APPENDIX C

Ecosystem Considerations for 2009

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

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EXECUTIVE SUMMARY OF RECENT TRENDS

Fishing Effects on Ecosystems

- 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 eastern Bering Sea fish community indicates there has not been a systematic decline in the amount of large fish from 1982 to 2006.
- Recent exploitation rates on biological guilds 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.
- Seventy-two (82%) BSAI fishing communities 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.
- Discards and discard rates have remained below those observed prior to 1998, when regulations were implemented prohibiting discards of pollock and cod.
- Five new closures implemented in 2008 as part of protection for Essential Fish Habitat encompass a large portion of the northern Bering Sea. Almost 50% of Alaska's EEZ is now closed to bottom trawling.
- In 2007, observed BS hook and line and bottom trawl effort decreased, AI and GOA bottom trawl effort increased and BS and AI pelagic trawl effort increased. Other gear effort remained relatively stable.
- The number of hook and line vessels participating in the groundfish fisheries off Alaska have decreased over the last 4 years (2004-2007); whereas, the number of pot and trawl vessels have remained relatively stable over the last four years (2004-2007).

Climate and Physical Environment Trends

- Negative values of the PDO developed in 2007 and have persisted into 2008. It is highly uncertain whether the PDO will remain negative for an extended period. A positive PDO is associated with positive coastal sea surface temperature anomalies.
- Near-neutral ENSO conditions became established in the summer of 2008 and these conditions are expected to persist into spring 2009, implying a low predictability for the North Pacific climate system in the upcoming 6-9 months.
- In the Bering Sea, the year 2008 was the third sequential year with cold temperatures and extensive springtime sea ice cover, partially due to La Nina and a positive Arctic Oscillation.
- Bering Sea bottom and sea surface temperatures were cold in summer 2008. In the summers of 2006-2008, the extent of the cold pool increased from low values observed during 2000-2005. Cold pool size and location may affect the distribution and dynamics of Bering Sea fish species.
- The Bering Sea contrasted with much of the larger Arctic which had extreme summer minimum sea ice extents in 2007 and 2008 and positive autumn 2007 surface temperature anomalies north of Bering Strait of greater than 5°C.
- 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 five years we should look for the next shift back toward warmer temperatures and less sea ice.
- Eddy energy in the Aleutian Islands region was lower than average in the spring of 2008
- In the GOA, there was a prevalence of westerly wind anomalies over the last year, resulting in an increase in the North Pacific Current in the eastern North Pacific. Since the flow in the California Current System has also been stronger, while the flow in the coastal Gulf of Alaska has changed little, the proportion of the flow across the Pacific entering the Gulf has been lower than normal.

- The air temperature in the coastal Gulf was on the cool side during the spring and summer of 2008, which probably implies somewhat delayed snowmelt, and depressed glacial melt.
- In the Gulf of Alaska, higher eddy kinetic energy values were observed in the spring of 2007 and 2008. This implies phytoplankton biomass likely extended farther off the shelf and cross-shelf transport of heat, salinity, and nutrients were greater than in 2005-2006.

Climate Effects on Ecosystems and Ecosystem Trends

- In a comparison between warm years (2002 to 2005) and cold years (2006 and 2007) in the Bering Sea BASIS survey, age-0 EBS pollock appear to be more broadly distributed and of higher relative abundance during warm years. They tended to be more cannibalistic in warm years and had lower energy density; whereas, in cool years they tended to switch to euphausiid-foraging and had higher energy densities. Juvenile sockeye salmon tended to consume age-0 pollock during warm years and also switched to sandlance and euphausiids in cool years. Overall there appears to be a negative relationship between relative abundance of age-0 pollock from the BASIS survey (high in recent warm years) and subsequent recruitment to age-1 pollock (low following warm years). Finally, declines in biomass of most species of jellyfish were observed in the BASIS survey in 2006 and 2007 compared to 2004 and 2005.
- Bering Sea zooplankton biomass appears to have returned torwards average levels in 2006-2007 since a prolonged low period in 2001-2005.
- The relative CPUE of Arctic cod increased dramatically in the area of the cold pool in the summer Bering Sea bottom trawl survey.
- Togiak herring abundance in 2007 was below average but the stock is considered stable.
- EBS groundfish condition was low in 1999 and tended to be high in 2002-2003. Condition also tended to be higher on the outer shelf, but this may be due to the survey sampling timing.
- Spring wind-driven advection of rock sole larvae was onshore to favorable nursery areas in 2008 suggesting the potential for an above average strength 2008 year class.
- In the Bering Sea, there was an indication of a return to below average groundfish recruitment across multiple stocks in 2004. There is strong indication for above-average groundfish recruitment in the GOA from 1994-2000 and below-average recruitment since 2001.
- Overall annual surplus production in the GOA and EBS has been relatively stable. Annual surplus production of all non-pollock species in the EBS, however, decreased significantly from 1977 to 1995, increased and then has been very stable since 2000.
- EcoFOCI's pollock survival indices based on measured precipitation and wind, indicate the 2008 yearclass of GOA pollock will be average to strong and average, respectively.
- Mesozooplankton abundance in the GOA tended to peak later in the year and was longer in duration in cool, PDO-negative years compared to warmer, PDO-positive years, when the peak abundance was earlier in the year and of shorter duration. Preliminary data suggest peak mesozooplankton abundance occurred later in the year in 2008.
- The purse seine herring sac roe harvests are still closed in Prince William Sound because projected biomass is below the threshold spawning biomass.
- 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.
- 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 2007 GOA large mesh survey caught a record number of Tanner crabs at some stations in Ugak Bay. Arrowtooth flounder continues to be the main component of the offshore catches, while Tanner crab and flathead sole were the largest catches inshore. Also, Pacific cod catches were noticeably low inshore in 2007.

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SUMMARY OF MAJOR CHANGES

- **Added the following contributions in October 2008:**

- **Updated the following sections/contributions in October 2008:**

- **Updated the following sections/contributions in September 2008:**

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

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.

3. "*In last year's ecosystem chapter, the SSC was pleased to see the new zooplankton index but noted that it was not updated for this year. Zooplankton are important and yearly update of this information is desirable*."

The author of the Bering Sea zooplankton contribution updated that time series this year. Also, a time series of continuous plankton recorder data for the Gulf of Alaska was added to the report this year.

4. "*Also, it would be interesting to estimate the production of forage fish in addition to their standing stock*."

This estimate is now provided as part of the trophic guild trend analysis in the Ecosystem Assessment (this report).

5. "*We also note that some of the 2006 SSC requests were not fulfilled and request that they continue to be listed under "responses to SSC comments" until they are dealt with. In particular, the SSC again requests that condition indices (weight-at-length, age-1 weights) be included*."

Past SSC requests will be kept in this section until they are fulfilled. We continue to work towards fulfilling requests as efficiently as possible.

December 2006 SSC Comments

1. ….it would be useful to include condition indices (weight-at-length) in the ecosystem considerations chapter, which should be readily available for most exploited species and would provide an indication of poor prey availability.

Response:
The condition of several groundfish in the Bering Sea was estimated as residuals from log-transformed length-weight relationships (see the Bering Sea Groundfish condition contribution in the Groundfish section).

2. The SSC notes that the assessment is quite extensive (66 pages). In future iterations, a separate abstract or summary of the ecosystem assessment would be useful and/or the assessment itself could be streamlined to highlight changes from previous years (more extensive discussions could be included by reference).

Response:
We are currently working on the Ecosystem Assessment to make it more concise. We are attempting to rate and vet indicators that we use in the assessment, and blend data analyses and modeling to come up with fewer indicators that clearly communicate the state possible future directions of the ecosystems. We are also working towards having a short (~2 page) summary or report card of trends.

3. …we encourage the authors to add a single table summarizing recent changes in the biomass and year-class strength for all assessed fish populations, as well as a brief overview of status or trend indicators for other marine mammal populations, in particular whales and ice-associated seals.

Response:
There is a concise figure that does summarize groundfish biomass and recruitment trends in the Groundfish section of the report. The Ecosystem Assessment and Executive Summary are sections where we are working towards concise summaries of important ecosystem trends.

4. Bering Sea jellyfish: it should be noted in the contribution that in early part of time series, jellyfish were often thrown out and not quantified and probably weren't quantified until later in the time series.

Response:
This statement was added to the Bering Sea jellyfish contribution.

5. Will the GOA zooplankton time series be continued past 2003?

Response:
Russ Hopkroft and Ken Coyle were funded by NPRB to continue the zooplankton sampling along the Seward transect in the Gulf of Alaska; however, that time series was not updated in the report this year. Also, a time series of continuous plankton recorder data for the Gulf of Alaska was added to the report this year.

6. Mammals: were there any updates? Need to get counters on surveys. Need regular update on mammals

Response:
Contributions summarizing trends in Bowhead whale, harbor seal, and ice seal populations were added to the report in 2007. Minor editorial updates were added to the Bowhead whale section in October 2008. The 2008 data analyses for Steller sea lions and Northern fur seals were not yet completed at the time this report was compiled.

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….page 88
2. Maps of sea surface temperatures and sea level pressures in the North Pacific…pages 80-85
3. An index of the Aleutian Low (North Pacific Index)….page 87
2. Eddies in the AI….page 110
3. Distribution of rockfish species along environmental gradients in the Gulf of Alaska and Aleutian Islands bottom trawl surveys….page 112
4. Forage -AI (relative mean CPUE and frequency of occurrence of forage species)….page 125
5. Miscellaneous species -AI (relative mean CPUE and frequency of occurrence of miscellaneous species)….page 133
6. HAPC Biota -AI (relative mean CPUE and frequency of occurrence of HAPC species)…. page 111
7. Pelagic trawl fishing effort in the AI….page 140
8. Pot fishing effort in the AI….page 140
9. Trophic level of the catch in the AI (including a plot of catch by trophic level over time)....page 140
10. Total AI catch of groundfish, halibut and crab….page 140
11. Time trends in groundfish discards were separated for the AI….page 121

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 directionsof 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 section to the annual SAFE report. Each new Ecosystem Considerations section provides updates and new information to supplement the original section. The original 1995 section 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 Ecosystem Considerations section provided additional information on biological features of the North Pacific, and highlighted the effects of bycatch and discards on the ecosystem. The 1997 Ecosystems Considerations section 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, an overview of the effects of fishing gear on habitat, El Nino, collection of local knowledge, and other ecosystem information. The 1999 section 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 section 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 2000-2008 Ecosystem Considerations sections 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 2002, stock assessment scientists began using indicators in this chapter to systematically assess ecosystem factors such as climate, predators, prey, and habitat that might affect a particular stock. Also, information regarding a particular fishery's catch, bycatch and temporal/spatial distribution will 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 chapter 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 we spend more time 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 report and data for many of the time series presented in the report 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 Chapter 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 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 year's assessment, we derived 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 have 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.

Objective	Drivers	Pressures/Effects	Significance Threshold	Indicators
Maintain predator-prey relationships and Energy flow	Need for fishing; per captia 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:	Trophic level of the catch Trends in catch, bycatch, discards, and offal production by guild and for entire ecosystem 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)
		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	Total catch levels Invasive species observations
Maintain diversity	Need for fishing; per captia seafood demand	Effects on species 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 Population levels of target, nontarget species relative to MSST or ESA listing thresholds, linked to fishing removals (qualitative) 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	Guild diversity or size diversity changes linked to fishing removals (qualitative) 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	Community 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 captia 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) 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

Results

A.

Issue: Predator prey relationships and energy flow
Objectives: Maintain predator prey relationships and energy flow
Drivers: Need for fishing, per capita seafood demand, and concern about climate change
Pressures: Pelagic forage availability, removal of top predators, energy re-direction, energy removal relative to production
Status and Impacts Indices:

1. Biomass, Catch, and exploitation rates of biological guilds (Bering Sea only).

Contributed by Kerim Aydin and Sarah Gaichas, NMFS

Index: While species-specific fishing may not wholly account for "ecosystem influences" of fishing, whole-ecosystem indices such as trophic level of the catch may be too coarse, especially if pervasive "fishing down the food web" issues are minor. Further, as with recent concerns of arrowtooth flounder in the Gulf of Alaska, it is important to evaluate "balance" between different broad biological subcomponents (Guilds) in the ecosystem. For the EBS, species identified by food web models (Aydin et al. 2008) were separated 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, available time trends of biomass, catch, and exploitation rate (catch/biomass) are presented. For biomass time trends, stock assessment estimates are used where available for each species within the guild; where no stock assessment models are available survey data is used. If neither time series are available, the species is assumed to have a constant value equal to the mid-1990s level estimated in Aydin et al. (2008). Multi-species model estimates are not used here; however, a minimal consumption estimate from diet data and ration estimates was used to calculate a single survey q for forage fish catch in the bottom-trawl surveys (see Aydin et al. 2007 for methods). Catch data was directly taken from stock assessments or the Catch Accounting System for non-target species. For 2009-2010, the stock assessment authors' recommended catch and estimated biomass time series were used; for survey data biomass was assumed to be equal to 2008 levels.

Status and trends: Biomass, catch, and explotation rates have beeen within +/- one standard deviation of 1982-2007 levels for all guilds except pelagic foragers; this guild is dominated by walleye pollock (80% of guild biomass in 2007). The decrease in pollock along 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 2005-2007, however the decreased catchs in 2008, and recommended lower ABC in 2009-2010, has brought the exploitation rate of this guild back towards its long-term mean. A second trend of interest is that for copepods; the data shown is a strata-weighted average of the data presented in Napp and Yamaguchi (this document). Standing stock of copepods was low in 2001-2005 but 2006 and 2007 values showed a return towards the mean.

1. 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 BS 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 BS or GOA.

2. 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 BS (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 BS, 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 BS, 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 BS 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, BS, 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 BS was low, but also peaked in 2001. Bycatch in the BS is primarily from along the Alaska Peninsula and along the BS 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 BS was lower and concentrated along the

BS shelf. BS 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.

B.
Issue: Predator-prey relationships and energy flow
Objective: Maintain Predator-prey relationships
Driver: Need for fishing; Per capita seafood demand
Pressure: Energy redirection
Status and Impacts Indices:

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 2003-07 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 two 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 four years. Discards in all three areas are much lower than the amounts observed in 1996 (AI) and 1997 (BS and GOA), before implementation of improved-retention regulations.

Factors Causing Trends: Decreases in discards 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.

C.
Issue: Predator-prey relationships and energy flow
Objective: Maintain Predator-prey relationships
Driver: Need for fishing; Per capita seafood demand
Pressure: Energy redirection
Status and Impacts Indices:

1. Total catch levels

See next section on invasive species

D.
Issue: Predator-prey relationships and energy flow
Objective: Maintain Predator-prey relationships
Driver: Need for fishing; Per capita seafood demand
Pressure: Introduction of non-native species
Status and Impacts Indices:

1. 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."

2. 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 eastern BS 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 decreased due to decreases in pollock catch.

Total catch in the AI is much lower than in the BS 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 Bering Sea. 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.

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

E.

Issue: Habitat
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 Indices:

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 have historically been high. Additional measures to protect declining western stocks of the Steller Sea Lion began in 1991 with some simple restrictions based on rookery and haulout locations, to specific fishery restrictions 2000 and 2001. For 2001, over 90,000 nmi of the EEZ off Alaska was closed to trawling year-round. Additionally 40,000 nmi were closed on a seasonal basis.

State waters (0-3nm) are also closed to bottom trawling in most areas. Closures implemented in 2006 as part of protection for Essential Fish Habitat encompass a large portion of the Aleutian Islands. The largest of these closures is called the Aleutian Islands Habitat Conservation area and closes 279,000 nmi to bottom trawling year round. Five new closures implemented in 2008 as part of protection for Essential Fish Habitat encompass a large portion of the northern Bering Sea. These five closures add 134,500 nm2 to the area closed to bottom trawling year round. By implementing these closures, almost 50% of Alaska's EEZ is 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: In general, bottom trawl effort in the Gulf of Alaska and Aleutian Islands has been relatively low since 2004, with a slight increase in 2007. Bottom trawl effort in the Bering Sea remained relatively stable from 2001 through 2006 and decreased in 2007. Hook and line effort in the Bering Sea increased from 1990 to 2004 before it decreased in 2005-2007. In the Aleutian Islands, hook and line effort has been relatively low for the last 5 years. In the Gulf of Alaska hook and line effort has been relatively stable over the last 10 years. Pelagic trawl effort in the BS was relatively stable during 1999-2006 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 increased slightly in 2007. The observed pot fishing effort has been relatively stable in the BS, GOA, and AI in the last few years.

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 BS, 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. 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, Trends, and Factors Causing Trends: In the BSAI, catches of HAPC biota decreased 2003-2007. The catch of HAPC biota in the GOA is approximately 50 times lower than in the BSAI and has varied annually.

Factors Causing Trends: Benthic tunicates comprise the majority of HAPC biota catches in the BSAI, caught mainly by the flatfish fishery; this catch has decreased since 2004. 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, recovery rates of HAPC biota in the areas fished (NMFS 2007; http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm).

4. 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 BS 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, 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. In the BS, over the last eight years, sea whip and sea anemone CPUE has increased, whereas, sponge CPUE has decreased. 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 BS 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 able 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.
5. an index that reflects the amount of fish habitat that is damaged, such as: proportion of habitat damaged by fishing gear, or the area (km^2) with HAPC biota closed to fishing relative to the area with HAPC biota that is open to fishing.

F.
Issue: Diversity
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

Indices: 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. Utilizing the NMFS standard bottom trawl survey data, the average number of fish and major invertebrate taxa per haul and the average Shannon index of diversity (based on weight CPUE; Magurran 1988) by haul were computed for the GOA (west of 147°N) and EBS. Indices were based on a total of 53 taxa in the GOA and 46 taxa in the EBS (Table 1 in Mueter & Litzow 2008). Taxa were included at the lowest possible taxonomic level, i.e. at a level that was consistently identified throughout all surveys. Indices 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 by modeling haul-specific indices as a function of geographic location, depth, date of sampling, area swept, and year.

Status and Trends: Average species richness and diversity of the groundfish community in the Gulf of Alaska increased from 1990 to 1999 with both indices peaking in 1999 and sharply decreasing between 1999 and 2001. Species richness and diversity on the Eastern Bering Sea shelf have undergone significant variations from 1982 to 2006. 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.

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 lead to 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 hauls and how evenly CPUE is distributed among the species. In the GOA both average species diversity and local richness showed very similar trends, suggesting that relative species composition (evenness) was relatively stable. In contrast, trends in species diversity in the EBS differed markedly from those in richness. For example, low species diversity in the EBS 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 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.

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:
    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.

Status and Trends: The current overall Alaska FSSI is 114.5 of a possible 140, based on updates through June 2008. The overall Bering Sea score is 68.5 of a possible maximum score of 88. The BSAI groundfish score is 48.5 of a maximum possible 52 and BSAI king and tanner crabs score 20 of a possible score of 36. The Gulf of Alaska groundfish score is 42 of a maximum possible 48. The sablefish, which are managed as a BSAI/GOA complex, score is 4. Since the inception of the FSSI index in 2005, scores expressed as a proportion of the total possible scores have been above 0.88 and 0.93 for GOA and BSAI groundfish, respectively, and 0.5 or higher for BSAI king and tanner crabs.

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. 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 groundfish stocks that had low scores in the BSAI include rougheye rockfish (1.5). The reasons for this low score are: it is undefined whether this stock is overfished and unknown if it is approaching an overfished condition. The stocks that scored low in the GOA are shortspine thornyhead rockfish (indicator species for thornyhead rockfish complex) and yelloweye rockfish (indicator species for demersal shelf rockfish complex), which both scored 1.5. 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.

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). 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. Three marine mammal species are considered depleted and three species of birds are considered species of concern. 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, sperm whales and minke, 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.

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=23,107) and 2007 (N=23,118). This was the same general conclusion reached following the incomplete survey of 2006. However, there are significant regional differences in recent trends: increases between 2004 and 2007 in the eastern AI (E ALEU), western Gulf of Alaska (W GULF) and central GULF (C GULF) have largely been offset by decreases in the eastern-central AI (eastern C ALEU) and eastern GULF (E GULF). 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., in press).

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 1996), 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 2000), 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; however, this interaction warrants research consideration and may require large-scale experimentation, as proposed by the National Research Council (NRC 2003) and the Steller Sea Lion Recovery Team (NMFS 2006), to unravel.

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 127,008 pups were born on the Pribilof Islands in 2006: 109,937 (SE = 1,521) pups were born on St. Paul Island and 17,070 (SE = 144) 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

G.
Issue: Climate
Driver: Concern about climate change
Pressure: Change in atmospheric forcing (resulting in changes in the ocean temperature, currents, ice extent, etc)
Status/Impacts Indices:

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 and Trends: The North Pacific atmosphere-ocean system from fall 2007 through summer 2008 featured relatively cool sea surface temperature (SST) along its northern flank along a band 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 that promoted enhanced westerly winds across most of the northern portion of the basin during fall through spring. The SLP anomaly pattern itself is consistent with the remote forcing from the tropical Pacific. In particular, a La Nina developed in late 2007, as signified by a negative sense for the NINO3.4 index. Two other climate indices commonly used to represent this system, the Pacific Decadal Oscillation for the ocean, and the North Pacific index (NPI) for the atmosphere, were negative and positive, respectively, for most of the last year. The Arctic Oscillation (AO) was also largely positive during the winter of 2008.

Factors Causing Trends: Large-scale atmospheric forcing causes the trends observed in these indices of climate conditions.

Implications: Near-neutral ENSO conditions became established in the summer of 2008, and given the expectation that these conditions would persist into spring 2009, implies relatively low predictability for the North Pacific climate system in the upcoming 6-9 months.

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 inidces 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 2008 was a third sequential year with cold temperatures and extensive springtime sea ice cover. The Bering Sea contrasted with much of the larger Arctic which had extreme summer minimum sea ice extents in 2007 and 2008 (39 % below climatology) and positive autumn 2007 surface temperature anomalies north of Bering Strait of greater than 5°C. These three 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 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. La Nina and a positive Arctic Oscillation (see North Pacific review) contributed to the cool pattern in 2008.

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 five years we should look for the next shift back toward warmer temperatures and less sea ice.

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: In the summers of 2006-2008, the extent of the cold pool increased from low values observed during 2000-2005. The volume of the cold pool, which includes midwater layers, also increased in 2006. The center of the cold pool is located further to the southeast during the cold years (Spencer, in press).

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

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.

Table 2. Species and stock composition of guilds in the eastern Bering Sea guild analysis, and percent biomass according to 2007 surveys/stock assessment biomass estimates.

Guild	Species	Percent of 2007 biomass			Percent of 2007 biomass
Apex predators	P. Cod	30.1%	Pelagic foragers	W. Pollock	60.0%
	Arrowtooth	28.9%		W. Pollock_Juv	16.8%
	Grenadiers	12.6%		Myctophidae	3.5%
	Alaska skate	9.5%		Misc. fish shallow	3.0%
	Lg. Sculpins	6.7%		Herring	2.8%
	P. Halibut	3.9%		Squids	2.4%
	Gr. Turbot	2.5%		Fin Whales	1.9%
	Other skates	1.3%		Sandlance	1.9%
	Kamchatka fl.	1.2%		Eulachon	1.6%
	Sleeper shark	0.9%		Oth. managed forage	0.8%
	N. Fur Seal	0.4%		Scyphozoid Jellies	0.8%
	Wintering seals	0.4%		Herring_Juv	0.7%
	Minke whales	0.3%		Bathylagidae	0.7%
	Sablefish	0.3%		Capelin	0.6%
	Sperm and Beaked Whales	0.2%		Atka mackerel	0.5%
	Resident seals	0.2%		POP	0.5%
	Belugas	0.2%		Oth. pelagic smelt	0.5%
	Murres	0.1%		Salmon returning	0.3%
	Misc. fish deep	0.1%		Atka mackerel_Juv	0.2%
	Porpoises	0.0%		Northern Rock	0.1%
	Rougheye Rock	0.0%		Salmon outgoing	0.1%
	Steller Sea Lion	0.0%		Humpbacks	0.1%
	Resident Killers	0.0%		Other Sebastes	0.0%

	Sea Otters	0.0%
	Kittiwakes	0.0%
	Fulmars	0.0%
	Puffins	0.0%
	Shearwater	0.0%
	Kamchatka fl._Juv	0.0%
	N. Fur Seal_Juv	0.0%
	Cormorants	0.0%
	Transient Killers	0.0%
	Gulls	0.0%
	Albatross Jaeger	0.0%
	Steller Sea Lion_Juv	0.0%
	Storm Petrels	0.0%
Benthic foragers	YF. Sole	27.9%
	N. Rock sole	24.0%
	AK Plaice	21.9%
	FH. Sole	11.7%
	Other sculpins	4.5%
	Misc. Flatfish	2.9%
	YF. Sole_Juv	1.6%
	P. Cod_Juv	1.3%
	N. Rock sole_Juv	1.3%
	FH. Sole_Juv	1.3%
	Walrus Bd Seals	0.8%
	Rex Sole	0.4%
	Gray Whales	0.2%
	Shortraker Rock	0.1%
	Shortspine Thorns	0.0%
	Greenlings	0.0%
	P. Halibut_Juv	0.0%
	Dover Sole	0.0%
	Arrowtooth_Juv	0.0%
Benthic production	Benthic Detritus	99.7%
	Benthic microbes	0.3%
Infauna	Bivalves	83.3%
	Benthic Amphipods	6.0%
	Misc. Crustacean	5.1%
	Polychaetes	3.6%
	Misc. worms	1.9%
Discards and offal	Offal	82.9%
	Discards	17.1%

	Bowhead Whales	0.0%
	Sei whales	0.0%
	Gr. Turbot_Juv	0.0%
	Sablefish_Juv	0.0%
	Right whales	0.0%
	Auklets	0.0%
	Sharpchin Rock	0.0%
	Dusky Rock	0.0%
Pelagic production	Pelagic Detritus	97.8%
	Pelagic microbes	1.3%
	Sm Phytoplankton	0.8%
	Lg Phytoplankton	0.1%
	Macroalgae	0.0%
Shrimp	Pandalidae	83.5%
	NP shrimp	16.5%
Structural epifauna	Urochordata	55.0%
	Hydroids	15.8%
	Sea Pens	11.9%
	Anemones	9.6%
	Sponges	7.3%
	Corals	0.3%
Mesozooplankton	Euphausiids	79.5%
	Pelagic Amphipods	7.8%
	Mysids	6.3%
	Chaetognaths	3.1%
	Gelatinous filter feeders	2.2%
	Pteropods	1.0%
	Fish Larvae	0.1%
Motile epifauna	Brittle stars	27.2%
	Urchins dollars cucumbers	19.7%
	Sea stars	16.3%
	Eelpouts	10.0%
	Hermit crabs	7.4%
	Opilio	6.1%
	Snails	4.5%
	Misc. crabs	4.1%
	Bairdi	2.6%
	King Crab	1.7%
	Octopi	0.4%
Copepods	Copepods	100.0%

Conclusions

Climate: Monitoring climate variability is necessary to understanding changes that occur in the marine environment and may help predict potential effects on biota. Near-neutral ENSO conditions became established in the summer of 2008 and these conditions are expected to persist into spring 2009, implying a low predictability for the North Pacific climate system in the upcoming 6-9 months. Large scale climate factors resulted in relatively cool sea surface temperatures in the GOA and BS in the fall 2007 through spring 2008. These large-scale climate factors also determine the size and location of the cold pool in the Bering Sea. In the summers of 2006-2008, 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, and an index that reflects the amount of fish habitat that is damaged by fishing gear

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. In the GOA both average species diversity and local richness showed very similar trends, suggesting that relative species composition (evenness) was relatively stable. In contrast, trends in species diversity in the EBS differed markedly from those in richness. Changes in BS species richness have been attributed to changes in subarctic fish species distribution relative to the cold pool (Mueter & Litzow 2008). BS species diversity has been low in recent years, suggesting 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., in press). 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 BS 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 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 componenets 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

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Last updated: September 2007

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 (2006) conditions. This section begins with an overview of North Pacific climate for 2006, 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 2008

Summary. *The North Pacific atmosphere-ocean system from fall 2007 through summer 2008 featured relatively cool sea surface temperature (SST) along its northern flank along a band 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 that promoted enhanced westerly winds across most of the northern portion of the basin during fall through spring. The SLP anomaly pattern itself is consistent with the remote forcing from the tropical Pacific. In particular, a La Nina developed in late 2007, as signified by a negative NINO3.4 index. Two other climate indices commonly used to represent this system, the Pacific Decadal Oscillation for the ocean, and the North Pacific index (NPI) for the atmosphere, were negative and positive, respectively, for most of the last year. The Arctic Oscillation (AO) was also largely positive during the winter of 2008. Near-neutral ENSO conditions became established in the summer of 2008, and given the expectation that these conditions would persist into spring 2009, implies relatively low predictability for the North Pacific climate system in the upcoming 6-9 months.*

1. SST and SLP Anomalies

The state of the North Pacific from autumn 2007 through summer 2008 is summarized in terms of seasonal mean sea surface temperature (SST) and sea level pressure (SLP) anomaly maps (Figures 1a and 1b). 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
As will be shown below, the anomalies during the past year were substantial over large regions of the North Pacific.

The autumn (September-November, (SON)) of 2007 featured positive SST anomalies in the central North Pacific, with maximum amplitudes exceeding 2° C magnitude near 35° N, 165° W, and negative SST anomalies in the eastern North Pacific. The SST was also colder than normal in the eastern equatorial Pacific in association with the development of La Nina. The corresponding pattern of anomalous SLP included a negative center (~-7 mb) over the Bering Sea, and a positive center (~3 mb) near 45° N, 150° W. The consequence of this pressure pattern was enhanced westerly winds across the entire North Pacific north of 45° N, and hence anomalous equatorward Ekman transports in the upper ocean, and upwelling-favorable wind anomalies in coastal regions from the south side of the Aleutian Islands to the Pacific Northwest.

During the winter (December-February (DJF)) of 2007-08, a band of positive SST anomalies was prominent from the coast of southeast Asia across the central North Pacific to north of the Hawaiian Islands (Figure 2a). Negative SST anomalies extended from the northern Bering Sea across the Gulf of Alaska (GOA) to along the west coast of the lower 48 states. The signature of the moderately intense La Nina is evident in the equatorial Pacific (Figure 2b). The SLP was consistent with La Nina, based on historical precedent, in particular with regards to the substantial positive anomalies (~7 mb) present over the eastern North Pacific. In conjunction with weakly negative SLP anomalies in the northern GOA, the wind anomalies were from the west to northwest across the North Pacific from the northern Bering Sea to California, which resulted in a rather cool winter from Alaska to the Pacific Northwest.

The distribution of SST in spring (March-May (MAM)) of 2008 (Figure 3a) indicates some weakening of the band of positive SST anomalies extending from the western North Pacific to north of the Hawaiian Islands, and strengthening of the negative anomalies from the Bering Sea across the GOA to the coast of California. The equatorial Pacific showed the effects of a declining La Nina, with negative SST anomalies persisting near the dateline, and weak signals to the east. The concomitant SLP anomaly map (Figure 3b) shows positive anomalies in the western Bering Sea and west of Oregon, and negative center near 35° N and the dateline. This pattern favored the continuance of cool conditions over the southeast Bering Sea shelf, GOA and Pacific Northwest, and relatively low precipitation over California.

The pattern of anomalous SST in summer (June-August (JJA)) 2008 features positive values over much of the central and western North Pacific, and negative anomalies in a semi-circle extending from the subtropical eastern Pacific to off the coast of the Pacific Northwest and into the eastern Bering Sea (Figure 4a). La Nina was basically over, with just weak negative anomalies remaining near the dateline, and somewhat larger positive SST anomalies in the eastern equatorial Pacific. The SLP distribution for summer (Figure 4b) included negative anomalies in the GOA and positive anomalies from the southern Bering Sea to about 35° N and just west of the dateline. This distribution favored anomalous winds from the north over the eastern Bering Sea, a relatively stormy GOA, and fairly typical upwelling along the west coast from Vancouver Island to San Francisco Bay.

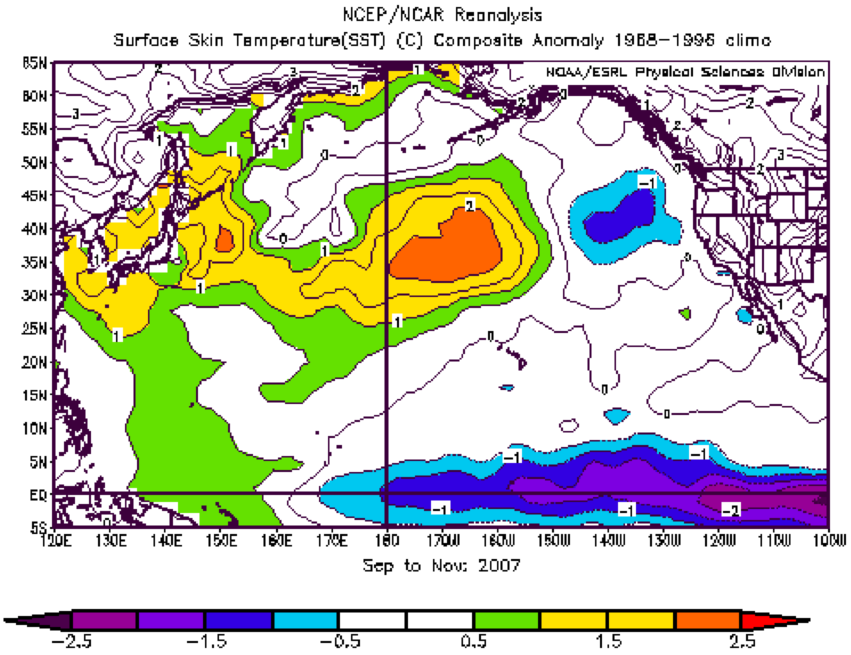

Figure 1a SST anomalies for September-November 2007.

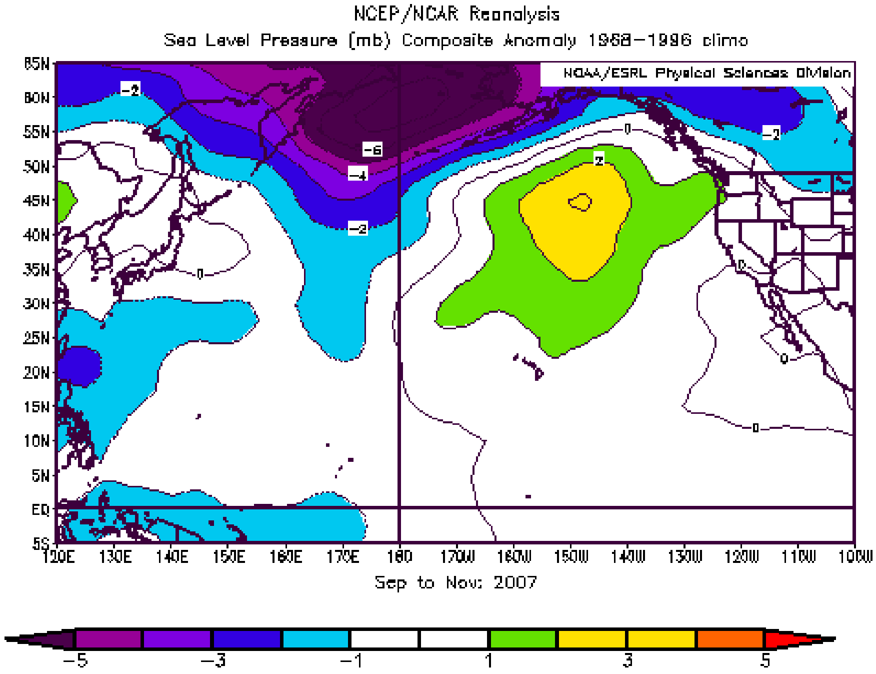

Figure 1b SLP anomalies for September-November 2007.

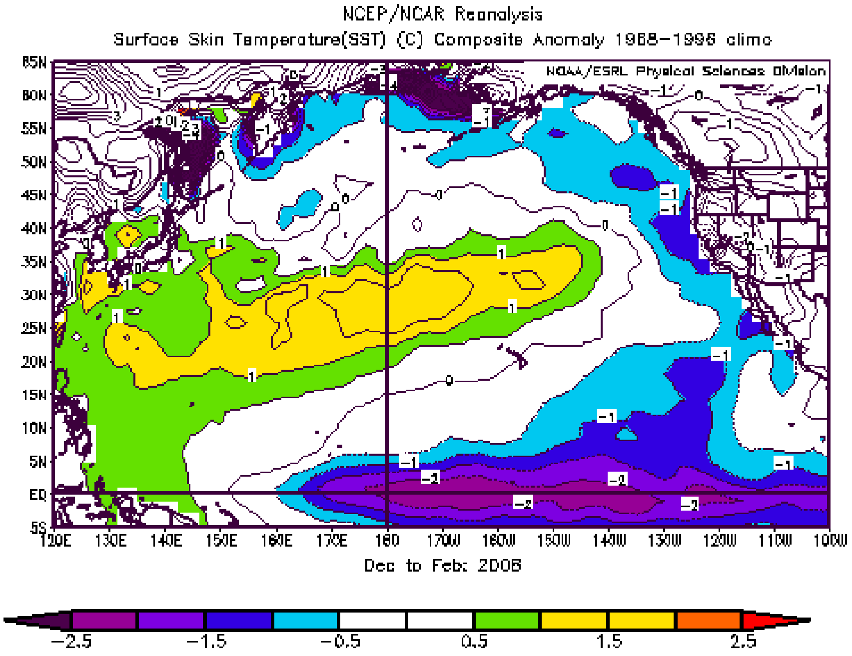

Figure 2a SST anomalies for December 2007-February 2008.

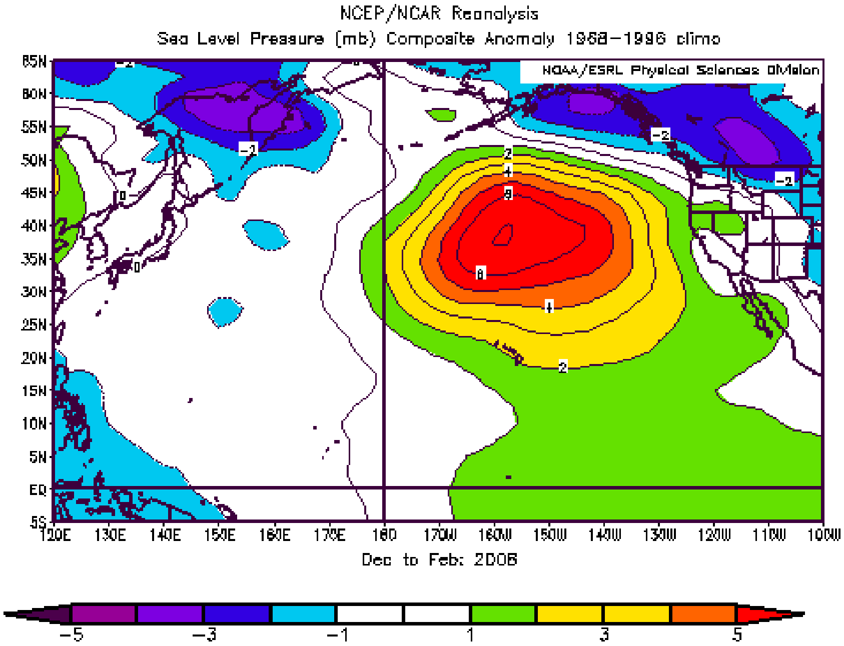

Figure 2b SLP anomalies for December 2007-February 2008.

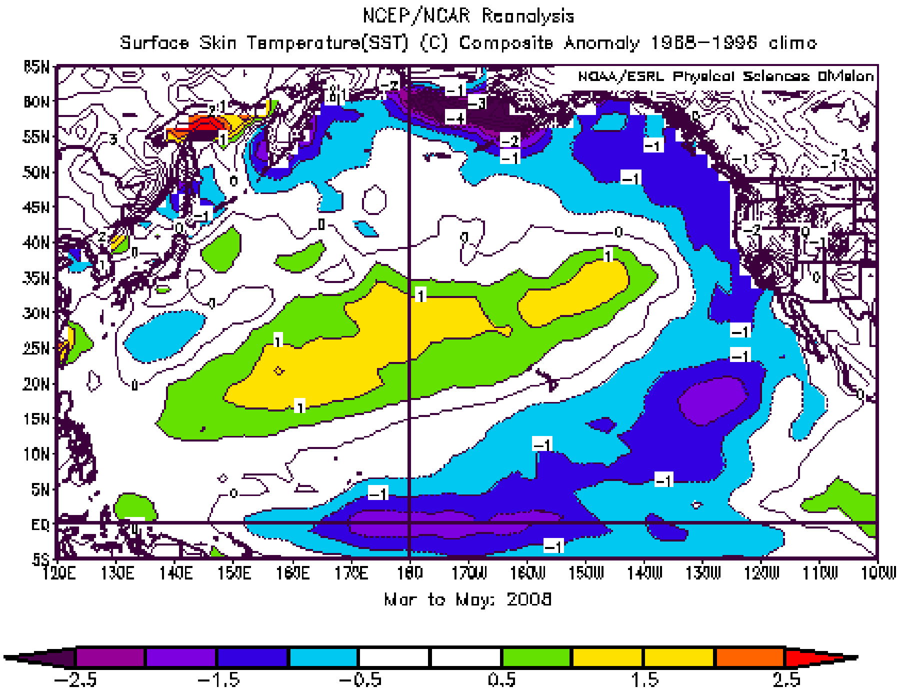

Figure 3a SST anomalies for March-May 2008.

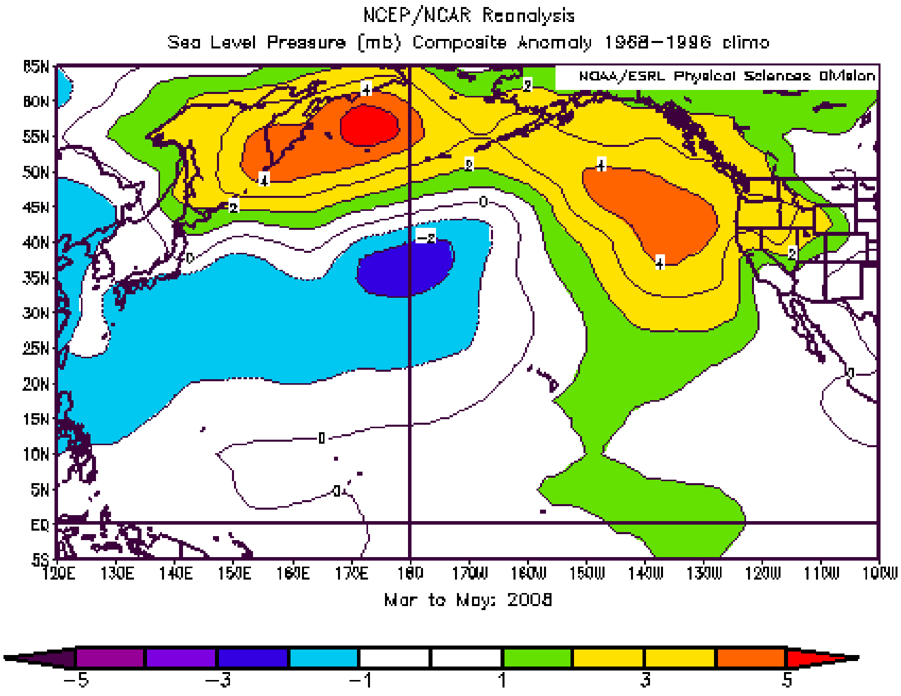

Figure 3b SLP anomalies for March-May 2008.

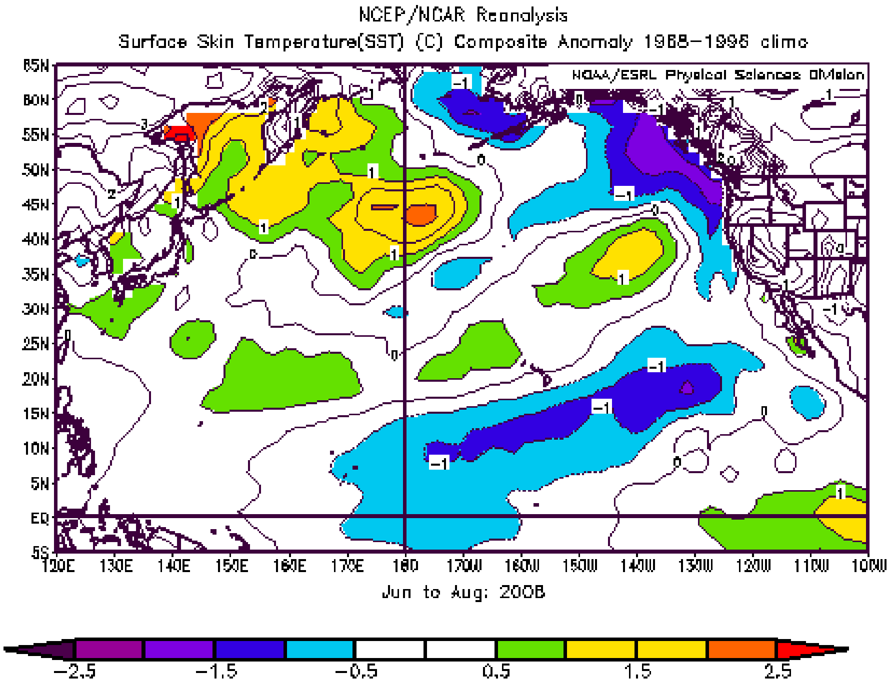

Figure 4a SST anomalies for June-August 2008.

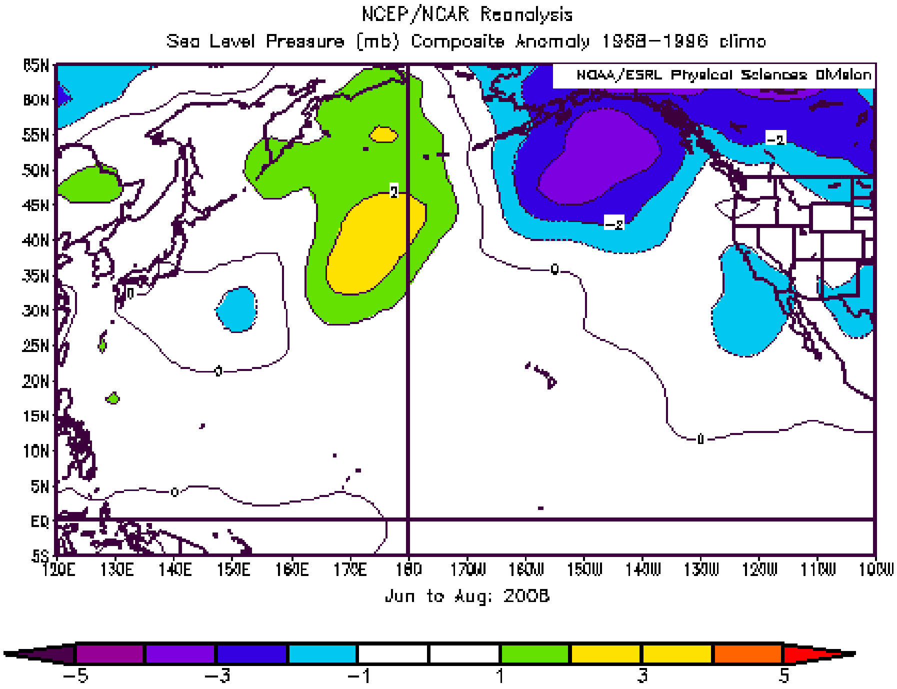

Figure 4b SLP anomalies for June-August 2008.

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 appears to have been an important driver of the North Pacific climate during 2007-08. The NINO3.4 index (Figure 5) bottomed out at a value of about -2.2 during early 2008; this metric (along with others) indicates that the recent La Nina was slightly stronger than the events of 1998-99 and 1999-2000 but somewhat weaker than that of 1988-89. The SLP anomaly pattern in the eastern North Pacific, in particular the relatively high pressure centered near 40°N, 160°W, resembles its counterparts during the last four La Nina winters (1975-76, 1988-89, 1998-99, and 1999-2000). The NINO3.4 index has trended positive since early 2008 and at the time of writing of this report, is indicating a near neutral state for ENSO going into autumn 2008.

Negative values of the PDO developed in 2007 and have persisted into 2008 (Figure 5). This transition in the PDO is also consistent with past La Ninas. The last time the PDO was as significantly negative for as long was in association with the La Nina of 1999-2000. It is highly uncertain whether the PDO will remain negative for an extended period since the return to a neutral ENSO state implies low predictability in the atmospheric circulation over the North Pacific, and hence relatively large uncertainty in the atmospheric forcing of the PDO over the near term.

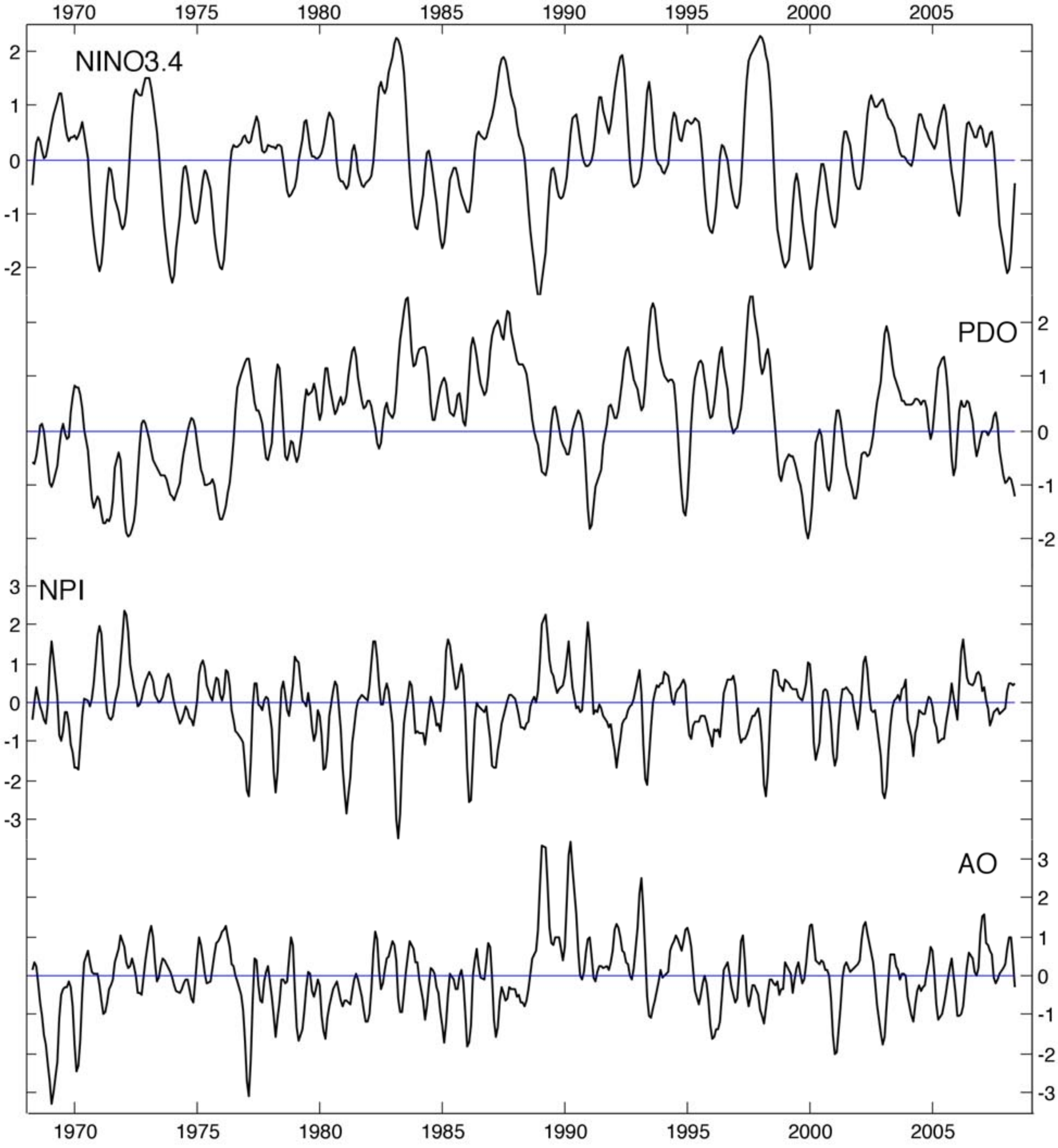

Figure 5. Time series of the NINO3.4, PDO, NPI, and AO indices. Each time series represents monthly values that are normalized and then smoothed by 3-month running means applied twice. More information on these indices is available from NOAA's Earth Systems Laboratory at http://www.cdc.noaa.gov/ClimateIndices/.

The NPI is one of several measures used to characterize the strength of the Aleutian low. The positive state of the NPI since late 2007 (Figure 5) is consistent with the historical record in that the Aleutian low tends to be weak, and sometimes split into two centers, in association with La Nina, especially during winter. Therefore, while the NPI reflects the influence of the tropical Pacific on the higher latitude atmospheric circulation, it does not necessarily indicate any long-lasting shift in the climate of the North Pacific.

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 positive state during late 2007 into early 2008 and since has become negative. It is interesting that the last 5 La Nina winters have been accompanied by a positive state for the AO; the previous six La Nina events all coincided with a negative AO. This distinction is meaningful in that La Nina winters feature westerly wind anomalies across the North Pacific north of 45°N when the AO is positive, and northwesterly wind anomalies during La Ninas when the AO is negative.

3. Regional Highlights

a. **West Coast of Lower 48** – The fall of 2007 represented a return of relatively strong northerly (upwelling-favorable) winds, after a summer of extremely low upwelling. The upwelling remained greater than normal through the winter in general, and then was near its seasonal norms from late spring through summer 2008. The precipitation was generally slightly above normal in Washington and Oregon, with high mountain snowpacks, and slightly below normal in California, with the latter being particularly dry in spring 2008. The combination of enhanced upwelling and the remote forcing by La Nina in terms of coastally-trapped oceanic phenomena, resulted in cooling of coastal SSTs, relative to their seasonal norms, from fall 2007 until spring 2008. The ecosystem's response to this combination of local and remote forcing is unknown, but based on prior experience and limited sampling, it should be expected that the spring/summer of 2008 included average to above average primary production, and a relative preponderance of sub-arctic versus sub-tropical zooplankton.

b. **Gulf of Alaska** – The data from Argo profiling floats, available at http://www.pac.dfo-mpo.gc.ca/sci/osap/projects/argo/Gak_e.htm, can be used to characterize upper ocean conditions in the Gulf of Alaska. As might be expected based on the prevalence of westerly wind anomalies over the last year, the Argo data shows an increase in the North Pacific Current (West Wind Drift) in the eastern North Pacific. Since the flow in the California Current System has also been stronger, while the flow in the coastal Gulf of Alaska has changed little, the proportion of the flow across the Pacific entering the Gulf has been lower than normal. The mixed layer depths in the Gulf of Alaska appear to have been near normal during most of the last year. The air temperature in the coastal Gulf was on the cool side during the spring and summer of 2008, which probably implies somewhat delayed snowmelt, and depressed glacial melt. Since the precipitation was close to normal, in an overall sense, presumably the runoff of freshwater onto the shelf was also relatively low. 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 2008.

c. **Alaska Peninsula and Aleutian Islands** – This region experienced westerly wind anomalies from the fall of 2007 through early 2008 as implied by the SLP anomaly maps of Figures 1b and 26b. Westerly winds act to suppress the poleward flow of warm Pacific water through the Aleutian passes (especially Unimak Pass), while easterly winds enhance these transports. This mechanism is apt to have played a role in the anomalously cold conditions that occurred in the southern Bering Sea. The SST anomalies themselves were negative in the vicinity of the Alaska Peninsula and near normal to the west along the Aleutian Island chain.

d. **Bering Sea** – The Bering Sea has been relatively cool since the winter of 2007-08. The extremely low ice extent in the central Arctic going into the fall of 2007 probably helped delay the development of seasonal sea ice in the northern Bering Sea early in the winter, but once the weather conditions become favorable for ice, near the end of 2007, there was rapid ice growth and advance of the ice pack southward. SSTs remained cool in the eastern Bering Sea through summer 2008 due to a combination of relatively inclement weather (less insolation and more wind mixing) and northerly wind anomalies. More detail on physical conditions in the Bering Sea during last year is provided in the Bering Sea section.

e. **Arctic** – The past year was marked by some recovery from a record low total area of sea ice in the Arctic in early fall 2007. At the time of the writing of this report, the sea ice is relatively thin and in low concentrations over much of the Arctic, and it is possible that there will be very rapid melting and ultimately, a minimum ice extent in 2008 not much different from that in 2007. The circulation in the central Arctic has not been as favorable for the export of ice in 2008 as it was in 2007, but there is very little thick, multi-year ice, and so the region is susceptible to continued low ice extent.

4. Seasonal Projections from NCEP

Seasonal projections from the NCEP coupled forecast system model (CFS03) for SSTs are shown in Figure 6. The SST anomaly maps indicate the persistence of cool SSTs in the equatorial Pacific. This result is within the envelope of ENSO forecasts (not shown) from the host of dynamical and statistical models in present use, which indicate near-neutral conditions through spring 2009 in a consensus sense. The CFS03 model indicates the maintenance of relatively cold SSTs in the North Pacific from the Bering Sea, across the Gulf of Alaska to the west coast of the lower 48 states through fall, with subsequent weakening. By spring 2009, the only signal emerging above the climate "noise" is relatively cool SSTs in the Gulf of Alaska. The corresponding atmospheric anomalies (not shown) include lower than normal pressure over Alaska and higher than normal pressure in the eastern sub-tropical Pacific. This pattern is consistent with a cool Gulf of Alaska, and a weaker tendency for a cool Pacific Northwest. The latter signal is barely above the noise, but may serve to counteract the slow warming trend in association with climate change. It is noteworthy that the equivalent forecasts made one year ago were largely correct on the basin-scale. The previous forecasts had the benefit of the relatively systematic effects of La Nina; for the upcoming year this source of predictability is lacking. That being said, the coupled model forecasts do have some skill, and should be considered in making projections at least through the winter of 2008-09.

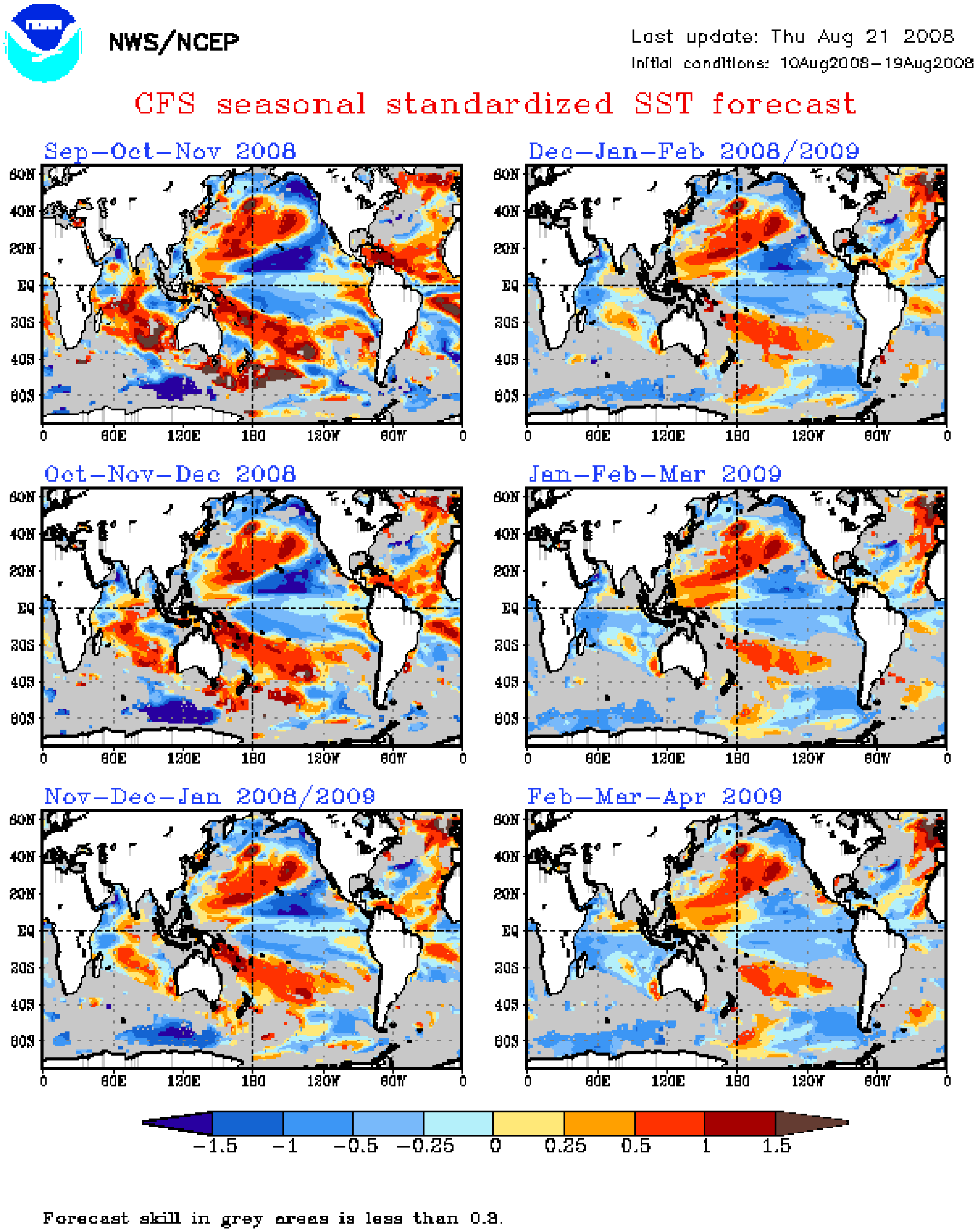

Figure 6. Seasonal forecast of SST anomalies from the NCEP coupled forecast system model.

GULF OF ALASKA

Pollock Survival Indices –EcoFOCI

Contributed by S. A. Macklin, NOAA/PMEL
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Last updated: August 2008

Using a conceptual model of early-life survival of western Gulf of Alaska walleye pollock (Megrey et al., 1996) for guidance, Ecosystems & Fisheries-Oceanography Coordinated Investigations (EcoFOCI) maintains several annual environmental indices. The indices are formulaic elements of a yearly prediction, during the year the fish are spawned, of the number of fish that will recruit as two-year olds. Some indices are determined qualitatively; the two reported here, seasonal rainfall at Kodiak and wind mixing in the southwestern exit region of Shelikof Strait, are determined numerically. Although data sources have changed somewhat over the years, chiefly with information used to estimate wind-mixing energy, every effort has been expended to make inter-year comparisons accurate and reliable.

Presently, the EcoFOCI program is developing a modified approach (Megrey et al., 2005; Lee et al., submitted) to its annual forecast algorithm. When modifications are complete, it is probable that new indices will become available for this report. At the same time, it is possible that the indices presented here and in past years may be discontinued. Until a significantly long time series of new annual indices is available, the old indices will continue to be updated and published in this report.

Seasonal rainfall at Kodiak

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Last updated: August 2008

EcoFOCI uses measured Kodiak rainfall as a proxy for freshwater discharge that promotes formation of baroclinic instabilities (eddies) in the Alaska Coastal Current (ACC) flowing through Shelikof Strait (Megrey et al. 1996). Measured monthly rainfall amounts drive a simple model that produces an index of survival for age-0 walleye pollock. These young fish may benefit from spending their earliest developmental stages within eddies (Schumacher and Stabeno 1994). The model assumes that greater-than-average late winter (January, February, March) precipitation produces a greater snow pack. When the snow melts during spring and summer, it promotes discharge of fresh water through rivers and streams into the ACC. Similarly, greater than average spring and early summer rainfall, with their nearly immediate run-off, also favor increased baroclinity after spawning. Conversely, decreased rainfall is likely detrimental to pollock survival because they do not find the circulation features that promote their survival.

The time series of EcoFOCI's pollock survival index based on measured precipitation is shown in Figure 7. Although there is large interannual variability, a trend toward increased survival potential is apparent from 1962 (the start of the time series) until the mid 1980s. Since then, the survival potential has been more level. Like 2007, 2008 was again a year of extremes. The season began with drying in January, followed by wetter than normal (30-year mean) months through March. This increased the potential for formation of baroclinic instabilities prior to and during spawning. April was relatively dry, however the later spring months brought record rain, with May 2008 being the all-time wettest May. As in 2007, these spring conditions may have presented favorable habitat for late larval- and early juvenile-stage walleye pollock.

Based on this information, the forecast element for Kodiak 2008 rainfall is 2.49, which corresponds to "average to strong" recruitment on the 5-category continuum from 1 (weak) to 3 (strong), and "strong" using three categories. Interestingly, the precipitation-based survival index does not appear to track any of the long-term climate indices, e.g., AO, PDO, with any consistency, possibly because of the way winter and spring precipitation are used in the model. In the 3-yr running mean of the precipitation survival index, there is a change from decreasing to increasing survival potential in 1989. In that year, there was an abrupt shift in the AO.

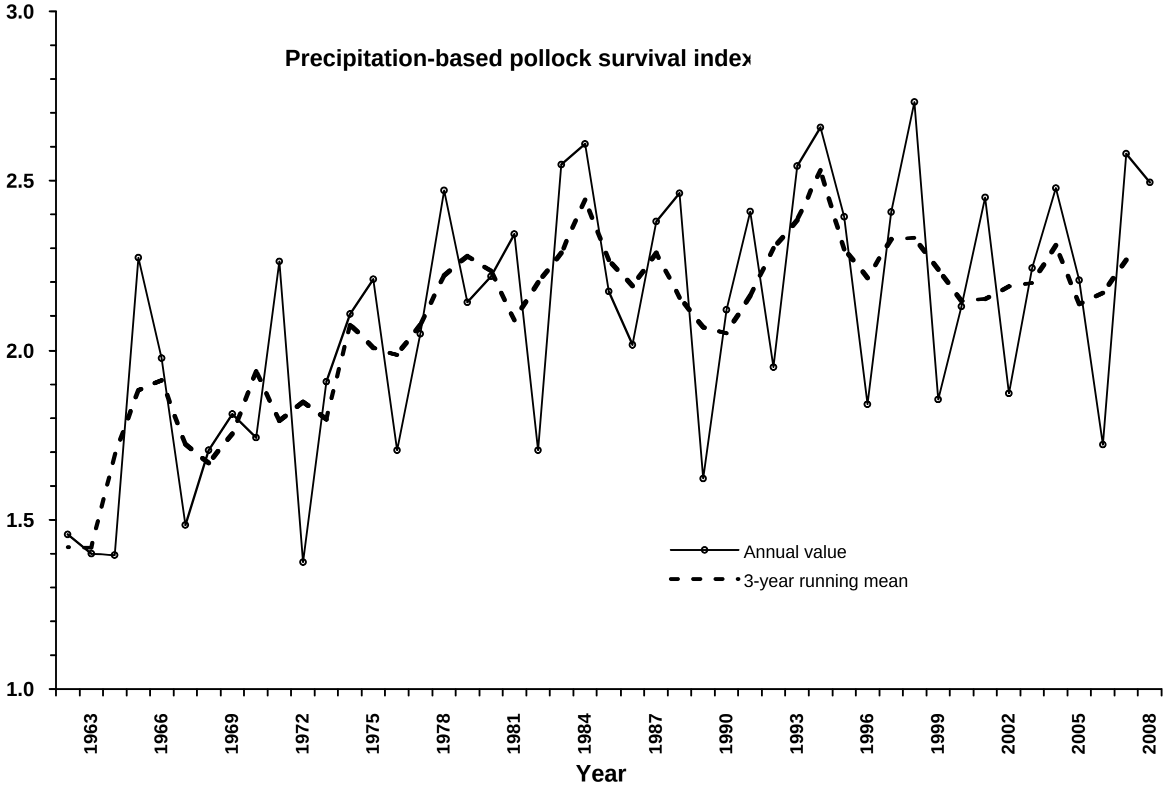

Figure 7. Index of pollock survival potential based on measured precipitation at Kodiak from 1962 through 2008. The solid line shows annual values of the index; the dashed line is the 3-year running mean.

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

Rainfall is only one indicator of early-life-stage pollock survival. EcoFOCI hypothesizes that a series of indices (proxies for environmental conditions, processes and relationships), assembled into a predictive model, provides a method for predicting recruitment of walleye pollock. A time series of wind mixing energy (W m-2) at [57°N, 156°W] near the southwestern end of Shelikof Strait is the basis for a survival index wherein stronger than average mixing before spawning and weaker than average mixing after spawning favor survival of pollock (Megrey et al. 1996). The wind-mixing index is produced from twice-daily surface winds created from a model (Overland et al. 1980) using NCEP reanalyzed sea-level-pressure fields. The model is tuned to the region using information determined by Macklin et al. (1993).

A time series of the wind-mixing index is shown in Figure 8. Wind mixing at the southern end of Shelikof Strait was below the long-term average for most of the first six months of 2008. This year's scenario produced a wind mixing score of 1.97, which equates to "average". As with precipitation at Kodiak, there is wide interannual variability with a less noticeable and shorter trend to increasing survival potential from 1962 to the late 1970s. Survival potential has declined generally since the turn of the century. Except for March 2003, March 2005, June 2006, April 2007 and May 2008, monthly averaged wind mixing in Shelikof Strait has been below the 30-year (1962-1991) mean for the last ten January through June periods (1998-2008). This may be further evidence that the North Pacific climate regime has shifted in the past decade.

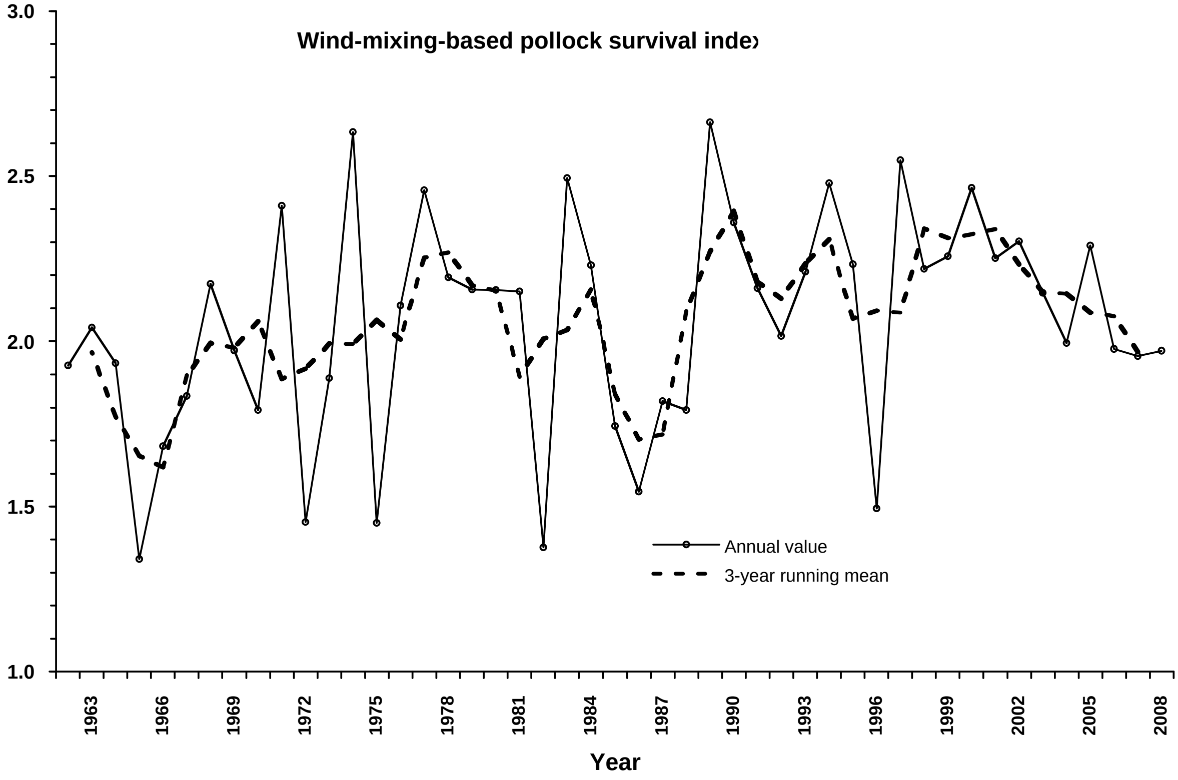

Figure 8. Index of pollock survival potential based on modeled wind mixing energy at [57°N, 156°W] near the southwestern end of Shelikof Strait from 1962 through 2008. The solid line shows annual values of the index; the dashed line is the 3-year running mean.

Eddies in the Gulf of Alaska – FOCI

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Eddies in the northern Gulf of Alaska have been shown to influence distributions of nutrients (Ladd et al. 2005, Ladd et al. 2007) and phytoplankton biomass (Brickley and Thomas 2004) 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 have occurred 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 9). 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 9). By averaging EKE over region c (see box in Figure 9), we obtain an index of energy associated with eddies in this region (Figure 10).

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 ~15-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. This may have implications for the ecosystem. Phytoplankton biomass was probably more tightly confined to the shelf during 2005-2006 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 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).

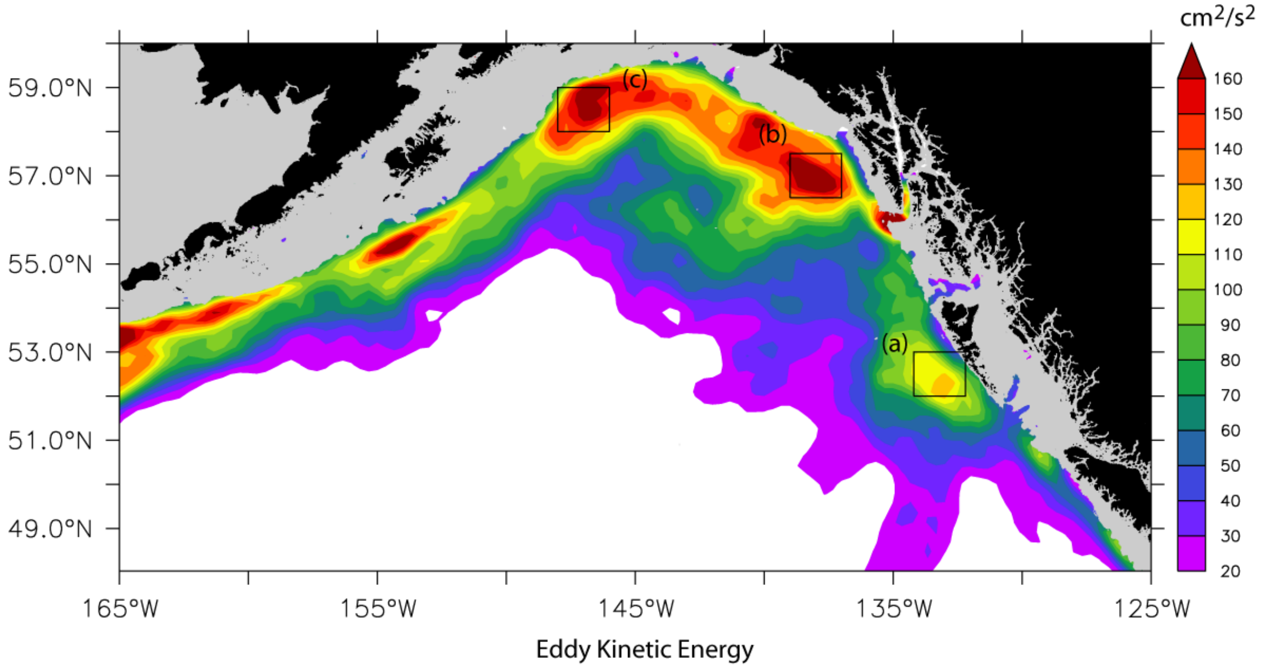

Figure 9. Eddy Kinetic Energy averaged over October 1993-October 2007 calculated from satellite altimetry. Region (c) denotes region over which EKE was averaged for Figure 10.

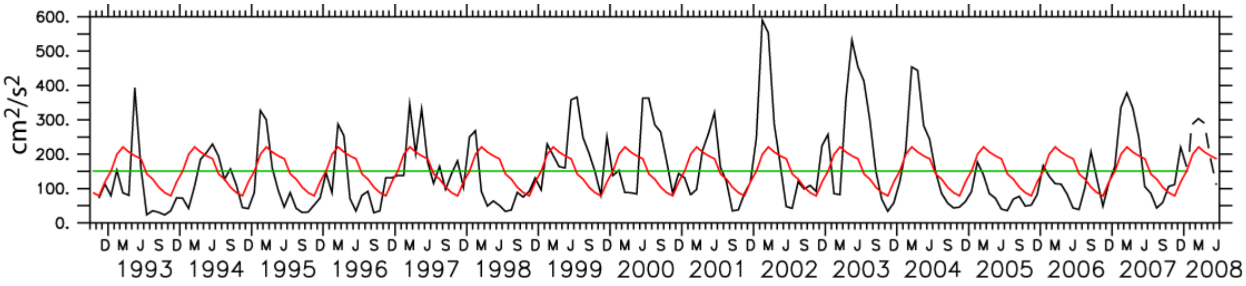

Figure 10. Eddy kinetic energy (cm^2 s^{-2}) averaged over Region (c) shown in Figure 9. Black (line with highest variability): monthly EKE. Red: seasonal cycle. Green (straight line): mean over entire time series.

Ocean Surface Currents – Papa Trajectory Index

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Last updated: August 2008

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 (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 2007 (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 11) 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 11 and 12). This was strongly influenced by the extreme southward 2002. During 2004-2006 values were near neutral, 2007 was northward, and 2008 was southward (Figures 11 and 12).

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. The time-series has been updated with winter 2008 calculations and shows circulation was southward. Once the 5-year running mean crosses the zero line it usually stays there for several years.

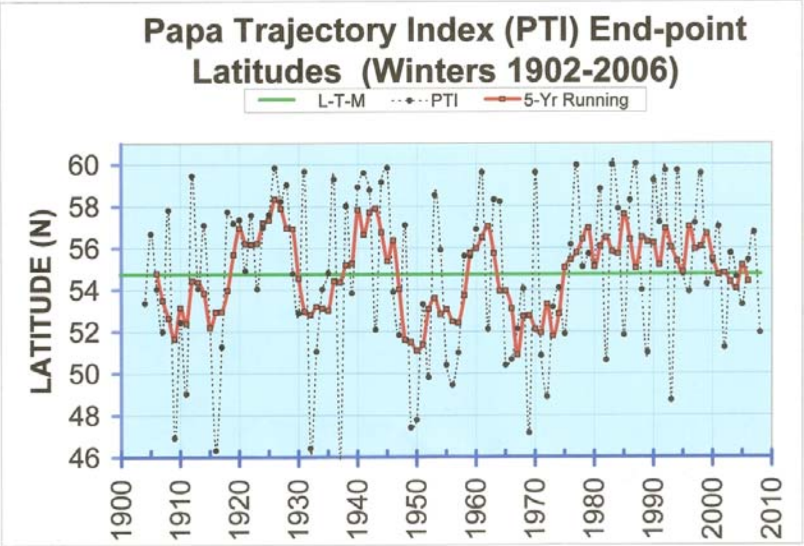

Figure 11. Annual, long-term mean and 5-year running mean values of the PAPA Trajectory Index (PTI) time-series from winter 1902-2008. Large black dots are annual values of latitude of the end points of 90-day trajectories which start at Ocean Weather Station PAPA (50º N, 145º W) each December 1, 1901-2007. 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.

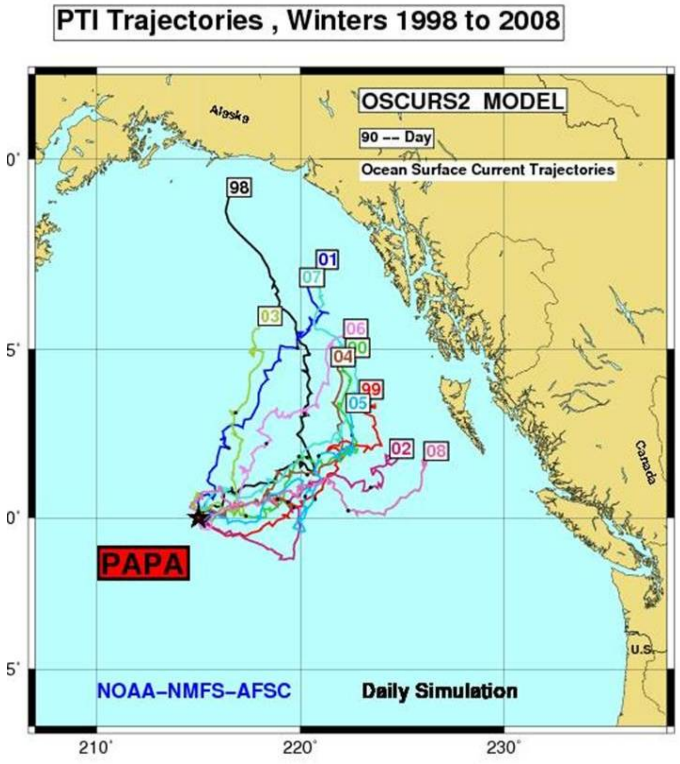

Figure 12. Papa trajectory end points for winters 1998-2008. End points of 90-day trajectories which start at Ocean Weather Station PAPA (50º N, 145º).

Gulf of Alaska Survey Bottom Temperature Analysis

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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

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

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Last updated: August 2008

Summary. *The year 2008 was a third sequential year with cold temperatures and extensive springtime sea ice cover. The Bering Sea contrasted with much of the larger Arctic which had extreme summer minimum sea ice extents in 2007 and 2008 (39 % below climatology) and positive autumn 2007 surface temperature anomalies north of Bering Strait of greater than 5 °C. These three 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 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. The second lesson is that the eastern Bering Sea is characterized by large monthly, interannual, and multi-annual variability, driven by large scale climate patterns. La Nina and a positive Arctic Oscillation (see North Pacific review) contributed to the cool pattern in 2008. 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 five years we should look for the next shift back toward warmer temperatures and less sea ice.*

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 were the coldest since the 1970s, near -5° C (Figure 13 top). After a mild fall, winter months were colder than normal, which continued through spring. On long time scales (Figure 13 bottom), cold anomalies had their first major appearance in 2006 and 2006-2008 is now the coldest period since pre-1978 conditions.

The Bering Sea pressure index (BSPI), defined as the area-weighted averages of sea level pressure (SLP) for winter (DJFM) in the southeast Bering Sea, continued with near neutral values in 2008 (Figure 14). Negative values of the BSPI indicate predominance of low pressure with both more or stronger storms and warmer temperatures. With this close-to-zero anomaly for a second year in a row, it seems that a decade of major below normal SLP conditions came to an end, yet there is no indication of a return to climate regime conditions of higher SLP prior to 1977.

Spring was anomalously cold in the southeast Bering Sea during 2008 (Figure 15). The Bering Sea was part of the extensive region of cold temperatures throughout the North Pacific (see North Pacific description). In contrast the Arctic was warmer than normal. The proximate cause of the cold spring in 2008 is shown by the SLP anomaly field in Figure 16. The Siberian high pressure region (orange colors) was displaced to the east to a location over the western Bering Sea and the Aleutian low pressure region had higher than normal SLP indicating weaker or fewer storm systems entering the Bering Sea. The "bull's eye" of cold southeastern Bering Sea temperatures relates to anomalous northwest winds (clockwise flow around the pressure maximum), bringing cold air from Siberia. What also stands out for 2007 and 2008 is that the warm temperatures of 2000-2005 continued in Chukchi Sea, but not in the southeast Bering Sea.

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. Ice extent in 2008 (Figure 17) is close to a record, and contrasts to the warm years of 2000-2005 (except 2002). The Ice Retreat Index (Figure 18), defined as sea ice present over 56-58°N, 163-165°W after March 15, shows the recent increase in 2006 to 2008 relative to 2000-2005, with 2008 having the fourth largest value since the record began in 1978. With regard to sea ice, the southeast Bering Sea is again showing different conditions than north of Alaska. September 2007 and 2008 both showed extreme sea ice loss in the Arctic. We thought that the major loss of Arctic sea ice in autumn of 2007 might retard the maximum sea ice extent in the Bering Sea during the following spring. However, 2008 is a strong counter example: minimum record sea ice during September in the Arctic was followed by a maximum extent the following spring in the Bering Sea. 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 2008 compared with 2000-2005 (Figure 19 bottom), while 2005 was the warmest year on record. The upper figure (Figure 19) shows whether sea ice was present in the southeast Bering Sea in each year (blue line). The cold pool (Figure 20), 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 2008 rivals 2006 and 2007 as the most prominent since 1999.

Further information from the M2 mooring, the vertical distribution of temperature and chlorophyll fluorescence measurements over time (Figure 21), relate 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 21). This was followed by the warm, sea ice-free years. Water column conditions in the winter of 2008 were cold for much longer than 2006 and 2007. As noted in the cold pool figure (Figure 20), the southeastern Bering Sea is now a reservoir of cold sea temperatures. Maximum near surface temperatures in summer 2008 was 9°C, compared to nearly 15°C earlier in the century.

The most important aspects of the physical environmental in the eastern Bering Sea during 2008 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.

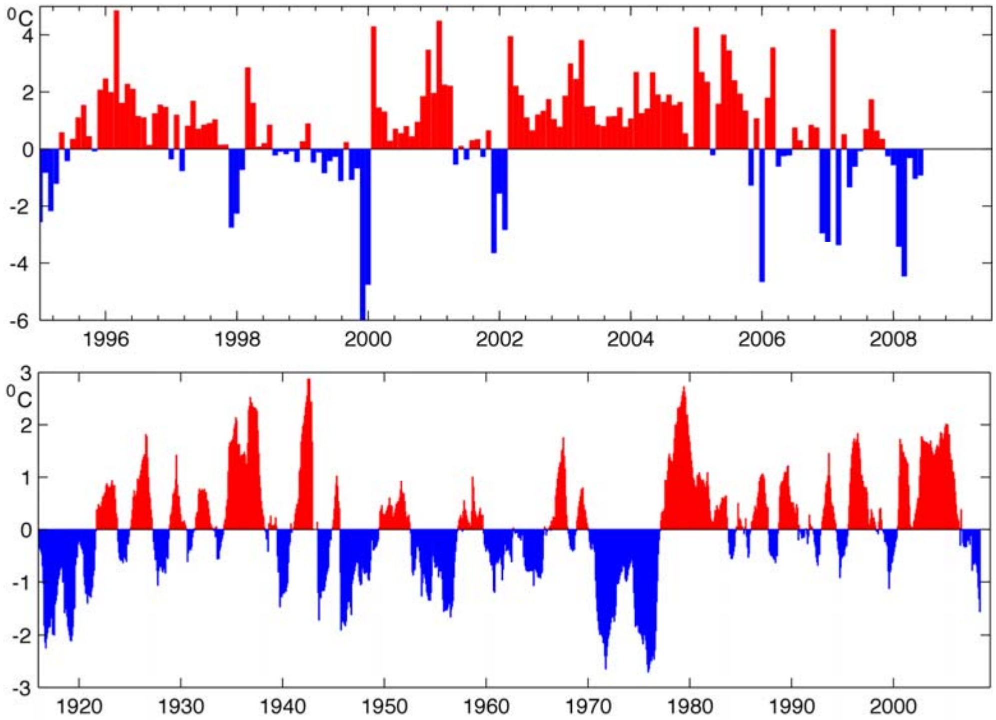

Figure 13. Mean monthly surface air temperatures anomalies in St. Paul, Pribilof Islands, a) unsmoothed, January 1995 through July 2008, and b) smoothed by 13-month running averages, January 1916 through July 2008. The base period for calculating anomalies is 1961-2000.

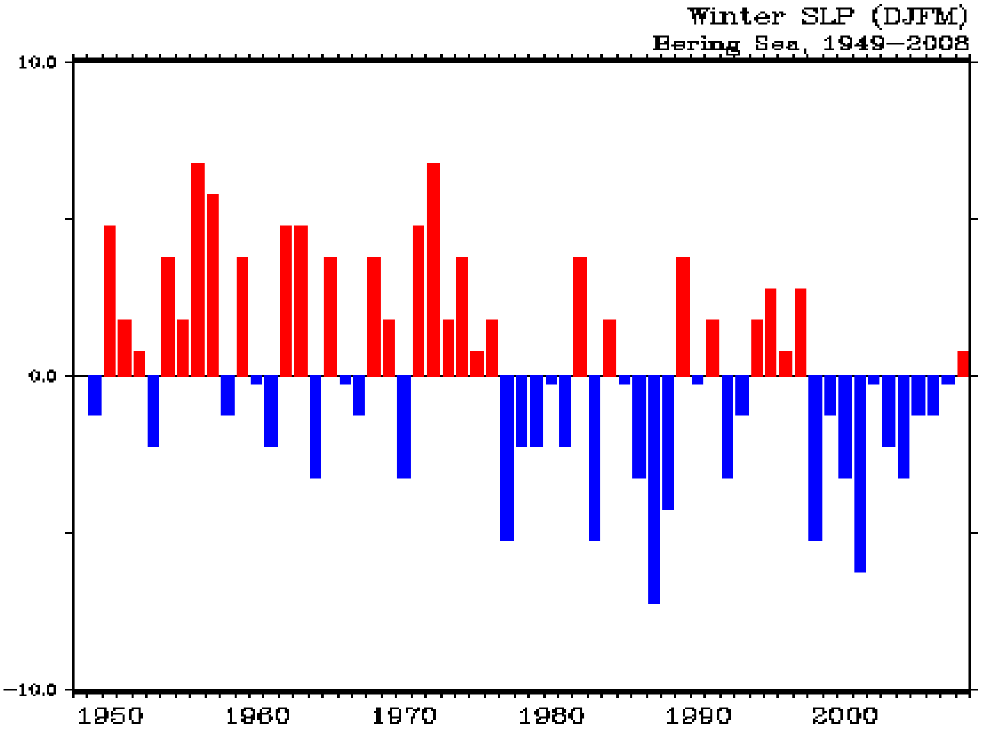

Figure 14. The BSPI is defined as area-weighted Sea Level Pressure anomalies between 55-65 deg.N, and 170E-160 deg.W for winter (DJFM).

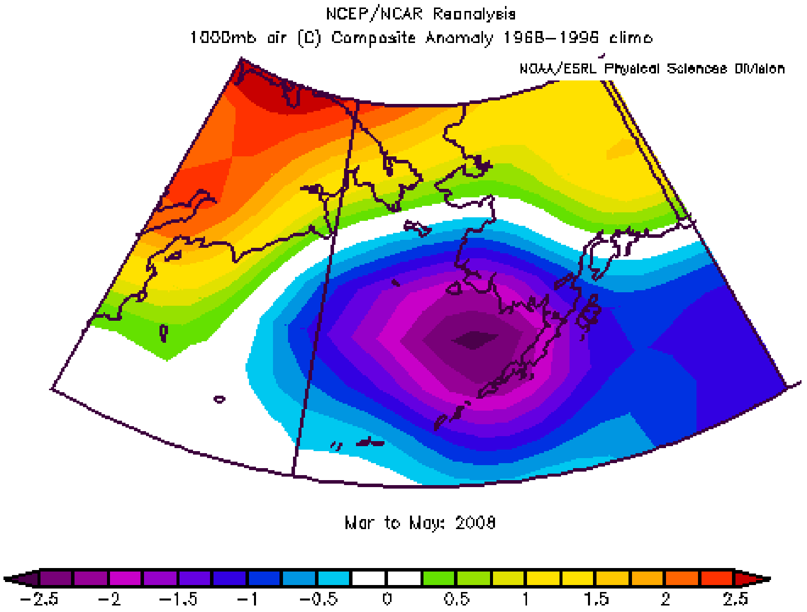

Figure 15. Surface air temperature anomaly over the greater Bering Sea region for spring 2008. Cold surface air temperature anomalies were present in the southeastern Bering Sea (blue shading). Note the contrast to the warm anomalies in northern Siberia.

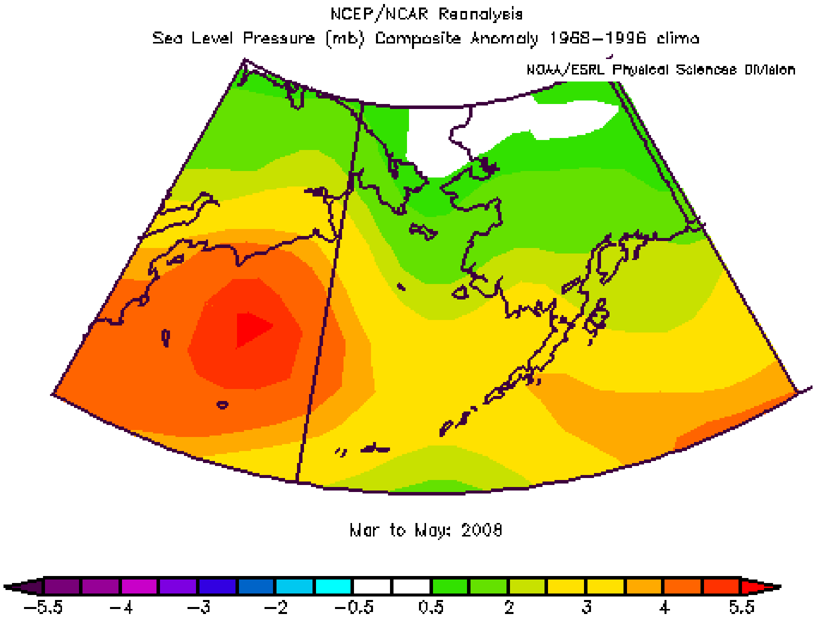

Figure 16. Sea level pressure (SLP) anomaly field for spring 2008. Higher than normal SLP was present throughout the region. The maximum in the western Bering sea supports northwest wind anomalies bringing cold air over the SE Bering Sea from Siberia.

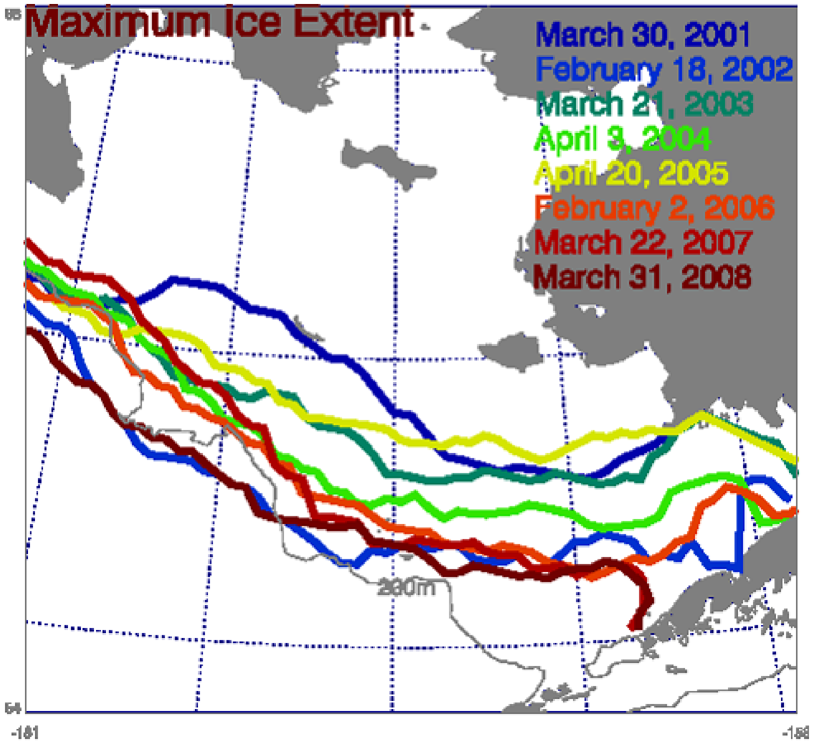

Figure 17. Recent springtime ice extents in the Bering Sea. Ice extent in 2006 through 2008 exceed the minimums of the early 2000s.

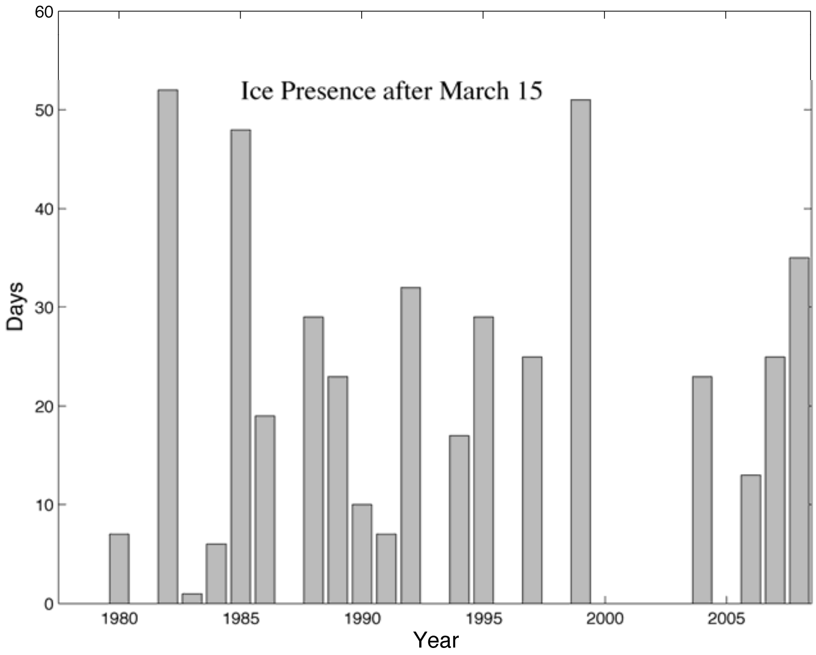

Figure 18. Sea ice retreat index, which is defined as ice presence over 56-58°N, 163-165°W box surrounding Mooring 2 after March 15.

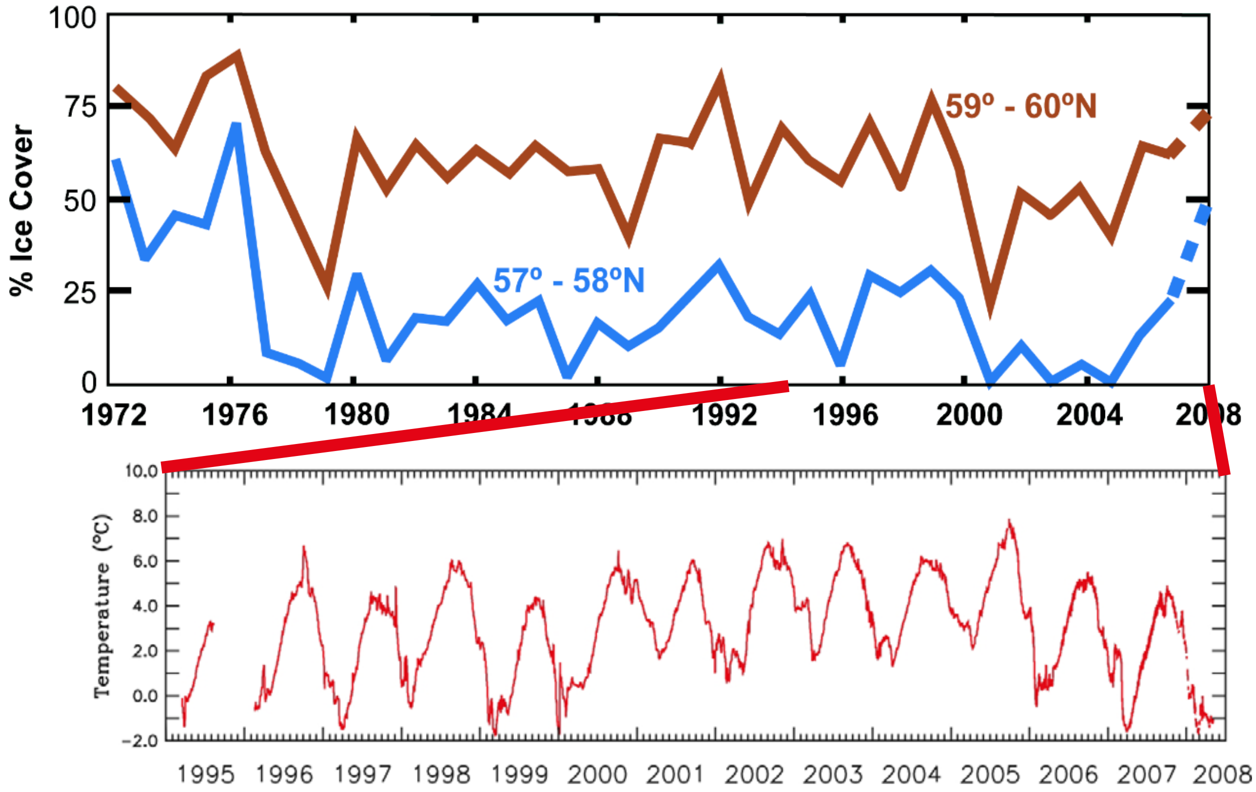

Figure 19. (Bottom) Depth averaged temperature measured at Mooring 2, 1995-2007 (°C). (Top) sea ice coverage in the north and south Bering Sea.

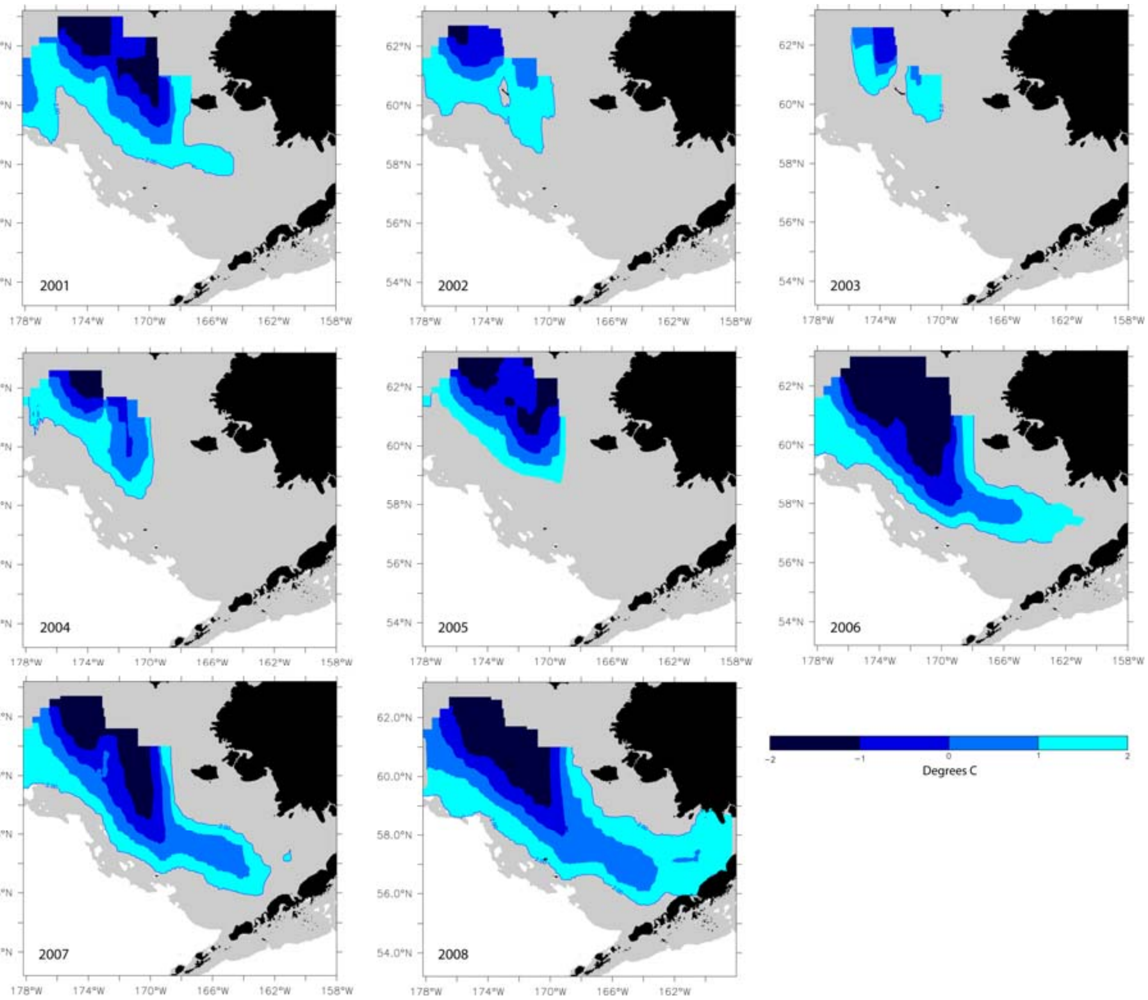

Figure 20. Cold Pool locations in southeast Bering Sea from 2001 to 2008.

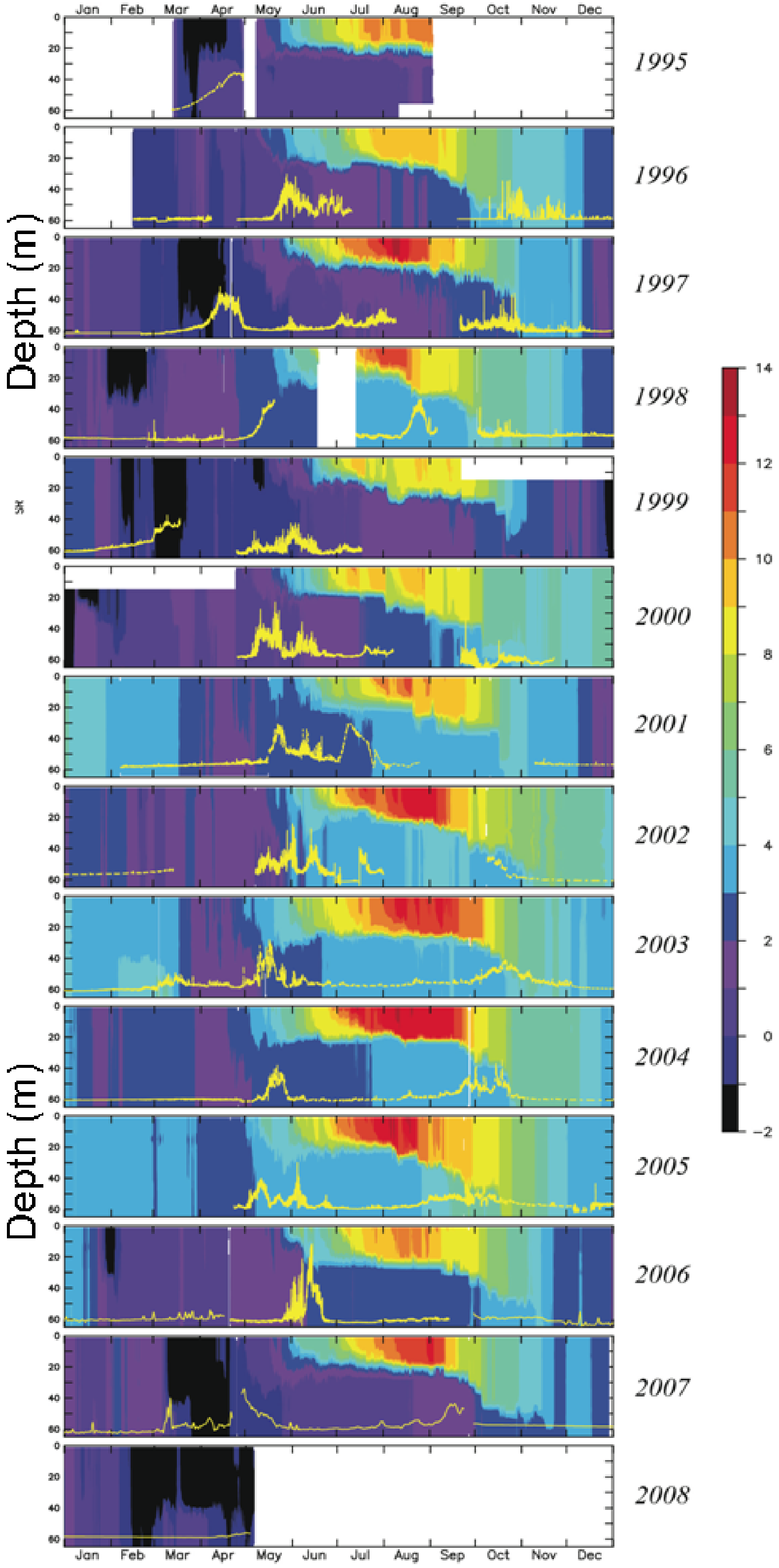

Figure 21. Temperature measured at Mooring 2, 1995-2008 (°C). Temperatures < 1°C (black) occurred when ice was over the mooring. The yellow line is fluorescence measured at ~11 m.

Summer bottom and surface temperatures – Eastern Bering Sea

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Last updated: October 2008

The annual AFSC bottom trawl survey for 2008 started on 3 June and finished on 25 July. To standardize water temperatures to a mean survey day for all survey years from 1982 to 2008, a generalized additive model was developed to predict temperature for each station on a standard date (July 1) using Julian day, annual average temperature, Julian day X annual average temperature, and a categorical variable for each station. The standardized average bottom temperature in 2008 was 1.34oC, which was well below the 1982-2007 mean of 2.54oC (Figure 22). Standardized bottom water temperature anomalies from the long-term standardized station means were negative over the entire shelf region ranging from -1.37 to -1.13°C (Figure 23). Maximum anomalies occurred mostly in the northwestern half of the shelf. The extent of the 'cold pool', usually defined as an area with temperatures < 2°C, was very similar to 1999 which was the coldest year in the EBS bottom trawl survey time series (Figure 23).

The 2008 standardized average surface temperature, 4.59oC, was 1.82°C lower than that observed in 2007 and 2.06°C lower than the long-term mean of 6.65oC. The entire EBS shelf had decreases in standardized surface water temperature anomalies ranging from -2.27 to -2.04°C (Figure 23).

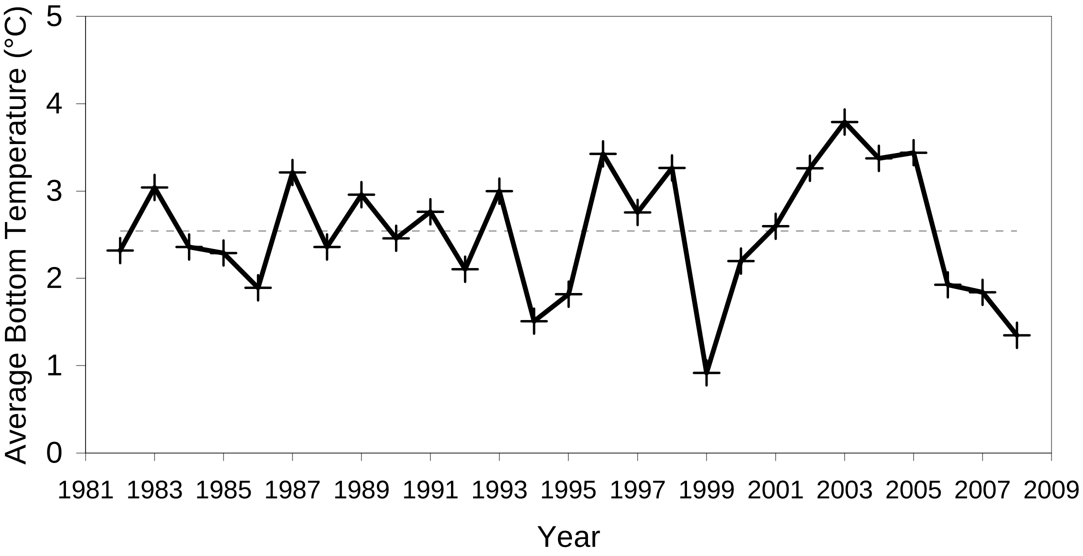

Figure 22. Mean summer bottom temperature (^{o}C) in the standard bottom trawl survey area of the eastern Bering Sea Shelf, 1982-2008. Temperatures for each tow are weighted by the proportion of their assigned stratum area.

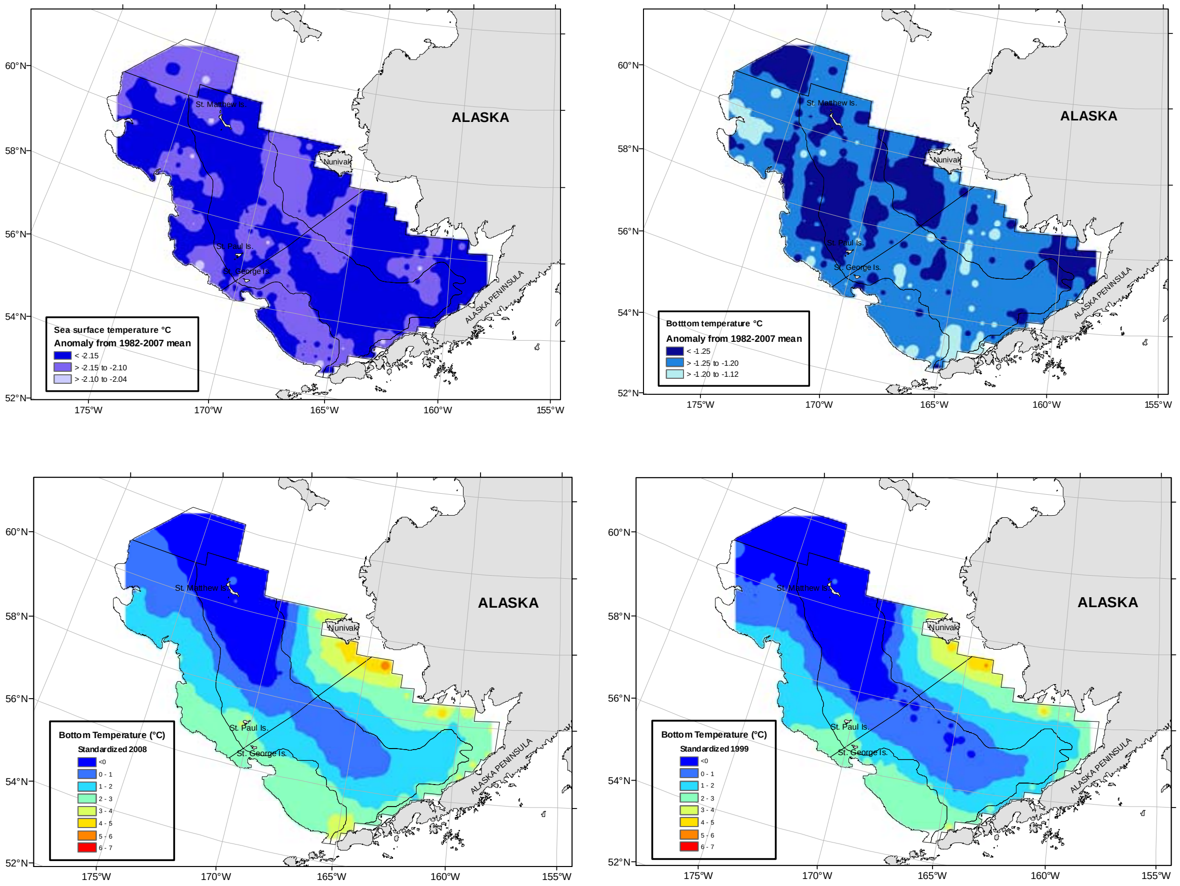

Figure 23. Standardized (to a sampling date of July 1) 2008 summer surface and bottom temperature anomalies (top panels) compared to the 1982-2007 standardized means for the standard bottom trawl survey stations in the eastern Bering Sea. The bottom left panel is standardized bottom temperatures for 2008, and for comparison the bottom right is the same for the coldest survey year in the survey time series-1999.

Arctic Sea Ice Cover -From the Arctic Report Card

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NEW: October 2008

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J. Toole, B. Veenhuis, D. Walker, J. Walsh, M. Wang, A. Weidick, C. Zöckler (2008). Arctic Report Card 2008, http://www.arctic.noaa.gov/reportcard

Summary

The continued significant reduction in the extent of the summer sea ice cover is a dramatic illustration of the pronounced impact increased global temperatures are having on the Arctic regions. There has also been a significant reduction in the relative amount of older, thicker ice.

Extent and thickness

Satellite-based passive microwave images of the sea ice cover have provided a reliable tool for continuously monitoring changes in the extent of the Arctic ice cover since 1979. During 2008 the summer minimum ice extent, observed in September, reached 4.7 million km2 (Figure 24, right panel). While slightly above the record minimum of 4.3 million km2, set just a year earlier in September 2007 (Figure 24, left panel), the 2008 summer minimum further reinforces the strong negative trend in summertime ice extent observed over the past thirty years. At the record minimum in 2007, extent of the sea ice cover was 39% below the long-term average from 1979 to 2000. A longer time series of sea ice extent, derived primarily from operational sea ice charts produced by national ice centers, suggests that the 2007 September ice extent was 50% lower than conditions in the 1950s to the 1970s (Stroeve et al. 2008). The spatial pattern of the 2008 minimum extent was different than in 2007. The 2007 summer retreat of the ice cover was particularly pronounced in the East Siberian and Laptev Seas, the Beaufort Sea, and the Canadian Archipelago. In 2008, there was less loss in the central Arctic, north of the Chukchi and East Siberian Seas and greater loss in the Beaufort, Laptev and Greenland Seas.

The annual maximum sea ice extent typically occurs in March. In March 2008, the maximum ice extent was 15.2 million km2 (Figure 24, center panel). This marked a second year of slight recovery in winter ice extent from the record minimum of 14.4 million km2 for the period 1979–2008, which was observed in 2006.

For comparison, the mean monthly ice extent for March and September, for the period 1979–2008, is 15.6 and 6.7 million km2, respectively.

The annual variation of the extent of the Arctic sea ice cover in 2007 and 2008, relative to past years, is shown in Figure 25. As explained in Comiso et al. (2008), the 2007 Arctic ice cover was comparable to the 2005 ice cover through mid-June but then began a more precipitous decline. In 2008, the rapid decline did not begin until mid-August. Five-year averages from 1980 through 2004 show a general decrease in the Northern Hemisphere sea ice extent throughout the seasonal cycle, with this pattern being especially strong in the late summer and early fall. The 2007 ice extent rebounded with a rapid early autumn growth, albeit with an exceptionally slow recovery in the Chukchi and Barents Seas. By early November 2007, the ice extent conditions were comparable to those observed in recent years, while remaining well below the long-term (1979-2007) average.

Figure 26 shows the time series of the anomaly in ice extent in March and September for the period 1979-2008. Both winter and summer have a negative trend in extent: -2.8% decade^{-1} for March and -11.1% decade^{-1} for September. The seasonality of the observed ice retreat, with a great rate of reduction of the summer extent versus winter extent, is consistent with model projections (e.g., Stroeve et al. 2007).

Ice thickness is intrinsically more difficult to monitor. With satellite-based techniques (Laxon et al. 2003, Kwok et al. 2004, 2007) only recently introduced, observations have been spatially and temporally limited. This said available data from a variety of sources consistently indicate a net thinning of the Arctic sea ice cover. Data from submarine-based observations indicate that over the period of available records, 1975 to 2000, the annual mean thickness of the ice cover declined from a peak of 3.71 m in 1980 to a minimum of 2.46 m in 2000, a decrease of 1.25 m (Rothrock et al. 2008). Satellite-derived estimates of sea-ice age and thickness, combined to produce a proxy ice thickness record for 1982–2007, also indicate the ice has thinned significantly between 1982 and 2007 (Maslanik et al. 2007). Helicopter-borne and ice-based electromagnetic measurements indicate a reduction of modal and mean sea ice thicknesses in the region of the North Pole of up to 53 and 44%, respectively, between 2001 and 2007 (Haas et al. 2008). In contrast to the central Arctic, measurements of the seasonal and coastal ice cover do not indicate any statistically significant change in thickness in recent decades (Melling et al. 2005, Haas 2004, Polyakov et al. 2003). This observation indicates that the thinning of the ice cover is primarily the result of changes in the characteristics of the perennial ice.

Seasonal versus perennial ice

The Arctic sea ice cover is composed of perennial ice (the ice that survives year-round) and seasonal ice (the ice that melts during the summer). Consistent with the diminishing trends in the extent and thickness of the cover is a significant loss of the older, thicker perennial ice in the Arctic (Figure 27). Data from the NASA QuikSCAT launched in 1999 (Nghiem et al. 2007) and a buoy-based Drift-Age Model (Rigor and Wallace, 2004) indicate that the amount of perennial ice in the March ice cover has decreased from approximately 5.5 to 3.0 million km2 over the period 1958–2007. While there is considerable interannual variability, an overall downward trend in the amount of perennial ice began in the early 1970s. This trend appears to coincide with a general increase in the Arctic-wide, annually averaged surface air temperature, which also begins around 1970. In recent years, the rate of reduction in the amount of older, thicker perennial ice has been increasing, and now very little ice older than 5 yr remains (Maslanik et al. 2007).

Many authors have recently acknowledged that a relatively younger, thinner ice cover is more susceptible to the effects of atmospheric and oceanic forcing (e.g. Gascard et al. 2008, Stroeve et al. 2008, Kwok 2007, Ogi and Wallace 2007, Maslanik et al. 2007, Serreze et al. 2007, Shimada et al. 2006). In the face of the predictions for continued warming temperatures (Christensen et al. 2007), the persistence of recent atmospheric (Comiso et al. 2008, Kwok 2008) and oceanic circulation patterns (Steele et al. 2008, Polyakov et al. 2007), and the amplification of these effects through the ice albedo feedback mechanism (Perovich et al. 2008), it is becoming increasingly likely that the Arctic will change from a perennially ice-covered to an ice-free ocean in the summer.

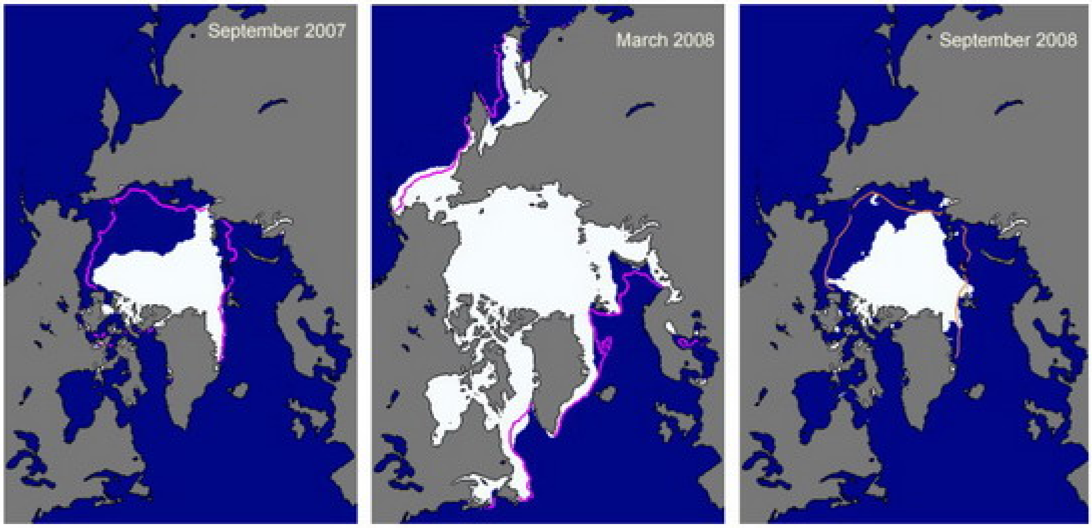

Figure 24. Sea ice extent in (left) September 2007, (center) March 2008 and (right) September 2008, illustrating the respective winter maximum and summer minimum extents. The magenta line indicates the median maximum and minimum extent of the ice cover, for the period 1979-2000. The September 2007 minimum extent marked a record minimum for the period 1979-2008. [Figures from the National Snow and Ice Data Center Sea Ice Index: nsidc.org/data/ seaice_index.]

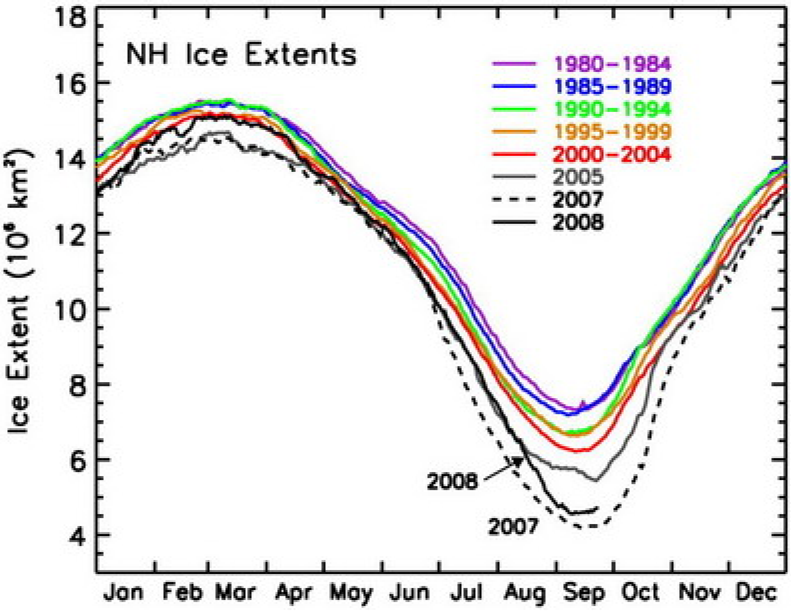

Figure 25. Daily ice extents 2005, 2007, and 2008, and averaged over the 5-yr periods 1980-84 through 2000-04. Values are derived from satellite passive microwave data from NASA's SMMR and the Department of Defense's SSM /I. (Adapted from Comiso et al. 2008.)

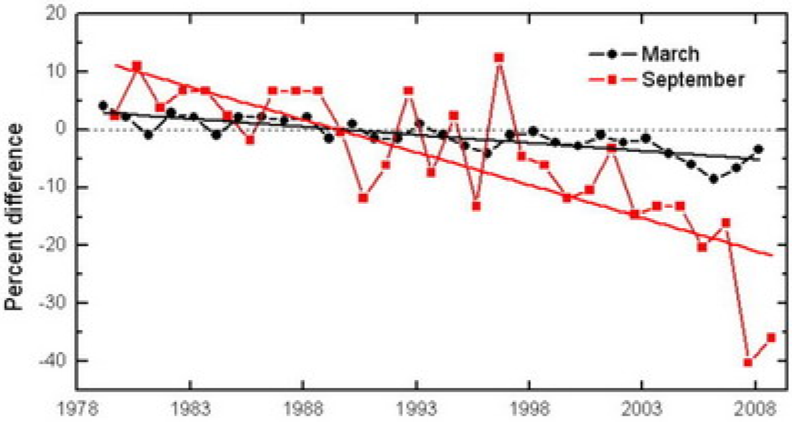

Figure 26. Time series of the difference in ice extent in March (the month of ice extent maximum) and September (the month of ice extent minimum) from the mean values for the time period 1979-2007. Based on a least squares linear regression, the rate of decrease for the Mar and Sep ice extents was -2.8% and -11.1% per decade, respectively.

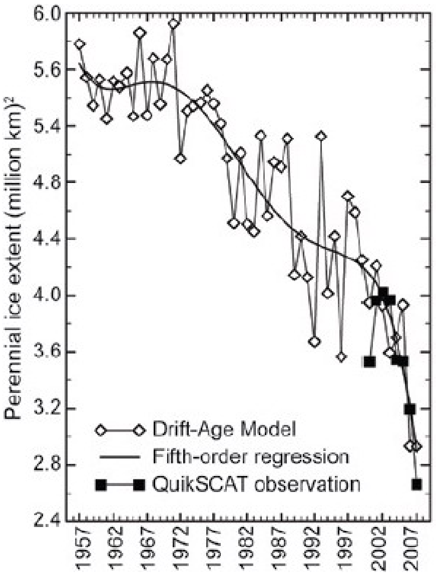

Figure 27. Time series of area of perennial sea ice extent in March of each year estimated by the Drift-Age Model and observed by QuikSCAT satellite scatterometer within the model domain. In each year, the model result was an average over March, and the satellite observation was on the spring equinox (21 Mar). (Adapted from Nghiem et al. 2007).

Variations in water mass properties during fall 2000-2007 in the eastern Bering Sea-BASIS

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Last updated: August 2008

Oceanographic and fisheries data have been collected in the Eastern Bering Sea (EBS) during fall 2000-2007 for the U.S. component of a multiyear international research program, Bering-Aleutian Salmon International Survey (BASIS). Stations were located between 54°N and 70°N, at 30-60 km resolution, although spatial coverage varied by region and by year. Bristol Bay stations were sampled from mid August to early September during all six years. While, stations in the central and northern EBS were generally sampled from mid September to early October. Oceanographic data were obtained from vertical conductivity-temperature-depth (CTD) profiles and laboratory analyses of discrete water samples at select depths (2003-2007). Oceanographic variables include temperature, salinity, nutrients, chlorophyll a, and phytoplankton taxonomic characteristics (based on phytoplankton species identification and chlorophyll a size fractionation). A long-term goal of this research is to characterize interannual variations in the abundance and distribution of lower and higher trophic level organisms in relation to oceanographic features in the EBS (see *Nutrients and Productivity* and *Forage Fish* sections of this report).

The surface temperatures and salinities for 2002-2007 in the Eastern Bering Sea are shown in Figure 28. Bristol Bay surface temperatures were warmer in 2002-2005 than in 2006-2007, and in 2000-2001 (data not shown). The lower surface salinities near the coast indicate major freshwater input from the Yukon and Kuskoquim rivers and can be used to estimate the Inner Front location. The location of the cold pool, deep cold water formed during ice melt, can impact fish distributions. The cold pool was observed south of St. Lawrence Is. (between 168 and 174°W and 60 to 63°N) in 2002, 2004, and 2005 (warm years) and as far south as 56-57.5°N in 2007 and 2006, respectively, (cold years) (Figure 29).

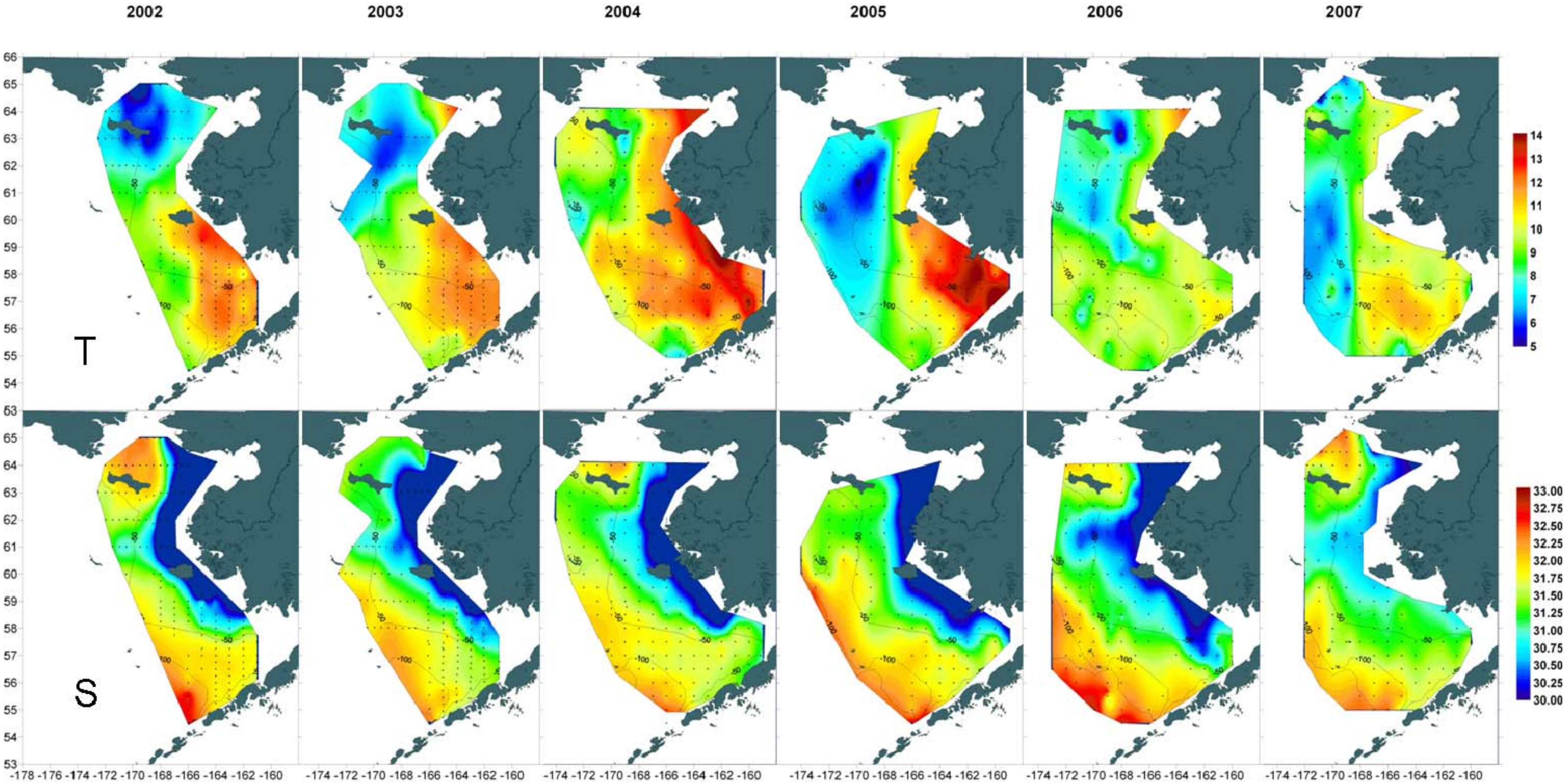

Figure 28. Mean temperature (deg.C) and salinity above the pycnocline in the Bering Sea, 2002-2007.

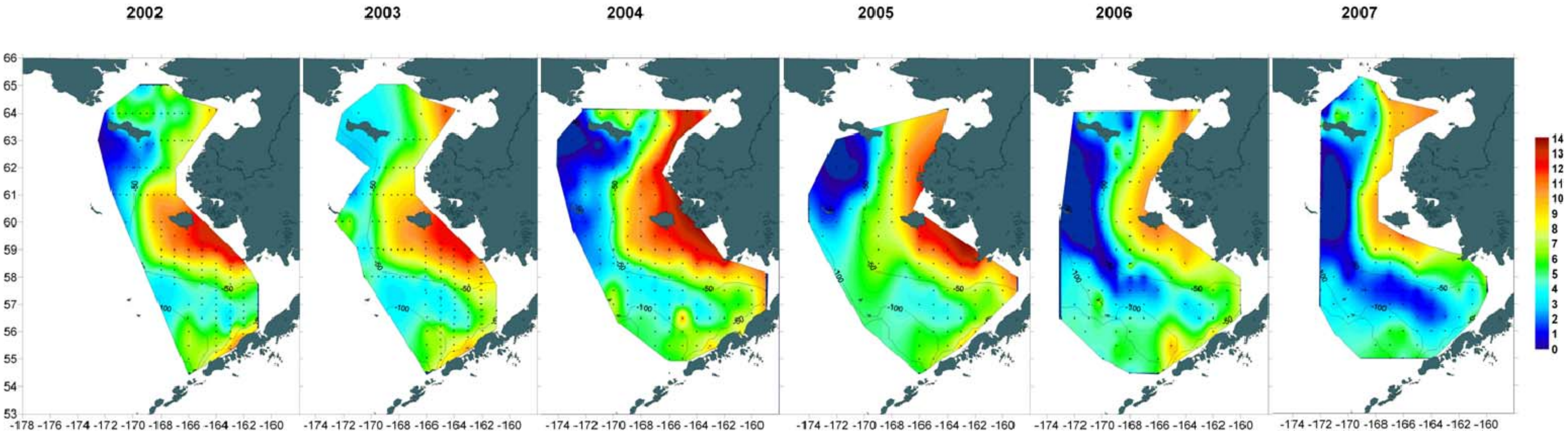

Figure 29. Mean temperature (deg.C) below the pycnocline in the Bering Sea, 2002-2007.

ALEUTIAN ISLANDS

Eddies in the Aleutian Islands –FOCI

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Last updated: August 2008

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 30) 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 31) provides an index of eddy energy likely to influence the flow through Amukta Pass. 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 the spring of 2008.

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

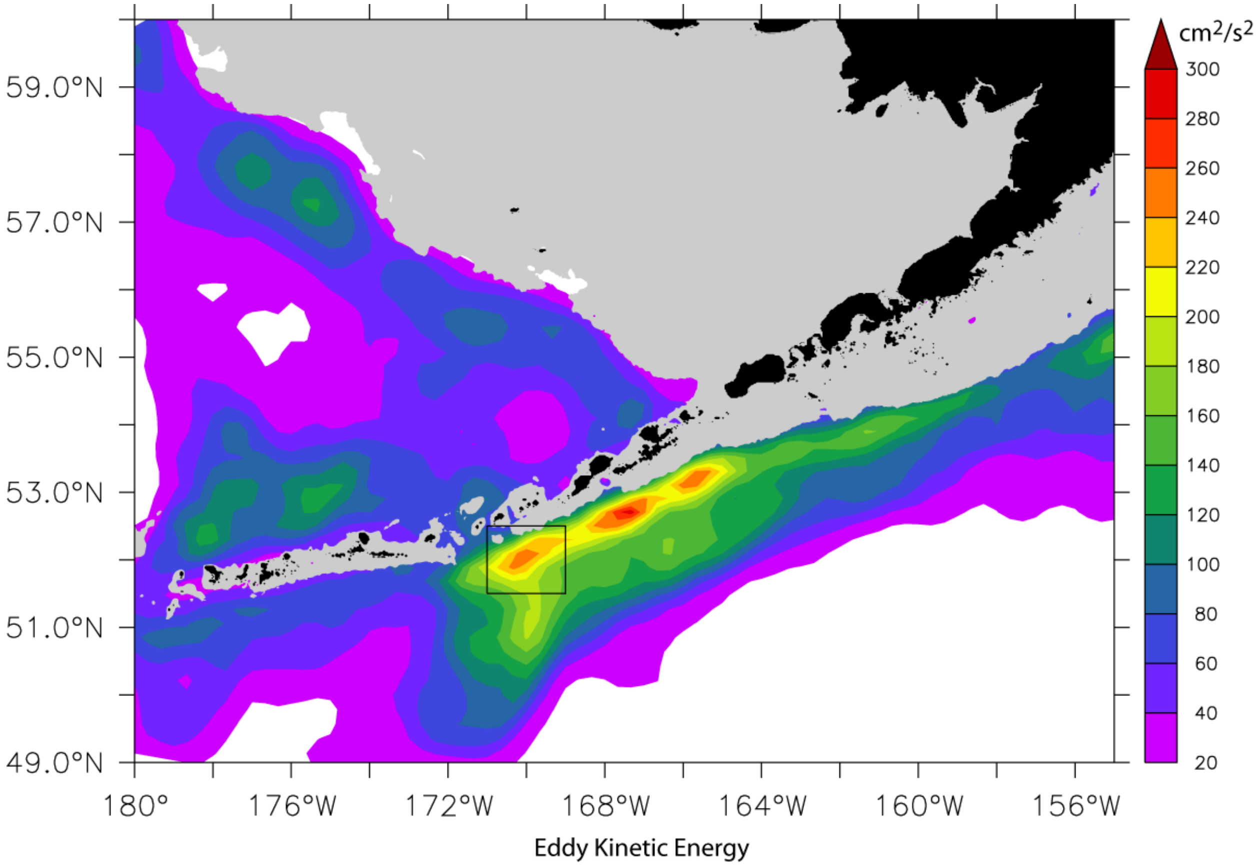

Figure 30. Eddy Kinetic Energy averaged over October 1993 – October 2007 calculated from satellite altimetry. Square denotes region over which EKE was averaged for Figure 31.

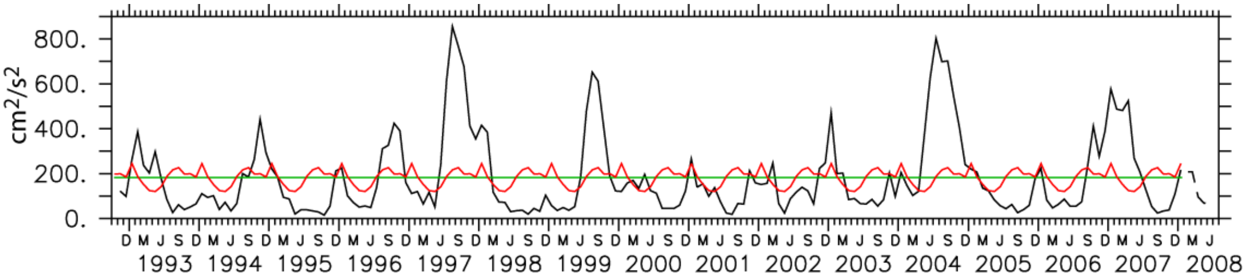

Figure 31. Eddy kinetic energy ($cm^2\ s^{-2}$) averaged over region shown in Figure 30. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product). Red: seasonal cycle. Green (straight line):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

Water temperature data collections – Aleutian Islands Trawl Surveys

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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

Habitat

HAPC Biota – Gulf of Alaska

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

HAPC Biota – Bering Sea

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Last updated: October 2008

Groups considered to be HAPC biota include: seapens/whips, corals, anemones, and sponges. Corals are rarely encountered on the Bering Sea shelf so were not included here. It is difficult to detect trends of HAPC groups on the Bering Sea shelf from the RACE bottom trawl survey results from 1982 to 2008 because of the relatively large variability in relative CPUE (Figure 32). Further research on gear selectivity and the life history characteristics of these organisms is needed to interpret these trends. For each species group, the largest catch over the time series was arbitrarily scaled to a value of 1 and all other values were similarly scaled. The standard error (+/- 1) was weighted proportionally to the CPUE to get a relative standard error.

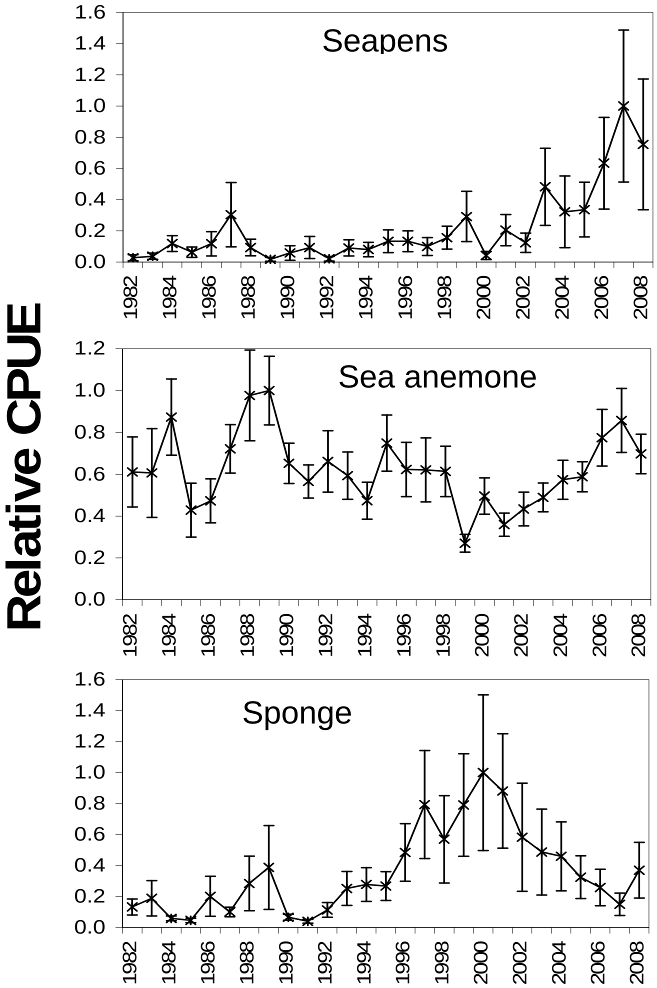

Figure 32. Relative CPUE trends of HAPC biota from the RACE bottom trawl survey of the Bering Sea shelf, 1982-2008. Data points are shown with standard error bars.

HAPC Biota – Aleutian Islands

Contributed by: Michael Martin, Alaska Fisheries Science Center
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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

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

Contributed by Chris Rooper, NMFS, AFSC, RACE
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Last updated: August 2008

Environmental variability affects the distributions of most marine fish species. In an analysis of rockfish (*Sebastes* spp.) in Alaska, five species assemblages were defined based on similarities in their distributions along environmental gradients (Figure 33). Data from 14 bottom trawl surveys of the Gulf of Alaska and Aleutian Islands (n = 6,767) were used. The distinct assemblages of rockfish were defined by geographical position, depth, and temperature (Rooper 2008). The 180 m and 275 m depth contours were major divisions between assemblages inhabiting the shelf, shelf break, and lower continental slope. Another noticeable division was between species centered in southeastern Alaska and those found in the northern Gulf of Alaska and Aleutian Islands.

In this time-series, the mean-weighted distribution of six rockfish species along the three environmental gradients (depth, temperature, and position) was calculated for the Gulf of Alaska and Aleutian Islands. Position is the distance of each trawl haul from Hinchinbrook Island, Alaska. A weighted mean value for each environmental variable was computed for each survey as:

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

where *fi* is the CPUE of each rockfish species group in tow *i* and *xi* is the value of the environmental variable at tow *i*. The weighted standard error (*SE*) was then computed as:

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

where *n* is the number of tows with positive catches. Details of the calculations and analyses can be found in Rooper (2008).

There were no definitive trends in distribution over the time series for position or depth in the Aleutian Islands (Figure 34). Mean-weighted temperature distributions for all species were within about 1°C over the entire time series. There was high variability in the mean-weighted variables in the 1991 Aleutian Islands survey, but after that the time series was remarkably stable. This is in contrast to the trends in rockfish distribution in the Gulf of Alaska.

There were no trends in distribution over the time series for depth or temperature in the Gulf of Alaska, although the distributions of rockfish species across temperatures were more contracted in 2007 than in previous years (Figure 35). However, there did appear to be a continued movement of the mean-weighted distribution towards the north and east (as indicated by the position variable). This may indicate a change in rockfish distribution around the Gulf of Alaska and is especially apparent in the distribution of juvenile POP.

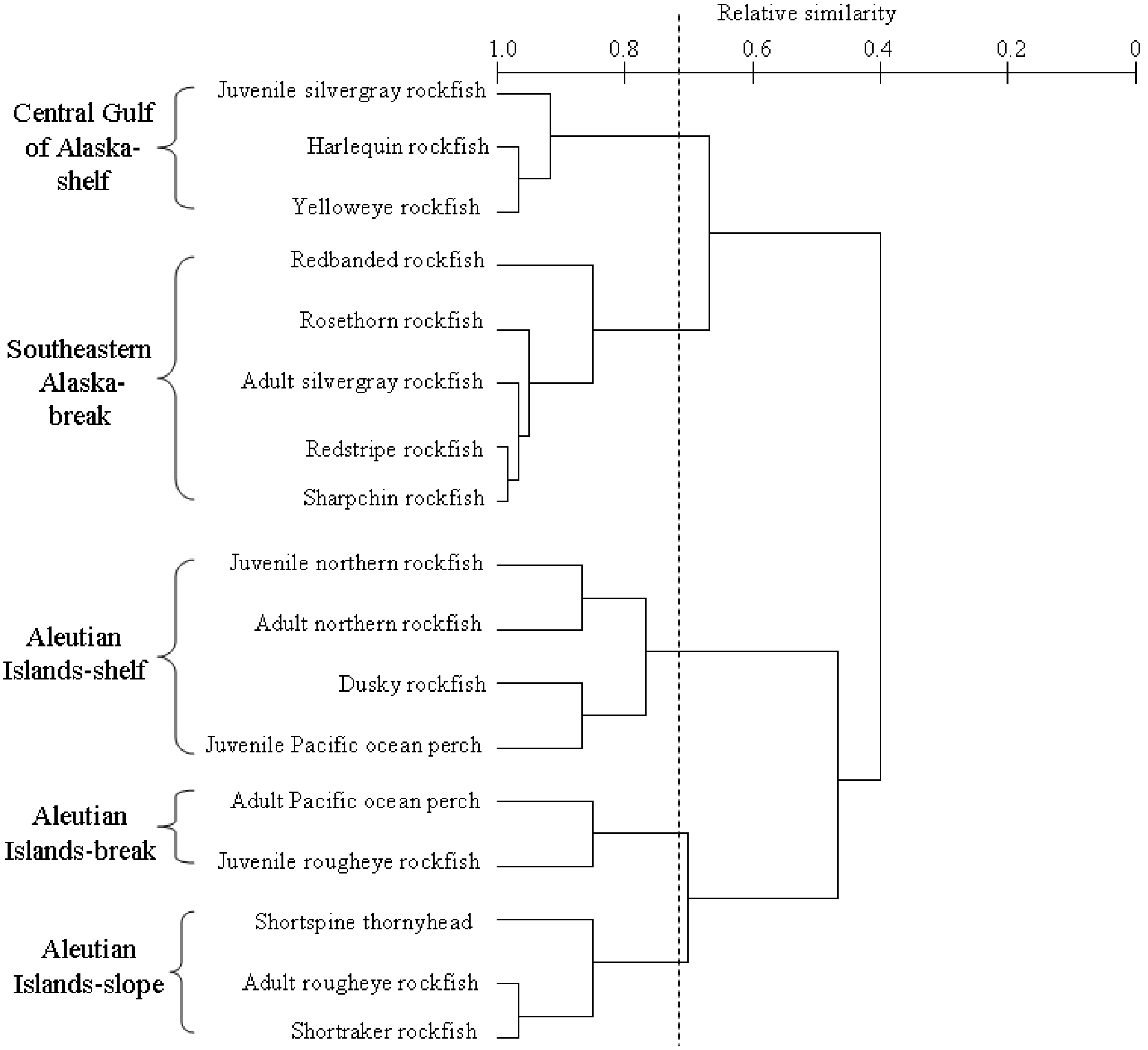

Figure 33. The results of cluster analysis of rockfish showing relative similarity amongst species-subgroups. The x-axis shows the relative similarity among species derived from the multinomial overlap indices among species-group pairs along the three environmental gradients (depth, position, and temperature). The dashed line (0.73) is where rockfish species assemblages were defined based on a similarity of 0.9 across the three environmental gradients (reprinted from Rooper (2008)).

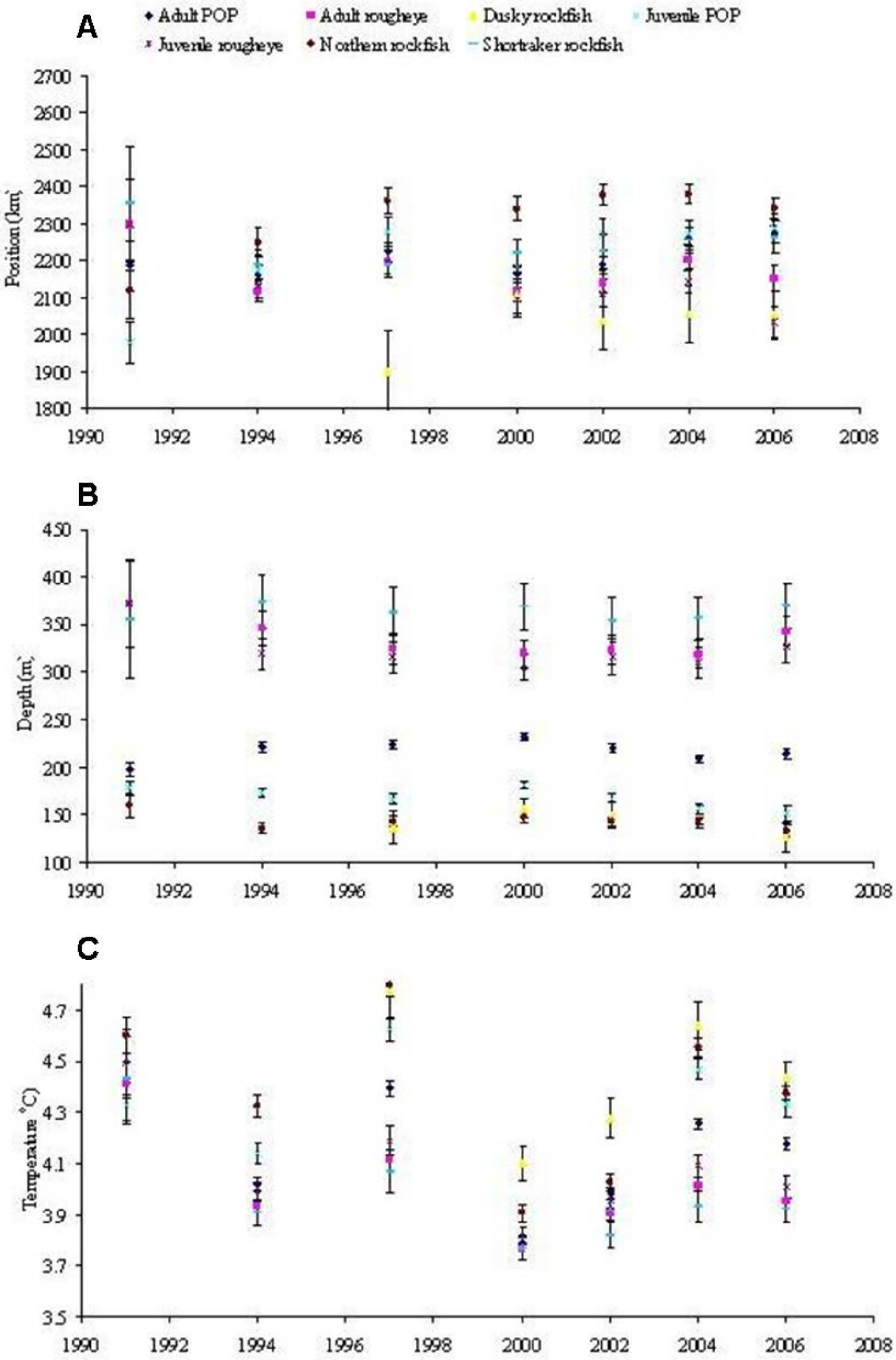

Figure 34. Plots of mean weighted (by catch per unit effort) distributions (and SEs) of seven rockfish species-groups along three environmental variables in the Aleutian Islands. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance from Hinchinbrook Island, Alaska, with positive values west of this central point in the trawl surveys and negative values in southeastward.

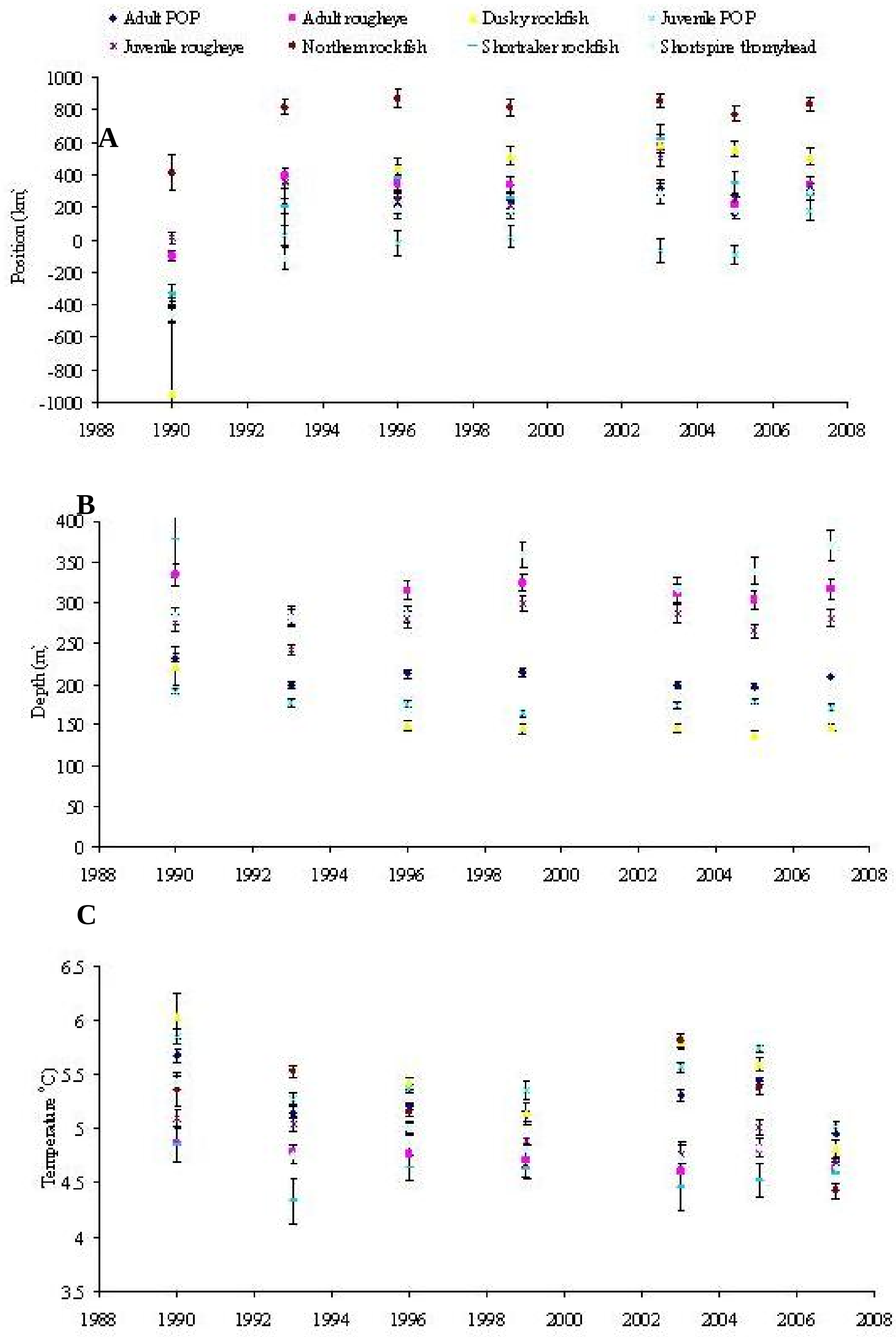

Figure 35. Plots of mean weighted (by catch per unit effort) distributions (and SEs) of seven rockfish species-groups along three environmental variables in the Gulf of Alaska. Mean weighted distributions of rockfish species-groups are shown for A) position, B) depth, and C) temperature. Position is the distance from Hinchinbrook Island, Alaska, with positive values west of this central point in the trawl surveys and negative values in southeastward.

Effects of Fishing Gear on Seafloor Habitat

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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

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

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

Variations in phytoplankton and nutrients during fall 2000-2006 in the eastern Bering Sea- BASIS

Contributed by Lisa Eisner, Kristen Cieciel, Ed Farley, and Jim Murphy, Auke Bay Laboratory, NMFS
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Last updated: August 2008

Oceanographic and fisheries data have been collected in the Eastern Bering Sea (EBS) during fall 2000-2007 for the U.S. component of a multiyear international research program, Bering-Aleutian Salmon International Survey (BASIS). Stations were located between 54°N and 70°N, at 30-60 km resolution, although spatial coverage varied by region and by year. Bristol Bay stations were sampled from mid August to early September during all eight years. While, stations in the central and northern EBS were generally sampled from mid September to early October. Oceanographic data were obtained from vertical conductivity-temperature-depth (CTD) profiles and laboratory analyses of discrete water samples at select depths (data available for 2003 - 2006). Oceanographic variables include temperature, salinity, nutrients, chlorophyll a, and phytoplankton taxonomic characteristics (based on phytoplankton species identification and chlorophyll a size fractionation). A long-term goal of this research is to characterize interannual variations in the abundance and distribution of lower and higher trophic level organisms in relation to oceanographic features in the EBS (see the *Physical Environment* and *Forage Fish* sections of this report).

Upwelling through Unimak Pass provided nitrate that fueled phytoplankton growth, indicated by high surface chlorophyll a and nitrate in coastal waters near Amak Is., south Bristol Bay in 2003 -2006 (Figures 36 and 37). Surface phytoplankton cells were generally small (< 10 µm) except in a few locations near-shore, where diatoms were likely abundant (Figure 36). High nitrate concentrations were seen below the pycnocline in the Middle and Outer Domains, particularly in the southeastern Bering Sea (Figure 38). Subsurface phytoplankton blooms were observed near the base of the pycnocline in Bristol Bay (mid August to early September) at depths where nitrate was replete. High ammonium concentrations were observed below the pycnocline in the Middle Domain (Figure 38). These ammonium values may provide a broad indicator of prior production over the growing season.

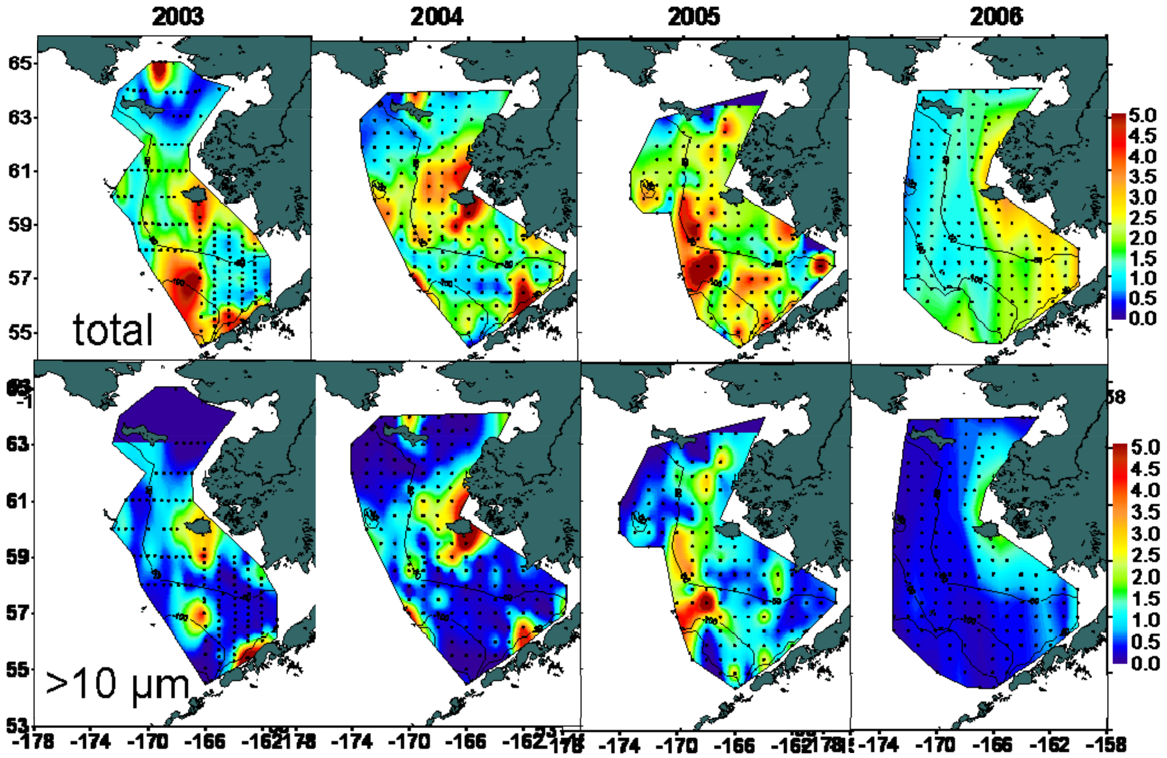

Figure 36. Total chlorophyll (top panel) and chlorophyll for phytoplankton cells >10µm (primarily diatoms).

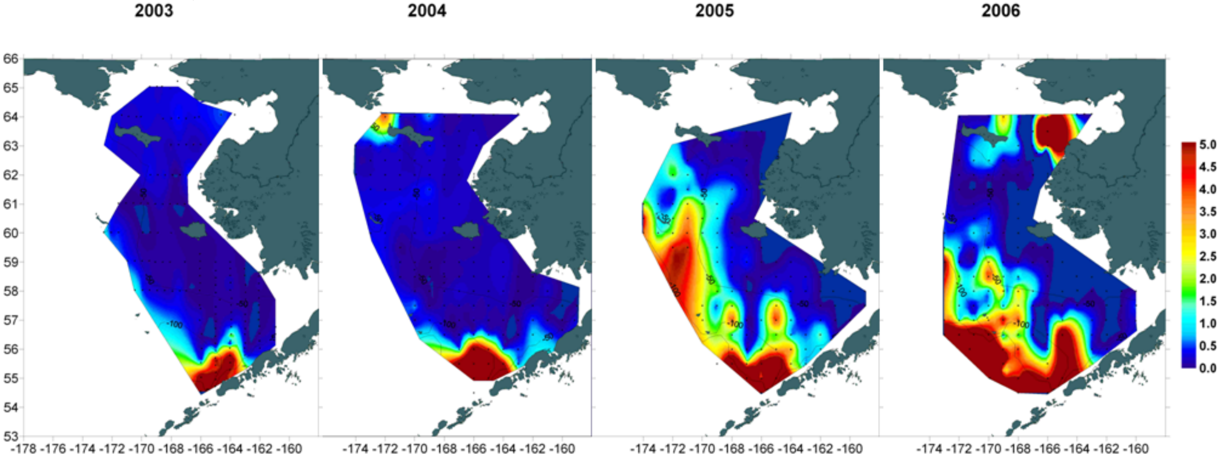

Figure 37. Mean nitrate (µM) above pycnocline (maximum set at 5 µM for this display).

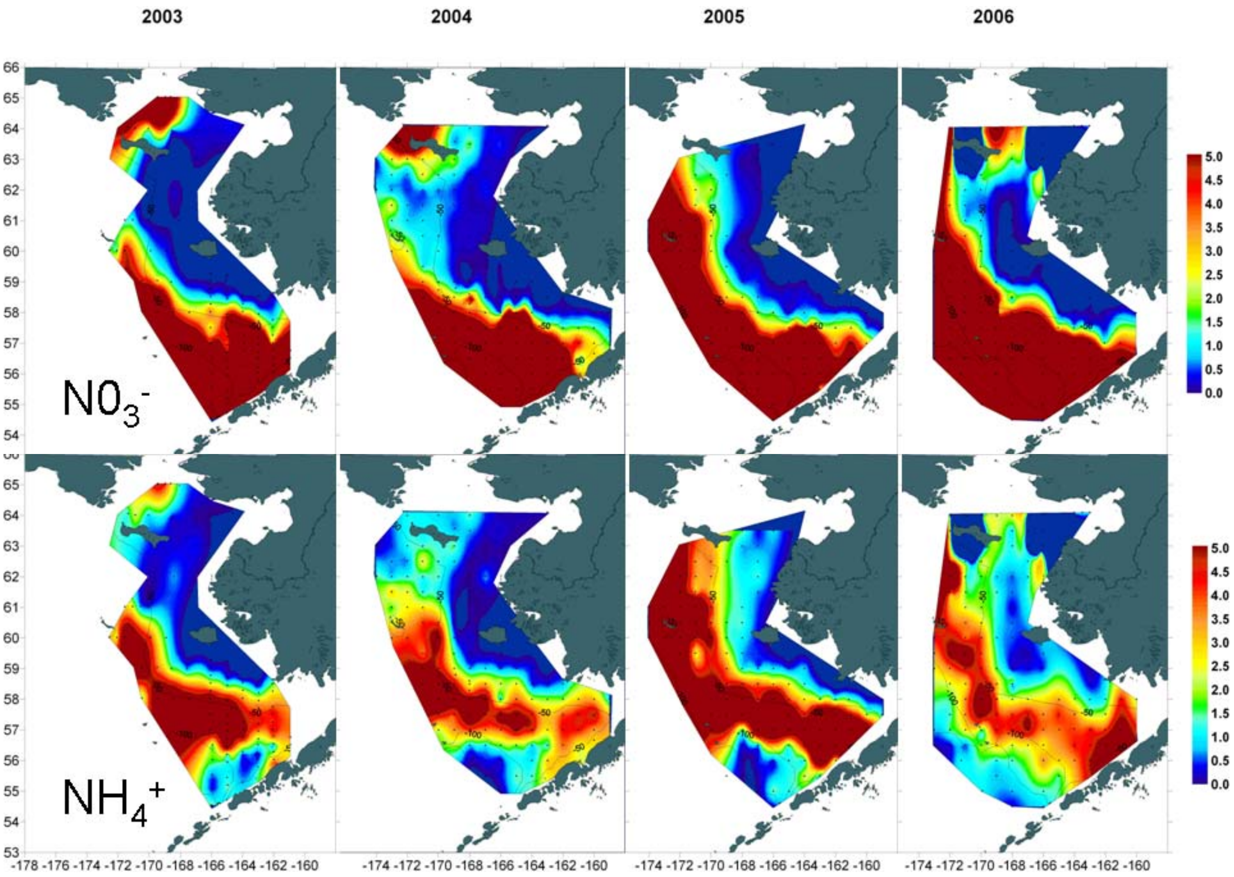

Figure 38. Mean nitrate and ammonium concentrations (µM) below pycnocline (maximum set at 5 µM for this display).

Zooplankton

Gulf of Alaska Zooplankton

Contributed by K.O. Coyle, Institute of Marine Science, University of Alaska Fairbanks and A.I. Pinchuk, Alaska SeaLife Center, University of Alaska Fairbanks,
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Last updated: August 2006

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

Continuous Plankton Recorder data in the Northeast Pacific

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NEW: October 2008

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 and onto Japan; only the Gulf of Alaska transects are discussed here) a total of ~nine times per year since 2000. Plankton samples were collected with a filtering mesh and then microscopically processed in the lab for plankton abundance. The survey has so far accumulated 3,648 processed samples (with approximately three times as many archived without processing) each representing 18km of a transect and containing abundance data on over 290 phytoplankton and zooplankton taxa.

The dominant contributors to the spring mesozooplankton biomass are the copepods *Neocalanus plumchrus* and *N. flemingeri*. The timing of their peak abundance varies from year to year (Mackas et al. 1998, Mackas et al. 2007). Although the exact mechanism is not yet known, environmental forcing through water temperature, stratification effects and/or differential survival of the young copepodites produced during the late winter are likely to play a role. The CPR data show (Figure 39) that at the start of the times series (2000/01) when the Pacific Decadal Oscillation was negative and the NE Pacific was somewhat cool, the peak in abundance was later in the year and the period of abundance was relatively long. In the warmer, PDO-positive years 2003-2005, the peak was earlier in the year, with a shorter duration of high abundance. The switch to cooler, PDO-negative conditions that took place in late 2006 has apparently caused the timing to shift back again to somewhat later in 2007, but it is not yet as late as in the earlier part of the time series. Samples from 2008 are mid-way through being processed but preliminary data suggest that the timing of peak mesozooplankton abundance has shifted to later in the year, similar to the pattern observed in 2000/01. Early July 2008 mesozooplankton abundances were again quite high. Timing of peak prey abundance is likely to have an impact on higher trophic levels that depend on *Neocalanus* as a spring food resource so determining the extent of the variability under rapidly alternating modes of the PDO will be important.

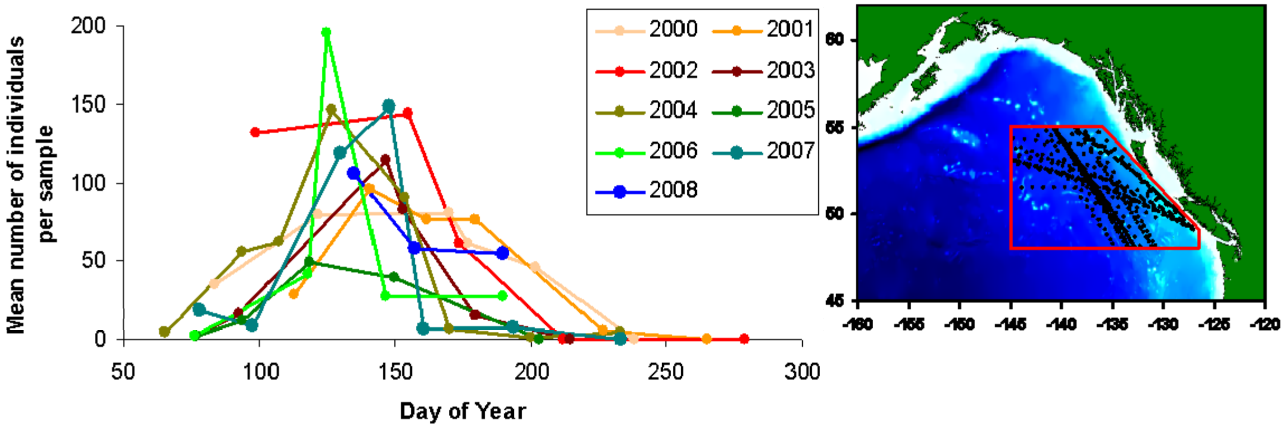

Figure 39. The mean abundance of *Neocalanus plumchrus* and *N. flemingeri* copepodites (stages 2-5) on each sampling of the region shown on the adjacent map. Note that ship tracks vary from month to month. Data for 2008 are provisional.

Bering Sea Zooplankton

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Last updated: September 2008

Summer zooplankton biomass data are collected in the eastern Bering Sea by the Hokkaido University research vessel T/S Oshoru Maru. The cruises began in 1954 and continue today. 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. Hunt et al. (2008) addressed recent (up to 2005) declines in summer zooplankton biomass in relation to a warming of the eastern Bering Sea (2001-2005). The figure below (Figure 40) updates the time series to 2007 extending the time series into a cold period in the eastern Bering Sea and presents the data as biomass (wet weight) over the time period sampled. Up to 1998 there were no discernable trends in the time series for any of the four geographic domains (Napp et al. 2002). 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 (Figure 40). Part of the decrease in biomass over the middle shelf was most likely due to decreases in the abundance of *Calanus marshallae*, the only "large" copepod found in that area and euphausiids (Hunt et al. 2008). It is not clear what might be the cause of declines in other regions.

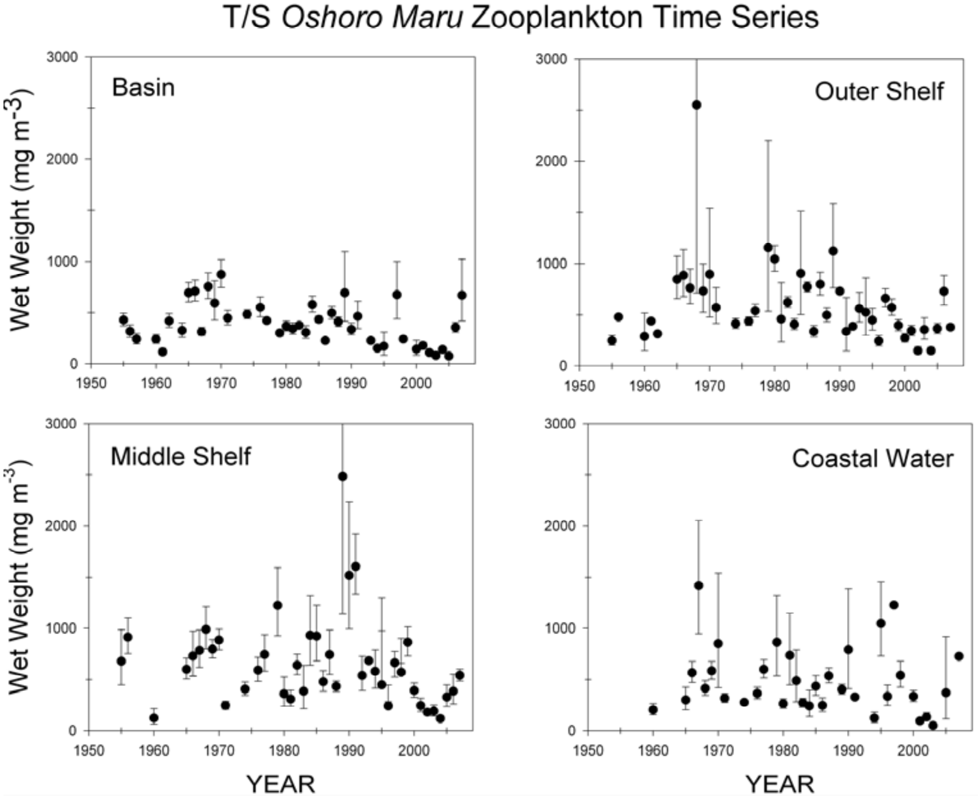

Figure 40. Zooplankton biomass at stations in regions of the deep basin of the Bering Sea and in the outer, middle and coastal domains of the southeastern Bering Sea shelf sampled during the T/S Oshoro Maru Summer Cruises. Data from 1977 to 1994 from Sugimoto and Tadokoro (1998). Data from 1995 to 2004 from Dr. N. Shiga. Data from 2005 to 2007 from Dr. A. Yamaguchi, all from the Graduate School of Fisheries, Hokkaido University, Japan.

Forage Fish

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

Contributed by Miriam Doyle and Mick Spillane, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, and Susan Picquelle and Kathryn Mier, Alaska Fisheries Science Center.
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Last updated: August 2006

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

Fisheries and oceanographic data are collected in the Eastern Bering Sea (EBS) during fall 2002-2007 for the U.S. component of a multiyear international research program, Bering-Aleutian Salmon International Survey (BASIS). Stations were located between 54°N and 64°N, at 60 km resolution. Stations east of 165°W and south of 60°N were sampled from mid August to early September while, stations in the central (west of 165°W and south of 60°N) and northern (north of 60°N) Bering Sea were generally sampled from mid September to early October. Oceanographic data were obtained from vertical conductivity-temperature-depth (CTD) profiles and laboratory analyses of discrete water samples at select depths (2003-2007). Oceanographic variables include temperature, salinity, nutrients, chlorophyll a, and phytoplankton taxonomic characteristics (based on phytoplankton species identification and chlorophyll a size fractionation). Fish were sampled with a surface trawl.

A long-term goal of this research is to characterize interannual variations in the abundance and distribution of lower and higher trophic level organisms in relation to oceanographic features in the EBS (see the Physical Environment and Nutrients and Productivity sections of this report). Sea temperatures during spring can have a profound effect on the ecology of the Bering Sea, affecting bottom-up control of the ecosystem, fish distribution, and overall fitness of marine fish (Hunt et al. 2002; Farley et al. 2007a). During warm years (2002-2005; Figure 41), age-0 pollock and juvenile Bristol Bay sockeye salmon were broadly distributed across the eastern Bering Sea shelf (Figure 42). In contrast, during cool years (2006-2007; Figure 41), distribution of age-0 pollock were constricted to the Middle Domain and juvenile sockeye salmon were constricted to inner Bristol Bay (Figure 42). The diets of age-0 pollock also varied between years with warm and cool spring temperatures (Figure 43). Cannibalism was more prevalent in warm years (2004-2005), with smaller age-0 pollock accounting for 21.9% of the diet by weight as compared to 5.0% in cool years (2006-2007). The diversity of zooplankton prey consumed was greater and included many small (≤ 2mm total length) species during warm years (2004-2005). The most important prey item in terms of weight shifted from smaller age-0 pollock to euphausiids in cool years (2006-2007). Euphausiids accounted for 14.6% of the diet by weight during 2004-2005, and 36.5% during 2006-2007 (Moss et al. in review). In addition, recent caloric content analyses (Moss et al. in review) indicated that the energy density (J•g-1) of age-0 pollock was positively correlated with wet weight (R2 = 0.1404), and mean energy density was higher during 2006 (4184, 499 SD) than in 2004 (3889, 443 SD) and 2005 (3674, 377 SD). Farley et al. (2007a) also found that juvenile sockeye salmon diets shifted from predominately age-0 pollock during warm years to Pacific sand lance and euphausiids during cool years. The size of juvenile sockeye salmon was lower during cool years, and these small fish tended to have lower marine survival (Farley et al. 2007b).

The relative abundance indices for juvenile salmon are shown in Figure 44a. Juvenile sockeye salmon are primarily from Bristol Bay, juvenile Chinook and chum salmon are from the Yukon and Kuskokwim Rivers and juvenile pink salmon are primarily from western Alaska watersheds. Relative abundance of juvenile salmon generally increased during 2002 to 2005, declined during 2006, but was up again during 2007. We note that the higher juvenile salmon relative abundance indices tend to be followed by higher returns of adult salmon to western Alaska. We are attempting to use theses relative abundance indices for juvenile salmon as a recruitment index for western Alaska adult returns as these juvenile salmon indices could be useful in run reconstruction models for a number of studies including western Alaska salmon bycatch models.

Relative abundance of age-0 pollock also increased during 2002 to 2005, but declined during 2006 and 2007 (Figure 44b). We note however that there appears to be a negative relationship between relative abundance of age-0 pollock from our survey and subsequent recruitment to age-1 pollock. Moss et al. (in review) suggested the inverse relationship between brood year abundance of age-0 to age-1 pollock was likely due to: a) top-down control - predation of age-0 pollock by piscivorous fishes during warm years and/or b) water column stability – during warm years– that limited post-bloom production on the shelf, reducing the abundance of energy rich prey (i.e., euphausiids) for age-0 pollock, negatively impacting their energetic status and over-winter survival. We also note that the relative abundance of age-0 Pacific cod was highest during 2005 and 2006 (Figure 44b).

Spring sea temperatures during 2008 were also anomalously cool (Figure 41). We would expect to see restricted distributions and low abundance of age-0 pollock. However, because the area surveyed and number of stations has been substantially reduced we will not be able to determine how these cold sea temperatures may affect relative abundance estimates or distributions of commercially important fish species (Figure 45). In addition, the loss of the more northerly and offshore stations impacts assessments of age-0 pollock and Pacific cod and eliminates annual indices of juvenile western Alaska salmon abundance and health used to inform western Alaska bycatch models.

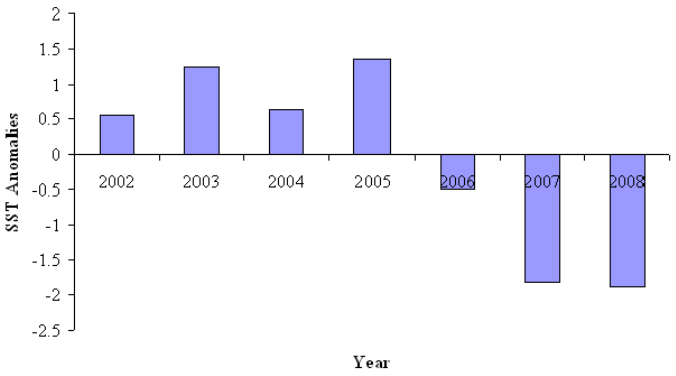

Figure 41. May sea surface temperature anomalies (SST) in the eastern Bering Sea. Date from http://www.beringclimate.noaa.gov/. Anomalies are deviations from the mean SST value (1970 to 2008; 2.75ºC) normalized by the standard deviation (1970 to 2008; 0.60ºC).

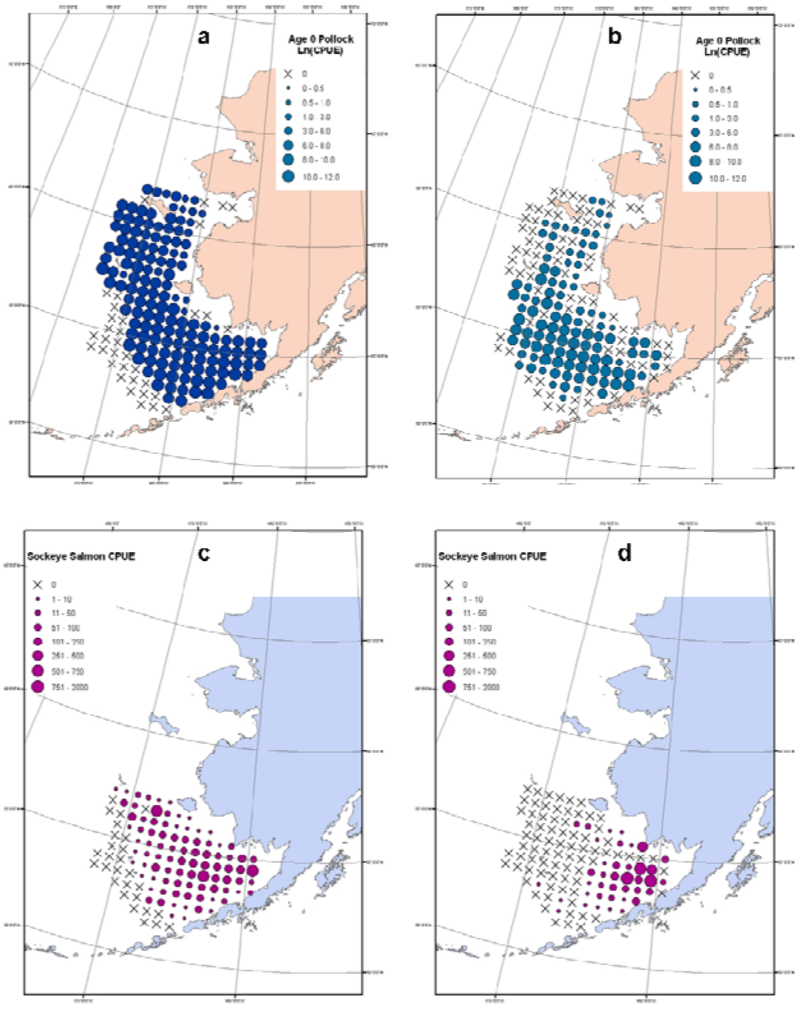

Figure 42. Distribution, average catch per unit effort (ln(CPUE)), of age-0 pollock in 2002-2005 (a), 2006-2007 (b) and the distribution (CPUE) of juvenile Bristol Bay sockeye salmon in 2002-2005 (c) and 2006-2007 (d). Stations north of 60N were not shown for juvenile sockeye salmon as this region does not contain Bristol Bay sockeye salmon at the time of the survey. Years with warm spring and summer sea temperatures included 2002-2005; years with cool spring temperatures included 2002-2005.

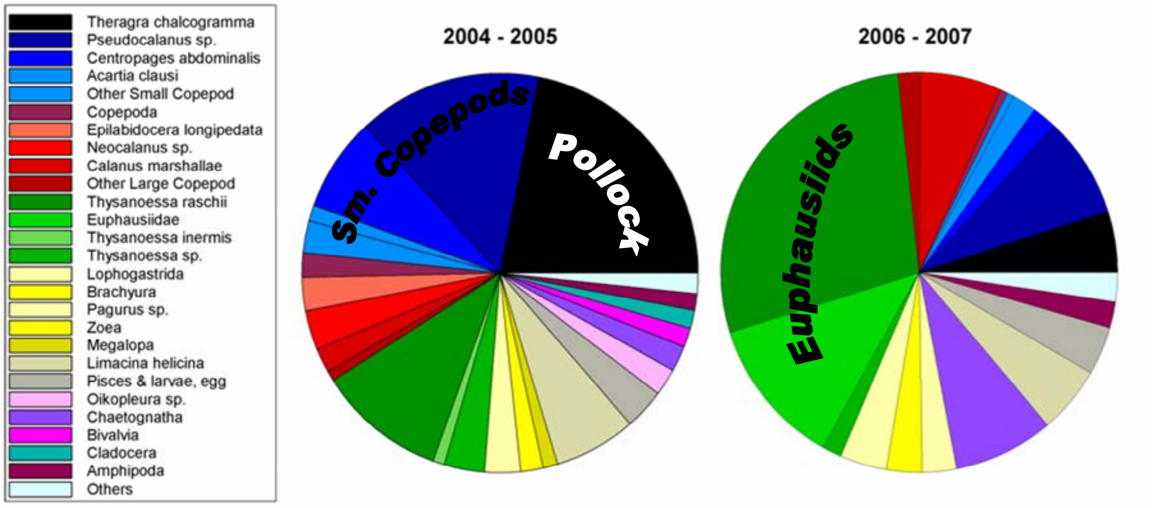

Figure 43. Eastern Bering Sea age-0 pollock diet composition by weight during years of warm (2004-2005) and cool (2006-2007) sea surface temperatures.

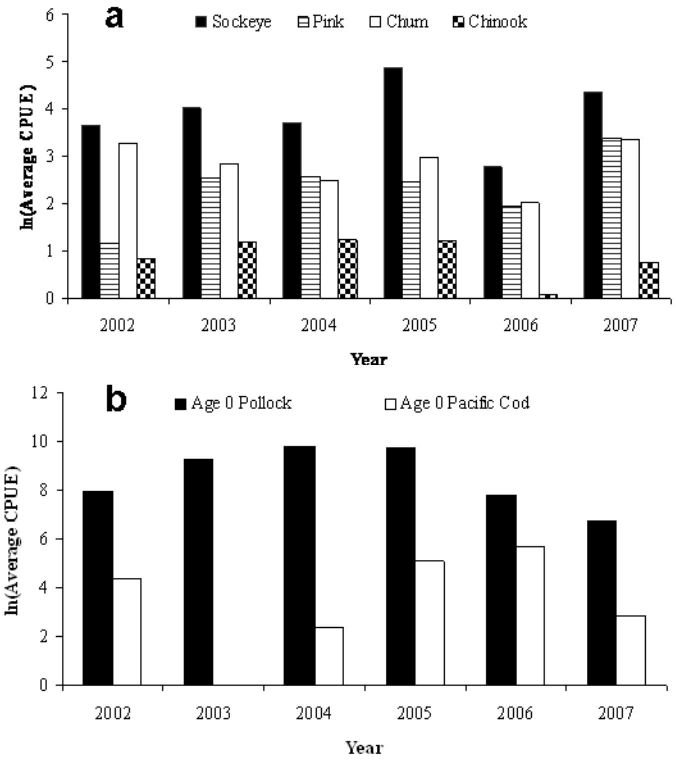

Figure 44. Relative abundance (natural log of average catch per unit effort (CPUE)) for a) western Alaska juvenile sockeye, pink, chum, and chinook salmon and b) age-0 pollock and Pacific cod. Data from the BASIS research survey along the eastern Bering Sea Aug to Oct, 2002 to 2007

Figure 45. Proposed survey stations of the NOAA Ship Oscar Dyson BASIS survey in the eastern Bering Sea, September 8 - 30, 2008.

Forage 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

Forage – Eastern Bering Sea

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Last updated: October 2008

The North Pacific Fishery Management Council defined several groups as forage species for management purposes. These groups include: gunnels, lanternfish, sandfish, sandlance, smelts, stichaeids, and euphausiids. Some of these groups are captured incidentally in the RACE bottom trawl survey of the eastern Bering Sea shelf, which may provide an index of abundance (Figure 46). For each species group, the largest catch over the time series was arbitrarily scaled to a value of 1 and all other values were similarly scaled. The standard error (+/- 1) was weighted proportionally to the CPUE to get a relative standard error. Sandfish are generally in low abundance in the trawl surveys and are usually caught in high abundance in only a few hauls in the shallower stations (Figure 46). Stichaeids, which include the longsnout prickleback (*Lumpenella longirostris*), daubed shanny (*Lumpenus maculatus*) and snake prickleback (*Lumpenus sagitta*), are small benthic-dwelling fish. Their relative abundance in trawl survey catches was generally higher in trawl survey catches prior to 1999. Similar to stichaeids, the relative CPUEs of sandlance were generally higher prior to 1999. Eulachon relative CPUE was higher than the past four years. Capelin catches in the survey have been relatively low, with the exception of one year (1993) when CPUE was very high (Figure 46). The late retreat of ice and lower temperatures on the EBS shelf is probably the reason for the dramatic rise in the relative CPUE of Arctic cod in 2008 (Figure 47).

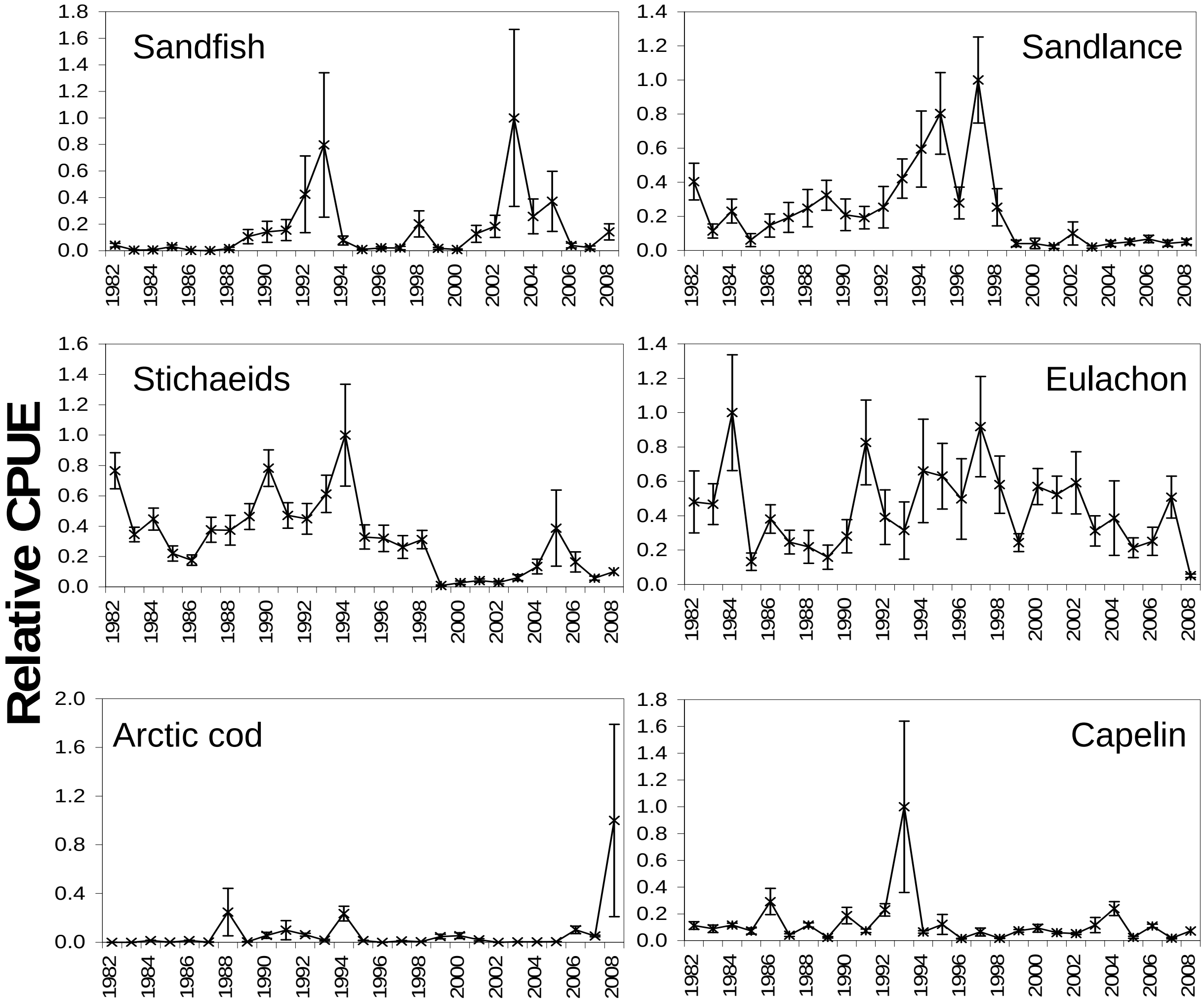

Figure 46. Relative CPUE of several forage fish groups from the eastern Bering Sea summer bottom trawl survey, 1982-2008. Data points are shown with standard error bars.

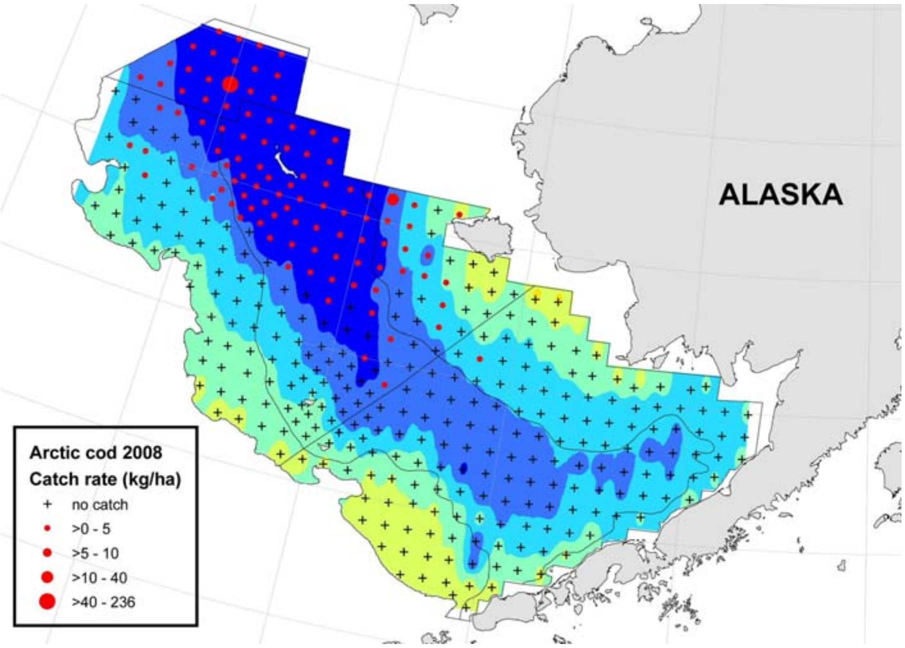

Figure 47. Arctic cod catch rates (kg/ha) and bottom temperatures in the eastern Bering Sea summer bottom trawl survey, 2008. Dark blue colors represent bottom temperatures less than 0ºC; lighter shades of blue and green colors represent increases in temperature of 1ºC.

Forage – 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

The Alaska Department of Fish and Game (ADF&G) has completed Pacific herring stock assessments in Prince William Sound (PWS) since ~1973. Population trends were initially monitored with aerial surveys to estimate biomass and the linear extent of beach used for spawning (Brady 1987), and have continued almost without interruption. Age, sex, and size data has been collected from most fisheries and spawning aggregations since 1973 (e.g., Baker et al. 1991). Dive surveys to estimate spawning biomass began with feasibility studies in 1983 and 1984 and continued in 1988-1992 (Brown and Baker 1998) and 1994-1997 (Willette et al. 1999). In 1993, ADF&G in cooperation with the Prince William Sound Science Center began fall acoustics surveys (e.g., Thomas and Thorne 2003). Spring (March/April) acoustics surveys have been conducted during 1995-2008. Age structured models have been used since 1993 to estimate historical population parameters and project future biomass, recruitment, and abundance (Funk 1994).

In the 1980s a strong recruitment occurred approximately every four years (Figure 48). The recruitment as age-3 fish from the 1984 and 1988 year classes were particularly large (~ 1 billion fish from 1984 brood year). The prefishery run biomass estimate peaked in 1988 and 1989 at >100,000 metric tons (mt; Figure 48). The 1993 biomass projection was >100,000 mt; however, the 1993 observed biomass was < 30,000 mt (Marty et al. 2003). The stock collapsed and the biomass has remained (1993 – 2008) at levels less than half of the 1980-1992 average of 84,000 mt. The causes of the decline have been hypothesized to be related to effects of the 1989 T/V Exxon Valdez oil spill, commercial harvesting, or environmental effects (Carls et al. 2002, Pearson et al. 1999, Thomas and Thorne 2003).

The PWS Pacific herring fisheries are managed to allow harvest of from 0-20% of the biomass above a spawning biomass threshold of 22,000 tons (20,020 mt). Since the stock collapse in 1993, purse seine sac roe harvest has only occurred in 1997 and 1998 (2 of 16 years). The fishery is also closed for the fall 2008 and spring 2009 fisheries because the projected biomass is below the threshold spawning biomass.

The variability of recruitment in Prince William Sound herring is probably at least related to large-scale environmental factors (Williams and Quinn 2000), smaller-scale environmental factors (Norcross et al. 2001) and disease (Marty et al. 2003, 2004). Disease assessments (1993-2002) indicate viral hemorrhagic septicemia virus (VHSV) and associated ulcers were related to population declines in 1993/1994 and 1998; and Ichthyophonus hoferi was related to a population decline in 2001 (Marty et al. 2004). The prevalence of I. hoferi increased significantly between 2002 (14%) and 2005 and 2006 (25%), and this may cause increased mortality in the older age classes. The 2009 forecast model is a modified version of the 2006 model (Marty et al. 2004) and integrates disease assessment and spring acoustics survey data directly into the model (Hulson et al. 2008).

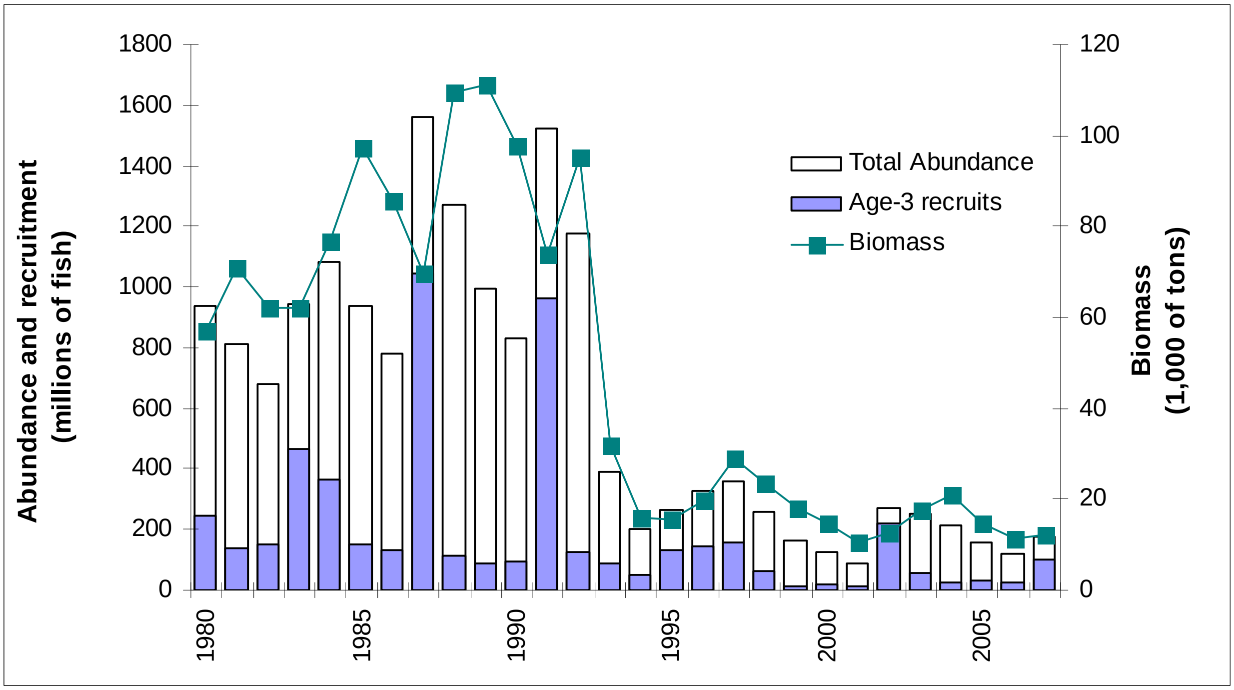

Figure 48. Age-3 recruitment, total prefishery abundance and run biomass (metric tons) of Pacific herring in Prince William Sound, 1980-2008. The abundance values and biomass are outputs of the age-structured model used to produce the 2009 projections.

Southeastern Alaska herring

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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

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

An age-structured analysis model was used to assess Pacific herring population trends in the Togiak District of Bristol Bay (Funk et al. 1992). Abundance peaked in the early 1980s with approximately 1.6 billion fish when herring from the 1977 and 1978 spawners recruited into the fishery as age-4 fish in 1981 and 1982 (Figure 49). This recruitment event was likely linked to the regime shift experienced in the late 1970s. From that point total abundance declined until more modest recruitment events occurred in 1991 and 1992 from the 1987 and 1988 spawners. Temporal trends in Togiak herring abundance show that total abundance from the early 1980s to the mid-1990s was above the 1978 - 2006 average (763 million fish), with the exception of 1989 (669 million fish) and 1990 (621 million fish). Total abundance again fell below the long term average in 1995 and has remained below average through 2007 (with the exception of 2000 and 2001 where the population was estimated to have been 780 and 771 million fish respectively) (Figure 49). Whether this is a picture of a stock in decline or of a stock that is stable (though cyclic) at a lower level of abundance is not clear although we are inclined towards the later view.

The high abundance estimates in the early 1980s may be an artificial result of backwards projecting from the ASA model which was used beginning in 1993. The model has a tendency to over hindcast biomass estimates from the 1980s and early 1990s, however it should be noted that the model was not initially designed to hindcast population size.

Pacific herring recruitment trends are highly variable, with large year classes occurring at intervals of approximately 9 or 10 years, with the most recent events occurring from the 1996 and 1997 year classes which recruited into the fishery as age-4 fish in 2000 and 2001 (Figure 49). These large recruitment events drive the Togiak herring population. Environmental conditions may be the critical factor that influences the strength of herring recruitment. Williams and Quinn (2000) have demonstrated that Pacific herring populations in the North Pacific are closely linked to environmental conditions with temperature having the strongest correlation. A general consensus in fisheries points towards the larval stage of herring life history as being the most important factor for determining year class strength (Cushing 1975, Iles and Sinclair 1982). Ocean conditions relative to spawn run timing would greatly influence the strength of each year class. Closer examination of trends in sea surface temperature, air temperature, and Bering Sea ice cover specific to the Bristol Bay area may find a specific correlate for Togiak herring recruitment.

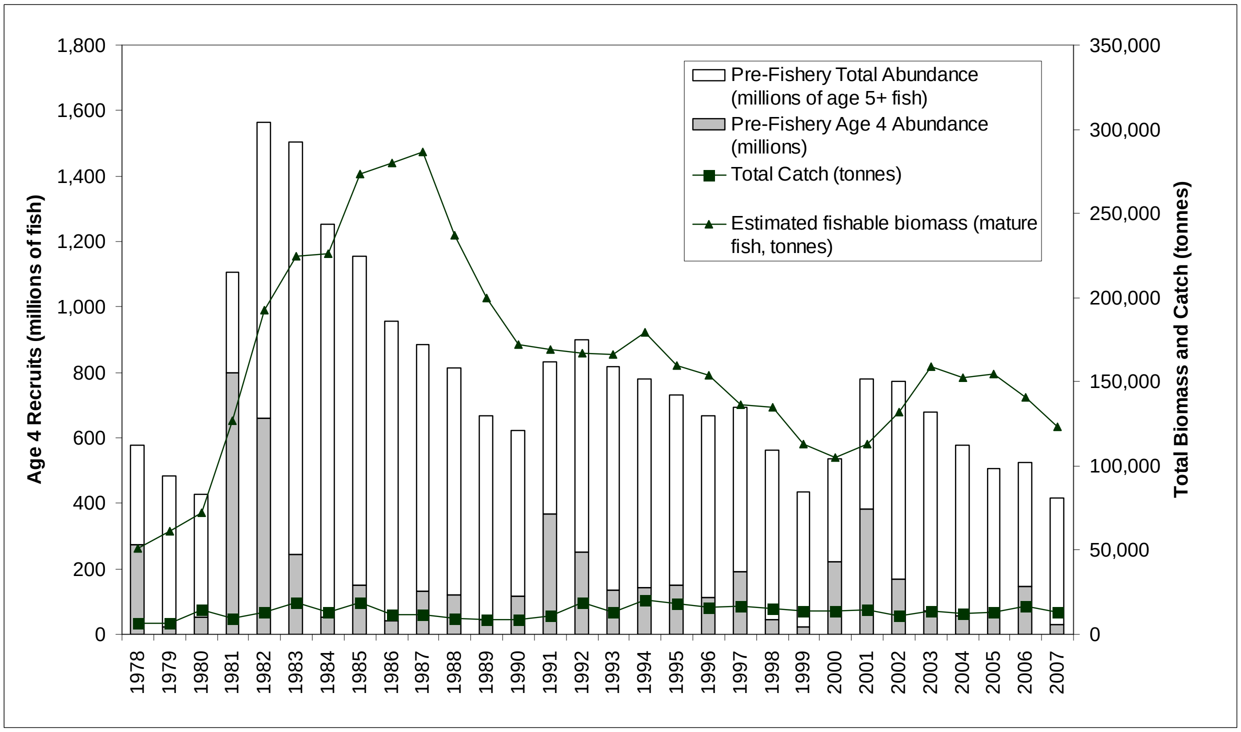

Figure 49. Total age-4+ abundance, abundance of age-4 recruits, mature biomass, and total harvest of Pacific herring in the Togiak District of Bristol Bay, 1978 – 2007.

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: October 2008

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 (2007 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, 2008). 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. A description of STARS and software is available at: http://www.beringclimate.noaa.gov/index.html. 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.

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. Some fluctuations in the total biomass have occurred, with biomass below the 1978-to-present average occurring in 1978-82, 1990-91, and 2006-2008 (Figure 50). Walleye pollock is the dominant species throughout the time series and has influenced observed fluctuations in total biomass, particularly the decreased biomass in recent years.

Gulf of Alaska groundfish biomass trends (Figure 50) 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. 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. Total GOA biomass levels in 2007 were still above the 1978-present average.

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 51-53 and Table 3).

Most roundfish (gadids, sablefish, and Atka mackerel) typically did not show a shift in survival in 1976-77 or 1988-89 in the BSAI or GOA (Figures 51 and 52). Instead, shifts were observed in the early 1970s and early 1980s. Sablefish showed significant negative shifts in 1965 and 1983 and a positive shift in 1977.

Several BSAI flatfish had high survival prior to the late 1980s and lower survival in the 1990s, including arrowtooth flounder, yellowfin sole, northern rock sole and flathead sole (Figure 51 and Table 3). This was not the case for most GOA flatfish, which tended to show shifts in the mid- late 1990s. GOA arrowtooth flounder had negative step-changes in survival in 1980 and 1989; 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 3). After the mid-1980s, there was a decreasing trend in log(R/S) anomalies (Figures 51 and 52). BS POP also showed a negative shift in 1989, whereas, GOA POP showed a negative shift in 1969 and 2001 (Figures 51 and 52 and Table 3). Other rockfish showed shifts in other years or no shifts at all.

Conclusions

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.

The survival of roundfish generally did not appear to be affected by the 1976-77 or the 1988-89 climate regime shifts. Examination of the average recruit per spawning biomass anomalies, however, indicates roundfish experience similar trends in survival within and between ecosystems. For example, pollock and cod have similar recruit per spawner trends within both the BSAI and GOA. Barbeaux et al. (2003) found that Aleutian Island pollock (not included in this analysis) and Atka mackerel show similar patterns in recruitment. This may be an indication that roundfish 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. Examination of the recruitment of winter-spawning flatfish in the Bering Sea in relation to decadal atmospheric forcing indicates favorable recruitment may be linked to wind direction during spring (Wilderbuer et al. 2002; Wilderbuer and Ingraham, this report). 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.

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.

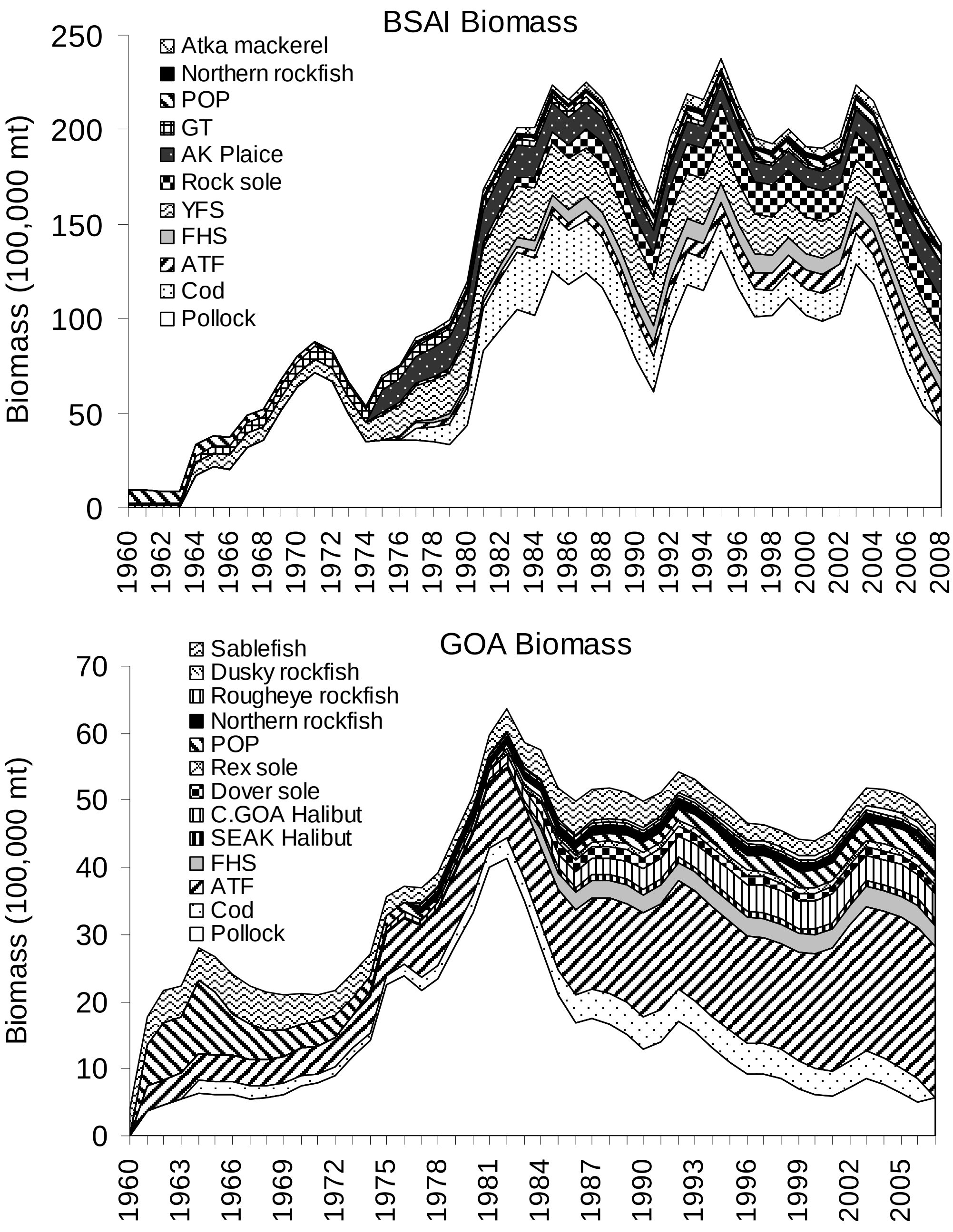

Figure 50. Groundfish biomass trends (100,000 metric tons) in the BSAI (1960-2008) and GOA (1960-2007), as determined from age-structured models of the Alaska Fisheries Science Center reported by NPFMC (2007 a, b). Halibut data provided by the IPHC (S. Hare, personal communication), but not updated for 2008 in this graph.

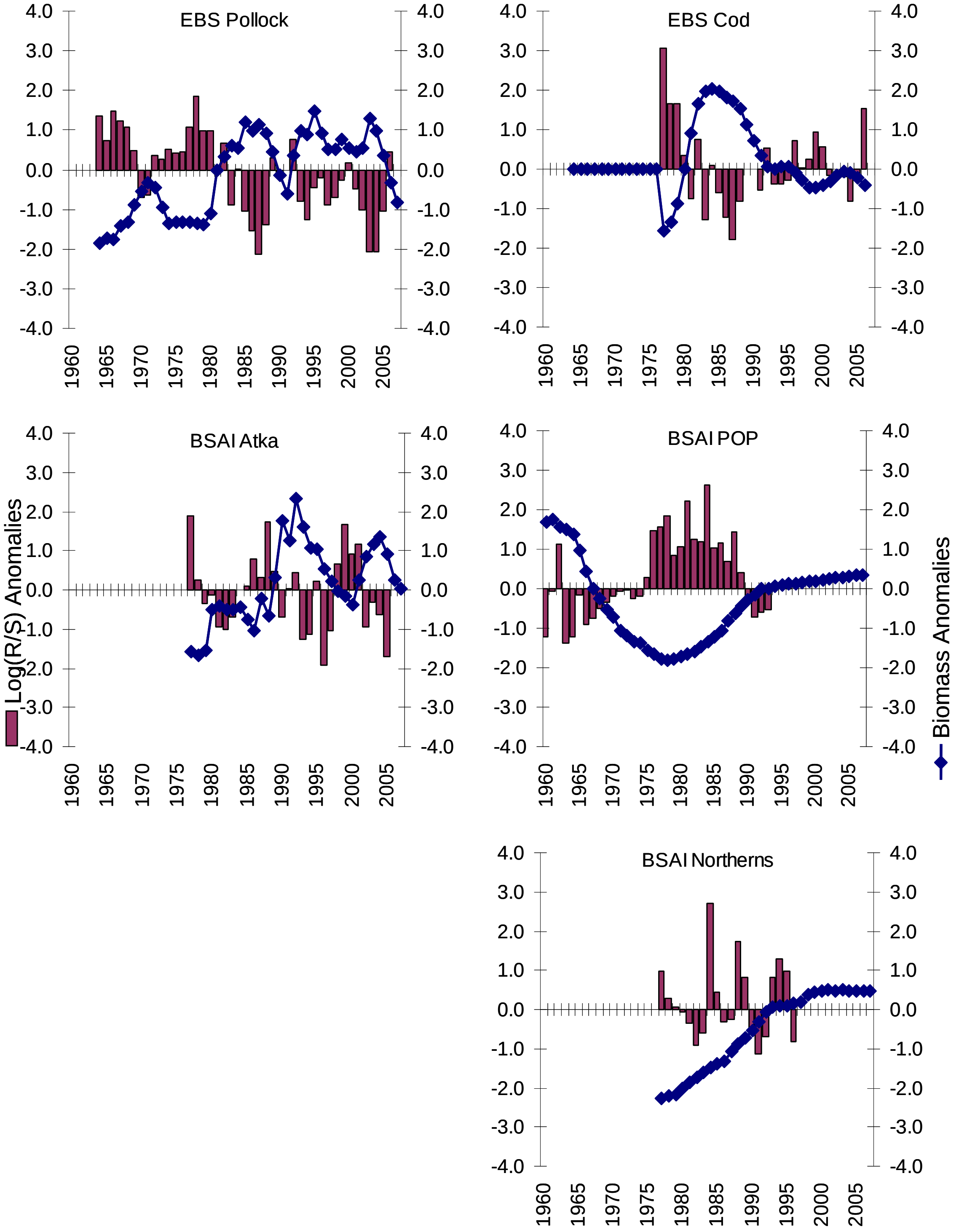

Figure 51. Median log recruit per spawning biomass anomalies and biomass anomalies for BSAI groundfish species assessed with age- or size-structured models, 1960-2008. EBS = Eastern Bering Sea, BS = Bering Sea, AI = Aleutian Islands, POP = Pacific ocean perch, Northerns = Northern rockfish, Atka = Atka mackerel.

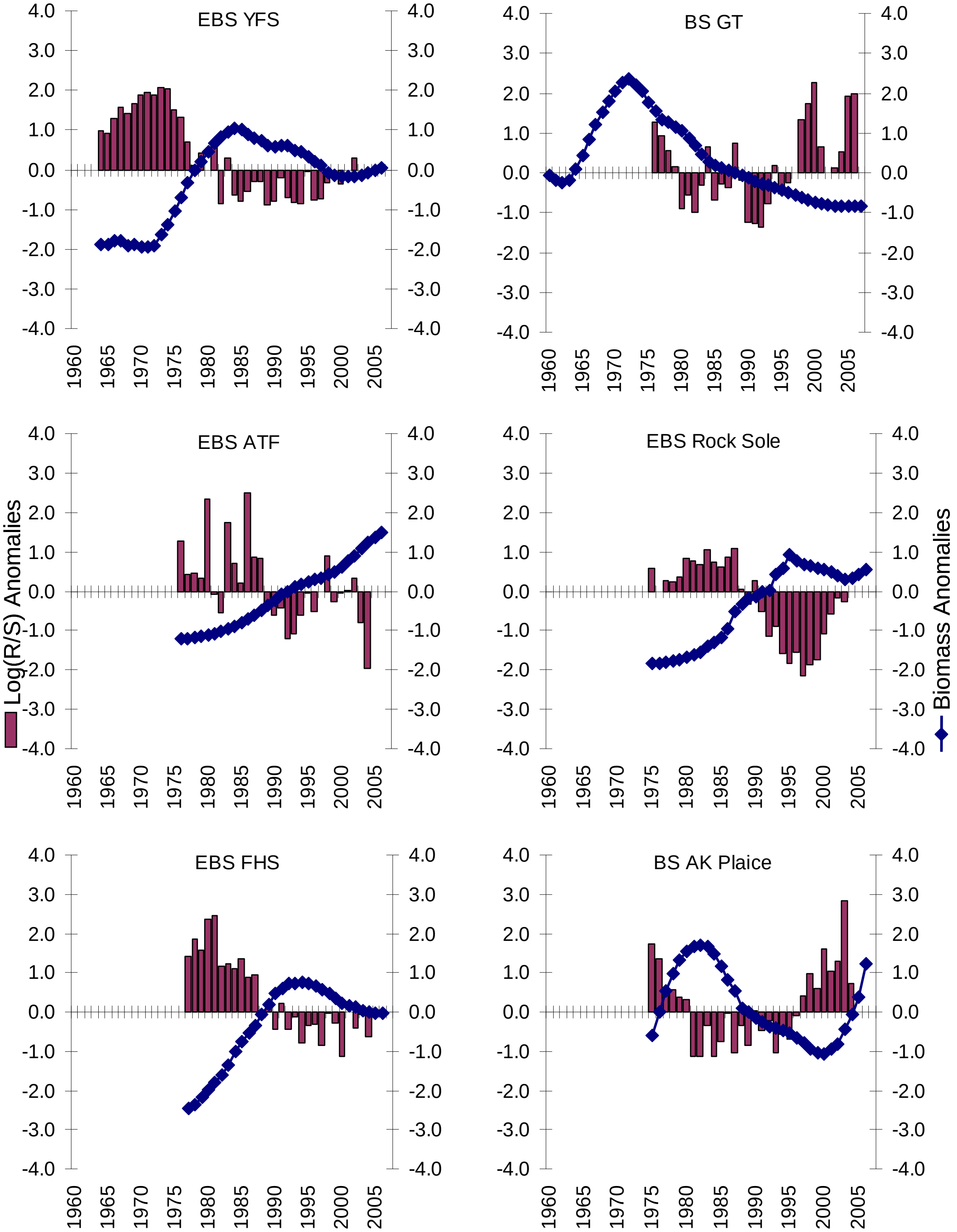

Figure 51 continued. Median log recruit per spawning biomass anomalies and biomass anomalies for BSAI groundfish species assessed with age- or size-structured models, 1960-2008. EBS = Eastern Bering Sea, BS = Bering Sea, AI = Aleutian Islands, YFS = yellowfin sole, ATF = arrowtooth flounder, FHS = flathead sole, GT = Greenland turbot.

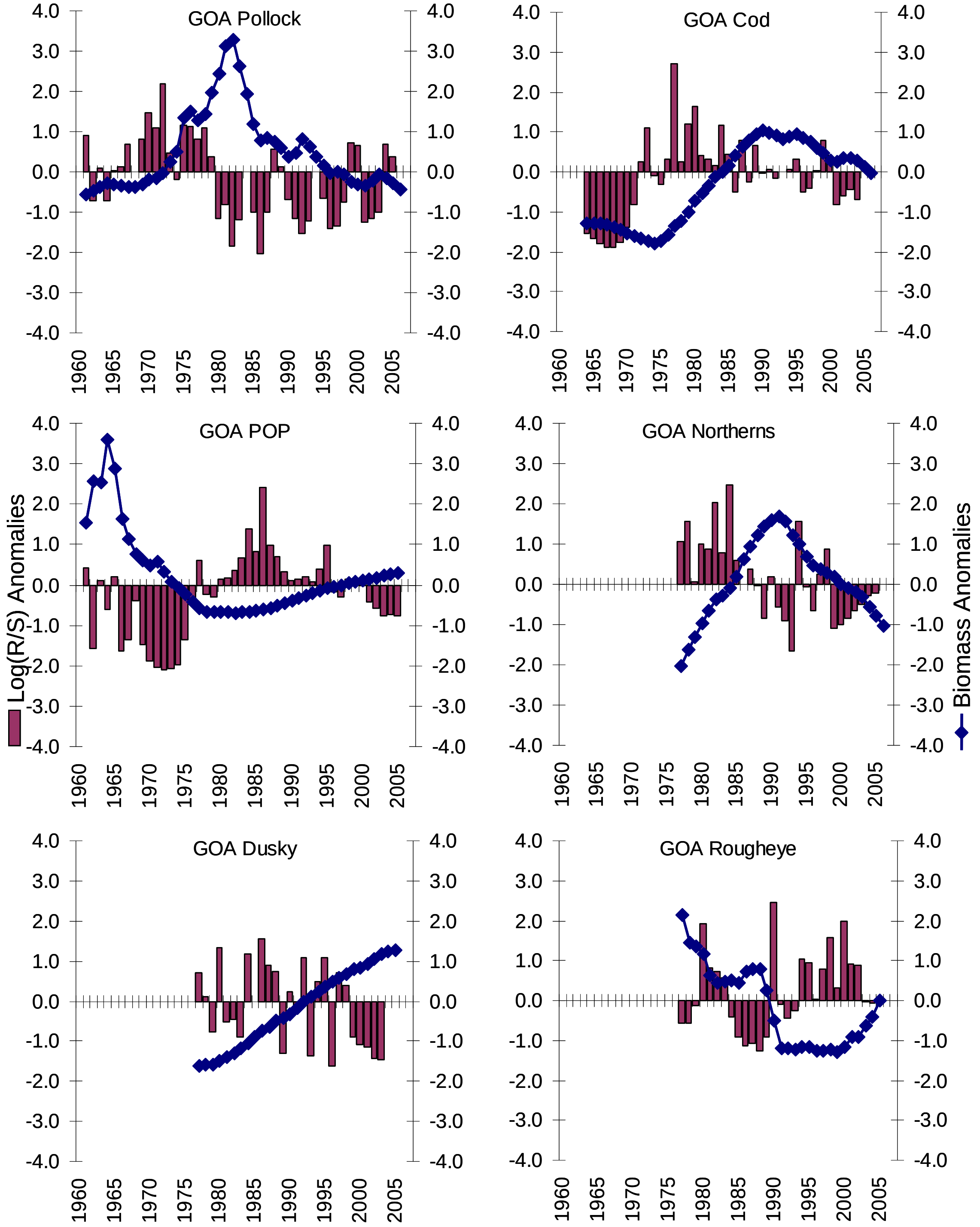

Figure 52. Median log recruit per spawning biomass anomalies and biomass anomalies for GOA groundfish species assessed with age- or size-structured models, 1960-2007. GOA = Gulf of Alaska, POP = Pacific ocean perch, Northerns = Northern rockfish, Dusky = Dusky rockfish, Rougheye = Rougheye rockfish.

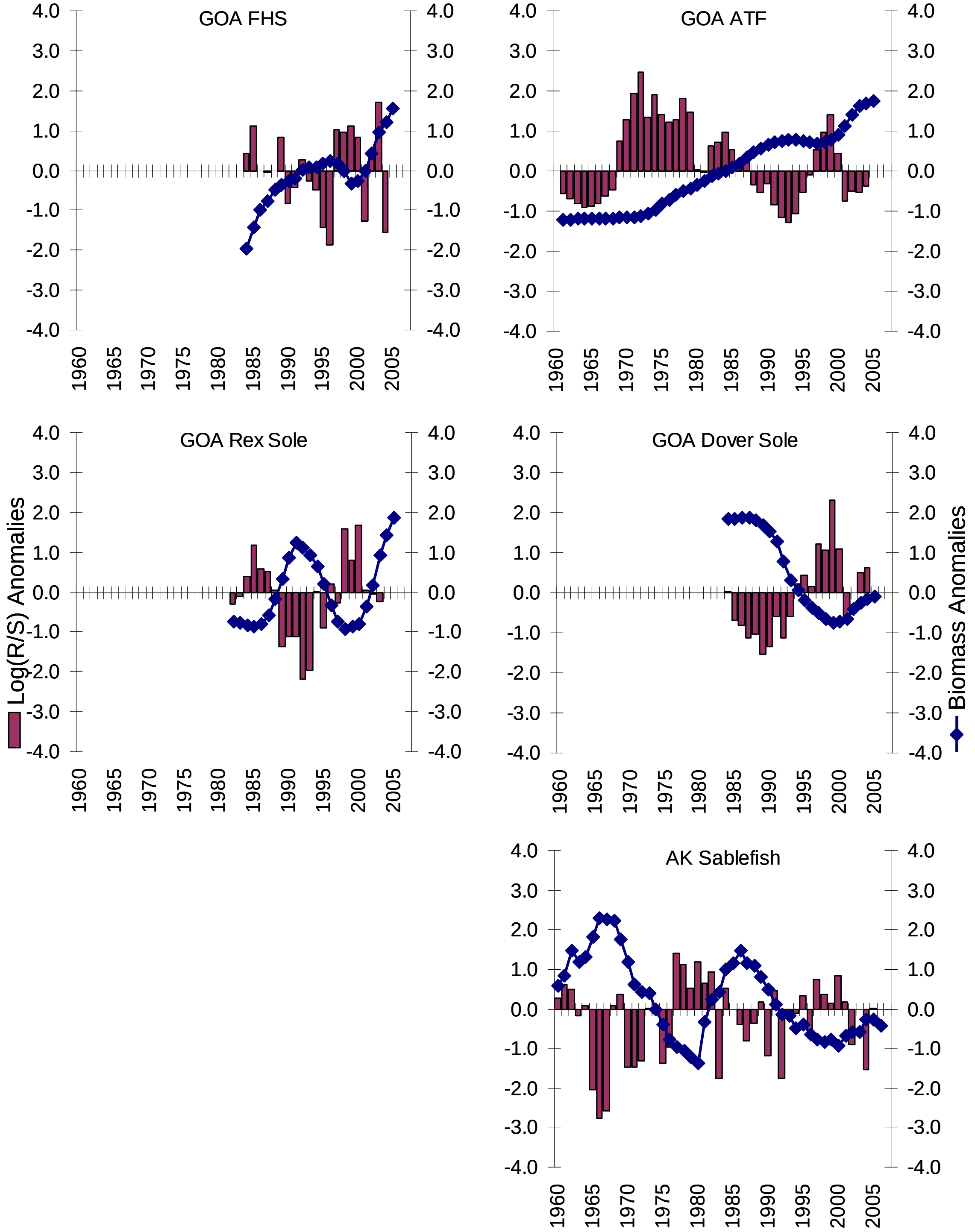

Figure 52 continued. Median recruit per spawning biomass anomalies and biomass anomalies for GOA groundfish species assessed with age- or size-structured models, 1960-2007. GOA = Gulf of Alaska, FHS = flathead sole, ATF = arrowtooth flounder, Rex = Rex sole.

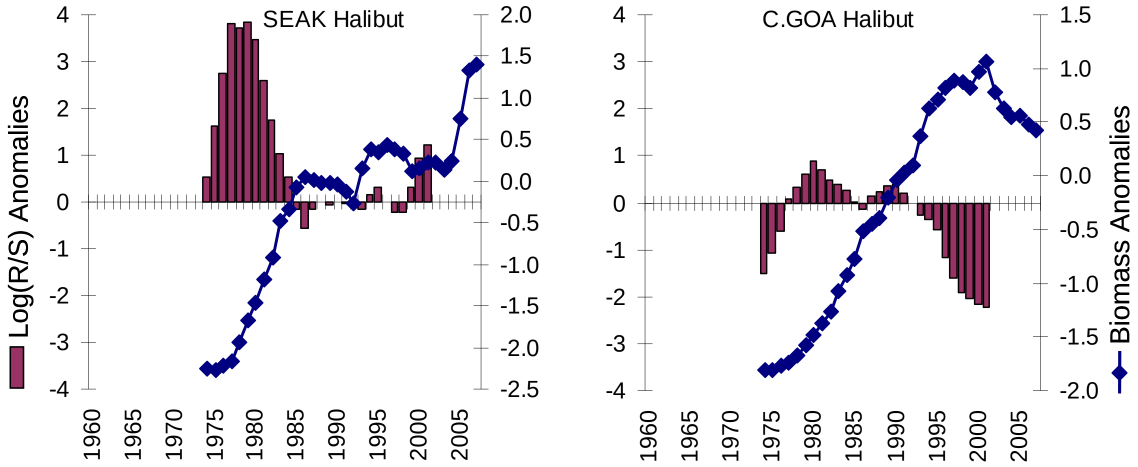

Figure 52 continued. Median log recruit per spawning biomass anomalies and biomass anomalies for halibut, 1974-2007. C.GOA = central Gulf of Alaska, SEAK = southeast Alaska.

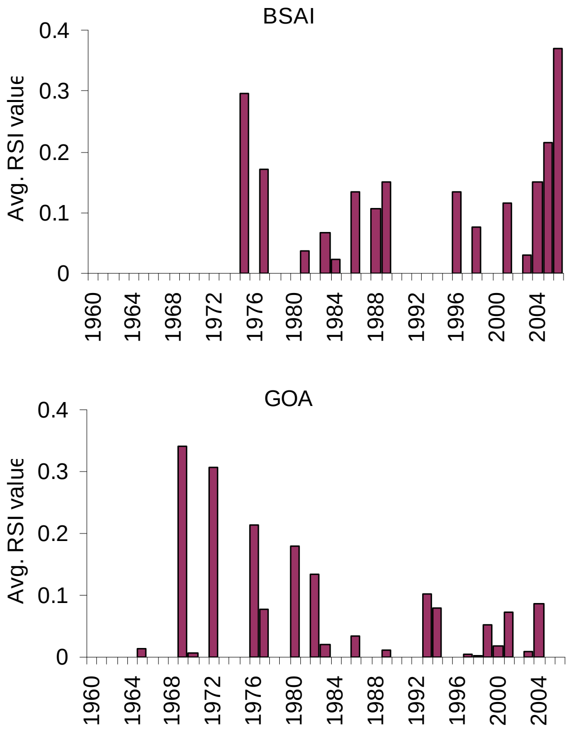

Figure 53. Average regime shift indices (RSI) values from the STARS (Rodionov 2005, Rodionov and Overland 2005) analysis (absolute values that indicate strength of step change) on log recruit per spawning biomass anomalies in each year for the BSAI and GOA.

Table 3. 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).

BSAI	Years of Significant change
Pollock	(1983), (2003)
Cod	(1983), 1996, *2006*
FHS	(1986), *(2004)*
ATF	(1989), *(2004)*
POP	1975, (1989)
Northern rockfish	*(1996)*
YFS	(1977), (1984), 2001
GT	1998
Rock sole	(1988), 2001
AK Plaice	(1981), 1996
Atka mackerel	*(2005)*

GOA	Years of Significant change
Pollock	1970, (1980), 2004
Cod	1972, (2001)
FHS	1997
ATF	1969, (1980), (1989)
POP	(1969), 1976, (2001)
Northern rockfish	(1986)
Dusky rockfish	(1999)
Rougheye rockfish	1994, (2003)
Rex sole	1998
Dover sole	1994
SEAK Halibut	(1982), 2000
CGOA Halibut	(1993)
AK Sablefish	(1965), 1977, (1983)

Bering Sea Groundfish Condition

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NEW: October 2008

Index: Length-weight residuals are an indicator of somatic growth (Brodeur et al. 2004) and, therefore, a measure of fish condition. Fish condition is an indicator of how heavy a fish is per unit body length, and may be an indicator of ecosystem productivity. Positive length-weight residuals indicate fish are in better condition (i.e., heavier per unit length); whereas, negative residuals indicate fish are in poorer condition (i.e., lighter per unit length). Fish condition may affect fish growth and subsequent survival (Paul 1997, Boldt and Haldorson 2004). NMFS Eastern Bering Sea shelf bottom trawl survey data was utilized to acquire lengths and weights of individual fish for walleye pollock, Pacific cod, arrowtooth flounder, yellowfin sole, flathead sole, northern rock sole, and Alaska plaice. Only summer standard survey strata and stations were included in analyses (i.e., no corner stations were included). Survey strata 31 and 32 were combined as stratum 30; strata 61 and 62 were combined as stratum 60; strata 41, 42, and 43 were combined as stratum 40. Strata 82 and 90 were excluded from analyses because they are not standard survey strata. Length-weight relationships for each of the seven species were estimated with a linear regression of log-transformed values over all years where data was available (during 1982-2008). Predicted log-transformed weights were calculated and subtracted from measured log-transformed weights to calculate residuals for each fish. Length-weight residuals were averaged for the entire EBS and for the 6 strata sampled in the standard summer survey. Temporal and spatial patterns in residuals were examined. To test the null hypothesis that an indicator of fish condition is not related to fish survival, length-weight residuals were correlated with an index of survival (log(recruits per spawner)) and P-values were adjusted for autocorrelation following Pyper and Peterman (1998).

Status and Trends: Length-weight residuals varied over time for all species with a few notable patterns (Figure 54). Residuals for all species where there was data were negative in 1999, a cold year in the Bering Sea (Figure 54). Residuals became positive or more positive in 2002 for five of the seven species examined. Flatfish residuals were generally positive from 2002 to 2004 or 2005 depending on species. In 2008, all species except flathead sole and walleye pollock had negative residuals. Trends in walleye pollock and yellowfin sole residuals were nearly identical ($y = 1.427x + 0.004$, $R^2 = 0.898$). There was not much data available for arrowtooth flounder.

Spatial trends in residuals were also apparent for some species. Generally, fish were in better condition on the outer shelf (strata 50 and 60; Figure 55). For 4 of the 7 species (pollock, cod, Alaska plaice, and northern rock sole), residuals were almost always positive on the northern outer shelf (stratum 60; Figure 55). In addition to having positive residuals on the outer shelf, gadids tended to have negative residuals on the inner shelf (Figure 55). Pollock residuals were generally positive in strata 50 and 60 and negative in strata 10, 20, and 40. Cod residuals were generally positive in stratum 60 and negative in strata 10 and 20. Spatial patterns in flatfish residuals were also apparent but varied among species. Yellowfin sole residuals were always positive in the northern mid-shelf (stratum 40); whereas, Alaska plaice residuals were almost always negative in that area. Instead, Alaska plaice residuals were always positive in the northern outer shelf (stratum 60). Northern rock sole residuals were also always positive in the outer shelf (strata 50 and 60). Flathead sole residuals were often positive in strata 40 and 50 (Figure 55).

There were four species that had more than six years of data for both survival (log(recruits per spawner)) and condition (length-weight residuals): pollock, cod, flathead sole, and Alaska plaice. Of those, there were no significant correlations between survival and condition (Table 4).

Factors causing observed trends: One potential factor causing the observed temporal variability in length-weight residuals is temperature. The year 1999 was a particularly cold year in the Bering Sea and also a year of negative length-weight residuals for all groundfish examined (where data existed). Despite the abundant large crustacean zooplankton and relatively high microzooplankton productivity present in 1999 (Hunt et al. 2008), the spatial distribution of some groundfish species is affected by temperatures and a cold year may, therefore, have affected the spatial overlap of fish and their prey. Cold temperatures may have also affected fish energy requirements and prey productivity.

Other factors that could affect length-weight residuals include survey sampling timing and fish migration. The date of the first length-weight data collected annually varied from late May to early June (except 1998, where the first data available was collected in late July). Also, the bottom trawl survey is conducted throughout the summer months, and as the summer progresses, we would expect fish condition to improve. Since the survey begins on the inner shelf and progresses to the outer shelf, the higher fish condition observed on the outer shelf may be due to the fact that they are sampled later in the summer. We also expect that some fish will undergo seasonal and, for some species, ontogenetic migrations through the survey months. For example, seasonal migrations of pollock occur from overwintering areas along the outer shelf to shallow waters (90-140 m) for spawning (Witherell 2000). Pacific cod concentrate on the shelf edge and upper slope (100-250 m) in the winter, and move to shallower waters (generally <100 m) in the summer (Witherell 2000). Arrowtooth flounder are distributed throughout the continental shelf until age 4, then, at older ages, disperse to occupy both the shelf and the slope (Witherell 2000). Flathead sole overwinter along the outer shelf, and move to shallower waters (20-180 m) in the spring (Witherell 2000). Yellowfin sole concentrate on the outer shelf in the winter, and move to very shallow waters (<30 m) to spawn and feed in the summer (Witherell 2000). How these migrations affect the length-weight residuals is unknown at this time.

Implications: A fish's condition may have implications for its survival. For example, in Prince William Sound, the condition of herring prior to the winter may in part determine their survival (Paul and Paul 1999). The condition of Bering Sea groundfish, may therefore partially contribute to their survival and recruitment; however, there were no significant correlations between fish condition and survival. The time series of length-weight residuals and corresponding indices of survival, such as log(recruits per spawner) anomalies, are short in duration for groundfish species. In the future, as years are added to the time series, the relationship between length-weight residuals and subsequent survival can be examined further. It is likely, however, that the relationship is more complex than a simple correlation. Also important to consider is the fact that condition of all sizes of fish were examined and used to predict survival. Perhaps, it would be better to examine the condition of juvenile fish, not yet recruited to the fishery, or the condition of adult fish and correlations with survival.

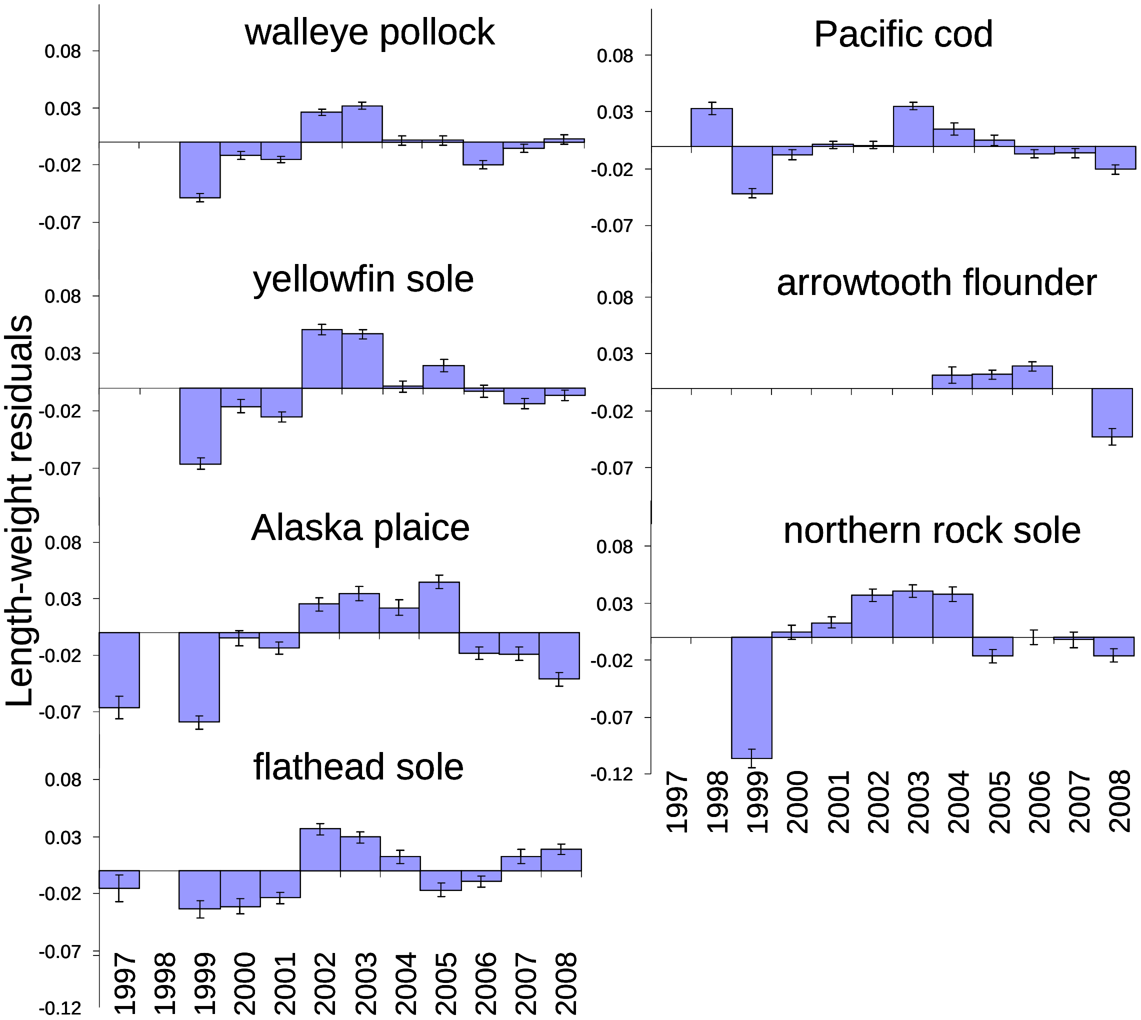

Figure 54. Length-weight residuals for seven Eastern Bering Sea groundfish sampled in the NMFS standard summer bottom trawl survey, 1997-2008.

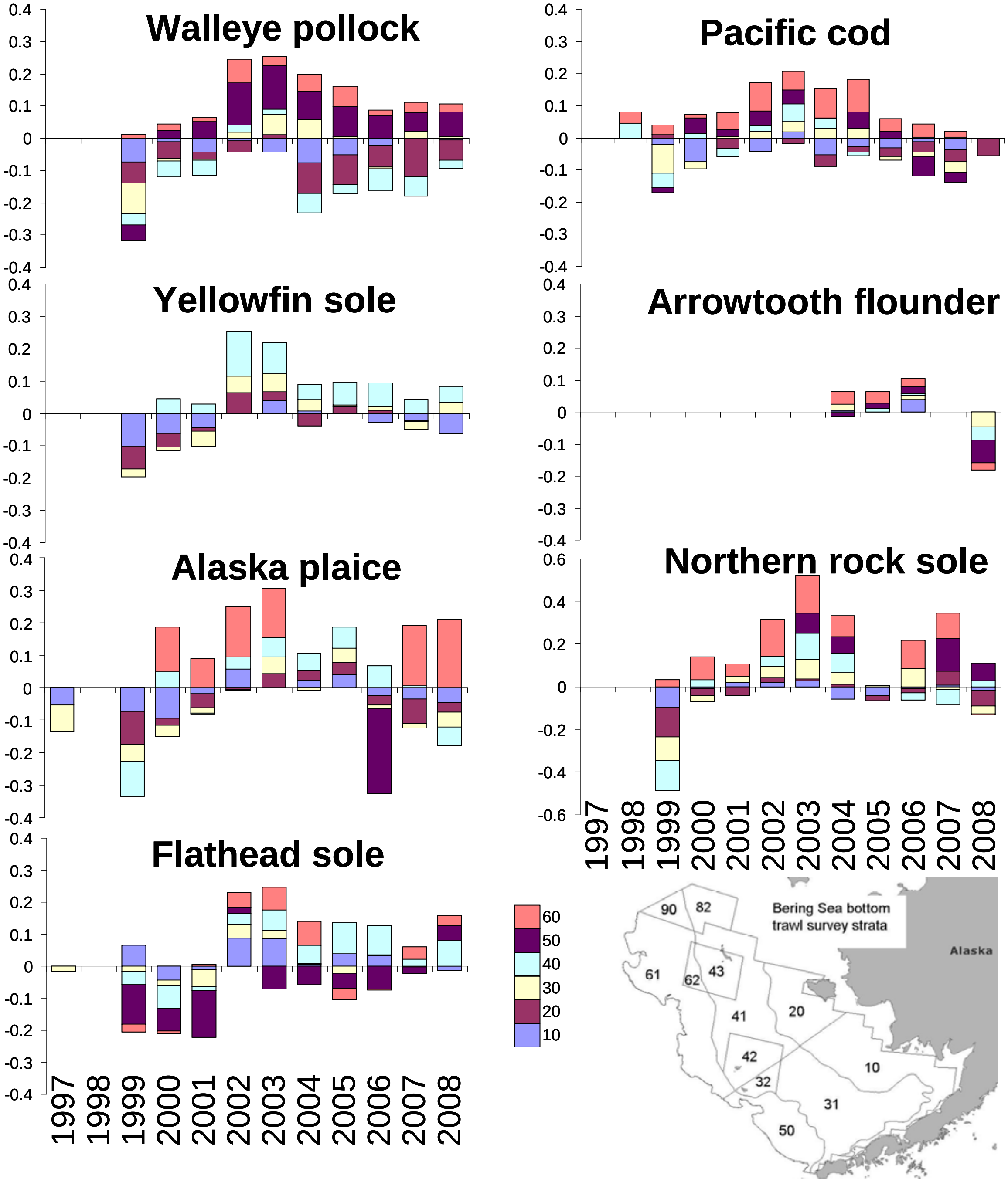

Figure 55. Length-weight residuals for seven Eastern Bering Sea groundfish sampled in the NMFS standard summer bottom trawl survey, 1997-2008, by survey strata (10 – 60). NMFS summer bottom trawl survey strata are shown in the lower right panel. Survey strata 31 and 32 were combined as stratum 30; strata 61 and 62 were combined as stratum 60; strata 41, 42, and 43 were combined as stratum 40. Strata 82 and 90 were excluded from analyses because they are not standard survey strata. *Note the y-axis is different for northern rock sole.

Table 4. Sample sizes, R^2, and P-values for straight line least squared regressions between an index of survival (log(R/S)) and condition (length-weight residuals) for five groundfish (where n>6). P-values were adjusted for autocorrelation following Pyper and Peterman (1998).

Species	n	R^2	P-value
Alaska plaice	7	0.442	0.119
Flathead sole	7	0.086	0.523
Pacific cod	9	0.315	0.116
Walleye pollock	8	0.455	0.138

Update on EBS winter spawning flatfish recruitment and wind forcing

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Last updated: August 2008

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 2008 (Figure 56).

Six out of eight OSCURS runs for 2001-2008 were consistent with those which produced above-average recruitment in the original analysis, 2005 and 2007 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 56). 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 2008 was onshore, suggesting the potential for an above average strength year class of northern rock sole in 2008.

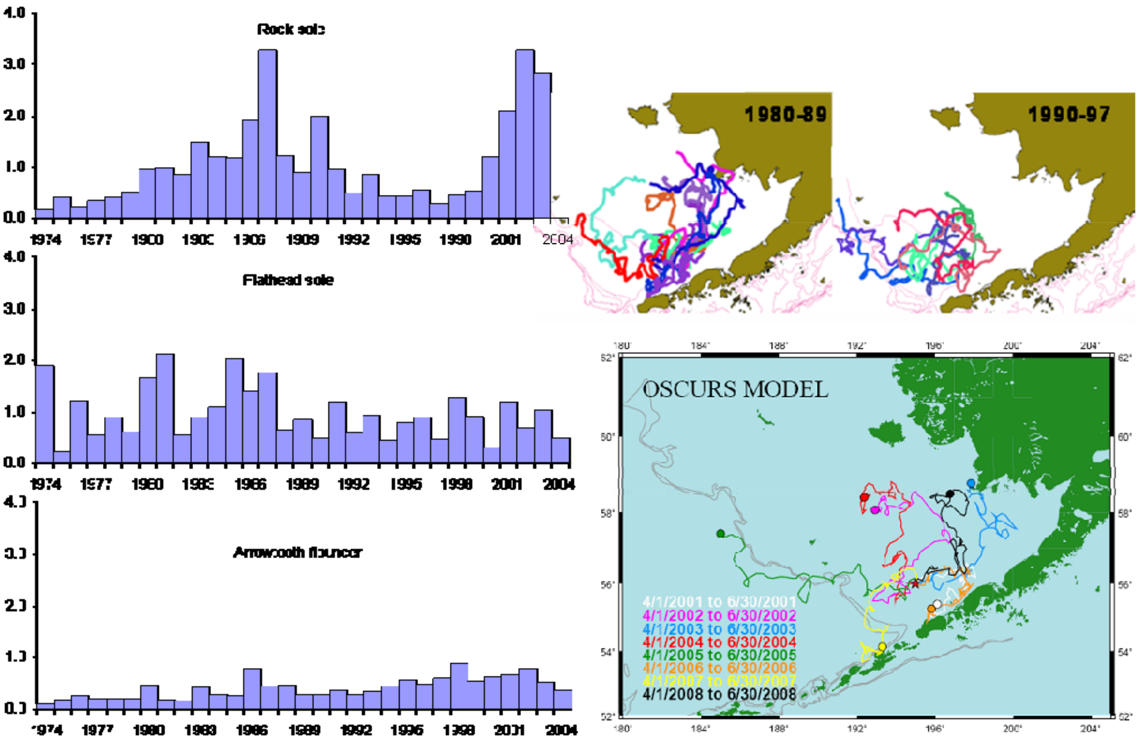

Figure 56. The left column shows recruitment of northern rock sole (1974-2003), flathead sole (1974-2004), and arrowtooth flounder (1974-2004) in the Bering Sea. The right column shows the OSCURS (Ocean Surface Current Simulation Model) trajectories from starting point 56° N, 164° W from April 1-June 30 for three periods: 1980-89, 1990-97, and 2001-2008.

Relationships between EBS flatfish spatial distributions and environmental variability from 1982-2004

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Last updated: September 2005

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

Benthic Communities and Non-target Fish Species

ADF&G Gulf of Alaska Trawl Survey

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Last updated: October 2008

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 57) are broadly representative of the survey results across the region. These areas have been surveyed continuously 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. Gadid catches in 1976-1977 were comprised of 88% Pacific cod and 10% walleye pollock, but catch compositions reversed in 2007 with Pacific cod comprising 19% and walleye pollock comprising 81% of the gadid catches.

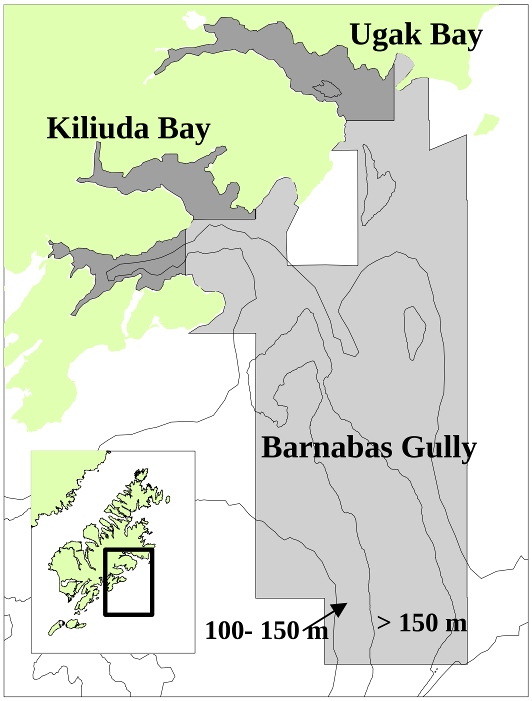

Figure 57. Adjoining survey areas on the east side of Kodiak Island used to characterize inshore (dark gray, 14 stations) and offshore (light gray, 33 stations) trawl survey results.

The most significant result of the 2007 survey was the record number of Tanner crabs caught in some stations in Ugak Bay (Figure 58). Arrowtooth flounder continues to be the main component of the offshore catches, while Tanner crab and flathead sole were the largest catches inshore. Also, Pacific cod catches were noticeably low inshore in 2007. Overall catch rates have increased inshore (Kiliuda and Ugak Bays), but the offshore (Barnabas Gully) catches show a significant decline in 2006 – 2007 for all species (Figure 59).

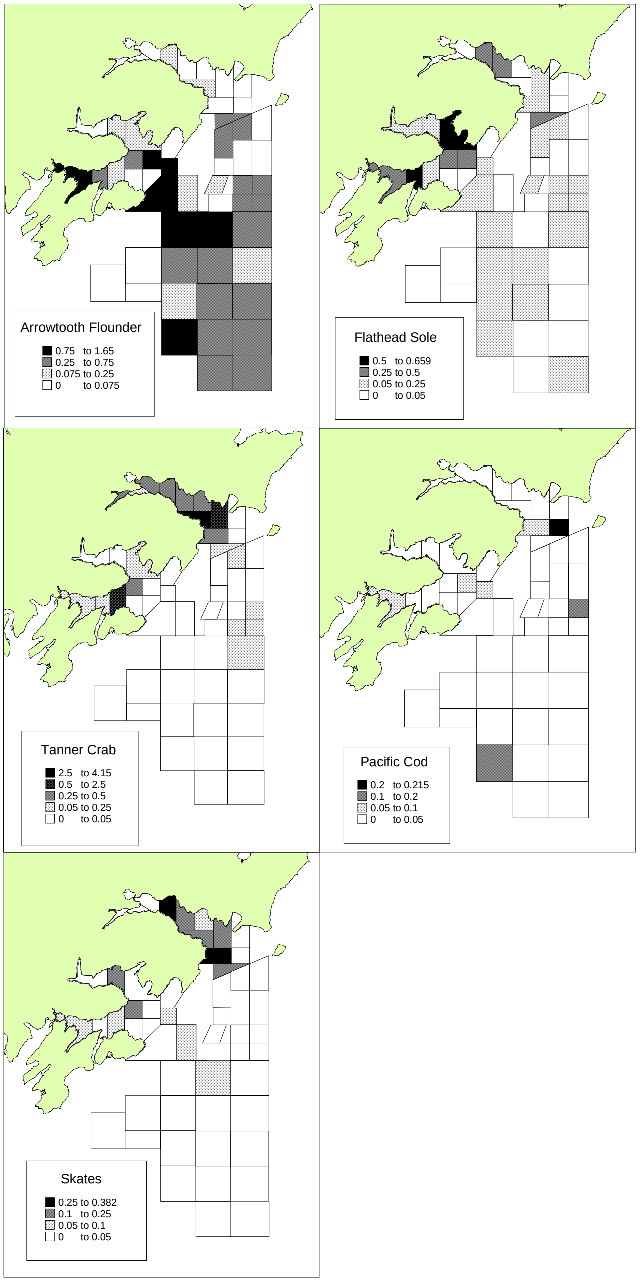

Figure 58. The catch in mt/km of selected species during the 2007 ADFG trawl survey from Kiliuda and Ugak Bays and Barnabas Gully on the east side of Kodiak Island.

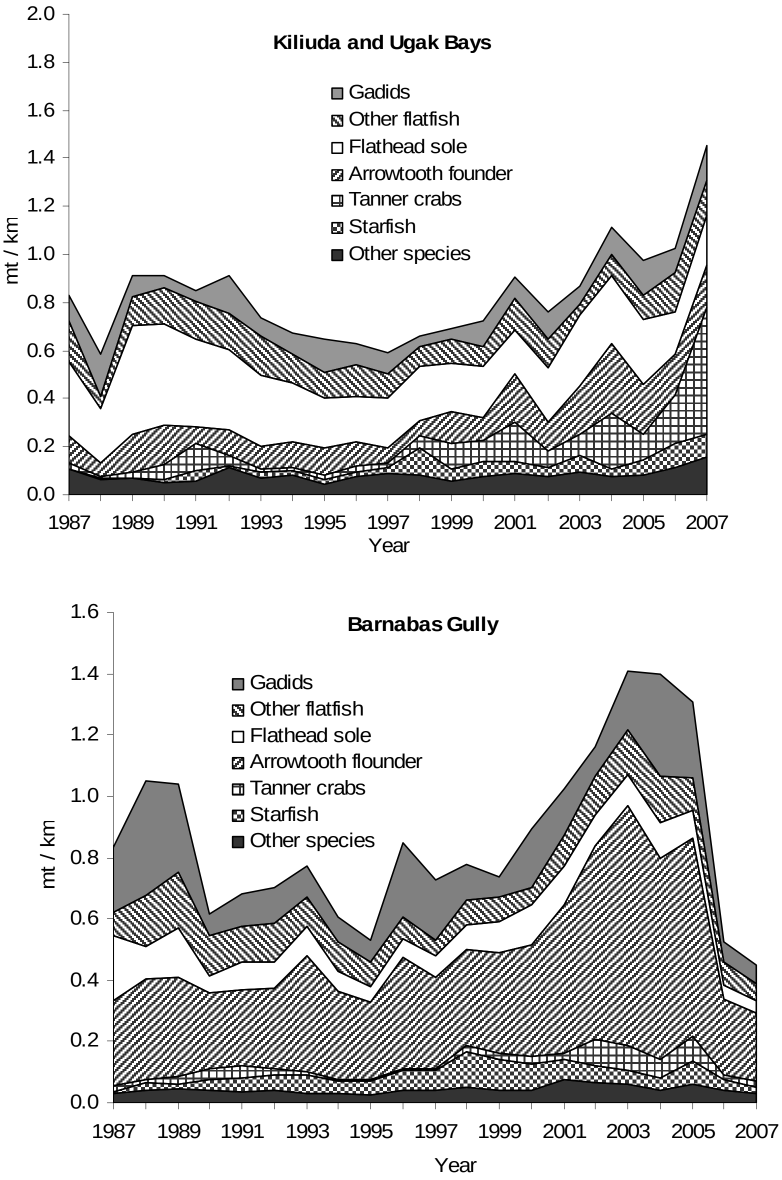

Figure 59. Total catch per km towed (mt/km) during the ADF&G trawl survey from adjacent areas off the east side of Kodiak Island, 1987 to 2007.

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 60). The increased catches have contributed to the wide distribution of positive values for the standardized anomalies in the recent past. In 2007, above average anomaly values were recorded for skates and specifically inshore Tanner crabs (> 6.0), while arrowtooth flounder and flathead sole have decreased to below average levels. Pacific cod catches continue to be below average 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 what factors are contributing to these changes.

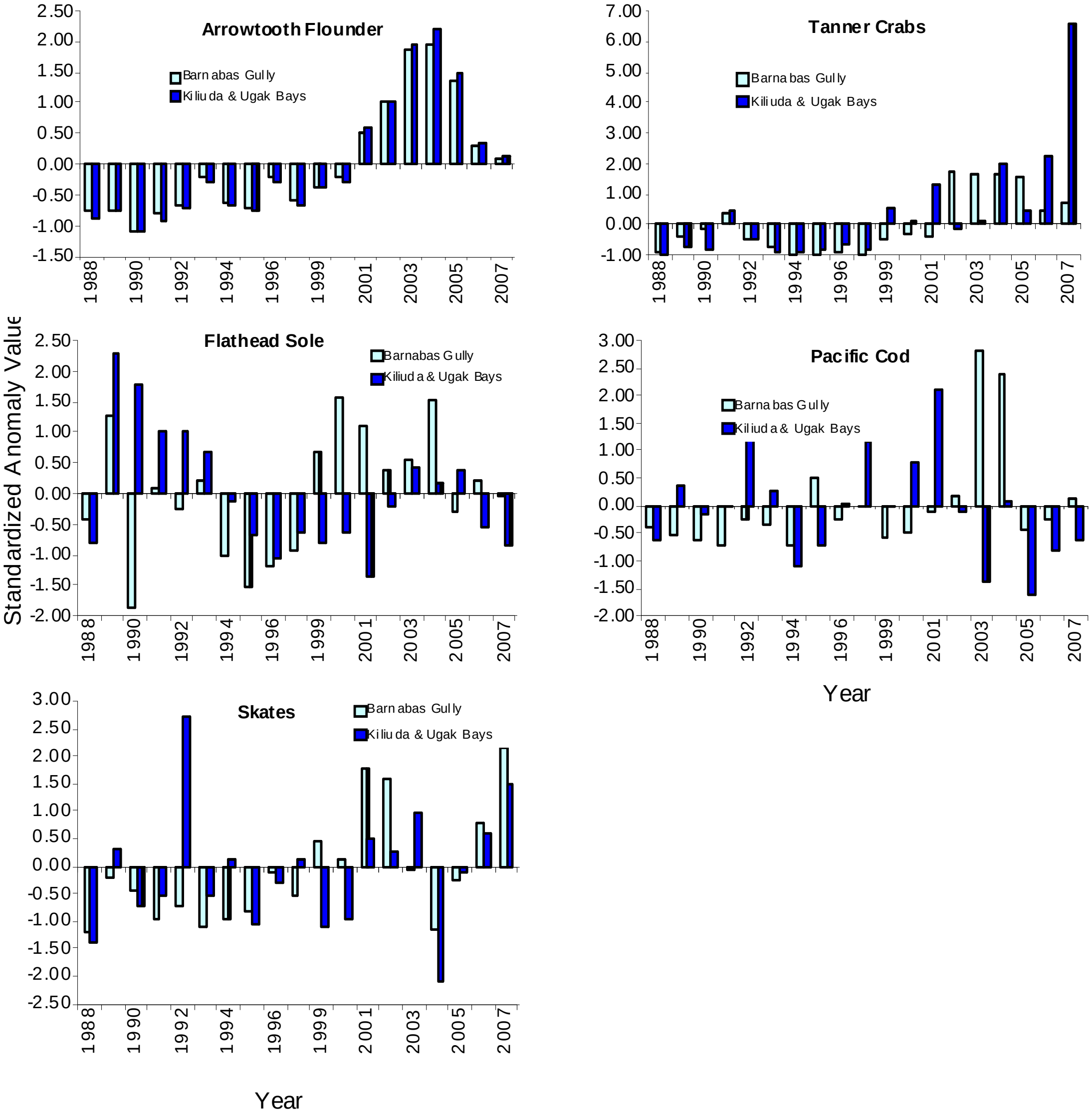

Figure 60. A comparison of standardized anomaly values for selected species caught from 1988-2007 in Kiliuda and Ugak Bays and Barnabas Gully during the ADF&G trawl surveys.

Gulf of Alaska Small Mesh Trawl Survey Trends

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Last updated: August 2008

Annual small-mesh trawl surveys of the nearshore Gulf of Alaska have been conducted by NOAA Fisheries and ADF&G using standard methods since 1972 (n = 9,019 hauls). Sampling in 2007 occurred between 25 September and 26 October around Kodiak Island (Chiniak, Inner and Outer Marmot, Uyak, Uganik, Ugak, Kiliuda and Alitak Bays and Two-Headed Gully) and the Alaska Peninsula (Kukak, Puale, Wide and Pavlof Bays) (n = 120 hauls). This contribution describes trends in the abundance of some ecologically important taxa which may serve as indicators of community state. More detailed results for the 2007 survey can be found in Jackson (2008).

The small-mesh survey time series shows the transition from a community rich in shrimp and capelin to a community rich in groundfish following the 1976/1977 Pacific Decadal Oscillation (PDO) regime shift (Anderson and Piatt 1999). Catches through 2007 do not show any significant deviation from the groundfish-dominated community state. Here I present catch data for ecologically important taxa that were either responsive to the 1976/1977 PDO regime shift or that have shown recent changes in catch per unit effort (CPUE, kg km hauled-1). These include taxa that showed declining CPUE following the regime shift (capelin *Mallotus villosus* and pink shrimp *Pandalus borealis*), taxa that showed CPUE increases after the regime shift (arrowtooth flounder *Atheresthes stomias*, Pacific cod *Gadus macrocephalus* and jellyfish [Scyphozoa]), and taxa with more recent increases in CPUE (spiny dogfish *Squalas acanthias* and eulachon *Thaleicthys pacificus*). Data come from the seven most consistently sampled bays (Inner Marmot, Kiliuda, Alitak, Two-Headed, Pavlof, Kuiukta and Chignik/Castle), five of which were sampled in 2007. CPUE is presented as the grand mean (± SD) of mean CPUE values from individual bays.

Capelin CPUE remained low in 2007 (0.006 ± 0.01 kg km-1), one to two orders of magnitude lower than peak values observed in the 1970s and early 1980s (Figure 61a). Pink shrimp CPUE (8.79 ± 14.13 kg km-1) also continued at low post-regime shift levels, more than an order of magnitude below 1970s values (Figure 61b). CPUE of arrowtooth flounder (24.37 ± 18.67 kg km-1) remained at the high levels observed since the mid 1980s (Figure 61c). Spiny dogfish catches also remain high (4.00 ± 4.25 kg km-1) but they were largely absent from small-mesh catches prior to 1998, with the exception of catches in Kiliuda Bay in the 1980s (Figure 61f). The recent increase in spiny dogfish CPUE is apparently part of a general increase in spiny dogfish abundance throughout the central and eastern Gulf of Alaska (Wright and Hulbert 2000).

Both eulachon (0.72 ± 0.43 kg km-1) and jellyfish (4.34 ± 2.96 kg km-1) catches declined dramatically in 2007 (Figures 61d and g). The eulachon catch was just 10% of the average for the past six years and was one of the lowest of the time series (Jackson 2008). Pacific cod CPUE (5.43 ± 1.53 kg km-1) continued the recent trend of lower values, reduced nearly an order of magnitude from values observed during the 1980s and 1990s (Figure 61e)

First consistently seen in the survey area in 2004, the smooth pink shrimp (*Pandalus jordani*) was captured in six different survey areas around Kodiak Island (inner and outer Marmot, Kiliuda, Uyak, and Uganik Bays and Twoheaded Gully). In the three years since its appearance, the estimated biomass has increased to over 200 mt (Jackson 2008). *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. The magnitude of the catches seen in the last 3 surveys is unprecedented in the time series. One possible explanation for these recent *P. jordani* catches is a northward distribution shift in response to recent warming of the Gulf of Alaska (Litzow 2006), although further years of observation will be needed to assess the abundance trends of *P. jordani* in the study area.

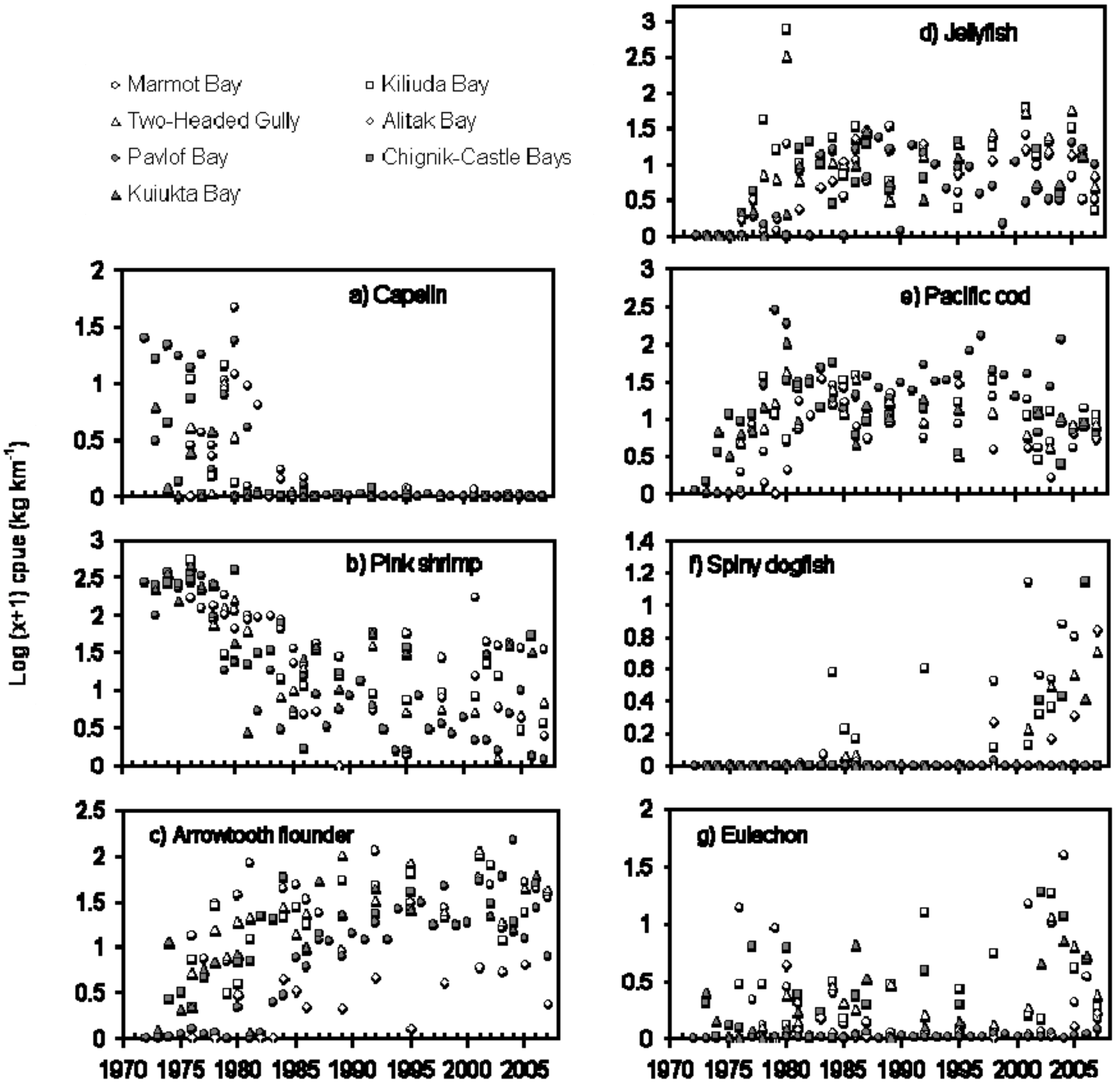

Figure 61. Catch per unit effort (CPUE) trends for selected taxa in small-mesh surveys of seven Kodiak Island and Alaska Peninsula Bays, 1972-2007.

Bering Sea Crabs

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Last updated: October 2006

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

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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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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NEW: October 2008

Index: Lingcod catch is managed by the state of Alaska (Alaska Department of Fish and Game (ADFG)) in Alaska's waters, out to 200 nautical miles from shore. Directed fishing varies around the state, but in the Gulf of Alaska (GOA) it is through a commissioner's permit (regulatory authority given to area managers to manage a species). Within the last 5 years, there has not been any directed effort in the GOA. The state, however, allows 20% bycatch of lingcod in other groundfish fisheries in the GOA. In most years this bycatch has been minimal (Table 5).

Status and Trends: Beginning in 2005, an increase in bycatch, particularly in the bottom trawl fleet, was observed (Tables 5 and 6). In 2008, bycatch increased dramatically. Through the end of August 2008, bycatch of lingcod in the trawl fleet was over 300,000 pounds. ADF&G reduced the allowed bycatch retention from 20% to 3% effective September 5, 2008. As of September 13, 2008 lingcod harvest was 469,448 pounds (212 mt). Most harvest appeared to occur in the rock sole- and arrowtooth flounder-targeted fishing trips. The majority of this harvest has occurred in waters northeast of Kodiak Island.

Factors Causing Trends: It is unknown what factors are causing the increase in lingcod bycatch. Potential factors that are being investigated include a change in the spatial or temporal distribution of the fisheries, changes in fishing practices, and an increase in the lingcod abundance. An increase in the lingcod population size is the most likely cause of the increased bycatch and may have led to changes in their spatial distribution as they expanded. Two different types of fishing practices have changed that may have had a partial effect on the bycatch levels. First, the Rockfish Pilot Program allowed fishing during times of the year that were not previously fished. Second, with increases in the incidental harvest (likely attributable to a population increase), the exvessel value of lingcod increased significantly, making them a valuable bycatch species.

Table 5. Lingcod harvest from the Kodiak, Chignik, and South Alaska Peninsula Areas, 1988-2007.

Year	Kodiak	Chignik	South Alaska Peninsula	Total [a] Pounds
1988	136,294	0	0	136,294
1989	13,888	Confidential	Confidential	N/A
1990	10,735	0	0	10,735
1991	8,520	Confidential	0	N/A
1992	18,653	Confidential	Confidential	N/A
1993	3,800	Confidential	Confidential	N/A
1994	5,444	0	0	N/A
1995	31,464	2,813	4,640	N/A
1996	51,133	7,106	Confidential	N/A
1997	26,092	Confidential	0	N/A
1998	10,985	Confidential	Confidential	N/A
1999	13,927	Confidential	Confidential	N/A
2000	11,873	Confidential	Confidential	N/A
2001	13,737	Confidential	Confidential	N/A
2002	14,261	0	0	14,261
2003	14,069	969	0	15,038
2004	25,378	Confidential	0	N/A
2005	66,055	667	171	66,893
2006	67,293	686	26	68,005
2007	112,895	1,021	253	114,169

[a] Some totals not available (N/A) due to confidentiality restrictions.

Table 6. Lingcod harvest by gear type from the Kodiak, Chignik, and South Alaska Peninsula Areas, 1988-2007.

	Gear type [a]				
Year	Jig	Longline	Pot	Trawl	Total [b]
1988	Confidential	43	0	Confidential	136,294
1989	Confidential	0	0	14,324	N/A
1990	1,418	Confidential	Confidential	8,839	11,846
1991	8,375	501	Confidential	739	N/A
1992	5,569	4,269	Confidential	10,959	N/A
1993	Confidential	Confidential	0	4,778	N/A
1994	4,820	803	0	Confidential	N/A
1995	34,573	3,567	Confidential	1,996	N/A
1996	43,403	7,898	0	10,929	N/A
1997	12,637	6,499	Confidential	5,267	N/A
1998	5,756	1,771	200	3,514	11,241
1999	1,358	4,294	11,216	5,003	21,870
2000	3,400	8,993	3,280	4,511	20,184
2001	527	6,753	Confidential	7,272	N/A
2002	6,132	7,645	2,856	7,750	18,281
2003	Confidential	10,973	0	11,269	N/A
2004	2,464	6,851	Confidential	15,407	N/A
2005	772	27,934	9,189	28,998	66,893
2006	Confidential	17,531	26,892	23,292	N/A
2007	Confidential	30,385	33,696	50,053	N/A

[a] Some confidential harvest occurred in 1992 with sunken gill net gear.

[b] Some totals not available (N/A) due to confidentiality restrictions.

Jellyfish – Eastern Bering Sea
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Last updated: October 2008

The time series of jellyfish caught as bycatch in the annual Bering Sea bottom trawl survey was updated for 2008 (Figure 62). The largest catch over the time series was arbitrarily scaled to a value of 1 and all other values were similarly scaled. The standard error (+/- 1) was weighted proportionally to the CPUE to get a relative standard error. The trend for increasing relative CPUE that began around 1989 reported by Brodeur et al. (1999) did not continue in 2001-2008. The relative CPUE of jellyfish decreased dramatically in 2001 and the relative CPUE has since remained close to levels seen in the 1980s and early 1990s. Outbursts in jellyfish populations, such as the one in 2000, may be related to shifts in the physical or biological conditions on the eastern Bering Sea shelf.

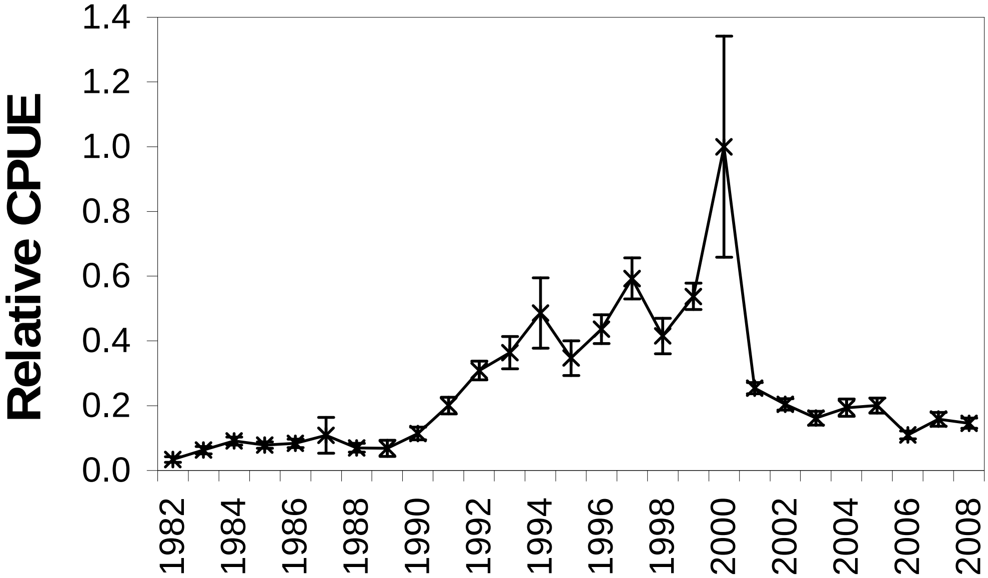

Figure 62. Relative CPUE of large medusae during the summer in the eastern Bering Sea from the NMFS bottom trawl survey, 1982-2008.

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 continues through 2008. All jellyfish medusae caught in the surface trawl (top 18 m of 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 domain were uneven for all years (Figure 63). Of the six species sampled, *Chrysaora melanaster* had the highest density for all years, followed by *Aequorea sp*., *Cyanea. capillata*, *S. mertensi*, *A. labiata*, and *P. camtschatica* (Figure 64). 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.

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.

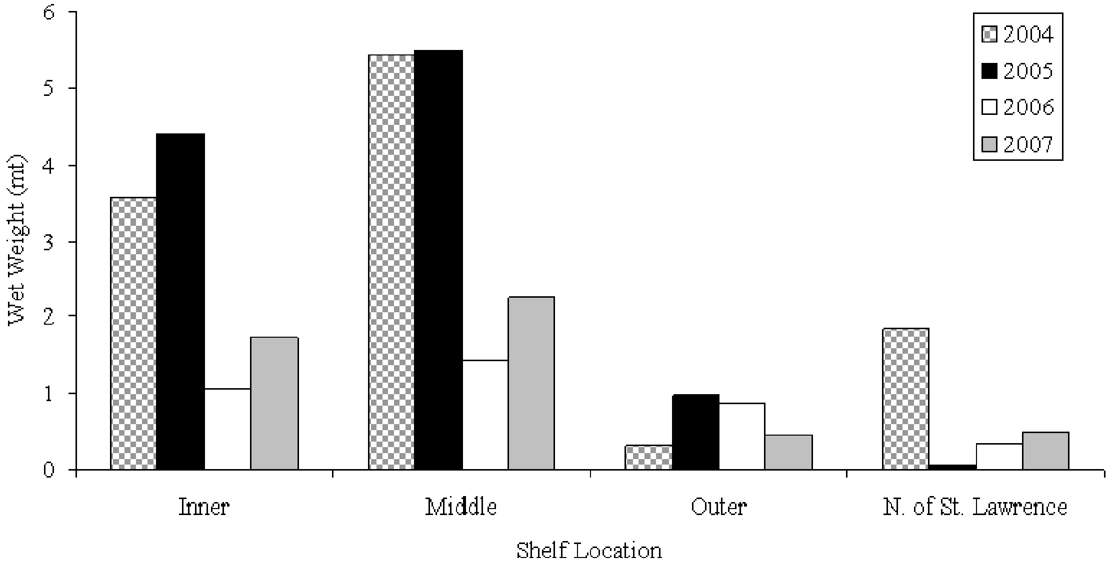

Figure 63. Catch by year for each shelf location in the Eastern Bering Sea. Wet weight is defined as the total weight of all large jellyfish species caught in a 30 minute trawl. Shelf locations (domains) are by depth, Inner 0-50m, Middle 50-100m, and Outer >100m. North of St. Lawrence includes all stations sampled above 64° N latitude.

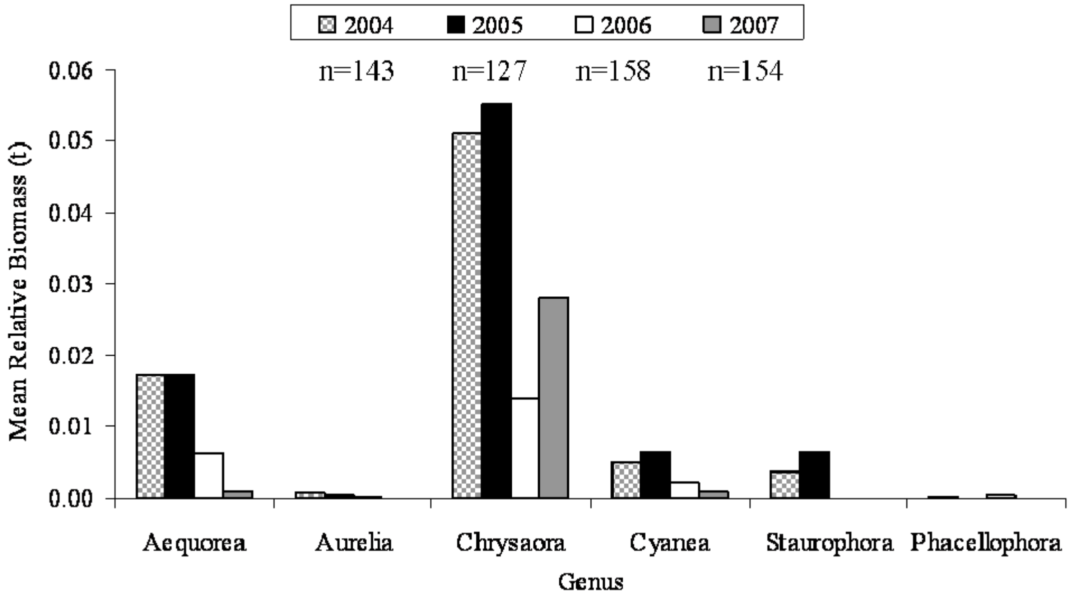

Figure 64. Mean relative biomass (mt) by genus for 2004-2007 in the Eastern Bering Sea. Relative biomass is defined as the total weight of a particular species in a 30 minute trawl. Sample size (n) is indicated below figure key.

Miscellaneous species - Eastern Bering Sea

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Last updated: October 2008

Three species of eelpouts are predominant on the eastern Bering Sea shelf: marbled eelpout (*Lycodes raridens*), wattled eelpout (*L. palearis*) and shortfin eelpout (*L. brevipes*). For each species group, the largest catch over the time series was arbitrarily scaled to a value of 1 and all other values were similarly scaled. The standard error (+/- 1) was weighted proportionally to the CPUE to get a relative standard error. The relative CPUE of this group appeared higher in the early 1980s than in the late 1980s to present (Figure 65), and there was a significant drop in relative CPUE from 2006 to 2008 to the lowest level since 1999. The relative CPUE of poachers is dominated by the sturgeon poacher (*Podothecus acipenserinus*) and the poacher CPUE was low in the early 1980s but increased in the late 1980s to the mid-1990s. The relative CPUE appeared to be on the rise during since 2000 but took a sharp turn downward in 2006 and now are back to the 2000 level (Figure 65). The composition of echinoderms in trawl catches on the shelf are dominated by the purple-orange seastar (*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 relative CPUE values for the echinoderm group have remained fairly level since 2001 but were lowest in 1985, 1986, and 1999, and highest in 1997. Fully understanding relative CPUE trends of eelpouts, poachers, and echinoderms will require more specific research on survey trawl gear selectivity and on the life history characteristics of each species.

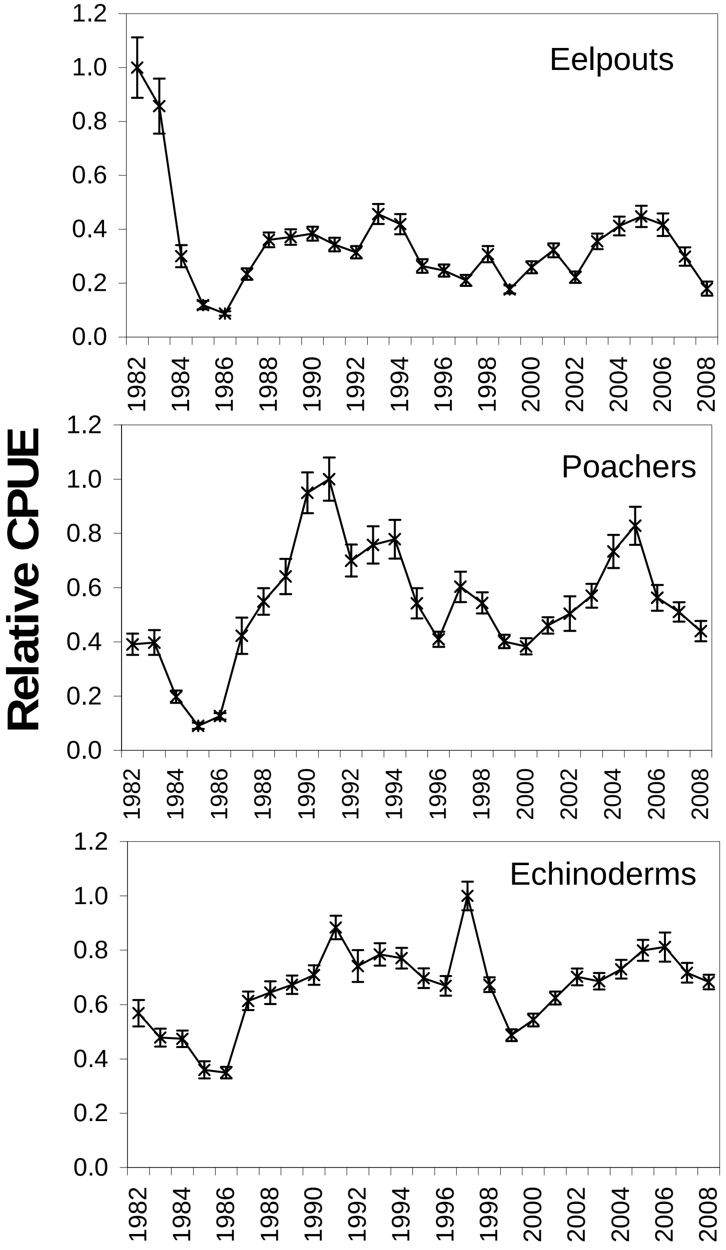

Figure 65. Relative CPUE of miscellaneous species caught in the eastern Bering Sea summer bottom trawl survey, 1982-2008. Data points are shown with standard error bars.

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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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*) **Last updated: October 2007**
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Northern fur seal (*Callorhinus ursinus*) **Last updated: October 2007**
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Harbor Seals (*Phoca vitulina*) **Last updated: October 2007**
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See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Arctic ice seals: Bearded seal, ribbon seal, ringed seal, spotted seal **Last updated: October 2007**
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See the 2006 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Cetaceans

Bowhead whale (*Balaena mysticetus*)
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Last updated: October 2008

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 7 (Angliss and Outlaw 2008) and Figure 66 (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) and one in 2008 (Blatchford 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 7 (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)		

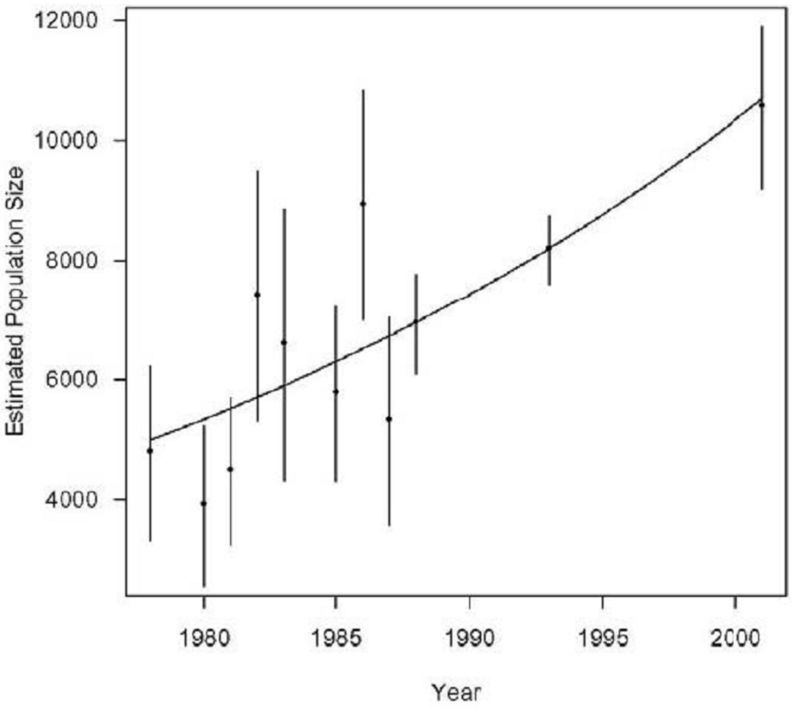

Figure 66 (George et al. 2004). Population abundance estimates for the Western Arctic stock of bowhead whales, 1977-2001, as computed from ice-based counts, acoustic locations, and aerial transect data collected during bowhead whale spring migrations past Barrow, Alaska. Error bars show +/- 1 standard 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 2006 report in the "Assessment Archives" for the **full** November 2006 contribution at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Included below are the **updated** (August 2008) Seabird distribution and Seabird bycatch (November 2008) sections of the *Seabirds* contribution:

Seabird distribution

Contributed by Leslie Slater, Kathy Kuletz and Rob Suryan
Last updated: August 2008

Maps depicting historic (1970s - 1980s) distribution of selected seabirds and fishing effort can be viewed in the Ecosystem Considerations for 2002 report (NPFMC 2001). The seabird data for these maps were taken from the North Pacific Pelagic Seabird Database (NPPSD 2004). At that time, the NPPSD was primarily comprised of data from surveys conducted during the Outer Continental Shelf Environmental Assessment Program. The pelagic distribution of seabirds in Alaskan waters has not been examined comprehensively in recent years, but several studies have been implemented that will provide current data on seabird distribution and abundance at sea. One such study is the stationary seabird surveys on longline and trawl fisheries research vessels. This program was initiated in 2002 by the Washington Sea Grant Program in collaboration with the International Pacific Halibut Commission, the Alaska Department of Fish and Game, and NMFS to complete "bird-feeder" type surveys on charter vessels conducting halibut and sablefish surveys. Counts of seabird abundance (for select groups) were performed after each set was brought aboard and within a standardized area astern. In 2004 the program was expanded to include groundfish charters operated by the Alaska Fisheries Science Center. The resulting data were used to examine the distribution of seabird species susceptible to longline bycatch (Melvin et al. 2004), and subsequently, a proposal to the NPFMC to reduce mitigation devices for seabirds in 'inside waters'.

In 2006, the U.S. Fish and Wildlife Service (USFWS) received a grant from the North Pacific Research Board to initiate an at-sea survey program for marine birds using ships of opportunity. From 2006 to 2008 the USFWS conducted at-sea surveys throughout Alaska, with collaboration from NOAA-Fisheries and other vessel-based research programs. These surveys were supported by the North Pacific Research Board (NPRB), and a similar survey program will continue through 2010, as part of the NPRB Bering Sea Integrated Ecosystem Research Program. The USFWS surveys provide new information on the distribution and relative abundance of all marine birds and mammals in the changing conditions of the North Pacific.

Albatross

The surveys in 2006-2008 provided extensive coverage of the Bering Sea shelf (Figures 67-69). Although most of the shelf was well covered, all three species of albatross that frequent Alaska waters (Laysan, Black-footed, and Short-tailed albatrosses) were found primarily over shelf-edge waters (Figures 67-69). As found in earlier surveys (NPPSD 2005) the highest densities of albatrosses occurred along the Aleutian Archipelago, with the Laysan albatross predominate in the Aleutians and the Bering Sea, and the Black-footed albatross found primarily over the Gulf of Alaska shelf. The 2006-2008 surveys, however, found relatively high numbers of Laysan albatross along the entire length of the Bering Sea shelf edge, particularly near the underwater canyons such as the Pribilof Canyon (Figure 67). Black-footed albatross were also found near the Pribilof Canyon (Figure 68). During these surveys, Short-tailed albatross were found only along the shelf edge, from Unimak Pass to Russian waters (Figure 69).

Another avenue for determining seabird distribution at sea is via satellite telemetry, used to track far-ranging ocean wanderers. Rob Suryan (Oregon State University) has been tracking the endangered short-tailed albatross from its breeding colonies in Japan to its feeding grounds in Alaskan waters (Suryan et al. 2006). 2008 is the third year of tracking adults during the chick-rearing period. Information on the Albatross Project, and tracking maps for some of the short-tailed albatrosses are available at:

-http://www.wfu.edu/biology/albatross/shorttail/shorttail3.htm (direct to 2008 maps)
-http://www.wfu.edu/biology/albatross/shorttail/shorttail.htm (start here to follow links for more information and maps)
-http://www.wfu.edu/biology/albatross/index.htm (Albatross Project homepage)

One of the key goals of the short-tailed albatross recovery plan is to establish additional breeding colonies for the species. The translocation of 10 short-tailed albatross chicks (just over 1 month old) from Torishima to Mukojima (Bonin Islands/Ogasawara) in February was very successful. These 10 chicks were hand-reared until they fledged from the colony in late May. The Yamashina Institute for Ornithology reports that the chicks are eating and growing well. The translocated chicks were also fitted with solar powered GPS transmitters, as will an equal number of chicks from Torishima Island. This is a pilot study to assess whether the translocated chicks do well when at-sea.

Murres, Kittiwakes, and Shearwaters

During summer, the Bering Sea shelf edge had some of the highest densities of some of the most abundant species in the Bering Sea, Common and Thick-billed murres (Figure 70) and Black-legged kittiwakes (Figure 71). In particular, these species were found near the shelf edge canyons. High densities of these species were also found near their breeding colonies on St. Matthew Island and the Pribilof Islands.

Two of the most abundant non-breeding summer visitors to Alaska are short-tailed shearwaters (mainly in the Bering Sea) and sooty shearwaters (mainly in the Gulf of Alaska). Although they are widespread throughout the pelagic waters of Alaska, the recent surveys reinforced the importance of Unimak Pass (Jahncke et al. 2005), where millions of shearwaters gather for certain periods of late summer, and where shearwaters occur throughout the summer months (Figure 72).

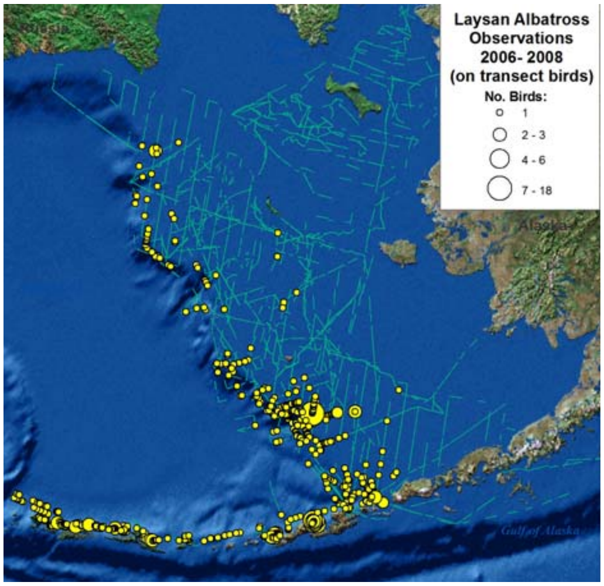

Figure 67. Distribution of Laysan albatross in the Bering Sea/Aleutian Islands, 2006-2008.

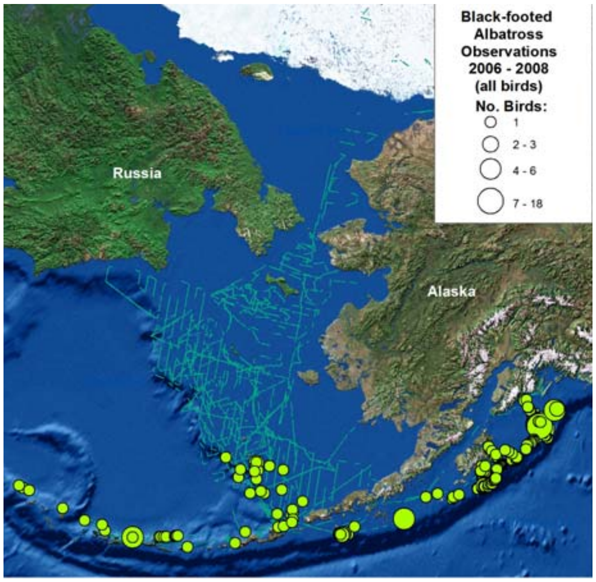

Figure 68. Distribution of black-footed albatross in the Bering Sea/Aleutian Islands, 2006-2008.

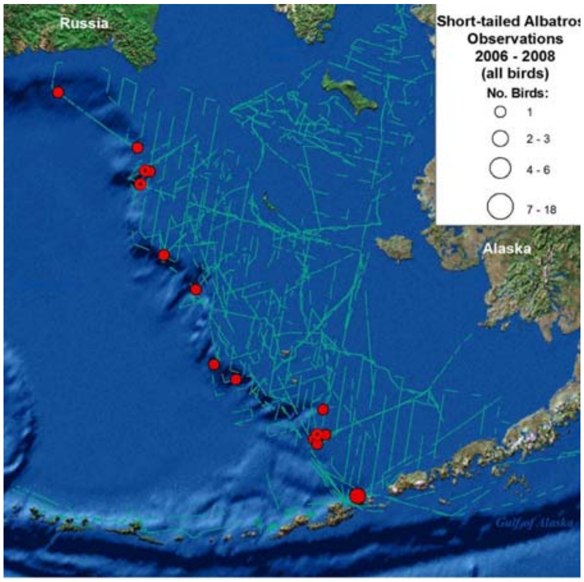

Figure 69. Distribution of short-tailed albatross in the Bering Sea/Aleutian Islands, 2006-2008.

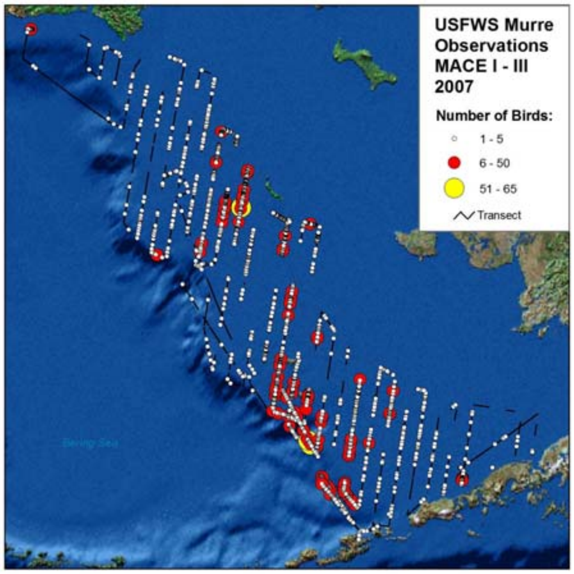

Figure 70. Distribution of common and thick-billed murres during NOAA's June and July pollock acoustic surveys in 2007. (Unpublished data from K. Kuletz, USFWS, Anchorage, AK).

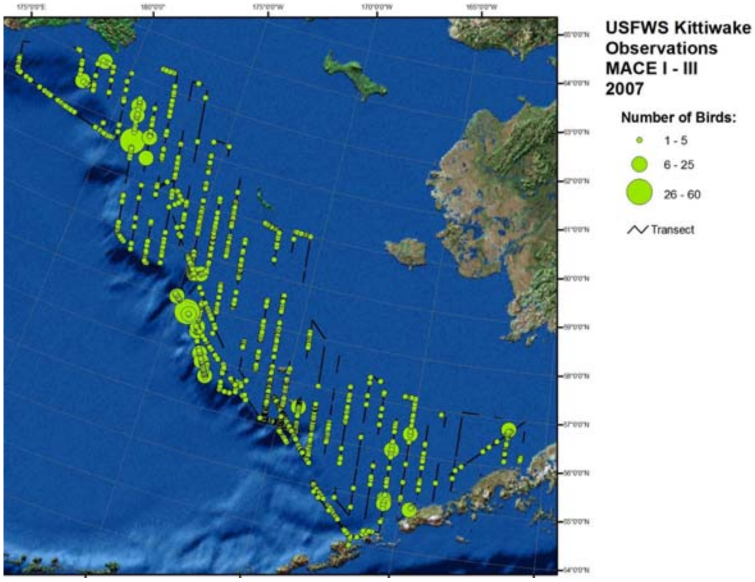

Figure 71. Distribution of black-legged kittiwakes during NOAA's June and July Pollock acoustic surveys in 2007. (Unpublished data from K. Kuletz, USFWS, Anchorage, AK).

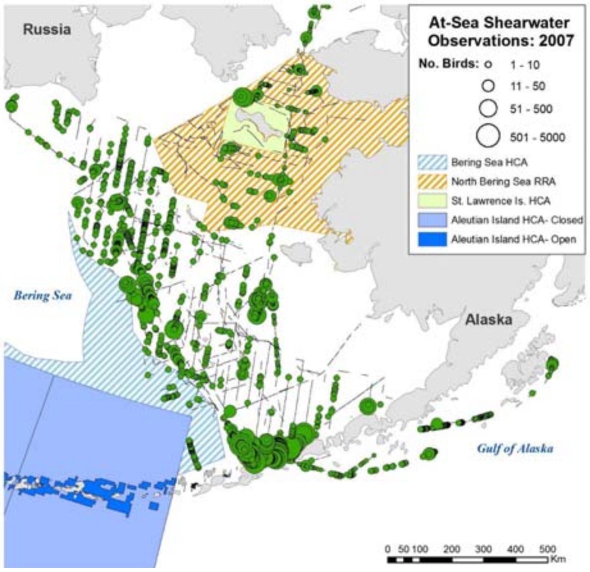

Figure 72. Observations of sooty shearwaters during USFWS at-sea surveys in 2007. Also shown are some of the major current and proposed habitat conservation areas. (unpublished data from K. Kuletz, USFWS, Anchorage, AK).

Summary of Seabird Bycatch in Alaskan Groundfish Fisheries, 1993 through 2006

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Last updated: November 2008

Introduction

This document provides a summary of seabird bycatch in federal groundfish fisheries in Alaskan waters from 1993 through 2006. Information that describes fisheries, vessel operations, observer sampling methodology, or analytical processes for estimation are available elsewhere (see Web links below). The purpose of this report is to make the estimates of seabird bycatch in federal groundfish fisheries available annually to the public.

Estimates of seabird bycatch from Alaskan groundfish fisheries are completed by NOAA Fisheries' Alaska Fisheries Science Center (AFSC) staff each year using two sources of information. The first is data obtained from the AFSC Observer Program (Observer Program). These data are composed of, among other information, total catch and species composition from direct monitoring of fishing operations by NMFS-certified groundfish observers (AFSC 2006). The second source of information is from the Alaska Regional Office catch accounting system that reports total catch. Observer methods are detailed in the North Pacific Groundfish Observer Program Documents while a description of the catch accounting database is available at Alaska Groundfish Catch Accounting System. Staff at the AFSC National Marine Mammal Laboratory analyze the data using ratio-estimation techniques similar to that used in the estimation of marine mammal incidental takes (Perez 2006).

Groundfish fisheries include fixed gear (pot and demersal longline) and trawl gear in federal waters of the Alaskan EEZ. Fishing takes place in three areas defined in North Pacific Fisheries Management Council Fishery Management Plans – the Aleutian Islands (AI), Bering Sea (BS), and the Gulf of Alaska (GOA). The Alaskan Groundfish fishery is described in detail in the Alaska Groundfish Fisheries Final Programmatic SEIS (NMFS 2004).

Fishery Interactions

Seabird bycatch summarized here is reported by the species or reporting groups developed in consultation with the U.S. Fish and Wildlife Service Migratory Birds Management Division (Anchorage, Alaska) (Table 8). At least 23 individual species, represented as a species or unidentified category, have been taken in the groundfish fisheries, including Laysan albatross (*Diomedea immutabilis*), black-footed albatross (*Diomedea nigripes*), short-tailed albatross (*Phoebastria albatrus*), Northern fulmar (*Fulmarus glacialis*), sooty shearwater (*Puffinus griseus*), short-tailed shearwater (*Puffinus tenuirostris*), unidentified storm petrel (*Oceanitidea*), herring gull (*Larus argentatus*), glaucus gull (*Larus hyperboreus*), glaucus-winged gull (*Larus glaucescens*), black-legged kittiwake (*Larus tridactyla*), red-legged kittiwake (*Larus brevirostris*), thick-billed murre (*Uria lomvia*), common murre (*Uria aalge*), tufted puffin (*Fratercula cirrhata*), king eider (*Somateria spectabilis*), loon unidentified (*Gaviidae*), grebe unidentified (*Podicipedidae*), cormorant unidentified (*Phalocrocoracidae*), jaeger/skua unidentified (*Stercorarius spp.*), tern unidentified (*Sternidae*), guillomot unidentified (*Cepphus spp.*), auklet/murrelet unidentified (*Alcidae:* several genera).

The estimates provided here are based on observer sample data only. Seabird mortalities do occur in association with vessels but are outside of normal sampling protocols. These mortalities, such as vessel collisions or interactions with trawl net or sonar cables, are not represented in the estimates provided in this report.

Bycatch in Longline Fisheries: Longline, or hook and line, fisheries in Alaskan waters are demersal sets that target groundfish or halibut. Observer coverage is not required in the halibut fishery, so information reported here are for demersal groundfish longline fisheries only, although that information does include some operations where halibut was retained due to individual fishing quota shares being available while fishing for groundfish. Longline fisheries in the BS and AI Regions are typically undertaken by vessels that are larger, stay at sea longer (up to 30 days), have onboard processing abilities, target Pacific cod (*Gadus macrocephalus*) and Greenland turbot (*Reinhardtius hippoglossoides*), use auto-bait systems, and deploy up to 55,000 hooks per day (Melvin et al. 2001). Conversely, longline vessels in the GOA typically are smaller, have shorter trip lengths (6 days), deliver bled fish on ice to shoreside processing plants, target sablefish (*Anoplopoma fimbria*), use tub or hand bait gear, and deploy up to 10,500 hooks per day (Melvin et al. 2001).

The total estimated seabird bycatch in 2006 was 4,530 birds representing a 29% decrease from 2005. This is the second lowest annual total (Table 9, Figure 73). Between 1993 and 2006 the average annual bycatch in the combined Alaskan longline fisheries was 12,021 birds (Table 9). Large inter-annual variation in seabird bycatch was common through 2001, even after the implementation of the first generation of seabird avoidance regulations in 1997 (Figure 73). With the use of seabird mitigation gear in the form of streamer lines seabird bycatch has been relatively stable. Seabird bycatch is highest in the BS, where fishing is prosecuted predominantly by cod freezer longliners (Melvin et al. 2001), and lower in the AI and GOA Areas (Tables 10-12, Figure 74). The average annual bycatch for all demersal groundfish fisheries (excludes Pacific Halibut) in Alaska during the period 2002-2006 was 5,138 (Table 9). Species composition during this period (with the average number in parenthesis) was: Northern fulmar – 39% (2,046); Gull sp. – 39% (2,019); shearwater sp. – 8% (432); unidentified birds – 7% (378); Laysan albatross – 2% (102); black-footed albatross – 2% (82); and unidentified procellarid, alcid sp., and other species categories all at 1% with 26 birds each. There was an annual average of 2 unidentified albatross at < 1%. Figure 75 depicts the general species composition by region for this time period. In 2006, the predominant bycatch species group was Gulls (2,161) followed by Northern fulmars (1,454), shearwaters unidentified (428), and unidentified birds (285). A total of 192 albatross were taken (see below).

Total seabird bycatch is the result of overall fishing effort and catch rate. Generally, while overall effort increased from 1993 to 2003, the bycatch rates decreased substantially (Figure 76). During 1993-2006, the average annual bycatch rates (birds per 1,000 hooks) were 0.050 overall. The rates for this time period in the AI, BS, and GOA areas were 0.061, 0.057, and 0.019 respectively (Table 9). Those rates have dropped in the last few years, with the running 5-year average now (2002-2006) at 0.018, 0.019, and 0.008 for AI, BS, and GOA respectively, with an overall rate of 0.017 for all regions combined. In the AI, effort and bycatch have generally tracked together (Figure 77). Catch rates have declined while effort has trended upwards in the BS (Figure 78). In the GOA, effort was low and bycatch rates were their highest in 1998. Since then, effort has nearly doubled while bycatch rates have dropped dramatically (Table 9, Figure 79), although both the bycatch rate and effort increased from 2005 to 2006. In all three regions, bycatch rates were quite variable from year to year prior to 2001 and have stabilized at much lower rates since then, matching the period when streamer line use began. Bycatch rates in all three regions have been decreasing since highs in the 1998-1999 period.

Albatross bycatch has fallen drastically, with the lowest totals in 2002 but relatively low numbers since then (Figure 80). Although the proportion of unidentified albatross was high in early years, improved training and albatross identification materials have reduced the overall number of unidentified albatross (Figure 80 and Tables 10-12). The bycatch of black-footed albatross (BFAL) exceeded that of Laysan albatross in only 2 years – 1991 and 2006. Regionally, we see the highest Laysan albatross bycatch in the AI, followed by the BS and lowest in the GOA (Figure 81). The reverse is true for black-footed albatross, which are caught predominantly in the GOA. These regional patterns are reflected in the primary, or target, fisheries that operate in each area. BFAL are caught in the IFQ sablefish/halibut fishery, accounting for 85% of the take, while the cod freezer longline fishery accounts for 15% (Figure 82). Laysan albatross bycatch was distributed more evenly, with 54% of the bycatch in the IFQ fishery and 45% in the open-access freezer longliner fishery for cod and turbot (Figure 83). The total estimated mortality of albatross in 2006 was 57 Laysan and 135 black-footed albatross.

The substantial reduction in seabird bycatch starting in 2001 can likely be attributed to seabird mitigation measures. Washington Sea Grant, in collaboration with the longline industry and NOAA Fisheries, conducted research on seabird mitigation gear during 1999 and 2000 (Melvin et al. 2001). Paired streamer lines meeting specific performance standards had proven to be very effective in reducing seabird bycatch during this study. In 2002 many freezer-longliners fishing in the BSAI adopted the use of streamer lines and the performance standards recommended by Melvin et al. (2001). NMFS completed the revisions to seabird avoidance regulations that made seabird avoidance measures mandatory for all longline vessels in February 2004. Among other requirements, vessels longer than 55 feet in overall length must use paired streamer lines except in certain weather conditions. During the period before widespread use of streamer lines (1993 through 2000) the average annual seabird bycatch rate was 16,507. In the 5 years since streamer line use has become widespread and later required by regulation (2002-2006) the annual average bycatch of seabirds was 5,138. There is a pronounced change in the average bycatch levels calculated for the 5-year periods before and after streamer lines were adopted (Figure 84). The Washington Sea Grant research indicated that streamer lines were especially effective for deterring albatross. The average annual albatross bycatch for 1993 through 2000 was 1,051 while the annual average between 2002 and 2006 was 185, an 83% reduction. In 2004, groundfish observers also began recording results of the use of seabird mitigation gear on vessels 60 feet length overall and greater. Since then observers have checked 66% of longline sets and observed that single or double streamer lines were used in 96.1% of those sets (Table 13). Compliance appears to be near 100% given allowances to not use seabird mitigation gear in heavy weather due to concerns for crew safety.

Pot: Seabird bycatch from groundfish pot fishing has traditionally been very limited. The overall average bycatch in this fishery, 1993 through 2006, is 73 seabirds (Table 14). In 2006 the 17 observed takes led to an estimated total of 230 birds, the highest number recorded to date. No albatross have been taken in pot gear. Northern fulmars accounted for 219 of the 230 estimated birds in 2006. These surface-feeding birds obviously did not enter the pot while it was actively fishing on the bottom. Previous speculation that these birds entered the pots while the ship was in transit and died inside, and were thus set with the pot, have recently been corroborated by several groundfish observers.

Trawl: Seabird bycatch in trawl fisheries are reported in Tables 15 to 17 and in Figures 85 through 92. We previously reported two alternative estimates for seabird bycatch in the Alaskan trawl fleet. This was due to not having recorded the sample size used to monitor for seabirds during zero seabird bycatch hauls (observers were instructed to use the largest sample available, but not all observers did this). The issue was resolved in 2004, when the sample size used for monitoring was always recorded whether birds were taken or not. Based on estimates derived since then and other parameters we are able to determine which alternate to use for the 1993 through 2003 period. The remainder of this section provides what we determine to be the best available estimate. However, these estimates are biased low. The estimates reported represent only those birds in the observer sample. The sample is taken from the fish catch, which is contained by the codend (Figure 85). From reports in other trawl fisheries globally, and from ad hoc reports by groundfish observers on Alaskan trawl vessels, we know that seabird mortalities occur from birds encountering trawl cables. This includes the main cables that run from the winches, through heavy blocks, and into the water down to the trawl doors known as main wires or warps. It also applies to the smaller cable known as the third wire that runs from the upper stern deck down to the trawl sonar package attached to the headrope. Seabirds on the water and in the air can collide with these wires.

While many of these collisions are harmless, some can lead to mortalities (Melvin et al. in prep). We have reports from observers on fulmar mortalities from warps and third wires in pollock, cod, and Atka mackerel fisheries, and of Laysan albatross in the catcher/processor cod fishery in the AI and BS. We are currently unable to derive estimates from these, although some pilot work has been done to explore other means of monitoring (McElderry et al. 2004). Dietrich and Melvin (2007) provide a first attempt at characterizing albatross bycatch in these trawl fisheries and discuss where attention should first be focused for additional monitoring projects.

In 2006 an estimated 2,873 seabirds were taken in the Alaskan groundfish trawl fleet, an 84% increase over the 1,561 seabirds from 2005. The estimates derived from observer sampling average 934 birds per year, 1993-2006, with low numbers throughout but increasing during 1996-1998, remaining near 1,000 birds per year through 2004, then increasing again in 2005 and 2006 (Figure 86). By region, seabird bycatch is lowest in the GOA and generally higher in the BS, with the AI being intermediate but highest in 1993, 1996, 2001, and 2003 (Figure 87). Northern fulmars are again the most common species taken, constituting about 36% of the overall seabird bycatch in the combined groundfish trawl fleet when using the 1993-2006 average annual estimates (Figure 88). That composition stays about the same, 37%, when using the 2002-2006 annual average estimates (Figure 89). When using the 2000 through 2004 annual average estimate however, fulmar bycatch is about 76% (Tables 15-17). These large changes are due to large estimates in some years for species groups such as unidentified birds (2,092 in 2006 but 89 on average otherwise).

The highest annual average seabird bycatch (2002-2006) occurred in the Pacific cod fishery and the pollock fishery had the second highest seabird bycatch (Figure 90). Pollock however had a total catch that far exceeded the other target fishery and thus had a very low overall bycatch rate. The cod fishery, with its much lower total catch, had the highest bycatch rate. The flatfish fisheries also had a low catch rate.

Albatross bycatch in the groundfish trawl fleet includes only unidentified (1993, 1995 and 2006) and Layson albatross (Figure 91). No black-footed or short-tailed albatross have been recorded by observers, either as part of their sample or from other sources of mortality. Short-tailed albatross have been seen around trawl vessels however. Because of their proximity, and the use of Laysan albatross mortalities as a proxy, the trawl fleet was included in the Short-tailed albatross biological opinion (USFWS 2003). Work has since been accomplished to characterize the likely interaction between albatross species and groundfish trawl fisheries (Dietrich and Melvin 2007) and to develop means of assessing the risk to short-tailed albatross recovery (Zador et al. 2008a) or the likelihood of interactions based on fishery sectors and short-tailed sightings (Zador et al. 2008b). During 2002-2006, the bycatch of Laysan albatross appears to mostly be an issue for fisheries operating in the AI, with very limited takes in the BS (Figure 92). No albatross were taken in the GOA during this period.

Several projects are underway to further explore trawl cables (warps, third wires, and paravanes) as a source of mortality for seabirds on trawl vessels. An observer special project was done during 2004-2006 and will be implemented again for the 2008 season. A preliminary report on the first period is currently in preparation. A collaborative project was started in 2004 between the Alaska Fisheries Science Center and the Pollock Conservation Cooperative to promote development of seabird mitigation measures for groundfish catcher processor vessels. Funds were obtained from the NOAA Fisheries National Cooperative Research Program to assist with the development of these measures. Parallel to that, the Pollock Conservation Cooperative had been collaborating with Washington Sea Grant to conduct some preliminary work on interaction rates and further develop protocols drafted by Sea Grant, AFSC and University of Washington staff to be able to develop a rigorous field test of these measures (Melvin et al. 2004). Washington Sea Grant coordinated with the Pollock Conservation Cooperative (with support from the AFSC and USFWS) to conduct such a rigorous test of these gear under commercial fishing conditions in the summer of 2005. A report of that work is also in prep (Melvin et al. in prep). In addition, Washington Sea Grant, with partial financial support from the National Seabird Program completed an extensive study to characterize the trawl fleet, identify warp and third wire effort, and note overlaps as determined from sighting or telemetry work (Dietrich and Melvin 2007). In order for interactions to first occur birds must be in attendance at the ship. The provision of offal is a key attractant for birds. Zador and Fitzgerald (2008) present results on this issue, based on an observer special project which also will again occur during the 2009 season. Through these completed studies, other ongoing efforts, and proposals submitted for funding we hope to evaluate which fishery sectors have additional seabird interactions and develop an improved monitoring plan to support viable estimates of seabird mortalities.

Acknowledgements

Reporting of seabird bycatch numbers would not be possible without the dedication and hard work of the many North Pacific Groundfish Observers deployed each year. Their efforts are here gratefully acknowledged. Staff of the North Pacific Groundfish Observer Program work to support observers in the field, and to ensure proper quality control measures are integrated into every step of the program, working to ensure that these data are of the highest quality possible. They too deserve credit for their diligence. Mike Perez of the National Marine Mammal Lab conducts the analysis of seabird bycatch each year, with partial financial support from the Alaska Region Protected Resources Division.

Web links

For additional information on seabird regulations, biological opinions, and other related matters, refer to the Alaska Region Protected Resources Division Alaska Seabird Incidental Take Reduction Program and Longline Gear Seabird Avoidance Measures.

For information on North Pacific Groundfish Observer Program protocols see http://www.afsc.noaa.gov/refm/observers

For general fisheries management information also see the North Pacific Fisheries Management Council website at http://www.fakr.noaa.gov/npfmc

For research on seabird avoidance measures and seabird distribution refer to the Washington Sea Grant website at http://www.wsg.washington.edu/research/living/seabirds.html

Table 8. Species and species group categories used in this report. Any species or species group heading not listed in a table means that there was no bycatch in that category[1].

Species/species Group	Includes	Scientific Name
Short-tailed Albatross	n/a	*Phoebastria albatrus*
Laysan Albatross	n/a	*Phoebastria immutabilis*
Black-footed Albatross	n/a	*Phoebastria nigripes*
Unidentified Albatross	Short-tailed, Laysan, or black-footed.	n/a
Northern Fulmar	n/a	*Fulmarus glacialis*
Shearwaters	Unidentified Shearwater	*Puffinus* spp
	Sooty Shearwater	*Puffinus griseus*
	Short-tailed shearwater	*Puffinus tenuirostris*
Unidentified Procellarid	All of the above	Procellariiformes
Gull	Unidentified gull	*Laridae*
	Herring gull	*Larus argentatus*
	Glaucous gull	*Larus hyperboreus*
	Glaucous-winged gull	*Larus glaucescens*
Alcid	Unidentified alcid,	*Alcidae*
	Guillemot	*Cepphus* spp.
	Murre	*Uria* spp.
	Puffin	*Fraturcula* spp.
	Murrelet and auklet	Several genera
Other Seabird	Miscellaneous birds – could include:	
	Loons	*Gaviidae*
	Grebe	*Podicipededae*
	Cormorant	*Phalocrocoracidae*
	Seaduck	*Anatidae*
	Jaeger/skua	*Stercorariidae*
	Kittiwake	*L. tridactyla, L. brevirostris*
	Terns	*Sternidae*
	Storm petrel	*Oceanitidae*
Unidentifid Seabird	All of the above	

[1] A complete list of the species and species group categories used by North Pacific Groundfish Observers while monitoring is available in the Groundfish Observer Manaual (AFSC 2006).

Table 9. Annual estimates of fishery effort, total birds taken, catch rates, and percent hooks observed in Alaskan groundfish demersal longline fisheries by fishery management region and for all Alaskan waters combined, 1993 through 2006.

Area and Year	Effort (No. of hooks in 1,000s)	Number of Birds	95% Confidence Bounds	Incidental catch rate (Birds per 1,000 hooks)	Percent of hooks observed
Aleutian Islands					
1993	37,009.6	2,485	1,927-3,204	0.067	21.1
1994	17,171.1	1,440	1,170-1,771	0.084	25.2
1995	11,846.7	1,531	1,170-2,004	0.129	23.2
1996	11,885.3	791	573-1,088	0.066	25.8
1997	13,177.2	958	698-1,318	0.073	18.9
1998	20,388.2	1,770	1,472-2,129	0.087	25.8
1999	14,588.5	1,901	1,266-2,854	0.130	19.8
2000	28,461.7	1,545	1,144-2,087	0.054	20.7
2001	34,220.7	1,189	906-1,561	0.035	20.7
2002	8,649.0	66	41-107	0.008	31.2
2003	11,294.7	372	236-586	0.033	11.5
2004	10,700.0	124	81-193	0.012	16.9
2005	9,110.6	184	129 - 262	0.020	16.3
2006	11,024.4	181	132 - 248	0.016	18.5
Aleutian Island Average Annual Estimates					
1993-2006	17,109.1	1,038	944-1,142	0.061	21.2
2002-2006	10,155.8	185	149 - 231	0.018	18.4
Bering Sea					
1993	85,605.4	5,364	4,683-6,142	0.063	26.2
1994	118,840.4	9,393	8,446-10,448	0.079	24.2
1995	131,313.3	17,944	16,664-19,323	0.137	24.1
1996	131,832.2	7,814	7,004-8,716	0.060	23.3
1997	176,756.6	20,187	18,404-22,145	0.114	21.2
1998	156,150.3	22,912	21,185-24,780	0.147	23.0
1999	144,070.5	10,396	9,202-11,746	0.072	24.2
2000	164,567.4	16,766	15,278-18,399	0.102	22.3
2001	193,457.1	8,888	8,020-9,849	0.046	20.8
2002	208,861.2	3,805	3,327-4,351	0.018	22.0
2003	267,234.5	4,818	4,348-5,339	0.018	22.6
2004	259,288.4	4,694	4,284-5,141	0.018	19.8
2005	265,103.0	5,762	5,288 - 6,278	0.022	20.9
2006	194,375.1	3,534	2,706 - 4,615	0.018	19.4
Bering Sea Average Annual Estimates					
1993-2006	178,390.3	10,163	9,869-10,466	0.057	22.0
2002-2006	238,972.4	4,522	4,260 -4,801	0.019	21.0
Gulf of Alaska					
1993	56,431.2	1,322	1,090-1,606	0.023	10.2
1994	49,461.6	532	419-676	0.011	4.9
1995	42,775.5	1,544	1,341-1,779	0.036	12.6
1996	33,416.5	1,649	1,273-2,137	0.049	10.7
1997	28,756.6	474	339-663	0.016	9.7

Area and Year	Effort (No. of hooks in 1,000s)	Number of Birds	95% Confidence Bounds	Incidental catch rate (Birds per 1,000 hooks)	Percent of hooks observed
1998	30,029.9	1,587	1,016-2,480	0.053	7.9
1999	32,354.9	965	765-1,216	0.030	8.5
2000	35,813.0	782	484-1,262	0.022	6.4
2001	34,637.8	476	318-710	0.014	7.7
2002	37,501.5	238	143-396	0.006	9.2
2003	53,192.0	511	328-798	0.010	6.5
2004	56,099.1	161	84-307	0.003	5.0
2005	46,660.8	424	314 - 573	0.009	5.3
2006	60,032.1	815	531 – 1,252	0.014	5.8
Gulf of Alaska average annual estimates					
1993-2006	42,654.5	820	742-906	0.019	7.7
2002-2006	50,697.1	430	346-535	0.008	6.2
All Alaska fishery management regions combined					
1993	179,046.2	9,171	8,225-10,226	0.051	20.1
1994	185,473.0	11,364	10,361-12,467	0.061	19.2
1995	185,935.5	21,019	19,657-22,477	0.113	21.4
1996	177,134.0	10,254	9,309-11,291	0.058	21.1
1997	218,699.3	21,619	19,803-23,607	0.099	19.5
1998	206,568.4	26,270	24,380-28,306	0.127	21.1
1999	191,013.9	13,263	11,839-14,858	0.069	21.2
2000	228,842.1	19,093	17,493-20,839	0.083	19.6
2001	262,315.5	10,552	9,609-11,588	0.040	19.1
2002	255,011.7	4,108	3,614-4,669	0.016	20.5
2003	331,721.1	5,701	5,157-6,303	0.017	19.6
2004	326,087.5	4,979	4,554-5,444	0.015	17.2
2005	320,874.4	6,370	5,875-6,906	0.020	18.5
2006	265,431.6	4,530	3,624-5,661	0.017	16.3
All Alaska fishery management regions combined average annual estimates					
1993-2006	238,153.9	12,021	11,701-12,350	0.050	19.4
2002-2006	299,825.3	5,138	4,856-5,435	0.017	18.4

Table 10. Estimated incidental take and actual number of seabirds observed taken in the Aleutian Islands fishery management region groundfish demersal longline fishery, 1993 through 2006. Numbers in parenthesis (shaded rows) are the 95% confidence intervals.

		Albatrosses			Northern	Shear-	Unid. Procel-			Other Sea-	Unid.	
Year	No. Obs.	Laysan	Black- footed	Unid.	Fulmar	waters	larids	Gulls	Alcids	birds	Seabirds	Totals
		571	12	355	1,017	0	0	184	3	0	343	2,485
1993	550	(437-746)	(5-29)	(228-555)	(611-1,695)			(133-253)	(1-13)		(157-746)	(1,927-3,204)
		307	37	76	434	27	0	24	0	0	535	1,440
1994	388	(228-414)	(17-78)	(50-116)	(300-628)	(8-94)		(21-30)			(348-823)	(1,170-1,771)
		316	23	26	1,006	22	10	99	0	0	29	1,531
1995	390	(176-567)	(11-50)	(16-43)	(689-1,469)	(10-48)	(2-42)	(62-156)			(14-61)	(1,170-2,004)
		106	20	34	160	304	2	23	0	0	142	791
1996	222	(72-155)	(6-70)	(18-64)	(100-254)	(148-623)	(1-7)	(13-42)			(78-258)	(573-1,088)
		270	8	10	599	20	9	10	0	0	32	958
1997	179	(185-394)	(2-36)	(3-32)	(373-963)	(5-73)	(3-28)	(3-32)			(16-64)	(698-1,318)
		449	4	0	638	125	4	167	0	4	379	1,770
1998	460	(295-683)	(1-18)		(474-859)	(83-188)	(1-18)	(109-257)		(1-15)	(243-591)	(1,472-2,129)
		232	18	0	1,535	9	4	100	0	0	5	1,903
1999	399	(178-301)	(7-41)		(933-2,527)	(2-41)	(1-18)	(48-210)			(1-23)	(1,267-2,856)
		196	11	5	1,149	27	0	110	0	0	47	1,545
2000	325	(144-268)	(3-35)	(1-23)	(772-1,712)	(13-56)		(71-171)			(24-92)	(1,144-2,087)
		131	0	0	946	65	0	43	0	0	5	1,189
2001	245	(79-215)			(678-1,319)	(40-103)		(24-76)			(1-22)	(894-1,547)
		47	0	0	10	5	0	4	0	0	0	66
2002	18	(25-86)			(4-25)	(1-23)		(1-15)				(41-107)
		135	0	0	216	0	0	0	0	21	0	372
2003	74	(63-290)			(118-394)					(6-74)		(236-586)
		52	0	0	28	16	0	10	0	0	18	124
2004	24	(27-100)			(13-61)	(3-78)		(3-32)			(8-40)	(81-193)
		50	0	0	32	16	0	85	0	0	0	184
2005	40	(29-87)			13-77	Jun-43		48-151				129-262
		44	3	0	89	0	0	45	0	0	0	181
2006	38	(24-82)	(1-12_		(55-144)			(25-81)				(132-248)
Average Annual Estimates												
		208	10	36	561	45	2	65	0	2	110	1,038
1993-2006	na	(182-236)	(7-14)	(26-50)	(480-657)	(31-66)	(1-4)	(55-77)	(0-1)	(1-5)	(84-143)	(944-1,142)
		66	1	0	75	8	0	29	0	4	4	185
2002-2006	na	(45-95)	(0-2)		(51-110)	(3-19)		(19-43)		(1-15)	(2-8)	(149-231)

Table 11. Estimated incidental take and actual number of seabirds observed taken in the Bering Sea fishery management region groundfish demersal longline fishery, 1993 through 2006. Numbers in parenthesis (shaded rows) are the 95% confidence intervals.

		Albatrosses											
Yr	No. Obs.	Short-tailed	Laysan	Black-footed	Unid.	Northern Fulmar	Shear-waters	Unid. Procel-larids	Gulls	Alcids	Other Sea-birds	Unid. Seabirds	Totals
1993	1,392	0	49	0	0	3,153	65	0	647	11	4	1,435	5,364
			(29-83)			(2,582-3,849)	(34-123)		(430-974)	(4-36)	(1-16)	(1,200-1,716)	(4,683-6,142)
1994	2,312	0	4	0	0	4,555	656	351	1,718	4	4	2,101	9,393
			(1-20)			(3,954-5,247)	(495-870)	(247-499)	(1,333-2,214)	(1-20)	(1-18)	(1,568-2,814)	(8,446-10,448)
1995	4,442	0	148	43	12	8,811	308	474	3,892	4	45	4,207	17,944
			(104-210)	(19-96)	(5-31)	(7,884-9,847)	(221-429)	(295-760)	(3,268-4,635)	(1-17)	(24-84)	(3,538-5,003)	(16,664-19,323)
1996	1,780	4	130	0	27	5,571	185	14	1,484	46	50	303	7,814
		(1-19)	(79-216)		(13-53)	(4,806-6,457)	(118-288)	(6-37)	(1,250-1,762)	(14-144)	(25-103)	(235-389)	(7,004-8,716)
1997	3,944	0	125	4	3	15,187	354	169	3,429	0	9	907	20,187
			(86-183)	(1-19)	(1-15)	(13,505-17,079)	(206-609)	(112-257)	(2,667-4,408)		(3-28)	(606-1,356)	(18,404-22,145)
1998	5,390	8	982	5	4	14,955	1,018	17	4,252	53	45	1,573	22,912
		(3-24)	(720-1,339)	(1-23)	(1-17)	(13,391-16,701)	(846-1,226)	(8-39)	(3,626-4,985)	(31-90)	(23-89)	(1,288-1,926)	(21,185-24,780)
1999	2,565	0	315	0	0	6,082	451	418	2,177	4	49	902	10,396
			(253-387)			(5,048-7,329)	(353-575)	(224-778)	(1,810-2,618)	(1-15)	(23-102)	(625-1,302)	(9,202-11,746)
2000	3,537	0	260	5	10	9,864	539	86	4,454	5	16	1,527	16,766
			(172-391)	(2-21)	(3-29)	(8,558-11,369)	(415-698)	(54-137)	(3,853-5,151)	(1-22)	(8-35)	(1,171-1,992)	(15,278-18,399)
2001	1,742	0	290	5	5	4,602	394	96	2,436	2	33	1,026	8,888
			(204-412)	(1-21)	(1-21)	(3,907-5,420)	(293-528)	(61-153)	(2,053-2,890)	(1-8)	(15-74)	(765-1,376)	(8,020-9,849)
2002	859	0	5	0	5	695	149	20	2,537	10	17	367	3,805
			(1-24)		(1-22)	(585-826)	(102-219)	(7-53)	(2,095-3,071)	(3-32)	(7-40)	(277-485)	(3,327-4,351)
2003	1,047	0	47	10	0	2,768	292	14	1,374	11	45	257	4,818
			(23-94)	(3-32)		(2,427-3,158)	(222-383)	(4-46)	(1,089-1,734)	(4-29)	(26-76)	(192-343)	(4,348-5,339)
2004	894	0	37	11	3	1,934	710	97	1,260	39	23	580	4,694
			(18-74)	(4-36)	(1-10)	(1,661-2,253)	(558-904)	(59-160)	(1,055-1,505)	(20-76)	(11-51)	(448-750)	(4,284-5,141)
2005	1,209	0	18	5	0	2,596	511	0	2,283	16	19	314	5,762
			Jul-44	23-Jan		2,288-2,945	422-619		1,958-2,663	Jun-41	Sep-40	221-445	5,288-6,278
2006	699	0	3	5	0	1,154	424	0	1,692	6	5	245	3,534
			(3-3)	(1-24)		(917-1,452)	(331-541)		(1,002-2,858)	(1-28)	(1-23_	(183-327)	(2,706-4,615)
Average Annual Estimates													
1993-2006	na	1	172	7	5	5,852	433	125	2,403	15	26	1,124	10,163
		(0-2)	(148-201)	(4-11)	(3-8)	(5,604-6,111)	(399-468)	(101-156)	(2,262-2,551)	(11-22)	(21-33)	(1,036-1,220)	(9,869-10,466)
2002-2006	na	0	22	6	2	1,829	417	26	1,829	17	22	352	4,522
			(14-34)	(3-13)	(1-5)	(1,705-1,963)	(371-469)	(17-40)	(1,613-2,075)	(11-26)	(15-31)	(308-403)	(4,260-4,801)

Table 12. Estimated incidental take and number of seabirds observed taken in the Gulf of Alaska fishery management region groundfish demersal longline fishery, 1993 through 2006. Numbers in parenthesis (shaded rows) are the 95% confidence intervals.

		Albatrosses										
Year	No. Obs.	Laysan	Black-footed	Unid.	Northern Fulmar	Shear-waters	Unid. Procel-larids	Gulls	Alcids	Other Sea-birds	Unid. Sea-birds	Totals
1993	318	128	29	3	842	59	0	45	0	3	213	1,322
		(78-211)	(15-57)	(1-14)	(648-1,094)	(31-114)		(23-90)		(1-11)	(131-346)	(1,090-1,606)
1994	126	169	7	8	258	26	0	30	0	0	33	531
		(106-269)	(2-22)	(3-24)	(181-368)	(10-70)		(7-127)			(13-84)	(419-676)
1995	374	68	239	378	529	40	6	105	0	4	175	1,544
		(42-109)	(181-317)	(290-493)	(381-733)	(20-81)	(1-25)	(67-166)		(2-11)	(120-256)	(1,341-1,779)
1996	250	155	665	0	674	15	0	121	0	0	19	1,649
		(104-233)	(490-903)		(424-1,071)	(4-52)		(30-498)			(6-57)	(1,273-2,137)
1997	74	31	97	0	281	8	0	47	0	0	10	474
		(7-127)	(51-187)		(177-449)	(2-24)		(24-93)			(3-33)	(339-663)
1998	184	241	321	4	952	13	0	57	0	0	0	1,588
		(117-495)	(125-825)	(1-18)	(506-1,788)	(4-42)		(29-116)				(1,016-2,480)
1999	159	214	184	0	242	50	0	249	0	9	16	964
		(147-312)	(91-370)		(165-354)	(21-118)		(145-430)		(2-43)	(5-55)	(765-1,216)
2000	72	96	155	0	317	0	0	180	0	0	34	782
		(47-195)	(89-271)		(140-716)			(55-592)			(7-174)	(484-1,262)
2001	45	69	73	17	191	20	0	96	6	0	3	475
		(29-165)	(36-146)	(4-86)	(116-314)	(4-99)		(25-365)	(1-29)		(1-14)	(318-710)
2002	51	0	33	0	107	0	0	81	0	0	17	238
			(17-65)		(52-219)			(27-237)			(6-44)	(143-396)
2003	37	12	155	0	233	0	0	49	46	0	16	511
		(5-30)	(58-417)		(124-436)			(16-149)	(8-270)		(3-80)	(328-798)
2004	17	31	24	0	0	0	0	93	0	0	13	161
		(11-88)	(10-58)					(35-244)			(3-62)	(84-307)
2005	67	15	38	0	156	33	0	160	0	0	23	424
		Jun-38	9-150		95-256	15-76		107-239			13-May	314-573
2006	105	10	126	0	212	5	0	423	0	0	40	815
		(3-32)	(54-298)		(120-374)	(1-20)		(208-859)			(14-116)	(531-1,252)
Average Annual Estimates												
1993-2006	na	89	153	29	357	19	0	124	4	1	44	820
		(72-109)	(123-191)	(23-38)	(301-423)	(14-27)	(0-2)	(93-167)	(1-19)	(1-3)	(33-57)	(742-906)
2002-2006	na	14	75	0	142	8	0	161	9	0	22	430
		(8-25)	(44-130)		(103-194)	(4-16)		(105-247)	(2-54)		(11-43)	(346-535)

Table 13. Seabird avoidance measures used by demersal groundfish longline vessels, 2004 -- 2006. Data are from observer spot-checks of set operations from catcher-processor (CP) and catcher (CV) vessels in the Aleutian Islands (AI), Bering Sea (BS), and Gulf of Alaska (GOA).

						Use of Streamer Lines in Examined Sets			
Region	Vessel Type	Total Sets	Sets not checked	Sets Checked	% sets checked	Paired Streamers	Single Streamer	No Streamers	% Paired or Single
AI	CV	61	9	52	85.2	35	17	0	100.0
AI	CP	4,234	1,705	2,468	58.3	2,261	69	138	94.4
BS	CV	290	21	269	92.8	237	28	4	98.5
BS	CP	44,621	15,286	29,335	65.7	25,405	2,781	1,149	96.1
GOA	CV	2,945	554	2,391	81.2	2,066	230	95	96.0
GOA	CP	4,542	1,686	2,856	62.9	2,685	90	81	97.2
Total		56,632	19,261	37,371	66.0	32,689	3,215	1,467	96.1

Table 14. Estimated incidental take and actual number of seabirds observed taken in the demersal pot fishery in Alaskan waters, 1993 through 2006, all fishery management regions combined. Numbers in parentheses (shaded rows) are the 95% confidence intervals.

Year	No. Obs.	Northern Fulmar	Shearwaters	Unid. Procellarids	Gulls	Alcids	Other Seabirds	Unid. Seabirds	Totals
1993	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0
1995	6	9	7	0	4	19	0	0	39
		(3-33)	(1-33)		(1-15)	(4-92)			(15-103)
1996	9	80	0	2	0	0	0	7	89
		(27-235)		(1-8)				(2-30)	(33-238)
1997	4	16	0	0	0	11	0	0	27
		(6-43)				(2-52)			(10-68)
1998	2	19	0	0	15	0	0	0	34
		(4-92)			(3-73)				(10-114)
1999	47	166	9	14	0	0	0	0	189
		(95-290)	(2-43)	(5-35)					(114-313)
2000	1	0	0	0	0	0	0	42	42
								(9-207)	(9-207)
2001	3	14	0	0	3	0	0	0	17
		(4-52)			(1-12)				(6-53)
2002	6	18	0	0	0	0	0	3	21
		(8-42)						(1-13)	(10-44)
2003	10	91	4	0	0	59	0	0	154
		(36-230)	(1-16)			(12-290)			(63-372)
2004	5	60	0	0	0	0	0	0	60
		(20-183)							(20-183)
2005	11	102	13	0	0	0	0	0	115
		(29-363)	(5-34)						(36-364)
2006	17	219	7	0	0	0	4	0	230
		(84-570)	(1-31)				(1-19)		(92-575)
Average Annual Estimates									
1993-2006	na	57	3	1	2	6	0	4	73
		(38-85)	(1-6)	(1-3)	(0-5)	(2-21)	(0-1)	(1-15)	(51-103)
2002-2006	na	98	5	0	0	12	1	1	116
		(55-175)	(2-10)			(2-58)	(0-4)	(0-3)	(68-196)

Table 15. Estimated incidental take and actual number of seabirds observed taken in the Aleutian Islands fishery management region groundfish trawl fleet, 1993 through 2006.

Year	No. Obs.	Laysan Albatross	Unidentified Albatross	Northern Fulmar	Shearwaters	Gulls	Alcids	Unidentified Seabirds	Totals
1993	3	0	0	0	440	0	0	0	440
					(107 – 1,812)				(107 – 1,812)
1994	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0
1996	1	0	0	0	0	0	0	215	215
								(39 - 1,181)	(39 – 1,181)
1997	4	133	0	0	0	0	0	42	175
		(15 – 1,197)						(3 - 649)	(24 – 1,279)
1998	9	313	0	11	0	2	0	0	326
		(74 – 1,314)		(2 - 65)		(0 - 58)			(81 – 1,309)
1999	21	9	0	157	8	0	0	0	174
		(4 - 17)		(32 - 777)	(1 - 50)				(63 - 477)
2000	7	0	0	121	0	0	0	0	121
				(29 - 499)					(29 - 499)
2001	11	8	0	253	467	0	0	0	728
		(1 - 61)		(52 – 1,234)	(135 – 1,619)				(261 – 2,032)
2002	8	2	0	189	0	0	0	0	191
		(1 - 13)		(63 - 567)					(65 - 567)
2003	6	166	0	202	0	86	86	0	540
		(25 – 1,130)		(40 – 1,023)		(17 – 441)	(17 - 441)		(186 – 1,559)
2004	3	0	0	298	0	0	0	0	298
				(73 – 1,218)					(73 – 1,218)
2005	5	56	0	191	0	0	0	0	247
		(9 - 357)		(52 - 701)					(79 – 774)
2006	4	0	2	8	126	0	0	0	137
			(1-115)	(2-226)	(24-656)				(28-679)
Average Annual Estimates									
1993 – 2006	n/a	49	0	102	74	6	6	18	255
		(17 - 143)	(0-8)	(54 - 193)	(30 - 184)	(1 - 32)	(1 – 32)	(4 - 91)	(163 – 404)
2002-2006	n/a	45	0	177	25	17	17	0	281
		(9 - 225)	(0-23)	(81 - 386)	(5 - 131)	(3 - 88)	(3 - 88)		(150 - 528)

Table 16. Estimated incidental take and actual number of seabirds observed taken in the Bering Sea fishery management region groundfish trawl fleet, 1993 through 2006.

		Albatross									
Year	No. Obs.	Laysan	Unidentified	Northern Fulmar	Shearwaters	Unident. Procel-larids	Gulls	Alcids	Other Seabirds	Unidentified Seabirds	Totals
1993	20	0	224	0	27	4	0	2	0	64	321
			(16-3,243)		(27-27)	(1-17)		(2-2)		(4-1,106)	(33-3,177)
1994	45	0	0	57	89	0	6	0	0	8	160
				(8-402)	(22-366)		(1-45)			(3-25)	(50-515)
1995	19	0	95	29	0	0	0	9	0	110	243
			(14-666)	(8-106)				(1-61)		(19-648)	(68-870)
1996	18	0	0	26	2	10	6	3	0	14	61
				(9-78)	(0-23)	(2-58)	(1-33)	(1-16)		(5-40)	(30-121)
1997	50	0	0	13	135	0	0	200	0	142	490
				(4-42)	(84-218)			(40-1,008)		(36-559)	(205-1,176)
1998	35	0	0	134	81	2	421	283	2	11	934
				(26-686)	(1-9,839)	(1-4)	(5-38,403)	(111-722)	(0-25)	(3-41)	(21-42,600)
1999	131	0	0	484	170	0	0	229	5	14	901
				(253-927)	(59-484)			(4-13,003)	(2-13)	(3-67)	(327-2,483)
2000	93	0	0	253	18	5	64	3	0	121	463
				(133-481)	(10-31)	(2-13)	(9-476)	(1-10)		(27-543)	(237-904)
2001	129	3	0	225	20	21	10	3	6	159	446
		(1-12)		(189-266)	(10-41)	(11-42)	(4-24)	(1-11)	(2-17)	(33-768)	(232-857)
2002	58	0	0	184	11	0	9	11	2	116	333
				(42-818)	(6-21)		(6-13)	(6-20)	(0-37)	(25-541)	(115-966)
2003	70	0	0	156	3	3	2	11	0	3	177
				(89-275)	(1-12)	(1-11)	(0-67)	(5-24)		(1-11)	(107-294)
2004	65	0	0	162	85	0	3	131	7	21	410
				(82-321)	(22-321)		(1-13)	(28-622)	(3-18)	(7-64)	(204-826)
2005	119	0	0	266	213	0	0	830	0	3	1,312
				(183-387)	(11-4,190)			(160-4,307)		(1-11)	(327-5,257)
2006	166	1	0	417	20	2	199	3	0	2,092	2,735
		(1-34)		(245-711)	(12-35)	(1-5)	(39-1,013)	(1-12)		(411-10,645)	(722-10,365)
Average Annual Estimates											
1993- 2006	n/a	0	23	172	59	3	51	101	2	206	616
		(0-2)	(2-220)	(132-223)	(10-698)	(2-6)	(1-2,910)	(13-782)	(1-3)	(57-743)	(163-2,329)
2002- 2006	n/a	0	0	236	55	1	42	138	2	447	921
		(0-7)		(166-337)	(29-106)	(0-2)	(9-201)	(36-523)	(1-6)	(95-2,109)	(383-2,219)

[1] Observers were instructed to use the largest sample size available when monitoring for seabirds. Alt 1 likely represents a closer approximation of estimated incidental takes.

Table 17. Estimated incidental take and actual number of seabirds observed taken in the Gulf of Alaska fishery management region groundfish trawl fleet, 1993 through 2006.

Year	Total Catch	Northern Fulmar	Shear-waters	Unid. Procel-larids	Alcids	Unid. Seabirds	Totals
1993	1	0	52	0	0	0	52
			(10-286)				(10-286)
1994	0	0	0	0	0	0	0
1995	2	0	26	0	0	2	28
			(5-139)			(2-2)	(6-138)
1996	1	0	0	3	0	0	3
				(2-3)			(2-3)
1997	1	73	0	0	0	0	73
		(15-366)					(15-366)
1998	1	98	0	0	0	0	98
		(20-497)					(20-497)
1999	2	0	0	0	11	0	11
					(0-696)		(0-696)
2000	1	116	0	0	0	0	116
		(22-625)					(22-625)
2001	1	48	0	0	0	0	48
		(9-254)					(9-254)
2002	3	239	0	0	0	0	239
		(79-724)					(79-724)
2003	2	186	0	0	0	0	186
		(54-645)					(54-645)
2004	1	0	0	0	7	0	7
					(3-17)		(3-17)
2005	1	0	0	0	3	0	3
					(1-6)		(1-6)
2006	0	0	0	0	0	0	0
Average Annual Estimates							
1993- 2006	n/a	54	6	0	2	0	63
		(28-106)	(1-22)		(0-50)		(29-139)
2002-2006	n/a	85	0	0	2	0	87
		(36-202)			(1-3))		(37-203)

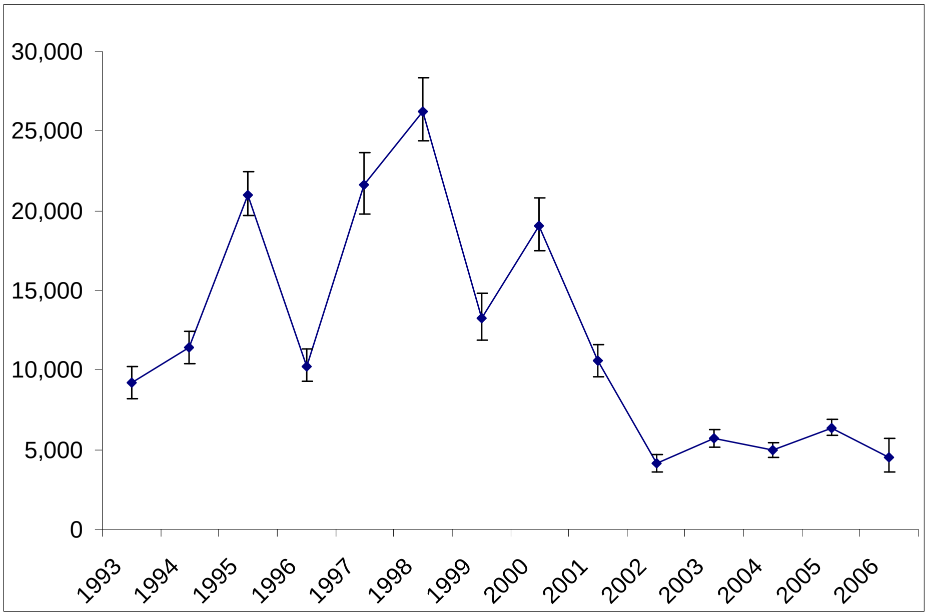

Figure 73. Total incidental take of seabirds in Alaskan combined demersal longline groundfish fisheries, 1993 through 2006. Mitigation measures (streamer lines) were voluntarily implemented by a large part of the fleet in 2002, followed by regulations in 2004 that required all groundfish longline vessels that observers monitor to deploy mitigation measures.

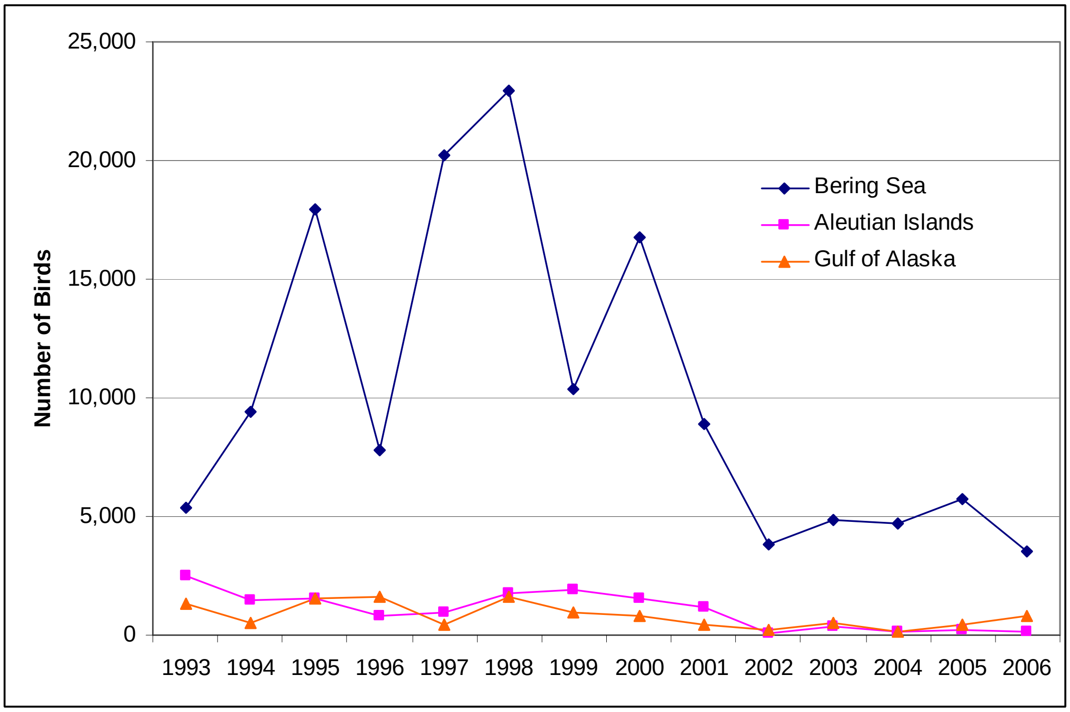

Figure 74. Seabird bycatch in the Alaskan demersal groundfish longline fisheries by Fishery Management Region, 1993 through 2006.

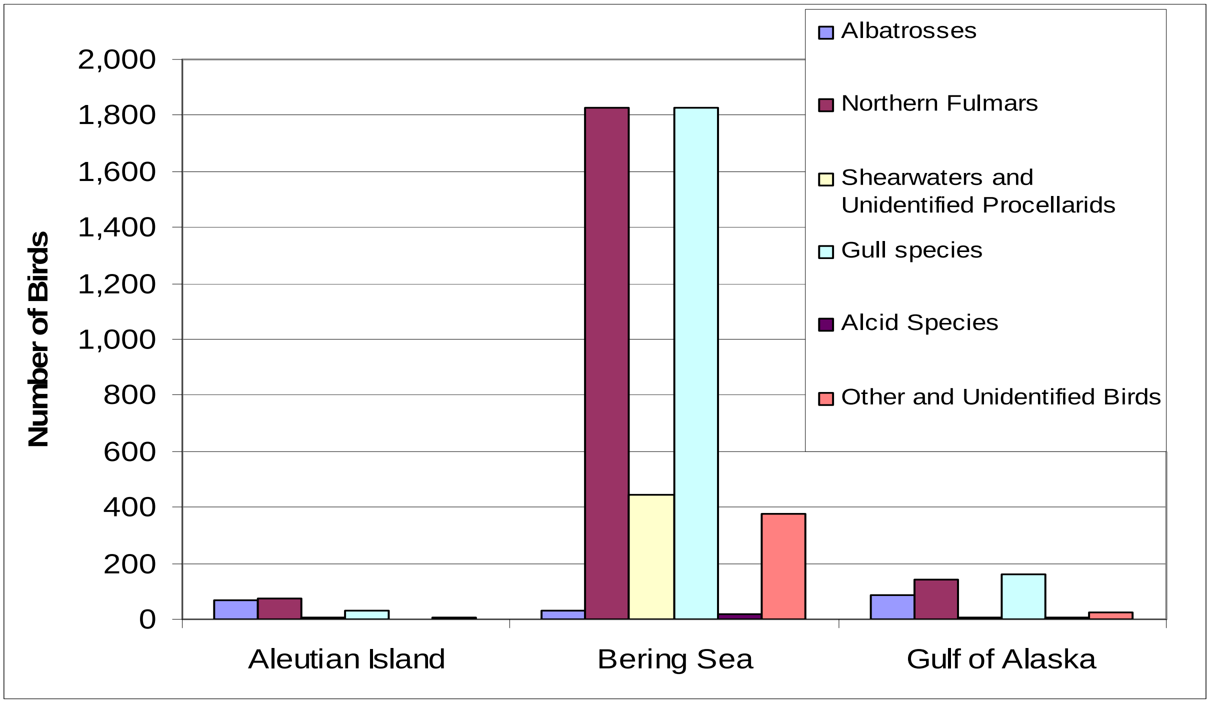

Figure 75. Species composition of the Alaskan groundfish longline fishery, by region, based on estimates of the 2002-2006 annual average mortality.

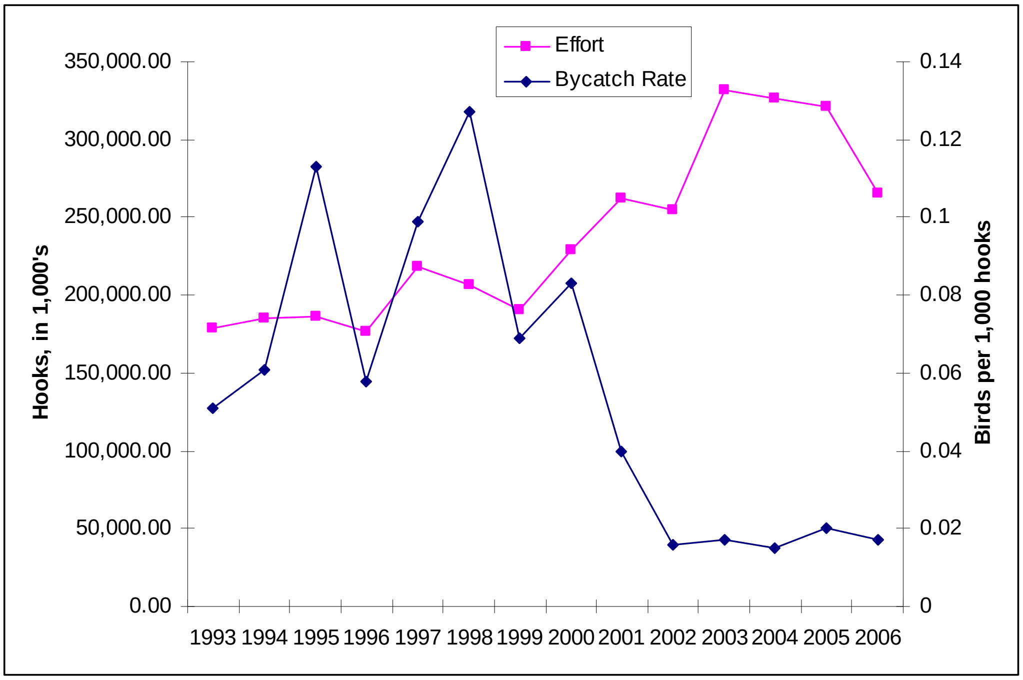

Figure 76. Total estimated hooks (in thousands) and bycatch rate of birds (birds per 1,000 hooks) in the Alaskan demersal groundfish longline fishery, 1993 through 2006.

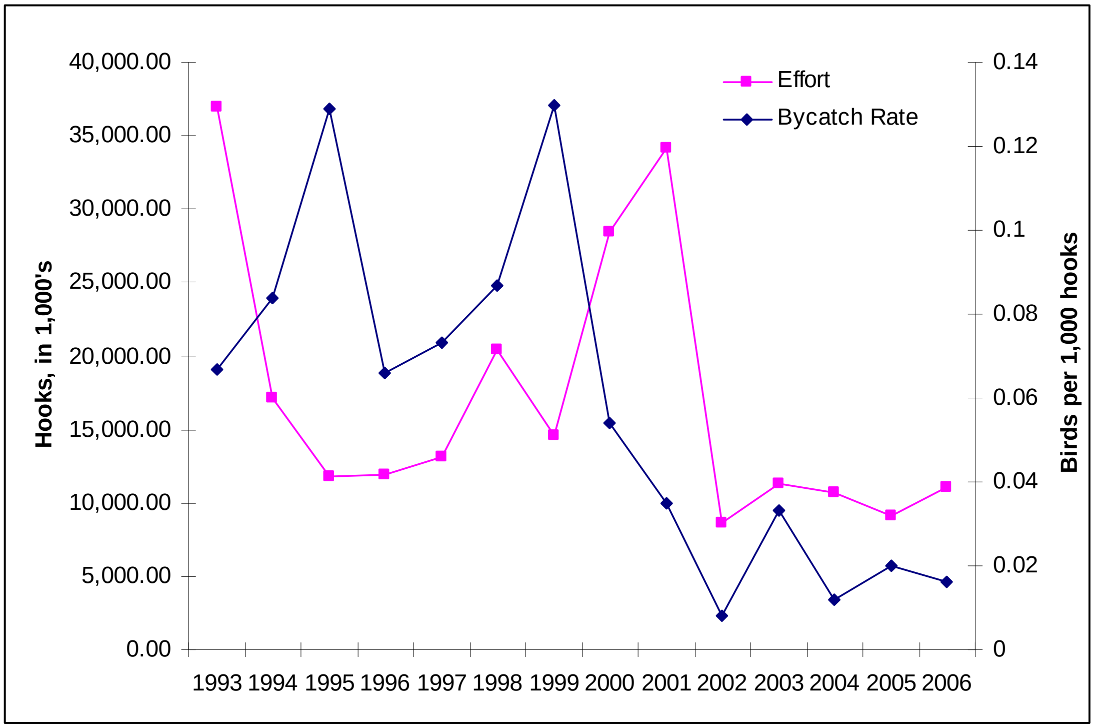

Figure 77. Total estimated hooks (in thousands) and bycatch rate of birds (birds per 1,000 hooks) in the Aleutian Islands demersal groundfish longline fishery.

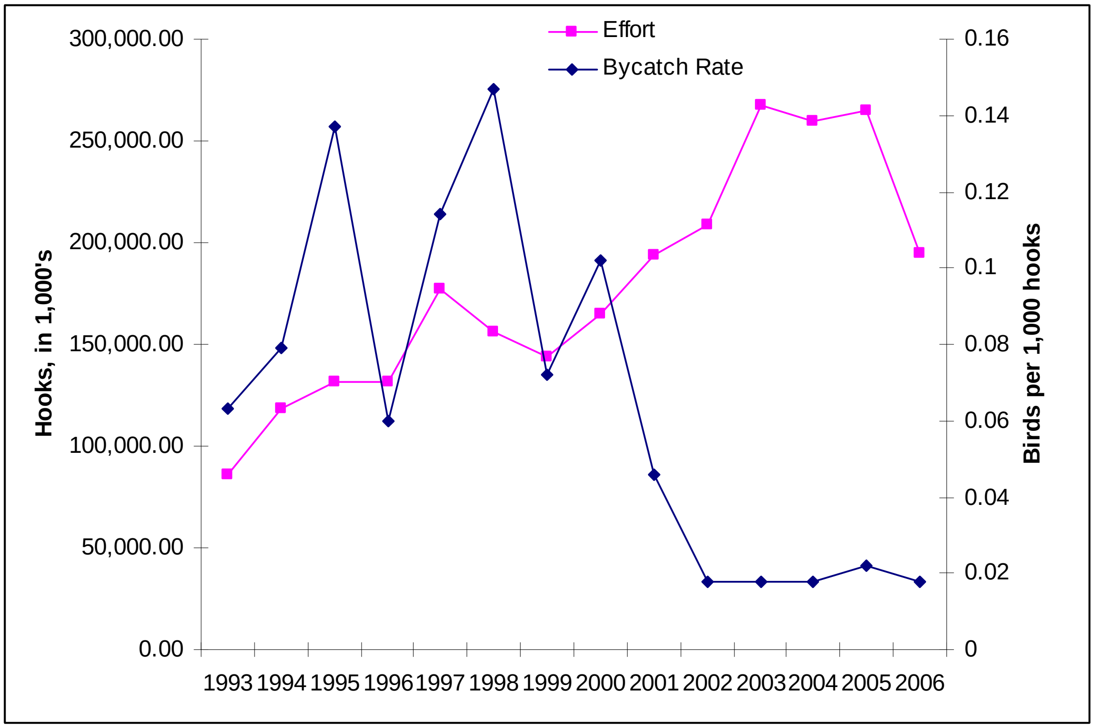

Figure 78. Total estimated hooks (in thousands) and bycatch rate of birds (birds per 1,000 hooks) in the Bering Sea demersal groundfish longline fishery.

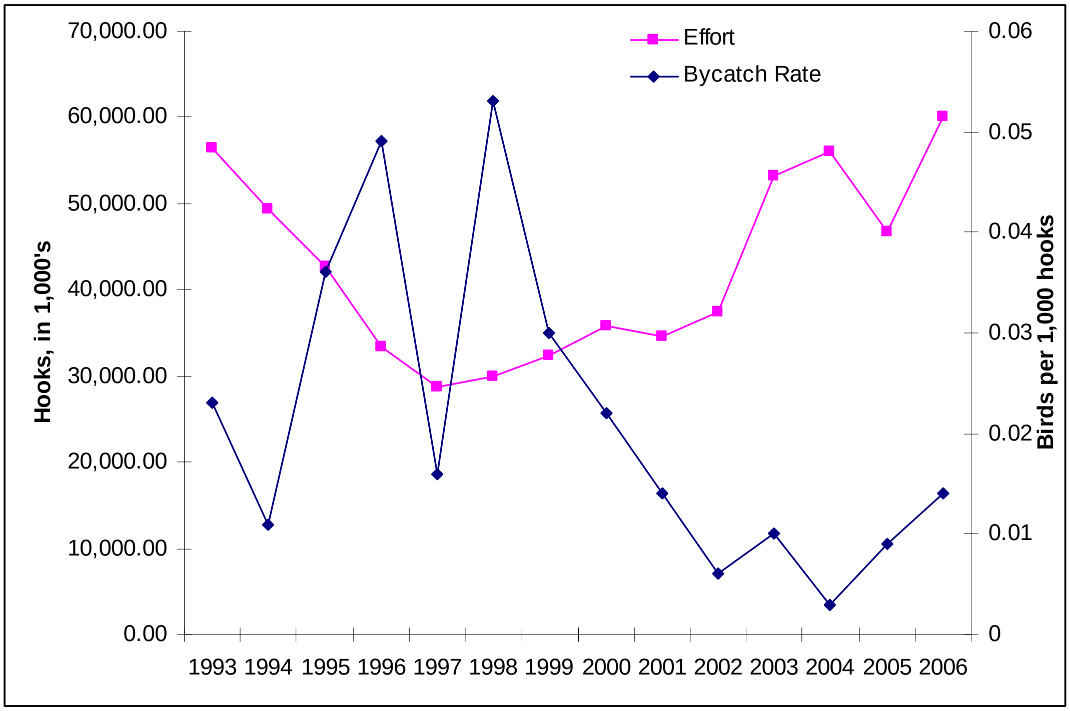

Figure 79. Total estimated hooks (in thousands) and bycatch rate of birds (birds per 1,000 hooks) in the Gulf of Alaska demersal groundfish longline fishery.

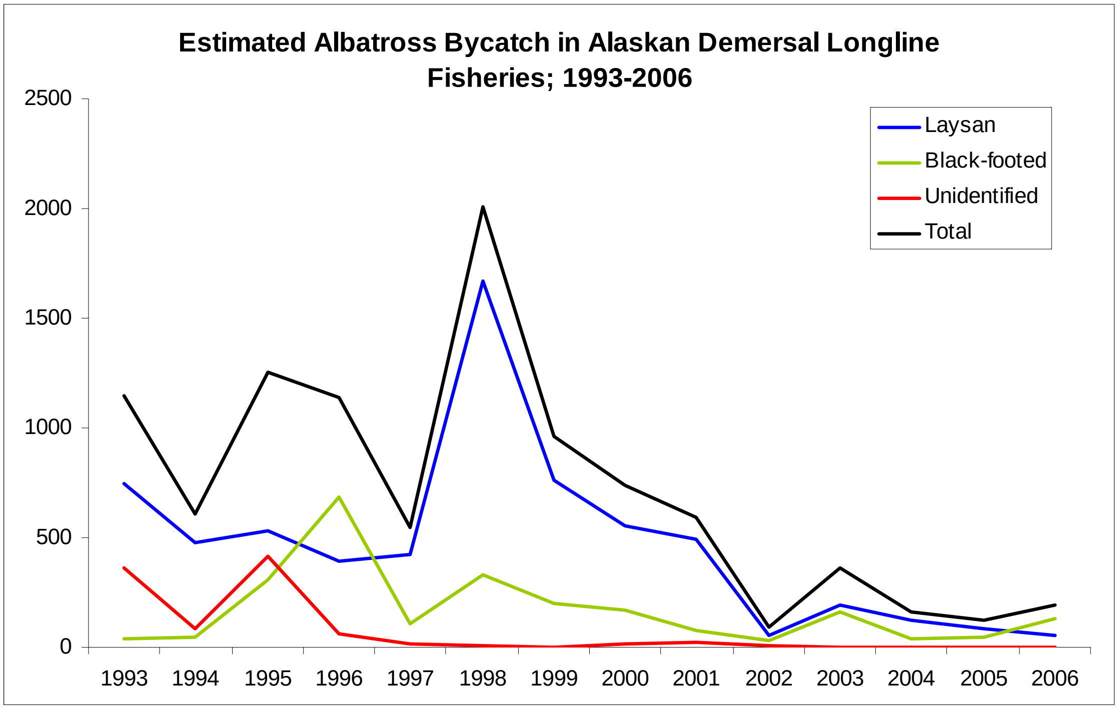

Figure 80. Estimated Albatross bycatch in the Alaskan demersal longline fisheries, 1993-2006.

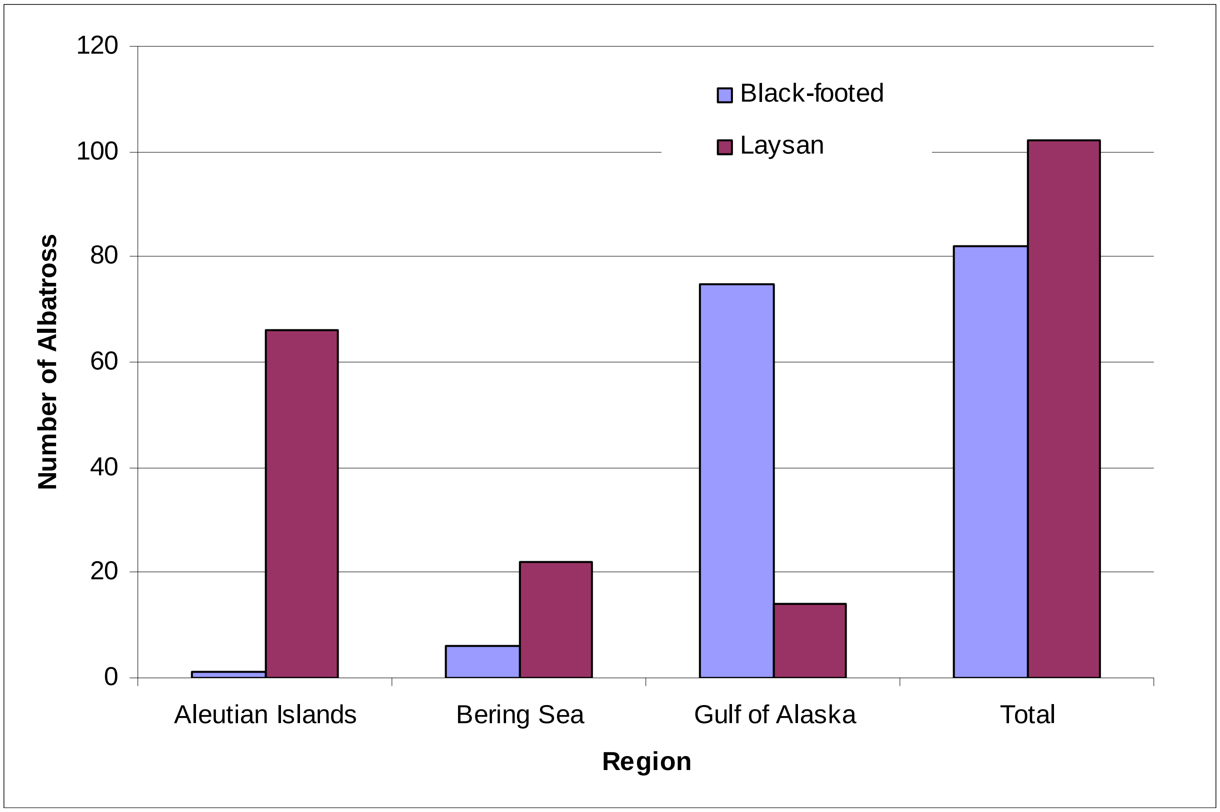

Figure 81. Estimated annual average albatross bycatch, 2002 through 2006, by Alaska demersal longline fisheries.

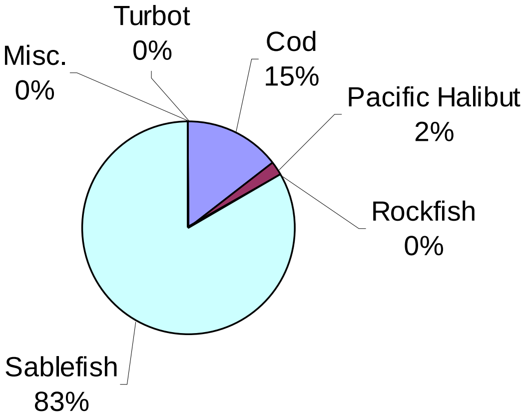

Figure 82. Proportion of Black-footed albatross taken by longline fisheries based on target species.

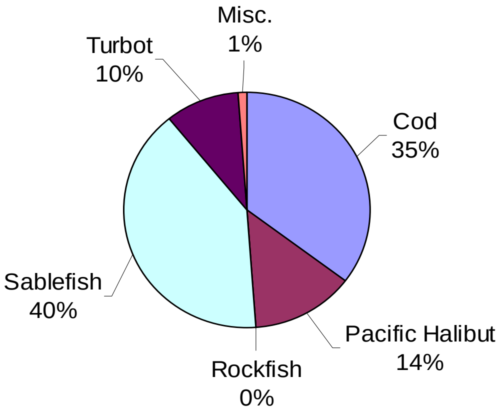

Figure 83. Proportion of Laysan Albatross taken by longline fisheries based on target species.

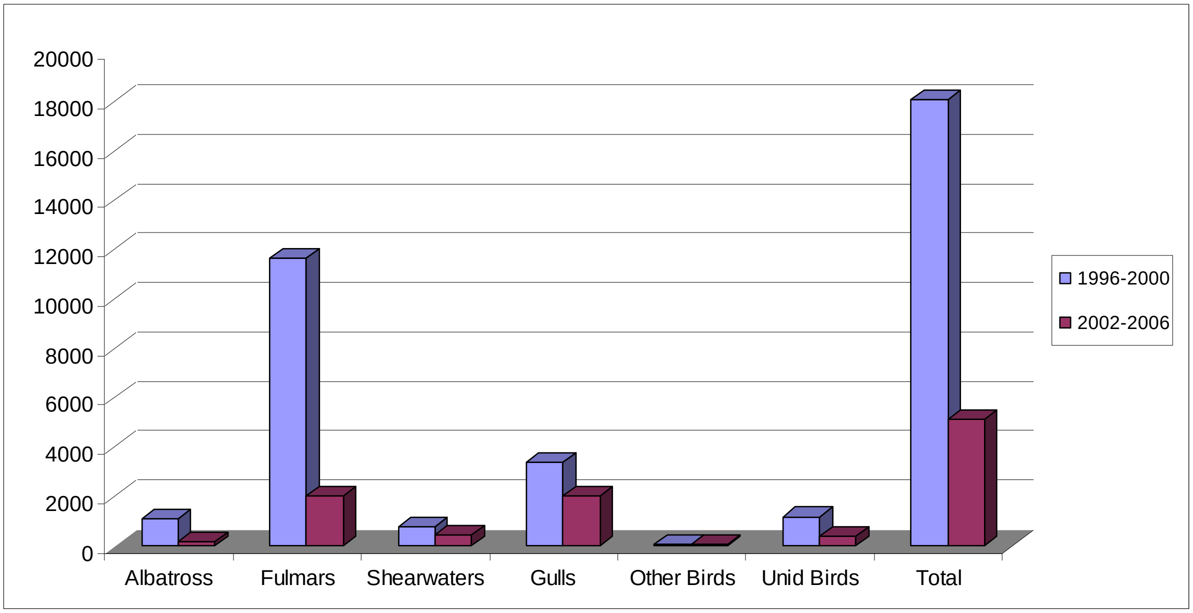

Figure 84. Seabird bycatch in the Alaskan demersal longline fishery during the 5 years periods before and after streamer line usage was widespread. Streamer lines were not required by regulation until early 2004, but the majority of freezer longliners had voluntarily started using them in 2002-2003.

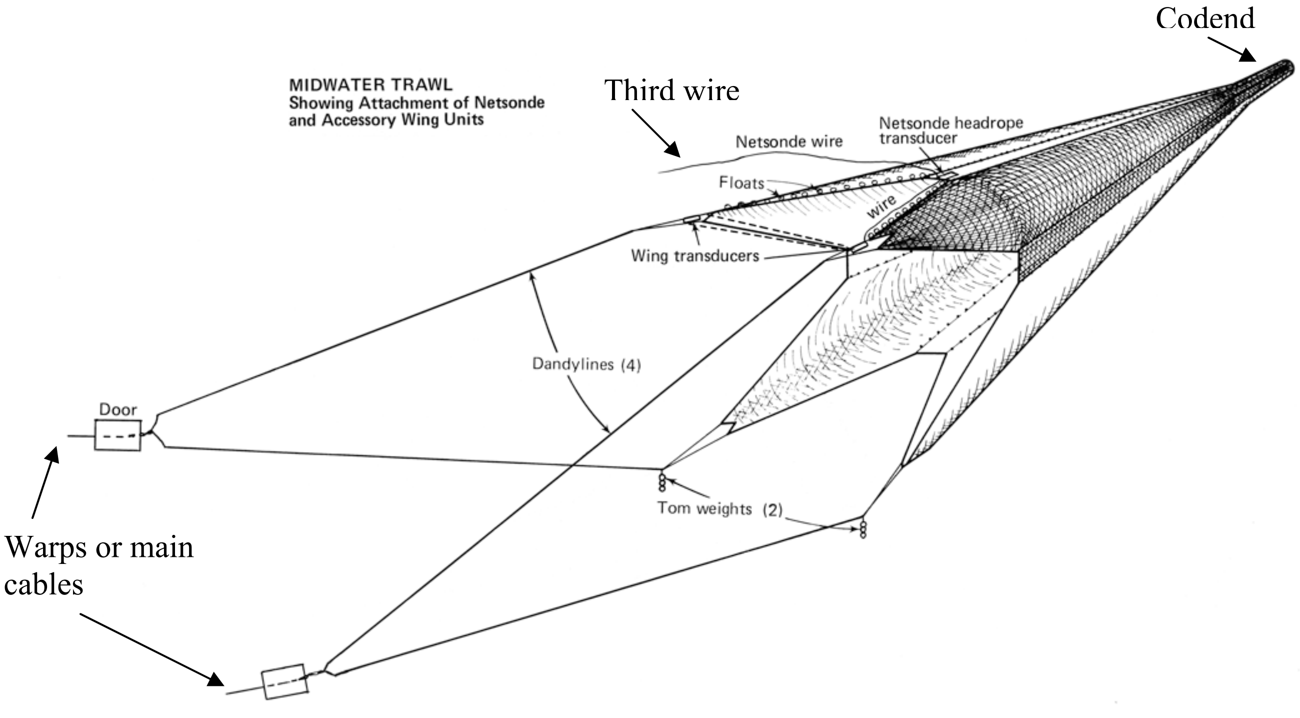

Figure 85. A midwater trawl.

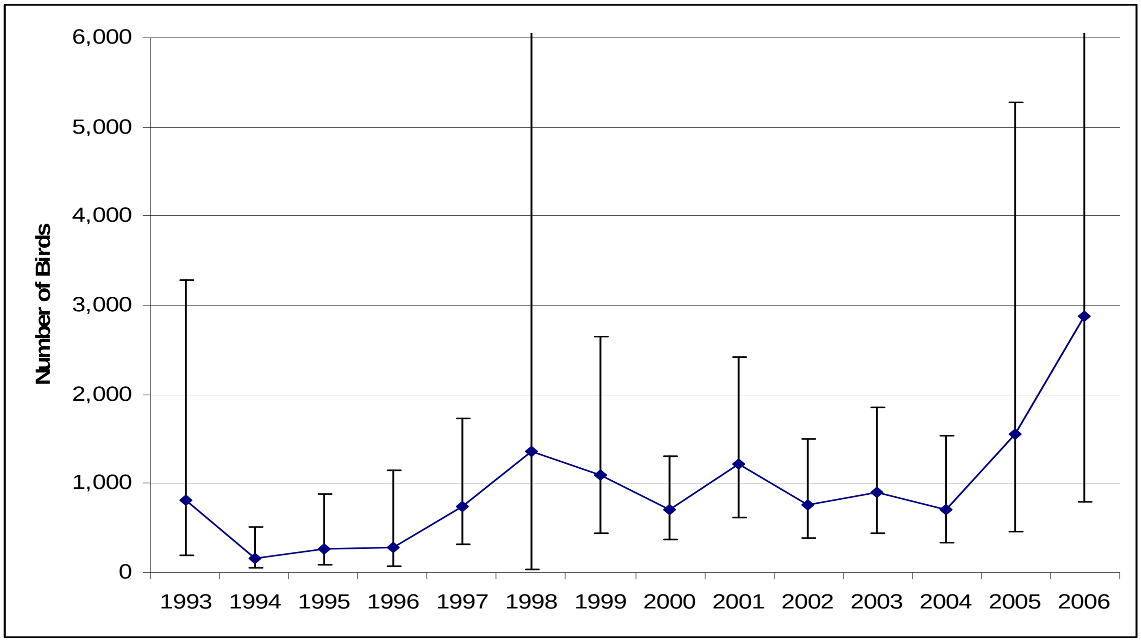

Figure 86. Seabird bycatch estimates for the Alaskan groundfish trawl fleet using the best available estimates, 1993-2006. Upper confidence intervals for 1998 and 2006 exceed 10,000 birds.

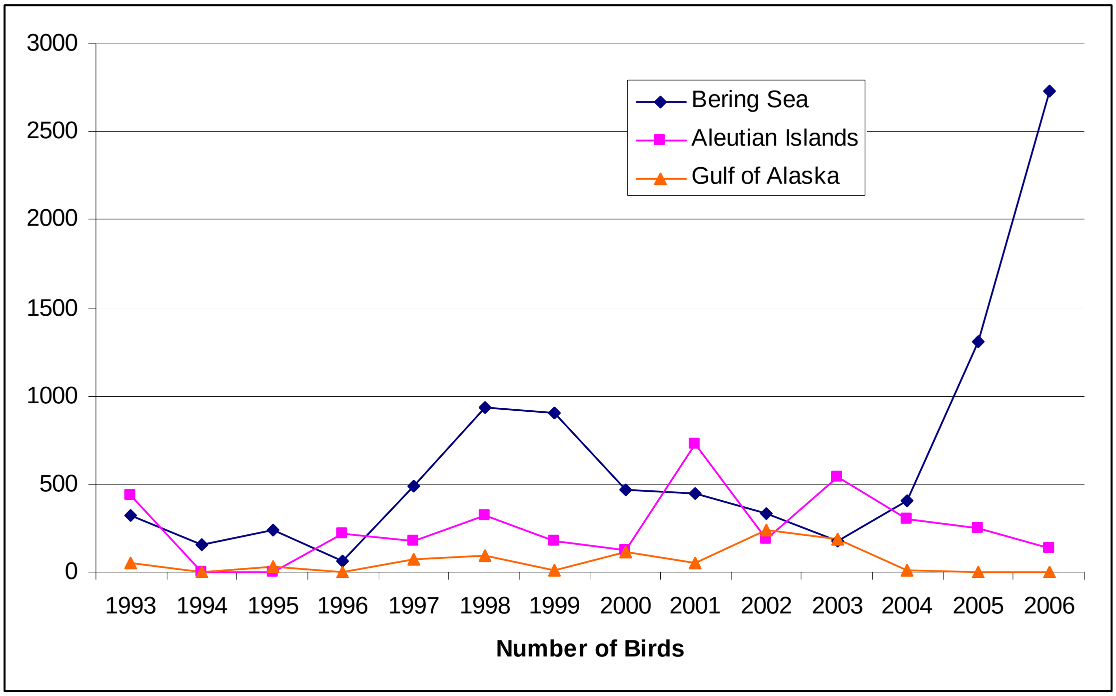

Figure 87. Seabird bycatch in groundfish trawl fisheries by area, using the best available estimates, 1993-2006.

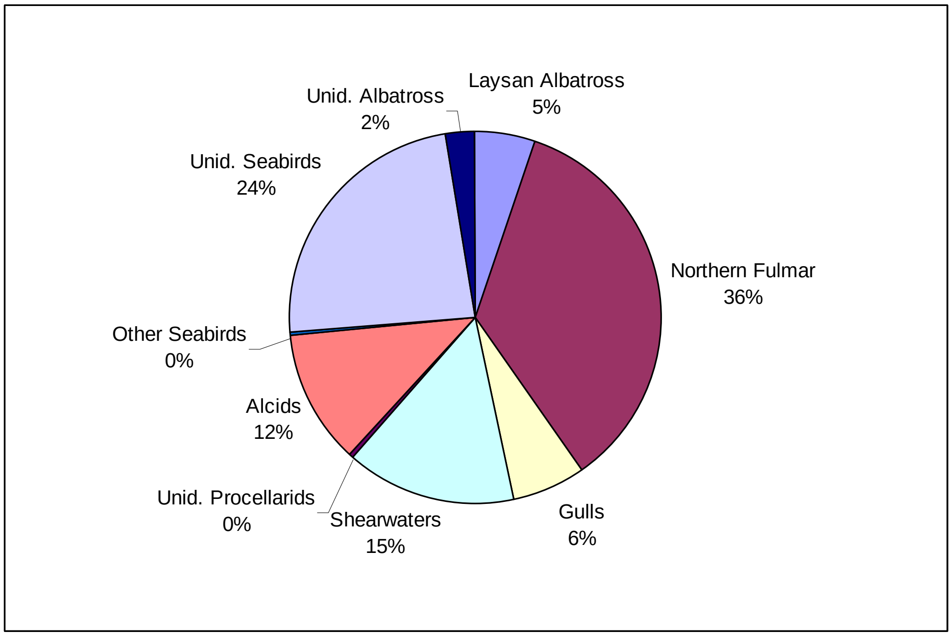

Figure 88. Species composition of seabird bycatch in the combined Alaskan groundfish trawl fisheries using the average annual estimates, 1993 through 2006.

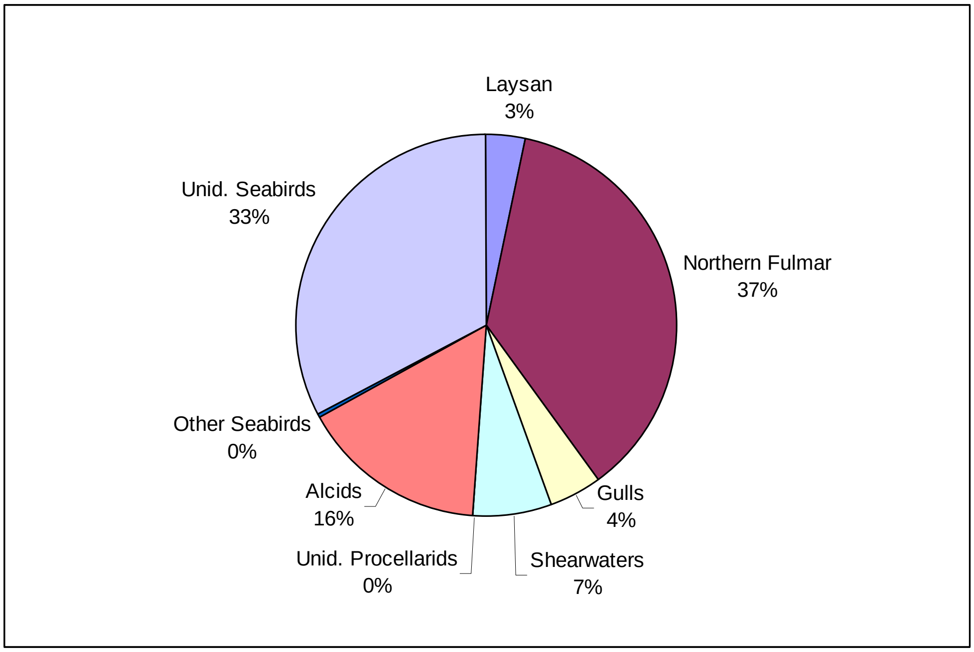

Figure 89. Species compostion of seabird bycatch in the combined Alaskan groundfish trawl fisheries using the average annual estimates 2002 through 2006.

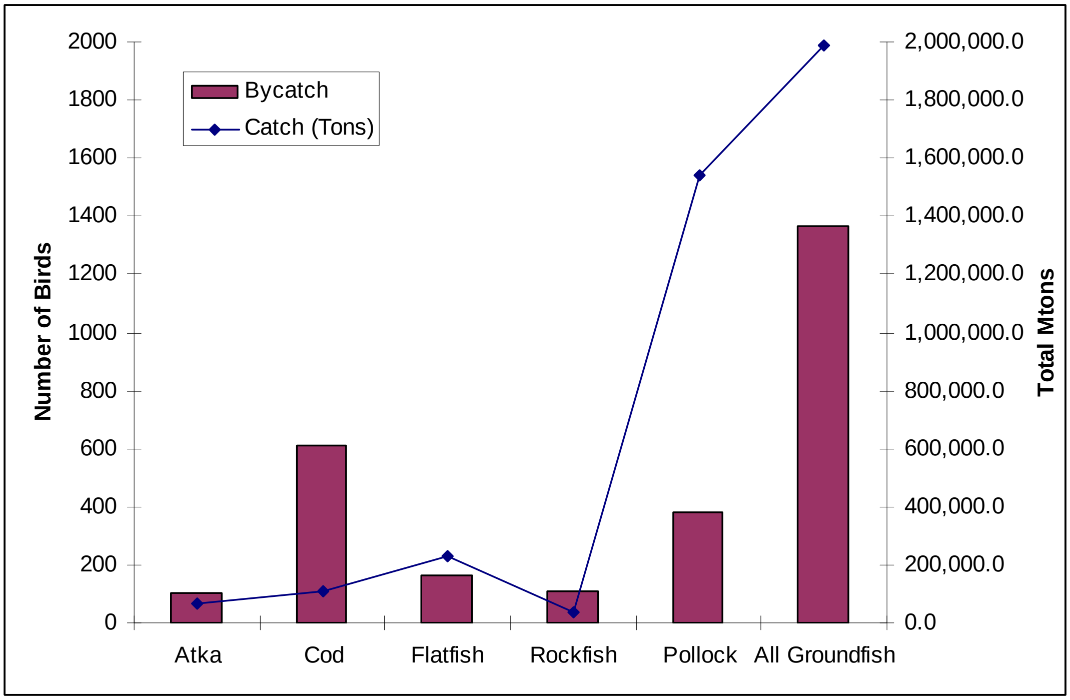

Figure 90. The annual average seabird bycatch levels for the period 2002-2006 and total fishery catch in metric tons by Alaskan groundfish trawl fisheries.

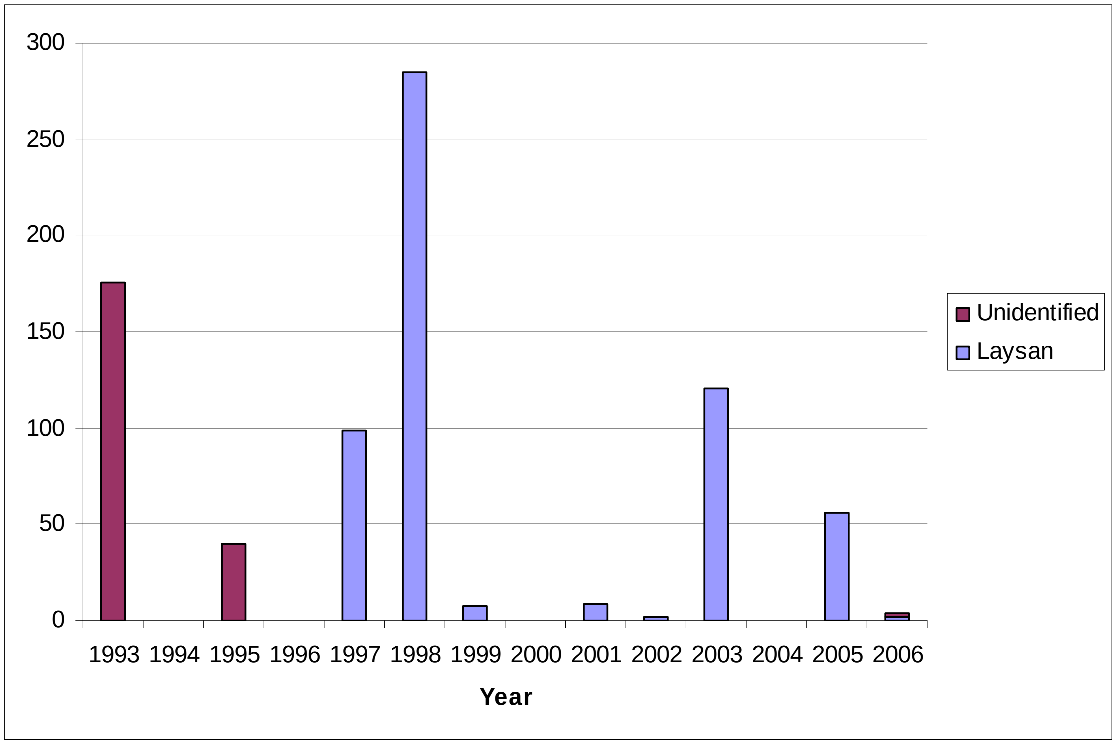

Figure 91. Albatross bycatch in the Alaskan groundfish trawl fishery.

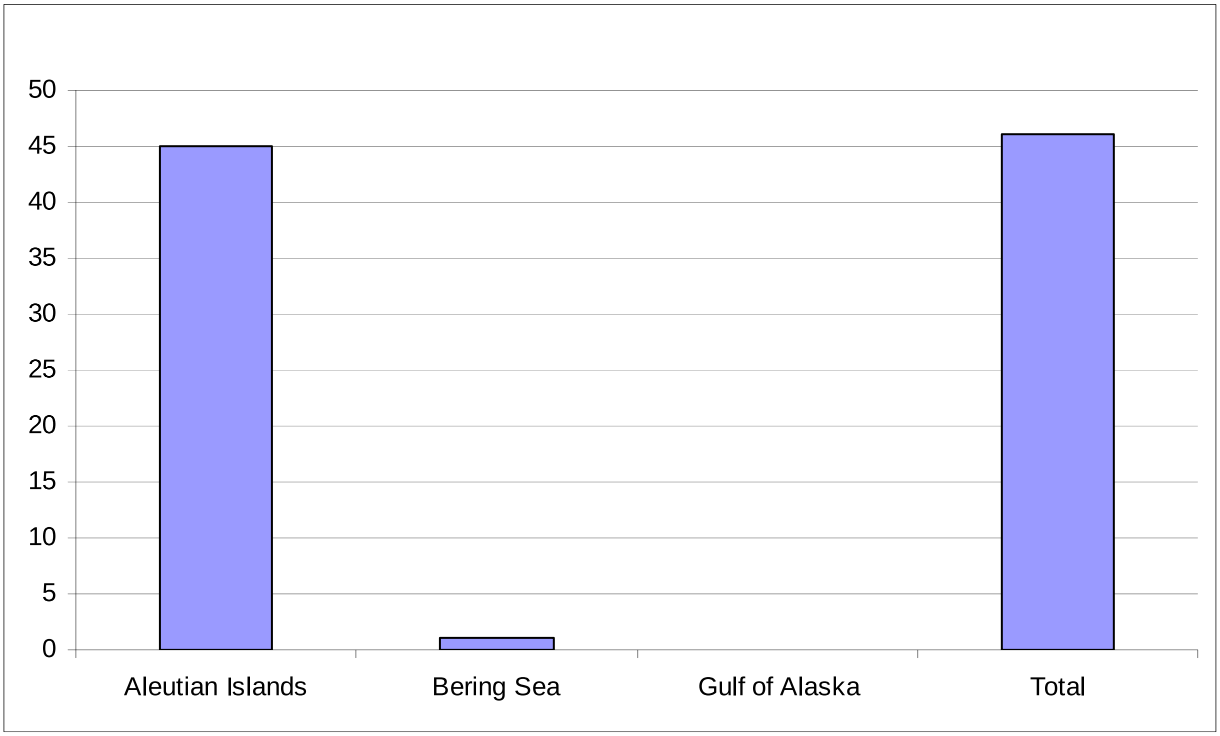

Figure 92. Five-year (2002-2006) average annual bycatch of Laysan albatross in the groundfish trawl fishery, by region. All albatross bycatch in the Aleutian Islands is from the cod fishery; Bering Sea albatross bycatch is in the pollock fishery.

Ecosystem or Community Indicators

Alaska Native Traditional Environmental Knowledge of Climate Regimes

Contributed by Heather Lazrus, Alaska Fisheries Science Center
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Last updated: November 2005

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

Contributed by Franz Mueter, University of Alaska Fairbanks
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Last updated: October 2008

Description of indices: Indices of overall 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) are provided. 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. A Ricker, Beverton-Holt, and hockey-stick model (with or without first-order autocorrelated errors) were fit to each stock's recruitment and female spawning biomass data and the model with the best fit (based on the small-sample Akaike Information Criterion) was used to compute the SR index. 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). Time series were lined up by year-class for the period 1970-2003, resulting in matrices of logR or SR indices by year with missing values at the beginning and end of many series. A combined standardized index of recruitment (CSI_R) and survival (CSI_{SR}) was computed by simply averaging indices within a given year across stocks. Prior to standardizing the series, missing values at the ends of several series were estimated by imputation using additive regression, bootstrapping, and predictive mean matching as implemented in the "hmisc" package for S-Plus and R (Frank Harrell, Univ. of Virginia, available at StatLib at http://lib.stat.cmu.edu/). Multiple imputations were obtained through bootstrap resampling to estimate the variability in the averaged index that results from filling in missing values. Because missing values are not missing at random, it is assumed that correlations between time series did not change over the period 1970-2004. 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 (Figure 93). 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.

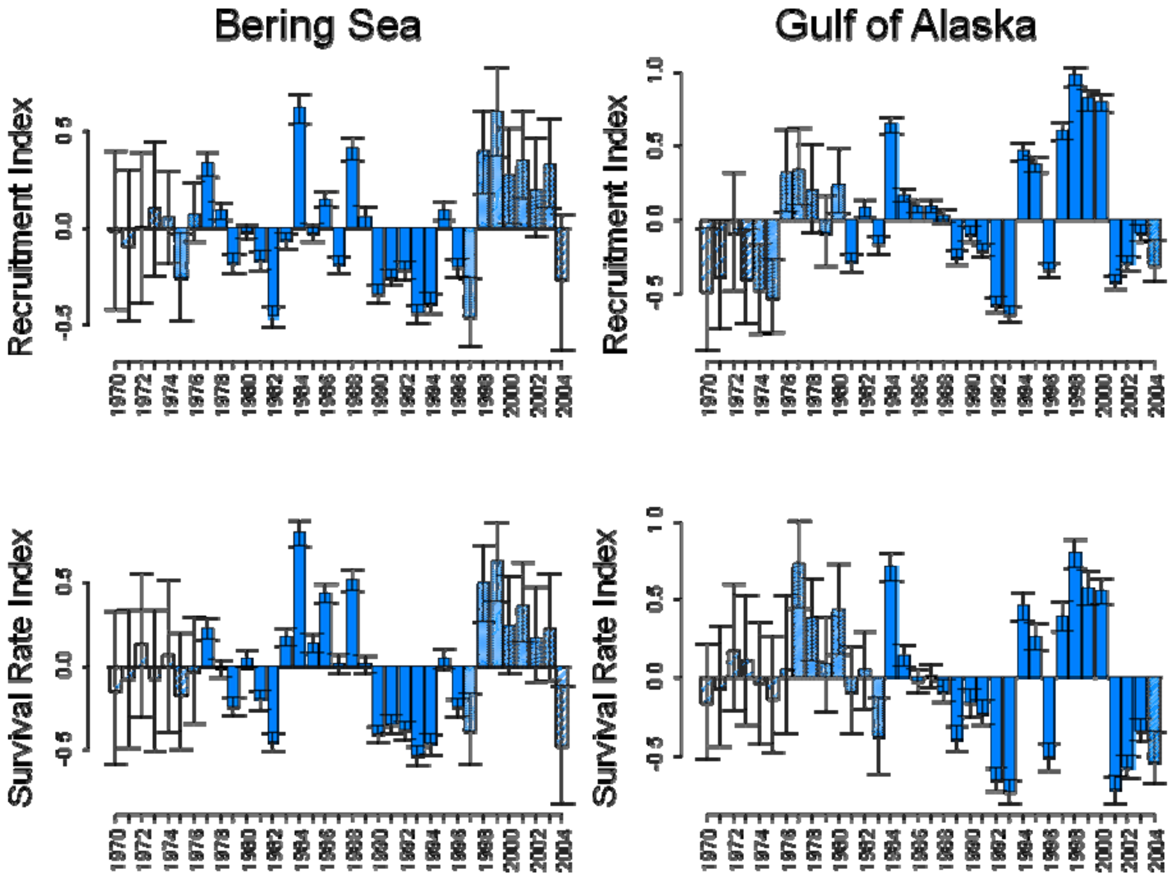

Figure 93. Combined Standardized Indices of recruitment (top) and survival rate (stock-recruit residuals, bottom) by year class across demersal stocks in the Bering Sea / Aleutian Island region (11 stocks) and in the Gulf of Alaska (11 stocks). Solid blue bars represent years with data for all stocks or stock groups. Lighter shading corresponds to years with more missing stocks. Series were truncated in 1970 and only years with data for at least 6 stocks were included. Bootstrap confidence intervals (95%) depict uncertainty resulting from filling in missing values, but assume that survival and recruitment are estimated without error.

Average local species richness and diversity of the groundfish community

Contributed by Franz Mueter, Sigma Plus, Fairbanks, Alaska
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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

Total catch-per-unit-effort of all fish and invertebrate taxa in bottom trawl surveys

Contributed by Franz Mueter, Sigma Plus, Fairbanks, Alaska
Contact: fmueter@alaska.net
Last updated: August 2007

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

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
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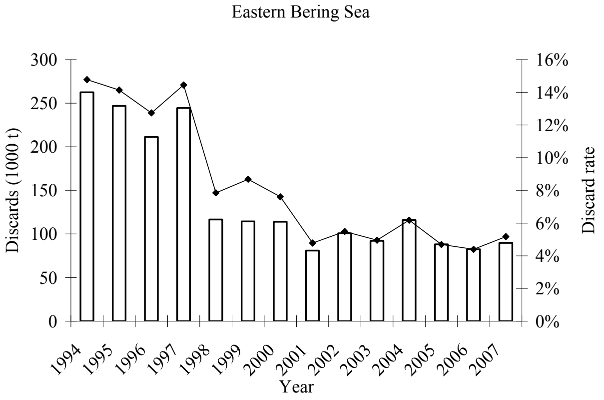
Last updated: October 2007

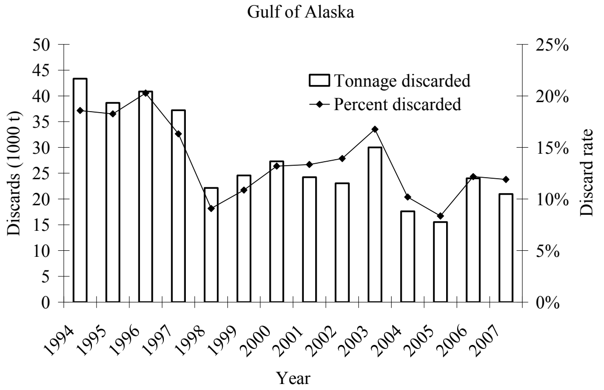
See the 2007 report in the "Assessment Archives" at: http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Time trends in groundfish discards

Contributed by Terry Hiatt, Alaska Fisheries Science Center
Contact: Terry.Hiatt@noaa.gov
Last updated: October 2008

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 94). 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 two 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 four 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. Estimates of discards for 1994-2002 come from NMFS Alaska Region's blend data; estimates for 2003-07 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.


Eastern Bering Sea


Gulf of Alaska

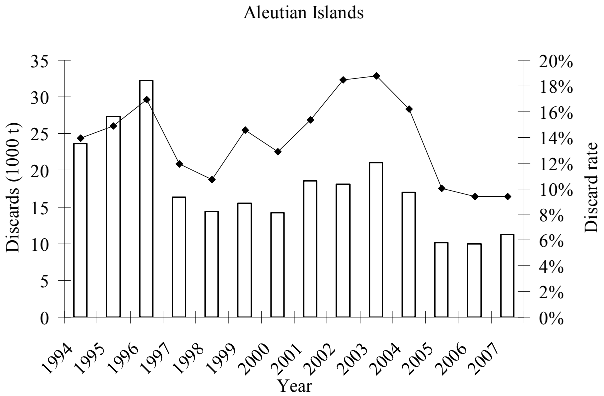


Figure 94. Total biomass and percent of total catch biomass of managed groundfish discarded in the GOA, EBS and AI areas, 1994-2007. (Includes only catch counted against federal TACS).

Time Trends in Non-Target Species Catch

Contributed by Sarah Gaichas and Jennifer Boldt, Alaska Fisheries Science Center

Last updated: November 2007

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

Ecosystem Goal: Maintain and Restore Fish Habitats

Areas closed to bottom trawling in the EBS/ AI and GOA

Contributed by John Olson, NMFS

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Last updated: October 2008

Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut) (Table 18 and Figure 95). 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 18. 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, to specific fishery restrictions in 2000 and 2001. For 2001, over 90,000 nm2 of the EEZ off Alaska was closed to trawling year-round. Additionally 40,000 nm2 were closed on a seasonal basis. State waters (0-3nmi) are also closed to bottom trawling in most areas.

Five new closures implemented in 2008 as part of protection for Essential Fish Habitat encompass a large portion of the northern Bering Sea. They are the Northern Bering Sea Research Area, the Bering Sea Habitat Conservation Zone (HCZ), the St. Matthews HCA, the St. Lawrence HCA, and the Nunivak/Kuskokwim Closure Area (Figure 95). The largest of these closures is the Northern Bering Sea Research Area, and these five closures add 134,500 nm2 to the area closed to bottom trawling year round. By implementing these closures, almost 50% of Alaska's EEZ is closed to bottom trawling. For additional background on fishery closures in the Alaska EEZ see Witherell and Woodby (2005).

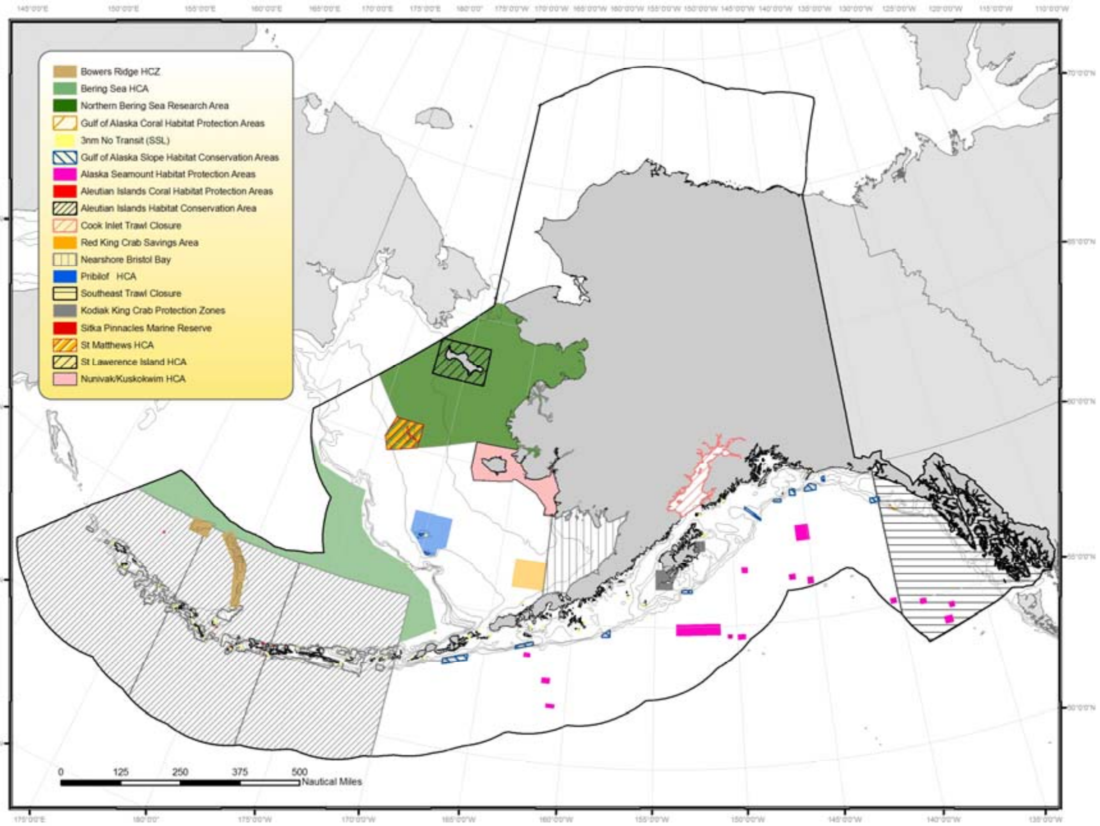

Figure 95. Year-round groundfish closures in Alaska's Exclusive Economic Zone.

Table 18. 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. Lawerence HCA	No bottom trawl all year	7,000 nm^2
	Nunivak/Kuskokwim Closure Area	No bottom trawl all year	9,700 nm^2

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: October 2008

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 96. 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 97-102 show the spatial patterns and intensity of longline effort, based on observed data as well as anomalies for 2007 based on the 1990-2007 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.

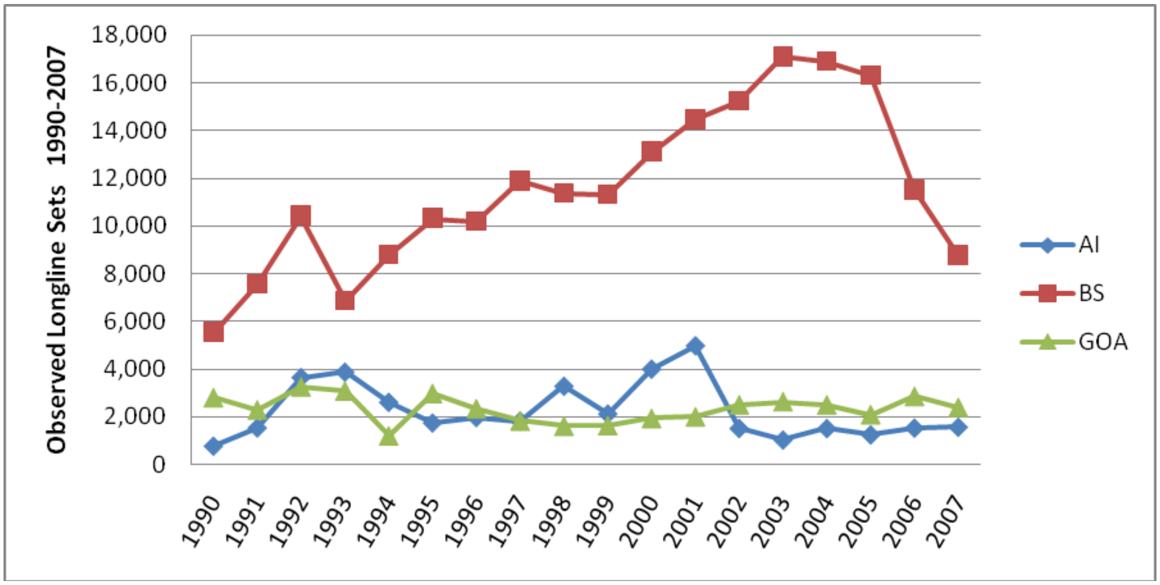

Figure 96. Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of longline sets, 1990-2007.

Bering Sea

For the period 1990-2007, there were a total of 207,636 observed longline sets in the Bering Sea fisheries. Spatial patterns of fishing effort were summarized on a 10km2 grid (Figure 97). 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 2007, fishing effort was anomalously low along the outer shelf break of area 521 and there were spots of anomalously high effort in the southeast Bering Sea (Figure 98).

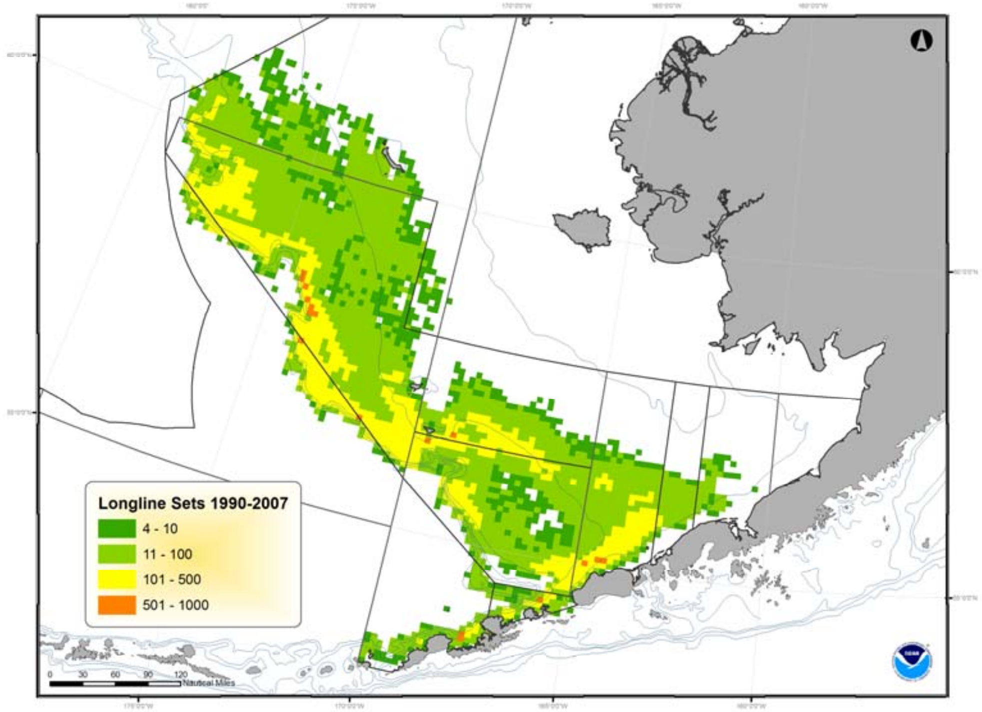

Figure 97. Longline effort (sets) in the Bering Sea 1990-2007.

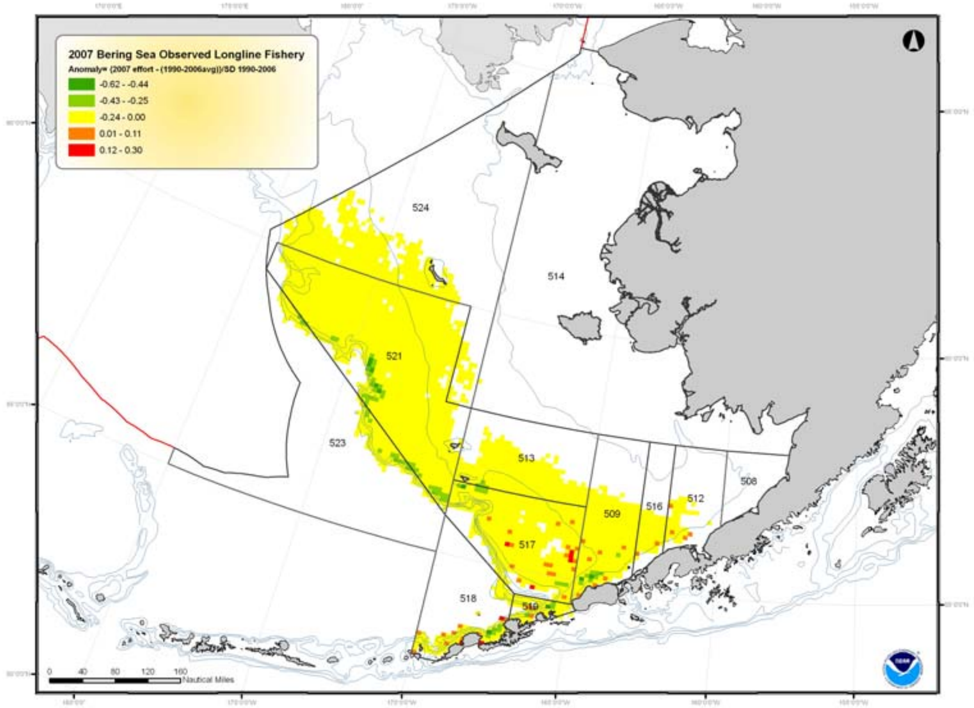

Figure 98. Observed hook and line fishing effort in 2007 relative to the 1990-2007 average in the Bering Sea. Anomalies calculated as (estimated effort for 2007 – average effort from 1990-2007)/stdev(effort from 1990-2007).

Aleutian Islands

For the period 1990-2007 there were 40,384 observed hook and line sets in the Aleutian Islands. The spatial pattern of this effort was dispersed over a wide area. Patterns of high fishing effort were dispersed along the shelf edge (Figure 99). 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 2007, fishing effort was anomalously low in areas 541 and 542 and was based primarily within the Pacific cod and sablefish fisheries. Some decreases occurred in the entire AI region with specific increases some local areas (Figure 100).

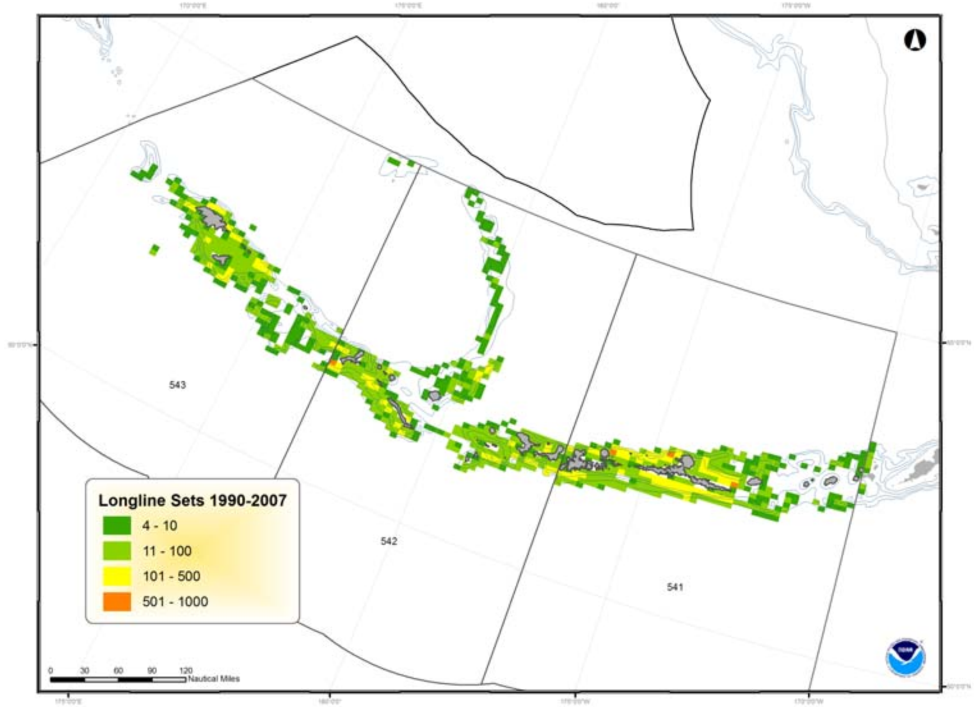

Figure 99. Longline effort (sets) in the Aleutian Islands, 1990-2007.

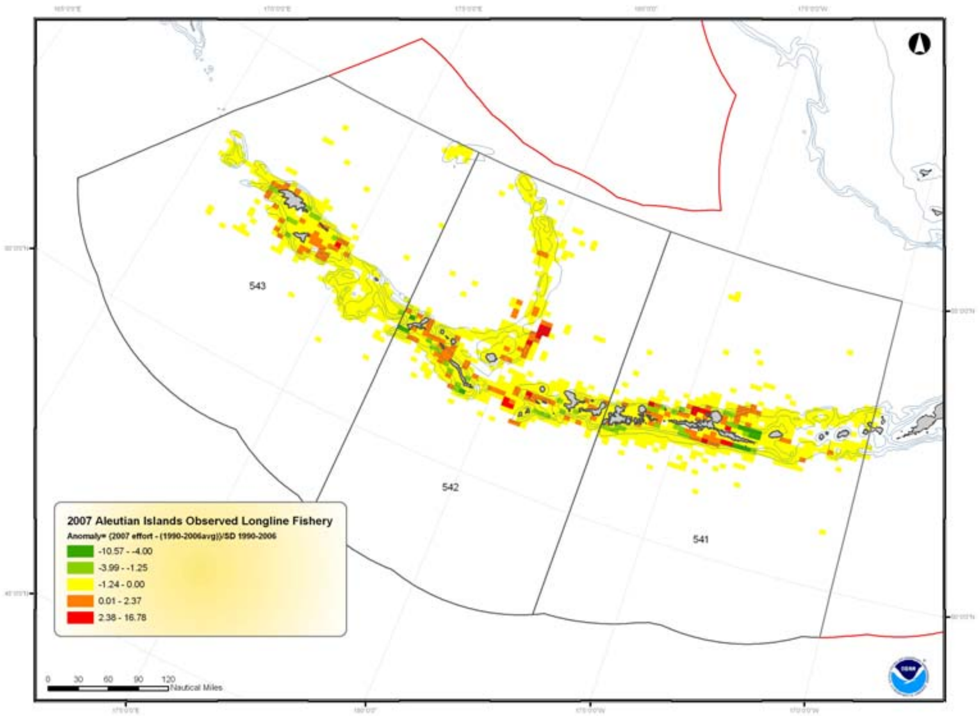

Figure 100. Observed hook and line fishing effort in 2007 relative to the 1990-2007 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2007 - average effort from 1990-2007)/stdev(effort from 1990-2007).

Gulf of Alaska

For the period 1990-2007 there were 41,937 observed hook and line sets in the Gulf of Alaska. Patterns of high fishing effort were dispersed along the shelf (Figure 101). 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 2007, fishing effort anomalies were not readily attributable to seasonal allocations (Figure 102).

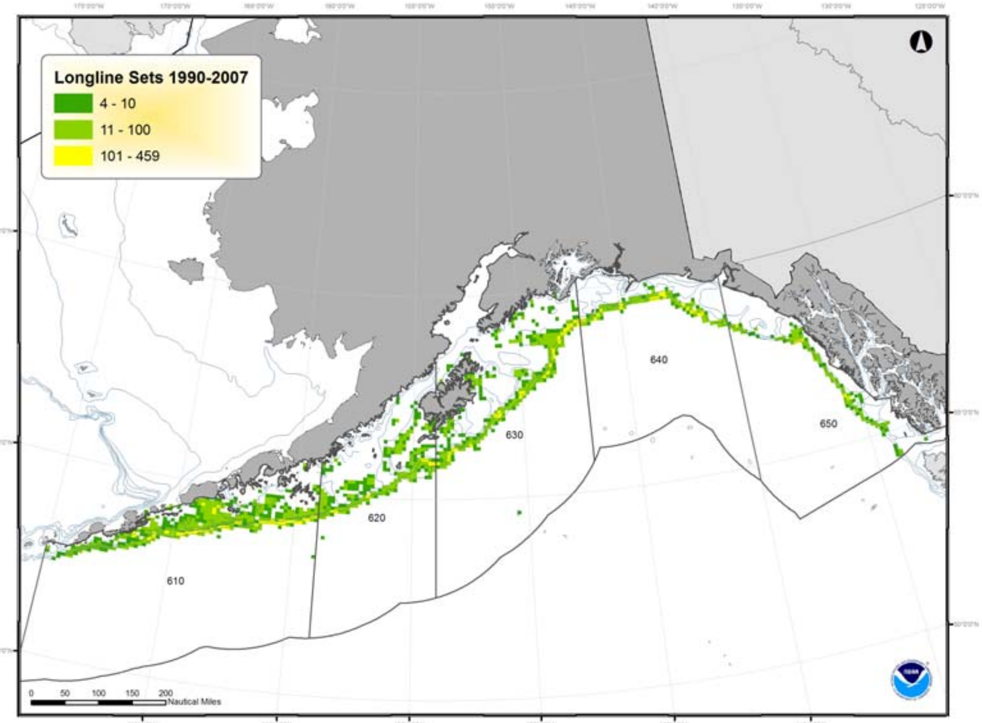

Figure 101. Longline effort (sets) in the Gulf of Alaska, 1990-2007.

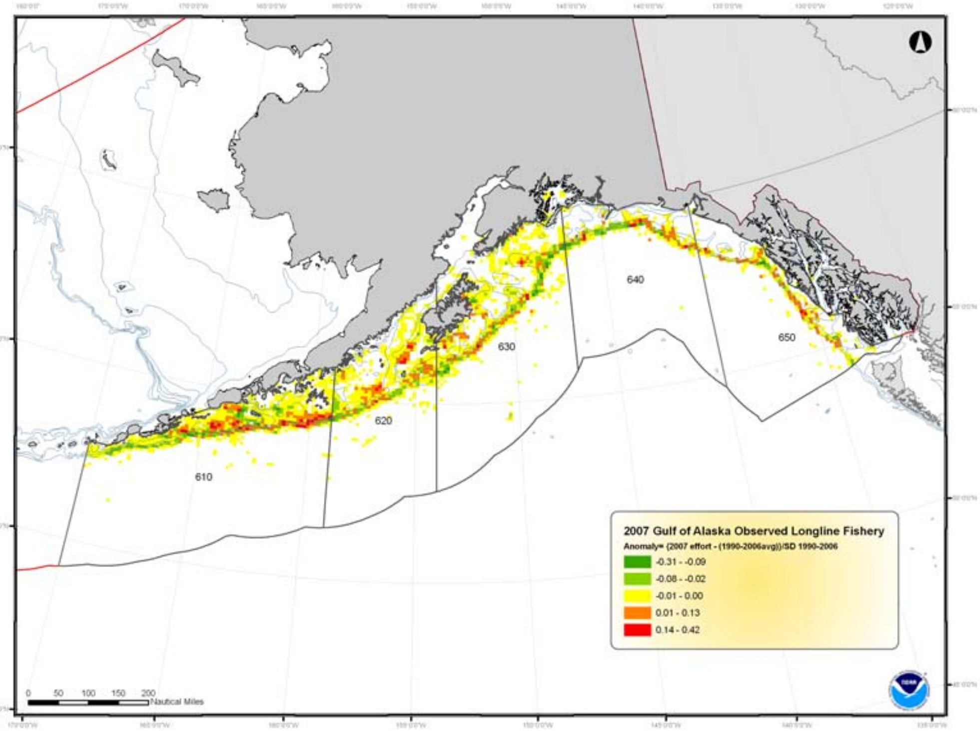

Figure 102. Observed hook and line fishing effort in 2007 relative to the 1990-2007 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2007 - average effort from 1990-2007)/stdev(effort from 1990-2007).

Groundfish bottom trawl fishing effort in the Gulf of Alaska, Bering Sea and Aleutian Islands

Contributed by John Olson, NMFS
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Last updated: October 2008

The amount of effort (as measured by the number of days fished) 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 103). Effort in the Bering Sea remained relatively stable between 1993 and 2006, with a decline in 2007 (Figure 103). Some of the reduction of effort can be attributed to changes in the structure of the groundfish fisheries due to rationalization. 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., 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).

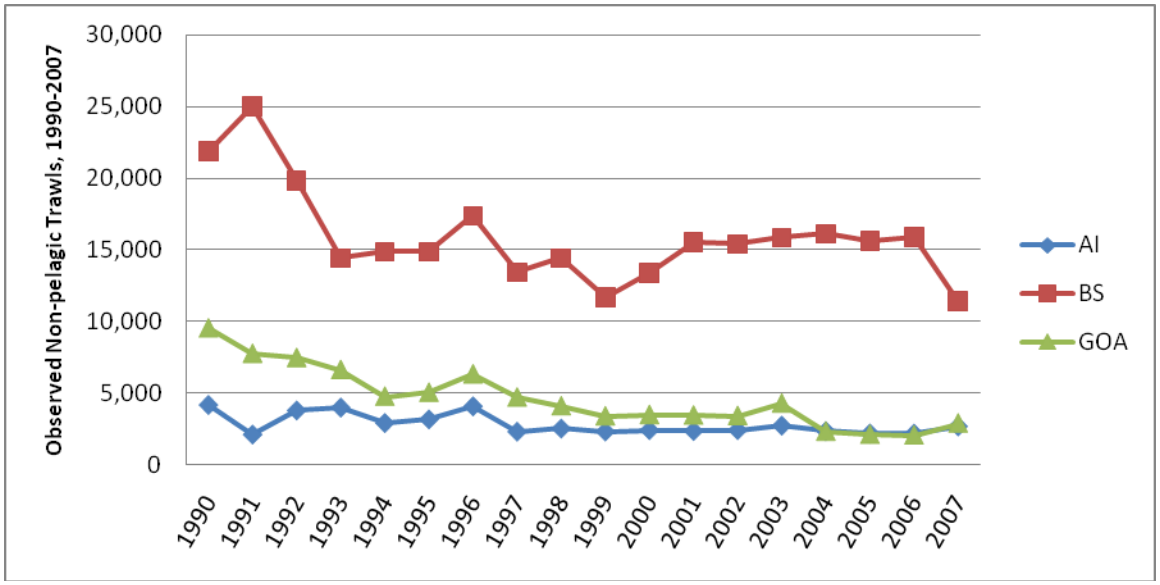

Figure 103. Gulf of Alaska, Bering Sea, and Aleutian Islands non-pelagic trawl effort (number of observed tows), 1990-2007.

Bering Sea

For the period 1990-2007, there were a total of 287,051 observed bottom trawl tows in the Bering Sea fisheries. During 2007, trawl effort consisted of 11,406 tows which was low relative to the past 17 years. Spatial patterns of fishing effort were summarized on a 10 km2 grid (Figure 104). 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. The primary catch in these areas was Pacific cod and yellowfin sole. In 2007, fishing effort was lower than average in the southern portion of areas 509 and 517 and also in areas east, west, and south of St. George Island (Figure 105).

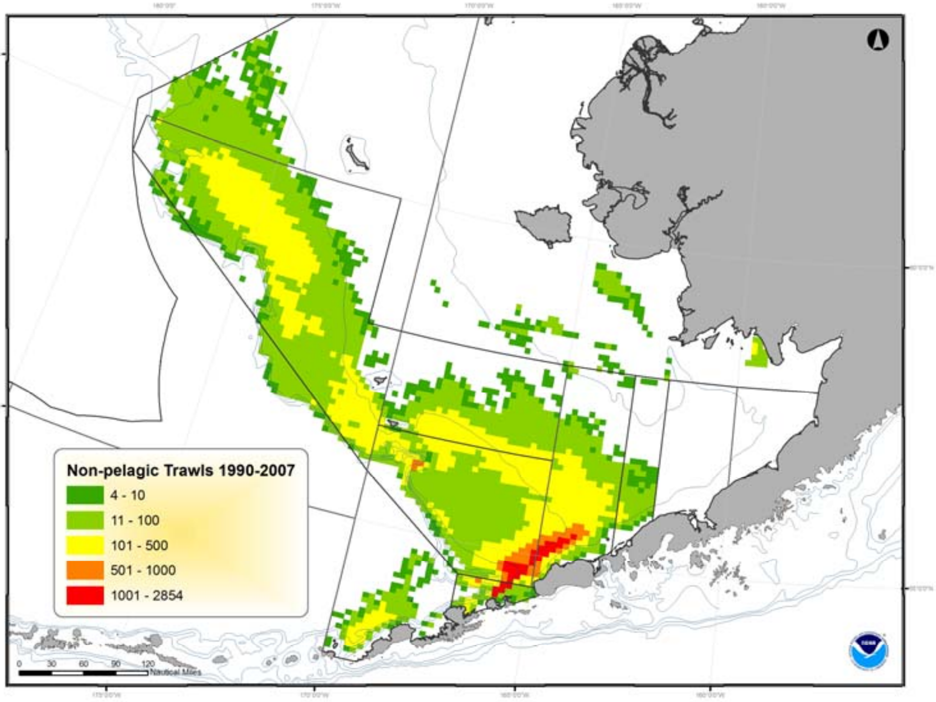

Figure 104. Spatial location and density of non-pelagic trawling in the Bering Sea, 1990-2007.

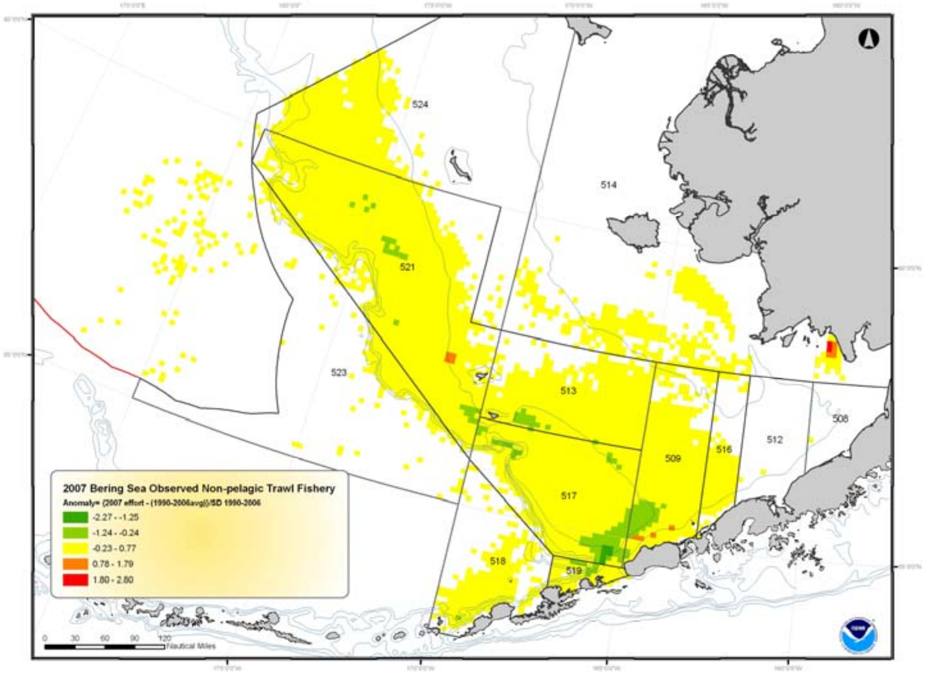

Figure 105. Observed non-pelagic trawl fishing effort in 2007 relative to the 1990-2007 average in the Bering Sea. Anomalies calculated as (estimated effort for 2007 - average effort from 1990-2007)/stdev(effort from 1990-2007).

Aleutian Islands

For the period 1990-2007 there were 50,500 observed bottom trawl tows in the Aleutian Islands. During 2007, the amount of trawl effort was 2,669 tows, which was about average for the 17-year period. Patterns of high fishing effort were dispersed along the shelf edge (Figure 106). The primary catches in these areas were pollock, Pacific cod, and Atka mackerel. Catch of Pacific ocean perch by bottom trawls was also high in earlier years. In 2007, fishing effort was anomalously high in some areas and was comprised of Atka mackerel, Pacific cod and rockfish fisheries (Figure 107). Some areas now have lower patterns of fishing which could be due to new management. In 2007, the Aleutian Islands Habitat Conservation Area (AIHCA) closed approximately 279,114 nm2 to bottom trawl fishing in the three AI management areas.

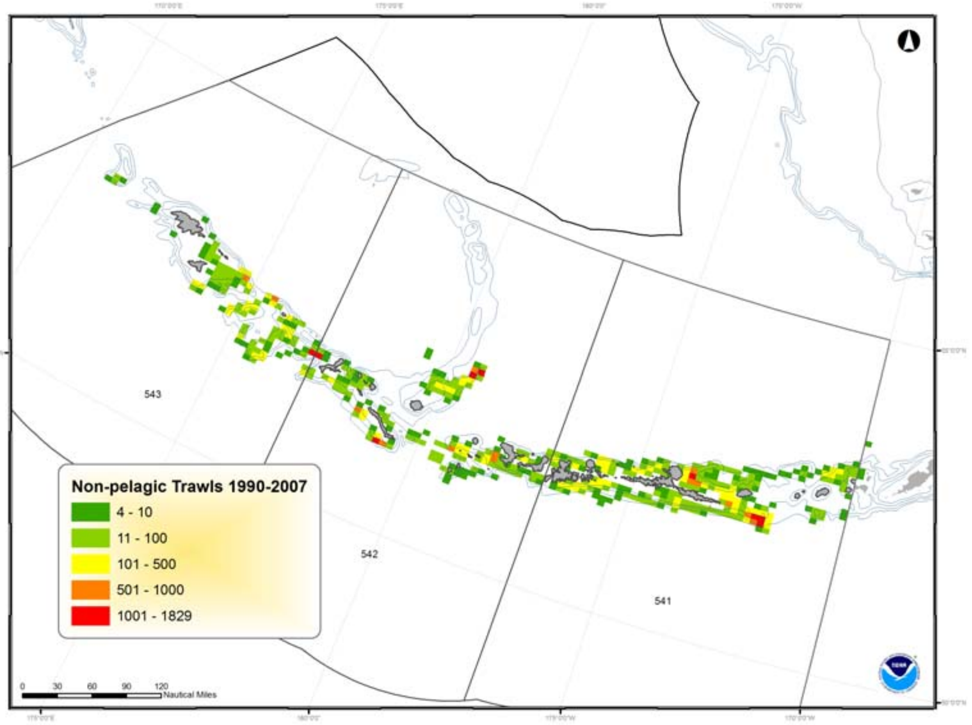

Figure 106. Spatial location and density of bottom trawl effort in the Aleutian Islands, 1990-2007.

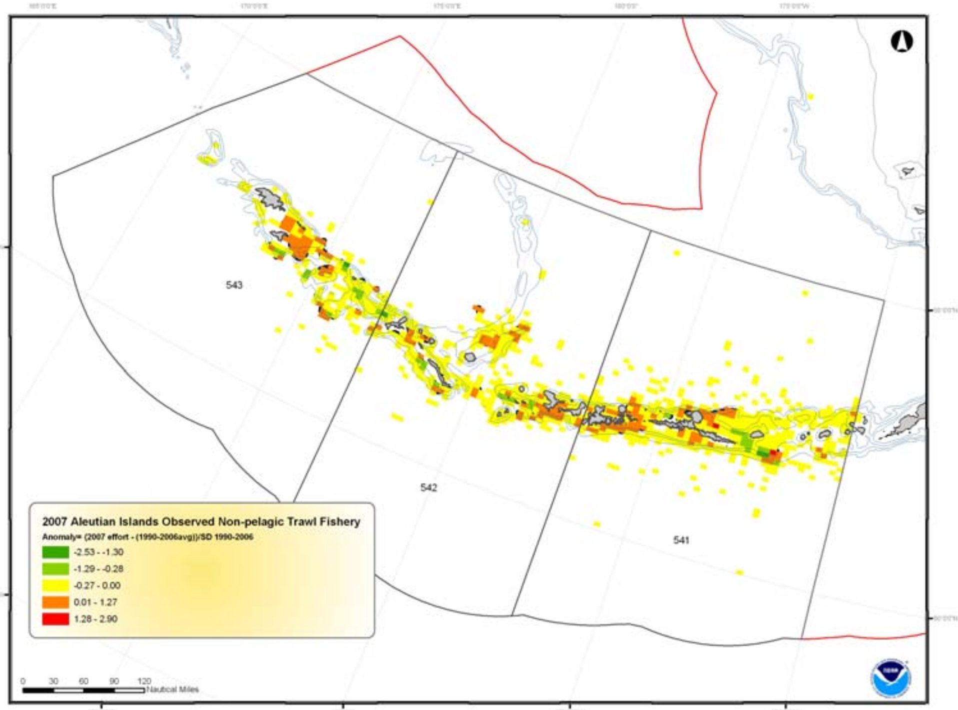

Figure 107. Observed non-pelagic trawl fishing effort in 2007 relative to the 1990-2007 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2007 - average effort from 1990-2007)/stdev(effort from 1990-2007).

Gulf of Alaska

For the period 1990-2007 there were 83,775 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 2007, the amount of trawl effort was 2,888 tows, which was below average for the 17-year period but similar to the last three years. 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 108). 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 2007, fishing effort was mixed, with areas of higher and lower than average effort scattered throughout the Central and Western Gulf (Figure 109).

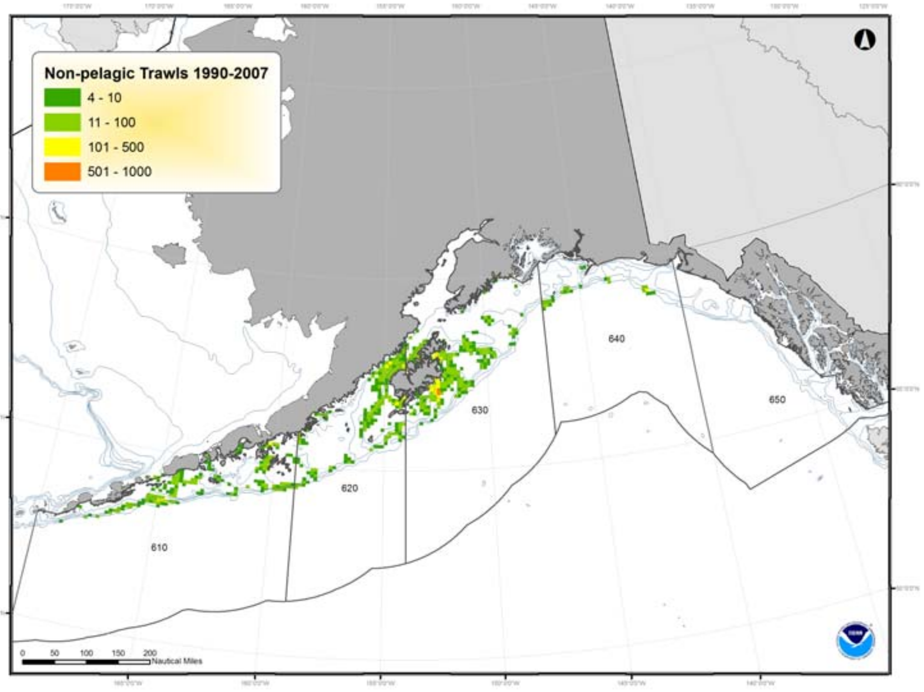

Figure 108. Spatial location and density of bottom trawl effort in the Gulf of Alaska, 1990-2007.

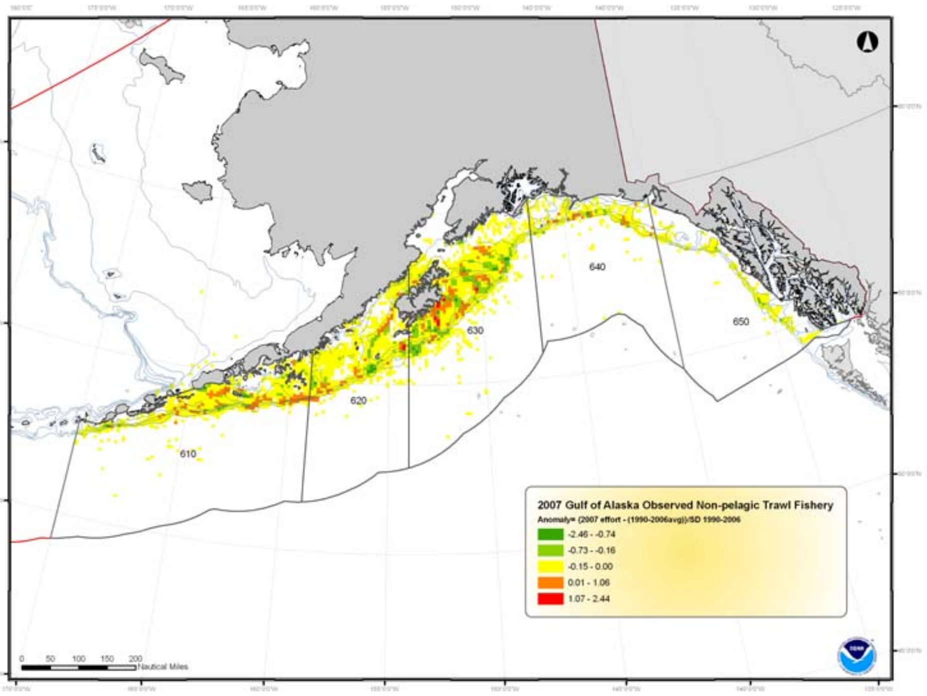

Figure 109. Observed non-pelagic trawl fishing effort in 2007 relative to the 1990-2007 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2007 - average effort from 1990-2007)/stdev(effort from 1990-2007).

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: October 2008

Effort in the pelagic trawl fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 110. 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 111-115 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.

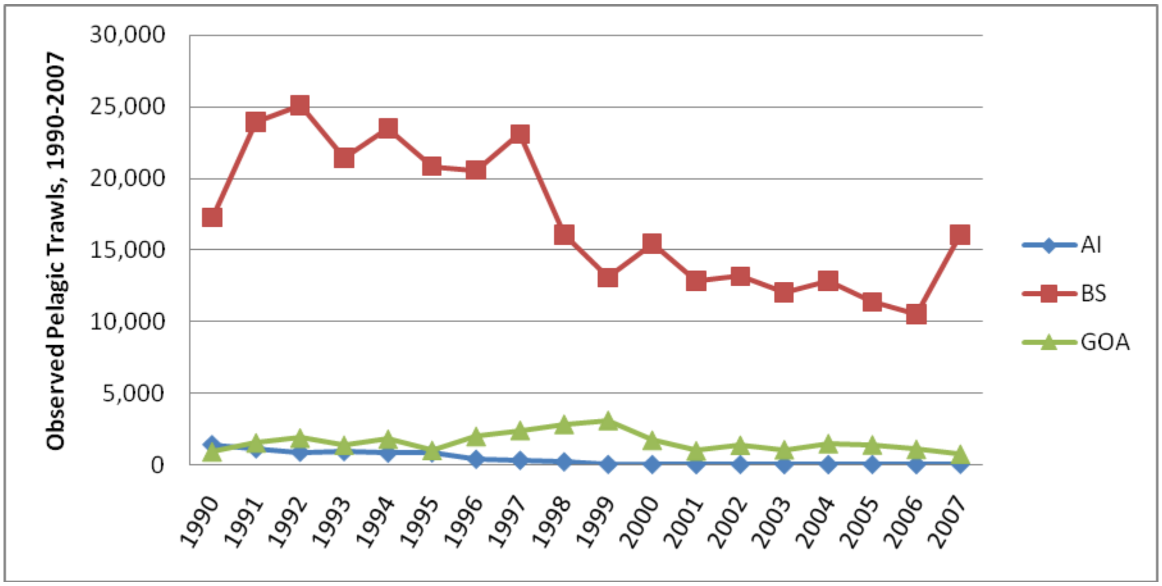

Figure 110. Gulf of Alaska, Aleutian Islands, and Bering Sea pelagic trawl effort (observed pelagic trawl tows), 1990-2007.

Bering Sea

Areas of high fishing effort are north of the Aleutian Islands near Bogoslof Island along the shelf edge represented by the boundary of report areas 509 and 519. 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 2007, fishing effort was anomalously low north of Unimak Island, an area of normally high fishing effort. Increased fishing effort occurred on the outer shelf from the southeast BS to the northwest boundary of area 524 (Figure 111). 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.

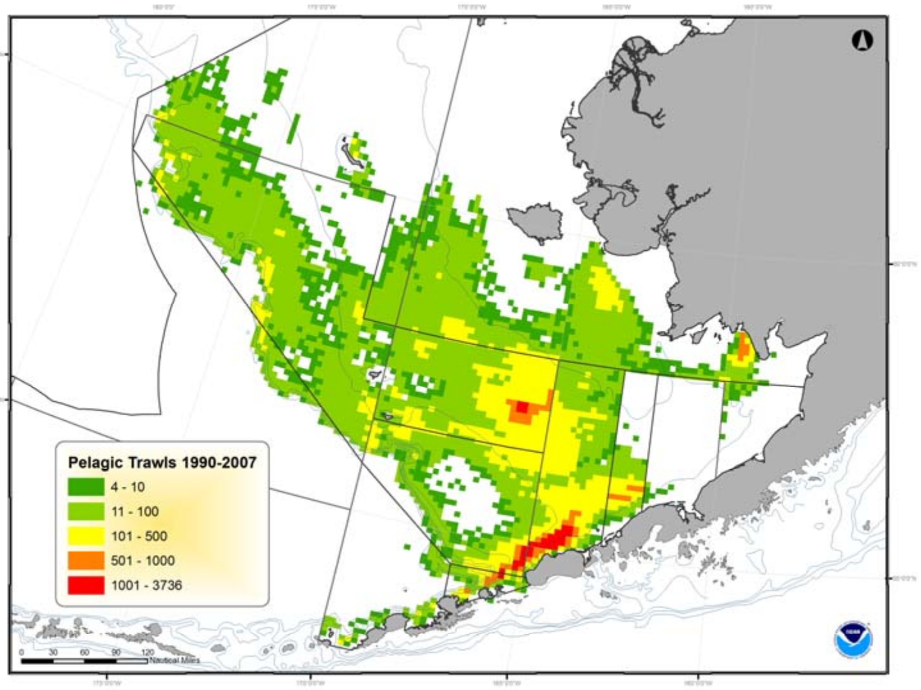

Figure 111. Spatial location and density of pelagic trawl effort in the eastern Bering Sea, 1990-2007.

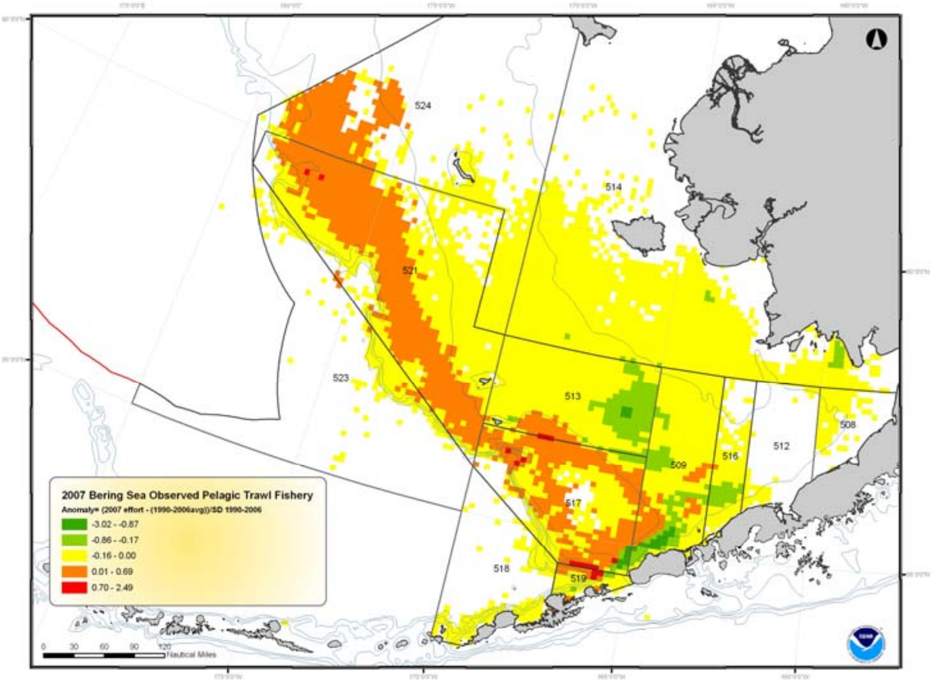

Figure 112. Observed pelagic trawl fishing effort in 2007 relative to the 1990-2007 average in the Bering Sea. Anomalies calculated as (estimated effort for 2007 - average effort from 1990-2007)/stdev(effort from 1990-2007).

Aleutian Islands

For the period 1990-2007 there were 6,936 observed bottom trawl tows in the Aleutian Islands. In 2001, 2003, 3004, and 2006 there were no observed pelagic trawl tows. There were only 17 observed tows in 2007. Patterns of high fishing effort were historically dispersed along the shelf edge.

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.

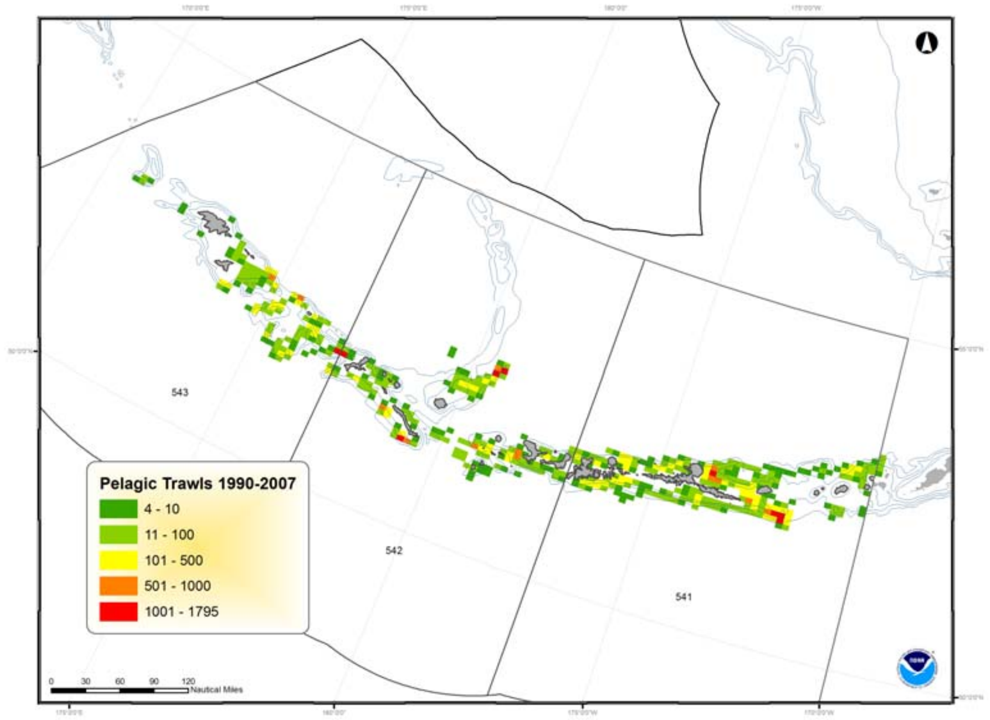

Figure 113. Spatial location and density of pelagic trawl effort in the Aleutian Islands, 1990-2007.

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 1990-2007 there were 17,034 observed pelagic trawl tows in the Gulf of Alaska. The spatial pattern of this effort is much more dispersed than in the Bering Sea region. During 2007, the amount of trawl effort was 750 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.

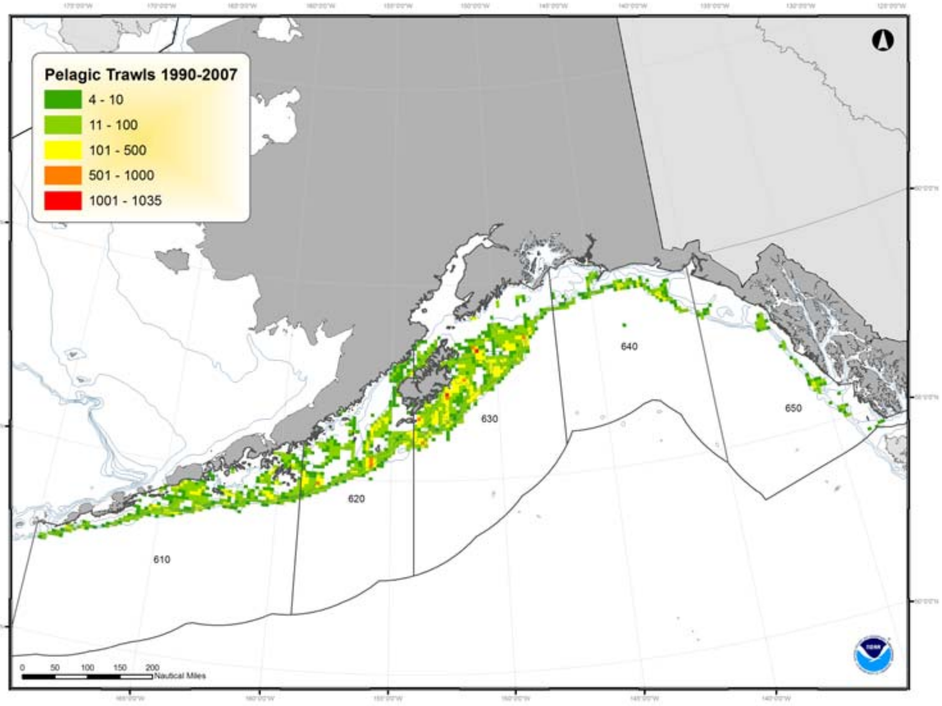

Figure 114. Spatial location and density of pelagic trawl effort in the Gulf of Alaska, 1990-2007.

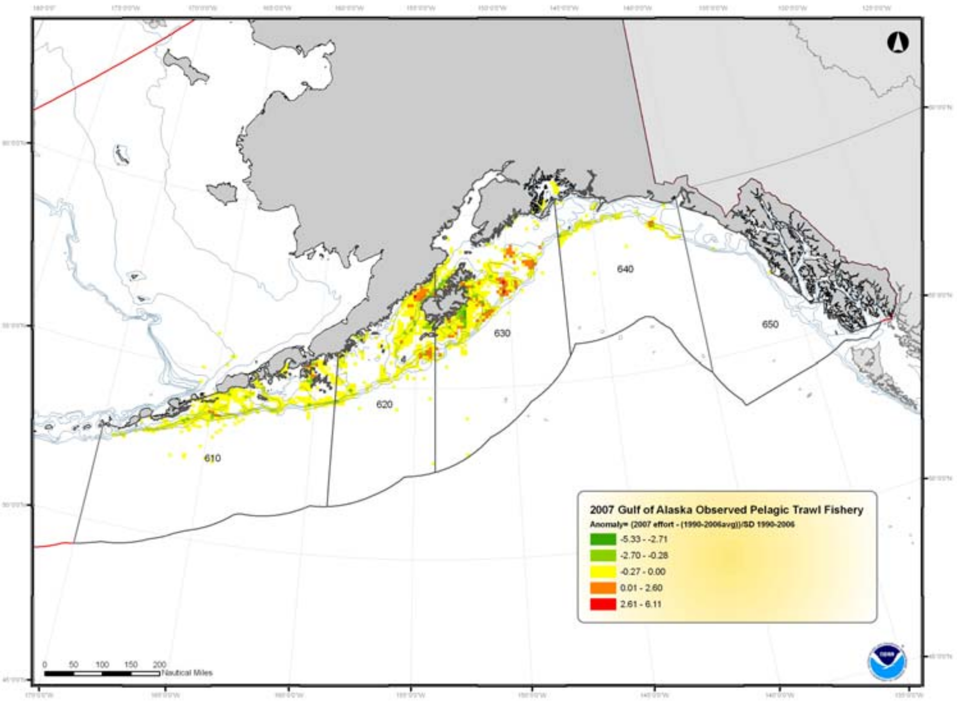

Figure 115. Observed pelagic trawl fishing effort in 2007 relative to the 1990-2007 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2007 - average effort from 1990-2007)/stdev(effort from 1990-2007).

Pot fishing effort in the Gulf of Alaska, Bering Sea, and Aleutian Islands

Contributed by John Olson, NMFS
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Last updated: October 2008

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 116. The amount of pot effort fluctuates annually by region. However, annual observed estimates of pot lifts does 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.

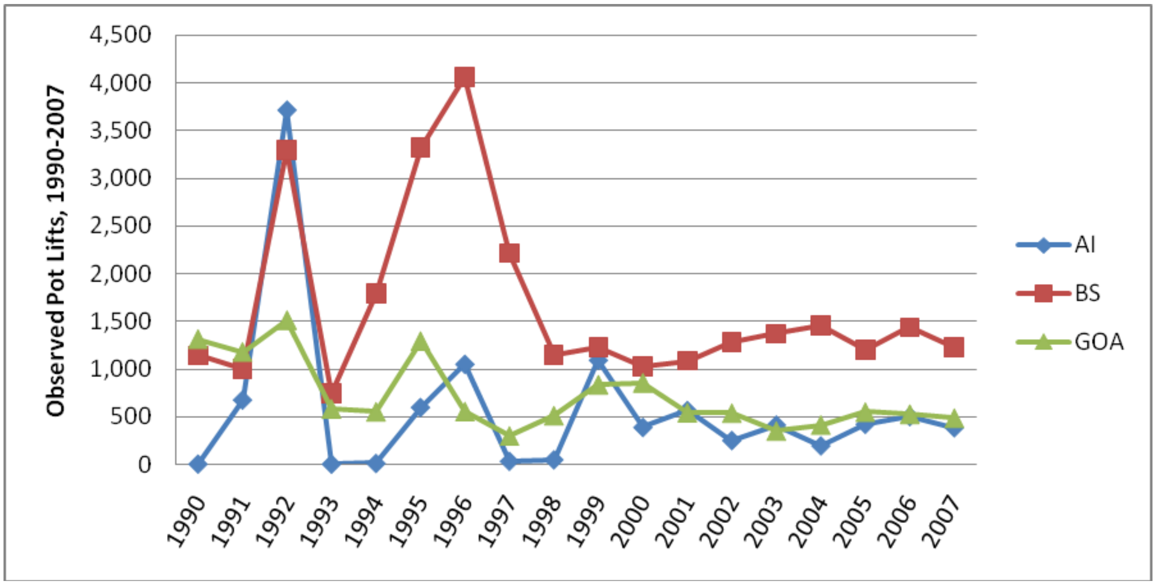

Figure 116. Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of pot lifts, 1990-2007.

Bering Sea

For the period 1990-2007, there were a total of 30,034 observed pot lifts in the Bering Sea fisheries. Spatial patterns of fishing effort were summarized on a 10km2 grid (Figure 117). Areas of high fishing effort are north of Akutan and Unalaska. This fishery occurs mainly for Pacific cod which form dense aggregations for spawning in the winter months. Effort anomalies occurred in some areas but were not readily attributable to seasonal allocations. Spatial and temporal changes to the fishery have occurred due to current Steller Sea Lion regulations.

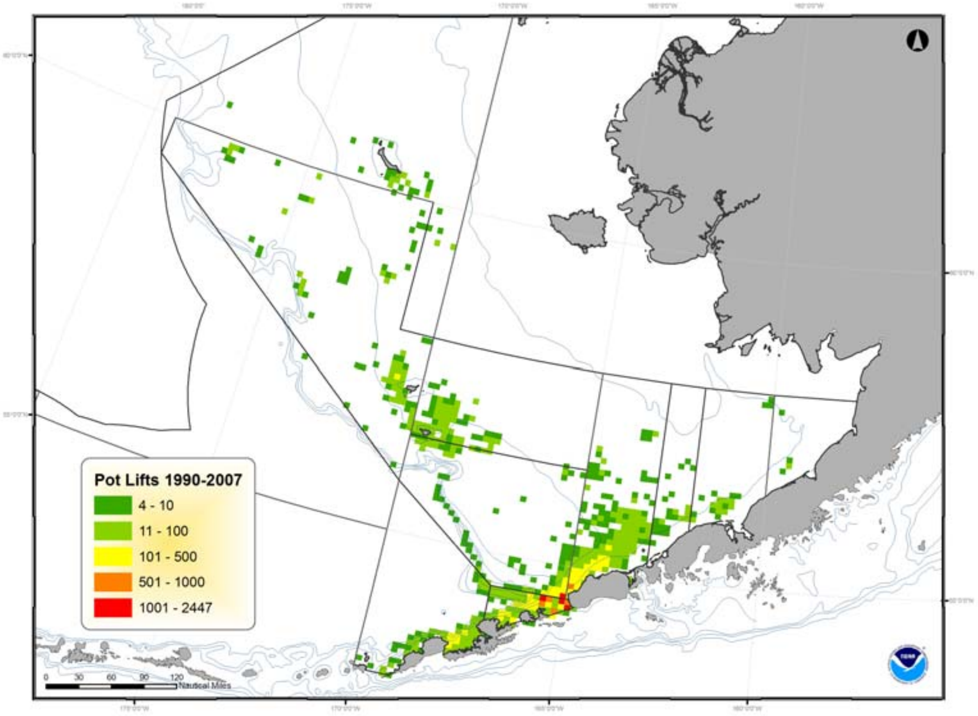

Figure 117. Spatial location and density of observed pot effort (observed number of pot lifts) in the Bering Sea, 1990-2007.

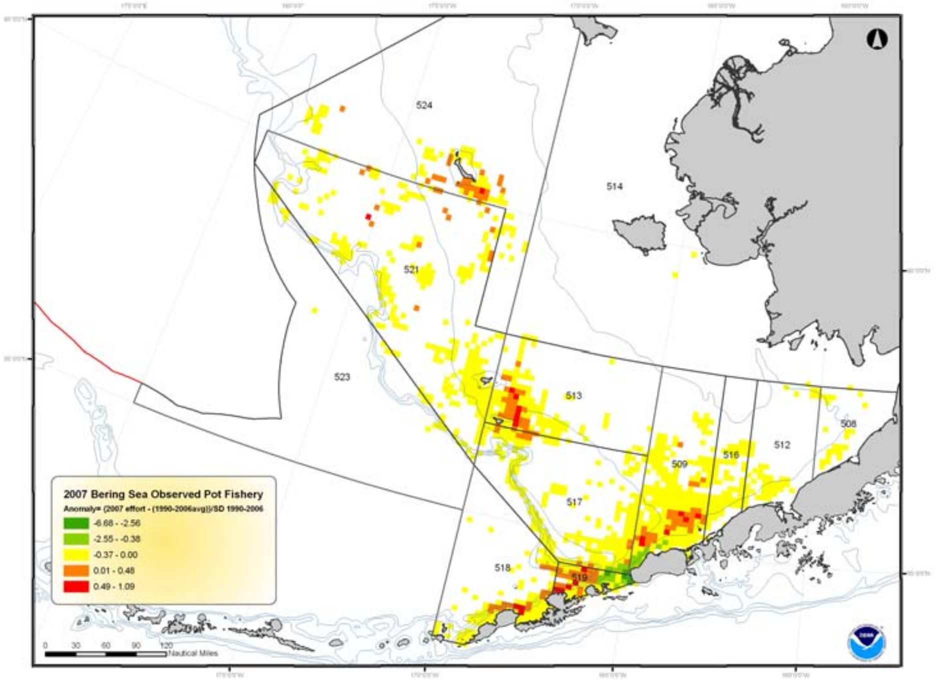

Figure 118. Observed pot fishing effort in 2007 relative to the 1990-2007 average in the Bering Sea. Anomalies calculated as (estimated effort for 2007 - average effort from 1990-2007)/stdev(effort from 1990-2007).

Aleutian Islands

For the period 1990-2007 there were 10,295 observed pot lifts in the Aleutian Islands. High fishing effort was dispersed along the shelf edge with high effort near Attu and Agattu Islands (Figure 119). In 2007, fishing effort was anomalously low between Adak and Atka Islands and high in the eastern portion of area 541 (Figure 120).

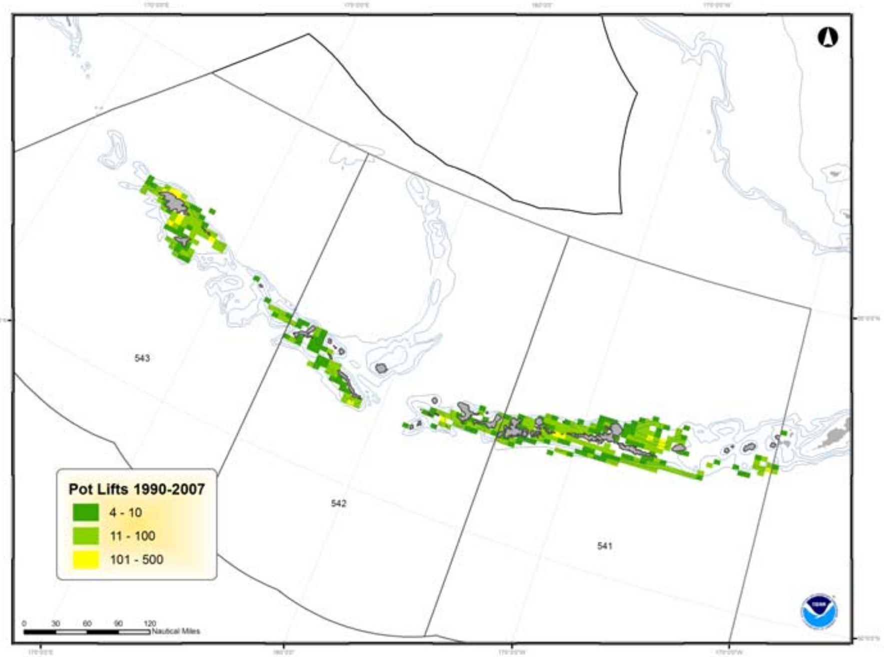

Figure 119. Spatial location and density of observed pot effort (observed number of pot lifts) in the Aleutian Islands, 1990-2007.

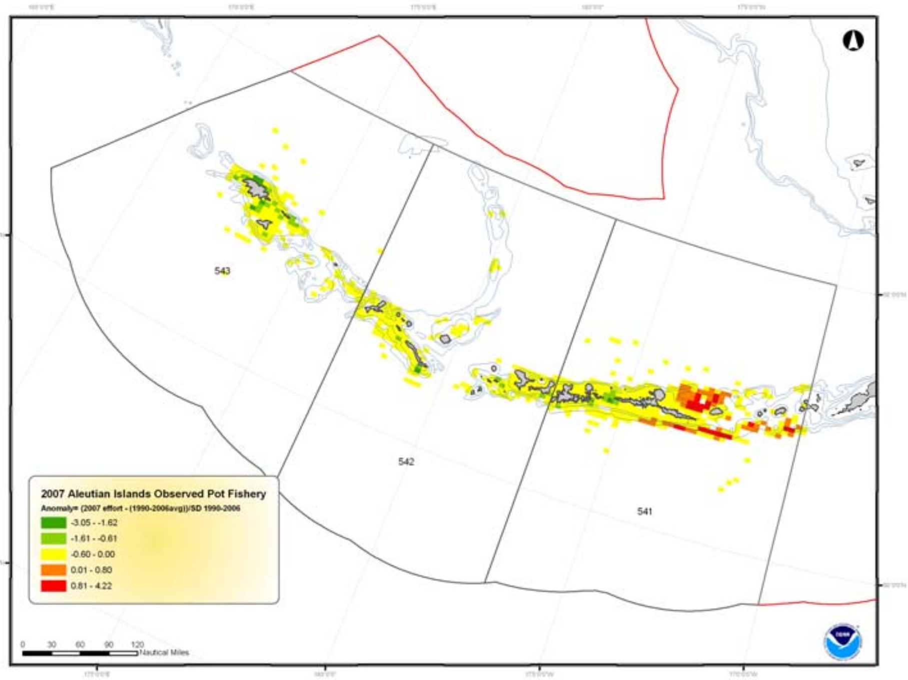

Figure 120. Observed pot fishing effort in 2007 relative to the 1990-2007 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2007 - average effort from 1990-2007)/stdev(effort from 1990-2007).

Gulf of Alaska

For the period 1990-2007 there were 13,239 observed pot lifts in the Gulf of Alaska. Patterns of high fishing effort were dispersed along the shelf with high concentrations around Kodiak Island (Figure 121). Fishing effort in 2007 was lower than the long-term average east of Kodiak Island (Figure 122). 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.

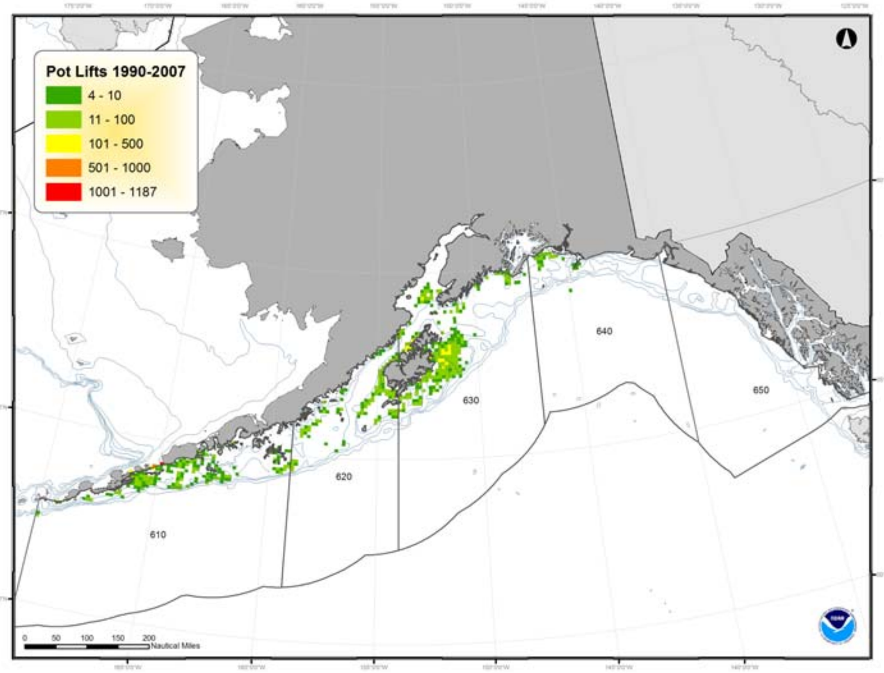

Figure 121. Spatial location and density of observed pot (observed number of pot lifts) effort in the Gulf of Alaska, 1990-2007.

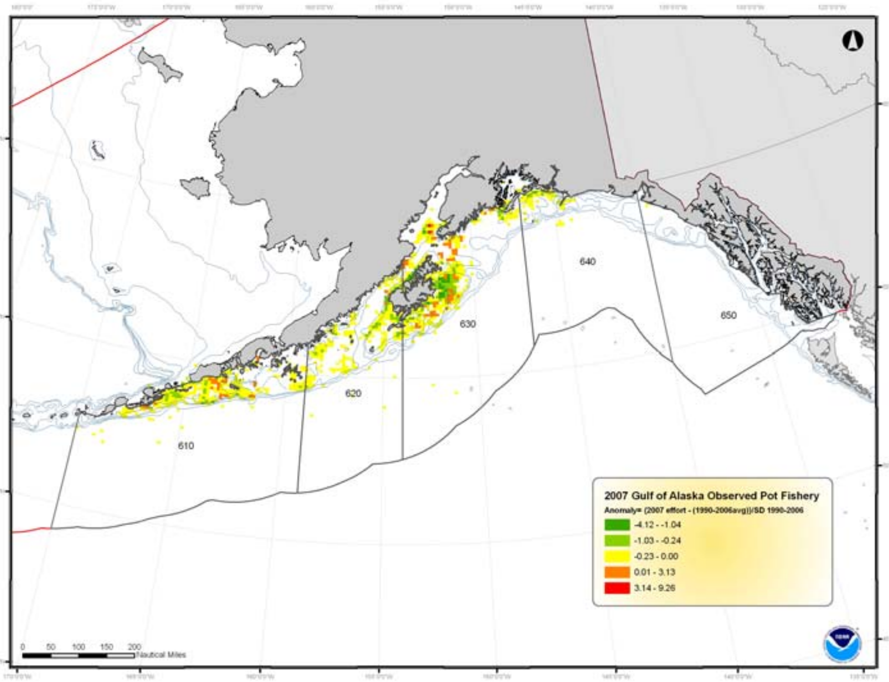

Figure 122. Observed pot fishing effort in 2007 relative to the 1990-2007 average in the Gulf of Alaska. Anomalies calculated as (estimated effort for 2007 - average effort from 1990-2007)/stdev(effort from 1990-2007).

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

Trophic level of the catch

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Last updated: October 2008

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, Aleutian Islands, and Gulf of Alaska 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):

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

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 123). Other dominant species groups in the catch were rockfish prior to the 1970s in the Aleutian Islands and the Gulf of Alaska, and Atka mackerel in the 1990s in the Aleutian Islands.

Stability in the trophic level of the total fish and invertebrate catches in the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska (Figure 124) 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 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 124) 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.

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 BS throughout the period.

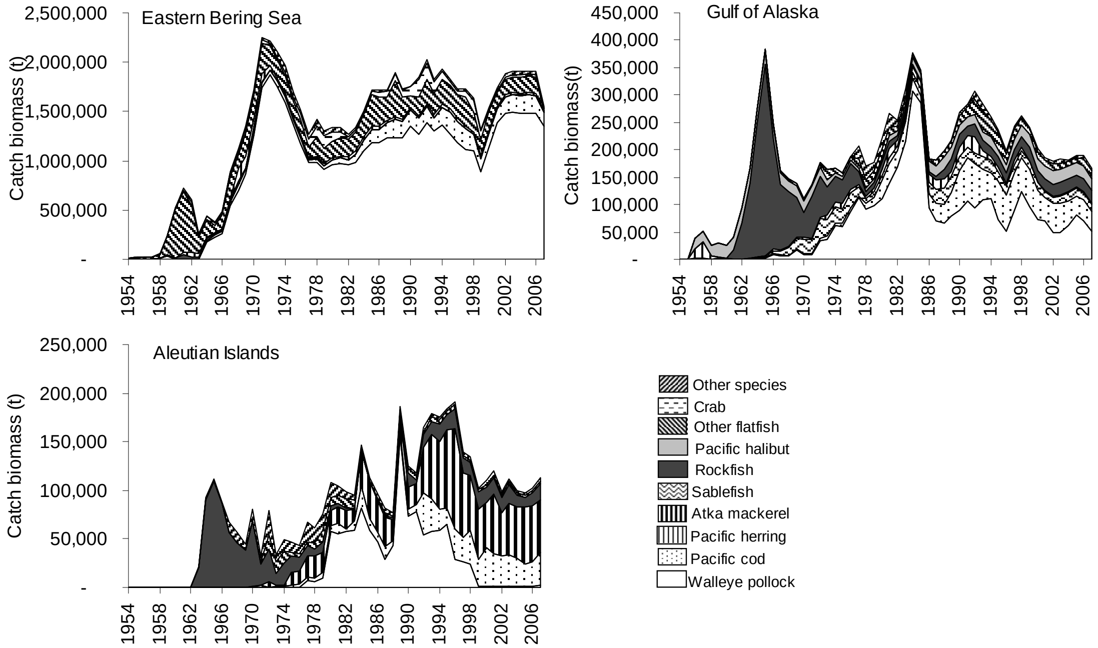

Figure 123. Total catch biomass (except salmon) in the EBS, GOA, and AI, 1954-2007.

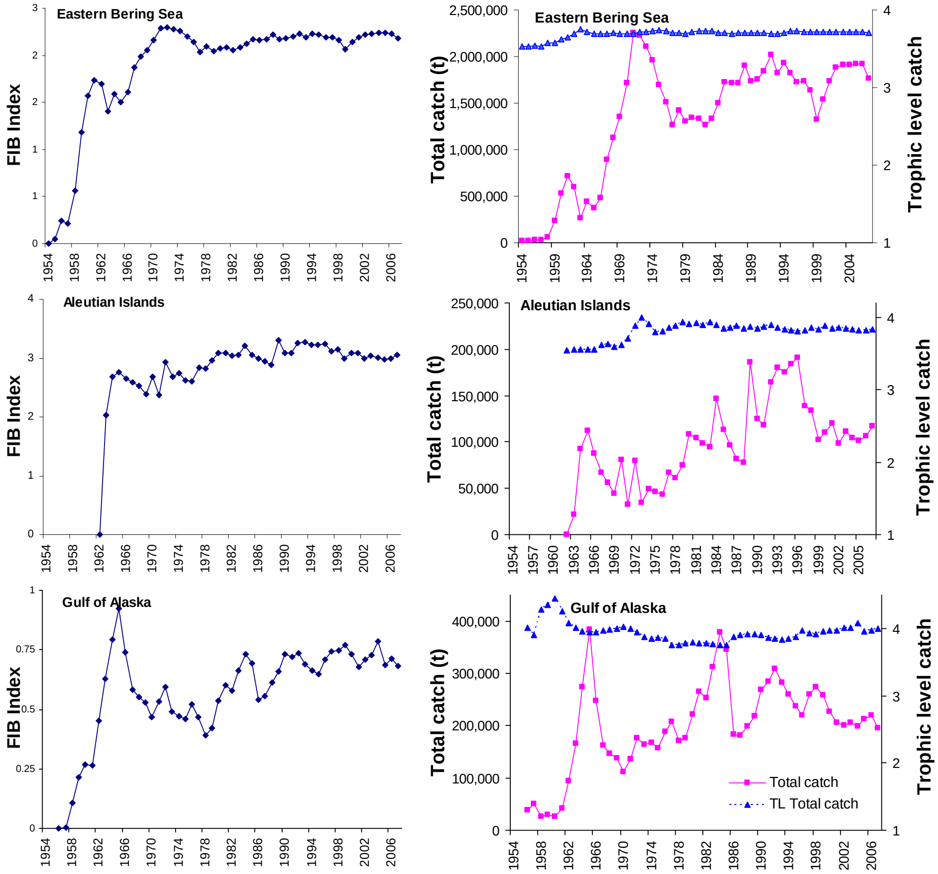

Figure 124. Total catch (groundfish, herring shellfish, and halibut) and trophic level of total catch in the EBS/AI and GOA, 1954-2007 (right column). Left column shows FIB index values for the EBS, AI and GOA, 1954-2007.

Fish Stock Sustainability Index and status of groundfish, crab, salmon and scallop stocks

Contributed by Jennifer Boldt, University of Washington
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Last Updated: June 2008

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. Since there are 230 stocks in the U.S, an overall FSSI score of 920 would be achieved if every stock scored a 4. 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.

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:

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 19 and 20) Halibut is a major stock that is not subject to overfishing, is not approaching an overfished condition, and is not considered overfished. 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 (Tables 19 and 20).

The current overall Alaska FSSI is 114.5 of a possible 140, based on updates through June 2008. The overall Bering Sea score is 68.5 of a possible maximum score of 88. The BSAI groundfish score is 48.5 of a maximum possible 52 and BSAI king and tanner crabs score 20 of a possible score of 36. The Gulf of Alaska groundfish score is 42 of a maximum possible 48. The sablefish, which are managed as a BSAI/GOA complex, score is 4.

Factors causing trends: The groundfish stocks that had low scores in the BSAI include rougheye rockfish (1.5). The reasons for this low score are: it is undefined whether this stock is overfished and unknown if it is approaching an overfished condition.

The stocks that scored low in the GOA are shortspine thornyhead rockfish (indicator species for thornyhead rockfish complex) and yelloweye rockfish (indicator species for demersal shelf rockfish complex), which both scored 1.5. 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 19. Description of major and minor stocks managed under federal fishery management plans off Alaska, June 2008. (Major stocks have landings of 200 thousand pounds or greater.)

Stock Group	Number of Stocks and Stock Complexes	Overfishing?					Overfished?					Approaching overfished condition?		
		Yes	No	Not Known	Not Defined	NA	Yes	No	Not Known	Not Defined	NA	Yes	No	Not known
FSSI	35	0	32	3	0	0	1	28	0	6	0	0	28	7
Non-FSSI	35	0	21	8	6	0	0	1	0	34	0	0	1	34
Total	70	0	53	11	6	0	1	29	0	40	0	0	29	41

Table 20. 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 The information presented in this table was updated June 2008.

Region	Stock	Overfishing? (Is Fishing Mortality above Threshold?)	Overfished? (Is Biomass below Threshold?)	Approaching Overfished Condition?	Mgt Action Required	Rebuilding Program Progress	B/Bmsy or B/Bmsy Proxy	FSSI Stock Score
GOA	Walleye Pollock - Western/Central	No	No	No	N/A	N/A	0.75	3
GOA	Pacific Cod	No	No	No	N/A	N/A	1.42	4
GOA	Arrowtooth Flounder	No	No	No	N/A	N/A	2.98	4
GOA	Pacific Ocean Perch (Includes Western, Central And Eastern)	No	No	No	N/A	N/A	1.16	4
GOA	Northern Rockfish - Western / Central	No	No	No	N/A	N/A	1.49	4
GOA	Flathead Sole	No	No	No	N/A	N/A	2.69	4
GOA	Dusky Rockfish (Indicator Species For Pelagic Shelf Rockfish Complex) 39	No	No	No	N/A	N/A	1.51	4
GOA	Dover Sole (Indicator Species For Deepwater Flatfish Complex) 40	No	No	No	N/A	N/A	2.35	4
GOA	Rex Sole	No	No	No	N/A	N/A	2.6	4
GOA	Shortspine Thornyhead (Indicator Species For Thornyhead Rockfish Complex) 41	No	Undefined	Unknown	N/A	N/A	not estimated	1.5
GOA	Yelloweye Rockfish (Indicator Species For Demersal Shelf Rockfish Complex) 42	No	Undefined	Unknown	N/A	N/A	not estimated	1.5
GOA	Rougheye Rockfish 43	No	No	No	N/A	N/A	1.6	4
BSAI	Walleye Pollock - Eastern Bering Sea	No	No	No	N/A	N/A	0.73	3
BSAI	Walleye Pollock - Aleutian Islands	No	No	No	N/A	N/A	1.83	4
BSAI	Pacific Cod	No	No	No	N/A	N/A	1.1	4
BSAI	Yellowfin Sole	No	No	No	N/A	N/A	1.82	4
BSAI	Greenland Turbot	No	No	No	N/A	N/A	1.74	4
BSAI	Arrowtooth Flounder 44	No	No	No	N/A	N/A	3.29	4
BSAI	Rock Sole 45	No	No	No	N/A	N/A	2.51	4
BSAI	Flathead Sole 46	No	No	No	N/A	N/A	2.05	4
BSAI	Pacific Ocean Perch	No	No	No	N/A	N/A	1.32	4
BSAI	Atka Mackerel	No	No	No	N/A	N/A	1.34	4
BSAI	Alaska Plaice	No	No	No	N/A	N/A	2.64	4
BSAI	Northern Rockfish	No	No	No	N/A	N/A	1.62	4

BSAI	Rougheye Rockfish[43]	No	Undefined	Unknown	N/A	N/A	not estimated	1.5
GOA/BSAI	Sablefish[47]	No	No	No	N/A	N/A	1.05	4
BSAI	Blue King Crab - Pribilof Islands	No[48]	Yes	N/A	continue rebuilding	5/10-year plan	0.1	2
BSAI	Blue King Crab - Saint Matthews Island	No[48]	No - rebuilding	N/A	continue rebuilding[1]	8/10-year plan	0.71	3
BSAI	Golden King Crab -Aleutian Islands	Unknown	Undefined	Unknown	N/A	N/A	not estimated	0
BSAI	Red King Crab - Aleutian Islands, Adak	Unknown	Undefined	Unknown	N/A	N/A	not estimated	0
BSAI	Red King Crab - Bristol Bay	No	No	No	N/A	N/A	2.05	4
BSAI	Red King Crab - Norton Sound	Unknown	Undefined	Unknown	N/A	N/A	not estimated	0
BSAI	Red King Crab - Pribilof Islands	No[48]	No	Unknown[2]	N/A	N/A	3.39	4
BSAI	Snow Crab - Bering Sea	No	No - rebuilding	No	continue rebuilding[1]	8/10-year plan	0.66	3
BSAI	Tanner Crab - Eastern Bering Sea	No	No	No	N/A	Rebuilt	1.32	4

39. 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.

40. 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.

41. 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.

42. 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.

43. Rougheye Rockfish consists of Rougheye Rockfish and Blackspotted Rockfish. Rougheye Rockfish is the indicator species for this complex.

44. 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.

45. 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.

46. 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.

47. 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.

Total annual surplus production and overall exploitation rate of groundfish

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Last updated: October 2008

Description of indices: Total annual surplus production (ASP) of groundfish on the Eastern Bering Sea (EBS) and Gulf of Alaska (GoA) shelves 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 retained in bottom trawl surveys. Assuming that all biomass estimates correspond to beginning of year estimates (prior to when the fishery occurs), 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, All estimates of B and C are based on 2007 stock assessments, data for Pacific halibut from IPHC, 2007 assessment):

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

An index of total exploitation rate within each region was estimated by dividing the total groundfish catch across the major commercial species by the combined biomass at the beginning of the year:

$$u_t = C_t / B_t$$

For details, see Mueter & Megrey (2006).

Status and trends: The resulting indices suggest high variability in groundfish production in the EBS (Figure 125) and a non-significant decrease in production between 1977 and 2005 (slope = - 65,400 mt / year, t = -1.771, p = 0.087). Annual surplus production in the GoA was much lower on average, less variable, and decreased slightly over the same time period (slope = - 8,460 mt/ year, t = -1.410, p = 0.170).

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 125). Total exploitation has remained relatively constant in both systems from the mid-1980s to the present. The overall exploitation rate in the EBS reached a low of 7% in 1999 and increased to 11% by 2006 and 2007, while the exploitation rate in the Gulf of Alaska has generally been less than 5% except in the mid-1980s and 1999/2000.

Because trends in annual surplus production in the Eastern Bering Sea are almost entirely driven by variability in walleye pollock, I computed ASP_t for the Bering Sea without walleye pollock (Figure 126). The results suggest a pronounced decrease in aggregate surplus production of all non-pollock species from 1977 – 1995, followed by an increase and very stable non-pollock ASP since 2000. 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 displayed the opposite trend (increasing ASP over time, followed by decreases in recent years).

Factors causing 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). 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 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). A plot of total ASP against total mid-year biomass suggests that biomass has generally been above the biomass that would be expected to yield maximum surplus production under the Graham-Schaefer model applied to total aggregated surplus production (Figure 127). The patterns in ASP reflect at least in part a density-dependent response to observed changes in biomass and I was unable to identify significant environmental effects on surplus production.

Exploitation rates are primarily determined by management and reflect a relatively precautionary management regime with rates that have averaged less than 10% across species 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 is excluded, rates are comparable to those in the EBS.

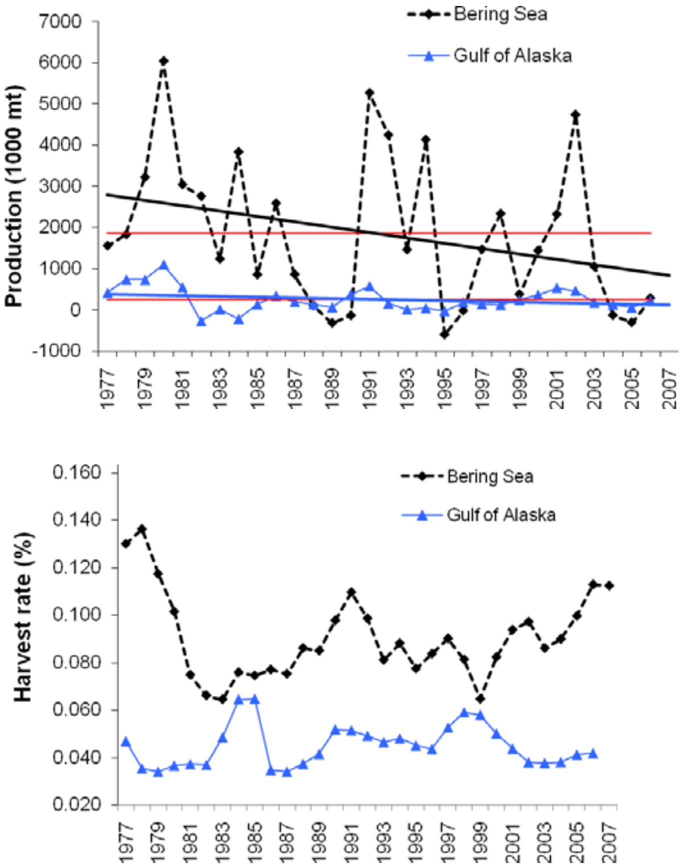

Figure 125. Total annual surplus production (change in biomass plus catch) across all major groundfish species in the Gulf of Alaska and Bering Sea with estimated linear trends (solid lines) and long-term means (red) and total harvest rate (total catch / total biomass) across all major groundfish species in the Gulf of Alaska and Bering Sea.

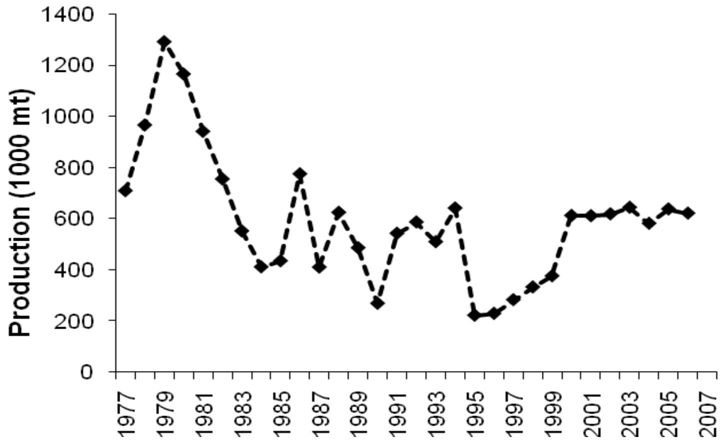

Figure 126. Total annual surplus production (change in biomass plus catch) across all major groundfish species, excluding walleye pollock.

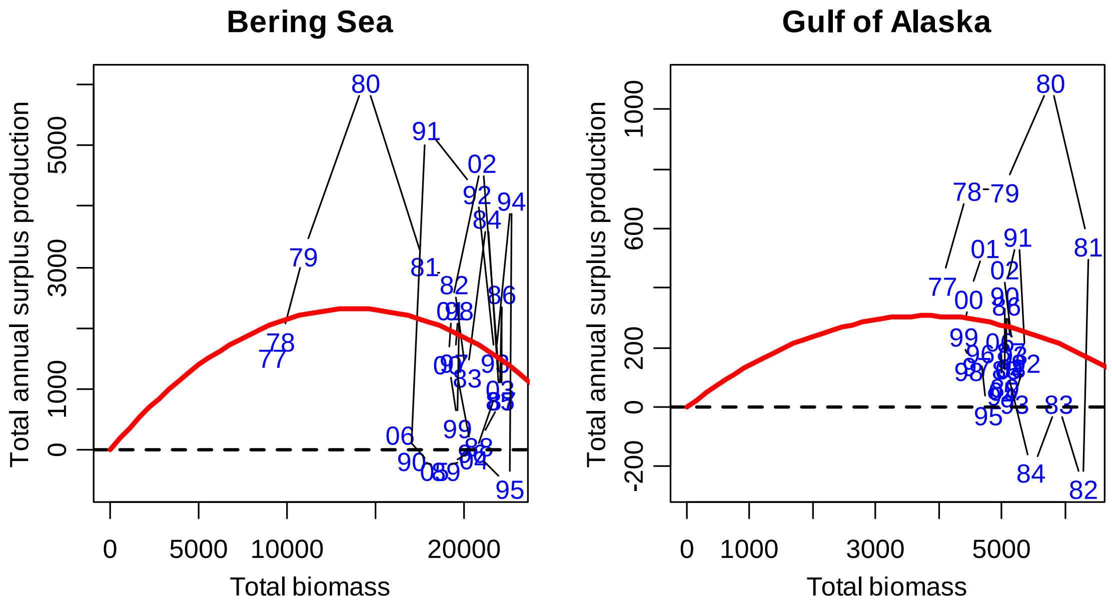

Figure 127. Estimated annual surplus production against total biomass with fitted Graham-Schaefer model.

Community size spectrum of the bottom trawl-caught fish community of the eastern Bering Sea

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Last updated: August 2008

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 (Figures 128 and 129; 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. 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. CSS slopes and heights vary temporally for different groups of taxa that are exposed to different levels of exploitation (Boldt et al. in review). Changes in CSS slopes were not due to significant shifts in species composition and not correlated with fishing intensity or bottom temperature variability (Boldt et al. in review).

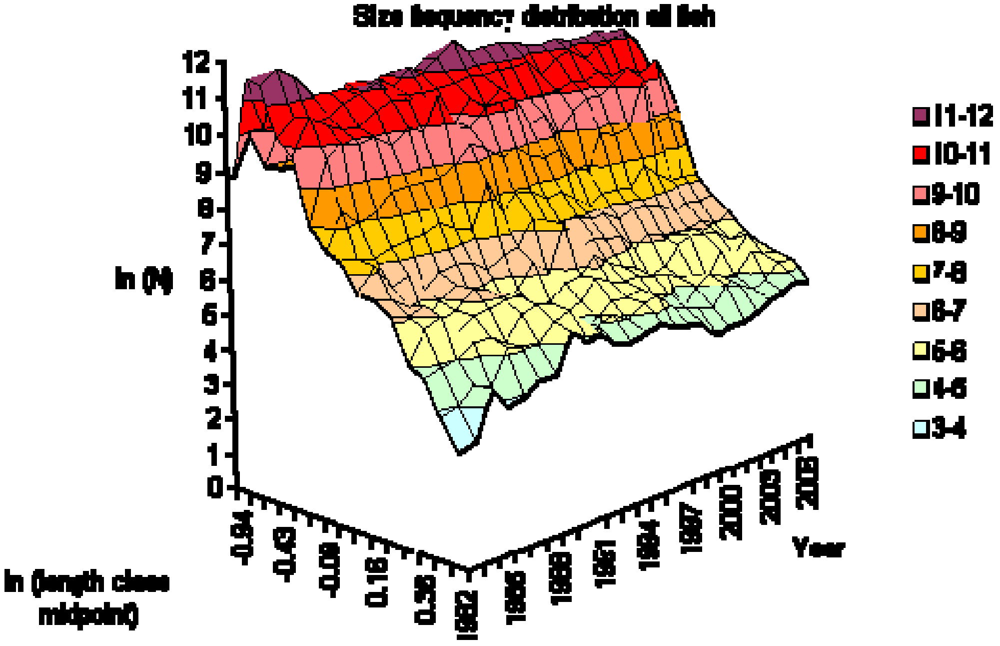

Figure 128. Eastern Bering Sea fish (20-90 cm) community size spectrum (CSS), 1982-2006. Abundance is represented on the z-axis (ln(N)) and the colour scale; size class anomalies are represented on the y-axis (ln (length class midpoint)); year is shown on the x-axis.

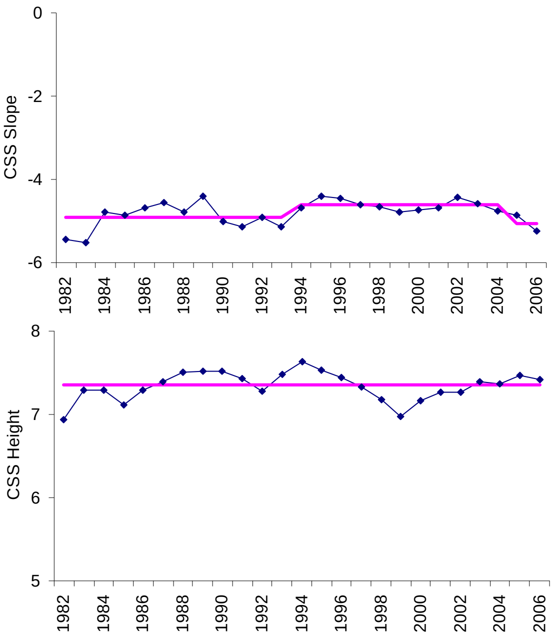

Figure 129. Community size spectra slopes and heights for all bottom trawl survey-caught fish in the eastern Bering Sea, 1982-2006. No significant linear trends were detected. Solid lines indicate if and when significant step-changes occurred in the time series, using a sequential t-test analysis (STARS, cutoff = 10, p=0.05; Rodionov 2004; Rodionov and Overland 2005).

Ecosystem Goal: Humans are part of ecosystems

Fishing overcapacity programs

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Last updated: August 2008

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) has developed several programs to address overcapacity in the Alaskan fisheries. Moratorium programs were implemented in the crab 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). However, rights-based management such as individual transferable quotas and dedicated allocations to cooperatives has increasingly being used to “rationalize” fisheries.

An Individual Fishing Quota (IFQ) program 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 (hence the term “three-pie” program), and provides for voluntary harvesting cooperatives. Some features of this crab program had to be authorized by Congressional action. The Council also is considering comprehensive rationalization of Gulf of Alaska (GOA) groundfish fisheries and sector allocations of groundfish in the BSAI. Congress has provided additional statutory tools to help relieve overcapacity. The American Fisheries Act (AFA) retired nine catcher-processors, 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. Congress later authorized a BSAI crab “buyback” program that, after approval by industry, retired crab licenses, vessels, and vessel histories prior to implementation of the crab quota program. A similar program has been implemented for BSAI longline catcher/processor vessels and is authorized for other sectors in those areas.

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. 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 . The quota may be used annually to provide dedicated allocations to harvesting cooperatives or pooled in a limited access fishery; or quota holders may “opt out” of the program.

Moratorium on New Vessels

NMFS implemented a moratorium on new vessel entry into the federally managed groundfish and crab fisheries in 1996. The program was considered a place holder 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 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 third year under rationalization, 128 were licensed and 87 fished under rationalized fisheries, respectively. The number of current LLP groundfish licenses (1,826) 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 1,465 groundfish LLP licenses name vessels. However, the LLP is more restrictive in terms of the crab fisheries in which a license holder may participate, the groundfish 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 is being 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. Under this provision, 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) might 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. NMFS is currently developing implementing regulations for this program revision.

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 Rationalization and Buyback

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. 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 August 2008, 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 third crab fishing year under rationalization, 478 persons were holding harvesting QS and 29 were holding PQS. Of the persons holding harvesting QS, 283 held "owner" type, and 211 individual persons held "crew" type. Consolidation has occurred in the crab fisheries, due largely to widespread use of cooperatives. During the first three years under rationalization, the numbers of vessels authorized, and actually used, to harvest crab decreased from 154 to 128; and from 101 to 87, respectively.

Starting with the fourth crab fishing year on July 1, 2008 NMFS is implementing a change required by statute as part of crab FMP Amendment 25 (73 FR 29979, May 23, 2008). This change will allow 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 would be 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 is developing regulations under crab FMP Amendment 27 to implement this provision, 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 is analyzing a number of proposed program changes. The Council plans to undergo a major program review at its October 2008 meeting, after three complete crab fishing years have occurred under rationalization.

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. IFQs have 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. 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 2007, 3,078 persons held halibut QS and 857 held sablefish QS. The number of vessels landing halibut in the IFQ fishery declined from 3,450 in 1994 to 1,211 at the end of 2007; the number landing sablefish in the IFQ fishery declined from 1,191 in 1994 to 373 in 2007.

American Fisheries Act

The AFA, passed in late 1998, among other things limited the number of harvesting and processing vessels that would be allowed to participate in the BSAI pollock fishery. 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. For 2003 to 2005, and again in 2007, two vessels were idle during the winter and four vessels were idle in the summer season. In 2006, two vessels were idle in the winter season and three vessels were idle in the summer season. 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 three years 2005-2007.

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, and then fell to 83 in 2007.

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 dedicated access privilege (DAP) 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. long. to 159 W. long. 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. 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; and may conduct inter-cooperative allocation transfers. 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 would 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 modifies 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.

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 is currently developing 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 licenses 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.

The Council is considering additional measures to supplement guided sport needs, including a program to use “guided angler fish” (GAF) in which annual allocation of halibut could be purchased from the commercial fishery for use in guided sport fisheries.

Groundfish fleet composition

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Last updated: October 2008

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 the number of hook-and-line vessels (and, consequently, also in the total number of vessels) in 2003 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 872 in 2007, the most recent year for which we have complete data (Figure 130). Hook and line vessels accounted for about 1,225 and 534 of these vessels in 1994 and 2007, respectively. The number of vessels using trawl gear decreased from 257 in 1994 to 190 in 2007. 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 188 in 2007. Vessel counts in these tables were compiled from blend and Catch-Accounting System estimates and from fish ticket and observer data.

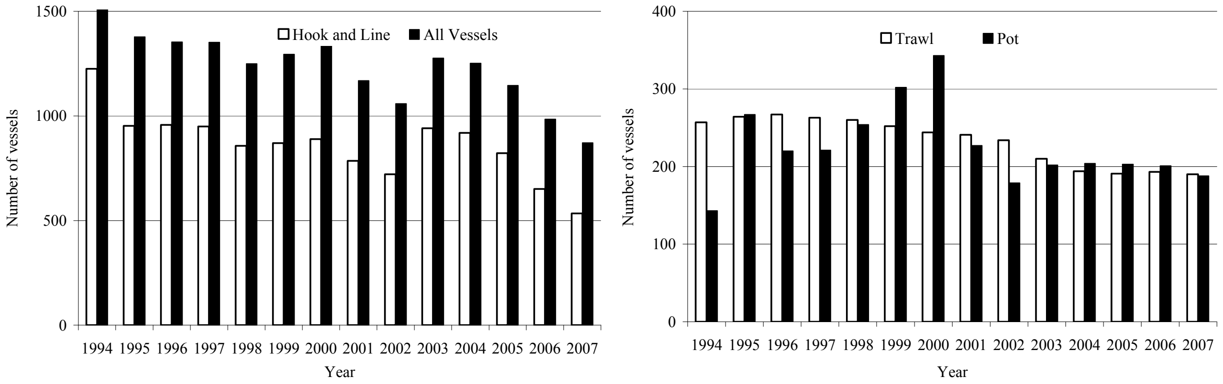

Figure 130. Number of vessels participating in the groundfish fisheries off Alaska by gear type, 1994-2007.

Distribution and abundance trends in the human population of the Gulf of Alaska

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Last updated: October 2007

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

Distribution and abundance trends in the human population of the Bering Sea/Aleutian Islands

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Last updated: August 2008

Description of Indices: This report describes the distribution and abundance over time of human populations in Bering Sea/Aleutian Island (BSAI) fishing communities (Figure 131). Population was calculated by aggregating Census values for selected Bering Sea communities into Census Areas for each decade between 1920- 2000 (data from U.S. Census Bureau), and yearly between 1990- 2007 (data from the Alaska Department of Labor and Workforce Development (ADLWD)). This approach is concordant with research on arctic communities that uses crude population growth or loss as a general index of community viability (Aarsaether and Baerenholdt 2004). A more detailed discussion of these and other demographic issues is contained in the Economics Appendix of 2008 SAFE.

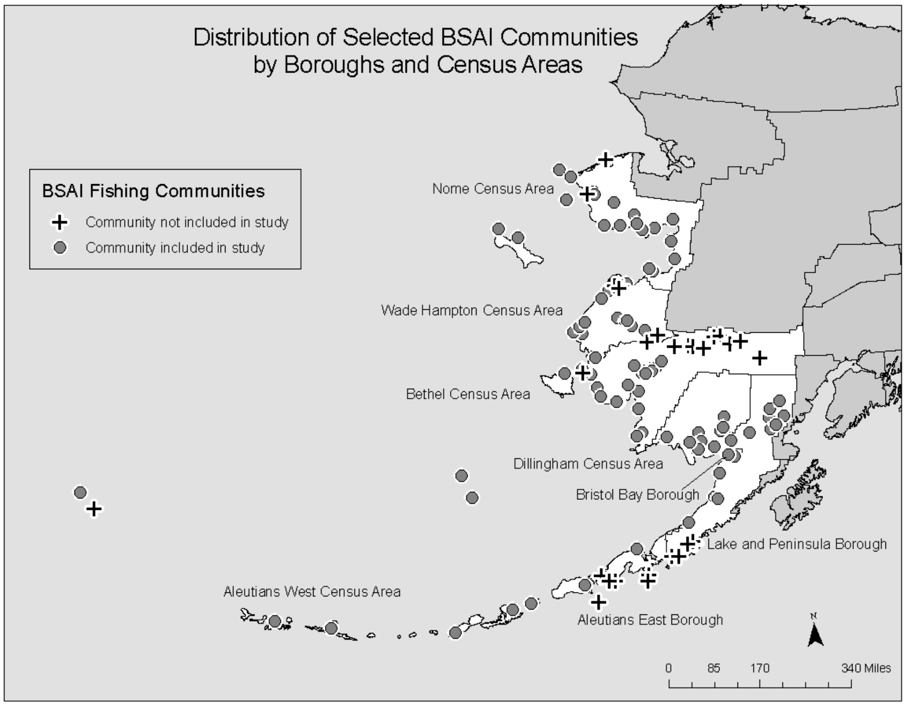

Figure 131. Distribution of selected BSAI communities by boroughs and census areas.

The 94 BSAI fishing communities selected for use in this report comprise most of the population in each of these Census Areas (between 79% for Aleutians East and West and 99% for Dillingham Census Area) and were chosen due to their proximity and historical involvement in Bering Sea subsistence or industrial fisheries (Figure 131). Following CDQ community selection parameters however, towns near the Bering Sea but located on the Gulf of Alaska Large Marine Ecosystem (LME) or Arctic LME were excluded.

The US Census counts populations based on place of residence on April 1 of the Census year. In many fishing communities in Alaska, the population fluctuates greatly during the year according to the fishing season. Due to an influx of processing workers, salmon communities may have much higher populations in the summer, crab and groundfish communities in the winter. Census data does not differentiate between long-term residents and transient residents, and does not capture seasonal population fluctuations.

Status and Trends:

The overall population of BSAI fishing communities in 2000 was almost seven times larger than its 1920 population - growing from 6,215 to 43,237 (Figure 132). The proportion of people living in BSAI communities relative to the total Alaskan population has declined from around 11% of the state total of 55,036 in 1920 to around 6.8% of the total Alaska population of 626,932 in 2000.

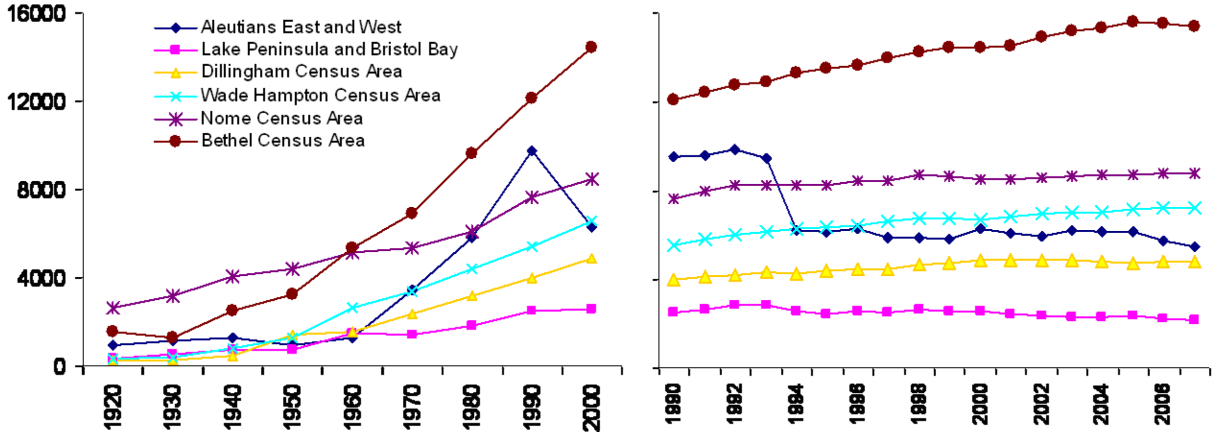

Figure 132. Population of BSAI communities per census areas: a.) every 10 years during 1920-2000 (data source: US Census Bureau) and b.) every year during 1990-2007 (data source: ADLWD)

Nearly all of Alaska's rural areas, including BSAI, have had a positive average population growth rate since 1990, however, in the past decade these upward trends have been slowing. Seventy-two BSAI fishing communities (or 82%, not including seasonal use areas) have had a positive average annual percent change during the period between 1990 and 2007 (Figures 132 and 133). One community, Nome, showed zero percent average annual change over the same time period and 15 had a negative average annual percent change. Communities with a negative annual percent change during this time period appear to be concentrated in Aleutians East and West along with Lake and Peninsula and Bristol Bay Boroughs. The sharp decrease (seen above) in the Aleutians East and West area is largely due to the military base closure in Adak.

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

Alaska has the highest share of indigenous Americans of any US state (one person in five), and Alaska Natives make up 82% of the population in remote rural census areas, 90% when excluding regional hubs (Goldsmith et al. 2004). In the BSAI, the percent Native population is lowest among the Aleutians East

(38.6%) and Aleutians West (22.5%) and highest in Wade Hampton (94.9%) and Bethel (85.5%), though there is significant variation between communities.

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

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

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

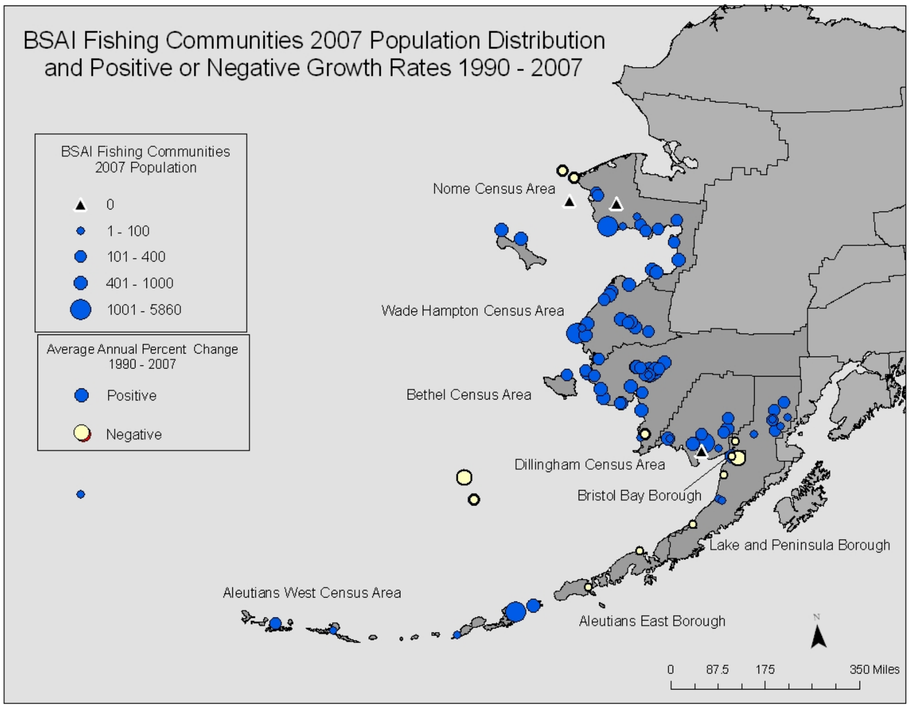

Figure 133. BSAI fishing communities 2007 population distribution and positive or negative growth rates, 1990-2007. Map by Amanda Poole.

Impacts: Population decline or growth in small communities can factor into health care provision, education, land use, environmental impacts, transportation, and other social services (Williams 2004a). Over 36% of federal dollars allocated to Alaska depend in some way on population, State programs attach many services to population, and CDQ quota shares are also provisioned in relation to population numbers.

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APPENDIX 2

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

Determining the value of habitat to juvenile rockfish in the Aleutian Islands. Principal Principal Investigators - Chris Rooper and Mark Zimmermann (AFSC – RACE), and Jennifer Boldt (University of Washington)
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Bogoslof Island mapping and colonization. Principal Investigators - Mark Zimmermann (AFSC - RACE), Jennifer Reynolds (U. Alaska Fairbanks), and Chris Rooper (AFSC - RACE)
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Last updated: October 2008

We are studying the colonization process of benthic invertebrates at hard-bottom sites about 10-200 years old on Bogoslof Volcano to provide estimates of habitat recovery rates from benthic fishing activities. Bogoslof provides a potential natural laboratory for our study because lava and tephra (fragments of volcanic rock and lava) from historical eruptions (since 1796) have resurfaced different areas of the shallow seafloor around the island. The purpose is to provide information needed for fisheries management by defining an upper bound on the time needed for recovery.

The project involves three separate stages of research: mapping the seafloor; matching seafloor areas to specific eruptions (dates); and conducting an ROV census of benthic invertebrates within seafloor areas of known ages. The first phase of the project was completed in July 2004 when a contract survey company successfully mapped the seafloor surrounding Bogoslof with a 100 kHz Reson SeaBat 8111 multibeam at depths from 20 to 750 m. In the summer of 2008, progress was made on interpreting the multibeam imagery.

Large-scale observations based on the multibeam sonar data include the following: A small number of flank vents are observed, but Bogoslof does not have well-developed flank rift zones characteristic of larger submarine volcanoes. Instead, the great majority of volcanic eruptions on Bogoslof occur through vents on the summit platform, where Bogoslof Island and Fire Island are located. These summit eruptions have produced both fragmental volcanic debris and lava ridges that extend hundreds of meters down the slopes of the volcano. Debris fans blanket the seafloor between these ridges, and are expected to include volcanic products from historical eruptions. The lava ridges predate the historical eruptions. Most are eroded, and all have accumulated sediment on relatively flat areas. Below 400-500 m the slopes are dominated by volcaniclastic debris. Relative age relationships can be established both among the lava ridges and the debris fans. There are no signs of major landslides or slope failure on Bogoslof.

Age predictions can be made with confidence in two locations, and probably in a third. 1) A young debris deposit is present on the uppermost slope north of Fire Island, identifiable to a depth of about 150 m. Fire Island formed in the 1882-1883 eruption, and subsequently went through a period of rapid erosion. Significant erosion may also have occurred during explosive eruptions in 1906-1910. The effective age range for this substrate, then, is 1883-1910, or 125-95 years. 2) The southeast tip of the platform is a large, young debris deposit that extends to at least 450 m depth. The position of this deposit is apparently controlled by southeast-directed waves and currents that sweep the summit platform, rather than proximity to eruption vents. The deposit is interpreted to contain products of the 1927 tephra eruption, with erosion and redeposition by 1935. The surface age of this slope is thus predicted to be 81-73 years. 3) A much smaller debris deposit off the northeast edge of the platform, to about 90 m depth, may be the same age.

We have acquired video recordings from two Phantom ROV dives on the upper slopes of Bogoslof (90–230 m) conducted by Rick Brodeur and Morgan Busby (NOAA) in 1995. The first dive is located on the young, southeast debris deposit, and the second crosses an eroded lava ridge and older volcaniclastic debris on the northeast slope. The dive navigation appears to be excellent, as changes in seafloor character observed in the dive video match features in the multibeam bathymetry data. These videos show clear differences in substrate character and invertebrate colonization between the two sites, and lend support to the concept of this study.

The bathymetry map shows an anomalous cluster of small pinnacles, up to 10 m high, tentatively identified as sponge reefs (bioherms). This cluster is on the south slope of the volcano, at 290-315 m depth. Sponge reefs were first discovered in British Columbia coastal waters in 1988, and were found on the continental slope off Washington in 2007. If confirmed, this would be the first site located in Alaska and would greatly extend their known geographic distribution.

Deep-sea coral distribution and habitat in the Aleutian Archipelago. Principal Investigators - Robert Stone (AFSC - ABL), Jon Heifetz (AFSC - ABL), Doug Woodby (ADFG), and Jennifer Reynolds (University of Alaska, Fairbanks)
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Red tree coral (*Primnoa* spp.) habitat in the eastern Gulf of Alaska.
Principal Investigator - Robert Stone (AFSC - ABL)
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Last updated: October 2007

Nursery habitat mechanisms and function for juvenile flatfishes. Principal Investigator – Allan W. Stoner (AFSC - RACE)
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Last updated: August 2007

Short-term trawling effects and recovery monitoring in the eastern Bering Sea (2001-present). Principal Investigators - Robert A. McConnaughey and Stephen Syrjala (AFSC - RACE Division)
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Last updated: October 2007

A systematic framework for assessing mobile fishing gear effects. Principal Investigators Robert A. McConnaughey and Cynthia Yeung (AFSC – RACE Division)
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Last updated: October 2008

To some degree, our understanding of fishing gear impacts is constrained by the experimental methods being used. In general, the process of understanding mobile gear effects has three distinct phases. It begins with the identification of changes caused by gear contact, followed by controlled studies to determine the ecological effects and, ultimately, decision making based on some form of cost-benefit analysis. Nearly all of the research to date has targeted the specific changes in benthic invertebrate populations that occur when mobile fishing gear, particularly bottom trawls, contact the seabed. This worldwide focus on benthic invertebrates reflects their limited mobility and vulnerability to bottom-tending gear, and observations that structurally complex seabeds are an important element of healthy productive benthic systems. Effects are typically measured as changes in abundance or community structure. However, despite decades of intensive research, the overall impact of mobile fishing gear on marine ecosystems and, in particular, on fish production is largely unknown. This reflects a need for substantially more research on the ecology of the affected invertebrates and their linkages to managed fish stocks, as well as more systematic studies of disturbance effects. Although certain gross generalities are possible, site-specific results are likely, given variation in the composition of the benthos as well as the intensity, severity and frequency of both natural and anthropogenic disturbances. Because of the manner in which study areas are typically selected, any application of findings to other geographic areas is extremely tenuous. As such, there is a strong need to examine the issue more systematically so that research can move ahead from "case studies" of effects to the more interpretive (i.e. second) phase of investigation. To this end, we are working to identify areas with distinct invertebrate assemblages within which replicated experiments (not samples) could be placed and the aggregate findings applied to the entire area. The approaches being investigated are of two primary types and are detailed in sections that follow: (1) mapping surficial sediments as a physical proxy for invertebrate assemblages, given benthic organisms have demonstrated strong affinities for particular substrates (McConnaughey and Smith 2000; Yeung and McConnaughey 2008; sections: "Infauna community as indicator of essential fish habitat in the southeastern Bering Sea" and "Evaluating single-beam acostics for characterizing groundfish and crab habitats in the eastern Bering Sea") and (2) analyzing spatial patterns of the benthic invertebrates themselves (section: "Spatial and temporal patterns in eastern Bering Sea invertebrate assemblages"; Yeung and McConnaughey 2006). Whereas the former approach has potential advantages in terms of cost and relatively rapid spatial coverage, the latter has clear advantages related to the direct nature of the measurements since, after all, invertebrates are the *de facto* measure of gear effects.

Evaluating a calibrated vertical-incidence echosounder for synoptic seabed classification. Principal Investigators Robert A. McConnaughey and Stephen Syrjala (AFSC – RACE Division)
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Reconnaissance mapping with side scan sonar. Principal Investigators Robert A. McConnaughey and Cynthia Yeung (AFSC – RACE Division)
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Last updated: October 2008

Upon completion of the 2002 bottom trawl impacts study in the eastern Bering Sea, a reconnaissance of Bristol Bay seafloor habitats was undertaken using a high-resolution 455 kHz side scan sonar (Klein 5410). The Klein 5410 side scan sonar system is co-owned with the NOAA Office of Coast Survey. The reconnaissance effort was centered on an 800 mi^2 area of central Bristol Bay that has never been surveyed by NOAA hydrographers or their predecessors. The primary research objective is to identify large homogenous regions that would be the basis for more systematic study of mobile gear effects. Secondary objectives include (1) a comparison of expert and unsupervised classification methods for EFH characterization, (2) a study of walrus feeding ecology, (3) an evaluation of the usefulness of sonar backscatter data for characterizing groundfish distributions, and (4) potential updates of nautical charts for the area.

A 150 m swath of bathymetric data and imagery was collected along survey lines totaling nearly 600 linear miles. The survey intentionally intersected six of the Bering Sea trawl study corridors currently being studied in order to provide a spatial context for these results. In support of coordinated EFH characterization studies in the area, the reconnaissance survey also crossed 18 RACE Division trawl survey stations and followed 78 mi of seabed previously classified using a *QTC View* single beam acoustic system. Imagery was systematically groundtruthed using an underwater video camera and van Veen grab samples. Overall, a great diversity of complex sand-bedforms and other geological features were encountered in the survey area.

A subset of the data was classified using geological (expert) and statistical (unsupervised) methods. A new software product, *QTC Sideview*, uses automated processing techniques to read the data on a line by line basis, segment the imagery, extract features based on pixel intensity and image texture, and classify the segments using multivariate statistics. Thirteen distinct acoustic classes were identified. A geologist identified seven major bottom types: (1) degraded bedforms, (2) hummocky seabed, (3) mixed sediments, (4) sand lenses, (5) smooth seabed, (6) sand ribbons, and (7) sand waves, with subdivisions loosely based on scale and shape of features, acoustic reflectivity, and presence or absence of walrus feeding tracks. There was general agreement, albeit with important differences, between the methods. The statistical classification did not seem to identify the differing scales of bedforms identified by the geologist, nor did it distinguish between sand waves and sand ribbons. On the other hand, the statistical classification used information at the scale of the acoustical wavelength (~3 mm) that may not have been considered by the geologist. Further experimentation with the image patch size chosen for the statistical classification may improve the correlation between the methods.

The distribution of two types of feature associated with walrus foraging were observed: (a) small (<<1 m diameter) shallow pits, often in clusters ranging in density from 5 pits per hectare to 35 pits per hectare; and, (b) more abundant, narrow, sinuous furrows, typically 5 to 10 m long with some reaching 20 m or more. Most foraging marks were in less than 60 m water depth in areas of sandy seafloor that were smooth, hummocky or characterized by degraded bedforms; the absence of foraging marks in other areas may be related, in part, to their more dynamic nature (Bornhold et al. 2005).

Acoustic variables from *QTC* software processing of raw digital backscatter data were used in multiple linear regression to model individual species abundance from bottom-trawl survey data. The acoustic variables are the three Q-values (Q1, Q2, Q3) representing the first three principal components of the data derived from image analysis of backscatter echoes, and a complexity metric (compx) measuring the variance of Q-values in a geographic area. Habitat models for flathead sole (*Hippoglossoides elassodon*), Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*), red king crab (*Paralithodes camtschaticus*), basket star (*Gorgonocephalus eucnemis*), and sponges (Porifera) include acoustic variables as significant predictors. For these six taxa, full models explained 67-86% of variability in abundance, with 9-54% of that total contributed by the acoustic predictors (Figure 134). These results suggest that acoustic data could advance habitat research for some bottom-associated marine species (Yeung and McConnaughey 2008).

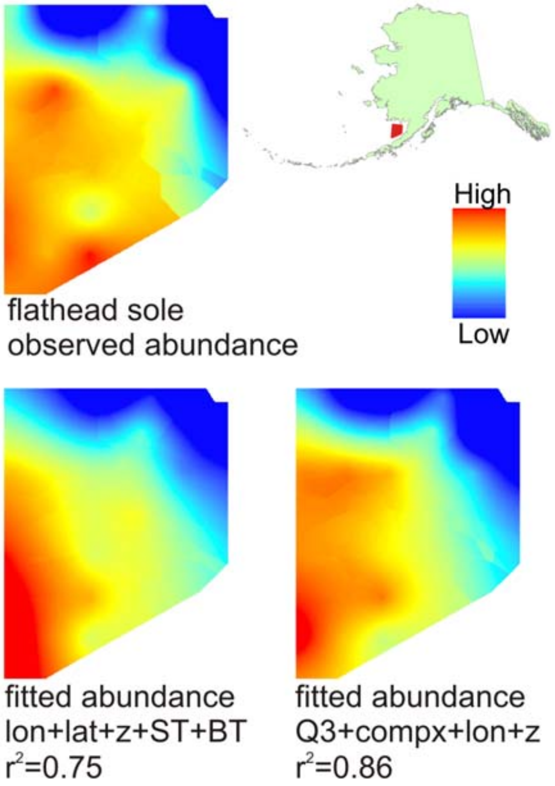

Figure 134. Abundance of flathead sole (log kg/ha) in 2002 modeled by multiple linear regression using only standard environmental variables available from trawl survey (lat = latitude; lon = longitude; z = depth; BT = bottom temperature; ST = surface temperature), and using the best combination of these environmental variables and additional acoustic variables from a 38 kHz vertical-incidence echosounder (which significantly improved the model fit). The Bristol Bay study area is indicated in red in inset map of Alaska.

Infauna as a component of essential fish habitat in the southeastern Bering Sea.

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Basic ecological information on the benthic infauna community, such as species composition, geographic distribution, diversity, and habitat associations, is necessary to gauge the impact of climate and human activities and model species habitat. Infauna community structure is a key indicator of biodiversity and anthropogenic/natural changes in marine environments. Studies on gear effects, for example, employ changes in the species composition and size structure of the infauna community before and after disturbance as a metric (McConnaughey et al. 2000; McConnaughey et al. 2005). Polychaetes are the quintessential indicator group for infauna because of their high dominance and functional diversity. They are also an important component of the marine food web and a necessary input for its energy budgets, constituting substantial portions of the diets of many important commercial species in the EBS (Yang 2007, Yang et al. in review). Since food availability is a strong driving factor in the distribution of marine species, the structure of the polychaete community could be useful in characterizing and predicting favorable habitat for fish/invertebrate predators. Thus, several studies have been initiated to assemble current information on the benthic infauna community in the EBS to support ecosystem and habitat research.

One such study was conducted in conjunction with the FISHPAC acoustic benthic survey in 2006 (http://www.afsc.noaa.gov/RACE/groundfish/hrt/fishpac.php; Yeung et al. in review). Two grab samples were taken at each of 26 selected stations in the EBS. All of these stations lie within the established sampling area of the annual RACE EBS bottom-trawl survey, and many were at fixed trawl stations. The collector was a 0.1 m^2 van Veen grab sampler on a Seabed Observation and Sampling System (SEABOSS), which also had a digital camera to photograph the bottom area where the sample was taken. One sample at each station was used for grain size analysis to aid the interpretation of bottom types and groundtruthing of acoustic data; the other was processed for infauna. Polychaetes were by far the most abundant infauna in the samples and were identified to at least the family taxonomic level. This representative infauna community (at the family level) was described in correspondence with habitat variables such as surficial sediment texture and composition, temperature, and depth. Further, the distribution of the polychaete community was related to the distribution and diet of some polychaete-feeding fishes common in bottom trawls through co-correspondence analysis. The ultimate purpose was to infer trophic interactions between predators and the prey community from co-occurrence, and characterize the habitat where such associations occurred. Trawl species distributions were obtained from the RACE EBS bottom-trawl surveys; diet data were obtained from the REFM food habits database.

In this study, surficial sediment is the most important factor in organizing polychaete community, over the common environmental variables of depth and temperature. Polychaete families that are most frequent in stomach contents, Maldanidae and Nephtyidae, are widely distributed across the EBS shelf in diverse sediment types, as are the principal polychaete-feeding trawl species, Alaska plaice and northern rock sole. So far, there is no clear evidence of any specific spatial correspondence between predator and prey, nor that of predators targeting particular polychaete taxa. Rather, it appears that general polychaete prey availability, a function of abundance, size, and catchability, dictates consumption. Clearer and more conclusive trophic relationships will likely emerge as data accumulate with further studies. The analytical approach demonstrated in this study of combining species-environment analysis of predator and prey communities with analysis of predator stomach content will be useful in elucidating these relationships.

Evaluating single-beam acoustics for characterizing groundfish and crab habitats in the eastern Bering Sea. Principal Investigators Robert A. McConnaughey and Stephen Syrjala.

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Last updated: October 2008

Acoustic technology is particularly suited to synoptic substrate mapping since quantitative data are collected rapidly and in a cost-effective manner. The QTC View seabed classification system (Quester Tangent Corporation, Sidney, B.C.) is capable of background data acquisition during routine survey operations. Echo returns from the seafloor were simultaneously collected at two frequencies (38 and 120 kHz; Simrad EK-500) along a 17,000 km trackline in the eastern Bering Sea (EBS) during a 1999 hydroacoustic fishery survey on the NOAA ship *Miller Freeman* (Preston et al. 2004). Acoustic diversity directly represents substrate diversity. Surface roughness, acoustic impedance contrast, and volume homogeneity are characteristic of different seabed types, and these factors influence echo returns from a vertical-incidence echo sounder. The standard QTC method uses a set of algorithms to extract features from individual echoes. These features include cumulative amplitude and ratios of samples of cumulative amplitude, amplitude quantiles, amplitude histogram, power spectrum, and wavelet packet transform. Principal components analysis (PCA) is used to reduce the full set of features to the three linear combinations that explain a large fraction of echo (seabed) variance. A three-factor cluster analysis can then be used to group the echoes into distinct seabed types based on their acoustic diversity. Variation in continuous seabed properties is thus represented in discrete classes of seabed. The optimum classification scheme for any particular data set strikes a balance between high information content (i.e., many acoustic classes) and high confidence in the assigned class (e.g., if only one class). Clustering methods typically require significant user input to decide which class to split next and when to stop splitting. To overcome this subjectivity and develop a fully-automated objective process, a new application of the Bayesian form of the Akaike Information Criterion (BIC) was developed to guide the clustering process. Because of the computational intensity of the Bayesian method, analytical methods based on simulated annealing have been introduced to improve the program's ability to locate the global minimum (rather than a local minimum) of the BIC function. A total of 14 distinct classes of bottom types (clusters) were identified from the 38 kHz data. Alternatively, the three continuous-valued principal components ("Q-values") may themselves be used to represent acoustic seabed diversity as continuous variables.

Groundfish and benthic invertebrates are not randomly distributed over the continental shelf of the eastern Bering Sea (EBS) and annual trawl surveys reveal patterns of distribution that vary according to species. Substantial interannual variation in these patterns suggests some degree of environmental control. We are developing quantitative habitat models to explain the distribution and abundance of EBS species. Simple models based on readily available data (temperature, depth) are informative, but are generally limited by the correlation between independent variables. Earlier research in the EBS indicates that surficial sediments affect the distribution and abundance of EBS groundfish. However, traditional sampling (grabs, cores) is impractical over large areas, indicating a need for a different sampling strategy. Acoustic tools are suitable for broad-scale surveying and therefore promising, but it is unknown if they measure the relevant properties of sediments.

As a first step toward evaluating the utility of vertical-incidence acoustic sampling and statistical characterization of the seabed, the three Q-values derived from over 6 million echoreturns collected in 1999 were merged with 23 years of RACE trawl survey data for eight species of EBS groundfish and two species of crab, namely: Alaska plaice (*Pleuronectes quadrituberculatus*), yellowfin sole (*P. asper*), flathead sole (*Hippoglossoides elassodon*), rock sole (*Lepidopsetta* spp.), arrowtooth flounder (*Atheresthes stomias*), Pacific halibut (*Hippoglossus stenolepis*), Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*), snow crab (*Chionoecetes bairdi*), and opilio crab (*C. opilio*). A GAM analysis investigated the extent to which the Q-values added to our ability to predict species density (as measured by cpue) over and above the present ability based on available environmental variables. Initially, the transformed cpue values were fit to year (as a discrete factor accounting for annual variation in abundance) and covariates depth, surface-water temperature and bottom-water temperature. Then the Q-values, each fit with its own smooth function, were added to the model individually, in pairs, and all three together. The analysis showed the three Q-values improved the statistical fit of the best models for each species. The final models (also including year, depth, and bottom temperature as independent predictors) explained 28-77% of variability in abundance, including a marginal contribution of 2–13% by the acoustic predictors (Figure 135; McConnaughey and Syrjala, in review). Although the marginal contributions from the basin-scale single-beam acoustic data are relatively small, these findings are consistent with those from a similar study in the Bristol Bay region of the EBS (Yeung and McConnaughey 2008). Taken together, they suggest the relationship is reasonably robust, since substantially different areas of the EBS were studied using distinctly different classes of sonar and backscatter processing, and both parametric and non-parametric methods were used to analyze the data. The most likely explanation for these observed associations between acoustic data and fish abundances is the well-known deterministic effect of sediments on echoreturns from the seabed, combined with the sediment preferences and substrate-mediated food habits of the species examined (McConnaughey and Smith, 2000). Although this "once removed" connection between acoustics and prey distributions has not been examined directly, the utility of acoustic data in habitat models is nonetheless supported for the EBS continental shelf.

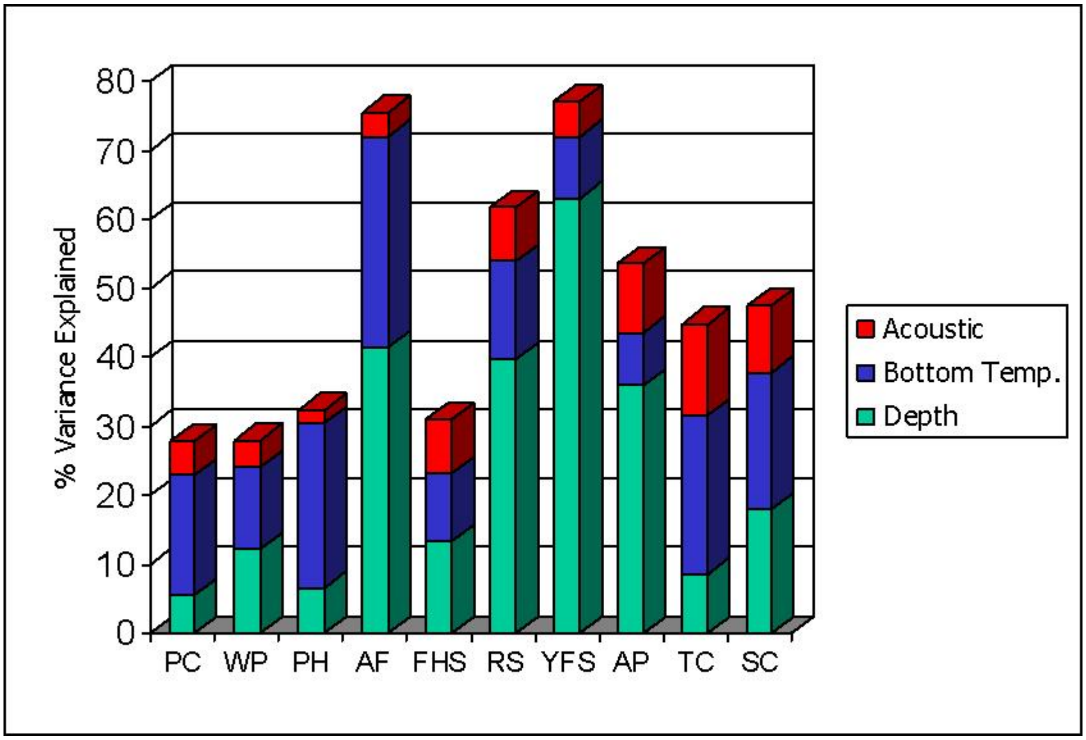

Figure 135. Variability in 1982-2004 trawl-survey estimates of abundance for Pacific cod (PC), walleye pollock (WP), Pacific halibut (PH), arrowtooth flounder (AF), flathead sole (FHS), rock sole (RS), yellowfin sole (YFS), Alaska plaice (AP), Tanner crab (TC) and snow crab (SC) that is explained by the final GAM models

Development of a long-range side scan sonar for EFH research.

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Last updated: October 2008

The broad scope of the EFH mandate requires an efficient process for identifying and mapping habitat. Although research indicates surficial sediments affect the distribution and abundance of many groundfish species, direct sampling with benthic grabs and remote sensing with multibeam echosounders are prohibitively expensive over large areas. The development of a quantitative Long Range Side Scan Sonar (LRSSS; 180 kHz) capable of very broad coverage (>1 km swath) at high tow speeds (100% bottom coverage at 7.5 kts with 12 kts maximum) addresses the need for greater efficiency when mapping and characterizing the seafloor for fisheries and habitat research. In addition to side scan sonar, the LRSSS towfish also carries an independent vertical-incidence echosounder, an integrated multibeam echosounder, sophisticated navigational instruments, and a triplet of optical scatter sensors that measures the concentration of chlorophyll-a (green 470 nm), dissolved organics (red 370 nm) and total particulate concentration (blue 660 nm).

Research and development of the LRSSS and its fiber-optic interface have been progressing since 2004. A prototype LRSSS was successfully deployed and data were acquired during the 2006 FISHPAC experiment in the southeastern Bering Sea (http://www.afsc.noaa.gov/RACE/surveys/cruise_archives/cruises2006/results_FW-FISHPAC2006.pdf). Additional acceptance testing of the LRSSS near Catalina Island and field trials in Puget Sound occurred in 2008. A limited field survey was also conducted in Bristol Bay aboard NOAA ship *Fairweather*. Surveying began on 8 August and *Fairweather* returned to Dutch Harbor on the morning of 10 August. Reconnaissance data were collected along two cross-shelf transects totaling 220 nmi at depths of 80-1300 meters.

Evaluating acoustic backscatter for efficient characterization of Essential Fish Habitat in the eastern Bering Sea (FISHPAC). Robert A. McConnaughey, Cynthia Yeung (AFSC – RACE Division), LT Jay Lomnicky (NOAA Corps, billeted to AFSC – RACE Division).
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The first FISHPAC field experiment was conducted in the southeastern Bering Sea in the summer of 2006 aboard the NOAA ship FAIRWEATHER (http://www.afsc.noaa.gov/RACE/groundfish/hrt/fishpac.php). The scientific objective of the cruise was to evaluate the utility of acoustic backscatter data for characterizing EFH, while simultaneously comparing the performance of five different sonar systems. The five systems included two hull-mounted multibeam echosounders on *Fairweather* (50 kHz, 100 kHz); a high-resolution interferometric side scan sonar (455 kHz), a prototype long-range side scan sonar (LRSSS; 180 kHz), and a vertical incidence echosounder (38 kHz) mounted on the LRSSS towfish. Multiple passes were made along 720 nm of survey tracklines spanning strong gradients of groundfish abundance, as represented in a time series of fixed-station annual trawl survey catches. Three sampling devices - (1) a Free Fall Cone Penetrometer (FFCPT), (2) a SEABed Observation and Sampling System (SEABOSS), and (3) a Towed Auto-Compensating Optical System (TACOS) - were used at selected stations on the tracklines to groundtruth acoustic backscatter and assemble a multifaceted understanding of the seafloor. The performance of each acoustical system will be evaluated based on the degree of statistical correlation between normalized backscatter and fish density. The benefits and costs of each system will be compared to identify the most appropriate system for broad-scale mapping of the Bering Sea shelf. Acoustic data are being processed in collaboration with FISHPAC research partners: the University of New Hampshire Center for Coastal and Ocean Mapping and the NOAA Pacific Hydrographic Branch. FFCPT data processing and sediment grain size analysis have been completed. Infauna identification in collaboration with scientists in the AFSC Resource Ecology and Fisheries Management (REFM) division is also completed. Processing and analysis of sonar data, as well as TACOS and SEABOSS imagery are underway. As part of NOAA's Integrated Coastal and Ocean Mapping effort, modern bathymetry data have been submitted for updating nautical charts of the area (http://www.afsc.noaa.gov/Quarterly/ond2006/divrptsRACE2.htm#fishpac).

Additional field work was conducted in the Bering Sea in summer 2008. Most of the scientific equipment was pre-installed during *Fairweather*'s scheduled Homer in-port (5-8 July). Final mobilization in Dutch Harbor began 21 July and *Fairweather* departed Dutch Harbor on 7 August after reaching minimum staffing level, completing winch repairs, and conducting local gear trials. Surveying began on 8 August and *Fairweather* returned to Dutch Harbor on the morning of 10 August. There were a number of significant accomplishments despite limited sea time. During pre-cruise testing near Dutch Harbor, the capability to deploy both a side scan sonar and the FFCPT to simultaneously collect seabed backscatter, sound velocity profiles and geotechnical properties of sediment (groundtruth) was demonstrated while underway at 6 kts. The project also:

1. Collected new Reson 8111 and 8160 survey data along a previously surveyed (2006 FISHPAC) transect to enable interannual comparison of backscatter characteristics;
2. Completed multibeam and side scan sonar surveys at active hydrothermal features near the port of Dutch Harbor;
3. Collected new infauna samples as part of a continuing project to characterize these communities in the EBS;
4. Collected LRSSS reconnaissance data along two cross-shelf transects totaling 220 nmi at depths of 80-1300 meters;
5. Collected continuous dissolved organics (red 370 nm), chlorophyll-a (green 470 nm), and total particulate concentration (blue 660 nm) data from the pelagic environment along two cross-shelf transects totaling 220 nmi;
6. Acquired hydrographic-quality bathymetry data for updating NOAA nautical charts of an area with outdated or non-existent information; and thus
7. Further demonstrated the feasibility of the multi-mission Integrated Ocean and Coastal Mapping (IOCM) concept.