Ecosystem Considerations

2014
DRAFT

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Executive Summary of Recent Trends

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

Physical and Environmental Trends

- The state of the North Pacific atmosphere-ocean system during 2013-2014 featured the development of strongly positive SST anomalies south of Alaska; the warm upper ocean conditions persisted through the summer of 2014 (p. 24).
- The unusual winter weather appears to be largely due to intrinsic variability rather than associated with leading modes of climate variability such as ENSO (p. 24).
- The Pacific Decadal Oscillation (PDO) underwent a transition from negative to positive during the past year (p. 29).
- The models used to forecast ENSO, as a group, are indicating weak-moderate El Niño conditions for the winter of 2014-15, which should serve to maintain a positive sense to the PDO (p. 31).

Arctic

- There is reduced sea ice cover in the Arctic during the summer of 2014 compared to seasonal norms, but not to the extent that occurred in 2011 and 2012 (p. 24).
- There was an earlier onset of ice on the Beaufort Sea shelf in fall 2013 than most previous years; the onset in the Chukchi Sea was more typical of the recent past. (p. 24).

Eastern Bering Sea

- The Bering Sea shelf experienced a much lighter ice year than during the previous years of the recent cold period dating back to 2007 (p. 24).
- Anomalous warming was particularly prominent during spring 2014. The summer cold pool during 2014 was mostly restricted to north of 60°N. There was less storminess than usual (p. 24).

Aleutian Islands

- The wind anomalies in this region were of the sense to produce reduced flow of Pacific water northward through Unimak Pass and a relatively broad and weak Alaskan Stream over much of the last year, with spring 2014 being an exception (p. 24).

- Eddy energy in the region was from the fall 2012 through July 2014, indicating that average volume, heat, salt, and nutrient fluxes through Amukta Pass were likely smaller during the this time (p. 36).
- Sea surface temperature values warmed from near normal to above normal during the past year (p. 25).

Gulf of Alaska

- The upper ocean in this region was fresher than usual with a relatively strong pycnocline (p. 24).
- The coastal winds were upwelling favorable in an anomalous sense, which helped maintain relatively normal SST along the coast as compared with the much warmer than normal water offshore (p. 24).
- The sub-arctic front was farther north than usual, which is consistent with the poleward surface currents shown in the Ocean Surface Currents - Papa Trajectory Index (p. 40).
- Eddy Kinetic Energy (EKE) levels in the western Gulf of Alaska were particularly weak in summer of 2014. Thus, phytoplankton biomass were likely more tightly confined to the shelf in those years and cross-shelf transport of heat, salinity and nutrients were probably weak (p. 38).
- In the northern Gulf, relatively high eddy kinetic energy was observed in the summer of 2014 (p. 38).
- It now appears the filtered PAPA Trajectory Index may shift back to northerly flow, which would indicate that the recent period of predominantly southern flow (mid-2000s to present) will have been the shortest and weakest in the time series (p. 40).

Ecosystem Trends

Alaska-wide

- The 2013 estimated numbers of bycaught seabirds in groundfish fisheries are the lowest since bycatch estimates began in 1993 (p. 93).
- There seems to be a generally decreasing trend in seabird bycatch since the new estimation procedures began in 2007, indicating no immediate management concern other then continuing our goal of decreased seabird bycatch (p. 93).

Bering Sea

- During the BASIS surveys from 2003-2012, the highest phytoplankton biomass was observed in the Outer shelf inshore of Bering Canyon, near the Pribilof Islands, along the Aleutian Islands, north of St Lawrence, and in the south Inner shelf. Lowest biomass was observed in the north Bering and SE Middle shelf (in a region of high stability) (p. 45).
- Larger phytoplankton were seen on the Inner shelf and near the Pribilofs. Smaller phytoplankton were seen on the SE Middle shelf (an area of lower total chla), and in the Outer shelf (an area of higher total chla) (p. 45).
- In the south Bering Sea, the mean size of phytoplankton assemblages were higher in warm (2003-2005) than in cold (2006-2-12) years, and higher in 2003-2005 and 2011-2012 than in 2006-2010 in the north. Typically years with higher integrated chla had a greater fraction of large phytoplankton(p. 45).
- Late summer concentrations of surface silicate may serve as an indicator of nutrient availability, with higher concentrations seen during windy lower stratification years and low concentrations seen when storm activity is minimal and stratification is high (p. 49).

- Age-0 pollock weights and surface silicate concentrations are positively correlated (p. 49).
- Continuous plankton recorder observations indicated that the 2013 copepod community size was anomamously low in the southern Bering Sea regions; however, mesozooplankton biomass was near average and large diaton abundance was above average (p. 62).
- The fall 2013 survey of jellyfish occurred only north of 60°, where biomass of the was similar to previous years. The southern area which had shown record biomass the previous year was not surveyed (p. 52).
- The 2012-2014 springtime drift patterns do not appear to be consistent with years of good recruitment for northern rock sole, arrowtooth flounder and flathead sole (p. 81).
- The 2011 Temperature Change (TC) index value was below the long term average, therefore slightly below average numbers of pollock are expected to survive to age-3 in 2014. In the future, the TC values in 2013 and 2014 indicate above average abundances of age-3 pollock in 2014 and 2015 (p. 83).
- A multivariate seabird index indicates that 2013 was a generally successful year reproductively for Pribilof seabirds with the exception of kittiwake productivity. Years of high pink salmon abundance, the odd-numbered years after 1997, correlate with poor kittiwake productivity (p. 90).
- The leading principal component of 16 biological time series from the EBS shows a transition to negative values around 2009, similar in sign but lower in magnitude than before the 1976/77 regime shift which resulted in highly disruptive changes to ecosystems and fisheries. Recent scores show a linear relationship with winter SST, thus reflecting a possible response to recent changes in climate (p. 98)

Aleutian Islands

- No updated information at this time.

Gulf of Alaska

- The highest density of euphausiids was consistently observed in Barnabas Trough during acoustic surveys in 2003, 2005, 2011, and 2013. The highest overall abundance was observed in 2011, with lowest euphausiid abundance in 2003 (p. 54).
- Total Icy Strait zooplankton density was anomalously low for all months during the 2013 summer survey. Density anomalies were mostly negative from 1997-2005, positive in 2006-2009, and negative in 2010-2013 (p. 56).
- Icy Strait zooplankton were numerically dominated by calanoid copepods. In 2013, large calanoids and larvaceans were anomalously high while small calanoids were anomalously low (p. 56).
- In the Alaskan Shelf region sampled by the continuous plankton recorder, copepod community size and mesozooplankton biomass anomalies became negative in 2013 while large diatom abundance anomalies remained positive (p. 62).
- Overall catch rates of juvenile pollock in the 2013 smallmesh survey were the highest since 1979, although eulachon, herring, and pink shrimp catches remained low (p. 65).
- Although the estimated total mature herring biomass in southeastern Alaska has been above the long-term (1980-2013) median of 90,495 tons since 2003 through 2013, an apparent decrease in biomass has been observed since the peak in 2011. The most notable drop in biomass was observed in Hoonah Sound (p. 67).
- Ecosystem indicators predict a low pink salmon harvest in 2014 of about 30 M fish (p. 75).

- A new Southeast Alaska Coastal Monitoring project Chinook salmon index is the abundance estimate of ocean age-1 fish sampled in Icy Strait, lagged two years later to their ocean year of recruitment as ocean age-3 fish, the age when most reach legal size. Based on this Chinook index, June 1-ocean abundance has been below average in 8 of the past ten years. Most recently, Chinook salmon fishery recruitment appears weak in 2014 and 2016, but strong in both 2013, and particularly in 2015 (p. 79).
- Ecosystem indicators predict below average recruitment events for age-2 sablefish are expected in 2013 and 2015, and a slightly above-average recruitment event is expected in 2014 (p. 86).
- The leading principal component of 18 biological time series from the GOA shows a transition to lower-magnitude positive values around 2006. Recent scores show a linear relationship with winter SST, thus reflecting a possible response to recent changes in climate (p. 98)

Fishing and Fisheries Trends

Alaska-wide

- At present, no BSAI or GOA groundfish stock or stock complex is subjected to overfishing, and no BSAI or GOA groundfish stock or stock complex is considered to be overfished or to be approaching an overfished condition. The only crab stock considered to be overfished is the Pribilof Islands blue king crab stock, which is in year 11 of a 10-year rebuilding plan. None of the non-FSSI stocks are subject to overfishing, known to be overfished, or known to be approaching an overfished condition (Table 10) (p. 139).
- 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. 107).
- Catch of HAPC biota and assorted invertebrates in 2013 were the highest in the time series (p. 107).
- The pattern of changes in the total number of vessels harvesting groundfish and the number of vessels using hook and line gear have been very similar since 1994. Numbers have generally decreased since 1994 but have remained relatively stable in the last 5 years (2009-2013). The total number of vessels was 1,518 in 1994 and 936 in 2012. The number of vessels using trawl gear decreased from 257 in 1994 to 177 in 2012 (p. 147).

Bering Sea

- The maximum potential area of seafloor disturbed by trawling remained relatively stable in the 2000s, decreased in 2009-2010 but in 2012 returned to levels seen in the early 2000s. In 2013, the estimated area was 94,975 km^2 (p. 113).
- Trends in total non-target catch in the groundfish fisheries have varied in the EBS. The catch of Scyphozoan jellyfish has fluctuated over the last ten years with peaks in 2009, 2011, and 2013. HAPC biota catch decreased from 2003 to 2007 and has been generally steady since. Sea anemones comprised the majority of the catch (p. 107).

Aleutian Islands

- Trends in total non-target catch in the groundfish fisheries have varied in the AI. The catch of Scyphozoan jellies has been variable and shows no apparent trend over time. HAPC biota and assorted invertebrate catches reached new packs in 2013 (p. 107).

Gulf of Alaska

- Discarded tons of groundfish have remained relatively stable in the past few years with the exception of fixed gear, in which discard rates jumped from 6% to to 21% in 2013. Improved observer coverage on vessels less than 60' long and on vessels targeting IFQ halibut may account for the increase (p. 104).
- 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. 107).

Contents

***Executive Summary** **1**

Physical and Environmental Trends 1

Ecosystem Trends 2

Fishing and Fisheries Trends 4

***Responses to SSC comments** **19**

Ecosystem Indicators **24**

Ecosystem Status Indicators 24

Physical Environment 24

*North Pacific Climate Overview 24

*Sea Surface Temperature and Sea Level Pressure Anomalies 25

*Climate Indices 29

*Seasonal Projections from the National Multi-Model Ensemble (NMME) 31

ARCTIC 33

*Arctic Sea Ice Cover 33

EASTERN BERING SEA 33

Eastern Bering Sea Climate - FOCI 33

Summer Bottom and Surface Temperatures - Eastern Bering Sea 36

Spatial patterns in near-bottom oceanographic variables on the EBS slope 36

Regional Water Mass Characteristics in the Northern Bering Sea 36

ALEUTIAN ISLANDS 36

*Eddies in the Aleutian Islands - FOCI 36

Water Temperature Data Collections - Aleutian Islands Trawl Surveys 38

GULF OF ALASKA 38

*Eddies in the Gulf of Alaska - FOCI 38

*Ocean Surface Currents - PAPA Trajectory Index 40

Gulf of Alaska Survey Bottom Temperature Analysis 43

Spatial patterns in near-bottom oceanographic variables in the Gulf of Alaska 44

Habitat 44

Structural Epifauna (HAPC Biota) - Eastern Bering Sea 44

Structural Epifauna (HAPC Biota)- Aleutian Islands 44

Structural Epifauna (HAPC Biota)- Gulf of Alaska 44

Primary Production 44

*Phytoplankton Biomass and Size Structure During Late Summer to Early Fall in the Eastern Bering Sea 45

*Surface silicate as a potential indicator of nutrient availability during summer/early fall in the eastern Bering Sea; implications for age-0 walleye pollock condition 48

Gulf of Alaska Chlorophyll a Concentration off the Alexander Archipelago 51

Zooplankton 51

Bering Sea Zooplankton 51

Late Summer/Fall Abundances of Large Zooplankton in the Eastern Bering Sea . . . 52

Jellyfish - Eastern Bering Sea 52

*Trends in Jellyfish Bycatch from the Bering Aleutian Salmon International Survey (BASIS) 52

*Gulf of Alaska Euphausiids ("krill") 53

*Long-term Zooplankton and Temperature Trends in Icy Strait, Southeast Alaska . . 56

*Continuous Plankton Recorder Data from the Northeast Pacific 62

Forage Fish 65

Fall Condition of YOY Predicts Recruitment of Age-1 Walleye Pollock 65

Forage Fish CPUE - BASIS 65

*Gulf of Alaska Small Mesh Trawl Survey Trends 65

Regional Distribution of Juvenile Salmon and Age-0 Marine Fish in the Gulf of Alaska 66

Herring 67

Togiak Herring Population Trends 67

Prince William Sound Pacific Herring 67

*Southeastern Alaska Herring . . . 67

Salmon . . . 70

Historical and Current Alaska Salmon Trends . . . 70

*Forecasting Pink Salmon Harvest in Southeast Alaska . . . 74

†Using Ecosystem Indicators to develop a Chinook Salmon Abundance Index for Southeast Alaska . . . 79

Groundfish . . . 81

*Update on Eastern Bering Sea Winter Spawning Flatfish Recruitment and Wind Forcing 81

*Pre- and Post-Winter Temperature Change Index and the Recruitment of Bering Sea Pollock . . . 83

Trends in Groundfish Biomass and Recruits per Spawning Biomass . . . 84

Bering Sea Groundfish Condition . . . 85

Gulf of Alaska Ichthyoplankton Abundance Indices 1981-2011 . . . 85

*Southeast Coastal Monitoring Survey Indices and the Recruitment of Gulf of Alaska Sablefish . . . 86

Distribution of Rockfish Species in Gulf of Alaska and Aleutian Islands Trawl Surveys 88

Benthic Communities and Non-target Fish Species . . . 88

Spatial Variability of Catches in Bering Sea and Gulf of Alaska Crab Fisheries . . . 89

Bering Sea/Aleutian Islands King and Tanner Crab Stocks . . . 89

Miscellaneous Species - Eastern Bering Sea . . . 89

Miscellaneous Species - Aleutian Islands . . . 89

ADF&G Gulf of Alaska Trawl Survey . . . 89

Miscellaneous Species - Gulf of Alaska . . . 90

Seabirds . . . 90

*Multivariate Seabird Indices for the Eastern Bering Sea . . . 90

*Seabird Bycatch Estimates for Alaskan Groundfish Fisheries, 1993-2013 . . . 93

Marine Mammals . . . 96

Steller Sea Lions . . . 96

Northern Fur Seals . . . 97

Harbor Seals . . . 97

Arctic Ice Seals: Bearded Seal, Ribbon Seal, Ringed Seal, Spotted Seal . . . 97

Bowhead Whales . . . 97

Ecosystem or Community Indicators 97

*Regime shift indicators for the Gulf of Alaska and eastern Bering Sea 98

Total Catch-Per-Unit-Effort of All Fish and Invertebrate Taxa in Bottom Trawl Surveys 103

Biodiversity of the Groundfish and Invertebrate Community for the Eastern Bering Sea Slope 103

Average Local Species Richness and Diversity of the Groundfish Community 103

Combined Standardized Indices of Recruitment and Survival Rate 103

Spatial Distribution of Groundfish Stocks in the Eastern Bering Sea 103

Ecosystem-Based Management Indicators 104

Diversity 104

*Time Trends in Groundfish Discards 104

*Time Trends in Non-Target Species Catch 107

Fish Habitats 109

Areas Closed to Bottom Trawling in the EBS/ AI and GOA 109

*Area Disturbed by Trawl Fishing Gear in the Eastern Bering Sea 113

*Observed Fishing Effort in the Eastern Bering Sea 116

*Observed Fishing Effort in the Aleutian Islands 125

*Observed Fishing Effort in the Gulf of Alaska 131

Sustainability 139

*Fish Stock Sustainability Index and Status of Groundfish, Crab, Salmon and Scallop Stocks 139

Total Annual Surplus Production and Overall Exploitation Rate of Groundfish 145

Community Size Spectrum of the Bottom Trawl-Caught Fish Community of the Eastern Bering Sea 147

Humans as part of ecosystems 147

*Groundfish Fleet Composition 147

Distribution and Abundance Trends in the Human Population of the Bering Sea/Aleutian Islands 148

Distribution and Abundance Trends in the Human Population of the Gulf of Alaska . 148

References **150**

* indicates contribution updated in 2014
† indicates new contribution
Editor's Note: Incomplete citations are marked with a ?, and will be finalized in the next

draft.

List of Tables

1 Normalized anomalies calculated for 2003 to 2012 or to 2009 (stability) for the south Bering Sea Middle shelf (Bering Project regions 3 and 6) for temperature (T) above and below the pycnocline, stability over top 70 m, integrated chla and ratio of large (> 10 μm) to total chla over top 50 m data (August-September) from BASIS data, and friction velocity cubed (u^{*3}) near mooring M2 (August) from NCEP data. Data normalized to maximum anomaly for each variable. 49

2 Zooplankton long-term mean total density (numbers^{-3}) and taxonomic percent composition in Icy Strait, Southeast Alaska, 1997-2013. Data represent 4 stations sampled annually across the strait ($\leq$ 200 m depth) with a 0.6 m diameter 333-μm mesh Bongo net (double-oblique trajectory). Values are references for the 0-lines shown in Figures 23 and 24 interannual anomalies. 59

3 The two best SECM pink salmon forecast models for the 2013 SEAK harvest. 78

4 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 ($p < 0.05$). 83

5 Sablefish estimates from **?**, predictor variables used in the model (2001-2012), model estimates and standard errors (2001-2012), and forecast estimates; SE = standard error; SST = sea surface temperature. 87

6 Total **estimated** seabird bycatch in Alaskan groundfish fisheries, all gear types and Fishery Management Plan areas combined, 2007 through 2013. Note that these numbers represent extrapolations from observed bycatch, not direct observations. See text for estimation methods. 95

7 Groundfish trawl closure areas, 1995-2009. License Limitation Program (LLP); Habitat Conservation Area (HCA); Habitat conservation zone (HCZ). 112

8 Summary of status for FSSI and non-FSSI stocks managed under federal fishery management plans off Alaska, updated through June 2014. 140

9 FSSI stocks under NPFMC jurisdiction updated June 2014, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`. See Box A for endnotes and definition of stocks and stock complexes. 143

9 FSSI stocks under NPFMC jurisdiction updated June 2014, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`. See Box A for endnotes and definition of stocks and stock complexes. 144

10 Non-FSSI stocks, Ecosystem Component Species, and Stocks managed under an International Agreement updated June 2014, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`. See website for endnotes and definition of stocks and stock complexes. 146

List of Figures

1 SST anomolies for autumn, winter, spring, and summer. 27

2 SLP anomolies for autumn, winter, spring, and summer. 28

3 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`. 30

4 Predicted SST anomalies from the NMME model for OND (1 month lead), DJF (3 month lead), and FMA (5 month lead) for the 2014-2015 season. 32

5 Arctic sea ice extent for August 17, 2014 was 6.11 million square kilometers (2.36 million square miles). The magenta line shows the 1981 to 2010 median extent for that day. The black cross indicates the geographic North Pole. Credit: National Snow and Ice Data Center 34

6 Arctic sea ice extent as of August 17, 2014, along with daily ice extent data for the record year. 2014 is shown in blue and 2012 in green. The 1981 to 2010 average is in dark gray. Credit: National Snow and Ice Data Center 35

7 Eddy Kinetic Energy averaged over October 1993 - October 2013 calculated from satellite altimetry. Square denotes region over which EKE was averaged for Figure 8. 37

8 Eddy kinetic energy ($cm^2\ s^{-2}$) averaged over region shown in Figure 7. 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. 38

9 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 10. . . . 39

10 Eddy kinetic energy ($cm^2\ s^{-2}$) averaged over Region (d) (top) and Region (c) (bottom) shown in Figure 9. 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. 40

11 Simulated surface drifter trajectories for winters 2004-2014 (endpoint year). End points of 90-day trajectories for simulated surface drifters released on Dec. 1 of the previous year at Ocean Weather Station PAPA are labeled with the year of the endpoint (50°N, 145°W). . . . 41

12 Annual, long-term mean (green line) and 5-year running mean (red line and squares) of the PAPA Trajectory Index time-series (dotted black line and points) for 1902-2014. 42

13 Contours of integrated total chla (mg m^{-2}) (A) and integrated >10μm chla (B) averaged over 2003-2012, and stability (C) averaged over 2003-2009. Bathymetry contours are shown for 50 m, 100 m and 200 m (shelf break). 46

14 Integrated total chla (A) and ratio of large assemblages to total (>10μm /total chla) (B) in the Middle Domain in the south (54.5 59.5 °N, Bering project regions 3 and 6) and north (60 63 °N, Bering project regions 9 and 10) for 2003-2012. 47

15 Linear regression between mean August u^{*3}, an indicator of wind mixing, at mooring M2 and integrated chla for the southeastern Bering Sea Middle shelf in Bering Project Region 3 (region around M2) for 2003-2012. 48

16 Box and whisker plots depicting the median (solid horizontal line), mean values (circle with cross), and extremes (whiskers) of surface; phytoplankton uptake (μg $L^{-1}hr^{-1}$) (A), silicate (Si(OH)4, μM) (B) Chla (mg m^{-3}) (C) and ¿10 μm size Chla (mg m^{-3}) (D). Data are from primary production station locations (inner and middle domains only) with the exception of 2008 and 2012, where data are from Region 3. Asterisks indicate outliers from 95% CI. Outliers (for the year 2007 only) in plots A, B, and C are from the same date and location (57.5°N, 168.77°W). Due to an excess of outliers, they are not shown for plot D. 50

17 Inter-annual variability of normalized surface silicate ($Si(OH)_4$, from Region 3) and normalized mean weights of age-0 pollock (south of 60°N). Values were normalized by subtracting the mean from each value and dividing by the standard deviation. 51

18 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. 53

19 BASIS surface trawl Biomass (1000t) by genus for 2004-2013 in the Eastern Bering Sea during August -October. Biomass was calculated using average effort per survey area in km^2 by year. 54

20 Spatial distribution of acoustic backscatter density (s_A at 120 kHz, m^2 nmi^{-2}) attributed to euphausiids in key areas around Kodiak Island (Shelikof Strait, Barnabas Trough, and Chiniak Trough, as labeled in upper left panel) during the 2003, 2005, 2011, and 2013 Gulf of Alaska summer acoustic-trawl surveys. 55

21 Acoustic backscatter estimate of euphausiid abundance from NOAA-AFSC Gulf of Alaska summer acoustic-trawl survey. Error bars are approximate 95% confidence intervals computed from geostatistical estimates of relative estimation error (Petitgas 1993). 56

22 Marine climate relationships for the northern region of Southeast Alaska from the SECM 17-year time series, 1997-2013. Upper panel: mean monthly temperatures (°C, 20-m integrated water column) in Icy Strait; lower panel: correlation of mean annual temperature (°C, 20-m integrated water column) with the Multivariate ENSO Index (MEI), showing warm and cold years. Long-term mean temperatures are indicated in the top panel key by month. 58

23 Total zooplankton, euphausiid and large Calanoid density and composition anomalies for the SECM 17-yr time series from Icy Strait, Southeast Alaska, 1997-2013. Long-term monthly means are indicated by the 0-line (values given in Table 2). Data (shaded bars) are deviations for total density (number/m^3; top left panel), and taxonomic percent composition.. No samples were available for August 2006 or May 2007. Warm years are indicated in boxes on the x-axis; see Figure 22. 60

24 Small Calanoind, Larvacean and amphipod density and composition anomalies for the SECM 17-yr time series from Icy Strait, Southeast Alaska, 1997-2013. Long-term monthly means are indicated by the 0-line (values given in Table 2). Data (shaded bars) are deviations for total density (number/m^3; top left panel), and taxonomic percent composition. No samples were available for August 2006 or May 2007. Warm years are indicated in boxes on the x-axis; see Figure 22. 61

25 Boundaries of the three regions described in this report. Dots indicate actual sample positions (note that for the Alaskan Shelf region the multiple transects, more than 50, overlay each other almost entirely). 62

26 Annual anomalies of three indices of lower trophic levels (see text for description and derivation) for each region shown in (Figure 25). Note that sampling of this Alaskan Shelf region did not begin until 2004. 64

27 Anomalies from the long-term mean of forage species CPUE (kg km^{-1}) captured during the smallmesh survey in the Gulf of Alaska, 1972-2013. 66

28 Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 abundance (black line) at eight major spawning locations in southeastern Alaska, 1980-2013. Estimates of age-3 abundance for Tenakee Inlet were unavailable by time of publication. 69

29 Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 abundance (black line) at Sitka Sound spawning location in southeastern Alaska, 1980-2013. 70

30 Estimated combined annual mature herring biomass (including and excluding Sitka) at major southeastern Alaska spawning areas, 1980-2013. 71

31 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.) . . . 72

32 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. 73

33 Marine survival of Prince William Sound hatchery pink salmon by year of return (brood year +2 years). Data reproduced from Botz et al.(2013). 74

34 Previous SECM pink salmon pre-season forecast model predictions (with 80% confidence intervals) and actual SEAK harvests over the past decade. Harvest data from the SEAK pink salmon fishery still incomplete for 2014, and 2014 SECM surveys still ongoing for the 2015 forecast. 76

35 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`). 77

36 An alternate approach to forecasting pink salmon returns using a hind cast regression of the average ranks of the six significant ecosystem metrics (shaded green in Figure 35) and SEAK pink salmon harvest the ensuing year. The average rank in 2013 is 13th and projects a harvest in 2014 of about 28 M fish. This approach gives a similar harvest number to the 30 M predicted by the step-wise regression method. 78

37 Monthly correlations of juvenile and immature ocean age-1 Chinook salmon catch per unit effort in SECM surveys in Icy Strait lagged to ocean entry year and subsequent brood year survivals of wild and hatchery Chinook salmon stocks in Southeast Alaska over the 1995-2005 brood years (1997-2007 ocean years). Note the significant positive correlations of CPUE of ocean age-1 fish in June and salmon survival of most stock groups. 80

38 The SECM Chinook salmon index estimate of ocean age 1 fish sampled in Icy Strait in June, lagged two years later to potential recruitment of ocean age 3 fish, 1999-2016. No trawling was conducted in June of 2009, so the index was not available for 2011 81

39 OSCURS (Ocean Surface Current Simulation Model) trajectories from starting point 56°N, 164°W from April 1-June 30 for 2006-2014. 82

40 The Temperature Change index value from 1950-2014. 84

41 Normalized times series values of the temperature change index (t-2) and the estimated abundance of age-3 walleye pollock in the eastern Bering Sea (t)) from Table 1.21 in Ianelli et al. 2013. 85

42 Age-2 sablefish modeled as a function of chlorophyll *a* during the age-0 stage (t-2), sea temperature during the age-0 stage (t-2), and juvenile pink salmon productivity during the age-0 stage and overwintering survival to age-1 (based on adult pink salmon in year t-1). 88

43 Loadings (absolute correlations) measuring the strength of association between individual time series and the first (PC1, top) and second (PC2, bottom) principal components. The datasets are labeled in order with a 4-letter bird species code following American Ornithological Union convention (e.g., BLKI: black-legged kittiwake), a 2-letter island code (SP: St. Paul; SG: St. George), and H if it is a hatch date time series. 91

44 The value of PC1 (top) and PC2 (bottom) over time. Higher values of PC1 indicate earlier seabird hatch dates and higher cormorant and murre reproductive success (except for St. George thick-billed murres). Higher values of PC2 indicate higher kittiwake reproductive success, and new with the inclusion of 2012 data, St. Paul thick-billed murre reproductive success and St. Paul black-legged kittiwake hatch dates. 92

45 Seabird bycatch in Alaskan groundfish fisheries, all gear types combined, 1993 to 2013. Total estimated bird numbers are shown in the left-hand axis while estimated albatross numbers are shown in the right-hand axis 94

46 Winter (NDJFM) SST for the Gulf of Alaska and southeastern Bering Sea, 1965-2012. Recent years (2006-2012, green) and years prior to the 1976/77 PDO shift (1965-1976, blue) are highlighted for comparison. 99

47 Time series and loadings for PC1-3 in southeast Bering Sea biological time series. Dots in left-hand panels indicate annual values, with error bars = 95% CI, reflecting uncertainty associated with estimating missing values. Red lines indicate mean values of regimes defined by STARS. Bars in right-hand columns indicate loadings for taxa most strongly associated with each PC (absolute values > 0.2). 100

48 Time series and loadings for PC1 in Gulf of Alaska biological time series. Dots in left-hand panels indicate annual values, with error bars = 95% CI, reflecting uncertainty associated with estimating missing values. Red line indicates mean values of regimes defined by STARS. Bars in right-hand columns indicate loadings for taxa most strongly associated with PC1 (absolute values > 0.2). 101

49 Time-dependent climate-biology relationships in the Bering Sea and Gulf of Alaska: SST-PC1 relationships before and after 1988/89 climate shift (Hare and Mantua, 2000). Regressions are best non-parametric models, with smoothing limited to ? 3 effective degrees of freedom. SST values are 3-yr running means. 102

50 Total biomass and percent of total catch biomass of managed groundfish discarded in the BSAI and GOA fixed gear, pollock trawl, and non-pollock trawl sectors, 1993-2013. (Includes only catch counted against federal TACS) 106

51 Total catch of non-target species (tons) in the EBS, AI, and GOA groundfish fisheries (2003-2013). **Please note the different y-axis scales** between regions and species groups. 108

52 Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska, excluding most SSL closures. 111

53 (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 115

54 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. 117

55 Bering Sea observed fishing effort, 1990-2013. 118

56 Observed longline effort (sets) in the Bering Sea 2003-2013. 119

57 Observed longline fishing effort in 2011 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (observed effort for 2013 - average observed effort from 2003-2013)/stdev(effort from 2003-2013). 119

58 Spatial location and density of observed pelagic trawling in the Bering Sea 1998-2013. 120

59 Observed pelagic trawl fishing effort in 2013 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (estimated effort for 2013 - average effort from 2003-2013)/stdev(effort from 2003-2013). 121

60 Spatial location and density of observed bottom trawling in the Bering Sea 1998-2013. 122

61 Observed bottom trawl fishing effort in 2013 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (estimated effort for 2013 - average effort from 2003-2013)/stdev(effort from 2003-2013). 122

62 Spatial location and density of pot effort (observed number of pot lifts) in the Bering Sea 1998-2013. 123

63 Observed pot fishing effort in 2012 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2013)/stdev(effort from 2003-2013). 124

64 Aleutian Islands observed fishing effort 1990-2013. 126

65 Observed longline effort (sets) in the Aleutian Islands, 2003-2013. 127

66 Observed longline fishing effort in 2011 relative to the 2003-2013 average in the Aleutian Islands. Anomalies calculated as (observed effort for 2013 - average observed effort from 2003-2013)/stdev(effort from 2003-2013). 127

67 Spatial location and density of observed bottom trawl effort in the Aleutian Islands, 1998-2012. 128

68 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). 129

69 Spatial location and density of pot effort (observed number of pot lifts) in the Aleutian Islands, 1998-2012. 130

70 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). 130

71 Gulf of Alaska observed fishing effort, 1990-2013. 133

72 Observed longline effort (sets) in the Gulf of Alaska, 2003-2012. 133

73 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). 134

74 Spatial location and density of observed pelagic trawl effort in the Gulf of Alaska, 1998-2012. 135

75 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). 135

76 Spatial location and density of observed bottom trawl effort in the Gulf of Alaska, 1998-2012. 136

77 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). 137

78 Spatial location and density of pot effort (observed number of pot lifts) in the Gulf of Alaska, 1998-2012. 138

79 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). 138

80 The trend in total Alaska FSSI from 2006 through 2014. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries`. The maximum possible FSSI score is 140 in all years. 141

81 Number of vessels participating in the groundfish fisheries off Alaska by gear type, 1994-2012. 148

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

December 2013 SSC Comments

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

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

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

Editor's summaries will be included in the November draft as more information is available to synthesize.

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

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

Some of the indicators we follow are products of the Integrated Ecosystem Studies (IERP). Regional Distribution of Juvenile Salmon and Age-0 Marine Fish in the Gulf of Alaska (p. 67) is a product of the Gulf of Alaska IERP. This year we will also have a new contribution, Modeled and Realized

Bioenergetic-Based Daily Food Rations of EBS Groundfish Species (p. tbd), which is a Bering Sea IERP product. In addition, the ecosystem assessments in the November draft will be reformatted to more closely align with NOAA's Integrated Ecosystem Assessment (IEA) organization, including risk assessment and management strategy evaluation. The eastern Bering Sea ecosystem assessment will highlight modeling efforts that are part of the Bering Sea IERP.

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

An update to the Arctic assessment section is in progress and will be included in the November draft.

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

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

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

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

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

1. *Despite the increase in Calanus copepods, the low water temperatures in 2012 apparently led to fewer and smaller age-0 pollock, possibly because temperatures were too low for early survival;*
2. *The small age-0 pollock had low total energy content in 2012, suggesting that recruitment to*

age-1 for this year class may be weak;

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

Conditions in the eastern Bering Sea during 2014 are proving to be quite different from 2013 and recent years. Ice broke out earlier and the cold pool is much reduced as described in Nick Bond's contributions on North Pacific Climate (p. 24). There will be a more comprehensive review of 2014 conditions in the November draft when the surveys are completed and data are available.

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

This topic will be discussed in the Editor's review of the seabird section in the November report.

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

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

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

Survey data from summer 2014 may help to inform this question as conditions have warmed considerably.

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

It now appears the filtered PAPA Trajectory Index may shift back to northerly flow, in contrast to the conclusion last year, which would indicate that the recent period of predominantly southern flow (mid-2000s to present) will have been the shortest and weakest in the time series (p. 40). Also, the Gulf of Alaska has experienced record warm anomalies this winter through summer (p. 24); the extent of biological response to this warming is still being determined. A sablefish recruitment prediction index is included in this report (p. 86). Based on sea temperature, chlorophyll a, and pink salmon productivity, the model predicts below average recruitment events for age-2 sablefish in 2013 and 2015, and a slightly above-average recruitment event is expected in 2014

The SSC supports the development of an acoustic index of euphausiid abundance and distribution

in the Gulf similar to that available for the Bering Sea.

New this year we include a contribution on a newly developed euphausiid index for the GOA (p. 54).

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

This report includes a new contribution titled Using Ecosystem Indicators to develop a Chinook Salmon Abundance Index for Southeast Alaska (p. 79). The authors state that contrary to many of the assumptions of negative impacts of pink salmon on other species, in the case of these two strong year classes of Chinook, they coincide with the same ocean entry years of the high juvenile pink salmon abundances in 2010 and 2012. This suggests that both juvenile Chinook and pink salmon mutually benefited from favorable ocean conditions in 2010 and 2012, or the smaller, more abundant juvenile pink salmon proved to be a predator buffer to the larger Chinook salmon juveniles. The upcoming 2015 Chinook salmon harvest and abundance of legal sized (age 3-ocean) will be a good test of this index.

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

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

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

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

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

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

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

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

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

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

Ecosystem Indicators

Ecosystem Status Indicators

Indicators presented in this section are intended to provide detailed information and updates on the status and trends of ecosystem components. Older contributions that have not been updated are excluded from this report. Please see archived versions available at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Physical Environment

North Pacific Climate Overview

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Last updated: September 2014

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

Regional Highlights:

Arctic. There was an earlier onset of ice on the Beaufort Sea shelf in fall 2013 than most previous years; the onset in the Chukchi Sea was more typical of the recent past. The winter along the Arctic coast was relatively warm, with surface air temperature anomalies of 4° C. There is reduced

sea ice cover in the Arctic during the summer of 2014 compared to seasonal norms, but not to the extent that occurred in 2011 and 2012.

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

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

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

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

Sea Surface Temperature and Sea Level Pressure Anomalies

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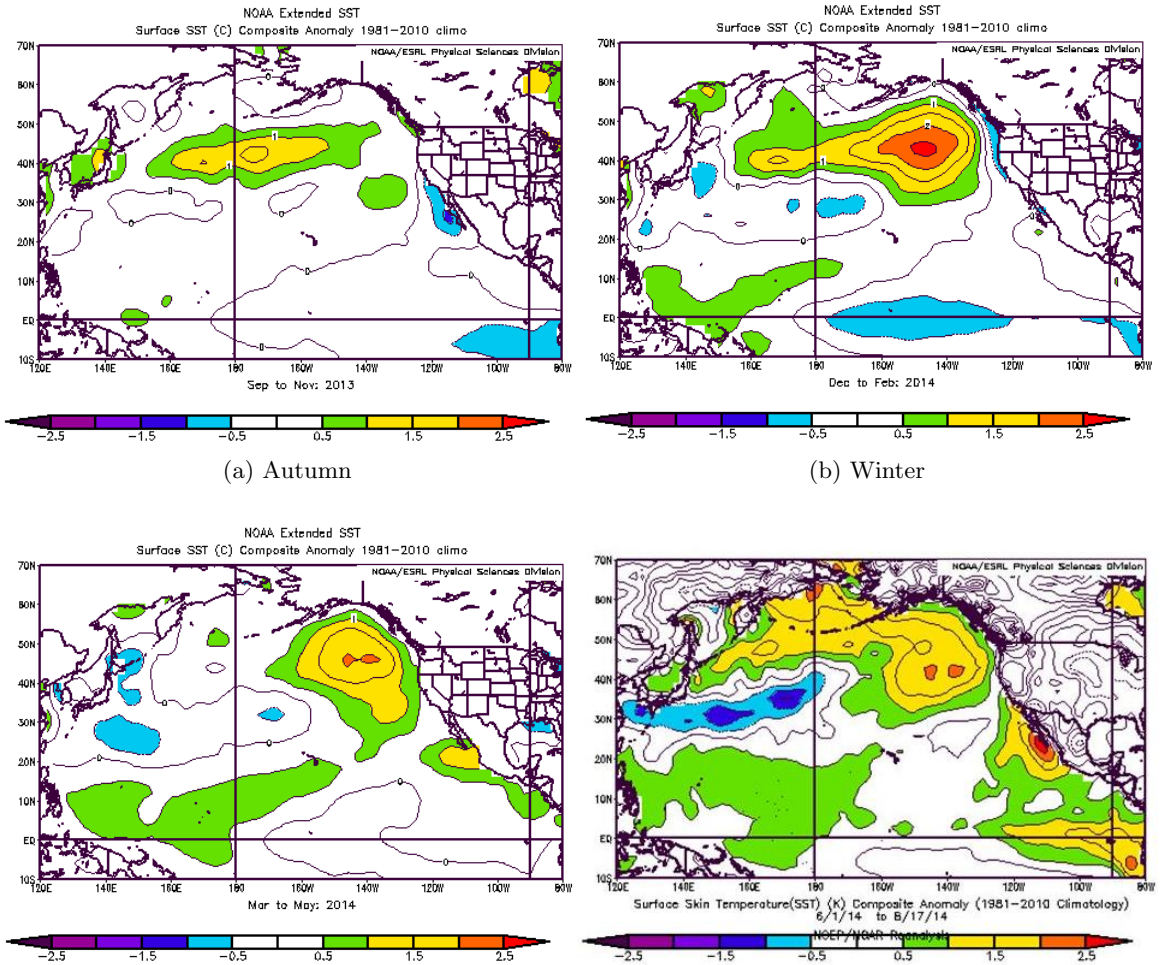
Description of indices: The state of the North Pacific from autumn 2012 through summer 2013 is summarized in terms of seasonal mean sea surface temperature (SST) and sea level pressure (SLP) anomaly maps. The SST and SLP anomalies are relative to mean conditions over the period of 1981-2010. The SST data are from NOAA's Extended Reconstructed SST analysis; the SLP data are from the NCEP/NCAR Reanalysis project. Both data sets are made available by NOAA's Earth System Research Laboratory at `http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl`.

Status and trends: The climate forcing of the North Pacific during the year beginning with the autumn of 2013 featured a transition from a negative to a positive state in the Pacific Decadal Oscillation (PDO). This transition was accompanied by a shift in tropical Pacific SST, specifically the NINO3.4 region, was slightly cooler than normal to warmer than normal. The tropical Pacific does not appear to have been a primary cause of the conditions that developed in the North Pacific, in that the tropical Pacific conditions were not too different from normal, and the patterns in the anomalies in the North Pacific little resembled those that have accompanied past changes in ENSO.

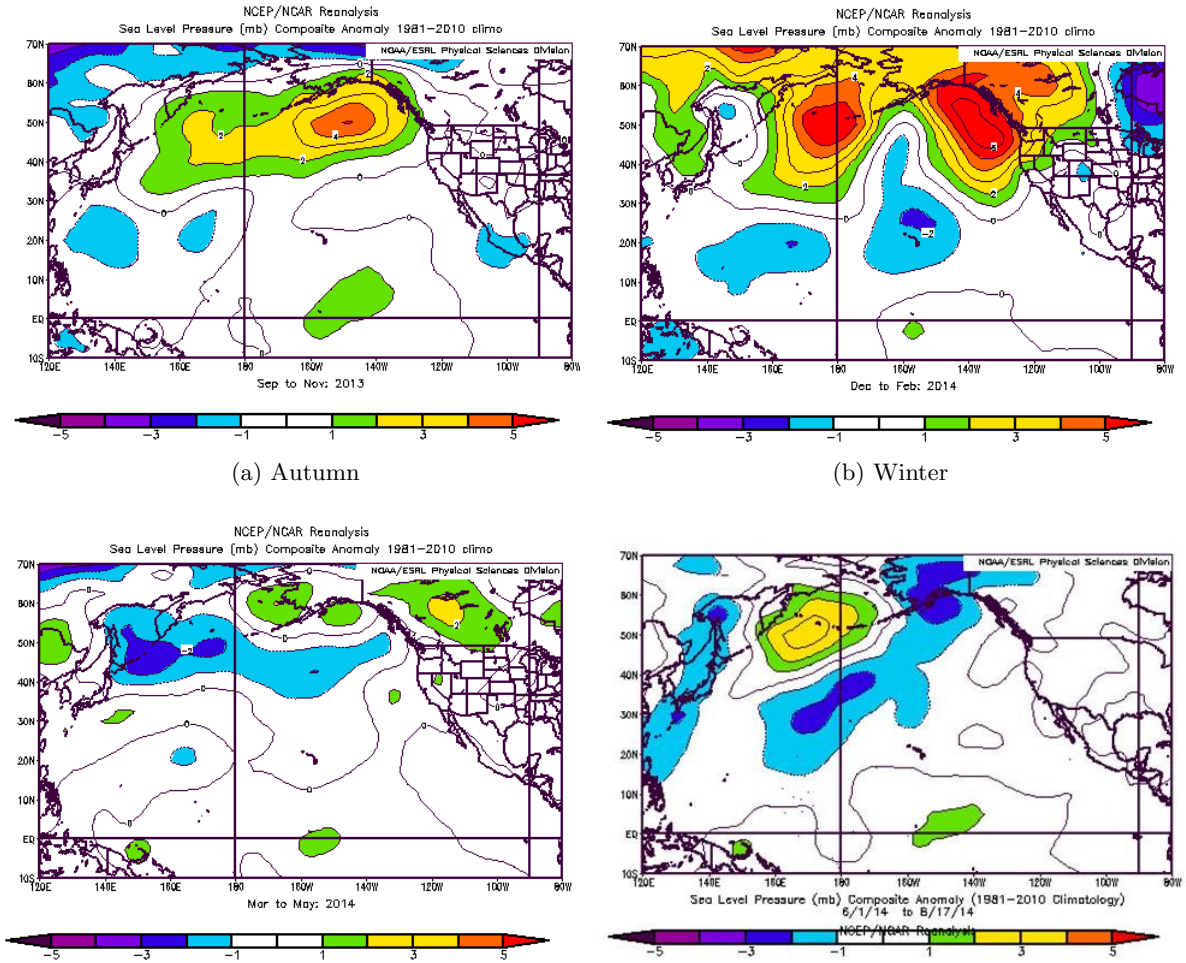
The SST anomalies in the North Pacific during the autumn (Sep-Nov) of (Figure 1a) were minimal over much of the basin, with the most prominent exception of an east-west oriented band of positive anomalies along 40° centered near the dateline. The pattern of anomalous SLP during autumn 2013 featured strongly positive anomalies from roughly 40° to 60°N across virtually the entire North Pacific, with particularly large anomalies south of Alaska (Figure 2a). This pattern implies anomalous upwelling in the coastal waters extending from the south side of the Alaska Peninsula through the Gulf of Alaska (GOA) to the Pacific Northwest.



(a) Autumn (b) Winter

(c) Spring (d) Summer

Figure 1: SST anomolies for autumn (September-November 2013), winter (December 2013 -February 2014), spring (March - May 2014), and summer (June - August 2014).



(a) Autumn (b) Winter

(c) Spring (d) Summer

Figure 2: SLP anomolies for autumn (September-November 2013), winter (December 2013 -February 2014), spring (March - May 2014), and summer (June - August 2014).

Remarkably warm SST anomalies developed in the northeast Pacific during winter (Dec-Feb) of 2013-14 (Figure 1b). The maximum values of these anomalies exceeded 2.5°C. The anomalies for most of the rest of the basin were little changed from the previous season. The development of the positive SST anomalies off the west coast of North America can be attributed to the continuation of much higher than normal SLP in the northeast Pacific (Figure 2b). This region experienced an unusually strong and persistent ridge of high pressure or "block". This block resulted in fewer storms and hence abnormally low magnitude of heat loss from the upper ocean to the atmosphere and also less mixing of cool water from depth into the waters near the surface. It also implies easterly wind anomalies and hence poleward Ekman transport anomalies. Much higher than normal SLP was also present from east Siberia across the Bering Sea to south of the Aleutian Island. The overall pressure pattern favored fewer and weaker cold-air outbreaks than normal over the northern Bering Sea and mainland Alaska, leading to relatively warm surface air temperatures (not shown). Coastal winds from the GOA to California continued to be upwelling favorable in an anomalous sense.

The distribution of anomalous SST in the North Pacific during spring (Mar-May) of 2014 (Figure 1c) resembled that of the season before, with lessening of the positive anomalies off the coast of the Pacific Northwest. The SST anomalies in the tropical Pacific were weakly positive in the west and near neutral in the east. There was some warming, but the overall tropical Pacific atmosphere-ocean system remained in the near-neutral category. The SLP anomaly pattern (Figure 2c) for spring 2014 was substantially different than that for the previous winter. The most prominent feature was a region of negative anomalies extending from the southern portion of the Sea of Okhotsk to near 50°N and the dateline, with an extension of weaker negative anomalies stretching almost to Vancouver Island.

The SST in summer (Jun-Aug) 2014 (Figure 1d) indicated anomalous warmth across the northern portion of the Pacific bain from the Kamchatcka to nearly the west coast of North America. A much smaller band of relatively cool water was present west of the dateline along about 30°N. The tropical Pacific included substantial warming in its far eastern portion off the coast of South America. The overall distribution represented a positive expression of the PDO, with the most positive anomalies in the northeastern Pacific to the west of their location in the classic PDO pattern. The distribution of anomalous SLP (Figure 2d) during summer 2014 featured a dipole of higher than normal SLP over the western Aleutian Islands and lower than normal SLP to the south extending from 30° N and the dateline northeastward into the Gulf of Alaska and mainland Alaska. The SLP and associated wind anomalies were very weak over virtually the entire North Pacific east of about 150°W.

Climate Indices

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Last updated: August 2014

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

The focus here is on five commonly used indices: the NINO3.4 index to characterize the state of the El Niño/Southern Oscillation (ENSO) phenomenon, Pacific Decadal Oscillation (PDO) index (the leading mode of North Pacific SST variability), North Pacific Index (NPI), North Pacific Gyre Oscillation (NPGO) and Arctic Oscillation (AO). The time series of these indices from 2004 through early summer 2014 are plotted in Figure 3.

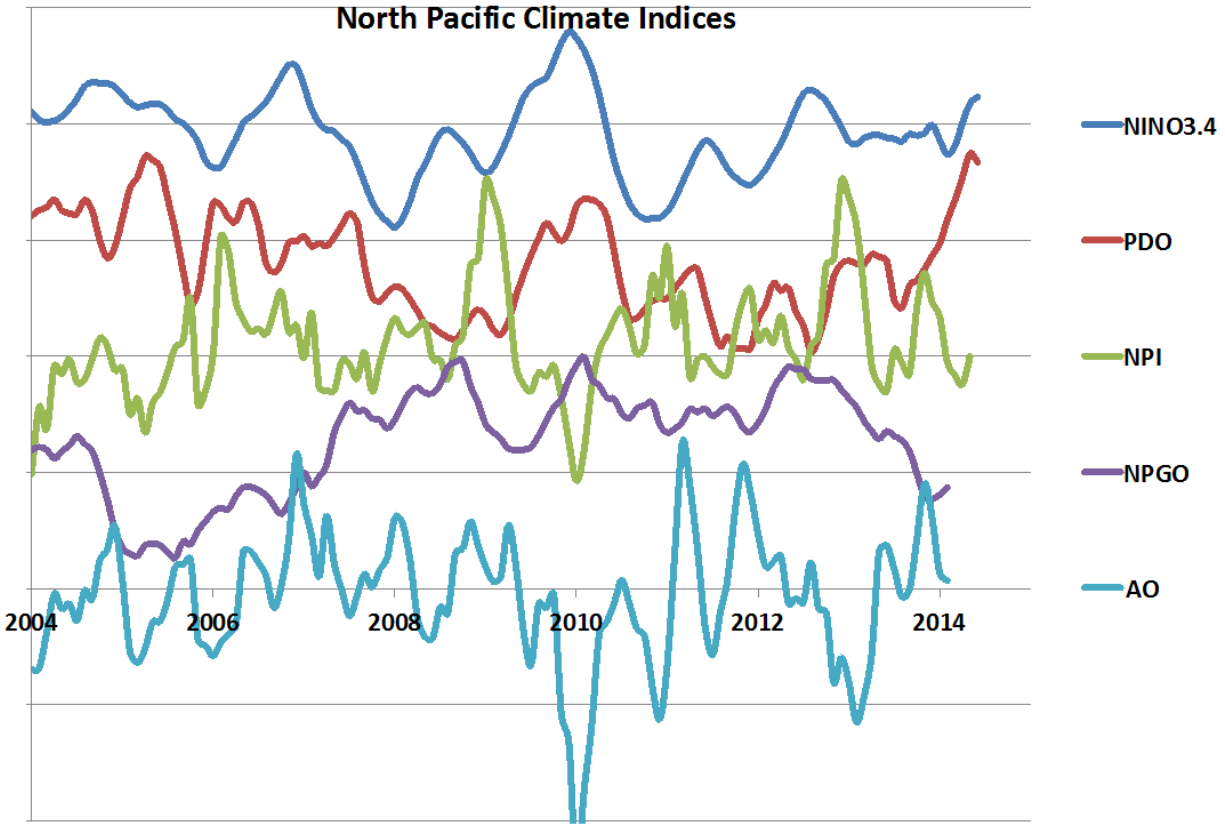

Figure 3: Time series of the NINO3.4 (blue), PDO (red), NPI (green), NPGO (purple), and AO (turquoise) indices. Each time series represents monthly values that are normalized and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 2 standard deviations. More information on these indices is available from NOAA's Earth Systems Laboratory at `http://www.esrl.noaa.gov/psd/data/climateindices`.

Status and trends: The North Pacific atmosphere-ocean climate system underwent significant changes during 2013-14. These kinds of changes in previous years have often been associated with ENSO events. For the present case, however, ENSO has been in a near-neutral state over the past year, as indicated by the time series of the NINO3.4 index shown in Figure 5. The PDO became significantly positive during the past year in a continuation of a general increasing trend that began in autumn 2012. Changes in the PDO typically lag those in ENSO by a few months due to the North Pacific oceanic response to atmospheric teleconnection patterns emanating from the tropical Pacific, but the past year appears to represent an exception. The NPI was positive (implying a weak Aleutian Low) during the last few months of 2013. This often occurs in association with La Niña, but as discussed above, was not the case in this instance.

The North Pacific Gyre Oscillation (NPGO) represents the second leading mode of variability

for the North Pacific, and has been shown to relate to chemical and biological properties in the northeastern Pacific, in particular the Gulf of Alaska. The NPGO has undergone a systematic decrease from a strongly positive state in 2012 to weakly negative in 2014. A negative sense of this index implies a reduced west wind drift and projects on weaker than normal flows in both the Alaska Current portion of the Subarctic Gyre and the California Current. The AO represents a measure of the strength of the polar vortex, with positive values signifying anomalously low pressure over the Arctic and high pressure over the Pacific and Atlantic, at a latitude of roughly 45°N. It has a weakly positive correlation with sea ice extent in the Bering Sea. The AO was positive late in 2013 and decreased to near-zero on average during the early part of 2014. It does not appear that the variations in the AO were strongly related to conditions in the vicinity of Alaska during the last year or so. The fluctuations in the AO during the last 5-10 years, and in particular the linkages between the AO and arctic sea ice, continue to be a subject of interest and controversy for the climate community.

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

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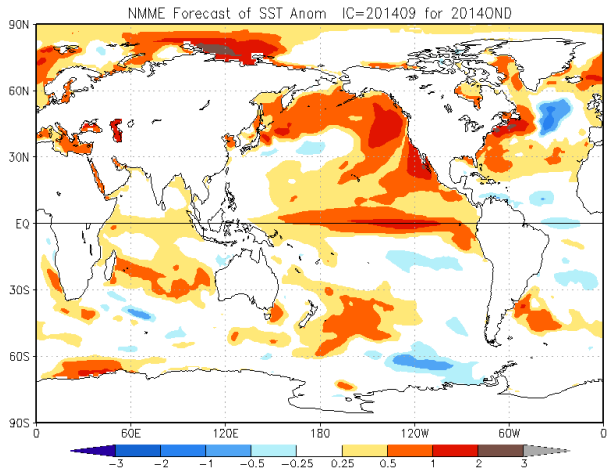
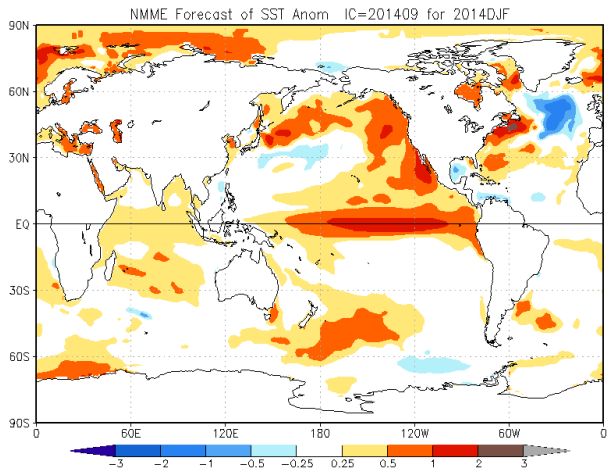
Last updated: September 2014

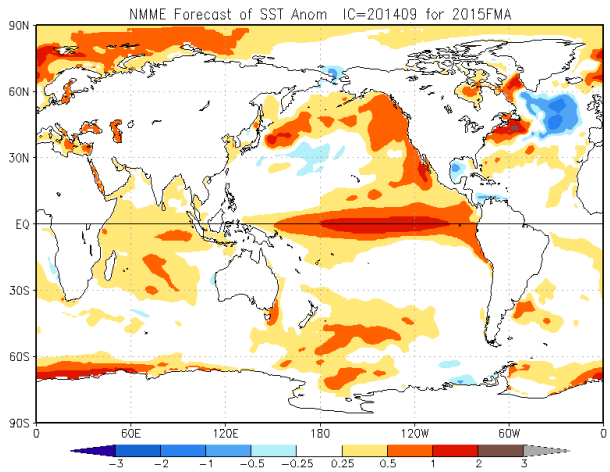
Description of index: Seasonal projections of SST from the National Multi-Model Ensemble (NMME) are shown in Figure 4. The uncertainties and errors in the predictions from any single climate model can be substantial. An ensemble approach incorporating different models is particularly appropriate for seasonal and longer term simulations; the NMME represents the average of 6 models. More detail on the NMME, and projections of other variables, are available at the following website: `http://www.cpc.ncep.noaa.gov/products/NMME/`.



(a) Months OND



(b) Months DJF



(c) Months FMA

Figure 4: Predicted SST anomalies from the NMME model for OND (1 month lead), DJF (3 month lead), and FMA (5 month lead) for the 2014-2015 season.

Status and trends: These NMME forecasts of 3-month average SST anomalies indicate a continuation of warm conditions in the northern and eastern portions of North Pacific between the Hawaiian Islands and Alaska through the end of the year (Oct-Nov 2014) with a smaller region of slightly cooler water than normal in the western North Pacific (Figure 4a). This overall pattern is maintained, with a slight weakening in magnitude, through the 3-month periods of December 2013 - February 2014 (Figure 4b) and February - April 2015 ((Figure 4c). These SST patterns project onto a positive sense for the PDO, which represents a marked contrast with the previous year. All three 3-month periods feature weak-moderate El Niño conditions in the tropical Pacific.

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

Arctic

Arctic Sea Ice Cover

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Last updated: August 2014

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

Status and trends: Arctic sea ice extent is well below average, and large areas of low concentration ice are observed in the Beaufort Sea and along the Siberian coast (Figure 5). However, it is highly unlikely to set a record low at the end of this years melt season.

Sea ice declined at slightly slower than average rates through the first part of August (Figure 6). By mid-August, extent was similar to this time last year, which makes it unlikely that this years minimum extent will approach the record low level observed in September 2012.

Eastern Bering Sea

Eastern Bering Sea Climate - FOCI

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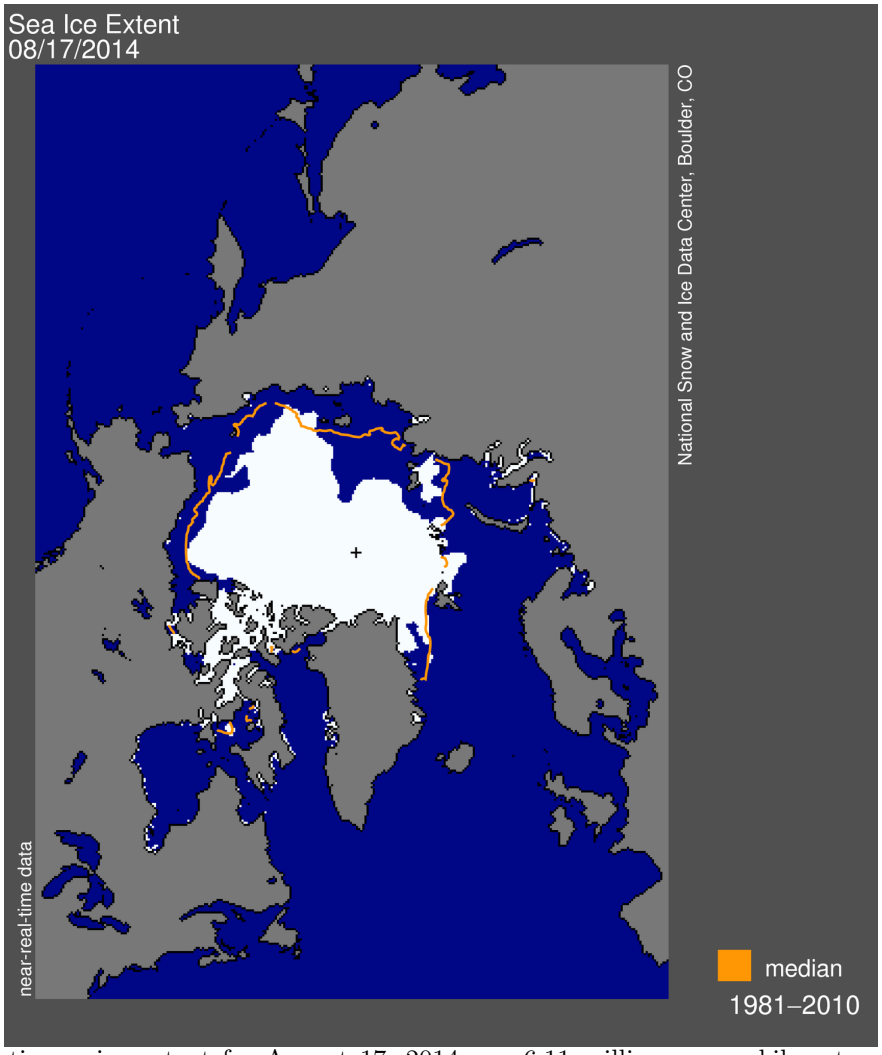

Figure 5: Arctic sea ice extent for August 17, 2014 was 6.11 million square kilometers (2.36 million square miles). The magenta line shows the 1981 to 2010 median extent for that day. The black cross indicates the geographic North Pole. Credit: National Snow and Ice Data Center

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

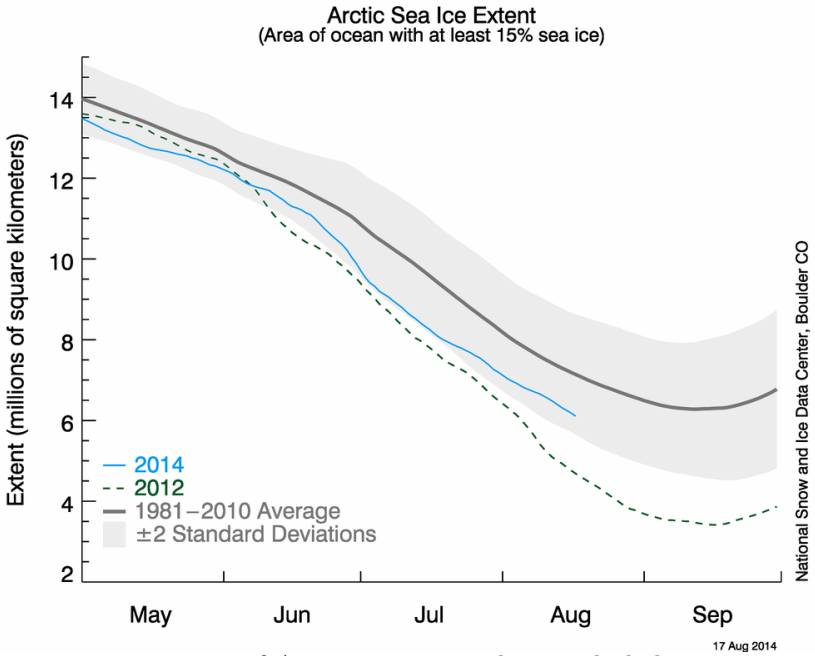

Figure 6: Arctic sea ice extent as of August 17, 2014, along with daily ice extent data for the record year. 2014 is shown in blue and 2012 in green. The 1981 to 2010 average is in dark gray. Credit: National Snow and Ice Data Center

Summer Bottom and Surface Temperatures - Eastern Bering Sea

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Last updated: October 2013

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

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

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Last updated: October 2013

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

Regional Water Mass Characteristics in the Northern Bering Sea

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

Aleutian Islands

Eddies in the Aleutian Islands - FOCI

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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 7) 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 8) 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).

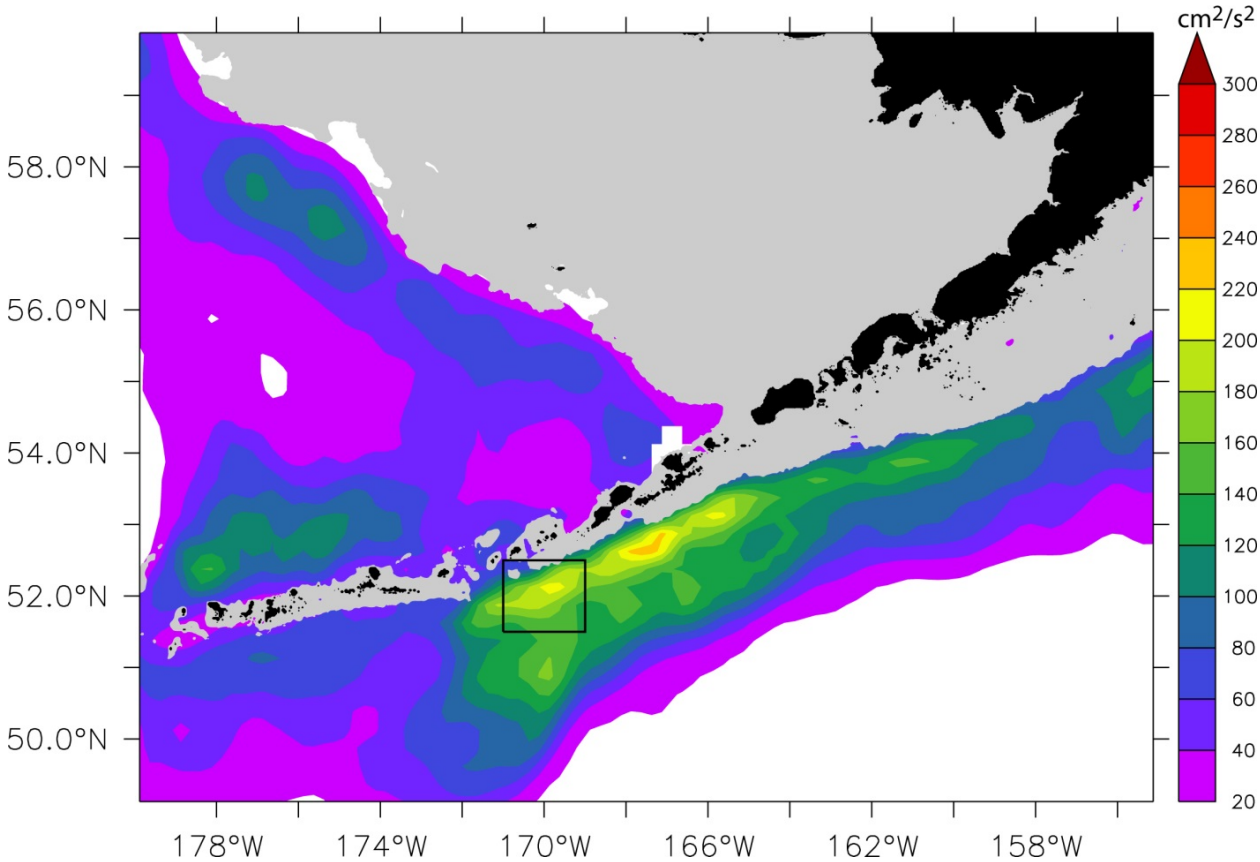

Figure 7: Eddy Kinetic Energy averaged over October 1993 - October 2013 calculated from satellite altimetry. Square denotes region over which EKE was averaged for Figure 8.

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

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

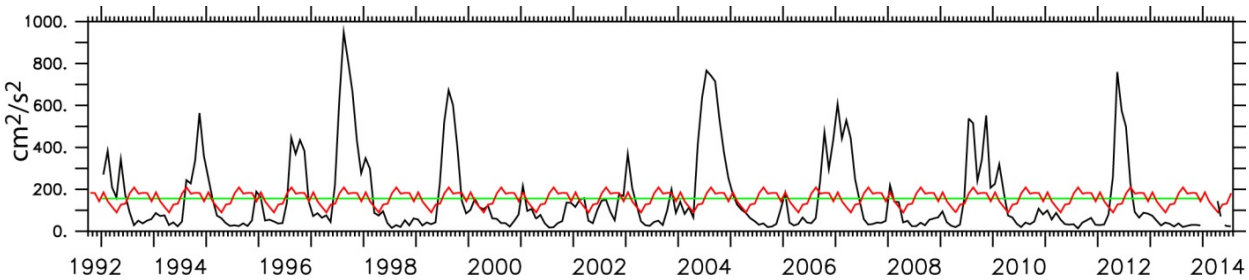

Figure 8: Eddy kinetic energy (cm^2 s^{-2}) averaged over region shown in Figure 7. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product). Red: seasonal cycle. Green (straight line): mean over entire time series.

Implications: These trends indicate that higher than average volume, heat, salt, and nutrient fluxes to the Bering Sea through Amukta Pass may have occurred in 1997/1998, 1999, 2004, 2006/2007, 2009/2010, and summer 2012. These fluxes were likely smaller during the period from fall 2012 until early 2014.

Water Temperature Data Collections - Aleutian Islands Trawl Surveys

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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

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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 9; 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 9). 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 9). By averaging EKE over regions c and d (see boxes in Figure 9), we obtain an index of energy associated with eddies in these regions (Figure 10). The altimeter products were produced by the CLS Space Oceanography Division (AVISO, 2012).

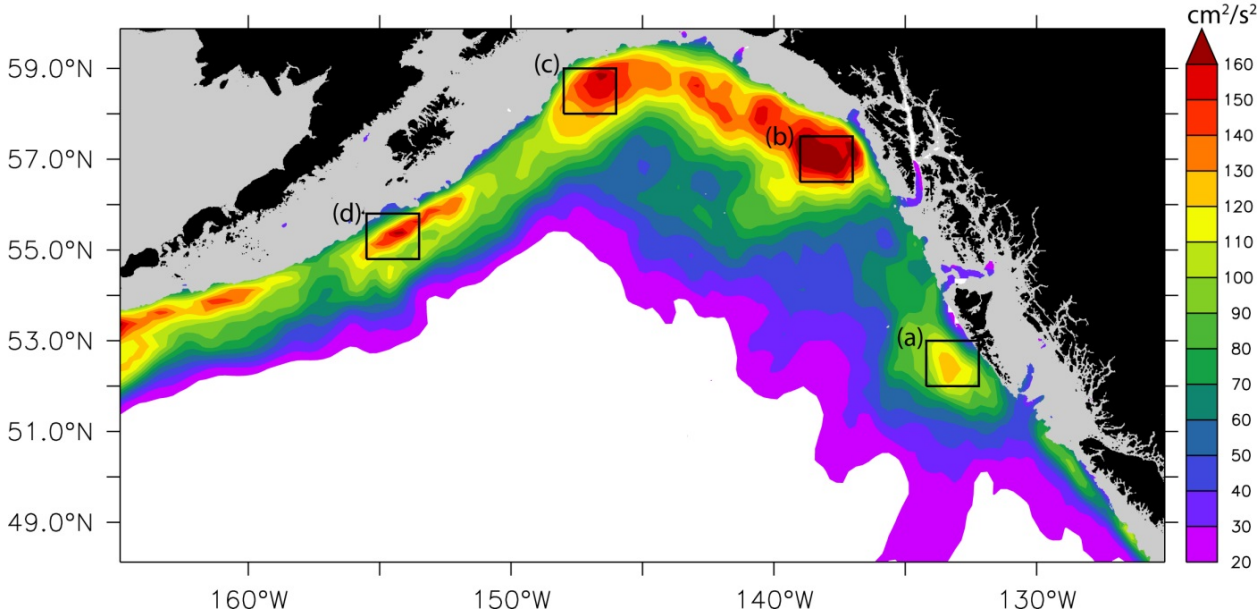

Figure 9: Eddy Kinetic Energy averaged over October 1993-October 2011 calculated from satellite altimetry. Regions (c) and (d) denote regions over which EKE was averaged for Figure 10.

Status and trends: The seasonal cycle of EKE averaged over the two regions (c and d) are out of phase with each other. Region (c) exhibits high EKE in the spring (March-May) and lower EKE in the autumn (September-November) while region (d) exhibits high EKE in the autumn and low EKE in the spring. EKE was particularly high in region (c) in 2002-2004 when three large persistent eddies passed through the region. In region (d), high EKE was observed in 1993, 1995, 2000, 2002, 2004, 2006, 2007, 2010, 2012, and 2013. Relatively high EKE was observed in the summer of 2014 in region (c) while EKE was particularly weak in region (d). The summer 2014 EKE is calculated from near-real-time altimetry data which has lower quality than the delayed time data and may be revised.

Factors causing observed trends: In the eastern Gulf of Alaska, interannual changes in surface

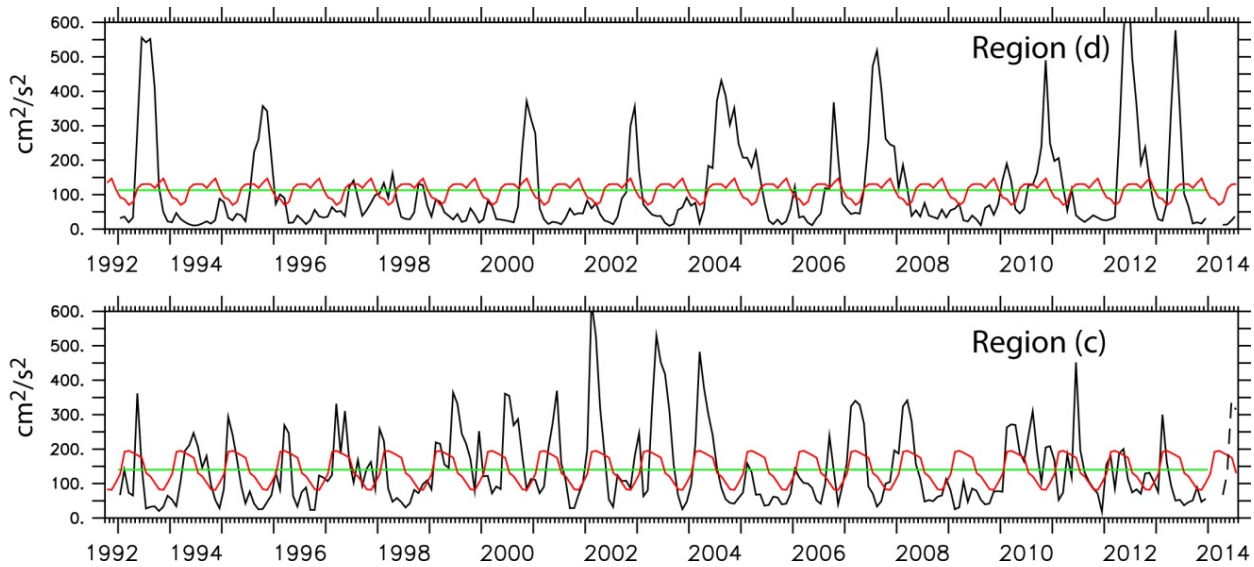

Figure 10: Eddy kinetic energy (cm^2 s^{-2}) averaged over Region (d) (top) and Region (c) (bottom) shown in Figure 9. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product), Red: seasonal cycle. Green (straight line): mean over entire time series.

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

Implications: EKE may have implications for the ecosystem. Phytoplankton biomass was probably more tightly confined to the shelf during 2009 due to the absence of eddies, while in 2007, 2010, 2012 and 2013 (region (d)), phytoplankton biomass likely extended farther off the shelf. In addition, cross-shelf transport of heat, salinity and nutrients were probably weaker in 2009 than in 2007, 2010, 2012 and 2013 (or other years with large persistent eddies). Eddies sampled in 2002-2004 were found to contain different ichthyoplankton assemblages than surrounding slope and basin waters indicating that eddies along the slope may influence the distribution and survival of fish (Atwood et al., 2010). In addition, carbon isotope values suggest that cross-shelf exchange due to eddies may be important to the marine survival rate of pink salmon (Kline, 2010).

Ocean Surface Currents - Papa Trajectory Index

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Last updated: August 2014

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 11). The simulation for each year is conducted using the "Ocean Surface CURrent Simulator" (OSCURS; `http://las.pfeg.noaa.gov/oscurs`). Using daily gridded atmospheric pressure fields, OSCURS calculates the speed and direction of water movement at the ocean's surface at the location of a simulated surface drifter. It uses this information to update the position of the simulated drifter on a daily basis over a specified time period. For the index presented here, OSCURS was run for 90 days to simulate a surface drifter released at Ocean Station PAPA on December 1 for each year from 1901 to 2013 (trajectory endpoints years 1902-2014).

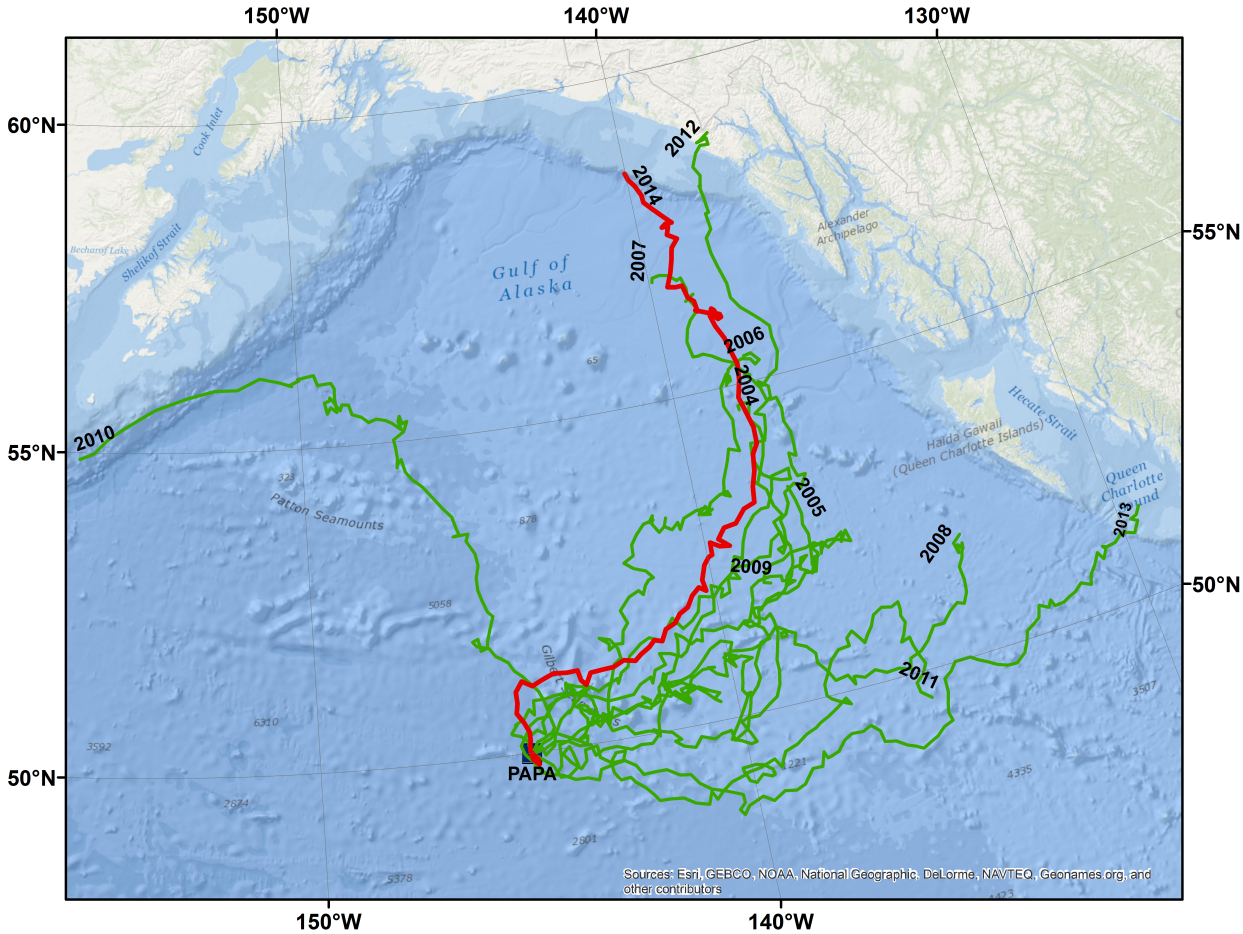

Figure 11: Simulated surface drifter trajectories for winters 2004-2014 (endpoint year). End points of 90-day trajectories for simulated surface drifters released on Dec. 1 of the previous year at Ocean Weather Station PAPA are labeled with the year of the endpoint (50°N, 145°W).

Status and trends: In general, the trajectories fan out northeastwardly toward the North American continent (Figure 11). The 2009/2010 trajectory was an exception and resulted in the westernmost trajectory endpoint for the entire set of model runs (1902-2014). This trajectory is, however, consistent with the atmospheric conditions that existed during the winter of 2009-2010 (N. Bond, pers. comm.). Under the influence of contemporaneous El Niño conditions, the Aleutian Low in

the winter of 2009-2010 was anomalously deep and displaced to the southeast of its usual position in winter (Bond and Guy, 2010), resulting in anomalously high easterly (blowing west) wind anomalies north of Ocean Station PAPA. The 2011/2012 trajectory followed the general northeastwardly path of most drifters, but was notable because its ending latitude was the northernmost of all trajectories since 1994. The 2012/2013 trajectory was notable as ending up the furthest east among trajectories in recent years. However, the ending latitude was only somewhat southerly of the average ending latitude for all trajectories (Figure 12) and certainly not atypical. This is consistent with the northeast Pacific wind forcing, which featured very strong westerly anomalies. The 2013/14 trajectory was quite similar to the 2011/12 trajectory, although it did not reach as far north as the latter. The mean wind anomalies in the vicinity of the simulated drifter were from the southeast in December 2013, and from the south in January 2014, but then transitioned rapidly to out of the northeast in February 2014, with the latter period limiting the northward extent of the modeled trajectory.

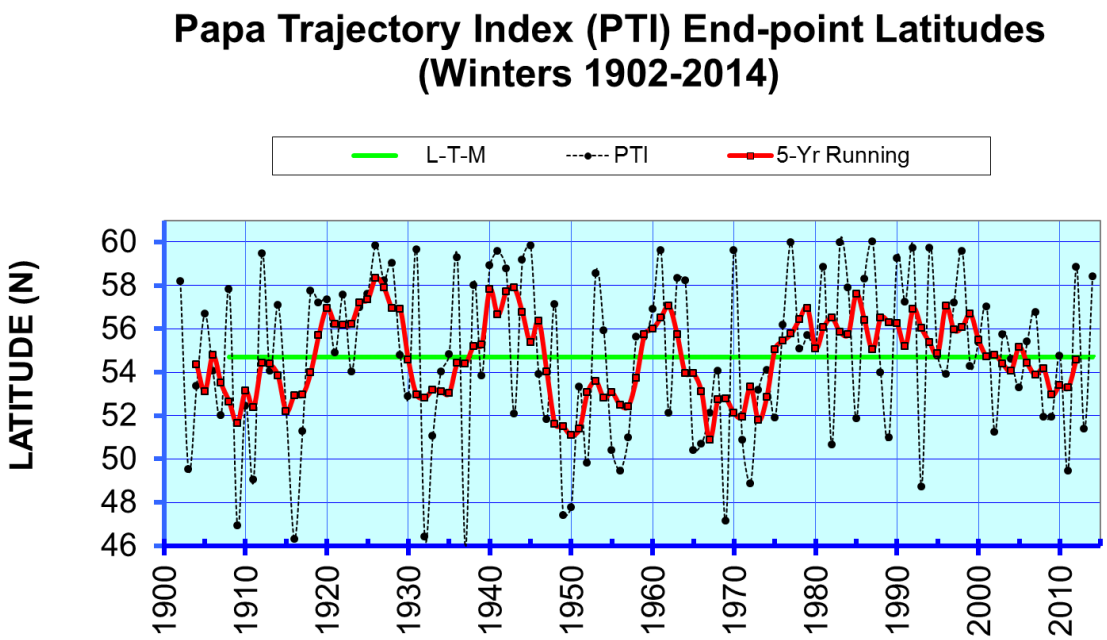

Figure 12: Annual, long-term mean (green line) and 5-year running mean (red line and squares) of the PAPA Trajectory Index time-series (dotted black line and points) for 1902-2014.

The PTI time series (Figure 12, black dotted line and points) indicates high interannual variation in the north/south component of drifter trajectories, with an average between-year change of >4° and a maximum change of greater than 13° (between 1931-1932). The change in the PTI between 2010/11 and 2011/12 was the largest since 1994, while the changes between 2011/12 and 2012/13, and between 2012/13 and 2013/14, represented reversals with slightly less, but diminishing, magnitude. However, such swings are not uncommon over the entire time series.

Using a 5-year running mean boxcar filter to smooth the raw PTI reveals multidecadal-scale oscillations in the north/south component of the drift trajectories (Figure 12), red line and squares), with amplitudes over 7° latitude. Over the past century, the filtered PTI has undergone four complete oscillations with distinct crossings of the mean, although the durations of the oscillations are not identical: 26 years (1904-1930), 17 years (1930-1947), 17 years (1947-1964), and 41 years (1964-2005). The filtered index indicates that a shift occurred in the mid 2000s to predominantly

southerly anomalous flow following a 20+ year period of predominantly northerly anomalous flow. This was indicative of a return to conditions (at least in terms of surface drift) similar to those prior to the 1977 environmental regime shift. This part of the cycle may have ended rather quickly, however, as it now appears the filtered PTI is about to cross the mean in the opposite direction. If this occurs, the recent period of predominantly southern flow will have been the shortest and weakest in the time series.

Factors influencing observed trends: Filtered PTI values greater than the long-term mean are indicative of increased transport and/or a northerly shift in the Alaska Current, which transports warm water northward along the west coast of Canada and southeast Alaska from the south and consequently plays a major role in the Gulf of Alaska's heat budget. Individual trajectories also reflect interannual variability in regional (northeast Pacific) wind patterns.

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

Gulf of Alaska Survey Bottom Temperature Analysis

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Last updated: October 2013

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

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

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Last updated: October 2013

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

Habitat

Structural Epifauna (HAPC Biota) - Eastern Bering Sea

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Structural Epifauna (HAPC Biota)- Aleutian Islands

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Structural Epifauna (HAPC Biota)- Gulf of Alaska

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Primary Production

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

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Last updated: August 2014

Description of index: BASIS conducted fisheries oceanography surveys in the eastern Bering Sea, mid-August to late September, for three warm years (2003-2005) followed by one average (2006) and six cold years (2007-2012). Variations in chlorophyll [a] (chla) were used to evaluate spatial and interannual differences in total phytoplankton biomass and size structure (an indication of phytoplankton species). Large (>10 μm) phytoplankton biomass and fraction of total biomass (>10 μm / total chla) were estimated from discrete water samples filtered through GFF and 10 μm filters. Integrated chla values were estimated from CTD fluorescence profiles, calibrated with discrete chla (GFF) samples. Chla data (total and >10 μm) were averaged over the top 50 m of the water column or to the bottom for shallower stations. Water column stability was estimated over the top 70 m or to the bottom for shallower stations (Simpson et al., 1978). Friction velocity cubed (u^{*3}), a proxy for wind mixing, were obtained from NCEP reanalysis for PMEL mooring 2 (M2) (courtesy of Nick Bond).

Spatial variations for all years combined are shown for integrated chla (total and >10μm size fraction) for 2003-2012 and for stability for 2003-2009 (Figure 13). Interannual variations (2003-2012) in integrated chla and size structure are shown for the north and south Bering Sea Middle shelf (50-100 m station depths) (Figure 14). We evaluated the relationship between wind mixing 2-3 weeks prior to sampling (August u^{*3}) and integrated chla for the southeastern Middle shelf (Figure 15). Anomalies of temperature, u^{*3}, stability, integrated chla and large size fraction chla are shown for the southeastern Bering Sea Middle shelf for 2003-2012 (Table 1).

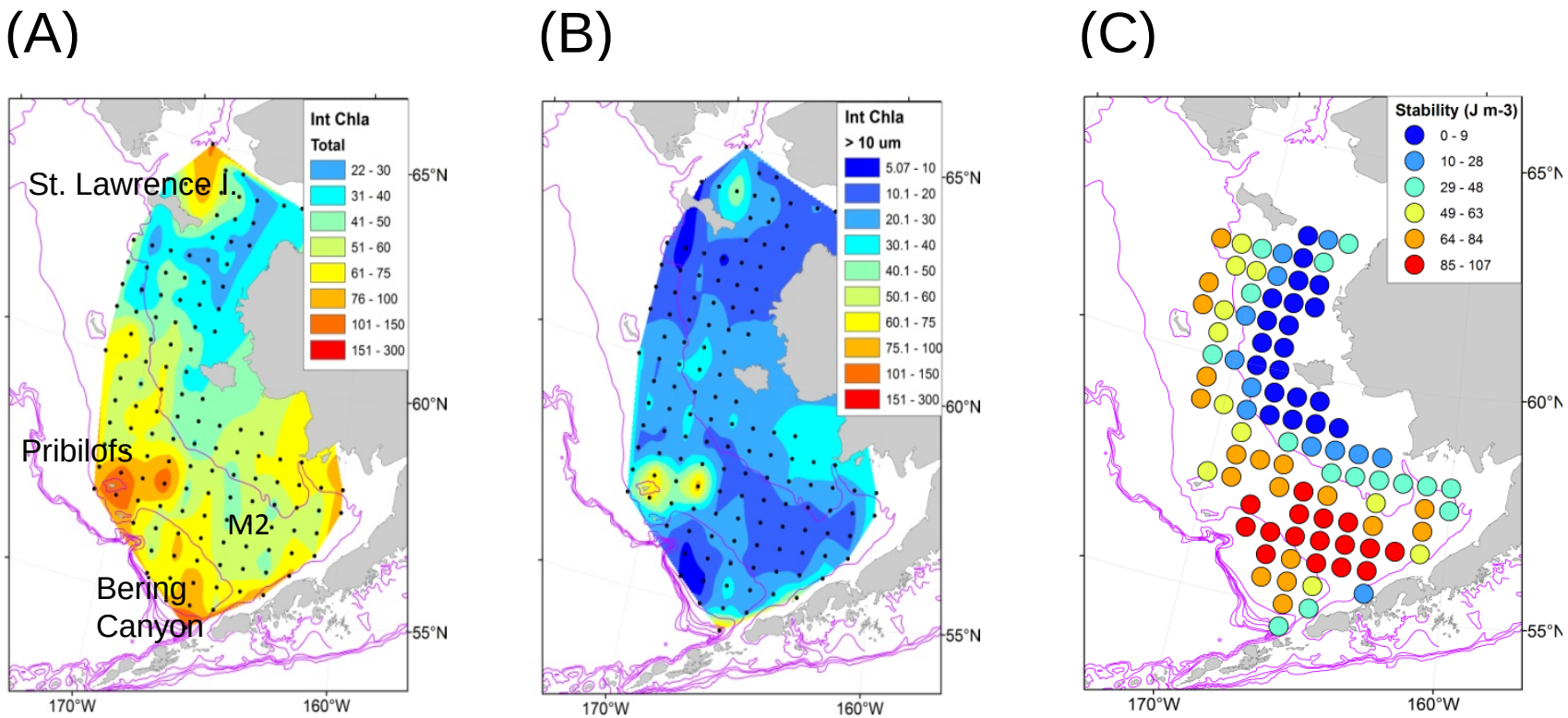

Figure 13: Contours of integrated total chla (mg m^{-2}) (A) and integrated >10μm chla (B) averaged over 2003-2012, and stability (C) averaged over 2003-2009. Bathymetry contours are shown for 50 m, 100 m and 200 m (shelf break).

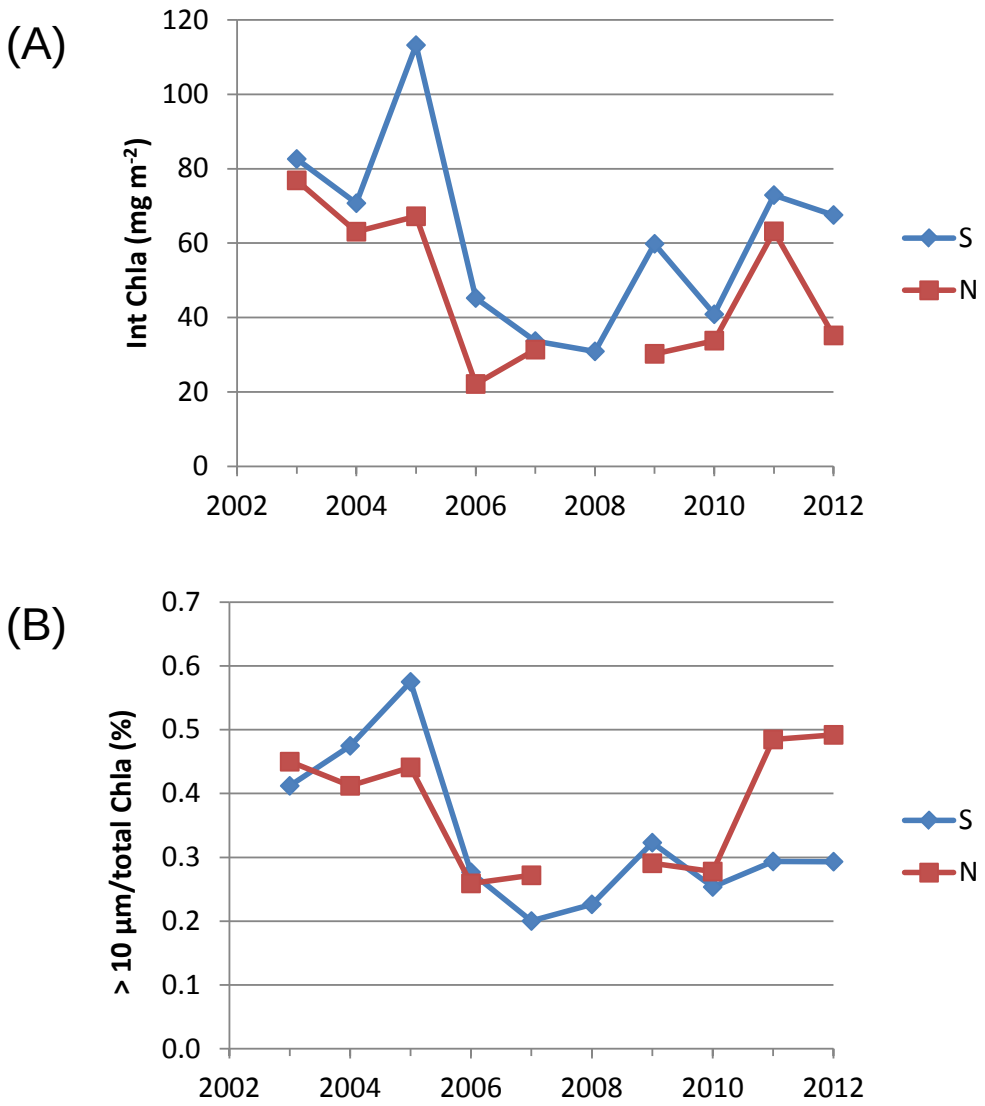

Figure 14: Integrated total chla (A) and ratio of large assemblages to total (>10μm /total chla) (B) in the Middle Domain in the south (54.5 59.5 °N, Bering project regions 3 and 6) and north (60 63 °N, Bering project regions 9 and 10) for 2003-2012.

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

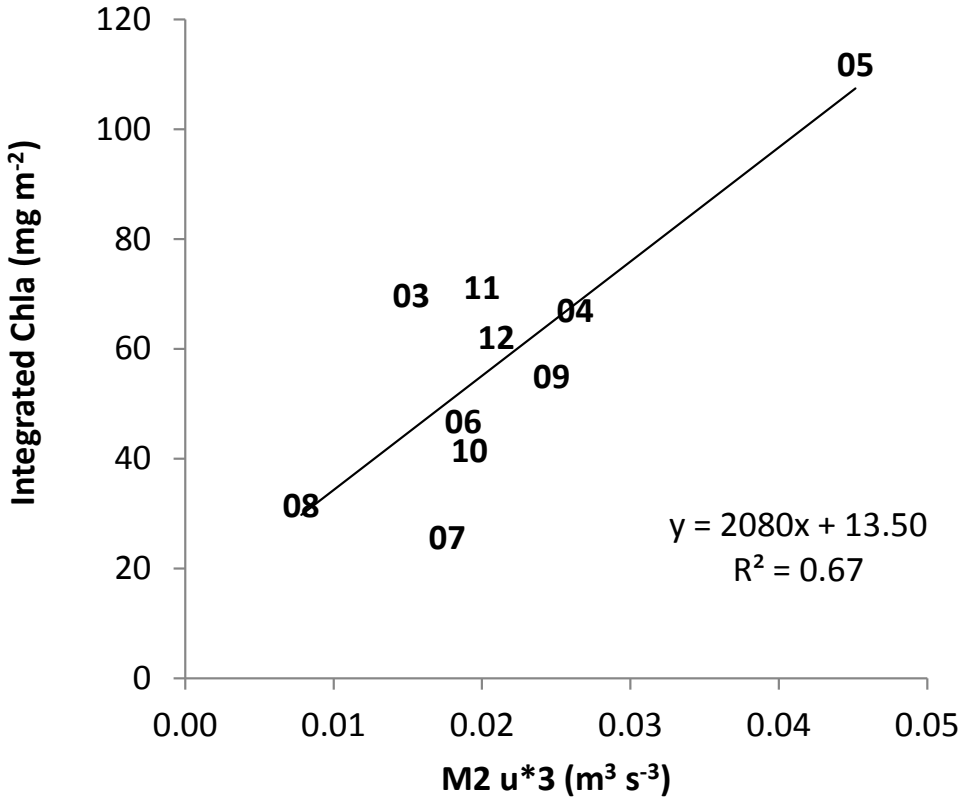

Figure 15: Linear regression between mean August u^{*3}, an indicator of wind mixing, at mooring M2 and integrated chla for the southeastern Bering Sea Middle shelf in Bering Project Region 3 (region around M2) for 2003-2012.

Factors influencing trends: Water column stability, wind and temperature can influence interannual and spatial variations in phytoplankton biomass. For the south Middle shelf, a positive association was observed between August wind mixing and integrated chla in the top 50 m (Figure 15). Deep nutrient-rich waters may be mixed to the surface to fuel production of large assemblages during periods of high winds and low water column stability. Phytoplankton growth may be enhanced at higher temperatures, depending on species. For example, the highest chla and largest size fractions were seen in 2005, a period with high August wind mixing, average stability and high water column temperature (Table 1). While, the lowest chla and smallest size fractions were observed in 2008, a period with low wind mixing, high stability and low water column temperature. Spatially, low chla and small phytoplankton assemblages were seen in the area of highest stability, in the southeastern Middle shelf near M2.

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

Table 1: Normalized anomalies calculated for 2003 to 2012 or to 2009 (stability) for the south Bering Sea Middle shelf (Bering Project regions 3 and 6) for temperature (T) above and below the pycnocline, stability over top 70 m, integrated chla and ratio of large (> 10 μm) to total chla over top 50 m data (August-September) from BASIS data, and friction velocity cubed (u^{*3}) near mooring M2 (August) from NCEP data. Data normalized to maximum anomaly for each variable.

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

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

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Last updated: August 2014

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

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

Status and trends: Late summer primary productivity (uptake of carbon by phytoplankton), surface Chla, and surface silicate concentrations in the south EBS had significantly lower values during 2007 (Figure 16). Silicate concentrations were below 2 μM during late summer of 2007, a value observed in laboratory experiments to be a threshold, below which, diatom dominance is no longer possible (**?**). Age-0 pollock weights were also very low in 2007. In addition to 2007, 2012 had lowered silicate concentrations and age-0 pollock weights compared with other years (2006-2012). When age-0 weights and silicate concentrations are plotted together, a strong positive correlation is seen (Figure 17). The same inter-annual trend is not seen for surface total Chla (or primary productivity) and silicate concentrations.

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

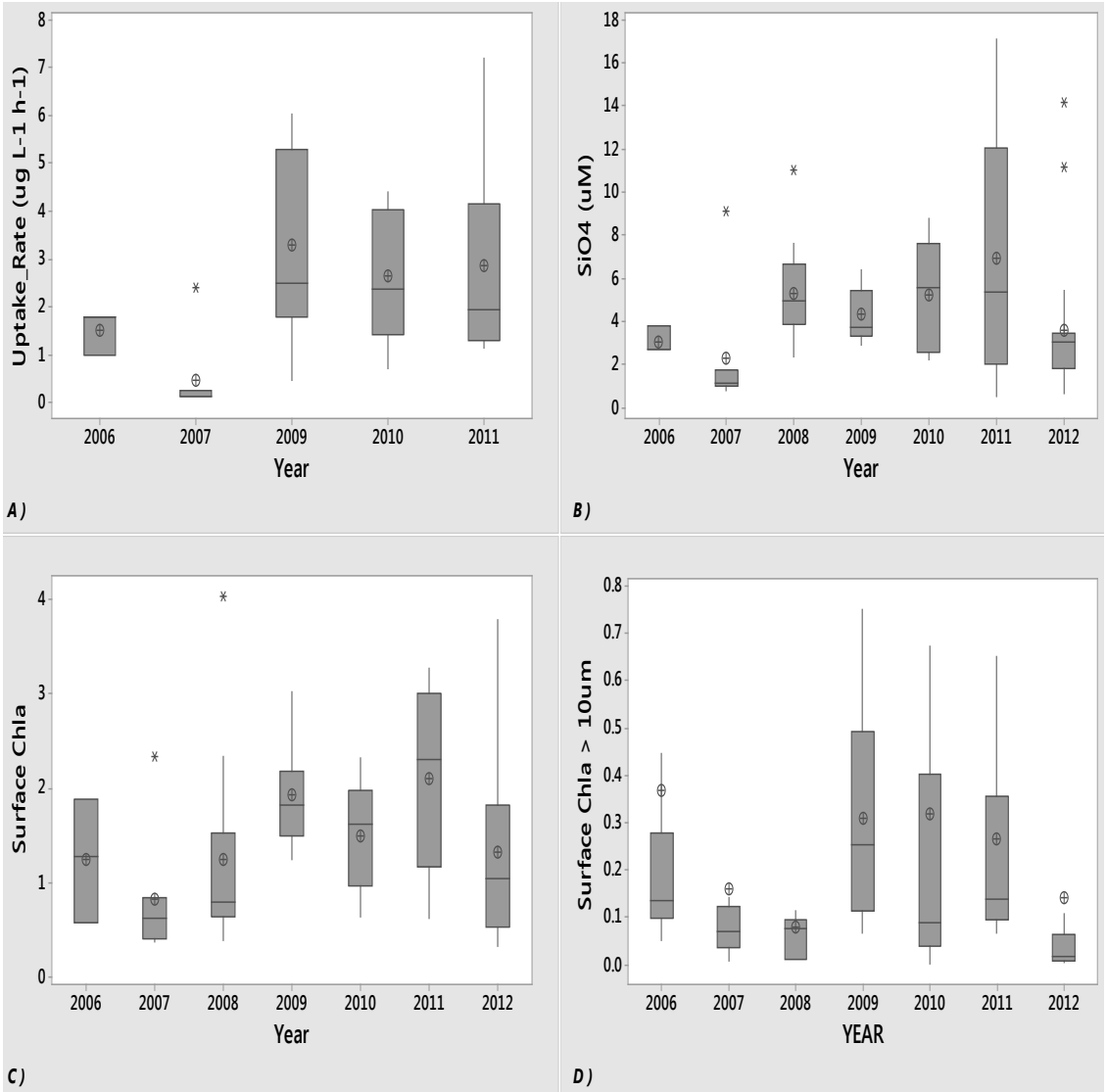

Figure 16: Box and whisker plots depicting the median (solid horizontal line), mean values (circle with cross), and extremes (whiskers) of surface; phytoplankton uptake (μg $L^{-1}hr^{-1}$) (A), silicate (Si(OH)4, μM) (B) Chla (mg m^{-3}) (C) and ¿10 μm size Chla (mg m^{-3}) (D). Data are from primary production station locations (inner and middle domains only) with the exception of 2008 and 2012, where data are from Region 3. Asterisks indicate outliers from 95% CI. Outliers (for the year 2007 only) in plots A, B, and C are from the same date and location (57.5°N, 168.77°W). Due to an excess of outliers, they are not shown for plot D.

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

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

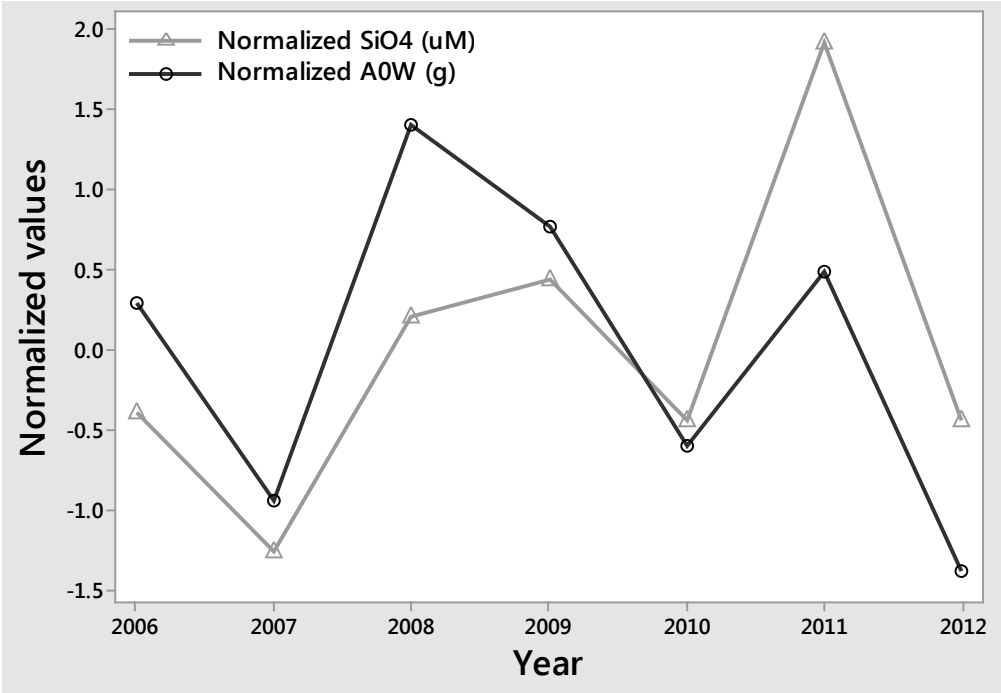

Figure 17: Inter-annual variability of normalized surface silicate ($Si(OH)_4$, from Region 3) and normalized mean weights of age-0 pollock (south of 60°N). Values were normalized by subtracting the mean from each value and dividing by the standard deviation.

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

Gulf of Alaska Chlorophyll a Concentration off the Alexander Archipelago

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Zooplankton

Bering Sea Zooplankton

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

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Jellyfish - Eastern Bering Sea

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

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Description of index: Jellyfish sampling was incorporated aboard the BASIS (Bering Aleutian Salmon International Surveys) vessels beginning in 2004 and continuing through 2014. All jellyfish medusae caught in the surface trawl (top 18-20 m of the water column) are sorted by species and subsampled for bell diameter and wet weight. Six species are commonly caught with the surface trawl: *Aequorea* sp., *Chrysaora melanaster*, *Cyanea capillata*, *Aurelia labiata*, *Phacellocephora camtschatica*, and *Staurophora mertensi*. Biomass is calculated for each species and compared across species, and oceanographic domains on the Bering Sea shelf.

Status and trends: The coverage for the 2013 survey did not include anything below 60°N. The biomass for the North remained relatively similar to previous years (Figure 18). The dominant species in terms of biomass and abundance was *C. melanaster*. The highest recorded biomass year occurred in 2012 for our survey. One station in the southern Bering Sea portion of our grid during that time was responsible for half the total catch of the entire survey. During 2010, another high biomass year, combined jellyfish species was double the previous high of 2004. Unlike in 2012, half the total catch did not come from a single station but was spread out over the entire sampling grid. Yearly distributions throughout the sample grid for all species have been patchy. Despite uneven distributions throughout oceanographic domains, highest concentrations of all species were found to occur in the Middle Domain. Of the six species sampled, *C. melanaster* had the highest CPUE (catch per unit effort) for all years.

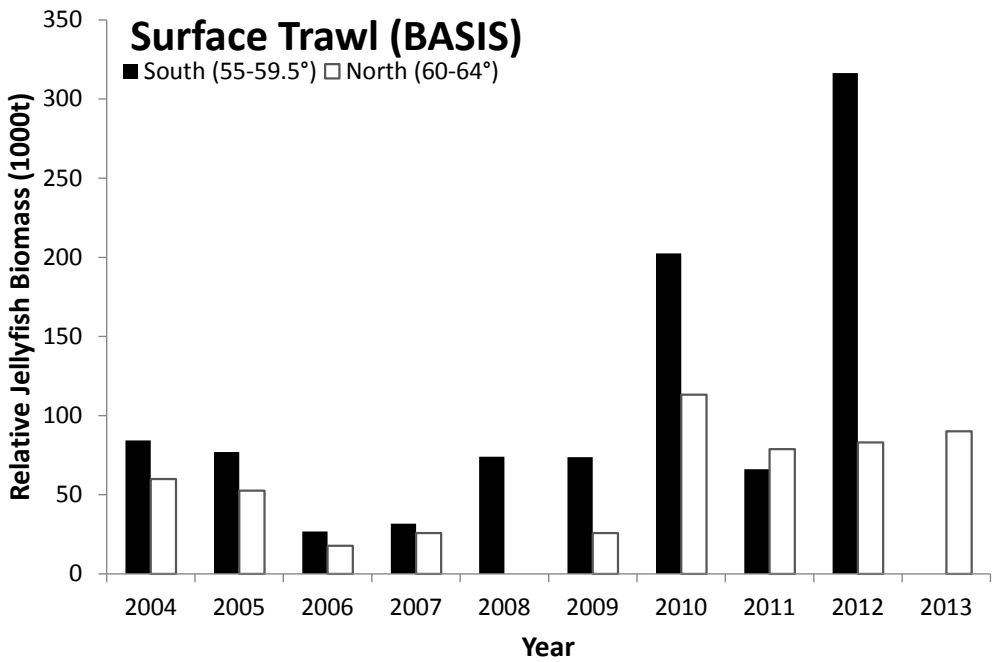

Figure 18: Total jellyfish biomass (1000 t) by year. Includes combined species caught in surface trawls in the Eastern Bering Sea during August-October. Biomass was calculated using average effort per survey area in km^2 by year.

Starting in 2007, notable declines in jellyfish species compostion were observed for all taxa except *C. melanaster* and continued through 2012 (Figure 19). The dominant species continues to be *C. melanaster*, nearly quadrupling its biomass in 2012 compared to 2004. During 2007-2012, biomass of all other species have remained low in comparison to 2004-2006, suggesting the trend for the region has shifted from multiple species to a single species dominant.

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

Implications: Significant increases in jellyfish biomass may redirect energy pathways in the eastern Bering Sea foodweb through jellyfish predation on zooplankton and larval fish, and could result in limiting carbon transfer to higher trophic levels (Condon et al., 2011).

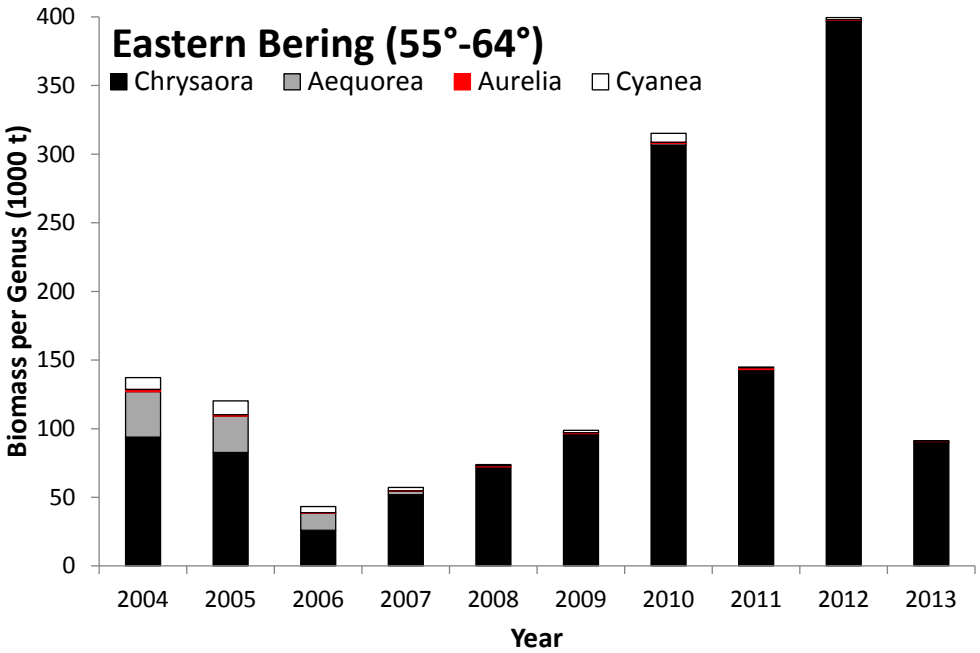

Figure 19: BASIS surface trawl Biomass (1000t) by genus for 2004-2013 in the Eastern Bering Sea during August -October. Biomass was calculated using average effort per survey area in km^2 by year.

Gulf of Alaska Euphausiids ("krill")

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Description of index: The Gulf of Alaska survey of the abundance and distribution of euphausiids ('krill', principally *Thysanoessa* spp.) is under development based on methods developed by Ressler et al. (2012) in the Bering Sea. The survey incorporates both acoustic and Methot trawl data from the summer Gulf of Alaska acoustic-trawl surveys for pollock conducted in 2003, 2005, 2011, and 2013 by NOAA-AFSC. Acoustic backscatter per unit area (s_A at 120 kHz, m^2 nmi^{-2}) classified as euphausiids was integrated over the water column and then across the surveyed area to produce an annual estimate of acoustic abundance (s_A * area, proportional to the total abundance of euphausiids). Approximate 95% confidence intervals on these estimates were computed from geostatistical estimates of relative estimation error (Petitgas, 1993). The index is limited to areas that were consistently sampled by the surveys (Figure 20). These data are preliminary and will change.

Status and trends: In all years euphausiid backscatter was detected throughout the survey area, but was patchy in distribution. The highest density of euphausiids was consistently observed in Barnabas Trough (Figure 20). Results indicate that highest abundance of euphausiids was observed in 2011, with lowest euphausiid abundance in 2003 (Figure 21).

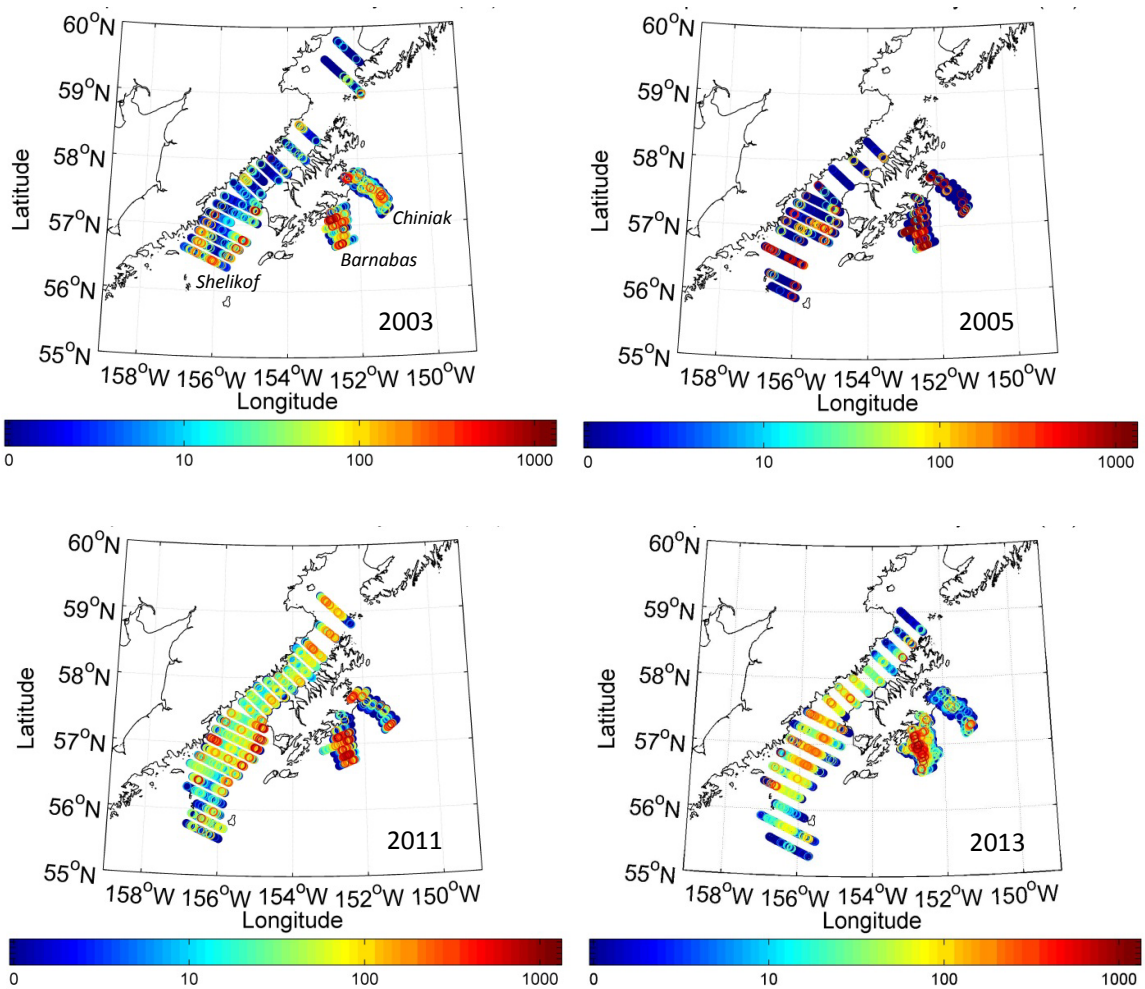

Figure 20: Spatial distribution of acoustic backscatter density (s_A at 120 kHz, m^2 nmi^{-2}) attributed to euphausiids in key areas around Kodiak Island (Shelikof Strait, Barnabas Trough, and Chiniak Trough, as labeled in upper left panel) during the 2003, 2005, 2011, and 2013 Gulf of Alaska summer acoustic-trawl surveys.

Factors influencing observed trends: In 2005, euphausiid backscatter was more patchily distributed (Figure 1), leading to wider confidence bands on the estimate (Figure 21). Also, we suspect the 2005 value may be biased low because of increased mixing of euphausiids with other acoustically important organisms in 2005; this is currently under investigation. Finally, as in the Bering Sea, the physical and environmental factors that influence the abundance and distribution of euphausiids in the Gulf of Alaska are not well understood. There is some preliminary evidence that temperature and chlorophyll *a* may influence interannual differences.

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

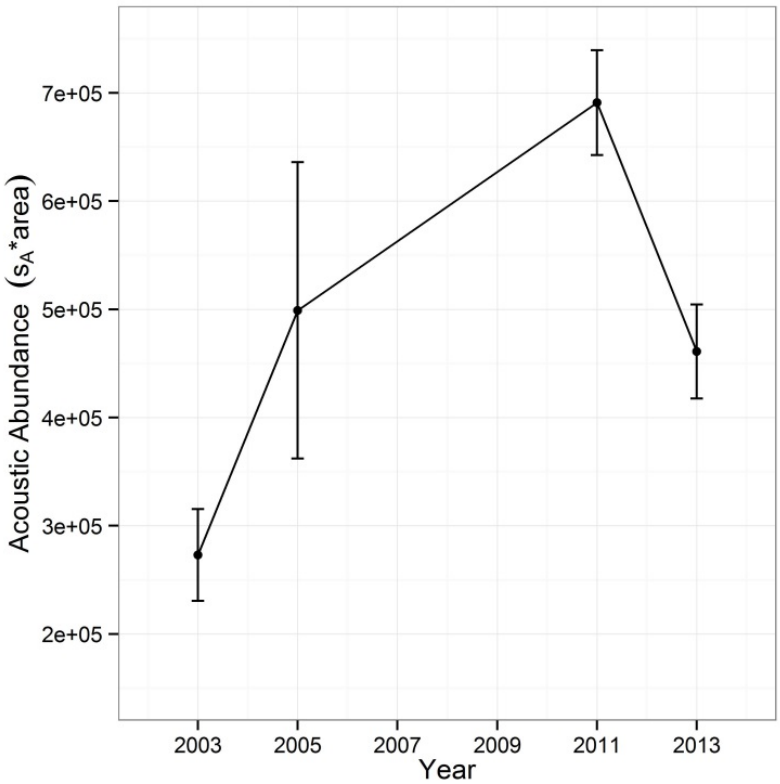

Figure 21: Acoustic backscatter estimate of euphausiid abundance from NOAA-AFSC Gulf of Alaska summer acoustic-trawl survey. Error bars are approximate 95% confidence intervals computed from geostatistical estimates of relative estimation error (Petitgas 1993).

an abundant prey source for many species during this time.

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

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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 2013 monthly temperature and zooplankton data measured in relation to long-term trends in Icy Strait. The Icy Strait Temperature Index (ISTI, °C) is computed from CTD data at 1-m increments over the 20-m upper water column (≥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: Overall, monthly mean temperatures ranged from approximately 7 °C to 10 °C and anomalies did not exceed ±1.5 °C (Figure 22, top). During 2013, temperatures were anomalously cool in May and June and warm in July and August. The ISTI was significantly correlated with the MEI (Figure 22, bottom), with 9 years warmer and 8 years colder than average (9.3 °C)); mean ISTI was average in 2013. Warm and cold years typically had positive and negative MEI values, respectively. In the most anomalous years, all 4 months were warm (2003 and 2005) or cold (2002, 2006, 2008, 2012; Figure 22, top), whereas moderately warm or cold years had unique months of temperature reversal. For example, the warm years of 2004 and 2010 were actually colder than average in June and July, respectively.

Overall, long-term mean zooplankton density peaked in May and June at ∼1,600 organisms per m^3, and declined ∼50% by August (Table 1). During 2013, total density was anomalously low for all months. Density anomalies were mostly negative from 1997-2005, positive in 2006-2009, and negative in 2010-2012 (Figures 23 and 24). Total density showed little correspondence with annual temperature trends, with both positive and negative monthly anomalies in both warm and cold years.

Overall, zooplankton was numerically dominated by calanoid copepods, including small species (≤2.5 mm length; ≤74% composition; primarily *Pseudocalanus* spp.) and large species (>2.5 mm; ≤34% composition; primarily *Metridia* spp.) (Table 2). Four other taxa important in fish diets (Sturdevant et al. 2012; Fergusson et al. 2013) contributed small percentages (euphausiids, ≤7%; decapod larvae, ≤1%; amphipods, ≤2%; and larvaceans, ≤6%). For 2013, large calanoids and larvaceans were anomalously high while small calanoids were anomalously low. Small and large calanoids typically had inverse monthly composition anomalies that indicated different seasonality and temperature response (Figures 23 and 24). However, these anomalies varied from year to year, suggesting different innate timing cues. In some years, high percentages of euphausiid larvae (2000, 2002, 2010), larvaceans (2010), or pteropods (2012) contributed to monthly composition anomalies (Figure 23). 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

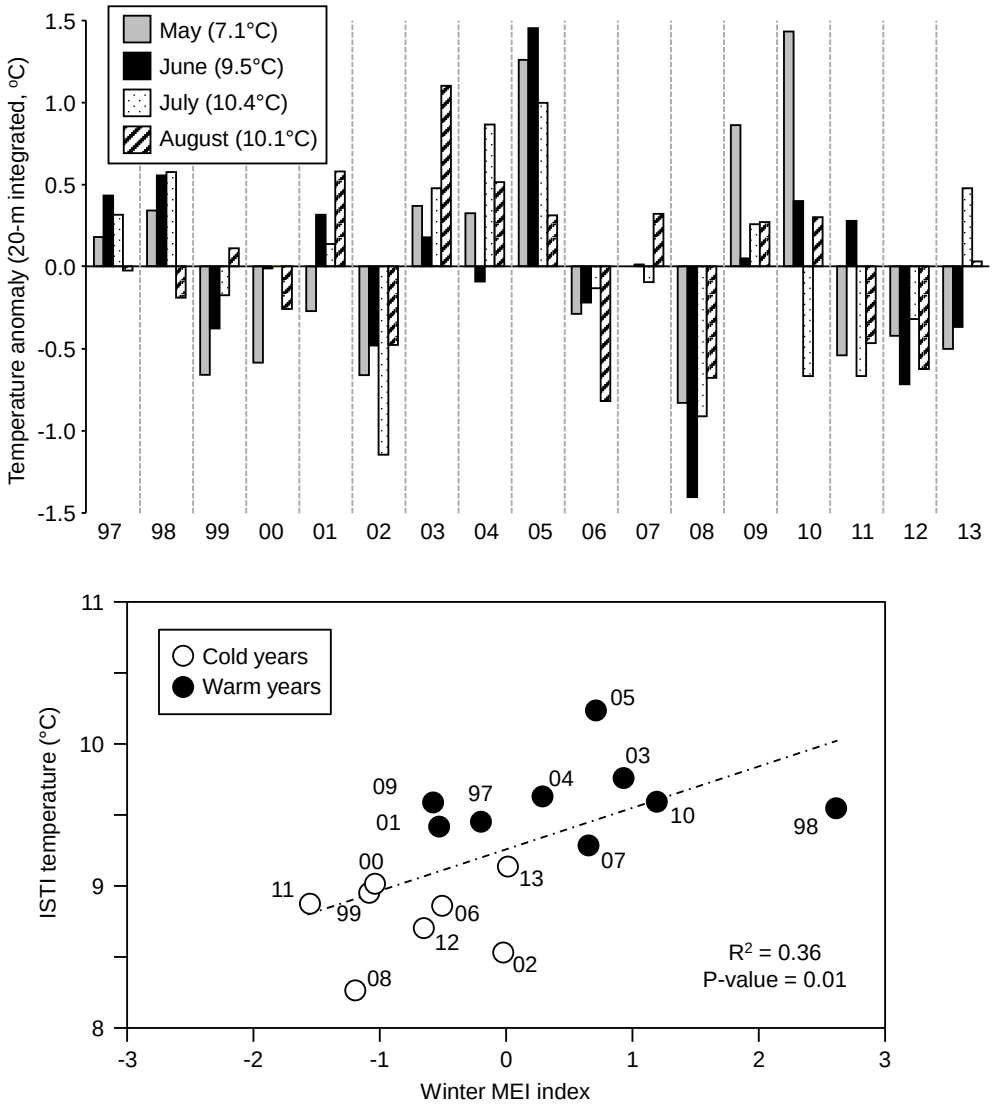

Figure 22: Marine climate relationships for the northern region of Southeast Alaska from the SECM 17-year time series, 1997-2013. Upper panel: mean monthly temperatures (°C, 20-m integrated water column) in Icy Strait; lower panel: correlation of mean annual temperature (°C, 20-m integrated water column) with the Multivariate ENSO Index (MEI), showing warm and cold years. Long-term mean temperatures are indicated in the top panel key by month.

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 typically follow seasonal cycles of abundance, responses to climate change may be species-specific based on life history, seasonal timing cues, physiology, and environmental parameters other than temperature (Mackas et al., 2012), and these responses could depend on the monthly timing, magnitude, and duration of temperature anomalies in warm or cold years. Therefore, the simple ISTI may not explain shifts in abundance and composition of these prey fields, particularly at broad taxonomic scales. Further analysis of specific target prey at a species specific level is planned to

Table 2: Zooplankton long-term mean total density (numbers^{-3}) and taxonomic percent composition in Icy Strait, Southeast Alaska, 1997-2013. Data represent 4 stations sampled annually across the strait ($\leq$ 200 m depth) with a 0.6 m diameter 333-μm mesh Bongo net (double-oblique trajectory). Values are references for the 0-lines shown in Figures 23 and 24 interannual anomalies.

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

refine this index so it more accurately reflects critical trophic interactions with respect to climate change.

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).

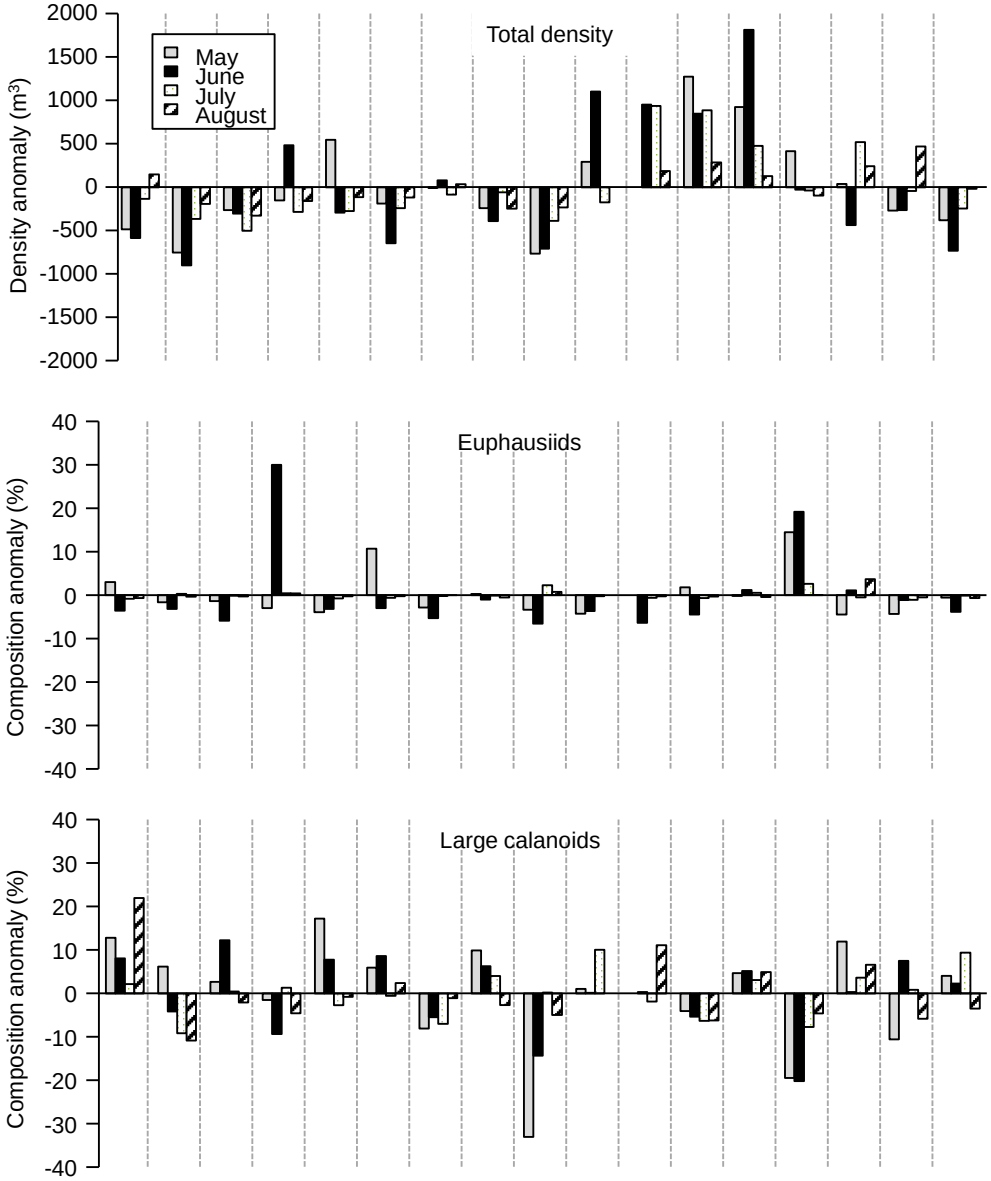

Figure 23: Total zooplankton, euphausiid and large Calanoid density and composition anomalies for the SECM 17-yr time series from Icy Strait, Southeast Alaska, 1997-2013. Long-term monthly means are indicated by the 0-line (values given in Table 2). Data (shaded bars) are deviations for total density (number/m^3; top left panel), and taxonomic percent composition.. No samples were available for August 2006 or May 2007. Warm years are indicated in boxes on the x-axis; see Figure 22.

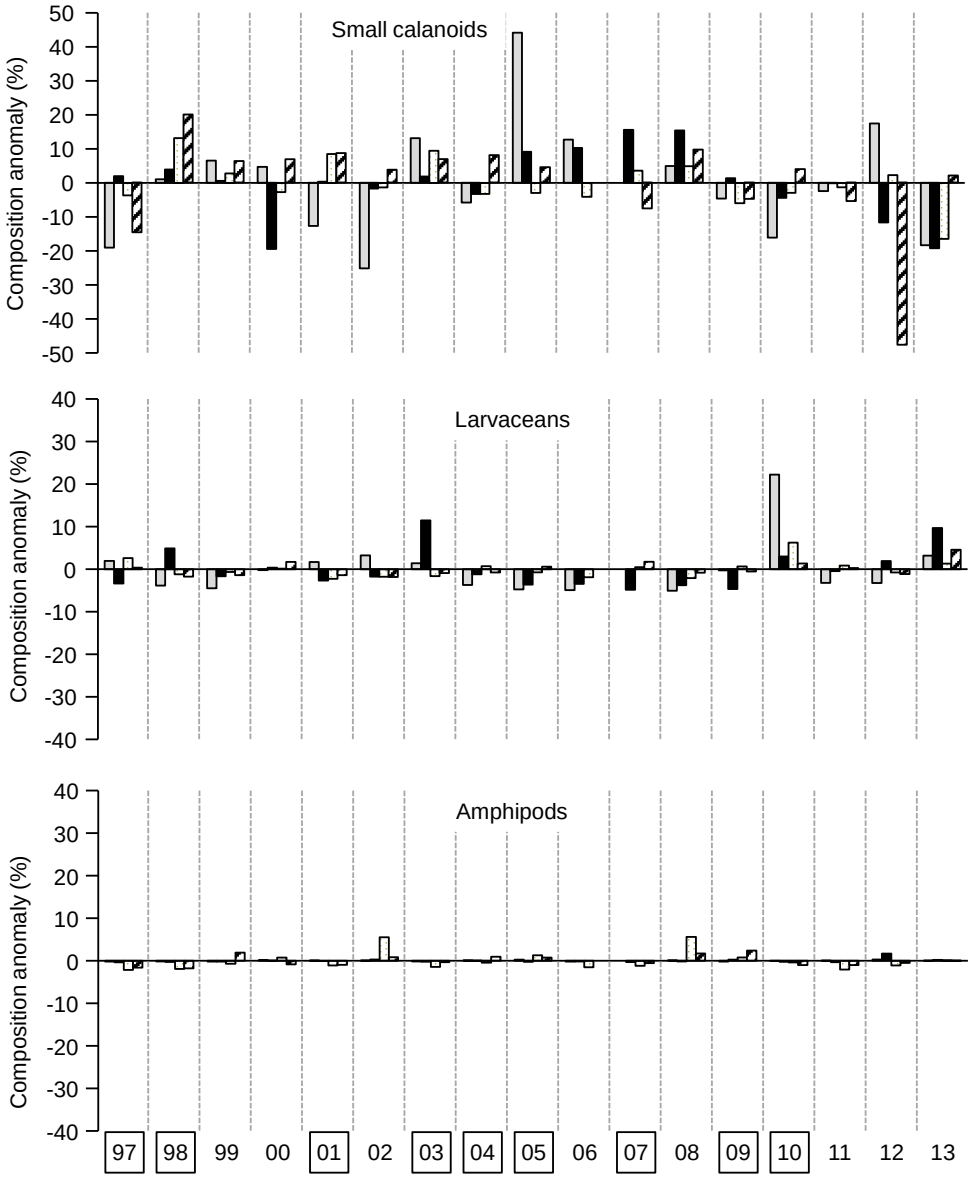

Figure 24: Small Calanoind, Larvacean and amphipod density and composition anomalies for the SECM 17-yr time series from Icy Strait, Southeast Alaska, 1997-2013. Long-term monthly means are indicated by the 0-line (values given in Table 2). Data (shaded bars) are deviations for total density (number/m^3; top left panel), and taxonomic percent composition. No samples were available for August 2006 or May 2007. Warm years are indicated in boxes on the x-axis; see Figure 22.

Continuous Plankton Recorder Data from the Northeast Pacific

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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 ($\sim$ Apr-Sept) which terminates in Cook Inlet, the second sampled 3 times per year which follows a great circle route across the Pacific terminating in Japan. Several indicators are now routinely derived from the CPR data and updated annually. In this report we update three indices for three regions (Figure 25); large diatoms (the CPR only retains large, hard-shelled phytoplankton so while a large proportion of the community is not sampled, the data are internally consistent and may reveal trends), mesozooplankton biomass (estimated from taxon-specific abundance data) and mean copepod community size (Richardson et al., 2006) as an indicator of community composition. Anomaly time series of each index have been calculated as follows: A monthly mean value (geometric mean) for all sampled years was first calculated. Each sampled month was then compared to the mean of that month and an anomaly calculated (Log_{10}). The mean anomaly of all sampled months in each year was calculated to give an annual anomaly (Figure 26).

The indices are calculated for three regions; the oceanic North-East Pacific, the Alaskan shelf SE of Cook Inlet and the deep waters of the southern Bering Sea (Figure 25). 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.

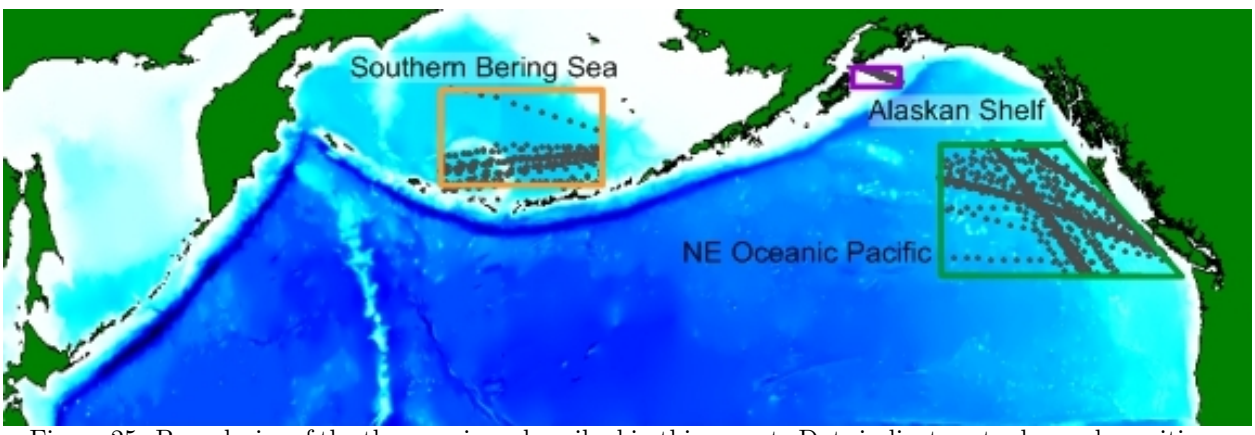

Figure 25: Boundaries of the three regions described in this report. Dots indicate actual sample positions (note that for the Alaskan Shelf region the multiple transects, more than 50, overlay each other almost entirely).

Status and trends: 2013 saw values of each these indices within the range seen before, in all 3 regions, so 2013 was not an unusual year. Large diatoms continued to show a positive anomaly on the Alaskan Shelf, increasing slightly in 2013. They continued to show a negative anomaly in the

oceanic Pacific, though not especially low. The Southern Bering Sea region had a positive anomaly for diatoms, however, since this region is only sampled once in spring, and the timing varies from year to year, it is more difficult to detect trends here. Mesozooplankton biomass was down slightly on the Alaskan Shelf and oceanic NE Pacific. The copepod community was comprised of smaller organisms than in 2013 in the Southern Bering sea and most noticeably on the Alaskan shelf.

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

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

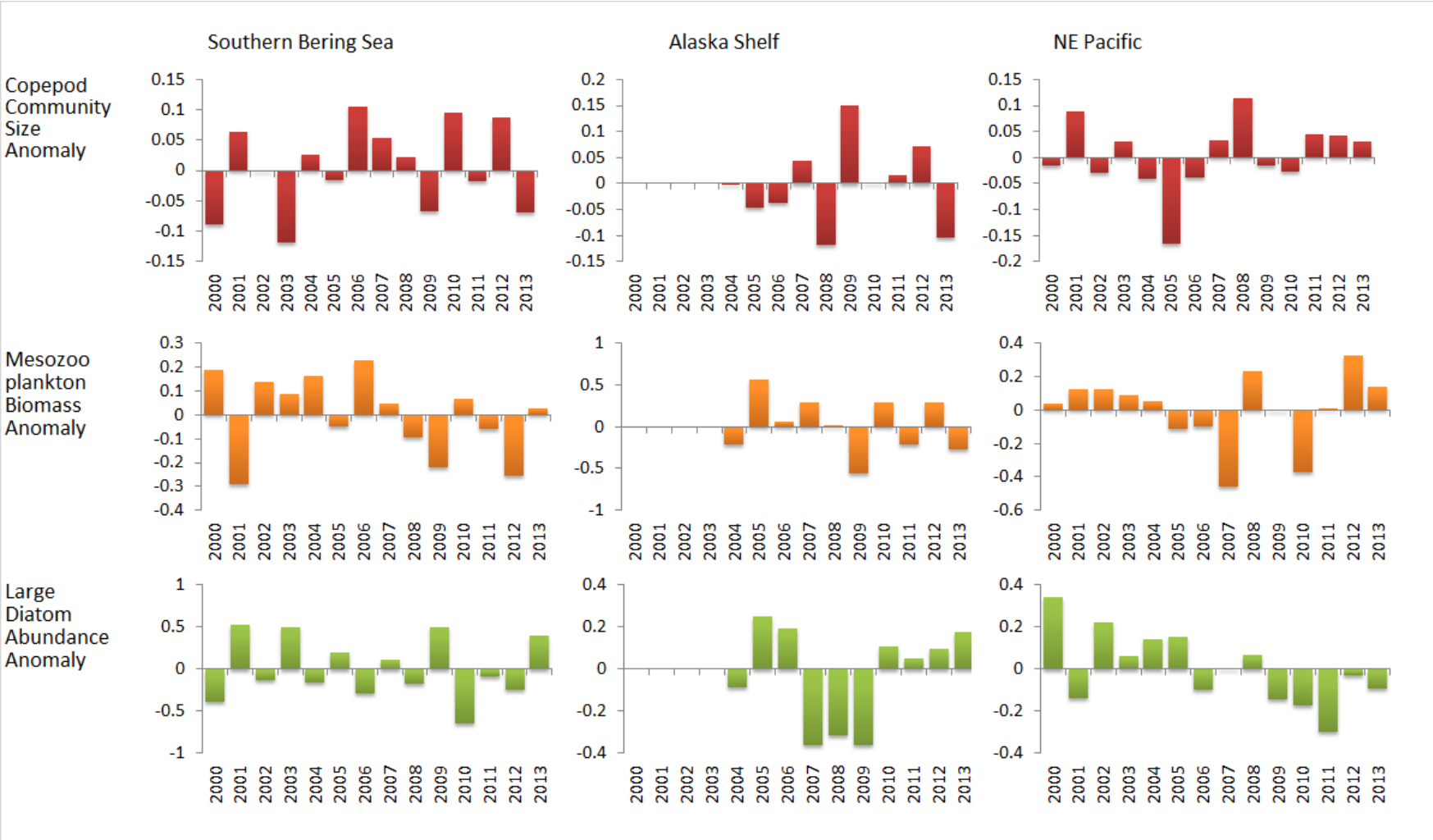

Figure 26: Annual anomalies of three indices of lower trophic levels (see text for description and derivation) for each region shown in (Figure 25). Note that sampling of this Alaskan Shelf region did not begin until 2004.

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
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Last updated: August 2013

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

Forage Fish CPUE - Bering Aleutian Salmon International Survey - BASIS

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Gulf of Alaska Small Mesh Trawl Survey Trends

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Last updated: August 2014

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

The CPUE time series was used to calculate gulf-wide anomalies from the long-term mean CPUE of pink shrimp *Pandalus eous*, juvenile pollock ($\leq$ 20 cm) *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: While herring and pink shrimp catches remain well below the rates of the 1970s and early 1980s (Figure 27) (Anderson and Piatt, 1999), the gulf-wide catch rate of juvenile pollock of 16.5 kg km^{-1} was the highest observed since 1979 (Figure 27). Both pink shrimp and

juvenile pollock were widely distributed across the survey area but the catch rates were highly variable. Pink shrimp catches of over 100 kg km^{-1} were found in Wide, Uyak, and Izhut Bays. For juvenile pollock, catches of over 100 kg km^{-1} occurred in Pavlof, Wide, and Uyak Bays. In over 75% of stations, however, the catches of these species were less than 20 kg km^{-1}.

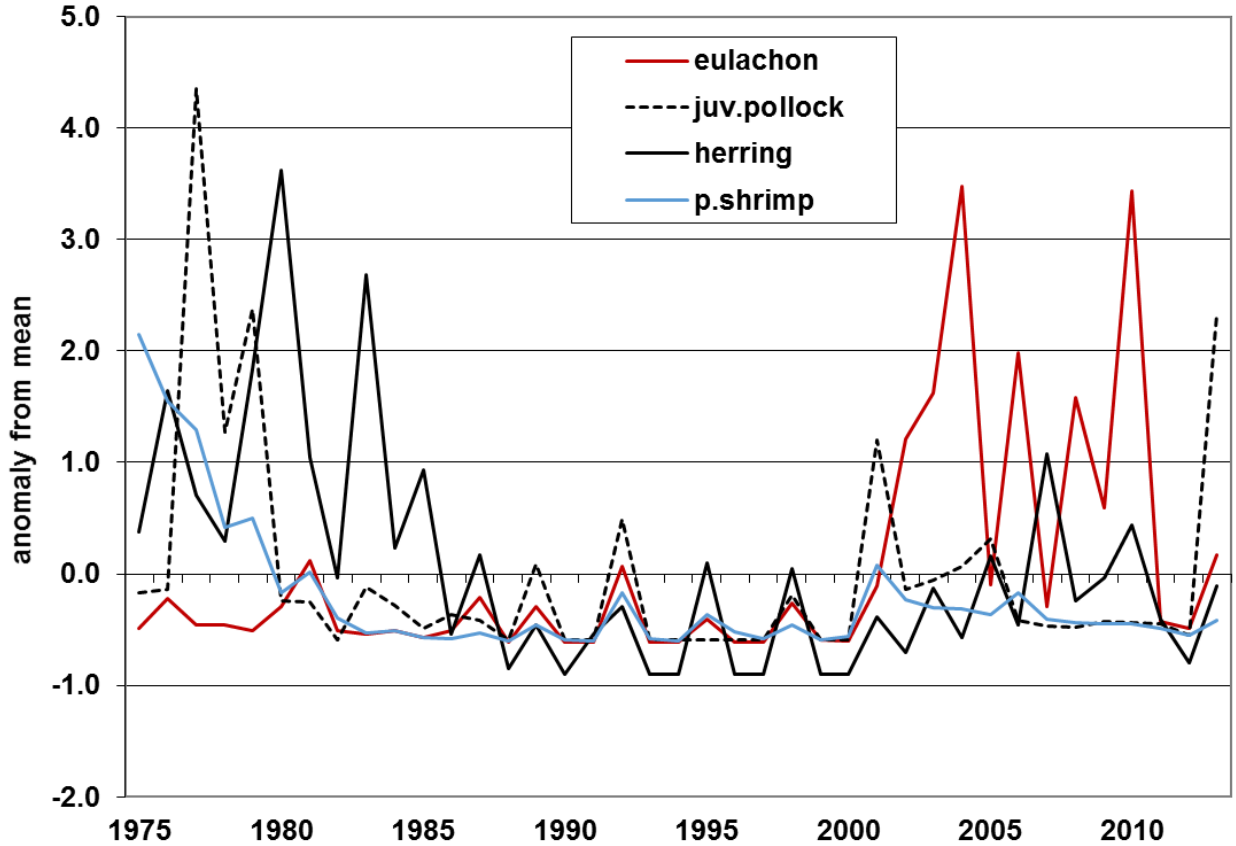

Figure 27: Anomalies from the long-term mean of forage species CPUE (kg km^{-1}) captured during the smallmesh survey in the Gulf of Alaska, 1972-2013.

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

Implications: While the community changes in the marine ecosystem caused by the environmental changes of 1976/1977 appeared strong and widespread across the GOA, the Pacific Decadal Oscillation has not recently had as a dramatic effect (Bond et al., 2003; Litzow, 2006; Mueter et al., 2007), limiting its value as a predictive tool for groundfish managers. Linkages between ocean climate and the marine ecosystem are still important (Di Lorenzo et al., 2008) so improving our understanding of the changing ocean environment requires continued careful monitoring of the physical and biological systems. While our understanding of the linkages between climate changes and the marine ecosystem have improved in the last 30 years, we still lack the ability to forecast trends in a way that is useful to fishery managers (Noakes and Beamish, 2009; **?**).

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

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Last updated: August 2012

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Herring

Togiak Herring Population Trends

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Last updated: October 2013

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

Prince William Sound Pacific Herring

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

Southeastern Alaska Herring

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Last updated: August 2014

Description of index: Pacific herring (*Clupea pallasi*) populations in southeastern Alaska are monitored by the Alaska Department of Fish and Game. Populations are tracked using spawn indices. Stock assessments that combine spawn indices with age and size information have been conducted each fall by the Alaska Department of Fish and Game for nine spawning areas in southeastern Alaska for most years since 1980. The magnitude and regularity of spawning in these areas has warranted annual stock assessment surveys and potential commercial harvests at these

locations during most of the last 30 years. Although spawning occurs at other locales throughout southeastern Alaska, little or no stock assessment activity occurs at these locations other than occassional aerial surveys to document the miles of spawn along shoreline. Spawning at the nine primary sites for which regular assessments are conducted probably accounts for the majority of the spawning biomass in southeastern Alaska in any given year.

Status and trends: Herring spawning biomass estimates in southeastern Alaska often change markedly from year to year, rarely exhibiting consistent, monotonic trends (Figures 28, 29). Over the period 1980 through 2013, some stocks have undergone increasing trends (Sitka Sound, Craig, Seymour Canal, Hoonah Sound), while others have declined (Kah Shakes/Cat Island, Lynn Canal not shown in figures), and yet others have exhibited no obvious trend (West Behm Canal, Hobart Bay/Port Houghton, Tenakee Inlet, Ernest Sound).

Although the estimated total mature herring biomass in southeastern Alaska has been above the long-term (1980-2013) median of 90,495 tons since 2003 through 2013, an apparent decrease in biomass has been observed since the peak in 2011 (Figure 30). The most notable drop in biomass has been observed in Hoonah Sound where the mature biomass dropped from 16,411 tons to 375 tons in just two years. Although it is apparent that the herring population in southeastern Alaska has come down a period of high productivity during about 2005-2011, most spawning areas rebounded in 2013 following lower spawning biomass in 2012 (Figure 1a). The herring biomass in Sitka Sound continues to be by far the highest in the region. Since 1980, herring biomass near Sitka has contributed between 37% and 72% (median of 57%) of the total estimated annual mature biomass among the nine surveyed spawning locations. Excluding the Sitka biomass from the combined estimate, southeastern Alaska herring biomass has been above the 34-year median of 41,073 tons in every year since 2003 (Figure 30).

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 28, 29). The number of age-3 herring has been estimated for Seymour Canal and Sitka for most years since 1980, for Craig in every year since 1988, for Tenakee Inlet every years since 1997, and for West Behm Canal, Ernest Sound, Hobart Bay-Port Houghton, and Hoonah Sound for most years since 1995. An oscillating recruitment pattern with strong recruit classes every three to five years was observed for Sitka Sound and Craig stocks prior to 1997. For Sitka Sound, the stock with the greatest annual recruit abundance, oscillating years of extremely high and low recruit abundance in the 1980s and early 1990s changed to more consistent, intermediate recruit abundances in the mid-1990s through 2013 (Figure 29).

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

There has been some speculation and debate about the extent to which commercial harvests may

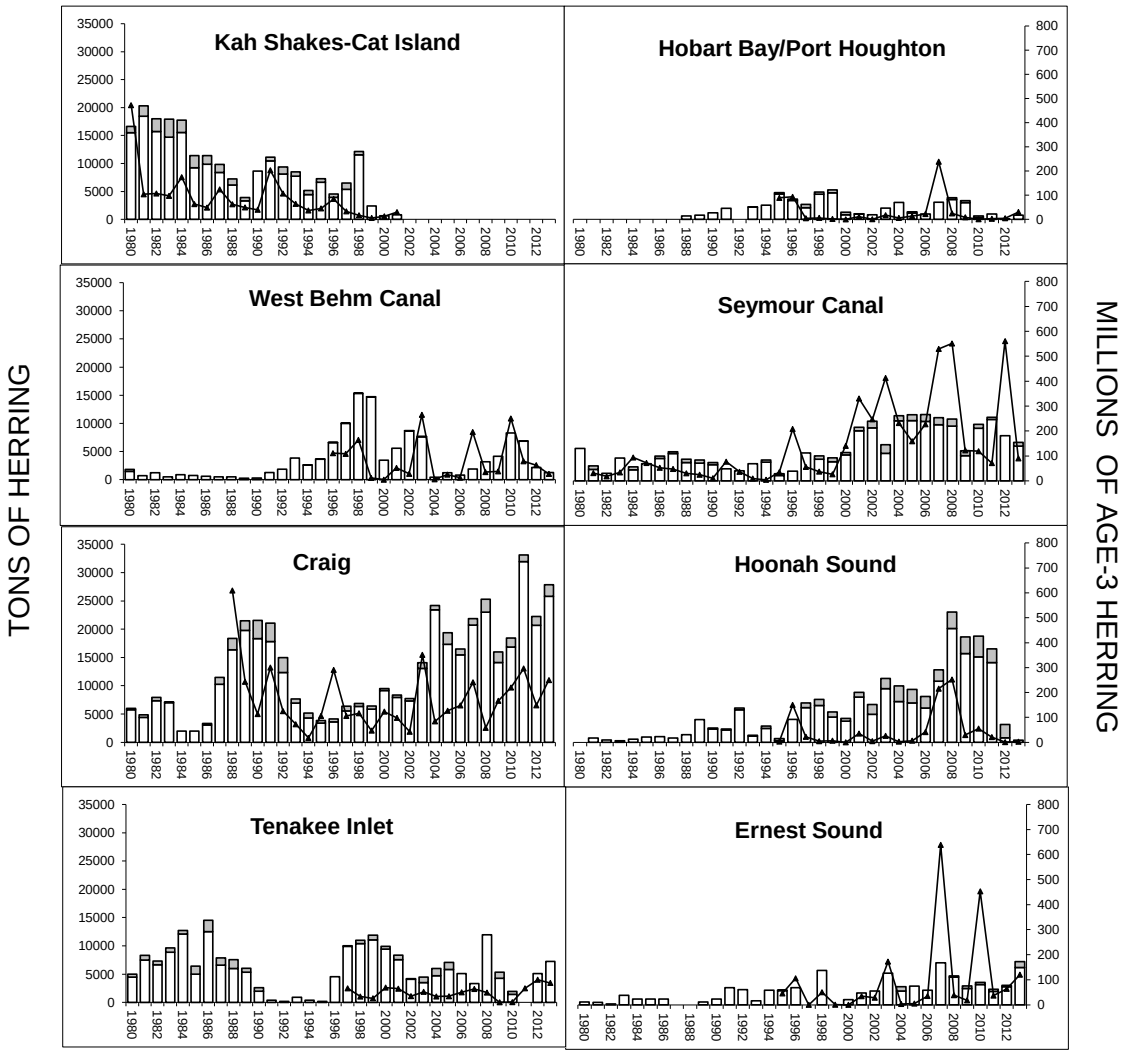

Figure 28: Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 abundance (black line) at eight major spawning locations in southeastern Alaska, 1980-2013. Estimates of age-3 abundance for Tenakee Inlet were unavailable by time of publication.

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

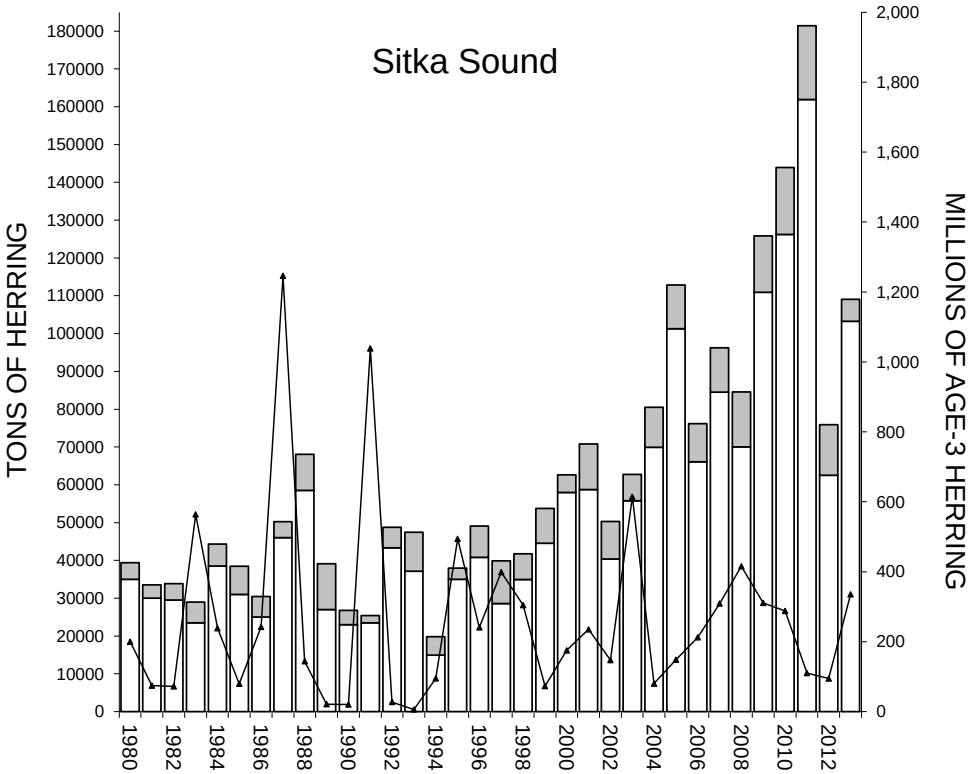

Figure 29: Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 abundance (black line) at Sitka Sound spawning location in southeastern Alaska, 1980-2013.

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

Salmon

Historical and Current Alaska Salmon Trends

Contributed by Andy Whitehouse[1] and Todd TenBrink[2]
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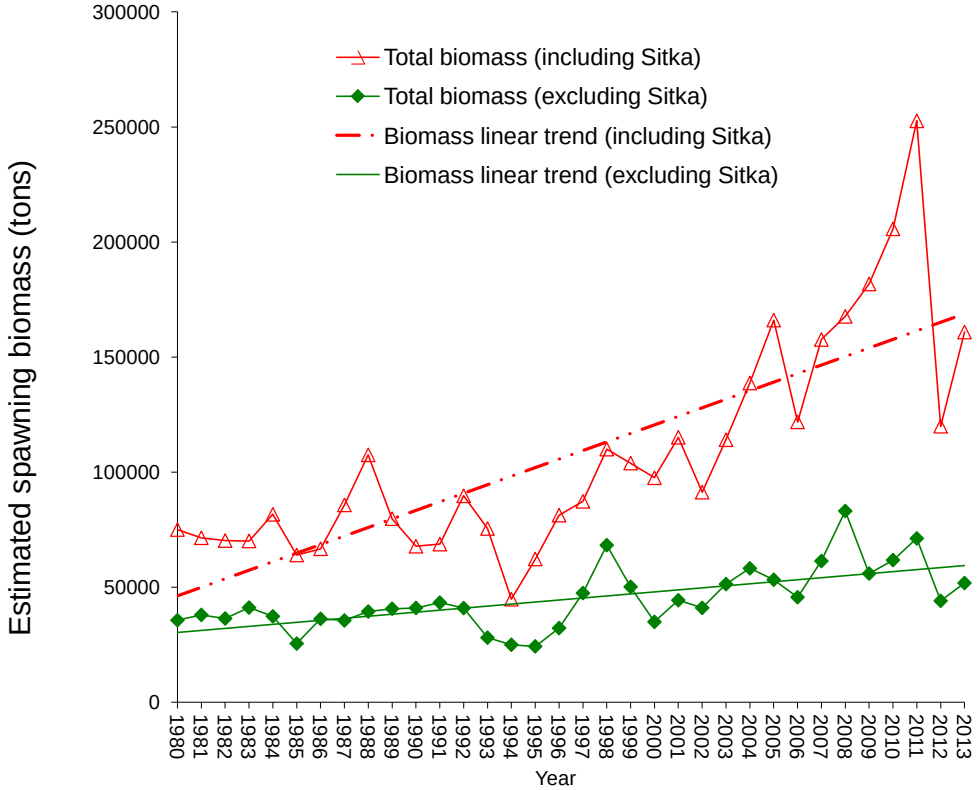

Figure 30: Estimated combined annual mature herring biomass (including and excluding Sitka) at major southeastern Alaska spawning areas, 1980-2013.

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 31) 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.

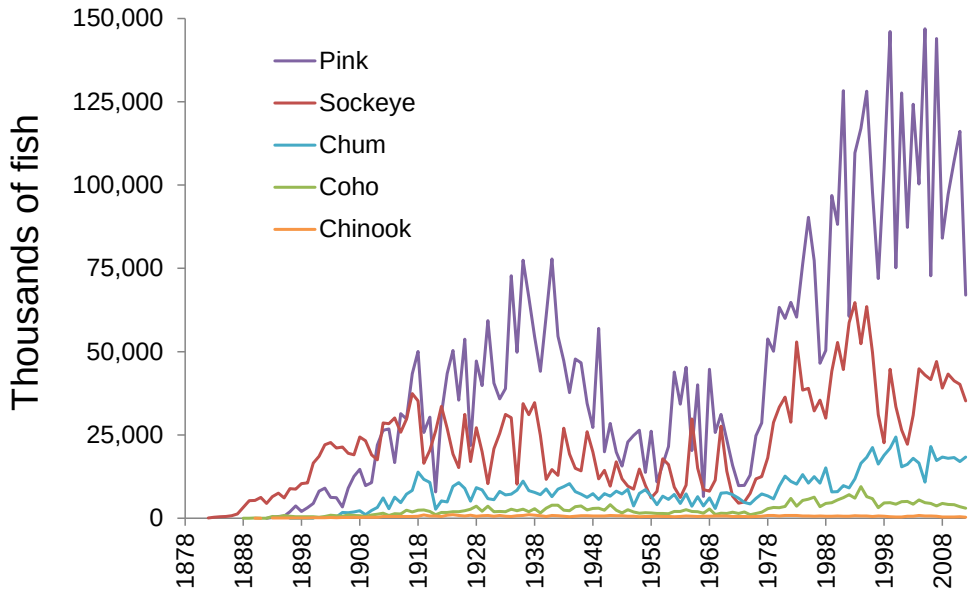

Figure 31: Alaskan historical commercial salmon catches. 2012 values are preliminary. (Source: ADF&G, `http://www.adfg.alaska.gov`. ADF&G not responsible for the reproduction of data.)

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 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 32). 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.

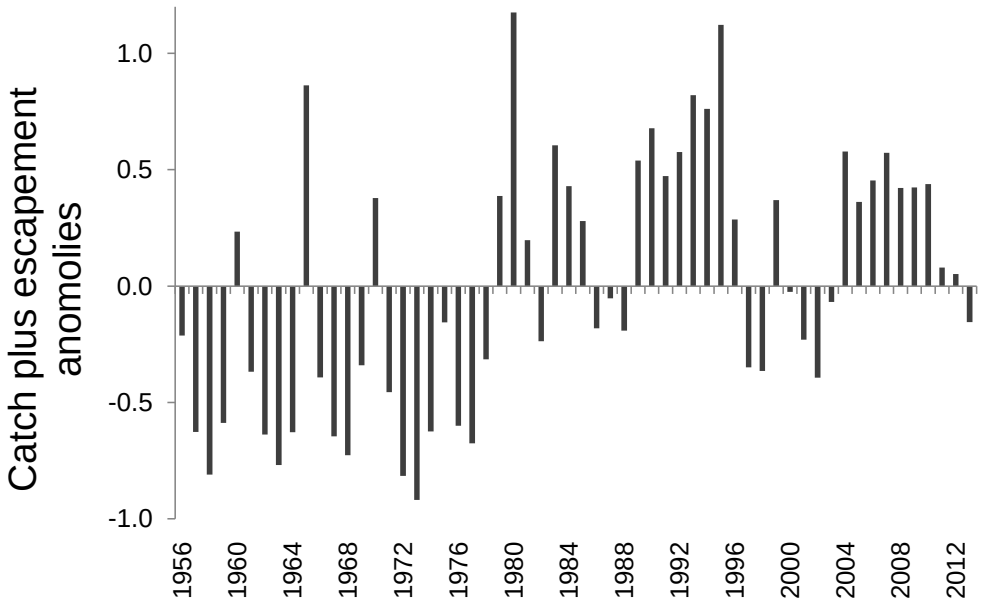

Figure 32: Historical catch plus escapement anomalies of Bristol Bay sockeye salmon, 1956-2013. Data provided by Charles Brazil (ADF&G). Note: the value for 2013 is preliminary and subject to revision.

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 William Sound hatchery pink salmon does not appear to have shifted after the 1988/89 or the 1998/99 climate regime shifts (Figure 33). 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).

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

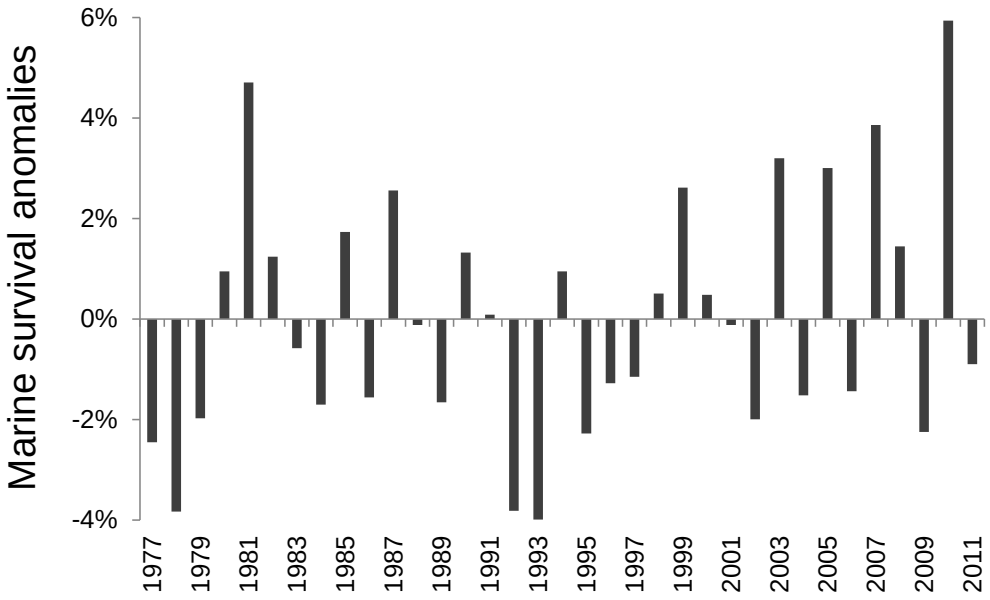

Figure 33: Marine survival of Prince William Sound hatchery pink salmon by year of return (brood year +2 years). Data reproduced from Botz et al.(2013).

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

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Last updated: August 2014

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

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

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

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

Status and trends: Since 1960 pink salmon year-class success has varied widely, with annual harvests ranging from 3 to 95 M fish in SEAK (ADFG 2013). Pink salmon are an ecologically and economically important resource in SEAK, and reached a record harvest (95 M) and value ($125 M) in 2013. These returns also show decadal abundance trends and alternating odd-even year brood line dominance patterns. This variability may result from dynamic ocean conditions or ecological interactions that affect juvenile salmon or overwintering adults above the transition domain in the

North Pacific. Additionally, pink salmon production in SEAK is predominately derived from >97% wild stocks of varied run timings that originate from >2,000 anadromous streams throughout the region. Pink salmon in SEAK are a key stock group proposed for monitoring in the North Pacific (**?**). For pink salmon forecasting, SECM data is used with other regional and basin-scale data sources to construct an ecosystem matrix of input variables related to the response variable of SEAK harvest.

Forecasting information from SECM research has been provided to stakeholders of the pink salmon resource of SEAK since 2004 (**?**). These forecasts have allowed stakeholders to anticipate the harvest with more certainty than previous forecasting methods. For example, in eight of the past ten years, SECM forecast estimates have only deviated from the actual harvests by an average of 7% (`http://www.afsc.noaa.gov/abl/msi/msi_sae_psf.htm`) (Figure 34). Data from juvenile pink salmon catches (CPUE) are also shared with the Alaska Department of Fish and Game (ADFG) to help refine their SEAK pink salmon harvest forecast that is developed by a different method.

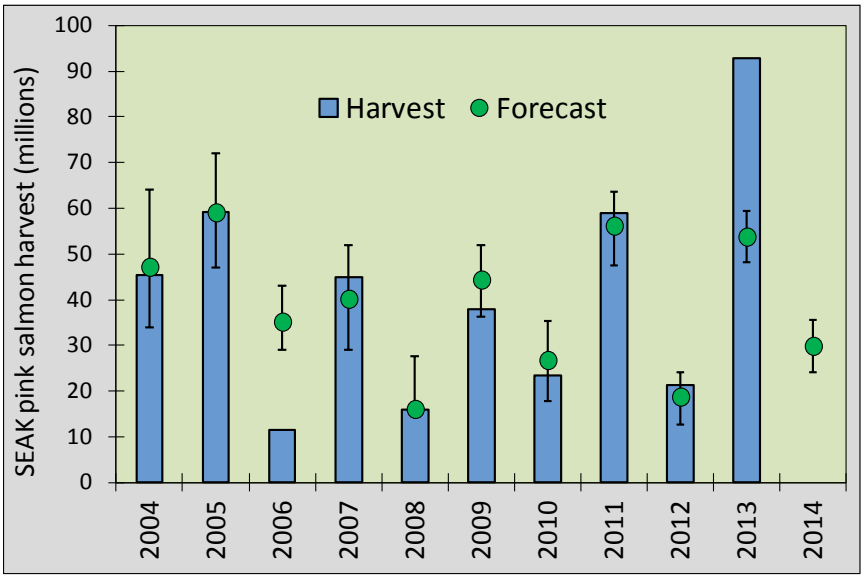

Figure 34: Previous SECM pink salmon pre-season forecast model predictions (with 80% confidence intervals) and actual SEAK harvests over the past decade. Harvest data from the SEAK pink salmon fishery still incomplete for 2014, and 2014 SECM surveys still ongoing for the 2015 forecast.

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

A chronological set of ecosystem metrics associated with SEAK adult pink harvest over the 17-year SECM time series are shown in Table 2 below. Note that in addition to CPUE, four other variables are significantly correlated with harvest (Peak migration month, %pink in June-July trawl hauls, the North Pacific Index, and Adult coho predation impact) and **these ecosystem indicators in concert suggest a low pink salmon harvest in 2014**. Additionally, this matrix shows that anomalously low (red: 2000, 2006, 2008, 2012) or high (green: 1999, 2001, 2005, 2011, 2013) return

years always flag 3-5 ecosystem indicators of the respective color signal in each row. For the 2014 forecast, however, there were only "red" and "yellow" ecosystem indicator flags. The Icy Strait temperature index (ISTI) shown in the last column is not significantly correlated with harvest, but is an important secondary parameter to explain the error in the CPUE and harvest regression model.

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

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

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

Figure 35: 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`).

Implications: Pink salmon returns to SEAK were the largest in history in 2013 and were a

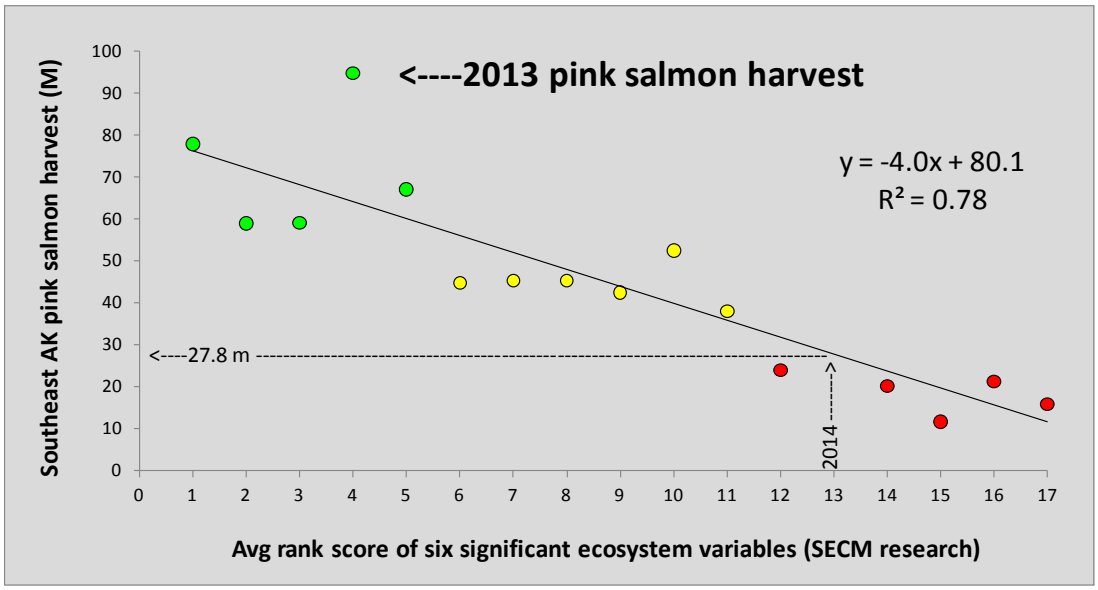

Figure 36: An alternate approach to forecasting pink salmon returns using a hind cast regression of the average ranks of the six significant ecosystem metrics (shaded green in Figure 35) and SEAK pink salmon harvest the ensuing year. The average rank in 2013 is 13th and projects a harvest in 2014 of about 28 M fish. This approach gives a similar harvest number to the 30 M predicted by the step-wise regression method.

Table 3: The two best SECM pink salmon forecast models for the 2013 SEAK harvest.

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

significant fish harvest component in the GOA ecosystem. In 2013, it was estimated that pink salmon represented 46% of the 643,779 metric tons of fish commercially harvested off Alaska in the GOA and adjacent coastal waters. Of these total fish landings in 2013, the commercial harvest component of SEAK pink salmon represented about 21%. Based on ecosystem metrics, the pink salmon harvest to SEAK in 2014 is forecasted to be around 30 M fish, somewhat below the historical average, thus continuing a depressed even year cycle that began nearly a decade ago in 2006, off the poor ocean conditions in 2005 (Figure 35).

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

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Last updated: August 2014

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

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

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

fish would provide managers and stakeholders in SEAK with a leading ecological indicator of year class strength a year or two prior to fishery recruitment.

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

Chinook stock analysis of coded-wire tags recovered from fish sampled during SECM surveys in SEAK indicate they represent both wild and hatchery stocks from the northern region of SEAK. Nearly all these fish are immature and are represented by primarily ocean age-1 fish, mostly in June. Since there is a significant correlation between ocean age-1 abundance of Chinook salmon caught in SECM surveys in June and Chinook salmon brood year survival of selected wild and hatchery stocks (Orsi et al., 2013), a SECM Chinook index of ocean age-1 abundance in June would identify a future production trend for SEAK stocks (Figure 37).

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

Southeast AK		Number of	Average Chinook monthly CPUE Ln(20 min haul catch + 1)					
Chinook		brood year	**Juvenile age -.0**			**Immature age -.1+**		
Stock	Run	cycles	***June***	***July***	***Aug***	***June***	***July***	***Aug***
Stikine	**Wild**	5	0.54	0.19	0.19	0.51	-0.80	-0.40
Taku	**Wild**	11	0.44	0.40	0.53	0.53	0.19	0.12
Chilkat	**Wild**	6	0.23	0.25	0.31	0.84*	0.00	-0.24
LPW	**Hatchery**	10	0.05	0.14	-0.09	-0.12	0.10	0.51
Hidden Falls	**Hatchery**	11	-0.14	0.34	0.11	0.70*	0.20	0.55
DIPAC	**Hatchery**	10	0.13	0.38	0.03	0.86**	0.47	0.40

Figure 37: Monthly correlations of juvenile and immature ocean age-1 Chinook salmon catch per unit effort in SECM surveys in Icy Strait lagged to ocean entry year and subsequent brood year survivals of wild and hatchery Chinook salmon stocks in Southeast Alaska over the 1995-2005 brood years (1997-2007 ocean years). Note the significant positive correlations of CPUE of ocean age-1 fish in June and salmon survival of most stock groups.

Factors influencing observed trends:

Implications: As in most of Alaska, Chinook salmon returns to SEAK have been in decline for almost a decade. This trend is also apparent in the SECM Chinook salmon abundance index (Figure 38). Based on this index of age 1-ocean fish, there appears to be two strong Chinook salmon year classes emerging: one as age 3-ocean fish in 2103 and a stronger one appearing two years later in

2015. Contrary to many of the assumptions of negative impacts of pink salmon on other species, in the case of these two strong year classes of Chinook, they coincide with the same ocean entry years of the high juvenile pink salmon abundances in 2010 and 2012. This suggests that both juvenile Chinook and pink salmon mutually benefitted from favorable ocean conditions in 2010 and 2012, or the smaller, more abundant juvenile pink salmon proved to be a predator buffer to the larger Chinook salmon juveniles. The upcoming 2015 Chinook salmon harvest and abundance of legal sized (age 3-ocean) will be a good test of this index.

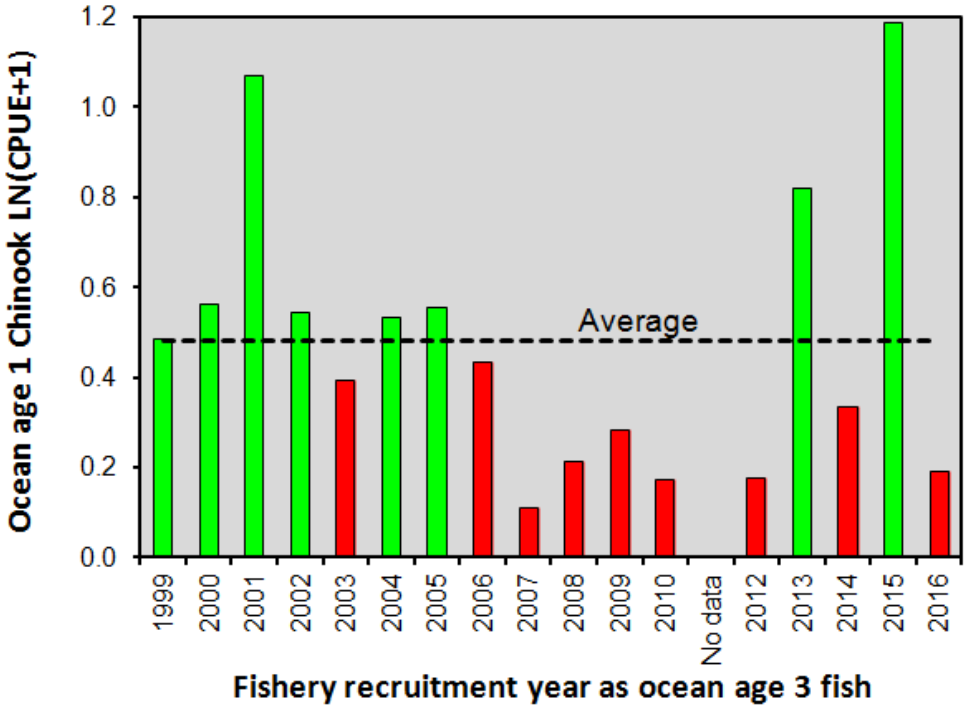

Figure 38: The SECM Chinook salmon index estimate of ocean age 1 fish sampled in Icy Strait in June, lagged two years later to potential recruitment of ocean age 3 fish, 1999-2016. No trawling was conducted in June of 2009, so the index was not available for 2011

Groundfish

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

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Last updated: August 2014

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 2014 and shown for 2006 through 2014 in (Figure 39).

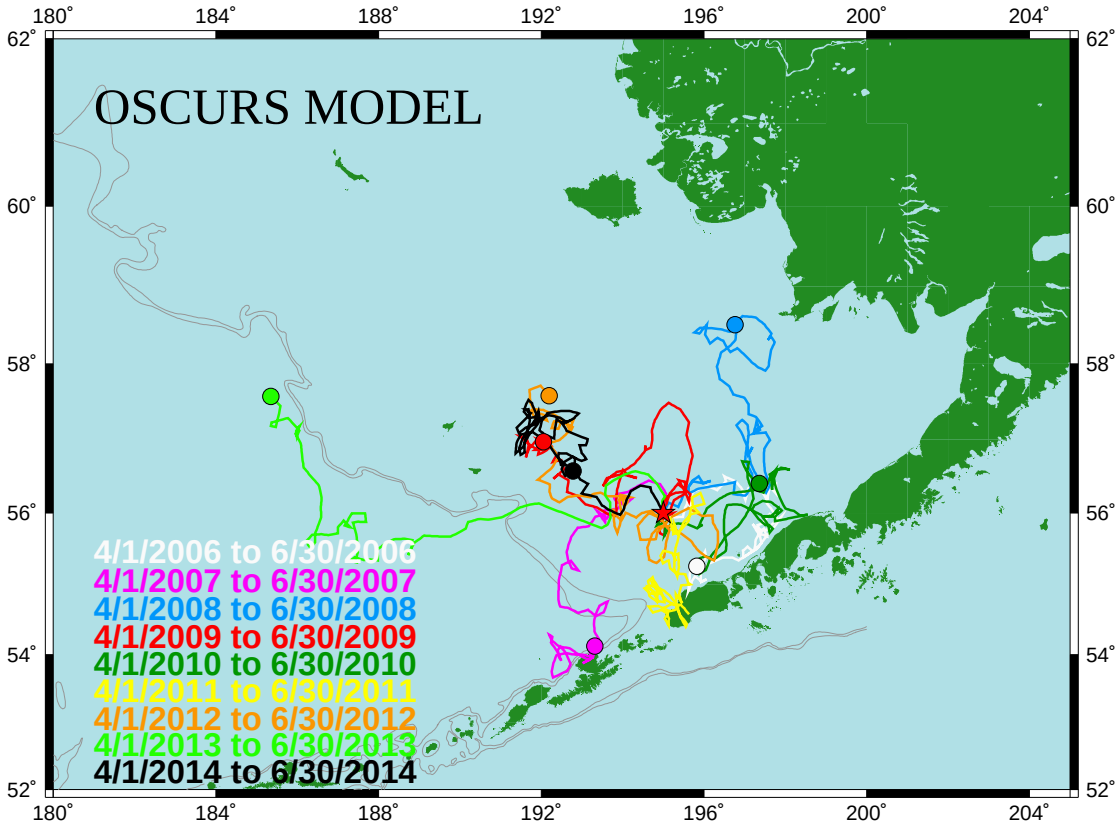

Figure 39: OSCURS (Ocean Surface Current Simulation Model) trajectories from starting point 56°N, 164°W from April 1-June 30 for 2006-2014.

Status and trends: The 2014 springtime drift patterns do not appear to be consistent with years of good recruitment for winter-spawning flatfish. Three out of nine OSCURS runs for 2006-2014 were consistent with those which produced above-average recruitment in the original analysis (2006, 2008, 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, larval occurrence and settlement preferences than northern rock role. In the case of flathead sole, the 2001 and 2003 year-classes appear stronger than the weak recruitment that has persisted since the 1990s.

Implications: The 2012-2014 springtime drift patterns do not appear to be consistent with years

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

of good recruitment for northern rock sole, arrowtooth flounder and flathead sole. 2010 featured a mixture of wind direction as there were strong northerly winds for part of the spring but also southerly winds that would suggest increased larval dispersal to Unimak Island and the Alaska Peninsula. In 2011 the pattern was more across-shelf in a northerly direction, opposite of 2010.

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

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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 40) in an area of the southern region of the eastern Bering Sea (56.2°N to 58.1°N latitude by 166.9°W to 161.2°W longitude). Time series of average monthly sea surface temperatures were obtained from the NOAA Earth System Research Laboratory Physical Sciences Division website. Sea surface temperatures were based on NCEP/NCAR gridded reanalysis data (Kalnay et al., 1996, data obtained from `http://www.esrl.noaa.gov/psd/cgi-bin/data/timeseries/timeseries1.pl`). Less negative values represent a cool late summer during the age-0 phase followed by a warm spring during the age-1 phase for pollock.

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

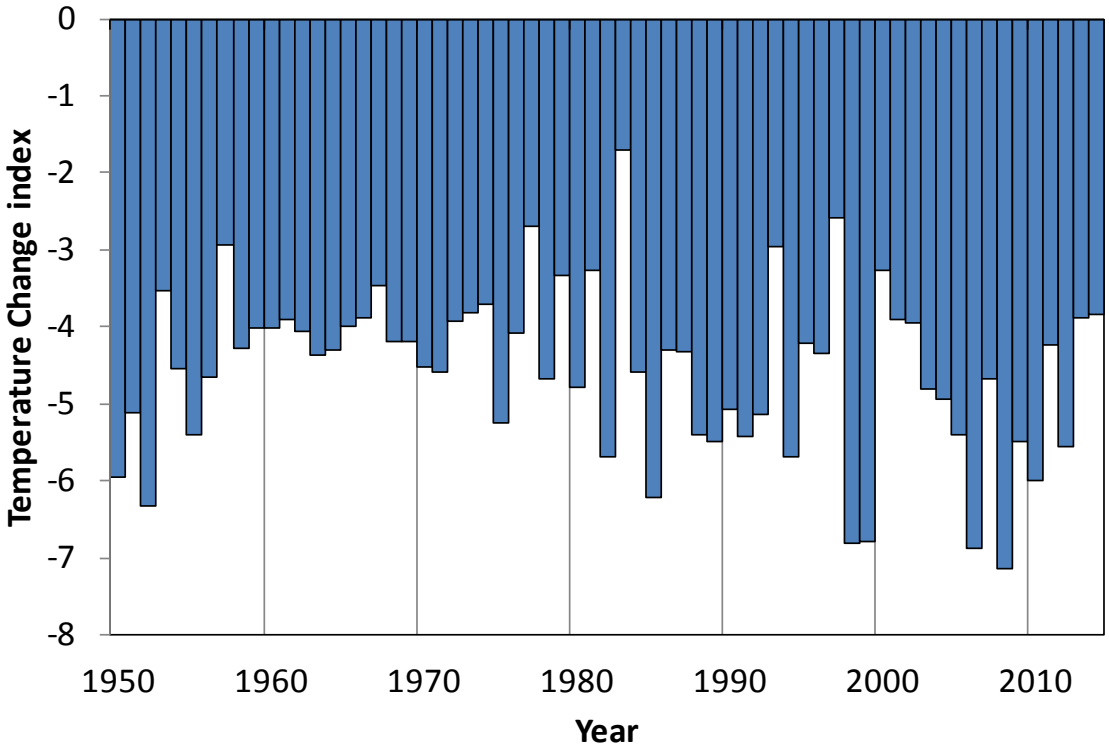

Figure 40: The Temperature Change index value from 1950-2014.

Factors causing observed trends: Age-0 pollock are more energy-rich and have higher over-wintering survival to age-1 in a year with a cooler late summer (Coyle et al., 2011; Heintz et al., 2013). The age-0 pollock are more energy-rich and have higher over- wintering survival to age-1 in a year with a cooler late summer (Hunt et al., 2002, 2011; Coyle et al., 2011). Colder later summers during the age-0 phase followed by warmer spring temperatures during theage-1 phase are assumed favorable for the survival of pollock from age-0 to age-1.

Implications: In 2012, the TC index value of -5.56 was below the long-term average of-4.57, therefore we expect slightly below average numbers of pollock to survive to age-3 in 2014 (Figure 40). In the future, the TC values in 2013 (TC=-3.89) and in 2014 (TC=-3.84) indicate above average abundances of age-3 pollock in 2015 and 2016 (Figure 41).

Trends in Groundfish Biomass and Recruits per Spawning Biomass

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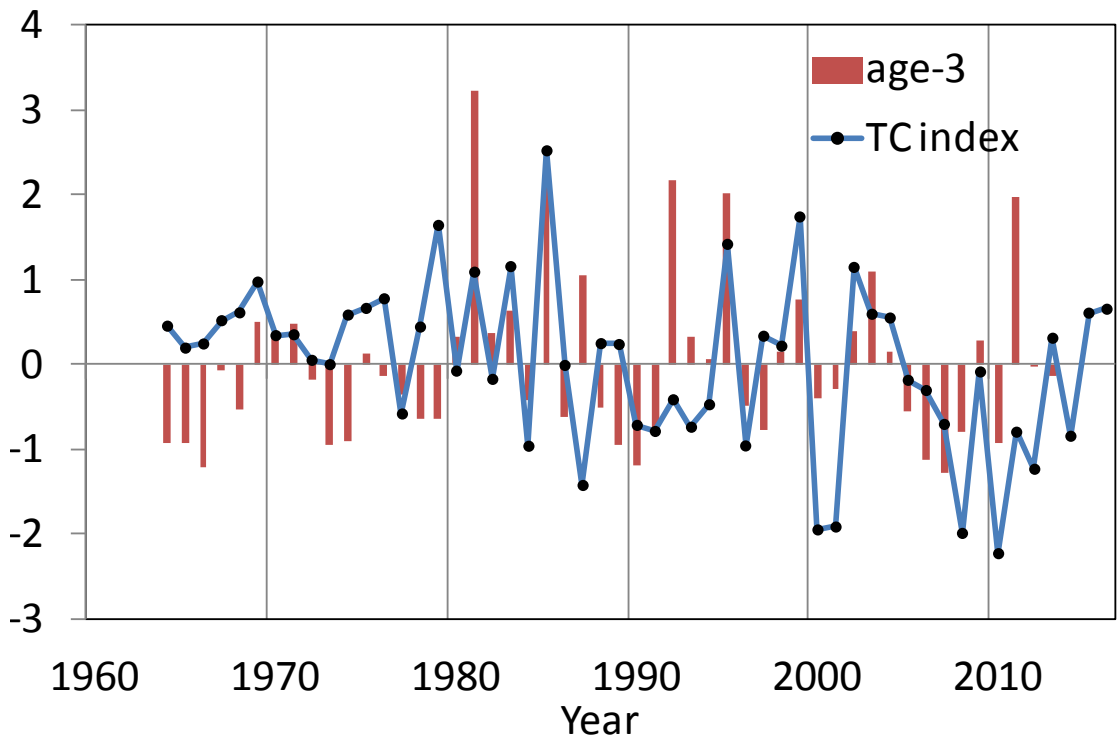

Figure 41: Normalized times series values of the temperature change index (t-2) and the estimated abundance of age-3 walleye pollock in the eastern Bering Sea (t)) from Table 1.21 in Ianelli et al. 2013.

Last updated: October 2011

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

Bering Sea Groundfish Condition

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Last updated: October 2013

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

Gulf of Alaska Ichthyoplankton Abundance Indices 1981-20011

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Last updated: August 2013

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

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

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Last updated: August 2014

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

Status and trends: Age-2 sablefish recruitment was described as a function of late August sea temperature, late August chlorophyll a, and juvenile pink salmon productivity index during the age-0 stage (based on adult salmon returns to southeast Alaska during the age-1 stage) in a multiple regression model (Figure 42; Table **??**). Chlorophyll *a* during the age-0 phase was most strongly correlated with sablefish recruitment ($R^2 = 0.80$; $p = 0.00003$) with a three-fold increases in chlorophyll *a* in 2000 and recruitment (age-2) in 2002. Sea temperature and pink salmon productivity explained an additional 15% of the variation in sablefish recruitment ($R^2 = 0.950$; $p = 0.00001$).

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

Table 5: Sablefish estimates from **?**, predictor variables used in the model (2001-2012), model estimates and standard errors (2001-2012), and forecast estimates; SE = standard error; SST = sea surface temperature.

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

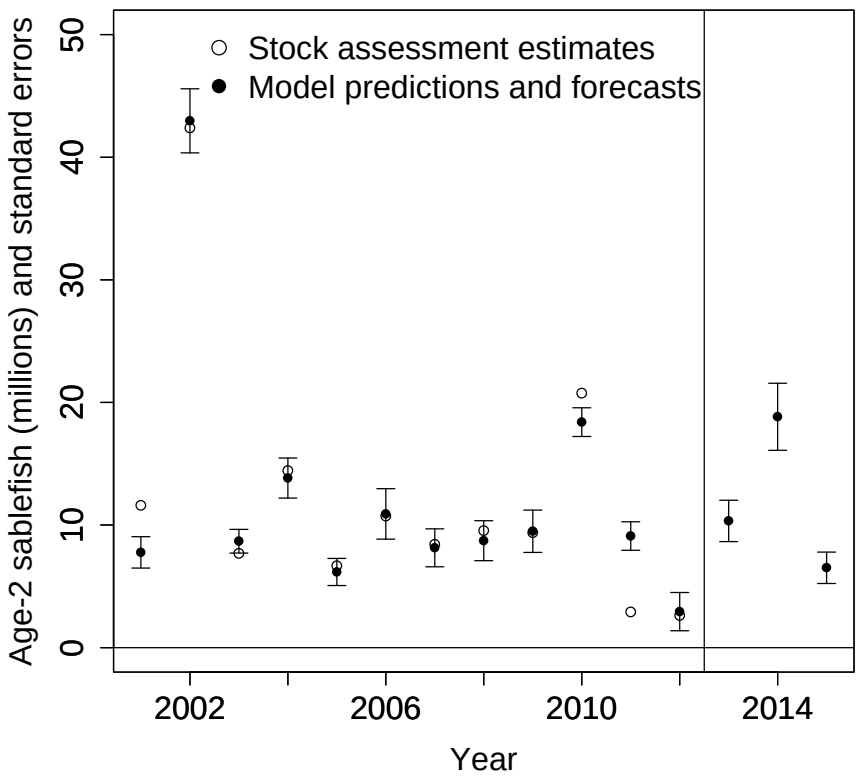

Figure 42: Age-2 sablefish modeled as a function of chlorophyll *a* during the age-0 stage (t-2), sea temperature during the age-0 stage (t-2), and juvenile pink salmon productivity during the age-0 stage and overwintering survival to age-1 (based on adult pink salmon in year t-1).

overwintering survival from age-0 to age-1, and overall survival to age-2.

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

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

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Benthic Communities and Non-target Fish Species

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

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Bering Sea/Aleutian Islands King and Tanner Crab Stocks

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Miscellaneous Species - Eastern Bering Sea

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Miscellaneous Species - Aleutian Islands

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ADF&G Gulf of Alaska Trawl Survey

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Seabirds

Multivariate Seabird Indices for the Eastern Bering Sea

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Description of index: The index is derived from the first two principal components of a principal components analysis (PCA) that combines reproductive effort data (mean hatch date and reproductive success) from common murre *Uria aalge*, thick-billed murre *U. lomvia*, black-legged kittiwake *Rissa tridactyla*, red-legged kittiwake *R. brevirostris*, and red-faced cormorants *Phalacrocorax urile* breeding on the Pribilof Islands. Data are collected by the USFWS Alaska Maritime National Wildlife Refuge. The most recent PCA includes 17 individual data sets spanning 1996 to 2013. St Paul red-faced cormorant reproductive success could not be monitored in 2012, so I substituted the long-term mean value for this year. Removing the cormorant time series and repeating the PCA did not change the results meaningfully.

All data were standardized (mean of zero and variance of 1) to assure equal weighting. PCAs were performed using the prcomp function in R. We considered the 2 leading principal components (PC1 and PC2) successful candidates for combined seabird indices if they explained a sufficient level (>20% each) of the variance in the datasets. Inspection of the time series of breeding parameters loading most strongly on each PC (loading strength >0.2) enabled interpretation of the biological

meaning of the indices. Methodological detail can be found in Zador et al. (2013).

Status and trends: The PCA on the 18 yr annual time series (1996-2013) explained 66.2% of the variance in the data in the first two components. All seabird phenology, common murre and St. Paul thick-billed murre reproductive success time series were associated (loadings >0.2) with PC1, which explained 42.7% of the total variance (Figure 43). All kittiwake reproductive success time series were strongly associated (loadings >0.4) with PC2, which explained 23.5% of the total variance. With the addition of 2013 data, St. Paul thick-billed murre reproductive success and black-legged and red-legged kittiwake hatch dates were also associated with PC2, although not as strongly as the kittiwake reproductive success time series (loadings = 0.23, 0.22, and 0.26, respectively). Also, St. George thick-billed murre reproductive success, which grouped with kittiwake reproductive success in PC2 in previous years, was not associated with either PC.

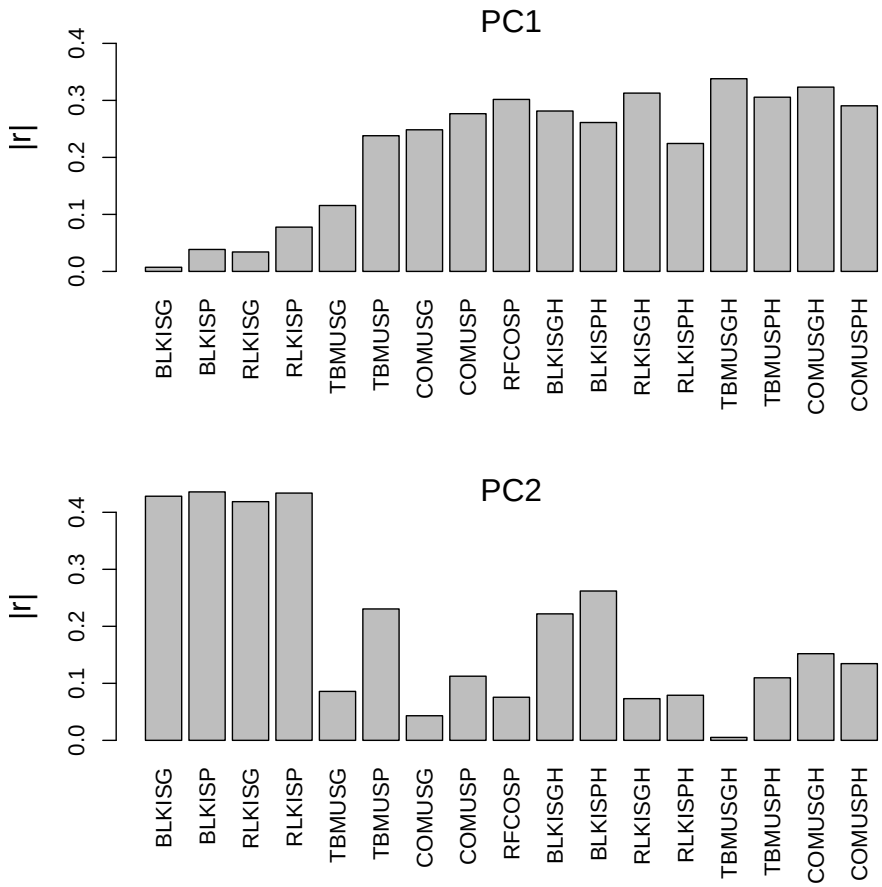

Figure 43: Loadings (absolute correlations) measuring the strength of association between individual time series and the first (PC1, top) and second (PC2, bottom) principal components. The datasets are labeled in order with a 4-letter bird species code following American Ornithological Union convention (e.g., BLKI: black-legged kittiwake), a 2-letter island code (SP: St. Paul; SG: St. George), and H if it is a hatch date time series.

The temporal trend in PC1 continued to increase since 2011, indicating earlier hatch dates and higher reproductive success for common murres and St. Paul thick-billed murres (Figure 44). The

temporal trend in PC2 continued the nearly annual trend reversal with the 2013 value showing a decrease from the previous year and indicating an increase in kittiwake reproductive success.

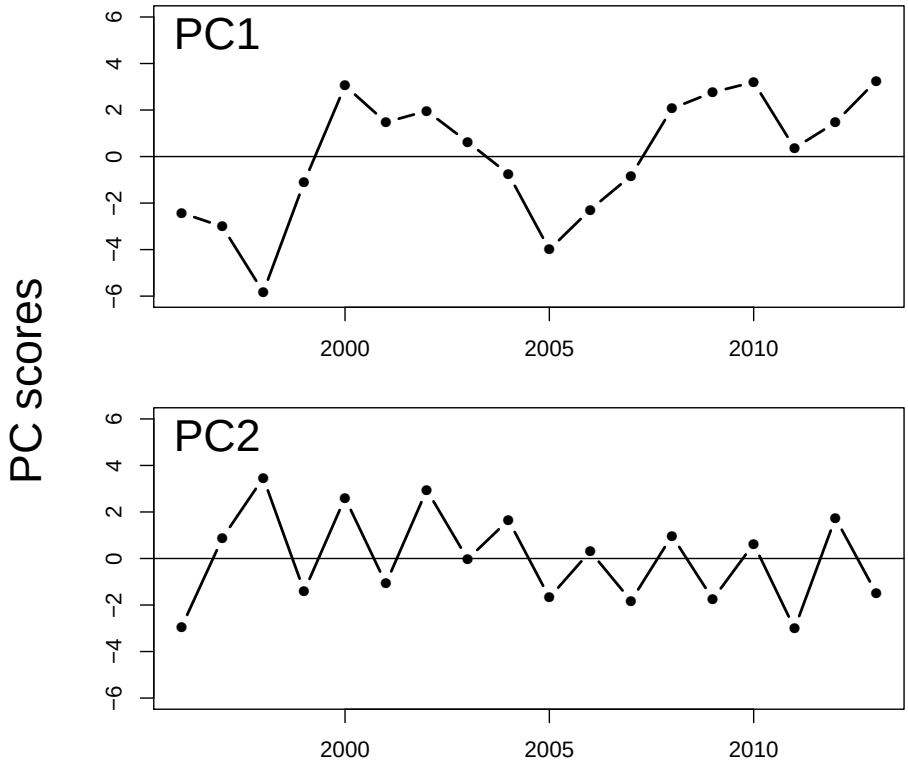

Figure 44: The value of PC1 (top) and PC2 (bottom) over time. Higher values of PC1 indicate earlier seabird hatch dates and higher cormorant and murre reproductive success (except for St. George thick-billed murres). Higher values of PC2 indicate higher kittiwake reproductive success, and new with the inclusion of 2012 data, St. Paul thick-billed murre reproductive success and St. Paul black-legged kittiwake hatch dates.

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

Implications: These results indicate that 2013 was a generally successful year reproductively for Pribilof seabirds with the exception of kittiwake productivity. Years of high pink salmon abundance, the odd-numbered years after 1997, correlates with poor kittiwake productivity. This correspondence may be a result of competition between abundant zooplanktivorous pink salmon and kittiwakes or related responses to environmental conditions. The winter distribution of kittiwakes overlaps with the pink salmon in the North Pacific, thus broad-scale environmental exposure may

be similar.

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

Seabird Bycatch Estimates for Alaskan Groundfish Fisheries, 1993-2013

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Description of index: This report provides estimates of the numbers of seabirds caught as bycatch in commercial groundfish fisheries in Alaska operating in federal waters of the U.S. Exclusive Economic Zone for the years 2007 through 2013. Fishing gear types represented are demersal longline, pot, pelagic trawl, and non-pelagic trawl. These numbers do not apply to gillnet, seine, or troll fisheries. Data collection on the Pacific halibut longline fishery began in 2013 with the restructured observer program, although some small amounts of halibut fishery information were collected in years previous when an operator had both halibut and sablefish individual fishing quota.

Estimates are based on two sources of information, (1) data provided by NMFS-certified Fishery Observers deployed to vessels and floating or shoreside processing plants (, AFSC), and (2) industry reports of catch and production. The AFSC produced the estimates from 1993-2006 (Fitzgerald et al., 2008). The NMFS Alaska Regional Office Catch Accounting System (CAS) produced the estimates from 2007-2013 (Cahalan et al., 2010). The main purpose of the CAS is to provide near real-time delivery of accurate groundfish and prohibited species catch and bycatch information for inseason management decisions. It is also used for the provision of estimates of non-target species (such as invertebrates) and seabird bycatch in the groundfish fisheries. At each data run, the CAS produces estimates based on current data sets, which may have changed over time. Changes in the data are due to errors that were discovered during observer debriefing, data quality checks, and analysis. Examples of the possible changes in the underlying data are: changes in species identification; deletion of data sets where data collection protocols were not properly followed; or changes in the landing or at-sea production reports where data entry errors were found.

Status and trends: Figure 45 depicts seabird bycatch in the groundfish fisheries from 1993 through 2013 using results from the two analytical methods noted above. The 2013 estimated numbers for the combined groundfish fisheries are the lowest since we began estimating bycatch in 1993. Since we implemented the CAS (Table 6) the 2013 estimates are 62% of the running 5-year average for 2008-2012 of 7,558 birds and are the lowest total since we began using the CAS in 2007.

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

Northern fulmar (*Fulmaris glacialis*) bycatch remained the highest proportion in the catch at 69%. Fulmar bycatch increased by 8% from the year before but remained 30% below the 5-year average. Fulmar bycatch has ranged between 45 to 76% of the total seabird bycatch since 2007. Average annual mortality for fulmars since 2007 has been 4,472. When compared to estimates of the total population size in Alaska of 1.4 million (Denlinger, 2006), this represents an annual 0.33% mortality due to fisheries. However, there is some concern that the mortality could be colony-specific possibly leading to local depletions (Hatch et al., 2010).

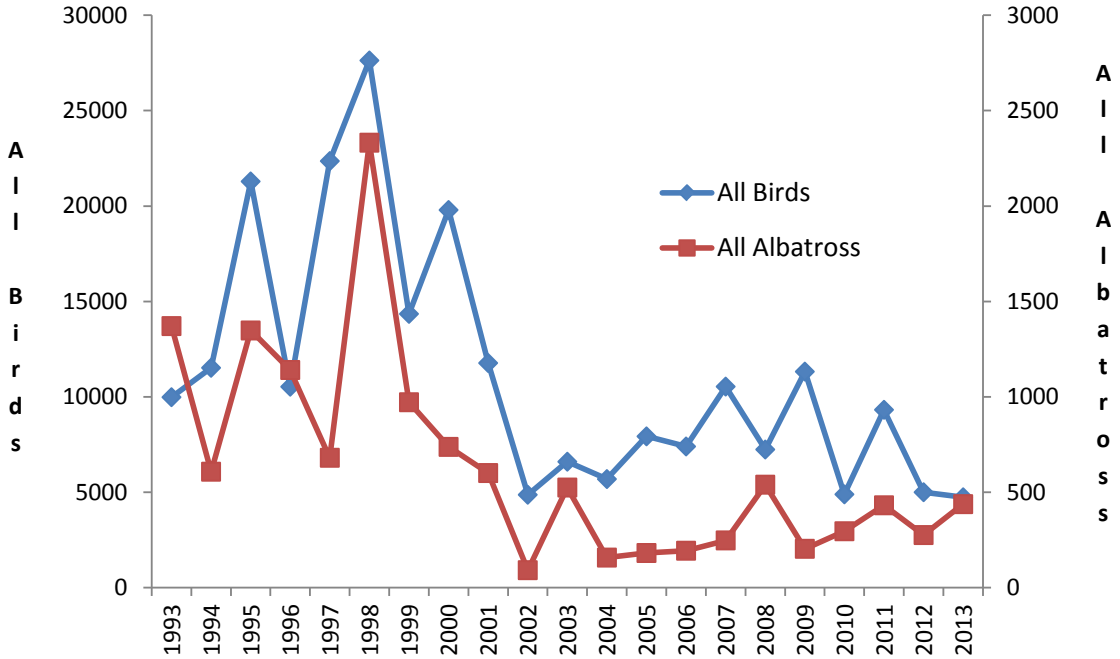

Figure 45: Seabird bycatch in Alaskan groundfish fisheries, all gear types combined, 1993 to 2013. Total estimated bird numbers are shown in the left-hand axis while estimated albatross numbers are shown in the right-hand axis

The demersal longline fishery in Alaska typically drives the overall estimated bycatch trends (but

Table 6: Total **estimated** seabird bycatch in Alaskan groundfish fisheries, all gear types and Fishery Management Plan areas combined, 2007 through 2013. Note that these numbers represent extrapolations from observed bycatch, not direct observations. See text for estimation methods.

Species/Species Group	2007	2008	2009	2010	2011	2012	2013
Unidentified Albatross	23	0	0	0	0	0	0
Short-tailed Albatross	0	0	0	15	5	0	0
Black-footed Albatross	208	314	56	48	221	141	249
Laysan Albatross	17	226	148	233	206	135	189
Northern Fulmar	4806	3334	8200	2452	6214	3022	3277
Shearwaters	3587	1224	620	653	194	514	191
Storm Petrels	1	44	0	0	0	0	0
Gull	1360	1551	1335	1145	2158	890	556
Kittiwake	10	0	16	0	6	5	3
Murre	6	6	13	102	14	6	3
Puffin	0	0	0	5	0	0	0
Auklets	0	3	0	0	0	7	4
Other Alcid	0	0	105	0	0	0	0
Other	0	0	136	0	0	0	0
Unidentified	522	541	696	240	306	285	267
Grand Total	10540	7243	11325	4894	9324	5005	4740

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

Factors influencing observed trends: The marked decline in overall numbers of birds caught after 2002 (Figure 45) 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 6).

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

Marine Mammals

The Marine Mammal Protection Act requires stock assessment reports to be reviewed annually for stocks designated as strategic, annually for stocks where there are significant new information available, and at least once every 3 years for all other stocks. Each stock assessment includes, when available, a description of the stock's geographic range, a minimum population estimate, current population trends, current and maximum net productivity rates, optimum sustainable population levels and allowable removal levels, and estimates of annual human-caused mortality and serious injury through interactions with commercial fisheries and subsistence hunters. The most recent Alaska Marine Mammal stock assessment was released in May 2012 and can be downloaded at `http://www.nmfs.noaa.gov/pr/sars/region.htm`.

Steller Sea Lions

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Northern Fur Seals

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Harbor Seals

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Arctic Ice Seals: Bearded Seal, Ribbon Seal, Ringed Seal, Spotted Seal

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Bowhead Whales

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Ecosystem or Community Indicators

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

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

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

Status and trends: During 2006-2012, winter SST in each ecosystem reached low values not observed since before the 1976/77 Pacific Decadal Oscillation (PDO) shift (Figure 46). PC1 scores showed a transition to negative values in the Bering Sea around 2009 (Figure 47, $p < 0.0001$), and a transition to lower-magnitude positive values in the Gulf of Alaska around 2006 (Figure 48, $p = 0.03$). No persistent changes were observed during the last two decades in Bering Sea PC2-3. For a summary of the individual time series associated with PC scores, see Figures 47 and 48.

Factors influencing observed trends: Variability in PC1 (and possibly subsequent axes) appears to be related to climate variability and climate change (Hare and Mantua, 2000; **?**). Recent PC1 scores in both ecosystems show a linear relationship with winter SST (Figure 49). However, the community response to SST variability since the onset of cold temperatures around 2006 has been of a smaller magnitude than the non-linear response observed across the 1976/77 PDO shift. In other words, SST-PC1 relationships appear to follow time-dependent functions in both ecosystems (Figure 49). **Implications:** Enough years of observation are now available following the onset of

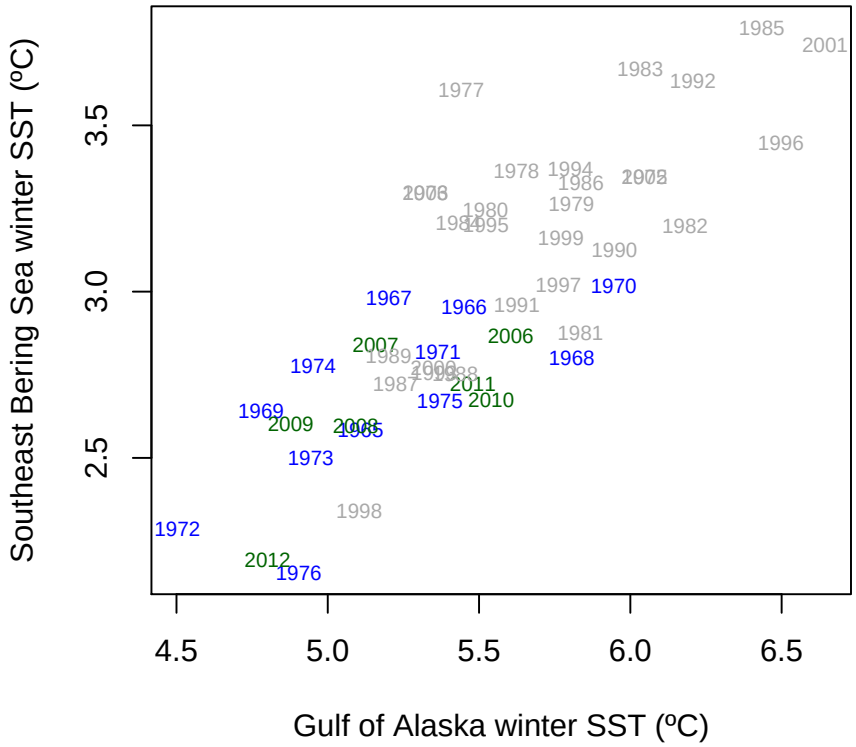

Figure 46: Winter (NDJFM) SST for the Gulf of Alaska and southeastern Bering Sea, 1965-2012. Recent years (2006-2012, green) and years prior to the 1976/77 PDO shift (1965-1976, blue) are highlighted for comparison.

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

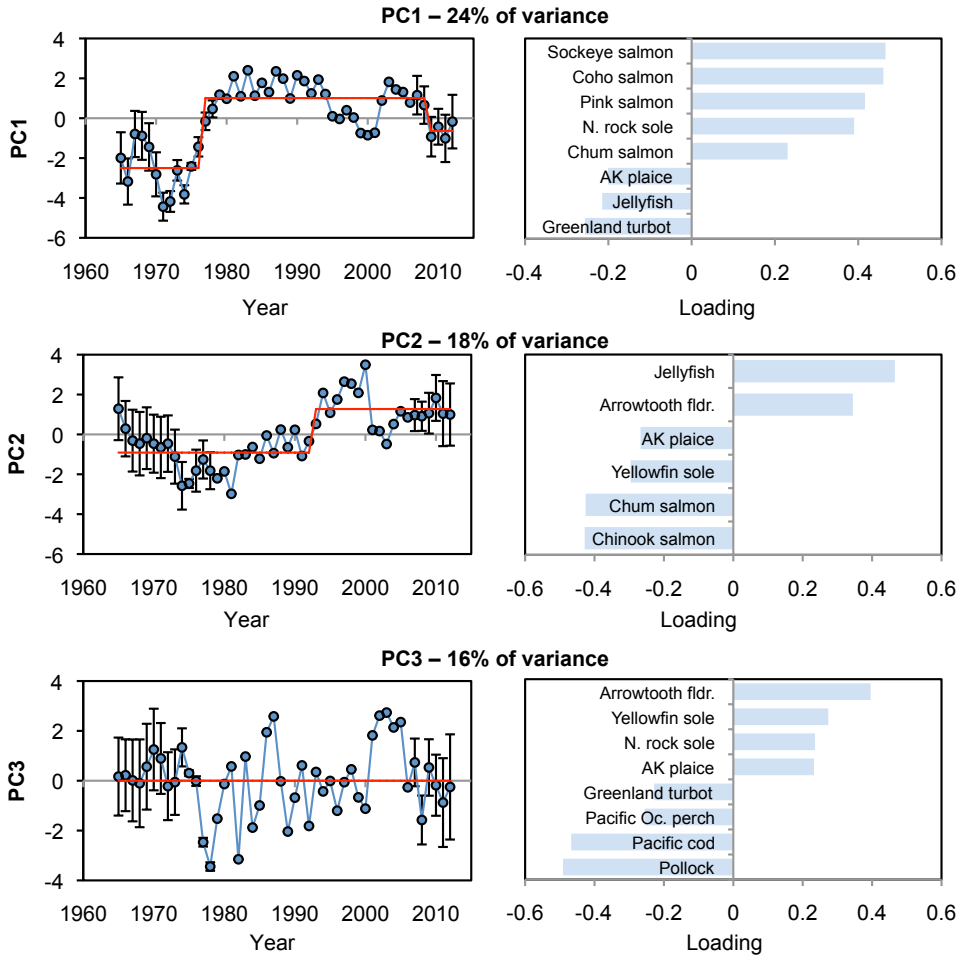

Figure 47: Time series and loadings for PC1-3 in southeast Bering Sea biological time series. Dots in left-hand panels indicate annual values, with error bars = 95% CI, reflecting uncertainty associated with estimating missing values. Red lines indicate mean values of regimes defined by STARS. Bars in right-hand columns indicate loadings for taxa most strongly associated with each PC (absolute values > 0.2).

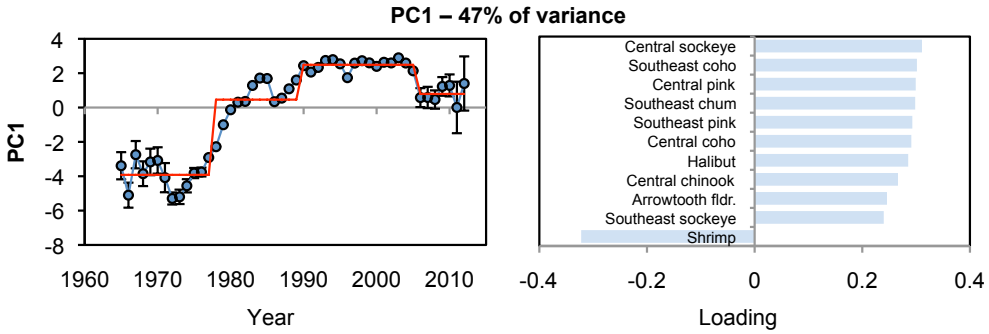

Figure 48: Time series and loadings for PC1 in Gulf of Alaska biological time series. Dots in left-hand panels indicate annual values, with error bars = 95% CI, reflecting uncertainty associated with estimating missing values. Red line indicates mean values of regimes defined by STARS. Bars in right-hand columns indicate loadings for taxa most strongly associated with PC1 (absolute values > 0.2).

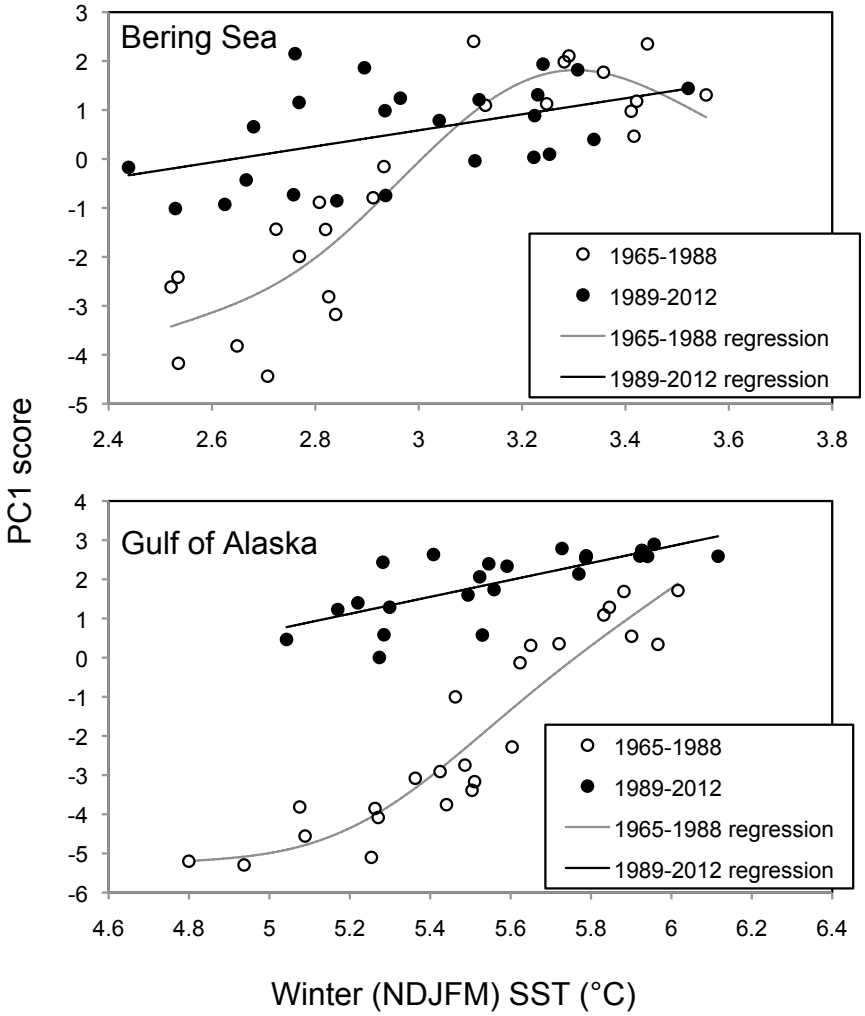

Figure 49: Time-dependent climate-biology relationships in the Bering Sea and Gulf of Alaska: SST-PC1 relationships before and after 1988/89 climate shift (Hare and Mantua, 2000). Regressions are best non-parametric models, with smoothing limited to ? 3 effective degrees of freedom. SST values are 3-yr running means.

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

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

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

Average Local Species Richness and Diversity of the Groundfish Community

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Last updated: October 2012

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Combined Standardized Indices of Recruitment and Survival Rate

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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

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Ecosystem-Based Management Indicators

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

Maintaining Diversity

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 2014

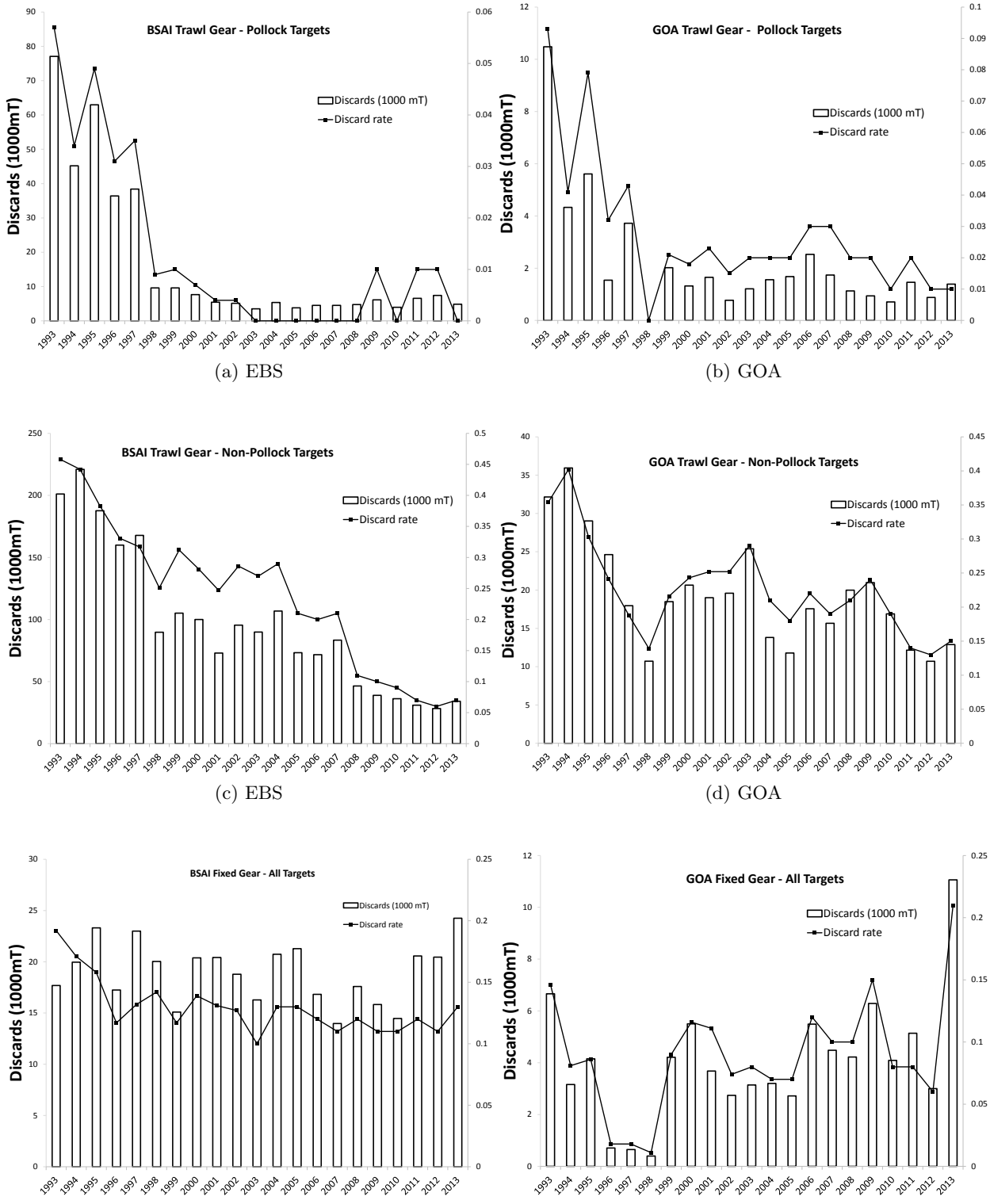
Description of index: Estimates of discards for 1994-2002 are sourced from NMFS Alaska Region's blend data, while estimates for 2003 and later come from the Alaska Region's catch-accounting system. Although these sources provide the best available estimates of discards, the estimates are not necessarily accurate because they are based on visual observations by observers rather than data from direct sampling.

Status and trends: Since 1993, discard rates of managed groundfish species in federally-managed Alaskan groundfish fisheries have generally declined in the trawl pollock fisheries in both the Bering Sea/Aleutian Islands (BSAI) and the Gulf of Alaska (GOA), as well as in the BSAI non-pollock trawl sector (Figure 50). In the GOA non-pollock trawl sector, discard rates dropped from 40% in 1994 to less than 15% in 1998, trended upwards from 1998 to 2003, and have generally declined

over the last ten years. Discard rates in the BSAI fixed gear sector fell from around 20% in 1993 to 12% in 1996, and since then have generally fluctuated between 10% and 14%. Rates in the GOA fixed gear sector over the last 20 years have varied from a high of 21% in 2013 to a low of 1% in 1998.

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

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



(a) EBS (b) GOA

(c) EBS (d) GOA

(e) EBS (f) GOA

Figure 50: Total biomass and percent of total catch biomass of managed groundfish discarded in the BSAI and GOA fixed gear, pollock trawl, and non-pollock trawl sectors, 1993-2013. (Includes only catch counted against federal TACS)

Time Trends in Non-Target Species Catch

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Last updated: August 2014

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

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

Total catch of non-target species is estimated from observer species composition samples taken at sea during fishing operations, scaled up to reflect the total catch by both observed and unobserved hauls and vessels operating in all FMP areas. Catch since 2003 has been estimated using the Alaska Region's Catch Accounting System. This sampling and estimation process does result in uncertainty in catches, which is greater when observer coverage is lower and for species encountered rarely in the catch.

Status and trends: The catch of all three non-target species groups has been highest in the EBS (Figure 51). Scyphozoan jelly catches in the GOA are two orders of magnitude lower than the EBS and three orders of magnitude lower in the AI. Catches of HAPC biota are intermediate in the AI and lowest in the GOA. The catches of assorted invertebrates in the EBS are about twice the catch in the GOA. The catch of assorted invertebrates is lowest in the AI.

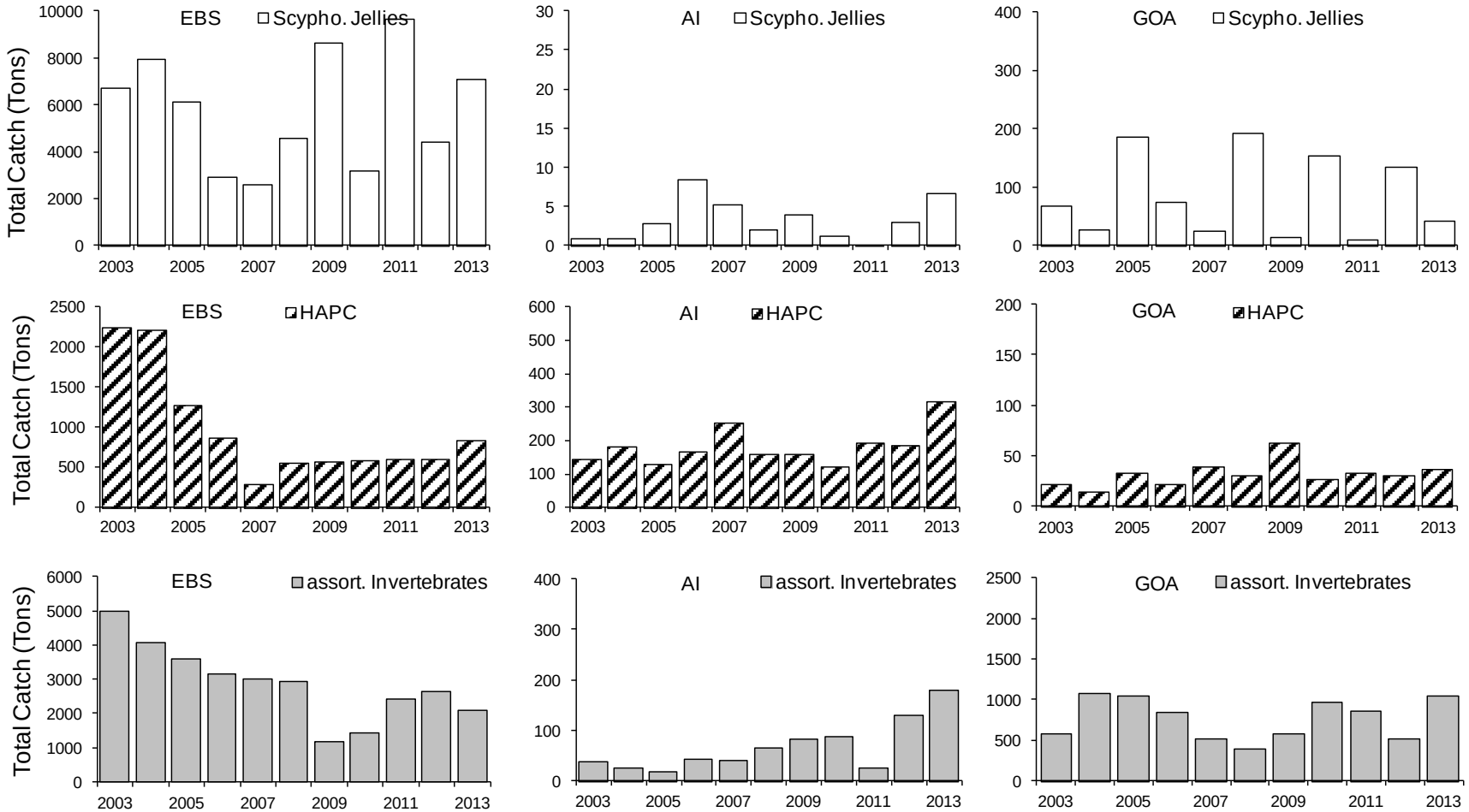

Figure 51: Total catch of non-target species (tons) in the EBS, AI, and GOA groundfish fisheries (2003-2013). **Please note the different y-axis scales** between regions and species groups.

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

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

The catch of Scyphozoan jellies in the GOA has been variable from 2003-2013. Since 2007, the catch of Scyphozoan jellies has alternated between years of low (odd years) to relatively higher catches (even years). The 2013 catch follows this pattern, and is a substantial drop from the 2012 catch, Scyphozoan 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. The catch of assorted invertebrates in 2013 was nearly double the catch in 2012, and was the third highest over the time period 2003-2013.

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

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

Maintaining and Restoring 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

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Last updated: August 2013

Description of index: Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut) (Figure 52, Table 7) 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.

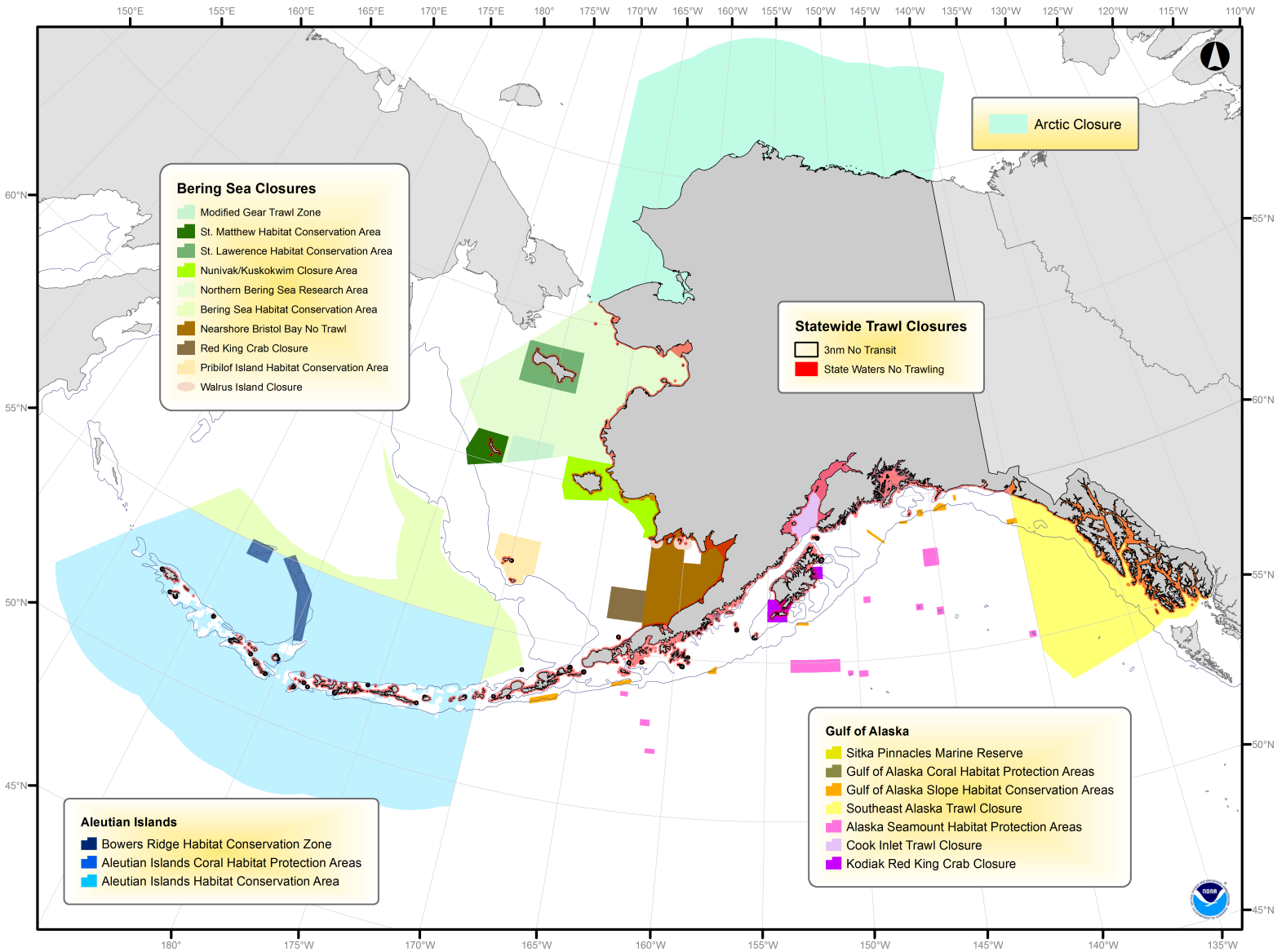

Figure 52: Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska, excluding most SSL closures.

Table 7: Groundfish trawl closure areas, 1995-2009. License Limitation Program (LLP); Habitat Conservation Area (HCA); Habitat conservation zone (HCZ).

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

Status and trends: Additional measures to protect the declining western stocks of the Steller sea lion began in 1991 with some simple restrictions based on rookery and haulout locations; in 2000 and 2001 more specific fishery restrictions were implemented. In 2001, over 90,000 nm^2 of the Exclusive Economic Zone (EEZ) of Alaska was closed to trawling year-round. Additionally, 40,000 nm^2 were closed on a seasonal basis. State waters (0-3 nmi) are also closed to bottom trawling in most areas. A motion passed the North Pacific Management Council in February 2009 which closed all waters north of the Bering Strait to commercial fishing as part of the development of an Arctic Fishery management plan. This additional closure adds 148,300 nm^2 to the area closed to bottom trawling year round.

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

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

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

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

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

Steller Sea Lion closure maps are available here:

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

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

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

Area Disturbed by Trawl Fishing Gear in the Eastern Bering Sea

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Last updated: June 2014

Description of index: Fishing gear can affect habitat used by a fish species for the processes of spawning, breeding, feeding, or growth to maturity. An estimate of the area of seafloor disturbed by trawl gear may provide an index of habitat disturbance. The area disturbed in the Eastern Bering Sea floor was calculated from observer trawl data each year from 1990-2013. The duration of every trawl haul was multiplied by a fishing effort adjustment as outlined in Appendix B of the January 2005 EFH EIS (`http://www.fakr.noaa.gov/habitat/seis/efheis.htm`). Table B.2-4 in the EIS document lists the adjustment factor for each gear type and vessel class. The adjustment converted trawl haul duration to area disturbed based on the type of trawl gear used (pelagic or bottom) and the vessel length. The adjustment also expanded smaller vessel fishing effort, which has 30% observer coverage, to simulate 100% coverage. Records missing trawl haul duration data and short wire hauls (hauls pulled in but not immediately brought on board) were assigned the average trawl haul duration over all years of 228 minutes (no more than 5% of hauls in any given year needed this adjustment).

An upper limit of the total area potentially disturbed by trawl hauls was estimated by assuming that no trawl hauls overlapped spatially. To find the percent disturbed, it was necessary to find the total area of the Eastern Bering Sea being considered (Figure 53a). 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 53b).

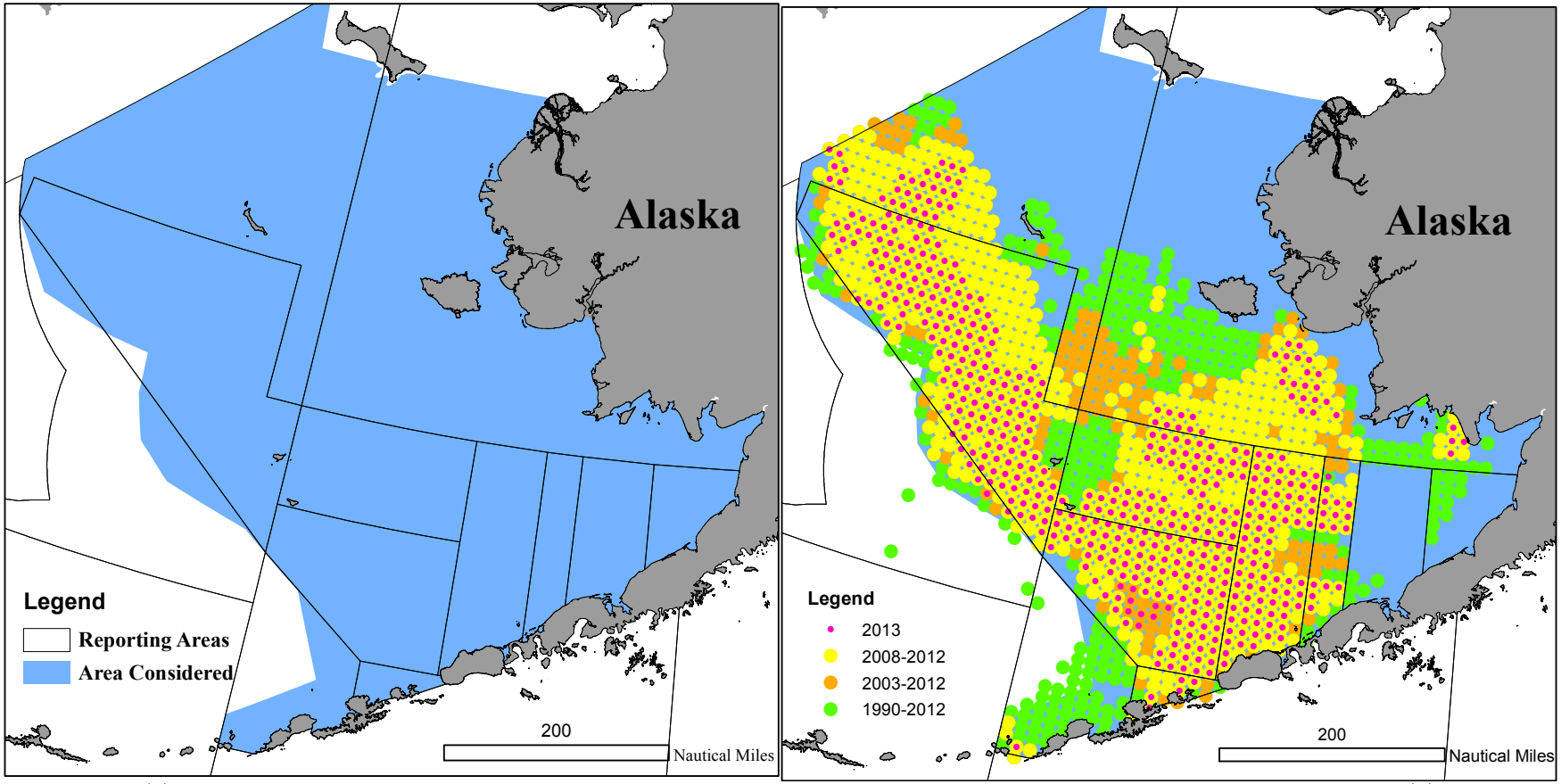

Figure 53: (a) Map of Eastern Bering Sea area considered when estimating percent area potentially disturbed by trawl fishing gear. (b) Map of 400 square kilometer cells with some trawling in cumulative time periods. Cells with fewer than 3 vessels are not shown

Status and Trends: The maximum total area of seafloor in the Eastern Bering Sea potentially disturbed by trawls in 2013 was 94,975 km^2. This estimate varied around 120,000 km^2 in the 1990s and decreased in the late 1990s to approximately 90,000 km^2. The area disturbed has remained relatively stable since then with the exception of declines in 2009 and 2010 and a sharp increase in 2011. The percent of total area disturbed varied between 12% and 20% in the 1990s and less than 15% in the 2000s, however due to trawls overlapping the same area the more realistic area disturbed was less than 10% from the mid 1990s on. The exceptions to this trend are an increase with non-pelagic gear in 2008 and an increase in pelagic gear in 2011. Reduction in the hours fished in the 2000s indicates greater fishing efficiency.

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

During 1993-1999, fishing effort was more concentrated in the southern area compared to 1990-1992 and from 2000 onward, where effort was spread out spatially, particularly towards the northwest. This may, in part, explain the larger difference between the upper and lower estimates of percent area disturbed (with no overlap and with overlap within 400 km^2 cells, respectively) during 1993-1998 relative to other years (Figure 54).

As of 1999 only pelagic trawls can be used in the Bering Sea pollock fisheries. To check to see if this affected the trends the figure was recalculated making no distinction between gears. The result showed no change to the trend. The sharp uptick in potential area disturbed in 2011 may reflect increased search time for pollock, an increase in pollock quota, and/or avoidance of salmon bycatch. Short-wiring was only identified in the database from 1995 onward, however short-wiring accounts for only 2% of the total hauls and does not explain the early 1990 trends.

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

Observed Fishing Effort in the Eastern Bering Sea

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
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Last updated: August 2014

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

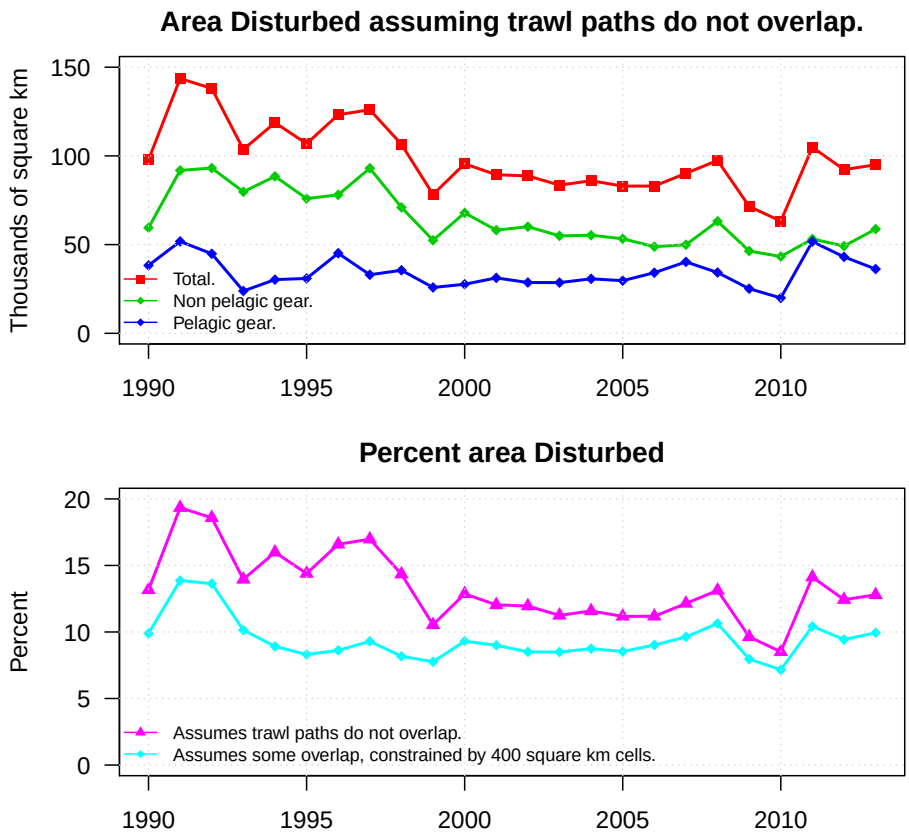

Figure 54: Total maximum potential area disturbed (assuming no spatial overlap of trawls), and the percent area disturbed. The green line, representing percent area disturbed, sums the area disturbed assuming no spatial overlap of trawl hauls in a year, thus providing an upper limit to the estimate of area disturbed. The blue line represents the percent area disturbed with spatial overlap of trawl hauls within 400 km^2 cells, thereby, limiting the disturbance of trawls recorded in a cell to 400 km^2.

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

Status and trends: Effort in the longline, pelagic trawl, non-pelagic trawl, and pot fisheries in the eastern Bering Sea is shown in Figure 55.

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

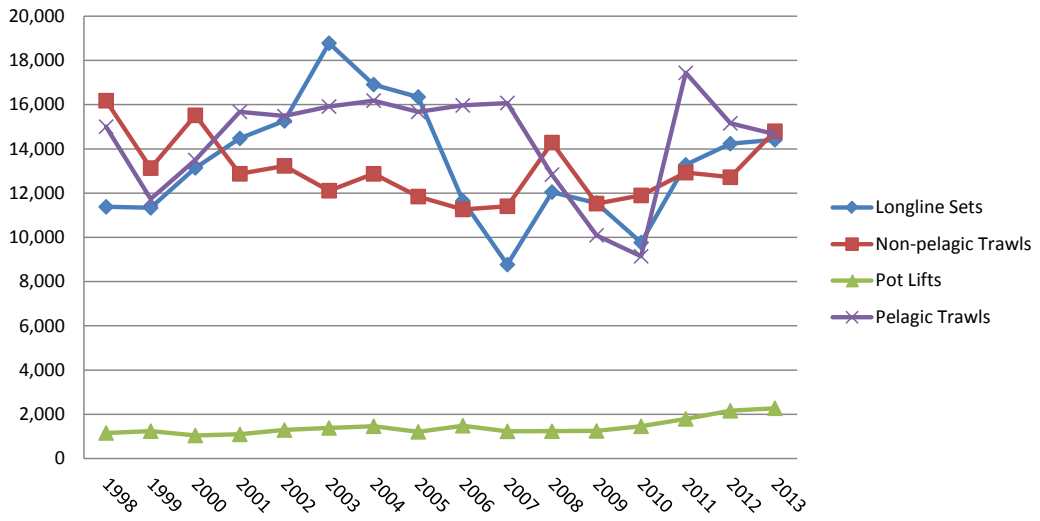

Figure 55: Bering Sea observed fishing effort, 1990-2013.

Bering Sea fisheries. Spatial patterns of fishing effort were summarized on a 10 km^2 grid (Figure 56). 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 57).

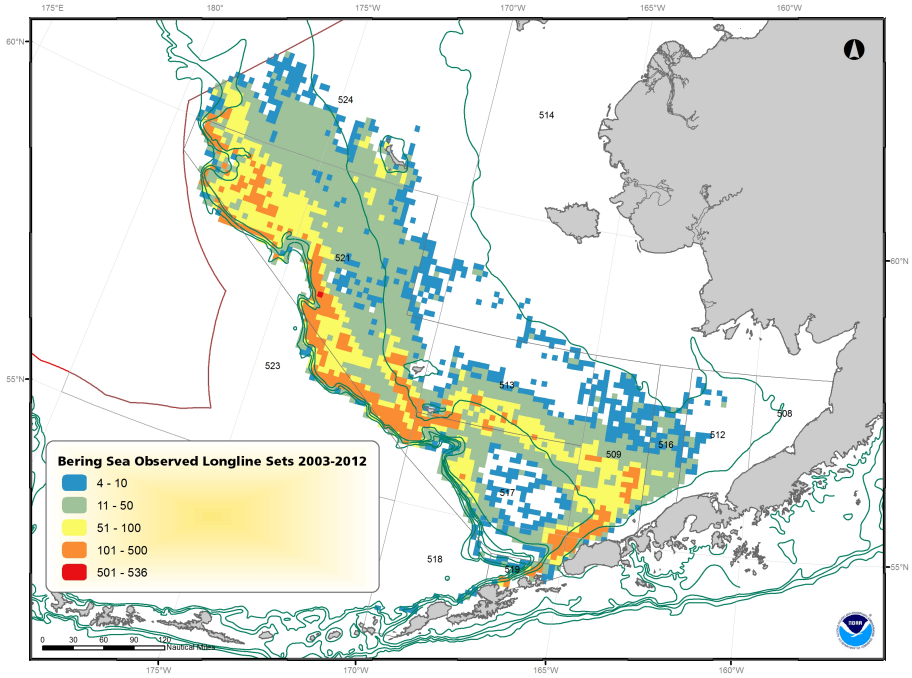

Figure 56: Observed longline effort (sets) in the Bering Sea 2003-2013.

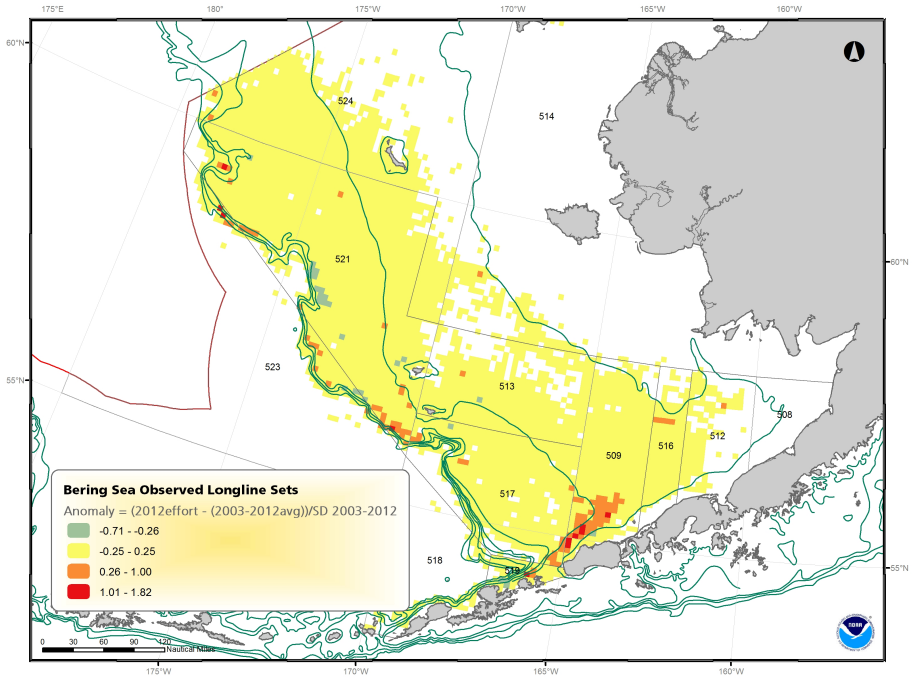

Figure 57: Observed longline fishing effort in 2011 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (observed effort for 2013 - average observed effort from 2003-2013)/stdev(effort from 2003-2013).

Pelagic trawl. For the period 2003-2012 there were 144,486 observed pelagic trawl tows in the Bering Sea (Figure 58). 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 59). Increased fishing effort also occurred to the southeast of St George Island. Some changes in fleet movement may be attributed to the AFA fishing coop structure and voluntary rolling hotspot closures to reduce the incidental take of Chinook and "Other Salmon" bycatch; whereas, other changes in fishing effort might be attributed to changes in pollock distribution.

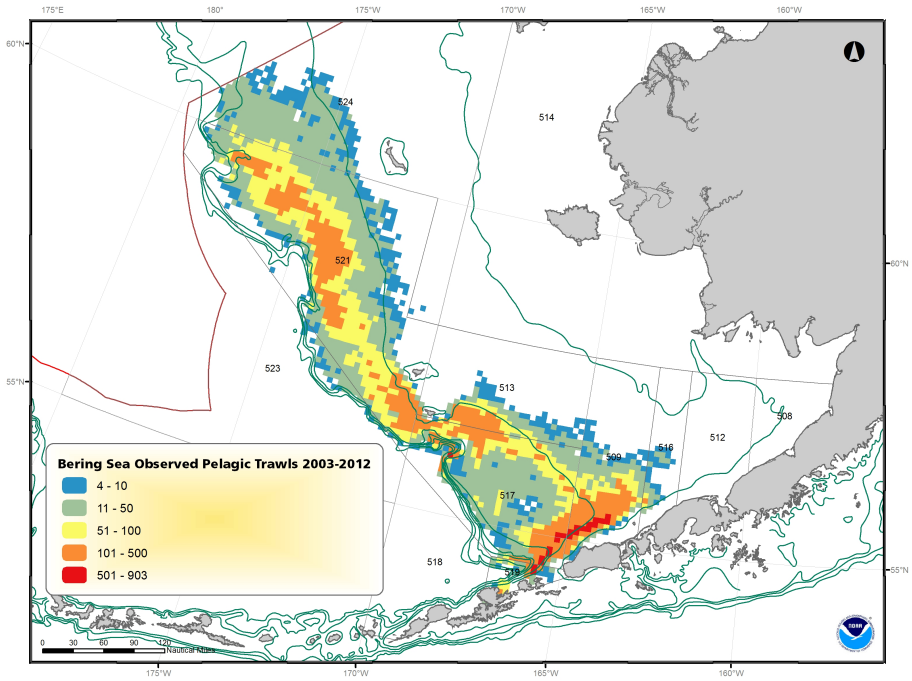

Figure 58: Spatial location and density of observed pelagic trawling in the Bering Sea 1998-2013.

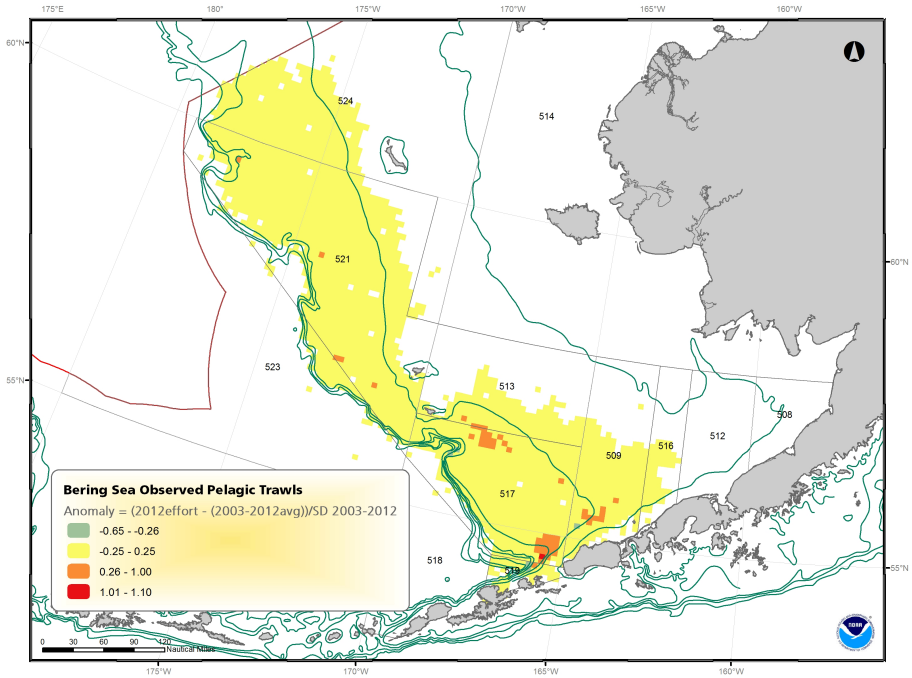

Figure 59: Observed pelagic trawl fishing effort in 2013 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (estimated effort for 2013 - average effort from 2003-2013)/stdev(effort from 2003-2013).

Non-pelagic trawl. For the period 2003-2012, there were a total of 122,948 observed bottom trawl tows in the Bering Sea fisheries. During 2012, observed bottom trawl effort consisted of 12,720 tows, which was slightly above average compared to the past 10 years. Spatial patterns of fishing effort are summarized on a 10 km2 grid (Figure 60). 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 61).

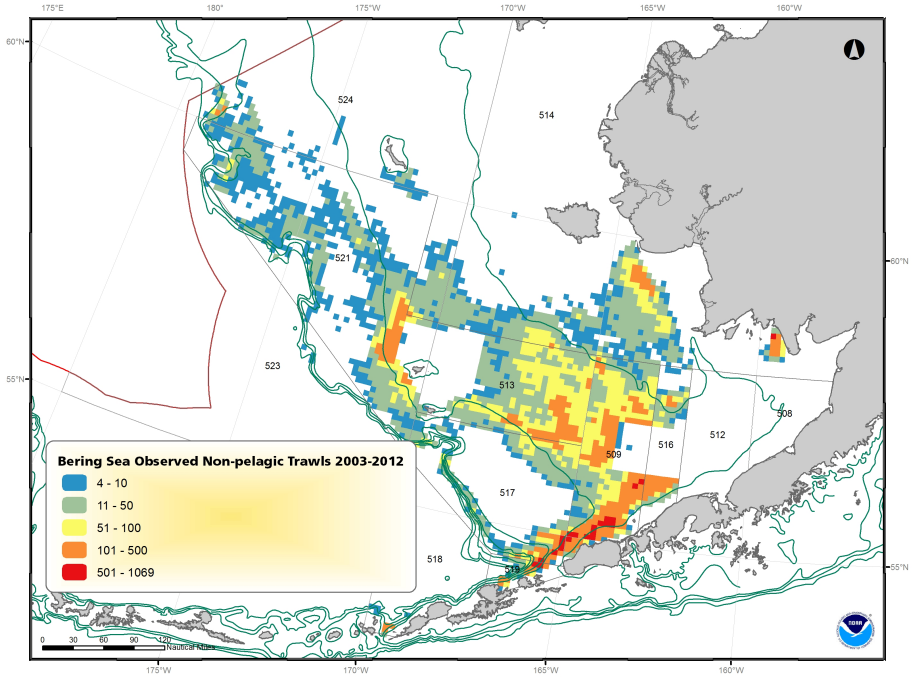

Figure 60: Spatial location and density of observed bottom trawling in the Bering Sea 1998-2013.

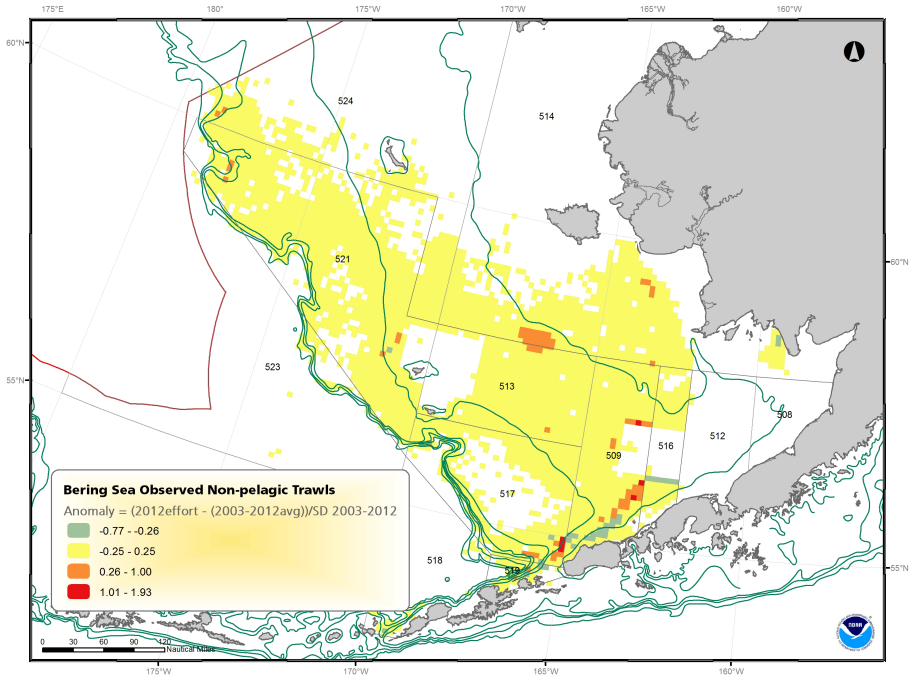

Figure 61: Observed bottom trawl fishing effort in 2013 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (estimated effort for 2013 - average effort from 2003-2013)/stdev(effort from 2003-2013).

Pot. For the period 2003-2012, there were a total of 14,653 observed pot lifts in the Bering Sea fisheries. During 2012, the amount of observed pot effort was 2,158 lifts, which was higher than the 10-year average of 1,465 and also an increase from 2011. Spatial patterns of fishing effort were summarized on a 10 km2 grid (Figure 62). 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 63). Spatial and temporal changes to the fishery may have occurred in the past 10 years due to current Steller Sea Lion regulations as well as changes in Pacific cod TAC.

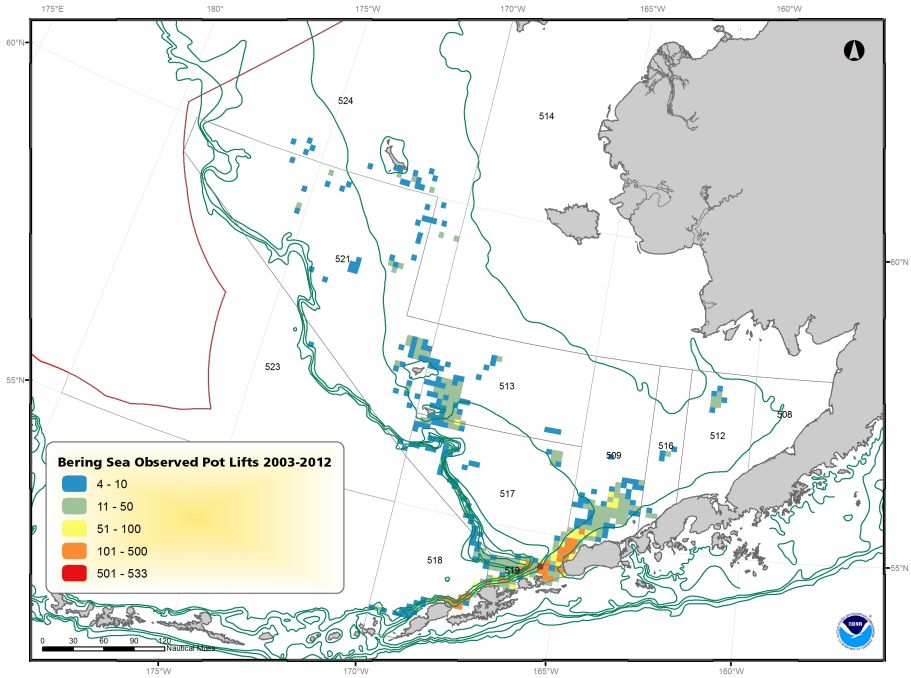

Figure 62: Spatial location and density of pot effort (observed number of pot lifts) in the Bering Sea 1998-2013.

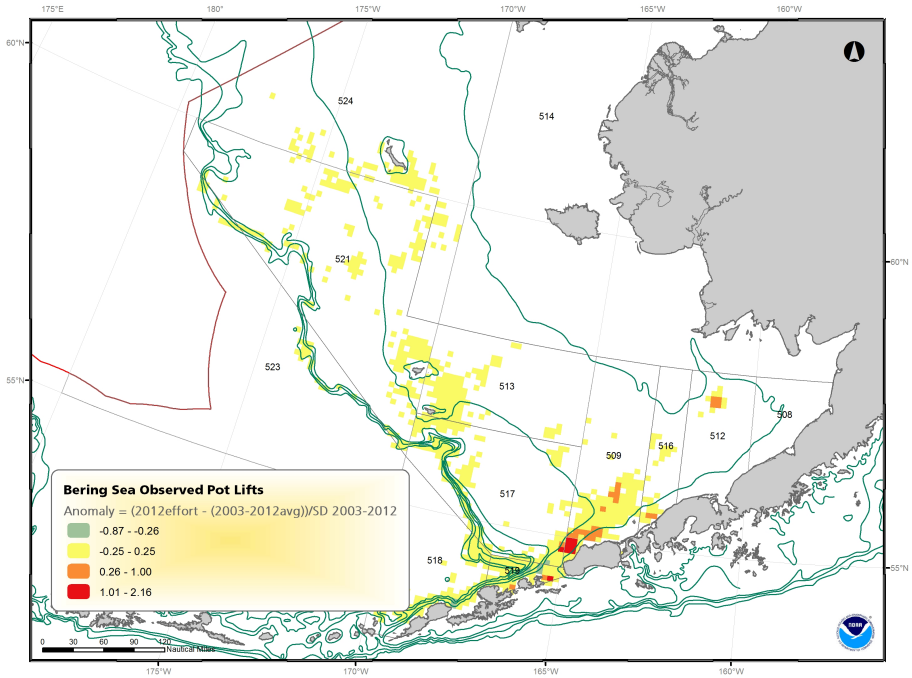

Figure 63: Observed pot fishing effort in 2012 relative to the 2003-2013 average in the Bering Sea. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2013)/stdev(effort from 2003-2013).

Factors influencing observed trends: Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures) as well as changes in markets and bycatch rates of non-target and prohibited species. Hook and line effort in the Bering Sea occurs mainly for Pacific cod, Greenland turbot, halibut and sablefish. The Bering Sea pollock fishery is the largest volume U.S. Fishery, and most pollock is harvested with pelagic trawl nets. Effort in the Bering Sea remained at a relatively stable through 2007. Effort (and TAC) declined through 2010, at which point pelagic trawl effort again increased near the long-term average in 2011 and 2012. Some of the consistency of effort can be attributed to changes in the structure of the groundfish fisheries due to rationalization. Some of the reduction in bottom trawl effort in the Bering Sea after 1997 can be attributed to changes in the structure of the groundfish fisheries due to rationalization. As of 1999, only pelagic trawls can be used in the Bering Sea pollock fisheries. Fluctuations in bottom trawl effort track well with overall landings of primary bottom trawl target species, such as flatfish and to a lesser extent cod and pollock.

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

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

Implications: The effects of changes in fishing effort on habitat are largely unknown. It is possible that increases in hook and line and pot fisheries could result in increased habitat loss/degradation due to fishing gear effects on benthic habitat and other species have the opposite effect. The footprint of habitat damage likely varies with gear (type, weight, towing speed, depth of penetration), the physical and biological characteristics of the areas fished, recovery rates of living substrates in the areas fished, and management changes that result in spatial redistribution of fishing effort (NMFS, 2007)(`http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm`). The pot fishery occurs mainly for Pacific cod which form dense spawning aggregations in the winter months. In the Bering Sea, fluctuations in the pot cod fishery may be dependent on the duration and timing of crab fisheries. There is also a state-managed fishery in State waters.

Observed Fishing Effort in the Aleutian Islands

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

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

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

interact with benthic habitat include the pot. The fishery is prosecuted with catcher vessels.

Status and trends: Effort in the longline, pelagic trawl, non-pelagic trawl, and pot fisheries in the Aleutian Islands is shown in Figure 64. 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 **??**). 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.

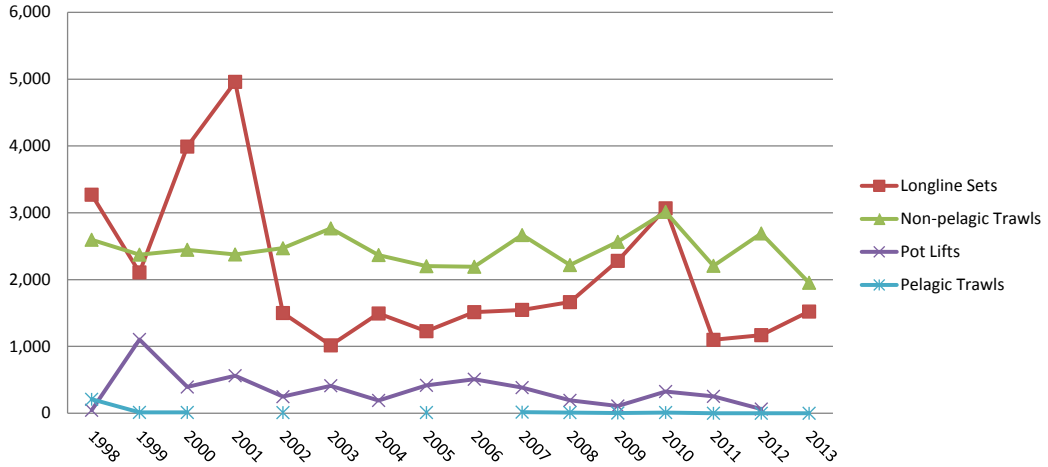

Figure 64: Aleutian Islands observed fishing effort 1990-2013.

Longline. For the period 2003-2012 there were 16,076 observed hook and line sets in the Aleutian Islands. During 2012, the amount of observed longline effort was 1,169 sets, which is significantly below the 10-year average an increase over 2011. The spatial pattern of this effort was dispersed over a wide area. Patterns of high fishing effort were dispersed along the shelf edge (Figure 65). 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 66).

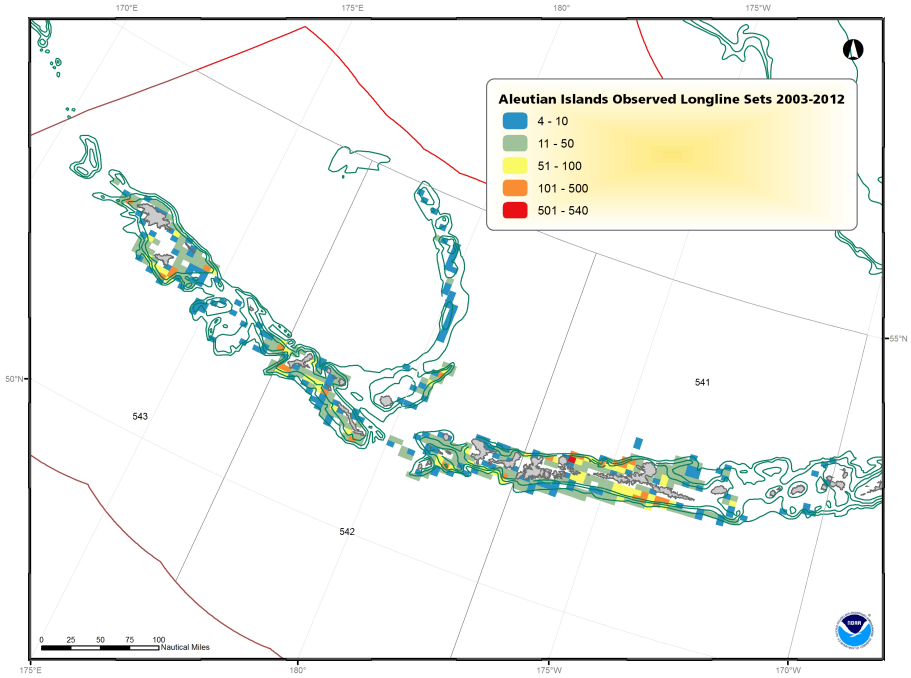

Figure 65: Observed longline effort (sets) in the Aleutian Islands, 2003-2013.

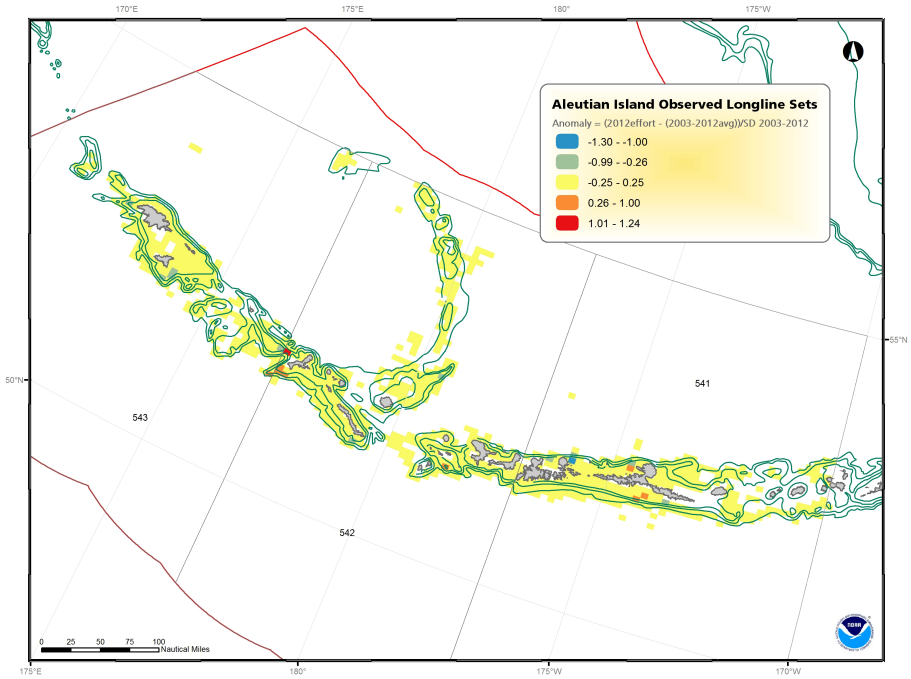

Figure 66: Observed longline fishing effort in 2011 relative to the 2003-2013 average in the Aleutian Islands. Anomalies calculated as (observed effort for 2013 - average observed effort from 2003-2013)/stdev(effort from 2003-2013).

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

Non-pelagic trawl. For the period 2003-2012 there were 24,892 observed bottom trawl tows in the Aleutian Islands. During 2012, the amount of observed bottom trawl effort was 2,691 tows, which was about average for the 10-year period. It represents an increase over 2011. Patterns of high fishing effort are Aleutian Islands, Bering Sea, and Gulf of Alaska dispersed throughout the Aleutian Islands (Figure 67). 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 68). Some areas now have lower patterns of fishing effort which could be due to the implementation of new management measures, including SSL measures in areas 542 and 543 in 2011. In 2006, the Aleutian Islands Habitat Conservation Area (AIHCA) closed approximately 279,114 nm2 to bottom trawl fishing in the three AI management areas.

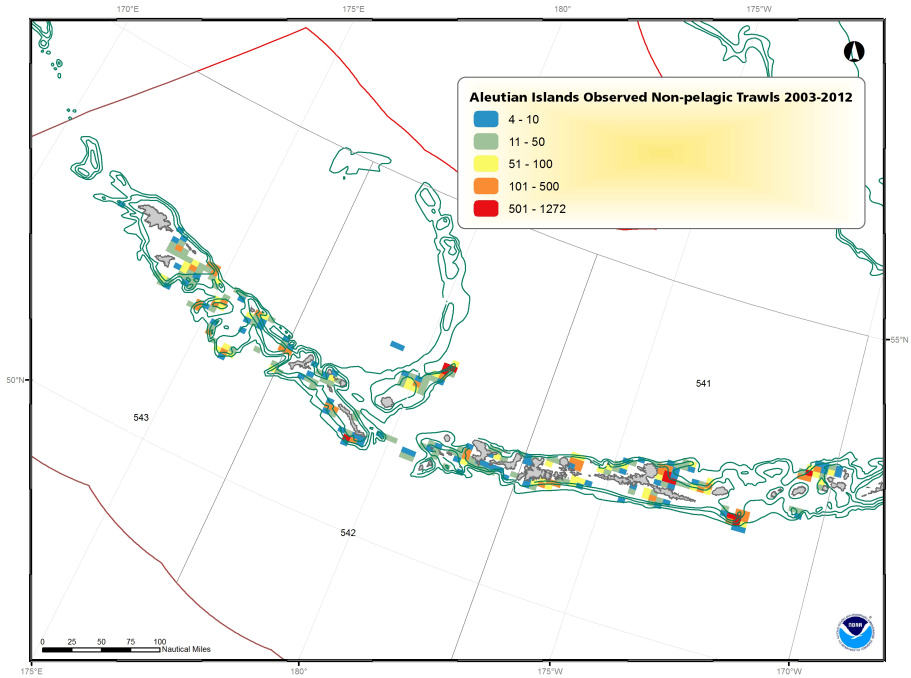

Figure 67: Spatial location and density of observed bottom trawl effort in the Aleutian Islands, 1998-2012.

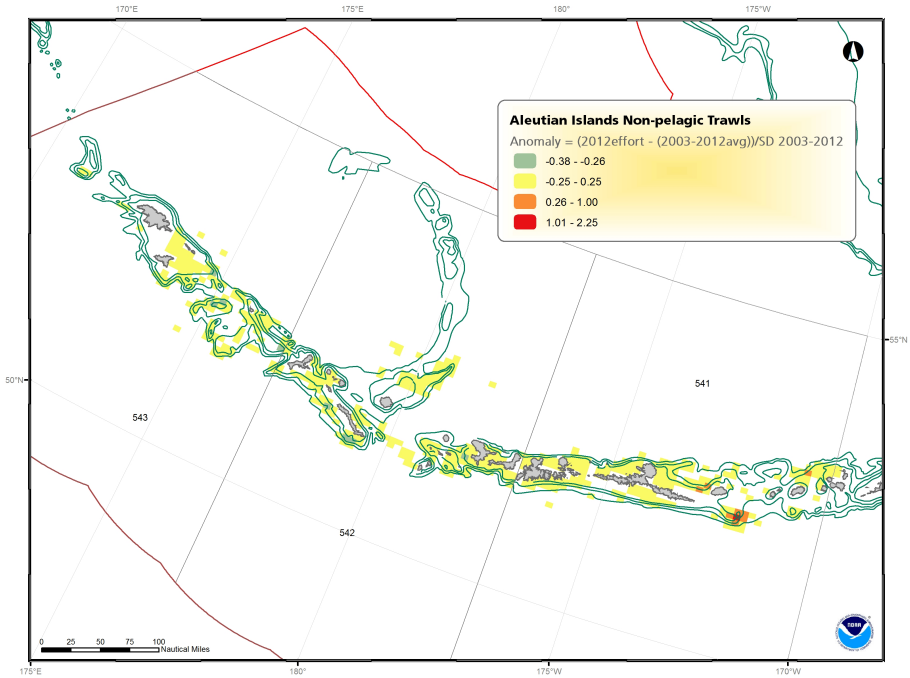

Figure 68: Observed bottom trawl fishing effort in 2012 relative to the 2003-2012 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

Pot. For the period 2003-2012 there were 2,857 observed pot lifts in the Aleutian Islands. During 2012, the amount of observed pot effort was 63 lifts, which represents a substantial decline from 2011 and is well below the 10-year average of 286. Fishing effort was dispersed along the shelf edge with high effort near Amlia and Seguam Islands (Figure 69). In 2012, the fishing anomaly throughout the region was minimal (Figure 70).

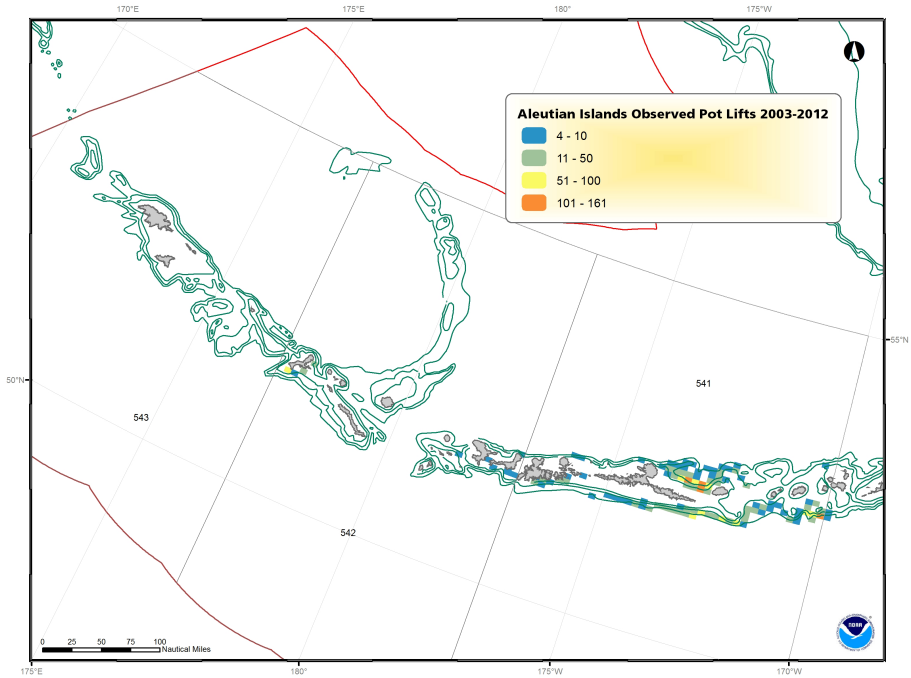

Figure 69: Spatial location and density of pot effort (observed number of pot lifts) in the Aleutian Islands, 1998-2012.

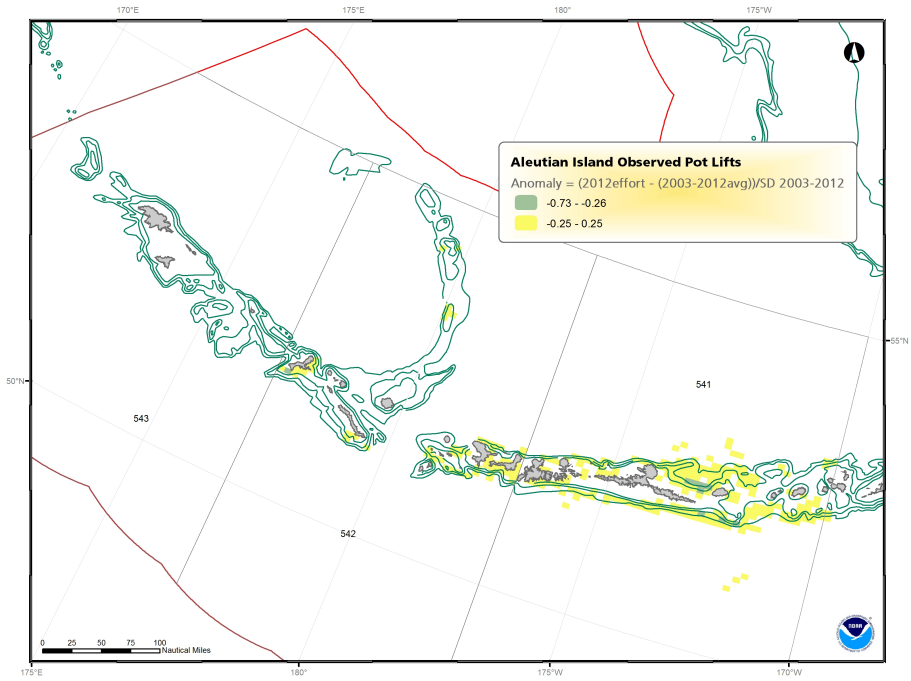

Figure 70: Observed pot fishing effort in 2012 relative to the 2003-2012 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

Factors influencing observed trends: Spatial changes in fisheries effort may in part be affected by many factors, including fishing closure areas (i.e., habitat closures, Steller sea lion protection measures) as well as changes in markets, environmental conditions, and/or increased bycatch rates of non-target species. Hook and line effort in the Aleutian Islands occurs mainly for Pacific cod, Greenland turbot, halibut and sablefish. Effort in the AI has trended downward in the last decade, in part due to restricted fishing from Steller sea lion protection measures.

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

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

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

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

Observed Fishing Effort in the Gulf of Alaska

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Last updated: August 2014

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

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

Status and trends: Effort in the longline, pelagic trawl, non-pelagic trawl, and pot fisheries in the Gulf of Alaska is shown in Figure 71.Effort in the pelagic trawl fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure **??**. 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 59, 59, and 75 show the spatial patterns and intensity of pelagic trawl effort by region, based on observed data.

Longline. For the period 2003-2012 there were 24,754 observed hook and line sets in the Gulf of Alaska. During 2012, the amount of observed longline effort was 2,109 sets, which is below the 10-year average. Patterns of high fishing effort were dispersed along the shelf in all management areas (Figure 72). 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

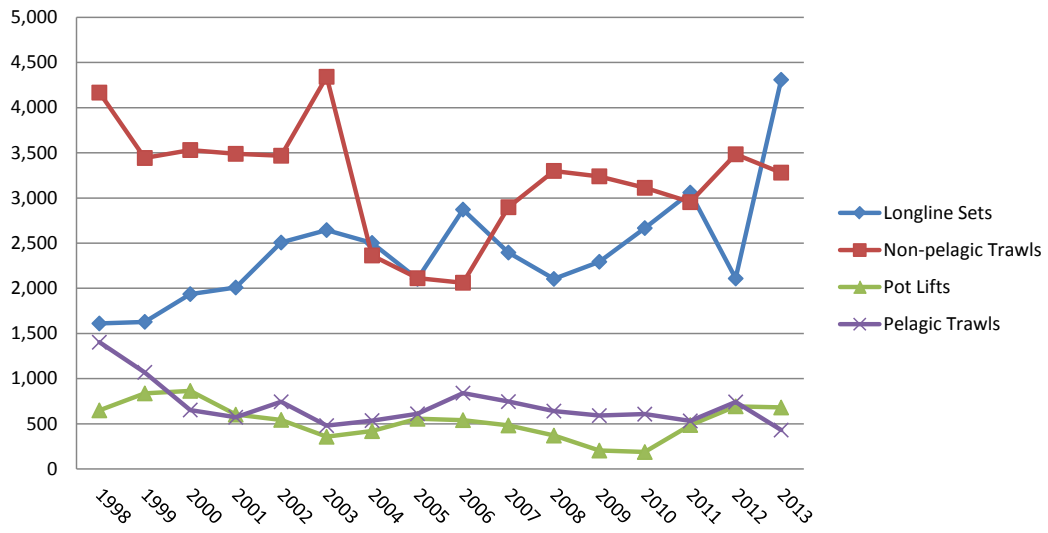

Figure 71: Gulf of Alaska observed fishing effort, 1990-2013.

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 73).

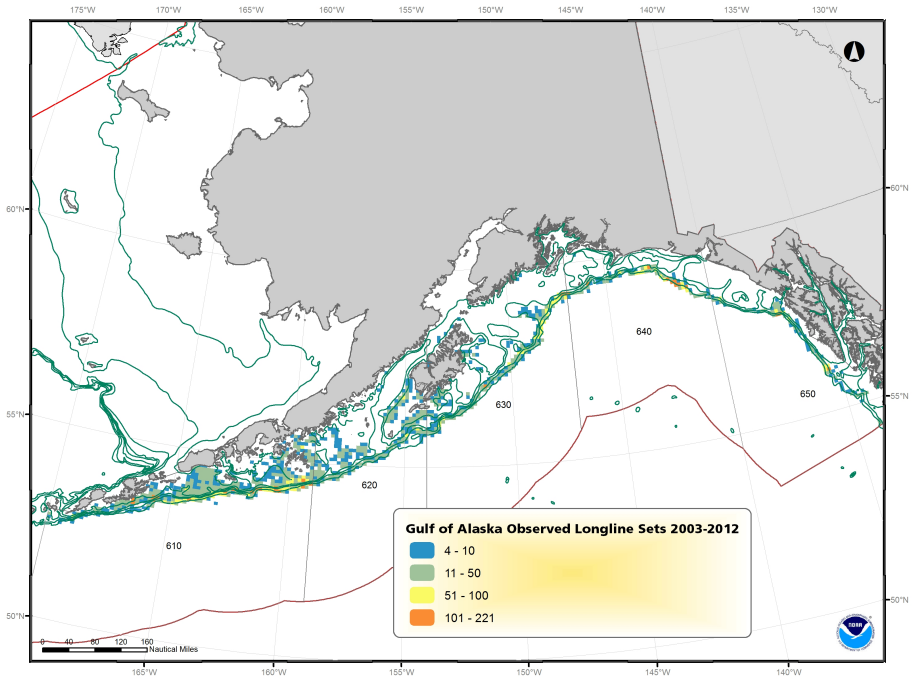

Figure 72: Observed longline effort (sets) in the Gulf of Alaska, 2003-2012.

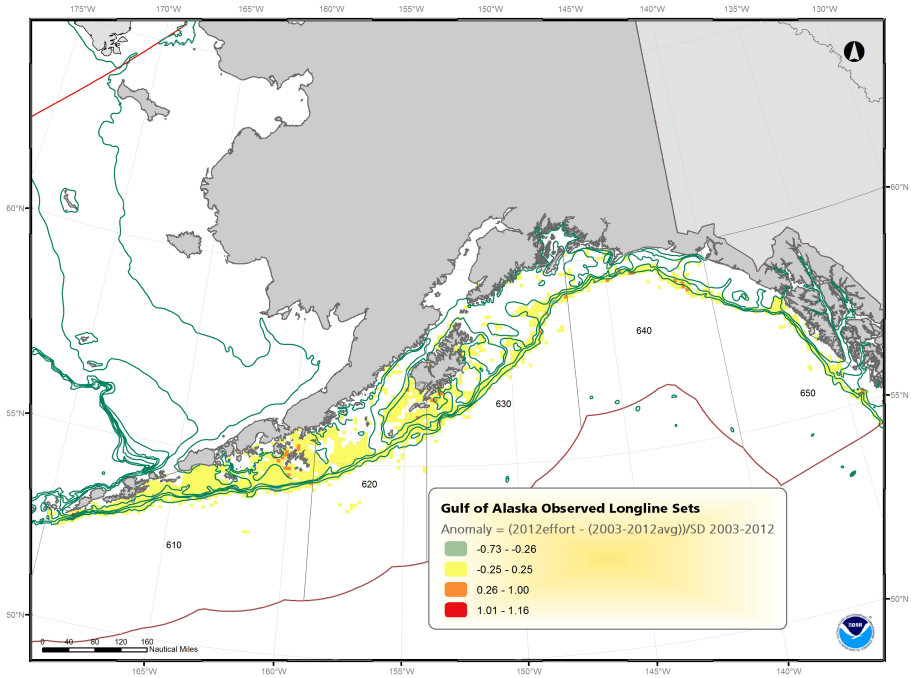

Figure 73: Observed longline fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

Pelagic trawl. The primary target of the GOA pelagic trawl fishery is pollock (Figure 74). 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 75).

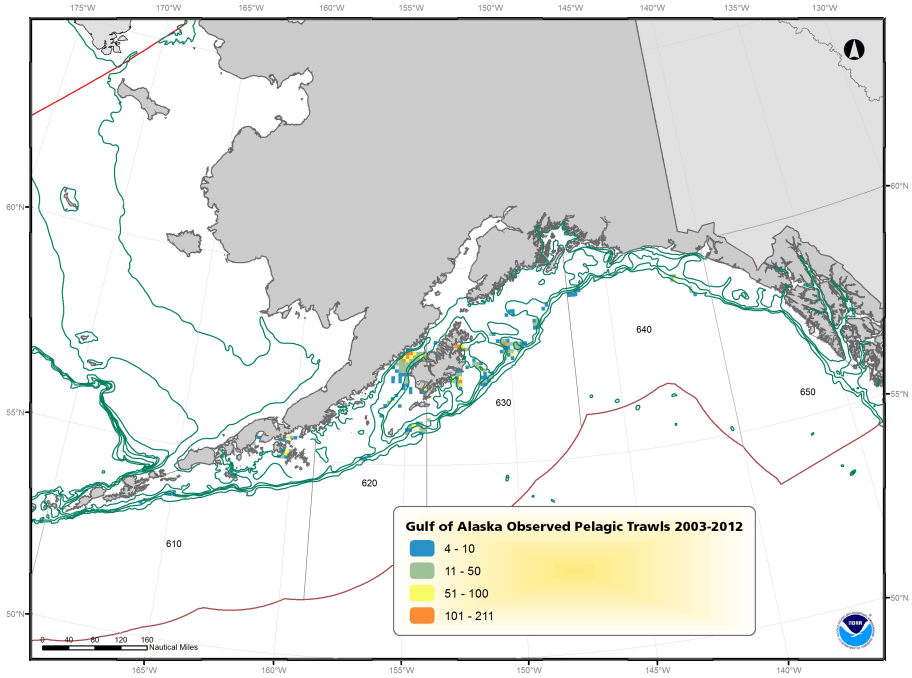

Figure 74: Spatial location and density of observed pelagic trawl effort in the Gulf of Alaska, 1998-2012.

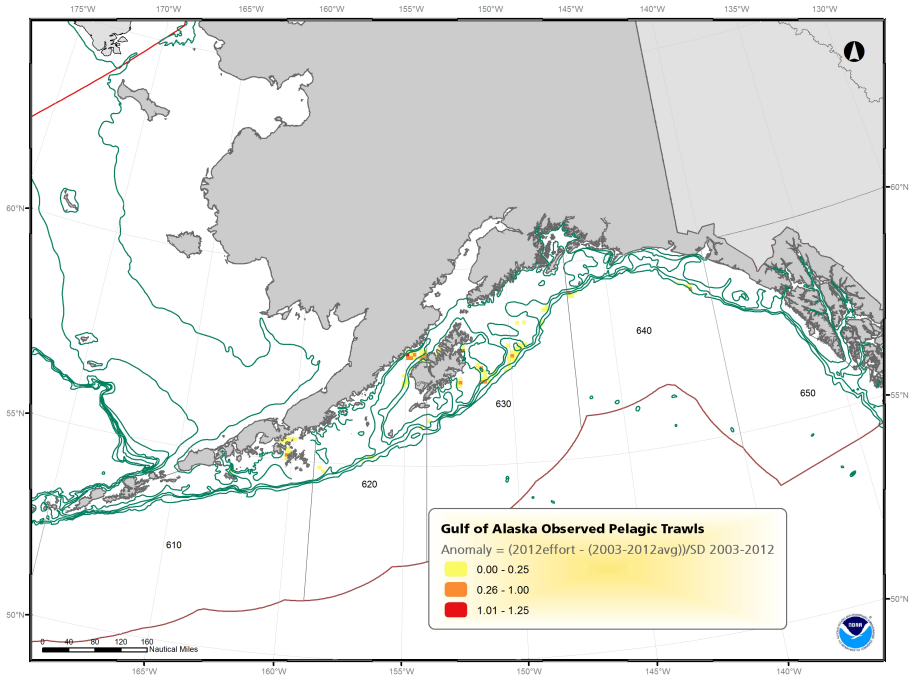

Figure 75: Observed pelagic trawl fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

Non-pelagic trawl. For the period 2003-2012 there were 29,869 observed bottom trawl tows in the Gulf of Alaska. The spatial pattern of this effort was much more dispersed than in the Bering Sea region. During 2012, the amount of trawl effort was 3,484 tows, which was an increase over 2011 and also above the average for the 10-year period. For 2012, fishing effort did not display any distinct patterns of anomaly; rather, small areas of small increases were evident over arease 620 and 630. Patterns of high fishing effort were dispersed along the shelf edge with high pockets of effort near Chirkoff, Cape Barnabus, Cape Chiniak and Marmot Flats (Figure 76). 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 77).

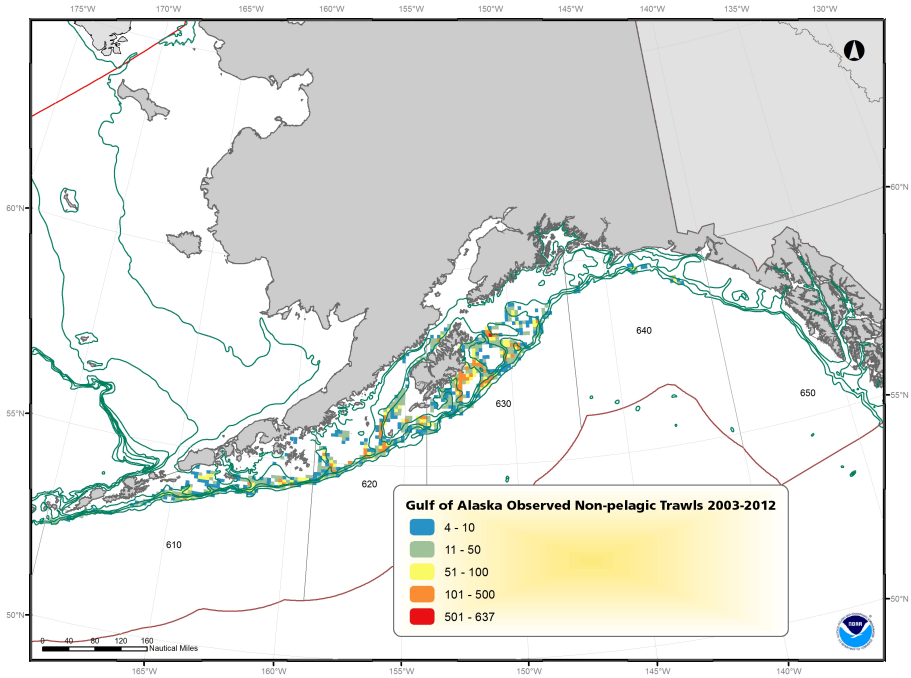

Figure 76: Spatial location and density of observed bottom trawl effort in the Gulf of Alaska, 1998-2012.

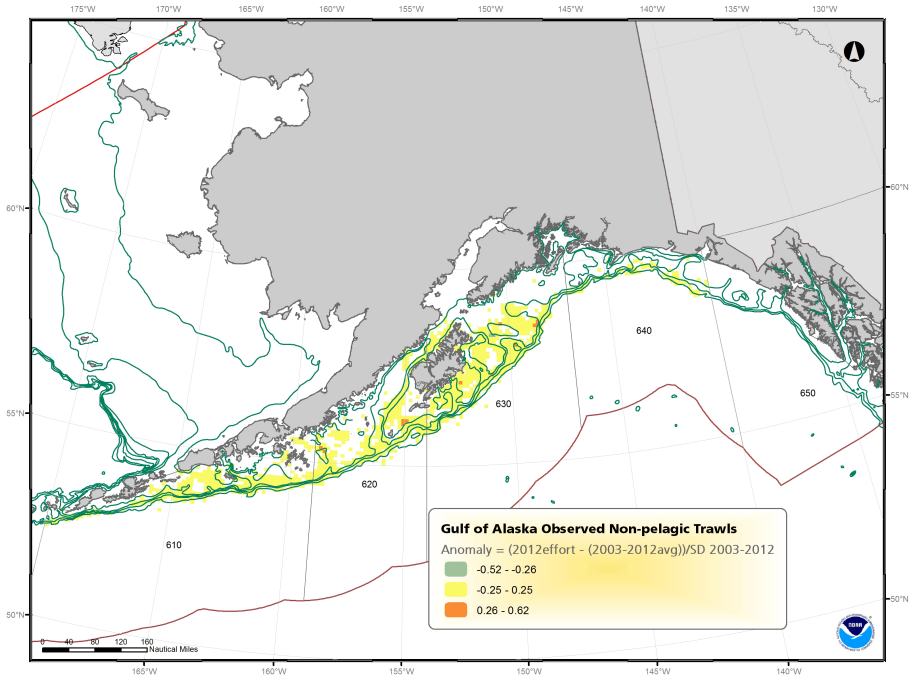

Figure 77: Observed bottom trawl fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

Pot. For the period 2003-2012 there were 4,298 observed pot lifts in the Gulf of Alaska. During 2012, the amount of observed pot effort was 694 lifts, which represents an increase from 2011 and is above the 10-year average of 430. Patterns of higher fishing effort were dispersed along the shelf to the east of Kodiak Island (Figure 78). 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 79). Approximately 100 boats participate in this fishery. There is also a state-managed fishery in state waters. Vessels used in the inshore fishery are all catcher vessels of small (less than 60-foot LOA) and medium size (60- to 125-foot LOA). The offshore fishery includes some catcher-processors ranging from 90 to over 125 feet. The A season fishery begins on January 1st and concludes in early March. The B season fishery opens September 1 and can be expected to last 6 weeks or less. There is also a state-managed fishery in state waters.

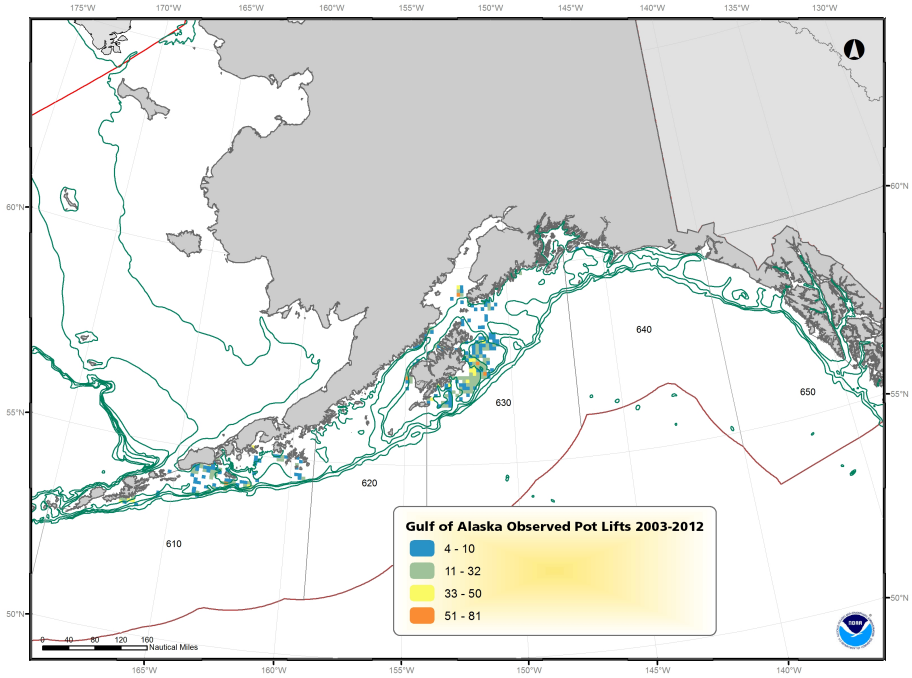

Figure 78: Spatial location and density of pot effort (observed number of pot lifts) in the Gulf of Alaska, 1998-2012.

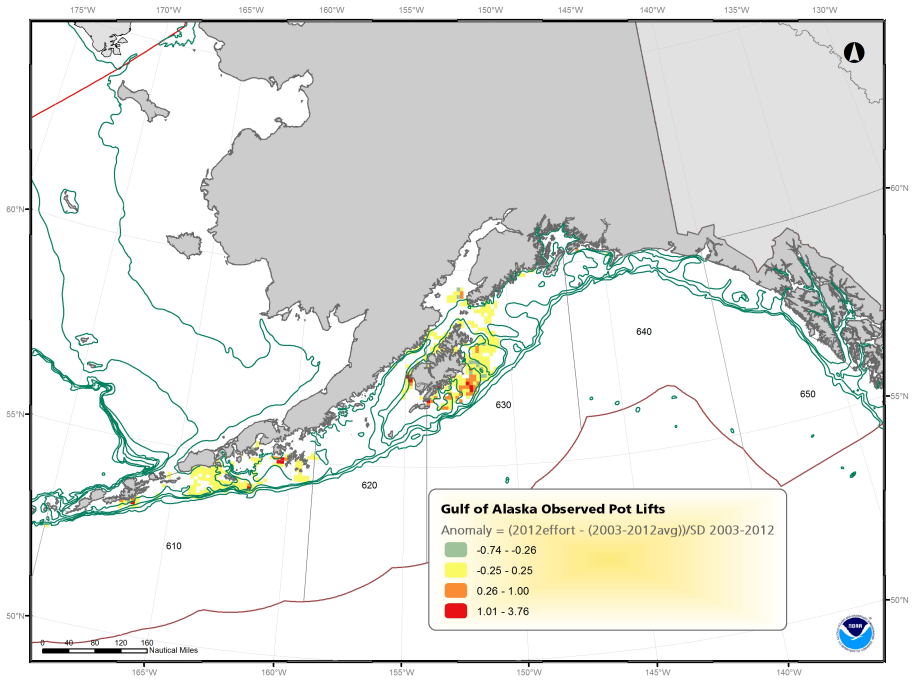

Figure 79: Observed pot fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

Factors causing observed trends: Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures), changes in markets, changes in environmental conditions, and increased bycatch rates of non-target species. The predominant hook and line fisheries in the Gulf of Alaska are composed of halibut, sablefish and Pacific cod. In southeast Alaska, there is a demersal rockfish fishery dominant species include yelloweye rockfish (90%), with lesser catches of quillback rockfish. Sablefish and halibut have been an IFQ fishery since 1995, which has reduced the number of vessels, crowding, gear conflicts and gear loss, and increased efficiency. Effort in the GOA has trended downward in the last decade, in part due to restricted fishing from Steller sea lion protection measures.

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

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

Sustainability (for consumptive and non-consumptive uses)

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

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

1. Stock has known status determinations:
   (a) overfishing = 0.5

Table 8: Summary of status for FSSI and non-FSSI stocks managed under federal fishery management plans off Alaska, updated through June 2014.

Jurisdiction	Stock Group	Number of Stocks	Overfishing				Overfished				Approaching Overfished Condition
			Yes	No	Unk	Undef	Yes	No	Unk	Undef	
NPFMC	FSSI	35	0	35	0	0	1	30	4	0	0
NPFMC	NonFSSI	30	0	29	1	0	0	5	25	0	0
	Total	65	0	64	1	0	1	35	29	0	0

(b) overfished = 0.5

2. Fishing mortality rate is below the "overfishing" level defined for the stock = 1.0
3. Biomass is above the "overfished" level defined for the stock = 1.0
4. Biomass is at or above 80% of the biomass that produces maximum sustainable yield (B_{MSY}) = 1.0 (this point is in addition to the point awarded for being above the "overfished" level)

The maximum score for each stock is 4. There are 227 FSSI stocks in the U.S., with a maximum possible score of 920. The FSSI previously contained 230 stocks. Two FSSI stocks from the Gulf of Mexico are no longer managed under federal fishery management plans (FMPs), and a third FSSI stock from the Gulf of Mexico is now managed as a combined Gulf of Mexico/South Atlantic stock; this has reduced the total number of FSSI stocks from 230 to 227. To provide, continuity in the FSSI, the final point score for these 3 stocks remains in the index until FY 2015 (max FSSI possible 920) (`http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/status_updates.html`).

The value of the FSSI is the sum of the individual stock scores. In the Alaska Region, there are 35 FSSI stocks and an overall FSSI of 140 would be achieved if every stock scored the maximum value, 4 (Tables 8 and 9). Additionally, there are 30 non-FSSI stocks, two ecosystem component species complexes, and Pacific halibut which are managed under an international agreement (Table 8 and 10).

Status and trends: As of June 30, 2014, no BSAI or GOA groundfish stock or stock complex is subjected to overfishing, and no BSAI or GOA groundfish stock or stock complex is considered to be overfished or to be approaching an overfished condition (Tables 8). The only crab stock considered to be overfished is the Pribilof Islands blue king crab stock, which is in year 11 of a 10-year rebuilding plan. The rebuilding plan for this stock is being revised by the NPFMC. None of the non-FSSI stocks are subject to overfishing, known to be overfished, or known to be approaching an overfished condition (Table 10).

The current overall Alaska FSSI is 124 out of a possible 140, based on updates through June 2014 (Table 9). The overall Bering Sea/Aleutian Islands score is 81 out of a possible maximum score of 92. The BSAI groundfish score is 54 (including BSAI/GOA sablefish, see Endnote-h in Box A) of a maximum possible 56, and BSAI king and tanner crabs score is 27 out of a possible 36. The

Gulf of Alaska groundfish score is 43 of a maximum possible 48 (excluding BSAI/GOA sablefish). Overall, the Alaska total FSSI score increased 1.5 points from 2013 to 2014 (Figure 80).

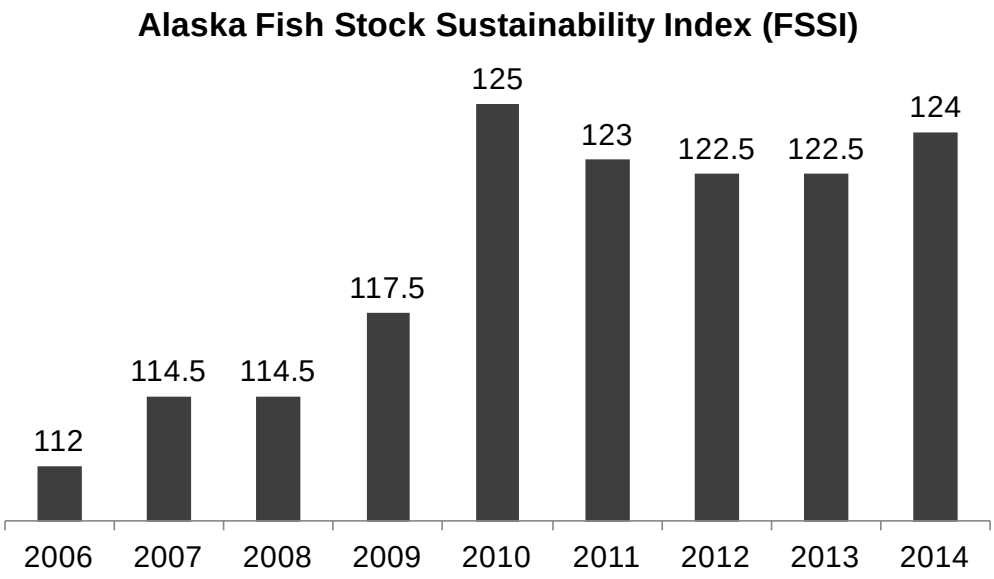

Figure 80: The trend in total Alaska FSSI from 2006 through 2014. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries`. The maximum possible FSSI score is 140 in all years.

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

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

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

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

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

Table 9: FSSI stocks under NPFMC jurisdiction updated June 2014, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`. See Box A for endnotes and definition of stocks and stock complexes.

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

Table 9: FSSI stocks under NPFMC jurisdiction updated June 2014, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`. See Box A for endnotes and definition of stocks and stock complexes. (continued)

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

Box A. Endnotes and stock complex definitions for FSSI stocks listed in Table 9, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`.

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

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

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

(d) BSAI Blackspotted and Rougheye Rockfish consists of Blackspotted Rockfish and Rougheye Rockfish. An assessment of the combined species provides the overfished determination, and the OFL is based on the combined-species assessment.

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

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

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

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

(i) GOA Blackspotted and Rougheye Rockfish consists of Blackspotted Rockfish and Rougheye Rockfish. An assessment of the combined species provides the overfished determination, and the OFL is based on the combined-species assessment.

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

(k) The Demersal Shelf Rockfish Complex consists of the following stocks: Canary Rockfish, China Rockfish, Copper Rockfish, Quillback Rockfish, Rosethorn Rockfish, Tiger Rockfish, and Yelloweye Rockfish. The overfishing determination is based on the OFL, which is computed by using estimates of Yelloweye Rockfish and then increased by 10% to account for the remaining members of the complex.

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

Table 10: Non-FSSI stocks, Ecosystem Component Species, and Stocks managed under an International Agreement updated June 2014, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`. See website for endnotes and definition of stocks and stock complexes.

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

Total Annual Surplus Production and Overall Exploitation Rate of Groundfish

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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

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Humans as part of ecosystems

Groundfish Fleet Composition

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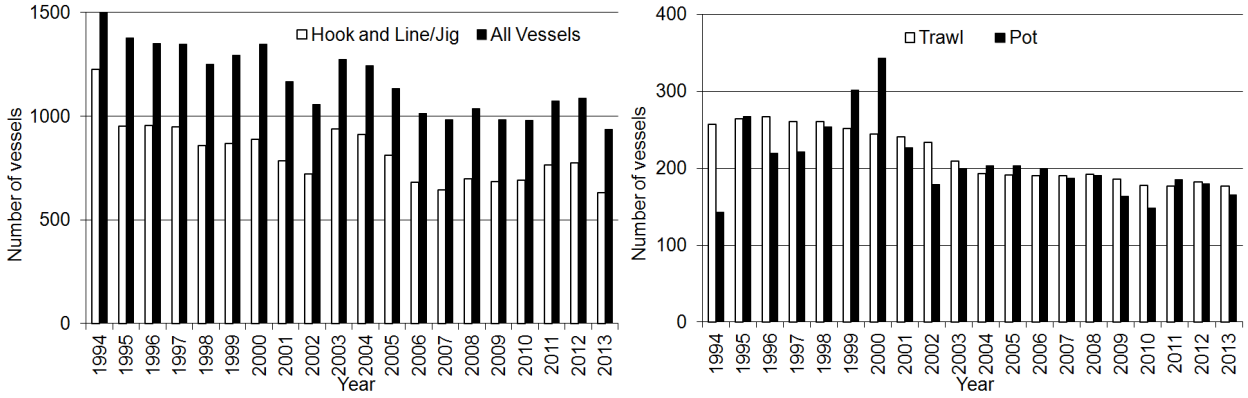
Last updated: August 2014

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

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

using pot gear peaked in 2000 at 343, and decreased to 165 in 2013.



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

Figure 81: Number of vessels participating in the groundfish fisheries off Alaska by gear type, 1994-2012.

Factors influencing observed trends: The increase in 2003 in the number of hook-and-line/jig and pot vessels (and, thus, also in the total number of vessels) results from replacement of the old blend system with the Catch-Accounting System (CAS) as the official estimates of groundfish catch. The new CAS data include the Federal Fisheries Permit numbers of catcher vessels delivering both to motherships and to shoreside processors, making possible a more complete count of participating vessels. Vessel counts before and after 2003 are not directly comparable due these changes in data source.

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

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

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Last updated: August 2013; most recent data available are from 2010

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

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

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

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