish
2. species associated with Habitat Areas of Particular Concern-HAPC species (seapens/whips, sponges, anemones, corals, tunicates)
3. Assorted invertebrates (bivalves, brittle stars, hermit crabs, miscellaneous crabs, sea stars, marine worms, snails, sea urchins, sand dollars, sea cucumbers, and other miscellaneous invertebrates).

Total catch of non-target 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. Catch since 2003 has been estimated using the Alaska Region's Catch Accounting System. 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.

Status and trends: The catch of all three non-target species groups has been highest in the EBS (Figure 97). Scyphozoan jellyfish catches in the GOA are two orders of magnitude lower than the EBS and three orders of magnitude lower in the AI. Catches of HAPC biota are intermediate in the AI and lowest in the GOA. The catches of assorted invertebrates in the EBS are about twice the catch in the GOA. The catch of assorted invertebrates is lowest in the AI.

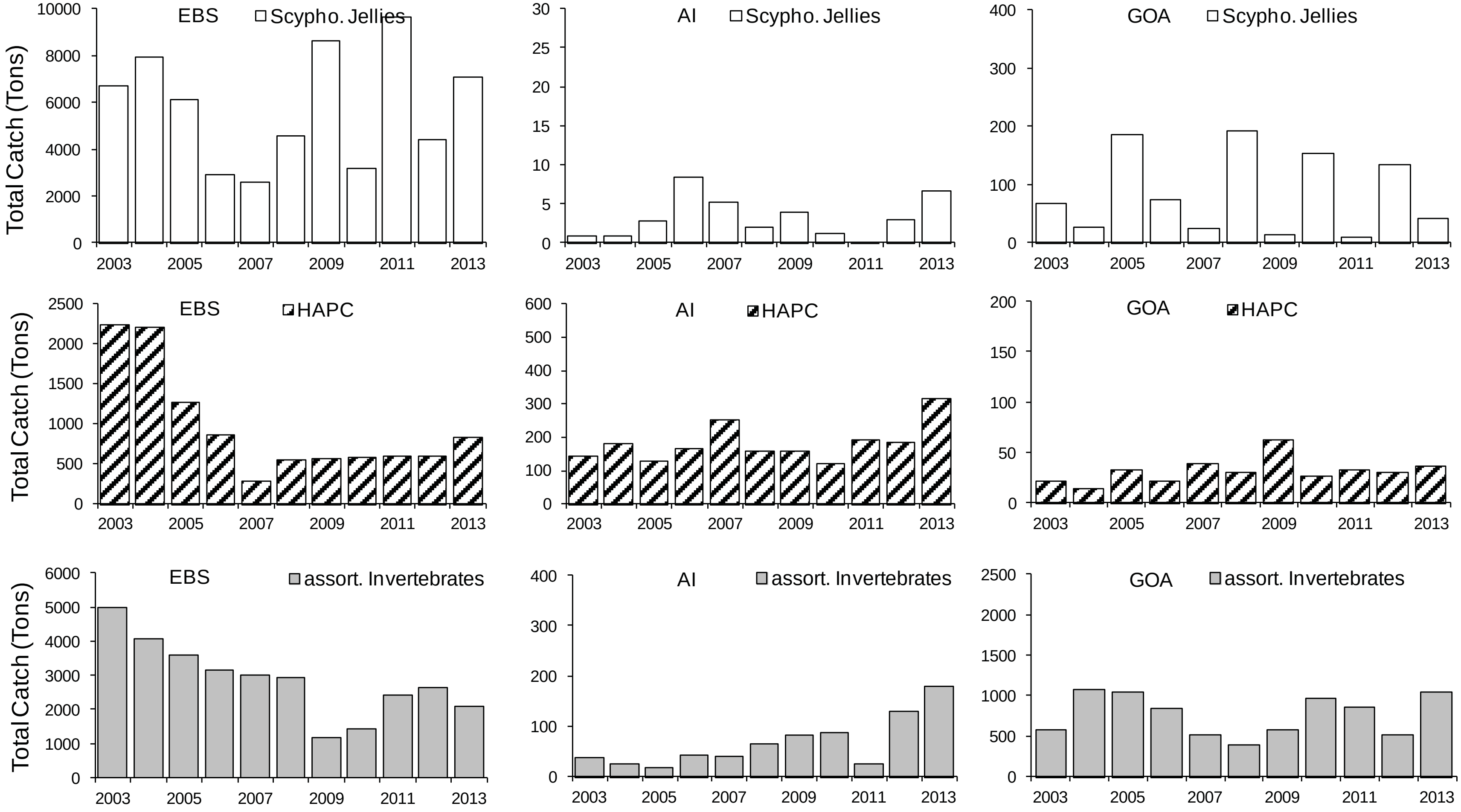

Figure 97: Total catch of non-target species (tons) in the EBS, AI, and GOA groundfish fisheries (2003-2013). **Please note the different y-axis scales** between regions and species groups.

In the EBS, the catch of Scyphozoan jellyfish has fluctuated over the last ten years with a peak in 2011, followed by a sharp drop to an intermediate level in 2012. The catch of jellyfish increased 59% from 2012 to 2013. Jellyfish are primarily caught in the pollock fishery. HAPC biota catch decreased from 2003 to 2007 and has been generally steady since. Benthic urochordata, caught mainly by the flatfish fishery, comprised the majority of HAPC biota catches in the EBS from 2003 through 2008, From 2009-2013, benthic urochordata accounted for most of the HAPC catch except for 2011 when it was surpassed by sponges and 2013 when it was surpassed by sea anemones. Sea stars dominate the catch of assorted invertebrates in all years (2003-2013) and are primarily caught in flatfish fisheries.

In the AI, the catch of Scyphozoan jellyfish has been variable and shows no apparent trend over time. The catch in 2013 is the second highest since 2003. HAPC catch has been variable over time in the AI and peaked in 2013. The HAPC catch is driven primarily by sponges caught in the trawl fisheries for Atka mackerel, rockfish and cod. Assorted invertebrate catches have generally trended upward from 2005 to a peak in 2013, with the exception of 2011 where the catch dropped back to nearly the 2005 level. Over that same span the assorted invertebrate catch has been dominated by sea stars and unidentified invertebrates. Assorted invertebrates are primarily caught in the trawl fisheries for Atka mackerel, cod, and rockfish.

The catch of Scyphozoan jellyfish in the GOA has been variable from 2003-2013. Since 2007, the catch of Scyphozoan jellies has alternated between years of low (odd years) to relatively higher catches (even years). The 2013 catch follows this pattern, and is a substantial drop from the 2012 catch. Scyphozoan jellyfish are primarily caught in the pollock 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 assorted invertebrates has been variable and shown little trend. Sea stars are caught primarily in the cod pot fishery and have dominated the assorted invertebrate catch, accounting for more than 90% of the total in each year. The catch of assorted invertebrates in 2013 was nearly double the catch in 2012, and was the third highest over the time period 2003-2013.

Factors influencing observed trends: The catch of non-target species may change if fisheries change, if ecosystems change, or both. Because non-target 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 non-target catch may indicate ecosystem changes. Catch trends may be driven by changes in biomass or changes in distribution (overlap with the fishery) or both.

Implications: The catch of HAPC species and assorted invertebrates in all three ecosystems is very low compared with the catch of target species. HAPC species may have become less available to the EBS fisheries (or the fisheries avoided them more effectively) since 2005. The interannual variation and lack of a clear trend in the catch of scyphozoan jellyfish in all three ecosystems may reflect interannual variation in jellyfish biomass or changes in the overlap with fisheries.

Seabird Bycatch Estimates for Alaskan Groundfish Fisheries, 1993-2013

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Last updated: August 2014

Description of index: This report provides estimates of the numbers 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 2013. Fishing gear types represented are demersal longline, pot, pelagic trawl, and non-pelagic trawl. These numbers do not apply to gillnet, seine, or troll fisheries. Data collection on the Pacific halibut longline fishery began in 2013 with the restructured observer program, although some small amounts of halibut fishery information were collected in years previous when an operator had both halibut and sablefish individual fishing quota.

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 (, AFSC), and (2) industry reports of catch and production. The AFSC produced the estimates from 1993-2006 (Fitzgerald et al., 2008). The NMFS Alaska Regional Office Catch Accounting System (CAS) produced the estimates from 2007-2013 (Cahalan et al., 2010). The main purpose of the CAS is to provide near real-time delivery of accurate groundfish and prohibited species catch and bycatch information for inseason management decisions. It is also used for the provision of estimates of non-target species (such as invertebrates) and seabird bycatch in the groundfish fisheries. At each data run, the CAS produces estimates based on current data sets, which may have changed over time. Changes in the data are due to errors that were discovered during observer debriefing, data quality checks, and analysis. Examples of the possible changes in the underlying data are: changes in species identification; deletion of data sets where data collection protocols were not properly followed; or changes in the landing or at-sea production reports where data entry errors were found.

Status and trends: Figure 98 depicts seabird bycatch in the groundfish fisheries from 1993 through 2013 using results from the two analytical methods noted above. The 2013 estimated numbers for the combined groundfish fisheries are the lowest since we began estimating bycatch in 1993. Since we implemented the CAS (Table 10) the 2013 estimates are 62% of the running 5-year average for 2008-2012 of 7,558 birds and are the lowest total since we began using the CAS in 2007.

While the fisheries achieved the lowest overall seabird bycatch since 1993, albatross bycatch increased in 2013 to 438 birds (249 black-foots and 189 Laysan), an increase of 25% compared to the previous 5 year average of 350. The 2013 numbers included the halibut fishery where previous years did not. However, the increase in albatross bycatch in the sablefish fisheries(>100) surpassed the new contribution from the halibut fishery (53 birds) while other fisheries (cod freezer longline) experienced reduced albatross bycatch numbers. Overall, Laysan albatross (*Phoebastria immutabilis*) bycatch increase by 40% and black-footed albatross (*P. nigripes*) increased by 70%. Although the black-footed albatross is not endangered (unlike its relative, the short-tailed albatross), it is considered a Bird of Conservation Concern by the U.S. Fish and Wildlife Service. This designation means that without additional conservation actions, these birds of concern are likely to become candidates for listing under the Endangered Species Act. Of special interest is the endangered short-tailed albatross (*Phoebastria albatrus*). Since 2003, bycatch estimates were above zero only in 2010 and 2011, when 2 birds and 1 bird were incidentally hooked respectively, resulting in estimated takes of 15 and 5 birds. This incidental take occurred in the Bering Sea area. No observed takes occurred in 2012 or 2013.

Northern fulmar (*Fulmaris glacialis*) bycatch remained the highest proportion in the catch at 69%. Fulmar bycatch increased by 8% from the year before but remained 30% below the 5-year average.

Fulmar bycatch has ranged between 45 to 76% of the total seabird bycatch since 2007. Average annual mortality for fulmars since 2007 has been 4,472. When compared to estimates of the total population size in Alaska of 1.4 million (Denlinger, 2006), this represents an annual 0.33% mortality due to fisheries. However, there is some concern that the mortality could be colony-specific possibly leading to local depletions (Hatch et al., 2010).

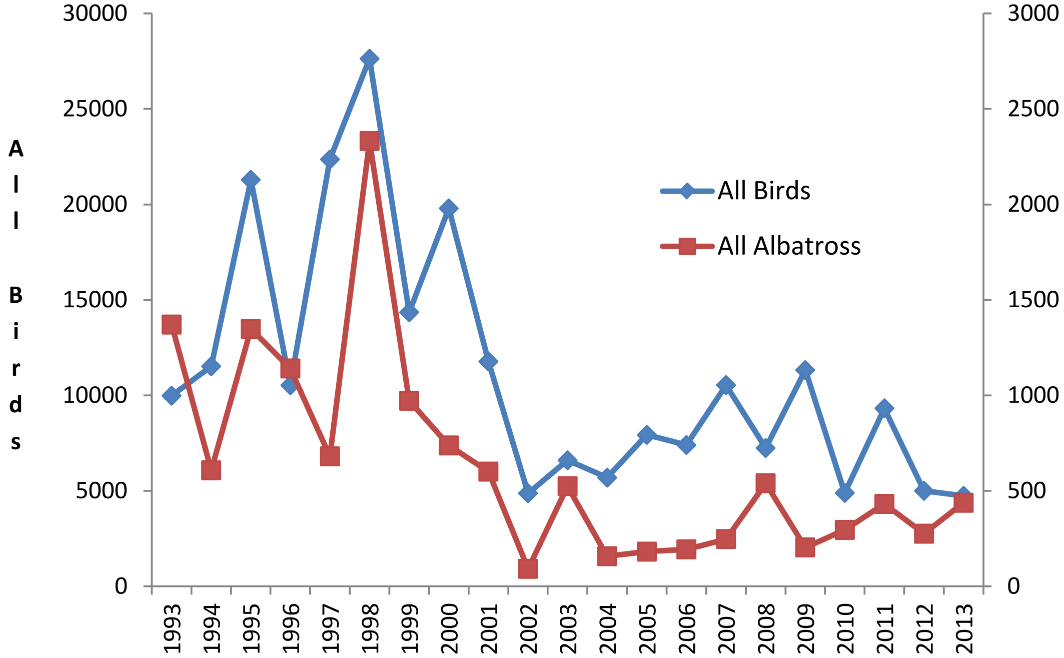

Figure 98: Seabird bycatch in Alaskan groundfish fisheries, all gear types combined, 1993 to 2013. Total estimated bird numbers are shown in the left-hand axis while estimated albatross numbers are shown in the right-hand axis

The demersal longline fishery in Alaska typically drives the overall estimated bycatch trends (but see comment regarding trawl estimates below). Bycatch in the longline fishery showed a marked decline beginning in 2002 due to the deployment of streamer lines as bird deterrents. Since then, annual bycatch has remained below 10,000 birds, dropping as low as 4,007 in 2010. Numbers increased to 8,940 in 2011, the second highest in the streamer line era, but fell back to 4,571 in 2012 and furthur decreased to 4,246 in 2013. The increased numbers in 2011 were due to a doubling of the gull (Larus spp) numbers (1,088 to 2,157) and a 3-fold increase in fulmars, from 1,882 to 5,848. These species group numbers have decreased in 2012 as well, to 553 and 2,795 respectively. The addition of observers to many vessels in the Gulf of Alaska contributed important data for our understanding of seabird bycatch patterns and quantities. Note that in the year an entire fishery (halibut) was added the overall estimated seabird bycatch was the lowest ever, even while albatross bycatch increased, as was expected. The GOA typically accounts for few numbers of birds in most species groups except albatross.

Factors influencing observed trends: The marked decline in overall numbers of birds caught after 2002 (Figure 98) reflects the increased use of seabird mitigation devices. A large portion of the freezer longline fleet adopted these measures in 2002, followed by regulation requiring them for the rest of the fleet beginning in February 2004. There are many factors that may influence annual variation in bycatch rates, including seabird distribution, population trends, prey supply,

Table 10: Total **estimated** seabird bycatch in Alaskan groundfish fisheries, all gear types and Fishery Management Plan areas combined, 2007 through 2013. Note that these numbers represent extrapolations from observed bycatch, not direct observations. See text for estimation methods.

Species/Species Group	2007	2008	2009	2010	2011	2012	2013
Unidentified Albatross	17	0	0	0	0	0	0
Short-tailed Albatross	0	0	0	15	5	0	0
Black-footed Albatross	200	314	56	48	221	141	249
Laysan Albatross	17	226	148	233	206	135	189
Northern Fulmar	4700	3334	8199	2452	6214	3022	3268
Shearwaters	3586	1224	620	653	194	514	191
Storm Petrels	1	44	0	0	0	0	0
Gull	1345	1551	1335	1145	2158	890	556
Kittiwake	10	0	16	0	6	5	3
Murre	6	6	13	102	14	6	3
Puffin	0	0	0	5	0	0	0
Auklets	0	3	0	0	0	7	4
Other Alcid	0	0	105	0	0	0	0
Other	0	0	136	0	0	0	0
Unidentified	514	541	696	240	306	285	267
Grand Total	10397	7243	11323	4894	9324	5005	4731

and fisheries activities. Work has continued on developing new and refining existing mitigation gear (Dietrich and Melvin, 2008).

The longline fleet has traditionally been responsible for about 91% of the overall seabird bycatch in Alaska, as determined from the data sources noted above. However, standard observer sampling methods on trawl vessels do not account for additional mortalities from net entanglements, cable strikes, and other sources. Thus, the trawl estimates are biased low (Fitzgerald et al., in prep). For example, the 2010 estimate of trawl-related seabird mortality is 823, while the additional observed mortalities (not included in this estimate and not expanded to the fleet) were 112. Observers now record the additional mortalities they see on trawl vessels and the AFSC Seabird Program is seeking funds to support an analyst to work on how these additional numbers can be folded into an overall estimate. The challenge to further reduce seabird bycatch is great given the rare nature of the event. For example, Dietrich and Fitzgerald (2010) found in an analysis of 35,270 longline sets from 2004 to 2007 that the most predominant species, northern fulmar, only occurred in 2.5 of all sets. Albatross, a focal species for conservation efforts, occurred in less than 0.1 of sets. However, given the vast size of the fishery, the total bycatch can add up to hundreds of albatross or thousands of fulmars (Table 10).

Implications: There seems to be a generally decreasing trend in seabird bycatch since the new estimation procedures began in 2007, indicating no immediate management concern other than continuing our goal of decreased seabird bycatch. It is difficult to determine how seabird bycatch numbers and trends are linked to changes in ecosystem components because seabird mitigation gear is used in the longline fleet. There does appear to be a link between poor ocean conditions and the peak bycatch years, on a species-group basis. Fishermen have noted in some years that the birds appear “starved” and attack baited longline gear more aggressively. In 2008 general seabird bycatch in Alaska was at relatively low levels (driven by lower fulmar and gull bycatch) but albatross numbers were the highest at any time between 2002 and 2013. This could indicate poor ocean conditions in the North Pacific as albatross traveled from the Hawaiian Islands to Alaska. Broad changes in overall seabird bycatch, up to 5,000 birds per year, occurred between 2007 and 2013. This probably indicates changes in food availability rather than drastic changes in how well the fleet employs mitigation gear. A focused investigation of this aspect of seabird bycatch is needed and could inform management of poor ocean conditions if seabird bycatch rates (reported in real time) were substantially higher than normal.

Maintaining and Restoring Fish Habitats

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

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Last updated: August 2013

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 99, Table 11) 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.

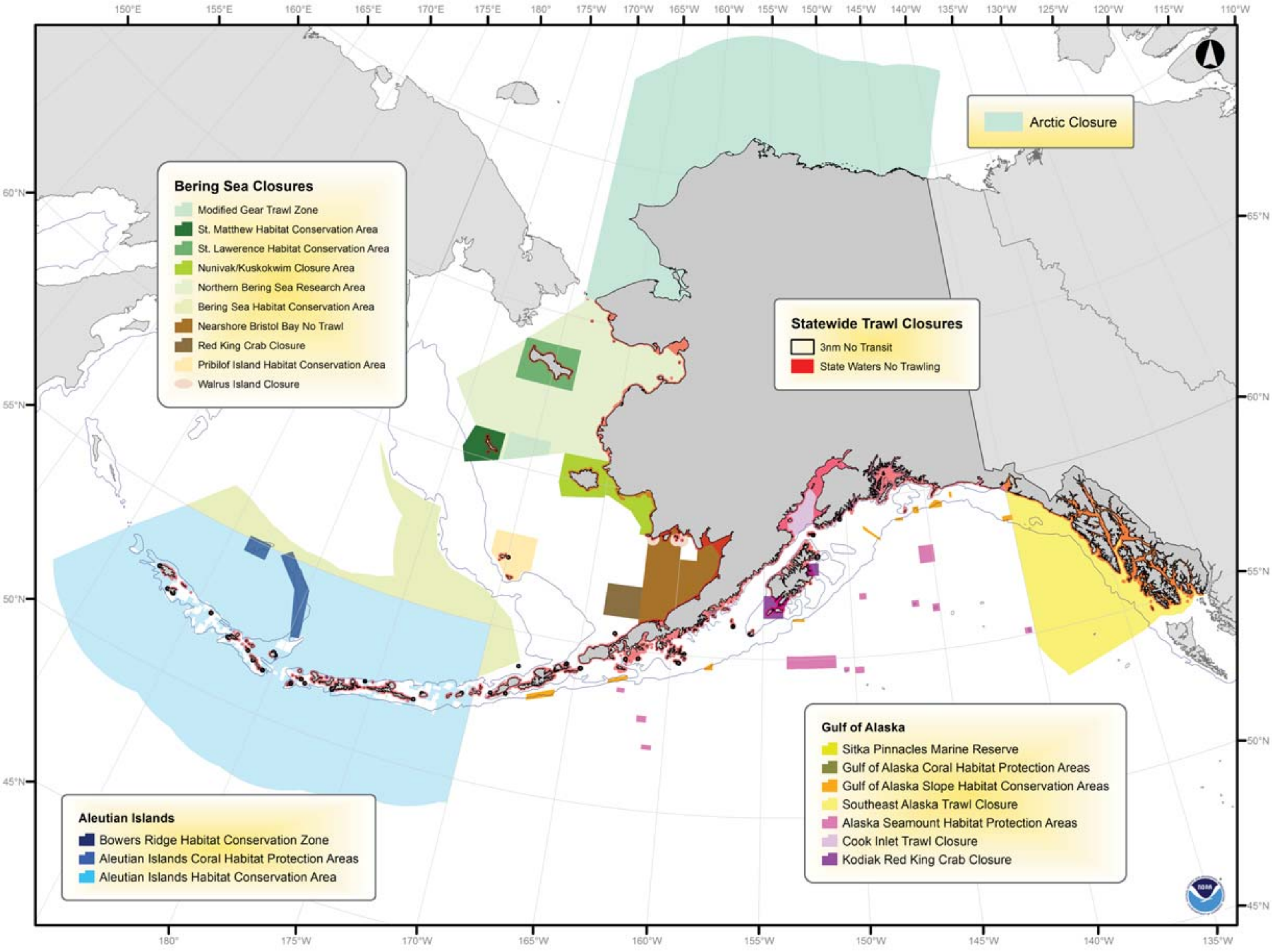

Figure 99: Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska, excluding most SSL closures.

Table 11: Groundfish trawl closure areas, 1995-2009. License Limitation Program (LLP); Habitat Conservation Area (HCA); Habitat conservation zone (HCZ).

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

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 nm^2 of the Exclusive Economic Zone (EEZ) of Alaska was closed to trawling year-round. Additionally, 40,000 nm^2 were closed on a seasonal basis. State waters (0-3 nmi) are also closed to bottom trawling in most areas. 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) as well as longlining for Pacific cod in early 2011 as part of mitigation measures for Steller sea lions. Management area 543 and large sections of 542 are included in this closure.

In 2013, the Council adopted six Areas of Skate Egg Concentrations has Habitat Areas of Particular Concern. No management measures or closures are associated with these HAPCs.

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

For additional background on fishery closures in the U.S. EEZ off Alaska, see (Witherell and Woodby, 2005).

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`

Area Disturbed by Trawl Fishing Gear in the Eastern Bering Sea

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Last updated: June 2014

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 1990-2013. 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 228 minutes (no more than 5% of hauls in any given year needed this adjustment).

An upper limit of the total area potentially disturbed by trawl hauls was estimated by assuming that no trawl hauls overlapped spatially. To find the percent disturbed, it was necessary to find the total area of the Eastern Bering Sea being considered (Figure 100a). 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 100b).

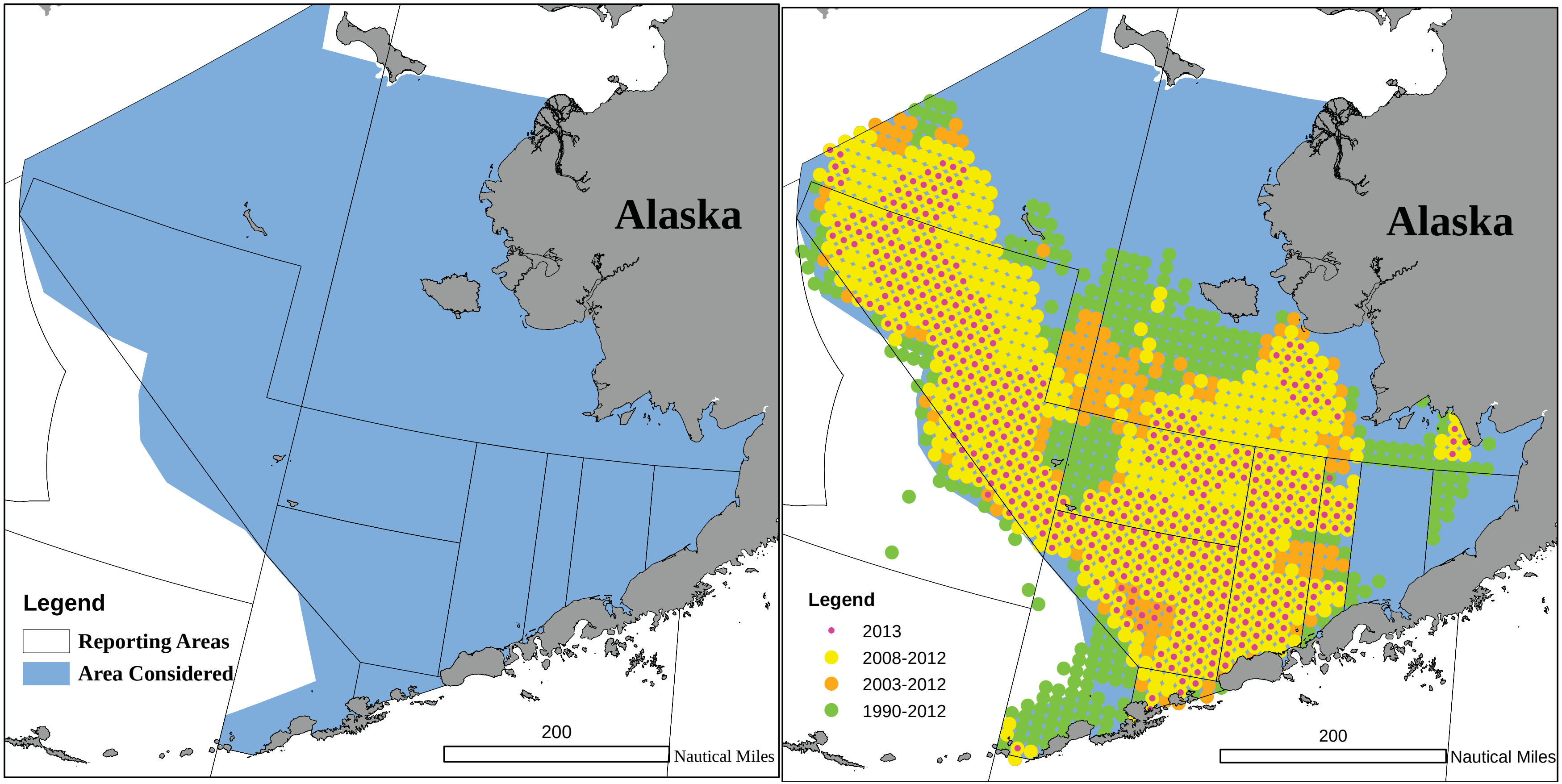

Figure 100: (a) Map of Eastern Bering Sea area considered when estimating percent area potentially disturbed by trawl fishing gear. (b) Map of 400 square kilometer cells with some trawling in cumulative time periods. Cells with fewer than 3 vessels are not shown

Status and Trends: The maximum total area of seafloor in the Eastern Bering Sea potentially disturbed by trawls in 2013 was 94,975 km^2. This estimate varied around 120,000 km^2 in the 1990s and decreased in the late 1990s to approximately 90,000 km^2. The area disturbed has remained relatively stable since then with the exception of declines in 2009 and 2010 and a sharp increase in 2011. The percent of total area disturbed varied between 12% and 20% in the 1990s and less than 15% 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. The exceptions to this trend are an increase with non-pelagic gear in 2008 and an increase in pelagic gear in 2011. Reduction in the 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 from 2000 onward, 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 101).

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 figure was recalculated making no distinction between gears. The result showed no change to the trend. The sharp uptick in potential area disturbed in 2011 may reflect increased search time for pollock, an increase in pollock quota, and/or avoidance of salmon bycatch. Short-wiring was only identified in the database from 1995 onward, however short-wiring accounts for only 2% of the total hauls and does not explain the early 1990 trends.

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

Observed Fishing Effort in the Eastern Bering Sea

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
Contact: john.v.olson@noaa.gov
Last updated: August 2014

Description of index: Observed fishing effort is used as an indicator of total fishing effort. It should be noted, however, that many all fishing effort is not observed. Previously, catcher vessels under 60' were not observed and vessels between 60'-125 required 30% observer coverage. Starting in January 2013, a restructured observer system was implemented whereby all sectors of the groundfish fishery, including vessels less than 60' and the commercial halibut sector would be observed. NMFS now has the flexibility to decide when and where to deploy observers based on a scientifically defensible deployment plan. More information is available `http://alaskafisheries.noaa.gov/sustainablefisheries/observers/`.

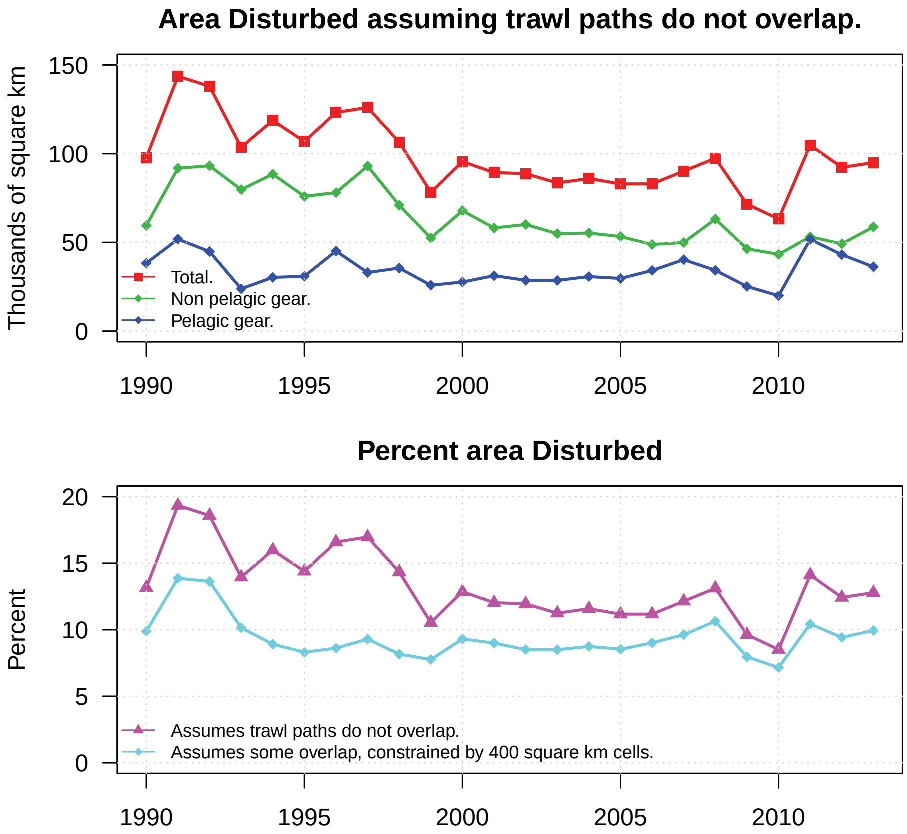

Figure 101: Total maximum potential area disturbed (assuming no spatial overlap of trawls), and the percent area disturbed. The green line, representing percent area disturbed, sums the area disturbed assuming no spatial overlap of trawl hauls in a year, thus providing an upper limit to the estimate 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.

Longline fishing effort is measured by the number of observed longline sets. 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 and catcher-processor vessels. Pelagic trawl fishing effort is measured by the number of observed tows. This fishery is prosecuted with towed pelagic trawls. Gear components which may interact with benthic habitat include the trawl sweeps and footrope. The fishery is prosecuted with both catcher and catcher-processor vessels. Non-pelagic trawl fishing effort is measured by the number of observed tows. This fishery is prosecuted with towed non-pelagic trawls. Gear components which may interact with benthic habitat include the trawl doors, sweeps, and footropes. The fishery is prosecuted with both catcher and catcher-processor vessels. Pot fishing effort is measured by the number of observed pot lifts. This fishery is prosecuted with set pots, which are generally converted from crab pots with triggers. Gear components which may interact with benthic habitat include the pot. The fishery is prosecuted with catcher vessels.

Status and trends: Effort in the longline, pelagic trawl, non-pelagic trawl, and pot fisheries in the eastern Bering Sea is shown in Figure 102.

Longline. For the period 2003-2012, there were a total of 133,338 observed longline sets in the

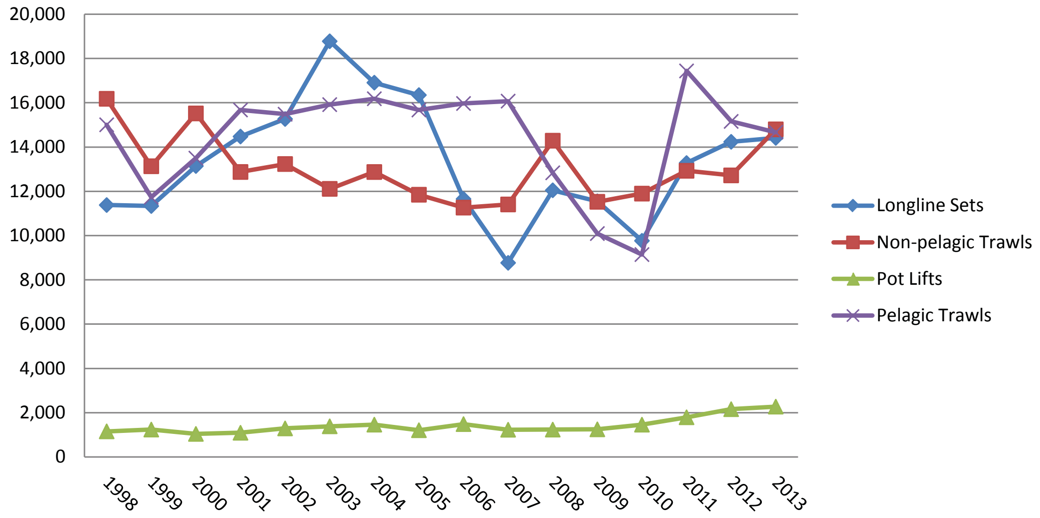

Figure 102: Bering Sea observed fishing effort, 1990-2013.

Bering Sea fisheries. Spatial patterns of fishing effort were summarized on a 10 km^2 grid (Figure 103). During 2012, the amount of observed longline effort was 14,237 sets, which represents an increase over 2011 and is slightly above the 10-year average for the fishery. Areas of high fishing effort are to the north and west of Unimak Island, the shelf edge represented by the boundary of report area 521, and to the south and west of St. George and St. Paul Islands. This fishery occurs mainly for Pacific cod, Greenland turbot, and sablefish. In 2012, fishing effort was anomalously high to the north of Unimak Island, with other areas to the west of St. George and north of Zhemchug Canyon also showing small localized increases (Figure 104).

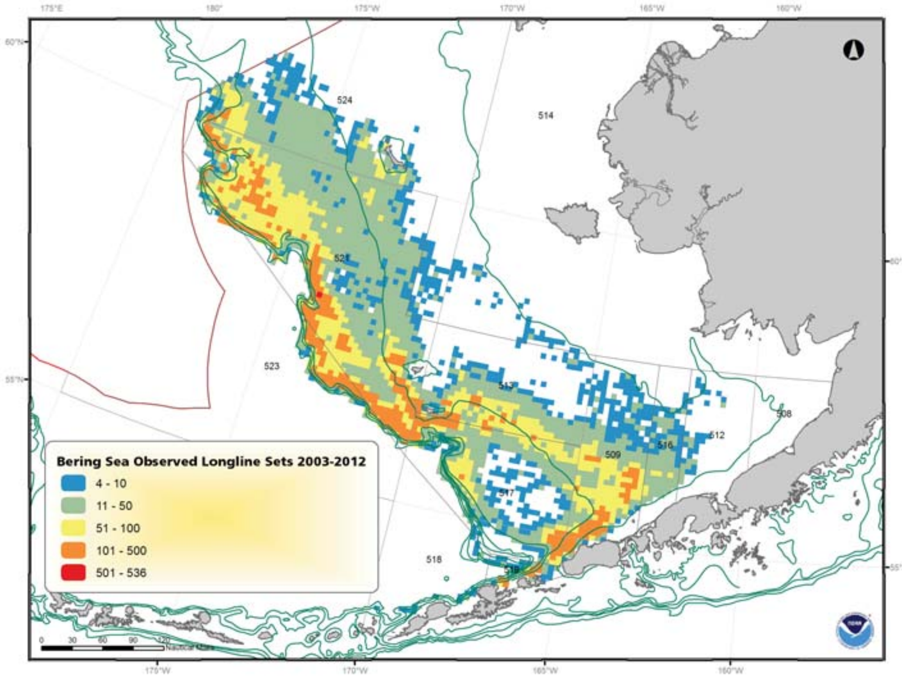

Figure 103: Observed longline effort (sets) in the Bering Sea 2003-2013.

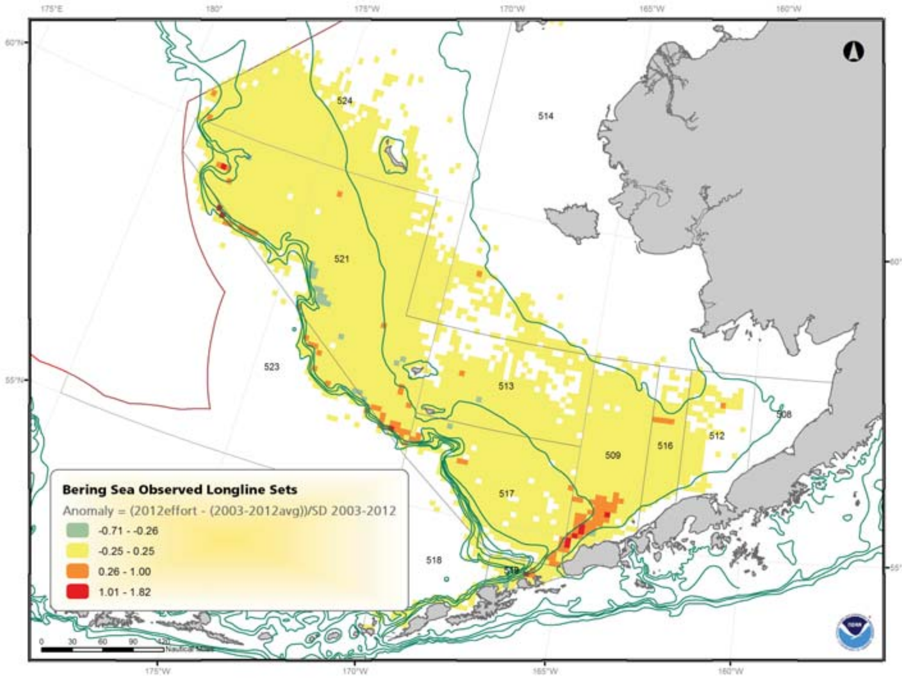

Figure 104: Observed longline fishing effort in 2011 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (observed effort for 2013 - average observed effort from 2003-2013)/stdev(effort from 2003-2013).

Pelagic trawl. For the period 2003-2012 there were 144,486 observed pelagic trawl tows in the Bering Sea (Figure 105). There were 15,159 observed tows in 2012, which is just slightly higher than the 10-year average and a decrease from 2011. Areas of high fishing effort are north of Unimak Island and between the 100 and 200m contours in management areas 509, 513, 517, 519, and 521. 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. Pollock occur on the sea bottom, the midwater and up to the surface. Most catch of pollock is taken at 50-300m. In 2012, fishing effort was slightly higher than normal north of Unimak Island, an area of normally high fishing effort (Figure 106). Increased fishing effort also occurred to the southeast of St George Island. 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.

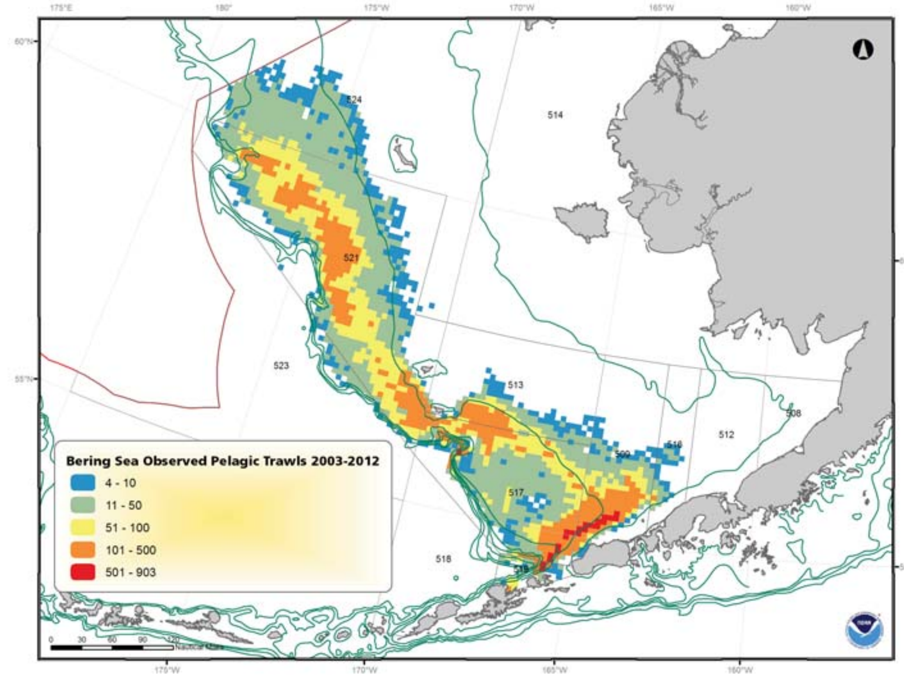

Figure 105: Spatial location and density of observed pelagic trawling in the Bering Sea 1998-2013.

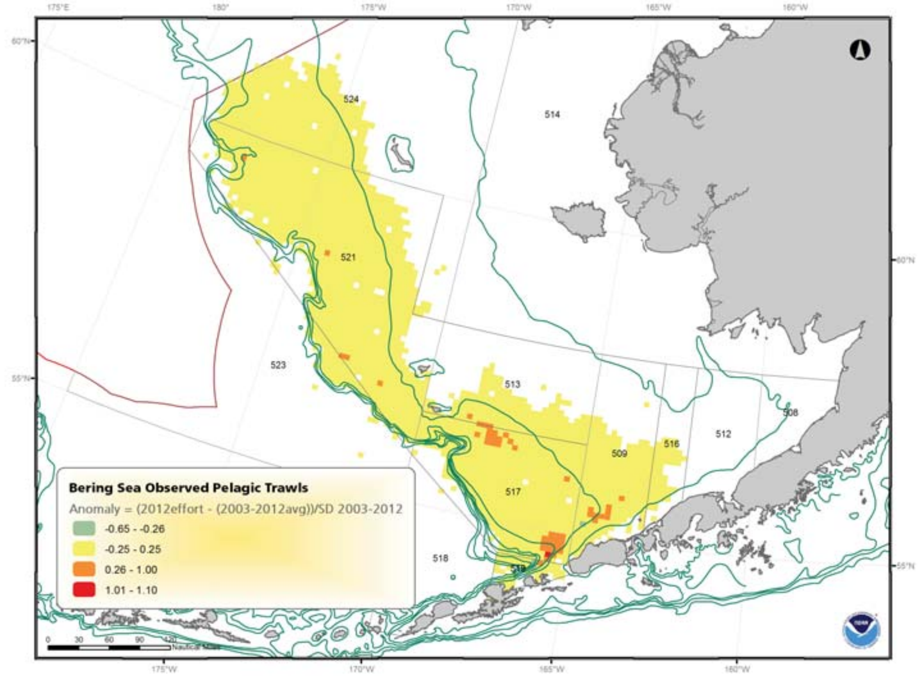

Figure 106: Observed pelagic trawl fishing effort in 2013 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (estimated effort for 2013 - average effort from 2003-2013)/stdev(effort from 2003-2013).

Non-pelagic trawl. For the period 2003-2012, there were a total of 122,948 observed bottom trawl tows in the Bering Sea fisheries. During 2012, observed bottom trawl effort consisted of 12,720 tows, which was slightly above average compared to the past 10 years. Spatial patterns of fishing effort are summarized on a 10 km2 grid (Figure 107). Areas of high fishing effort are north of Unimak Pass/Island as well the southeast portion of Area 51, western portions of Area 509, and to the west of St. Paul Island in Area 521. Additional small areas of concentration exist near Cape Constantine and off of Kuskokwim Bay. The primary catch in these areas was Pacific cod and yellowfin sole. In 2012, fishing effort was higher than average north of Unimak Island and the Alaska Peninsula in the southern portion of area 509, as well as to the north of Area 513 (Figure 108).

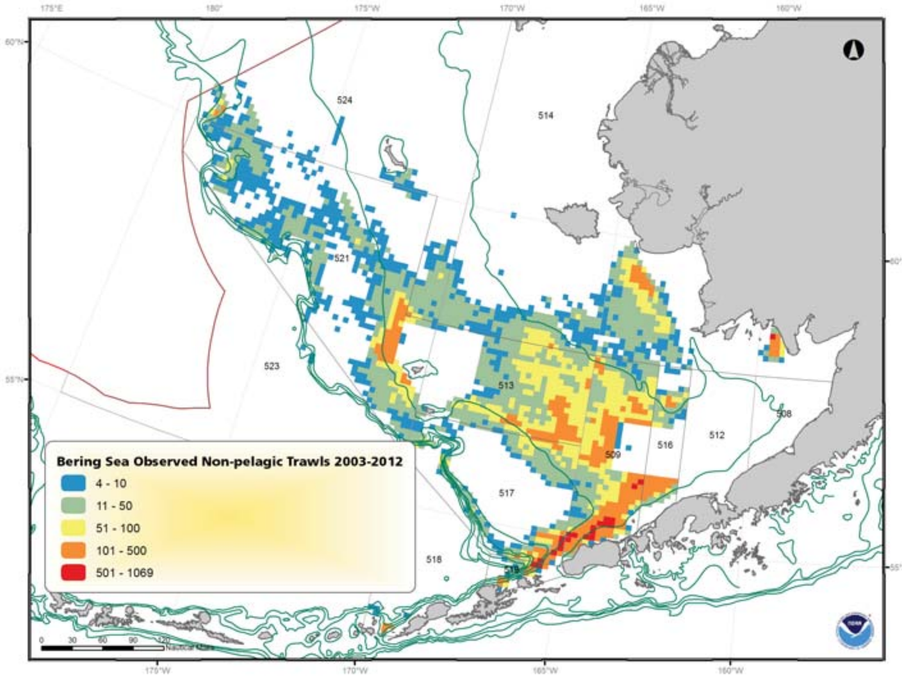

Figure 107: Spatial location and density of observed bottom trawling in the Bering Sea 1998-2013.

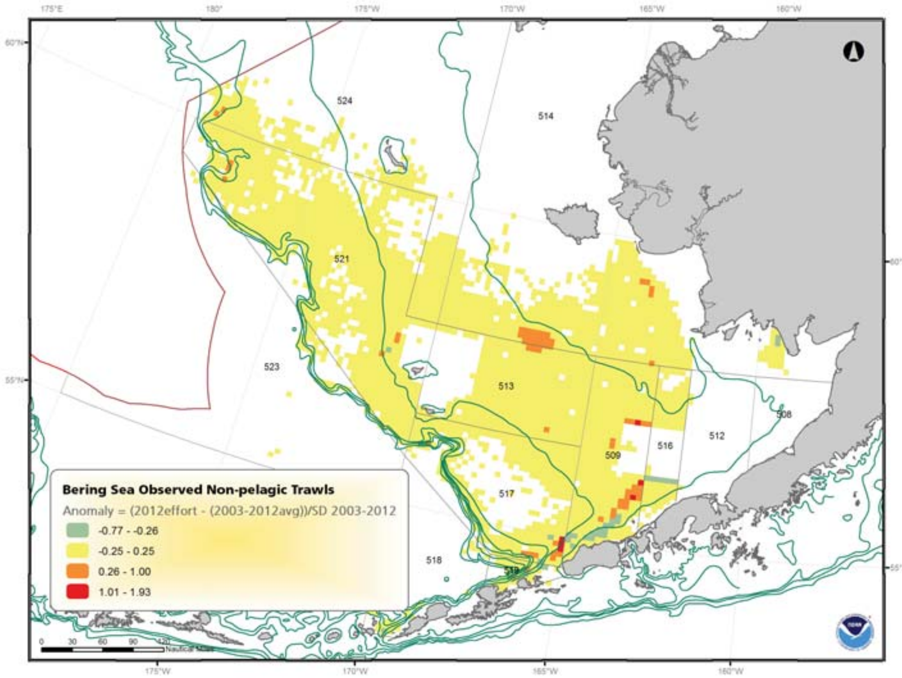

Figure 108: Observed bottom trawl fishing effort in 2013 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (estimated effort for 2013 - average effort from 2003-2013)/stdev(effort from 2003-2013).

Pot. For the period 2003-2012, there were a total of 14,653 observed pot lifts in the Bering Sea fisheries. During 2012, the amount of observed pot effort was 2,158 lifts, which was higher than the 10-year average of 1,465 and also an increase from 2011. Spatial patterns of fishing effort were summarized on a 10 km2 grid (Figure 109). Areas of high fishing effort are west of Unimak Island. 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 (higher effort in 2011)(Figure 110). Spatial and temporal changes to the fishery may have occurred in the past 10 years due to current Steller Sea Lion regulations as well as changes in Pacific cod TAC.

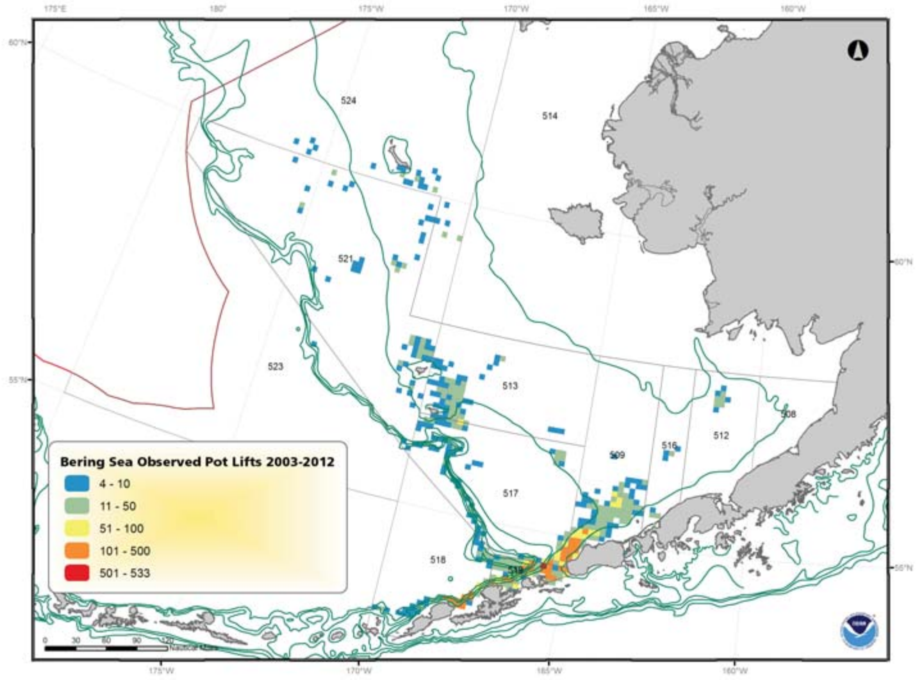

Figure 109: Spatial location and density of pot effort (observed number of pot lifts) in the Bering Sea 1998-2013.

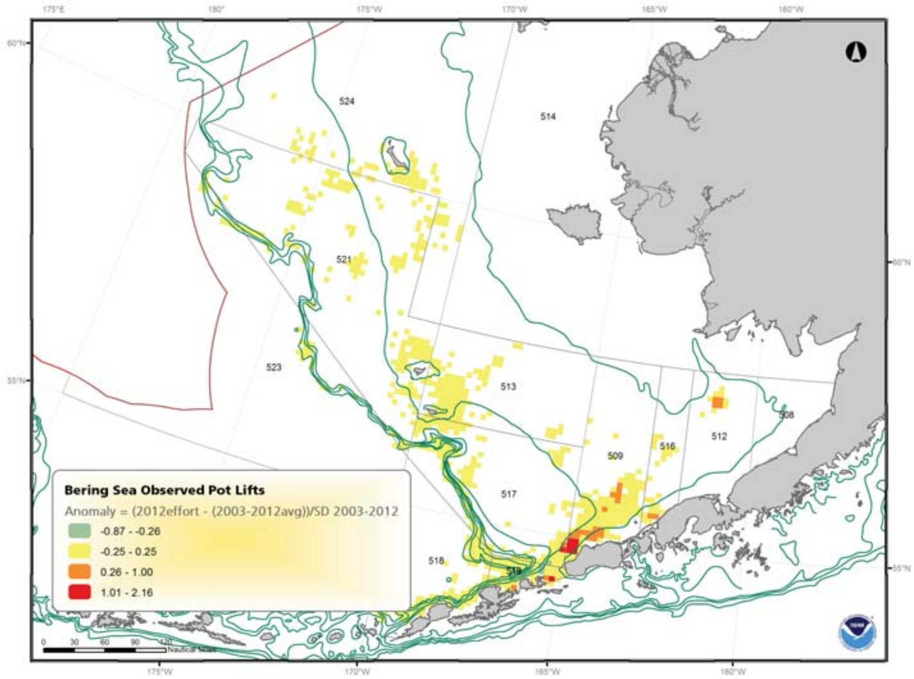

Figure 110: Observed pot fishing effort in 2012 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2013)/stdev(effort from 2003-2013).

Factors influencing 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 the Bering Sea occurs mainly for Pacific cod, Greenland turbot, halibut and sablefish. 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 remained at a relatively stable through 2007. Effort (and TAC) declined through 2010, at which point pelagic trawl effort again increased near the long-term average in 2011 and 2012. Some of the consistency of effort can be attributed to changes in the structure of the groundfish fisheries due to rationalization. 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.

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`.

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`). 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.

Observed Fishing Effort in the Aleutian Islands

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Last updated: August 2014

Description of index: Observed fishing effort is used as an indicator of total fishing effort. It should be noted, however, that many all fishing effort is not observed. Previously, catcher vessels under 60' were not observed and vessels between 60'-125 required 30% observer coverage. Starting in January 2013, a restructured observer system was implemented whereby all sectors of the groundfish fishery, including vessels less than 60' and the commercial halibut sector would be observed. NMFS now has the flexibility to decide when and where to deploy observers based on a scientifically defensible deployment plan. More information is available http://alaskafisheries.noaa.gov/sustainablefisheries/observers/.

Longline fishing effort is measured by the number of observed longline sets. 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 and catcher-processor vessels. Pelagic trawl fishing effort is measured by the number of observed tows. This fishery is prosecuted with towed pelagic trawls. Gear components which may interact with benthic habitat include the trawl sweeps and footrope. The fishery is prosecuted with both catcher and catcher-processor vessels. Non-pelagic trawl fishing effort is measured by the number of observed tows. This fishery is prosecuted with towed non-pelagic trawls. Gear components which may interact with benthic habitat include the trawl doors, sweeps, and footropes. The fishery is prosecuted with both catcher and catcher-processor vessels. Pot fishing effort is measured by the number of observed pot lifts. This fishery is prosecuted with set pots, which are generally converted from crab pots with triggers. Gear components which may interact with benthic habitat include the pot. The fishery is prosecuted with catcher vessels.

Status and trends: Effort in the longline, pelagic trawl, non-pelagic trawl, and pot fisheries in the Aleutian Islands is shown in Figure 111.

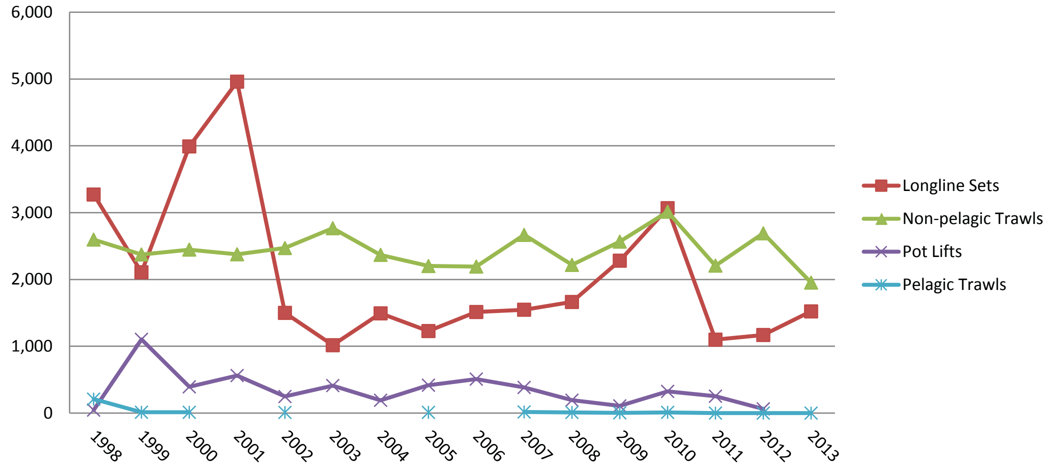

Figure 111: Aleutian Islands observed fishing effort 1990-2013.

Longline. For the period 2003-2012 there were 16,076 observed hook and line sets in the Aleutian Islands. During 2012, the amount of observed longline effort was 1,169 sets, which is significantly below the 10-year average an increase over 2011. The spatial pattern of this effort was dispersed over a wide area. Patterns of high fishing effort were dispersed along the shelf edge (Figure 112). 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 2012, fishing effort anomaly showed no specific patterns, with a few small increases near Atka and Kiska (Figure 113).

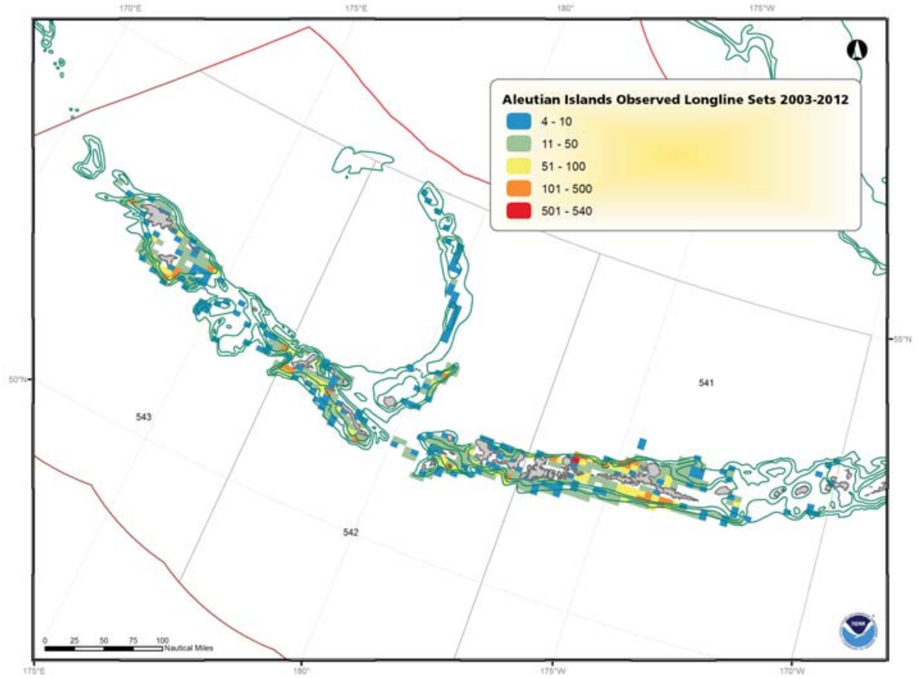

Figure 112: Observed longline effort (sets) in the Aleutian Islands, 2003-2013.

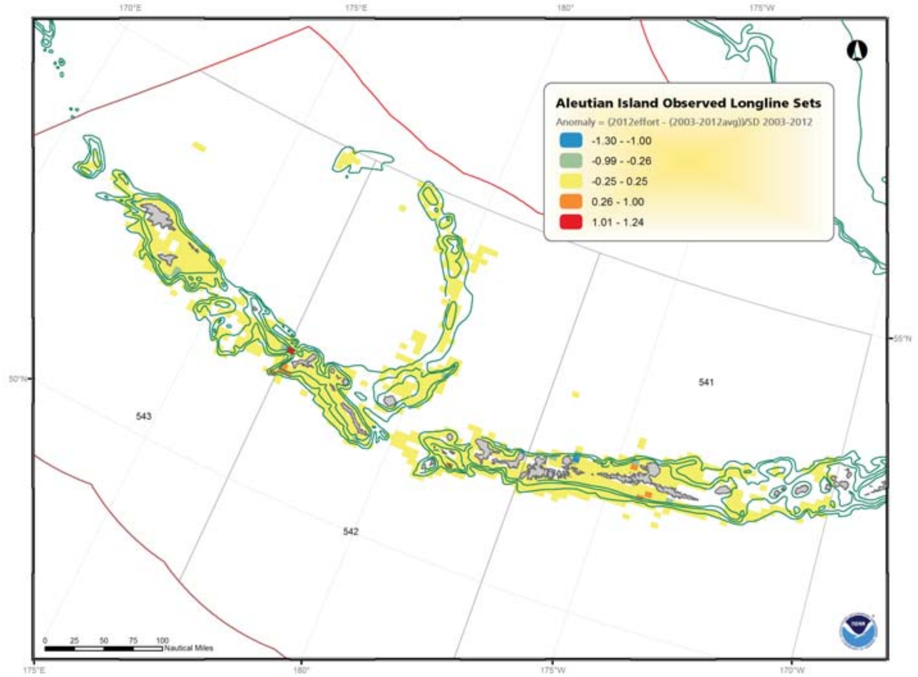

Figure 113: Observed longline fishing effort in 2011 relative to the 2003-2013 average in the Aleutian Islands. Anomalies calculated as (observed effort for 2013 - average observed effort from 2003-2013)/stdev(effort from 2003-2013).

Pelagic trawl. For the period 2003-2013 there were a total of 53 observed pelagic trawl tows in the Aleutian Islands. In 2001, 2003, 2004, 2006, 2011 and 2012 there were no observed pelagic trawl tows. Patterns of high fishing effort, mainly before 1999, were historically dispersed along the shelf edge. As there have been no tows were recorded in the Aleutian Islands in 2012, maps of effort and anomaly are not included.

Non-pelagic trawl. For the period 2003-2012 there were 24,892 observed bottom trawl tows in the Aleutian Islands. During 2012, the amount of observed bottom trawl effort was 2,691 tows, which was about average for the 10-year period. It represents an increase over 2011. Patterns of high fishing effort are Aleutian Islands, Bering Sea, and Gulf of Alaska dispersed throughout the Aleutian Islands (Figure 114). 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 2012, areas of anomalous fishing effort were minimal but scattered throughout the region, with higher than average observed effort south of Sequam Island (Figure 115). Some areas now have lower patterns of fishing effort which could be due to the implementation of new management measures, including SSL measures in areas 542 and 543 in 2011. In 2006, the Aleutian Islands Habitat Conservation Area (AIHCA) closed approximately 279,114 nm2 to bottom trawl fishing in the three AI management areas.

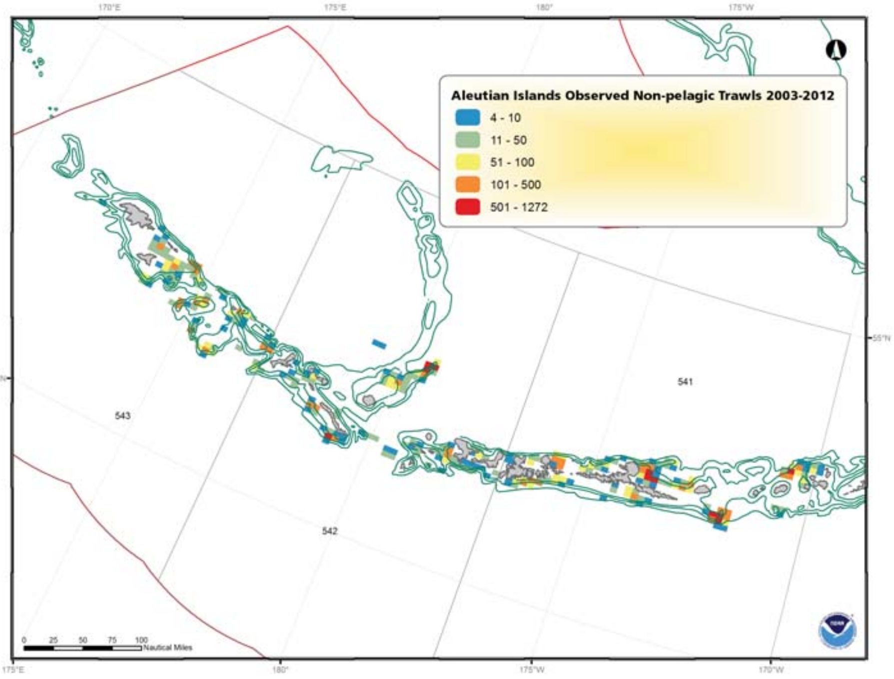

Figure 114: Spatial location and density of observed bottom trawl effort in the Aleutian Islands, 1998-2012.

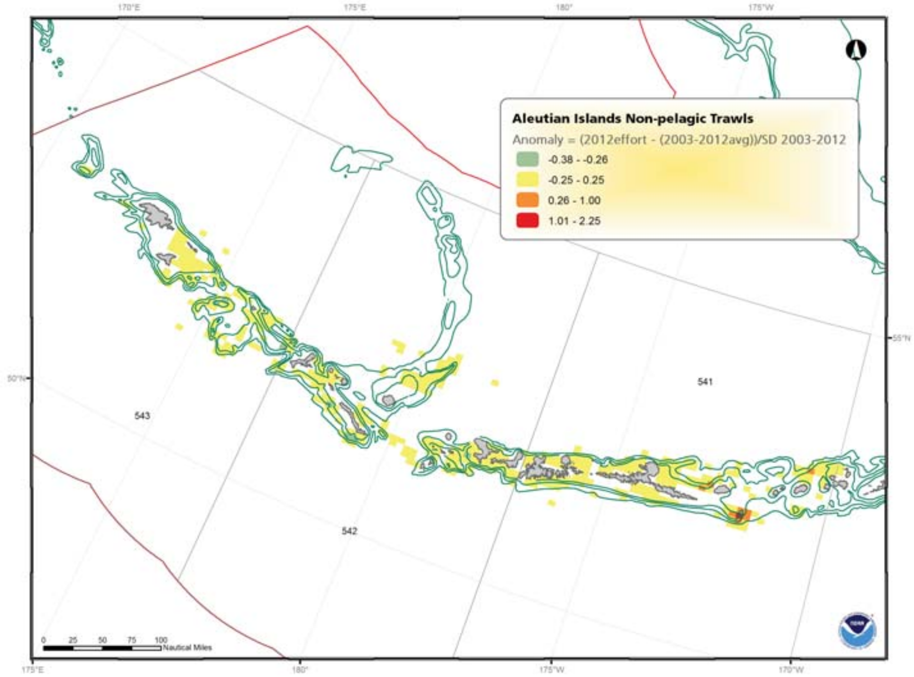

Figure 115: Observed bottom trawl fishing effort in 2012 relative to the 2003-2012 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

Pot. For the period 2003-2012 there were 2,857 observed pot lifts in the Aleutian Islands. During 2012, the amount of observed pot effort was 63 lifts, which represents a substantial decline from 2011 and is well below the 10-year average of 286. Fishing effort was dispersed along the shelf edge with high effort near Amlia and Seguam Islands (Figure 116). In 2012, the fishing anomaly throughout the region was minimal (Figure 117).

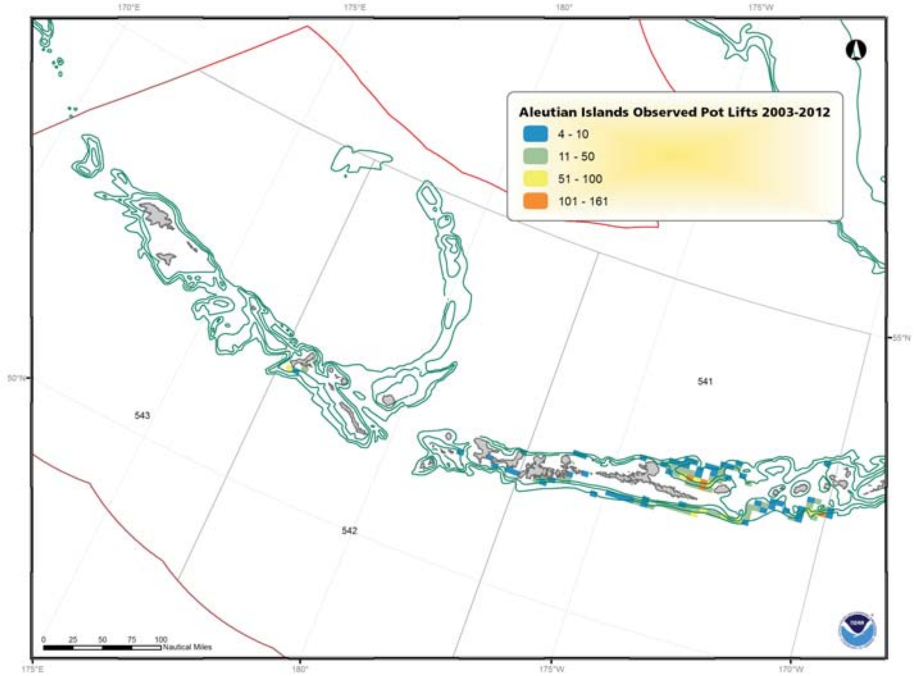

Figure 116: Spatial location and density of pot effort (observed number of pot lifts) in the Aleutian Islands, 1998-2012.

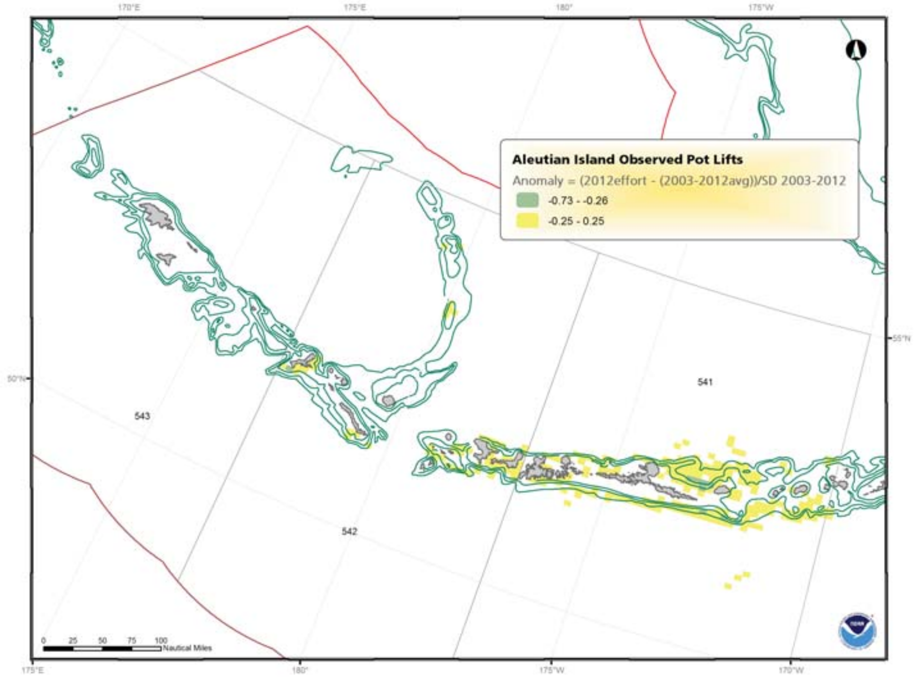

Figure 117: Observed pot fishing effort in 2012 relative to the 2003-2012 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

Factors influencing 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. Hook and line effort in the Aleutian Islands occurs mainly for Pacific cod, Greenland turbot, halibut and sablefish. Effort in the AI has trended downward in the last decade, in part due to restricted fishing from Steller sea lion protection measures.

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`). Also, much of the fleet in the Bering Sea has adopted the use of sweep modifications on their nets.

Observed Fishing Effort in the Gulf of Alaska

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Last updated: August 2014

Description of index: Observed fishing effort is used as an indicator of total fishing effort. It should be noted, however, that many all fishing effort is not observed. Previously, catcher vessels under 60' were not observed and vessels between 60'-125 required 30% observer coverage. Starting in January 2013, a restructured observer system was implemented whereby all sectors of the groundfish fishery, including vessels less than 60' and the commercial halibut sector would be observed. NMFS now has the flexibility to decide when and where to deploy observers based on a scientifically defensible deployment plan. More information is available http://alaskafisheries.noaa.gov/sustainablefisheries/observers/.

Longline fishing effort is measured by the number of observed longline sets. 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 and catcher-processor vessels. Pelagic trawl fishing effort is measured by the number of observed tows. This fishery is prosecuted with towed pelagic trawls. Gear components which may interact with benthic habitat include the trawl sweeps and footrope. The fishery is prosecuted with both catcher and catcher-processor vessels. Non-pelagic trawl fishing effort is measured by the number of observed tows. This fishery is prosecuted with towed non-pelagic trawls. Gear components which may interact with benthic habitat include the trawl doors, sweeps, and footropes. The fishery is prosecuted with both catcher and catcher-processor vessels. Pot fishing effort is measured by the number of observed pot lifts. This fishery is prosecuted with set pots, which are generally converted from crab pots with triggers. Gear components which may interact with benthic habitat include the pot. The fishery is prosecuted with catcher vessels.

Status and trends: Effort in the longline, pelagic trawl, non-pelagic trawl, and pot fisheries in the Gulf of Alaska is shown in Figure 118.

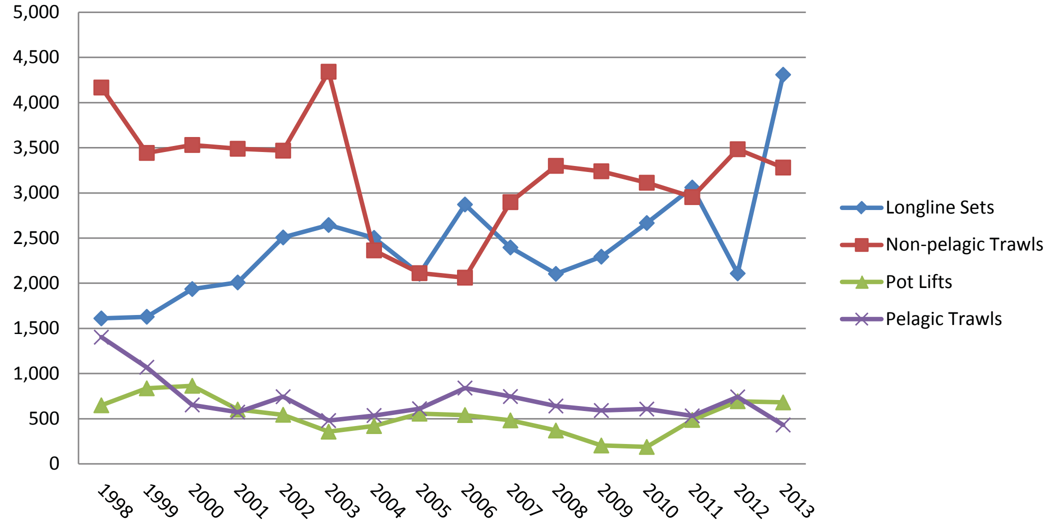

Figure 118: Gulf of Alaska observed fishing effort, 1990-2013.

Longline. For the period 2003-2012 there were 24,754 observed hook and line sets in the Gulf of Alaska. During 2012, the amount of observed longline effort was 2,109 sets, which is below the

10-year average. Patterns of high fishing effort were dispersed along the shelf in all management areas (Figure 119). The predominant hook and line fisheries in the Gulf of Alaska are composed of sablefish and Pacific cod. In southeast Alaska, there is a demersal rockfish fishery; dominant species include yelloweye rockfish (90%), with lesser catches of quillback rockfish. The demersal shelf rockfish fishery occurs over bedrock and rocky bottoms at depths of 75 m to >200 m. The sablefish longline fishery occurs over mud bottoms at depths of 400 to ¿1000 m. This fishery is often a mixed halibut/sablefish fishery, with shortraker, rougheye, and thornyhead rockfish also taken. Sablefish has been an IFQ fishery since 1995, which has reduced the number of vessels, crowding, gear conflicts and gear loss, and increased efficiency. The cod longline fishery generally occurs in the western and central Gulf of Alaska, opening on January 1st and lasting until early March. Halibut prohibited species catch sometimes curtails the fishery. The cod fishery occurs over gravel, cobble, mud, sand, and rocky bottom, in depths of 25 fathoms to 140 fathoms. In 2012, fishing effort anomalies were varied throughout the region, with higher than average fishing occurring near the Shumagin Islands west in Area 610 and between Sitkinak and Barnabas in Area 630 (Figure 120).

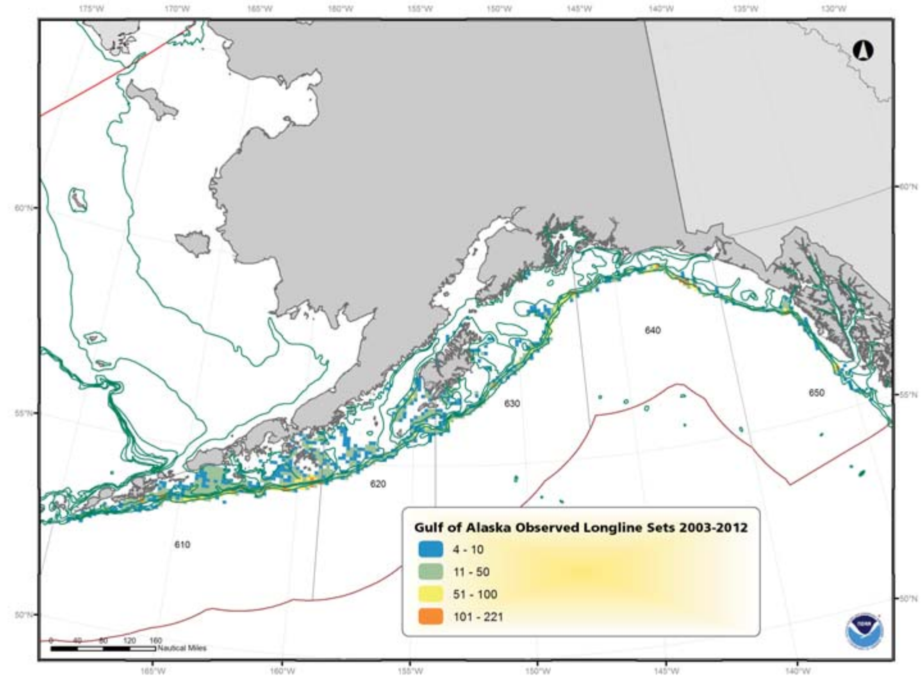

Figure 119: Observed longline effort (sets) in the Gulf of Alaska, 2003-2012.

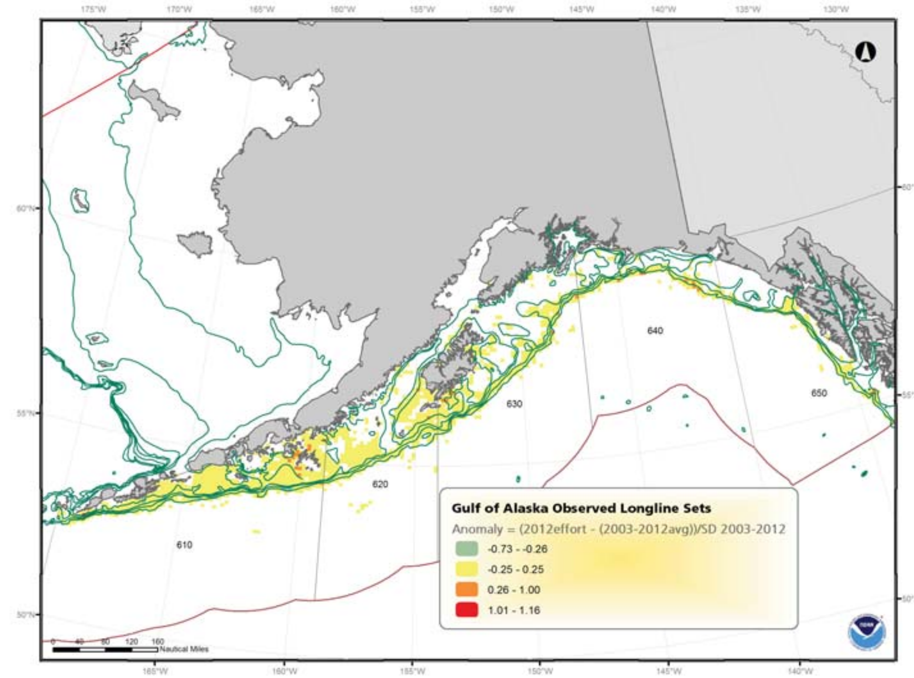

Figure 120: Observed longline fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

Pelagic trawl. The primary target of the GOA pelagic trawl fishery is pollock (Figure 121). The fleet is comprised of trawl catcher vessels that deliver their catch onshore for processing. For the period 2003-2012 there were 6,326 observed pelagic trawl tows in the Gulf of Alaska. The spatial pattern of this effort centers around Kodiak, specifically Chiniak Gully, Marmot Bay and Shelikof Strait, with limited fishing on the shelf break to the east and west. During 2012, the amount of trawl effort was 742 tows, which was above average for the 10-year period. A large portion of the trawl fleet in Kodiak is comprised of smaller catcher vessels that require 3% observer coverage, indicating that the actual amount of trawl effort is likely much higher since a large portion is unobserved. The catch anomaly for 2012 was variable, with the highest anomaly centered in Shelikof Strait (Figure 122).

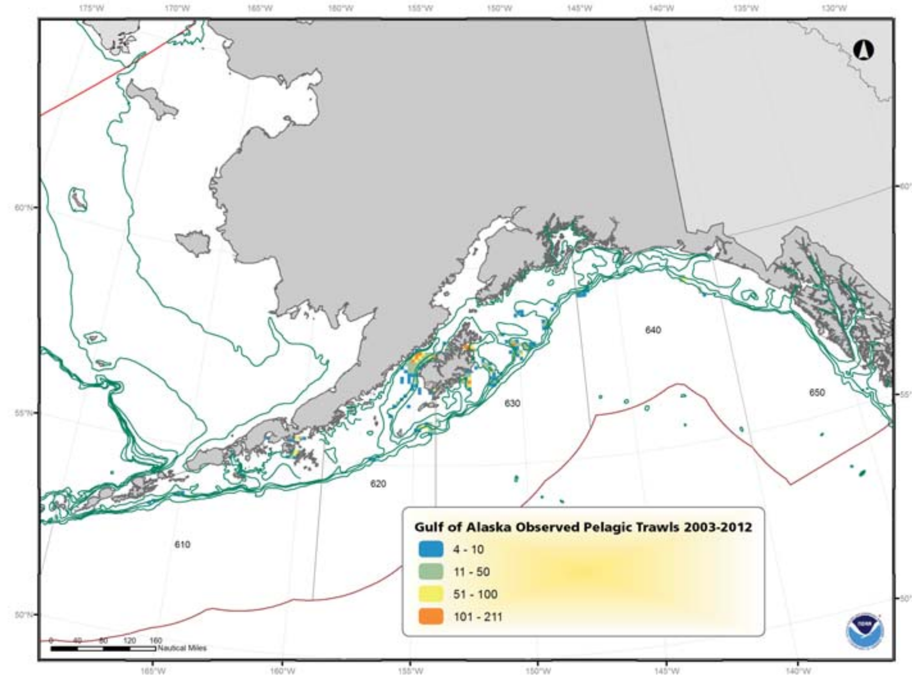

Figure 121: Spatial location and density of observed pelagic trawl effort in the Gulf of Alaska, 1998-2012.

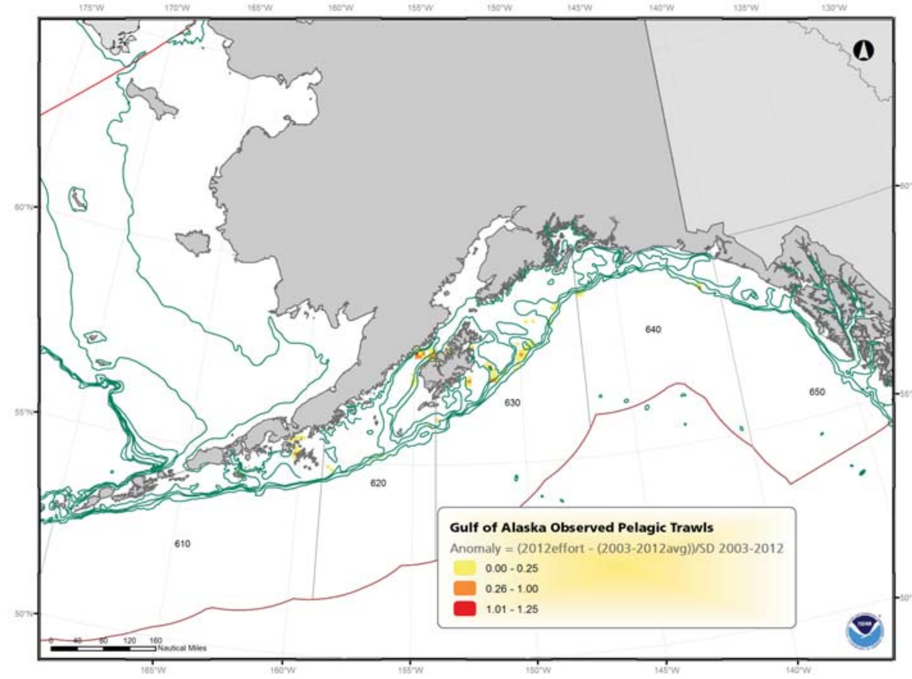

Figure 122: Observed pelagic trawl fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

Non-pelagic trawl. For the period 2003-2012 there were 29,869 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 2012, the amount of trawl effort was 3,484 tows, which was an increase over 2011 and also above the average for the 10-year period. For 2012, fishing effort did not display any distinct patterns of anomaly; rather, small areas of small increases were evident over arease 620 and 630. 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 123). 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 2011, areas of higher and lower than average fishing effort were scattered throughout the Central and Western Gulf (Figure 124).

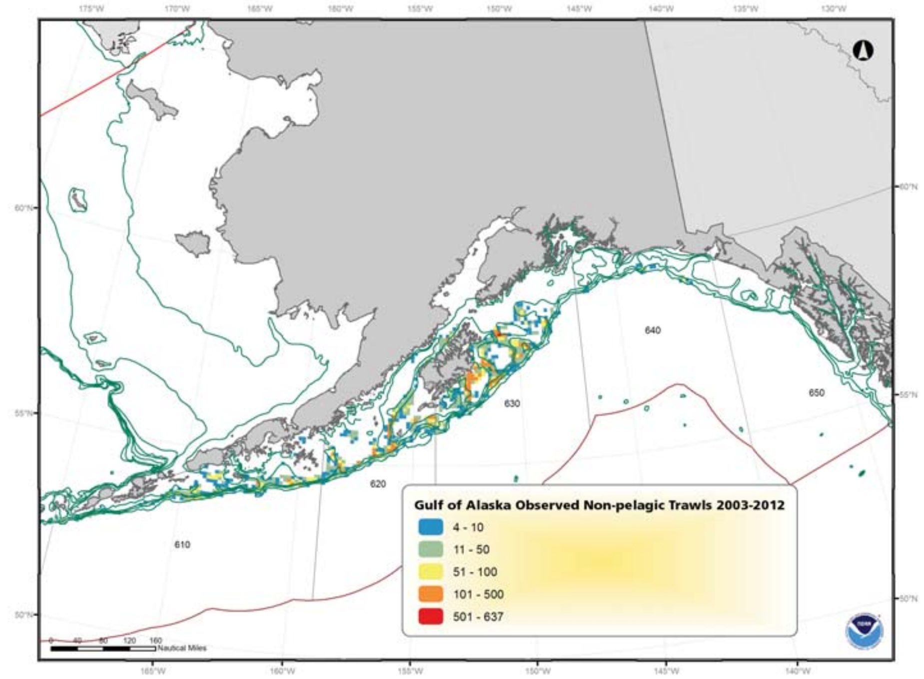

Figure 123: Spatial location and density of observed bottom trawl effort in the Gulf of Alaska, 1998-2012.

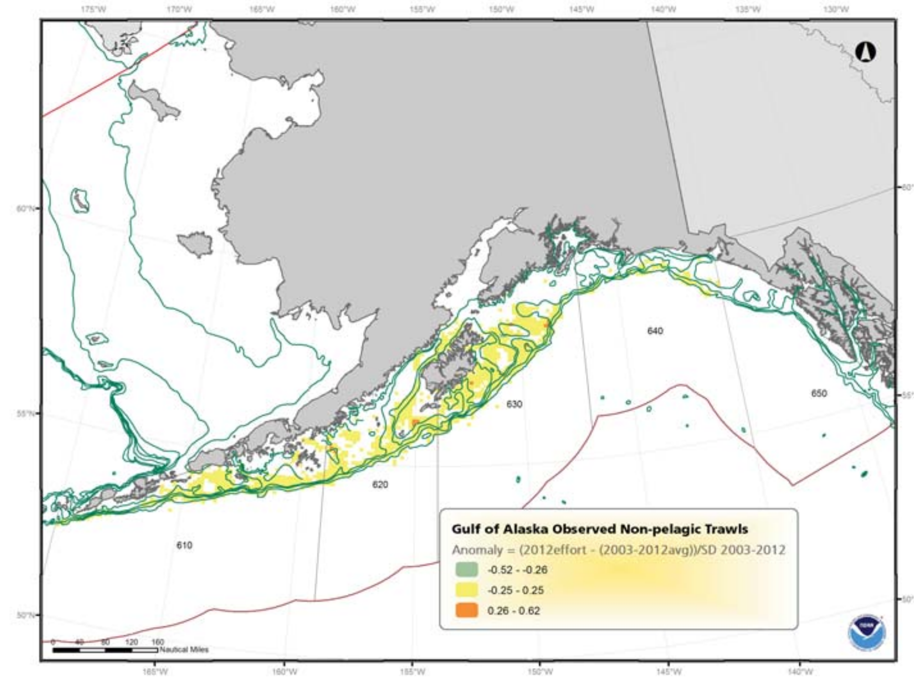

Figure 124: Observed bottom trawl fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

Pot. For the period 2003-2012 there were 4,298 observed pot lifts in the Gulf of Alaska. During 2012, the amount of observed pot effort was 694 lifts, which represents an increase from 2011 and is above the 10-year average of 430. Patterns of higher fishing effort were dispersed along the shelf to the east of Kodiak Island (Figure 125). Fishing effort in 2012 showed increases in areas 610 and 630, particularly near Shumagin Islands, Middle Cape, and the southern and eastern portions of Kodiak Island (Figure 126). Approximately 100 boats participate in this fishery. There is also a state-managed fishery in state waters. 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.

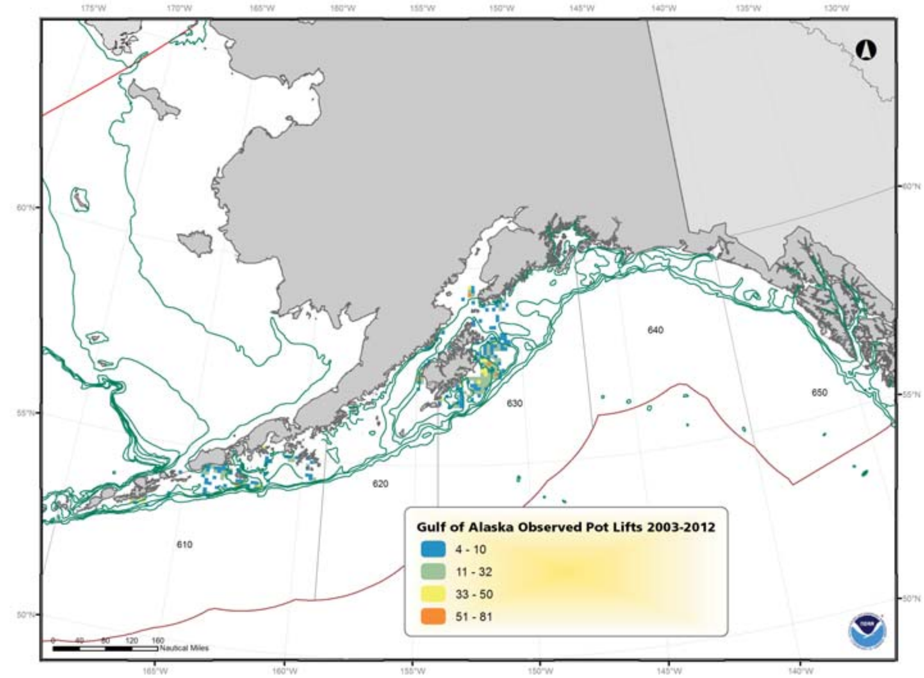

Figure 125: Spatial location and density of pot effort (observed number of pot lifts) in the Gulf of Alaska, 1998-2012.

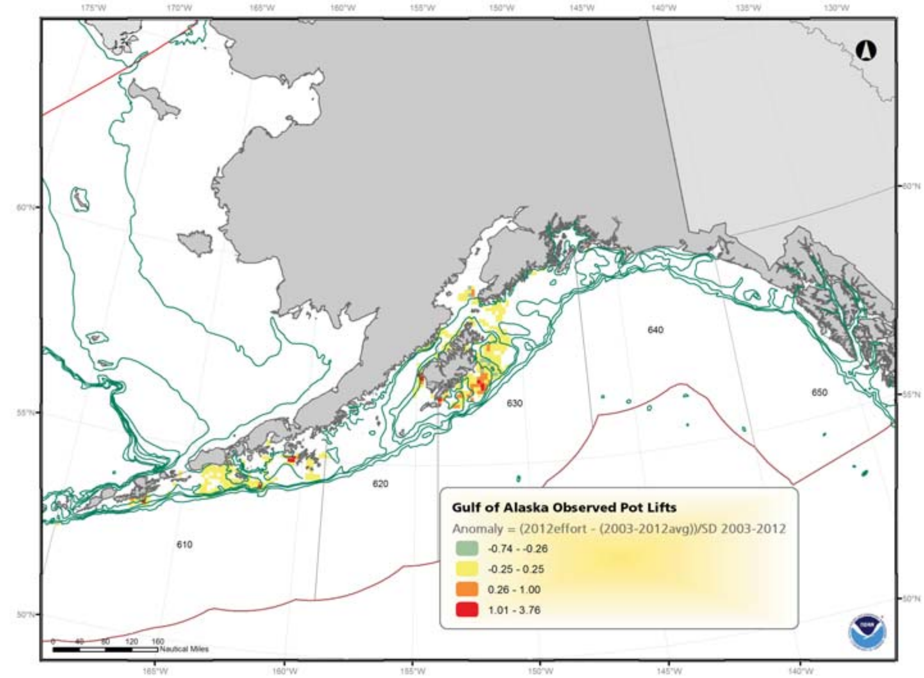

Figure 126: Observed pot fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

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 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. Effort in the GOA has trended downward in the last decade, in part due to restricted fishing from Steller sea lion protection measures.

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`).

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: July 2014

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/fisheries_eco/status_of_fisheries`). 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

Table 12: Summary of status for FSSI and non-FSSI stocks managed under federal fishery management plans off Alaska, updated through June 2014.

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	30	4	0	0
NPFMC	NonFSSI	30	0	29	1	0	0	5	25	0	0
	Total	65	0	64	1	0	1	35	29	0	0

(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 the biomass that produces maximum sustainable yield (B_{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. There are 227 FSSI stocks in the U.S., with a maximum possible score of 920. The FSSI previously contained 230 stocks. Two FSSI stocks from the Gulf of Mexico are no longer managed under federal fishery management plans (FMPs), and a third FSSI stock from the Gulf of Mexico is now managed as a combined Gulf of Mexico/South Atlantic stock; this has reduced the total number of FSSI stocks from 230 to 227. To provide, continuity in the FSSI, the final point score for these 3 stocks remains in the index until FY 2015 (max FSSI possible 920) (`http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/status_updates.html`).

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 12 and 13). Additionally, there are 30 non-FSSI stocks, two ecosystem component species complexes, and Pacific halibut which are managed under an international agreement (Table 12 and 14).

Status and trends: As of June 30, 2014, no BSAI or GOA groundfish stock or stock complex is subjected to overfishing, and no BSAI or GOA groundfish stock or stock complex is considered to be overfished or to be approaching an overfished condition (Tables 12). The only crab stock considered to be overfished is the Pribilof Islands blue king crab stock, which is in year 11 of a 10-year rebuilding plan. The rebuilding plan for this stock is being revised by the NPFMC. None of the non-FSSI stocks are subject to overfishing, known to be overfished, or known to be approaching an overfished condition (Table 14).

The current overall Alaska FSSI is 124 out of a possible 140, based on updates through June 2014 (Table 13). The overall Bering Sea/Aleutian Islands score is 81 out of a possible maximum score of 92. The BSAI groundfish score is 54 (including BSAI/GOA sablefish, see Endnote-h in Box A) of a maximum possible 56, and BSAI king and tanner crabs score is 27 out of a possible 36. The

Gulf of Alaska groundfish score is 43 of a maximum possible 48 (excluding BSAI/GOA sablefish). Overall, the Alaska total FSSI score increased 1.5 points from 2013 to 2014 (Figure 127).

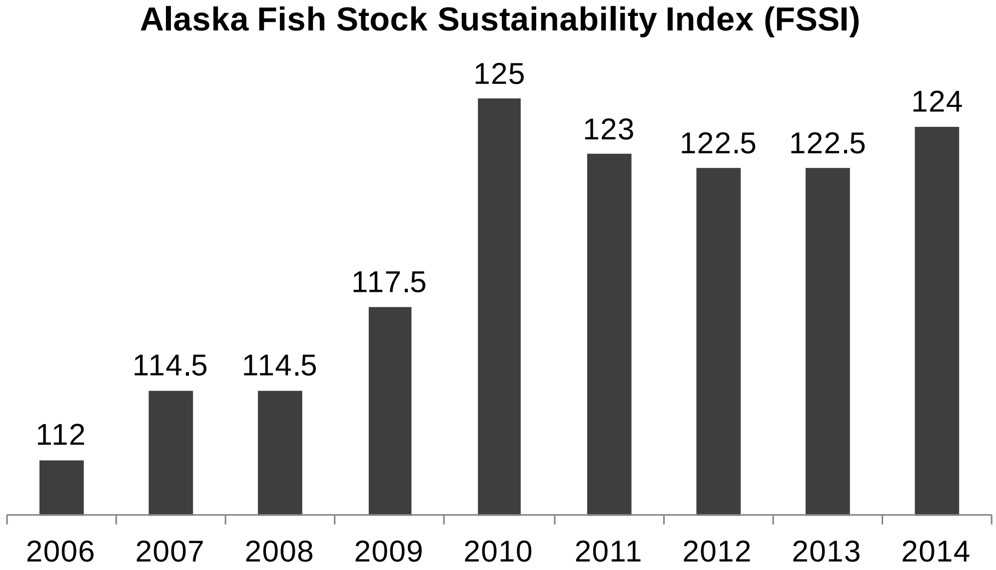

Figure 127: The trend in total Alaska FSSI from 2006 through 2014. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries`. The maximum possible FSSI score is 140 in all years.

Factors influencing observed trends: The FSSI score changed for two stocks from 2013 to 2014 resulting in a net gain of 1.5 points for the total Alaska FSSI. A single point was lost for the St. Matthews Island blue king crab stock biomass falling below 80% of the biomass that produces B_{MSY}. The FSSI for the GOA deepwater flatfish complex increased two and a half points following the acceptance of a new age-structured model for Dover sole and the use of this species as an indicator species for status determinations (overfished level defined, overfished status, and B/B_{MSY}) of this complex.

Crab groups in the BSAI region with FSSI scores less than 4 are golden king crab-Aleutian Islands (FSSI=1.5), blue king crab-St. Matthews Island (FSSI=3), blue king crab-Pribilof Islands (FSSI=2), red king crab-Pribilof Islands (FSSI=3), and red king crab-Western Aleutian Islands (FSSI=1.5). Both the golden king crab-Aleutian Islands and the red king crab-Western Aleutian Islands earn a half point for having a defined overfishing level and a whole point for having a fishing mortality rate that is below the defined overfishing level. These two stocks lose 2.5 points because the overfished status determination is not defined and it is therefore unknown if the biomass is above the overfished level or if biomass is at or above 80% of B_{MSY}. Both the red king crab-Pribilof Islands and blue king crab-St. Matthews Island stocks lose a point because their biomass is below 80% of B_{MSY}. The blue king crab-Pribilof Islands stock loses two points, one for being in an overfished state and another for having biomass below 80% of B_{MSY}.

Two BSAI groundfish stocks have FSSI scores less than 4; blackspotted and rougheye rockfish complex (FSSI=3) and Greenland halibut (FSSI=3). Both of these stocks lose one point for biomass below 80% of B_{MSY}.

GOA stocks that had low FSSI scores (1.5) are the thornyhead rockfish complex (shortspine thornyhead rockfish as the indicator species), and the demersal shelf rockfish complex (yelloweye rockfish as the indicator species). The low scores of these groups are because the overfished status determination is not defined and it is therefore unknown if the biomass is above the overfished level or if biomass is at or above 80% of B_{MSY}.

Implications: The majority of Alaska groundfish fisheries appear to be sustainably managed. A single stock is considered to be overfished (Pribilof Islands blue king crab), no stocks are subject to overfishing, and no stocks or stock complexes are known to be approaching an overfished condition.

Table 13: FSSI stocks under NPFMC jurisdiction updated June 2014, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`. See Box A for endnotes and definition of stocks and stock complexes.

Stock	Overfishing	Overfished	Approaching	Action	Progress	B/Bmsy	FSSI Score
Blue king crab - Pribilof Islands[a]	No	Yes	N/A	N/A	Year 11 of 10	0.15	2
Blue king crab - Saint Matthews Island[b]	No	No	No	N/A	N/A	0.79	3
Golden king crab - Aleutian Islands	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
Red king crab - Bristol Bay	No	No	No	N/A	N/A	1.1	4
Red king crab - Norton Sound	No	No	No	N/A	N/A	1.3	4
Red king crab - Pribilof Islands[c]	No	No	No	N/A	N/A	0.77	3
Red king crab - Western Aleutian Islands	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
Snow crab - Bering Sea	No	No	No	N/A	N/A	1.1	4
Southern Tanner crab - Bering Sea	No	No	No	N/A	N/A	1.77	4
BSAI Alaska plaice	No	No	No	N/A	N/A	1.96	4
BSAI Atka mackerel	No	No	No	N/A	N/A	1.16	4
BSAI Arrowtooth Flounder	No	No	No	N/A	N/A	3.05	4
BSAI Blackspotted and Rougheye Rockfish[d]	No	No	No	N/A	N/A	0.75	3
BSAI Flathead Sole Complex[e]	No	No	No	N/A	N/A	2.18	4
BSAI Rock Sole Complex[f]	No	No	No	N/A	N/A	2.06	4
BSAI Greenland halibut	No	No	No	N/A	N/A	0.57	3
BSAI Northern rockfish	No	No	No	N/A	N/A	1.64	4
BS Pacific cod[g]	No	No	No	N/A	N/A	1.14	4
BSAI Pacific Ocean perch	No	No	No	N/A	N/A	1.7	4
Walleye pollock - Aleutian Islands	No	No	No	N/A	N/A	0.92	4
Walleye pollock - Eastern Bering Sea	No	No	No	N/A	N/A	1.25	4
BSAI Yellowfin sole	No	No	No	N/A	N/A	1.58	4
BSAI GOA Sablefish[h]	No	No	No	N/A	N/A	1	4

Table 13: FSSI stocks under NPFMC jurisdiction updated June 2014, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`. See Box A for endnotes and definition of stocks and stock complexes. (continued)

Stock	Overfishing	Overfished	Approaching	Action	Progress	B/Bmsy	FSSI Score
GOA Arrowtooth flounder	No	No	No	N/A	N/A	2.97	4
GOA Flathead sole	No	No	No	N/A	N/A	2.7	4
GOA Blackspotted and Rougheye Rockfish complex[i]	No	No	No	N/A	N/A	1.5	4
GOA Deepwater Flatfish Complex[j]	No	No	No	N/A	N/A	2.62	4
GOA Demersal Shelf Rockfish Complex[k]	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
GOA Dusky Rockfish	No	No	No	N/A	N/A	1.73	4
GOA Thornyhead Rockfish Complex[l]	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
Northern rockfish - Western / Central GOA	No	No	No	N/A	N/A	1.82	4
GOA Pacific cod	No	No	No	N/A	N/A	1.84	4
GOA Pacific Ocean perch	No	No	No	N/A	N/A	1.31	4
GOA Rex sole	No	No	No	N/A	N/A	2.72	4
Walleye pollock - Western / Central GOA	No	No	No	N/A	N/A	1.34	4

Box A. Endnotes and stock complex definitions for FSSI stocks listed in Table 13, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`.

(a) The NPFMC is revising the rebuilding plan for this stock, which will extend the rebuilding target date. In the meantime, there is no directed fishing for the blue king crab-Pribilof Islands and the majority of blue king crab habitat is closed to bottom trawling.

(b) Fishery in the EEZ is closed; therefore, fishing mortality is very low.

(c) Fishery in the EEZ is closed; therefore, fishing mortality is very low.

(d) BSAI Blackspotted and Rougheye Rockfish consists of 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.

(e) Flathead Sole Complex consists of Flathead Sole and Bering Flounder. Flathead Sole accounts for the overwhelming majority of the biomass and is regarded as the indicator species for the complex. The overfished determination is based on the combined abundance estimates for the two species; the overfishing determination is based on the OFL, which is computed from the combined abundance estimates for the two species.

(f) Rock Sole Complex consists of Northern Rock Sole and Southern Rock Sole (NOTE: These are two distinct species, not two separate stocks of the same species). Northern Rock Sole accounts for the overwhelming majority of the biomass and is regarded as the indicator species for the complex. The overfished determination is based on the combined abundance estimates for the two species; the overfishing determination is based on the OFL, which is computed from the combined abundance estimates for the two species.

(g) The former BSAI Pacific cod assessment was split into separate Bering Sea and Aleutian Islands assessments in 2013. Separate overfishing levels and annual catch limits are specified for the BS and AI management areas starting with the 2014 fishing season. The overfishing determination is based on a determination of the combined BSAI stock until separate Bering Sea-only catch can be compared to its corresponding overfishing level.

(h) Although Sablefish is managed separately in the Gulf of Alaska, Bering Sea, and Aleutian Islands, with separate overfishing levels, ABCs, and TACs based on the proportion of biomass in each respective region, separate assessments are not conducted for each of these three regions; the assessment is based on aggregated data from the Gulf of Alaska, Bering Sea, and Aleutian Islands regions. Therefore, it is not appropriate to list separate status determinations for these three regions.

(i) GOA Blackspotted and Rougheye Rockfish consists of 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.

(j) The Deep Water Flatfish Complex consists of the following stocks: Deepsea Sole, Dover Sole, and Greenland Turbot. A new age-structured model was accepted for Dover Sole in 2013, so this stock is now the indicator species for determining the status of this stock complex.

(k) The Demersal Shelf Rockfish Complex consists of the following stocks: 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.

(l) The Thornyhead Rockfish Complex consists of the following stocks: Longspine Thornyhead and Shortspine Thornyhead. The overfishing determination is based on the OFL, which is computed using abundance estimates of Shortspine Thornyhead.

Table 14: Non-FSSI stocks, Ecosystem Component Species, and Stocks managed under an International Agreement updated June 2014, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`. See website for endnotes and definition of stocks and stock complexes.

Stock	Jurisdiction	Overfishing	Overfished	Approaching
Golden king crab - Pribilof Islands	NPFMC	No	Unknown	Unknown
BSAI Octopus Complex	NPFMC	No	Unknown	Unknown
BSAI Other Flatfish Complex	NPFMC	No	Unknown	Unknown
BSAI Other Rockfish Complex	NPFMC	No	Unknown	Unknown
BSAI Sculpin Complex	NPFMC	No	Unknown	Unknown
BSAI Shark Complex	NPFMC	No	Unknown	Unknown
BSAI Skate Complex	NPFMC	No	No	No
BSAI Squid Complex	NPFMC	No	Unknown	Unknown
BSAI Kamchatka flounder	NPFMC	No	No	No
BSAI Shortraker rockfish	NPFMC	No	Unknown	Unknown
Walleye pollock - Bogoslof	NPFMC	No	Unknown	Unknown
AI Pacific cod	NPFMC	Unknown	Unknown	Unknown
GOA Atka mackerel	NPFMC	No	Unknown	Unknown
GOA Big skate	NPFMC	No	Unknown	Unknown
GOA Octopus complex	NPFMC	No	Unknown	Unknown
GOA Squid Complex	NPFMC	No	Unknown	Unknown
GOA Other Rockfish Complex	NPFMC	No	Unknown	Unknown
GOA Sculpin Complex	NPFMC	No	Unknown	Unknown
GOA Shallow Water Flatfish Complex	NPFMC	No	No	No
GOA Shark Complex	NPFMC	No	Unknown	Unknown
GOA Alaska skate Complex	NPFMC	No	Unknown	Unknown
GOA Longnose skate	NPFMC	No	Unknown	Unknown
GOA Shortraker rockfish	NPFMC	No	Unknown	Unknown
Walleye pollock - Eastern Gulf of Alaska	NPFMC	No	Unknown	Unknown
Alaska Coho Salmon Assemblage	NPFMC	No	No	No
Chinook salmon - E. North Pacific Far North Migrating	NPFMC	No	No	No
Weathervane scallop - Alaska	NPFMC	No	Unknown	Unknown
Arctic cod - Arctic FMP	NPFMC	No	Unknown	Unknown
Saffron cod - Arctic FMP	NPFMC	No	Unknown	Unknown
Snow crab - Arctic FMP	NPFMC	No	Unknown	Unknown
Ecosystem Component Species				
Fish resources of the Arctic mgmt. area - Arctic FMP	NPFMC	No	Unknown	Unknown
Scallop fishery off Alaska	NPFMC	Undefined	Undefined	N/A
Stocks managed under an International Agreement				
Pacific halibut - Pacific Coast / Alaska	IPHC/NPFMC/PFMC	Undefined	No	No

Total Annual Surplus Production and Overall Exploitation Rate of Groundfish

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

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Humans as part of ecosystems

Groundfish Fleet Composition

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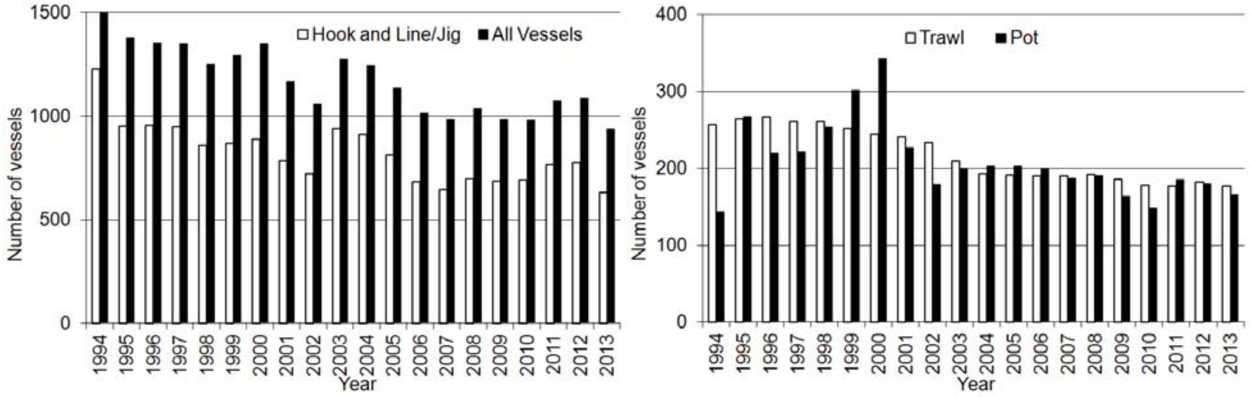
Description of index: Fishing vessels participating in federally-managed groundfish fisheries off Alaska principally use trawl, hook and line, and pot gear. Vessel counts were compiled from NMFS Alaska Region's blend and Catch-Accounting System estimates and from fish ticket and observer data through 2013.

Status and trends: The total number of vessels participating in federally-managed fisheries off Alaska has generally decreased since 1994, though participation has remained relatively relative stable over last the last 5 years (2009-2013). Vessels using longline gear, including hook and line and jig gear, have accounted for most of the participating vessels from 1994 to 2013; 633 longline vessels participated in 2013, down from a high of 1,225 in 1994. The number of vessels using trawl gear decreased from 257 in 1994 to 177 in 2012. During the same period, the number of vessels using pot gear peaked in 2000 at 343, and decreased to 165 in 2013.



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

Figure 128: Number of vessels participating in the groundfish fisheries off Alaska by gear type, 1994-2012.

Factors influencing observed trends: The increase in 2003 in the number of hook-and-line/jig and pot vessels (and, thus, 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 groundfish 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. Vessel counts before and after 2003 are not directly comparable due these changes in data source.

Implications: Monitoring the numbers of fishing vessels provides general measures of fishing effort, the level of capitalization in the fisheries, and the potential magnitude of effects on industry stakeholders caused by management decisions.

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

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

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