APPENDIX C

Ecosystem Considerations for 2010

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

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November 16, 2009
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EXECUTIVE SUMMARY OF RECENT TRENDS

Climate and Physical Environment Trends

- The North Pacific atmosphere-ocean system from fall 2008 through summer 2009 featured relatively cool sea surface temperature (SST) along its northern flank extending from the BS through the GOA to off the coast of California.
- Consequences of a weak Aleutian low during the past winter and spring included relatively cold conditions and heavy sea ice for the EBS, and mostly upwelling-favorable wind anomalies from the GOA to the Pacific Northwest.
- The 2008/09 winter included a La Nina of modest amplitude; the higher latitude response to the tropical Pacific was stronger than that during the past winter, even though the La Nina was weaker.
- The summer of 2009 featured a shift in the wind pattern and an overall moderation of coastal SSTs.
- El Nino conditions developed in the summer of 2009; this will likely persist and probably strengthen into 2010. This is liable to bring about a positive state for the PDO and relatively warm SSTs along the west coast of North America.
- In August 2009, the sea ice cover for the Arctic as a whole was about 1×10^6 km^2 greater than that at the same time during 2007, but still 1.3×10^6 km^2 less than the 1979-2000 average. From an Alaskan perspective, it is interesting that the ice edge in the Beaufort Sea is presently near its long-term climatological position.
- The 2008/09 winter was the third in a series of notably cold winters in the EBS, leaving behind a prominent cold pool of water (<2˚ C) on the middle shelf. The offshore extent of the cold pool during 2009 is comparable, but not quite to that which was observed in 2008.
- A substantial coccolithophore bloom developed in the EBS during 2009.
- In the EBS, the average surface temperature, 4.7°C, was slightly higher than 2008 but still 2.1°C lower than the long-term mean of 6.8°C. The average bottom temperature in 2009 was 1.22°C, which was below the grand mean for the fourth consecutive year.
- Eddy kinetic energy (EKE) in the AI was lower than average in 2008 and in the spring of 2009, suggesting possibly reduced volume, heat, salt, and nutrient fluxes to the BS compared to periods of high EKE.
- The western AI experienced southerly wind anomalies early in the period and northerly wind anomalies during the past summer, 2009. The SST here was warm during the latter part of 2008, cooling to near normal by summer 2009 relative to seasonal norms.
- The eastern portion of the Alaska Peninsula and AI experienced suppressed storminess during winter and spring 2009; the sense of the wind anomalies since late 2008 is from the east to southeast, which is associated with enhanced transports through Unimak and the other shallow passes in the eastern AI.
- Based on the winds along the northern GOA coast, the Alaska Coastal Current on the shelf was probably relatively weak during the winter and spring, returning to near-normal transports in the summer.
- In the GOA, eddy kinetic energy values were low during spring 2009. This implies phytoplankton biomass was likely tightly confined to the shelf, and cross-shelf transport of heat, salinity, and nutrients was likely to be smaller than in 2007-2008.
- In 2009, there was a relatively weak and broad Alaska Current off the coast of SE Alaska, as compared with 2008, accompanied by relatively shallow mixed layer depths in the winter and spring of 2009.

Climate indices – All regions

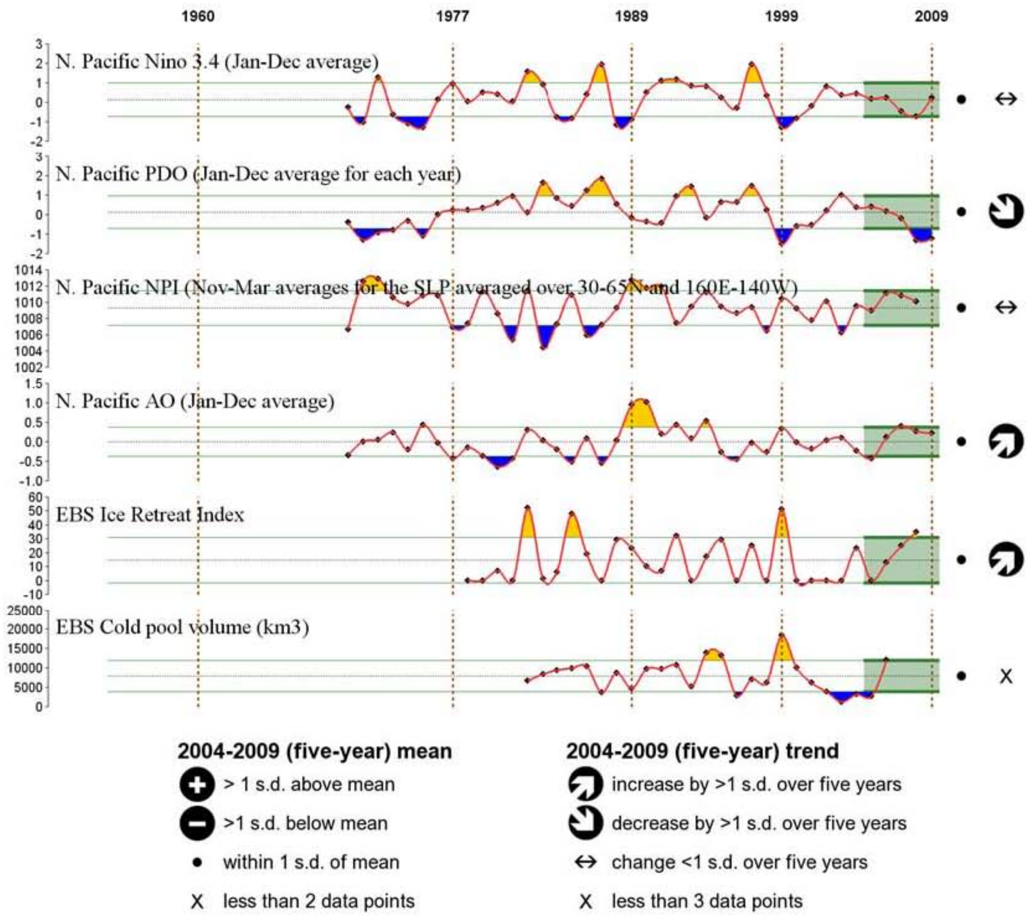

Figure A. Climate indices – All regions. Green shaded area shows +/- one standard deviation of time series over measured time period.

Ecosystem Trends

- Bering Sea zooplankton biomass appeared to return towards average levels in 2006-2007 after a prolonged low period in 2001-2005.
- Mesozooplankton abundance in the GOA tends to peak later in the year and is longer in duration during cool, PDO-negative years compared to warmer, PDO-positive years. In 2008, a cold year, mesozooplankton biomass peaked later and persisted longer.
- Biomass of all jellyfish but *Chrysaora* declined in the BS BASIS survey during 2008.
- Jellyfish relative CPUE in bottom-trawl surveys in the EBS increased dramatically during 2009. The magnitude of increase from the previous year was the largest since the year 2000.
- The Pribilof Islands blue king crab was declared overfished in 2002 and remains at a low biomass. St. Matthew blue king crab was declared overfished in 1999 and is officially considered rebuilt this year. The Tanner crab stock is approaching an overfished status based on the 2009 survey estimates.
- The relative CPUE of Arctic cod increased dramatically in the area of the cold pool in the 2008 EBS bottom trawl survey.
- Togiak herring abundance in 2007 was below average but the stock is considered stable.
- The 2008 and 2005 estimates of herring spawning biomass in Southeast Alaska were the two highest in the 25-year time series. Mature age-3 herring abundance is at low levels, but there has been recruitment to spawning stocks at older ages.
- Abundance of eulachon in the Central and Eastern GOA appears to have increased in recent years, possibly indicating increased availability of eulachon to fish, bird and mammal species.
- Spring wind-driven advection of EBS northern rock sole larvae was offshore away from favorable nursery areas in 2009 suggesting that this year class may be below the long-term average.
- The area occupied by arrowtooth flounder is inversely related to the area of the cold pool in the EBS. The area occupied by the rock sole and arrowtooth flounder stocks significantly increased with stock size, suggesting that the spatial distribution is related to density-dependent habitat selection.
- There appears to be a negative relationship between relative abundance of age-0 pollock from the BS BASIS survey (high in warm years) and subsequent recruitment to age-1 pollock (low following warm years).
- EBS groundfish condition was low in 1999 and tended to be high in 2002-2003.
- There was an indication of a return to below average groundfish recruitment across multiple stocks in the EBS in 2004. There is strong indication for above-average groundfish recruitment in the GOA from 1994-2000 and below-average recruitment since 2001.
- Annual surplus production indices suggest high variability in EBS groundfish production and a decrease in production between 1977 and 2007.
- Arrowtooth, flathead sole, and other flatfish continued to dominate the catches in the ADF&G GOA trawl survey. A decrease in overall biomass was apparent in 2007 and 2008 from years of record high catches seen from 2002 to 2005.
- Annual surplus production in the GOA was lower than that of the EBS, less variable and decreased slightly over the same time period.
- The mean-weighted distribution of GOA rockfish (1990-2007), especially juvenile POP, appeared to be farther north and east and was more contracted in 2007, possibly indicating a change in rockfish distribution around the GOA. The distribution of rockfish in the AI during 1991-2006 has not changed relative to depth, temperature, or position.
- Seabird reproductive success at the Pribilofs has trended upwards or remained stable. Hatch dates have trended earlier or remained stable. Half of the populations are within one standard deviation of their long-term mean, three of eight are below, and one is above.
- Fur seal pup counts during 2008 at St. Paul Island continued to decline, but increased at St. George.
- Steller sea lion non-pup counts during 2008 increased in the eastern GOA, declined in the central and western AI, and remained relatively stable in between.
- The Western Arctic stock of bowhead whale has been increasing in recent years and may be approaching its carrying capacity.

Ecosystem trends – Pribilof Islands top predators

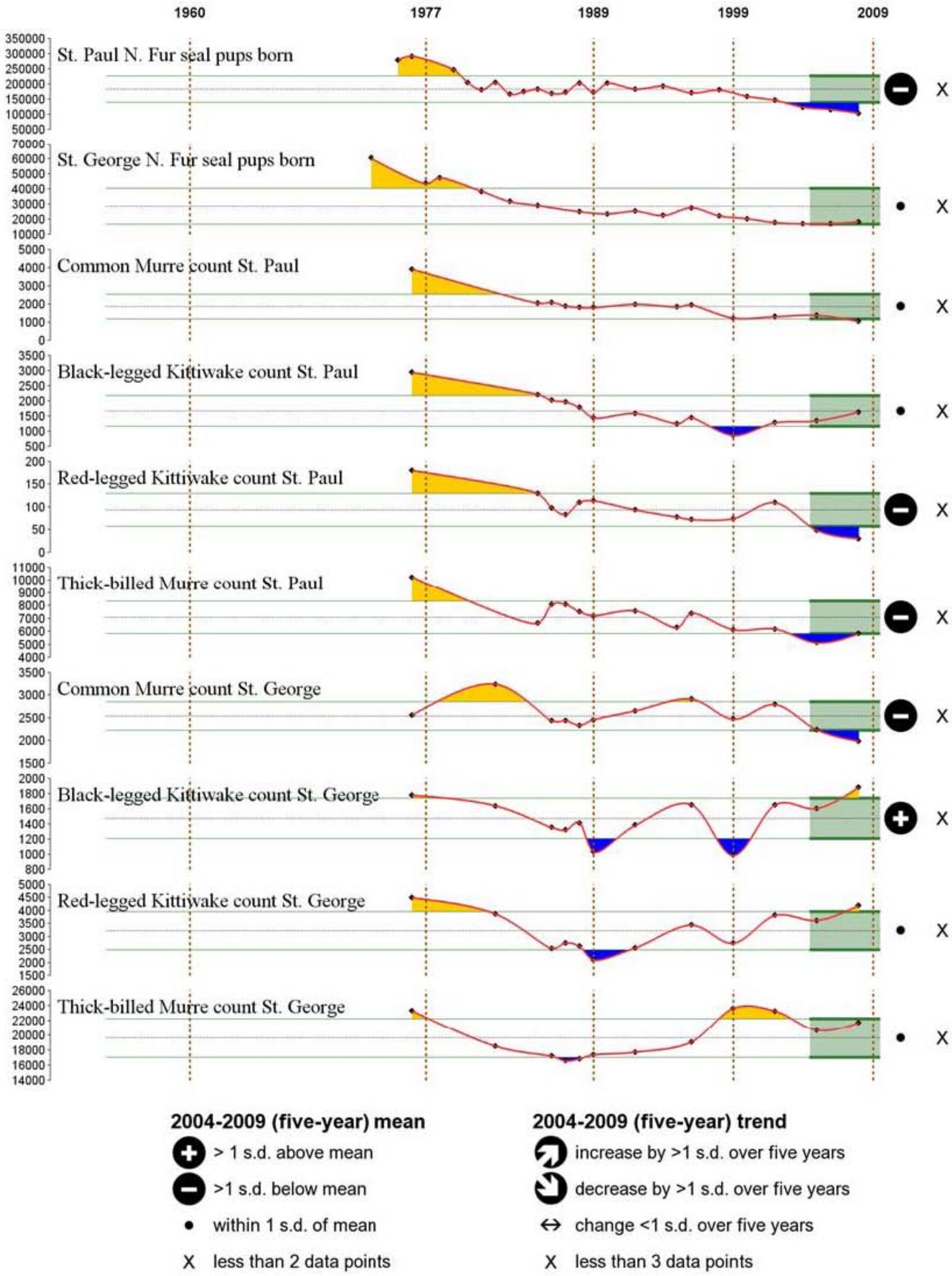

Figure B. Ecosystem trends – Pribilof Islands top predators. Green shaded area shows +/- one standard deviation of time series over measured time period.

Ecosystem trends – Eastern Bering Sea

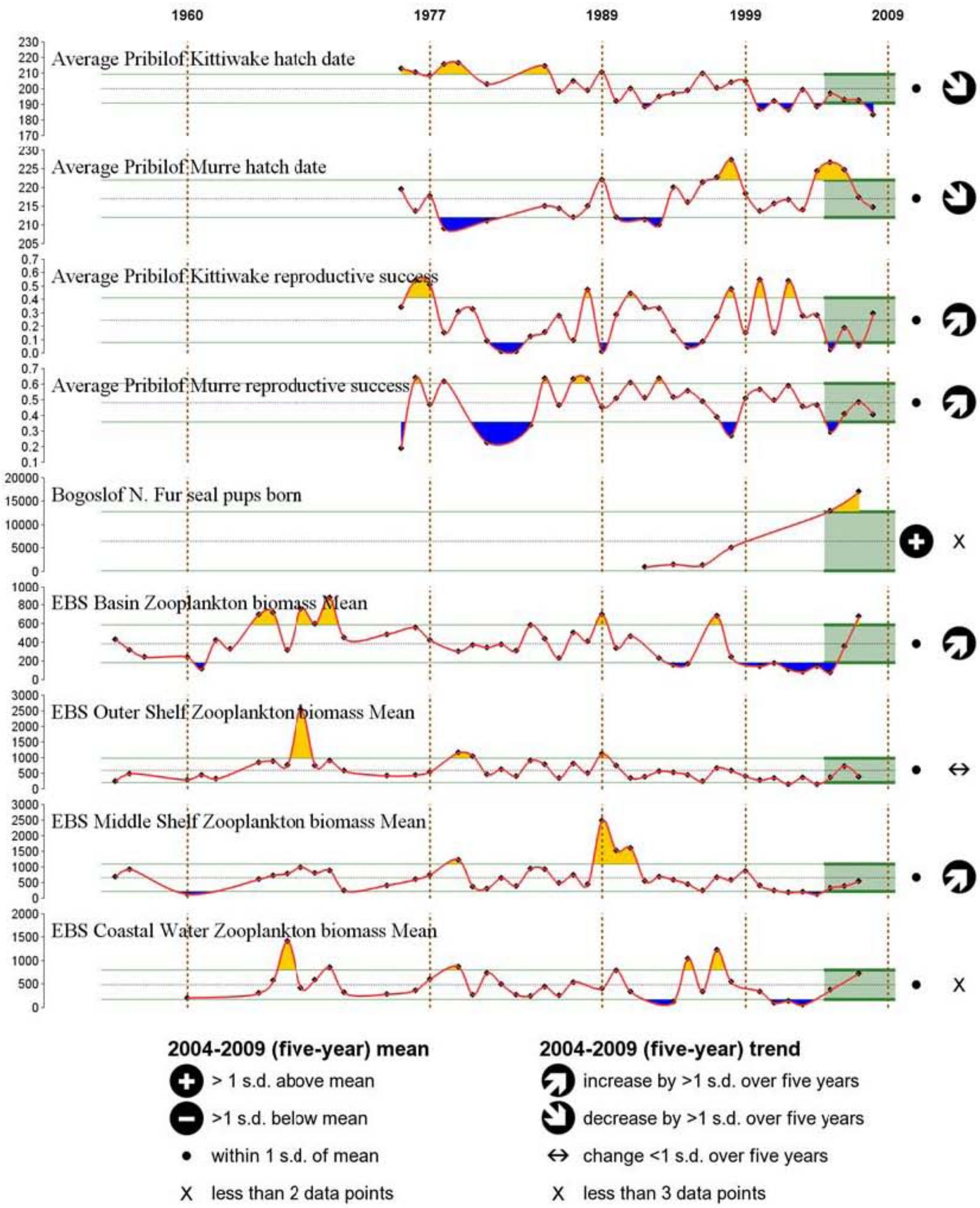

Figure C. Ecosystem trends – Eastern Bering Sea. Green shaded area shows +/- one standard deviation of time series over measured time period.

Ecosystem trends – Eastern Bering Sea

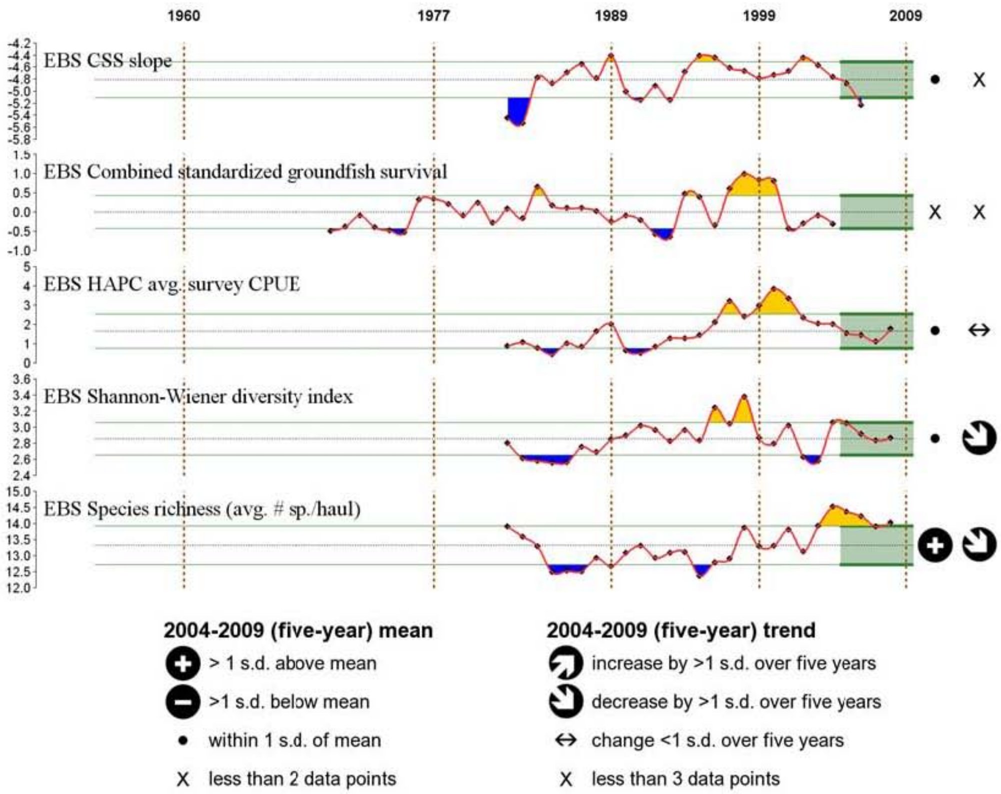

Figure D. Ecosystem trends – Eastern Bering Sea. Green shaded area shows +/- one standard deviation of time series over measured time period.

Ecosystem trends – Eastern Bering Sea biomass by guild

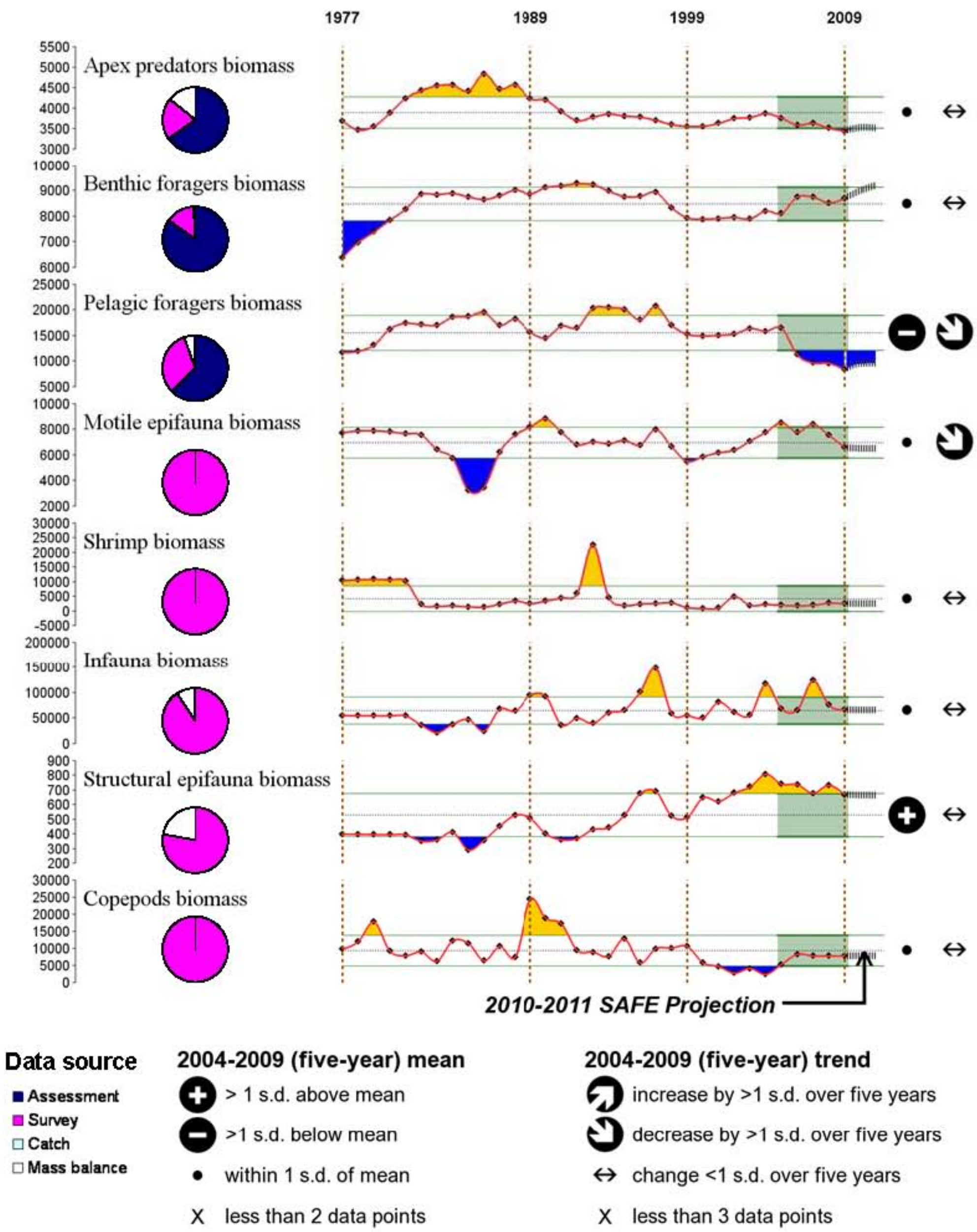

Figure E. Ecosystem trend – Eastern Bering Sea biomass by guild. Green shaded area shows +/- one standard deviation of time series over measured time period.

Ecosystem trends – Aleutian Islands

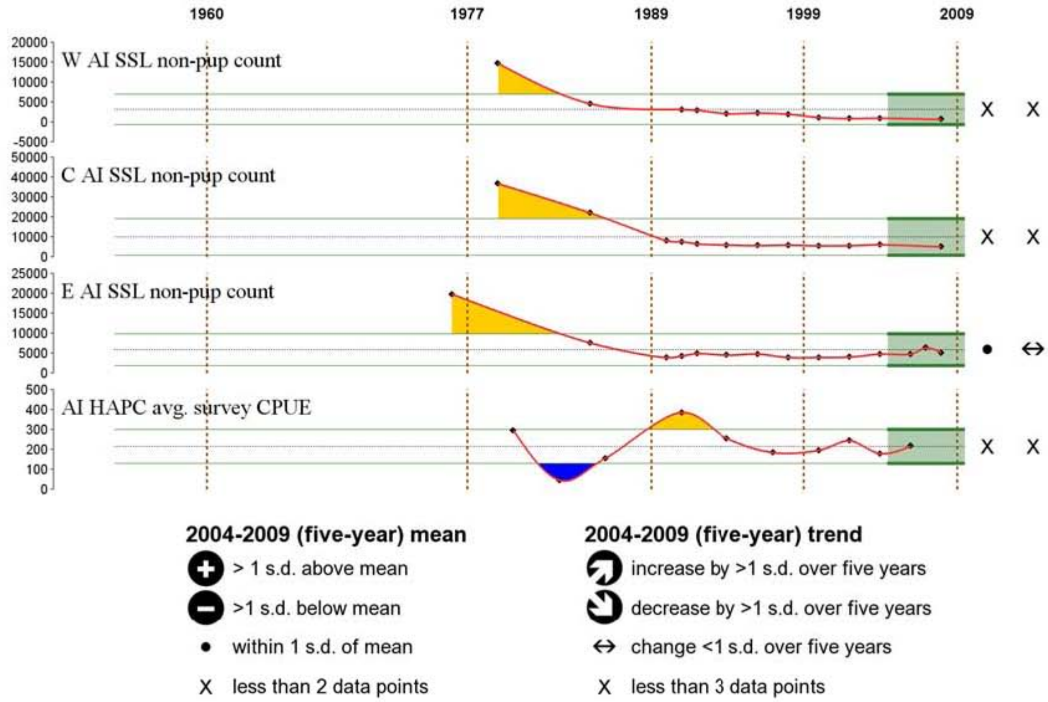

Figure F. Ecosystem trends – Aleutian Islands. Green shaded area shows +/- one standard deviation of time series over measured time period**.**

Ecosystem Trends – Gulf of Alaska

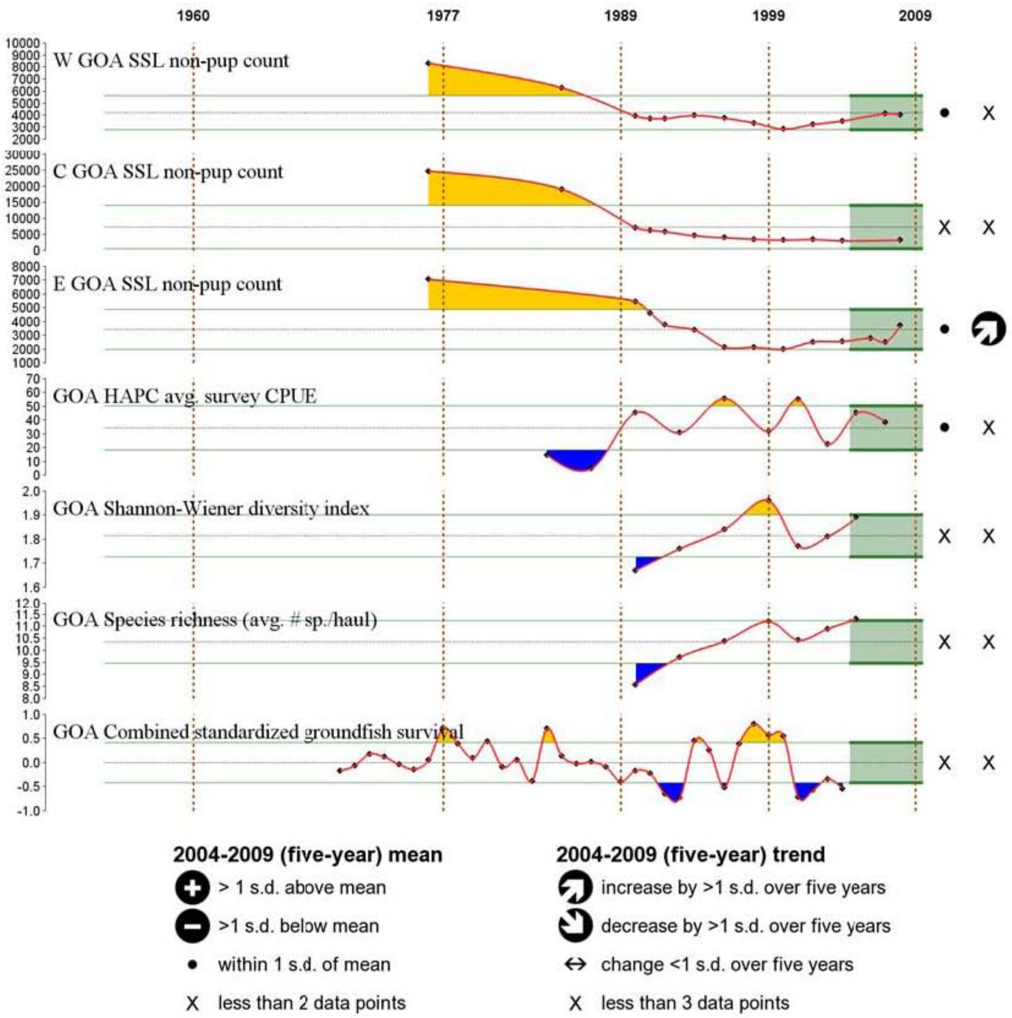

Figure G. Ecosystem trends – Gulf of Alaska. Green shaded area shows +/- one standard deviation of time series over measured time period.

Ecosystem trends – Gulf of Alaska biomass by guild

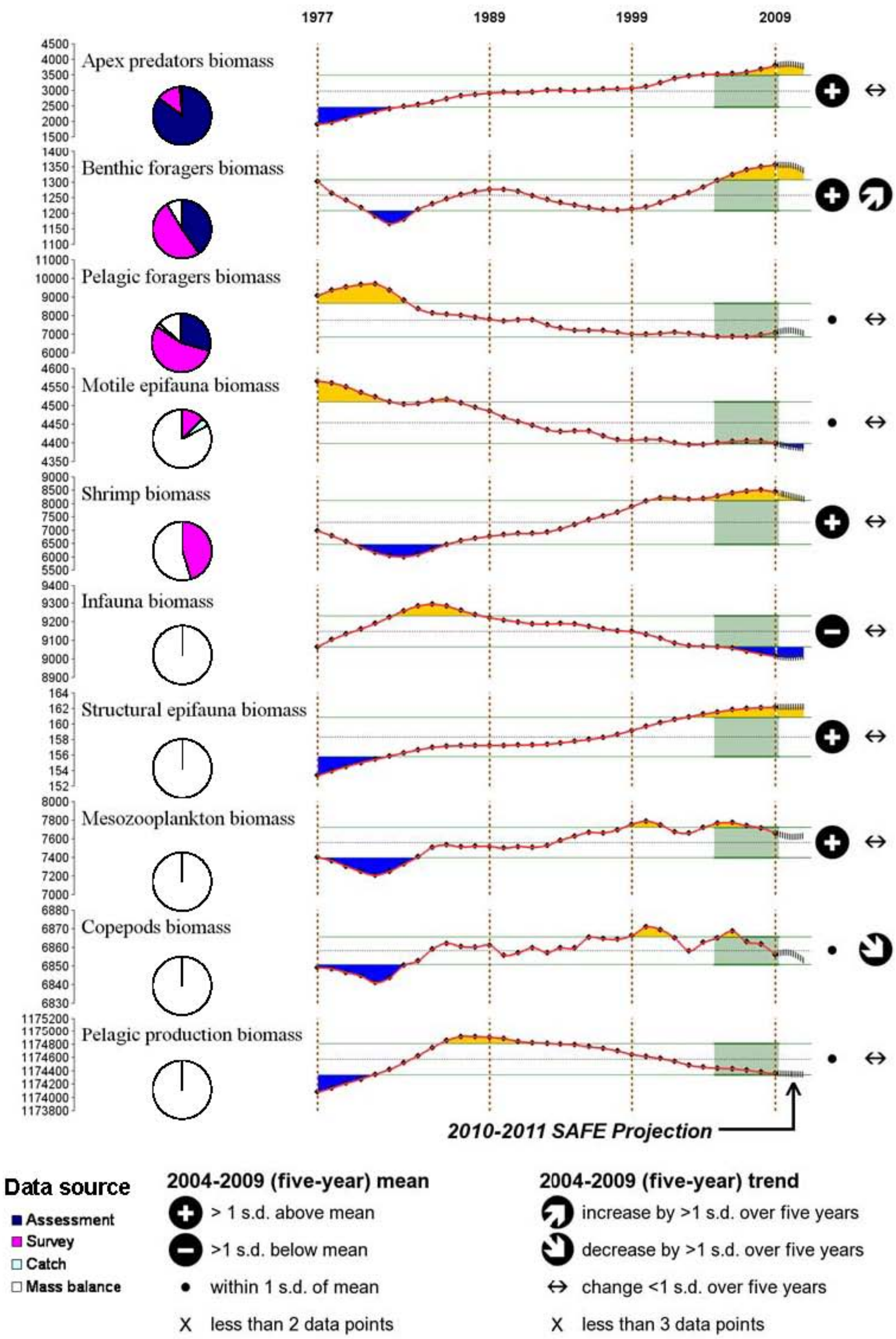

Figure H. Ecosystem trends – Gulf of Alaska guild analysis: biomass. Green shaded area shows +/- one standard deviation of time series over measured time period.

Fishing and Fisheries Trends

- A motion passed the NPFMC in February 2009 which would close all waters north of the Bering Strait to commercial fishing as part of the development of an Arctic Fishery management plan.
- 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. One crab stock is overfished.
- Community size spectrum analysis of the EBS fish community indicates there was not a systematic decline in the amount of large fish during 1982 to 2006.
- Recent exploitation rates on EBS biological guilds were within one standard deviation of long-term mean levels, except for forage species (dominated by walleye pollock) which had relatively high exploitation rates 2005-2007 as the stock declined. The 2008 and 2009-recommended catch levels were within one standard deviation of the historical mean.
- Discards and discard rates in 2008 increased slightly in the GOA and decreased in the EBS and AI. All remained below those observed prior to 1998, when regulations were implemented prohibiting discards of pollock and cod.
- An increase in lingcod bycatch in the GOA bottom trawl fleet targeting rock sole and arrowtooth flounder northeast of Kodiak Island was observed from 2005, with a dramatic increase in 2008.
- The number of trawl and pot vessels remained similar in 2008, but the number of hook and line vessels increased slightly.
- In 2008, observed EBS hook and line effort increased but was still below the 11-year average, and was near average in the AI and GOA. Bottom trawl effort in 2008 was near or below the 11-year average in all regions. Pot effort was similar to that seen in the last 8 or 9 years in all regions.
- Seventy-two BSAI fishing communities (or 82%, not including seasonal use areas) have had increasing populations between 1990 and 2007. Communities with decreases during this time period are concentrated in Aleutians East and West along with Lake and Peninsula and Bristol Bay Boroughs.

Fishing and Fisheries – Eastern Bering Sea

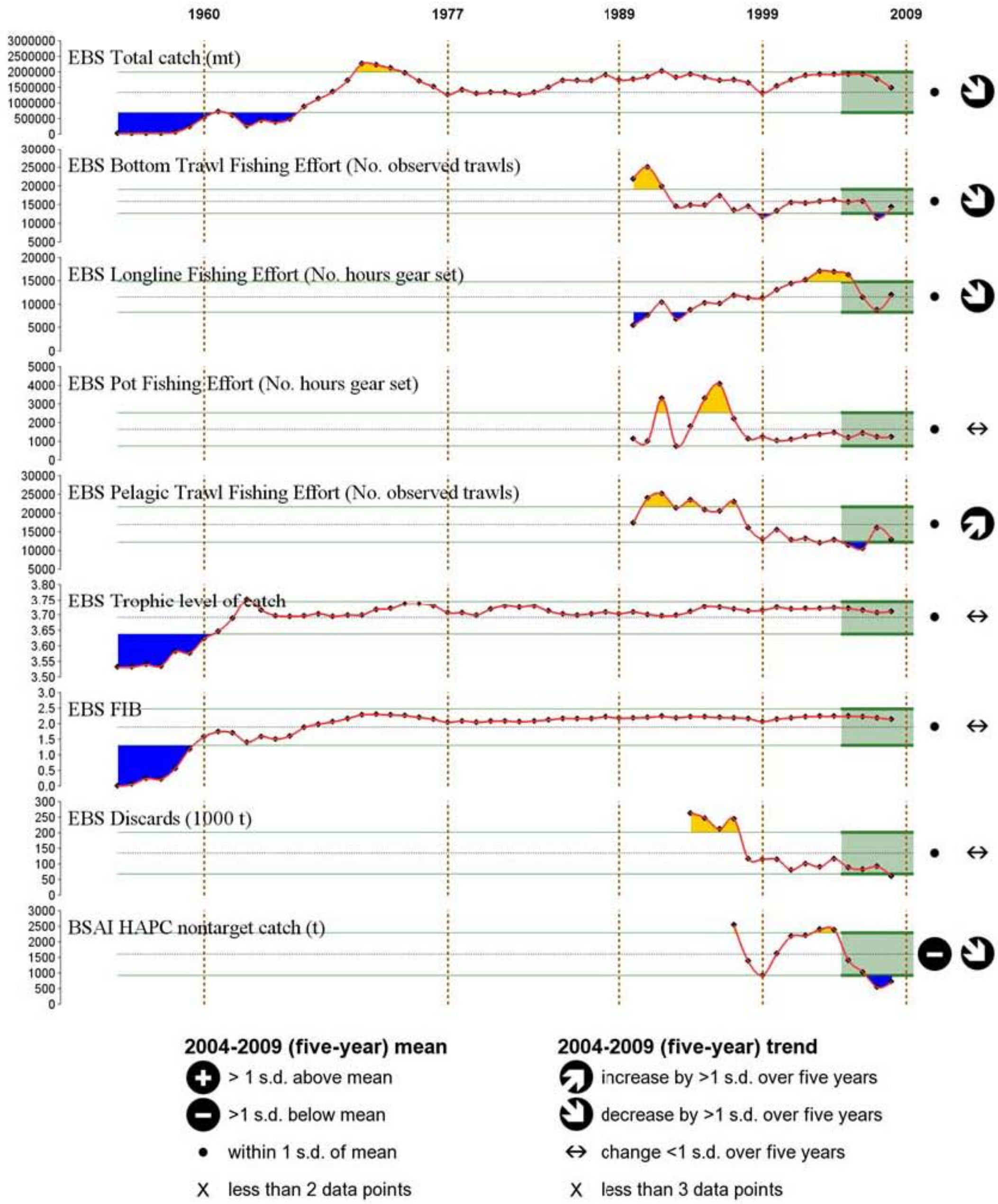

Figure I. Fishing and fisheries − Eastern Bering Sea. Green shaded area shows +/- one standard deviation of time series over measured time period.

Fishing and Fisheries – Aleutian Islands

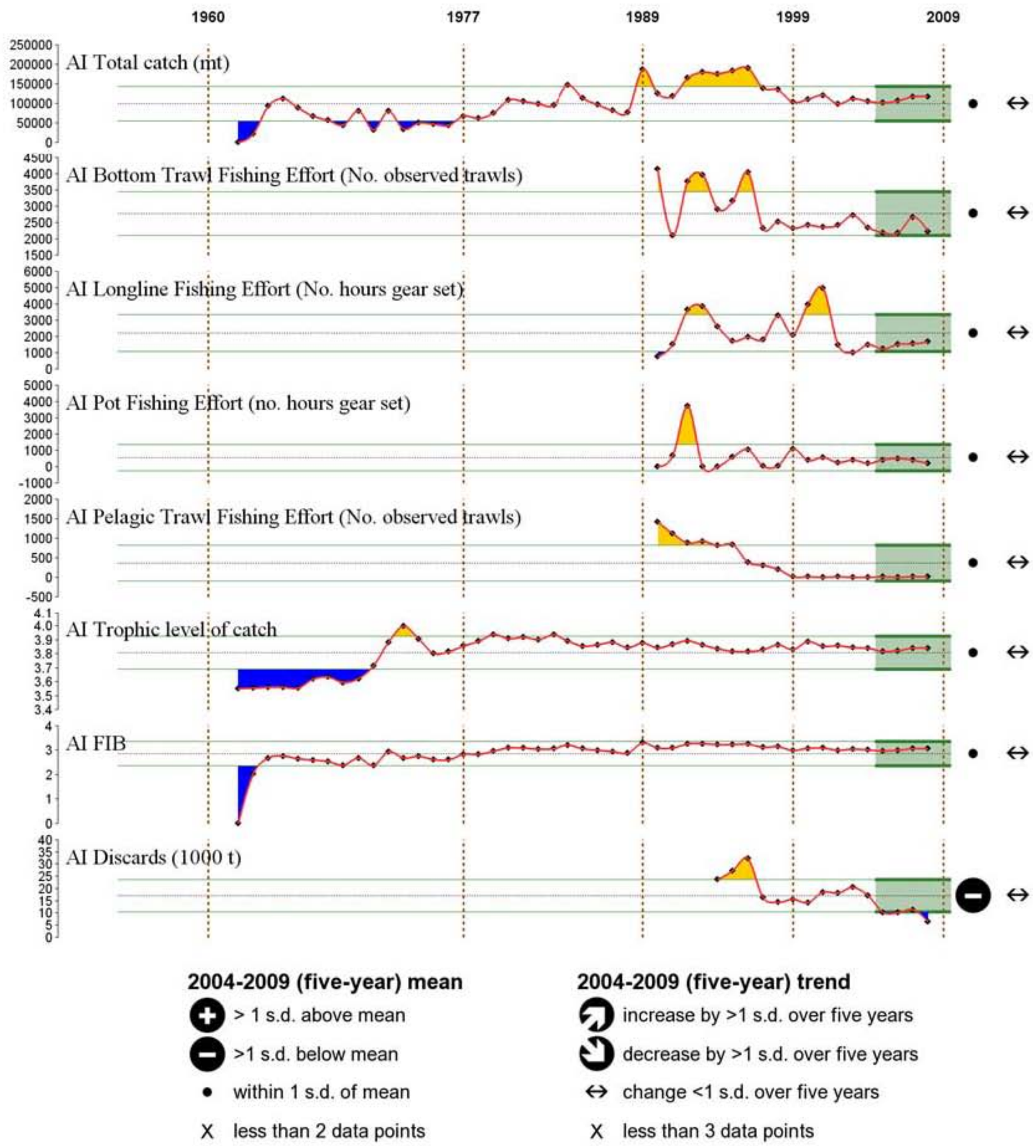

Figure J. Fishing and fisheries – Aleutian Islands. Green shaded area shows +/- one standard deviation of time series over measured time period.

Fishing and Fisheries – Gulf of Alaska

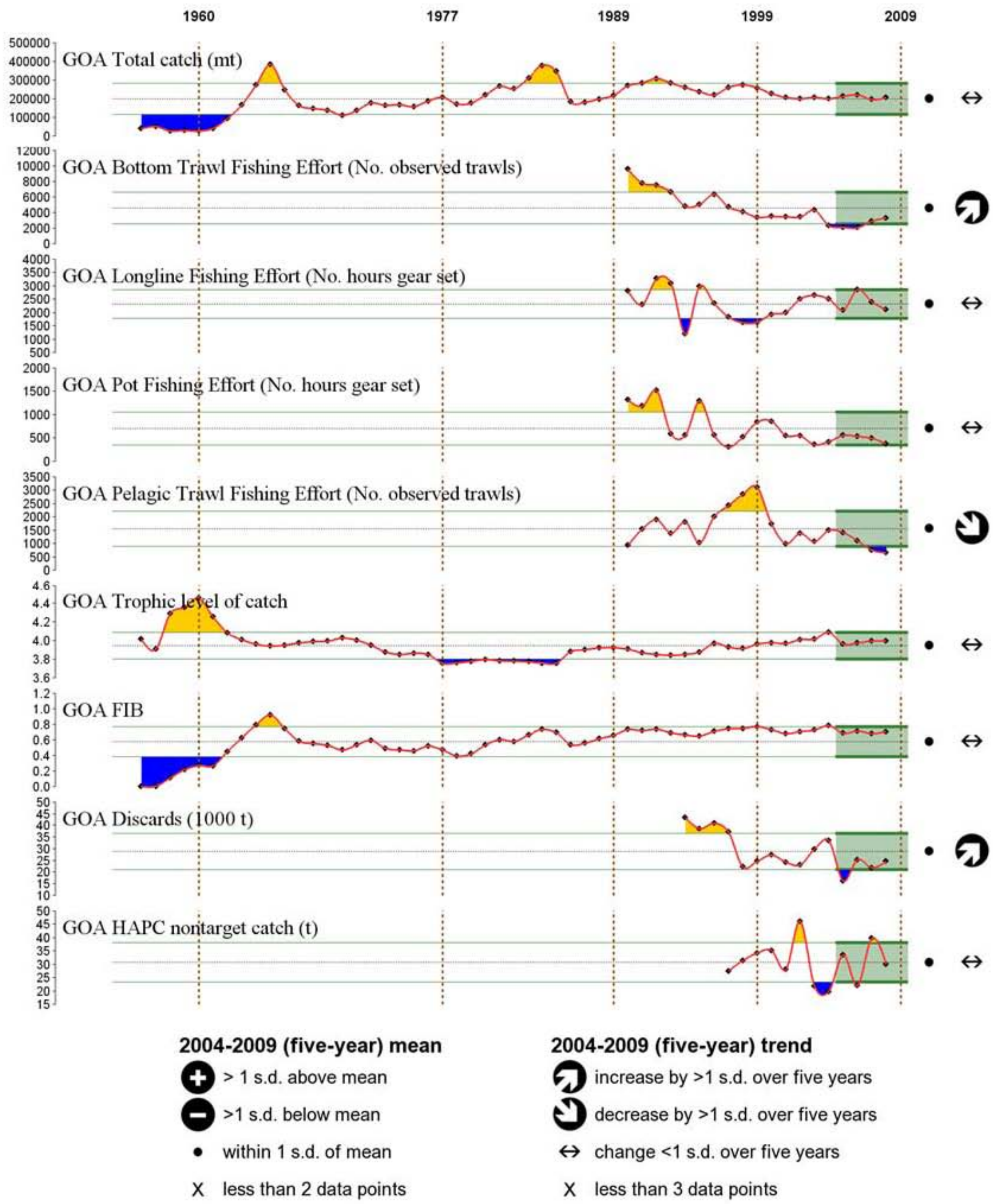

Figure K. Fishing and fisheries – Gulf of Alaska. Green shaded area shows +/- one standard deviation of time series over measured time period.

Fishing and fisheries -- Eastern Bering Sea fisheries catch and exploitation rate by guild

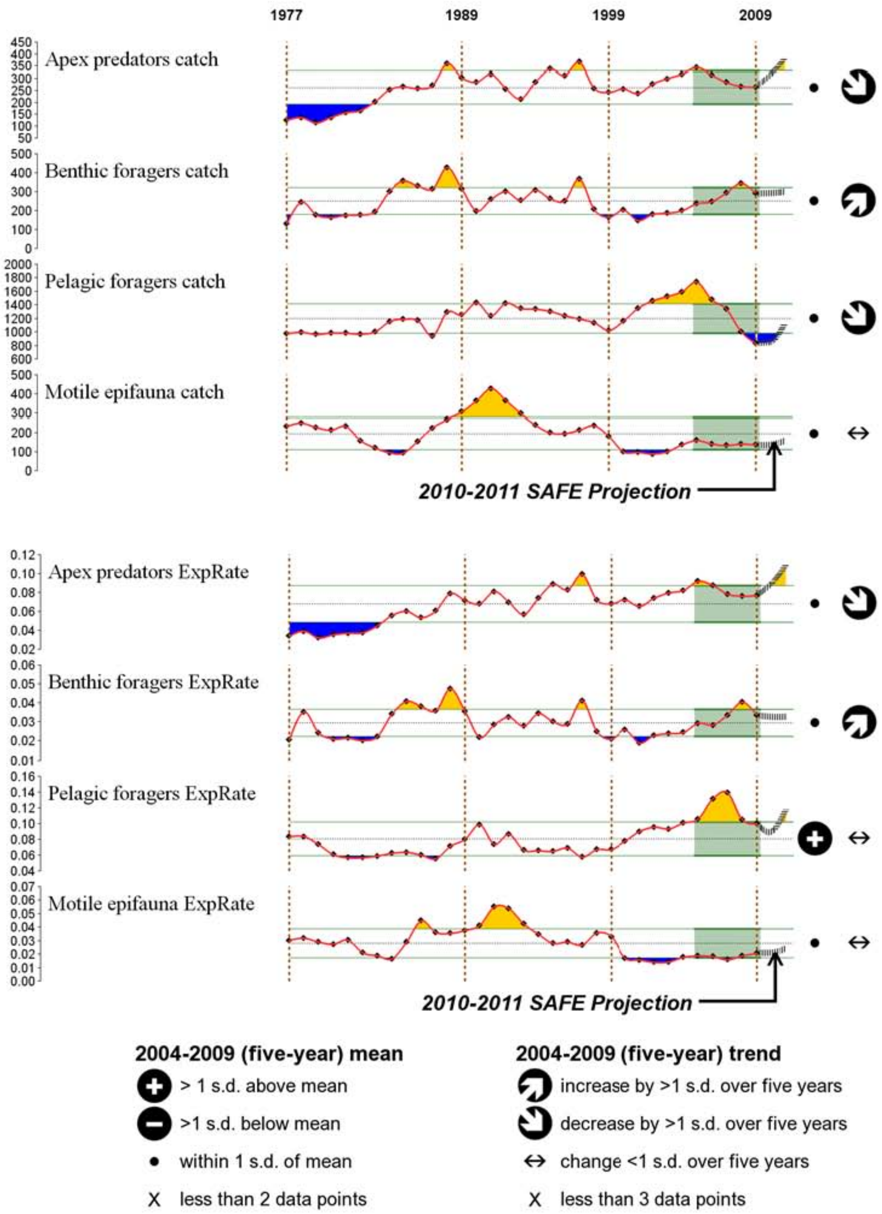

Figure L. Fishing and fisheries -- Eastern Bering Sea fisheries catch and exploitation rate by guild. Green shaded area shows +/- one standard deviation of time series over measured time period.

Fishing and fisheries -- Gulf of Alaska fisheries catch and exploitation rate by guild

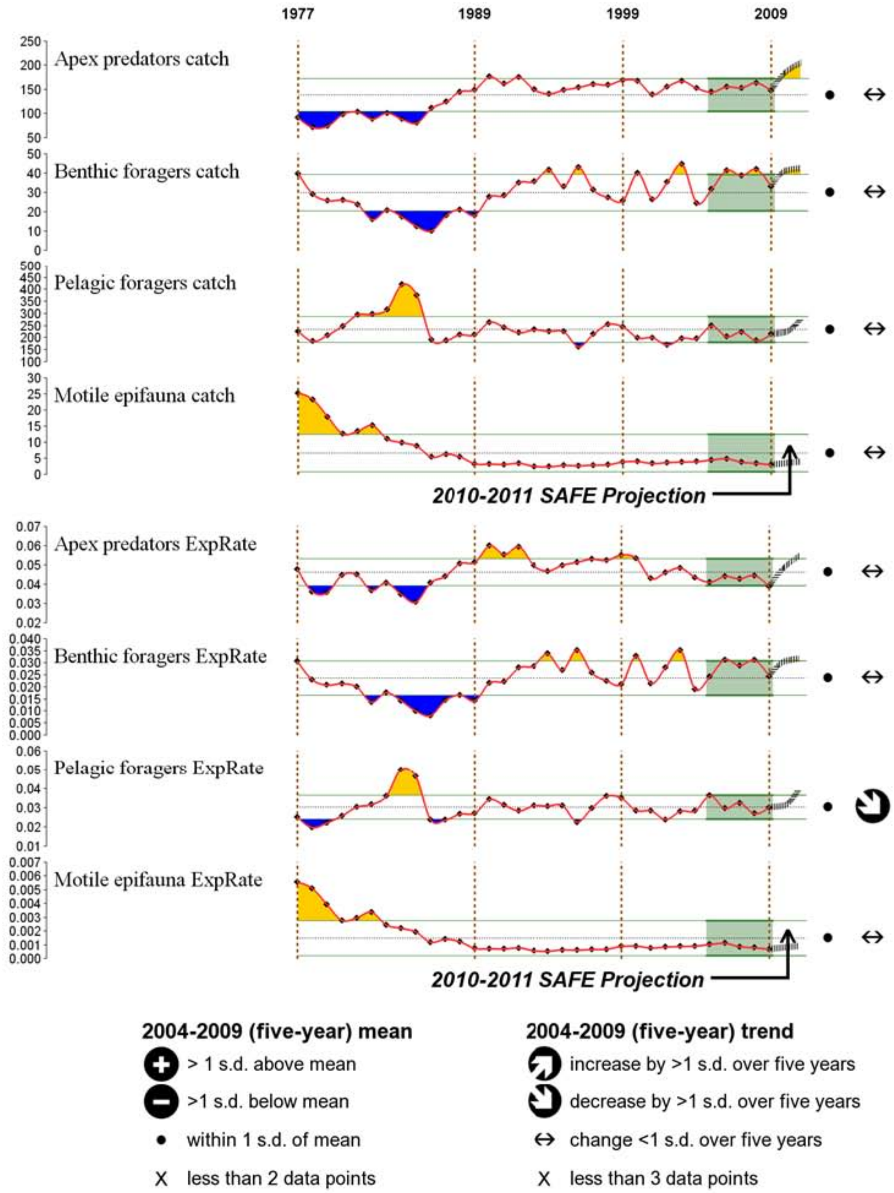

Figure M. Fishing and fisheries -- Gulf of Alaska fisheries catch and exploitation rate by guild. Green shaded area shows +/- one standard deviation of time series over measured time period.

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SUMMARY OF MAJOR DOCUMENT CHANGES

- **Added the following new contributions in September 2009:**

- **Updated the following sections/contributions in September 2009:**

- **Updated the following sections/contributions in November 2009:**

RESPONSES TO COMMENTS OF THE SCIENTIFIC AND STATISTICAL COMMITTEE (SSC)

December 2008 SSC Comments

1. *The communication tools presented by Dr. Aydin appear to hold promise as a concise way of packaging large amounts of complex information. The SSC suggested that he continue work on selection and standardization of these tools and that he consider, for aggregated information, the most appropriate groups to aggregate if the purpose is to distinguish bottom-up effects of environmental change from the effects of fishing. A potentially useful index of fisheries effects on the ecosystem is the bycatch of seabirds. Projections for various indices need to be better explained and should consider taking survey CVs into account.*

Ecosystem Assessment authors continue to work towards a concise synthesis and presentation of ecosystem information. Authors improved explanations of projections and considered accounting for survey CVs.

2. *As more information is added …, good summaries are increasingly important…The SSC found the summary bullets in the Executive Summary helpful. It would be valuable for each of the authors supplying a section to give a one or two sentence summary of the importance of the information presented, and how it can be used to inform management decisions. The great value of this Ecosystem Considerations Chapter is to provide all with a summary of the newest and most important findings and trends as a heads-up for developing management responses and research priorities. The most important of these items could be brought to the reader's attention in the Executive Summary.*

In the past, contributors to the Ecosystem Considerations report were asked to provide a description of their contributed index/information, summarize the historical trends and current status of the index, and identify potential factors causing those trends. New this year, 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 as well as with the assembly of the Executive Summary.

3. *Two items of information stood out as particularly important for informing management and research efforts:*

i) The apparent recovery of mesozooplankton biomass with the return of ice-associated, early blooms suggests that the prey resources for juvenile (and adult) pollock may support a rebuilding population. That said, we lack an explanation as to why zooplankton increased in all domains, including those in which Neocalanus spp. predominate, as they not known to be affected by ice cover or the ice-associated bloom. Likewise, euphausiids (krill) appear to have recovered over the middle shelf, given the important results of the BASIS program. Again, we lack information on the mechanisms whereby climate variability may influence the availability of this important prey type either in spring or in summer. There is a need for research on the mechanisms that control the abundance of large zooplankton in all domains, including the abundance of euphausiids over the shelf and shelf edge.

ii) The findings of the BASIS program that age-0 pollock were more numerous in the warm years of 2002-2005, but were in poorer condition and, in the absence of euphausiids and large copepods, were subject to greater predation by larger pollock and juvenile salmon is an important addition to our understanding of controls on early life survival of pollock in the eastern Bering Sea and may eventually help improve estimates of year class strength at early stages.

The new information on zooplankton and age-0 pollock points to the great value of the BASIS program. The SSC recognizes the importance of full coverage of the BASIS grid and the importance of the time series now being developed.

We agree.

4. *In the reporting of data on zooplankton abundance, it is important to provide information on the methods used and the timing of sampling, particularly when comparing long-term data collected under different programs. Likewise, when looking at the size composition, condition and diets of fish, it would be helpful to present these by domain and latitude, and if appropriate, by season (date) of capture.*

This SSC comment has been passed along to the pertinent contributors.

5. *In the reporting of condition factor, the size and birth date of age-0 fish should be considered. Fish may use energy primarily for growth at certain ages and for storage at other ages. Since there is considerable variability in the dates when pollock spawn within a given year as well as between years, in making interannual comparisons of fish condition, age-0 birth date and the date of sampling should be considered.*

This SSC comment has been passed along to the pertinent contributors.

6. *The SSC encourages continued research underlying recent declines in surplus production for a number of species*

Okay.

7. *The SSC appreciates the clear timeline of when various sections were updated (pages xiv-xvi) and the listing of the four sections new to 2008 version of this chapter (page xiv). It was also most helpful to have a clear list of responses to the previous comments by the SSC, and plans for future responses where work was still in progress (xvii-xix). In contrast to the many excellent contributions presented in the Chapter, a number of sections were represented solely by reference to website presentations. This is appropriate when no new information is available since the last report. However, when dealing with issues of considerable potential management impact, it is important to obtain annual updates. In this regard, the lack of sections on pinnipeds was particularly unfortunate. Two species, Steller sea lion and northern fur seal, have been identified as is endangered or depleted, and the ice seals are being considered for listing. There are concerns in the case of the first two species that competition with fisheries may be a problem. Under these circumstances it seems particularly important for the best possible evaluation of the status of these pinnipeds and their ecological needs be included annually in the Ecosystem Considerations Chapter. We also noted the lack of updated information on salmon, which was likely requested and available, but not transmitted to staff for the development of this report.*

Marine mammal updates were requested but not provided, in part due to the timing of the field survey and report due dates. It is difficult to get a comprehensive summary of salmon run information. We will attempt to improve this section in future drafts.

8. *Executive Summary of Recent Trends: There were no bullets addressing trends in seabirds, marine mammals, or bycatch of seabirds/mammals. These were addressed under the Ecosystem Assessment, but could also be noted in the Executive Summary.*

Okay. We will continue to work on the Executive Summary. Sometimes bullets are not included if the information was not updated, but older information is still summarized in the Ecosystem Assessment due to its importance to ecosystem-based management objectives. Occasionally the addition of bullets is overlooked due to the timing of receipt of the information and the editor's ability to incorporate the information and remember everything prior to report due dates!

9. *Table 1: Why not use piscivorous birds and mammals as indicators of forage fish?*

This is a good idea. One potential drawback is that, due to the timing of field surveys, we often do not get updated information on marine mammals and, particularly, seabirds for the latest year of consideration.

10. *Page 6, and 168: Pollock are in many ways a low trophic level fish. As the major fishery, their exploitation masks any shifts in trophic level of secondary species in the overall catch. It would be helpful to calculate this index with and without pollock. It would also be of interest to see this index with and without arrowtooth flounder.*

Although there has been a general increase in the amount of catch since the late 1960s in all areas, the trophic level of the catch has been high and stable over the last 25 years. The overall trophic level of the catch did not decrease with time when pollock were excluded from the catches. Excluding pollock from EBS catches did result in more temporal variability in the trophic level of the catch.

The EBS FIB index decreased during 2007-2008 due to decreased pollock catches. When pollock were excluded from EBS catches, the FIB index was lower, but still relatively stable, fluctuating around 1.7 for approximately the last 30 years. Pollock catch has had a 'stabilizing' effect on the trophic level and FIB index of the Eastern Bering Sea catch, since it comprised the majority of the catch since the late 1960s. Another species of interest is arrowtooth flounder because of recent population increases. Since this species comprises a small proportion of the catches, it has virtually no effect on the trophic level of the catch or the FIB index in the EBS or GOA.

11. *Page 9: When referring to zooplankton please be specific- copepods, euphausiids, etc. Identify the important species or groups, as sampling methods for one group may be entirely inadequate for another.*

We will try!

12. *Page 10 and elsewhere: There is no Alaska EEZ. Please refer to the US EEZ off of Alaska as an alternative.*

Okay!

13. *Page 11: Is it possible that the reduction in HAPC biota bycatch is the result of prior disturbance?*

This was added as a possible cause for the reduction in HAPC biota bycatch.

14. *Page 14: If arrowtooth flounder were not in the mix, would the CSS be declining? And, against what baseline is the CCS measured? Are the fish as big as they were at the very start of Bering Sea fisheries?*

The CSS slopes did not decrease over the period 1982-2006. The decline in CSS slopes observed in the last 5 years of the time series was due to an increase in 20 cm size class of fish. If the 20 cm size class is excluded from the slope estimation, there is no decrease in CSS slopes in the last five years of the time series. If arrowtooth flounder are excluded from the analysis, the overall trend in CSS slopes does not change. The trends in the CSS slopes were described for the period of 1982-2006, when consistent sampling gear and protocols were used. It is unknown if the fish are as big as they were at the very start of Bering Sea fisheries.

15. *Page 16: It is unclear that Minke whales should be included here. Were they ever the target of whaling?*

Minke whales were exploited, but to a lesser extent than other whale species.

16. *Page 17: The idea of large scale experiments has been raised many times and judged to be unfeasible. It might be better not to resurrect this issue again.*

Okay.

17. *Page 34: The SSC found the brief explanation of the importance of this finding helpful. It could be a model for similar brief statement of significance at the ends of other contributions.*

New in 2009, contributors were asked to describe why the index they are providing is important to groundfish fishery management and the 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.

18. *Page 38, 39 and Fig. 7, 8: What is the skill of this model? Has a formal analysis been conducted? At least, put in the observed year class strength so that we can qualitatively judge the efficacy of this model.*

This SSC comment was passed along to the pertinent contributor. The contributing author stated that seasonal rainfall and wind mixing are two of the input components to the FOCI Recruitment Forecast. They are not meant to be stand alone predictors, but an assessment of two of the crucial "switches" necessary for pollock survival. These two models were removed from the Ecosystem Considerations report, since they are included in the GOA pollock stock assessment.

19. *Page 67: Upwelling is more likely through Bering Canyon, rather than through Unimak Pass.*

This SSC comment has been passed along to the pertinent contributors.

20. *Page 75: Isn't figure 45 the actual survey stations for 2008 BASIS, not the 'Proposed' stations?*

This SSC comment has been passed along to the pertinent contributors.

21. *Page 79: Are there other sources of information that might support the high numbers of herring projected to have been present in the 1980s? Landings? Local knowledge?*

This SSC comment has been passed along to the pertinent contributors.

22. *Page 90: Rather than just rejecting the hypothesis, use AIC approaches to investigate the relative importance of various factors such as predation, temperature, condition, etc.*

This is a good idea. Additional analyses are underway to examine this subject further.

23. *Page 98: Can you determine whether the recent changes are more likely due to temperature or predation pressure?*

The author states in the updated contribution that it is unknown if predation, environmental changes, or fishing effort are contributing to these changes.

24. *Page 119: The section on seabird bycatch could be reduced, as some of the tables and figures are repetitive and this level of detail is not needed for this report. It will be more effective in this document if it focuses on highlights. For example, why was there such an increase in the magnitude of bycatch in 2006? Was there a change in the fishery, or perhaps there is evidence that the birds may have changed their distribution of behaviors?*

This SSC comment has been passed along to the pertinent contributors.

25. *Page 140: Why are the points joined in Figure 90?*

This SSC comment has been passed along to the pertinent contributors.

Selected December 2007 SSC Comments

1 "*….Of concern is the increased bycatch of Chinook salmon in the Bering Sea pollock fishery, and the increased bycatch of forage fish. For the first time ever, the Chinook Salmon Savings Area was closed to fishing during the pollock A season in 2006. Also the catch of forage fish increased in the BSAI and decreased in the GOA. The SSC notes that Table 1.2 of the GOA pollock chapter shows increased bycatch in that fishery but those data were not discussed in the Ecosystems chapter nor were the ecosystem implications of these removals discussed*."

Prohibited species bycatch, including bycatch of chinook salmon, is tracked and discussed in the Ecosystem Considerations report (pp. 182-184 in last year's report). The increased bycatch of chinook salmon was also noted in the Executive Summary of last year's Ecosystem Considerations report. Time trends in forage species are also tracked and discussed in the Ecosystem Considerations report in the "Time trends of non-target catch" (pp. 185-187 in last year's report), in the Ecosystem Assessment (p. 35 in last year's report), and in the Executive Summary (p. 17 in last year's report). Potential implications of the bycatch were not specifically addressed in the Ecosystem Assessment and this is something the authors will try to incorporate.

2. "*The SSC suggests that the findings from the BEST/BSIERP programs may be useful and interesting and requests that at least a summary of that work be included in future ecosystems appendices (BEST/BSIERP start in 2008, NPRB and NSF will combine resources for three years of field research on the eastern Bering Sea Shelf, from St. Lawrence Island to the Aleutians, followed by two more years for analysis and reporting)*."

The authors agree and will incorporate summaries of that work as they become available.

RESPONSES TO THE ALEUTIAN ISLANDS FISHERY ECOSYSTEM PLAN (AI FEP)

The North Pacific Fishery Management Council appointed a Team to produce an Aleutian Islands (AI) Fishery Ecosystem Plan (FEP). The goal of the FEP is to provide enhanced scientific information and measurable indicators to evaluate and promote ecosystem health, sustainable fisheries, and vibrant communities in the Aleutian Islands region. The FEP is intended to be an educational tool and resource that can provide the Council with both an 'early warning system', and an ecosystem context to decisions affecting the Aleutian Islands area. The AI FEP Team utilized information and indicators presented in this report (Ecosystem Considerations report) and also suggested improvements or new indicators that could be used to improve the assessment of important interactions in the AI (http://www.fakr.noaa.gov/npfmc/current_issues/ecosystem/AIFEP507.pdf). In collaboration with AI FEP Team scientists, efforts to produce and improve AI indicators in the Ecosystem Considerations report have begun. Part of these efforts include requesting that contributing authors break out the AI from the Bering Sea as well as include some new AI-specific indicators in this report. Most recommended indices have been requested from existing or potential contributing authors. In the 2007 draft, two indicators were added: 1. Pot fishing effort in the AI, and 2. Eddies in the AI. There was also an AI-specific climate summary added to the North Pacific Climate contribution. Some improvements recommended by the AI FEP Team that were included in this and past reports include: 1. Forage -AI (relative mean CPUE and frequency of occurrence of forage species), 2. Miscellaneous species -AI (relative mean CPUE and frequency of occurrence of miscellaneous species), 3. HAPC Biota -AI (relative mean CPUE and frequency of occurrence of HAPC species), 4. Trophic level of the catch in the AI, and 5. Pelagic trawl fishing effort in the AI. Additionally, a contribution examining the distribution of rockfish species along environmental gradients in the Gulf of Alaska and Aleutian Islands bottom trawl surveys was added to the report in 2007 and updated in 2008. Some indices and information recommended by the AI FEP team, such as predator and prey trends, are included in individual stock assessments. It is expected that in future drafts we will be incorporating more of the AI FEP- recommended indices.

1. AI-specific climate summary added to the North Pacific Climate contribution
2. Maps of sea surface temperatures and sea level pressures in the North Pacific
3. An index of the Aleutian Low (North Pacific Index)
2. Eddies in the AI

3. Distribution of rockfish species along environmental gradients in the Gulf of Alaska and Aleutian Islands bottom trawl surveys
4. Forage -AI (relative mean CPUE and frequency of occurrence of forage species)
5. Miscellaneous species -AI (relative mean CPUE and frequency of occurrence of miscellaneous species)
6. HAPC Biota -AI (relative mean CPUE and frequency of occurrence of HAPC species)
7. Pelagic trawl fishing effort in the AI
8. Pot fishing effort in the AI
9. Trophic level of the catch in the AI (including a plot of catch by trophic level over time)
10. Total AI catch of groundfish, halibut and crab
11. Time trends in groundfish discards were separated for the AI

INTRODUCTION

The Ecosystem Considerations appendix is comprised of three main sections:

I. Ecosystem Assessment
II. Ecosystem Status Indicators
III. Ecosystem-based Management Indices and Information.

The purpose of the first section, Ecosystem Assessment, is to summarize historical climate and fishing effects on the eastern Bering Sea/Aleutian Islands and Gulf of Alaska ecosystems using information from the other two sections and stock assessment reports. 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. We are currently working on a more concise ecosystem assessment utilizing a blend of data analysis and modeling to clearly communicate the current status and possible future directions of ecosystems.

The purpose of the second section, Ecosystem Status Indicators, is to provide new information and updates on the status and trends of ecosystem components to stock assessment scientists, fishery managers, and the public. The goals are 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.

The purpose of the third section, Ecosystem-based Management Indices and Information, is 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.

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. This enhancement, which will take several years to fully realize, will 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 be built upon in future years. Evaluation of the meaning of the observed changes needs to be done separately and 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. Future evaluations will need to 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 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. New 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.

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.

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.

It is particularly important that more time is spent in the development of ecosystem-based management indices. Ecosystem-based management indices should be developed to 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.

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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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 and Gulf of Alaska 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 (Elliot 2002).

In applying this framework we initially determined four objectives based, in part, on stated ecosystem-based management goals of the NPFMC: maintain predator-prey relationships, maintain diversity, maintain habitat, and incorporate/monitor effects of climate change. Drivers and pressures pertaining to those objectives were identified and a list of candidate indicators were selected that address each objective and candidate indicators were chosen based on qualities such as, availability, sensitivity, reliability, ease of interpretation, and pertinence for addressing the objectives (Table 1). 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 NOAA’s 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.

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.

Objective	Drivers	Pressures/Effects	Significance Threshold	Indicators
Maintain predator-prey relationships and energy flow	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 & 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
Maintain diversity	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
Maintain habitat	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
Incorporate/ monitor effects of climate change	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

Results

Objective: Maintain predator prey relationships and energy flow
Drivers: Need for fishing, per capita seafood demand
Pressures: Availability, removal, or shift in ration between critical functional guilds
Status and impacts indicators:

1. Biomass, catch, and exploitation rates of ecological guilds.
Contributed by Kerim Aydin and Sarah Gaichas, NMFS

Index: For the EBS and GOA, all species included in food web models (Aydin et al. 2007) were aggregated into 12 guilds by trophic role. The guilds span the trophic levels between phytoplankton and apex predators and include a separate pathway for pelagic and benthic components of the ecosystem (Table 2). For each guild, time trends of biomass are presented for 1977-2009. Catch and exploitation rate (catch/biomass) are presented for guilds with exploitation rates exceeding 0.0001. Differences in time series data availability led to different methods for EBS and GOA ecosystem guild analysis. EBS biomass trends are summed stock assessment model estimates or scaled survey data, where available, for each species within the guild. If neither time series are available, the species is assumed to have a constant biomass equal to the mid-1990s mass balance level estimated in Aydin et al. (2007). Inconsistencies in the GOA trawl survey time series in depth and area surveyed made ecosystem model fits to trends more reasonable than summing scaled survey data. The GOA ecosystem model was forced by stock assessment model estimates where available for each species within the guild, and fit to survey time series, catch data, groundfish diet data, and the mid-1990's mass balance for all other species. In both regions, catch data was directly taken from the Catch Accounting System and/or stock assessments for historical reconstructions. Pie charts indicate the relative contribution of each data type to the average biomass within each guild (Figs. E, H). For 2010-2011 projections, the stock assessment authors' recommended catch and estimated biomass time series were used in both regions.

EBS status and trends: Current (2004-2009) mean biomass, catch, and exploitation rates have been within +/- one standard deviation of 1977-2009 levels for all guilds except pelagic foragers (biomass below mean, exploitation rate above mean) and structural epifauna (biomass above mean). Apex predators and pelagic foragers have decreasing trends in biomass, catch, and exploitation rates, while benthic foragers have increasing catch and exploitation rate trends. The apex predator trends are driven largely by a decrease in Pacific cod biomass and catch. The pelagic foragers guild is dominated by walleye pollock (77% of guild biomass in 2009), whose decrease with general declines in other forage species has brought the biomass of this group to overall low levels. Exploitation rate was over one standard deviation above the mean from 2004-2007, however the decreased catches in 2008 and 2009 have decreased the pelagic foragers exploitation rate back towards its long-term mean. Increasing trends in benthic forager catch and exploitation rate reflect increased ABCs for flatfish species allowable under the 2 million metric ton OY cap with decreased pollock ABCs. Copepod trends through 2007 have been returning towards the mean from historically low levels observed between 2001-2004; no new data are available since 2007.

GOA status and trends: Current (2004-2009) mean biomass is more than one standard deviation above 1977-2009 mean levels for apex predators and benthic foragers, and trends for catch and exploitation rate are also increasing for these guilds. The apex predator guild is driven by the stock assessment-estimated increase in arrowtooth flounder, and to a lesser extent in Pacific halibut and Pacific cod, while the benthic forager guild is driven by a stock assessment-estimated increase in flathead sole and survey trends for increasing skates and flatfish. In contrast, pelagic foragers recent mean biomass is one standard deviation below the long term mean, driven by the stock assessment estimated decline in pollock. Catch and exploitation rates for pelagic foragers remain within one standard deviation of the long term mean. GOA shrimp are above long term mean biomass, a trend which agrees with trawl survey results. Based on assessment and survey results for the data rich guilds, current status of infauna is estimated to be below long term average; structural epifauna, mesozooplankton, and copepods are predicted to be above long term average; and pelagic primary production remains close to the long term average.

Table 2. EBS and GOA guild composition and percent biomass based on 2009 surveys/assessments.

EBS Apex predators		GOA Apex predators	
Arrowtooth	31.49%	Arrowtooth	59.19%
P. Cod	29.67%	P. Cod	13.26%
Grenadiers	12.49%	P. Halibut	10.04%
Alaska skate	7.96%	Grenadiers	8.64%
Lg. Sculpins	6.26%	Sablefish	4.00%
P. Halibut	4.02%	Rougheye Rock	1.35%
Gr. Turbot	2.42%	Lg. Sculpins	0.82%
Other skates	1.29%	Dogfish	0.59%
Kamchatka fl.	1.16%	Sperm and Beaked Whales	0.36%
Sleeper shark	0.87%	Longnose skate	0.36%
N. Fur Seal	0.42%	Other skates	0.28%
Wintering seals	0.39%	Misc. fish deep	0.28%
Minke whales	0.31%	Salmon shark	0.21%
Sablefish	0.31%	Porpoises	0.14%
Sperm and Beaked Whales	0.23%	Sleeper shark	0.12%
Resident seals	0.17%	N. Fur Seal	0.08%
Belugas	0.16%	Steller Sea Lion	0.07%
Murres	0.11%	Puffins	0.05%
Misc. fish deep	0.11%	Murres	0.04%
Porpoises	0.05%	Sea Otters	0.03%
Rougheye Rock	0.03%	Resident seals	0.02%
Steller Sea Lion	0.02%	Minke whales	0.02%
Resident Killers	0.02%	Resident Killers	0.01%
Sea Otters	0.01%	Kittiwakes	0.01%
Kittiwakes	0.01%	Fulmars	0.01%
Fulmars	0.01%	Gulls	0.00%
Puffins	0.01%	Cormorants	0.00%
Shearwater	0.01%	N. Fur Seal_Juv	0.00%
Kamchatka fl._Juv	0.00%	Transient Killers	0.00%
N. Fur Seal_Juv	0.00%	Shearwater	0.00%
Cormorants	0.00%	Storm Petrels	0.00%
Transient Killers	0.00%	Albatross Jaeger	0.00%
Gulls	0.00%	Steller Sea Lion_Juv	0.00%
Albatross Jaeger	0.00%		
Steller Sea Lion_Juv	0.00%		
Storm Petrels	0.00%		

EBS Motile epifauna		GOA Motile epifauna	
Brittle stars	27.15%	Brittle stars	30.83%
Sea stars	19.11%	Hermit crabs	23.77%
Urchins dollars cucumbers	14.38%	Misc. crabs	11.37%
Hermit crabs	8.18%	Urchins dollars cucumbers	10.84%
Opilio	7.89%	Eelpouts	6.88%
Eelpouts	7.52%	Snails	5.61%
Snails	5.72%	Octopi	5.27%
Misc. crabs	4.97%	Bairdi	4.54%
Bairdi	2.89%	Sea stars	0.85%
King Crab	1.90%	King Crab	0.04%
Octopi	0.29%		

EBS Infauna		GOA Infauna	
Bivalves	69.23%	Bivalves	45.60%
Polychaetes	11.15%	Benthic Amphipods	21.08%
Benthic Amphipods	9.35%	Polychaetes	13.54%
Misc. Crustacean	7.29%	Misc. worms	12.66%
Misc. worms	2.98%	Misc. Crustacean	7.13%

EBS Structural epifauna		GOA Structural epifauna	
Urochordata	45.42%	Urochordata	44.02%
Hydroids	19.84%	Hydroids	19.73%
Sea Pens	12.37%	Sponges	19.32%
Sponges	11.58%	Anemones	15.97%
Anemones	10.48%	Corals	0.86%
Corals	0.32%	Sea Pens	0.10%

EBS Benthic foragers		GOA Benthic Foragers	
YF. Sole	26.22%	Other sculpins	23.75%
N. Rock sole	25.97%	FH. Sole	23.18%
AK Plaice	21.05%	Dover Sole	8.68%
FH. Sole	11.69%	S. Rock sole	7.63%
Other sculpins	3.98%	Rex Sole	7.53%
YF. Sole_Juv	3.04%	YF. Sole	5.37%
Misc. Flatfish	2.45%	N. Rock sole	4.31%
FH. Sole_Juv	1.72%	Misc. Flatfish	4.14%
P. Cod_Juv	1.17%	P. Cod_Juv	3.22%
N. Rock sole_Juv	1.16%	FH. Sole_Juv	2.69%
Walrus Bd Seals	0.83%	Big skate	2.58%
Rex Sole	0.37%	Arrowtooth_Juv	1.93%
Gray Whales	0.24%	Shortraker Rock	1.78%
Shortraker Rock	0.07%	Gray Whales	1.30%
Shortspine Thorns	0.03%	Shortspine Thorns	1.16%
P. Halibut_Juv	0.00%	AK Plaice	0.33%
Greenlings	0.00%	Greenlings	0.30%
Dover Sole	0.00%	P. Halibut_Juv	0.10%
Arrowtooth_Juv	0.00%	Shortspine Thorns_Juv	0.00%

EBS Pelagic foragers		GOA Pelagic Foragers	
W. Pollock	63.10%	Capelin	33.29%
W. Pollock_Juv	13.85%	Sandlance	11.61%
Herring	3.84%	Squids	6.84%
Myctophidae	3.38%	Oth. managed forage	6.43%
Misc. fish shallow	2.80%	Eulachon	5.09%
Sandlance	2.19%	POP	4.58%
Squids	2.18%	Misc. fish shallow	4.56%
Fin Whales	1.85%	W. Pollock	3.87%
Oth. managed forage	1.68%	Salmon returning	3.56%
Capelin	1.10%	Oth. pelagic smelt	2.74%
Scyphozoid Jellies	0.86%	Myctophidae	2.68%
Herring_Juv	0.71%	W. Pollock_Juv	2.28%
Bathylagidae	0.66%	Atka mackerel	1.96%
Atka mackerel	0.49%	Northern Rock	1.46%
Salmon returning	0.36%	Sharpchin Rock	1.41%
Eulachon	0.33%	Herring	1.28%
Atka mackerel_Juv	0.15%	Fin Whales	1.12%
Northern Rock	0.07%	Herring_Juv	0.96%
Oth. pelagic smelt	0.06%	Dusky Rock	0.94%
Salmon outgoing	0.06%	Humpbacks	0.85%
Humpbacks	0.05%	Atka mackerel_Juv	0.70%
Other Sebastes	0.05%	Scyphozoid Jellies	0.60%
POP	0.04%	Other Sebastes	0.48%
Bowhead Whales	0.03%	Bathylagidae	0.34%
Sei whales	0.03%	POP_Juv	0.12%
Gr. Turbot_Juv	0.02%	Sei whales	0.09%
Sablefish_Juv	0.02%	Salmon outgoing	0.08%
Right whales	0.01%	Sablefish_Juv	0.07%
Auklets	0.01%	Right whales	0.02%
Sharpchin Rock	0.01%	Auklets	0.00%
Dusky Rock	0.00%		

EBS Shrimp		GOA Shrimp	
Pandalidae	83.02%	NP shrimp	56.80%
NP shrimp	16.98%	Pandalidae	43.20%

EBS Mesozooplankton		GOA Mesozooplankton	
Euphausiids	78.72%	Euphausiids	84.36%
Pelagic Amphipods	7.82%	Pelagic Amphipods	4.85%
Mysids	6.36%	Gelatinous filter feeders	4.37%
Chaetognaths	3.12%	Pteropods	2.30%
Gelatinous filter feeders	2.90%	Chaetognaths	2.24%
Pteropods	1.02%	Mysids	1.86%
Fish Larvae	0.05%	Fish Larvae	0.01%

2. Trophic level of the catch

Contributed by Jennifer Boldt, UW, and Pat Livingston, NMFS

Index: An index that has been suggested as a measure of overall top-down control of the ecosystem due to fishing is the trophic level of the fishery; in particular, the notion of “fishing down the food web” has been popularized in recent years. The trophic level of the catch and the Fishery in Balance (FIB) indices have been monitored in the BS, AI, and GOA ecosystems to determine if fisheries have been "fishing-down" the food web by removing top-level predators and subsequently targeting lower trophic level prey. The FIB index was developed by Pauly et al. (2000) to ascertain whether trophic level catch trends are a reflection of deliberate choice or of a fishing-down the food web effect. This index declines only when catches do not increase as expected when moving down the food web (i.e., lower trophic levels are more biologically productive), relative to an initial baseline year. The single metrics of TL or FIB indices, however, may hide details about fishing events.

Status and Trends: Although there has been a general increase in the amount of catch since the late 1960s in all three areas of Alaska, the trophic level of the catch has been high and relatively stable over the last 25 years.

Factors Causing Trends: In general, it appears that fishing events on different species are episodic in the AI and GOA, while pollock steadily dominate catches in the EBS throughout the period.

Implications: Unlike other regions in which this index has been calculated, such as the Northwest Atlantic, the FIB index and the trophic level of the catch in the EBS, AI, and GOA have been relatively constant and suggest an ecological balance in the catch patterns. Further examination supports the idea that fishing-down the food web is not occurring in Alaska, and there does not appear to be a serial addition of lower-trophic-level fisheries in the EBS or GOA.

3. Bycatch of sensitive top predators

Index: Groundfish fishery bycatch of sensitive species such as, marine mammals and seabirds, provides an index of the total fishery removal of top predators in ecosystems.

Status and Trends: Incidental mortality of pinnipeds in groundfish fisheries was low from 1998-2005, and did not exceed PBRs, and are not expected to have a direct effect on the population status of pinnipeds (Sinclair et al. 2006). Between 1998 and 2005, an average of 24 harbor seals was taken annually in fisheries in both SEAK and the GOA, and an average of 1 was taken in the EBS (Sinclair et al. 2006). An annual average of 2.6 and 24.6 Steller sea lions were taken in the Eastern and Western Pacific (Sinclair et al. 2006). Sixteen Northern fur seals on average were taken in the East North Pacific annually Sinclair et al. 2006).

Most seabird bycatch is taken with longline gear (65-94%), although some bycatch is taken with trawls (6-35%) or pots (1%). The average annual longline bycatch of seabirds is comprised of primarily fulmars, gulls, and some unidentified birds, albatross, and shearwaters. Of the total longline seabird bycatch in 2004, 94.3% was caught in the EBS, 2.5% in the AI, and 3.2% in the GOA. Pots catch primarily Northern fulmars, whereas trawl and longline fisheries catch a wider variety of seabirds. In 2002, total catch of seabirds was 4,694 in the EBS, 124 in the AI, and 161 in the GOA (Fitzgerald et al. 2006). Between 1993 and 2004 the average annual bycatch in the combined Alaskan longline fisheries was 13,144 birds (Fitzgerald et al. 2006). Over this period the average annual bycatch rates (birds per 1,000 hooks) were 0.065 in the AI and EBS areas and 0.021 in the GOA (Fitzgerald et al. 2006). Those rates have dropped in the last few years, with the running 5-year average now (2000-2004) at 0.035, 0.036, and 0.010 for the AI, EBS, and GOA regions respectively.

Catch of spiny dogfish in groundfish fisheries varies spatially and temporally. Catches of spiny dogfish were highest in 1998 and 2001 in many areas of the central and western GOA and Prince William Sound (Courtney et al. 2004; Boldt et al. 2003). Spiny dogfish catch in the EBS was low, but also peaked in 2001. Bycatch in the EBS is primarily from along the Alaska Peninsula and along the EBS shelf (Courtney et al. 2004; Boldt et al. 2003). There was no apparent temporal pattern in sleeper shark bycatch in the GOA or PWS (Courtney et al. 2004; Boldt et al. 2003). Bycatch in the EBS was lower and concentrated along the EBS shelf. EBS sleeper shark bycatch in 2001 was the highest since 1997 (Courtney et al. 2005; Boldt et al. 2003). Courtney et al. (2005) state that: "…a 2% reduction in biomass per year due to fishing is likely less than natural mortality for Pacific sleeper sharks, unless they are extremely long lived. Based upon this risk criterion, Pacific sleeper sharks do not appear to be at risk of overfishing at current levels of incidental catch."

Factors Causing Trends: Trends in bycatch may reflect changes in populations due to environmental and/or biological factors, but could also be due to changes in management and bycatch avoidance measures. Also, seabird mortality in Alaska groundfish fisheries represents only a portion of the fishing mortality that occurs, particularly with the albatrosses.

Objective: Maintain predator-prey relationships
Driver: Need for fishing; per capita seafood demand
Pressure: Energy redirection
Status and Impacts Indicator:

1. Discards and discard rates
Contributed by Terry Hiatt, NMFS

Index: Estimates of discards for 1994-2002 come from NMFS Alaska Region's blend data; estimates for 2003-08 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 groundfish fisheries dropped to less than 10% of the total groundfish catch in both the Bering Sea/Aleutian Islands and the Gulf of Alaska. Discards in the Gulf of Alaska increased somewhat between 1998 and 2003, declined in 2004 and 2005, and have increased again in the last three years. Discard rates in the Aleutian Islands (AI) dropped significantly in 1997, trended generally upwards from 1998 through 2003, and have declined again over the last five 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 Trends: The decline in discards in both the AI and the EBS in 2008 are largely due to enactment of improved retention/utilization regulations by the North Pacific Fishery Council for the trawl head-and-gut fleet.

Objective: Maintain predator-prey relationships
Driver: Need for fishing; per capita seafood demand
Pressure: Energy redirection
Status and Impacts Indicator:

1. Total catch levels
See next section on invasive species

Objective: Maintain predator-prey relationships
Driver: Need for fishing; per capita seafood demand
Pressure: Introduction of non-native species
Status and Impacts Indicators:

1. Total catch levels

Index: Total catch provides an index of how many groundfish fishing vessels are potentially exchanging ballast water resulting in the possible introduction of non-native species.

Status and Trends: Total catch in the EBS was relatively stable from 1984 to the mid-1990s at approximately 1.7 million t. In 1999 there was a decrease in catch primarily due to decreased catches of pollock and flatfish, catches then increased to approximately 1.9 million t annually in 2002-2004, and recently in 2007-2008 decreased due to decreases in pollock catch.

Total catch in the AI is much lower than in the EBS and has been more variable (from 61,092 to 190,750 t between 1977 and 2004). Total catch peaked in 1989, comprised mainly of pollock, and in 1996, comprised of pollock, Pacific cod, Atka mackerel, and rockfish. Pollock were a large proportion of catches from the late 1970s to the early 1990s. In 2007, cod catches increased.

In the GOA, total catch has ranged from less than 50,000 t in the 1950s to highs of 384,242 t in 1965, which was associated with high rockfish catches, and 377,809 t in 1984, which was associated with high pollock catches. Since the 1985, total catch has varied between 180,301 t (1987) and 307,525 t (1992). Catches of pollock and Pacific cod determine the major patterns in catch variability.

Factors Causing Trends: Pollock and flatfish catches drive the catch trends in the EBS. Catch trends in the AI are driven by catches of pollock, Pacific cod, Atka mackerel, and rockfish. In the GOA, catch trends are driven by catches of pollock and Pacific cod. The potential for introductions of invasive species through groundfish fishery ballast water exchange likely increased in the 1960s with increased catches.

Implications: The effects of the introduction of invasive species via the movement of large ships and their ballast water in Alaska marine ecosystems is largely unknown.

2. Invasive species observations
Information from Fay (2002)

Index: Invasive species are those that are not native to Alaska and that could harm the environment, economics, and/or human health of the region (Fay 2002). The main marine invasive species that are in Alaska or that could potentially be introduced to Alaska include: Atlantic salmon (*Salmo salar*), green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), oyster spat and associated fauna, bacteria, viruses, and parasites.

Status and Trends: Currently, Alaska has relatively few aquatic (including marine) invasive species. Natural spawning of escaped Atlantic salmon has been observed in British Columbian streams, indicating that this could also occur in Alaska. Chinese mitten crab, native to China, is now established in California and may have spread to the Columbia River (Fay 2002). Uncertified oyster spat that is imported to Alaska for farming purposes can introduce not only oyster spat (although it is thought that Alaskan waters are too cold for oysters to reproduce), but also other invertebrate larvae, bacteria and viruses (Fay 2002).

Factors Causing Trends: The introduction of aquatic invasive species in Alaska can occur in a number of ways, such as those that Fay (2002) lists, including: "fish farms, the intentional movement of game or bait fish from one aquatic system to another, the movement of large ships and their ballast water from the United States West Coast and Asia, fishing vessels docking at Alaska's busy commercial fishing ports, construction equipment, trade of live seafood, aquaculture, and contaminated sport angler gear brought to Alaska's world-renowned fishing sites."

Implications: The potential implications of introductions of non-native species to Alaska marine ecosystems are largely unknown. Fay (2002), however, states: "It is thought Atlantic salmon would most likely compete with native steelhead, cutthroat trout, Dolly Varden, and coho salmon, and may also adversely impact other species of Pacific salmon." The green crab, which is capable of surviving in Alaskan nearshore waters, could pose a competitive threat to Alaskan tanner and Dungeness crab stocks since they utilize the same nearshore areas as nurseries. Fay (2002) states: "With a catadromous life history [the Chinese mitten crab] can move up rivers hundreds of miles where it may displace native fauna, and it is known to feed on salmonid eggs, which could affect salmon recruitment." Fay (2002) states: "Little is known about the threat of the movement of bacteria, viruses, and parasites within or to Alaska. Devastations from the Pacific herring virus in PWS is well known and documented…movement of ballast water from one place to another within Alaska coastal waters could result in injury to other fisheries. Atlantic Ocean herring disease could also be introduced into Alaska through the import of frozen herring that are used as bait by Alaskan commercial fishers."

Gaps in predator-prey relationship knowledge:
Information or indicators that would improve our understanding of predator-prey relationships in Alaska marine ecosystems includes:

1. a time series of zooplankton biomass in the GOA and AI
2. a time series of forage fish species in all areas
3. an indicator of the degree of spatial and temporal concentration of groundfish fisheries

Objective: Maintain Diversity
Driver: Need for fishing; per capita seafood demand
Pressure: Effect of fishing on diversity
Status and Impacts Indices:

1. Groundfish survey species richness and diversity
Contributed by Franz Mueter, University of Alaska, and Robert Lauth, AFSC

Index: The number of species and the proportions of species in an ecosystem can be affected by fishing in a variety of ways, including the removal of species and the removal of invertebrate species that provide fish habitat (e.g., sponge). The effect of fishing on species richness and diversity are poorly understood at present. Because fishing primarily reduces the relative abundance of some of the dominant species in the system, species diversity is expected to increase relative to the unfished state. However, changes in local species richness and diversity are strongly confounded with natural variability in spatial distribution and relative abundance. The Shannon-Wiener diversity index and species richness index are standard indices of the numbers and proportions of species. This section provides indices of local species richness and diversity based on standard bottom trawl surveys in the eastern Bering Sea (EBS). We computed the average number of fish and major invertebrate taxa per haul (richness) and the average Shannon index of diversity (Magurran 1988) by haul based on CPUE (by weight) of each taxon. Indices were based on 45 taxa that were consistently identified throughout all surveys (Table 1 in Mueter & Litzow, 2008, excluding Arctic cod because of unreliable identification in early years) and were computed following Mueter & Norcross (2002). Briefly, annual average indices of local richness and diversity were estimated by first computing each index on a per-haul basis, then estimating annual averages across the survey area using a Generalized Additive Model that accounted for the effects of variability in geographic location, depth, date of sampling, and area swept.

Status and trends: Species richness and diversity on the Eastern Bering Sea shelf have undergone significant variations from 1982 to 2008. The average number of species per haul has increased by one to two species since 1995, while the Shannon Index increased from 1985 through 1998 and decreased sharply in 1999 with high variability in recent years.

Factors causing trends: The average number of species per haul depends on the spatial distribution of individual species (taxa). If species are, on average, more widely distributed in the sampling area the number of species per haul increases. Spatial shifts in distribution from year to year can cause high variability in local species richness in certain areas, for example along the 100m contour in the Eastern Bering Sea. These shifts appear to be the primary drivers of changes in species richness. Local species diversity is a function of how many species are caught in a haul and how evenly CPUE is distributed among the species. Both time trends and spatial patterns in species diversity differed markedly from those in species richness. For example, low species diversity in 2003 occurred in spite of high average richness, primarily because of the high dominance of walleye pollock, which increased from an average of 18% of the catch per haul in 1995-98 to 30% in 2003, but decreased again to an average of 21% in 2004. The increase in species richness, which was particularly pronounced on the middle shelf, 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 & Litzow, 2008). However, species diversity 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. Spatially, species richness tends to be highest along the 100 m contour, whereas species diversity is highest on the middle shelf because the middle shelf region is less dominated by a few abundant species.

Implications: The effect of fishing on species richness and diversity are poorly understood at present and this index likely reflects changes in spatial distribution and species composition that can only be interpreted in the context of environmental variability in the system. Local species richness may be particularly sensitive to long-term trends in bottom temperature as the cold pool extent changes (Mueter and Litzow 2008) and may provide a useful index for monitoring responses of the groundfish community to projected climate warming.

2. Size Diversity

Contributed by Jennifer Boldt, University of Washington, and Shannon Bartkiw, Pat Livingston, Jerry Hoff, and Gary Walters, AFSC

Index: Marine food web relationships are strongly influenced by animal size. One important indicator of the diversity of animal size in the food web is the slope of the community size spectrum (CSS). The CSS examines the relationship between abundance and size of animals in a community, and has been found to explain some fishing-induced changes at a system-wide level. For example, in an exploited fish assemblage, larger fish generally suffer higher fishing mortality than smaller individuals and this may be one factor causing the size distribution to become skewed toward the smaller end of the spectrum (Zwanenburg 2000), leading to a decrease in the slope of the size relationship over time with increasing fishing pressure. The community size spectrum slopes and heights were estimated for the Bering Sea fish community using data from standard NMFS bottom trawl survey, 1982-2006 (Boldt et al., in review).

Status and Trends: There were no linear trends or step-changes in the eastern Bering Sea fish CSS heights (Boldt et al., in review). The EBS CSS slopes did not have a significant linear trend, but significant step changes indicate the slope was lower (less negative) during 1984-2005 (Boldt et al., in review).

Factors Causing Trends: Changes in CSS slopes and intercepts reflect changes in fish size and abundance, respectively, and can be due to fishing intensity and/or climate variability. CSS slopes and heights vary temporally for different groups of taxa that are exposed to different levels of exploitation (Boldt et al., in review). These changes in CSS slopes and heights were not due to significant shifts in species composition and not correlated with fishing intensity or bottom temperature variability (Boldt et al., in review).

Implications: Unlike other marine ecosystems, the eastern Bering Sea CSS indicates that there has not been a linear decreasing trend in groundfish size or abundance during 1982-2006 (Boldt et al., in review). In fact, there were more large fish in the latter part of the times series, which is contrary to expectations if fishing were removing large individuals.

3. Groundfish Status

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:
    i) overfishing 0.5
    ii) overfished 0.5
2) Fishing mortality rate is below the “overfishing” level defined for the stock 1.0
3) Biomass is above the “overfished” level defined for the stock 1.0
4) Biomass is at or above 80% of maximum sustainable yield (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. 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. There are also 25 non-FSSI stocks in Alaska. There are 230 FSSI stocks in the U.S., with a maximum possible score of 920.

Status and Trends: The current overall Alaska FSSI is 117.5 of a possible 140, based on updates through March 2009. The overall Bering Sea/Aleutian Islands score is 74 of a possible maximum score of 88. The BSAI groundfish score is 51 of a maximum possible 52 and BSAI king and tanner crabs score 23 of a possible score of 36. The Gulf of Alaska groundfish score is 39.5 of a maximum possible 48. The sablefish, which are managed as a BSAI/GOA complex, score is 4. For the entire U.S., the score is 557.5 of a possible maximum score of 920.

Factors Causing Trends: Groundfish FSSI scores are high because it is thought that they are conservatively managed. 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 (Table 3). Halibut is a major stock (but a non-FSSI stock, since it is jointly managed by PFMC and NPFMC) that is not subject to overfishing, is not approaching an overfished condition, and is not considered overfished. The stocks that had low FSSI scores (1.5) in the GOA are shortspine thornyhead rockfish (indicator species for thornyhead rockfish complex), yelloweye rockfish (indicator species for demersal shelf rockfish complex), and rex sole. The reasons for these low scores are: it is undefined whether these species are overfished and unknown if they are approaching an overfished condition. One BS crab stock is considered overfished: Pribilof Island blue king crab. Three stocks of crabs are under continuing rebuilding plans: BS snow crab, Pribilof Island blue king crab, and St. Matthew Island blue king crab. The EBS Tanner crab stock is considered rebuilt.

Implications: The majority of Alaska groundfish fisheries appear to be sustainably managed.

Table 3. Fisheries Stock Sustainability Indices.

Jurisdiction	Stock Group	Number of Stocks	Overfishing					Overfished					Approaching Overfished Condition
			Yes	*No*	*Not known*	*Not defined*	*N/A*	*Yes*	*No*	*Not known*	*Not defined*	*N/A*	
NPFMC	FSSI	35	0	33	2	0	0	1	29	0	5	0	0
NPFMC (and IPHC for halibut)	NonFSSI	25	0	17	1	7	0	0	2	0	23	0	0
	Total	60	0	50	3	7	0	1	31	0	28	0	0

4. Number of endangered or threatened species

With contributions from Shannon Fitzgerald, Lowell Fritz, Kathy Kuletz, Marcia Muto, Elizabeth Sinclair, and Ward Testa, NFMS

Index: Another measure of diversity in ecosystems in the number of species that are listed as threatened or endangered through the Endangered Species Act (ESA). The list of threatened and endangered species below was reported on the U.S. Fish and Wildlife service (http://ecos.fws.gov/tess_public//pub/stateListingAndOccurrence.jsp?state=AK, August 22, 2008) and on the NOAA Fisheries Office of Protected Resources (http://www.nmfs.noaa.gov/pr/species/mammals/, August 22, 2008) websites. To have a proactive approach to the conservation of species, we also list species of concern, which are those species about which NOAA's National Marine Fisheries Service (NMFS) has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the Endangered Species Act (ESA). Depleted stocks are those listed under the Marine Mammal Protection Act. Some species that may or may not be listed here have been officially proposed as either threatened or endangered in a Federal Register notice after the completion of a status review and consideration of other protective conservation measures (e.g., Cook Inlet beluga whales). Additionally, bearded, ribbon, ringed, and spotted seals are candidate species (i.e., being considered for listing as endangered or threatened under the ESA). Conservation status of seabirds are taken from the U.S. Fish & Wildlife Service (USFWS) Migratory Bird Management Nongame Program Alaska seabird information series (http://alaska.fws.gov/mbsp/mbm/seabirds/pdf/asis_complete.pdf; Denlinger 2006).

Status and Trends: There are 9 species listed as endangered and 5 species that are listed as threatened in Alaska (Table 4). Three marine mammal species are considered depleted and three species of birds are considered “highly imperiled”. The USFWS considers three seabird species as highly imperiled in Alaska: black-footed albatross, red-legged kittiwakes, and Ancient murrelets. Also, the USFWS considers seven seabird species in Alaska of high concern: Laysan albatross, pelagic cormorants, red-faced cormorants, Arctic terns, marbled murrelets, Kittlitz’s murrelets, and Cassin’s auklets. Ten seabird species in Alaska are of moderate concern: Northern fulmars, Leach’s storm-petrels, black-legged kittiwakes, Aleutian terns, black guillemot, pigeon guillemot, Least auklets, whiskered auklets, crested auklets, and horned puffins. Low to moderate concern was identified for parasitic jaegers and herring gulls in Alaska. Low concern was identified for fork-tailed storm-petrels, Pomarine jaegers, Sabine’s gulls, common murres, Parakeet auklets, and Rhinoceros auklets in Alaska. Fourteen other seabird species in Alaska are not of concern or do not have a conservation status. Two endangered fish species that migrate to Alaskan waters include Lower Columbia River chinook salmon and upper Willamette River chinook salmon.

Factors Causing Trends: Exploitation in the early part of the 20th century reduced populations of large whales, such as North Pacific right, blue, fine, sei, humpback, and sperm whales, and sea otters to the point of depletion. Relatively recent surveys suggest that humpback, fin, and minke whales were abundant in old whaling grounds (Zerbini et al. 2004). Currently, potential causes of declines in marine mammals include direct takes in fisheries, resource competition, indirect competition, and environmental change (see Steller sea lion section below). Reduced polar bear numbers have been attributed to climate change and the loss of sea ice, representing a loss of habitat, in the Arctic. Trends in seabird populations may be related to fishery mortality, climate variability, predation, nesting habitat destruction, prey availability, and/or food provisioning (see Seabirds, this report). Bycatch of salmon in Alaska has the potential to affect the endangered lower Columbia River and upper Willamette River chinook salmon, but is closely monitored.

Table 4. Species in Alaska that are listed as endangered or threatened, marine mammals listed as depleted, species of concern, and seabirds considered highly imperiled.

Species	Endangered	Threatened	Depleted	Species of Concern	Highly imperiled
Steller sea lion (western stock)	X				
Steller sea lion (eastern stock)		X			
Northern fur seal			X		
Blue whale*	X				
Bowhead whale	X				
Humpback whale	X				
Fin whale	X				
Right whale (northern Pacific)*	X				
Sperm whale*	X				
Beluga whale (Cook Inlet)			X	X	
Killer whale (AT1 transient)			X		
Northern sea otter (southwest AK)		X			
Polar bear		X			
Leatherback sea turtle	X				
Short-tailed albatross	X				
Spectacled eiders		X			
Steller's eiders		X			
Black-footed albatross					X
Red-legged kittiwakes					X
Ancient murrelets					X
Lower Columbia R. Chinook salmon	X				
Upper Willamette R. Chinook salmon	X				
Pinto abalone (southeast AK)				X	

* ESA website lists these as endangered but does not include them as being distributed in Alaska. The NOAA Fisheries Office of Protected Resources lists these whales as endangered and indicates their distribution includes Alaska.

5. Steller sea lion non-pup counts and pup production

Contributed by Lowell Fritz and Elizabeth Sinclair, NMML

Indices: The western stock, which occurs from 144°W (approximately at Cape Suckling, just east of Prince William Sound, Alaska) westward to Russia and Japan, was listed as "endangered" in June 1997 (62 Federal Register 24345, May 5, 1997). The eastern stock, which occurs from Southeast Alaska southward to California, remained classified as threatened (since 1990). To elucidate trends in Steller sea lion stocks, non-pup counts and pup production are two indices that are monitored. Population assessment for Steller sea lions is currently achieved by aerial photographic surveys of non-pups (adults and juveniles at least 1 year-old) and pups, supplemented by on-land pup counts at selected rookeries each year. Trends in the non-pup western stock in Alaska are monitored by surveys at groups of 'trend sites' (all rookeries and major haul-outs) that have been surveyed consistently since the mid-1970s (N=87 sites) or 1991 (N=161 sites). To investigate spatial differences in population trends, counts at trend sites within sub-areas of Alaska are monitored.

Status and Trends: NMFS estimated that the western Steller sea lion population increased approximately 11-12% from 2000 to 2004 (Fritz and Stinchcomb 2005). Although counts at some trend sites are missing for both 2006 and 2007, available data indicate that the size of the adult and juvenile portion of the western Steller sea lion population throughout much of its range in Alaska has remained largely unchanged between 2004 (N=20,533) and 2008 (N=21,489). However, there are significant regional differences in recent trends: increases between 2004 and 2008 in the GOA and eastern AI have largely been offset by decreases in the central and western AI. Winship and Trites (2006) also noted that significant differences in regional trends could affect the species' ability to occupy its present range in the future.

Steller sea lion pup production at western stock trend rookeries in the Kenai to Kiska area (C GULF west through C ALEU) declined 40% in the 1990s. However, from 2001 to 2005, there were small increases in pup numbers of 4% (+265 pups) at trend rookeries in the Kenai to Kiska area and 3% (+239 pups) across the range of the western stock in Alaska. These recent trends in pup counts, while encouraging, were less than those observed in non-pup counts from 2000 to 2004, which increased 11-12% (Fritz and Stinchcomb 2005). The ratio of pups to non-pups (at trend sites) has declined steadily since the early 1990s, and may reflect a decline in the reproductive rates of adult females (Holmes and York 2003, Holmes et al. 2007).

Factors Causing Trends: NMFS, along with its research partners in the North Pacific, is exploring several hypotheses to explain these trends, including climate or fisheries related changes in prey quality or quantity, and changes in the rate of predation by killer whales.

There is both direct and indirect overlap in the species and size of primary prey consumed by marine mammals and targeted in commercial fisheries. For example, adult and juvenile walleye pollock are both consumed by adult and juvenile Steller sea lions (Merrick and Calkins 1996, Sinclair and Zeppelin 2002, Zeppelin et al. 2004). The hypothesis is that either direct or indirect competition for food with commercial fisheries may limit the ability of apex predators to obtain sufficient prey for growth, reproduction, and survival (NRC 1996). In the case of Steller sea lions, direct competition with fisheries may occur for walleye pollock, Atka mackerel, salmon, and Pacific cod (Calkins and Pitcher 1982, Sinclair and Zeppelin 2002, Zeppelin et al. 2004). Competition may also exist where marine mammal foraging areas and commercial fishing zones overlap. More difficult to identify are the indirect effects of competition between marine mammals and fisheries for prey resources. Such interactions may limit foraging success through localized depletion (Lowe and Fritz 1997), destabilization of prey assemblages (Freon et al. 1992, Nunnallee 1991, Laevastu and Favorite 1988), or disturbance of the predator itself.

There is considerable uncertainty on how and to what degree environmental factors, such as the 1976/77 regime shift (Benson and Trites 2002), may have affected both fish and marine mammal populations. Some authors suggest that the regime shift changed the composition of the fish community resulting in reduction of prey diversity in marine mammal diets (Sinclair 1988, Sinclair et al. 1994, Piatt and Anderson 1996, Merrick and Calkins 1996), while others caution against making conclusions about long-term trends in Steller sea lion diets based on small samples collected prior to 1975 (Fritz and Hinckley 2005). Shima et al. (2000) hypothesized that the larger size and restricted foraging habitat of Steller sea lions, especially for juveniles that forage mostly in the upper water column close to land, may make them more vulnerable than other pinnipeds to changes in prey availability, and spatial and temporal changes in prey, especially during the critical winter time period. Determining the individual magnitudes of impacts that fisheries and climate changes have had on localized prey availability for foraging marine mammals is difficult.

6. Northern fur seal pup production

Contributed by Lowell Fritz, NMML

Index: Northern fur seals were listed as depleted under the MMPA in 1988 because population levels had declined to less than 50% of levels observed in the late 1950s, with no compelling evidence that carrying capacity had changed (NMFS 1993). Fisheries regulations were implemented in 1994 (50 CFR 679.22(a)(6)) to create a Pribilof Islands Area Habitat Conservation Zone, in part, to protect the northern fur seals. Under the MMPA, this stock remains listed as "depleted" until population levels reach at least the lower limit of its optimum sustainable population (estimated at 60% of carrying capacity). A Conservation Plan for the northern fur seal was written to delineate reasonable actions to protect the species (NMFS 1993). The population size and trends of northern fur seals on the Pribilof Islands are estimated by NMFS biennially using a mark-recapture method (shear-sampling) on pups of the year.

Status and Trends: NMFS estimated that 120,834 pups were born on the Pribilof Islands in 2008: 102,674 (SE = 1,084) pups were born on St. Paul Island and 18,160 (SE = 288) pups were born on St. George Island. Pup production on St Paul Island has been declining since the mid-1990s (Towell et al. 2006), and was 43% less in 2006 than in 1994. Pup production on St George was relatively stable between 2002 and 2006, but declined 23% between 1994 and 2006. Estimated pup production on both Pribilof Islands in 2006 was similar to the level observed in 1916; however the population trend at the beginning of the 20th century was much different than at beginning of the 21st. In 1916, the northern fur seal population was increasing at approximately 8% per year following the cessation of extensive pelagic sealing, while currently (1998 through 2006), pup production on both Pribilof Islands is estimated to be decreasing at approximately 6% per year. The trend in pup production on Bogoslof Island in the 1990s has been opposite those observed on the Pribilofs. Pup production increased at approximately 20% per year on Bogoslof Island between 1995 and 2007.

Factors Causing Trends: The increase in pup production rate on Bogoslof Island is faster than what could be expected from a completely closed population of fur seals, indicating that at least some of it is due to females moving from the Pribilof Islands (presumably) to Bogoslof to give birth and breed. However, declines observed on the Pribilof Islands are much greater than the increase in numbers on Bogoslof, indicating that the decline on the Pribilofs cannot be due entirely to emigration. Differences in trends between the predominately shelf-foraging Pribilof fur seals and the predominately pelagic-foraging Bogoslof fur seals are unlikely related to large-scale spatio-temporal changes in the North Pacific Ocean (e.g., regime shifts, Pacific Decadal Oscillation), since these populations are almost entirely sympatric.

There is both direct and indirect overlap in the species and size of primary prey consumed by marine mammals and targeted in commercial fisheries (see Steller sea lions, above). The hypothesis is that either direct or indirect competition for food with commercial fisheries may limit the ability of apex predators to obtain sufficient prey for growth, reproduction, and survival (NRC 1996). In the case of northern fur seals, direct competition with fisheries may occur for walleye pollock and salmon (Kajimura 1984, Perez and Bigg 1986, Lowry 1982, Sinclair et al. 1994, 1996). Competition may also exist where marine mammal foraging areas and commercial fishing zones overlap. Female northern fur seals from the Pribilof Islands forage extensively at distances greater than 81 nm (150 km) from rookeries (Robson 2001), placing them within range of commercial groundfish vessels fishing for walleye pollock on the eastern Bering Sea shelf during the summer and fall.

Gaps in diversity knowledge:
Information or indicators that would improve our understanding of diversity in Alaska marine ecosystems includes:
1. an index of guild diversity
2. trophic level of ecosystem
3. better understanding of diversity indices and what causes trends
4. ratio of target to nontarget fish catches

Objective: Maintain habitat
Driver: Need for fishing; per capita seafood demand
Pressure: Habitat loss/degradation due to fishing gear effects on benthic habitat, HAPC biota, and other species
Status and Impacts Indicators:

1. Areas closed to bottom trawling in the EBS/ AI and GOA
Contributed by John Olson, NFMS

Index and Status: Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut). 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. 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) off Alaska was closed to trawling year-round. Additionally, 40,000 nm^2 were closed on a seasonal basis. State waters (0-3 nmi) are also closed to bottom trawling in most areas. A motion passed the North Pacific Management Council in February 2009 which would close 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. By implementing this closure, almost 65% of the U.S. EEZ off Alaska would be closed to bottom trawling.

2. Fishing effort
Contributed by John Olson, NMFS

Index: Fishing effort is an indicator of damage to or removal of Habitat Areas of Particular Concern (HAPC) biota, modification of nonliving substrate, damage to small epifauna and infauna, and reduction in benthic biodiversity by trawl or fixed gear. Intensive fishing in an area can result in a change in species diversity by attracting opportunistic fish species which feed on animals that have been disturbed in the wake of the tow, or by reducing the suitability of habitat used by some species. Trends in fishing effort will reflect changes due to temporal, geographic, and market variability of fisheries as well as management actions. Bottom trawl and hook and line effort are measured as the number of observed days fished; whereas, pot fishing effort is measured as the number of observed pots fished. Observed fishing effort is used as an indicator of total fishing effort. It should be noted, however, that most of the vessels using pot gear are catcher vessels either under 60’ or between 60’-125’. These vessels either do not require an observer present or only on 30% of the fishing days.

Status, Trends: Bottom trawl effort in the Gulf of Alaska, Bering Sea, and Aleutian Islands was near or below the 11-year average in 2008. In 2008, observed EBS and AI hook and line effort increased but was still below the 11-year average, and was near average in the GOA. Pelagic trawl effort in the EBS was relatively stable during 1999-2008 with a small increase in 2007. There has been very little or no pelagic trawl effort in the AI in recent years. Pelagic trawl effort in the GOA in 2008 was the lowest in 16 years. The observed pot fishing effort was similar to that seen in the last 8 or 9 years in all regions.

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

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

The pot fishery occurs mainly for Pacific cod which form dense spawning aggregations in the winter months. In the Bering Sea, fluctuations in the pot cod fishery may be dependent on the duration and timing of crab fisheries. There is also a state-managed fishery in State waters.

There are spatial variations in fishing effort in the EBS, GOA, and AI (see fishing effort contributions, this report). Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures) as well as changes in markets and increased bycatch rates of non-target species.

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

3. Area disturbed (EBS)

Contributed by: Angie Greig, AFSC

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 1990-2008. The duration of each 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). 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. 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.

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

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

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

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

Implications: Habitat damage varies with the physical and biological characteristics of the areas fished, recovery rates of HAPC biota in the areas fished, and management changes that result in spatial changes in fishing effort (NMFS 2007).

4. HAPC biota catch

Index: In addition to prohibited and target species catches, groundfish fisheries also catch non-target species. HAPC biota (seapens/whips, sponges, anemones, corals, tunicates) comprise a portion of the non-target species catches. HAPC biota are taxa which form living substrate, and are identified by NMFS as meeting the criteria for special consideration in resource management. HAPC biota are used by fish, including commercially important groundfish, as habitat. Bycatch of HAPC species in both trawl and longline gear is of concern. Concentrations of HAPC species often occur in nearshore shallow areas but also are found in offshore deep water areas with substrata of high microhabitat diversity. Trends in fishery catches of HAPC biota may be indicators of total HAPC biota removals. In addition to tracking removal of HAPC biota, fishery catches of HAPC biota may also reflect changes in management actions, fishing effort, the spatial distribution of the fishery, and/or in HAPC biota abundance; however, distinguishing between these is not possible and not the purpose of this index here. Catches are estimated based on visual observations by observers rather than from direct sampling; therefore, may be less accurate than target fish catch estimates.

Status and Trends: In the BSAI, catches of HAPC biota have generally decreased since 2004. The catch of HAPC biota in the GOA is lower than in the BSAI and has varied annually.

Factors Causing Trends: Benthic urochordata, caught mainly by the flatfish fishery, comprised the majority of HAPC biota catches in the BSAI in all years except 2007 and 2009, when sponges were the majority. Sea anemones comprise the majority of HAPC biota catch in the GOA and they are caught primarily in the flatfish fishery.

Implications: The reduction in HAPC biota catches imply that removal of those taxa by fishing gear has been reduced in the BSAI and been relatively stable in the GOA in recent years. The cause of this decrease is largely unknown but could be due to a combination of factors, such as the reduction in bottom trawl fishing effort in the Bering Sea, variation in gear (type, weight, towing speed, depth of penetration), changes in areas fished and the physical and biological characteristics of the areas, prior disturbance, and recovery rates of HAPC biota in the areas fished (NMFS 2007; http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm).

5. HAPC biota survey CPUE

Contributed by Michael Martin and Robert Lauth, NMFS

Index: As mentioned above, HAPC biota are taxa that form living substrate which are used by fish, including commercially important groundfish, as habitat. HAPC biota include seapens/whips, sponges, anemones, corals, and tunicates. NMFS bottom trawl survey catches of HAPC biota provide one potential indicator of HAPC biota abundance trends. Sampling is done over the same large areas annually in the EBS and biennially in the AI and GOA. This is, however, not the ideal indicator of abundance trends because the survey gear is not designed for efficient capture of all HAPC biota, it does not perform well in many of the areas where these groups are thought to be more prevalent and survey effort is quite limited in these areas as a result, catches are highly variable, and the survey gear and onboard sampling techniques have changed over time. Examination of the frequency of occurrence in hauls may address some of these issues (see HAPC biota for the three regions, this report).

Status and Trends: Despite the caveats, a few general patterns are clearly discernible. The CPUE of HAPC biota is highest in the Aleutian Islands. In the AI, HAPC biota CPUE has been variable, but relatively stable for the last 5 survey years. The CPUE of HAPC biota in the Bering Sea peaked in the late 1990s to the early 2000s, and has decreased since then. Sea whip and sea anemone CPUE generally increased in the EBS during the 2000s with a peak in 2007. In contrast, sponge CPUE decreased during the same time period, but with a slight uptick in 2008. Both the mean CPUE and frequency of occurrence of gorgonians seem to have decreased since 1994 in the AI; this is opposite the trends seen in stony corals over the same time period. HAPC biota CPUE in the GOA have been relatively low and stable, with a slight decline during the last 4 survey years. The frequency of occurrence of sponge and sea anemones in the GOA, however, seems to have increased since 1984.

Factors Causing Trends: Trends in both the EBS and AI are driven primarily by sponge CPUE. Sea anemone and sponge CPUE drive trends observed in the GOA. Prior to 1990, Japanese vessels using large tire gear performed the majority of tows in both the AI and GOA. This allowed these vessels to sample in areas considered untrawlable with current survey gear, so damage to HAPC biota likely exceeded later years, even though catches were generally smaller. This gear difference is thought to largely account for the abrupt change in relative abundance patterns after 1987. There are also regional trends within each of the three ecosystems (see HAPC biota for the three regions, this report).

Implications: Survey catches of HAPC biota may not necessarily reflect population abundance trends; therefore, the implications of survey catch trends of HAPC biota are largely unknown. The population trends of HAPC biota are not necessarily represented by survey catches because surveys are currently unable to devote effort to sampling untrawlable areas that have the highest HAPC biota abundance, especially in the AI.

Gaps in habitat knowledge:
Information or indicators that would improve our understanding of habitat in Alaska marine ecosystems includes:

1. habitat disturbance as a function of fishing intensity
2. HAPC biota population abundance and distribution, particularly in areas currently untrawlable with standard survey gear.
3. the importance of HAPC biota as habitat for different species and life stages of fish
4. the relationship between physical factors such as sediment type, bathymetry, and oceanography and the abundance and distribution of HAPC biota.

Objective: Incorporate/monitor effects of climate change
Driver: Concern about climate change
Pressure: Change in atmospheric forcing (resulting in changes in the ocean temperature, currents, ice extent, etc)
Status and Impacts Indicators:

1. North Pacific climate and SST indices
Contributed by Nick Bond (UW/JISAO), and Jim Overland (NOAA/PMEL)

Indices: To examine potential effects of climate on groundfish distribution, recruitment and survival, indices of climate conditions are assessed. Four indices of climate conditions that influence the north Pacific are: the NINO3.4 index to characterize the state of the El Nino/Southern Oscillation (ENSO) phenomenon, the Pacific Decadal Oscillation (PDO) index (the leading mode of North Pacific sea surface temperature (SST) variability), and two atmospheric indices, the North Pacific index (NPI) and Arctic Oscillation (AO). The NPI is one of several measures used to characterize the strength of the Aleutian low. The AO signifies 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, and hence anomalously westerly winds across the northern portion of the Pacific and Alaska. These indices, along with measures of sea surface temperature (SST) and sea level pressure (SLP) provide information on the climate conditions in the north Pacific.

Status, Trends, and Factors Causing Trends: The North Pacific atmosphere-ocean system from fall 2008 through summer 2009 featured relatively cool sea surface temperature (SST) along its northern flank extending from the Bering Sea through the Gulf of Alaska to off the coast of California. These SST anomalies were associated with a sea-level pressure (SLP) pattern accompanying a weak Aleutian low during the past winter and spring. The consequences of the latter included relatively cold conditions and heavy sea ice for the Bering Sea and mostly upwelling-favorable wind anomalies from the Gulf of Alaska to the Pacific Northwest. The summer of 2009 has featured a shift in the wind pattern and an overall moderation of coastal SSTs. The past winter included a La Nina of modest amplitude; the higher latitude response to the tropical Pacific was stronger than that during the past winter, even though the La Nina was weaker. El Nino conditions developed in the summer of 2009.

Implications: There is a strong consensus of the available forecast models that this El Nino will persist, and probably strengthen, into 2010. This is liable to bring about a positive state for the PDO and relatively warm SSTs along the west coast of North America. This could have a broad range of effects on Alaska marine ecosystems.

2. Combined standardized indices of groundfish recruitment and survival
Contributed by Franz Mueter, University of Alaska

Index: Decadal scale varability in climate may affect groundfish survival and recruitment (Hollowed et al. 2001). Indices of recruitment and survival rate (adjusted for spawner abundance) across the major commercial groundfish species in the Eastern Bering Sea / Aleutian Islands (BSAI, 11 stocks) and Gulf of Alaska (GOA, 11 stocks) provide an index that can be examined for decadal-scale variability. Time series of recruitment and spawning biomass for demersal fish stocks were obtained from the 2007 SAFE reports to update results of Mueter et al (2007). Only recruitment estimates for age classes that are largely or fully recruited to the fishery were included. Survival rate (SR) indices for each stock were computed as residuals from a spawner-recruit model. Each time series of log-transformed recruitment (logR) or SR indices was standardized to have a mean of 0 and a standard deviation of 1 (hence giving equal weight to each stock in the combined index, see below). A combined standardized index of recruitment (CSI_R) and survival (CSI_{SR}) was computed by simply averaging indices within a given year across stocks. Uncertainty in the stock-specific estimates of logR and SR indices was not accounted for; therefore the most recent estimates of the combined indices should be interpreted with caution.

Status and Trends: The CSI_R and CSI_{SR} suggest that survival and recruitment of demersal species in the GOA and BSAI followed a similar pattern with below-average survival/recruitments during the early 1990s (GOA) or most of the 1990s (BSAI) and above-average indices across stocks in the late 1990s/early 2000s. Because estimates at the end of the series were based on only a few stocks and are highly uncertain, we show the index through 2004 only, the last year for which data for at least 6 stocks was available in each region. There is strong indication for above-average survival and recruitment in the GOA from 1994-2000 (with the exception of 1996, which had a very low indices) and below-average survival / recruitment since 2001. From 2001 to 2004, 9 out of 11 or 8 out of 10 stocks have had below average-CSI_{SR} and CSI_R indices in the GOA. In the Bering Sea, recruitment estimates were available for fewer stocks, but there was no strong indication of below average recruitment across multiple stocks until 2004, when 6 of 6 stocks had below average recruitment and 5 out of 6 stocks had below-average stock-recruit indices. Therefore there was no evidence that the conditions that led to a series of below-average recruitments in Pacific cod and walleye pollock in the Bering Sea affected other species in the same way. Besides pollock and cod only flathead sole and atka mackerel had more than one year of below-average recruitment in the period 2001-2004.

Factors Causing Trends: Trends in recruitment are a function of both spawner biomass and environmental variability. Trends in survival rate indices, which are adjusted for differences in spawner biomass, are presumably driven by environmental variability but are even more uncertain than recruitment trends. Typically, spawner biomass accounted for only a small proportion of the overall variability in estimated recruitment. The observed patterns in recruitment and survival suggest decadal-scale variations in overall groundfish productivity in the Gulf of Alaska and Bering Sea that are moderately correlated between the two regions (CSI_R: $r = 0.42$; CSI_{SR}: $r = 0.47$). These variations in productivity are correlated with and may in part be driven by variations in large-scale climate patterns such as the PDO or more regional measures such as ocean temperatures. The Nov-Mar PDO index for the preceding winter was positively correlated with all of the indices, but none of the correlations were significant at the 95% level.

3. Ice indices

Contributed by Muyin Wang, Carol Ladd, Jim Overland, Phyllis Stabeno, Nick Bond, and Sigrid Salo, PMEL/NOAA

Indices: Sea ice extent and time of retreat in the Bering Sea, which are determined by large-scale climate factors, determine the size and location of the cold pool (water <2°C; see Volume of cold pool, below) in the Bering Sea as well as the timing and extent of the spring bloom. It is valuable to examine several indices to understand trends in ice. Two indices are the ice retreat index, which is the number of days that ice remains in a 2° by 2° box surrounding Mooring 2 in the southeastern Bering Sea, and the number of days past March 15 that ice is present in the same 2° by 2° box surrounding Mooring 2.

Status and Trends: The year 2009 was a fourth sequential year with cold temperatures and extensive springtime sea ice cover. The Bering Sea again contrasted with much of the larger Arctic which had extreme summer minimum sea ice extents in 2007 through 2009 (39 % below climatology) and positive autumn surface temperature anomalies north of Bering Strait of greater than 4°C. Sea ice extent in 2009, as well as 2007 and 2008 was close to record extents, not seen since the early 1970s, and contrast to the warm years of 2000-2005 (except 2002). These four recent cold years in the eastern Bering Sea followed a sequence of warm years earlier in the century.

Factors Causing Trends: Bering Sea climate conditions are primarily controlled by local or North Pacific processes through winter, spring and summer, and tend to be decoupled from the continued major sea ice loss and warming taking place throughout the greater Arctic regions. Also, the eastern Bering Sea is characterized by large monthly, interannual, and multi-annual variability, driven by large scale climate patterns.

Implications: Despite continuing warming trends throughout the Arctic, Bering Sea climate will remain controlled by large multi-annual natural variability, relative to a small background trend due to an anthropogenic (global warming) contribution. Over the next year we should see a modest shift back toward more normal temperatures and less sea ice, ending the run of cold years, as weak to moderate El Nino conditions have developed and are projected to influence Alaska through fall and winter (see North Pacific review).

4. Volume of cold pool

Contributed by Jim Overland, Muyin Wang, Carol Ladd, Phyllis Stabeno, Nick Bond, and Sigrid Salo, PMEL/NOAA and Troy Buckley, Angie Greig, and Paul Spencer, NMFS

Index: The Bering Sea cold pool, defined by temperatures < 2°C, influences the mid-water and near-bottom biological habitat, groundfish distribution, the overall thermal stratification, the timing of the spring phytoplankton bloom, and the mixing of nutrient-rich water from depth into the euphotic zone during summer. It is hypothesized that the timing of the spring bloom, as influenced by the presence of ice and water temperature, influences secondary production and, hence, groundfish survival and recruitment (Oscillating Control Hypothesis; Hunt et al. 2002). Warm conditions tend to favor pelagic over benthic components of the ecosystem (Hunt et al. 2002, Palmer 2003).

Status and Trends: Extensive sea ice on the Bering Sea shelf during the winter 2008/2009 effectively left behind a prominent cold pool of water of less than 2˚ C on the middle shelf. The offshore extent of the cold pool during 2009 is comparable, but not quite to that which was observed in 2008.

Factors Causing Trends: Sea ice extent and time of retreat (see Ice indices, above), which are determined by large-scale climate factors, determine the size and location of the cold pool in the Bering Sea.

Implications: Changes in the cold pool could affect the summer distribution of groundfish. For example, subarctic and arctic species that moved further north in warm years (Mueter and Litzow 2008) could move south. Changes in the cold pool could also affect the distribution and feeding migration of walleye pollock, because they tend to avoid the cold pool (Francis and Bailey 1983) and their feeding migration is delayed in colder years (Kotwicki et al. 2005). Also, flathead sole and rock sole, which tend to be distributed further northwest in warm years relative to cold years (Spencer in press), could move further south. The cold pool can also affect the spatial overlap between predators and prey, such as predatory Pacific cod and juvenile snow crab, thereby affecting predation mortality (Livingston 1989). These effects in combination with others, such as changes in stratification, production, and community dynamics, however, are largely unknown.

5. Summer zooplankton biomass in the EBS

Contributed by Jeff Napp, NMFS, and Atsushi Yamaguchi, Hokkaido University, Japan

Index: Summer zooplankton biomass data are collected in the eastern Bering Sea by the Hokkaido University research vessel T/S *Oshoru Maru*. The time series (up to 1998) was re-analyzed by Hunt et al. (2002) and Napp et al. (2002) who examined the data by oceanographic domain. The data continues to be collected annually.

Status and Trends: Up to 1998 there were no discernable trends in biomass anomalies in the time series for any of the four geographic domains (Napp et al. 2002). However, the updated time series depicts a strong decrease in biomass during 2000-2004. There was a strong decrease in biomass 2000 to 2004 or 2005 depending on the region. The biomass now appears to be increasing, although the number of observations in some of the regions is very low. What is remarkable is that the trends appear to occur in all four domains although the initiation or time of the end of a trend may be slightly different.

Factors Causing Trends: Part of the decrease in biomass over the middle shelf was most likely due to recent decreases in the abundance of *Calanus marshallae*, the only “large” copepod found in that area (Hunt et al. 2008). It is not clear what might be the cause of declines in other regions.

Implications: It is possible the increased biomass of zooplankton in recent years could positively affect the growth and, hence, survival and recruitment of planktivorous fish.

Gaps in climate-related knowledge:

Information or indicators that would improve our understanding of climate-related knowledge in Alaska marine ecosystems includes:

1. knowledge of the effects of increased climate variation on ecosystem components
2. indicators of ocean acidification and its effect on shell-building animals and their predators
3. indicators of harmful algal blooms and their effects on ecosystem components

Conclusions

Climate: Monitoring climate variability is necessary to understanding changes that occur in the marine environment and may help predict potential effects on biota. El Nino conditions developed in the summer of 2009 and are likely to persist, and probably strengthen into 2010. This is liable to bring about a positive state for the PDO and relatively warm 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 2006-2009, 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 HAPC biota. 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 HAPC biota as habitat for different species and life stages of fish, estimates of HAPC biota 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 HAPC biota.

Diversity: Measures of diversity are subject to bias and we do not know how much change in diversity is acceptable (Murawski 2000). 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 & 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. in review). 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.

Predator-prey relationships and energy flow: Unlike other regions, such as the Northwest Atlantic, the FIB index and the trophic level of the catch in the EBS, AI, and GOA have been relatively constant and suggest an ecological balance in the catch patterns. Further examination supports the idea that fishing-down the food web is not occurring in Alaska, and there does not appear to be a serial addition of lower-trophic-level fisheries in the EBS or GOA. Recent exploitation rates on biological guilds in the Bering Sea are within one standard deviation of long-term mean levels. An exception was for the forage species of the Bering Sea (dominated by walleye pollock) which has relatively high exploitation rates 2005-2007 as the stock declined. The 2008 and 2009-recommended catch levels are again within one standard deviation of the historical mean. This is a more direct measure of catch with respect to food-web structure than are trophic level metrics.

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.

Conclusions and future research needs: No significant adverse impacts of fishing on the ecosystem relating to predator/prey interactions and energy flow/removal, diversity, or habitat are noted. There are, however, several cases where those impacts are unknown because of incomplete information on population abundance of certain species such as forage fish or HAPC biota that are not well-sampled by surveys. Identification of thresholds and limits through further analyses, research, and modeling is also needed to identify impacts. Also, not included in this assessment was an objective that addressed socio-economic factors. This is something that should be included in future drafts.

ECOSYSTEM STATUS INDICATORS

The purpose of this section is to provide new information and updates on the status and trends of ecosystem components to stock assessment scientists, fishery managers, and the public. The goals are 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. As we learn more about the role that climate, humans, or both may have on ecosystems, we will be able to derive ecosystem indicators that reflect this new understanding.

Physical Environment

Ecosystem Indicators and Trends Used by FOCI

Edited by S. Allen Macklin, NOAA/PMEL
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Last updated: August 2009

FOCI's scientists employ a number of climate, weather, and ocean indices and trends to help describe and ascribe the status of the ecosystem to various patterns or regimes. This document presents some of these with respect to current (2009) conditions. This section begins with an overview of North Pacific climate for 2008-2009, including an examination of trends and tendencies in multidecadal and decadal climate regimes. Following this section are sections dealing explicitly with the western Gulf of Alaska and eastern Bering Sea. Within these are continuations of discussions begun in 2003 on eddy kinetic energy in the Gulf of Alaska and modeled drift trajectories for the Bering Sea.

North Pacific Climate Overview

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Last updated: August 2009

***Summary**. The North Pacific atmosphere-ocean system from fall 2008 through summer 2009 featured relatively cool sea surface temperature (SST) along its northern flank extending from the Bering Sea through the Gulf of Alaska to off the coast of California. These SST anomalies were associated with a sea-level pressure (SLP) pattern accompanying a weak Aleutian low during the past winter and spring. The consequences of the latter included relatively cold conditions and heavy sea ice for the Bering Sea, and mostly upwelling-favorable wind anomalies from the Gulf of Alaska to the Pacific Northwest. The summer of 2009 has featured a shift in the wind pattern and an overall moderation of coastal SSTs. The past winter included a La Nina of modest amplitude; the higher latitude response to the tropical Pacific was stronger than that during the past winter, even though the La Nina was weaker. El Nino conditions developed in the summer of 2009. There is a strong consensus of the available forecast models that this El Nino will persist, and probably strengthen, into 2010. This is liable to bring about a positive state for the PDO and relatively warm SSTs along the west coast of North America.*

1. SST and SLP Anomalies

The state of the North Pacific from autumn 2008 through summer 2009 is summarized in terms of seasonal mean SST and sea level pressure (SLP) anomaly maps. The SST and SLP anomalies are relative to mean conditions over the periods of 1971-2000 and 1968-1986, respectively. The SST data is from NOAA's Optimal Interpolation (OI) analysis; the SLP data is from the NCEP/NCAR Reanalysis projects. Both data sets are made available by NOAA's Earth System Research Laboratory at http://www.cdc.noaa.gov/cgi-bin/Composites/printpage.pl. From the perspective of the climate forcing, and basin-scale response, the year of 2008-09 bears quite a bit of resemblance to that of the previous year.

The autumn (September-November, SON) of 2008 featured positive SST anomalies in the central North Pacific, with maximum amplitudes exceeding 2˚ magnitude near 45˚ N, 160˚ E (Figure 1a). Negative SST anomalies occurred along the west coast of North America from the Bering Sea to central California, and in the central and eastern subtropical North Pacific. The corresponding pattern of anomalous SLP included a moderate maximum (2-3 mb) over the Bering Sea (Figure 1b). Otherwise, relatively weak anomalies, and hence also near-normal winds prevailed over most of the North Pacific.

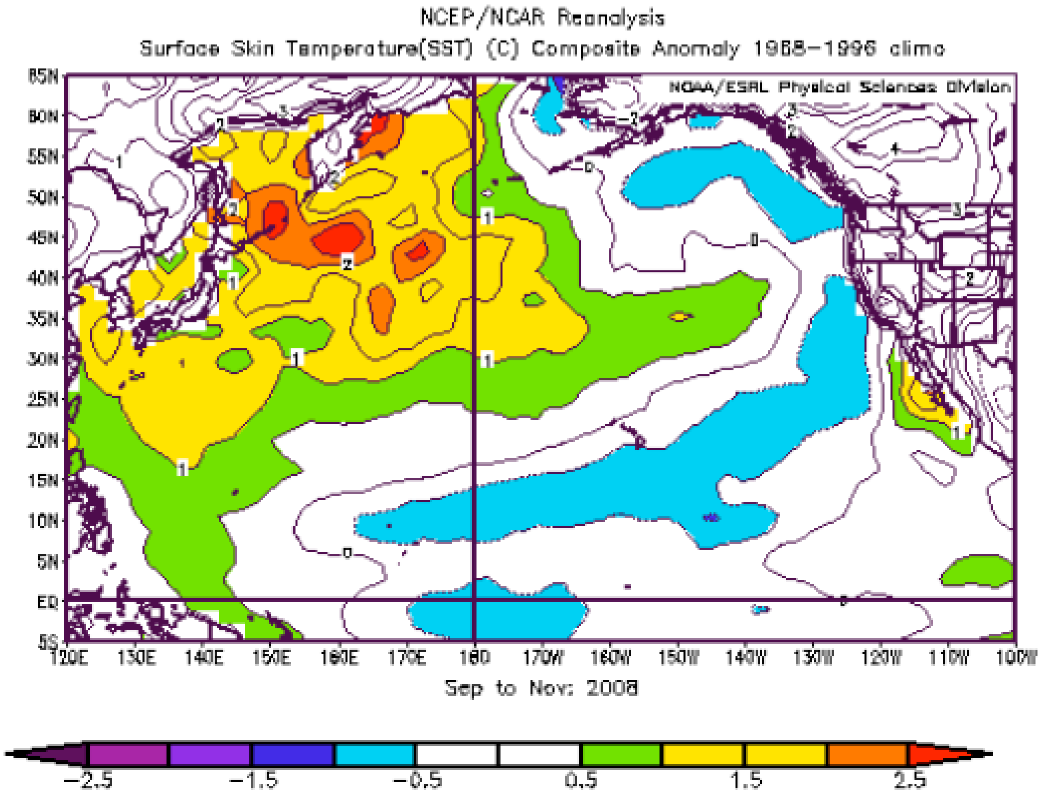

Figure 1a. SST anomalies for September-November 2008**.**

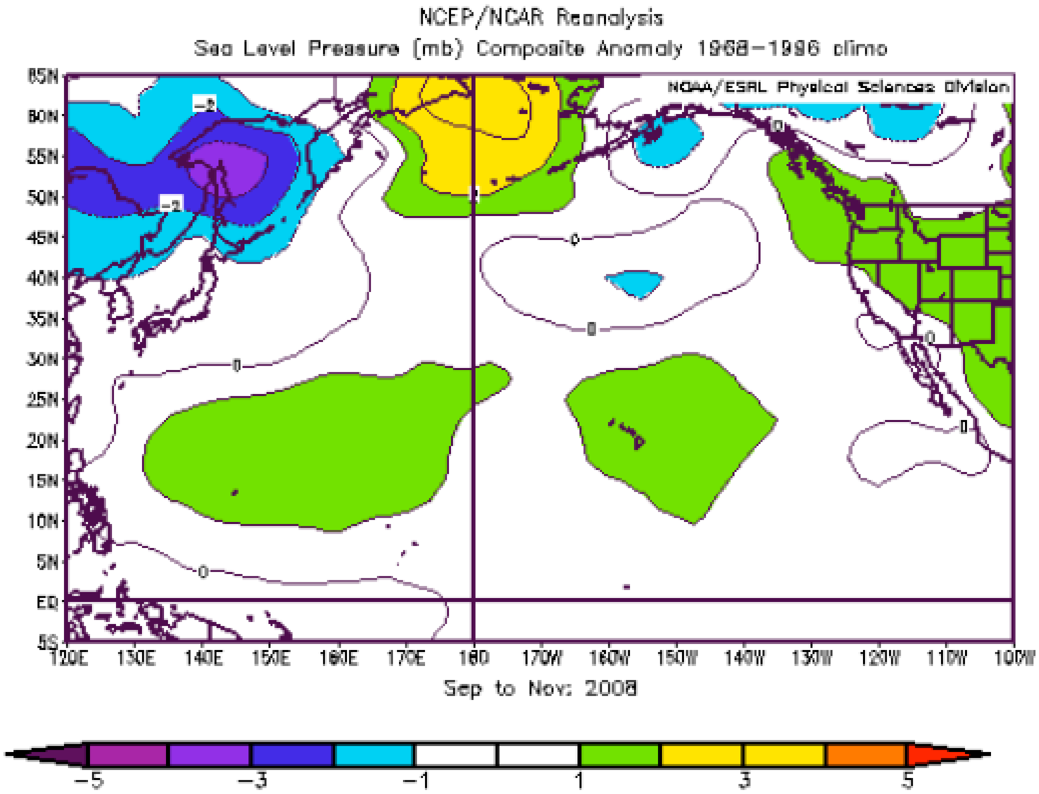

Figure 1b. SLP anomalies for September-November 2008.

The pattern of anomalous SST during winter (December-February, DJF) of 2008-09 was similar to that during the fall of 2008 (Figure 2a). The primary changes that occurred over this interval were the development of cool conditions in the eastern Bering Sea, and a shift in the positive anomaly center to east of the dateline. There was also substantial cooling (relative to seasonal norms) in the eastern and central tropical Pacific in association with a return of weak La Nina conditions. The SLP during winter 2008-09 featured a large positive anomaly (~10 mb) in the northeastern Pacific. The sense and location of this anomaly is consistent with that which has occurred during past La Nina winters, but its magnitude is greater than usual, particularly considering the modest intensity of La Nina. By way of comparison, the previous winter's La Nina was on the order of 50% stronger, but the atmospheric perturbation over the North Pacific, as gauged by the SLP, was about 30% weaker. This comparison of the two years illustrates that the linkage between ENSO and the mid-latitude atmospheric circulation is subject to noise. Whatever the cause(s), the anomalous SLP pattern shown in Figure 2b indicates anomalous westerlies in the mean across the northern portion of the basin from the dateline to southeast Alaska, and anomalous northerlies in the far eastern North Pacific.

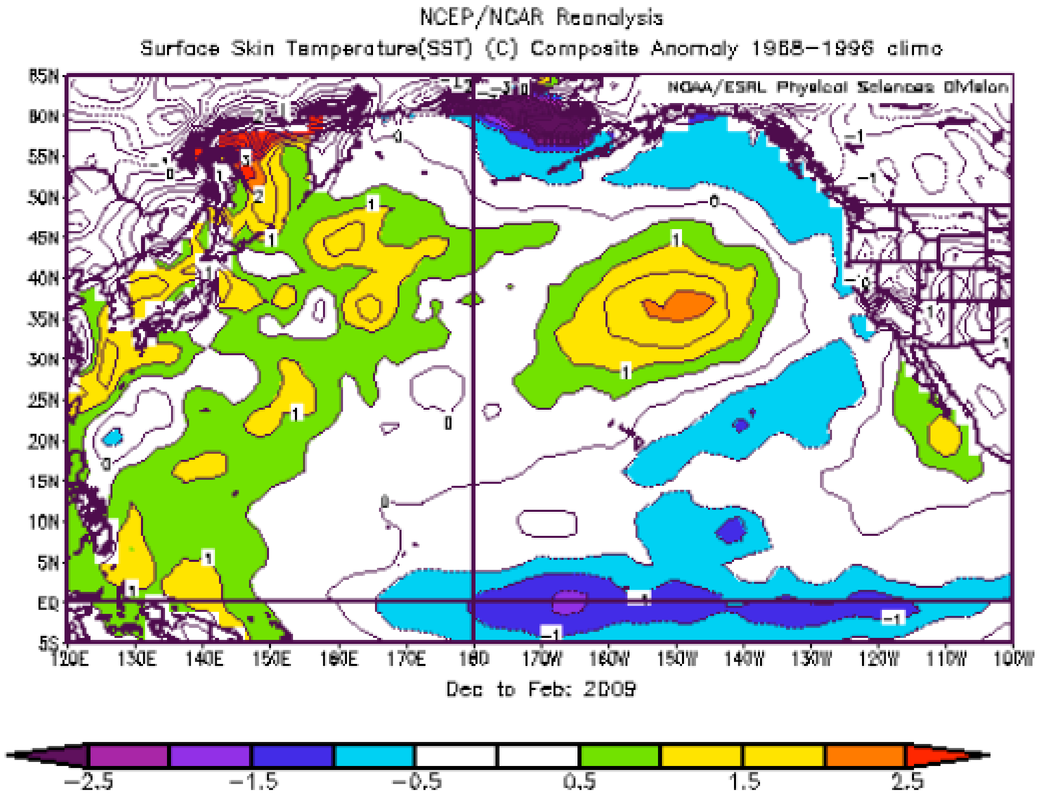

Figure 2a. SST anomalies for December 2008-February 2009.

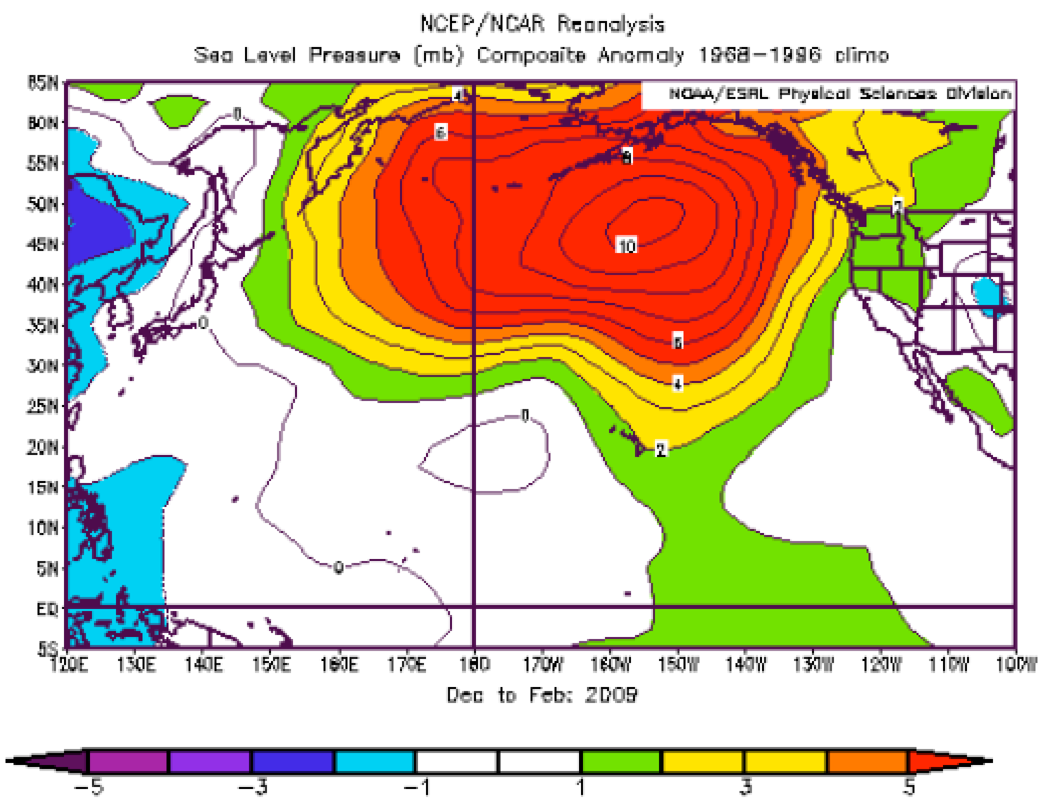

Figure 2b. SLP anomalies for December 2008-February 2009.

The distribution of SST in spring (March-May, MAM) of 2009 (Figure 3a) indicates an overall weakening of the positive anomalies in the central portion of the basin and cooling along the west coast of North America from Alaska to California. Only weak remnants of La Nina were present in the tropical Pacific. The concomitant SLP anomaly map (Figure3b) indicates relatively high pressure over the Bering Sea and Gulf of Alaska and near normal pressure south of about 35˚ N. This pattern served to support relatively cool northerly winds and enhanced coastal upwelling for the Gulf of Alaska and Pacific Northwest.

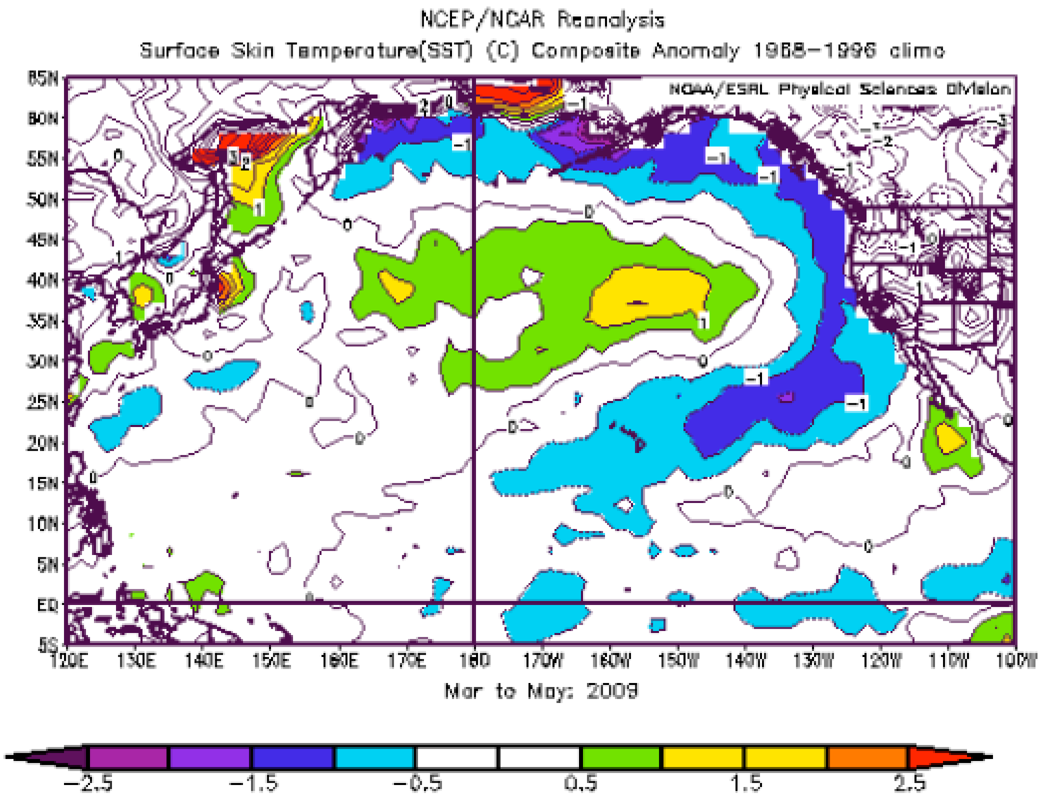

Figure 3a. SST anomalies for March-May 2009.

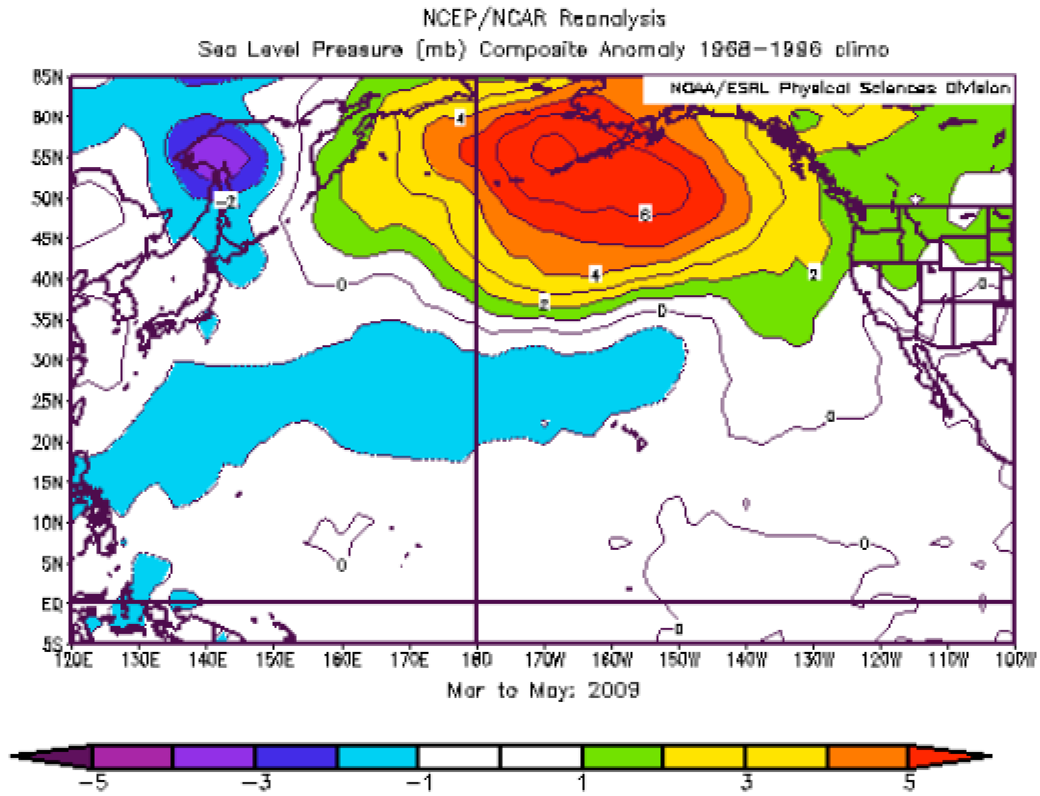

Figure 3b. SLP anomalies for March-May 2009.

The pattern of anomalous SST in summer (June-August, JJA) 2009 included near-normal values along the west coast of North America from the Gulf of Alaska to California after a cooler than normal spring. Relatively cool SSTs persisted in the eastern Bering Sea (Figure 4a). For the basin as a whole, the distribution of SST less resembled that than is characteristic of the negative state of the PDO. There were relatively warm SSTs in the tropical Pacific, especially east of about 130˚ W where temperatures were more than 1˚ C greater than normal in association with a developing El Nino. The SLP distribution in summer 2009 featured anomalously low pressure in the central Pacific from about 25˚ N to Bering Strait (Figure 4b). This anomaly represented a marked change from the higher than normal SLP in the central North Pacific observed over the previous two seasons. Less extensive SLP features included a negative anomaly extending from Vancouver Island to off the coast of Northern California, and a positive anomaly in the Gulf of Alaska. As a consequence, there was weaker than normal upwelling along the west coast of the lower 48 states, and stronger than normal upwelling from Kodiak Island to Vancouver Island.

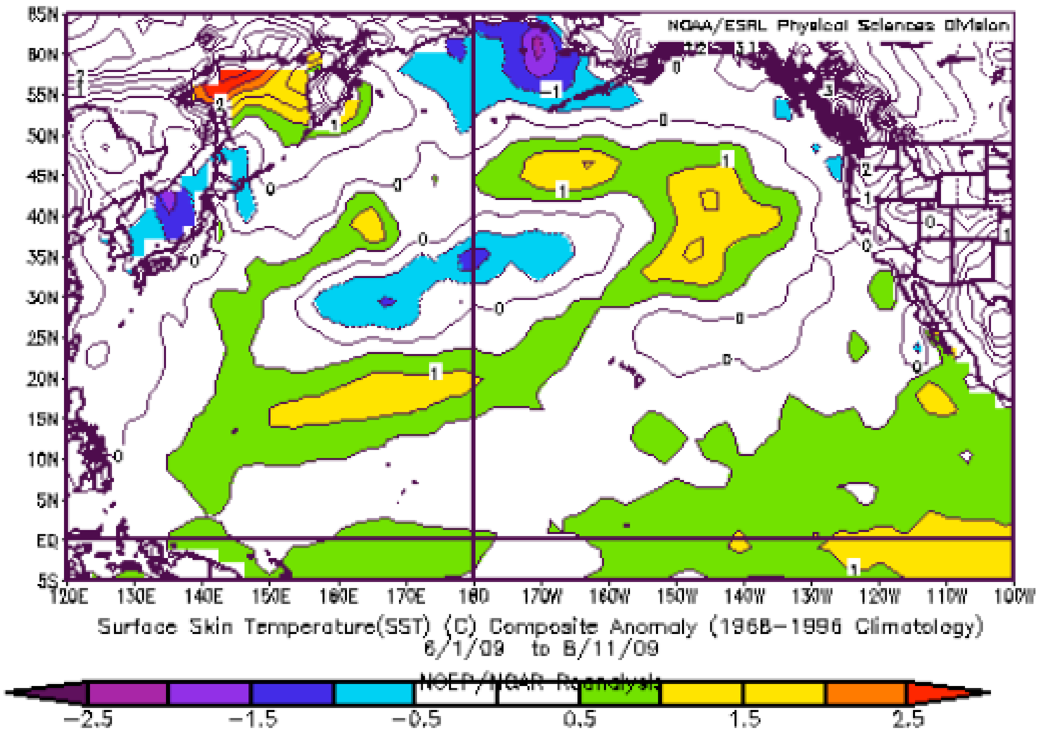

Figure 4a. SST anomalies for June-August 2009.

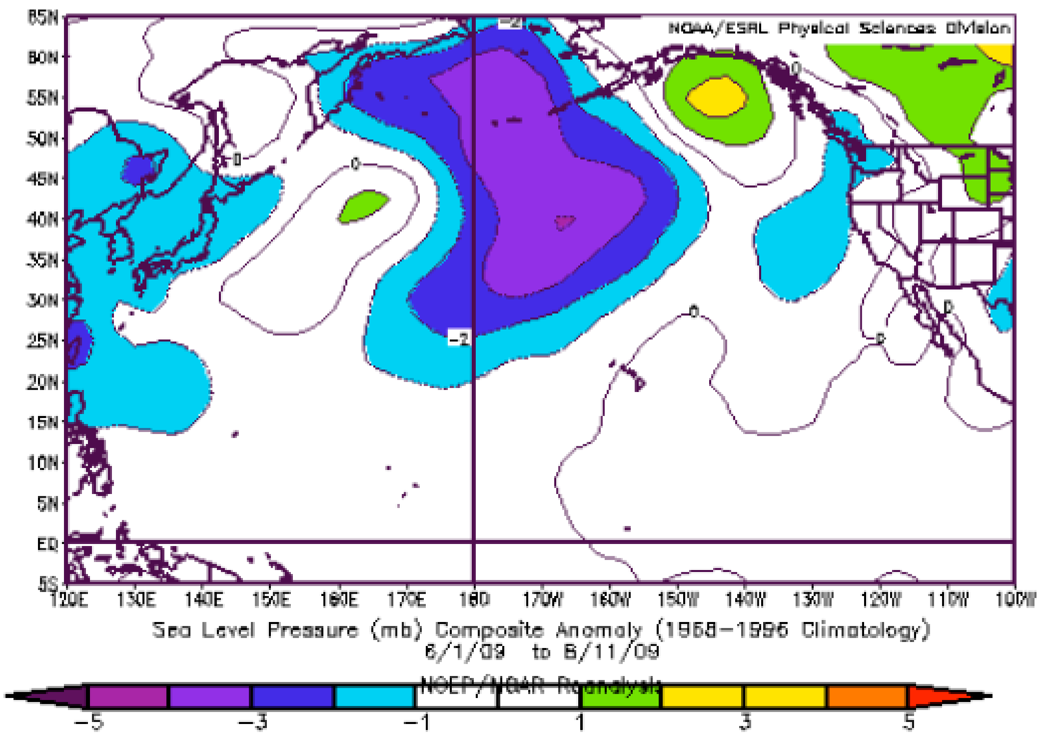

Figure 4b. SLP anomalies for June-August 2009.

2. Climate Indices

The SST and SLP anomaly maps for the North Pacific presented above can be placed in the context of the overall climate system through consideration of climate indices. For the present purposes we focus on four indices: the NINO3.4 index to characterize the state of the El Nino/Southern Oscillation (ENSO) phenomenon, the Pacific Decadal Oscillation (PDO) index (the leading mode of North Pacific SST variability), and two atmospheric indices, the North Pacific index (NPI) and Arctic Oscillation (AO).

ENSO probably played an important role in determining the state of the North Pacific climate during 2008-09. As mentioned above, while the La Nina was actually stronger in 2007-08 than during the past year, as encapsulated by the NINO3.4 index (Figure 5), the concomitant SLP anomalies were stronger in the more recent winter. The tropical Pacific underwent a transition during spring 2009 and is now characterized by weak-moderate El Nino conditions, and there is a strong consensus of the dynamical and statistical models used to forecast ENSO that this El Nino will strengthen into the winter of 2009-10.

The PDO underwent a general decline from early 2003 to early 2009 and since then, has trended positive. Note the correspondence between the PDO and ENSO as indicated by NINO3.4; the correlation coefficient between the NINO3.4 and PDO indices is ~0.6 over the period of record. Given the expectation of El Nino over the upcoming fall and winter, it is also probable that the PDO will revert back to a positive state. On the other hand, while the sense of the PDO tends to match that associated with ENSO, the magnitudes of the PDO's extrema do not correspond tightly with those with ENSO. The key here is the strength of the Aleutian low (the stronger the low the more positive the PDO) and there are factors other than ENSO that help determine the strength, and position, of the Aleutian low.

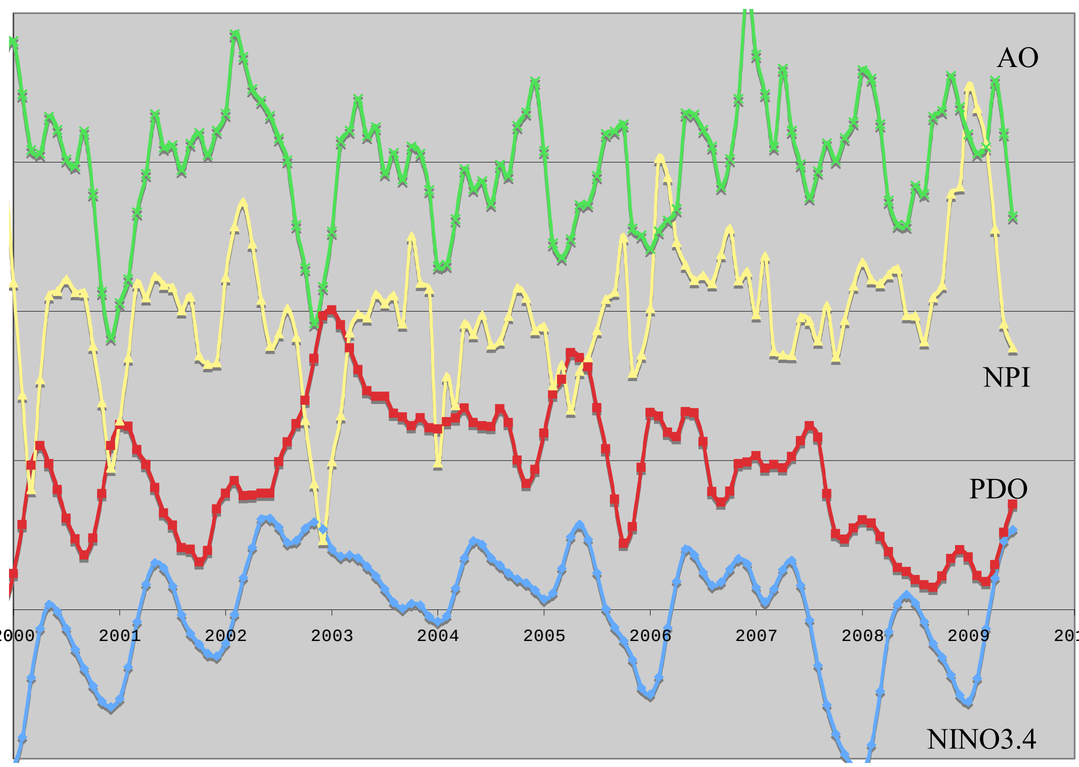

Figure 5. Time series of the NINO3.4 (blue), PDO (red), NPI (yellow), and AO (green) indices. Each time series represents monthly values that are normalized and then smoothed with the application of 3-month running means. The distance between the horizontal grid lines represents 2 standard

deviations. More information on these indices is available from NOAA's Earth Systems Laboratory at http://www.cdc.noaa.gov/ClimateIndices/.

The NPI is one of several measures used to characterize the strength of the Aleutian low. The NPI was strongly positive from late 2008 through 2009 (Figure 5), as also indicated by the SLP anomaly maps of Figs. 2b and 3b. While the NPI has certainly trended strongly negative during 2009, and the remote effects of ENSO make it probable that this trend will continue into 2010, the intrinsic variability of the middle to higher latitude atmospheric circulation precludes making any definitive projections for the future state of the NPI.

The AO signifies 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. The AO includes considerable energy on daily to decadal time scales; the time series of the three-month running mean plotted in Figure 5 shows it was in a mostly positive state from late 2006 through spring 2009, and recently shifted to a negative phase. The response of the atmospheric circulation in the North Pacific to ENSO tends to be enhanced (suppressed) during periods of a negative (positive) state in the AO. There is little predictability in the AO, but if it does remain mostly negative over the next two seasons, then it is likely that the upcoming El Nino will have relatively dramatic impacts on North Pacific air-sea interactions.

3. Regional Highlights

a. **West Coast of Lower 48 –** The focus here is on the upwelling that occurred during the last year. The winter and spring featured stronger than normal upwelling, particularly in the north. This is consistent with observations of a relatively high abundance of species that prosper in cool conditions, including sub-arctic zooplankton, from northern California to Oregon, and presumably, to the north. The winds, relative to their seasonal norms, shifted abruptly in late spring, resulting in anomalous downwelling in central and southern California, especially in June. These conditions are suspected to be a contributing cause of very high sea lion pup mortality in the Southern California Bight, and poor conditions in general for the other piscivores of the region such as cormorants.

b. **Gulf of Alaska –** The coastal Gulf of Alaska remained relatively cool during the past year. The data from Argo profiling floats, available at http://www.pac.dfo-mpo.gc.ca/sci/osap/projects/argo/Gak_e.htm, reveals a relatively weak and broad Alaska Current off the coast of SE Alaska, as compared with 2008. This region also had relatively shallow mixed layer depths in the winter and spring of 2009, as would be expected during periods of higher than normal SLP and hence suppressed storminess. Based on the winds along the northern Gulf of Alaska coast, the Alaska Coastal Current (ACC) on the shelf was probably relatively weak during the winter and spring, returning to near-normal transports in the summer. It bears noting that the scarcity of sub-surface data for the shelf regions of the Gulf of Alaska precludes making definitive statements about the actual state of the Alaska Coastal Current (ACC) during the review period.

c. **Alaska Peninsula and Aleutian Islands –** The eastern portion of this region experienced suppressed storminess during winter and spring; the sense of the wind anomalies since late 2008 is from the east to southeast, which is associated with enhanced transports through Unimak and the other shallow passes in the eastern Aleutians. The western Aleutians experienced southerly wind anomalies early in the period and northerly wind anomalies during the past summer. The SST here was warm during the latter part of 2008, cooling to near normal by summer 2009 relative to seasonal norms.

d. **Bering Sea –** The third in a series of notably cold winters occurred in the Bering Sea. This is consistent with a weaker than normal Aleutian low, in that when the Aleutian low is intense there is a greater frequency of cyclonic storms of maritime origin, versus migratory anticyclones of continental or Arctic origin. An important consequence of the extensive sea ice on the Bering Sea shelf during the past winter and spring was that it effectively left behind a prominent cold pool of water of less than 2° C on the middle shelf. The offshore extent of the cold pool during 2009 is comparable, but not quite to that which was observed in 2008. The SLP pattern over the Bering Sea has favored somewhat greater than normal wind speeds over the shelf during the summer of 2009, but at the time of the writing of this report, the extent to which this has been manifested in the mixing of nutrients from depth, and hence sustained primary production, is unknown.

e. Arctic – The past year was marked by some continuation in a recovery from a record low total area of sea ice in the Arctic in early fall 2007. At the time of writing, the sea ice cover for the Arctic as a whole was about $1 \times 10^6 km^2$ greater than that at the same time during 2007, but still $1.3 \times 10^6 km^2$ less than the 1979-2000 average. From an Alaskan perspective, it is interesting that the ice edge in the Beaufort Sea is presently near its long-term climatological position. The melt season will continue for another 5-6 weeks, and it is uncertain how the minimum ice extent will compare with past summers. The SLP pattern during winter and spring featured anomalously low values in the central Arctic in association with a positive state of the AO. A decidedly different SLP distribution prevailed in the summer of 2009 during which substantially higher than normal pressure occurred in the Arctic, especially in its western half.

4. Seasonal Projections from NCEP

Seasonal projections from the NCEP coupled forecast system model (CFS03) for SST are shown in Figure 6. The SST anomaly maps indicate increasingly positive SST anomalies in the equatorial Pacific. This model’s forecast of El Nino is on the high side, but within the envelope of ENSO forecasts (not shown) from the host of dynamical and statistical models in present use. The CFS03 model indicates an overall warming along the west coast of North America. Specifically, by late winter/early spring of 2010, it projects near normal temperatures on the eastern Bering Sea shelf, and significantly warmer than normal temperatures in the northeastern portion of the North Pacific, particularly off the coast of southeast Alaska. It turns out that the forecasts made by this model last year at this time reproduced the basin-wide pattern of the seasonal mean SST anomalies that were observed, but with an overall warm bias. In particular this atmosphere-ocean model did not forecast conditions promoting extremely heavy sea ice on the eastern Bering Sea shelf. Nevertheless, the favorable track record for this model over the last two years, and the extra North Pacific predictability associated with El Nino indicates it can provide useful guidance through at least the winter of 2009-10.

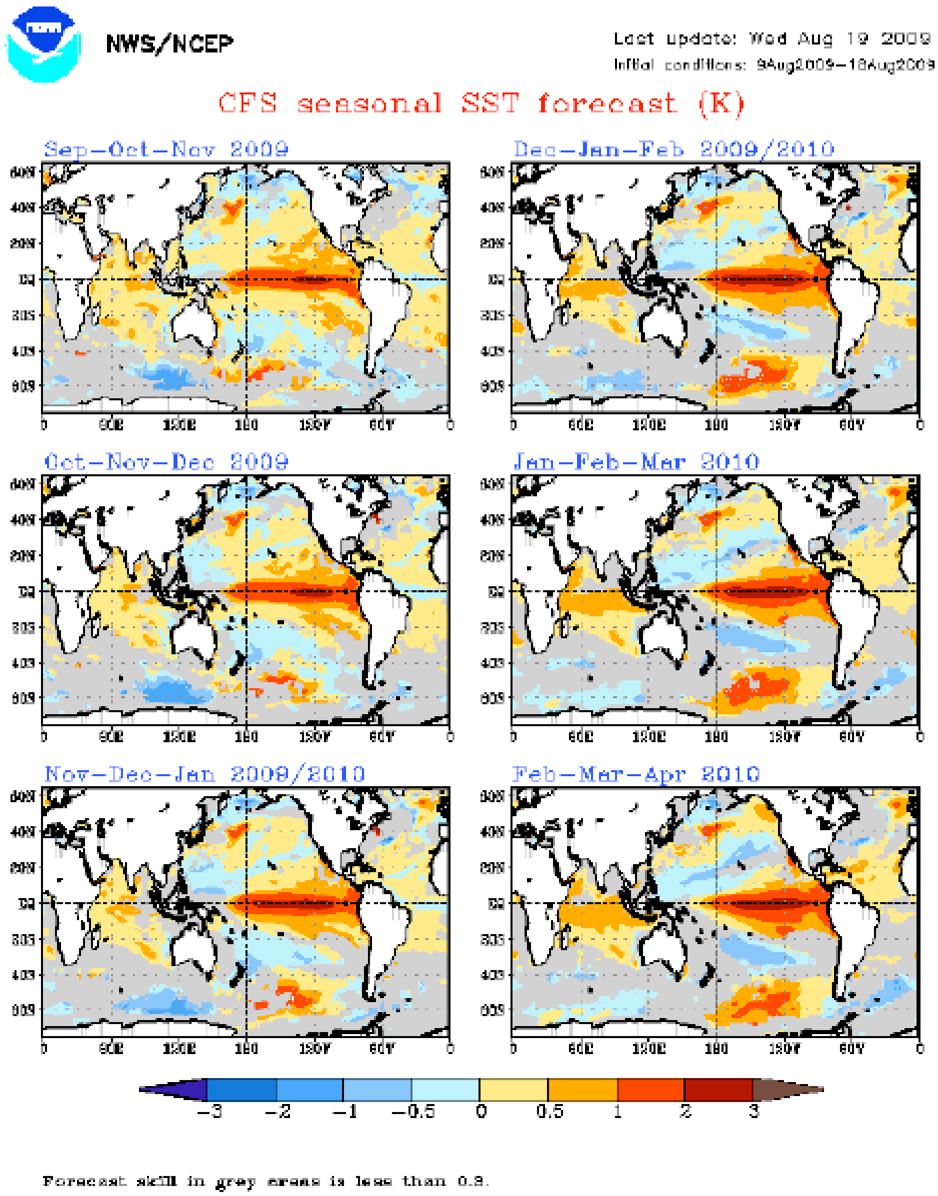

Figure 6. Seasonal forecast of SST anomalies from the NCEP coupled forecast system model**.**

GULF OF ALASKA

Pollock Survival Indices – EcoFOCI
Contributed by S. A. Macklin, NOAA/PMEL
Contact: S.Allen.Macklin@noaa.gov
Last updated: August 2008

See the 2008 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm
And see the GOA pollock stock assessment, as this contribution will no longer be updated in the Ecosystem Considerations report.

Seasonal rainfall at Kodiak
Contributed by S. A. Macklin, NOAA/PMEL
Contact: S.Allen.Macklin@noaa.gov
Last updated: August 2008

See the 2008 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm And see the GOA pollock stock assessment, as this contribution will no longer be updated in the Ecosystem Considerations report.

Wind mixing at the southwestern end of Shelikof Strait
Contributed by S. A. Macklin, NOAA/PMEL
Contact: S.Allen.Macklin@noaa.gov
Last updated: August 2008

See the 2008 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm And see the GOA pollock stock assessment, as this contribution will no longer be updated in the Ecosystem Considerations report.

Eddies in the Gulf of Alaska – FOCI
Contributed by Carol Ladd, NOAA/PMEL
Contact: Carol.Ladd@noaa.gov
Last updated: July 2009

Eddies in the northern Gulf of Alaska have been shown to influence distributions of nutrients (Ladd et al. 2005, Ladd et al. 2007), phytoplankton (Brickley and Thomas 2004) and ichthyoplankton (Atwood et al. submitted), 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). In most years, these eddies impinge on the shelf east of Kodiak Island in the spring. Using altimetry data from 1993 to 2001, Okkonen et al. (2003) found an eddy in that location in the spring of every year except 1998. They 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 (SSH). 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 three regions with local maxima (labeled a, b, and c in Figure 7). The first two regions are associated with the formation of Haida eddies (a) and Sitka eddies (b). Regions of enhanced EKE emanating from the local maxima illustrate the pathways of these eddies. Sitka eddies can move southwestward (directly into the basin) or northwestward (along the shelf-break). Eddies that move along the shelf-break often feed into the third high EKE region (c; Figure 7). By averaging EKE over region c (see box in Figure 7), we obtain an index of energy associated with eddies in this region (Figure 8).

The seasonal cycle of EKE averaged over Region (c) exhibits high EKE in the spring (March-May) with lower EKE in the autumn (September-November). EKE was particularly high in 2002-2004 when three large persistent eddies passed through the region. Prior to 1999, EKE was generally lower than the ~16-year average, although 1993 and 1997 both showed periods of high EKE. Low EKE values were observed for 2005-2006 indicating a reduced influence of eddies in the region. Higher EKE values were observed in the spring of 2007 and 2008 as eddies moved through the region. EKE levels were low in the spring of 2009. This may have implications for the ecosystem. Phytoplankton biomass was probably more tightly confined to the shelf during 2005-2006 and 2009 due to the absence of eddies, while in 2007 and 2008 phytoplankton biomass likely extended farther off the shelf. In addition, cross-shelf transport of heat, salinity and nutrients were likely to be smaller in 2005-2006 and 2009 than in 2007 and 2008 (or other years with large persistent eddies). The altimeter products were produced by the CLS Space Oceanography Division (AVISO 2008).

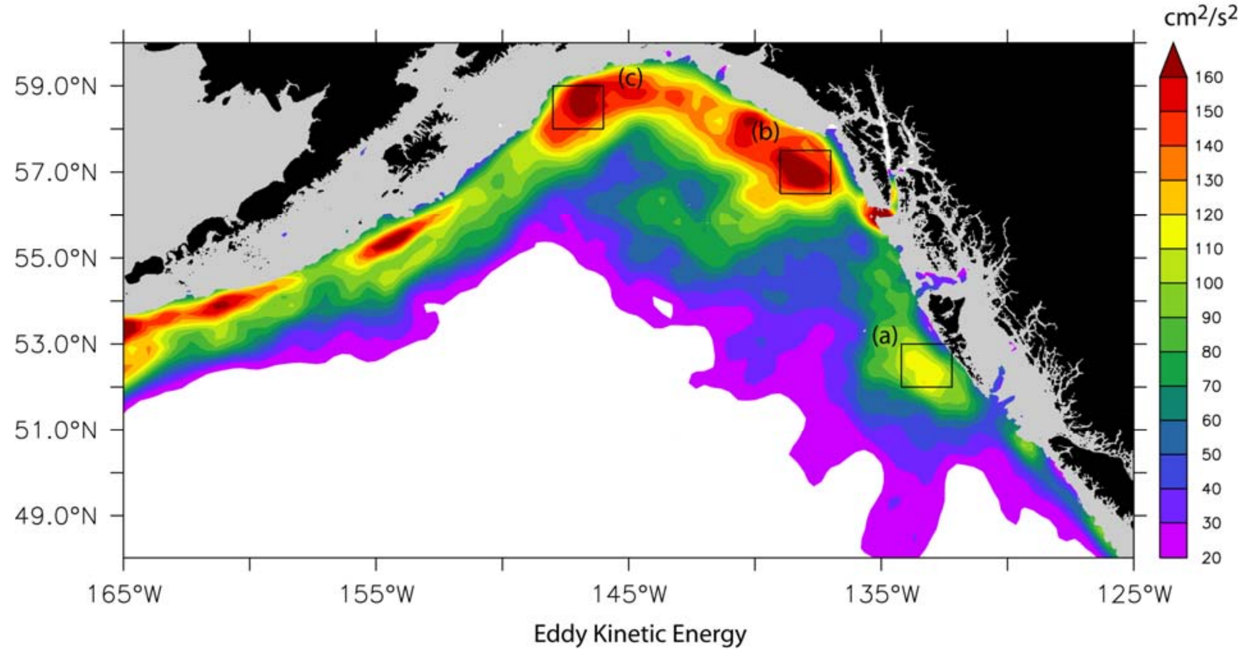

Figure 7. Eddy Kinetic Energy averaged over October 1993-October 2008 calculated from satellite altimetry. Region (c) denotes region over which EKE was averaged for Figure 8.

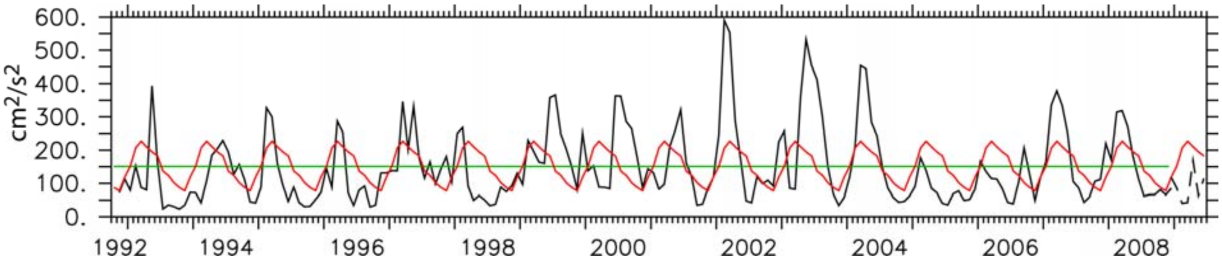

Figure 8. Eddy kinetic energy ($cm^2\ s^{-2}$) averaged over Region (c) shown in Figure 7. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product), Red: seasonal cycle. Green (straight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

Ocean Surface Currents – Papa Trajectory Index

Contributed by W. James Ingraham, Jr., Alaska Fisheries Science Center (Retired)
Contact: jim.ingraham@wavecable.com

Last updated: July 2009

Exploring historic patterns of ocean surface currents with the "Ocean Surface CURrent Simulator" (OSCURS) provides annual or seasonal indices of ocean currents for the North Pacific and Bering Sea, and thus, contributes to our understanding of the year-to-year variability in near surface water movements. This variability has been shown to have an important effect on walleye pollock survival and spatial overlap with predators (Wespestad et al. 2000) and have an influence on winter spawning flatfish recruitment in the eastern Bering Sea (see update on EBS winter spawning flatfish recruitment and wind forcing, this volume; and Wilderbuer et al. 2002).

Simulation experiments using the OSCURS model can be run by the general public on the World Wide Web by connecting to the live access server portion of the NOAA-NMFS Pacific Fisheries Environmental Lab's (PFEL) web site. See the information article, "Getting to Know OSCURS", for a summary of such experiments that have already been run.

The Papa Trajectory Index (PTI) is an example of long-term time-series data computed from a single location in the Gulf of Alaska. OSCURS was run 105 times starting at Ocean Station Papa (50º N, 145º W) on each December first for 90 days for each year from 1901 to 2008 (ending February 28 of the next year). The trajectories fan out northeastwardly toward the North American continent and show a predominately bimodal pattern of separations to the north and south. The plot of just the latitudes of the end points versus time (Figure 9) illustrates the features of the data series and the variability of the winter Alaska Current.

To reveal decadal fluctuations in the oceanic current structure relative to the long-term mean latitude (green horizontal line at 54.74º N), the trajectories were smoothed in time with a 5-year running mean boxcar filter. Values above the mean indicate five winters adjacent to that year have an average of anomalously northward (faster speed) surface water circulation in the eastern Gulf of Alaska; values below the mean indicate winters with anomalously southward (slower speed) surface water circulation.

In the winter of 2003 and 2004 the long expected change in modes from north to south narrowly occurred in the 5-year running mean centered on the winter 2003 (Figures 9 and 10). This was strongly influenced by the extreme southward transport in 2002. During 2004-2006 values were near neutral, in 2007 values were northward, and in 2008 values were southward. The time-series has been updated with winter 2009 calculations and shows circulation was southward for the second consecutive year.

The century plot of the 5-year running mean shows four complete oscillations with distinct crossings of the mean; but the time intervals of the oscillations were not constant; 26 years (1904-1930), 17 years (1930-1947), 17 years (1947-1964), and 39 years (1964-2003). The drift from Ocean Weather Station Papa has fluctuated between north and south modes about every 25 years over the last century. When the 5-year running mean crosses the zero line it usually stays there for several years.

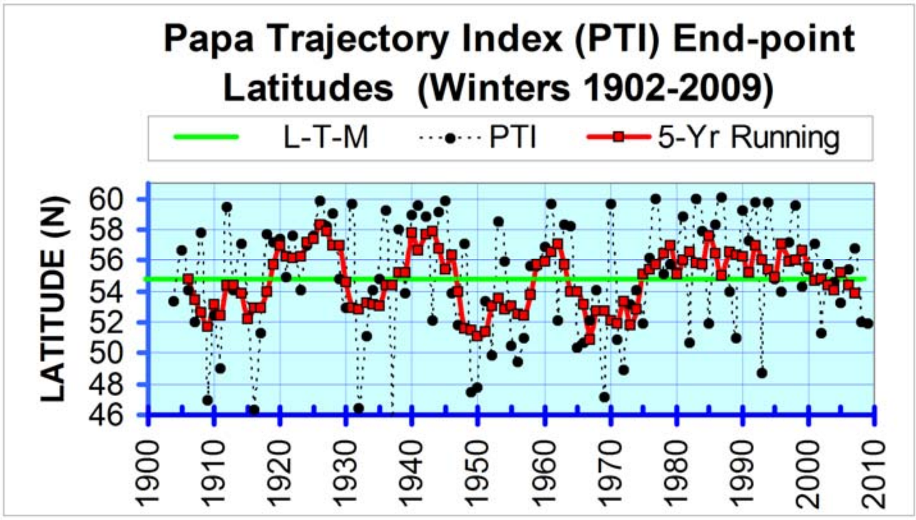

Figure 9. Annual, long-term mean and 5-year running mean values of the PAPA Trajectory Index (PTI) time-series from winter 1902-2009. Large black dots are annual values of latitude of the end points of 90-day trajectories which start at Ocean Weather Station PAPA (50º N, 145º W) each December 1, 1901-2008. The straight green line at 54º 44' N is the mean latitude of the series. The thick red oscillating line connecting the red squares is the 5-year running mean. This shows the variations in the onshore (northeastward) flow, eras when winter mixed layer water drifting from PAPA ended farther north or south after 90 days.

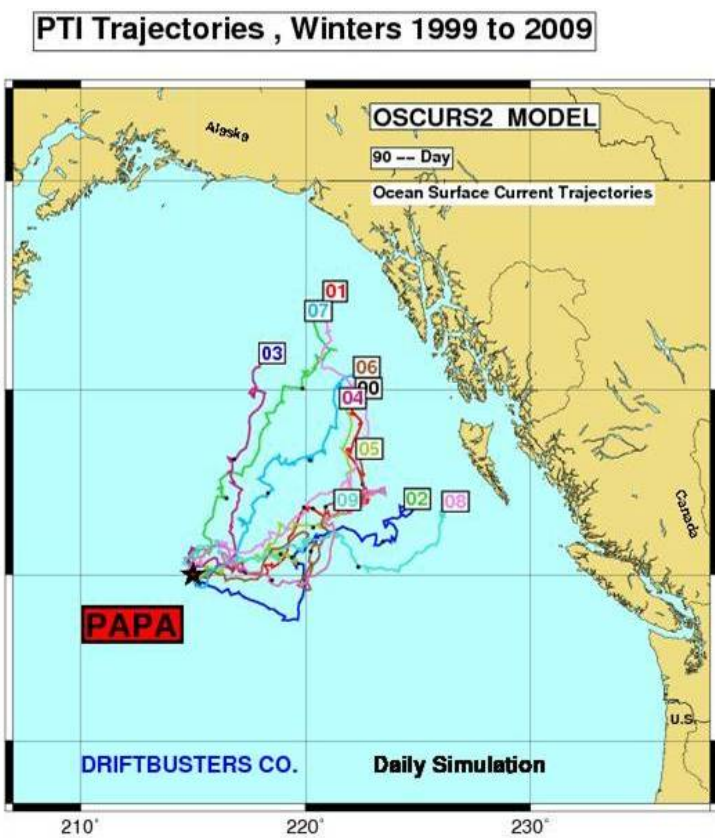

Figure 10. Papa trajectory end points for winters 1999-2009. End points of 90-day trajectories which start at Ocean Weather Station PAPA (50º N, 145º).

Gulf of Alaska Survey Bottom Temperature Analysis
Contributed by Michael Martin, Alaska Fisheries Science Center
Contact: Michael.Martin@noaa.gov
Last updated: October 2009

Ocean circulation in the Gulf of Alaska (GOA) is dominated by two current systems, the Alaska Current and the Alaska Coastal Current (Stabeno et al., 2004). The Alaska Current is driven by the West Wind Drift of the subarctic gyre in the North Pacific basin and flows to the north-northwest from the survey boundary at Dixon Entrance. It is characterized by numerous eddies and meanders until forced to the southwest around Prince William Sound, forming the origins of the Alaska Coastal Current. The majority of this water flows through Shelikof Strait, with the remainder passing to the south of Kodiak Island, forming the origins of the Alaska Stream which continues to flow to the west along the Aleutian Islands (Stabeno et al., 1995, Shumacher et al., 1989). In addition, tidal forces dominate circulation in some local areas, particularly around Cook Inlet and in and around many of the bays along the Alaska Peninsula.

Water temperature data have been routinely collected on bottom trawl hauls using micro-bathythermographs since 1993. In earlier years, temperature data were often collected near trawl haul sites using expendable bathythermographs; however these earlier data were not considered in this analysis. Groundfish assessment survey periods have ranged from early May to late September, and sampling has usually progressed from west to east. Notable exceptions exist to this general pattern, particularly for the two surveys in the 1980's involving Japanese vessels. The beginning date of the survey over the period included in the analysis has ranged from the middle of May to the first week in June, while the last day of the survey has ranged from the third week in July to the first week of September. In addition, the area covered by the survey and the depths sampled have not been consistent in all years.

These differences in sampling patterns in time and space complicate inter-annual comparison due to the strong relationship between date of collection and water temperature at all depths throughout the GOA survey area. In order to account for these problems and make inter-annual comparisons more meaningful, an attempt was made to remove the effect of date of collection on water temperature, in effect standardizing temperatures to an approximate median date for most GOA surveys (July 10). This was achieved by using generalized additive modeling techniques to model the effects of day of year and depth on temperature. The model was then used to predict the temperature at a new date (July 10) at the same depth, and the residuals of the original model were added to the prediction for the final estimate. All further analyses used these predicted temperatures. In order to facilitate visualization of the modeled temperatures, the data were binned into 0.5 degree latitude and multiple depth increments and a mean temperature in each increment was calculated. Depth increments were much finer at shallower depths to capture the rapid changes in water temperatures often seen in these depths. The results are shown in figure 11.

The inter-annual differences in sampling areas and depths, clearly shown in figure 11, complicate comparisons between years; however some patterns are clearly discernible. Water temperatures observed during the 2007 and 2009 surveys exhibited a markedly different pattern than other surveys. Temperatures decreased rapidly from the surface to 6 degrees C or less at around 50 m over the entire survey area, often with warmer water below. The very warm near-surface temperatures that were observed in 2001, 2003, and 2005 were largely absent in these years, although surface waters in the western portion of the survey area were generally warmer in 2009 than in 2007. Figure 12 also shows the colder water patterns in 2007 and 2009, particularly in the 100 – 200 m depth range.

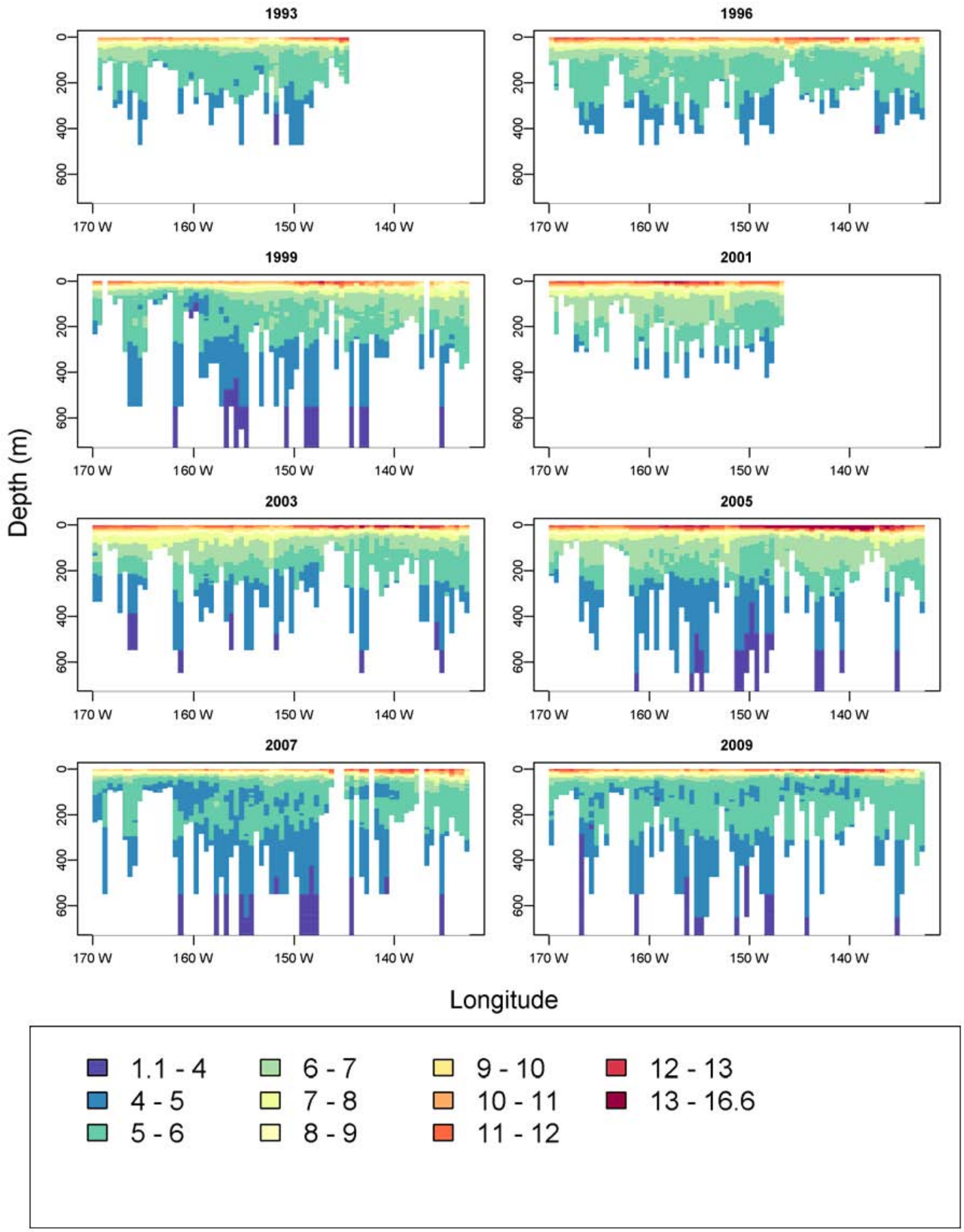

Figure 11. Date adjusted temperature profiles by ½ degree longitude intervals for years 1993-2009.

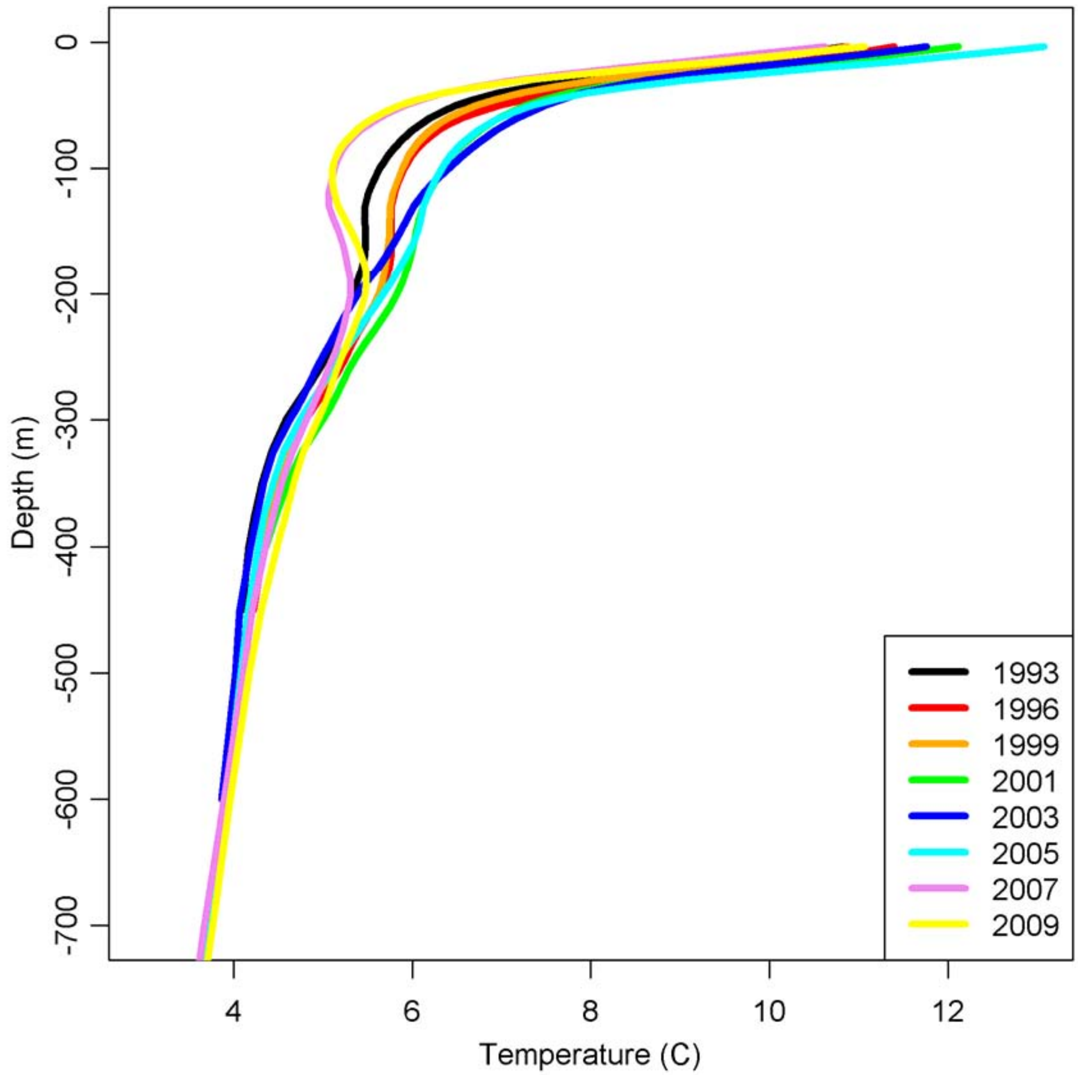

Figure 12. Date adjusted temperature smoothed mean profiles for depths to 800 m for years 1993-2009.

Winter Mixed Layer Depths at GAK 1 in the Northern Gulf of Alaska

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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

EASTERN BERING SEA

Eastern Bering Sea Climate – FOCI

Contributed by J. Overland, P. Stabeno, M. Wang, C. Ladd, N. Bond, and S. Salo, PMEL/NOAA
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Last updated: September 2009

Summary. *The year 2009 was a fourth sequential year with cold temperatures and extensive springtime sea ice cover. The Bering Sea again contrasted with much of the larger Arctic which had extreme summer minimum sea ice extents in 2007 through 2009 (39 % below climatology) and positive autumn surface temperature anomalies north of Bering Strait of greater than 4° C. These four recent cold years in the eastern Bering Sea followed a sequence of warm years earlier in the century. A major lesson is that Bering Sea climate conditions are primarily controlled by local or North Pacific processes through winter, spring and summer, and tend to be decoupled from the continued major sea ice loss and warming taking place throughout the greater Arctic regions. Over the next year we should see a modest shift back toward more normal temperatures and less sea ice, ending the run of cold years, as weak to moderate El Nino conditions have developed and are projected to influence Alaska through fall and winter (see North Pacific review).*

Surface temperatures are easily measured and provide an available long term measure of the state of the climate. Winter (December-March (DJFM)) average surface air temperatures on St. Paul Island continued cold in 2009 (Figure 13 top). On long time scales (Figure 13 bottom), cold anomalies had their first major appearance in 2006 and 2006-2009 is now the coldest period since pre-1978 conditions.

As in 2008, winter and spring during 2009 was anomalously cold in the southeast Bering Sea (Figure 14). The Bering Sea was part of a region of cold temperatures extending eastward across Alaska and western Canada. In contrast to 2008 the western Pacific Ocean to the southwest switched to warmer temperatures in 2009, while the Arctic remains warmer than normal. The proximate cause of the cold winter and spring in 2009 is similar to 2008 and is shown by the sea level pressure (SLP) anomaly field in Figure 15. The Aleutian low pressure region had much higher than normal SLP indicating weaker or fewer storm systems entering the Bering Sea and east-west trending SLP contours suggest the presence of cold Arctic air masses over the central Bering Sea. What also stands out for 2007 through 2009 is that the warm temperatures of 2000-2005 continue in Chukchi Sea, but not in the southeast Bering Sea.

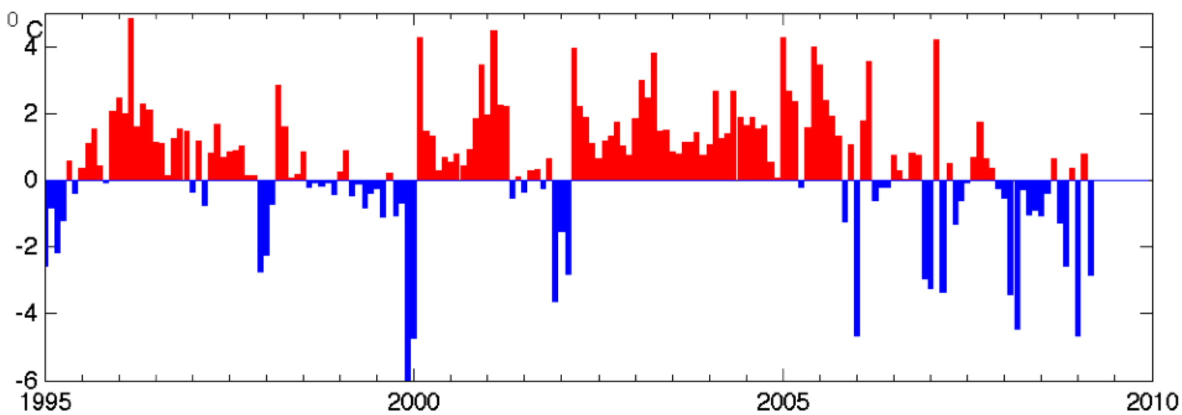
The four year major cold period in the Bering Sea will probably come to an end with more average conditions prevailing through winter and spring 2009-2010. Modest El Nino conditions are now established and forecasts project these conditions will persist in the North Pacific (See North Pacific climate section). El Ninos can have a direct impact in warming the Bering Sea, called Nino North, but if the northern atmospheric jet stream is also strong, the El Nino impact is less. While we cannot be certain of a warm Bering Sea, we generally can say that the Bering will most likely shift to more average temperatures and sea ice extent in 2010.

Seasonal sea ice is a defining characteristic of the Bering Sea shelf. The presence of sea ice influences the timing of the spring bloom and bottom temperatures throughout the year. Sea ice extent in 2009, as well as 2007 and 2008, (Figure 16) was close to record extents, not seen since the early 1970s, and contrast to the warm years of 2000-2005 (except 2002). With regard to sea ice, the southeast Bering Sea is again showing different conditions than north of Alaska. September 2007, 2008 and 2009 all showed extreme sea ice loss in the summer Arctic. But in fall 2007 and 2008 sea ice extent moved rapidly southward in the northern Bering Sea by December. This supports that the southeastern Bering Sea climate system is mostly decoupled from the continuing warming trend of the greater Arctic.

Along with cold air temperatures and extensive sea ice, ocean temperatures at the M2 mooring site continued to be sharply lower in winter 2006 through winter 2009 compared with 2000-2005 (Figure 17), while 2005 was the warmest year on record. The cold pool (Figure 18), defined by bottom temperatures < 2°C, influences not only near-bottom biological habitat, but also the overall thermal stratification and ultimately the mixing of nutrient-rich water from depth into the euphotic zone during summer. The extent of the cold pool for summer 2009 is the most prominent since 1999, and is even more extensive than 2007 or 2008.

Further information from the M2 mooring, the vertical distribution of temperature for different years (Figure 19) relates to biological productivity. Prior to 2000, ice was observed in the location of M2 on the southeast Bering Sea shelf almost every winter (black shading of temperatures, Figure 19). This was followed by the warm, sea ice-free years. Water column conditions in the winter of 2008 and 2009 were cold for much longer than even 2006 and 2007. As noted in the cold pool figure (Figure 18), the southeastern Bering Sea is now a reservoir of cold sea temperatures.

The most important aspects of the physical environmental in the eastern Bering Sea during 2009 was the multi-year sequential continuation of cold air temperatures, more extensive sea ice, and cold ocean temperatures relative to the previous decade and the apparent decoupling of this cold climate response from the larger scale warming trend of the Arctic. These conditions may moderate in winter 2009-2010.



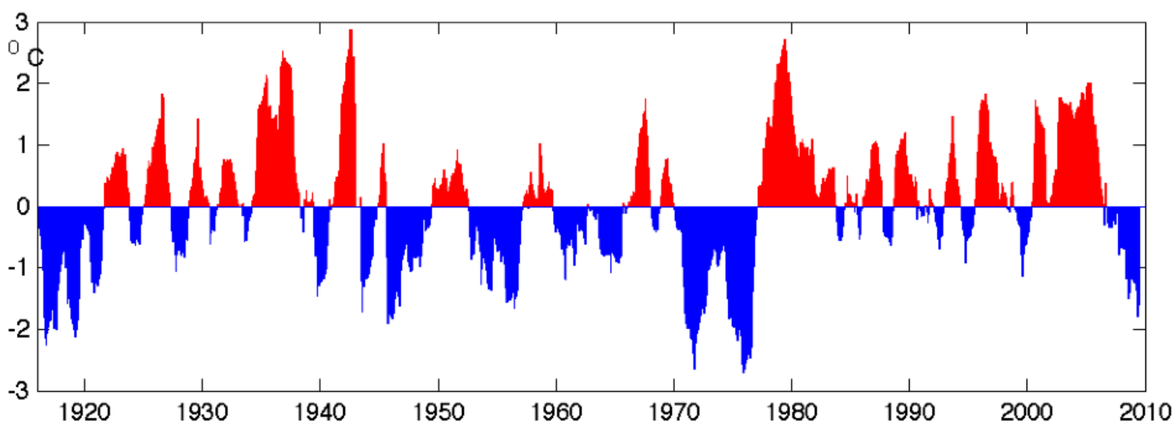


Figure 13. Mean monthly surface air temperatures anomalies in St. Paul, Pribilof Islands, a) unsmoothed, January 1995 through April 2009, and b) smoothed by 13-month running averages, January 1916 through April 2009. The base period for calculating anomalies is 1961-2000.

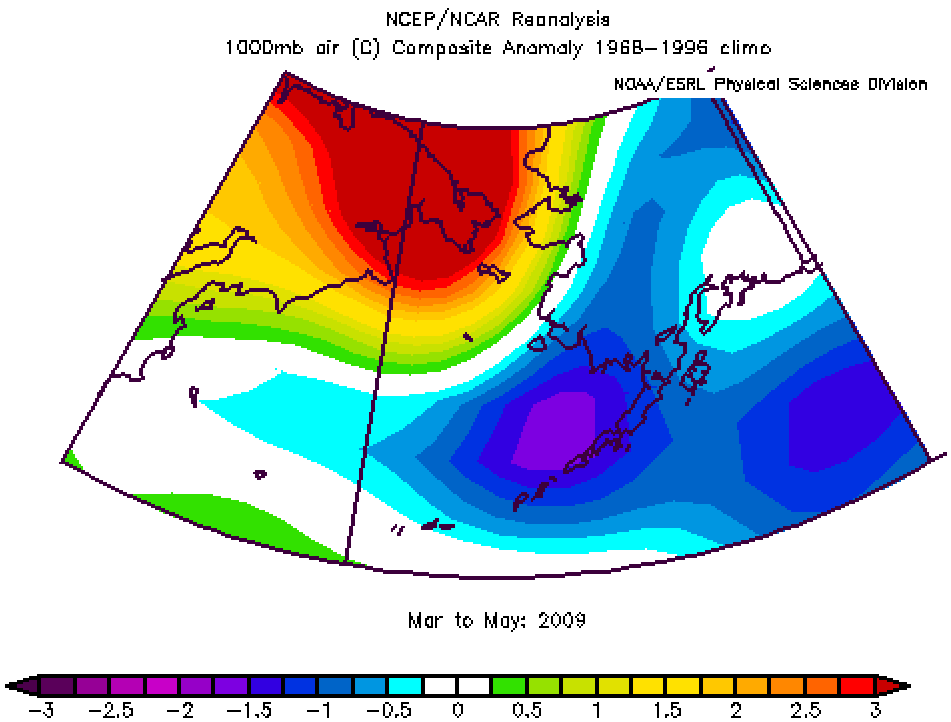


Figure 14. Surface air temperature anomaly over the greater Bering Sea region for spring 2009. Cold surface air temperature anomalies were present in the southeastern Bering Sea (blue shading). Note the contrast to the warm anomalies in northern Siberia.

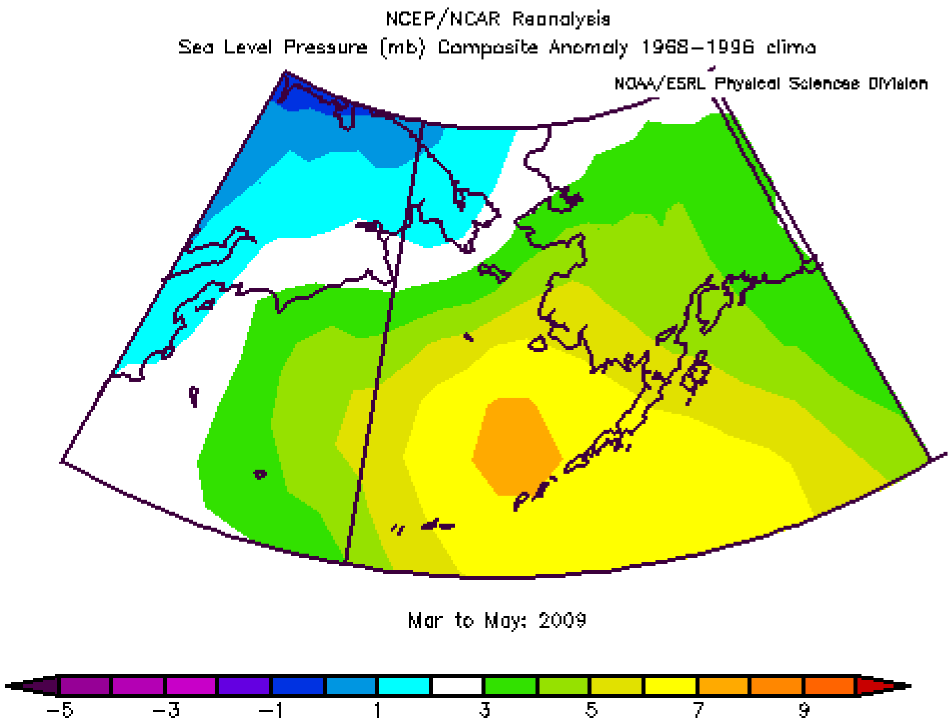


Figure 15. Sea level pressure (SLP) anomaly field for spring 2009. Much higher than normal SLP was present throughout the region. The maximum in the southeast Bering Sea supports weak or west winds anomalies supporting cold air over the SE Bering Sea.

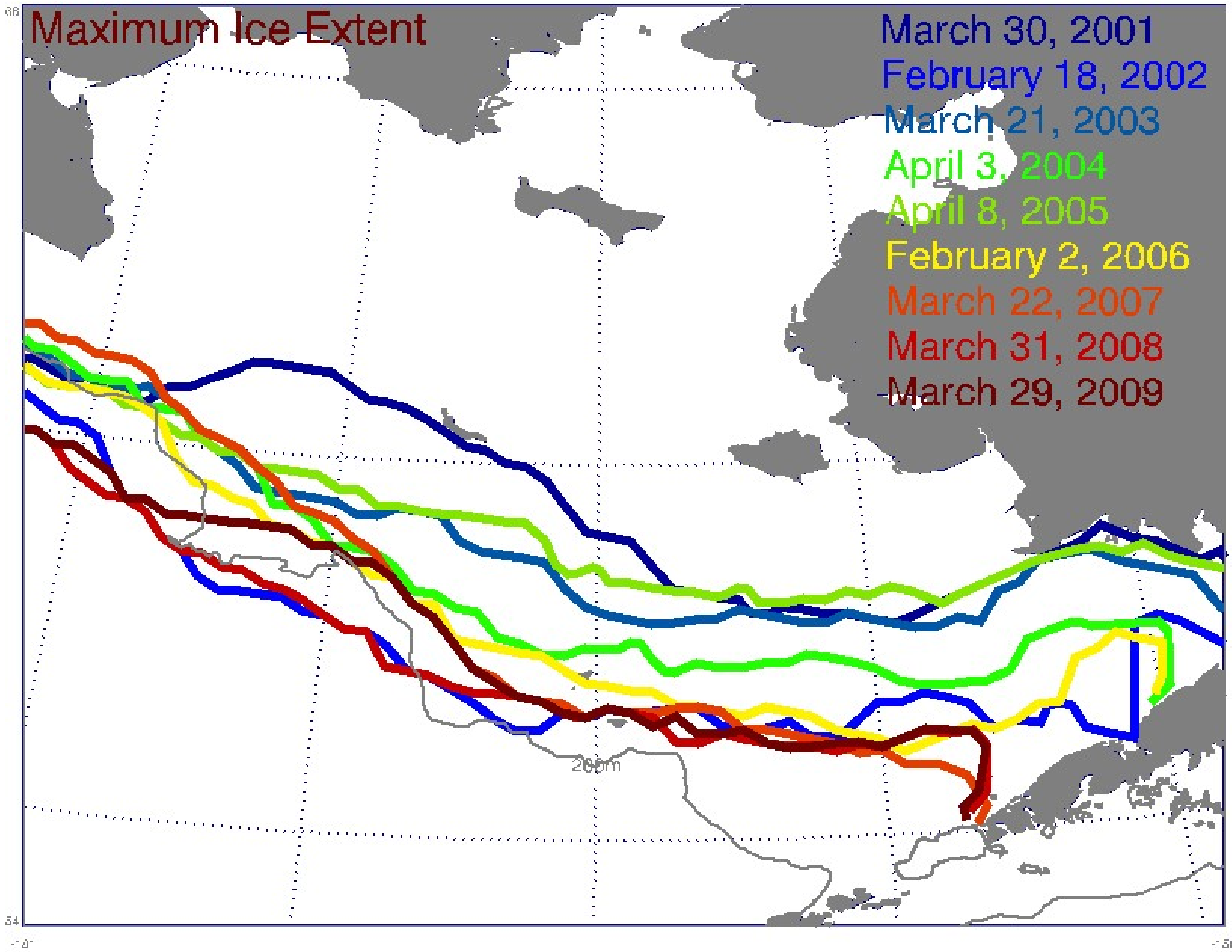


Figure 16. Recent springtime ice extents in the Bering Sea. Ice extent in 2006 through 2009 exceed the minimums of the early 2000s.

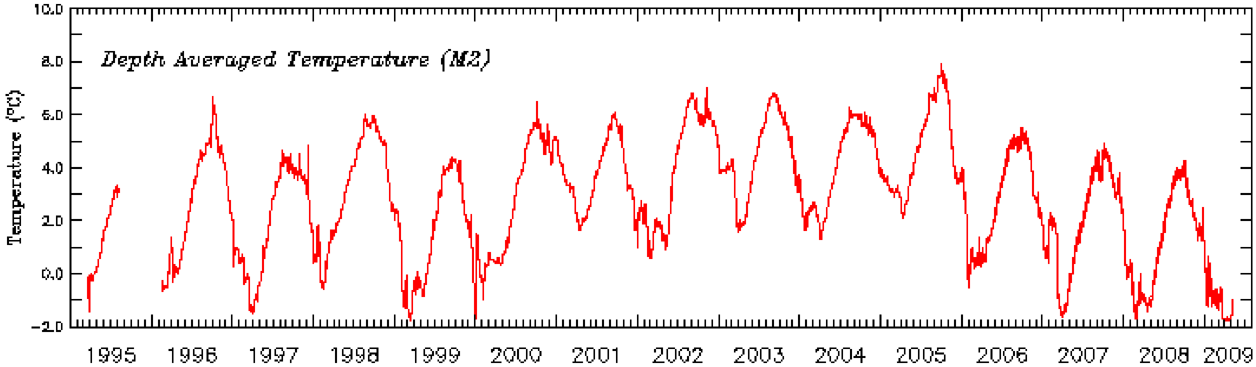


Figure 17. Depth averaged temperature measured at Mooring 2, 1995-2009 in the southeast Bering Sea (°C).

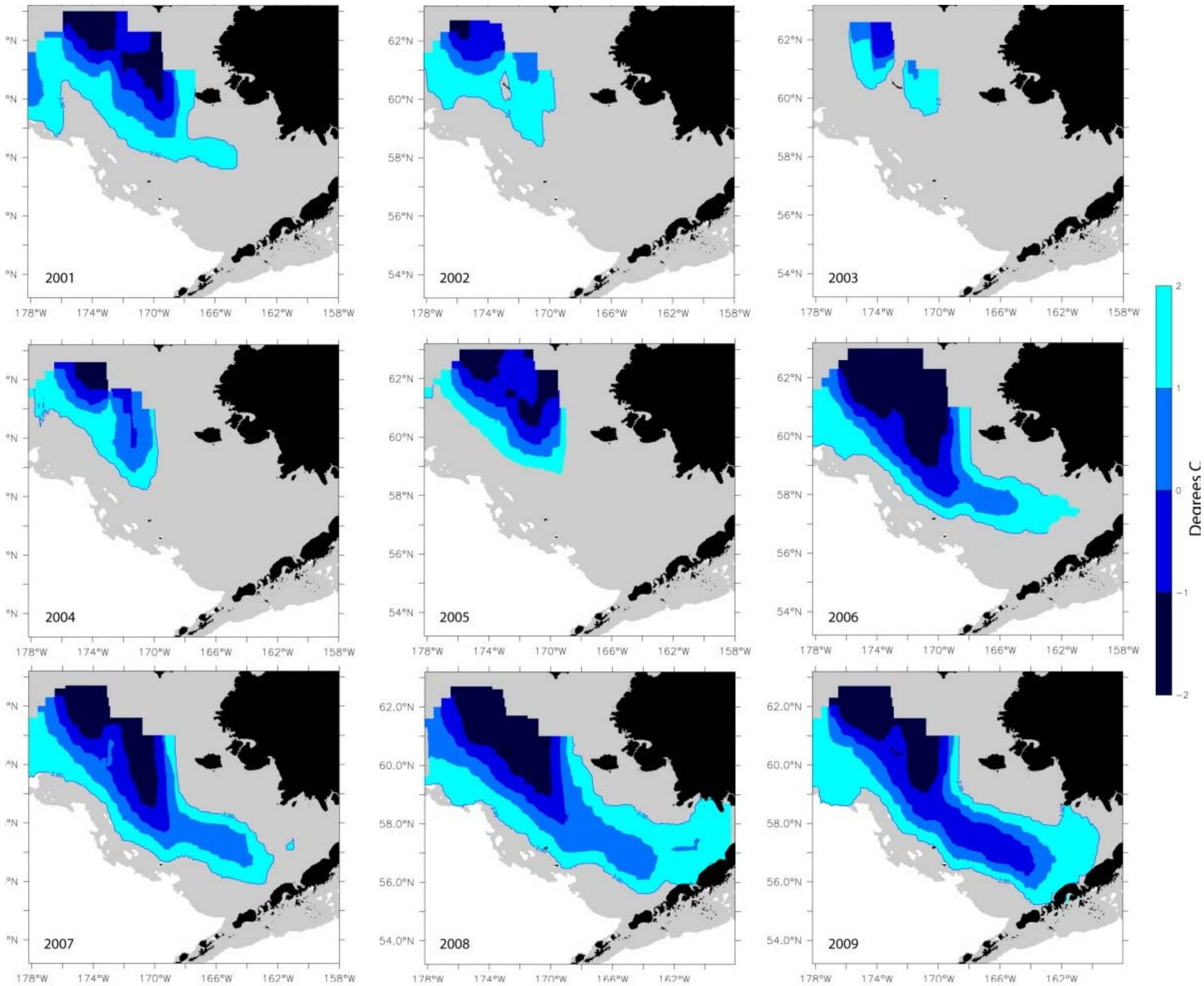


Figure 18. Cold Pool locations in southeast Bering Sea from 2001 to 2009. 2009 represents the maximum southeastward extent of the cold pool of the decade.

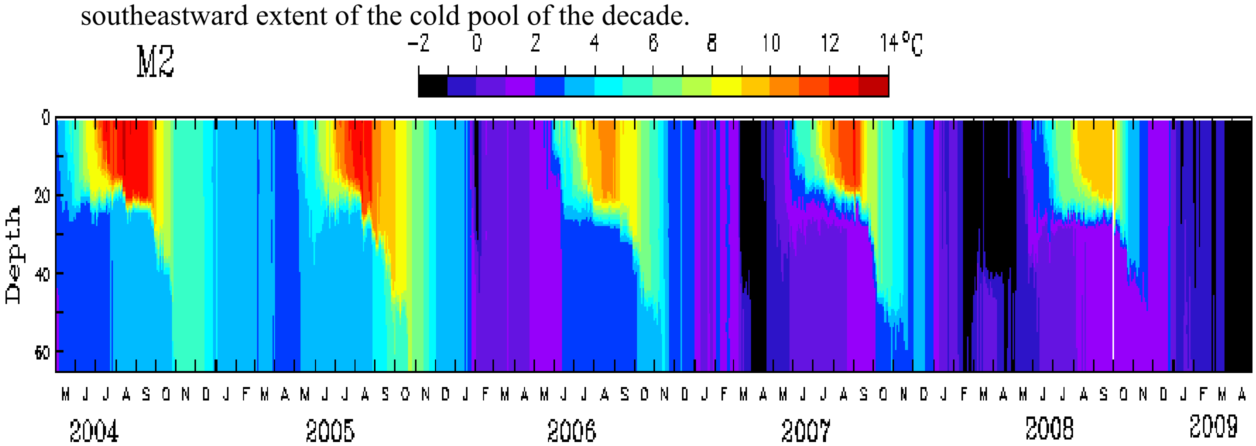


Figure 19. Temperature versus depth and time of year measured at the Mooring 2, 2004-2009 in the southeastern Bering Sea. Temperatures < 1°C (black) occurred when ice was over the mooring. Note the contrast of the warm years of 2004 and 2005 versus 2007-2009.

Summer Bottom and Surface Temperatures – Eastern Bering Sea
Contributed by Robert Lauth, Alaska Fisheries Science Center
Contact: Bob.Lauth@noaa.gov
Last updated: October 2009

The annual AFSC bottom trawl survey for 2009 started on 2 June and finished on 19 July. The average surface temperature, 4.7°C, was slightly higher than 2008 but still 2.1°C lower than the long-term mean of 6.8°C (Figure 20). The average bottom temperature in 2009 was 1.22°C, which was below the grand mean for the fourth consecutive year. The 'cold pool', usually defined as an area with bottom temperatures < 2°C, extended down the middle shelf to the Alaska Peninsula and into Bristol Bay similar to other years when bottom temperatures were below the grand mean (Figure 21). Warm and cold years are the result of interannual variability in the extent, timing, and retreat of sea ice in the EBS shelf. During cold years, sea ice extent is further south and sea ice retreat occurs later. The relatively large interannual fluctuations in bottom temperature on the EBS shelf can influence the spatial and temporal distribution of groundfishes and the structure and ecology of the marine community (Kotwicki et al. 2005; Meuter and Litzow 2008; Spencer 2008). The timing of phytoplankton and subsequent zooplankton blooms are also affected by the extent of sea ice and timing of its retreat which in turn can affect survival and recruitment in larval and juvenile fishes as well as the energy flow in the system (Hunt et al. 2002).

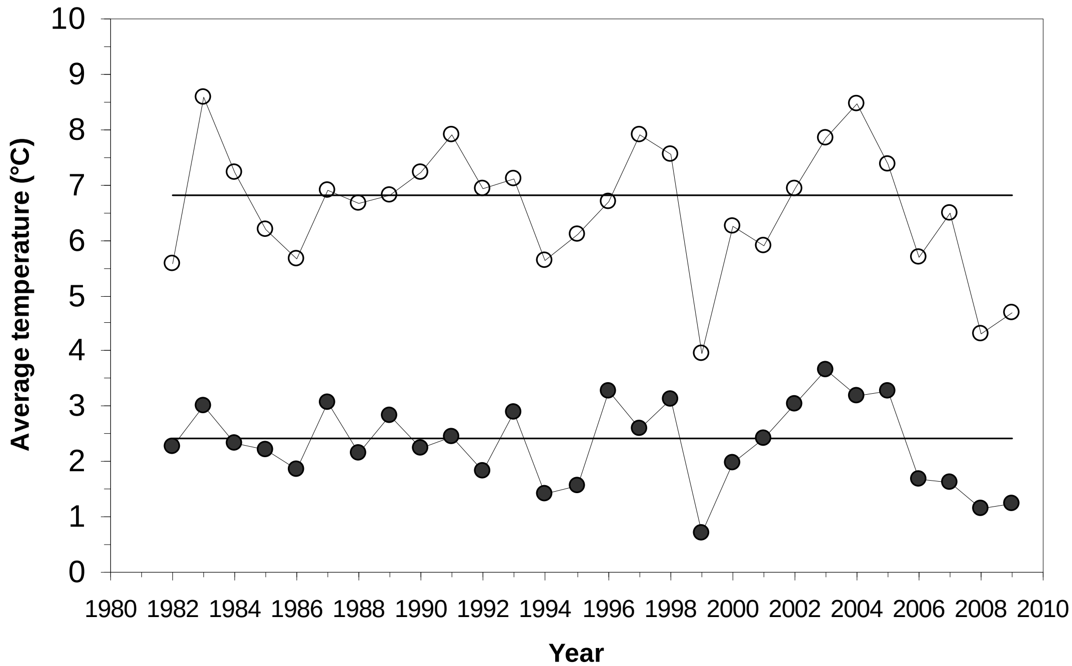


Figure 20. Average summer surface (open circles) and bottom (closed circles) temperatures (°C) of the eastern Bering Sea shelf collected during the standard bottom trawl surveys from 1982-2008. Survey water temperatures for each year were weighted by the proportion of their assigned stratum area.

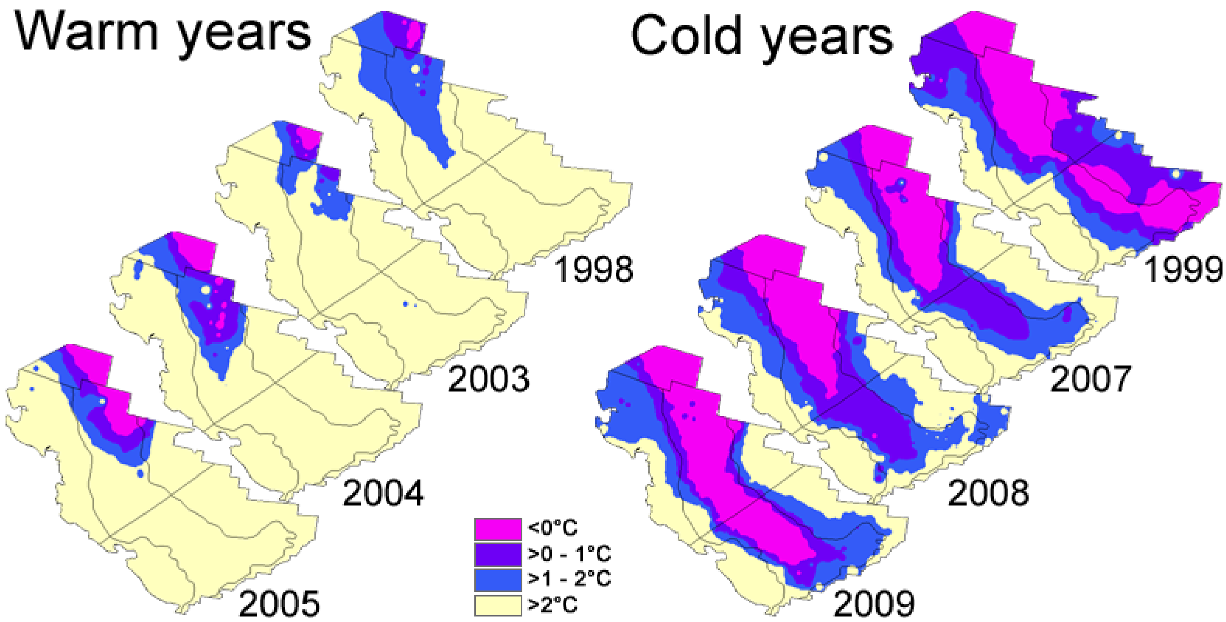


Figure 21. Temperature plots of average bottom temperature from the eastern Bering Sea shelf bottom trawl survey comparing the extent of the cold pool (<2°C) during years warmer and colder than the 1982-2008 grand mean.

Arctic Sea Ice Cover - From the Arctic Report Card

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Last updated: October 2008

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

Variations in Water Mass Properties During Fall 2000-2007 in the Eastern Bering Sea-BASIS

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Last updated: August 2008

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

ALEUTIAN ISLANDS

Eddies in the Aleutian Islands – FOCI

Contributed by Carol Ladd, NOAA/PMEL
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Last updated: July 2009

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. 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 22) 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 23) 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). Particularly strong eddies were observed south of Amukta Pass in 1997/1998, 1999, 2004, and 2006/2007. Eddy energy in the region was lower than average in 2008 and in the spring of 2009, suggesting possibly reduced volume, heat, salt, and nutrient fluxes to the Bering Sea compared to periods of high EKE.

The altimeter products were produced by the CLS Space Oceanography Division (AVISO 2008).

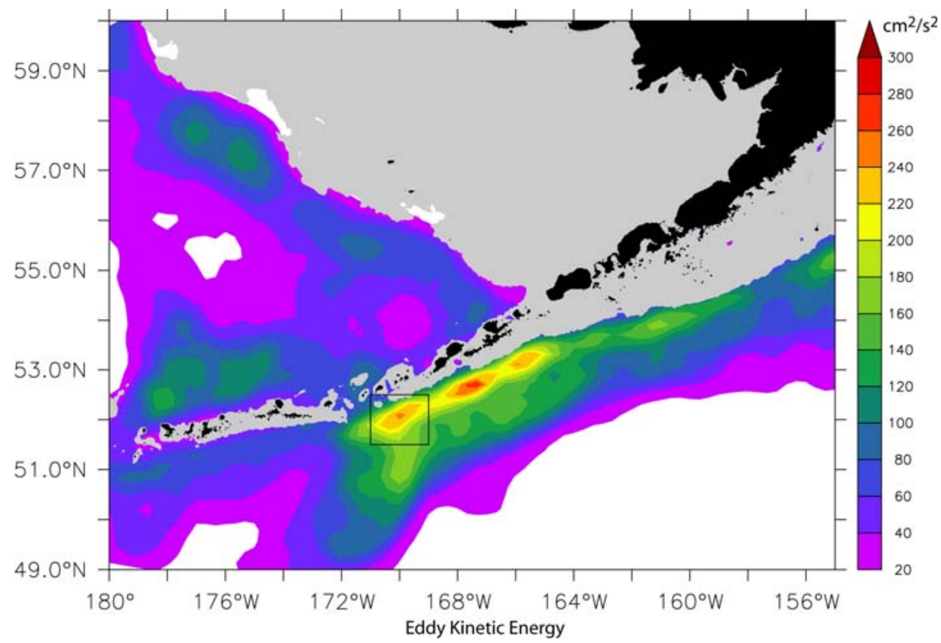

Figure 22. Eddy Kinetic Energy averaged over October 1993 – October 2008 calculated from satellite altimetry. Square denotes region over which EKE was averaged for Figure 23.

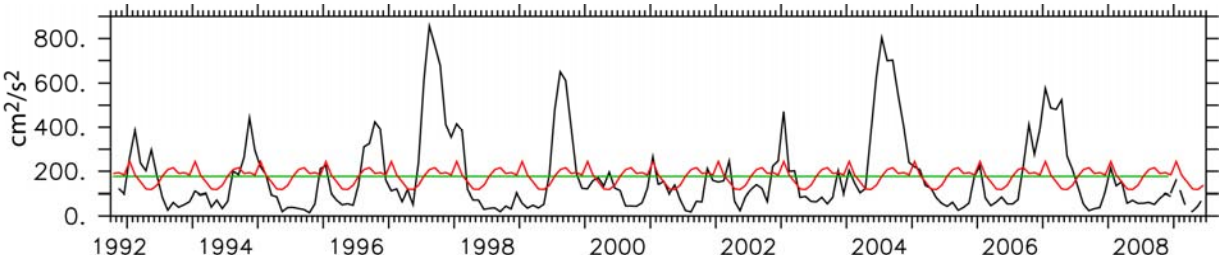

Figure 23. Eddy kinetic energy ($cm^2 s^{-2}$) averaged over region shown in Figure 22. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product). Red: seasonal cycle. Green (straight line): mean over entire time series.

Water Temperature Data Collections – Aleutian Islands Trawl Surveys
Contributed by Michael Martin, Alaska Fisheries Science Center
Contact: Michael.Martin@noaa.gov
Last updated: October 2007

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

Habitat

HAPC Biota – Gulf of Alaska
Contributed by: Michael Martin, Alaska Fisheries Science Center
Contact: Michael.Martin@noaa.gov
Last updated: October 2009

Description of index: Groups considered to be Habitat Area of Particular Concern (HAPC) biota include seapens/seawhips, corals, anemones, and sponges. The biennial survey in the Gulf of Alaska (GOA) does not sample any of the HAPC fauna well. The survey gear does not perform well in many of the areas where these groups are thought to be more prevalent. As a result, survey effort is quite limited in these areas. Even in areas where these habitats are sampled, the gear used in the survey is ill-suited for efficient capture of these groups. Variability in mean CPUE is also an important issue as point estimates are often strongly influenced by a very small number of catches. Another complicating factor in interpreting these results is that the gears used by the Japanese vessels in the surveys prior to 1990 were quite different from the survey gear used aboard American vessels in subsequent surveys and likely resulted in different catch rates for many of these groups. In recent years, more emphasis has been placed on the collection of more detailed and accurate data collection on HAPC species. This increased emphasis could have also influenced the results presented here. For each species group, the largest catch over the time series was arbitrarily scaled to a value of 100 and all other values were similarly scaled. The standard error (+/-) was weighted proportionally to the CPUE to get a relative standard error.

Status and trends: Despite the caveats, a few general patterns are clearly discernible. Sponge and sea anemone abundances generally decrease from west to east across the GOA (Figure 24). The frequency of occurrence for both of these groups seems to have increased over time in all areas. Gorgonians seem to be most abundant in the eastern GOA, but the frequency of occurrence is quite low and the pattern may therefore be deceiving. Sea pen and soft coral frequency of occurrence rates are also very low and no abundance trends are discernible from this limited information. Stony corals appear to be much more abundant and are also captured more frequently in the areas sampled in the western GOA.

Factors causing the trends: Unknown

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

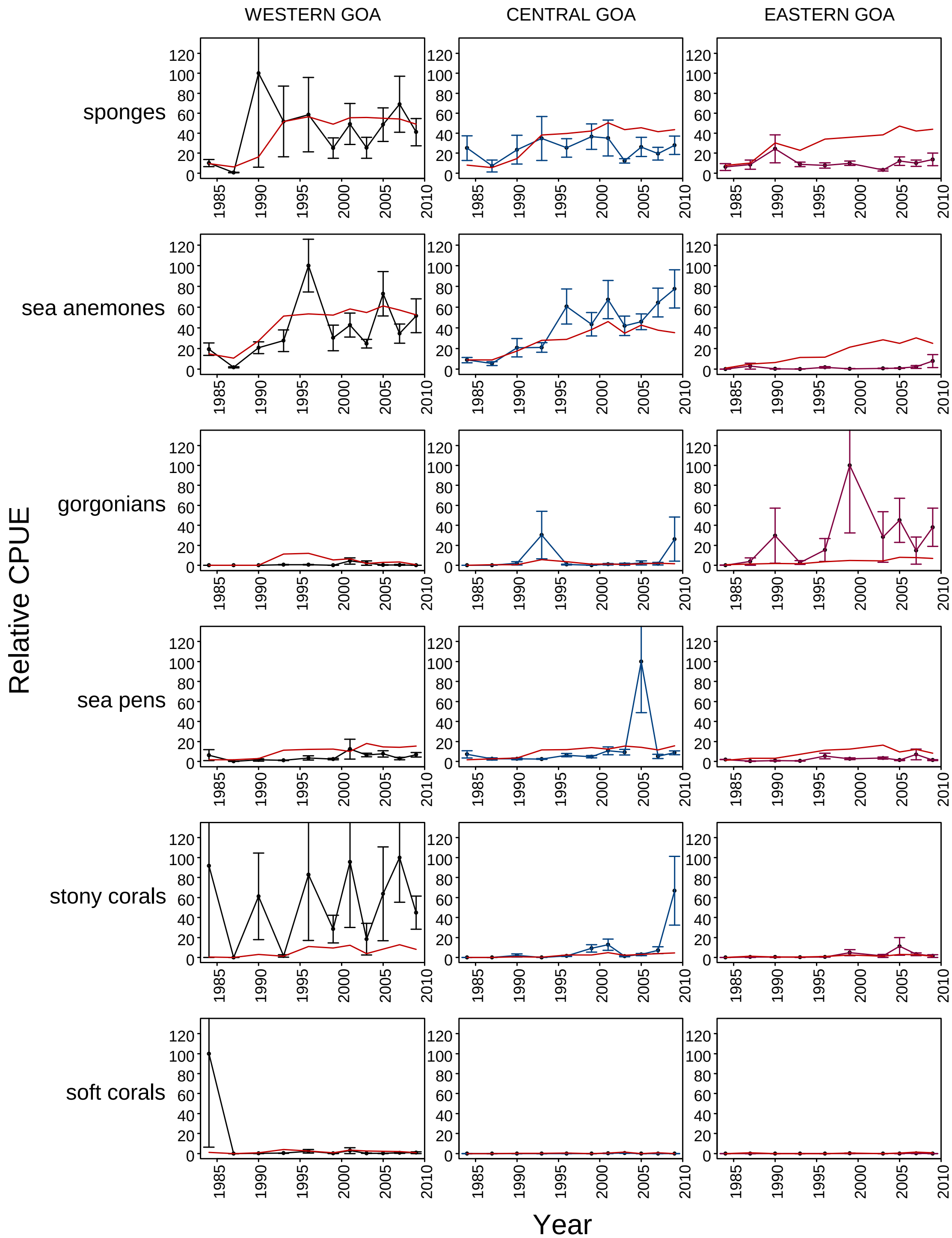

Figure 24. Mean CPUE of HAPC species groups by area from RACE bottom trawl surveys in the Gulf of Alaska from 1984 through 2009. Error bars represent standard errors. The red lines represent the percentage of non-zero catches.

HAPC Biota – Bering Sea
Contributed by Robert Lauth, Alaska Fisheries Science Center
Contact: Bob.Lauth@noaa.gov
Last updated: October 2009

Groups considered to be HAPC biota include: seapens/whips, corals, anemones, and sponges. Corals are rarely encountered on the Bering Sea shelf so they were not included here. Relative CPUE was calculated and plotted for each species group by year for 1982-2009. Relative CPUE was calculated by setting the largest biomass in the time series to a value of 1 and scaling other annual values proportionally. The standard error (+/- 1) was weighted proportionally to the CPUE to produce a relative standard error. It is difficult to detect trends of HAPC groups in the Bering Sea shelf from the RACE bottom trawl survey results because there is taxonomic uncertainty within the HAPC biota groups and because the quality and specificity of field identifications have varied over the course of the time series (Stevenson and Hoff 2009). Moreover, relatively large variability in the relative CPUE values makes trend analysis difficult (Figure 25). Further research in several areas would benefit the interpretation of HAPC biota trends including systematics and taxonomy of Bering Sea shelf invertebrates; survey gear selectivity; and the life history characteristics of the epibenthic organisms captured by the survey trawl.

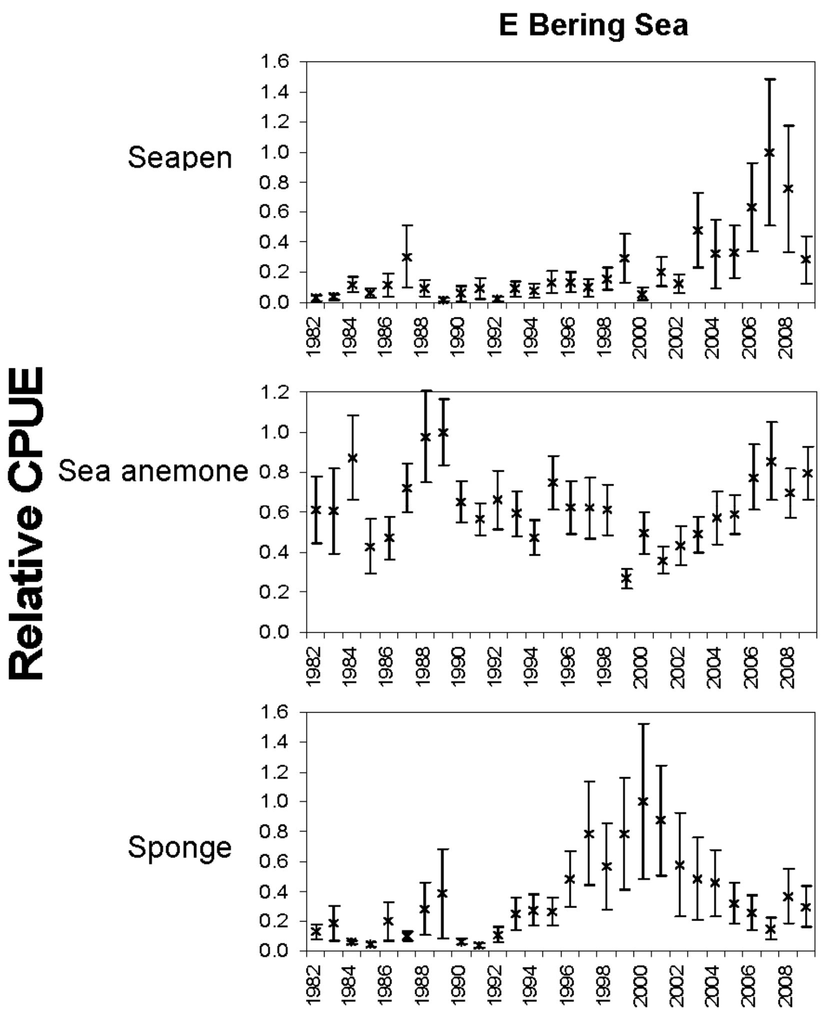

Figure 25. Relative CPUE trends of HAPC biota from the RACE bottom trawl survey of the Bering Sea shelf, 1982-2009. Data points are shown with standard error bars.

HAPC Biota – Aleutian Islands
Contributed by: Michael Martin, Alaska Fisheries Science Center
Contact: Michael.Martin@noaa.gov
Last updated: November 2006

See the 2006 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
Contributed by Chris Rooper, NMFS, AFSC, RACE
Contact: Chris.Rooper@noaa.gov
Last updated: August 2008

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

Effects of Fishing Gear on Seafloor Habitat
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Contact: Jon.Heifetz@noaa.gov
Last updated: November 2005

See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm
And: http://www.afsc.noaa.gov/abl/MarFish/geareffects.htm

Area Disturbed by Trawl Fishing Gear in the Eastern Bering Sea
Contributed by Angie Greig
Contact: Angie.Greig@noaa.gov
***NEW*: August 2009**

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 1990-2008. The duration of each 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). 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 26). 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.

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

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

During 1993-1999, fishing effort was more concentrated in the southern area compared to 1990-1992 and 2000-2008, where effort was spread out spatially, particularly towards the northwest. This may, in part, explain the larger difference between the upper and lower estimates of percent area disturbed (with no overlap and with overlap within 400 km^2 cells, respectively) during 1993-1998 relative to other years (Figure 27).

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 hauling accounts for only 2% of the total hauls and does not explain the early 1990 trends.

Implications: Habitat damage varies with the physical and biological characteristics of the areas fished, recovery rates of HAPC biota in the areas fished, and management changes that result in spatial changes in fishing effort (NMFS 2007).

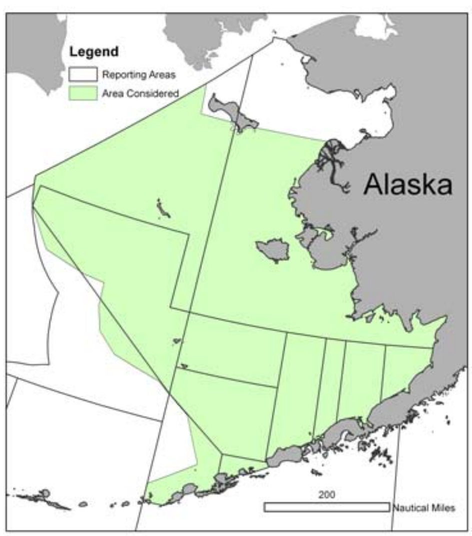

Figure 26. Map of Eastern Bering Sea area considered when estimating percent area potentially disturbed by trawl fishing gear.

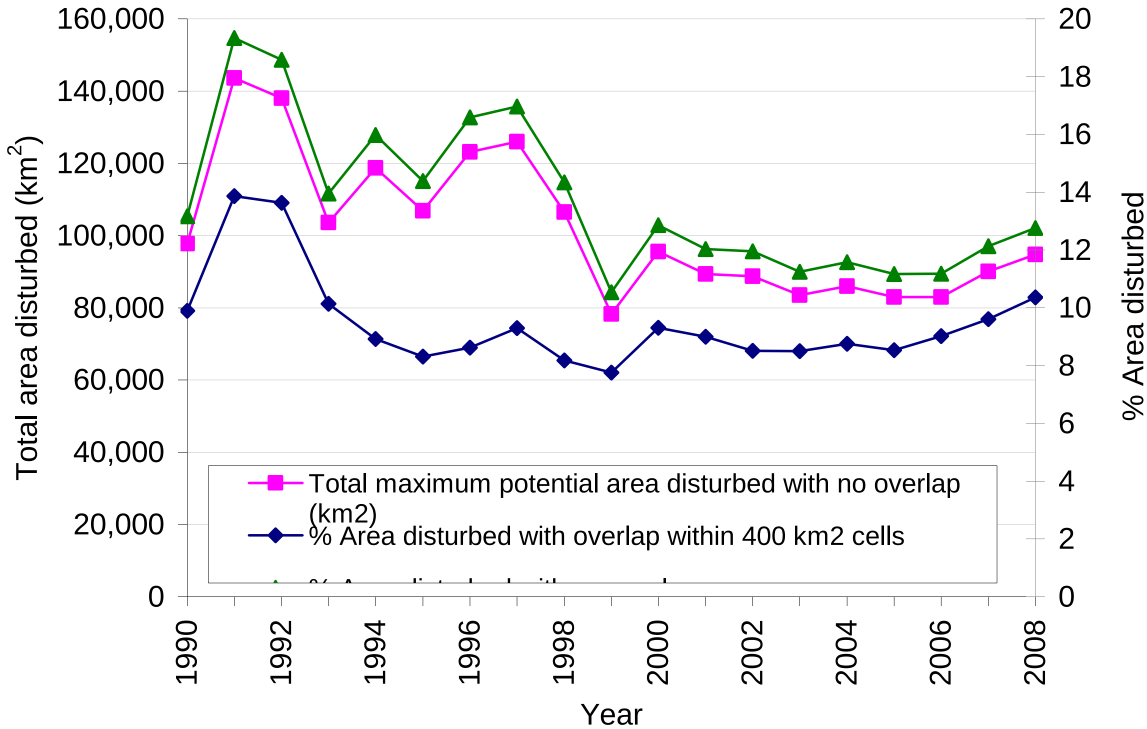

Figure 27. Total maximum potential area disturbed (assuming no spatial overlap of trawls), and the percent area disturbed. The green line, representing percent area disturbed, sums the area disturbed assuming no spatial overlap of trawl hauls in a year, thus providing an upper limit to the estimate of 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.

Nutrients and Productivity

Nutrient and Chlorophyll Processes on the Gulf of Alaska Shelf

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Last updated: November 2004

See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Nutrients and Productivity Processes in the Southeastern Bering Sea

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Last updated: November 2005

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Variations in Phytoplankton and Nutrients During Fall 2000-2006 in the Eastern Bering Sea-BASIS

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Zooplankton

Gulf of Alaska Zooplankton

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Continuous Plankton Recorder Data in the Northeast Pacific

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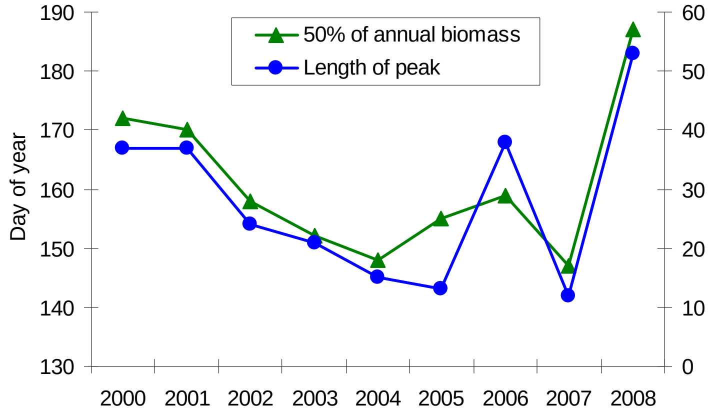
Continuous Plankton Recorders have been towed behind commercial ships along two transects across the Gulf of Alaska (Juan de Fuca Strait to Cook Inlet, and Juan de Fuca Strait to Unimak pass, across the Bering Sea to Japan) a total of ~nine times per year since 2000. Samples are collected with a filtering mesh and are then microscopically processed in the lab for plankton abundance. The survey has so far accumulated 3,890 processed samples (with approximately three times as many samples archived without processing) each representing 18 km of the transect and containing abundance data on over 290 phytoplankton and zooplankton taxa.

NE Pacific

Both transects originate at Juan de Fuca Strait giving the northeast Pacific the most extensive sample coverage (6 to 9 times per year between March and October, area shown in Figure 28). By interpolating between sampling dates and calculating daily cumulative biomass from spring to autumn (25th March to 1st September encompasses the period sampled in most years) the start, middle and end of the seasonal cycle can be defined as the 25th, 50th and 75th percentiles respectively (Greve 2001 and 2005). Figure 28 shows the midpoint (50th percentile) and length (number of days between the 25th and 75th percentile) of the mesozooplankton biomass peak for each year.



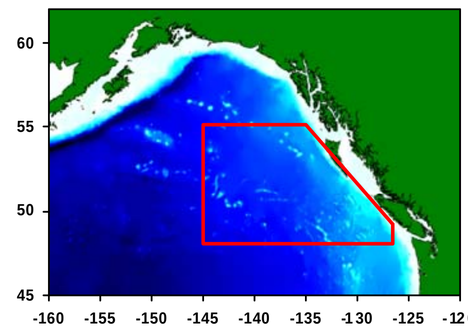


Figure 28. Midpoint (day of year) and length (days) of the mesozooplankton biomass peak in the region shown to the right.

Both the duration of the peak and the timing of when it occurs are significantly negatively ($p<0.02$) correlated with the Pacific Decadal Oscillation (PDO). When the PDO is negative (2000, 01 and 08) conditions in the NE Pacific tend to be cool. The mesozooplankton biomass peak is later in these years and persists for a longer period of time; 2008 was the most extreme year in the time series and upper ocean temperatures in this area were the coolest for over 50 years (Crawford and Irvine 2009). Conversely, when the PDO is positive (2003-2006), the mesozooplankton biomass peak is earlier and shorter in duration. Availability of prey to higher trophic levels will change accordingly.
Community composition also changes from year to year. Figure 29 shows the contribution of several groups to the summer (July and August) mesozooplankton biomass for the same region.

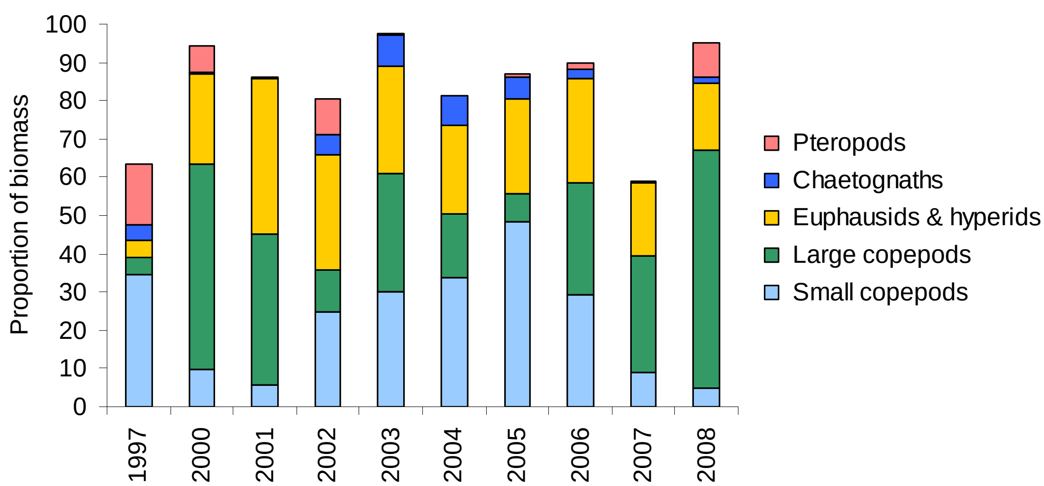


Figure 29. Mean contribution to the mesozooplankton biomass in July/August by major taxonomic groups.

A focus on data collected in the summer enables the inclusion of 1997 pilot project data to be included, which was at the start of a strong El Niño event. In warm years, such as 1997 and 2005, small copepods make up a larger proportion of the biomass while large copepods are less important. Conversely, in cold years such as 2000, 01 and 2008 large copepods make up a much higher proportion of the biomass. This is partly because the seasonal cycle of the large subarctic species is lengthened and delayed in cool years so more are still present in surface waters in the summer (in warm years they may have entered diapause before the end of June; Mackas et al. 2007). Additionally, cool conditions favor the large subarctic copepods so they are more abundant in cool years. Chaetognaths prey on smaller copepods and their numbers tend to be higher in warm years when their prey is more common. Euphausiids and hyperiid amphipods do not show a strong interannual signal although individual species are probably more variable. Data for the nine year period in the northeast Pacific show that the mesozooplankton respond strongly and rapidly to changes in ocean climate, and that the last decade has been quite variable. The timing of the seasonal peak, its duration, and the composition of summer zooplankton all co-vary with physical conditions.

Bering Sea

The east-west transect extends through the southern Bering Sea on route to Japan. This transect is sampled three times per year (though only once in 2000 and 2001): in April, June and September. Since the ship is engaged in commercial activities, in some years, samples are also collected in May, July and October. Even with nine years of sampling the seasonal coverage is not ideal (Figure 30); for example, August has yet to be sampled. June has been sampled in the majority of years giving some idea of interannual variability (a high in 2000, a low in 2001) but whether this is the result of changes in seasonality or changes in absolute abundance of organisms is not yet clear.

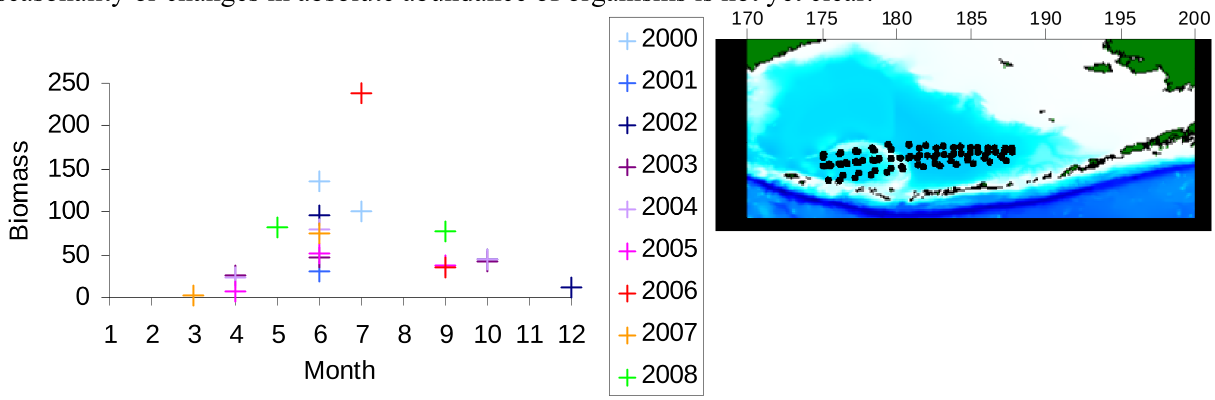


Figure 30. Mean monthly mesozooplankton biomass (mg dry weight sample^{-1}) for the southern oceanic Bering Sea area (shown in right panel). Samples were collected between 172°W and 175°E.

Some idea of changes in seasonality can be gained by examining the relative proportions of separate copepodite stages of the dominant copepods *Neocalanus plumchrus* and *N. flemingeri* (which are not routinely separated in CPR analysis). These copepods molt and mature in surface waters before descending to diapause depths later in the year at the sub adult stage. Figure 31 shows the relative proportions of copepodite stages 2 to 5 (the stage that enters diapause) in the June or July sampling of each year.

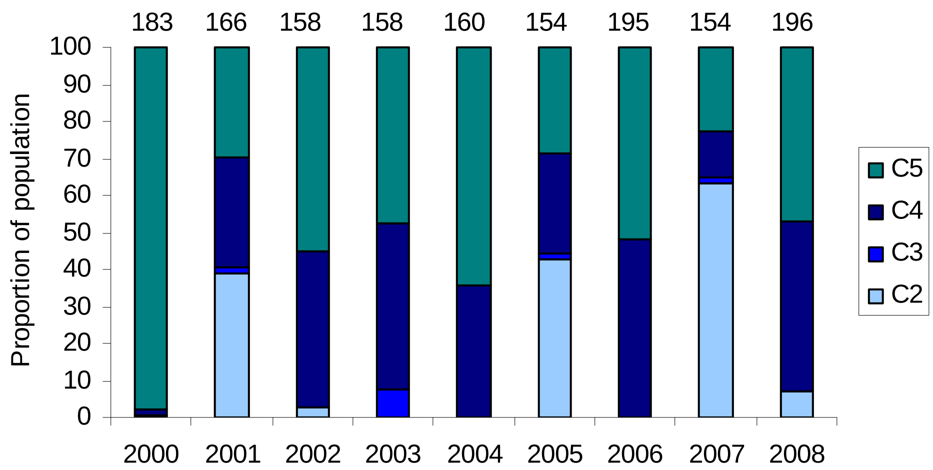


Figure 31. Relative contribution of copepodite stages C2-C5 to the June/July *Neocalanus plumchrus/fleminger*i population. Day of year at which sampling occurred is shown above each bar.

In early July 2000, most of the population was at the C5 stage while in July 2008 only about half of the population was C5 (Figure 31). This suggests that the season was advanced in 2000 and the large biomass (Figure 30) may have been because a high proportion of the copepod population was at a more advanced, larger stage. Samples in 2002 and 2003 were collected on exactly the same day of the year and the population composition was virtually identical (Figure 31), suggesting that the higher biomass in 2002 over 2003 (Figure 30) was likely due to higher abundances in 2002 and not a change in seasonality. More work needs to be done on the data from the southern Bering Sea to understand the underlying processes and this will become easier as the time series lengthens.

Bering Sea Zooplankton

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Last updated: September 2008

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

Forage Fish

Exploring Links between Ichthyoplankton Dynamics and the Pelagic Environment in the Northwest Gulf of Alaska

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See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Variations in Distribution, Abundance, Energy Density, and Diet of Age-0 Walleye Pollock, *Theragra chalcogramma*, in the Eastern Bering Sea

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Last updated: August 2007

See the 2007 report in the "Assessment Archives" 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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Last updated: August 2008

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

Forage Species– Gulf of Alaska

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Last updated: October 2009

Description of index: The North Pacific Fishery Management Council has defined several groups as forage species for management purposes in the Gulf of Alaska (GOA). These groups include gunnels, lanternfish, sandfish, sandlance, smelts, stichaeids, and euphausiids. Several of these groups are captured incidentally in the Gulf of Alaska biennial RACE bottom trawl survey. Since all of these species are quite small relative to the size of the mesh used in the survey gear, the capture efficiency for these species is quite low. Many of these species are rarely encountered during the survey and therefore trends in abundance are difficult to discern, due to the high variance of the resulting estimates. A possible exception to this generalization would appear to be eulachon (*Thaleichthys pacificus*). Eulachon are generally captured in a relatively large number of tows, and although they are not sampled well by the gear, it is possible that trends in abundance may be discernible from the survey data. For each species group, the largest mean area cpue over the time series was arbitrarily scaled to a value of 100 and all other values were similarly scaled. The standard error (+/- 1) was weighted proportionally to the CPUE to get a relative standard error.

Status and trends: There appears to be a general increase in the abundance of eulachon since 1999, particularly in the central GOA (Figure 32). It is also interesting to note that the eulachon frequency of occurrence increases from west to east, although the biomass seems to be highest in the central GOA.

Factors causing the trends: Unknown

Implications of the trends: GOA survey results provide limited information about abundance or abundance trends for these species due to problems in catchability. Therefore, the indices presented are of limited value to fisheries management for most species. The one possible exception is eulachon, which are encountered in a large fraction of survey tows. Abundance of eulachon appears to have increased in recent years, particularly in the Central and Eastern GOA and this could indicate increased availability of eulachon to fish, bird and mammal species that depend on eulachon for part of their diet.

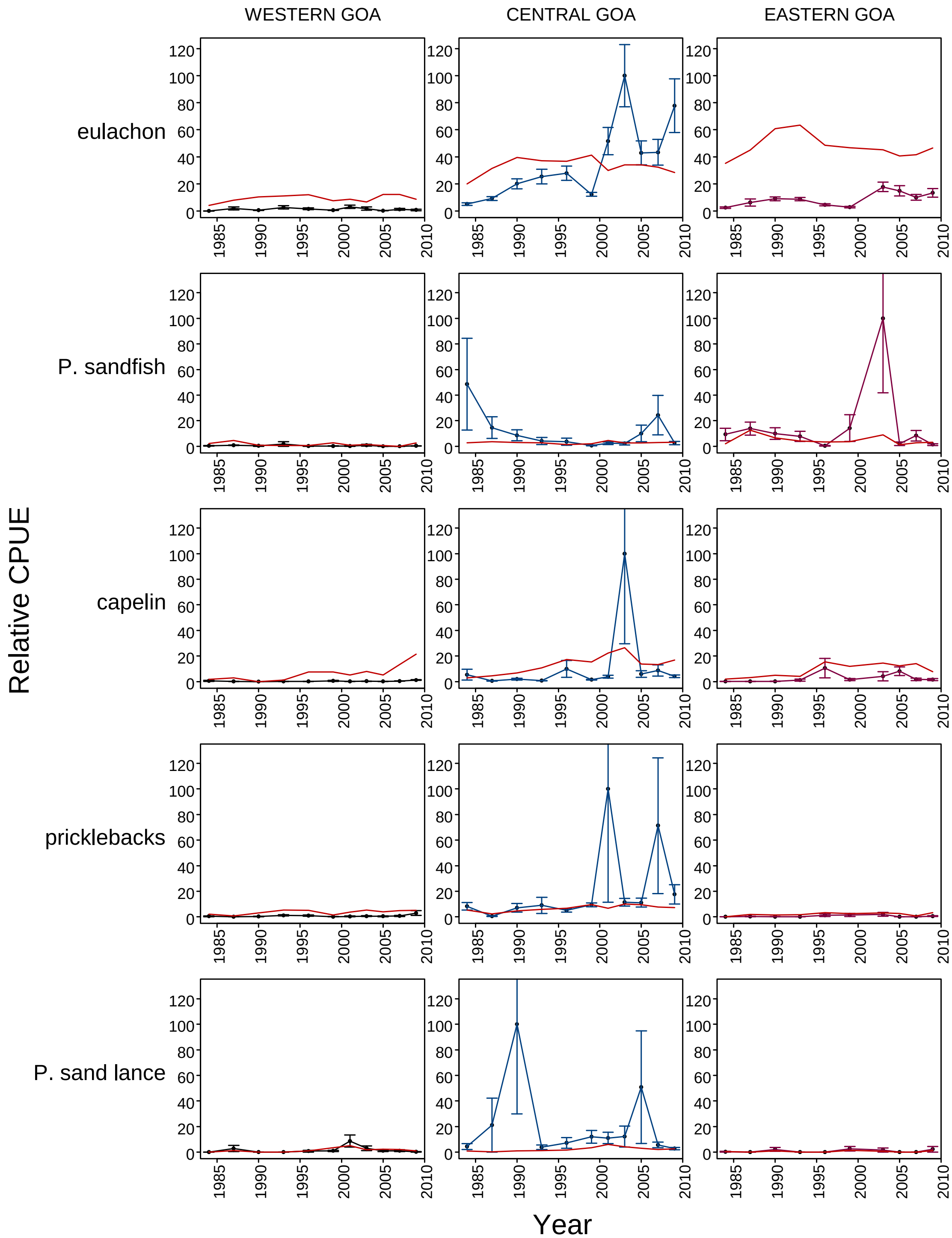

Figure 32. Relative mean CPUE of forage fish by area from RACE bottom trawl surveys in the Gulf of Alaska from 1984 through 2009. Error bars represent standard errors. The red lines without error bars represent the percentage of non-zero catches.

Forage Species – Eastern Bering Sea

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The North Pacific Fishery Management Council defined several groups as forage species for management purposes. These groups include: gunnels (Pholidae), lanternfish (Myctophidae), sandfish (*Trichodon trichodon*), sandlance (*Ammodytes hexapterus*), smelts (Osmeridae), stichaeids (Stichaeidae), and euphausiids. Forage fishes are important prey items for piscivorous fishes and marine birds and mammals. Changes in distribution and abundance of forage species can dramatically alter the community structure of the marine ecosystem and affect foraging success and survival of predators. Although the AFSC eastern Bering Sea shelf survey bottom trawl and procedures are not specifically designed to assess the abundance of these species, the survey time series may be useful for investigating coarse changes in distribution or relative abundance of these forage species over time (Figure 33). Relative CPUE was calculated and plotted for each species or species group by year for 1982-2009. Relative CPUE was calculated by setting the largest biomass in the time series to a value of 1 and scaling other annual values proportionally. The standard error (+/- 1) was weighted proportionally to the CPUE to produce a relative standard error. Sandfish were generally in low abundance in the trawl surveys (Figure 33) because they are typically caught in only a few stations at shallower depths. Stichaeids, which include the longsnout prickleback (*Lumpenella longirostris*), daubed shanny (*Lumpenus maculatus*) and snake prickleback (*L. sagitta*), are small benthic-dwelling fish. Their relative abundance was generally higher prior to 1999. Similar to stichaeids, the relative CPUEs of sandlance were generally higher prior to 1999. Eulachon (*Thaleichthys pacificus*) relative CPUE changed little over the past four years and capelin (*Mallotus villosus*) relative CPUE remained relatively low, with the exception of one year (1993; Figure 33). The relative CPUE of Arctic cod (*Boreogadus saida*), an Arctic fish species, was higher in cold years (1999-2000, 2006-2009) compared to warm years (1996-98, 2002-2005) probably because of its association with the southern intrusion of the Arctic cold pool (<2°C) down the middle shelf during the cold years.

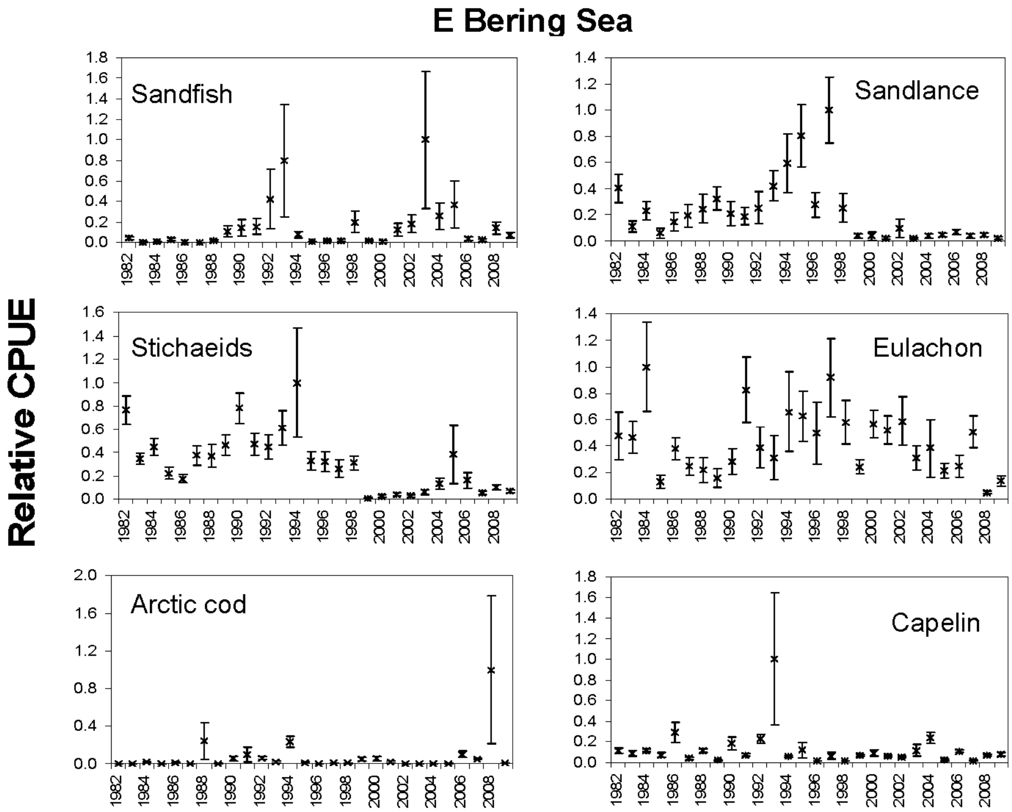

Figure 33. Relative CPUE of several forage fish groups from the eastern Bering Sea summer bottom trawl survey, 1982-2009. Data points are shown with standard error bars.

Forage Species – Aleutian Islands
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Last updated: November 2006

See the 2006 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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Last updated: October 2008

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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Last updated: October 2009

Herring *(Clupea pallasi)* stock assessments have been conducted each fall by the Alaska Department of Fish and Game at nine spawning areas in southeastern Alaska for most years since 1980. Recurrent, annual spawning and biomass levels have warranted yearly stock assessment surveys, and potential commercial harvests, at these locations during most of the last 25 years. Limited spawning occurs at other locales throughout southeastern Alaska, and other than aerial surveys to document shoreline miles of spawning activity, little stock assessment activity occurs at these locations. Spawning at the nine primary sites for which regular assessments are conducted have probably accounted for 95-98% of the spawning biomass in southeastern Alaska in any given year.

Herring spawning biomass estimates in southeastern Alaska often change markedly from year to year, rarely exhibiting consistent, monotonic trends (Table 5, Figs. 34 and 35). Since 1980, four of the nine primary locations (Sitka Sound, Hoonah Sound, Seymour Canal, and Craig) have exhibited long term trends of increasing biomass and one area (Kah Shakes/Cat Island) has had a pronounced downward trend (Fig. 35). Other areas have shown fluctuations in spawning biomass without a pronounced long term trend. Since 1997, the southeastern Alaska spawning herring biomass estimate has been above the long-term median of 85,754 tons (1980-2008; Table 5, Fig. 34). The 2008 and 2005 estimates of spawning biomass were the two highest in the 25-year time series. Since 1980, herring biomass at Sitka has contributed 37 to 68% (median: 54%) of the total estimated annual biomass among the nine spawning locations. Excluding the Sitka biomass from a combined estimate, southeastern Alaska herring biomass has been above the 25-year median of 40,923 in every year since 1997, except for 2000 (Table 5, Fig. 34).

Estimated abundance of age-3 herring recruits to the mature population has varied greatly among and within stocks over time (Table 7, Fig. 35). The number of age-3 recruits has been estimated for Kah Shakes-Cat Island, Seymour Canal, Sitka, and Tenakee Inlet for most years since 1980; for Craig in every year since 1988; and for West Behm Canal, Ernest Sound, Hobart Bay-Port Houghton, and Hoonah Sound for most years since 1995. An oscillating recruitment pattern with strong recruit classes every three to five years is apparent for Kah Shakes/Cat Island, Craig, and Sitka Sound stocks prior to 1997. For Sitka Sound, the stock with the greatest annual recruit abundance, oscillating years of extremely high and low recruit abundance in the 1980s and early 1990s has changed to more consistent, intermediate recruit abundances in the mid-1990s to early 2000s. Every stock exhibited low recruitment in 2007 and 2008 in relation to other years. A recent phenomenon observed for many stocks is continued high or increasing abundance with low levels of mature age-3 herring. Although mature age-3 herring abundance is and has been at low levels, there has been recruitment to spawning stocks at older ages. Age-structured modeling of the Sitka Sound stock, for which the most information exists in southeastern Alaska, suggests that there has been a change in the maturation schedule. This is also evident from samples of herring in other spawning areas, where age-4 or age-5 fish are present one or two years, respectively, following an absence of age-3 fish.

There has been some speculation and debate about the extent to which commercial harvests may have contributed to marked declines in estimated abundance and/or localized changes in herring spawning sites in a few areas in southeastern Alaska, notably Revillagigedo Channel (Kah Shakes/Cat Island) and Lynn Canal. Some spawning areas are sufficiently close to one another so interannual movement between areas may also contribute to year-to-year fluctuations in local abundance. In the Revillagigedo Channel area, significant spawning and a fishery occur at Annette Island, a site outside the management jurisdiction of the State and from which limited data are gathered by the department. Although spawning activity at the

Kah Shakes and Cat Island sites in Revillagigedo Channel has declined in recent years, this decline may be at least partially attributable to a shift in spawning grounds to Annette Island, bordering Revillagigedo Channel.

A threshold management policy in southeastern Alaska allows for harvests ranging from 10 to 20% of forecast spawning biomass when the forecast biomass is above a minimum threshold biomass. The rate of harvest depends upon how much the forecast exceeds the threshold. Consequently, catch, at most areas, has varied roughly in proportion to forecast biomass (Tables 5 and 6, Figs. 34 and 35).

Table 5. Estimates of mature herring biomass (tons) for nine primary spawning areas in southeastern Alaska, 1980-2008. Values indicate either spawn deposition survey estimates plus catch (regular font) or hydro-acoustic estimates (italics).

	Spawning Area										
Year	Kah Shakes - Cat Island	W. Behm Canal	Craig	Ernest Sound	Hobart Bay-Port Houghton	Seymour Canal	Sitka	Hoonah Sound[b]	Tenakee Inlet	TOTAL (including Sitka)	TOTAL (excluding Sitka)
1980	16,640	1,823	6,011	500	[c]	5,695	39,385	[c]	4,989	75,043	35,658
1981	20,290	700	4,867	410	[c]	2,633	33,506	750	8,310	71,466	37,960
1982	17,979	1,250	7,958	160	[c]	1,340	33,863	398	7,304	70,252	36,389
1983	17,939	500	7,139	1,640	[c]	4,015	28,950	265	9,638	70,086	41,136
1984	17,732	875	2,000	1,000	[c]	2,468	44,330	540	12,719	81,664	37,334
1985	11,396	750	2,000	1,000	[c]	3,000	38,475	928	6,431	63,979	25,504
1986	11,388	625	3,352	1,000	[c]	4,342	30,443	994	14,540	66,684	36,241
1987	9,840	500	11,481	[d]	[c]	5,102	50,216	740	7,875	85,754	35,538
1988	7,237	500	18,364	[d]	635	3,786	68,075	1,325	7,577	107,499	39,424
1989	3,912	250	21,491	500	768	3,662	39,135	4,000	6,050	79,769	40,634
1990	8,624	283	21,571	1,000	1,202	3,211	26,804	2,499	2,595	67,789	40,985
1991	11,110	1,274	21,073	3,000	2,000	2,100	25,408	2,341	400	68,705	43,297
1992	9,356	1,868	14,966 [b]	2,650	4,100	1,780	48,786	6,003	200	89,709	40,923
1993	8,478	3,854	7,656 [b]	692	2,238	3,005	47,436	1,234	904	75,497	28,061
1994	5,162	2,621	5,167 [b]	2,544	2,554	3,675	19,794	2,859	400	44,776	24,982
1995	7,258	3,659	3,857 [b]	2,581	4,850	1,252	37,967	637	200	62,260	24,293
1996	4,534	6,606	4,120 [b]	2,996	3,675	1,703	49,076	4,023	4,560	81,292	32,217
1997	6,505	10,022	6,370	[c]	2,694	4,913	39,866	6,903	10,023	87,296	47,430
1998	12,157	15,346	6,880 [b]	5,998	4,938	4,390	41,728	7,547	11,005	109,990	68,262
1999	2,407	14,721	6,425 [b]	[c]	5,350	4,044	53,776	5,326	11,884	103,933	50,158
2000	642	3,478	9,510	920	1,293	4,984	62,607	4,187	9,919	97,540	34,933
2001	819	5,574	8,345	2,052	993	9,423	70,813	8,774	8,351	115,145	44,331
2002	[c]	8,706	7,720	2,406	827	10,489	50,271	6,643	4,220	91,281	41,010
2003	[c]	7,681	14,075 [b]	5,509	2,022	6,362	62,725	11,224	4,471 [b]	114,068	51,343
2004	[c]	443	24,188 [b]	3,161 [b]	3,063	11,434	80,524	9,894	6,000 [b]	138,707	58,183
2005	[c]	1,231	19,382 [b]	3,268	1,371	11,601	112,825	9,294	7,093 [b]	166,064	53,239
2006	[c]	814	16,498 [b]	2,538	987	11,640	76,181	8,054	5,110	121,823	45,642
2007	[c]	1,911	21,850 [b]	7,353	3,089	11,078	96,263	12,742	3,346	157,632	61,369
2008	[c]	3,178	25,294 [b]	5,041 [b]	3,921	10,838	84,569 [a]	22,884	11,958	167,683	83,114

[a] Estimate based on 2008 ASA estimate because of large variability in survey estimate.
[b] Estimates are approximated because they include harvest estimates that are based on a conversion of spawn-on-kelp product to tons of herring (assumes 100% mortality of pounded herring).
[c] Unavailable due to low spawn and therefore no sampling.
[d] Unavailable due to no sampling.

Table 6. Southeastern Alaska catch-related herring mortality (tons) for nine primary spawning areas in Southeast Alaska, 1980-2008.

	Spawning Area										
Year	Kah Shakes - Cat Island	W. Behm Canal	Craig	Ernest Sound	Hobart Bay - Port Houghton	Seymour Canal	Sitka	Hoonah Sound[a]	Tenakee Inlet	TOTAL (including Sitka)	TOTAL (excluding Sitka)
1980	1,140	343	261	0	0	0	4,385	0	504	6,633	2,248
1981	1,840	0	467	0	0	618	3,506	0	810	7,241	3,735
1982	2,279	0	608	0	0	0	4,363	0	654	7,904	3,541
1983	3,239	0	139	0	0	0	5,450	0	768	9,596	4,146
1984	2,182	0	0	0	0	518	5,830	0	619	9,149	3,319
1985	2,161	0	0	0	0	0	7,475	0	1,431	11,067	3,592
1986	1,538	0	302	0	0	392	5,443	0	2,040	9,715	4,272
1987	1,440	0	1,231	0	0	302	4,216	0	1,275	8,464	4,248
1988	1,087	0	2,014	0	0	586	9,575	0	1,577	14,839	5,264
1989	592	0	1,691	0	0	547	12,135	0	690	15,655	3,520
1990	0	0	3,221	0	0	361	3,804	149	595	8,130	4,326
1991	660	0	3,273	0	0	0	1,908	166	0	6,006	4,098
1992	1,256	0	2,616 [a]	0	0	0	5,435	289	0	9,596	4,161
1993	737	0	700 [a]	[b]	32	0	10,286	135	0	[b]	[b]
1994	749	12	842 [a]	0	[b]	382	4,853	409	0	[b]	[b]
1995	626	9	442 [a]	111	260	319	2,977	363	0	5,107	2,130
1996	605	20	500 [a]	[b]	259	0	8,249	0	0	[b]	[b]
1997	1,137	29	813	[b]	594	0	11,255	813	98	[b]	[b]
1998	616	27	534 [a]	0	380	586	6,786	1,075	586	10,590	3,804
1999	0	30	552 [a]	[b]	544	706	9,222	900	835	[b]	[b]
2000	0	0	346	0	463	426	4,619	459	494	6,807	2,188
2001	0	0	408	0	33	649	12,058	827	775	14,750	2,692
2002	0	11	392	0	0	1,169	9,905	1,708	135	13,319	3,414
2003	0	43	1,010 [a]	0	0	1,519	6,956	1,801	942 [a]	12,271	5,315
2004	0	0	773 [a]	748 [a]	0	879	10,617	2,752	1,272 [a]	17,041	6,424
2005	0	0	2,044 [a]	0	204	1,032	11,520	2,370	1,268 [a]	18,438	6,918
2006	0	0	1,051	0	0	1,187	10,069	2,026	0	14,334	4,264
2007	0	0	1,132	0	0	1,219	11,762	1,992	0	16,106	4,344
2008	0	0	2,301	213	306	1,208	14,560	2,909	0	21,497	6,937

[a] Includes harvest values that are approximated based on a conversion of spawn-on-kelp product to tons of herring (assumes 100% mortality of pounded herring).
[b] Data is confidential due to fewer than three participants.

Table 7. Estimated number of age-3 herring recruits (millions of fish) at nine primary spawning areas in southeastern Alaska, 1980-2008. Where no value is listed, estimates are not available.

	Spawning Area								
Year	Kah Shakes - Cat Island*	W. Behm Canal	Craig*	Ernest Sound	Hobart Bay - Port Houghton	Seymour Canal*	Sitka*	Hoonah Sound	Tenakee Inlet*
1980	466.8					50.1	179.1		
1981	102.4					18.5	67.1		
1982	105.7					12.4	63.2		49.2
1983	96.1					20.7	518.4		214.2
1984	172.5					55.3	218.9		158.3
1985	62.3					43.0	72.5		46.9
1986	48.0					31.2	220.8		51.2
1987	122.5					26.5	1146.7		94.4
1988	61.7		465.4			18.7	132.6		12.3
1989	48.8		168.1			15.1	19.4		4.0
1990	39.4		68.9			4.3	16.7		1.3
1991	200.9		253.0			42.6	948.6		10.4
1992	105.5		102.7			23.9	25.2		1.7
1993	63.3		71.9			5.9	5.1		3.3
1994	36.3		23.3			1.8	85.1		0.1
1995	44.9		81.2	45.4	88.7	18.1	453.6	2.9	18.5
1996	83.6	107.6	205.5	105.8	93.1	102.6	221.5	150.1	730.0
1997	32.8	104.7	72.8		4.6	22.9	357.9	22.1	128.5
1998	16.8	161.5	69.3	50.2	6.3	16.3	279.8	4.4	44.7
1999	5.8	26.6	46.0		0.8	17.0	82.9	4.7	43.5
2000	12.5	46.0	104.3	4.6	3.3	46.7	268.1	27.0	167.9
2001	29.6	45.9	98.7	19.1	10.6	45.7	391.9	32.2	122.0
2002		16.3	209.5	18.8	1.1	33.5	577.6	4.0	68.3
2003		216.5	224.1	140.7	13.7	25.8	295.9	14.1	35.3
2004		0.8	140.6	4.1	4.4	21.1	208.1	1.7	11.3
2005		3.7	120.4	5.7	5.6	34.1	180.8	1.6	2.8
2006		1.0	49.5	2.3	0.6	47.4	147.5	0.4	
2007		7.0	6.2	12.1	10.7	19.7	74.1	5.1	
2008				0.0	0.0	20.4	78.3		

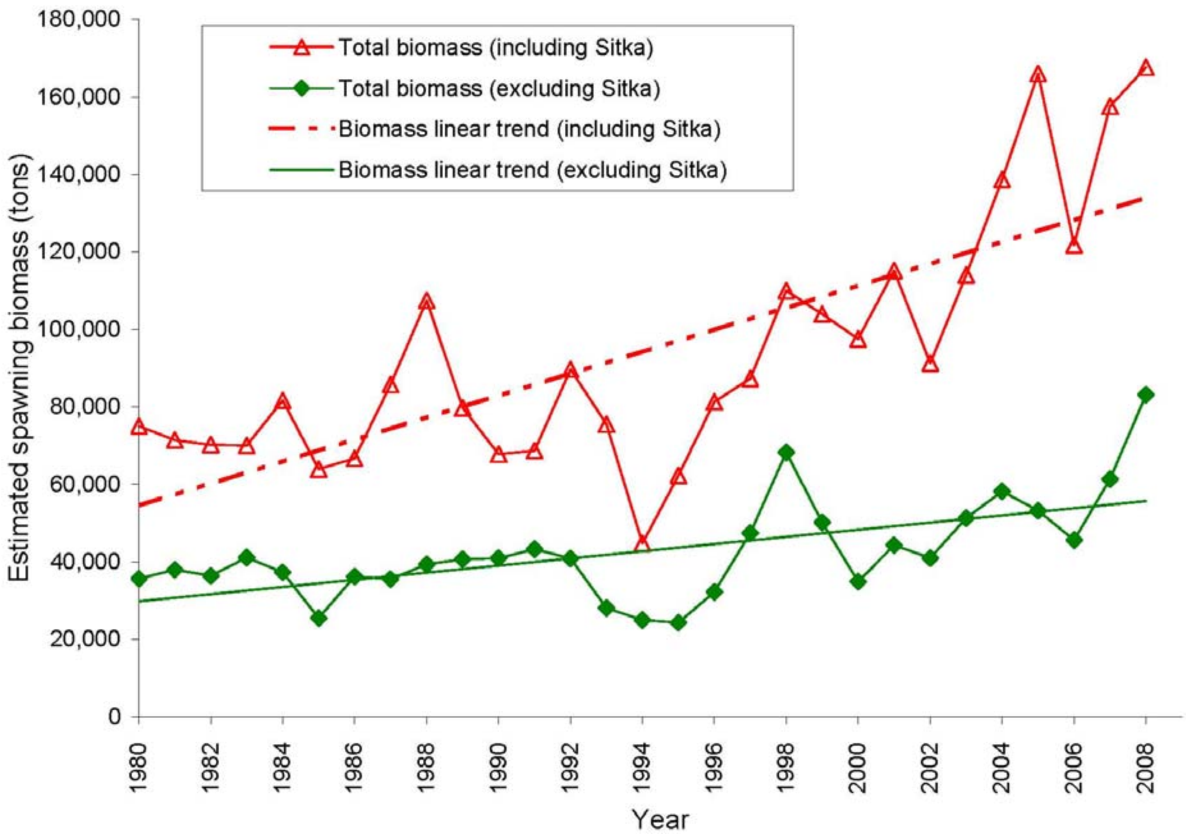

Figure 34. Estimated combined annual mature herring biomass (including and excluding Sitka) at major southeastern Alaska spawning areas, 1980-2008.

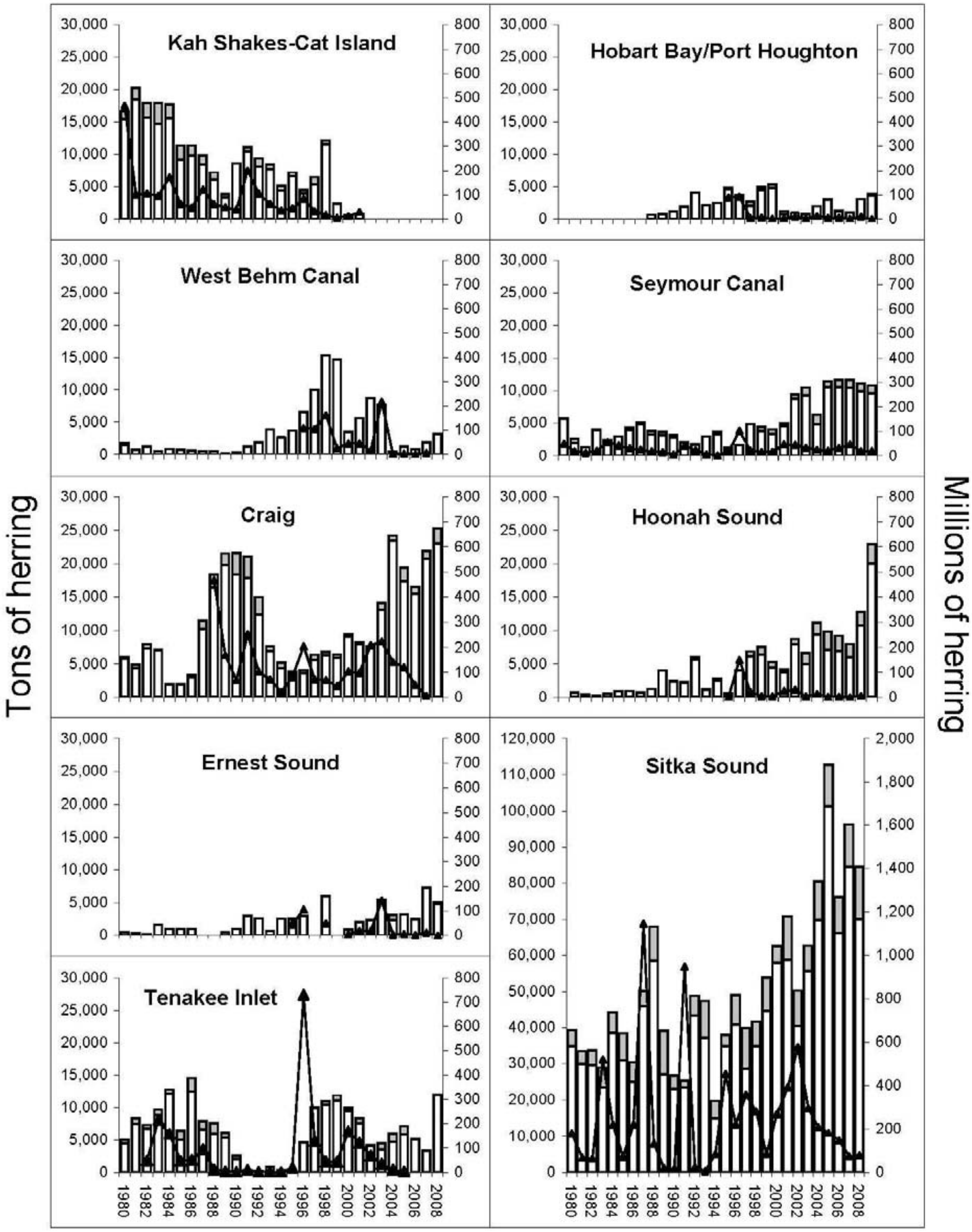

Figure 35. Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 recruitment to mature population (black line) at nine major spawning locations in southeastern Alaska, 1980-2008.

Togiak Herring Population Trends
Contribution by Fred West and Greg Buck, Alaska Department of Fish and Game
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Last updated: October 2008

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

Salmon

Historical Trends in Alaskan Salmon
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Last updated: November 2006

See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Western Alaska Juvenile Ecology Along the Eastern Bering Sea Shelf
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Last updated: April 2005

See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Groundfish

Trends in Groundfish Biomass and Recruits per Spawning Biomass
By Jennifer Boldt*, University of Washington; Julie Pearce, Alaska Fisheries Science Center; Steven Hare, International Pacific Halibut Commission; and the Alaska Fisheries Science Center Stock Assessment Staff
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Last updated: June 2009

Description of indices: Groundfish biomass and an index of survival were examined for temporal trends. Median recruit per spawning biomass (log(R/S)) anomalies were calculated for groundfish, assessed with age- or size-structured models in the Bering Sea/Aleutian Islands (BSAI) and the Gulf of Alaska (GOA), to provide an index of survival. Biomass, spawner abundance, and recruitment information is available in the NPFMC stock assessment and fishery evaluation reports (2008 a, b) and on the web at: http://www.afsc.noaa.gov/refm/stocks/assessments.htm. Halibut information was provided by the International Pacific Halibut Commission (IPHC, S. Hare, personal communication; these time series were not updated this year, 2009). In stocks that are abundant, the relationship between recruits and spawners will not be linear and density dependent factors may limit recruitment. Under these circumstances, the pattern of recruits per spawner will appear as an inverse of the pattern of spawning biomass as annual rates of production have leveled off. For this reason, it is important to also consider recruitment, as well as recruits per spawning biomass. Abundance of recruits for each species was lagged by the appropriate number of years to match the spawning biomass that produced them. For graphical display, the median of each time series was subtracted from the log-transformed recruit per spawning biomass ratios and expressed as a proportion of the median. A sequential t-test analysis of regime shifts (STARS; Rodionov 2005, Rodionov and Overland 2005) was used to determine if there were significant shifts in the logged recruit per spawning biomass ratios. The STARS method sequentially tests whether each data point in a time series is significantly different from the mean of the data points representing the latest regime (Rodionov and Overland 2005). The last data point in a time series may be identified as the beginning of a new regime; and, as more data is added to the time series, this is confirmed or rejected. At least two variables are needed for the STARS method: the cutoff value (minimum length of regimes) and the p-value (probability level). For this analysis, a cutoff value of 10 years and a p-value of 0.10 were chosen. An analysis of recruitment is not included in this section; however, Mueter (see contribution in this report and Mueter et al. 2007) examined combined standardized indices of groundfish recruitment and survival rate. Mueter's indices of survival rate are calculated as residuals from stock-recruit relationships, thereby, accounting for density dependence and providing an alternative examination of groundfish survival. A description of STARS and software is available at: http://www.beringclimate.noaa.gov/index.html.

Status and Trends:

Biomass

Total biomass of BSAI groundfish was apparently low in the late 1970s but increased in the early 1980s to around 20 million metric tons. Walleye pollock, which is the dominant species in the EBS throughout the time series, has influenced observed fluctuations in total biomass, particularly the decreased biomass in recent years (Figure 36).

Gulf of Alaska groundfish biomass trends (Figure 36) are different from those in the BSAI. Although biomass increased in the early 1980s, as also seen in the BSAI, GOA biomass declined after peaking in 1982 at over 6 million metric tons, primarily due to changes in walleye pollock biomass. Total biomass has been fairly stable since 1985, however the species composition has changed. Pollock were the dominant groundfish species prior to 1986 but arrowtooth flounder has increased in biomass and is now dominant. The 2007 IPHC stock assessment of halibut, ages 6 and older, for the GOA (areas 2C and 3A) indicates halibut biomass increased from 1978 to 1996, declined slightly during 2001-2004.

Recruit per spawning biomass

Several stocks experienced step-changes in survival, as indicated by log(R/S), in the late 1970s and 1980s; however, in general, there was no indication of uniform step changes in all stocks in either time period for the GOA or BSAI (Figures 37-40 and Table 8).

Most roundfish, pollock, cod, and Atka mackerel (but not sablefish), did not show a shift in survival in 1976-77 or 1988-89 in the BSAI or GOA (Figures 37-39). There was, however, above average pollock survival prior to and below average survival after the early 1980s. Shifts were observed in 1970 (GOA pollock), in the early 1980s (GOA pollock, EBS pollock, and EBS cod), in the 1990s (AI pollock, EBS cod), and in the early 2000s (GOA pollock, and potentially GOA cod, EBS pollock, and EBS cod). Sablefish showed significant negative shifts in 1967 and 1986 and a positive shift in 1977.

Several BSAI flatfish had high survival prior to the 1980s and lower survival in the 1990s, including arrowtooth flounder, yellowfin sole, northern rock sole and flathead sole (Figure 37 and Table 8). All shifts for these species have been negative with the exception of a positive shift for Northern rock sole in 2001. Alaska plaice survival also decreased in 1981, but increased in 1997. Greenland turbot showed an increase in survival in 1998.

There were positive shifts in GOA flatfish survival mid- late 1990s. GOA arrowtooth flounder had negative step-changes in survival in 1979 and 1987; however the total biomass of arrowtooth flounder has been increasing since the mid-1970s.

Pacific ocean perch showed positive shifts in the mid- 1970s in both the BSAI and GOA (Table 8). After the mid-1980s, there was a decreasing trend in log(R/S) anomalies in both the BSAI and GOA (Figures 37-39). BS POP also showed a negative shift in 1989, whereas, GOA POP showed a negative shift in 1969 and 2001 (Figures 37-39 and Table 8). Other rockfish showed shifts in the mid- to late- 1990s, as well as some other years.

Factors causing observed trends: Several stocks experienced step-changes in survival in the late 1970s and 1980s; however, in general, there was no indication of uniform step changes in all stocks in either time period for the GOA or BSAI. Mueter et al. (2007) found, however, that when groundfish time series are combined, there does appear to be a system-wide shift in groundfish survival and recruitment within the BSAI and GOA in the late 1970s with mixed results in the late 1980s. This indicates that there may be some overall response to changes resulting from environmental forcing.

Examination of the average recruit per spawning biomass anomalies indicates gadids experience similar trends in survival within and between ecosystems. EBS cod and pollock experience similar trends in survival, and EBS and GOA pollock show similar trends in survival. This may be an indication that gadids respond in similar ways to large-scale climate changes.

Flatfish survival did appear to be related to known climate regime shifts, especially the late 1980s shift. In particular, the BSAI winter spawning flatfish (rock sole, flathead sole and arrowtooth flounder) showed a negative shift in survival in the late 1980s-early 1990s. Favorable recruitment was linked to wind-driven advection of winter-spawning flatfish larvae during spring (Wilderbuer et al. 2002). Years of consecutive strong recruitment for these species in the 1980s corresponds to years when wind-driven advection of larvae to favorable inshore nursery grounds in Bristol Bay prevailed. The pattern of springtime wind changed to an off-shore direction during the 1990s which coincided with below-average recruitment. This pattern is being examined further for northern rock sole (Wilderbuer, this report).

Pacific ocean perch survival also appears to be related to decadal-scale variability since it responded positively to the mid-1970s shift (BS and GOA) and negatively to the late 1980s shift (BS). The mechanism causing these shifts in survival is unknown. Recruit per spawning biomass ratios are autocorrelated in long-lived species, such as rockfish.

Implications: Large-scale climate changes may affect the survival of some groundfish stocks. Years of shifts in groundfish survival varies among individual species; however, combined groundfish survival does show a system-wide shift within the BSAI and GOA in the late 1970s with mixed results in the late 1980s.

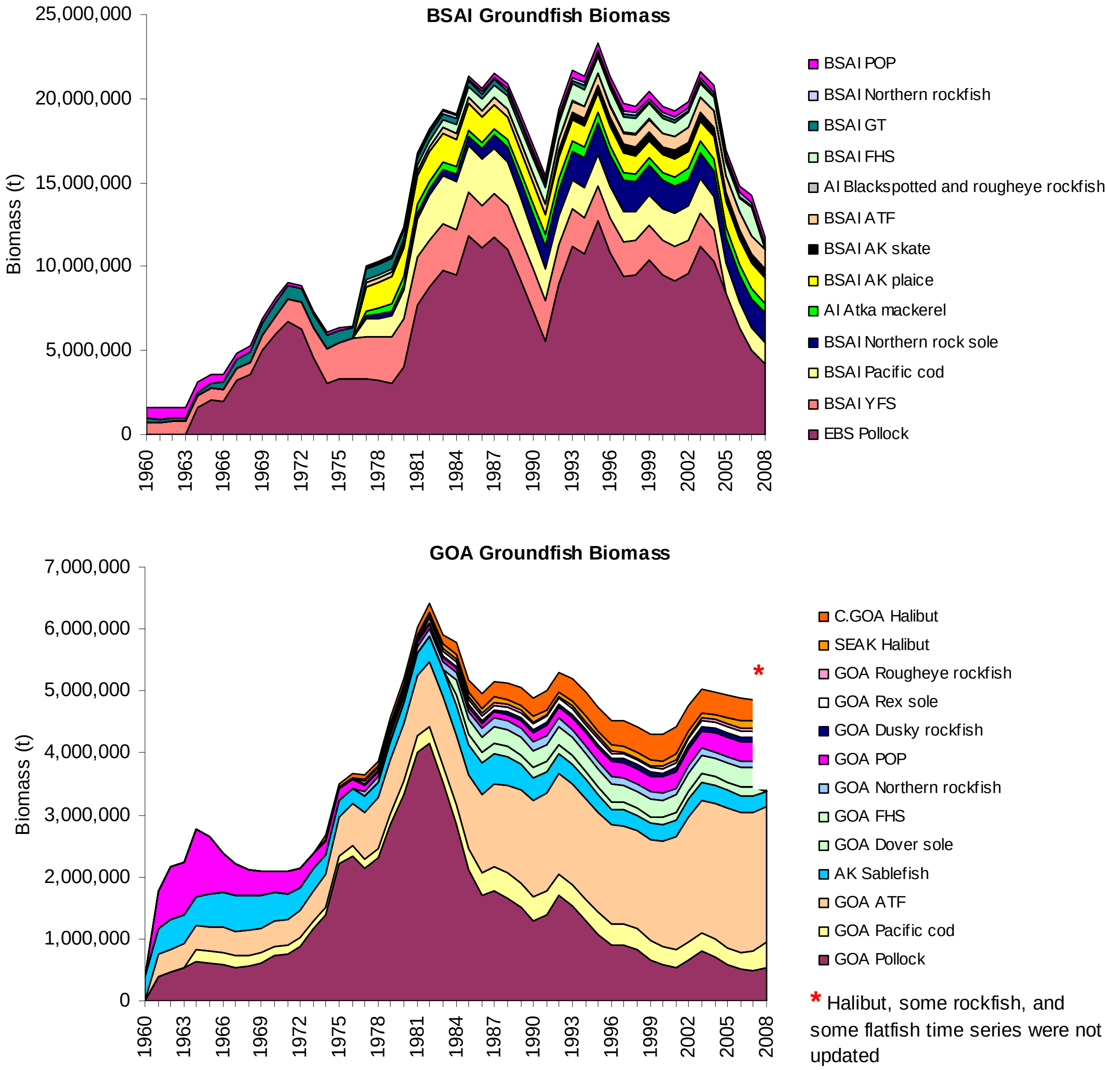

Figure 36. Groundfish biomass trends (metric tons) in the BSAI (1960-2008) and GOA (1960-2008), as determined from age-structured models of the Alaska Fisheries Science Center reported by NPFMC (2008 a, b). Halibut data provided by the IPHC (S. Hare, personal communication), but not updated for 2008 in this graph. Some rockfish and flatfish species in the GOA were also not updated for 2008 in this graph.

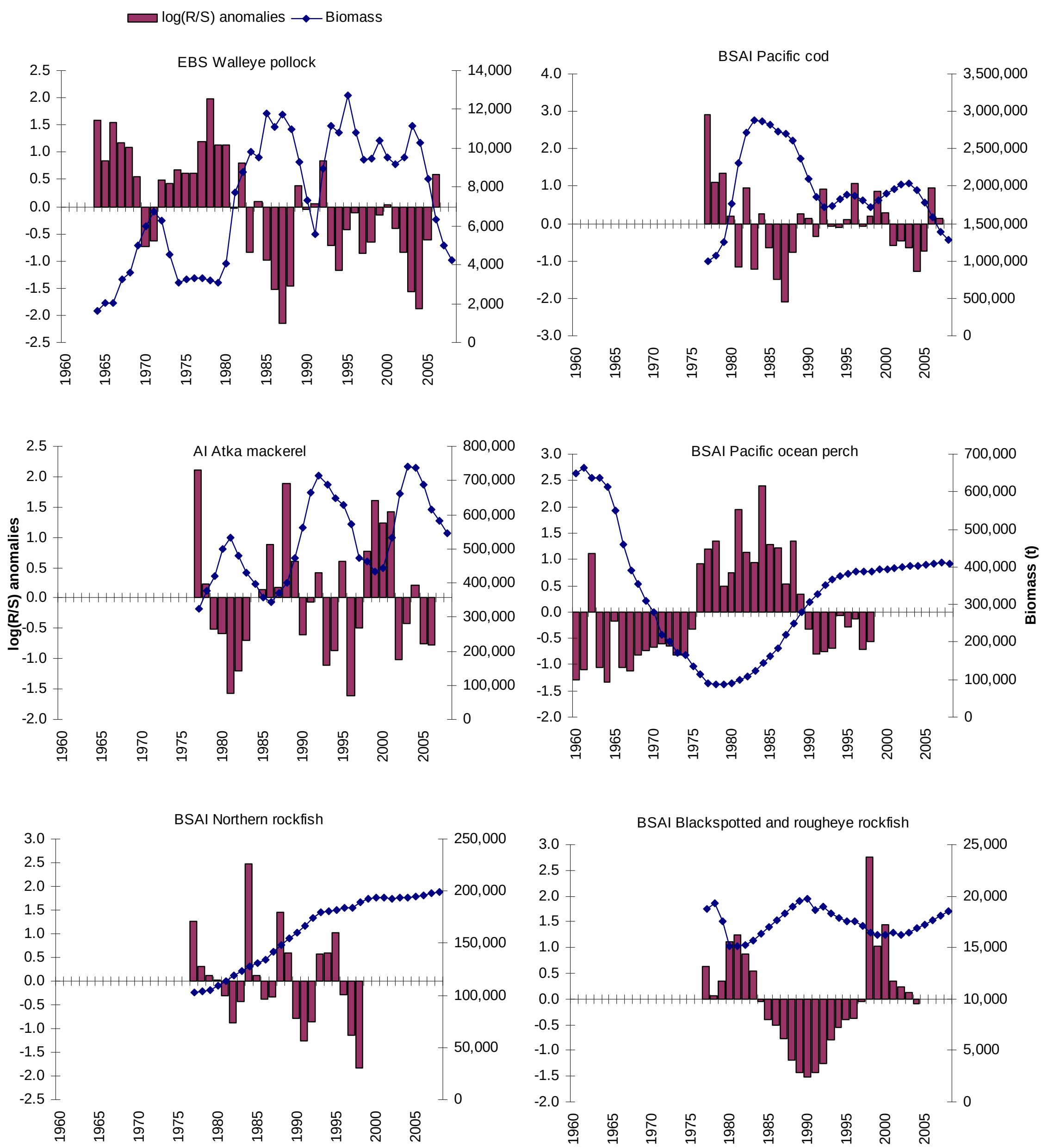

Figure 37. Median log recruit per spawning biomass anomalies and biomass for BSAI groundfish species assessed with age- or size-structured models, 1960-2008. EBS = Eastern Bering Sea, BS = Bering Sea, AI = Aleutian Islands.

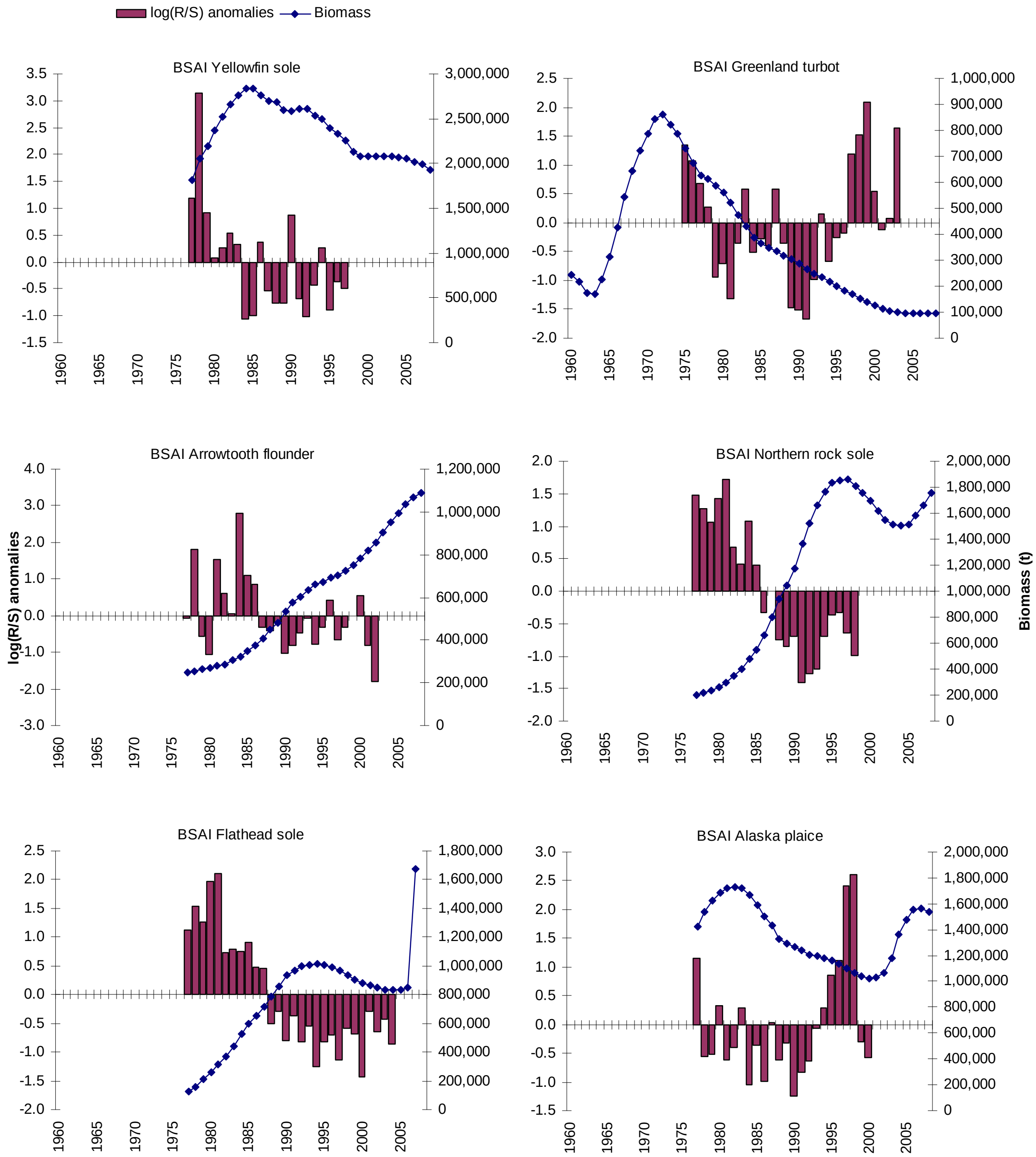

Figure 37 (cont.). Median log recruit per spawning biomass anomalies and biomass for BSAI groundfish species assessed with age- or size-structured models, 1960-2008. EBS = Eastern Bering Sea, BS = Bering Sea, AI = Aleutian Islands.

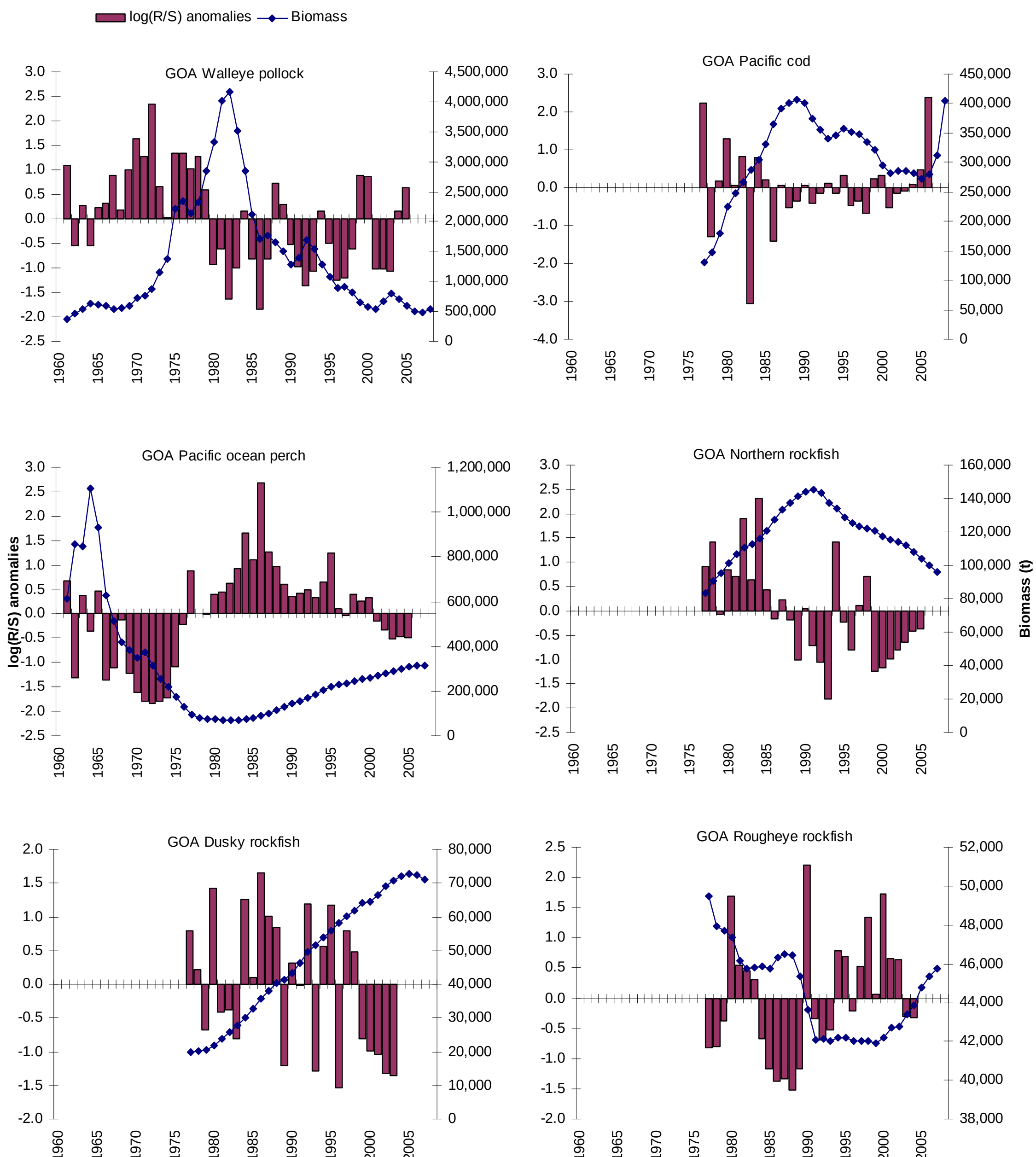

Figure 38. Median log recruit per spawning biomass anomalies and biomass for GOA groundfish species assessed with age- or size-structured models, 1960-2007 or 2008. GOA = Gulf of Alaska.

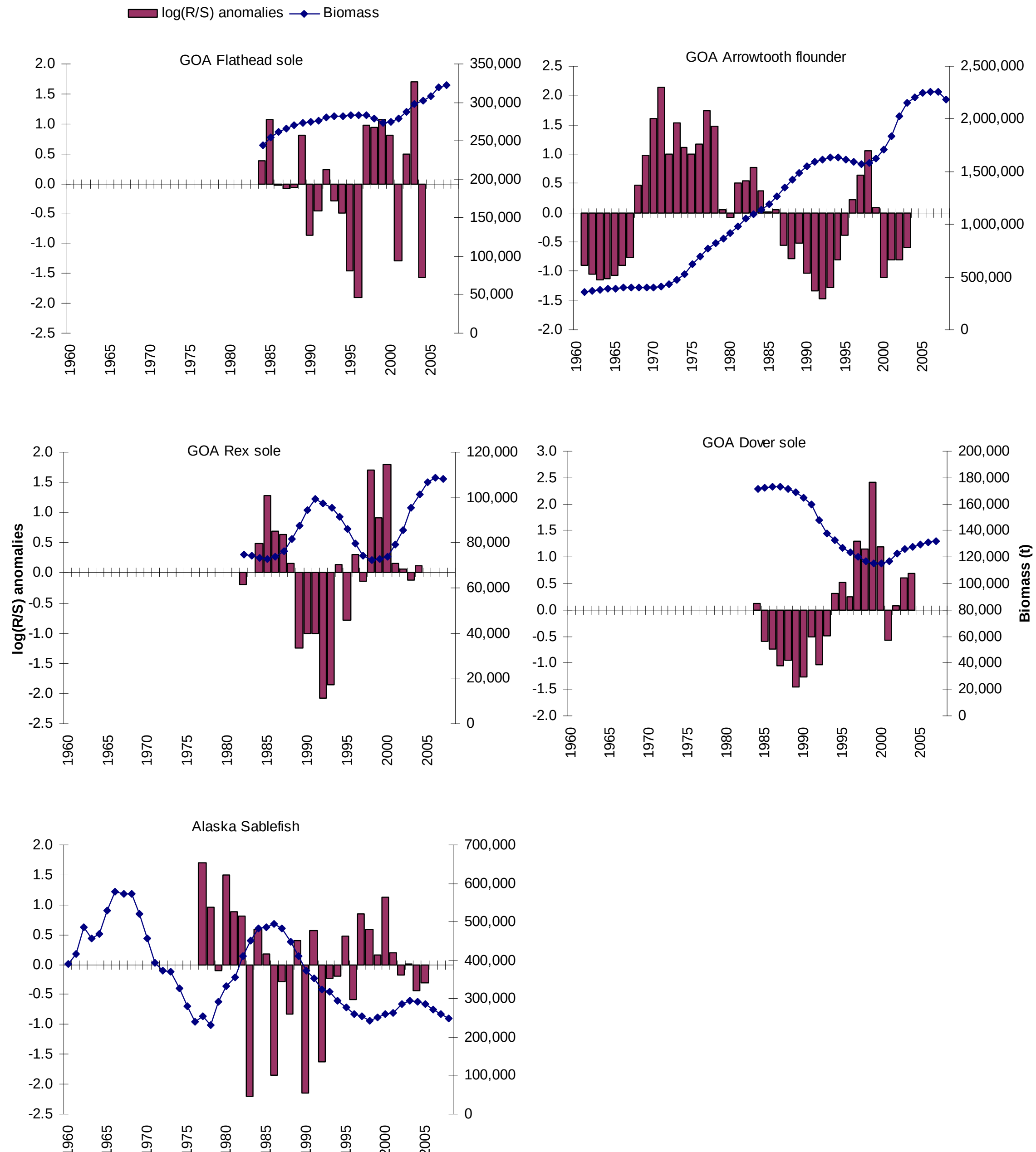

Figure 38 (cont.). Median recruit per spawning biomass anomalies and biomass for GOA groundfish species assessed with age- or size-structured models, 1960-2007 or 2008. GOA = Gulf of Alaska.

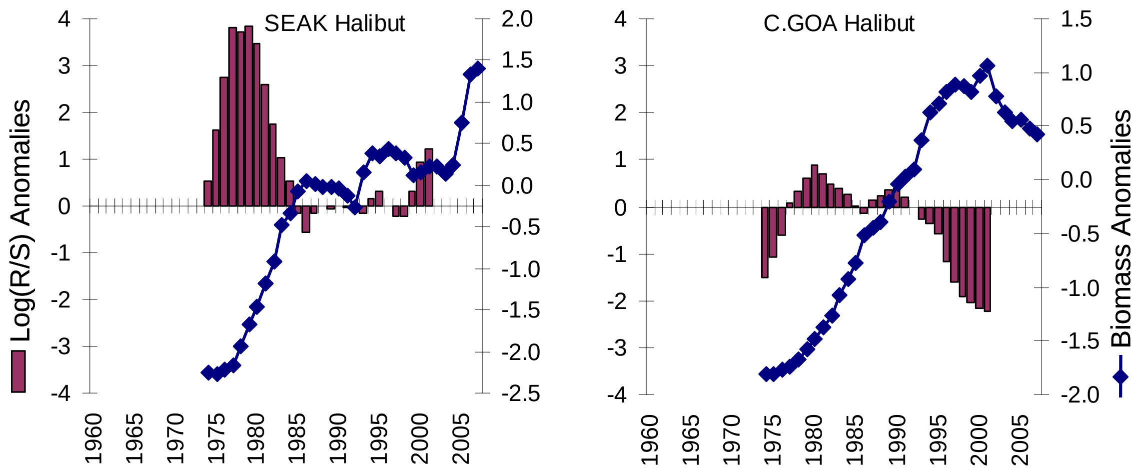

Figure 39. Median log recruit per spawning biomass anomalies and biomass for halibut, 1974-2007. C.GOA = central Gulf of Alaska, SEAK = southeast Alaska.

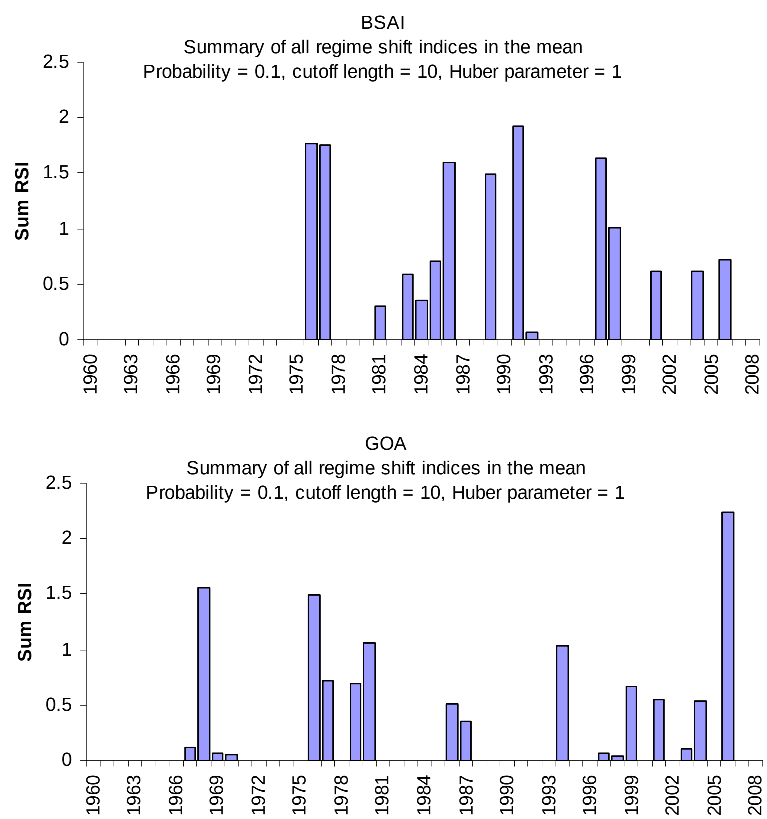

Figure 40. Summed regime shift index (RSI) values from the STARS (Rodionov 2005, Rodionov and Overland 2005) analysis (absolute values that indicate strength of step change) on log recruit per spawning biomass anomalies in each year for the BSAI and GOA.

Table 8. Years of significant step-changes in log-recruit per spawning biomass anomalies in the Bering Sea/Aleutian Islands (BSAI) and the Gulf of Alaska (GOA). Regular font represent years of positive changes, parentheses represent years of negative changes, and italics represent a significant step-change in the final year of the time series (i.e., likely to change with the addition of newer data).

Bering Sea and Aleutian Islands	Years of significant change	Gulf of Alaska	Years of significant change
EBS Pollock	(1983), *2006*	GOA Pollock	1970, (1980), 2004
AI Pollock	1998	GOA Pacifc cod	*2006*
BSAI Pacific cod	(1983), 1992, (2001)	GOA Arrowtooth flounder	1968, (1979), (1987), 1996
BSAI Yellowfin sole	(1977), (1984)	GOA Rex sole	1998
BSAI Arrowtooth flounder	(1989), (2004)	GOA Flathead sole	1997
BSAI Alaska plaice	(1981), 1997	GOA Dover sole	1994
BSAI Rougheye rockfish	(1985), 1997	GOA Pacific ocean perch	(1969), 1976, (2001)
BSAI Flathead sole	(1986)	GOA Northern rockfish	(1986)
BSAI Greenland turbot	1998	GOA Dusky rockfish	(1999)
BSAI Northern rock sole	(1991), 2001	GOA Rougheye rockfish	1994, (2003)
BSAI Northern rockfish	(1997)	Alaska Sablefish	(1967), 1977, (1986)
BSAI Pacific ocean perch	1976, (1989)		

Bering Sea Groundfish Condition
Contributed by Jennifer Boldt, University of Washington and Jerry Hoff, AFSC, NMFS
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Last Update: October 2008

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

Update on EBS Winter Spawning Flatfish Recruitment and Wind Forcing
Contributed by Tom Wilderbuer and Jim Ingraham, AFSC
Contact: Tom.Wilderbuer@noaa.gov
Last updated: July 2009

Wilderbuer et al. (2002) summarized a study examining the recruitment of winter-spawning flatfish in relation to decadal atmospheric forcing, linking favorable recruitment to the direction of wind forcing during spring. OSCURS model time series runs indicated in-shore advection to favorable nursery grounds in Bristol Bay during the 1980s. The pattern change to off-shore in the 1990-97 time series coincided with below-average recruitment for northern rock sole, arrowtooth flounder and flathead sole, relative to the 1980s. The time series is updated through 2009 (Figure 41).

Five out of eight OSCURS runs for 2002-2009 were consistent with those which produced above-average recruitment in the original analysis, 2005, 2007 and 2009 being the exceptions. The north-northeast drift pattern suggests that larvae may have been advected to favorable, near-shore areas of Bristol Bay by the time of their metamorphosis to a benthic form of juvenile flatfish. Preliminary estimates of rock sole recruitment in recent years are consistent with this larval drift hypothesis (Figure 41). For arrowtooth flounder and flathead sole, the correspondence between the springtime drift pattern from OSCURS and estimates of year class strength have weakened since the 1990s. Arrowtooth flounder produced year classes of average strength during some off-shore drift years, suggesting that this species may have different settlement preferences than northern rock role. In the case of flathead sole, weak recruitment has persisted since the 1990s with no apparent response to the surface wind advection pattern in the early 2000s.

The end point of the drift trajectory in 2009 was offshore, suggesting that this year class of northern rock sole may be below the long-term average.

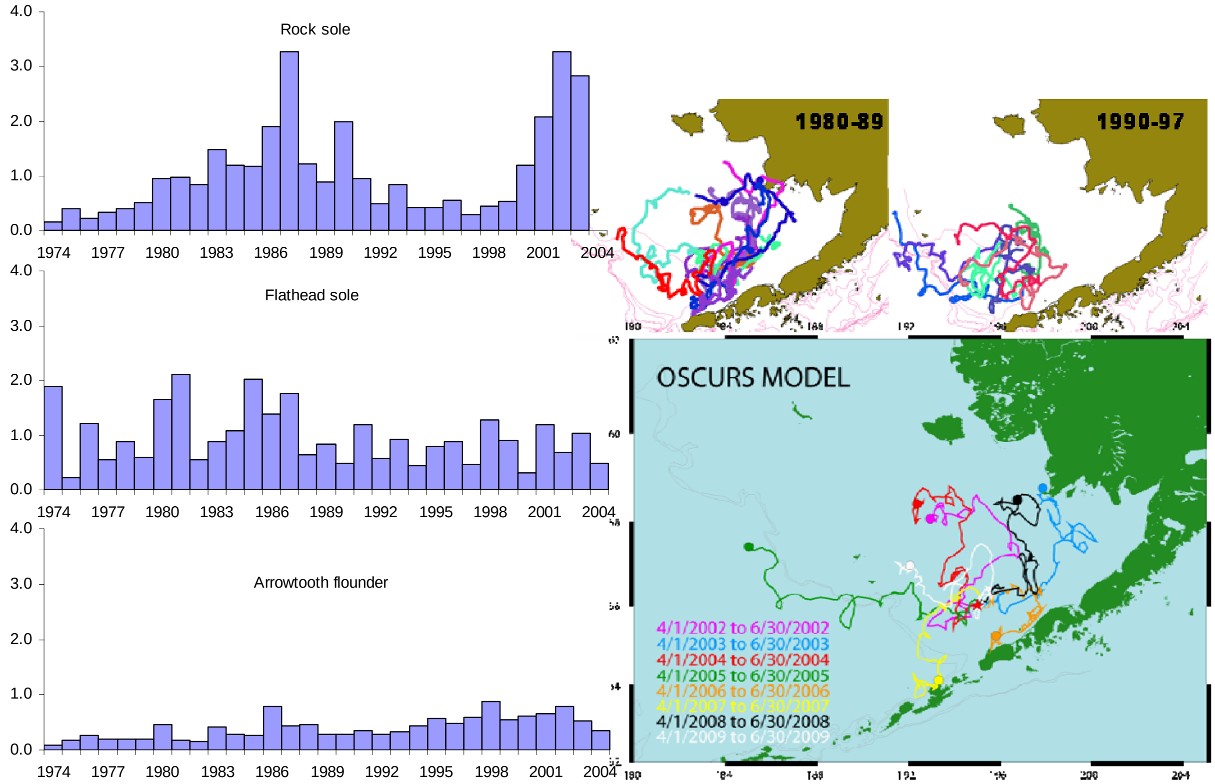

Figure 41. The left column shows recruitment of northern rock sole (1974-2003), flathead sole (1974-2004), and arrowtooth flounder (1974-2004) in the Bering Sea. The right column shows the OSCURS (Ocean Surface Current Simulation Model) trajectories from starting point 56° N, 164° W from April 1-June 30 for three periods: 1980-89, 1990-97, and 2002-2009.

Density-Independent and Density-Dependent Factors Affecting Spatial Distributions of Eastern Bering Sea Flatfish from 1982-2006

Contributed by Paul Spencer (Alaska Fisheries Science Center – REFM)
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Last updated: October 2009

The general warming of the eastern Bering Sea (EBS) and the wide range of abundance exhibited by several eastern Bering Sea flatfish motivate an examination of how density-dependent and density-independent factors may influence the spatial distributions of EBS flatfish. In this study, EBS trawl survey data from 1982 to 2006 were used to examine how temporal changes in the distributions of six flatfish species groups (yellowfin sole (*Limanda aspera*), rock sole (*Lepidopsetta* sp.), flathead sole (*Hippoglossoides* sp.), Alaska plaice (*Pleuronectes quadrituberculatus*), arrowtooth flounder (*Atheresthes* sp.), and Greenland turbot (*Reinhardtius hippoglossoides*)) are related to temporal changes in the location of the “cold pool” (bottom water < 2˚ C), and how the area occupied by flatfish are related to the cold pool and population abundance.

For flathead sole and rock sole, significant correlations were found between the proportion of the fish distributions located in the southeast (SE) strata and the proportion of the cold pool located in the SE strata, whereas non-significant relationships were found for yellowfin sole, Alaska plaice, and arrowtooth flounder (Figure 42). Reduced proportions of the flathead sole and rock sole distributions were found in the SE strata during recent warm years, suggesting that these populations had redistributed to the northwest as the cold pool also shifted to the northwest. In the cold year of 1999 the proportion of the cold pool and the rock sole and flathead sole distributions in the SE strata were dramatically increased as compared to 1998; this increase was also noted for yellowfin sole, although the overall relationship was non-significant (Figure 42).

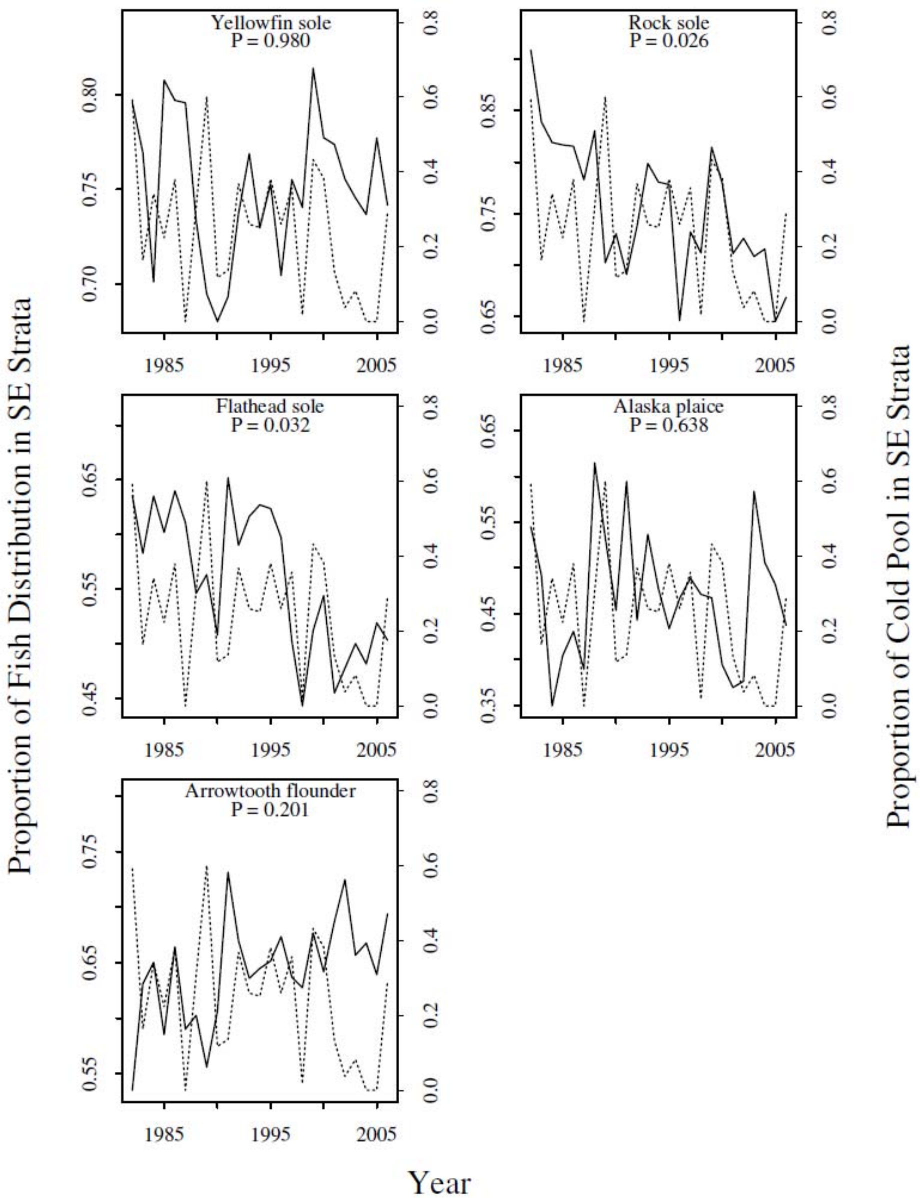

Figure 42. Time series of the proportion of a stock (solid line) and cold pool (dashed line) occurring within the eastern Bering Sea southeast survey strata, based upon EBS shelf survey data; *P*-values indicate significance of correlation tests.

The area occupied by arrowtooth flounder is inversely related to the area of the cold pool ($P<0.01$, Figure 43), whereas this relationship was not significant for the other flatfish stocks. The area occupied is measured as the minimum estimate of the survey area for which the cumulative survey catch-per-unit-effort (CPUE) was equal to 95% of the cumulative CPUE for all stations (Swain and Sinclair 1994).

Additionally, the area occupied by the rock sole and arrowtooth flounder stocks significantly increased with stock size ($P<0.001$) (Figure 43), suggesting that the spatial distribution of the stock is related to density-dependent habitat selection. Although the overall relationship between area occupied by rock sole and stock abundance is significant, this relationship is driven by the strong increases in both area occupied and stock size from 1982 to 1989, a time period in which rock sole mean length at age decreased (Walters and Wilderbuer 2000). The observations of decreasing length at age, increasing abundance, and expanding population range during the 1980s are consistent with the classic theory of density-dependent habitat selection in which intra-specific competition results in range expansion.

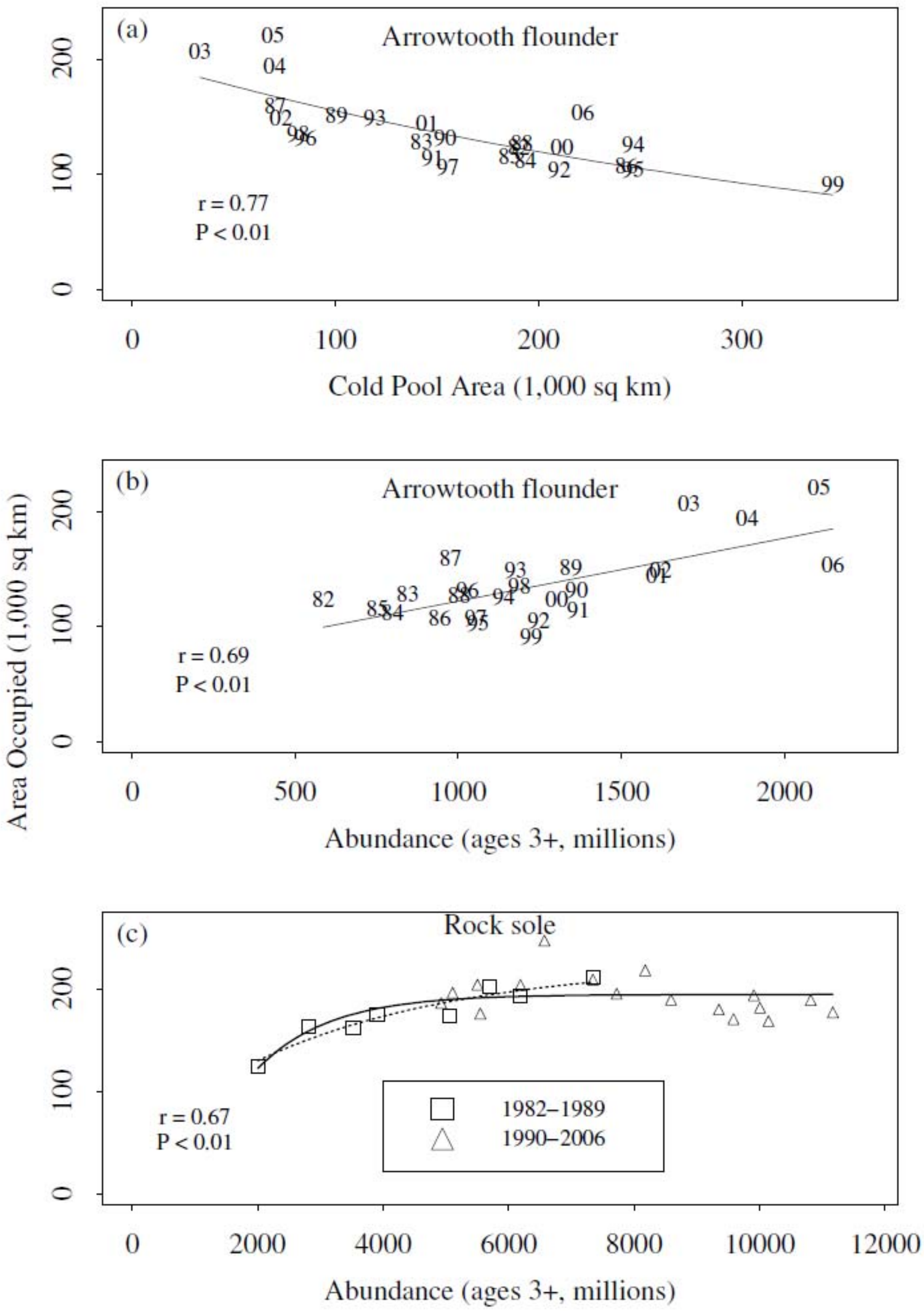

Figure 43. Relationship between area occupied by arrowtooth flounder and area of the cold pool (a) and abundance (b). The relationship between the area occupied by rock sole and abundance is shown for 1982 to 1989 (squares; dotted line) and 1990-2006 (triangles); the solid line is the fitted curve for all years (c).

Arrowtooth flounder also showed density-dependent habitat selection in which expansion to the middle shelf is related to population increases, but a multivariate analysis indicates this movement is more strongly related to the reduction in cold pool area in warm years. It is notable that the three years in which arrowtooth flounder occupied the most area, 2003-2005, were also the three years of the smallest cold pool area and very large population sizes (Figure 43). In 2006 some contrast is provided, as the area occupied by arrowtooth flounder and the areas of the cold pool dramatically decreased while the arrowtooth flounder population remained very large.

In summary, considerable variability occurs in how flatfish spatial distributions have responded to the generally increasing temperatures of the EBS shelf, with both density-independent and density-dependent factors emerging as potential mechanisms. These results suggest that the factors that determine temporal changes in EBS flatfish distributions extend beyond solely temperature and likely differ between species.

Benthic Communities and Non-target Fish Species

ADF&G Gulf of Alaska Trawl Survey

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Last updated: October 2009

The Alaska Department of Fish and Game continued its trawl survey for crab and groundfish in 2008. The 400 Eastern trawl net is targeted on areas of crab habitat around Kodiak Island, the Alaska Peninsula, and the Eastern Aleutian Islands. 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 44) 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.

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, also using a 400 Eastern trawl net (Blackburn 1979). Today, the Ugak Bay species composition is markedly different than in 1976. Red king crabs 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, and while Pacific cod made up 88% and walleye pollock 10% of the gadid catch in 1976-1977, catch compositions have reversed in 2008 with Pacific cod making up 19% of catch and walleye pollock 75%.

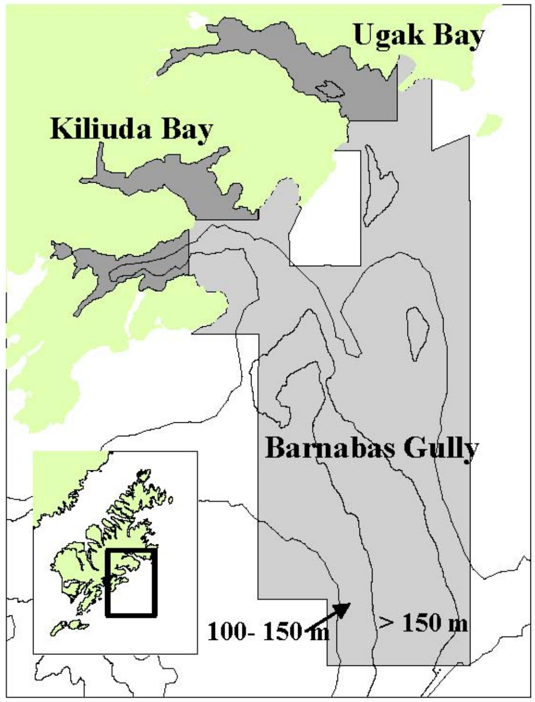


Figure 44. Adjoining survey areas on the east side of Kodiak Island used to characterize inshore (dark gray, 14 stations) and offshore (light gray, 33 stations) trawl survey results.

Arrowtooth flounder continues to be the main component of the offshore catches, while flathead sole and Tanner crab were the largest catches inshore (Figure 45). Also, Pacific cod catches were noticeably low inshore in 2008. Overall catch rates have decreased inshore (Kiliuda and Ugak Bays) and offshore (Barnabas Gully) for all species (Figure 46) except Tanner crabs which have slightly increase in the offshore areas.

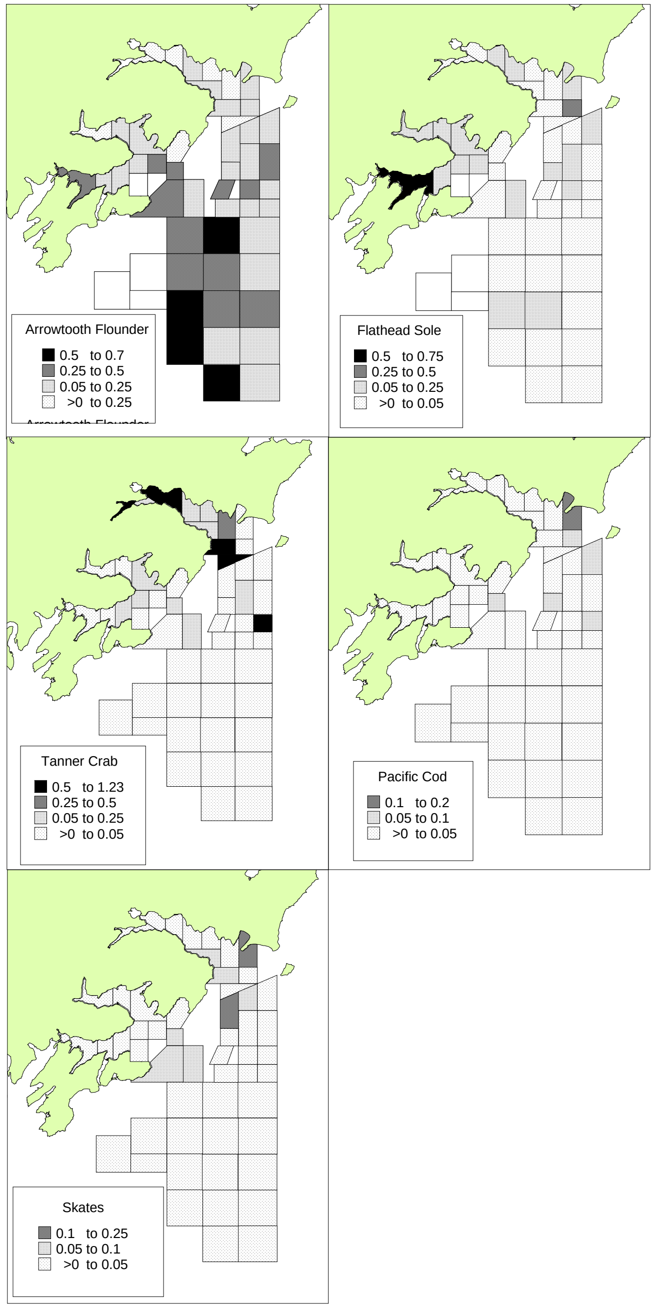
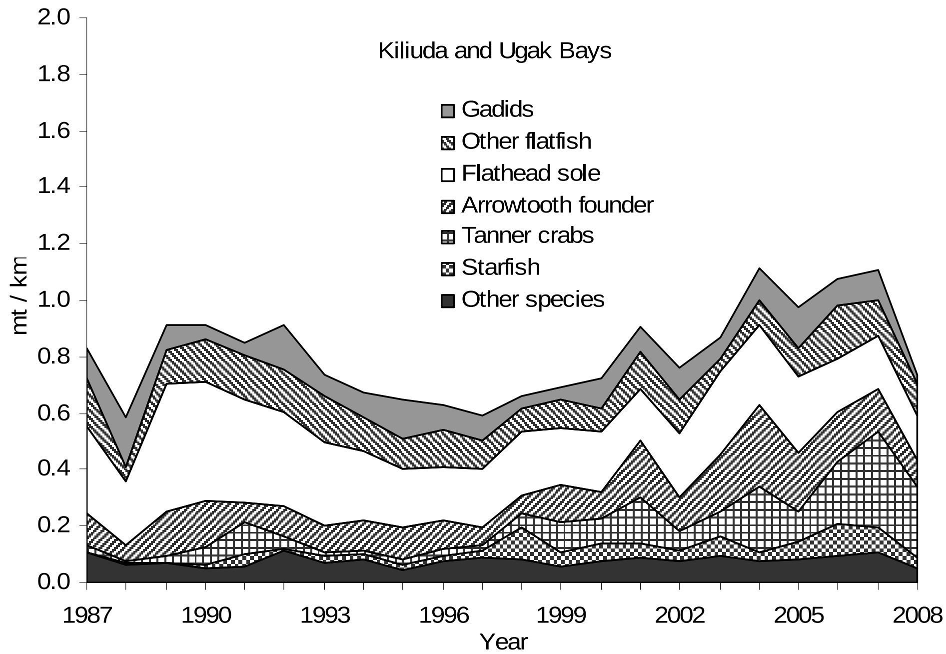


Figure 45. The catch in mt/km of selected species during the 2008 ADFG trawl survey from Kiliuda and Ugak Bays and Barnabas Gully on the east side of Kodiak Island.



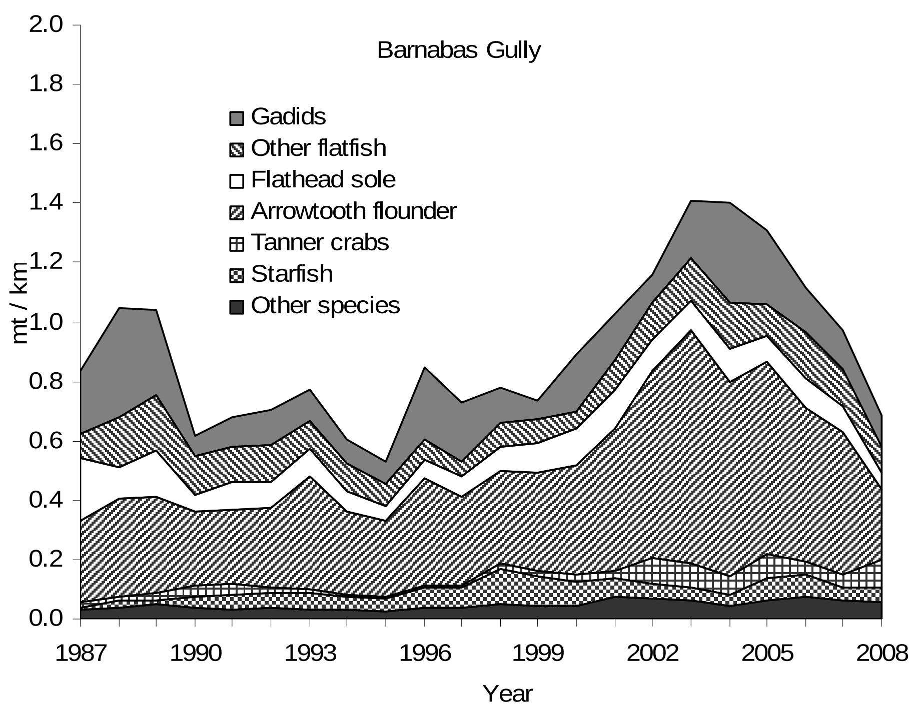


Figure 46. Total catch per km towed (mt/km) during the ADF&G trawl survey from adjacent areas off the east side of Kodiak Island, 1987 to 2008.

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, flathead sole, Tanner crab, Pacific cod, and skates,) using the method described by Link et al.

(2002) (Figure 47). In 2008, above average anomaly values were recorded for offshore skates and both offshore and inshore Tanner crabs, while arrowtooth flounder and flathead sole have decreased to below average levels. The Pacific cod anomaly continued to be below average value inshore. It appears that significant changes in volume and composition of the catches on the east side of Kodiak are occurring for these species, but it is unknown if predation, environmental changes, or fishing effort are contributing to these changes.

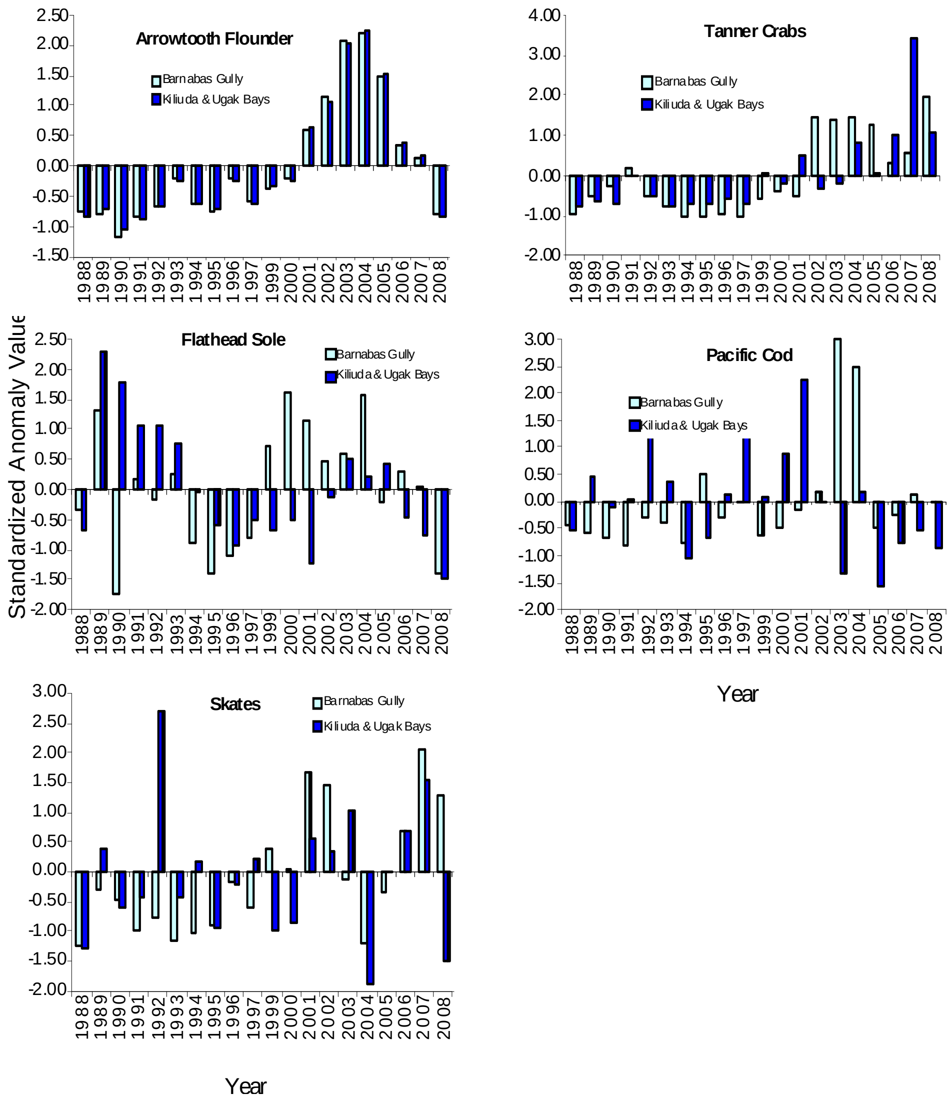


Figure 47. A comparison of standardized anomaly values for selected species caught from 1988-2008 in Kiliuda and Ugak Bays and Barnabas Gully during the ADF&G trawl surveys.

Bottom temperatures for each haul have been consistently recorded since 1990 (Figure 48). Temperature anomalies for both inshore, Kiliuda and Ugak Bays and offshore stations, Barnabas Gully, from 1990 to 2008, show similar oscillations with periods of above average temperatures corresponding to El Niño years (http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html) (Figure 48). The lower overall catch from

1991 to 1994 (Figure 46), may be a reflection of the warmer water El Niño effects on overall production while years of average or cooler temperatures correspond to the years of greater production and catch. Conversely, lower than average temperatures have been recorded in both 2007 and 2008 along with decreasing overall abundances indicating a possible lag in response to less optimal environmental conditions or other factors that maybe influencing this trend that are not yet apparent.

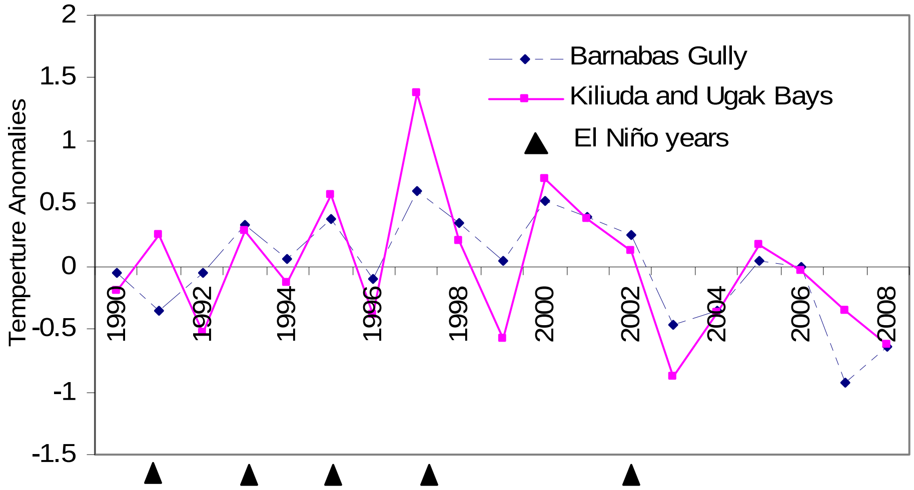


Figure 48. Bottom temperature anomalies recorded from the ADF&G trawl survey for Barnabas Gully and Kiliuda and Ugak Bays from 1990 to 2008, with corresponding El Niño years represented.

Although trends in abundance in the trawl survey appear to be affected by major oceanographic events such as El Niño, local environmental changes, predation, and fishery effects may influence species specific abundances and need to be studied further. Monitoring these trends is important for establishing harvest levels for state water fisheries.

Summary

Arrowtooth, flathead sole, and other flatfish continue to dominate the catches in the ADF&G trawl survey. A decrease in overall biomass is apparent in 2007 and 2008 from years of record high catches seen from 2002 to 2005. These trends are likely influenced by El Nino events, although local environmental conditions, predation, and fishing effects may also play an important role in species abundance. 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.

Gulf of Alaska Small Mesh Trawl Survey Trends

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Last updated: August 2009

Annual smallmesh trawl surveys of the nearshore Gulf of Alaska have been conducted by Alaska Fisheries Science Center and Alaska Department of Fish and Game using standard methods since 1972 (n

= 9,240 hauls). Although originally conducted for shrimp assessment, weights and counts of other invertebrates and groundfish have also been recorded. The length of the smallmesh time series makes it an important source of information on the changes to the marine ecosystem that have occurred in the North Pacific. For example, the time series was instrumental in documenting the transition from a community rich in shrimp and capelin to a community rich in groundfish following the 1976/1977 regime shift tied to the Pacific Decadal Oscillation (Anderson and Piatt 1999, Mueter and Norcross 2000). Results showed declining capelin *Mallotus villosus* and pink shrimp *Pandalus borealis* CPUE and increases in arrowtooth flounder *Atheresthes stomias* and Pacific cod *Gadus macrocephalus* CPUE following the regime shift. The most recent survey occurred between September 23 and October 24, 2008 (n = 129 hauls) around Kodiak Island (Chiniak Bay, Inner and Outer Marmot Bay, lower Shelikof Strait), and along the Alaska Peninsula between Wide Bay and Pavlof Bay. In 2008, CPUE was calculated from data collected at four of the most consistently sampled bays over the time series (Inner Marmot, Pavlof, Kuiukta and Chignik/Castle Bays). CPUE is presented as the total kilograms captured divided by the total distance towed (± SD).

Capelin CPUE remained low in 2008 (0.0004 ± 0.004 kg km^{-1}), one to two orders of magnitude lower than peak values observed in the 1970s and early 1980s. Pink shrimp CPUE (5.29 ± 25.72 kg km^{-1}) also continued at low post-regime shift levels, more than an order of magnitude below 1970s values although catch rates varied widely across the surveyed area. Arrowtooth flounder CPUE (6.60 ± 18.23 kg km^{-1}) and Pacific cod CPUE (5.43 ± 1.53 kg km^{-1}) remained at the high levels observed since the mid 1980s but continued the recent trend of lower values. Basically, catches through 2008 do not show any significant deviation from the groundfish-dominated community state illustrated by the Pavlof Bay panel in Figure 49.

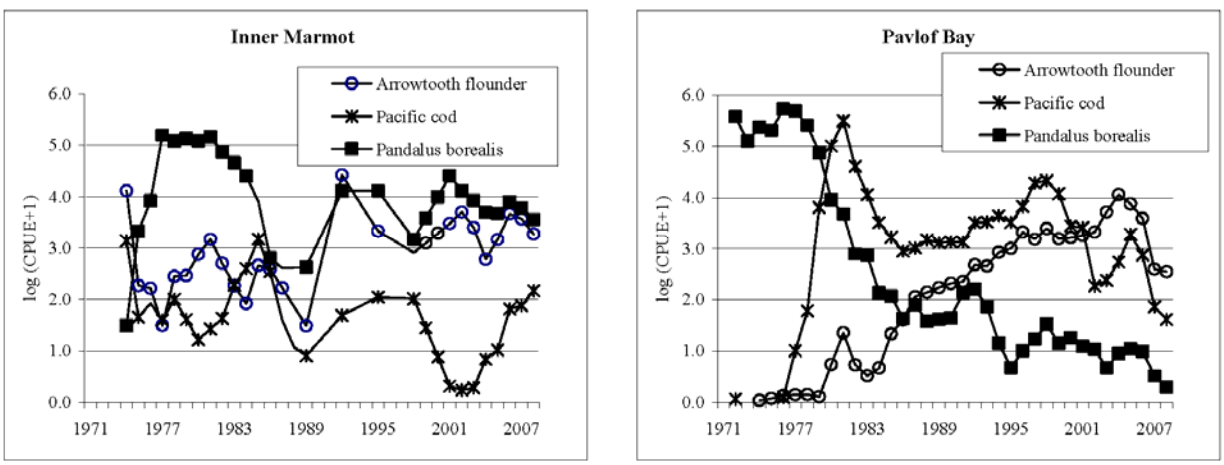

Figure 49. Log of catch per unit effort (kg/km + 1) of arrowtooth flounder, Pacific cod, and pink shrimp from smallmesh trawl surveys in Inner Marmot Bay and Pavlof Bay, plotted as a 3 year running average when data points are available.

First consistently seen in the survey area in 2004, the smooth pink shrimp (*Pandalus jordani*) was captured in eight different survey areas around Kodiak Island and as far west as the Shumagin Islands. *P. jordani* is a lower-latitude species that is commercially fished off British Columbia and the west coast of the U.S. This species was sporadically caught in the small-mesh survey during 1974-1983 (n = 14 total catches), although the close similarity with *P. borealis* casts some doubt on the validity of those records due to identification errors. While the number of areas where *P. jordani* was found increased in 2008, the catch rates declined sharply from the previous several years. Catch rates in outer Marmot Bay, where it has been most commonly seen in recent years, fell from a high of 3.34± 4.90 kg km^{-1} in 2007 to 0.40 ±

0.76 kg km^{-1} in 2008. Declining catch rates may be in response to water temperatures which have been decreasing since 2001.

The long-term response to the 1976/1977 regime shift has not been uniform across the surveyed region. The CPUE trends from Inner Marmot Bay on the northeast Kodiak archipelago and those of Pavlof Bay on the south coast of the Alaska Peninsula illustrate these differences (Figure 49). Both bays saw dramatic shifts in community composition following the 1976/1977 PDO regime shift, but in Marmot Bay shrimp catch rates stabilized at a much higher level (CPUE in 2008 of 16.94 ± 33.14 kg km^{-1}) compared to Pavlof Bay where CPUE has continued to decline (CPUE in 2008 of 0.49 ± 1.19 kg km^{-1}). The reason for these differences is not fully understood, but the physical oceanography of the two areas is quite different. Marmot Bay is tied to the GOA deep basin by the Stephenson Trough and Marmot Gully but Pavlof Bay's connection to the basin is relatively more constricted. Differences in the coastal bathymetry may affect the cross-shelf transport of nutrients and plankton caused by mesoscale eddies in the Gulf of Alaska or by the tidal mixing of flow into the gullies (Ladd et al. 2005, Di Lorenzo et al. 2008, Combes and Di Lorenzo 2009) which in turn affects coastal productivity and dispersal of larval stages. It was hypothesized that bathymetric differences in smallmesh survey areas around Kodiak Island might explain differences in the community structure (Mueter and Norcross 2000).

While the community changes in the marine ecosystem caused by the environmental changes of 1976/1977, as indicated by a shift in the Pacific Decadal Oscillation index (PDO), appeared strong and widespread across the GOA, the PDO is not the only indicator of spatial variability in sea surface temperature and sea level pressure (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 important (Di Lorenzo et al. 2008) and improving our understanding of the changing ocean environment requires continued careful monitoring of the physical and biological systems.

Bering Sea Crabs

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Last updated: October 2009

Eastern Bering Sea crab abundance indices are based on the annual National Marine Fisheries Service bottom trawl survey area swept estimates, Alaska Department of Fish and Game (ADF&G) trawl surveys, ADF&G pot surveys, and from commercial catch data. There are ten crab stocks in the current Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs: four red king crab *Paralithodes camtschaticus* (Bristol Bay, Pribilof Islands, Norton Sound, and Adak), two blue king crab *Paralithodes platypus* (Pribilof District and St Matthew Island), two golden king crab *Lithodes aequispinus* (Aleutian Islands and Pribilof Islands), and two Tanner crab stocks (southern Tanner crab *Chionoecetes bairdi* and snow crab *C. opilio*). Overfishing and overfished status of crab stocks are based on a five tier system where mature male biomass is currently used as a measure of the productive capacity of the stock (B). Snow crab and Bristol Bay red king crab are managed as Tier 3 stocks with length-based models where proxy limit reference points are estimated based on life history information. Snow crab was declared overfished in 1999 and is under a rebuilding plan. Tanner crab, Pribilof Islands red and blue king crab, and St. Matthew blue king crab are Tier 4 stocks where data on life history and a spawner-recruit relationship are lacking. The Pribilof Islands blue king crab was declared overfished in 2002 and remains at a low biomass. St. Matthew blue king crab was declared overfished in 1999 and is officially considered rebuilt this year. The Tanner crab stock is approaching an overfished status based on the 2009 survey estimates. The remaining stocks are Tier 5 stocks with no reliable estimates of B or natural mortality and are managed on average catch data. Fluctuations in crab stocks have coincided with variable fishing pressure and changes in environmental conditions affecting benthic organisms in the eastern Bering Sea, although no one cause has been identified to explain the wild fluctuations in some stocks and the precipitous decline from the 1970s and 1980s in other stocks.

Red king crab

Bristol Bay red king crab estimates of total survey abundance of adult males increased to 101 million crab in 1977 decreased sharply to a low of 11 million crab in 1983, and then remained steady between 12 and 20 million crab through 2009 (Fig. 50). Recent above-average year classes have recruited into the fished population and there is no evidence any strong year classes recruiting.

Pribilof Islands red king crab were not prevalent in the Pribilof Islands until the early 1990s. The large male abundance peaked in the 1990s at 10 million crab and then declined to abundances between 0.25 and 2 million crab between 1998 and 2009. Recruitment indices are not well understood for Pribilof red king crab largely due to the difficulty in catching the smaller crab in the nearshore habitat and due to their small numbers. There was a substantial decrease in abundance for all crab size groups in this stock in 2009.

Norton Sound red king crab adult male abundance was highest during the 1970s around 6 million crab, declined into the 1980s and 1990s to a low of 1 million crab, and has gradually increased to an average of 1.5 million crab since 1996. Juvenile male abundance has fluctuated over the time series but has increased gradually in recent years to over 1 million crab in 2009.

Adak red king crab estimates of abundance are not available for this stock. Fishery catches decreased from a 21 million pound peak in the 1960s to less than 1 million pounds in the late 1990s. Since the end of the 2003/2004 fishing season the fishery has been closed due to poor recruitment indices from periodic pot surveys.

Blue king crab

Pribilof Island blue king crab adult male abundance peaked in the late 1970s between 15 and 18 million crab before a precipitous decline to less than 1 million crab in 1985. Abundance estimates have remained low in this designated overfished stock with average estimates of less than 0.25 million crab. Juvenile male blue king crab in the Pribilof Islands fluctuated between 0 and 1 million crab in the last decade. Survey results from 2009 showed an increase in adult males with no apparent incoming year classes.

St. Matthew blue king crab adult male abundance fluctuated between low and high abundance over three periods: 1978 to 1985, 1986 to 1999, and 2000 to current. Historical peaks in adult male abundance were 8 million crab in 1982 and 6 million crab in 1997. Currently the stock has increased from a low of 0.75 million crab in 2004 to the current abundance estimates of 3 million crab.

Tanner crab

Tanner crab adult male abundance peaked in the 1970s around 200 million and early 1990s at 180 million crab (Fig. 50). From 1990s through 2007, adult male abundance increased to 93 million. However, in 2008 and 2009 there was a substantial decrease to 52 million crab. Juvenile male crab have fluctuated similarly with peaks of 545, 459, and 386 million crab in 1980, 1989, and 2006. Recent juvenile crab abundance estimates have declined to less than 150 million crab in 2009.

Snow crab

Snow crab adult male abundance peaked in the mid to late 1970s and again at 1,300 million adult male crab in 1990 and 958 million crab in 1996 (Fig. 50). After a decline to 190 million adult male crab in 2000 the stock has gradually increased to the current adult male abundance of 372 million crab. Snow crab recruitment has varied substantially with peaks of 3,500 and 4,500 million juvenile males in 1987 and 1993 respectively. Recent juvenile male snow crab abundances were estimated between 900 and 1,500 million crab.

Golden king crab

Stock abundance estimates are not available for golden king crab stocks in the eastern Bering Sea/ Aleutian Islands. Fluctuations in Aleutian Islands golden king crab and Pribilof Islands golden king crab fishery catch per unit effort have led to speculation about changes in recruitment. In the Pribilof Islands, commercial catches ranged from 0.010 and 0.090 million crab in the late 1990s and early 2000s and have dropped to 0 in recent years. In the Aleutian Islands, catches of golden king crab averaged 1.5 million in the 1980s, 0.6 million in the 1990s and 2000s.

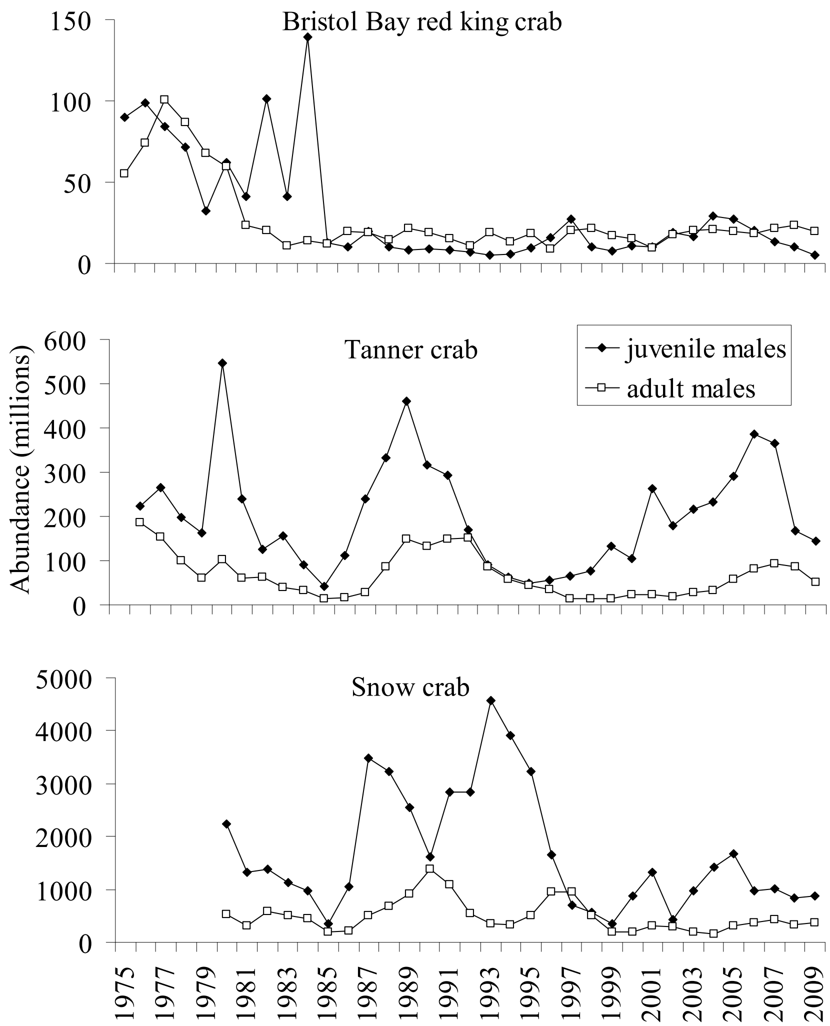

Figure 50. Eastern Bering Sea red king crab, Tanner crab, and snow crab survey abundance of adult and juvenile males.

Stock-Recruitment Relationships for Bristol Bay Red King Crabs
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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

Miscellaneous Species – Gulf of Alaska
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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

Lingcod Catches in the Gulf of Alaska
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Last Updated: September 2009

Lingcod *Ophiodon elongatus* are the largest member of the greenling family (Family Hexagrammidae). The State of Alaska has management authority for lingcod in all waters of the Exclusive Economic Zone (0-200 nm) off Alaska. Commercial regulations in the Kodiak Management Area restrict all lingcod harvest to the period of July 1 to December 31 and require fish to be a minimum of 35 inches in total length. All legal commercial gear types can be used to harvest lingcod although regional registration and a commissioner's permit are required for directed fishing. Most lingcod harvest occurs as bycatch (historically up to 20% by weight of the targeted species) in other fisheries, but some directed harvest with jig gear has occurred.

The 2008 Kodiak Management Area (KMA) commercial lingcod harvest of 521,257 pounds was the largest lingcod harvest on record and represented a substantial increase from the 2007 harvest of approximately 105,000 pounds (Table 9). There was no directed fishery for lingcod in 2008. Most lingcod were harvested as bycatch to federal commercial groundfish fisheries outside of state waters.

The high level of trawl caught lingcod in 2008 was likely a result of strong exvessel prices for lingcod. Lingcod generally commanded a much higher price at the dock compared to the flatfish species targeted by trawlers.

Bycatch rates for lingcod were lowered to 5% at the beginning of 2009 to reduce overall harvest. Harvest through October 2009 was 57,990 pounds, similar to years prior to 2008. Some dockside data has been collected, but remains unanalyzed at this time.

Table 9. Lingcod harvest (whole pounds) from the Kodiak, Chignik, and South Alaska Peninsula Areas, 1988-2008.

Year	Jig	Longline	Pot	Trawl	Total
1988	59	43	0	136,191	136,294
1989	69	0	0	14,324	14,394
1990	1,418	158	402	8,839	10,816
1991	8,375	501	386	663	9,925
1992	5,569	4,261	72	10,897	20,799
1993	0	511	0	4,778	5,289
1994	4,820	803	0	229	5,852
1995	34,574	3,467	79	1,191	39,311
1996	43,403	7,878	0	10,929	62,209
1997	12,637	6,499	4,251	5,267	28,654
1998	5,756	1,771	0	3,514	11,041
1999	1,358	3,802	4,189	4,593	13,941
2000	3,400	6,734	2,676	2,127	14,938
2001	527	4,063	3,597	5,688	13,875
2002	29	6,131	2,749	5,380	14,290
2003	229	9,740	0	5,069	15,037
2004	2,990	6,865	205	16,731	26,791
2005	772	18,831	7,983	14,078	41,663
2006	289	16,028	20,127	12,670	49,114
2007	35	28,163	32,024	45,419	105,641
2008	1,518	31,637	21,278	466,824	521,257

Jellyfish – Eastern Bering Sea

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Last updated: October 2009

The time series of jellyfish (principally *Chrysaora melanaster*) caught in EBS bottom trawls was updated for 2009 (Figure 51). Relative CPUE was calculated by setting the largest biomass in the time series to a value of 1 and scaling other annual values proportionally. The standard error (+/- 1) was weighted proportionally to the CPUE to produce a relative standard error. Jellyfish relative CPUE increased dramatically in 2009. The magnitude of increase from the previous year was the largest since the year 2000. The increasing trend in jellyfish biomass throughout the 1990's was first reported by Brodeur et al. (1999). The peak in the year 2000 was followed by a precipitous decline and stabilization until this most recent survey. The ecological implications of increases in jellyfish biomass and links between jellyfish biomass and biophysical indices are discussed by Brodeur et al. (2002, 2008).

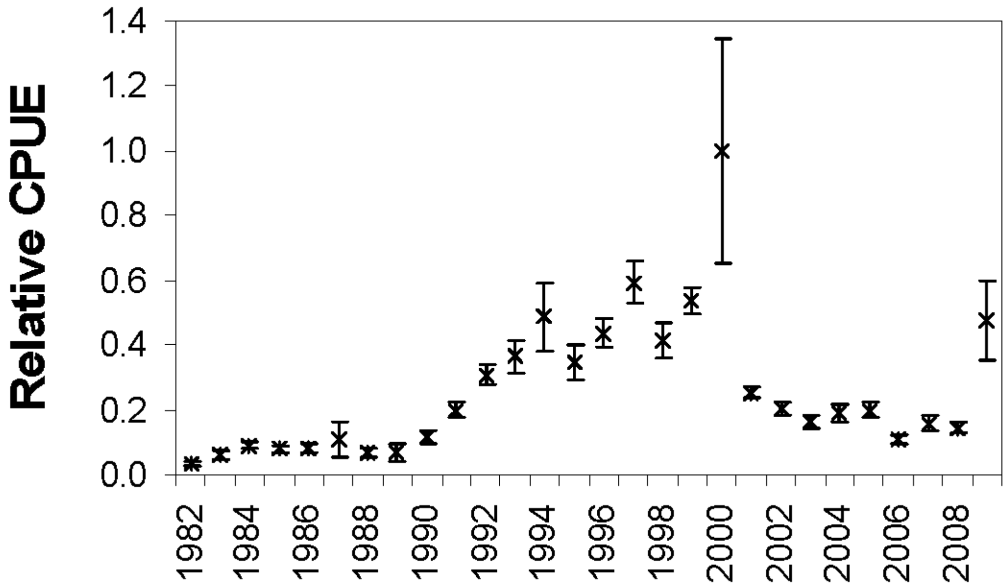

Figure 51. AFSC eastern Bering Sea bottom trawl survey relative CPUE for jellyfish during the May to August time period from 1982-2009.

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

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Last updated: August 2008

Jellyfish sampling was incorporated aboard the US BASIS (Bering Aleutian Salmon International Surveys) vessels beginning in 2004 and will continue through 2010. 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*. Distributions have been patchy for all species in the sampling grid for each year. Highest concentrations of all species combined, were found to occur in the Middle Shelf Domain, although distributions throughout the domains were uneven for all years (Figure 52). Of the six species sampled, *Chrysaora melanaster* had the highest catch weight for all years, followed by *Aequorea sp., Cy. capillata, S. mertensi, A. labiata, and P. camtschatica*. Notable declines in jellyfish biomass for five of the species were observed in 2006 and 2007 compared to 2004 and 2005. Only *P. camtschatica* had a recorded increase in biomass in 2006. In 2007, *C. melanaster* biomass doubled compared to 2006 but was still far below the 2004 and 2005 year measurements. In 2008 our station grid was significantly reduced and is not included in Figure 52. However, comparisons with past years using the same areas from 2008 indicate similar trends in species composition and distribution patterns with the exception of *Aequorea sp*., which substantially decreased in abundance and biomass (Figure 53).

As 2006 has been described as a cold year, the decline in jellyfish biomass may be partially attributed to a decline in zooplankton and other prey availability, as suggested by Hunt's Oscillating Control Hypothesis (Hunt et al. 2002). Physical ocean factors (temperature and salinity) alone do not seem to be causing shifts in biomass distributions, but environmental forcing earlier in the growing season or during an earlier life history stage (polyp) may influence large medusae biomass and abundances.

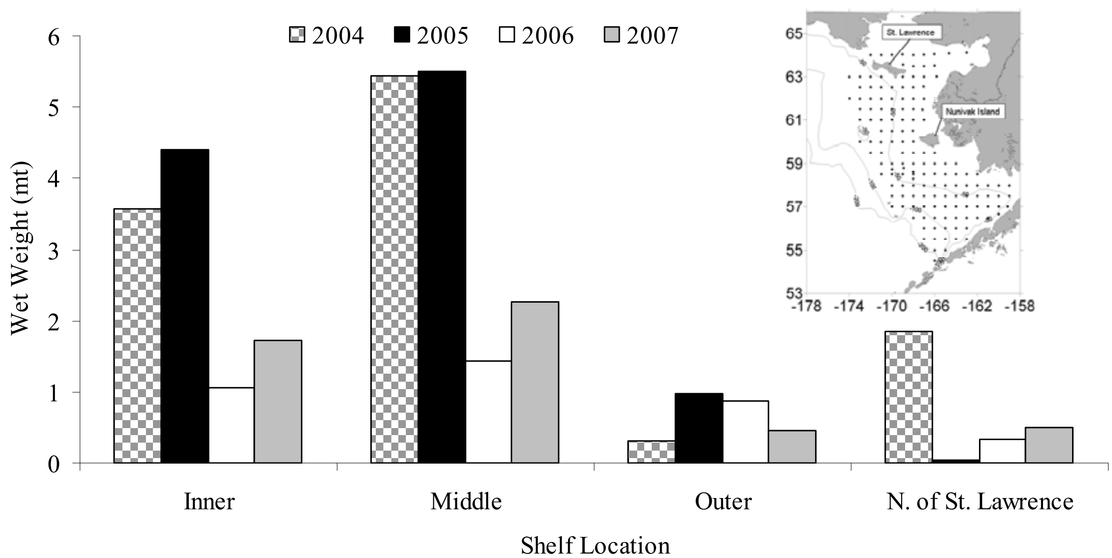

Figure 52. Catch by year for each shelf location in the Eastern Bering Sea. Wet weight is defined as the total weight of all large jellyfish species caught in a 30 minute trawl. Shelf locations (domains) are by depth, Inner 0-50m, Middle 50-100m, and Outer >100m. North of St. Lawrence is all stations sampled above 64° N latitude.

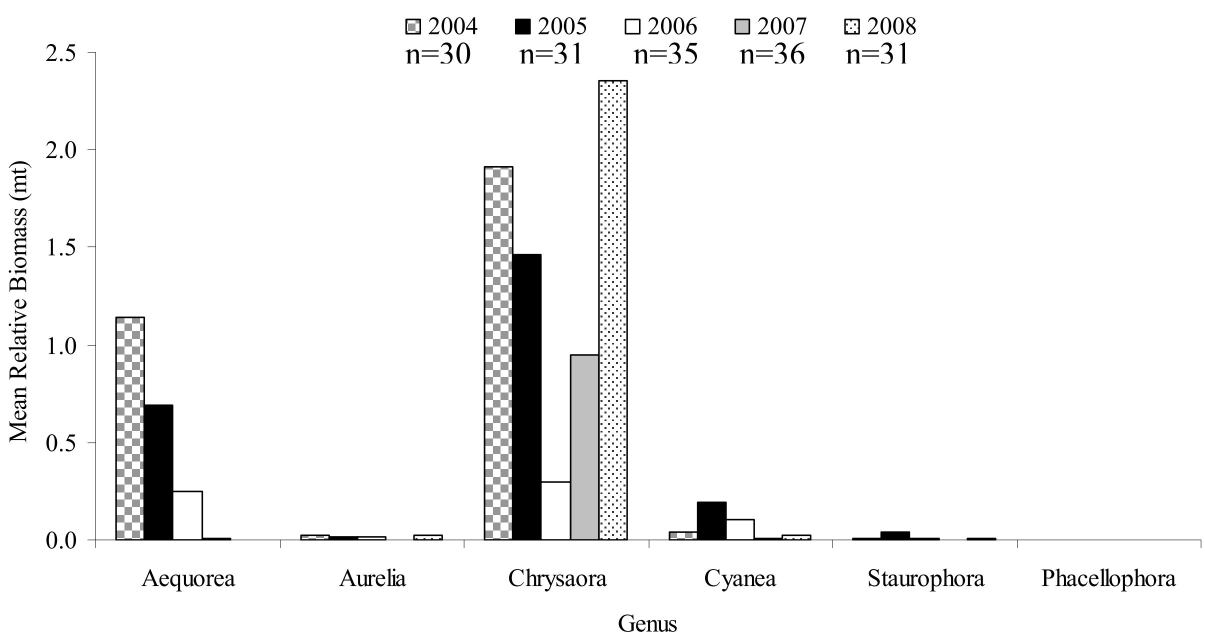

Figure 53. Mean relative biomass (mt) by genus for 2004-2008 in the Eastern Bering Sea. Relative biomass is defined as the total weight of a particular species in a 30 minute trawl. Sample size (n) is indicated below figure key.

Miscellaneous Species – Eastern Bering Sea

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Last updated: October 2009

“Miscellaneous” species fall into three groups: eelpouts (Zoarcidae), poachers (Agonidae) and sea stars (Asteroidea). The three dominant species comprising the eelpout group are marbled eelpout (*Lycodes raridens*), wattled eelpout (L. *palearis*) and shortfin eelpout (*L. brevipes*). The composition of sea stars in shelf trawl catches are dominated by the purple-orange sea star (*Asterias amurensis*), which is found primarily in the inner/middle shelf regions, and the common mud star (*Ctenodiscus crispatus*), which is primarily an inhabitant of the outer shelf. The biomass of poachers is dominated by a single species, the sturgeon poacher (*Podothecus acipenserinus*). Relative CPUE was calculated and plotted for each species or species group by year for 1982-2009. Relative CPUE was calculated by setting the largest biomass in the time series to a value of 1 and scaling other annual values proportionally. The standard error (+/- 1) was weighted proportionally to the CPUE to produce a relative standard error. With few exceptions, the trend in relative CPUE for all three species groups was very similar (Figure 54). Determining whether this trend represents a real response to environmental change or is simply an artifact of standardized survey sampling methodology will require more specific research on survey trawl gear selectivity and on the life history characteristics of these epibenthic species.

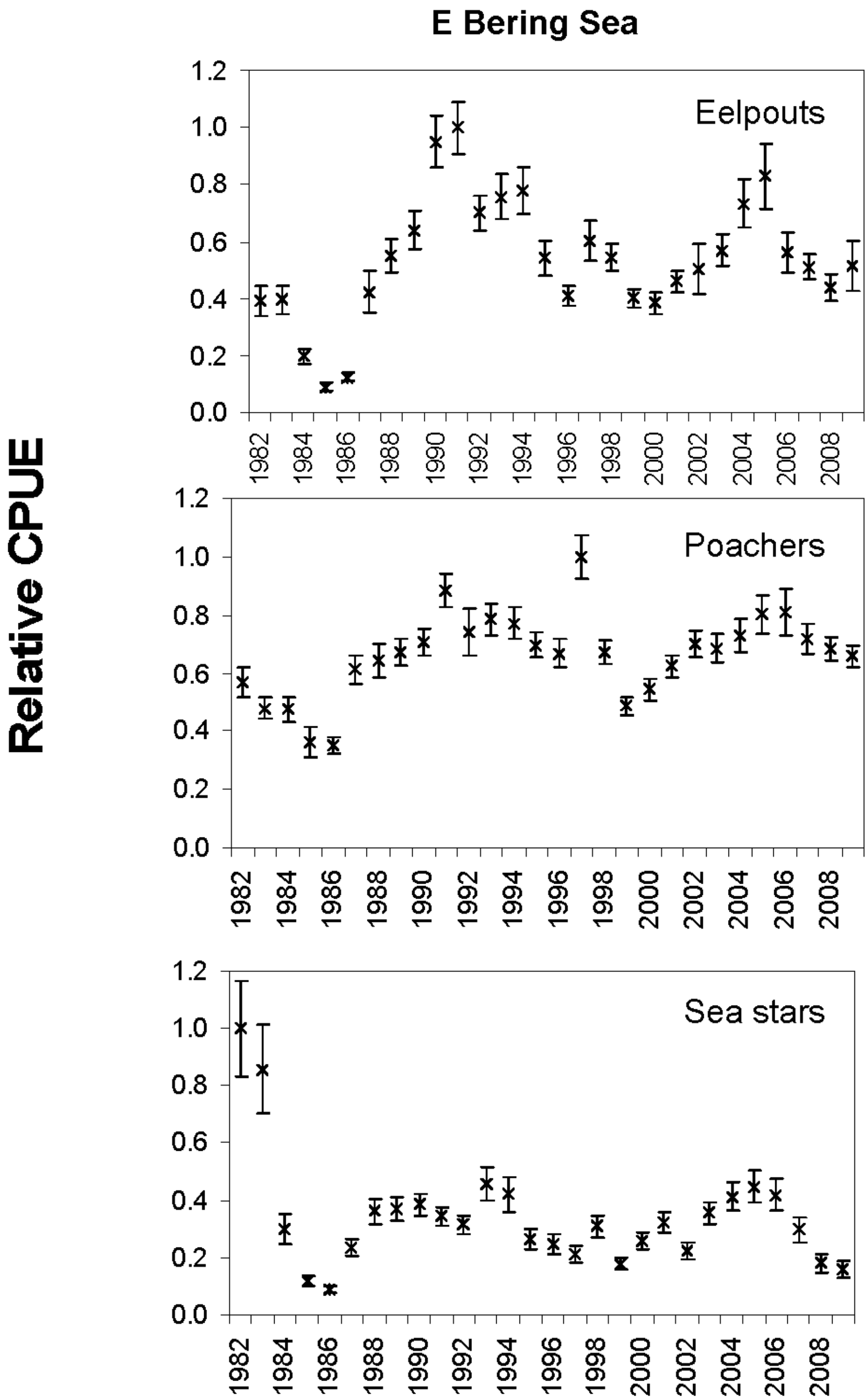

Figure 54. Relative CPUE of miscellaneous species caught in the eastern Bering Sea summer bottom trawl survey, 1982-2009. Data points are shown with standard error bars.

Miscellaneous Species – Aleutian Islands
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Last updated: November 2006

See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Marine Mammals
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Last updated: October 2008

Note: Research summaries and data, as well as slides and posters of recent research efforts into population trends among marine mammals are available electronically on: http://nmml.afsc.noaa.gov and ***http://www.nmfs.noaa.gov/prot_res/PR2/Stock_Assessment_Program/sars.html***

Also see the 2006 report in the "Assessment Archives" at:
http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Pinnipeds

Steller sea lion (*Eumetopias jubatus*)
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Last updated: October 2007

See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Northern fur seal (*Callorhinus ursinus*)
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See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Harbor Seals (*Phoca vitulina*)
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Arctic ice seals: Bearded seal, ribbon seal, ringed seal, spotted seal

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Last updated: July 2009

Stock definitions and geographic ranges

The four species of ice associated seals (i.e., bearded, spotted, ribbon, and ringed seals), often referred to collectively as "ice seals", are important resources for northern coastal Alaska Native communities, and are likely to be key ecological components of arctic marine ecosystems.

Bearded seals (*Erignathus barbatus*) have a circumpolar distribution from approximately 45°N to 85°N. In Alaskan waters they are distributed over the shallow (less than 200 m) continental shelf of the Bering, Chuchki, and Beaufort Seas. Recent spring surveys indicated that in many areas bearded seals may be more abundant 20-100 nmi offshore than within 20 nmi of shore (Bengtson et al. 2000). Some seals migrate through the Bering Strait from April to June and spend the summer along the ice edge in the Chuchki Sea; while others appear to remain in the open ocean during this time.

Ribbon seals (*Histriophoca fasciata*) inhabit the North Pacific Ocean and southern parts of the Arctic Ocean. In Alaskan waters, they range northward from Bristol Bay, in the Bering Sea, into the Chuchki and Western Beaufort Seas. Ribbon seals are usually found on or near pack ice in the open sea, and rarely along the coast or on fast ice. From March to May they inhabit the Bering Sea ice front and are most abundant in the central and western Bering Sea. They move north with the receding ice edge in late-spring and later some continue to migrate north through the Bering Strait while most others remain pelagic throughout the ice-free Bering Sea.

Ringed seals (*Phoca hispida*) have a circumpolar distribution in the arctic and sub-arctic. In Alaskan waters, and depending on ice cover, they are found as far south as the southern Bering Sea. Ringed seals have an affinity for ice-covered waters and tend to prefer areas within 20 nmi of shore (Bengtson et al. 2005). Recent spring surveys suggest that the density of ringed seals is higher in the eastern part of the Alaskan Beaufort Sea than in the west. Ringed seals are believed to follow the ice edge north as it melts in summer, but the details of this migration are unknown.

Spotted seals (*Phoca largha*) are distributed along the continental shelf of the Beaufort, Chuchki, Bering, and Okhotsk Seas, and south into the northern Yellow Sea and western Sea of Japan. In Alaskan waters, they are known to occur as far south at the Pribilof Islands, Bristol Bay, and the eastern Aleutian Islands. Spotted seals are easily mistaken for harbor seals. There is little morphological difference between the two species and their geographic ranges overlap in the southern Bering Sea. However, only the spotted seal is regularly associated with pack ice.

A lack of significant genetic, phenotypic and population response data does not warrant subdividing the bearded, ribbon, ringed or spotted seals stocks. As such, in U.S. waters, only the Alaska stocks are recognized.

Population sizes, status and trends

Reliable range-wide estimates for the current minimum population size, abundance and trend of bearded, ribbon, ringed or spotted seals are considered unavailable. However, there are crude estimates available in the historical literature, and more recent efforts have estimated the abundances of some species on more regional scales. For example, early estimates of the Bering-Chuchki Sea population of bearded seals range from 250,000 to 300,000 (Popov 1976 and Burns 1981a). And Burns (1981b) estimated the worldwide population of ribbon seals at 240,000 in the mid 1970s, with an estimate for the Bering Sea at 90,000-100,000. Using historical distribution maps and density estimates from recent aerial surveys, Boveng et al. (2008) calculated rough estimates of 49,370 ribbon seals in the eastern Bering Sea, 115,453 in the entire Bering Sea and a range-wide estimate of 215,377. However, the authors suggest using these numbers only for identifying gross changes in distribution or density and caution against their use as indicators of population trends. Similarly rough estimates for the numbers of ringed seals in Alaska include 1-1.5 million (Frost 1985) or 3.3-3.6 million (Frost el al. 1988); about 230,000 are estimated to inhabit the Alaska coastal regions of the Chukchi Sea (Bengtson et al. 2005). The worldwide population of spotted seals was estimated by Burns (1973) to be in the range of 335,000-450,000, with an estimate for the Bering Sea of 200,000-450,000.

Bearded, ribbon, ringed or spotted seals are not listed as “depleted” under the MMPA or listed as “threatened” or “endangered” under the Endangered Species Act. Current and reliable estimates of the minimum population size, total abundance, PBR (potential biological removal) and human-caused injury or mortality are not available. There is also a lack of information suggesting that subsistence hunting is adversely affecting these stocks and because of minimal evidence of interactions with U.S. fisheries the Alaska stocks of bearded, ribbon, ringed or spotted seals are not classified as strategic stocks.

Issues

The distributions and densities of ice-dwelling seals are sensitive to suitable sea ice conditions, and as such, these seals may be particularly vulnerable to climatic change. Changes in sea ice extent have been non-uniform; therefore, the effects on seals are likely to occur on regional scales, emphasizing the need for quality data throughout their range.

Abundance, population discreteness, annual survival and reproductive rates (together with information on food habits, seasonal movements and distribution), are essential to making sound management and conservation decisions. Unfortunately, current knowledge and monitoring programs are insufficient to allow for the timely detection of changes in population trend.

Ecological data is also important and future studies should focus on assessing the natural causes of fluctuations in the numbers and distribution of ice seals. For example, it is unknown how many ribbon seals remain in the Bering Sea and to what extent they compete with the pollock fishery in summer. Information on the specific habitat requirements for breeding, molting, feeding, etc. of these species is also lacking. This is particularly important with regards to the future effects of global warming. A significant reduction or change in ice cover could directly affect the survival of these species, particularly ringed seals which are so well adapted to occupying seasonal and permanent ice.

Finally, the extent to which these populations are affected by human caused mortality is also poorly known. Their interactions with commercial fisheries (e.g., entanglement in nets) are not well described as these data are collected voluntarily and are self-reported by each vessel. In addition, the physical similarities between spotted and harbor seals makes interpreting any data from these species problematic. Bearded and ringed seals are actively targeted in the Alaska Native subsistence harvest, with an average of 6,788 and 9,567 taken each year (ADF&G 2000a, b). There is significant annual variation in these numbers however, and without reliable estimates of the minimum population of these species PBRs can not be calculated and the resulting effects on the populations can not be estimated or managed for.

Recent projects by the National Marine Mammal Laboratory are beginning to address some of these knowledge gaps. Current satellite-tagging studies are providing some of the first information on the seasonal movements, habitat use, and foraging ecology of bearded, ribbon and spotted seals (Cameron 2005, Cameron 2006, Cameron 2007, and Boveng et al. 2007). Similarly, recent abundance surveys will provide estimates of the different ice seal populations inhabiting U.S. waters (Bengtson et al. 2000, Cameron 2006, Cameron and Boveng, 2007, and Cameron et al. 2008).

Cetaceans

Bowhead whale (*Balaena mysticetus*)
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Last updated: September 2009

All stocks of bowhead whales (Balaena mysticetus) were severely depleted by commercial whaling (Woodby and Botkin 1993) and were classified as protected by the International Whaling Commission (IWC) under the 1946 International Convention for the Regulation of Whaling. The IWC currently recognizes the Okhotsk Sea, Spitsbergen, Eastern Canada-West Greenland, and Western Arctic stocks of bowhead whales (IWC 2007a). The Western Arctic stock, also known as the Bering Sea (Burns et al. 1993) or Bering-Chukchi-Beaufort Seas (Rugh et al. 2003) stock, is the only stock of bowheads in U.S. waters (Angliss and Outlaw 2008, George et al. 2007, IWC 2007a). In the U.S., this stock is classified as endangered under the Endangered Species Act (ESA) of 1973 and depleted under the Marine Mammal Protection Act of 1972; thus, it is also considered a strategic stock. However, the Western Arctic stock has been increasing in recent years (George et al. 2004) and may be approaching its carrying capacity (Brandon and Wade 2006).

Western Arctic bowheads generally migrate between wintering areas in the Bering Sea and summering areas in the eastern Beaufort Sea (Braham et al. 1980, Moore and Reeves 1993). Systematic ice-based visual counts during this migration have been conducted since 1978 (Krogman et al. 1989). A summary of the resulting abundance estimates, corrected for whales missed during the census (Zeh et al. 1993, Clark et al. 1996), is provided in Table 10 (Angliss and Outlaw 2008) and Figure 55 (George et al. 2004); however, these estimates have not been corrected for a small, unknown portion of the population that does not migrate past Point Barrow during the survey (Angliss and Outlaw 2008). The most recent population abundance estimate in 2001 of 10,545 (CV=0.128) whales in the Western Arctic stock was calculated from ice-based census counts (George et al. 2004, Zeh and Punt 2004). The rate of increase and the record high count of 121 calves in 2001 suggest a steady recovery of the stock (George et al. 2004).

Alaskan Natives living in villages along the migration route of the Western Arctic stock of bowheads have hunted these whales for at least 2,000 years (Marquette and Bockstoce 1980, Stoker and Krupnik 1993), and the IWC has regulated subsistence takes since 1977 (IWC 1978). Alaskan Natives landed 832 whales between 1974 and 2003 (Suydam and George 2004), 36 whales in 2004 (Suydam et al. 2005), 55 in 2005 (Suydam et al. 2006), 31 in 2006 (Suydam et al. 2007), and 41 in 2007 (Suydam et al. 2008). Russian subsistence hunters harvested one whale in 1999 and one in 2000 (IWC 2002), three in 2003 (Borodin 2004), and one in 2004 (Borodin 2005). Canadian Natives also harvested one whale in both 1991 and 1996 (Angliss and Outlaw 2008). At its annual meeting in 2007, the IWC renewed the existing 5-year bowhead quota for the 5-year period from 2008 to 2012 (IWC 2007b); the quota currently includes up to 280 whales landed, with no more than 67 whales struck in any year and up to 15 unused strikes carried over each year.

Oil and gas development in the Arctic has the potential to impact bowheads through increased risks of exposure to pollution and to the sound produced by exploration, drilling operations, and increased vessel traffic in the area (Angliss and Outlaw 2008). Past studies have indicated that bowheads are sensitive to sounds from seismic surveys and drilling operations (Richardson and Malme 1993, Richardson 1995, Davies 1997) and will avoid the vicinity of active seismic operations (Miller et al. 1999), active drilling operations (Schick and Urban 2000), and the resulting vessel traffic (Richardson et al. 2004). Each year since 1979, the U.S. Department of the Interior's Minerals Management Service (MMS) has funded and/or conducted aerial surveys of bowhead whales during their fall migration through the western Beaufort Sea. In 2007, as part of an Inter-Agency Agreement between the MMS and NMFS, the National Marine Mammal Laboratory (NMML) took over the coordination of the MMS Bowhead Whale Aerial Survey Project (BWASP) and has expanded the survey area to include the northeastern Chukchi Sea. To facilitate mitigation of future oil and gas development along the migration route of the Western Arctic stock of bowheads, a multi-year study (2007-2010) administered by NMFS and funded by the MMS will estimate relationships among bowhead whale prey, oceanographic conditions, and bowhead whale feeding behavior in the western Beaufort Sea (NMML 2007).

Table 10 (from Angliss and Outlaw 2008). Summary of population abundance estimates for the Western Arctic stock of bowhead whales. The historical estimates were made by back-projecting using a simple recruitment model. All other estimates were developed by corrected ice-based census counts. Historical estimates are from Woodby and Botkin (1993); 1978-2001 estimates are from George et al. (2004) and Zeh and Punt (2004).

Year	**Abundance Estimate (CV)**	**Year**	**Abundance Estimate (CV)**
Historical estimate	10,400-23,000	1985	5,762 (0.253)
End of commercial whaling	1,000-3,000	1986	8,917 (0.215)
1978	4,765 (0.305)	1987	5,298 (0.327)
1980	3,885 (0.343)	1988	6,928 (0.120)
1981	4,467 (0.273)	1993	8,167 (0.017)
1982	7,395 (0.281)	2001	10,545 (0.128)
1983	6,573 (0.345)		

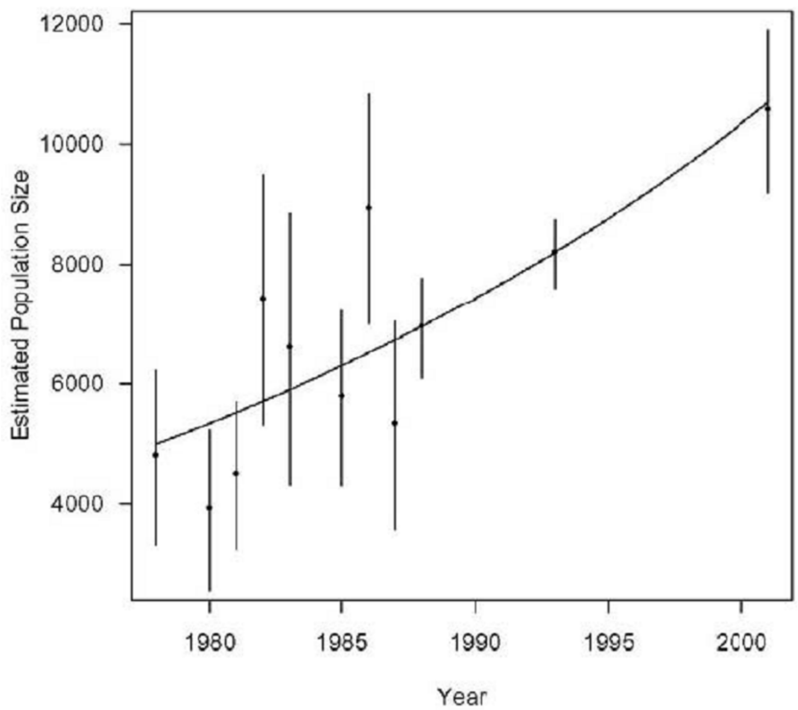

Figure 55 (George et al. 2004). Population abundance estimates for the Western Arctic stock of bowhead whales, 1977-2001, as computed from ice-based counts, acoustic locations, and aerial transect data collected during bowhead whale spring migrations past Barrow, Alaska. Error bars show +/- 1 standard error.

Potential Causes of Declines in Marine Mammals
Last updated November 2006

See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Seabirds
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Last updated: November 2008

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

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Last updated: August 2008

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

Summary of Seabird Bycatch in Alaskan Groundfish Fisheries, 1993 through 2006
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Last updated: November 2008

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

Ecosystem or Community Indicators

Alaska Native Traditional Environmental Knowledge of Climate Regimes
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See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Combined Standardized Indices of Recruitment and Survival Rate
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Last updated: October 2008

See the 2008 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
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Last updated: August 2009

Description of indices: This section provides indices of local species richness and diversity based on standard bottom trawl surveys in the eastern Bering Sea (EBS). We computed the average number of fish and major invertebrate taxa per haul (richness) and the average Shannon index of diversity (Magurran 1988) by haul based on CPUE (by weight) of each taxon. Indices were based on 45 taxa that were consistently identified throughout all surveys (Table 1 in Mueter & Litzow, 2008, excluding Arctic cod because of unreliable identification in early years) and were computed following Mueter & Norcross (2002). Briefly, annual average indices of local richness and diversity were estimated by first computing each index on a per-haul basis, then estimating annual averages across the survey area using a Generalized Additive Model that accounted for the effects of variability in geographic location, depth, date of sampling, and area swept.

Status and trends: Species richness and diversity on the Eastern Bering Sea shelf have undergone significant variations from 1982 to 2008 (Figure 56). The average number of species per haul has increased by one to two species since 1995, while the Shannon Index increased from 1985 through 1998 and decreased sharply in 1999 with high variability in recent years.

Factors causing observed trends: The average number of species per haul depends on the spatial distribution of individual species (taxa). If species are, on average, more widely distributed in the sampling area the number of species per haul increases. Spatial shifts in distribution from year to year can cause high variability in local species richness in certain areas, for example along the 100m contour in the Eastern Bering Sea. These shifts appear to be the primary drivers of changes in species richness. Local species diversity is a function of how many species are caught in a haul and how evenly CPUE is distributed among the species. Both time trends (Figure 56) and spatial patterns in species diversity (Figure 57) differed markedly from those in species richness. For example, low species diversity in 2003 occurred in spite of high average richness, primarily because of the high dominance of walleye pollock, which increased from an average of 18% of the catch per haul in 1995-98 to 30% in 2003, but decreased again to an average of 21% in 2004. The increase in species richness, which was particularly pronounced on the middle shelf, 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 & Litzow, 2008). However, species diversity 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. Spatially, species richness tends to be highest along the 100 m contour, whereas species diversity is highest on the middle shelf because the middle shelf region is less dominated by a few abundant species.

Implications: The effect of fishing on species richness and diversity are poorly understood at present and this index likely reflects changes in spatial distribution and species composition that can only be interpreted in the context of environmental variability in the system. Local species richness may be particularly sensitive to long-term trends in bottom temperature as the cold pool extent changes (Mueter and Litzow 2008) and may provide a useful index for monitoring responses of the groundfish community to projected climate warming.

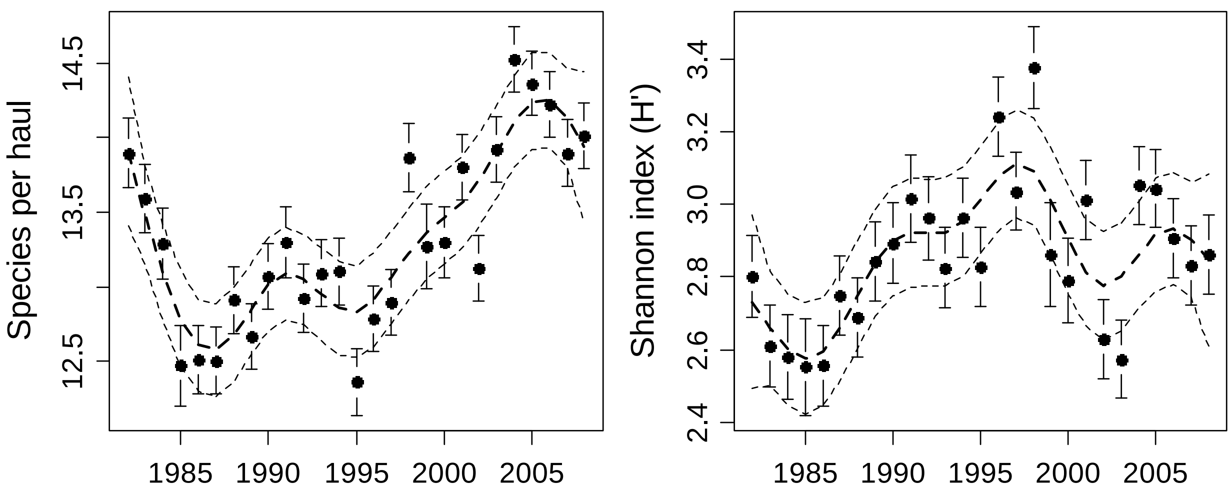

Figure 56. Model-based annual averages of species richness (average number of species per haul), and species diversity (Shannon index) in the Eastern Bering Sea, 1982-2008, based on 45 fish and invertebrate taxa collected by standard bottom trawl surveys with 95% confidence intervals. Model means were adjusted for differences in area swept, depth, date of sampling, and geographic location among years.

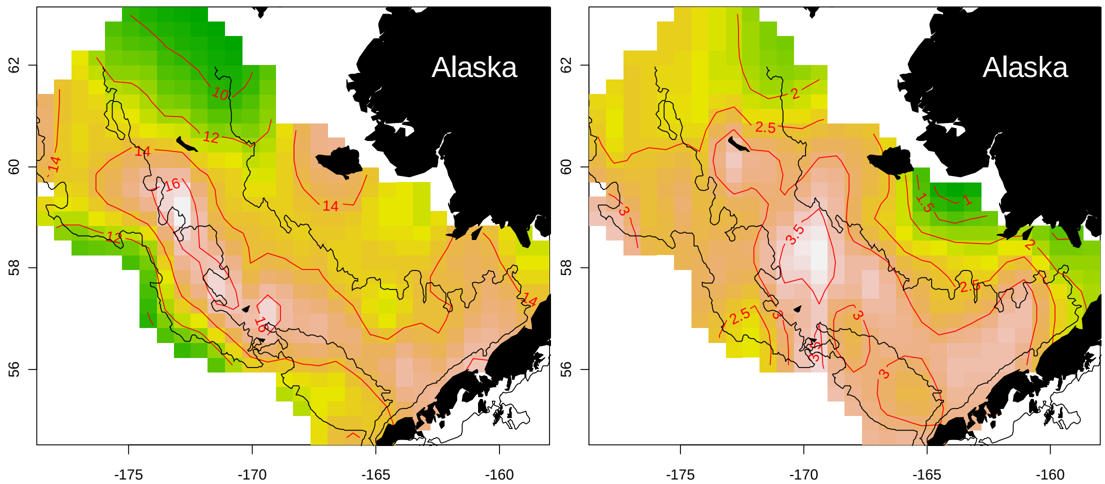

Figure 57. Average spatial patterns in local species richness (left, number of taxa per haul) and Shannon diversity in the Eastern Bering Sea. The 50m, 100m, and 200 m depth contours are shown as black lines.

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

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Last updated: August 2009

Description of index: The index provides a measure of the overall biomass of demersal and benthic fish and invertebrate species. We computed catch-per-unit-effort (CPUE in kg km^{-2}) of fish and major invertebrate taxa for each successful haul completed during standardized bottom trawl surveys on the eastern Bering Sea shelf (EBS, 1982-2008) and on the Gulf of Alaska shelf (GOA, 1990-2007). Total CPUE for each haul was estimated as the sum of the CPUEs of all fish taxa (except salmonidae) and major invertebrate taxa (crab, shrimp, squid, octopus, and starfish). To obtain an index of average CPUE by year across the survey region, we modeled log-transformed total CPUE (N = 10028, 4633, and 1240 hauls in the EBS, western GOA, and eastern GOA, respectively) as smooth functions of depth, net width, and location (latitude / longitude in the EBS, alongshore distance and sampling stratum in the GOA) using Generalized Additive Models following Mueter & Norcross (2002). Although catches were standardized to account for the area swept by each haul we included net width in the model for the Bering Sea because of differences in catchability of certain taxa with changes in net width (von Szalay & Somerton 2005) and because there was strong evidence that total CPUE tends to decrease with net width, all other factors being constant. The CPUE index does not account for gear or vessel differences, which are strongly confounded with interannual differences and may affect results prior to 1988 in the Bering Sea.

Status and trends: Total log(CPUE) in the western GOA varied over time with an increasing trend (not significant) and a decrease from 2005 to 2007, the most recent survey years (Figure 58). Total log(CPUE) in the EBS shows an apparent long-term increase from 1982-2005, followed by a decrease during the recent cold years (2006-2008; Figure 59). However, estimated means prior to 1988 may be biased due to unknown gear effects and because annual differences are confounded with changes in mean sampling date. The overall increasing trend in the EBS was particularly pronounced in the portion of the middle-shelf area that is typically occupied by the cold pool and appears to be related to the increasing colonization of this area by subarctic demersal species as the cold pool has retreated over recent decades (Mueter & Litzow 2008).

Factors causing observed trends: Commercially harvested species account for over 70% of survey catches. Fishing is expected to be a major factor determining trends in survey CPUE, but environmental variability is likely to account for a substantial proportion of the observed variability in CPUE through variations in recruitment, growth, and distribution. The increase in survey CPUE in the EBS in the early 2000s primarily resulted from increased abundances of walleye pollock and a number of flatfish species (arrowtooth flounder, yellowfin sole, rock sole, and Alaska plaice) due to strong recruitments in the 1990s. Decreases in recent years were largely a result of decreases in walleye pollock abundance. In addition, models including bottom temperature suggest that, in the EBS, CPUE is greatly reduced at low temperatures (< 1˚C) as evident in reduced CPUEs in 1999 and 2006-2008, when the cold pool covered a substantial portion of the shelf. At present, it is unclear whether this effect is primarily due to actual changes in abundance or temperature-dependent changes in catchability of certain species. A sharp increase in CPUE in the western GOA between 2001 and 2003 was largely due to a substantial increase in the abundance of arrowtooth flounder, which accounted for 43% of the total survey biomass in 2003. The significant increase in total CPUE in the eastern GOA was associated with increases in arrowtooth flounder (particularly 1990-93), several rockfish species, Pacific hake, and spiny dogfish.

Implications: This indicator can help address concerns about maintaining adequate prey for upper trophic level species and other ecosystem components. Relatively stable or increasing trends in the total biomass of demersal fish and invertebrates, together with a relatively constant size composition of commercial species (Boldt et al. 2008), suggest that the prey base has remained stable or has increased over recent decades. Decreasing CPUE in the eastern Bering Sea in recent years is a potential concern.

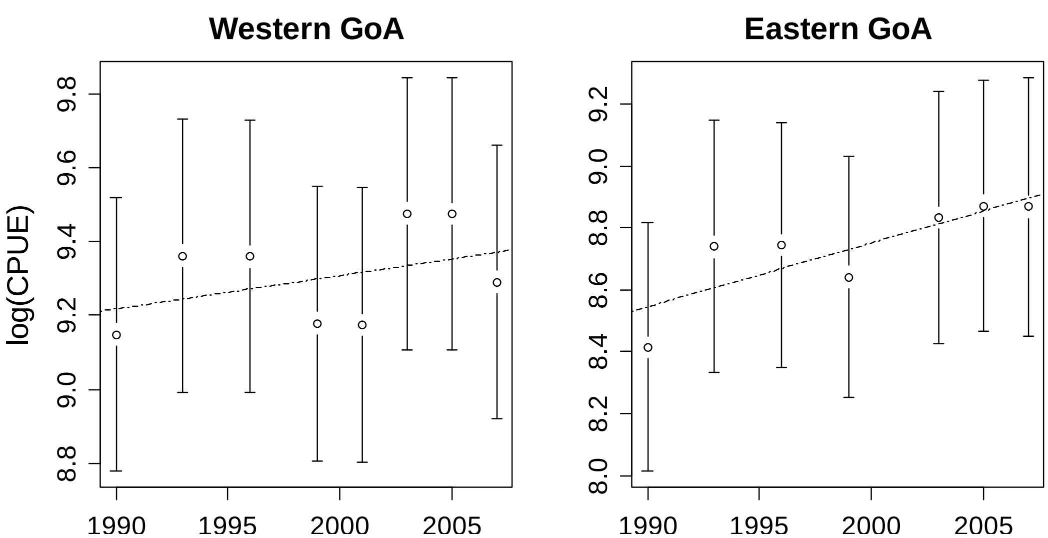

Figure 58. Model-based estimates of total log(CPUE) for major fish and invertebrate taxa captured in bottom trawl surveys from in the western Gulf of Alaska (west of 147˚ W) by survey year with approximate 95% confidence intervals. Estimates were adjusted for differences in depth and sampling locations (alongshore distance) among years. Linear trends based on generalized least squares regression assuming 1st order auto-correlated residuals (West: t = 0.846, p = 0.430; East: t = 3.43, p = 0.019).

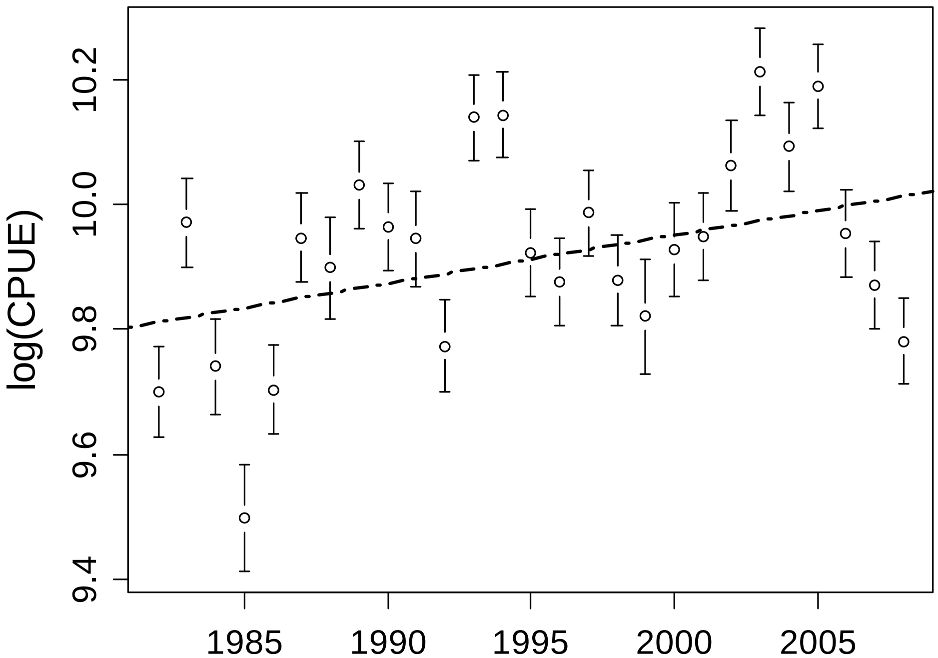

Figure 59. Model-based estimates of total log(CPUE) for major fish and invertebrate taxa captured in bottom trawl surveys from 1982 to 2004 in the Bering Sea with approximate pointwise 95% confidence intervals and long-term linear trend. Estimates were adjusted for differences in depth, day of sampling, net width and sampling location among years. Gear differences prior to 1988 were not accounted for. Linear trend based on generalized least squares regression assuming 1st order auto-correlated residuals (t = 1.26, p = 0.221).

Spatial Distribution of Groundfish Stocks in the Bering Sea

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***NEW*: August 2009**

Description of indices: We provide indices of changes in the spatial distribution of groundfish on the eastern Bering Sea shelf. The first index provides a simple measure of the average North-South displacement of major fish and invertebrate taxa from their respective centers of gravity (e.g. Woillez et al 2009) based on AFSC-RACE bottom trawl surveys for the 1982-2008 period. Annual centers of gravity for each taxon were computed as the CPUE-weighted mean latitude across 285 standard survey stations that were sampled each year and an additional 58 stations sampled in 26 of the 27 survey years. Each station (N=343) was also weighted by the approximate area that it represents based on a Dirichlet (Voronoi) tesselation. Initially, we selected 46 taxa as in Table 1 of Mueter and Litzow (2008). Taxa that were not caught at all in one or more years were not included, resulting in a total of 39 taxa for analysis. In addition to quantifying N-S shifts in distribution, we computed CPUE and area-weighted averages of depth to quantify changes in depth distribution. Because much of the variability in distribution may be related to temperature variability, we removed linear relationships between changes in distribution and temperature by regressing distributional shifts on annual mean bottom temperatures. Residuals from these regressions are provided as an index of temperature-adjusted shifts in distribution.

Status and trends: Both the latitudinal and depth distribution of the demersal community on the eastern Bering Sea shelf show clear directional trends over the last three decades, indicating significant distributional shifts to the North and into shallower waters (Figure 60). Moreover, strong shifts in distribution over time remain evident even after adjusting for linear temperature effects (Figure 60). Although the average distribution shifted slightly south after the very warm years of 2004/05, there is little evidence that recent cold temperatures in 2006-2008 have led to a commensurate reversal of the long-term northward shifts reported in Mueter and Litzow (2008). Average spatial displacements by year suggest that most interannual shifts in distribution occur along a NW-SE axis (i.e. along the main shelf/slope axis), but that a pronounced shift to the Northeast and onto the shelf occurred between the 1990s and 2000s (Figure 61).

Factors causing trends: Many populations shift their distribution in response to temperature variability. Such shifts may be the most obvious response of animal populations to global warming (Parmesan and Yohe 2003). However, distributional shifts of demersal populations in the Bering Sea are not a simple linear response to temperature variability (Mueter and Litzow 2008, Figure 60). For example, displacements of the center of gravity to the north and into shallower areas of the shelf have persisted (Figure 61) in spite of several years with an extensive cold pool. The reasons for residual shifts in distribution that are not explained by temperature changes remain unclear but could be related to density-dependent responses (Spencer 2008) and to internal community dynamics (Mueter and Litzow 2008).

Implications: Changes in distribution have important implications for the entire demersal community, for other populations dependent on these communities, and for the fishing industry. The demersal community is affected because distributional shifts change the relative spatial overlap of different species, thereby affecting trophic interactions among species and, ultimately, the relative abundances of different species. Upper trophic level predators, for example fur seals and seabirds on the Pribilof Islands and at other fixed locations, are affected because the distribution and hence availability of their prey changes. Finally, fisheries are directly affected by changes in the distribution of commercial species, which alters the economics of harvesting because fishing success within established fishing grounds may decline and travel distances to new fishing grounds may increase. A better understanding of the observed trends and their causes is needed to evaluate the extent to which fishing may have contributed to these trends and to help management and fishers adapt to apparent directional changes in distribution that are likely to be further exacerbated by anticipated warming trends associated with increasing CO_2 concentrations.

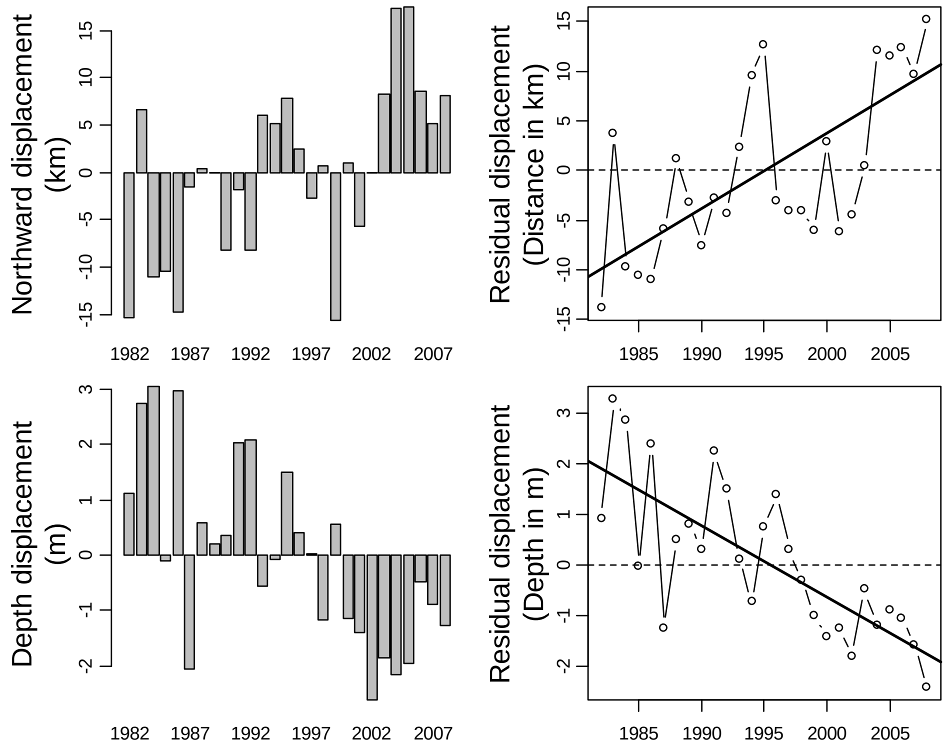

Figure 60. Left: Distributional shifts in latitude (average northward displacement in km from species-specific mean latitudes) and shifts in depth distribution (average vertical displacement in m from species-specific mean depth, positive indices indicate deeper distribution). Right: Residual displacement from species-specific mean latitude (top) and species-specific mean depth (bottom) after adjusting the indices on the left for linear effects of mean annual bottom temperature on distribution. Residuals were obtained by linear weighted least-squares regression with first-order auto-correlated residuals over time (Northward displacement: $R^2 = 0.24$, $t = 3.73$, $p = 0.001$; depth displacement: $R^2 = 0.21$, $t = -3.22$, $p = 0.004$). Solid lines denote linear regressions of residual variability over time (top: $R^2 = 0.52$, $t = 2.98$, $p = 0.006$; bottom: $R^2 = 0.57$, $t = -5.74$, $p < 0.001$).

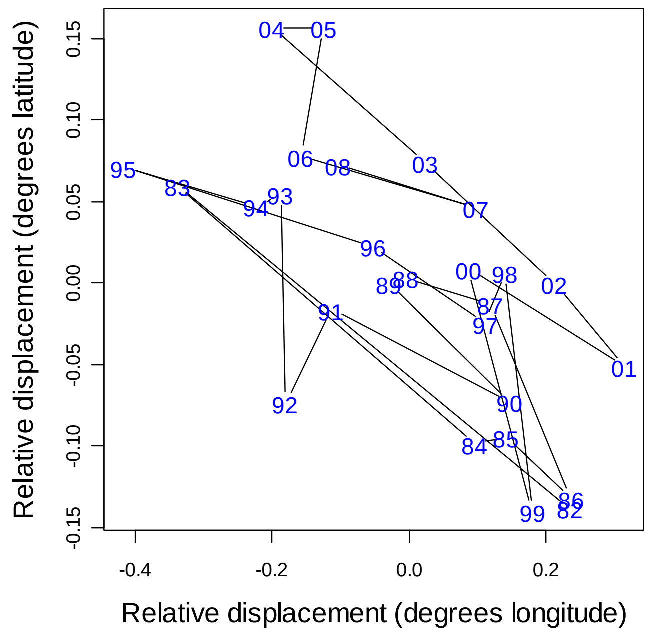

Figure 61. Average North-South and East-West displacement across 39 taxa on the eastern Bering Sea shelf relative to species-specific centers of distribution.

ECOSYSTEM-BASED MANAGEMENT INDICES AND INFORMATION

Indices 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 Bycatch of Prohibited Species

Contributed by Alan Haynie and Terry Hiatt, Alaska Fisheries Science Center
Contact: Terry.Hiatt@noaa.gov
Last updated: October 2007

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

Time Trends in Groundfish Discards

Contributed by Terry Hiatt, Alaska Fisheries Science Center
Contact: Terry.Hiatt@noaa.gov
Last updated: October 2009

In 1998, the amount of managed groundfish species discarded in federally-managed 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 62). 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. Discards in the Gulf of Alaska increased somewhat between 1998 and 2003, declined in 2004 and 2005, and have increased again in the last three years. Discards in both the EBS and the GOA are much lower than the amounts observed in 1997, before implementation of improved-retention regulations. Discard rates in the Aleutian Islands (AI) dropped significantly in 1997, trended generally upwards from 1998 through 2003, and have declined again over the last five 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. The decline in discards in both the AI and the EBS in 2008 are largely due to enactment of improved retention/utilization regulations by the North Pacific Fishery Council for the trawl head-and-gut fleet.

Estimates of discards for 1994-2002 come from NMFS Alaska Region's blend data; estimates for 2003-08 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.

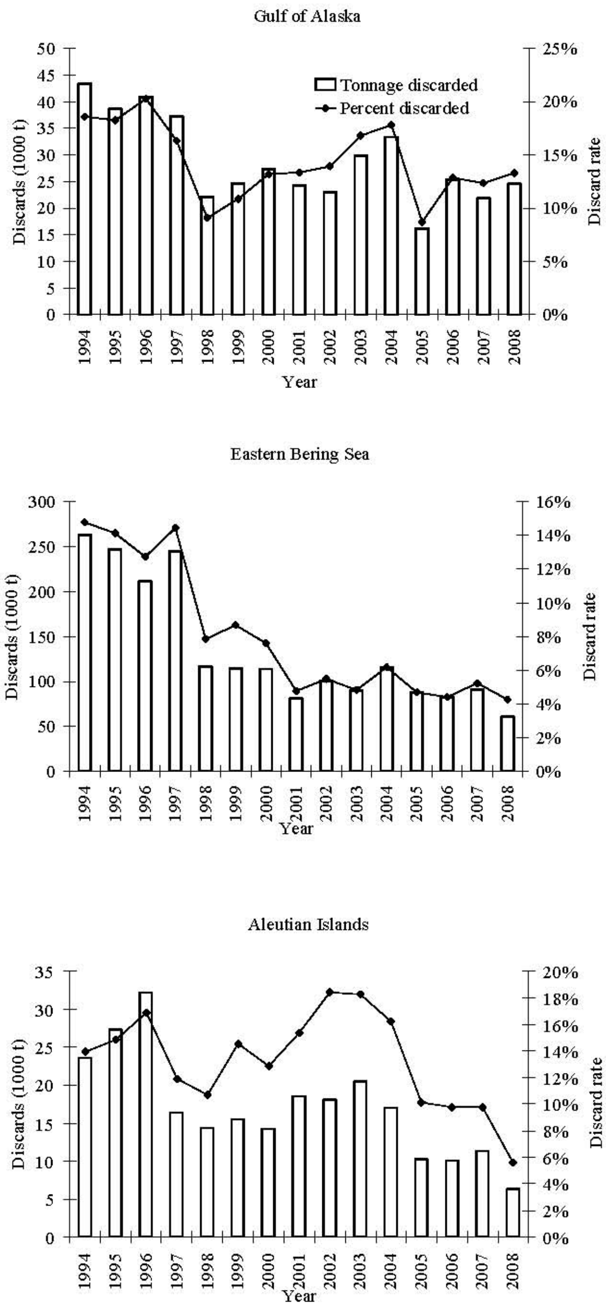

Figure 62. Total biomass and percent of total catch biomass of managed groundfish discarded in the GOA, EBS and AI areas, 1994-2008. (Includes only catch counted against federal TACS).

Time Trends in Non-Target Species Catch
Contributed by Sarah Gaichas and Jennifer Boldt, Alaska Fisheries Science Center
Last updated: August 2009

In addition to prohibited and target species catches, groundfish fisheries also catch non-target species (Figure 63). There are four categories of non-target species: 1.) forage species (gunnels, stichaeids, sandfish, smelts, lanternfish, sandlance), 2.) HAPC (seapens/whips, sponges, anemones, corals, tunicates), 3.) non-specified species (grenadiers, crabs, starfish, jellyfish, unidentified invertebrates, benthic invertebrates, echinoderms, other fish[1], birds, shrimp), and 4.) other species (sculpins, unidentified sharks, salmon sharks, dogfish, sleeper sharks, skates, octopus, squid). The "other species" catch is included in the groundfish discards (Hiatt, this report).

In both the BSAI and GOA, non-specified catch comprised the majority of non-target catch during 1997-2007 (Figure 63). Non-specified catches are of the same order of magnitude in the BSAI and GOA. Catches of HAPC biota are higher in the BSAI than in the GOA and the catch of forage is higher in the GOA than in the BSAI.

In the BSAI, the catch of non-specified species decreased 2003-2007 but increased again in 2008-2009. Scyphozoan jellyfish, grenadiers and sea stars comprise the majority of the non-specified catches in the BSAI, and the recent increase in catch appears to be driven by jellyfish. Grenadiers (including the Giant grenadier) are caught primarily in the flatfish, sablefish, and cod fisheries. Jellyfish 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 BSAI in all years except 2007 and 2009, when sponges were the majority. The catch of forage species in the BSAI increased in 2006 and 2007 and was comprised mainly of eulachon that was caught primarily in the pollock fishery; however, forage catch decreased to the low levels in 2008-2009.

The catch of non-specified species in the GOA has been generally consistent aside from a peak in 1998 and a low in 2009 (incomplete data). 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. Preliminary data also suggest lower forage fish catches in 2009. The main species of forage fish caught are eulachon and they are primarily caught in the pollock fishery.

It should be noted that while total catch estimates are based on standardized quantitative sampling protocols, observers are instructed to visually estimate the percent retained for each species. Estimated discards, therefore, may be less accurate than target estimates because they are based on visual observations by observers rather than data from direct sampling. Catch since 2003 has been estimated using the Alaska Region's new Catch Accounting system.

[1] In 2008, dark rockfish (*Sebastes ciliatus*) were removed from the BSAI and GOA FMPs and management was taken over by the State of Alaska; therefore dark rockfish catch is now included in the non-specified category. This catch amounted to 19 tons (2008) and 46 tons (2009 as of August 3) in the GOA, and 4 tons (2008) and less than 1 ton (2009 as of August 3) in the BSAI.

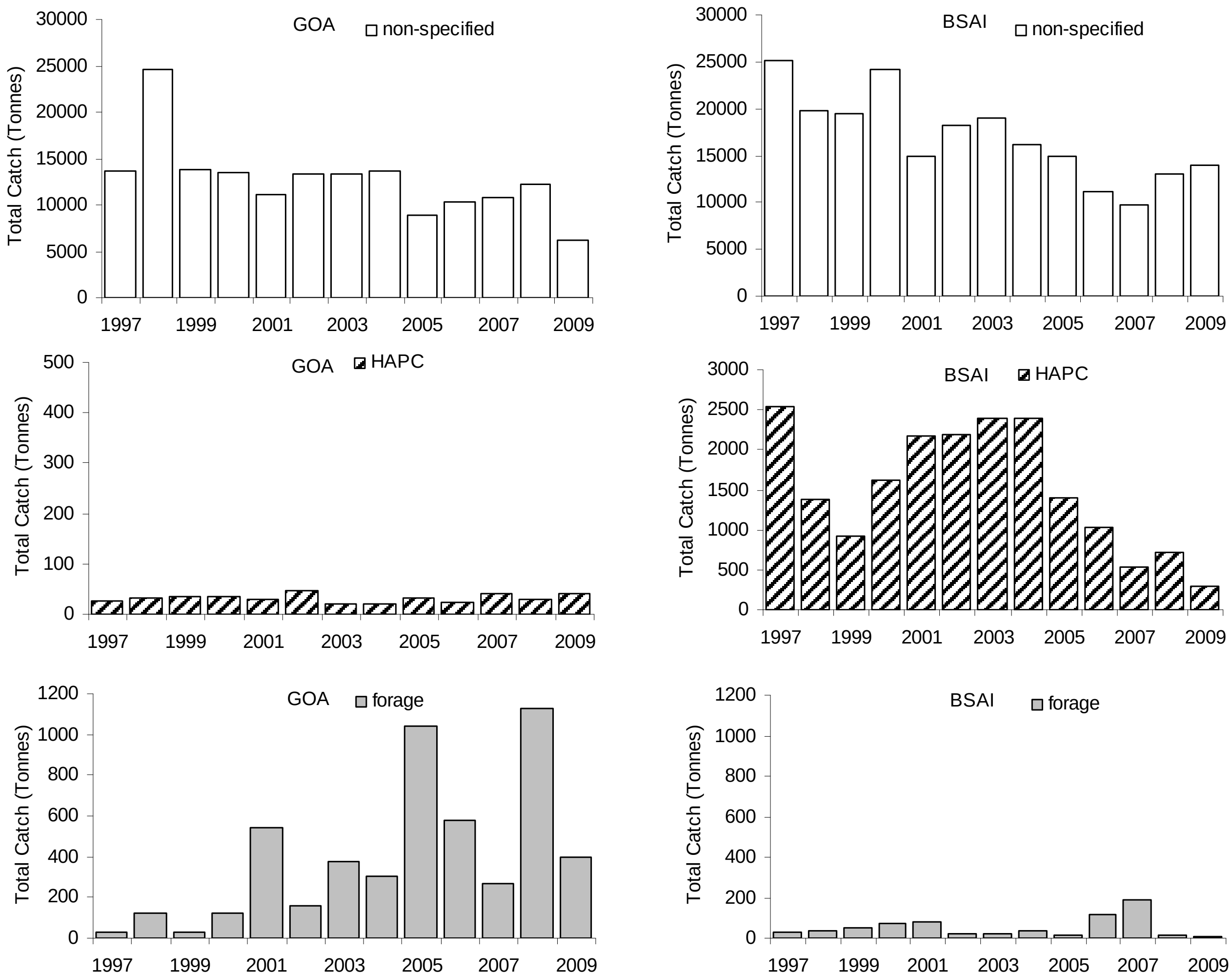

Figure 63. Total catch of non-target species (tonnes) in the GOA and BSAI areas by groundfish fisheries. Note: the scales of the y-axes are different in the HAPC biota graphs, and 2009 data are incomplete. We include information available as of August 3, 2009.

Ecosystem Goal: Maintain and Restore Fish Habitats

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

Contributed by John Olson, NMFS
Contact: john.v.olson@noaa.gov
Last updated: August 2009

Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut) (Table 11 and Figure 64). Some of the trawl closures are in effect year-round while others are seasonal. A review of trawl closures implemented since 1995 is provided in Table 11. 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. 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) off Alaska was closed to trawling year-round. Additionally, 40,000 nm^2 were closed on a seasonal basis. State waters (0-3 nmi) are also closed to bottom trawling in most areas.

A motion passed the North Pacific Management Council in February 2009 which would close all waters north of the Bering Strait to commercial fishing as part of the development of an Arctic Fishery management plan (Figure 64). This additional closure adds 148,300 nm^2 to the area closed to bottom trawling year round. By implementing this closure, almost 65% of the U.S. EEZ off Alaska would be closed to bottom trawling. Of this area, almost 55% of is <1000 m deep, which can be considered a proxy for defining fishable area. For additional background on fishery closures in the U.S. EEZ off Alaska see Witherell and Woodby (2005).

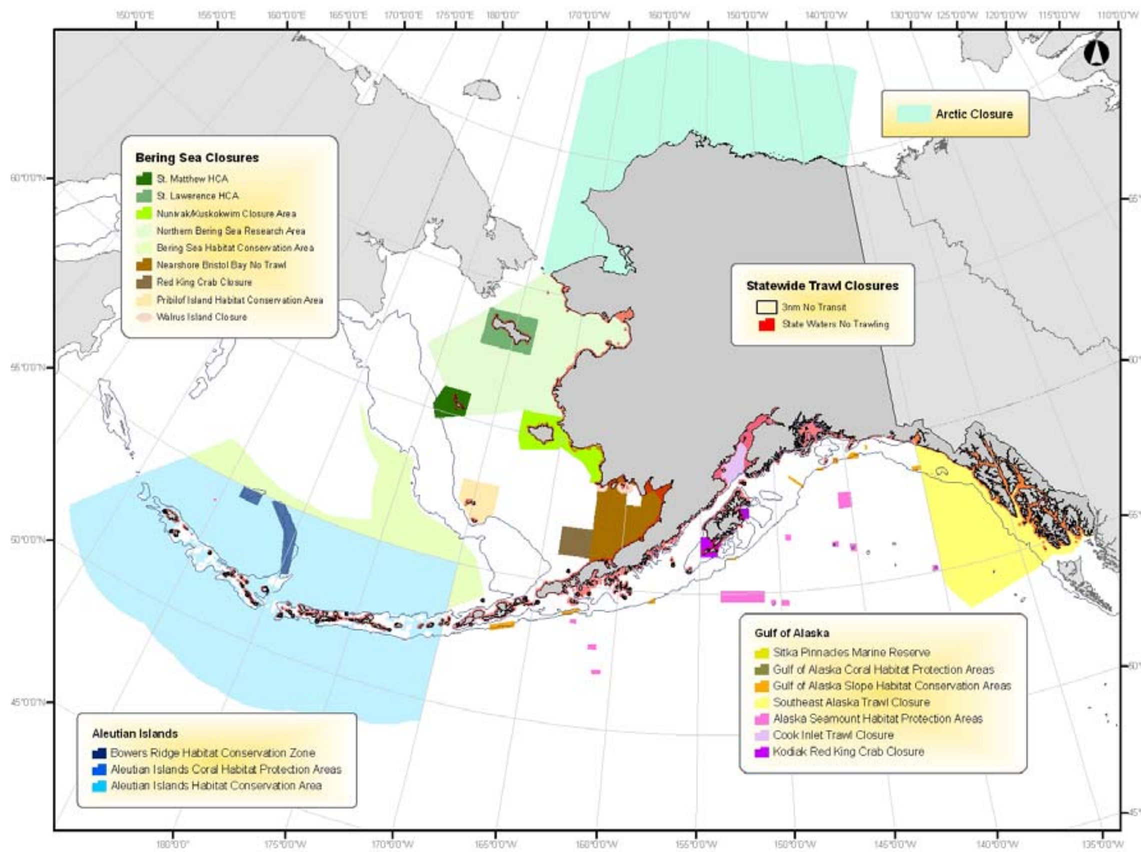

Figure 64. Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska.

Table 11. Time series of groundfish trawl closure areas in the BSAI and GOA, 1995-2008. LLP= License Limitation Program; HCA = Habitat Conservation Area; HCZ = habitat conservation zone.

Bering Sea/Aleutian Islands

Year	Location	Season	Area size	Notes
1995	Area 512	year-round	8,000 nm^2	closure in place since 1987
	Area 516	3/15-6/15	4,000 nm^2	closure in place since 1987
	Chum Salmon Savings Area	8/1-8/31	5,000 nm^2	re-closed at 42,000 chum salmon
	Chinook Salmon Savings Area	trigger	9,000 nm^2	closed at 48,000 Chinook salmon
	Herring Savings Area	trigger	30,000 nm^2	trigger closure
	Zone 1	trigger	30,000 nm^2	trigger closure
	Zone 2	trigger	50,000 nm^2	trigger closure
	Pribilofs HCA	year-round	7,000 nm^2	
	Red King Crab Savings Area	year-round	4,000 nm^2	pelagic trawling allowed
	Walrus Islands	5/1-9/30	900 nm^2	12 mile no-fishing zones
	SSL Rookeries	seasonal ext.	5,100 nm^2	20 mile extensions at 8 rookeries
1996	Nearshore Bristol Bay Trawl Closure	year-round	19,000 nm^2	expanded area 512 closure
	C. opilion bycatch limitation zone	trigger	90,000 nm^2	trigger closure
2000	Steller Sea Lion protections			
	Pollock haulout trawl exclusion zones for EBS, AI * areas include GOA	* No trawl all year	11,900 nm^2	
		No trawl (Jan-June)*	14,800 nm^2	
		No Trawl Atka Mackerel restrictions	29,000 nm^2	
2006	Essential Fish Habitat			
	AI Habitat Conservation Area	No bottom trawl all year	279,114 nm^2	
	AI Coral Habitat Protection Areas	No bottom contact gear all year	110 nm^2	
	Bowers Ridge Habitat Conservation Zone	No mobile bottom tending fishing gear	5,286 nm^2	
2008	Northern Bering Sea Research Area	No bottom trawl all year	66,000 nm^2	
	Bering Sea HCA	No bottom trawl all year	47,100 nm^2	
	St. Matthews HCA	No bottom trawl all year	4,000 nm^2	
	St. Lawrence HCA	No bottom trawl all year	7,000 nm^2	
	Nunivak/Kuskokwim Closure Area	No bottom trawl all year	9,700 nm^2	
2009	Arctic Closure Area	No Commercial Fishing	148,393 nm2	

Gulf of Alaska

Year	Location	Season	Area size	Notes
1995	Kodiak King Crab Protection Zone Type 1	year-round	1,000 nm^2	red king crab closures, 1987
	Kodiak King Crab Protection Zone Type 2	2/15-6/15	500 nm^2	red king crab closures, 1987
	SSL Rookeries	year-round	3,000 nm^2	10 mile no-trawl zones
1998	Southeast Trawl Closure	year-round	52,600 nm^2	adopted as part of the LLP
	Sitka Pinnacles Marine reserve	year-round	3.1 nm^2	
2000	Pollock haulout trawl exclusion zones for GOA* areas include EBS, AI	No trawl all year	11,900 nm^2*	
		No trawl (Jan-June)	14,800 nm^2	
2006	Essential Fish Habitat			
	GOA Slope Habitat Conservation Area	No bottom trawl all year	2,100 nm^2	
	GOA Coral Habiat Protection Measures	No bottom tending gear all year	13.5 nm^2	
	Alaska Seamount Habitat Protection Measures	No bottom tending gear all year	5,329 nm^2	

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

Contributed by John Olson, NMFS
Contact: john.v.olson@noaa.gov

Last updated: August 2009

The amount of effort (as measured by the number of longline sets fished) in hook and line fisheries can be used as a proxy for habitat effects. Effort in the hook and line fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 65. This fishery is prosecuted with stationary lines, onto which baited hooks are attached. Gear components which may interact with benthic habitat include the anchors, groundline, gangions, and hooks. The fishery is prosecuted with both catcher vessels and freezer longliners. Figures 66-71 show the spatial patterns and intensity of longline effort, based on observed data as well as anomalies for 2008 based on the 1998-2008 average. Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures) as well as changes in markets and increased bycatch rates of non-target species. Changes in fishing effort are shown in anomaly plots that look at current effort relative to historical effort.

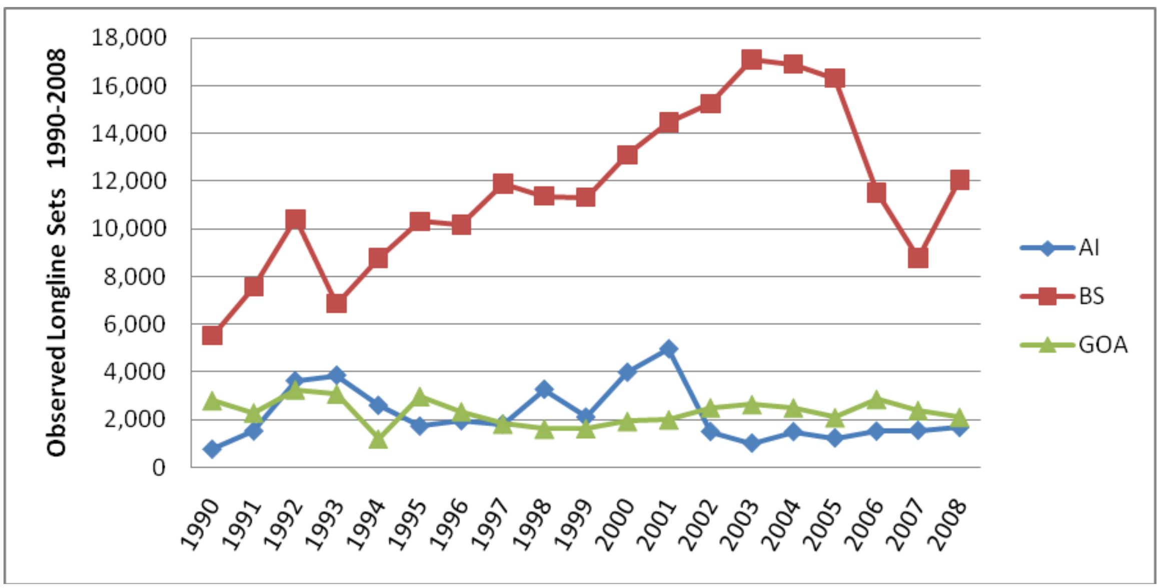

Figure 65. Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of longline sets, 1990-2008.

Bering Sea

For the period 1998-2008, there were a total of 148,150 observed longline sets in the Bering Sea fisheries. Spatial patterns of fishing effort were summarized on a 10 km^2 grid (Figure 66). During 2008, the amount of longline effort was 12,047 sets, which represents an increase from 2007 but is lower than the 11-year average. Areas of high fishing effort are north of False Pass (Unimak Island), the shelf edge represented by the boundary of report areas 513 and 517, as well as the outer boundaries of areas 521 and 517. This fishery occurs mainly for Pacific cod, Greenland turbot, and sablefish. In 2008, fishing effort was anomalously low at the southeastern boundaries of areas 509 and 517 and higher in the remainder of 509 and much of 521 (Figure 67).

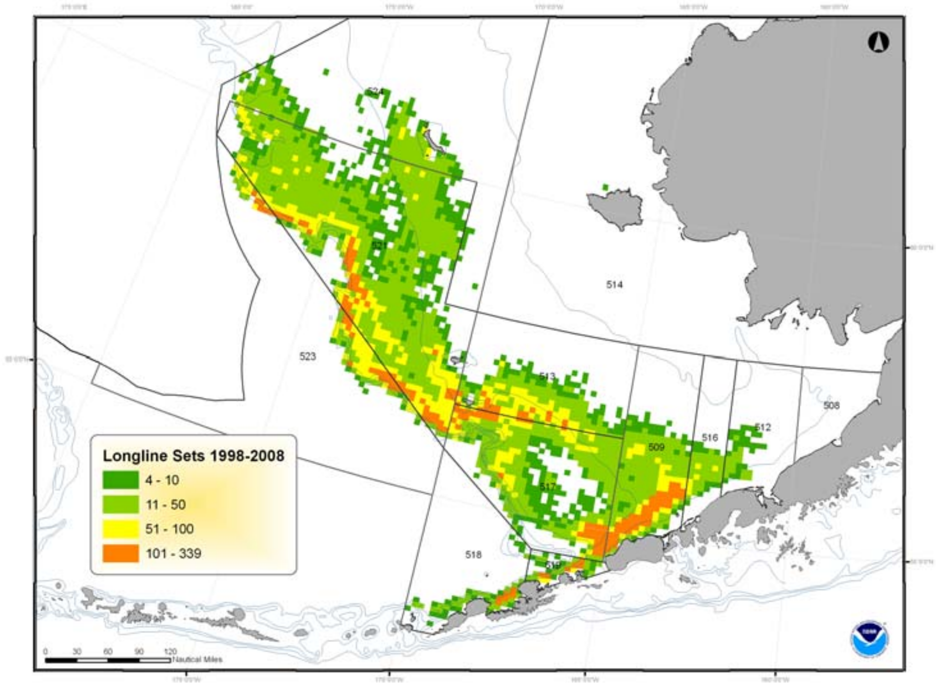

Figure 66. Longline effort (sets) in the Bering Sea 1998-2008.

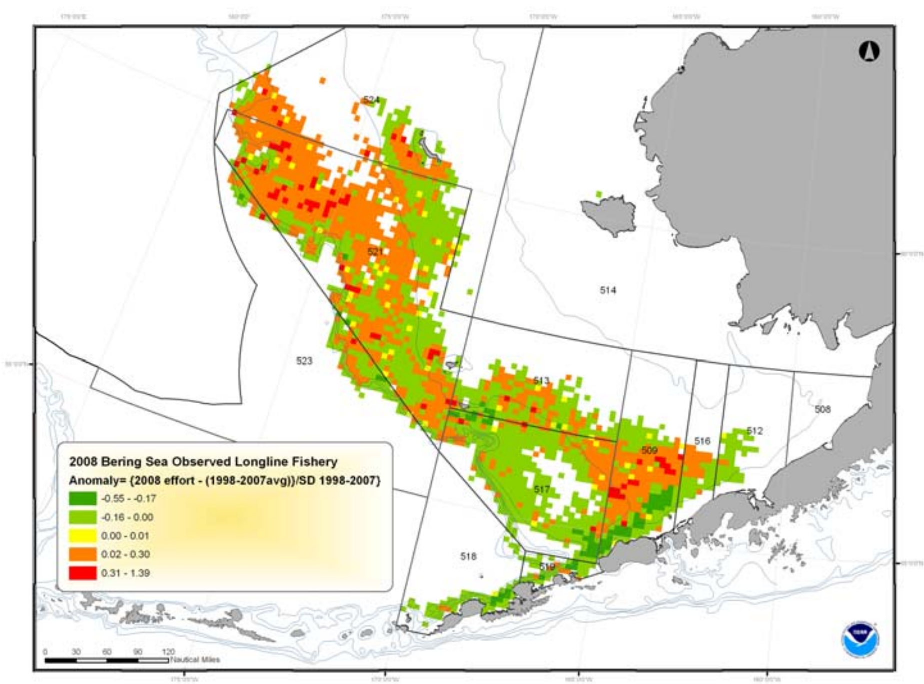

Figure 67. Observed hook and line fishing effort in 2008 relative to the 1998-2008 average in the Bering Sea. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2008)/stdev(effort from 1998-2008).

Aleutian Islands

For the period 1998-2008 there were 24,236 observed hook and line sets in the Aleutian Islands. During 2008, the amount of longline effort was 1,663 sets, which is lower than the 11-year average. The spatial pattern of this effort was dispersed over a wide area. Patterns of high fishing effort were dispersed along the shelf edge (Figure 68). This fishery occurs mainly on Pacific cod, Greenland turbot, and sablefish. The catcher vessel longline fishery occurs over mud bottoms. In the summer, the fish are found in shallow (150-250 ft) waters, but are deeper (300-800 ft) in the winter. Catcher-processors fish over more rocky bottoms in the Aleutian Islands. The sablefish/Greenland turbot fishery occurs over silt, mud, and gravel bottom at depths of 150 to 600 fm. In 2008, fishing effort anomaly showed no specific patterns, with some decreases occurring in the entire AI region with specific increases some local areas (Figure 69).

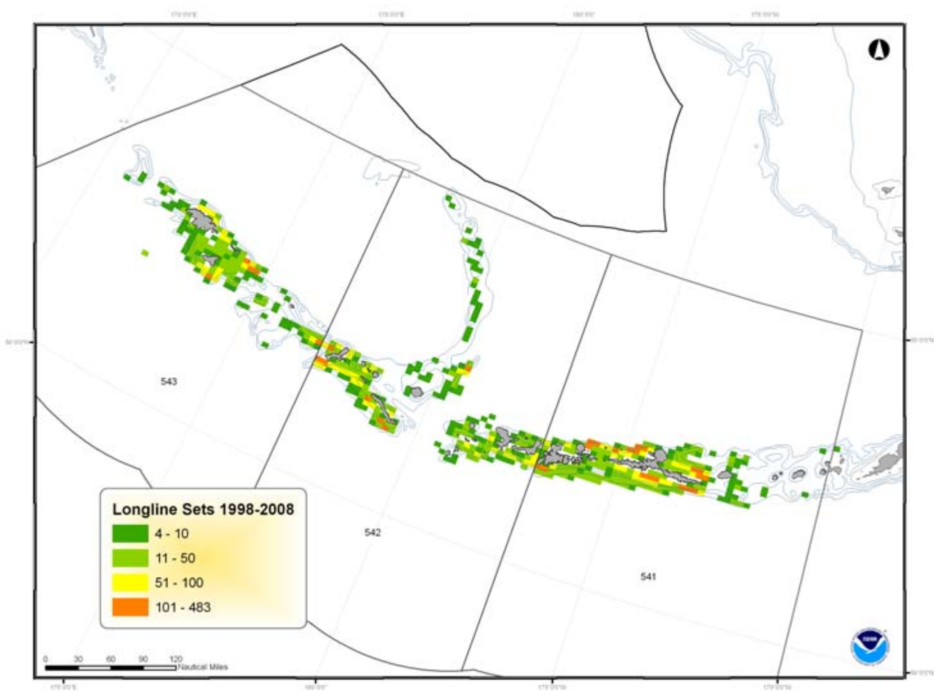

Figure 68. Longline effort (sets) in the Aleutian Islands, 1998-2008.

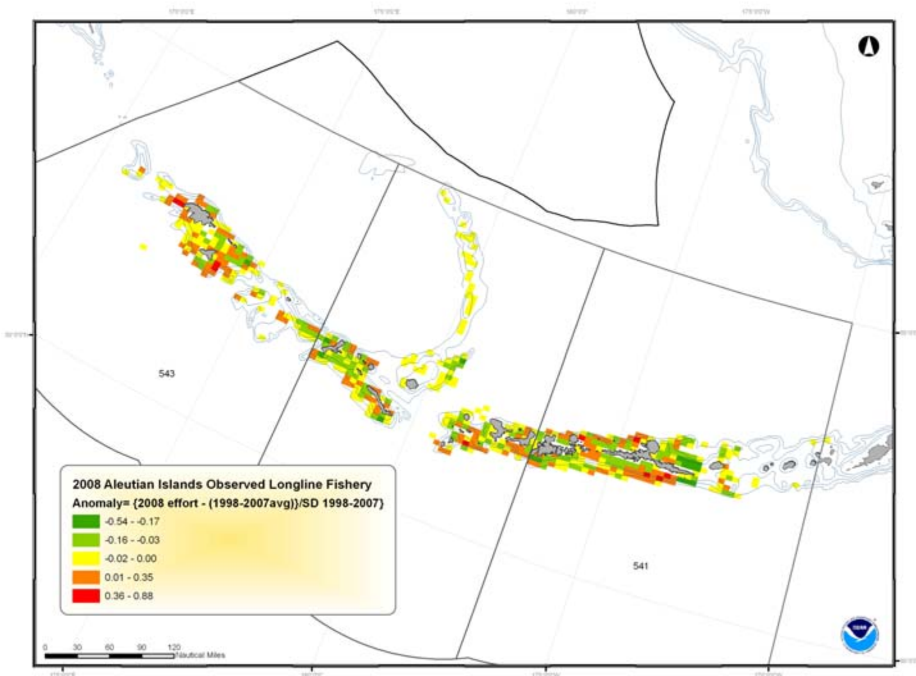

Figure 69. Observed hook and line fishing effort in 2008 relative to the 1998-2008 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2008)/stdev(effort from 1998-2008).

Gulf of Alaska

For the period 1998-2008 there were 24,273 observed hook and line sets in the Gulf of Alaska. During 2008, the amount of longline effort was 2,104 sets, which is near the 11-year average. Patterns of high fishing effort were dispersed along the shelf (Figure 70). The predominant hook and line fisheries in the Gulf of Alaska are composed of sablefish and Pacific cod. In southeast Alaska, there is a demersal rockfish fishery; dominant species include yelloweye rockfish (90%), with lesser catches of quillback rockfish. The demersal shelf rockfish fishery occurs over bedrock and rocky bottoms at depths of 75 m to >200 m. The sablefish longline fishery occurs over mud bottoms at depths of 400 to >1000 m. This fishery is often a mixed halibut/sablefish fishery, with shortraker, rougheye, and thornyhead rockfish also taken. Sablefish has been an IFQ fishery since 1995, which has reduced the number of vessels, crowding, gear conflicts and gear loss, and increased efficiency. The cod longline fishery generally occurs in the western and central Gulf of Alaska, opening on January 1st and lasting until early March. Halibut prohibited species catch sometimes curtails the fishery. The cod fishery occurs over gravel, cobble, mud, sand, and rocky bottom, in depths of 25 fathoms to 140 fathoms. In 2008, fishing effort anomalies were varied throughout the region, with no specific patterns (Figure 71).

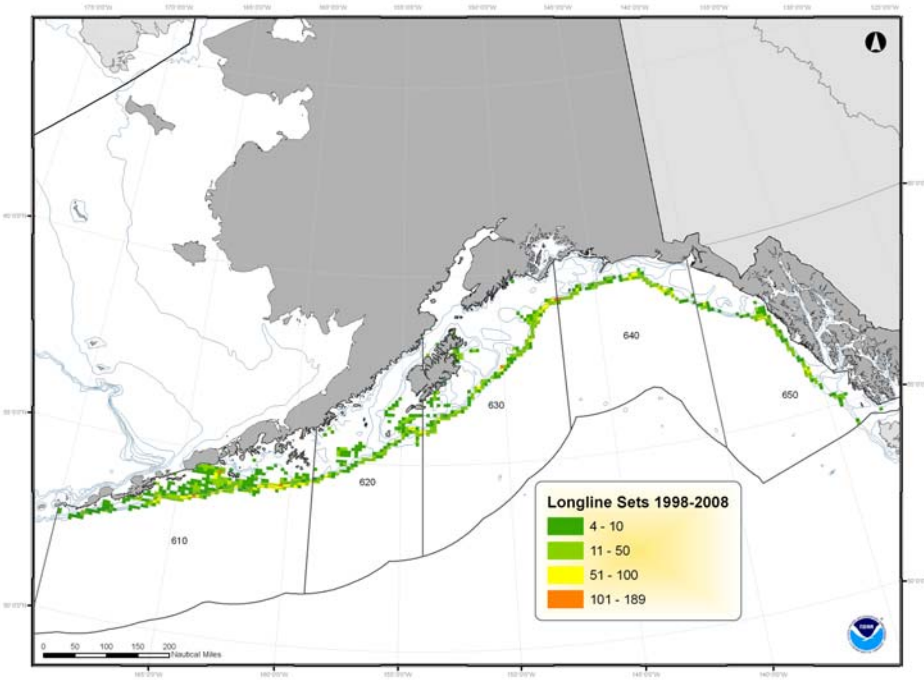

Figure 70. Longline effort (sets) in the Gulf of Alaska, 1998-2008.

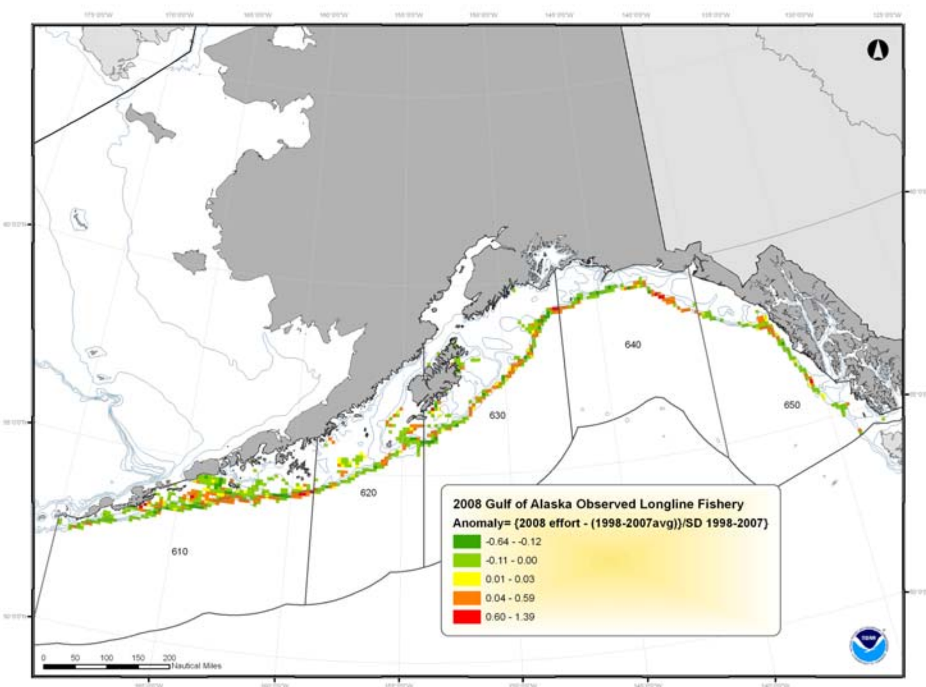

Figure 71. Observed hook and line fishing effort in 2008 relative to the 1998-2008 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2008)/stdev(effort from 1998-2008).

Groundfish Bottom Trawl Fishing Effort in the Gulf of Alaska, Bering Sea and Aleutian Islands
Contributed by John Olson, NMFS
Contact: john.v.olson@noaa.gov
Last updated: August 2009

The amount of effort (as measured by the number of tows) in bottom trawl (non-pelagic trawl) fisheries can be used as proxy for the effects of trawling on habitat. In general, bottom trawl effort in the Gulf of Alaska and Aleutian Islands has declined as pollock and Pacific cod TACs have been reduced (Figure 72). Effort in the Bering Sea remained relatively stable between 1993 and 2008, with the exception of a decline in 2007 (Figure 72). The magnitude of the Bering Sea trawl fisheries is twice as large in terms of effort as the Aleutian Islands and Gulf of Alaska fisheries combined. Fluctuations in fishing effort track well with overall landings of primary bottom trawl target species, such as flatfish and to a lesser extent pollock and cod. As of 1999, only pelagic trawls can be used in the Bering Sea pollock fisheries.

The locations where bottom trawls have been used are of interest for understanding habitat effects. The following figures show the spatial patterns and intensity of bottom trawl effort, based on observed data. Spatial changes in fisheries effort may in part be affected by many factors, including fishing closure areas (i.e., habitat closures, Steller sea lion protection measures) as well as changes in markets, environmental conditions, and/or increased bycatch rates of non-target species. These changes in effort can be observed by examining effort for the current year relative to the average effort in prior years of fishing (effort anomalies).

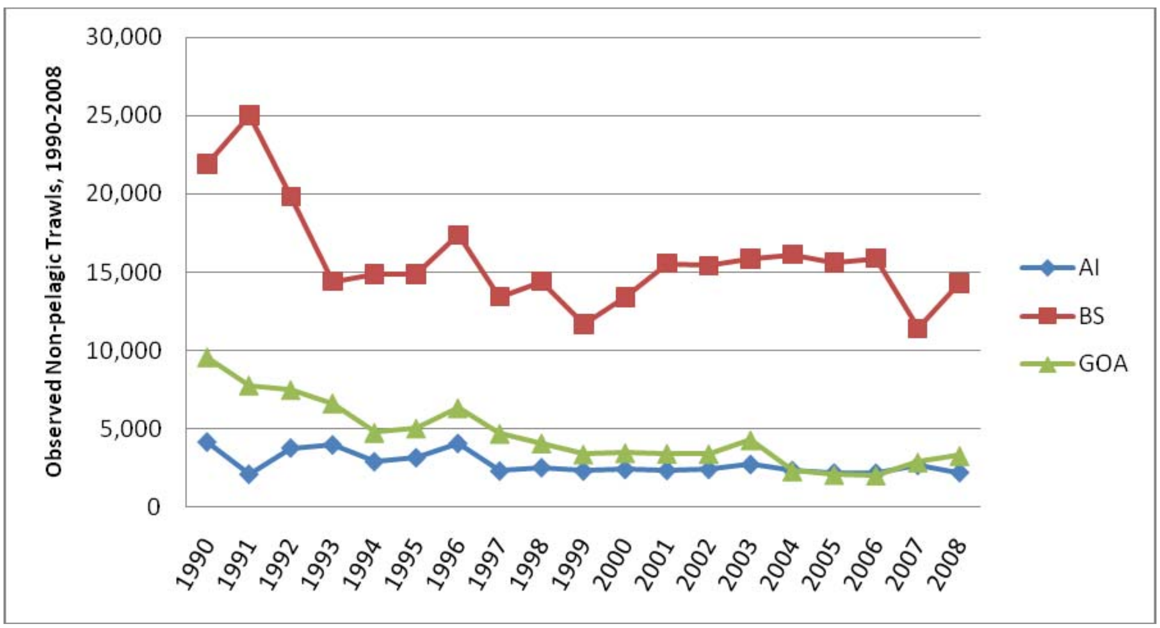

Figure 72. Gulf of Alaska, Bering Sea, and Aleutian Islands non-pelagic trawl effort (number of observed tows), 1990-2008.

Bering Sea
For the period 1998-2008, there were a total of 159,648 observed bottom trawl tows in the Bering Sea fisheries. During 2008, trawl effort consisted of 14,287 tows, which was average compared to the past 11 years. Spatial patterns of fishing effort were summarized on a 10 km^2 grid (Figure 73). Areas of high fishing effort are north of False Pass (Unimak Island) as well as the shelf edge represented by the

boundary of report areas 513 and 517 and the northeastern section of area 513. The primary catch in these areas was Pacific cod and yellowfin sole. In 2008, fishing effort was lower than average in the southern portion of areas 509 and 517 as well as some larger areas of the central and northwestern Bering Sea. Higher fishing effort occurred in portions of 509 and 513, as well as to the northwest of the Pribilof Islands in 521.

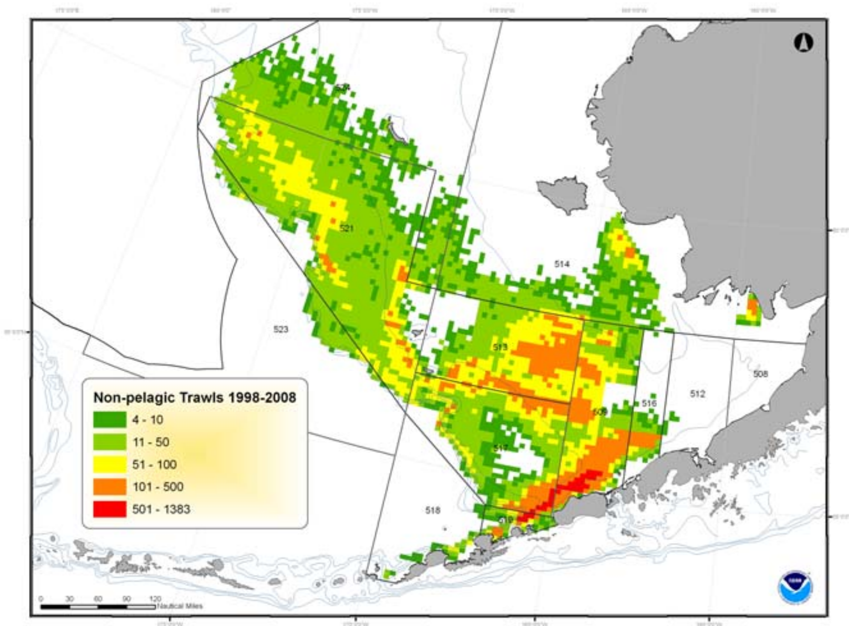

Figure 73. Spatial location and density of non-pelagic trawling in the Bering Sea, 1998-2008.

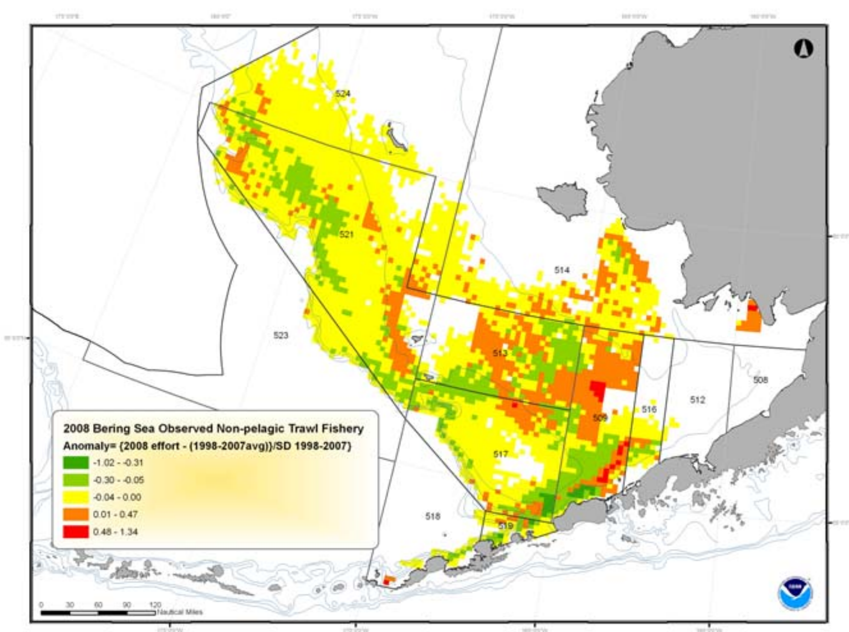

Figure 74. Observed non-pelagic trawl fishing effort in 2008 relative to the 1998-2008 average in the Bering Sea. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2008)/stdev(effort from 1998-2008).

Aleutian Islands

For the period 1998-2008 there were 26,345 observed bottom trawl tows in the Aleutian Islands. During 2008, the amount of trawl effort was 2,218 tows, which was about average for the 11-year period. Patterns of high fishing effort were dispersed along the shelf edge (Figure 75). The primary catches in these areas were Pacific cod and Atka mackerel. Catch of Pacific ocean perch by bottom trawls was also high in earlier years. In 2008, areas of anomalous fishing effort were scattered throughout the region and catch was comprised of Atka mackerel, Pacific cod and rockfish (Figure 76). Some areas now have lower patterns of fishing effort which could be due to the implementation of new management measures. In 2006, the Aleutian Islands Habitat Conservation Area (AIHCA) closed approximately 279,114 nm^2 to bottom trawl fishing in the three AI management areas.

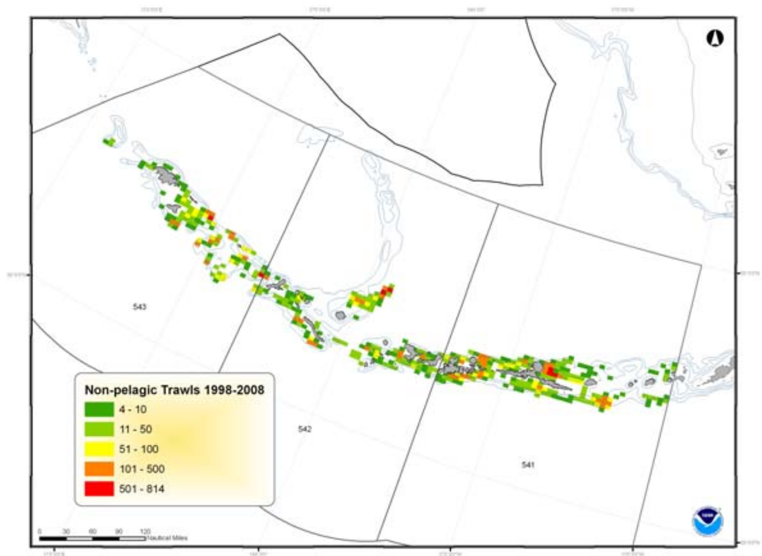

Figure 75. Spatial location and density of bottom trawl effort in the Aleutian Islands, 1998-2008.

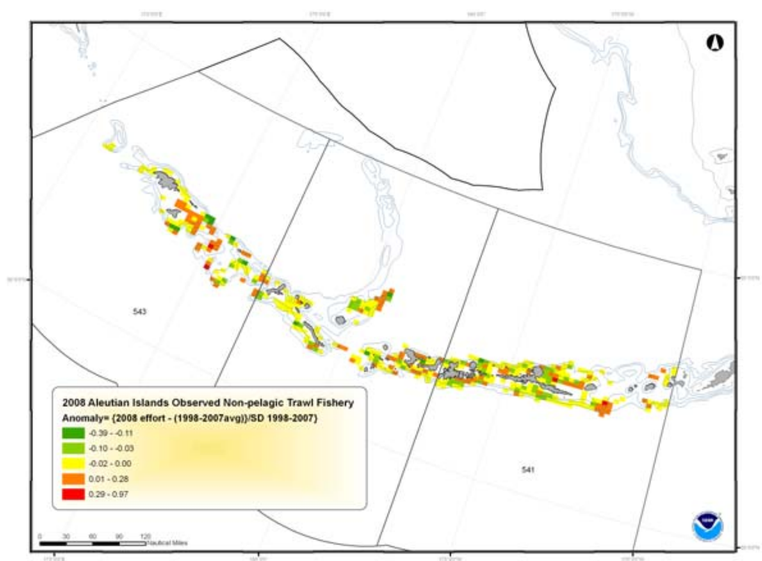

Figure 76. Observed non-pelagic trawl fishing effort in 2008 relative to the 1998-2008 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2008)/stdev(effort from 1998-2008).

Gulf of Alaska

For the period 1998-2008 there were 34,754 observed bottom trawl tows in the Gulf of Alaska. The spatial pattern of this effort was much more dispersed than in the Bering Sea region. During 2008, the amount of observed trawl effort was 3,300 tows, which was near the average for the 11-year period. Patterns of high fishing effort were dispersed along the shelf edge with high pockets of effort near Chirkoff, Cape Barnabus, Cape Chiniak and Marmot Flats (Figure 77). Primary catches in these areas were Pacific cod, flatfish and rockfish. A larger portion of the trawl fleet in Kodiak is comprised of smaller catcher vessels that require 30% observer coverage, indicating that the actual amount of trawl effort would be much higher since a large portion is unobserved. In 2008, much like 2007, areas of higher and lower than average fishing effort were scattered throughout the Central and Western Gulf (Figure 78).

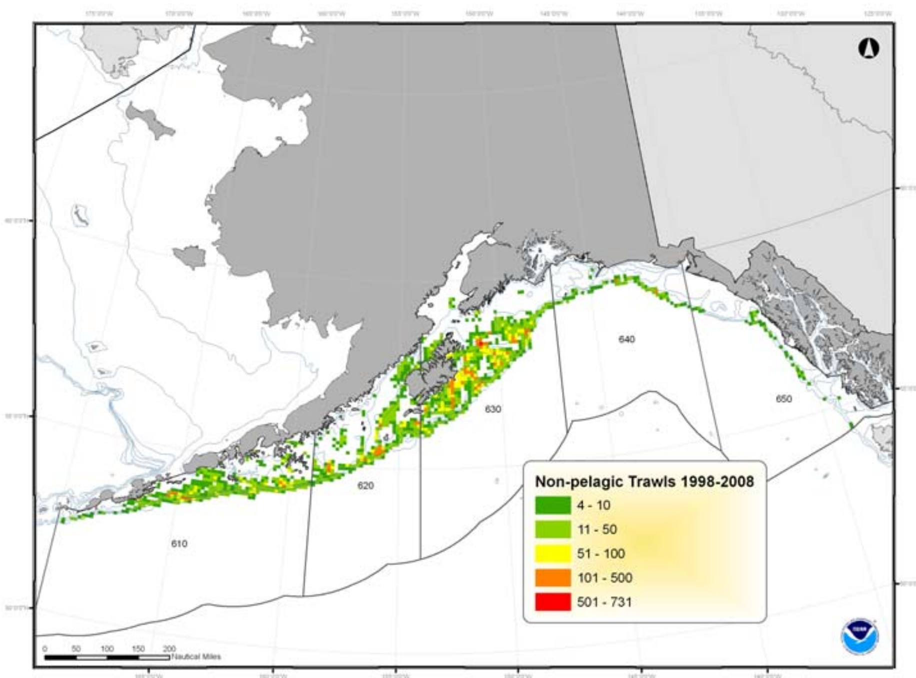

Figure 77. Spatial location and density of bottom trawl effort in the Gulf of Alaska, 1998-2008.

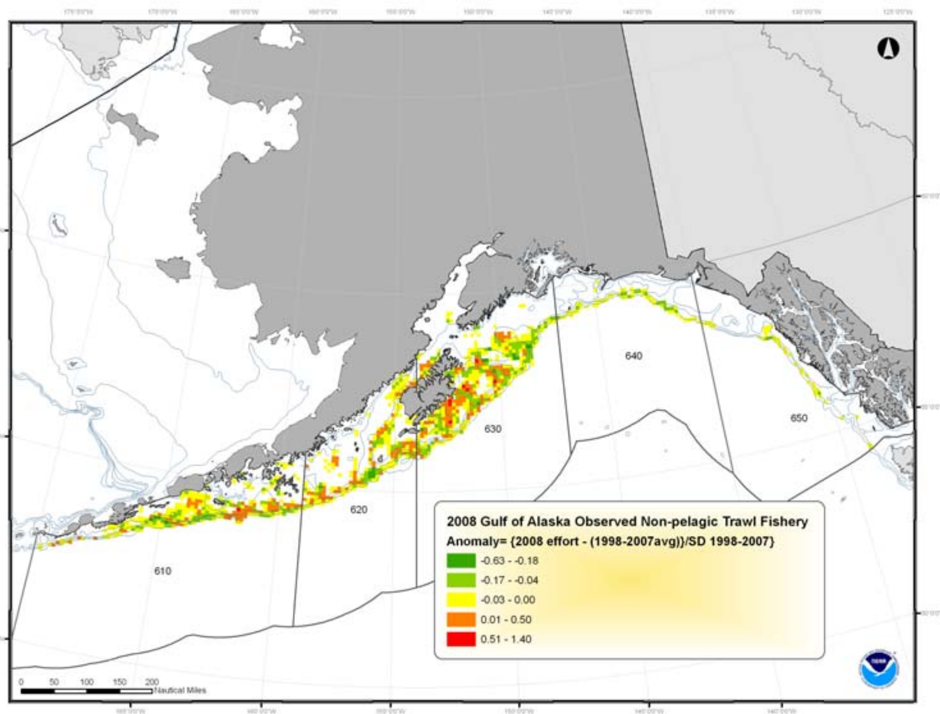

Figure 78. Observed non-pelagic trawl fishing effort in 2008 relative to the 1998-2008 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2008)/stdev(effort from 1998-2008).

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

Contributed by John Olson, NMFS
Contact: john.v.olson@noaa.gov

Last updated: August 2009

Effort in the pelagic trawl fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 79. The magnitude of the Bering Sea trawl fisheries effort is four times larger than effort in both the Aleutian Islands and Gulf of Alaska combined. While this fishery is much larger than in the other two regions, smaller vessels that only require 30% observer coverage occur in larger proportions in the GOA and AI resulting in less documented fishing effort. Figures 80-83 show the spatial patterns and intensity of pelagic trawl effort by region, based on observed data. Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures), changes in markets, changes in environmental conditions, and increased bycatch rates of non-target species. The Bering Sea pollock fishery is the largest volume U.S. Fishery, and most pollock is harvested with pelagic trawl nets. Effort in the Bering Sea has remained relatively stable from 1995 through present. Some of the consistency of effort can be attributed to changes in the structure of the groundfish fisheries due to rationalization. Effort in both the GOA and AI has decreased in the last six years, in part due to restricted fishing from Steller sea lion protection measures.

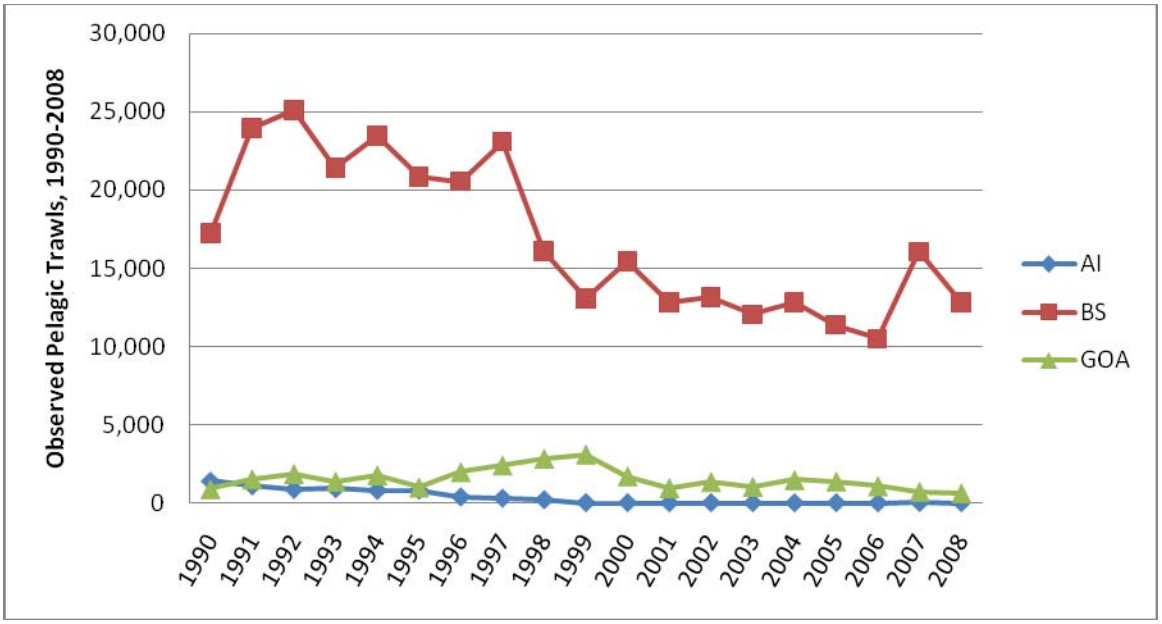

Figure 79. Gulf of Alaska, Aleutian Islands, and Bering Sea pelagic trawl effort (observed pelagic trawl tows), 1990-2008.

Bering Sea

For the period 1998-2008 there were 146,258 observed pelagic trawl tows in the Bering Sea. There were 12,837 observed tows in 2008, which is somewhat lower than the 11-year average. Areas of high fishing effort are north of Unimak Island along the shelf edge represented by the shelf edge connecting management areas 509, 517, and 519 (Figure 80). The predominant species harvested within the eastern Bering Sea is walleye pollock (*Theragra chalcogramma*). Pollock occur on the sea bottom, the midwater and up to the surface. Most catch of pollock is taken at 50-300m.

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

Pollock fishermen formed fish harvesting cooperatives to “rationalize” fishing activities, including resolving problems of overcapacity, promoting conservation and enhancing utilization of fishery resources. Under a co-op arrangement, fewer vessels are fishing and daily catch rates by participating vessels are significantly reduced since the “race for fish” ended in 1999.

In 2008, fishing effort was anomalously low north of Unimak Island, an area of normally high fishing effort, as well as along the 100m line between areas 513 and 517. Increased fishing effort occurred in the core areas of the fishery (509, 517) as well as in areas 521 and 524 (Figure 81). Some changes in fleet movement may be attributed to the AFA fishing coop structure and voluntary rolling hotspot closures to reduce the incidental take of Chinook and “Other Salmon” bycatch; whereas, other changes in fishing effort might be attributed to changes in pollock distribution.

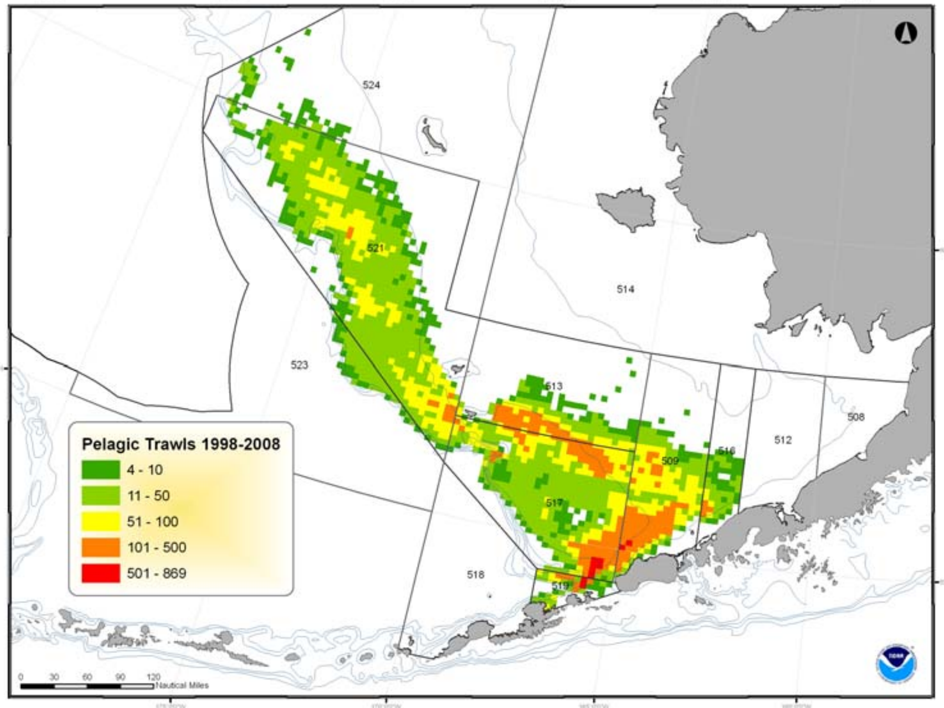

Figure 80. Spatial location and density of pelagic trawl effort in the eastern Bering Sea, 1998-2008.

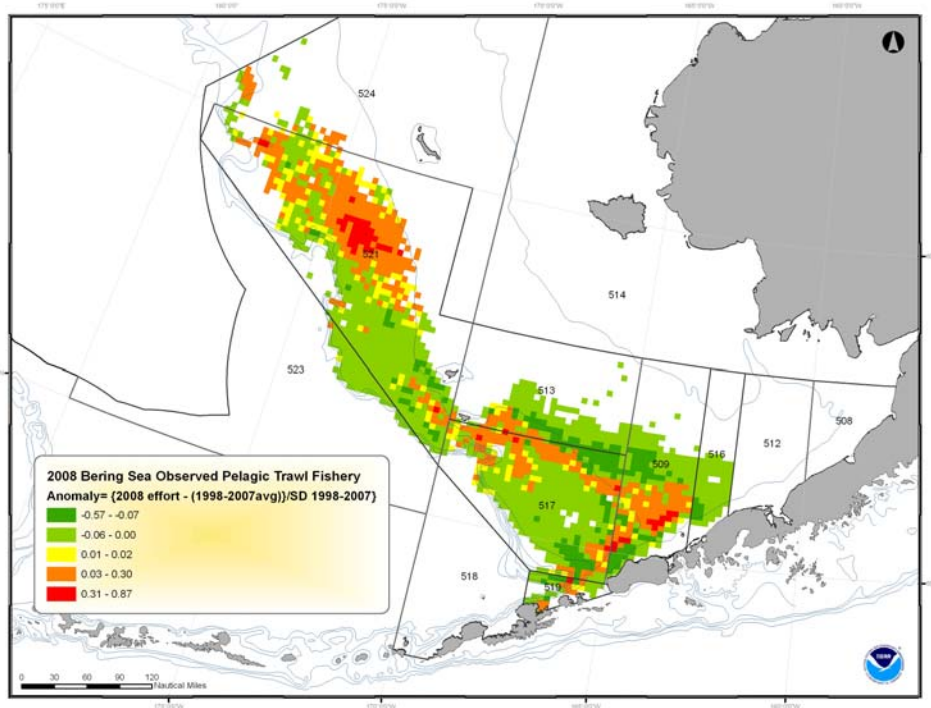

Figure 81. Observed pelagic trawl fishing effort in 2008 relative to the 1998-2008 average in the Bering Sea. Anomalies calculated as (estimated effort for 2007 - average effort from 1998-2007)/stdev(effort from 1998-2008).

Aleutian Islands

For the period 1998-2008 there were 274 observed bottom trawl tows in the Aleutian Islands. In 2001, 2003, 3004, and 2006 there were no observed pelagic trawl tows. There were only 10 observed tows in 2008. Patterns of high fishing effort were historically dispersed along the shelf edge (Figure 82).

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

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

Additionally, closures implemented in 2006 as part of protection for Essential Fish Habitat will limit the areas where bottom trawl fishing can occur. The Aleutian Islands Habitat Conservation Area (AIHCA) closed approximately 279,114 nm2 to bottom trawl fishing in the three AI management areas.

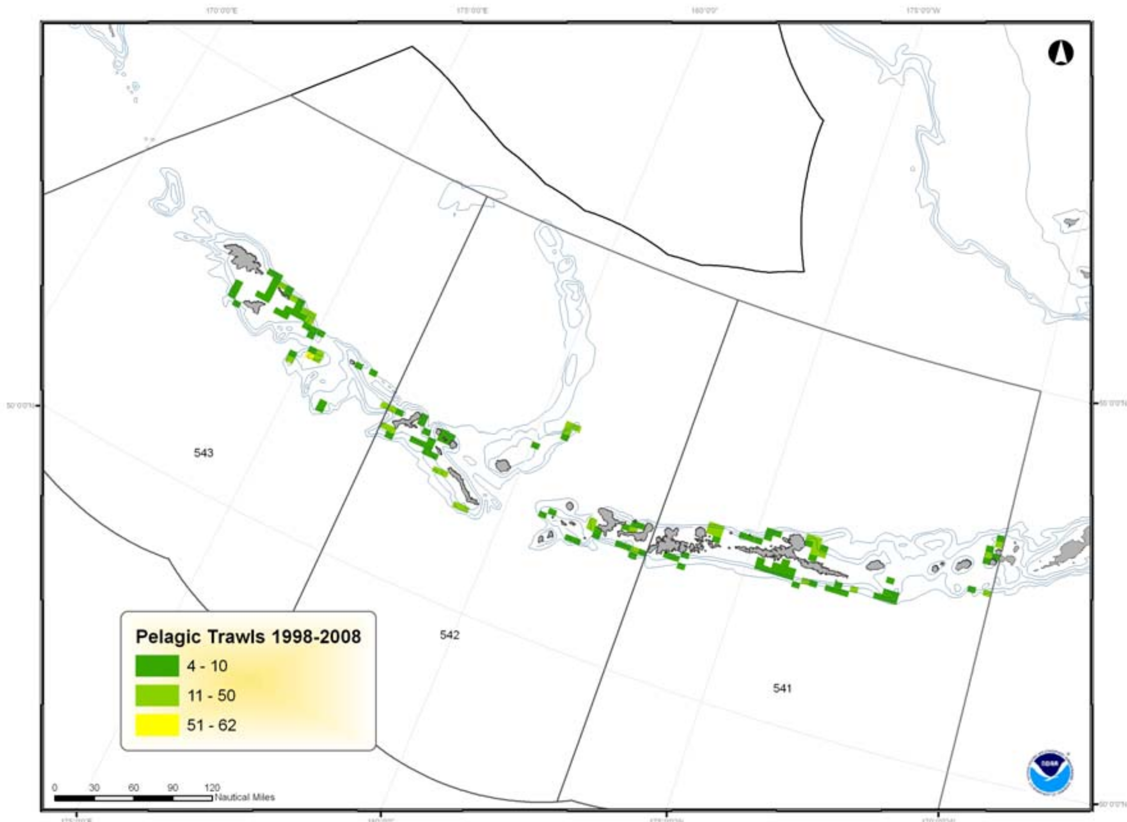

Figure 82. Spatial location and density of pelagic trawl effort in the Aleutian Islands, 1998-2008.

Gulf of Alaska

The primary target of the GOA pelagic trawl fishery is pollock. The fleet is comprised of trawl catcher vessels that deliver their catch onshore for processing. For the period 1998-2008 there were 16,513 observed pelagic trawl tows in the Gulf of Alaska. The spatial pattern of this effort centers around Kodiak, with limited fishing on the shelf break to the east and west (Figure 83). During 2008, the amount of trawl effort was 648 tows, which was the low for the 16 year period. A large portion of the trawl fleet in Kodiak is comprised of smaller catcher vessels that require 30% observer coverage, indicating that the actual amount of trawl effort is likely much higher since a large portion is unobserved. The catch anomaly for 2008 was variable, but most effort was centered in areas 620-630.

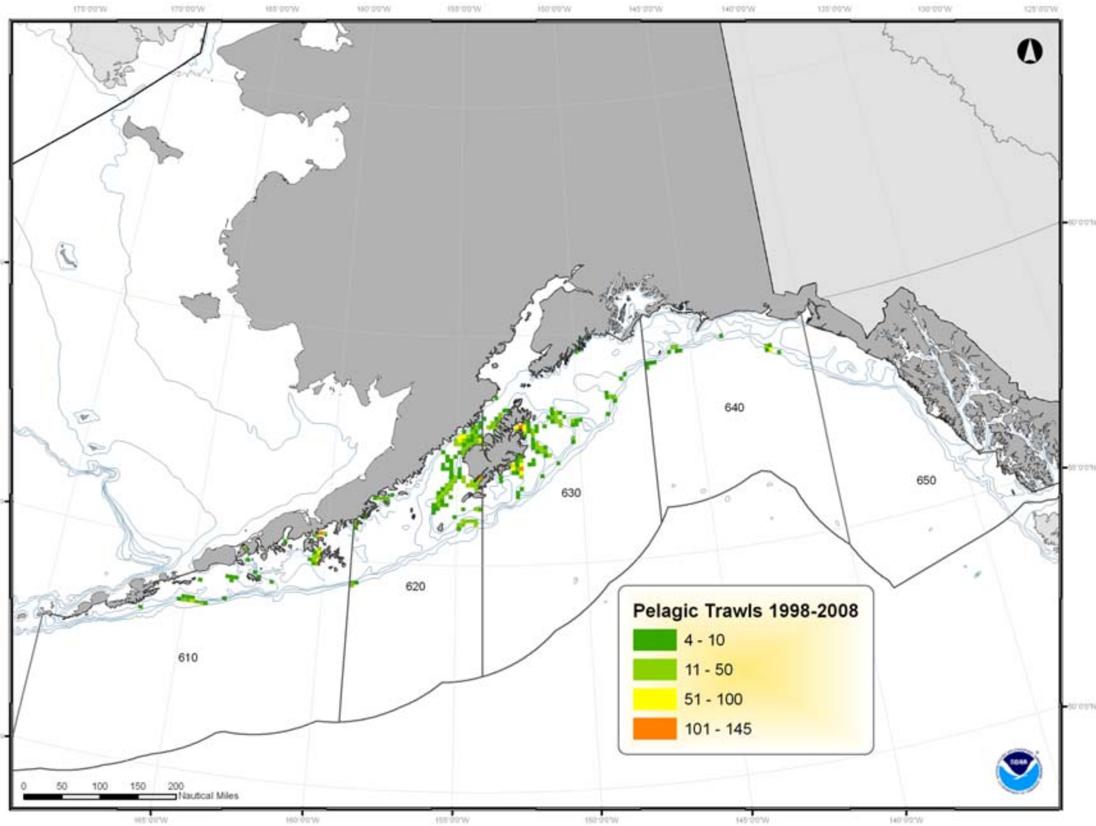

Figure 83. Spatial location and density of pelagic trawl effort in the Gulf of Alaska, 1998-2008.

Pot Fishing Effort in the Gulf of Alaska, Bering Sea, and Aleutian Islands
Contributed by John Olson, NMFS
Contact: john.v.olson@noaa.gov
Last updated: August 2009

The amount of effort (as measured by observed pot lifts) in pot fisheries is used as a proxy for fishing effects on benthic habitat. Effort in the pot fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 84. The amount of pot effort fluctuates annually by region. However, annual observed estimates of pot lifts do not reflect the entire pot fishery. Most of the vessels using pot gear are catcher vessels either under 60' or between 60'-125'. These vessels either do not require an observer present or only on 30% of the fishing days. Fluctuations in the pot cod fishery may also be dependent on the duration and timing of the crab fisheries.

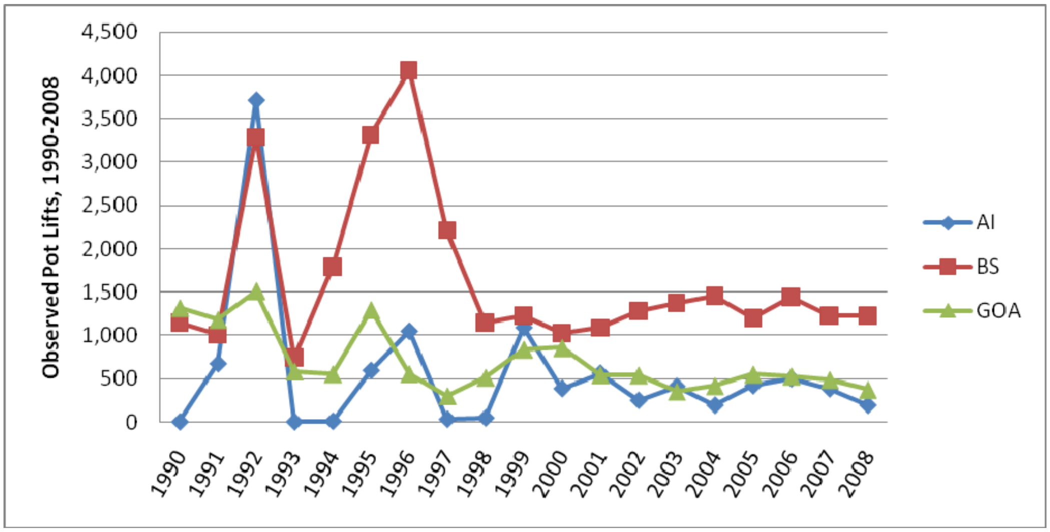

Figure 84. Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of pot lifts, 1990-2008.

Bering Sea

For the period 1998-2008, there were a total of 13,703 observed pot lifts in the Bering Sea fisheries. Spatial patterns of fishing effort were summarized on a 10 km^2 grid (Figure 85). Areas of high fishing effort are west of Unimak Island and to the north of Akutan, as well as around the Pribilof Islands. This fishery occurs mainly for Pacific cod which form dense aggregations for spawning in the winter months. Effort anomalies occurred mainly to the west of Unimak Island (lower effort) and to the north of the Fox Islands (higher)(Figure 86). Spatial and temporal changes to the fishery have occurred in the past 10 years due to current Steller Sea Lion regulations.

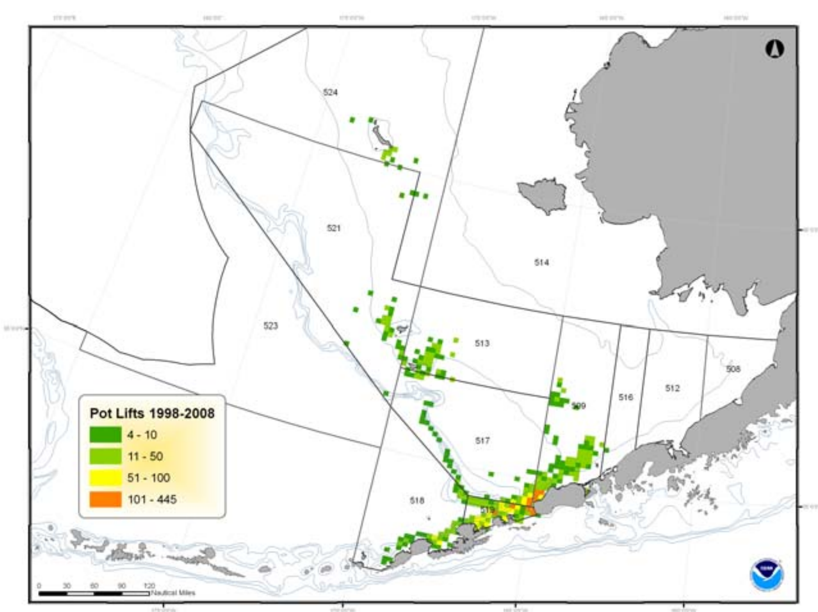

Figure 85. Spatial location and density of observed pot effort (observed number of pot lifts) in the Bering Sea, 1998-2008.

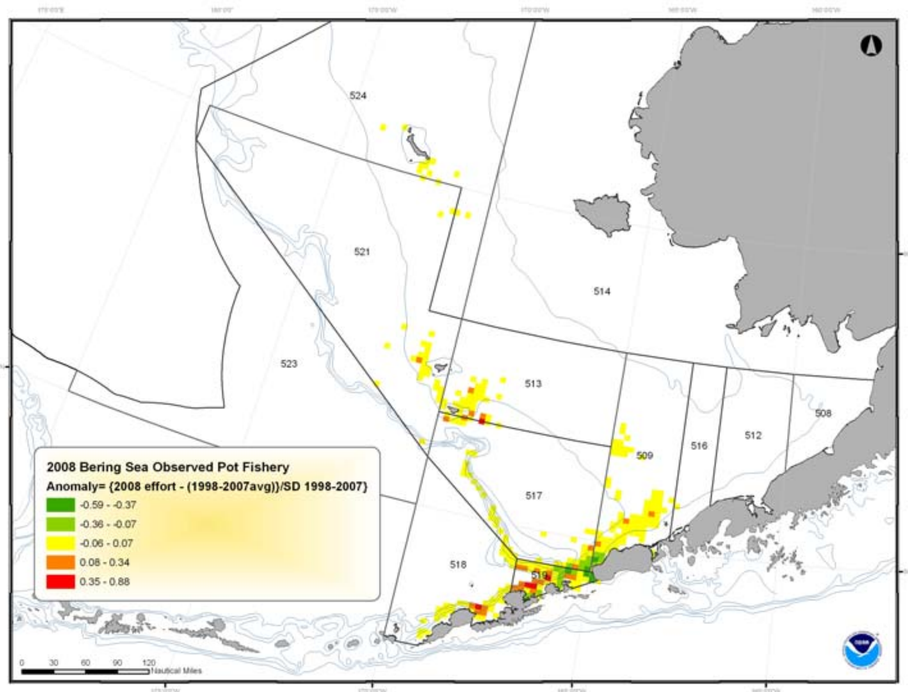

Figure 86. Observed pot fishing effort in 2008 relative to the 1998-2008 average in the Bering Sea. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2008)/stdev(effort from 1998-2008).

Aleutian Islands

For the period 1998-2008 there were 4,423 observed pot lifts in the Aleutian Islands. High fishing effort was dispersed along the shelf edge with high effort near Seguam Island (Figure 87). In 2008, fishing effort was anomalously high around Atka and Amlia Islands (Figure 88).

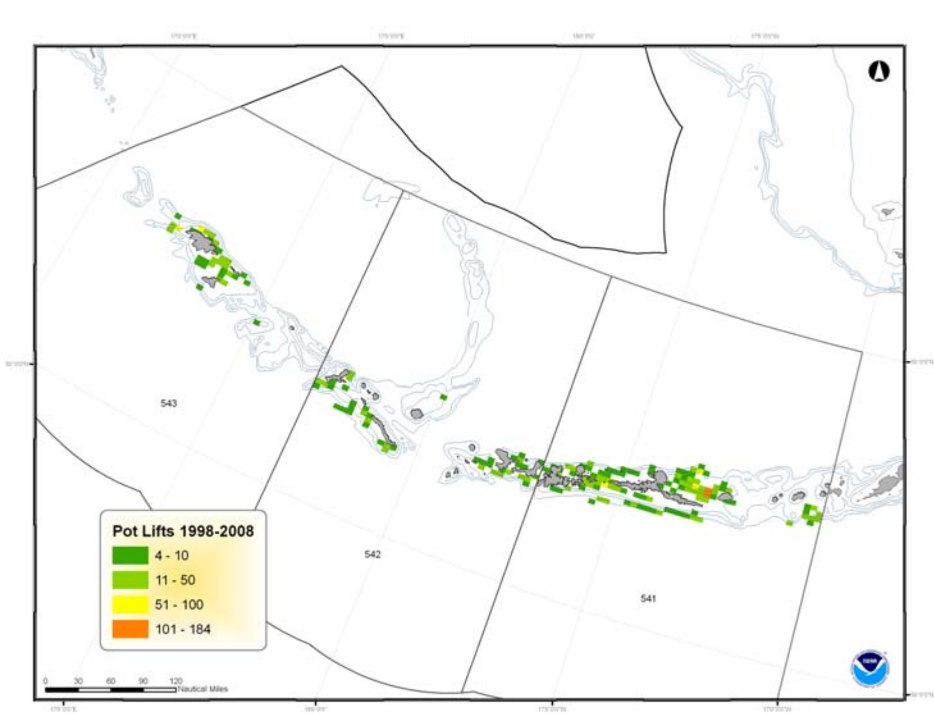

Figure 87. Spatial location and density of observed pot effort (observed number of pot lifts) in the Aleutian Islands, 1998-2008.

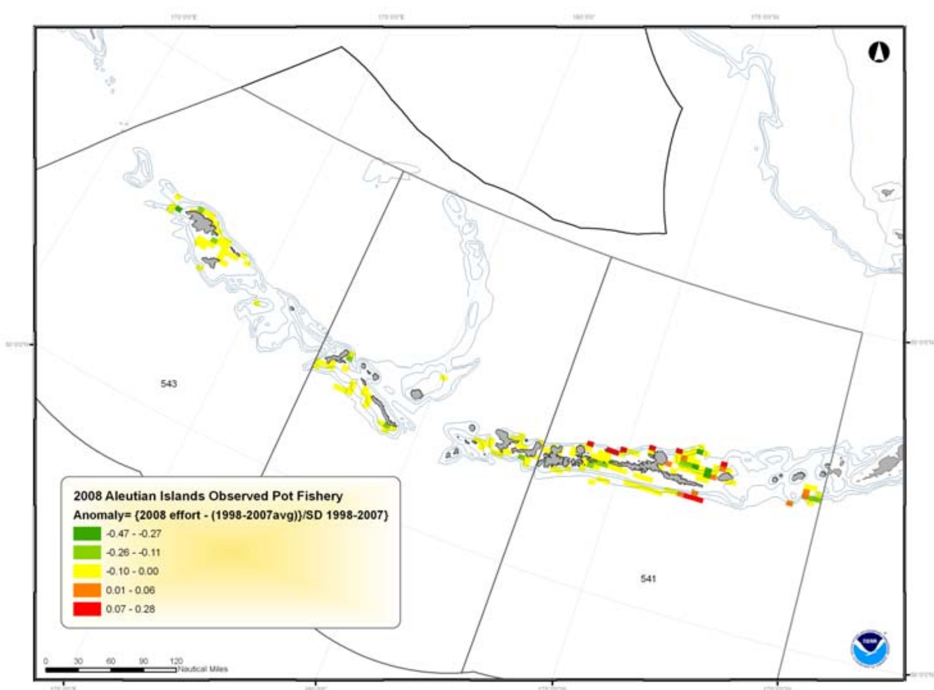

Figure 88. Observed pot fishing effort in 2008 relative to the 1998-2008 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2008)/stdev(effort from 1998-2008).

Gulf of Alaska

For the period 1998-2008 there were 6,035 observed pot lifts in the Gulf of Alaska. During 2008, the amount of observed pot effort was 377 lifts, which represents a decline from 2007 and also well below the 11-year average. Patterns of higher fishing effort were dispersed along the shelf around Kodiak Island (Figure 89). Fishing effort in 2008 was varied in areas 610 and 630, with areas of both above and below long term averages (Figure 90). Approximately 100 boats participate in this fishery. Vessels used in the inshore fishery are all catcher vessels of small (less than 60-foot LOA) and medium size (60- to 125-foot LOA). The offshore fishery includes some catcher-processors ranging from 90 to over 125 feet. The A season fishery begins on January 1st and concludes in early March. The B season fishery opens September 1 and can be expected to last 6 weeks or less. There is also a state-managed fishery in state waters.

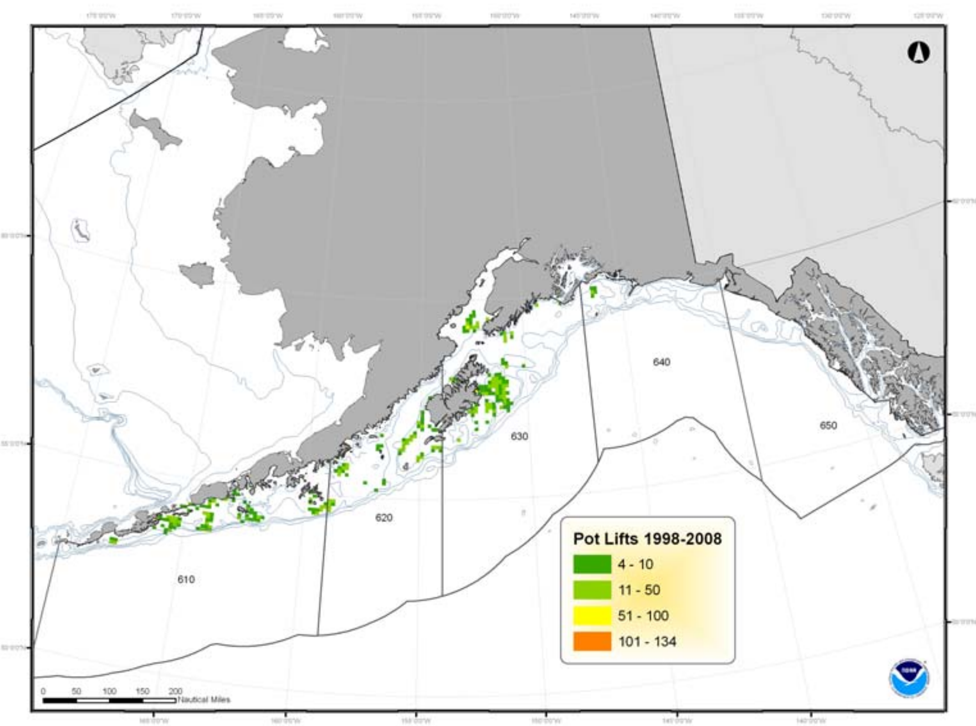

Figure 89. Spatial location and density of observed pot (observed number of pot lifts) effort in the Gulf of Alaska, 1998-2008.

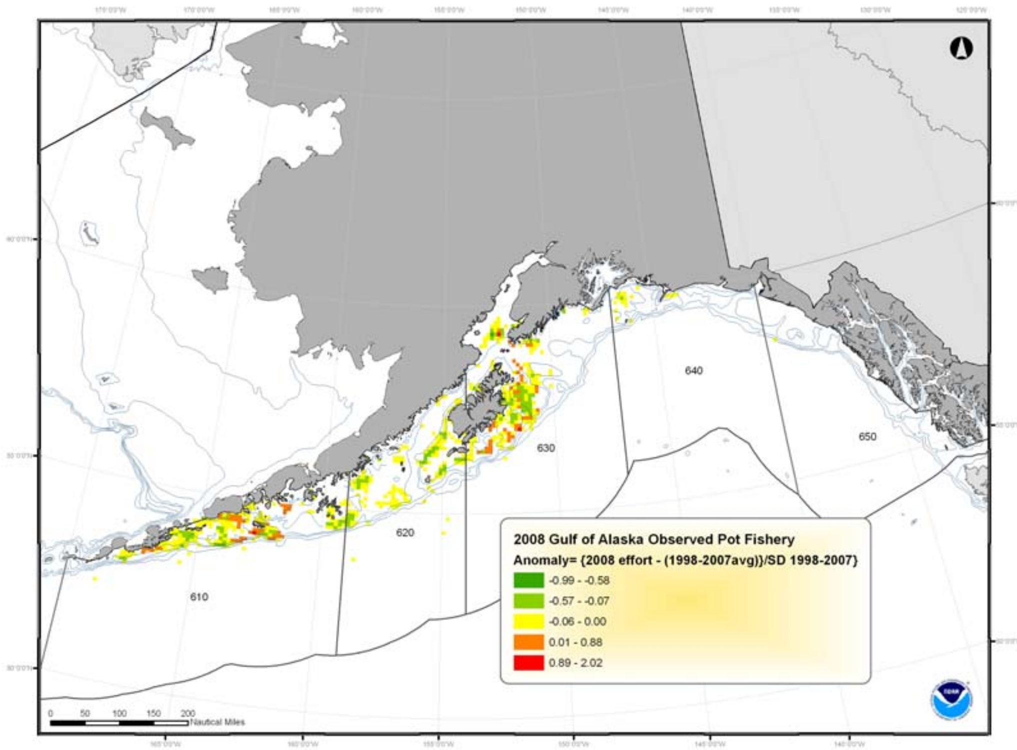

Figure 90. Observed pot fishing effort in 2008 relative to the 1998-2008 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2008 - average effort from 1998-2008)/stdev(effort from 1998-2008.

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

Trophic Level of the Catch

Contributed by Pat Livingston, Alaska Fisheries Science Center and Jennifer Boldt, University of Washington

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Last updated: June 2009

To determine whether North Pacific fisheries were "fishing-down" the food web, the total catch, trophic level of the catch, and the Pauly et al. (2000) Fishery In Balance (FIB) Index in the eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) areas were determined. To estimate the trophic level of the catch, the catch of each species in a given year was multiplied by the trophic level of that species; products were summed across all species in a given year and divided by the total catch in that year. To calculate the FIB index (Pauly et al. 2000):

$$FIB=\log(Y_i \cdot (1/TE)^{TL_i})-\log(Y_0 \cdot (1/TE)^{TL_0}),$$

where Y_i is the catch in year i, TL_i the mean trophic level in the catch in year i, TE the transfer efficiency (assumed to be 0.1), and 0 refers to a year used as a baseline (first year in the time series).

Total catch levels and composition for the three regions show the dominance of walleye pollock in the catch from around the 1970s to at least the early 1990s (Figure 91). Other dominant species groups in the catch were rockfish prior to the 1970s in the AI and the GOA and Atka mackerel in the 1990s in the AI. EBS catches decreased during 2007-2008 due to reduced walleye pollock catches.

Stability in the trophic level of the total fish and invertebrate catches in the EBS, AI, and GOA (Figure 92) indicate that the "fishing-down" effect is not occurring in these regions. Although there has been a general increase in the amount of catch since the late 1960s in all areas, the trophic level of the catch has been high and stable over the last 25 years. The overall trophic level of the catch did not decrease with time when pollock were excluded from the catches (Figure 92). Excluding pollock from EBS catches did result in more temporal variability in the trophic level of the catch.

The Fishery in Balance Index (FIB) of Pauly et al. (2000) was developed to ascertain whether trophic level catch trends are a reflection of deliberate choice or of a “fishing down the food web” effect. This index declines only when catches do not increase as expected when moving down the food web, relative to an initial baseline year. The FIB index for each Alaskan region was calculated (Figure 92) to allow an assessment of the ecological balance of the fisheries. Unlike other regions in which this index has been calculated, such as the Northwest Atlantic, catches and trophic level of the catch in the EBS, AI, and GOA have been relatively constant and suggest an ecological balance in the catch patterns. The EBS FIB index decreased during 2007-2008 due to decreased pollock catches. When pollock were excluded from EBS catches, the FIB index was lower, but still relatively stable, fluctuating around 1.7 for approximately the last 30 years (Figure 92). Pollock catch has had a ‘stabilizing’ effect on the trophic level and FIB index of the Eastern Bering Sea catch, since it comprised the majority of the catch since the late 1960s (Figure 92). Another species of interest is arrowtooth flounder because of recent population increases. Since this species comprises a small proportion of the catches, it has virtually no effect on the trophic level of the catch or the FIB index in the EBS or GOA.

Graphs illustrating the total catch by trophic level increments, similar to those created by Essington et al. (2006), reveal patterns not easily seen in the total trophic level values or FIB index. This further examination supports the idea that fishing-down the food web is not occurring in Alaska. In general, it appears that fishing events on different species are episodic in the AI and GOA, while pollock steadily dominate catches in the EBS throughout the period (Figure 93).

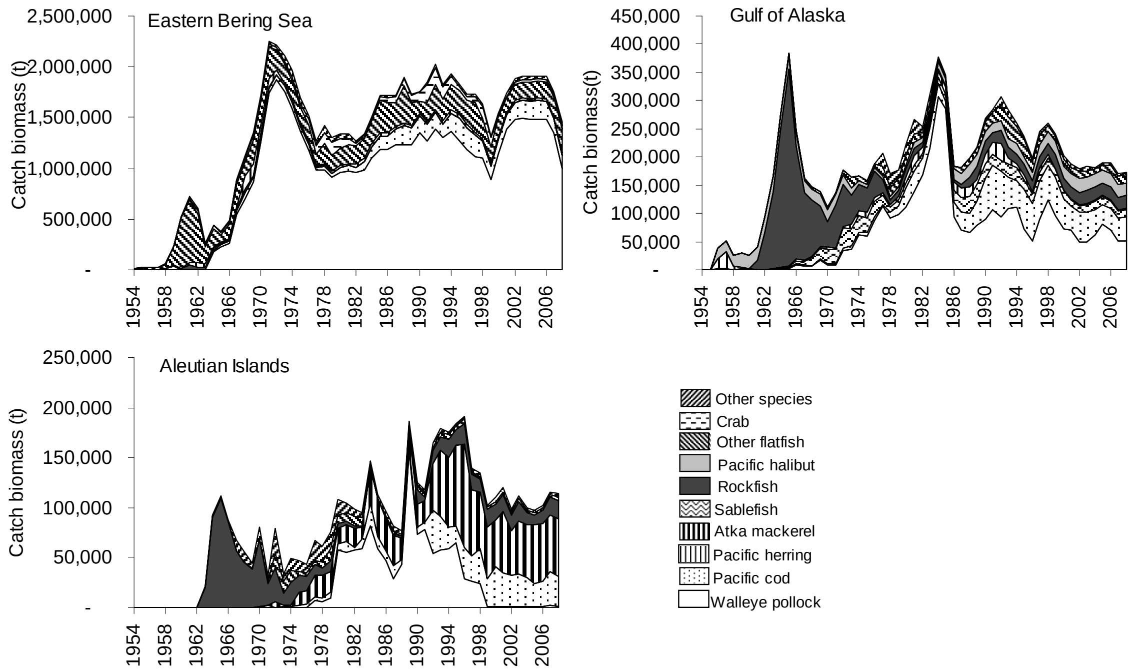

Figure 91. Total catch biomass (except salmon) in the EBS, GOA, and AI, 1954-2008.

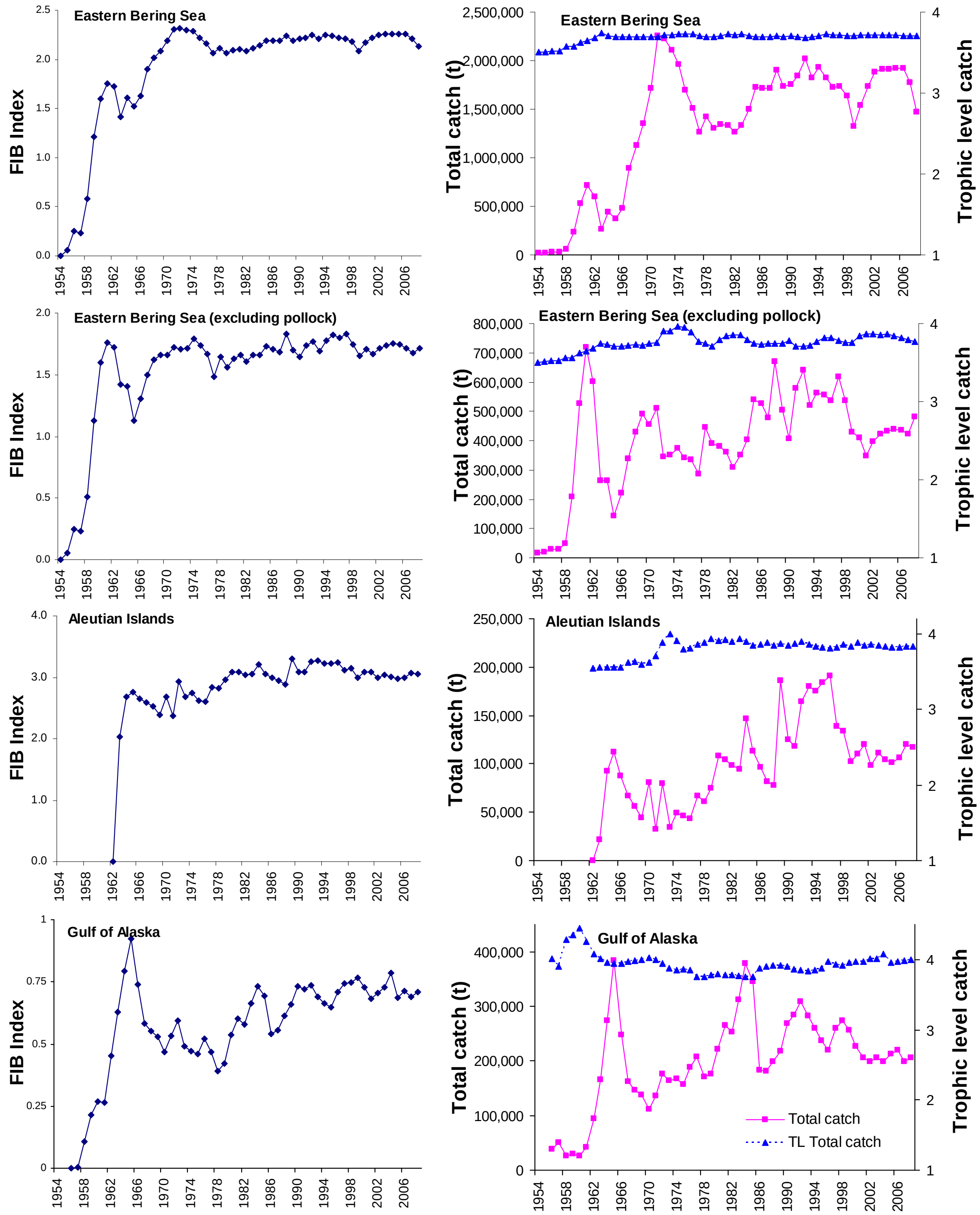

Figure 92. Total catch (groundfish, herring shellfish, and halibut) and trophic level of total catch in the EBS, EBS (excluding pollock), AI and GOA, 1954-2008 (right column). Left column shows FIB index values for the EBS, AI and GOA, 1954-2008.

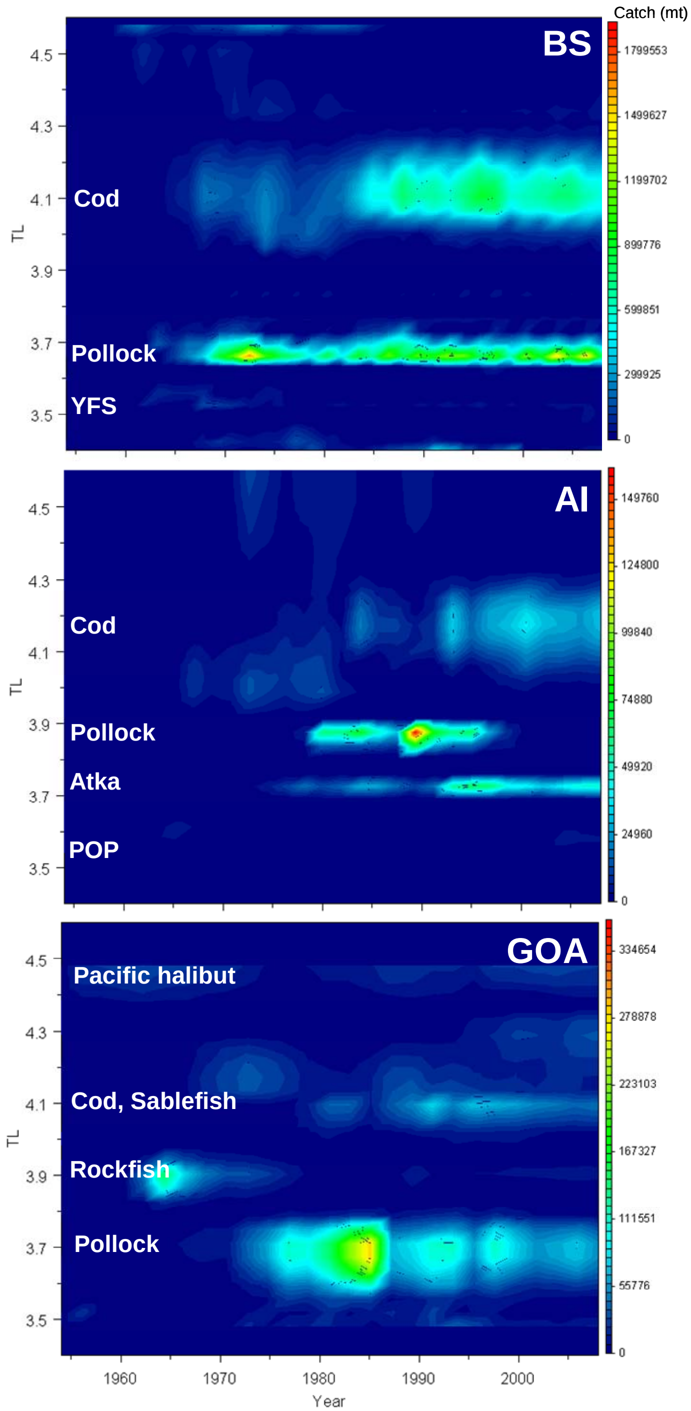

Figure 93. Total catch of all species plotted as color contours by trophic level and year for the Bering Sea, Aleutian Islands, and Gulf of Alaska, 1954-2008. Note: Catch scales are different for each ecosystem. The species that comprise the majority of catches are labeled on the contour plots at the appropriate trophic levels.

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

Updated by Jennifer Boldt, JISAO, University of Washington
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Last Updated: July 2009

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

1. Stock has known status determinations:
    - a) overfishing 0.5
    - b) overfished 0.5
2. Fishing mortality rate is below the "overfishing" level defined for the stock 1.0
3. Biomass is above the "overfished" level defined for the stock 1.0
4. Biomass is at or above 80% of maximum sustainable yield (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. The value of the FSSI is the sum of the individual stock scores. In the Alaska Region, there are 35 FSSI stocks and an overall FSSI of 140 would be achieved if every stock scored the maximum value, 4 (Tables 12 and 13). There are also 25 non-FSSI stocks in Alaska (Tables 12 and 14). There are 230 FSSI stocks in the U.S., with a maximum possible score of 920.

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 GOA Groundfish FMP. In the BSAI Groundfish FMP, similar determinations are made for some stocks in the sharks, skates, sculpins, octopus, rockfish, and flatfish complexes.

Status and trends: As of March 2009, 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 12 and 13). One stock is considered overfished: Pribilof Island blue king crab. Three stocks of crabs are under continuing rebuilding plans: BS snow crab, Pribilof Island blue king crab, and St. Matthew Island blue king crab. EBS Tanner crab is considered rebuilt. New as of March 2009: 12 stocks are no longer contained in the Bering Sea/Aleutian Islands King and Tanner Crabs FMP and the state of Alaska will continue to manage these stocks as they currently do under the deferred management authority of the FMP; Norton Sound Red king crab is not subject to overfishing (was previously unknown) and it is not overfished (was previously unknown); BSAI rougheye rockfish is not overfished (was previously unknown); GOA Rex sole is unknown with respect to its overfished status (was previously not overfished); Pacific halibut is a non-FSSI stock that is now undefined in terms of its overfishing status because it was determined that there is no overfishing definition contained in the FMP (only an overfishing target).

The current overall Alaska FSSI is 117.5 of a possible 140, based on updates through March 2009 (Table 13). The overall Bering Sea/Aleutian Islands score is 74 of a possible maximum score of 88. The BSAI groundfish score is 51 of a maximum possible 52 and BSAI king and tanner crabs score 23 of a possible score of 36. The Gulf of Alaska groundfish score is 39.5 of a maximum possible 48. The sablefish, which are managed as a BSAI/GOA complex, score is 4. For the entire U.S., the score is 557.5 of a possible maximum score of 920.

Factors causing trends: The stocks that had low FSSI scores (1.5) in the GOA are shortspine thornyhead rockfish (indicator species for thornyhead rockfish complex), yelloweye rockfish (indicator species for demersal shelf rockfish complex), and rex sole. The reasons for these low scores are: it is undefined whether these species are overfished and unknown if they are approaching an overfished condition.

Table 12. Description of FSSI and non-FSSI stocks managed under federal fishery management plans off Alaska, March 2009.

Jurisdiction	Stock Group	Number of Stocks	Overfishing					Overfished					Approaching Overfished Condition
			Yes	*No*	*Not known*	*Not defined*	*N/A*	*Yes*	*No*	*Not known*	*Not defined*	*N/A*	
NPFMC	FSSI	35	0	33	2	0	0	1	29	0	5	0	0
NPFMC (and IPHC for halibut)	NonFSSI	25	0	17	1	7	0	0	2	0	23	0	0
	Total	60	0	50	3	7	0	1	31	0	28	0	0

Table 13. This table was adapted from the Status of U.S. Fisheries website, which is updated quarterly: http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm. Information presented in this table is for FSSI stocks and was updated July 2009 (note that these are updated through March 2009 and posted online in July 2009).

Stock	Jurisdiction	Overfishing? (Is Fishing Mortality above Threshold?)	Overfished? (Is Biomass below Threshold?)	Approaching Overfished Condition?	Management Action Required	Rebuilding Program Progress	B/Bmsy or B/Bmsy proxy	Official FSSI Score
Blue king crab - Pribilof Islands	NPFMC	No[47]	Yes	N/A	Continue Rebuilding	Year 6 of 10-year plan	0.07	2
Blue king crab - Saint Matthews Island	NPFMC	No[47]	No - Rebuilding[48]	No	Continue Rebuilding	Year 9 of 10-year plan	1.31	3
Golden king crab - Aleutian Islands	NPFMC	Unknown	Undefined	Unknown	N/A	N/A	not estimated	0
Red king crab - Bristol Bay	NPFMC	No	No	No	N/A	N/A	1.14	4
Red king crab - Norton Sound	NPFMC	No	No	No	N/A	N/A	1.23	4
Red king crab - Pribilof Islands	NPFMC	No[47]	No	Unknown	N/A	N/A	1.70	4
Red king crab - Western Aleutian Islands	NPFMC	Unknown	Undefined	Unknown	N/A	N/A	not estimated	0
Snow crab - Bering Sea	NPFMC	No	No - Rebuilding	No	Continue Rebuilding	Year 9 of 10-year plan	0.69	3
Southern Tanner crab - Bering Sea	NPFMC	No	No	No	N/A	N/A	0.79	3
Alaska plaice - Bering Sea / Aleutian Islands	NPFMC	No	No	No	N/A	N/A	2.46	4
Atka mackerel - Aleutian Islands	NPFMC	No	No	No	N/A	N/A	1.72	4
Bering Sea / Aleutian Islands Arrowtooth Flounder Complex[49]	NPFMC	No	No	No	N/A	N/A	3.53	4
Bering Sea / Aleutian Islands Flathead Sole Complex[50]	NPFMC	No	No	No	N/A	N/A	2.10	4
Bering Sea / Aleutian Islands Rock Sole Complex[51]	NPFMC	No	No	No	N/A	N/A	2.38	4
Greenland halibut - Bering Sea / Aleutian Islands	NPFMC	No	No	No	N/A	N/A	1.46	4
Northern rockfish - Bering Sea / Aleutian Islands	NPFMC	No	No	No	N/A	N/A	1.42	4
Pacific cod - Bering Sea / Aleutian Islands	NPFMC	No	No	No	N/A	N/A	1.00	4
Pacific ocean perch - Bering Sea / Aleutian Islands	NPFMC	No	No	No	N/A	N/A	1.27	4
Blackspotted and Rougheye Rockfish Complex - Bering Sea / Aleutian Islands[52]	NPFMC	No	No	No	N/A	N/A	1.11	4
Walleye pollock - Aleutian Islands	NPFMC	No	No	No	N/A	N/A	0.86	4
Walleye pollock - Eastern Bering Sea	NPFMC	No	No	No	N/A	N/A	0.66	3
Yellowfin sole - Bering Sea / Aleutian Islands	NPFMC	No	No	No	N/A	N/A	1.94	4
Sablefish - Eastern Bering Sea / Aleutian Islands / Gulf of Alaska[53]	NPFMC	No	No	No	N/A	N/A	1.05	4
Arrowtooth flounder - Gulf of Alaska	NPFMC	No	No	No	N/A	N/A	2.98	4
Flathead sole - Gulf of Alaska	NPFMC	No	No	No	N/A	N/A	2.69	4
Gulf of Alaska Deepwater Flatfish Complex[54]	NPFMC	No	No	No	N/A	N/A	2.35	4
Gulf of Alaska Demersal Shelf Rockfish Complex[55]	NPFMC	No	Undefined	Unknown	N/A	N/A	not estimated	1.5
Gulf of Alaska Pelagic Shelf Rockfish Complex[56]	NPFMC	No	No	No	N/A	N/A	1.51	4
Gulf of Alaska Thornyhead Rockfish Complex[57]	NPFMC	No	Undefined	Unknown	N/A	N/A	not estimated	1.5
Northern rockfish - Western / Central Gulf of Alaska	NPFMC	No	No	No	N/A	N/A	1.49	4
Pacific cod - Gulf of Alaska	NPFMC	No	No	No	N/A	N/A	0.91	4
Pacific ocean perch - Gulf of Alaska	NPFMC	No	No	No	N/A	N/A	1.16	4
Rex sole - Gulf of Alaska	NPFMC	No	Undefined[56]	Unknown	N/A	N/A	not estimated	1.5
Blackspotted and Rougheye Rockfish Complex - Gulf of Alaska[52]	NPFMC	No	No	No	N/A	N/A	1.60	4
Walleye pollock - Western / Central Gulf of Alaska	NPFMC	No	No	No	N/A	N/A	0.78	3

47. Fishery in the EEZ is closed; therefore, fishing mortality is very low.
48. Although the most recent stock assessment estimated that B/Bmsy = 1.31, the stock cannot be declared rebuilt until B/Bmsy exceeds 1 in two consecutive years.
49. Arrowtooth Flounder consists of Arrowtooth Flounder and Kamchatka Flounder. Arrowtooth Flounder 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.

50. Flathead Sole 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.
51. Rock Sole 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.
52. 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.
53. 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.
54. The Deep Water Flatfish Complex consists of the following stocks: Deepsea Sole, Dover Sole, and Greenland Turbot. The overfished determination is based on Dover Sole as an indicator species; the overfishing determination is based on the OFL, which is computed by using the dover sole assessment combined with abundance estimates for the remainder of the complex.
55. 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.
56. The Pelagic Shelf Rockfish Complex consists of the following stocks: Dark Rockfish, Dusky Rockfish, Widow Rockfish, and Yellowtail Rockfish. The overfished determination is based on Dusky Rockfish as an indicator species; the overfishing determination is based on the OFL, which is computed by using the dusky rockfish assessment combined with abundance estimates for the remainder of the complex.
57. 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.
58. The most recent stock assessment concluded that the previous determination of not overfished for Rex Sole is invalid.

Table 14. This table was adapted from the Status of U.S. Fisheries website, which is updated quarterly: http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm. Information presented in this table is for non-FSSI stocks and was updated July 2009 (note that these are updated through March 2009 and posted online in July 2009).

Stock	Jurisdiction	Overfishing? (Is Fishing Mortality above Threshold?)	Overfished? (Is Biomass below Threshold?)	Approaching Overfished Condition?	Management Action Required	Rebuilding Program Progress
Golden king crab - Pribilof Islands	NPFMC	Unknown	Undefined	Unknown	N/A	N/A
Bering Sea / Aleutian Islands Other Flatfish Complex[35]	NPFMC	No	Undefined	Unknown	N/A	N/A
Bering Sea / Aleutian Islands Other Rockfish Complex[36]	NPFMC	No	Undefined	Unknown	N/A	N/A
Bering Sea / Aleutian Islands Other Species Complex[37]	NPFMC	No	Undefined	Unknown	N/A	N/A
Bering Sea / Aleutian Islands Squid Complex[38]	NPFMC	No	Undefined	Unknown	N/A	N/A
Shortraker rockfish - Bering Sea / Aleutian Islands	NPFMC	No	Undefined	Unknown	N/A	N/A
Walleye pollock - Bogoslof	NPFMC	No	Undefined	Unknown	N/A	N/A
Atka mackerel - Gulf of Alaska	NPFMC	No	Undefined	Unknown	N/A	N/A
Big skate - Gulf of Alaska	NPFMC	No	Undefined	Unknown	N/A	N/A
Gulf of Alaska Other Skates Complex[39]	NPFMC	No	Undefined	Unknown	N/A	N/A
Gulf of Alaska Other Slope Rockfish Complex[40]	NPFMC	No	Undefined	Unknown	N/A	N/A
Gulf of Alaska Other Species Complex[41]	NPFMC	Undefined	Undefined	Unknown	N/A	N/A
Gulf of Alaska Shallow Water Flatfish Complex[42]	NPFMC	No	Undefined	Unknown	N/A	N/A
Longnose skate - Gulf of Alaska	NPFMC	No	Undefined	Unknown	N/A	N/A
Shortraker rockfish - Gulf of Alaska	NPFMC	No	Undefined	Unknown	N/A	N/A
Walleye pollock - Eastern Gulf of Alaska	NPFMC	No	Undefined	Unknown	N/A	N/A
Alaska Coho Salmon Assemblage[43]	NPFMC	No	No	No	N/A	N/A
Chinook salmon - Eastern North Pacific Far North Migrating	NPFMC	No	No	No	N/A	N/A
Bering scallop - Alaska	NPFMC	Undefined	Undefined	N/A	N/A	N/A
Giant rock scallop - Alaska	NPFMC	Undefined	Undefined	N/A	N/A	N/A
Reddish scallop - Alaska	NPFMC	Undefined	Undefined	N/A	N/A	N/A
Spiny scallop - Alaska	NPFMC	Undefined	Undefined	N/A	N/A	N/A
Weathervane scallop - Alaska	NPFMC	No	Undefined	N/A	N/A	N/A
White scallop - Alaska	NPFMC	Undefined	Undefined	N/A	N/A	N/A
Pacific halibut - Pacific Coast / Alaska	PFMC/NPFMC	Undefined	No	No	N/A	N/A

35. The Other Flatfish Complex consists of the following stocks: Arctic Flounder, Butter Sole, Curlfin Sole, Deepsea Sole, Dover Sole, English Sole, Longhead Dab, Pacific Sanddab, Petrale Sole, Rex Sole, Roughscale Sole, Sakhalin Sole, Sand Sole, Slender Sole, and Starry Flounder. The overfishing determination is based on the OFL, which is computed by using abundance estimates of the complex.
36. The Other Rockfish Complex consists of the following stocks: Dark Rockfish, Dusky Rockfish, Harlequin Rockfish, Redbanded Rockfish, Redstripe Rockfish, Sharpchin Rockfish, Shortspine Thornyhead, and Yelloweye Rockfish. The overfishing determination is based on the OFL, which is computed by using abundance estimates of the complex.
37. The Other Species Complex consists of the following stocks: Antlered Sculpin, Arctic Staghorn Sculpin, Armorhead Sculpin, Banded Irish Lord, Bigmouth Sculpin, Blackfin Sculpin, Blacknose Sculpin, Blob Sculpin, Bride Sculpin, Broadfin Sculpin, Butterfly Sculpin, Crescent-tail Sculpin, Crested Sculpin, Darkfin Sculpin, Eyeshade Sculpin, Flabby Sculpin, Fourhorn Sculpin, Great Sculpin, Grunt Sculpin, Leister Sculpin, Longfin Irish Lord, Longfin Sculpin, Northern Sculpin, Pacific Hookear Sculpin, Pacific Staghorn Sculpin, Plain Sculpin, Purplegray Sculpin, Red Irish Lord, Ribbed Sculpin, Roughskin Sculpin,

Roughspine Sculpin, Sailfin Sculpin, Scaled Sculpin, Scalybreasted Sculpin, Scissortail Sculpin, Slim Sculpin, Smoothcheek Sculpin, Spatulate Sculpin, Spectacled Sculpin, Spinyhead Sculpin, Sponge Sculpin, Tadpole Sculpin, Thorny Sculpin, Threaded Sculpin, Uncinate Sculpin, Warty Sculpin, Wide-eye Sculpin, Yellow Irish Lord, Flapjack Devilfish, Giant Pacific Octopus, Pelagic Octopus, Smoothskin Octopus, Octopus *Benthoctopus oregonensis* , Octopus *Gran* Octopus *Bathypolypus arcticus* , Pacific Sleeper Shark, Salmon Shark, Spiny Dogfish, Alaska Skate, Aleutian Skate, Bering Skate, Big Skate, Butterfly Skate, Commander Skate, Deepsea Skate, Mud Skate, Okhotsk Skate, Roughshoulder Skate, Roughtail Skate, Whiteblotched Skate, and Whitebrow Skate. The overfishing determination is based on the OFL, which is computed by using abundance estimates of skates and sculpins and average historical catch for sharks and octopus.

38. The Squid Complex consists of the following stocks: Squid *Belonella borealis* , Squid *Berryteuthis anonychus* , Squid *Berryteuthis magister* , Squid *Chiroteuthis calyx* , Squid *Cranchia scabra* , Squid *Eogonatus tinro* , Squid *Galiteuthis phyllura* , Squid *Gonatopsis borealis,* Squid *Gonatopsis makko* , Squid *Gonatus berryi* , Squid *Gonatus kamtschaticus* , Squid *Gonatus madokai* , Squid *Gonatus onyx* , Squid *Gonatus pyros* , Squid *Histioteuthis hoylei* , Squid *Moroteuthis robusta* , and Squid *Rossia pacifica* . The overfishing determination is based on the OFL, which is equal to average historical catch.

39. The Other Skates Complex consists of the following stocks: Alaska Skate, Aleutian Skate, Bering Skate, Deepsea Skate, Roughshoulder Skate, Routhtail Skate, and Whiteblotched Skate. The overfishing determination is based on the combined abundance estimates of these species.

40. The Other Slope Rockfish Complex consists of the following stocks: Blackgill Rockfish, Bocaccio, Chilipepper, Darkblotched Rockfish, Greenstriped Rockfish, Harlequin Rockfish, Northern Rockfish (Eastern GOA only), Pygmy Rockfish, Redbanded Rockfish, Redstripe Rockfish, Sharpchin Rockfish, Silvergray Rockfish, Splitnose Rockfish, Stripetail Rockfish, Vermilion Rockfish, and Yellowmouth Rockfish. The overfishing determination is based on the OFL, which is computed by using abundance estimates of the complex.

41. The Other Species Complex consists of the following stocks: Pacific Sleeper Shark, Salmon Shark, Spiny Dogfish, Antlered Sculpin, Armorhead Sculpin, Bigmouth Sculpin, Blackfin Sculpin, Blob Sculpin, Brightbelly Sculpin, Brown Irish Lord, Buffalo Sculpin, Crested Sculpin, Darkfin Sculpin, Dusky Sculpin, Eyeshade Sculpin, Fourhorn Sculpin, Frog Sculpin, Frogmouth Sculpin, Great Sculpin, Grunt Sculpin, Longfin Sculpin, Northern Sculpin, Pacific Staghorn Sculpin, Plain Sculpin, Red Irish Lord, Ribbed Sculpin, Roughspine Sculpin, Roughskin Sculpin, Sailfin Sculpin, Scissortail Sculpin, Silverspotted Sculpin, Slim Sculpin, Smoothcheek Sculpin, Smoothhead Sculpin, Spatulate Sculpin, Spectacled Sculpin, Spinyhead Sculpin, Sponge Sculpin, Spotfin Sculpin, Tadpole Sculpin, Thorny Sculpin, Threaded Sculpin, Threadfin Sculpin, Warty Sculpin, Yellow Irish Lord, Sculpin *Artediellus sp* ., Sculpin *Icelus euryops* , Flapjack Devilfish, Giant Pacific Octopus, Pelagic Octopus, Red Octopus, Smoothskin Octopus, Vampire Squid, North Pacific Bigeye Octopus, Squid *Berryteuthis an* Squid *Berryteuthis magister* , Squid *Chiroteuthis calyx* , Squid *Cranchia scabra* , Squid *Eogonatus tinro* , Squid *Galiteuthis phyllura* , Squid *Gonatopsis makko* , Squid *Gonatus berryi* , Squid *Gonatus kamtschaticus* , Squid *Gonatus madokai* , Squid *Gonatus onyx* , Squid *Gonatus pyros* , Squid *Histioteuthis hoylei* , Squid *Loligo opalescens* , Squid *Moroteuthis robusta* , Squid *Octopoteuthis deletron* , and Squid *Onychoteuthis borealijaponicus* . There is no OFL specified for this complex. The TAC is set at an amount less than or equal to 5 percent of the combined TACs for the remainder of the groundfish fishery.

42. The Shallow Water Flatfish Complex consists of the following stocks: Alaska Plaice, Butter Sole, C-O Sole, Curlfin Sole, English Sole, Northern Rock Sole, Pacific Sanddab, Petrale Sole, Sand Sole, Slender Sole, Southern Rock Sole, Speckled Sanddab, Starry Flounder, and Yellowfin Sole. The overfishing determination is based on the OFL, which is computed by using abundance estimates of the complex.

43. The coho salmon assemblage consists of coho, sockeye, pink, and chum salmon throughout southeast Alaska. There are 4 indicator stocks of coho salmon that are used to determine the status of the assemblage; these indicator stocks are Auke Creek, Berners River, Ford Arm Lake, and Hugh Smith Lake.

46. The resource is managed by treaty between the United States and Canada through recommendations of the International Pacific Halibut Commission. Pacific halibut is managed under the jurisdiction of the PFMC for WA, OR, and CA and under the jurisdiction of the NPFMC for Alaska.

Total Annual Surplus Production and Overall Exploitation Rate of Groundfish

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Last updated: August 2009

Description of indices: Total annual surplus production (ASP) of groundfish on the Eastern Bering Sea shelf (EBS) from 1977-2007 and on the Gulf of Alaska (GOA) shelf from 1977-2006 was estimated by summing annual production across major commercial groundfish stocks for which assessments were available. These species represent at least 70-80% of the total catch in bottom trawl surveys. Annual surplus production in year *t* can be estimated as the change in total adult groundfish biomass across species from year *t* (B_t) to year *t*+1 (B_{t+1}) plus total catches in year *t* (C_t):

$ASP_t = \Delta B_t + C_t = B_{t+1} - B_t + C_t$

All estimates of B and C are based on 2008 stock assessments in the EBS and 2007 assessments in the GOA. An index of total exploitation rate within each region was obtained by dividing the total groundfish catch across the major commercial species by the combined biomass at the beginning of the year:

$u_t = C_t / B_t$

Status and trends: The resulting indices suggest high variability in groundfish production in the eastern Bering Sea (Figure 94) and a decrease in production between 1977 and 2007 (slope = - 60,700 mt / year, t = -1.940, p = 0.062). Annual surplus production in the GOA was much lower on average, less variable, and decreased slightly over the same time period (slope = - 7,890 mt/ year, t = -0.675, p = 0.505). Total exploitation rates for the groundfish complex were generally much higher in the EBS than in the GOA and were highest in the early part of the time series due to high exploitation rates of walleye pollock (Figure 94). The overall exploitation rate in the EBS reached a low of 6.9% in 1999 and increased to 12% by 2006 and 2007, while the exploitation rate in the Gulf of Alaska has generally been less than 6% except in 1984/85.

Because trends in annual surplus production in the Eastern Bering Sea are almost entirely driven by variability in walleye pollock, ASP_t for the Bering Sea was also computed after excluding walleye pollock (Figure 95). The results suggest a pronounced decrease in aggregate surplus production of all non-pollock species over time from a high of over 1 million tons in 1979/1980, due to strong recruitment of a number of species, to lows of around 300,000 t in the late 1990s and in the most recent years. This trend was reflected in ASP of individual species and was particularly pronounced in yellowfin sole, Greenland turbot, and flathead sole, whereas arrowtooth flounder and northern rockfish showed an increasing trend in ASP over time, followed by decreases in recent years.

Factors causing observed trends: Annual Surplus Production is an estimate of the sum of new growth and recruitment minus deaths from natural mortality (i.e. mortality from all non-fishery sources) during a given year. It is highest during periods of increasing total biomass (e.g. 1991-92 in the EBS) and lowest during periods of decreasing biomass (e.g. 1982-1984 in the GOA and 2004-2007 in the EBS). In the absence of a long-term trend in total biomass, ASP is equal to the long-term average catch. Theory suggests that surplus production of a population will decrease as biomass increases much above B_{MSY}, which has been the case for a number of flatfish species (e.g. rock sole, flathead sole) and rockfish species (Pacific ocean perch, northern rockfish).

Exploitation rates are primarily determined by management and reflect a relatively precautionary management regime with rates that have averaged less than 10% across species in the EBS over the last decade. Exploitation rates are much lower in the GOA because of the very limited exploitation of arrowtooth flounder, which currently make up the majority of the biomass in the GOA. If arrowtooth flounder are excluded, rates are comparable to those in the EBS.

Implications: Under certain assumptions, aggregate surplus production can provide an estimate of the long-term maximum sustainable yield of these groundfish complexes (Mueter and Megrey 2006, Figure 96). A plot of aggregated ASP against aggregated mid-year biomass suggests very little contrast in total biomass over time. Nevertheless, it appears that biomass was generally above the level that would be expected to yield maximum surplus production under a Graham-Schaefer model fit to aggregate ASP (Figure 96). The recent decrease in aggregate biomass in the EBS from 2005 to 2007 (largely due to decreases in walleye pollock abundance) to levels last seen in the late 1970s was associated with an increase in aggregate ASP, suggesting that compensatory mechanisms may be starting to increase production through increases in growth or reduced predation mortality. However, recent aggregate ASP is still far below the levels in 1980, when aggregate biomass was very similar to 2007.

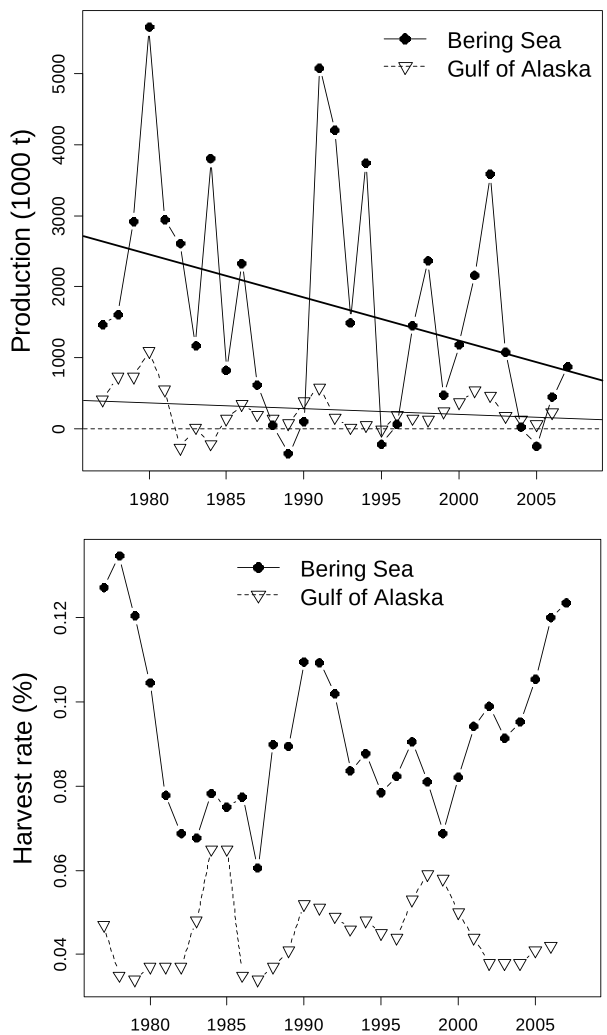

Figure 94. Total annual surplus production (change in biomass plus catch) across all major groundfish species in the Gulf of Alaska and Bering Sea with estimated linear trends (solid lines) and total harvest rate (total catch / beginning-of-year biomass) across all major groundfish species in the Gulf of Alaska and Bering Sea.

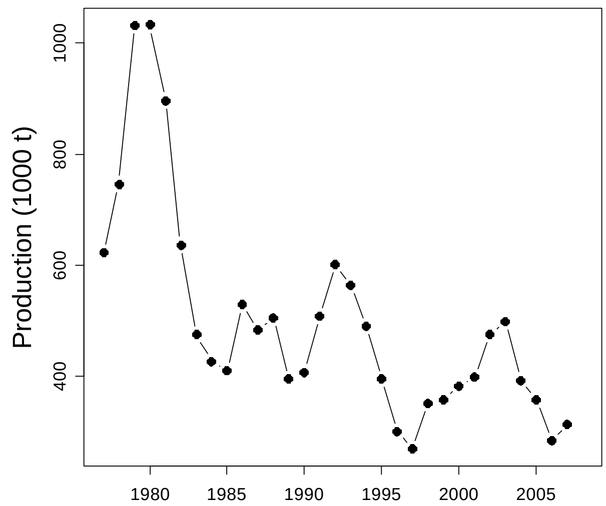

Figure 95. Total annual surplus production (change in biomass plus catch) in the Bering Sea across all major groundfish species, excluding walleye pollock.

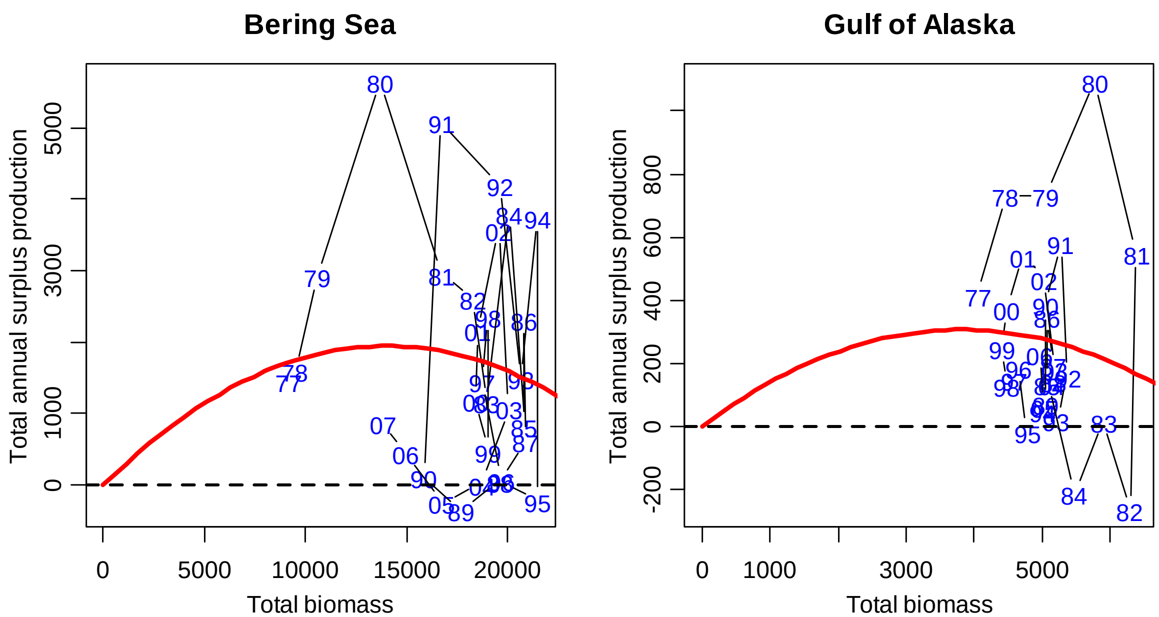

Figure 96. Estimated annual aggregated surplus production against total biomass of major commercial species with fitted Graham-Schaefer model.

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

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Last updated: August 2008

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

Ecosystem Goal: Humans are part of ecosystems

Fishing Overcapacity Programs

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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 overcapacity in the Alaskan fisheries. Moratorium programs were implemented in the crab scallop, and groundfish fisheries to limit the number of harvesting vessels that may be deployed off Alaska, and access has since been limited further by replacing the moratoria with license limitation programs (LLP). Capacity reduction ("buyback") programs have been used to permanently retire vessels, licenses, and participation histories through monetary compensation. However, rights-based management such as individual transferable quotas and dedicated allocations to cooperatives has increasingly being used to "rationalize" fisheries. And, "sideboard" measures prevent "spillover" effects due to imposition of right-based programs.

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 explicitly 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. A similar program developed by the Council, beginning in 2005, placed management of most crab fisheries of the Bering Sea and Aleutian Islands (BSAI) under a quota system, in which quota shares were issued to harvesters (including vessel captains) and processors. The program also includes community protection measures and provides for voluntary harvesting cooperatives. Some features of this crab program had to be authorized by Congressional action. As a prelude to a more complex GOA rationalization program, the National Marine Fisheries Service (NMFS), in response to a Congressional mandate and in consultation with the Council, developed a demonstration quota program for Central Gulf of Alaska rockfishes, since extended to five years. 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.

Moratorium on New Vessels

NMFS implemented a moratorium on new vessel entry into the federally managed groundfish and crab fisheries in 1996 and for scallops in 1997. The programs were considered place holders while more comprehensive management measures were developed. The owners of 1,864 groundfish and 653 crab vessels held moratorium fishing rights at the time the groundfish and crab program was sunsetted (December 31, 1999). In addition to limiting the number of vessels the moratorium also restricted the lengths of vessels that could be deployed under moratorium permits. Qualifying vessels that were less than 125' in length overall received licenses that had a maximum length overall of 120 percent of the qualifying vessel's length on June 24, 1992, or up to 125', whichever is less; vessels that were 125' or longer could not increase their length. The concern over increasing vessel length arises because such actions can increase harvesting capacity even though additional vessels are prohibited from entering a fishery, thus undermining the effectiveness of a moratorium.

License Limitation Program for Groundfish and Crab

The LLP for groundfish and crab vessels was implemented on January 1, 2000 to replace the vessel moratorium. The original LLP, approved in 1995, was intended as the second step in fulfilling the Council's commitment to develop a comprehensive and rational management program for fisheries off Alaska. Amendments to that program recommended by the Council in 1998 and April 2000 tightened the LLP program and included additional restrictions on crab vessel numbers and on fishery crossovers. The amendments also limited participation in the non-trawl BSAI Pacific cod fisheries. The LLP reduced the number of harvesting vessels eligible to participate in the BSAI crab fisheries by more than 50% relative to the vessel moratorium (down to about 347 licenses), of which for the fourth year under rationalization, 127 were licensed and 88 fished under rationalized fisheries, respectively. The number of current LLP groundfish licenses (1,824) is similar to the number that held moratorium permits and some of both types of licenses were or are not actively used. At present, only 1,468 groundfish LLP licenses name vessels. However, the groundfish LLP is more restrictive than that for the crab fisheries which indicate allowed fisheries. For groundfish, endorsements control areas in which a license holder can fish and the types of gear that may be deployed. Also important to note is that the vast majority of the vessels that can be deployed under the LLP are longline vessels less than 60' (and are eligible to participate only in Gulf of Alaska fisheries). These vessels have typically had relatively small catch histories in past years. The LLP Program was modified to accommodate changes implemented under the Crab Rationalization Program (CR Crab). In addition to crab endorsement changes resulting from new quota fisheries, some groundfish licenses were modified to incorporate "sideboard" restrictions, as they have become known, on GOA groundfish activities to avoid "spillover" effects of excess crab capital on groundfish fisheries.

In April, 2008 the Council recommended reducing "latent" capacity in trawl groundfish fisheries by creating a new "recent participation" requirement for licenses and endorsements. NMFS published a proposed rule (73 FR 79773, December 30, 2008) and preparing a final rule to implement the new requirements, under which harvesting privileges unused in recent years might be forfeit. Vessels not actively fishing as a result of provisions of existing programs (such as AFA cooperatives) would be exempted from these requirements. The Council also recommended adding an Aleutian Islands area endorsement to some trawl groundfish licenses to provide sufficient harvesting capacity, particularly for Pacific cod. This harvesting authority was not earned under original LLP eligibility rules due to absence of processors operating in the remote AI subarea in qualifying years.

To limit effort in the GOA Pacific cod fishery, at its April 2009 meeting, the Council recommended revising the LLP program by adding gear-specific (pot, hook-and-line, and jig) Pacific cod endorsements to Western and Central GOA fixed gear LLP licenses. Vessels will be required to hold a Pacific cod endorsement to participate in the directed Pacific cod fisheries in the Western and Central GOA. Endorsements would be based on license participation. NMFS is developing a proposed rule and implementing regulations.

License Limitation Program for Scallops (LLPS)

The LLPS was implemented in 2001 to replace a 1997 temporary vessel moratorium program for this fishery. Under the LLPS, nine persons were issued transferable licenses authorizing them to deploy vessels in the scallop fishery off Alaska. The licenses restrict the lengths of vessels and the size and amount of gear that may be used.

Bering Sea and Aleutian Islands Crab "Buyback" and Rationalization

The North Pacific Fishery Management Council developed, and NMFS has implemented, a plan to rationalize the BSAI crab fishery.

A statutory change to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) authorized an industry-funded buyback program for the crab fisheries. In late 1994, this program permanently retired the fishery endorsements of 25 vessels, and LLP crab licenses and vessel histories; as well as 15 limited entry licenses for groundfish (and some halibut quota share) associated with those histories. The program was approved by an industry referendum in which a majority of participants approved the proposed effort reduction and a debt retirement burden of $97.4 million.

The Council also developed, and NOAA Fisheries Service, has implemented, the Crab Rationalization Program (CR Crab). This program includes allocations to Community Development Quota Groups, an allocation of one species of king crab to the community of Adak, and a complex quota system for harvesters and processors called the "three-pie voluntary cooperative program". CR Crab program attempts to balance the interests of several identifiable groups that depend on these fisheries. Allocations of harvest shares are made to harvesters, including captains. Processors are allocated processing shares. Community protection measures are designed to help provide economic viability of fishery-dependent communities. Designated regions are allocated landings and processing activity to preserve their historic interests in the fisheries. Harvesters are permitted to form cooperatives to realize efficiencies through fleet coordination. The novelty of the program has compelled the Council to include several safeguards into the program, including a binding arbitration program for the resolution of price disputes and extensive economic data collection and review programs to assess the success of the rationalization program. These safeguards, together with the Council's continuing development of the program through a series of ongoing amendments and clarifications, demonstrate the Council's commitment to a fair and equitable rationalization program that protects the interests of those dependent on the BSAI crab fisheries.

As of July 2009, NOAA Fisheries Service has initially issued one or more types of harvesting quota to 489 distinct persons; and processing quota to 27 persons. For harvesters, NOAA Fisheries initially issued quota to 270 applicants who qualified based on holding a transferable LLP crab license; and to 231 individuals who qualified for "Captain" (also known as "crew") shares by virtue of both historic and recent participation in these crab fisheries. Fishing under Crab Rationalization began with two Aleutian Islands golden king crab fisheries, in August 2005. During the first year of the program, fishery managers determined that for conservation reasons, the Bering Sea *Chionoecetes bairdi* Tanner crab (BST) biomass should be managed in two separate fisheries. Just prior to the start of the second crab fishing year, NMFS issued all current holders of BST quota shares for both the new Eastern and Western Bering Sea *C. bairdi* fisheries. As of the end of the fourth crab fishing year under rationalization, 481 persons were holding harvesting quota share (QS), and 30 were holding PQS. Of the persons holding harvesting QS, 291 held "owner" type, and 206 individual persons held "crew" type. Consolidation has occurred in the crab fisheries, due largely to widespread use of cooperatives and to some attrition of initial issuees out of the fisheries without total replacement by new entrants. During the first four years under rationalization, the numbers of vessels authorized, and actually used, to harvest crab decreased from 154 to 127; and from 101 to 88, respectively. The Council has changed the rationalization program to address a number of issues, including those that relate to capacity in various sectors.

Starting with the fourth crab fishing year on July 1, 2008 NMFS implemented a change required by statute as part of crab FMP Amendment 25 (73 FR 29979, May 23, 2008). This change allows three corporations initially issued certain types of harvesting QS or processing PQS to annually combine the harvester and processor IFQ/IPQ held by them and their affiliates and change it into catcher processor IFQ for use in the north region. This program feature should preserve economic benefits from crab-related State tax revenues shared with northern communities while providing operational flexibility for program participants.

The Council recommended measures to both relieve some restrictions and create some new ones for holders and users of "crew" QS. Under FMP Amendment 26 "crew" quota share and IFQ are exempt from requirements for delivery to specific processors, delivery within specific geographic regions, and participation in an arbitration system to resolve price disputes, previously due to take effect in the fourth program year. NMFS published a final rule to implement Amendment 26 on June 20, 2008 (73 FR 35084). The Council also made recommendations at its April 2008 meeting on active participation criteria to ensure that persons obtaining, holding, and using "crew" QS and IFQ remain personally involved in crab harvesting activities.

The Council recommended exemptions for custom processed crab from IPQ use caps. NMFS implemented regulations under crab FMP Amendment 27 (74 FR 25449, May 28, 2009) which is intended to protect crab revenues historically available to fishery-dependent economies while providing operational and business flexibility to processors.

Finally, the Council received an 18-month status report on crab rationalization in April, 2007, and a major 3-year program review in December, 2008; and is analyzing a number of proposed program changes that might affect capacity.

Sablefish and Halibut Individual Fishing Quotas

The halibut and sablefish fisheries provide good examples of how the Council is working to control overcapacity in fisheries off Alaska. From 1975 to 1994 the Central Gulf of Alaska halibut fishing seasons decreased from approximately 125 days to single day openings, while catches increased. Faced with very short seasons and increasing fishing effort, the Council recommended an IFQ program for both the halibut and fixed gear sablefish fisheries. These programs were initiated in 1995. After implementation, the traditional short, pulse fisheries were extended to more than eight months long. Individual Fishing Quota has allowed participants to better match fishing capacity with the amount of fish they are allowed to harvest during a year, improving economic efficiency for harvesters and decreasing gear conflicts on fishing grounds, among other salutary effects. The program includes a means for non-profit representatives of small GOA communities to purchase quota for use by residents, protecting fishery-dependent revenue and employment. Since the start of the program, the numbers of vessels and QS holders have continued to decline, even as new persons entered the fisheries and the TACs increased. A total of 4,829 persons were initially issued halibut quota share (QS) and 1,054 were initially issued sablefish QS. At the end of 2008, 2,909 persons held halibut QS and 853 held sablefish QS. The number of vessels landing halibut in the IFQ fishery declined from 3,450 in 1994, just prior to the IFQ and CDQ halibut programs , to 1,157 at the end of 2008; the number landing sablefish in the IFQ fishery declined from 1,191 in 1994 to 359 in 2008.

American Fisheries Act

The American Fisheries Act (AFA), passed in late 1998, retired nine catcher-processors under a "buyback" program, limited entry of additional harvesting vessels, authorizes harvesting cooperatives to which a portion of the total allowable catch of BSAI pollock is granted, prevents pollock fishery participants from expanding historical activities to other fisheries, and stabilized deliveries to shoreside processors. Only harvesting and processing vessels that met specific requirements, based on their participation in the 1995-97 fisheries are eligible to harvest BSAI pollock. At the inception of the AFA, 21 catcher/processors and 112 catcher vessels qualified, or were specifically identified, as eligible to participate under the AFA guidelines. Nine other catcher/processors were bought out at a cost of $90 million.

Specific provisions in the AFA allow for the formation of cooperatives among catcher/processors, among the catcher vessels that deliver to the catcher-processors, among eligible motherships and catcher vessels in the mothership sector, and among the eligible catcher vessels in the inshore sector of the BSAI pollock fishery. Within each cooperative, each member company is then contractually allocated a percentage share of the total cooperative allocation based on its historical catch (or processing) levels. The catcher-processor cooperative is called the Pollock Conservation Cooperative (PCC) and is made up of eight companies that own 19 of the 20 catcher-processors currently eligible to fish in the pollock fishery (the fishing privileges of the 21st eligible vessel were purchased by the PCC in 2000, and one eligible vessel has not joined the PCC). The catcher vessel cooperative is called the High Seas Catchers' Cooperative (HSCC), and comprises seven catcher vessels authorized under the AFA to deliver to the eligible catcher/processors (these vessels had traditionally delivered the majority of their pollock to catcher/processors).

Under the AFA, the PCC is currently allocated 91.5% of the total offshore pollock allocation (the rest is allocated to members of the HSCC). When the new fishery cooperative structure was adopted in 1999, not all of the eligible catcher/processors fished during the 1999 late winter and early spring pollock seasons; four catcher/processors opted not to fish during the winter season and six chose not to fish during the summer season. This pattern continued in 2000 and 2001 when four and three catcher/processors were idle in the winter season, respectively. Five of the catcher/processors were idle in both 2000 and 2001 for the summer season. In 2002, three vessels were idle in the winter season and four were idle in the summer season. Two vessels were idle during the winter season in each of the six years from 2003 to 2008. During the summer season, three vessels were idle in 2006; four vessels were idle in 2003, 2004, 2005, and 2007; and five vessels were idle in 2008. The variations in vessel participation can probably be attributed to the variations in the pollock TAC.

The HSCC is allocated 8.5% of the offshore pollock allocation. However, since the formation of the cooperative, they have leased much of their TAC allocation for pollock to catcher/processors. In fact, since 1999, none of the seven HSCC vessels have engaged in directed fishing for pollock, choosing instead to lease their catch to the AFA catcher/processor fleet.

The AFA also authorizes three motherships to participate in the BSAI pollock fishery. In 1998, 31 vessels landed greater than 10 mt of pollock to be processed by offshore motherships. In 1999, this number decreased to 27. In 2000, the first year in which a cooperative was operating in the mothership sector, 19 of the 20 catcher vessels eligible to deliver pollock to these motherships actually did so. The same number of vessels made deliveries to motherships in 2001, dropped to 17 vessels annually in 2002 and 2003, increased to 18 in 2004, and dropped again to 17 annually for the four years 2005-2008.

In 1998 107 inshore catcher vessels each delivered more than 10 mt of pollock to inshore processors (including stationary floating processors). That number decreased slightly in 1999 (100 vessels), again decreased in the 2000 roe fishery (91 vessels), remained at that level in 2001, and dropped to 85 in 2002. The number of vessels delivering at least 10 mt of pollock to inshore processors remained at 85 vessels for the four years 2003-2006, fell to 83 in 2007, and remained at 83 in 2008.

Finally, it should be noted that the AFA also restricts eligible vessels from shifting their effort into other fisheries. "Sideboard" measures prevent AFA eligible vessels from increasing their catch in other fisheries beyond their average 1995-97 levels. Sideboard restrictions reduce the likelihood that the fishing capacity of AFA eligible vessels will spill over and compete in other fisheries.

Two recent acts of Congress provided additional authority and guidance to the Council and NMFS for developing and implementing limited access privilege (LAP) programs. Under these authorities, the Rockfish Pilot Program, a BSAI groundfish capacity reduction ("buyback") program, and Amendment 80 to the FMP for the BSAI are in various stages of development or implementation by the Council and/or NMFS.

Rockfish Pilot Program
Congress granted NMFS specific statutory authority to manage Central GOA rockfish fisheries in Section 802 of the Consolidated Appropriations Act of 2004 (Pub. L. 108-199; Section 802). The North Pacific Fishery Management (Council) was required to establish the Rockfish Pilot Program, to provide exclusive harvesting and processing privileges for a specific set of rockfish species and for associated species harvested incidentally to those rockfish in the Central GOA, an area from 147 ˚W to 159 ˚W. The Program is intended to increase resource and improve economic efficiency for harvesters and processors who participate in the fishery. Initially for two years, later extended to the five year period through December, 2011, exclusive harvesting and processing privileges were allocated for three primary rockfish species and for five incidentally harvested secondary species in the Central GOA, with annual associated pounds. NMFS also allocated a portion of the total GOA halibut mortality limit to participants based on historic halibut mortality rates in the primary rockfish species fisheries.

Under the Rockfish Program NMFS:
1. Assigned quota share (QS) for primary rockfish species to an LLP license with a trawl gear designation in the Central GOA.
2. Established eligibility criteria for processors to have an exclusive privilege to receive and process primary rockfish species and secondary species allocated to harvesters in this Program.
3. Allows a person holding a LLP license with QS to form a rockfish cooperative with other persons (i.e., harvesters) on an annual basis.
4. Allows rockfish cooperatives to transfer all or part of their CFQ to other rockfish cooperatives, with some restrictions.
5. Provides an opportunity (annually) for a person not in a rockfish cooperative, but who holds an LLP license with QS, to fish in a limited access fishery.
6. Establishes a small entry level fishery for Central GOA rockfish for harvesters and processors not eligible to receive QS under this Program.
7. Allows holders of catcher/processor LLP licenses to opt-out of the Program annually, with certain limitations.
8. Limits the ability of processors to process catch outside the communities in which they have traditionally processed primary rockfish species and associated secondary species.
9. Establishes catch limits, commonly called “sideboards”, to limit the ability of participants eligible for this Program to harvest fish in fisheries other than the Central GOA rockfish fisheries.
10. Created a monitoring and enforcement mechanism to ensure that harvesters maintain catches within their annual allocations and will not exceed sideboard limits.

In 2007, QS was initially awarded and attached to 62 distinct LLP licenses, 47 of which were catcher processor licenses and 15 of which were catcher vessel licenses. LLP holders formed 7 catcher vessel harvesting cooperatives in 2007 and 8. Cooperatives may transfer primary species allocation to other cooperatives.

Capacity Reduction in Non-Pollock Groundfish Fisheries of the Bering Sea and Aleutian Islands
Under the Consolidated Appropriations Act of 2005 (Public Law 108-447) and Consolidated Appropriations Act of 2004 (Public Law 108-199), NMFS implemented a capacity reduction program pursuant to applicable provisions of the MSA (15 U.S.C. 1861a(b-e)). The program reduced current and future effort in the non-pollock groundfish fisheries in the BSAI through a “buyback” program to retire vessels, licenses, and vessel histories. The legislation provided for a total loan of up to $75 million and authorizes specific amounts for four subsectors in the fishery: longline catcher processors, AFA trawl catcher processors, non-AFA catcher processors, and pot catcher processors. A separate program will be developed for each subsector, with the first, for longline catcher processors, in effect. 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

On September 29, 2006, NMFS published the final rule in the **Federal Register** (71 FR 57696) to implement this buyback program. On January 5, 2007, the Freezer Longline Conservation Cooperative (FLCC) submitted their Fishing Capacity Reduction Plan (Plan) to the NMFS Financial Services Division. The Plan included four (4) formal offers for catcher processor groundfish licenses that would be removed from the fishery, and that the FLCC members had selected. The 4 offers included three (3) active fishing licenses that were associated with 3 catcher processor vessels. The fourth offer was that of an inactive license, with no vessel associated with the license. The total amount of the government loan was $35 million, to be repaid over a thirty (30) year period using a percentage of future fish landings of BSAI Pacific cod.

On March 16, 2007 NMFS approved the FLCC's plan. On March 21, 2007, NMFS issued ballots to the voting members of the FLCC to vote in a referendum to determine industry support of the fishing capacity reduction loans. On April 6, 2007, voting in the referendum was completed, with 87 percent participation in the referendum. Thirty-four (34) voters cast ballots, unanimously in favor of the reduction plan. Therefore, the referendum was successful, and the referendum voters approved the repayment fees for the $35 million fishing capacity reduction loan.

On April 26, 2007, NMFS issued a payment tender notice in the Federal Register (72 FR 20836), and provided thirty (30) days for public notice before tendering payment. On May 29, 2007, NMFS disbursed payments to the owners of the 4 fishing licenses that were being relinquished as part of the reduction capacity program. In exchange for payment, the owners relinquished their fishing licenses, reduction privilege vessels where appropriate, and fishing histories.

Amendment 80

The Council adopted Amendment 80 in June, 2006 to meet the broad goals of: (1) improving retention and utilization of fishery resources by the non-AFA trawl catcher/processor fleet by extending the groundfish retention standard (GRS) to non-AFA trawl catcher/processor vessels of all lengths; (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.

In response to requirements of the Consolidated Appropriations Act of 2005 (Public Law 108-447) on September 14, 2007 NMFS published a Final Rule in the **Federal Register** with regulations to implement Amendment 80 to the FMP for the BSAI (72 FR 52668). Under this Amendment, vessels owned, and/or LLP licenses held, by eligible participants were allocated quota for target groundfish species, based on historic participation. Including combinations of allocated species and fishing areas, there are a total of 11 quota categories. Quota holders annually receive pound allocations based on quota holdings, and can elect to form harvesting cooperatives or participate in a limited access fishery. Cooperatives and the limited access fishery are each allocated amounts of bycatch of Pacific halibut and crab, which are prohibited species in groundfish fisheries; inter-cooperative allocation transfers are authorized. Caps limit the amounts of quota a person may hold at any time. Sideboard provisions limit "spillover" effects of this program on other fisheries and required reporting allows NMFS and the Council to monitor the efficacy of the program over time. Regulations list 28 vessels and LLP groundfish licenses that are be designated

Amendment 80 vessels and licenses, respectively. The groundfish species in the BSAI directly affected by Amendment 80 include:

- Atka mackerel
- Aleutian Islands Pacific ocean perch
- Flathead sole
- Pacific cod
- Rock sole
- Yellowfin sole

In addition, Amendment 80 modified the management of halibut and crab prohibited species catch (PSC) limits.

Amendment 85

At its April, 2006 meeting, the Council took final action to recommend Amendment 85 to the FMP for the BSAI, which would modify the current annual allocations of BSAI Pacific cod (after deductions for the CDQ fishery) 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. NMFS has implemented these changes starting in 2008.

Parallel Waters Fisheries

At its June, 2009 meeting, the Council took final action on a regulatory amendment package that limits access by federally-permitted pot and hook-and-line catcher processor vessels to the BSAI Pacific cod parallel State waters fishery and precludes 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 is developing implementing regulations. The Council also is considering limitations for Federally-permitted vessels fishing in GOA parallel waters fisheries.

Arctic FMP

The Council recommended a new Fishery Management Plan for Fish Resources of the Arctic Management Area (Arctic FMP) and Amendment 29 to the Fishery Management Plan for Bering Sea/ Aleutian Islands King and Tanner Crabs (Crab FMP). The Arctic FMP and Amendment 29 to the Crab FMP, if approved, would establish sustainable management of commercial fishing in the Arctic Management Area and move the northern boundary of the Crab FMP out of the Arctic Management Area south to Bering Strait. NMFS published a proposed rule to establish this FMP (74 FR 27498, June 10, 2009).

Guided Sport Halibut

On March 31, 2007 the Council recommended a moratorium on entry into the guided sport fishery for IPHC areas 2C and 3A, using a control date of December 9, 2005. NMFS published a proposed rule (74 FR 18179, April 21, 2009) with implementing regulations. This sector has been operating under a guideline harvest level (GHL) for several years. For both areas the GHL has been exceeded, in 2C by a substantial amount in the past few years, with future service demand expected to increase. Under the program, NMFS would issue Federal charter halibut permits (CHP) to individual U.S. citizens and to primarily U.S.-owned businesses with historical participation based on required State logbook reporting and State and USCG licensing. Other program features include:

1. minimum participation tests to receive a license(s);
2. caps on the number of licenses that could be held by a person;

3. transferability of most permits, with a prohibition on permit leasing;
4. permit endorsements for numbers of clients;
5. special licenses to be issued to communities identified under IFQ Amendment 66; and
6. a military hardship provision.

At its October, 2008 meeting the Council adopted a final preferred alternative to replace the current guideline harvest level program for the charter halibut fisheries in Area 2C (Southeast) and Area 3A (Southcentral) with a catch sharing plan between the charter sector and commercial setline IFQ fisheries in each of those areas. The purpose of the Plan is to establish a clear allocation, with sector accountability, between the charter and commercial setline sectors in each area. Under the plan the Council would request that the International Pacific halibut Commission (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 action also included a program to use "guided angler fish" (GAF), in which holders of charter halibut permits could purchase annual IFQ halibut from the commercial fishery for use in individual accounts, to support halibut retention by their guided sport anglers.

Groundfish Fleet Composition

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Last updated: October 2009

Fishing vessels participating in federally-managed groundfish fisheries off Alaska principally use trawl, hook and line, and pot gear. 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. They both were high in 1994 and then decreased annually through 1998 before increasing slightly in 1999 and 2000, and then declining again in 2001 and 2002. The increase, in 2003, in the number of hook-and-line vessels (and, consequently, also in the total number of vessels) is a result of the change from blend to Catch-Accounting System (CAS) data; CAS data now include the Federal Fisheries Permit number of catcher vessels delivering both to motherships and to shoreside processors, making possible a more complete count of participating vessels. The total number of vessels was about 1,518 in 1994, decreased to 1,250 in 1998, and was 920 in 2008, the most recent year for which we have complete data (Figure 97). Hook and line vessels accounted for about 1,225 and 585 of these vessels in 1994 and 2008, respectively. The number of vessels using trawl gear decreased from 257 in 1994 to 191 in 2008. During the same period, the number of vessels using pot gear peaked in 2000 at 343, decreased to a low of 179 in 2002, increased again to 204 in 2004, and then decreased to 193 in 2008. Vessel counts in these tables were compiled from blend and Catch-Accounting System estimates and from fish ticket and observer data.

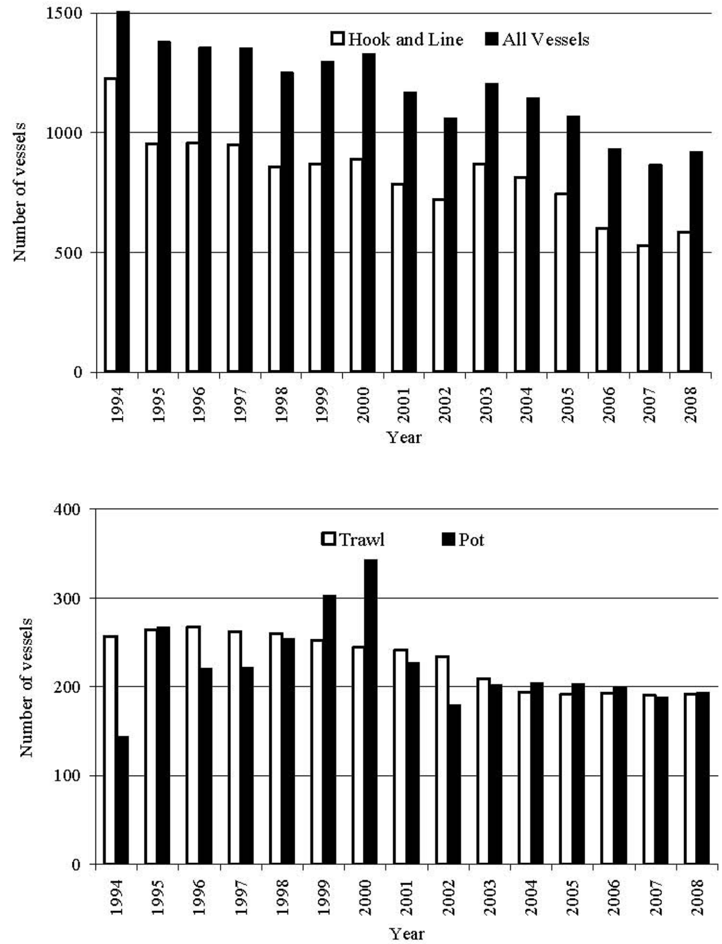

Figure 97. Number of vessels participating in the groundfish fisheries off Alaska by gear type, 1994-2007.

Distribution and Abundance Trends in the Human Population of the Gulf of Alaska
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See the 2007 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

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APPENDIX 1

Essential Fish Habitat Research by AFSC
See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Effects of Fishing Gear on Seafloor Habitat
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Last updated: October 2008

In 1996, the Alaska Fisheries Science Center (AFSC) initiated a number of seafloor habitat studies directed at investigating the effects of fishing on seafloor habitat. Each year a progress report for each of the projects is completed. Scientists primarily from the Auke Bay Laboratory (ABL) and the Resource Assessment and Conservation Engineering (RACE) Divisions of the AFSC have been conducting this work. A web page http://www.afsc.noaa.gov/abl/MarFish/geareffects.htm has been developed that highlights these research efforts. Included in this web page are a research plan, previous progress reports, and a searchable bibliography on the effects of mobile fishing gear on benthic habitats.

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