Ecosystem Considerations
2013

Edited by:
Stephani Zador
Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center,
National Marine Fisheries Service, NOAA
7600 Sand Point Way NE
Seattle, WA 98115

With contributions from:
Kerim Aydin, Steve Barbeaux, Sonia Batten, Jennifer Boldt, Nick Bond, Greg Buck, Kristin Cieciel, Miriam Doyle, Sherrie Dressel, Lisa Eisner, Ed Farley, Emily Fergusson, Shannon Fitzgerald, Jeanette Gann, Angie Greig, Kyle Hebert, Ron Heintz, Amber Himes-Cornell, Jerry Hoff, Carol Ladd, Ned Laman, Jean Lee, Mike Litzow, Ellen Martinson, Kate Mier, Franz Mueter, John Olson, Joe Orsi, James Overland, John Piatt, Heather Renner, Marc Romano, Chris Rooper, Sigrid Salo, Elizabeth Siddon, Phyllis Stabeno, William Stockhausen, Molly Sturdevant, Muyin Wang, Alex Wertheimer, Andy Whitehouse, Tom Wilderbuer, Matt Wilson, Carrie Worton, and Stephani Zador.

Reviewed by:
The Plan Teams for the Groundfish Fisheries of the
Bering Sea, Aleutian Islands, and Gulf of Alaska

November 18, 2013
North Pacific Fishery Management Council
605 W. 4th Avenue, Suite 306
Anchorage, AK 99301

Eastern Bering Sea 2013 Report Card

- The North Pacific atmosphere-ocean system during 2012-2013 reflected a combination of a **mostly near-neutral ENSO and intrisic variability**. **Neutral ENSO is expected again this winter**.
- **Ocean temperatures remained cool and sea ice remained extensive**. Dates of sea ice retreat, summer surface and bottom temperatures, and the extent of the cold pool were very similar to those during 2007.
- The summer ***Calanus*** **copepod time series showed an increase in abundance** in 2011 relative to 2010, but remained below the 2009 peak. 2011 was **the fourth year that concentrations remained well above average**, following patterns also seen in fall zooplankton abundance during cold years.
- **Jellyfish remained abundant** during summer, following a new peak fall biomass recorded in 2012.
- **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 in response to colder water over the last few years, rather than a population decline.
- **Thick-billed murre reproductive success on St. George Island was above average** in 2013, suggesting that **foraging conditions were favorable for piscivorous seabirds**.
- **Northern fur seal pup production for St. Paul Island increased from the previous count in 2010, but overall numbers remain low**. 2012 was the first year that pup production has not declined since 1998.
- The maximum potential **area of seafloor habitat disturbed by trawl gear in 2012 decreased slightly** from 2011, which was the highest level since 1998. The cause of the increase may be due to increased search time for pollock and/or avoidance of salmon bycatch.

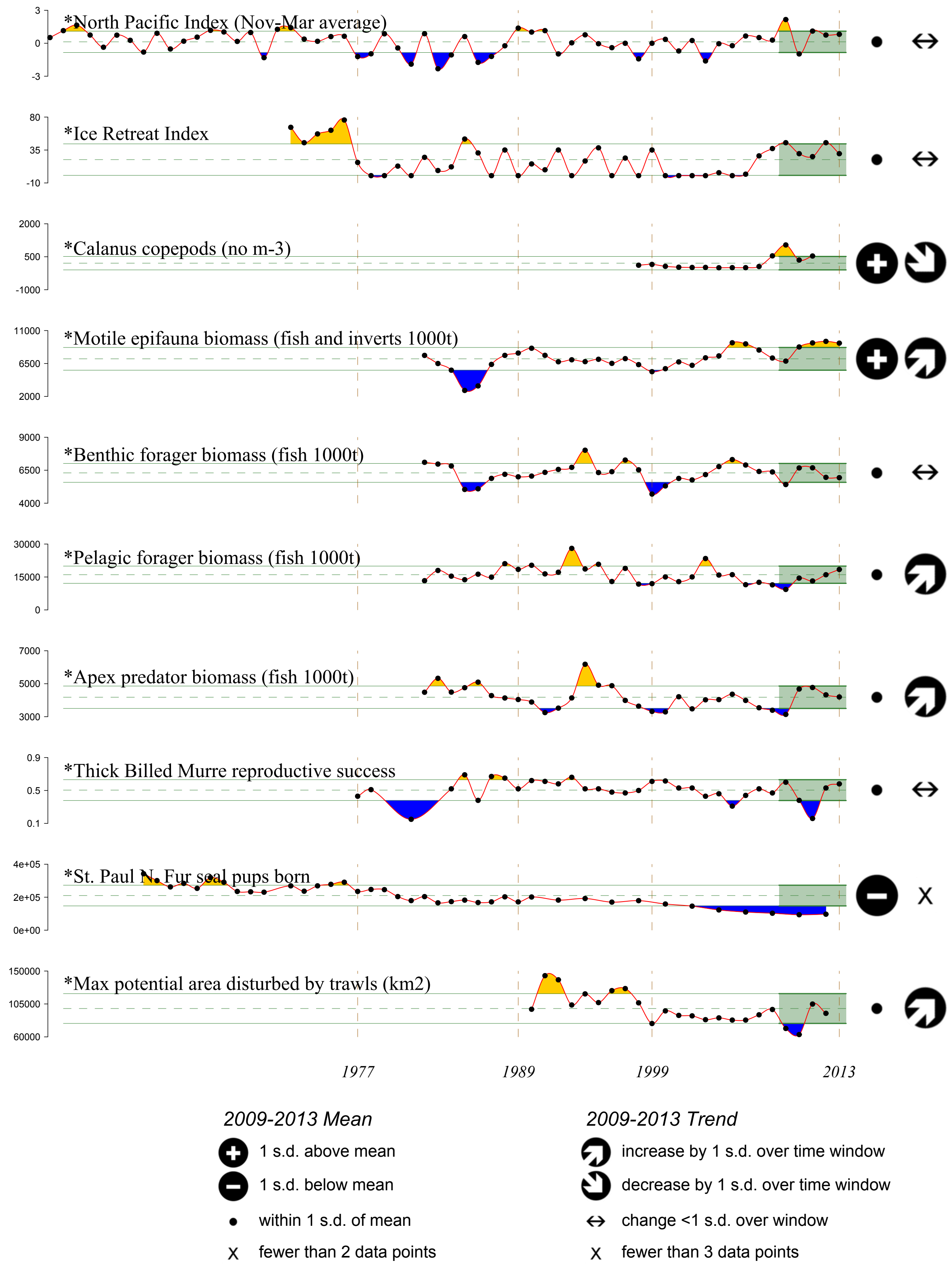


Figure 1: Eastern Bering Sea ecosystem assessment indicators; see text for descriptions. * indicates time series updated in 2013.

Aleutian Islands 2013 Report Card

Region-wide

- In 2012/2013, the winter North Pacific Index was strongly positive implying a **weak Aleutian Low pressure system and suppressed storminess** in the region. **Easterly wind anomalies prevailed** in this region for much of the past year, which may have **enhanced northward transport through Unimak Pass and perhaps also the Aleutian North Slope Current**.
- **Biomass of pelagic forager and apex fish predator foraging guilds decreased across the region** between the 2010 and 2012 surveys, although patterns varied among species. The overall decline **may indicate an underlying environmental shift, lower catchability due to cold water 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 increase 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.

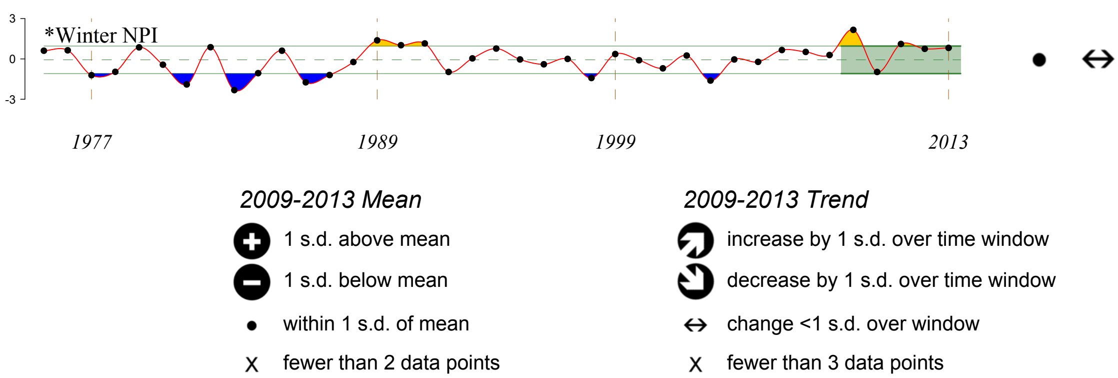


Figure 2: The winter North Pacific Index time series. * indicates time series updated in 2013.

Western Ecoregion

- Although at least 50% of nests produced chicks this year, **reproductive success of planktivorous auklets has shown an overall declining trend** in the past five years, **possibly indicating a return to average zooplankton foraging conditions** compared with the above average reproductive years of 2007-2009.
- **Forage fish show no recent trends** in tufted puffin chick diets. With the exception of *Ammodytes* (sand lance) in 2011, gadids, hexagrammids, and *Ammodytes* have been minimal in diets during the past five years.
- The **pelagic fish foraging guild biomass decreased** since 2010. Pollock, Pacific Ocean perch, and Atka mackerel contributed to this trend; whereas northern rockfish increased.
- The **decrease in the fish apex predators foraging guild** apparent in the 2012 trawl survey was driven by Pacific cod, skates and large sculpins, reversing the increasing trend in this foraging guild observed in 2010.
- The most recent counts of **otters show no trend**, in contrast to the steep decline during the early 2000s. A new survey is planned for 2014.
- Steller **sea lions remain well below their long-term mean** in this ecoregion. Between 1991 and 2008, non-pup counts declined 81%, or at a rate of -10% per year.
- The **amount of area trawled continues to decline** due to recent measures aiming at increasing protection for Steller sea lions.

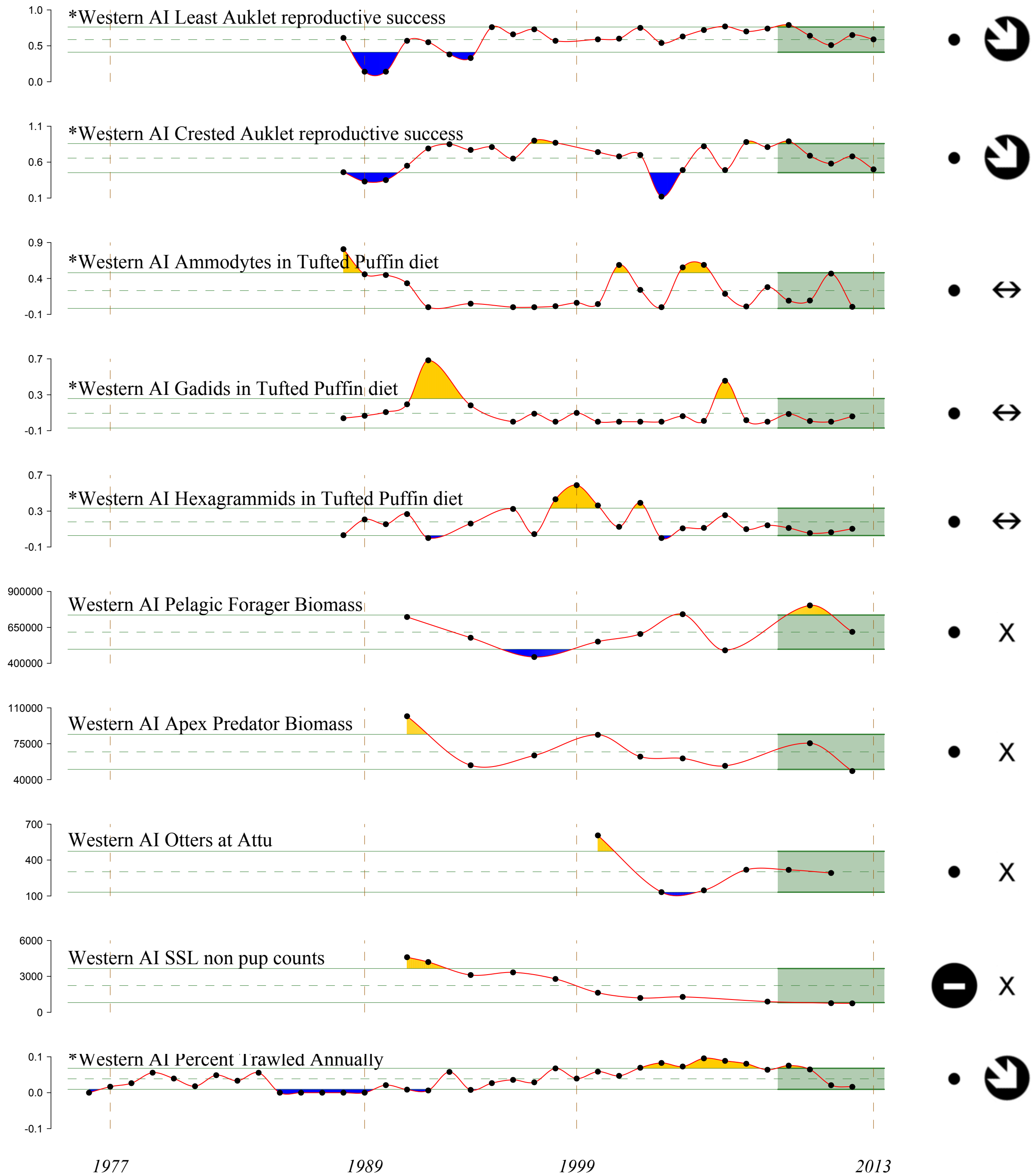


Figure 3: Western Aleutian Islands ecoregion indicators. * indicates time series updated in 2013. See Figure 2 for legend.

Central 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 declined** overall from 2010 to 2012, reversing an increasing trend since 1994. Most of the decline can be attributed to Atka mackerel, although Pacific Ocean perch biomass has increased.
- The **slight decline in fish apex predator foraging guild biomass** from 2010 to 2012 was largely driven by arrowtooth and Kamchatka flounders. Pacific cod biomass increased.
- Recent counts of sea **otters declined** between 2007 and 2011. A new survey is planned for 2014.
- **Counts of non-pup Steller sea lions in 2011 were more than one standard deviation below the long term mean**.
- **School enrollment has shown no trend** in recent years, following a decline since peak enrollment in 2000.
- The **amount of area trawled shows a declining trend**.

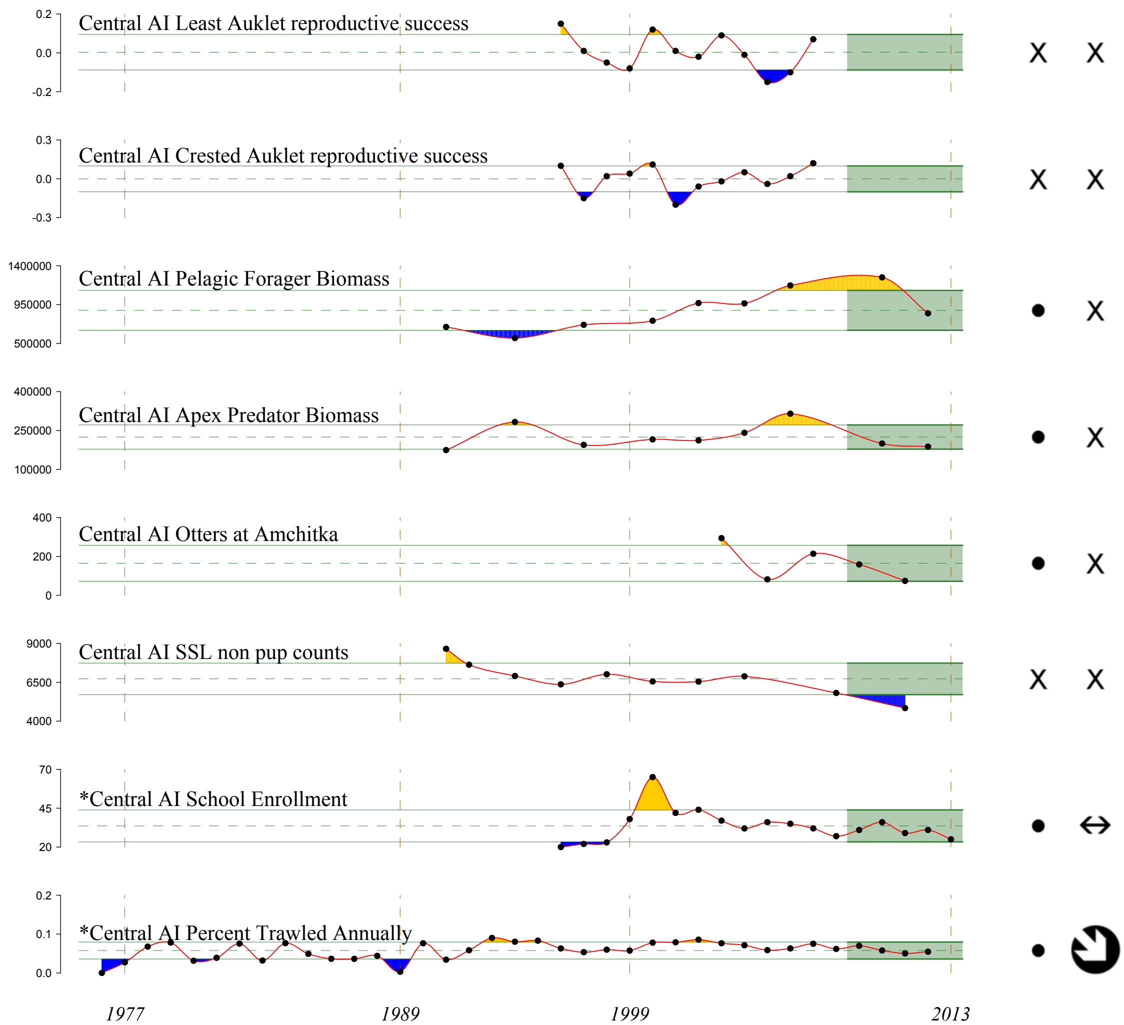


Figure 4: Central Aleutian Islands ecoregion indicators. * indicates time series updated in 2013. See Figure 2 for legend.

Eastern Ecoregion

- **Forage fish trends have varied** in tufted puffin chick meals. In general, ***Ammodytes* (sand lance) and gadids have shown opposite trends**. Gadids were more common through the 1990s and have been increasing recently. *Ammodytes* were more common from 1998 to 2008, and have remained stable in the past 5 years. Hexagrammids are uncommon in this region. These **patterns suggest puffins are responding to changes in forage fish availability**.
- During the most recent survey in 2012, the **fish pelagic forager biomass declined** to the lowest value since 2002. Pollock and Atka mackerel contributed to this trend.
- **Fish apex predator foraging guild biomass declined to the lowest in the time series** in 2012. All species groups exhibited declines from 2010 to 2012.
- In contrast to the other ecoregions, **non-pup counts of Steller sea lions remained high** during the last count 2011. Counts were largely stable through the 1990s, but increased at a rate of 3% per year between 2000 and 2008.
- **School enrollment has fluctuated** in this ecoregion, but has shown no overall trend in the past five years.

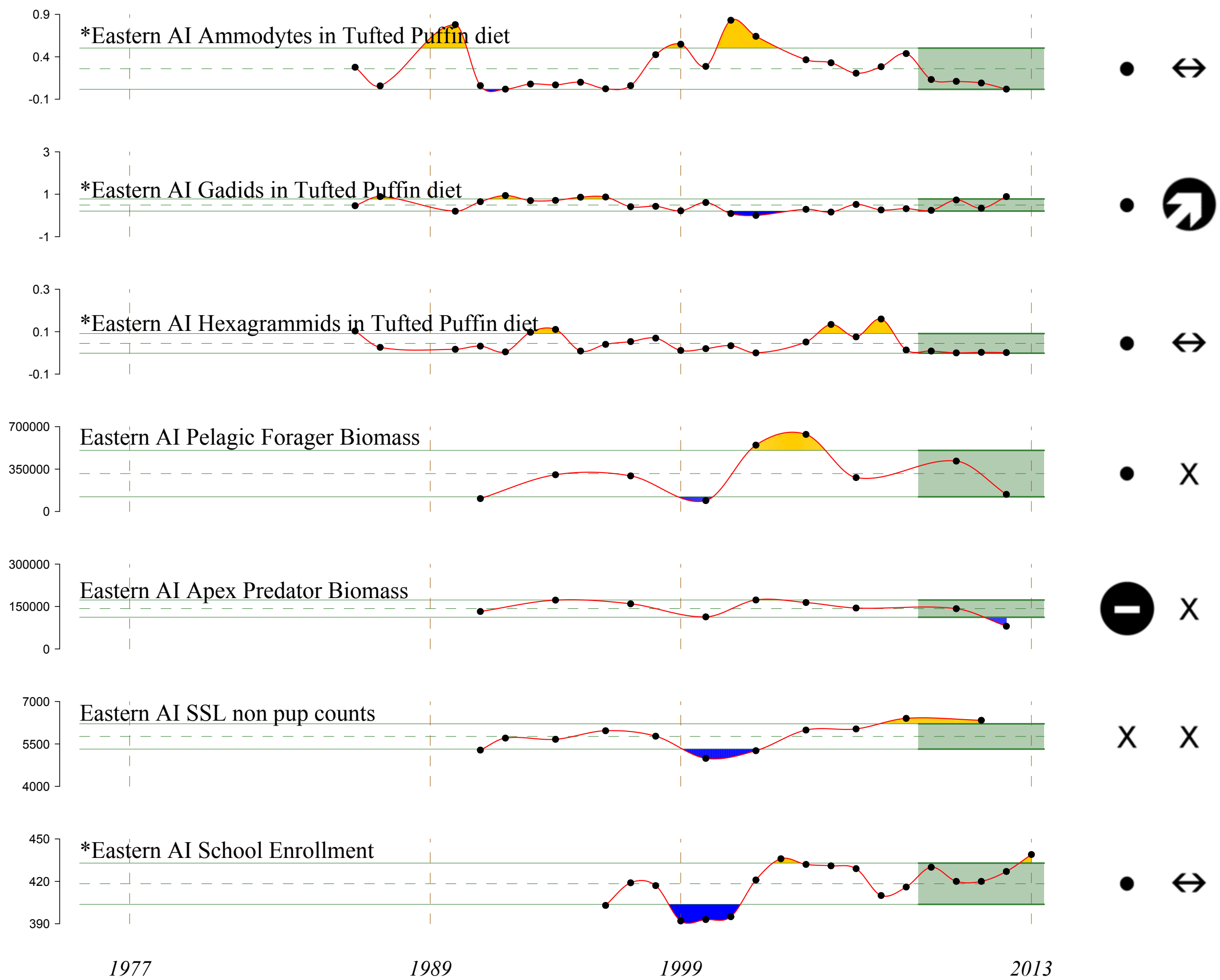


Figure 5: Eastern Aleutian Islands ecoregion indicators. * indicates time series updated in 2013. See Figure 2 for legend.

Executive Summary of Recent Trends

Physical and Environmental Trends

- The state of the North Pacific atmosphere-ocean system during 2012-2013 reflected the combination of mostly near-neutral ENSO conditions and intrinsic variability (p. 67).
- Cooler than normal upper ocean temperatures prevailed in the eastern portion of the North Pacific (p. 67,68).
- The Pacific Decadal Oscillation (PDO) has remained in a largely negative state since the latter part of 2007, and the North Pacific Gyre Oscillation has remained in a positive state during the same time period (p. 72).
- Models indicate a greater likelihood of near-neutral versus either El Niño or La Niña conditions for the winter of 2013-14 (p. 74).

Arctic

- There was reduced sea ice cover in the Arctic during the summer of 2013 compared to seasonal norms, but not to the extent that occurred in 2011 and 2012 (p. 67).
- The September average sea ice extent for 2013 was the sixth lowest in the satellite record. The 2012 September extent was 32% lower than this year's extent ((p. 76).
- Ice concentrations in the Chukchi Sea have been observed to be greater during the summer of 2013 than in 2012 (p. 67).

Eastern Bering Sea

- The year 2013 continues the unusual sequence of seven years with cold winter-spring temperatures (2007-2013), following the six warm temperature years (2000-2005) (p. 79)
- The eastern Bering Sea shelf experienced less storminess than normal in fall 2012 and spring 2013. On the other hand, the weather during fall and winter was cold, which resulted in another relatively heavy ice year (p. 67).
- Sea ice extent in 2008, 2010, 2012 and 2013 are close to record extents not seen since the early 1970s, and contrast to the warm years of 2000-2005 (except 2002). Spring 2013 had less sea ice in Bristol Bay than in 2012. Steady northeast winds throughout winter and spring during 2012 and 2013 contributed to the major extents (p. 79).
- Average surface and bottom temperatures in 2013 were similar to those in 2007. The 2013 average surface temperature was 6.4°C, slightly below the time-series mean from 1982-2012(6.5°C). The average bottom temperature in 2013 was 1.7°C, lower than the long-term mean of 2.3°C (p. 85).

- The cold pool, defined by bottom temperatures <2°C, was comparable to that in 2007 (p. 85).
- Oceanographic surveys of regions within the northern EBS between 2002-2012 have documented spatial variations in oceanographic characteristics (salinity, temperature, and zooplankton abundance). Norton Sound stands out as most distinct from other regions because of high surface and bottom temperatures, low surface and bottom salinities, and lower than average light transmission (p. 88)
- The RACE divison deployed new CTD units during the 2012 slope bottom trawl survey to document spatial variation in salinity, oxygen concentrations, pH, and turbidity (p. 101).

Alaska Peninsula and Aleutian Islands

- A strong eddy developed south of Amukta Pass during summer 2012, indicating that higher than average volume, heat, salt, and nutrient fluxes to the Bering Sea through Amukta Pass may have occurred during summer 2012 (p. 91).
- Easterly wind anomalies prevailed in this region during the fall of 2012 and spring of 2013. Anomalies in this sense tend to enhance the northward transport through Unimak Pass and perhaps also the Aleutian North Slope Current (p. 67).
- Eddy energy in the region was from the fall 2012 through early 2013, indicating that average volume, heat, salt, and nutrient fluxes through Amukta Pass were likely smaller during the this time (p. 91).
- Sea surface temperatures appear to have been near normal during the past year. Sea level pressure patterns indicated suppressed storminess (p. 68).

Gulf of Alaska

- The weather in this region included near normal air temperatures and below normal precipitation during fall 2012 to spring 2013 (p. 67).
- The mixed layer depths in the Gulf were slightly deeper than usual during the winter of 2012-2013 suggesting that the supply of nitrate to the euphotic zone for the spring bloom was also enhanced (p. 67).
- The winds during spring and summer 2013 were of the sense to favor more coastal upwelling than usual in the northern and eastern portions (p. 67).
- Eddy Kinetic Energy (EKE) levels in the western Gulf of Alaska were high in 2012 and 2013. Thus, phytoplankton biomass likely extended farther off the shelf in those years and cross-shelf transport of heat, salinity and nutrients were probably stronger (p. 93).
- In the northern Gulf, a spike of high EKE early in the year (February) was followed by low EKE from March through June 2013(p. 93).
- The 2012/2013 PAPA trajectory index 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 and certainly not atypical. This is consistent with the northeast Pacific wind forcing, which featured very strong westerly anomalies (p. 95).
- The 2013 pattern of water temperatures recorded during the bottom trawl survey was similar to the pattern seen in the 2011 survey. The water column appears stratified with relatively warm near-surface waters and temperatures rapidly dropping to 6°C or less in the upper 50 m across the entire Gulf. Overall water temperatures in GOA have been cooler since 2007 when compared with previous survey years (p. 98).
- The RACE divison deployed new CTD units during the 2013 bottom trawl survey to document spatial variation in salinity, oxygen concentrations, pH, and turbidity (p. 101).

Ecosystem Trends

Alaska-wide

- Total estimated seabird bycatch in all Alaskan groundfish fisheries in 2012 was 4,997 birds. This estimate is 40% below the running 5-year average for 2007-2011 of 8,295 birds (p. 159).
- 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 3,704 in 2010. Numbers increased to 8,914 in 2011, the second highest in the streamer line era, but fell back to 4,544 in 2012 (p. 159).
- The apparent absence of any recent abrupt shifts in leading axes of basin-wide biological variability indicates a continuation of the northeast Pacific ecosystem states that have existed over recent decades (p. 164)

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. 102).
- Acoustic surveys of euphausiids on the middle and outer shelf indicate that summertime euphausiid density increased from 2004-2009, but subsequently declined in 2010 and 2012 (p. 106).
- Continuous plankton recorder observations indicated that the 2012 copepod community size anomaly was high in southern Bering Sea regions, indicative of cool conditions where subarctic species predominate. However, mesozooplankton biomass appeared to be low in 2012 (p. 115).
- Jellyfish relative CPUE in 2013 was down slightly from 2012, but remained relatively high when compared to the last 10 years (p. 108).
- During fall BASIS survey, total jellyfish biomass more than doubled in 2012 compared to 2011 and was the highest recorded biomass over the surveys. One station in the southern Bering Sea was responsible for half the total catch for the entire survey. This differs from 2010, when combined jellyfish species biomass also nearly doubled compared to the previous highs, but was spread out over the sampling grid (p. 109).
- Oceanographic surveys of the northern EBS during late summers from 2002-2012 have found highest abundances of large and small zooplankton in the South Bering Strait and North Inner regions, respectively, which coincides with the highest regions of juvenile salmon CPUE (p. 88)
- Young of year pollock energy density increased from values near 3.6 kJ/g in 2003-2005 to values near 5.0 kJ/g in 2008-2012. In 2012 the average energy content was low (6.52 kJ/fish) suggesting that the number of age-1 recruits per spawner should be below the overall median level in 2013 and the biomass of age-3 recruits should be less than median in 2015 (p. 118).
- In 2013, aerial surveys of Togiak District herring recorded 169,020 tons, which is 113% of the most recent 10-year average and 115% of the 20-year average (p. 122).
- Historically, Bristol Bay sockeye salmon runs have been highly variable, but in recent years, 2004-2010, runs have been well above the long term mean. The 2011 and 2012 runs of 31.9 and 29.1 million fish respectively, were closer to the long-term historical average (1963-2011) of 32.38 million fish. The run size forecasted for 2013 Bristol Bay sockeye is 26.03 million.
- The 2013 springtime drift patterns based on OSCURS model time series runs do not appear to be consistent with years of good recruitment for winter-spawning flatfish such as northern rock sole, arrowtooth flounder and flathead sole (p. 143).

- The 2011 Temperature Change (TC) index value was slightly above the long term average, therefore slightly higher than average numbers of pollock are expected to survive to age-3 in 2013. In the future, the TC values in 2012 and 2013 indicate below average abundances of age-3 pollock in 2014 and above average abundances of age-3 pollock in 2015 (p. 143).
- Eelpouts, poachers, and sea stars show broadly similar time trends in trawl survey CPUE, but no outstanding changes for 2013 (p. 152).
- Species richness and diversity on the Eastern Bering Sea shelf suggest relative stability over the eleven year period with higher diversity in the southern and northern ends of the eastern Bering Sea areas. The central EBS showed consistently lower diversity.(p. 170).
- Groundfish length-weight residuals (a measure of fish condition) has 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. Trends in walleye pollock and yellowfin sole residuals were highly correlated. There has been a distinct negative trend in Pacific cod since a peak value in 2003. Spatial trends in residuals were also apparent for some species (p. 139)

Aleutian Islands

- The distributions of rougheye rockfish and shortspine thornyhead 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. 146).

Gulf of Alaska

- Icy Strait zooplankton density anomalies were strongly negative from 1997-2005, strongly positive in 2006-2009, and negative in 2010-2012. Total density showed little correspondence with annual temperature trends across years, with both positive and negative anomalies in both warm and cold years (p. 111).
- Icy Strait zooplankton were numerically dominated by calanoid copepods, including small and large species (long-term mean total density, 1997-2012) (p. 111).
- Lower trophic level productivity apparently increased in 2012 in the Alaskan Shelf region (northern GOA) in contrast to 2011. Copepod community size, mesozooplankton biomass, and large diatom abundance in 2012 all increased from 2011 levels (p. 115).
- The 2010 and 2011 mean abundance values of all ichthyoplankton taxa except rockfish (*Sebastes* spp.) deviated moderately from the long term survey means (p. 134).
- Forage species catch rates remain at low levels, well below the peak values observed in the 1970s and early 1980s. Pink shrimp and juvenile pollock remain widespread but catch rates varied widely both between bays and within bays. Highest catches of juvenile pollock were found in Marmot Bay but catches overall were generally low (p. 120).
- Although the estimated total mature herring biomass in southeastern Alaska has been above the long-term (1980-2012) median of 89,709 tons since 1998, and continues to be in 2012, an apparent decrease in biomass has been observed between 2011 and 2012. Notable drops in biomass were observed in Hoonah Sound and Sitka Sound (p. 124).
- 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 (p. 128).

- In addition to pink salmon CPUE, peak migration month, NPI, %pink in June-July trawl hauls, and the ADFG Escapement Index are significantly correlated with harvest and suggest a strong pink salmon harvest in 2013 (p. 131).
- 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 shallower. Changes in rockfish distribution with temperature have occurred most notably since 2007, when 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 was not significant (p. 146).
- 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 2012 from years of record high catches seen from 2002 to 2005 (p. 154).

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. 175).
- 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 the tenth year of a 10-year rebuilding plan. Of the non-FSSI stocks, only the BSAI octopus complex is subject to overfishing, and none are overfished or approaching an overfished condition. (p. 204).
- 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. 172).
- 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 (2008-2012). The total number of vessels was 1,518 in 1994 and 917 in 2012. The number of vessels using trawl gear decreased from 257 in 1994 to 182 in 2012.(p. 211).
- From 1990 to 2010, fishing community populations increased by 4.5% in the BSAI and 12.6% in the GOA (p. 212 and 215)

Bering Sea

- The maximum potential area of seafloor disturbed by trawling remained relatively stable in the 2000s, decreased in 2009-2010 and in 2012 returned to levels seen in the early 2000s (p. 179).
- Discarded tons of groundfish have continued a declining trend since 1994, but the 2012 values remained similar to 2011 (p. 171).
- 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 a peak in 2011, followed by a sharp

drop to an intermediate level in 2012. HAPC biota catch decreased from 2003 to 2007 and has been generally steady since. Benthic urochordata comprised the majority of HAPC biota catches in the EBS in all years except 2009-2012, when sponges and sea anemones increased in importance (p. 172).

Aleutian Islands

- Discard rates have declined over the past nine years. Discards and discard rates are much lower now than they were in 1996 (p. 171).
- Trends in total non-target catch in the groundfish fisheries have varied in the AI. The catch of Scyphozoan jellies and HAPC biota has been variable and shows no apparent trend over time. Assorted invertebrate catcheshave generally trended upward from 2005 to a peak in 2012, with the exception of 2011 when the catch dropped back to nearly the 2005 level. (p. 172).

Gulf of Alaska

- Discard rates in the Gulf of Alaska have varied over time but were lower than average in 2011 and 2012 (p. 171).
- 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. 172).

Contents

* indicates contribution updated in 2013
† indicates new contribution

List of Tables

List of Figures

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

December 2012 SSC Comments

The SSC appreciates the responsiveness of the authors to the 2011 SSC requests for improving the Ecosystem Considerations chapter. The chapter continues to improve in quality of presentation and relevance of the information presented. The reorganization of the presentations, both the "taxonomic order" and the subjects covered within the individual presentations on Ecosystem Status and Management Indicators, have improved the transfer of information. The inclusion of the Implications section is especially useful, though not all individual authors have done so. The start on the new Arctic section was excellent.

Thank you.

Two possible additional structural changes might be considered. For the reader to get the clearest view of the North Pacific as a whole as well as the four management regions under consideration (Gulf of Alaska, Aleutians, eastern Bering Sea, and Arctic), it might be helpful to separate the individual reports in the Ecosystem Status and Management Indicators section by management area. That would help the reader see the big picture for each area and would assist users in finding the indicator reports of greatest relevance to their needs.

We have considered this but decided against this structure as many of the individual reports in the Ecosystem Status and Management Indicators section cover multiple regions (e.g., Time Trends in Groundfish Discards (p. 171), Indicators of Basin-scale and Alaska-wide Community Regime Shifts (p. 164). Dividing these into separate reports would create redundancy. Instead, we hope that the continued development of the Ecosystem Assessment section, which is organized by region, will provide an overview of each region, with references to specific reports for greater detail.

A second structural change that would be helpful would be to develop brief, integrated, summaries of indices that are otherwise included in several reports. For example, the four reports on climate (Overland, Lauth, Eisner, and Bond) should be integrated. Similarly, the three reports that address flows into the Bering through the Aleutian Passes should be integrated and disparate findings resolved to reduce confusion. In another example, Bond suggests reduced flow because of westerly winds, Ladd suggests increased flow because of eddies to the south of Amukta Pass, and Laman's report on water temperatures in the Aleutians needs to address both of the forgoing to pull the picture together.

Likewise there are three reports on bottom temperatures on the eastern Bering Sea shelf that have some redundancies and call for a synthesis, as is also true for eastern Bering Sea zooplankton. If the individual report writers are unable to collaborate before turning in their report, perhaps the editor can add a brief synthesis after a group of reports on similar subjects to tie them together.

This year, we had planned to add an Editor's Summary at the beginning of the sections (e.g., zooplankton, salmon) within the Ecosystem Status and Management Indicators that have multiple individual reports, but were unable to accomplish this due to the furlough.

As the various indices become more established with solid time series behind them, effort should be made to test their skill in predicting recruitment, or forecast ecosystem responses.

We agree that this is important, and while we have not included a comprehensive analysis in this document, we hope to include more prediction evaluation in the near future. An example of this type of analysis already included in the document is in Martinson's Temperature Change Index update (p. 143). Further, measuring forecast skill is a specific immediate (1-2 year) goal of the AFSC's Integrated Ecosystem Assessment Program, as improved predictive hypotheses arising from the Bering Sea and Gulf of Alaska Integrated Ecosystem Research Programs transition into ongoing operational predictions. We hope to be able to reference and incorporate these types of forecasts into future ecosystem assessments in this document.

Where appropriate and possible, it would be useful to include error measures on all tables and graphs so the reader has a means of assessing the significance of the change being discussed (e.g., Fig. 38, Fig. 50, Table 4, Fig. 53, Fig., 54 [from 2012 report])

We have made extra effort to incorporate error estimates where appropriate.

Arctic Assessment: *Overall, this assessment is very well done, although brief. It will be important to develop additional ecosystem indicators: these could include data such as ice cover over the Chukchi and Beaufort seas shelves, George Divoky's information on black guillemots, a measure of subsistence hunter harvest rates and CPUE, the condition of polar bear and other harvested species.*

We have provided an update to the preliminary Arctic assessment, which contains a more specific list of potential indicators to develop. Some of the proposed indicators are in early stages (e.g., the DBO timeseries); others refer to data that are not currently available (e.g., black guillemots).

Relative to the presentation given, the SSC notes that the unusual mortality event (UME) for marine mammals is more extensive than just walrus. Unusual skin lesions and lethargy have been noted in a variety of arctic marine mammals (seals, walrus, polar bears) and is an area of active investigation. In addition, as ice cover is reduced, many different populations of marine mammals will be impacted (e.g. walruses crowding together on shore, changes in whale abundance and distribution, potential impacts on ice seals). These potential impacts are driving petitions to list several species of ice seals.

The preliminary Arctic assessment in the 2012 report included discussion of the unusual mortality event (UME) for both ice seals and walrus, but we were unaware of the impact on polar bears. We did not provide an update on this as to our knowledge, no seal or walrus UME have been reported in 2013.

Eastern Bering Sea: *The section on the EBS is strong, but in several areas could be strengthened by integrating different data streams. For example, in the consideration of top-down effects, it may* *be time to begin modeling the potential impact of great whales on zooplankton and forage fish stocks, including age-0 and age-1 pollock.*

As stated above, we plan to add an Editor's Summary at the beginning of the sections (e.g., zooplankton, salmon) within the Ecosystem Status and Management Indicators that have multiple individual reports. With these summaries and the updated ecosystem assessments, we hope to provide integrated ecosystem information to the Council. We agree that modelling the impact of great whales is an important topic to investigate, but is currently beyond the scope of this document.

In discussing Bering Sea large zooplankton (page 10), there is no mention of Themisto libellula. What is the status of this amphipod, and what are implications of changes in its biomass, if any?

We have been in contact with the author. The data are being compiled, but we were unable to include it in this year's document. We plan to do so next year.

If the non-specified catch increase in the Bering Sea (page 14) is primarily due to increased catches of capelin and eulachon, is this the result of an increase in these species? Please tie in these findings with the forage fish CPUE, page 129, also mentioned on page 11 and 191.

We have been in discussion with the author of the new forage fish stock assessments, Olav Ormseth, about how to partition discussion of forage fish. We have decided to focus on forage fish as ecosystem indicators and their function in the ecosystem in this document, and focus on assessing forage fish population trends in the forage fish stock assessments. We do, however, discuss recent increases in capelin within the pelagic foragers guild survey biomass estimates in the EBS report card and ecosystem assessment.

If there is a tie between forage fish abundance and mushy halibut syndrome in the Gulf of Alaska, is there any evidence of a connection between the survival of Chinook salmon in the Bering Sea and the distribution and/or abundance of forage fish there (page 54)? What might be the expected lag between a change in forage fish abundance and returns of Chinook to the Yukon River?

This is are good questions and would be useful to know. We support this type of research, and hope to be able to include these types of findings in future Ecosystem Considerations reports.

On page 55, it is suggested to examine selected indices by domain. This seems like a good idea, if feasible. Given the upcoming synthesis of the Bering Sea Project, which will attempt to work at the level of the BEST/BSIERP areas, it might be good to see whether the scale at which they hope to work might be appropriate.

This is a good suggestion, which we will keep in mind as the Bering Sea Project synthesis is completed.

On page 56, middle you refer to the need for research on the spatio-temporal distribution of Stellers sea lions and their prey. It would be good to include the spatio-temporal distribution of sea lion predators as well.

We agree and will pass this comment along to the primary sea lion researchers.

On page 56, middle, would it be possible to use industry CPUE as an index of fishery performance?

We will provide this suggestion at the next meeting of the EBS Ecosystem Assessment Team, during which the top EBS indicators will be re-evaluated. One promising avenue is to use tow and/or trip duration data from the observer program as an effort metric to relate to catch. An example of this is presented in the 2013 EBS Pollock stock assessment that shows catch (kg)/tow duration plotted for 10 day averages for several years.

On page 111, the graph indicates very low primary production in the summer/fall of 2007. That was a particularly weak year-class of pollock, and can any synthesis be pulled together that would help tie together the events and findings for 2007? (see also page 115, 118, 129, 132).

Interestingly, the year 2007 seems to be of particular importance again this year. Ice extent, retreat, and bottom and surface temperatures in 2013 were very similar to those in 2007 (p. 79, 85). However, we currently don't know the abundance and condition of this year class of pollock in the EBS. In the GOA, the 2013 pollock year class appears strong, although survival to fishery recruitment remains to be seen (p. 42). In the EBS, the condition (average energy content per fish) of the 2012 age-0 pollock was low, leading to the prediction of poor survival to age-1 (p. 118).

On page 194, the decrease in HAPC catch is discussed. Is it possible that the decrease is because of prior destruction of the HAPC? Relate to the catch of HAPC in the bottom trawl survey.

Interestingly, the trends in HAPC biotat in the NMFS bottom trawl survey have been increasing in the EBS (p. 102)while the catch as non-targets in the commerical fisheries has been stable, but low relative to the years 2003-2006 (p. 172). Some of the specific patterns are similar (e.g., sea anemones and sponges comprising most of the HAPC biota non-target catch in the recent few years coinciding with record high values in the trawl survey.

Aleutian Islands: *In the western Aleutians dusky/rougheye rockfish are being caught in unusually high numbers (western ecoregion, hot topic, page 4). How does this relate to recent stock assessments for these fish in this area?*

This is being addressed by the stock assessment author.

On page 62, where there is a recap of fish stocks in the Aleutians, it would be good to mention the status of cod. What is the role of cod in sea lion diets? Many years ago, cod may have been a principal prey.

We hope to address this in more detail next year when we have 2014 survey data and a more complete update to the Aleutian Islands ecosystem assessment.

Page 64: Is there a time series of puffin chick survival or growth available? Prey switching without some independent measure of availability or abundance could mean the increase of prey a rather than the decrease of prey b.

These data are available, and we hope to develop an indicator that addresses these comments in the near future.

Gulf of Alaska: *The SSC looks forward to the development and inclusion of a Report Card section for the Gulf of Alaska.*

Once again we have had to postpone the development of a Gulf of Alaska report card and assessment due to staff loss. We hope to convene an assessment team in early 2014.

The SSC expressed concern about the AFSC GOA ichthyoplankton survey going from an annual *effort to a biennial effort. Long-term (>25 years) continuous ichthyoplankton surveys are extremely rare, and effort should be made to ensure the survey continues at as frequent intervals as possible. The value of these studies of larval fish would be enhanced if there were some analyses of the relationships between larval abundance (and condition) and subsequent recruitment. On page 152, there is no mention of how well the index of larval abundance does at predicting recruitment. Ongoing evaluations of how predictions are performing over time are critical to continue.*

This analysis is in progress, and we hope to include a summary in the near future.

On page 173, is there any idea why there was a jump in the bycatch of seabirds 2011? Are the birds habituating to the streamers, and beginning to ignore them? Or is this due to increase in TAC? Scaling bycatch to hooks set might be useful.

An alternative hypothesis is that bycatch increases when ocean conditions are poor for foraging seabirds. This may explain the increase in bycatch during 2011. The link between ocean conditions and bycatch rates is discussed briefly in the EBS ecosystem assessment (p. 53) and the seabird bycatch contribution (p. 159).

In the Gulf of Alaska, there has apparently been a decline in forage fish and an increase in mushy halibut syndrome. Forage fish are also prey for Chinook salmon. Can any connections among these three factors be identified? It would also be appropriate to examine how changes in the abundance of humpback whales and zooplankton may be impacting forage fish availability or abundance.

This is an area of ongoing research that we hope to report on in a future Ecosystem Considerations report.

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 three main sections:

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

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

The purpose of the second section, the Ecosystem Assessment, is to synthesize historical climate and fishing effects on the eastern Bering Sea/Aleutian Islands and Gulf of Alaska ecosystems using information from the Ecosystem Status and Management Indicators section and stock assessment reports. Notable trends, "hot topics", that capture unique occurrences, changes in trend direction, or patterns across indicators are highlighted at the 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 third section, Ecosystem Status and Management Indicators, is to provide detailed information and updates on the status and trends of ecosystem components as well as to provide either early signals of direct human effects on ecosystem components that might warrant management intervention or to provide evidence of the efficacy of previous management actions. 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.

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

In 2002, stock assessment scientists began using indicators contained in this 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. Most of the time series data for contributions are now available on the web, with permission from the authors.

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

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

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

Ecosystem Assessment

Stephani Zador and Kerim Aydin

Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: stephani.zador@noaa.gov
Last updated: October 2013

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 new this year, 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 SAFE provides the historical perspective of status and trends of ecosystem components and ecosystem-level attributes using an indicator approach. For the purposes of management, this information must be synthesized to provide a coherent view of ecosystems effects in order to clearly recommend precautionary thresholds, if any, required to protect ecosystem integrity. The eventual goal of the synthesis is to provide succinct indices of current ecosystem conditions reflecting these ecosystem properties. In order to perform this synthesis, a blend of data analysis and modeling will need to be employed to place measures of current ecosystem states in the context of history and past and future climate.

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.

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

Sea. in 2012, we provided a preliminary ecosystem assessement 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.

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 expect to apply a team synthesis approach to the GOA ecosystem in 2014 and to the Arctic at a later time.

The entire ecosystem assessment is now organized into six 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 and eastern Bering Sea (including the eastern Bering Sea Report Card). For the Aleutians Islands, we updated the Report Card, but included only a description of the region and explanation of the indictors that were included in past assessments.

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, non-target) 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

Pacific walrus hauling out on the Chukchi Sea coast of Alaska

Description: Thousands of Pacific walrus hauled out on the Chukchi Sea coast of Alaska, near Pt. Lay in September 2013 (`http://www.afsc.noaa.gov/NMML/cetacean/research/Walrus-ASAMM2013.php`). Large numbers of Pacific walrus using coastal haulouts on the Chukchi Sea coast of Alaska have been observed several times since 2007 (Fischbach et al., 2009; Garlich-Miller et al., 2011) and are thought to be in response to recent declines in Arctic sea ice (Jay et al., 2012; Oakley et al., 2012).

Status and trends: Late summer and fall aggregations of Pacific walrus were observed at coastal haul outs on the northwestern coast of Alaska in 2007, 2009, 2010, 2011, and 2013. Sufficient amounts of remnant sea ice for hauling out and resting were present in 2008 and 2012, allowing Pacific walrus to remain offshore (`http://www.afsc.noaa.gov/NMML/cetacean/research/Walrus-ASAMM2013.php`).

Factors influencing observed trends: Pacific walrus forage on the seafloor for clams and other invertebrates (Fay, 1982) in waters generally less than 80 m depth (Fay and Burns, 1988). Pacific walrus use sea ice as a platform to haul out and rest between foraging excursions at offshore feeding areas over the shallow continental shelf of the Chukchi Sea. Record low sea ice coverage in recent summers has left the ice edge farther to the north over deeper waters beyond the continental shelf. There, the water is too deep for Pacific walrus to forage optimally. This has forced high numbers of Pacific walrus to haul out and rest on the Chukchi Sea coast of Alaska and to forage in waters within range of shore (Jay and Fischbach, 2008; Garlich-Miller et al., 2011; Jay et al., 2012; Oakley et al., 2012).

Implications: It is not known if the recent shore-based aggregations of Pacific walrus will lead to localized prey depletion near haul outs or if concentrating walrus near shore is forcing them to consume suboptimal prey (Jay et al., 2012; Oakley et al., 2012).

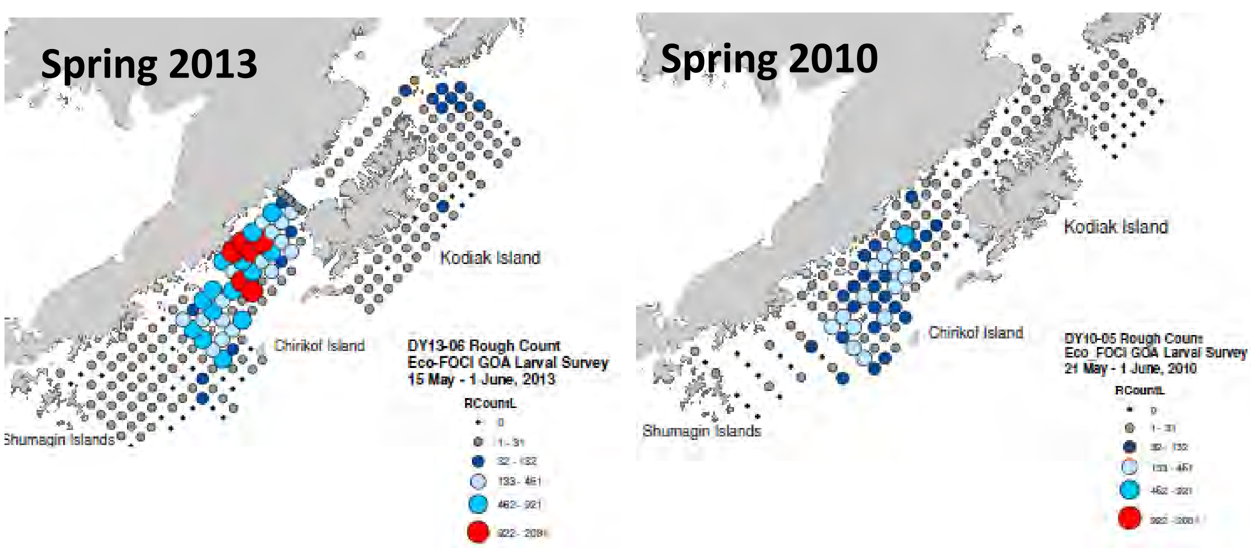
Pacific walruses at terrestrial haulouts can be disturbed by anthropogenic activity (e.g., hunters, vehicles, airplanes, boats, etc.) and predators. In response to disturbance walrus may stampede into or out of the water (Fay and Kelly, 1980; Fay, 1982). These stampedes may result in the death of hundreds to thousands of walrus annually; the deaths are the result of physical trauma associated with trampling by other Pacific walrus (Fay and Kelly 1980; Fischbach et al. 2009). The youngest and smallest members of the herd, particularly calves and yearlings, may have an elevated risk of death during stampedes (Garlich-Miller et al., 2011), which may have an effect on the larger population dynamics (Udevitz et al., 2013). Mitigation measures limiting anthropogenic disturbance at walrus haulouts may be an effective way to minimize haul out associated mortalities (MacCracken, 2012; Robards and Garlich-Miller, 2013).

Hot Topics: Gulf of Alaska

Large pulse of larval/age-0 pollock: strong 2013 year class?

Description: The Eco-FOCI group at the AFSC documented abundant young of the year pollock in the western Gulf of Alaska that were observed during larval trawl surveys in the spring and again as age-0's during the late summer. The spring ichthyoplankton survey was conducted from May 15 to June 1, 2013. The objectives of this cruise were to conduct an ichthyoplankton survey and process studies in the region between the Shumagin Islands and Shelikof Strait and from SE Kodiak to the Kenai Peninsula so that we could estimate the abundance, transport, and factors influencing the survival of young walleye pollock larvae. The standard gear for this survey was 20/60-cm bongos with 0.153/0.505-mm mesh netting. Tows were deployed to a maximum of 100 meters, or 10 meters off the bottom where water depth was shallower. A Sea-Bird FastCat was mounted above the 20/60 bongo array to provide depth, temperature, and salinity data. The late summer cruise was conducted August-September 2013. Cruise objectives were to extend a time series of juvenile walleye pollock abundance and monitor the environment and structure of the neritic community. Fish were collected with a Stauffer (aka anchovy) trawl equipped with a 3 mm codend liner and fished with 1.5 2.1 m steel-V otter doors (566 kg each). It was deployed at 50 m/min, allowed to settle at 200 m headrope depth or 20 m above the seafloor, whichever was shallowest, and then retrieved at 10 m/min. Net depth was monitored with a Furuno net sounder. Ship speed over ground was 2.5 to 3.0 knots.

The spring larval surveys had high rough counts of larval pollock mainly in the Shelikof sea valley west of Kodiak Island (Figure 6(a)). These counts were notably higher than counts taken during a similar survey from 21 May to 1 June in 2010 (Figure 6(b)).



(a) 2013 (b) 2010

Figure 6: Rough counts of pollock larvae during NOAA Eco-FOCI cruises during May 15- June 1 2013 and May 21 - June 1 2010

.

During late summer this year, both day and night tows caught high numbers of age-0 pollock. The pollock were widespread; only four trawl locations did not catch any pollock. The largest catches were between the Shumagins and south of Unimak Island.

Age-0 abundance at 26 sites (locations shown approximately within the circle in Figure 7) that have been sampled repeatedly from 2000-2013 is shown in Figure 8. The 2013 abundance at these stations is the second highest in the time series (2005 was the highest). These values are shown with the back-dated McKelvey Index (estimates of age-1 during the winter) and the age-1 abundance estimated in the stock assessment indicate that the correspondence among these different estimates of the same age-class of pollock is not always good (Figure 8).

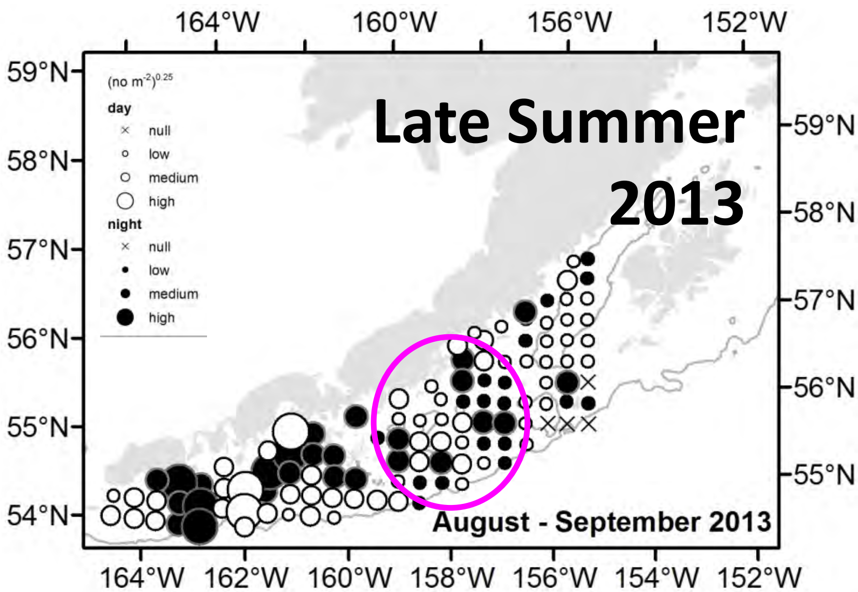


Figure 7: Age-o pollock abundance in low, medium, high categories during day (open circles) and night (closed circles) tows on NOAA Eco-FOCI cruises during August-September 2013. Pink circle indicates approximate location of 26 sites surveyed repeatedly (see Figure 8)

Implications: The abundant larval pollock that were detected during spring and appeared to persist through summer may indicate a strong year class in 2013. However, it is unknown what proportion of this year class will survive to age-1 or recruit to the fishery. Larval and age-0 pollock are an important source of prey for many marine predators.

"Mushy" Halibut Syndrome uncommon in 2013

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.

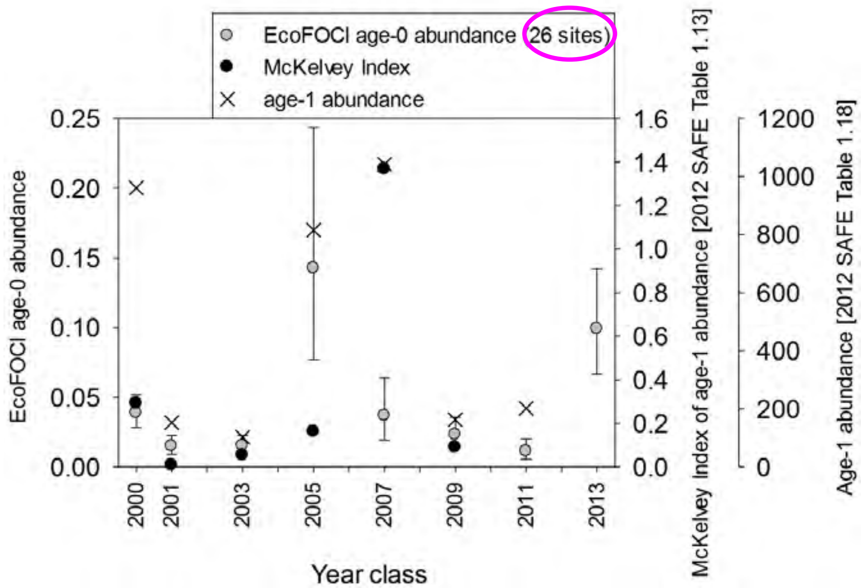


Figure 8: Abundance of year-classes of pollock measured as age-0's during late summer (Eco-FOCI), winter age-1 (McKelvey Index), and estimated as age-1 in the GOA pollock stock assessment (Dorn et al., 2012).

Status and trends: ADF&G received few reports of "mushy" halibut during the 2013 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.

Record pink salmon harvest in 2013

The Alaska Department of Fish and Game reported a record pink salmon harvest of 219 million fish, according to an Oct 10 press release (`http://www.adfg.alaska.gov/index.cfm?adfg=pressreleases.pr10102013`). The previous record harvest was 161 million in 2005. Orsi et al. (this document, p. 131) predicted a strong harvest in Southeast Alaska given the high peak juvenile pink CPUE, favorable July month of peak seaward migration, a high North Pacific Index, and a high average percentage of pink salmon caught among juveniles in June-July trawl hauls. However the preliminary harvest reported by ADF&G for the southeast region (89.4 M) was substantially higher that predicted (53.8 M) (`http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.bluesheet`). Favorable ecosystem conditions throughout their 2-year life cycle likely influenced their record returns.

Update to the 2012 Preliminary Assessment of the Alaska Arctic

Contributed by Andy Whitehouse[1] and Stephani Zador[2]

[1]Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
[2]Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA

Defining the Alaska Arctic assessment area

In last year's preliminary assessment of the Alaska Arctic, we proposed the inclusion of the northern Bering Sea (>approx. 60^{o}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^{o}N) but is now located south of St. Lawrence Island at 61.5^{o}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^{o}N as the southern boundary of the Alaska Arctic assessed area, coincident with the LME boundary revisions made by the Arctic Council.

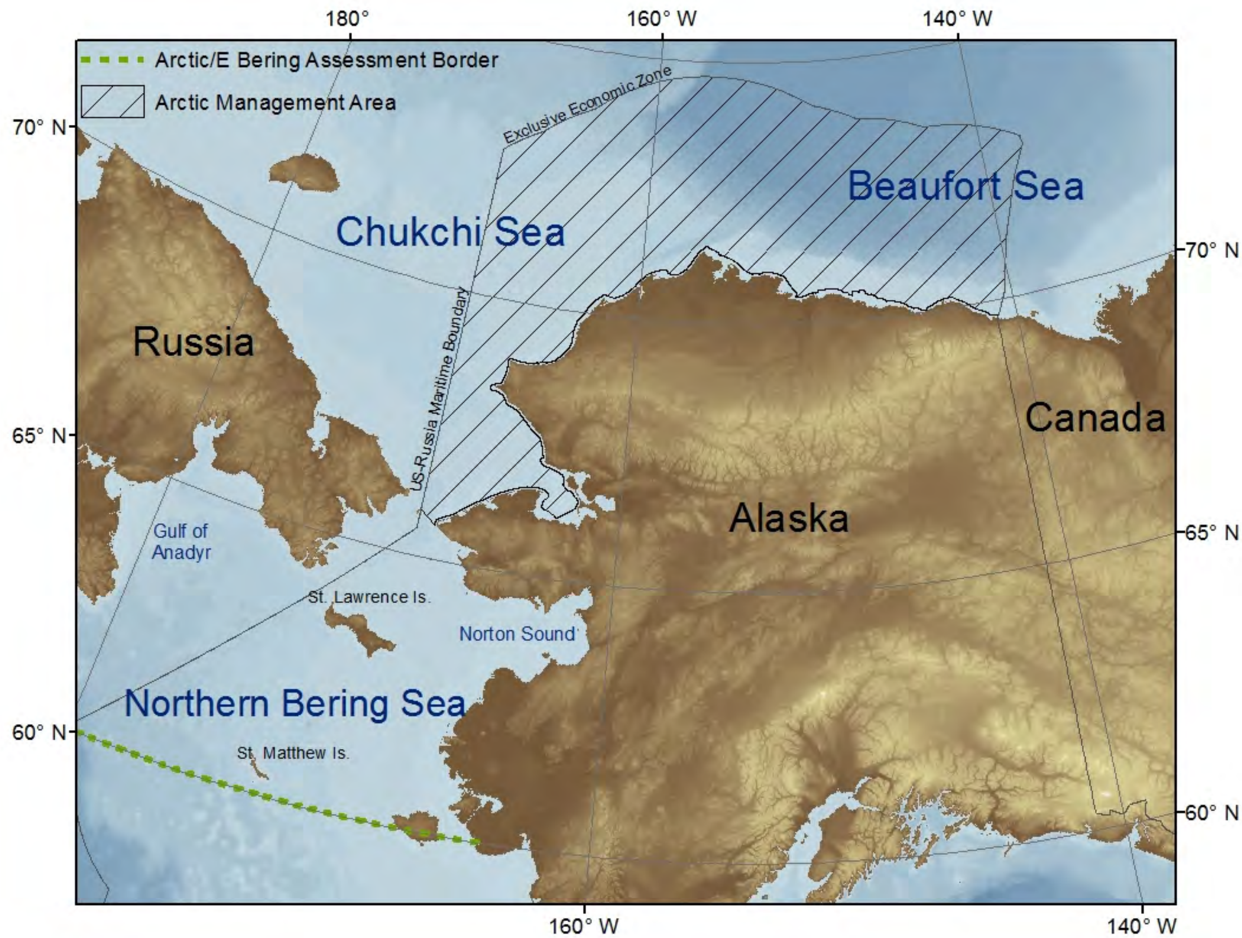


Figure 9: The proposed Arctic assessment area in Alaska, encompassing the northern Bering Sea, Chukchi Sea, and Beaufort Sea, within US territorial waters. The existing Arctic management area is filled with hatched lines.

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 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 that would be useful for fisheries managers 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`) and participants have been conducting standardized sampling at selected locations (transects) since 2010. DBO regions extend over a latitudinal gradient from the northern Bering Sea to the western Beaufort Sea (Figure 10) and are focused on areas of high biodiveristy and production, based on data that sometimes extend back to the 1970s (`http://www.arctic.noaa.gov/dbo/related_ts.html`). It is hoped that the sampling design of the DBO, across a range of latitude, will support the detection of emergent patterns and trends during a period of rapid climate change. 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.

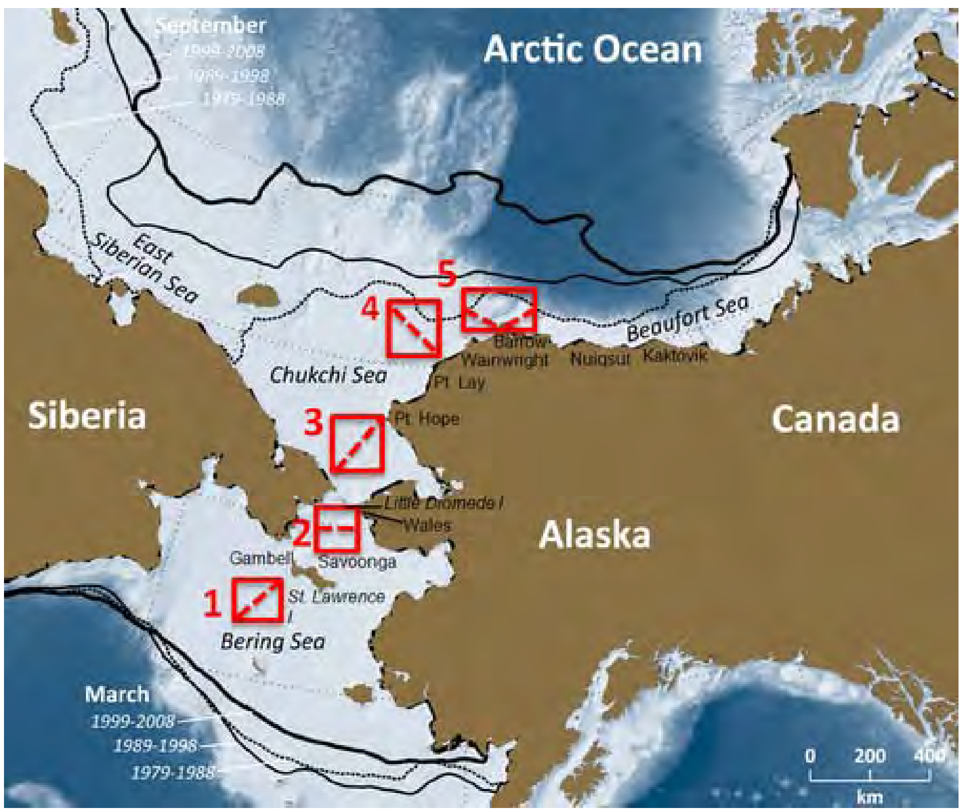


Figure 10: The Distributed Biological Observatory (DBO) in the Alaska Arctic. The red boxes are regional areas selected for observation and the dashed lines are the sampling transect lines. Figure from `http://www.arctic.noaa.gov/dbo/index.html`.

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).* Developing a time series of fish biomass estimates by species or foragin gguild derived from regular trawl surveys (or in combination with hydroacoustic data) could track possible changes in community composition and biomass over time, such as what might be expected with climate change (Hollowed et al., 2013). Recent demersal trawl survey work has helped to describe current baseline conditions in the northern Bering Sea and Chukchi Sea (e.g., Arctic EIS, `https://web.sfos.uaf.edu/wordpress/arcticeis/`) but continued work will be necessary for indicator development.

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

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

[1]Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
[2]Pacific Marine Environmental Lab, National Marine Fisheries Service, NOAA
[3]Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
[4]Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
[5]National Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries

Service, NOAA
[6]North Pacific Fisheries Management Council
[7]University of Alaska Fairbanks, 17101 Point Lena Road, Juneau, AK 99801
[8]Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA

Summary

Recap of 2012 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. New this year we are presenting an updated summary of last year (i.e., 2012) that includes 2012 information that we have received in 2013. Our goal is to provide a complete picture of 2012 based on the status of most of the indicators we follow. The next section will provide a summary of the 2013 ecosystem state based on indicators that are updated in the current year.

Conditions in the eastern Bering Sea in 2012 returned to the cold patterns of 2007-2010 that were 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 had moderated in 2011 with warmer bottom temperatures and less extensive maximum ice extent and cold pool. However, the surface temperature in 2011 was much lower than average, reflecting the unusually cold atmospheric conditions during that summer. The cool summer contributed to the continuation of multi-year sequential cold ocean temperatures, which in 2012 included the most extensive cold pool area of the recent decade and the latest ice retreat (along with 2009) in more than two decades.

While cold conditions in the eastern Bering Sea are typically associated with improved nutritional status of age-0 pollock prior to winter, 2012 demonstrated that conditions can be too cold to support good survival. In May of 2012 ice cover still reached as far south as the Alaska Peninsula, suggesting summer temperatures were very low when larvae were developing. Consequently, age-0 pollock sampled during the fall were the smallest in the 10 year time series. The pollock were energetically dense, as is usual in cold years, but with the combination of small size, the average energy content per fish was low. Thus their survival to age-1 is predicted to be lower than the overall median.

Zooplankton appeared to be less abundant overall than in previous years. Acoustic surveys of euphausiids on the middle and outer shelf indicated that summertime euphausiid density was highest in 2007-2010, with a peak in 2009, but that 2012 values were similar to those of 2006. It is worth noting that pelagic forager biomass, primarily pollock and capelin, increased 70% between 2009 and 2012, with possible top-down effects on euphausiid biomass. Similarly, mesozooplankton biomass anomalies recorded by Continuous Plankton Recorders, were low in the eastern Bering Sea, despite that they were high in the NE Pacific and Alaska shelf (GOA). However, the copepod community size anomaly was high in the eastern Bering Sea, indicating that fewer, but larger copepods were present.

Jellyfish, primarily *Chrysaora melanaster*, were abundant during both the summer and fall surveys. Summer bottom trawl surveys had the third largest CPUE of jellyfish during 2012, although this was a slight drop from the previous year. During the fall BASIS survey, total jellyfish biomass more than doubled in 2012 compared to 2011 and was the highest recorded biomass over the surveys. One station in the southern Bering Sea was responsible for half the total catch for the entire survey. Non-target catch of jellyfish in the groundfish fisheries showed a slightly different pattern; overall catch was lower in 2012 than 2011. An earlier increasing jellyfish biomass trend in the eastern Bering Sea was linked to a period of climatic transition from warm to moderate conditions, with a sharp decline in biomass at the transition back to a period of very warm conditions. The moderate winter of 2010/2011 seemed like it could have been the beginning of a transition out of the cold pattern seen for the previous 4 - 5 years, although the unusually cold summer and following cold winter did not allow these conditions to persist. Jellyfish biomass trends have also been linked to prey availability. Increased jellyfish abundance may indicate an increased source of mortality on their zooplankton and small fish prey.

Biomass estimates of motile epifauna, pelagic foragers and apex predators were all above the long-term mean in 2012 and showed an increasing trend in the past five years. Only the biomass of benthic foragers has remained relatively stable since 1982, with interannual variability driven by short-term fluctuations in yellowfin and rock sole abundance.Since the mid-1990s, the apex predator and pelagic forager series seem to reflect the failure of the early 2000's year classes and the good 2006 and 2008 year classes of both pollock and Pacific cod. It is hypothesized that cold conditions and high primary production could result in conditions that deliver food to both benthic and pelagic food webs. Unknown is whether or not top-down control (predation) will eventually occur once the biomass of these two guilds builds to a particular level (e.g. Oscillating Control Hypothesis).

In contrast to biomass trends, length-weight residuals, an indicator of groundfish condition, were negative in 2012 for all examined species but yellowfin sole. Groundfish condition is considered to be linked to ecosystem productivity, suggesting lower ecosystem productivity in 2012. Biomass trends combined with groundfish condition indicators suggest that there were more, but smaller, groundfish caught in the bottom trawl survey in 2012.

The status of representative air-breathing central place piscivorous foragers in the eastern Bering Sea, seabirds and Northern fur seals, showed improvement in 2012. The reproductive success of thick billed murres at St. George was slightly above the long-term mean (1977-2012), a substantial increase from the record low reproductive success they experienced in 2011. This suggests that foraging conditions were favorable for piscivorous seabirds. This assumption was supported by patterns in a multivariate Pribilof Island seabird index, which showed 2012 was a more successful year for Pribilof seabirds overall. In addition, seabird bycatch throughout Alaska was 40% below 5-year average (2007-2011), supporting the hypothesis that there may be a link between poor ocean conditions and the peak bycatch years, on a species-group basis.

Northern fur seal pup production on St. Paul Island increased from the previous count in 2010, despite that overall numbers remain low. 2012 was the first year that pup production has not declined since 1998.

The maximum potential area of seafloor habitat disturbed by trawl gear in 2012 decreased slightly from 2011, which was the highest level since 1998. The cause of the increase may be due to increased search time for pollock and/or avoidance of salmon bycatch. Recent changes in the maximum area trawled included a notable decrease in 2009 and 2010 followed by a rapid increase to the long-term mean in the past two years. The cause of these changes is currently unknown, but may be related to a combination changes in management regulations and fish distributions. The decrease in 2009 may have been influenced by Amendment 80 regulation implemention. The increase that began in 2011 may have been influenced by changes in pollock distribution which required greater searching time and/or avoidance of salmon bycatch which also may have altered fishing patterns.

Current conditions: 2013

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 euphasiids and large copepods for planktivorous feeders. These conditions moderated in 2011 with warmer botton 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. This year, dates of sea ice retreat, summer surface and bottom temperatures, and the extent of the cold pool were very similar to those during 2007.

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.

The 2013 springtime drift patterns based on OSCURS model time series runs do 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, length-weight residuals were positive for all but Pacific cod in 2013, indicating that foraging conditions and general ecosystem productivity were positive in 2013.

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.

The reproductive success of thick billed murres at St. George remained above the long-term mean (1977-2013). This suggests that foraging conditions were favorable for piscivorous seabirds. The data required for the multivariate seabird indices for the Pribilof Islands was not available in time to update the indices. Estimates of northern fur seal pup production in the Pribilof Islands are available 1 - 2 years after the surveys because of the bienniel survey and data analysis schedules. Thus, the next update will be in 2015, with the results of the 2014 survey.

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. 170). 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 2). Single-species stock assessment and projection models are the most commonly used tools employed to inform managers. Comprehensive assessments (e.g. Management Strategy Evaluation) are emerging as a new and potentially valuable modeling approach for use in assessing trade-offs of different strategic alternatives. In the case of management in the Eastern Bering Sea, end-to-end models and coupled biophysical models have been used primarily to advance scientific understanding, but have not been applied in a management context. In future synthesis attempts, we will add a section that brings forward predictions from different models to initiate an evaluation of the predictive skill of different assessment tools.

Aleutian Islands Ecosystem Assessment

Stephani Zador[1] and the Aleutian Islands Ecosystem Assessment Team: Kerim Aydin[1], Steve Barbeaux[1], Nick Bond[2], Jim Estes[3], Diana Evans[4], Dave Fraser[5], Lowell Fritz[6], Stephen Jewett[7], Carol Ladd[8], Elizabeth Logerwell[1], Sandra Lowe[1], John Olson[9], Ivonne Ortiz[1], John Piatt[10], Chris Rooper[11], Paul Wade[6], Jon Warrenchuk[12], Francis Weise[13], Jeff Williams[14], Stephani Zador[1] Additional data provided by Michael Martin[11]

[1]Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
[2]Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
[3]Long Marine Laboratory, University of California at Santa Cruz
[4]North Pacific Fisheries Management Council
[5]IMARIBA West, Port Townsend, WA
[6]National Marine Mammal Lab, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
[7]University of Alaska Fairbanks
[8]Pacific Marine Environmental Lab, NOAA

Table 2: 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	

[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

Editor's note: Due to both the furlough as well as the lack of new survey information, we updated only the Aleutian Islands Report Card. In this section we include the description of the ecoregions and explanations of the indicators from past assessments.

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°E.

The three Aleutian Islands ecoregions are defined from west to east as follows (Figure 11). The Western Aleutian Islands ecoregion spans 170° to 177°E. These are the same boundaries as the North Pacific Fishery Council fishery management area 543. This ecoregion was considered to be distinct from the neighboring region to the east by primarily northward flow of the Alaska Stream through wide and deep passes (Ladd, pers. comm.), with fewer islands relative to the other ecoregions.

The Central Aleutian Islands ecoregion spans 177°E to 170°W. This area encompasses the North Pacific Fishery Council fishery management areas 542 and 541. There was consensus among the group that the eastern boundary of this ecoregion occurs at Samalga Pass, which is at 169.5°W, but for easier translation to fishery management area, it was agreed that 170°W was a close approximation. The geometry of the passes between islands differs to the east and west of Samalga Pass (at least until Amchitka Pass). In the Central ecoregion the passes are wide, deep and short. The Alaska Stream, a shelf-break current, is the predominant source of water (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.These are briefly defined here and in more detail later in the document (Figure 11). The Western Aleutian Islands ecoregion spans 170° to 177°E. These are the same boundaries as the North Pacific Fishery Council fishery management unit 543. The Central Aleutian Islands ecoregion spans 177°E to 170°W. This area encompasses the North Pacific Fishery Council fishery management units 542 and 541. The Eastern Aleutian Islands ecoregion spans 170°W near Samalga Pass to False Pass at 164°W.

Indicators

The suite of indicators that form the basis for the assessment were 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

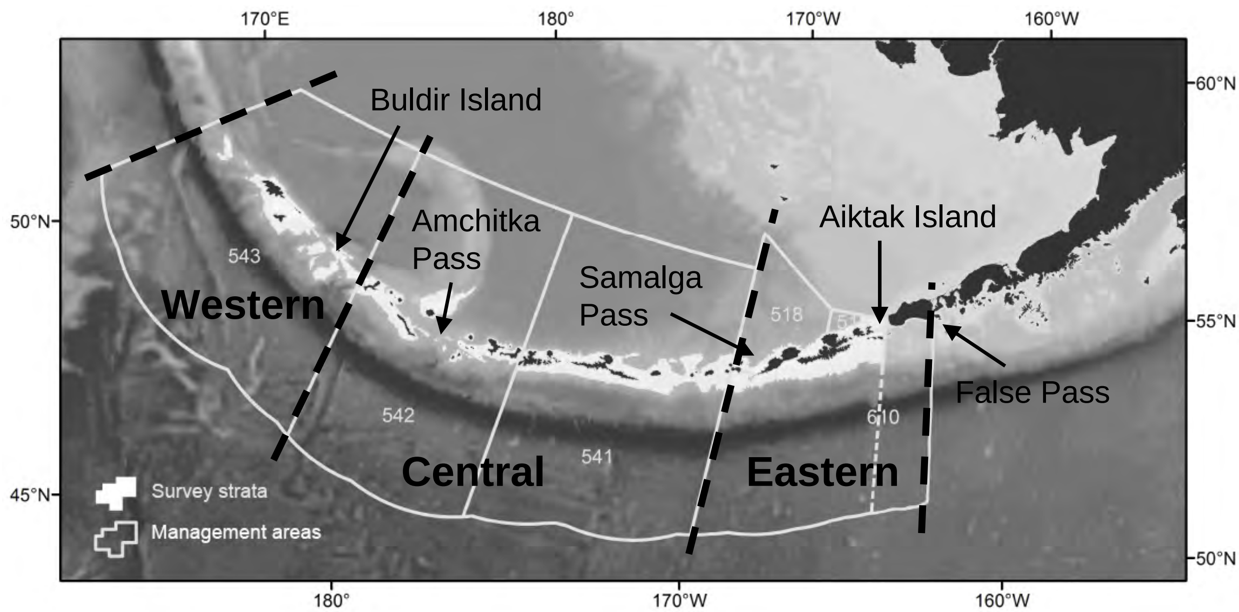


Figure 11: The three Aleutian Islands assessment ecoregions. Seabird monitoring islands are indicated by arrows.

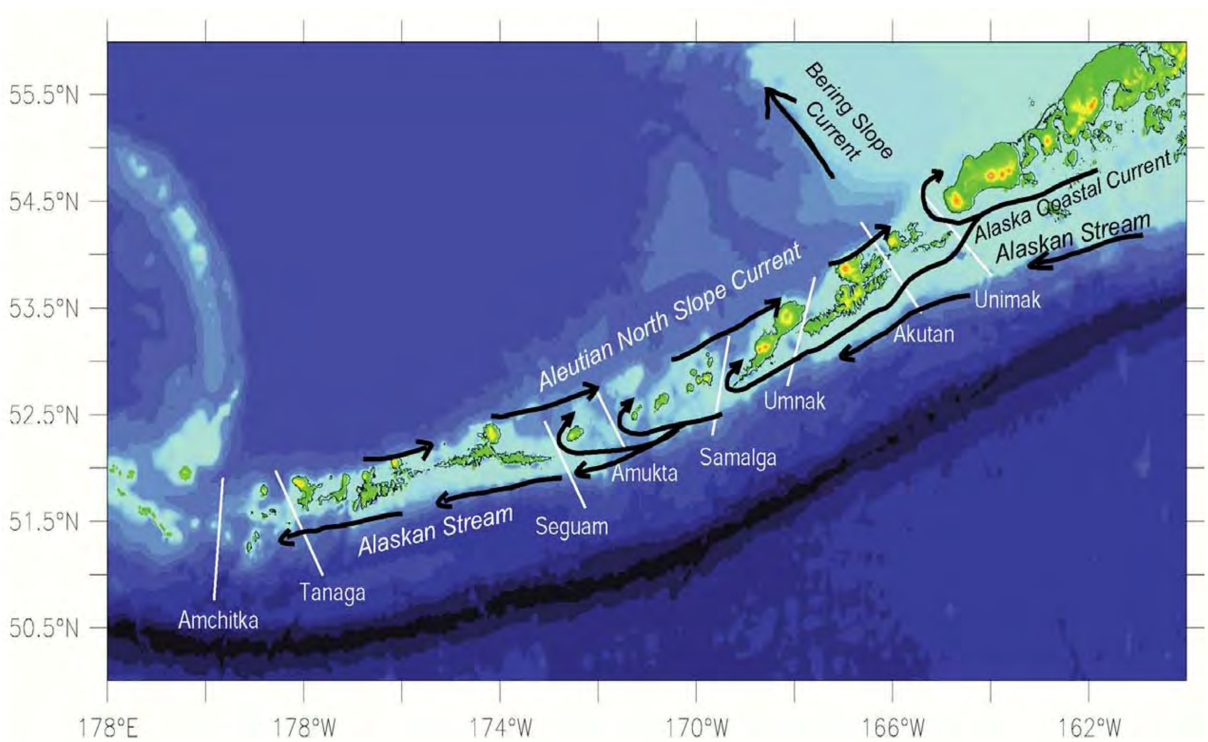


Figure 12: Ocean water circulation in the Aleutions. Currents are indicated with black lines. Passes are indicated with white lines. Image from Carol Ladd.

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 3.

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

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

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

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

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

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

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 are not 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

Contributed by N. Bond (UW/JISAO))
NOAA/PMEL, Building 3, 7600 Sand Point Way NE, Seattle, WA 98115-6349
Contact: nicholas.bond@noaa.gov
Last updated: August 2013

Summary: *The state of the North Pacific atmosphere-ocean system during 2012-2013 reflected the combination of mostly near-neutral ENSO conditions and intrinsic variability. The Aleutian low was weaker than usual in the winter of 2012-13, and the sea level pressure was higher than normal in the eastern portion of the basin for the year as a whole. Cooler than normal upper ocean temperatures prevailed in the eastern portion of the North Pacific and mostly warmer than normal temperatures occurred in the west-central and then central portion of the basin. This pattern reflects a continuation of a negative sense to the Pacific Decadal Oscillation (PDO). The models used to forecast ENSO, as a group, are indicating a greater likelihood of near-neutral versus either El Niño or La Niña conditions for the winter of 2013-14.*

Regional Highlights:

Arctic. There is reduced sea ice cover in the Arctic during the summer of 2013 compared to seasonal norms, but not to the extent that occurred in 2011 and 2012. The ice edge was very near the shore for much of the Beaufort Sea as late as early August 2013, but is rapidly retreating at the time of this writing (14 August). Ice concentrations in the Chukchi Sea have been observed to be greater during the summer of 2013 than in 2012. In general, the sea ice of the Arctic is thinner than its long-term climatological mean, and so there is the potential for a relatively swift reduction in ice cover over the remainder of summer.

Bering Sea. The Bering Sea shelf also experienced less storminess than normal in fall 2012 and spring 2013. On the other hand, the weather during fall and winter was cold, which resulted in another relatively heavy ice year. The extent of this ice on this shelf appears to have been more variable than usual, with a series of advances and retreats. Based on previous observations, it can be expected that the cold pool was somewhat more extensive than usual during the summer of 2013, but that is uncertain (at the time of this writing) due to the reduction in hydrological survey data.

Alaska Peninsula and Aleutian Islands. - Easterly wind anomalies prevailed in this region during the fall of 2012 and spring of 2013. Anomalies in this sense tend to enhance the northward transport through Unimak Pass and perhaps also the Aleutian North Slope Current. These periods also featured SLP patterns indicating suppressed storminess. 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) appear to have been near normal during the past year.

Gulf of Alaska. The weather in this region included near normal air temperatures and below normal precipitation. The mixed layer depths in the Gulf were slightly deeper than usual during the winter of 2012-2013 suggesting that the supply of nitrate to the euphotic zone for the spring bloom was also enhanced. The winds during spring and summer 2013 were of the sense to favor more coastal upwelling than usual in the northern and eastern portions.

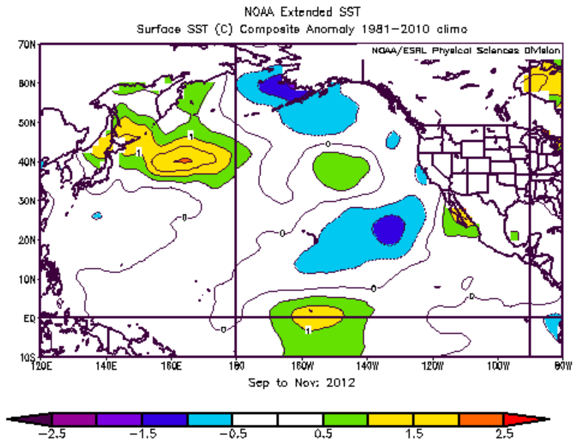
West Coast of Lower 48. This region experienced a relatively quiet winter, with less downwelling-favorable winds than normal, especially along the Oregon coast. The waters near the coast tended to be mostly cool and salty, with particularly low oxygen concentrations noted at depth during summer 2013. The cooler waters were accompanied by a greater preponderance of sub-arctic than sub-tropical zooplankton than usual in spring 2013 (B. Peterson, NOAA/NWFSC). For the spring and summer of 2013, the winds have tended to be more upwelling favorable than usual. 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

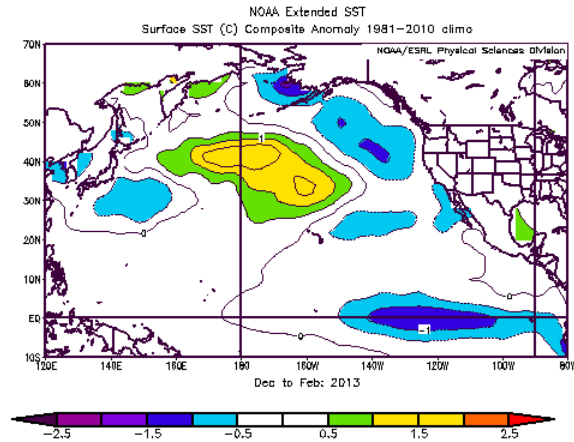
Contributed by N. Bond (UW/JISAO))
NOAA/PMEL, Building 3, 7600 Sand Point Way NE, Seattle, WA 98115-6349
Contact: nicholas.bond@noaa.gov
Last updated: August 2013

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`.

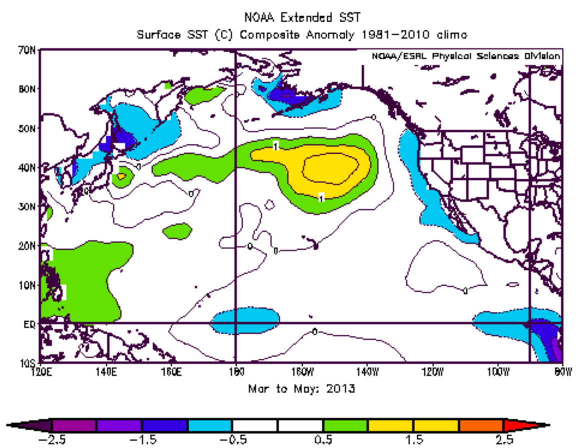
Status and trends: The climate forcing of the North Pacific during the year of 2012-13 began with a negative state for the PDO; the anomalies in the atmospheric forcing over the period considered here appears largely due to intrinsic variability. The tropical Pacific was warmer than normal during the autumn (Sep-Nov) of 2012(Figure 13a) and a majority of forecast models at that time indicated the probable development of a weak-moderate El Niño for the following winter. This often causes anomalous warming in the waters along the west coast of North America and in the Bering Sea, which then were mostly cooler than normal. The pattern of anomalous SLP during autumn 2012 featured strongly positive anomalies over the Bering Sea extending across Alaska into northwestern Canada (Figure 14a). This pattern corresponds with easterly wind anomalies from roughly 40 ^{o} to 50 ^{o}N across most of the North Pacific, and was essentially opposite to that which occurred the year before in fall 2011.



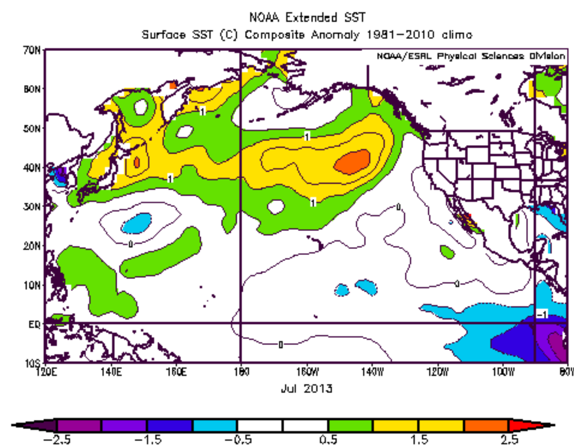
(a) Autumn



(b) Winter

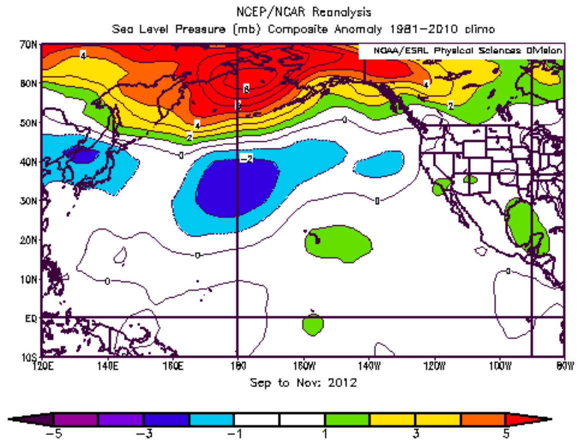


(c) Spring

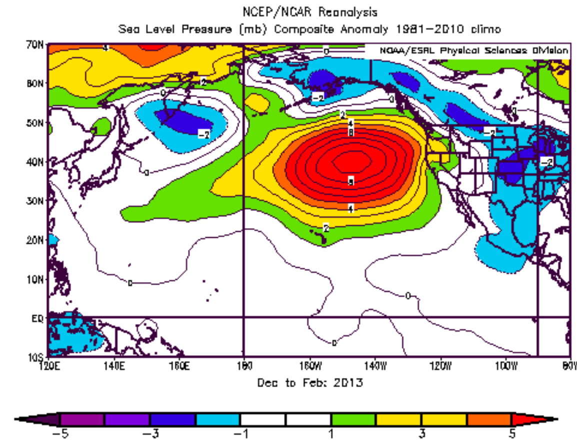


(d) Summer

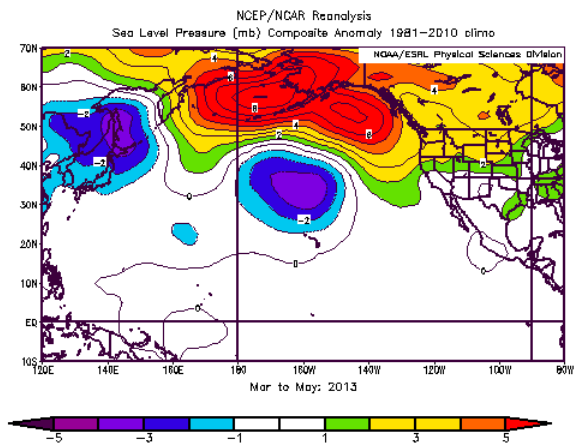
Figure 13: SST anomolies for autumn (September-November 2012), winter (December 2012 -February 2013), spring (March - May 2013), and summer (June - August 2013).



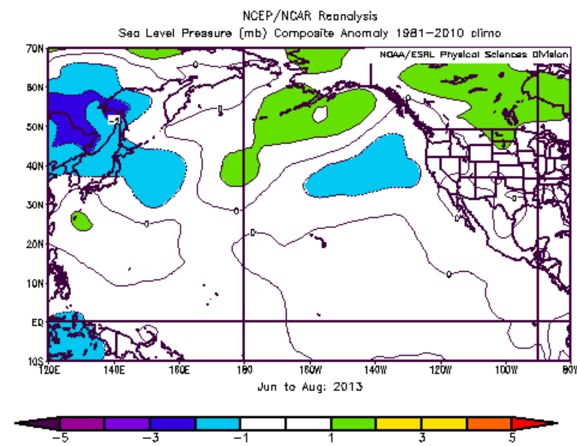
(a) Autumn



(b) Winter



(c) Spring



(d) Summer

Figure 14: SLP anomolies for autumn (September-November 2012), winter (December 2012 -February 2013), spring (March - May 2013), and summer (June - August 2013).

The pattern of anomalous SST in the North Pacific during winter (Dec-Feb) of 2012-13 (Figure 13b) resembled its counterpart during the previous fall. There was some modest cooling, relative to seasonal norms, in portions of the eastern North Pacific, and in the eastern tropical Pacific. The latter was insufficient to qualify as La Niña conditions. The anomalous SLP during winter 2012-13 was dominated by a large high (>10 mb) centered near 40 °N, 145 °W (Figure 14b). This anomaly pattern closely resembles that from a year ago. The anomalous SLP pattern shown in Figure 14b indicates westerly wind anomalies in the mean for the Gulf of Alaska and anomalous upwelling along the coast of California. For Alaskan waters, the SLP pattern promoted the delivery of cold air of Siberian origin to the Bering Sea and Gulf of Alaska; the higher than normal pressure west of California meant suppressed storminess in the far eastern North Pacific and below normal precipitation for the west coast of the lower 48 states.

The distribution of SST in spring (Mar-May) of 2013 (Figure 13c) indicates a continuation of colder than normal temperatures in the waters of the eastern Bering Sea and northwestern Gulf of Alaska waters and the development of anomalous warmth in the central North Pacific north of Hawaii. The SST anomalies in the tropical Pacific were generally weak, with more prominent anomalies developing in the far eastern portion off the coast of South America. The concomitant SLP anomaly map (Figure 14c) indicates a pattern closely resembling that of autumn 2012. This set-up implies suppressed storminess across the Bering Sea and Gulf of Alaska, and an early start to the upwelling season for the California Current System.

The pattern of anomalous SST in summer (Jun-Aug) 2013 (Figure 13d) featured the continued warming of the eastern North Pacific relative to seasonal norms. Positive anomalies developed along the coast of the northeastern portion of the Gulf of Alaska, and the eastern Bering Sea warmed to near-normal values. It remained slightly cooler than normal in the eastern tropical Pacific. The overall pattern represents a weakly negative expression of the Pacific Decadal Oscillation (PDO), as further discussed below. The distribution of anomalous SLP (Figure 14d) included a continuation of positive anomalies stretching from the eastern Bering Sea across the Gulf of Alaska into Canada. The associated wind anomalies from the east in the eastern North Pacific between about 35° and 45° N meant poleward Ekman transport anomalies, which is consistent with the warming in the same region. The gradients in the SLP anomalies along the west coast of North America supported slightly greater than normal upwelling in the southeast Gulf of Alaska and relatively weak upwelling along California. This result is for the summer months as a whole; the SLP and wind anomaly patterns in the eastern North Pacific during July and August were almost mirror images of one another.

Climate Indices

Contributed by N. Bond (UW/JISAO))
NOAA/PMEL, Building 3, 7600 Sand Point Way NE, Seattle, WA 98115-6349
Contact: nicholas.bond@noaa.gov
Last updated: August 2013

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 2003 through early summer 2013 are plotted in Figure 15.

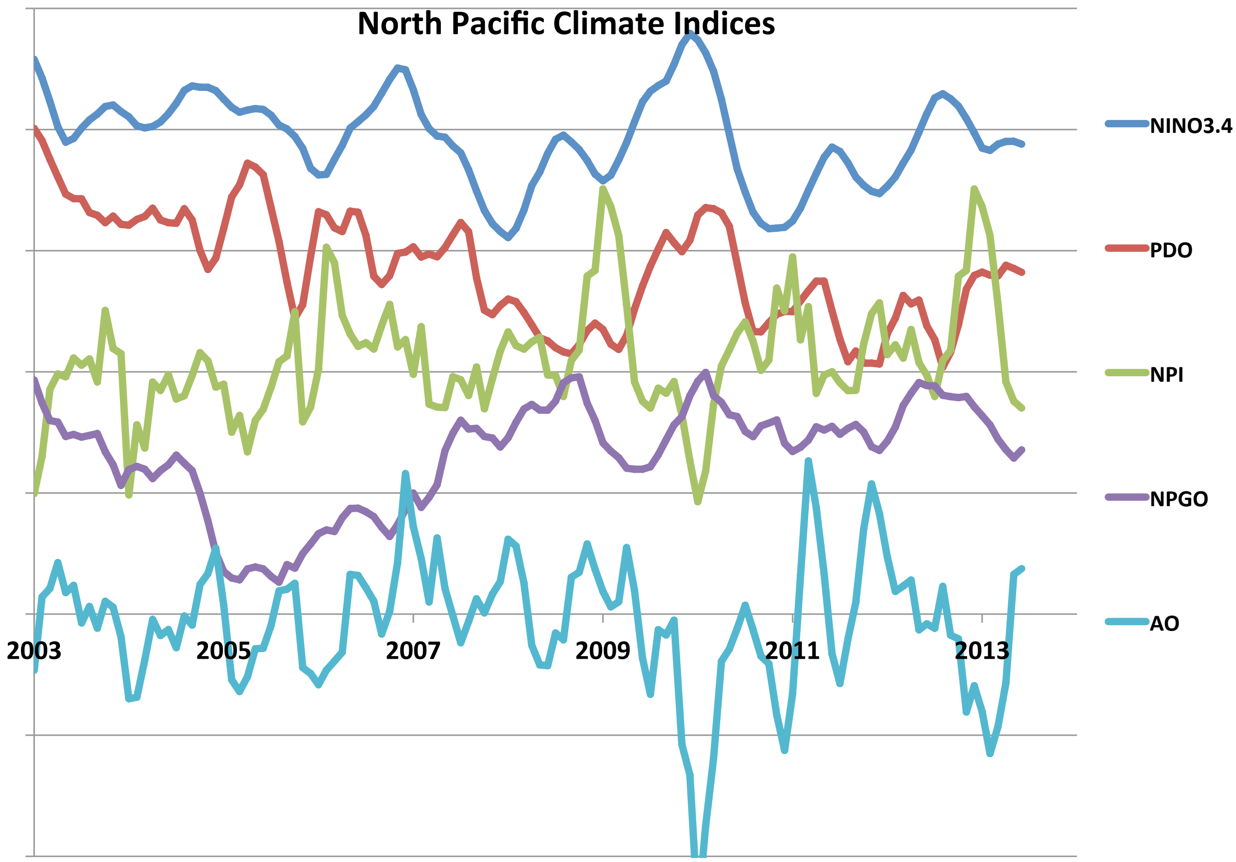


Figure 15: Time series of the NINO3.4 (blue), PDO (red), NPI (green), NPGO (purple), and AO (turquoise) indices. Each time series represents monthly values that are normalized and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 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: 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 Nio/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 2003 through early summer 2013 are plotted in Figure 15.

The state of the North Pacific atmosphere-ocean system reflected intrinsic variability during 2012-13. The NINO3.4 index was weakly positive in the fall of 2012, and has been slightly negative since late 2012. The small magnitude of this signal implies a near-neutral state for ENSO, and hence the tropical Pacific is unlikely to have contributed significantly to the perturbations in the climate of the North Pacific that have occurred over the last year. The overall positive trend in the NINO3.4

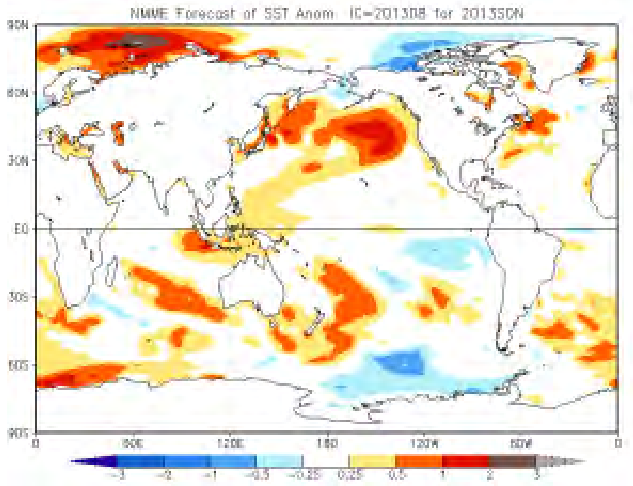
index is consistent with a positive trend in the PDO in the last year or so. The PDO has been in a largely negative state since the latter part of 2007; it is uncertain whether the recent tendency of an upward trend in the PDO will persist, or whether it will revert back to negative values. The NPI was strongly positive (implying a weak Aleutian Low) during the winter of 2012-2013. This often occurs in association with La Niña, but as mentioned 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 Gulf of Alaska and the southern portion of the California Current (Di Lorenzo et al., 2008, 2009). It has been in a positive state since 2007, which projects on stronger than normal flows in both the Alaska Current portion of the Subarctic Gyre and the California Current. The AO represents a measure of the strength of the polar vortex, with positive values signifying anomalously low pressure over the Arctic and high pressure over the Pacific and Atlantic, at a latitude of roughly 45 ^{o} N. It has a weakly positive correlation with sea ice extent in the Bering Sea. During periods of positive AO, cold air outbreaks to mid-latitudes are suppressed. The AO was strongly negative during the winter of 2012-13. That has been the case during three out of the last 4 winters, with 2011-12 being the exception. It has been suggested that the declines in sea ice coverage in the Arctic in fall may be responsible, in part, for the recent tendency for the AO to be negative in the following winter season. This is a matter of considerable controversy and interest to the polar climate community.

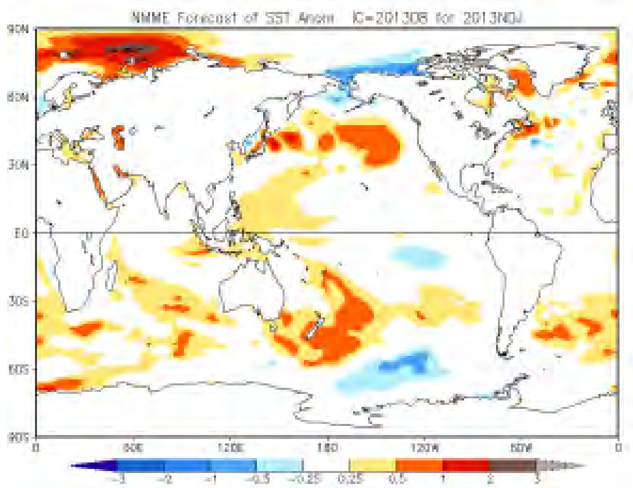
Seasonal Projections from the National Multi-Model Ensemble (NMME)

Contributed by N. Bond (UW/JISAO)
NOAA/PMEL, Building 3, 7600 Sand Point Way NE, Seattle, WA 98115-6349
Contact: nicholas.bond@noaa.gov
Last updated: August 2013

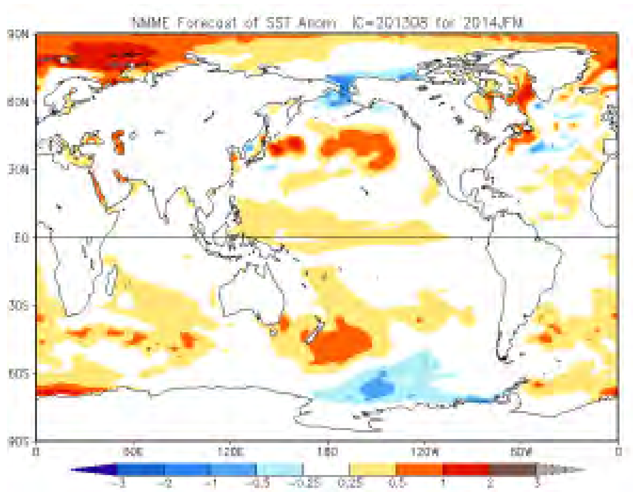
Description of index: Seasonal projections of SST from the National Multi-Model Ensemble (NMME) are shown in Figures 6a-c. The uncertainties and errors in the predictions from any single climate model can be substantial. An ensemble approach incorporating different models is particularly appropriate 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 SON



(b) Months NDJ



(c) Months JFM

Figure 16: Three-month forecasts of SST anomalies from the NMME model for SON, NDJ, and JFM of the 2013-2014 cool season.

Status and trends: These NMME forecasts of 3-month average SST anomalies indicate warming in the central North Pacific between the Hawaiian Islands and Alaska into fall (Sep-Nov 2013) and a continuation of slightly cooler water than normal in the northeastern Bering Sea (Figure 16a). This overall pattern is maintained, with some weakening in magnitude, through the 3-month periods of November 2013 - January 2014 (Figure 16b) and January 2014 - March 2014 (Figure 16c). In an overall sense, these patterns project onto a negative sense for the PDO, largely because of the relatively warm anomalies near the dateline. The NMME forecasts also include a slight warming in the tropical Pacific, especially in the western portion. The ensemble mean values of these anomalies are too weak to qualify as El Niño, but it is still possible that an ENSO event (probably of modest amplitude at best) could develop. At the time of this writing (early August 2013) 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 a slightly greater than 50% chance for a near-neutral state for ENSO and roughly equal and lesser odds of El Niño or La Niña. It bears noting the NMME projections are suggesting the continuation of rather cold upper ocean temperatures for most Alaskan waters. It is emphasized that the skill in these projections is limited. For example, during August 2012 there were strong indications of warming in the tropical Pacific, and concomitant effects on the North Pacific climate, that did not materialize.

Implications Based on not just the SST predictions shown in Figure 16, but also other forecast fields, it is likely that there will be a warming of Alaskan waters over the next 2-3 seasons, relative to the mostly cooler than normal temperatures that have prevailed over the last 5 years.

Arctic

Arctic Sea Ice Cover

Edited by Stephani Zador, Resource Ecology and Fishery Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: stephani.zador@noaa.gov
Last updated: October 2013

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: This summer, Arctic sea ice loss was held in check by relatively cool and stormy conditions. As a result, 2013 saw substantially more ice at summer's end, compared to last years record low extent. Arctic sea ice extent reached its annual minimum on September 13. After the minimum, extent remained largely unchanged for much of the middle of September, but increased rapidly toward the end of the month with the onset of strong autumn cooling. Arctic sea ice extent averaged for September 2013 was 5.35 million square kilometers (Figure 17). This was 1.17 million square kilometers below the 1981 to 2010 average extent. September 2013 ice extent was 1.72 million square kilometers higher than the previous record low for the month that occurred in 2012.

The rate of ice loss varied through the summer (Figure 18). Both May 2012 and May 2013 saw near average extents and rates of decline. This year, the rate of ice loss sped up in late June and early July, then settled into a near-average rate of decline, with extent approximately 500,000 square kilometers greater than the same time in 2012. Ice loss then slowed down in August to only a little faster than average rates of loss for that time of year. In comparison, during 2012, the rate of loss accelerated in early June and through July, then accelerated even more in August to produce a new record low extent in September 2012. Overall, 10.03 million square kilometers of ice were lost between the 2013 maximum and minimum extents.

September average sea ice extent for 2013 was the sixth lowest in the satellite record (Figure 19). The 2012 September extent was 32% lower than this year's extent, while the 1981 to 2010 average was 22% higher than this year's extent. Through 2013, the September linear rate of decline is 13.7 per decade relative to the 1981 to 2010 average.

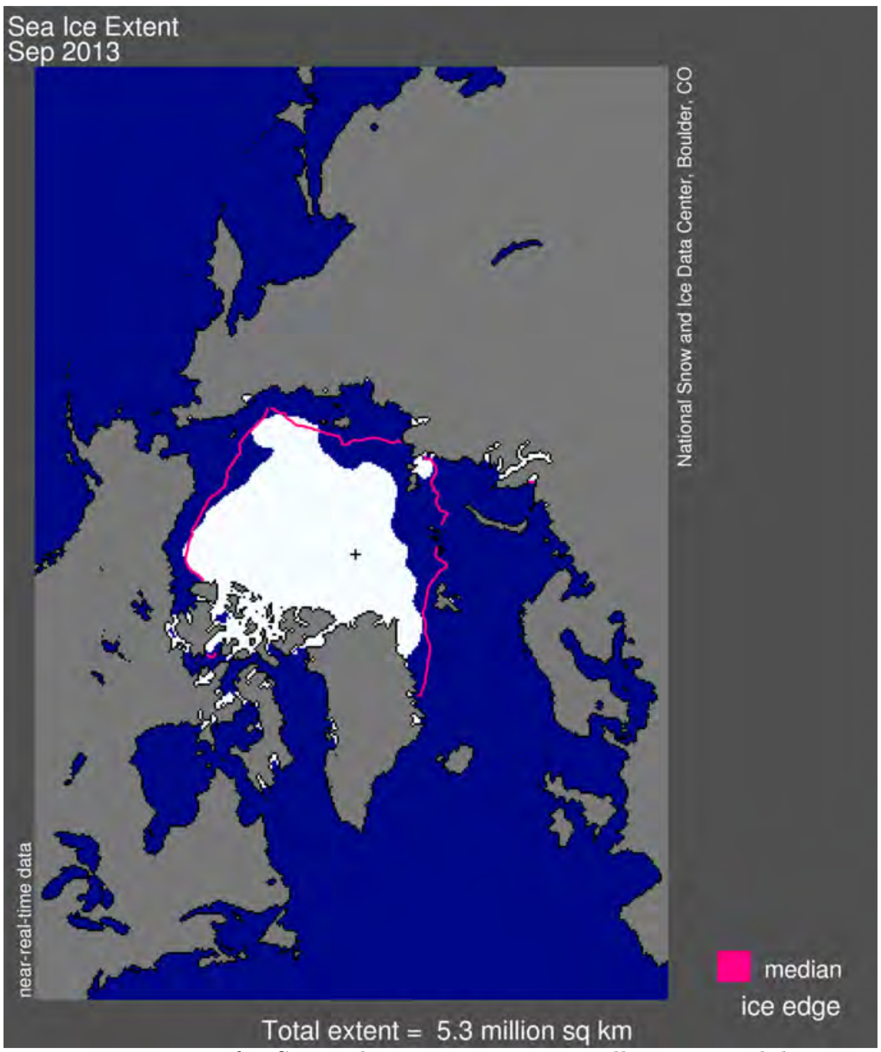


Figure 17: Arctic sea ice extent for September 2013 was 5.35 million square kilometers (2.07 million square miles). The magenta line shows the 1981 to 2010 median extent for that month. The black cross indicates the geographic North Pole. Credit: National Snow and Ice Data Center

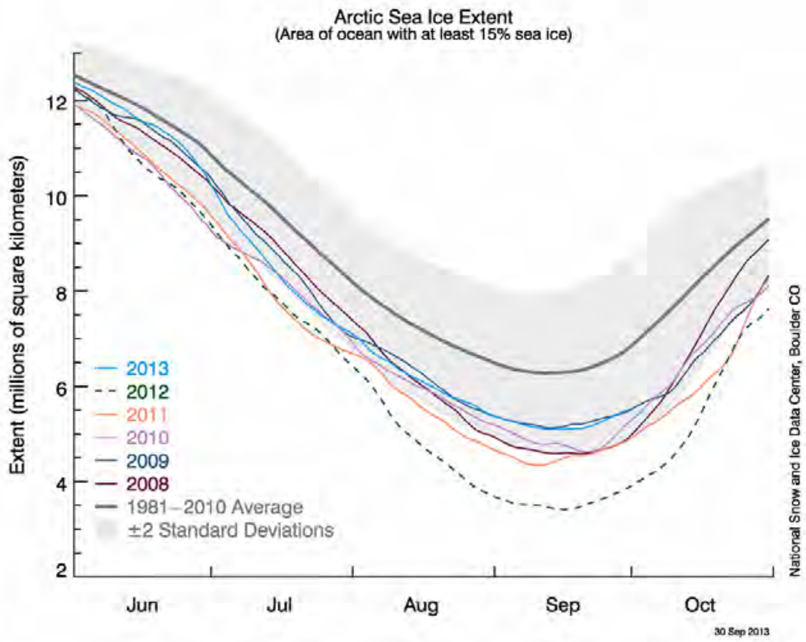


Figure 18: The graph above shows Arctic sea ice extent as of September 30, 2013, along with daily ice extent data for the previous five years. 2013 is shown in light blue, 2012 in green, 2011 in orange, 2010 in light purple, 2009 in dark blue, and 2008 in dark purple. The gray area around the average line shows the two standard deviation range of the data. Credit: National Snow and Ice Data Center

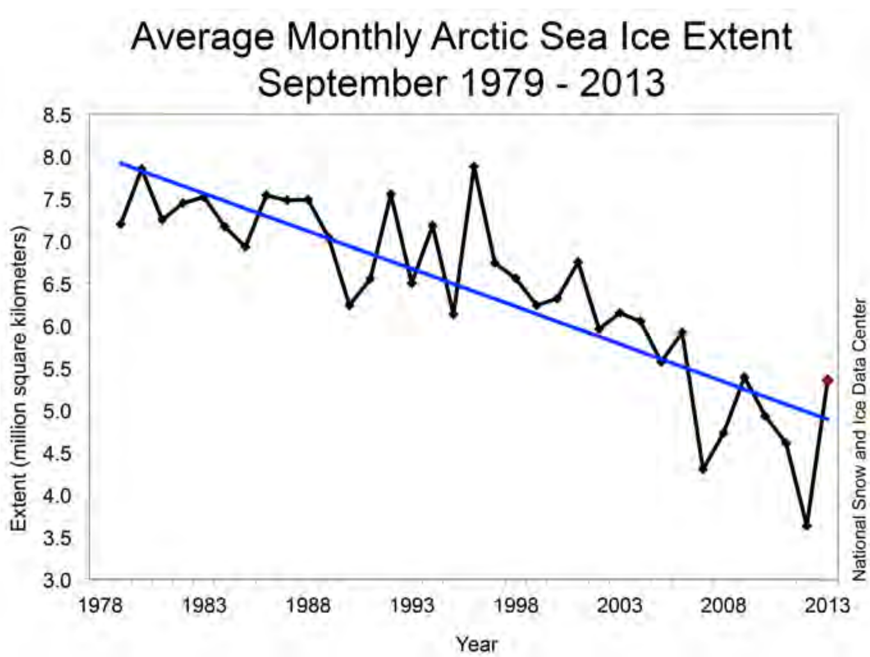


Figure 19: Monthly September ice extent for 1979 to 2013 shows a decline of 13.7% per decade. Credit: National Snow and Ice Data Center

Eastern Bering Sea

Eastern Bering Sea Climate - FOCI

Contributed by J. Overland, P. Stabeno, C. Ladd, S. Salo, M. Wang, and N. Bond (NOAA/PMEL)
Contact: james.e.overland@noaa.gov
Last updated September 2013

Summary. *The year 2013 continues the unusual sequence of seven years with cold winter-spring temperatures (2007-2013), following the six warm temperature years (2000-2005). The January-May near surface air temperature anomalies in the southeastern Bering Sea were -2.5°C, similar to 2012 at -3.0°C. Cold temperatures related to sea level pressures being particularly high over the Bering Sea, thus keeping storm tracks further south into the North Pacific with northeast cold winds over the Bering Sea. As in 2012, summer 2013 had near normal conditions over the Bering Sea, while warm temperature records were set over the Alaskan mainland. Bering Sea ocean temperatures remained cold and sea ice remained extensive, similar to 2008, 2010 and 2012. The cold pool extent for summer 2013 was extensive, but less than in the record years of 2010 and 2012.*

Air temperatures and sea level pressure. Surface air temperatures are easily measured and provide an available long term measure of the state of the climate. Winter and spring surface air temperatures in 2013 on St. Paul Island continued the cold sequence of years beginning in 2007 (Figure 20). Winter and spring during 2013 was colder than normal from February through May, centered in the SE Bering Sea (Figure 21), while the northern Bering Sea is part a continued Arctic warming that has lasted a decade. Near surface air temperature anomalies in the southeastern Bering Sea during 2013 were -2.5°C, similar to 2012 at -3.0°C. Sea level pressure (SLP) in winter-spring 2013 had positive anomalies over the southern Bering Sea (Figure 22). The minimum pressures, an indication of the storm track, are south of the Aleutian Islands. Straight east-west pressure contours over the Bering Sea indicate cold northeast winds. Summer had near normal temperatures over the Bering Sea proper, while mainland Alaska set warm temperature records (Figure 23). Many Alaskan land locations experienced temperatures above 37°C in June. Fairbanks experienced a record-number of thirty-six days with temperatures of 27°C or higher.

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 24) are close to record extents not seen since the early 1970s, and contrast to the warm years of 2000-2005 (except 2002). Spring 2013 had less sea ice in Bristol Bay than in 2012. Steady northeast winds throughout winter and spring during 2012 and 2013 contributed to the major extents.

Ocean temperatures. Along with cold air temperatures and extensive sea ice, ocean temperatures at the M2 mooring site were low in winter 2013 similar to 2006 through winter 2012 compared with 2000-2005 (Figure 25). The cold pool (Figure 26), 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 2013 was again prominent in the sequence of recent cold years, but was less than the most extensive areas of 2010 and 2012.

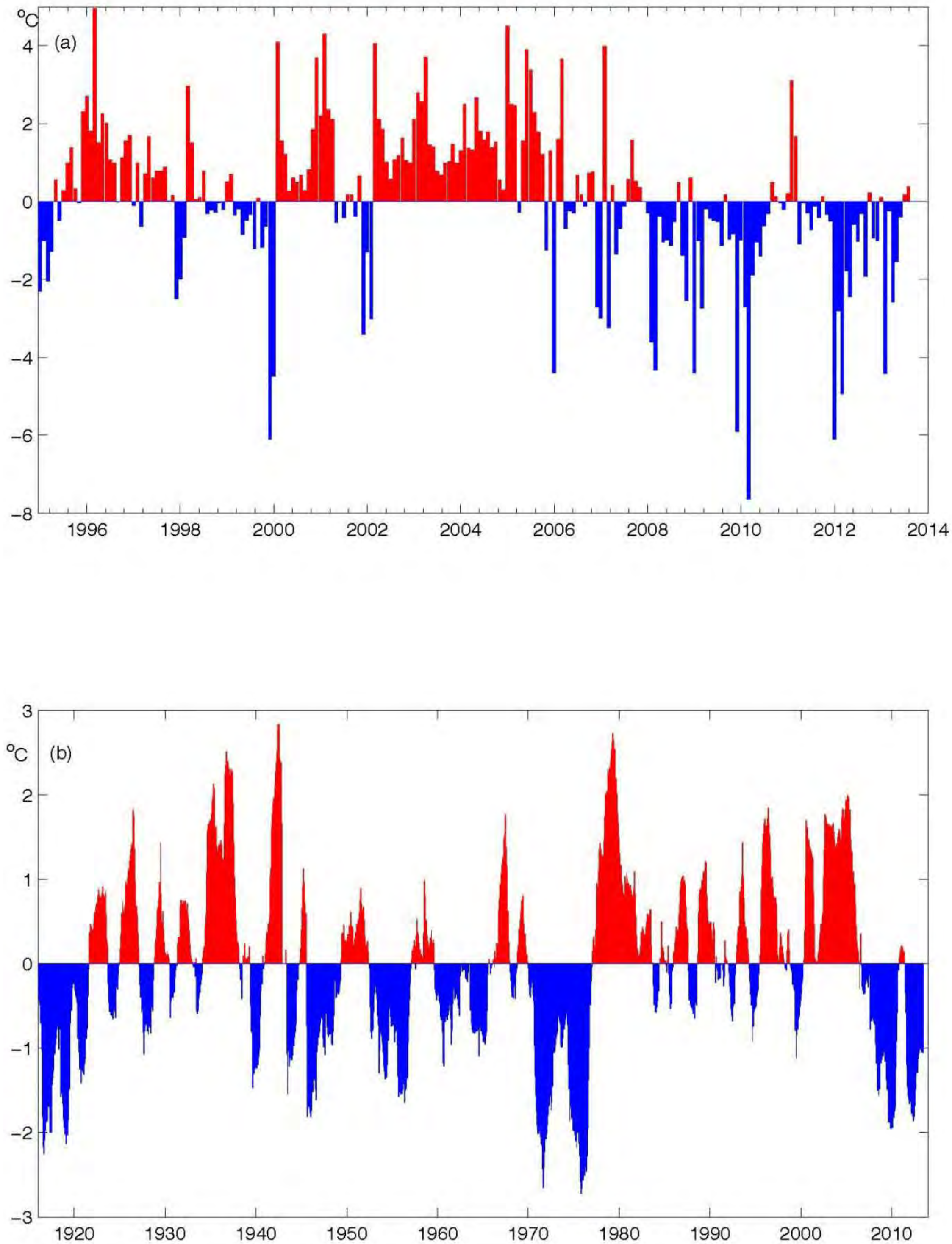


Figure 20: Mean monthly surface air temperatures anomalies in St. Paul, Pribilof Islands, a) unsmoothed, January 1995 through August 2013, and b) smoothed by 13-month running averages, January 1916 through June 2013. The base period for calculating anomalies is 1961-2000.

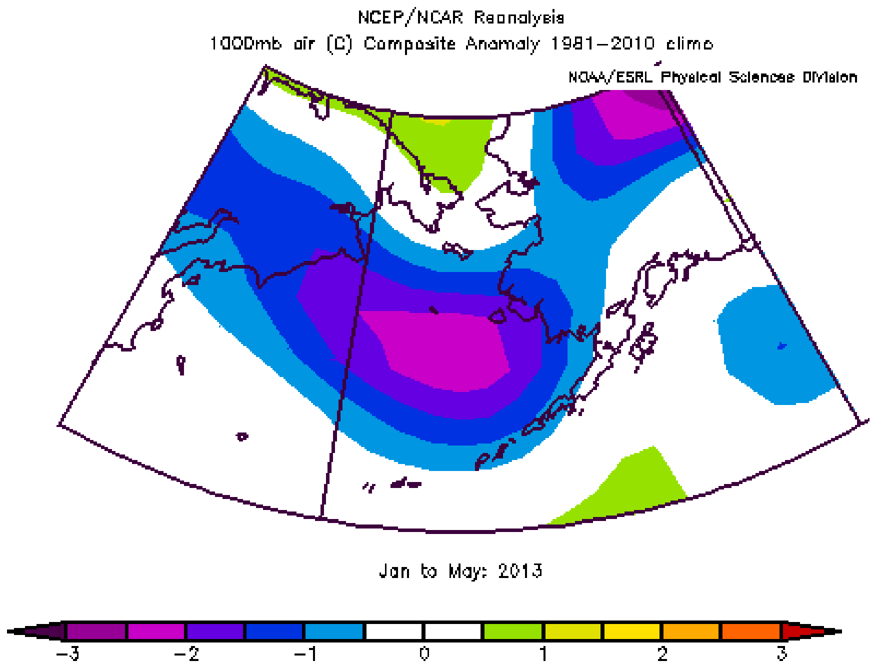


Figure 21: Surface air temperature anomaly over the greater Bering Sea region for Winter-Spring 2013. All individual months February-May resemble the composite.

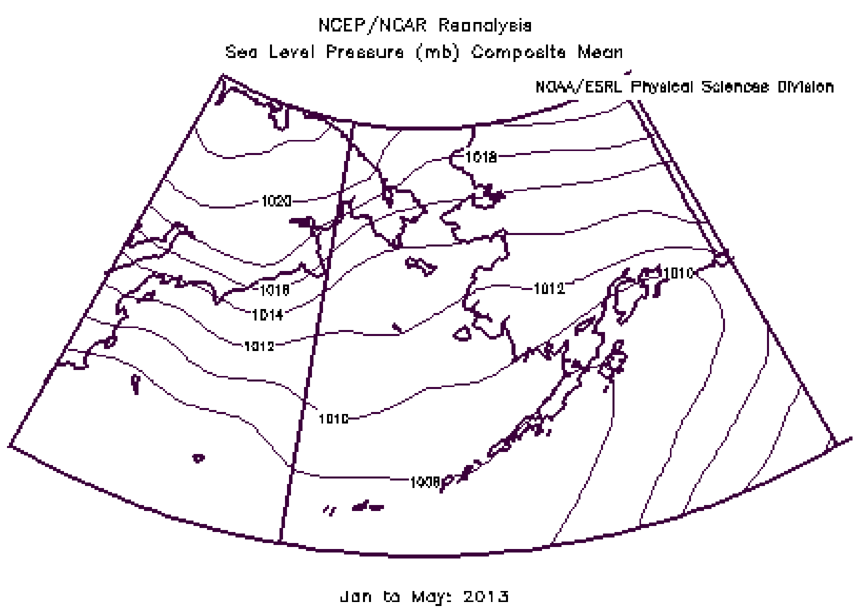


Figure 22: Sea level pressure (SLP) for January through May 2013. Note the center of the Aleutian low is centered south of the Aleutian chain.

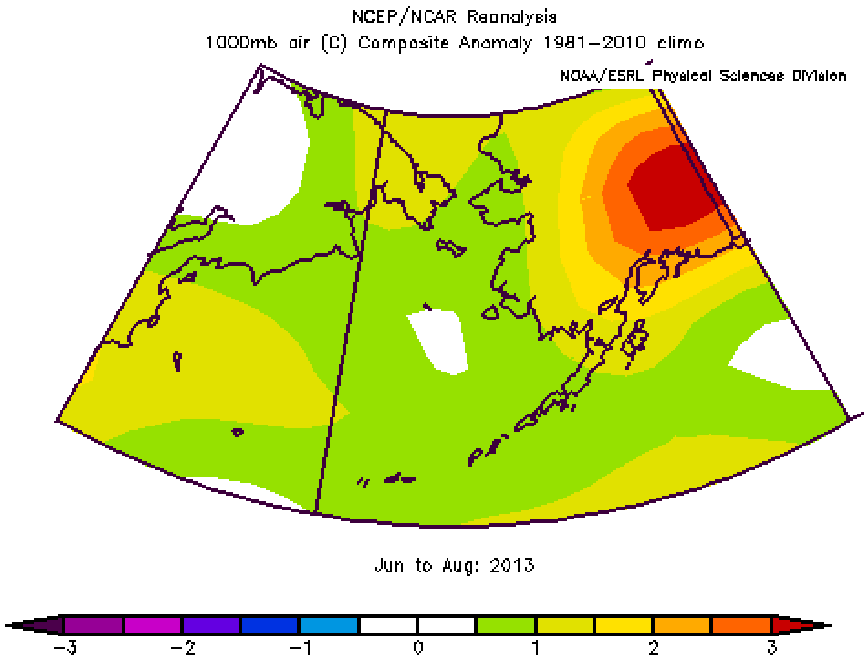


Figure 23: Surface air temperature anomaly over the greater Bering Sea region for June-August 2013. Central Alaska represents record air temperatures.

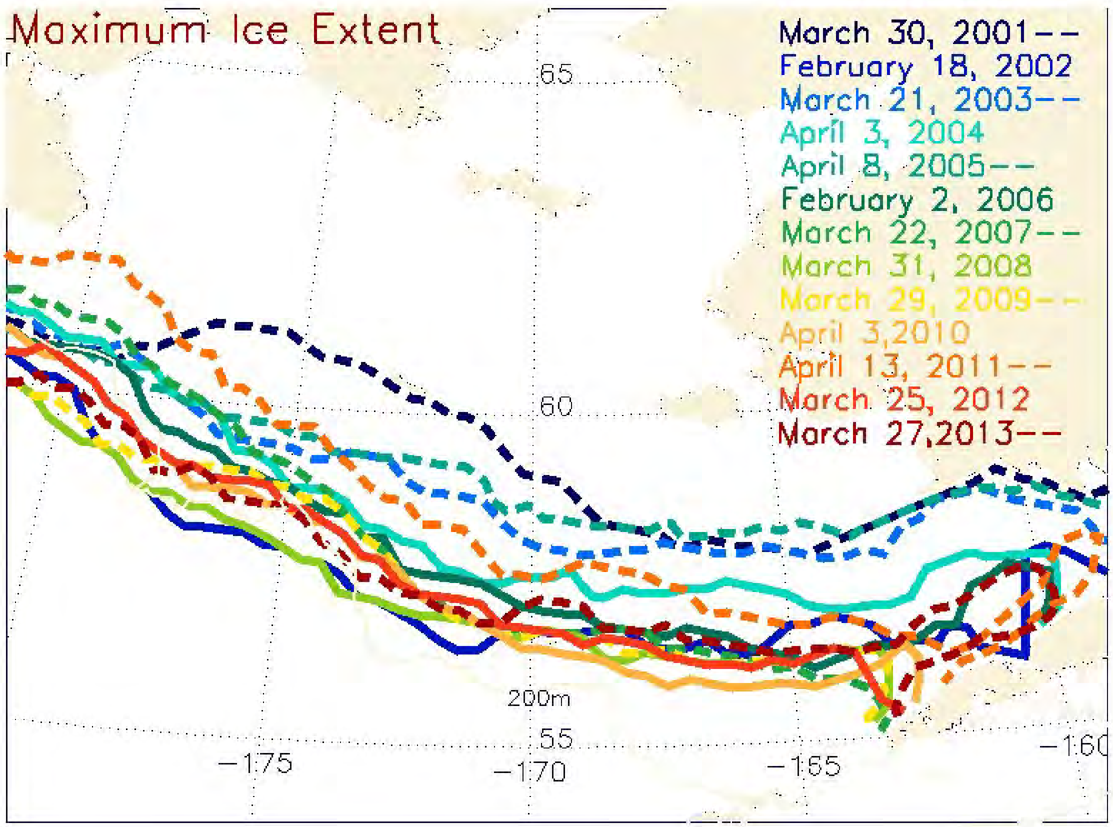


Figure 24: Recent springtime ice extents in the Bering Sea. Ice extent in 2006 through 2010 exceed the minimums of the early 2000s (except for 2002). Spring 2013 had less sea ice in Bristol Bay than in 2012.

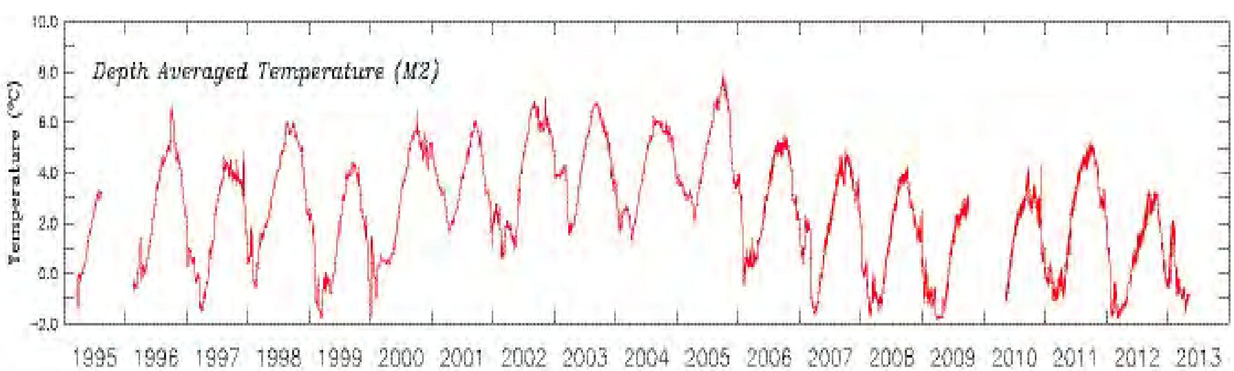


Figure 25: Depth averaged temperatures and temperature anomalies measured at Mooring 2, 1995-2013 in the southeast Bering Sea (°C).

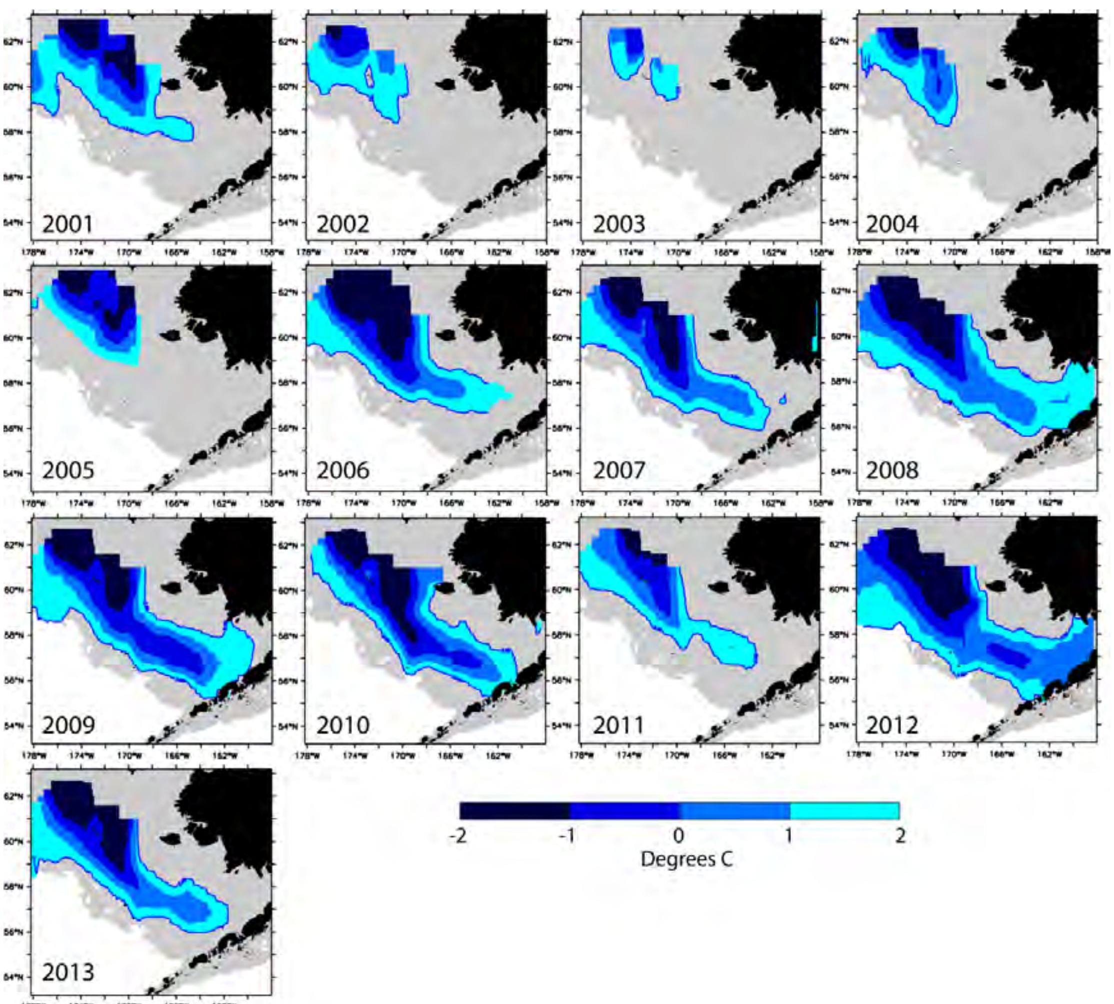


Figure 26: Cold Pool extent in southeast Bering Sea from 2001 to 2013. While extensive in the recent sequence of cold years, the year 2013 more resembles 2007 and 2008 rather than the maximum years of 2010 and 2012.

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
Contact: jerry.hoff@noaa.gov
Last updated: October 2013

Description of index: The annual AFSC bottom trawl survey for 2013 started on 29 May and finished on 6 August.

Status and trends: Average surface and bottom temperatures in 2013 were similar to those in 2007 (Figure 27). The 2013 average surface temperature was 6.4°C, which was higher than 2012 (5.1°C) and slightly below the time-series mean from 1982-2012(6.5°C). The average bottom temperature in 2013 was 1.7°C, which was higher than 2012 (0.9°C) and lower than the long-term mean of 2.3°C. The 'cold pool', defined as an area with temperatures <2°C, was comparable to 2007 (Figure 26).

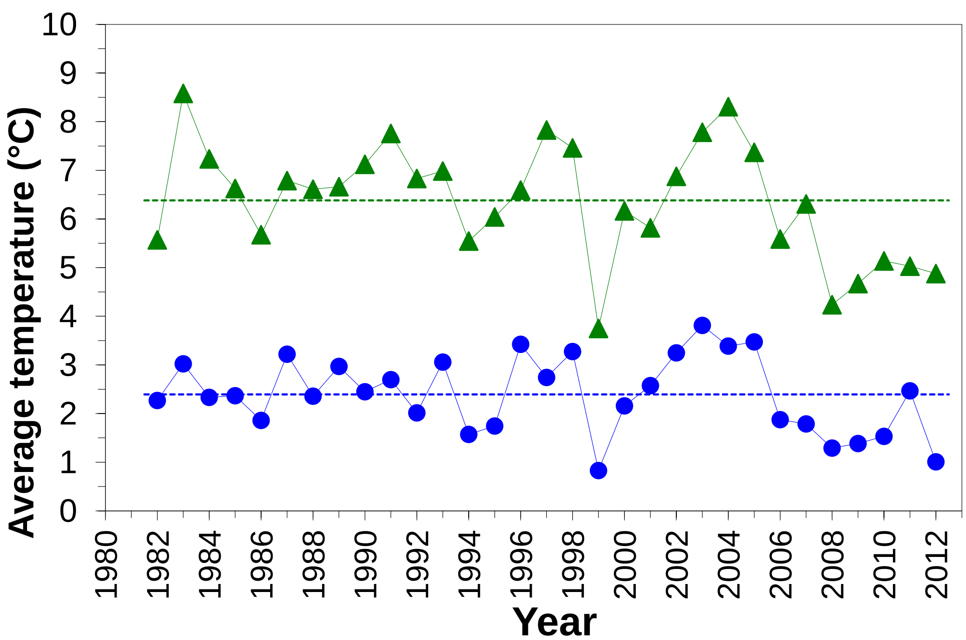


Figure 27: Average summer surface (green triangles) and bottom (blue dots) temperatures (°C) of the eastern Bering Sea shelf collected during the standard bottom trawl surveys from 1982-2013. Survey water temperatures for each year were weighted by the proportion of their assigned stratum area. Dotted line represents the time-series mean for 1982-2012.

Factors influencing observed trends: Warm and cold years are the result of interannual variability in the extent, timing, and retreat of sea ice in the EBS shelf. During cold years, sea ice extent is further south and sea ice retreat occurs later.

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

Contributed by Gerald Hoff and Chris Rooper, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: jerry.hoff@noaa.gov
Last updated: October 2013

Description of index: In 2012 the RACE Division purchased four SeaGuard CTD units (funded by the North Pacific Research Board and Deep Sea Coral Research and Technology Program). These units were purchased to increase the oceanographic data collections during bottom trawl surveys of the eastern Bering Sea slope, Gulf of Alaska and Aleutian Islands.

The CTD units collect concurrent depth, temperature, salinity, pH, oxygen and turbidity data. The units are deployed on the headrope of the AFSC bottom trawls during most survey hauls. To date, the data has been collected on the 2012 EBS slope and the 2013 GOA bottom trawl surveys.

The data are presented here as a series of maps of bottom variables (the average value of each variable during the on-bottom period of the bottom trawl haul). The data have been interpolated to a 1 km by 1 km raster using R software. For salinity, pH and oxygen kriging with a fitted exponential semi-variance model was used based on the spatial pattern in semi-variance plots. The turbidity data exhibited a linear decrease in semi-variance with distance, so inverse distance weighting was used for this variable. The EBS slope data collection in 2012 covered the entire continental slope (Figure 28).

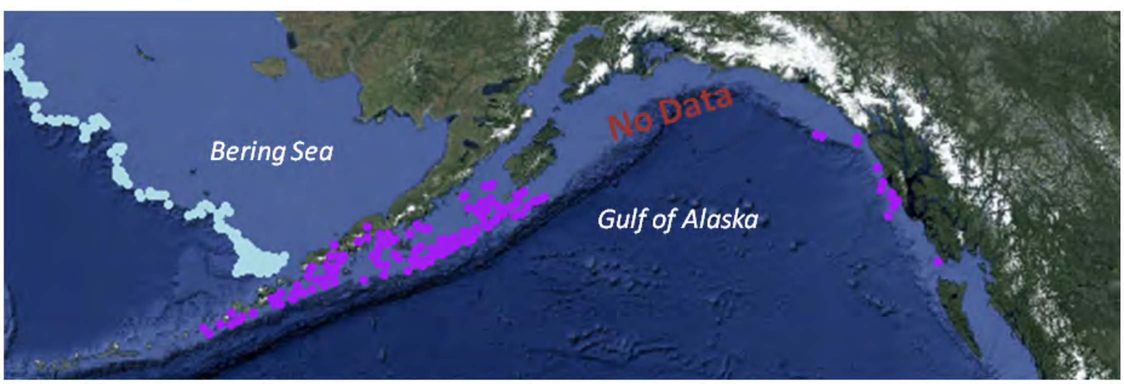


Figure 28: Sampling locations where bottom trawl hauls collected oxygen, pH, salinity and turbidity data from the net headrope. Light blue points were sampled on the eastern Bering Sea slope in 2012 (n = 167). Purple points were sampled in the Gulf of Alaska in 2013 (n = 164).

Status and trends: Patterns in salinity on the eastern Bering Sea slope mirrored depth, with high salinity water on the deeper portions of the slope and less saline waters on the upper slope and shelf (Figure 29). Oxygen concentrations were also higher in shallow areas of the slope, but there were also some areas of low oxygen concentration in the middle of Pribilof and Zhemchug canyons. pH distribution followed oxygen very closely. Turbidity was higher in the southern EBS slope in Bering Canyon and Pribilof Canyon and lower along the northern stretches of the slope, with the exception of the northern arm of Zhemchug canyon.

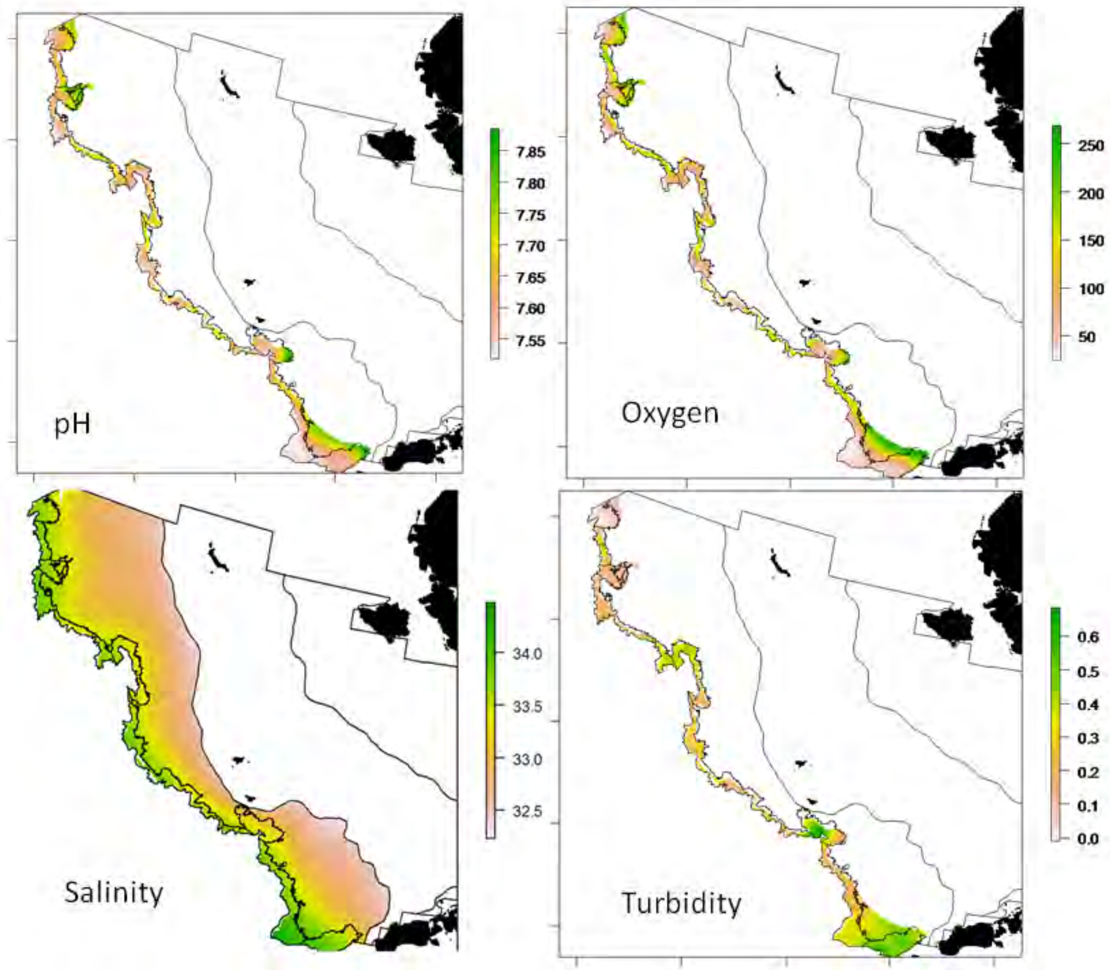


Figure 29: Maps of interpolated pH, oxygen, salinity and turbidity for the eastern Bering Sea upper slope. The data were collected at bottom trawl survey stations during the 2012 bottom trawl survey and were interpolated to a 1 km by 1 km grid for the upper slope and shelf. The salinity map includes data collected on the EBS shelf survey that allowed interpolation to the outer domain of the EBS shelf.

No time-series trends are reported because this was the first year of data collection.

Factors causing observed trends: The observed spatial trends in near bottom salinity are likely caused by relationships to depth in the EBS. The trends in other variables are likely the result of areas of differential primary production and other oceanographic features.

Implications: As more of this data is collected relationships between fish and invertebrate distributions will be explored. When multiple years of data have been collected, variability of spatial patterns may be important.

Regional Water Mass Characteristics in the Northern Bering Sea

Contributed by Jeanette Gann and Lisa Eisner, Auke Bay Laboratory, National Marine Fisheries Service, NOAA
Contact: jeanette.gann@noaa.gov
Last updated: July 2013

Description of index: The oceanography and shelf dynamics of the southern eastern Bering Sea (EBS) have been well-studied, while less attention has been given to the northern EBS, although commercially important fisheries are present in both the south and the north. Sea ice extent and duration, and freshwater inputs from the Yukon River are substantially higher in the north compared to the south, resulting in large variations in oceanography between the northern and southern EBS and between regions within the northern EBS. We describe spatial variations in oceanographic characteristics (salinity, temperature, and zooplankton abundance) for pre-defined regions (Figure 32) (Ortiz et al., in press), and compare these characteristics to juvenile salmon biomass (all species combined) in the northern EBS.

Sampling was conducted on a station grid using a CTD (SBE 19, 25 or 9-11) equipped with a Wet Labs fluorometer, and beam transmissometer. The survey grid (60 km station spacing) encompassed areas between 60° and 65° N latitude over the EBS shelf. Sampling took place during Aug.-Oct., 2002-2011. Zooplankton were collected over the water column: large taxa ($>505\mu$m) with oblique bongo-net tows (505 μm) and small taxa ($<505\mu$m) with a vertical Juday-net tow (168 μm). Samples were preserved in 5% formalin and enumerated at shore based facilities. Juvenile salmon were caught with a surface rope trawl (Can trawl model 400-580 spread 60 m (width) by 15 m (depth)), towed 30 min at 3.5 to 5 knots. Salmon weights were measured for each species (chum, pink, chinook, coho, sockeye), and the multispecies biomass catch per unit effort (CPUE) was estimated for all species combined. Bering Sea Integrated Ecosystem Research Program (BSIERP) region delineations were drawn by consensus across researchers based on observed oceanography, bathymetry, benthic fauna, fish, seabird and marine mammal distribution (Ortiz et al., in press). Data were broken out by BSIERP region for primary investigations. Some BSIERP regions were combined to investigate temporal trends (2002-2011) in parameters (salinity, temperature, large and small zooplankton abundance, and juvenile salmon biomass), with the combined North Inner and South Bering Strait regions (NI-SBS), and the combined North Middle and St. Mathews regions (NM-SM).

Status and trends: Norton Sound stands out as a distinct region within the northern EBS characterized by high surface and bottom temperatures, low surface and bottom salinities, and lower than average light transmission (Table 4). The South Bering Strait and North Inner regions are areas of high juvenile salmon biomass, as well as high numbers of large zooplankton (S Bering Strait) and high numbers of small zooplankton (N Inner). Highest light transmission values are seen with high bottom and surface salinity in the St. Lawrence region, while low transmission values are found with low bottom and surface salinity in Norton Sound. Analysis of yearly trends revealed a positive relationship between surface salinity and large zooplankton abundance (NI-SBS) until 2009-2010 (Figures **??** and **??**). There is a negative relationship between large and small zooplankton for NI-SBS, while a positive relationship is seen in NM-SM. Juvenile salmon biomass for NI-SBS increased in years with colder saltier bottom waters. In contrast, salmon biomass for NM-SM increased in years with warmer bottom temperatures.

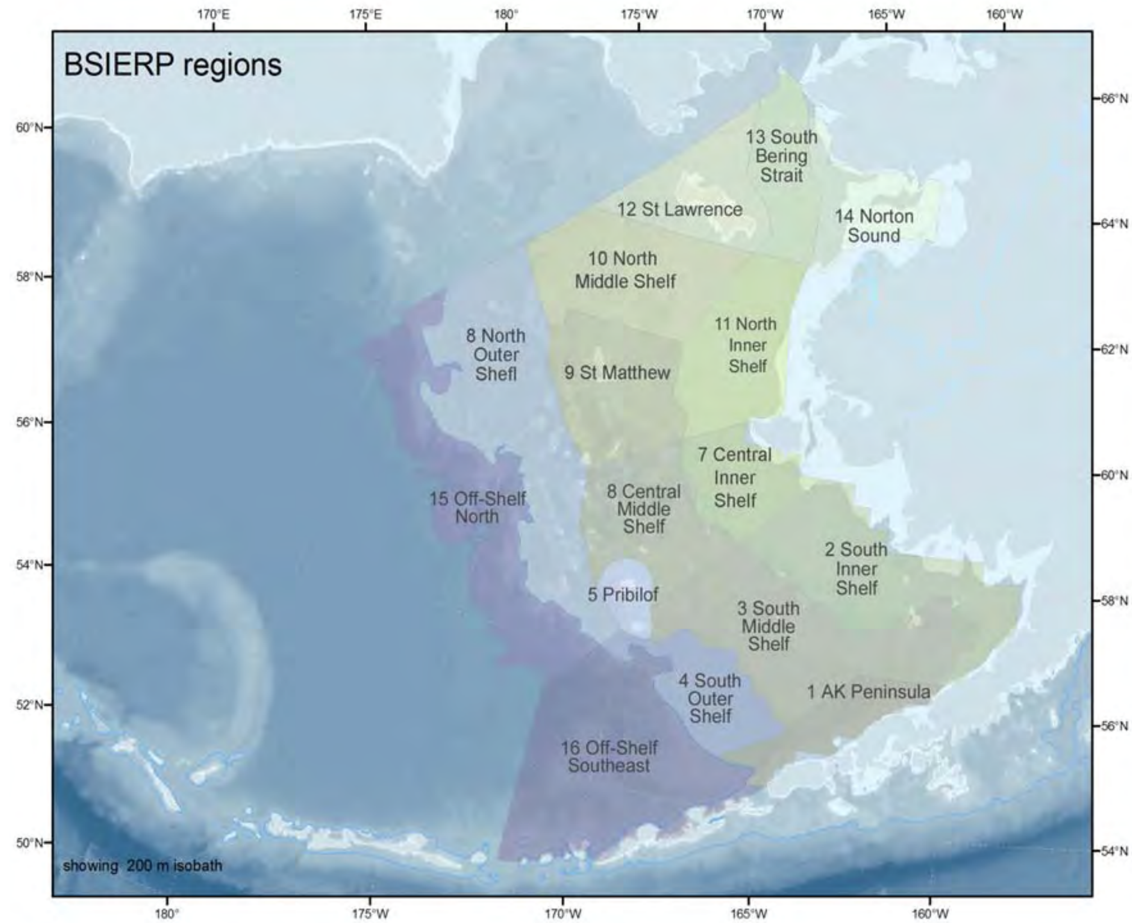


Figure 30: Bering Sea Integrated Ecosystem Research Program (BSIERP) regions from Ortiz et al. (in press)

Factors influencing observed trends: Initial findings reveal connections between juvenile salmon and bottom temperature, bottom salinity, and large and small zooplankton, depending on the region. Surface temperature and salinity changes over the northern EBS can change considerably from season to season, and from near to offshore. Ice melt and high fresh water run-off contribute to the low salinities in Norton Sound. Shallow depths contribute to higher temperatures in summer/early fall. Norton Sound has relatively low juvenile salmon biomass during late summer/early fall, while highest juvenile salmon biomass is found in South Bering Strait and North Inner regions. Future analysis will focus on individual salmon species while investigating their spatial and temporal relationships with oceanographic parameters.

Implications: The highest abundances of large and small zooplankton were seen in the South Bering Strait and North Inner regions, respectively, which coincided with the two highest regions of juvenile salmon CPUE. Thus, large zooplankton could be important prey for juvenile salmon in the South Bering Strait region, while small zooplankton could be important prey for juvenile salmon in the North Inner region.

Table 4: Average oceanographic parameters, large and small zooplankton abundance and juvenile salmon biomass by BSIERP region. Boldface indicates high/maximum values and italics indicate minimum values among parameters. Data presented are means from 2002-2011.

BSIERP region	Temp Top (°C)	Temp Bottom (°C)	Salinity Top	Salinity Bottom	Trans-mission (% light trans)	Large Zoop Abund. (# m-3)	Small Zoop Abund. ($\#/m^{-3}$)	Juvenile salmon biomass (kg km^{-2})
North Inner	8.25	6.53	30.63	30.92	82	84	**104,127**	**3,706**
North Middle	7.83	1.26	31.15	31.57	83	90	54,969	819
Norton Sound	**9.70**	**8.92**	*27.00*	*28.29*	*65*	41	13,037	575
South Bering Strait	7.51	5.15	31.11	31.59	82	**2,418**	10,399	**2,287**
St. Lawrence	7.65	2.97	31.80	32.20	89	183	13,108	194
St. Matthews	7.61	1.33	31.32	31.74	84	67	5,941	930

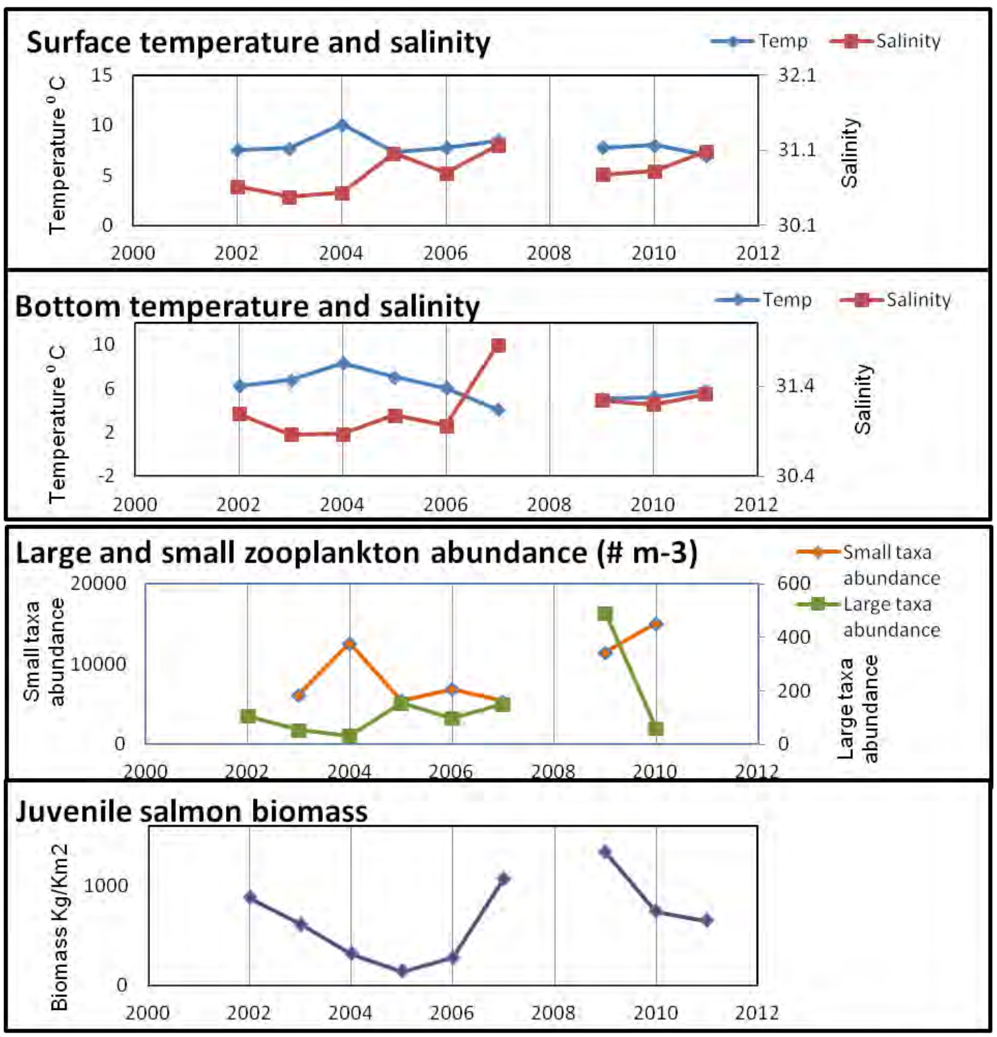


Figure 31: Temperature and salinity (a,b), large and small zooplankton abundance (< or >505μm, c) and juvenile salmon biomass (d) for combined BSIERP regions: N. Inner and S. Bering Straight (NI-SBS) for 2002-2011.

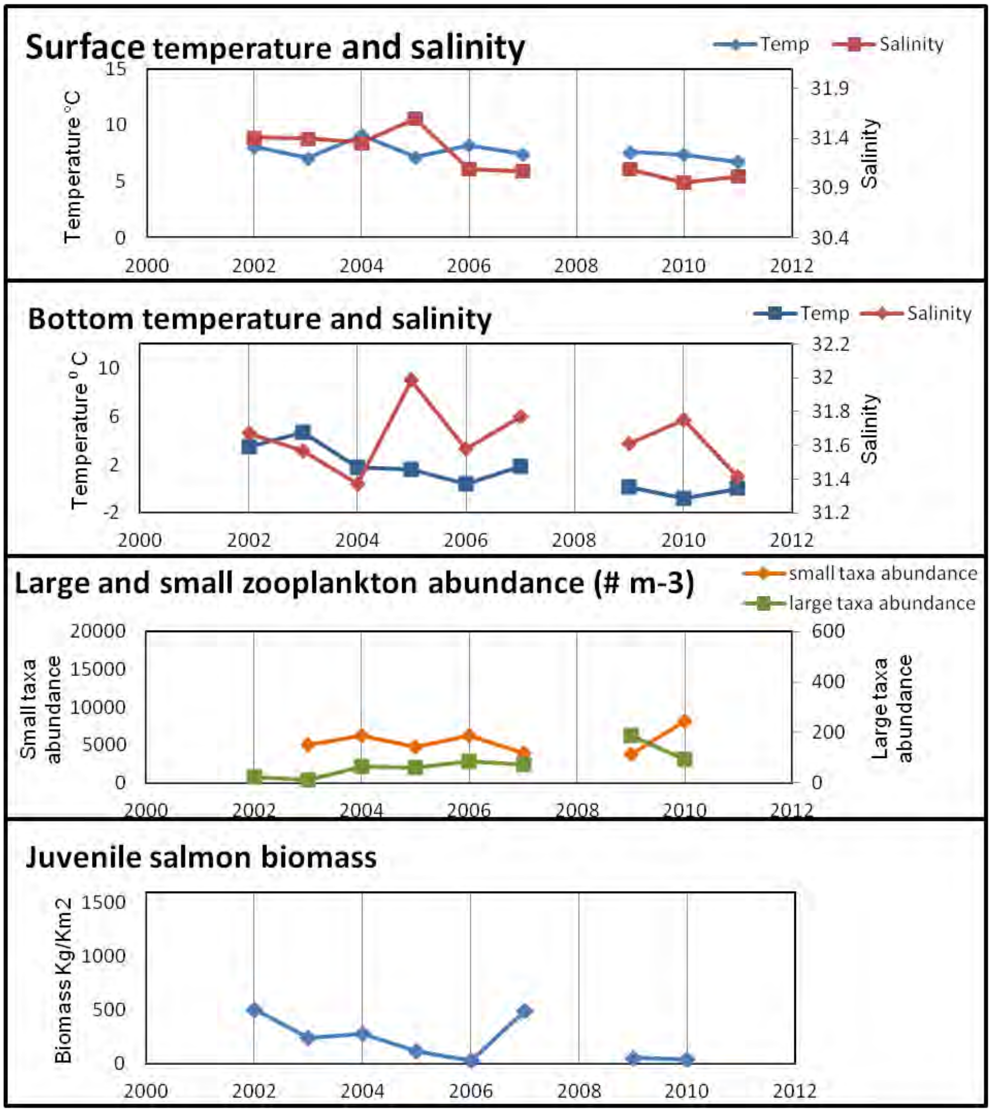


Figure 32: Temperature and salinity (a, b), large and small zooplankton abundance (< or >505μm, c), and juvenile salmon biomass (d) for combined BSIERP regions: N. Middle and St. Matthews (NM-SM) for 2002-2011.

Aleutian Islands

Eddies in the Aleutian Islands - FOCI

Contributed by Carol Ladd, NOAA/PMEL
Building 3, 7600 Sand Point Way NE, Seattle, WA 98115-6349
Contact: carol.ladd@noaa.gov
Last updated: August 2013

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 33) 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 34) 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).

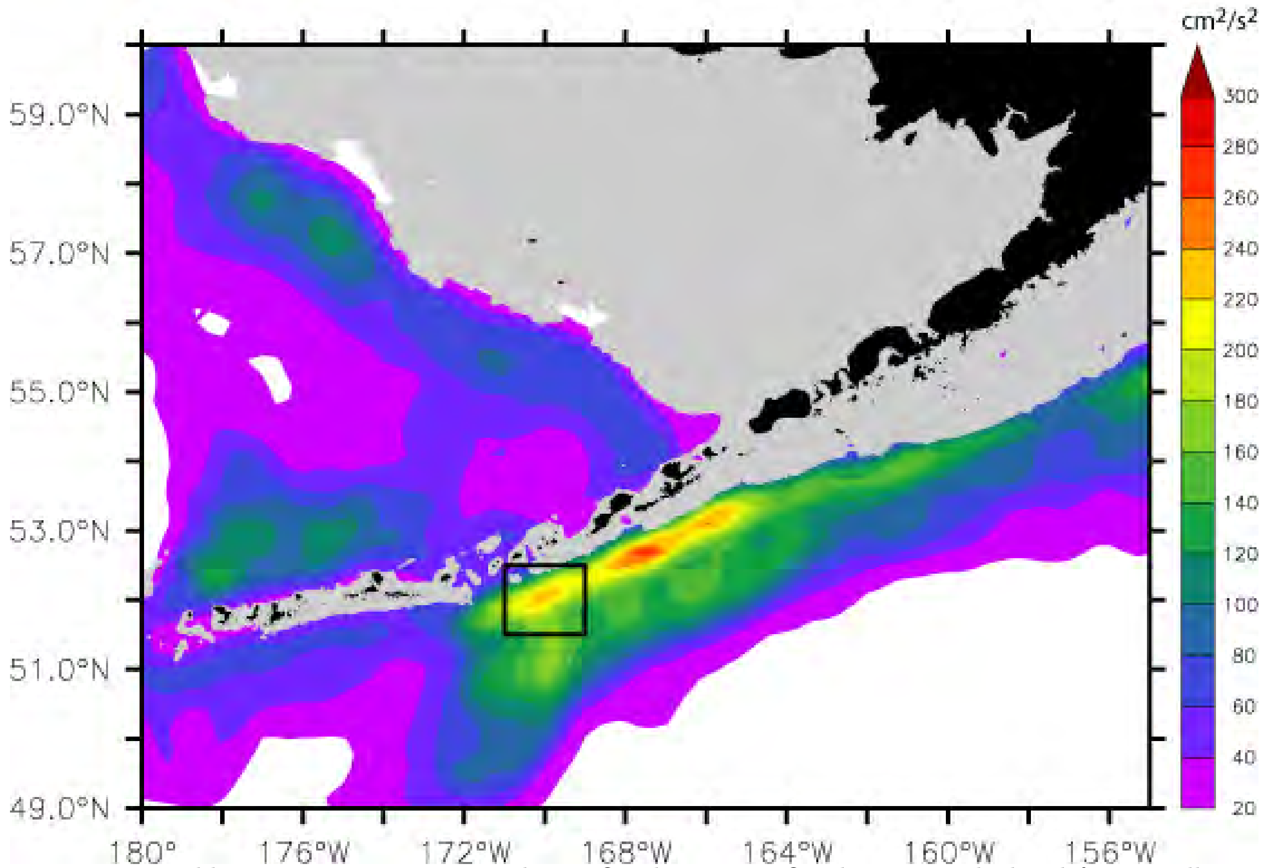


Figure 33: Eddy Kinetic Energy averaged over October 1993 - October 2012 calculated from satellite altimetry. Square denotes region over which EKE was averaged for Figure 34.

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 early 2013.

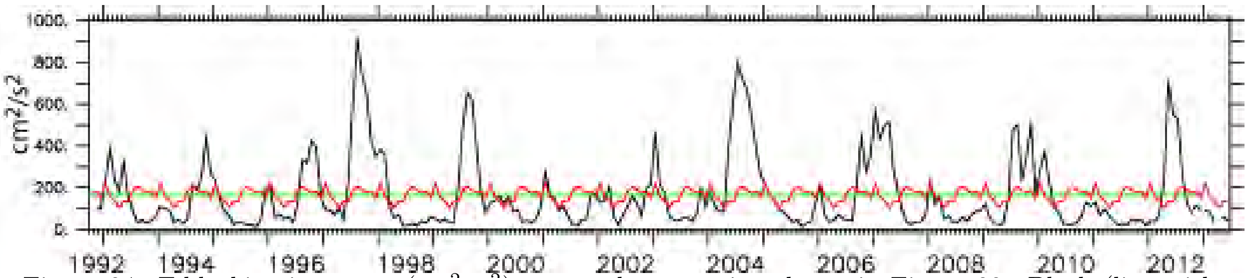


Figure 34: Eddy kinetic energy (cm^2 s^{-2}) averaged over region shown in Figure 33. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product). Red: seasonal cycle. Green (straight line): mean over entire time series.

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 2013.

Water Temperature Data Collections - Aleutian Islands Trawl Surveys

Contributed by Ned Laman, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: ned.laman@noaa.gov
Last updated: October 2012

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

Gulf of Alaska

Eddies in the Gulf of Alaska - FOCI

Contributed by Carol Ladd, NOAA/PMEL
Building 3, 7600 Sand Point Way NE, Seattle, WA 98115-6349
Contact: carol.ladd@noaa.gov
Last updated: August 2013

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 35; 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 35). 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 35). By averaging EKE over regions c and d (see boxes in Figure 35), we obtain an index of energy associated with eddies in these regions (Figure 36). The altimeter products were produced by the CLS Space Oceanography Division (AVISO, 2012).

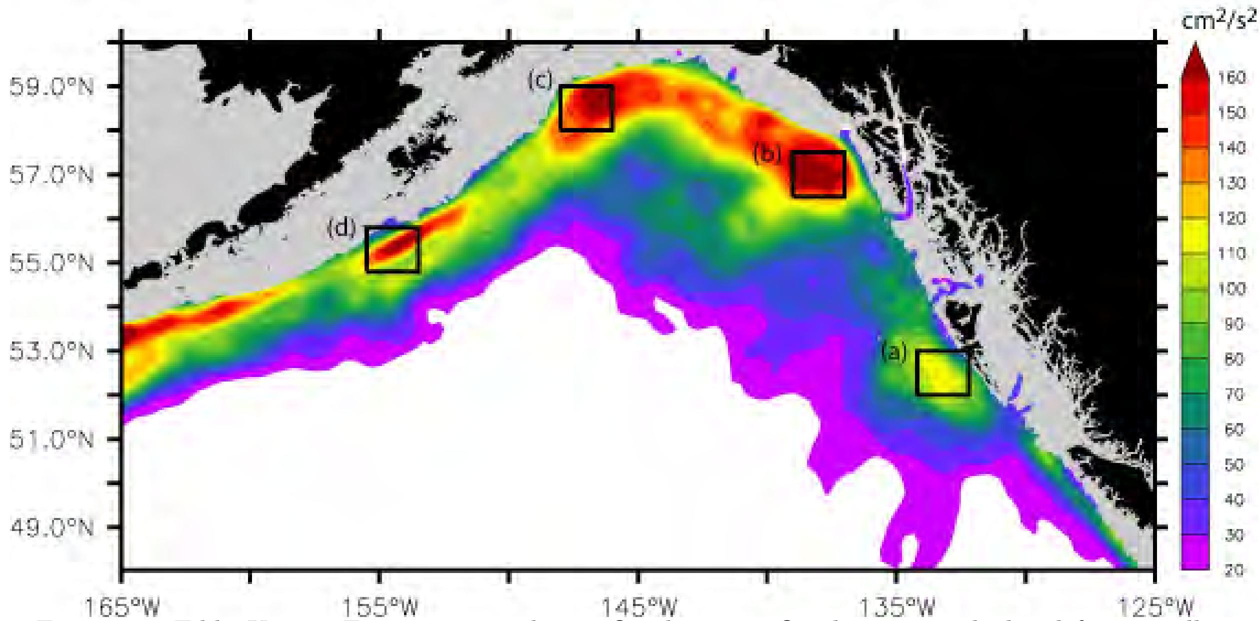


Figure 35: Eddy Kinetic Energy averaged over October 1993-October 2011 calculated from satellite altimetry. Regions (c) and (d) denote regions over which EKE was averaged for Figure 36.

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. In region (c), a spike of high EKE early in the year (February) was followed by low EKE from March through June 2013. The summer 2013 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

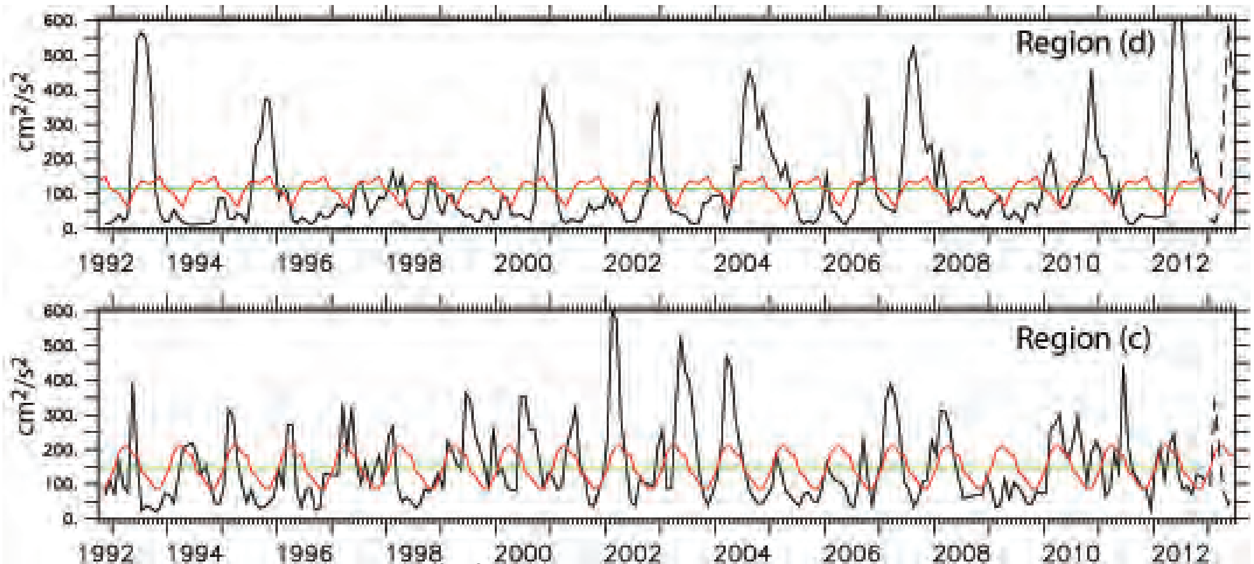


Figure 36: Eddy kinetic energy (cm^2 s^{-2}) averaged over Region (d) (top) and Region (c) (bottom) shown in Figure 35. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product), Red: seasonal cycle. Green (straight line): mean over entire time series.

winds (related to the Pacific Decadal Oscillation and El Niño) modulate the development of eddies (Combes and Di Lorenzo 2007). 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, 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

Contributed by William T. Stockhausen and W. James Ingraham, Jr. (Retired)
Resource Ecology and Fishery Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: william.stockhausen@noaa.gov
Last updated: August 2012

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 37). 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 2012.

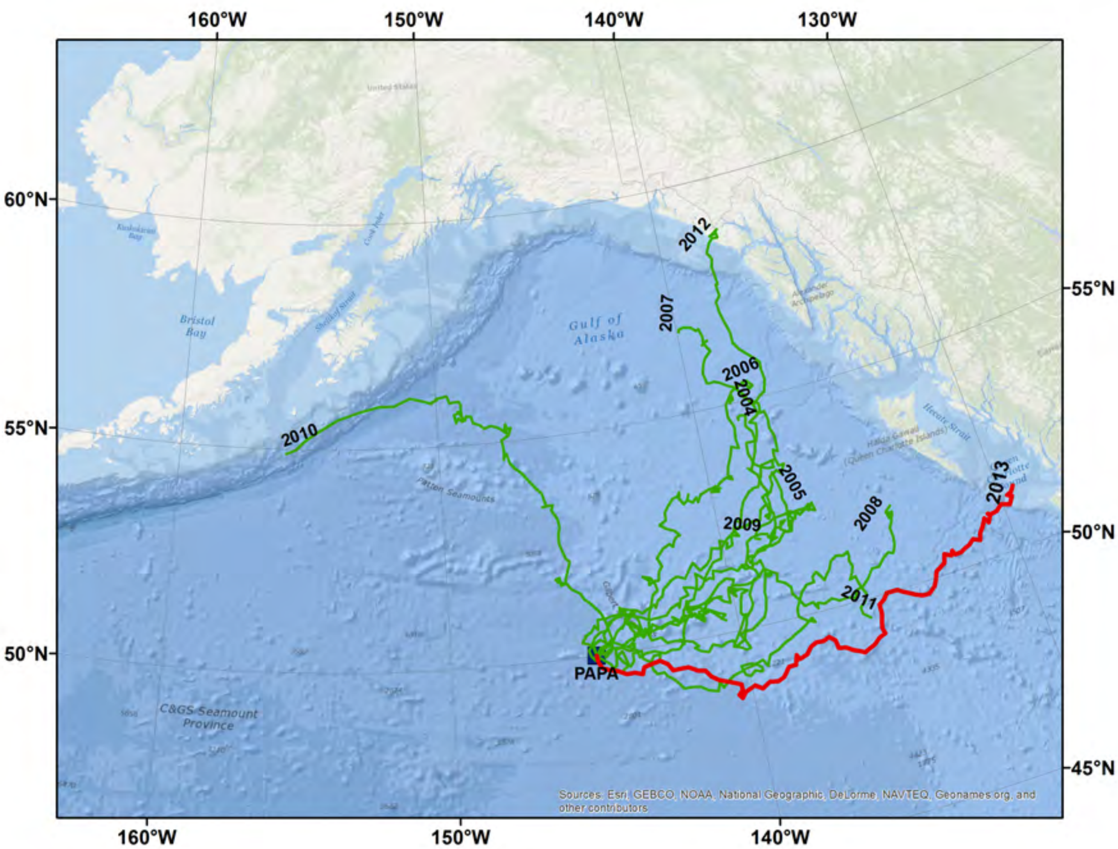


Figure 37: Simulated surface drifter trajectories for winters 2004-2013 (endpoint year). End points of 90-day trajectories for simulated surface drifters released on Dec. 1 of the previous year at Ocean Weather Station PAPA are labeled with the year of the endpoint (50°N, 145°W).

Status and trends: In general, the trajectories fan out northeastwardly toward the North American continent (Figure 37). The 2009/2010 trajectory was an exception and resulted in the westernmost trajectory endpoint for the entire set of model runs (1902-2012). 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 38) and certainly not atypical. This is consistent with the northeast Pacific wind forcing, which featured very strong westerly anomalies (see the sea level pressure (SLP) anomaly map p.71).

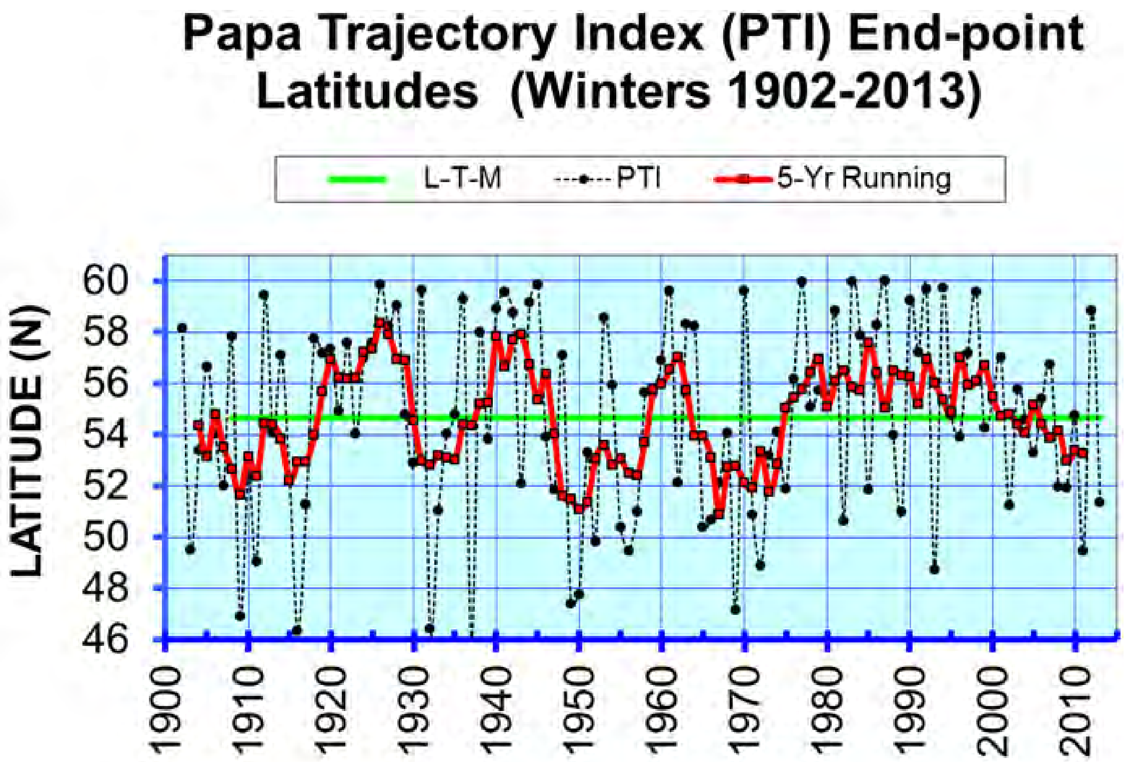


Figure 38: Annual, long-term mean (green line) and 5-year running mean (red line and squares) of the PAPA Trajectory Index time-series (dotted black line and points) for 1902-2013.

The PTI time series (Figure 38, black dotted line and points) indicates high interannual variation in the north/south component of drifter trajectories, with an average between-year change of $>4^{o}$ and a maximum change of greater than 13o (between 1931-1932). The change in the PTI between 2010/2011 and 2011/2012 was the largest since 1994, while the change between 2011/2012 and 2012/2013 reflected a reversal of only slightly less 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 38), red line and squares), with amplitudes over 7^{o} latitude. Over the past century, the filtered PTI has undergone four complete oscillations with distinct crossings of the mean, although the durations of the oscillations are not identical: 26 years (1904-1930), 17 years (1930-1947), 17 years (1947-1964), and 41 years (1964-2005). The filtered index indicates that a shift occurred in the mid 2000s to predominantly southerly anomalous flow following a 20+ year period of predominantly northerly anomalous flow. This indicates a return to conditions (at least in terms of surface drift) similar to those prior to the 1977 environmental regime shift.

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 (*Theragra chalcogramma*) by affecting its spatial overlap with predators (Wespestad et al., 2000), as well as to influence recruitment success of winter spawning flatfish in the eastern Bering Sea (EBS; Wilderbuer et al. (2002)). 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 substantially larger than the mean for 2011-12, it was smaller than the mean in both 2010/2011 and 2012/2013 and its current (5-year averaged) trend remains consistent with a return to conditions associated with the preceding "cold" regime. It may thus be a harbinger of a decadal-scale reduction in regional productivity. In addition, **the trajectory for 2012-13 indicates the potential for southeast Alaska to have experienced an influx of open ocean type organisms at the lower trophic levels**, as well as a southward shift in the "boundary" between sub-arctic and sub-tropical species.

Gulf of Alaska Survey Bottom Temperature Analysis

Contributed by Ned Laman, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: ned.laman@noaa.gov
Last updated: October 2013

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

Since 1993, water column temperatures have been routinely recorded by bathythermographs attached to the headrope of the net deployed during bottom trawl hauls on the GOA bottom trawl surveys. In earlier years, temperature data were often collected near trawl haul sites using expendable bathythermographs (XBTs); these earlier data were not used in this analysis. Individual surveys included in the analysis have start dates ranging from the middle of May to the first week in June, while end dates range from the third week in July to the first week in September. The areal extent and the maximum depth of the GOA survey have varied between survey years. In addition, water temperatures rise in the GOA over the course of the summer, particularly in the upper 200 m of the water column. This combination of changing spatial and temporal coverage along with its nearly 3-month duration complicates inter-annual temperature comparisons amongst GOA surveys. To account for these issues and to make inter-annual comparisons more meaningful, an attempt was made to remove the effect of collection date on water temperature by standardizing to a median date for all GOA bottom trawl surveys. This was achieved with generalized additive modeling (GAM) to estimate the effects of collection date on temperature at depth across survey areas and years which accounted for nearly 81% of the total deviance in the temperature data. The resulting model was used to predict the temperature at depth from the estimated median day of July 10 for all GOA survey trawl hauls. Residuals from the initial GAM were added to the predicted median day temperature-at-depth to produce the final temperature estimates for each survey year. To facilitate visualization, mean estimated temperatures were calculated from systematic depth bins in 0.5 degree longitude increments. Depth gradations were set finer in shallower depths (e.g., 5 m bins between 0 and 100 m, 10 m bins between 100 and 200 m, and 100 m bins between 500 and 1000 m) to capture the rapid changes in water temperatures often seen in these depths.

Status and trends: The 2013 pattern of water temperatures was similar to the pattern seen in the 2011 survey (Figure 39). The water column appears stratified with relatively warm near-surface waters and temperatures rapidly dropping to 6°C or less in the upper 50 m across the entire Gulf. In general, thermocline depths appear to be somewhat deeper in 2011 and 2013 as compared with the 2007 and 2009 GOA surveys, especially west of ca. 150°W. East of 135°W waters deeper than 50 m appear cooler in 2011 while west of 160W near surface temperatures (<25 m) appear slightly cooler compared with 2011. Overall water temperatures in GOA have been cooler since 2007 when compared with previous survey years.

Factors influencing observed trends: These data represent a snapshot of water temperatures collected during bottom trawl surveys in the Gulf of Alaska. Since each temperature bin represents data that were collected over a relatively short period as the vessels moved through the area, it is difficult to draw general conclusions as these temperatures are often greatly affected by short term events such as storm events, tidal currents, and changes in freshwater discharge. More persistent phenomena like mesoscale eddies, seasonal changes in solar heat flux, El Nio Southern Oscillation (ENSO) events, and changes in the Alaska Coastal Current also play an important role in mediating water column temperatures. The strength and persistence of eddies is believed to play a major role in the transport of both heat and nutrients across the continental shelf in the Gulf of Alaska (Ladd, 2007).

Implications: Water column temperatures influence the species assemblage, abundance, and growth rates of phytoplankton and zooplankton species. Ichthyoplankton distribution and growth are also related to location in relation to the warm core eddies that are a prominent feature of the central GOA (Atwood et al., 2010). Interannual differences in water column temperatures, their

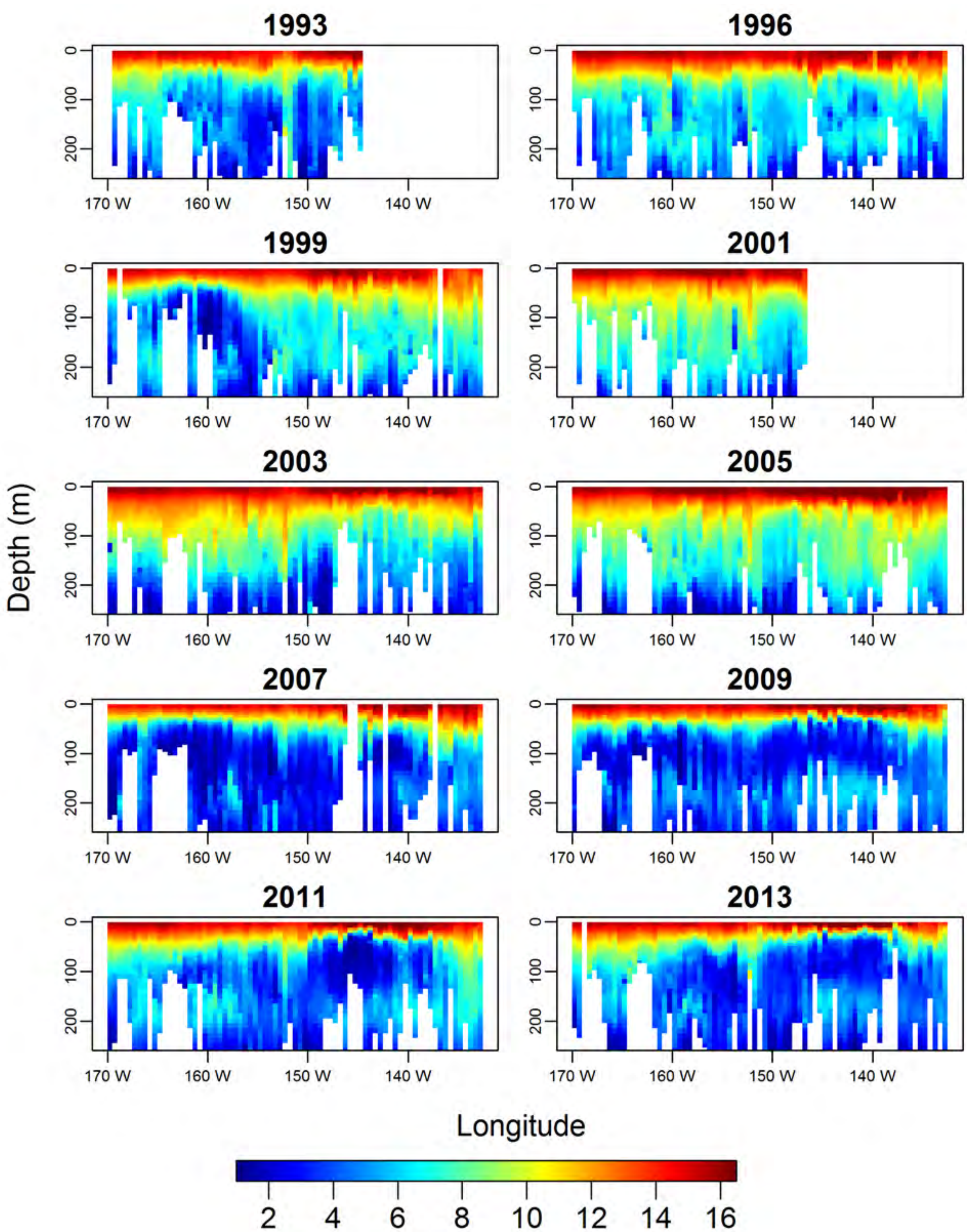


Figure 39: Date-adjusted temperature (°C) profiles predicted by systematic depth increments and $\frac{1}{2}$degree longitude intervals for years 1993-2013.

implications, and their possible effect on fish populations in the GOA requires more study to be better understood.

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

Contributed by Chris Rooper and Gerald Hoff, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: chris.rooper@noaa.gov
Last updated: October 2013

Description of index: In 2012 the RACE Division purchased four SeaGuard CTD units (funded by the North Pacific Research Board and Deep Sea Coral Research and Technology Program). These units were purchased to increase the oceanographic data collections during bottom trawl surveys of the eastern Bering Sea slope, Gulf of Alaska and Aleutian Islands.

The CTD units collect concurrent depth, temperature, salinity, pH, oxygen and turbidity data. The units are deployed on the headrope of the AFSC bottom trawls during most survey hauls. To date, the data has been collected on the 2012 EBS slope and the 2013 GOA bottom trawl surveys.

The data are presented here as a series of maps of bottom variables (the average value of each variable during the on-bottom period of the bottom trawl haul). The data have been interpolated to a 1 km by 1 km raster using R software. For salinity, pH and oxygen kriging with a fitted exponential semi-variance model was used based on the spatial pattern in semi-variance plots. The turbidity data exhibited a linear decrease in semi-variance with distance, so inverse distance weighting was used for this variable. In the Gulf of Alaska in 2013, this data was not collected during parts of the second and third survey legs resulting in a substantial data gap from Kodiak Island to the Fairweather Ground (Figure 40). The Gulf of Alaska data were not corrected for time of the year, so some within-season temporal effects could be present because of the prosecution of the survey from west to east from June to August.

Status and trends: Salinity in the Gulf of Alaska was highest on the upper slope southwest of Kodiak Island and on the southeastern Alaska outer shelf (Figure 40). Oxygen concentration was highest in areas to the west of the Shumagin Islands the on the middle and inner shelf and was uniformly low in SE Alaska. pH was low in a band across the shelf near the Shumagin Islands and generally was low on the outer shelf elsewhere in the Gulf of Alaska. Turbidity was low in all areas with the exceptions of what are probably some individual bottom trawl hauls on the inner and middle Gulf of Alaska shelf.

No time-series trends are reported because this was the first year of data collection.

Factors causing observed trends: The observed spatial trends in near bottom salinity are likely caused by relationships to freshwater runoff in the GOA. There may be a seasonal signal in the Gulf of Alaska salinity signal. The patterns of high turbidity in the Gulf of Alaska are probably caused by high turbidity in a select number of individual tows. The trends in other variables are likely the result of areas of differential primary production and other oceanographic features.

Implications: As more of this data is collected relationships between fish and invertebrate distri-

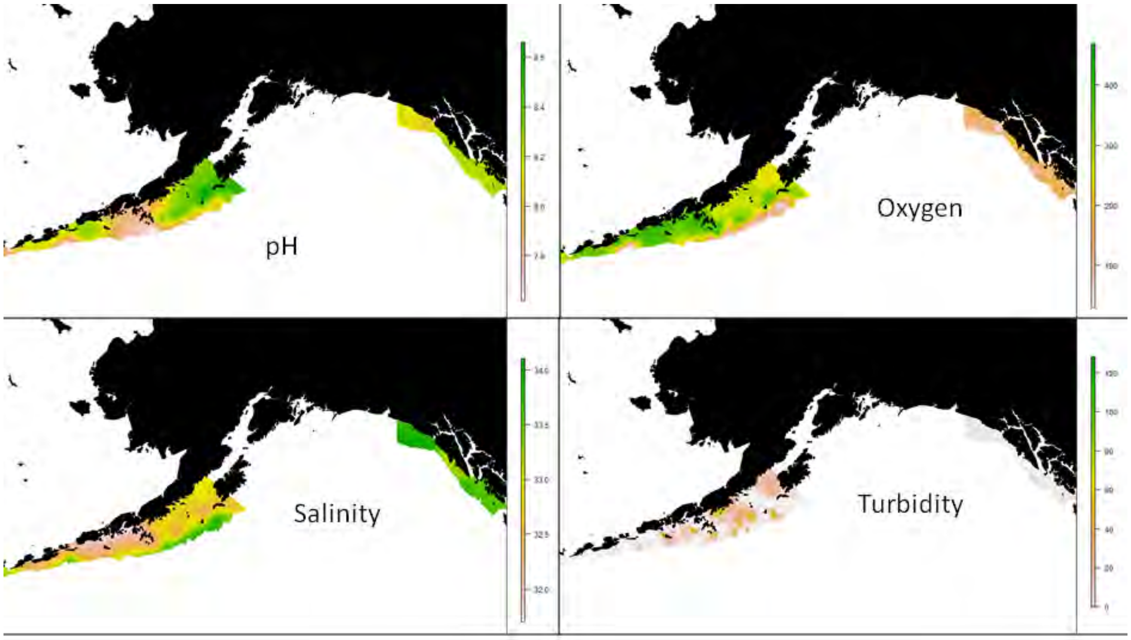


Figure 40: Maps of interpolated pH, oxygen, salinity and turbidity for the Gulf of Alaska shelf and upper slope. The data were collected at bottom trawl survey stations during the 2013 bottom trawl survey and were interpolated to a 1 km by 1 km grid for the upper slope and shelf. No data was collected in the area from Kodiak Island to the Fairweather Ground.

butions will be explored. When multiple years of data have been collected, variability of spatial patterns may be important.

Habitat

Structural Epifauna (HAPC Biota) - 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
Contact: jerry.hoff@noaa.gov
Last updated: October 2013

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 1982-2013. 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 ($\pm$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 41).

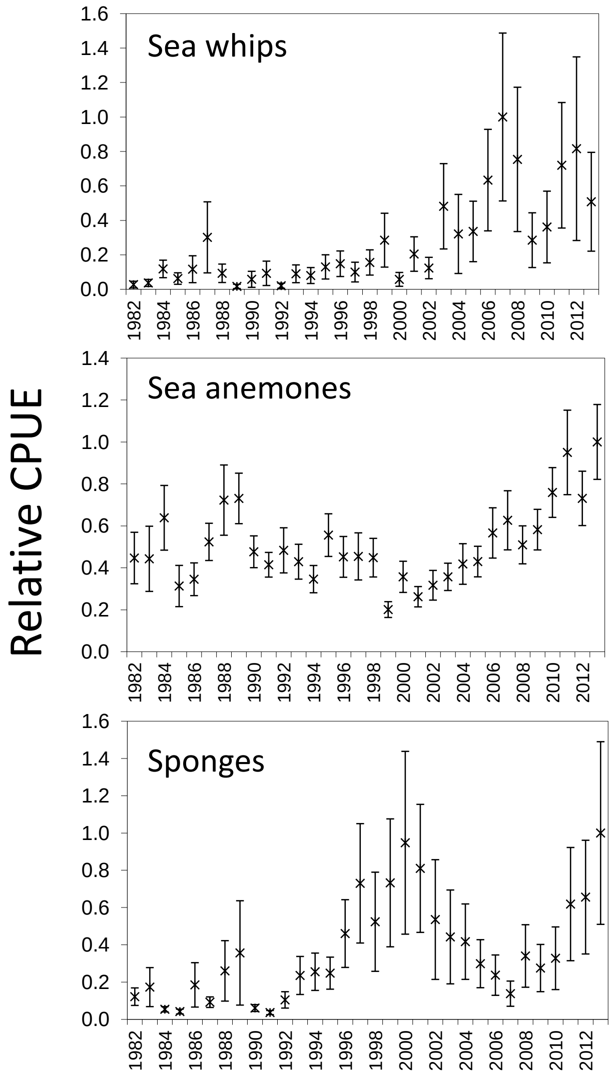


Figure 41: Relative CPUE trends of structural epifauna from the AFSC bottom trawl survey of the eastern Bering Sea shelf during the May to August time period from 1982-2013. Data points are shown with standard error bars.

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

Contributed by Chris Rooper, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: chris.rooper@noaa.gov
Last updated: October 2012

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

Structural Epifauna (HAPC Biota)- Gulf of Alaska

Contributed by Chris Rooper, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: Chris.Rooper@noaa.gov
Last updated: October 2013

Description of index: Structural epifauna groups considered to be Habitat Area of Particular Concern (HAPC) biota include sponges, anemones, gorgonians (sea fans/ sea whips), sea pens, and corals (both hard and soft). NOAA collects data on structural epifauna during the largely biennial RACE summer surveys in the Gulf of Alaska from 1984 - 2013. For each species group, the catches for each year were scaled to the largest catch over the time series (which was arbitrarily scaled to a value of 100). The standard error (±1) was weighted proportionally to the CPUE to get a relative standard error. The percentage of positive catches in the survey bottom trawl hauls was also calculated.

Status and trends: A few general patterns are clearly discernible (Figure 42). Sponges are caught in about 50% of bottom trawl survey hauls in all areas of the GOA. However, the CPUE is generally highest in the western GOA and decreases to the east. Sponge CPUE has generally declined in the western GOA during the time series, while CPUE has remained fairly constant in the two other areas. Anemones are caught in low abundance in the eastern GOA, while they are common (occur in ∼50% of tows) at a relatively constant abundance in the western and central GOA. Gorgonian corals show an opposite pattern, as they are in highest abundance in the eastern GOA, although they are relatively uncommon in catches for all areas. A peak abundance occurred in 1999 in the eastern GOA, and catches have declined in recent surveys. The sea pen time series is dominated by a large CPUE in 2005 in the central GOA, but they occur uncommonly in bottom trawl tows (<10% occurrence). Stony coral CPUE's have been highest and highly variable in the western GOA. Soft coral CPUE has been uniformly low with the exception of a large catch in the western GOA in the 1984 survey.

Factors influencing observed trends: The Gulf of Alaska survey does not sample any of these 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. Another complicating factor in interpreting these results is that the gears used by the Japanese vessels in the surveys prior to 1994 were quite different from the survey gear used aboard American vessels

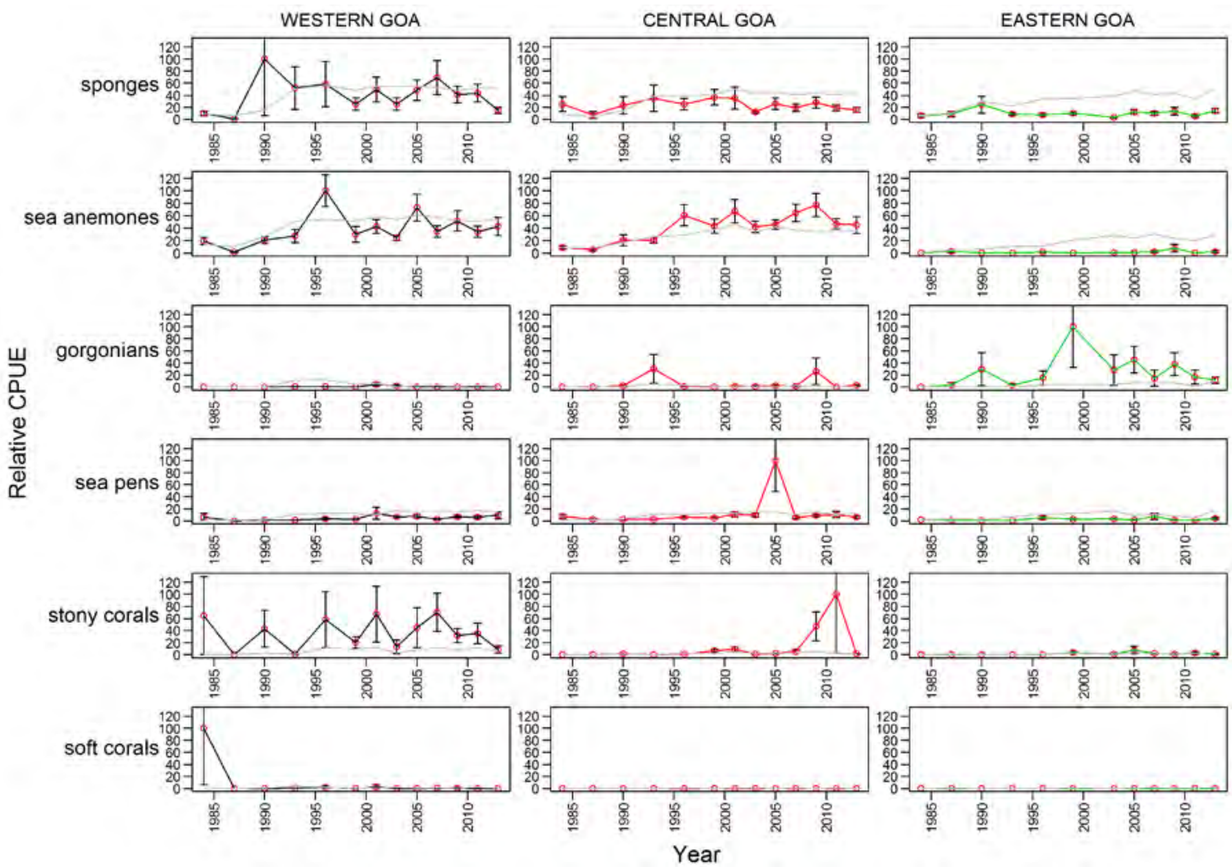


Figure 42: Mean CPUE of HAPC species groups by area from RACE bottom trawl surveys in the Gulf of Alaska from 1984 through 2013. Error bars represent standard errors. The gray lines represent the percentage of non-zero catches.

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 structural epifauna, and it is likely that this increased emphasis influenced the results presented here.

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

Primary Production

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

Contributed by Lisa Eisner, Kristin Cieciel, Jeanette Gann
Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: lisa.eisner@noaa.gov
Last updated: August 2012

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

Trends in Surface Carbon Uptake by Phytoplankton During Late Summer to Early Fall in the Eastern Bering Sea

Contributed by Jeannette Gann, Lisa Eisner, and Kristin Cieciel
Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: jeanette.gann@noaa.gov
Last updated: August 2012

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

Gulf of Alaska Chlorophyll a Concentration off the Alexander Archipelago

Contributed by Jamal Moss and Stacy K. Shotwell Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: jamal.moss@noaa.gov
Last updated: August 2011

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

Zooplankton

Bering Sea Zooplankton

Contributed by Patrick Ressler, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
[1]Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: patrick.ressler@noaa.gov
Last updated: August 2013

Description of index: Ressler et al. (2012) developed a survey of the abundance and biomass of euphausiids on the middle and outer shelf of the eastern Bering Sea, using acoustic and Methot trawl data from 2004-2010 surveys of midwater pollock (Honkalehto et al., 2012). Acoustically-estimated euphausiid density (no. m^3) along survey transects was averaged over the water column and then across the surveyed area to produce mean estimates for each year. Error (95% confidence intervals) were computed from geostatistical estimates of relative estimation error (Petitgas, 1993).

Status and trends: The observation from the 2012 acoustic-trawl survey of pollock was recently added. The conversion from acoustic backscatter to number of euphausiids per m^3 is based on length and species composition data from net samples collected between 2004 and 2009. Euphausiid length and species composition from 2010 and 2012 net samples have not yet been fully incorporated into the index, but they show no large differences from previous years in size and species encountered.

Figure 43 indicates that summertime euphausiid density increased from 2004-2009, but it subsequently declined in 2010 and 2012. Figure 44 shows the spatial distribution of acoustic backscatter at 120 kHz attributed to euphausiids in 2012.

Factors influencing observed trends: The processes controlling variation in the standing stock of these animals 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). A recent analysis, currently in review, used survey data to suggest that euphausiid abundance in recent years was better predicted by water temperatures during summer than by the abundance of walleye pollock, its single most important predator (Ressler et al., in review).

Implications: Euphausiids are prey 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 and 2012 compared to several recent prior summers. 2004 remains the year when euphausiids were least abundant in this time series.

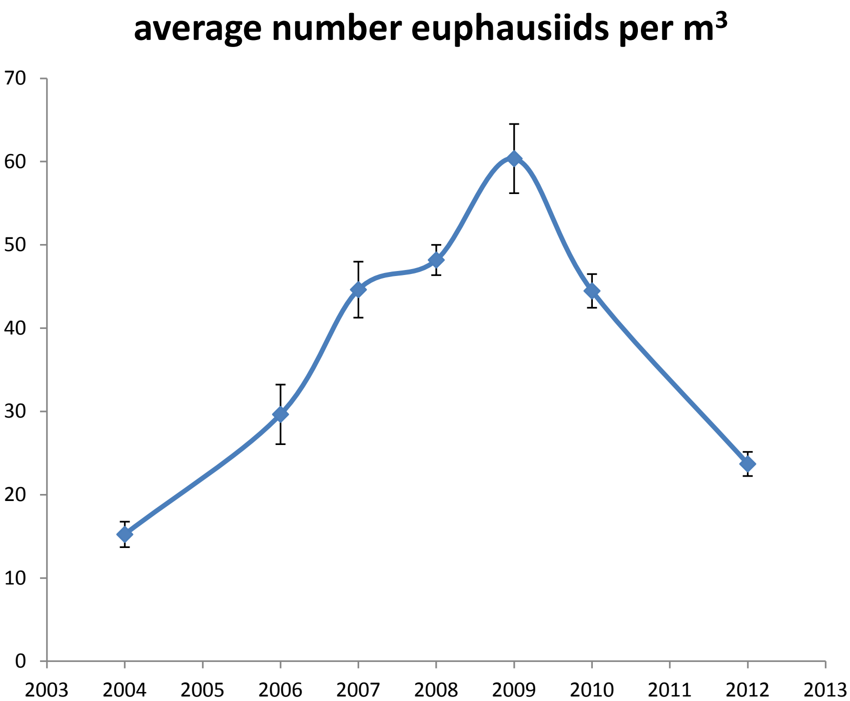


Figure 43: Acoustically-estimated euphausiid density (no. m^3) along AFSC survey transects. Error bars are 95% confidence intervals computed from geostatistical estimates of relative estimation error (Petitgas, 1993).

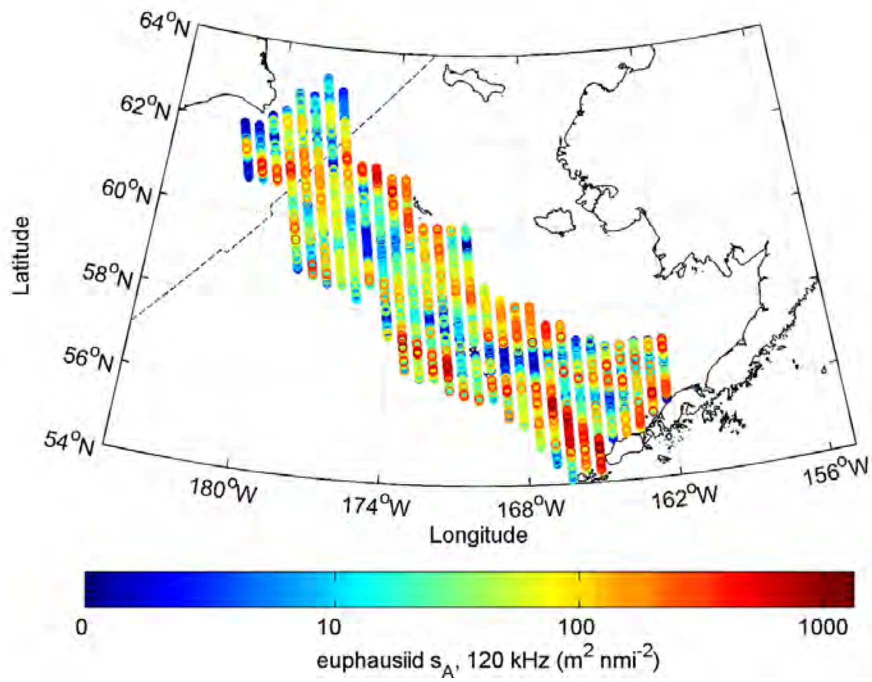


Figure 44: Spatial distribution of acoustic backscatter at 120 kHz attributed to euphausiids in 2012

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

Contributed by Alex Andrews[1], Lisa Eisner[1], and K. O. Coyle[2]
[1]Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
[2]Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, P.O. Box 757220, Fairbanks, AK
Contact: alex.andrews@noaa.gov
Last updated: October 2012

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

Jellyfish - 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
Contact: jerry.hoff@noaa.gov
Last updated: October 2013

Description of index: The time series of jellyfish (principally *Chrysaora melanaster*) was updated for 2013 (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.

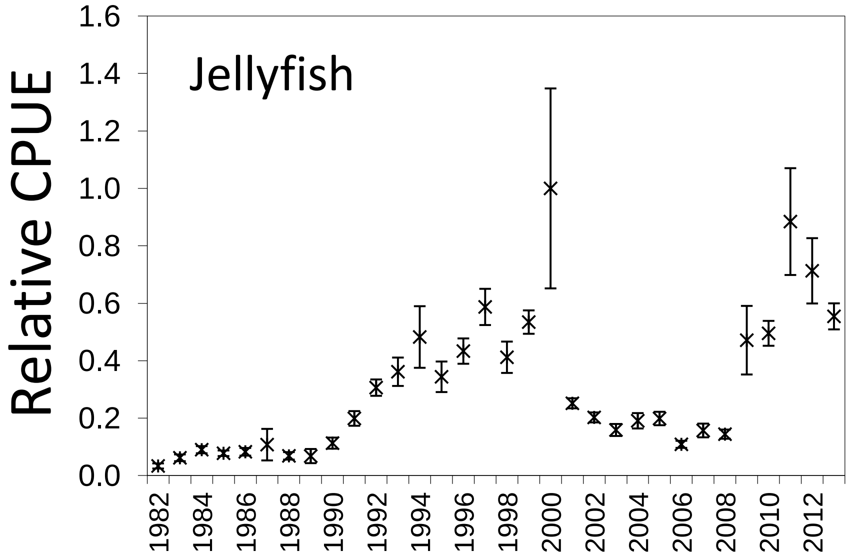


Figure 45: AFSC eastern Bering Sea bottom trawl survey relative CPUE for jellyfish during the May to August time period from 1982-2013.

Status and trends: Jellyfish relative CPUE in 2013 was down slightly from 2012, 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 2009-2013.

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)

Contributed by Kristen Cieciel, Jeanette Gann, and Lisa Eisner, Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: kristin.cieciel@noaa.gov
Last updated: July 2013

Description of index: Jellyfish sampling was incorporated aboard the BASIS (Bering Aleutian Salmon International Surveys) vessels beginning in 2004 and will continue through 2013. 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 (Inner Domain <50m, Middle Domain 50m-100m, Outer Domain ≥100m) Yearly distributions throughout the sample grid for all species have been patchy. Despite uneven distributions throughout oceanographic domains, highest concentrations of all species were found to occur in the Middle Shelf Domain. Of the six species sampled, *Chrysaora melanaster* had the highest weight per unit effort (kg) for all years.

Status and trends: In 2012 total jellyfish biomass more than doubled compared to 2011 and was the highest recorded biomass year for our survey (Figure 46). One station in the southern Bering Sea portion of our grid during 2012 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. 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.

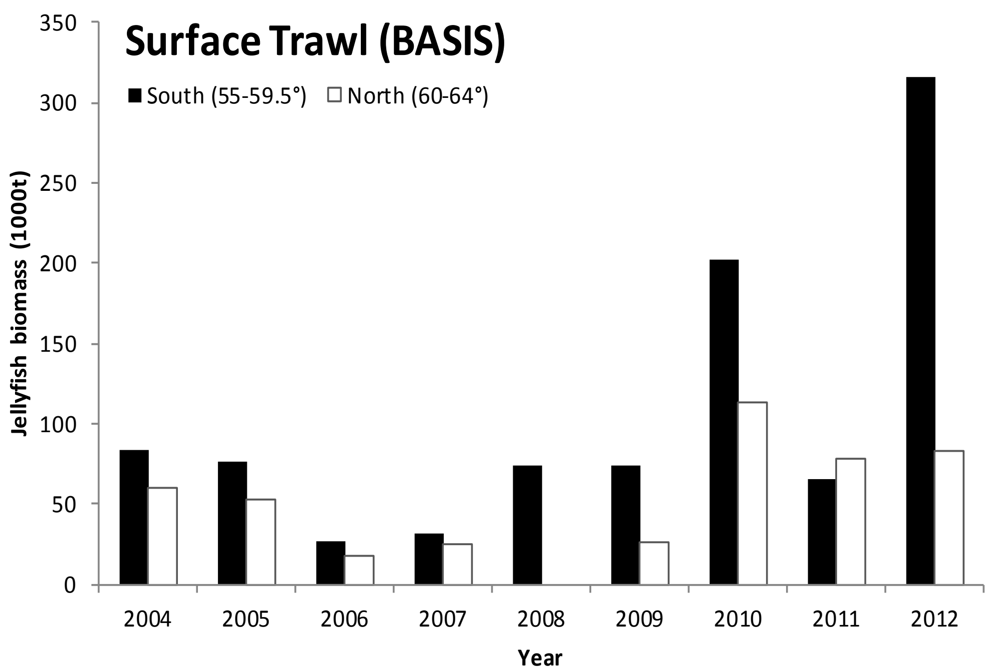


Figure 46: Total jellyfish biomass (1000 t) by year. Includes combined species caught in surface trawls in the Eastern Bering Sea during August-October. Biomass was calculated using average effort per survey area in km^2 by year.

Factors causing observed trends: The cause for these shifts in biomass and distribution do not seem to rely solely on physical ocean factors (temperature and salinity). These shifts could also be a result of environmental forcing earlier in the growing season or during an earlier life history stage

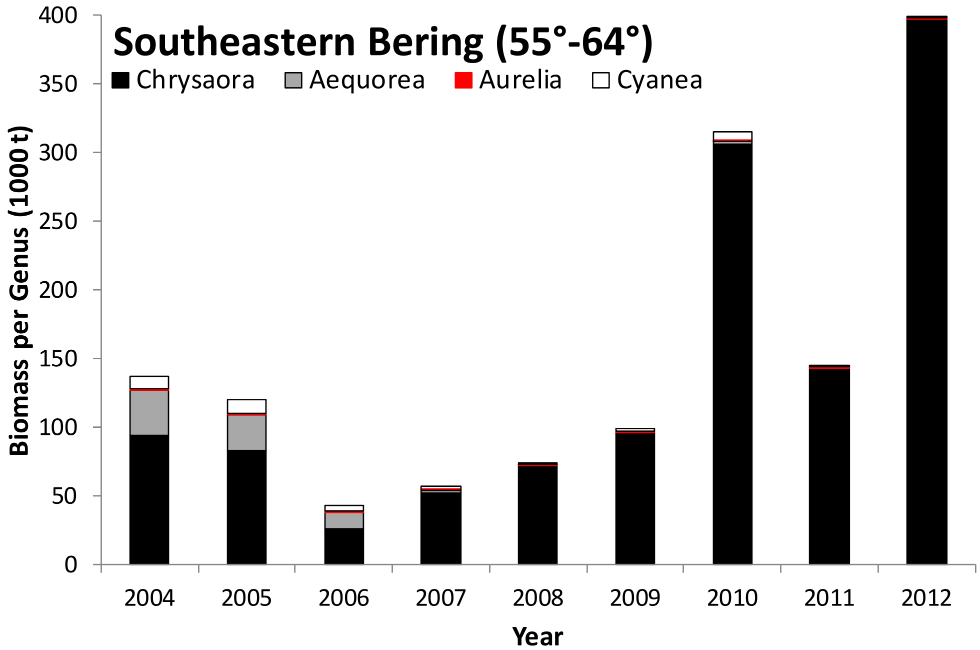


Figure 47: BASIS surface trawl Biomass (1000t) by genus for 2004-2011 in the Eastern Bering Sea during August -October. Biomass was calculated using average effort per survey area in km^2 by year.

(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).

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

Contributed by Molly Sturdevant, Emily Fergusson, and Joe Orsi, Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: molly.sturdevant@noaa.gov
Last updated: August 2013

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 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 longterm trends for monthly temperature and zooplankton 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 (≥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 (≤200 m depth) (Orsi et al., 2004; Park et al., 2004). Temperature and zooplankton anomalies were computed as deviations from the longterm 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: Monthly mean temperatures ranged from approximately 7 °C to 10 °C and anomalies did not exceed ±1.4 °C (Figure 48, top). The ISTI was significantly correlated with the MEI (Figure 48, bottom), with 9 years warmer and 7 years colder than average (9.3 °C). 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 48, top), whereas moderately warm or cold years had unique months of temperature reversal. For example, the warm years of 2001, 2004, and 2010, were actually colder than average in May, June, and July, respectively.

Long-term mean zooplankton density peaked in May and June at ~1,700 organisms per m^3, and declined ~50% by August (Table 1). Density anomalies were mostly negative from 1997-2005, positive in 2006-2009, and negative in 2010-2012 (Figure 49). Total density showed little correspondence with annual temperature trends, with both positive and negative monthly anomalies in both warm and cold years (Figure 49).

Zooplankton was numerically dominated by calanoid copepods, including small species (≤2.5 mm length; ≤74% composition; primarily *Pseudocalanus* spp.) and large species (>2.5 mm; ≤34% composition; primarily *Metridia* spp.) (Table 5). Five other taxa important in fish diets (Sturdevant et al. 2012; Fergusson et al. 2013) contributed small percentages. Small and large calanoids typically had inverse monthly composition anomalies that indicated different seasonality and temperature response (Figure 49). However, these anomalies varied from year to year, suggesting different innate timing cues. For example, both 2005 and 2010 were warm years, but positive temperature anomalies were sustained in 2005 (when both large and small calanoid trends reversed abruptly in July), compared to 2010 (when synchronous negative anomalies were sustained). In some years, high percentages of euphausiid larvae (2000, 2002, 2010), larvaceans (2010), or pteropods (2012) contributed to monthly composition anomalies (Figure 49). 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 relationships (Sturdevant et al., 2012, 2013; Fergusson et al., 2013). Although subarctic zooplankton

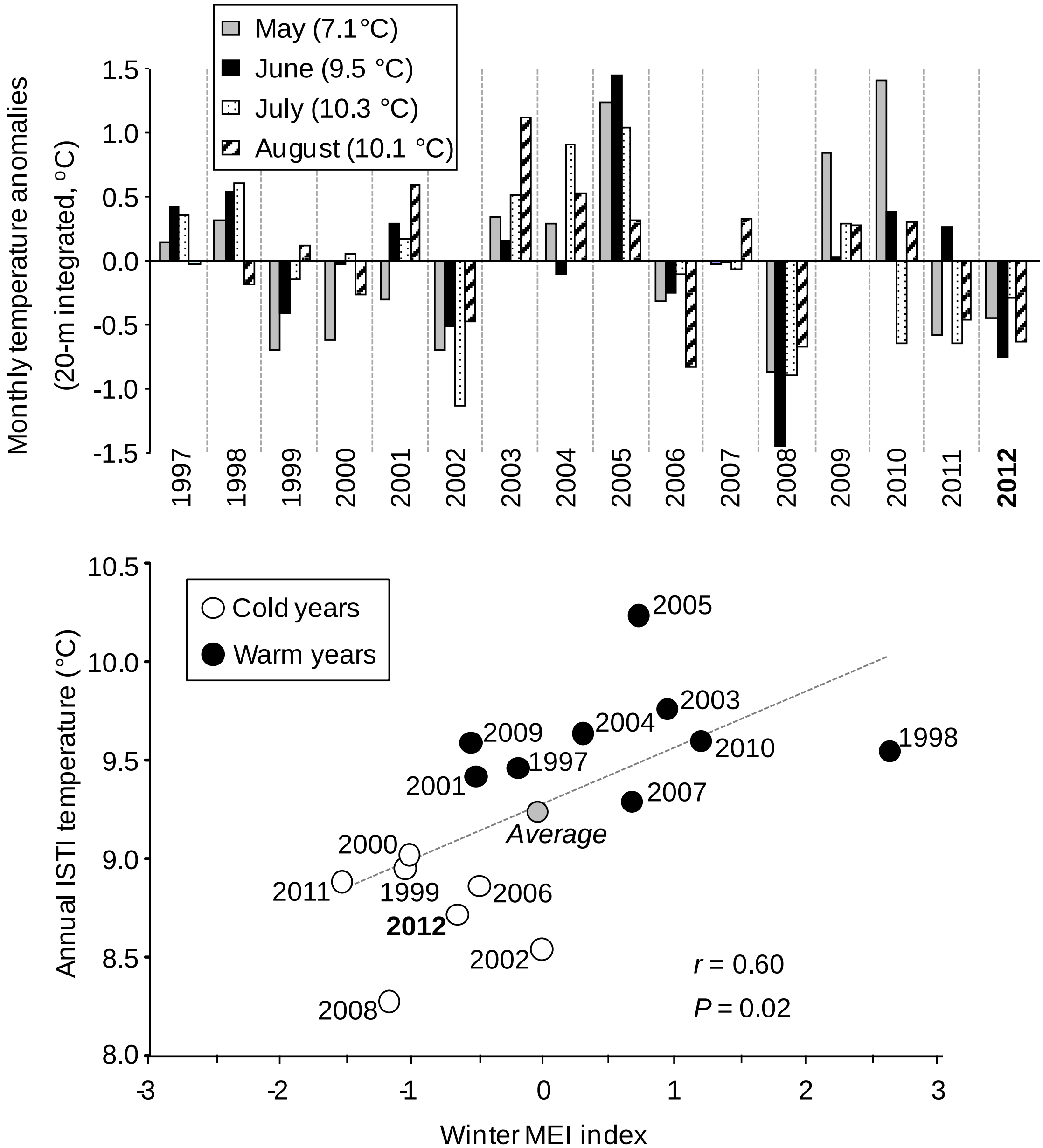


Figure 48: Marine climate relationships for the northern region of Southeast Alaska from the SECM 16-year time series, 1997-2012. Upper panel: mean monthly temperatures (°C, 20-m integrated water column) in Icy Strait; lower panel: correlation of mean annual temperature (°C, 20-m integrated water column) with the Multivariate ENSO Index (MEI), showing warm-versus-cold years. Long-term mean temperatures are indicated in the key.

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

Table 5: Zooplankton long-term mean total density (numbers^{-3}) and taxonomic percent composition in Icy Strait, Southeast Alaska, 1997-2012. 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 Figure 49 anomalies.

	Total organisms	% Large calanoids	% Small calanoids	% Euphausiid larvae	% Larvaceans	% Pteropods	% Amphipods	% Decapod larvae	% Other
May	1661	34	48	5	6	<1	<1	<1	6
June	1691	25	57	6	4	2	<1	<1	4
July	1219	15	74	1	3	<1	3	<1	4
August	886	15	71	1	2	4	3	<1	4

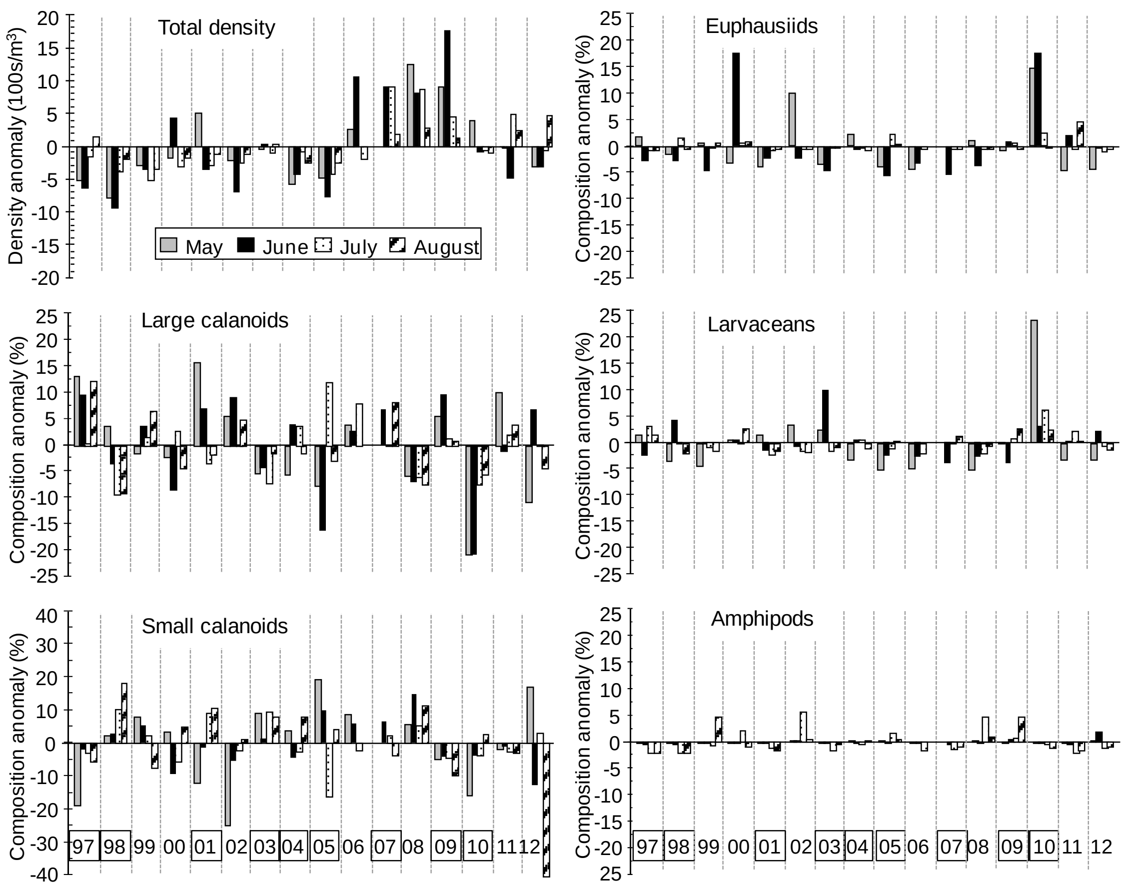


Figure 49: Zooplankton density and composition anomalies for the SECM 16-yr time series from Icy Strait, Southeast Alaska, 1997-20121. Long-term monthly means are indicated by the 0-line (values given in Table 5). Data (shaded bars) are deviations for total density (number/m^3; top left panel), and percent numerical composition of taxa important in fish diets. No samples were available for August 2006 or May 2007. Warm years are indicated in boxes on the x-axis; see Figure 48.

taxonomic scales.

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 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

Contributed by Sonia Batten, Sir Alister Hardy Foundation for Ocean Science
Contact: soba@sahfos.ac.uk
Last updated: July 2013

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 previous reports we have focussed only on zooplankton indices, however, larger hard shelled phytoplankton are also sampled by the CPR. Whilst undoubtedly under-sampling much of the phytoplankton community, the CPR is considered to be an internally consistent sampler and a time series of phytoplankton indices should, therefore, be informative. In this report we include large diatom anomalies for three regions (Figure 50). We also update zooplankton indicators for these same regions: mesozooplankton biomass 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 (Log10). The mean anomaly of all sampled months in each year was calculated to give an annual anomaly (Figure 51).

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 (Fig 1). 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.

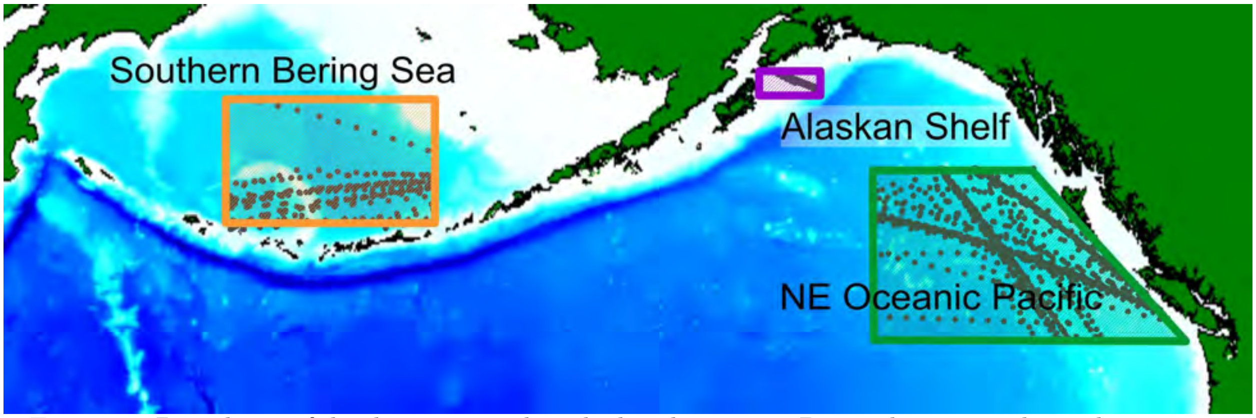


Figure 50: Boundaries of the three regions described in this report. Dots indicate actual sample positions (note that for the Alaskan Shelf region the multiple transects overlay each other almost entirely).

Status and trends: Lower trophic level productivity apparently increased in 2012 in the NE Pacific and Alaskan Shelf, in contrast to 2011 which saw the lowest levels of diatom and mesozooplankton biomass in many of the regions (not shown) sampled by the CPR. In fact, in the NE Pacific, mesozooplankton biomass had the most positive anomaly of the time series in 2012. Values for the southern Bering Sea were low in 2012, however. Copepod community size showed positive anomalies in all 3 regions, indicative of cool conditions where subarctic species predominate; all three regions had below average sea surface temperatures through spring and summer 2012.

Factors influencing observed trends: Changes in ocean climate can affect each of these indicators. There is a strong correlation between large diatom abundance and mesozooplankton abundance on the Alaskan shelf (where large diatoms are a larger component of the phytoplankton), less of a relationship in the NE Pacific and no relationship in the southern Bering Sea, where the diatoms retained by the CPR are likely a much smaller component of the phytoplankton community. Cool conditions are generally favourable for the larger subarctic copepod species which have high individual biomass.

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.

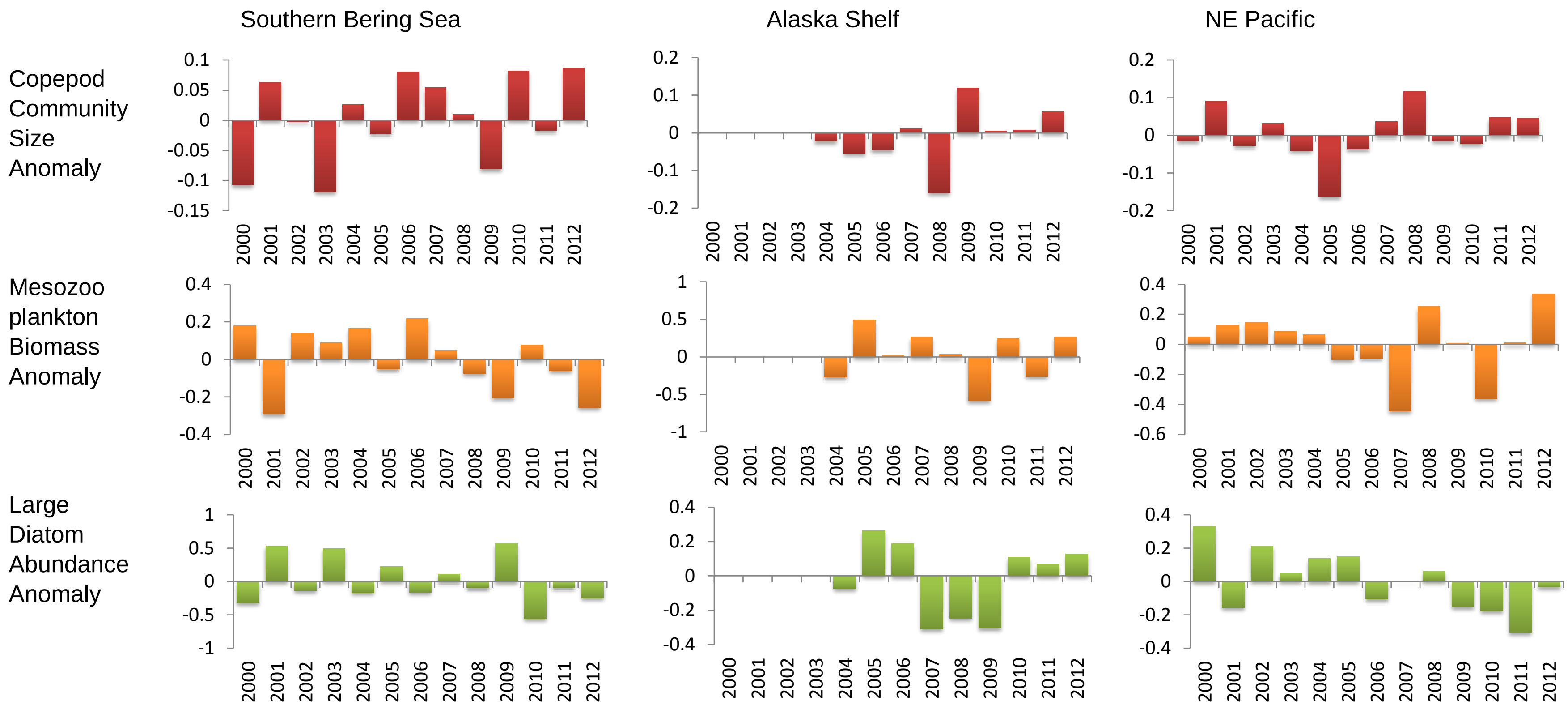


Figure 51: Annual anomalies of three indices of lower trophic levels (see text for description and derivation) for each region shown in Figure 1. Note that sampling of this Alaskan Shelf region did not begin until 2004.

Forage Fish

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

Contributed by Ron Heintz, Ed Farley, and Elizabeth Siddon, Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: ron.heintz@noaa.gov
Last updated: August 2013

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

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

Previously we have related AEC to the number of age-1 recruits per spawner using the index of adult female spawning biomass as an index to the number of spawners. This year we are able to introduce a comparison between AEC and the biomass of age-3 recruits per spawner because we have enough observations of energy density. We anticipate that estimates of the number of age-3 pollock in the eastern Bering Sea is a more stable estimate of recruitment in the stock assessment.

Status and trends: Energy density (kJ/g) and mass (g) of YOY pollock have been measured annually since 2003. Over that period energy density has varied with the thermal regime in the Bering Sea. Between 2003 and 2005 the southeastern Bering Sea experienced warm conditions characterized by an early ice retreat. Ice retreated much later in the years following 2006 and 2006 was intermediate. The transition between the warm and cool periods is clearly observed in plot relating energy density to collection year (Figure 52). Plotting energy density for each year reveals this transition; energy density increases from values near 3.6 kJ/g in 2003-2005 to values near 5.0 kJ/g in 2008-2012. In contrast, the size of the fish has been less influenced by thermal regime. In the warm years mass averaged 2.0 g compared with 2.3 g in the cold years.

Contrasting the AEC of YOY pollock with year class strength in the age-structured stock assessment suggests the condition of pollock prior to their first winter predicts their survival. The AEC of YOY pollock between 2003 and 2012 accounted for 83% of the variation in the number of age-1 recruits per spawner (Figure 53). Similarly, the AEC of YOY pollock accounted for 73% of the variation in the biomass of age-3 recruits starting in 2006. In 2012 the AEC of YOY pollock was low (6.52 kJ/fish) suggesting the number of age-1 recruits per spawner should below the overall median level in 2013 and the biomass of age-3 recruits should be less than median in 2015.

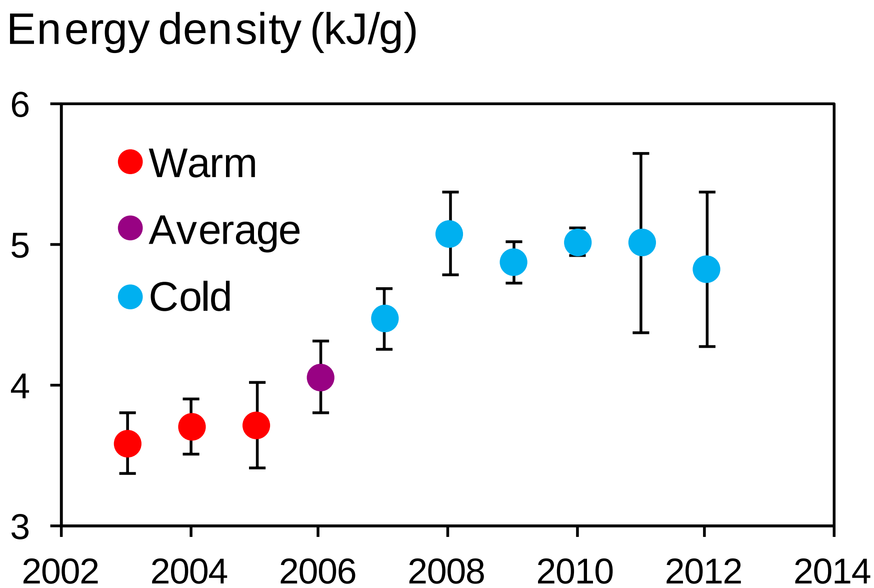


Figure 52: Annual changes in the average energy density of age-0 pollock sampled by surface trawl during BASIS surveys

Factors influencing observed trends: Pollock are susceptible to size dependent mortality during their first winter (Heintz et al., 2010). This effect can be particularly important in determining recruitment. For example, size dependent mortality during winter among salmon can be proportionally as high as mortality during the first 40 days at sea (Farley et al., 2007). Thus the critical size hypothesis posits a positive effect of size on winter survival. While size may be a good predictor within a year, BASIS data indicate a weak relationship between size and recruitment among years. Similarly, high energy density does not necessarily predict high survival among years because energy density is mass normalized and does not convey information about size. AEC of individual YOY pollock integrates information about size and energy density into a single index.

YOY pollock have a relatively narrow window within which they can provision themselves prior to winter. Larval pollock allocate the majority of their ingested energy into developmental processes leaving little energy for somatic growth or sequestration of energy stores. They can only invest energy in growth and storage after they have successfully transitioned into fully developed juveniles (Siddon et al., 2013). Their success at exploiting this window likely depends on water temperatures, prey quality and foraging costs. Cold years appear to be associated with greater densities of euphausiids, medium and large copepods in the middle domain (Hunt et al., 2011). These species are higher in lipid affording pollock a higher energy diet than that consumed in warm years. In addition the lower temperatures optimize their ability to store lipid (Kooka et al., 2007). While cold conditions in the Bering Sea are associated with improved nutritional status of YOY pollock prior to winter, **2012 demonstrates conditions can be too cold to support good survival**. In May of 2012 ice cover still reached as far south as the Alaska peninsula suggesting summer temperatures were very low when larvae were developing. Consequently, YOY pollock sampled on the BASIS survey were the smallest in the 10 year time series.

Implications: The current data indicate that recruitment to age-1 for the 2012 year class should be relatively weak. A return to warmer conditions than experienced in 2012 should improve re-

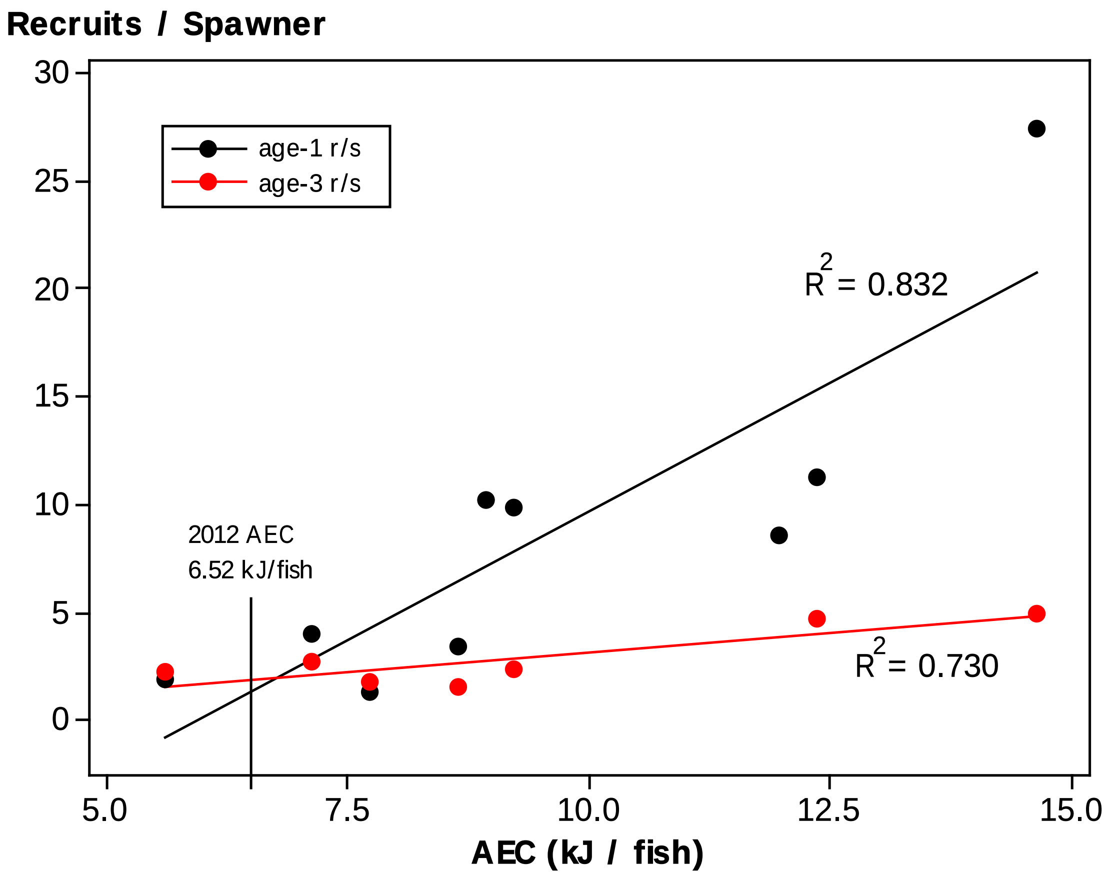


Figure 53: Relationship between average energy content (AEC) of individual age-0 pollock and the number of recruits per spawner as shown in the 2012 stock assessment (Ianelli et al., 2012). Recruits are measured as the number of age-1 pollock or the biomass of age-3 recruits.

cruitment of the 2013 year class.

Forage Fish CPUE - Bering Aleutian Salmon International Survey - BASIS

Contributed by Ed Farley and Wes Strasburger, Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: ed.farley@noaa.gov
Last updated: October 2012

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

Gulf of Alaska Small Mesh Trawl Survey Trends

Contributed by Dan Urban, Kodiak Laboratory, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA

Contact: dan.urban@noaa.gov
Last updated: September 2013

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 = 13,371 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 2012 (n = 148 hauls) in the bays on the northeast side of Kodiak Island, the Shelikof Strait and in bays along the south side Alaska Peninsula including Pavlof Bay on of the 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) *Theragra 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: Forage species catch rates remain at low levels, well below the peak values observed in the 1970s and early 1980s (Figure 54) (Anderson and Piatt, 1999). Historically, the average catch of pink shrimp for the period 1970 to 1985 exceeded 145 kg km^{-1} but over the last 10 years, the average catch has declined to 18 kg km^{-1}. The decline continued in 2012 with an average catch of 2.69 kg km^{-1}. Juvenile pollock showed a similar pattern over the last ten years period, declining from an average of 6.9 kg km^{-1} to 1.8 kg km^{-1}. Eulachon had been an exception to this pattern with the highest catch rates of the time series being observed from 2001-2010 but eulachon catches decreased in 2011 to a rate below the long-term average and was also low in the 2012 survey. Pink shrimp and juvenile pollock remain widespread but catch rates varied widely both between bays and within bays. The highest catches of pink shrimp were found in the central Shelikof Strait (7.09 $\pm$ 4.33 kg km^{-1}) and inner Marmot Bay (6.50 $\pm$ 5.46 kg km^{-1}) but half of the areas surveyed captured less than 2 kg km^{-1}. Highest catches of juvenile pollock were found in Marmot Bay but catches overall were generally low at 0.13 $\pm$ 0.03 kg km^{-1}.

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).

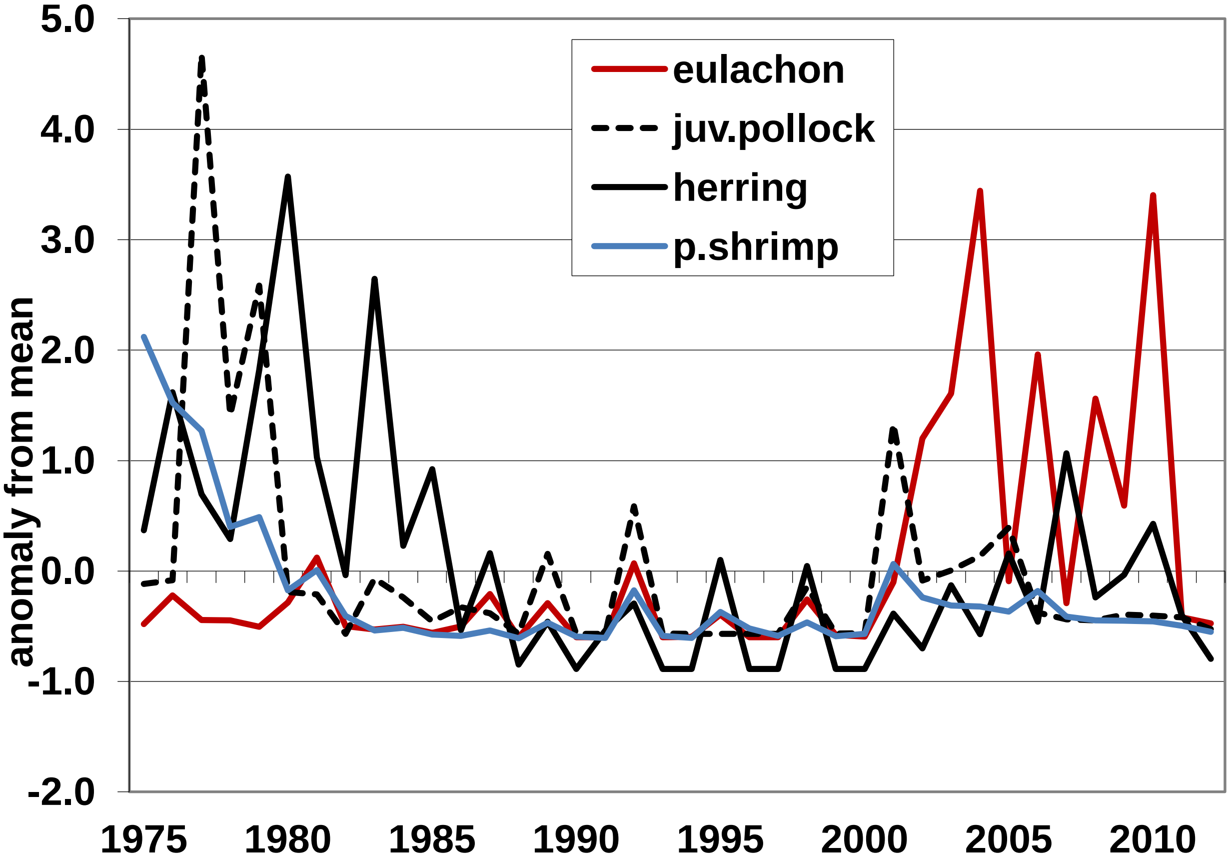


Figure 54: Anomalies from the long-term mean of forage species CPUE (kg km^{-1}) in the Gulf of Alaska, 1972-2012.

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

Contributed by Jamal H. Moss, Wyatt Fournier, and Stacy K. Shotwell, Auke Bay Laboratories, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 17109 Pt. Lena Loop Rd., Juneau, Alaska
Contact: jamal.moss@noaa.gov
Last updated: August 2012

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

Herring

Togiak Herring Population Trends

Contributed by Greg Buck, Alaska Department of Fish and Game
Contact: gregory.buck@alaska.gov

Last updated: October 2013

Description of index: The biomass of Pacific herring occurring in the Togiak District of Bristol Bay has been tracked through aerial surveys since the late 1970s using methods described by Lebida and Whitmore (1985). An age-structured analysis (ASA) model is used to forecast biomass (Funk et al., 1992; Zheng et al., 1993). This model uses age composition information collected from the fishery. While we don't believe that herring are fully recruited into the fishery until around age-8, the model takes this into account and provides an estimate of all age classes back through age-4 (Figure 55). While we believe that this estimate of age-4 abundance is a reasonably valid picture of recruitment trends in this population, we also believe that the model has a tendency to over hindcast recruitment in the early 1980s due to factors that include limited data from that period.

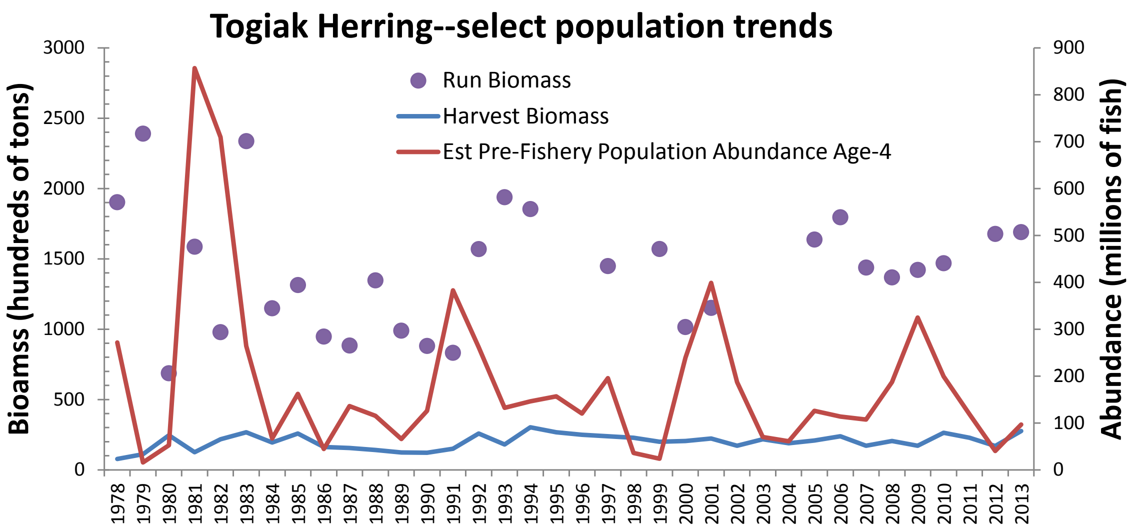


Figure 55: Observed total run and harvest biomass (hundreds of tons) with estimated abundance of age 4+ herring (millions of fish), for Pacific herring in Togiak District of Bristol Bay, Alaska 1978 - 2013.

Status and trends: The largest biomass observed in Togiak District of Bristol Bay occurred in 1979 when 239,022 tons was estimated while the smallest occurred in 1980 with 68,686 tons (Figure 55). In 2013 we observed 169,020 tons which is 113% of the most recent 10-year average and 115% of the 20-year average (Buck, In prep).

An active sac roe fishery is conducted on this population, primarily with gillnet and purse seine gear. A small spawn on kelp quota is allowed but has not been utilized in recent years. The sac roe fishery harvested 27,610 tons in 2013 which is 134% of the 10-year average and 128% of the 20-year average (Buck, In prep).

Factors causing observed trends: Pacific herring recruitment is both highly variable and cyclic with large recruitment events occurring roughly every 8 to 10 years in this population. Fish from the most recent large recruitment event began to show up in the commercial harvest around 2009 at age-4. Williams and Quinn (2000) demonstrate that Pacific herring populations in the North Pacific are closely linked to environmental conditions particularly water temperature. We believe that closer examination of environmental conditions such as sea surface temperature, air temperature, and Bering Sea ice cover specific to the Bristol Bay area may increase our understanding of the recruitment process at play in this population.

Implications: Herring are an important forage fish for piscivorous fish, seabirds, and marine mammals as well as the basis for a roe fishery. The cyclic nature of recruitment into this population has implications for predators and prey of Pacific herring as well as the fishery. We consider this population healthy and sustainable at current harvest levels.

Prince William Sound Pacific Herring

Contributed by Steve Moffitt, Alaska Department of Fish and Game
Contact: steve_moffitt@fishgame.state.ak.us
Last updated: October 2008

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

Southeastern Alaska Herring

Contributed by Kyle Hebert and Sherri Dressel, Alaska Department of Fish and Game, Commerical Fisheries Division, P. O. Box 110024, Juneau, AK 99811-0024
Contact: kyle.hebert@alaska.gov
Last updated: October 2012

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 56, 57). Over the period 1980 through 2012, several stocks have undergone at least moderate increasing trends, with four of the nine primary, surveyed locations (Sitka Sound, Hoonah Sound, Seymour Canal, and Craig) exhibiting a pronounced trend of increasing biomass, and one area (Kah Shakes/Cat Island) exhibiting a pronounced downward trend. Although the estimated total mature herring biomass in southeastern Alaska has been above the long-term (1980-2012) median of 89,709 tons since 1998, and continues to be in 2012, an apparent decrease in biomass has been observed between 2011 and 2012 (Figure 58). Notable drops in biomass were observed for some spawning areas in particular, including Hoonah Sound and Sitka Sound. Although the observed drop in biomass appears to be substantial, it is too early to conclude from a single year whether this represents the beginning of period of decline, or natural volatility of the population. 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 55%) 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 at or above the 25-year median of 41,010 tons in every year since 1998, except for 2000 (Figure 58).

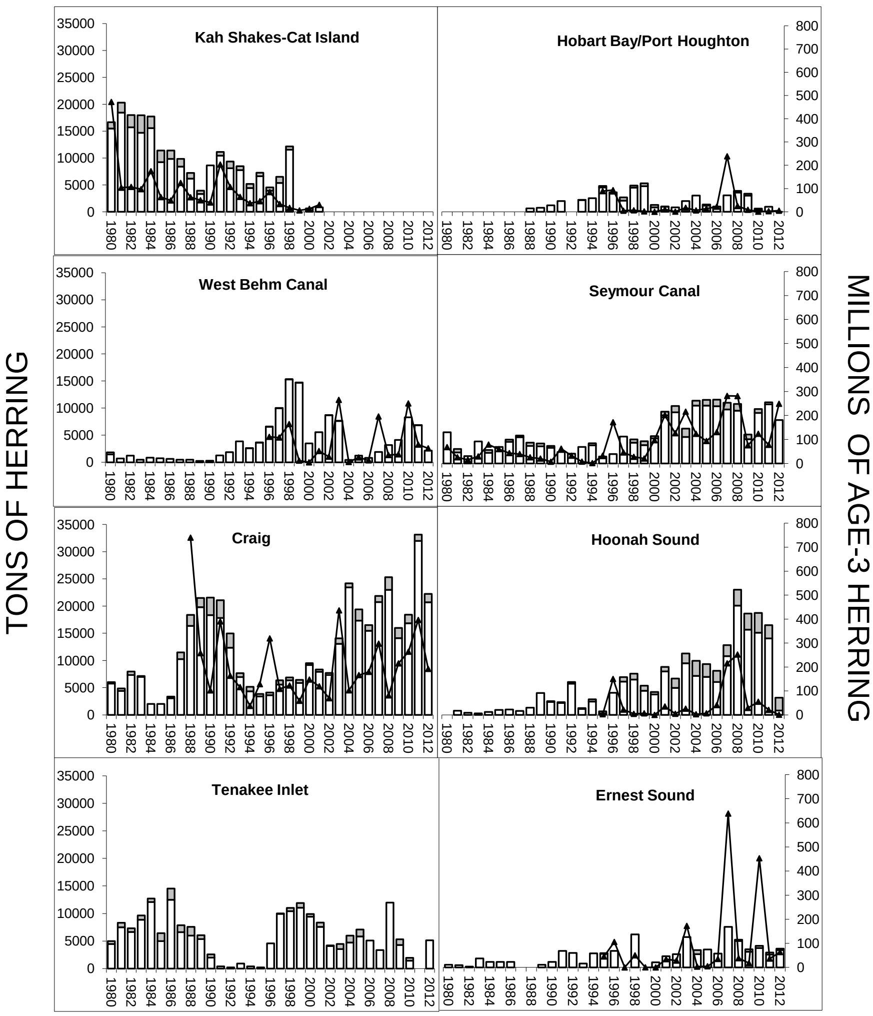


Figure 56: Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 abundance (black line) at eight major spawning locations in southeastern Alaska, 1980-2012. Estimates of age-3 abundance for Tenakee Inlet were unavailable by time of publication.

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 56, 57). 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; and for West Behm Canal, Ernest Sound, Hobart Bay-Port Houghton, and Hoonah Sound for most years since 1995. Estimates of age-3 herring abundance for Tenakee Inlet are not available at this time. 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

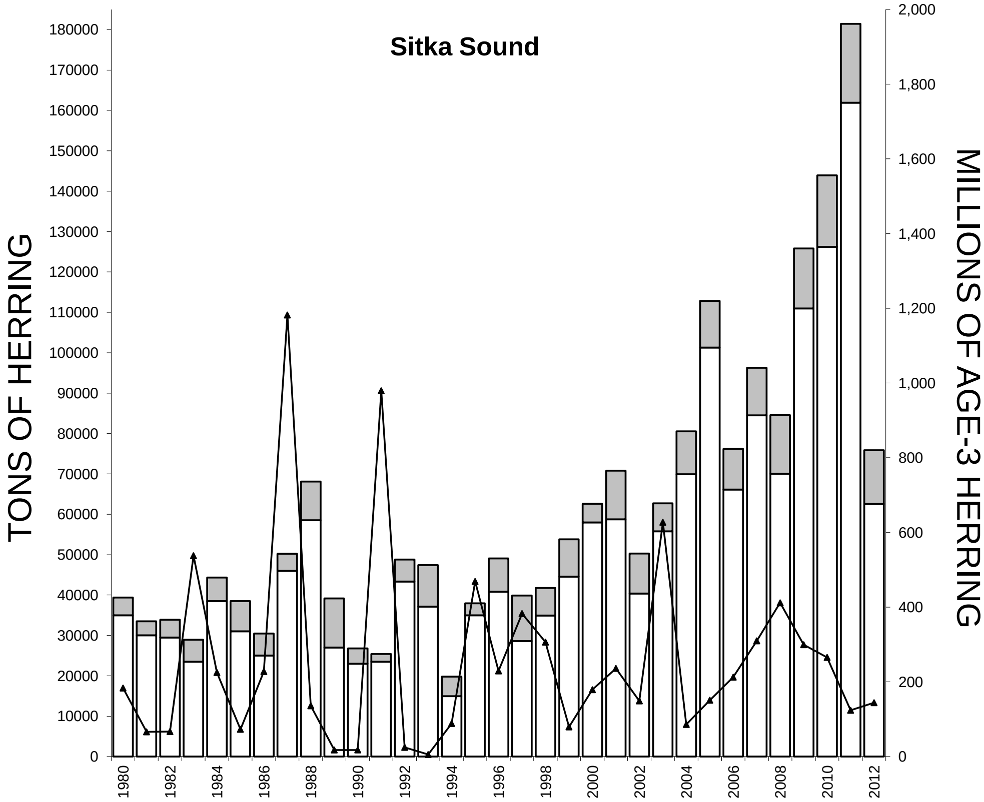


Figure 57: Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 abundance (black line) at Sitka Sound spawning location in southeastern Alaska, 1980-2012.

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 2011 (Figure 57).

Factors influencing observed trends: The generally increasing long-term trends of biomass observed for many herring stocks in southeastern Alaska, particularly over the past decade, are thought to be at least partially a result of higher survival rates among adult age classes. Age-structure analysis 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, for the period 1980-1998, survival has been estimated to be 58%, while for the period 1999-2012 survival is estimated at 77%. Similar shifts in survival have been estimated for the Craig and Seymour Canal stocks. These shifts in survival coincide with time periods of change in ocean conditions, as indexed by the Pacific Decadal Oscillation (PDO).

There has been some speculation and debate about the extent to which commercial harvests may have contributed to marked declines in estimated abundance and/or localized changes in herring spawning sites in a few areas in southeastern Alaska, notably Revillagigedo Channel (Kah Shakes/Cat Island) and Lynn Canal. In the Revillagigedo Channel area, significant spawning and a fishery occur at Annette Island, a site outside the management jurisdiction of the State and from which limited data are gathered by the department. Although spawning activity at the Kah Shakes and Cat Island sites in Revillagigedo Channel has declined in recent years, this decline may be at

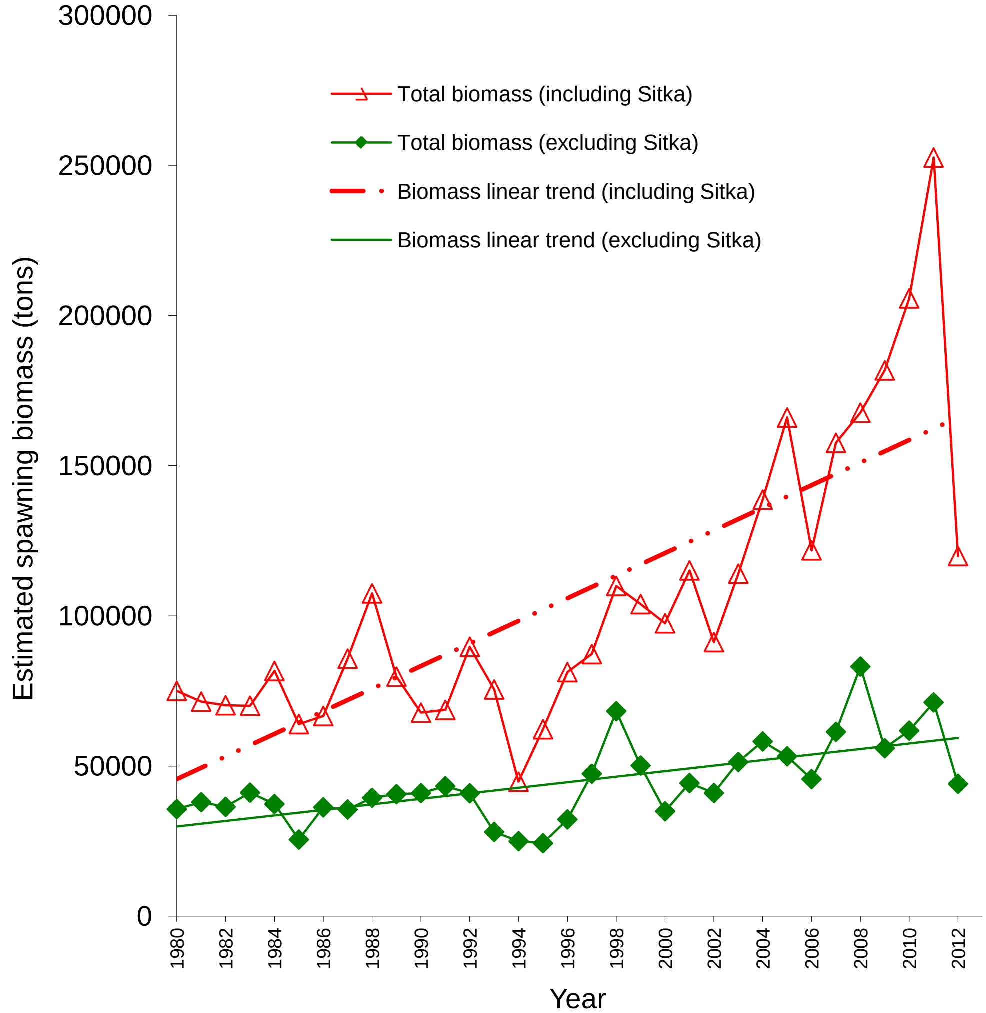


Figure 58: Estimated combined annual mature herring biomass (including and excluding Sitka) at major southeastern Alaska spawning areas, 1980-2012.

least partially attributable to a shift of herring to spawning grounds within the Annette Island Reserve, bordering Revillagigedo Channel. In the Lynn Canal spawning area surveys of spawning biomass have not been conducted regularly. Reasons for the biomass decline in the area are unknown but possibilities include 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 forecast 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.

Salmon

Historical and Current Alaska Salmon Trends

Contributed by Andy Whitehouse[1] and Todd TenBrink[2]
[1]Joint Institute for the Study of the Atmosphere and Ocean (JISAO), University of Washington, Seattle WA [2]Resource Ecology and Fishery Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: andy.whitehouse@noaa.gov
Last updated: August 2013

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., Eggers et al. (2013)).

Pacific salmon in Alaska are managed in four regions based on freshwater drainage basins, Southeast/Yakutat, Central (encompassing Prince William Sound, Cook Inlet, and Bristol Bay), Arctic-Yukon-Kuskokwim, and Westward (Kodiak, Chignik, and Alaska peninsula (`http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmonareas`). ADF&G prepares 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 59) but in total have been generally strong. According to ADF&G, total salmon commercial harvests from 2012 totaled 127.1 million fish, approximately 5 million less than the preseason forecast of 132.1 million. The 2012 total salmon harvest is about 50 million less than the 2011 total harvest of 177.1 million. ADF&G is forecasting an increase in the total commercial salmon catch to 178.8 million fish in 2013, due to an expected increase in the number of pink salmon. Projections for 2014 will not be available until February 2014.

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 during the 2012 summer season in the Yukon Area. In the Kuskokwim Area, Chinook salmon abundance was poor and only 2 of 9 escapement goals were met. In Bristol Bay, the 2012 Chinook salmon harvest was below average in every district, and overall was approximately 75% below the average for the last 20 years.

The 2012 catch of coho salmon in Bristol Bay was 26% above the recent 20 year average, with the majority of the catch in the Nushagak District. Coho salmon harvests were also above average in the Arctic-Yukon-Kuskokwim region. Chum salmon catches in Bristol Bay were 44% below the 20

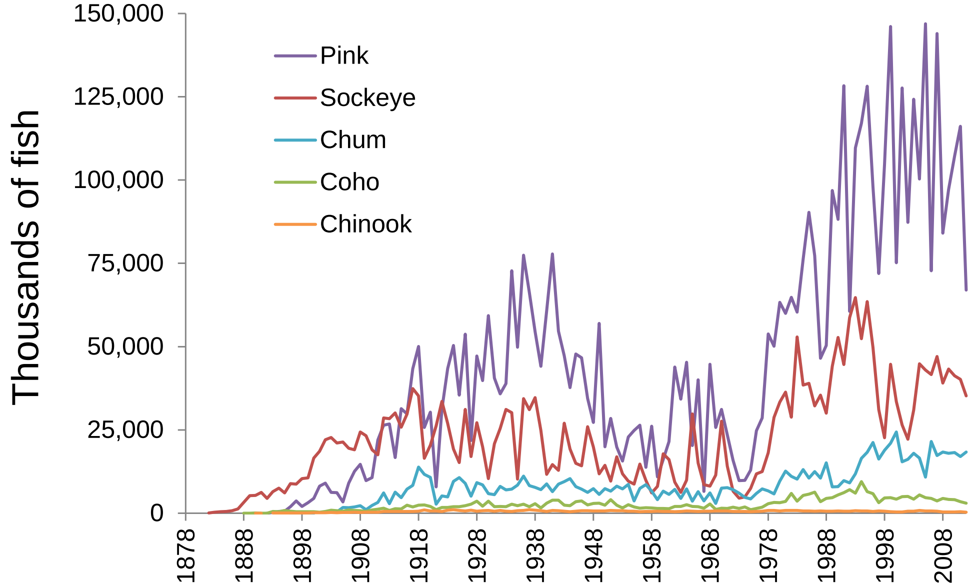


Figure 59: Alaskan historical commercial salmon catches. 2012 values are preliminary. (Source: ADF&G, `http://www.adfg.alaska.gov`. ADF&G not responsible for the reproduction of data.)

year average, while harvests were above average in the Arctic-Yukon-Kuskokwim region.

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. Bay-wide forecasts have been fairly accurate in recent years, although forecasts to individual rivers have been less accurate. Historically, total runs to Bristol Bay have been highly variable, but in recent years, 2004-2010, sockeye salmon runs have been well above the long term mean (Figure 60). The 2011 and 2012 runs of 31.9 and 29.1 million fish respectively, were closer to the long-term historical average (1963-2011) of 32.38 million fish. The run size forecasted for 2013 Bristol Bay sockeye is 26.03 million.

Gulf of Alaska In the Southeast/Yakutat region, 2012 salmon harvests totaled 37.0 million, which was well below the 53.7 million average harvest over the most recent ten years but was near the long-term average (since 1962) of 39.3 million fish. Pink salmon comprised 58% of the total number of salmon harvested. Since 2006 pink salmon returns have followed a cycle of strong odd years and weak even years. The total salmon harvested (pounds) in 2012 was less than 2011 but was comparable to 2010.

In the Prince William Sound Area of the Central region, the total salmon harvest was 35.0 million fish, of which 27.2 million were pink salmon. The purse seine commercial common property fishery harvest of 24.0 million pink salmon was the fourteenth highest since 1971, which included about 13% wild pink salmon. 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

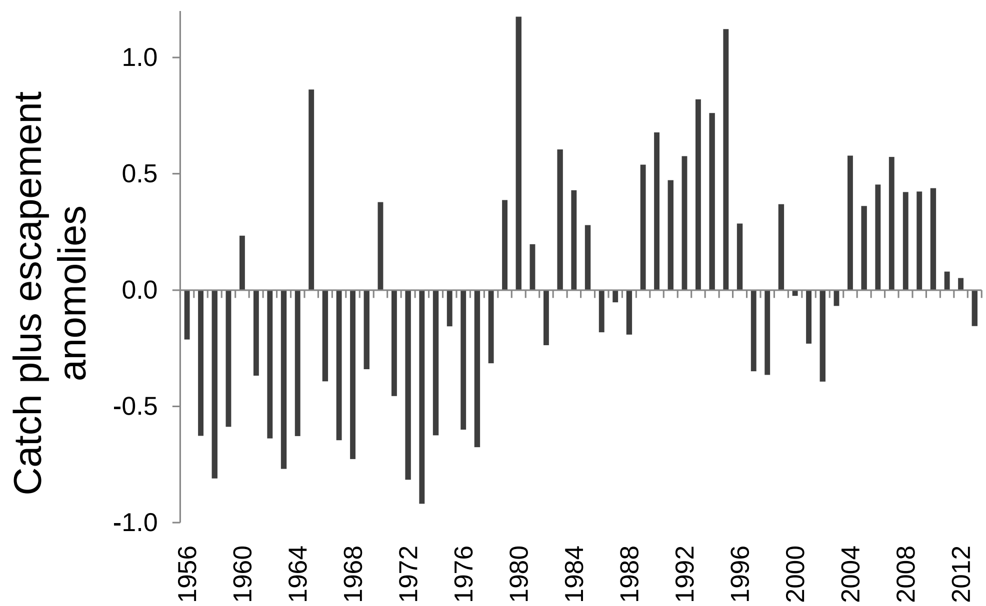


Figure 60: Historical catch plus escapement anomalies of Bristol Bay sockeye salmon, 1956-2013. Data provided by Charles Brazil (ADF&G). Note: the value for 2013 is preliminary and subject to revision.

William Sound hatchery pink salmon does not appear to have shifted after the 1988/89 or the 1998/99 climate regime shifts (Figure 61). Marine survival of 11.17% in 2010 (2008 brood year) was an all-time high since 1977 but dropped to 4.34% in 2011 (Botz et al. 2013).

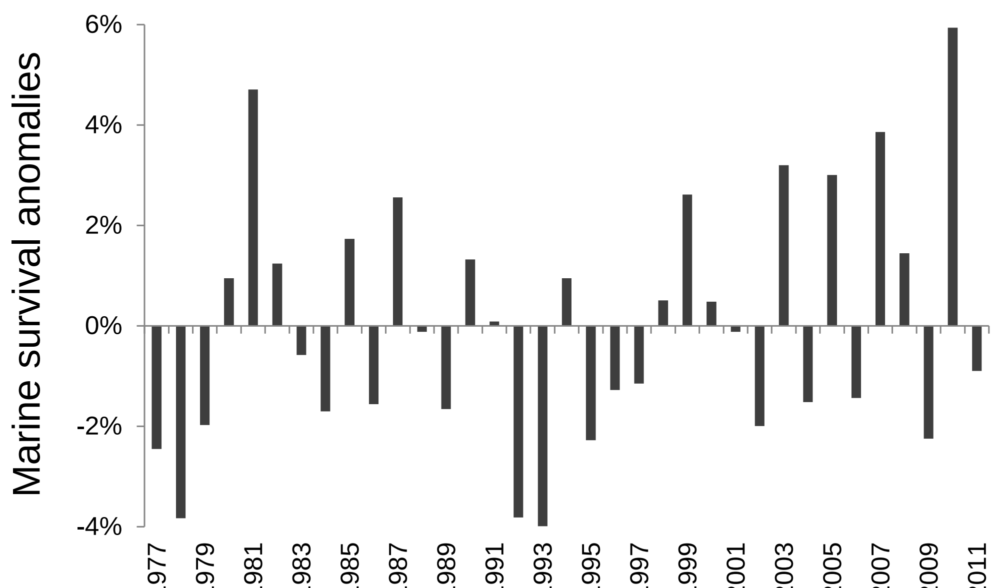


Figure 61: Marine survival of Prince William Sound hatchery pink salmon by year of return (brood year +2 years). Data reproduced from Botz et al.(2013).

In the Southeast/Yakutat region, the harvest of 282,000 Chinook salmon was near the long-term average harvest of 300,000 fish, but well below the recent 10-year average harvest of 359,000. Similarly, the harvest of 2.1 million coho salmon was equivalent to the long-term average but below the recent 10-year average of 2.6 million fish. In contrast, the commercial harvest of 12.4 million chum salmon in the Southeast/Yakutat region was above the recent 10-year average harvest (9.8 million) and well above the long-term average harvest (5.4 million).

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 or Nushagak district of Bristol Bay in 2012 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 climate conditions, for example, so more diverse sets of populations provide greater overall stability (Schindler et al., 2010).

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

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

Implications: Directed salmon fisheries are economically important for the state of Alaska. 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. The trend in total salmon catch in recent decades has been for generally strong harvests, despite annual fluctuations. A continued strong presence of salmon will maintain their influence on marine food webs.

Forecasting Pink Salmon Harvest in Southeast Alaska

Contributed by Joe Orsi, Emily Fergusson, Molly Sturdevant, and Alex Wertheimer
Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: joe.orsi@noaa.gov
Last updated: July 2013

Description of index: An objective of the Alaska Fisheries Science Center (AFSC), Auke Bay Laboratories (ABL) Southeast Alaska Coastal Monitoring (SECM) project `http://www.afsc.noaa.gov/abl/msi/msi_secm.htm` is to understand the effects of climate and ocean on year class strength of salmon and ecologically-related species in Southeast Alaska (SEAK). Since 1997, the SECM project has collected a time series of data using surface trawls and oceanographic instruments in coastal SEAK which has allowed an annual index of ecosystem metrics to be constructed and used for pre-season pink salmon (*Oncorhynchus gorbuscha*) forecast models. Pink salmon are an ecologically and economically important species in SEAK ($92.5 M in 2011) that do not lend themselves to traditional sibling or stock assessment models because of their brief ocean life history. Adult returns are notoriously difficult to forecast because their brief two-year life history includes only one ocean winter and therefore precludes the use of younger returning ocean age classes to predict cohort abundance. Thus, an SECM pink salmon pre-season forecast model was developed beginning in 2004 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 Gulf of Alaska (GOA) large marine ecosystem.

Status and trends: Since 1960 pink salmon year-class success has varied widely, with harvests ranging from 3 to 78 million fish annually in SEAK. This variability may result from dynamic ocean conditions or ecological interactions that affect juvenile salmon. Additionally, pink salmon production in SEAK is predominately derived from mostly (>95%) wild stocks of varied run timings that originate from >2,000 anadromous streams throughout the region. Therefore, the SECM approach has been to sample 4-65 km in the vicinity of Icy Strait on monthly research surveys. This sampling locality integrates an amalgam of SEAK stocks since it is the principal northward migration corridor in SEAK. Oceanographic sampling is conducted in May, June, July, and August, while surface trawling for epipelagic fish species is conducted in the latter three months as juvenile salmon are actively migrating. The SECM data has also been used to describe epipelagic fish assemblages in the Alaska Coastal Current compared to the California Current (Orsi et al., 2007), to define Essential Fish Habitat for Pacific salmon in the U.S. Exclusive Economic Zone of Alaska (Echave et al., 2012), and to document life history patterns of threatened and endangered salmon stocks off SEAK (Trudel et al., 2009). For the pink salmon forecasting, SECM data is used with other regional and basin-scale data sources to construct an ecosystem matrix of input and response variables.

Researchers from the SECM project have provided forecasting information 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 nine 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 62). 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.

Factors influencing observed trends: Selected ecosystem metrics associated with SEAK adult pink harvest over the 16-year SECM time series are shown in Figure 63 below. Note that in addition to CPUE, four other variables are significantly correlated with harvest (Peak migration month, NPI, %pink in June-July trawl hauls, and the ADFG Escapement Index) and suggest a strong pink harvest in 2013. Additionally, this matrix shows that anomalously low (red: 2000, 2006, 2008, 2012) or high (green: 1999, 2001, 2005, 2011) return years always flag 3-5 ecosystem indicators of the respective color signal in each row. For the 2013 forecast, however, no "red" ecosystem indicators were flagged. The Icy Strait temperature index (ISTI) shown in the last

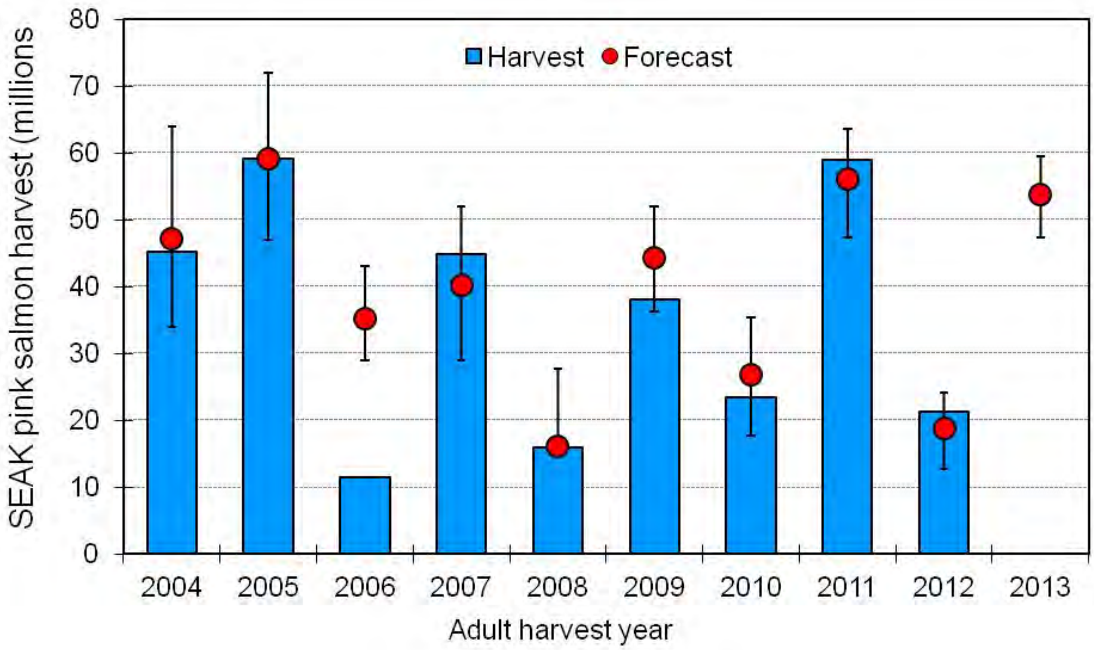


Figure 62: Previous SECM pink salmon forecast model predictions (with 80% confidence intervals) and actual SEAK harvests.

column is not significantly correlated with harvest, but is an important secondary parameter to explain the error in the CPUE and harvest regression model. For more details about the SECM pink salmon forecasts, please see: `http://www.afsc.noaa.gov/ABL/MSI/msi_sae_psf.htm`

Implications: Additional evidence from SECM research and other biological or ecosystem indicators suggests a **strong pink salmon harvest in SEAK of 53.8 M fish in 2013**. The strongest indicator for this favorable forecast is the 2012 peak juvenile pink salmon CPUE, which was the 4th highest on record. Other ecosystem indicators in 2012 that were significantly correlated (P ¡ 0.05) with SEAK pink salmon harvest (1998-2012) were: 1) a favorable July month of peak seaward migration; 2) a high North Pacific Index (NPI = 16.7); and 3) a high average percentage of pink salmon (40%) caught among juveniles in June-July trawl hauls. Less favorable ecosystem indicators were a below average ADFG escapement index for the pink salmon parent year (2011) in SEAK and a below average wild fry production in Auke Creek (2012). An additional indicator favoring a good harvest in 2013 was the ocean catch rates of juvenile pink salmon from a research survey downstream from the SECM project, the Gulf of Alaska Integrated Research Project (GOAIRP) conducted offshore of Baranof and Chichagof Islands both west and south of Icy Strait. Compared to the SECM surveys, pink salmon catch data from this project may better represent southern and coastal SEAK pink salmon stocks, and higher juvenile pink catches in 2012 than in 2011 suggest a higher harvest of these stocks in 2013 than in 2012.

Given the ecosystem conditions and SECM metrics sampled in 2012, the two best SECM forecast models for the 2013 SEAK pink salmon harvest are shown below in Table 6. 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 16-year time series of SECM data parameters with subsequent SEAK pink salmon harvests from 1998 to 2012, based on the R^2 and AICc.

Brood year (BY)		BY +1					BY	BY +1	BY +1
Adult pink salmon return year	SE pink harvest (response variable)	Ocean entry year	Juvenile peak pink CPUE June or July	Peak seaward migration month	North Pacific Index (June, July, Aug)	% pink in trawl hauls average June-July	Adult pink escapement index for SEAK	Auke Creek fry outmigration (1,000s) Lat 58° N	Upper 1-20 m avg. Icy Strait temp. "ISTI" May-Aug
	ADFG	$SECM_{year}$	NOAA	NOAA	CGD	NOAA	ADFG	NOAA	NOAA
1998	42.5	1997	2.5	July	15.6	12%	18.1	31.1	9.5
1999	77.8	1998	5.6	June	18.1	57%	14.8	60.8	9.6
2000	20.2	1999	1.6	July	15.8	8%	14.3	53.5	9.0
2001	67.0	2000	3.7	July	16.9	18%	27.3	132.1	9.0
2002	45.3	2001	2.9	July	16.8	19%	10.8	61.5	9.4
2003	52.5	2002	2.8	July	15.6	14%	18.6	150.1	8.6
2004	45.3	2003	3.1	July	16.1	24%	16.6	95.1	9.8
2005	59.1	2004	3.9	June	15.1	29%	20.0	169.6	9.7
2006	11.6	2005	2.0	Aug	15.5	19%	15.7	87.9	10.3
2007	44.8	2006	2.6	June	17.0	30%	19.9	65.9	8.9
2008	15.9	2007	1.2	Aug	15.7	9%	10.2	81.9	9.3
2009	38.0	2008	2.5	Aug	16.1	14%	17.6	117.6	8.3
2010	23.4	2009	2.1	Aug	15.1	22%	9.5	34.8	9.6
2011	58.5	2010	3.7	June	17.6	66%	12.7	121.6	9.6
2012	20.7	2011	1.4	Aug	15.7	21%	11.2	30.9	8.9
2013	53.8?	2012	3.2	July	16.7	40%	14.3	61.8	8.7
Pearson correlation "*r*"			0.93	-0.78	0.65	0.59	0.52	0.46	-0.06
P-value (*= significant @ <0.05)			0.00*	0.00*	0.01*	0.02*	0.05*	0.09	0.84

Figure 63: 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`).

Groundfish

Gulf of Alaska Ichthyoplankton Abundance Indices 1981-20011

Contributed by Miriam Doyle[1] and Kate Mier[2]
[1]Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, WA 98195; based at NOAA Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115
[2] Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: miriam.doyle@noaa.gov
Last updated: August 2013

Table 6: The two best SECM pink salmon forecast models for the 2013 SEAK harvest.

2013 SECM pink salmon forecast models	Adj. R^2	AIC_c	P	Prediction for 2013
(1-parameter) Peak CPUE	84.8%	98.1	<0.001	47.8 M (41.5-51.8)
(2-parameter) Peak CPUE+ISTi$_{\mathbf{20m\ temp}}$	91.2%	92.0	<0.001	**53.8 M (46.2-58.4)**

Description of index: The Alaska Fisheries Science Center's (AFSC) Ichthyoplankton Database (IchBASE) includes data from collections in the Gulf of Alaska (GOA) from 1972 to the present and with annual sampling from 1981 to 2011, and biennial sampling thereafter. Since 1985 these collections have been part of AFSC's recruitment processes research under the Ecosystems and Fisheries Oceanography Coordinated Investigations Program (EcoFOCI). The primary sampling gear used for these collections is a 60 cm bongo sampler fitted with 333 or 505 m mesh nets and oblique tows are carried out mostly from 100 m depth to the surface or from 10 m off bottom in shallower water (Matarese et al., 2003)(Ichthyoplankton Information System `http://access.afsc.noaa.gov/ichthyo/index.cfm`). Historical distribution of sampling effort extends from the coastal area to the east of Prince William Sound southwestwards along the Alaska Peninsula to Umnak Island, covering coastal, shelf and adjacent deep water but has been most intense in the vicinity of Shelikof Strait and Sea Valley during late spring, May 18-June 7 (Figure 64). From this area and time, a subset of four decades of data has been developed into a time-series of ichthyoplankton species abundance (Doyle et al., 2009) and it is now updated through 2011 (Table 7)).

Status and trends: Historical trends in late spring abundance are presented for the most abundant larval taxa in the GOA, representing commercially and ecologically important species (Figure 65). The time-series extends from 1981 through 2011 with no data for 1984 and 1986. Mean abundance values are normalized over the time-series. For all taxa except rockfish (*Sebastes* spp.), the 2010 and 2011 data points represent values that are moderate deviations from the long term means (Figure 65). These are low to moderate negative anomalies in both years with the exception of walleye pollock and southern rock sole which displayed moderately positive anomalies for 2010, and a slightly positive anomaly for flathead sole in 2011. For rockfish larvae, a moderate positive anomaly in 2010 was followed by a very high positive anomaly in 2011. Trends in abundance of these species (1981-2003) have been explored previously and investigated in relation to time-series of atmospheric and oceanographic variables on both the ocean basin and local scales (Doyle et al., 2009). Coherent patterns and synchronicity in trends were observed among groups of species, and with the extension of the time-series through 2009, these similarities and synchronicities were maintained (Doyle and Mier, 2012) and are described in last year's contribution to the Ecosystem Considerations report.

Factors influencing observed trends: Synchronies and similarities in larval abundance trends, and in GAM model-generated links to time-series of environmental variables (1981-2003), reflect early life history variation among species (Doyle et al., 2009). Similarities in response to environmental forcing were apparent among species that display similarities in patterns of early life history exposure to the environment. For instance, the deepwater spawners, northern lampfish, arrowtooth flounder, and Pacific halibut, were most abundant in the study area during the 1990s,

Table 7: Survey schedule and number of stations sampled within the chosen study area (Figure 64) from which the late-spring time-series of larval abundance indices were calculated. Median survey shift = number of days difference (+/-) between a particular year's median sampling survey date and the time-series median survey date (Julian Day 148).

Year	Cruise	Dates	Median survey shift	No. Stations
1981	3SH81	May 23-28	-4	34
	4MF81	May 21-24		59
1982	2DA82	May 23-28	-1	32
1983	1CH83	May 21-28	-2.5	52
1985	2PO85	May 23 - June 1	0	55
1987	3MF87	May 19-23	-6	40
1988	4MF88	May 21 - June 6	2	149
1989	4MF89	May 29 - June 5	4.5	95
1990	4MF90	May 30 - June 5	4	102
1991	4MF91	May 19-24	-6.5	70
1992	4MF92	May 18-26	-4.5	105
1993	5MF93	May 27 - June 1	0.5	74
1994	6MF94	May 24 - June 1	0	98
1995	8MF95	May 22-28	-3	77
1996	8MF96	May 25-31	1	96
1997	8MF97	May 24-30	-1	94
1998	5MF98	May 22-28	-2	95
1999	2WE99	May 25 - June 1	1	67
	5MF99	May 26-31		25
2000	6MF00	May 28 - June 2	3.5	81
2001	3MF01	May 27-31	1	78
2002	4MF02	May 27-30	0	59
2003	5MF03	May 28 - June 1	1.5	72
2004	5MF04	May 23 - June 3	1.5	84
2005	6MF05	May 22 - June 3	0	85
2006	4MF06	May 22 - June 1	-1	81
2007	5MF07	May 20-28	-4	79
2008	4DY08	May 24-30	-1	82
2009	4DY09	May 28 - June 6	4.5	83
2010	3DY10	May 23-28	-1	83
2011	2DY11	June 2-7	8.5	51
Total	Total	Range		Total
27	29	May 18 - June 7		2203

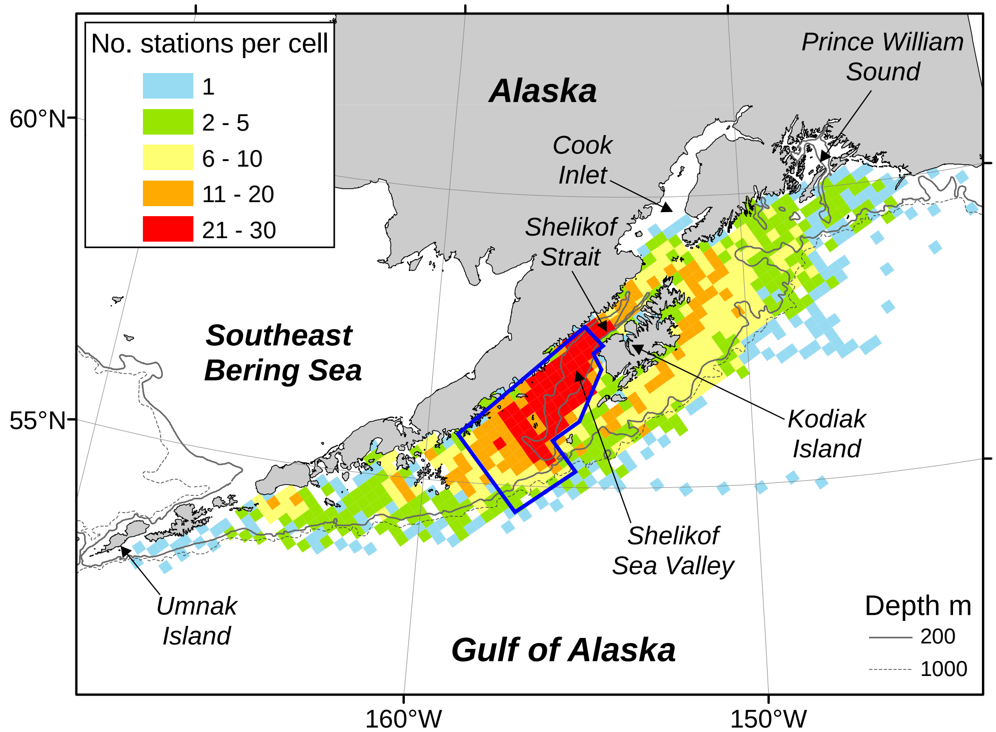


Figure 64: Distribution of ichthyoplankton sampling in the Gulf of Alaska by NOAA's Alaska Fisheries Science Center using a 60 cm frame bongo net. Sampling effort is illustrated by the total number of stations sampled in 20 km^2 grid cells over these years. A late spring time-series of mean abundance of ichthyoplankton species has been developed for the years 1981-2011, from collections in the polygonal area outlined in blue where sampling has been most consistent during mid-May through early June (Doyle et al., 2009).

in association with enhanced wind-driven onshore and alongshore transport. Years of high abundance for the late winter to early spring shelf spawners Pacific cod, walleye pollock, and northern rock sole were associated with cooler winters and enhanced alongshore winds during spring. High larval abundance for spring-summer spawning rockfish species and southern rock sole seemed to be favored by warmer spring temperatures later in the time-series.

Further evidence of environmental exposure-response connections among GOA species is provided by a recent study that incorporates multiple early life history characteristics into a comparative analysis of early ontogeny exposure patterns (Doyle and Mier, 2012). Species groups that emerged from this analysis were reflected in the NMDS ordination of the 1981-2009 larval abundance time-series.

With the current extension of the ichthyoplankton time-series through 2011, investigations continue both in terms of documenting species trends and identifying consistency or variability in the established relationships between species (and groups of species) and aspects of the GOA environment. In addition to larval abundance, larval mean lengths and length frequencies have been synthesized for selected species to identify possible phenological shifts in both peak spawning and larval hatching, or variation in larval growth rates, over the time-series (Doyle et al., in prep). Although there is a potential confounding factor from variation in timing of surveys over the time-series, the shift in

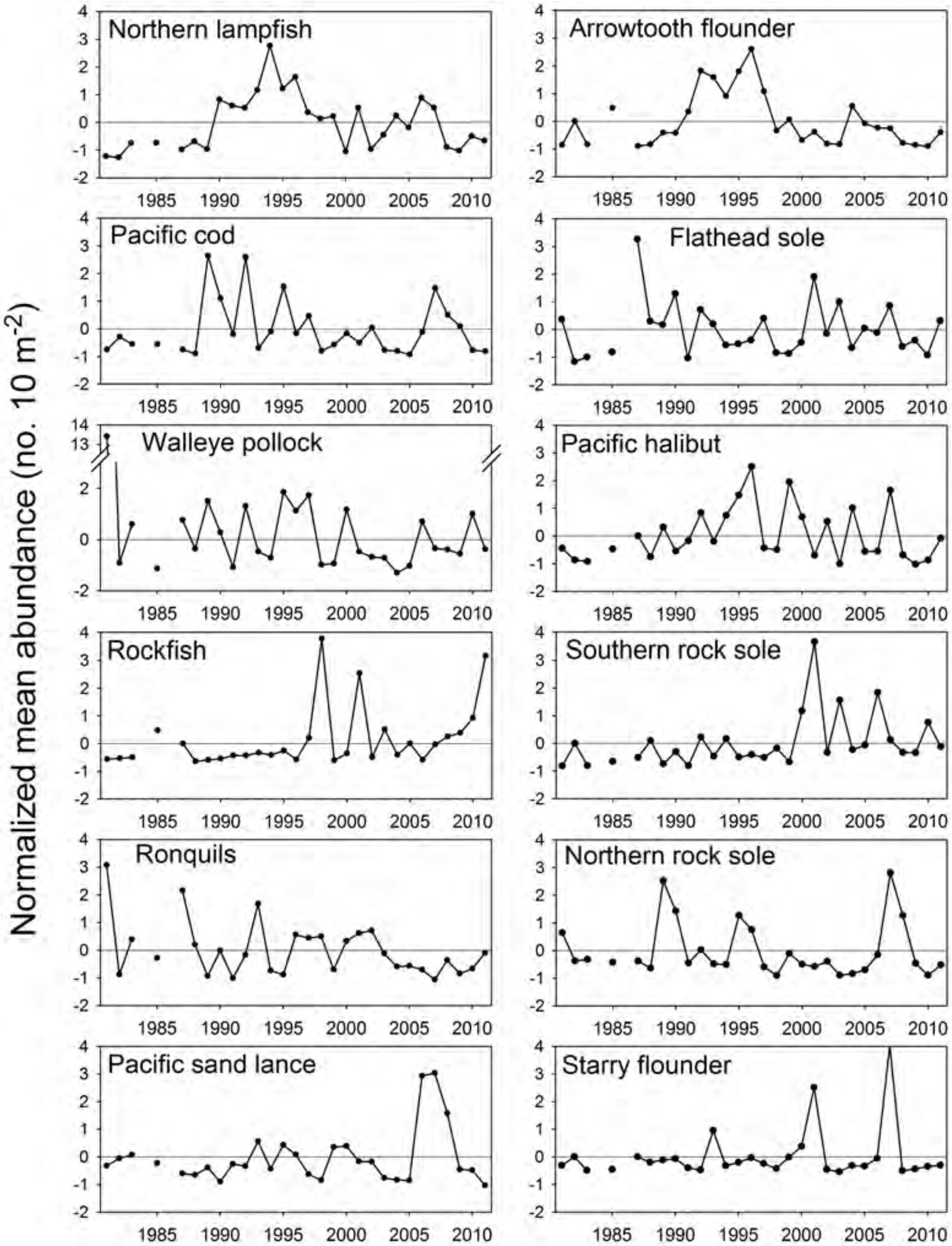


Figure 65: Interannual variation in late spring larval fish abundance for the most abundant species in the Gulf of Alaska. For each year, the larval abundance index is expressed as the log10 of mean abundance (no. 10 m^{-2}+1) standardized by the time-series mean and standard deviation.

the median survey date is less than a week except for 2011 when it was +8.5 days and all sampling was carried out in early June.

Implications: Understanding ecological connections between the early ontogeny stages of fish and the pelagic environment contributes to the evaluation of vulnerability and resilience among GOA species' early life history patterns to fluctuating oceanographic conditions. Analyses of these time-series also provides crucial information for the identification of environmental indicators that may have a broad-spectrum effect on multiple species early life history stages, as well as those that may be more species-specific in exerting control on early life history survival. Ongoing research addresses the hypothesis that we can utilize similarities in reproductive and early life history characteristics among species to identify: (1) ecologically determined species groups that are pre-disposed to respond to environmental forcing in similar ways, and (2) plausible environmental predictors of early life history aspects of recruitment variation. The decrease in sampling frequency of GOA ichthyoplankton (from annual to biennial) is unfortunate as this is one of very few annual ichthyoplankton abundance time-series in the world that extends beyond 25 years. In association with climate and ocean time-series it can illuminate early life history mechanisms that influence recruitment, as well as provide critical information on likely response patterns among species to environmental fluctuations in the GOA.

Trends in Groundfish Biomass and Recruits per Spawning Biomass

Contributed by Jennifer Boldt[1], Todd TenBrink[2], Steven Hare[3], and the Alaska Fisheries Science Center Stock Assessment Staff
[1]Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Rd, Nanaimo, BC, Canada V9T 6N7
[2]Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
[3]International Pacific Halibut Commission
Contact: jennifer.boldt@dfo-mpo.gc.ca
Last updated: October 2011

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

Bering Sea Groundfish Condition

Contributed by Jennifer Boldt[1], Chris Rooper[2], and Jerry Hoff[2]
[1]Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Rd, Nanaimo, BC, Canada V9T 6N7
[2]Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: chris.rooper@noaa.gov
Last updated: October 2013

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 (i.e., no corner stations were included). 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.

Status and trends: Length-weight residuals varied over time for all species with a few notable patterns (Figure 66). 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. In 2008, all species except flathead sole and walleye pollock had negative residuals. Trends in walleye pollock and yellowfin sole residuals were highly correlated ($y = 1.0532x + 0.0015$, $R^2 = 0.648$). There has been a distinct negative trend in Pacific cod since a peak value in 2003.

Spatial trends in residuals were also apparent for some species (Figure 67). 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 67). 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 67).

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 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.

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)

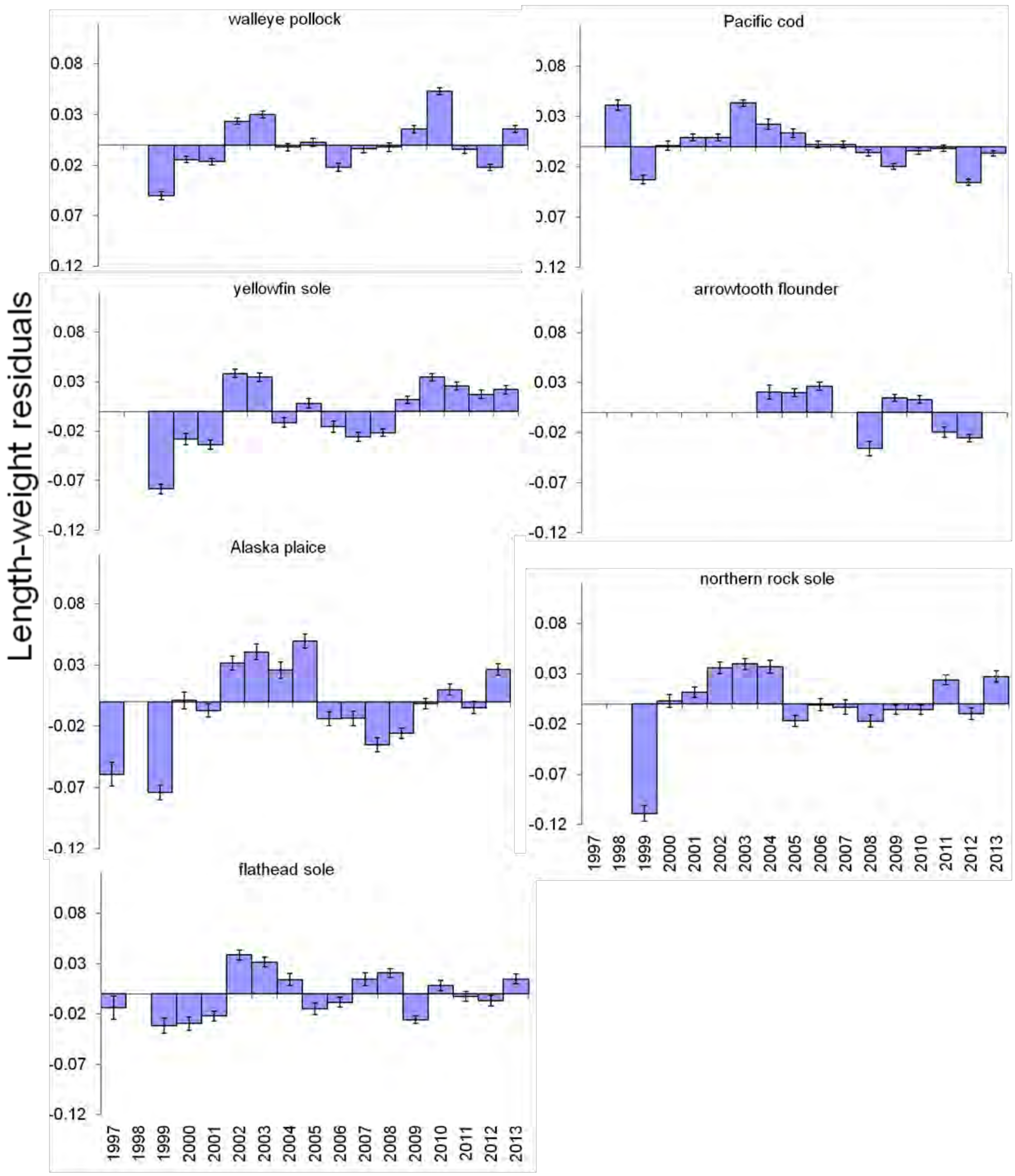


Figure 66: Length-weight residuals for seven Eastern Bering Sea groundfish sampled in the NMFS standard summer bottom trawl survey, 1997-2013.

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.

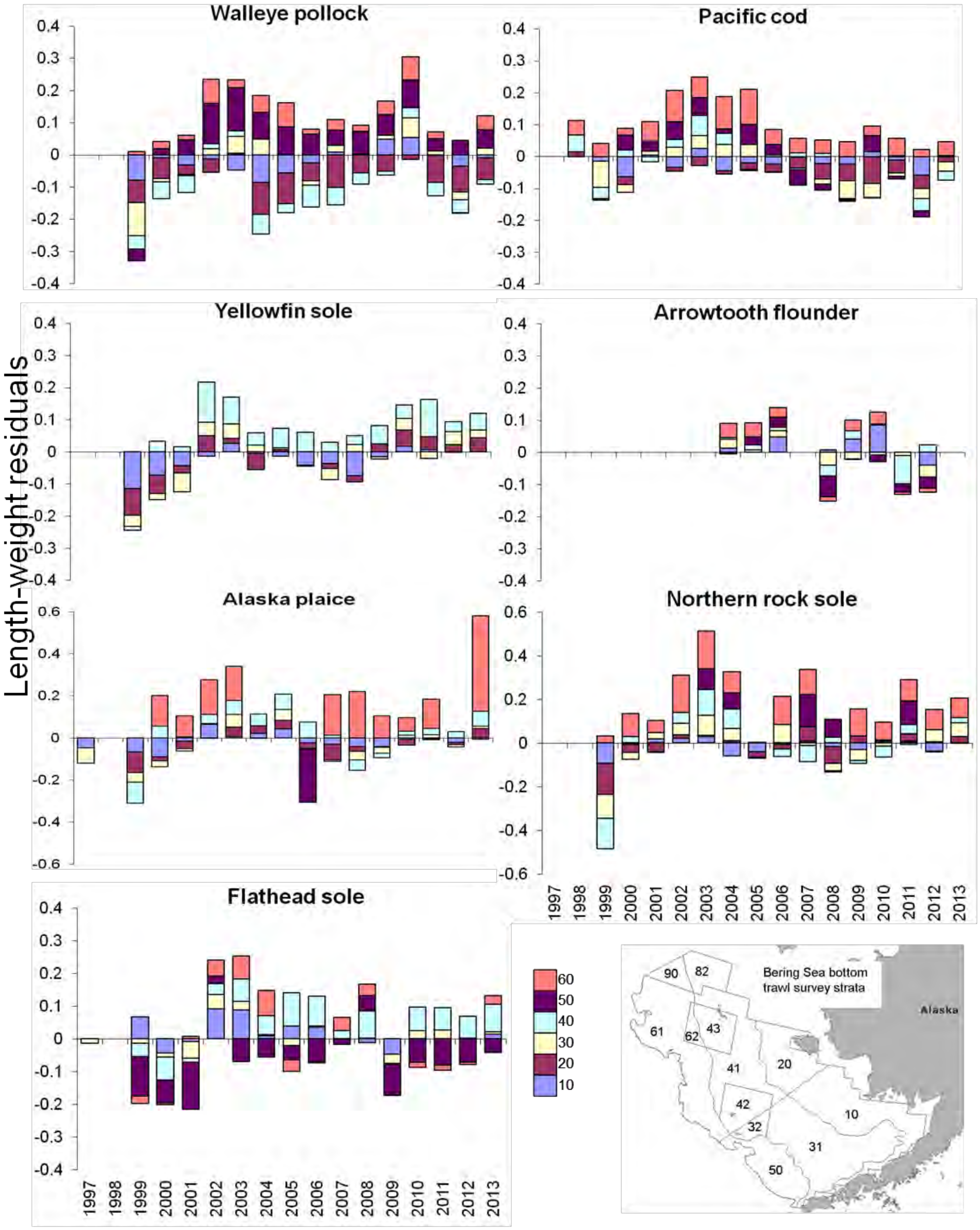


Figure 67: Length-weight residuals for seven Eastern Bering Sea groundfish sampled in the NMFS standard summer bottom trawl survey, 1997-2013, by survey strata (10 - 60). NMFS summer bottom trawl survey strata are shown in the lower right panel. Survey strata 31 and 32 were combined as stratum 30; strata 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.

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.

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

Contributed by Tom Wilderbuer and Jim Ingraham (retired), Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: tom.wilderbuer@noaa.gov
Last updated: September 2013

Description of index: Wilderbuer et al. (2002) summarized a study examining the recruitment of winter-spawning flatfish in relation to decadal atmospheric forcing, linking favorable recruitment to the direction of wind forcing during spring. OSCURS model time series runs indicated in-shore advection to favorable nursery grounds in Bristol Bay during the 1980s. The pattern change to off-shore in the 1990-97 time series coincided with below-average recruitment for northern rock sole, arrowtooth flounder and flathead sole, relative to the 1980s. Favorable springtime winds were present again in the early 2000s which also corresponded with improved recruitment. The time series is updated through 2013 (Figure 68).

Status and trends: The 2013 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 2005-2013 were consistent with those which produced above-average recruitment in the original analysis (2006, 2008, 2011). 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 the 1990s. Arrowtooth flounder produced year classes of average strength during some off-shore drift years, suggesting that this species may have different timing for spawning and larval occurrence than northern rock role. In the case of flathead sole, the 2001 and 2003 year-classes appear stronger than the weak recruitment that has persisted since the 1990s.

Implications: The 2012 and 2013 springtime drift patterns do not appear to be consistent with years of good recruitment for northern rock sole, arrowtooth flounder and flathead sole.

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

Contributed by Ellen Martinson, Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA

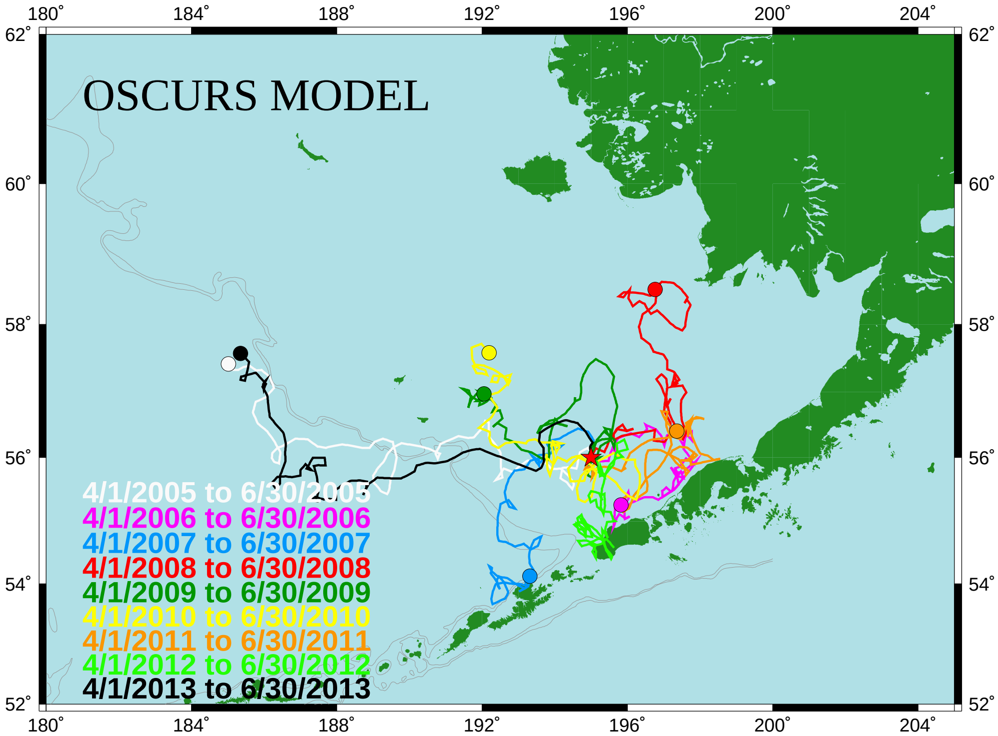


Figure 68: OSCURS (Ocean Surface Current Simulation Model) trajectories from starting point 56°N, 164°W from April 1-June 30 for 2004-2012.

Ted Stevens Marine Research Institute, 17109 Point Lena Loop Road, Juneau, Alaska 99801-8626
Contact: ellen.martinson@noaa.gov
Last updated: July 2013

Description of index: The temperature change (TC) index is a composite index for the pre- and post-winter thermal conditions experienced by pollock (*Theragra 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 69) 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 2013 TC index value is -3.89. The TC index is positively correlated with subsequent recruitment to age-1 through age-6 for based on abundance estimates from Table 1.21 in Ianelli et al. 2012 (Table 8). This relationship was more statistically significant (p-values were lower) for the age-4, -5 and -6 fish, than for the age-1, -2, and -3 fish for years 1995-2012. However, over the longer time period (1964-2012), the TC index was and more statistically significant for the age-1, age-2, and age-3 fish, than for the older fish (Table 8).

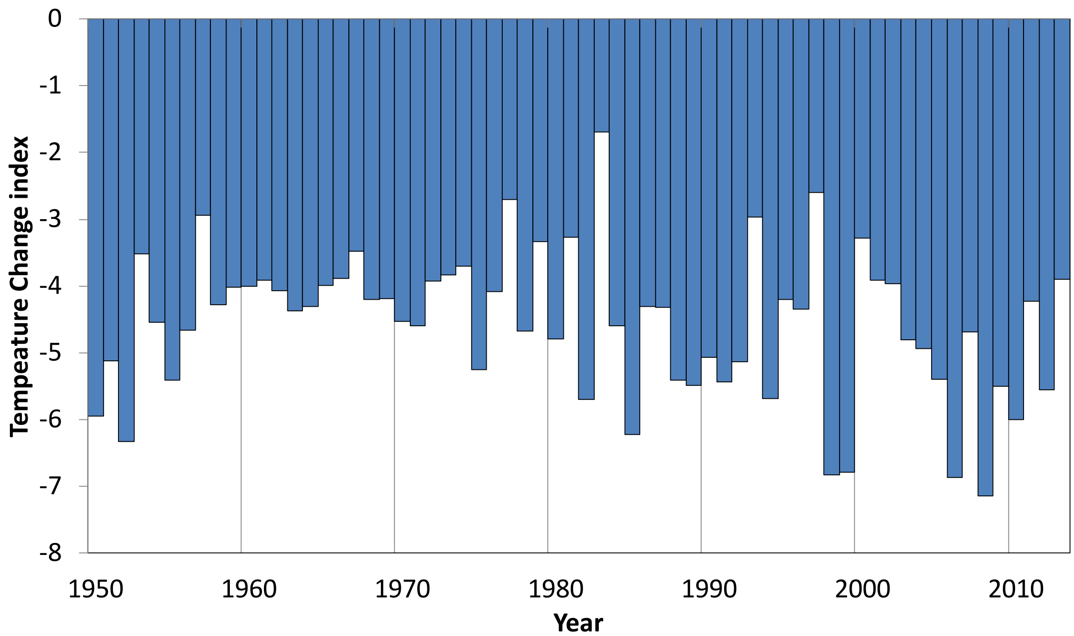


Figure 69: The Temperature Change index value from 1950-2013.

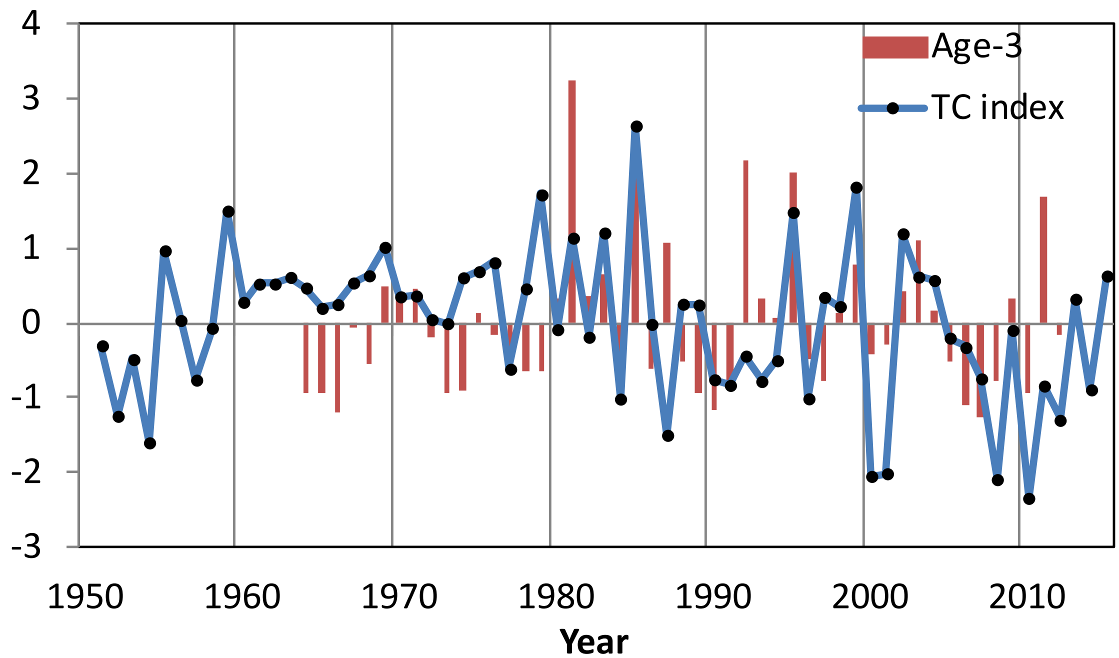


Figure 70: Normalized times series values of the temperature change index (t-2) and the estimated abundance of age-3 walleye pollock in the eastern Bering Sea (t).

Factors causing observed trends: The age-0 pollock are more energy-rich in a year with a cooler late summer (Coyle et al., 2011; Heintz et al., 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

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
1964-2012	**0.405**	**0.394**	**0.367**	**0.302**	**0.305**	**0.277**
1995-2012	**0.451**	**0.449**	**0.457**	**0.455**	**0.642**	**0.613**

age-1 phase are assumed favorable for the survival of pollock from age-0 to age-1.

Implications: In 2011, the TC index value of -4.23 was slightly above the long term average of -4.58, therefore we expect slightly higher than average numbers of pollock to survive to age-3 in 2013 (Figure 69). In the future, the TC values in 2012 (TC=-5.56) and 2013 (TC=-3.89) indicate below average abundances of age-3 pollock in 2014 and above average abundances of age-3 pollock in 2015 (Figure 70).

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

Contributed by Chris Rooper, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: chris.rooper@noaa.gov
Last updated: October 2013

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 71). 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^{o}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 72). 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 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.

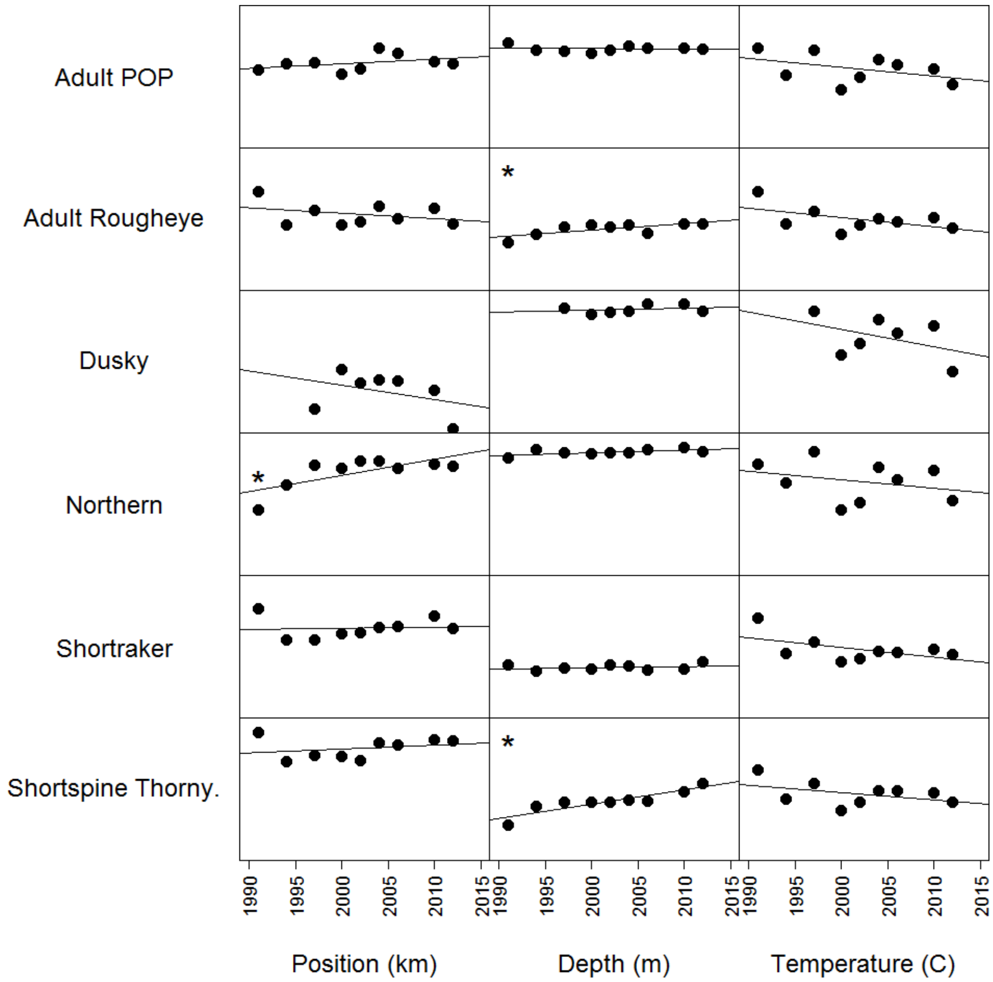


Figure 71: Plots of mean weighted (by catch per unit effort) distributions of six rockfish species-groups along three environmental variables in the Aleutian Islands. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance 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.

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

Contributed by Ellen Martinson, Joe Orsi, Molly Sturdevant, Emily Fergusson, Auke Bay Laboratories, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: ellen.martinson@noaa.gov
Last updated: October 2013

Description of index: 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.

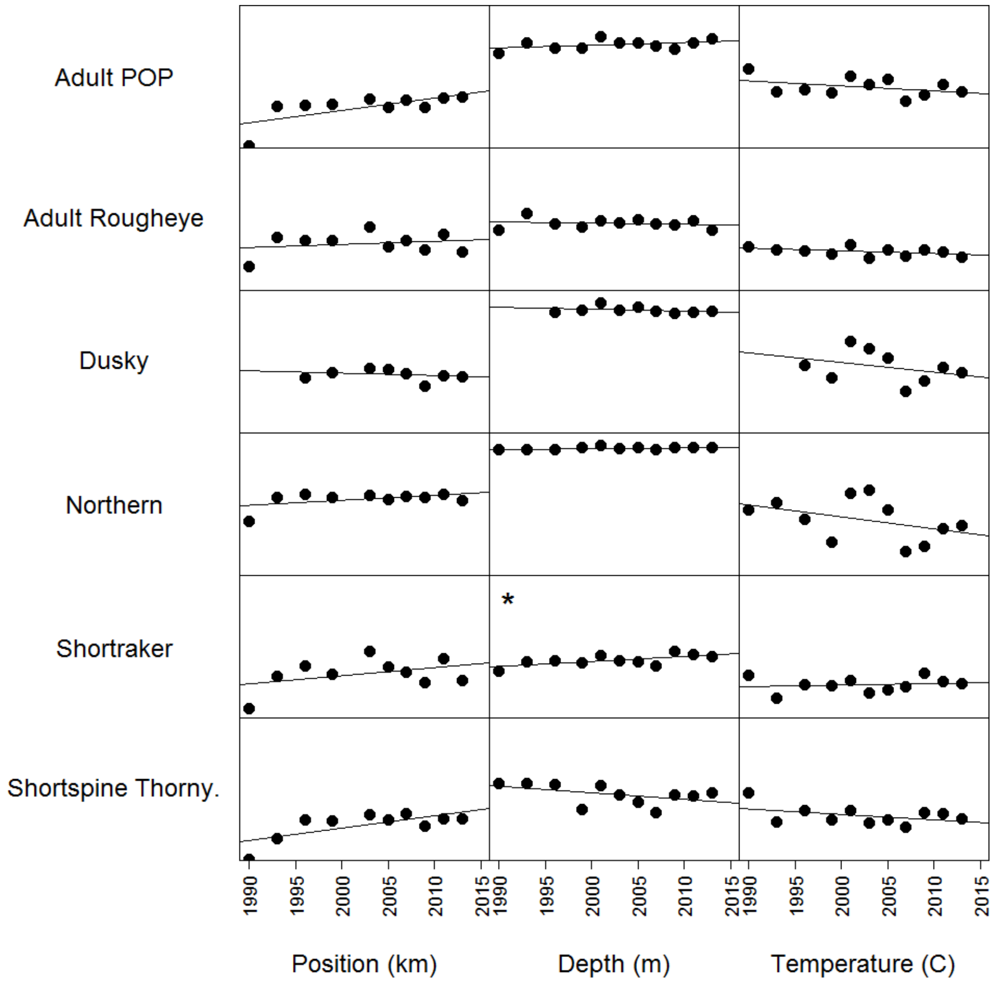


Figure 72: Plots of mean weighted (by catch per unit effort) distributions of six rockfish species-groups along three environmental variables in the Gulf of Alaska. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance 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.

These data are available from Emily Fergusson (NOAA) from 1999 to 2012. We only used metrics from Icy Strait station B. These oceanographic metrics may index sablefish recruitment, because sablefish use these waters as rearing habitat early in life. Estimates of age-2 sablefish abundance are from the 2012 sablefish stock assessment (Hanselman 2012).

Status and trends: In a linear regression model, age-2 sablefish recruitment was described as a function of sea temperature and chlorophyll during the age-0 stage and age-2 sablefish recruitment in the prior year. Chlorophyll during the age-0 phase was the main driver of sablefish recruitment ($R^2 = 0.77$; $p = 0.00009$) with a three-fold increases in chlorophyll in 2000 and recruitment in 2002. Sea temperature explained an additional 9% ($R^2 = 0.86$; $p = 0.0003$) of the variation in sablefish recruitment. The residuals of the model with sea temperature and chlorophyll had a strong alternating year pattern with recruitment underestimated in odd-numbered years (Figure 73). This variation in the residuals could be explained by a negative 1st and/or 3rd order process

Table 9: Parameters (Beta), standard error (S.E.), t-test, and p (Prob(t)) of the coefficients for the significant predictor variables in the generalized least squared regression model of age-2 sablefish recruitment ($R^2 = 0.915$; p = 0.00004; n = 12). Bold values are statistically significant. ST is sea temperature, Chl is chlorophyl, Sable is sablefish, and t is time in years

	ST(t-2)	Chl(t-2)	Sable(t-1)
Beta	33	1.03	-0.24
S.E.	0.11	0.11	0.10
t-test	3.15	9.70	-2.49
Prob(t)	0.01	0.00	0.03

of an autoressive model, adult pink salmon abundance, or age-2 sablefish in the prior year. Along with sea temperature and chlorophyll a, age-2 sablefish abundance in the prior year explained an additional 6% of the variation in recruitment ($R^2 = 0.92$; p = 0.00004) (Figure 74 and Table 9). However, the model underestimated recruitment from 2003 to 2006, a series of warm years.

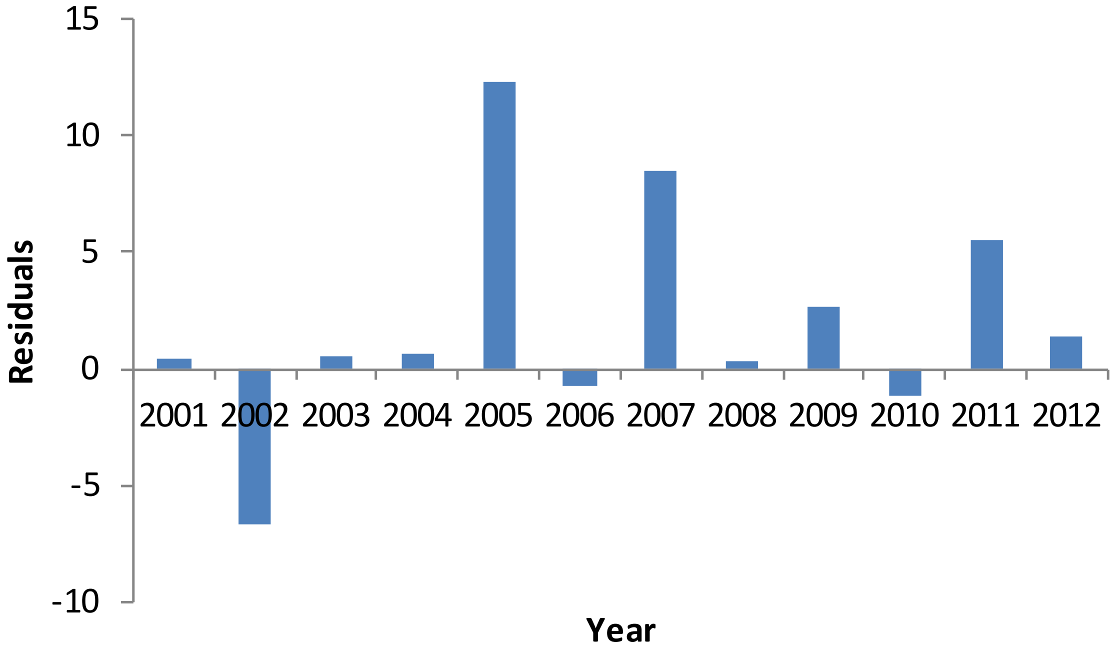


Figure 73: of the age-2 sablefish model with sea surface temperature and chlorophyll a.

Factors influencing observed trends: Higher chlorophyll content in sea water indicates higher primary productivity. Warmer sea temperatures are also associated with high sablefish recruitments events in later years (Sigler and Zenger, 1989). These conditions are assumed to be more favorable for age-0 sablefish. The alternating year pattern in the residuals of the model with sea temperature and chlorophyll is likely due to an interaction with pink salmon, or another predator, prey, or competitor with a two year life cycle.

Implications: Higher sea temperature and chlorophyll represent higher ocean productivity and better conditions for sablefish survival. Based on the second highest chlorophyll values (2.63) in

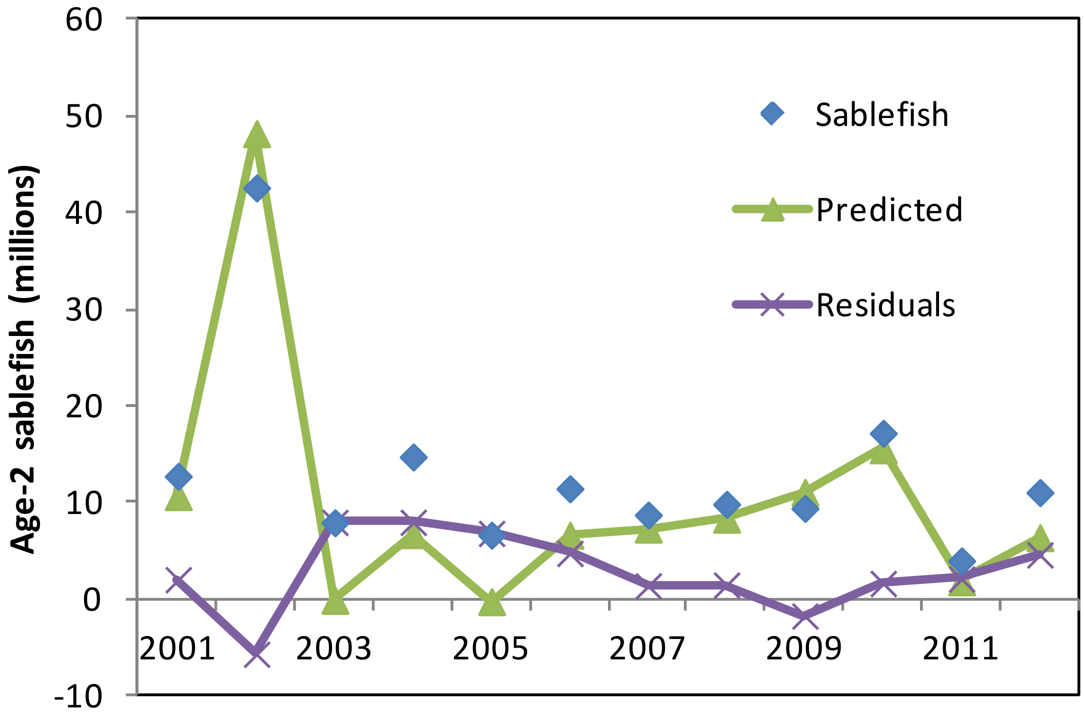


Figure 74: Age-2 sablefish modeled as a function of chlorophyll a in year t-2, sea temperature in year t-2, and sablefish in year t-1.

2011, above average sea temperature (12.2°C) in 2011, and even though year t-1 was an even-numbered year, **we expect above average recruitment of age-2 sablefish in 2013**.

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]
[1]The Farallon Institute, PO Box 750756, Petaluma, CA 94975
[2]University of Tasmania, Private Bag 129, Hobart, TAS, 7001, Australia
[3]University of Alaska Fairbanks, 17101 Pt. Lena Rd., Juneau, AK 99801
[4]Alaska Fisheries Science Center, 301 Research Ct., Kodiak, AK 99615
Contact: malitzow@utas.edu.au
Last updated: January 2012

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

Bering Sea/Aleutian Islands King and Tanner Crab Stocks

Contributed by Robert Foy, Kodiak Laboratory, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: robert.foy@noaa.gov
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
Contact: jerry.hoff@noaa.gov
Last updated: October 2013

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 1982-2013. Relative CPUE was calculated by setting the largest biomass in the time series to a value of 1 and scaling other annual values proportionally. The standard error (±1) was weighted proportionally to the CPUE to produce a relative standard error.

Status and trends: With few exceptions, the trend in relative CPUE for all three species groups was very similar (Figure 75).

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

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

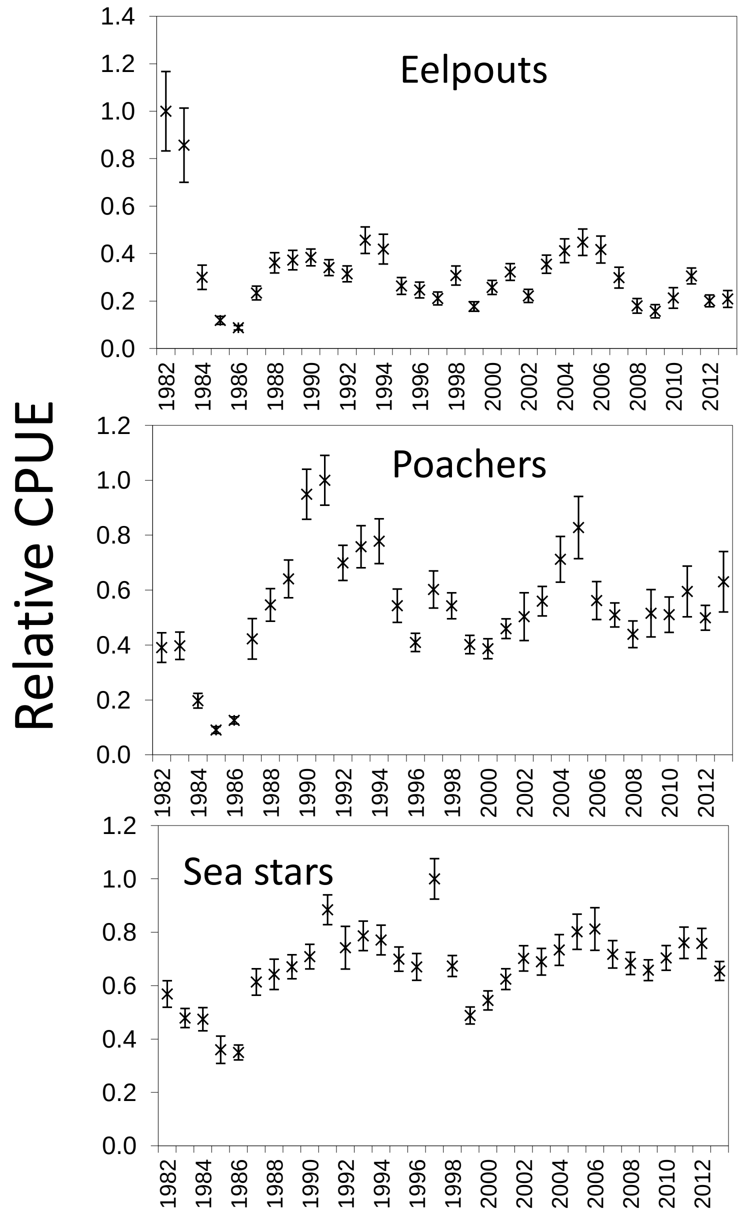


Figure 75: AFSC eastern Bering Sea bottom trawl survey relative CPUE for miscellaneous species during the May to August time period from 1982-2013.

Contact: chris.rooper@noaa.gov
Last updated: October 2012

Aleutian Islands survey are conducted in alternate even years. See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

ADF&G Gulf of Alaska Trawl Survey

Contributed by Carrie Worton, Alaska Department of Fish and Game, 211 Mission Road, Kodiak, AK 99615
Contact: carrie.worton@alaska.gov
Last updated: August 2013

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 76) are broadly representative of the survey results across the region. These areas have been surveyed annually since 1984, but the most consistent time series begins in 1988. Standardized anomalies, a measure of departure from the mean, for the survey catches from Kiliuda and Ugak Bays, and Barnabas Gully were calculated and plotted by year for selected species (arrowtooth flounder Atheresthes stomias, flathead sole Hippoglosoides elassodon, Tanner crab Chionoecetes bairdi, Pacific cod Gadus macrocephalus, and skates) using the method described by Link et al. (2002) (Figure 77). Bottom temperatures for each haul have been recorded since 1990 (Figure 78).

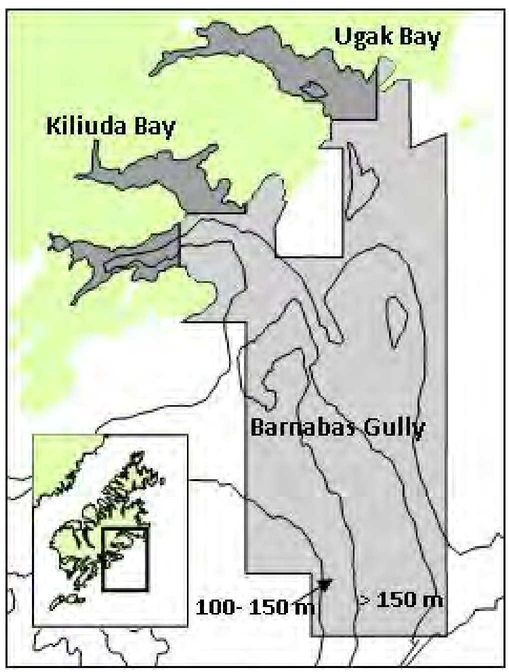


Figure 76: Adjoining survey areas on the east side of Kodiak Island used to characterize inshore (dark gray, 14 stations) and offshore (light gray, 33 stations) trawl survey results.

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 2012 from years of record high catches seen from 2002 to 2005 (Figure 79).

Prior to the start of our standard trawl survey in 1988, Ugak Bay was the subject of an intensive

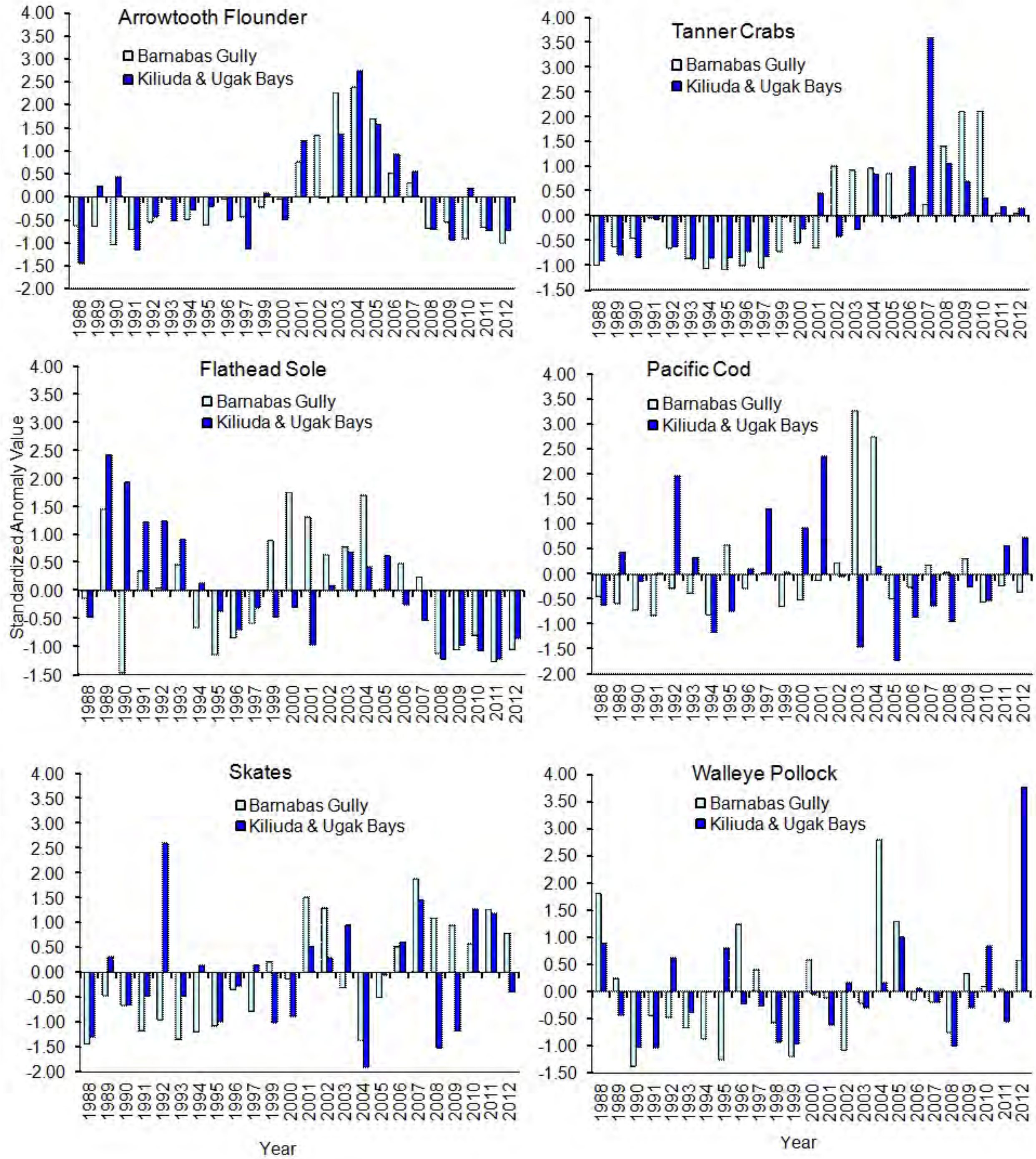


Figure 77: A comparison of standardized anomaly values for selected species caught from 1988-2012 in Barnabas Gully and Kiliuda and Ugak Bays during the ADF&G trawl surveys.

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

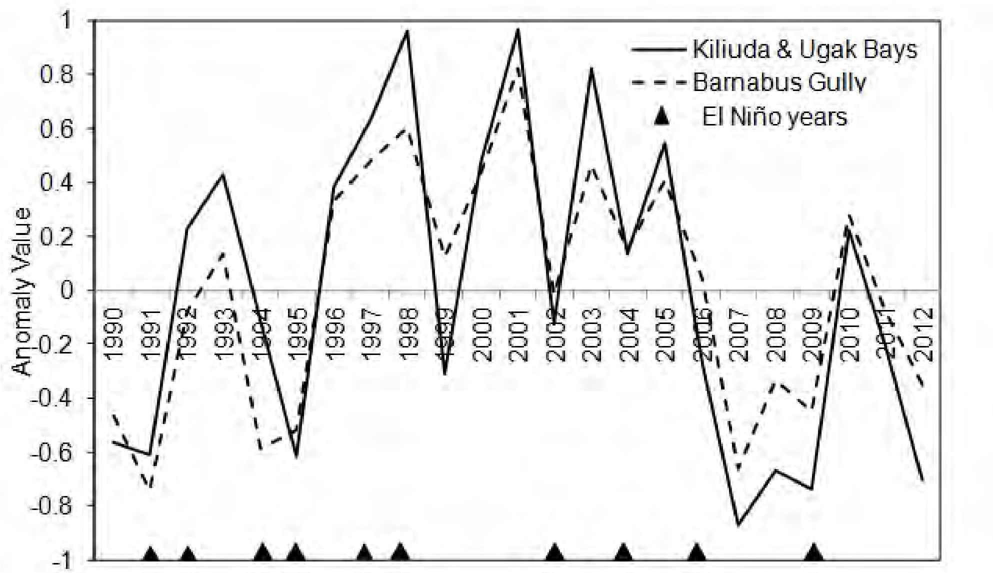


Figure 78: Bottom temperature anomalies recorded from the ADF&G trawl survey for Barnabas Gully and Kiliuda and Ugak Bays from 1990 to 2012, with corresponding El Niño years represented.

pollock 10% of the gadid catch in 1976-1977, catch compositions have reversed in 2012 with Pacific cod making up 8% of catch and walleye pollock 92%.

In 2012, overall gadid catches have slightly decreased in offshore area of Barnabus Gully, but increased in the inshore areas of Kiliuda and Ugak Bays (Figure 79). Above average anomaly values for Tanner crabs were recorded in 2012 for both inshore and offshore areas, while arrowtooth flounder and flathead sole values remain below average (Figure 77). Walleye pollock was well above average for both inshore and offshore areas, while Pacific cod remained above only in the inshore areas.

Temperature anomalies for both inshore, Kiliuda and Ugak Bays and offshore stations, Barnabas Gully, from 1990 to 2012, show similar oscillations with periods of above average temperatures corresponding to the strong El Niño years (1997-1998; Figure 78; `http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html`). Cooler temperatures are apparent in 2011 and 2012.

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 79) 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

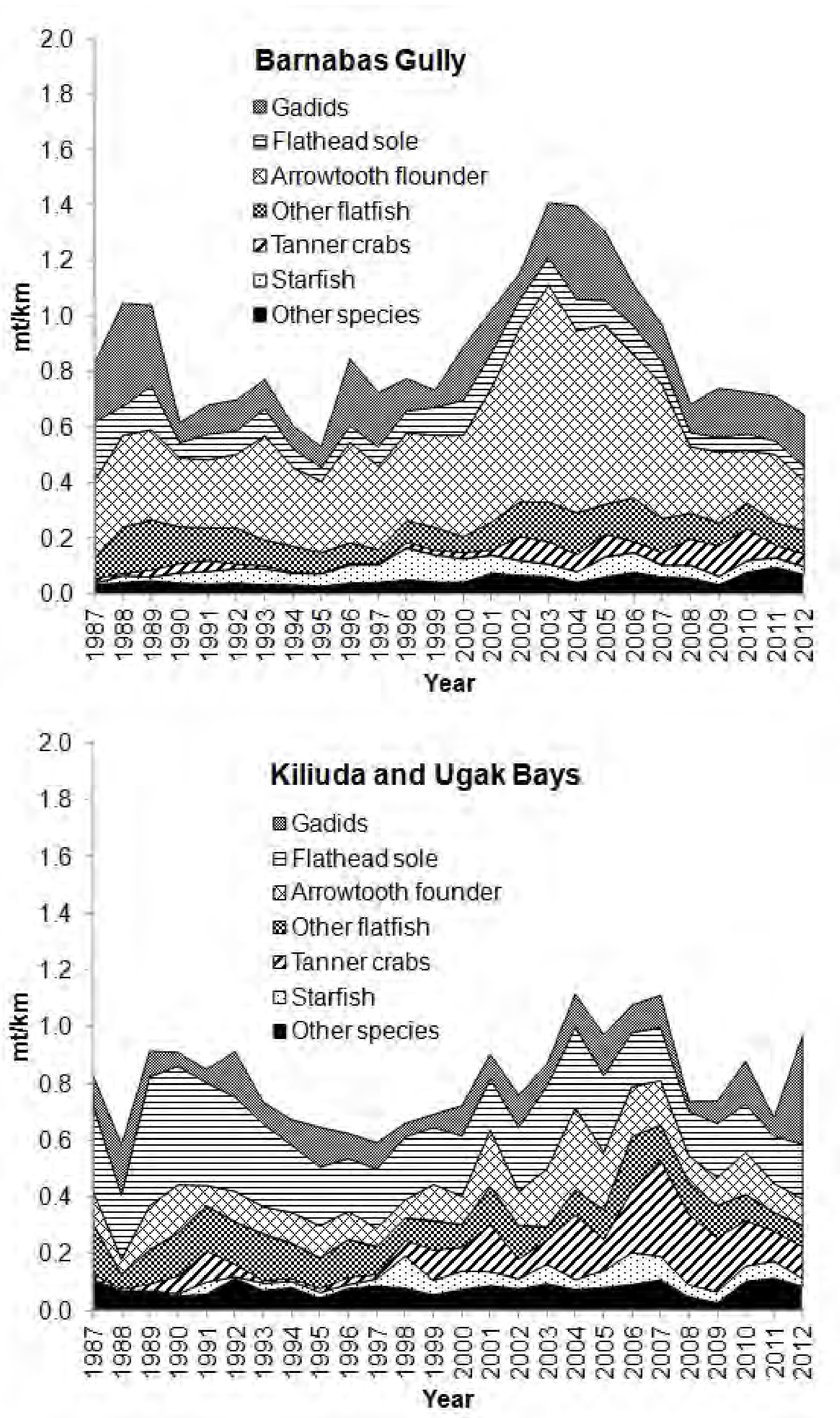


Figure 79: Total catch per km towed (mt/km) during the ADF&G trawl survey from adjacent areas off the east side of Kodiak Island, 1987 to 2012.

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.

Miscellaneous Species - Gulf of Alaska

Contributed by Chris Rooper, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: Chris.Rooper@noaa.gov
Last updated: October 2013

Description of index: RACE bottom trawl surveys in the Gulf of Alaska (GOA) are designed primarily to assess populations of commercially important fish and invertebrates. However many other species are identified, weighed and counted during the course of these surveys, and these data may provide a measure of relative abundance for some of these species. For each species group, the catches for each year were scaled to the largest catch over the time series (which was arbitrarily scaled to a value of 100). The standard error (+/- 1) was weighted proportionally to the CPUE to get a relative standard error. The percentage of positive catches in the survey bottom trawl hauls was also calculated.

Status and trends: Jellyfish mean catch per unit effort (CPUE) is typically higher in the central and eastern GOA than in other areas (Figure 80). The frequency of occurrence in trawl catches is generally high across all areas, but has been variable. Jellyfish catches in the western GOA have been uniformly low. Echinoderm catches have been highest in the central GOA and they are consistently captured in ∼50% of bottom trawl hauls in all areas. Eelpout CPUE has been variable, with peak abundances occurring in 1993, 2001 and 2009 in the western GOA, 2003 and 2011 in the central GOA and peak catches since 1999 in the eastern GOA. Poacher CPUE's have been in decline since the peak in 1993. Poachers have been uniformly in low abundance in the eastern GOA and have been variable, but somewhat higher in the central GOA.

Factors influencing observed trends: Many of these species are not sampled well by the gear or occur in areas that are not well sampled by the survey (hard, rough areas, mid-water etc.) and are therefore encountered in small numbers which may or may not reflect their true abundance in the GOA. The fishing gear used aboard the Japanese vessels that participated in all GOA surveys prior to 1990 was very different from the gear used by all vessels since. This gear difference almost certainly affected the catch rates for some of these species groups.

Implications: GOA 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.

Seabirds

Multivariate Seabird Indices for the Eastern Bering Sea

Contributed by Stephani Zador
Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National

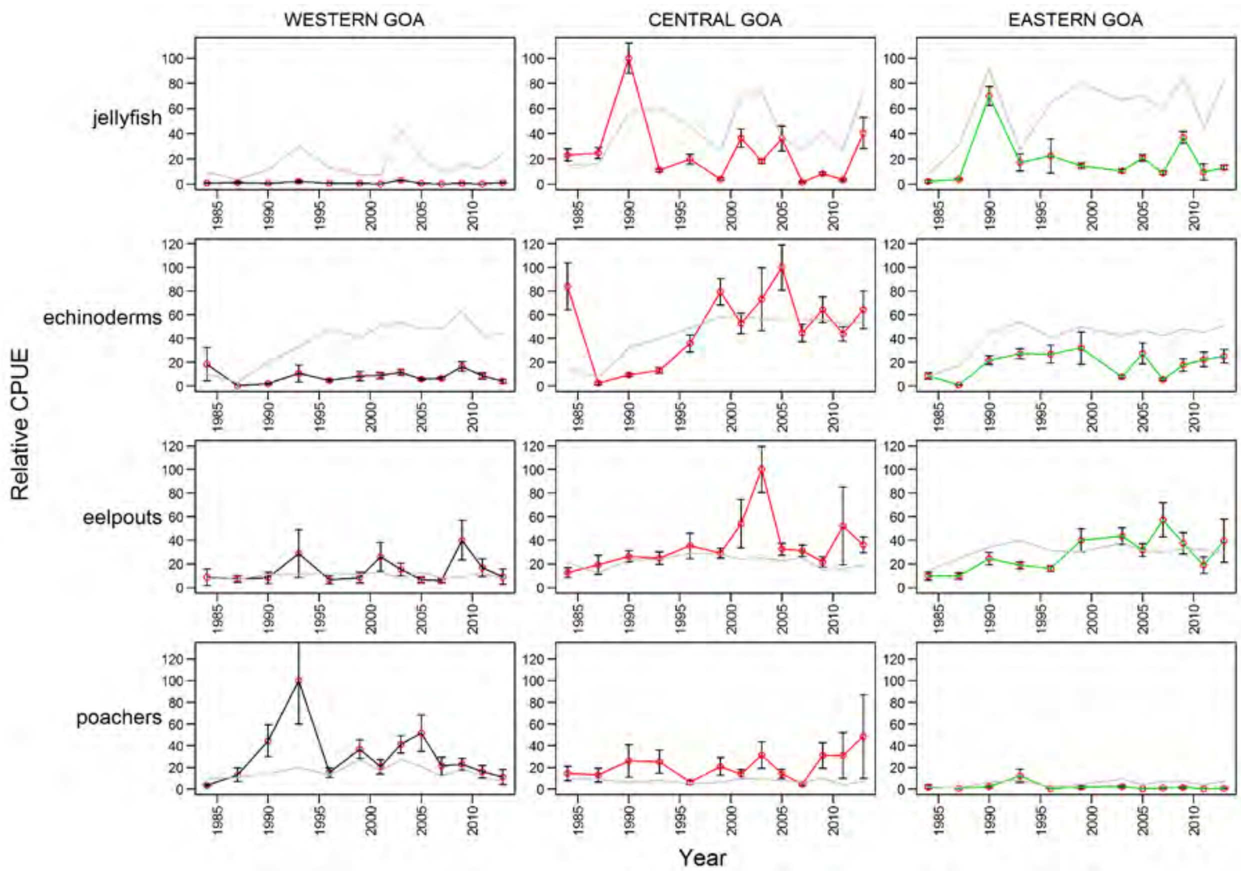


Figure 80: Relative mean CPUE of miscellaneous species by area from RACE bottom trawl surveys in the Gulf of Alaska from 1984 through 2013. Error bars represent standard errors. The gray lines represent the percentage of non-zero catches.

Marine Fisheries Service, NOAA, Seattle, WA
Contact: stephani.zador@noaa.gov
Last updated: October 2012

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

Seabird Bycatch Estimates for Alaskan Groundfish Fisheries, 1993-2011

Contributed by Shannon Fitzgerald
Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: shannon.fitzgerald@noaa.gov
Last updated: July 2013

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 2012. Fishing gear types represented are demersal longline, pot, pelagic trawl, and non-pelagic trawl. These numbers do not apply to gillnet, seine, troll, or halibut longline fisheries. Data collection on the Pacific halibut longline fishery began in 2013 and will be summarized in the Ecosystem Considerations report in 2014.

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 produced the estimates from 2007-2012 (Cahalan et al., 2010).

Status and trends: Figure 81 depicts seabird bycatch in the groundfish fisheries from 1993 through 2012 using results from the two analytical methods. The 2012 estimated numbers for the combined groundfish fisheries (Table 10) are 40% below the running 5-year average for 2007-2011 of 8,295 birds. Albatross bycatch was reduced in 2012 by 27% compared to the previous 5 years, with the greatest decrease in Laysan (*Phoebastria immutabilis*; 36% reduction) versus black-footed albatross (*P. nigripes*; 11% decline). Northern fulmar (*Fulmaris glacialis*) bycatch remained the highest proportion in the catch at 61%, but was down by 39% compared to the 5-year average and 52% from the year before. Fulmar bycatch has ranged between 45 to 76% of the total seabird bycatch since 2007. Average annual mortality for fulmars since 2007 has been 4,586. However, when compared to estimates of 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). The

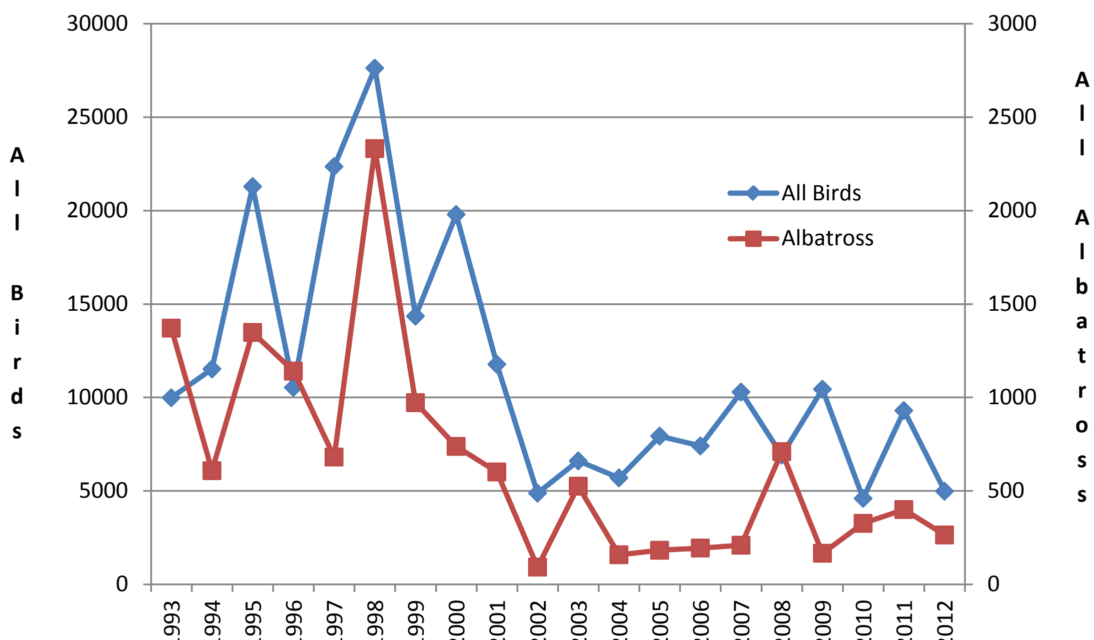


Figure 81: Seabird bycatch in Alaskan groundfish fisheries, all gear types combined, 1993 to 2012. Total estimated bird numbers are shown in the left-hand axis while estimated albatross numbers are shown in the right-hand axis

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

Table 10: Total **estimated** seabird bycatch in Alaskan groundfish fisheries, all gear types and Fishery Management Plan areas combined, 2007 through 2012. 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
Unidentified Albatross	16	0	0	0	0	0
Short-tailed Albatross	0	0	0	15	5	0
Laysan Albatross	17	420	114	267	189	128
Black-footed Albatross	176	290	52	44	206	136
Northern Fulmar	4,581	3,426	7,921	2,357	6,214	3,016
Shearwater	3,602	1,214	622	647	199	510
Storm Petrel	1	44	0	0	0	0
Gull	1,309	1,472	1,296	1,141	2,208	885
Kittiwake	10	0	16	0	6	5
Murre	7	5	13	102	14	6
Puffin	0	0	0	5	0	0
Auklet	0	3	0	0	0	7
Other Alcid	0	0	105	0	0	0
Other Bird	0	0	136	0	0	0
Unidentified	509	40	166	18	259	284
Total	10,228	6,914	10,441	4,596	9,298	4,997

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 3,704 in 2010. Numbers increased to 8,914 in 2011, the second highest in the streamer line era, but fell back to 4,544 in 2012. The increased numbers in 2011 were due to a doubling of the gull (*Larus* spp) numbers (1,084 to 2,206) and a 3-fold increase in fulmars, from 1,782 to 5,848. These species group numbers have decreased in 2012 as well, to 885 and 3,016 respectively.

Albatross bycatch varied annually. The greatest numbers of albatross were caught in 2008. In 2012, 57.0% of albatross bycatch occurred in the GOA (down from 87% in 2011). The GOA typically accounts for 10 to 20% of overall seabird bycatch. Only Laysan albatross were taken in the BSAI; all black-footed albatross were taken in the GOA (along with about 14 Laysan). While the estimated bycatch of black-footed albatross underwent a 4-fold increase in bycatch (44 to 206) between 2010 and 2011, the 2012 estimates are about 11% under the long-term average of 153 birds per year. 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 & 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. The expected incidental take, 4 birds every two years since the Biological Opinion was revised in 2003, totals to 20 observed takes while realized observed take has been 3 birds.

Factors influencing observed trends: The marked decline in overall numbers of birds caught after 2002 (Figure 81 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, 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: 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 2012. 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 2012. 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. In general however, there seems to be a generally decreasing trend since the new estimation procedures began in 2007 indicating no immediate management concern other then continuing our general goal of decreased seabird bycatch.

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

Contributed by Lowell Fritz and Rod Towell, National Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: lowell.fritz@noaa.gov
Last updated: October 2010

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

Northern Fur Seals

Contributed by Lowell Fritz and Rod Towell, National Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: lowell.fritz@noaa.gov
Last updated: October 2011

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

Harbor Seals

Contributed by Peter Boveng and Josh London, National Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: peter.boveng@noaa.gov
Last updated: October 2007

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

Contributed by Michael Cameron, National Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: peter.boveng@noaa.gov
Last updated: July 2009

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

Bowhead Whales)

Contributed by Marcia Muto, National Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: marcia.muto@noaa.gov
Last updated: August 2012

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

Ecosystem or Community Indicators

Indicators of Basin-scale and Alaska-wide Community Regime Shifts

Contributed by Mike Litzow[1,2] and Franz Mueter[3]
[1]Blue World Research, 2710 E. 20th Ave., Anchorage, AK 99508
[2]University of Tasmania, Private Bag 129, Hobart, TAS, 7001, Australia
[3]University of Alaska Fairbanks, 17101 Pt. Lena Rd., Juneau, AK 99801
Contact: malitzow@utas.edu.au
Last updated: August 2013

Description of index: The first and second principal components (PCs) for 64 biology time series from Baja California to the Bering Sea allow basin-scale patterns of biological variability to be monitored (Hare and Mantua, 2000). These data include 36 Alaskan time series (19 from the Gulf of Alaska and 17 from the Bering Sea). Alaskan time series include recruitment estimates for groundfish (n = 15) and herring (n = 3) populations, log-transformed and lagged to cohort year; commercial salmon catches (n = 16), log-transformed and lagged to year of ocean entry; and measures of invertebrate abundance (n = 2). These indices are useful for monitoring possible biological responses to the negative Pacific Decadal Oscillation (PDO)/positive North Pacific Gyre Oscillation (NPGO) conditions that have persisted since 2007/08 (Figure 82). We updated the Hare and Mantua biology time series for 1965-2008 (for the northeast Pacific) and 1965-2009 (for the Alaskan time series). Lags inherent in many time series meant that too many values were missing after 2008 (for the full data set) or after 2009 (for the Alaskan data) for PC analysis to be conducted. However, subsets of time series that could be updated at least through 2010 ($n = 23$ for the northeast Pacific; $n = 13$ for Alaska) allowed PC scores to be estimated through 2011.

Status and trends: *Basin-scale* - There was some evidence of an abrupt change in leading axes of basin-scale biological variability in 2008. Change in the PC1- 2 phase space for all 64 northeast Pacific time series from 2007 to 2008 was significantly greater than the mean for all other year-to-year changes since 1965-66 ($t_{41} = 22.69$, $p < 0.0001$, Figure 83). While the PC scores for more recent years cannot be estimated to assess the persistence of this apparent 2007/08 change in the full data set, PC1 from the reduced data set did not show continuing increases during 2009-11, and PC2 from the reduced data set showed a single anomalous value in 2008, with a return to negative values during 2009-11 (Figure 83). STARS (sequential t-tests for analysis of regime shifts) found no evidence of statistically significant shifts in either of the reduced basin-wide PC time series during 2008-11 (L = 15 years, H = 6 SD, autocorrelation accounted for with IP4N method, $p > 0.05$).

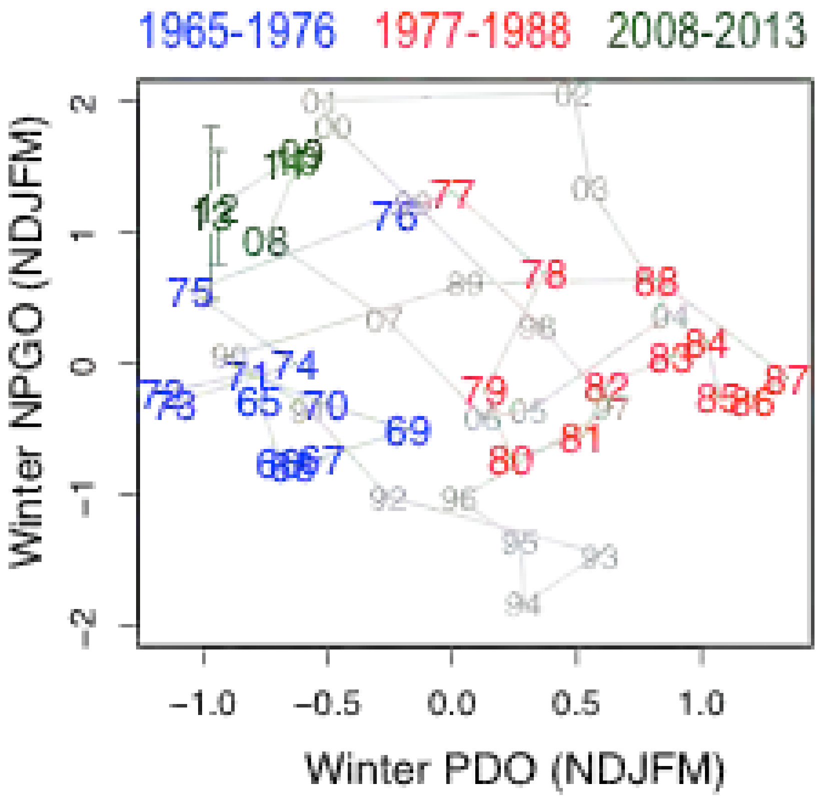


Figure 82: Winter (NDJFM) PDO-NPGO phase space, 1965-2013. Colors highlight recent years (2008-13) and two historical periods of strong PDO influence in the ecosystem (1965-77 and 1978-88). Plotted values are 3-year running means, except for 2013, which is a 2-year mean. Error bars for 2012-13 are 95% CI, reflecting uncertainty associated with estimating 2013 NPGO value.

Alaska-scale - The estimated 2011 value of PC1 for the reduced Alaska-wide data set was above 0, the first positive value in the time series since 1979 (Figure 84a). However, STARS showed no indication of a statistically-significant shift ($p > 0.05$), so these data do not show support for a recent change in this axis of variability. PC1 from the reduced data set is strongly correlated with PC1 from the full data set for the period of overlap (1965-2008, $r = 0.97$), so this result suggests that PC1 for the full data set is likely also not experiencing dramatic change since 2008. PC2 scores from the reduced data set did show a significant shift to more negative values in 2010 (STARS, $P = 0.002$, Figure 84b). However, values of PC2 from the full and reduced data sets are poorly correlated for the years of overlap ($r = 0.48$), so the observed 2010 shift provides weak inference concerning possible change in the second axis of variability across the full community.

Factors influencing observed trends: For the full set of 36 Alaskan time series over 1965-2008, PC1 shows strongest statistical relationships with regional climate change that is independent of basin-scale climate modes, and a weaker relationship with the PDO; PC2 shows strongest statistical relationships with the size of state-wide commercial catches and the NPGO (Litzow et al., 2013). The possibility of a biological response to persistent PDO-negative/NPGO-positive conditions since 2007/08 has received recent attention in the literature (Zwolinski and Demer, 2012; Hatch, 2013; Litzow et al., 2013). Based on historical precedents (e.g., the 1940s and 1970s PDO shifts), the consistent sign in both of these climate modes has the potential to produce abrupt community-level

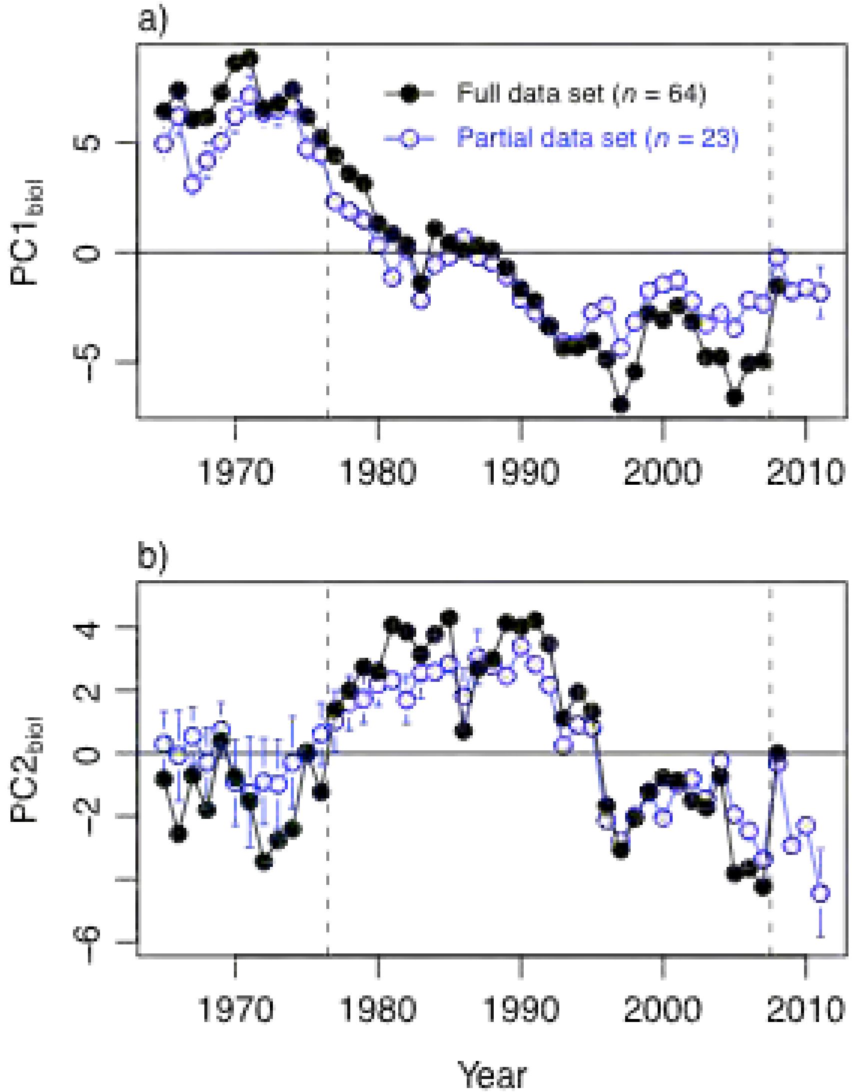


Figure 83: Assessing the evidence for post-2007/08 community-level biological change at the scale of the northeast Pacific. Time series for (a) PC1, and (b) PC2 from complete data set and from a subset of time series that could be updated at least through 2010, which allowed PC scores to be estimated through 2011. Error bars for PC scores calculated from partial data set = 95% CI, and reflect uncertainty associated with estimating missing values. Error bars for PC scores from full data set are omitted for clarity. Dashed vertical lines indicate 1976/77 climate regime shift and possible 2007/08 shift. Redrawn from Litzow and Mueter (in press).

change at basin-wide or Alaskan-wide spatial scales, though at this time only PC2 of the reduced Alaskan data set is showing evidence of a recent shift.

Implications: The apparent absence of any persistent shifts in leading axes of basin-wide biological variability (Figure 83), indicates a continuation of the northeast Pacific ecosystem states that have existed over recent decades (Hare and Mantua, 2000; Litzow et al., 2013). PC1 for Alaskan data tracks the change from abundant crustaceans to abundant salmon and groundfish that occurred in the 1980s, and there is currently no indication of abrupt change in the community state tracked by

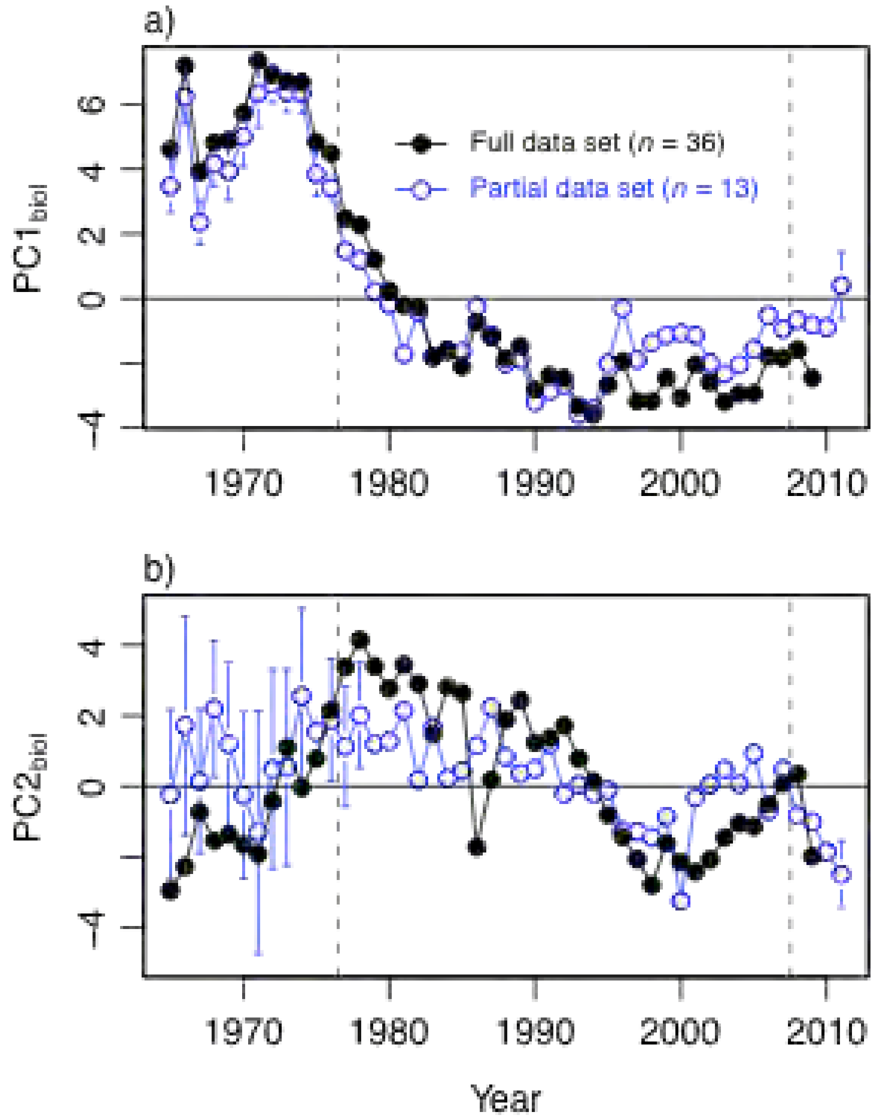


Figure 84: Assessing the evidence for post-2007/08 community-level biological change at the scale of Alaska (Bering Sea and Gulf of Alaska combined). Time series for (a) PC1 and (b) PC2, from complete data set and from a subset of time series that could be updated at least through 2010, which allowed PC scores to be estimated through 2011. Error bars for PC scores calculated from partial data set = 95% CI, and reflect uncertainty associated with estimating missing values. Error bars for PC scores from full data set are omitted for clarity. Dashed vertical lines indicate 1976/77 climate regime shift and possible 2007/08 shift.

this PC (Fig. 3a). The shift to more negative values for PC2 of the restricted Alaskan data suggests a trend of increases in Bering Sea jellyfish abundance and Pacific cod recruitment, increasing pink salmon catches in central and southeast Alaska and increasing coho salmon catches in southeast; and decreases Gulf of Alaska shrimp catches and decreases in the catch of coho salmon in western and central Alaska and sockeye salmon in southeast. Determining the persistence of the apparent change in PC2, and whether it indicates change in the second axis of variability for the larger community, as tracked by the full set of Alaskan time series, will require further years of observation.

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

Contributed by Franz Mueter, University of Alaska Fairbanks, 17101 Point Lena Road, Juneau, AK 99801
Contact: franz.mueter@uaf.edu
Last updated: October 2012

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

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

Contributed by Gerald R. Hoff, Kodiak Laboratory, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: jerry.hoff@noaa.gov
Last updated: September 2013

Description of index: The Hills modified ratio index (Ludwig and Reynolds, 1988; Hill, 1973; Alatalo, 1981; Hoff, 2006) was used as a species evenness and richness index to track the biodiversity and stability in the ecosystem community of the eastern Bering Sea upper continental slope over an eleven year period. The values for the evenness index range between one and zero, where one indicates complete biomass evenness amongst all species and zero indicates that a single species dominates the community. The Richness index describes the number of abundant species and indicates the number of dominant species that make up the community. The two indices together give a picture of the ecosystem health by providing information on diversity and the balance of the community structure. Hills indices are less sensitive to rare species, and therefore minimizes biases from sampling limitations and species recognition in survey data.

Data for indices were gathered from the eastern Bering Sea upper continental slope bottom trawl survey (200-1200m) conducted between 2002 and 2012 by the RACE Division of the Alaska Fisheries Science Center. The survey was conducted biennially between 2002 and 2012 with the exception of 2006 in which the survey was not conducted. The survey design is random-stratified by geographic area and depth with sampling effort being proportional to the estimated size of each stratum. Catch Per Unit Effort (CPUE in kg/ha) of fish and invertebrates was used as a measure of species abundance and used to estimate diversity indices for survey years 2002, 2008, and 2012. Index values were estimated for each haul and then averaged between hauls for each grouping (i.e. subarea or depth).

Status and trends: The richness and evenness indices can be interpreted as indicators of the stability of the EBS slope ecosystem by estimating the level of diversity of the key species driving the predator-prey relationships or competing for other key resources. Both indices suggest relative stability over the eleven year period with higher diversity in the southern and northern ends of the eastern Bering Sea areas (Figure 85). These areas are dominated by major marine canyons (Navarin, Pervenets, Pribilof, Bristol, Bering) with similar habitats. The central EBS showed consistently lower diversity. This area contains one of the world's largest canyon, Zhemchug, and vast stretches of steeper rugged areas between Pribilof and Zhemchug canyons and Zhemchug and Pervenets canyons.

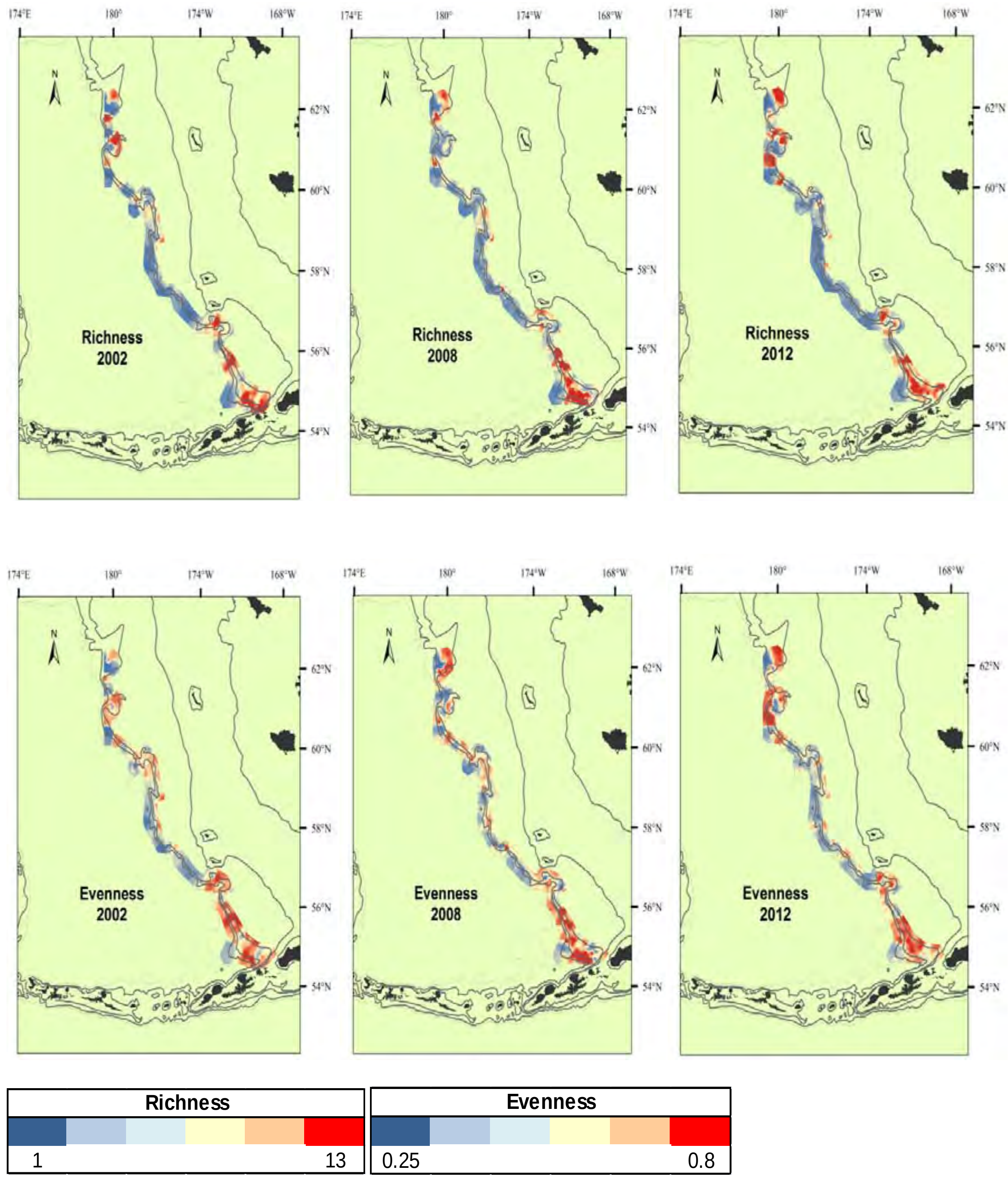


Figure 85: Richness (top) and evenness (bottom) for survey years 2002, 2008, and 2012 for the eastern Bering Sea uppercontinental slope survey.

Factors influencing observed trends: Both fish and invertebrate CPUE from the EBS slope bottom trawl survey serve as a broad indicator of diversity. Although species identification and recognition is given considerable effort during the surveys, some identifier inconsistencies and cryptic species may mask true diversity, especially when considering invertebrates. In addition, trawl catches that are predominantly single species display low diversity when many species may be present but are only minor component of the catch.

Implications: The diversity indices provide a gauge to monitor changes in species composition, which may have implications for ecosystem health. By monitoring trends spatially we can identify areas of changes that may be linked to environmental or anthropogenic activities. The current trends suggest a heterogeneous environment with areas of increased diversity, however trends are relatively stable during the period examined.

Average Local Species Richness and Diversity of the Groundfish Community

Contributed by Franz Mueter[1], Jason Waite[1], and Robert Lauth[2]
[1]University of Alaska Fairbanks, 17101 Point Lena Road, Juneau, AK 99801
[2]Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: franz.mueter@uaf.edu
Last updated: October 2012

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

Combined Standardized Indices of Recruitment and Survival Rate

Contributed by Franz Mueter, University of Alaska Fairbanks, 17101 Point Lena Road, Juneau, AK 99801
Contact: franz.mueter@uaf.edu
Last updated: August 2010

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

Spatial Distribution of Groundfish Stocks in the Eastern Bering Sea

Contributed by Franz Mueter[1], Michael Litzow[2,3] and Robert Lauth[4]
[1]University of Alaska Fairbanks, 17101 Point Lena Road, Juneau, AK 99801
[2]Blue World Research, 2710 E. 20th Ave., Anchorage, AK 99508
[3]University of Tasmania, Private Bag 129, Hobart, TAS, 7001, Australia
[4]Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: franz.mueter@uaf.edu
Last updated: October 2012

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

Ecosystem-Based Management Indicators

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

Ecosystem Goal: Maintain Diversity

Time Trends in Groundfish Discards

Contributed by Jean Lee, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA: and Alaska Fisheries Information Network, Pacific States Marine Fisheries Commission
Contact: jean.lee@noaa.gov
Last updated: August 2013

Description of index: Estimates of discards for 1994-2002 come from NMFS Alaska Region's blend data; estimates for 2003-2012 come from the Alaska Region's catch-accounting system. It should be noted that although these sources provide the best available estimates of discards, the estimates are not necessarily accurate because they are based on visual observations by observers rather than data from direct sampling.

Status and trends: In 1998, the amount of managed groundfish species discarded in federally-managed Alaskan groundfish fisheries dropped to less than 10% of the total groundfish catch in both the Eastern Bering Sea (EBS) and the Gulf of Alaska (GOA) (Figure 86). Discard rates in the Gulf of Alaska have varied over time but were lower on average in 2011 and 2012. Discard rates in the Aleutian Islands (AI) dropped significantly in 1997, trended generally upwards from 1998 through 2003, and have generally declined over the last nine years. As in the EBS and the GOA, both discards and discard rates in the AI are much lower now than they were in 1996.

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

Implications: The management of discards in commercial fisheries is important for the reason that discards add to the total human impact on the biomass without providing a benefit to the

Nation.

Time Trends in Non-Target Species Catch

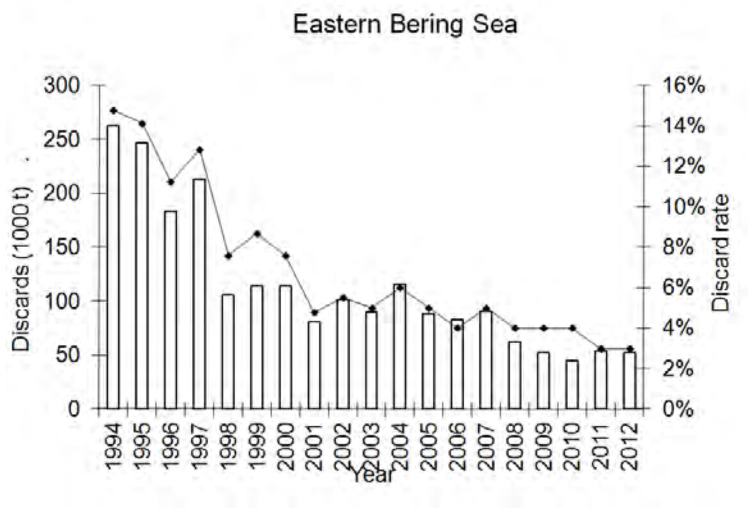
Contributed by Andy Whitehouse[1], Sarah Gaichas[2], and Stephani Zador[3]
[1]Joint Institute for the Study of the Atmosphere and Ocean (JISAO), University of Washington, Seattle WA,
[2]Ecosystem Assessment Program, Northeast Fisheries Science Center, National Marine Fisheries Service, NOAA, Woods Hole MA,
[3]Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: andy.whitehouse@noaa.gov
Last updated: August 2013

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. 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`). The three categories of non-target species we continue to track here are:

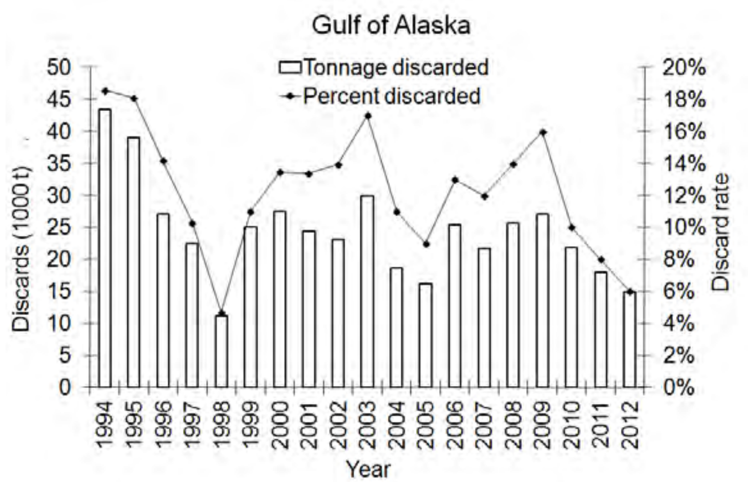
1. Scyphozoan jellyfish
2. species associated with Habitat Areas of Particular Concern-HAPC species (seapens/whips, sponges, anemones, corals, tunicates)
3. Assorted invertebrates (bivalves, brittle stars, hermit crabs, miscellaneous crabs, sea stars, marine worms, snails, sea urchins, sand dollars,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

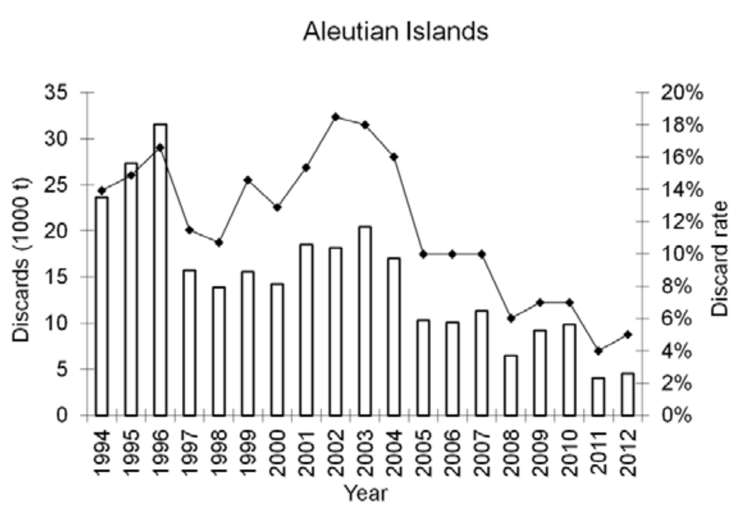
Status and trends: The catch of all three non-target species groups has been highest in the EBS (Figure 87). Scyphozoan jelly catches in the GOA are an order of magnitude lower than the EBS and three orders of magnitude lower in the AI. Catches of HAPC biota are intermediate in the AI and lowest in the GOA. The catches of assorted invertebrates in the GOA are an order of magnitude lower than the EBS, and are lowest in the AI.



(a) EBS



(b) GOA



(c) AI

Figure 86: Total biomass and percent of total catch biomass of managed groundfish discarded in the EBS, GOA, and AI areas, 1994-2012. (Includes only catch counted against federal TACS)

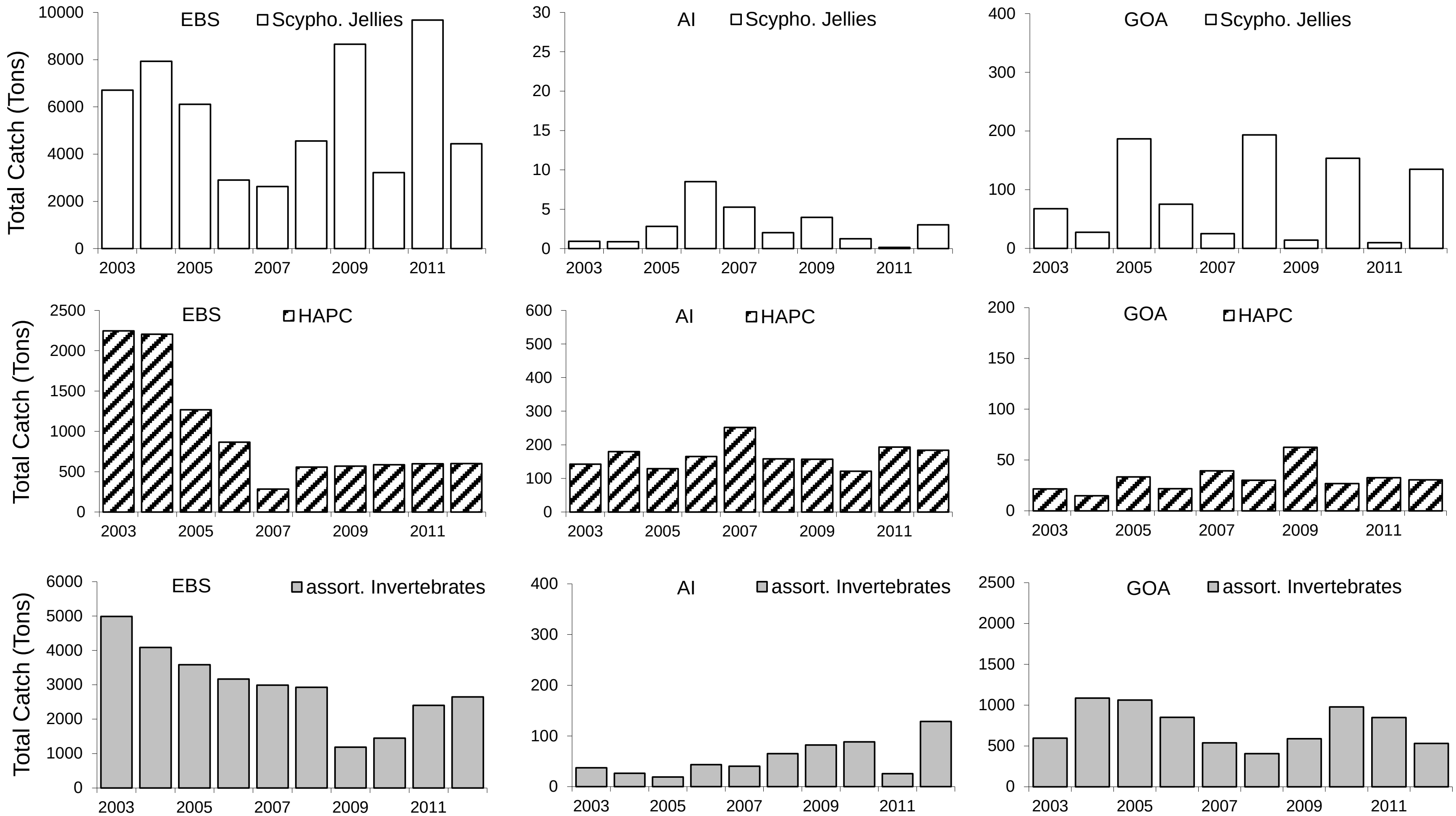


Figure 87: Total catch of non-target species (tons) in the EBS, AI, and GOA groundfish fisheries (2003-2012). **Please note the different y-axis scales** between regions and species groups.

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. 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 in all years except 2009-2012, when sponges and sea anemones increased in importance. Sea stars dominate the catch of assorted invertebrates in all years (2003-2012) and are primarily caught in flatfish fisheries.

In the AI, the catch of Scyphozoan jellies has been variable and shows no apparent trend over time. HAPC catch has been similarly variable over time in the AI, and is driven primarily by sponges caught in the trawl fisheries for Atka mackerel, rockfish and cod. Assorted invertebrate catches have generally trended upward from 2005 to a peak in 2012, 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 jellies in the GOA has been generally consistent and shown little trend over time. Scyphozoan jellies 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.

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 jellies in all three ecosystems may reflect interannual variation in jellyfish biomass or changes in the overlap with fisheries.

Ecosystem Goal: Maintain and Restore Fish Habitats

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

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
Contact: john.v.olson@noaa.gov
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 88, 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.

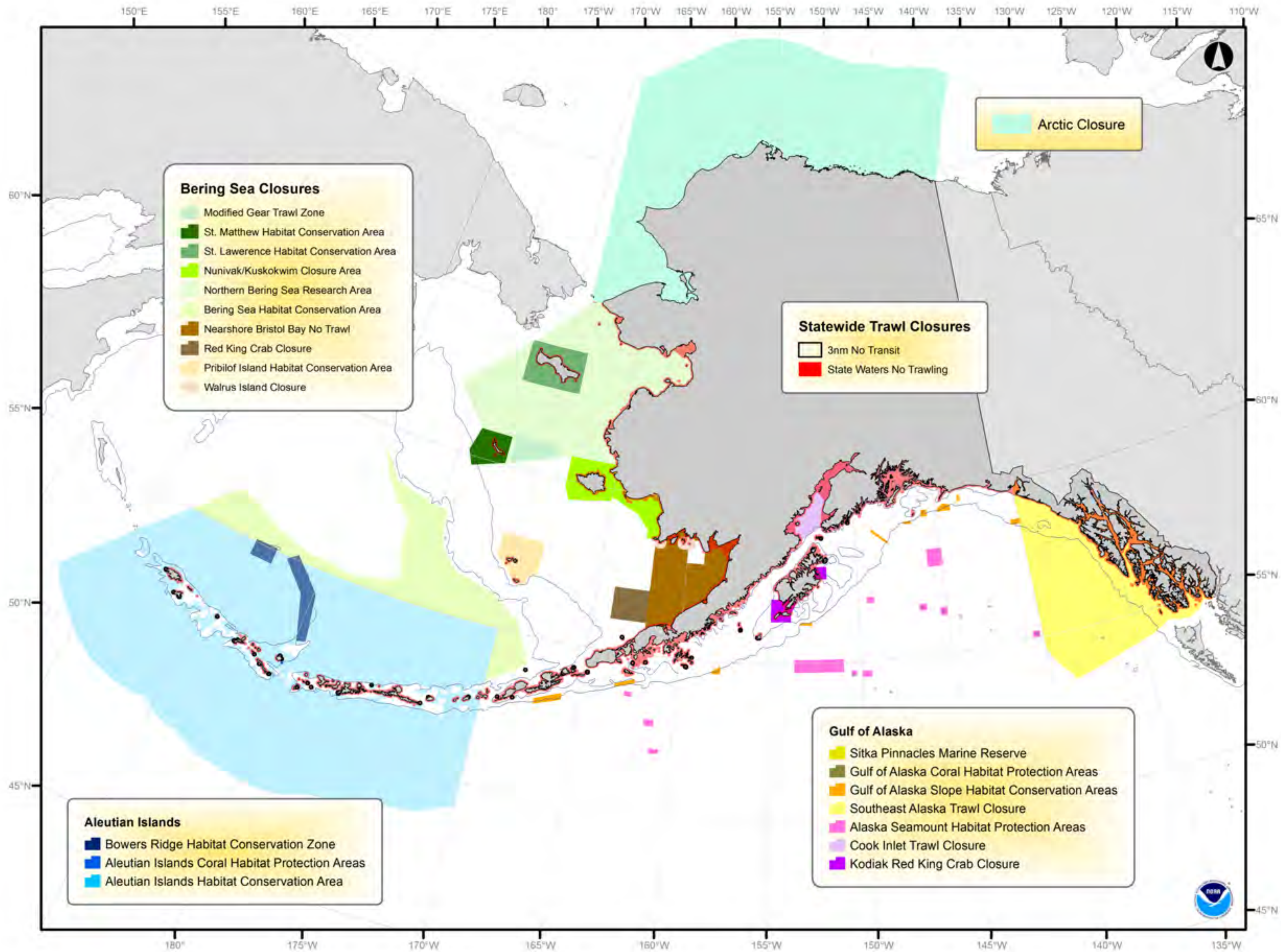


Figure 88: Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska, excluding most SSL closures.

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

Contributed by Angie Greig, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: angie.greig@noaa.gov
Last updated: June 2013

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 1990-2012. 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 89a). 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 89b).

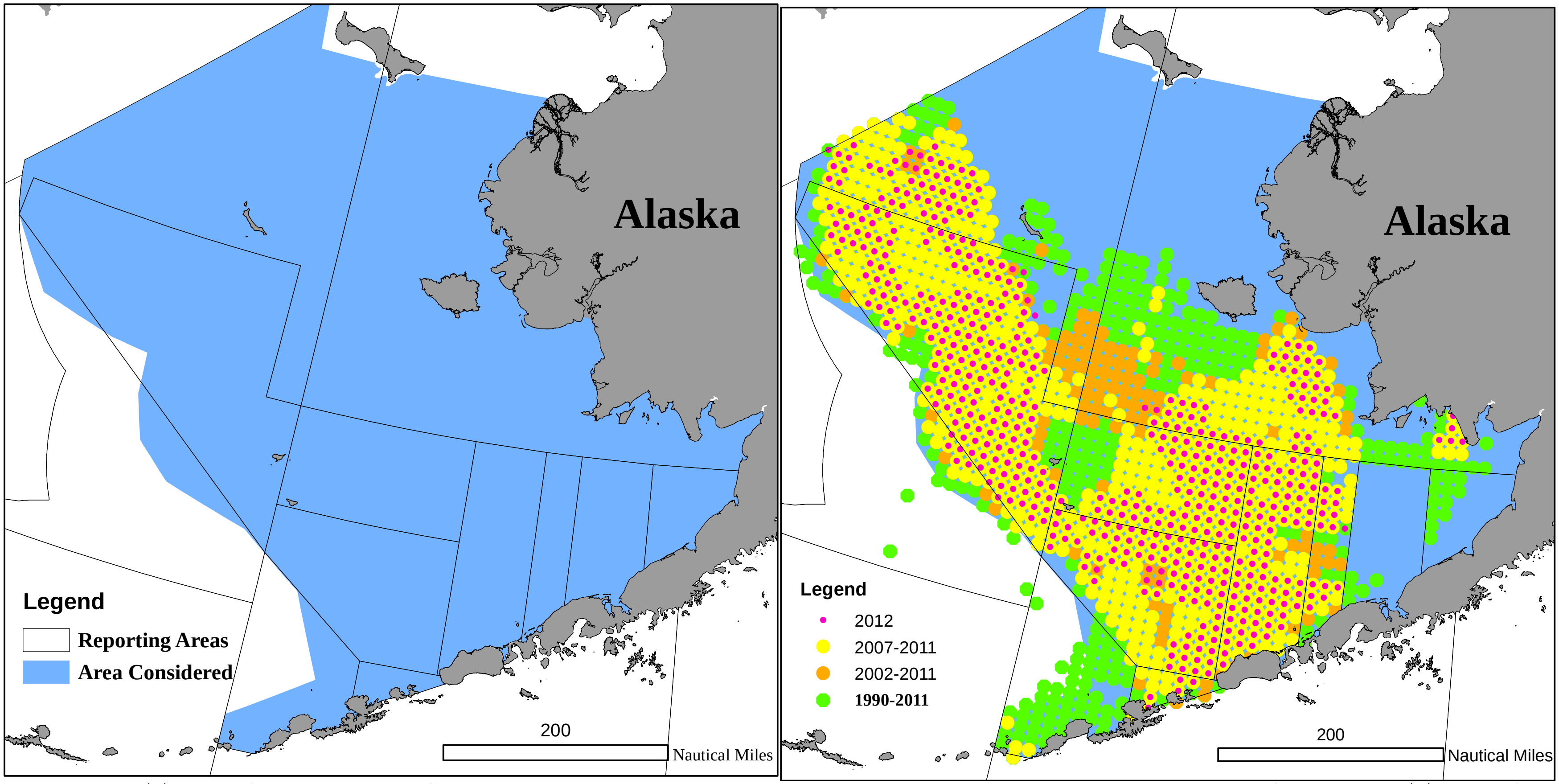


Figure 89: (a) Map of Eastern Bering Sea area considered when estimating percent area potentially disturbed by trawl fishing gear. (b) Map of 400 square kilometer cells with some trawling in cumulative time periods. Cells with fewer than 3 vessels are not shown

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

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

During 1993-1999, fishing effort was more concentrated in the southern area compared to 1990-1992 and 2000-2008, where effort was spread out spatially, particularly towards the northwest. This may, in part, explain the larger difference between the upper and lower estimates of percent area disturbed (with no overlap and with overlap within 400 km^2 cells, respectively) during 1993-1998 relative to other years (Figure 90).

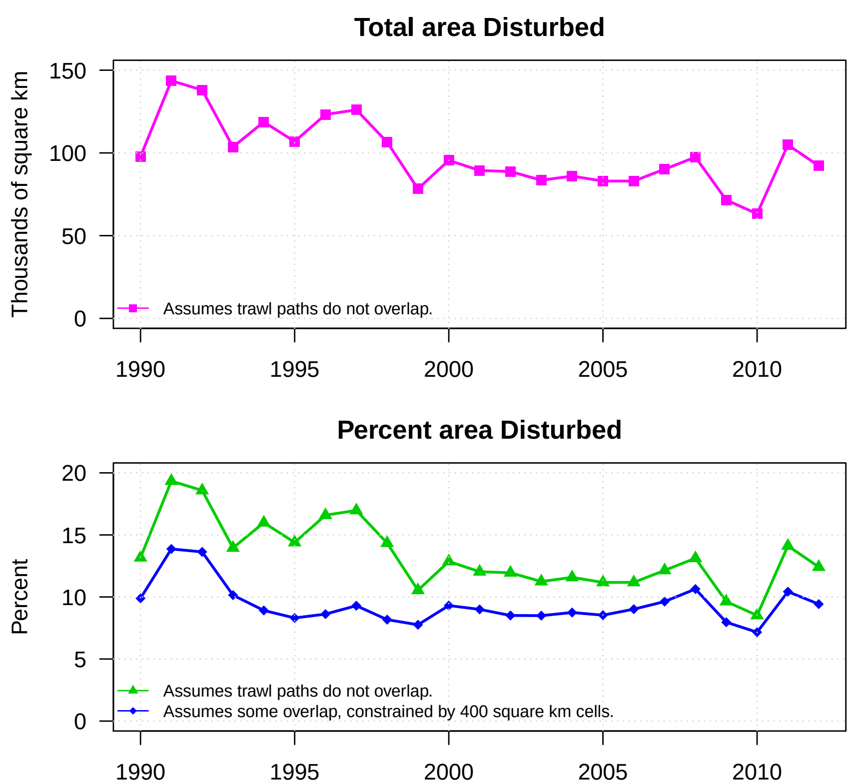


Figure 90: Total maximum potential area disturbed (assuming no spatial overlap of trawls), and the percent area disturbed. The green line, representing percent area disturbed, sums the area disturbed assuming no spatial overlap of trawl hauls in a year, thus providing an upper limit to the estimate of area disturbed. The blue line represents the percent area disturbed with spatial overlap of trawl hauls within 400 km^2 cells, thereby, limiting the disturbance of trawls recorded in a cell to 400 km^2.

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

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

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

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
Contact: john.v.olson@noaa.gov
Last updated: August 2013

Description of index: Observed fishing effort (as measured by observed longline sets) 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/`.

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.

Status and trends: Effort in the longline fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 91.

Bering Sea. For the period 2003-2012, there were a total of 133,338 observed longline sets in the Bering Sea fisheries. Spatial patterns of fishing effort were summarized on a 10 km^2 grid (Figure 92). 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 93).

Aleutian Islands. 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

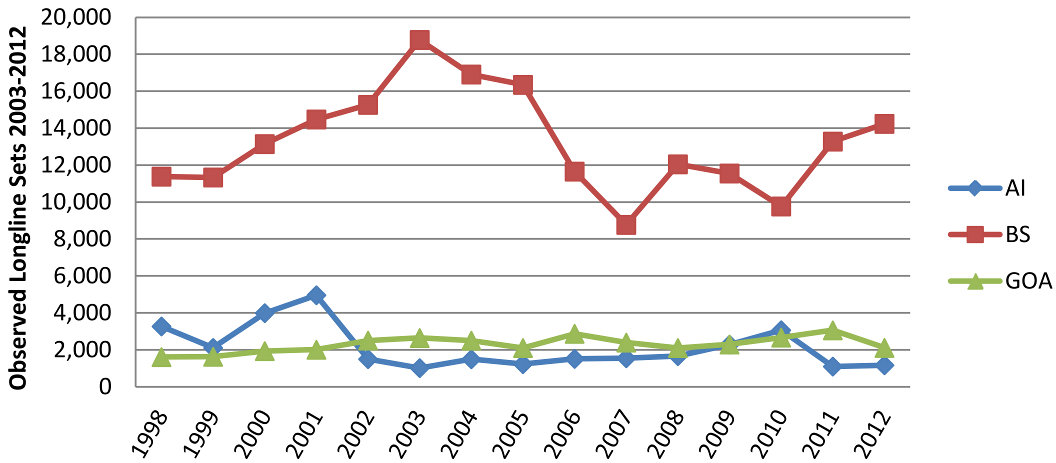


Figure 91: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of longline sets, 1990-2012.

dispersed over a wide area. Patterns of high fishing effort were dispersed along the shelf edge (Figure 94). 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 95).

Gulf of Alaska. 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 96). 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 97).

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

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

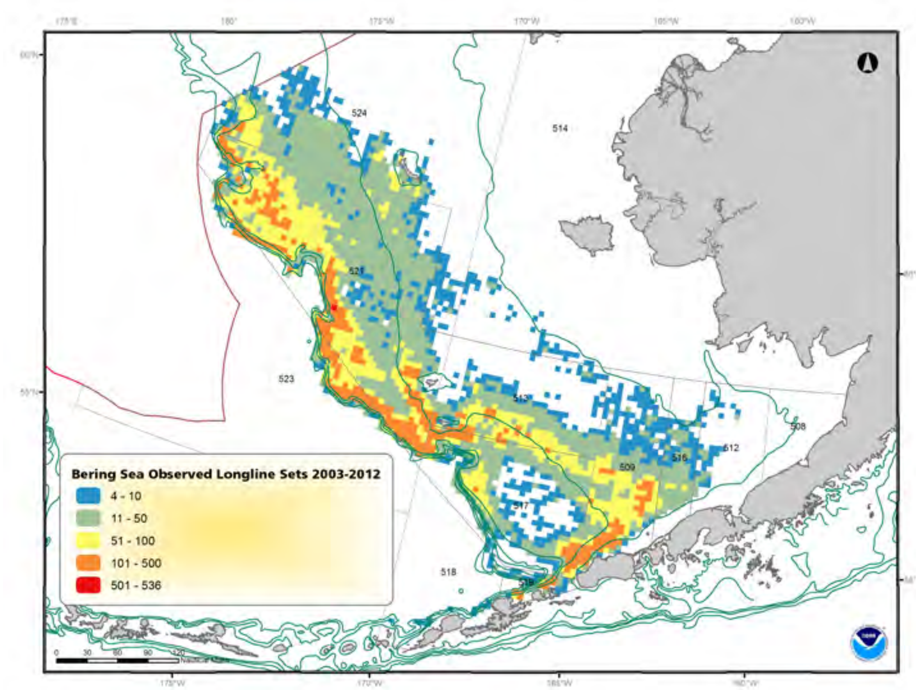


Figure 92: Observed longline effort (sets) in the Bering Sea 2003-2012.

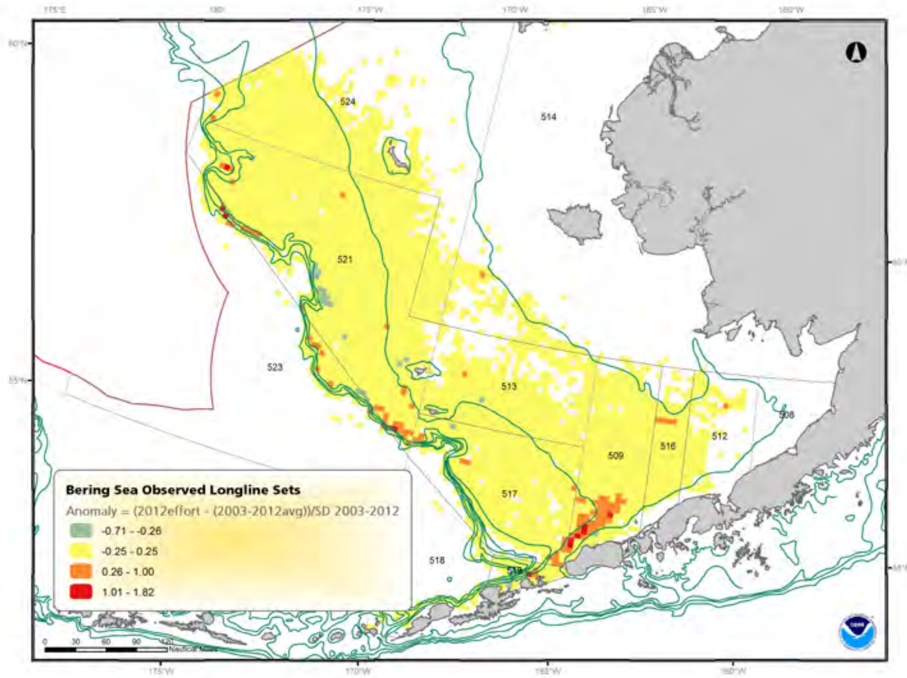


Figure 93: Observed longline fishing effort in 2011 relative to the 2003-2012 average in the Bering Sea. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

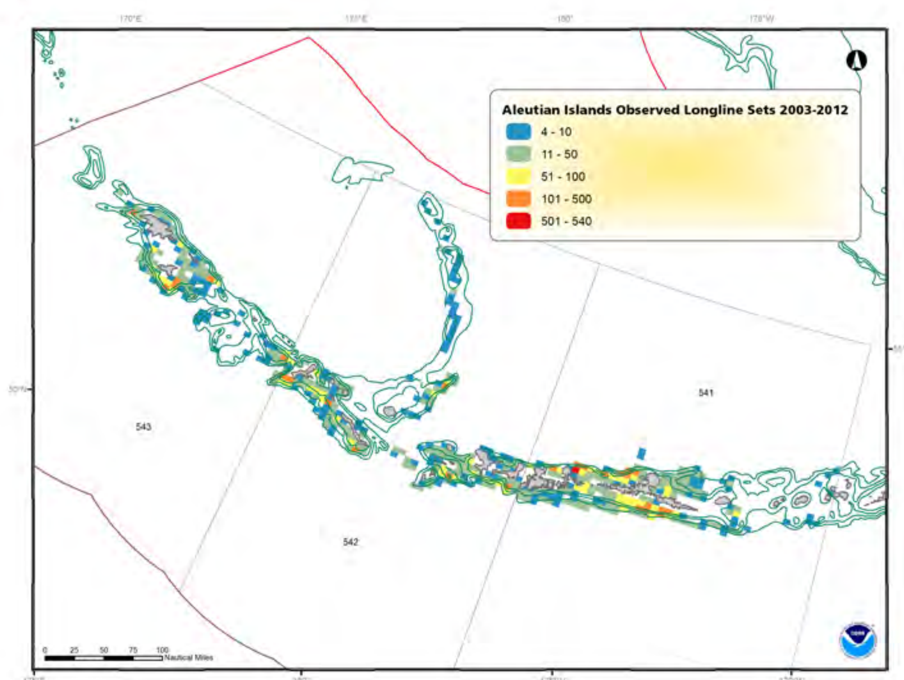


Figure 94: Observed longline effort (sets) in the Aleutian Islands, 2003-2012.

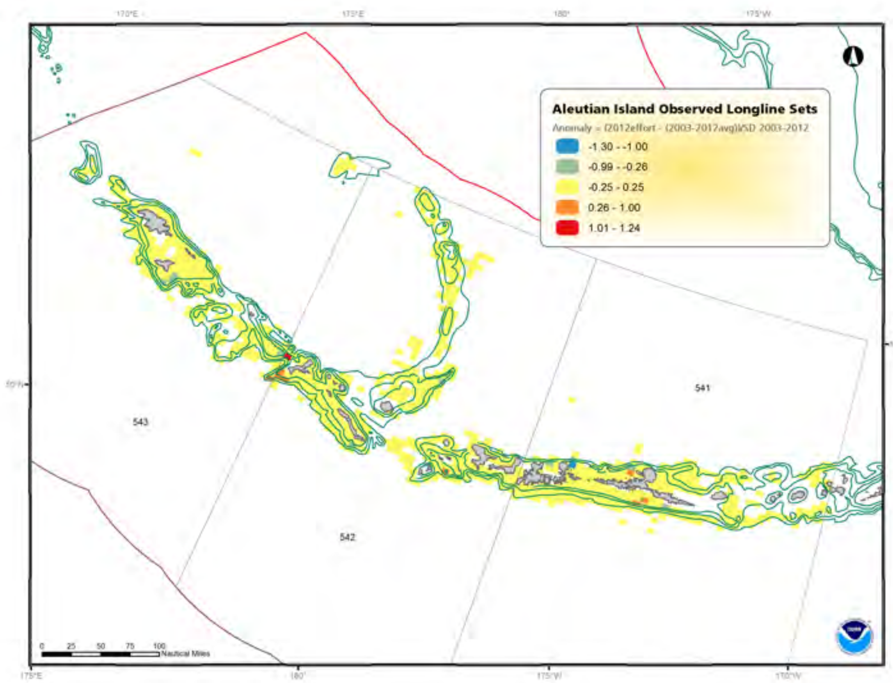


Figure 95: Observed longline fishing effort in 2011 relative to the 2003-2012 average in the Aleutian Islands. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

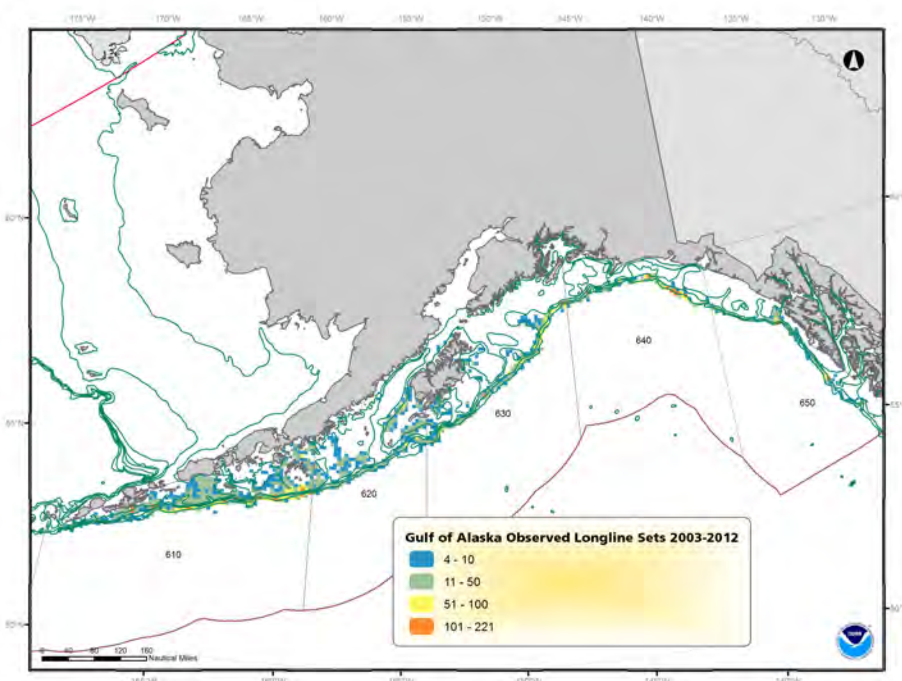


Figure 96: Observed longline effort (sets) in the Gulf of Alaska, 2003-2012.

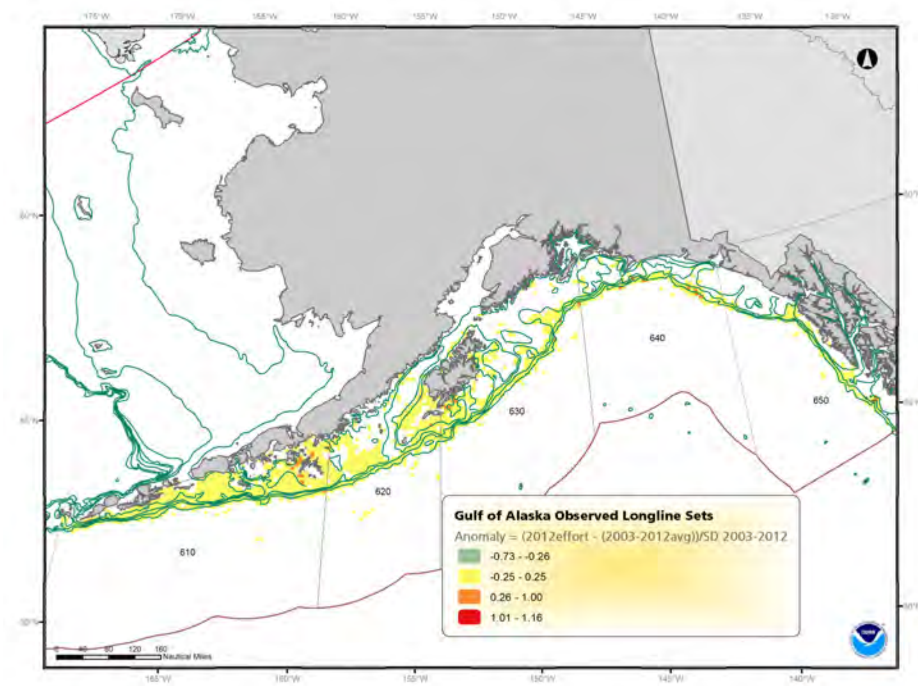


Figure 97: Observed longline fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

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

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
Contact: john.v.olson@noaa.gov
Last updated: August 2013

Description of index: Observed fishing effort (as measured by observed tows) 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/. 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.

Status and trends: In general, bottom trawl effort in the Bering Sea, Aleutian Islands, and Gulf of Alaska has been relative steady or slightly declining since 1998 (Figure 98). The magnitude of the Bering Sea trawl fisheries is more than four as large (in terms of effort) as the Aleutian Islands and Gulf of Alaska fisheries combined. Fluctuations in fishing effort track well with overall landings of primary bottom trawl target species, such as flatfish and to a lesser extent cod and pollock. As of 1999, only pelagic trawls can be used in the Bering Sea pollock fisheries.

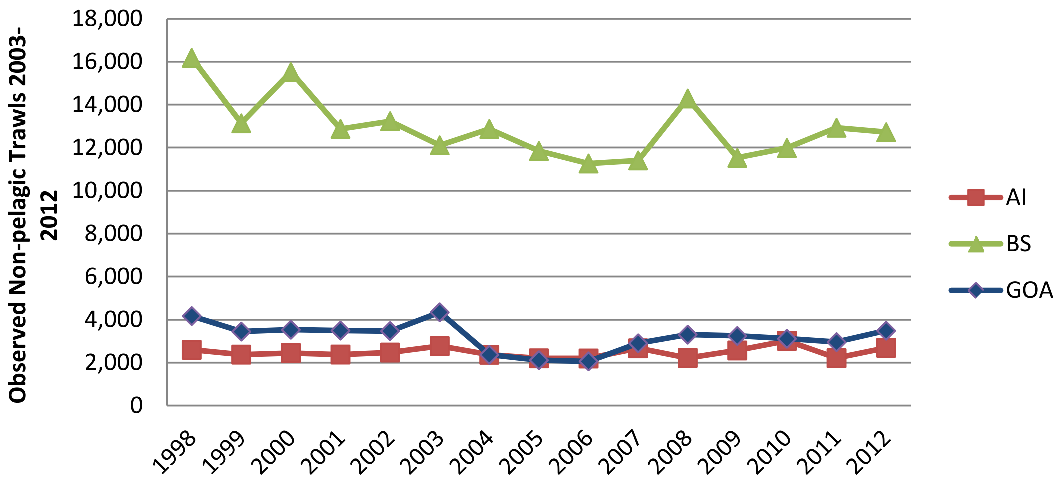


Figure 98: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of bottom trawl tows, 1990-2012.

Bering Sea. 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 99). 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 100).

Aleutian Islands. 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 101). 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 102). 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.

Gulf of Alaska. 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 103). 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 104).

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

Implications: Fishing effort is an indicator of damage to or removal of both living and nonliving bottom substrates, damage to small epifauna and infauna, and reduction in benthic biodiversity by mobile (trawl) or fixed (longline, pot) gear. Intensive fishing in an area can result in a change in species diversity by attracting opportunistic fish species which feed on animals that have been disturbed in the wake of the tow, or by reducing the suitability of habitat used by some species. Trends in fishing effort will reflect changes due to temporal, geographic, and market variability of fisheries as well as management actions. These changes in effort can be observed by examining effort for the current year relative to the average effort in prior years of fishing

The effects of changes in fishing effort on habitat are largely unknown. It is possible that the reduction in bottom trawl effort in all three ecosystems could result in decreased habitat loss/degradation due to fishing gear effects on benthic habitat and other species. The footprint of habitat damage likely varies with gear (type, weight, towing speed, depth of penetration), the physical and biological characteristics of the areas fished, recovery rates of living substrates in the areas fished, and management changes that result in spatial redistribution of fishing effort (NMFS, 2007)(`http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm`). Also, much of the fleet in the Bering Sea has adopted the use of sweep modifications on their nets.

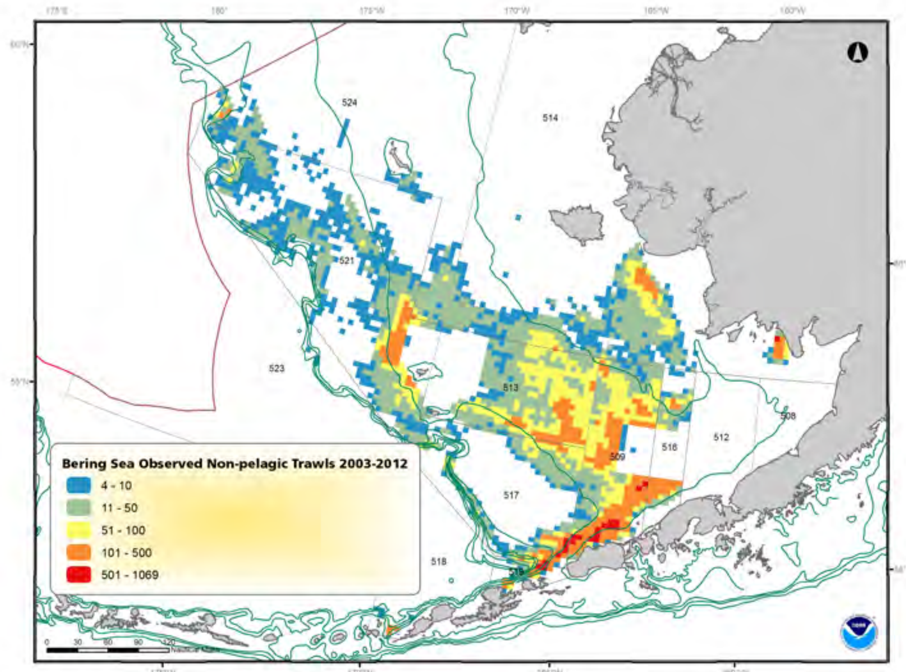


Figure 99: Spatial location and density of observed bottom trawling in the Bering Sea 1998-2012.

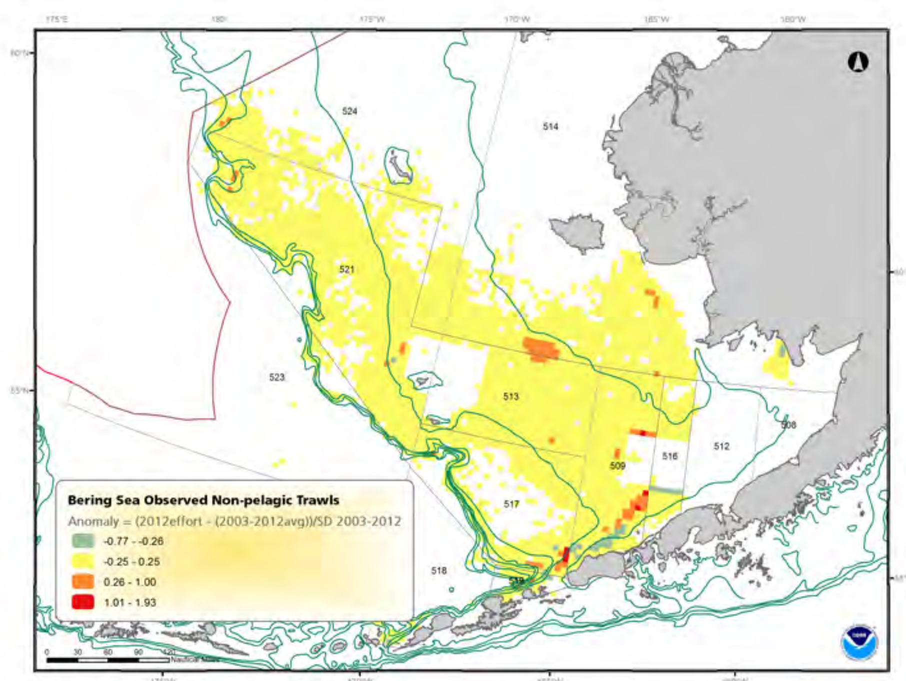


Figure 100: Observed bottom trawl fishing effort in 2012 relative to the 2003-2012 average in the Bering Sea. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

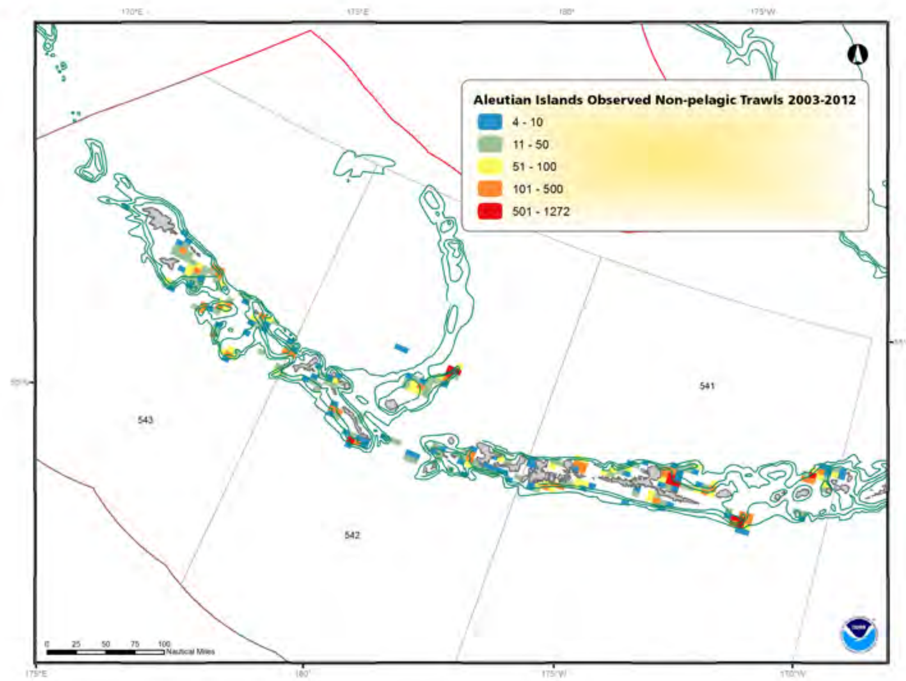


Figure 101: Spatial location and density of observed bottom trawl effort in the Aleutian Islands, 1998-2012.

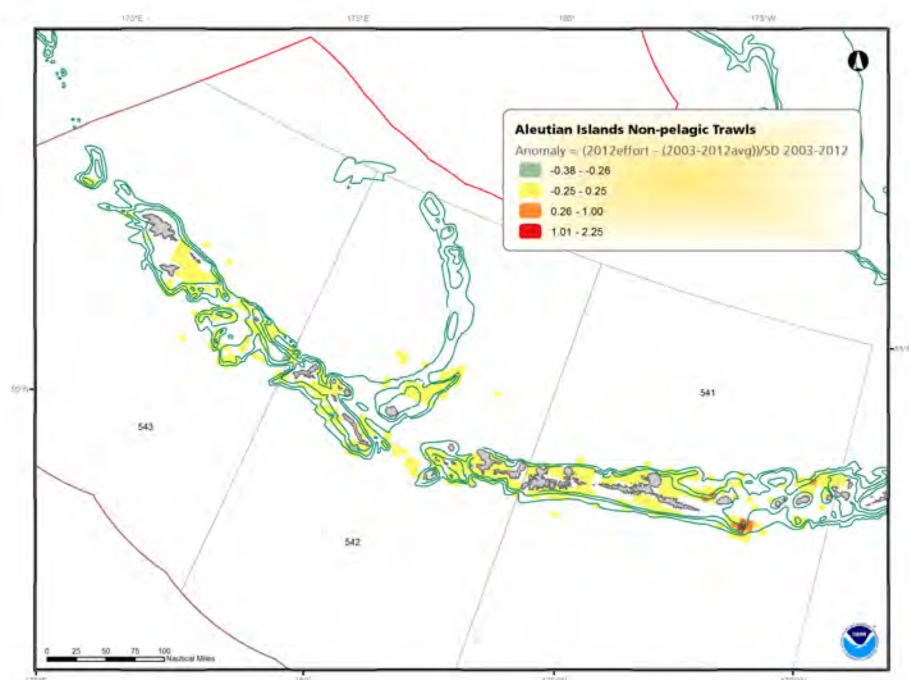


Figure 102: Observed bottom trawl fishing effort in 2012 relative to the 2003-2012 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

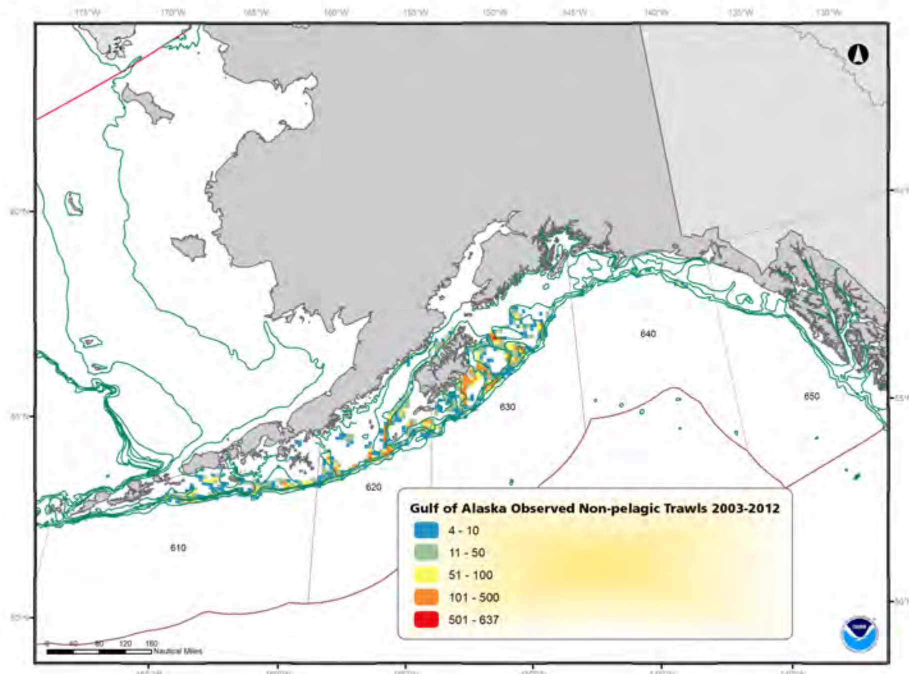


Figure 103: Spatial location and density of observed bottom trawl effort in the Gulf of Alaska, 1998-2012.

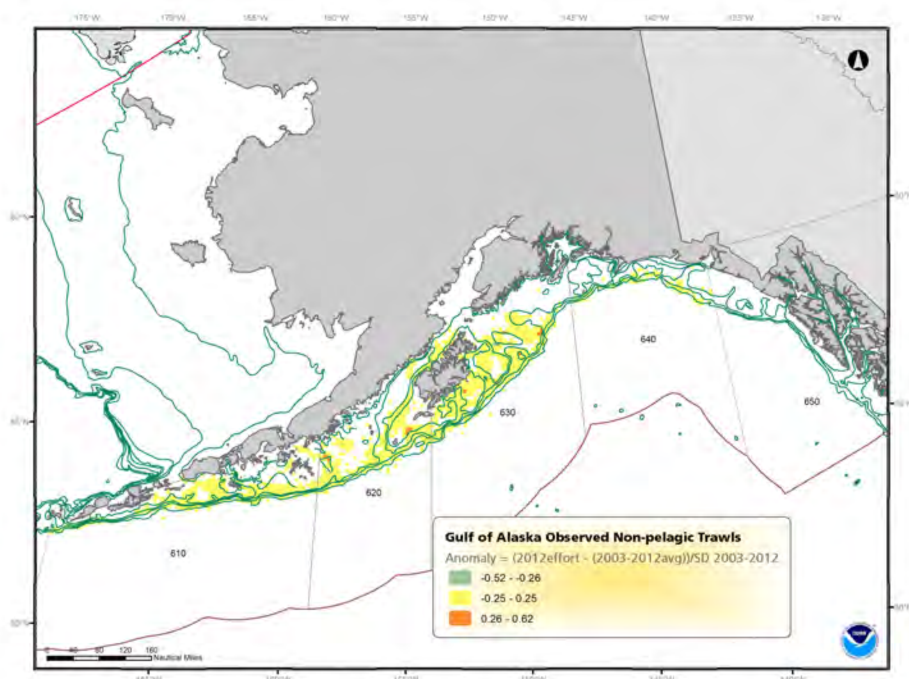


Figure 104: Observed bottom trawl fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

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

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
Contact: john.v.olson@noaa.gov
Last updated: August 2013

Description of index: Observed fishing effort (as measured by observed tows) 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/.

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.

Status and trends: Effort in the pelagic trawl fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 105. The magnitude of the Bering Sea trawl fisheries effort is four times larger than effort in both the Gulf of Alaska and Aleutian Islands (which has had no significant effort since 1998 and zero effort in 2011 and 2012) combined. While this fishery is much larger than in the other two regions, smaller vessels that only require 30% observer coverage occur in larger proportions in the GOA resulting in less documented fishing effort. Figures 107, 107, and 109 show the spatial patterns and intensity of pelagic trawl effort by region, based on observed data.

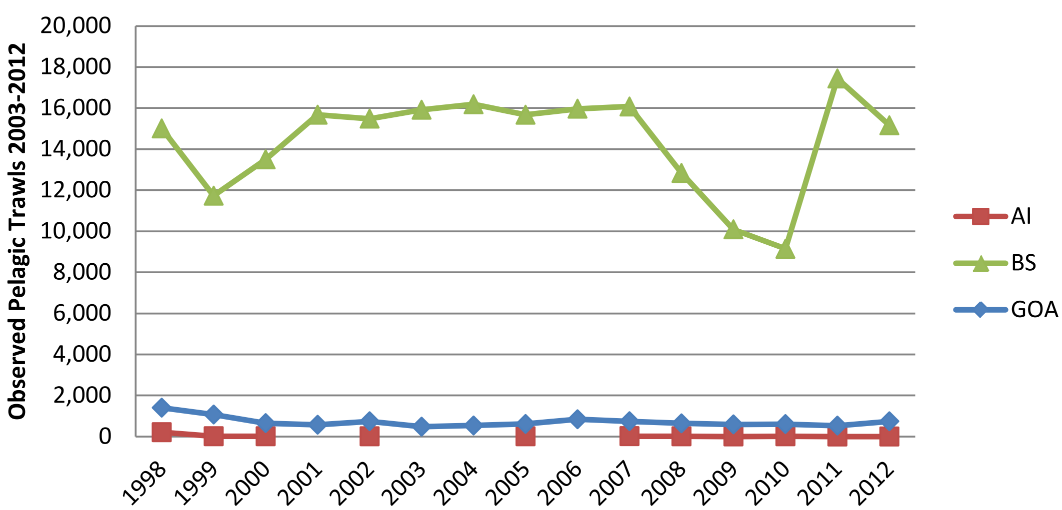


Figure 105: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of pelagic trawl tows, 1990-2012.

Bering Sea. For the period 2003-2012 there were 144,486 observed pelagic trawl tows in the Bering Sea (Figure 106). 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 107). 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.

Aleutian Islands. For the period 2003-2012 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.

Gulf of Alaska. The primary target of the GOA pelagic trawl fishery is pollock (Figure 108). 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 109).

Factors causing observed trends: Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures), changes in markets, changes in environmental conditions, and increased bycatch rates of non-target species. The Bering Sea pollock fishery is the largest volume U.S. Fishery, and most pollock is harvested with pelagic trawl nets. Effort in the Bering Sea 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. Effort in both the GOA and AI has trended downward in the last decade, in part due to restricted fishing from Steller sea lion protection measures.

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

Pollock fishermen formed fish harvesting cooperatives to "rationalize" fishing activities, including resolving problems of overcapacity, promoting conservation and enhancing utilization of fishery resources. Under a co-op arrangement, fewer vessels are fishing and daily catch rates by participating vessels are significantly reduced since the "race for fish" ended in 1999. Bering Sea chinook and chum bycatch led to NPFMC action limiting the total bycatch of these species. More information is available at http://www.fakr.noaa.gov/npfmc/bycatch-controls/BSChinookBycatch.html.

Management measurements have affected the pelagic trawl fishing effort in the Aleutian Islands. In recent years pollock fishing in the Aleutian Islands has been restricted by the Stellar Sea Lion Closures. The western distinct population segment of Steller sea lions occurs in the Aleutian Islands subarea and is listed as endangered under the Endangered Species Act (ESA). Critical habitat has been designated for this area, including waters within 20 nautical miles (nm) of haulouts and rookeries. Pollock is a principal prey species of Steller sea lions.

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

Implications: Fishing effort is an indicator of damage to or removal of both living and nonliving bottom substrates, damage to small epifauna and infauna, and reduction in benthic biodiversity by mobile (trawl) or fixed (longline, pot) gear. Intensive fishing in an area can result in a change in species diversity by attracting opportunistic fish species which feed on animals that have been disturbed in the wake of the tow, or by reducing the suitability of habitat used by some species. Trends in fishing effort will reflect changes due to temporal, geographic, and market variability of fisheries as well as management actions. These changes in effort can be observed by examining effort for the current year relative to the average effort in prior years of fishing

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

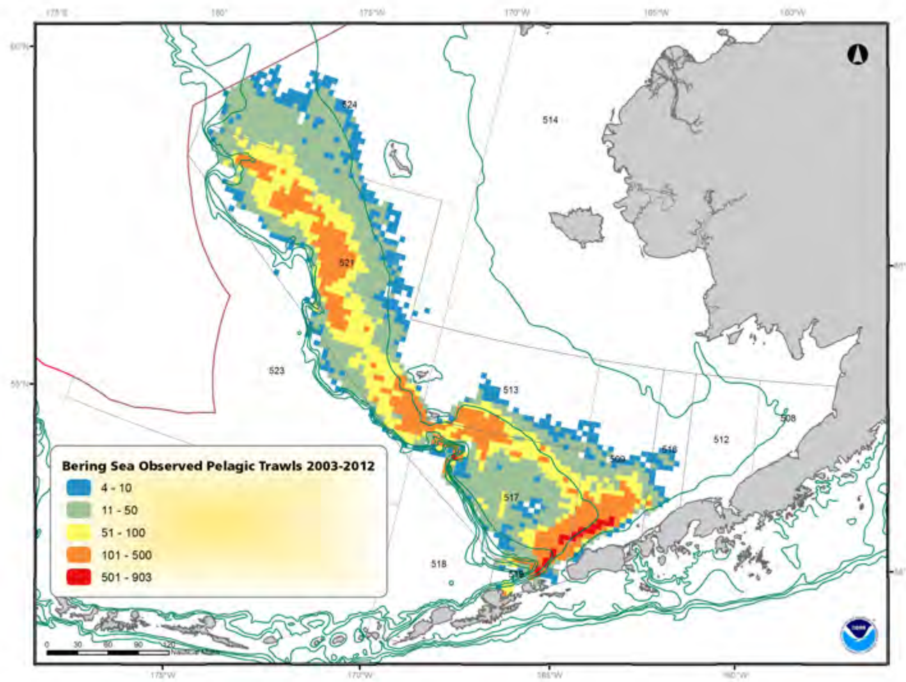


Figure 106: Spatial location and density of observed pelagic trawling in the Bering Sea 1998-2012.

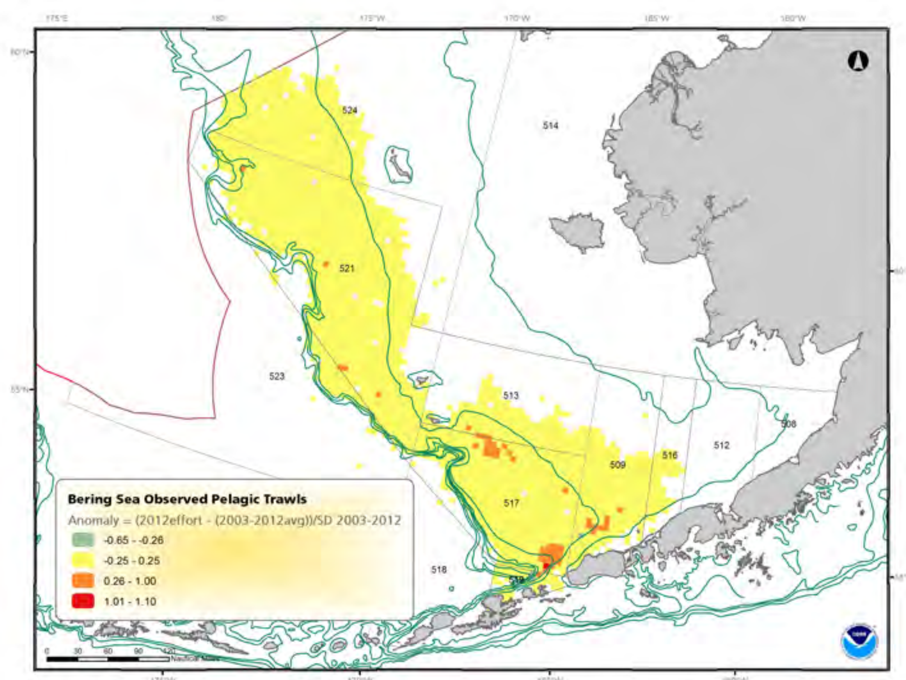


Figure 107: Observed pelagic trawl fishing effort in 2012 relative to the 2003-2012 average in the Bering Sea. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

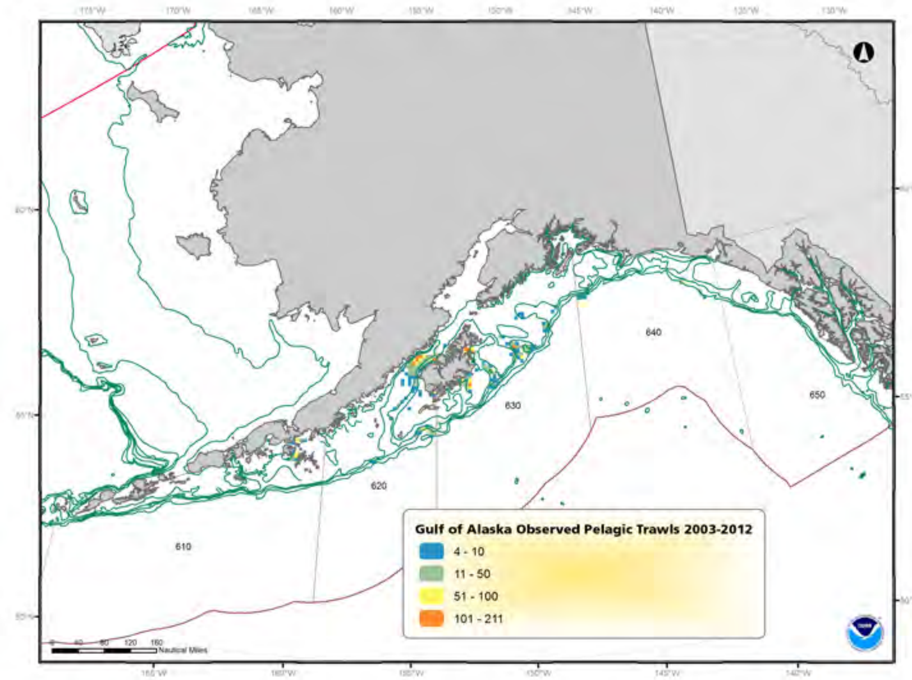


Figure 108: Spatial location and density of observed pelagic trawl effort in the Gulf of Alaska, 1998-2012.

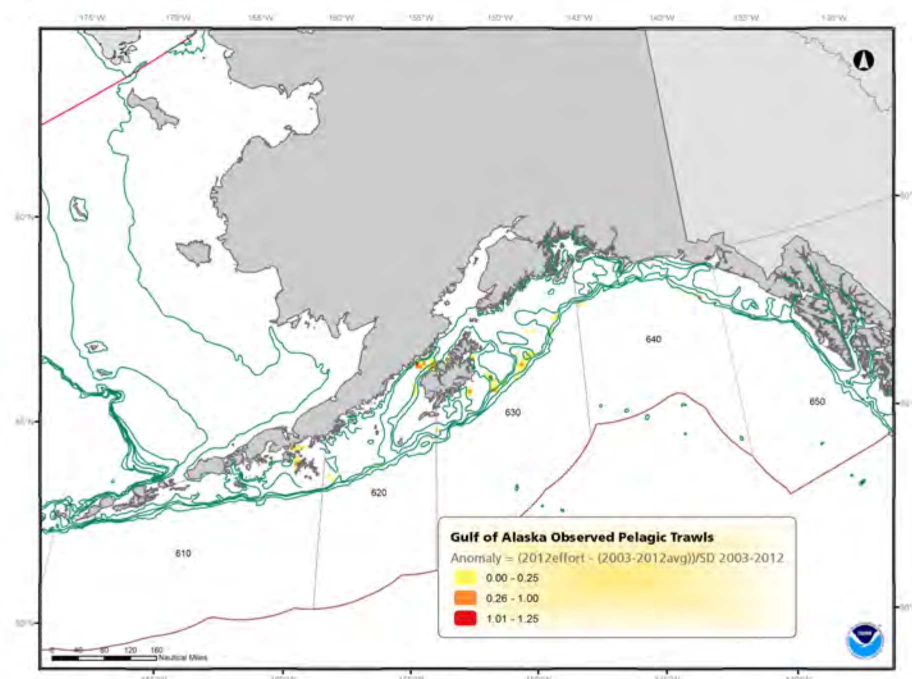


Figure 109: Observed pelagic trawl fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

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

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
Contact: john.v.olson@noaa.gov
Last updated: August 2013

Description of index: Observed fishing effort (as measured by observed pot lifts) 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/. 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: The observed pot fishing effort has increased in both the Bering Sea and Gulf of Alaska since 2010. Effort in the pot fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 110.

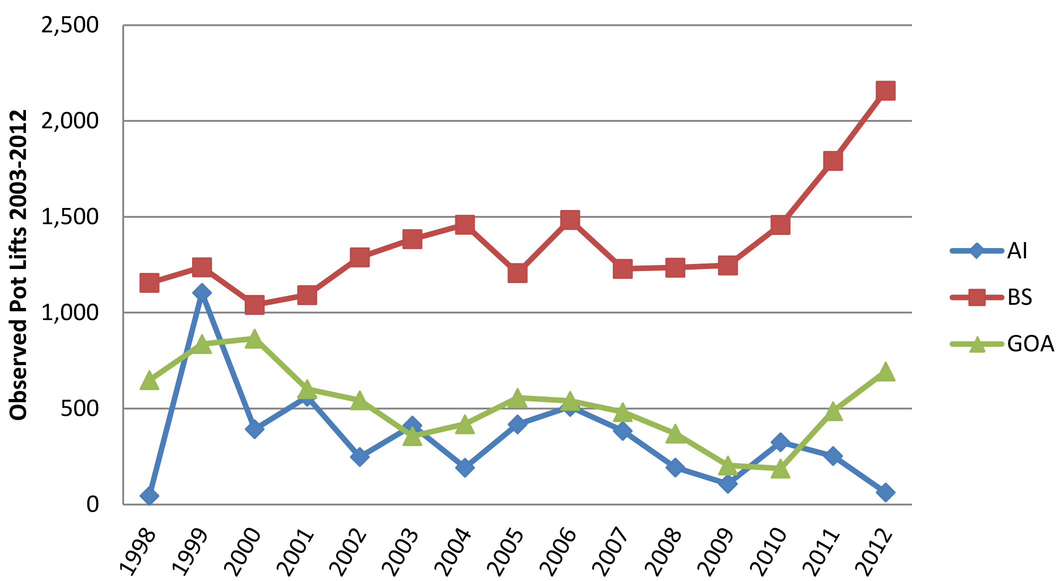


Figure 110: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of pot lifts, 1998-2012.

Bering Sea. 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 111). 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 112). 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.

Aleutian Islands. 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 113). In 2012, the fishing anomaly throughout the region was minimal (Figure 114).

Gulf of Alaska. 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 115). 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 116). 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.

Factors causing observed trends: Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures, crab and habitat closures) as well as changes in markets and increased bycatch rates of non-target species. The pot fishery occurs mainly for Pacific cod which form dense spawning aggregations in the winter months. In the Bering Sea, fluctuations in the pot cod fishery may be dependent on the duration and timing of crab fisheries. There is also a state-managed fishery in State waters.

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

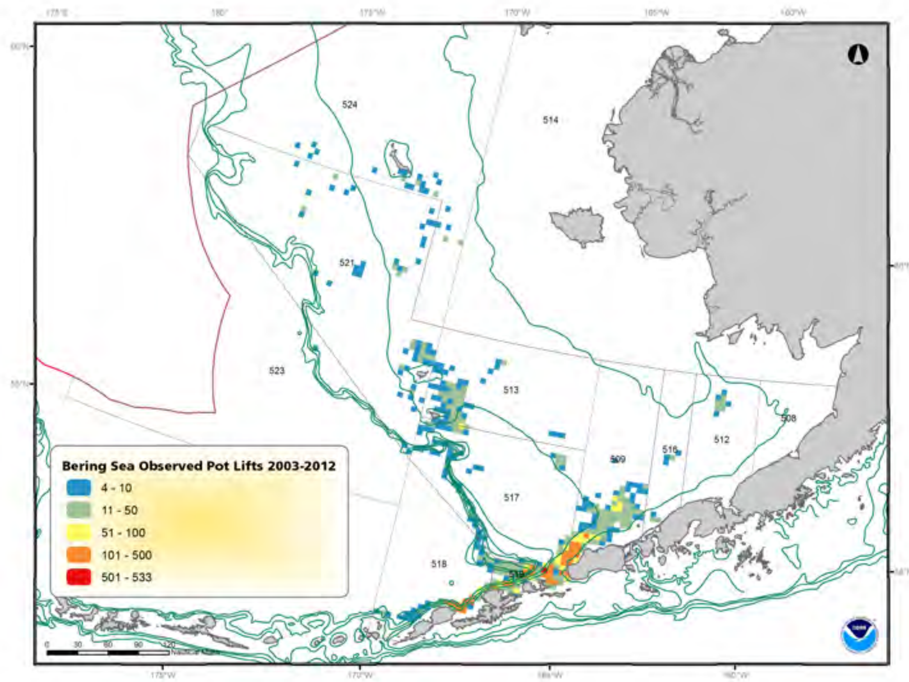


Figure 111: Spatial location and density of pot effort (observed number of pot lifts) in the Bering Sea 1998-2012.

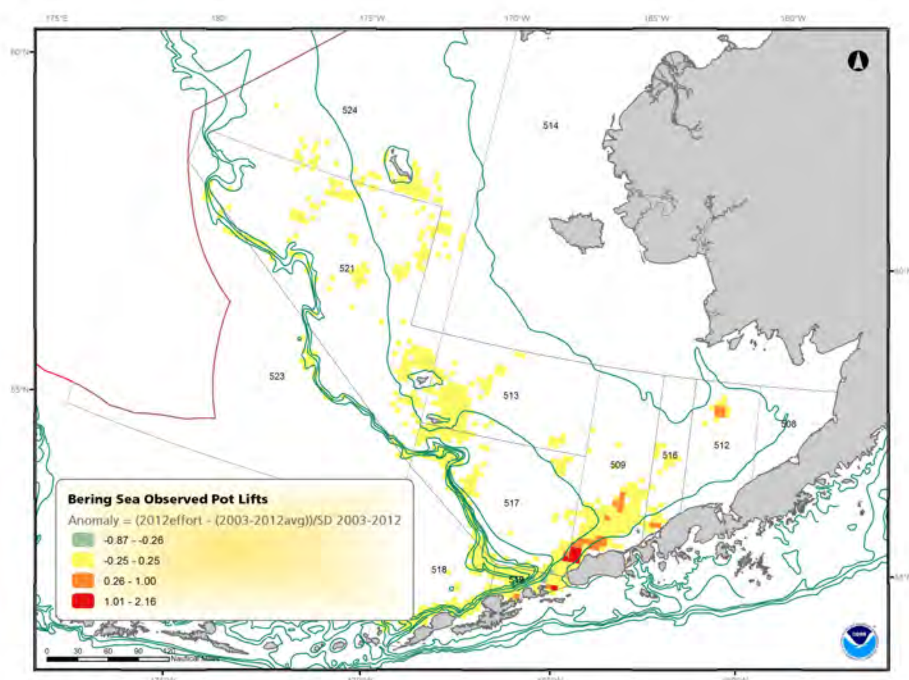


Figure 112: Observed pot fishing effort in 2012 relative to the 2003-2012 average in the Bering Sea. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

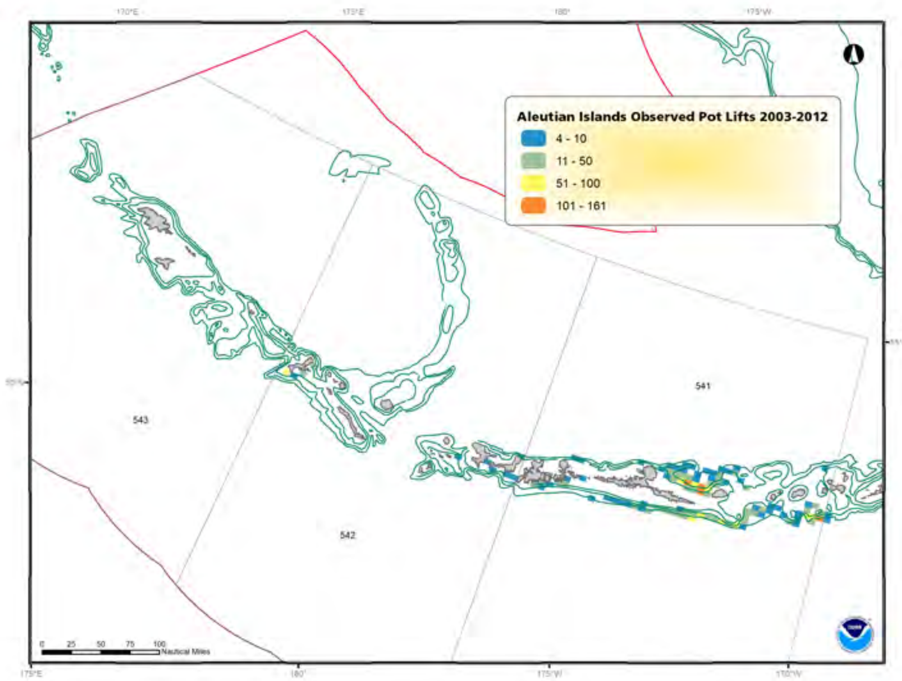


Figure 113: Spatial location and density of pot effort (observed number of pot lifts) in the Aleutian Islands, 1998-2012.

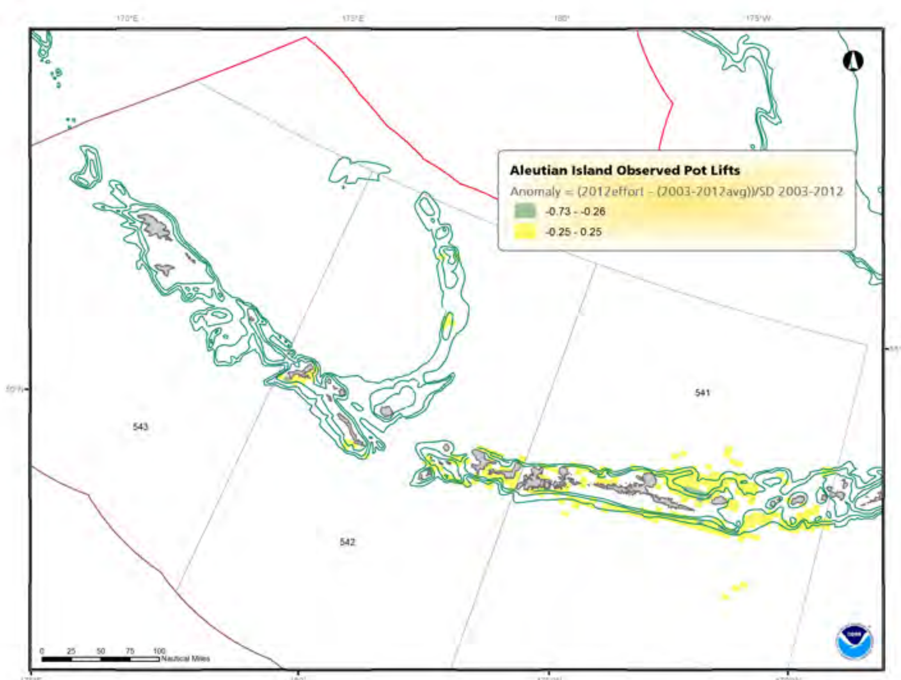


Figure 114: Observed pot fishing effort in 2012 relative to the 2003-2012 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

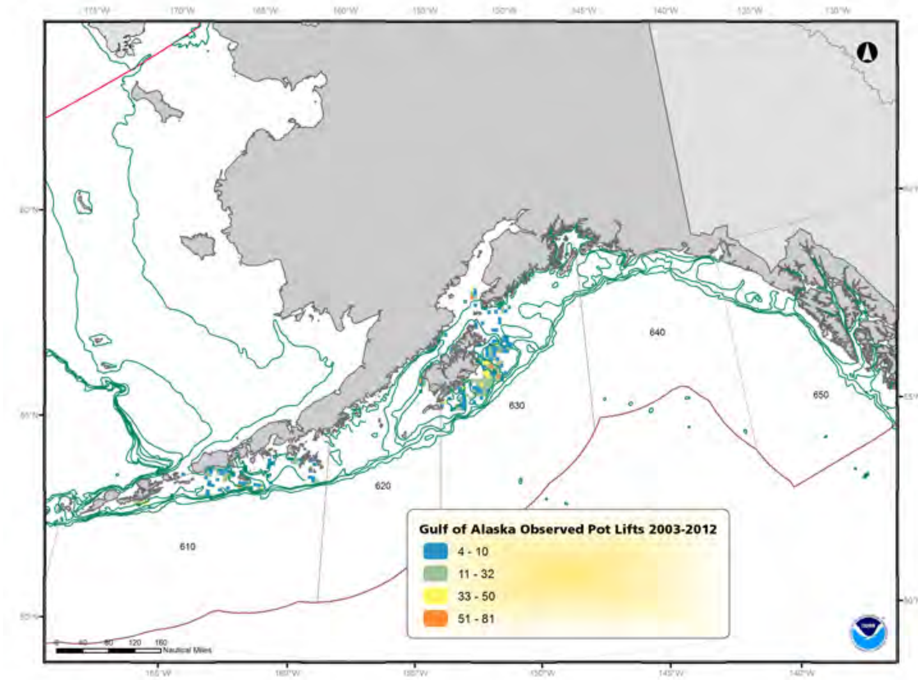


Figure 115: Spatial location and density of pot effort (observed number of pot lifts) in the Gulf of Alaska, 1998-2012.

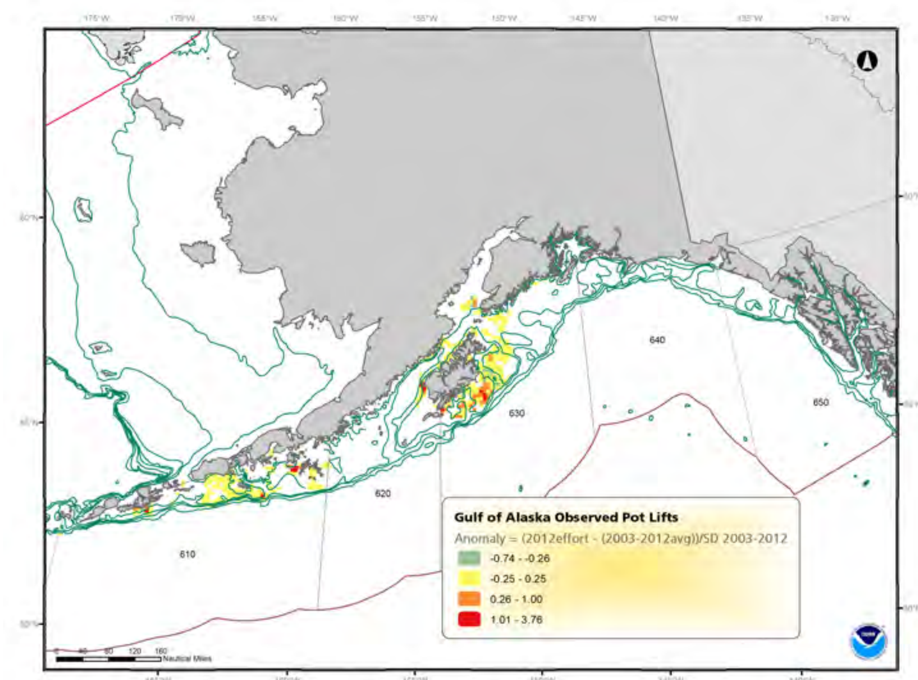


Figure 116: Observed pot fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

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

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

Contributed by Andy Whitehouse, Joint Institute for the Study of the Atmosphere and Ocean (JISAO), University of Washington, Seattle, WA
Contact: andy.whitehouse@noaa.gov
Last updated: August 2013

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

1. Stock has known status determinations:
   (a) overfishing 0.5
   (b) overfished 0.5
2. Fishing mortality rate is below the "overfishing" level defined for the stock 1.0
3. Biomass is above the "overfished" level defined for the stock 1.0
4. Biomass is at or above 80% of 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 230 FSSI stocks in the U.S., with a maximum possible score of 920. 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 29 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, 2013, 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 the tenth year of a 10-year rebuilding plan. Of the non-FSSI stocks, only the BSAI octopus complex is subject to overfishing, and none of the non-FSSI stocks are overfished or approaching an overfished condition (Table 14).

The current overall Alaska FSSI is 122.5 out of a possible 140, based on updates through June 2013 (Table 13). The overall Bering Sea/Aleutian Islands score is 82 out of a possible maximum score of 92. The BSAI groundfish score is 54 (including BSAI/GOA sablefish, see Endnote-g in Box A) of a maximum possible 56 and BSAI king and tanner crabs score is 28 out of a possible 36. The

Table 12: Summary of status for FSSI and non-FSSI stocks managed under federal fishery management plans off Alaska, updated through 2013.

Jurisdiction	Stock Group	Number of Stocks	Overfishing				Overfished				Approaching Over-fished Condi-tion
			Yes	No	Unk	Undef	Yes	No	Unk	Undef	
NPFMC	FSSI	35	0	35	0	0	1	29	5	0	0
NPFMC	NonFSSI	29	1	28	0	0	0	4	25	0	0
	Total	64	1	63	0	0	1	33	30	0	0

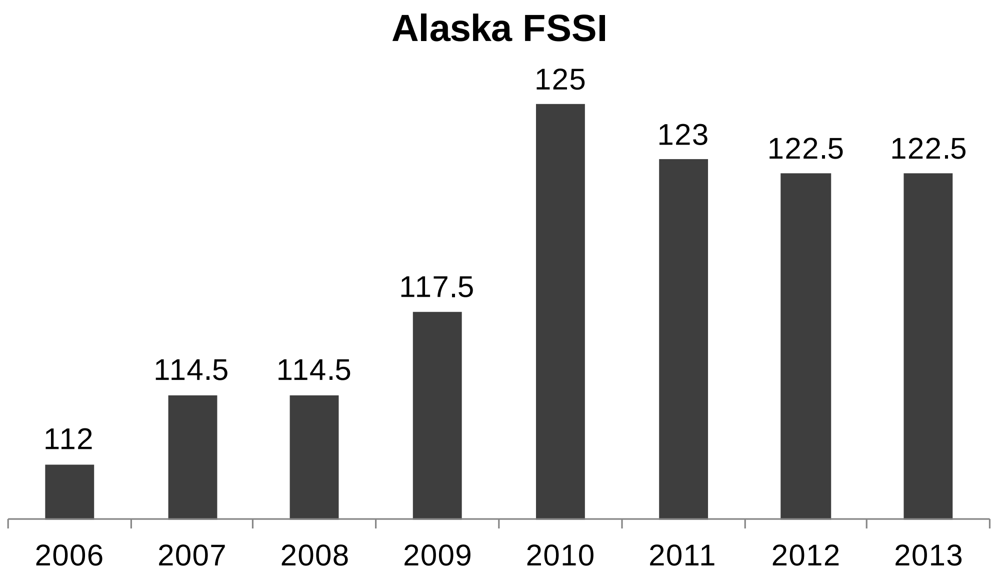


Figure 117: The trend in total Alaska FSSI from 2006 through 2013. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`. The maximum possible FSSI score is 140 in all years.

Gulf of Alaska groundfish score is 40.5 of a maximum possible 48 (excluding BSAI/GOA sablefish). Overall, the Alaska total FSSI score is unchanged from 2012 to 2013 (Figure 117).

Factors influencing observed trends: Though the total FSSI score held steady from 2012 to 2013, there were a few changes in how the points were awarded. Two points were gained for improvements with the Bering Sea southern tanner crab stock. One point was given for the stock biomass rising above the defined overfished biomass threshold and another point for the biomass being at or above 80% of BMSY. A point was lost for BSAI Greenland halibut biomass dropping below 80% of BMSY and another point was lost for the BSAI Blackspotted and Rougheye Rockfish complex for their biomass dropping below 80% of BMSY.

Groups in the BSAI region with FSSI scores less than 4 are golden king crab-Aleutian Islands

(FSSI=1.5), 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 BMSY. The red king crab-Pribilof Islands stock loses a point because the biomass is below 80% of BMSY.

GOA stocks that had low FSSI scores (1.5) are the thornyhead rockfish complex (shortspine thornyhead rockfish as the indicator species), the demersal shelf rockfish complex (yelloweye rockfish as the indicator species), and the deepwater flatfish complex (no 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 BMSY.

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), one stock is subject to overfishing (BSAI Octopus complex), and no stocks or stock complexes are approaching an overfished condition.

Table 13: FSSI stocks under NPFMC jurisdiction updated June 2013, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`.

Stock	Overfishing	Overfished	Approaching	Action	Progress	B/Bmsy	FSSI Score
Blue king crab - Pribilof Islands[a]	No	Yes	N/A	Rebuilding Program	Year 10 of 10	0.13	2
Blue king crab - Saint Matthews Island[b]	No	No	No	N/A	N/A	1.58	4
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	0.96	4
Red king crab - Norton Sound	No	No	No	N/A	N/A	1.21	4
Red king crab - Pribilof Islands[c]	No	No	Unknown	N/A	N/A	0.64	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	0.95	4
Southern Tanner crab - Bering Sea	No	No	No	N/A	N/A	1.28	4
BSAI Alaska plaice	No	No	No	N/A	N/A	1.94	4
BSAI Atka mackerel	No	No	No	N/A	N/A	1.16	4
BSAI Arrowtooth Flounder Complex	No	No	No	N/A	N/A	3.16	4
BSAI Blackspotted and Rougheye Rockfish[d]	No	No	No	N/A	N/A	0.71	3
BSAI Flathead Sole Complexe	No	No	No	N/A	N/A	2.17	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	0.6	3
BSAI Northern rockfish	No	No	No	N/A	N/A	1.68	4
BSAI Pacific cod	No	No	No	N/A	N/A	1.18	4
BSAI Pacific Ocean perch	No	No	No	N/A	N/A	1.77	4
Walleye pollock - Aleutian Islands	No	No	No	N/A	N/A	0.96	4
Walleye pollock - Eastern Bering Sea	No	No	No	N/A	N/A	1.08	4
BSAI Yellowfin sole	No	No	No	N/A	N/A	1.53	4
BSAI GOA Sablefish[g]	No	No	No	N/A	N/A	1.06	4

Table 13: FSSI stocks under NPFMC jurisdiction updated June 2013, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`. (continued)

Stock	Overfishing	Overfished	Approaching	Action	Progress	B/Bmsy	FSSI Score
GOA Arrowtooth flounder	No	No	No	N/A	N/A	2.99	4
GOA Flathead sole	No	No	No	N/A	N/A	2.87	4
GOA Blackspotted and Rougheye Rockfish complex[h]	No	No	No	N/A	N/A	1.48	4
GOA Deepwater Flatfish Complex[i]	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
GOA Demersal Shelf Rockfish Complex[j]	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
GOA Dusky Rockfish	No	No	No	N/A	N/A	1.57	4
GOA Thornyhead Rockfish Complex[k]	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
Northern rockfish - Western / Central GOA	No	No	No	N/A	N/A	1.7	4
GOA Pacific cod	No	No	No	N/A	N/A	1.51	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	2.74	4
Walleye pollock - Western / Central GOA	No	No	No	N/A	N/A	0.99	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/statusoffisheries/SOSmain.htm`.

(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) 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.

(h) 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.

(i) The Deep Water Flatfish Complex consists of the following stocks: Deepsea Sole, Dover Sole, and Greenland Turbot. Prior to 2011, Dover sole was the indicator stock for the deep-water flatfish assemblage. However, the 2011 assessment contained a recommendation that the existing age-structured model be rejected, including using Dover sole as an indicator species. The deep-water flatfish complex therefore no longer has an indicator species and an overfished determination can no longer be made. The complex was not subject to overfishing in 2010.

(j) 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.

(k) 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 2013, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`. See website for definition of stocks and stock complexes.

Stock	Jurisdiction	Overfishing	Overfished	Approaching
Golden king crab - Pribilof Islands	NPFMC	No	Unknown	Unknown
BSAI Octopus Complex	NPFMC	Yes	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	Unknown	Unknown
BSAI Shortraker rockfish	NPFMC	No	Unknown	Unknown
Walleye pollock - Bogoslof	NPFMC	No	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/NP,PFMC	Undefined	No	No

Total Annual Surplus Production and Overall Exploitation Rate of Groundfish

Contributed by Franz Mueter, University of Alaska Fairbanks, 17101 Point Lena Road, Juneau, AK 99801
Contact: franz.mueter@uaf.edu
Last updated: July 2010

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

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

Contributed by Jennifer Boldt[1], Shannon Bartkiw[1], Pat Livingston[1], Jerry Hoff[2], and Gary Walters[2]
[1]Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
[2]Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: jennifer.boldt@dfo-mpo.gc.ca
Last updated: August 2008

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

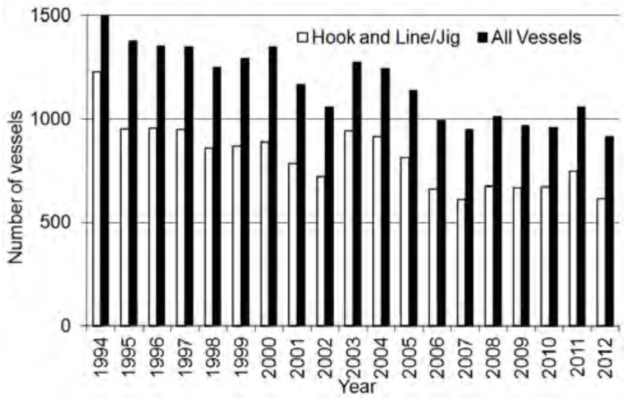
Ecosystem Goal: Humans are part of ecosystems

Groundfish Fleet Composition

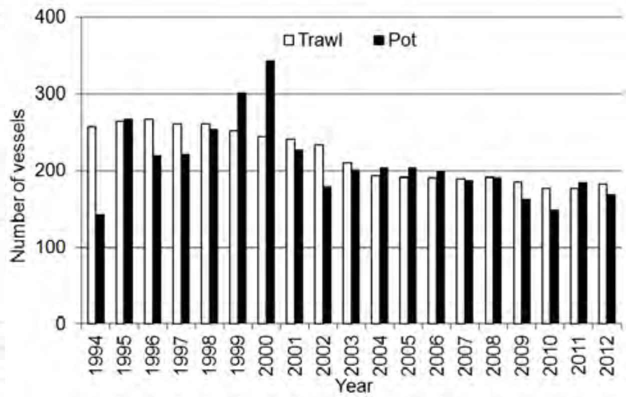
Contributed by Jean Lee, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA; and Alaska Fisheries Information Network, Pacific States Marine Fisheries Commission
Contact: jean.lee@noaa.gov
Last updated: August 2013

Description of index: Fishing vessels participating in federally-managed groundfish fisheries off Alaska principally use trawl, hook and line, and pot gear. Vessel counts in these tables were compiled from blend and Catch-Accounting System estimates and from fish ticket and observer data through 2012.

Status and trends: The pattern of changes in the total number of vessels harvesting groundfish and the number of vessels using hook and line gear have been very similar since 1994. Numbers have generally decreased since 1994 but have remained relatively stable in the last 5 years (2008-2012). The total number of vessels was 1,518 in 1994 and 917 in 2012 (Figure 118). Hook and line/jig vessels accounted for about 1,225 and 614 of these vessels in 1994 and 2012, respectively. The number of vessels using trawl gear decreased from 257 in 1994 to 182 in 2012. During the same period, the number of vessels using pot gear peaked in 2000 at 343, and decreased to 168 in 2012.



(a) Hook and Line, All vessels



(b) Trawl, Pot

Figure 118: 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. It should be noted that vessel counts before and after 2003 are not directly comparable due to the change in data source mentioned above.

Implications: Monitoring the numbers of fishing vessels is important to fisheries managers because it 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

Contributed by Amber Himes-Cornell
Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: amber.himes@noaa.gov
Last updated: August 2013; most recent data available are from 2010

Description of index: Human population is a significant factor in GOA groundfish fishery management given the reliance of many communities in the region on fisheries to support their economies and historical subsistence needs. This report describes the distribution and abundance over time of human populations in Bering Sea/Aleutian Island (BSAI) fishing communities. Population was calculated by aggregating community level demographic data for selected Bering Sea communities for 1990, 2000 and 2010 (data from U.S. Census Bureau), and yearly between 2001and 2009 and 2011 (data from the Alaska Department of Labor and Workforce Development). This approach is concordant with research on arctic communities that uses crude population growth or loss as a

Table 15: Bering Sea and Aleutian Island fishing community populations

	1920	1990	2010	% change 1990-2010
Alaska	55,036	538,347	706,498	31.2
BSAI fishing communities	6,215	45,394	47,459	4.5
% Alaskan pop in BSAI fishing communities	11.3%	8.4%	6.7%	

general index of community viability (Aarsaether and Baerenholdt 2004).

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

Status and trends: The overall population of BSAI fishing communities in 2010 was seven and a half times larger than its 1920 population - growing from 6,215 to 47,459. Overall population in the region grew 1.2% between 1990 and 2010. However, the proportion of people living in BSAI fishing communities relative to the total Alaskan population has declined from 11.3% in 1920 to 8.4% in 1990 and to 6.7% in 2010 (Table 15).

Nearly all of Alaska's rural areas, including BSAI, have had a positive average annual population growth rate since 2000 ; however, in the past decade these upward trends have been slowing. Seventy-six BSAI fishing communities (or 83.5%, not including seasonal use areas) have had a positive average annual percent change during the period between 2000 and 2010. Five communities showed between a zero and one percent average annual change over the same time period and 41 had a negative average annual percent change. Communities with a negative annual percent change during this time period appear to be concentrated in Aleutians East and West along with Lake and Peninsula and Bristol Bay Boroughs. The sharp decrease (seen above) in the Aleutians East and West area is largely due to the military base closure in Adak in 1997.

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

Alaska has the highest share of indigenous Americans of any U.S. state (20%), and Alaska Natives made up 82% of the population in remote rural census areas, 90% when excluding regional hubs (Goldsmith et al. 2004). In 2010, in the BSAI, the percent Native population is lowest among the Aleutians East (27.9%) and Aleutians West (15.4%) and highest in Wade Hampton (95.0%) and Bethel (82.9%), though there is significant variation between communities. In 2009, Alaska Natives made up 78.8% (34,379 people) of the total population of the BSAI.

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

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

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

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

Population decline or growth can affect community and regional specific pressures on fisheries resources. As populations throughout the BSAI expand and contract, so will pressures on groundfish resources. In 2011, 99 groundfish license limitation program (LLP) permits were fished by BSAI residents, representing 27% of all these permits fished by Alaska residents. In addition, approximately 1.26 billion pounds or 74% of all groundfish were landed in BSAI communities, thus contributing almost $233 million to the BSAI economy or 5% of the value of all groundfish landings at shore-based processors in the state (CFEC 2011).

Finally, population decline or growth in small communities can factor into health care provision, education, land use, environmental impacts, transportation, and other social services (Williams 2004a). Over 36% of federal dollars allocated to Alaska depend in some way on population, State programs attach many services to population, and CDQ quota shares are also provisioned in relation to population numbers. As an example, the CDQ entities distribute revenue from leasing and harvesting CDQ quota shares and provide CDQ funded programs and services to the 65 CDQ com-

Table 16: Gulf of Alaska (GOA) fishing community populations

	1920	1990	2010	% change 1990-2010
Alaska	55,036	538,347	706,498	31.2
Anchorage	na	226,338	291,826	28.9
GOA fishing communtities (incl. Anchorage)	18,533	345,230	447,134	29.5
GOA fishing communtities (excl. Anchorage)	na	118,892	150,292	12.6

munities in Western Alaska. Any changes to fisheries management programs that affect the overall revenue gained through the CDQ program could drastically affect the welfare of the population of those communities.

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

Contributed by Amber Himes-Cornell
Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
Contact: amber.himes@noaa.gov
Last updated: August 2013; most recent data available are from 2010

Description of index: Human population is a significant factor in GOA groundfish fishery management given the reliance of many communities in the region on fisheries to support their economies and historical subsistence needs. This report describes the distribution and abundance over time of human populations in the Gulf of Alaska (GOA) (including Southeast Alaska, Cook Inlet, and Prince William Sound). Population in the region was calculated by aggregating community level demographic data for 1990, 2000 and 2010 (U.S. Census Bureau 2011), and yearly between 2001 and 2009 (Alaska Department of Labor and Workforce Development 2011). This approach is concordant with research on arctic communities that uses crude population growth or loss as a general index of community viability (Aarsaether and Baerenholdt 2004).

The 105 GOA fishing communities selected for use in this report comprise most of the population that lives along the coast of the Gulf of Alaska. Communities were selected if they were within 25 miles of the coast, and/or based on their historical involvement in Gulf of Alaska subsistence or industrial fisheries, or if they were included in one of the North Pacific Fishery Management Council's GOA fishery programs, such as the Community Quota Entity program.

Status and trends: The proportion of people living in GOA fishing communities relative to the total Alaskan population has increased from around 34% in 1920 to 64.1% in 2009 (Table 1). The vast majority of the growth occurred in the city of Anchorage after 1950. Between 1990 and 2009, its population grew by 28.4%.

The overall population of GOA fishing communities (excluding Anchorage) in 2010 was 241 times larger than its 1920 population (Table 16). However, 57% of the communities experienced an average annual decline between 2000 and 2009. According to the U.S. Census Bureau, populations decreased to zero or near zero in 2010 for Annette Island, Whitestone logging camp, Cube Cove, Hobart Bay, Meyers Chuck and Thoms Place.

Alaska currently has the highest share of indigenous Americans of any U.S. state (20%). Alaska Natives made up 82% of the population of the remote rural Census Areas, 90% when excluding regional hubs (Goldsmith et al. 2004). According to the U.S. Census Bureau, in 2010, Alaska Natives made up 28% of the total population in the GOA, when excluding the population of Anchorage (9.5% if the Anchorage population is included).

Alaska has one of the highest population concentrations in the United States with 66% of its population currently concentrated in Anchorage. New York and Hawaii have the most similar population concentrations with 42.9% in New York City and 28.9% in Honolulu. With respect to distance from the nearest major American city, Anchorage (1432 miles to Seattle) is second only to Honolulu (2554 miles to Los Angeles).

Factors influencing observed trends: The overall population growth in the GOA region from 1990 to 2009 reflects state and national trends. The GOA population growth rate (28.6%) lags slightly behind state trends (25.9%) and is ahead of national trends (23.4%). The two key factors affecting these population growth rates are natural increase (births minus deaths) and migration. Except for the Matanuska-Susitna Borough, every area with positive population growth saw their natural increase outstrip their net migration between 2000 and 2004 (Williams 2006). Birth rates in the state were lowest in the Aleutian chain and in Southeast Alaska between 2000 and 2004.

Changes in patterns of natural resource extraction and military presence explain many of the recent population trends in the GOA. Cut-backs in the Coast Guard account for Kodiak's population decline in the 1990s (Williams 2006). The fishing industry accounted for community growth, decline, and in some cases abandonment in the Aleutians, Lake and Peninsula, and Kodiak areas. The Aleutians East gained population at this time because of the movement of a substantial amount of groundfish processing on shore (Williams 2004), while the population in Pelican declined 55% in part due to the closure of a processing plant. Other fishing communities, specifically those most dependent on salmon, were impacted by a sharp decline in ex-vessel prices. A loss of timber harvesting and wood processing jobs in the 1990s led to major population decreases in some Southeast communities, including Whitestone Logging Camp, which declined from 164 to 0 between 1990 and 2006, but has since increased to a population of 17 in 2010. Historically, the sharp increase in Anchorage's population began with the military buildup during and after WWII, but it was oil development beginning in the late 1970s that fueled unprecedented growth.

Implications: Population decline or growth can affect community and regional specific pressures on fisheries resources. As populations throughout the GOA expand and contract, so will pressures on groundfish resources. In 2009, 596 actively fished groundfish license limitation program (LLP) permits were held by GOA residents, representing 96.6% of all these permits issued to Alaska residents. In addition, in 2011, approximately 433.1 million pounds of groundfish were landed in GOA communities, thus contributing almost $201.6 million to the GOA economy or 46% of the value of all groundfish landings at shore-based processors in the state. Based on how population across GOA communities changes, changes in groundfish management could have implications for the stability of both regional and individual community economies.

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

References

Aagaard, K., and A. T. Roach. 1990. Arctic Ocean-shelf exchange: Measurements in Barrow Canyon. Journal of Geophysical Research-Oceans **95**:18163–18175.

(AFSC), A. F. S. C. 2011. Observer Sampling Manual for 2012. Available From: Fisheries Monitoring and Analysis Division, North Pacific Groundfish Observer Program. AFSC, 7600 Sand Point Way, NE.; Seattle WA; 98115. Technical report.

Alatalo, R. V. 1981. Problems in the measurement of evenness in ecology. Oikos **37**:199–204.

Alverson, D., and N. Wilimovsky. 1966. Fishery Investigations of the Southeastern Chukchi Sea, pages 843–860 . U.S. Atomic Energy Commission, Oak Ridge, TN.

A'mar, Z. T., A. E. Punt, and M. W. Dorn. 2008. The Management Strategy Evaluation Approach and the fishery for walleye pollock in the Gulf of Alaska., pages 317–346 . Alaska Sea Grant College Program, University of Alaska Fairbanks.

Amstrup, S. C., and C. Gardner. 1994. Polar bear maternity denning in the Beaufort Sea. Journal of Wildlife Management **58**:1–10.

Anderson, P. J. 2003. Gulf of Alaska small mesh trawl survey trends, In: J.L.Boldt (Ed.), Ecosystem Considerations for 2004. Appendix C of the BSAI/GOA Stock Assessment and Fishery Evaluation Reports. Technical report, North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Anderson, P. J., and J. F. Piatt. 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. Marine Ecology Progress Series **189**:117–123.

Anthony, R. G., J. A. Estes, and et al. 2008. Bald eagles and sea otters in the Aleutian archipelago: indirect effects of trophic cascades. Ecology **89**:2725–2735.

Arrigo, K. R., D. K. Perovich, R. S. Pickart, Z. W. Brown, G. L. van Dijken, K. E. Lowry, M. M. Mills, M. A. Palmer, W. M. Balch, F. Bahr, N. R. Bates, C. Benitez-Nelson, B. Bowler, E. Brownlee, J. K. Ehn, K. E. Frey, R. Garley, S. R. Laney, L. Lubelczyk, J. Mathis, A. Matsuoka, B. G. Mitchell, G. W. K. Moore, E. Ortega-Retuerta, S. Pal, C. M. Polashenski, R. A. Reynolds, B. Schieber, H. M. Sosik, M. Stephens, and J. H. Swift. 2012. Massive Phytoplankton Blooms Under Arctic Sea Ice. Science **336**:1408–1408.

Atwood, E., J. K. Duffy-Anderson, J. K. Horne, and C. Ladd. 2010. Influence of mesoscale eddies on ichthyoplankton assemblages in the Gulf of Alaska. Fisheries Oceanography **19**:493–507.

AVISO. 2012. Map of sea level anomalies.

Aydin, K. Y., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling.

Baier, C. T., and J. M. Napp. 2003. Climate-induced variability in Calanus marshallae populations. Journal of Plankton Research **25**:771–782.

Barber, W. E., R. L. Smith, M. Vallarino, and R. M. Meyer. 1997. Demersal fish assemblages of the northeastern Chukchi Sea, Alaska. Fishery Bulletin **95**:195–208.

Barber, W. E., R. L. Smith, and T. J. Weingartner. 1994. Fisheries oceanography of the northeast Chukchi Sea final report. Technical report.

Beamish, R. J., C. Neville, R. Sweeting, and K. Lange. 2012. The Synchronous Failure of Juvenile Pacific Salmon and Herring Production in the Strait of Georgia in 2007 and the Poor Return of Sockeye Salmon to the Fraser River in 2009. Marine and Coastal Fisheries **4**:403–414.

Beamish, R. J., R. M. Sweeting, and C. M. Neville. 2004. Improvement of Juvenile Pacific Salmon Production in a Regional Ecosystem after the 1998 Climatic Regime Shift. Transactions of the American Fisheries Society **133**:1163–1175.

Bluhm, B. A., K. Iken, S. M. Hardy, B. I. Sirenko, and B. A. Holladay. 2009. Community structure of epibenthic megafauna in the Chukchi Sea. Aquatic Biology **7**:269–293.

Boldt, J. L., and L. J. Haldorson. 2004. Size and condition of wild and hatchery pink salmon juveniles in Prince William Sound, Alaska. Transactions of the American Fisheries Society **133**:173–184.

Bond, A. L., I. L. Jones, W. J. Sydeman, H. L. Major, S. Minobe, J. C. Williams, and G. V. Byrd. 2011. Reproductive success of planktivorous seabirds in the North Pacific is related to ocean climate on decadal scales. Marine Ecology Progress Series **424**:205–218.

Bond, N. A., and L. Guy. 2010. North Pacific Climate Overview In: S. Zador and S. Gaichas (Ed.), Ecosystem Considerations for 2010. Appendix C of the BSAI/GOA Stock Assessment and Fishery Evaluation Report. Technical report, North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Bond, N. A., J. E. Overland, M. Spillane, and P. Stabeno. 2003. Recent shifts in the state of the North Pacific. Geophysical Research Letters **30**.

Bradstreet, M. S. W. 1982. Occurrence, habitat use, and behavior of seabirds, marine mammals, and Arctic cod at the Pond Inlet ice edge. Arctic **35**:28–40.

Bradstreet, M. S. W., K. Finley, A. Sekerak, W. Griffiths, C. Evans, M. Fabijan, and H. Stallard. 1986. Aspects of the biology of Arctic cod (Boreogadus saida) and its importance in Arctic marine food chains. Technical report.

Breen, P. A., T. A. Carson, and et al. 1982. Changes in subtidal community structure associated with British Columbia sea otter transplants. Marine Ecology Progress Series **7**.

Brickley, P. J., and A. C. Thomas. 2004. Satellite-measured seasonal and inter-annual chlorophyll variability in the Northeast Pacific and Coastal Gulf of Alaska. Deep-Sea Research Part Ii-Topical Studies in Oceanography **51**:229–245.

Brodeur, R., C. Mills, J. Overland, G. WAL-TERS, and J. Schumacher. 1999. Recent increase in jellyfish biomass in the Bering Sea: Possible links to climate change. Fish. Oceanogr **8**:286–306.

Brodeur, R., and D. M. Ware. 1992. Long-term variability in zooplankton biomass in the subarctic Pacific Ocean. Fisheries Oceanography **1**:32–37.

Brodeur, R. D., M. B. Decker, L. Ciannelli, J. E. Purcell, N. A. Bond, P. J. Stabeno, E. Acuna, and G. L. Hunt. 2008. Rise and fall of jellyfish in the eastern Bering Sea in relation to climate regime shifts. Progress in Oceanography **77**:103–111.

Brodeur, R. D., R. L. Emmett, J. P. Fisher, E. Casillas, D. J. Teel, and T. W. Miller. 2004. Juvenile salmonid distribution, growth, condition, origin, and environmental and species associations in the Northern California Current. Fishery Bulletin **102**:25–46.

Brodeur, R. D., H. Sugisaki, and G. L. Hunt. 2002. Increases in jellyfish biomass in the Bering Sea: implications for the ecosystem. Marine Ecology-Progress Series **233**:89–103.

Brown, Z. W., and K. R. Arrigo. 2012. Contrasting trends in sea ice and primary production in the Bering Sea and Arctic Ocean. Ices Journal of Marine Science **69**:1180–1193.

Buck, G. In prep. Abundance, age, sex and size statistics for Pacific herring in Togiak District of Bristol Bay, 2013. Technical report, Alaska Department of Fish and Game.

Burns, J. J. 1970. Remarks on the Distribution and Natural History of Pagophilic Pinnipeds in the Bering and Chukchi Seas. Journal of Mammalogy **51**:445–454.

Cahalan, J., J. Mondragon, and J. Gasper. 2010. Catch sampling and estimation in the Federal groundfish fisheries off Alaska. Technical report, U.S. Dep. Commer., NOA Tech. Memo. NMFS-AFSC-205, 42 p.

Cieciel, K., E. V. Farley Jr, and L. B. Eisner. 2009. Jellyfish and juvenile salmon associations with oceanographic characteristics during warm and cool years in the eastern Bering Sea. North Pacific Anadromous Fish Commission Bulletin **5**:209–224.

Coachman, L. K., K. Aagaard, and R. B. Tripp. 1975. Bering Strait : the regional physical oceanography. University of Washington Press, Seattle.

Comiso, J. C. 2012. Large Decadal Decline of the Arctic Multiyear Ice Cover. Journal of Climate **25**:1176–1193.

Condon, R. H., D. K. Steinberg, P. A. del Giorgio, T. C. Bouvier, D. A. Bronk, W. M. Graham, and H. W. Ducklow. 2011. Jellyfish blooms result in a major microbial respiratory sink of carbon in marine systems. Proceedings of the National Academy of Sciences **108**:10225–10230.

Conover, R. J., and M. Huntley. 1991. Copepods in ice-covered seasDistribution, adaptations to seasonally limited food, metabolism, growth patterns and life cycle strategies in polar seas. J Mar Syst **2**:1–41.

Conover, R. J., and T. D. Siferd. 1993. Dark-season survival strategies of coastal zone zooplankton in the Canadian Arctic. Arctic **46**:303–311.

Cooney, R. T., and T. M. Willette. 1997. Factors influencing the marine survival of pink salmon in Prince William Sound, Alaska. In: (Emmett, R. L. and Schiewe, M. H.) Estuarine and ocean survival of northeastern Pacific salmon. NOAA Tech Memo NMFS-NWFSC-29 .

Cota, G. F. 1985. Photoadaptation of high Arctic ice algae. Nature **315**:219–222.

Cota, G. F., and R. E. H. Smith. 1991. Ecology of bottom ice algae: II. Dynamics, distributions and productivity. Journal of Marine Systems **2**:279–295.

Coyle, K. O., L. Eisner, F. J. Mueter, A. Pinchuk, M. Janout, K. Cieciel, E. Farley, and A. Andrews. 2011. Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the Oscillating Control Hypothesis. Fisheries Oceanography **20**:139–156.

Coyle, K. O., and A. I. Pinchuk. 2002. Climate-related differences in zooplankton density and growth on the inner shelf of the southeastern Bering Sea. Progress in Oceanography **55**:177–194.

Daase, M., S. Falk-Petersen, . Varpe, G. Darnis, J. E. Sreide, A. Wold, E. Leu, J. Berge, B. Philippe, and L. Fortier. 2013. Timing of reproductive events in the marine copepod Calanus glacialis: a pan-Arctic perspective. Canadian Journal of Fisheries and Aquatic Sciences **70**:871–884.

Denlinger, L. M. 2006. Alaska Seabird Information Series. Technical report, Unpub. Rept. U.S. Fish and Wildl. Serv., Migr. Bird Manage., Nongame Program, Anchorage AK.

Di Lorenzo, E., J. Fiechter, N. Schneider, A. Bracco, A. J. Miller, P. J. S. Franks, S. J. Bograd, A. M. Moore, A. C. Thomas, W. Crawford, A. Pea, and A. J. Hermann. 2009. Nutrient and salinity decadal variations in the central and eastern North Pacific. Geophysical Research Letters **36**:L14601.

Di Lorenzo, E., N. Schneider, K. M. Cobb, P. J. S. Franks, K. Chhak, A. J. Miller, J. C. McWilliams, S. J. Bograd, H. Arango, E. Curchitser, T. M. Powell, and P. Riviere. 2008. North Pacific Gyre Oscillation links ocean climate and ecosystem change. Geophysical Research Letters **35**.

Dietrich, K. S., and E. F. Melvin. 2008. Alaska Trawl Fisheries: Potential Interations with North Pacific Albatrosses. Technical report, Washington Sea Grant.

Divoky, G. J. 1976. Pelagic feeding habits of Ivory and Ross' gulls. Condor **78**:85–90.

Dorn, M. W., K. Y. Aydin, S. Barbeaux, D. Jones, K. Spalinger, and W. Palsson. 2012. Chapter 1: Assessment of the Walleye Pollock Stock in the Gulf of Alaska. Technical report, N Pac Fish Manage Council, 605 W 4th Ave, Anchorage, AK 99510.

Doroff, A. M., J. A. Estes, and E. al. 2003. Sea otter population declines in the Aleutian archipelago. Journal of Mammalogy **84**:55–64.

Downton, M. W., and K. A. Miller. 1998. Relationships between Alaskan salmon catch and North Pacific climate on interannual and interdecadal time scales. Canadian Journal of Fisheries and Aquatic Sciences **55**:2255–2265.

Doyle, M., and K. Mier. 2012. A new conceptual framework for evaluating the early ontogeny phase of recruitment processes among marine fish species. Canadian Journal of Fisheries and Aquatic Sciences **69**:2112–2129.

Doyle, M. J., S. J. Picquelle, K. L. Mier, M. Spillane, and N. bond. 2009. Larval fish abundance and physical forcing in the Gulf of Alaska, 1981-2003. Progress in Oceanography **80**:163–187.

Ducet, N., P. Y. Le Traon, and G. Reverdin. 2000. Global high-resolution mapping of ocean circulation from TOPEX/Poseidon and ERS-1 and-2. Journal of Geophysical Research-Oceans **105**:19477–19498.

Duggins, D. O., C. A. Simenstad, and et al. 1989. Magnification of secondary production by kelp detritus in coastal marine ecosystems. Science **245**:170–173.

Dunton, K. H., J. L. Goodall, S. V. Schonberg, J. M. Grebmeier, and D. R. Maidment. 2005. Multi-decadal synthesis of benthic-pelagic coupling in the western arctic: Role of cross-shelf advective processes. Deep-Sea Research Part Ii-Topical Studies in Oceanography **52**:3462–3477.

Echave, K., M. Eagleton, E. Farley, and J. Orsi. 2012. A refined description of essential fish habitat for Pacific salmon within the U.S. Exclusive Economic Zone in Alaska. Technical report.

Eggers, D. M., C. Tide, and A. M. Carroll. 2013. Run Forecasts and Harvest Projections for 2013 Alaska Salmon Fisheries and Review of the 2012 Season.

Elliott, M. 2002. The role of the DPSIR approach and conceptual models in marine environmental management: an example for offshore wind power. Marine Pollution Bulletin **44**:iii–vii.

Estes, J. A., and D. O. Duggins. 1995. Sea otters and kelp forests in Alaska: generality and variation in a community ecological paradigm. Ecological Monographs **65**:75–100.

Fair, L. 2003. Bristol Bay sockeye salmon. In (Eggers, D. M.) Run Forecasts and Harvest Projections for 2003 Alaska Salmon Fisheries and Review of the 2002 Season. Juneau: Alaska Department of Fish and Game Regional Information Report No. 5J03-01. .

Fair, L. F., and A. Nelson. 1999. Southeast Chukchi Sea and Kotzebue Sound trawl survey, 1998. Technical report, Alaska Dept. of Fish and Game, Commercial Fisheries Division, AYK Region.

Farley, E., J. Moss, and R. Beamish. 2007. A Review of the critical size, critical period hypothesis for juvenile Pacific salmon. North Pacific Anadromous Fish Commission Bulletin **4**:311–317.

Fay, F. H. 1982. Ecology and biology of the Pacific walrus, Odobenus rosmarus divergens Illiger. North American Fauna **74**:1–279.

Fay, F. H., and J. J. Burns. 1988. Maximal feeding depth of walruses. Arctic **41**:239–240.

Fay, F. H., and B. P. Kelly. 1980. Mass natural mortality of walruses (Odobenus rosmarus) at St. Lawrence Island, Bering Sea, autumn 1978. Arctic **33**:226–245.

Feder, H. M., N. R. Foster, S. C. Jewett, T. J. Weingartner, and R. Baxter. 1994. Mollusks in the northeastern Chukchi Sea. Arctic **47**:145–163.

Feder, H. M., and S. C. Jewett. 1978. Survey of the epifaunal invertebrates of Norton Sound, southeastern Chukchi Sea, and Kotzebue Sound. Technical report, Institute of Marine Science, University of Alaska.

Feder, H. M., S. C. Jewett, and A. Blanchard. 2005. Southeastern Chukchi Sea (Alaska) epibenthos. Polar Biology **28**:402–421.

Feder, H. M., S. C. Jewett, and A. L. Blanchard. 2007. Southeastern Chukchi Sea (Alaska) macrobenthos. Polar Biology **30**:261–275.

Fergusson, E. A., M. V. Sturdevant, and J. A. Orsi. 2013. Trophic relationships among juvenile salmon during a 16-year time series of climate variability in Southeast Alaska. Technical report.

Fischbach, A., D. Monson, and C. V. Jay. 2009. Enumeration of Pacific walrus carcasses on beaches of the Chukchi Sea in Alaska following a mortality event, September 2009. Technical report.

Fischbach, A. S., S. C. Amstrup, and D. C. Douglas. 2007. Landward and eastward shift of Alaskan polar bear denning associated with recent sea ice changes. Polar Biology **30**:1395–1405.

Fitzgerald, S., M. Perez, and K. Rivera. 2008. Summary of Seabird Bycatch in Alaskan Groundfish Fisheries, 1993 through 2006. Technical report, North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Francis, R. C., S. R. Hare, A. B. Hollowed, and W. S. Wooster. 1998. Effects of interdecadal climate variability on the oceanic ecosystems of the NE Pacific. Fisheries Oceanography **7**:1–21.

Fritz, L. W., and S. C. 2005. Aerial, ship, and land-based surveys of Steller sea lions (Eumetopia jubatus) in the western stock in Alaska, June and July 2003 and 2004.

Frost, K. J., and L. F. Lowry. 1983. Demersal Fishes and invertebrates trawled in the northeastern Chukchi and western Beaufort seas, 1976-77. Technical report.

Frost, K. J., and L. F. Lowry. 1984. Trophic relationships of vertebrate consumers in the Alaskan Beaufort Sea, pages 381–401 . Academic Press, Orlando, FL.

Fujioka, J. T. 2006. A model for evaluating fishing impacts on habitat and comparing fishing closure strategies. Canadian Journal of Fisheries and Aquatic Sciences **63**:2330–2342.

Funk, F., L. Brannian, and K. Rowell. 1992. Age-Structured Assessment of the Togiak Herring Stock, 1978-1992, and Preliminary Forecast of Abundance for 1993. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J92-11, Juneau. .

Garlich-Miller, J., J. G. MacCracken, J. Snyder, R. Meehan, M. Myers, J. M. Wilder, E. Lance, and A. Matz. 2011. Status review of the Pacific walrus (Odobenus rosmarus divergens). Technical report.

George, J. C., H. P. Huntington, K. Brewster, H. Eicken, D. W. Norton, and R. Glenn. 2004. Observations on shorefast ice dynamics in arctic Alaska and the responses of the Inupiat hunting community. Arctic **57**:363–374.

Gosselin, M., M. Levasseur, P. A. Wheeler, R. A. Horner, and B. C. Booth. 1997. New measurements of phytoplankton and ice algal production in the Arctic Ocean. Deep-Sea Research Part Ii-Topical Studies in Oceanography **44**:1623–+.

Gradinger, R. R., and B. A. Bluhm. 2004. In-situ observations on the distribution and behavior of amphipods and Arctic cod (Boreogadus saida) under the sea ice of the High Arctic Canada Basin. Polar Biology **27**:595–603.

Grebmeier, J. M., and C. P. McRoy. 1989. Pelagic-benthic coupling on the shelf of the northern Bering and Chukchi Seas. III. Benthic food supply and carbon cycling. Marine Ecology-Progress Series **53**:79–91.

Grebmeier, J. M., C. P. McRoy, and H. M. Feder. 1988. Pelagic-benthic coupling on the shelf of the northern Bering and Chukchi seas. I. Food supply source and benthic biomass. Marine Ecology-Progress Series **48**:57–67.

Grebmeier, J. M., S. E. Moore, J. E. Overland, K. E. Frey, and R. Gradinger. 2010. Biological response to recent pacific arctic sea ice retreats. Eos **91**:161–162.

Grebmeier, J. M., J. E. Overland, S. E. Moore, E. V. Farley, E. C. Carmack, L. W. Cooper, K. E. Frey, J. H. Helle, F. A. McLaughlin, and S. L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. Science **311**:1461–1464.

Hare, S. R., and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography **47**:103–145.

Hatch, S. 2013. Kittiwake diets and chick production signal a 2008 regime shift in the Northeast Pacific. Marine Ecology Progress Series **477**:271–284.

Hatch, S. A., V. A. Gill, and D. M. Mulcahy. 2010. Individual and colony-specific wintering areas of Pacific northern fulmars (Fulmarus glacialis). Canadian Journal of Fisheries and Aquatic Sciences **67**:386–400.

Heintz, R., E. Farley, and E. Siddon. 2010. Fall Condition of YOY Predicts Recruitment of Age-1 Walleye Pollock. In: Zador and Gaichas (Eds.), Ecosystem Considerations for 2011. Appendix C of the BSAI/GOA Stock Assessment and Fishery Evaluation Reports. Technical report, North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Heintz, R. A., E. C. Siddon, E. V. Farley Jr, and J. M. Napp. 2013. Correlation between recruitment and fall condition of age-0 pollock (Theragra chalcogramma) from the eastern Bering Sea under varying climate conditions. Deep Sea Research Part II: Topical Studies in Oceanography .

Highsmith, R. C., and K. O. Coyle. 1992. Productivity of arctic amphipods relative to gray whale energy requirements. Marine Ecology-Progress Series **83**:141–150.

Hilborn, R., T. P. Quinn, D. E. Schindler, and D. E. rogers. 2003. Biocomplexity and fisheries sustainability. Proceedings of the National Academy of Sciences of the United States of America **100**:6564–6568.

Hill, M. O. 1973. Diversity and evenness. A unifying notation and its consequences. Ecology **54**:427–432.

Hill, V., and G. Cota. 2005. Spatial patterns of primary production on the shelf, slope and basin of the Western Arctic in 2002. Deep-Sea Research Part Ii-Topical Studies in Oceanography **52**:3344–3354.

Hinckley, S., B. A. Megrey, and T. W. Miller. 2009. Recruitment Prediction, pages 77–82 . H.C. Andersens Boulevard 44-46, 1553 Copenhagen V, Denmark.

Hoff, G. R. 2006. Biodiversity as an index of regime shift in the eastern Bering Sea. Fishery Bulletin **104**:226–237.

Hollowed, A. B., K. Y. Aydin, T. E. Essington, J. N. Ianelli, B. A. Megrey, A. E. Punt, and A. D. M. Smith. 2011. Experience with quantitative ecosystem assessment tools in the northeast Pacific. Fish and Fisheries **12**:189–208.

Hollowed, A. B., B. Planque, and H. Loeng. 2013. Potential movement of fish and shellfish stocks from the sub-Arctic to the Arctic Ocean. Fisheries Oceanography **22**:355–370.

Honkalehto, T., A. McCarthy, P. Ressler, K. Williams, and D. Jones. 2012. Results of the acoustic-trawl survey of walleye pollock (Theragra chalcogramma) on the U.S. and Russian Bering Sea shelf in June - August 2010 (DY1006). AFSC Processed Rep. 2012-01. Technical report, Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Hopcroft, R. R., K. N. Kosobokova, and A. I. Pinchuk. 2010. Zooplankton community patterns in the Chukchi Sea during summer 2004. Deep-Sea Research Part Ii-Topical Studies in Oceanography **57**:27–39.

Hovelsrud, G. K., M. McKenna, and H. P. Huntington. 2008. Marine mammal harvests and other interactions with humans. Ecological Applications **18**:S135–S147.

Hunt, G. L., K. O. Coyle, L. Eisner, E. Farley, R. Heintz, F. J. Mueter, J. M. Napp, J. E. Overland, P. Ressler, S. A. Salo, and P. Stabeno. 2011. Climate impacts on eastern Bering Sea food webs: A synthesis of new data and an assessment of the Oscillating Control Hypothesis. Ices Journal of Marine Science **68**:1230–1243.

Hunt, G. L., P. Stabeno, G. Walters, E. Sinclair, R. D. Brodeur, J. M. Napp, and N. A. Bond. 2002. Climate change and control of the southeastern Bering Sea pelagic ecosystem. Deep-Sea Research Part Ii-Topical Studies in Oceanography **49**:5821–5853.

Hunt, G. L., and P. J. Stabeno. 2005. Oceanography and ecology of the Aleutian Archipelago: spatial and temporal variation. Fisheries Oceanography **14**:292–306.

Hunt, G. L., P. J. Stabeno, S. Strom, and J. M. Napp. 2008. Patterns of spatial and temporal variation in the marine ecosystem of the southeastern Bering Sea, with special reference to the Pribilof Domain. Deep-Sea Research Part Ii-Topical Studies in Oceanography **55**:1919–1944.

Hunt, J., G. L. 1991. Marine birds and ice-influenced environments of polar oceans. Journal of Marine Systems **2**:233–240.

Huntington, H. P., C. Buckland, C. Elim, C. Koyuk, C. P. Lay, and C. Shaktoolik. 1999. Traditional knowledge of the ecology of beluga whales (Delphinapterus leucas) in the eastern Chukchi and northern Bering Seas, Alaska. Arctic **52**:49–61.

Ianelli, J. N. 2005. Assessment and fisheries management of eastern Bering Sea walleye pollock: is sustainability luck? Bulletin of Marine Science **76**:321–335.

Ianelli, J. N., T. Honkalehto, S. Barbeaux, S. Kotwicki, K. Y. Aydin, and N. Williamson. 2012. Assessment of the walleye pollock stock in the Eastern Bering Sea. Technical report, N Pac Fish Manage Council, 605 W 4th Ave, Anchorage, AK 99510.

Irons, D. B., R. G. Anthony, and et al. 1986. Foraging strategies of Glaucous-winged Gulls in rocky intertidal communities. Ecology **67**.

Jay, C. V., and A. Fischbach. 2008. Pacific walrus response to Arctic sea ice losses. Technical report.

Jay, C. V., A. S. Fischbach, and A. A. Kochnev. 2012. Walrus areas of use in the Chukchi Sea during sparse sea ice cover. Marine Ecology Progress Series **468**:1–13.

Ji, R. B., C. J. Ashjian, R. G. Campbell, C. S. Chen, G. P. Gao, C. S. Davis, G. W. Cowles, and R. C. Beardsley. 2012. Life history and biogeography of Calanus copepods in the Arctic Ocean: An individual-based modeling study. Progress in Oceanography **96**:40–56.

Ji, R. B., M. B. Jin, and . Varpe. 2013. Sea ice phenology and timing of primary production pulses in the Arctic Ocean. Global Change Biology **19**:734–741.

Kelly, B. P. 1988. Ringed seal, Phoca hispida, pages 57–75 . Marine Mammal Commission, Washington, D.C.

Kelly, B. P., J. L. Bengtson, P. Boveng, M. Cameron, S. Dahle, J. Jansen, E. A. Logerwell, J. E. Overland, C. Sabine, G. Waring, and J. Wilder. 2010. Status review of the ringed seal (Phoca hispida). Technical report.

Kenyon, K. W. 1962. Notes on Phocid Seals at Little Diomede Island, Alaska. Journal of Wildlife Management **26**:380–387.

Keyes, M. C. 1968. The Nutrition of Pinnipeds. Appleton-Century-Crofts, New York, NY.

King, J. 2005. Report of the Study Group on Fisheries and Ecosystem Responses to recent regime shifts. PICES Scientific Report No. 28. Technical report.

Kinnard, C., C. M. Zdanowicz, D. A. Fisher, E. Isaksson, A. de Vernal, and L. G. Thompson. 2011. Reconstructed changes in Arctic sea ice over the past 1,450 years. Nature **479**:509–U231.

Kline, J., T. C. 2010. Stable carbon and nitrogen isotope variation in the northern lampfish and Neocalanus, marine survival rates of pink salmon, and meso-scale eddies in the Gulf of Alaska. Progress in Oceanography **87**:49–60.

Kline, T. C., J. Boldt, E. Farley, L. J. Haldorson, and J. H. Helle. 2008. Pink salmon (Oncorhynchus gorbuscha) marine survival rates reflect early marine carbon source dependency. Progress in Oceanography **77**:194–202.

Kooka, K., O. Yamamura, A. Nishimura, T. Hamatsu, and T. Yanagimoto. 2007. Optimum temperature for growth of juvenile walleye pollock Theragra chalcogramma. Journal of Experimental Marine Biology and Ecology **347**:69–76.

Kotwicki, S., T. W. Buckley, T. Honkalehto, and G. Walters. 2005. Variation in the distribution of walleye pollock (Theragra chalcogramma) with temperature and implications for seasonal migration. Fishery Bulletin **103**:574–587.

Kvitek, R. G., P. Iampietro, and et al. 1998. Sea otters and benthic prey communities: a direct test of the sea otter as keystone predator in Washington state. Marine Mammal Science **14**:895–902.

Ladd, C. 2007. Interannual variability of the Gulf of Alaska eddy field. Geophysical Research Letters **34**.

Ladd, C., W. R. Crawford, C. Harpold, W. Johnson, N. B. Kachel, P. Stabeno, and F. Whitney. 2009. A synoptic survey of young mesoscale eddies in the Eastern Gulf of Alaska. Deep-Sea Research Part II **56**:2460–2473.

Ladd, C., N. B. Kachel, C. W. Mordy, and P. J. Stabeno. 2005. Observations from a Yakutat eddy in the northern Gulf of Alaska. Journal of Geophysical Research-Oceans **110**.

Ladd, C., C. W. Mordy, N. B. Kachel, and P. J. Stabeno. 2007. Northern Gulf of Alaska eddies and associated anomalies. Deep-Sea Research Part I-Oceanographic Research Papers **54**:487–509.

Lane, P. V. Z., L. Llins, S. L. Smith, and D. Pilz. 2008. Zooplankton distribution in the western Arctic during summer 2002: Hydrographic habitats and implications for food chain dynamics. Journal of Marine Systems **70**:97–133.

Lauth, R. R. 2011. Results of the 2010 eastern and northern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate fauna. Technical report.

Lebida, R. C., and D. C. Whitmore. 1985. Bering Sea Herring Aerial Survey Manual. Alaska Department of Fish and Game, Division of Commercial Fisheries, Bristol Bay Data Report No. 85-2, Anchorage. .

Legendre, L., S. F. Ackley, G. S. Dieckmann, B. Gulliksen, R. Horner, T. Hoshiai, I. A. Melnikov, W. S. Reeburgh, M. Spindler, and C. W. Sullivan. 1992. Ecology of sea ice biota. 2. Global significance. Polar Biology **12**:429–444.

Lentfer, J. W., and R. J. Hensel. 1980. Alaskan Polar Bear Denning. Bears: Their Biology and Management **4**:101–108.

Link, J. S., J. K. T. Brodziak, S. F. Edwards, W. J. Overholtz, D. Mountain, J. W. Jossi, T. D. Smith, and M. J. Fogarty. 2002. Marine ecosystem assessment in a fisheries management context. Canadian Journal of Fisheries and Aquatic Sciences **59**:1429–1440.

Litzow, M. A. 2006. Climate regime shifts and community reorganization in the Gulf of Alaska: how do recent shifts compare with 1976/1977? Ices Journal of Marine Science **63**:1386–1396.

Litzow, M. A., F. J. Mueter, and A. J. Hobday. 2013. Reassessing regime shifts in the North Pacific: incremental climate change and commercial fishing are necessary for explaining decadal-scale biological variability. Global Change Biology pages n/a–n/a .

Ljungblad, D. K., S. E. Moore, and D. R. VanSchoik. 1986. Seasonal patterns of distribution, abundance, migration and behavior of the western Arctic stock of bowhead whales, Balaena mysticetus in Alaskan seas. Rep. Int. Whal. Commn. Special Issue 8 pages 177–205 .

Lovvorn, J. R., L. W. Cooper, M. L. Brooks, C. C. De Ruyck, J. K. Bump, and J. M. Grebmeier. 2005. Organic matter pathways to zooplankton and benthos under pack ice in late winter and open water in late summer in the north-central Bering Sea. Marine Ecology-Progress Series **291**:135–150.

Lovvorn, J. R., S. E. Richman, J. M. Grebmeier, and L. W. Cooper. 2003. Diet and body condition of spectacled elders wintering in pack ice of the Bering Sea. Polar Biology **26**:259–267.

Lowry, L. F., K. J. Frost, and J. J. Burns. 1980. Feeding of bearded seals in the Bering and Chukchi seas and trophic interactions with Pacific walruses. Arctic **33**:330–342.

Ludwig, J. A., and J. R. Reynolds. 1988. Statistical ecology: a primer on methods and computing. John Wiley and Sons, New York, NY.

MacCracken, J. G. 2012. Pacific Walrus and climate change: observations and predictions. Ecology and Evolution **2**:2072–2090.

Mackas, D. L., W. Greve, M. Edwards, S. Chiba, K. Tadokoro, D. Eloire, M. G. Mazzocchi, S. Batten, A. J. Richardson, C. Johnson, E. Head, A. Conversi, and T. Peluso. 2012. Changing zooplankton seasonality in a changing ocean: Comparing time series of zooplankton phenology. Progress in Oceanography **97100**:31–62.

Mackas, D. L., W. T. Peterson, and J. E. Zamon. 2004. Comparisons of interannual biomass anomalies of zooplankton communities along the continental margins of British Columbia and Oregon. Deep Sea Research Part II: Topical Studies in Oceanography **51**:875–896.

Martinson, E. C., H. H. Stokes, and D. L. Scarnecchia. 2012. Use of juvenile salmon growth and temperature change indices to predict groundfish post age-0yr class strengths in the Gulf of Alaska and eastern Bering Sea. Fisheries Oceanography **21**:307–319.

Maslowski, W., R. Roman, and J. C. Kinney. 2008. Effects of mesoscale eddies on the flow of the Alaskan Stream. Journal of Geophysical Research-Oceans **113**.

Matarese, A. C., D. M. Blood, S. J. Picquelle, and J. L. Benson. 2003. Atlas of abundance and distribution patterns of ichthyoplankton from the northeast Pacific Ocean and Bering Sea ecosystems based on research conducted by the Alaska Fisheries Science Center (1972-1996). Technical report.

Matsuno, K., A. Yamaguchi, T. Hirawake, and I. Imai. 2011. Year-to-year changes of the mesozooplankton community in the Chukchi Sea during summers of 1991, 1992 and 2007, 2008. Polar Biology **34**:1349–1360.

McKenzie, J., and K. M. Wynne. 2008. Spatial and Temporal Variation in the Diet of Steller Sea Lions in the Kodiak Archipelago, 1999-2005. Marine Ecology Progress Series **360**:265–283.

McRoy, C. P., and J. J. Goering. 1974. The influence of ice on the primary productivity of the Bering Sea, pages 403–421 . Institute of Marine Science, University of Alaska Fairbanks.

Meier, W. N., J. Stroeve, and F. Fetterer. 2007. Whither Arctic sea ice? A clear signal of decline regionally, seasonally and extending beyond the satellite record. Annals of Glaciology **46**:428–434.

Methot, R. D. 2005. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. International North Pacific Fisheries Commission Bulletin **50**:259–277.

Moore, S. E., J. T. Clarke, and M. M. Johnson. 1993. Beluga distribution and movements offshore northern Alaska in spring and summer, 1980-84. Rep. Int. Whal. Commn. **43**:375–381.

Mordy, C. W., P. J. Stabeno, C. Ladd, S. Zeeman, D. P. Wisegarver, S. A. Salo, and G. L. Hunt. 2005. Nutrients and primary production along the eastern Aleutian Island Archipelago. Fisheries Oceanography **14**:55–76.

Mueter, F. J., J. L. Boldt, B. A. Megrey, and R. M. Peterman. 2007. Recruitment and survival of Northeast Pacific Ocean fish stocks: temporal trends, covariation, and regime shifts. Canadian Journal of Fisheries and Aquatic Sciences **64**:911–927.

Mueter, F. J., and M. A. Litzow. 2008. Sea ice retreat alters the biogeography of the Bering Sea continental shelf. Ecological Applications **18**:309–320.

Niebauer, J. H., V. Alexander, and R. T. Cooney. 1981. Primary production at the eastern Bering Sea ice edge: The physical and biological regimes, volume 2, pages 763–772 . U.S. Dep. Commer., NOAA, Office of Marine Pollution Assessment, University of Washington Press, Seattle, WA.

NMFS. 2007. Conservation Plan for the eastern Pacific stock of Northern fur seal (*Callorhinus ursinus*). December 2007. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NMFS Protected Resources Division, Alaska Region. 137 pp. `http://www.fakr.noaa.gov/protectedresources/seals/fur/cplan/final1207.pdf` .

NMFS. 2010. Endangered Species Act Section 7 Consultation, Biological Opinion. Authorization of groundfish fisheries under the fishery management plans for groundfish of the Bering Sea and Aleutian Islands management area and the Gulf of Alaska. NMFS Alaska Region, Juneau AK page 472 pp .

NOAA. 2004. Programmatic Supplemental Environmental Impact Statement for the Alaska Groundfish Fisheries Implemented Under the Authority of the Fishery Management Plans for the Groundfish Fishery of the Gulf of Alaska and the Groundfish of the Bering Sea and Aleutian Islands Area. Technical report.

Noakes, D. J., and R. J. Beamish. 2009. Synchrony of Marine Fish Catches and Climate and Ocean Regime Shifts in the North Pacific Ocean. Marine and Coastal Fisheries **1**:155–168.

Noongwook, G., H. P. Huntington, J. C. George, N. V. Savoonga, and N. V. Gambell. 2007. Traditional knowledge of the bowhead whale (Balaena mysticetus) around St. Lawrence Island, Alaska. Arctic **60**:47–54.

Norcross, B. L., B. A. Holladay, M. S. Busby, and K. L. Mier. 2010. Demersal and larval fish assemblages in the Chukchi Sea. Deep-Sea Research Part Ii-Topical Studies in Oceanography **57**:57–70.

NPFMC. 2009. Fishery Management Plan for Fish Resources of the Arctic Management Area. Technical report, North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage AK, 99501.

NPFMC. 2011. Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions. Technical report, North Pacific Fishery Management Council, 605 W. 4th Ave 306, Anchorage, AK 99501.

Oakley, K., M. Whalen, D. Douglas, M. Udevitz, T. Atwood, and C. Jay. 2012. Polar bear and walrus response to the rapid decline in Arctic sea ice. Technical report.

Okkonen, S. R. 1996. The influence of an Alaskan Stream eddy on flow through Amchitka Pass. Journal of Geophysical Research-Oceans **101**:8839–8851.

Okkonen, S. R., G. A. Jacobs, E. J. Metzger, H. E. Hurlburt, and J. F. Shriver. 2001. Mesoscale variability in the boundary currents of the Alaska Gyre. Continental Shelf Research **21**:1219–1236.

Okkonen, S. R., T. J. Weingartner, S. L. Danielson, D. L. Musgrave, and G. M. Schmidt. 2003. Satellite and hydrographic observations of eddy-induced shelf-slope exchange in the northwestern Gulf of Alaska. Journal of Geophysical Research-Oceans **108**.

Orensanz, J. M., B. Ernst, and D. A. Armstrong. 2007. Variation of female size and stage at maturity in snow crab (Chionoecetes opilio) (Brachyura : Majidae) from the eastern Bering sea. Journal of Crustacean Biology **27**:576–591.

Orsi, J., E. A. Fergusson, M. V. Sturdevant, W. R. Heard, and E. V. Farley Jr. 2012. Annual survey of juvenile salmon, ecologically-related species, and biophysical factors in the marine waters of southeastern Alaska, MayAugust 2011. Technical report, Auke Bay Lab., Alaska Fisheries Science Center, National Marine Fisheries, NOAA, NMFS, 17109 Point Lena Loop Road, Juneau, 99801, USA.

Orsi, J., A. Wertheimer, M. Sturdevant, E. Fergusson, D. Mortensen, and B. Wing. 2004. Juvenile chum salmon consumption of zooplankton in marine waters of southeastern Alaska: a bioenergetics approach to implications of hatchery stock interactions. Reviews in Fish Biology and Fisheries **14**:335–359.

Orsi, J. A., J. Harding, S. Pool, R. D. Brodeur, L. Haldorson, J. Murphy, J. H. Moss, E. V. Farley, R. M. Sweeting, J. F. T. Morris, M. Trudel, R. J. Beamish, R. Emmett, and E. A. Fergusson. 2007. Epipelagic Fish Assemblages Associated with Juvenile Pacific Salmon in Neritic Waters of the California Current and the Alaska Current. American Fisheries Society Symposium Series **57**:105–155.

Orsi, J. A., M. Sturdevant, and E. Fergusson. 2013. Connecting the dots? among coastal ocean metrics and Pacific salmon production in Southeast Alaska, 1997-2012. Technical report.

Ortiz, I., F. Weise, and A. Grieg. in press. Marine regions in the Bering Sea. Deep Sea Research II .

Osuga, D. T., and R. E. Feeney. 1978. Antifreeze glycoproteins from arctic fish. Journal of Biological Chemistry **253**:5338–5343.

PAME. 2013. Large Marine Ecosystems (LMEs) of the Arctic area-Revision of the Arctic LME map. Technical report.

Park, W., M. V. Sturdevant, J. A. Orsi, A. Wertheimer, E. A. Fergusson, W. R. Heard, and T. Shirley. 2004. Interannual abundance patterns of copepods during an ENSO event in Icy Strait, southeastern Alaska. Ices Journal of Marine Science **61**:464–477.

Parker-Stetter, S. L., J. K. Horne, and T. J. Weingartner. 2011. Distribution of polar cod and age-0 fish in the US Beaufort Sea. Polar Biology **34**:1543–1557.

Paul, J. M., A. Paul, and W. E. Barber. 1997. Reproductive biology and distribution of the snow crab from the northeastern Chukchi Sea, pages 287–294 . Bethesda, MD.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal Du Conseil **39**:175–192.

Petitgas, P. 1993. Geostatistics for fish stock assessments: a review and an acoustic application. ICES Journal of Marine Science: Journal du Conseil **50**:285–298.

Piatt, J. F., and P. J. Anderson. 1996. Response of Common Murres to the Exxon Valdez oil spill and long-term changes in the Gulf of Alaska marine ecosystem. American Fisheries Society Symposium **18**:720–737.

Pickart, R. S., G. W. K. Moore, D. J. Torres, P. S. Fratantoni, R. A. Goldsmith, and J. Y. Yang. 2009. Upwelling on the continental slope of the Alaskan Beaufort Sea: Storms, ice, and oceanographic response. Journal of Geophysical Research-Oceans **114**.

Pitcher, K. W., and F. H. Fay. 1982. Feeding by Steller Sea Lions on Harbor Seals. Murrelet **63**:70–71.

Purcell, J. E., R. A. Hoover, and N. T. Schwarck. 2009. Interannual variation of strobilation by the scyphozoan Aurelia labiata in relation to polyp density, temperature, salinity, and light conditions in situ. Marine Ecology Progress Series **375**:139–149.

Quakenbush, L. T., R. J. Small, and J. J. Citta. 2010. Satellite tracking of western arctic bowhead whales. Technical report.

Quast, J. C. 1974. Density distribution of juvenile Arctic cod, Boreogadus saida, in the eastern Chukchi Sea in the fall of 1970. Fishery Bulletin **72**:1094–1105.

Rand, K. M., and E. A. Logerwell. 2011. The first demersal trawl survey of benthic fish and invertebrates in the Beaufort Sea since the late 1970s. Polar Biology **34**:475–488.

Ream, R. R., J. T. Sterling, and T. R. Loughlin. 2005. Oceanographic features related to northern fur seal migratory movements. Deep-Sea Research Part Ii-Topical Studies in Oceanography **52**:823–843.

Reisewitz, S. E., J. A. Estes, and et al. 2006. Indirect food web interactions: sea otters and kelp forest fishes in the Aleutian archipelago. Oecologia **146**:623–631.

Ressler, P., A. De Robertis, J. D. Warren, J. N. Smith, and Kot. 2012. Developing an acoustic index of euphausiid abundance to understand trophic interactions in the Bering Sea ecosystem,. Dee **65-70**:184–195.

Richard, P. R., A. R. Martin, and J. R. Orr. 2001. Summer and autumn movements of belugas of the Eastern Beaufort Sea stock. Arctic **54**:223–236.

Richardson, A. J., A. W. Walne, A. G. J. John, T. D. Jonas, J. A. Lindley, D. W. Sims, D. Stevens, and M. Witt. 2006. Using continuous plankton recorder data. Progress in Oceanography **68**:27–74.

Riemer, S. D., and R. F. Brown. 1997. Prey of Pinnipeds at Selected Sites in Oregon Identified by Scat (Fecal) Analysis, 1983-1996. Oregon Department of Fish and Wildlife, Technical Report No.97-6-02. .

Rigor, I. G., J. M. Wallace, and R. L. Colony. 2002. Response of sea ice to the Arctic oscillation. Journal of Climate **15**:2648–2663.

Robards, M., and J. Garlich-Miller. 2013. Workshop on assessing Pacific walrus population attributes from coastal haul-outs. Technical report.

Rooper, C. N. 2008. An ecological analysis of rockfish (Sebastes spp.) assemblages in the North Pacific Ocean along broad-scale environmental gradients. Fishery Bulletin **106**:1–11.

Sakshaug, E. 2004. Primary and secondary production in the Arctic Seas, pages 57–81 . Springer, Berlin; New York.

Schindler, D. E., R. Hilborn, B. Chasco, C. P. Boatright, T. P. Quinn, L. A. Rogers, and M. S. Webster. 2010. Population diversity and the portfolio effect in an exploited species. Nature **465**:609–613.

Sease, J. L., and A. E. York. 2003. Seasonal Distribution of Steller's Sea Lions at Rookeries and Haul-Out Sites in Alaska. Marine Mammal Science **19**:745–763.

Siddon, E. C., R. A. Heintz, and F. J. Mueter. 2013. Conceptual model of energy allocation in walleye pollock (Theragra chalcogramma) from age-0 to age-1 in the southeastern Bering Sea. Deep Sea Research Part II: Topical Studies in Oceanography .

Sigler, M., D. Tollit, J. J. Vollenweider, J. F. Thedinga, D. J. Csepp, J. N. Womble, M. A. Wong, M. J. Rehberg, and A. W. Trites. 2009. Steller Sea Lion Foraging Response to Seasonal Changes in Prey Availability. Marine Ecology Progress Series **388**.

Sigler, M. F., M. Renner, S. L. Danielson, L. B. Eisner, R. R. Lauth, K. J. Kuletz, E. A. Logerwell, and J. Hunt, G. L. 2011. Fluxes, Fins, and Feathers Relationships Among the Bering, Chukchi, and Beaufort Seas in a Time of Climate Change. Oceanography **24**:250–265.

Sinclair, E. H., and T. K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (Eumetopia jubatus). Journal of Mammalogy **83**:973–990.

Smith, T. G., M. O. Hammill, and G. Taugbol. 1991. A review of the developmental, behavioral and physiological adaptations of the ringed seal, Phoca hispida, to life in the Arctic winter. Arctic **44**:124–131.

Somerton, D. A. 1981. Regional variation in the size of maturity of two species of tanner crab (Chionoecetes bairdi and C. opilio) in the eastern Bering Sea, and its use in defining management subareas. Canadian Journal of Fisheries and Aquatic Sciences **38**:163–174.

Spalinger, K. 2013. Bottom trawl survey of crab and groundfish: Kodiak, Chignik, South Peninsula, and Eastern Aleutian Management Districts, 2012. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Management Report No. 13-27, Anchorage. Technical report.

Sparks, A., and W. Pereyra. 1966. Benthic Invertebrates of the Southeastern Chukchi Sea, pages 817–838 . U.S. Atomic Energy Commission, Oak Ridge, TN.

Spencer, P. D. 2008. Density-independent and density-dependent factors affecting temporal changes in spatial distributions of eastern Bering Sea flatfish. Fisheries Oceanography **17**:396–410.

Spencer, P. D., T. K. Wilderbuer, and C. I. Zhang. 2002. A mixed-species yield model for eastern Bering Sea shelf flatfish fisheries. Canadian Journal of Fisheries and Aquatic Sciences **59**:291–302.

Springer, A. M., and C. P. McRoy. 1993. The paradox of pelagic food webs in the northern Bering Sea-III. Patterns of primary production. Continental Shelf Research **13**:575–599.

Springer, A. M., C. P. McRoy, and M. V. Flint. 1996. The Bering Sea Green Belt: Shelf-edge processes and ecosystem production. Fisheries Oceanography **5**:205–223.

Springer, A. M., C. P. McRoy, and K. R. Turco. 1989. The paradox of pelagic food webs in the northern Bering Sea-II. Zooplankton communities. Continental Shelf Research **9**:359–386.

Stabeno, P. J., N. A. Bond, A. J. Hermann, N. B. Kachel, C. W. Mordy, and J. E. Overland. 2004. Meteorology and oceanography of the Northern Gulf of Alaska. Continental Shelf Research **24**:859–897.

Stabeno, P. J., J. Farley, E. V., N. B. Kachel, S. Moore, C. W. Mordy, J. M. Napp, J. E. Overland, A. I. Pinchuk, and M. F. Sigler. 2012. A comparison of the physics of the northern and southern shelves of the eastern Bering Sea and some implications for the ecosystem. Deep-Sea Research Part Ii-Topical Studies in Oceanography **65-70**:14–30.

Stabeno, P. J., D. G. Kachel, N. B. Kachel, and M. E. Sullivan. 2005. Observations from moorings in the Aleutian Passes: temperature, salinity and transport. Fisheries Oceanography **14**:39–54.

Stabeno, P. J., R. K. Reed, and J. D. Schumacher. 1995. THE ALASKA COASTAL CURRENT - CONTINUITY OF TRANSPORT AND FORCING. Journal of Geophysical Research-Oceans **100**:2477–2485.

Stevenson, D. E., and G. R. Hoff. 2009. Species identification confidence in the eastern Bering Sea shelf survey (1982-2008). AFSC Processed Rep. 2009-04, Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv.,, 7600 Sand Point Way NE, Seattle WA 98115.

Stevenson, D. E., and R. R. Lauth. 2012. Latitudinal trends and temporal shifts in the catch composition of bottom trawls conducted on the eastern Bering Sea shelf. Deep-Sea Research Part II-Topical Studies in Oceanography **65-70**:251–259.

Stoker, S. W. 1981. Benthic invertebrate macrofauna of the eastern Bering/Chukchi continental shelf, volume 2, pages 1069–1090 . U.S. Dep. Commer., NOAA, Office of Marine Pollution Assessment, University of Washington Press, Seattle, WA.

Stroeve, J. C., M. C. Serreze, M. M. Holland, J. E. Kay, J. Malanik, and A. P. Barrett. 2012. The Arctic's rapidly shrinking sea ice cover: a research synthesis. Climatic Change **110**:1005–1027.

Sturdevant, M. V., R. Brenner, E. A. Fergusson, J. A. Orsi, and B. Heard. 2013. Does predation by returning adult pink salmon regulate pink salmon or herring abundance? Technical report.

Sturdevant, M. V., J. A. Orsi, and E. A. Fergusson. 2012. Diets and Trophic Linkages of Epipelagic Fish Predators in Coastal Southeast Alaska during a Period of Warm and Cold Climate Years, 19972011. Marine and Coastal Fisheries **4**:526–545.

Suydam, R. S. 2009. Age, growth, reproduction, and movements of beluga whales (Delphinapterus leucas) from the eastern Chukchi Sea. Ph.d. dissertation.

Trenberth, K., and J. W. Hurrell. 1994. Decadal atmosphere-ocean variations in the Pacific. Climate Dynamics **9**:303–319.

Trites, A. W., D. Calkins, and A. J. Winship. 2007. Diets of Steller Sea Lions (*Eumetopias jubatus*) in Southeast Alaska, 1993-1999. Fishery Bulletin **105**:234–248.

Trudel, M., J. Fisher, J. A. Orsi, J. F. T. Morris, M. E. Thiess, R. M. Sweeting, S. Hinton, E. A. Fergusson, and D. W. Welch. 2009. Distribution and Migration of Juvenile Chinook Salmon Derived from Coded Wire Tag Recoveries along the Continental Shelf of Western North America. Transactions of the American Fisheries Society **138**:1369–1391.

Turnock, B. J., and T. K. Wilderbuer. 2009. Gulf of Alaska Arrowtooth Flounder Stock Assessment. Technical report, N Pac Fish Manage Council, 605 W 4th Ave, Anchorage, AK 99510.

Udevitz, M. S., R. L. Taylor, J. L. Garlich-Miller, L. T. Quakenbush, and J. A. Snyder. 2013. Potential population-level effects of increased haulout-related mortality of Pacific walrus calves. Polar Biology **36**:291–298.

Waite, J. N., and V. N. Burkanov. 2006. Steller Sea Lion Feeding Habits in the Russian Far East, 2000-2003. University of Alaska, Fairbanks.

Walsh, J. J., C. P. McRoy, L. K. Coachman, J. J. Goering, J. J. Nihoul, T. E. Whitledge, T. H. Blackburn, P. L. Parker, C. D. Wirick, P. G. Shuert, J. M. Grebmeier, A. M. Springer, R. D. Tripp, D. A. Hansell, S. Djenidi, E. Deleersnijder, K. Henriksen, B. A. Lund, P. Andersen, F. E.

Mller-Karger, and K. Dean. 1989. Carbon and nitrogen cycling within the Bering/Chukchi seas: Source regions for organic matter effecting AOU demands of the Arctic Ocean. Progress in Oceanography **22**:277–359.

Wang, J., G. F. Cota, and J. C. Comiso. 2005. Phytoplankton in the Beaufort and Chukchi Seas: Distribution, dynamics, and environmental forcing. Deep-Sea Research Part Ii-Topical Studies in Oceanography **52**:3355–3368.

Weingartner, T., L. Eisner, G. L. Eckert, and S. Danielson. 2009. Southeast Alaska: oceanographic habitats and linkages. Journal of Biogeography **36**:387–400.

Welch, H. E., M. A. Bergmann, T. D. Siferd, K. A. Martin, M. F. Curtis, R. E. Crawford, R. J. Conover, and H. Hop. 1992. Energy flow through the marine ecosystem of the Lancaster Sound Region, Arctic Canada. Arctic **45**:343–357.

Wespestad, V. G., L. W. Fritz, W. J. Ingraham, and B. A. Megrey. 2000. On relationships between cannibalism, climate variability, physical transport, and recruitment success of Bering Sea walleye pollock (Theragra chalcogramma). Ices Journal of Marine Science **57**:272–278.

Wilderbuer, T. K., A. B. Hollowed, W. J. Ingraham, P. D. Spencer, M. E. Conners, N. A. Bond, and G. E. Walters. 2002. Flatfish recruitment response to decadal climatic variability and ocean conditions in the eastern Bering Sea. Progress in Oceanography **55**:235–247.

Willette, T. M., and R. T. Cooney. 1991. An empirical orthogonal functions analysis of sea surface temperature anomalies in the North Pacific Ocean and cross correlations with pink salmon (*Oncorhynchus gorbuscha*) returns to southern Alaska. In: (White, B., and Guthrie, I.) Proceedings of 15th Pink and Chum Salmon Workshop. Pacific Salmon Commission pages 111–121 .

Williams, E. H., and T. J. Quinn. 2000. Pacific herring, (Clupea pallasi), recruitment in the Bering Sea and north-east Pacific Ocean, I: relationships among different populations. Fisheries Oceanography **9**:285–299.

Williams, T. M. 2005. Reproductive energetic of sea lions: implications for the size of protected areas around Steller sea lion rookeries. Alaska Sealife Center, Seward, AK.

Winship, A. J., A. W. Trites, and D. A. S. Rosen. 2002. A Bioenergetic Model for Estimating the Food Requirements of Steller Sea Lions (*Eumetopias jubatus*) in Alaska, USA. Marine Ecology Progress Series **229**:291–312.

Witherell, D. 2000. Groundfish of the Bering Sea and Aleutian Islands Area: Species Profiles 2001. Technical report, North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501.

Witherell, D., and Woodby. 2005. Application of marine protected areas for sustainable production and marine biodiversity off Alaska. Marine Fisheries Review **67**:1.

Wolotira, R. J., T. M. Sample, and M. Morin. 1977. Demersal fish and shellfish resources of Norton Sound, the Southeastern Chukchi Sea, and adjacent waters in the baseline year 1976. Technical report.

Wolter, K. 2012. Multivariate ENSO Index (MEI).

Woodgate, R. A., K. Aagaard, and T. J. Weingartner. 2005. A year in the physical oceanography of the Chukchi Sea: Moored measurements from autumn 1990-1991. Deep-Sea Research Part Ii-Topical Studies in Oceanography **52**:3116–3149.

Wyllie-Echeverria, T., and W. S. Wooster. 1998. Year to-year variations in Bering Sea ice cover and some consequences for fish distributions. Fisheries Oceanography **7**:159–170.

Zador, S. G., and S. Gaichas. 2010. Ecosystem Considerations for 2011. Groundfish Stock Assessment and Fishery Evaluation Report.

Zheng, J., F. Funk, G. H. Kruse, and R. Fagen. 1993. Evaluation of threshold management strategies for Pacific herring in Alaska. University of Alaska Fairbanks, Alaska Sea Grant College Program Report 93-02.

Zwolinski, J., and D. A. Demer. 2012. A cold oceanographic regime with high exploitation rates in the Northeast Pacific forecasts a collapse of the sardine stock. Proceedings of the National Academy of Sciences **109**:4175–4180.