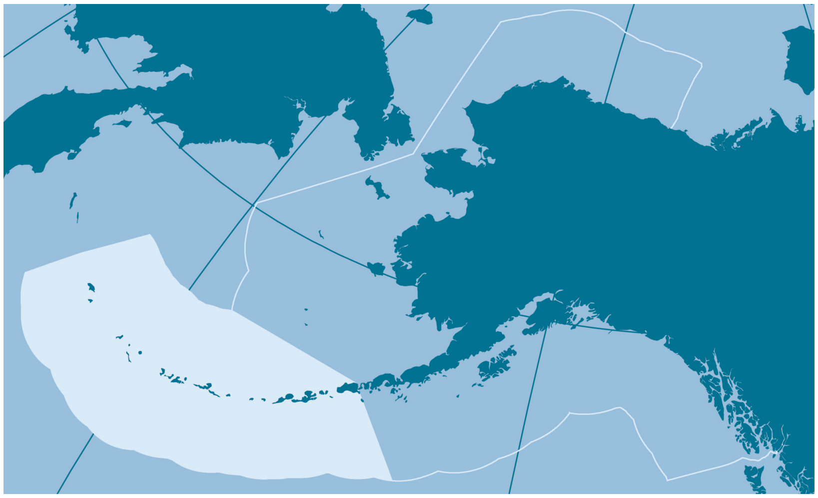
Ecosystem Considerations 2016

Status of the Aleutian Islands Marine Ecosystem



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Bering Sea, Aleutian Islands, and Gulf of Alaska

November 14, 2016
North Pacific Fishery Management Council
605 W. 4th Avenue, Suite 306
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Aleutian Islands 2016 Report Card

Region-wide

- **Biomass of pelagic forager and apex fish predator foraging guilds decreased across the region** between the 2014 and 2016 surveys, although patterns varied among species. The overall decrease **may indicate a response to the warmer water, such as poor condition or habitat shift, or reflect high variances commonly observed in estimated biomass among survey years**.
- The largest total biomass of both apex predators and pelagic foragers is located in the Central Aleutians, the region with the largest shelf area shallower than 500m. The lowest apex predator biomass is located in the Western Aleutians whereas that of pelagic foragers is found in the Eastern Aleutians.

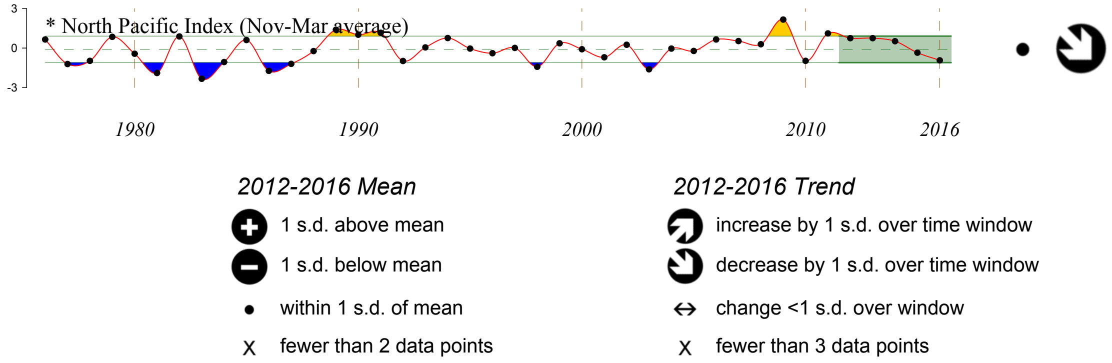

Figure 1: The winter North Pacific Index time series. * indicates time series updated in 2016.

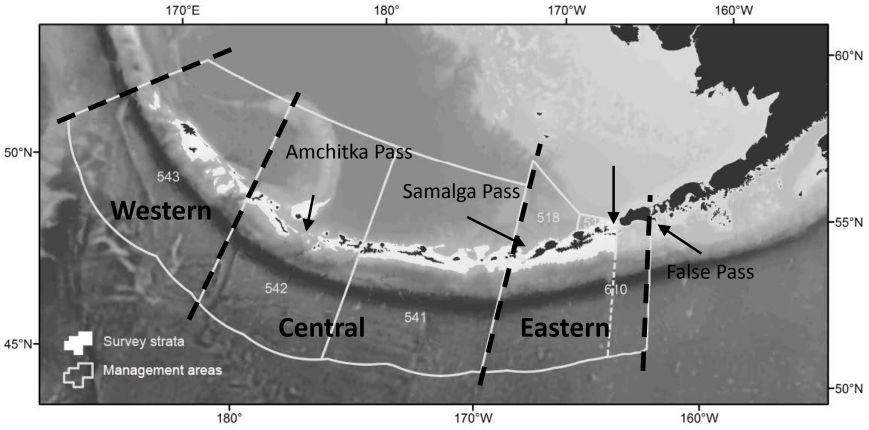

Figure 2: The Aleutian Islands ecoregions.

Western Aleutian Islands Ecoregion 2016

- The reproductive success of planktivorous least auklets increased in 2016 relative to 2015, and that of crested auklets has continued to increase from the low level seen in 2014. Crested auklets rely more on euphausiids than the copepod-specialist least auklets, thus **we can speculate that overall zooplankton availability was sufficient to support greater than average reproductive success in 2016**.
- Forage fish trends as indicated in tufted puffin chick meals have varied over the long term, with episodic peaks lasting 1-2 years. In general, sand lance have been absent since 2009, and age-0 gadids were at the long term average in 2016. The **number of hexagrammids (likely age-0 Atka mackerel) were also at the long-term average in 2016, in contrast to the recent peak years of 2013-2014, possibly indicating favorable recruitment in those years**.
- Steller **sea lions remain below their long-term mean** in this ecoregion, although there has been no significant trend in the past 5 years. The 2015 counts were the lowest in the time series.

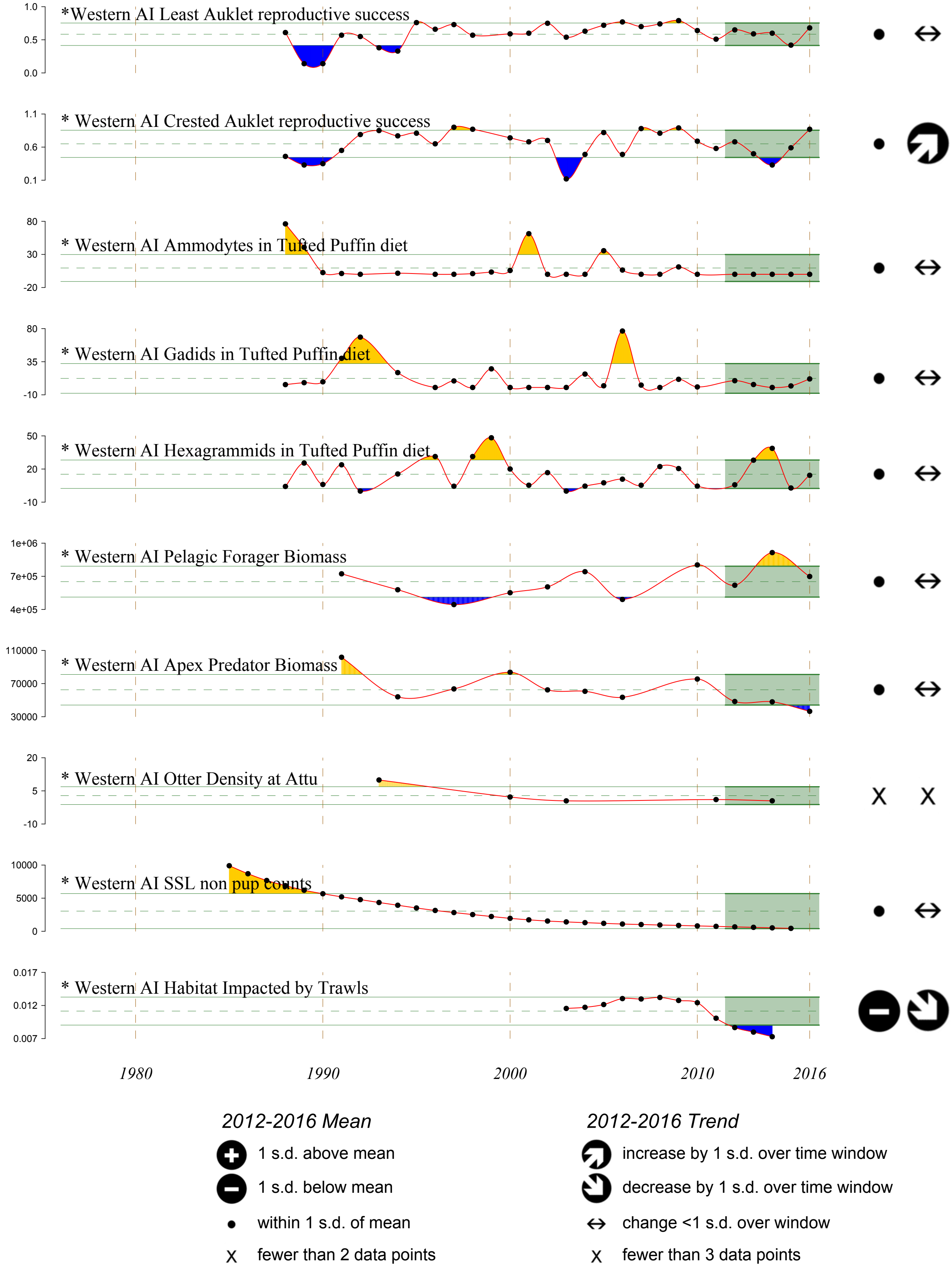

Figure 3: Western Aleutian Islands ecoregion indicators. * indicates time series updated in 2016.

Central Aleutian Islands Ecoregion 2016

- The most recent density estimates of sea **otters declined** from the last survey in 2011, continuing a pattern of mostly below-average abundance since the early 2000s.
- **Counts of non-pup Steller sea lions remain below the long term mean** although there is no significant trend in the past 5 years.
- **School enrollment has shown no trend** in recent years, following a decline since peak enrollment in 2000, and potentially indicating stability in the residential communities.

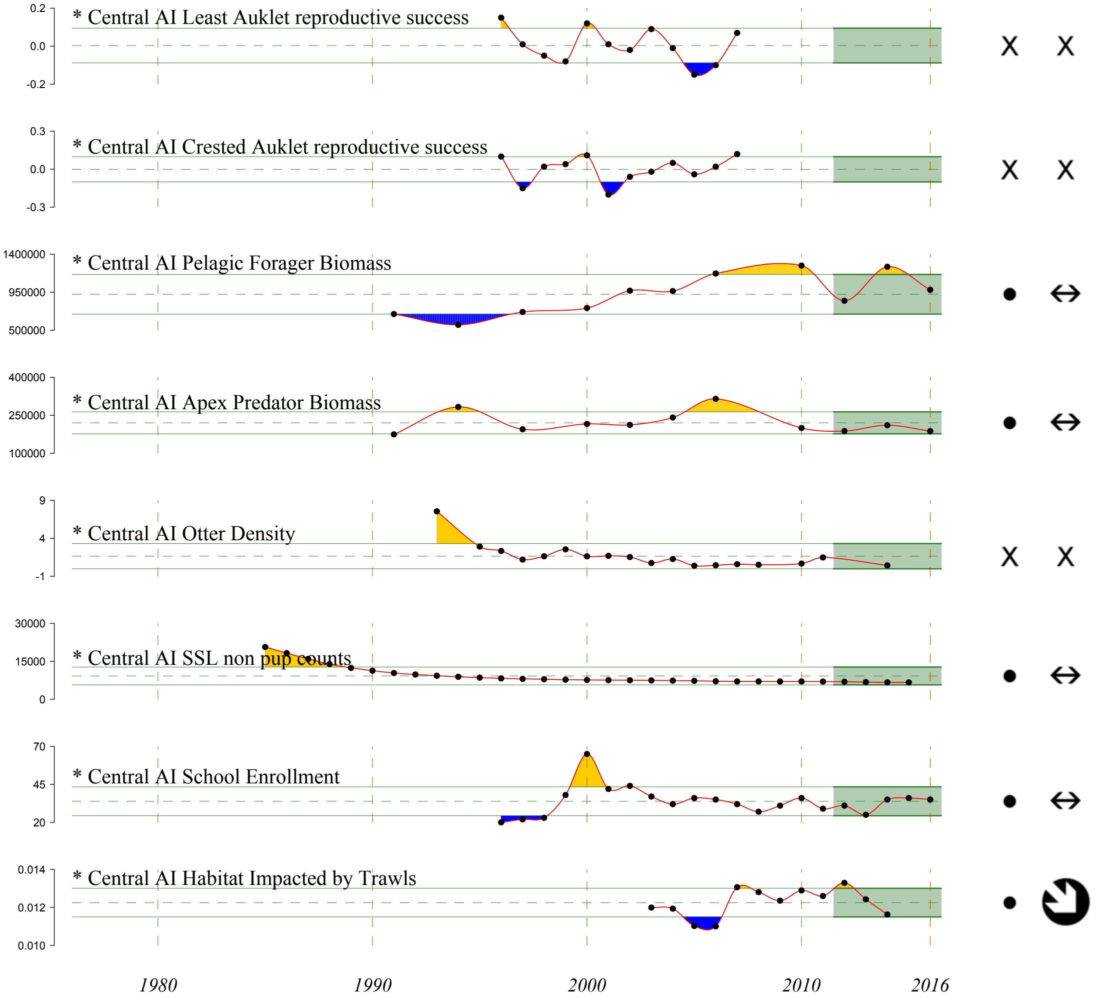

Figure 4: Central Aleutian Islands ecoregion indicators. * indicates time series updated in 2016. See Figure 3 for legend.

Eastern Aleutian Islands Ecoregion 2016

- Relative abundances of **gadids and *Ammodytes*** in prey brought back to feed puffin chicks **have shown opposite trends, although both increased from 2015 to 2016. Age-0 gadids, sand lance, and hexagrammids were near the long-term average in 2016**. Chick-provisioning patterns suggest puffins are responding to changes in forage fish availability.
- In contrast to the other ecoregions, **non-pup counts of Steller sea lions remained high** during the last count in 2015. The recent estimates have been above the long-term mean and are continuing an increasing trend. Counts were largely stable through the 1990s, but increased at a rate of 3% per year between 2000 and 2008.
- **School enrollment dropped substantially in 2016, leading to a recent declining trend following a peak in 2013**. It is unknown if this number represents a shift in community structure, or simply demographic variability.

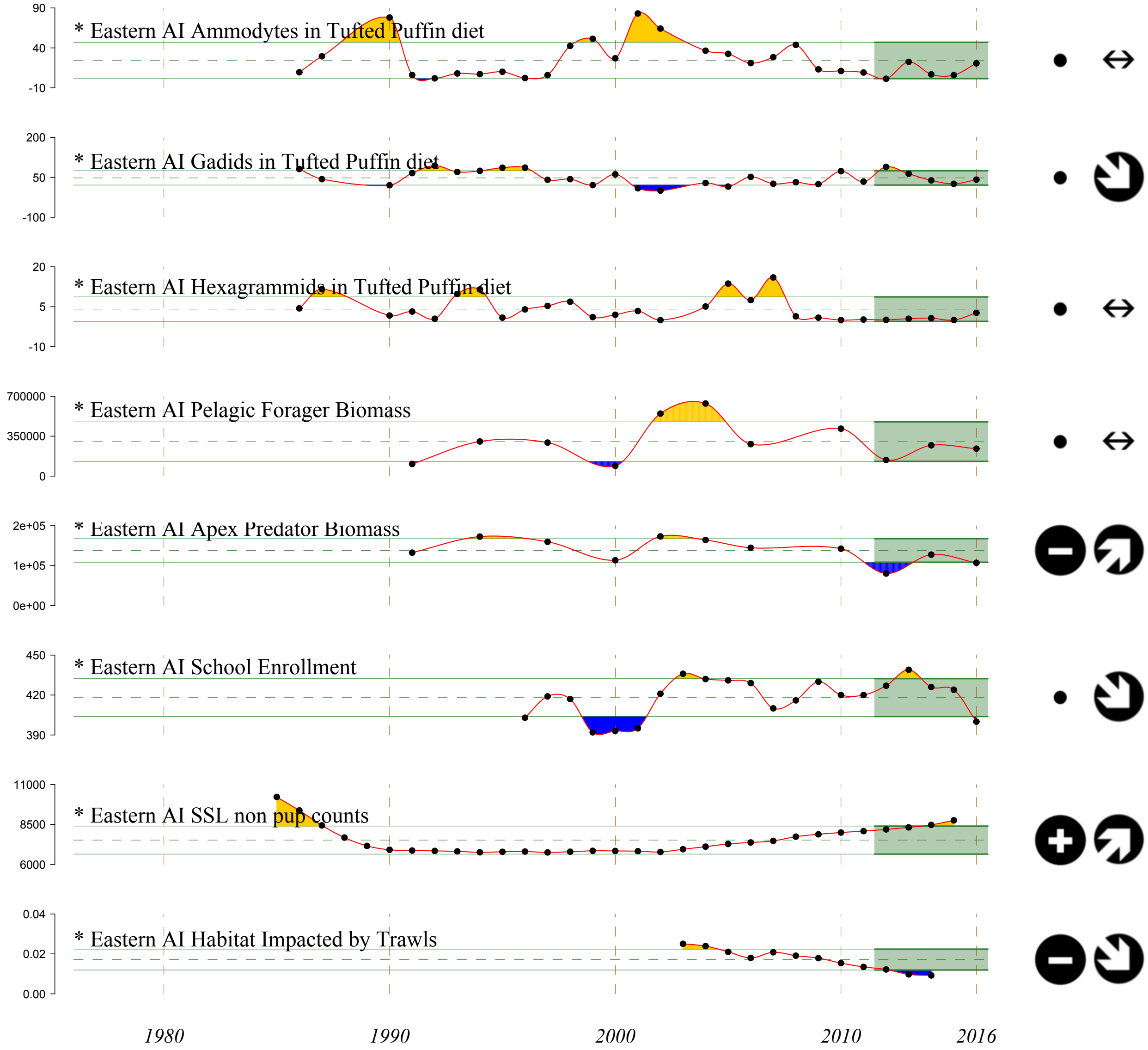

Figure 5: Eastern Aleutian Islands ecoregion indicators. * indicates time series updated in 2016. See Figure 3 for legend.

Executive Summary of Recent Trends in the Aleutian Islands

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

Physical and Environmental Trends

North Pacific

- The state of the North Pacific atmosphere-ocean system during 2015-2016 featured the continuance of warm sea surface temperature anomalies that became prominent late in 2013, with some changes in the pattern (p. 40).
- A strong El Niño developed during winter 2015-2016 (p. 45)
- However, the climate models used for seasonal weather predictions are indicating borderline to weak La Niña conditions for the winter of 2016-17 (p. 47).
- The Pacific Decadal Oscillation (PDO) remained positive during the past year (p. 45).
- The North Pacific Index (NPI) was strongly negative, implying a deeper than normal Aleutian Low, which was accompanied by anomalous winds from the south and relatively warm air along the west coast of North America (p. 45).
- The North Pacific Gyre Oscillation (NPGO) transitioned from negative in 2015 to near-neutral in 2016, implying that flows in the Alaska Current portion of the Subarccic Gyre and the California Current strengthened to normal (p. 45).
- Anomalously positive sea surface temperatures are predicted throughout much of the north east Pacific during the upcoming winter. The magnitude of the anomalies is projected to be greatest in the GOA and eastern Bering Sea (p. 47).
- The North Pacific climate may be in a state of rather low predictability, yet is unlikely that the upcoming winter in Alaska will be as mild as those of the last three years (p. 47).
- Model projections of a muted atmospheric response in the mid-latitudes to the equatorial Pacific during the next two seasons could be a reflection of the enormous amount of extra heat in the upper ocean now present along most of the west coast of North America (p. 47).

Aleutian Islands

- Waters in the Aleutian Islands region were relatively warm, especially in the fall of 2015 and summer of 2016, in part because of the overall warmth of the North Pacific and in part due to the weather, which featured above normal air temperatures (p. 40).
- Sea surface temperature values cooled to normal during winter and spring 2016 in part due to anomalous winds from northwest in association with extremely low sea level pressure (p. 42).
- The temperature anomaly profiles from the 2016 AI bottom trawl survey appear to be some of the warmest and most pervasive (vertically and longitudinally) recorded to date (p. 51).
- The Alaskan Stream had relatively strong westward flow from late 2015 into 2016, and there were pulses in the strength of the eastward flow associated with the Aleutian North Slope Current (p. 40).
- Eddy energy in the Aleutian Islands region remained low from the fall 2012 through July 2015, indicating the likelihood of smaller than average fluxes of volume, heat, salt, and nutrient fluxes through Amukta Pass, but a small eddy was present in early 2016, likely enhancing these fluxes (p. 49).
- CTD units were used to collect concurrent depth, temperature, salinity, pH, oxygen and turbidity data during most survey hauls of the bottom trawl survey in 2014 and 2016. A summary of temporal and spatial variability is presented. pH was not collected in 2016 due to equipment failure. As more of this data is collected relationships between fish and invertebrate distributions will be explored (p. 55).
- In both 2014 and 2016 there were some areas of low oxygen concentration in the farthest western areas of the survey (p. 55).

Ecosystem Trends

- The Aleutian islands trawl survey of structural epifauna showed variable distributions: Sponges are caught in most tows in the AI west of the southern Bering Sea. Abundance of coral in all areas has declined since about 1991-1993 surveys and is at generally low levels in all areas, but the frequency of occurrence has remained steady. Soft corals occur in relatively few tows, except in the eastern Aleutian Islands. Sea anemones are common, but sea pen abundance is low (p. 58).
- In the Bering Sea region north of the Western and Central Aleutian Islands that is sampled by the continuous plankton recorder, spring diatom abundances and mesozooplankton biomass anomalies were near neutral in 2015. However, the reduced average size of the copepod community suggests numerous, smaller prey items, which may require more work by predators to obtain their nutritional needs (p. 62).
- Likewise, copepod community size anomalies in 2015 were only represented by the fall sampling, but the values were the smallest since 2009 at this time of year (p. 62).
- Jellyfish mean catch per unit effort (CPUE) in the AI bottom trawl survey is typically higher in the western and eastern AI than in other areas. Catches and frequency of occurrence have been steadily increasing across the Aleutian Islands since the 2012 survey in all areas, but are below the “outbreak” abundances seen in 2006 (p. 66).
- Length-weight residuals (a measure of groundfish condition) for most species where there was data were negative from 2000 to 2006. Residuals were positive for all species but southern rock sole in 2010. In 2014 and 2016 length-weight residuals were negative for almost all species. For northern rockfish, Pacific cod and Pacific ocean perch there has been a declining trend in residuals over the years covered by the survey. Condition in the Western Aleutians appreared to improve between 2014 and 2016 (p. 68

- The distributions of rougheye rockfish, Pacific ocean perch, and shortraker rockfish have been shallower in the most recent surveys of the Aleutian Islands. Northern rockfish have shown a significant trend in their mean-weighted distribution towards the Western Aleutians. Mean-weighted temperature distributions for all rockfish species were stable within about 1°C over the entire time series. Increases in mean weighted temperature were been observed in 2016, likely because of the increased temperatures observed during the Aleutian Islands surveys (p. 69).
- Benthic communities and non-target species: there has been a decline in eelpout biomass in the western Aleutian Islands over the last three surveys. Poachers occur in a relatively large number of tows across the AI survey area, but mean CPUE trends are unclear. A new shrimp time series was calculated for 2016 and shows generally increasing trends in frequency of occurrence across all areas except the western Aleutian Islands since $\sim$1990 with the exception of a single peak in 2006 in the western Aleutian Islands (p. 74).

Fishing and Fisheries Trends

- Catch of non-target species: the non-target catch of Scyphozoan jellyfish was $\sim$25% of the catch in 2014, but shows no trend over time. The catch of structural epifauna, primarily sponges, has been variable over time and peaked in 2015. Assorted invertebrate catches have generally trended upward from 2005 to a peak in 2013. The catch of assorted invertebrates dropped considerably from 2013 to 2014 and has remained low in 2015 (p. 77).
- The numbers of seabirds estimated to be bycaught in Aleutian Islands fisheries in 2015 is the highest in the time series, which began in 2007. Numbers increased from $\leq$200 to 1,204, exceeding the bycatch in the Gulf of Alaska which is typically higherThe majority of those were Northern fulmars and Laysan albatross, both numbers which were the highest in the time series. In contrast, shearwaters had the second lowest numbers in 2015. This might be related to poor ocean conditions as the increase was Alaska-wide, and seabirds have been reported to attack baited longline gear more aggressively (p. 78).
- At present, no BSAI 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 2 of a new 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 7) (p. 87).
- Numbers of hook and line and trawl vessels have steadily declined since 1992. Numbers of jig and pot vessels have varied, but with no overall trend (p. 100).
- As of 2015 the total population of all AI communities was 5,939. The eastern AI has had the most steady population increase between 1880 and 2015, whereas the central and western AI experienced fluctuations. The western AI had a population of zero in 2015 (p. 95).
- Unemployment rates in the AI, between 1990 and 2015, were lower than state and national rates and has been decreasing in the past few years. This trend is sustained for 2016. The eastern AI had higher unemployment rates than central AI, and western AI data was insufficient to interpret any trends (p. 95).

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* indicates contribution updated in 2016
† indicates new contribution

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

December 2015 SSC Comments

As in the past, the Ecosystem Considerations Chapter of the SAFE documents is well written, informative, and continues to improve. The Editor and authors are to be congratulated on an excellent presentation covering a great deal of complex and important information. Perhaps most exciting are the efforts to develop prediction capacity. The Chapter is moving toward providing the sort of information that will allow the use of environmental information to predict future fish recruitment. The predictions may still be preliminary and qualitative, but it is great to see the attempt to go beyond recounting what has passed.

Thank you. This year, the ecosystem reporting efforts have benefited from the assistance of Elizabeth Siddon with the eastern Bering Sea report and Ellen Yasumiishi coordinating Auke Bay Lab's contributions.

The SSC was very pleased to see the first edition of the GOA report card. We commended the effort to develop a broader base for the process for selecting the list of indicators and we support the effort to continue to refine this list. The SSC appreciates having a Mobile Epifauna Biomass Index for the GOA. However, given the use of survey trawls with roller gear in the GOA that do not track as close to the bottom as the EBS trawl gear, consideration should be given as to whether this index is reliable. For instance, GOA trawl catches of crabs and scallops have been used as indices of presence/absence but generally not as a quantitative index of abundance. If the Mobile Epifauna Biomass Index is deemed reliable in the GOA, the SSC supports its continued inclusion in the report card.

Stephani Zador held a workshop session with the principal investigators of the GOA IERP project in early 2016 to refine the list of indicators. First, the majority of the group agreed that the differences between the western and eastern Gulf of Alaska warranted having two separate report cards. Thus, we present two report cards. While the general indicator categories are similar between the two report cards, some individual indicators differ. For example, the PDO was selected to be best climate indicator in the western, and the MEI (multivariate ENSO index) was selected to be the most appropriate in the east. However, as with the Aleutian Islands report card, the division highlights data gaps. For example, comparable forage fish indicators are not available for both regions. Also, while fresh water input was considered informative for the west, a comparable oceanographic indicator remains to be selected for the east. The version of the report card continues to include the motile epifauna trawl survey index until we find a more suitable index. However, it is only included for the west, as is the apex fish foraging guild, because summarizing these values for the eastern region, where survey efforts vary among years, was not finalized in time for this edition.

The SSC looks forward to continued development of the Arctic assessment and report card, as this will be critical to our overall understanding of the resources there and how they may best be managed.

We also look forward to continued development and hope to make plans for a workshop and/or report card development soon. This year we had very little to update in our preliminary Arctic assessment, and so have decided not to produce an annual update but rather focus of producing separate LME-based reports for the other areas (see below). We plan to have a complete and separate Arctic Ecosystem Considerations report next year.

The Editor and authors have been very responsive to the past comments of the SSC. The SSC notes the welcome addition of the section on Disease Ecology and the expanded information on the status of zooplankton in the EBS and GOA. The SSC found the ongoing effort to develop alternate sampling methods or platforms to provide information on forage fish trends very helpful. The SSC echoes the concerns of the PT regarding the ecosystem indicator that describes the trawl disturbance area. As currently estimated, there is potential for underestimating reductions in trawl effort and the SSC supports the PT recommendation that alternatives to this index be investigated.

Based on positive feedback for the Zooplankton Rapid Assessment, that indicator has been expanded to include seasonal updates from Fall 2015 through late Fall 2016. In addition, we received a new indicator based on the Zooplankton Rapid Assessment categories that developed a hindcast time-series of zooplankton abundance from 1997 - 2012. There are a few new forage fish indicators presented this year. Yasumiishi et al contributed new spatial analyses of capelin and herring trends in the eastern Bering Sea, and Zador and Frandsen present new multivariate capelin and sand lance indicators for the Gulf of Alaska. There has been a great deal of effort over the past year in developing new habitat disturbance indicators to replace the previous estimates of trawl disturbance. We present a new indicator based on the Fishing Effects model for the eastern Bering Sea, which has also replaced the previous one in the report card. We also replaced the previous trawl disturbance indicator in the Aleutian Islands report card. We anticipate several more indicators of this type, including for the Gulf of Alaska and updated to the previous calendar year, in next year's reports.

The EBS bottom temperature information and the OSCURS model results for 2014 and 2015 corroborate the BSAI stock authors and GPTs concerns/ discussions regarding the impacts of temperatures and advection on flatfish migration and behavioral responses to the survey trawl, both of which impact Q.

The SSC notes that there is a lack of attention to humans in the Ecosystem Considerations chapter. While there are historical reasons that partially explain this – the ecosystem SAFE was conceived after the treatment of some economic and social issues had been assigned to a separate economic SAFE – the SSC believes this separation should not continue. At a fundamental level, the subject of interest is how humans are contributing to changes in the ecosystems of which they are part, and how they are reacting to these changes. The SSC suggests that it is time to rethink how the *human component is incorporated into the SAFE process. As a specific example of how the current approach is deficient, the SSC notes that fisheries policy stands virtually alone, compared to other industry/policy settings, in the total absence of attention to the carbon footprint of commercial fishing and the influence of policy on that footprint.*

We agree that evaluating the carbon footprint of commercial fisheries would be a valuable research area and would support this analysis in these reports. This year, after consultation with AFSC's economists, we include new human dimensions indicators for all LMEs that focus on population and unemployment trends. As human dimensions in fisheries is an active area of research, we anticipate modifying and expanding this section in the future.

The document has grown over the years and the increasing length in some ways makes it difficult for the reader, despite the useful Report Card and Hot Topics sections. Not all parts are of equal value. It would be nice if the meat of the document were tightened up so that the important parts totaled 100 to 150 pages. That might help the reader to absorb more of the critical material. It might be useful to have a sub-committee try to sort out which, if any, indices might be dropped. For example, there are a number of indices or reports on herring. We recognize the importance of information on the status of the Togiak Bay (Bering Sea) spawning run, but perhaps the considerable set of reports on herring in Southeast Alaska (Gulf of Alaska) could consolidated into a broader overview of southeast regional trends.

As of this year, the Ecosystem Considerations report has been divided by LME into three separate documents. Within each LME, we have organized indicators by trophic level (Primary Production, Zooplankton, Groundfish, Benthic Communities and Non-target Fish Species, Ecosystem or Community Indicators, Disease Ecology Indicators). This accomplishes several objectives. First, the ecosystem status of each LME is more cohesively represented by report card, summary, assessment, and detailed contribution in a separate document. This makes it easier for the reader (and editors) to integrate across the broad scope of indicators available in each LME. Second, the arrangement highlights data gaps and research needs, which vary by LME. Third, this framework more easily allows for ecosystem experts to participate in the indicator curation and synthesis in their area of expertise. Fourth, each report is shorter and hopefully easier to absorb for those readers that may have more specific, regional interests. While many indicators and sections have developed over the past few years to allow for this restructuring, we acknowledge that there are some redundancies among reports that we will address in next year's editions. We welcome SSC and GPT feedback on the new structure.

Many of the individual Index Reports miss the opportunity to draw comparisons among regions (EBS, GOA, etc.), species, and other indices. Such integration would help the authors and readers see the "big picture". The Editor attempts to do this in the introductory portions of the Chapter, but if the Index Reports come in at the last moment, it is hard for the Editor to integrate them. It would be helpful to group indices by region- EBS, AI, GOA, then, within region by species or species group. Again, that would aid the reader in seeing the connections among indices.

As stated above, the indices have now been fully grouped be LME into separate reports. We understand that this might make inter-regions (i.e., Alaska-wide) comparisons more difficult, but we hope that the synthesis in the assessments allows for these comparisons when informative.

As in the past, a number of indices were not updated for this years Ecosystem Considerations Chapter. If these indices are important for management, then they should be updated in a timely *fashion. If not important, they can be dropped. For example, the EBS Sea Ice Index analysis was not updated, nor were the indices on the western sub-population of the Steller Sea Lion. Both would seem important.*

We acknowledge the importance of timely updates to indicators and that the SSC and GPT rely on this information annually. We will continue to make every effort to include updated indicator information. The Ice Retreat Index was updated this year.

In the discussion of jellyfish (Page 141), we learn for the first time that the BASIS Surveys have been shifted to alternate years. Since the BASIS survey has been of considerable importance in developing and testing of our understanding of the EBS, it would seem that this important change ought to be highlighted up front. The SSC is surprised and disappointed that this was not discussed with the Council before being implemented.

We acknowledge the importance of the BASIS survey and the numerous Ecosystem Indicators that result from that time series. The decision to transition to alternate years was based on budgetary constraints, although we note that special funds were acquired to execute a 2015 survey thereby augmenting the time series.

Introduction

The goal of the Ecosystem Considerations report is to provide stronger links between ecosystem research and fishery management and to spur new understanding of the connections between ecosystem components by bringing together the results of many diverse research efforts into one document. However, this year the report has been split into four separate documents, one for the Gulf of Alaska, Aleutian Islands, eastern Bering Sea, and the Arctic[1]. This new presentation allows for a more cohesive focus on each large marine ecosystem (LME). While this simplifies navigation for the reader, it also better highlights data gaps and research needs within each LME. As before, each report contains four main sections:

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

The purpose of the first section, the Report Cards, is to summarize the status of the top indicators selected by teams of ecosystem experts to best represent each ecosystem. Time series of indicators are presented in figures formatted similarly to enable comparisons across indicators. Recent trends in climate and the physical environment, ecosystems, and fishing and fisheries are highlighted in bulleted lists.

The purpose of the second section, the Executive Summary, is to provide a concise summary of the status of marine ecosystems in Alaska for stock assessment scientists, fishery managers, and the public. Page links to sections with more detail are provided.

The purpose of the third section, the Ecosystem Assessment, is to synthesize historical climate and fishing effects on Alaskan marine ecosystems using information from the Ecosystem Status and Management Indicators section and stock assessment reports. Notable items, called “Hot Topics”, that capture unique occurrences, changes in trend direction, or patterns across indicators are highlighted at the beginning. An ongoing goal is to produce ecosystem assessments utilizing a blend of data analysis and modeling to clearly communicate the current status and possible future directions of ecosystems. This assessment originally provided a short list of key indicators to track in the EBS, AI, and GOA, using a stepwise framework, the DPSIR (Drivers, Pressure, Status, Indicators, Response) approach (Elliott, 2002). In applying this framework we initially determined four

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[1] The Arctic report is under development

objectives based, in part, on stated ecosystem-based management goals of the NPFMC: maintain predator-prey relationships, maintain diversity, maintain habitat, and incorporate/monitor effects of climate change. Drivers and pressures pertaining to those objectives were identified and a list of candidate indicators were selected that address each objective based on qualities such as, availability, sensitivity, reliability, ease of interpretation, and pertinence for addressing the objectives (Table 1). Use of this DPSIR approach allows the Ecosystem Assessment to be in line with NOAA's vision of Integrated Ecosystem Assessments (IEA)(Figure 6).

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

Pressures/Effects	**Significance Threshold**	**Indicators**
Objective: Maintain predator-prey relationships and energy flow **Drivers: Need for fishing; per capita seafood demand**		
Availability, removal, or shift in ratio between critical functional guilds	Fishery induced changes outside the natural level of abundance or variability, taking into account ecosystem services and system-level characteristics and catch levels high enough to cause the biomass of one or more guilds to fall below minimum biologically acceptable limits. Long-term changes in system function outside the range of natural variability due to fishery discarding and offal production practices	• Trends in catch, bycatch, discards, and offal production by guild and for entire ecosystem • Trophic level of the catch • Sensitive species catch levels • *Population status and trends of each guild and within each guild* • *Production rates and between-guild production ratios ("balance")* • *Scavenger population trends relative to discard and offal production levels* • Bottom gear effort (proxy for unobserved gear mortality on bottom organisms)
Energy redirection		• Discards and discard rates • Total catch levels
Spatial/temporal concentration of fishery impact on forage	Fishery concentration levels high enough to impair long term viability of ecologically important, nonresource species such as marine mammals and birds	• Degree of spatial/temporal concentration of fishery on pollock, Atka mackerel, herring, squid and forage species (qualitative)
Introduction of nonnative species	Fishery vessel ballast water and hull fouling organism exchange levels high enough to cause viable introduction of one or more nonnative species, invasive species	• Total catch levels • Invasive species observations
Objective: Maintain diversity **Drivers: Need for fishing; per capita seafood demand**		
Effects of fishing on diversity	Catch removals high enough to cause the biomass of one or more species (target, nontarget) to fall below or to be kept from recovering from levels below minimum biologically acceptable limits	• Species richness and diversity • Groundfish status • Number of ESA listed marine species • Trends for key protected species
Effects on functional (trophic, structural habitat) diversity	Catch removals high enough to cause a change in functional diversity outside the range of natural variability observed for the system	• Size diversity • Bottom gear effort (measure of benthic guild disturbance) • HAPC biota bycatch

Effects on genetic diversity	Catch removals high enough to cause a loss or change in one or more genetic components of a stock that would cause the stock biomass to fall below minimum biologically acceptable limits	• Size diversity • Degree of fishing on spawning aggregations or larger fish (qualitative) • Older age group abundances of target groundfish stocks
Objective: Maintain habitat **Drivers: Need for fishing; per capita seafood demand**		
Habitat loss/ degradation due to fishing gear effects on benthic habitat, HAPC biota, and other species	Catch removals high enough or damage caused by fishing gear high enough to cause a loss or change in HAPC biota that would cause a stock biomass to fall below minimum biologically acceptable limits	• Areas closed to bottom trawling • Fishing effort (bottom trawl, longline, pot) • Area disturbed • HAPC biota catch • HAPC biota survey CPUE
Objective: Incorporate/ monitor effects of climate change **Drivers: Concern about climate change**		
Change in atmospheric forcing resulting in changes in the ocean temperatures, currents, ice extent and resulting effects on production and recruitment	Changes in climate that result in changes in productivity and/or recruitment of stocks	• North Pacific climate and SST indices (PDO, AO, NPI, and NINO 3.4) • Combined standardized indices of groundfish recruitment and survival • Ice indices (retreat index, extent) • Volume of cold pool • Summer zooplankton biomass in the EBS

We initiated a regional approach to ecosystem assessments in 2010 and presented a new ecosystem assessment for the eastern Bering Sea. In 2011, we followed the same approach and presented a new assessment for the Aleutian Islands based upon a similar format to that of the eastern Bering Sea. In 2012, we provided a preliminary ecosystem assessment on the Arctic. Our intent was to provide an overview of general Arctic ecosystem information that may form the basis for more comprehensive future Arctic ecosystem assessments. In 2015, we presented a new Gulf of Alaska report card and assessment, that has been divided into Western and Eastern Gulf of Alaska report cards this year.

While all sections follow the DPSIR approach in general, the eastern Bering Sea and Aleutian Islands assessments are based on additional refinements contributed by Ecosystem Synthesis Teams. For these assessments, the teams focused on a subset of broad, community-level indicators to determine the current state and likely future trends of ecosystem productivity in the EBS and ecosystem variability in the Aleutian Islands. The teams also selected indicators that reflect trends in non-fishery apex predators and maintaining a sustainable species mix in the harvest as well as changes to catch diversity and variability. Future assessments will address additional ecosystem objectives identified above. Indicators for the Gulf of Alaska report card and assessment were also selected by a team of experts, via an online survey instead of an in-person workshop. We plan to convene teams of experts to produce a report card and full assessment for the Arctic in the near future.

The purpose of the fourth section, Ecosystem Status and Management Indicators, is to provide detailed information and updates on the status and trends of ecosystem components as well as to provide either early signals of direct human effects on ecosystem components that might warrant

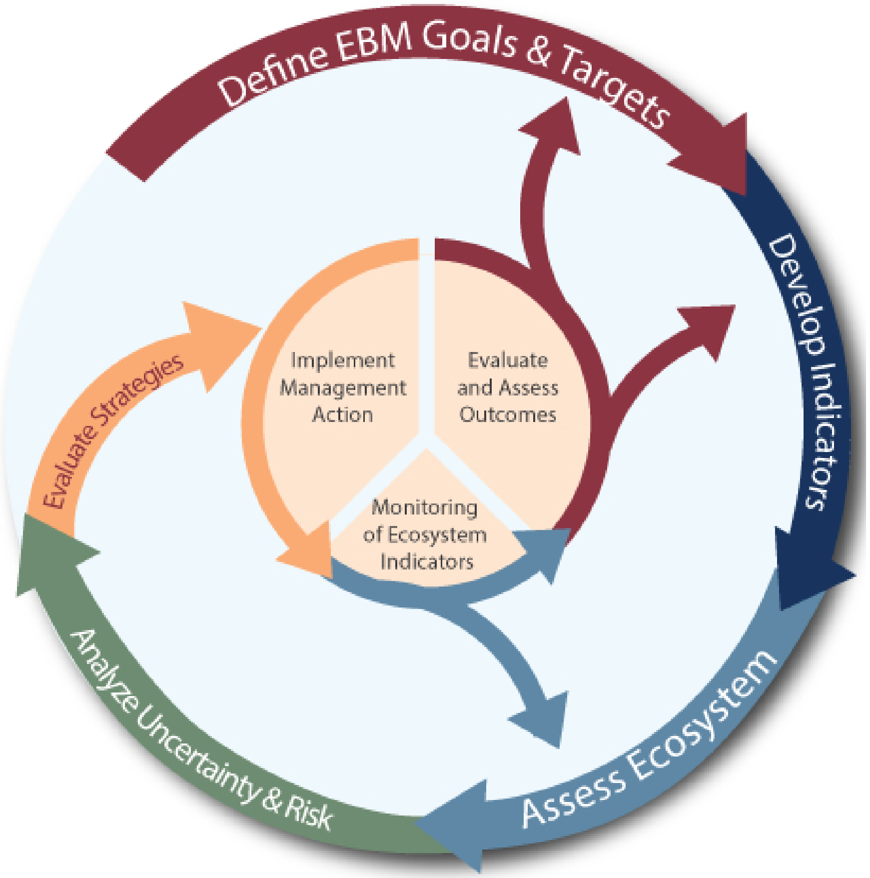

Figure 6: The IEA (integrated ecosystem assessment) process.

management intervention or evidence of the efficacy of previous management actions. Ecosystem-based management indicators should also track performance in meeting the stated ecosystem-based management goals of the NPFMC, which are:

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

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

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

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

Each year since then, the Ecosystem Considerations reports has included some new contributions in this regard and will continue to evolve as new information becomes available. Evaluation of the meaning of observed changes should be in the context of how each indicator relates to a particular ecosystem component. For example, particular oceanographic conditions such as bottom temperature increases might be favorable to some species but not for others. Evaluations should follow an analysis framework such as that provided in the draft Programmatic Groundfish Fishery Environmental Impact Statement that links indicators to particular effects on ecosystem components.

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

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

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

It was requested that contributors to the ecosystem considerations report provide actual time series data or make it available electronically. Many of the time series data for contributions are available on the web, with permission from the authors. We are in the process of improving online access to indicators and debuted a new webpage in early 2016.

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

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

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

Aleutian Islands Ecosystem Assessment

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Last updated: October 2016

Introduction

The primary intent of this assessment is to summarize and synthesize historical climate and fishing effects on the shelf and slope regions of the Aleutian Islands (AI) from an ecosystem perspective and to provide an assessment of the possible future effects of climate and fishing on ecosystem structure and function. The Ecosystem Considerations section of the Groundfish Stock Assessment and Fishery Evaluation (SAFE) report provides the historical perspective of status and trends of ecosystem components and ecosystem-level attributes using an indicator approach. For the purposes of management, this information must be synthesized to provide a coherent view of ecosystems effects in order to clearly recommend precautionary thresholds, if any, required to protect ecosystem integrity. The eventual goal of the synthesis is to provide succinct indicators of current ecosystem conditions. In order to perform this synthesis, a blend of data analysis and modeling is required annually to assess current ecosystem states in the context of history and past and future climate.

Hot Topics

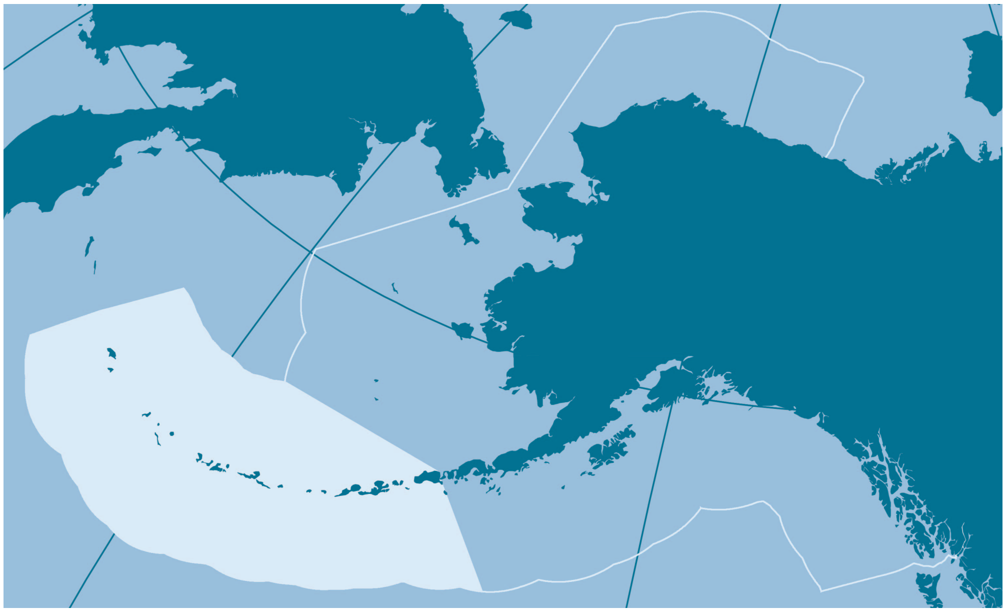
We present items that are either new or otherwise noteworthy and of potential interest to fisheries managers as Hot Topics.

The Aleutian Life Forum, August 2016

The Third Aleutian Life Forum, held in Dutch Harbor, brought forth some of the latest policy and science advancement as well as community involvement opportunities, and community concerns in the area. Videos of all presentation are available at `http://www.aleutianlifeforum.com/presentations/`. On the policy front, one of the major changes was the establishment of Areas to Be Avoided (ATBAs) by the International Maritime Organization. The areas, in effect since January 2016, essentially created 50 mi. buffers around the Aleutians with 4 passes open for vessel traffic. The modified routes add less than 1% to overall voyage lengths yet reduces potential exposure for Steller sea lions and northern sea otters by ∼21% and 22% respectively. Oil spill, vessel safety, and coastal habitats are at the forefront of simulations, improved maps and response plans.

The upcoming review of the Aleutian Islands Fisheries Ecosystem Plan raised awareness to the need to compile and evaluate the new information available since 2011 as well as ecosystem indicators used to date. Three major scientific issues of concern were highlighted: i) ocean acidification with potential impacts on fish and shellfish fisheries as well as hard (gorgonian) corals, ii) mercury, contaminants and their potential effects on populations, and iii) steadily decreasing trends on the populations of Steller sea lions, harbor seals, sea otters and red cormorants, most pronounced in the Western Aleutians. A large-scale look at Steller sea lions showed population declines and lower survival was prevalent in the Commander Island and western Aleutians, with populations improving eastward towards Kamchatka and the Kuril Islands as well as towards the Eastern Aleutians and the Alaska Peninsula.

Finally, new and important opportunities for the use of vessels of opportunity, citizen science, community involvement for the advancement of science and information networks were brought forth by multiple participants. Continuous Plankton Recorders (CPR) towed behind commercial ships on their transit from the North American west coast to Asia through the Aleutian Islands show seasonal trends in plankton communities across the archipelago but also show the western Aleutians have different community composition, particularly in summer. Smartphone apps and online mapping apps such as that of LEO (Local Environmental Observers Network), Citizen Sentinel (BeringWatch), along with the Coastal Community Ocean Observers (C2O2) kits, training and public outreach can coordinate and substantially strengthen the seasonal breadth and spatial resolution of monitoring along the Aleutians. Importantly, it standardizes observations and gives a stronger voice to the communities and year round residents which were an important present during the forum. Moreover, online access to the information provides real-time feedback as well as the opportunity to more quickly identify unusual events. The momentum created by the forum offers a unique opportunity for synergistic collaboration across platforms of operation and stakeholder sectors which, if sustained and further supported could greatly improve monitoring, real-time information, feedback loops and collaboration between managers, users and communities.



The Aleutian Islands ecosystem assessment area

The Aleutian Islands ecosystem assessment and Report Card are presented by three ecoregions. The ecoregions were defined based upon evidence of significant ecosystem distinction from the adjacent ecoregions by a team of ecosystem experts in 2011. The team also concluded that developing an assessment of the ecosystem at this regional level would emphasize the variability inherent in this large area, which stretches 1900 km from the Alaska Peninsula in the east to the Commander Islands in the west. For the purposes of this assessment, however, the western boundary is considered the U.S. - Russia border at 170°E.

The three Aleutian Islands ecoregions are defined from west to east as follows (Figure 7). The Western Aleutian Islands ecoregion spans 170° to 177°E. These are the same boundaries as the North Pacific Fishery Council fishery management area 543. This ecoregion was considered to be distinct from the neighboring region to the east by primarily northward flow of the Alaska Stream through wide and deep passes (Ladd, pers. comm.), with fewer islands relative to the other ecoregions.

The Central Aleutian Islands ecoregion spans 177°E to 170°W. This area encompasses the North Pacific Fishery Council fishery management areas 542 and 541. There was consensus among the team that the eastern boundary of this ecoregion occurs at Samalga Pass, which is at 169.5°W, but for easier translation to fishery management area, it was agreed that 170°W was a close approximation. The geometry of the passes between islands differs to the east and west of Samalga Pass (at least until Amchitka Pass). In the Central ecoregion the passes are wide, deep and short. The Alaska Stream, a shelf-break current, is the predominant source of water (Figure 8). There is more vertical mixing as well as bidirectional flow in the passes. This delineation also aligns with studies suggesting there is a biological boundary at this point based on differences in chlorophyll, zooplankton, fish, seabirds, and marine mammals (Hunt and Stabeno, 2005).

The Eastern Aleutian Islands ecoregion spans 170°W to False Pass at 164°W. The passes in this ecoregion are characteristically narrow, shallow and long, with lateral mixing of water and northward flow. The prominent source is from the Alaska Coastal Current, with a strong freshwater component. This area encompasses the NPFMC fishery management areas 518, 517 (EBS) and the western half of 610 (GOA).

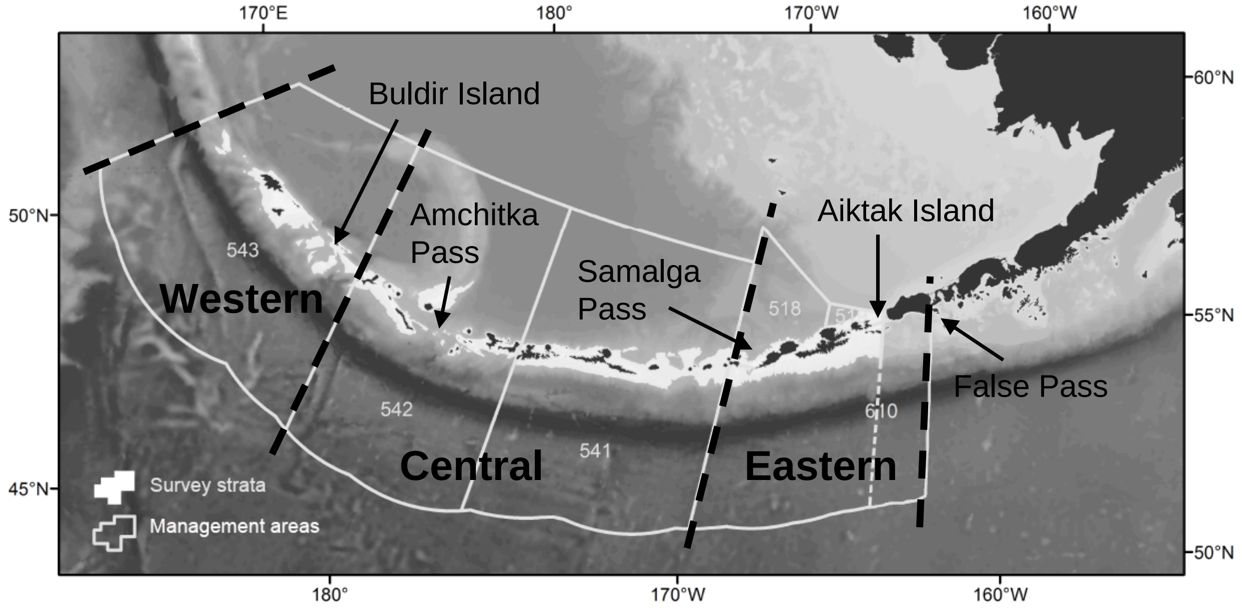


Figure 7: The three Aleutian Islands assessment ecoregions.

Summary

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

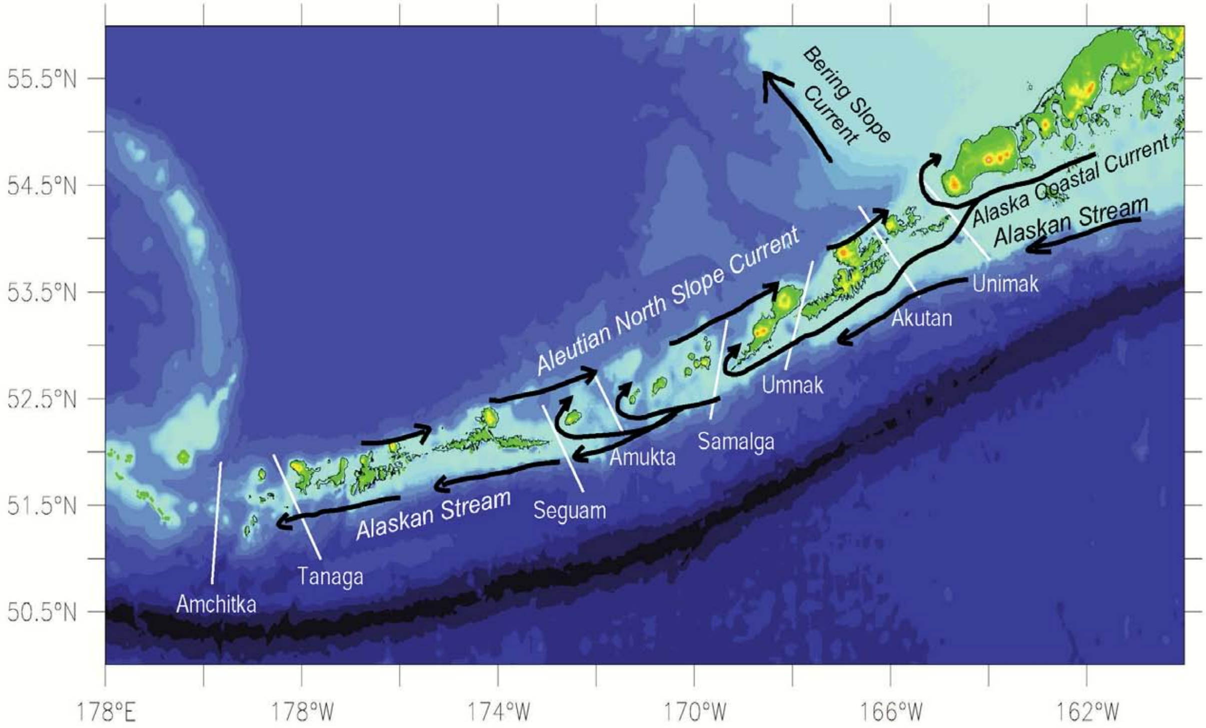


Figure 8: Ocean water circulation in the Aleutions. Currents are indicated with black lines. Passes are indicated with white lines. Image from Carol Ladd.

be as informative in the Aleutians. Therefore, our synthesis of ecosystem indicators by necessity includes speculation.

The state of the North Pacific atmosphere-ocean system during 2015-16 featured the continuance of warm sea surface temperature anomalies that became prominent late in 2013, with some changes in the pattern. The waters of this region were relatively warm, especially in the fall of 2015 and summer of 2016, but they did cool down to normal during winter and spring 2016. Bottom trawl survey temperatures appeared to be some of the warmest and most pervasive (vertically and longitudinally) recorded to date. The warm temperatures can be attributed in part to the overall warmth of the North Pacific and in part to the weather, which featured persistently above normal air temperatures during the past year with only short and minor exceptions. The Alaskan Stream appears to have had a relatively strong westward flow from late 2015 into 2016, and models suggest that there were pulses in the strength of the eastward flow associated with the Aleutian North Slope Current. Eddy energy in the Aleutian Islands region remained low from fall 2012 through July 2015, indicating the likelihood of smaller than average fluxes of volume, heat, salt, and nutrient fluxes through Amukta Pass, but a small eddy was present in early 2016, likely enhancing these fluxes.

The zooplankton community in the Aleutians is largely dominated by copepods, and the ecosystem itself is oceanic in nature. It therefore follows that both the Western and Central Aleutians have a larger total fish biomass of pelagic foragers compared to that of fish apex predators, while in the Eastern Aleutians the largest total biomass alternates between fish apex predators and fish pelagic foragers. This is consistent with higher reliance on plankton in the Western Aleutians vs more piscivorous and invertivores towards the east. The largest total biomass of both fish apex predators and pelagic foragers is located in the Central Aleutians, the ecoregion with the largest shelf area under 500m (Figure 9). The lowest apex predator biomass is located in the Western Aleutians whereas that of pelagic foragers is found in the Eastern Aleutians. This pattern has been consistent since 1991, though individual species groups fluctuations do not necessarily follow the same behavior. Length-weight residuals, a measure of fish condition, has shown below- average to average values for pelagic and apex foragers in the entire chain, possibly indicating poor conditions for groundfish in general. We note however, that for Pacific Ocean perch (POP) and northern rockfish, intraspecific competition might be a contributing factor, as their abundance has increased and their condition has decreased more than that of Atka mackerel and pollock. Conditions for planktivorous predators may have slightly improved this year as discussed in the sections below.

Total pelagic foragers biomass is slightly under 2 million tons over the entire Aleutian archipelago, with lower overall biomass across all three regions compared to 2014. This trend however, does not characterize all pelagic foragers; in fact, there is a consistent long term trend whereby the proportion of rockfish (POP, and northern rockfish shown in purple tones in the corresponding figure) has been consistently increasing compared to that of Atka mackerel and pollock biomass. What in the early 1990s was a system where two thirds of the pelagic foragers biomass was made up by Atka mackerel and pollock (shown in grey tones in the corresponding figure), is now half or even two thirds composed by rockfish. This may cause several minor but consistent disruptions in the structure of the system: i) on one hand Atka mackerel and pollock are shallow foragers distributed mostly between 100-200 m depth, while northern rockfish and POP are generally found in waters 100-300 m. This is relevant because Atka mackerel are an important fish prey for seabirds (such as tufted puffin), marine mammals (such as Steller sea lions), and a variety of other fish. In contrast, POP and northern rockfish are a much weaker trophic link across the Aleutians, very different from their role in the California Current where seabirds prey heavily on rockfish juveniles (at least based on summer diets for the Aleutians). Also importantly, the fact that POP and northern rockfish are located deeper in the water column and their populations have been increasing might account for the decreasing trend in their condition since 2000. Northern rockfish appear to be shifting their distributions toward the western ecoregion.

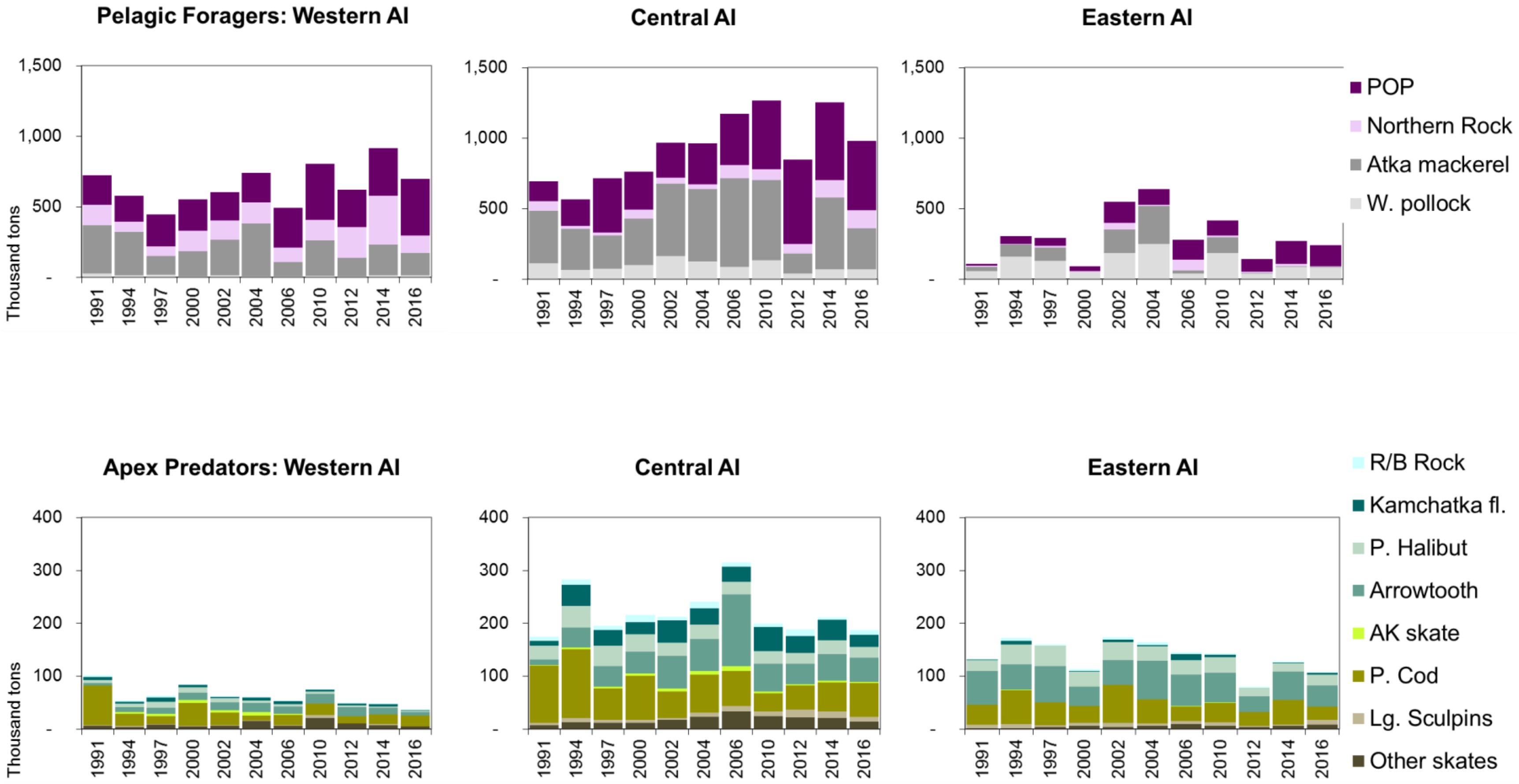


Figure 9: Estimated biomasses of fish apex predators and pelagic foraging guilds aggregated by Aleutian Islands ecoregions.

Overall apex predator fish biomass decreased across all Aleutian Islands regions. Both Pacific cod and arrowtooth flounder continue to be the largest biomasses within the guild across all AI regions as well. The apex predator fish guild can be roughly separated into three trophic preferences: those that eat primarily fish, fish and crustaceans/invertebrates or primarily crustaceans and invertebrates. Large rockfish and large flatfish eat mostly fish (shown in blue tones in corresponding figure), Pacific cod and AK skates feed approximately equal parts fish and crustaceans (AK skate less so) (shown in olive green tones), while large sculpins and other skates (shown in brown tones) feed primarily on crustaceans and invertebrates. Piscivorous apex predators make up the largest proportion in the Eastern Aleutians decreasing towards the Western Aleutians, where the shelf is wider and there are more apex predators feeding on crustaceans and invertebrates. While this is to be expected, there is a slow non-monotonic increasing trend in their biomass (large sculpin and other skates) not only in the Western, but also the Central and Eastern Aleutians (albeit to a lesser degree). Pacific cod, being able to switch equally between fish and crustacean/invertebrates availability, though shown here as an apex predator within fish, is in fact a prey source to a few other fish and marine mammals, so fluctuation in its biomass affect both prey and predators as well. Perhaps more important than the sheer biomass of apex predator fish, is their composition, as several of the piscivorous fish consume Atka mackerel and pollock and may be impacted by the larger proportion of rockfish in the system. Most pelagic psicivorous predators will complement their diets with squid and myctophids, however for central foragers (such as marine pinnipeds and seabirds, that implies longer trips from their respective colonies and haul outs. For Pacific cod, which feeds on both on Atka mackerel and pollock, the change in availability of these two prey species compared to that of POP and northern rockfish, may be a contributing factor to their decreasing abundance. The increase in seabird bycatch last year, mostly northern fulmars and Laysan albatross, may be additional evidence of the poor conditions for piscivorous predators.

Western Ecoregion In the western ecoregion specifically, the reproductive success of planktivorous auklets, serving as indicators of zooplankton production, increased from low values in 2015 to above average this year. The increase was seen in both crested auklets, which feed their chicks mainly euphausiids and copepods, and least auklets, which focus on copepods. Thus, we can speculate that sufficient zooplankton were available to support reproductive success. The slight increase in 2016 in the condition of Atka mackerel and pollock (both feeeding on zooplankton) would seem to further support the improved conditions for planktivorous predators as does the decrease in shearwater bycatch. Forage fish trends as indicated in tufted puffin chick meals have varied over the long term. In general, *Ammodytes* (sand lance) have been absent since 2010, and age-0 gadids (pollock and cod) uncommon, although gadids were observed near their long-term mean this year. The number of hexagrammids (likely age-0) varies among years, but was present in average values this year. It is still unknown whether the high number of hexagrammids seen in 2013 and 2014 possibly indicated high recruitment in Atka mackerel, as 80% of the hexagrammids in 2013 and 100% in 2014 were Atka mackerel. Atka mackerel and POP drive the biomass trend and on average make up 80% of the pelagic foragers biomass with the rest comprised mostly of northern rockfish. POP has been increasing (rebuilding) since 1991, although northern rockfish declined in 2016 relative to 2014. Steller sea lion non-pup counts from 2015 are the lowest in the time series. The declining sea lion trends are topics of active research on these apex piscivores whose diet consists primarily of commercially-fished species. The habitat area disturbed by trawls continued to decrease in 2014 following the sea lion protection measures that took effect in 2011.

Central Ecoregion Recent trends in auklet reproductive success in the central ecoregion are unknown due to the disruption of the monitored colony in 2008, when the volcano on Kasatochi Island erupted and the seabird research field camp and the monitored colonies were covered with ash. A suitable replacement indicator has not yet been identified. Forage fish trends as captured by puffins are not available from this ecoregion because puffins are not as numerous and nests are not monitored regularly. Both fish apex predator and pelagic foraging guild biomasses have decreased since the previous trawl survey in 2014. Atka mackerel and POP drive the pelagic foragers biomass trend making up 80% of the total biomass, with the remaining split between walleye pollock and northern rockfish. Recent sea lion estimates are low, but the rate of decline has stabilized. School enrollment has remained stable in the central ecoregion, potentially indicating stability in the residential communities. The amount of habitat disturbed by trawls was below average in 2014, possibly indicating a declining trend in habitat disturbance by trawls since 2012, when habitat recovery estimates following the sea lion closures took effect. It is important to keep in mind, however, that the trawlable shelf area in the Aleutians in a minor part of the sea floor landscape, as most is quite rocky and steep.

Eastern Ecoregion Planktivorous auklets are not as numerous in the Eastern ecoregion as in the Central and Western ecoregion and are not monitored in the Eastern ecoregion. Relative abundances of gadids and *Ammodytes* in prey brought back to feed puffn chicks have shown opposite trends, although both increased from 2015 to 2016, providing support for anecdotal observations of high numbers of age-0 pollock in the western GOA this year. Hexagrammids comprise a lower proportion of chick diets relative to those in the Western ecoregion. Chick-provisioning patterns suggest puffns are responding to changes in forage fish availability. Commonly more than half the pelagic foraging fish biomass is contributed by walleye pollock and POP. All groups fluctuate largely in this area which has the lowest total biomass of pelagic foragers. There is almost no northern rockfish in this area. Both Atka mackerel and pollock used to be the dominant biomasses until 2004, but POP has been gradually increasing and since 2006 has been either on a par or higher than either Atka mackerel or pollock. School enrollment had shown an overall increasing trend but a substantial drop in enrollment this year caused a shift to a declining recent trend. It is unknown whether this drop is due to inherent demographic variability of reflects a true shift in community structure in the eastern ecoregion communities.

Finally, several aspects of the new information presented at the Aleutian Life Forum seem to be particularly adequate for its inclusion in the revision of the AIFEP and/or the current suite of indicators for the Aleutians. On one hand, the ability to introduce vessel traffic as an indicator provides background information on oil spill risk and increased use of the area by other sectors. Regional trends in CPR plankton data can provide further insight into the seasonality and distinctions in lower trophic level dynamics across regions. The wide variety of apps combined with community engagement offer a window of opportunity for citizen science to become one of the pillars in the future for monitoring the islands, a key contribution as adapting to a changing climate challenges current financial and human resources in marine resource management, particularly in remote areas.

Indicators

The suite of indicators that form the basis for the assessment was selected to provide a comprehensive view of the Aleutian Island ecosystem reflecting across trophic levels from the physical environment to top predators and humans, as well as both the nearshore and offshore. Ideally, they could be regularly updatable across all ecoregions, thereby characterizing a global attribute with local conditions. Although a single suite of indicators were chosen for the entire ecosystem, not all are available or applicable in each of the three ecoregions. The final selection reflected the limitations of available data sets for this region.

1. Winter North Pacific Index anomaly relative to the 1961-2000 mean
2. Reproductive anomalies of planktivorous least auklet and crested auklets as indicators of zooplankton productivity
3. Proportions of *Ammodytes*, gadids, and hexagrammids in tufted puffin chick diets
4. Apex predator and pelagic forager fish biomass indices
5. Sea otter counts
6. Steller sea lion non pup counts (juveniles and adults)
7. Percent of shelf <500m deep trawled
8. K-12 enrollment in Aleutian Islands schools

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

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

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

Proportions of hexagrammids, gadids, and *Ammodytes* in tufted puffin chick diets Tufted puffins (*Fratercula cirrhata*) are medium-sized seabirds that nest in varying densities throughout the Aleutians. The USFWS stations field biologists to monitor puffin chick diets annually at Buldir and Aiktak Islands (Figure 7) and less frequently at other Aleutian islands on which they occur. Puffins carry multiple prey items in their bills when they return to their colonies to feed their chicks. Forage fish and squid comprise most of puffin chick diets. In the absence of direct measures of forage fish abundance, time series of percent biomass of hexagrammids, gadids, and *Ammodytes* in puffin chick meals were selected as indicators of forage fish recruitment and system-wide productivity.

Apex predator and pelagic forager fish biomass indices We present two foraging guilds to indicate the status and trends for fish in the Aleutian Islands: apex predators and pelagic foragers. Each is described in detail below. This guild analysis was based on the time series available as part of the NOAA summer bottom trawl survey for the Aleutian Islands (Western and Central ecoregions) and the Aleutian Islands and Gulf of Alaska combined (Eastern ecoregion). These two guilds are based on the aggregation of Aleutian species by trophic role, habitat and physiological status. The species included in each guild are listed in Table 2.

Table 2: Species included in foraging guild-based fish biomass indices for the Aleutian Islands

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

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

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

Sea otter survey methods are detailed in Doroff et al. Doroff et al. (2003). Skiff-based surveys of sea otters were conducted several times during 2003, 2005, 2007, 2009 and 2011 at Amchitka Island, Kiska and Little Kiska Islands, Attu Island, Agattu Island, Rat Island and the Semichi Islands when viewing conditions were good to excellent (Beaufort sea state of 1-2, and .1 km of clear visibility at sea level). Full surveys were not conducted in 2011 at Kiska and Little Kiska Islands, in 2003 at Rat Island, and in 2005 and 2011 at the Semichi Islands. Two or more observers counted sea otters from a 5.2-m skiff as it was run parallel to shore along the outer margins of kelp (*Alaria fistulosa*) beds at 15-22 km/h. Sea otters were counted with the unaided eye, using binoculars to confirm sightings or to count animals in large groups. The shoreline of each island was divided into contiguous segments, each 3-10 km in length and separated by distinctive topographic features (e.g., prominent points of land). Counts were recorded separately for each section. To maximize the time series available for this assessment, only counts of otters at Attu are presented for the Western ecoregion and counts at Amchitka for the Central ecoregion.

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

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

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

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

Habitat disturbance from trawls This new indicator uses output from the Fishing Effects (FE) model to estimate the habitat reduction of geological and biological features over the Bering Sea domain, utilizing spatially-explicit VMS data. The effects are cumulative, incorporating both estimated recovery time and disturbance. The time series for this indicator is available since 2003, when widespread VMS data became available. The monthly value in December is used as an annual indicator.

K-12 enrollment in Aleutian Islands schools The number of children enrolled in schools was selected as an indicator of vibrant, sustainable communities in the Aleutian Islands ecosystem. Community residents are closely tied to the ecosystem through sense of place and daily experience and activity. Enrollment statistics for kindergarten through twelfth (K-12) grades by school and region were compiled for the years 1996 through 2014 (`http://www.eed.state.ak.us/stats/`).

School enrollment numbers fluctuate widely and serve to highlight the difficulties in maintaining sustainable communities within the Aleutian Islands ecosystem.

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 edition of the report. Please see archived versions available at: `http://access.afsc.noaa.gov/reem/ecoweb/index.php`

Physical Environment

North Pacific Climate Overview

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Last updated: August 2016

Summary: *The state of the North Pacific atmosphere-ocean system during 2015-2016 featured the continuance of warm sea surface temperature (SST) anomalies that became prominent late in 2013, with some changes in the pattern. The evolution of the SST distribution can be attributed to the seasonal mean sea level pressure (SLP) and wind anomalies, particularly cyclonic wind anomalies in the central Gulf of Alaska in winter 2015-16 and spring 2016, with a reversal to anticyclonic flow in the following summer of 2016. The Bering Sea experienced the third consecutive winter of reduced sea ice, in what may turn out to be the early stage of an extended warm spell. The Pacific Decadal Oscillation (PDO) was positive during the past year, especially during spring 2016. The climate models used for seasonal weather predictions are indicating borderline to weak La Niña conditions for the winter of 2016-17, while maintaining North Pacific SST anomalies in a PDO-positive sense.*

Regional Highlights:

West Coast of Lower 48. This region continues to be impacted by warm ocean temperatures. These anomalies were not restricted to just the very upper part of the water column but rather extended to as much as 200-300 meters depth based on data from ARGO profilers. The winter of 2015-16 featured above-normal precipitation in the Pacific Northwest and below normal precipitation in southern California, with ∼1 standard deviation warmer than normal temperatures along the entire coast. The end of winter snowpack was above normal in the Pacific Northwest and near normal in northern California; relatively warm weather in spring 2016 resulted in an early melt. Many streams ran low and warm in the summer of 2016 but not as severe an extent as was observed in 2015. The spring and summer of 2016 from around Vancouver Island to Point Conception included relatively robust upwelling in the northern portion and a thin strip of water of moderate temperatures in the immediate vicinity of the coast. Further south, downwelling wind anomalies prevailed.

Gulf of Alaska. The upper ocean in this region was relatively salty in fall 2015, presumably at least in part due to the lack of lower elevation snow that was melted during the fall rains. On the other hand, there was an early freshening in 2016 due to the anomalously warm winter and hence more rain than snow than usual in coastal watersheds. 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 contribution in the Ecosystem Considerations 2016 for the Gulf of Alaska report. The coastal wind anomalies were generally downwelling favorable during winter and spring but switched to more upwelling favorable during the summer of 2016. A prominent eddy was located on the outer shelf south of the Kenai Peninsula during the summer of 2016 and probably contributed to enhanced cross-shelf exchanges in its immediate vicinity.

Alaska Peninsula and Aleutian Islands. The waters of this region were relatively warm, especially in the fall of 2015 and summer of 2016. In part this can be attributed to the overall warmth of the North Pacific and in part to the weather, which featured persistently above normal air temperatures during the past year with only short and minor exceptions. Based on synthetic data from NOAA's Global Ocean Data Assimilation System (GODAS), the Alaskan Stream appears to have had a relatively strong westward flow from late 2015 into 2016. The GODAS product suggests there were pulses in the strength of the eastward flow associated with the Aleutian North Slope Current.

Bering Sea. The Bering Sea shelf experienced a much warmer than normal winter and spring, for the 3rd year in a row. The warm weather can be attributed mostly to the deeper than usual Aleutian low and a preponderance of air masses of maritime rather than of Arctic or continental origins. There was little sea ice south of 59°N and consequently a lack of a cold pool in the middle domain of the southern Bering Sea shelf. The early summer of 2016 was also less stormy than typical. During August 2016, total heat contents on the shelf were at or near record levels.

Arctic. Remarkably warm air temperatures occurred in the central Arctic during the winter of 2015-16, mostly due to an anomalous atmospheric circulation leading to intrusions of mild air from the mid-latitudes. One implication is that there was probably less growth than usual in the thickness of first-year ice over much of the Arctic. A modest cold snap in late September in the Chukchi and Beaufort Seas marked the end of the 2015 melt season, but it was not until November 2015 before the shelf regions of these seas were covered by ice. A coastal polynya developed early in the season (the first week of May) in the eastern Chukchi Sea from approximately Cape Lisburne to Point Barrow. In the Beaufort Sea, rapid melting during August of a large area near the coast resulted in a broad band of open water from near Point Barrow to beyond the Mackenzie River delta. During summer 2016, the sea ice extent in the Beaufort Sea was considerably less than any of the previous 4 summers; for the Chukchi Sea the ice extent during the summer of 2016 has been comparable to that of recent summers. For the Arctic as a whole, the area of sea ice cover during the middle of August 2016 was slightly less than 2 standard deviations below normal, which represents the 3rd lowest value in the observational record.

Sea Surface Temperature and Sea Level Pressure Anomalies

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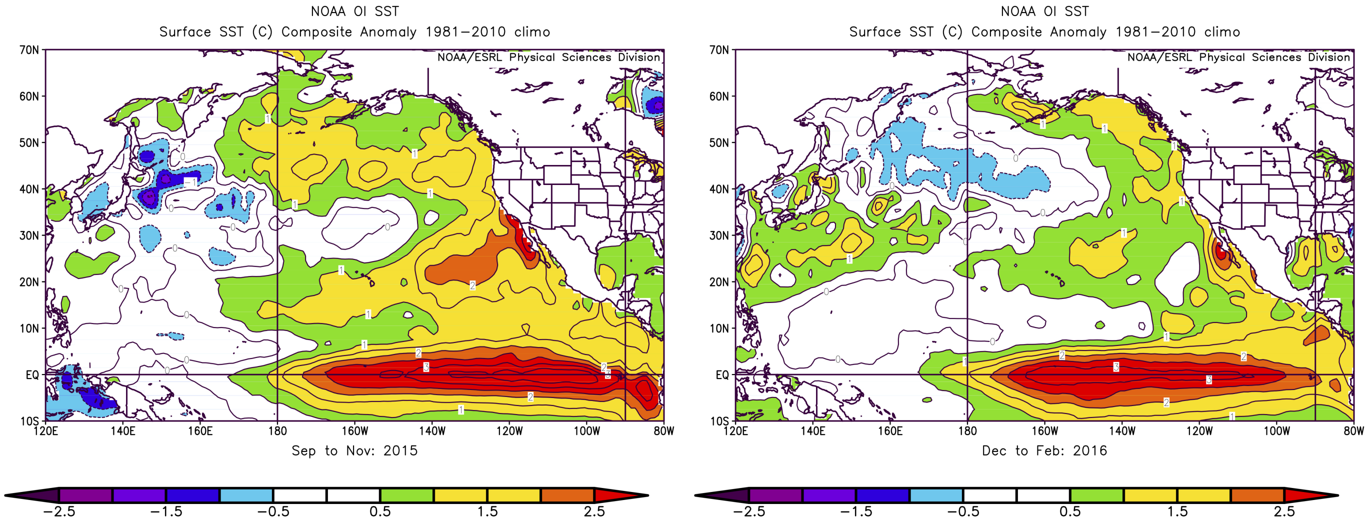
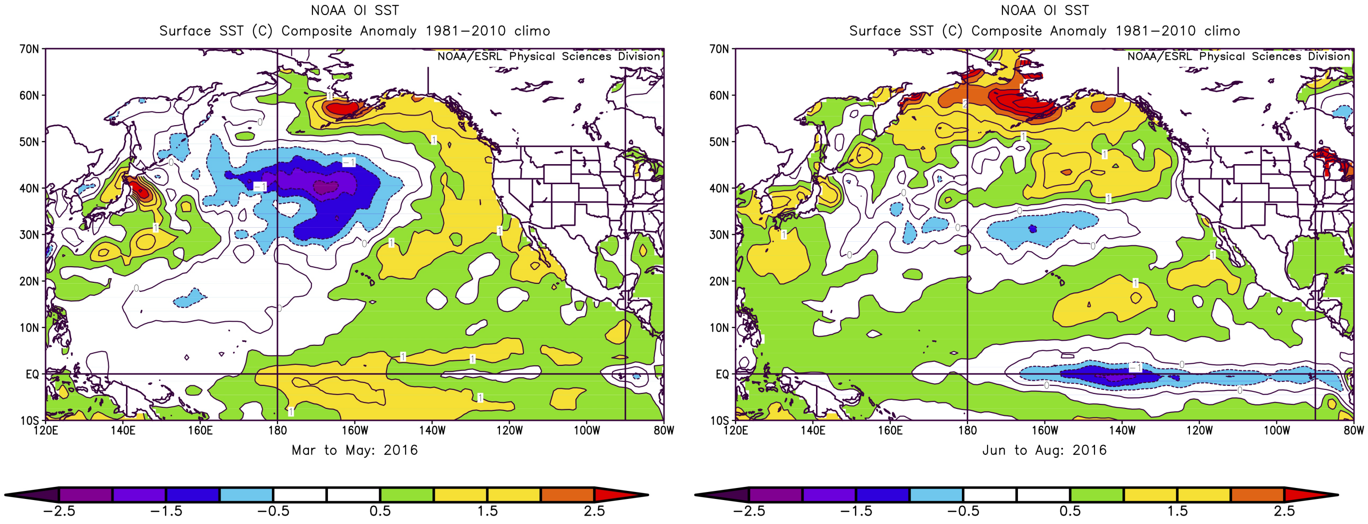
Description of indices: The state of the North Pacific climate from autumn 2015 through summer 2016 is summarized in terms of seasonal mean sea surface temperature (SST) and sea level pressure (SLP) anomaly maps. The SST and SLP anomalies are relative to mean conditions over the period of 1981-2010. The SST data are from NOAA's Optimum Interpolation Sea Surfacae Temperature (OISST) analysis; the SLP data are from the NCEP/NCAR Reanalysis project. Both data sets are made available by NOAA's Earth System Research Laboratory (ESRL) at `http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl`. Previous versions of this overview included SST anomaly distributions based on NOAA's Extended Reconstructed Sea Surface Temperature (ERSST) V4; here the OISST analysis is used because of its finer-scale resolution, and incorporation of satellite data, which is valuable in regions where direct observations of SST by ships and buoys are sparse.

Status and trends: The anomalies that occurred during the past year in the North Pacific beginning in autumn of 2015 reflect, to a large extent, the maintenance of conditions that developed during the previous 1-2 years. In particular, a leading large-scale climate index for the North Pacific, the Pacific Decadal Oscillation (PDO), remained positive, following a transition in sign early in 2014. More detail on the evolution of the SST and SLP from a seasonal perspective is provided directly below.

The SST in the North Pacific during the autumn (Sep-Nov) of 2015 (Figure 10a) was warmer than normal east of the dateline. The positive anomalies were especially prominent off southern and Baja California and in the eastern tropical Pacific, the latter in association with a strong El Niño. The pattern of anomalous SLP during autumn 2015 featured strongly negative anomalies extending from Bering Strait into northwestern Canada with higher than normal pressure from the Kamchatka Peninsula into the central Gulf of Alaska (GOA). This SLP pattern implies wind anomalies from the west across the Bering Sea and anomalous upwelling in the coastal waters of the GOA.

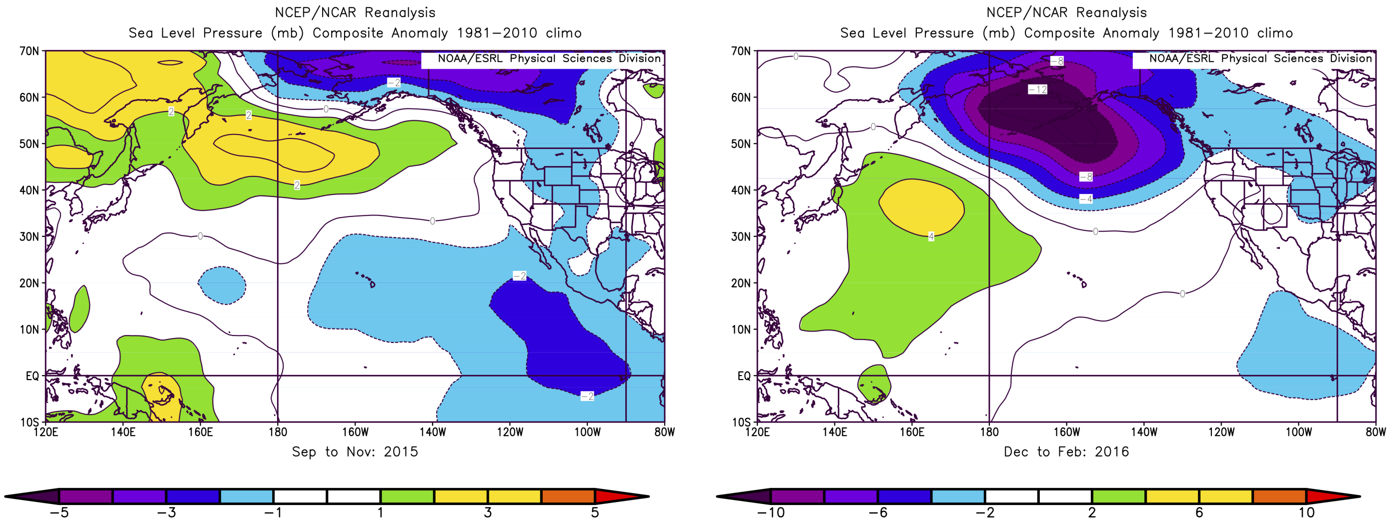


(a) Autumn (b) Winter

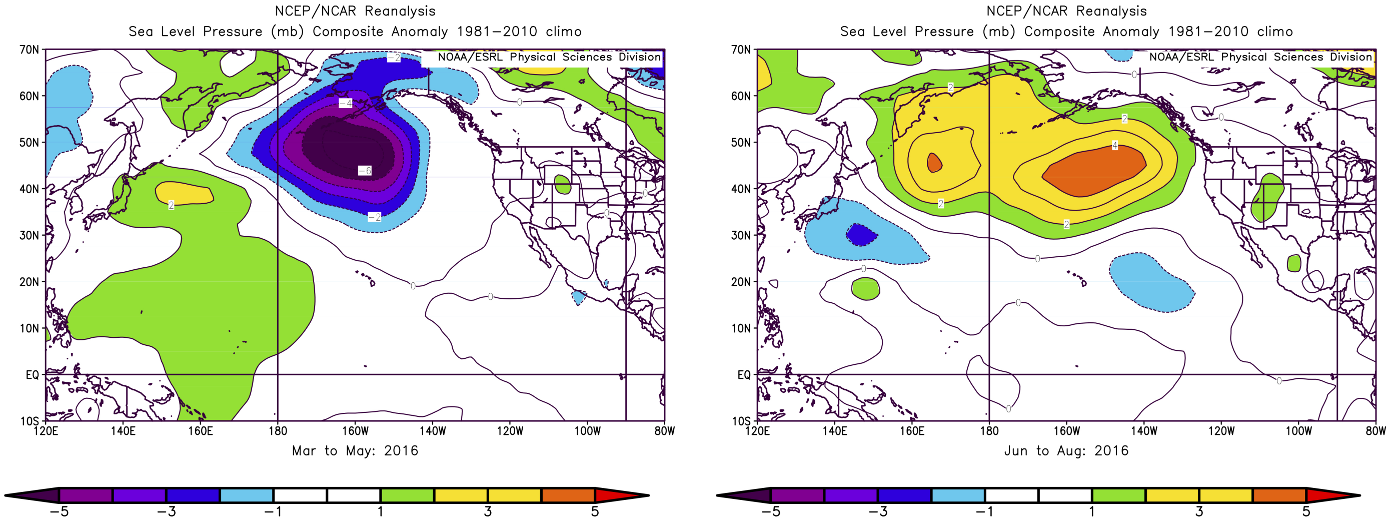


(c) Spring (d) Summer

Figure 10: SST anomolies for autumn (September-November 2015), winter (December 2015 -February 2016), spring (March - May 2016), and summer (June - August 2016).



(a) Autumn (b) Winter



(c) Spring (d) Summer

Figure 11: SLP anomolies for autumn (September-November 2015), winter (December 2015 -February 2016), spring (March - May 2016), and summer (June - August 2016).

The pattern of North Pacific SST during winter (Dec-Feb) of 2015-16 relative to the seasonal mean (Figure 10b) resembled that of the preceding autumn with the exception of the western Bering Sea and Aleutian Islands, which cooled to near normal. The latter cooling was associated with anomalous winds out of the northwest in association with extremely low SLP (negative anomalies exceeding 12 mb) over the eastern Bering Sea and western GOA (Figure 11b). For the area of 50°N to 60°N, 170°W to 150°W, the SLP was more than 3 mb lower than that during any other December through February in the record back to 1949. This meant relatively frequent gale force winds and high wave heights for the region. A deeper than normal Aleutian Low commonly occurs during El Niño (whose signature is prominent in Figure 10b) but the center of the anomalous SLP was displaced to the northwest from its usual position during winters with strong El Niños. The anomalous southerly flow to the east of the SLP anomaly minimum brought relatively warm air to the northern Gulf of Alaska, especially from late January into February during which surface air temperatures were about 6°C above normal. The coastal region of the GOA therefore received a greater proportion of rain versus snow than usual at lower elevations, but it is uncertain whether the GOA experienced significantly more freshwater runoff than typical for the season.

The distribution of anomalous SST in the North Pacific during spring (Mar-May) of 2016 (Figure 10c) bore some resemblance to that of the season before, with an increase in the magnitude of the positive anomalies in the eastern Bering Sea and GOA. Moderate cooling occurred in the central North Pacific in the vicinity of 40°N, 170°W. The overall pattern projected strongly on the positive phase of the Pacific Decadal Oscillation (PDO) as will be discussed further below. The SST anomalies in the central and eastern tropical Pacific decreased as El Niño wound down. The SLP anomaly pattern (Figure 11c) for spring 2016 was similar to that of the previous winter season, with a weaker negative anomaly shifted southeast of its previous location. Lower than normal SLP over a broad region extending from the southeastern Bering Sea towards the west coast of the lower 48 states often occurs in the springs following El Niño winters.

The SST anomaly pattern in the North Pacific during summer (Jun-Aug) 2016 is shown in Figure 10d. It was warmer than normal in the north, with especially positive anomalies region exceeding 3°C in the southeastern Bering Sea. Relatively cool water was present in a broad band between roughly 25°N and 40°N from the east coast of Asia to the central North Pacific, with the most negative anomalies located north of the Hawaiian Islands. Warm water persisted in the subtropical North Pacific. Finally, cold anomalies developed in a narrow strip along the equator in the east-central Pacific, signifying the demise of El Niño and the potential for the development of La Niña. The distribution of anomalous SLP (Figure 11d) during summer 2016 featured higher than normal pressure between the Alaska Peninsula and the Hawaiian Islands that was almost opposite to that of the previous season. The relatively high SLP extended into the Bering Sea and was associated with seasonally suppressed storminess and hence scant vertical mixing of the upper ocean, resulting in the very warm surface temperatures shown in Figure 10d. The higher than normal SLP off the coast of the Pacific Northwest and California brought about strong coastal upwelling, and a moderation of SST in the immediate vicinity of the coast.

Climate Indices

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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 2006 through early summer 2016 are plotted in Figure 12.

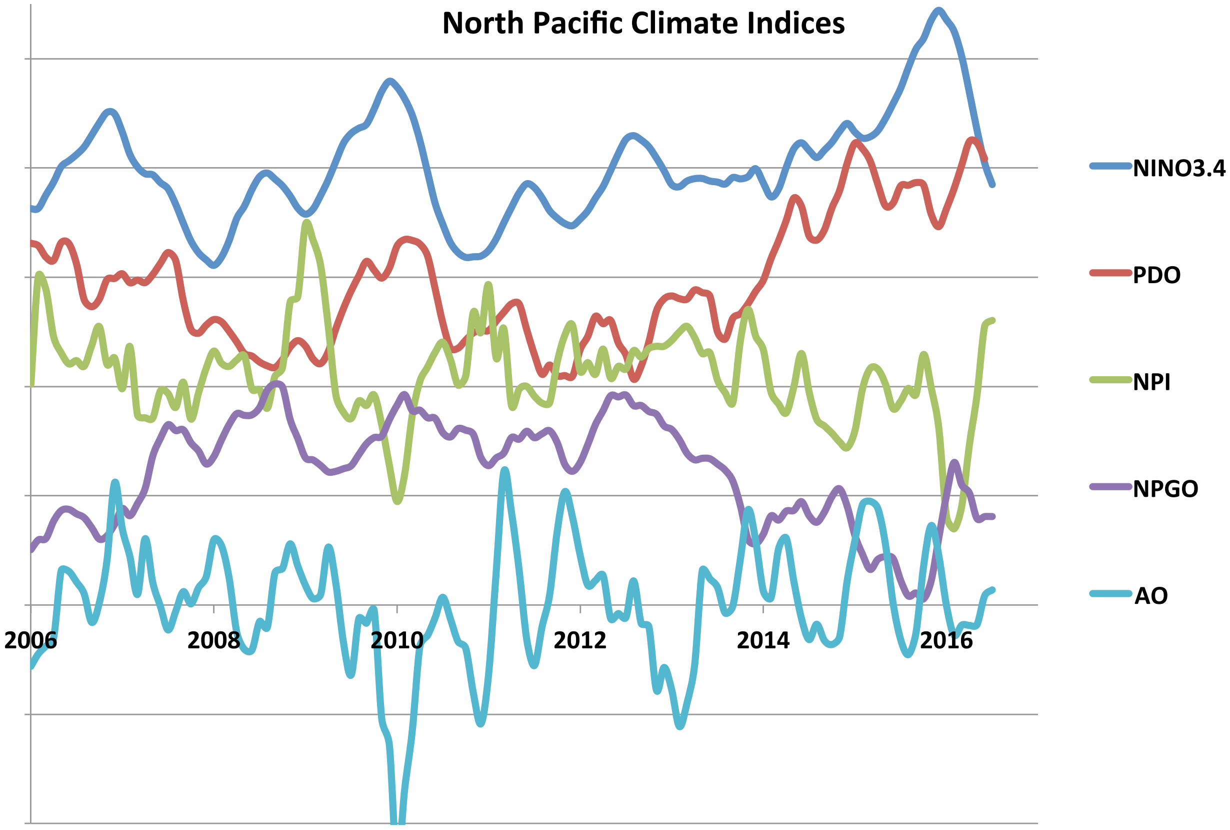

Figure 12: Time series of the NINO3.4 (blue), PDO (red), NPI (green), NPGO (purple), and AO (turquoise) indices. Each time series represents monthly values that are normalized and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 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 has been in a highly perturbed state recently. Specifically, NINO3.4 reached a peak value of 2.3 in December 2015 in association with the strong El Nino of 2015-16. This measure of ENSO has declined over the first 8 months of 2016 and is now slightly negative. The PDO has been positive (indicating warmer than normal SST along the west coast of North America and cooler than normal in the central and western North Pacific) during the last 2 years. The magnitude of the PDO actually decreased in 2015 during the ramp-up of El Niño, which is unusual. It generally tracks ENSO, with a lag of a few months, as illustrated here for the period of 2008-13 in Figure 12 The PDO did increase in early 2016 to a value exceeding +2, followed by a decrease in late spring/early summer 2015. The NPI was strongly negative during the past winter and spring, which implies a deeper than normal and often displaced Aleutian Low, as indicated in Figures 10b and 11b). This represents a typical atmospheric response to El Niño. The deep Aleutian Low was accompanied by anomalous winds from the south and relatively warm air along the west of North America, i.e., atmospheric forcing favoring a positive trend in the PDO.

The North Pacific Gyre Oscillation (NPGO) underwent a transition from negative in 2015 to a near-neutral state in 2016. A negative sense of this index, which is formally related to the 2nd mode of variability in sea surface height in the North Pacific, 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 Ocean, 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 during the latter portion of 2015, and then mostly negative during early 2016. Most winters since 2009-10 have included relatively strong and persistent (multi-month) signals in the AO, in either the positive and negative sense, but that was not the case for the winter of 2015-16.

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

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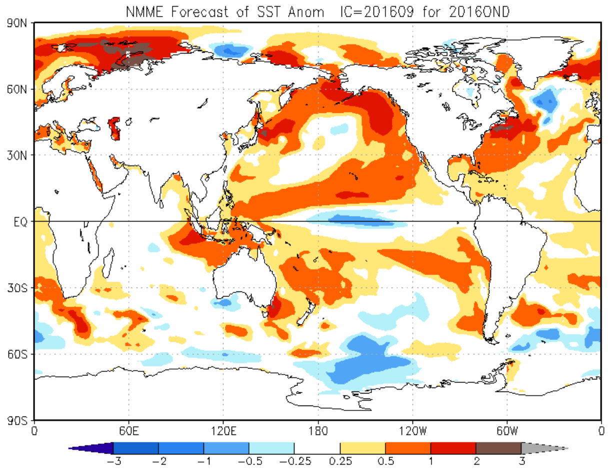
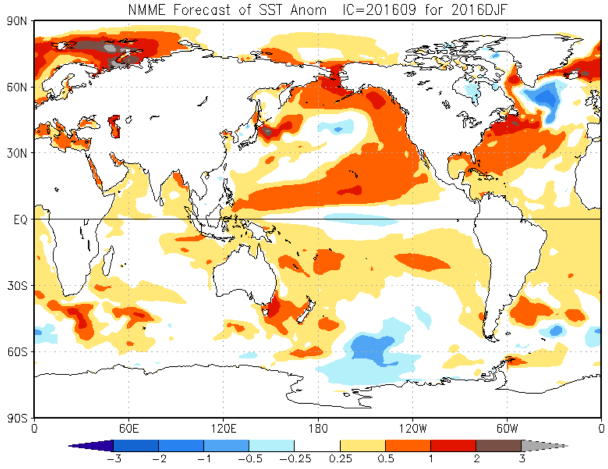
Last updated: August 2016

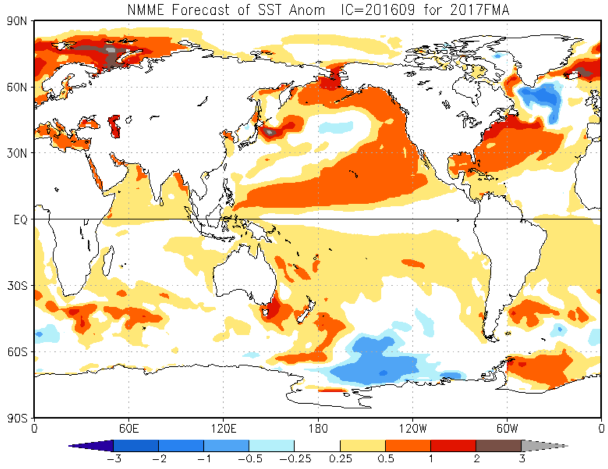
Description of indicator: Seasonal projections of SST from the National Multi-Model Ensemble (NMME) are shown in Figure 13. An ensemble approach incorporating different models is particularly appropriate for seasonal and longer-term simulations; the NMME represents the average of eight models. The uncertainties and errors in the predictions from any single climate model can be substantial. 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 13: Predicted SST anomalies from the NMME model for OND (1 month lead), DJF (3 month lead), and FMA (5 month lead) for the 2016-2017 season.

Status and trends: These NMME forecasts of three-month average SST anomalies indicate a continuation of warm conditions across most of the North Pacific through the end of the year (Oct-Dec 2016) with a smaller region of near normal temperatures northwest of the Hawaiian Islands (Figure 13a). The magnitude of the positive anomalies is projected to be greatest (exceeding 1^o) in the GOA and eastern Bering Sea. Negative SST anomalies are projected in the central equatorial Pacific. The latter are associated with the potential for a weak La Niña. As of August 2016, 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 winter indicates a 55 to 60% chance of La Niña by fall 2016. The overall pattern of SST anomalies across the North Pacific is maintained through the 3-month periods of December 2016 to February 2017 (Figure 13b) and February to April 2017 (Figure 13c) with a modest cooling in the central North Pacific and moderation of negative anomalies in the equatorial Pacific.

Implications It is unclear whether the equatorial Pacific will be perturbed enough, particularly with respect to the intensity and distribution of deep atmospheric convection, to cause the usual response to La Niña. Past La Niña events have included a weaker than normal Aleutian low and a relatively cold winter for Alaska, western Canada and the Pacific Northwest. On the other hand, the models comprising the NMME are indicating remote responses to the equatorial Pacific that are relatively weak, and in consensus, slightly warmer than normal temperatures for western North America. These competing signals suggest that the North Pacific climate may be in a state of rather low predictability. That being said, it is unlikely that the upcoming winter in Alaska and western Canada will be as mild as those of the last three years.

Also, the SST anomaly maps shown in Figure 13 share an unusual feature, and that is the co-existence of a relatively cold equatorial Pacific with a horseshoe-shaped pattern of warm water along the west coast of North America, a signature of the positive phase of the PDO. The closest analog to that situation in recent decades was from late 1980 into spring 1981. In that case, the PDO was not as strongly positive as predicted for the upcoming winter and spring, and the NINO3.4 anomalies were of modest amplitude (about -0.4 in early 1981). The maintenance of positive PDO conditions in the North Pacific during the upcoming year, despite an ENSO state that generally brings about an SST anomaly pattern associated with the negative phase of the PDO, could be a reflection of the enormous amount of extra heat in the upper ocean now present along most of the west coast of North America, and the model projections of a muted atmospheric response in the mid-latitudes to the equatorial Pacific during the next two seasons.

Eddies in the Aleutian Islands

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Description of indicator: 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 14) 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 15) 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 Ssalto/Duacs altimeter products were produced and distributed by the Copernicus Marine and Environment Monitoring Service (CMEMS) (`http://www.marine.copernicus.eu`).

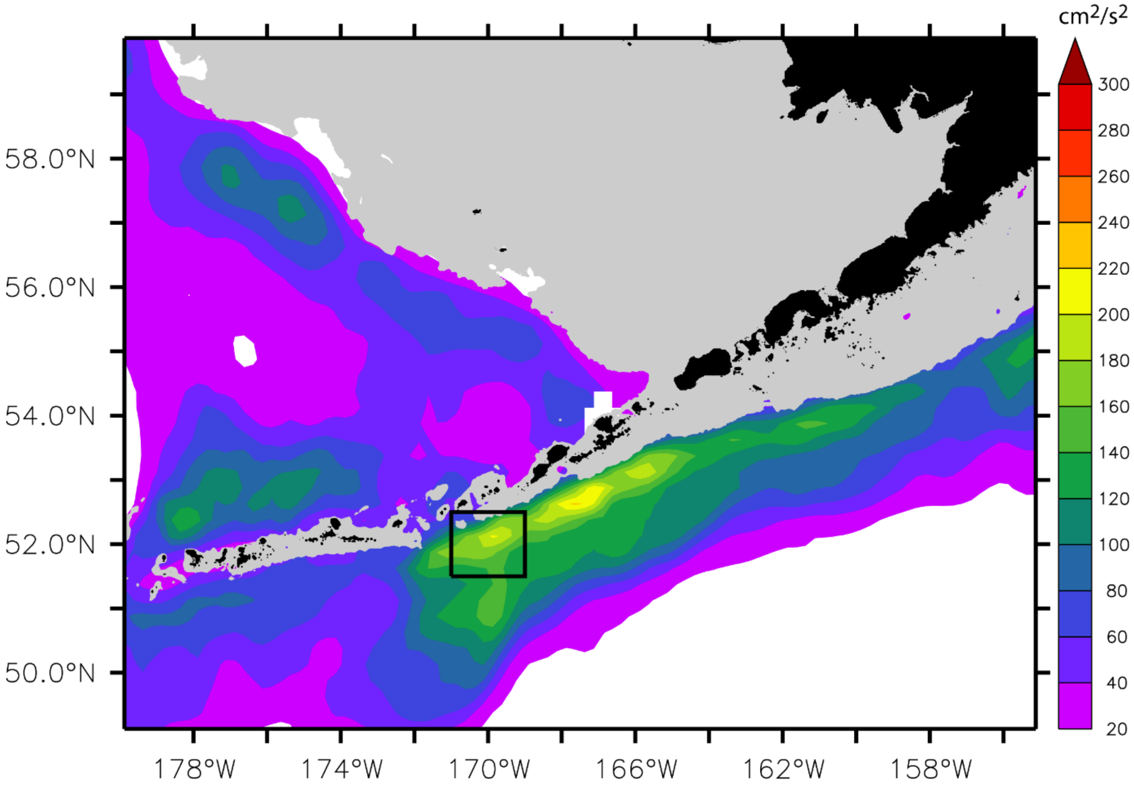

Figure 14: Eddy Kinetic Energy averaged over October 1993 - October 2015 calculated from satellite altimetry. Square denotes region over which EKE was averaged for Figure 15.

Status and trends: Particularly strong eddies were observed south of Amukta Pass in 1997, 1999, 2004, 2006/2007, 2009/2010, and summer 2012. Eddy energy in the region has been low from the fall 2012 through June 2015. In early 2016, a small eddy was present in the region, resulting in slightly above average EKE.

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

Implications: These trends indicate that higher than average volume, heat, salt, and nutri-

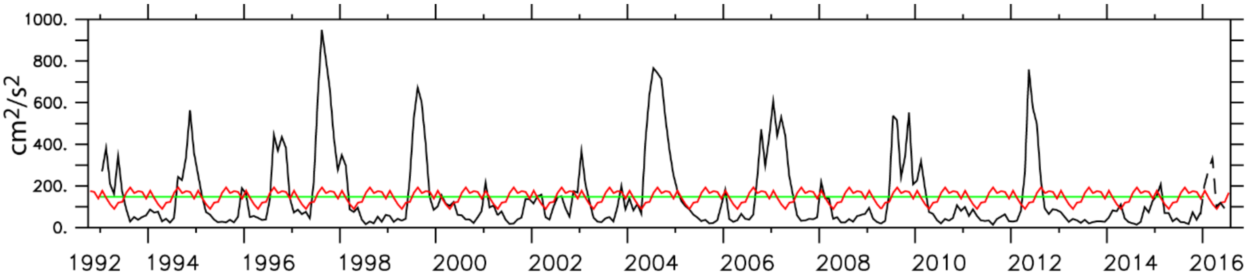

Figure 15: Eddy kinetic energy (cm^2 s^{-2}) averaged over region shown in Figure 14. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product). Red: seasonal cycle. Green (straight line): mean over entire time series.

ent 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 2015 and may have been slightly enhanced in early 2016.

Water Temperature Data Collections - Aleutian Islands Trawl Surveys

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Last updated: October 2016

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

Water temperature data have been routinely collected during National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering Division (RACE) AI bottom trawl surveys since 1994. Microbathythermographs attached to the headrope of the net measure and record temperature and depth during each trawl haul. In 2004, the SeaBird (SBE-39) microbathythermograph (Sea-Bird Electronics, Inc., Bellevue, WA) that is in use today replaced the Brancker XL200 data logger (Richard Brancker Research, Ltd., Kanata, Ontario, Canada) which had been in use since 1993. The analyses presented here utilize all available bathythermic data collected on AI bottom trawl surveys since 1994.

The RACE AI bottom trawl survey typically begins in late May-early June and proceeds west over the next three months of the summer. The anticipation of increasing water temperature with advancing collection date during as the survey progresses westward over the summer leads to spatially and temporally confounded data that complicates inter-annual comparisons. Additionally, in 2002 and 2006, our typical sampling progression was partially reversed with the later season survey progressing from west to east. There were three triennial AI bottom trawl surveys between 1994 and 2000; since 2000 the surveys have been conducted biennially (except in 2008 when there was no AI bottom trawl survey).

To account for the influence of changing day length on water temperatures over the course of the summer and to make inter-annual comparisons more meaningful, we used a generalized additive model (GAM) to assign a standardized collection day to water temperature measurements. The standard collection day was set to an approximate median date from all of our summer surveys (i.e., July 10). Collection day-standardized water temperatures from the trawl downcast (the period of time between when the trawl net is released to sink and the center of the footrope touches the bottom) were binned into depth intervals from a depth of 3 m to the deepest depth of the tow and averaged for each bin. Finer depth increments were employed nearer the surface to capture the rapid changes in water temperatures often seen in shallower depths; broader increments were used in deeper depths where changes are not as rapid. The resulting model was used to predict the temperature at depth on the standard date. Residuals from this GAM were added back to the predicted temperatures yielding an estimate of thermal anomaly from the model prediction. These median date-standardized temperature anomalies were then binned into ½ degree longitude-by-depth increments and the mean of each bin was reported. To enhance the visual separation of the mid-range temperature anomalies, we manipulated the color gradient in the plots so that predicted temperature anomalies > 7.5°C and < 3.5°C were fixed at 7.5 and 3.5°C (e.g., a 12.5°C temperature anomaly was recoded as 7.5°C for the graphic representation).

Status and trends: The temperature anomaly profiles from the 2016 AI survey data appear to be some of the warmest in our record (Figure 16). These warm anomalies are also some of the most pervasive (vertically and longitudinally) recorded to date. The profiles from 2016 are visually similar to those of 2014 and share the characteristics of widely distributed warm surface waters along with greater thermal stratification although the 2016 anomalies are more broadly dispersed and penetrate deeper. By contrast, the 2000 AI survey remains one of the coldest years in the record. These marked differences amongst survey years illustrate the highly variable and dynamic oceanographic environment found in the Aleutian archipelago.

Most survey years share common thermal profile features (Figure 16). These include warmer surface temperatures east of Amukta Pass (170° 30'W), between Seguam Pass (173° W) and Amchitka Pass (179° W), and west of Buldir Pass (175° E). The influence of these warmer surface temperatures generally extends to around 100 m depth, although in the warmest years it can be detected at deeper depths. Cooler temperatures at depths > 100 m consistently occur around Seguam Island (172° 30'W) and this seems to be a particularly striking feature in colder years (e.g., 2000, 2012). Cooler temperatures at depths ¿ 100 m are frequently a dominant feature west of 175° E, although in colder years this area of cooler water mass extends as far east as Amchitka Pass. Strong vertical mixing, indicated by relatively homogenous thermal profiles, dominate the Aleutian passes and, in cooler years, much of the region. During warmer years, mixing in the passes appears to weaken, resulting in more pronounced thermal stratification of the water column (e.g., 1997, 2014, and now, 2016). In the warmest years, these thermally stratified waters can be observed across the region.

Factors influencing observed trends: Water temperature data collected during RACE AI bottom trawl surveys are brief snapshots taken by our vessels as they move through a very broad area. Since each temperature-depth bin represents data collected over brief temporal (e.g., minutes) but broad spatial (i.e., nautical miles) scales, our ability to draw conclusions from these models can be greatly affected by short-term phenomena such as storm events, tidal current velocity, and/or direction and persistence of eddies. More recent and larger scale phenomena may have longer-lasting implications on water temperatures in the region. The thermal signal caused by the Ridiculously Resilient Ridge of atmospheric high pressure that helped to establish the persistent warm water Blob in the Northeast Pacific in 2014 2015 (Bond et al., 2015; Di Lorenzo and Mantua, 2016) and which likely intensified the El Niño Southern Oscillation (ENSO) event of 2015-16 (Levine and McPhaden, 2016) probably influenced the temperatures observed on our 2016 survey. Daily plots of sea surface temperature anomalies (SST) show warmer surface waters extending from east to west during the summer of 2016. Due to these and other sources of variation not accounted for in the temperature model presented here, caution should be exercised when interpreting these results.

Implications: There are no obvious trends across survey years when visually comparing the water temperatures modeled here. However, there are notable similarities within classes of colder or warmer years. During colder years (e.g., 2000 and 2012), the relatively homogeneous profiles suggest limited vertical thermal stratification and deeper penetration of the mixed layer. Increased thermal stratification and shallower mixed-layer-depths during warmer years appear to form a relatively consistent pattern amongst warm years. The persistence of a well-defined thermocline has important implications for oceanographic processes in the AI.

The strength and persistence of eddies is believed to play a major role in mediating the transport of both heat and nutrients into the Bering Sea through the Aleutian passes (Maslowski et al., 2008). The formation and intensification of the warm blob in 2014 and 2015 followed by the ENSO in 2015-16 almost certainly influenced the temperatures observed during the 2016 RACE AI bottom trawl survey. Phenomena like these influence both Aleutian Islands and Bering Sea ecosystems and fish populations.

Thermal regime and mixed-layer-depth differences are known to influence regional biological processes and impact fish populations. In the AI, the magnitude of primary production depends on mixed-layer-depth (Mordy et al., 2005) while ontogenesis of Atka mackerel eggs and larvae is temperature dependent (Lauth et al., 2007). In addition, shifting summer temperature regimes in the eastern Bering Sea have resulted in lower pollock catches there (Stevenson and Lauth, 2012). Recent investigations into habitat-based definitions of essential fish habitat (EFH) in the AI demonstrate that water temperature can be an important determinant of EFH for many groundfish species (Rooper et al., in prep.). By considering interannual differences in water column temperatures and their implications, we can better utilize our survey data to understand the state of fish populations in the Aleutian Islands.

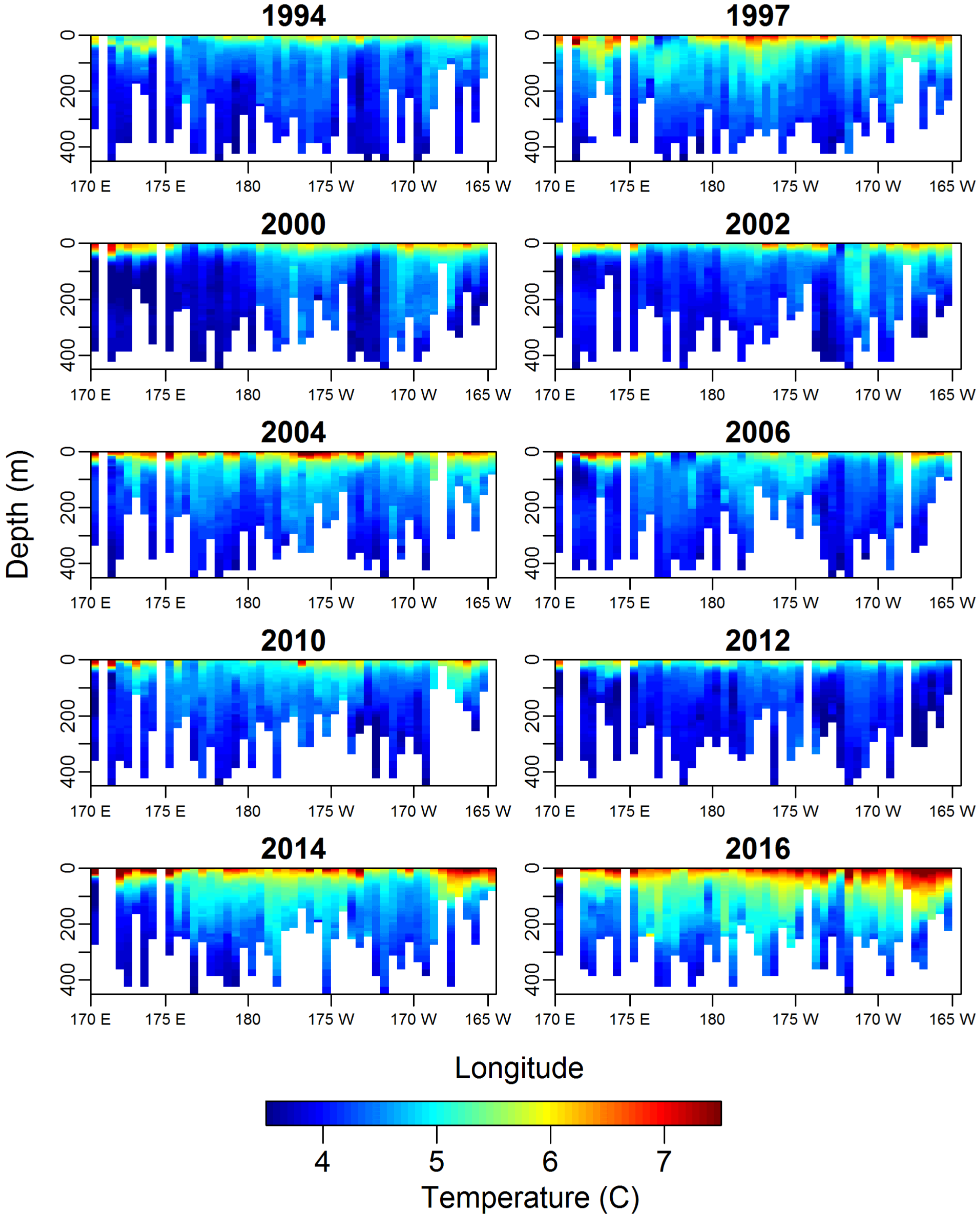

Figure 16: Date-standardized temperature (°C) anomaly profiles predicted by a generalized additive model (GAM) at systematic depth increments and ½-degree longitude intervals for Aleutian Islands bottom trawl survey years 1994-2016.

Spatial Patterns in Near Bottom Oceanographic Variables Collected during the Bottom Trawl Survey of the Aleutian Islands

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Last updated: October 2016

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

The CTD units collect concurrent depth, temperature, salinity, pH, oxygen and turbidity data. The units are deployed on the headrope of the AFSC bottom trawls during most survey hauls. To date, the data has been collected on the 2012 and 2016 EBS slope, the 2013 and 2015 GOA, and the 2014 and 2016 Aleutian Islands bottom trawl surveys.

The data are presented here as a series of maps of bottom variables (the average value of each variable during the on-bottom period of the bottom trawl haul). The data have been interpolated to a 1 km by 1 km raster using R software. For temperature, salinity, pH and oxygen kriging with a fitted exponential semi-variance model was used based on the spatial pattern in semi-variance plots. The turbidity data exhibited a linear decrease in semi-variance with distance, so inverse distance weighting was used for this variable. In the Aleutian Islands in 2014, there was no data collected east of Seguam Island, while in 2016 there is a gap in data collection between Samalga Pass and Petrel Bank (Figure 17). There were more than twice as many samples (n = 127) collected in 2014 than in 2016 (n = 52). The Aleutian Islands data were not corrected for time of the year, so some within-season temporal effects could be present because of the prosecution of the survey from east to west in the AI from June to August.

Status and trends: Bottom temperature appeared to be higher in 2016 than 2014 in areas where measurements were collected in both seasons (Figure 18). Consistent spatial patterns in the temperature and salinity data across were not apparent. However, salinities measured in both years ranged only from 32-35 ppt. Oxygen concentrations were similar between 2014 and 2016 in the western Aleutian Islands, where there were some areas of low oxygen concentration in the farthest western areas of the survey. The central AI in 2014 had higher oxygen concentrations than other areas of the survey, with the exception of Unimak Pass in 2016. pH was not collected in 2016 due to equipment failure. pH and oxygen varied spatially in the Aleutian Islands and also changed with depth. Both variables exhibited lower values on underwater banks (such as Petrel Bank) and generally the two values appeared to be correlated in 2014 and 2016. There were very low values of turbidity in 2014. This is very suspicious and may be the result of instrument failure. Values of turbidity were highest in 2016 in the southern Bering Sea and near Buldir Strait.

Factors influencing observed trends: The observed spatial trends in near bottom temperature and salinity are likely due to the relatively oceanic regime in the Aleutians west of Samalga Pass. The warmest and freshest water was found in the eastern Aleutian Islands and southern Bering Sea where Gulf of Alaska oceanography may have higher influence on water properties than in the

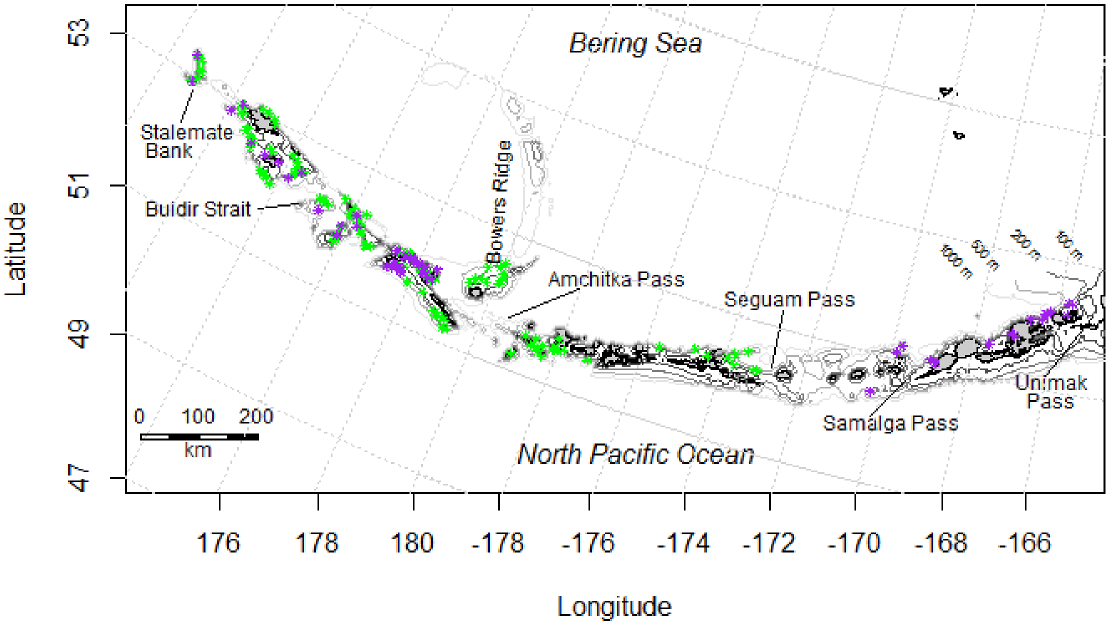

Figure 17: Locations for 2014 (green, n = 127) and 2016 (purple, n = 52) CTD deployments on the headrope of the bottom trawl used in the Aleutian Islands bottom trawl survey.

central and western AI. The observed trends in oxygen and pH in the Aleutian Islands are probably a result of the interaction between depth and currents moving through the passes. The turbidity is suspicious given the magnitude of the difference between the two years (all values < 1 in 2014 and up to $\sim$20 in 2016).

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

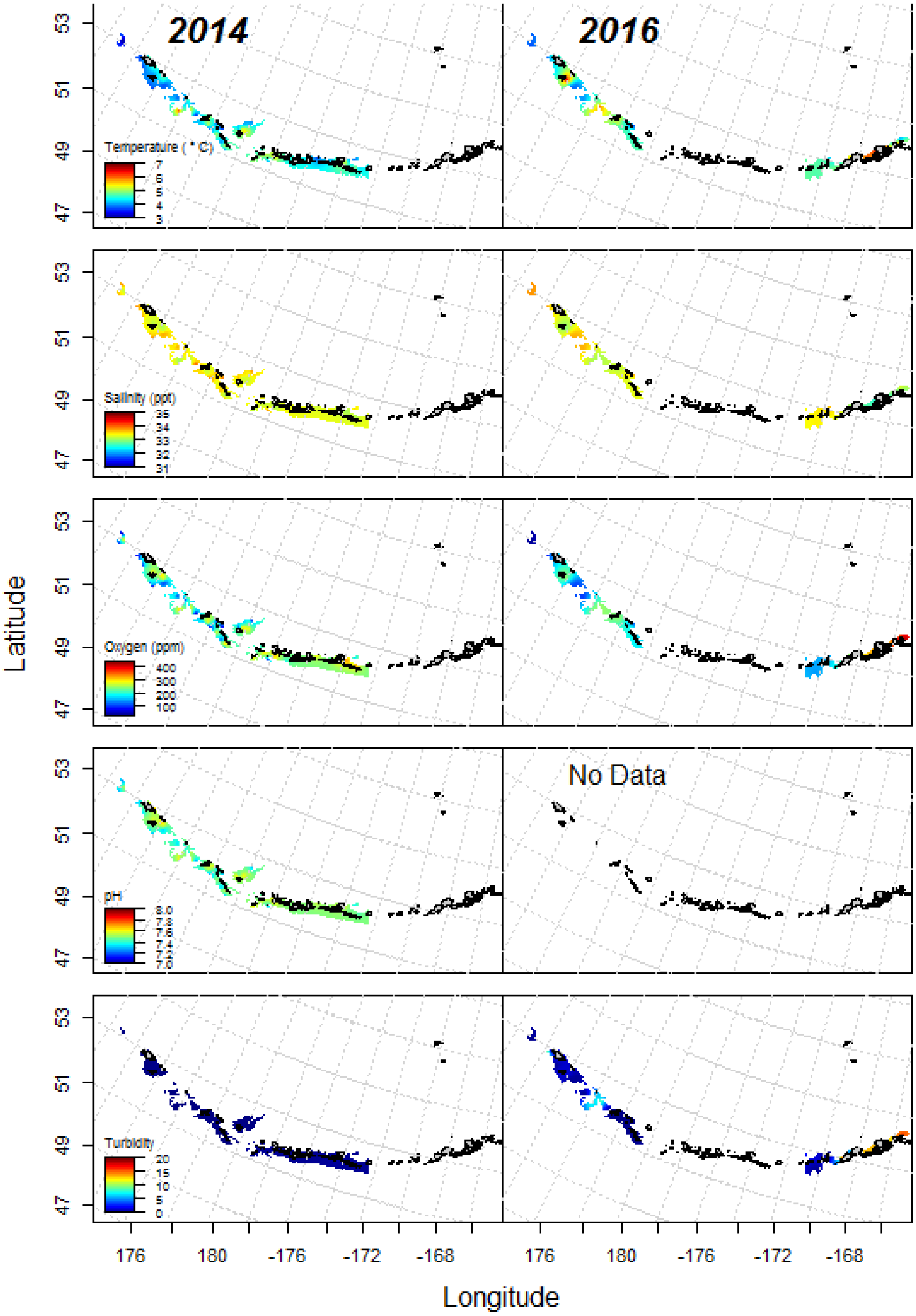

Figure 18: Spatial patterns in oceanographic variables (temperature, salinity, O2, pH and turbidity) measured on the seafloor during bottom trawl hauls in the Aleutian Islands groundfish survey in 2014 and 2016.

Habitat

Structural Epifauna - Aleutian Islands

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Description of indicator: Groups considered to be structural epifauna, formerly known as Habitat Area of Particular Concern (HAPC) biota, include seapens/seawhips, corals, anemones, and sponges. The biennial survey in the Aleutian Islands (AI) does not sample estimate the density of HAPC fauna well, but does seem to capture spatial trends in presence or absence Rooper et al. 2016, Rooper et al. in review). However, survey effort in rough or rocky areas where these groups are likely to be more abundant and survey effort is quite limited. The gears used by the Japanese vessels in the surveys prior to 1991 were quite different from the survey gear used aboard U.S. vessels in subsequent surveys and likely resulted in different catch rates for many of these groups. For each species group, the largest catch over the time series was arbitrarily scaled to a value of 100 and all other values were similarly scaled. The standard error (±1) was weighted proportionally to the CPUE to get a relative standard error.

Sponges include unidentified porifera, calcareous sponges, hexactinellid sponges and demosponges, which are the dominant group. Gorgonians include families of upright branching coral (primnoidae, plexauridae, isididae, etc.). Hydrocorals include stylasterid corals and stony corals. Soft corals are uncommon in the Aleutian Islands bottom trawl survey, but are represented by species such as gersemia. Sea anemones include all sea anemones captured in the bottom trawl surveys and pennatulaceans include sea pens and sea whips.

Status and trends: A few general patterns are clearly discernible (Figure 19). Sponges are caught in most tows (>80%) in the Aleutians west of the southern Bering Sea. Interestingly, the frequency of occurrence of sponges in the southern Bering Sea is relatively high, but sponge abundance is much lower than other areas. The sponge estimates for the 1983 and 1986 surveys are much lower than other years, probably due to the use of different gear, including large tire gear that limited the catch of most sponges and possibly recording inconsistencies. In recent years, the abundance of sponges in the western and central Aleutian Islands and the frequency of occurrence have been declining.

Gorgonian corals occur in about 20-40% of bottom trawl survey tows. Abundance of coral in all areas has declined since about 1991-1993 surveys and is at generally low levels in all areas, but the frequency of occurrence has remained steady. Hydrocorals are commonly captured, except in the southern Bering Sea. They typically occur in about 20-40% of tows in other areas. Similar to sponges, hydrocoral frequency of occurrence and abundance has decreased in the western and central Aleutian Islands over recent surveys (from a peak in the 2000 survey).

Soft corals occur in relatively few tows, except in the eastern Aleutian Islands where they occur in about 20% of tows. Their abundance time series is dominated by a couple of years (1986 in the western Aleutians and 1991 in the central Aleutians).

Sea anemones are also common in survey catches (∼20-40% of tows) but abundance trends are not clear for most areas. In the Southern Bering Sea abundance and frequency of occurrence have been increasing during recent surveys.

Sea pens are much more likely to be encountered in the southern Bering Sea and eastern AI than in areas further west. Abundance estimates are low across the survey area and large apparent increases in abundance, such as that seen in the eastern AI in 1997, are typically based on a single large catch.

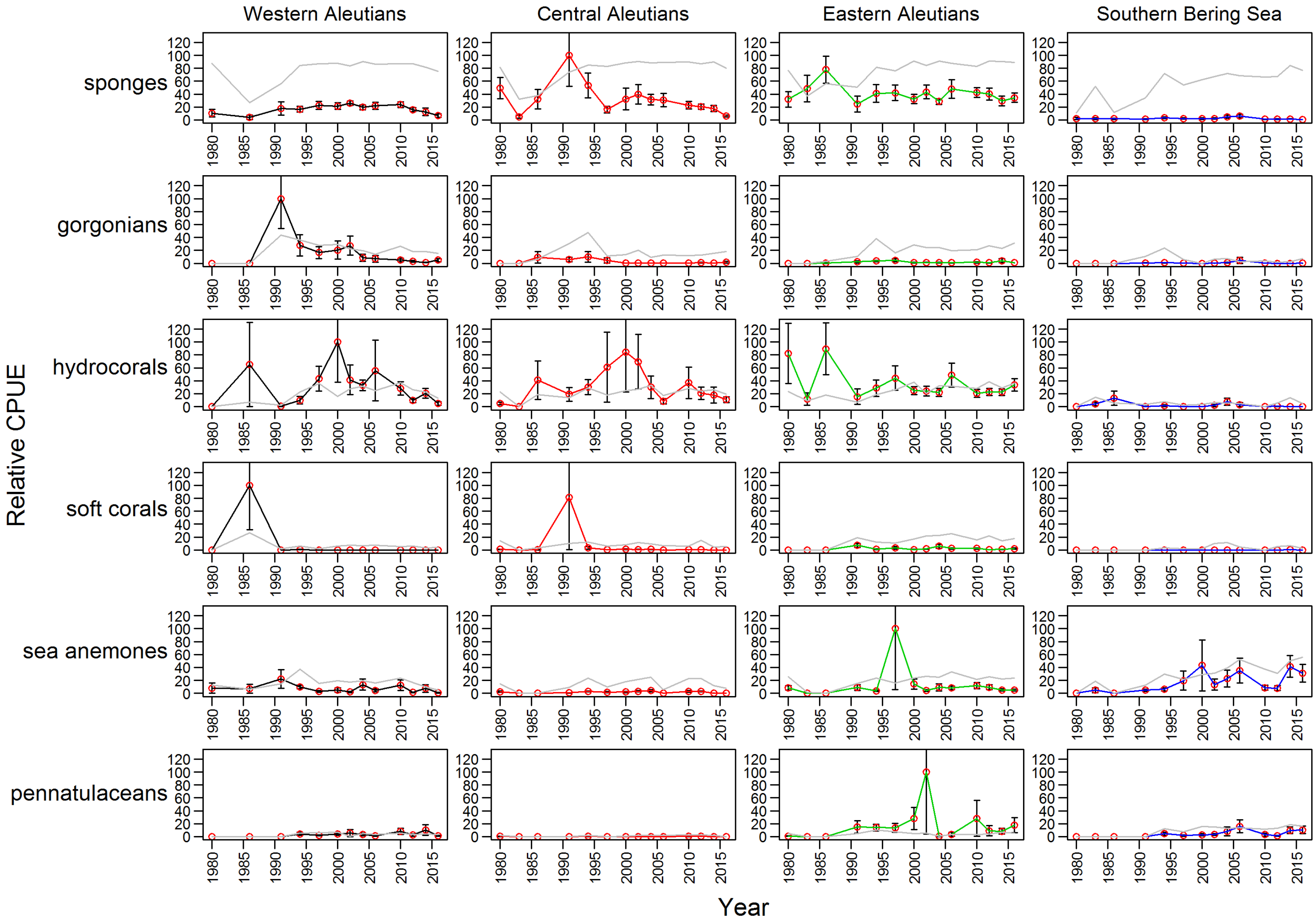

Figure 19: Mean CPUE of structural epifauna groups by area from RACE bottom trawl surveys in the Aleutian Islands from 1980 through 2016. Error bars represent standard errors. The gray lines represent the percentage of non-zero catches.

Factors influencing observed trends: The two major threats to populations of benthic invertebrates in the Aleutian Islands have been identified as fishing impacts and impacts of climate change. Both of these processes are occurring in the Aleutian Islands. Much of the benthic habitat in the Aleutians (∼50% of the shelf and slope to depths of 500 m) has been protected from mobile fishing gear since 2006, however, no studies have been conducted to determine potential recovery or expansion of populations due to the closures. As indicated by the 2016 bottom trawl survey temperature time series (p. 51), temperatures for the last two biennial surveys have been warmer than historical records. Non-motile organisms are sensitive to these changes in the benthic environment as well.

Implications: The Aleutian Islands bottom trawl survey is not particularly good at measuring the abundance trends of structural epifauna. However, the bottom trawl surveys are reasonably adept at capturing presence or absence trends as indicated by recent distribution model validation studies for the species groups. The recent declines in sponge, gorgonians and hydrocorals in the western and central Aleutian Islands should continue to be monitored.

Primary Production

There are no updates to primary production indicators in this year's report. See the contribution archive for previous indicator submissions at: `http://access.afsc.noaa.gov/reem/ecoweb/index.php`

Zooplankton

Continuous Plankton Recorder Data from the Northeast Pacific: Lower Trophic Levels in 2015

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Description of indicator: Continuous Plankton Recorders (CPRs) 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 is sampled monthly (∼Apr-Sept) and terminates in Cook Inlet; the second is sampled 3 times per year and 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 20); 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 weights and 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) is first calculated. Each sampled month is then compared to the mean of that month and an anomaly calculated (Log_{10}). The mean anomaly of all sampled months in each year is calculated to give an annual anomaly.

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 20). The oceanic NE Pacific region has the best temporal 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. Note that in 2015 the Bering Sea region was only sampled in the fall owing to a ship change in the spring so that the transect was cancelled, and a severe storm in the summer causing the ship to divert south away from the region.

Status and trends: Ocean conditions in 2015 were warm across much of the north Pacific, with strongly positive values of the Pacific Decadal Oscillation (PDO) through the year, and continued influence from the warm Blob first noted in 2014 (Bond et al., 2015) plus a strong El Niño that developed during the year. The lower trophic level indices showed some similarities to what was reported for 2014, driven largely by the warmth (Figure 21).

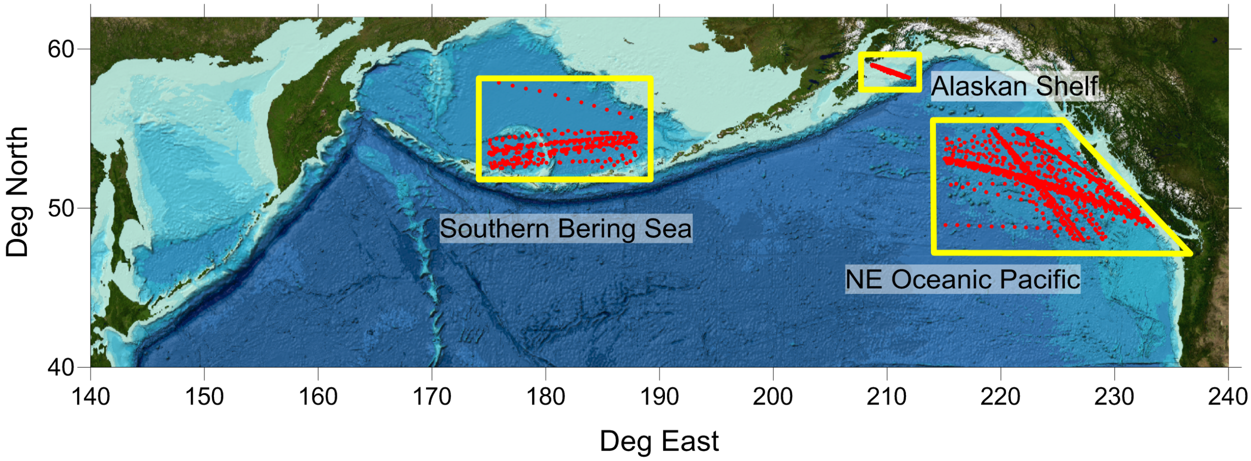

Figure 20: Boundaries of the three regions described in this report. Dots indicate actual sample positions (note that for the Alaskan Shelf region the multiple (>50) transects overlay each other almost entirely).

Diatom abundance anomalies were higher in 2015 on the Alaskan shelf and the oceanic region than they were in 2014. However, spring abundances were still low, and it was increased abundances later in the year which caused the overall anomalies to be more positive.

The Copepod Community Size index saw negative anomalies for all three regions. While the Alaska Shelf region had seen a bias towards smaller species since 2013, this was the first year since 2010 that the oceanic NE Pacific region had shown a negative anomaly. The Bering Sea data are only represented by the fall sampling but 2015 values were the smallest since 2009 at this time of year.

The mesozooplankton biomass anomalies were neutral in the oceanic NE Pacific region and Bering Sea region. For the Alaskan shelf region the value was quite high and similar to that of 2014, but it was the late summer/fall values that were unusually high with spring and summer values near average.

Factors influencing observed trends: Spring diatom abundances for the Alaskan Shelf and oceanic NE Pacific regions were low, and these communities contained a higher than usual proportion of pennate-type taxa. These taxa generally do better in lower nutrient conditions as their high surface area to volume ratio facilitates nutrient uptake compared to centric taxa. Diatom numbers had increased by the summer and fall, leading to positive anomalies in both regions and suggesting a change in the ocean conditions mid-way through the year.

The negative anomalies for the Copepod Community Size Index are consistent with the warmer water favoring the smaller-bodied species which generally have a more southerly center to their distribution. It is interesting that on the shelf this switch to smaller species occurred in 2013 when the warmth first became apparent, while in the oceanic region it was not until 2015 that the anomaly became negative. Abundance of zooplankton organisms was generally higher than average so that biomass anomalies remained neutral despite smaller organisms.

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 and composition 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. For example, while mesozooplankton biomass anomalies remained neutral or positive, the reduced average size of the copepod community suggests that the biomass was packaged into numerous, but smaller, prey items. This may require more work by predators to obtain their nutritional needs.

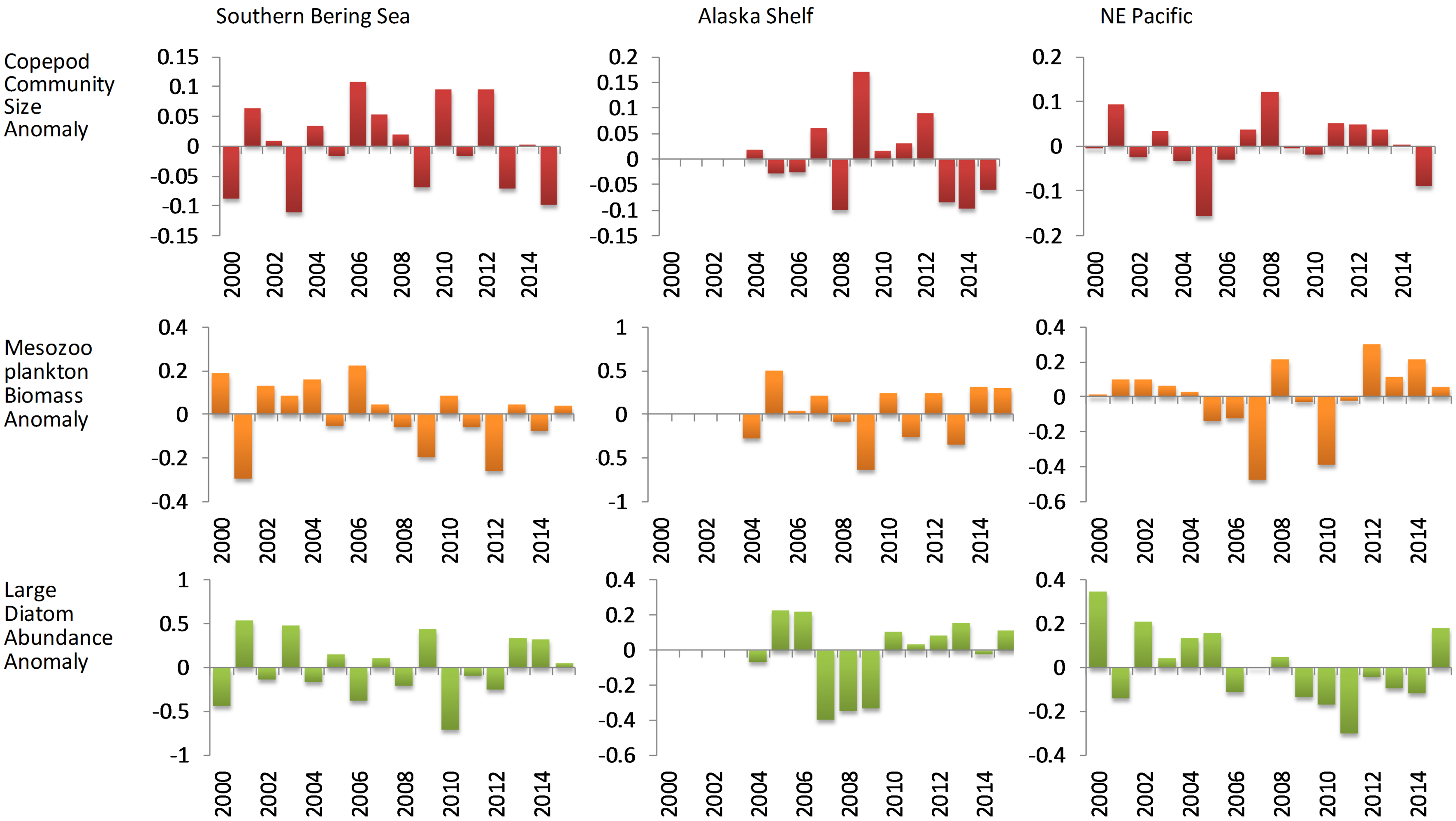

Figure 21: Annual anomalies of three indices of lower trophic levels (see text for description and derivation) for each region shown in (Figure 20). Note that sampling of this Alaskan Shelf region did not begin until 2004.

Jellyfish

Jellyfish in the Bottom Trawl Survey

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Last updated: October 2016

Description of indicator: RACE bottom trawl surveys in the Aleutian Islands (AI) are designed primarily to assess populations of commercially important fish and invertebrates. However many other species are identified, weighed and counted during the course of these surveys and these data may provide a measure of relative abundance for some of these species. Jellyfish are probably not sampled well by the gear due to their fragility and potential for catch in the mid-water during net deployment or retrieval. Therefore jellyfish encountered in small numbers which may or may not reflect their true abundance in the AI. The fishing gear used aboard the Japanese vessels that participated in all AI surveys prior to 1990 was very different from the gear used by all vessels since. This gear difference almost certainly affected the catch rates for jellyfish. For jellyfish, the catches for each year were scaled to the largest catch over the time series (which was arbitrarily scaled to a value of 100). The standard error (± 1) was weighted proportionally to the CPUE to get a relative standard error. The percentage of positive catches in the survey bottom trawl hauls was also calculated.

Status and trends: Jellyfish mean catch per unit effort (CPUE) is typically higher in the western and eastern AI than in other areas (Figure 22). The frequency of occurrence in trawl catches is generally from 20-60% across all areas, but has been variable. The 2006 AI survey experienced peak biomasses in all areas, whereas the 1992 survey had high abundance in the western AI only. Jellyfish catches and frequency of occurrence in the AI bottom trawl survey have been steadily increasing since the 2012 survey in all areas, but still have not reached the peak abundance from 2006.

Factors influencing observed trends: Unknown

Implications: The steady increase in the last three surveys in both frequency of occurrence and abundance of jellyfish has coincided with warming temperatures found during the AI survey. These data indicate that jellyfish are becoming more common in the Aleutian Islands, although an "outbreak" of jellyfish, such as happened in 2006 across all areas is not apparent.

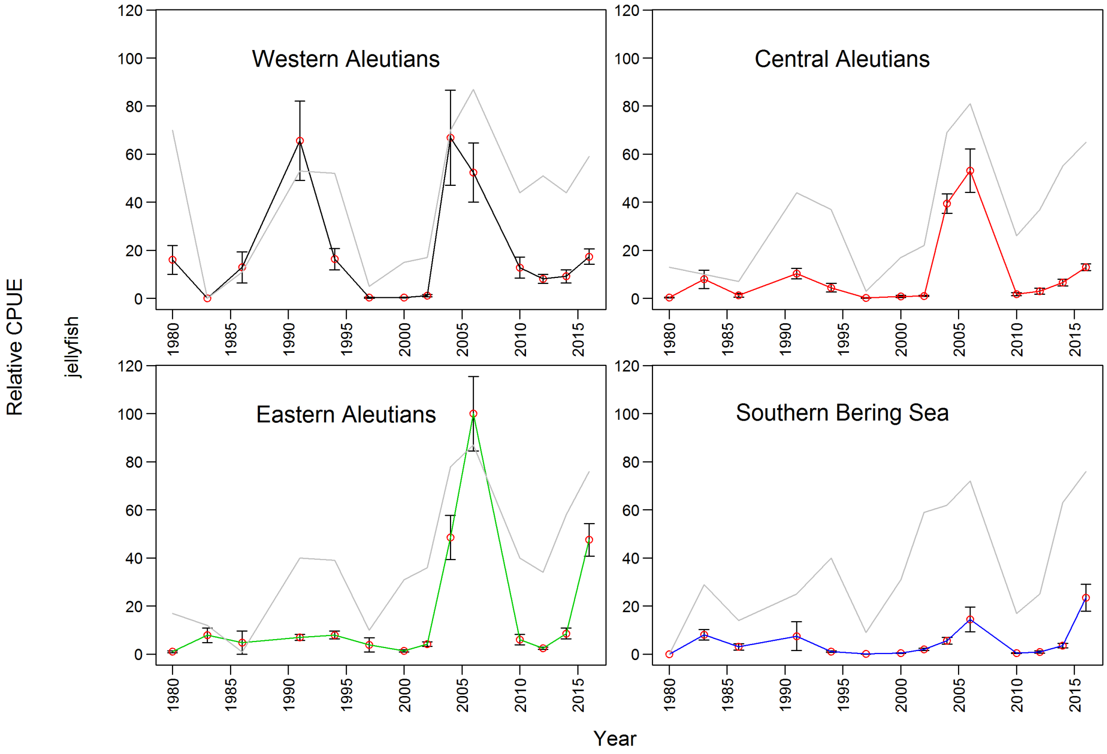

Figure 22: Relative mean CPUE of jellyfish species by INPFC area from RACE bottom trawl surveys in the Aleutian Islands from 1980 through 2016. Error bars represent standard errors. The gray lines represent the percentage of non-zero catches.

Ichthyplankton

There are no ichthyoplankton indicators in this year's report. See the contribution archive for previous indicator submissions at: `http://access.afsc.noaa.gov/reem/ecoweb/index.php`

Forage Fish

There are no individual contributions with forage fish indicators in this year's report, other than the pelagic foragers guild and the puffin indicators in the Report Card. See the contribution archive for previous indicator submissions at: `http://access.afsc.noaa.gov/reem/ecoweb/index.php`

Groundfish

Aleutian Islands Groundfish Condition

Contributed by Jennifer Boldt[1], Chris Rooper[2], and Jerry Hoff[2]
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Last updated: October 2016

Description of indicator: Length-weight residuals are an indicator of somatic growth (Brodeur et al., 2004) and, therefore, a measure of fish condition. Fish condition is an indicator of how heavy a fish is per unit body length, and may be an indicator of ecosystem productivity. Positive length-weight residuals indicate fish are in better condition (i.e., heavier per unit length); whereas, negative residuals indicate fish are in poorer condition (i.e., lighter per unit length). Fish condition may affect fish growth and subsequent survival (Paul et al., 1997; Boldt and Haldorson, 2004). The AFSC Aleutian Islands bottom trawl survey data was utilized to acquire lengths and weights of individual fish for walleye pollock, Pacific cod, arrowtooth flounder, southern rock sole, Atka mackerel, northern rockfish, and Pacific ocean perch. Only standard survey stations were included in analyses. Data were combined by INPFC area; Southern Bering sea, Eastern Aleutian Islands, Central Aleutian Islands, and Western Aleutian Islands. Length-weight relationships for each of the seven species were estimated with a linear regression of log-transformed values over all years where data was available (during 1984-2016). Additionally, length-weight relationships for age 1+ walleye pollock (length from 100-250 mm) were also calculated independent from the adult life history stage. Predicted log-transformed weights were calculated and subtracted from measured log-transformed weights to calculate residuals for each fish. Length-weight residuals were averaged for the entire AI and for the 3 INPFC areas sampled in the standard summer survey. Temporal and spatial patterns in residuals were examined.

Status and trends:: Length-weight residuals varied over time for all species with a few notable patterns (Figure 23). Residuals for most species where there was data were negative from 2000 to 2006. Residuals were positive for all species but southern rock sole in 2010. In 2012-2014 length-weight residuals were negative across most species, and the trendline has been negative since 2010. For northern rockfish, Pacific cod and Pacific ocean perch there has been a declining trend in residuals over the years covered by the survey.

Spatial trends in residuals were also apparent for some species (Figure 24). Most species were generally in better condition in the southern Bering Sea (with the exception of Pacific cod). Species generally exhibited the worst condition in the Western Aleutians (with the exception of pollock and southern rock sole) Even in years where length weight residuals were positive overall (such as the early years in the northern rockfish time series), length weight residuals were lower (although still positive) in the western Aleutian Islands relative to other areas.

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

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

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

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

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Last updated: October 2016

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

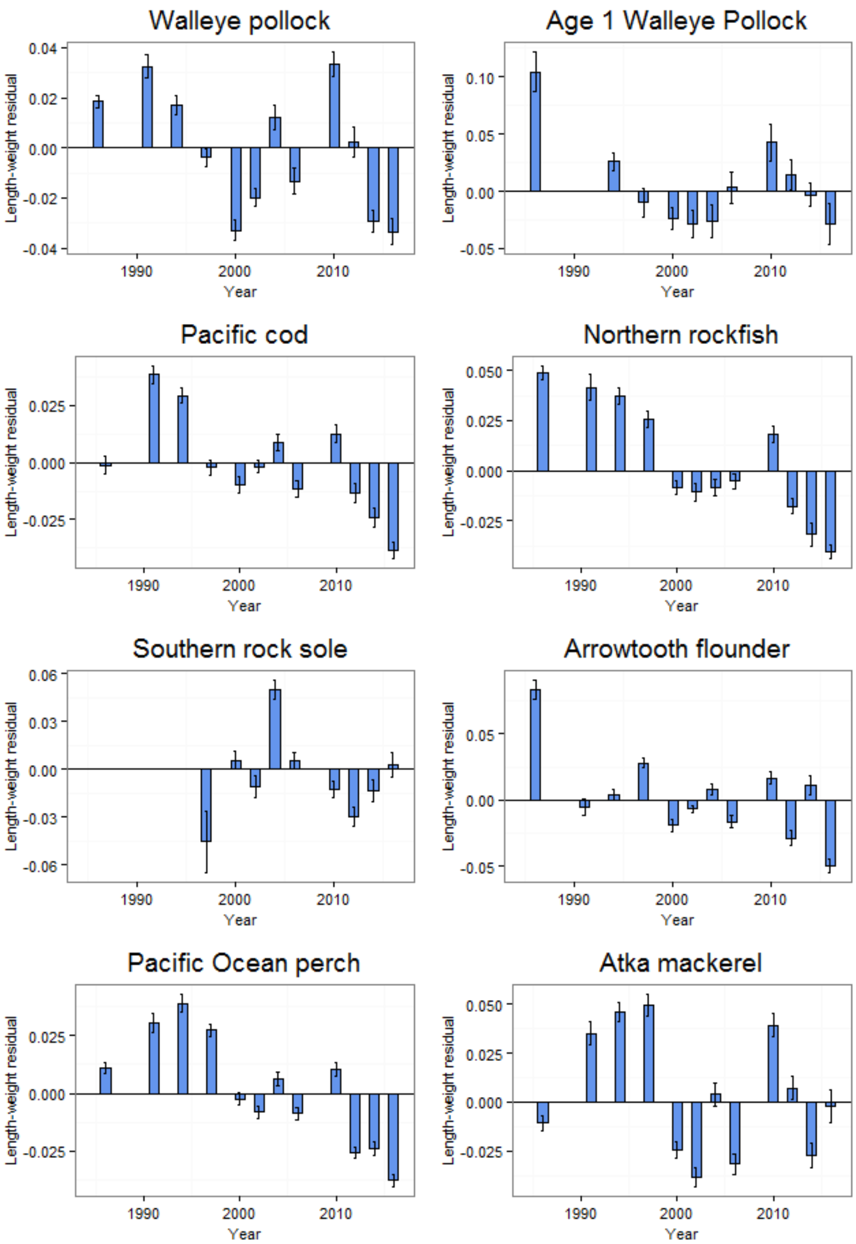

Figure 23: Length-weight residuals for seven Aleutian Islands groundfish sampled in the NMFS standard summer bottom trawl survey, 1984-2016.

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

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

where f_i is the CPUE of each rockfish species group in tow i and x_i is the value of the environmental

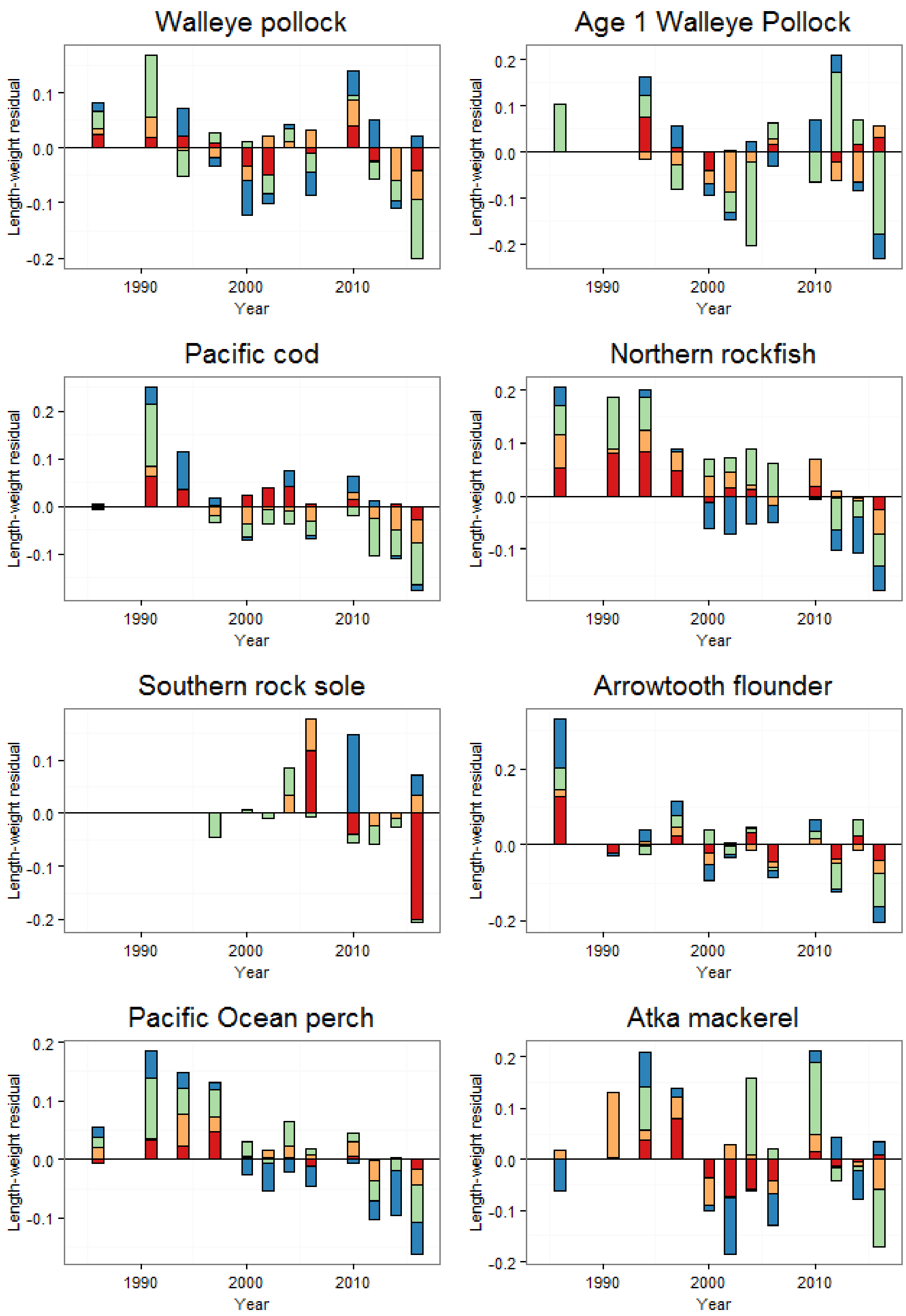

Figure 24: Length-weight residuals for seven Aleutian Islands groundfish sampled in the NMFS standard summer bottom trawl survey, 1984-2016, by INPFC area. Green = southern Bering Sea; orange = Eastern Aleutians; red = Central Aleutians; blue = Western Aleutians.

variable at tow i. The weighted standard error (SE) was then computed as:

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

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

Status and trends: There are three statistically significant depth-related trends over the time series that have continued over the last couple of surveys, as the distribution of adult rougheye rockfish, adult Pacific Ocean perch and shortraker rockfish have been shallower in the most recent surveys of the Aleutian Islands (Figure 25). Northern rockfish have continued to show a significant trend over the last few surveys in their mean-weighted distribution towards the western Aleutians, although the trend has been flat over the last few surveys. There were no significant trends in mean-weighted temperature distributions for any species, and all species were found within about 1°C over the entire time series. Probably because of the increased temperatures observed during the Aleutian Islands surveys in 2016, increases in mean weighted temperature have been observed for this year. This is a trend to continue monitoring in the next survey if water temperatures remain high.

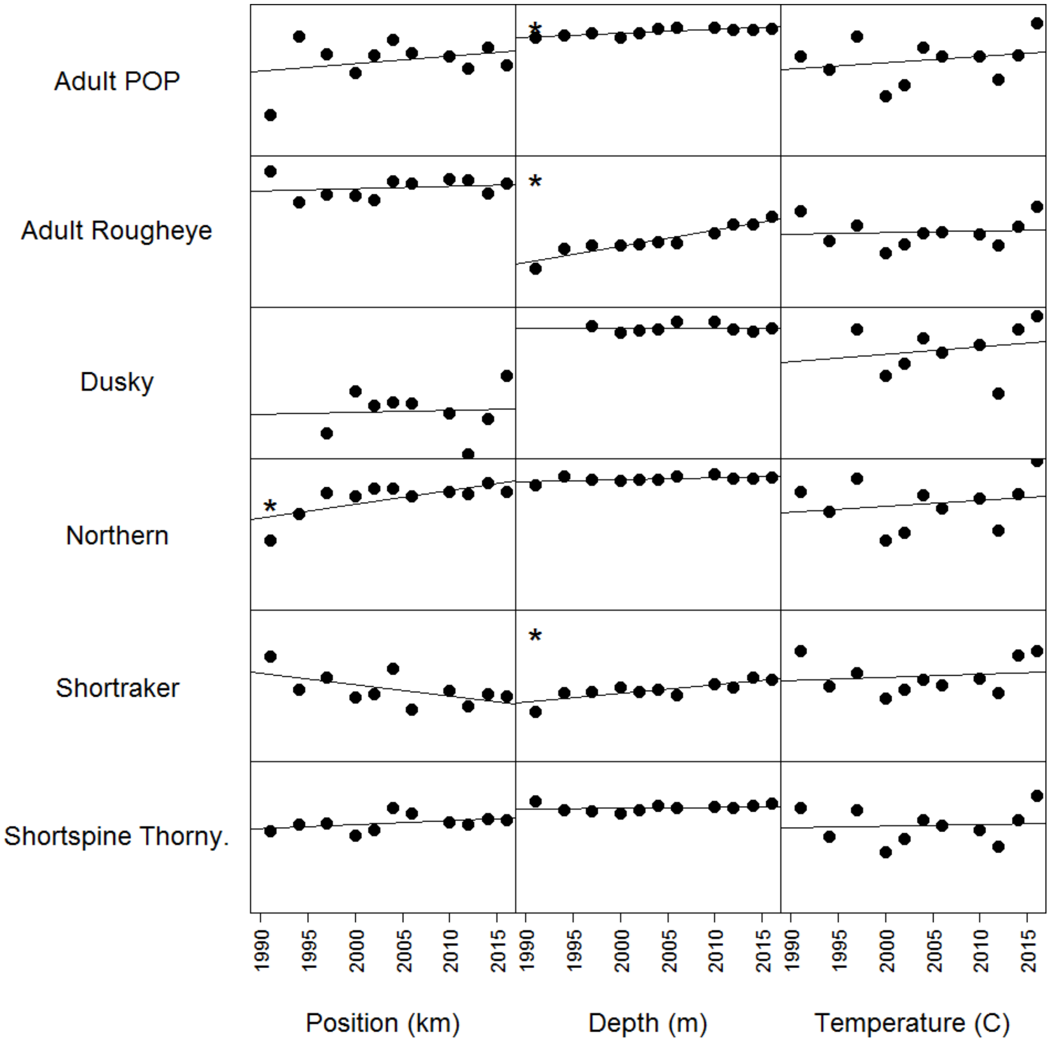

Figure 25: Plots of mean weighted (by catch per unit effort) distributions of six rockfish species-groups along three environmental variables in the Aleutian Islands. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance from Hinchinbrook Island, Alaska, with positive values west of this central point in the trawl surveys and negative values in southeastward. Asterisk indicates significant trend over the time series.

Factors causing observed trends: The observed changes in depth and spatial distributions for adult rougheye rockfish, shortraker rockfish, northern rockfish and adult Pacific Ocean perch in the AI are probably related to changes (increases) in overall abundance. Although it is interesting to note that in the cases of adult rougheye rockfish, adult Pacific Ocean perch, and shortraker rockfish their depth range has become shallower while the temperatures occupied by the species have not changed significantly in recent surveys (with the exception of possibly the 2016 survey).

Implications: The trends in the mean-weighted distributions of rockfish should continue to be monitored, with special attention to potential causes of the shift in depth and position distributions of rockfish, especially as they relate to changing temperatures. In 2016 all five rockfish groups were found at the highest mean-weighted temperature in the time series and the trend for all species has been upward since the 2012 survey.

Benthic Communities and Non-target Fish Species

Miscellaneous Species - Aleutian Islands

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Last updated: October 2016

Description of indicator: RACE bottom trawl surveys in the Aleutian Islands (AI) are designed primarily to assess populations of commercially important fish and invertebrates. However many other species are identified, weighed and counted during the course of these surveys and these data may provide a measure of relative abundance for some of these species. Many of these species are not sampled well by the gear or occur in areas that are not well sampled by the survey (hard, rough areas, mid-water etc.) and are therefore encountered in small numbers which may or may not reflect their true abundance in the AI. The fishing gear used aboard the Japanese vessels that participated in all AI surveys prior to 1991 was very different from the gear used by all vessels since. This gear difference almost certainly affected the catch rates for some of these species groups. Apparent abundance trends for a few of these groups are shown in Figure 26. For each species group, the largest catch over the time series was arbitrarily scaled to a value of 100 and all other values were similarly scaled. The standard error (± 1) was weighted proportionally to the CPUE to get a relative standard error.

Status and trends: Echinoderms are frequently captured in all areas of the AI surveys occurring in 80-90% of all bottom trawl hauls. Echinoderm mean catch per unit effort (CPUE) is typically higher in the central and eastern AI than in other areas, although frequency of occurrence in trawl catches is consistently high across all areas. The lowest echinoderm CPUE has usually been in the southern Bering Sea, but has been increasing for the last two surveys. Eelpout CPUEs have generally been highest in the central and eastern AI. There has been a decline in eelpout biomass in the western Aleutian Islands over the last three surveys. Eelpouts generally occur in <10% of survey hauls across all areas. Poachers occur in a relatively large number of tows across the AI survey area (about 30-40% consistently), but mean CPUE trends are unclear and abundance appears low. A new shrimp time series has been calculated for 2016. The shrimp time series shows generally increasing trends in frequency of occurrence across all areas except the western Aleutian Islands since ∼1990. However, the CPUE is dominated by a single peak in 2006 in the western Aleutian Islands.

Factors influencing observed trends: Unknown

Implications: AI survey results provide limited information about abundance or abundance trends for these species due to problems in catchability. Therefore, the indices presented are likely of limited value to fisheries management. These species are not typically commercially important, but the trends in shrimp especially should be monitored as these are an important prey base for benthic commercial species.

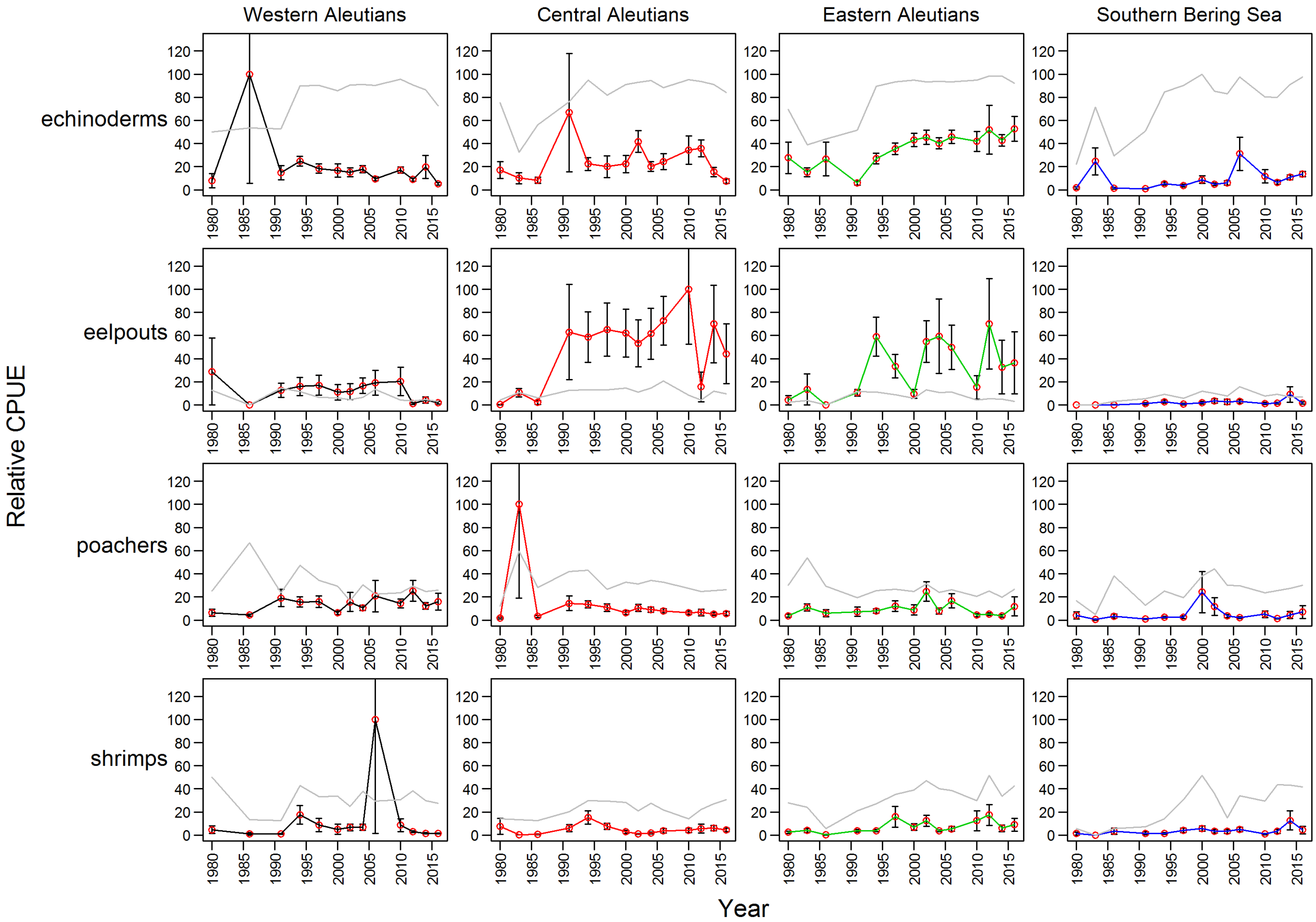

Figure 26: Relative mean CPUE of miscellaneous species by area from RACE bottom trawl surveys in the Aleutian Islands from 1980 through 2016. Error bars represent standard errors. The gray lines represent the percentage of non-zero catches. The Western, Central, and Eastern Aleutians correspond to management areas 543, 542, and 541, respectively. The Southern Bering Sea corresponds to management areas 519 and 518.

Seabirds

There are no seabird indicators in this year's report, with the exception of those in the Report Card. See the contribution archive for previous indicator submissions at: `http://access.afsc.noaa.gov/reem/ecoweb/index.php`

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 (2014) Alaska Marine Mammal stock assessment was released in August 2015 and can be downloaded at `http://www.nmfs.noaa.gov/pr/sars/region.htm`.

There are no updates to marine mammal indicators in this year's report, with the exception of those in the Report Card. See the contribution archive for previous indicator submissions at: `http://access.afsc.noaa.gov/reem/ecoweb/index.php`

Ecosystem or Community Indicators

There are no ecosystem or community indicators in this year's report. See the contribution archive for previous indicator submissions at: `http://access.afsc.noaa.gov/reem/ecoweb/index.php`

Disease Ecology Indicators

There are no disease ecology indicators in this year's report. See the contribution archive for previous indicator submissions at: `http://access.afsc.noaa.gov/reem/ecoweb/index.php`

Ecosystem-Based Management Indicators

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

Maintaining Diversity: Discards and Non-Target Catch

Time Trends in Groundfish Discards

Contributed by Jean Lee, Resource Ecology and Fisheries Management Division, AFSC, NMFS, NOAA, and Alaska Fisheries Information Network, Pacific States Marine Fisheries Commission
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Last updated: November 2015

Time Trends in Non-Target Species Catch

Contributed by Andy Whitehouse[1], Sarah Gaichas[2], and Stephani Zador[3]
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Last updated: September 2016

Description of indicator: 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 sand lance, 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`). Invertebrate species associated with habitat areas of particular concern, previously known as HAPC biota (seapens/whips, sponges, anemones, corals, and tunicates) are now referred to as structural epifauna. Starting with the 2013 Ecosystem Considerations Report, the three categories of non-target species we continue to track here are:

1. Scyphozoan jellyfish
2. Structural epifauna (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: In the AI, the catch of Scyphozoan jellies has been variable and shows no apparent trend over time (Figure 27). The catch in 2015 was ∼25% of the catch in 2014. The catch of structural epifauna has been variable over time in the AI and peaked in 2015. The catch of structural epifauna in the AI is driven primarily by sponges caught in fisheries for Atka mackerel, rockfish and Pacific 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. The catch of assorted invertebrates dropped considerably from 2013 to 2014 and has remained low in 2015. Over that same span the assorted invertebrate catch has been dominated by sea stars and unidentified invertebrates. Assorted invertebrates are primarily caught in fisheries for Atka mackerel, Pacific cod, and rockfish.

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. Fluctuations in the abundance of jellyfish in the EBS are influenced by a suite of biophysical factors affecting the survival, reproduction, and growth of jellies including temperature, sea ice phenology, wind-mixing, ocean currents, and prey abundance (Brodeur et al., 2008).

Implications: The catch of structural epifauna and assorted invertebrates in all three ecosystems is very low compared with the catch of target species. Structural epifauna may have become less available to the EBS fisheries (or the fisheries avoided them more effectively) since 2005. The interannual variation and lack of a clear trend in the catch of scyphozoan jellyfish in all three ecosystems may reflect interannual variation in jellyfish biomass or changes in the overlap with fisheries. Abundant jellyfish may have a negative impact on fishes as they compete with planktivorous fishes for prey resources (Purcell and Sturdevant, 2001), and additionally, jellyfish may prey upon the early life history stages (eggs and larvae) of fishes (Purcell and Arai, 2001; Robinson et al., 2014).

Seabird Bycatch Estimates for Groundfish Fisheries off the Aleutian Islands, 2007-2015

Contributed by Stephani Zador[1], Shannon Fitzgerald[1] and Jennifer Mondragon[2]
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Last updated: October 2016

Description of indicator: This report provides estimates of the numbers of seabirds caught as bycatch in commercial groundfish fisheries operating in federal waters off the Aleutian Islands of the U.S. Exclusive Economic Zone for the years 2007 through 2015. Estimates of seabird bycatch

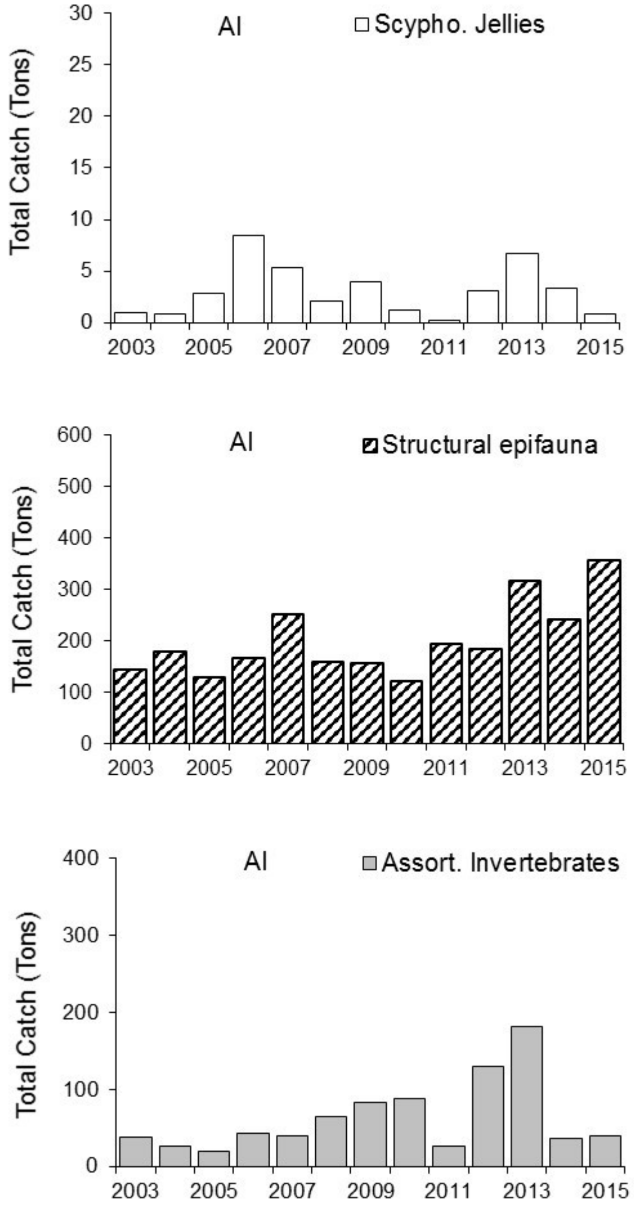

Figure 27: Total catch of non-target species (tons) in the AI and groundfish fisheries (2003-2015). Note the different y-axis scales between species groups.

from earlier years using different methods are not included here. 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, 2011), and (2) industry reports of catch and production. The NMFS Alaska Regional Office Catch Accounting System (CAS) produces the estimates (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: The numbers of seabirds estimated to be bycaught in Aleutian Islands fisheries in 2015 is the highest in the time series, which began in 2007 (Table 3). This follows four years (2011-2014) with relatively low numbers caught. The majority of those estimated to be caught were Northern fulmars and Laysan albatross, both numbers which were the highest in the time series. In contrast, shearwaters, which were the most numerous species group bycaught in 2007, had the second lowest numbers caught in 2015. The estimated numbers of birds bycaught in the Aleutians exceeded that in the Gulf of Alaska, which typically has a greater number of estimated bycaught birds (Figure 28).

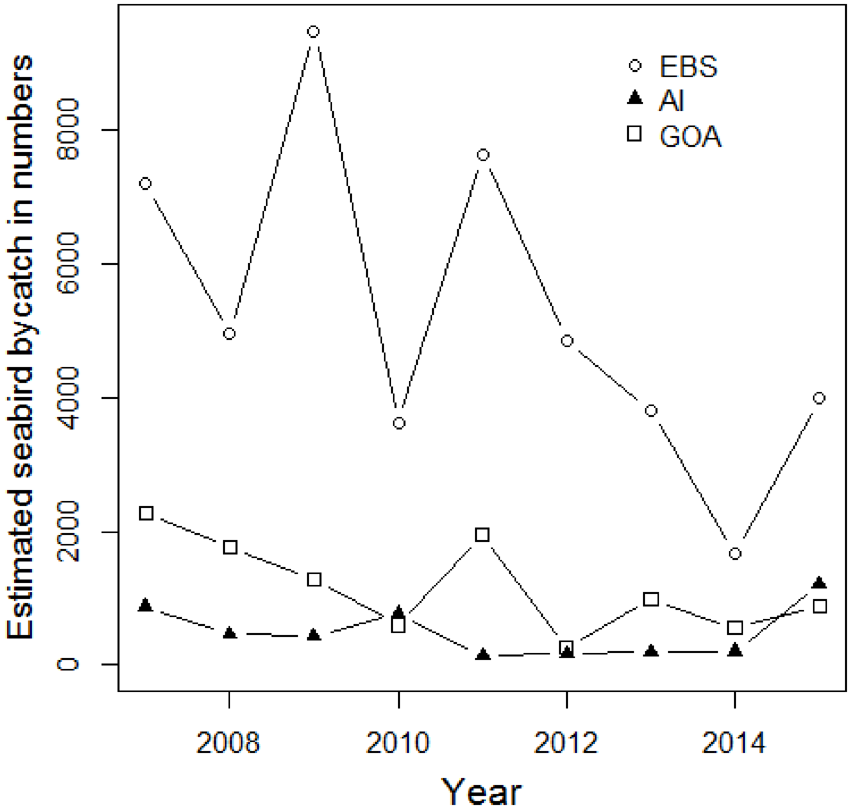

Figure 28: Total estimated seabird bycatch in eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) groundfish fisheries, all gear types combined, 2007 to 2015.

Table 3: **Estimated** seabird bycatch in Aleutian Islands groundfish fisheries and all gear types, 2007 through 2015. Note that these numbers represent extrapolations from observed bycatch, not direct observations. See text for estimation methods.

Species Group	2007	2008	2009	2010	2011	2012	2013	2014	2015
Unidentified Albatross	0	0	0	0	0	0	0	21	0
Short-tailed Albatross	0	0	0	0	0	0	0	0	0
Black-footed Albatross	0	0	0	0	5	0	12	17	19
Laysan Albatross	12	50	35	122	12	76	109	46	149
Northern Fulmar	77	307	307	369	50	15	36	53	977
Shearwaters	734	39	49	88	42	60	0	62	23
Storm Petrels	0	44	0	0	0	0	0	0	0
Gull	38	19	37	176	22	12	24	0	37
Kittiwake	0	0	0	0	0	0	0	0	0
Murre	0	0	0	0	0	0	0	0	0
Puffin	0	0	0	0	0	0	0	0	0
Auklets	0	0	0	0	0	0	0	2	0
Other	0	0	0	0	0	0	0	0	0
Unidentified	5	1	7	17	0	3	9	0	0
Grand Total	867	460	434	772	133	166	190	202	1204

Factors influencing observed trends: A marked decline in overall numbers of birds caught after 2002 reflected 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 3).

Implications: The large increase seen in seabird bycatch in 2015 reverses a general declining trend seen since the new estimation procedures began in 2007. There is some concern that the mortality could be colony-specific, particularly for Northern fulmars, possibly leading to local depletions (Hatch et al., 2010). However as an increase in bycatch was noted in the AI, GOA and EBS, there is reason to believe that there was a widespread change in seabird distribution, fishing effort and/or seabird prey supply, all of which could impact bycatch. The recent warm oceanic conditions, the "Blob", have been linked to changes in the ecosystem and lower productivity. It is difficult to determine how seabird bycatch numbers and trends are linked to changes in ecosystem components because seabird mitigation gear is used in the longline fleet. There does appear to be a link between poor ocean conditions and the peak bycatch years, on a species-group basis. Fishermen have noted in some years that the birds appear "starved" and attack baited longline gear more aggressively. In 2008 general seabird bycatch in Alaska was at relatively low levels (driven by lower fulmar and gull bycatch) but albatross numbers were the highest at any time between 2002 and 2013. This could indicate poor ocean conditions in the North Pacific as albatross traveled from the Hawaiian Islands to Alaska. Broad changes in overall seabird bycatch, up to 5,000 birds per year, occurred between 2007 and 2013. This probably indicates changes in food availability rather than drastic changes in how well the fleet employs mitigation gear. A focused investigation of this aspect of seabird bycatch is needed and could inform management of poor ocean conditions if seabird bycatch rates (reported in real time) were substantially higher than normal.

Maintaining and Restoring Fish Habitats

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

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Last updated: October 2016

Description of indicator: Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut) (Figure 29, Table 4) 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.

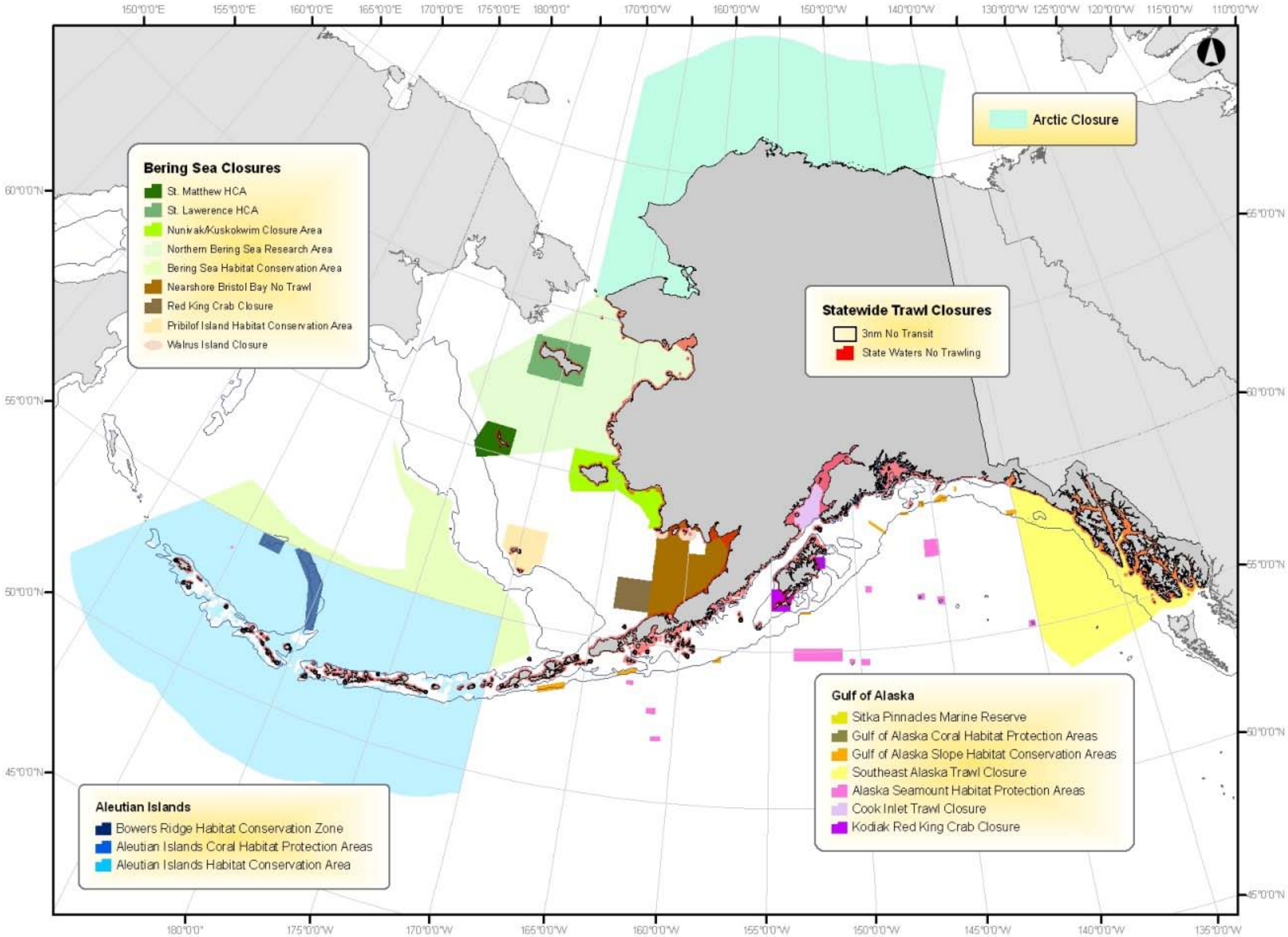

Figure 29: Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska, excluding most SSL closures.

Table 4: 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. The western and central Aleutian Islands were subsequently reopened to trawling in 2014.

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`

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

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Last updated: August 2015

Sustainability (for consumptive and non-consumptive uses)

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

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Last updated: September 2016

Description of indicator: 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
   - (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.

In the Alaska Region, there are 36 FSSI stocks and an overall FSSI of 144 would be achieved if every stock scored the maximum value, 4 (Tables 5 and 6). Over time, the number of stocks included in the FSSI has changed as stocks have been added and removed from Fishery Management Plans (FMPs). Prior to 2015 there were 35 FSSI stocks and maximum possible score of 140. To keep FSSI scores for Alaska comparable across years we report the total Alaska FSSI as a percentage of the maximum possible score (i.e., 100%). Additionally, there are 29 non-FSSI stocks, two ecosystem component species complexes, and Pacific halibut which are managed under an international agreement (Tables 5 and 7).

Status and trends: As of June 30, 2016, 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 (Table 5). The only crab stock considered to be overfished is the Pribilof Islands blue king crab stock, which is in year 2 of a rebuilding plan. None of the non-FSSI stocks are subject to overfishing, known to be overfished, or known to be approaching an overfished condition.

The current overall Alaska FSSI is 132.5 out of a possible 144, or 92%, based on updates through June 2016 (Table 6). The overall Bering Sea/Aleutian Islands score is 85.5 out of a maximum

Table 5: Summary of status for FSSI and non-FSSI stocks managed under federal fishery management plans off Alaska, updated through June 2016.

Jurisdiction	Stock Group	Number of Stocks	Overfishing					Overfished				Approaching Overfished Condition
			Yes	No	Unk	Undef	N/A	Yes	No	Unk	Undef	
NPFMC	FSSI	36	0	36	0	0	0	1	32	3	0	0
NPFMC	NonFSSI	29	0	29	0	0	0	0	3	26	0	0
	Total	65	0	65	1	0	0	1	35	29	0	0

possible score of 92. The BSAI groundfish score is 59 (including BSAI/GOA sablefish, see Endnote-g in Box A) of a maximum possible 60 and BSAI king and tanner crabs score is 26.5 out of a possible 32. The Gulf of Alaska groundfish score is 47 of a maximum possible 52 (excluding BSAI/GOA sablefish). Overall, the Alaska total FSSI score decreased slightly from 92.7% 2015 to 92.0% in 2016 (Figure 30).

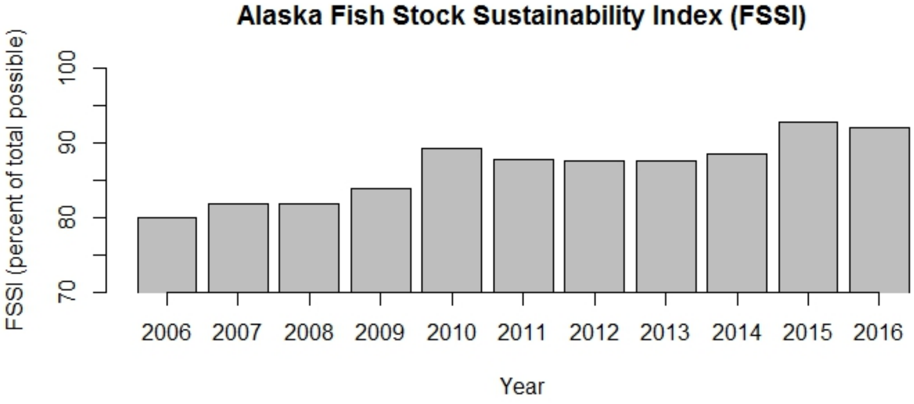

Figure 30: The trend in Alaska FSSI, as a percentage of the maximum possible FSSI from 2006 through 2016. The maximum possible FSSI is 140 for 2006 to 2014, and from 2015 on it is 144. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries`.

Factors influencing observed trends: One point was lost from last year's FSSI to this year for the St. Matthew Island blue king crab stock having their biomass drop below 80% of B_{MSY}. This one point loss accounts for the 0.7% drop in the overall Alaska FSSI score. Other crab groups in the BSAI region with FSSI scores less than 4 are golden king crab-Aleutian Islands (FSSI=1.5) and blue king crab-Pribilof Islands (FSSI=2). Neither of these king crab stocks are subject to overfishing. The Pribilof Islands blue king crab stock is considered overfished and is in year 2 of a rebuilding plan. Biomass for this stock is less than 80% of B_{MSY}. It is unknown if the golden king crab-Aleutian Islands stock is overfished and B_{MSY} is not estimated.

The only BSAI groundfish stock with an FSSI score less than 4 is the Greenland halibut, which loses a point for biomass being less than 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 6: FSSI stocks under NPFMC jurisdiction updated June 2016, 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/B_{MSY}	FSSI Score
Blue king crab - Pribilof Islands[a]	No	Yes	N/A	Year 2 of plan	Continue Rebuilding	0.06	2
Blue king crab - Saint Matthews Island[b]	No	No	No	N/A	N/A	0.67	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	1.04	4
Red king crab - Norton Sound	No	No	No	N/A	N/A	1.07	4
Red king crab - Pribilof Islands[c]	No	No	No	N/A	N/A	1.55	4
Snow crab - Bering Sea	No	No	No	N/A	N/A	0.94	4
Southern Tanner crab - Bering Sea	No	No	No	N/A	N/A	2.67	4
BSAI Alaska plaice	No	No	No	N/A	N/A	1.87	4
BSAI Atka mackerel	No	No	No	N/A	N/A	1.49	4
BSAI Arrowtooth Flounder	No	No	No	N/A	N/A	2.75	4
BSAI Blackspotted and Rougheye Rockfish[d]	No	No	No	N/A	N/A	0.80	4
BSAI Flathead Sole Complex[e]	No	No	No	N/A	N/A	2.15	4
BSAI Rock Sole Complex[f]	No	No	No	N/A	N/A	2.38	4
BSAI Skate Complex[g]	No	No	No	N/A	N/A	1.76	4
BSAI Greenland halibut	No	No	No	N/A	N/A	0.52	3
BSAI Northern rockfish	No	No	No	N/A	N/A	1.89	4
BS Pacific cod	No	No	No	N/A	N/A	1.42	4
BSAI Pacific Ocean perch	No	No	No	N/A	N/A	1.58	4
Walleye pollock - Aleutian Islands	No	No	No	N/A	N/A	0.97	4
Walleye pollock - Eastern Bering Sea	No	No	No	N/A	N/A	1.75	4
BSAI Yellowfin sole	No	No	No	N/A	N/A	1.60	4
BSAI GOA Sablefish[h]	No	No	No	N/A	N/A	1.00	4

Table 6: FSSI stocks under NPFMC jurisdiction updated June 2016, 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/B_{MSY}	FSSI Score
GOA Arrowtooth flounder	No	No	No	N/A	N/A	3.26	4
GOA Flathead sole	No	No	No	N/A	N/A	2.54	4
GOA Blackspotted and Rougheye Rockfish complex[i]	No	No	No	N/A	N/A	1.96	4
GOA Deepwater Flatfish Complex[j]	No	No	No	N/A	N/A	2.46	4
GOA Shallow Water Flatfish Complex[k]	No	No	No	N/A	N/A	2.18	4
GOA Demersal Shelf Rockfish Complex[l]	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
GOA Dusky Rockfish	No	No	No	N/A	N/A	1.61	4
GOA Thornyhead Rockfish Complex[m]	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
Northern rockfish - Western / Central GOA	No	No	No	N/A	N/A	1.45	4
GOA Pacific cod	No	No	No	N/A	N/A	1.78	4
GOA Pacific Ocean perch	No	No	No	N/A	N/A	1.55	4
GOA Rex sole	No	No	No	N/A	N/A	2.08	4
Walleye pollock - Western / Central GOA	No	No	No	N/A	N/A	0.96	4

Box A. Endnotes and stock complex definitions for FSSI stocks listed in Table 6, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/`.

(a) A new rebuilding plan for this stock was implemented January 1, 2015 but does not specify a target rebuilding date because it is not known when the stock is expected to rebuild. 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, and beginning in 2015 there is a prohibition on directed cod pot fishing in the Pribilof Islands Habitat Conservation Zone (PIHCZ).

(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 Skate Complex consists of Alaska Skate, Aleutian Skate, Bering Skate, Big Skate, Butterfly Skate, Commander Skate, Deepsea Skate, Mud Skate, Okhotsk Skate, Roughshoulder Skate, Roughtail Skate, Whiteblotched Skate, and Whitebrow Skate. Alaska Skate is assessed and is the indicator species for this complex.

(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. Dover Sole is the indicator species for determining the status of this stock complex.

(k) The Shallow Water Flatfish Complex consists of the following stocks: Alaska Plaice, Butter Sole, C-O Sole, Curlfin Sole, English Sole, Northern Rock Sole, Pacific Sanddab, Petrale Sole, Sand Sole, Slender Sole, Southern Rock Sole, Speckled Sanddab, Starry Flounder, and Yellowfin Sole. The overfishing determination is based on the OFL, which is computed by using abundance estimates of the complex. A single, assemblage-wide OFL is specified, but overfishing was not defined for the thershallow-water flatfish stocks per se, because they are part of the overall shallow-water flatfish assemblage. SAFE report indicates that the shallow water flatfish complex was not subjected to overfishing and that neither of the indicator species (northern and southern rock sole) is overfished or approaching a condition of being overfished.

(l) 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.

(m) 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 7: Non-FSSI stocks, Stocks managed under an International Agreement, and Ecosystem Component Species, updated June 2016, 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
BSAI Golden king crab - Pribilof Islands	NPFMC	No	Unknown	Unknown
BSAI Red king crab - Western Aleutian 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	No	Unknown	Unknown
GOA Atka mackerel	NPFMC	No	Unknown	Unknown
GOA Big skate	NPFMC	No	Unknown	Unknown
GOA Octopus complex	NPFMC	No	Unknown	Unknown
GOA Squid Complex	NPFMC	No	Unknown	Unknown
GOA Other Rockfish Complex	NPFMC	No	Unknown	Unknown
GOA Sculpin Complex	NPFMC	No	Unknown	Unknown
GOA Shallow Water Flatfish Complex	NPFMC	No	No	No
GOA Shark Complex	NPFMC	No	Unknown	Unknown
GOA Alaska skate Complex	NPFMC	No	Unknown	Unknown
GOA Longnose skate	NPFMC	No	Unknown	Unknown
GOA Shortraker rockfish	NPFMC	No	Unknown	Unknown
Walleye pollock - Southeast 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 Management Area	NPFMC	No	Unknown	Unknown
Saffron cod - Arctic Management Area	NPFMC	No	Unknown	Unknown
Snow crab - Arctic Management Area	NPFMC	No	Unknown	Unknown
Stocks managed under an International Agreement				
Pacific halibut - Pacific Coast / Alaska	IPHC/NPFMC PFMC	Unknown	No	No
Ecosystem Component Species				
Fish resources of the Arctic mgmt. area - Arctic FMP	NPFMC	N/A	N/A	N/A
Scallop fishery off Alaska	NPFMC	N/A	N/A	N/A

Humans as Part of Ecosystems

Trends in Human Population and Unemployment in the Aleutian Islands

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Last updated: September 2016

Description of indicator: Human population and unemployment, the social indices presented in this report, are significant factors in the Aleutian Islands (AI) ecoregion, and groundfish fishery management, as many communities in the region rely upon fisheries to support their economies and to meet subsistence and cultural needs. As with other areas neighboring the Arctic, population and unemployment are important indicators of community viability (Rasmussen et al. 2015). Advancements in socio-ecological systems (SES) research has demonstrated the importance of incorporating social variables in ecosystem management and monitoring, and these indices reflect aspects of the social (population) and economic (unemployment) settings of a SES (Turner et al. 2003; Ostrom 2007). For example, variation in resource access or availability or employment opportunities may influence human migration patterns, which in turn may decrease human activity in one area of an ecosystem while increasing activity in another.

This report summarizes trends in human population and unemployment rates over time in the Aleutian Islands chain including the eastern, central, and western areas. The 7 AI fishing communities included in analysis comprise the population that resides along the chain. Population was calculated by aggregating community level data between 1890 and 1990 (DCCED 2016) and annually from 1990-2015 (ADLWD 2016a). Unemployment data was also aggregated and weighted to account for varying community populations across Alaska Boroughs. Estimates are presented annually from 1990-2015 (ADLWD 2016a).

Status and trends: As of 2015 the total population of all AI communities was 5,939. The total population of the AI has fluctuated since 1880 with the greatest population increase of 374.0% occurring between 1960 and 1970 (Table 8 and Figures 31-32). Population trends of the AI are not consistent with State trends where the greatest increase of 75% was between 1950 and 1960. Population of the AI increased from 1920 to 1940, and from 1960 to 1990. Between 1990 and 2015 the population declined by 30.2%. The Aleutian Islands overall has had sporadic population cycles. Notable decreases occurred between 1900 and 1910 between 1940 and 1950 and between 1990 and 2000. The eastern AI has had the most steady population increase between 1880 and 2015, whereas the central and western AI experienced fluctuations. The western AI had a population of zero in 2015. Most of the population increase of Alaska was in urban areas, such as Anchorage, where 40% of Alaskas population currently resides (ADLWD 2016a; 2016b).

Table 8: Aleutian Islands population 1880-2015. Percent change rates are decadal until 2010.

Year	Alaska	% change	AI East	% change	AI Central	% change	AI West	% change	AI Total	% change
1880	33426		192		132		107		431	
1890	32052	-4.11	397	106.77	132	0	101	-5.61	630	46.17
1900	63592	98.4	488	22.92	128	-3.03		-100	616	-2.22
1910	64356	1.2	281	-42.42	0	-99.22			281	-54.38
1920	55036	-14.48	448	59.43	56	5500			504	79.36
1930	59278	7.71	465	3.79	103	83.93	29		597	18.45
1940	72524	22.35	563	21.08	89	-13.59	44	-51.72	696	16.58
1950	128643	77.38	365	-35.17	85	-4.49		-100	450	-35.34
1960	226167	75.81	458	25.48	119	40			577	28.22
1970	302583	33.79	398	-13.1	2337	1863.87			2735	374
1980	401851	32.81	1611	304.77	3408	45.83			5019	83.51
1990	550043	36.88	3782	134.76	4731	38.82			8513	69.62
2000	626932	13.98	5099	34.82	408	-91.38	20		8650	-35.08
2010	710231	13.29	5456	7	387	-5.15	21	5	8895	6.1
2015	737625	3.86	5596	2.57	343	-11.37	0	-100	8466	1.28

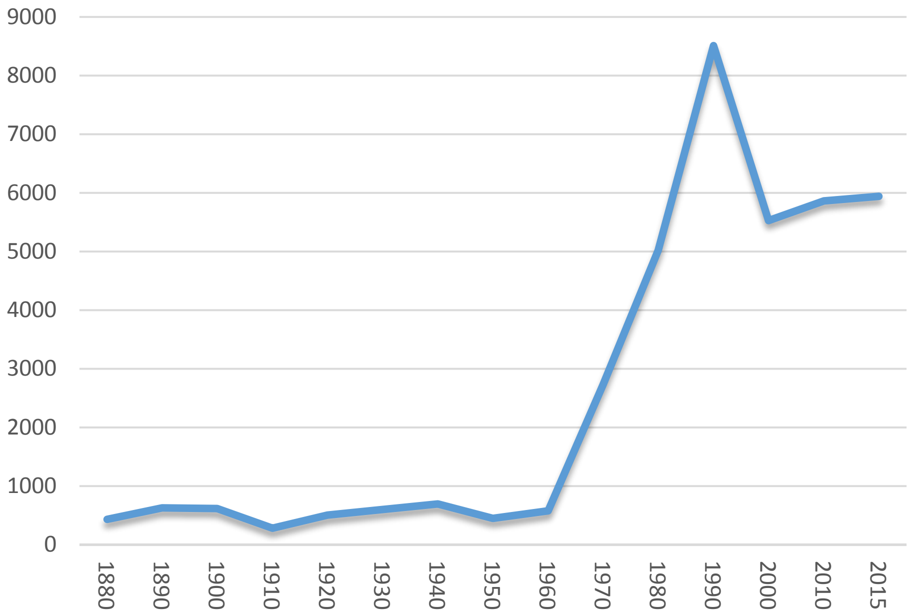

Figure 31: Total Aleutian Islands population

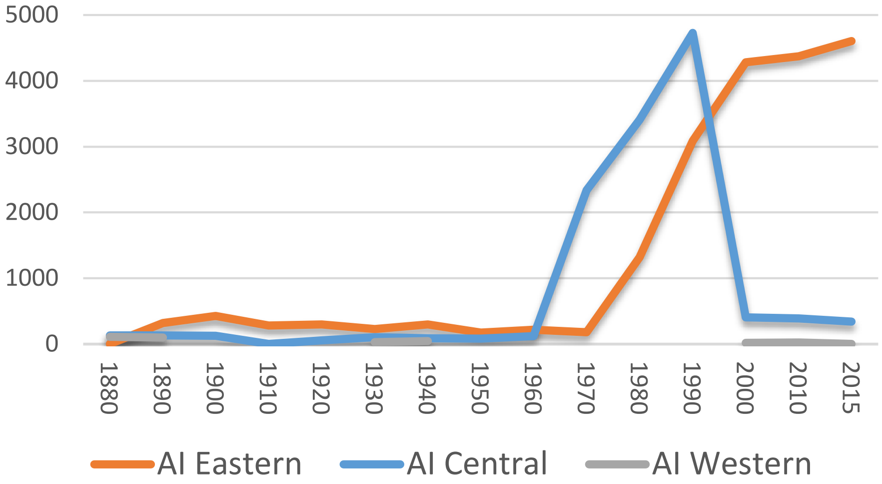

Figure 32: Eastern, central and western Aleutian Islands population

The population of most AI communities decreased between 1990 and 2015. Adaks (central AI) population decreased by 94.0%. Attu Station (western AI) had zero residents as of 2015. Akutan and Unalaska (eastern AI) had steady population increases during this time period. Although Indigenous Americans comprise up to 82% of the population of small communities in remote areas and more Native Americans reside in Alaska than any U.S. state (Goldsmith et al. 2004), only 42% of the AI population identified as Native American alone or combination with another race (DCCED

2016). The higher proportion of Native Americans was in Atka and Nikolski. There has been increased migration of Alaska Natives from rural to urban areas (Goldsmith et al. 2004; Williams 2004) and the majority of population growth that has occurred in Alaska is of the Caucasian demographic (ADLWD 2016b).

Unemployment rates in the AI, between 1990 and 2015, were lower than State and national rates (Figures 33-34). The eastern AI had higher unemployment rates than central AI, and western AI data was insufficient to interpret any trends. In the eastern AI, unemployment peaked in 1998 (4.0%), 2004 (4.5%), 2009 (4.8%), and 2012 (4.5%) which is consistent with State and national trends. The central AI maintained rates less than 1.0% which is lower than all regions of Alaska.

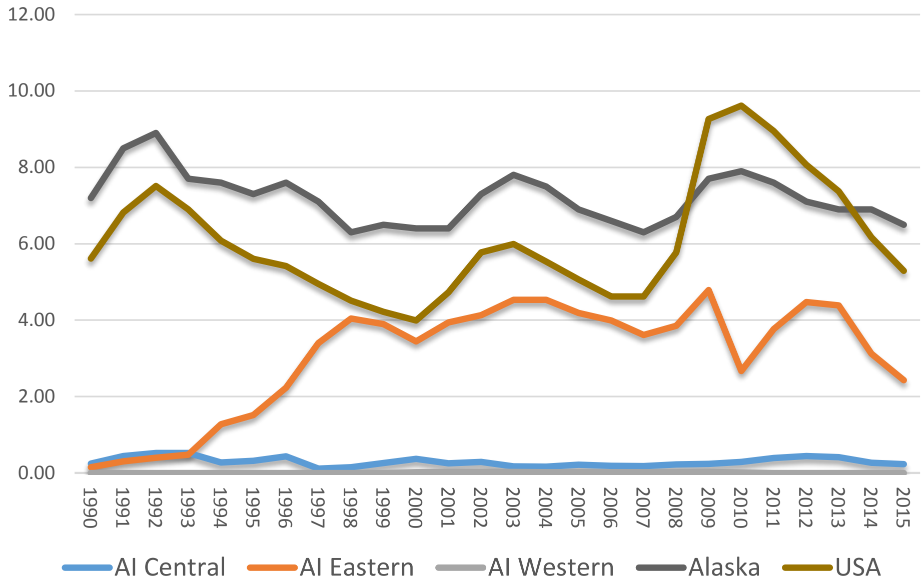

Figure 33: Unemployment rates for Aleutian Islands, Alaska and USA.

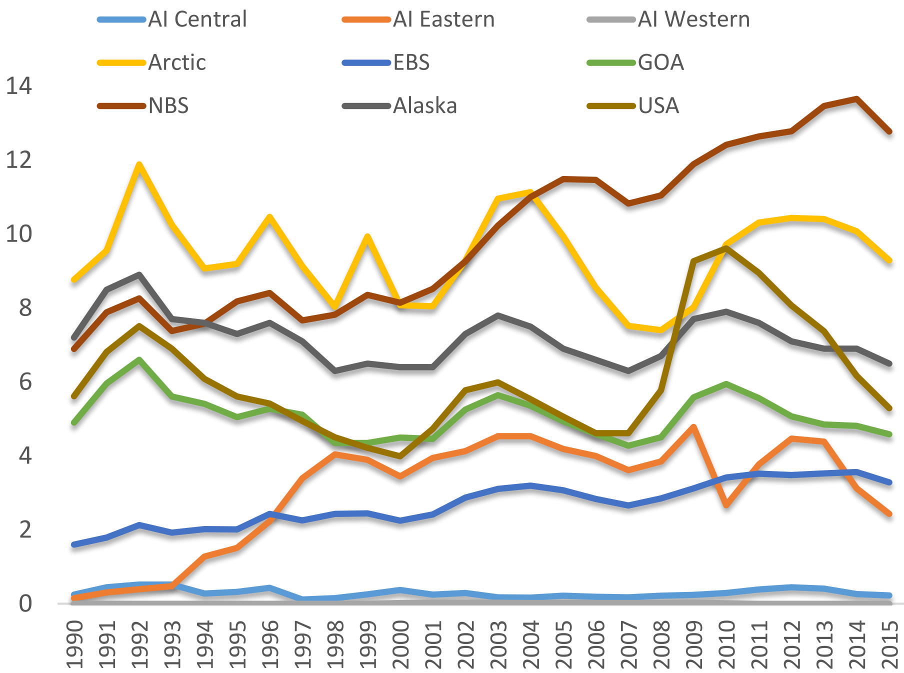

Figure 34: Unemployment rates for all regions, Alaska and USA.

Factors influencing observed trends: The population decrease of the AI between 1990 and 2015 (30.2%) was inconsistent with State trends (increase of 34.1%). Alaska has high rates of population turnover because of migration, and population growth has occurred mainly in urban areas (ADLWD 2016b). The main factors that affect population growth are natural increase (births minus deaths) and migration, with the latter being the most unpredictable aspect of population change (Williams 2004; ADLWD 2016b). In 2010, 61% of Alaskas population was born out of State (Rasmussen et al. 2015). In terms of natural growth, from 2013 to 2014 the birth rate in Alaska was 1.5 per 100 people which was higher than the national rate of 1.3. The Aleutian chain had the lowest natural increase (0.0- 0.5%) whereas the NBS area had the highest (1.5- 3.0%). In regard to migration, the net annual migration of the AI was low (<0- 100) (Williams 2004; ADLWD 2016b). The highest net migration occurs in the GOA region and the Matanuska-Susitna Borough has the highest growth rate in the State (ADLWD 2016b).

Population trends in Alaska are largely the result of changes in resource extraction and military activity (Williams 2004). Historically, the gold rush of the late 19th century doubled the States population by 1900, and later WWII activity and oil development fueled the population growth (ADLWD 2016b). However, the population of some communities declined in the 1990s because of Coast Guard cut-backs and military base closures (Williams 2006). For example, the closure of a Coast Guard base in Attu Station in western AI has left the community abandoned explaining the zero population in 2015. The fishing industry also influences population and this is evident in the AI with Unalaska and Akutan, the most populous communities of the AI, being landings for substantial volumes of seafood. The Aleutian Islands, and Kodiak, have the most transient populations because of the seafood processing industry (Williams 2004). Factors that influence population shifts and migration include employment, retirement, educational choices, cost of living, climate, and quality of life, (Donkersloot and Carothers 2016).

Alaska State has experienced several boom and bust economic cycles. Peaks in employment occurred during the construction of the Alaska pipeline in the 1970s and oil boom of the 1980s, whereas unemployment peak occurred following completion of the pipeline, during the oil bust of the late 1980s, and during the great recession of 2007-2009 (ADLWD 2016c) . However, during the great recession, Alaskas employment decreased only 0.4% whereas the national drop was 4.3% partly because of the jobs provided by the oil industry (ADLWD 2016d). Between 1990 and 2015, the eastern AI had the lowest unemployment rate in 1990 and highest in 2009 during the great recession (Figures 33-34).

Implications: Population shifts can affect pressures on fisheries resources, however inferences about human impacts on resources should account for economic shifts and global market demand for seafood and other extractive resources of the ecoregion. Population change in Alaska is largely fueled by increased net migration rather than natural increase, and there has been increased migration from rural to urban areas. AI communities are among the most transient with in-migration of foreigners working in processing plants, yet employment in fisheries is what maintains these communities, such as Unalaska and Akutan. Fisheries contribute to community vitality and changes in groundfish policy and management, such as increased regulations, may have implications for small communities of the Aleutian and Pribilof Island Community Development Association entity. Also, with almost half of the population of the AI being Native Alaskans, resource managers may benefit from working with communities holding traditional ecological knowledge (TEK) to incorporate TEK into ecosystem management (Huntington et al. 2004).

Groundfish Fleet Composition

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Description of indicator: 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 2014. These figures count vessels only for trips where groundfish is targeted.

Status and trends: Figure 35 shows the number of vessels by gear type off the Aleutian Islands. The total number of vessels participating in federally-managed fisheries Alaska-wide has generally decreased since 1992, though participation has remained relatively stable in recent years. Vessels using hook and line or jig gear have accounted for most of the participating vessels from 1992 to 2015. Approximately 600 such vessels participated in 2015, compared to over 1,000 vessels annually from 1992 to 1994. The number of active trawl-gear vessels has decreased steadily from over 250 annually in the period from 1992 to 1999 to around 180 in each of the last 5 years. Pot-gear activity has steadily declined since a peak of 343 vessels in 2000, with 154 pot vessels active in 2015.

Vessel counts before and after 2003 may not be directly comparable due to changes in fishery monitoring and reporting methods. The Catch Accounting System (CAS), implemented in 2003 for in-season monitoring of groundfish catch, registers the Federal Fisheries Permit number of catcher vessels delivering to motherships and shoreside processors, thus giving a more complete accounting of participating vessels than the previous "blend" system. The increase in 2003 in hook and line/jig vessel counts, in particular, is likely attributable this change.

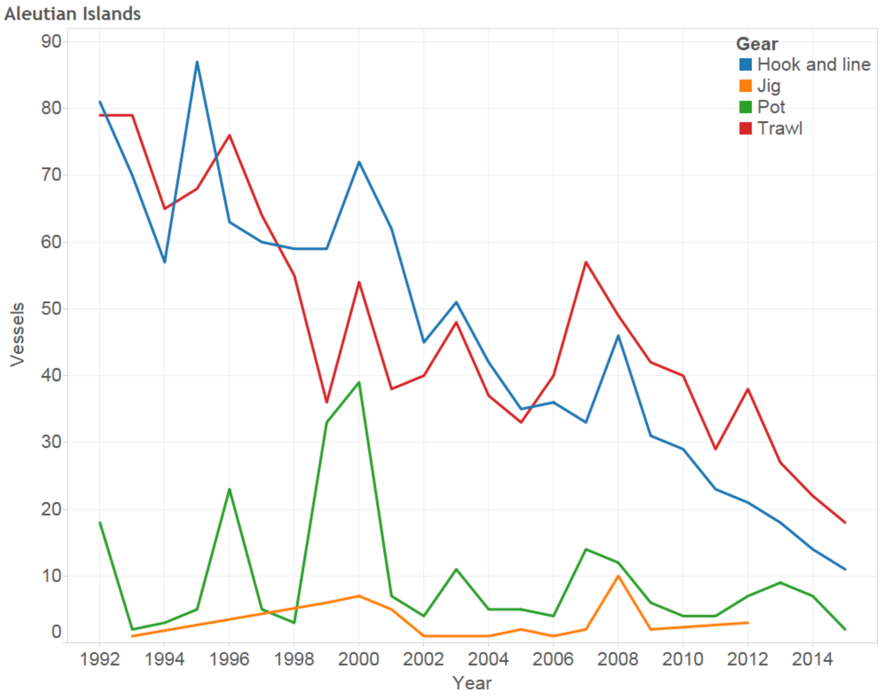

Figure 35: Number of vessels participating in the groundfish fisheries off the Aleutian Islands by gear type, 1992-2015.

Factors influencing observed trends: Participation in groundfish fisheries off Alaska since the early 1990s has been driven by a number of interacting factors. These include fluctuations in market conditions, stock levels, and allowable catch quotas; the availability of fishing opportunities in alternative fisheries; and the introduction of management measures intended to address issues such as bycatch, protected species, and overcapitalization.

Aleutian Islands

- Steller sea lion protection measures in the Aleutian Islands have primarily affected fisheries for prey species (pollock, cod, and Atka mackerel). The AI trawl pollock fishery was closed for Steller sea lion recovery from 1999 to 2004, and participation has been limited since the fishery reopened in 2005 with additional area restrictions and full allocation of the TAC to the Aleut Corporation.

- Participation in the trawl Atka mackerel fishery declined sharply in 1994 following the implementation of Amendment 28 to the BSAI Groundfish FMP, which divided the Aleutian Islands into three districts for spatially allocating TAC.

- In the fixed gear sablefish fishery, participation by hook and line vessels has declined gradually since implementation of the IFQ program (from 66 vessels in 1995 to 8 vessels in 2015). As in the Bering Sea, sablefish fishing with pot gear increased beginning in 2000 and has leveled off in recent years.

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.

References

AFSC. 2011. Observer Sampling Manual for 2012. Technical report, Alaska Fisheries Science Center, Fisheries Monitoring and Analysis Division, North Pacific Groundfish Observer Program, 7600 Sand Point Way, NE.; Seattle WA; 98115.

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

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

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

Bond, N. A., M. F. Cronin, H. Freeland, and N. Mantua. 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific. Geophysical Research Letters **42**:3414–3420.

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

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

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

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

Di Lorenzo, E., and N. Mantua. 2016. Multi-year persistence of the 2014/15 North Pacific marine heatwave. Nature Clim. Change **advance online publication**.

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

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

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

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

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

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

Fritz, L. W., and C. Stinchcomb. 2005. Aerial, ship, and land-based surveys of Steller sea lions (Eumetopias jubatus) in the western stock in Alaska, June and July 2003 and 2004. Technical report, U.S. Department of Commerce, NOAA Tech. Memo. NMFS-AFSC-153.

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

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

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

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

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

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

Lauth, R. R., J. Guthridge, D. G. Nichol, S. W. McEntire, and N. Hillgruber. 2007. Timing and duration of mating and brooding periods of Atka mackerel (Pleurogrammus monopterygius) in the North Pacific Ocean. Fishery Bulletin **105**:560–570.

Levine, A. F. Z., and M. J. McPhaden. 2016. How the July 2014 easterly wind burst gave the 20152016 El Nio a head start. Geophysical Research Letters **43**:6503–6510.

Maslowski, W., R. Roman, and J. C. Kinney. 2008. Effects of mesoscale eddies on the flow of the Alaskan Stream. Journal of Geophysical Research-Oceans **113**.

McKenzie, J., and K. M. Wynne. 2008. Spatial and Temporal Variation in the Diet of Steller Sea Lions in the Kodiak Archipelago, 1999-2005. Marine Ecology Progress Series **360**:265–283.

Mordy, C. W., P. J. Stabeno, C. Ladd, S. Zeeman, D. P. Wisegarver, S. A. Salo, and G. L. Hunt. 2005. Nutrients and primary production along the eastern Aleutian Island Archipelago. Fisheries Oceanography **14**:55–76.

NMFS. 2010. Endangered Species Act Section 7 Consultation, Biological Opinion. Authorization of groundfish fisheries under the fishery management plans for groundfish of the Bering Sea and Aleutian Islands management area and the Gulf of Alaska. NMFS Alaska Region, Juneau AK page 472 pp .

Okkonen, S. R. 1996. The influence of an Alaskan Stream eddy on flow through Amchitka Pass. Journal of Geophysical Research-Oceans **101**:8839–8851.

Paul, J. M., A. Paul, and W. E. Barber. 1997. Reproductive biology and distribution of the snow crab from the northeastern Chukchi Sea, pages 287–294 . Bethesda, MD.

Pitcher, K. W., and F. H. Fay. 1982. Feeding by Steller Sea Lions on Harbor Seals. Murrelet **63**:70–71.

Purcell, J. E., and M. N. Arai. 2001. Interactions of pelagic cnidarians and ctenophores with fish: a review. Hydrobiologia **451**:27–44.

Purcell, J. E., and M. V. Sturdevant. 2001. Prey selection and dietary overlap among zooplanktivorous jellyfish and juvenile fishes in Prince William Sound, Alaska. Marine Ecology Progress Series **210**:67–83.

Reed, R. K. 1987. Salinity characteristics and flow of the Alaska Coastal Current. Continental Shelf Research **7**:573–576.

Reisewitz, S. E., J. A. Estes, and et al. 2006. Indirect food web interactions: sea otters and kelp forest fishes in the Aleutian archipelago. Oecologia **146**:623–631.

Richardson, A. J., A. W. Walne, A. G. J. John, T. D. Jonas, J. A. Lindley, D. W. Sims, D. Stevens, and M. Witt. 2006. Using continuous plankton recorder data. Progress in Oceanography **68**:27–74.

Riemer, S. D., and R. F. Brown. 1997. Prey of Pinnipeds at Selected Sites in Oregon Identified by Scat (Fecal) Analysis, 1983-1996. Oregon Department of Fish and Wildlife, Technical Report No.97-6-02. .

Robinson, K. L., J. J. Ruzicka, and M. B. Decker. 2014. Jellyfish, Forage Fish, and the Worlds Major Fisheries .

Rooper, C. N. 2008. An ecological analysis of rockfish (Sebastes spp.) assemblages in the North Pacific Ocean along broad-scale environmental gradients. Fishery Bulletin **106**:1–11.

Schumacher, J. D., and R. K. Reed. 1986. On the Alaska Coastal Current in the western Gulf of Alaska. Journal of Geophysical Research: Oceans **91**:9655–9661.

Sease, J. L., and A. E. York. 2003. Seasonal Distribution of Steller's Sea Lions at Rookeries and Haul-Out Sites in Alaska. Marine Mammal Science **19**:745–763.

Sigler, M., D. Tollit, J. J. Vollenweider, J. F. Thedinga, D. J. Csepp, J. N. Womble, M. A. Wong, M. J. Rehberg, and A. W. Trites. 2009. Steller Sea Lion Foraging Response to Seasonal Changes in Prey Availability. Marine Ecology Progress Series **388**.

Sinclair, E. H., and T. K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (Eumetopia jubatus). Journal of Mammalogy **83**:973–990.

Stabeno, P. J., D. G. Kachel, N. B. Kachel, and M. E. Sullivan. 2005. Observations from moorings in the Aleutian Passes: temperature, salinity and transport. Fisheries Oceanography **14**:39–54.

Stevenson, D. E., and R. R. Lauth. 2012. Latitudinal trends and temporal shifts in the catch composition of bottom trawls conducted on the eastern Bering Sea shelf. Deep-Sea Research Part Ii-Topical Studies in Oceanography **65-70**:251–259.

Trenberth, K., and J. W. Hurrell. 1994. Decadal atmosphere-ocean variations in the Pacific. Climate Dynamics **9**:303–319.

Trites, A. W., D. Calkins, and A. J. Winship. 2007. Diets of Steller Sea Lions (*Eumetopias jubatus*) in Southeast Alaska, 1993-1999. Fishery Bulletin **105**:234–248.

Waite, J. N., and V. N. Burkanov. 2006. Steller Sea Lion Feeding Habits in the Russian Far East, 2000-2003. University of Alaska, Fairbanks.

Williams, T. M. 2005. Reproductive energetic of sea lions: implications for the size of protected areas around Steller sea lion rookeries. Alaska Sealife Center, Seward, AK.

Winship, A. J., A. W. Trites, and D. A. S. Rosen. 2002. A Bioenergetic Model for Estimating the Food Requirements of Steller Sea Lions (*Eumetopias jubatus*) in Alaska, USA. Marine Ecology Progress Series **229**:291–312.

Witherell, D., and D. Woodby. 2005. Application of marine protected areas for sustainable production and marine biodiversity off Alaska. Marine Fisheries Review **67**:1–28.

Appendix

Table 9: Summary of Alaska Fisheries Science Center surveys as of May 2016 compiled by Jennifer Ferdinand and Mike Sigler.

Project name (short)	Start year	Survey frequency	Purpose	Comments
Spring ecosystem survey, Gulf of Alaska	1985	biennial; parts of this survey date back to 1972	Fisheries oceanography	
Spring ecosystem survey, southeastern Bering Sea	1995	biennial	Fisheries oceanography	
Late summer ecosystem survey, southeastern Bering Sea	2001	biennial	Fisheries oceanography	Funding uncertain each year
Southeast Alaska Coastal Monitoring	1995	annual	Fisheries oceanography	
Late summer ecosystem survey, Gulf of Alaska	2012	biennial	Fisheries oceanography	Funding uncertain each year
Moorings, Bering Sea	1995	annual	Oceanography	
Moorings, Gulf of Alaska	1995	annual	Oceanography	
Bottom trawl survey, southeastern Bering Sea	1982	annual	Stock assessment	
GOA/EBS/AI Longline Stock Assessment Survey	1988	annual	Stock assessment	
Bottom trawl survey, Gulf of Alaska	1987	biennial	Stock assessment	
Bottom trawl survey, Aleutian Islands	1992	biennial	Stock assessment	
Bottom trawl survey, Bering Sea slope	2002	intermittent	Stock assessment	
Acoustic survey, southeastern Bering Sea	2004	biennial		
Acoustic survey, Gulf of Alaska	2010	biennial	Stock assessment	
Acoustic survey, Gulf of Alaska, pre-spawning, Shelikof	1991	annual	Stock assessment	
Acoustic survey, Gulf of Alaska, pre-spawning, Shumagin/Sanak	2009	annual	Stock assessment	

Project name (short)	Start year	Survey frequency	Purpose	Comments
Acoustic survey, Bogoslof	1988-2007	annual; now biennial (see below)	Stock assessment	
Acoustic survey, Bogoslof	2009	biennial	Stock assessment	
Humpback whale predator/prey	2011	annual	special project	
Yukon chinook	2014	annual	special project	
Deepwater Rockfish Tagging	2014	annual	special project	
Sablefish and Deepwater Rockfish Maturity	2014	annual	special project	
Fishing Technology Studies to Reduce Bycatch and Habitat Effects of Fishing		intermittent	special project	
Arctic Aerial Calibration Experiments	2015	BOEM & Navy-funded; one-time	marine mammal	
Foraging ecology and health of adult female Steller sea lions	2010	annually (when possible)	marine mammal	
Ice-associated seal ecology	2005	intermittent; every 1-2 years	marine mammal	
Northern fur seal population studies at Bogoslof Island	1980	3-5 years	marine mammal	
Steller sea lion vital rate and pup health studies	mid-1980s	annual	marine mammal	
Steller sea lion vital rates studies in the Gulf of Alaska	mid-1980s	annual; marking stopped in 2005	marine mammal	
Steller sea lion vital rates studies in western and central Aleutian Islands	2011	mark animals biennially; conduct observations annually	marine mammal	
Harbor seal tagging in the western Aleutians	2014	annual	marine mammal	
Ice-associated seal aerial surveys	2012	biennial	marine mammal	
Harbor seal aerial surveys	1990s	annual	marine mammal	
Cook Inlet beluga aerial surveys	mid-1990s	annual; changed to biennial in 2013	marine mammal	
CHAOZ, CHAOZ-X (Chukchi Sea Acoustics, Oceanography, and Zooplankton)	2010	BOEM-funded; annual	marine mammal	
ASAMM	2008	BOEM-funded; annual	marine mammal	
Steller sea lion pup counts	1961	biennial	marine mammal	
Steller sea lion non-pup counts	1904	annual (some years inconsistent)	marine mammal	

Project name (short)	Start year	Survey frequency	Purpose	Comments
Southeast Alaska cetacean survey	mid-1990s	annual	marine mammal	
Arctic Coastal Ecosystem Survey and Shelf Habitat and Ecology of Fish and Zooplankton	2013-2014	one-time	ecosystem assessment	
North Pacific Domestic Fishery Observer Data	1986	continuous	catch accounting	
Gulf of Alaska small-mesh survey (ADF&G and NMFS)	1953	annual, discontinued	ecosystem assessment and shrimp biomass	
Arctic Integrated Ecosystem Survey	2012	intermittent	ecosystem assssment	
Beaufort Sea fish and shellfish survey	2008	one-time	ecosystem assssment	