Appendix C

Ecosystem Considerations DRAFT

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Executive Summary of Recent Trends

Physical and Environmental Trends

- The state of the North Pacific atmosphere-ocean system during 2011-2012 reflected the combination of a response to La Niña and intrinsic variability. The Aleutian low was weaker than usual in the winter of 2011-12, and the sea level pressure was higher than normal in the eastern portion of the basin for the year as a whole. (p. 84)
- Cooler than normal upper ocean temperatures prevailed in the eastern portion of the North Pacific and warmer than normal temperatures occurred in the west-central and then central portion of the basin. This pattern reflects a continuation of a negative sense to the Pacific Decadal Oscillation (PDO). (p. 84)
- The ENSO indices for the tropical Pacific indicate a warming trend for the first half of 2012; the models used to forecast ENSO are indicating outcomes for the winter of 2012-13 ranging from near neutral to a weak-moderate El Niño. (p. 84).
- It is likely that there will be a warming of Alaskan waters over the next 2-3 seasons, relative to the mostly cooler than normal temperatures that have prevailed over the last 5 years. (p. 91).

Arctic

- The tendency for reduced sea ice cover in the Arctic during the summer has continued into 2012. The distribution of the arctic sea ice in early August 2012 differs somewhat from recent years. Specifically, high ice concentrations have persisted in the Chukchi and in the western portion of the Beaufort Sea. (p. 84).
- If the ice pack retreats to well north of Alaska, as it has in recent summers, there should again be a delay the development of ice in marginal seas such as the Bering Sea during the following cold season. (p. 84).

Bering Sea

- The Bering Sea shelf experienced another relatively heavy ice year, especially in terms of maximum ice extent. (p. 84).
- Unlike a year ago, the summer of 2012 has been relatively calm. (p. 84, 93).
- The combination of El Niño expected this winter and a continuation of reduced ice cover in the central Arctic (more on this below) should yield a lighter ice year for the Bering in 2013.(p. 84).

Gulf of Alaska

- The poleward branch of the Alaska Current in the southeastern portion of the Gulf increased markedly from summer into fall of 2011, and after declining over the course of the winter, again increased from spring into summer 2012. These changes from season to season are consistent with the winds. (p. 84).
- The mixed layer depths in the Gulf were shallower than usual during the winter of 2011-2012 but by early summer 2012 were near their seasonal norms. (p. 84).
- Eddy Kinetic Energy (EKE) levels were approximately average off Kodiak and high in the northern Gulf of Alaska in 2011. (p. 93).
- Phytoplankton biomass was probably more tightly confined to the shelf during 2009 due to the absence of eddies, while in 2007, 2010 and 2011, phytoplankton biomass likely extended farther off the shelf (p. 93).
- Cross-shelf transport of heat, salinity and nutrients were probably weaker in 2009 than in 2007, 2010, and 2012 (or other years with large persistent eddies) (p. 93).
- The 2011/2012 PAPA trajectory followed the general northeastwardly path of most drifters, but was notable because its ending latitude was the northernmost of all trajectories since 1994. (p. 95).

Alaska Peninsula and Aleutian Islands

- Westerly wind anomalies have prevailed in this region for much of the past year. Anomalies in this sense tend to suppress the northward transport through Unimak Pass and perhaps also the Aleutian North Slope Current. A possible implication is a reduced supply of nutrients onto the southern Bering Sea shelf, but the importance of this mechanism is poorly known.(p. 84).
- Eddy energy south of Amutka Pass was low from the spring of 2010 through early 2012, but recent data shows the existence of an eddy in the region beginning in late April 2012. (p. 98).
- These trends indicate that higher than average volume, heat, salt, and nutrient fluxes to the Bering Sea through Amukta Pass may have occurred in 1997/1998, 1999, 2004, 2006/2007, 2009/2010 and summer 2012. These fluxes were likely smaller during the period from spring 2010 until early spring 2012.(p. 98).

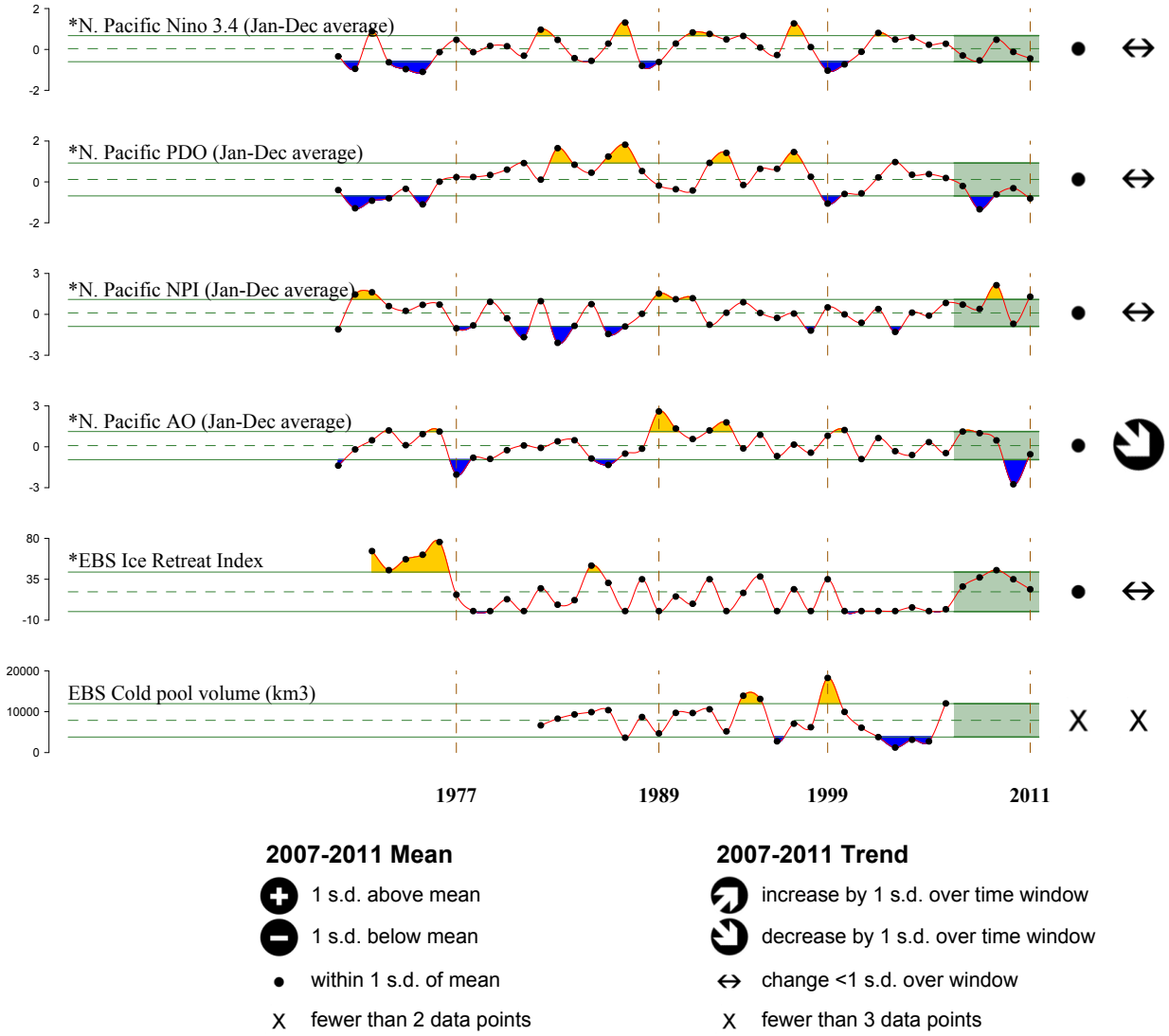

Figure 1: North Pacific and Eastern Bering Sea climate indices. *Time series updated in 2011. These will be updated in the November draft.

Ecosystem Trends

Bering Sea

- Mesozooplankton biomass appeared to be low in southern Bering Sea regions in 2011
- Mean monthly copepod community size from 2011 was similar to the long term mean for the southern Bering Sea and Alaskan shelf, suggesting that the low biomass was not the result of an absence of a particular group of copepods.(p. 111).
- Temporal trends in surface carbon uptake rates over the SEBS (inner and middle domains combined) remain relatively invariable from 2006-2011 with an exception during 2007, where median ^{13}C uptake rates decreased by a factor greater than 5 (P = 0.008). Significant decreases in phytoplankton carbon uptake and chlorophyll biomass during late summer/early fall will negatively impact energy flow to higher trophic levels.(p. 104).
- The 2011 Bristol Bay sockeye run of 30.3 million fish was close to the long-term average of 30.6 million, but 21% below the forecasted run size.(p. 122).
- In 2010, the Temperature Change index value was below the long term average, therefore we expect below average numbers of pollock to survive to age-3 in 2012. In the future, the Temperature Change values in 2011 and 2012 indicate above average abundances of age-3 pollock in 2013 and below average abundances of age-3 pollock in 2014. (p. 133).
- In 2011 total jellyfish biomass decreased by almost half compared to the previous year. However, for the first time since sampling started in 2004, the biomass was recorded higher in the north than in the south(p. 116).

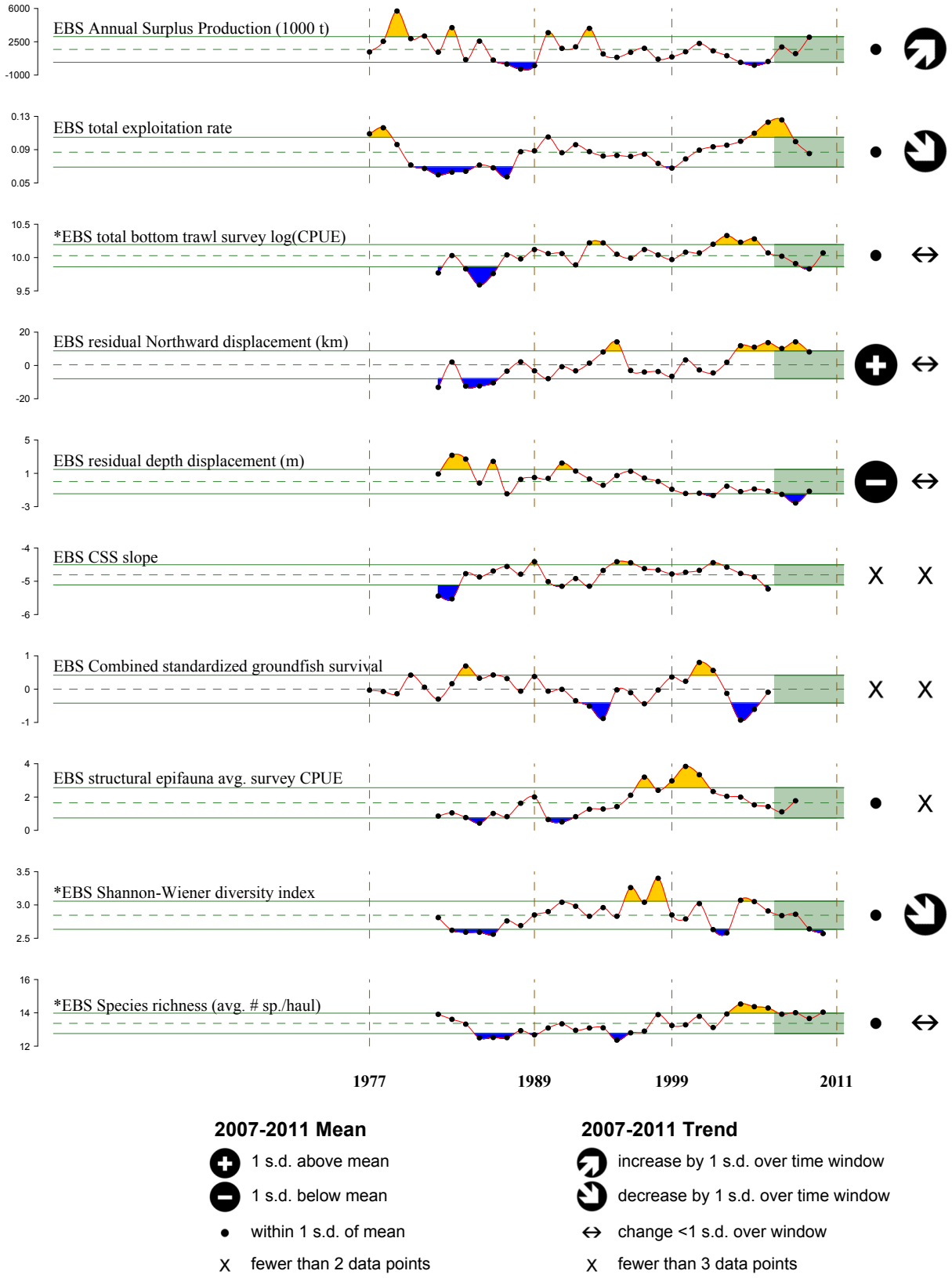

Figure 2: Eastern Bering Sea ecosystem indices. *Time series updated in 2011. These will be updated in the November draft.

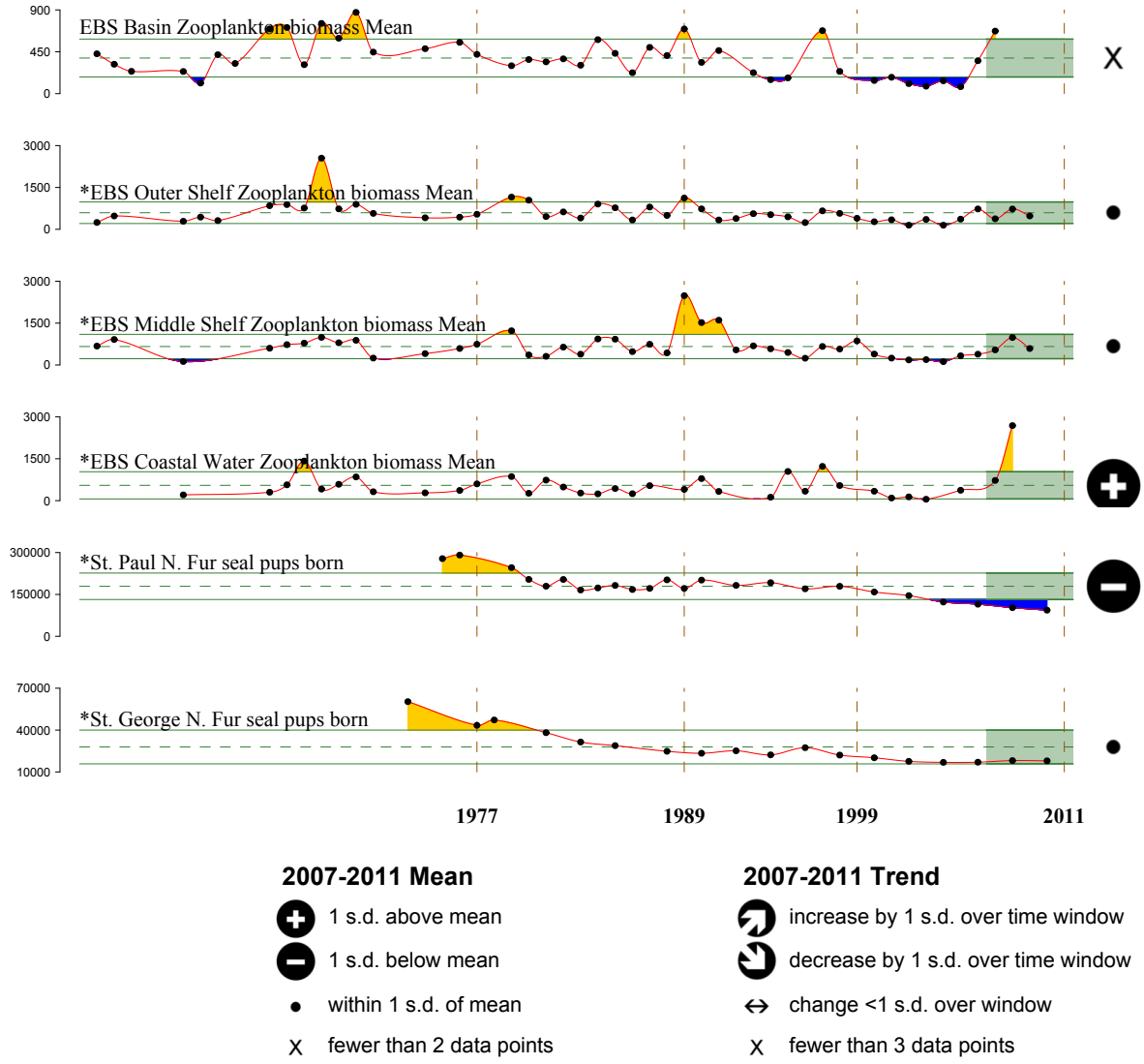

Figure 3: Eastern Bering Sea ecosystem indices. *Time series updated in 2011. These will be updated in the November draft.

Gulf of Alaska

- Mesozooplankton biomass was apparently low in the Alaskan shelf region (northern GOA) in 2011, while the oceanic Northeast Pacific showed a late and extended biomass peak. Larger species were present in the northeast Pacific later into summer than average, consistent with cool La Niña conditions delaying their development. (p. 111).
- Coherent patterns and synchronicity in ichthyoplankton trends were observed among groups of species from 1981 to 2009. (p. 129).
- Presently, four of the five crab fisheries analyzed show no increases in the spatial variability of the catch, and thus are not showing patterns that might be consistent with declining resilience and an increased chance of sudden collapse. (p. 135).
- Forage species catch rates remain at low levels, one to two orders of magnitude lower than peak values observed in the 1970s and early 1980s. Eulachon, which in recent years has had the highest catch rates of the time series, decreased in 2011 to a rate below the long-term average. (p. 119).
- Marine survival of Prince William Sound hatchery pink salmon does not appear to have shifted after the 1988/89 or the 1998/99 climate regime shifts. Marine survival in 2010 (2008 brood year) is at an all-time high since 1977. (p. 122).
- Arrowtooth flounder, flathead sole, and other flatfish continue to dominate the catches in the ADF&G trawl survey. A decrease in overall biomass is apparent from 2007 to 2011 from years of record high catches seen from 2002 to 2005. (p. 138).

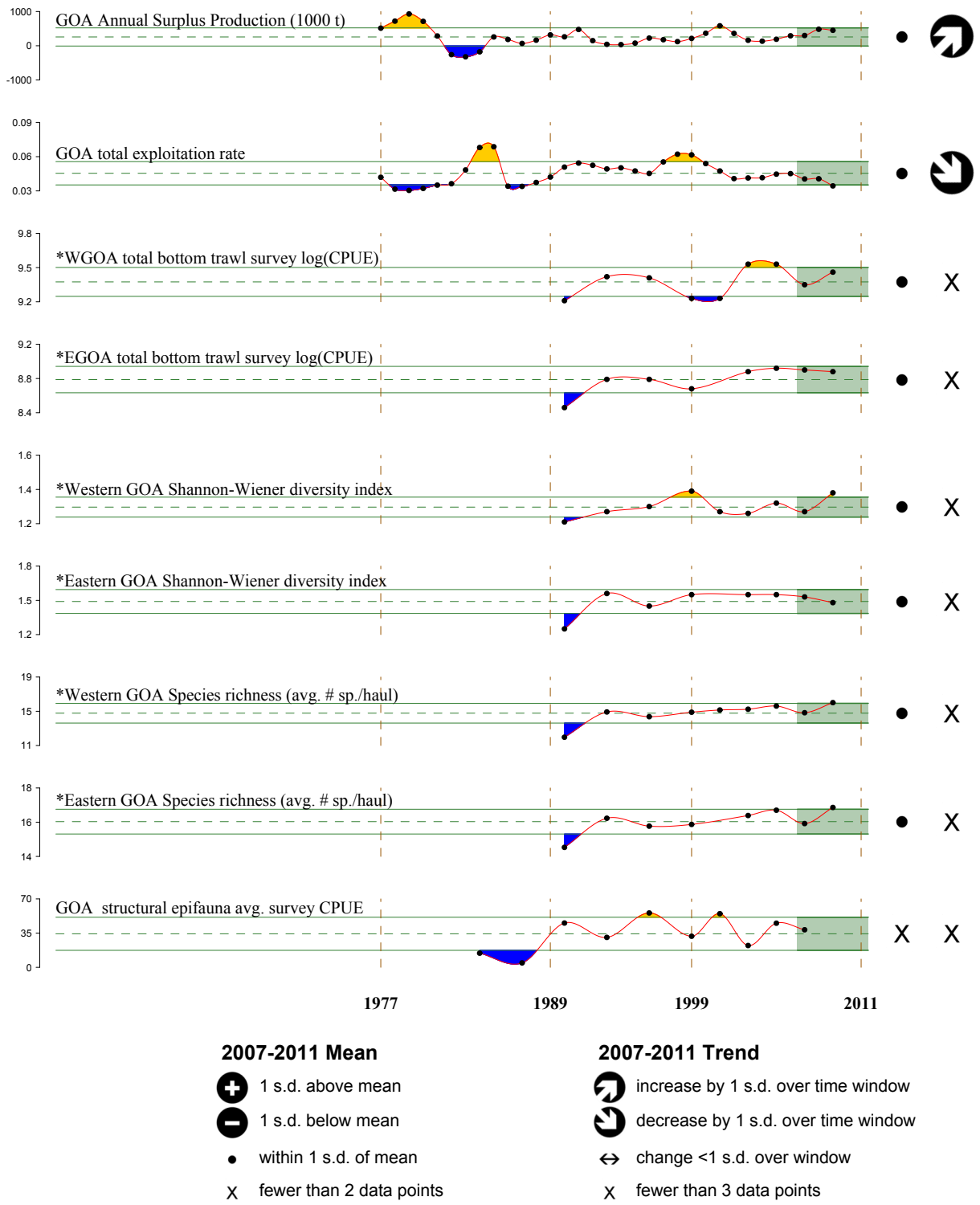

Figure 4: Gulf of Alaska ecosystem indices. *Time series updated in 2011.These will be updated in the November draft.

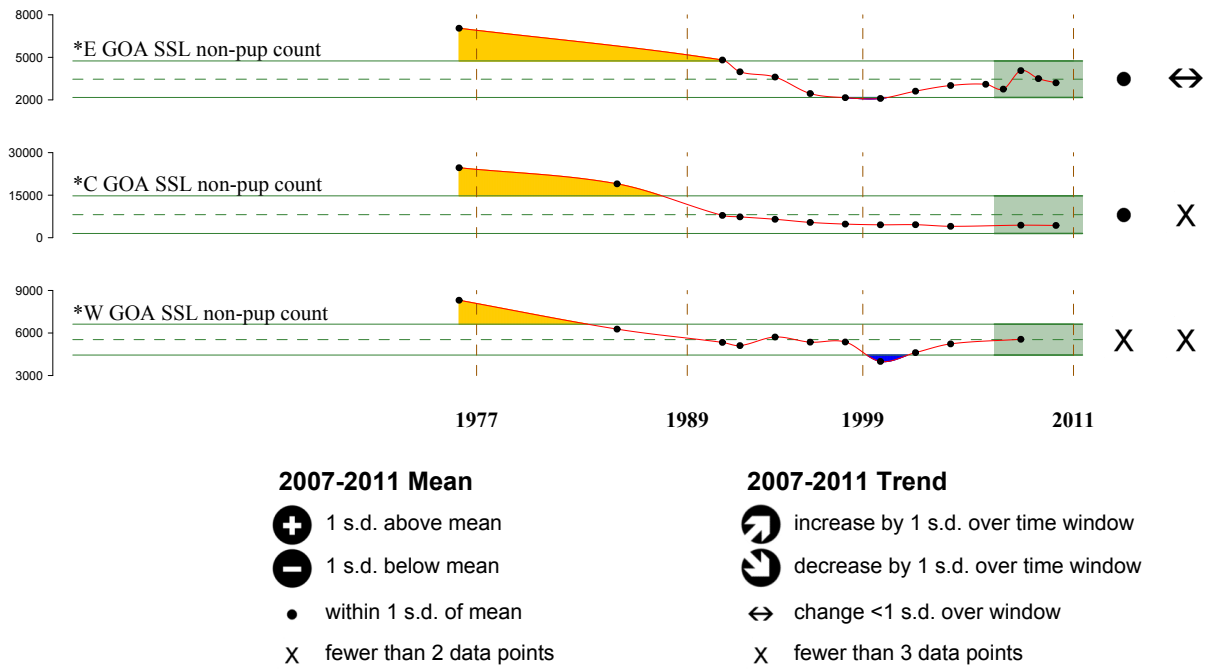

Figure 5: Gulf of Alaska ecosystem indices. *Time series updated in 2011.These will be updated in the November draft.

Aleutian Islands

- There is an overall decreasing trend in Pacific cod biomass, which contributes the largest proportion to the fish apex predator foraging guild. Arrowtooth flounder, Kamchatka flounder and skates all show an increasing trend.(p. 60)
- There are several species showing longitudinal trends in the fish pelagic foragers foraging guild: the biomass of walleye pollock increases towards the east, whereas that of northern rockfish and Pacific ocean perch increases towards the west. (p. 60)
- In the Western ecoregion (defined in the Aleutian Islands assessment, p. 60), reproductive success of planktivorous auklets have been higher than average for the past five years. The increase in the fish apex predators foraging guild apparent in the 2010 trawl survey is driven by Pacific cod, reversing the declining trend in this foraging guild since 2000. Recent counts of otters show no trend, in contrast to the steep decline during the early 2000s. Steller sea lions continue their decades-long decline in this ecoregion. Between 1991 and 2008, non-pup counts declined 81%, or at a rate of -10% per year .
- In the Central ecoregion, the fish apex predator trend is also largely driven by Pacific cod. Kamchatka flounder contributes the second largest biomass. Atka mackerel and Pacific ocean perch drive the biomass trend, making up 80% of the pelagic foragers biomass, with the remaining split between walleye pollock and northern rockfish. Recent counts of sea otters continue to decline. Counts of non-pup Steller sea lions in the central Aleutians declined 33% overall between 1991 and 2008, a rate of -2% per year (p. 60).
- In the Eastern ecoregion, fish apex predator biomass declined relative to past surveys. This trend is driven by Pacific cod and Arrowtooth flounder jointly, which alternate as the largest biomass in the area. More than half the fish pelagic forager biomass is commonly contributed by walleye pollock

and Atka mackerel. Atka mackerel show an increasing trend, but only in the data from the northern portion of the islands. In contrast to the other ecoregions, non-pup counts of Steller sea lions increased 21% overall between 1991 and 2008. Counts were largely stable through the 1990s, but increased at a rate of 3% per year between 2000 and 2008 (p. 60).

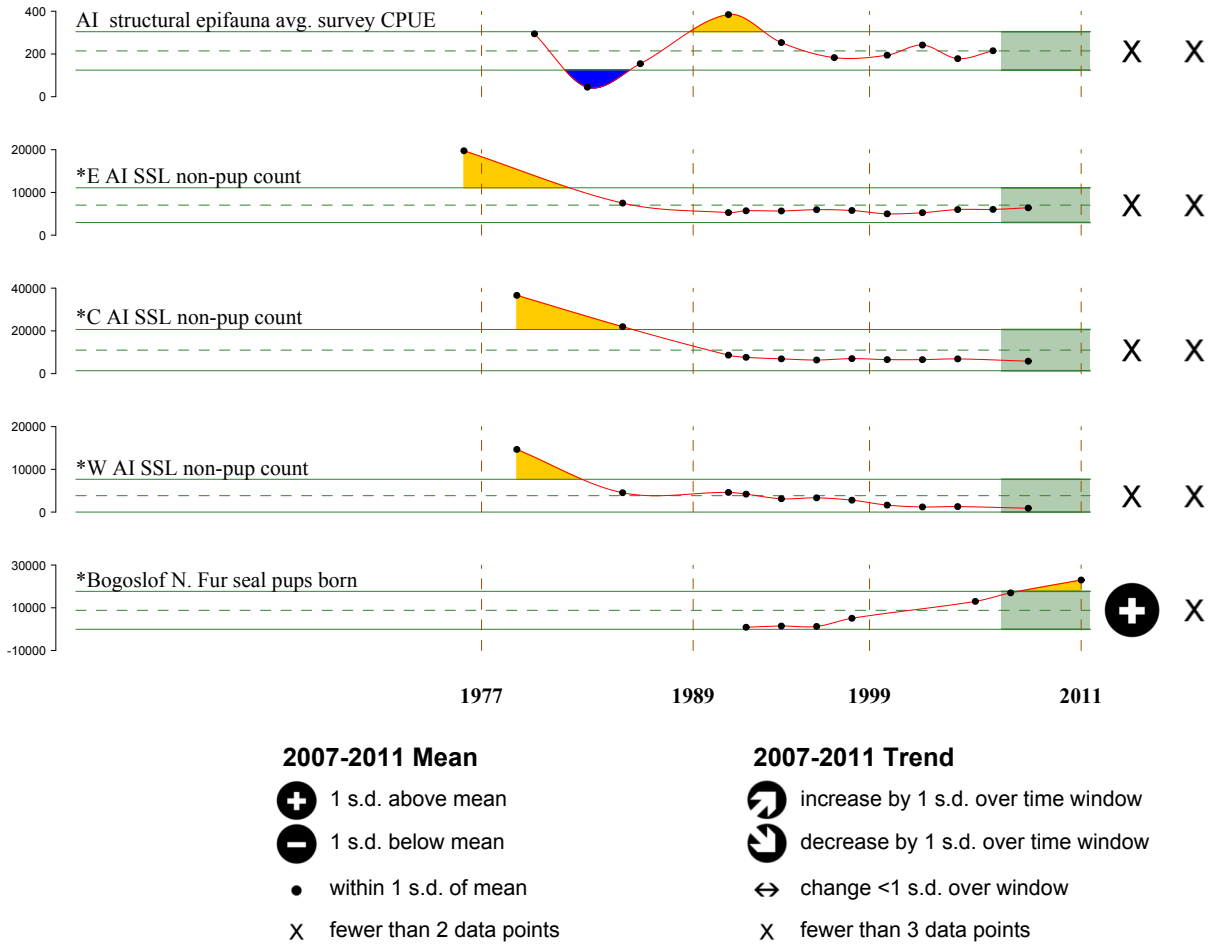

Figure 6: Aleutian Islands ecosystem indices. *Time series updated in 2011. These will be updated in the November draft.

Fishing and Fisheries Trends

Bering Sea

- At present, no BSAI or GOA groundfish stock or stock complex is overfished and no BSAI or GOA groundfish stock or stock complex is being subjected to overfishing. Stocks that are considered overfished are Pribilof Island blue king crab and BSAI Tanner crab. The Pribilof Island blue king crab is on a continuing rebuilding plan (year 9 of 10-year plan) while the management required for the Tanner crab stock is to develop a rebuilding plan. The status of the Bering Sea snow crab rebuilding program has changed from rebuilding to rebuilt. (p. 157).
- The catch of non-specified species has decreased overall since the late 1990s. The 2008-2009 increase in non-specified catch was driven by jellyfish. HAPC biota catch has generally decreased since 2004. The catch of forage species in the EBS increased in 2006 and 2007 and was comprised mainly of eulachon that was caught primarily in the pollock fishery; however, forage catch decreased in 2008-2010. The forage catch increased again in 2011, primarily due to capelin and eulachon. (p. 151).
- The maximum potential area of seafloor disturbed by trawling remained relatively stable in the 2000s with a slight decrease in 2009-2010. (p. 100).

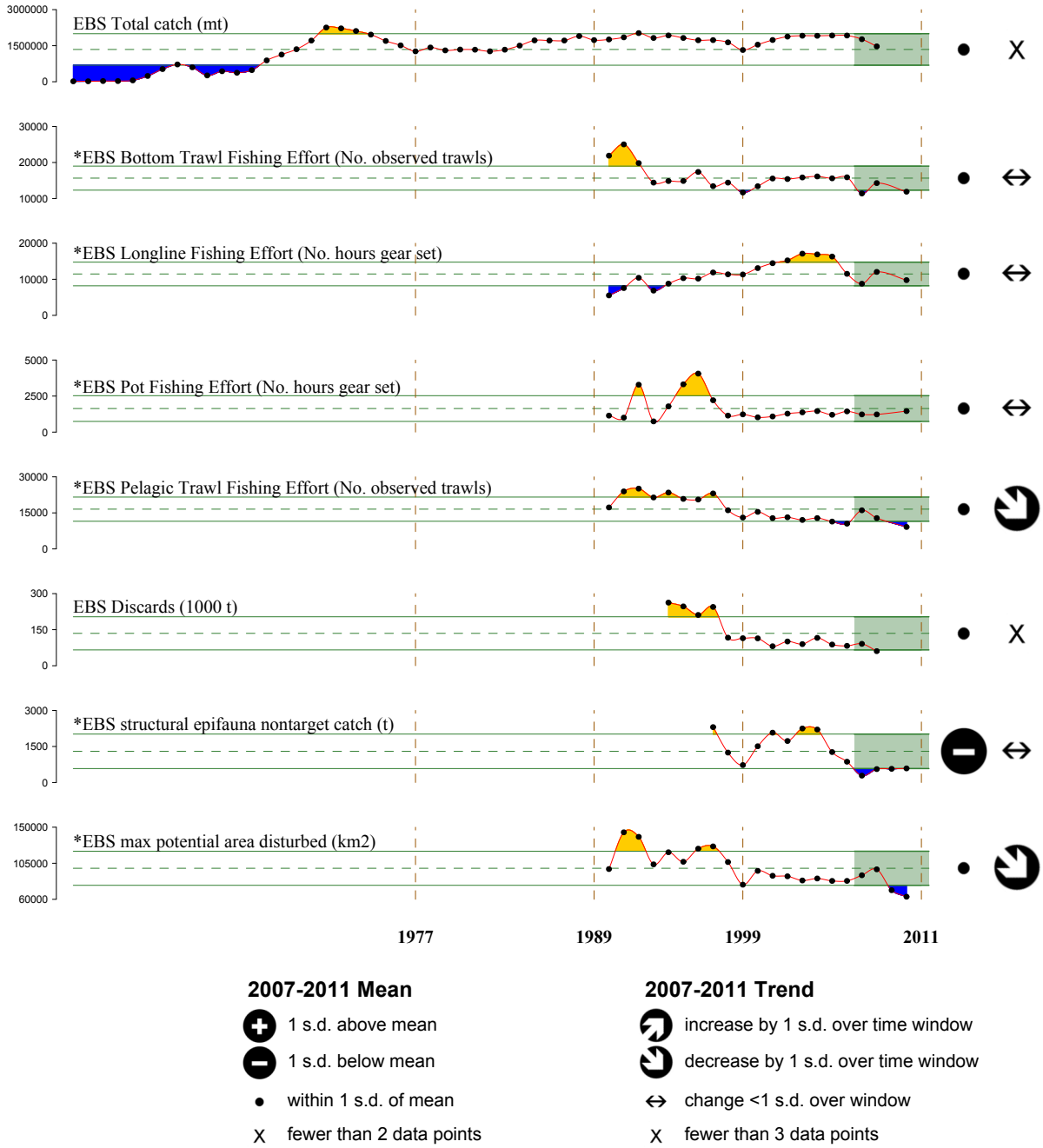

Figure 7: Eastern Bering Sea fisheries indices. *Time series updated in 2011. These will be updated in the November draft.

Gulf of Alaska

- Discard rates in the Gulf of Alaska have varied over time but were lower than average in 2010 and 2011. (p. 150).

- The catch of non-specified species in the GOA has been generally consistent aside from a peak in 1998 and lows in 2009 and 2010. The catch of forage species increased in 2010-2011, primarily due to eulachon and other osmerids. (p. 151).

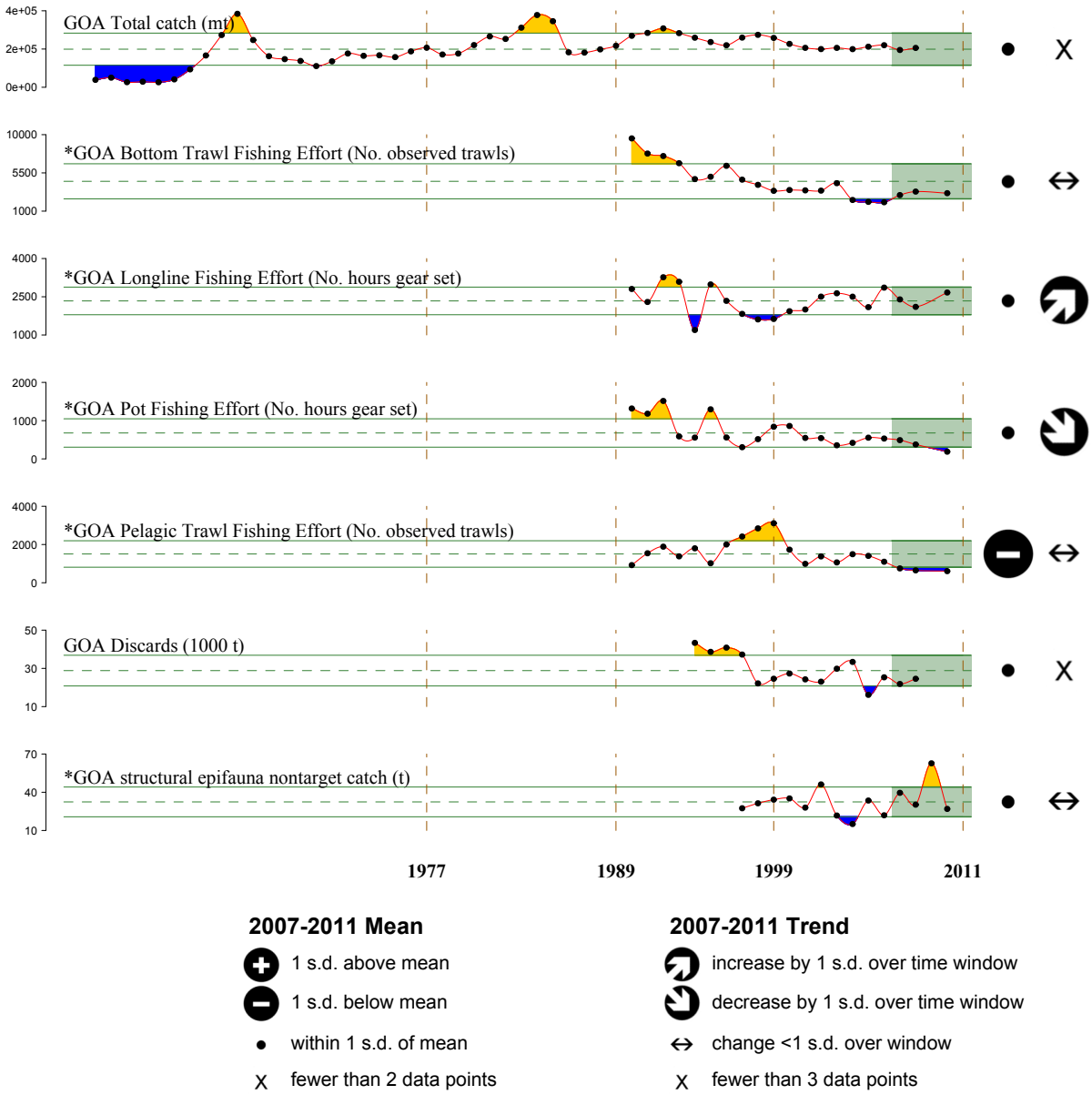

Figure 8: Gulf of Alaska fisheries indices. *Time series updated in 2011. These will be updated in the November draft.

Aleutian Islands

- Discard rates have declined over the past eight years. Discards and discard rates are much lower now than they were in 1996. (p. 150).
- The catch of non-specified species shows little trend over time, although the highest catches were recorded in 2009-2010. The non-specified catch dropped in 2010-2011, primarily due to a reduction in the catch of giant grenadiers. HAPC catch has been similarly variable over time in the AI, and is driven primarily by sponges caught in the trawl fisheries for Atka mackerel, rockfish and cod. Forage fish catches in the AI are minimal, amounting to less than 1 ton per year, with the exception of 2000 when the catch estimate was 4 tons, driven by (perhaps anomalous) sandfish catch in the Atka mackerel fishery. (p. 151).

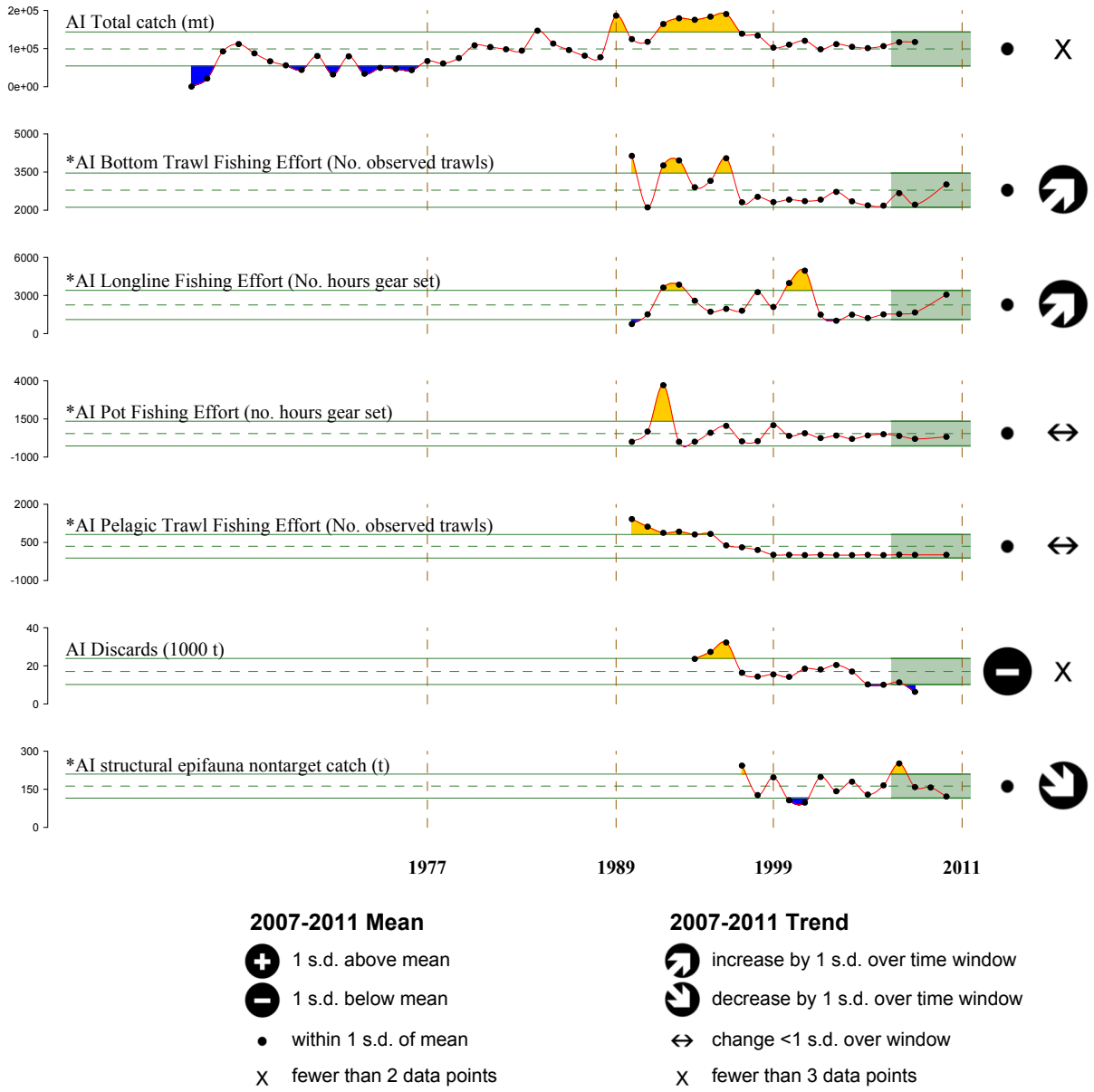

Figure 9: Aleutian Islands fisheries indices. *Time series updated in 2011. These will be updated in the November draft.

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

December 2012 SSC Comments

The SSC commends the Ecosystem editors and contributors for continued improvement and for their responsiveness to SSC comments. The Eastern Bering Sea (EBS) and Aleutian Islands (AI) (new) Report Cards and the Hot Topics sections highlight interesting changes and are informative. It might be preferable to move the Hot Topics section to the report card, as it is short and provides information of immediate concern. The SSC looks forward to the preparation of a Gulf of Alaska (GOA) Report Card.

Thank you. We plan to update the Report Cards and Hot Topics sections in the November draft when we have all of the updated information. Due to staff loss, we have postponed the development of a GOA Report Card and Assessment until winter, 2013.

These report card and hot topics sections would be even more useful if there was a short set of paragraphs that synthesized the views of the authors and Plan Teams as to the management implications of any findings.

We plan to incorporate these comments into the Report Cards and Hot Topics when the report is complete.

The Ecosystem Trends section was succinct and useful. The listing of critical information gaps and research needs for each region will be helpful for the assembly of the Research Priorities report later in the year. New indices include EBS phytoplankton biomass and size structure, GOA Chlorophyll a, Icy Strait zooplanktoRigoun trends, forecasts for SE Alaska pink salmon harvests, EBS slope groundfish and invertebrate community biodiversity, a multivariate seabird index for the EBS, and an index of Alaska-wide community regime shifts. The new seabird index shows some interesting results that may be useful in future ecosystem evaluations.

Thank you.

The executive summaries were useful, but ordering the indicators and key points from physical through consumers in a way that aligns them with the trophic structure would improve readability. In addition, some consistency in order of the indicators across regions would be appreciated.

We have rearranged the presentation order of some of the indicators in the Ecosystem Status and Management Indicators section as well as the Executive Summary to better reflect trophic structure. For example, the entries on jellyfish have been grouped with zooplankton and the ADF&G small mesh survey results have been moved to the forage fish section. We plan more reorganization in the November draft when the contents of the report are complete.

The SSC also appreciates the attempt (page 58) to test predictions made in the December 2010 Ecosystem Considerations chapter. In the future, it would be useful to denote all predictions in the chapter in bold, and then systematically test which ones were accurate the following year. Those predictions that prove reliable could then be moved into the individual species' assessments.

Thank you. We plan to systematically test all predictions made in the assessments annually. We will explore formatting options for grouping and/or highlighting predictions made throughout the report.

The sections on community trends in school enrollments and population size were informative. The SSC suggests adding information on trends in employment or wage-paying jobs and average wages. Because of their importance, sections on school enrollments should be separate paragraphs at the end of each ecoregion discussion. It is also possible that these socio-economic indices should be in the Economic SAFE.

The Aleutian Islands Ecosystem Assesment Teams discussed several other indicators, such as deck and other fishing licenses, to represent human trends in the AI ecosystem, but decided that school enrollment was the best indicator of the sustainibility of human communities. Alternate socio-economic indicators were considered more appropriate for the Economic SAFE. We will coordinate our review of these indicators with the Economics group to avoid reduncancy.

The SSC had some concern over the baseline dataset used when reporting anomalies, especially physical anomalies. Currently, the baseline period differs by parameter, and the time frame used to define the baseline is not always clear and often not legible in the figures. This makes it difficult to compare responses across variables directly. Please show the baseline over which the anomalies are determined and attempt to standardize to the extent practicable.

We plan to clarify this in the final draft.

Leading indicators should provide predictive value and they should integrate upwards to predicted impacts on commercially important species and species of conservation concern. The SSC encourages a rigorous evaluation of which indicators provide good insight into ecosystem status. An example of an indicator with too little data to be a useful leading indicator at present is the analysis of AI tufted puffin chick diets. Those indicators that cannot be updated in a timely fashion, preferably up to the summer before the SAFE document preparation may be more appropriately raised in the section on key data gaps.

We included the puffin chick diets because we knew that more complete time series of data existed. The editor has been assured that these data will be available in time for the November draft. One of the criteria for indicator selection in both the EBS and AI assessments was that they be regularly updatable. If they prove not to be, we will move them to the the section on data gaps.

The authors recognize the need for improved data on forage species, and the SSC reiterates its concern that lack of data on forage fish, particularly myctophids, sand lance, and squid, continues

to limit the evaluation of potential changes to these important prey groups for apex fish, seabird and marine mammal predators. Equally important is the lack of data on prey species during fall, specifically euphausiid abundance and distribution. The SSC encourages efforts to incorporate forage fish sampling and acoustic surveys for euphausiids during the fall BASIS surveys.

We plan to address forage fish data needs in a few ways. One is to include expanded seabird diet datasets (as described above). The other is to use the extensive food habits database to investigate forage fish temporal patterns in the diets large predatory fish such as halibut. The editor is coordinating with the forage fish assessment assessment author to develop new time series of forage fish. Regarding fall acoustic surveys, the editor has been in contact with the lead scientist, but these data are not yet available for presentation.

There seems to be disagreement between the ecosystem SAFE and the forage fish chapter about the underlying reliability and utility of CPUE and stock assessment for the various forage species. Clarification of CPUE data origin (trawl, acoustic, seabird) and the limitations of these sources should be included, and some effort made to coordinate data with the authors in charge of the forage fish chapter.

The editor is currently coordinating with the lead forage fish assessment assessment author to develop new time series of forage fish as well as to reduce possible redundancy and/or conflicts between the Ecosystem Considerations report and the forage fish stock assessment.

Relative to marine mammals, this document seems overly focused on northern fur seals and Steller sea lions, with no mention made of recent changes in the conservation status of walrus (recently listed as a candidate species under ESA), spotted seals (the Southern Distinct Population Segment recently listed as threatened) or the pending resolution of conservation status of other ice seal species, not to mention small, piscivorous cetaceans. Many of these species rely heavily on large zooplankton, forage fish species, euphausiids, and juvenile cod/groundfishes, and their population distributions and foraging behaviors are influenced by many of the physical variables mentioned in the Ecosystem Considerations chapter. There is a need to encapsulate fully the ecosystem considerations relative to these stocks. Inclusion of ice seals and walrus in the Bering Sea Ecosystem Chapter is particularly important, as these are food resources for many coastal communities, and changes in their status may influence human behavior.

We plan to incorporate more information on marine mammals in the next draft.

A number of specific questions, minor edits and comments have been provided to the editor.

General Comments:

It would be very helpful if all place names mentioned in the text were also displayed on a map.

We will work on developing a single map of place names.

All figure legends, especially internal legends, need to be checked for readability at the size found in a printed document. Likewise, when possible, figures should be intelligible in a black and white printed version.

We have attempted to address this as much as possible in this draft and will continue to work on this in the next draft.

It would help the SSC if tables and figures in the PowerPoint presentations include document page numbers to facilitate finding the originals.

We will follow this suggestion in all future powerpoint presentations.

When feasible, the SSC would like to have the editor of the Ecosystem Considerations Chapter provide the presentation to the SSC so that questions can be answered in depth and so that the editor can have a better understanding of the comments of the SSC.

We agree.

Introduction

The goal of the Ecosystem Considerations report is to provide stronger links between ecosystem research and fishery management and to spur new understanding of the connections between ecosystem components by bringing together many diverse research efforts into one document. There are three main sections:

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

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

The purpose of the second section, the Ecosystem Assessment, is to synthesize historical climate and fishing effects on the eastern Bering Sea/Aleutian Islands and Gulf of Alaska ecosystems using information from the Ecosystem Status and Management Indicators section and stock assessment reports. Notable trends, "hot topics", that capture unique occurrences, changes in trend direction, or patterns across indicators are highlighted at the beginning. An ongoing goal is to produce ecosystem assessments utilizing a blend of data analysis and modeling to clearly communicate the current status and possible future directions of ecosystems. In future drafts, the Ecosystem Assessment section will also provide an assessment of the possible future effects of climate and fishing on ecosystem structure and function.

The purpose of the third section, Ecosystem Status and Management Indicators, is to provide detailed information and updates on the status and trends of ecosystem components as well as to provide either early signals of direct human effects on ecosystem components that might warrant management intervention or to provide evidence of the efficacy of previous management actions. Ecosystem-based management indicators should also track performance in meeting the stated ecosystem-based management goals of the NPFMC, which are:

1. Maintain biodiversity consistent with natural evolutionary and ecological processes, including dynamic change and variability
2. Maintain and restore habitats essential for fish and their prey

3. Maintain system sustainability and sustainable yields for human consumption and nonextractive uses

4. Maintain the concept that humans are components of the ecosystem

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

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

1. Track ecosystem-based management efforts and their efficacy,

2. Track changes in the ecosystem that are not easily incorporated into single-species assessments,

3. Bring results from ecosystem research efforts to the attention of stock assessment scientists and fishery managers,

4. Provide a stronger link between ecosystem research and fishery management, and

5. Provide an assessment of the past, present, and future role of climate and humans in influencing ecosystem status and trends.

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

In 2002, stock assessment scientists began using indicators contained in this appendix to systematically assess ecosystem factors such as climate, predators, prey, and habitat that might affect a particular stock. Information regarding a particular fishery's catch, bycatch and temporal/spatial

distribution can be used to assess possible impacts of that fishery on the ecosystem. Indicators of concern can be highlighted within each assessment and could be used by the Groundfish Plan Teams and the Council to justify modification of allowable biological catch recommendations or time/space allocations of catch.

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

It was requested that contributors to the ecosystem considerations appendix provide actual time series data or make it available electronically. Most of the time series data for contributions are now available on the web, with permission from the authors.

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

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

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

Ecosystem Assessment

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Last updated: November 2011

Editor's note: The November draft will include updates to the Eastern Bering Sea and Aleutian Island ecosystem assessments as well as evaluations of predictions made in the 2011 assessments. Due to staff loss, production of the new Gulf of Alaska ecosystem assessment was postponed until winter 2013.

Introduction

The primary intent of this assessment is to summarize and synthesize historical climate and fishing effects on the shelf and slope regions of the eastern Bering Sea, Aleutian Islands, Gulf of Alaska, and new this year, the Arctic, from an ecosystem perspective and to provide an assessment of the possible future effects of climate and fishing on ecosystem structure and function. The Ecosystem Considerations section of the Groundfish SAFE provides the historical perspective of status and trends of ecosystem components and ecosystem-level attributes using an indicator approach. For the purposes of management, this information must be synthesized to provide a coherent view of ecosystems effects in order to clearly recommend precautionary thresholds, if any, required to protect ecosystem integrity.

The eventual goal of the synthesis is to provide succinct indices of current ecosystem conditions reflecting these ecosystem properties. In order to perform this synthesis, a blend of data analysis and modeling will need to be employed to place measures of current ecosystem states in the context of history and past and future climate. In this assessment, we have provided a short list of key indicators to track in the EBS, AI, and GOA, using a stepwise framework, the DPSIR (Drivers, Pressure, Status, Indicators, Response) approach (Elliott, 2002).

In applying this framework we initially determined four objectives based, in part, on stated ecosystem-based management goals of the NPFMC: maintain predator-prey relationships, maintain diversity, maintain habitat, and incorporate/monitor effects of climate change. Drivers and pressures pertaining to those objectives were identified and a list of candidate indicators were selected that address each objective and candidate indicators were chosen based on qualities such as, avail-

ability, sensitivity, reliability, ease of interpretation, and pertinence for addressing the objectives (Table 1). In future drafts, we plan to more fully address the human responses (Response portion of the DPSIR approach) to changes in status and impacts. Use of this DPSIR approach will enable the Ecosystem Assessment to be in line with NOAAs vision of Integrated Ecosystem Assessments. For each objective, driver and pressure identified, indicators are briefly described and the status and trends of the indicators are explained. Where possible, factors that caused those trends are discussed and the potential implications are described. Some gaps in knowledge are listed for each objective.

We initiated a regional approach to ecosystem assessments in 2010 and presented a new ecosystem assessment for the eastern Bering Sea. Last year we followed the same approach and present a new assessment for the Aleutian Islands based upon a similar format to that of the eastern Bering Sea. This year, we include a new section on the Arctic. Our intent is to provide an overview of general Arctic ecosystem information that may form the basis for more comprehensive future Arctic assessments. The entire assessment is now organized into seven sections. In the first "Hot topics" section we present a succinct overview of potential concerns for fishery management, including endangered species issues, for each of the four ecosystems. In the next four sections, we present the region-specific assessments. The fifth section addresses indicators common to all ecosystems, and the final section summarizes conclusions based upon all regions.

While all sections follow the DPSIR approach in general, the eastern Bering Sea and Aleutian Islands assessments are based on additional refinements contributed by Ecosystem Synthesis Teams. For these assessments, the teams focused on a subset of broad, community-level indicators to determine the current state and likely future trends of ecosystem productivity in the EBS and ecosystem variability in the Aleutian Islands. The teams also selected indicators thought to best guide managers on ensuring the needs of non-fishery apex predators and maintaining a sustainable species mix in the harvest, given the current state and likely future ecosystem trends. Future assessments will address additional ecosystem objectives identified above. We expect to apply a team synthesis approach to the GOA ecosystem in 2013 and to the Arctic at a later time.

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

Pressures/Effects	**Significance Threshold**	**Indicators**
Objective: Maintain predator-prey relationships and energy flow **Drivers: Need for fishing; per capita seafood demand**		
Availability, removal, or shift in ratio between critical functional guilds	Fishery induced changes outside the natural level of abundance or variability, taking into account ecosystem services and system-level characteristics and catch levels high enough to cause the biomass of one or more guilds to fall below minimum biologically acceptable limits. Long-term changes in system function outside the range of natural variability due to fishery discarding and offal production practices	• Trends in catch, bycatch, discards, and offal production by guild and for entire ecosystem • Trophic level of the catch • Sensitive species catch levels • *Population status and trends of each guild and within each guild* • *Production rates and between-guild production ratios (balance)* • *Scavenger population trends relative to discard and offal production levels* • Bottom gear effort (proxy for unobserved gear mortality on bottom organisms)

Energy redirection		• Discards and discard rates • Total catch levels
Spatial/temporal concentration of fishery impact on forage	Fishery concentration levels high enough to impair long term viability of ecologically important, nonresource species such as marine mammals and birds	• Degree of spatial/temporal concentration of fishery on pollock, Atka mackerel, herring, squid and forage species (qualitative)
Introduction of nonnative species	Fishery vessel ballast water and hull fouling organism exchange levels high enough to cause viable introduction of one or more nonnative species, invasive species	• Total catch levels • Invasive species observations
Objective: Maintain diversity **Drivers: Need for fishing; per capita seafood demand**		
Effects of fishing on diversity	Catch removals high enough to cause the biomass of one or more species (target, nontarget) to fall below or to be kept from recovering from levels below minimum biologically acceptable limits	• Species richness and diversity • Groundfish status • Number of ESA listed marine species • Trends for key protected species
Effects on functional (trophic, structural habitat) diversity	Catch removals high enough to cause a change in functional diversity outside the range of natural variability observed for the system	• Size diversity • Bottom gear effort (measure of benthic guild disturbance) • HAPC biota bycatch
Effects on genetic diversity	Catch removals high enough to cause a loss or change in one or more genetic components of a stock that would cause the stock biomass to fall below minimum biologically acceptable limits	• Size diversity • Degree of fishing on spawning aggregations or larger fish (qualitative) • Older age group abundances of target groundfish stocks
Objective: Maintain habitat **Drivers: Need for fishing; per capita seafood demand**		
Habitat loss/ degradation due to fishing gear effects on benthic habitat, HAPC biota, and other species	Catch removals high enough or damage caused by fishing gear high enough to cause a loss or change in HAPC biota that would cause a stock biomass to fall below minimum biologically acceptable limits.	• Areas closed to bottom trawling • Fishing effort (bottom trawl, longline, pot) • Area disturbed • HAPC biota catch • HAPC biota survey CPUE
Objective: Incorporate/ monitor effects of climate change **Drivers: Concern about climate change**		
Change in atmospheric forcing resulting in changes in the ocean temperatures, currents, ice extent and resulting effects on production and recruitment	Changes in climate that result in changes in productivity and/or recruitment of stocks	• North Pacific climate and SST indices (PDO, AO, NPI, and NINO 3.4) • Combined standardized indices of groundfish recruitment and survival • Ice indices (retreat index, extent) • Volume of cold pool • Summer zooplankton biomass in the EBS

Hot Topics

Editor's note: The Hot Topics will be updated in the November draft. The topics below are from 2011.

Hot Topics: Eastern Bering Sea

Endangered short-tailed albatross bycatch

A short-tailed albatross was incidentally caught and killed on a longline fishing hook in the Bering Sea in late October this year. The event occurred along the EBS shelf (Figure 10) on a longline vessel fishing for Paific cod. This was the first recored death of this species by a U.S. commercial fishing vessel this year and follows the two deaths recorded in the same fishery last year. Previous to 2010, the last recorded death in a U.S. commercial fishery was in 1998.

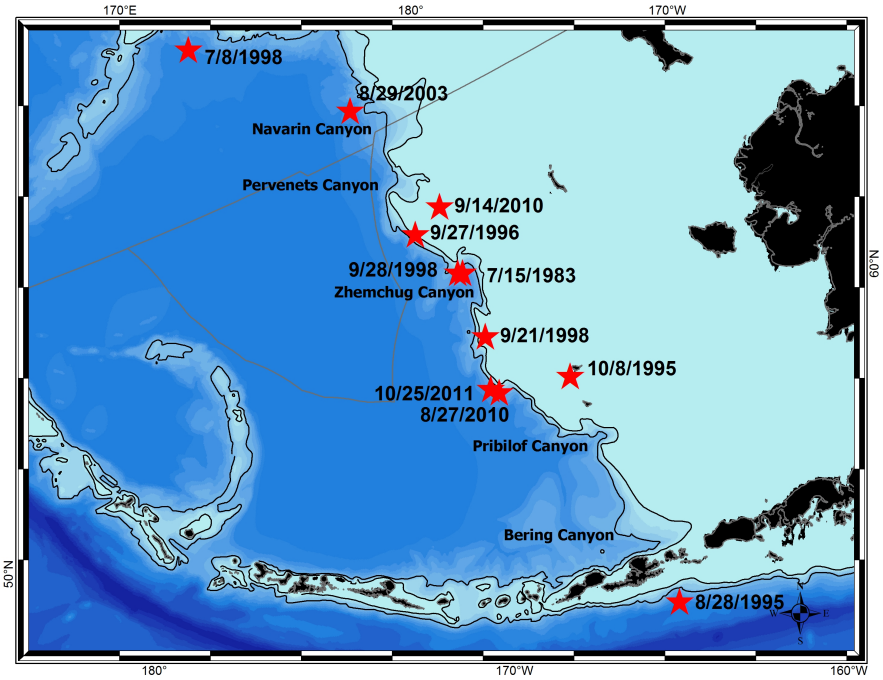

Figure 10: Locations and dates of short-tailed albatross bycatch. Figure courtesy Rob Suryan, OSU.

Short-tailed albatross were federally listed as endangered under the US Endangered Species Act in 2000. The current ESA biological opinion specifies that the expected take (bycatch) in the longline fishery is four in any 2-year period. In the event that a fifth bird is bycaught, an ESA Section 7 consultation involving the U.S. Fish and Wildlife Service and the National Marine Fisheries Service must be initiated. This process can lead to additional regulatory action on the fishery.

The short-tailed albatross were hunted to near extinction from the 1880s to the 1930s; by 1949 there were no known breeding colonies left. Since that time, the population has been increasing rapidly due to a combination of high annual breeding success (≥54%) and high adult and juvenile survival (≥95% and ≥91%, respectively) (Zador et al., 2008*b*). These high survival rates suggest that fishery-related mortality currently appears to be a low risk for this population. However, given that the short-tailed albatross population is expanding rapidly (∼7% annually; **?**, Zador et al. (2008*b*)) it has been suggested that their spatial and temporal overlap with the Alaskan commercial fisheries will become more extensive (Zador et al., 2008*a*). Specifically, increases in the cod quota may lead to more bycatch incidents. Recent actions by the Council to restructure the observer program and increase data quality may allow for more detailed monitoring and analysis of bycatch incidents.

Recent increases in jellyfish

Time series of jellyfish catch-per-unit-effort are collected in the eastern Bering Sea during the summer NOAA bottom trawl surveys (p. 116) and during the autumn BASIS surface trawl surveys (p. 116). The summer time series dates back to 1982, whereas the autumn survey began in 2004. The species composition in both surveys has been dominated by *Chrysaora melanaster*. The autumn survey in particular has demonstrated a decline in other jellyfish species caught since 2004, suggesting that the trend has shifted to a single species-dominant catch.

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

At the time of this study, most climate models suggest continued warming was likely in the Bering Sea, so Brodeur et al. (2008) predicted that the jellyfish populations would remain at moderate levels there but will likely shift northward into the Arctic Ocean. However, following this analysis, the eastern Bering Sea experienced cool conditions. In fact, 2006 was the beginning of an ongoing cycle of cool conditions. There was no change in jellyfish CPUE until a notable increase in 2009 and 2010. CPUE in 2011 was nearly double that of the previous two years and nearly the same as the peak value in 2000. The autumn survey also showed a dramatic increase, but not until 2010. Cieciel et al. (p. 116, this report) state that the cause for these shifts in biomass and distribution does not seem to rely solely on physical ocean factors (temperature and salinity). These shifts could also be a result of environmental forcing earlier in the growing season or during an earlier life history stage (polyp), which may influence large medusae biomasses and abundances (Purcell et al., 2009).

Current conditions in the eastern Bering Sea appear favorable overall for jellyfish, particularly

Chrysaora melanaster. These significant increases in jellyfish biomass may redirect energy pathways in the food web through their predation on zooplankton and small fish.

Hot Topics: Gulf of Alaska

"Mushy" Halibut Syndrome

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

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

Infectious salmon anemia

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

Hot Topics: Aleutian Islands

Fishery changes in the western and central AI ecoregions in 2011

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

Aleutian Islands risk assessment released

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

A Preliminary Assessment of the Alaskan Arctic

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

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Rationale to include the Alaskan Arctic

In recognition of the changing climatic and ecological conditions in the Arctic, the Council and the National Marine Fisheries Service implemented the Arctic Fishery Management Plan (FMP) in 2009. The Arctic FMP prohibits commercial fishing in the Arctic management area until such a time that a sufficient amount of information becomes available to support the implementation of a sustainable fishery, and outlines the criteria and process for authorization of any future commercial fisheries. The intent of adding the Alaskan Arctic to the Ecosystem Considerations chapter is to provide an overview of general ecosystem information that may form the basis for more comprehensive future Arctic assessments that would be useful for fishery managers making decisions on the authorization of new fisheries. Consistent with ecosystem assessments of the eastern Bering Sea, Gulf of Alaska, and Aleutian Islands, we intend for the future Arctic assessments to include a list of indicators that directly address ecosystem-level processes and attributes that can inform fishery management advice by communicating indicator history, current status, and possible future directions.

The area considered the Alaskan Arctic for the purposes of this report includes the entire Arctic management area (NPFMC, 2009). Additionally, we propose the inclusion of the northern Bering Sea, which at present is not included in the eastern Bering Sea ecosystem assessment (Figure 11). The northern Bering Sea is widely regarded as having an ecosystem that is physically and biologically distinct from the southeastern Bering Sea (Grebmeier et al., 2006; Mueter and Litzow, 2008; Stabeno et al., 2010, 2012). A recent analysis of the biology and oceanography of the Bering, Chukchi, and Beaufort seas identified the northern Bering (north of St. Lawrence Island) and Chukchi seas as a single, distinct biogeographic province (Sigler et al., 2011). Studies of groundfish distribution in the northern and eastern Bering Sea have similarly identified a change in groundfish community composition with latitude (Cui et al., 2009; Stevenson and Lauth, 2012). Thus, there is sufficient evidence to support including the northern portions of the Bering Sea (> approx. 60°N) in an Arctic assessment. This will create a continuum of assessed areas throughout Alaskan marine waters and will not cause any disruption or alteration to the existing northern boundary of the eastern Bering Sea assessment area.

General Ecosystem Information

Most of the Alaskan Arctic is covered by sea ice for some portion of the year and the seasonal presence and dynamics of sea ice has a strong influence on ecosystem structure and function. During years of low ice coverage, the most southerly portions of the northern Bering Sea may only be covered by sea-ice for a few weeks or not at all. The Chukchi and Beaufort seas are covered by sea ice for about 6 to 8 months of the year. During years of heavy summer ice coverage, portions

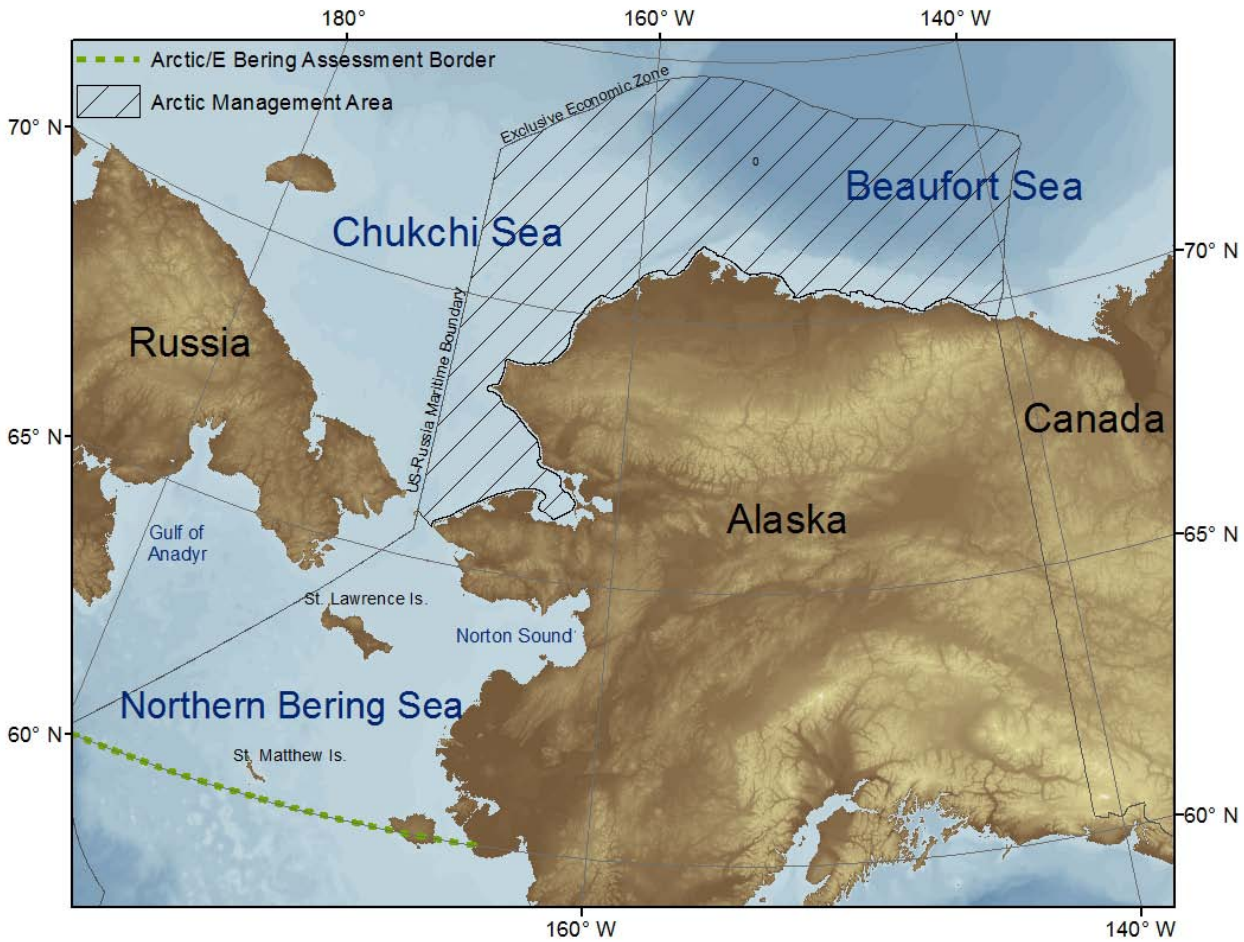

Figure 11: The proposed Alaskan Arctic assessment area, encompassing the northern Bering Sea, Chukchi Sea, and Beaufort Sea, within US territorial waters. The existing Arctic management area is filled with hatched lines.

of the northern Chukchi and Beaufort seas may retain their ice coverage throughout the year. However, Arctic sea ice cover has declined over recent decades, with the six lowest annual sea ice minima over the satellite record (1979-present) occurring in the last 6 years, 2007-2012 (Comiso, 2012; Stroeve et al., 2012)(`http://nsidc.org`). A recent reconstruction of Arctic sea ice cover over the last 1,450 years has indicated that the observed declines in sea ice starting in the 1990's are the lowest over this time period, and fall outside the range of variability in previous observations (Kinnard et al., 2011). Regionally, some of the most pronounced declines of September ice extent in recent decades have been observed in the Chukchi and Beaufort seas (Meier et al., 2007).

The persistence of sea ice during the summer season has implications for the primary productivity regimes in these northern systems. Primary production during winter is limited by ice coverage and shortened day length, including periods of arctic night in the Chukchi and Beaufort seas. Phytoplankton growth begins in late winter with the return of daylight and an ice algae bloom that continues until the onset of ice melt (Cota, 1985; Cota and Smith, 1991)). At a time when food may be limited, the ice algae bloom provides early season forage for ice-associated invertebrates, which

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

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

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

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

The net flow of water through the northern Bering and Chukchi seas is northward (Coachman et al., 1975; Walsh et al., 1989; Woodgate et al., 2005). High levels of primary production in the northern Bering and southern Chukchi seas is maintained throughout the open water season by nutrient rich water advected from the Bering Sea continental slope and the Gulf of Anadyr (Springer and McRoy, 1993; Springer et al., 1996). During the open water season, primary production in the northern Chukchi Sea is focused in the vicinity of the ice edge (Wang et al., 2005) and Barrow Canyon where occasional flow reversals allow for upwelling of Arctic basin waters, which promote phytoplankton blooms (Aagaard and Roach, 1990; Hill and Cota, 2005; Woodgate et al., 2005). Primary production in the Beaufort Sea may be enhanced during summer when sea ice retreats beyond the shelf break allowing for phytoplankton blooms driven by upwelling along the shelf break (Pickart et al., 2009).

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

Species of commercial interest

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

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

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

Gaps and needs for future Arctic assessments

There is an immediate need to convene Arctic experts to identify a list of indicators and corresponding time series data that will best capture ecosystem components and trends that would be of value to fishery managers. Several biomass indices are presently used as indicators in the ecosystem assessments of the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska. Times series data to support similar indices in the Alaskan Arctic are lacking. The identification of available data sets would provide important first steps at indicator development and would provide critical help in identifying future indicator needs.

Potential indicators

Climate Index: The Arctic Oscillation (AO) index (`www.cpc.ncep.noaa.gov`) is a candidate indicator that tracks climate patterns in the Arctic and offers some capacity to predict the presence and extent of Arctic sea ice (Rigor et al., 2002). The AO describes the dominant pattern in sea-level pressure over the Arctic region (Figure 12)(Thompson and Wallace, 1998). A positive AO phase is associated with low pressure dominating over the polar region and with the development of a counter-clockwise anomaly in sea ice circulation in the eastern Arctic (Eurasian Arctic), which results in increased transport of sea ice out of the Arctic into the north Atlantic and decreased transport of ice from the Beaufort Sea into the Chukchi Sea (Rigor et al., 2002; Rigor and Wallace, 2004; Stroeve et al., 2011). In general, the positive phase of the AO is associated with the loss of thick multi-year ice, which in turn promotes the development of thinner first year ice (Rigor et al., 2002). The thinning of sea ice preconditions it for greater summer melt, resulting in reduced September sea ice extent (Maslanik et al., 2007; Serreze et al., 2007; Stroeve et al., 2012). During a negative AO phase, sea-level pressure is higher than normal, and the sea ice tends to have a clockwise motion, which favors the retention and thickening of Arctic sea ice.

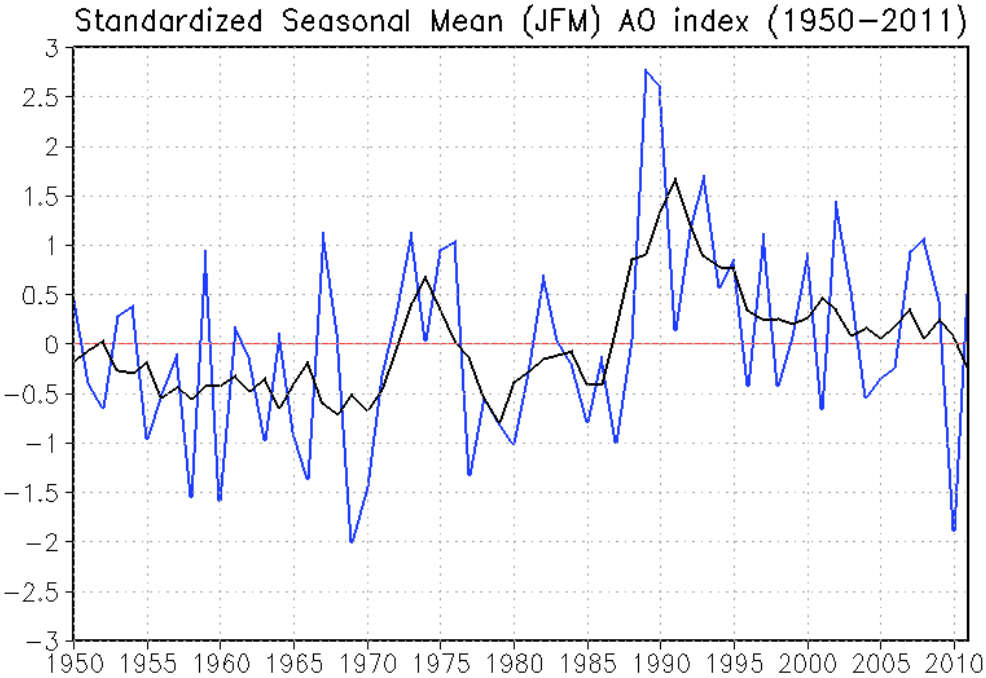

Figure 12: The standardized seasonal mean (Jan, Feb., Mar.) Arctic oscillation index (blue line) from 1950 through 2011. The black line represents the standardized five year running mean of the index. Image source: NOAA/National Weather Service/Climate Prediction Center, `http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/ao.shtml`.

The capacity of the AO to predict sea ice conditions has recently fallen under some scrutiny as the negative phase of the AO observed during the winter of 2009/10 failed to result in the retention of sea ice during the following summer, but rather resulted in the fourth lowest September sea ice minima in the satellite record (Stroeve et al., 2011). This observed lack of sea ice retention in 2010

has been partly attributed to changes in the wind field resulting in lower retention of sea ice in the Beaufort Gyre, an overall thinning of Arctic sea ice (Kwok et al., 2009), and a general rise in Arctic temperatures rendering the sea ice more susceptible to summer melt (Serreze et al., 2009; Stroeve et al., 2011).

Sea Ice Index: The September sea ice index (`http://nsidc.org/data/seaice_index/`) tracks the status and trend of September sea ice coverage for the entire Arctic (Figure 13). The end of the melt season and the annual minimum in total Arctic sea ice coverage occurs in September (Stroeve et al., 2012). As an indicator, the September sea ice index may serve to compliment the AO index and provide a means to evaluate the predictive capacity of the AO index. Much recent discussion in the primary literature and in the popular media has centered on whether the Arctic has passed a tipping point (Wassmann and Lenton, 2012). The term "tipping point" is generally taken to mean a critical threshold or variable value, beyond which an abrupt change takes place, altering the system qualitatively (Lenton et al., 2008). Tipping points as a threshold, may mark the transition between multiple alternative stable states but are not necessarily points of no return, leading to irreversible change (Lenton, 2012). For the Arctic, much of this discussion has centered on observed declines in sea ice coverage and thickness, and whether or not the Arctic is now headed towards, or has already passed a tipping point (e.g., overall warming) leading to a largely ice-free summer state (Lindsay and Zhang, 2005).

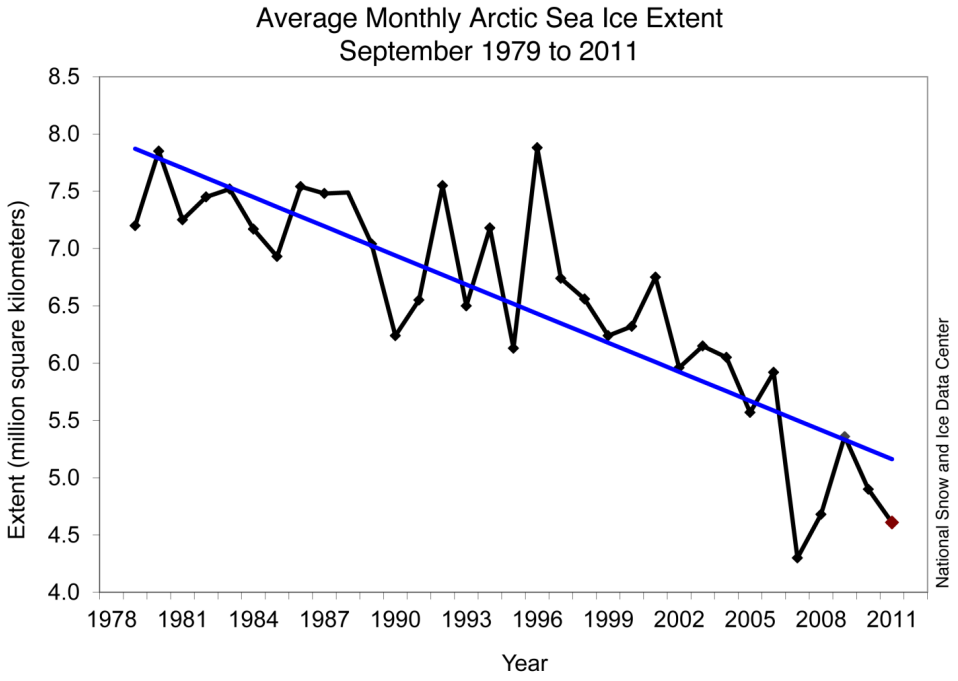

Figure 13: The average September sea ice extent over the years 1979 to 2011, with the linear trend line. Image source: National Snow and Ice Data Center, `http://nsidc.org/arcticseaicenews/category/analysis/`.

Primary Production Time Series: Arctic sea ice coverage has declined over recent decades (Meier et al., 2007; Stroeve et al., 2007; Comiso et al., 2008) and this has exposed an increasing area of open water to solar radiation. Recent increases in Arctic annual primary production since the late 1990's have been attributed to increases in the duration of the phytoplankton growing

season and increases in open water area associated with sea ice loss (Arrigo et al., 2008; Pabi et al., 2008). Further declines in Arctic sea ice coverage are expected through the rest of the century (Boe et al., 2009; Wang and Overland, 2009; Douglas, 2010) and these continued declines are expected to result in further increases in Arctic primary production (Arrigo and van Dijken, 2011). Suitable time series of in situ estimates of primary production are not presently available and the development of a primary production index would provide a means to track any continued changes in the primary production regime in the Alaskan Arctic. Satellite estimates of primary production may be spotty due to persistent cloud cover, and may be confounded by the presence of chromophoric dissolved organic matter (CDOM, compounds that appear the same as phytoplankton chlorophyll a to satellite viewing), and may underestimate production due to the presence of a subsurface chlorophyll maximum (Arrigo and van Dijken, 2011; Matsuoka et al., 2011). However, recent analysis of satellite data (Sea-viewing Wide Field-of-view Sensor, SeaWiFS) has offered some hope, indicating it may be possible to account for these inaccuracies (Arrigo and van Dijken, 2011).

Editor's note: The Eastern Bering Sea assessment will be updated in the November draft. The assessment below is from 2011.

Eastern Bering Sea Ecosystem Assessment for 2012

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

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

Summary

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

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

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

Biomass estimates of four fish foraging guilds (apex predators, pelagic foragers, benthic foragers, and motile epifauna) were not updated this year due to staff loss, so current trends are unknown. In early years, the apex predator and pelagic forager series seem to be correlated and in phase with each other. In later years, they may be correlated, but out of phase. It is hypothesized that cold conditions and high primary production could result in conditions that deliver food to both benthic and pelagic food webs. Unknown is whether or not top-down control (predation) will eventually occur once the biomass of these two guilds builds to a particular level (e.g. Oscillating Control Hypothesis).

Top-down control continues to be a concern in the ecosystem, particularly with the increase in arrowtooth flounder. Arrowtooth generally avoid areas with cold bottom temperatures during

summer, with the result that their distribution and predatory impacts increase across the shelf during warm years. Reductions in the extent of the cold pool, as occurred during summer 2011, may facilitate their expansion onto the shelf as seen during the warm years of 2003-2005.

Northern fur seals and seabirds breeding on the Pribilof Islands are representative of the air-breathing central place piscivorous foragers in the eastern Bering Sea. Northern fur seal pup production in the Pribilof Islands continued their overall decline in 2010, the last year they were counted. The breeding populations of the western stock of Steller sea lions, meanwhile, continue to respond differently despite the fact that both fur seals and sea lions forage extensively in the southeast Bering Sea. Pup counts at rookery sites have either declined or have stabilized in the western and central Aleutian Islands but have shown an increase in the eastern Aleutian Islands (see Aleutian Islands ecosystem assessment for more detail, p. 60).

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

Evaluation of 2010 predictions

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

years.

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

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

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

Additional EBS indicators

Zooplankton biomass index Macrozooplankton are intermediaries in the transfer of carbon from primary production to living marine resources (commercial fisheries and protected species). Understanding the mechanisms that control secondary production is an obvious goal toward building better ecosystem syntheses. In the absence of direct measurements of secondary production in the eastern Bering Sea we must rely on estimates of biomass. We have chosen to use and interpret estimates of summertime euphausiid and large copepod biomass for the eastern Bering Sea shelf as an index of the forage available to planktivorous fish, seabirds, and marine mammals. These time series (Figure 14) are relatively short compared to those of climate and fisheries, however they appear to be in agreement with much longer time series of total zooplankton biomass from the T/S Oshoro Maru begun in 1954 as shown in the Report Card. In future assessments we plan to replace the T/S Oshoro Maru time series in the Report Card with a combined euphausiid and copepod

time series. In this section we describe the *Calanus* spp. and euphausiid time series (Figure 15).

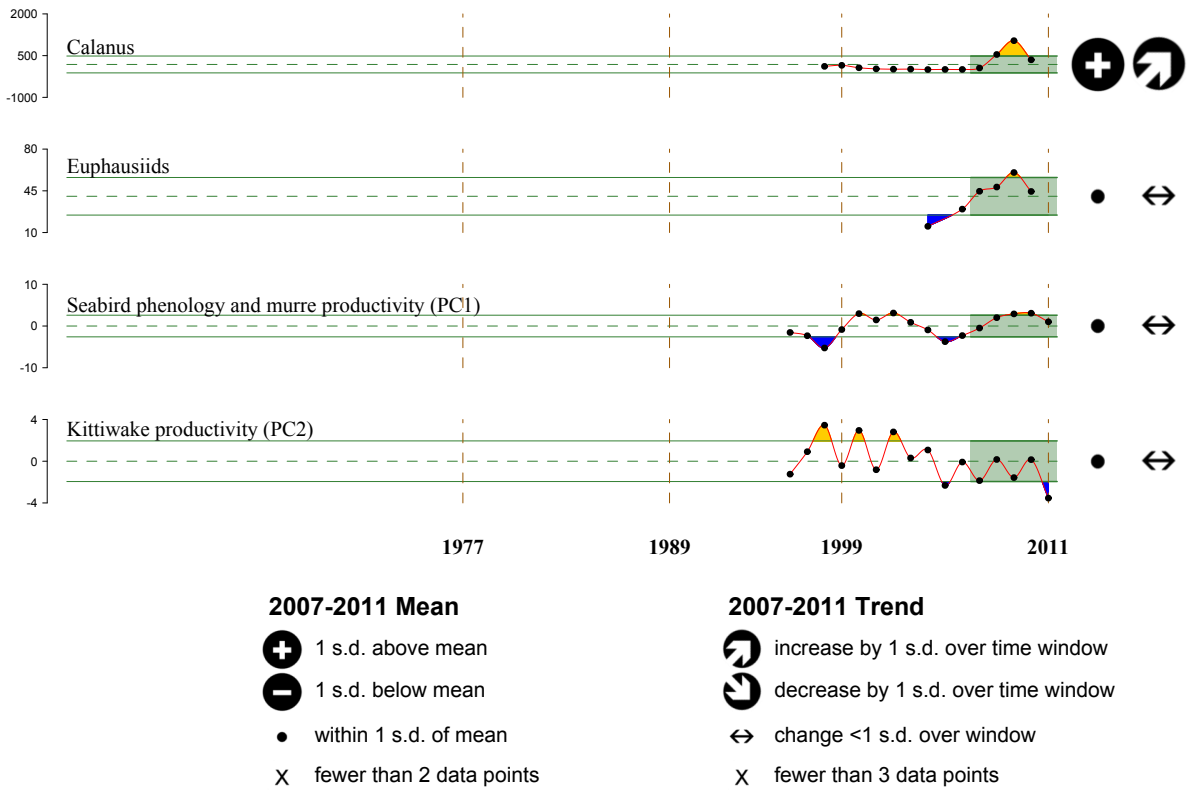

Figure 14: Additional eastern Bering Sea indicator time series.

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

Stabeno et al. (accepted) computed the abundance of *Calanus* spp. (all copepodite stages) on the middle shelf of the eastern Bering Sea from summer net tows on multiple vessels (1981; PROBES, 1998 - 2008; T/S Oshoro Maru and 2009-2010; AFSC RACE Groundfish Assessment cruises). Shown are the mean and standard error. Raw data were fourth root transformed before calculation of the summary statistics and then back transformed before plotting.

Status and Trends: Both series show a large increase since 2001-2005 ("warm years" according to Stabeno et al., accepted), with the copepod increase lagging that for euphausiids. Both series showed a smaller decline in 2010 but remained well above 2001-2005 levels. The areas of the Bering Sea shelf sampled for copepods and euphausiids were not exactly the same, but we assume that the interannual variability in mean density indicated in the plot is correctly represented for both groups of animals, and that these groups are reasonable proxies for the trend in density of all large

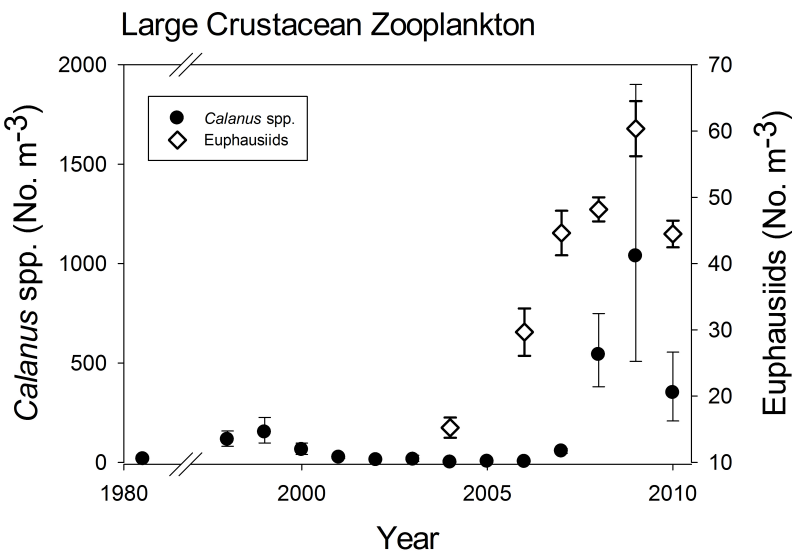

Figure 15: *Calanus* spp. and euphausiid time series.

copepods and euphausiids on the Bering Sea shelf. These two main groups of large crustacean zooplankton are important in the Bering Sea ecosystem and in the diet of many predators. For example, ecosystem modeling indicates that the biomass densities of euphausiids and copepods in the Bering Sea are of the same order (Aydin et al. 2007, p. 77; Aydin and Mueter, 2007, Fig. 3) and that they are of comparable importance in the diet of walleye pollock (Aydin et al. 2007, p. 51).

Interpretation and Implications: Standing stock of invertebrate forage is both a function of secondary production and consumption by planktivorous species. Euphausiids are a key zooplankton component of the Bering Sea food web (Aydin et al., 2007) and euphausiids and large copepods are important dietary components of multiple life history stages of walleye pollock (**??**Brodeur et al., 2002; **?**; **?**). These taxa are more numerous in cold as opposed to warm years (Baier and Napp, 2003; Coyle et al., 2008; Hunt et al., 2008) The relative contributions of production and predation to the standing stock are not yet known, however the high standing stocks from 2008 to 2010 are encouraging and suggest that overall food availability for planktivorous species is high (ignoring mismatch in spatial distributions). Age-0 pollock, in particular, may be dependent on the availability of sufficient prey to generate enough depot lipids to survive their first winter. Thus, in the absence of compensatory predation on the early life history stages, we predict that the survival of

this particular year class of fishes may be better than average. The same may be true for other planktivorous species.

Seabird indices During the initial meetings in 2010, the Team decided that the ideal indicator of seabird productivity in the Bering Sea would be a multivariate index representing all combinations of piscivores and planktivores, divers and surface feeders. In the absence of this, they elected to choose a single sentinel species to represent seabird productivity on the Bering Sea shelf, thick-billed murres nesting on St George. Zador and TenBrink developed new multivariate seabird indicators representing all species nesting on the Pribilofs using a principal components analysis to combine annual hatch dates and reproductive success values. Further information can be found in this document on p.145. Strong and distinct trends were noted in the first two principal components. The first captured mainly the hatch dates and murre productivity trends; the second captured kittiwake productivity trends. The loadings on the two principal components followed the same patterns when 2011 data was added to produce index values for this year and indicated poorer productivity for both indices (Figure 16). These two indices may therefore serve as useful indicators to follow to capture more comprehensive seabird trends. Although a single index would be preferable, the analysis suggests that the two divergent patterns in the data could not be captured in a single index.

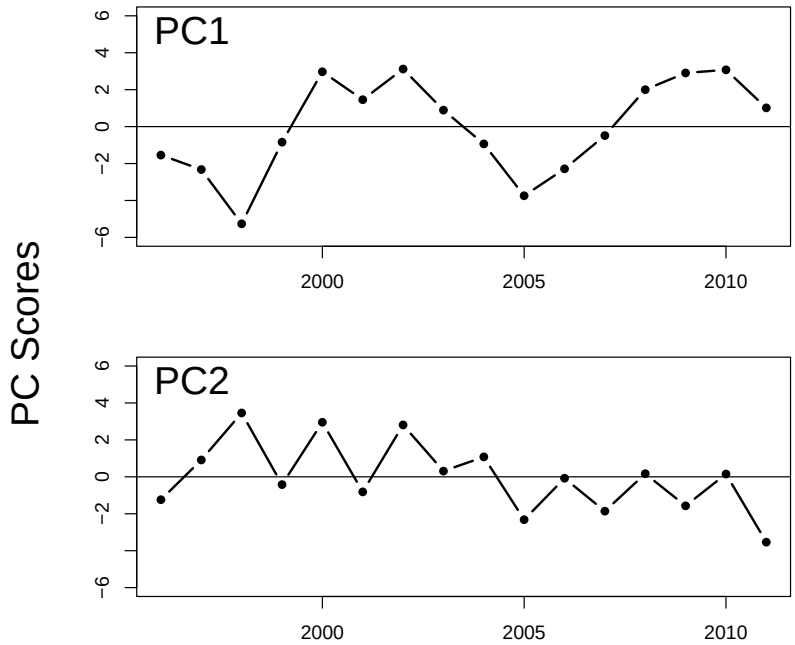

Figure 16: Time series of the first two leading principal components for combined seabird productivity and mean hatch date extended through 2011. For PC1, a more positive value indicates higher murre and cormorant productivity and earlier mean hatch dates. For PC2, higher values indicate increased kittiwake productivity. See contribution on p.

Gaps and needs for future EBS assessments

This section is unchanged from the 2010 assessment

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

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

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

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

Spatial scales for assessment: The team reviewed EBS bottom trawl survey data at the guild level to determine whether there were striking changes in distribution patterns over time. No patterns of immediate concern were detected; however, the team felt that including a thorough spatial investigation of key indices would be a high priority in upcoming assessments. For example, spatial distributions of zooplankton, benthos, and forage fish would be critical for predicting the foraging success of central place foragers such as seabirds and pinnipeds. It may be desirable to examine the selected indices by domain (e.g., outer, middle, and inner shelf) rather than EBS-wide. Distributional indices could be developed for foraging guilds, indicator species, and fisheries (see below) similar to some already presented in the Ecosystem Considerations SAFE (e.g. Mueter et al. on p. 149). In addition, an index of cold-pool species or other habitat specific groups could be developed and tracked. Spatially explicit indicators could be used to investigate observed patterns such as the relative success of commercial crabs in Bristol Bay versus further out on the EBS shelf.

Considerable work is already underway to address processes at different spatial scales, in particular for central place foragers. NMML has the following active fur seal research programs at the Pribilof Islands:

1. Bienniel pup production estimation at each rookery
2. Adult female summer foraging, physiology and energy transfer to pup with specific focus on differences by rookery and foraging habitat in the eastern Bering Sea
3. Adult female and pup over-winter satellite tracking to determine foraging and pelagic habitat differences by year and rookery
4. Pup and adult female tagging to determine fur seal survival and reproductive rates

These programs have been underway since the early 2000s, but particularly in the case of item 4 above, take many years (e.g., decades to determine reproductive rates of such a long-lived species) to produce results. NMML needs to continue this field work, and couple it with habitat and ecosystem models to help us understand the differences in fur seal population responses between Bogoslof and the Pribilof Islands, and differences in responses between air-breathing and fish apex predator responses over the last 20 years.

Differences in Steller sea lion population response between the Pribilofs and the eastern Aleutian Islands also requires further research, and may be related to spatial-temporal distribution and abundance of prey.

Fishery performance index needed: Several measures of the performance of current management relative to the goals and objectives of the NPFMC should be considered. An obvious candidate is an index of the catch relative to the TAC, ABC and OFL. The phase diagram showing the distribution of current biomass/Bmsy and catch / OFL provides a quick assessment of whether the stock is overfished or whether overfishing is occurring. However, for some stocks, the TAC is set well below the ABC and OFL. Therefore an assessment of whether the TAC is fully utilized may serve as a better indicator of the performance of the fishery relative to the predicted level of catch. Likewise, catch relative to TAC may be a useful indicator for the efficiency of pollock because the 2 million t cap constrains this fishery when the stock is in high abundance.

Other measures of net income or revenue might be considered as fishery performance indicators. For example, when stocks are low, the price may increase, this may compensate for longer search time. Thus, when pollock is at a high abundance, and search time is low, the price per pound may be lower than when pollock are scarce.

Integration with stock assessments: Ecosystem indicators specific to stocks and ABC decisions within single species stock assessments will be developed in a separate workshop, to be scheduled in early 2011. However, integration of the stock assessments and this ecosystem assessment will continue to be developed. The group noted that dominant species often dictate the time trend in aggregate indicators. Several times the group strayed into conversations that were focused on relationships between a select group of species. It is important that the synthesis chapter is dynamically linked to the single species ecosystem assessments so that specifics on how climate impacts dominant species, their prey, and their distribution can be readily obtained if a person wishes to drill down to the single species interactions underlying the guild responses provided.

The development of predictive models for single species or a small group of interacting species (e.g. multispecies stock assessments) is moving ahead at a rapid pace. Some stock assessments already include forecasts that incorporate climate forcing and efforts to address predation on natural mortality rate and prey availability on growth are currently underway. As noted above it will be

important to provide a dynamic link between the description of these innovations to stock assessments and the synthesis chapters. We expect that description of the models will continue to appear in the stock assessment. This will allow a thorough review of the mathematical formulations used to depict the relationships between predators, prey, competition and environmental disturbance within the assessment.

Future use of ecosystem/climate models in development: Several reviews of the utility of ecosystem models are available. Hollowed et al (in press) examined which quantitative modeling tools were needed to support an Ecosystem Approach to Management (EAM) in the EBS. This review revealed that a diverse suite of models were utilized to support an EAM in the EBS (Table 2). Single-species stock assessment and projection models are the most commonly used tools employed to inform managers. Comprehensive assessments (e.g. Management Strategy Evaluation) are emerging as a new and potentially valuable modeling approach for use in assessing trade-offs of different strategic alternatives. In the case of management in the Eastern Bering Sea, end-to-end models and coupled biophysical models have been used primarily to advance scientific understanding, but have not been applied in a management context. In future synthesis attempts, we will add a section that brings forward predictions from different models to initiate an evaluation of the predictive skill of different assessment tools.

Table 2: Suite of models used for implementation of an ecosystem approach to management in the Bering Sea (From Hollowed et al. (2011)).

Model	**Application**	**Issue**	**Example reference**
Stock assessment models	Tactical	Evaluate stock status	Ianelli (2005); Methot (2005)
Stock projection models	Tactical	Assessing overfished condition	Turnock and Wilderbuer (2009)
Management strategy evaluation	Strategic	Assessing the performance of a harvest strategy	A'mar et al. (2008); NOAA (2004)
Habitat assessment	Strategic	Evaluating the long-term impact of fishing on EFH	**?**
Multispecies Yield-per-recruit	Strategic	Assessing the implications of prohibited species caps	Spencer et al. (2002)
Multispecies technical interaction model	Strategic	Assessing the performance of harvest strategies on combined groundfish fisheries	NOAA (2004)
Coupled biophysical models	Research	Assessing processes controlling recruitment and larval drift	Hinckley et al. (2009)
Integrated Ecosystem Assessments	Strategic	Assessing ecosystem status	Zador and Gaichas (2010)
Mass Balance models	Strategic	Describing the food-web	Aydin et al. (2007)
Dynamic food web models	Strategic	Describing trade-offs of different harvest strategies through food-web	Aydin et al. (2007)
FEAST	Strategic	End-to-end model	

Gulf of Alaska

This report does not include a current ecosystem assessment of the Gulf of Alaska. A workshop is scheduled for winter 2013, during which a new Gulf of Alaska Ecosystem Assessment team will develop an assessment following the procedure and format of the EBS and AI assessments.

Editor's note: The Aleutian Islands assessment will be updated in the November draft. The assessment below is from 2011.

Aleutian Islands Ecosystem Assessment for 2012

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

Summary

We present this summary of the Aleutian Islands ecosystem by three ecoregions. These are briefly defined here and in more detail later in the document (Figure 17). The Western Aleutian Islands

ecoregion spans 170° to 177°E. These are the same boundaries as the North Pacific Fishery Council fishery management unit 543. The Central Aleutian Islands ecoregion spans 177°E to 170°W. This area encompasses the North Pacific Fishery Council fishery management units 542 and 541. The Eastern Aleutian Islands ecoregion spans 170°W near Samalga Pass to False Pass at 164°W.

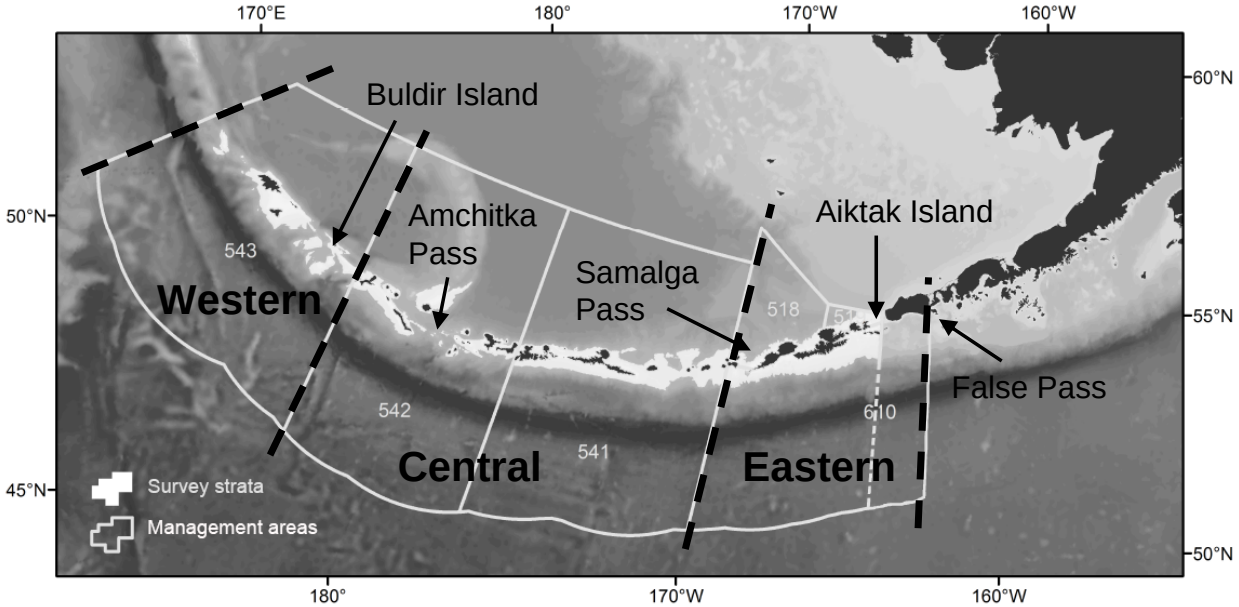


Figure 17: The three Aleutian Islands assessment ecoregions. Seabird monitoring islands are indicated by arrows.

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

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

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

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

Central Ecoregion Recent trends in auklet reproductive success are unknown but the predicted continued positive state of the NPI indicates favorable foraging conditions for planktivores. Forage fish trends as captured by puffins are not available from this ecoregion because puffins are not as numerous and nests are not monitored regularly. Fish apex predator and pelagic foraging guild biomasses have declined since the previous trawl survey in 2006, in contrast to the trend in the Western ecoregion. The decline apex predators is largely driven by Pacific cod, although Kamchatka flounder has increased. Atka mackerel and Pacific ocean perch make up 80% of the pelagic foraging

guild biomass. The recent decline is largely driven by Atka mackerel, as Pacific ocean perch biomass has increased. Recent counts of sea otters continue to decline, possibly indicated poor conditions in the nearshore environment for this species. Counts of non-pup Steller sea lions in the central Aleutians declined 33% overall between 1991 and 2008, a rate of -2% per year. While this decline is occuring at a lower rate compared to that in the Western ecoregion, there is a still concern for these apex piscivores. School enrollment has shown no trend in recent years, following a decline since peak enrollment in 2000.

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

Objectives, selection and evaluation of key Aleutian Islands indicators

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

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

The ecoregions were defined based upon evidence of significant ecosystem distinction from the neighboring ecoregions. The team also concluded that developing an assessment of the ecosystem at this regional level would emphasize the variability inherent in this large area, which stretches 1900 km from the Alaska Peninsula in the east to the Commander Islands in the west. For the

purposes of this assessment, however, the western boundary is considered the U.S. - Russia border at 170°E.

The three Aleutian Islands ecoregions are defined from west to east as follows (Figure 17). The Western Aleutian Islands ecoregion spans 170° to 177°E. These are the same boundaries as the North Pacific Fishery Council fishery management area 543. This ecoregion was considered to be distinct from the neighboring region to the east by primarily northward flow of the Alaska Stream through wide and deep passes (Ladd, pers. comm.), with fewer islands relative to the other ecoregions.

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

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

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

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

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

8. K-12 enrollment in Aleutian Islands schools

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

In the sections below, we give a brief rationale for each indicator's selection, describe the indicator, the appropriate ecoregion, its status and trends, and provide a statement of its individual implications for fishery management. The summary section above provides a synthetic assessment based on all of the indicators available in each ecoregion. Time series of all indicators are presented in Figures 18, 19, 20, and 21.

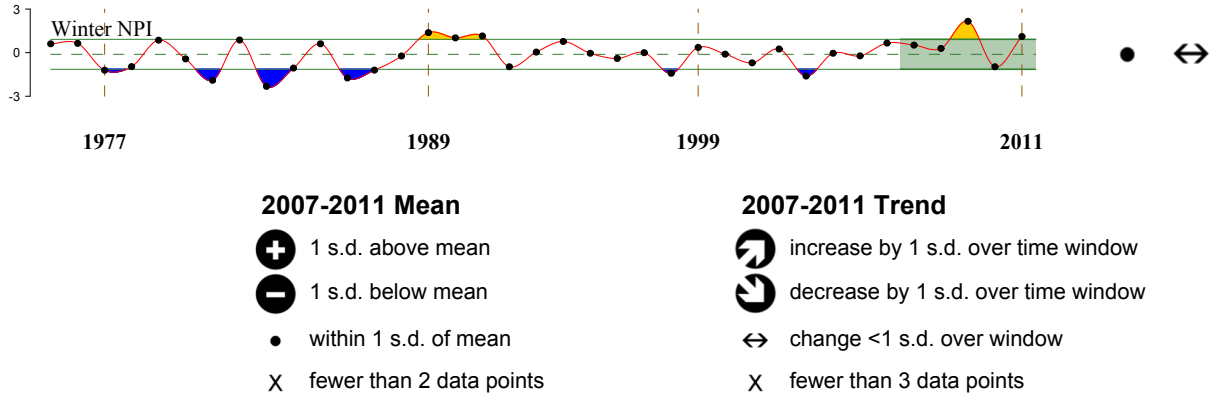


Figure 18: The winter North Pacific Index time series.

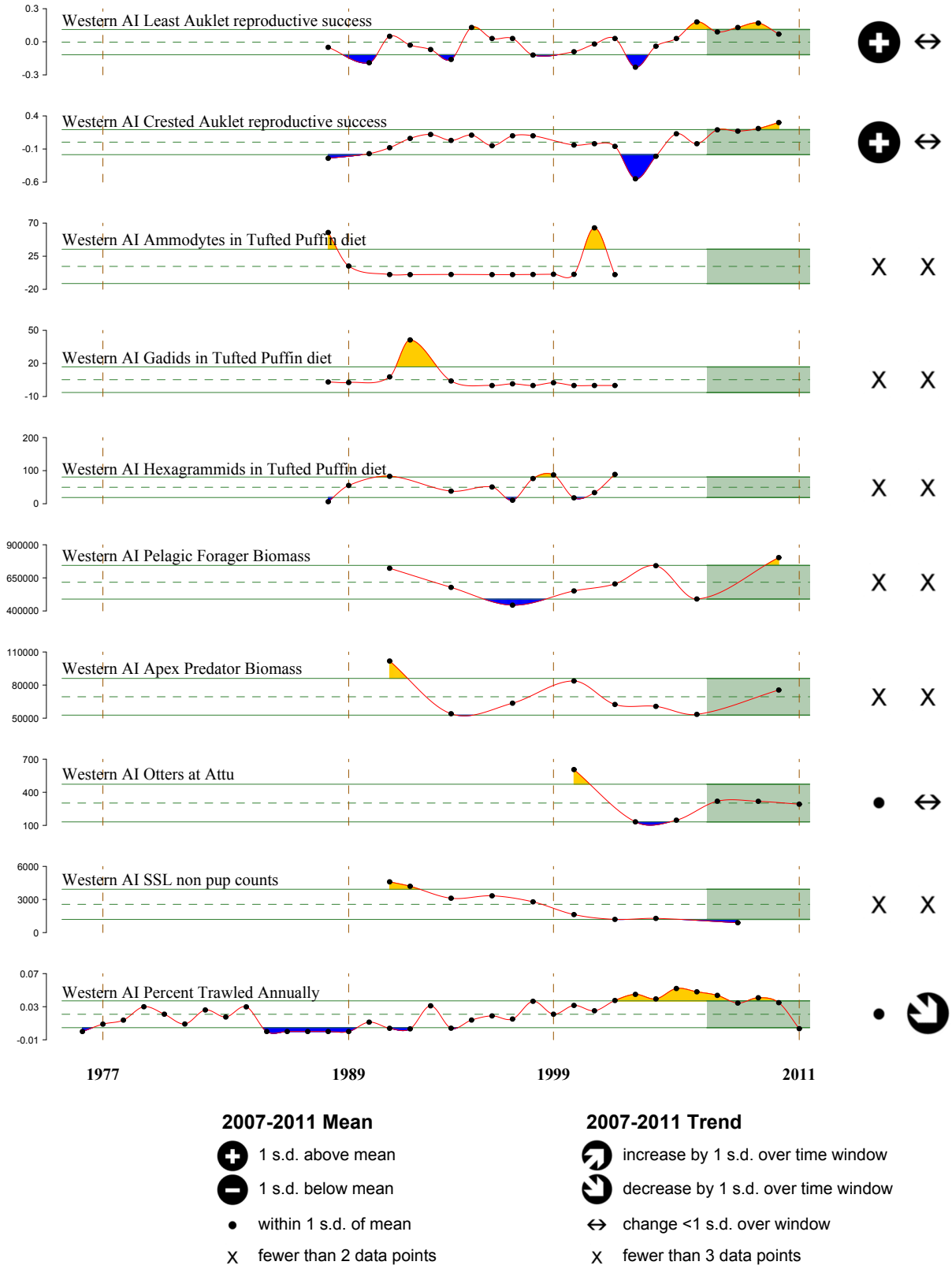


Figure 19: Aleutian Islands Western ecoregion indicators.

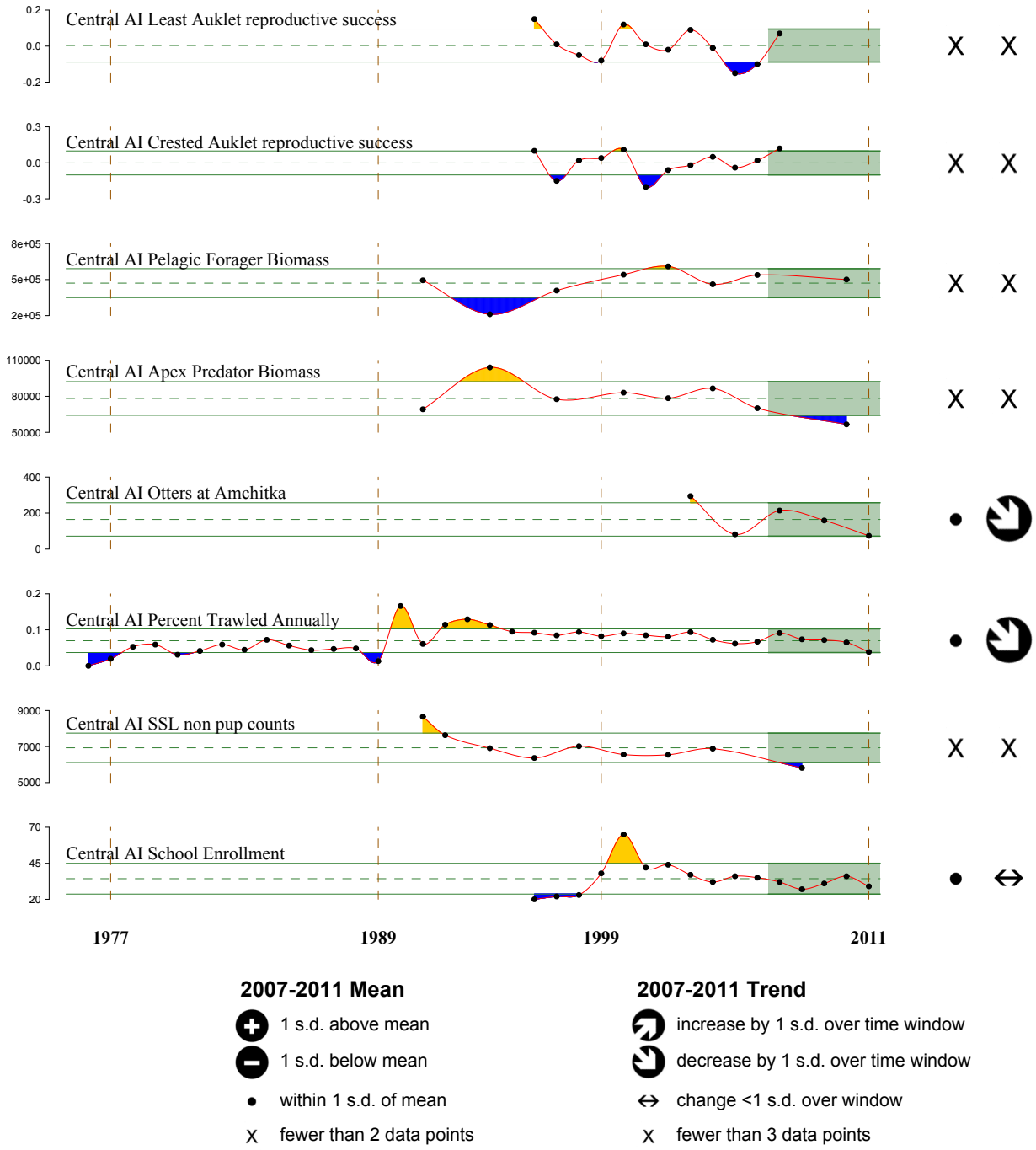


Figure 20: Aleutian Islands Central ecoregion indicators.

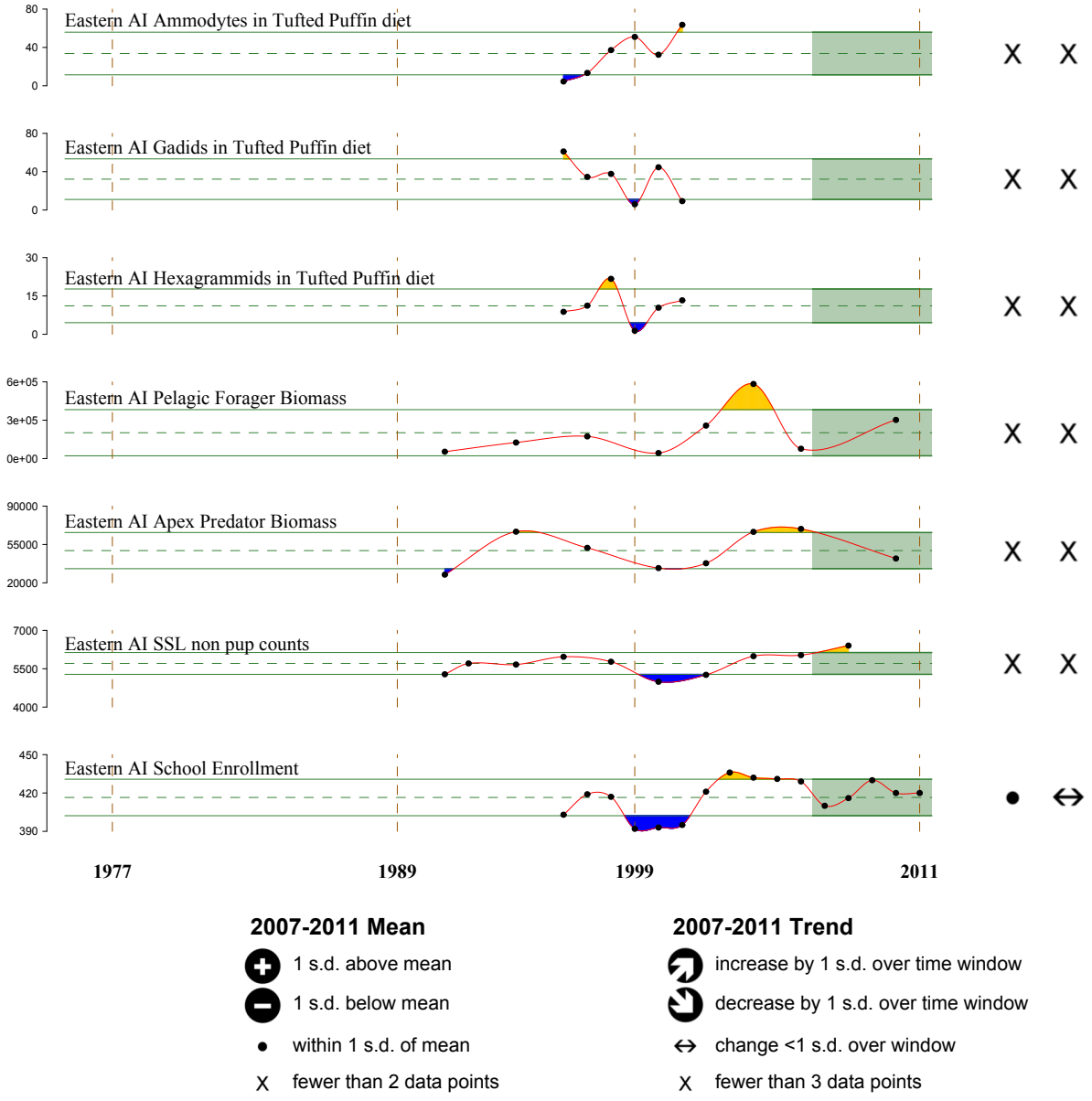


Figure 21: Aleutian Islands Eastern ecoregion indicators.

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

by the mean (8.65) and standard deviation (2.23) for 1961-2000.

The winter NPI was near-average or negative through most of the 1990s through 2005 (Figure 18). Since 2005, the index has been positive every year except 2010. In 2011, the winter NPI index (November 2010 - March 2011) was positive by more than one standard deviation implying a weaker Aleutian Low pressure system and less storminess in the region than average. This is expected to continue into the winter 2011/2012, due in part to projected La Niña conditions (see p. 84).

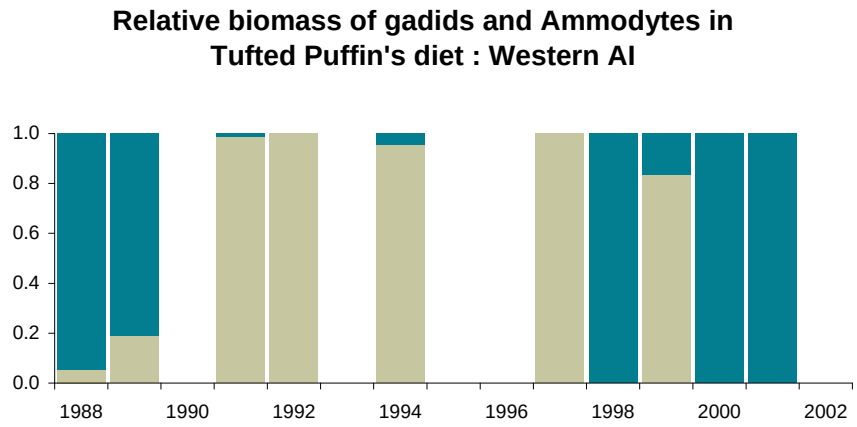
Reproductive anomalies of planktivorous least auklet and crested auklets Least auklets (*Aethia pusilla*) and crested auklets (*A. cristatella*) are small, abundant seabirds that nest in the Aleutian Islands. The USFWS stations field biologists to monitor auklet chick diets and reproductive success annually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

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

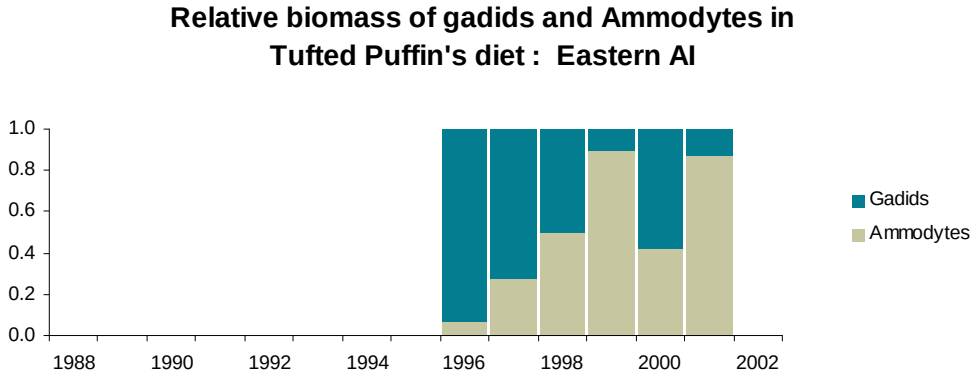
In the Western ecoregion, reproductive success trends differed between the auklet species in earlier years, but have trended similarly in recent years (Figure 19). Crested auklets trends were near the mean throughout most of the 1990s. From 2000 onward reproductive success has trended similarly. Both species fared poorly in 2003, but reproductive success have been higher than average for the past five years. In the Central ecoregion, auklet reproductive success trends differed between the species, with exceptionally poor years in 1997 and 2001 for crested auklets and in 2005 for least auklets. Recent trends are unknown (see above)(Figure 20).

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 17) and less frequently at other Aleutian islands on which they occur. Puffins carry multiple prey items in their bills when they return to their colonies to feed their chicks. Forage fish and squid comprise most of puffin chick diets. In the absence of direct measures of forage fish abundance, time series of percent biomass of hexagrammids, gadids, and *Ammodytes* in puffin chick meals were selected as indicators of forage fish recruitment and system-wide productivity.

Relative percent biomass of prey in diets of tufted puffin chicks have been collected most years since 1988 at Buldir Island in the Western ecoregion and since 1996 at Aiktak Island in the Eastern ecoregion (Figure 22). Data are not currently available for samples collected after 2002 on Buldir and 2001 on Aiktak Islands, but are expected to be available in the near future. Data included here were extracted from reports produced by the Alaska Maritime National Wildlife Refuge. Earlier data may be available from other studies.



(a)



(b)

Figure 22: Relative biomass of gadids and *Ammodytes* in tufted puffin chick diets at Buldir Island in the Western ecoregion and Aiktak Island in the Eastern ecoregion.

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

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

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

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

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

Fish apex predators aggregate biomass There is an overall decreasing trend in Pacific cod biomass, which contributes the largest proportion to this guild across regions (Figure 23). Arrowtooth flounder, Kamchatka flounder and skates, all show an increasing trend.

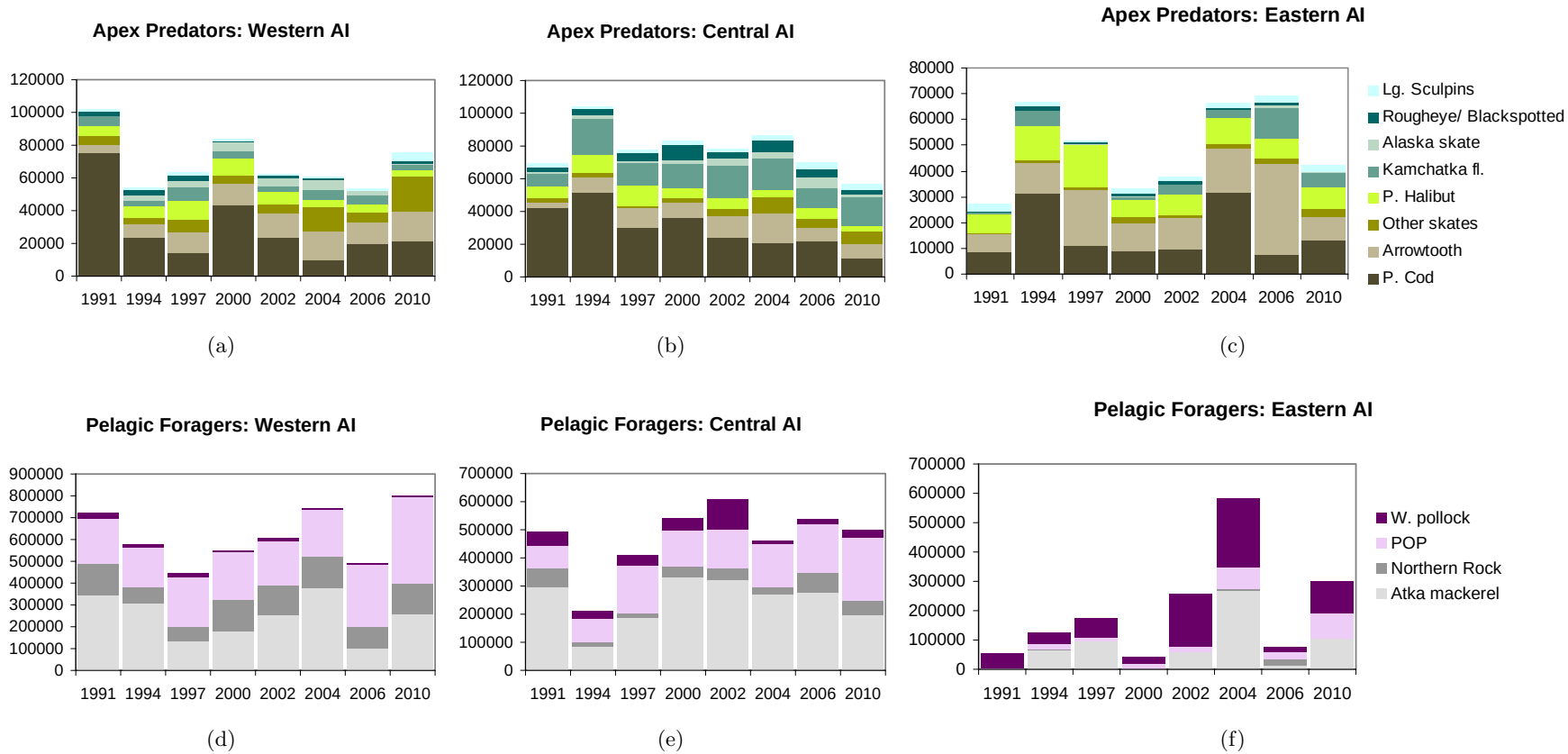


Figure 23: Composition in fish apex predator and pelagic fish foraging guilds by Aleutian Islands ecoregion.

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

Fish pelagic foragers aggregate biomass Pacific ocean perch is increasing in all areas (Figure 23). There are several species showing longitudinal trends in this group: the biomass of walleye pollock increases towards the east, whereas that of northern rockfish and Pacific ocean perch increases toward west. Both walleye pollock and northern rockfish comprise a very low proportion of the total pelagic foragers at the lower end of their distribution. Overall pelagic foragers increase towards the west while benthic foragers increase towards the east (benthic foragers not shown due to limited reliable time series).

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

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

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

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

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

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

Status and trend of Steller sea lion populations in Alaska are assessed using aerial photographic surveys of a series of 'trend' terrestrial haul-outs and rookeries that have been consistently surveyed each summer breeding season, when the proportion of animals hauled out is the highest during the year (Sease and York, 2003). Since 2004, NMFS has used high-resolution vertical photography (computer-controlled camera mounted in the belly of the plane) in its sea lion surveys in Alaska. This replaced the oblique, hand-held photographic techniques used from the first surveys in the 1960s and 1970s through 2002. Counts from vertical high resolution photographs were found to be 3.6% higher than those from oblique photos, necessitating the use of a correction factor to correctly compare recent counts with the rest of the time series (Fritz and C, 2005). Trend sites include the vast majority (>90%) of animals observed in each survey. Adults and juvenile (non-pup) numbers

used for population trend assessment are sums of counts at trend sites within sub-areas or across the range of the western DPS in Alaska (NMFS, 2010). Replicate surveys conducted in the summers of 1992 and 1994 indicated that sub-area trend site counts of non-pups are stable within each breeding season (coefficients of variation of ∼5%; NMFS, unpublished data).

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

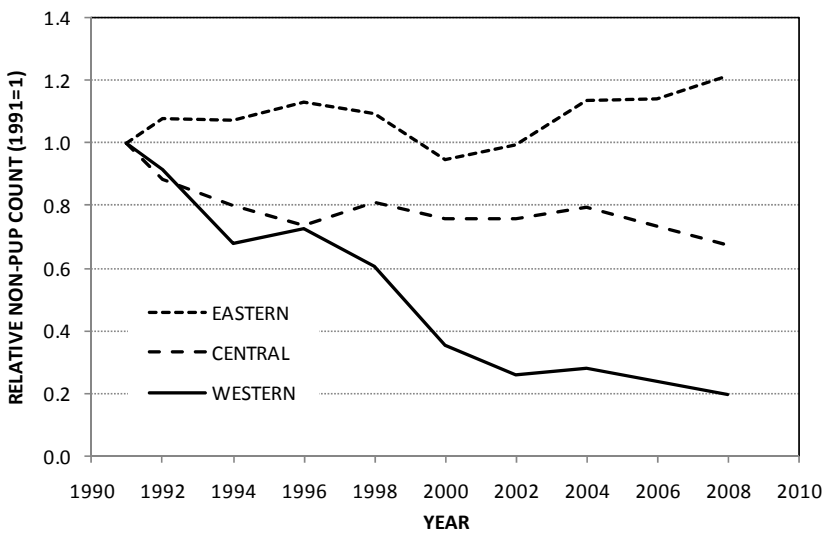


Figure 24: Relative change in counts of adult and juvenile (non-pup) Steller sea lions in the western, central and eastern Aleutian Island sub-areas, 1991-2008.

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

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

There is a strong west-east gradient in Steller sea lion population trends over the last 20 years in the Aleutian Islands (Figure 24). Between 1991 and 2008, non-pup counts declined 81% in the

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

Percent of shelf <500m trawled The annual and cumulative percentage of AFSC RACE 5 km x 5 km survey cells with observed commercial trawling, was developed from the North Pacific Observer Program foreign and domestic database in the Aleutian Islands region in waters with a bottom depth shallower than 500 meters (Figure 25). For the annual index, a cell is counted as trawled if there is a single trawl in the cell for that year. For the cumulative index, a cell is counted as trawled if there is a single observed trawl end position in the cell for the entire time series in each period: 1977-1989, 1990-1999, 2000-2010. Periods were chosen based on significant policy changes: 1990 marks the start of the domestic fisheries, while in 1999 and 2000 the US government issued emergency interim rules to further protect Steller sea lions. These rules expanded the number of seasonal and year-round pollock trawl exclusion zones around important rookeries and haulouts, implemented measures to disperse pollock fishing effort spatially and tempoarlly, and closed the Aleutian Islands to pollock trawling; additional restrictions were placed on the Atka mackerel fishery in the AI. New extensive protection measures for Steller sea lion were implemented in 2011 which significantly expand closures.

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

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

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

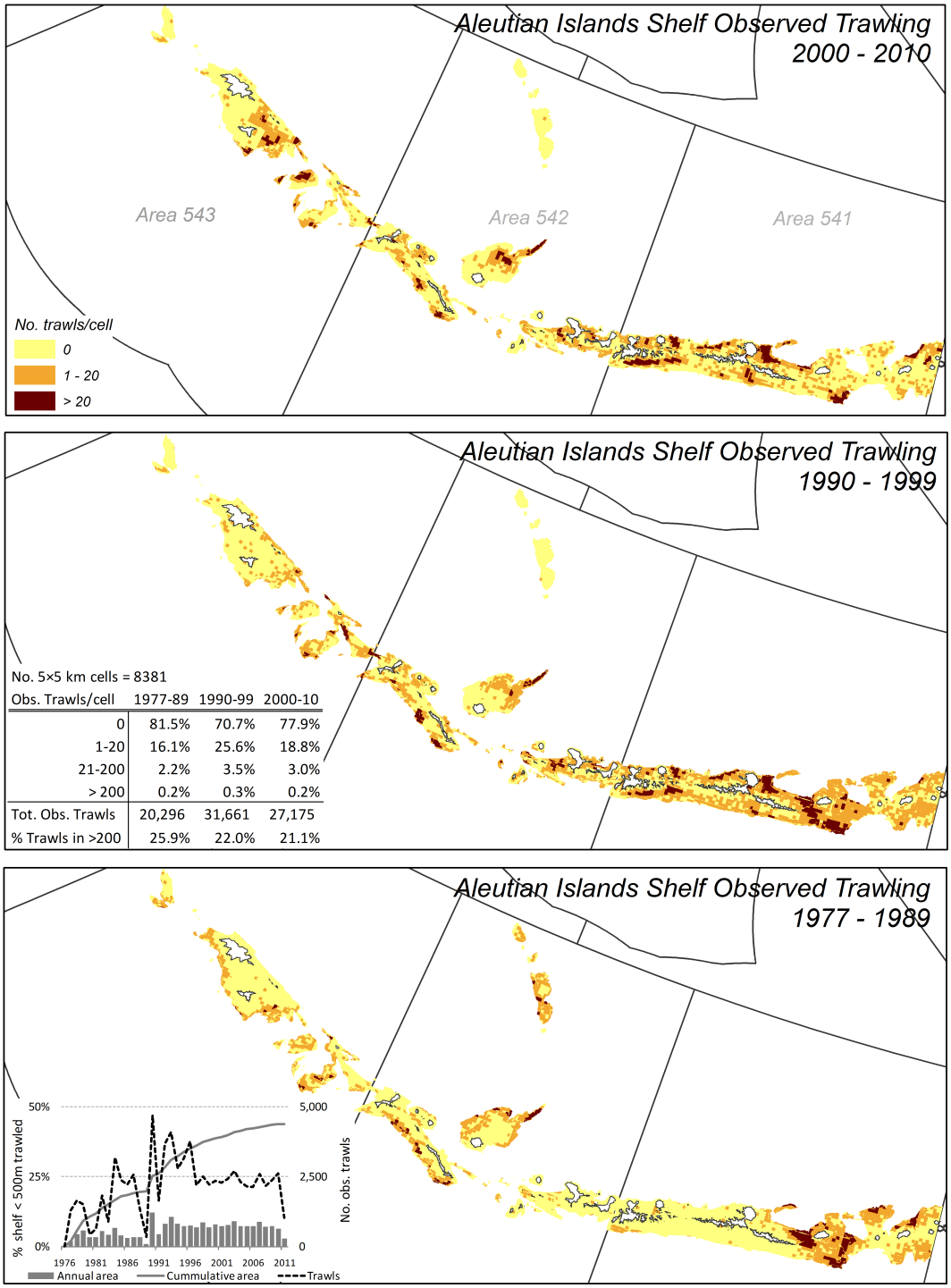


Figure 25: The annual and cumulative percentage of AFSC RACE 5 km5 km survey cells with observed trawling by decade.

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

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

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

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

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

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

to 5-6 children enrolled for the 2010 and 2011 school years.

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

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

Gaps and Needs

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

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

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

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

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

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

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

Indicators common to all ecosystems

Editor's note: This section will be updated in the November draft.

Objective: Maintain predator prey relationships and energy flow

Indicator: Discards and discard rates

Indicator: Invasive species observations

Gaps in predator-prey relationship knowledge common to all ecosystems

Objective: Maintain diversity

Indicator: Groundfish status

Indicator: Number of endangered or threatened species

Indicator: Steller sea lion non-pup counts and pup production

Gaps in diversity knowledge common to all ecosystems

Objective: Maintain habitat

Indicator: Areas closed to bottom trawling in the eastern Bering Sea, Aleutian Islands and the Gulf of Alaska

Indicator: Fishing Effort

Gaps in habitat knowledge common to all ecosystems

Objective: Incorporate and/or monitor effects of climate change

Indicator: North Pacific climate indices

Indicator: Combined standardized indices of groundfish recruitment and survival

Gaps in climate-related knowledge common to all ecosystems

Conclusions

Editor's note: This section will be updated in the November draft. The conclusions below are from 2011.

Climate Monitoring climate variability is necessary to understanding changes that occur in the marine environment and may help predict potential effects on biota. La Niña conditions developed again in the summer of 2011, following on the heels of the same pattern last year. This is liable to bring about relatively cool SSTs along the west coast of North America. This could have a broad range of effects on Alaska marine ecosystems. These large-scale climate factors determine the size and location of the cold pool in the Bering Sea. In the summers of 2006-2010, the extent of the cold pool increased from low values observed during 2000-2005. Changes in the cold pool size and location may affect the distribution of some fish species and may also affect stratification, production, and community dynamics in the Bering Sea. Observed changes in the physical environment in the Bering Sea may be, in part, responsible for the increased zooplankton biomass observed in the last two or three years. The increased zooplankton biomass may have positive effects on zooplanktivorous fish, such as juvenile walleye pollock, in the Bering Sea. It is apparent that many components of the Alaskan ecosystems respond to variability in climate and ocean dynamics. Predicting changes in biological components of the ecosystem to climate changes, however, will be difficult until the mechanisms that cause the changes are understood (Minobe, 2000).

Habitat It is difficult to assess the effects of fishing on habitat and structural epifauna. Increased knowledge of habitat disturbance as a function of fishing intensity would improve our ability to assess this objective. Also, it would be beneficial to have improved knowledge of the importance of structural epifauna as habitat for different species and life stages of fish, estimates of structural epifauna population abundance and distribution, particularly in areas currently untrawlable with standard survey gear, the relationship between physical factors such as sediment type, bathymetry, and oceanography and the abundance and distribution of structural epifauna.

Diversity Measures of diversity are subject to bias and we do not know how much change in diversity is acceptable (**?**). Furthermore, diversity may not be a sensitive indicator of fishing effects (Livingston et al., 1999; Jennings and Reynolds, 2000). We, therefore, attempted to look at a variety of indicators for the diversity objective. EBS species richness has increased since 1995 and this has been attributed to subarctic species spreading into the former cold pool area as the extent of the cold pool has decreased over recent decades (Mueter and Litzow, 2008). Species diversity in the EBS, however, has been relatively low in recent years, compared to the 1990s, which suggests that

species remain patchily distributed such that a given haul may be dominated by one or a few species. With regards to size diversity of fish in the Bering Sea, unlike other marine ecosystems, there has not been a linear decreasing trend in groundfish size or abundance during 1982-2006 (Boldt et al., 2008). No groundfish species is overfished or subject to overfishing; however, Pribilof Island blue king crab are considered overfished. These indices, however, apply only to fish and invertebrate species. There are eight endangered and five threatened marine mammal and seabird species in Alaska. One of those endangered species is the western stock of Steller sea lions, of which, the adult females may be experiencing declines in reproductive rates since the early 1990s (Holmes and York, 2003; Holmes et al., 2007). The number of northern fur seal pups born on the Pribilof Islands and Bogoslof Island show opposite trends, which can not be explained by immigration/emigration, or large-scale spatio-temporal environmental changes in the North Pacific Ocean. Further research is needed to improve our understanding of diversity indices and what causes some of these trends.

Gaps in knowledge There are gaps in understanding the system-level impacts of fishing and spatial/temporal effects of fishing on community structure and prey availability. Validation and improvements in system-level predator/prey models and indicators are needed along with research and models focused on understanding spatial processes. Improvements in the monitoring system should include better mapping of corals and other benthic organisms, development of a system for prioritizing non-target species bycatch information in groundfish fisheries, and identification of genetic subcomponents of stocks. In the face of this uncertainty, additional protection of sensitive or rare ecosystem components such as corals or local spawning aggregations should be considered. Improvements in understanding both the nature and direction of future climate variability and effects on biota are critical. An indicator of secondary production or zooplankton availability would improve our understanding of marine ecosystem dynamics and in prediction of groundfish recruitment and survival.

Ecosystem Status and Management Indicators

Ecosystem Status Indicators

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

Physical Environment

North Pacific Climate Overview

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Last updated: August 2012

Summary: The state of the North Pacific atmosphere-ocean system during 2011-2012 reflected the combination of a response to La Niña and intrinsic variability. The Aleutian low was weaker than usual in the winter of 2011-12, and the sea level pressure was higher than normal in the eastern portion of the basin for the year as a whole. Cooler than normal upper ocean temperatures prevailed in the eastern portion of the North Pacific and warmer than normal temperatures occurred in the west-central and then central portion of the basin. This pattern reflects a continuation of a negative sense to the Pacific Decadal Oscillation (PDO). The ENSO indices for the tropical Pacific indicate a warming trend for the first half of 2012; the models used to forecast ENSO are indicating outcomes for the winter of 2012-13 ranging from near neutral to a weak-moderate El Niño.

Regional Highlights:

West Coast of Lower 48. This region experienced conditions during 2011-2012 that mostly resembled those during past periods of La Niña and negative PDO. The waters near the coast tended to be mostly cool, with varying salinity, relative to normal. The cooler waters were accompanied by a greater preponderance of sub-arctic than sub-tropical zooplankton than usual, except for during fall

2011 (B. Peterson, NOAA/NWFSC). There was a rather late start to the upwelling in spring 2012, and the winds have tended to be somewhat less upwelling favorable than usual north of 40°N. Additional information on the state of the California Current system is available at `www.pacoos.org` and `http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/bb-midyear-update.cfm`.

Gulf of Alaska. The data from Argo profiling floats, available at `http://www.pac.dfo-mpo.gc.ca/science/oceans/Argo/Alaska-Argo-eng.htm`, are useful for diagnosing the sub-surface physical properties of this region. Based on the gradient in dynamic height from Argo, the poleward branch of the Alaska Current in the southeastern portion of the Gulf increased markedly from summer into fall of 2011, and after declining over the course of the winter, again increased from spring into summer 2012. These changes from season to season are consistent with the winds, as can be deduced from the SLP anomaly patterns shown in Figs. 1b-4b. The mixed layer depths in the Gulf were shallower than usual during the winter of 2011-2012 but by early summer 2012 were near their seasonal norms.

Alaska Peninsula and Aleutian Islands. Westerly wind anomalies have prevailed in this region for much of the past year. Anomalies in this sense tend to suppress the northward transport through Unimak Pass and perhaps also the Aleutian North Slope Current. A possible implication is a reduced supply of nutrients onto the southern Bering Sea shelf, but the importance of this mechanism is poorly known.

Bering Sea. The Bering Sea shelf experienced another relatively heavy ice year, especially in terms of maximum ice extent. The weather was punctuated by periods of unusually frigid temperatures at around the first of the year, the end of January and much of March. Westerly wind anomalies occurred during spring, which resulted in a late ice retreat from the southern shelf, but not to extent of some recent years, notably 2010. Unlike a year ago, the summer of 2012 has been relatively calm. This has resulted in a relatively thin (10 m) mixed layer that rapidly warmed in June through July, especially in the north. The water at depth is still cold and the onset of the fall storms should result in rapid cooling near the surface. The combination of El Niño expected this winter and a continuation of reduced ice cover in the central Arctic (more on this below) should yield a lighter ice year for the Bering in 2013.

Arctic. The tendency for reduced sea ice cover in the Arctic during the summer has continued into 2012. The distribution of the arctic sea ice in early August 2012 differs somewhat from recent years. Specifically, high ice concentrations have persisted in the Chukchi and in the western portion of the Beaufort Sea. The extent to which this ice will melt back during the remainder of summer depends on the weather of August and September. If the ice pack retreats to well north of Alaska, as it has in recent summers, there should again be a delay the development of ice in marginal seas such as the Bering Sea during the following cold season.

Sea Surface Temperature and Sea Level Pressure Anomalies

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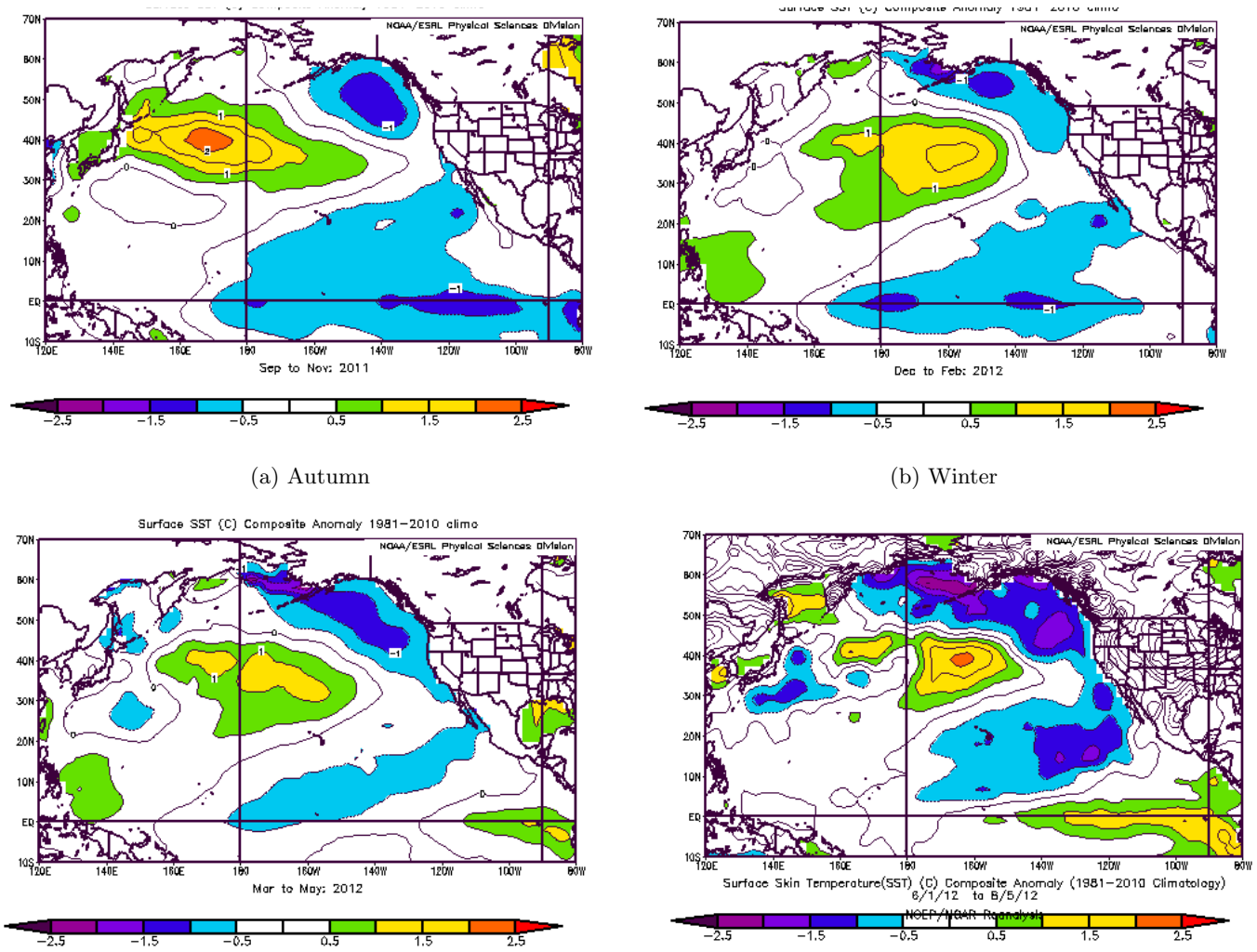
Description of indices: The state of the North Pacific from autumn 2011 through summer 2012 is summarized in terms of seasonal mean sea surface temperature (SST) and sea level pressure (SLP) anomaly maps. The SST and SLP anomalies are relative to mean conditions over the period of 1981-2010. The SST data are from NOAAs Extended Reconstructed SST analysis; the SLP data are from the NCEP/NCAR Reanalysis project. Both data sets are made available by NOAAs Earth System Research Laboratory at `http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl`.

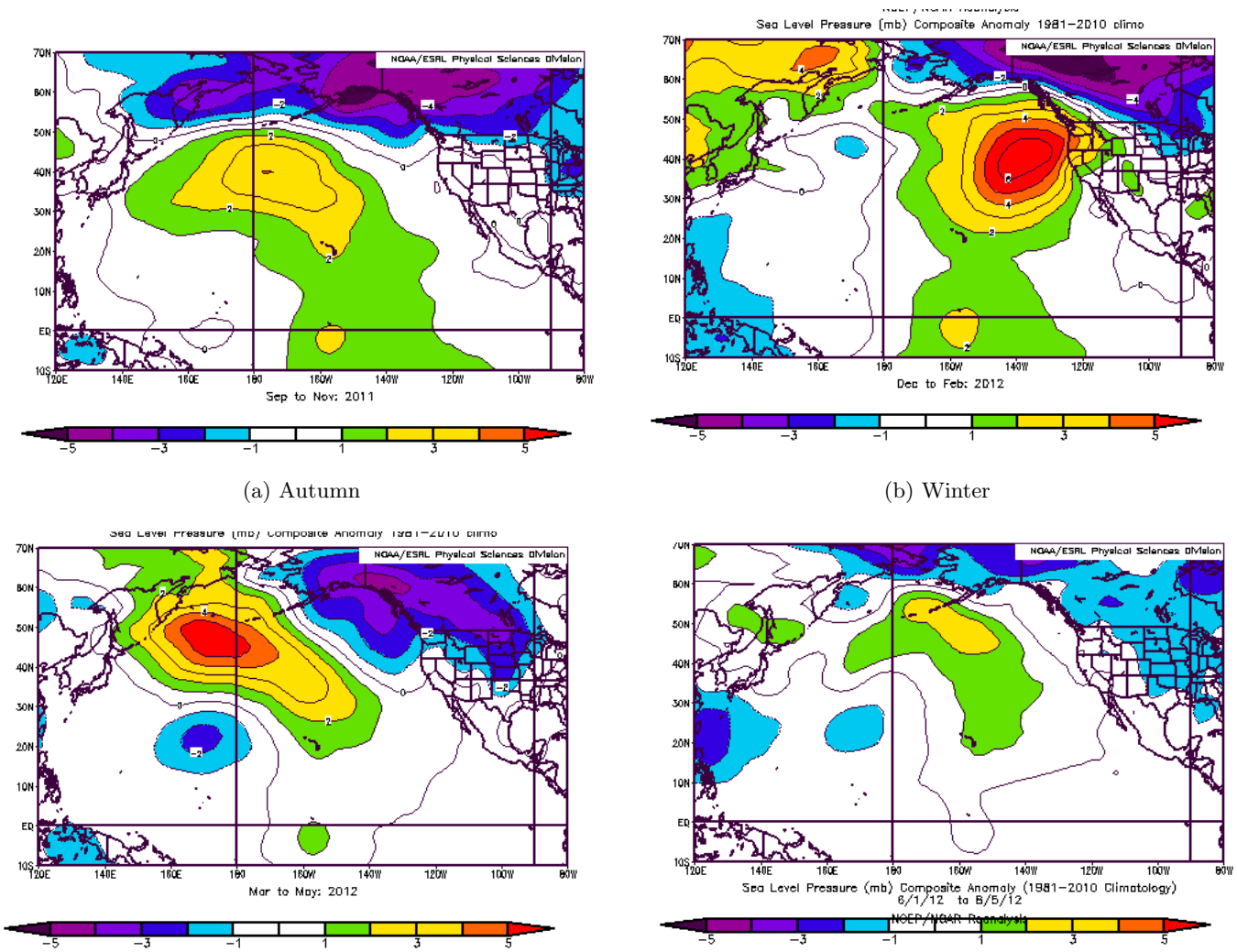
Status and trends: In an overall sense, the climate forcing of the North Pacific during the year of 2011-12 was dominated by the response to a weak-moderate La Niña that developed in late summer of 2011 and waned in spring 2012. The autumn (Sep-Nov) of 2011 included weak to moderate negative SST anomalies in the northern and eastern North Pacific, and moderate to strong positive SST anomalies in the central and western North Pacific in a band between 30° and 50°N. Cooler than normal SSTs occurred in the central and eastern tropical Pacific in association with the re-development of La Ni^{o}a (Figure 26a). The corresponding pattern of anomalous SLP included negative anomalies north of 50°N from eastern Siberia into central Canada and positive anomalies in the central north Pacific (Figure 27a). This pattern corresponds with westerly wind anomalies from roughly 40° to 50°N across most of the North Pacific.



(a) Autumn (b) Winter

(c) Spring (d) Summer

Figure 26: SST anomolies for autumn (September-November 2011), winter (December 2011 -February 2012), spring (March - May 2012), and summer (June - August 2012).



(a) Autumn

(b) Winter

(c) Spring

(d) Summer

Figure 27: SLP anomolies for autumn (September-November 2011), winter (December 2011 -February 2012), spring (March - May 2012), and summer (June - August 2011).

The pattern of anomalous SST during winter (Dec-Feb) of 2011-12 (Figure 26b) resembled its counterpart during the previous fall. There was some modest cooling, relative to seasonal norms, in the eastern Bering Sea, and continuation of La Niña in the tropical Pacific. The anomalous SLP during winter 2011-12 was dominated by a large high (¿6 mb) centered near 40°N, 140°W 27b). This anomaly was located well to the southeast of its usual location during La Niña. The anomalous SLP pattern shown in Figure 27b indicates anomalous westerlies in the mean for the Bering Sea and Gulf of Alaska and anomalous upwelling along the coast of California. This promotes the delivery of cold air of Siberian origin to the Bering Sea and Gulf of Alaska; the higher than normal pressure west of California meant suppressed storminess in the far eastern North Pacific and below normal precipitation for the western US.

The distribution of SST in spring (Mar-May) of 2012 (Figure 26c) indicates a continuation of colder than normal temperatures in Alaskan waters and anomalous warmth in the central North Pacific. There was a marked decline in La Nia in the tropical Pacific, with positive anomalies developing in the far eastern portion of the coast of South America. The concomitant SLP anomaly map (Figure 27c) indicates high pressure centered just south of the Aleutians, which is a more typical response to La Nña than was observed during the previous season. Anomalous low pressure extended from Alaska into western and central Canada. This set-up brought about an anomalous flow of cold air from the northwest across the Bering Sea and Gulf of Alaska, ultimately producing a cold and wet spring for the Pacific Northwest.

The pattern of anomalous SST in summer (Jun-Aug) 2012 (Figure 26d) featured the continued warming of the eastern tropical Pacific relative to seasonal norms. Negative anomalies persisted in a horseshoe pattern extending form the Bering Sea to the west coast of the US and curving back towards the southwest to the dateline. Warm water remained in the central North Pacific north of the Hawaiian Islands. This pattern represents a negative expression of the Pacific Decadal Oscillation (PDO), as further discussed below. The distribution of anomalous SLP (Figure 27d) included a band of positive anomalies stretching from the southeastern Bering Sea to the southeast into the central-eastern North Pacific. Relatively low pressure occurred from far eastern Siberia across Alaska across Canada. The gradients in the SLP anomalies, and hence anomalous winds, were weak in many regions, e.g., along the west coast of North America. This is typical for the summer season, when atmospheric circulation anomalies tend to be lower in amplitude compared to other times of the year.

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 2002 through spring 2012 are plotted in Figure 28.

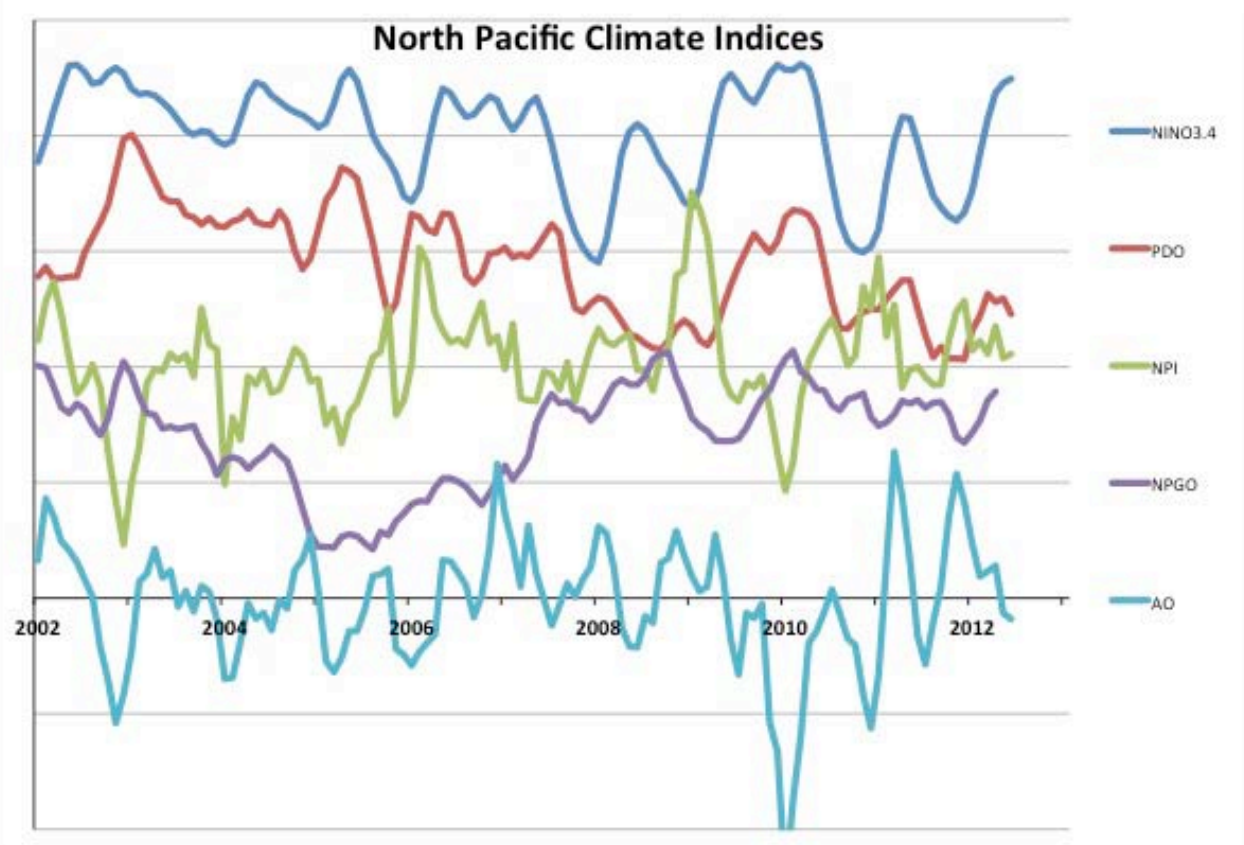

Figure 28: Time series of the NINO3.4 (blue), PDO (red), NPI (green), NPGO (purple), and AO (turquoise) indices. Each time series represents monthly values that are normalized and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 2 standard deviations. More information on these indices is available from NOAA's Earth Systems Laboratory at `http://www.esrl.noaa.gov/psd/data/climateindices`.

Status and trends: The state of the North Pacific atmosphere-ocean system reflected the influences of ENSO during 2011-12. The Aleutian Low tends to be weaker during La Niña winters, and while this was the case to an extent, the SLP anomalies during the past year (Fig. 2b) featured a positive anomaly center displaced to the southeast from its average location near 50°N, 160°W. Note that while ENSO is dominated by year-to-year variability it also varies on multi-year time scales. In particular, it was in a predominantly positive state from 2002 through 2005, and a negative state from late 2007 through early 2012, with La Niña present during four of the last five winters. As of summer 2012, recent warming in the tropical Pacific has transitioned ENSO into a positive state. The projections of the dynamical and statistical models used to forecast ENSO are discussed in the last section of this overview.

The PDO has manifested a largely downward trend since the winter of 2002-03. This reflects a multi-year shift from relatively warm to cool water in an arc extending from the Bering Sea through the Gulf of Alaska to along the west coast of North America, and SST anomalies of the opposite sign in the western and central North Pacific. There has been a return towards a more neutral

state since late 2011, at least in part due to the influence of ENSO on the PDO through the formers impacts on the atmospheric circulation over the North Pacific. The potential predictability of the PDO appears to be largely associated with its connection to ENSO.

The NPI is a commonly used measure of the strength of the Aleutian Low. The prominence of its short-term variability can be attributed to the nature of the North Pacific atmospheric circulation, which undergoes substantial fluctuations on short time scales (days) as well as years to decades. Note the negative correspondence with the NINO3.4 index in general. That being said, the NPI had a rather muted response to ENSO during the past La Niña.

The North Pacific Gyre Oscillation (NPGO) represents the second leading mode of variability for the North Pacific, and has been shown to relate to chemical and biological properties in the Gulf of Alaska and the southern portion of the California Current (Di Lorenzo et al., 2008). It has been in a positive state since 2007, which projects on stronger than normal flows in both the Alaska Current portion of the Subarctic Gyre and the California Current. It has been suggested that the NPGO may influence ENSO through its association with the strength of the trade winds in the sub-tropical eastern Pacific, but the mechanisms behind this potential linkage are poorly understood.

The AO represents a measure of the strength of the polar vortex, with positive values signifying anomalously low pressure over the Arctic and high pressure over the Pacific and Atlantic, at a latitude of roughly 45° N. It has a weakly positive correlation with sea ice extent in the Bering Sea. During periods of positive AO, cold air outbreaks to mid-latitudes are suppressed. The AO had a record negative value during the winter of 2009-10; it was also strongly negative during the early portion of the winter of 2010-11. The overall sense of the AO was positive during the winter of 2011-12 and since has been in a near neutral state. There are no reliable forecast tools at present for seasonal prediction of the AO, but there is some tendency for it to be in a negative state during El Niño.

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

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Last updated: August 2012

Description of index: Seasonal projections from the NCEP coupled atmosphere-ocean forecast system model (CFS) for SST are shown in Figure 29.

Status and trends: These projections of 3-month average anomalies indicate systematic declines in the magnitudes of the cold anomalies in the northeastern and southeastern portions of the basin, and of the warm anomaly centered near 40°N and the dateline. Changes of this nature imply a transition to a near neutral state for the PDO and are consistent with the changes in SST anomalies that have occurred during previous El Niños. Note that for the tropical Pacific itself, that the CFS is predicting some increase in the intensity of the warm anomalies, i.e., the development of a weak-moderate El Niño over the remainder of 2012. A slow decrease in the amplitude of El Niño is forecast during late winter 2013. The CFS is also forecasting a stronger than normal Aleutian Low, that is, negative SLP anomalies, for the winter of 2012-13 (not shown). The scenario described here

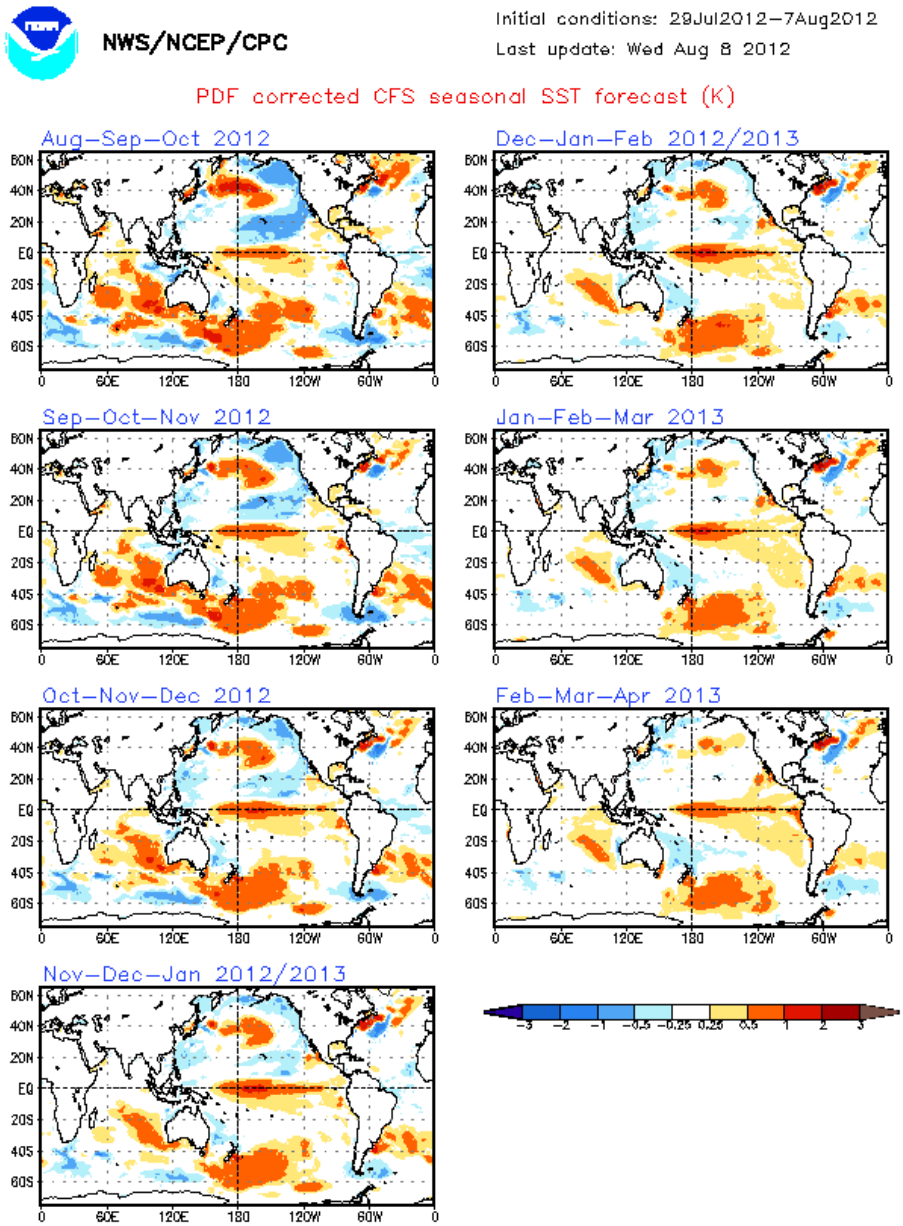

Figure 29: Seasonal forecast of SST anomalies from the NCEP coupled forecast system model for August 2012 through April 2013.

resembles that of three years ago. A moderate El Niño developed over the summer and fall of 2009 after the back-to-back La Niñas of 2007-08 and 2008-09; the presently developing El Niño event is occurring with similar precursor conditions. The CFS forecasts for late 2009 through summer 2010 were reasonably accurate; there is the expectation that the present CFS forecasts will also have value. The CFS predictions for El Niño are supported by the consensus of the predictions from a variety of dynamical and statistical approaches used by modeling centers towards forecasting ENSO.

Implications Based on not just the SST predictions shown in Figure 29, but also other forecast fields, it is likely that there will be a warming of Alaskan waters over the next 2-3 seasons, relative to the mostly cooler than normal temperatures that have prevailed over the last 5 years.

Eastern Bering Sea

Eastern Bering Sea Climate - FOCI

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Summer Bottom and Surface Temperatures - Eastern Bering Sea

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

Gulf of Alaska

Eddies in the Gulf of Alaska - FOCI

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Last updated: July 2012

Description of index: Eddies in the northern Gulf of Alaska have been shown to influence distributions of nutrients (Ladd et al., 2009, 2005, 2007), phytoplankton (Brickley and Thomas, 2004) and ichthyoplankton (Atwood et al., 2010), and the foraging patterns of fur seals (Ream et al., 2005). Eddies propagating along the slope in the northern and western Gulf of Alaska are generally formed in the eastern Gulf in autumn or early winter (Okkonen et al., 2001). Using altimetry data from 1993 to 2001, Okkonen et al. (2003) found that strong, persistent eddies occur more often after 1997 than in the period from 1993 to 1997. Ladd (2007) extended that analysis and found that, in the region near Kodiak Island, eddy energy in the years 2002-2004 was the highest in the altimetry record (1993-2006).

Since 1992, the Topex/Poseidon/Jason/ERS satellite altimetry system has been monitoring sea surface height. Eddy kinetic energy (EKE) can be calculated from gridded altimetry data (merged TOPEX/Poseidon, ERS-1/2, Jason and Envisat; (Ducet et al., 2000). A map of eddy kinetic energy in the Gulf of Alaska averaged over the altimetry record (updated from Ladd (2007)) shows four

regions with local maxima (labeled a, b, c and d in Figure 30). The first two regions are associated with the formation of Haida (a) and Sitka (b) eddies. Eddies that move along the shelf-break often feed into the third and fourth high EKE regions (c and d; Figure 30). By averaging EKE over regions c and d (see boxes in Figure 30), we obtain an index of energy associated with eddies in these regions (Figure 31).

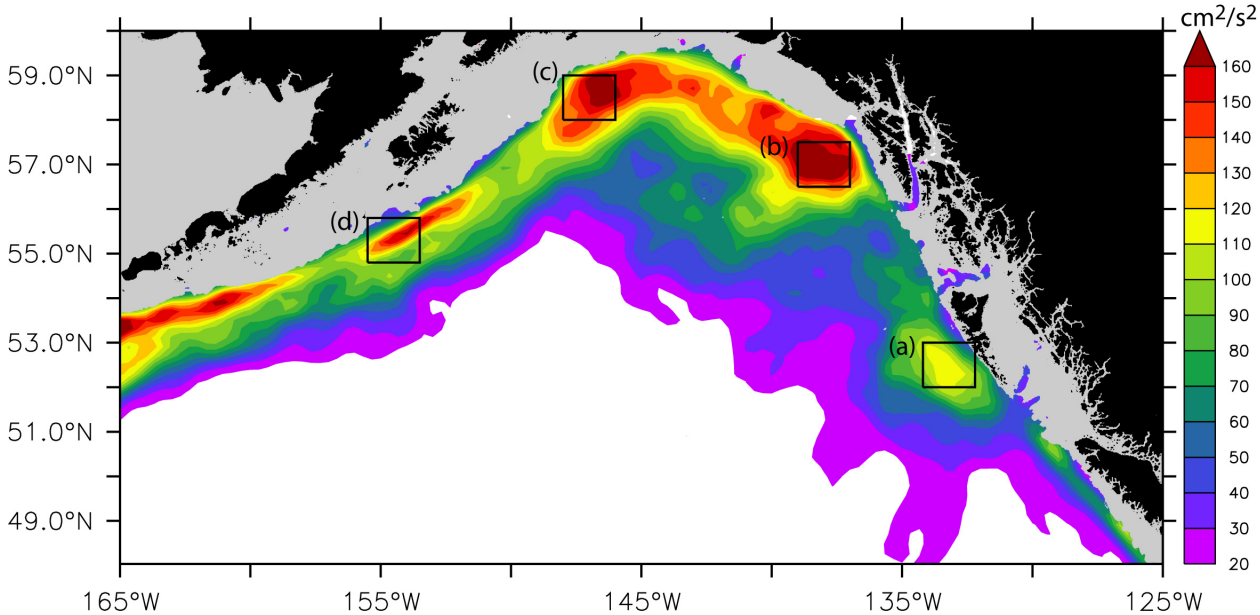

Figure 30: Eddy Kinetic Energy averaged over October 1993-October 2011 calculated from satellite altimetry. Regions (c) and (d) denote regions over which EKE was averaged for Figure 31.

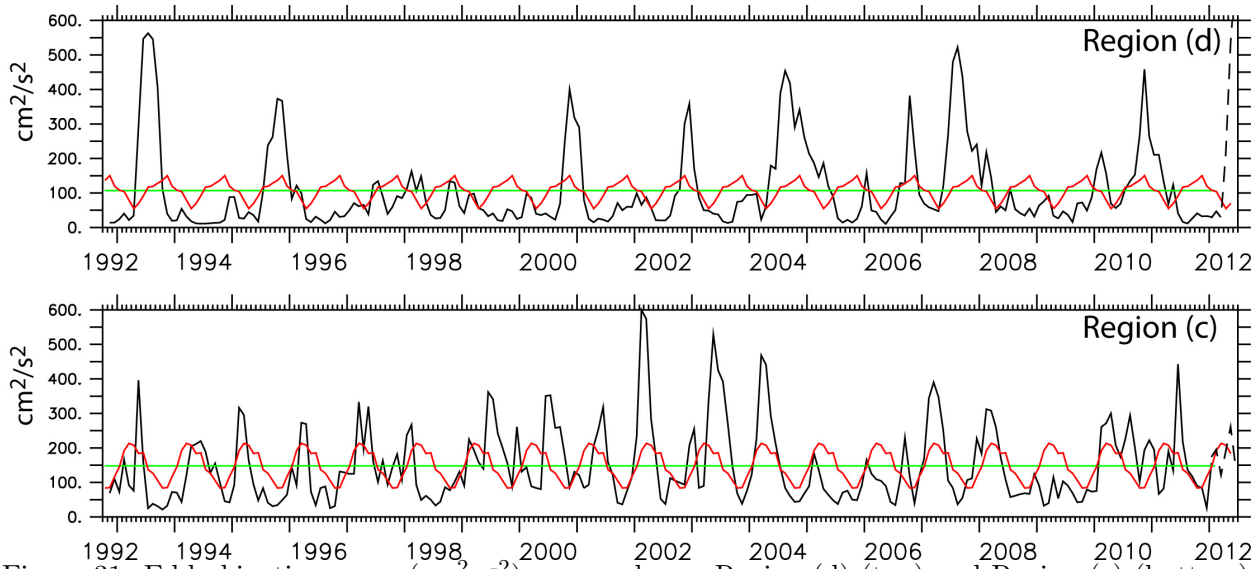

Figure 31: Eddy kinetic energy ($cm^2\ s^{-2}$) averaged over Region (d) (top) and Region (c) (bottom) shown in Figure 30. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product), Red: seasonal cycle. Green (straight line): mean over entire time series.

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

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

Implications: EKE may have implications for the ecosystem. Phytoplankton biomass was probably more tightly confined to the shelf during 2009 due to the absence of eddies, while in 2007, 2010 and 2012 (region (d)), phytoplankton biomass likely extended farther off the shelf. In addition, cross-shelf transport of heat, salinity and nutrients were probably weaker in 2009 than in 2007, 2010, and 2012 (or other years with large persistent eddies). Eddies sampled in 20022004 were found to contain different ichthyoplankton assemblages than surrounding slope and basin waters indicating that eddies along the slope may influence the distribution and survival of fish (Atwood et al., 2010). In addition, carbon isotope values suggest that cross-shelf exchange due to eddies may be important to the marine survival rate of pink salmon (Kline, 2010). The altimeter products were produced by the CLS Space Oceanography Division (AVISO, 2012).

Ocean Surface Currents - Papa Trajectory Index

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Last updated: August 2012

Description of index: The year-to-year variability in near-surface water movements in the North Pacific Ocean has been shown to have important effects on the survival of walleye pollock (*Theragra chalcogramma*) by affecting its spatial overlap with predators (Wespestad et al., 2000), as well as to influence recruitment success of winter spawning flatfish in the eastern Bering Sea (EBS; Wilderbuer et al. (2002)). The PAPA Trajectory Index (PTI) provides an annual index of this variability, based on the trajectory of a simulated surface drifter released at Ocean Station PAPA (50° N, 145° W; Figure 32) . The simulation for each year is conducted using the "Ocean Surface CURrent Simulator" (OSCURS; `http://las.pfeg.noaa.gov/oscurs`). Using daily gridded atmospheric pressure fields, OSCURS calculates the speed and direction of water movement at the ocean's surface at the location of a simulated surface drifter. It uses this information to update the position of the simulated drifter on a daily basis over a specified time period. For the index presented here, OSCURS was run for 90 days to simulate a surface drifter released at Ocean Station PAPA on December 1 for each year from 1901 to 2011.

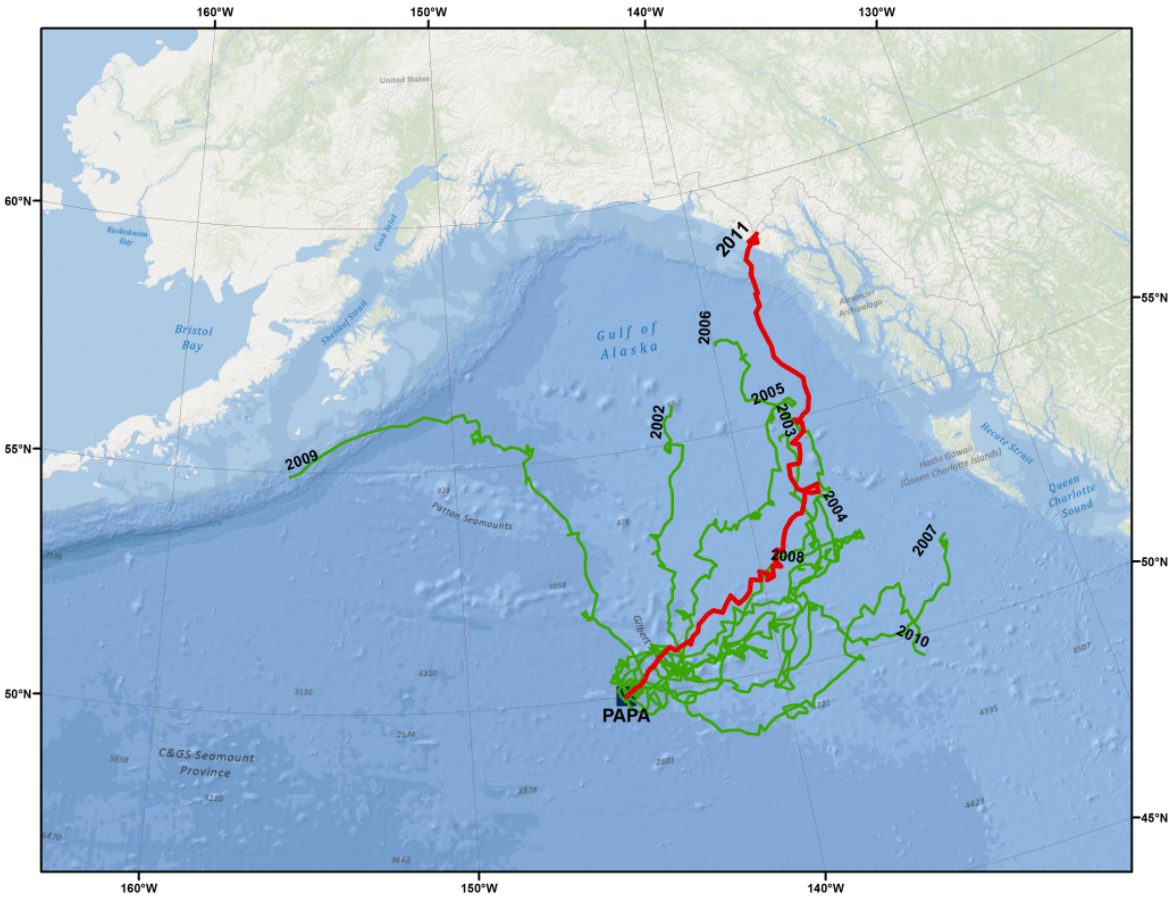

Figure 32: Simulated surface drifter trajectories for winters 2002-2012. End points of 90-day trajectories for simulated surface drifters released on Dec. 1 at Ocean Weather Station PAPA are labelled with the year of the release (50° N, 145° W).

Status and trends: In general, the trajectories fan out northeastwardly toward the North American continent (Figure 32). The 2009/2010 trajectory was an exception and resulted in the westernmost trajectory endpoint for the entire set of model runs (1902-2012). This trajectoy is, however, consistent with the atmospheric conditions that existed during the winter of 2009-2010 (N. Bond, pers. comm.). Under the influence of contemporaneous El Niño conditions, the Aleutian Low in the winter of 2009-2010 was anomalously deep and displaced to the southeast of its usual position in winter (Bond and Guy, 2010), resulting in anomalously high easterly (blowing west) wind anomalies north of Ocean Station PAPA. The 2011/2012 trajectory followed the general northeastwardly path of most drifters, but was notable because its ending latitude was the northernmost of all trajectories since 1994.

The PTI time series (Figure 33), black dotted line and points) indicates high interannual variation in the north/south component of drifter trajectories, with an average between-year change of ∼4° and a maximum change of greater than 13° (between 1931-1932). The change in the PTI between 2010/2011 and 2011/2012 was the largest since 1994. However, such swings are not uncommon

over the entire time series.

Using a 5-year running mean boxcar filter to smooth the raw PTI reveals multidecadal-scale oscillations in the north/south component of the drift trajectories (Figure 33), red line and squares), with amplitudes over 7° latitude. Over the past century, the filtered PTI has undergone four complete oscillations with distinct crossings of the mean, although the durations of the oscillations are not identical: 26 years (1904-1930), 17 years (1930-1947), 17 years (1947-1964), and 41 years (1964-2005). The filtered index indicates that a shift occurred in the mid 2000s to predominantly southerly anomalous flow following a 20+ year period of predominantly northerly anomalous flow. This indicates a return to conditions (at least in terms of surface drift) similar to those prior to the 1977 environmental regime shift.

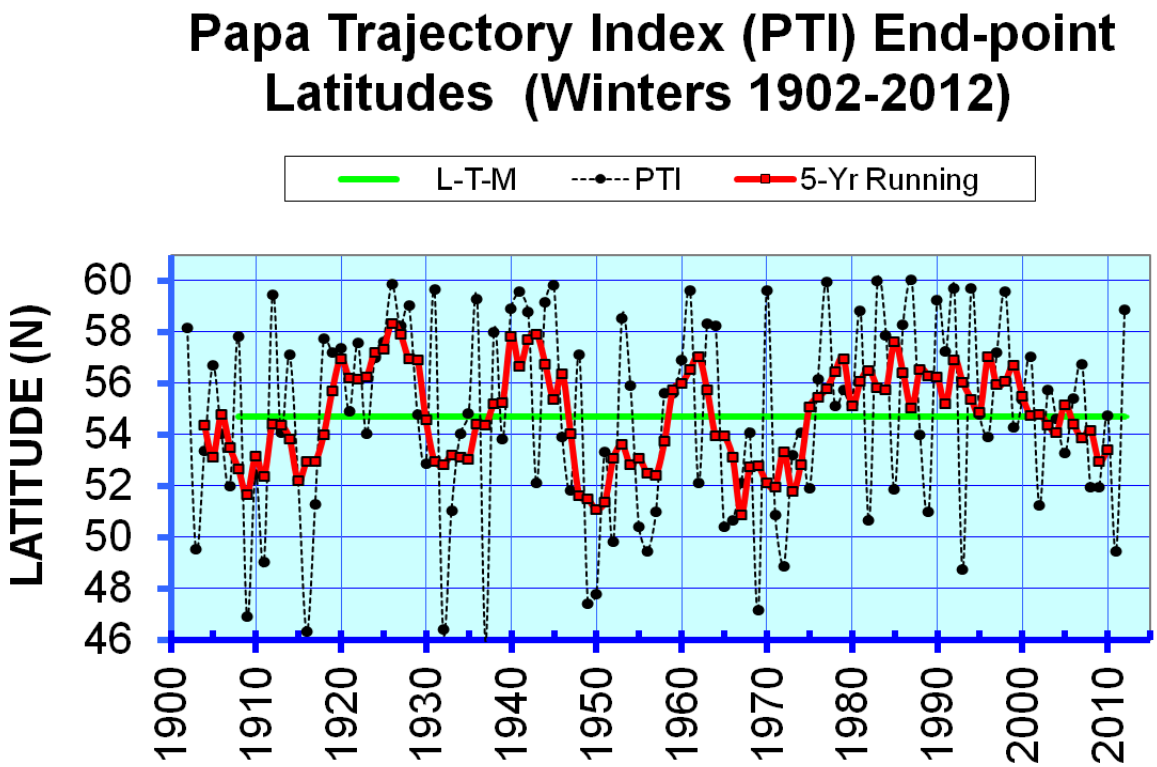

Figure 33: Annual, long-term mean (green line) and 5-year running mean (red line and squares) of the PAPA Trajectory Index time-series (dotted black line and points) for 1902-2012.

Factors causing observed trends: Filtered PTI values greater than the long-term mean are indicative of increased transport and/or a northerly shift in the Alaska Current, which transports warm water northward along the west coast of Canada and southeast Alaska from the south and consequently plays a major role in the Gulf of Alaska's heat budget.

Implications: Interdecadal changes in the PTI reflect changes in ocean climate that appear to have widespread impacts on biological variability at multiple trophic levels (King, 2005). There is strong evidence that the productivity and possibly the carrying capacity of the Alaska Gyre and of the continental shelf were enhanced during the recent "warm" regime that began in 1977. Zooplankton production was positively affected after the 1977 regime shift (Brodeur and Ware,

1992). Recruitment and survival of salmon and demersal fish species also improved after 1977. Recruitment of rockfish (Pacific ocean perch) and flatfish (arrowtooth flounder, halibut, and flathead sole) increased. However, shrimp and forage fish such as capelin were negatively affected by the 1977 shift (Anderson, 2003). The reduced availability of forage fish may have been related to the decline in marine mammal and seabird populations observed after the 1977 shift (Piatt and Anderson, 1996).

Although the PTI was substantially larger than the mean for 2011-12, its current (5-year averaged) trend remaions consistent with a return to conditions associated with the preceding "cold regime. It may thus be a harbinger of a decadal-scale reduction in regional productivity.

Gulf of Alaska Survey Bottom Temperature Analysis

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Last updated: October 2011

Gulf of Alaska surveys are conducted in alternate even years. For most recent data, see the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Aleutian Islands

Eddies in the Aleutian Islands - FOCI

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Description of index: Eddies in the Alaskan Stream south of the Aleutian Islands have been shown to influence flow into the Bering Sea through the Aleutian Passes (Okkonen, 1996). By influencing flow through the passes, eddies could impact flow in the Aleutian North Slope Current and Bering Slope Current as well as influencing the transports of heat, salt and nutrients (Mordy et al., 2005; Stabeno et al., 2005) into the Bering Sea.

Since 1992, the Topex/Poseidon/Jason/ERS satellite altimetry system has been monitoring sea surface height. Eddy kinetic energy (EKE) can be calculated from gridded altimetry data (merged TOPEX/Poseidon, ERS-1/2, Jason and Envisat; (Ducet et al., 2000)). Eddy kinetic energy (EKE) calculated from gridded altimetry data (Ducet et al., 2000) is particularly high in the Alaskan Stream from Unimak Pass to Amukta Pass (Figure 34) 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 35) provides an index of eddy energy likely to influence the flow through Amukta Pass. Numerical models have suggested that eddies passing near Amukta Pass may result in increased flow from the

Pacific to the Bering Sea (Maslowski et al., 2008). The altimeter products were produced by the CLS Space Oceanography Division (AVISO, 2012).

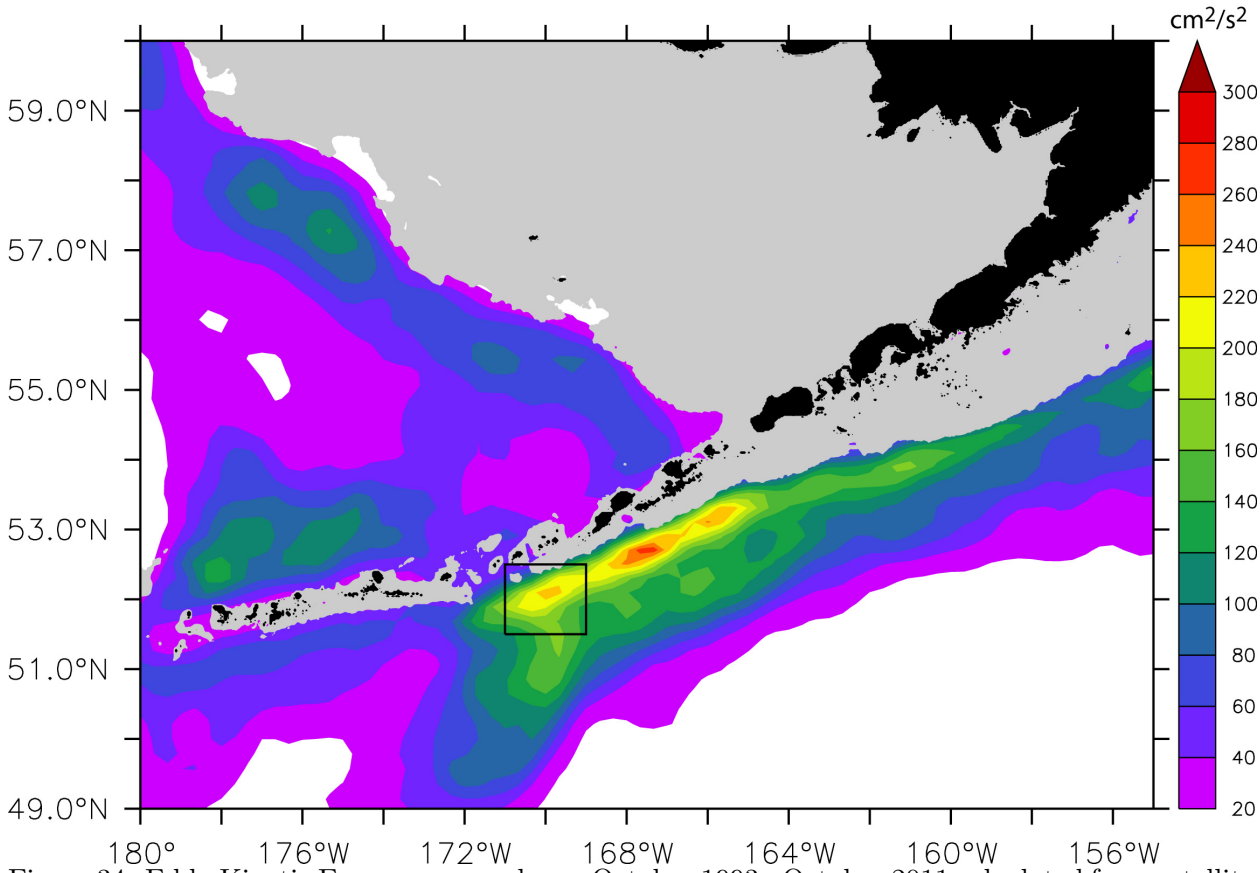

Figure 34: Eddy Kinetic Energy averaged over October 1993 - October 2011 calculated from satellite altimetry. Square denotes region over which EKE was averaged for Figure 35.

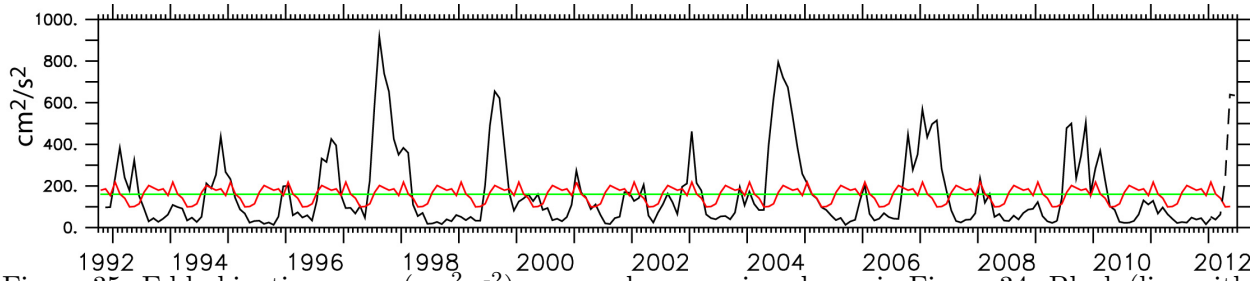

Figure 35: Eddy kinetic energy ($cm^2\ s^{-2}$) averaged over region shown in Figure 34. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product). Red: seasonal cycle. Green (straight line): mean over entire time series.

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

spring of 2010 through early 2012, but recent data shows the existence of an eddy in the region beginning in late April 2012.

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

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

Water Temperature Data Collections - Aleutian Islands Trawl Surveys

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

Habitat

Area Disturbed by Trawl Fishing Gear in the Eastern Bering Sea

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Description of index: Fishing gear can affect habitat used by a fish species for the processes of spawning, breeding, feeding, or growth to maturity. An estimate of the area of seafloor disturbed by trawl gear may provide an index of habitat disturbance. The area disturbed in the Eastern Bering Sea floor was calculated from observer trawl data each year from 1990-2011. The duration of every trawl haul was multiplied by a fishing effort adjustment as outlined in Appendix B of the January 2005 EFH EIS (`http://www.fakr.noaa.gov/habitat/seis/efheis.htm`). Table B.2-4 in the EIS document lists the adjustment factor for each gear type and vessel class. The adjustment converted trawl haul duration to area disturbed based on the type of trawl gear used (pelagic or bottom) and the vessel length. The adjustment also expanded smaller vessel fishing effort, which has 30% observer coverage, to simulate 100% coverage. Records missing trawl haul duration data and short wire hauls (hauls pulled in but not immediately brought on board) were assigned the average trawl haul duration over all years of 228 minutes (no more than 5% of hauls in any given year needed this adjustment).

An upper limit of the total area potentially disturbed by trawl hauls was estimated by assuming

that no trawl hauls overlapped spatially. To find the percent disturbed, it was necessary to find the total area of the Eastern Bering Sea being considered (Figure 36a). NMFS reporting areas for the Bering Sea were used as a baseline; however, Norton Sound was excluded because it is beyond the range of many commercially fished groundfish species. The Bering Sea Habitat Conservation boundary was used to exclude areas beyond the shelf break. The resulting total area considered was 742,647 km^2. The percent of area disturbed was estimated in two ways: 1) with no spatial overlap of trawl hauls in a given year, providing an estimate of the maximum potential percent of area disturbed and 2) with spatial overlap of trawl hauls within 400 km^2 cells to limit the disturbance of trawls recorded in a cell to 400 km^2, providing an estimate of potential percent of area disturbed. The average distance of a haul based on recorded start and end locations is 14 km with a standard deviation of 10 km. The cell size was chosen to reflect this spatial resolution of the hauls. Though this cell size allows some overlap of hauls, it still may over estimate the percent area disturbed in a year. The map below shows in what areas trawling disturbances accumulated over various time intervals (Figure 36b).

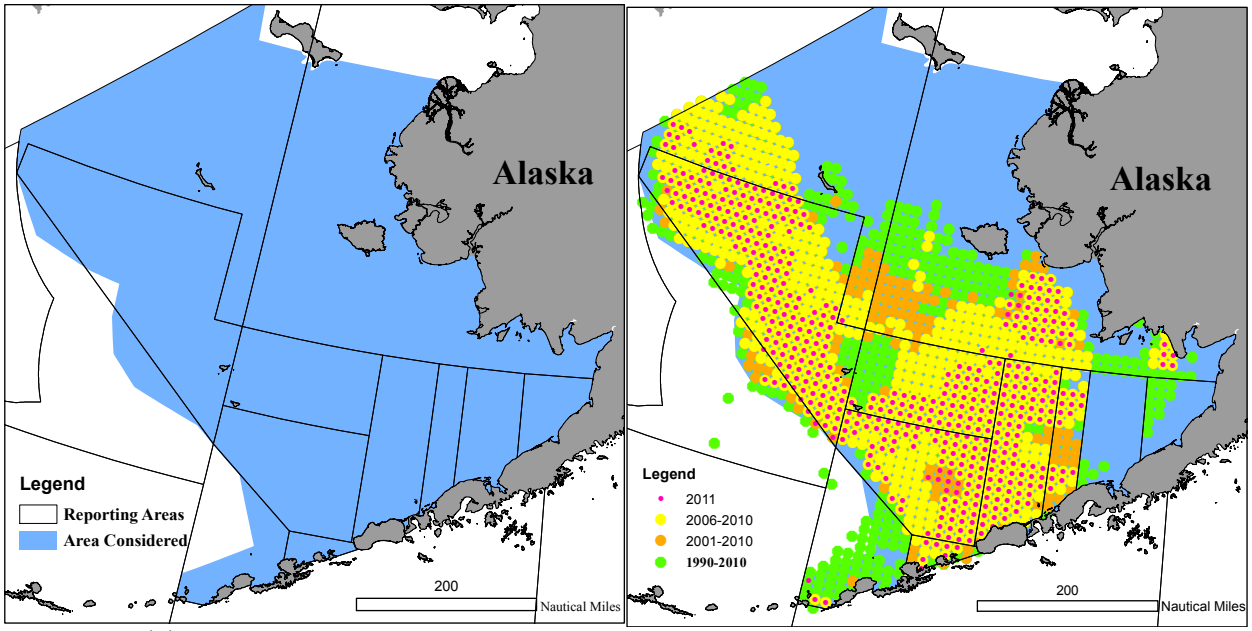

Figure 36: (a) Map of Eastern Bering Sea area considered when estimating percent area potentially disturbed by trawl fishing gear. (b) Map of 400 square kilometer cells with some trawling in cumulative time periods. Cells with fewer than 3 vessels are not shown

Status and trends: The maximum total area of seafloor in the Eastern Bering Sea potentially disturbed by trawls varied around 120,000 km^2 in the 1990s and decreased in the late 1990s to approximately 90,000 km^2. The area disturbed remained relatively stable in the 2000s with a slight decrease in 2009-2010. The percent of total area disturbed varied between 10% and 15% in the 1990s and between 9% and 11% in the 2000s, however due to trawls overlapping the same area the more realistic area disturbed was less than 10% from the mid 1990s on. Reduction in hours fished in the 2000s indicates greater fishing efficiency.

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

fishing skills (e.g., increased ability to find fish), and changes in vessel horsepower and fishing gear.

During 1993-1999, fishing effort was more concentrated in the southern area compared to 1990-1992 and 2000-2008, where effort was spread out spatially, particularly towards the northwest. This may, in part, explain the larger difference between the upper and lower estimates of percent area disturbed (with no overlap and with overlap within 400 km^2 cells, respectively) during 1993-1998 relative to other years (Figure 37).

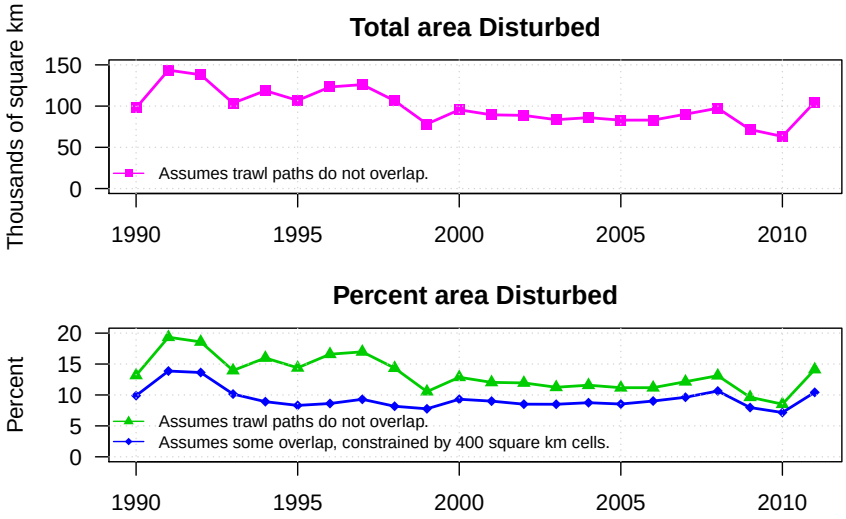

Figure 37: Total maximum potential area disturbed (assuming no spatial overlap of trawls), and the percent area disturbed. The green line, representing percent area disturbed, sums the area disturbed assuming no spatial overlap of trawl hauls in a year, thus providing an upper limit to the estimate of area disturbed. The blue line represents the percent area disturbed with spatial overlap of trawl hauls within 400 km^2 cells, thereby, limiting the disturbance of trawls recorded in a cell to 400 km^2.

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

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

Structural Epifauna - Bering Sea

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Structural Epifauna - Gulf of Alaska

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Gulf of Alaska surveys are conducted in alternate even years. For most recent data, see the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

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

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Structural Epifauna - Aleutian Islands

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Nutrients and Productivity

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

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See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Trends in surface carbon uptake by phytoplankton during late summer to early fall during late summer to early fall in the eastern Bering Sea

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Last updated: August 2012

Description of index: Primary production experiments were carried out aboard ship during late summer/early fall as a means to help understand the flow of energy from plankton to fish. Autumn is a critical time for young forage fish to increase body mass for winter survival. Production experiments were performed during the Bering Aleutian Salmon International Surveys (BASIS) during August Sept, 2006-2011. Water samples were collected at surface (<10m, 50% light) depths, inoculated with $NaH^{13}CO^3$, covered with screen to simulate the 50% light level, and incubated in a polycarbonate tank at surface seawater temperatures for 6 daylight hours encompassing solar noon. Samples were then filtered through a GF/F filter and frozen at -80°C until analyzed for isotope ratios of $^{13}C/^{12}C$ by the University of Alaska Fairbanks stable isotope laboratory. Water samples were analyzed for chlorophyll a and inorganic nutrients at the same station and depth as the experimental stations.

Surface carbon (^{13}C) uptake rates (ug $L^{-1}h^{-1}$) by phytoplankton were normalized to chlorophyll a concentrations and compared across years (2006-2011, excluding 2008), oceanographic domains (inner 0-50 m, and middle 50-100 m), and North-South regions (≤60°N≥) using Kruskall Wallis non-parametric tests. Yearly comparisons in uptake of ^{13}C by phytoplankton were made only for the southeast Bering shelf (SEBS) due to insufficient data in the northeast Bering shelf (NEBS) during 2007.

Status and trends: Temporal trends in surface carbon uptake rates over the SEBS (inner and middle domains combined) remain relatively invariable from 2006-2011 with an exception during 2007, where median ^{13}C uptake rates decreased by a factor greater than 5 ($P = 0.008$) (Figure 38). The 2007 chlorophyll a surface concentrations, and silicate concentrations at the experimental stations were also significantly lower compared with other years ($P = 0.038$ and $P = 0.015$) (Figures

39 and 40). Inorganic nitrogen and phosphate levels did not vary significantly during the years studied. No significant differences were seen in uptake rates of carbon between north and south regions of the eastern Bering Sea during 2006-2011 ($P \geq 0.05$), nor were any significant differences seen between inner and middle oceanographic domains ($P \geq 0.05$).

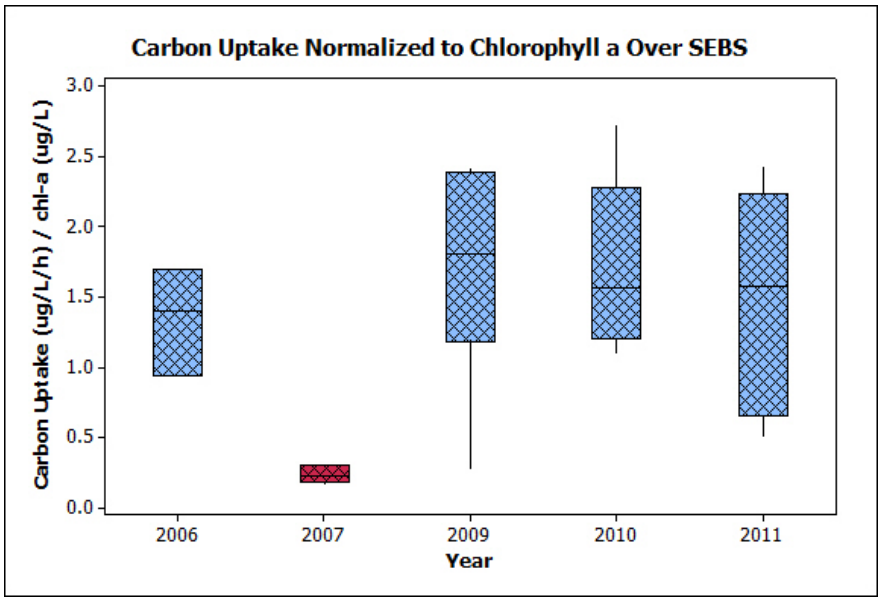

Figure 38: Surface carbon uptake normalized to chlorophyll a concentrations over the southeast Bering Shelf (SEBS) showing a significant drop (in red) in 2007 uptake rates compared with other years. Single outlier removed from 2007 dataset.

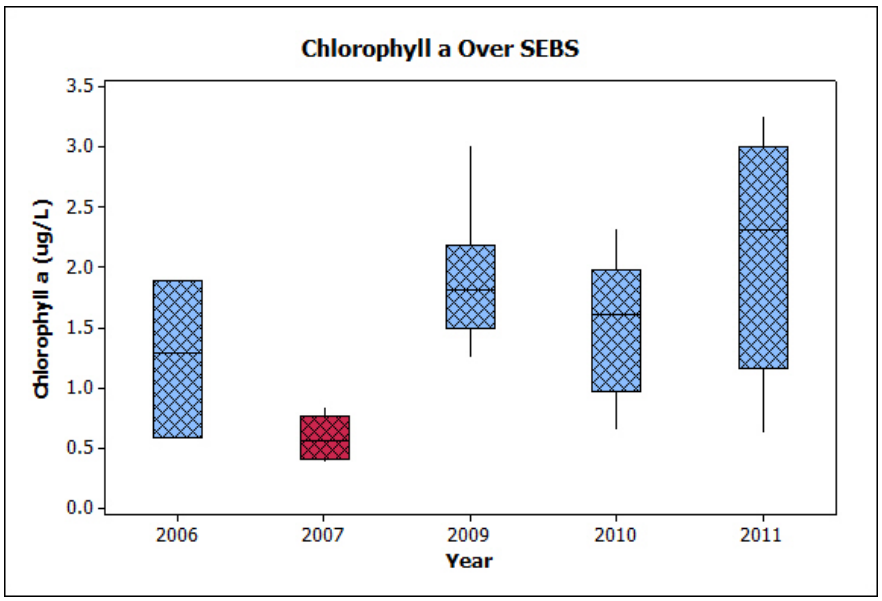

Figure 39: Surface chorophyll a concentrations at production stations over the southeast Bering Shelf (SEBS) showing a significant drop (in red) in 2007. Single outlier removed from 2007 dataset.

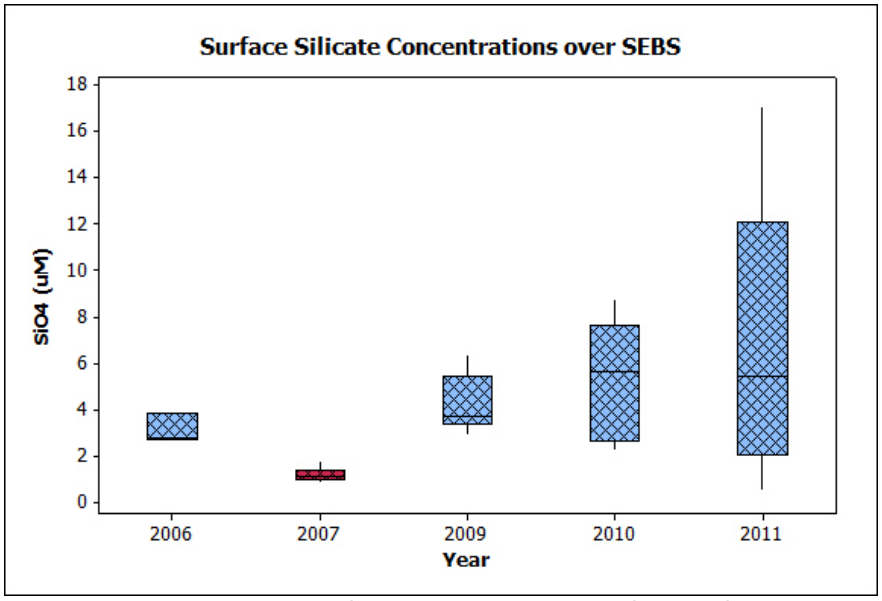

Figure 40: Silicate concentrations at production stations over the southeast Bering Shelf (SEBS) showing a significant drop (in red) during 2007. Single outlier removed from 2007 dataset.

Factors causing observed trends: Significant decreases in both chlorophyll a concentrations and carbon uptake rates during 2007 may have been due to; lower than normal silicate concentrations, high water column stability (Coyle et al., 2011), or species changes in phytoplankton community.

Implications: Significant decreases in phytoplankton carbon uptake and chlorophyll biomass during late summer/early fall will negatively impact energy flow to higher trophic levels. Low food availability to young forage fishes during this time of year may make overwintering difficult and following year recruitments could suffer.

Gulf of Alaska Chlorophyll a Concentration off the Alexander Archipelago

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Zooplankton

Bering Sea Zooplankton

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

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

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Last updated: August 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Long-term Zooplankton Trends in Icy Strait, Southeast Alaska

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Last updated: August 2012

Description of index: The Southeast Coastal Monitoring (SECM) project of Auke Bay Laboratories, AFSC, has collected zooplankton and temperature data during fisheries oceanography surveys annually since 1997 (Orsi et al. 2012; `http://www.afsc.noaa.gov/abl/msi/msi_secm.htm`). The SECM project primarily samples 8 stations in the vicinity of Icy Strait in the northern region of southeastern Alaska (SEAK), including monthly sampling with CTDs and plankton nets in May-August. Surface trawling for juvenile Pacific salmon (*Oncorhynchus* spp.), the most abundant forage species in local epipelagic waters in day time, and associated nekton is conducted in June-August. The primary goals of this research are to investigate how climate change may affect SEAK ecosystems, to increase understanding of the early marine ecology of salmon and their trophic linkages, and to develop an annual forecast of the adult pink salmon (*O. gorbuscha*) anticipated to

Table 5: Zooplankton longterm mean total density (numbers^{-3}) and percent composition for taxa important in fish diets by month in Icy Strait, Southeast Alaska. Data represent 4 stations sampled annually across the strait ($\leq$ 200 m depth) with a 0.6 m diameter 333-μm mesh Bongo net (double-oblique trajectory) from 1997-2011. Values are references for the 0-lines shown in Figure 42 anomalies.

	Total organisms	% Large calanoids	% Small calanoids	% Euphausiid larvae	% Larvaceans	% Pteropods	% Amphipods	% Decapod larvae	% Other
May	1682	35	47	5	6	<1	<1	<1	6
June	1711	25	58	6	4	2	<1	<1	4
July	1223	15	73	11	3	<1	3	<1	4
August	853	16	74	1	2	<1	3	<1	4

return the following year (Sturdevant et al. 2004; Orsi et al. 2004, 2009, 2012; Sturdevant et al. 2012). Biophysical parameters representing temperature, zooplankton prey, and fish abundance and condition are used to characterize seasonal and interannual ecosystem conditions for inside waters of northern Southeast Alaska.

This report presents longterm trends for temperature and zooplankton in Icy Strait. The temperature data was an index of the 20-m upper water column and was linked to a climate metric, the El Niño/La Niña-Southern Oscillation (ENSO) Multivariate ENSO Index (MEI) (Wolter 2012). The temperature index was computed from CTD data at 1-m increments for 8 stations in Icy Strait ($\geq$ 160 monthly observations per year). The MEI Index data used was the mean for 12 months beginning in September of the year prior to the sample year, to capture the lag effect of propagating ocean-atmospheric teleconnections from the equatorial Pacific Ocean. Zooplankton total density (number -3) and percent composition were computed from 333-μm bongo net samples collected at 4 stations ($\leq$ 200 m depth) (Park et al. 2004). Anomalies were computed as deviations from the longterm monthly mean values. These indices may help to explain variation in prey fields for diverse fish communities.

Status and trends: Monthly temperatures ranged from approximately 7°C to 10.5^{o}C for the 20-m upper water column. Anomalies did not exceed these means by more than $\pm$ 1.4 ^{o}C (Figure 41, top) and their direction was usually consistent within a year. The annual temperature index was significantly correlated with the MEI (Figure 41, bottom). Overall, 9 years were characterized as warmer than average (9.3^{o}C), typically with positive MEI values; conversely, 6 years were characterized as colder than average, typically with negative MEI values. However, for the most anomalous years, all 4 months were warm (2003 and 2005) or cold (2002, 2006, and 2008; Figure 41, top). In contrast, moderately warm or cold years had unique months of temperature reversal. For example, the warm years of 2001, 2004, and 2010, were actually colder than average in May, June, and July, respectively.

Longterm mean zooplankton density peaked in May and June at approximately 1,700 organisms per m^{-3}, and declined 50% by August (Table 5). Density anomalies were strongly negative from 1997-2005, strongly positive in 2006-2009, then reversed in both 2010 and 2011 (Figure 42, top left). Total density showed little correspondence with annual temperature trends, with both positive and negative anomalies in both warm and cold years.

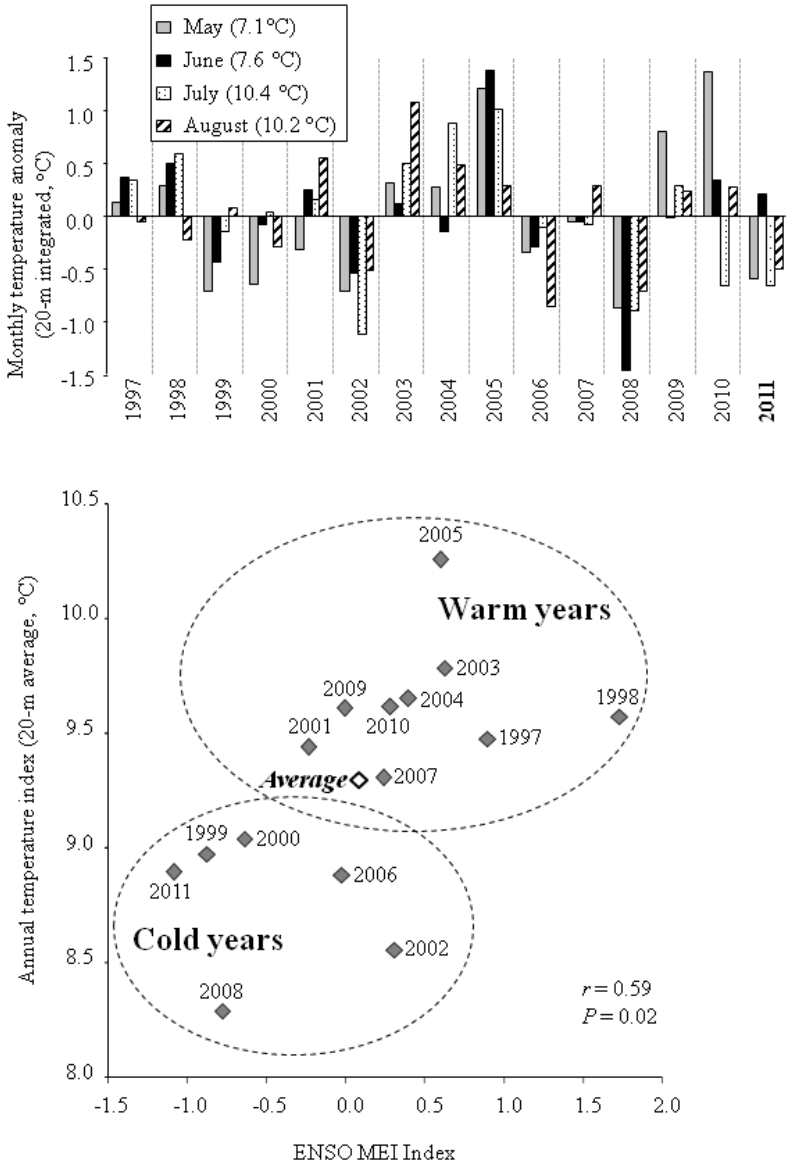

Figure 41: Marine climate relationships for the northern region of Southeast Alaska from the SECM 15-year time series, 1997-2011. Upper panel: mean monthly temperatures (°C, 20-m integrated water column) in Icy Strait; lower panel: correlation of mean annual temperature (°C, 20-m integrated water column) with the Multivariate ENSO Index (MEI), showing warm-versus-cold years. Longterm mean temperatures are indicated in the key.

Zooplankton was numerically dominated by calanoid copepods, including small species ($\leq$ 2.5 mm Total length, TL; $\leq$ 74% composition; primarily Pseudocalanus spp.) and large species ($>$ 2.5 mm TL; $\leq$ 35% composition; primarily *Metridia* spp.) (Table 5). Five other taxa important in

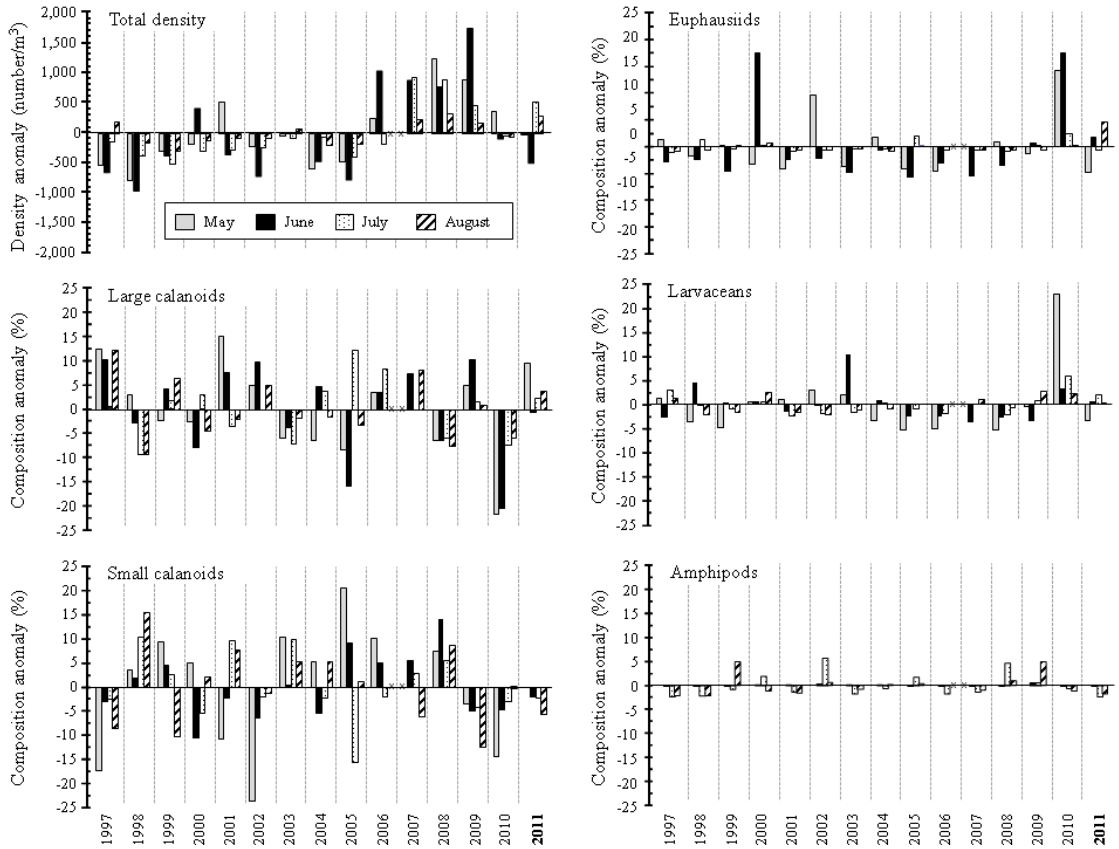

Figure 42: Zooplankton density and composition anomalies for the SECM 15-yr time series from Icy Strait, Southeast Alaska, 1997-2011. Longterm monthly means are indicated by the 0-line (values given in Table 5). Data (shaded bars) are deviations for total density (number/m^3; top left panel), and percent numerical composition of taxa important in fish diets. No samples were collected in August 2006, and the May 2007 night time values were omitted (denoted by x).

fish diets (Sturdevant et al. 2004, 2012) contributed minor numerical percentages. Small and large calanoids typically deviated by 10-20% from the longterm average, with inverse monthly anomalies that indicated different seasonalities (Figure 42). However, these composition anomalies varied from year to year, suggesting different innate timing cues. For example, both 2005 and 2010 were warm years, but positive temperature anomalies were sustained in 2005 (when both large and small calanoid trends reversed abruptly in July), compared to 2010 (when synchronous negative anomalies were sustained for all months). The unusual pattern in 2010 occurred when total zooplankton densities were near average and two other prey taxa showed strongly positive anomalies (euphausiid larvae and larvaceans). Such changes could lead to mismatched timing of prey fields for planktivorous fish.

Factors influencing observed trends: Our research in SEAK over the past 15 years describes annual trends in temperature, prey fields, and other biophysical factors (Orsi et al. 2012). We documented a link between local marine temperatures and a multivariate, basin-scale climate index (MEI) (Sturdevant et al. 2012). Although subarctic zooplankton typically follow seasonal cycles of abundance, responses to climate change may be species-specific based on life history, seasonal timing cues, physiology, and environmental parameters other than temperature (Mackas et al. 2012), and

these responses could depend on the monthly timing, magnitude, and duration of temperature anomalies in warm or cold years. Therefore, a simple annual temperature index may not explain shifts in abundance and composition of these prey fields, particularly at broad taxonomic scales.

Implications: Climate change can have broad impacts on key trophic linkages in marine ecosystems by changing relationships of the biophysical environment with seasonal abundance, composition, timing, and utilization of prey (Mackas et al. 2004, 2012; Coyle et al. 2011). Although links between climate and plankton have been documented in Alaskan waters, mechanisms are poorly understood. In the Bering Sea, the magnitude and timing of production of the large copepod, *Calanus marshallae*, varied among years, reflecting interannual ocean-atmosphere conditions (Baier and Napp 2003), and in Southeast Alaska, large copepods with long life spans were thought to be more sensitive to climate fluctuation than small copepods (Park et al. 2004). In the Bering Sea, changes in energy flow led to poor recruitment of juvenile salmon and pollock when diets shifted between warm (2003-2006) and cool (2006-2009) years in response to zooplankton and temperature shifts (Coyle et al. 2011). Conversely, in the Strait of Georgia, although juvenile salmon diet composition did not show dramatic interannual shifts between 1997-2002, feeding intensity and fish size increased and survival was greater after the 1998 climate shift (Beamish et al. 2004). In dynamic ecosystems such as SEAK (Weingartner et al. 2008), the effects of climate variation on prey fields are likely to be complex, varied, and difficult to distinguish from natural variation, particularly if annual temperature changes are moderate. No climate effect on planktivorous fish diets was found in SEAK (Sturdevant et al. 2012). However, further analysis of the potentially more direct links between monthly temperature and zooplankton secondary production may lead to improved understanding of marine mechanisms that influence fish recruitment during periods of climate change (Downtown and Miller 1998; Francis et al. 1998).

Continuous Plankton Recorder data from the Northeast Pacific

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Last updated: August 2012

Description of indices: Continuous Plankton Recorders (CPR) have been deployed in the North Pacific routinely since 2000. Two transects that originate in the Strait of Juan de Fuca are sampled seasonally. One is sampled monthly (Apr-Sept) and terminates in Cook Inlet; the second is sampled 3 times per year, follows a great circle route across the North Pacific, and terminates in Japan. Several indicators are now routinely derived from the CPR data and updated annually. They include indicators of mesozooplankton (1) biomass, (2) phenology (timing), and (3) community.

Mesozooplankton biomass and mean copepod community size are estimated for three regions. The eastern-most region has the best sampling resolution as both transects intersect here. This region has been sampled up to 9 times per year with some months sampled twice. Regions to the west are sampled only 3 times per year. Regions to the north are sampled 5-6 times per year.

The calanoid copepod *Neocalanus plumchrus* is a dominant component of the spring mesozooplankton in the subarctic North Pacific and Bering Sea. Because N. plumchrus normally has a single dominant annual cohort, its seasonal timing can be indexed from measurements of total population biomass or by following progressive changes in stage composition. The eastern North Pacific

(offshore BC region in Figures 43 and 44) is sampled by both transects, giving sufficient sampling resolution to determine the timing of the peak of *Neocalanus plumchrus*. Further information on these indices can be found in Batten and Mackas (2009).

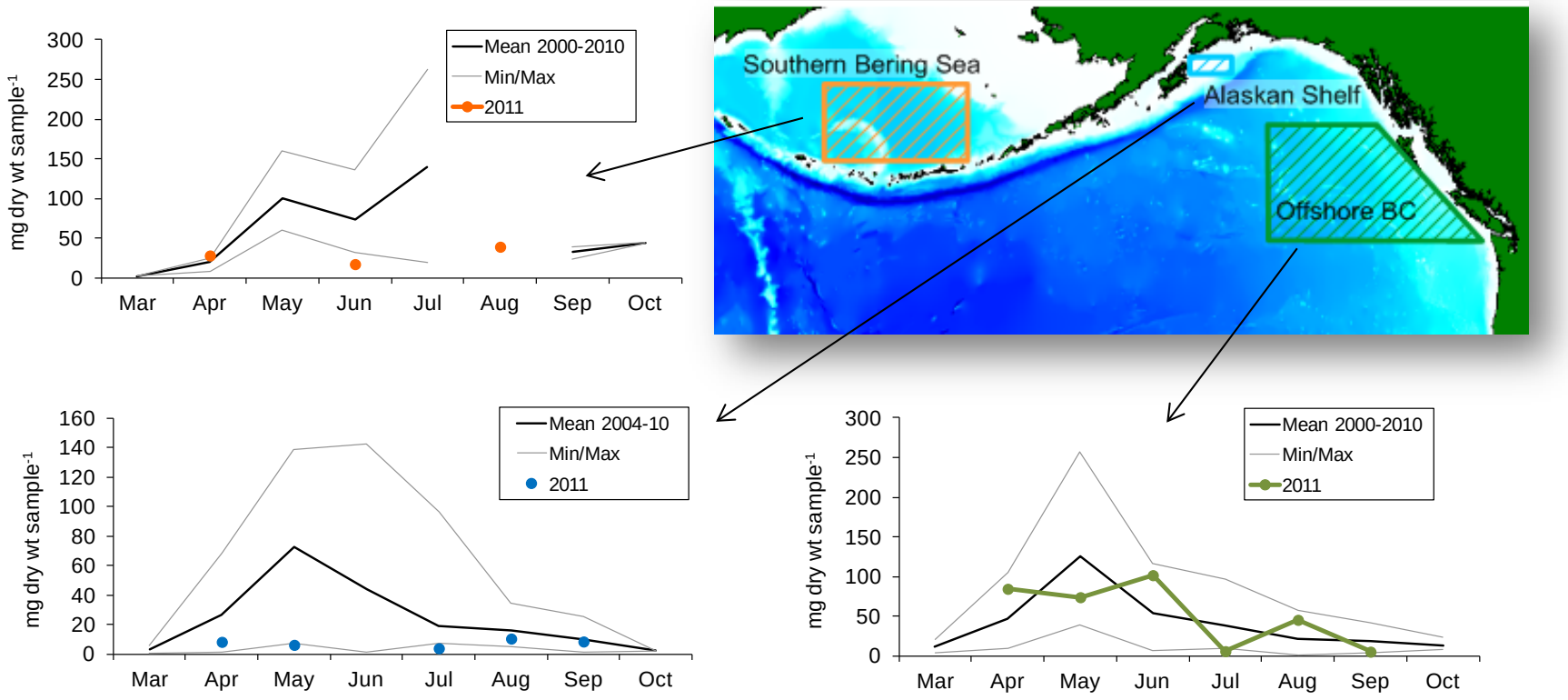

Figure 43: Mean (black lines), minimum and maximum (grey lines) monthly mesozooplankton biomass for the NE Pacific CPR sampling of the regions shown above right (2000 to 2010 except Alaskan Shelf regions where time series extends from 2004 to 2010), together with monthly data for 2011 overlaid as points.

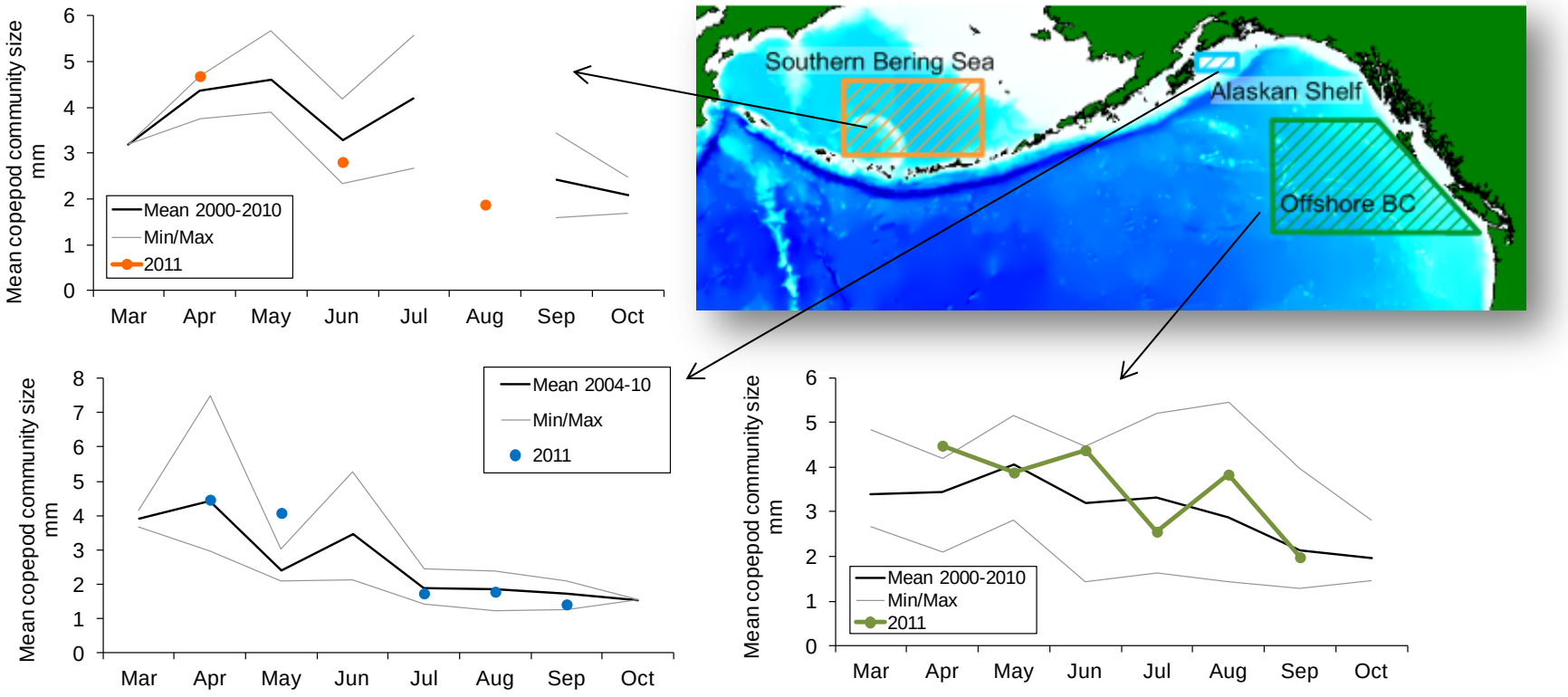

Figure 44: Mean (black lines), minimum and maximum (grey lines) copepod community size for the NE Pacific CPR sampling of the regions shown above right (2000 to 2010 except Alaskan Shelf regions where time series extends from 2004 to 2010), together with monthly data for 2011 overlaid as points.

Status and trends: Monthly mesozooplankton biomass estimates from three regions are shown in Figure 43, with 2011 data overlaid for comparison with previous years. Mesozooplankton biomass was apparently low in both the Alaskan shelf and southern Bering Sea regions in 2011 while the oceanic Northeast Pacific showed a late and extended biomass peak.

Time series of the day of the year when peak biomass is projected to have occurred and the length of the season (defined as the number of days between the 25th and 75th percentile of cumulative biomass) are shown in Figure 45. Note that the date could not be calculated for 2008 as sampling did not begin until May, when the copepodites were too advanced. In 2011, values were towards the middle of the range seen in the time series, slightly earlier and shorter than in 2010.

Mean monthly copepod community size for each region is shown in Figure 44 (for method of calculation see (Richardson et al., 2006)). All three regions have the largest copepods in the spring/summer when the larger subarctic species are dominant. Mean size declines into late summer and fall when smaller species become more abundant and the large species are in diapause at depth. Values from 2011 were similar to the long term mean for the southern Bering Sea and Alaskan shelf, suggesting that the low biomass was not the result of an absence of a particular group of copepods. The data for the northeast Pacific show that larger species were present later into summer than average, consistent with cool La Niña conditions delaying their development.

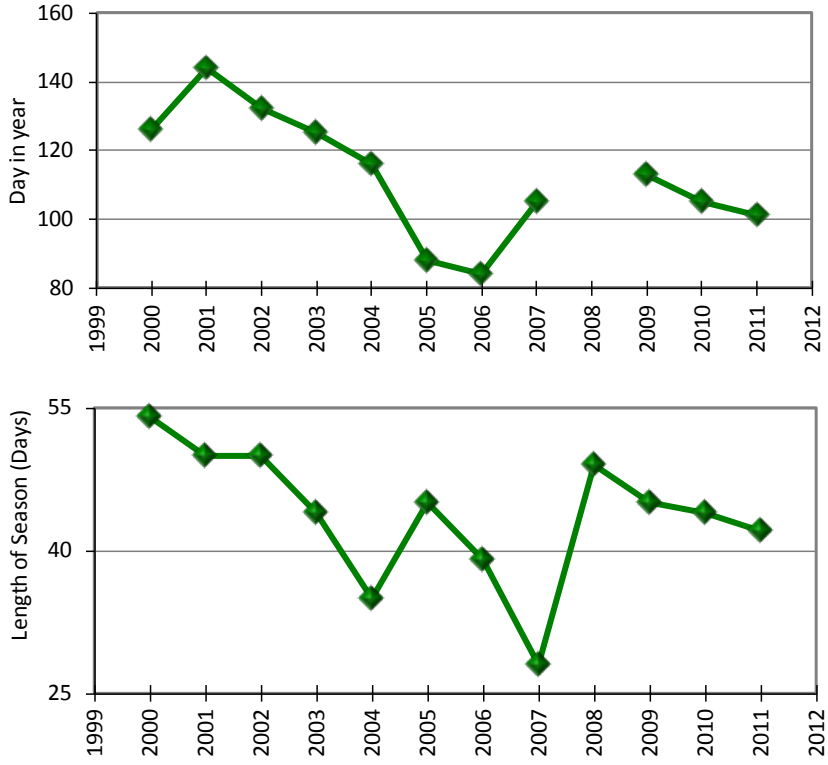

Figure 45: Day of the year when peak biomass of *Neocalanus plumchrus* occurred (based on stage composition, when 50% population was at copepodite stage 5), upper panel. Lower panel shows the length of the season calculated as the number of days between the 25th and 75th percentile of cumulative biomass.

Factors causing observed trends: Changes in ocean climate can affect each of these indicators. Previous studies have shown interdecadal and latitudinal variation in seasonal developmental timing, with peak biomass occurring earlier in years and places with warmer upper ocean temperatures Mackas et al. (1998); Batten et al. (2003); Mackas et al. (2007).

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

Jellyfish - Eastern Bering Sea

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Last updated: October 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

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

Contributed by Kristen Cieciel, Jeanette Gann, and Lisa Eisner, Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
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Last updated: August 2012

Description of index: Jellyfish sampling was incorporated aboard the BASIS (Bering Aleutian Salmon International Surveys) vessels beginning in 2004 and will continue through 2012. All jellyfish medusae caught in the surface trawl (top 18-20 m of the water column) are sorted by species and subsampled for bell diameter and wet weight. Six species are commonly caught with the surface trawl: *Aequorea* sp., *Chrysaora melanaster*, *Cyanea capillata*, *Aurelia labiata*, *Phacellocephora camtschatica*, and *Staurophora mertensi*. Biomass is calculated for each species and compared across species, and oceanographic domains on the Bering Sea shelf (Inner Domain <50m, Middle Domain 50m-100m, Outer Domain ≥100m) Yearly distributions throughout the sample grid for all species have been patchy. Despite uneven distributions throughout oceanographic domains, highest concentrations of all species were found to occur in the Middle Shelf Domain. Of the six species sampled, *Chrysaora melanaster* had the highest weight per unit effort (kg) for all years.

Status and trends: In 2011 total jellyfish biomass decreased by almost half compared to the previous year. However, for the first time since sampling started in 2004, the biomass was recorded higher in the north than in the south (Figure 46). During 2010, combined jellyfish species biomass nearly doubled compared to the previous highs of 2004 and 2005. Notable declines in jellyfish species compostion were observed for all taxa except *C. melanaster* starting in 2006 and continuing

through 2011 (Figure 47). The dominant species, *C. melanaster* continued to increase in 2010, nearly tripling its biomass compared to 2009. In 2008 our station grid was significantly reduced. However, comparisions with past years using the same survey area as 2008 indicate similar trends in species composition and distribution patterns. During 2006-2009, biomass of all other species remained low in comparison to 2004 and 2005, suggesting the trend for the region has shifted from multiple species to a single species dominant catch.

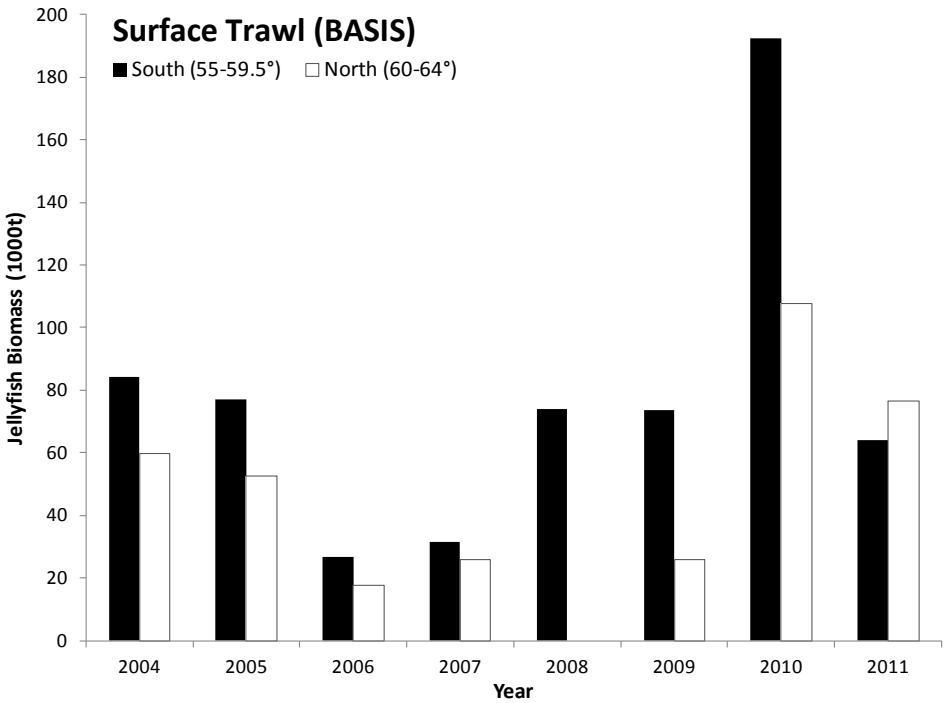

Figure 46: Total jellyfish biomass (1000 t) by year. Includes combined species caught in surface trawls in the Eastern Bering Sea during August-October. Biomass was calculated using average effort per survey area in km^2 by year.

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

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

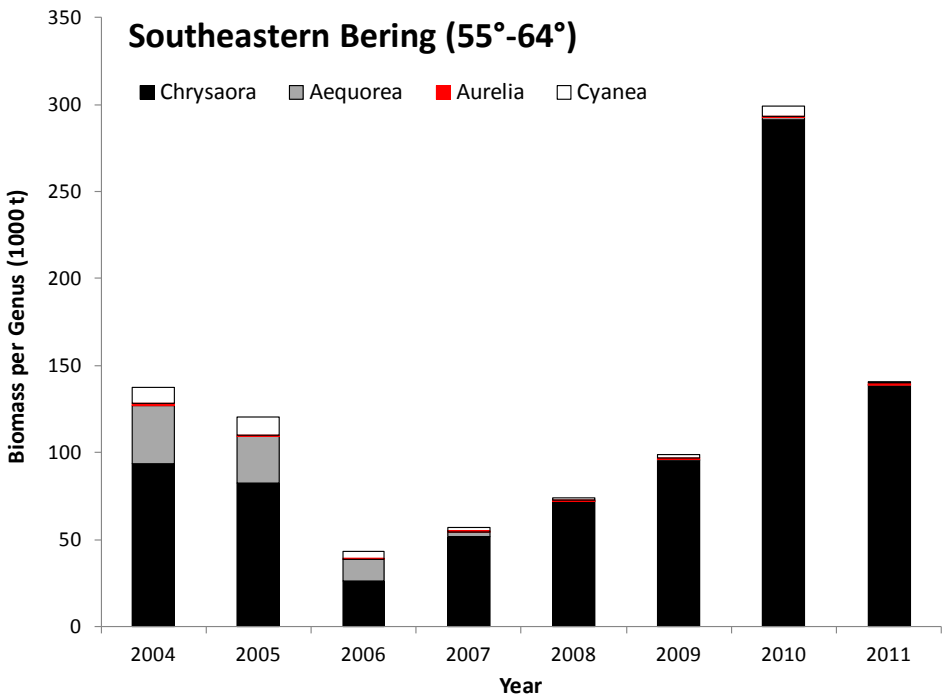

Figure 47: BASIS surface trawl Biomass (1000t) by genus for 2004-2011 in the Eastern Bering Sea during August -October. Biomass was calculated using average effort per survey area in km^2 by year.

Forage Fish

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

Contributed by Ron Heintz, Ed Farley, and Elizabeth Siddon, Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
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See the 2010 report at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Variations in juvenile salmon, age -0 pollock, and age-0 Pacific cod catch per unit effort and distributions during fall 2002-2007 in the eastern Bering Sea- BASIS

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

Forage Species - Eastern Bering Sea

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See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Forage Species - Gulf of Alaska

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Gulf of Alaska surveys are conducted in alternate odd years. For most recent data, see the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Gulf of Alaska Small Mesh Trawl Survey Trends

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Description of index: Smallmesh trawl surveys of the nearshore Gulf of Alaska have been conducted by the Alaska Fisheries Science Center and Alaska Department of Fish and Game using standard methods since 1972 (n = 13,223 hauls). The most recent survey occurred in September and October of 2011 (n = 135 hauls) in the bays around Kodiak Island, the Shelikof Strait and in Pavlof Bay on the south side of the Alaska Peninsula. The smallmesh survey results are presented as fish and invertebrate CPUEs (kilograms captured per kilometer towed ± SD).

The CPUE time series was used to calculate two indices. First, gulf-wide anomalies from the long-term mean CPUE of pink shrimp *Pandalus borealis*, juvenile pollock (≤ 20 cm) *Theragra chalcogramma*, eulachon *Thaleichthys pacificu*, and Pacific herring *Clupea pallasi* are reported. These species were selected because they are key prey items of many commercial species. The

timing, location, and gear used on the smallmesh survey provides a unique opportunity to collect information on these forage species.

The second index uses the increased spatial variance in the catch of Pacific cod and their prey in Pavlof Bay as a leading indicator of an approaching, abrupt community reorganization such as the well-documented community reorganization of 1976/77 (Litzow et al., 2008; Anderson and Piatt, 1999; Mueter and Norcross, 2000). Developing methods that would allow for the early detection of impending ecosystem transition could allow managers to take steps to help prevent ecosystem collapse (Peterson et al., 2003). The coefficient of variation of the log (cod:prey) CPUE ratio is used here as the measure of spatial variance following methods of Litzow et al. (2008). Prey species used include those that are vulnerable to top-down control by cod (capelin *Mallotus villosus*, pink shrimp, coonstripe shrimp *Pandalus hypsinotus*, humpy shrimp *P.goniurus*, and sidestripe shrimp *Pandalopsis dispar*). Sequential t tests for the analysis of regime shifts (STARS, available at: `www.beringclimate.noaa.gov/regimes/index.html`, Rodionov and Overland (2005)) was used to test for statistically significant shifts between alternate states.

Status and trends: Forage species catch rates remain at low levels, one to two orders of magnitude lower than peak values observed in the 1970s and early 1980s (Figure 48). Eulachon, which in recent years has had the highest catch rates of the time series, decreased in 2011 to a rate below the long-term average. Forage species catch rates are not uniform across the region, however. For example, both pink shrimp and juvenile pollock were captured in all bays surveyed but catch rates varied widely both between bays and within bays. The 2011 catch rate for pink shrimp in Pavlof Bay was 1.01 ± 2.60 kg km^{-1}, while in inner Marmot Bay it was 21.12 ± 34.70 kg km^{-1}. Juvenile pollock catch rates ranged from 7.37 ± 7.40 kg km^{-1} in Uyak Bay on the west side of Kodiak Island (one haul catching nearly 19 kg km^{-1} to <0.005 ± 0.008 kg km^{-1} in Ugak Bay on the east side of Kodiak.

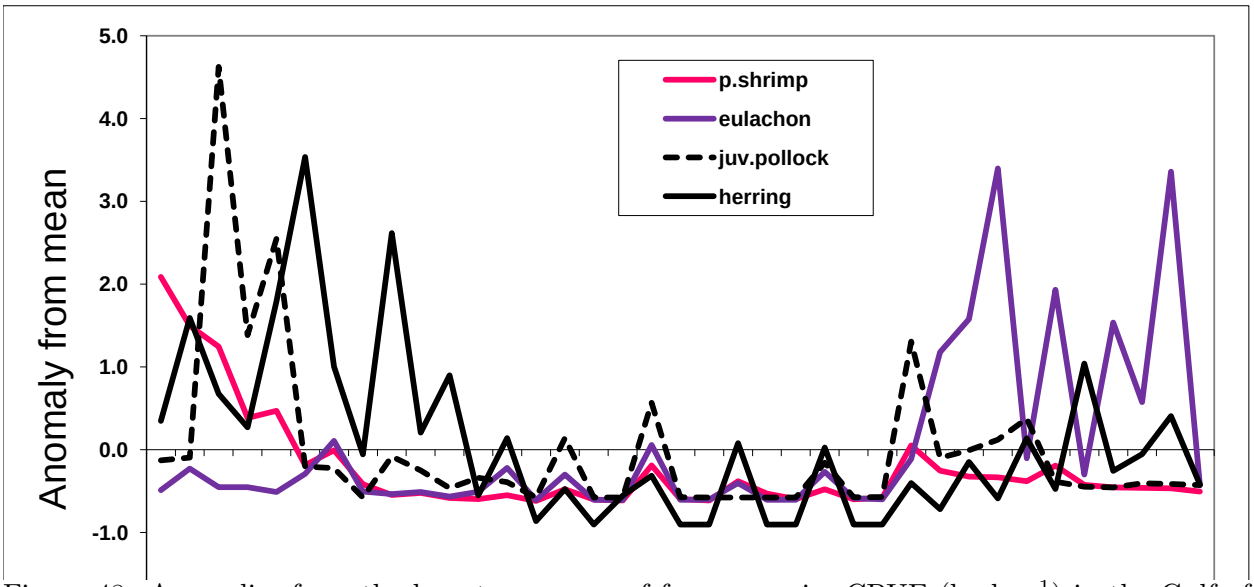

Figure 48: Anomalies from the long-term mean of forage species CPUE (kg km^{-1}) in the Gulf of Alaska, 1972-2011.

The STARS analysis of the cod:prey ratio in Pavlof Bay detected increased spatial variability surrounding the period of the community reorganization of 1976/77 (Figure 49) but did not detect the weaker shift in 1998/99 (Overland et al., 2008; Litzow, 2006). Qualitatively, however, these

shifts can be seen in the CPUE anomalies of the forage fish (Figure 48). An impending shift in the marine community was not indicated by the STARS analysis including the 2011 data.

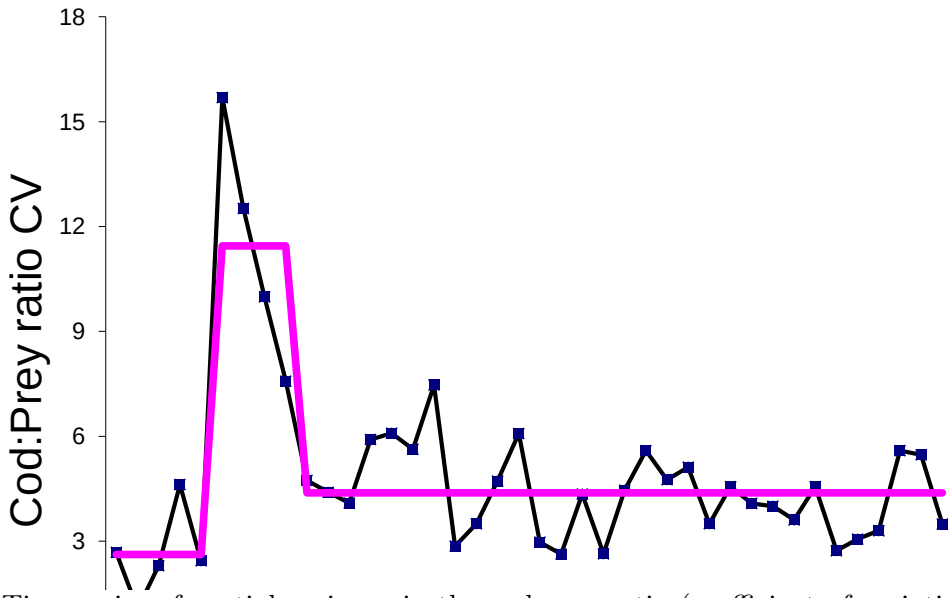

Figure 49: Time series of spatial variance in the cod:prey ratio (coefficient of variation in CPUE log + 10 ratio) in Pavlof Bay (line and squares) as adapted from Litzow et al. (2008). Heavy line indicates distinct states in the times series as defined by sequential t tests for analysis of regime shifts (STARS, $p = 0.03$, l = 5, H = 2).

Factors causing observed trends: Climate forcing on the marine community has often been implicated in explaining changes in community organizations. Large transitions are not, however, uniform within the community (Duffy-Anderson et al., 2005), as seen in recent eulachon abundance levels, and may involve different time lag periods for different species (Overland et al., 2008). Changes to the cod:prey ratio and input parameters to the STAR algorithm may be necessary to better capture phase transitions in the GOA that are weaker than the 1976/77 event.

Implications: While the community changes in the marine ecosystem caused by the environmental changes of 1976/1977 appeared strong and widespread across the GOA, the Pacific Decadal Oscillation has not recently had as a dramatic effect (Bond et al., 2003; Litzow, 2006; Mueter et al., 2007), limiting its value as a predictive tool for groundfish managers. Linkages between ocean climate and the marine ecosystem are still important (Di Lorenzo et al., 2008) but improving our understanding of the changing ocean environment requires continued careful monitoring of the physical and biological systems.

Forage Species - Aleutian Islands

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

Herring

Prince William Sound Pacific herring

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

Southeastern Alaska Herring

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Togiak Herring Population Trends

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Last updated: October 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Salmon

Historical and Current Alaska Salmon Trends

Contributed by Andy Whitehouse[1] and Todd Tenbrink[2]
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Last updated: August 2012

Description of index: This contribution provides historic and current catch information for salmon of the Bering Sea and Gulf of Alaska and takes a closer look at two stocks that could be informative from an ecosystem perspective, Bristol Bay sockeye salmon and Prince William Sound hatchery pink salmon. This contribution summarizes available information that is included in current Alaska Department of Fish and Game (ADF&G) agency reports (e.g., Eggers and Carroll (2012)).

Pacific salmon in Alaska are managed in four regions based on freshwater drainage basins, Southeast, Central (encompassing Prince William Sound, Cook Inlet, and Bristol Bay), Arctic-Yukon-Kuskokwim, and Westward (Kodiak, Chignik, and Alaska peninsula (`http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmonareas`). ADFG prepares harvest projections for all areas rather than conducting run size forecasts for each salmon run. There are five Pacific salmon species with directed fisheries in Alaska; they are sockeye salmon (*Oncorhynchus nerka*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), Chinook salmon (*O. tshawytscha*), and coho salmon (*O. kisutch*).

Status and trends: Catches from directed fisheries on the five salmon species have generally fluctuated over the last 35-40 years (Figure 50). According to ADF&G, total salmon commercial harvests from 2011 totaled 177.1 million fish, approximately 26.4 million less than the preseason forecast of 203.5 million. ADF&G is forecasting a decrease in the total commercial catch to 132.1 million fish in 2012, due to an expected decrease in the number of pink salmon. Projections for 2013 will not be available until February 2013.

Bering Sea. Chinook salmon production for many stocks in the Yukon River has been declining in recent years. The Chinook harvest for 2011 in the Arctic-Yukon-Kuskokwim region was considerably below average and no commercial periods targeting Chinook salmon were allowed during the 2011 summer season in the Yukon Area. In Bristol Bay, the 2011 Chinook harvest was below average in every district. In the Kuskokwim Area, Chinook salmon abundance was poor and only 4 of 10 escapement goals were met. The coho catch in Bristol Bay was 85% below the recent 20 year average, with the majority of the catch in the Togiak District. Chum salmon catches in Bristol Bay, depending on the district, have been above or below the 20 year average. In the past, chum salmon in the Yukon River have been classified as stocks of concern (Eggers, 2003). The preliminary estimate of the 2011 fall run of Yukon River chum salmon is estimated to be above the upper end of the preseason forecast range (605,000-870,000 fish), and the fall chum salmon harvest (238,979 fish) was the highest since 1995.

Recruitment for most Bristol Bay sockeye salmon stocks was moderate to strong in the 1980s and into the mid-1990s. Beginning with the 1973 brood year (>1979 return year) of Bristol Bay sockeye salmon, the number of returning adults produced from each spawner showed a dramatic increase across most stocks (Fair, 2003). Poor returns in 1996-98, however, suggested a return to a level of productivity similar to the pre-1978 period (Fair, 2003)). Fish from the 1996-98 return years reared in the ocean when temperatures were above average, whereas, cooler than average ocean temperatures characterized the pre-1978 period. Bay-wide forecasts have been fairly accurate in recent years, although forecasts to individual rivers have been less accurate. Historically, total runs

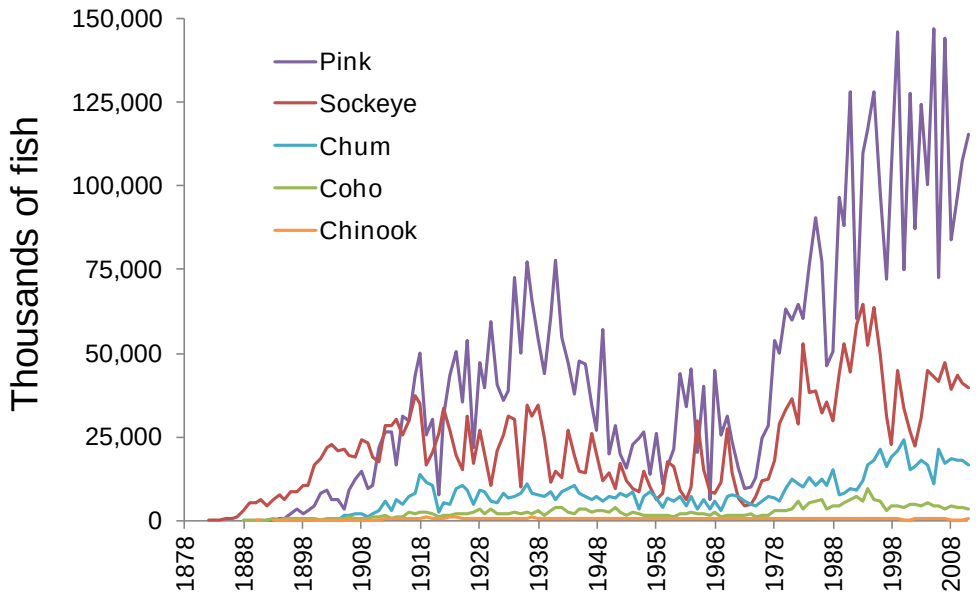

Figure 50: Alaskan historical commercial salmon catches and ex-vessel values. 2011 values are preliminary. (Source: ADF&G, `http://www.adfg.alaska.gov`. ADF&G not responsible for the reproduction of data.)

to Bristol Bay have been highly variable, but in recent years, 2004-2010, sockeye salmon runs have been well above the long term mean (Figure 51). The 2011 run of 30.3 million fish was close to the long-term average of 30.6 million, but 21% below the forecasted run size. The run size forecasted for 2012 Bristol Bay sockeye is 32.3 million fish.

Gulf of Alaska. In southeast Alaska and the Yakutat region, 2011 harvests totaled 73.6 million fish, which was 35% above the 54.4 million average harvest over the most recent ten years and well above the long-term average since 1962 of 38.6 million fish. In the Central region, the Prince William Sound fishing area harvests the majority of the total catch. In 2011, pink salmon comprised 85% of the Prince William Sound commercial salmon harvest. The purse seine commercial common property fishery (CPF) harvest of 26.9 million pink salmon was the tenth highest since 1971. Historically, pink salmon catches increased in the late 1970s to the mid-1990s and have generally remained high in all regions in the last decade. Commercial Chinook salmon fisheries occur in Copper River and the Southeast Alaska troll fishery. Catches in this fishery declined in the late 1990s. The 2011 catch of 346,000 Chinook was just below the recent ten-year harvest average of 349,000. Coho fisheries in Central and Western Alaska are not fully developed, but the harvest of 2.3 million in 2011 was just above the recent 10 year average of 2.1 million. Directed chum salmon fisheries occur on hatchery runs in Prince William Sound and Southeast Alaska. The 2011 harvest of 10.7 million chum salmon in Southeast Alaska and Yakutat regions was above the long-term average of 5.4 million fish (1962-2009) and equivalent to the most recent 10 year average of 9.6 million fish.

Marine survival of Prince William Sound hatchery pink salmon does not appear to have shifted after the 1988/89 or the 1998/99 climate regime shifts. Hatchery pink salmon marine survival in

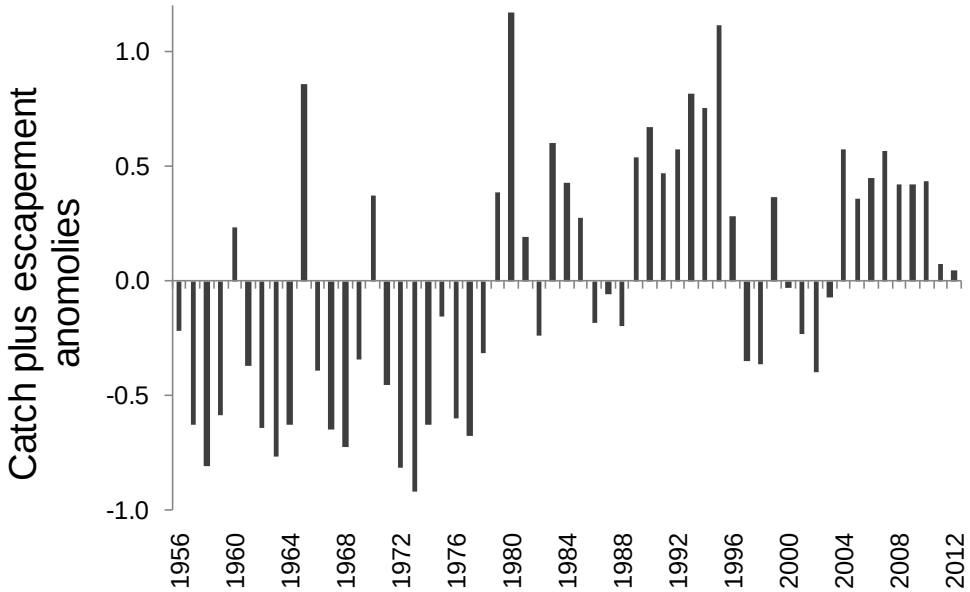

Figure 51: Historical catch plus escapement anomalies of Bristol Bay sockeye salmon, 1956-2011. Data provided by Charles Brazil (ADF&G). Note: the value for 2012 is preliminary and subject to revision.

2007 (2005 brood year) was the second highest recorded during the 1977-2009 time period. Marine survival in 2010 (2008 brood year) is at an all-time high since 1977 (Figure 52).

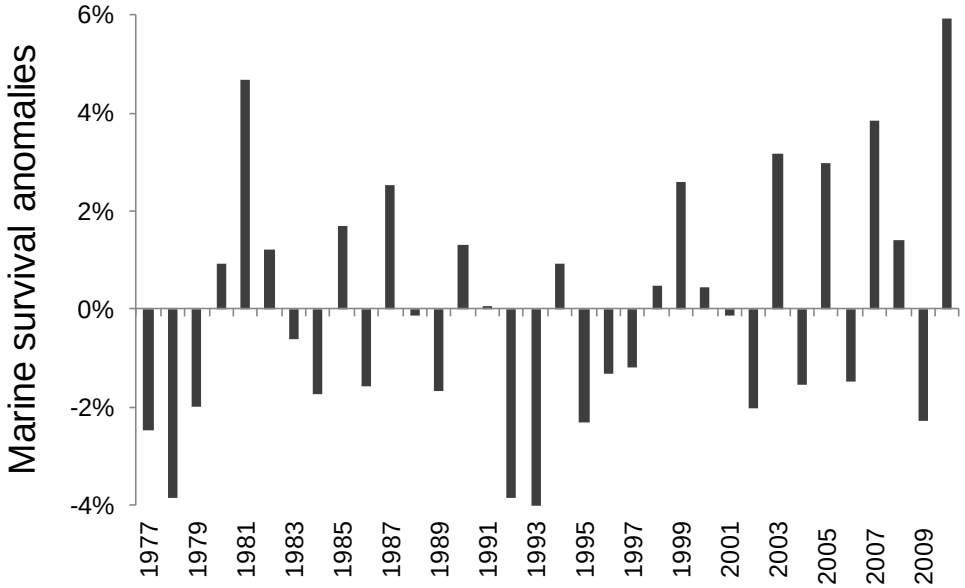

Figure 52: Marine survival of Prince William Sound hatchery pink salmon by year of return (brood year +2 years). Data reproduced from Botz et al. (2012).

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

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

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

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

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

Forecasting Pink Salmon Harvest in Southeast Alaska

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Last updated: August 2012

Description of index: An objective of the Alaska Fisheries Science Center (AFSC), Auke Bay Laboratories (ABL) Southeast Alaska Coastal Monitoring (SECM) project `http://www.afsc.noaa.gov/abl/msi/msi_secm.htm` is to understand the effects of climate and ocean on year class strength of salmon and ecologically-related species in Southeast Alaska (SEAK). Since 1997, the SECM project has collected a time series of data using surface trawls and oceanographic instruments in coastal SEAK which has allowed an annual index of ecosystem metrics to be constructed and used for pre-season pink salmon (*Oncorhynchus gorbuscha*) forecast models. Pink salmon are an ecologically and economically important species in SEAK ($ 92.5 M in 2011) that do not lend themselves to traditional sibling or stock assessment models because of their brief ocean life history. Consequently, adult returns are notoriously difficult to forecast; their 2-year life history with one ocean winter precludes the use of younger returning age classes to predict cohort abundance. Thus, an SECM pink salmon pre-season forecast model was developed to aid fishery managers and to help better understand mechanisms in play in the Gulf of Alaska ecosystem.

Status and trends: Since 1960 in SEAK, pink salmon year-class success has varied widely, with harvests ranging from 3 to 78 million fish annually. This variability may result from dynamic ocean conditions that affect juveniles. Therefore, the SECM approach has been to sample 4-65 km offshore along coastal localities in the vicinity of Icy Strait on monthly research surveys. Oceanographic sampling is conducted in May, June, July, and August, while surface trawling for epipelagic fish species is conducted in the latter three months. The SECM data has also been used to describe epipelagic fish assemblages in the Alaska Coastal Current compared to the California Current, to define Essential Fish Habitat for Pacific salmon in the U.S. Exclusive Economic Zone of Alaska, and to document life history patterns of threatened and endangered salmon stocks off SEAK. For the pink salmon forecasting, SECM data is used with other regional and basin-scale data sources to construct an ecosystem matrix of input and response variables.

Researchers in the SECM project have provided forecasting information to stakeholders of the pink salmon resource of SEAK since 2004, enabling them to anticipate the harvest with more certainty than previous forecasting methods have allowed (`http://www.afsc.noaa.gov/abl/msi/msi_sae_psf.htm`). In 7 of the past 8 years, these forecast estimates have deviated from the actual harvests by an average of only 7% (Figure 53). Data from juvenile pink salmon catches (CPUE) are also shared with the Alaska Department of Fish and Game (ADFG) to help refine their SEAK pink salmon harvest forecast that is developed by a different method.

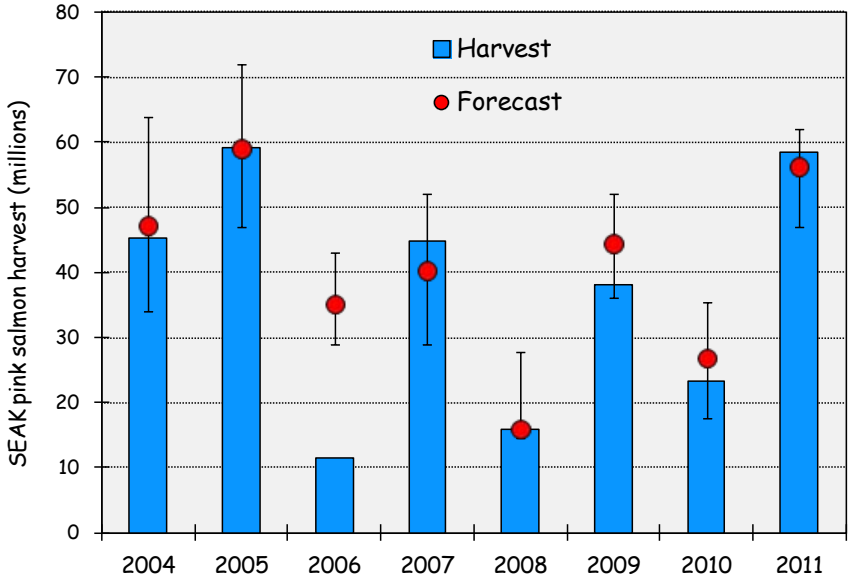

Figure 53: Previous Southeast Alaska (SEAK) pink salmon forecast model predictions (with 80% confidence intervals) and harvests.

Factors influencing observed trends: Selected ecosystem metrics associated with SEAK adult pink harvest over the 15-year SECM time series are shown in Figure 54 below. Subsets in the value ranges for each metric are color-coded, with the 5 highest in green, the 5 lowest in red, and the 5 intermediate values in grey. Metrics to the right of the response variable column for SEAK pink harvest are ordered by declining significance (increasing "P-value" = declining significance); the corresponding correlation coefficient "r" and "P-value" are shown below each metric. Note that in addition to CPUE, 3 other variables are significantly correlated with harvest (peak migration

month, NPI, and %pink in catch) and suggest a low to intermediate pink harvest in 2012. Although not significantly correlated with SEAK harvest, the low SEAK pink escapement index for the adult parent year and the low Auke Creek fry production for the juvenile year corroborate the low juvenile CPUE from trawl catches. May 20-m temp was not significantly correlated with harvest, but has served as an important secondary parameter to explain the error in the CPUE and harvest regression model.

"BEST" values (upper 3rd)			"OK" values (middle 3rd)							"WORST" values (lower 3rd)		
Brood year (BY) +2			BY + 1					BY		BY+1		BY+1
Adult pink salmon return year	SEAK pink salmon harvest (response variable)		Ocean entry year	Juvenile peak pink $CPUE_{June-July}$	Peak seawrd migration month	N Pacific Index (June, July, Aug)	% pink in juvenile salmon catch		ADF&G adult pink escapment index SEAK		Auke Creek fry outmigration (1,000s) Lat 58 ° N		Upper water column (1-20 m) Icy Strait temperatures -May
Data sources:		--->		NOAA	NOAA	CGD	NOAA		ADFG		NOAA		NOAA
1998	42.5		1997	2.5	July	15.6	18%		18.1		31.1		7.3
1999	77.8		1998	5.6	June	18.1	69%		14.8		60.8		7.8
2000	20.2		1999	1.6	July	15.8	22%		14.3		53.5		6.5
2001	67.0		2000	3.7	July	17.0	29%		27.3		132.1		6.6
2002	45.3		2001	2.9	July	16.8	39%		10.8		61.5		7.1
2003	52.5		2002	2.8	July	15.6	48%		18.6		150.1		6.4
2004	45.3		2003	3.1	July	16.1	42%		16.6		95.1		7.4
2005	59.1		2004	3.9	June	15.1	40%		20.0		169.6		7.6
2006	11.6		2005	2.0	Aug	15.5	31%		15.7		87.9		8.3
2007	44.8		2006	2.6	June	17.0	44%		19.9		65.9		6.7
2008	15.9		2007	1.2	Aug	15.7	21%		10.2		81.9		7.0
2009	38.0		2008	2.5	Aug	16.1	59%		17.6		117.6		6.1
2010	23.4		2009	2.1	Aug	15.1	24%		9.5		34.8		7.3
2011	58.5		2010	3.7	June	17.6	59%		12.7		121.6		8.3
2012	???		2011	1.3	Aug	15.7	36%		11.2		30.9		6.7
Pearson correlation "*r*" =				0.92	-0.75	0.64	0.63		0.48		0.40		0.08
P-value (* = significant @ <.05) =				0.00*	0.00*	0.01*	0.02*		0.08		0.16		0.79

Figure 54: Matrix of ecosystem metrics considered for pink salmon forecasting.

Implications: Additional evidence from SECM research and other indicators suggested a low pink harvest for SEAK in 2012. The strongest sign was that the 2011 peak juvenile pink CPUE was the second lowest on record. Over the 15-year SECM time series, both the ADFG escapement index for the pink salmon parent year (2010) in SEAK and subsequent wild pink salmon fry production from Auke Creek in 2011 were the third lowest values. Also, ocean catch rates of juvenile pink salmon from two trawl surveys in the eastern Gulf of Alaska (GOA) were lower in 2011 than in 2010 (GOA Integrated Research Project and SECM sampling along the Icy Point transect).

Table 6: The two best SECM pink salmon forecast models for the 2012 SEAK harvest.

2012 SECM pink salmon forecast models	Adj. R^2	AIC_c	P	Prediction for 2012
(1-parameter) Peak CPUE	83%	99.3	<0.001	17.1 M (13-24)
(2-parameter) Peak CPUE+May20m temp	89%	95.9	<0.001	18.8 M (13-25)

Given the ecosystem conditions and SECM metrics sampled in 2011, the two best SECM forecast models for the 2012 SEAK pink salmon harvest are shown below in Table 6. Each forecast model value has an 80% bootstrap confidence interval shown in parentheses. The 2-parameter model was the best fit predictor for the relationship of the 15-year time series of SECM data parameters with subsequent SEAK pink salmon harvests from 1998 to 2011, based on the R^2 and AIC_c.

Groundfish

Gulf of Alaska Ichthyoplankton Abundance Indices 1981-2009s

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Description of index: The Alaska Fisheries Science Center's (AFSC) Ichthyoplankton Database (IchBASE) includes data from collections in the Gulf of Alaska (GOA) from 1972 to the present and with annual sampling since 1981. Since 1985 these collections have been part of AFSC's recruitment processes research under the Ecosystems and Fisheries Oceanography Coordinated Investigations Program (EcoFOCI). The primary sampling gear used for these collections is a 60 cm bongo sampler fitted with 333 or 505 μm mesh nets and oblique tows are carried out mostly from 100 m depth to the surface or from 10 m off bottom in shallower water (Matarese et al., 2003)(Ichthyoplankton Information System `http://access.afsc.noaa.gov/ichthyo/index.cfm`). Historical distribution of sampling effort extends from the coastal area to the east of Prince William Sound southwestwards along the Alaska Peninsula to Umnak Island, covering coastal, shelf and adjacent deep water but has been most intense in the vicinity of Shelikof Strait and Sea Valley during late spring, May 18-June 6 (Figure 55). From this area and time, a subset of three decades of data has been developed into a time-series of ichthyoplankton species abundance (Doyle et al., 2009).

Historical trends in late spring abundance are presented for the most abundant larval taxa in the GOA, representing commercially and ecologically important species (Figure 56). The time-series extends from 1981 through 2009 with no data for 1984 and 1986. Abundance values are normalized over the time-series. Trends in abundance of these species (1981-2003) have been previously explored and investigated in relation to time-series of atmospheric and oceanographic variables on both the ocean basin and local scales (Doyle et al., 2009).

Status and trends: Coherent patterns and synchronicity in trends were observed among groups of

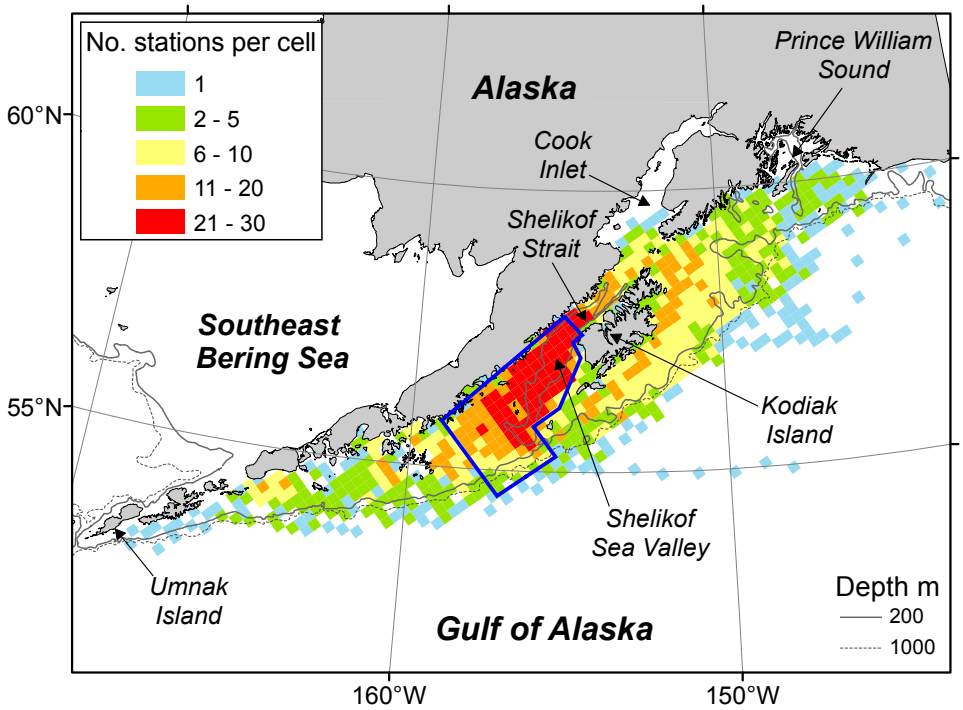

Figure 55: Distribution of ichthyoplankton sampling in the Gulf of Alaska by NOAAs Alaska Fisheries Science Center from 1972 through 2009 using a 60 cm frame bongo net. Sampling effort is illustrated by the total number of stations sampled in 20 km^2 grid cells over these years. A late spring time-series of mean abundance of ichthyoplankton species has been developed for the years 1981-2009, from collections in the polygonal area outlined in blue where sampling has been most consistent during mid-May through early June (Doyle et al., 2009).

species, and with the extension of the time-series through 2009, these similarities and synchronicities are maintained (**?**). For instance, Pacific cod, walleye pollock, and northern rock sole display a high degree of synchrony in abundance with periodic years of high abundance primarily during the 1990s and after 2005. Northern lampfish, arrowtooth flounder, and Pacific halibut show a pattern of enhanced abundance during the 1990s and 2004-2007 relative to the 1980s, 2000-03, 2008 and 2009. Interannual patterns for rockfish (*Sebastes* spp.), southern rock sole, and starry flounder are characterized by low to moderate abundance through most of the 1980s to mid-1990s, followed by some dramatic swings in abundance including occasional high anomalies in the second half of the time-series. Trends for these and other species are described further and analyzed statistically with non-metric multidimensional scaling (NMDS) ordination in Doyle et al. (2009) and **?**. The annual sampling for the GOA ichthyoplankton time-series ends in 2011 with plans for biennial sampling from 2013 onwards due to decreases in funding and ship time.

Factors causing observed trends: Synchronies and similarities in larval abundance trends through 2003, and in GAM model-generated links to time-series of environmental variables, reflect early life history variation among species (Doyle et al., 2009). Similarities in response to environmental forcing were apparent among species that display similarities in patterns of early life

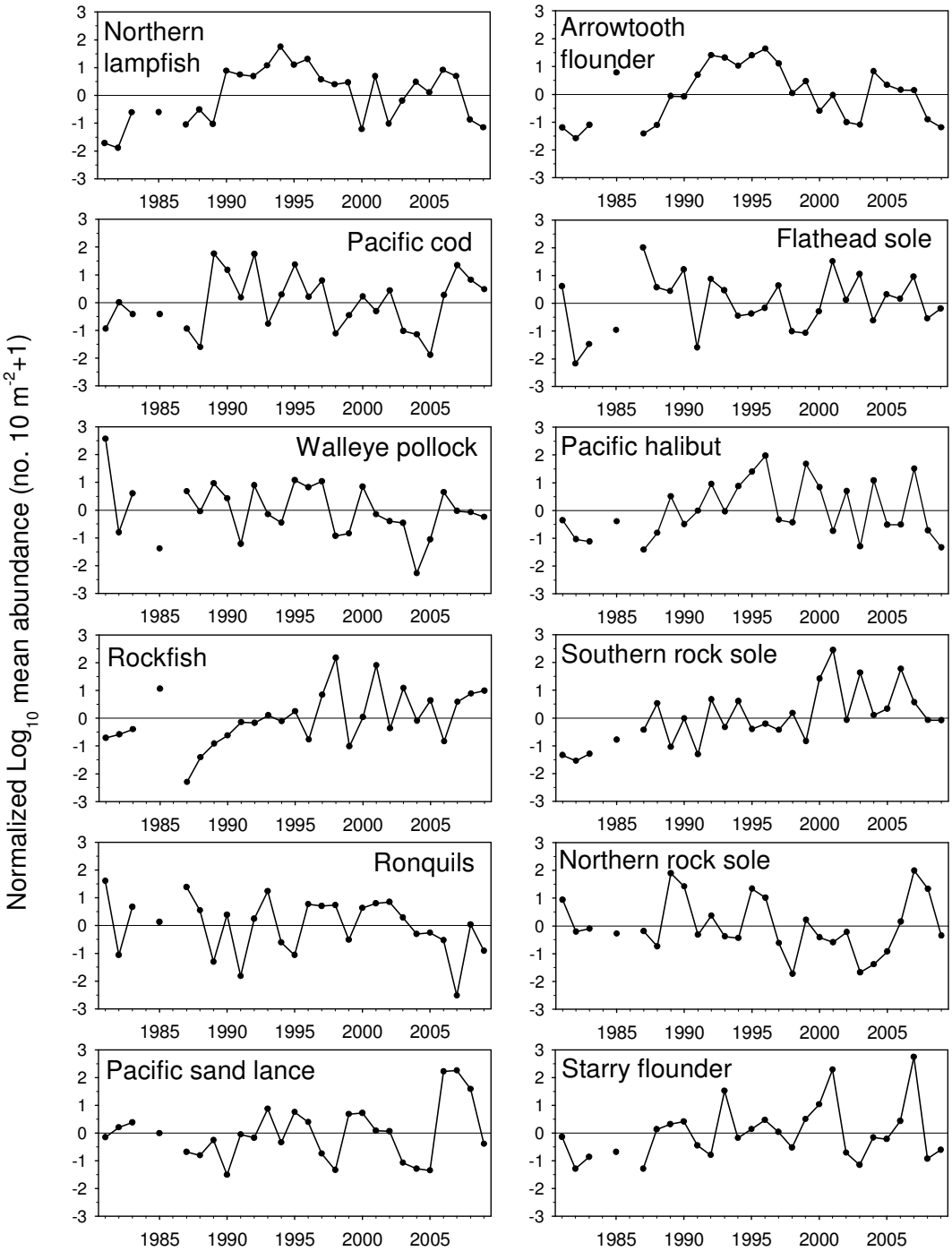

Figure 56: Interannual variation in late spring larval fish abundance for the most abundant species in the Gulf of Alaska. For each year, the larval abundance index is expressed as the log10 of mean abundance (no. 10 m^{-2}+1) standardized by the time-series mean and standard deviation.

history exposure to the environment. For instance, the deepwater spawners, northern lampfish, arrowtooth flounder, and Pacific halibut, were most abundant in the study area during the 1990s, in association with enhanced wind-driven onshore and alongshore transport. Years of high abundance for the late winter to early spring shelf spawners Pacific cod, walleye pollock, and northern rock sole were associated with cooler winters and enhanced alongshore winds during spring. High larval abundance for spring-summer spawning rockfish species and southern rock sole seemed to be favored by warmer spring temperatures later in the time-series. Further evidence of environmental exposure-response connections among GOA species is provided by a recent study that incorporates multiple early life history characteristics into a comparative analysis of early ontogeny exposure patterns (**?**). Species groups that emerged from this analysis were reflected in the NMDS ordination of the 1981-2009 larval abundance time-series. With the current extension of the ichthyoplankton time-series through 2011, and associated environmental variables, GAMs will be re-run as in Doyle et al. (2009) to investigate for consistency and variability in the established relationships between species (and groups of species) abundance and aspects of the GOA environment. For commercial populations, species-environment relationships will also be investigated using time-series of recruitment metrics. These new analyses will further illuminate mechanistic linkages and enhance the predictive potential with respect to species early life history response to varying environmental conditions. Syntheses of these results will be presented in future Ecosystem Considerations reports.

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

Trends in Groundfish Biomass and Recruits per Spawning Biomass

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Last updated: October 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Bering Sea Groundfish Condition

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Last updated: October 2008

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

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Last updated: August 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Pre- and post-winter temperature change index and the recruitment of Bering Sea pollock

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Last updated: August 2012

Description of index: The temperature change (TC) index is a composite index for the pre- and post-winter thermal conditions experienced by pollock (*Theragra chalcogramma*) from age-0 to age-1 in the eastern Bering Sea (Martinson et al., 2012). The TC index (year t) is calculated as the difference in the average monthly sea surface temperature in June (t) and August (t-1) (Figure 57) in an area of the southern region of the eastern Bering Sea (56.2°N to 58.1°N latitude by 166.9°W

Table 7: Pearson's correlation coefficient relating the temperature change index (t+x) to subsequent estimated year class strength of pollock (Age-x+1). Bold values are statistically significant ($p < 0.05$).

	Correlations					
TC Index	t	t+1	t+2	t+3	t+4	t+5
Pollock	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6
1964-2011	0.415	0.407	0.385	0.343	0.289	0.281
1995-2011	0.505	0.509	0.611	0.659	0.616	0.533

to 161.2°W longitude). Less negative values represent a cool late summer during the age-0 phase followed by a warm spring during the age-1 phase for pollock.

Status and trends: The 2012 TC index value -5.56 is based on a cooler than average late summer in 2011 (8.65°C) followed by the coldest June temperature (3.09°C) recorded since 1948 (Figure 57). The TC index is positively correlated with subsequent recruitment to age-1 through age-6 based on abundance estimates from (Ianelli et al., 2011) (Figure 58). This relationship has improved over time (Table 7).

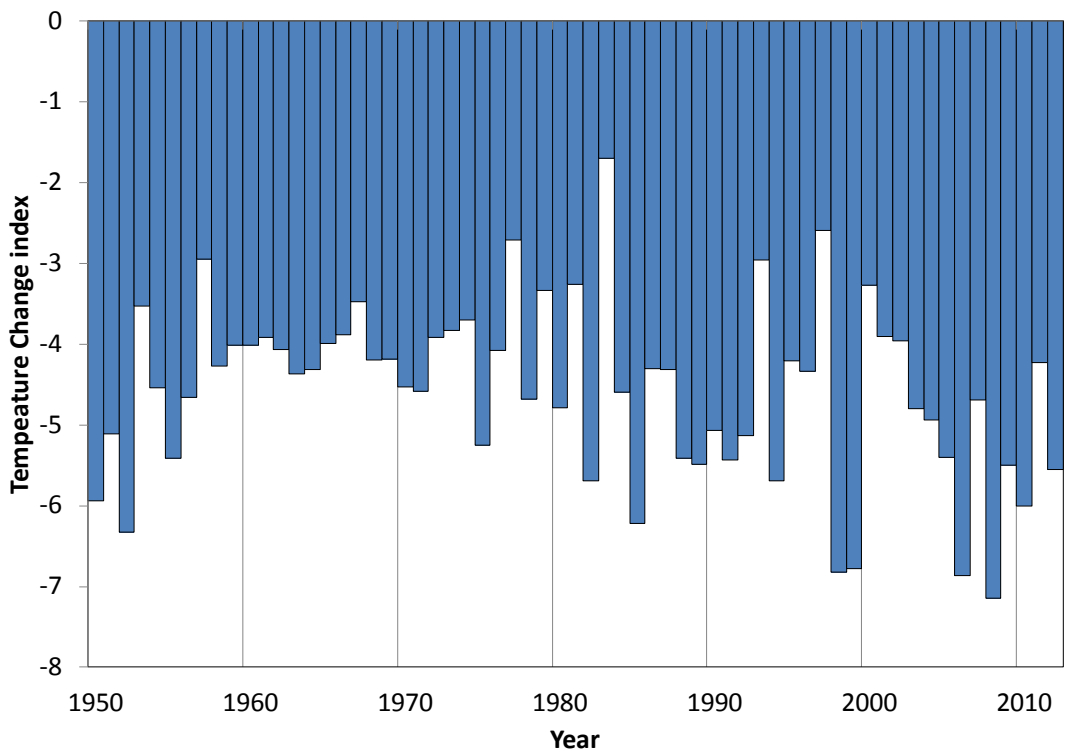

Figure 57: The Temperature Change index value from 1950-2012.

Factors causing observed trends: The age-0 pollock are more energy-rich in a year with a cooler late summer (Heintz, personal communication). Warmer spring temperatures lead to an earlier ice retreat, a later oceanic and pelagic phytoplankton bloom, and more food in the pelagic waters at an optimal time for use by pelagic species (Hunt et al., 2002, 2011; Coyle et al., 2011).

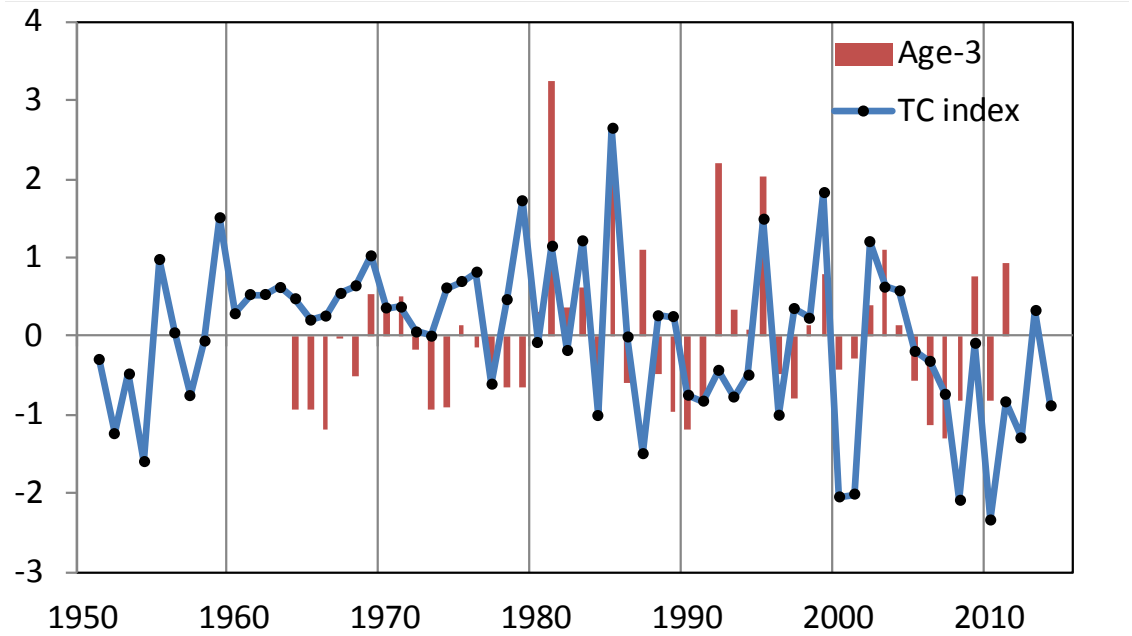

Figure 58: Normalized times series values of the temperature change index (t-2) and the estimated abundance of age-3 walleye pollock in the eastern Bering Sea (t).

These conditions are assumed more favorable for the overwintering survival of pollock from age-0 to age-1.

Implications: In 2010, the TC index value of -6.00 was below the long term average of -4.58, therefore we expect below average numbers of pollock to survive to age-3 in 2012. In the future, the TC values in 2011 (TC=-4.23) and 2012 (TC=-5.56) indicate above average abundances of age-3 pollock in 2013 and below average abundances of age-3 pollock in 2014.

Benthic Communities and Non-target Fish Species

Spatial variability of catches in Bering Sea and Gulf of Alaska crab fisheries

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Last updated: January 2012

Description of index: Ecosystem models predict that key system parameters should exhibit increasing variability as resilience declines and a shift between alternate stable states approaches (**?**). Tracking system variability has received great attention as a possible tool for providing early warning of population collapse and ecosystem reorganization, although this technique has received

little empirical evaluation to date (**?**). However, historical collapses in Alaskan crustacean fisheries were preceded by rising spatial variability in catches (Litzow et al. in prep.), providing empirical evidence that variance tracking may be a useful tool for detecting impending collapses in crustacean fisheries (Figure 59). In this contribution, we calculate contemporary trends in the spatial variability of catches (among ADF&G statistical areas) to make inferences about the resilience of five commercially exploited crab populations. Fisheries analyzed included Bristol Bay red king crab, Eastern Bering Sea Tanner and snow crab, and Kodiak and South Alaska Peninsula Tanner crab. The measure of variability that we use is the standard deviation of log-transformed catch data. Our analysis only includes years during which these fisheries were managed under limited entry or IFQs, as the transition from derby-style fisheries to limited entry/IFQs produced obvious changes in fleet behavior and catch statistics.

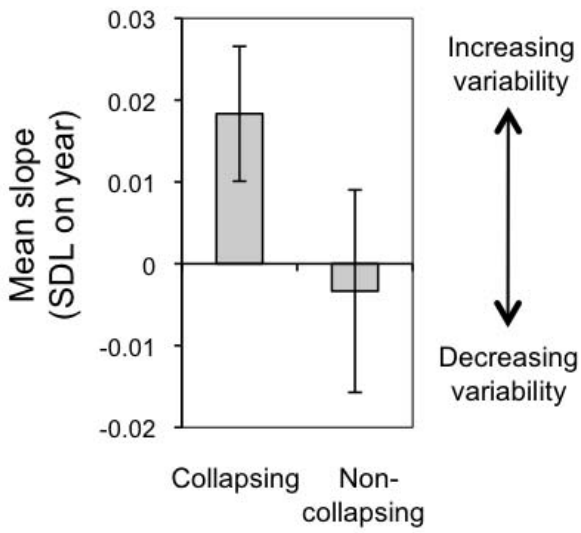

Figure 59: Trends in variability (SDL, standard deviation of log-transformed catch data) for historical crustacean catch data from the Bering Sea and Gulf of Alaska during the 1960s-2000s. Collapsing fisheries (n = 12) showed positive average slopes (i.e., increasing variability) prior to collapse, while non-collapsing fisheries (n = 2) did not show increasing variability. Differences in trend were statistically significant between the two groups (one-tailed P = 0.02). Error bars = 95% CI, figure redrawn from Litzow et al. (in prep.).

Status and trends: Only one of the five fisheries (Kodiak Tanner crab) showed a statistically significant increase in variability (one-tailed P = 0.03). Other fisheries showed either stable (EBS Tanner and snow crab) or declining (Bristol Bay red king crab and South Peninsula Tanner crab) variability (Figure 60).

Factors causing observed trends: The significant increase in catch SDL for the Kodiak Tanner crab fishery was largely driven by elevated variability in the 2011 season (Figure 60). The fishery expanded in this year: the GHL roughly doubled (1,490,000 pounds in 2011 compared to 700,000 pounds in 2010), and four sections of the Kodiak District were open to fishing compared with three sections in 2010 (**??**). As a result of this expansion in the fishery, catches were reported

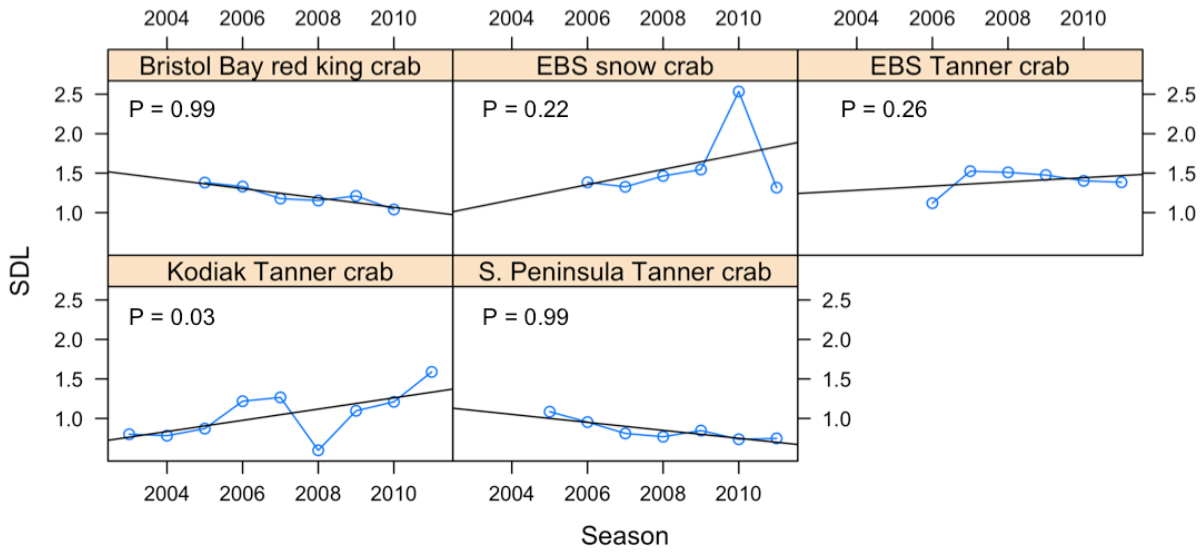

Figure 60: Current trends in spatial variability of catches for five crab fisheries in the Bering Sea and Gulf of Alaska. Fishing seasons are plotted to the calendar year including December for Bristol Bay red king crab, and to the year including January for all others. Black lines are best-fit linear trends, and P values are for one-tailed tests for increasing trends in SDL (standard deviation of log-transformed catch data).

from 21 statistical areas, compared with 15 in 2010. Four of these statistical areas produced catches below 20 pounds, and a fifth produced only 320 pounds, and these very low totals drove up variability (average catch among statistical areas was approximately 73,000 pounds). So while rising variability may generally signal impending population collapse, we conclude in this case that a more parsimonious explanation is the addition of low-catch statistical areas through expansion of the fishery. Conversely, persistent increases in variability in coming years would be more likely to represent a decline in resilience of Kodiak Tanner crab populations.

Implications: Although the notion of rising variability prior to population collapses has a strong theoretical background, the use of "variance tracking" in a management context is in its infancy. However, patterns of rising variability did apparently distinguish collapsing from non-collapsing Alaskan crustacean fisheries in the past (Figure 59), so there is specific support for using changes in variability to monitor the status of crab stocks. Analysis of historical catch data shows statistically significant increases in variability up to five years prior to stock collapse, suggesting that this indicator may provide adequate warning for management action to avert an impending collapse (Litzow et al. in prep.). Presently, four of the five crab fisheries that we analyzed show no increases in the spatial variability of the catch, and thus are not showing patterns that might be consistent with declining resilience and an increased chance of sudden collapse. Two of these fisheries (Bristol Bay red king crab and South Peninsula Tanner crab) showed evidence of decreasing catch variability (Figure 60), which may indicate continuing development of these fisheries under the new limited entry/IFQ management systems. The fifth fishery (Kodiak Tanner crab) does show a statistically significant increase in variability, but, considering a plausible alternate explanation (addition of low-catch areas with fishery expansion in 2011), we conclude that this trend will be cause for

concern only if it continues in future years.

Bering Sea/Aleutian Islands King and Tanner Crab stocks

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

Miscellaneous Species - Eastern Bering Sea

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See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

ADF&G Gulf of Alaska Trawl Survey

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Last updated: August 2012

Description of index: The Alaska Department of Fish and Game conducts an annual trawl survey for crab and groundfish in Gulf of Alaska targeting areas of crab habitat around Kodiak Island, the Alaska Peninsula, and the Eastern Aleutian Islands (Spalinger, 2010). While the survey covers a large portion of the central and western Gulf of Alaska, results from Kiliuda and Ugak Bays (inshore) and the immediately contiguous Barnabas Gully (offshore) (Figure 61) are broadly representative of the survey results across the region. These areas have been surveyed annually since 1984, but the most consistent time series begins in 1988. Standardized anomalies, a measure of departure from the mean, for the survey catches from Kiliuda and Ugak Bays, and Barnabas Gully were calculated and plotted by year for selected species (arrowtooth flounder *Atheresthes stomias*, flathead sole *Hippoglosoides elassodon*, Tanner crab *Chionoecetes bairdi*, Pacific cod *Gadus macrocephalus*, and skates) using the method described by Link et al. (2002) (Figure 62). Bottom temperatures for each haul have been consistently recorded since 1990 (Figure 63).

Status and trends: Arrowtooth flounder, flathead sole, and other flatfish continue to dominate the catches in the ADF&G trawl survey. A decrease in overall biomass is apparent from 2007 to

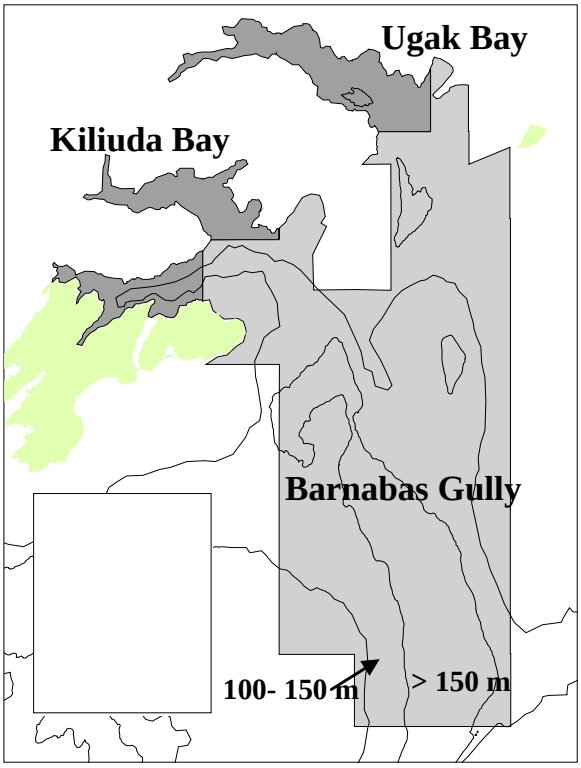

Figure 61: Adjoining survey areas on the east side of Kodiak Island used to characterize inshore (dark gray, 14 stations) and offshore (light gray, 33 stations) trawl survey results.

2011 from years of record high catches seen from 2002 to 2005.

Prior to the start of our standard trawl survey in 1988, Ugak Bay was the subject of an intensive seasonal trawl survey in 1976-1977 (Blackburn, 1977). Today, the Ugak Bay species composition is markedly different than in 1976. Red king crabs *Paralithodes camtschaticus* were the main component of the catch in 1976-1977, but now are nearly non-existent. Flathead sole, skate, and gadid catch rates have all increased roughly 10-fold. While Pacific cod made up 88% and walleye pollock 10% of the gadid catch in 1976-1977, catch compositions have reversed in 2011 with Pacific cod making up 17% of catch and walleye pollock 82%. Overall catches have decreased slightly in 2011 (Figure 64) with arrowtooth flounder, flathead sole, and Tanner crab predominating the catch for both inshore and offshore areas (Figure 64).

The increased catches are reflected in the wide distribution of positive values for the standardized anomalies in the recent past. In 2011, above average anomaly values for Tanner crabs, Pacific cod, and skates were recorded for both inshore and offshore areas, while arrowtooth flounder and flathead sole values remain below average.

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

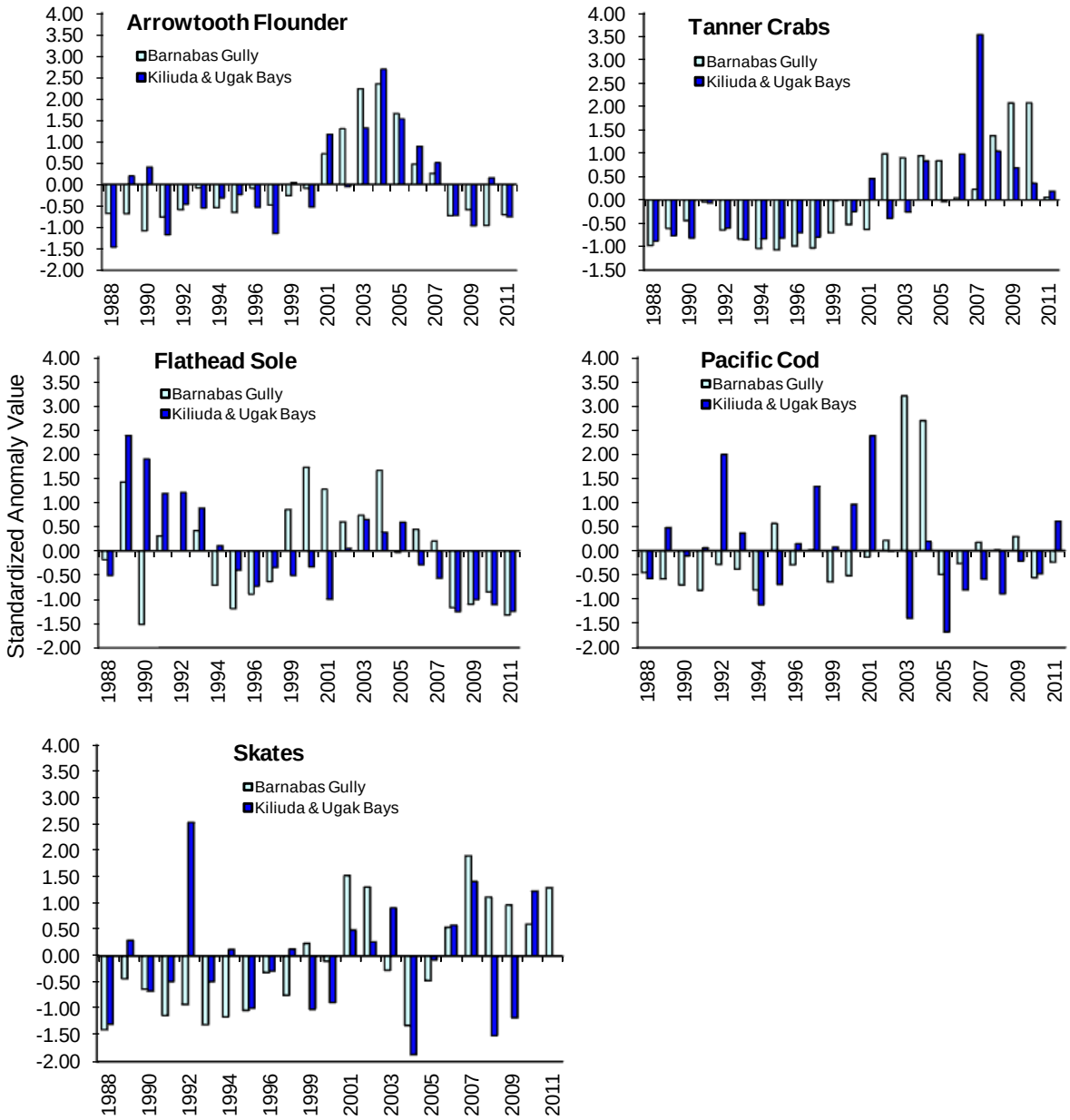

Figure 62: A comparison of standardized anomaly values for selected species caught from 1988-2011 in Kiliuda and Ugak Bays and Barnabas Gully during the ADF&G trawl surveys.

Factors causing observed trends It appears that significant changes in volume and composition of the catches on the east side of Kodiak are occurring, but it is unknown if predation, environmental changes, or fishing effort are contributing to these changes. The lower overall catch from 1993 to 1999 (Figure 64) may be a reflection of the greater frequency of El Niño events on overall production while the period of less frequent El Niño events, 2000 to 2006, corresponds to years of greatest production and corresponding catches. Lower than average temperatures have been recorded from 2007 to 2009 along with decreasing overall abundances. This may indicate a possible lag in response to changing environmental conditions or some other factors may be affecting abundance that are

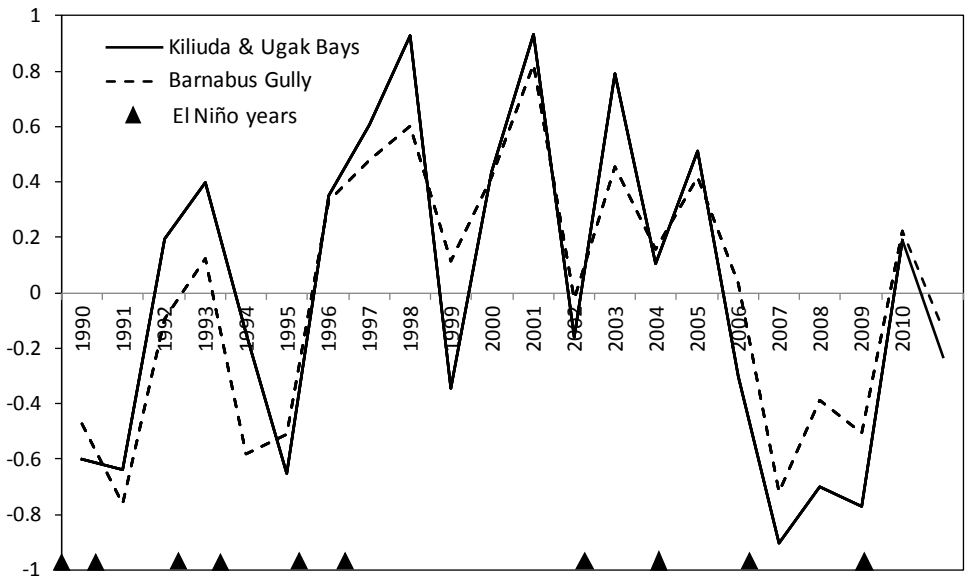

Figure 63: Bottom temperature anomalies recorded from the ADF&G trawl survey for Barnabas Gully and Kiliuda and Ugak Bays from 1990 to 2010, with corresponding El Niño years represented.

not yet apparent.

Implications Although trends in abundance in the trawl survey appear to be influenced by major oceanographic events such as El Niño, local environmental changes, predation, movements, and fishery effects may influence species specific abundances and need to be studied further. Monitoring these trends is an important process used in establishing harvest levels for state water fisheries. The survey data is used directly to establish guideline harvest levels of state managed fisheries and supply abundance estimates of the nearshore component of other groundfish species such as Pacific cod and pollock. Decreases in species abundance will most likely be reflected in decreased harvest guidelines.

Miscellaneous Species - Gulf of Alaska

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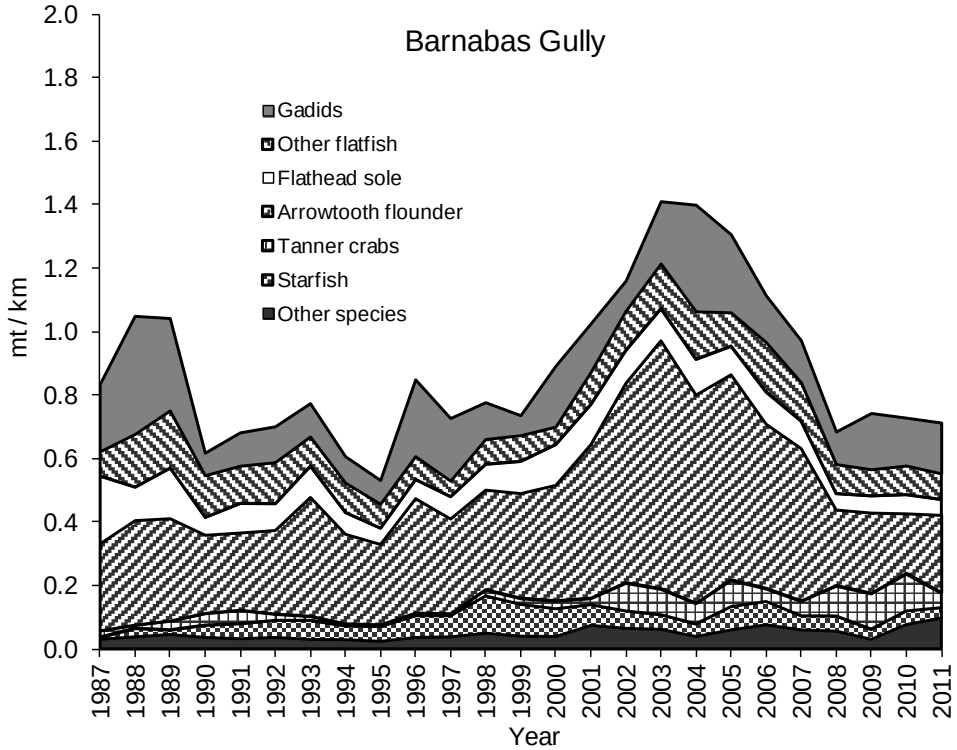
Last updated: October 2011

Gulf of Alaska surveys are conducted in alternate odd years. See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`



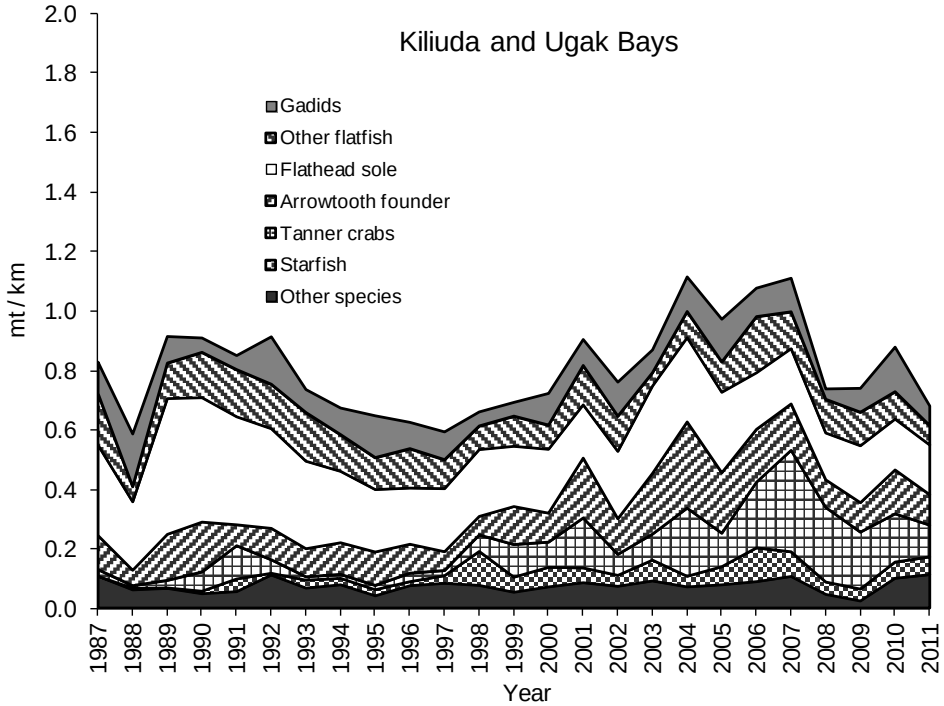


Figure 64: Total catch per km towed (mt/km) during the ADF&G trawl survey from adjacent areas off the east side of Kodiak Island, 1987 to 2011.

Lingcod Catches in the Gulf of Alaska

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See the 2009 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Miscellaneous Species - Aleutian Islands

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

Marine Mammals

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

Steller sea lion (*Eumetopias jubatus*)

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Last updated: October 2010

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

Northern fur seal (*Callorhinus ursinus*)

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Last updated: October 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Harbor Seals (*Phoca vitulina*)

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Last updated: October 2007

See the 2007 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Arctic ice seals: Bearded seal, ribbon seal, ringed seal, spotted seal

Contributed by Michael Cameron, National Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
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Last updated: July 2009

See the 2009 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Bowhead whale (*Balaena mysticetus*)

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Last updated: August 2010

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

Seabirds

Multivariate Seabird Indices for the Eastern Bering Sea

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Last updated: August 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Seabird Bycatch Estimates for Alaskan Groundfish Fisheries, 1993-2010

Contributed by Stephani Zador and Shannon Fitzgerald
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Last updated: August 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Ecosystem or Community Indicators

Indicators of basin-scale and Alaska-wide community regime shifts

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Last updated: August 2012

Description of indices: The first and second principal components (PCs) for 64 biology time series from Baja California to the Bering Sea allow basin-scale patterns of biological variability to be monitored (Hare and Mantua). We updated the Hare and Mantua biology time series for the years 1965-2008; too many values were missing after 2008 for PC analysis to be conducted. Our update included 35 Alaskan time series (19 from the Gulf of Alaska and 16 from the Bering Sea). Alaskan time series include recruitment estimates for groundfish (n = 15) and herring (n = 3) populations, log-transformed and lagged to cohort year; commercial salmon catches (n = 15), log-transformed and lagged to year of ocean entry; and measures of invertebrate abundance (n =

2). These indices are useful for monitoring possible biological responses to the negative Pacific Decadal Oscillation (PDO)/positive North Pacific Gyre Oscillation (NPGO) conditions that have persisted since 2007/08 (Figure 65).

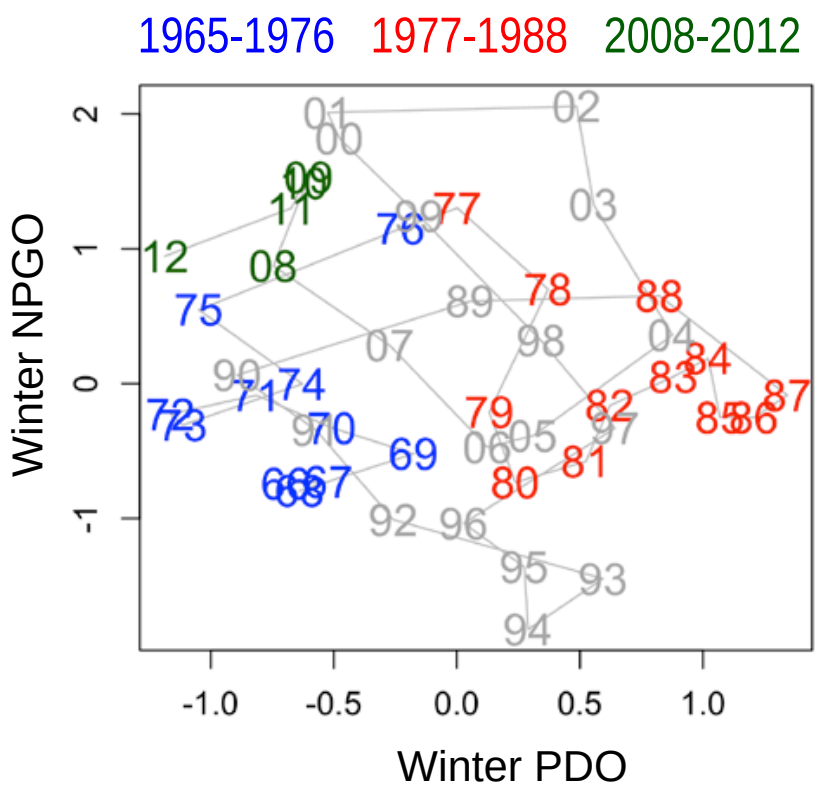

Figure 65: Winter (NDJFM) PDO-NPGO phase space, 1965-2012. Colors highlight recent years (2008-12) and two historical periods of strong PDO influence in the ecosystem (1965-77 and 1978-88). Plotted values are 3-year running means, except for 2012, which is a 2-year mean.

Status and trends: There is some evidence that an abrupt change in leading axes of basin-scale biological variability occurred in 2008. Change in the PC1-PC2 phase space for all 64 northeast Pacific time series from 2007 to 2008 was significantly greater than the mean for all other year-to-year changes since 1965-66 ($t_{41} = 22.69$, $p < 0.0001$, Figure 66). However, this biological change was not evident at the scale of Alaska. While PC1 and PC2 for the Alaskan time series show some evidence of declining amplitude in recent years (Figure 67), STARS (sequential t-tests for analysis of regime shifts) found no evidence of recent, statistically significant shifts in either Alaskan PC time series ($L = 15$ years, $H = 6$ SD, autocorrelation accounted for with IP4N method, $P > 0.05$).

Factors causing observed trends: Coherent shifts in climate and biology time series in the northeast Pacific have traditionally been interpreted as evidence of a causal relationship, though the underlying climate-biology covariation has rarely been evaluated with formal hypothesis testing. The abrupt change in PC1 and PC2 for all 64 time series between 2007 and 2008 (Figure 66) is suggestive of a basin-scale biological response to recent cool temperatures and PDO-negative/NPGO-positive conditions in the northeast Pacific. The possibility of a return to persistent PDO-negative

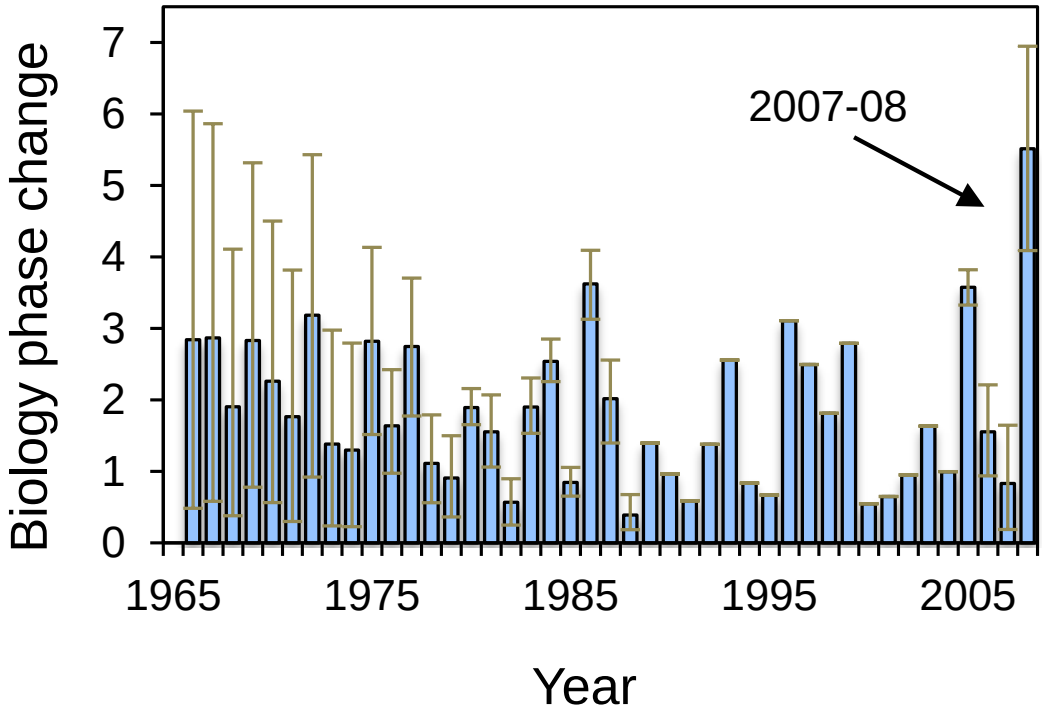

Figure 66: Total change in the PC1-PC2 phase space for 64 biology time series, Baja California to the Bering Sea, 1965-66 to 2007-08. Each column plots a year-to-year change in the phase space, calculated as the length of the hypotenuse joining PC1 and PC2 vectors. Error bars = 95% CI associated with estimating missing values. The 2007-08 change was 311% of the mean change for other years ($t_{41} = 22.69$, $p < 0.0001$).

conditions has received recent attention in the literature (e.g., (**??**)). However, we have no ability to predict either the behavior of the PDO or the biological response to large-scale climate fluctuations. Additionally, while we excluded recent recruitment estimates that were poorly supported by data from our analysis, there is some chance that the PC scores are subject to unquantified increases in variability in the most recent years of observation. Further years of observation will therefore be required before the persistence and true magnitude of the apparent shift in basin-scale patterns of biological variability can be known.

While Alaska has experienced the lower coastal temperatures that have recently been observed in the rest of the northeast Pacific(**?**), PC1 and PC2 of Alaskan biology time series through 2008 do not show any evidence of abrupt change (Figure 67).

Implications: Abrupt, community-level biological changes that are spatially coherent at the scale of the northeast Pacific are rare events; only one (1976/77) has occurred during the time period of the Hare and Mantua dataset. However, though rare, these events are extremely disruptive to

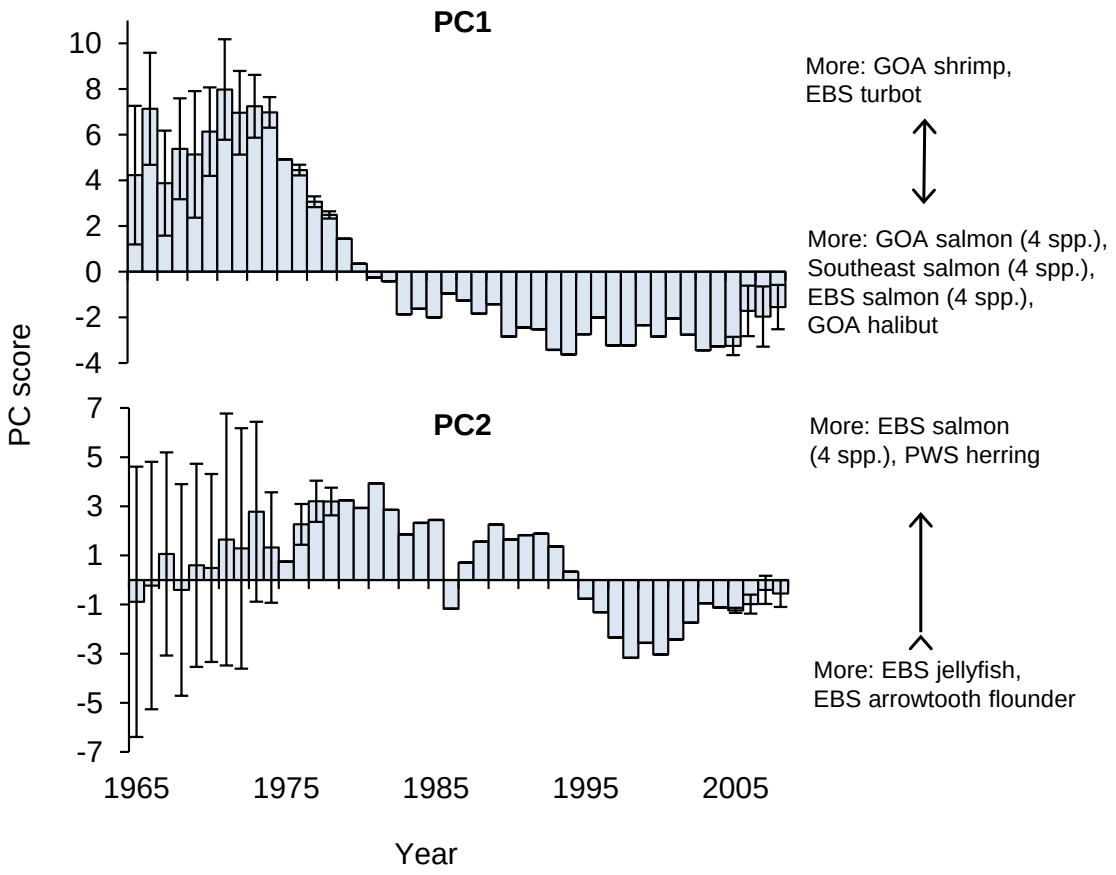

Figure 67: Time series of first two PC scores for 35 Alaskan biology time series, 1965-2008. Error bars = 95% CI associated with uncertainty through estimation of missing time series values; columns with no error bars indicate years with no missing values. Individual populations listed to the right of panels are time series showing strongest loading (≥ 0.2) on each PC score.

Alaskan fisheries. We found no evidence of recent abrupt biological change in Alaska, although the abrupt 2007-08 change in basin-scale data (Figure 66) suggests some possibility of ongoing changes across the northeast Pacific, possibly in response to a large change in the PDO-NPGO phase space between 2006 and 2008 (Figure 65). Lags in availability for many time series mean that community-wide patterns of biological variability during 2009-2012 cannot yet be evaluated.

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

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Last updated: July 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

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

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Last updated: July 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Average Local Species Richness and Diversity of the Groundfish Community

Contributed by Franz Mueter[1], Jason Waite[1], and Robert Lauth[2]
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Combined Standardized Indices of recruitment and survival rate

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

Spatial Distribution of Groundfish Stocks in the Bering Sea

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

Ecosystem-Based Management Indicators

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

Ecosystem Goal: Maintain Diversity

Time Trends in Groundfish Discards

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Last updated: July 2012

Description of index: Estimates of discards for 1994-2002 come from NMFS Alaska Region's blend data; estimates for 2003-10 come from the Alaska Region's catch-accounting system. It should be noted that although these sources provide the best available estimates of discards, the estimates are not necessarily accurate because they are based on visual observations by observers rather than data from direct sampling.

Status and trends: In 1998, the amount of managed groundfish species discarded in federally-managed Alaskan groundfish fisheries dropped to less than 10% of the total groundfish catch in both the Eastern Bering Sea (EBS) and the Gulf of Alaska (GOA) (Figure 68). Discard rates in the Gulf of Alaska have varied over time but were lower than average in 2010 and 2011. Discard rates in the Aleutian Islands (AI) dropped significantly in 1997, trended generally upwards from 1998 through 2003, and have generally declined over the last eight years. As in the EBS and the GOA, both discards and discard rates in the AI are much lower now than they were in 1996.

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

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

Time Trends in Non-Target Species Catch

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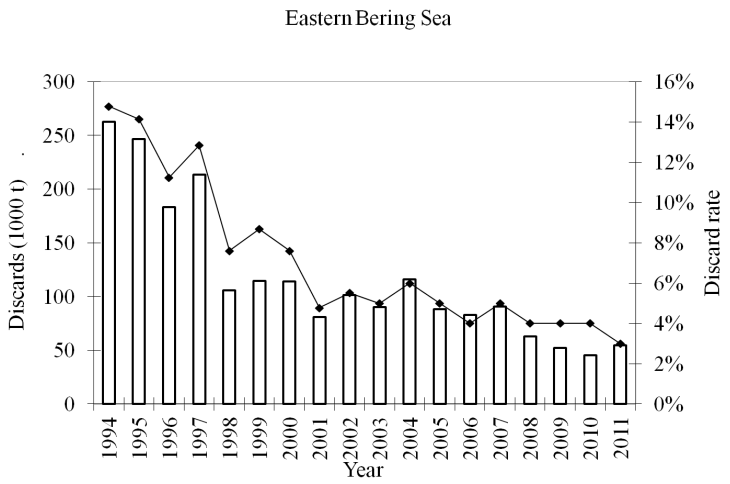
Last updated: August 2012

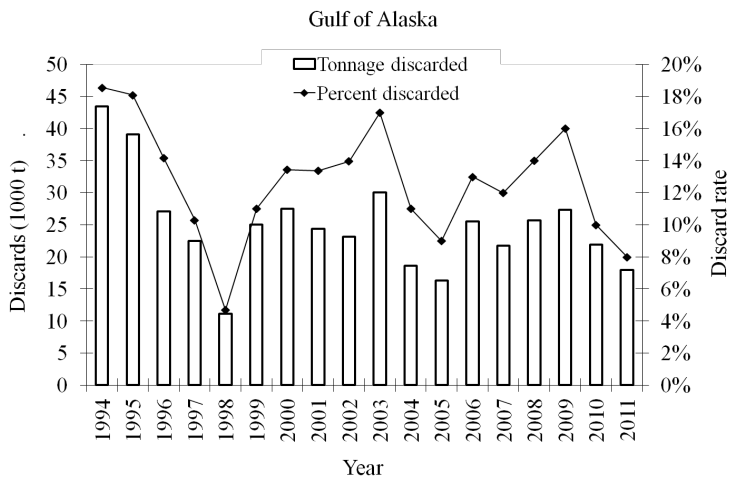
Description of index: We monitor the catch of non-target species in groundfish fisheries in the Eastern Bering Sea (EBS), Gulf of Alaska (GOA) and Aleutian Islands (AI) ecosystems (Figure 69). There are three categories of non-target species: 1) forage species (gunnels, stichaeids, sandfish, smelts, lanternfish, sand lance), 2) species associated with Habitat Areas of Particular Concern-HAPC species (seapens/whips, sponges, anemones, corals, tunicates), and 3) non-specified species (grenadiers, crabs, starfish, jellyfish, unidentified invertebrates, benthic invertebrates, echinoderms, other fish, birds, shrimp). Stock assessments have been developed for all groups in the other species (sculpins, unidentified sharks, salmon sharks, dogfish, sleeper sharks, skates, octopus, squid) category, so we do not include trends for "other species" here (see AFSC stock assessment website at http://www.afsc.noaa.gov/refm/stocks/assessments.htm).

Total catch of nontarget species is estimated from observer species composition samples taken at sea during fishing operations, scaled up to reflect the total catch by both observed and unobserved hauls and vessels operating in all FMP areas. From 1997-2002, these estimates were made at the AFSC using data from the observer program and the NMFS Alaska Regional Office. Catch since 2003 has been estimated using the Alaska Region's new Catch Accounting system. These methods should be comparable. This sampling and estimation process does result in uncertainty in catches, which is greater when observer coverage is lower and for species encountered rarely in the catch. Until 2008, observer sample recording protocols prevented estimation of variance in catch; however, we are developing methods to estimate variance for 2008 on which will be presented in future reports.

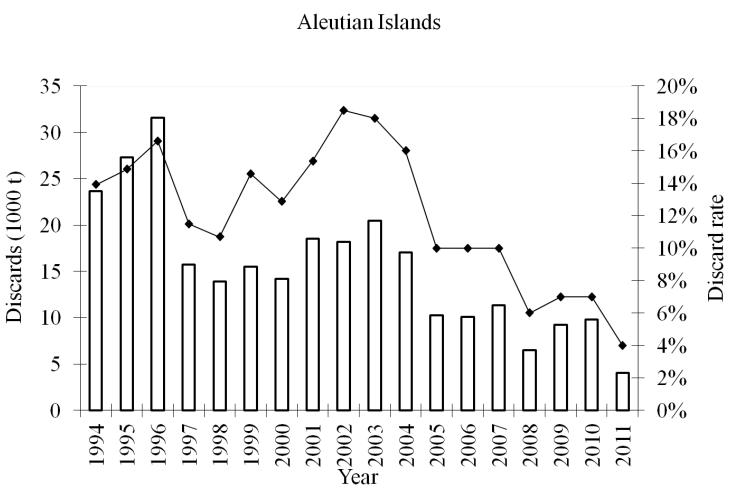
Status and trends: In all three ecosystems, non-specified catch comprised the majority of non-target catch during 1997-2011 (Figure 69). Non-specified catches are similar in the EBS and GOA, but are an order of magnitude lower in the AI. Catches of HAPC biota are highest in the EBS, intermediate in the AI and lowest in the GOA. The catch of forage fish is highest in the GOA, low in the EBS and very low in the AI.



(a) EBS



(b) GOA



(c) AI

Figure 68: Total biomass and percent of total catch biomass of managed groundfish discarded in the EBS, GOA, and AI areas, 1994-2011. (Includes only catch counted against federal TACS)

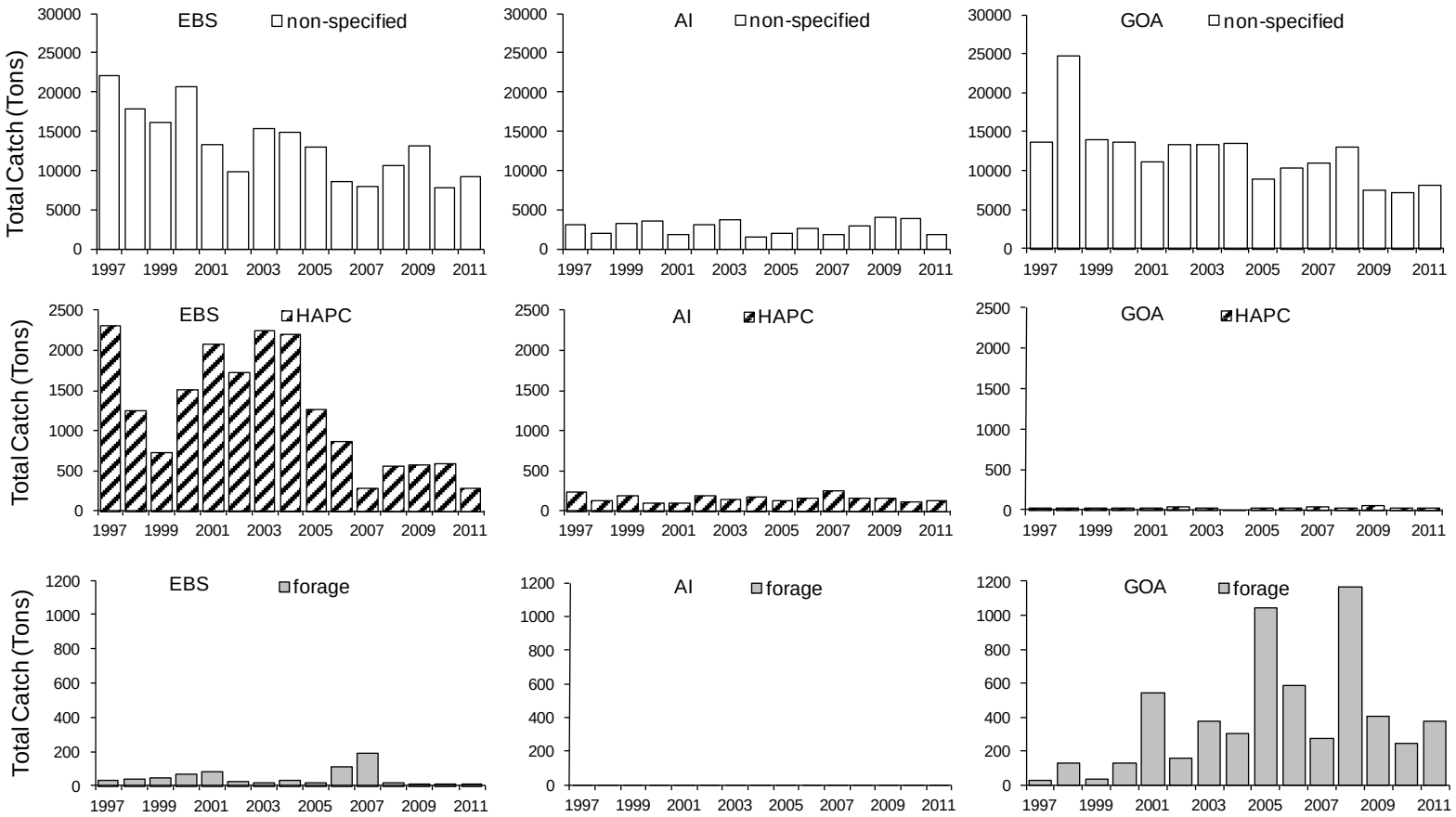


Figure 69: Total catch of non-target species (tons) in the EBS, AI, and GOA groundfish fisheries.

In the EBS, the catch of non-specified species appears to have decreased overall since the late 1990s. Scyphozoan jellyfish, grenadiers and sea stars comprise the majority of the non-specified catches in the EBS. The 2008-2009 and 2010-2011 increase in non-specified catch was driven by jellyfish. Grenadiers (including the Giant grenadier) are caught in the flatfish, sablefish, and cod fisheries. Jellyfish are caught in the pollock fishery and sea stars are caught primarily in flatfish fisheries. HAPC biota catch has generally decreased since 2004. Benthic urochordata, caught mainly by the flatfish fishery, comprised the majority of HAPC biota catches in the EBS in all years except 2009-2011, when sponges and sea anemones increased in importance. The catch of forage species in the EBS increased in 2006 and 2007 and was comprised mainly of eulachon that was caught primarily in the pollock fishery; however, forage catch decreased in 2008-2010. The forage catch increased again in 2011, primarily due to capelin and eulachon.

In the AI, the catch of non-specified species shows little trend over time, although the highest catches were recorded in 2009-2010. The non-specified catch dropped in 2010-2011, primarily due to a reduction in the catch of giant grenadiers. Grenadiers comprise the majority of AI non-specified species catch and are taken in flatfish and sablefish fisheries. HAPC catch has been similarly variable over time in the AI, and is driven primarily by sponges caught in the trawl fisheries for Atka mackerel, rockfish and cod. Forage fish catches in the AI are minimal, amounting to less than 1 ton per year, with the exception of 2000 when the catch estimate was 4 tons, driven by (perhaps anomalous) sandfish catch in the Atka mackerel fishery.

The catch of non-specified species in the GOA has been generally consistent aside from a peak in 1998 and lows in 2009 and 2010. Grenadiers comprise the majority of non-specified catch and they are caught primarily in the sablefish fishery. Sea anemones comprise the majority of the variable but generally low HAPC biota catch in the GOA and they are caught primarily in the flatfish fishery. The catch of forage species has undergone large variations, peaking in 2005 and 2008 and decreasing in 2006-2007 and 2009-2010. The catch of forage species increased in 2010-2011, primarily due to eulachon and other osmerids. The main species of forage fish caught are eulachon and they are primarily caught in the pollock fishery.

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

Implications: Catch of non-specified species is highest in the non-target category and has remained stable or possibly recently declined in all three ecosystems. Overall, the catch of HAPC and forage species in all three ecosystems is very low compared with the catch of target and non-specified species. HAPC species may have become less available to the EBS fisheries (or the fisheries avoided them more effectively) during the late 2000s. Forage fish may be more available to fisheries in the GOA during the 2000s.

Ecosystem Goal: Maintain and Restore Fish Habitats

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

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Last updated: August 2012

Description of index: Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut)(Figure 70). Some of the trawl closures are in effect year-round while others are seasonal. In general, year-round trawl closures have been implemented to protect vulnerable benthic habitat. Seasonal closures are used to reduce bycatch by closing areas where and when bycatch rates had historically been high. For additional background on fishery closures in the U.S. EEZ off Alaska, see **?**.

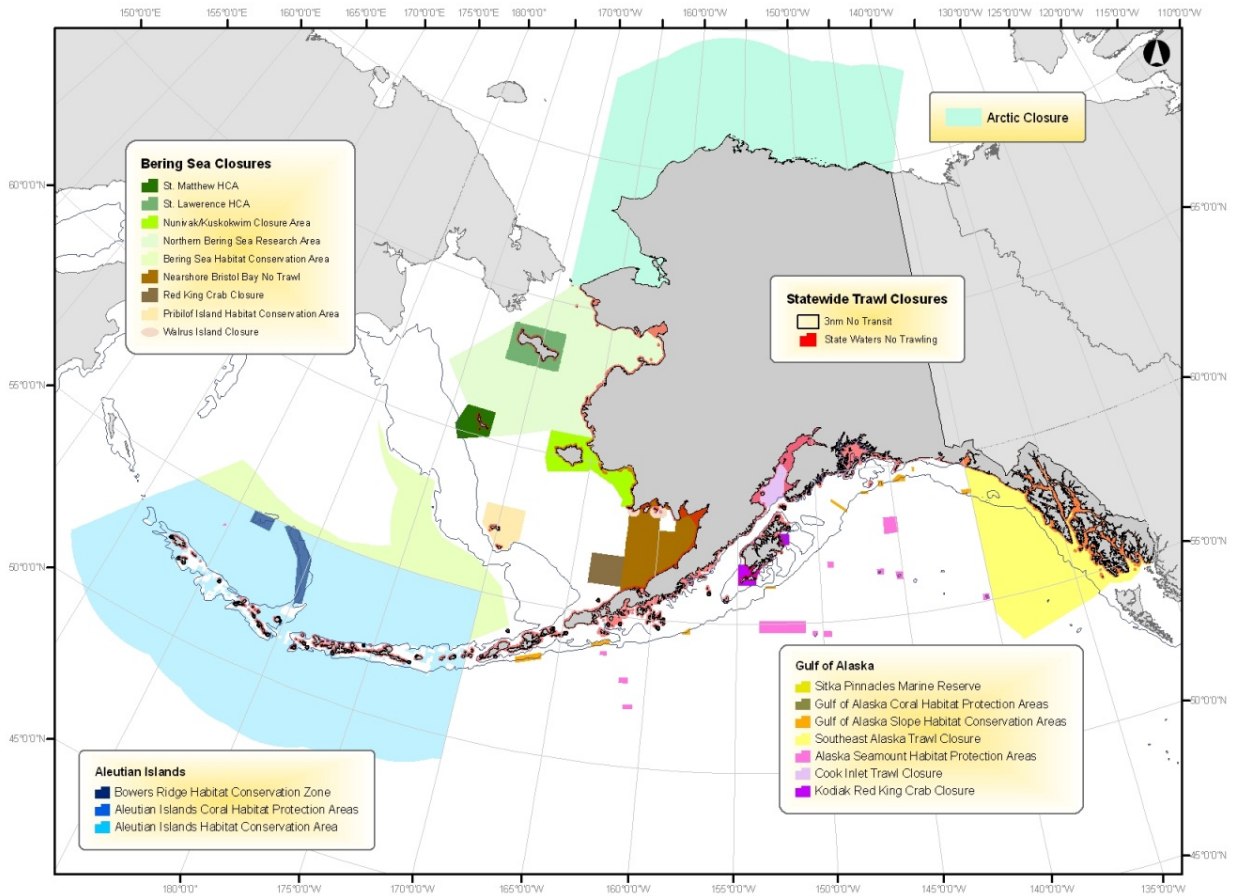

Figure 70: Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska, excluding most SSL closures.

Status and trends: Additional measures to protect the declining western stocks of the Steller sea lion began in 1991 with some simple restrictions based on rookery and haulout locations; in

2000 and 2001 more specific fishery restrictions were implemented. In 2001, over 90,000 nm^2 of the Exclusive Economic Zone (EEZ) of Alaska was closed to trawling year-round. Additionally, 40,000 nm2 were closed on a seasonal basis. State waters (0-3 nmi) are also closed to bottom trawling in most areas. A motion passed the North Pacific Management Council in February 2009 which closed all waters north of the Bering Strait to commercial fishing as part of the development of an Arctic Fishery management plan. This additional closure adds 148,300 nm^2 to the area closed to bottom trawling year round.

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

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

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

Steller Sea Lion closure maps are available here:

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

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

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

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

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Last updated: October 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

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

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Last updated: October 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

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

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See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

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

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Last updated: October 2011

See the 2011 report in the "Assessment Archives" at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

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

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

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Last updated: August 2012

Description of index: The Fish Stock Sustainability Index (FSSI) is a performance measure for the sustainability of fish stocks selected for their importance to commercial and recreational fisheries (`http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`). The FSSI will increase as overfishing is ended and stocks rebuild to the level that provides maximum sustainable yield. The FSSI is calculated by assigning a score for each fish stock based on the following rules: 1. Stock has known status determinations: a) overfishing 0.5 b) overfished 0.5 2. Fishing mortality rate is below the "overfishing" level defined for the stock 1.0 3. Biomass is above the "overfished" level

Table 8: Summary of status for FSSI and non-FSSI stocks managed under federal fishery management plans off Alaska, 2011.

Jurisdiction	Stock Group	Number of Stocks	Overfishing					Overfished				Approaching Overfished Condition
			Yes	No	Unk	Undef	NA	Yes	No	Unk	Undef	
NPFMC	FSSI	35	0	35	0	0	0	2	28	0	5	0
NPFMC	NonFSSI	29	0	21	6	1	1	0	4	4	21	0
	Total	64	0	56	6	1	1	2	32	4	16	0

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

The maximum score for each stock is 4.There are 230 FSSI stocks in the U.S., with a maximum possible score of 920. The value of the FSSI is the sum of the individual stock scores. In the Alaska Region, there are 35 FSSI stocks, and an overall FSSI of 140 would be achieved if every stock scored the maximum value, 4 (Tables 8 and9). Additionally, there are 29 non-FSSI stocks, two ecosystem component species complexes, and Pacific halibut which are managed under an international agreement (Tables 8 and 10).

Many species in Alaska are monitored as part of a group or complex, but are considered individually for the purposes of the report. The overfishing determination for the individual species is listed as "unknown", but the species' complex is determined to be "not subject to overfishing" based on the abundance estimates for the entire complex. This determination is applicable for some sharks, skates, sculpins, octopus, and squid complexes in the Gulf of Alaska (GOA) Groundfish FMP. In the Bering Sea-Aleutian Islands (BSAI) Groundfish FMP, similar determinations are made for some stocks in the sharks, skates, sculpins, octopus, rockfish, and flatfish complexes. For this year's chapter, groups previously reported in the larger "Other Species" complex, have been separated out into their respective assemblage units (e.g. Sculpin complex).

Status and trends: : As of June 30, 2011, no BSAI or GOA groundfish stock or stock complex is overfished and no BSAI or GOA groundfish stock or stock complex is being subjected to overfishing (Tables 8 and 9). Stocks that are considered overfished are Pribilof Island blue king crab and BSAI Tanner crab. The Pribilof Island blue king crab is on a continuing rebuilding plan (year 9 of 10-year plan) while the management required for the Tanner crab stock is to develop a rebuilding plan. The status of the Bering Sea snow crab rebuilding program has changed from rebuilding to rebuilt.

The current overall Alaska FSSI is 122.5 out of a possible 140, based on updates through June 2012(Table 9). This is a half point reduction from last year (the overall Alaska FSSI of 119 reported in last year's document should have been 123). The overall Bering Sea/Aleutian Islands score is 82 out of a possible maximum score of 92 (the overall BSAI possible maximum FSSI was incorrectly reported as 88 in last year's document). The BSAI groundfish score is 56 (including BSAI/GOA sablefish, see (g) in Box A) of a maximum possible 56 (the BSAI groundfish maximum possible score was incorrectly reported as 52 in last year's document) and BSAI king and Tanner crabs score 26 of a possible score of 36. The Gulf of Alaska groundfish score is 40.5 of a maximum possible 48 (excluding BSAI/GOA sablefish). Overall, the Alaskan total FSSI score increased from

2006 through 2010, then decreased slightly in 2011 and 2012 (Figure 71)

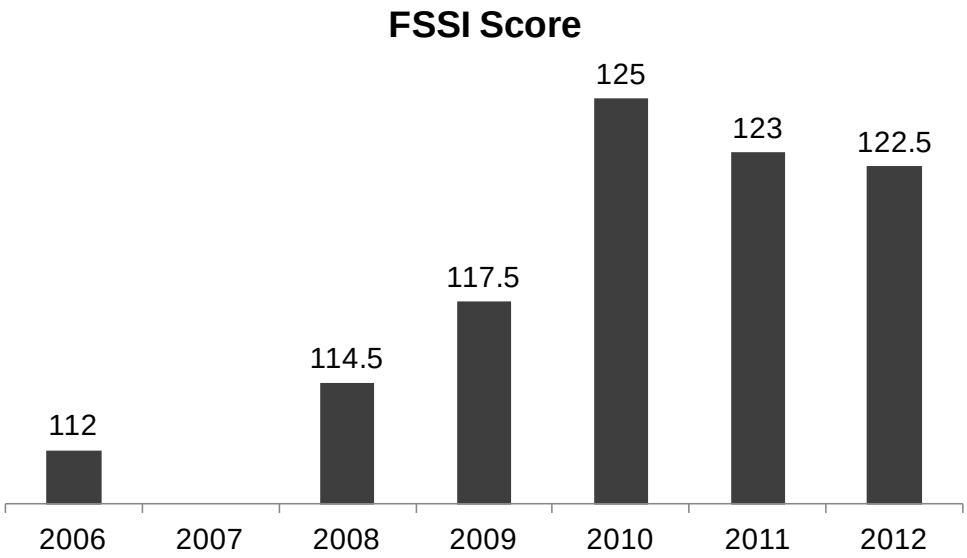

Figure 71: The trend in total Alaskan FSSI score from 2006 through 2012. All scores are the reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`. The maximum possible FSSI score is 140 in all years. Scores for 2007 were not available at the time of document preparation.

Factors causing observed trends: The total Alaskan FSSI dropped two points from 125 in 2010 to 123 in 2011. One point was lost because the biomass of the Pribilof Islands stock of red king crab dropped below 80% of B_{MSY}. The second point was lost for the Bering Sea southern Tanner crab stock becoming overfished.

From 2011 to 2012 another half point was lost in the total Alaskan FSSI. This was the net result of a two stocks each gaining a point, while a third stock lost points. One point was gained because the biomass of eastern Bering Sea pollock increased to a level at or above 80% of B_{MSY}. BSAI king and Tanner crabs also increased by one point because Bering Sea snow crab biomass increased to be at or above 80% of B_{MSY}. The FSSI score for GOA groundfish dropped by 2.5 points due to changes in the FSSI for the deep water flatfish complex. Following the recommendations of the most recent assessment report, the GOA deep water flatfish complex no longer has an indicator species, therefore an overfished determination can no longer be made, it is unknown whether they are approaching an overfished condition, and the ratio of B:BMSY is not estimated. The 2.5 point reduction in the GOA deep water flatfish complex FSSI offsets the two points gained by eastern Bering Sea walleye pollock and Bering Sea snow crab and explains the half point reduction in the total Alaskan FSSI.

Other 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 two rockfish complexes are because it is undefined whether these species are overfished, it is unknown if they are approaching an overfished condition, and the ratio of B:BMSY is not estimated.

Implications: The majority of Alaska groundfish fisheries appear to be sustainably managed. Two stocks or stock complexes are overfished (Pribilof Islands blue king crab and Bering Sea southern Tanner crab), no other stocks or stock complexes are approaching an overfished condition, and no stock or stock complex is subject to overfishing.

Table 9: FSSI stocks under NPFMC jurisdiction updated June 2012, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`.

Stock	Overfishing	Overfished	Approaching	Action	Progress	B/Bmsy	FSSI Score
Blue king crab - Pribilof Islands	No[a]	Yes	N/A	Rebuilding Program	Year 9 of 10	0.065	2
Blue king crab - Saint Matthews Island	No	No	No	N/A	N/A	2.204	4
Golden king crab - Aleutian Islands	No	Undefined	Unknown	N/A	N/A	not estimated	1.5
Red king crab - Bristol Bay	No	No	No	N/A	N/A	1.197	4
Red king crab - Norton Sound	No	No	No	N/A	N/A	1.739	4
Red king crab - Pribilof Islands	No1	No	Unknown	N/A	N/A	0.535	3
Red king crab - Western Aleutian Islands	No	Undefined	Unknown	N/A	N/A	not estimated	1.5
Snow crab - Bering Sea	No	No	No	Rebuilt	N/A	1.333	4
Southern Tanner crab - Bering Sea[b]	No	Yes	N/A	Rebuilding Program	N/A	0.321	2
BSAI Alaska plaice	No	No	No	N/A	N/A	2.04	4
BSAI Atka mackerel	No	No	No	N/A	N/A	1.692	4
BSAI Arrowtooth Flounder Complex[c]	No	No	No	N/A	N/A	3.156	4
BSAI Blackspotted and Rougheye Rockfish[d]	No	No	No	N/A	N/A	1.328	4
BSAI Flathead Sole Complex[e]	No	No	No	N/A	N/A	2.122	4
BSAI Rock Sole Complex[f]	No	No	No	N/A	N/A	2.057	4
BSAI Greenland halibut	No	No	No	N/A	N/A	2.714	4
BSAI Northern rockfish	No	No	No	N/A	N/A	1.615	4
BSAI Pacific cod	No	No	No	N/A	N/A	1.141	4
BSAI Pacific Ocean perch	No	No	No	N/A	N/A	1.627	4
Walleye pollock - Aleutian Islands	No	No	No	N/A	N/A	0.846	4
Walleye pollock - Eastern Bering Sea	No	No	No	N/A	N/A	1.034	4
BSAI Yellowfin sole	No	No	No	N/A	N/A	1.639	4
BSAI GOA Sablefish[g]	No	No	No	N/A	N/A	1.09	4

Table 9: FSSI stocks under NPFMC jurisdiction updated June 2012, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`. (continued)

Stock	Overfishing	Overfished	Approaching	Action	Progress	B/Bmsy	FSSI Score
GOA Arrowtooth flounder	No	No	No	N/A	N/A	2.94	4
GOA Flathead sole	No	No	No	N/A	N/A	2.809	4
GOA Blackspotted and Rougheye Rockfish complex	No	No	No	N/A	N/A	1.492	4
GOA Deepwater Flatfish Complex[h]	No	Undefined	Unknown	N/A	N/A	not estimated	1.5
GOA Demersal Shelf Rockfish Complex[i]	No	Undefined	Unknown	N/A	N/A	not estimated	1.5
GOA Dusky Rockfish[j]	No	No	No	N/A	N/A	1.677	4
GOA Thornyhead Rockfish Complex[k]	No	Undefined	Unknown	N/A	N/A	not estimated	1.5
Northern rockfish - Western / Central GOA	No	No	No	N/A	N/A	1.851	4
GOA Pacific cod	No	No	No	N/A	N/A	1.198	4
GOA Pacific Ocean perch	No	No	No	N/A	N/A	1.302	4
GOA Rex sole	No	No	No	N/A	N/A	2.713	4
Walleye pollock - Western / Central GOA	No	No	No	N/A	N/A	1.004	4

Box A. Endnotes and stock complex definitions for FSSI stocks listed in Table 9, adapted from the Status of U.S. Fisheries website: http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm. **a** Fishery in the EEZ is closed; therefore, fishing mortality is very low. **b** The North Pacific Fishery Management Council was notified by the Alaska Regional Office on October 1, 2010 that Southern Tanner crab is overfished. The NPFMC has 2 years from this date to implement a rebuilding plan for Southern Tanner crab - Bering Sea. **c** The Arrowtooth Flounder Complex consists of Arrowotooth flounder only. Beginning in 2010, Kamchatka flounder was separated into its own assessment, so the arrowtooth flounder assessment now represents arrowtooth flounder only, but management will continue to be based on the "arrowtooth flounder" assemblage. **d** Blackspotted and Rougheye Rockfish consists of Blackspotted Rockfish and Rougheye Rockfish. An assessment of the combined species provides the overfished determination, and the OFL is based on the combined-species assessment. **e** Flathead Sole Complex consists of Flathead Sole and Bering Flounder. Flathead Sole accounts for the overwhelming majority of the biomass and is regarded as the indicator species for the complex. The overfished determination is based on the combined abundance estimates for the two species; the overfishing determination is based on the OFL, which is computed from the combined abundance estimates for the two species. **f** Rock Sole Complex consists of Northern Rock Sole and Southern Rock Sole (NOTE: These are two distinct species, not two separate stocks of the same species). Northern Rock Sole accounts for the overwhelming majority of the biomass and is regarded as the indicator species for the complex. The overfished determination is based on the combined abundance estimates for the two species; the overfishing determination is based on the OFL, which is computed from the combined abundance estimates for the two species. **g** Although Sablefish is managed separately in the Gulf of Alaska, Bering Sea, and Aleutian Islands, with separate overfishing levels, ABCs, and TACs based on the proportion of biomass in each respective region, separate assessments are not conducted for each of these three regions; the assessment is based on aggregated data from the Gulf of Alaska, Bering Sea, and Aleutian Islands regions. Therefore, it is not appropriate to list separate status determinations for these three regions. **h** The Deep Water Flatfish Complex consists of the following stocks: Deepsea Sole, Dover Sole, and Greenland Turbot. Prior to 2011, Dover sole was the indicator stock for the deep-water flatfish assemblage. However, the 2011 assessment contained a recommendation that the existing age-structured model be rejected, including using Dover sole as an indicator species. The deep-water flatfish complex therefore no longer has an indicator species and an overfished determination can no longer be made. The complex was not subject to overfishing in 2010. **i** 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. **j** Prior to 2011, dusky rockfish was the indicator species for the "pelagic shelf rockfish" complex. Now, however, dusky rockfish is assessed as a single stock and the remaining two members of the former "pelagic shelf rockfish" assemblage (yellowtail and widow rockfish) have been combined with the former "other slope rockfish" assemblage to create a new "other rockfish" assemblage. Overfishing was not defined in 2010 for the dusky rockfish stock per se, but the former pelagic shelf rockfish complex was not subject to overfishing. **k** The Thornyhead Rockfish Complex consists of the following stocks: Longspine Thornyhead and Shortspine Thornyhead. The overfishing determination is based on the OFL, which is computed using abundance estimates of Shortspine Thornyhead.

Table 10: Non-FSSI stocks, Ecosystem Component Species, and Stocks managed under an International Agreement updated June 2012, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`. See website for definition of stocks and stock complexes.

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

Total Annual Surplus Production and Overall Exploitation Rate of Groundfish

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

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Last updated: August 2008

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Ecosystem Goal: Humans are part of ecosystems

Fishing Overcapacity Programs

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Last updated: August 2012

Overview: Overcapacity, wherein there is an excessive level of investment or effort relative to the available fisheries resources, is considered a problem in fisheries throughout the world. The problem is often manifested in short fishing seasons, increased enforcement and safety problems, and reduced economic viability for vessel owners and crew-members. Overcapacity can, under certain conditions, have grave implications for conservation as well.

The North Pacific Fishery Management Council (Council) and Congress have developed numerous tools and programs to address increasing effort in fully- or over-subscribed Alaskan fisheries. Some "traditional" tools have been refined to allowed more responsive management and avoidance of TAC

overruns; for example, comprehensive and electronic reporting systems and broad observer coverage have improved the level of detail and timeliness of catch, discard, and landings information available to in-season managers. However, more significant has been development of management programs that limit the numbers of participants or that control size and/or effort of those participants.

Trends: Since the 1990s, the Alaskan management trend has been towards increasingly specific management, from more finely divided allocations (by season, area, gear, sectors), to capacity removal, to rights-based" catch share management such as Community Development Quota (CDQ) allocations, cooperatives and individual quotas. Rights-based management has successfully addressed many ills typical of open access, as well as introducing some new issues. Alaskan programs have been designed to meet socioeconomic goals such as protecting the economic interests of historical participants and preventing excessive consolidation, in order to minimize negative impacts on fishery-dependent communities, while maintaining sustainable, economically viable fisheries. For example, recent Council catch share recommendations are intended to maintain active harvesting participation by quota holders, including "holder-on-board" provisions and revocation of privileges for latent participants. The Council also requested, and NMFS implemented, community purchase programs and loan programs to assist entry into the two major individual quota fisheries. Implementation of catch share management programs has enabled continued expansion of electronic reporting and observer coverage along with consideration of newer technologies such as video recording particularly for small vessel fleets. Catch share management also facilitated development of additional bycatch controls through implementation of quotas to address bycatch concerns while providing flexibility in bycatch use among participants. NMFS plans to expand cost recovery to additional catch share programs, under which landing fees help defray public costs of managing and enforcing dedicated access privileges. Finally, Federal and State management are increasingly coordinated to manage fisheries holistically, including bycatch, and throughout their range.

Text overviews (through mid-2010) of Alaskan limited access management programs can be found in 2010 Ecosystem Consideratins report (Zador and Gaichas, 2010). Additionally, a thorough review of Alaskan catch share programs and a document containing fleet profiles prepared by Council staff and are posted on its website, at `http://www.fakr.noaa.gov/npfmc/PDFdocuments/catch_shares/Fina_CatchShare_411.pdf` and `http://www.fakr.noaa.gov/npfmc/PDFdocuments/resources/FleetProfiles412.pdf`, respectively. For current management programs: program information; links to analyses, proposed, and final rules and current regulations; and application forms and reports including current issued permits, are posted on the NMFS, Alaska Region website: `http://www.alaskafisheries.noaa.gov/ram`. A variety of online constituent services are offered to foster industry self-determination and resource stewardship and support efficient and timely operations.

Following is a brief description of each major Alaskan capacity reduction permit program.

Vessel Moratorium Programs. License "Moratorium" programs for crab and groundfish (1996), and scallops (1997) fixed the number of harvesting vessels that could be deployed off Alaska and set limits on vessel and gear characteristics, operational types, and/or fishing areas. At the time these programs were replaced with License Limitation Permit (LLP) programs in late 1999, 1,864 groundfish and 653 crab vessel owners held moratorium fishing rights, and fewer than a dozen held Scallop Moratorium Permits.

Vessel License Limitation Programs. License Limitation programs (LLPs) established a fixed number of transferable harvesting licenses, with combinations of gear, area, species/fishery, vessel length,

and operation type endorsements. Over time, the crab and groundfish programs have been re-implemented to remove latent effort and licenses, prevent "crossover" and "spillover" effects into other fisheries, and for groundfish, to add community benefit in form of issuance of licenses to eligible communities to help preserve and build fishery revenues. No new developments have occurred in the crab program since 2005 when the crab rationalization program catch share program replaced the requirement for an LLP for most fisheries. Residual LLP fisheries are managed by the State of Alaska. Currently, there are about 350 crab LLP permits, about half the number of vessels eligible to fish under the Moratorium. At present there are 1,839 LLP groundfish, and nine scallop licenses.

Capacity Reduction ("Buyback") Programs. Direct "Capacity Reduction" programs have been used to permanently retire vessels, licenses, fishery endorsements, and/or participation histories through monetary compensation ("buyback" programs), administered by the NOAA Fisheries, Financial Services Division. In addition, vessels may not be reflagged under any other nation. By 1998 statute, nine American Fisheries Act (AFA) catcher/processor vessels were removed by a combination of Agency funding and repayable industry loan, and were physically scrapped. In more recent programs, after a bid process programs approved by industry referenda have been funded by Government loans repayable through landing fees on program participants. The Crab Capacity Reduction Program (2004) removed 25 vessels and their histories. A subsequent statute authorizes buyback programs for four groundfish fishery subsectors, to be developed separately; a recent implementation removed three vessels and multiple licenses from the longline catcher-processor subsector, and a recent proposed addition to the latter would remove an additional latent license. The objective of the program is to achieve a permanent reduction of capacity to: increase post-reduction harvester's productivity, help financially stabilize the fishery, and help conserve and manage fishery resources.

Rights-based Management Programs. Rights-based management such as individual transferable quotas and dedicated allocations to cooperatives and industry "sectors" have increasingly being used to "rationalize" fisheries. Often, "sideboard" measures prevent "spillover" effects due to imposition of right-based programs.

The following "rights-based" programs have been implemented in Alaska. An overview of these programs follows:

The **American Fisheries Act (AFA)** established by statute which harvesting and processing vessels could participate in Bering Sea/Aleutian Islands pollock fisheries, authorized pollock harvesting cooperatives, established allocations for inshore and offshore processing, and established allocations of pollock Total allowable Catch (TAC) to BS/AI communities eligible for a Community Development Quota program. Under the AFA, 109 catcher, 21 catcher-processor, and 3 mothership vessels and 8 inshore processors are authorized to participate; vessels may be replaced or (more recently) removed, and their histories reassigned. Six inshore-delivering vessel cooperatives are licensed and catcher-processor vessel owners formed a voluntary industry cooperative.

The first rights-based management program in Alaska was the **Individual Fishing Quota (IFQ)** program, which has been used to manage the halibut and fixed gear sablefish fisheries since 1995. Rather than limiting the number of harvesting vessels, this program grants quota holders the privilege of harvesting a specified percentage of the Total Allowable Catch (TAC) each year. The Council included, and has since added, numerous provisions that protect many pre-existing practices and provide additional operational flexibility while moving the bulk of the fishery to-

ward a small vessel, owner-operator fleet. In addition, a Community purchase provision added in 2004 was intended as an opportunity to reverse the rapid attrition of quota from residents of small coastal communities through voluntary transfers. The IFQ program includes cost recovery. The number of QS holders has decreased from 4,829 and 1,054 for halibut and sablefish, to 2,637 and 841 respectively. Participating vessels decreased from 3450 to 1,051 for halibut; and 1,191 to 362 (sablefish). A history of IFQ development authored by the Council and detailed annual reports as well as transfer studies and community quota profiles can be found at: `http://www.alaskafisheries.noaa.gov/ram/ifqreports.htm`.

A similar program developed by the Council, **Crab Rationalization**, was implemented in 2005 by statute. This program includes allocations to Community Development Quota Groups; for one golden king crab species, an allocation to the community of Adak; and a complex quota system for harvesters and processors called the "three-pie voluntary cooperative program." The quota program provides benefits for historic license holder and crew harvesters and for processors, authorizes harvesting cooperatives, and provides protections for crab revenue in fishery-dependent communities, and is largely paid for by cost recovery. The initial eight fisheries were expanded to nine when after the first year the Chionoecetes bairdi Tanner crab (BST) fishery was divided into two fisheries for more accurate stock management. Crab QS or PQS was initially issued to 511 persons (490 received harvesting QS and 27 PQS), but through transfers this has increased to 524 holders (500 hold QS and 30 hold PQS, including a number of entities representing communities). Consolidation has occurred in the crab fisheries, due largely to widespread use of cooperatives. The Council has changed the rationalization program to address a number of issues, including those that relate to capacity in various sectors, to improving operational flexibility through on-line transfers and regional delivery exemptions; and has recommended or is considering requirements for quota holders to actively participate in harvesting. Detailed annual reports can be found at: `http://www.alaskafisheries.noaa.gov/sustainablefisheries/crab/crfaq.htm`

As a prelude to an overarching GOA rationalization program, NMFS, in response to a Congressional mandate and in consultation with the Council, developed a **demonstration quota program for Central Gulf of Alaska rockfishes**, later extended to five years. This program provided exclusive harvesting and processing privileges for a specific set of rockfish and associated species harvested incidentally to those rockfish in the Central GOA and was replaced in 2012 with a permanent regulatory program. Quota issuance was based on LLP license use and attached to those licenses; currently, 54 holders realize annual TAC (and in some cases, bycatch allocations) only through cooperatives or a shared limited access fishery.

Most recently, in a program implemented under statutory authority, NMFS attached quota to LLP licenses for historic participants in the non-AFA catcher/processor sector (**"Amendment 80"**). The quota may be used annually to provide dedicated allocations to harvesting cooperatives or pooled in a limited access fishery to meet the broad goals of: (1) improving retention and utilization of fishery resources by the non-AFA trawl catcher/processor; (2) allocating fishery resources among BSAI trawl harvesters in consideration of historic and present harvest patterns and future harvest needs; (3) authorizing the allocation of groundfish species to harvesting cooperatives and establishing a limited access privilege program (LAPP) for the non-AFA trawl catcher/processors to reduce potential GRS compliance costs, encourage fishing practices with lower discard rates, and improve the opportunity for increasing the value of harvested species; and (4) limiting the ability of non-AFA trawl catcher/processors to expand their harvesting capacity into other fisheries not managed under a LAPP. Currently, 24 persons hold Amendment 80 quota.

Sector allocations. NMFS implemented Council recommendations to the FMPs for the BSAI and GOA, which provides annual allocations of Pacific among jig, trawl, and fixed gear (hook-and-line and pot) subsectors. The recommended allocations were determined based on a set of historic participation criteria, with consideration for small boats and coastal communities dependent on the Pacific cod resource. The Council also recommended seasonal apportionments for jig and trawl gear and a hierarchy for reallocating projected unused allocations among the various sectors. The number of eligible persons subject to this Amendment would be reduced to the extent that prior capacity reduction programs first reduce the size of the fleet.

State-Federal Coordination: Parallel Waters Fisheries. In 2012, NMFS implemented a 2009 Council recommendation to limit access by federally-permitted pot and hook-and-line catcher processor vessels to the BSAI Pacific cod parallel State waters fishery and preclude those vessels from fishing past the end of the sector closures. The Council's action complements the December 2008 action by the Alaska Board of Fisheries that limits the size of vessels using hook-and-line gear in the BSAI Pacific cod parallel State waters fishery to 58 ft LOA. NMFS' action requires certain license endorsements for participation, and stays divestiture of some Federal permits or endorsements.

Arctic FMP. The Council recommended a new Fishery Management Plan for Fish Resources of the Arctic Management Area (Arctic FMP). Established in 2009, the Arctic FMP in intended to provide for sustainable management of commercial fishing in the Arctic Management Area. The Arctic FMP prohibits the expansion of commercial fishing in federal Arctic waters until researchers gather sufficient information to prevent adverse impacts of commercial harvesting activity on the ecosystem.

Guided Sport Halibut Management. The Charter Halibut Limited Entry Program halted entry into the guided sport fishery for International Pacific Halibut Commission (IPHC) areas 2C and 3A. This replaces management under a guideline harvest level (GHL), which had been exceeded for several years in each area. Under the program, NMFS issued Federal charter halibut permits (CHP) to historical participants based on required State logbook reporting and licensing. Eligible communities and military morale and welfare and recreational programs may request a limited number of free permits.

NMFS is drafting regulations to implement the Council's recommendation for an allocation system to replace the current GHLs for charter fisheries in Areas 2C and 3A with a "catch sharing plan". Under the plan the Council would request that the IPHC annually set a combined charter and setline catch limit to which the allocation percentage for each area automatically would be applied to establish domestic harvest targets for each sector. This proposal also included a "guided angler fish" (GAF), feature, under which holders of CHPs could purchase annual IFQ halibut from the commercial fishery for use in individual accounts, to support halibut retention by their clients.

Groundfish Fleet Composition

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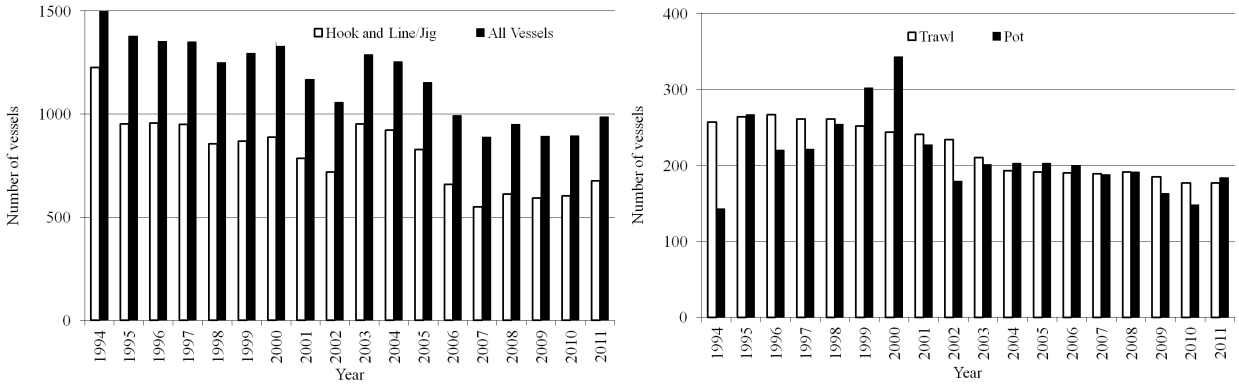
Description of index: Fishing vessels participating in federally-managed groundfish fisheries off Alaska principally use trawl, hook and line, and pot gear. Vessel counts in these tables were compiled from blend and Catch-Accounting System estimates and from fish ticket and observer data through 2011.

Status and trends: The pattern of changes in the total number of vessels harvesting groundfish and the number of vessels using hook and line gear have been very similar since 1994. Numbers have generally decreased since 1994 and were low in the past 5 years (2007-2011). The total number of vessels was 1,518 in 1994 and 987 in 2011 (Figure 72). Hook and line/jig vessels accounted for about 1,225 and 676 of these vessels in 1994 and 2011, respectively. The number of vessels using trawl gear decreased from 257 in 1994 to 177 in 2011. During the same period, the number of vessels using pot gear peaked in 2000 at 343, and decreased to 184 in 2011.



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

Figure 72: Number of vessels participating in the groundfish fisheries off Alaska by gear type, 1994-2010.

Factors causing observed trends: The increase, in 2003, in the number of hook-and-line/jig and pot vessels (and, thus, also in the total number of vessels) results from replacement of the old blend system with the Catch-Accounting System (CAS) as the official estimates of groundfish catch. The new CAS data include the Federal Fisheries Permit numbers of catcher vessels delivering both to motherships and to shoreside processors, making possible a more complete count of participating vessels. It should be noted that vessel counts before and after 2003 are not directly comparable due to the change in data source mentioned above. The increase in the number of vessels in 2011 relative to 2010 is primarily attributable to the entry of new jig-gear vessels targeting Pacific cod in the Gulf of Alaska.

Implications: Monitoring the numbers of fishing vessels is important to fisheries managers, because it provides big-picture measures of fishing effort, the level of capitalization in the fisheries, and the potential magnitude of effects on industry stakeholders caused by management decisions.

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

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

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