APPENDIX C

Ecosystem Considerations
for 2003

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

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ECOSYSTEM CONSIDERATIONS –2003
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INDICATOR SUMMARY

The following table is a summary of most of the indicators contained in this document. Eventually, the document will contain a more complete set of indicators. The document still lacks status and trend information for other managed resources such as crab, herring, and salmon. Bycatch information needs to be updated and broken down by region (EBS, AI, GOA). Also, lower trophic level status and trend information is presently lacking in these regions and systematic sampling needs to be initiated to obtain this type of information.

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.

This year, stock assessment scientists will begin 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.

Next year, it is hoped that information in this chapter can be used in habitat and ecosystem assessment chapters to accompany the single-species assessment chapters that traditionally comprise the SAFE. These new chapters could assess aggregate effects of groundfish fisheries on ecosystem and habitat and could result in advice regarding changes in aggregate catch levels (OY cap), species mix of the catch, discard amounts, and systems of closed areas.

INDICATOR	OBSERVATION	INTERPRETATION
Physical Oceanography		
Arctic Oscillation Index	Shift to negative in last few years is not holding. Presently positive	When positive it supports a weak Aleutian low, helps drive a negative PDO pattern. Impending El Nino may not have much effect on N. Pacific and Bering Sea due to negative PDO and positive AO.
Pacific Decadal Oscillation	Cool coastal pattern in GOA from 1998 through May 2002	Indicates shift in PDO to negative phase. Enhanced coastal production in WA-OR and inhibited production in AK
EBS summer temperature	Bottom temperatures were generally warmer and surface temperatures were about average in 2002	Pollock shift more to middle shelf was noted
EBS sea ice extent	Strong southerly winds kept sea ice northward of 60N in 2001, early ice retreat in 2002	Low ice year in 2001, kept middle shelf bottom temperatures warmer last year
AI summer bottom temperature	One of the 3 coldest years thus far detected	Colder than average year
GOA summer temperature	Bottom temperatures in 2001 appeared above average	Bottom temperature at depths 50-150 did not track 2001 PDO trend
Papa Trajectory Index	Surface water circulation in the eastern Gulf of Alaska shows beginning of a southward shift	Southerly drift pattern of Subarctic current
Habitat		
Area closed to trawling BSAI and GOA	More area closed in 2000-2002 compared with 1999	Less trawling on bottom in certain areas though may concentrate trawling in other areas
Groundfish bottom trawling effort in GOA	Bottom trawl time in 2001 was similar to 1998-00 and lower than 1990-1997	Less trawling on bottom
Scallop tows in GOA	Number of tows decreased in 2001/2002 in EGOA but increased in Kodiak relative to 2000/01	Generally decreasing number of scallop tows by area since 1997/98
Longline effort in GOA	Effort levels were about the same in 2000 and 2001	Generally stable or decreasing levels of longline effort in 1990's to present
HAPC biota bycatch in GOA groundfish fisheries	Estimated at 32 t for GOA in 2000	About constant in GOA 1997-2000

INDICATOR	OBSERVATION	INTERPRETATION
HAPC biota biomass indices from GOA bottom trawl survey	Survey may provide biomass index for anemones and sponges. Possible increase or stable anemones observed in central and western GOA	More research needed to understand and interpret trends
Groundfish bottom trawling effort in EBS	Bottom trawl time in 2001 was similar to 1999 and lower than 1991-1997	Less trawling on bottom relative to 1991-97
Groundfish bottom trawling effort in AI	About the same in 2001 compared with 2000, generally decreasing trend since 1990	Less trawling on bottom
Scallop tows in EBS/AI	Number of tows decreased in 2001/02 in western AK	Generally decreasing number of scallop tows since 1997/98
Longline effort in BSAI	Higher in 2001 relative to 2000	Generally increasing levels of longline effort in 1990's to present
HAPC biota bycatch in EBS/AI groundfish fisheries	Estimated at 560t for BSAI in 2000	Lower in BSAI during 2000 relative to 1997-98
HAPC biota biomass indices in EBS bottom trawl survey	Survey may provide biomass index for seapens, anemones, and sponges. These groups have been better identified in the survey in the 1990's to present.	More research needed to understand trends.
HAPC biota biomass indices in AI bottom trawl survey	Survey may provide biomass index for seapens, anemones, and sponges.	More research needed to understand trends.
Target Groundfish		
Groundfish fleet	Total number of vessels actually fishing about the same in 2001 relative to 1999	Relatively stable number of vessels participating.
Groundfish discards	Slightly decreasing rates in 2001 relative to 2000, 1998-2002 amounts are lower than 1997	Fairly stable rates of discarding since 1998.
Total groundfish catch EBS	Total catch about same in 2001 as in 1990's, pollock dominant	Catch biomass about same from 1984-2001
Total groundfish catch AI	Total catch in 2001 shows decline since about 1996, Atka mackerel dominant	Total catch returning to lower levels
Total biomass EBS/AI	Total about same in 2000 as in 1999, pollock dominant	Relatively high total biomass since around 1981
EBS recruitment	Some above average recruitment in early 1990s, mostly below average	Groundfish recruitment is low in mid-late 1990's
BSAI groundfish stock status	In 2001, 0 stocks overfished, 13 not overfished, and 100 unknown	Many major stocks are not overfished, 10 major groundfish stocks have unknown status

INDICATOR	**OBSERVATION**	**INTERPRETATION**
Total groundfish catch GOA	Total catch lower in 2001 than 2000	Total catch similar from 1985-present
Total biomass GOA	Declining abundance since 1982, arrowtooth dominant	Relatively low total biomass compared to peak in 1982
GOA recruitment	Groundfish recruitment in 1990s is mostly below average for age structured stocks, except POP	Groundfish recruitment is low in 1990's
GOA groundfish stock status	In 2001, 0 stocks overfished, 9 not overfished, 93 unknown	Many major stocks are not overfished, 19 major stocks in GOA have unknown status
Forage		
Forage bycatch EBS	72 t in 2000,32-49t in 97-99, mostly smelts	Higher smelt catch rates in 2000
Age-0 walleye pollock EBS	Index area counts were high in 2001 but juveniles were smaller	Higher abundance around the Pribilofs, uncertain survival
Forage biomass indices from EBS bottom trawl survey	Survey may provide biomass index for some species	More research needed to interpret trends
Forage biomass indices from AI bottom trawl survey	Survey may not sample these well enough to provide biomass indices	
Forage bycatch GOA	Ranged from 20-120 t in 1997-2000, over 500t in 2001, mostly smelts	Higher smelt catch rates in 2001
Forage biomass indices from GOA bottom trawl survey	Survey may provide biomass index for sandfish and eulachon, eulachon index increased in 2001 in central and westernGOA	More research needed to interpret trends
Forage biomass indices from ADF&G inshore small mesh survey in GOA	Osmerid biomass index increased in 2001	Increase due primarily to increase in eulachon abundance
Miscellaneous and other managed species		
EBS jellyfish	Large decreases in 2001 and 2002 relative to 2000	Possible return to 1980's low levels of jellyfish biomass
NMFS bottom trawl survey – EBS	2001 trends indicate poachers and echinoderms higher in 1990s, eelpouts lower in 1990s	More research on life history characteristics of species needed to interpret trends
NMFS bottom trawl survey – AI	2002 trends are unclear	More research needed to interpret trends
Crab stock status BSAI	2 stocks overfished (BS Tanner, St. Matt blue king), BS snow crab is rebuilding, 4 stocks not overfished, 14 stocks unknown status	Mixed crab stock status

INDICATOR	OBSERVATION	INTERPRETATION
Scallop stock status	1 stock – not overfished	
Salmon stock status	0 stocks overfished, 5 stocks not overfished, 0 stocks unknown	
Spiny dogfish	Observer bycatch rates in 2000 show mixed trends by area in GOA	Both increasing and decreasing catch rates observed over time by area
Spiny dogfish	IPHC bycatch rates 97 to 2000 show peaks in 1998 but declines since then	Possible distribution changes caused peaks in 1998
Sleeper shark	Mixed trends by area (Observer, IPHC, ADF&G)	Stable or slight increase in most areas in 2000, large increases noted in Kodiak region
Salmon shark	Highest bycatch rates in Kodiak region	Similar catch rates in recent years
ADF&G large mesh inshore-GOA	2001 catch rates of Tanner crab are increasing, flathead sole pollock and cod are higher than prior to the regime shift	Increasing Tanner crab, other species slightly increasing last 4-5 years
ADF&G small mesh inshore survey-GOA	Pandalid shrimp increased in 2001	Possible increase in Kodiak area pandalid shrimp
NMFS bottom trawl survey – GOA	2001 trends indicate possible increase in eelpouts, and starfish in 1990's, unclear trends for jellyfish	More research needed to interpret trends
Prohibited species bycatch	2001 bycatch rates show increase in halibut and chinook salmon, declines in other salmon, herring, other Tanner crab, and red king crab, and little change in bairdi and other king crab bycatch rates relative to 2000	Prohibited species bycatch rates are mixed
Other species bycatch	Other species bycatch was higher in 2000 relative to 1999 but similar to 1997-98 rates	Dominant species in catch were skates and sculpins
Non-specified species bycatch	Non specified species bycatch was higher in 2000 relative to 1999 but was similar to 1997 rate	Dominant species in non specified bycatch were jellyfish, grenadier, and starfish
Marine Mammals		
Alaskan sea lion western stock pup counts	Composite 2001/2002 count showed continuing decline (WGOA only area with an increase)	Kenai to Kiska areas has annual decrease averaging about 4%/yr since 1994

INDICATOR	OBSERVATION	INTERPRETATION
Alaskan sea lion western stock non-pup counts	2002 non-pup counts increased by 5.5% from 2000	First region-wide increase in 2 decades. Average long-term trend 1991-2002 shows decline of 4.2%/yr. Western Aleutians still showing strong decline
Alaskan eastern stock sea lion counts	Overall increase from 1991-2002 was 15.4%	Stable or slightly increasing at average of about 2%/yr
Northern fur seal pup counts	Annual rate of decline on both islands combined during 1998-2002 was 5.2%/yr	Pup production at low levels not seen since 1921 (St. Paul) and 1916 (St. George)
Seabirds		
Seabird breeding chronology	Overall seabird breeding chronology was earlier than average or unchanged in 2000	Earlier hatching times are associated with higher breeding success
Seabird productivity	Overall seabird productivity was average or above average in 2000	Average or above average chick production
Population trends	Mixed: 12 increased, 7 showed no change, 8 decreased	Variable depending on species and site
Seabird bycatch	2001 BSAI longline bycatch is lower than 2000, N. fulmars dominate the catch (GOA longline bycatch is small and relatively constant) Trawl bycatch rates are variable and perhaps increasing	Unclear relationship between bycatch and colony population trends
Aggregate Indicators		
Regime shift scores	Some evidence for regime shift after 1998 but 2001 shows weakening of that evidence	Possible regime shift but more time and biological series needed to see if trend continues
Trophic level catch EBS and AI	Constant, relatively high trophic level of catch since 1960s	Not fishing down the food web
Trophic level catch GOA	Constant, relatively high trophic level of catch since 1970s	Not fishing down the food web
Total catch EBS (excludes salmon)	Total catch about same in 2001 as in 1990's, pollock dominant	Catch biomass about same from 1984-2001
Total catch AI (excludes salmon)	Total catch in 2001 shows decline since about 1996, Atka mackerel dominant	Total catch returning to lower levels
Total catch GOA (excludes salmon)	Total catch lower in 2001 than 2000	Total catch similar from 1985-present

INTRODUCTION

Since 1995, the North Pacific Fishery Management Councils (NPFMC) Groundfish Plan Teams have prepared a separate Ecosystem Considerations section to the annual SAFE report. The intent of the Ecosystems Considerations section is to provide the Council with information about the effects of fishing from an ecosystem perspective, and the effects of environmental change on fish stocks. The effects of fishing on ecosystems have not been incorporated into most stock assessments, in part due to data limitations. Most single species models cannot directly incorporate the breadth and complexity of much of this information. ABC recommendations may or may not reflect discussion regarding ecosystem considerations. This information is useful for effective fishery management and maintaining sustainability of marine ecosystems. The Ecosystems Considerations chapter attempts to bridge this gap by identifying specific ecosystem concerns that should be considered by fishery managers, particularly during the annual process of setting catch limits on groundfish.

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. If you wish to obtain a copy of a previous Ecosystem Considerations Chapter, please contact the Council office (907) 271-2809.

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

The 2000 and 2001 Ecosystem Considerations sections included some new contributions in this regard and will be built upon in future years. It is particularly important that we spend more time in the development of ecosystem-based management indices, which are still poorly represented in this year's document. Ecosystem-based management indices should be developed that 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 non-extractive uses.
4. Maintain the concept that humans are components of the ecosystem.

Ecosystem Considerations sections from 2000 to the present are available on the Alaska Fisheries Science Center website at: http://www.afsc.noaa.gov/refm/reem/Assess/Default.htm.

WHAT'S NEW IN ECOSYSTEM-BASED MANAGEMENT?

Incorporating Ecosystem Considerations in to Individual Stock Assessments

Contributed by Pat Livingston

Last year it was proposed to the NPFMC Groundfish Plan teams that the Ecosystem Considerations Chapter of the SAFEs include an assessment component beginning in 2002. The assessment would need to be done by the experts actively involved in assessing the ecosystem component of interest. Below is outlined a proposed assessment procedure for including ecosystem considerations in individual groundfish stock assessment chapters. The proposed assessment procedure also follows the NMFS conservation recommendation in the November 30,2000 Comprehensive Biological Opinion to have a more comprehensive groundfish stock assessment process that considers a variety of ecosystem issues on a fishery-by-fishery basis. These additions to each stock assessment chapter might be used by the Plan teams to change the allowable biological catch recommendation or the time/area allocation of catch based on ecosystem factors.

The present structure of groundfish stock assessment chapters has the following main sections:
INTRODUCTION
FISHERY
DATA
ANALYTIC APPROACH
MODEL EVALUATION
RESULTS
PROJECTIONS AND HARVEST ALTERNATIVES

Occasionally a stock assessment author might add a section called OTHER CONSIDERATIONS that briefly discusses predator-prey relationships. This year it is suggested that authors add a new section entitled ECOSYSTEM CONSIDERATIONS at the end of the chapter. Within this section, authors should consider three subsections: 1) Ecosystem Effects on Stock, 2) Fishery Effects on the Ecosystem and 3) Data gaps and research priorities. These subsections would provide information on how various ecosystem factors might be influencing their stock or how the specific stock fishery might be affecting the ecosystem and what data gaps might exist that prevent assessing certain effects.

Stock assessment authors would be encouraged to rely on information in the Ecosystem Considerations chapter to assist them in developing stock-specific analysis and recommending new information to the Ecosystem Considerations chapter that might be required in future years to improve the analysis. Time-series that are in the Ecosystem Chapter would be referred to by the author and not duplicated in their chapter. In cases where the authors have time-series or relationships that are specific to their stock, that information should be in their assessment chapter and not in the Ecosystem chapter.

In the ECOSYSTEM EFFECTS ON THE STOCK section, there are several factors that should be considered for each stock. These include:

1) Prey availability/abundance trends (historically and in the present and foreseeable future). These prey trends could affect growth or survival of a target stock.

2) Predator population trends (historically and in the present and foreseeable future). These trends could affect stock mortality rates over time.

3) Changes in habitat quality (historically and in the present and foreseeable future). These would primarily be changes in the physical environment such as temperature, currents, or ice distribution that could affect stock migration and distribution patterns, recruitment success, or direct effects of temperature on growth.

In the FISHERY EFFECTS ON THE ECOSYSTEM section, the following factors should be considered:

1) Fishery-specific contribution to bycatch of prohibited species, forage (including herring and juvenile pollock), HAPC biota, marine mammals and birds, and other sensitive non-target species (including top predators such as sharks, expressed as a percentage of the total bycatch of that category of bycatch.

2) Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components.

3) Fishery-specific effects on amount of large size target fish.

4) Fishery-specific contribution to discards and offal production.

5) Fishery-specific effects on age-at-maturity and fecundity of the target species.

6) Fishery-specific effects on EFH non-living substrate (using gear specific fishing effort as a proxy for amount of possible substrate disturbance).

Authors are advised to summarize the results of these analyses into a table as shown below:

Table X. Analysis of ecosystem considerations for STOCK NAME and the STOCK NAME fishery.

Indicator	***Observation***	***Interpretation***	***Evaluation***
ECOSYSTEM EFFECTS ON STOCK			
Prey availability or abundance trends	summarize the past, present and foreseeable future trends	provide interpretation of how the trend affects the stock	indicate whether the trend is of : no concern possible concern definite concern
Predator population trends			
Changes in habitat quality			

Indicator	*Observation*	*Interpretation*	*Evaluation*
FISHERY EFFECTS ON ECOSYSTEM			
Fishery contribution to bycatch	summarize the past, present and foreseeable future trends	provide interpretation of how the trend affects the ecosystem	indicate whether the trend is of : no concern possible concern definite concern
Prohibited species			
Forage (including herring, Atka mackerel, cod, and pollock)			
HAPC biota (seapens/whips, corals, sponges, anemones)			
Marine mammals and birds			
Sensitive non-target species			
Fishery concentration in space and time			
Fishery effects on amount of large size target fish			
Fishery contribution to discards and offal production			
Fishery effects on age-at-maturity and fecundity			

Aggregate effects of all groundfish fisheries on the ecosystem should be considered in a separate Ecosystem Assessment Chapter. The format of this chapter will be developed in 2003 and an initial draft will be presented to the Plan teams in Fall, 2003. It is anticipated that the ecosystem assessment will look like the PSEIS draft chapter 4. 9 analysis, which considered predator/prey relationships, energy flow and balance, and diversity as categories for analysis. The development of a Habitat Assessment Chapter will aslo be encouraged. These new chapters could provide advice regarding changes in aggregate catch levels (OY cap), species mix of the catch, discard amounts, and systems of closed areas.

Decision Analysis: Can it Provide an Effective Tool for Fishery Management?

A workshop sponsored by the David and Lucile Packard Foundation

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Decision-making in the fishery management world is driven increasingly by process and by approaches to dealing with uncertainty. Even when adequate information is available, conflicting perceptions and values can push decision processes away from the basis of a factual, defensible record. In resource contexts outside fisheries, management agencies and industries have developed tools to create alternative approaches for risk analysis and decision-making.

Is decision analysis a framework that should be explored further in application to fishery management decision making? To help address this question a workshop on decision analysis was conducted on July 2, 2002 by the National Fisheries Conservation Center in San Jose with support from the Packard Foundation and will be repeated in the fall on the east coast. At the workshop, Mike Sutton of the David and Lucile Packard Foundation in Los Altos asked three dozen fishery managers, scientists, advocates and policy makers to give this question their consideration. The group concluded, at the end of the July workshop that included theoretical instruction, case studies, and hands-on work with decision analysis models, that it should.

The group overall was most comfortable with the application of decision analysis to tactical level issues such as stock assessments, providing a framework for conveying scientific information, and analyzing possible outcomes of alternative action choices. Although participants discussed the potential benefits of decision analysis for examining longer-term, strategic direction, they felt the scope and complexity of the problem at that level was daunting.

Max Henrion of Lumina Decision Systems, Inc. in Los Gatos provided basic instruction in decision analysis theory. He said its most critical function is to guide decision makers in using their own intuition. The technique, Henrion explained, is a combination of quantitative thinking that is logical and analytic, and qualitative thinking, which is intuitive and synthetic. Decision analysts use computer models to list, weight, calculate and compare various decision options and their outcomes or consequences. The technique provides a tool to facilitate decision making among conflicting stakeholders by including all concerns and assigning weights to them.

Astrid Scholz presented an analytical model that is being developed for the west coast groundfish fishery by the Stanford Fisheries Policy Project in cooperation with Ecotrust. The project will attempt to use decision analysis to step back and examine long-term strategic thinking about management of groundfish on the west coast. The group believes it will provide an alternative to the traditional adversarial management process. They will examine alternative strategies including aggressive harvest, environmental protection, support for small coastal communities, and ecosystem based management. Evaluation of each possible strategy would include examination and testing of management actions and outcomes.

Ellen Pikitch of the Wildlife Conservation Society in New York presented a case study on Atlantic bluefin tuna where decision analysis was applied in a fishery context, to examine the relative risks and consequences of two stock assessment scenarios. She said a benefit of using decision analysis was that it provides a way to frame scientific advice in a manner that forces managers to look at the consequences of their decisions. Beth Babcock, also of the Wildlife Conservation Society, presented another case study on the use of Bayesian statistical methods in a decision analysis as a means to include information from diverse sources and forecast probabilities. The method was applied to a stock assessment for large coastal sharks in the Gulf of Mexico, enabling managers to examine the likelihood of population recovery or decrease given alternative management actions.

Although the decision analysis workshop was not designed to produce a consensus outcome, participants expressed agreement on elements such as the worth of exploring decision analysis in fishery management applications, the benefits of the tool in handling scientific uncertainty, and the value of providing sensitivity and risk analysis for stock assessments. There were also several issues on which participants clearly held divergent points of view.

1. Strategic versus tactical applications of D-A in the fishery context. Although the presentation of the Stanford/Ecotrust groundfish model was well-received, participants seemed less comfortable with the wide scope and far-reaching implications of such a model. Numerous commenters stated they did not understand the strategic model as clearly as the tactical one and were not sure of its application in the work they do as managers. Some of the concerns with use of the approach for strategic analysis of large, complex issues were its cost, complexity of the model, the expertise required to design one to handle variables as numerous, for example, as ecosystem indicators, the time (especially given the deadline framework for fishery decision-making), and the difficulty in capturing and displaying long term social and economic benefits. One suggestion was to try to break down the elements of the larger model into component parts for incremental analysis. Another was to use it to focus on particular decisions to fit within resource and time constraints.

2. Use of D-A in analyzing long-term versus short-term actions and consequences. A related concern was how to apply decision analysis in examining long-term benefits and consequences of different management actions. The presenters agreed that it is more difficult than using it for short-term actions for a variety of reasons: questions are not framed to a longer time horizon, it is difficult to measure and quantify long-term social and economic effects, and humans are biased for short-term feedback and have trouble thinking over a longer time horizon. On the other hand, the presenters thought that a formal structure such as that provided by decision analysis can help stakeholders and managers see the longer time horizon and decision consequences more clearly.

3. Implementation of D-A from the top down or the bottom up? Perhaps one of the most striking differences among participants related to their views of how to get decision analysis into practice, reflected by two prevailing scenarios. The “top down” proponents said the use of decision analysis needed to be legislated, codified in regulation, or at least made a priority by top officials at NMFS. Speakers from this view argued for getting buy-in from the National Marine Fisheries Service, getting a directive from NOAA Fisheries’ Assistant Administrator Dr. William Hogarth, or even seeking amendments to the Magnuson Stevens Fishery Management Act. The “bottom up” proponents argued that existing authority in M-S FCMA, California’s Marine Life Protection Act and fishery management statutes, National Environmental Policy Act and other administrative rules and guidance provide sufficient authority to begin using decision analysis now. Use of decision analysis and Bayesian statistical analysis in the tuna and shark cases provides some evidence that this is the case. Speakers from this group feared that making decision analysis into a legislative or regulatory mandate would torpedo it from the outset by galvanizing opposition to another new idea or procedural requirement. They advocated incremental application of the model and approaches immediately in ongoing processes, and in fact, managers from California Fish and Game already have sought follow-up advice on model development from Max Henrion.

Participants highlighted several benefits of using the approach in the fishery management context during discussion, including identifying stakeholders’ values and objectives, creating a more transparent record and basis of decisions, and providing a framework for presenting and analyzing scientific information and its uncertainties. Participants agreed that, while the approach would not remove disagreements or litigation, it could provide a framework for examining how decisions are made, and whether they increase or reduce risks to fish and fishing communities.

Recommendations to the Packard Foundation to consider as possible next steps were to:

- Instruct more decision makers and analysts in the technique.
- Use decision analysis in ongoing processes, such as analyses conducted in environmental impact statements.
- Provide resources for modeling and application of decision analysis in ongoing decision processes.
- Scale the tool to be used for small, tractable increments of decision-making.
- Develop a model and a process to demonstrate how stakeholder participation in decision analysis can be used to articulate values and objectives for fishery management, and then use the model to instruct other managers and stakeholders interested in using the technique.
- Examine past decisions using decision analysis to see whether its approaches for incorporating uncertainty and risk, and displaying the consequences of alternative actions, would have led to different decisions.

Decision Analysis in Fishery Management Context

Pros

- The timing is right to use a new approach because we have the impetus of fishery collapses to jolt and stimulate new thinking and receptiveness.
- D-A provides a framework for working with both scientific information and values-based preferences, thereby avoiding unproductive conflict.
- D-A models provide a mechanism to show dynamic, real-time processes, which could be very useful and illustrative as a procedural step in ongoing decision-making processes.
- If used in an iterative manner, D-A can help build support for a decision as well as refine the analysis of alternatives.
- Displays the elements of decision making within a concrete structure.
- D-A not only recognizes uncertainty, but provides tools for incorporating it in modeling and using it to clarify consequences of alternative measures.
- D-A creates avenues for bringing different scientific views, hypotheses and information to the table and integrating them into one analysis.
- D-A helps to explain how decisions are linked and shows the end results of various options.
- D-A highlights the sources of critical differences in outcomes and values, thereby providing a framework for negotiation and potential conflict resolution.
- As a result of these features, D-A is well suited to the analysis of alternatives required by NEPA.

Cons

- There is a lack of awareness of the approach, and stakeholders and decision makers are skeptical of models and “black boxes.”
- It can take time and significant resources to implement, and requires expertise, software and hardware.
- Current processes and fishery management participants have had difficulty framing questions and stating consensus objectives. It will be difficult to develop alternatives to examine in a decision analysis framework unless D-A techniques and facilitation are used at the outset to articulate agreed objectives, issues or concerns.
- Not all interest groups want openness, and the transparency of D-A makes it harder to justify a bad decision when all the steps to it are laid out.
- It goes against the evolution of technocrat/expert judgement and will be resisted by managers because it will illuminate bad decisions.

- It will make it harder to cut deals.

Staff/Facilitators
Brock Bernstein, National Fisheries Conservation Center
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ECOSYSTEM STATUS INDICATORS

The main purpose of this section on Ecosystem Status Indicators is to provide new information and updates on the status and trends of ecosystem components. This section has two purposes. The first is to bring the results of ecosystem research efforts to the attention of stock assessment scientists and fishery managers, which will provide stronger links between ecosystem research and fishery management. The second purpose, and perhaps the main one, is to spur new understanding of the connections between ecosystem components by bringing together many diverse research efforts into one document. As we learn more about the role that climate, humans, or both may have on the system, we will be able to derive ecosystem indicators that reflect that new understanding.

Physical Environment

Empirical Evidence for a 1998/1999 North Pacific Regime Shift (not updated for 2002)

Contributed by N.J. Mantua (1) and S.R. Hare (2)
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Washington USA.
(2) International Pacific Halibut Commission, Seattle Washington USA.

Anecdotal, indirect, and direct physical evidence suggests to many observers that a number of important physical and biotic changes in the North Pacific took place between 1998 and 1999. In this study we revisit an earlier analysis of 100 empirical indicators for North Pacific climate and fisheries by simply extending the time series in our dataset and reapplying the same analyses used by Hare and Mantua (2000). In spite of a paucity of fishery data for the post-1998 period, there appears to be evidence for changes in the North Pacific that are consistent with a 1998/1999 regime shift. This is perhaps most evident in the time series for PC1, which also captures much of the interdecadal variability associated with the 1976/1977 regime shift.

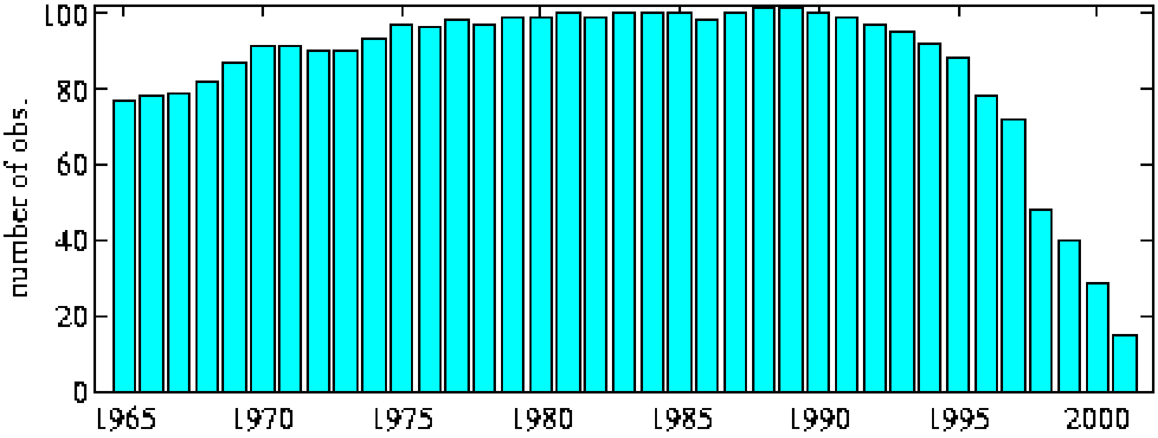

Figure 1. Number of observations in each year. Note that the data available for 1998-2001 is quite limited, with almost no fishery data in our matrix.

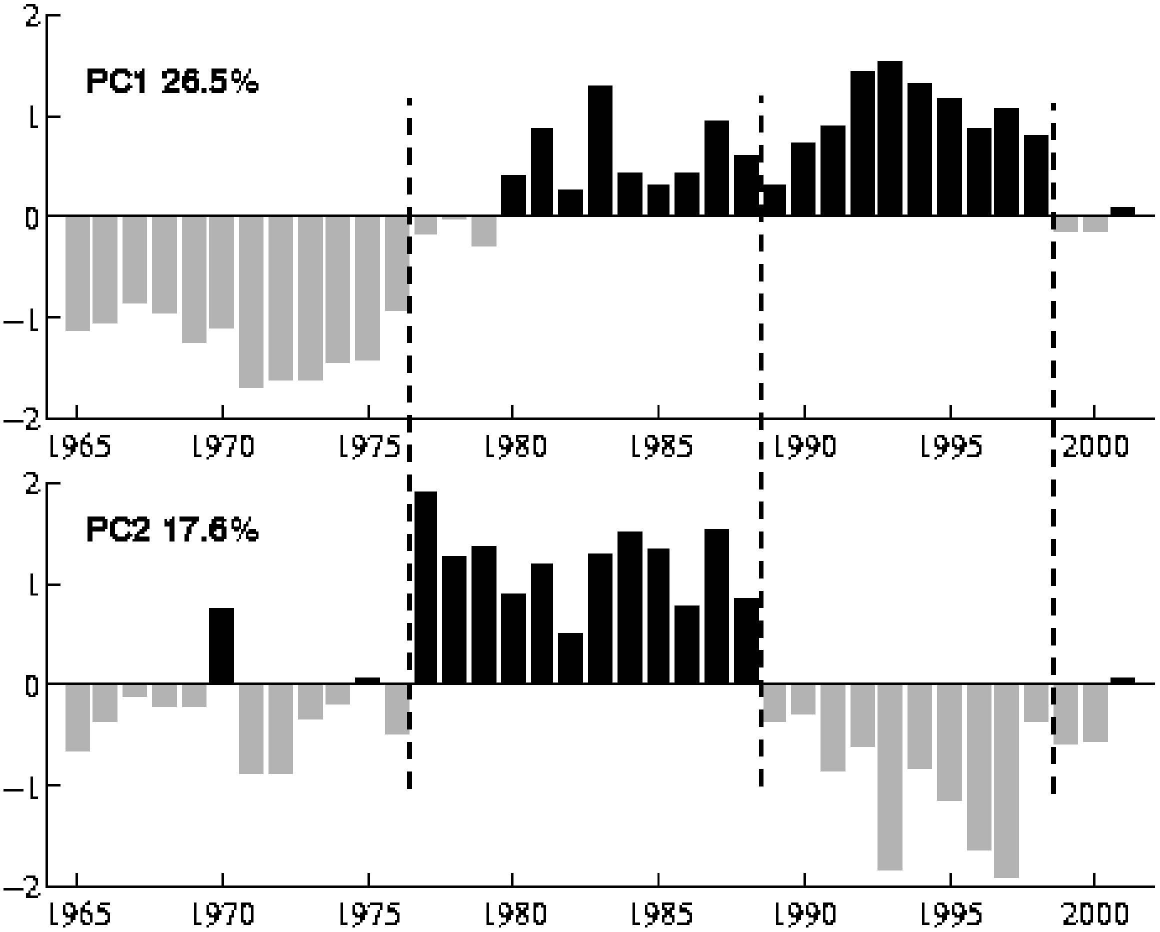

Figure 2. The first two principal component scores from a principal component analysis of the 100 environmental time series. The scores are normalized time series and vertical bars are shown before the data points for 1977, 1989, and 1999.

Difference maps for October-March surface temperatures and sea level pressures (SLP) for the period 1989-98 to 1999-2001 indicate the spatial nature of the changes. For surface temperatures, the data indicate warmer temperatures over most of the Northern Hemisphere for the 1999-2001 period, and cooler winter temperatures especially over the Northeast Pacific and Bering Sea, relative to those observed in 1989-98. The largest sea level pressure changes were recorded over Arctic latitudes for October-March, as well as a change to higher SLPs northeast of Hawaii and lower SLPs over the Gulf of Alaska. Changes for April-September have similar spatial patterns, though generally smaller amplitudes for both fields.

Some of the most remarkable environmental changes in the North Pacific have been identified by Gary Lagerloef's EOF analysis of TOPEX altimeter data for the 1993-2001 period of record (unpublished). The leading EOF of Northeast Pacific sea surface height, shown in the bottom panel, has a time history depicting rapid changes to lower heights in the Northeast Pacific and higher heights in the central Pacific beginning in 1998. The largest changes took place very rapidly, then persisting for the next two years. The sea surface height changes mimic those depicted by October-March surface temperatures.

In spite of the small number of observations for recent years in our data matrix, our analysis finds evidence for coherent changes in North Pacific climate taking place after 1998 with relatively weak signs of persistence over the past 3 years. Surface temperature changes in both summer and winter show the strong cooling observed in the Northeast Pacific along with the even stronger warming centered over the western and central North Pacific. Scores for PC1 show a stronger change after 1998 than those for PC2, however the small number of observations now in our data matrix for the post-1997 period make these results preliminary at best, and potentially misleading at worst. In contrast, the strong large scale changes in sea surface heights noted by Lagerloef's analysis of Topex altimeter data are strongly suggestive of a North Pacific regime-shift taking place sometime late in 1998.

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Ecosystem Indicators and Trends Used by FOCI (partial update for 2002)

Contributed by FOCI

Fisheries-Oceanography Coordinated Investigations (FOCI) comprises physical and biological oceanographers, atmospheric scientists, and fisheries biologists from federal and academic institutions. FOCI studies the ecosystems of the North Pacific Ocean and Bering Sea with the goals of improving understanding of ecosystem dynamics and applying that understanding to aid management of marine resources. In their endeavors, 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 (2002) conditions. An important finding is that interannual variability can be a dominating portion of ecosystem signals. This means that from year to year, ecosystem characteristics can be very different from those expected during a given climate regime.

NORTH PACIFIC REGION (SSTs and PDO)– 2002

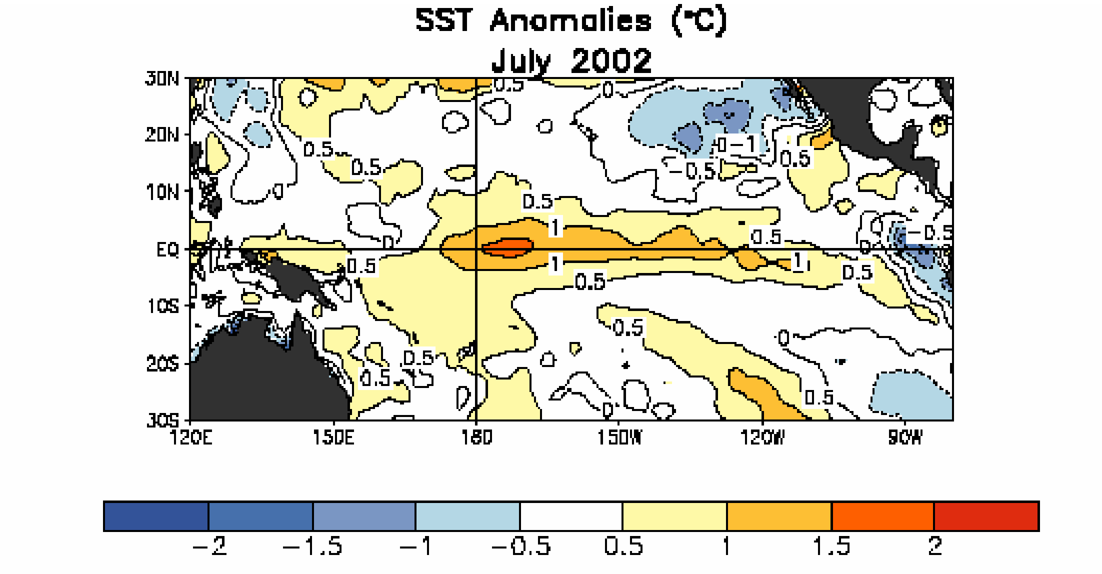

Figure 1. Sea surface temperature (SST) anomalies during July 2002. Departures from average (anomalies) are computed based on the 1971-2000 base period means. Units are °C. (Analysis based on NOAA/PMEL TAO buoy data, NOAA/AVHRR satellite data and ships of opportunity.)

El Niño conditions are developing in the tropical Pacific Ocean (Fig. 1) and are forecast to persist for the rest of this year and into 2003. Effects of the still developing El Niño are transmitted to the North Pacific Ocean by atmospheric teleconnections and oceanic waves traveling northward along the west coast of North America. Because La Niña conditions in 1998-1999 cooled the coastal waters of the Pacific Northwest and Gulf of Alaska, the massive ocean warming that was associated with the 1997-1998 El Niño may not happen. Compare the sea surface temperature (SST) maps for May 2001 and May 2002 (Fig. 2) to see the persistence of the coastal cooling. For June 2002, the entire North Pacific basin and coastal regions experienced negative SST anomalies. The temporal origin of this cool coastal pattern is shown as a change in sign of the Pacific Decadal Oscillation (PDO) from positive to negative (Fig. 3, top)

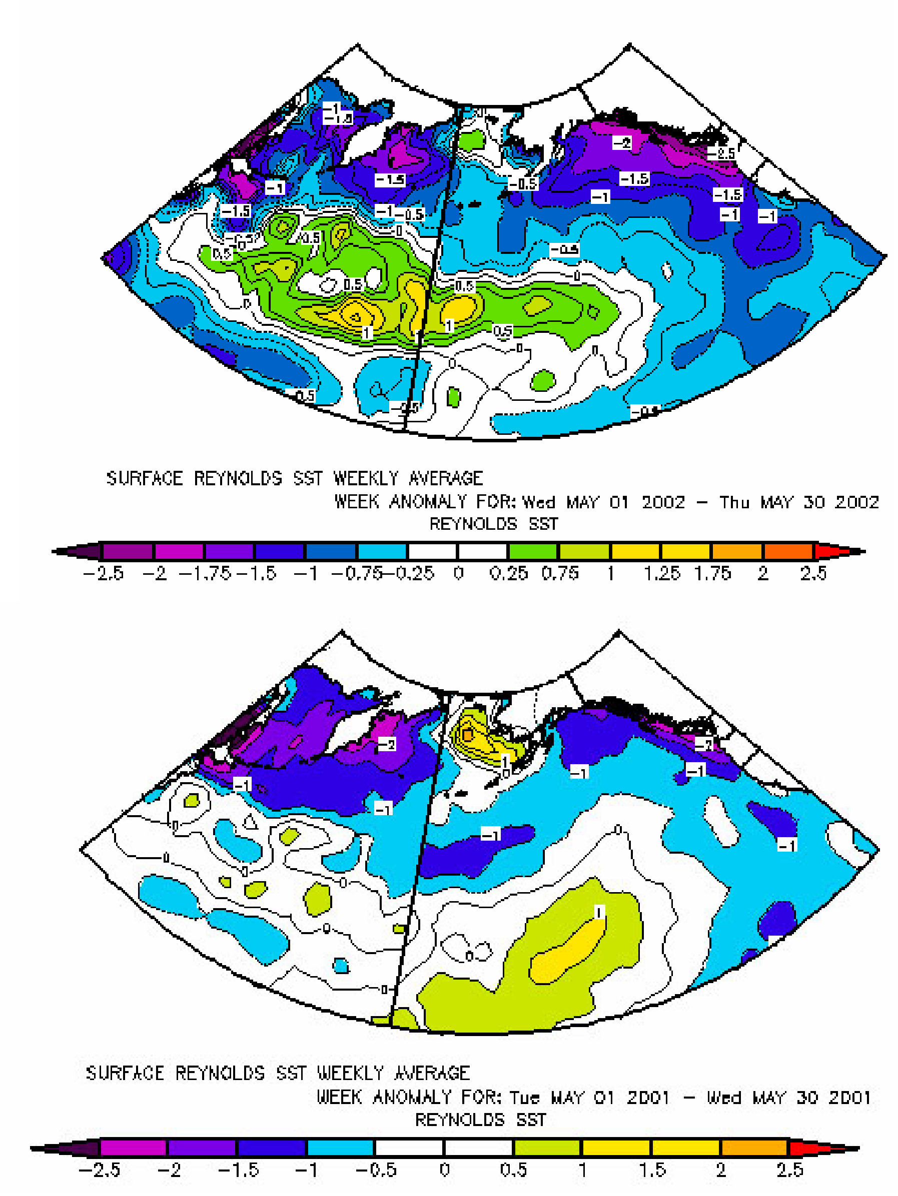

Figure 2. The pattern of sea surface temperature anomalies for May 2001 (top) and May 2002 (bottom) shows persistence of cool coastal water.

after 1998. The negative phase of the PDO is associated with enhanced coastal productivity along Oregon and Washington and inhibited productivity in Alaska. Positive PDO patterns produce the opposite north–south pattern of marine ecosystem productivity. The purported change in phase of the Arctic Oscillation (AO, Fig. 3, bottom) from positive to negative in the last years does not appear to be holding. This implies that the Aleutian Low will be weaker. It is partly the ocean circulation resulting from a strong Aleutian Low that advects relatively warm Pacific basin water to coastal western US, Canada, and Alaska.

Thus, there is conflicting evidence about the state of the North Pacific. An El Niño seems imminent, but its effect on North Pacific and Bering Sea waters may be blunted by the still negative PDO and positive AO.

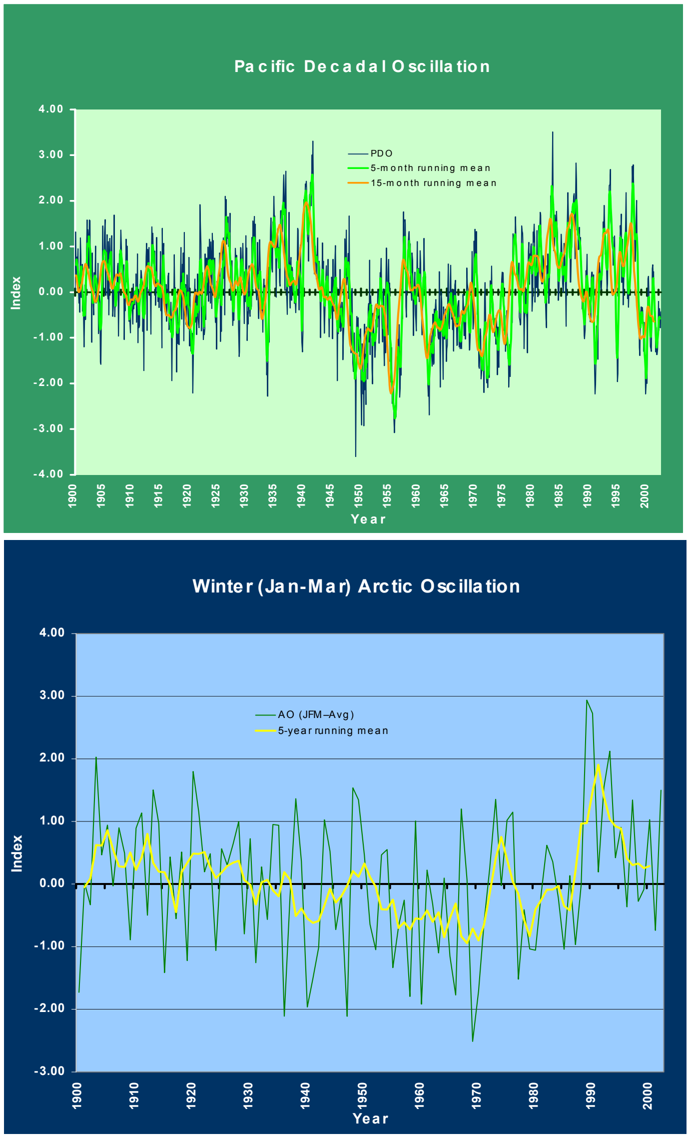

Figure 3. Top: Monthly and smoothed (black line) values of the Pacific Decadal Oscillation (PDO) index, 1900-2001 (updated from Mantua et al. 1997). **Bottom:** Monthly and smoothed (black line) relative values of the Arctic Oscillation (AO) index, 1900-2001.

Ocean Surface Currents – Papa Trajectory Index

Contributed by W. James Ingraham, Jr., Alaska Fisheries Science Center

Ocean surface current modeling with the "Ocean Surface CURrent Simulator" (OSCURS) provides annual indices ocean currents for the North Pacific and Bering Sea, and thus, has contributed to our understand of the year-to-year variability in movements, survival, and spatial overlap with predators of walleye pollock in the eastern Bering Sea (Wespestad et al., 1999). 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) home page, http://www.afsc.noaa.gov/refm/docs/oscurs/default.htm , and clicking on "OSCURS". To run this numerical model just pick your own inputs: 1) a longitude-latitude start-point on the graphic chart; 2) any start-day (0000Z) from January, 1967 to July, 2002 (updated monthly); and 3) a duration, the number of days for surface mixed layer water (about 10 to 30 m deep) to drift. In about 20 seconds up pops a chart showing the vectors of daily water movement strung together in a snake-like red trajectory line giving you the net drift of water from the start-point. By running the same experiment for a number of different years, and analyzing the historical patterns provides some limited forecasting value from the probable reoccurrence of these patterns.

These synthetic data, derived through empirical modeling and calibration, provide insights, which far exceed their accuracy limitations. OSCURS daily surface current vector fields are computed using empirical functions on a 90 km ocean-wide grid based on the U.S. Navy Fleet Numerical Meteorology and Oceanography Center's (FNMOC) gridded daily sea level pressures (1967-2002) with long-term-mean geostrophic currents (0/2000 db) added. The model was tuned to reproduce trajectories of satellite-tracked drifters with shallow (15-20 m) drogues that were deployed from ships in the eastern North Pacific Ocean to track the movement of mixed layer water.

OSCURS' output is in 2 forms; 1) a graphic image chart (.gif) with trajectory in red and a black dot located at the first of each month or 2) an ascii data file of daily, sequential latitude-longitudes of the water movement. Trajectories replicate satellite-tracked drifter movements quite well on time scales of a few months (Ingraham and Ebbesmeyer, 1998). You can produce trajectories for as long as a few days or months or for several years, but their absolute accuracy diminishes with time. Repeating the runs from the same start-point year-by-year gives the time history of surface current variability from that location. This serves one of the main purposes of OSCURS, the comparison with fisheries data at a particular location versus time. See the information article, getting to know OSCURS, for a summary of such experiments I have already run on the NOAA-NMFS-AFSC-REFM home page under status of stocks heading at or go directly to the NOAA-NMFS-PFEL site at http://www.pfeg.noaa.gov/products/las/OSCURS.html for model calculations. Your e-mail feedback is welcome at jim.ingraham@noaa.gov.

An example of a century of the kind of OSCURS' time-series data computed from a single location in the Gulf of Alaska is the Papa Trajectory Index (PTI) in Figure 1 (original figure is from the 2001 Ecosystems Considerations Report; this is the same figure updated with data from the winter of 2001-2002). To create the data series, OSCURS was run 100 times starting at Ocean Station Papa (50° N, 145° W) on each December first for 90 days for each year from 1901 to 2001 (ending February 28 in the following year). The trajectories fan out northeastwardly toward the North American continent and show a predominately bimodal pattern of separations to the north and south, thus, the plot of just the latitudes of the end points versus time (Fig.1) illustrates the features of the data series.

To reveal decadal fluctuations in the oceanic current structure relative to the long-term mean latitude (green horizontal line at 54.74° N), the trajectories were smoothed in time with a 5-year running mean boxcar filter. Values above the mean indicate winters with anomalous northward surface water circulation in the eastern Gulf of Alaska; values below the mean indicate winters with anomalous southward surface water circulation. The 5-year running mean shows four complete oscillations but the time intervals were not constant; 28 years (1903-1930), 17 years (1930-1947), 17 years (1947-1964), and 36 years and continuing (1964-2000). The drift from Ocean Weather Station Papa has fluctuated between north and south modes about every 23 years over the last century and the shift from north to south modes appeared to be overdue in the 2001 report (at least the longest oscillation this century). The time-series has been updated with winter 2002 calculations and shows the beginning of the possible shift. The 5-year running mean is starting to fall but it takes two to three years with the yearly data below the mean to create a zero crossing. Once the 5-year running mean crosses the zero line it usually stays there for several years.

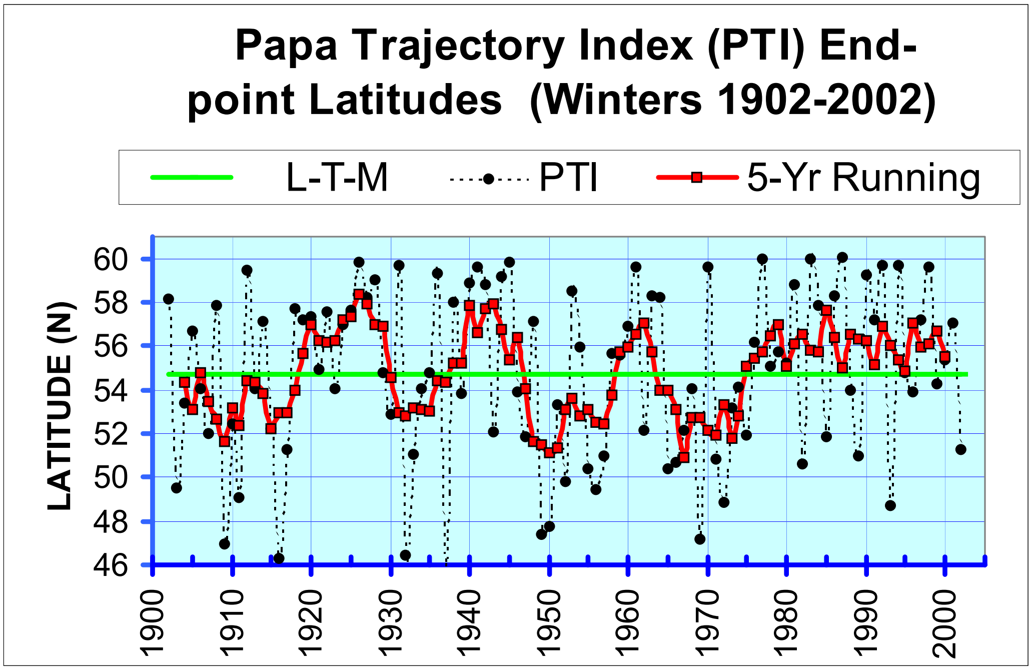

Figure 1. Annual, long-term mean, and 5-year running mean values of the PAPA Trajectory Index (PTI) time-series from winter 1902-2002. Large black dots are annual values of latitude of the end points of 90-day trajectories started at Ocean Weather Station PAPA (50º N, 145º W) each December 1, 1901-2001. 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.

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Wespestad, Vidar G., Lowell W. Fritz, W. James Ingraham, and Bernard A. Megrey. 2000. On Relationships between Cannibalism, climate variability, physical transport and recruitment success of Bering Sea Walleye Pollock, Theragra chalcogramma. ICES *Journal of Marine Science*, 57: 272-278.

GULF OF ALASKA

Gulf of Alaska Survey Bottom Temperature Analysis (no new information for 2002)

Contributed by Michael Martin, Alaska Fisheries Science Center

Groundfish assessment surveys in the Gulf of Alaska (GOA) were conducted triennially between 1984 and 1999 between Islands of Four Mountains (170°W) and Dixon Entrance (132°30'W) at depths between 15 and 500 m. Beginning in 1999, the GOA survey moved to a biennial schedule. In 2001, the area east of about 147°W was not sampled. In 1984, 1987 and 1999, the survey area was extended to the 1000 m contour. The first two surveys, in 1984 and 1987 were conducted jointly with the Fisheries Agency of Japan. Due to vessel availability, the sampling pattern of these two surveys was quite variable (Figure 1). Prior to 1996, the Resource Assessment and Conservation (RACE) Division was responsible for that portion of the survey area west of 144°30'W and the Auke Bay Laboratory (ABL) was responsible for the area east of this line. The surveys in these areas were conducted independently and usually simultaneously. Beginning in 1996, the RACE Division took responsibility for the entire GOA survey effort. These changes in survey area, period and execution have resulted in a quite variable pattern of temperature data collection by date and location (Figure 1), therefore, inter-annual bottom temperature comparisons required consideration of collection date and geographic position for the results to be meaningful.

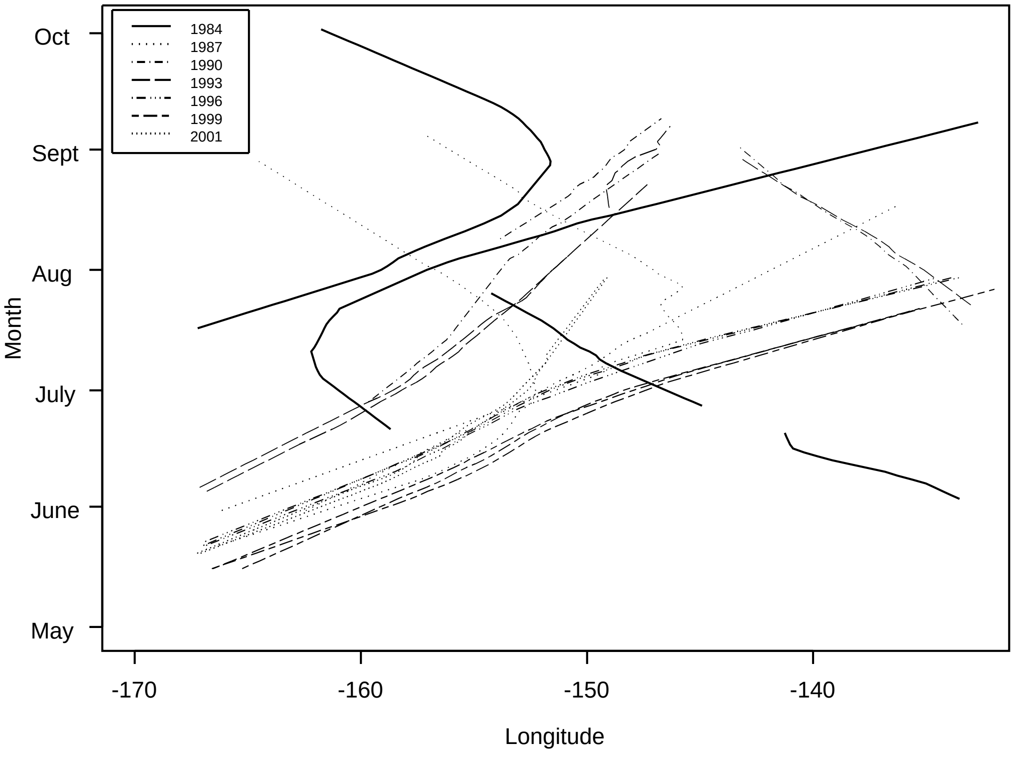


Figure 1. GOA survey data collection by longitude and date.

It is also important to note that the method of temperature data collection has also changed over the years. Prior to 1993, bottom temperature data were collected with XBT's when available, usually after completion of the tow. Beginning in 1993, data were collected using MBT's attached to the headrope of the trawl during each tow.

To examine inter-annual bottom temperature differences, data were binned into depth strata (<50, 51-100, 101-150, 151-200, 201-300, 301-400, 401-500, 501-700 and 701-1000). For each depth stratum, a generalized additive model was constructed with the form:

Bottom Temperature = loess (Julian Date) + loess (Latitude, Longitude)

Each survey year's data was given equal weight in the analysis to account for different sample sizes between years. The mean and standard error of the residuals were then calculated by year to examine inter-annual differences in bottom temperature. The results are presented in Figures 2 and 3. Figure 2 shows the results plotted by depth with year on the x axis, while Figure 3 presents the same information by year with depth plotted on the x axis. Values appearing above the horizontal line can be considered as being warmer than normal, and those below, cooler.

In general, the warmest years noted were in 1984 and 2001, although temperatures in the upper 50 meters were unusually cool in 1984 (but sample size was quite small). Temperatures were also quite warm in 1984 between 51 and 200 meters, with unusually cool temperatures in the shallowest waters, similar to 1987. The coolest years at depths between 51 and 150 meters were in 1990 and 1999. It is interesting to note that the pattern of temperature changes in these depths seems to match the pattern exhibited by the Pacific Decadal Oscillation index developed by Steve Hare and Nate Mantua based on sea-surface temperature anomalies in the North Pacific (plotted as a dotted line in Figure 2). The exception to this pattern appears to be the 2001 data, which appear to be unusually warm.

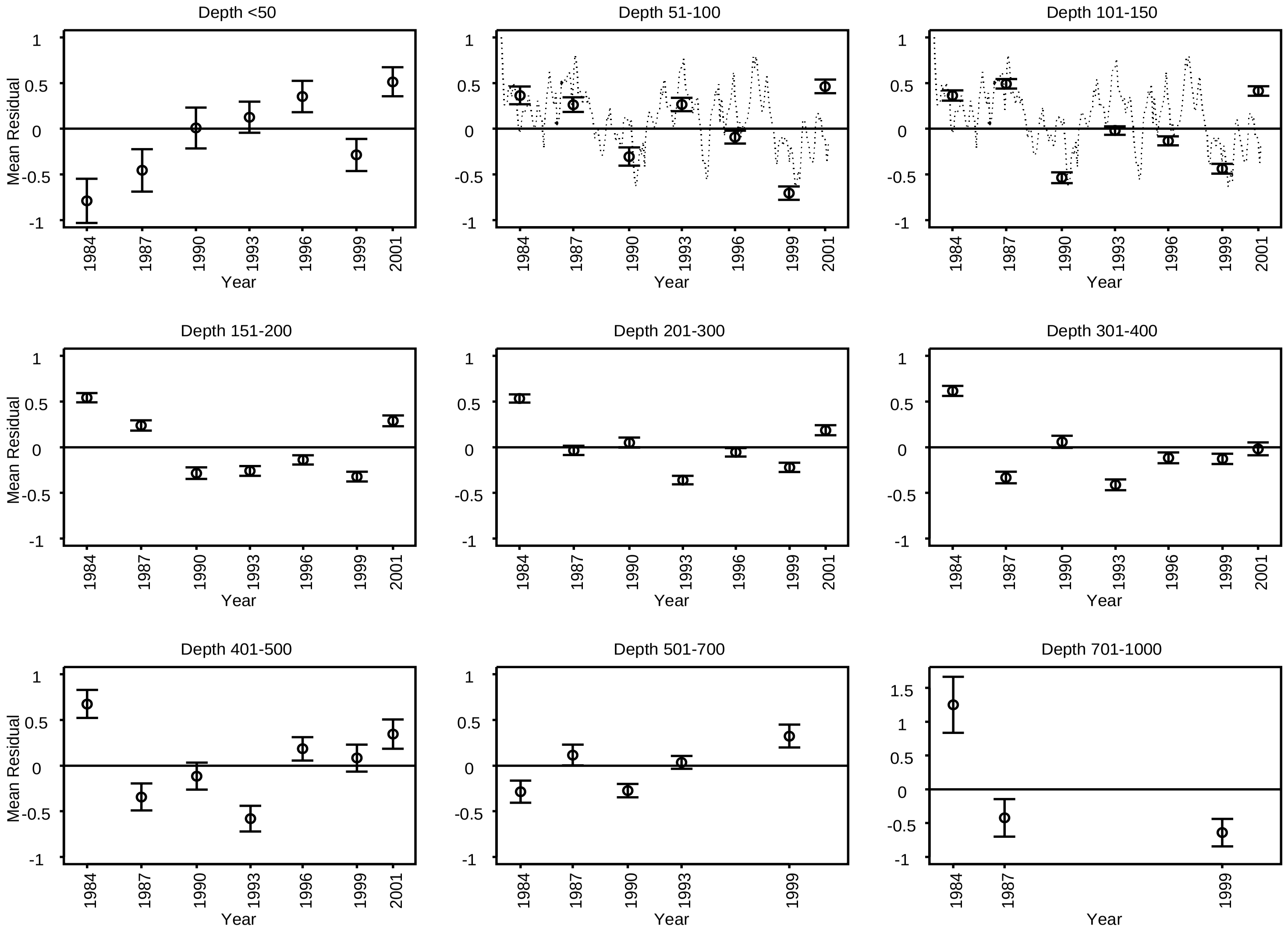


Figure 2. Mean temperature anomalies plotted by year within each depth stratum. Dotted line represents Pacific Decadal Oscillation index. Note expanded scale in 701-1000 m plot.

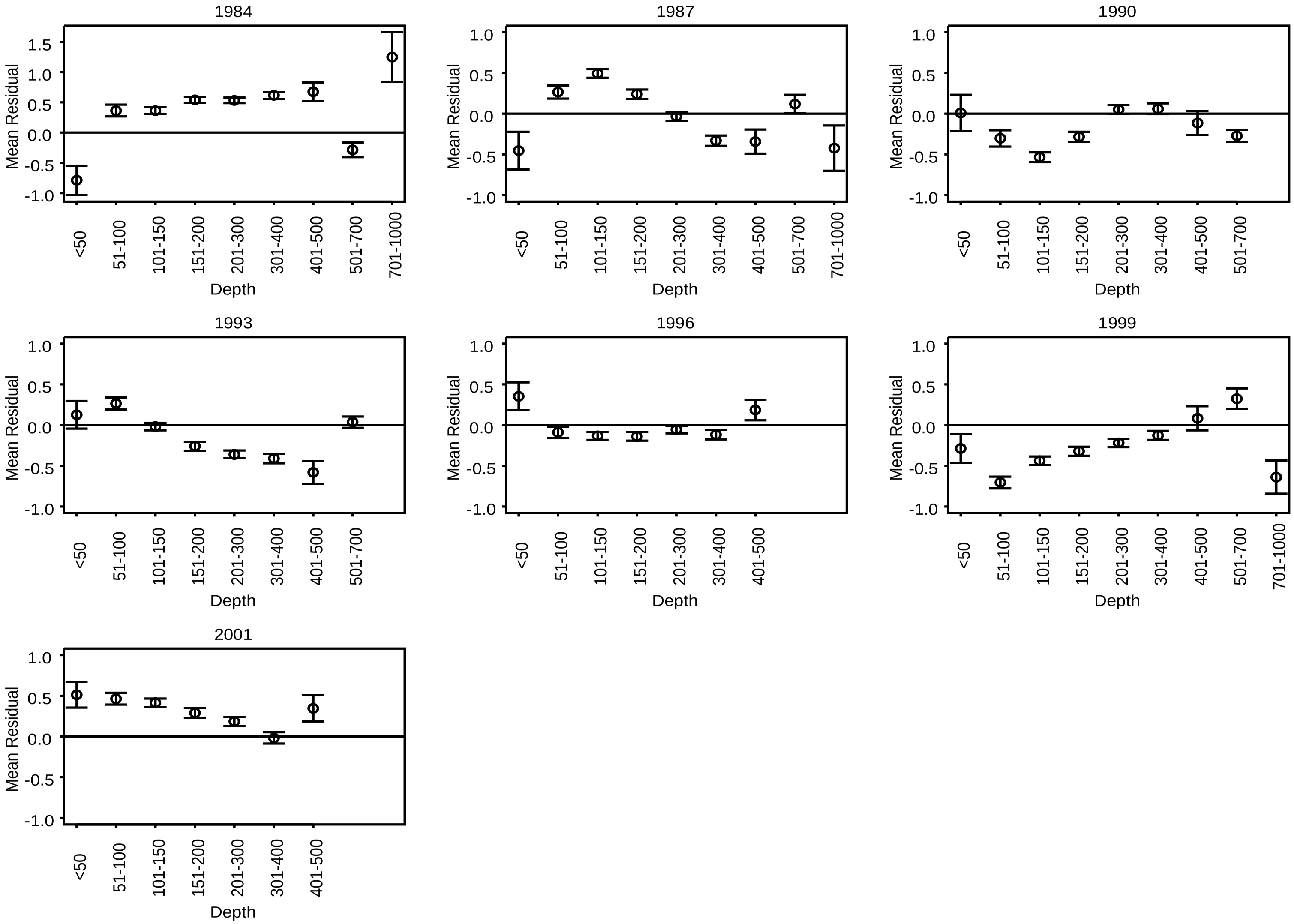


Figure 3. Mean temperature anomolies plotted by depth stratum within each year. Note expanded scale in 1984 plot.

Seasonal rainfall at Kodiak

A time series of Kodiak rainfall (inches) is a proxy for baroclinity and thus an index for survival success of species such as walleye pollock that benefit from spending their earliest stages in eddies. Greater than average late winter (January, February, March) precipitation produces a greater snow pack for spring and summer freshwater discharge into the ACC. Similarly, greater than average spring and early summer rainfall also favor increased baroclinity after spawning. Conversely, decreased rainfall is likely detrimental to pollock survival. FOCI's pollock survival index based on precipitation is shown in Figure 4. 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. Over the last 15 years, the survival potential has been more level. Survival potential dropped in 2002 due to the dry spring. During April 2002, the Kodiak NWS station received only 7% of its average monthly rainfall (based on the 30-year average for April from 1962 through 1991).

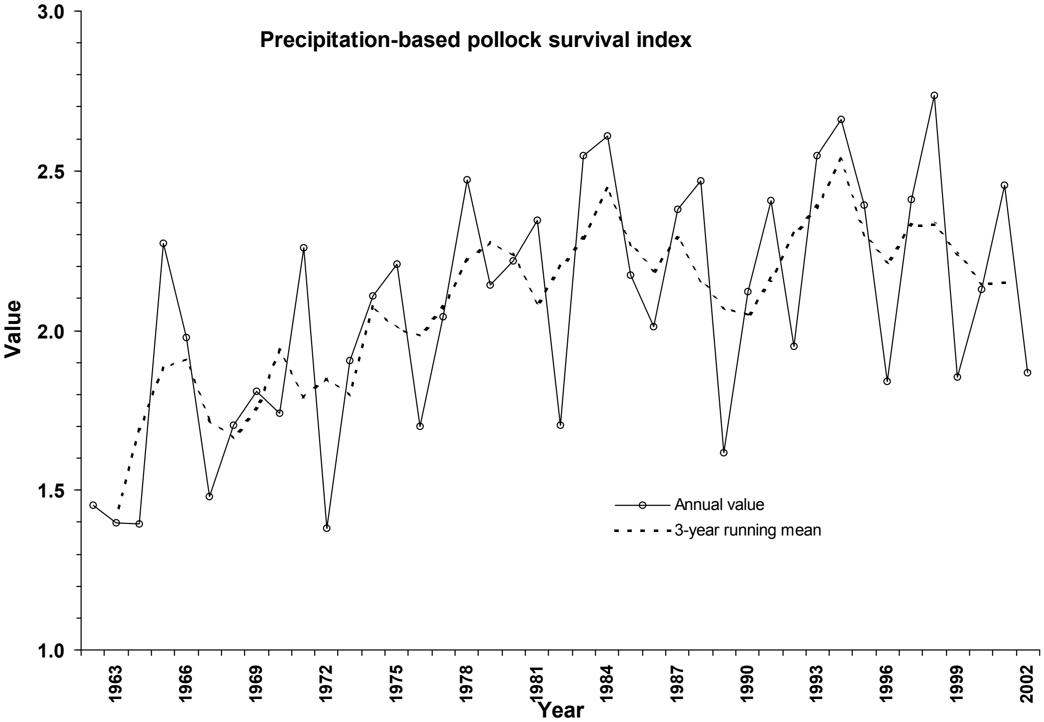


Figure 4. Index of pollock survival potential based on measured precipitation at Kodiak from 1962 through 2002. The solid line shows annual values of the index; the dashed line is the 3-year running mean.

Wind mixing south of Shelikof Strait

A time series of wind mixing energy (W m^{-2}) at [57°N, 156°W] near the southern end of Shelikof Strait is the basis for a survival index (Fig. 5) wherein stronger than average mixing before spawning and weaker than average mixing after spawning favor survival of pollock. 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. Recent survival potential has been high. Monthly averaged wind mixing in Shelikof Strait has been below the 30-year (1962-1991) mean for the last five January through June periods (1998-2002). This may be further evidence that the North Pacific climate regime has shifted in the past few years.

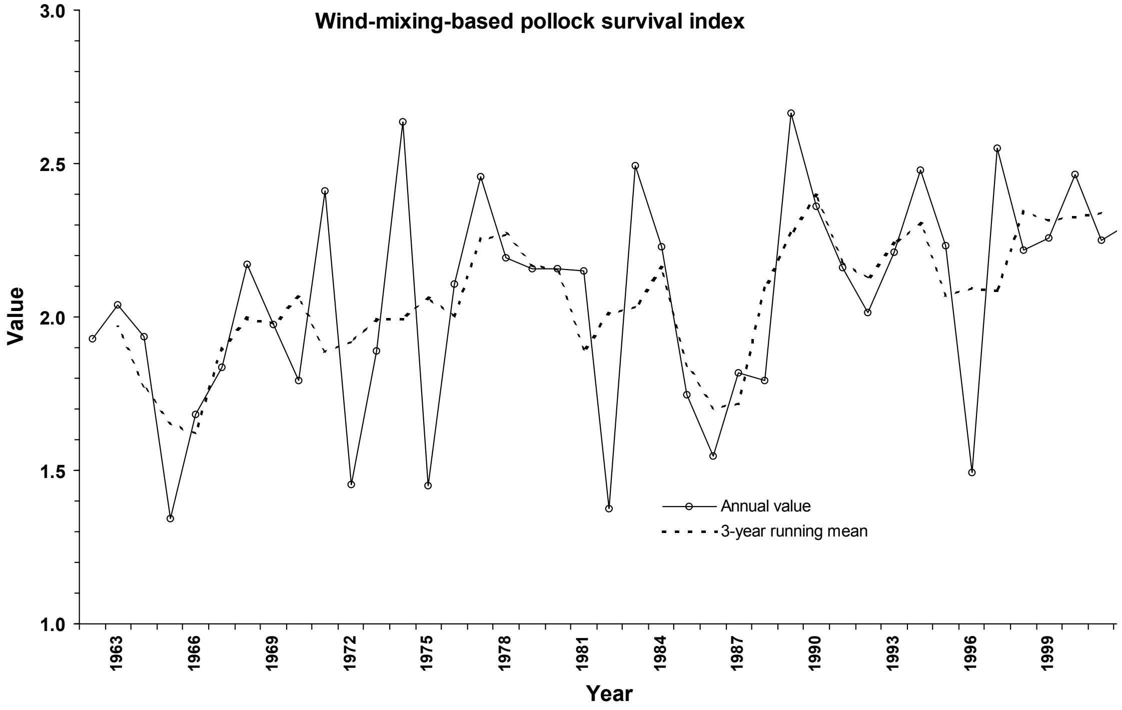


Figure 5. Index of pollock survival potential based on estimated wind mixing energy at a location south of Shelikof Strait from 1962 through 2002. The solid line shows annual values of the index; the dashed line is the 3-year running mean.

Ocean transport in the western Gulf of Alaska

The seasonal strength of the Alaskan Stream and Alaska Coastal Current (ACC) is an important factor for overall productivity on the shelf of the Gulf of Alaska. FOCI uses satellite-tracked drift buoys, drogued at mid mixed-layer depths (~40 m), to measure ocean currents as a function of time and space.

The drifter trajectories shown in Figure 6 are from October 18, 2001. Each red line represents the track of the drift buoy for the past five days. There is strong flow down Shelikof Strait, but outside this region, the flow is convoluted with many small meanders. The complete movies can be downloaded from http://www.pmel.noaa.gov/foci/visualizations/drifter/shel2001.html or http://www.pmel.noaa.gov/foci/visualizations/drifter/aleu2001.html for the Aleutian passes.

In general, the flow of the ACC down Shelikof Strait was weaker than usual from May 15-September 10, 2001. This was caused by weak alongshore winds. Weak flow through Kennedy and Stevenson Entrances results in less vertical mixing and limits the amount of nutrients available in the Shelikof Sea valley. After September 10, a series of strong storms spun up the ACC and resulted in strong flow down Shelikof Strait.

In contrast the Alaskan Stream was well defined, with strong transport from May onward. Flow through the Aleutian Passes was intermittent which is typical. When water flows through the passes, it is vertically mixed, introducing nutrient rich water into the euphotic zone.

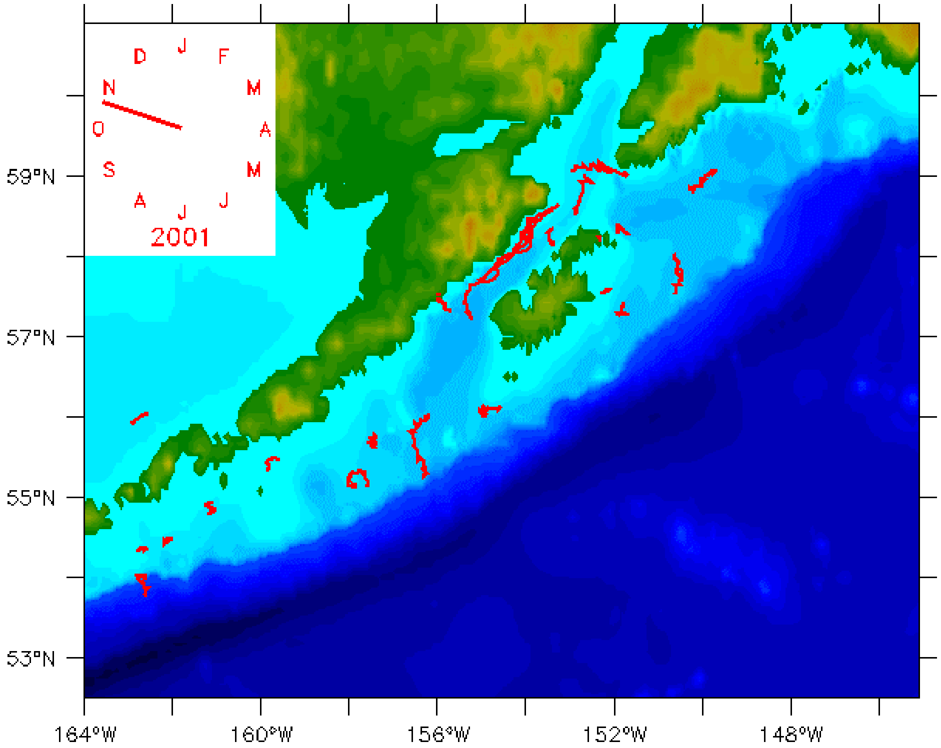


Figure 6. Tracks of satellite-tracked drifters for the period October 14-18, 2001, show sluggish flow on the shelf, except for within Shelikof Strait.

During 2002, flow was again weak in the western Gulf of Alaska. This section will be updated in fall 2002.

EASTERN BERING SEA

Sea ice extent and timing

The extent and timing of seasonal sea ice over the Bering Sea shelf plays an important, if not the determining, role in the timing of the spring bloom and modifies the temperature and salinity of the water column. Sea ice is formed in polynyas and advected southward across the shelf. The leading edge continues to melt as it encounters above freezing waters. The ice pack acts as a conveyor belt with more saline waters occurring as a result of brine rejection in the polynyas and freshening occurring at the leading edge as the ice melts. Over the southern shelf, the timing of the spring bloom is directly related to the presence of ice. If ice is present in mid-March or later, a phytoplankton bloom will be triggered that consumes the available nutrients. If ice is not present during this time, the bloom occurs later, typically during May, after the water column has stratified.

The presence of ice will cool the water column to -1.7°C. Usually spring heating results in a warm upper mixed layer that caps the water column. This insulates the bottom water, and the cold water (<2°C) will persist through the summer as the "cold pool." Fish, particularly pollock, appear to avoid the very cold temperatures of the cold pool. In addition the cold temperatures delay the maturing of fish eggs and hence affect their survival.

The amount of ice cover over the Bering Sea shelf exhibits decadal behavior similar to other climate features. The 1970s were cold, extensive ice years for the Bering. Following the regime shift at the end of the 1970s, the Bering experienced a decade or so of warmer temperatures and less ice. During the 1990s, sea ice coverage has been more extensive, but not as much as in the 1970s. In any of the regimes, strong interannual variability is the norm with sea ice as well as with many other ecosystem responses to physical forcing.

Figure 7 shows the maximum southward extent of ice over the southeastern shelf during the last half-decade (top) and the weekly percent of ice cover between 57° and 58° N during the same period (bottom). Excluding 2001, the maximum ice cover did not differ radically between years. However, the timing of maximum ice extent did. In 2001, as a result of strong southerly winds, ice was not advected southward over the shelf beyond about 60° N. Thus, ice coverage varies immensely on temporal and spatial scales despite the climate regime that characterizes the ecosystem. Again in 2002 (not shown), ice built up rapidly during December and retreated early in the spring. This section will be updated in fall 2002.

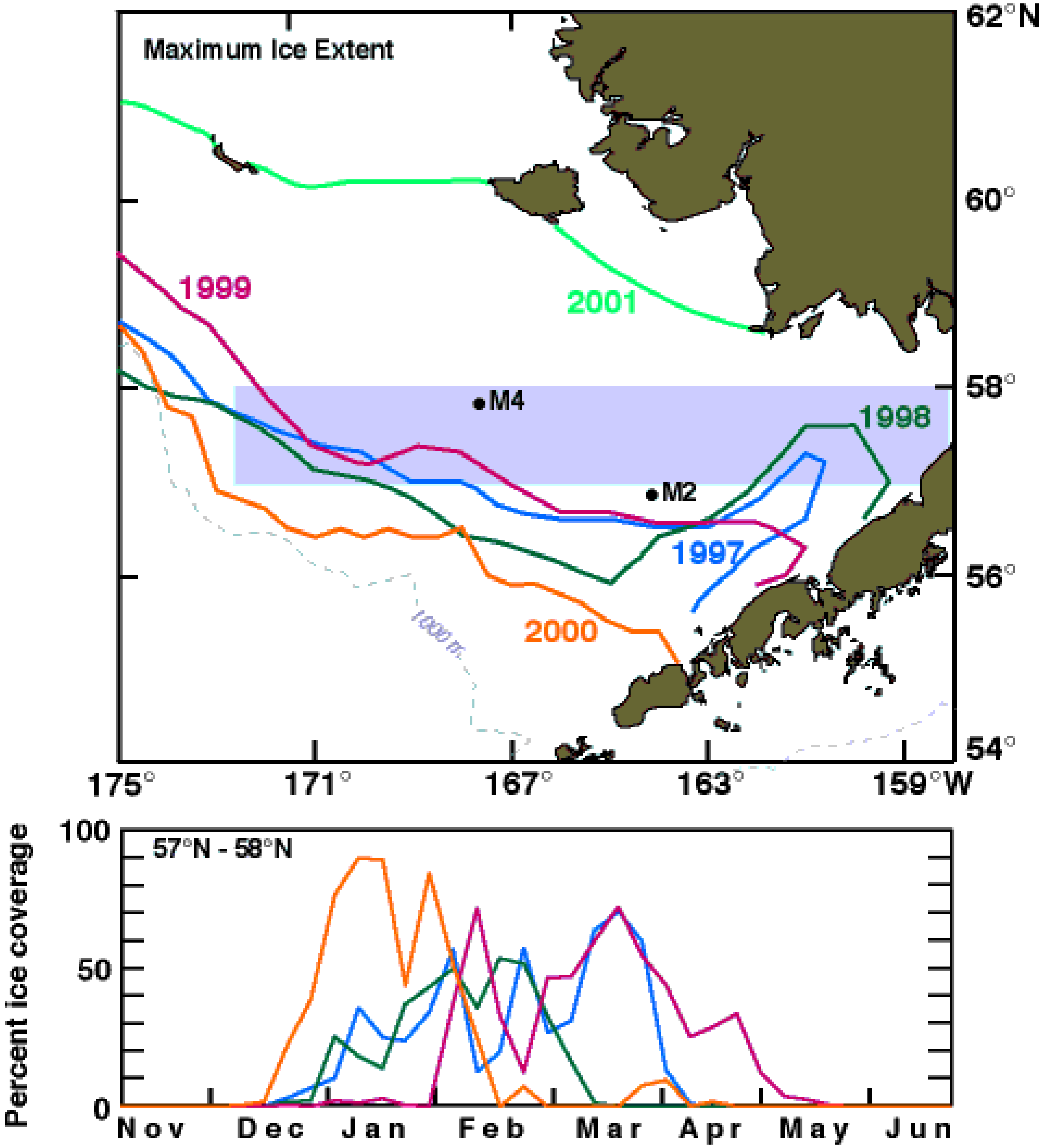
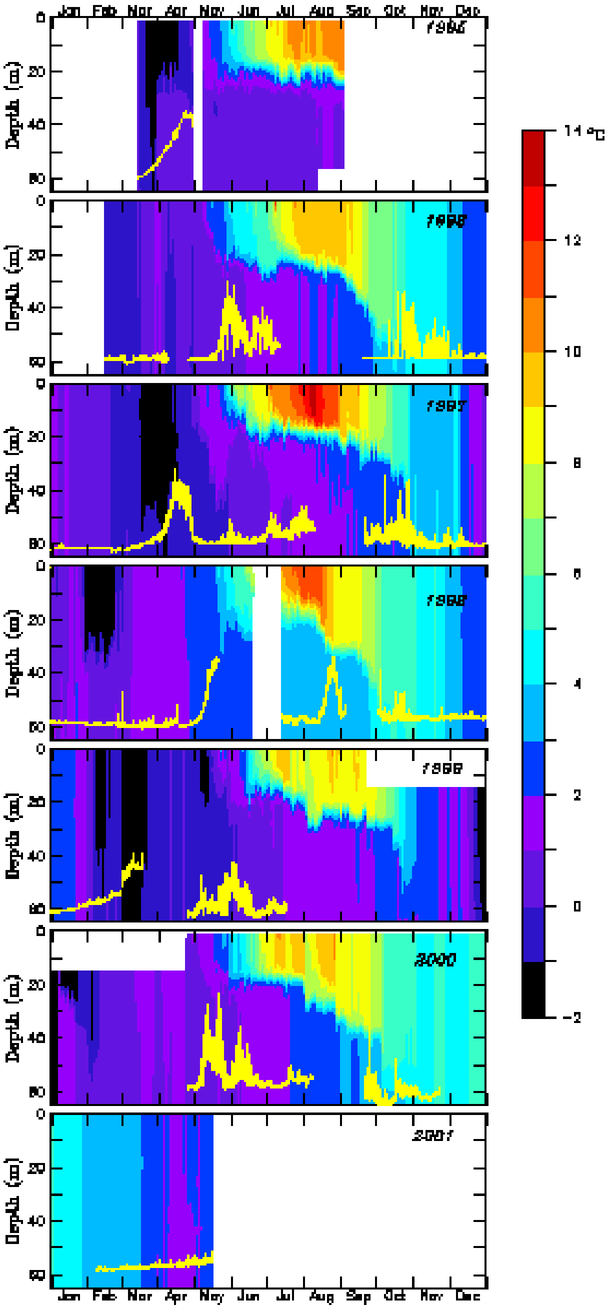


Figure 7. Top: Maximum ice extent during the period 1997-2001. **Bottom:** Weekly percent ice cover of the area indicated by the shaded box in the top figure (57° N – 58°N) for the same 5-year period.

Mooring 2: The cycle in the middle shelf



The cycle in water column temperatures is similar each year. In January, the water column is well mixed. This condition persists until buoyancy is introduced to the water column either through ice melt or solar heating. The very cold temperatures (shown in black in Fig. 8) that occurred in 1995, 1997, 1998 and 1999, resulted from the arrival and melting of ice. Shelf temperature during 1999 was the coldest, well below 1995 and 1996, and approaching the cold temperatures of the negative PDO phase of the early 1970s. During 1996, ice was present for only a short time in February, however no mooring was in place. A phytoplankton bloom occurs with the arrival of the ice pack in March and April. If ice is not present during this period, the spring bloom does not occur until May or June, as in 1996, 1998, 2000, and 2001. The winter of 2001 was particularly warm, with no ice occurring over the southeastern shelf. This section will be updated for 2002 conditions in the fall of 2002.

Generally, stratification develops during April. The water column exhibits a well defined two-layer structure throughout the summer consisting of a 15 to 25-m wind-mixed layer and a 35 to 40-m tidally mixed bottom layer (the cold pool if temperatures are sufficiently low). Deepening of the mixed layer by strong winds and heat loss begins in August, and by early November the water column is again well mixed.

The depth of the upper mixed layer and the strength of the thermocline contribute to the amount of nutrients available for primary production. A deeper upper mixed layer makes available a greater amount of nutrients. In addition, a weak thermocline (more common with a deeper upper mixed layer) permits more nutrients to be “leaked” into the upper layer photic zone and thus permits prolonged production. The temperature of the upper layer influences the type of phytoplankton that will flourish. For instance, warmer sea surface temperatures (>11°C) during 1997 and 1998 may have supported the establishment of an extensive coccolithophorid bloom that has reappeared each year since, despite a return to colder water temperatures.

Summer bottom and surface temperatures- Eastern Bering Sea

Contributed by Gary Walters, Alaska Fisheries Science Center

The annual AFSC bottom trawl survey for 2002 was started on June 2, 2002 and finished on July 24, 2002, very near the traditional period for the time series. In general, temperatures continued to climb from the 1999 record low. The average bottom temperature was 3.27°C, well above the 1982-2001 mean of 2.44°C (Fig. 1). The average surface temperature was also higher at 6.88°C (long term mean 6.58°C), but not as markedly. Bottom temperature increases were evident in all areas (Fig. 2) except the southeast outer domain, just north of Unimak Pass. Bottom temperature anomalies from the long-term station means were positive over the whole shelf except the shelf edge and a few spots in the shallow inner bay (Fig. 3). Maximum anomalies occurred in the middle domain with several stations over +3 degrees. This was also reflected in the distribution of walleye pollock in the bottom trawl survey. When middle domain bottom temperatures are warmer, distributions shift into the area. When the cold pool is dominant, distributions seem to shift to the outer domain.

Surface anomalies reflected the nearness to the long-term mean, where over 200 stations of the 355 nominal count were +/- 1 degree (Fig. 3). Like the bottom trawl results, areas of the middle domain showed the largest anomalies.

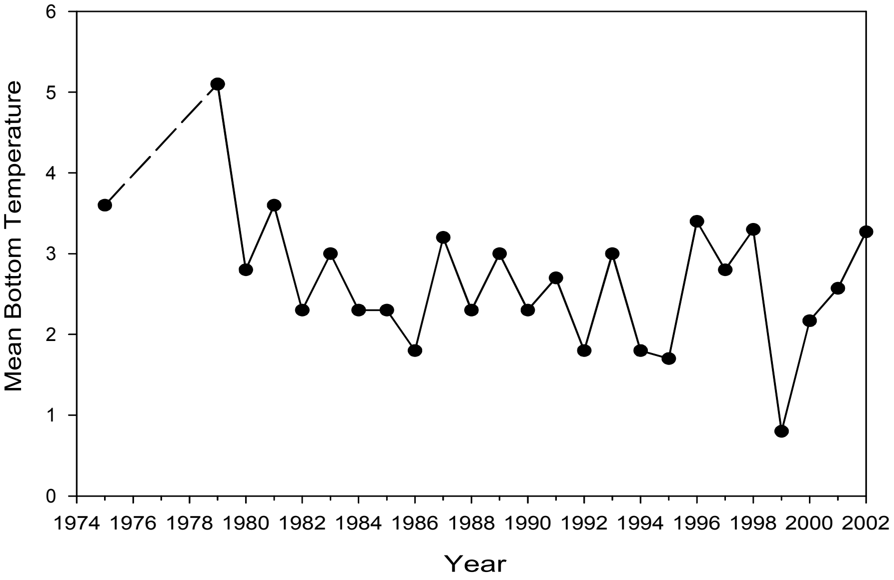


Figure 1. Mean summer bottom temperature (degrees C) in the standard bottom trawl survey area of the eastern Bering Sea shelf, 1974-2002.

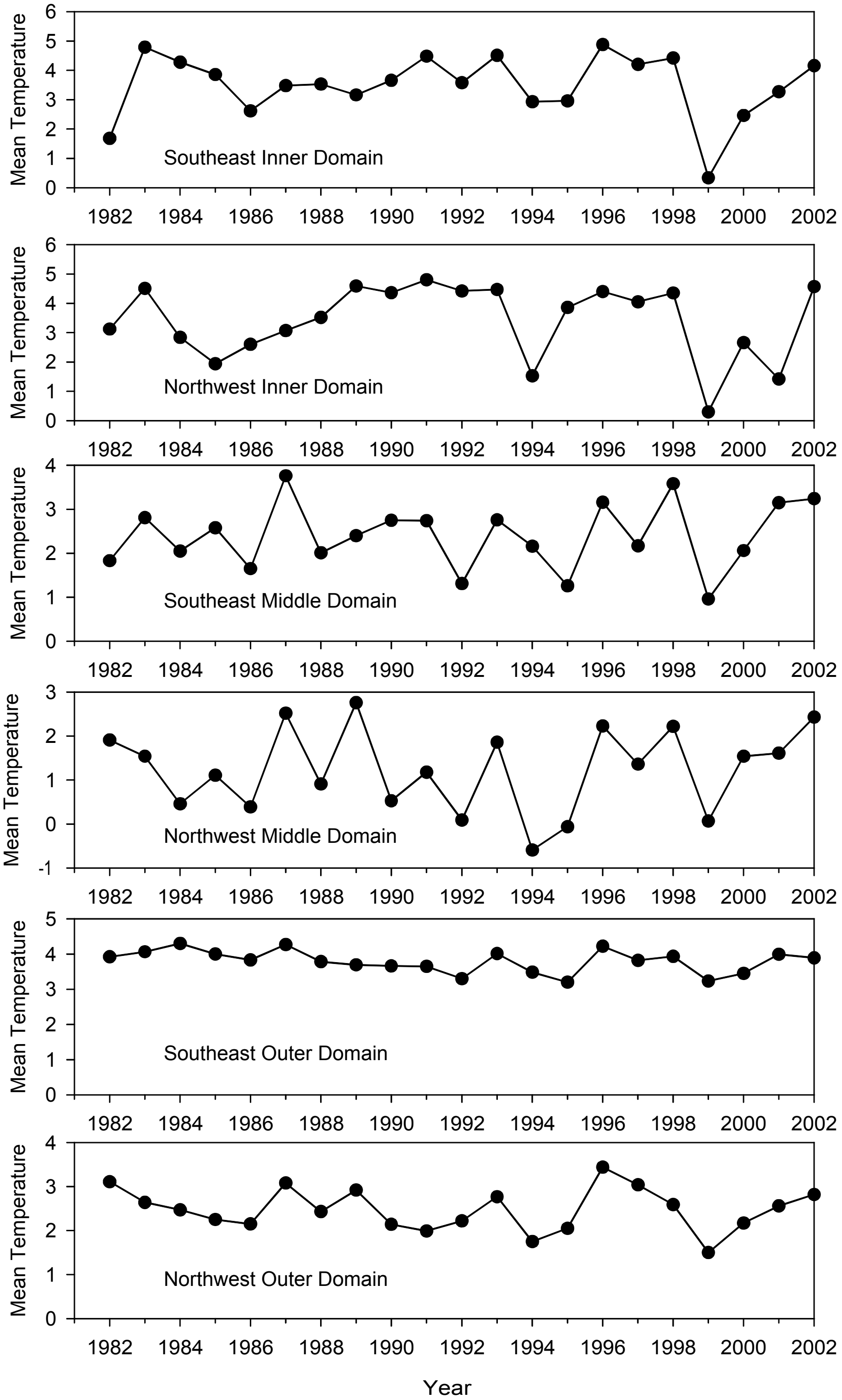


Figure 2. Mean summer bottom temperature (degrees C) by domain in the standard bottom trawl survey area of the eastern Bering Sea, 1982-2002.

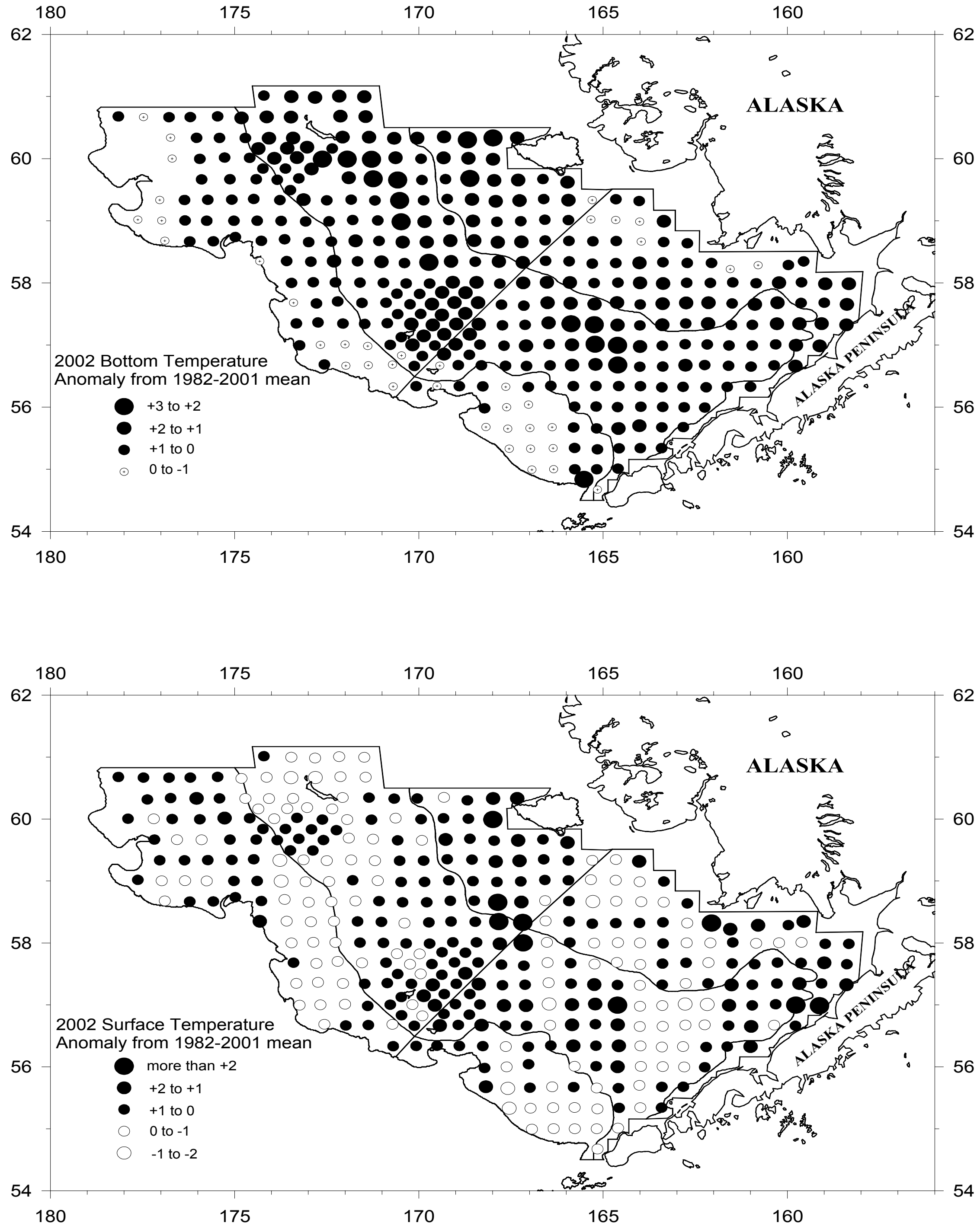


Figure 3. Summer bottom (top panel) and surface (bottom panel) temperature anomalies in 2002 from the 1982-2001 mean at standard bottom trawl survey stations in the eastern Bering Sea.

ALEUTIAN ISLANDS

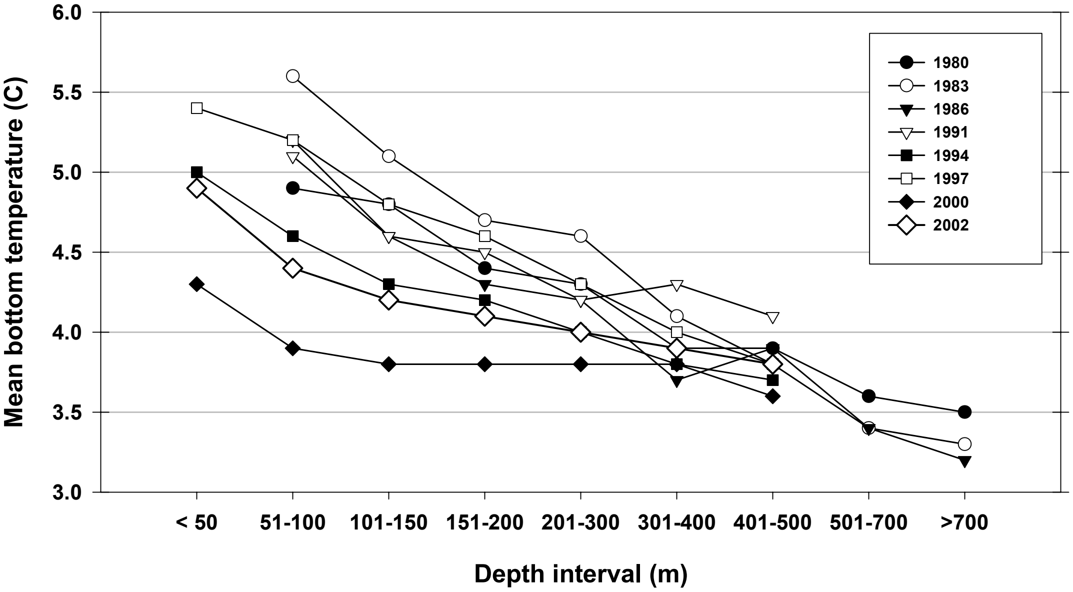
Summer bottom temperatures – Aleutian Archipelago

Contributed by Harold Zenger

Groundfish assessment surveys conducted in the Aleutian region occurred on a more or less triennial basis between 1980 and 2000. Beginning in 2000 the survey switched to a biennial schedule. Survey periods have ranged from early May to late September, with no fixed sampling pattern or time schedule. Generally, sampling progresses from east to west. Bottom temperatures have been routinely collected in conjunction with bottom trawl hauls. Of the eight survey years cited in the figure below, all except 1991 had temperature samples from throughout the entire Aleutian region.

Tidal currents that flow across the relatively narrow Aleutian shelf and upper slope are often very strong, as vast amounts of water are exchanged between the north Pacific Ocean and the Bering Sea. Bottom temperatures are most influenced by those large water masses

AFSC Aleutian groundfish surveys, mean bottom temperatures



In the Aleutian region, the year 2000 produced the coldest bottom temperatures yet detected during summer AFSC groundfish surveys. The warmest years tend to be lagged about a year behind El Niño events. The three coldest years thus far detected (1994, 2000, and 2002) have occurred within the last eight years, with one of the warmest (1997) occurring in their midst. Generally, mean temperatures at depth intervals shallower than 300m vary more than those from waters deeper than 300m. Perhaps the year 2000 temperatures are not as anomalous as they appear, but many individual fish were visibly thinner than during other surveys. Unfortunately, we have no data to compare for the intervening years.

Habitat

Indices of contaminant levels in sediments, groundfish and their prey. (not updated for 2002)

Summarized from the NOAA National Status and Trends for Marine Environmental Quality Program

The NOAA National Status and Trends Program (NS&T) has produced a summary of Alaska marine environmental quality through its research and sampling projects, including the Mussel Watch Project and the Benthic Surveillance Project and the report is available on the NOAA web site at:
http://ccmaserver.nos.noaa.gov/NSandT/BrochurePDFs/NSandTSpecialPubs.html

This report was produced in 1999 and will be updated periodically. It found that the major and trace element levels found in sediment probably reflect local mineralogy and not anthropogenic effects. DDTs and metabolites were present in fish liver and mussel tissues but the trends in mussel tissue concentrations indicated a decreasing amount over time, reflecting the ongoing ban of the use of these chemicals. The report also concludes that environmental conditions in Alaska, as determined using results of the NS&T Program mussel tissue samples, indicate no obvious trends in contaminant concentrations during the monitoring effort (1986 to 1995).

Harmful Algal Blooms

Contributed by Vera Trainer, Northwest Fisheries Science Center

The huge coastal area of Alaska makes PSP testing impossible in all regions where shellfish and crabs can be harvested. Therefore, testing for PSP and ASP is done only in areas where commercial operations are found. Because such a small area of coastline is monitored relative to areas where shellfish can be found, at least one human illness is documented each year. This is due, in part, to the rich Native American cultural tradition of eating shellfish for subsistence in Alaska. At times it may be difficult for Native Americans and other people living in remote areas to resist the temptation of harvesting shellfish from non-certified areas. An epidemiological study estimated that Alaskan natives are ten times more likely to contract PSP than the average resident of Kodiak.

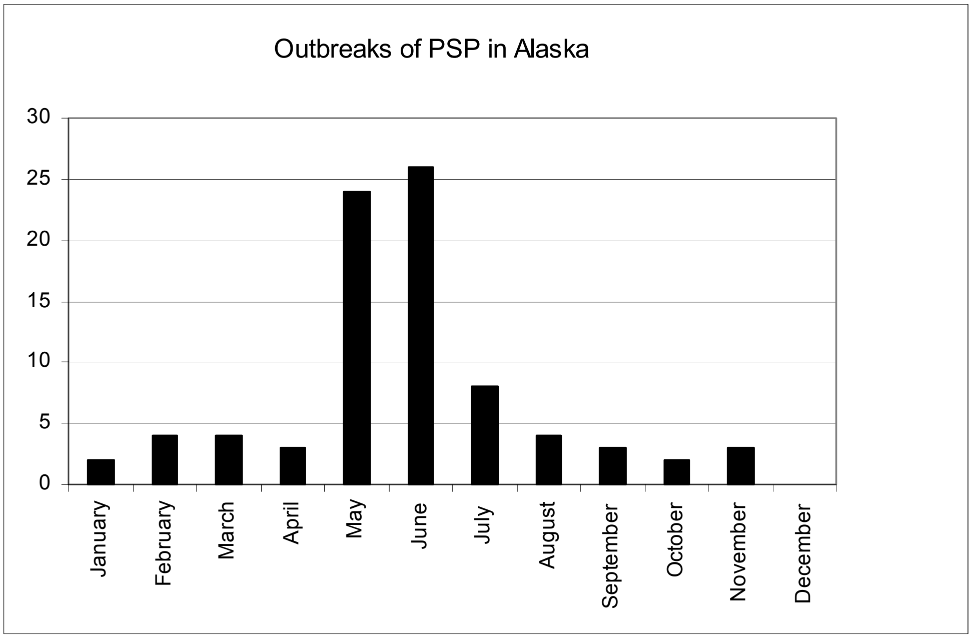


Figure 1. Reported PSP cases in Alaska from 1973-1994 (from Gnesser and Schloss, 1996)

In Alaska between 1973 and 1994, 143 people were believed to have become sick due to PSP. During 1995-2000, at least 51 people became ill. Due to under-reporting of illnesses, or misdiagnosis, the number of people suffering from PSP in Alaska is likely to be 10-30 times higher than reported. Most of the illnesses occurred in May and June (Fig. 1). Among the 61 outbreaks where the shellfish species was known, most involved the ingestion of butter clams (*Saxidomus giganteus*) and mussels (*Mytilus edulis* or *M. californianus*). Cockles (*Clinocardium nuttalli*), razor clams (*Siliqua patula*), and littleneck clams (*Protothaca staminea*) were also eaten and caused some of the illnesses. It is interesting that most outbreaks of PSP occurred on Kodiak Island, the southern edge of the eastern half of the Aleutian Islands and Southeastern Alaska. No outbreaks of PSP have yet resulted from shellfish collected from Cook Inlet. The most common symptoms of PSP were paresthesia (tingling on skin), lip numbness and tingling, nausea and numbness of extremities.

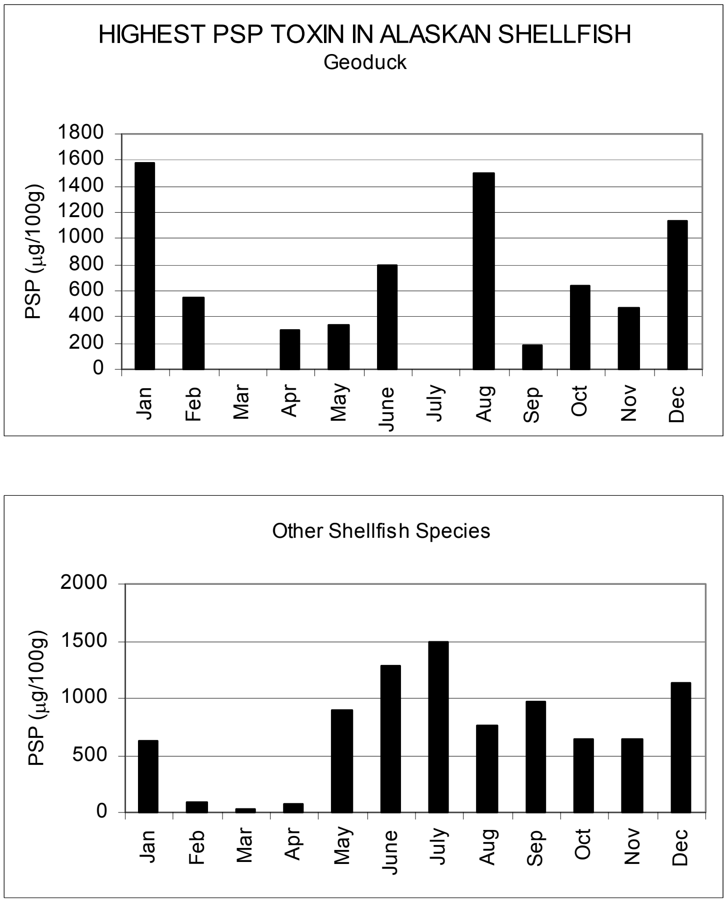


Figure 2. Highest PSP toxin in Alaska by month for the year 2000

In Alaska, shellfish (oysters, mussels or clams), crab (king crab, Dungeness crab, Tanner crab, hair crab), and sea snails (*Fusitriton orgegonensis*) are tested for PSP. Alaska's current bivalve shellfish fishery consists of the native littleneck clam, razor clam and geoduck clam. A PSP sampling plan for commercially or aquaculturally-produced shellfish, crabs, and snails is implemented by the Alaska Department of Environmental Conservation (ADEC) from its single testing laboratory located in Palmer, 60 km north of Anchorage. There is no agency responsible to monitor beaches for recreational or subsistence harvests. The ADEC regulations require strict compliance with a tiered program that decreases sampling requirements after set time periods of PSP-free samples. Not only do the shellfish and aquaculture operations pay for the collection and shipping of samples, a dry, temperature-controlled holding facility is required for storage of the harvest out of water until the laboratory tests are completed. Consequently, PSP not only causes direct economic impact during toxic events, but the coast of shipping, testing, and storing commercially-harvested shellfish also increases the cost of doing business. Domoic acid testing is done only for the one commercial razor clam operation on the east side of Cook Inlet. There is also a recreational razor clam fishery on Cook Inlet.

Seasonality

The seasonality of PSP in Alaska is dependent on shellfish species and location. However, the earliest incidence of PSP in March-May of each year is generally in the Juneau area (SE Alaska). Human illnesses have also been documented in this area more frequently than when monitoring began. High PSP levels are measured farther north (north of the Aleutian chain) later in the spring and early summer. Shellfish south of the Aleutian chain often have high toxin levels whereas areas north of the chain are often toxin free. Generally, areas have lower levels of PSP in the spring and fall (Fig. 2, example from

2000), while summer and early winter are times when high levels of PSP are generally observed. However, some exceptions exist. In Steamboat Bay (SE Alaska) and Grabina Island (outside Ketchikan), geoducks are toxic all year. In Simons Bay (outside Sitka), there was one peak level of PSP in Jan 1996 (240 µg/100g), but this area is generally free of PSP. The highest level of PSP ever measured in Alaska was 20,606 µg in blue mussels at Kamisan Bay, Kodiak Island on May 27, 1997 (Fig. 3).

The highest PSP levels in all shellfish species tested are shown in Figs. 3 and 4. There has been some recent documentation of PSP in Alaska where no prior occurrences have been seen. Levels of PSP in oysters have recently been measured in areas of SE Alaska where previously there was no problem. Little testing for ASP is done in Alaska, and since 1991, levels have been near the detection limit. The highest level was 11 ppm in blue mussel from Cook Inlet.

Figure 3. Locations and levels of highest PSP toxin measured in blue mussel, butter clam, Dungeness crab, cockle, and littleneck clam.

Causative organisms

Three species of *Alexandrium* occur on the U.S. west coast . *A. catenella* (Whedon and Kofoid) Balech occurs from southern California to southeast Alaska, forms chains, blooms when the water temperature is about 20^{o}C, and occurs in both estuarine and open coast environments. *A. tamarense* (Lebour) Balech, prefers cooler temperatures and less saline waters than *A. catenella*. It has been found in the Gulf of Alaska (RaLonde, 1996). *A. fundyense* Balech has been found at Porpoise Island, Alaska. These are the three primary *Alexandrium* species in Alaska believed to cause PSP.

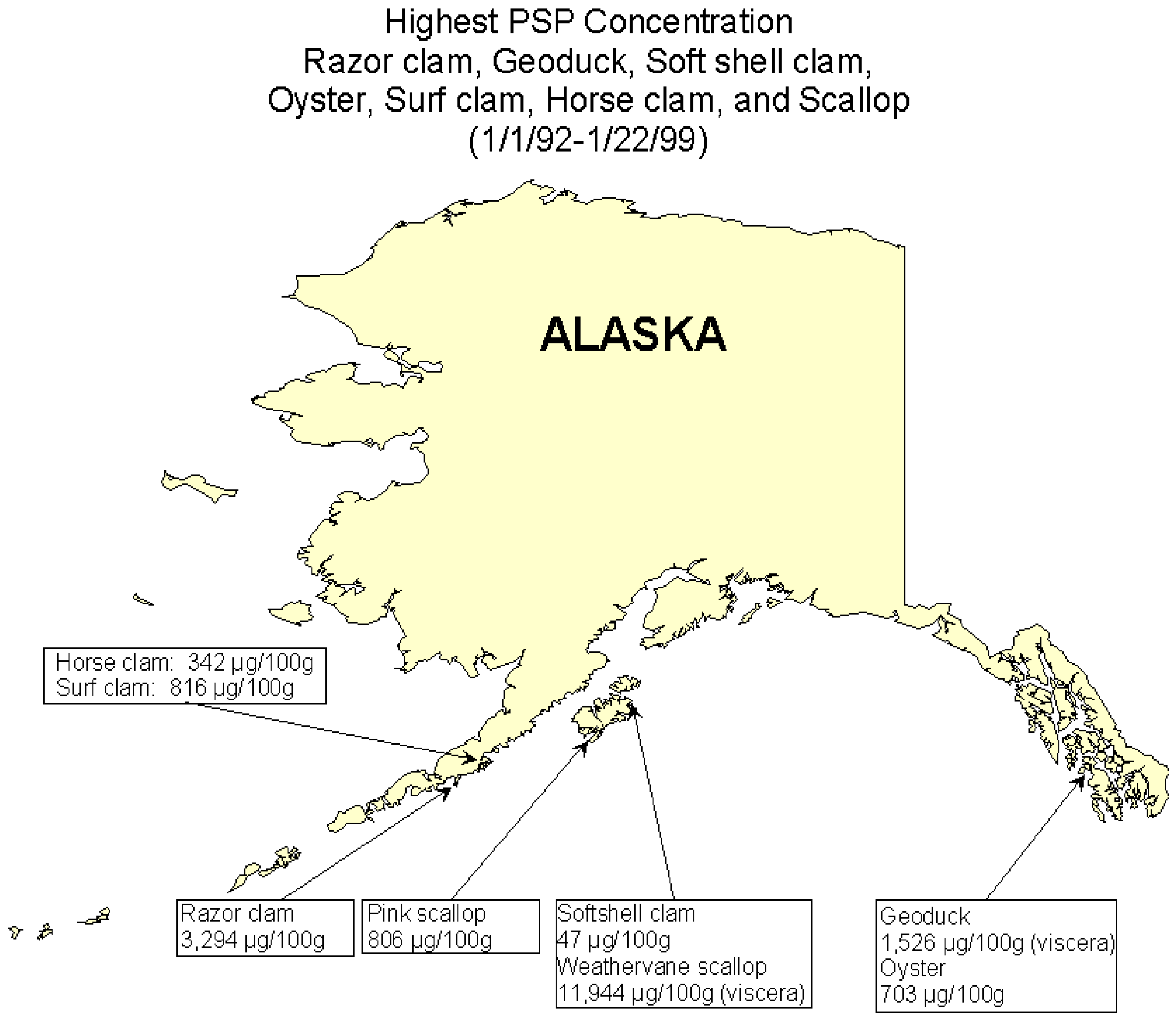


Figure 4. Locations and levels of highest PSP toxin measured in razor clam, geoduck, softshell clam, oyster, surf clam, horse clam, and scallop

Pseudo-nitzschia species occur from at least Point Barrow and probably throughout the Bering Sea (listed as *Nitzschia* spp. section *Pseudonitzschia* from shelf-break stations near Unimak Pass by Schandelmeier and Alexander 1981). *Pseudo-nitzschia* spp. probably occur throughout the Gulf of Alaska (records from American Mail Line ships of opportunity cruises between Seattle and Yokohama in 1968-1972). *Pseudo-nitzschia* are also known to occur in Port Valdez since the early 1970s. However, all of the earlier records are of *N. seriata*, which is possibly identified correctly to the species level for the farthest north samples, but is probably not correct for all of the Gulf of Alaska and Southeast Alaska.

Impacts

Alaska has the largest, most productive fishery (shellfish and fish) in the U.S., contributing 54% to the total U.S. landings. The cost of PSP to the commercial fishery, recreational harvest, and aquaculture surpasses $10 million annually. The economic consequences of PSP in Alaska have drastically impacted the development of a clam fishery where an estimated 50 million pounds are available for harvest. In 1917, five million pounds of shellfish were harvested from Alaskan waters, but today the state's commercial bivalve industry is virtually nonexistent. The value of the sustainable, but presently unexploited, shellfish resource in Alaska is estimated to be $50 million per year. An example of the impacts of PSP to a specific fishery is realized in the reduced value of the geoduck fishery. In 2000, the geoduck fishery was receiving $1.60 per pound for processed geoduck that needed evisceration. The price for whole geoduck, in contrast, was $7.00 per pound. Because of the uncertainties of PSP levels in this commercial shellfish, most of the harvested geoduck needed to be sold as eviscerated product. In 1998, the value of the geoduck fishery was $1.2 million. Because processing was required, however, the gross value of the final product was about $500,000, resulting in a loss of revenue of almost $800,000.

The potential problem of PSP and testing requirements are major factors preventing development of a surf clam (*Spisula polynyma*) harvest in the Bering Sea. The sustainable harvest of the Bering Sea surf clam is estimated at about 29,000 metric tons with an annual worth of about $9 million (Hughes et al. 1977). The harvest of other clam species that are affected by PSP and net worth of these fisheries is shown in Table 2.

Further information about the impacts of both PSP and ASP on Alaskan fisheries can be viewed at http://www.nwfsc.noaa.gov/hab/newsletter/HAB_impacts_Alaska.htm

Table 2. Average commercial clam harvest in pounds (thousands) and income in US dollars (thousands), 1990-1999.

Littleneck clam				**Razor clam**		**Geoduck clam**	
Southeast Alaska		*Kachemak Bay*		*Cook Inlet*		*Southeast Alaska*	
Harvest	Income	Harvest	Income	Harvest	Income	Harvest	Income
7.6	21.3	50.7	68.4	289	156.1	222	499.5

Income is based on ex-vessel price paid to the fishermen and is averaged over the fishing season price.

HAPC Biota – Bering Sea

Contributed by Gary Walters, Alaska Fisheries Science Center

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. RACE bottom trawl survey results from 1982 to 2001 show trends in the biomass index of these groups on the Bering Sea shelf (Figure 1). Seapens/whips trends show the possibility of two abundance increases in the late 1980’s and in the late 1990’s. Biomass trends of anemones seem to indicate higher biomass in the 1980’s than in the 1990’s, although biomass of these groups tends to show rather larger fluctuations from year to year. The sponge biomass index appears to show an increasing trend in the 1990's. Further research on the life history characteristics of these organisms is needed to interpret these biomass trends.

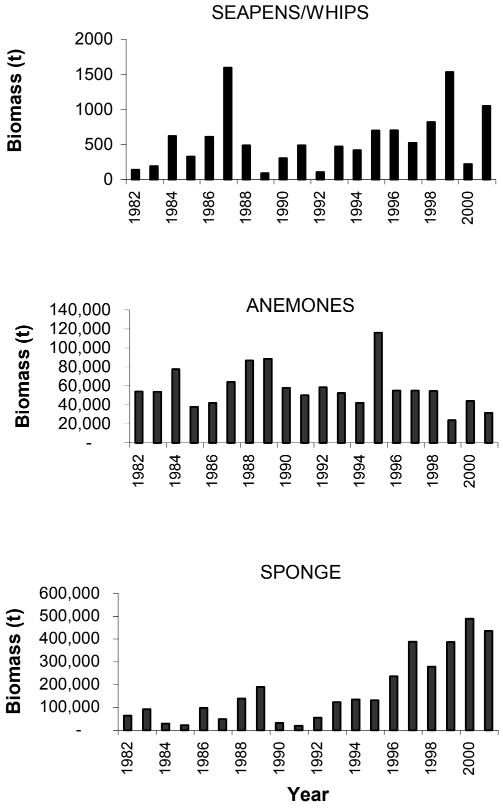


Figure 1. Biomass trends of HAPC biota from the RACE bottom trawl survey of the Bering Sea shelf, 1982-2001.

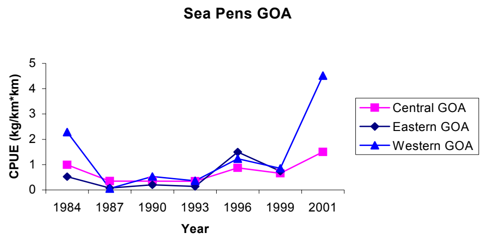
HAPC Biota – Gulf of Alaska

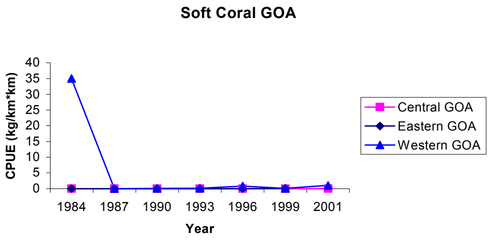
Contributed by Eric Brown, Alaska Fisheries Science Center

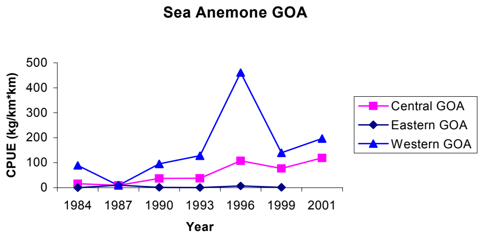
This is the first look at biomass index trends of HAPC biota (seapens/whips, coral, sponges, and anemones) from the RACE bottom trawl survey in the Gulf of Alaska. This survey is not designed to assess these organisms and in most cases may represent an inappropriate tool for tracking abundance levels. Further detailed examinations of these results are needed to assess whether there are meaningful trends.

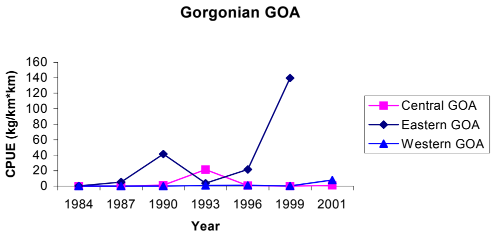
Several of the groups representing the HAPC biota exhibited large apparent changes in abundance but rather than being a result of comparable catches over a broad area, the estimates were driven by only one or two atypical catches resulting in highly variable estimates with correspondingly large confidence intervals. Examples of this are the sea pens, which are infrequent and small components of Gulf trawl survey catches. The apparent large increase in abundance in the western Gulf of Alaska during the 2001 survey was primarily driven by only two catches totaling less than 7 kg each. Similarly, the high apparent abundance of soft coral in the western Gulf of Alaska during the 1984 survey was due to a single large catch far exceeding observed catches in subsequent surveys. Also, the large increase of Gorgonians (primarily the red tree coral) seen in the eastern Gulf of Alaska during the 1999 survey, was mainly due to several unusually large catches of 482 kg and 187 kg. The stony coral group also exhibit highly variable abundance estimates.

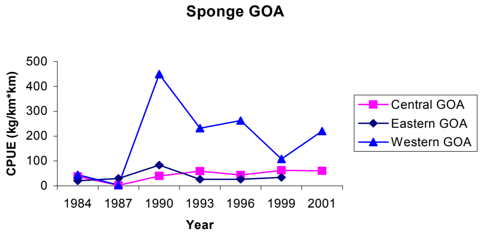
Perhaps the most likely groups for providing useful information are the sea anemones and sponges that commonly appear in survey catches, especially in the western Gulf. However, it should be emphasized that the survey trawl equipped with rubber bobbin roller gear is not well suited for sampling these types of sessile organisms.

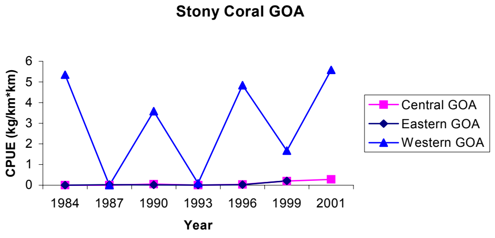










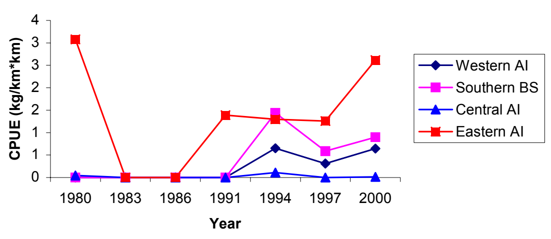


HAPC Biota – Aleutian Islands

Contributed by Eric Brown, Alaska Fisheries Science Center

This is the first look at biomass index trends of HAPC biota (seapens/whips, coral, sponges, and anemones) from the RACE bottom trawl survey in the Aleutian Islands. This survey is not designed to assess these organisms and further detailed examination of these results is needed to assess whether there are meaningful trends.

Sea anemones are common in trawl catches but the apparent large increase seen in the southern Bering Sea in 2000 was due to two large catches of 27 kg and 48 kg with other catches rarely exceeding 3 kg. Similarly, the apparent increase in abundance of soft corals in the central Aleutians in 1991, gorgonian corals in the western Aleutians in 1991 and stony corals in the central Aleutians in 1997 was highly influenced by a few unusually large catches. The relative abundance of sea pens appears to be increasing in most areas however catch rates tend to be quite low. In contrast, the frequency of occurrence and relative abundance of sponges has been consistently high in each of the three Aleutian regions but like many of these groups, it is unknown whether the survey is an appropriate tool for measuring or tracking abundance.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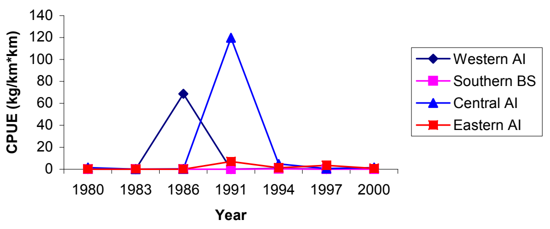
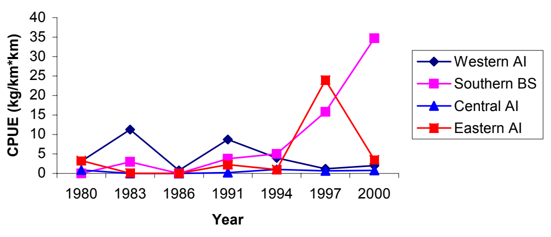
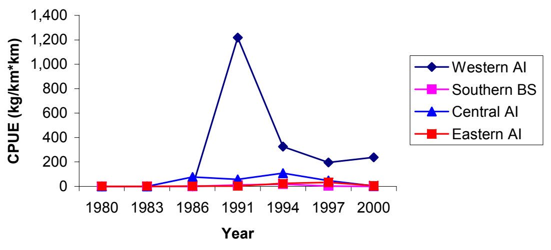
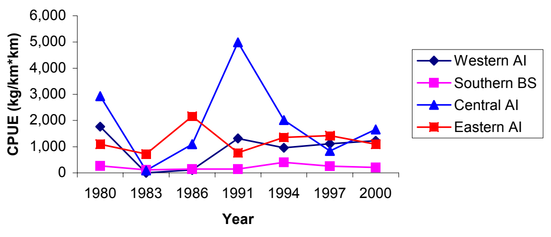
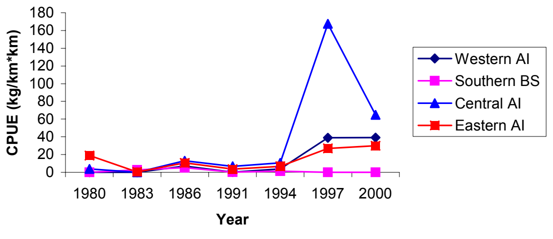

Soft Coral AI


Sea Anemone AI


Gorgonian AI


Sponge AI


Stony Coral AI

Progress Report on Essential Fish Habitat Research

Contributed by K Koski, Alaska Fisheries Science Center, Auke Bay Laboratory

Project**:**	**Defining Habitat of Juvenile Pacific Cod.**
Principal Investigator:	Alisa A. Abookire
Division:	RACE Division, Kodiak Laboratory

Very little is known about the habitat requirements of Pacific cod (*Gadus macrocephalus*), particularly during their early-life stages. Yet, the economic importance of the Pacific cod fishery in coastal Alaskan communities is considerable, and Pacific cod are a major prey item for Steller sea lions (*Eumetopias jubatus*) around Kodiak Island. Much of what we assume about the distribution of Pacific cod is based on either ancillary data from investigations focused on other species or investigations of Atlantic cod (*Gadus morhua*). Defining the nursery areas utilized by Pacific cod is a preliminary step toward identifying essential habitat and monitoring growth, survival, and subsequent recruitment.

The objective of this one-year study was to identify juvenile Pacific cod habitat in Chiniak Bay, Alaska. A variety of nearshore habitats were sampled between August 10 and 22, 2002. Stations were sampled along depth transects such that each transect had one station at depths of <5, 10, 15, 20, 25, and 30 m. At each of the 68 stations sampled, the relative abundance of juvenile cod and groundfishes was measured along with habitat characteristics. Habitat complexity (sediment type, vertical relief, % algae cover, associated invertebrates) was recorded at each station with an underwater video camera with real-time video. Vertical profiles of water temperature and salinity were measured at each station, and a sediment sample was archived for grain size analysis that will verify the sediment type observed in the video.

A total of 6,077 fishes were captured, and juvenile Pacific cod ranked number 6 in abundance. There were a total of 333 juvenile Pacific cod captured, with lengths ranging from 40 to 113 mm. This study verified the presence of juvenile Pacific cod in nearshore areas of Chiniak Bay. Once the distribution of juvenile Pacific cod is related to habitat complexity and physical properties (such as sediment grain size, depth, temperature, and salinity) then the habitat characteristics of their nursery areas can be defined.

Project:	**Identification and Characterization of Atka Mackeral (Pleurogrammus monopterygius) Reproductive Habitat**
Principal Investigators:	Bob Lauth and Scott McEntire
Division:	RACE Division, Seattle

Atka mackerel is one of 10 species of hexagrammids that are endemic to the North Pacific Ocean. Although not a scombrid or true "mackerel", it is valued as a food fish. The Atka mackerel's schooling behavior is uncharacteristic among hexagrammids and their high abundance in the Aleutian Islands supports a multimillion-dollar a year commercial trawl fishery. Historical accounts and fish bones from Aleut Indian middens indicate Atka mackerel was also an important subsistence fish for indigenous populations. Furthermore, larval, juvenile and adult Atka mackerel play a key role in the marine ecosystem as an essential forage species for planktivores, marine birds, picsivorous fishes and marine mammals, including the endangered Steller sea lion.

Despite its ecological, commercial, and anthropological value, the basic biology of Atka mackerel is poorly studied. Major research efforts currently focus on offshore waters where a large percentage of the Atka mackerel population lives a semi pelagic existence during much of the year. Of particular interest to behavioral and stock assessment biologists, however, is the Atka mackerel's annual spawning migration. Males move to nearshore areas of the Aleutian Islands during the early summer and establish nesting sites where females come to lay eggs after which males guard the nests. Since surveys of nesting sites in the Aleutian Islands have never been done, it is unknown to what extent Atka mackerel utilize the nearshore habitat surrounding the islands or deeper offshore where the commercial fishery operates. In terms of managing this species, knowing more about their reproductive ecology seems prudent. The potential impact of trawl fishing on the population cannot be assessed without first understanding annual migration patterns or the spatial extent of nesting sites. Understanding annual migration patterns should be an essential first step for developing a strategy for estimating the abundance of Atka mackerel. Also critical is knowledge of how spawning habitat overlaps with the commercial fishery. Nest or nesting habitat destruction by commercial trawls or direct removal of guardian males during the nesting period could adversely impact survival of embryos and ultimately the population.

This study was the first to locate and characterize an Atka mackerel nesting area in the U.S. Exclusive Economic Zone. In the nearshore areas of Finch Cove, Seguam Island, we were able to estimate clutch density and document on video the behavior associated with courtship, spawning and nest guarding. In 2002, the F/V *Morning Star*, F/V *Sea Storm*, and the U.S. Fish and Wildlife's R/V *Tiglax* were used as support vessels for further investigation of Atka mackerel nesting habitat. On May 31, an *in situ* time-lapse camera was deployed at the Finch Cove nesting site before male Atka mackerel were present. Footage from the retrieved video camera revealed that an aggregation of males established the nesting site in mid June. Clutches of eggs were present and males were still exhibiting nest fidelity when a time-lapse camera was last reset on August 31rst. The camera will continue to sample daily footage for one minute per day through December 2002 so that we can observe when males finally depart the nesting site. Temperature, current and depth data loggers attached to time-lapse cameras will be used to see how utilization of the nesting habitat varies with changes in the physical environment. At the same site, two 30 m SCUBA transects were established to count clutches to see how the number varied over time. The number of egg clutches was 0 in May and peaked at 30 clutches in late August. One freshly laid clutch of eggs and several of unknown age were sampled at the beginning of August. These eggs are being incubated at the Alaska Fisheries Science Center in a controlled environment similar to what is found at the nesting site. The resulting developmental series will be a useful tool for estimating the age of egg samples obtained from clutches at various nesting sites. In this way we can estimate how long males would have to remain at the nesting site assuming they stay until all eggs are hatched.

To expand our capabilities for searching, verifying, and quantifying Atka mackerel reproductive habitat, we developed the Quadrat Underwater Assessment Drop Camera (QUADCAM) in 2001. The QUADCAM collects sequential still photographic images of a fixed area (0.25 m^2) using a digital video camera. The new camera system was deployed successfully this summer using a 16" inflatable skiff outfitted with a portable winch and boom. Images from the digital video camera were clear and detailed. A real time navigation camera connected to a topside monitor was used to navigate the QUADCAM along bottom so it would not hang up. In over 200 drops in depths ranging from 15 m to 160 m, the QUADCAM photographed two Atka mackerel egg clutches. Still photographic images will be used to describe the physical and biological characteristics of the nesting habitat. Several deployments were made in Seguam Pass to depths below 150 m and one in Amukta Pass to 100 m. The bottom was prolific with colorful corals, sponges and other invertebrates and great numbers of Atka mackerel were seen scattered along the bottom. On the deeper deployments, no egg clutches were observe and no male Atka mackerel were exhibiting nesting behavior. In shallower deployments, it was observed that nesting male Atka mackerel reacted to the QUADCAM's strobe lights. A low density of egg clutches, a small area of coverage of the QUADCAM, or both probably accounted for the low number of clutches observed. Egg clutches on vertical faces or under ledges would also be hard to detect.

After trying a variety of methods, we decided the best and quickest means for documenting nesting sites was to use a regular drop camera without lights. The drop camera did not affect behavior and we were able to use it to locate aggregations of brightly colored yellow males. These males exhibited the typical nesting behaviors we documented using time-lapse cameras, hence, we were able to use them for identifying nesting sites. Using this methodology, we located other nesting areas within the Aleutian Islands located including: 1) Austin Cove and Chigahof Island on Attu Island, 2) NW corner of Buldir Island, 3) western side of Amukta Island, and 4) Wharf and Lava Points on Seguam Island. Nesting sites were absent at many areas adjacent to these as well as other areas including Sweeper Cove on Adak Island, south end of Kagalaska Island, Umak Island and Kasatouchi Island. At all sites, temperature, depth and position data were collected with the camera drops for comparing the physical and biological environment.

Project:	**Use of Nearshore Habitats by Commercially Important Fish Species**
Principal Investigators:	Scott W. Johnson and John F. Thedinga
Division:	Auke Bay Laboratory

Out of necessity, groundfish sampling in Alaska has been predominately on the continental shelf and slope to obtain knowledge for fishery management. Thus, sampling has been limited in nearshore areas. This is especially true along the remote and rugged coastline of southeastern Alaska. Nearshore, rocky bottoms >50 m deep, are the most poorly known of all marine habitats because of the difficulties of sampling or studying them closely. In addition, the importance of nearshore vegetated habitats (e.g., eelgrass, kelps) for fish communities is also poorly known in southeastern Alaska. Information is needed on fish distribution and habitat use in nearshore areas so managers can protect and conserve those habitats essential to maintain healthy fisheries. Nearshore habitats are a priority because of the potential risks of adverse effects from shoreline and upland development.

In 2002, we completed the second year of a three year study to establish index sites for monitoring long-term changes in habitat quantity, habitat quality, and species diversity that may result from human disturbance (e.g., shoreline development) or changes in climate (e.g., global warming). Six eelgrass (*Zostera marina*) meadows sampled in 2001 were again sampled in 2002 for fish assemblages and area of each meadow was measured by GPS. Other habitat parameters measured included eelgrass stem density and biomass. To date, 26 seine hauls have yielded over 75,000 fish of 38 species. Total number of fish captured has been dominated by a few species (e.g., Pacific sandlance, chum salmon) that were sometimes captured in large numbers. Other commercially important species captured were Pacific cod, Pacific herring, and juvenile coho salmon. Area and density of eelgrass meadows varied by site; areas ranged from about 500 m^2 to over 75,000 m^2, whereas density ranged from about 450 stems m^2 to over 2,200 stems m^2. Each of these eelgrass sites will be sampled again in summer 2003. Additionally, because information is scarce on the use of eelgrass habitat in winter, we will also sample these sites in January 2003. Establishing a solid baseline of habitat and fish diversity information will allow us to monitor these habitats periodically over the next 10 years for changes that may result from human or natural disturbance.

In 2002, we also tested a GPS tracking system with a remotely operated vehicle (ROV) to quantify fish abundance in a variety of habitat types. Detailed 3-D bathymetry maps were first used to identify specific habitat types (e.g., ridges, troughs) and then the ROV was deployed in these areas to examine fish distribution and abundance. We successfully completed several ROV dives near Benjamin Island in southeastern Alaska and were able to track and record fish observations along a route displayed by the tracking system. More tests will be conducted next summer, but it appears that we may be able to map habitat boundaries and quantify fish abundance in specific habitat types.

Characterization of nearshore fish assemblages and habitat by seine and ROV is also providing valuable information on available prey to Steller sea lions in southeastern Alaska. One hypothesis for the decline in the western population of Steller sea lions is decreased prey availability. Some of our nearshore study sites are close to sea lion haulout areas in southeastern Alaska. Thus, in conjunction with satellite tagging of sea lions and scat surveys, our nearshore studies will help provide a complete picture of sea lion forage locations, what prey is available, and what sea lions consume.

Project:	**Essential Fish Habitat in Estuarine Wetlands of Southeast Alaska**
Principal Investigator:	Mitch Lorenz
Division:	Auke Bay Laboratory

Fish and habitat characteristics at four estuaries in northern southeast Alaska were sampled to help develop a database for EFH mapping in Alaska estuaries. Two of the estuaries were on a relatively exposed coastline along a deepwater inlet (Chatham Strait) and two were adjacent to a more protected bay type environment (Port Frederick). All of the estuaries were associated with logged watersheds. In the exposed estuaries, salmonids were the predominant FMP species and species diversity was relatively low. Fish habitat at those estuaries was generally characterized by small deltaic formations and gravel beaches that supported narrow bands of emergent marsh, eelgrass, and kelp. Flatfish were the most abundant FMP species in the more protected estuaries and species diversity was greater than at the more exposed sites. Fish habitat at those sites was characterized by relatively complex deltaic formations that supported extensive emergent wetlands, eelgrass stands, and mudflats.

A GIS is being developed to associates field data with a preliminary basemap of southeast Alaska estuaries that has been compiled from a variety of spatial imagery and map sources. Field data is being used to refine the estuarine basemap and to help develop habitat classifications that can be used to assess EFH distribution and relative fish productivity of Alaska estuaries. The preliminary GIS basemap will also be extended this year to include nearshore areas as far north and west as Resurrection Bay on the Kenai Peninsula.

A Master of Science thesis was completed this past summer by Lynn Mattes at the University of Alaska Fairbanks on “Habitat Utilization by Flatfish in Mendenhall Wetlands, Juneau, Alaska”. This project was supported by EFH and copies of the thesis will be available shortly.

Current Research on the Effects of Fishing Gear on Seafloor Habitat in the North Pacific

Contributed by Jonathan Heifetz, Alaska Fisheries Science Center, Auke Bay Laboratory

In 1996, the Alaska Fisheries Science Center (AFSC) initiated a number of seafloor habitat studies directed at investigating the impact of fishing on the seafloor and evaluation of technology to determine bottom habitat type. A progress report for each of the major projects is included below. A list of publications that have resulted from these projects is also included. 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) has been developed that highlights these research efforts. Included in this web page is a searchable bibliography on the effects of mobile fishing gear on benthic habitats.

A model for evaluating fishery impacts on habitat Principal investigators - Jeffrey Fujioka and Craig Rose (Alaska Fisheries Science Center - ABL and RACE)

The final regulations for essential fish habitat (EFH) require Councils to act if a fishing activity adversely affects EFH in a manner that is “more than minimal and not temporary in nature .....”. Lacking further guidance from NMFS Habitat Office, the North Pacific Fishery Management Council's EFH Committee asked scientists of the Alaska Fisheries Science Center to provide guidance on criteria for determining "minimal" and "temporary". After considerable deliberation, it became clear a basic logical mathematically consistent framework was needed to evaluate fishery impact.

The term "temporary" was considered as a qualitative description associated with a high rate at which a habitat recovers from an impact and the term "minimal" as a low rate at which a habitat is impacted. Since we are primarily concerned with the net result of a habitat's recovery rate and the rate at which it is impacted, differential equations were used to model recovery rate and impact rates on habitat, and compute the level of impacted and unimpacted habitat over time. At constant rates of recovery and impact, equilibrium levels of impacted and unimpacted habitat would be reached.

Habitat was assumed be in two different conditions or states: H = unimpacted habitat, h = impacted habitat. I = the rate at which habitat is impacted, and ρ = recovery rate of impacted habitat back to an unimpacted condition. Impact rate, I, decreases the amount of unimpacted habitat, H, over time in the same way instantaneous fishing rate, F, decreases the amount of fish over time and can be parameterized similarly. In the absence of any habitat recovery, H would decrease exponentially just as a closed fish population would decrease under constant F. F is expressed as F= f q where f = fishing effort and q = catchability coefficient and I can be expressed as $I = f\ q_H$ for the same f and q_H = habitat impact coefficient per unit effort.

Recovery rate, ρ , reflects the rate of change of impacted habitat, h, back to unimpacted habitat, H. In the absence of further impacts, h would decrease exponentially till all habitat was in H, the unimpacted condition. The recovery time, R, can be thought of as the average amount of time the impacted habitat stays in the impacted state, which would equal $1/\rho$ (in the absence of further impacts). Each habitat type has different recovery times.

Integrating the differential equations, we get an equilibrium proportion of unimpacted habitat at $t = \infty$:

$$H'_{equil.} = \rho S/(I + \rho S) .$$

$$S = e^{-I}$$

It can be seen as the impact rate I increases, H_{equil} occurs at a lower level, while a higher recovery rate, ρ, results in a higher level of H_{equil}. Both impact rate and recovery rate are necessary to determine the degree of impact, the level of H_{eq}. The terms temporary and minimal alone do not reflect the degree of impact. A recovery rate would have to be extremely high (temporary) to declare any impact to be insignificant without considering the corresponding impact rate. It takes recovery rates greater than ρ =1.0 (or average recovery times less than 1 year) to keep H_{eq} above 80% of H_0 at I's approaching the upper range of F's reported in the NPFMC groundfish fisheries. Thus, if an impact that qualifies as temporary need not be considered as possibly adverse regardless of impact rate, temporary should be considered as having a recovery rate equal to more than 1.0 (Even at ρ =1.00, only 63% of the habitat will recover in one year). Likewise, it takes an extremely low rate to result in an insignificant reduction in H_{eq} if recovery rate is low.

The parameterization of fishing impact allows effort data from the Observer Program to be utilized. While the lack of information on the habitat impact per unit of effort, recovery rates of different habitat or habitat features, and the distribution of bottom habitat will likely prevent definitive conclusions, the model provides a mathematically consistent framework to unify the elements of fishing impacts on habitat. Currently applied analyses are underway for the evaluation and development of alternatives for mitigating impacts of NPFMC fisheries. The analyses provides estimates of the reduction habitat features ($1-H'_{eq}$) for different fisheries conditional on assumed values of impact per unit of effort, recovery rates, and habitat distribution.

Ecological consequences of lost habitat structure for juvenile flatfishes Principal Investigator – Allan W. Stoner (Alaska Fisheries Science Center - RACE)

Distributions of flatfishes are ordinarily associated with depth, temperature, and sediment type. However, recent descriptive and experimental studies have shown that some juvenile flatfishes have strong preferences for habitats with physical structure created by large epibenthic invertebrates, biogenic structures in the sediment, and sand waves. For example, beam trawl collections made in nearshore areas of Kodiak Island during July 2002, revealed that densities of age-0 rock sole and age-0 Pacific halibut were correlated with habitat structure provided by empty shells and sedentary invertebrates collected as bycatch in the tows.

New laboratory experiments indicate that reductions in habitat heterogeneity may have important ecological consequences for flatfishes, through both direct and indirect mechanisms. First, some flatfishes have a preference for structured habitats. Juveniles of northern rock sole and Pacific halibut were offered pairwise choices of smooth bare sand and habitats with physical structure (sand plus sponges, bryozoans, bivalve shells, or sand waves). Age-0+ and age-1+ fish of both species had strong preferences for the structured habitats regardless of structure type. Second, structured habitats can reduce mortality rates on juvenile flatfishes. Predation rates by age-2+ halibut on age-0+ rock sole and halibut were tested in large laboratory mesocosms with and without physical structure, in this case smooth bare sand versus sand plus sponges. Mortality rates for both prey species were significantly higher in the sand habitat than in the structured habitat. Age-0+ halibut were encountered by the predators 4 times more frequently in sand than in sponges. The difference in encounter rates with rock sole were not significant; however, the numbers of prey captured per unit effort were significantly lower in the sponge habitat than in bare sand for both rock sole and halibut prey.

The laboratory findings are being examined in light of invertebrate bycatch data collected from heavily trawled and untrawled areas straddling the northeast boundary of Crab and Halibut Protection Zone 1 (CHPZ1) in the eastern Bering Sea, which serves as an important nursery ground for flatfishes. Sedentary macrofauna such as anemones, soft corals, sponges, gastropod eggs, bryozoans, and ascidians, and whelks and empty mollusc shells that provide habitat for small flatfishes were all more abundant in the unfished area.

Trawl impact studies in the Eastern Bering Sea Principal Investigator - Robert A. McConnaughey (Alaska Fisheries Science Center - RACE)
This study is being conducted to experimentally investigate possible adverse effects of bottom trawls on a soft-bottom area of the eastern Bering Sea and to evaluate a state of the art side scan sonar and swath bathymetry system for mapping benthic habitats. Whereas earlier work focused on chronic effects of trawling, the present multi-year study is a process-oriented investigation of short-term effects and recovery using a BACI experimental design. In 2001, 12 10-mi long research corridors were surveyed before and after trawling with commercial gear (NETS 91/140 Aleutian cod combination). To investigate the recovery process, these same corridors were resampled in 2002 during a 21-day cruise aboard the 155' trawler *F/V Ocean Explorer*. All scientific systems were successfully implemented on the chartered vessel, including an ultra-short baseline (USBL) tracking system, two complete side scan sonar systems with tow winches, a trawl mensuration system, and a survey-grade integrated navigation system with DGPS, two gyroscopic compasses and a vertical reference unit. All systems were tested and calibrated during the 6-7 June gear trials in Puget Sound. During the June 18- July 8 Alaska cruise, biological, physical and chemical characteristics of the seabed were randomly sampled in six experimental-control

corridor pairs. Biological sampling consisted of 15-min research trawls for epifauna (n=36 total) and 0.1 m^2 van Veen grab samples for infauna (n=72 total at 2 per epifauna site). At each infauna sampling site, a second grab sample (n=72 total) was collected for characterizing carbon and nitrogen levels in surficial sediments, as well as grain size properties. Sampling effort was equally divided between experimental and control corridors and was consistent with the level of effort in 2001. Each of the experimental and control corridors was also surveyed using a Klein 5410 side scan sonar system to study possible changes in physical characteristics of the seafloor as a result of trawling. Preliminary observations indicate a very diverse epifaunal community (approximately 90 distinct taxa) on very-fine olive-gray sand at 60 m depth. The seafloor appears to be brushed smooth in the side scan imagery, probably due to sizable storm waves and strong tidal currents that regularly disturb the area. Occasional video deployments on the trawls indicated somewhat greater complexity. Final processing of the 2001 navigation data and biological samples is nearly complete and statistical analyses will be undertaken. Side scan processing is ongoing and will be followed by a quantitative change analysis.

Upon completion of the bottom trawl study, a reconnaissance survey of Bristol Bay habitats was undertaken using the Klein 5410 side scan sonar. This system is new technology that not only produces extremely high-resolution images of the seafloor, but also simultaneously gathers swath bathymetry data using interferometry. Approximately 1 megabyte (MB) of data are collected from the towfish each second. Prior to deployments in Alaska, the research team developed an improved software interface during laboratory testing and sea trials in Portsmouth Harbor, NH and Puget Sound, WA. The reconnaissance effort was centered on an 800 mi^2 area of central Bristol Bay that has never been hydrographically-surveyed by NOAA. Bathymetric data and imagery were collected along survey lines totaling nearly 600 linear miles. In support of coordinated EFH characterization studies in the area, the reconnaissance survey intentionally crossed 18 RACE Division trawl survey stations and followed 78 mi of seabed previously classified using a *QTC View* single beam acoustic system. The survey also intersected six of the trawl study corridors (above) in order to provide a spatial context for these results. Overall, a great diversity of complex sand-bedforms and other geological features were encountered in the survey area. The Klein system is being co-purchased with the NOAA Office of Coast Survey using accrued lease credits, and reconnaissance data will be used for nautical chart updates. The imagery will also be classified using supervised ("expert") and unsupervised methods in an effort to identify large homeogenous regions that would be the basis for more systematic study of mobile gear effects.

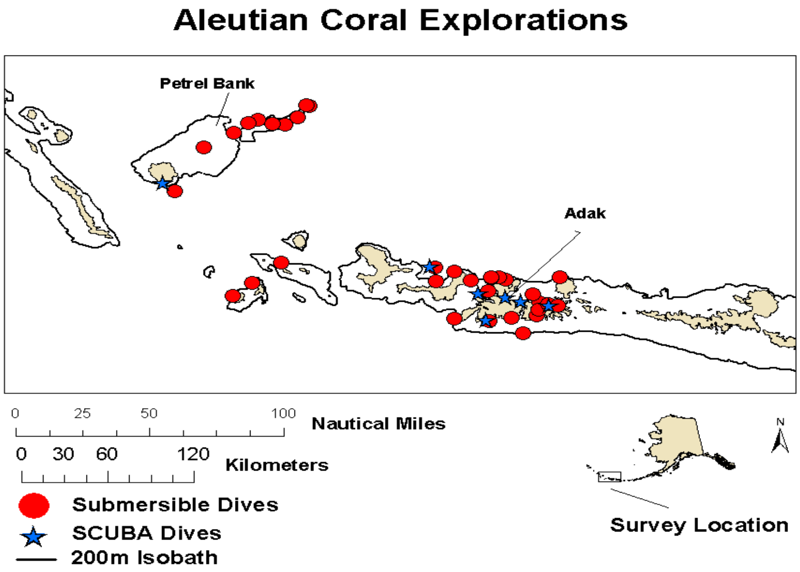
Habitat evaluation of major fishing grounds Principal investigators Jonathan Heifetz, Robert Stone, and Jeffrey Fujioka (Alaska Fisheries Science Center - ABL)

The Sustainable Fisheries Act of 1996 was passed to attain long term protection of essential fish habitat and specifically required that the NMFS minimize adverse impacts to essential fish habitat by fisheries that it manages. While considerable legal and administrative effort has been expended to meet the requirements of the Act, no specific measures to minimize fishery impacts have been enacted, and in Alaskan waters there has been little effort to observe the habitat where ongoing fisheries occur. The NMFS has limited knowledge of bottom habitat where major fisheries occur. Any regulatory measures adopted to minimize impacts without the knowledge of whether or where vulnerable habitat is at risk, may be ineffective or unnecessarily restrictive. This study, initiated in summer 2001, is an effort to attain such knowledge.

Portlock Bank, northeast of Kodiak, was chosen as the study area. Using the research submersible *Delta*, six sites were observed. Two were relatively flat sites on the north end of the Bank, one lightly fished and one in an area fished for Pacific Ocean perch. Two were sloping sites along the eastern slope edge and two sites were toward the middle of the Bank, one fished for flatfish, the other lightly fished. Little evidence of trawling was observed on the low relief grounds of the continental shelf where perhaps the level bottom did not induce door gouging and there was a lack of boulders to be turned over or dragged.

The most common epifauna were crinoids, small non-burrowing sea anemones, glass sponges, stylasterid corals and brittlestars. Occasional large boulders were located in depressions were the only anomaly in the otherwise flat seafloor. These depressions may have afforded some protection to fishing gear, as the glass sponges and stylasterid corals attached to these boulders were larger than were typically observed. In contrast, there was evidence of boulders turned over or dragged by trawling in the areas of the upper slope. The uneven bottom perhaps induced gouging by the trawl doors. The substrate was mostly small boulders, cobble, and gravel. In summary, for this very limited sample of the outer Portlock Bank, there was very little high relief benthic habitat that would be at risk to further fishing. No large corals and very few large sponges were seen. The extent past fishing may have contributed to this condition is not known.

Exploration of coral and sponge habitat in the Aleutian Islands Principal Investigators Robert Stone and Jonathan Heifetz (Alaska Fisheries Science Center - ABL)
In July 2002, scientists used the manned submersible *DSV Delta* and scuba to explore coral and sponge habitat in the Aleutian Islands near the Andreanof Islands and on Petrel Bank (Figure 1). Dive observations confirmed that coral and sponges are widely distributed in that region; corals and sponges were found at 30 of 31 submersible dive sites. Disturbance to epifauna, likely anthropogenically induced, was observed at most dive sites and may have been more evident in heavily fished areas. Percent coverage of corals ranged from approximately 5% on low-relief pebble substrate to 100% coverage on high-relief bedrock outcrops. Unique coral habitat consisting of high density "gardens" of corals, sponges, and other sessile invertebrates was found at 5 sites between 150 and 350 m depth. These "gardens" were similar in structural complexity to tropical coral reefs and shared several important characteristics with tropical reefs including complex vertical relief and high taxonomic diversity.



1. Submersible and scuba dive locations near the Andreanof Islands and Petrel Bank.

Mapping of habitat features of major fishing grounds Principal investigators Jonathan Heifetz and Dean Courtney (Alaska Fisheries Science Center - ABL)

Little of the continental shelf and slope of the Alaska EEZ has been adequately described using geophysical and biological data. The objective of this study is to map limited areas of the Alaska EEZ for habitat characterization using state-of-the-art technology. During July 2002 approximately 500 km^2 of seafloor in the vicinity of the commercial fishing grounds near Yakutat were mapped using a high-resolution multibeam echosounder that included coregistered backscatter data. Survey depths ranged from about 100 m to 750 m. The area mapped is characterized as a formerly glaciated area of irregular seabed with mixed sediments (mostly sand, mud, and gravel) and high-relief areas consisting mostly of boulders. Combined with submersible observations and fishing effort data this mapping will allow habitat and geological characterization of the areas in relation to fishing intensity.

This mapping effort is complementary to similar mapping that was done last year on Portlock Bank northeast of Kodiak and in the vicinity of Cape Omaney in southeast Alaska. On Portlock Bank, approximately 900 km^2 of seafloor in the vicinity of the commercial fishing grounds were mapped. Survey depths ranged from less than 100 m to about 750 m. On Portlock Bank, analysis of the multibeam and backscatter data indicated at least a dozen macro- or meso-habitats. The megahabitats are the result of past glaciation and are presently being reworked into moderate (cm-m) relief features. Submarine gullies notch the upper slope and provide steep relief with alternating mud-covered and consolidated sediment exposures. The Cape Omaney site (180 km^2) ranged in depth from approximately 150 m - 300 m. This site is characterized as an irregular seabed with mixed sediments (mostly sand and gravel) and high-relief rocky outcrops and pinnacles.

Effects of bottom trawling on soft-bottom sea whip habitat in the central Gulf of Alaska. Principal Investigator - Robert P. Stone (Alaska Fisheries Science Center - ABL)

In April 1987 the North Pacific Fishery Management Council closed two areas around Kodiak Island, Alaska to bottom trawling and scallop dredging (Type 1 Areas). These areas were designated as important rearing habitat and migratory corridors for juvenile and molting crabs. The closures are intended to assist rebuilding severely depressed Tanner and red king crab stocks. In addition to crab resources, the closed areas and areas immediately adjacent to them, have rich stocks of groundfish including flathead sole, butter sole, Pacific halibut, arrowtooth flounder, Pacific cod, walleye pollock, and several species of rockfish.

These closures provide a rare opportunity to study the effects of an active bottom trawl fishery on soft-bottom, low-relief marine habitat because bottom trawling occurs immediately adjacent to the closed areas. In 1998 and 1999 the NMFS, Auke Bay Laboratory, initiated studies to determine the effects of bottom trawling on these soft-bottom habitats. Direct comparisons were possible between areas that were consistently trawled each year and areas where bottom trawling had been prohibited for 11 to 12 years. The proximity of the closed and open sites allowed for comparison of fine-scale infauna and epifauna diversity and abundance and microhabitat and community structure. During 2002 focus was on data interpretation and analysis. Three manuscripts are in preparation from this work.

In June 2001 a study was initiated to investigate the immediate effects of intensive bottom trawling on soft-bottom habitat and in particular an area colonized by sea whips. Sea whip biological characteristics and their resistance to two levels of trawling were studied. Sea whips are highly visible and changes in their abundance can be readily quantified. Within the study site, at least two species of sea whips (*Halipterus* sp., and *Protoptilum* sp.) are present with densities up to 10 individuals per m^2. Sea whip beds provide vertical relief to this otherwise homogeneous, low relief habitat. This habitat may be particularly vulnerable since sea whips can be removed, dislodged, or broken by bottom fishing gear.

Furthermore, since sea whips are believed to be long-lived, recolonization rates may be very slow.

The study plan consisted of three phases. In *Phase 1*, baseline data was collected. The *Delta* submersible was used to collect *in situ* videographic documentation of the seafloor along 20 predetermined transects within the study area. Additionally, a bottom sampler was deployed from the submersible tender vessel to collect sediment samples (n=42) from the seafloor. During *Phase 2*, a commercial trawler outfitted with a Bering Sea combination 107/138 net, mud gear, and two NETS High Lift trawl doors made a single trawl pass in one corridor of the study area and repetitively trawled (six trawl passes) a second corridor. A third corridor was the control and was not trawled. *Phase 3* repeated the videographic and sediment sampling (n= 42) following the trawling phase. A scientist on board the *Delta* observed the seafloor and verbally identified biota and evidence of trawling including damaged or dislodged biota and marks on the seafloor from the various components of the bottom trawl (e.g., trawl door furrows, and ground gear striations) in synchrony with the external cameras. Analyses of sediment, chemical, and infauna abundance and diversity were completed in 2002. Video analysis of epifauna data will be completed in January 2003.

Evaluation of acoustic technology for seabed classification Principal Investigator - Robert A. McConnaughey (RACE Division, Alaska Fisheries Science Center)

Detailed knowledge of seafloor properties is required to design effective studies of fishing gear impacts. Because benthic organisms have strong affinities for particular substrates, experimental areas must be carefully selected so as to minimize confounding effects. Moreover, substrate properties may help define areas of similar sensitivity to fishing gear, which would enable more systematic studies of natural and fishing gear disturbances. 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.; QTC) is capable of background data acquisition during routine survey operations. Nearly 8 million digitized echo returns from the seafloor were simultaneously collected at two frequencies (38 and 120 kHz) along a 9,000 nm trackline in the eastern Bering Sea during a 1999 hydroacoustic fishery survey by the *Miller Freeman*. Collaborative analyses with the QTC are continuing in order to develop an optimum seabed classification scheme for the eastern Bering Sea shelf. Once this is accomplished, it will be possible to evaluate the *QTC View* system for benthic habitat studies using standardized measures of fish and invertebrate abundance from annual trawl surveys. Preliminary analyses indicate the *QTC View* system is able to detect and map seabed types with distinct acoustic properties. However, in order to have *habitat* mapping utility, this acoustic variability must correspond to environmental features that influence the distribution of demersal and benthic biota.

Acoustic diversity directly represents substrate diversity. Surface roughness, acoustic impedance, and volume homogeneity influence echo returns from a vertical-incidence echo sounder and are characteristic of different seabed types. The standard QTC method uses a set of proprietary algorithms to extract features from individual echoes. Principal components analysis (PCA) reduces these features to three linear combinations that explain a large fraction of echo (seabed) variance. A three-factor cluster analysis then groups 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 scheme for any particular data set strikes a balance between high information content (i.e., many classes) and high confidence in the assigned class (e.g., if only one class).

Current clustering methods 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 Bayesian Information Theory was applied to guide the clustering process. However, because of the computational intensity of the Bayesian method and the very large size of the two data sets, only subsets of the data could be used for the analyses. Even so, over 200 CPU-hours were required to estimate the global minimum in the Bayesian Index indicating the true number of seabed classes for each data set. Significantly better methods for finding minima in multi-dimensional spaces have been developed in the study of inverse problems, particularly simulated annealing (SA), and further developments based on SA. In order to use the full data sets for clustering, we have been investigating use of SA in 2002 for efficiently identifying global minima in the Bayesian Index. Once this matter is resolved, objective large-scale seabed classification and mapping with vertical incidence echo sounders will be possible.

Living substrates in Alaska: distribution, abundance and species associations Principal Investigator - Patrick W. Malecha (Alaska Fisheries Science Center - ABL)

"Living substrates" have been identified as important marine habitat and are susceptible to impacts from fishing activities. In the Gulf of Alaska and Bering Sea, little is known about the distribution of deepwater living substrates such as, sponges (Phylum Porifera), sea anemones (Order Actiniaria), sea whips and sea pens (Order Pennatulacea), sea squirts (Class Ascidiacea), and ectoprocta (Phylum Bryozoa). In order to facilitate management practices that minimize fishery impacts to these living substrates, distributional maps were created based on National Marine Fisheries Service trawl survey data from 1975 through 2000. In general, the five groups of living substrates were observed along the continental shelf and upper slope in varying densities. Catch per unit effort (CPUE) of sponges was greatest along the Aleutian chain, while CPUE of sea squirts and ectoprocta was greatest in the Bering Sea. Large CPUEs of sea anemones, sea pens and sea whips were observed in both the Bering Sea and Gulf of Alaska. Species associations between living substrates and commercial fish and crab were also investigated. Flatfish were most commonly associated with sea squirts and ectoprocta; gadids with sea anemones, sea pens and sea whips; rockfish and Atka mackerel with sponges; and crab with sea anemones and sea squirts.

Growth and recruitment of an Alaskan shallow-water gorgonian. Principal Investigator - Robert P. Stone (Alaska Fisheries Science Center - ABL)

This study to examine the growth and recruitment of *Calcigorgia spiculifera*, a shallow-water Alaskan gorgonian continued in 2002. Two sites established in July 1999 were revisited during Cruise 02-11 aboard the NOAA Ship John N. Cobb. At these two sites, 30 of 35 colonies originally tagged in 1999 were relocated and video images recorded. These images will be digitized and growth determined from baseline images collected during the three previous years. A third study site was established in Kelp Bay, Baranof Island in 2000 where 30 colonies were tagged and images recorded. This site was unique in that it contained more than 1000 colonies, many of which were young (i.e., non-arborescent). At this site 18 of 30 colonies were relocated and video images were recorded. Branch samples were collected from untagged colonies at all three locations and will be examined microscopically to determine the gonadal morphology, gametogenesis, and reproductive schedule for this species. This will be the first work on the reproductive biology of any Alaskan coral species and should provide insights into the larval dynamics of gorgonians.

Growth rates of sponges in nearshore Alaska waters Principal Investigator - Lincoln Freese (Alaska Fishery Science Center - ABL)

Results of a recent study indicate that sponges in cold Alaska waters subjected to trawling impacts are slow to attain pre-trawl population densities or to repair damage caused by the trawl. Accordingly, this study was initiated during the 2001 field season to determine rates of sponge growth in Alaska waters. A small community of sponges located in shallow (<40 m) water in Seymour Canal, about 70 miles south of Juneau, Alaska, are being monitored on a long-term basis. Species present include *Geodia* sp., *Aphrocallistes* sp., and *Phykettia* sp. All three are known to occur in much deeper water on the continental shelf in the GOA. A total of 34 sponges were tagged in April, 2001, and video images of each specimen (with a measuring device in the field of view) were taken. The images will be analyzed with computer imaging software and compared with those obtained in the future. In April 2002 we removed cores samples of a known diameter from the individual tagged sponges to obtain information related to rates of regeneration of the sponges. Preliminary observations in September 2002 indicate that regeneration rates are highly variable among the species.

A second community of sponges located in the vicinity of Benjamin Is., Lynn Canal, Alaska, is also being monitored. Sponges were tagged, measured and cored in December 2001. Divers failed to relocate the reef upon which the sponges were located during a September 2002 cruise due to high levels of turbidity and low underwater visibility. We plan to return to the area in the winter of 2002-3, when visibility will be greater, and survey the area with a ROV before beginning followup diving operations.

Identification of Habitat Areas of Particular Concern (HAPC) Principal Investigator - Lincoln Freese (Alaska Fisheries Science Center - ABL)

Habitat features such as deep-water seamounts and shallower pinnacles are often highly productive because of their physical oceanography, and host a rich variety of marine fauna. Perusal of oceanographic charts for the Gulf of Alaska reveals that these features are relatively rare. In summer of 1999 and 2000 dives were conducted on isolated pinnacles from the research submersible *Delta*. The pinnacle surveyed in 1999 is located on the continental shelf approximately 40 nautical miles south of Kodiak, Alaska and rises from a depth of about 40 meters to within 16 meters of the surface. The surrounding habitat is relatively featureless sand. The pinnacle hosted large aggregations of dusky rockfish, kelp greenling, and lingcod, similar to aggregations noted on a pinnacle located in the vicinity of the Sitka Pinnacles Marine Reserve. The pinnacle provides substrate for dense aggregations of macrophytic kelps beginning at the 20 meter isobath and continuing to the top of the pinnacle. These kelp beds may provide essential rearing habitat, as evidenced by the numerous juvenile fish (presumably rockfish) observed swimming among the kelp fronds. Although no evidence of fishing gear impacts were noted from the submersible, it is located SW of Kodiak Island adjacent to areas that are extensively trawled.

The pinnacles surveyed in 2000 were located in southeast Alaska west of Cape Omaney. The survey was designed to determine if the site met the criteria for designation as HAPC. The extent of the site was successfully charted from the *R/V Medeia.* The site measures approximately 400 x 600 m and contains a series of pinnacles. Maximum vertical relief is approximately 55 m, and water depths range between 201 and 256 m. Seven dives at the site were completed to document habitat and associated biota. An additional 5 dives were performed to collect specimens of red tree coral, sponges, and predatory starfish. The substrate is primarily bedrock and large boulders, most likely composed of mudstone, and provides abundant cover in the form of caves and interstices of various sizes. The epifaunal community is rich and diverse, much more so than the surrounding low-relief habitat. The largest epifauna were gorgonian red tree coral colonies and several species of sponges. These organisms are not evenly distributed at the study site. Review of the video and audio data may provide insights into habitat features or oceanographic processes affecting distributions of coral and sponges. Numerous species of fish, including several species of rockfish, are present in relatively large numbers. Redbanded rockfish and shortraker/rougheye rockfish were often associated with gorgonian coral colonies and at least one species of sponge. Also of interest was the presence of a pod of several hundred juvenile golden king crab on acorn barnacle shell hash on a sloping ledge on one of the pinnacles. We believe this is the first documented observation of juveniles of this species in the Gulf of Alaska. Water currents at the site are generally very strong, but are variable in both direction and strength depending on location. Numerous sections of derelict longline gear were observed on certain areas of the pinnacle, and damage to red tree corals was evident.

In 2001 a series of surveys were completed from the submersible *Delta* in areas of the GOA offshore from Seward southeastward to Yakutat, Alaska. Purpose of the surveys was to determine presence and relative abundance of red tree coral. Choice of survey sites was based on catch of red tree coral brought up in NMFS trawl survey tows. A number of those tows resulted in high catch rates (up to 5800 kg per tow) of coral. In 2001 a total of 18 submersible dives were made at some of these locations. Preliminary analysis of the data reveals that most of these sites were bereft of red tree coral. Three of the sites had small numbers of coral colonies attached to scattered boulders or rock substrates. Most sites were of low-relief with relatively fine substrate and provide relatively low levels of habitat complexity. One such site contained widely scattered boulders, some with attached sponges (*Aphrocallistes* sp.). Numerous juvenile (5-10 cm) rockfish were observed closely associated with the sponges. No juvenile rockfish were found on boulders devoid of sponges. Two dives were made at sites selected based on bathymetric features rather than past trawl survey results. The sites were located along the northwestern and southwestern edges of the Fairweather Grounds, and consisted of high-relief, rocky substrates. One site contained extremely high densities of very large red tree coral. The second site, although similar to the first, was devoid of red tree coral. Observations made during the 2001 survey indicate that red tree coral colonies in the areas studied exhibit patchy distribution and that abundance and distribution estimates of the species based on trawl survey data may be imprecise. In 2002 focus was on collection of data from the submersible videos.

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Zooplankton, Chlorophyll and Nutrients

Contributed by FOCI

Anecdotal evidence from scientist's at-sea observations in summer of 2001 and 2002 showed no evidence of coccolithophorid blooms. In 2001, a few stations in the middle shelf region of the eastern Bering Sea had growing coccolithophore populations but not sufficient enough to discolor the water. No patches of the copepod, *Calanus marshallae*, were found over the middle shelf while previous years showed large concentrations.

Forage Fish

Forage Fish Background and Life History Information

Contributed by Mark W. Nelson, University of Washington/JISAO

In 1999, amendments 36 (BSAI) and 39 (GOA) to the fishery management plan (FMP) created a new forage fish category of species that were previously non-specified or contained within the other species category (Table 1). The species in this group are known to be critical food sources for many groundfish, marine mammals and seabirds (Wepestad 1987, Yang and Nelson 2000). This step was taken to allow for specific management actions intended to conserve and manage the forage fish resource. Current management of this category prohibits the development of a directed fishery, limits bycatch and places limits on the sale, barter, trade or processing of any species included in the group (FMP Amendment 36 and 39, 3/17/98, 63 FR 13009).

Table 1 – Family / Species contained within the forage fish category.

Forage Fish
Family Osmeridae (capelin, eulachon and other smelts)
Family Myctophidae (lanternfishes)
Family Bathylagidae (deep-sea smelts)
Family Ammodytidae (Pacific sand lance)
Family Trichodontidae (Pacific sand fish)
Family Pholidae (gunnels)
Family Stichaeidae (pricklebacks, warbonnets, eelblennys, cockscombs and shannys)
Family Gonostomatidae (bristlemouths, lightfishes and angle mouths
Order Euphausiacea (krill)

The forage fish category includes a diverse collection of species. They range in depth from intertidal to 1000+ meters, are found in the water column from the epinekton to the benthos, and have vastly divergent life histories. One member of the category isn't even a vertebrate (order Euphausiacea). The characteristic they all share is that they all act as an important food source for other species of fish, marine mammals and seabirds.

Bycatch of forage fish is a small part of commercial trawl fisheries catch. From 1997 to 2000 total catch of forage fish, from all fisheries ranged from 31.8 to 72.2 tons in the BSAI area and 27.2 to 124.9 tons in the GOA (Table 2). Of the familial groups within the category, osmerids make up the vast majority of the forage fish bycatch (>90% of total forage fish bycatch most years). In 2001, bycatch of osmerids in the

GOA exceeded 500t, compared with a range of 23-124t in 1997-2000. In the BSAI region the bulk of the osmerids are caught in the yellowfin sole fishery whereas the majority of the osmerids in the GOA are caught in the pollock and rockfish fisheries. By law, forage fish can not make up more than 2 percent of the catch in any particular fishery. Catches that exceed the limit rarely occur, therefore forage fish bycatch is unlikely to affect groundfish fisheries in Alaska.

Since none of the species in this category have been actively targeted by a fishery, very little is known about their abundance and distribution. Also, none of the current sampling programs are designed to specifically sample forage fish populations. Some members of the forage fish category are caught in the various surveys conducted by NMFS and ADF&G but these surveys do not target forage fish directly and may not provide a reliable index that would be needed to provide a proper stock assessment. To address these problems NMFS is in the process of developing a forage fish assessment program.

The AFSC has placed a high priority on improving stock assessment information on the species within the forage fish category. Better understanding of forage fish abundance is needed to better estimate energy flows in the ecosystem and to assess the state of the prey base for groundfish, seabirds and marine mammals, such as Steller sea lions. Of the species groups in the category, osmerids are of the most interest. Smelts can attain large population sizes and form dense schools, which can be exploited by predators. Capelin are one of the more abundant of the osmerids in the GOA region and therefore will be the first species of this group to be examined.

Table 2 – Estimated total catch (t) of forage fish, by region, from 1997-2000

	BSAI				GOA			
	1997	1998	1999	2000	1997	1998	1999	2000
Smelt	29.8	36.6	45.3	51.7	23.1	122.7	26.1	123.8
Sandfish	1.1	0.4	3.3	20.3	3.7	2.2	0.5	0.3
Sticheidae	0.4	0.2	0	0.1	0.3	0	3.5	0.5
Lanternfish	0.4	0.4	0	0.1	0	0	0	0
Sandlance	0.1	0	0	0	0	0	0.1	0.4
Gunnel	0	0	0	0	0.1	0	0	0
Total	31.8	37.6	48.6	72.2	27.2	124.9	30.2	125.0

Capelin

Life History

Capelin (*Mallotus villosus*) is a small, schooling, pelagic fish belonging to the family Osmeridae. Capelin have circumpolar distribution and are found along the entire coastline of Alaska, including the Bering Sea and the Gulf of Alaska, south along the west coast of British Columbia and into the Straight of Juan de Fuca (Pahlke 1985, Hart 1973). In Alaskan waters capelin grow to 25 cm and can be as old as 5 years. Spawning takes place between 2-4 years of age. In some years, due to ocean conditions and growth rates, cohorts can fail to mature, leading to a weak year class. This can be followed by a strong year class due to multiple cohorts maturing and spawning concurrently.

Capelin are primarily beach spawners. They tend to favor beaches in bays with coarse sand or fine gravel. The spawning season is May through August. Capelin spawn earlier in the southern part of their distribution and later in their northern range. Large sex-specific schools of capelin aggregate at the spawning site and commence spawning near the nighttime high tide. Beach spawning has also been witnessed during heavily overcast days. The total spawning period at a beach can last one night to several days.

During the spawning process two males accompany a female in on a wave and initiate spawning as they are carried along the beach driven by the force of the wave. The mortality rate of spawning capelin is very high. Spawning capelin often get stranded creating large mats of dead fish on the beach. Males that do not get stranded return to the aggregation and attempt to spawn with another mate and do so until they have used all their reserves. Females, having spawned all their eggs do not return to spawn again. Theoretically, females could survive to repeat spawning but in Alaskan waters, little evidence of repeat spawning has been found (Pahlke 1985, Huse 1998).

Capelin eggs are adhesive and are buried by wave action. Fish can be a voracious predator on eggs spawned in deeper water but are not a significant predator in shallow water. In some areas amphipods have been shown to be major predators of eggs in the intertidal zone (Blackburn et al.1985). Capelin eggs are robust and can sustain broad ranges of temperature, salinity and exposure. The incubation period (15 – 30 days) is highly dependent on temperature (Pahlke 1985). Once hatched, capelin larvae suffer heavy mortality through predation. Ocean conditions can also have an effect on larval survival. Anderson and Piatt (1999) discuss that the timing of the zooplankton production may have a profound effect on the recruitment of fish in the GOA. Capelin larvae are some of the latest to hatch and enter the water column. They hypothesize that an early peak zooplankton biomass could negatively affect larval capelin survival.

Distribution

In the BSAI region, small numbers of adult capelin are caught in inner shelf areas during the EBS summer groundfish survey. However, capelin may exhibit a seasonal migration following the sea-ice edge. Thus, in summer time, most of the capelin would be found north of the EBS survey area. This would explain the reason why capelin are not commonly found in the survey but are a substantial source of prey for marine mammals and sea birds found along the ice edge (Wespestad 1987).

In the GOA, capelin distribution is not dictated by sea ice because the area stays ice-free. Anderson and Piatt (1999) describe a precipitous decline in the occurrence of capelin in the NMFS and ADF&G inshore small-mesh trawl survey after the late 1970's. This survey has been conducted since 1953 in the central and western GOA. The primary design of the survey was to sample shrimp populations in the GOA. In this paper the authors describe a transformation in the ebibenthic community due to an oceanic climate regime shift. Before the shift, the bottom community in the inshore regions of the GOA was largely dominated by crustaceans and has since changed to be dominated by a complex of flatfish. It is hypothesized that the reduction in the catch of capelin was due to recruitment failure and predation caused by the regime change.

Hollowed et al. (2002) described the mesoscale distribution of capelin in two trough systems off Kodiak Island. They found that capelin spatial distribution was strongly correlated with thermal fronts, not depth or specific bottom traits. This association to thermal cues has also been shown in Atlantic populations (Carscadden and Nakashima 1997).

The ocean regime shift witnessed in the late 1970s resulted in warmer costal water temperatures. Hollowed et al. (2002) hypothesized that the rapid decline in the catches in the inshore small-mesh survey may have been a result of capelin being displaced by warm water in the nearshore areas that the survey has been designed to study. In other words, following water temperature cues capelin moved out of the survey area and were therefore not caught by the survey. This could explain the continuing high predation rates of capelin by groundfish seen in the more offshore shelf areas of the GOA sampled by the NMFS groundfish survey (Yang and Nelson 1998).

Potential sources of data

As stated earlier, data on capelin abundance is limited. There is not a directed fishery for capelin to provide a reliable CPUE estimate and current surveys, which do not target capelin directly, may or may not give accurate indexes of abundance. Therefore we must either devise a new survey or examine the multiple data sets to develop a better index that can be used to model the population. NMFS and ADF&G have eight data sets that may be able to supply data for a capelin model. These sources are:

1. The NMFS and ADG&G small mesh survey (previously discussed).
2. ADF&G aerial spawning surveys.
3. NMFS larval fish abundance surveys.
4. Age-weight-length (AWL) data from ADF&G, UAK and NMFS surveys.
5. Bycatch statistics from observer data.
6. CPUE data from groundfish trawl surveys.
7. Acoustic and trawl data from NMFS and USFWS in the GOA.
8. Ocean Carrying Capacity high speed surface trawl data.

It is our hope that we will be able to formulate a reasonable assessment from existing data but the resolution of our model could be limited. For a proper assessment, a survey that better samples capelin will need to be developed.

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Consequences of a superabundance of walleye pollock larvae in the Gulf of Alaska

Contributed by Janet Duffy-Anderson, FOCI

Abundances of larval walleye pollock in Shelikof Strait, Gulf of Alaska, in 1981 were far greater than any recorded estimates before that time or since (some estimates exceeded 100,000 larvae 10 m^{-2}) (Figure 1). In spite of this extraordinary input, the ensuing 1981 year class was relatively poor. An examination of the feeding habits of larvae collected from inside and outside dense larval patches revealed that, in 1981, larval walleye pollock consumed significantly more invertebrate eggs ($\bar{x}$ = 66.7% of the total diet) and fewer copepod nauplii ($\bar{x}$ = 13.6%) inside of larval patches relative to outside ($\bar{x}$ = 11.4% and 63.2%, respectively). These observations suggest that density-dependent competition inside patches may have locally depleted the primary food source, copepod nauplii, prompting a diet switch to a lower quality but more abundant prey resource, invertebrate eggs. Results from a bioenergetics simulation support this theory, indicating that dense patches of walleye pollock larvae in 1981 were capable of exhausting naupliiar prey resources in Shelikof Strait in a relatively short period of time (14 - 40 days). Our observations contrast with other studies that suggest that ichthyoplankton exert little or no influence on microzooplankton standing stocks. Rather, we present evidence that, in certain unusual circumstances, particularly dense aggregations of larvae are capable of locally depleting the prey community. Such events may weaken larval condition and exacerbate natural death rates, which may have contributed to the poor recruitment success of the 1981 year class.

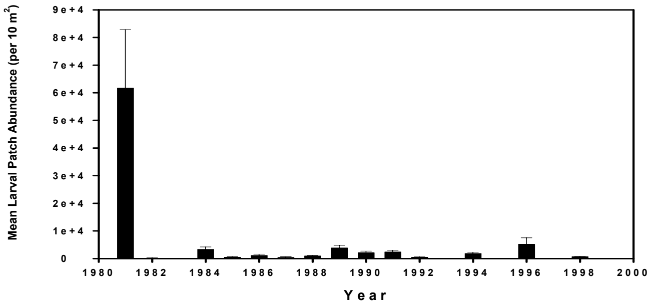


Figure 1. Yearly comparisons of maximum observed abundances of larval walleye pollock in April in the Gulf of Alaska. Some years have no data plotted due to lack of sampling at the appropriate time.

Age-0 Walleye Pollock (*Theragra chalcogramma*) and Capelin (*Mallotus villosus*) in the Western Gulf of Alaska: Potential Competitive Interaction?

Contributed by Matthew T. Wilson and Janet T. Duffy-Anderson, FOCI

The potential for competitive interaction between age-0 pollock and capelin is currently being examined using data from a small-mesh trawl study conducted in the western Gulf of Alaska (GOA) during September 2000 and 2001. Essentially, we want to know what effect capelin have on age-0 pollock rearing in a major nursery. Capelin inhabit coastal areas that are also utilized by juvenile pollock, so competition is most likely to occur in pollock nurseries. Age-0 pollock and capelin are similar in size, and both are zooplanktivores. The diets of capelin and age-0 pollock have been shown to consist primarily of copepods and euphausiids, but no detailed, direct comparison has been conducted. Furthermore, our sampling was conducted in late summer, a time when plankton densities undergo a seasonal decline, which might further increase the chance for competition among these fishes. Therefore, our objective is to examine the overlap in geographic distribution and diet between age-0 pollock and capelin to assess the potential for competitive interaction.

To address this, fish and plankton were collected from a grid of stations situated in the middle of the main pollock nursery in the GOA. The grid covers about 10,500 nmi sq of a variety of habitat types: bays, valleys, banks, and slope. At each station, fish were collected with a small-mesh midwater trawl, equipped with a codend liner (3 mm mesh size), towed obliquely from 200 m to the surface. Almost every station was sampled once at day and again at night to account for diel variation in feeding and net sampling efficiency. Similarly, CTD and plankton samples were collected, but these data are not yet available. Calculation of mean catches and size compositions included standardization to a common unit of effort (fish per m^2).

To examine diet overlap, age-0 pollock and capelin were collected in 19 different trawl hauls made during September 2000. Stomachs were excised from about ten individuals of each species per sample. The gut contents were teased apart and identified to broad taxonomic categories, counted, and weighed. Horn's index of overlap was used to compare diet overlap. Index values range from 0, no overlap, to 1, complete overlap.

$$R_0 = \frac{\sum(p_{ij}+p_{ik})\ln(p_{ij}+p_{ik}) - \sum p_{ij}\ln p_{ij} - \sum p_{ik}\ln p_{ik}}{2\ln 2}$$

where

p_{ij} = abundance or weight of prey in ith category as a proportion of all prey in j^{th} species; and

p_{ik} = abundance or weight of prey in ith category as a proportion of all prey in k^{th} species.

We used this overlap index to compare the proportional diet composition by prey item count and weight. There are three parts to the preliminary results: 1) geographic overlap, which covers both years of sampling, 2) size composition for September 2000, and 3) diet overlap for September 2000.

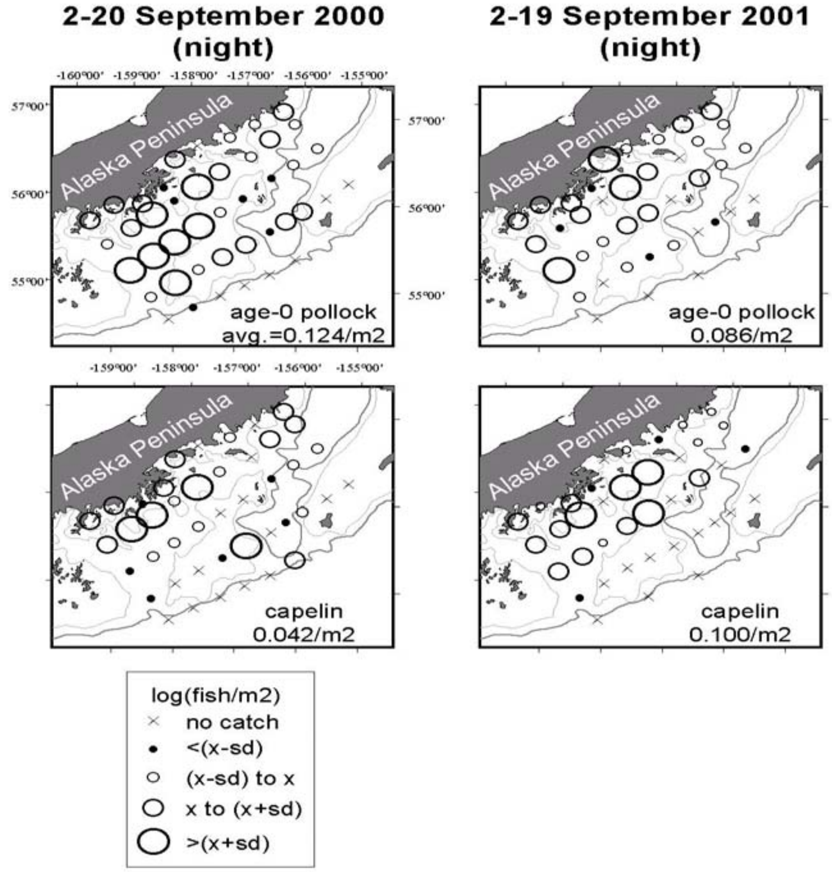


Figure 1.--Log$_{10}$-transformed abundance (fish/m^2) of age-0 pollock and capelin collected at night in midwater trawl hauls during September 2000 and 2001. Non-zero catch bins, and the associated plot symbol size, were constructed using the mean (x) and standard deviation (sd) for each species and year.

Only the nighttime data are presented here because the daytime patterns were similar although fewer fish were caught. Both species in each year were most abundant over the middle and inner shelf with some tendency for high abundance in the southwestern part of the grid (Fig. 1). In 2000, pollock averaged about 0.124 fish per m^2 as compared to 0.042 for capelin. In 2001, pollock averaged 0.086 fish per m^2, capelin averaged 0.100 fish per m^2. Age-0 pollock occurred at more stations (81% of 43 stations sampled in 2000, and 74% of 39 stations sampled in 2001) than did capelin (65%, 59%). But the percent frequency of co-occurrence (63%, 59%) was similar to the percent occurrence of capelin. In other words, capelin almost always occurred with pollock, but not *vice versa*. Considering only co-occurrences, the correlation between pollock and capelin density was not significant during 2000 (Pearson r=-0.01, p>0.05, n=28), but it was significant during 2001 (Pearson r=0.86, p<0.01, n=23). Thus, the geographic overlap was much higher during 2001 when capelin were more abundant.

There was considerable overlap in the lengths of age-0 pollock and capelin collected at night during September 2000, although capelin tended to be slightly larger (Fig. 2). Based on their length, most of the capelin were probably age-1 individuals. There is a notable absence of larger capelin, but this is probably not attributable to gear avoidance because many larger pollock and eulachon were collected. Overlap in size occurred over the 60 – 100 mm SL interval. Many of the pollock were smaller indicating that, if their growth rate exceeds that of capelin, this overlap in size would increase with the onset of winter.

The diets of age-0 pollock and capelin were very similar (Fig. 3). Numerically, both predators mostly ate small copepods (<2 mm prosome length) followed by pteropods, and euphausiids. In terms of biomass, euphausiids dominated the diet but were followed by fish and copepods. Incidentally, most of the prey fish were likely larval capelin. Pollock had a slightly broader diet in that they consumed crab larvae and amphipods, which were either absent or relatively scarce in capelin diets. At least at this taxonomic level, and over all fish, there was high overlap between predator diets whether by abundance (R_o=0.97) or biomass (R_o=0.96). On a haul-by-haul basis,

however, Horn's overlap varied widely from
0.0 to 0.97 for prey abundance, and from 0.04 to 0.98
1.0 for prey weight.

Feeding chronology was examined as a possible explanation for the high variability in diet overlap among hauls. For both species, the frequency of empty stomachs decreased during daylight hours and the mean number of prey in stomachs increased during daytime indicating that both species ate during the day. This trend, however, was more pronounced among capelin than among age-0 pollock. Therefore, diet overlap was low during the night when capelin stopped feeding but pollock continued to feed although at low intensity. During the day feeding by both species increased with a consequent increase in R_o. This conclusion is supported by a temporal pattern in R_o among samples.

In conclusion, we found high potential for competitive interaction between age-0 pollock and capelin. Competition may occur between these fishes when prey are in short supply (e.g., seasonal decline, predator outburst), but it is unclear which predator would be most adversely affected. Alternatively, high overlap may indicate a relatively unlimited prey resource, at least during the time and location of our study.

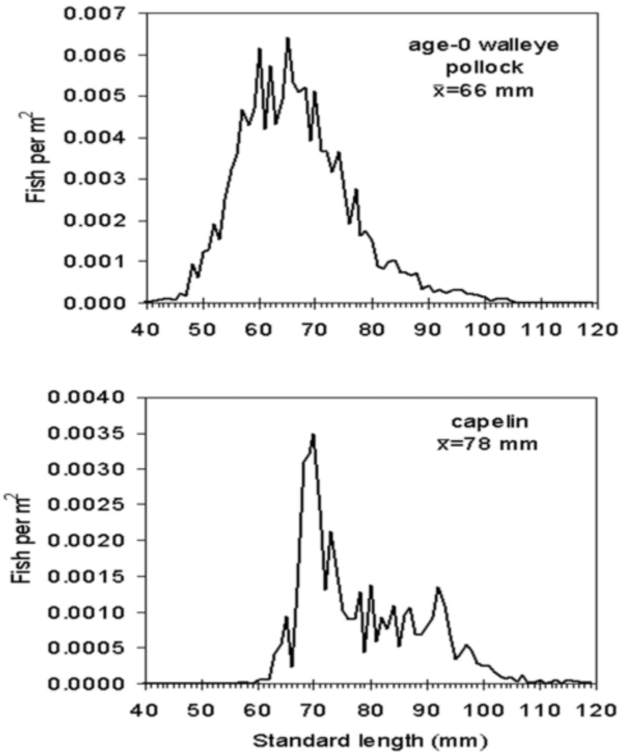


Figure 2.--Length composition of age-0 pollock and capelin collected at night in midwater during 2-20 September 2000.

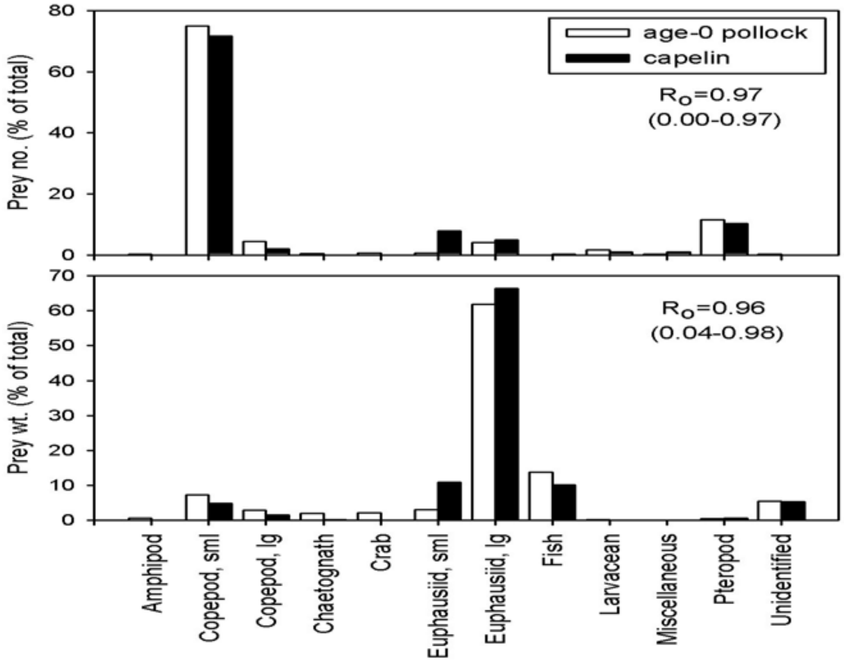


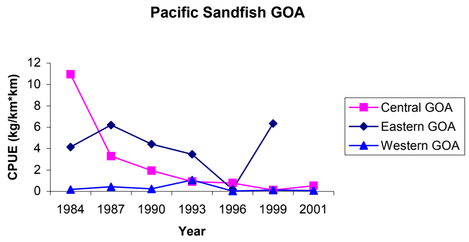
Figure 3.--Percent composition by number and by weight of the diet of all age-0 pollock and capelin collected in 19 trawl hauls made during September 2000.

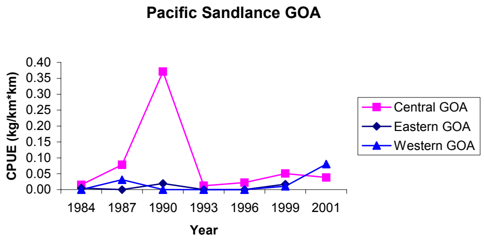
Forage – Gulf of Alaska

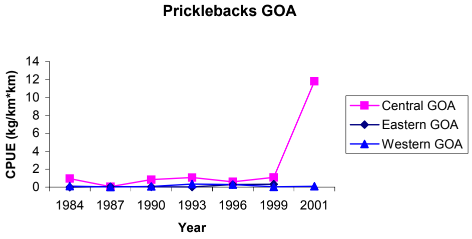
Contributed by Eric Brown, Alaska Fisheries Science Center

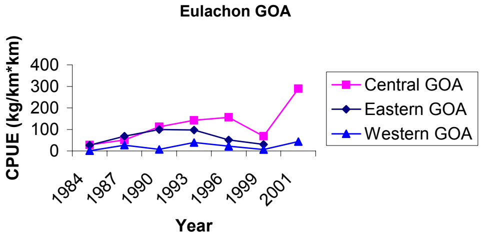
Several groups have been defined as forage species by the North Pacific Fishery Management Council for management purposes. These groups include gunnels, lanternfish, sandfish, sandlance, smelts, stichaeids, and euphausiids. Several of these groups are captured incidentally in the RACE bottom trawl survey of the shelf, which may provide an index of abundance (Figure 1). This survey is not designed to assess these types of organisms and further detailed examinations of these results are needed to assess whether there are meaningful trends.

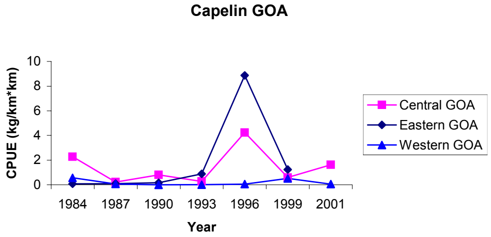
Several of these forage species exhibited highly variable patterns of distribution and abundance. Pacific sandlance appear only sporadically in survey catches and in very small quantities. These typically small fish are generally not readily available to the bottom trawl, probably due to a combination of their vertical distribution within the water column and their ability to pass through the meshes of the survey trawl. The large spike seen in the central Gulf in 1990 was due to a single catch consisting of 150 individuals. Pricklebacks also typically occur in small quantities but in 2001, one unusually large catch of 123 kg (632 fish) in the central Gulf contrasted sharply with catch patterns from previous surveys. Similarly, the increases in abundance seen for capelin in the central and eastern Gulf were influenced by a very few and unusually large catches. Of these species, only Pacific sandfish and eulachon exhibit catch rates not unduly influenced by a few large catches.


Pacific Sandfish GOA


Pacific Sandlance GOA


Pricklebacks GOA


Eulachon GOA

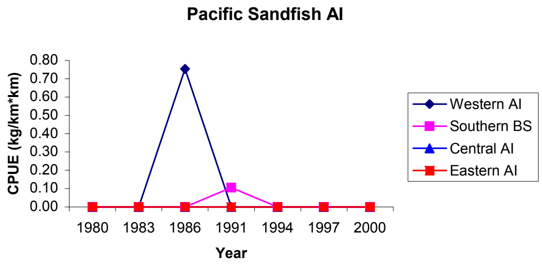

Capelin GOA

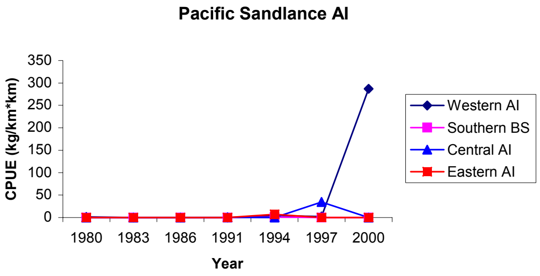
Forage – Aleutian Islands

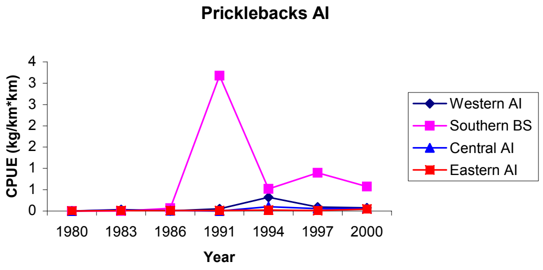
Contributed by Eric Brown, Alaska Fisheries Science Center

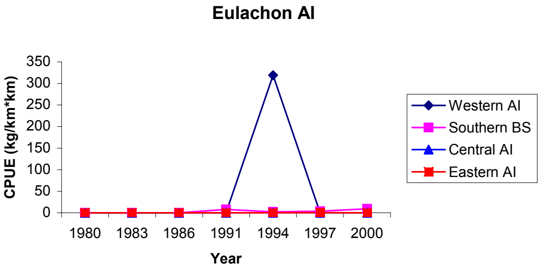
Several groups have been defined as forage species by the North Pacific Fishery Management Council for management purposes. These groups include gunnels, lanternfish, sandfish, sandlance, smelts, stichaeids, and euphausiids. Some of these groups are captured incidentally in the RACE bottom trawl survey of the shelf, which may provide an index of abundance (Figure 1). This survey is not designed to assess these organisms and further detailed examinations of these results are needed to assess whether there are meaningful trends.

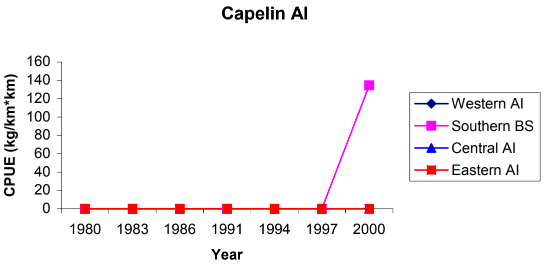
The Aleutian Islands forage species appear only sparingly in survey catches with occasional higher than normal catches. The spike of Pacific sandfish seen in the western Aleutian Islands in 1986 is a result of only 4 individuals appearing in one catch. Similarly, the highest catch rates for pricklebacks, eulachon and capelin are driven by only two to three unusually high catches. The large increase in pricklebacks seen in the western Aleutians in 1991 was due to only three catches, the largest being less than 8 kg. The high abundance of eulachon in the western Aleutians in 1994 was due to only two unusually large catches of 431 kg and 63 kg while the high cpue of capelin in the southern Bering Sea in 2000 was mainly due to one very unusually large catch of 221 kg.











Bering Sea Juvenile Walleye Pollock (not updated for 2002)

Contributed by Ric Brodeur, Northwest Fisheries Science Center

Summer sampling for age-0 walleye pollock in the Middle and Outer Shelf around the Pribilof Islands by the Japanese research vessel *Oshoro Maru* continued in 2000. Moderate catches of age-0 pollock were observed in 2000, with the largest catch occurring in the northwest part of the grid (Figure 1). Average densities within a consistent grid of stations (box on figure) were less than half of those estimated for 1999. The two highest years in the series (1996 and 1999) were years of good pollock recruitment in the eastern Bering Sea (J. Iannelli, pers. comm.). Preliminary results from the 2001 survey indicate very high densities of juvenile pollock based on rough counts made at sea. The mean density of juveniles for the index area was 269 fish per 10m^2 sea surface area, which is about five times as large as the previous high year. However, the juveniles were smaller than in previous years, possibly due to a later spawning or slower growth, and presumably would still be subjected to substantial mortality at this time of year. Thus, it is not yet clear whether this high count is indicative of an above-average yearclass.

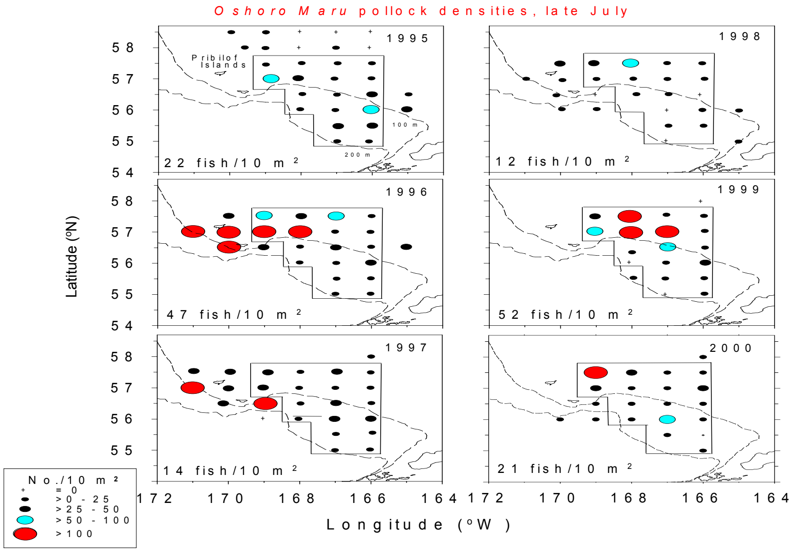


Figure 1. Densities of age-0 walleye pollock sampled in summer on the Oshoru Maru, 1995-2000. Number at the bottom of each panel indicates the density inside the outlined standard sampling area.

Forage – Eastern Bering Sea

Contributed by Gary Walters, Alaska Fisheries Science Center

Several groups have been defined as forage species by the North Pacific Fishery Management Council 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 shelf, which may provide an index of abundance (Figure 1). Sandfish appeared in the trawl surveys around the early 1990's but have otherwise not appeared to be abundant in the survey area. Stichaeids, which likely 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 is relatively low and was very low in the last three survey years, 1999-2001. Similarly, sandlance appeared to be increasing in survey catches until the last three survey years when they were found in very low abundance. Eulachon biomass index values in the summer survey appeared relatively stable in the 1990's. Capelin catches in the survey have been relatively stable with the exception of one year (1993) when it had a very high biomass index.

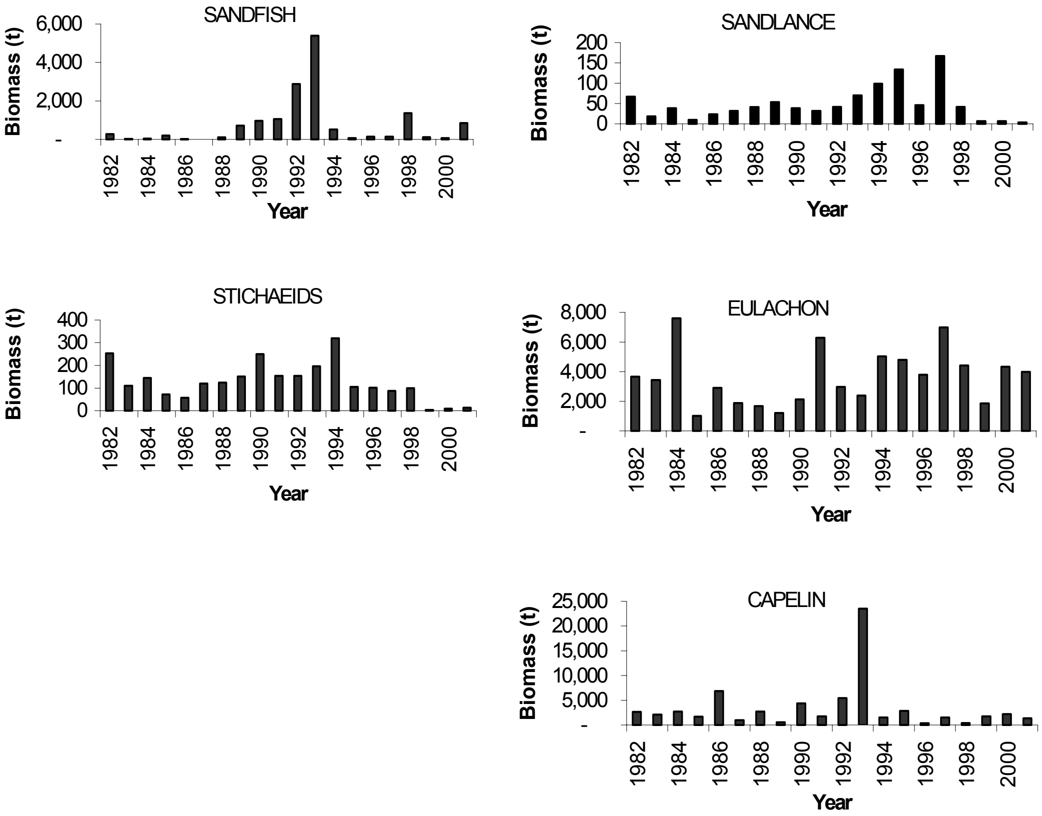


Figure 1. Biomass index values of several forage fish groups from the eastern Bering Sea summer bottom trawl survey, 1982-2001.

Groundfish Biomass and Recruitment Trends (not updated for 2002)

By Alaska Fisheries Science Center Stock Assessment Staff

Biomass trends of groundfish assessed in 2000 with age or size structured models in the BSAI and GOA regions show different trends (Figure 1) according to assessment information in NPFMC (2000a, b), also available on the web at: http://www.refm.noaa.gov/stocks/specs/Data%20Tables.htm. Total biomass of BSAI groundfish was apparently low in the late 1970's but increased in the early 1980's to around 20 million metric tons. Some fluctuations in the total biomass have occurred, with biomasses below the 1979 to present average occurring in 1990-91 and 1997-98 (Figure 2). Walleye pollock was the dominant species in the groundfish biomass and the fluctuations in total biomass are due to changes in population biomass of pollock.

Gulf of Alaska groundfish biomass trends (Figure 1) are different from those in the BSAI. Although biomass increased in the early 1980's, as also seen in the BSAI, GOA biomass declined after peaking in 1982 at over 6 million metric tons. Although total biomass was fairly stable from around 1985-1993, it has been below the 1979 to present average since 1994 and continued to decline through 2000 (Figure 2). Pollock started out at the dominant groundfish species but arrowtooth flounder has increased in biomass and is now dominant. Pacific halibut, assessed by the International Pacific Halibut Commission (IPHC), is not included in these biomass trends. IPHC stock assessment in 2000 for the central GOA area (IPHC area 3A) indicates halibut biomass increased from 1979 to 1986 to almost twice the 1979 level and biomass levels in 2000 are still above the 1979 levels (IPHC 2000).

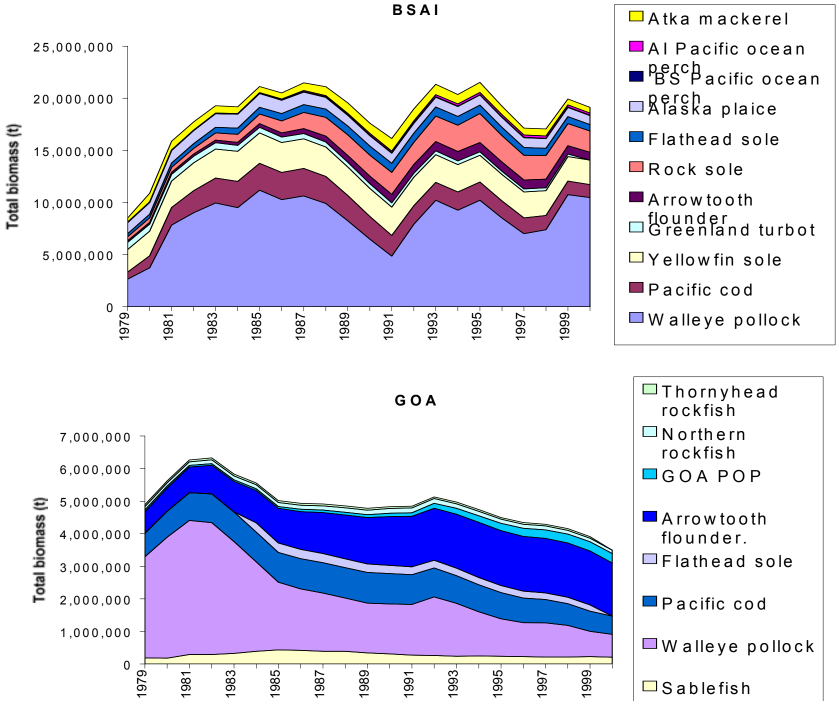


Figure 1. Groundfish biomass trends in the BSAI and GOA from 1979 to 2000, as determined from age-structured models of the Alaska Fisheries Science Center reported by NPFMC (2000a,b).

Recruitment trends of assessed groundfish in the BSAI and GOA since the 1977 regime shift show a variety of patterns (Figure 3). The 1980's appeared to be a period of above-average recruitment for many species while the 1990's appear to be below average. There is a tendency for more recent year classes to be underassessed in more recent years and yearclass strength for some species in the 1990's may turn out higher as more years of observations for these yearclasses are obtained. Similarly, yearclass strengths for Pacific halibut in GOA IPHC area 3A showed higher recruitment in the 1980s and declining recruitment after around 1987.

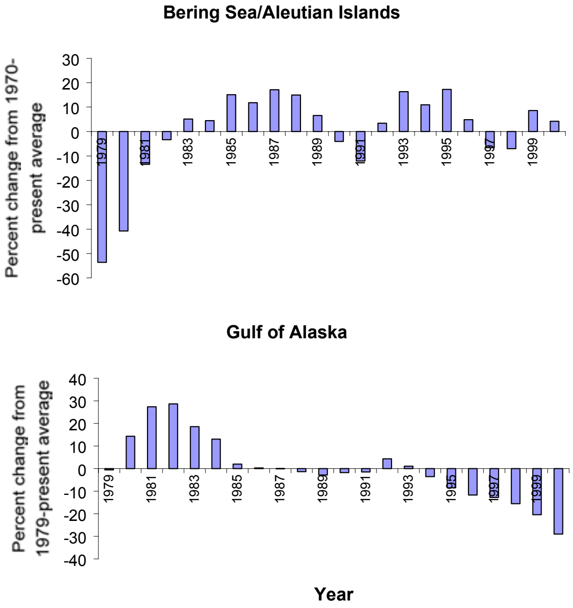


Figure 2. Total biomass trends (percent change from time series average) for BSAI and GOA groundfish assessed by age-structured models of the Alaska Fisheries Science Center, 1979-2000.

Temporal trends in flatfish production in the Eastern Bering Sea are consistent with the hypothesis that decadal scale climate variability influences marine survival during the early life history period. Examination of the recruitment of winter-spawning flatfish in the Bering Sea (rock sole, flathead sole and arrowtooth flounder) in relation to decadal atmospheric forcing indicates favorable recruitment may be linked to wind direction during spring (Wilderbuer et al. 2001). Years of consecutive strong recruitment for these species in the 1980s corresponds to years when wind-driven advection of larvae to favorable in-shore nursery grounds in Bristol Bay prevailed (Figure 4). The pattern of springtime wind changed to an off-shore direction during the 1990s which coincided with below-average recruitment.

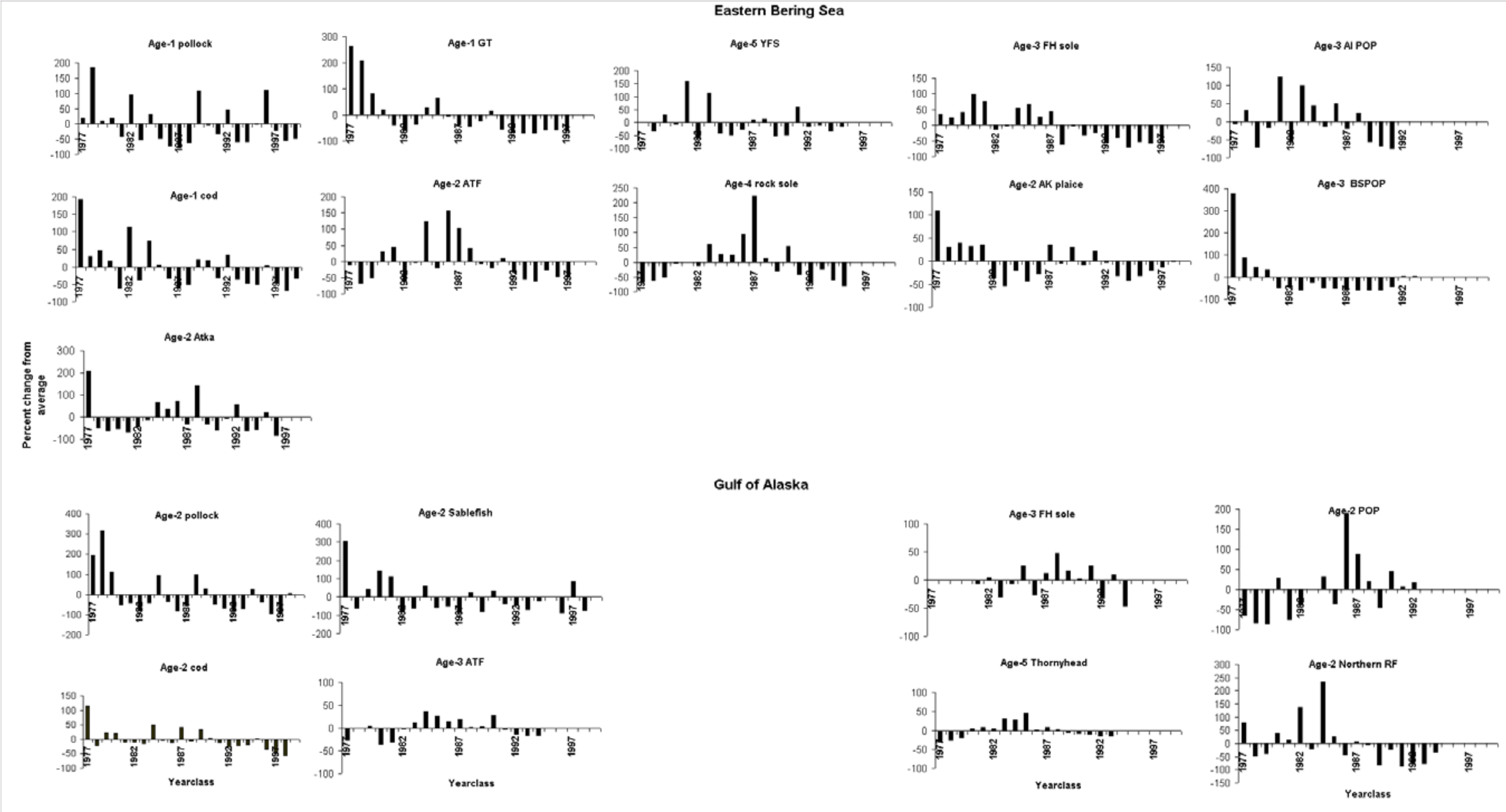


Figure 3. Groundfish recruitment trends (percent change from the 1977-present average) as determined from the age structure models of the Alaska Fisheries Science Center reported in NPFMC (2000a, b).

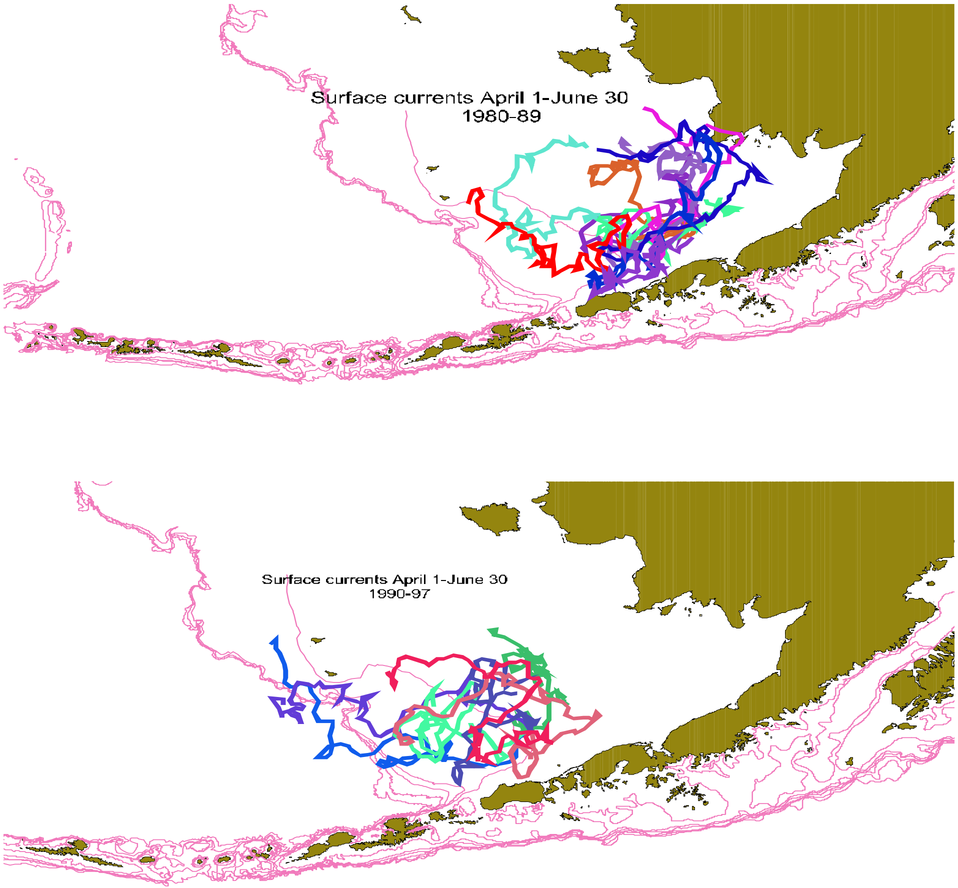


Figure 4.—OSCURS (Ocean Surface Current Simulation Model) trajectories from starting point 56^0 N, 164^0 W from April 1-June 30 for the 1980s (upper panel) and 1990-1996 (lower panel).

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International Pacific Halibut Commission (IPHC). 2000. Pacific halibut stock assessment and fishery evaluation. In: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501

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Wilderbuer, T., A Hollowed, P. Spencer, G. Walters, and N. Bond. 2001. Flatfish Recruitment Response to Decadal Climatic Variability and Ocean Conditions in the Eastern Bering Sea. Submitted to PICES 10th Annual Meeting, October 2001.

Update on EBS winter spawning flatfish recruitment and wind forcing

Contributed by Jim Ingraham and Tom Wilderbuer

In last year's Ecosystem Considerations chapter on groundfish was an examination of 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 run 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. The time series is updated (1998-2002; Figure 1) for the last 5 years.

Four out of five OSCURS run for 1998-2002 were consistent with those which produced above-average recruitment in the original analysis. 2000 being the exception. The north-northeast drift pattern suggests that larvae may metamorphosis to a benthic form of juvenile flatfish.

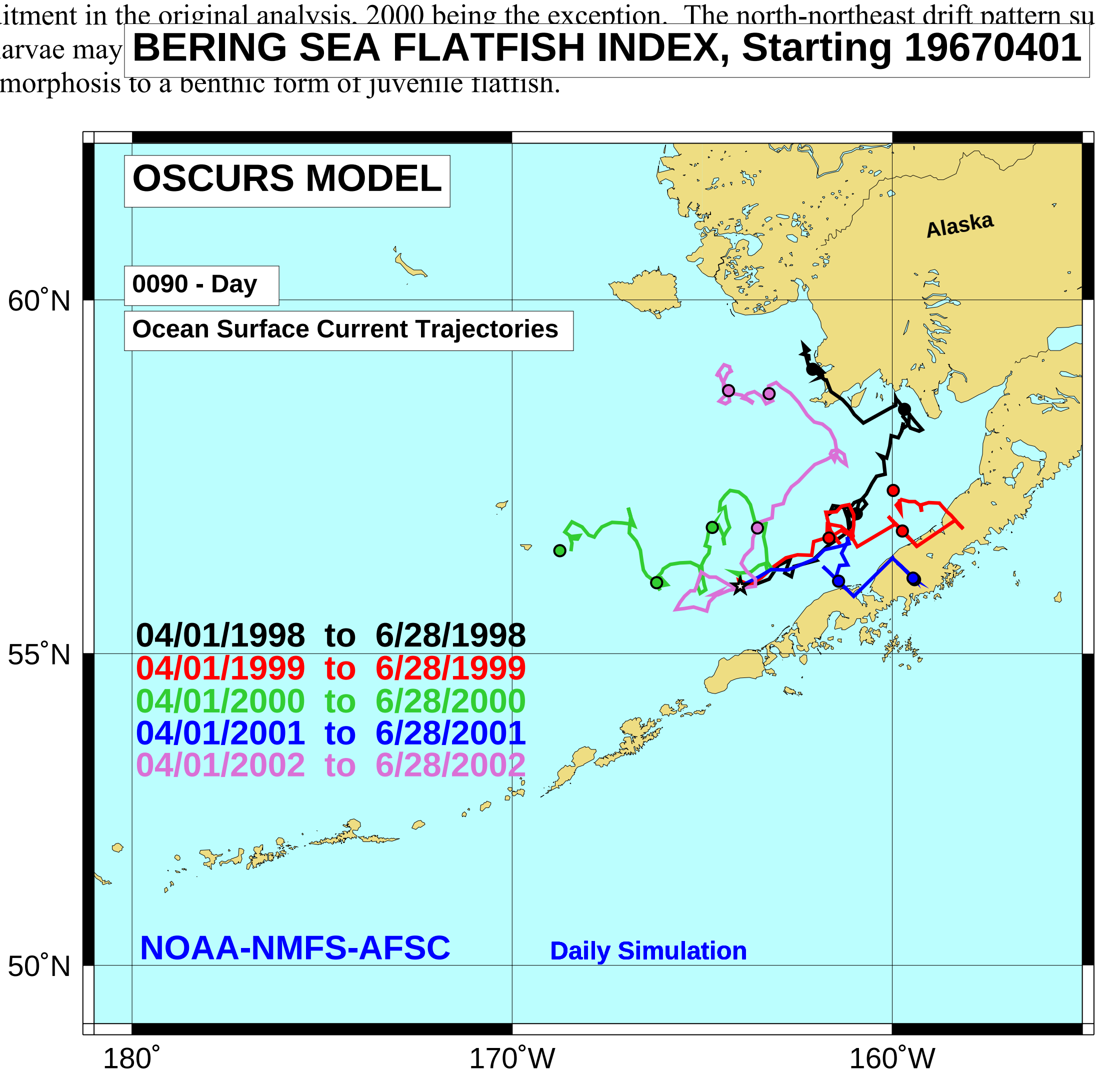

Figure 1.—OSCURS (Ocean Surface Current Simulator) model trajectories from starting point 56˚N, 164˚W from April 1-June 30 for 1998-2002.

Other Species

Sharks and shark bycatch in Alaska State and Federal waters (not updated for 2002)

Contributed by: Kenneth J. Goldman, Elasmobranch Ecology Program,Virginia Institute of Marine Science, P.O. Box 1346, Gloucester Point, VA 23062 e-mail: keng@vims.edu

Sharks species in Alaska waters

Sharks exhibit a life history strategy characterized by slow growth, late maturity, low fecundity and, therefore, extremely low intrinsic rates of population increase (Holden 1974 and 1977, Hoenig and Gruber 1990). This fact, in combination with heavy exploitation rates and a lack of management, has led to rapid stock declines and fishery failures worldwide (Compagno 1990, Hoff and Musick 1990, Castro et al. 1999). Successful conservation and management of salmon sharks in Alaska waters begins with knowledge of basic life history parameters such as growth rates, age at maturity and longevity.

A modest array of nine or ten shark species may occur in Alaska waters (Camhi 1999). The three most abundant species are spiny or piked dogfish (*Squalus acanthias*), Pacific sleeper (*Somniosus pacificus*) and salmon sharks (*Lamna ditropis*). Other species include blue (*Prionace glauca*), sixgill (*Hexanchus griseus*) and tope or soupfin sharks (*Galeorhinus galeus*).

Spiny dogfish

Spiny dogfish are possibly the most abundant shark species in the world and the only one that has supported a large and long-term fishery comparable to many teleost fishes (Compagno 1984, Bonfil 1999, Castro et al. 1999). They are cosmopolitan and widely distributed in the North Atlantic and Pacific, as well as around the southern tips of South America, Africa, Australia and New Zealand (Compagno 1984). In the North Pacific, they range from 30°N-65°N latitudeon the western side and from 23°N-65°N on the eastern side (Eschmeyer et al. 1983, Compagno 1984). Along the eastern North Pacific they are most abundant off Washington and British Columbia (BC) where there has been an active fishery for over 126 years (Bonfil 1999). Maximum size in the eastern North Pacific is around 150 cm total length, and maximum weight is approximately 9kg (Hart 1973, Compagno 1984). They are typically found in waters ranging from 6°C to 15°C and have a depth distribution from shallow nearshore waters to a depth of 900m. They are highly gregarious, forming extremely large, localized (and yet highly mobile) schools that tend to be of uniform size and sex (Compagno 1984, Castro et al. 1999).

Usually coastal and demersal, spiny dogfish migrate north and south as well as nearshore and offshore. These movements are not fully understood, but appear to be tied to water temperature and prey availability. The stock structure of spiny dogfish in the eastern North Pacific is unknown. The current belief is that there is a coastal stock residing in the Strait of Georgia-Puget Sound area and an offshore stock that extends from Alaska to Baja California, Mexico (Ketchen 1986, Bonfil 1999). This hypothesis is based on short-term tag-recapture data and geographic differences in mercury levels found in tissues, however no population genetics study has been initiated to examine stock structure. Several long-term tag-recaptures of spiny dogfish from the eastern North Pacific have demonstrated long-ranging movements to central Baja California, Mexico and to Japan (Bonfil 1999, Compagno 1984), but the degree of trans-Pacific movements is probably insignificant (Ketchen 1986).

Spiny dogfish have an aplacental viviparous mode of reproduction. They possess the longest known gestation period of any vertebrate, with estimates ranging from 21 to 25 months (Castro et al. 1999). Size at parturition is 22 to 25cm total length. Litter sizes range from 1 to 20 with an average of 6 and a sex ratio of 1:1 (Compagno 1984, Weber and Fordham 1997, Castro et al. 1999). Mating occurs during the winter months (Ketchen 1972, Compagno 1984, Nammack et al. 1985, Saunders and McFarlane 1993).

In several geographic areas, mature dogfish are often found in more inshore waters while immature individuals predominate in offshore waters.

Estimates of age and length at maturity and longevity vary considerably with geographic location (Nammack et al. 1985, McFarlane and Beamish 1987, Weber and Fordham 1997). Historic estimates of the age at 50% maturity for the eastern North Pacific range from 20 to 34 years. However, ages from the spines of oxytetracycline (OTC) injected animals provided validation of an age-length relationship and indicate that 50% sexual maturity occurs at 35.3 years of age (Beamish and McFarlane 1985, McFarlane and Beamish 1987). The same study also showed that longevity in the eastern North Pacific is between 80 and 100 years, and stated that several earlier published ages at maturity (and therefore longevity) were lower due to the rejection of difficult to read spines and the grouping of annuli that were very close together. This is one of the few shark species where validation using OTC has been completed, and it demonstrates the need to do so whenever possible (Cailliet 1990).

Spiny dogfish are opportunistic and adaptable in their feeding behavior. The majority of their diet is teleost fishes such as herring (and other clupeids), smelt (*Osmeridae*), hake (*Merluccius*), pollock and tomcod (Gadidae), sandlance (*Ammodytes*), flatfishes (*Pleuronectiformes*), lingcod (*ophiodon*) and salmon (*Oncorhynchus*). They also prey on mollusks, cephalopods and crabs (Hart 1973, Eschmeyer et al. 1983, Compagno 1984). Along the North American west coast spiny dogfish have shown a strong association with hake and with several other species of groundfish including sablefish (*Anoplopoma fimbria*), arrowtooth flounder (*Atheresthes stomias*), yellowtail rockfish (*Sebastes flavidus*) and walleye pollock (*Theragra chalcogramma*) (Bonfil 1999).

Pacific sleeper shark

Pacific sleeper sharks occur year-round in the boreal and temperate waters of the North Pacific. They live on the continental shelf and slope areas from 35°N to70°N in the western Pacific and from 25°N to 70°N in the eastern Pacific and can be found in polar waters year-round (Compagno 1984). Maximum documented total length is 430cm (Eschmeyer et al. 1983, Compagno 1984), however the average length and weight are around 365cm and 320-365kg respectively (Castro 1983). In the northern part of its range it can range from near surface waters to the bottom, while in the southern part of its range catches tend to occur in deep water (200 to 2000m) (Eschmeyer et al. 1983, Compagno 1984,), although this has not necessarily been found to be the case in parts of the western North Pacific (Orlov and Moiseev 1998). They appear to prefer colder water and have been captured in water temperatures between -0.16°C and 4.1°C (Orlov 1999).

Virtually nothing is known about the space utilization or net movements of Pacific sleeper sharks. The Alaska Department of Fish and Game has tagged approximately 300 sleeper sharks in Prince William Sound since 1997, recapturing five. The longest distance traveled was 23.8 nautical miles (211 days at large), while the longest time at large was 603 days (22.8 nm) (Bill Bechtol pers. comm.). This preliminary tag-return data indicates that at least some sleeper sharks are resident in Prince William Sound throughout the year and that they likely have relatively small home ranges.

Pacific sleeper sharks are presumed to have an aplacental viviparous mode of reproduction. This is based upon large eggs (up to 300 of them) found in a few females, however no pregnant females have ever been captured (Compagno 1984). There is no documentation of gestation time or litter sizes for this species.

Nothing is known about the life history parameters of Pacific sleeper sharks. As with many other Squaliform sharks (without dorsal spines) there appears to be no way to age this species. The vertebrae do not show any obvious banding pattern or markings that can be used to denote annuli. Current research is attempting to use a variety of dyes and stains as well as soft-tissue X-rays in order to further examine this question (Goldman unpub. data). The inability to accurately age these species and obtain data on their basic life history parameters makes it extremely difficult to gain a better understanding of their ecology.

Sleeper sharks are known to feed on a wide variety of mid-water and benthic prey as well as to take carrion (Hart 1973, Castro 1983, Compagno 1984). Their diet includes flatfishes (*Pleuronectiformes*), salmon (*Oncorhynchus*), rockfishes (*Sebastes*) and walleye pollock (*Theragra chalcogramma*). They also feed on a number of invertebrate species including tanner crab (*Chionoecetes*), cephalopods, gastropods and occasionally even feed on sponges (Compagno 1984, Orlov and Moiseev 1998, Orlov 1999, Yang and Page 1999). Pacific sleeper sharks do consume seals, however, whether they are preying on living seals or feeding upon them as carrion, or both, is not well documented.

Salmon shark

Salmon sharks are widely distributed (coastal and oceanic) in subarctic and temperate waters of the North Pacific, ranging between 35°N-65°N in the western Pacific and 30°N-65°N in the eastern Pacific (Strasburg 1958; Farquhar 1963, Compagno 1984). Maximum size has been reported at 305cm total length (TL), but no specimens over 260cm TL have actually been documented (Goldman and Musick in press). Adult salmon sharks can weigh upwards of 220kg. They occur individually and in large aggregations. They are found in sea-surface temperatures of 5°C to 18°C and their depth distribution ranges from the surface to at least 150m.

While sexual segregation is relatively common in sharks, a remarkable sex ratio difference occurs in salmon sharks across the North Pacific basin. The western side is male dominated and the eastern side female dominated, with dominance increasing with latitude (Sano 1962; Nagasawa 1998, Goldman and Musick in press). Larger sharks range farther north than smaller individuals, and southern catches generally occur in deeper waters (Nagasawa 1998; Goldman and Musick, unpublished data).

A north-south seasonal migration appears to occur in the western and eastern North Pacific (Iino 1939, Kosugi and Tsuchisaki 1950, Tanaka 1980, Gorbatenko and Cheblukova 1990, Balgaderov 1994, Nakano and Nagasawa 1994, Nakano and Nagasawa 1996), however salmon sharks are present in the Gulf of Alaska and the Prince William Sound throughout the year (Goldman and Human, in press). Very little is known about trans-Pacific movements, although they are suspected to take place (Tanaka 1980, Nakano and Nagasawa 1996, Goldman and Musick in press). The stock structure of salmon sharks is not well understood at this time, however a population genetics study is currently underway. Current information from the western and central North Pacific implies that salmon sharks constitute a single stock, however there is no current information for the Japan Sea or the eastern North Pacific (Sano 1962, Tanaka 1980, Blagaderov 1994, Nagasawa 1998).

Salmon sharks have an aplacental viviparous mode of reproduction, which includes a stage of oophagy whereby fetuses in the uteri are nourished by ovulated yolk-filled egg capsules (Tanaka 1986 cited in Nagasawa 1998, Gilmore 1993). Litter size in the western North Pacific is four to five pups and litters are male dominated 2.2:1 (Tanaka 1980). The number of pups and sex ratio of eastern North Pacific litters is currently unknown. Gestation appears to be nine months with mating occurring during the late summer and early fall, and parturition occurring in the spring (Tanaka 1980, Nagasawa 1998, Goldman and Human in press, Goldman and Musick unpublished data). Size at parturition is between 60-65cm pre-caudal length (PCL) in both the eastern and western North Pacific (Tanaka 1980, Goldman and Musick in preparation).

A salmon shark pupping and nursery ground exists along the transitional boundary of the subarctic and central Pacific currents (Nakano and Nagasawa, 1996). A second pupping and nursery ground appears to range from the Alaska-Canada border to the northern end of Baja California, Mexico, with central California being the most common area for ages zero and one (Goldman and Musick unpublished data).

Tanaka (1980) studied salmon shark age and growth in the western North Pacific and stated that maximum age is around 25 years for males and 17 for females. He estimated Von Bertalanffy growth coefficients (k values) of 0.171 and 0.136 for males and females respectively, and estimated age and size at maturity to be 5 years and 140cm pre-caudal length (PCL) for males and at 8-10 years and 170-180cm PCL for females. Current research on salmon sharks in the eastern North Pacific shows that they have a faster rate of growth (higher 'k' coefficient), become sexually mature at an earlier age, and attain greater length and weight than those in the western North Pacific (Goldman and Musick, in preparation). They also appear to have a slightly greater longevity.

Salmon sharks are opportunistic feeders, sharing the highest trophic level of the food web in subarctic Pacific waters with marine mammals and seabirds (Brodeur 1988, Nagasawa 1998, Goldman and Musick in press). They feed on a wide variety of prey including salmon (*Oncorhynchus*), rockfishes (*Sebastes*), sablefish (*Anoplopoma*), lancetfish (*Alepisaurus*), daggerteeth (*Anotopterus*), lumpfishes (Cyclopteridae), sculpins (Cottidae), atka mackerel (*Pleurogrammus*), mackerel (*Scomber*), pollock and tomcod (Gadidae), herring (Clupeidae), capelin (*Osmeridae*), spiny dogfish (*Squalus acanthias*), tanner crab (*Chionocetes*), and squid and shrimp (Sano, 1960, 1962; Farquhar, 1963; Okada and Kobayashi, 1968; Hart, 1973; Urquhart, 1981; Compagno, 1984; Nagasawa, 1998).

As with all members of the family Lamnidae, this species is endothermic, retaining heat created by their own oxidative metabolism via *retia mirabilia* (Carey et al. 1985, Lowe and Goldman, 2001). Body temperature measurements from moribund or recently dead specimens have shown elevations (over sea-surface temperature) of 8°C to 11°C in smaller specimens and up to 13.6°C in larger specimens (Smith and Rhodes 1983, Anderson and Goldman 2001). Body temperature elevation over ambient water temperature in free-swimming salmon sharks can exceed 20.0°C (Goldman et al. in review).

Shark bycatch in the central Gulf of Alaska and Prince William Sound

Successful conservation and management of sharks in Alaska waters requires knowledge of their basic life history parameters such as growth rates, age at maturity and longevity, and an understanding of their demographics and movements. Most shark population studies have been implemented after or during heavy stock depletion (Hoff and Musick 1990, Compagno 1990). Hence, Alaska finds itself in a unique situation: having the ability to gain an understanding of the basic biology of its shark species and to provide information essential to guiding management and conservation before stock collapse. The commercial fishing potential of these species can also be examined.

There are currently no directed commercial fisheries for sharks in Alaska state or federal waters. The state prohibited directed commercial fishing for sharks in 1998 and set limits for the modest sport fishery that currently exists (2 sharks per person per year, 1 on any given day). This made Alaska the first state ever to implement precautionary management before allowing a commercial fishery or large sport fishery to develop (Camhi 1999). Additionally, the North Pacific Fishery Management Council (NPFMC) is in the process of developing a management program for sharks (and skates) in Alaska's federal waters (an EA/RIR has been drafted). Despite these management efforts, shark landings in Alaska's fisheries are nearly as high as the combined shark landings for California, Oregon and Washington (Camhi 1999). The bycatch of elasmobranchs appears to be very high in Alaska's groundfish and other fisheries, and the majority (up to 90%) of this bycatch is discarded (Fritz 1998, Camhi 1999). Much of the catch and landing data for sharks in Alaska is not useful for assessing relative abundance because species are lumped into a single category of "shark". However, in recent years the National Marine Fisheries Service (NMFS) Groundfish Observer Program, the International Pacific Halibut Commission (IPHC) and the Alaska Department of Fish and Game (ADF&G) have begun to document their shark catch by species making preliminary estimates of relative abundance possible. The NMFS Observer database contains estimated weights (in tons) for species, while the IPHC and ADF&G databases contain data on shark bycatch from fishery-independent halibut and sablefish surveys respectively.

Sources of bycatch data

This report uses fisheries dependent and independent shark bycatch data collected by the agencies listed above. It includes 11 years of commercial fisheries catch data from the NMFS Groundfish Observer Program, 8 years of data from the IPHC halibut survey and 5 years of data from ADF&G sablefish survey. Assessing the abundance of shark species (particularly using short-term data series) is best done with a cautious and conservative approach. This allows the most productive use of the available data and is of particular importance with the data used herein. A brief description of each agency's data set used herein and their collection methods follows.

The NMFS data are currently being summarized by NMFS (and here) as two data series (1990-1996 and 1997-2000) because of differences in how data were assigned to a groundfish target fishery, which determines how observed catch is scaled up to estimate total catch (catches presented herein represent total bycatch). Gear used by target fisheries includes longlines, pots, pelagic and bottom trawls. Catch is summed across gear types in this report, however it should be noted that bottom trawls and longlines were responsible for the majority of sleeper shark and spiny dogfish bycatch while pelagic trawls caught most of the salmon sharks. The 1990-1996 data were assigned to a target fishery based on total catch weight of allocated species in individual hauls, while 97-00 observer data were assigned to a target fishery based on the retained catch weight of allocated species for an entire week on an individual vessel, gear type and area combination. The latter method is how the Regional NMFS Office assigns target species and is believed to be more accurate. Therefore, these data sets are cautiously comparable; one potential problem being that mismatches in target fisheries may result in inappropriate estimates (S. Gaichas pers. comm.). Additionally, trends in catch may not necessarily reflect trends in CPUE, however, these data are worth examining in their current form. Effort is currently being estimated for the various target fisheries, gear types and areas, so that CPUE can be calculated, allowing a better look at shark bycatch and relative abundance. It is important to remember that differences in catch can be driven by numerous factors including changes in target fishery effort within and across statistical areas, gear types used in different target fisheries and areas, and the catchability of different gear types and vessels.

The IPHC conducts an annual standard station halibut longline survey (6 skates per set, 100 hooks per skate). The 8 years of bycatch data are summarized herein as 2 data sets (1993-1996 and 1997-2000). Comparison problems stem from changes in the method of data collection and a drastic change in the identification of sharks to species vs. non-species specific identification (lumped into a "shark" or "unidentified shark" category). Between 1993 and 1996, every hook was observed as they came from the water while from 1997 to 2000 (and currently) 20 hooks per skate were sub-sampled (120 hooks per skate) in a non-random manner. Observations were usually made on the first 20 hooks from each skate, however, other times the 20-hook sub-sample began at a haphazard point in a skate. Even under the (likely valid) assumption that the catchability is equal for all hooks on a skate, it is questionable whether these methods are comparable. For example, the non-random sub-sampling method does not allow a variance to be calculated, and attempts to do so would almost certainly underestimate the true variance. The IPHC is currently conducting field studies and statistical analyses to examine this question (H. Gilroy pers. comm.). The geographical area surveyed also expanded around this time. In addition to the change in their sampling method, 18.5% of the sharks caught between 1993 and 1996 were categorized as "unidentified shark" compared to only 0.4% between 1997 and 2000. Therefore, catch per unit effort (CPUE) calculations for the 1993 to 1996 data set underestimate the real CPUE for those surveys. As with the NMFS data set, the IPHC data are cautiously comparable.

The ADF&G sablefish longline survey, conducted in Prince William Sound (PWS), has been documenting shark bycatch since 1996. While the survey methods have not changed (~675 hooks per set), the areas sampled within PWS are not the same for every year of the survey. Therefore, these data cannot be analyzed in a single time series. In 1996, only the northwest area of the sound was surveyed. In 1997 and 1999, the northwest and southwest areas of the sound were surveyed, while in 1998 and 2000 the northwest and eastern areas of PWS were surveyed. Therefore, there are only two sets of directly comparable data in this series (1997 to 1999, and 1998 to 2000). However, these data will soon be further 'broken down' so that relative abundance in the northwest area of PWS can be analyzed.

Seven shark species appear in the bycatch data, however catch of blue (*Prionace glauca*), sixgill (*Hexanchus griseus*), soupfin (*Galeorhinus galeus*) and brown catsharks (*Apristurus brunneus*) are nominal. As such, this report will focus on the spiny dogfish (*Squalus acanthias*), the Pacific sleeper shark (*Somniosus pacificus*) and the salmon shark (*Lamna ditropis*).

Spiny dogfish

Recent summaries of fisheries survey data (including the IPHC and ADF&G data shown here) have been reported to indicate that a dramatic increase in spiny dogfish abundance in the GOA and PWS has occurred since the early 1990's, and anecdotal information has been stated to support this claim (Hulbert 2000). However, no statements were made about the nature of these data, the changes in methodology that occurred through the years of sampling, addition of sampling areas or the discrepancy in the number of unidentified sharks reported in one data set vs. another. These are all critical factors to consider in attempting to accurately access shark abundance in Alaska. It is important to note a clear distinction between density and stock abundance. Fluctuations in the density of spiny dogfish in particular areas does not necessarily mean that the stock abundance is increasing or decreasing at a rapid rate, as exemplified by the population off of British Columbia, Canada, (Bonfil 1999).

NMFS GOA Area 630

The NMFS Observer data from 1990 to 1996 are shown in Figure 1a. The data from Area 630 had a maximum catch of 322t (tons) in 1993, a minimum catch of 103t in 1995 and the average catch over these years was 195t. The catch varies widely during this time. This degree of fluctuation in catch is not uncommon for a mobile species with a patchy distribution and offers little information on changes in spiny dogfish abundance.

The 1997 to 2000 data series had a maximum catch of 266t in 1997, a minimum of 148t in 2000, and the average catch over these years was 211t (Figure1b). The catch slightly decreased each subsequent year in the series. If viewed as one continuous time series, and effort is assumed to be relatively constant, the declining catch suggests a decrease in spiny dogfish abundance since 1996. However, the mean catch for both data series is very close (195t between 1990-1996 and 211t between 1997-2000), which may indicate that spiny dogfish have a relatively stable abundance in NMFS Area 630.

NMFS GOA Area 640

Area 640 had a considerably smaller amount of catch than Area 630 (Figure 1). Between 1990 and 1996 the maximum catch was 23t in 1996, the minimum catch was 1.8t in 1992 and the average catch over these years was 8.5t (Figure 1a). There was an extremely small increase during this time. From 1997 through 2000, the Area had a maximum catch of 576t in 1998, a minimum catch of 38.8t in 1999 and the average catch over those years was 185.3t (Figure 1b). The peak catch in 1998 was also a high catch year for the majority of surveys and survey areas in all data sets. (If 1998 is excluded, the mean catch becomes 55.6t yr^{-1}). Potential causes for this large increase are briefly touched on later, but determining what might cause such an increase would require lengthy investigation. The high variability in catches prevents any conclusion from being reached regarding changes in relative abundance of spiny dogfish in Area 640 between 1997 and 2000. If the two data sets are assumed to be comparable and are viewed as one continuous time series then it would appear that there has been a nominal increase in spiny dogfish bycatch in Area 640 since 1990.

NMFS GOA Area 650

Area 650 had similar catch amounts to Area 640, showing fairly consistent levels of catch (Figure 1). Between 1990 and 1996 the maximum catch was 33.6t in 1994, the minimum catch was 5.6t in 1993 and the average catch over those years was 20.3t (Figure 1a). From 1997 through 2000, the Area had a maximum catch of 334.7t in 1997, a minimum catch of 26.1t in 1998 and the average catch over those years was 140.7t (Figure 1b). This was one of the few Areas in which 1998 did not have the highest catch amount, but (in fact) the smallest amount of catch. The fluctuations from 1997 through 2000 do not appear to indicate any significant increase in spiny dogfish in Area 650 during these years. If the two data sets are viewed as one continuous time series, it would appear that Area 650 has had a small increase in the abundance of spiny dogfish since 1990. Two things that stand out from the data from these three Areas are that Area 630 consistently has the highest catch of spiny dogfish and that there is a decrease in spiny dogfish catch moving across the GOA from Area 630 to 650. The eastern GOA is closed to trawling making longlines the dominant gear used, so the low catch observed here (and possibly Area 640) could be an artifact of allowable gear types.

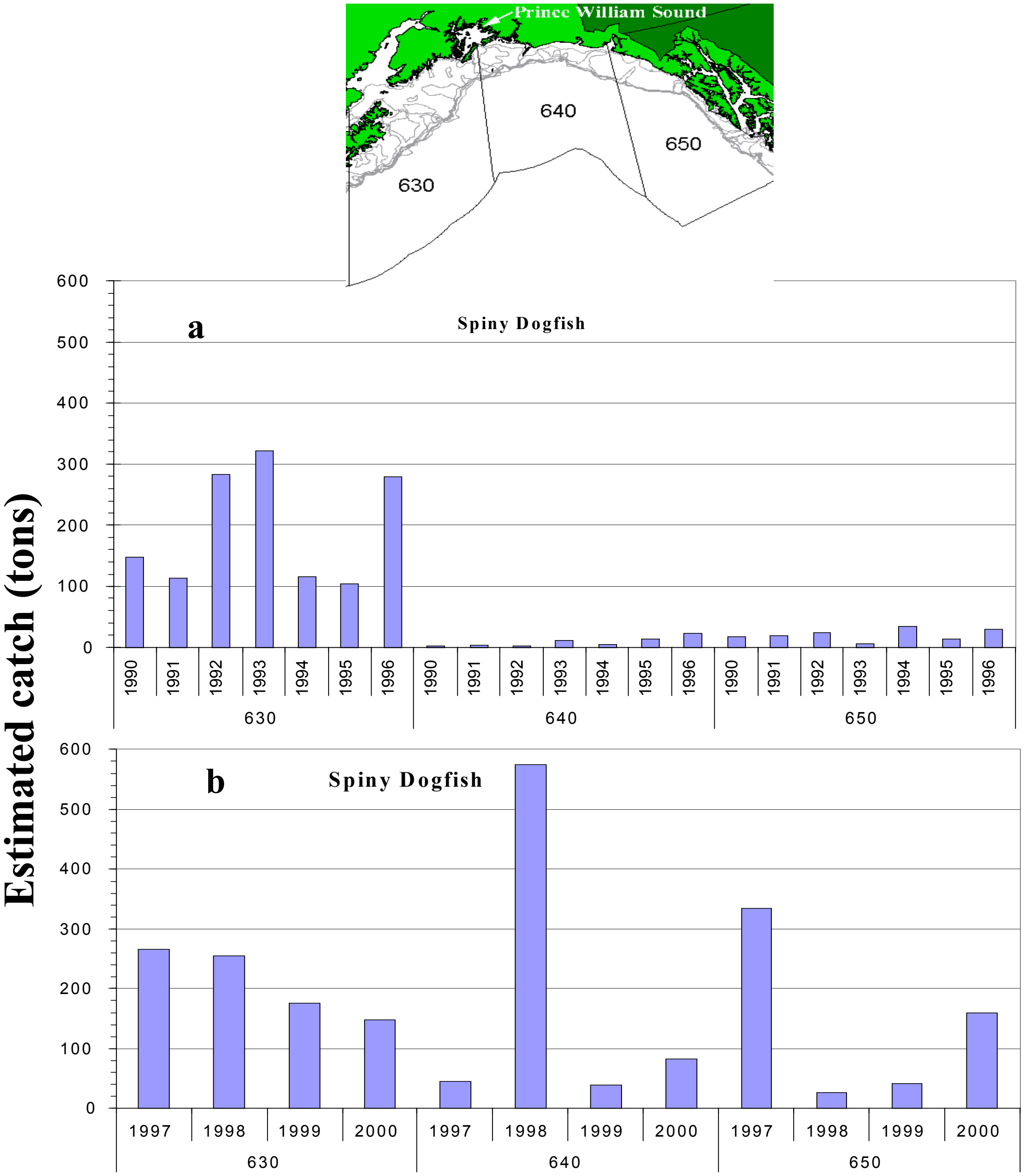

Figure 1. Spiny dogfish bycatch in the central GOA (from the NMFS Observer Program).

IPHC Statistical Areas 240, 250 and 260

These three IPHC statistical Areas encompass roughly ½ of NMFS Area 630 (note – all other IPHC Areas within NMFS 630 had shark bycatch that is not presented in this report). Between 1992 and 1996, the CPUE in these Areas ranged between 0.8 and 11.8 sharks per 100 hooks (catch per unit effort hereafter will always mean the "number of sharks per 100 hooks") (Figure 2a). The CPUE was nominally different across these Areas during these years. Between 1997 and 2000, CPUE ranged from 5.3 to 23.9 (the peak year being 1998 – Figure 2b). The CPUE decreased by almost half in Area 240 during this time, but was fairly constant in Areas 250 and 260. Overall these three Areas show a relatively constant CPUE from 1997 through 2000 (Figure 2b). If the two data sets (93-96 and 97-00) are viewed as one continuous time series, it could be suggested that spiny dogfish abundance has about doubled in these Areas since 1993. However caution should be used in making this assessment because of the substantial discrepancy between data sets in the number of unidentified sharks and the changes in data collection methods previously mentioned. The discrepancy in the number of unidentified sharks in the early data series means that CPUE in these years underestimates the actual CPUE (by how much is under investigation).

IPHC Statistical Areas 185 to 230

Survey Areas 185, 190, 200, 210, 220 and 230 did not appear in this author's copy of the IPHC 1993 to 1996 data set. Data from these Areas (for 1996) will be obtained and included in the overall analysis soon, however, comparisons will not be made here. (In 1996-97, the survey expanded to cover new Areas from the Hinchinbrook entrance to Cape Spencer). However, IPHC Areas 210, 220 and 230 cover virtually the same area as NMFS Area 640 and IPHC Areas 185, 190 and 200 are encompassed by NMFS Area 650. As previously stated, trends in catch may not necessarily reflect trends in CPUE, but it is worth examination. Similarities in trends would not necessarily mean agreement between them and dissimilar trends would not necessarily mean disagreement. The nature of the data (fisheries dependent and independent) and other factors involving sampling design and gear types would need to be considered in detail prior to making any conclusions. Catch per unit effort estimates for the NMFS data are being calculated in order to better compare all data.

The CPUE for Areas 185 through 230 (from 1997 to 2000) ranged from 7.8 to 37.5 sharks per 100 hooks (Figure 2b). Area 185 shows almost a doubling in CPUE in 4 years, beginning in 1998 (which was not the peak year). The other Areas also showed relatively large increases in CPUE for 1998 and then dropped again in 1999 and appear to have randomly fluctuated up and down over the rest of the period. Aside from 1998, there appears to be a variable yet level amount of spiny dogfish bycatch on the IPHC survey in Areas 185 through 230. All years included, it may be that a combination of the patchy distribution of spiny dogfish, their gregarious mobile behavior and their associations to several prey species are playing significant roles in a given year's catch. The abundance and distribution of those prey species relative to the dogfish abundance and distribution needs thorough investigation.

Areas 190 through 230 had a consistently higher CPUE than Areas 185, 240, 250 and 260 and may indicate a slight increase in abundance moving east across the GOA (to Area 185). This is somewhat in contrast to the NMFS data that shows an increase in bycatch moving west across the GOA (Figure 1). However, the NMFS Observer Program data do reflect the IPHC data in that no consistent increase in spiny dogfish abundance appears to have taken place in the central GOA over time.

ADF&G and IPHC PWS Areas

As stated earlier, ADF&G has been documenting their shark bycatch in PWS since 1996 (Figure 3a). In 1996, only the northwest Area of the sound was surveyed. In 1997 and 1999, the northwest and southwest Areas of the sound were surveyed, while in 1998 and 2000 the northwest and eastern Areas of PWS were surveyed. Therefore, there are only two sets of directly comparable data in this series (1997 and 1999, and 1998 and 2000). This survey shows a decrease in spiny dogfish CPUE for both directly comparable Areas. Again we see that 1998 was a "banner year" for spiny dogfish on this survey. This, as well as any possible meaning of the relative drop from 1998 to 2000 for the northwest and eastern portions of PWS should not be over-analyzed. It is extremely difficult to conclude anything about the high CPUE for 1998 at this point in time. The IPHC data for PWS shows an overall higher CPUE than those from ADF&G, but aside from IPHC station 4138 (in 1998) the CPUE was never higher than 4.2 in any area surveyed and appears relatively small and similar in each comparable Area (Figure 3b).

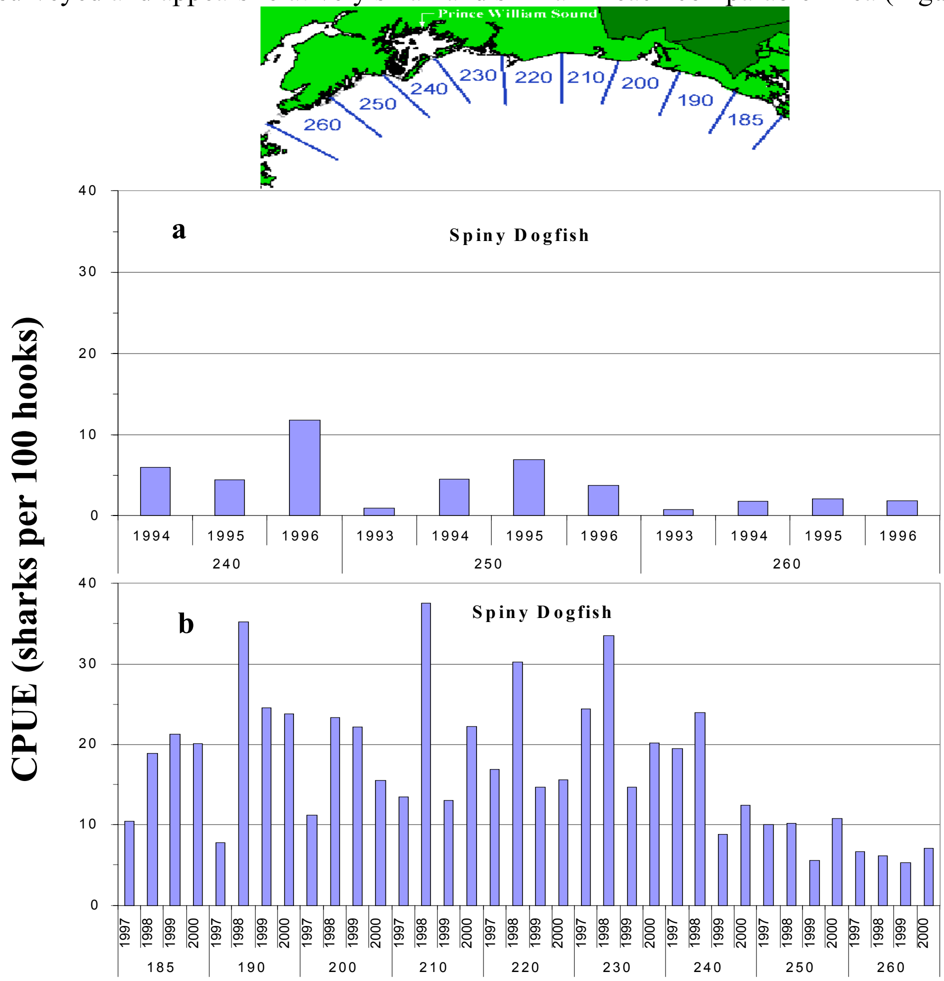

Figure 2. Spiny dogfish bycatch in the central GOA (from the IPHC).

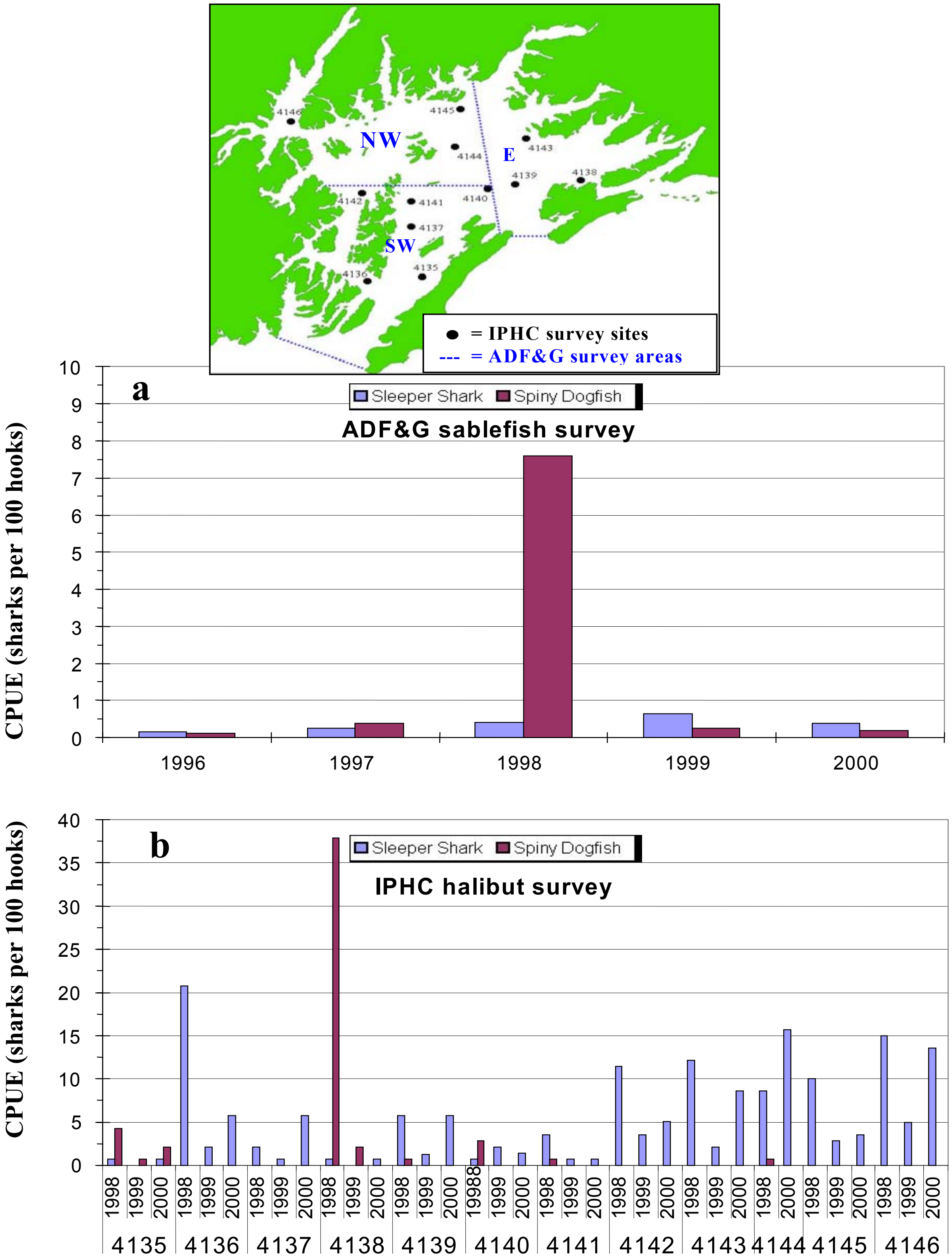

Figure 3. Spiny dogfish and sleeper shark bycatch from PWS. a) ADF&G data b)IPHC data.

Pacific sleeper shark

The number of Pacific sleeper sharks in the central GOA and PWS has, like the spiny dogfish, recently been reported to have dramatically increased since the early 1990's (Hulbert 2000) using the IPHC and ADF&G shark bycatch data. However, as mentioned earlier there are several important factors that affect the potential comparability of the data across years.

NMFS GOA Areas 630, 640 and 650

The NMFS data from 1990 to 1996 are shown in Figure 4a. Sleeper shark catch did not exceed 79.5t from 1990 through 1996 and catch was relatively stable over that time. The 1997 through 2000 data show a more than 4-fold increase in catch (weight) took place after 1998 with a maximum of 454.7t in 1999. Sleeper sharks are not thought to be a highly mobile or migratory species. The small amount of tag return data from ADF&G would support this statement leaving no immediate answer to the increased catch in 1999 and 2000. It is obvious that this catch time series needs to continue to be monitored in order to gain a better understanding of sleeper shark abundance in the GOA over time. Areas 640 and 650 showed virtually no sleeper shark catch between 1990 and 1996 or between 1997 and 2000 (Figure 4), which may be due to differences in groundfish target fishery effort and gear type. However, no 'unprecedented' increase is indicated by these data.

IPHC Statistical Areas

Records of sleeper sharks are virtually absent in the 1993 to 1996 IPHC data set. This could easily be due to the high number of unidentified sharks in that data series. The data from 1997 through 2000 shows sleeper shark CPUE in Areas 185 through 260 ranged from 0.62 to 8.6 sharks per 100 hooks (Figure 5). Area 220 showed the highest CPUE fluctuations, and is the only location to even possibly show an increase. These (short-term) data indicate that the relative abundance of Pacific sleeper shark is either stable or has increased very slightly.

ADF&G and IPHC PWS Areas

The ADF&G sleeper shark bycatch data are shown in Figure 3a. Looking at the two sets of comparable years (1997 vs. 1999, and 1998 vs. 2000), the CPUE marginally increased from 1997 to 1999 and was virtually identical in 1998 and 2000. The IPHC data show that CPUE either remained similar or decreased in all stations for 1999 except #4140, which showed a slight increase (Figure 3b). Most 2000 CPUE values remained near those from 1999, except for #'s 4143 and 4146, where CPUE more than doubled.

Sleeper shark bycatch data from certain IPHC Areas in PWS are comparable to ADF&G Areas for those same years. The eastern and northwest Area surveyed by ADF&G encompasses six IPHC sites (see map on Figures 3 and 6). Similarly, the northwest and southwest Areas surveyed by ADF&G encompass nine IPHC sites. When blocked into the northwest and eastern ADF&G sampling Areas, the 1998 and 2000 IPHC data provide another look at the consistency of CPUE within the various surveys (Figure 6). The same is true of the northwest and southwest Areas for 1999. Since catch rate does not show great differences across PWS, a difference in the CPUE when grouping the IPHC data would not be expected and indeed the values are similar. Again we see that CPUE was lowest in 1999 (Figure 6), which is opposite of the ADF&G survey where 1999 was the highest CPUE (Figure 3a). As with the IPHC GOA data, both of these short-term data sets indicate that the relative abundance of Pacific sleeper shark is either stable or has slightly increased. In either case, they do not demonstrate a large increase in the relative abundance of sleeper sharks. There is a great need to continue to monitor the abundance of this species, particularly considering the paucity of data on its life history and general biology.

Salmon shark

Salmon sharks have also been included in recent reports describing increases in shark abundance in the GOA and PWS, however the majority of this information is anecdotal (Hulbert 2000). Aggregations of salmon sharks in certain areas of PWS are not uncommon between May and October and have been reported for over 20 years (Paust and Smith 1986).

GOA and PWS data Salmon shark bycatch in the NMFS Groundfish Observer Program has been relatively small (Figure 7). The vast majority of salmon shark are caught in mid-water trawls. Area 630 contained the highest amount of bycatch, while salmon sharks were virtually absent from the catch in Areas 640 and 650. The maximum amount taken between 1990 and 1996 was 63.1t, and the maximum taken between 1997 and 2000 was107.4t in 1997. However, all of the other years (between 1997 and 2000) have about the same relative catch as was seen between 1990 and 1996 (Figure 7).

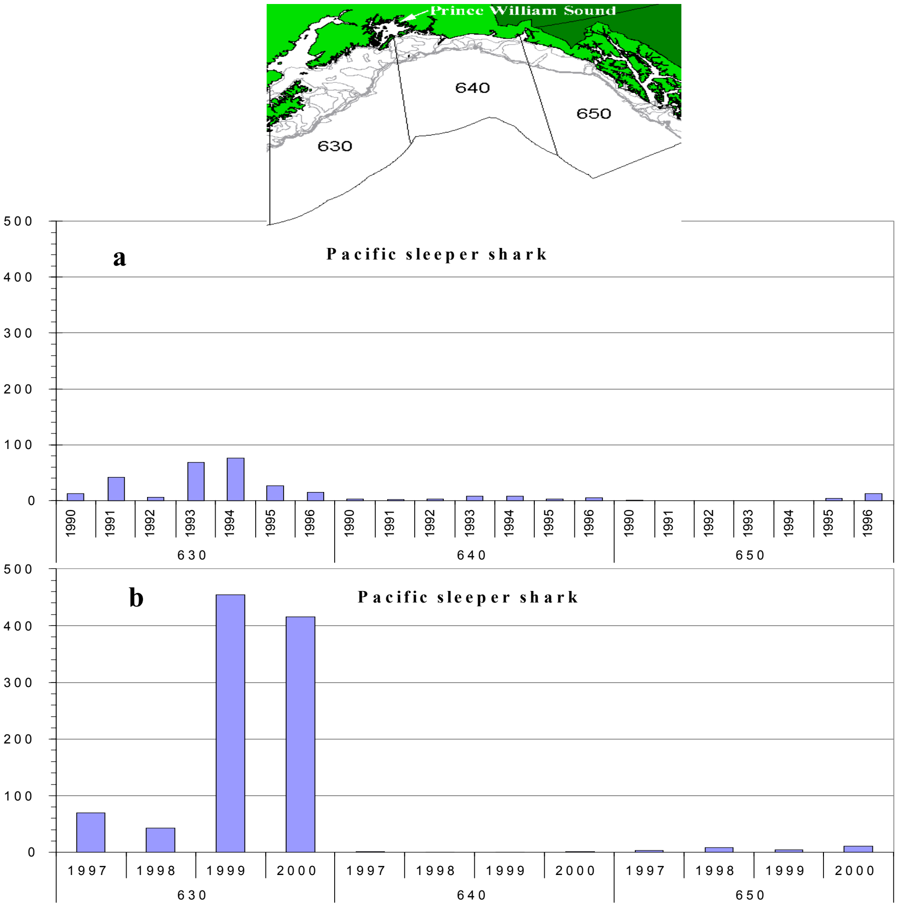

Figure 4. Pacific sleeper shark bycatch in the central GOA (from the NMFS Observer Program).

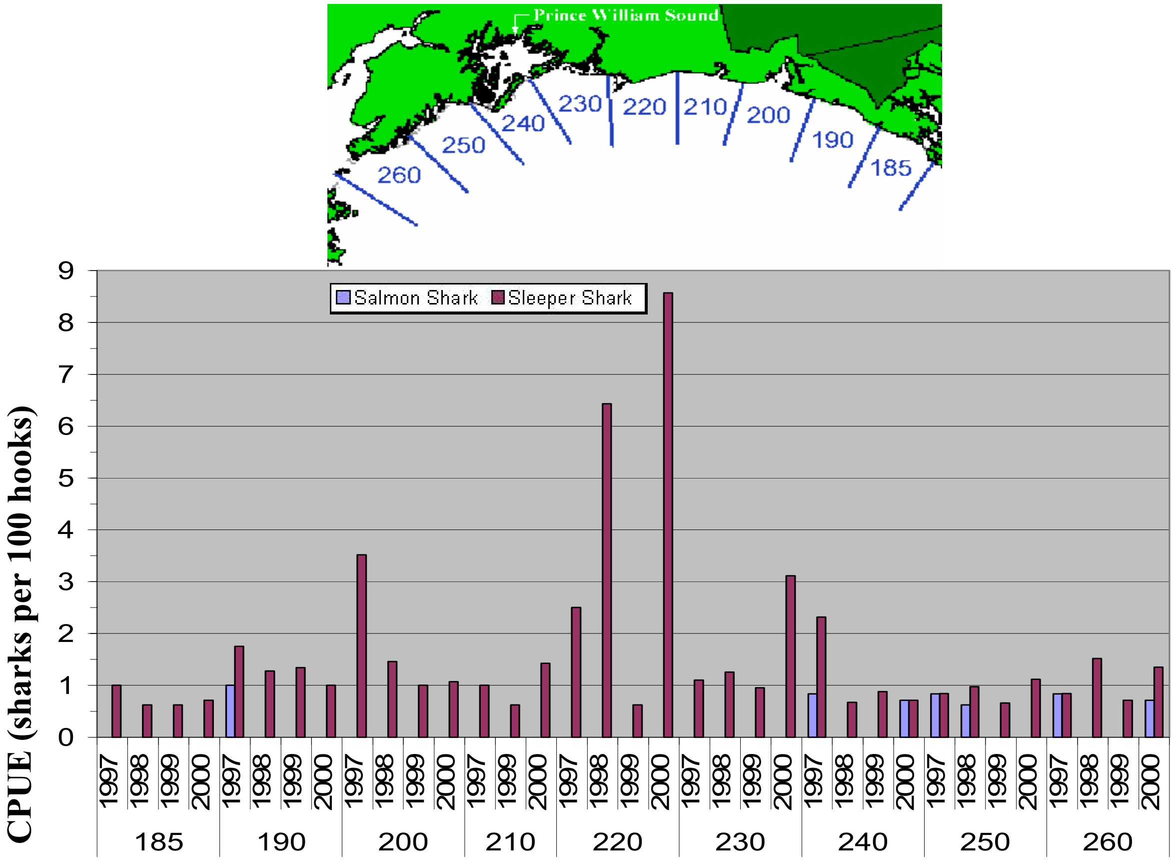

Figure 5. Sleeper and salmon shark bycatch in the central GOA (from the IPHC).

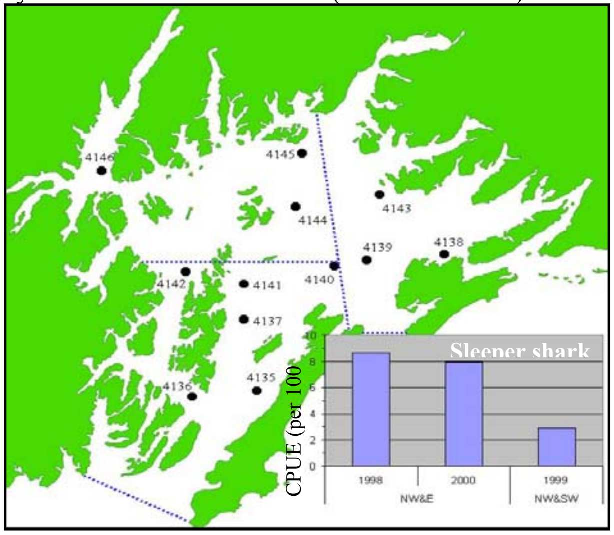

Figure 6. IPHC areas encompassed by ADF&G areas with comparative CPUE chart (see text).

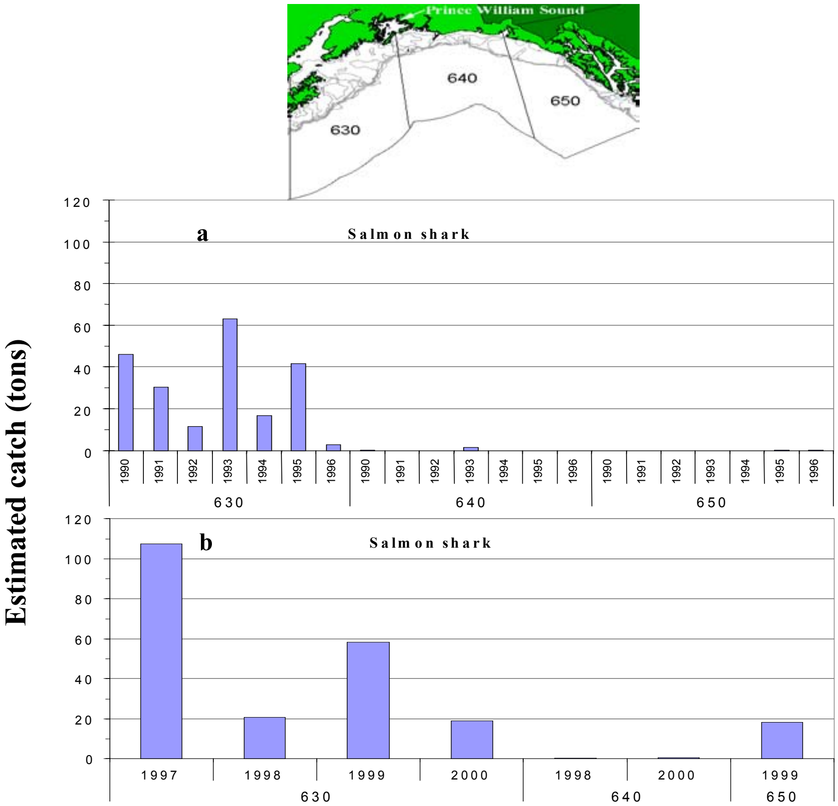

Figure 7. Salmon shark bycatch in the central GOA (from the NMFS Observer Program).

Salmon shark CPUE in the IPHC halibut longline survey in the GOA between 1993 and 1996 was extremely low, never higher than 0.21 sharks per 100 hooks. It was also low between 1997 and 2000, always between 0.5 and 1.0 (Figure 5). No salmon sharks were caught on IPHC survey in PWS, and the ADF&G survey has only taken two salmon sharks since 1996 (one in 1996 and another in 1998). This is likely a result of longline gear that is only fishing the bottom. Data from the sport fishery is being compiled and will be analyzed in the near future (S. Meyer pers. comm.).

Shark bycatch in other Areas not included in this report

Shark bycatch data from NMFS Observer Program and IPHC halibut survey for other Statistical Areas of the GOA, the Aleutian Islands and the Bering Sea are currently being analyzed. A brief mention of some of those data is appropriate to include here. Data (from ADF&G) on commercial and recreational bycatch in Alaska State waters are being acquired for inclusion in future Alaska shark bycatch reports.

The NMFS Groundfish Observer Program covers the entire GOA, Aleutian Islands and Bering Sea. There are two additional Areas that NMFS includes in their coverage of the GOA that extend west of Area 630 ending at 170^{o}W. Continuing west from there, NMFS Areas become grouped into an Aleutian Island (AI) group and there is a Bering Sea (BS) series of Statistical Areas as well. From 1997 to 2000, the AI and BS Areas had extremely low spiny dogfish bycatch, with a maximum of 8.6t in the AI and 0.49t in the BS. Sleeper shark bycatch was lower overall in the GOA than in the BS during 1997 and 1998 (the BS Area averaging around 300t), but sleeper shark bycatch was higher in the GOA during 1999 and 2000. The AI Areas showed a lower bycatch of sleeper sharks than either the GOA or the BS. Salmon shark bycatch was low in the BS and AI Areas. The BS had a maximum catch of 29.5t in 1999, and the AI Areas had even lower catches (maximum of 3.5t in 2000). The Seattle NMFS office is also calculating the catch estimate numbers for 1998 through 2000 (2000 numbers are complete and being analyzed). The IPHC shark bycatch data from other Statistical Areas in the GOA, AI and BS are currently being analyzed along with additional shark bycatch data from both the NMFS and ADF&G Kodiak offices. It is difficult to assess whether the amount of shark bycatch represents a threat to the status of shark stocks in Alaska waters at this point in time. It is even more difficult to attempt to determine the cause of the 1998 'spike' in spiny dogfish CPUE and catches that was seen in virtually all data sets.

Shark bycatch is currently a topic of major concern around the world. Stevens et al. (2000) estimate that around 50% of the estimated global catch of chondrichthyan fishes (sharks, skates, rays and chimaeras) is taken as bycatch that is unmanaged and does not appear in official fisheries statistics. As a result, species of skate, sawfish and some deep-sea dogfish have been virtually extirpated from large areas. With the depleted status of numerous shark populations worldwide (Compagno 1990), it is all the more crucial that any approach to assessing shark bycatch levels and relative abundance in Alaska be carried out using the strictest possible scientific criteria. As further analysis of these data and the sampling of shark bycatch continue we will begin to better understand the relative abundance and overall status of sharks in Alaska waters, and determine if the current levels of shark bycatch are too high. Careful analysis of the available data and knowledge of life history parameters, demographics and movements will allow Alaska's fishery managers to better understand the biology and overall ecology of sharks in the GOA, PWS, BS and AI.

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A New Analysis of Pacific Sleeper Shark (*Somniosus pacificus*) Abundance Trends

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Pacific sleeper sharks (*Somniosus pacificus*) are a deepwater shark of the north Pacific. Some information suggests their abundance is increasing. However no quantitative statistical analysis of the trends in abundance has been completed to date. Our purpose was to analyze existing sleeper shark data to determine the trend in abundance and whether any change was statistically significant.

Methods

Pacific sleeper sharks are occasionally caught during longline surveys. These surveys include NMFS sablefish longline surveys of the upper continental slope and deepwater gullies of the continental shelf and International Pacific Halibut Commission (IPHC) halibut longline surveys of the continental shelf. We examined the trend of sleeper shark catch from the NMFS sablefish longline surveys because the sleeper shark data from these time series is longer (1979-present) than the IPHC halibut longline surveys (1997-present).

Survey methods

NMFS sablefish longline surveys have sampled the upper continental slope and deepwater gullies of the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands region annually since 1979. The survey time series consists of two surveys, the Japan-U.S. cooperative longline survey, which ran from 1979-1994, and the domestic longline survey, which ran from 1988-present. The surveys sampled the same locations (stations), with the same bait (squid), hook spacing (2 meters), and effort (usually 7,200 hooks per station). The surveys differed in two principal ways. The domestic longline survey gear consists of heavier-weight beckets and ganions than the cooperative longline survey, so that a shark is more likely to escape from the cooperative longline survey gear. The domestic longline survey gear uses a circle hook, whereas the cooperative longline survey used a type of J-hook called a tara hook.

Analytical methods

Relative population numbers (RPN's, an index of relative abundance in numbers) were calculated for the Japan-U.S. cooperative survey and for the domestic survey. The number of fish caught per skate (catch per unit effort or CPUE) was calculated by species for each stratum of a station. RPN's were computed from the CPUE's to determine the relative numbers of each species (Sasaki 1985; Gulland 1969; Quinn et al. 1982). The CPUE for each stratum of a station was multiplied by the area of the stratum and the resultant values were averaged within the area to obtain an RPN for each stratum and area.

95 % bootstrap confidence intervals were calculated for the domestic survey. The bootstrap method (Efron and Tibshirani 1986) was applied to estimate the variability of the abundance estimates (Sigler and Fujioka 1988). A station was randomly chosen with replacement and the resultant station RPN's were averaged for the area. The areas were summed and the resultant value is termed the bootstrap replicate. A confidence interval for the abundance estimate was created from a distribution of 1,000 bootstrap replicates by the percentile method (Efron and Tibshirani 1986).

Results

A total of 1,091 Pacific sleeper sharks were captured during sablefish longline surveys from 1979-2000 (Table 1). Pacific sleeper shark catches have increased during the survey from a low of 0 in 1979 and 1983 to a high of 175 in 1994. The most recent available catch is 111 Pacific sleeper sharks in 2000.

Pacific sleeper shark CPUE (catch per 10,000 hooks) has increased steadily from a low of 0 in 1979 to a high of 2 in the year 2000 (Table 1).

Most Pacific sleeper sharks (59%) were captured in the 201 - 300 m depth stratum (Table 2) from stations located in gullies of the Bering Sea and Gulf of Alaska continental shelf (Table 3). Most Pacific sleeper sharks (487 [45%] of 1,091) were captured in one gully - Shelikof Trough (Table 3).

CPUE and RPN of Pacific sleeper sharks were calculated separately for the Japan-U.S. cooperative survey and the domestic survey because their effectiveness for capturing Pacific sleeper sharks likely differ. CPUE and RPN analysis was limited to standard survey stations and to effective skates (defined as less than or equal to 5 ineffective hooks). For statistical analysis, CPUE and RPN estimation was further limited to the years 1982-1994 for the Japan-U.S. cooperative survey and to the years 1989-2000 for the domestic survey which are considered standard survey years for each survey.

A total of 991 Pacific sleeper sharks were captured with effective skates at standard stations during the years 1979-2000 (Table 4). The catch of Pacific sleeper shark in the Japan-U.S. cooperative survey fluctuated during the years 1982-1994 ranging from 0 in 1979 and 1983 to 50 in 1994 (Table 4), and CPUE (catch per 1,000 skates) ranged from 0 in 1979 and 1983 to 5 in 1994 (Table 5). Catch of Pacific sleeper shark in the domestic survey increased from a low of 3 in 1988 to a high of 103 in 2000 (Table 4), and CPUE (catch per 1,000 skates) ranged from 0.5 in 1988 to 10 in 2000 (Table 5).

The relative population numbers (RPN's) of Pacific sleeper shark captured in the Japan-U.S. cooperative longline survey also fluctuated during the years 1979-1994 ranging from 0 in 1979 and 1983 to 354 in 1994 (Table 6, Figure 1). RPN's of Pacific sleeper shark captured in the domestic survey increased from a low of 79 in 1988 to a high of 1,779 in 2000 (Table 6, Figure 1). The increase in RPN's of the domestic survey was most pronounced between the years 1992 and 1993 and was driven largely by the increase Pacific sleeper shark RPN's in Shelikof Trough (Table 7).

95% bootstrap confidence intervals were calculated for the domestic longline survey between the years 1989 - 2000. The confidence intervals did not overlap for all years suggesting that there has been a significant increase in Pacific sleeper shark RPN's for some years between 1989 and 2000 (at the 95 % confidence level, Figure 1). The most substantial increase in RPN's occurred between 1992 and 1993 and RPN's remained high from 1994-2000 (Figure 1).

Pacific sleeper sharks captured during sablefish longline surveys were found mainly in the Shelikof Trough and were relatively abundant in this area. Pacific sleeper sharks may be relatively abundant in other areas of the continental shelf not sampled by sablefish longline surveys but that may be sampled by IPHC halibut longline surveys. We plan to analyze data from the IPHC halibut longline surveys in the future.

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Table 1. Catch (in numbers) and CPUE (catch per 10,000 hooks) of Pacific sleeper shark from the sablefish longline survey during the years 1979-2000 in the Gulf of Alaska, Aleutian islands and Bering Sea.

Year[a]	Number of sleeper sharks	Skates	% of Total	Hooks	Catch/10,000 hooks	% of Total
1979	0	8069	2.01%	363105	0.00	0.00%
1980	1	11153	2.77%	501885	0.02	0.14%
1981	1	11469	2.85%	516105	0.02	0.13%
1982	1	16950	4.21%	762750	0.01	0.09%
1983	0	16344	4.06%	735480	0.00	0.00%
1984	5	17139	4.26%	771255	0.06	0.45%
1985	10	17062	4.24%	767790	0.13	0.91%
1986	9	16959	4.22%	763155	0.12	0.82%
1987	27	16844	4.19%	757980	0.36	2.48%
1988	21	25909	6.44%	1165905	0.18	1.25%
1989	45	26980	6.71%	1214100	0.37	2.58%
1990	33	28572	7.10%	1285740	0.26	1.79%
1991	34	28192	7.01%	1268640	0.27	1.87%
1992	74	28728	7.14%	1292760	0.57	3.98%
1993	110	28749	7.15%	1293705	0.85	5.92%
1994	175	29415	7.31%	1323675	1.32	9.20%
1995	61	11176	2.78%	502920	1.21	8.44%
1996	86	12281	3.05%	552645	1.56	10.83%
1997	103	13920	3.46%	626400	1.64	11.45%
1998	91	12030	2.99%	541350	1.68	11.70%
1999	93	12475	3.10%	561375	1.66	11.53%
2000	111	11895	2.96%	535275	2.07	14.43%
Total	**1,091**	**402,311**		**18,103,995**		

[a] Sablefish longline survey time line.
1979, First year of Japan-U.S. cooperative sablefish longline survey.
1982, First year of cooperative survey in the Bering Sea.
1987, Experimental domestic sablefish longline survey in Gulf of Alaska (using herring as bait), not included in database.
1988, First year of experimental domestic sablefish longline survey in Gulf of Alaska (using squid as bait) in database.
1990, First year of standardized domestic sablefish longline survey in Gulf of Alaska.
1994, Last year of Japan-U.S. cooperative sablefish longline survey.
1996, First year of standardized domestic sablefish longline survey in the Aleutian Islands (Aleutians sampled every other year hereafter).
1997, First year of standardized domestic sablefish longline survey in the Bering Sea (Bering Sea sampled every other year hereafter).
1997, Experimental fishing along side a submersible in the Gulf of Alaska.

Table 2. Catch (in numbers) and CPUE (catch per 10,000 hooks) of Pacific sleeper shark grouped by depth stratum from the sablefish longline survey during the years 1979-2000 in the Gulf of Alaska, Aleutian islands and Bering Sea.

Stratum[a]	Min depth	Max depth	Number	% of Total	Skates	% of Total	Hooks	Catch/10,000 hooks	% of Total
NA			3	0.27%				NA	
1	0	100	0	0.00%	1503	0.37%	67635	0.00	0.00%
2	101	200	83	7.61%	80421	19.99%	3618945	0.23	6.56%
3	**201**	**300**	**643**	**58.94%**	**71656**	**17.81%**	**3224520**	**1.99**	57.02%
4	301	400	72	6.60%	46049	11.45%	2072205	0.35	9.94%
5	401	600	137	12.56%	94182	23.41%	4238190	0.32	9.24%
6	601	800	123	11.27%	82441	20.49%	3709845	0.33	9.48%
7	801	1000	30	2.75%	24584	6.11%	1106280	0.27	7.75%
8	1001	1200	0	0.00%	1416	0.35%	63720	0.00	0.00%
9	1200	Greater	0	0.00%	59	0.01%	2655	0.00	0.00%
Total			**1,091**		**402,311**		**18,103,995**		

Table 3. Catch (in numbers) and CPUE (catch per 10,000 hooks) of Pacific sleeper shark grouped by area from the sablefish longline survey during the years 1979-2000 in the Gulf of Alaska, Aleutian Islands and Bering Sea.

Area	Number	% of Total	Min Lon	Max Lon	Skates	% of Total	Hooks	Catch/10,000 hooks	% of Total
NA	1				640	0.16%	28800	0.35	1.00%
Bering 5 (Zamchumg Canyon)	51	4.67%	-178.85501	-177.38001	7400	1.84%	333000	1.53	4.43%
SE Aleutians	12	1.10%	-178.60999	-173.50501	24558	6.10%	1105110	0.11	0.31%
NE Aleutians	11	1.01%	-177.58333	-170.14167	19981	4.97%	899145	0.12	0.35%
Bering 4	71	6.51%	-177.5818333	-174.3	14034	3.49%	631530	1.12	3.25%
Bering 3	57	5.22%	-174.16999	-170.57167	20654	5.13%	929430	0.61	1.77%
Bering 2	73	6.69%	-169.95	-166.03001	30893	7.68%	1390185	0.53	1.52%
Bering 1	53	4.86%	-169.25	-165.66667	13006	3.23%	585270	0.91	2.62%
Shumagin slope	34	3.12%	-169.09867	-161.04666	45762	11.37%	2059290	0.17	0.48%
Chirikof slope	17	1.56%	-158.55667	-154.79666	32222	8.01%	1449990	0.12	0.34%
Shumagin Gully	2	0.18%	-158.50667	-158.00617	1453	0.36%	65385	0.31	0.88%
West Semidi	0	0.00%	-157.50534	-157.50534	160	0.04%	7200	0.00	0.00%
Shelikof Trough	**487**	**44.64%**	**-156.2281667**	**-155.0406667**	**8403**	**2.09%**	**378135**	**12.88**	**37.24%**
Kodiak slope	4	0.37%	-153.0813333	-148.34017	41663	10.36%	1874835	0.02	0.06%
Chiniak Gully	0	0.00%	-151.698	-151.698	159	0.04%	7155	0.00	0.00%
Amatuli gully	71	6.51%	-149.9116667	-146.976	9594	2.38%	431730	1.64	4.76%
W Yakutat slope	12	1.10%	-146.8548333	-141.33333	37369	9.29%	1681605	0.07	0.21%
W-grounds	5	0.46%	-143.59551	-143.389	1936	0.48%	87120	0.57	1.66%
Yakutat Valley	**71**	**6.51%**	**-141.27051**	**-140.93667**	**1936**	**0.48%**	**87120**	**8.15**	**23.57%**
E Yakutat slope	19	1.74%	-139.48333	-137.37334	13437	3.34%	604665	0.31	0.91%
Alsek Strath	13	1.19%	-139.33483	-139.08416	960	0.24%	43200	3.01	8.70%
Spencer Gully	1	0.09%	-137.08867	-137.08867	2098	0.52%	94410	0.11	0.31%
Southeastern slope	8	0.73%	-136.5395	-134.25	39695	9.87%	1786275	0.04	0.13%
Southeastern shelf	1	0.09%	-135.4	-135.4	4430	1.10%	199350	0.05	0.15%
Southeastern	0	0.00%	-136.29733	-136.11033	1440	0.36%	64800	0.00	0.00%
Ommaney Trench	11	1.01%	-134.9773333	-134.90366	1937	0.48%	87165	1.26	3.65%
Iphigenia Gully	0	0.00%	-134.66966	-134.407	966	0.24%	43470	0.00	0.00%
Dixon Entrance	5	0.46%	-133.153	-132.84383	1937	0.48%	87165	0.57	1.66%
NW Aleutians	0	0.00%	172.71667	179.91667	9687	2.41%	435915	0.00	0.00%
SW Aleutians	1	0.09%	172.95667	179.56667	13901	3.46%	625545	0.02	0.05%
Total	**1,091**				**402,311**		**18,103,995**		

Table 4. Catch of Pacific sleeper shark from the combined sablefish longline survey, the domestic sablefish survey, and Japan-U.S. cooperative sablefish survey in the Gulf of Alaska, Aleutian islands and Bering Sea during the years 1979-2000.

Year	All effective[1] skates	All effective[1] skates, and standard[2] hauls	Domestic survey	Cooperative survey
1979	0	0		0
1980	1	1		1
1981	1	1		1
1982	1	1		1
1983	0	0		0
1984	5	5		5
1985	6	6		6
1986	5	5		5
1987	25	25		25
1988	20	15	3	12
1989	26	23	15	8
1990	29	26	25	1
1991	29	28	27	1
1992	71	40	26	14
1993	103	88	69	19
1994	155	117	67	50
1995	61	53	53	
1996	83	83	83	
1997	95	88	88	
1998	84	79	79	
1999	84	78	78	
2000	107	103	103	
Total	991	865	716	149

[1] Effective skates have less than or equal to 5 ineffective hooks.
[2] Standard hauls do not include experimental stations.

Table 5. CPUE (catch per 1,000 skates) of Pacific sleeper shark from the combined sablefish longline survey, the domestic sablefish survey, and Japan-U.S. cooperative sablefish survey in the Gulf of Alaska, Aleutian islands and Bering Sea during the years 1979-2000.

Year	All effective[1] skates	All effective[1] skates, and standard[2] hauls	Domestic survey	Cooperative survey
1979	0.00	0.00		0.00
1980	0.09	0.11		0.11
1981	0.09	0.11		0.11
1982	0.06	0.08		0.08
1983	0.00	0.00		0.00
1984	0.29	0.39		0.39
1985	0.57	0.77		0.77
1986	0.46	0.62		0.62
1987	1.95	2.57		2.57
1988	0.79	0.79	0.46	0.97
1989	1.24	1.37	1.85	0.92
1990	1.39	1.54	3.07	0.11
1991	1.62	1.95	3.33	0.16
1992	2.79	2.15	3.15	1.36
1993	3.83	4.41	8.39	1.62
1994	5.92	6.30	8.16	4.83
1995	5.55	5.90	5.90	
1996	6.89	8.58	8.58	
1997	7.00	8.14	8.14	
1998	7.13	7.77	7.77	
1999	7.49	8.02	8.02	
2000	9.43	10.35	10.35	

[1] Effective skates have less than or equal to 5 ineffective hooks.

[2] Standard hauls do not include experimental stations.

Table 6. Relative population numbers (RPN's) of Pacific sleeper shark from the combined sablefish longline survey, the domestic sablefish survey, and Japan-U.S. cooperative sablefish survey in the Gulf of Alaska, Aleutian islands and Bering Sea during the years 1979-2000.

Year	All effective[1] skates, and standard[2] hauls	Domestic Survey	Cooperative Survey
1979	0.00		0.00
1980	6.89		6.89
1981	3.92		3.92
1982	6.20		6.20
1983	0.00		0.00
1984	47.39		47.39
1985	92.10		92.10
1986	206.50		206.50
1987	186.61		186.61
1988	152.61	78.67	101.75
1989	216.12	136.07	164.72
1990	307.54	361.13	4.78
1991	362.23	405.80	5.30
1992	521.04	462.14	85.29
1993	1,477.41	1,371.52	148.38
1994	1,728.08	1,532.47	353.68
1995	908.90	908.90	
1996	1,445.18	1,445.18	
1997	929.61	929.61	
1998	1,405.24	1,405.24	
1999	1,443.26	1,443.26	
2000	1,778.93	1,778.93	

[1] Effective skates have less than or equal to 5 ineffective hooks.
[2] Standard hauls do not include experimental stations.

Table 7. Relative population numbers (RPN's) of Pacific sleeper shark captured by the domestic sablefish longline survey during the years 1989-2000 in the Gulf of Alaska, Aleutian islands and Bering Sea.

Pacific sleeper shark RPN's by year

Survey areas	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Bering Sea												
Bering 5												
Bering 4									73		35	
Bering 3									37		12	
Bering 2									159		10	
Bering 1									102		8	
Aleutian Islands												
NW Aleutians												
SW Aleutians												
NE Aleutians										0		0
SE Aleutians								0		0		0
Gulf of Alaska												
Shumagin [1]	0	34	38	0	17	6	0	0	0	17	0	0
Shumagin Gully [2,5]	7	0	0	0	0	0	0					
Chirikof [2]	8	0	5	0	0	6	0	6	2	4	2	1
Shelikof Trough [2]	61	102	227	371	1,181	973	809	1,314	387	1,181	1,320	1,635
Kodiak [2]	0	0	0	0	0	0	6	0	0	0	0	29
Amatuli Gully [2]	0	157	81	53	124	532	69	0	37	106	42	16
W Yakutat [3]	11	0	10	0	0	0	3	5	2	0	0	11
E Yakutat [4]	0	0	4	1	1	0	0	0	28	1	0	10
W-grounds [3]	0	0	0	12	12	0	0	0	0	0	0	4
Yakutat Valley [3]	43	65	35	8	16	0	12	121	65	36	5	47
Alsek Strath [4,5]	0	4	6	17	20	8						
Southeast [4]	6	0	0	0	0	3	0	0	37	3	0	0
Spencer Gully [4]	0	0	0	0	0	0	2	0	0	0	0	0
Ommaney Trench [4]	0	0	0	0	0	6	0	0	0	12	8	26
Iphigenia Trench [4,5]	0	0	0	0	0	0						
Dixon Entrance [4]	0	0	0	0	0	0	8	0	1	44	0	0

[1] Western Gulf stations

[2] Central Gulf stations

[3] Eastern Gulf stations (West Yakutat)

[4] Eastern Gulf stations (East Yakutat / Southeast Outside)

[5] Discontinued stations, not included in Gulf of Alaska Summary

Table 7. Continued.

Pacific sleeper shark RPN's by year

Gulf of Alaska INPFC areas	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Western	0	34	38	0	17	6	0	0	0	17	0	0
Central	69	259	313	424	1,306	1,510	884	1,319	426	1,291	1,364	1,682
West Yakutat	54	65	45	21	28	0	15	125	67	36	5	61
East Yakutat / Southeast Outside	6	0	4	1	1	9	10	0	66	61	8	36

Pacific sleeper shark RPN's by year

Gulf of Alaska totals	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Gulf of Alaska total	129	358	400	446	1,352	1,525	909	1,445	559	1,405	1,377	1,779
Difference in totals by year		177%	12%	11%	203%	13%	-40%	59%	-61%	151%	-2%	29%

Pacific sleeper shark RPN's by year

Gulf of Alaska gully station* totals	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Gulf of Alaska gully stations	104	324	342	445	1,333	1,511	900	1,435	490	1,379	1,375	1,728
Percent of total in gullies	81%	91%	86%	100%	99%	99%	99%	99%	88%	98%	100%	97%

*Shelikof Trough, Amatuli Gully, W-grounds, Yakutat Valley, Spencer Gully, Ommaney Trench, and Dixon entrance

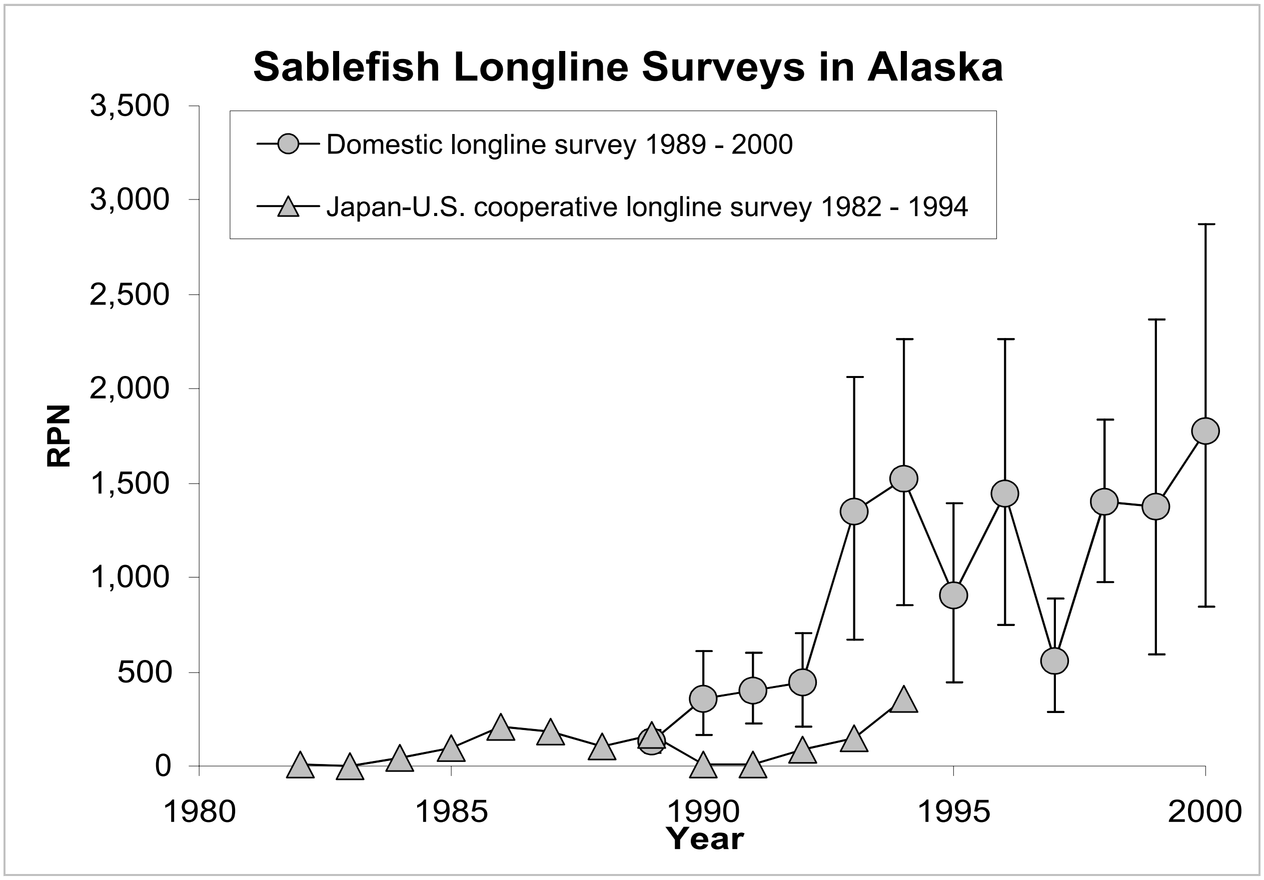


Figure 1. Relative population numbers (RPN's) of Pacific sleeper shark captured in the Gulf of Alaska, Aleutian Islands, and Bering Sea during the years 1982-1994 by the Japan-U.S. cooperative sablefish longline survey, and in the Gulf of Alaska during the years 1989-2000 by the domestic sablefish longline survey (with 95% bootstrap confidence intervals for the domestic survey).

Benthic Communities and Non-target fish species

GULF OF ALASKA

ADF&G Large Mesh Survey (no new information available in 2002)

Contributed by Dan Urban, Alaska Department of Fish and Game

The Alaska Department of Fish and Game began using the 400 Eastern trawl for surveys of crab stocks starting in the late 1960's. By 1988, standard survey stations had been defined in the central and western Gulf of Alaska and were being surveyed on an annual basis (Figure 1). The department nets are rigged to fish hard on the bottom and can only be used on relatively soft bottoms.

While the survey covers a huge area, results from Kiliuda and Ugak Bays and the immediately contingouus offshore Barnabas Gully (Figure 2) are broadly representative of survey results across the region. This area has been surveyed with a trawl continuously since 1984, and Ugak Bay was also the subject of an intensive trawl study in 1976 (Blackburn 1977). Except for the work in 1976, the same vessel and captain have been used for these surveys.

The change in catch rates of a number of species in Ugak Bay from 1976 as compared to the present is striking (Table 1), and are likely related to the well documented regime shift. King crab went from being a main component of the catch to being nearly non-existent, while at the same time Tanner crab catch rates have increased dramatically, although this increase is a recent phenomena (Figure 3). Also notable is the increase in flathead sole CPUE.

Table 1. Comparison of catch rates (kg/km) of selected species from trawl surveys in Ugak Bay, Kodiak Island from 1976 and 2001.

Species	1976	2001
King crab	25.5	1.8
Tanner crab	22.5	163.1
Yellow Irish Lord	6.7	0.0
Flathead sole	13.7	188.5
Pollock	0.4	38.1
Pacific cod	18.6	32.1

Arrowtooth flounder dominate the offshore catch while flathead sole remain the most common component of the bay areas. Both the biomass and numbers of Tanner crabs continue to increase in the bay stations with the numbers of Tanner crab at 500% of the 1984-2001 average. The overall catch rate of all species combined appears to have been increasing for the last 4 or 5 years (Figure 3), although the increase is small.

It is obvious the Gulf of Alaska, as reflected by these two areas, remains a dynamic ecosystem. It is tempting to speculate that the increase in Tanner crab is one of the first signals of a return to ecosystem similar to the early 1970's but it may also be related to Pacific cod removals from nearshore waters during the state water cod fishery. The ADF&G large mesh trawl survey will continue to monitor this portion of the Gulf of Alaska and make its findings available for researchers.

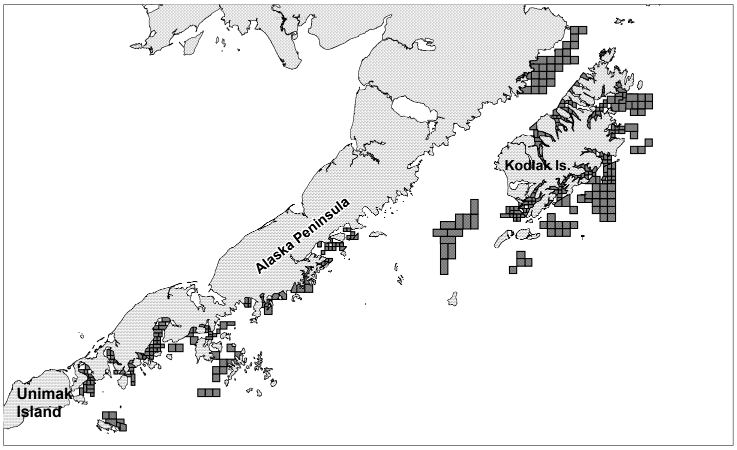


Figure 1. Stations fished during the 2001 ADF&G trawl survey, one haul per station.

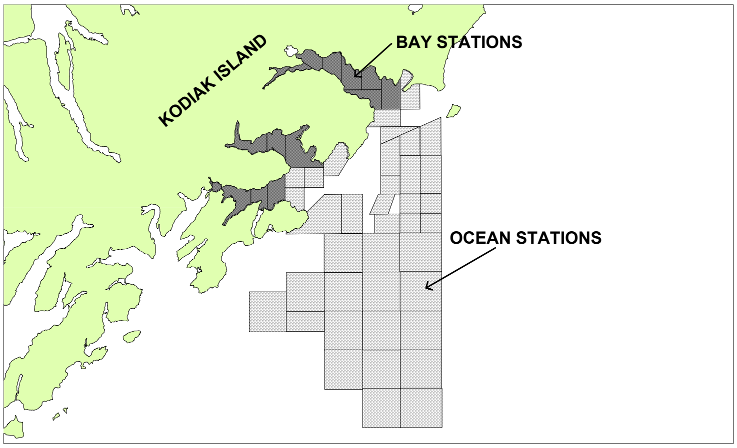


Figure 2. Adjoining trawl stations on the east side of Kodiak Island used to characterize nearshore and offshore ecosystem trends.

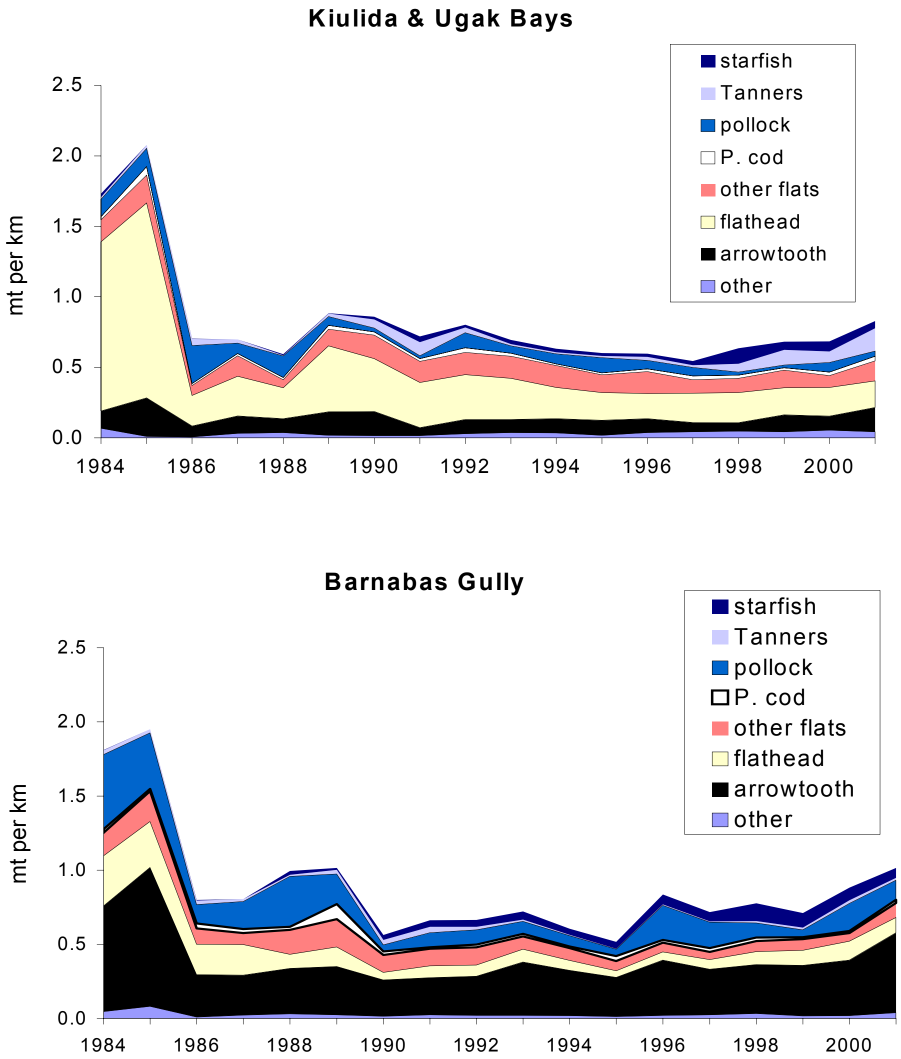


Figure 3. Metric tons per kilometer caught during the ADF&G large mesh trawl survey from adjacent areas off the east side of Kodiak Island.

References

Blackburn, James E. 1977. Demersal and Shellfish Assessment in Selected Estuary Systems of Kodiak Island. *In* Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the year ending March 1977. Volume X. Receptors—Fish, Littoral, Benthos. Outer Continental Shelf Environmental Assessment Program. U.S. Department of Commerce, NOAA, Environmental Research Laboratory, Boulder Colorado.

GOA Small-mesh Survey Update for 2002 (includes capelin trends)

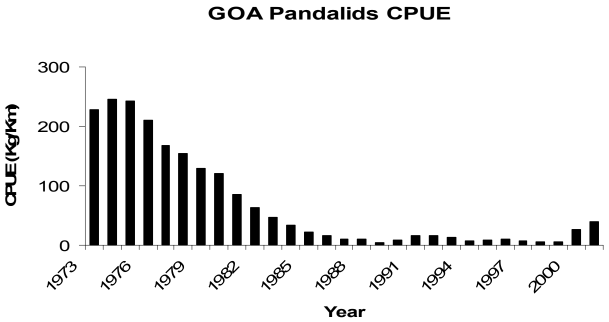
Contributed by Paul Anderson, Alaska Fisheries Science Center

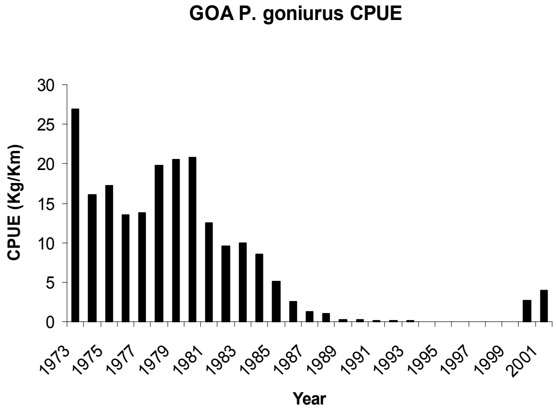
On the surface it seems that the GOA is in the early stage of a significant shift in the community structure of the GOA. However I think it would be misleading to characterize this preliminary data analysis in this way. Most of the data that have recently been added to the database came from the 2001 ADF&G small mesh survey (96 tows). This survey was concentrated mostly around Kodiak Island and the adjacent Alaska peninsula areas. This area did show changes occurring in the species community structure. However another survey conducted by NMFS to the west along the Alaska peninsula (Pavlof Bay) showed none of the changes evident in the Kodiak area. This spatial partition in changing community structure needs to be studied and better understood. Fortunately, funding has been obtained through Steller sea lion research funds to re-survey areas in Kodiak and to expand the survey effort westward along the Alaska peninsula this fall. The changes in the Kodiak area were striking, and certainly argue that the system oscillates between two general community structures. One dominated by cod and some flatfish species and another dominated by shrimp, forage fish, and possibly over time with other crustaceans (crab).

Furthermore in-depth analysis of the data at hand will be needed to discern any possible spatial patterns that may exist. Complementary surveys sample the same locations in the same manner will be conducted again this fall to help us understand the recent results and any possible restructuring in the species community that may be underway.

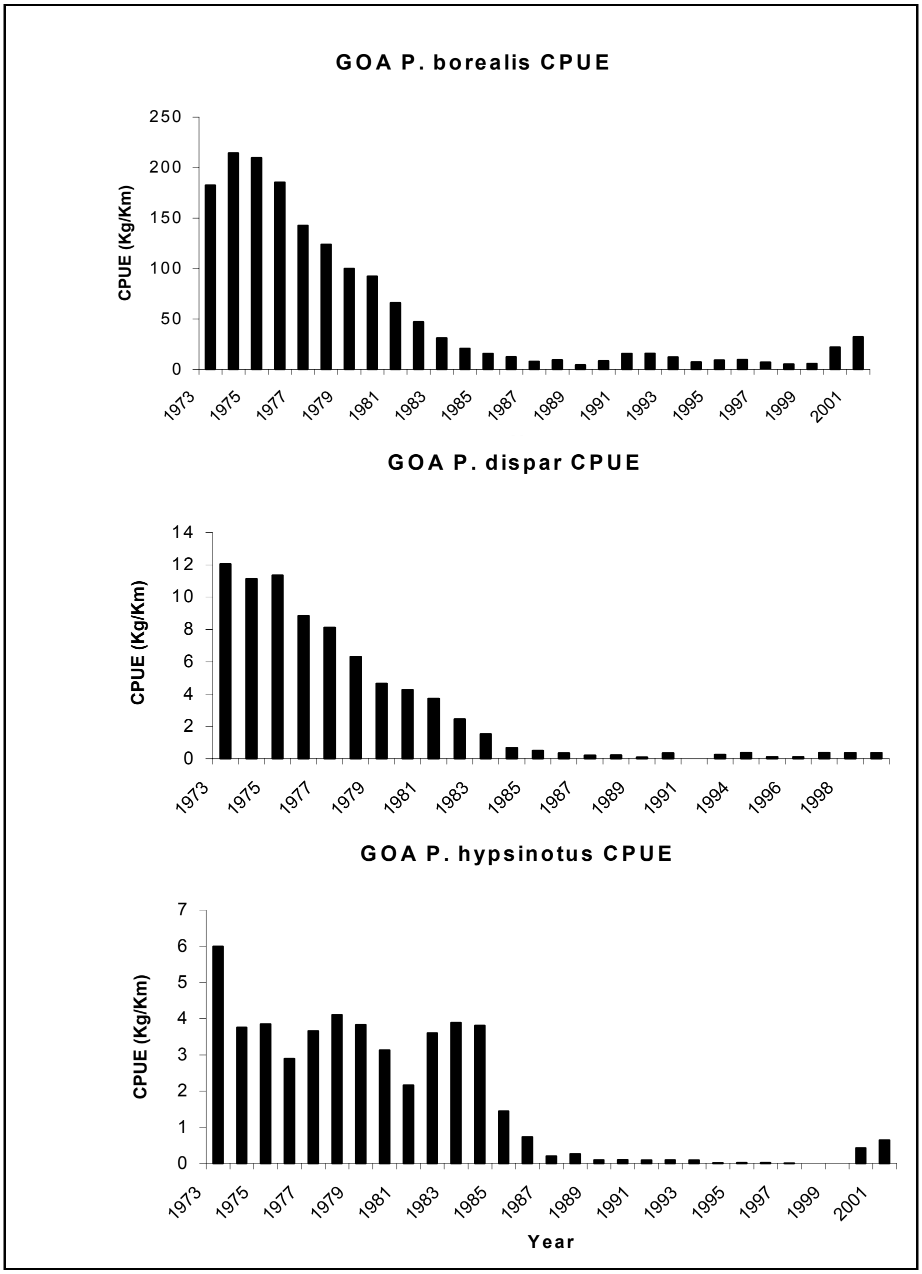
Pandalid Shrimp

Pandalid shrimp increased notably during the 2001 survey. Average catch per tow for all pandalids combined increased to over 75 kg/km. Relative Pandalid shrimp abundance at this level last occurred in survey results twenty years ago in1981. The years 1995 and 1998 (the most comparable sampling effort to the 2001 survey) indicated only 20 and 13 kg/km respectively.



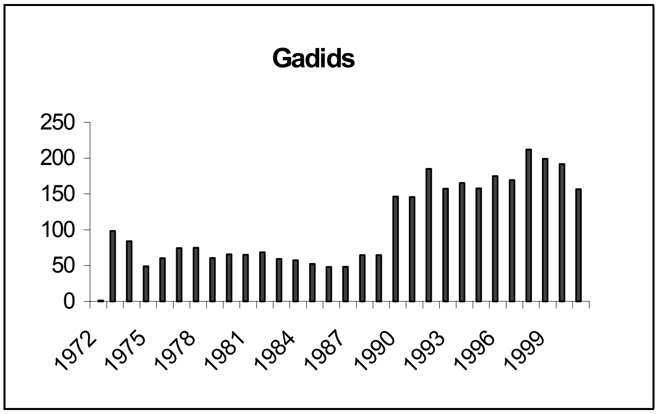


Of all the pandalid species the most significant recovery has occurred with *Pandalus goniurus*. This species which has a comparatively shallow depth distribution and became almost functionally extinct in this region of the GOA increased in certain shallow bays. Overall abundance was 7.9 kg/km the highest cpue recorded for this species since 1984 (10.3 kg/km). Other pandalids showed high relative abundance in 2001; *P. borealis* (61.2 kg/km), *P. hypsinotus* (1.3 kg/km), and *Pandalopsis dispar* (3.5 kg/km). All of these values for the respective species approach the abundance found in the early 1980s for the survey series. Therefore survey results support the notion that pandalid shrimp as a group are showing signs of regaining importance in the community structure of the GOA.



Gadids

In 2001 the relative abundance of all gadids (codes 21700 through 21749) declined to 111.8 kg/km the lowest abundance in this survey series since 1990 when gadid abundance was at 42.9 kg/km. In contrast, juvenile walleye pollock (code 21741), fish less than 20 cm in length, are at their highest relative abundance 11.4 kg/km in 2001 since 1983 when they registered 10.2 kg/km. Walleye pollock both adults and juveniles combined showed their lowest abundance since 1990. Pacific cod also reached their lowest abundance since 1990 (4.2 kg/km) falling to 12.3 kg/km in 2001.

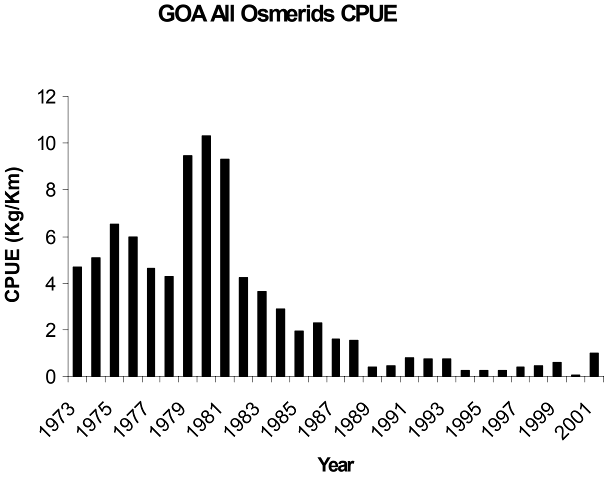


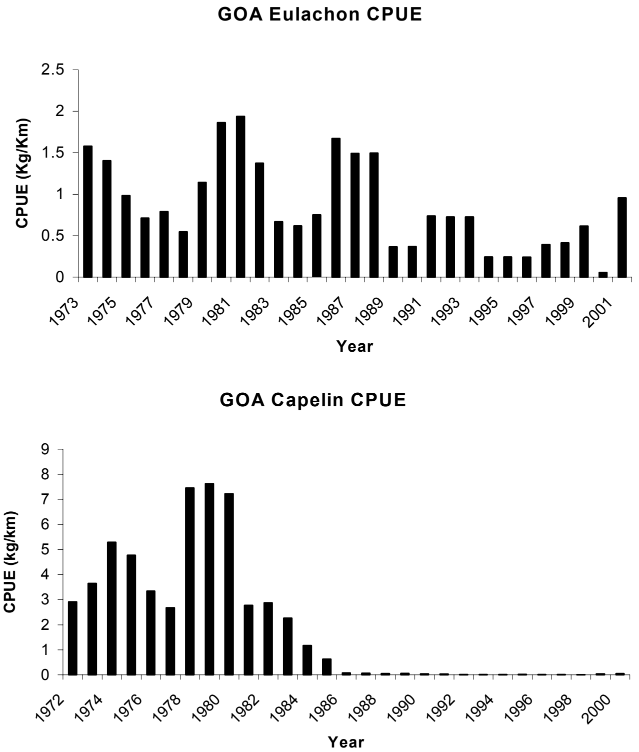
Pleuronectids

Flatfish as a group averaged 121.2 kg/km during the 2001 survey. That did not vary significantly from the 1999-2001 average of 125.7 kg/km for the species group. Individual species like arrowtooth did show moderate increases in abundance increasing to 44.8 kg/km, the highest CPUE recorded for this species in the last thirty years. Flathead sole and yellowfin sole showed no significant change.

Osmerids

Osmerids as a group (species codes 23000 through 23099) increased to 2 kg/km in 2001. This is the highest relative level of abundance measured since 1992 when 2.2 kg/km was caught. Eulachon was found at an average 1.9 kg/km during the 2001 survey. This is the highest level observed since 1992 when they had an average catch of 2.1 kg/km. Capelin remained at relatively low levels of just 0.1 kg/km, yet this was the highest relative abundance measured since 1989 when they were caught at an average of 0.12 kg/km. Capelin still remain well below their historic peak abundance in 1980 in the GOA when a peak abundance in the survey series was noted of 16.8 kg/km.



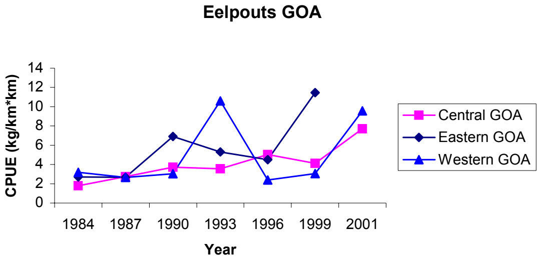


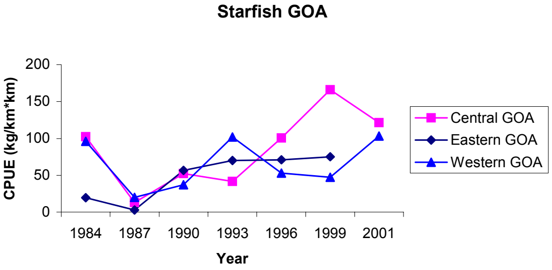
Miscellaneous Species – Gulf of Alaska

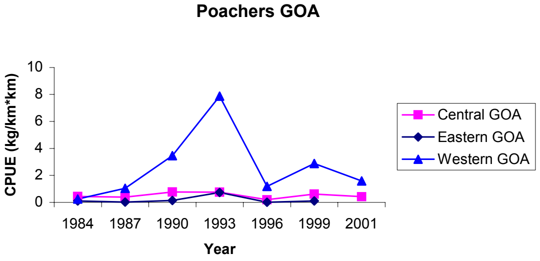
Contributed by Eric Brown, Alaska Fisheries Science Center

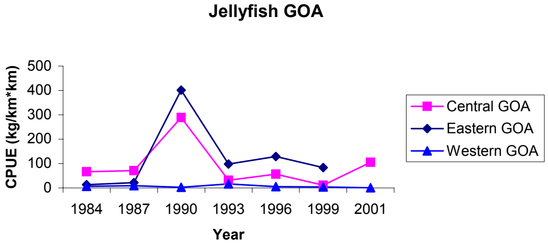
A variety of non-target species are seen in the RACE bottom trawl survey in the Gulf of Alaska. It is possible that the survey may provide information about possible relative abundance changes for some of these species. Some initial results at summarizing these trends are shown (Figure 1). This survey is not designed to assess these organisms and further detailed examinations of these results are needed to assess whether there are meaningful trends.

The starfish and eelpout groups commonly occur in survey trawl catches with starfish being a magnitude of abundance higher than eelpouts. Poachers occur occasionally at very low abundance levels. Their apparent large increase in abundance observed in 1993 was the result of two unusually "large" catches of 11 and 15 kg. Trends in abundance of the jellyfish group may be difficult to interpret since much of the catch may occur higher in the water column as the trawl is being set or retrieved.







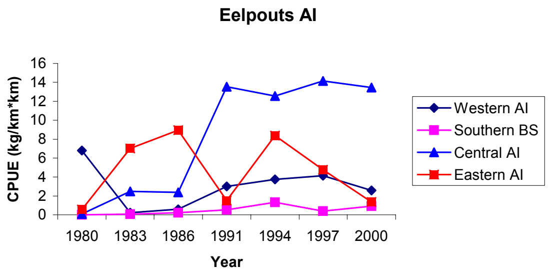


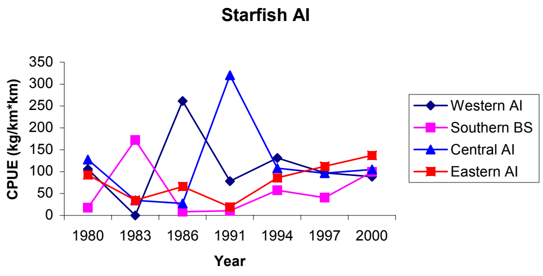
Miscellaneous Species – Aleutian Islands

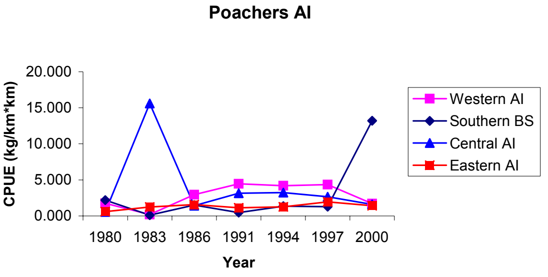
Contributed by Eric Brown, Alaska Fisheries Science Center

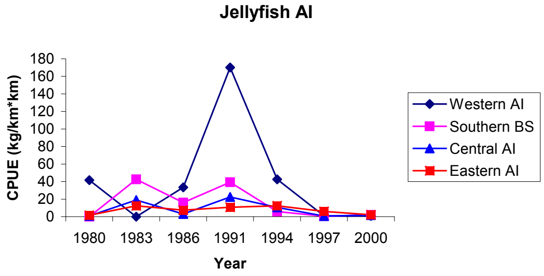
A variety of non-target species are seen in the RACE bottom trawl survey in the Aleutian Islands. It is possible that this survey may provide information about possible relative abundance changes in some of these species. Some initial results at summarizing these trends are shown (Figure 1). This survey is not designed to assess these organisms and further detailed examinations of these results are needed to assess whether there are meaningful trends.

Eelpouts and poachers are relatively common in trawl catches but generally occur at very low catch rates so that any apparent increases in abundance may be driven by one or two catches of only a few fish. Starfish and jellyfish are also quite common but exhibit much higher apparent abundance levels. As mentioned earlier, jellyfish may primarily occur higher in the water column and be caught during setting and retrieval of the trawl.









EASTERN BERING SEA

Jellyfish

Contributed by Gary Walters, Alaska Fisheries Science Center

The time series of jellyfish caught as by-catch in the annual Bering Sea bottom trawl survey was updated for 2001 (Figure 1). The trend for increasing abundance that began around 1989 reported by Brodeur et al. (1999) did not continue in 2001 and 2002. In fact, the 2001 and 2002 catches decreased dramatically and were close to levels seen in the 1980's and early 1990's. The overall area biomass index for 2002 is 68,700 t and the catch on the NW shelf is 47,900 t and on the SE shelf is 20,800 t. It is unknown whether this decline is due to a change in availability or actual abundance.

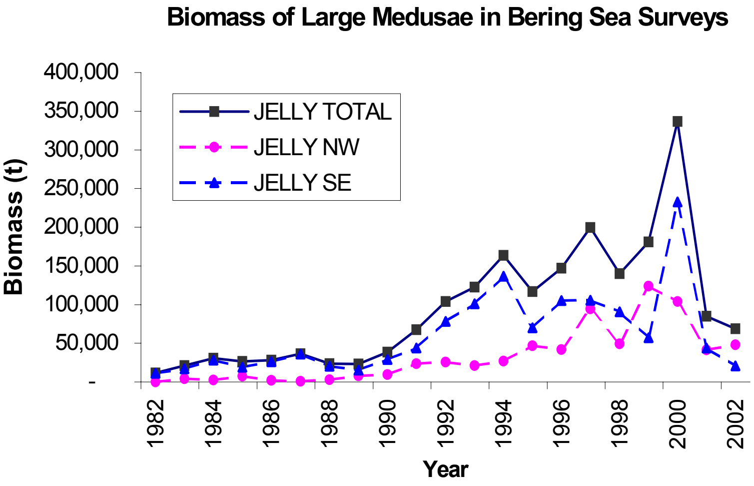


Figure 1. Index of large medusae biomass during summer in the eastern Bering Sea from the NMFS bottom trawl survey, 1982-2001.

Miscellaneous species - eastern Bering Sea

Contributed by Gary Walters, Alaska Fisheries Science Center

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). Total biomass of this group appeared higher in the early 1980's than in the late 1980's to the present. Although lower, biomass appears to be relatively stable in the recent time period. Further analysis at the species level should be done to look at biomass trends by species.

Poachers, likely dominated by sturgeon poacher (Podothecus acipenserinus) showed a biomass trend opposite to the eelpouts. Lower biomass index values were seen in the early 1980's but biomass has increased and was fairly stable in the late 1980's to the mid-1990's. Biomass appears to be lower in recent years and may be returning to levels seen in the early 1980's.

Echinoderms on the shelf consist mostly of purple-orange seastar (Asterias amurensis), which is found more in the inner/middle shelf regions, and common mud star (Ctenodiscus crispatus), which is a more of an outer shelf inhabitant. Total biomass index values for this group on the shelf appear to be higher from the mid-1980's to the present than in the early 1980's.

More research on the life history characteristics of non-target species is required to understand the possible reasons for these biomass trends.

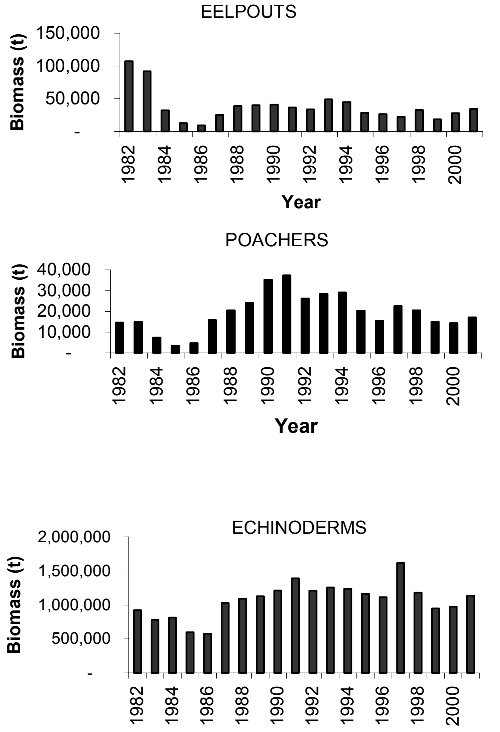


Figure 1. Biomass index values of miscellaneous species caught in the eastern Bering Sea summer bottom trawl survey, 1982-2001.

Marine Mammals

Compiled by Elizabeth Sinclair, National Marine Mammal Laboratory

Contributors: Rich Ferrero, Lowell Fritz, Carolyn Gudmundson, Sarah Hinckley, Thomas Loughlin, Rolf Ream, Bruce Robson, John Sease, Elizabeth Sinclair, Rod Towell, Anne York, Tonya Zeppelin

Note: the material that follows has been directly excerpted from published literature or, in some cases, from manuscripts in preparation. As a courtesy to the authors, please contact the compilation editor prior to citing the information provided.

The Bering Sea and Gulf of Alaska support one of the richest assemblages of marine mammals in the world. Twenty-six species are present from the orders Pinnipedia (seals, sea lion, and walrus), Carnivora (sea otter and polar bear), and Cetacea (whales, dolphins, and porpoises) in areas fished by commercial groundfish fleets (Lowry and Frost 1985, Springer *et al.* 1999). Most species are resident throughout the year, while others migrate into or out of the management areas seasonally. Marine mammals occur in diverse habitats, including deep oceanic waters, the continental slope, and the continental shelf (Lowry *et al.* 1982).

The high cost of conducting marine mammal surveys along with limited funding has meant that most marine mammal stocks in Alaska are not surveyed with enough regularity to track trends in population health. Trends in distribution and abundance of these apex predators serve as an important reflection of ecosystem health. Three species of pinnipeds that are regularly surveyed; Steller sea lions (*Eumetopias jubatus*), northern fur seals (*Callorhinus ursinus*), and harbor seals (*Phoca vitulina*); have each demonstrated significant population declines over the past three decades. Declines are thought to be related to diet changes and indirect interaction with commercial fisheries. Recent data on population trends, diet, and foraging distribution for Steller sea lions and northern fur seals are presented here.

The most recent stock assessment information on other Alaska marine mammals is available at:
http://www.nmfs.noaa.gov/prot_res/PR2/Stock_Assessment_Program/sars.html#Overview

Steller Sea Lion (*Eumetopias jubatus*)

Natural History

Steller sea lions range along the North Pacific Ocean rim from northern Japan to California (Loughlin *et al.* 1984), with centers of abundance and distribution in the GOA and Aleutian Islands, respectively. The northernmost breeding colony in the Bering Sea is on Walrus Island in the Pribilof Islands and in the Gulf of Alaska on Seal Rocks in Prince William Sound (Kenyon and Rice 1961).

Habitat includes both marine waters and terrestrial rookeries (breeding sites) and haulouts (resting sites). Although most often within the continental shelf region, they may be found in pelagic waters as well (Bonnell *et al.* 1983, Fiscus and Baines 1966, Fiscus *et al.* 1976, Kenyon and Rice 1961). Pupping and breeding occur during June and July on relatively remote islands, rocks, and reefs called rookeries. During the breeding season, rookeries are occupied primarily by adults and pups of the year. Adult females of a related member (northern fur seals) of this family of pinnipeds (Otariidae) generally return to rookeries where they were born to give birth to a single pup and mate (Baker *et al.* 1995; Kenyon and Wilke 1953) and it has been suggested that Steller sea lions behave in a similar fashion (Sinclair and Zeppelin 2002). The mother nurses the pup during the day and after staying with her pup for the first week she goes to sea on nightly feeding trips. Pups may be weaned before the next breeding season, but it is not unusual for a female to nurse her offspring for a year or more (Loughlin *et al.*, in press). Females reach sexual maturity between 3 and 8 years of age and may breed into their early 20s. Females can have a pup every year but may skip years as they get older or when nutritionally stressed. Males also reach sexual maturity at about the same ages, but do not have the physical size or skill to obtain and keep a breeding territory prior to nine years of age or more. Males may hold breeding territory for up to 7 years, but 3 years is more typical (Gisiner, 1985). While on the territory during the breeding season adult males may not eat for 1-2 months. The rigors of fighting to obtain and hold a territory and the physiological stress over time during the mating season reduce the life expectancy of these animals. They rarely live beyond their mid-teens while females may live as long as 30 years.

All ages and both sexes occur in large aggregations during the nonbreeding season. Steller sea lions do not migrate, but they do disperse widely at times of the year other than the breeding season. Generally, animals up to about 4 years-of-age tend to disperse farther than adults. As they approach breeding age, they have a propensity to stay in the general vicinity of the breeding islands. Recent diet information indicates that females may stay within the region of their birth throughout their lifetime (Sinclair and Zeppelin, 2002).

Population Trends

In November 1990, the NMFS listed Steller sea lions as "threatened" range-wide under the U.S. Endangered Species Act (55 Federal Register 49204, November 26, 1990) in response to a population decrease of 50% - 60% during the previous 10 - 15-year period. Several years later, two population stocks were identified, based largely on differences in genetic identity, but also on regional differences in morphology and population trends (Bickham *et al.*, 1996; Loughlin, 1997). The western stock, which occurs from 144 W long. (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, remains classified as threatened.

Population assessment for Steller sea lions is achieved primarily by aerial surveys of non-pups and on-land pup counts. Historically, this included surveys of limited geographical scope in various portions of the species' range, in many cases conducted using different techniques, and occasionally during different times of year. Consequently, reconstructing population trends for Steller sea lions from the 1970s and earlier, and over a large geographical area, such as the western stock in Alaska, includes a patchwork of regional surveys conducted over many years.

Aerial surveys conducted from 1953 through 1960 resulted in combined counts of 170,000 to 180,000 Steller sea lions in what we now define as the western stock in Alaska (Mathisen, 1959; Kenyon and Rice, 1961). Surveys during 1974-1980 suggested an equivocal increase to about 185,000, based on maximal counts at sites over the same area, as summarized by Loughlin *et al.* (1984). It was concurrent with the advent of more systematic aerial surveys that population declines were first observed. Braham *et al.* (1980) documented declines of at least 50% from 1957 to 1977 in the eastern Aleutian Islands, the heart of what now is the western stock. Merrick *et al.* (1987) estimated a population decline of about 50% from the late 1950s to 1985 over a much larger geographical area, the central Gulf of Alaska through the central Aleutian Islands. The population in the Gulf of Alaska and Aleutian Islands declined by about 50% again from 1985 to 1989, or an overall decline of about 70% from 1960 to 1989 (Loughlin *et al.*, 1992).

Loughlin *et al.* (1992) described Southeast Alaska as the only region of Alaska in which the Steller sea lion population appeared to be stable in 1989. Calkins *et al.* (1999) estimated that the Steller sea lion population in Southeast Alaska increased by an average of 5.9% per year from 1979 to 1997, based on counts of pups at the three rookeries in the region. From 1989 to 1997, however, pup numbers increased by only 1.7% and counts of non-pups at 12 index sites were stable (average change of +0.5% per year).

Much of the population trend analyses during recent years has focused on "trend sites" as espoused by the Steller Sea Lion Recovery Team (NMFS 1992b, NMFS 1995a; Loughlin and York 2000). Trend sites are those rookeries and haul-out sites with comparable series of counts from the 1970s to the present, thus allowing analysis of population trends on a decadal scale. Trend sites include the majority of animals (70 - 75%) observed in each survey.

Population Status

The National Marine Mammal Laboratory (NMML) at Alaska Fisheries Science Center and the Southwest Fisheries Science Center (SWFSC) conducted surveys of Steller sea lions across Alaska during June and July 2002 (Sease and Gudmundson, in review). The NMML aerial survey of non-pups took place 14 to 25 June, covering the Alaska portion of the western stock from the eastern Gulf of Alaska through the western Aleutian Islands (Figure 1). Aerial survey counts, made from 35-mm oblique photographs, include all adult and juvenile sea lions, animals 1 or more years old, that are on rookeries and haul-out sites. The NMML counted pups at 21 western stock rookeries during two simultaneous ship-based expeditions from 24 June to 10 July. One vessel surveyed the Aleutian Islands (Attu to Dutch Harbor), the second vessel surveyed the Gulf of Alaska (Dutch Harbor to Prince William Sound). Land-based field parties counted pups at three other rookeries (Fish I., Marmot I., and Ugamak I.). The SWFSC surveyed Steller sea lions from the eastern stock in Southeast Alaska, counting both pups and non-pups from medium-format (5-inch) vertical photographs. The results of counts conducted in 2002 for both the western and eastern stocks are reported here, however eastern stock counts are preliminary (NMFS/SWFSC, La Jolla, CA unpublished data).

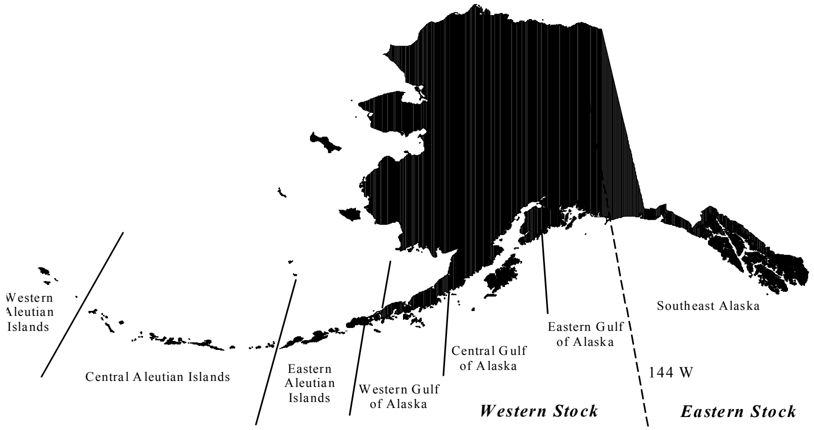


Figure 1. Geographical regions of Alaska employed for presentation of survey results, including delineation between eastern and western stocks at 144° W Longitude.

Western Stock

Non-pups: Numbers of adult and juvenile sea lions at the 84 western stock rookery and haul-out trend sites in Alaska increased by 5.5% from 2000 to 2002. This was the first region-wide increase observed during more than two decades of surveys (Loughlin and York 2000; Sease and Gudmundson in review). Despite this increase, the 2002 count was still down 5% from 1998 and 34% from 1991 (Table 1, Figure 2). The average, long-term trend was a decline of 4.2% per year from 1991 to 2002. Trends were similar in the Kenai-to-Kiska subarea (four regions from the central Gulf of Alaska through the central Aleutian Islands), another geographical region used as a population index (Table 1, Figure 2). Counts at the 70 Kenai-to-Kiska trend sites increased by 4.8% from 2000 to 2002 but decreased by 26% from 1991 to 2002. The long-term trend across the Kenai-to-Kiska region was a decline of 3.1% per year from 1991 to 2002 (Loughlin and York 2000; Sease and Gudmundson in review).

Although numbers of non-pups increased in five of the six western stock sub-regions from 2000 to 2002 (Table 1, Figure 3), these changes involved only a few hundred animals. The region that continued to decline was the western Aleutian Islands, where numbers decreased by 24% from 2000 to 2002 following a 44% decline from 1998 to 2000. The overall decline in the western Aleutian Islands was 75% from 1991 to 2002.

Pups: Pups counts introduce disturbance to the rookeries and are logistically difficult to conduct. Consequently, complete pup counts are attempted only every four years, with counts at selected rookeries during intervening years. The composite 2001/2002 pup count for the western stock, which included counts from 24 rookeries in 2002 and seven in 2001, showed continuing decline in pup production (Table 2, Figure 4). For the Kenai-to-Kiska index area, the area with longest series of region-wide counts, pup numbers were down 7.8% from 1998, 24.5% from 1994, and 42.4% from 1990/1991. Pup counts increased in one region (western Gulf of Alaska: +5.5%) from 1998 to 2002, but declined in the five other regions. The western Aleutian Islands experienced the worst decline (39%) from 1998 to 2002.

Table 1.--Regional counts of adult and juvenile (non-pup) Steller sea lions observed at rookery and haul-out trend sites in Alaska during June and July aerial surveys from 1991 to 2002, including overall percent change since 1991 and 2000 and estimated annual rates of change from 1991 to 2002 (from Sease and Gudmundson, in review).

		Gulf of Alaska			Aleutian Islands				
Year	Southeast Alaska (n=10)	Eastern (n=10)	Central (n=15)	Western (n=9)	Eastern (n=11)	Central (n=35)	Western (n=4)	Kenai to Kiska (n=70)	Western stock (n=84)
1991	8,621	4596	6270	3732	4228	7496	3083	21726	29405
1992	7,555	3738	5739	3716	4839	6398	2869	20692	27299
1994	9,001	3365	4516	3981	4419	5820	2035	18736	24136
1996	8,231	2132	3913	3739	4715	5524	2187	17891	22210
1998	8,693	2,110[1]	3467	3360	3841	5749	1911	16417	20,438[1]
2000	9,862	1,975	3,180	2,840	3,840	5,419	1,071	15,279	18,325
2002	9,951[2]	2,500	3,366	3,221	3,956	5,480	817	16,023	19,340
% change 1991 to 2002	+ 15.4	- 45.6	- 46.3	- 13.7	- 6.4	- 26.9	- 73.5	- 26.25	- 34.23
% change 2000 to 2002	+ 0.9	+ 26.6	+ 5.8	+ 13.4	+ 3.0	+ 1.1	- 23.7	+ 4.87	+ 5.54
est. annual % change 1991 to 2002	+ 1.8	- 7.0	- 6.3	- 2.2	- 1.6	- 2.3	- 11.4	- 3.09	- 4.15

[1] 1999 counts substituted for sites in the eastern Gulf of Alaska not surveyed in 1998.

[2] 2002 counts for Southeast Alaska are preliminary (NMFS/SWFSC, LaJolla, CA, unpublished data).

Table 2.--Regional counts of Steller sea lion pups at rookeries in Alaska from 1990/1991 to 2002, including overall percent change from earlier years and estimated annual rates of change from 1991 to 2001/2002. The composite count for 2001/2002 includes pup counts from 7 rookeries in 2001(from Sease and Gudmundson, in review).

		Gulf of Alaska			Aleutian Islands			
Count year(s)	Southeast Alaska (n=3)	Eastern (n=2)	Central (n=5)	Western (n=4)	Eastern[1] (n=5)	Central[2] (n=11)	Western (n=4)	Kenai to Kiska (n=25)
1990/1991	3600		4801	1857	2075	3568		12301
1994	3770	903	2831	1662	1776	3109		9378
1996	3714	584						
1997	4160	610					979	
1998	4234	689	1876	1493	1474	2834	803	7677
2001/2002	4706	570	1543	1575	1385	2577	488	7080
Percent change								
1990 to 2001/2002	+30.7		-67.9%	-15.2%	-33.3%	-27.8%		-42.4%
1994 to 2001/2002	+24.8	-36.9%	-45.5%	-5.2%	-22.0%	-17.1%		-24.5%
1998 to 2001/2002	+11.1	-17.3%	-17.8%	+5.5%	-6.0%	-9.1%	-39.2%	-7.8%
est. annual % change 1994 to 2002	+3.3	-4.7	-8.1	-0.8	-3.3	-2.5	-15.1	-3.8

[1] Does not include Sea Lion Rocks (Amak) or Ogchul.

[2] Does not include Semisopochnoi, Amchitka-East Cape, or Amlia-Sviechnikof Harbor.

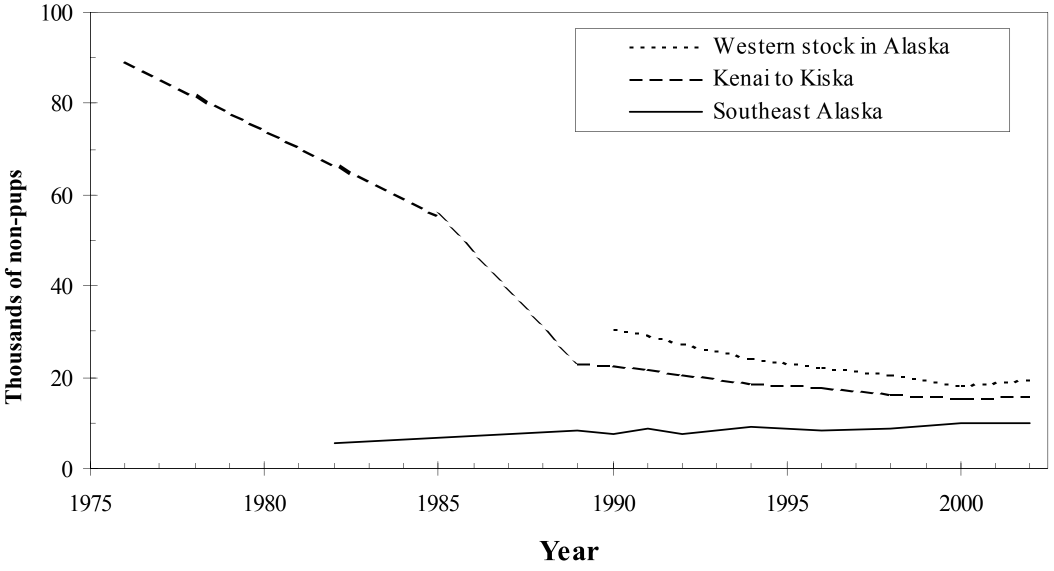


Figure 2.--Numbers of non-pup (adult and juvenile) Steller sea lions on trend sites in the western stock in Alaska, in the Kenai-to-Kiska index area, and in Southeast Alaska (eastern stock) from June aerial surveys, 1970s to 2002 (from Sease and Gudmundson, in review).

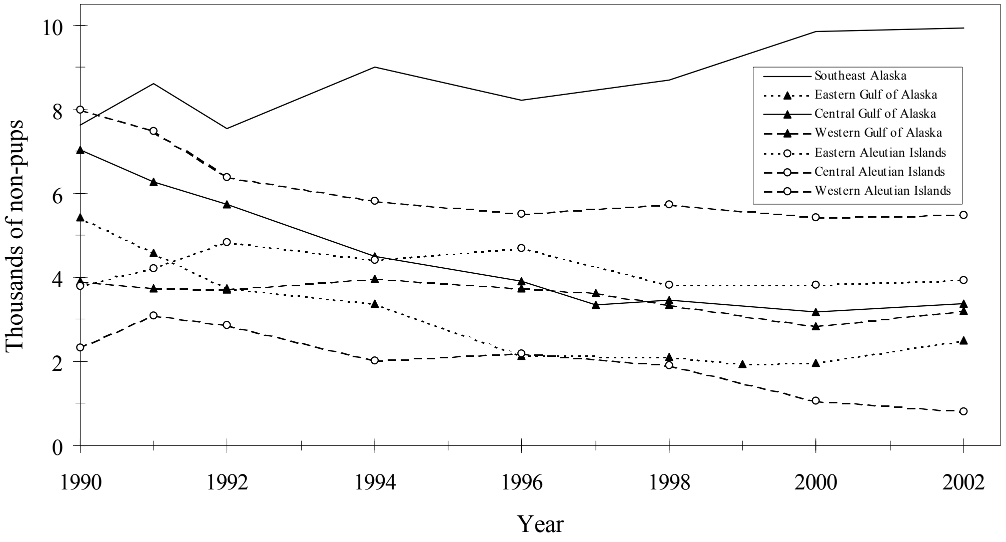


Figure 3.--Numbers of non-pup (adult and juvenile) Steller sea lions on trend sites in seven sub-regions of Alaska from June aerial surveys, 1991 to 2002. Southeast Alaska is part of the eastern stock, the other regions are part of the western stock (from Sease and Gudmundson, in review).

Eastern Stock

Non-pups: As noted above, count results for the 10 trend sites in Southeast Alaska are preliminary, but they suggest no change in the long-term trends for this region (Table 1, Figures 2 and 3). Non-pup numbers have increased by approximately 2% per year over the last decade for Southeast Alaska.

Pups: Pups in Southeast Alaska were counted from medium-format vertical photographs. Preliminary results suggest that numbers of pups in Southeast Alaska increased by about 11% from 1998 to 2002. (Table 2, Figure 4). This is consistent with an average rate of about 3% per year observed over the last decade.

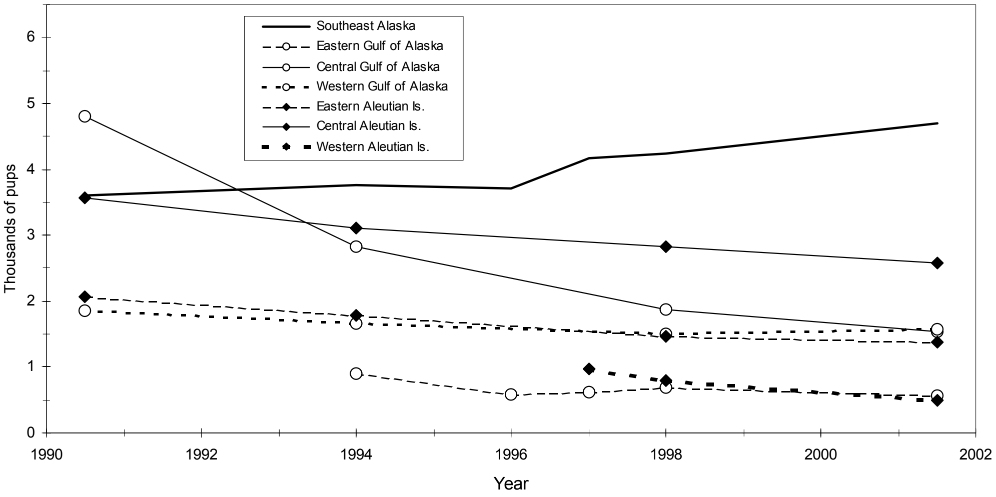


Figure 4.--Numbers of Steller sea lion pups at rookeries in seven subareas of Alaska from 1990 to 2001/2002. Southeast Alaska is part of the eastern stock, the other six regions are part of the western stock (from Sease and Gudmundson, in review).

Diet and Foraging Behavior

A number of factors are potentially contributing to, or compounding the rates of decline among western stock Steller sea lions (Loughlin and York, 2000). Much of the recent effort to understand the decline of Steller sea lions has focused on their diet and foraging behavior, particularly in light of indications that either direct or indirect competition for food with commercial fisheries may limit their ability to obtain sufficient prey for growth, reproduction and survival.

Historically, diet studies on marine mammals were based on the remains of prey in the stomach contents of the predator. Currently, the primary method of identifying prey species consumed by pinnipeds is through analysis of bony remains in fecal (scat) collections. Typically, the rank importance of any given prey species in marine mammal diet studies is based on some combination of two factors: the number of individuals of a particular species represented across all samples (prey number); and the number of samples containing that species across all samples containing prey remains (frequency of occurrence).

Diet

Steller sea lions specialize on particular prey throughout the water column in the epipelagic, demersal, and semi-demersal zones (Sinclair and Zeppelin, 2002). Selected prey varies in body size from approximately 10-70 cm (Zeppelin *et al.*, in prep.). Seasonal and regional patterns in prey consumption by western stock Steller sea lions (Sinclair and Zeppelin, 2002) indicate that they target prey when they are densely schooled in spawning aggregation nearshore (over or near the continental shelf) or along oceanographic boundary zones. This pattern is true in summer when collected scats are primarily from adult females, and in winter when scats are presumably from some increased proportion of juveniles and adult males as well as females.

A comparison of 1990–1998 trends in prey consumption across the western stock (Sinclair and Zeppelin, 2002) depicted walleye pollock (*Theragra chalcogramma*) and Atka mackerel (*Pleurogrammus monopterygius*) as the two dominant prey species, followed by Pacific salmon (Salmonidae) and Pacific cod (*Gadus macrocephalus*). Other primary prey species consistently occurring at frequencies of 5% or greater included arrowtooth flounder (*Atheresthes stomias*), Pacific herring (*Clupea pallasi*), Pacific sandlance (*Ammodytes hexapterus*), Irish lord (*Hemilepidotus sp*.), and cephalopods (squid and octopus). Species that occurred among the top three prey items in certain island regions included: snailfish (Liparididae), rock greenling (*Hexagrammos lagocephalus*), kelp greenling (*Hexagrammos decagrammus*), sandfish (*Trichodon trichodon*), rock sole (*Lepidopsetta bilineata*), northern smoothtongue (*Leuroglossus schmidti*), skate (Rajidae), and smelt (Osmeridae).

Sites along the western stock where the FO of prey was most similar were identified using Principal Components and Agglomerative Hierarchical Cluster Analysis (Ward, 1963; Ramsey and Schafer, 1996) resulting in regions of diet similarity (Sinclair and Zeppelin, 2002). These newly defined diet regions were used to compare regional and seasonal differences in prey. The diet divisions closely parallel those defined as metapopulations based on patterns in population decline by York *et al.* (1996) suggesting that diet and decline are linked (Figure 5).

Significantly (P = 0.01) strong seasonal patterns occur within each of the defined diet regions (Sinclair and Zeppelin, 2002). Pacific cod FO is significantly larger in winter in every region. Salmon FO is significantly lower during winter in the western Gulf of Alaska through the eastern Aleutian Islands, and higher in winter throughout the central and western Aleutian Islands. In the western Gulf, where arrowtooth flounder is most abundant in scats and well represented year-round, its FO is significantly lower in winter. Atka mackerel is significantly lower in the winter in the central and western Aleutians where it is the dominant prey species year-round. Forage fishes (herring and Pacific sand lance) are significantly different between seasons, however, there is no general trend among the regions. Walleye pollock is an important prey year-round in all regions up to the central Aleutian Islands where it is replaced by Atka mackerel. Likewise, cephalopod FO is not significantly different between seasons in any Region. Irish lord FO is generally higher in winter than in summer and, though rarely occurring during summer, sandfish and snailfish have relatively high occurrences during the winter across all regions (Figure 6).

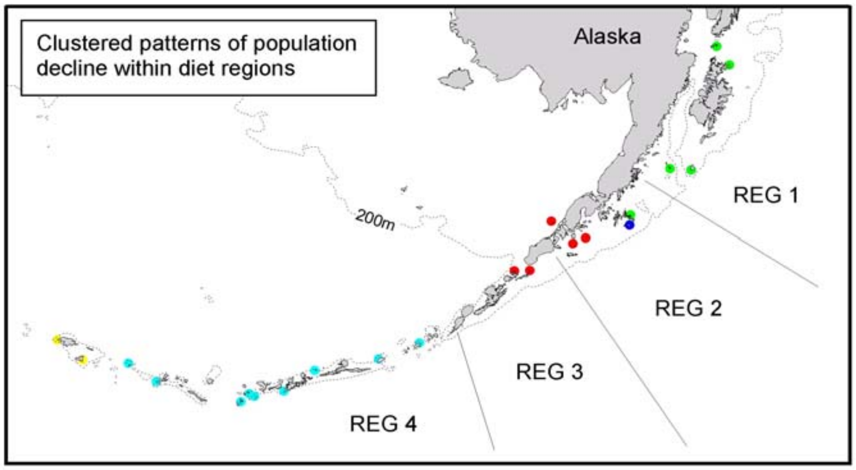


Figure 5. Population trends of Steller sea lions (York *et al.* 1996) within regions (REG) of diet defined in Sinclair and Zeppelin (2002). Colors represent sites clustered together based on patterns of decline between 1976-1994 and are still descriptive of current patterns in population.

The close parallel of diet data (Sinclair and Zeppelin, 2002) with those of metapopulation patterns of decline (York *et al.*, 1996) suggests that diet and decline of Steller sea lions are linked; that diet diversity is highest where population trends are most positive; and that regional diet patterns generally reflect regional foraging strategies learned at or near the natal rookery site on seasonally dense prey patches characteristic of that area. These data do not reflect Steller sea lion diet outside the range of the U.S. western stock.

The Unimak Pass area as well as Sea Lion Rock (Amak Island) on the continental shelf just eastward of the Pass encompassed the regions of highest prey diversity (Sinclair and Zeppelin, 2002). This is also the area of greatest population stability across the western stock (York *et al.*, 1996). Implications of the importance of diversity in otariid diet (Merrick *et al.*, 1997; Sinclair *et al.*, 1994) and the effect of commercial fisheries on diversity of prey in the water column should be further addressed, with special attention given to the dynamics of physical and bottom-up processes that influence nearshore habitat of rookery regions and ultimately, the population stability of Steller sea lions.

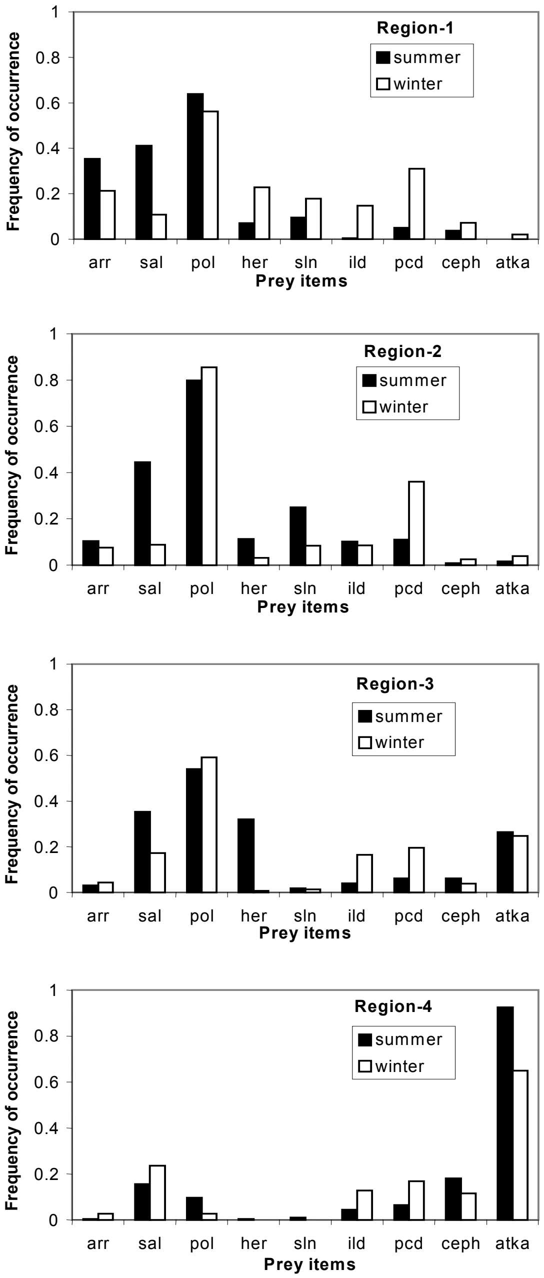


Figure 6. Frequency of occurrence of prey items occurring in Steller sea lion scats, in all regions and seasons, 1990-1998 (Sinclair and Zeppelin, 2002). (arr=arrowtooth flounder; sal = salmon; pol = walleye pollock; her = herring; sln=sandlance; ild=Irish Lord; pcd=Pacific cod; ceph=cephalopods; atka=Atka mackerel)

The findings of earlier diet studies conducted on western stock Steller sea lions (Imler and Sarber 1947; Mathisen *et al.*, 1962; Thorsteinson and Lensink, 1962; Tikhomirov, 1964; Fiscus and Baines, 1966) vary from recent analyses (Pitcher, 1981; Frost and Lowry, 1986; Merrick *et al.*, 1997; Calkins, 1998; Sinclair and Zeppelin, 2002) in that pollock were weakly represented or absent from Steller diet prior to the 1970's. Capelin was important in Steller diet through the 1970's (Fiscus and Baines, 1966; Pitcher, 1981), but do not have an occurrence greater than 5% in recent studies (Merrick *et al.* 1987; Sinclair and Zeppelin, 2002). Other differences between current and historical studies include salmon, which were present in early studies, but not at the frequencies currently found in diet across the western range during the summer. The occurrence of flatfish, especially arrowtooth flounder, in the Gulf of Alaska is substantially higher now than any previous studies. These dietary changes reflect observed changes throughout the ecosystem since the regime shift of 1976 (NRC 1996; Hunt *et al.* 2002) in trophic structure. Cephalopods were among the top prey items found in Steller sea lion stomachs in many early studies, sometimes ranking as the most frequently occurring prey item (Fiscus and Baines, 1966). Cephalopod occurrence in Sinclair and Zeppelin (2002) was primarily limited to the central and western Aleutian Islands and highest during the summer months, but never reached the high frequencies of the 1960s. While most differences between historical and current diets are thought to reflect true changes in diet, the absence of octopus in current diet studies may be due to differences in representation of cephalopod beaks in scats versus stomachs.

Foraging Behavior

An important consideration in evaluating effects of changing diets or prey abundance on Steller sea lions is not only the quantity, but the quality of the prey balanced against the energetic cost of obtaining that prey. Lipid and protein content are just two important measures of energetic value of a prey, and both vary greatly among Steller sea lion prey species, and within prey species depending upon life history stage, location and time of year (Stansby, 1976; Van Pelt *et al.*, 1997; Payne *et al.*, 1999; Anthony *et al.*, 2000). Atka mackerel and gadids are generally lower energy dense prey species (ranging within about 3 kJ/g – 6 kJ/g, though few data exist for Atka mackerel), while forage fish such as eulachon, herring, or capelin have generally higher energy contents (up to about 11 kJ/g). Because energy densities are seasonally variable, this is not an absolute relationship. For example, capelin and sandlance declined in lipid content, and therefore energy density, throughout the summer, from 6.7 kJ/g to 3.7 kg/g and 6.5 kJ/g to 4.8 kJ/g respectively (Anthony *et al.*, 2000). The ultimate net energy gain imparted to an animal from ingesting a particular prey item not only depends upon the energy content of the prey, but also on the costs associated with traveling to, finding, capturing, handling, and digesting the prey. It thus also depends on the prey item's individual size, total biomass, availability, behavior, degree of aggregation, temporal and spatial distribution, and so on. That is, the value of any particular prey type depends on the net gain to a sea lion from foraging on that prey, and net gain is a function of multiple factors of which lipid content is an important, but not the only, determinant.

One way of measuring the energetic cost of obtaining prey is by tracking foraging depth and distance from land through satellite telemetry. The NMML began satellite telemetry to collect information on Steller sea lion foraging ecology in the late 1980's. Satellite transmitters attached to sea lions provide information on location, depth and patterns of dive, time on land and distance traveled to sea. The current focus of research is on sea lions 6 months old to 2+ years of age whose survival rate is considered an important component in the decline of Steller sea lions. A recently completed study (Loughlin *et al.*, in press) defined three types of movements for juvenile Steller sea lions at sea, that vary with age and body mass: 1) transits between land sites with a mean distance of 66.6 km; 2) long-range trips (>15 km and >20 h) and; 3) short-range trips (<15km and <20 h). Maximum depths recorded for individual adult females in summer are in the range from 100 to 250 m; maximum depth in winter is greater than 250 m. The maximum depth measured for yearlings in winter is 288 m (Loughlin *et al.*, in press; Merrick and Loughlin 1997; Swain and Calkins 1997.

Modeling

Several models are being developed that are designed to help us understand the effects of changing prey densities and distributions on Steller sea lions. At the AFSC, a project, "Individual-based modeling of foraging behavior and bioenergetics of sea lions" (S. Hinckley, coordinator), consists of three coupled models: a model of individual sea lions, how they forage and the consequences of foraging success on growth, condition and survival; a dynamic model of prey distribution; and a dynamic, individual-based model of fishing fleet dynamics. This set of coupled models should enable us to examine hypotheses about how local, small-scale changes in prey distribution, density and species affects individuals at different life stages. Of particular interest is the theory of "local depletion", ie. whether small-scale, perhaps transient changes in fish distribution caused by fishing can significantly affect sea lions (i.e. constitutes "adverse modification of critical habitat").

A second set of integrated models is being developed at the Sea Mammal Research Unit at the University of St-Andrews, Scotland (Ian Boyd, coordinator). The intent of these models is to examine how foraging success, as a function of changes in prey density and distribution, affects population success. There are two basic components to this effort: a spatially explicit, state-based, large-scale model of "profitability" of foraging over the range of sea lions, and how this changes with changes in prey availability; results of this model are fed into a stochastic, size-structured population model. This set of models should allow larger-scale questions to be asked about how changes in the density and distribution of prey affects the population.

A working group (S. Hinckley, coordinator) has been formed to coordinate the efforts of these two groups, ensure that there is no duplication of effort, to share parts of the models that are common to both (such as the prey fields and bioenergetics), and to review each others work.

Northern fur seal (*Callorhinus ursinus*)

Natural History

The northern fur seal ranges throughout the North Pacific Ocean from southern California north to the Bering Sea and west to the Okhotsk Sea and Honshu Island, Japan. Breeding is restricted to only a few sites (i.e., the Commander and Pribilof Islands, Bogoslof Island, and the Channel Islands) (NMFS 1993a). During the breeding season, approximately 74% of the worldwide population is found on the Pribilof Islands with the remaining animals spread throughout the North Pacific Ocean. Of the seals in U.S. waters outside of the Pribilof Islands, approximately one percent of the population is found on Bogoslof Island in the southern Bering Sea and San Miguel Island off southern California (Lloyd *et al.* 1981, NMFS 1993a). Two separate stocks of northern fur seals are recognized within U.S. waters: An Eastern Pacific stock and a San Miguel Island stock.

Like other otariids, northern fur seals have a highly polygynous mating system, breeding in dense colonies on islands located near highly productive marine areas (Gentry 1998). The northern fur seal breeding cycle is highly stable, with adult males arriving on land during May and June to establish territories at traditional breeding areas (Bigg 1986). Females and juvenile males arrive on the breeding islands in late June through August with arrival times occurring progressively earlier as seals increase in age. Northern fur seals exhibit strong site fidelity and philopatry (Baker *et al.* 1995; Gentry 1998). The tendency to return to land at the natal area increases with age for both juvenile male and female northern fur seals (Baker *et al.* 1995). Female northern fur seals give birth to a single pup within 1-2 days after arrival on land and mate within 4-7 days after parturition (Bartholomew and Hoel 1953). Northern fur seal females undergo a period of delayed implantation characteristic of all pinnipeds (Boyd 1991); the embryo does not implant in the uterus and begin to develop until late November (York and Scheffer

1997). The perinatal visit lasts approximately 7-8 days post-partum after which lactating females begin a series of foraging trips to sea alternating with visits of 1-2 days on land to nurse their pups (Gentry *et al.* 1986).

Most females, pups and juveniles leave the Bering Sea by late November and are pelagic during the late fall, winter and early spring (Bartholomew and Hoel 1953). Pups are weaned in October and November, at about 125 days of age, and go to sea soon afterward (Gentry and Kooyman 1986). In 1989-90, radio-tagged pups departed St. Paul Island in mid-November and entered the North Pacific Ocean through the Aleutian islands from Samalga Pass to Unimak Pass an average of 10-11 days later (range of 4 - 35 days; Ragen *et al.* 1995). Of four fur seal pups tracked by satellite for 2.5 - 4.5 months during 1996, two pups left the Bering Sea after 10 and 13 days, while two other pups traveled northwest of St. Paul Island and remained in the Bering Sea for 50 and 68 days until late January. Adult females, pups and juveniles migrate south as far as southern California in the eastern North Pacific and Japan in the western North Pacific where they remain pelagic offshore and along the continental shelf until March, when they begin migrating northward toward the rookeries. Adult males appear to migrate only as far south as the GOA and Kurile Islands (Kajimura and Fowler 1984, Loughlin *et al.* 1999).

Population Trends

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 1950's and no compelling evidence existed that carrying capacity had changed substantially since that time (NMFS 1993a). Following that, 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 1993a).

Pup production on the Pribilof Islands decreased at a rate of 4%-8% per year 1976 to 1981 or 1982 (York and Kozloff 1987). A negative exponential model fit to the numbers of pups born on each island (York *et al.*, in prep.) shows that the decrease in pup production occurred more rapidly on St. Paul Island, however the proportion of the population lost on St. Paul Island from 1975-2002 was much less than the loss on St. George Island during the same time period.

Population Status

The NMML estimated numbers of northern fur seal pups by mark-recapture on every rookery of the Pribilof Islands in August 2002 (York *et al.*, in prep). An estimated 145,701 (SE = 1,629) pups were born on St. Paul Island; 8,262 (SE =191) were born on Sea Lion Rock, a small island approximately 500 m from St. Paul Island; and 17,060 (SE = 526.6) pups were born on St. George Island (Tables 3 and 4). During 1998-2002, the annual rate of decline on St. Paul Island was 5.14% (SE = 0.26%, P=0.03), and 5.35% (SE = 0.67%, P = 0.08) on St. George Island. The rate of decline on St. Paul and St. George Islands combined was 5.20% per year (SE = 0.19%, P = 0.02). Estimated pup production has now declined to levels not seen since 1921 on St. Paul Island and since 1916 on St. George Island. On Sea Lion Rock, pup production is slightly greater than the 8,061 pups counted in 1922. The estimate of the number of pups born for both St. Paul and St. George Islands reflects the ongoing downward trend in population (Figure 7).

Table 3. Numbers of northern fur seal, *Callorhinus ursinus*, pups born on St. Paul Island, AK in 2002. Estimates are shown of numbers alive at the time of shearing (live), counts of dead pups (dead), estimates of pups born, counts of breeding males (HB), estimates of pup mortality rate (%), and the ratio of pups to breeding males (P:HB) (from York *et al*., in prep).

Rookery	**Live**	**Dead**	**Born**	**SE**	**Mortality**	**HB**	**P:HB**
Lukanin	3,212	145	3,357	91.5	4.3	110	30.5
Kitovi	5,314	150	5,464	204.5	2.7	162	33.7
Reef	15,868	544	16,412	1,427.5	3.3	476	34.5
Gorbatch	11,308	476	11,784	158.0	4.0	291	40.5
Ardiguen	1,440	57	1,497	74.0	3.8	53	28.2
Morjovi	10,473	241	10,714	97.0	2.2	269	39.8
Vostochni	23,778	696	24,474	277.5	2.8	782	31.3
Polovina	2,773	100	2,873	121.0	3.5	52	55.2
Polovina Cliffs	13,439	277	13,716	367.0	2.0	321	42.7
Tolstoi	16,958	709	17,667	458.5	4.0	354	49.9
Zapadni Reef	5,384	203	5,587	172.0	3.6	139	40.2
Little Zapadni	12,276	440	12,716	208.5	3.5	217	58.6
Zapadni	18,628	737	19,365	127.5	3.8	441	43.9
Little Polovina	73	2	75	4.2	2.7	2	37.5
Total:	**140,924**	**4,777**	**145,701**	**1,629.0**	**3.3**	**3,669**	**39.7**
Sea Lion Rock	8,098	164	8,262	191.0	1.9	NA	NA
Total (including SLR)	**149,022**	**4,941**	**153,963**	**1,640.2**	**3.2**	**NA**	**NA**

Table 4. Numbers of northern fur seal, *Callorhinus ursinus*, pups born on St. George Island, AK in 2002. Estimates are shown of numbers alive at the time of shearing (live), counts of dead pups (dead), estimates of pups born, counts of breeding males (HB), estimates of pup mortality rate (%), and the ratio of pups to breeding males (P:HB) (from York *et al*., in prep).

Rookery	**Live**	**Dead**	**Pups.Born**	**SE**	**Mortality**	**HB**	**P:HB**
South	3,518	173	3,691	51.5	4.7	212	17.4
North	6,181	167	6,348	18.0	2.6	306	20.7
East Reef	794	11	805	18.5	1.4	66	12.2
East Cliffs	3,124	82	3,206	42.5	2.6	182	17.6
Staraya Artil	1,161	19	1,180	79.0	1.6	43	27.4
Zapadni	2,282	81	2,363	244.5	3.4	90	26.3
Total	**17,060**	**533**	**17,593**	**526.6**	**3.0**	**899**	**19.6**

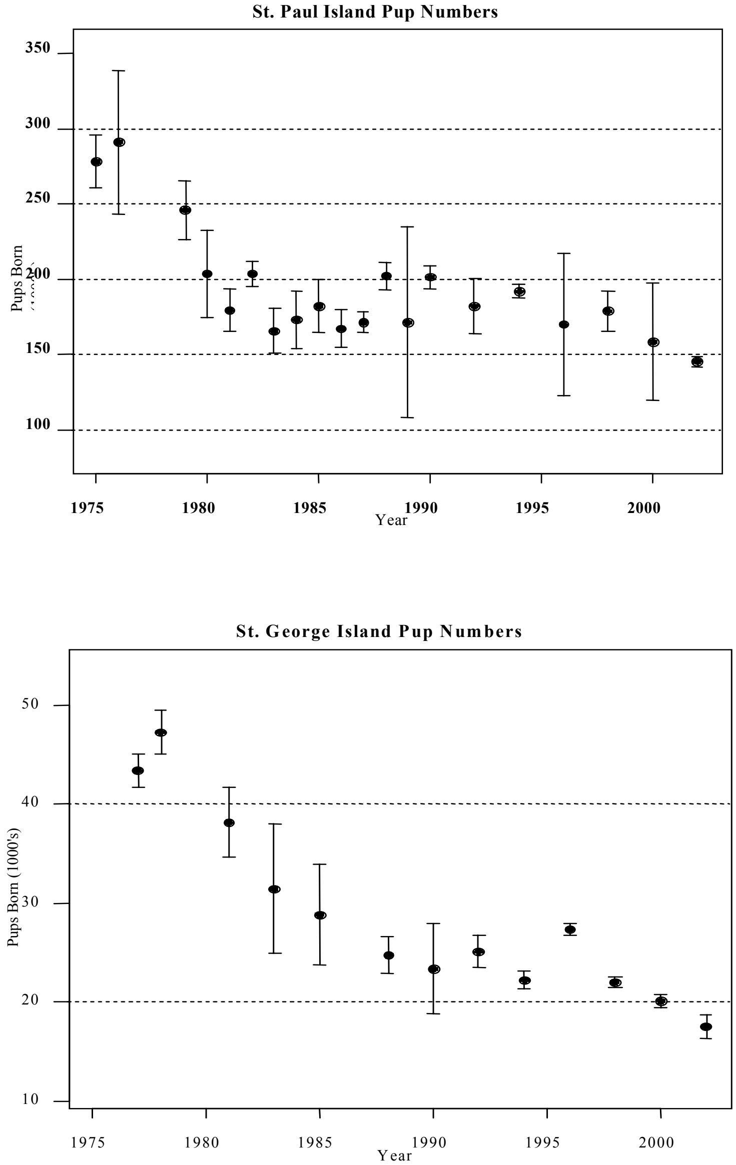


Figure 7. Northern fur seal *Callorhinus ursinus* pups born on the Pribilof Islands, Alaska, 1975-2002. Error bars are approximate 95% confidence intervals. Pup counts reflect a continuation of the overall downward trend in the northern fur seal population (from York *et al.*, in prep).

Diet and Foraging Behavior

During the breeding and pup rearing season (June - October), female fur seals commute to marine foraging areas between nursing visits on shore (Gentry 1998). Sinclair *et al.* (1994) concluded that adult female northern fur seals are size-selective mid-water feeders during summer and fall in the eastern Bering Sea.

Diet The most extensive research on fur seal diet was based on the remains from over 18,000 stomachs collected between 1958 and 1974 (Perez and Bigg 1986). During that time, the diet consisted of 67% fish (34% pollock, 16% capelin, 6% Pacific herring, 4% deep-sea smelt and lantern fish, 2% salmon, 2% Atka mackerel, and no more than 1% eulachon, Pacific cod, rockfish, sablefish, sculpin, Pacific sand lance, flatfish, and other fish) and 33% squid (Perez 1990). These data showed marked seasonal and geographic variation in the species consumed. In the eastern Bering Sea, pollock, squid, and capelin accounted for about 70% of the energy intake. In contrast, sand lance, capelin, and herring were the most important prey in the GOA .

As with other diet studies of apex predators in the Gulf of Alaska and Bering Sea a marked change in northern fur seal diet has occurred since the 1970's (Sinclair *et al.* 1994; Piatt and Anderson 1996; Sinclair *et al.* 1996; NRC 1997; Antonelis *et al.* 1997). Some prey items, such as capelin, have disappeared entirely from fur seal diets in the eastern Bering Sea and squid consumption has been markedly reduced. At the same time, pollock consumption has tripled. Adult female fur seals eat adult pollock, but age-0 and age-1 pollock now predominate in the diet. Consumption of pollock, gonatid squid, and bathylagid smelt in the eastern Bering Sea has, however, remained consistently important in all diet studies, despite the wide variety of prey available to fur seals within their diving range (Sinclair *et al.*, 1994). Overall, pollock and squid are currently the most frequently eaten prey in the EBS, and a positive correlation exists between pollock year-class strength and the frequency of pollock in fur seal diets (Sinclair *et al.*, 1994). Similarly to harbor seals, Steller sea lions, and piscivorous birds, groundfish consumption has increased as forage fishes have decreased (Sinclair *et al.*, 1994; 1996). Trites (1992) estimated that 133,000 mt of walleye pollock (ages 1 to 2) are consumed annually by northern fur seals in the eastern Bering Sea. A comparison of current diet based on stomach data vs. scats demonstrated close results using the two methods (Sinclair *et al.*, 1996).

Foraging Behavior On the Pribilof Islands, lactating female fur seals usually forage within 81 - 135 nm (150 - 250 km) of the rookeries, but occasionally as far away as 243 nm (450 km) during the breeding season (Kajimura 1984, Loughlin *et al.* 1987, Goebel *et al.* 1991, Robson 2001). The maximum distance from the breeding site averaged 130.1 ± 41.4 nm (241 ± 76.7 km) for lactating females from St. Paul and St. George Islands tracked by satellite during 1995-96 (n = 119 foraging trips for 97 females). For the same seals, the median distance from the breeding site of individual locations within a foraging trip averaged 97.0 ± 32.1 nm (179.7 ± 59.5 km), indicating that females from both islands forage extensively at distances greater than 81 nm (150 km) from the rookery (Robson 2001). These measurements are consistent with foraging distances 86 - 108 nm (160 - 200 km) reported by Loughlin *et al.* (1987) for lactating females tracked by ship from the breeding site to feeding locations in 1984. Preliminary analysis of satellite telemetry data for juvenile male fur seals indicates that juvenile males in the Bering Sea range farther from the breeding rookeries than lactating females. Twelve juvenile males tracked for 14 foraging trips during 1996 averaged 261.2 ± 126.4 nm (483.7 ± 234 km) maximum distance from St. Paul Island. Foraging trips as far away as St. Matthew Island have been recorded for adult male fur seals during October-December prior to their departure from the Bering Sea. (Loughlin *et al.* 1999). In contrast with the extensive foraging range for Pribilof Island fur seals, fur seals breeding at Bogoslof Island appear to forage in close proximity to the rookery. Lactating females (n = 6) tracked by satellite during 1997 had an average maximum distance of 27.7 nm (51.2 km) from the island on foraging trips which were often less than 24 hours and never greater than 4 days (Ream *et al.* 1999).

Early studies demonstrated differences in dive patterns among individual females attributed to foraging habitat and diet (Gentry *et al.* 1986; Goebel *et al.* 1991; Sinclair *et al.* 1994). Females foraging over the shallow continental shelf dive throughout the day to depths averaging over 125m, while female fur seals foraging off-shelf dive to shallow depths averaging ≤75m (Gentry *et al.*, 1986). These patterns in dive depth reflect vertical distribution of on-shelf vs. off-shelf prey (Sinclair *et al.*, 1994). Lactating females from breeding sites on St. Paul and St. George Islands tend to travel in different directions to forage depending on their pupping site, resulting in habitat partitioning both between and within islands (Robson 2001). These patterns indicate that female fur seals from the same site often share a common foraging area while females from different breeding sites tend to forage in different areas and hydrographic domains where fisheries removals may vary over time. Meta-home range areas calculated for the instrumented females in 1995-1996 (Robson 2001) showed discrete foraging areas for females from southwest St. Paul Island, northeast St. Paul Island and St. George Island. Meta-home range areas and the overlap between sites are shown in Figure 8a.

Altogether, the definitive site-specific foraging areas for fur seals (Robson 2001), variable consumption rates of pollock with foraging location (Antonelis *et al.* 1997); and abundance of different age classes of pollock in the foraging environment (Swartzman and Haar 1983, Sinclair *et al.* 1996); provide a unique opportunity to examine the potential impact of the Bering Sea pollock fishery on northern fur seals.

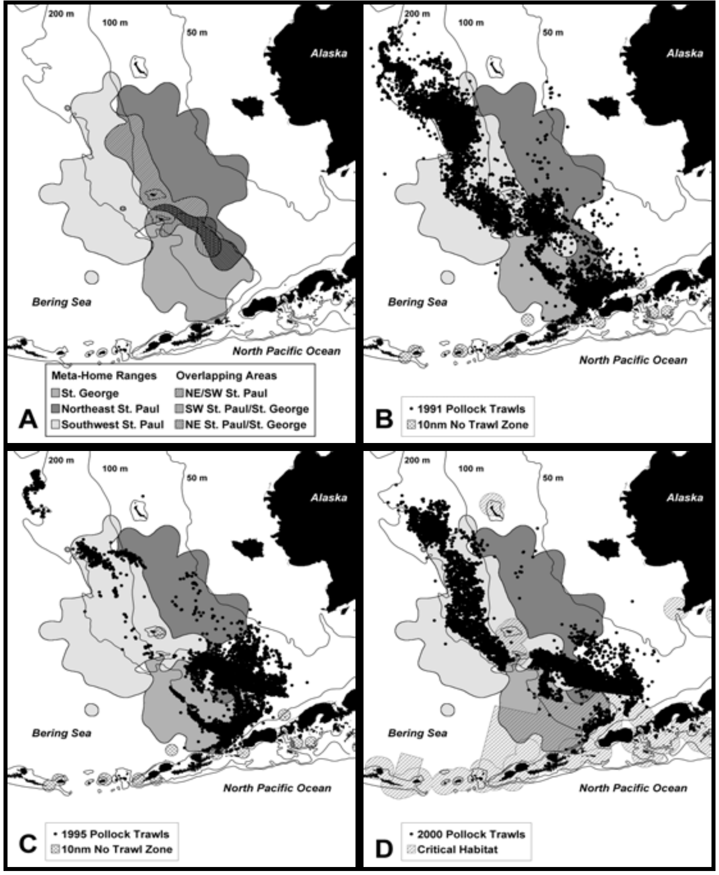


Figure 8. Meta-home ranges for lactating northern fur seals from southwest St. Paul, northeast St. Paul and St. George Islands (A) and the zone of overlap between combinations of sites (Robson 2001). Panels B-D show meta-home ranges, sea lion critical habitat and the location of trawls (dots) during the summer-fall eastern Bering Sea pollock fishery in 1991, 1995 and 2000 (from Robson and Fritz, in prep)

Ecological Interactions Between Marine Mammals and Commercial Fisheries

Ecological interactions between marine mammals and commercial fisheries are difficult to identify in most cases. Examples of observable interactions are generally restricted to direct mortality in fishing gear. Even then, the ecological significance of the interaction is related to the number of animals killed and subsequent population level responses. More difficult to identify and potentially more serious are interactions resulting indirectly, from competition for resources that represent both marine mammal prey and commercial fisheries targets. Spatial and temporal overlap between foraging marine predators and fisheries may result in competition for target and bycatch species (Lowry and Frost, 1985, Beddington *et al.*, 1985, Sinclair *et al.*, 1994; Pauly *et al.* 1998). Such interactions may limit foraging success through localized depletion, dis-aggregation of prey or disturbance of the predator itself and could be more energetically costly to foraging marine mammals. Thus, the timing and location of fisheries, relative to foraging patterns of marine mammals may be a more relevant management concern than total removals of prey resources.

Such a case for concern over possible localized depletion has been identified for Steller sea lions and the Atka mackerel fishery in the western and central Aleutian Islands. The Atka mackerel fishery is concentrated in several compressed locations, most of which are adjacent to Steller sea lion haulouts and rookeries, inside critical habitat. Evidence of Atka mackerel localized depletion has been presented by Lowe and Fritz (1996) based on reductions in catch per unit effort (CPUE) of Atka mackerel over the course of the fishing season. The potential for impacts to Steller sea lion recovery efforts was recognized by NMFS and the NPFMC, warranting action to move fishing effort away from sea lion critical habitat beginning in 1999.

Repeated vessel traffic and fishing activity within an area may result in competitive exclusion of predators that avoid vessel activity. Vessel traffic alone may temporarily cause fish to compress into tighter, deeper schools (Freon *et al.* 1992) or split schools into smaller concentrations (Laevastu and Favorite 1988). In addition, the effects of repeated trawling by many vessels over several days or weeks on fish school structure, and the resulting impact on prey availability has not been documented.

A case study of northern fur seals

A recent study (Robson and Fritz, in prep) examines the spatial and temporal overlap between the Bering Sea pollock fishery and northern fur seal foraging areas. In particular, Robson and Fritz (in prep) examine whether management actions designed to protect prey resources in Steller sea lion critical habitat have shifted the concentration and timing of the Bering Sea pollock fishery in a way that has resulted in greater competition between northern fur seals and the fishery for adult pollock in northern fur seal foraging habitat.

Catches of pollock from June-October 1991-2001 within fur seal home ranges were estimated using data collected by groundfish fishery observers and the NMFS Alaska Regional Office estimates of catch by various industry sectors (Robson and Fritz, in prep). The spatial distribution of pollock catch by the observed pollock fishery was assumed to represent the distribution of pollock catch by the total pollock fishery for each year and industry sector. Using this assumption, observed haul-by-haul estimates of pollock catch were multiplied by the ratio of total observed pollock catch for the year in each sector. These extrapolation ratios ranged from 1.0003 for the 2000 CDQ (Community Development Quota) pollock fishery (that has 100% observer coverage on each haul) to a high of 4.04 for catcher vessels (in 1991), but most were less than 1.75. Estimates of the amount of pollock caught from June-October each year within each fur seal home range were made using ArcGIS 8.1 software to select the appropriate hauls and sum the extrapolated pollock catch weights and trawl durations.

The total June-October pollock catch in fur seal foraging habitat (defined as the combined meta-home ranges for females from St. Paul and St. George islands; Figure 8a) decreased in the early 1990s from a high of approximately 587,700 mt in 1991 to a low of 146,000 mt in 1996. Catch rates increased again in the late 1990s reaching 497,600 mt in 2001. Fishing was broadly distributed over the outer continental shelf during the early 1990s but was concentrated primarily south of St. George Island in the mid 1990s (Figure 8c). In the late 1990s fishing was again dispersed northward across the outer-shelf domain, due in part to trawl closures and measures designed to shift fishing effort for pollock outside of Steller sea lion critical habitat during June-October (Figure 8d). The proportion of total catch in fur seal foraging habitat averaged 51% in 1991-98 increasing to 68% in 1999-2001 (Figure 9). Conversely, the proportion of pollock catch in Steller sea lion critical habitat decreased from an average of 41% in 1995-98 to 16% in 1999-2000, due in large part to the court ordered closure of Steller sea lion critical habitat to trawlers from August –November, 2000. Trawl restrictions were reduced during the June-October fishery in 2001 and 54% of the pollock catch occurred within sea lion critical habitat.

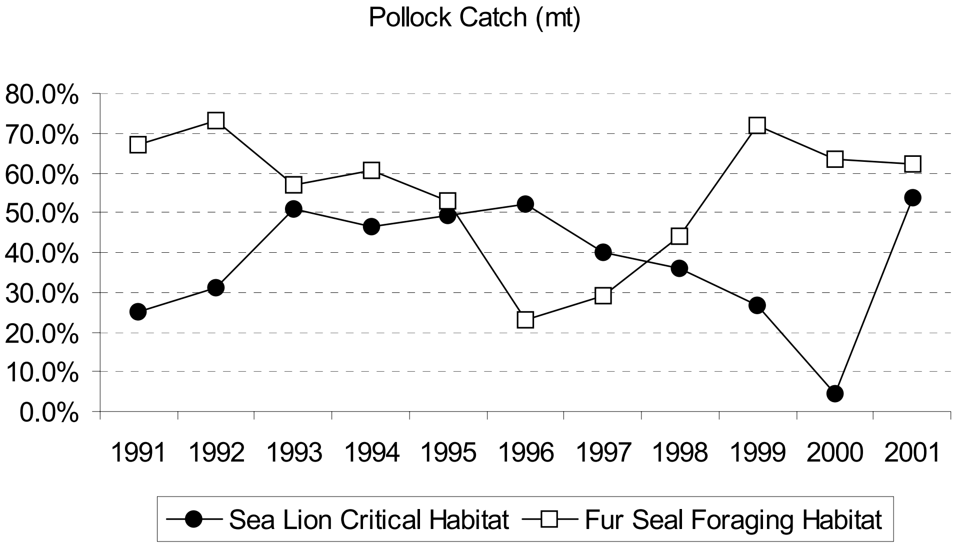


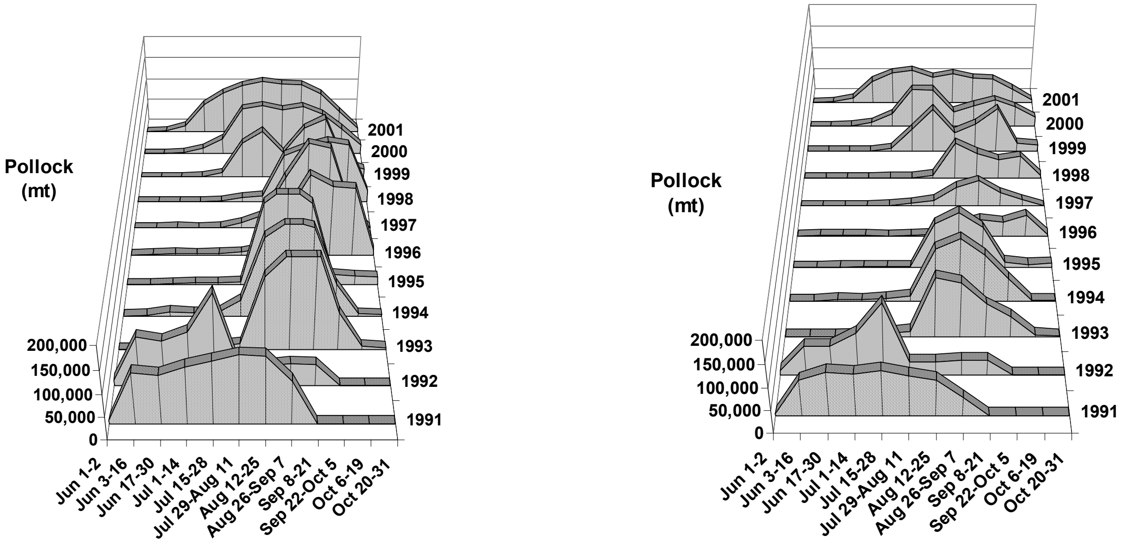
Figure 9. Percent of total catch (mt) during the summer and fall Bering Sea pollock fishery inside Steller sea lion critical habitat and northern fur seal habitat (defined as the combined meta-home ranges of lactating females from St. Paul and St. George Islands.

From 1993-99 the proportion of the summer pollock catch in the meta-home range of lactating fur seals from St. George Island was consistently higher than the catch in foraging areas used by St. Paul Island females. Higher catch levels occurred in the southwest St. Paul Island meta-home range during 1991-92 and 2000-01 reflecting the greater northward extent of the fishery along the outer continental shelf and slope during those years (Figure 8).

In 1991 the North Pacific Fisheries Management Council split the Bering Sea pollock fishery into a winter fishery and a late summer fishery. In 1991-92 a substantial portion of the catch in fur seal foraging habitat occurred prior to the peak of pupping in mid-July, however the timing of the catch shifted to late August through October during 1993-98 (Figure 10). Protection measures for Steller sea lions enacted in 1999 dispersed fishing effort temporally to avoid localized depletion of prey. This expanded the timing of the summer/fall fishery from primarily September and October to the entire period when fur seals breed and provision their offspring on the Pribilof Islands (mid-June through October). The percentage of the total catch taken at two week intervals from northern fur seal foraging habitat (between June 17 and

October 31) averaged 46.7% from 1991-98, increasing to 69.8% on average in 1999-2001 (Figure 10). While this change may slow the pace of the fishery it may also increase the likelihood of localized effects due to the concentration of the fishery in fur seal foraging habitat (Robson and Fritz, in prep).

The continuing decline in population numbers of northern fur seals on the Pribilof Islands (York *et al.*, in prep) along with the fact that pollock represents up to 80% of northern fur seal diet in the Bering Sea during summer and fall (Sinclair *et al.* 1994; Antonelis *et al.*, 1997) and that the diet of lactating fur seals on St. George Island contains a higher proportion of 3-5 year old pollock in some years than St. Paul Island females (Antonelis *et al.*, 1997) make the potential for competition with fisheries a significant concern. Differences in population trends and diet between St. Paul and St. George Islands suggest that changes in pollock fishery catch levels may result in differences in local rates of competition for fur seal prey or disturbance to foraging fur seals during a critical period for pupping and breeding. In this regard, the extent to which Steller sea lion protection measures change the spatial extent of the fishery in fur seal foraging habitat should be considered (Robson and Fritz, in prep).



A

B

Figure 10. The seasonal distribution of (A) total catch and (B) catch in the combined meta-home ranges of lactating fur seals from St. Paul and St. George Island during the 1991-2001 summer and fall Bering Sea pollock fishery (from Robson and Fritz, in prep).

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Seabirds

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Seabirds spend the majority of their life at sea rather than on land. The group includes the albatrosses, shearwaters, and petrels (*Procellariiformes*), cormorants (*Pelecaniformes*), and two families of the *Charadriiformes*: gulls (*Laridae*), and auks, such as puffins, murres, auklets, and murrelets (*Alcidae*). Several species of sea ducks (*Merganini*) also spend much of there life in marine waters. Other bird groups contain pelagic members such as swimming shorebirds (*Phalaropodidae*), but they seldom interact with groundfish fisheries and, therefore, will not be discussed further. For detailed descriptions of seabird life histories, population biology, and foraging ecology, see section 3.5.1 of the draft Programmatic SEIS on Alaska Groundfish Fisheries (DPSEIS, NMFS 2001a).

This current section is limited to minimal background material plus new information such as: updated seabird population and diet information; maps with updated fishing effort relative to seabird colony locations, short-tailed albatross (*Phoebastria albatrus*), Laysan albatross and black-footed albatross observation locations, movement of satellite-tagged short-tailed albatross and northern fulmars (*Fulmarus glacialis*); and updated seabird bycatch estimates.

Thirty-eight species of seabirds breed in Alaska. More than 1600 colonies have been documented, ranging in size from a few pairs to 3.5 million birds (Figure 1). The U.S. Fish & Wildlife Service (USFWS) is the lead Federal agency for managing and conserving seabirds and is responsible for monitoring populations, both distribution and abundance. Breeding populations are estimated to contain 36 million individuals in the Bering Sea (BS) and 12 million individuals in the GOA (Table 1); total population size (including subadults and nonbreeders) is estimated to be approximately 30 percent higher. Five additional species occur in Alaskan waters during the summer months and contribute another 30 million birds (Table 2).

The sizes of seabird colonies and their species composition differ among geographic regions of Alaska, due to differences in marine habitats and shoreline features. In the southeastern GOA, there are about 135 colonies, and they tend to be small (<60,000 birds, and often < 5,000). These colonies are concentrated near the outer waters of southeast Alaska, or near large inland straits and fjords, such as Glacier Bay, and Icy and Sumner straits. Exceptions are two colonies with 250,000-500,000 birds at Forrester and St. Lazaria Islands (Figure 2). Along the coast of northcentral GOA, colonies are generally small but number over 850 locations, with larger colonies at the Barren and Semidi island groups. Moving west along the Alaska Peninsula (with 261 colonies) and throughout the Aleutians (144 colonies), colonies increase in size, and include several with over 1 million birds and two with over 3 million birds. Large colonies are also found on the large islands of the BS, where each may have over 3 million birds. Relatively few colonies are located along the mainland of the BS coast, and colonies along the Chukchi and Beaufort seas are small and dispersed.

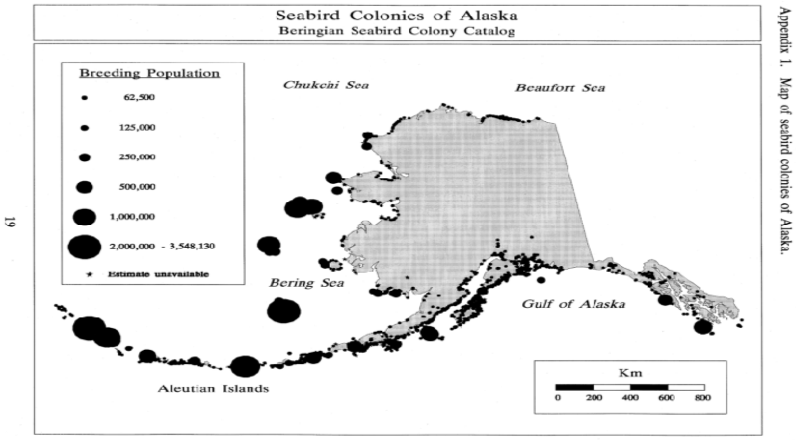


Figure 1. Seabird Colonies of Alaska. Beringian Seabird Colony Catalog, 2000. USFWS.

Table 1. Estimated populations and principal diets of seabirds that breed in the Bering Sea and Aleutian Islands and Gulf of Alaska regions.

Species	**Population** [1,2]		**Diet** [3,4]
	BSAI	**GOA**	
Northern Fulmar (*Fulmarus glacialis*)	1.500,000	600,000	Q,M,P, S,F,Z,I,C
Fork-tailed Storm-Petrel (*Oceanodroma furcata*)	4,500,000	1,200,000	Q,I,Z,C,P,F
Leach's Storm-Petrel (*Oceanodroma lucorrhoa*)	4,500,000	1,500,000	Z,Q,F,I
Double-crested Cormorant(*Phalacrocorax auritis*)5	9,000	8,000	F,I
Pelagic Cormorant (*Phalacrocorax pelagicus*)	80,000	70,000	S,C,P,H,F,I
Red-faced Cormorant (*Phalacrocorax urile*)	90,000	40,000	C,S,H,F,I
Brandt's Cormorant (*Phalacrocorax penicillatus*)	0	Rare	H,F,G,I
Pomarine Jaeger (*Stercorarius pomarinus*)	Uncommon-Rare	Uncommon	C,S,F
Parasitic Jaeger (*Stercorarius parasiticus*)	Uncommon	Uncommon	C,S,F
Long-tailed Jaeger (*Stercorarius longicaudus*)	Uncommon	Rare	C,S,F
Bonaparte's Gull (*Larus philadelphia*)	Rare	Uncommon	Z,I,F
Mew Gull (*Larus canus*) [5]	700	40,000	C,S,I,D,Z
Herring Gull (*Larus argentatus*) [5]	50	300	C,S,H,F,I,D
Glaucous-winged Gull (*Larus glaucescens*)	150,000	300,000	C,S,H,F,I,D
Glaucous Gull (*Larus hyperboreus*)[5]	30,000	2,000	C,S,H,I,D
Black-legged Kittiwake (*Rissa tridactyla*)	800,000	1,000,000	C,S,H,P,F,M,Z
Red-legged Kittiwake (*Rissa brevirostris*)	150,000	0	M,C,S,Z,P,F
Sabine's Gull (*Xema sabini*)	Uncommon	Uncommon	F,Q,Z
Arctic Tern (*Sterna paradisaea*) [5]	7,000	20,000	C,S,Z,F,H
Aleutian Tern (*Sterna aleutica*)	9,000	25,000	C,S,Z,F
Common Murre (*Uria aalge*)	3,000,000	2,000,000	C,S,H,G,F,Z

Thick-billed Murre (*Uria lomvia*)	5,000,000	200,000	C,S,P,Q,Z,M,F,I
Pigeon Guillemot (*Cepphus columba*)	100,000	100,000	S,C,F,H,P,I,G,Q
Black Guillemot (*Cepphus grylle)*	Rare	0	S,F,I
Marbled Murrelet (*Brachyramphus marmoratus*)	Uncommon	Common	C,S,H,P,F,G,Z,I
Kittlitz's Murrelet (*Brachyramphus brevirostris*)	Uncommon	Uncommon	S,C,H,Z,I,P,F
Ancient Murrelet (*Synthliboramphus antiquus*)	200,000	600,000	Z,F,C,S,P,I
Cassin's Auklet (*Ptychoramphus aleuticus*)	250,000	750,000	Z,Q,I,S,F
Least Auklet (*Aethia pusilla*)	9,000,000	50	Z
Parakeet Auklet (*Cyclorrhynchus psittacula*)	800,000	150,000	F,I,S,P,Z,C,H
Whiskered Auklet (*Aethia pygmaea*)	30,000	0	Z
Crested Auklet (*Aethia cristatella*)	3,000,000	50,000	Z,I
Rhinoceros Auklet (*Cerorhinca monocerata*)	50	200,000	C,S,H,A,F
Tufted Puffin (*Fratercula cirrhata*)	2,500,000	1,500,000	C,S,P,H,F,Q,Z,I
Horned Puffin (*Fratercula corniculata*)	500,000	1,500,000	C,S,P,H, F,Q,Z,I
Total	36,000,000	12,000,000	

Notes; 1 = Source of population data for colonial seabirds that breed in coastal colonies: modified from USFWS 1998. Estimates are minima, especially for storm-petrels, auklets, and puffins.

2 = Numerical estimates are not available for species that do not breed in coastal colonies. Approximate numbers: abundant $\geq 10^6$; common = 10^5-10^6; uncommon = 10^3-10^5; rare $\leq 10^3$.

3 = Abbreviations of diet components: M, Myctophid; P, walleye pollock; G, other gadids; C, capelin; S, sandlance; H, herring; A, Pacific saury; F, other fish; Q, squid; Z, zooplankton; I, other invertebrates; D, detritus; ?: no information for Alaska. Diet components are listed in approximate order of importance. However, diets depend on availability and usually are dominated by one or a few items (see NPFMC 2000).

4 = Sources of diet data: see species accounts in seabird section of NPFMC 2000.

5 = Species breeds both coastally and inland; population estimate is only for coastal colonies.

Table 2. Comparative population estimates and diets of nonbreeding seabirds that frequent the Bering Sea and Aleutian Islands and Gulf of Alaska regions**.**

Species	**Population** [1,2]			**Diet** [3,4]
	BSAI	GOA	World[5]	
Short-tailed Albatross (*Phoebastria albatrus*)	Rare	Rare	1,600	Q,F,I
Black-footed Albatross (*Phoebastria nigripes*)	Uncommon	Common	250,000	Q,M,F,I,D
Laysan Albatross (*Phoebastria immutabilis*)	Common	Common	2.5 million	Q,M,F,I
Sooty Shearwater (*Puffinus griseus*)	Common	Abundant	>30 million	M,C,S,A,Q,S,F,Z,I
Short-tailed Shearwater (*Puffinus tenuirostris*)	Abundant	Common	23 million	Z,I, C,Q, F,S
Ivory Gull (*Pagophila eburnea*)	Uncommon	0	~35,000	M,P,R,I,F,Q

1. Source of population data for colonial seabirds that breed in coastal colonies: modified from USFWS 1998. Estimates are minima, especially for storm-petrels, auklets, and puffins.
2. Numerical estimates are not available for species that do not breed in coastal colonies. Approximate numbers: abundant $\geq 10^6$, common = 10^5-10^6, uncommon = 10^3-10^5; rare $\leq 10^{3.}$
3. Abbreviations of diet components: M, Myctophid; P, walleye pollock; G, other gadids; C, capelin; S, sandlance; H, herring; A, Pacific saury; F, other fish; Q, squid; Z, zooplankton; I, other invertebrates; D, detritus; ?, no information for Alaska. Diet components are listed in approximate order of importance. However, diets depend on availability and are usually dominated by one or a few items (see text seabird section of NPFMC 2000).
4. Sources of diet data: see species accounts in text.
5. World population estimates are provided solely to provide a relative scale. In populations where multiple breeding colonies exist, any analysis of effects on populations must be considered at the colony level, not at the global level. These estimates provided by: Hasegawa, pers. comm.; Whittow, 1993; Whittow, 1993; C. Baduini, pers. comm.; Oka et al 1987; USFWS.
6. Species breeds both coastally and inland; population estimate is only for coastal colonies.

Seabird Demographic Trends

Population trends and reproductive success are monitored at 3 to 14 colonies per species (Figure 2). There have been considerable changes in the numbers of seabirds breeding in Alaskan colonies since the original counts made in the mid-1970s. Trends are reasonably well known for species that nest on cliffs or flat ground such as cormorants, glaucous-winged gulls, kittiwakes, murres, and tufted puffins (Table 3). Trends are known for a few small areas of the state for pigeon guillemots, murrelets, storm-petrels, and terns (Tables 3, 4). In some cases, the trend information is sparse and only covers up to the early 1990s, such as for horned puffins (Piatt and Kitaysky 2002). Trends are unknown at present for other species [jaegers, most auklets; (Byrd and Dragoo 1997, Byrd *et al.* 1998, 1999)]. Population trends differ among species. Trends in many species vary independently among areas of the state, due to differences in food webs and environmental factors.

Trends in Productivity

The most recent, comprehensive summary available for monitored seabird colonies is from the 2000 breeding season (Dragoo, Byrd *et al.* 2001). Overall, seabird breeding chronology in 2000 was earlier than average or unchanged (Table 5). Most species in the SE Bering Sea began nesting earlier than average. Seabirds also nested earlier on Buldir Island in the Aleutians, and sites in the GOA and Southeast Alaska. The one exception was the black-legged kittiwake colony on Middleton Island. This is in sharp contrast to the 1999 season (Dragoo, Byrd *et al.* 2000), when most colonies began nesting later or were unchanged compared to the averages for previous years.

Seabird productivity was generally better than average or equal throughout Alaska in 2000 (Table 6). Exceptions were the murres at Kasatochi Island in the central Aleutians, where both murre species had lower than average productivity. Nearly all piscivorous seabirds had better productivity than past years, whereas the more planktivorous species tended to show no change from previous year's performances (Dragoo, Byrd *et al.* 2001). For the piscivorous birds at least, the higher productivity in 2000 was nearly opposite their relative performance in 1999, when most piscivorous birds had lower than average productivity (Dragoo, Byrd *et al.* 2000). Again, the planktivorous birds showed little change between 1999 and 2000 trends. The 'earlier' nesting in 2000 by many seabirds in various locations of Alaska, might be indicative of a large-scale oceanographic condition resulting in changes in the prey base. Presumably because of favorable oceanograhic effects on the seabirds' prey, 'early' nesting is often associated with cooler water temperatures and higher breeding success (Ainley and Boekelheide 1990). In 2000, there were reports of capelin in the GOA (D. Roseneau, USFWS, Homer, AK), and capelin appeared to be abundant in Prince William Sound in 2001 (K. Kuletz, pers. comm.). Capelin are a high-lipid fish (Anthony, Roby *et al.* 2000, Roby, Jodice *et al.* 2000), and availability of high-lipid prey is often associated with good productivity in seabirds. High lipid and high energetic content is critical to chick growth and fledging mass (Harris and Hislop 1978), and several studies in the GOA have demonstrated the importance of high-lipid fish to seabird growth rates, reproductive success, and population trends (Anthony and Roby 1997, Golet 1998, Piatt, Abookire *et al.* 1998, Roby, Turco *et al.* 1998, Golet, Kuletz *et al.* 2000, Suryan, Irons *et al.* 2000, 2002). The generally higher productivity (compared to previous years at the same site) of piscivorous birds in particular, suggest that availability of forage fish was improved in 2000. Reproductive success of seabirds also depends on synchronization of breeding with prey availability (Gaston and Nettleship 1981, Furness and Monaghan 1987, Ainley and Boekelheide 1990), although the mechanisms responsible for synchronization are unclear.

Figure 2. Location of seabird colony sites in Alaska monitored by the U.S. Fish and Wildlife Service and the USGS Biological Research Division. Some sites are monitored annually (circles), while others are monitored on three-year rotation (triangles).

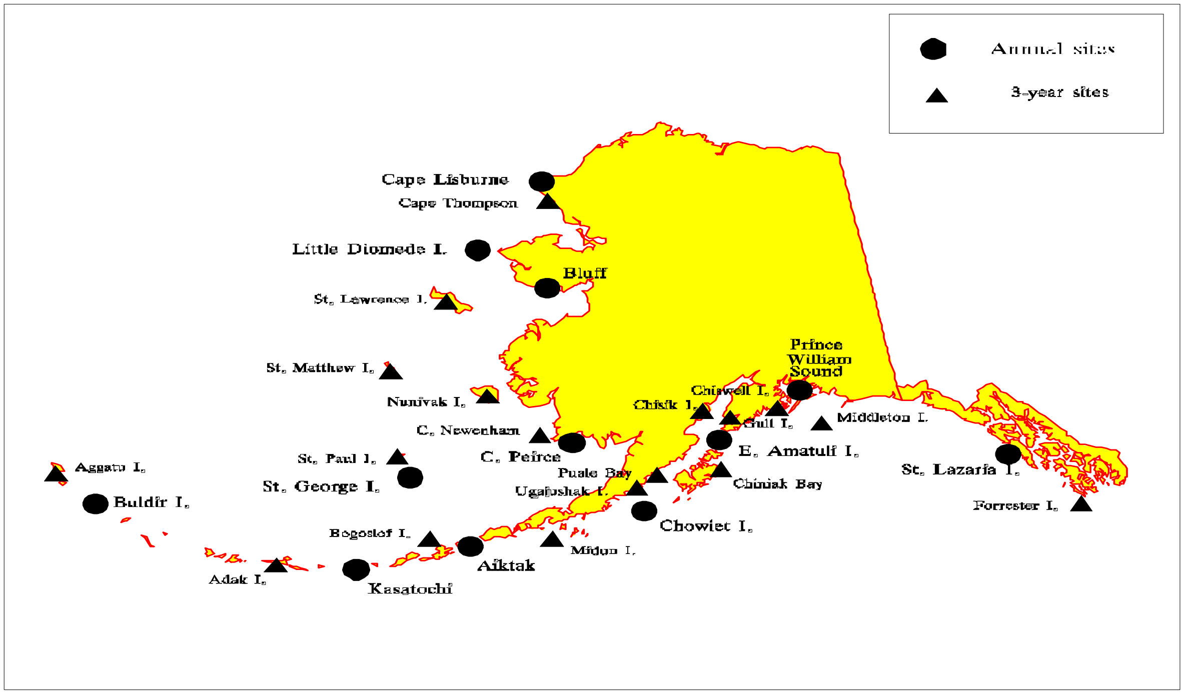


Table 3. Seabird population trends compared within regions[a]. Only sites which were counted in 2000 are included. This table is printed with permission of the Alaska Maritime National Wildlife Refuge, from their report: Breeding Status and Population Trends of Seabirds in Alaska in 2000.

Region	*Site*	*STPE*	*PECO*	*UNCO*	*GWGU*	*BLKI*	*RLKI*	*COMU*	*UNMU*	*LEAU*	*CRAU*	*RHAU*	*TUPU*
N. Bering/ Chukchi	*Bluff*					+		+					
SE Bering	*C. Peirce*		=			–		–					
	Bogoslof I.												+
	Aiktak I.	+			=				=				+
SW Bering	*Kasatochi I.*			=	=					=	=		
	Koniuji I.						=						
Gulf of Alaska	*Chiniak Bay*					+							
	Gull I.		–			+		+					
	P. William Snd					+							
	Middleton I.		–			–			–				
Southeast	*St. Lazaria I.*	+	+		=				–			=	

[a]Codes:

"– " indicates negative population trend for this site or region,

"=" indicates no discernable trend

"+" indicates positive population trend for this site or region.

Species' codes: FTSP = fork-tailed storm petrel; LHSP = Leach's storm petrel; RFCO = red-faced cormorant; PECO = pelagic cormorant; GWGU = glaucous-winged gull; BLKI = black-legged kittiwake; RLKI = red-legged kittiwake; COMU = common murre; TBMU = thick-billed murre; PAAU = parakeet auklet; LEAU = least auklet; WHAU = whiskered auklet; CRAU = crested auklet; RHAU = rhinoceros auklet; TUPU = tufted puffin.

Table 4. Population trends of seabirds that nest non-colonially or in small, dispersed colonies, for areas where trend data is available. Trends ('-',decreasing; '0' no clear trend; '+', increasing) incorporate surveys in the early 1990s to 2000-2002. (Data from Shawn Stephensen or Kathy Kuletz, USFWS, Anchorage, and John Piatt, USGS/BRD, Anchorage, unpublished data).

Site	Arctic Tern & Aleutian Tern	Pigeon Guillemot	Marbled Murrelet	Kittlitz's Murrelet
Prince William Sound	-	-	-	-
eastern Kodiak Island	-	0	?	?
Kenai Fjords	?	?	-	-
Malaspina / Icy Bay	0	0	-	-
Glacier Bay, SEAK	+	0	-	-

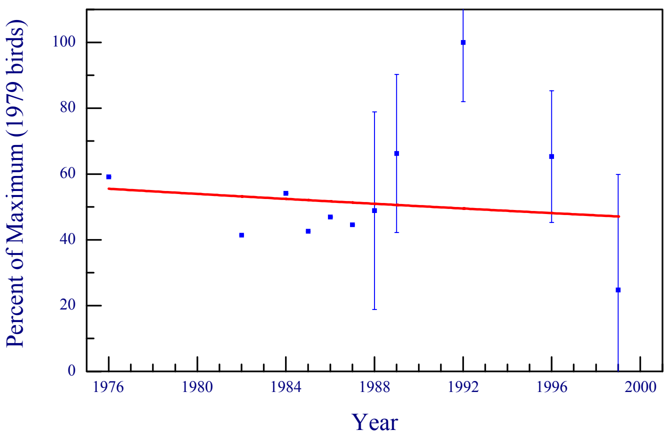
Population Trends

Population trends (Table 3) were more mixed among birds and sites than were the productivity trends. Although population trends are affected by changes in seabird productivity (see review NPFMC 2000), seabirds are long-lived, and changes in the sub-adult and adult population would not be expected on an annual basis (Russell 1999). As of the 2000 censuses, 12 populations (species-site combinations) showed an increase from previous averages, 7 showed no change and 8 showed decreases. Black-legged kittiwakes increased at most sites in the GOA, although the Middleton Island colony continued to decline. Red-legged kittiwakes continued to decline at Koniuji Island, as they had at the Pribilofs in 1999 (Dragoo, Byrd *et al.* 2000). Tufted puffins and storm petrels were more abundant than average in the southeast Bering Sea, but kittiwakes and murres declined.

Between the 1980s and 2002, several nearshore-feeding seabirds have shown declines in coastal breeding areas (Table 4). These species are usually monitored by their numbers at-sea, because it is difficult to monitor their small, dispersed colonies (guillemots), or their colonies are impermanent (terns), or they do not nest in colonies (murrelets). Data are available for Prince William Sound (Stephensen et al. 2001), Glacier Bay (Robards, Drew *et al.* 2002), Kodiak Island (Stephensen, Zwiefelhofer *et al.* 2001), Kenai Fjords (data on terns and guillmots still pending), and the Malaspina Forelands/Icy Bay (USFWS, Anchorage, unpubl. data). During this period, arctic terns have declined by 60% in Prince William Sound and eastern Kodiak Island, but have increased in Glacier Bay. Pigeon guillemots have declined by 55% in Prince William Sound and 20% in Glacier Bay (although this decline was not statistically significant), but have remained relatively stable in Kodiak Island and Icy Bay. Marbled and Kittlitz's murrelets combined have declined by 55% in Prince William Sound and about 60% in Glacier Bay, with similar declines along the Malaspina Forelands and the Kenai Fjords. The apparent declines in many areas for some nearshore seabirds may be indicative of widespread changes in the nearshore prey base or other aspects of nearshore waters.

Northern fulmar populations. – Population trends of northern fulmars are of particular interest because fulmars comprise the largest proportion of seabird bycatch in the BSAI and GOA groundfish fisheries, and they are the only procellarid ('tubenose' family) with high bycatch rates that also breeds in Alaska. Over 95% of northern fulmars in Alaska nest at four locations: the Semidi Islands (monitored at Chowiet Island) in the GOA has an estimated 440,000 birds, Chagulak Island in the Aleutians with 500,000 birds, the Pribilofs (monitored at St. George Island) in the central BS with 80,000 birds, and St. Matthew/Hall Islands in the northern BS with 450,000 birds (Hatch and Nettleship 1998).

In the Pribilof Islands (Figure 3), the smaller population on St. Paul Island shows an increase in numbers of fulmars since 1990, although data is only available to 1996. On nearby St. George Island, fulmar numbers have been more erratic, with an unusually high number in 1992, and sharply decreasing numbers between 1992 and 1999. (The Pribilofs are being censused by Alaska Maritime National Wildlife Refuge biologists in 2002, but because the breeding season continues through September, results are not ready for this draft report). On Chowiet Island in the Semidi Island group (Figure 4), the study plots monitored by S. Hatch (U.S. Geologic Survey/Biological Resources Division, USGS/BRD, Anchorage, unpublished data) indicate that fulmar numbers remained relatively steady prior to a spike between 1993 - 1995, followed by a steep decline in 1998 and 2001. No trend data exist for the fulmar colonies at St. Matthew/Hall or Chagulak Islands. Data on reproductive success of fulmars is difficult to obtain and productivity parameters of fulmars have not been regularly monitored at any site in Alaska.


Northern Fulmar, St. George I.

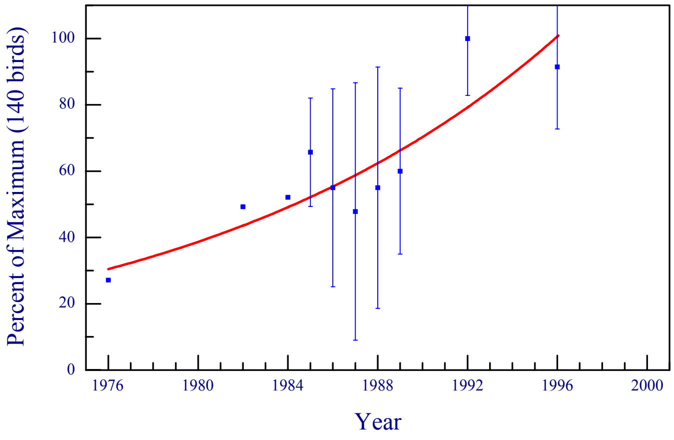

Northern Fulmar, St. Paul I.

Fig. 3. Population trends of northern fulmars in the Pribilof Islands, based on plot counts on St. George I., 1976 - 1999 (Top) and St. Paul I., 1976 - 1996 (Bottom). Percent of Maximum is based on the number of birds on the study plots only. The majority of the estimated 80,000 fulmars on the Pribilof Islands nest on St. George I. (Data reprinted with permission from Dragoo et al. 2000).

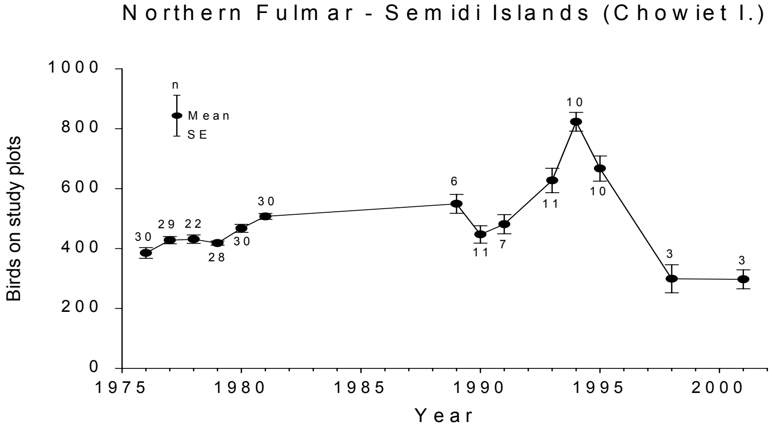


Figure 4. Population trends of northern fulmar on Chowiet Island, based on plot counts taken during summer, 1975 - 2001. (Unpublished data and graphic provided by Scott Hatch, USGS/BRD, Anchorage).

The breeding populations of fulmars in Alaska are fairly well localized and their main colonies are distributed over a large geographic area. For this reason, the fulmar colonies might experience different impacts from environmental as well as fishery-related influences. Fulmars may benefit by obtaining food during fishery operations, but the effects of bycatch mortality might offset such potential gains. To assist in building population models to examine trends and the effects of mortality or food supplementation, affected populations need to be identified and monitored. An effort to identify the colony of origin for fulmars caught in BSAI and GOA groundfish fisheries was begun in 2001 and continues in 2002, through a USFWS funding initiative to the USGS/BRD, in cooperation with the NMFS North Pacific Groundfish Observer Program (see Research Initiatives, below). This project will use genetic markers to compare bycaught fulmars with those at specific colonies. Additional information could be obtained by insuring that observers record the color phase of bycaught fulmars, which range from light to dark in plumage. Light-phase fulmars nest at the large colonies in the central and north Bering Sea, whereas dark-phase fulmars predominate along the Aleutians and in the Semidis (Hatch and Nettleship 1998).

Seabird Diets and Biomass Consumption

A review of seabird foraging ecology, historical records of seabird diet in Alaska, and evidence of impacts on seabirds from changes in their prey base, were provided in NMFS 2001a. Dragoo, Byrd *et al.* (2001) has summarized seabird diets by location, species, and age-class, for those colony sites and species monitored by the U.S. Fish and Wildlife Service. Here, we provide a broad, geographically oriented synthesis of the use of fishes (omitting most invertebrates) during the breeding season from the late 1990s to 2000, which can be examined in detail in the Dragoo, Byrd *et al.* 2001 report. We give a brief review of the prey species most commonly used by seabirds in Alaska. We also provide a review of the estimated biomass consumed by seabirds in Alaska, taken from Hunt, Kato *et al.* 2000, with suggested implications to ecosystem management.

Seabird prey species. – Seabird diets consist mainly of fish or squid less than 15 cm long, large zooplankton, or a combination of both. The fish and invertebrates taken by seabirds varies by season, location and bird species, and can vary between adults and juveniles of the same species in the same location. Most of our information on seabird diet has been obtained during the breeding season, often from the prey that adults bring to their chicks.

Seabirds use the juvenile age-classes (age-class 0-1) of a variety of commercial fish, including Pacific herring (*Clupea pallasi*), walleye pollock (*Theragra chalcogramma*), Pacific tomcod *(Microgadus proximus*), salmon (*Oncorhynchus* spp.), rockfish (*Sebastes* spp.), lingcod (*Ophiodon elongatus*), smelts (Osmeridae spp.), and flatfish (Pleuronectiformes spp.). Squid are also a favored prey of many seabird species. Bottom-feeding birds such as scoters, cormorants, and guillemots may also consume juvenile stages of commercial shrimp and crab species. Non-commercial forage fish include juveniles and adults of Pacific sand lance (*Ammodytes hexapterus*), capelin *(Mallotus villosus*) Pacific sandfish (*Trichodon trichodon*), greenlings (Hexagrammidae spp.), and several species of lanternfish, or myctophids (Myctophidae spp). Birds that feed near the coast and near the sea floor may also take sculpins, blennies, octopus, molluscs and small crustacea.

Most of the fish used by seabirds are caught in shallow waters (< 100 m; usually < 50 m) or in the upper portions of the water column. Deep-water fish like the myctophids are usually taken at night, when they make their vertical migration to surface waters. Fish that in general have high energetic value to seabirds include the myctophids, herring, sand lance, and capelin, whereas the fish with lower energetic value include pollock and most other bottom-dwelling fish (Anthony, Roby *et al.* 2000, Roby, Jodice *et al.* 2000).

Seabird diet at monitored sites. – In the northern-most colonies bordering the Chukchi Sea, birds at Cape Lisburne were feeding primarily on gadids, most likely pollock. Thick-billed murres, common murres, and black-legged kittiwakes also took sand lance, capelin, herring, and squid. In the central Bering Sea, at the St. Matthew/Hall islands, northern fulmars were taking primarily pollock, or other gadids (S. Hatch, USGS, Anchorage, pers. comm.). Birds at the Pribilofs took a wide variety of fish, squid, and smaller invertebrates. The most frequently used fish at the Pribilofs were myctophids, which comprised the primary prey for northern fulmars and red-legged kittiwakes, but were also prominent in the diet of black-legged kittiwakes. Pollock were also taken frequently in the Pribilofs, and they were the primary prey for black-legged kittiwakes and common murres. Northern fulmars also took sand lance, and black-legged kittiwakes included sand lance and greenling in their diet. The thick-billed murres in this region relied solely on squid and euphausiids, although between 1975 and 1985, pollock had been an important part of their diet as well (Dragoo, Byrd *et al.* 2001).

Myctophid fish were also the primary prey for most seabirds in the western Aleutians, at the Buldir Island colonies. These fatty fish were the main food item for fork-tailed storm petrels, red-legged kittiwakes and black-legged kittiwakes. These birds also consumed euphausiids and greenling. Squid was the main prey for both common and thick-billed murres, with the common murre also taking pollock and herring and the thick-billed murre taking some myctophids. The Leach's storm petrel also used myctophids, but relied more on euphausiids and other large plankton.

In the central Aleutians, at Koniuji Island, black-legged kittiwakes fed on myctophids. Further east, on Aiktak Island, thick-billed murres fed primarily on pollock, and glacous-winged gulls took primarily herring, but both species also utilized sand lance. To the east, in the Semidi islands, three species of seabirds, rhinocerous auklets, common murres, and northern fulmars, used sand lance as the primary prey (fulmar data from S. Hatch, USGS). Secondary prey for murres was pollock, and capelin was also used by murres and fulmars. In the northern GOA, on the Barren Islands, capelin was in all diets, and was the main prey for common murres. Black-legged kittiwakes took mainly sand lance and tufted puffins took mainly pollock.

In Prince William Sound, black-legged kittiwakes took a variety of prey over the years, including sand lance, herring, salmon, capelin, and some pollock. These same fish were also taken by other birds in the area, including marbled and Kittlitz's murrelets, tufted and horned puffins, glaucous-winged gulls and arctic terns (Kuletz, pers. obs.). In Southeast Alaska, on St. Lazaria Island, myctophids were the main prey of fork-tailed storm petrels and Leach's storm petrels.

To summarize the regional breakdown of seabird diet since the late 1990s, and based on a limited number of sample sites and seabird species, most of the more frequently used forage fish species appeared througout Alaska waters, although some patterns emerge. In the Chukchi and north-central Bering Sea, pollock predominated, and in the western and northern GOA, pollock was present, but usually secondary to other species. Pollock were rare in Prince William Sound and absent at St. Lazaria Island. Myctophids predominated in the Pribilofs and the western and central Aleutians, and on St. Lazaria, but were absent from western and northern GOA. Sand lance was found from the Pribilofs to the eastern Aleutians and along the northern GOA to Prince William Sound. The use of capelin was more restricted, and appeared in seabird diets from the Semidi Islands and Shelikof Strait up to Prince William Sound. Herring comprised small proportions of overall diet in the Aleutians, and was common in Prince William Sound, but elsewhere it was not observed in seabird diets. However, herring are an important food for the same species of seabirds in British Columbia (Vermeer, Sealy *et al.* 1987, Vermeer and Ydenberg 1989), are therefore probably used by seabirds in Southeast Alaska. The storm petrels that are monitored at St. Lazaria would not be good indicators of the availabiltiy or use of herring, since they feed primarily on myctophids and large plankton (Dragoo, Byrd *et al.* 2001).

Biomass consumption by seabirds. – Estimates of the biomass consumed by seabirds have been made for certain areas and specific groups of birds, and the results were reviewed and summarized in Hunt, Kato *et al.*(2000). Using these results, and extrapolating from what was estimated for bird abundance and known about marine bird energy requirements, Hunt, Kato *et al.* (2000) modeled the biomass taken by seabirds in the North Pacific during summer (92 days, June - August/September, depending on species). The Hunt, Kato *et al.* report also provides regional summaries of seabird abundance and diet (including pre-1990s data), and estimates of metric tons of prey consumed by selected seabird species within each region. For our purposes, we summarized total prey consumption for four of the eight sub-regions defined in their model (Table 7a). Three of the sub-regions correspond to waters within the Alaska fishing regions (the Bering Sea Continental Shelf, the GOA Continental Shelf, and the Eastern Subarctic), and a large portion of the fourth overlaps with Alaskan waters (the Bering Sea Pelagic). The latter, however, also includes the western BS and shelf regions, which do not directly pertain to Alaska fisheries.

Among the four sub-regions defined by the PICES report (Hunt, Kato *et* al. 2000), we focus on the eastern BS and GOA shelf regions. The former has the greatest number of birds, but the latter, with its smaller surface area, has the highest biomass of birds, and the highest daily energy consumption (Table 7a). The Eastern Subarctic, which includes waters between the GOA shelf break and the Eastern Tropical Zone, has a relatively low biomass of birds and very low daily energy consumption. The Bering Sea Pelagic has fairly high daily energy consuption rates, but includes waters beyond the EEZ.

The PICES model examined prey consumption in two ways, total metric tons consumed (mt), and as metric tons consumed per square kilometer (mt/km$^{2)}$. Because the energy density of prey can affect the amount of fish that seabirds will need to survive and reproduce, the model also derived the estimates using two assumptions, being that, either all prey were high energy density fish (7 kj/g; such as myctophids or herring) or all prey were of low energy density (3 kj/g; such as cod or pollock). The results (Table 7a), indicate that total prey consumption in the Eastern BS could range from 656,000 mt (with high energy fish) to 1,530,000 mt (with low energy fish), and in the GOA shelf, could range from 316,000 mt to 738,000 mt. Prey consumption per km^2 was actually higher in the GOA. Partly because low energy fish such as pollock are more commonly taken by seabirds in the BS, the total mt of low energy fish consumed in the Eastern BS was nearly 50x greater than the amount taken in the GOA shelf waters. Medium energy density fish, such as capelin and sand lance, were taken in roughly equal amounts between the two regions, and comprised the bulk of prey taken by birds in the GOA. High energy fish, such as myctophids, had greater consumption in the Eastern BS, but in either region the total biomass was dwarfed by low and medium energy density fish.

Zooplankton and other invertebrates comprised a slightly greater proportion of seabird diet in the Eastern BS than in the GOA, and as a result, fish accounted for 47 % of the total biomass consumed by birds in the former, and 51% in the latter. The importance to seabirds of zooplankton, cephalopods and other invertebrates (Hunt, Kato, *et al.* 2000), highlights the need to better understand the physical and biological factors that may control abundance and availability of these prey as well.

Implications of seabird diet to ecosystem management. – The PICES model relied on many generalizations and assumptions, and its authors acknowledge that the parameters and values will need to be changed as new infomation is obtained. Nonetheless, it provides a quantitative starting point by which to integrate seabirds into ecosystem mangement. The model also provides for continued fine-tuning of prey requirements by using sub-regions in the analyses, which could be updated with changes in the diet of seabirds or their population trends, by species or region. A cautionary factor, however, is that the estimate of prey consumption indicates a minimum amount required by birds during the breeding season, but it does not estimate the biomass of fish needed for efficient food-finding and capture of prey, which likely requires a much greater biomass (Hunt, Mehlum *et al.* 1999). As stated earlier (NMFS 2001a), we need a better understanding of the factors limiting seabird prey availability. Further, the model does not attempt to incorporate the seasonal changes that are known to occur in prey use, energy density of fish, or in the bird's energetic requirements (Hunt, Kato *et al.* 2000).

Pollock appear to be an important and widespread prey for seabirds, despite their low energy denstiy, and are likely the most abundant or most available prey for seabirds during the breeding season in the BS. Pollock were used by seabirds throughout the BSAI and GOA, although for most seabirds they were the primary prey only in the Chukchi Sea and at the large islands of the BS. (Exceptions were the tufted puffins and murres, which used pollock in the GOA). The cannibalism of juvenile pollock by adult pollock has been hypothesized as a regulating factor in pollock abundance. Additionally, adult pollock eat other species of small forage fish used by seabirds. Hunt and Stabeno (2002) suggested that the negative correlation between adult pollock biomass in the eastern BS and reproductive success of black-legged kittiwakes in the Pribilofs is evidence of indirect effects of abundant adult pollock consuming and thus reducing availability of forage fish to seabirds. This suggests that seabird productivity could be affected by fishery management decisions, and that the indirect effect of pollock harvest on seabirds could be incorporated into ecosystem-based models.

The general survey of diet data available in Dragoo, Byrd *et al.*(2001) suggests other areas where research efforts or management considerations could focus. For example, capelin and sand lance are important prey for the birds in the northern GOA, but little is known about the fishes' spawning grounds, or to what degree those areas overlap with the relatively nearshore bottom trawling in that region. Fishing activities can also directly interfere with foraging of seabirds. For example, myctophids are an important prey for many birds in the southern BS and Aleutian islands, and for petrels in southeast Alaska. Because birds likely feed on these deep water fish at night when myctophids migrate to surface waters, interference with seabird foraging would most likely occur in these regions, especially when bright lights are used by fishing vessels. Incidents of vessel strikes may be one indication of such interference (see 'Vessel Strikes', below).

Seabirds Interfacing with Fisheries

For detailed descriptions of ecological interactions affecting seabirds and factors that influence the availability of food to seabirds, see the seabird section in the "Ecosystem Considerations in 2001" appendix (NPFMC 2000) and section 3.5.2 in the DPSEIS, respectively (NMFS 2001a).

Seabird Colony Distribution and Groundfish Fisheries

A major constraint on breeding for seabirds is the distance between the breeding grounds on land and the feeding zones at sea (Weimerskirch and Cherel 1998). Seabirds must have access to prey within efficient foraging range of the breeding colony in order to raise their chicks successfully (Piatt and Roseneau 1998, Suryan, Irons *et al.* 1998a, Suryan, Irons *et al.* 2000, Golet, Kuletz *et al.* 2000). If food supplies are reduced below the amount needed to generate and incubate eggs, or the specific species and size of prey needed to feed chicks is unavailable, local reproduction by seabirds will fail (Hunt et al. 1996, Croxall and Rothery 1991).

Most of the groundfish fisheries have occurred between September and April (Appendix E, NMFS 2001a), and do not overlap temporally with the main seabird breeding period that occurs from May through August (DeGange and Sanger 1987, Hatch and Hatch1990, Dragoo, Byrd *et al.* 2000, 2001). However, some species, such as larids, pigeon guillemots, and murrelets, may arrive at breeding sites in April, and others, including fulmars, puffins, and murres, are still rearing young in September. Among the 'latest' breeding species are the fulmars, which have a long incubation and chick-rearing periods and generally fledge chicks in September or early October. Both fork-tailed and Leach's storm-petrels do not fledge young until October (DeGange and Sanger 1987, Hatch and Hatch 1990, Dragoo, Byrd *et al.* 2000). Seabird attachment to the colony is thus most likely to overlap with fisheries effort during the early (pre and early egg-laying) and during the late (late chick-rearing and fledging) portion of their breeding season. Juvenile birds, generally on their own and not experienced foragers, would also be most abundant at sea during the fall fisheries. Fishery seasons have shifted and could do so in the future. For example, since 2000, the Pacific cod longline fishery in the BSAI has begun in August, and in the GOA, a large portion of the catcher-vessel trawl pollock fishery occurs in June and September (Appendix E, NMFS 2001b).

Indirect effects of groundfish fisheries might affect prey availability around seabird colonies even though they do not overlap with the seabird's breeding season. These potential effects include boat disturbance, alteration of predator-prey relations among fish species, habitat disturbance, or direct take of fish species whose juveniles are consumed by seabirds (see seabird section in Ecosystem Considerations chapter, NPFMC 2000, for review). Competition for prey may also be involved, as suggested by the negative relationship between age-3+ pollock biomass in the eastern Bering Sea and the reproductive success of black-legged kittiwakes in the Pribilof Islands (Livingston, Low *et al.* 1999, Hunt and Stabeno 2002). The interpretation of this relationship is that adult pollock consume the small fish (mainly, age-1 pollock and adult capelin) required by kittiwakes to successfully raise young (Hunt and Stabeno 2002). Thus, higher catch levels of some top-level species such as pollock might indirectly benefit piscivorous birds. This scenario is complicated, however, by the effects of warm vs cold-water regimes, which can directly affect some forage species such as capelin, and indirectly drive the system by altering top-down or bottom-up regulatory processes (Hunt, Stabeno *et al.* 2002). Additionally, the benefit of reducing the biomass of key predators such as pollock might be lost if populations of other large predatory fish increase due to reduced competition with pollock (Hunt and Stabeno 2002).

If seabirds are in competition with other upper-trophic level consumers, it suggests that the seabirds might, at a local scale, also impact fish populations. Overall consumption of fish biomass by seabirds is generally low, estimated at < 4 % (Livingston 1993), however, seabirds may impact fish stocks within foraging range of seabird colonies during summer (Springer, Roseneau *et al.* 1986, Birt, Birt *et al.* 1987). Fifteen to eighty percent of the biomass of juvenile forage fish may be removed by birds each year near breeding colonies (Wiens and Scott 1975, Furness 1978, Springer, Roseneau *et al.* 1986, Logerwell and Hargreaves 1997). Consequently, seabirds may therefore be vulnerable to factors that reduce forage fish stocks in the vicinity of colonies (Monaghan, Walton *et al.* 1994).

To examine the overlap between fisheries effort and seabird colonies, we combined seabird colony data from the Alaska Seabird Colony Database (S. Stephensen, USFWS, Anchorage, AK) with coverage of fisheries effort (NPFMC, Anchorage, AK). The maps illustrate areas of overlap between seabirds and fisheries both in terms of potential risk of seabird bycatch, and potential for indirect interactions with the seabird's prey base. These interactions are primarily relevant during the seabird's breeding season, which for most species extends from late April through September, but varies by region and species, and may not always intersect with fishery effort in every region.

For the colony maps, we included only piscivorous seabird species (Table 7b), since those species include the groups most susceptible to bycatch, and their prey base may be more subject to influence from the fisheries. Although the fisheries data is current (between 1998-2001), the colony data has been collected since the 1970's, and many of the smaller colonies, in particular, have not recently been surveyed. Colony sizes, therefore, may not be current, although the order of magnitude and distribution of the colonies should be reliable. Larger colonies and regularly monitored sites (Figure 2) include current data.

Table 5. Seabird relative breeding chronology compared to averages for past years within regions[a]. Only sites for which there were data from 2000 are included. This table is printed with permission of the Alaska Maritime National Wildlife Refuge, from their report: Breeding Status and Population Trends of Seabirds in Alaska in 2000.

Region	Site	FTSP	LHSP	PECO	GWGU	BLKI	RLKI	COMU	TBMU	PAAU	LEAU	WHAU	CRAU	RHAU	TUPU
SE Bering	St. Paul I.					–	–	–	=						
	St. George I.					–	–	–	=						
	C. Peirce			=		–		–							
	Aiktak I.	–	=		–										–
SW Bering	Buldir I.					–	=	–	=	–	=	–	=		
	Kasatochi I.										=		=		
	Bogoslof I.						+								
Gulf of Alaska	Gull I.					–		–							
	Chisik/Duck I.					=		–							
	Middleton I.			–	–	+								–	–
Southeast	St. Lazaria I.	–	–		=			=	=						

[a] Codes:

"– " indicates hatching chronology was > 3 days earlier than average for this site or region,

"=" indicates within 3 days of average

"+" indicates hatching chronology was > 3 days later than average for this site or region.

Species' codes: FTSP = fork-tailed storm petrel; LHSP = Leach's storm petrel; RFCO = red-faced cormorant; PECO = pelagic cormorant; GWGU = glaucous-winged gull; BLKI = black-legged kittiwake; RLKI = red-legged kittiwake; COMU = common murre; TBMU = thick-billed murre; PAAU = parakeet auklet; LEAU = least auklet; WHAU = whiskered auklet; CRAU = crested auklet; RHAU = rhinoceros auklet; TUPU = tufted puffin.

Table 6. Seabird relative productivity levels compared to averages for past years within regions[a]. Only sites for which there were data from 2000 are included. This table is printed with permission of the Alaska Maritime National Wildlife Refuge, from their report: Breeding Status and Population Trends of Seabirds in Alaska in 2000.

Region	Site	FTSP	LHSP	RFCO	PECO	GWGU	BLKI	RLKI	COMU	TBMU	PAAU	LEAU	WHAU	CRAU	RHAU	TUPU
N. Bering/ Chukchi	C. Lisburne						=									
	Bluff						+									
SE Bering	St. Paul I.			+			+	+	=	=						
	St. George I.			=			+	+	=	=						
	C. Peirce				=		+		=							
	Bogoslof I.			=	=	=	+	=	+	+						=
	Aiktak/ Ugamak Is.	=	=	=	+	=			+	+						+
SW Bering	Buldir I.						+	=		=	=	=	=	=		
	Ulak I.	=		+	+											
	Kasatochi I.			+	+				–	–		=		=		
	Koniuji I.						=									
Gulf of Alaska	Chiniak Bay						=									
	Gull I.						+		+							
	Duck I.						=		0							
	Pr. Will. Snd.						=									
	Middleton I.				+	+	=								=	=
Southeast	St. Lazaria I.	=	=		+	=			=	=						

[a] Codes: "– " indicates productivity was > 20% below average for this site or region,
"=" indicates within 20% of average
"+" indicates productivity was > 20% above average for this site or region.

Table 7a. Seabird abundance, biomass, and prey consumption in Alaskan waters during 92 summer days (June - August), as estimated in PICES Scientific Report No. 14 (Hunt, Kato *et al.* 2000). Note that the Bering Sea Pelagic sub-region includes the western Bering Sea and shelf along Russia. Na = not available.

Sub-region	**Eastern Bering Sea/ Continental Shelf**	**GOA / Continental Shelf**	**Eastern Subarctic**	**Bering Sea Pelagic (Russia/ Aleutians)**
Number of bird species	37	38	24-30	45
Individuals (No. Of birds)	34,690,000	16,140,000	7,905,000	22,325,000
Density (individual birds km^{-2})	34	38	2	16
Biomass (kg•km^{-2})	18.6	21.5	0.8	7.0
Daily Energy Consumption (kj•km^{-2}•d^{-1})x 10^3	48.8	56.2	2.1	18.7
Assuming all prey with Energy Density of 7kj•g^{-1} Total Prey Consumption (x 1,000 mt)	656	316	99	333
Prey Consumption mt•km^{-2}	0.64	0.74	0.03	0.25
Assuming all prey with Energy Density of 3 kj•g^{-1} Total Prey Consumption (x 1,000 mt)	1,530	738	230	777
Prey Consumption mt•km^{-2}	1.50	1.72	0.06	0.57
Total Metric tons consumed Low energy density fish	251,053	5,128	na	466
Medium energy density fish	260,920	246,873	na	6,609
High energy density fish	12,094	78	na	12
With all fish & all other food sources	1,109,409	494,046	na	219,334

Table7b List of Piscivorous Seabird Species or Species Groups included in the Piscivorous Seabird Colony Maps (see Figures 3 and 4).

Species Code	**Piscivorous Species or Species Group**
NOFU	Northern Fulmar (Fulmarus glacialis)
HEGU	Herring Gull (Larus argentatus)
GWGU	Glaucous_winged Gull (Larus glaucescens)
GHGU	Glaucous_winged/Herring Gull hybrid (Larus spp.)
GLGU	Glaucous Gull (Larus hyperboreus)
GGGU	Glaucous_winged/Glaucous gull hybrid (Larus spp.)
MEGU	Mew Gull (Larus canus)
BLKI	Black_legged Kittiwake (Rissa tridactyla)
RLKI	Red_legged Kittiwake (Rissa brevirostris)
UNGU	Unidentified Gull (Larus spp.)
COTE	Common Tern (Sterna hirundo)
ARTE	Arctic Tern (Sterna paradisaea)
ALTE	Aleutian Tern (Sterna aleutica)
UNTE	Unidentified Tern (Sterna spp.)
BLGU	Black Guillemot (Cepphus grylle)
PIGU	Pigeon Guillemot (Cepphus columba)
UNIG	Unidentified Guillemot (Cepphus spp.)
MAMU	Marbled Murrelet (Branchyrampus brevirostris)
ANMU	Ancient Murrelet (Synthilboramphus antiquus)
PAAU	Parakeet Auklet (Aethia psittacula)
RHAU	Rhinoceros Auklet (Cerorhinca monocerata)
TUPU	Tufted Puffin (Fratercula cirrhata)
HOPU	Horned Puffin (Fratercula corniculata)
UNPU	Unidentified Puffin (Fratercula spp.)
TOCO	Total Cormorant (all cormorant species combined)
TOMU	Total Murre (all murre species combined)

Piscivorous Seabird Colonies and Trawl Effort. – In the GOA, seabird colonies are generally small, but are numerous and dispersed along most of the coastline. The main areas of overlap with the trawl fisheries include the east side of the Kodiak Archipelago, and to a lesser extent, the Semidi Islands and Shumagin Islands (Figure 5). Those birds that primarily forage near their colonies, such as cormorants, pigeon guillemots, terns, small larids, and the non-colonial marbled and Kittlitz's murrelets, might be the species most influenced by fisheries in these immediate areas by disturbance or indirect interactions with the prey. Interaction with these 'near shore' foraging species would be most direct during the limited June trawl fishery. Because this fishery extends to the shelf edge, birds from these colonies that may forage >40 km from their colonies, such as fulmars and larger gulls and alcids, have potential for greater interaction and bycatch in these offshore waters. Alcids are, in fact, one of the seabird groups most frequently taken as bycatch in trawl fisheries (see section here, "Bycatch of Seabirds in Fishing Gear"), and trawl fisheries account for most alcid bycatch. Because murres and puffins (the large alcids in this area) are often still raising chicks in September, they would also have the greatest temporal overlap with those fisheries occurring in September. Fulmars nesting on Chowiet Island in the Semidis could likewise interact with trawl fisheries in this region and north along Kodiak and the shelf edge, during both the June and September-October fishery.

In the BSAI, trawl effort is concentrated between Unimak Pass and the Pribilof islands, over a wide area of the shelf waters (Figure 5). The main temporal overlap between trawl fisheries and seabird colonies in BSAI would be late in the bird's breeding season, in August and September. Seabird colonies are sparse along the BS side of the Alaska Peninsula, but the area of Unimak Pass west to Unalaska Island has numerous small colonies (Figure 5). One of the largest colonies, which includes fulmars, is on St. George Island in the Pribilofs, and these birds would have the greatest spatial overlap with the trawl fisheries. Chagulak Island in the Aleutians and St. Matthew/Hall islands in the northern BS support the other two large colonies of piscivorous birds, including fulmars. Trawl effort is absent or at some distance from these colonies. At St. Matthew/Hall islands, birds with greater foraging distances, such as fulmars, could interact with fisheries to the southwest of the islands in late summer or early fall.

Piscivorous Seabird Colonies and Longline Effort.– The longline fisheries have the greatest overlap with seabird colonies in the BSAI, although temporal overlap would be primarily in April and August - September. The hook and line Pacific cod fishery extends farther north along the shelf edge than the trawl fisheries (Figure 6). Again, birds nesting in the Pribilofs, including one of the largest fulmar colonies on St. George Island (~80,000 fulmars), have the greatest potential for interaction with this fishery. Because the St. George Island fulmar breeding population is relatively small compared to the other three primary fulmar sites, they might have the greatest potential to experience colony-level effects from bycatch mortality. However, because of the concentration of the fishery north along the shelf edge, birds in the St. Matthew/Hall islands colonies may interact with this fishery as well, and this colony has a much larger fulmar population (~450,000 birds; Hatch and Nettleship 1998) than the Pribilofs. Birds nesting throughout the Aleutian chain overlap in near shore areas, but there is little longline effort beyond the narrow shelf along the islands. As a result, birds foraging near shore or near their colonies, such as cormorants, pigeon guillemots, terns, small larids, and the non-colonial marbled and Kittlitz's murrelets, might be most influenced by these fisheries, either by disturbance or indirect interactions with the prey. Because of the limited temporal overlap with fisheries, the indirect effects of fishing on the seabird prey base could be more important along the Aleutians, although such indirect effects are not well understood.

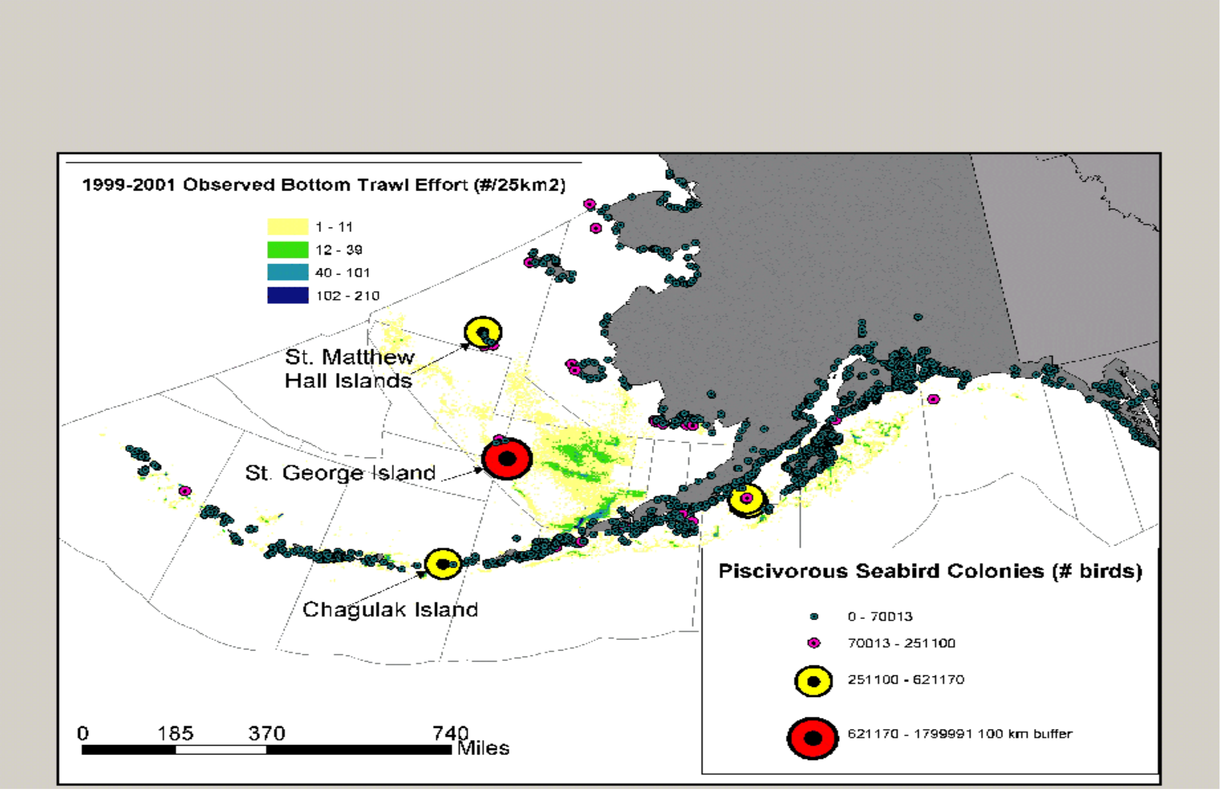


Figure 5: Location and relative size of seabird colonies (counting piscivorous birds only) in Alaska, relative to the 1999-2001 observed trawl effort (hauls/25 km2).

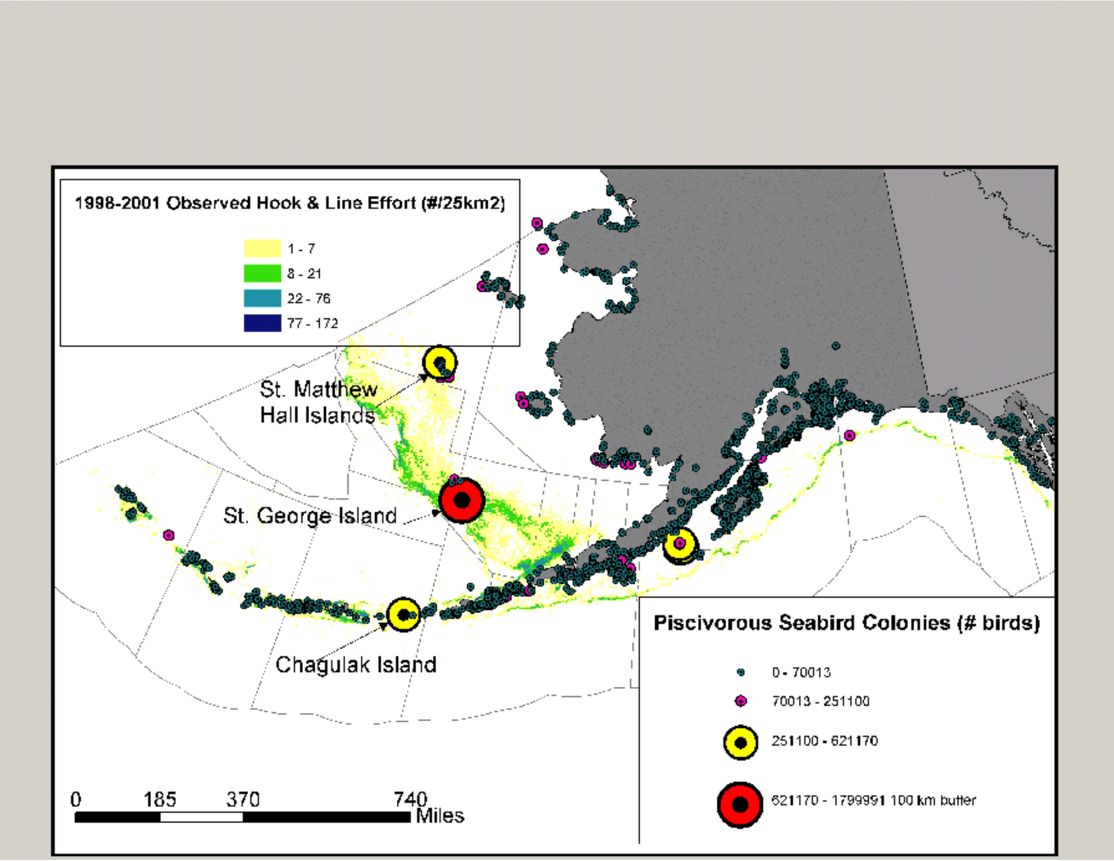


Figure 6: Location and relative size of seabird colonies (counting piscivorous birds only) in Bering Sea/Aleutian Islands region of Alaska, relative to the 1999-2001 observed hook-and-line Pacific cod fishery effort (sets/25 km2).

Satellite Telemetry Tracking of Fulmars. – A more precise and current example of fulmar foraging from a colony was provided by satellite telemetry (Scott Hatch, USGS/BRD, Anchorage, AK, unpublished data). In June 2001, two northern fulmars were captured in the Pribilofs on St. George Island. Both birds had laid eggs but did not complete nesting. One bird, tracked through September, remained in the southern Bering Sea, while the other, tracked through November, crossed into the GOA in early October. Both of the 2001 birds demonstrated a foraging pattern similar to that indicated by the pelagic distribution of fulmars recorded during surveys conducted in the 1970-80s (see below). Both birds ranged along the BS shelf edge, extending from northwest of St. Matthew Island to the Alaska Peninsula. The forage areas overlapped extensively with the 1998-2000 longline fishery effort (Figure 7A).

In 2002, five fulmars fitted with satelite transmitters in June, showed less overlap with longline fisheries (Figure 7B). One bird banded on Chagulak Island in the central Aleutians, abandoned its nest and traveled west along the Aleutians and up to an area about 150 miles northwest of St. Matthew Island. The remaining birds were banded on Hall Island (next to St. Matthew Island). These four birds, three of which are still raising chicks (as of late August), primarily travel between Hall Island and the same specific area northwest of St. Matthew Island where the Chagulak bird was located. This area, where all five tagged fulmars have been foraging, is not heavily fished by U. S. vessels (Figure 7B), however, it is right on the International line where foreign vessels congregate (Anchorage Daily News, 2001). It may be that foreign fishing activity attracts fulmars to this region, which might provide food for birds from the Hall colony, but could also pose an unmonitored bycatch threat. This pilot study demonstrated an ability to obtain precise foraging patterns of individual birds throughout the season, and could further be used to determine the extent that individuals depend on the fishery directly for food in different regions.

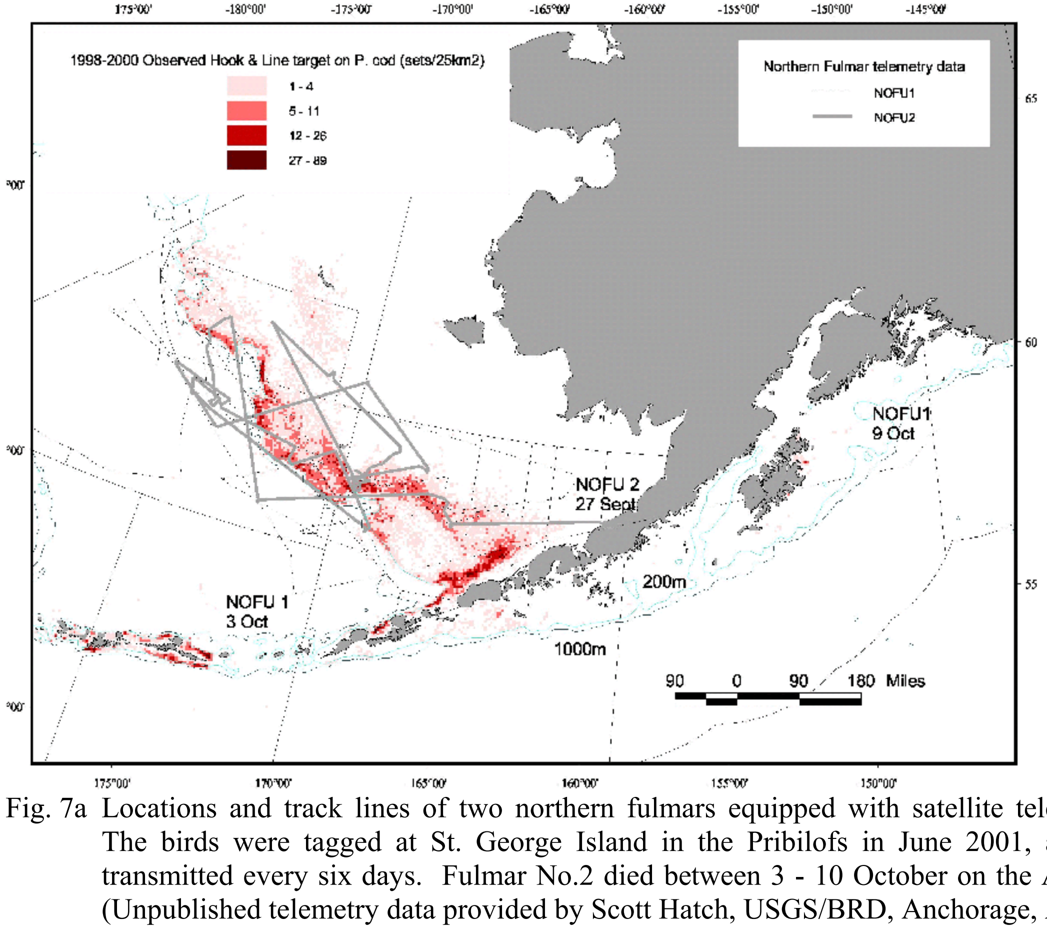


Fig. 7a Locations and track lines of two northern fulmars equipped with satellite telemetry packages. The birds were tagged at St. George Island in the Pribilofs in June 2001, and signals were transmitted every six days. Fulmar No.2 died between 3 - 10 October on the Alaska Peninsula. (Unpublished telemetry data provided by Scott Hatch, USGS/BRD, Anchorage, Alaska)

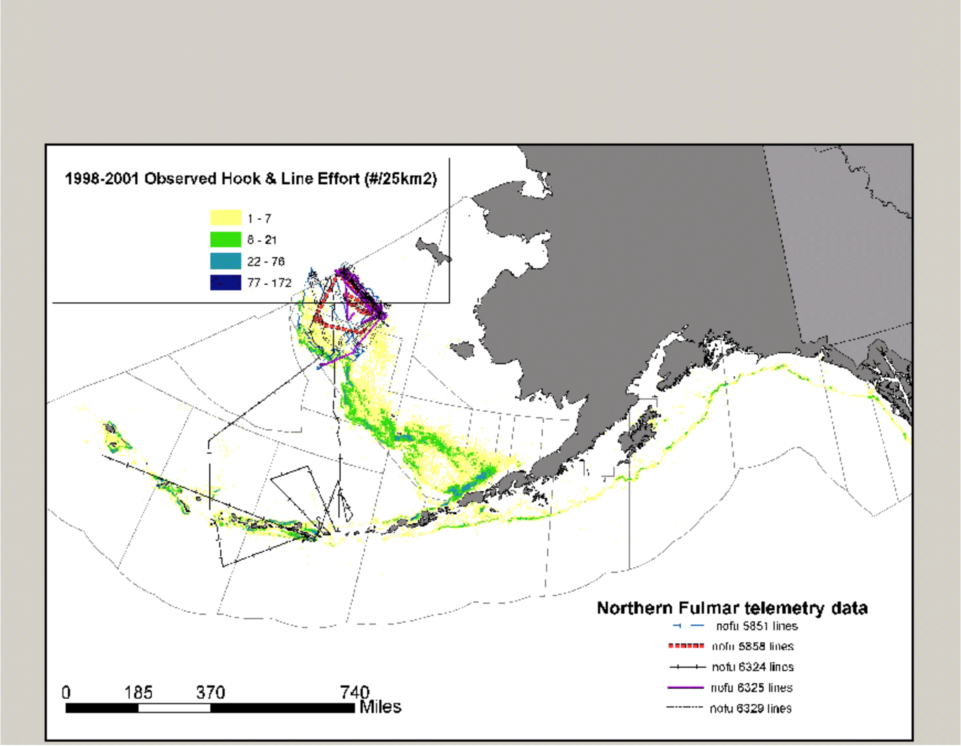


Fig. 7B Locations and track lines of northern fulmars equipped with satellite telemetry packages in June, 2002. Five birds were tagged, one at Chagulak and four at Hall Island, near St. Matthew Island.

Seabird Distribution at Sea and Groundfish Fisheries

All species of seabirds depend on one or more oceanographic processes that concentrate their prey at the necessary time and place, such as upwellings, stratification, ice edges, fronts, gyres, or tidal currents (Schneider 1990, Schneider *et al.* 1987, Coyle *et al.* 1992, Elphick and Hunt 1993, Hunt and Harrison 1990, Hunt 1997, review in Hunt *et al.* 1999, Springer *et al.* 1999). Thus, the distribution of birds at sea might be expected to follow patterns similar to those of the commercial fisheries, which also rely on oceanographic processes that concentrate fish. Although some overlap of fisheries effort and seabird distribution is self-evident from bycatch records and observer sightings, there has been little effort to examine this relationship in Alaska.

We examined the at-sea distribution of selected birds relative to the fishing effort in longline and trawl fisheries in Alaska. The selected species include those that are either abundant in Alaska and comprise a significant portion of the seabird bycatch in the groundfish fisheries, or they are species of concern. The seabird data is a preliminary subset of data currently being incorporated into the North Pacific Pelagic Seabird Database (NPPSD) by the USGS/BRD, USFWS, and Mineral Management Service (MMS). The NPPSD will eventually include all available at-sea survey data for the North Pacific, but the data available to date consists of subsets of data collected during cruises of the Outer Continental Shelf Environmental Assessment Program (OCSEAP). Thus, the seabird data, gathered from 1975-1985, may not reflect current population levels, however, it has the advantage of being independent of fishery observer effort, and thus useful to illustrate general distribution at sea. We assumed that general seabird distribution has not altered appreciably at the scale used for this application. (For a detailed explanation of the database, contact John Piatt, USGS/BRD, Anchorage, AK, or David Irons or Shawn Stephensen, USFWS, Anchorage, AK).

Table 8. Estimated Total Incidental Catch of Seabirds by Species or Species Groups[a] in Bering Sea and Aleutian Islands Longline Fisheries, 1993–2001. Values in Parentheses are 95% Confidence Bounds.

Year	Actual Number Taken [b]	STAL	BFAL	LAAL	NOFU	Gull	SHWR	Unid. Tubenoses	Alcid	Other	Unid. ALB	Unid. Seabird	Total
Bering Sea and Aleutian Islands													
1993	1,942	0	11 (4-21)	617 (458-777)	4,251 (3416-5103)	853 (576-1130)	64 (22-107)	0	15 (4-30)	4 (1-10)	352 (188-517)	1,799 (1399-2200)	7,975 (6981-8968)
1994	2,700	0	37 (7-66)	311 (218-404)	4,826 (4185-5467)	1,734 (1297-2172)	675 (487-864)	350 (226-475)	4 (1-13)	4 (1-11)	76 (43-109)	2,615 (1956-3274)	10,633 (9604-11662)
1995	4,832	0	66 (26-107)	463 (267-660)	9,628 (8613-10643)	3,954 (3274-4634)	330 (225-434)	475 (253-697)	4 (1-11)	45 (16-74)	38 (19-57)	4,211 (3489-4933)	19,214 (17853-20576)
1996	2,002	4 (1-13)	20 (5-48)	234 (156-313)	5,636 (4817-6455)	1,487 (1232-1741)	487 (246-728)	14 (4-26)	46 (9-103)	49 (13-86)	60 (31-90)	442 (326-558)	8,480 (7594-9366)
1997	4,123	0	9 (2-22)	343 (252-433)	13,611 (12109-15122)	2,755 (2276-3234)	300 (154-445)	173 (103-243)	0	7 (2-16)	14 (3-28)	852 (519-1185)	18,063 16491-19634)
1998	5,851	8 (2-15)	9 (2-21)	1,431 (1068-1734)	15,533 (13873-17192)	4,413 (3732-5093)	1,131 (936-1326)	21 (5-38)	53 (24-82)	48 (15-81)	4 (1-11)	1,941 (1584-2297)	24,592 (22769-26415)
1999	3,293	0	18 (4-34)	573 (475-675)	7,843 (6477-9209)	2,208 (1816-2600)	449 (358-540)	409 (144-673)	4 (1-10)	47 (12-85)	0	859 (551-1167)	12,409 (10,940-13,877)
2000	3,868	0	16 (5-33)	441 (320-562)	10,941 (9,503-12,378)	4,504 3,857-5150	556 (414-697)	85 (44-125)	5 (1-14)	16 (4-30)	15 (3-30)	1,576 (1,166-1,985)	18,154 (16,462-19,746)
2001	1,987	0	4 (1-12)	425 (304-547)	5,517 (4,701-6,332)	2,459 (2,044-2,873)	457 (337-578)	94 (49-139)	2 (1-6)	33 (6-61)	5 (1-14)	997 (698-1,295)	9,992 (9,027-10,958)
Average Annual Estimate													
1993-1996	na	1 (0-4)	33 (18-48)	406 (336-477)	6,087 (5667-6508)	2,007 (1784-2230)	389 (307-471)	210 (146-274)	17 (3-33)	26 (13-38)	132 (89-175)	2,267 (2001-2533)	11,576 (11034-12117)
1997-2001	na	2 (0-4)	11 (5-18)	643 (558-728)	10,689 (10,069-11,309)	3,268 (3,028-3,507)	578 (514-643)	156 (100-213)	13 (6-19)	30 (18-43)	7 (2-13)	1,245 (1,091-1,399)	16,642 (15,966-17,318)
1993-2001	na	1 (0-3)	21 (14-29)	538 (481-595)	8,644 (8,252-9,036)	2,707 (2,541-2,874)	494 (443-545)	180 (137-223)	15 (7-23)	28 (19-37)	63 (43-82)	1,699 (1,553-1,845)	14,390 13,944-14,836

Notes: [a] Species or species group codes.
[b] Actual number taken is the total number of seabirds recorded dead in the observed hauls.
STAL – Short-tailed albatross,

LAAL – Laysan’s albatross
BFAL – Black-footed albatross
NOFU – Northern fulmar
Gull – Unidentified gulls (herring gulls, glaucous gulls, glaucous-winged gulls)
SHWR – Unidentified shearwaters (unidentified dark shearwaters, sooty shearwaters, short-tailed shearwaters)
Unidentified Tubenose – Unidentified procellariiformes (albatrosses, shearwaters, petrels)
Alcid – Unidentified alcids (guillemots, murres, puffins, murrelets, auklets)
Other – Miscellaneous birds (could include loons, grebes, storm-petrels, cormorants, waterfowl, eiders, shorebirds, phalaropes, jaeger/skuas, red-legged kittiwakes, black-legged kittiwakes, terns)
Unidentified ALB – Unidentified albatrosses (could include short-tailed albatrosses, Layson’s albatrosses, black-footed albatrosses)

Source: (NMFS observer data; analyzed by Alaska Fisheries Science Center/National Marine Mammal Laboratory, 2002).

Spectacled eider, Steller’s eider, marbled murrelet, red-legged kittiwake, and Kittlitz’s murrelet were not reported by observers in any observed sample from 1993 to 2001. Although of these birds only the 2 eider species are listed under ESA in the action area, USFWS identifies the other 3 species as ‘species of concern’ because of low and/or declining population levels. ‘Species of concern’ is an informal classification by the USFWS, Office of Migratory Bird Management. Inclusion on the ‘species of concern’ list has no regulatory implications.

Table 9. Estimated Total Incidental Catch of Seabirds by Species or Species Groups[a] in Gulf of Alaska Longline Fisheries, 1993–2001. Values in Parentheses are 95% Confidence Bounds.

Year	Actual Number Taken [b]	STAL	BFAL	LAAL	NOFU	Gull	SHWR	Unid. Tubenoses	Alcid	Other	Unid. ALB	Unid. Seabird	Total
Gulf of Alaska													
1993	318	0	29 (9-50)	125 (62-187)	833 (615-1052)	45 (12-77)	59 (18-99)	0	0	3 (1-7)	3 (1-9)	213 (107-318)	1,309 (1056-1563)
1994	126	0	7 (2-16)	169 (89-250)	258 (165-351)	30 (2-81)	26 (5-54)	0	0	0	8 (2-18)	33 (8-66)	532 (397-668)
1995	374	0	236 (169-304)	67 (35-99)	520 (348-692)	99 (53-145)	39 (9-69)	6 (1-16)	0	3 (2-6)	376 (275-476)	173 (105-240)	1,519 (1302-1736)
1996	250	0	658 (455-860)	154 (90-128)	665 (349-982)	121 6-317)	14 (2-35)	0	0	0	0	19 (3-42)	1,631 (1203-2059)
1997	74	0	99 (32-167)	40 (5-109)	307 (164-451)	46 (14-79)	9 (2-21)	0	0	0	0	12 (2-30)	514 (338-689)
1998	184	0	289 (25-596)	217 (56-378)	919 (308-1530)	53 (14-92)	13 (3-30)	0	0	0	4 (1-12)	0	1,495 (792-2198)
1999	159	0	183 (70-297)	202 (123-280)	277 (156-399)	358 (136-581)	50 (8-93)	0	0	7 (1-21)	0	16 (4-37)	1,093 (812-1375)
2000	72	0	139 (53-225)	93 (25-160)	297 (70-524)	179 (15-415)	0	0	0	0	0	34 (2-102)	742 (392-1,032)
2001	45	0	72 (20-124)	67 (6-128)	230 (115-344)	98 (4-244)	20 (1-58)	0	6 (1-18)	0	15 (1-44)	3 (1-9)	512 (311-713)
Average Annual Estimate													
1993-1996	na	0	233 (179-287)	129 (97-160)	569 461-677)	74 (21-127)	35 (19-50)	1 (0-4)	0	1 (0-3)	97 (71-122)	109 (76-142)	1,248 (1108-1388)
1997-2001	na	0	156 (86-227)	124 (81-167)	406 (268-544)	147 (75-219)	18 (6-31)	0	1 (0-4)	1 (0-5)	4 (0-10)	13 (1-28)	871 (696-1,047)
1993-2001	na	0	190 144-236	126 (98-154)	479 (388-569)	114 (68-161)	26 (16-36)	1 (0-2)	1 (0-2)	1 (0-4)	45 (33-57)	56 (39-73)	1,039 (923-1,154)

Notes: [a] Species or species group codes.
[b] Actual number taken is the total number of seabirds recorded dead in the observed hauls.

STAL – Short-tailed albatross
LAAL – Laysan albatross
BFAL – Black-footed albatross
NOFU – Northern fulmar
Gull – Unidentified gulls (herring gulls, glaucous gulls, glaucous-winged gulls)
SHWR – Unidentified shearwaters (unidentified dark shearwaters, sooty shearwaters, short-tailed shearwaters)
Unidentified Tubenose – Unidentified procellariiformes (albatrosses, shearwaters, petrels)
Alcid – Unidentified alcids (guillemots, murres, puffins, murrelets, auklets)
Other – Miscellaneous birds (could include loons, grebes, storm-petrels, cormorants, waterfowl, eiders, shorebirds, phalaropes, jaeger/skuas, red-legged kittiwakes, black-legged kittiwakes, terns)
Unidentified ALB – Unidentified albatrosses (could include short-tailed albatrosses, Layson’s albatrosses, black-footed albatrosses)

Source: (NMFS Observer data; analyzed by Alaska Fisheries Science Center/National Marine Mammal Laboratory, 2002).

Spectacled eider, Steller’s eider, marbled murrelet, red-legged kittiwake, and Kittlitz’s murrelet were not reported by observers in any observed sample from 1993 to 2001. Although of these birds only the 2 eider species are listed under ESA in the action area, USFWS identifies the other 3 species as ‘species of concern’ because of low and/or declining population levels. ‘Species of concern’ is an informal classification by the USFWS, Office of Migratory Bird Management. Inclusion on the ‘species of concern’ list has no regulatory implications.

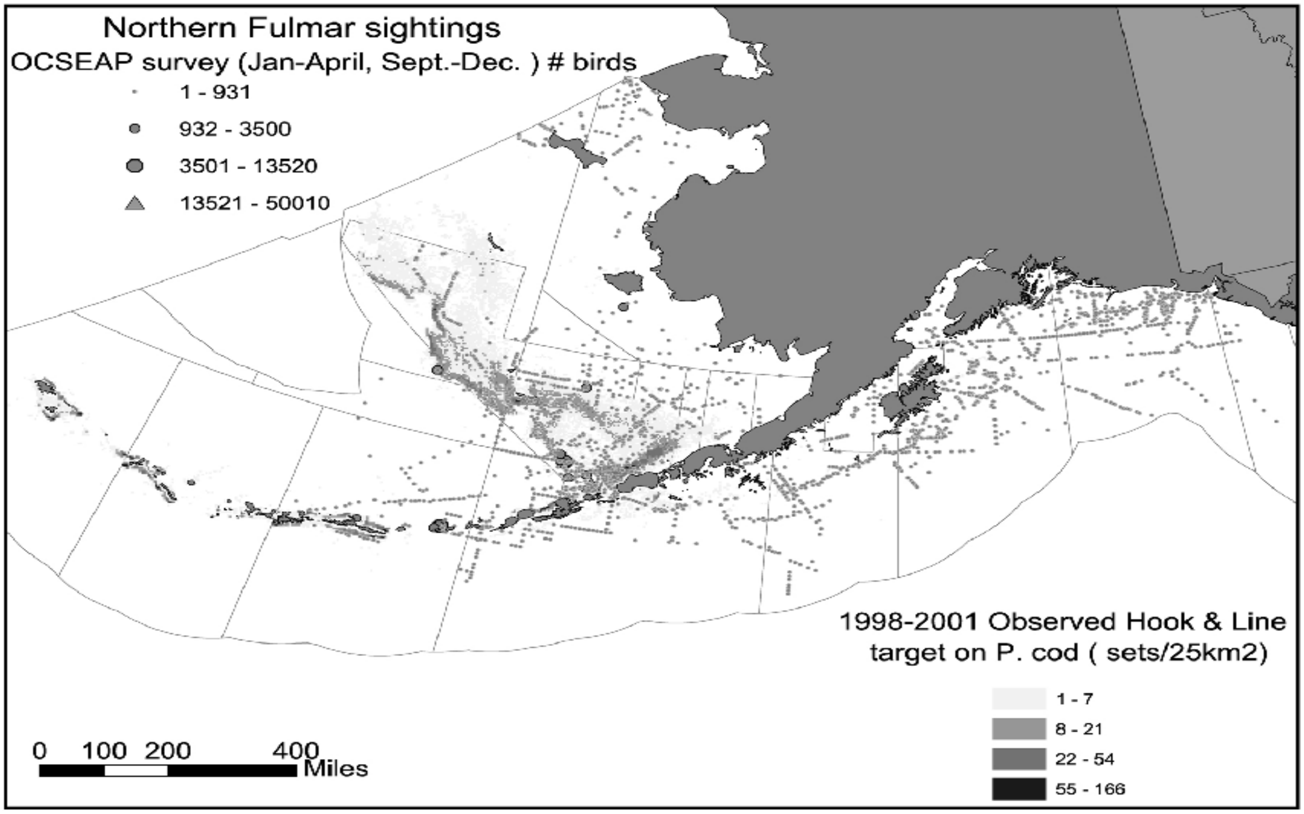


Figure 8: Distribution of northern fulmars at sea in Alaska, as determined from boat-based surveys conducted between 1975-1985. Data are a subset of the North Pelagic Seabird Database, under development by the USGS/BRD and USFWS in Anchorage, AK. Hook-and-line fishery

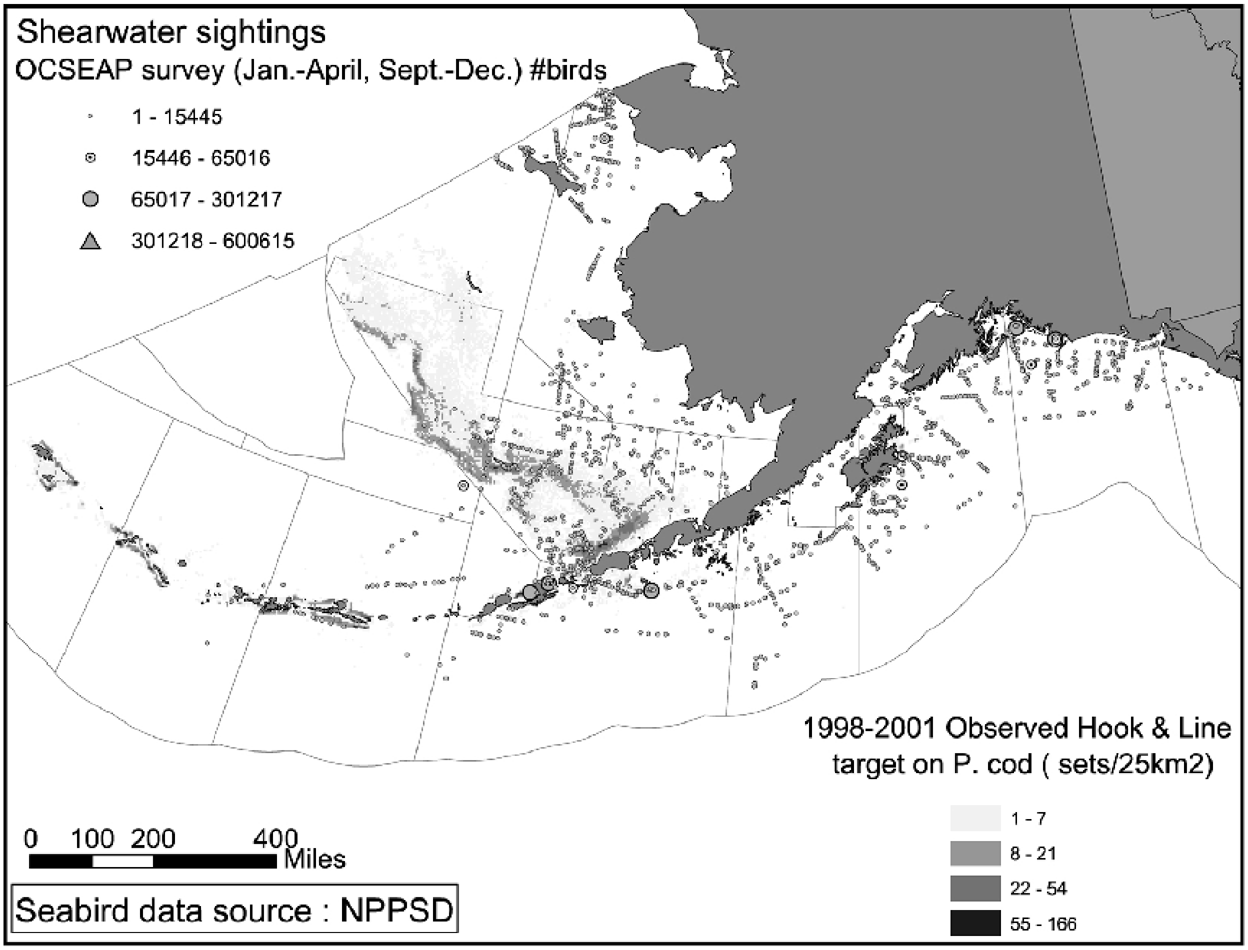


Figure 9: Distribution of shearwaters (primarily sooty and short-tailed spp) at sea in Alaska, as determined from boat-based surveys conducted between 1975-1985. Data are a subset of the North Pelagic Seabird Database, under development by the USGS/BRD and USFWS in Anchorage, AK. Hook-and-line fishery target on Pacific cod (sets/25km2) using observer data from 1998-2001 is also displayed.

At-sea Distribution of Northern Fulmars. – In both the BSAI and GOA, the northern fulmar comprises the majority of seabird bycatch. The fulmars are the only tubenose that is both a significant portion of the seabird bycatch and breeds in Alaska. Over 90% of the fulmars in Alaska nest on four large islands, Chowiet in the GOA, Chagulak in the Aleutians, St. George in the central BS, and St. Matthew/Hall islands in the northern BS (Hatch and Nettleship 1998). The year-round presence of fulmars in Alaska's waters, together with their foraging habits, likely are factors contributing to the large numbers incidentally caught in the BSAI and GOA groundfish fisheries. Additionally, the continued presence and high overlap of fulmars with fisheries effort may partially explain why they are the only species which shows a relationship between fishing effort (number of hooks deployed) and the estimated number of birds taken (NMFS 2001a).

To examine fulmar distribution at-sea during the period of greatest temporal overlap with longline fisheries, we selected only those bird sightings from the months of January through April and September through December, when the vast majority of the hook-and-line Pacific cod harvest occurs. Fulmar distribution shows a strong spatial overlap with the hook-and-line fishery in the BS, primarily in the area between Unimak Pass and the Pribilof Islands, over a wide area of the continental shelf (Figure 8). Fulmars are also scattered northeast toward the mainland side of the shelf edge, and along the central Aleutian chain. In the GOA, longline effort is relatively low, and occurs mainly east of Kodiak. Fulmars appear to be less dense in the GOA, and widely dispersed along the shelf edge. As might be expected, longline bycatch of fulmars in GOA is considerably lower than in the BS (Tables 8 and 9).

At-sea Distribution of Sooty and Short-tailed Shearwaters. – Sooty shearwaters breed in New Zealand and Australia or South America, and short-tailed shearwaters breed in Australia and Tasmania. Both species are trans-equatorial migrants that travel into Alaskan waters where they reside, roughly between May and September (Oka et al. 1987, Harrison et al. 1983). For both species, some non-breeders may remain in Alaska throughout the winter. The increase in shearwater bycatch during late summer/early fall (Figure 16) may reflect a seasonal shift in their distribution just prior to their migration back to their southern breeding grounds.

We examined both species of shearwater together during the months of January through April and September through December (Figure 9), to coincide with the majority of the hook-and-line Pacific cod harvest. In the BS, shearwaters were concentrated at Unimak Pass and to the north, which overlaps with the longline fishery. However, there was a gap in shearwater distribution along the shelf, where the fishery was concentrated, and shearwater abundance is much greater eastward toward the mainland side of the shelf, where fishing effort was low or absent. Few shearwaters were observed along the Aleutian chain. Shearwaters were also distributed along the GOA shelf, particularly near the Semidi Islands, northeastern Kodiak Island, and off the Copper River Delta. There should be little overlap in the GOA between shearwaters and longliners, and shearwaters are not taken in large numbers in that region (Table 9). Trawl fisheries, however, take a large portion of the total shearwater take in bycatch (Table 11), and the distribution of trawl effort (see Figure 5) suggests that shearwaters could overlap in both the BS and the GOA with that fishery.

At-sea Distribution of Black-footed Albatross. – Black-footed albatross breed primarily in the Northwestern Hawaiian Islands and forage in Alaska waters during the summer months, which is reflected in the increased proportion of black-footed albatross of the total seabird bycatch (Figure 16). However, nonbreeders may remain in Alaska, and some breeding birds may travel to Alaska to forage, based on movements of radio-tagged birds.

We pooled observations for all months to examine the distribution of black-footed albatross relative to the hook-and-line Pacific cod fishery. This albatross is found primarily in the GOA, along the shelf edge from the Shumagin Islands area north, particularly the northern portion of the GOA, between Cape Suckling and Yakutat (Figure 10). Low numbers were observed near Nunivak Island in the northern BS, and along the Aleutian Islands. The distribution of black-footed albatrosses is reflected in the much larger numbers of them taken in the GOA longline fishery compared to the BS longline fishery (Tables 9 and 8), despite the lower fishing effort in the GOA. Although the trawl fishery effort is relatively greater in the GOA, black-footed albatross have not been reported by observers as taken in that fishery.

At-sea Distribution of Laysan Albatross. – Laysan albatross, which also breed primarily in the Northwestern Hawaiian Islands, are the most abundant of the three albatross species that visit Alaska in the summer. This species is found in both the BS and the GOA (Figure 11), which is evident in the similar bycatch rates for those regions in the longline fishery (Tables 8 and 9). In the BS, low numbers of

Laysan albatross are found south and west of the shelf break, with little overlap with the hook-and-line Pacific cod fishery, which is concentrated along the shelf edge (Figure 11). Larger numbers of Laysan albatross occurred along the central and western Aleutian chain, where the nearshore longline fishery is also concentrated in that region. In the GOA, Laysan albatross are found along the shelf edge, primarily between the Shumagin Islands and eastern Kodiak Island.

Most of the bycatch of Laysan albatross occurs in the longline fishery, and this interaction may be important despite low fishing effort in the GOA. The trawl fishery, which has an effort more equally distributed between the GOA and BS, has occasionally shown relatively high bycatch levels of Laysan albatross (i.e., 1998; Table 11). The distribution of Laysan albatross and fishing effort suggest that the trawl bycatch could more likely occur on the shelf edge of the GOA or closer to shore in the western Aleutians.

At-sea Distribution of Short-tailed Albatross. – The short-tailed albatross is listed as endangered under the ESA, and thus its interactions with the groundfish fisheries are of great interest. Ideally, the at-sea distribution of this (primarily) summer visitor would be independent from the fishery itself. A pilot study was implemented in 2001 to equip short-tailed albatross with satelite telemetry packs at their breeding grounds in Japan, with the goal of tracking their movements throughout the year (G. Balogh, USFWS, Anchorage). This effort was continued in 2002. To date, following the breeding season, the short-tailed albatross appear to move north along the coast of Japan to the southern tip of the Kamchatka Peninsula. From there the birds moved east to the western Aleutians (USFWS, unpubl. data). Thus, prior to following the Aleutian Island chain and BS and GOA shelf breaks (Figures 12 and 13), these albaross spend considerable time along the coast of the western Pacific, where they would be exposed to additional fishery encounters.

The most extensive data coverage available for short-tailed albatross is derived from the NMFS Observer database and sightings from commercial fishing vessels, and this was used to illustrate their distribution in Alaskan waters (Figures 12 and 13). In the BS, the hook-and-line Pacific cod fishery overlaps with short-tailed albatross sightings primarily along the Aleutian chain, although some sightings also overlapped with the fishing effort along the shelf edge (Figure 12). A large portion of the sightings were recorded during the short-tailed breeding season (November to May), and thus may represent primarily immature and non-breeding birds. Most of the recorded take of short-tailed albatross occurred in the northern portion of the shelf edge in the BS, despite relatively fewer sightings there, compared to the Aleutians and with one exception, the takes were of juvenile or sub-adult (i.e. non-breeding) individuals (NMFS, 2001c).

In the GOA (Figure 13), the short-tailed albatross was sighted almost exclusively along the shelf edge, although to what extent this represents the bias of the observer's platforms is unknown. A large part of the trawl effort in the GOA extends from the Shumagin Islands to eastern Kodiak and to the north, but there were few sightings of short-tailed albatross inside of the shelf edge. Two recorded takes of the short-tailed albatross occurred in the GOA near Unimak Pass and Middleton Island in the northern GOA.

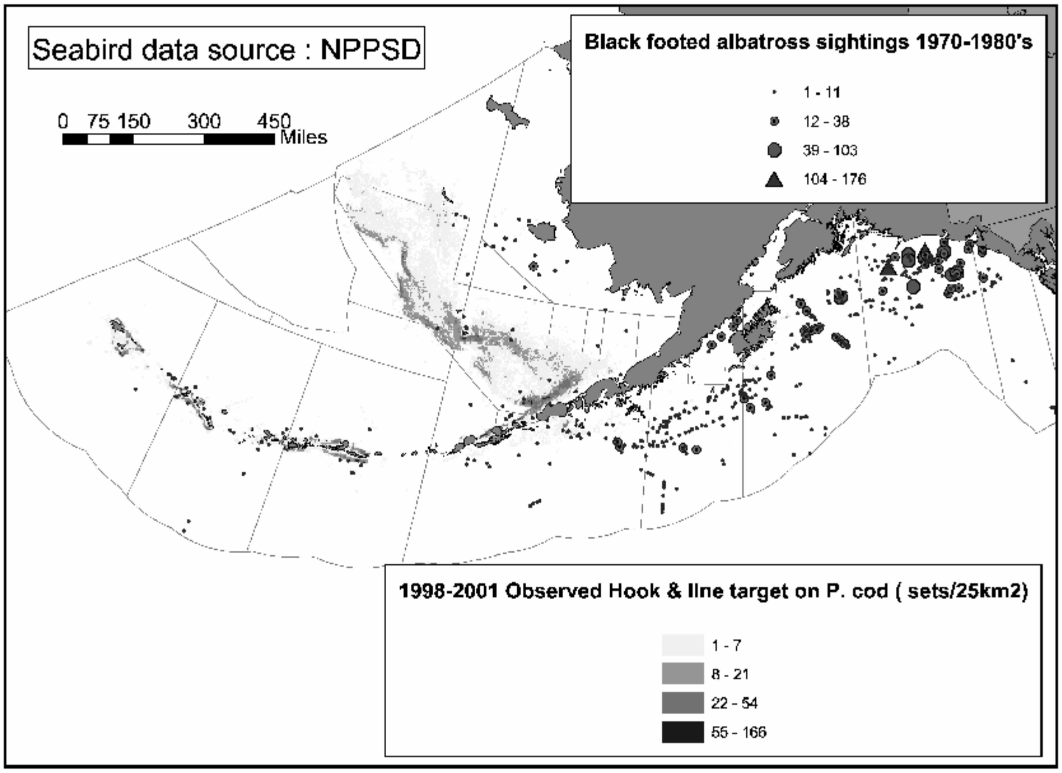


Figure 10: Distribution of black-footed albatross in Alaska, as determined from boat-based surveys conducted between 1975-1985. Data are a subset of the North Pacific Pelagic Seabird Database, under development by the USGS/BRD and USFWS in Anchorage, AK. Hook-and -line fishery target on Pacific cod using observer data from 1998-2001 is also displayed.

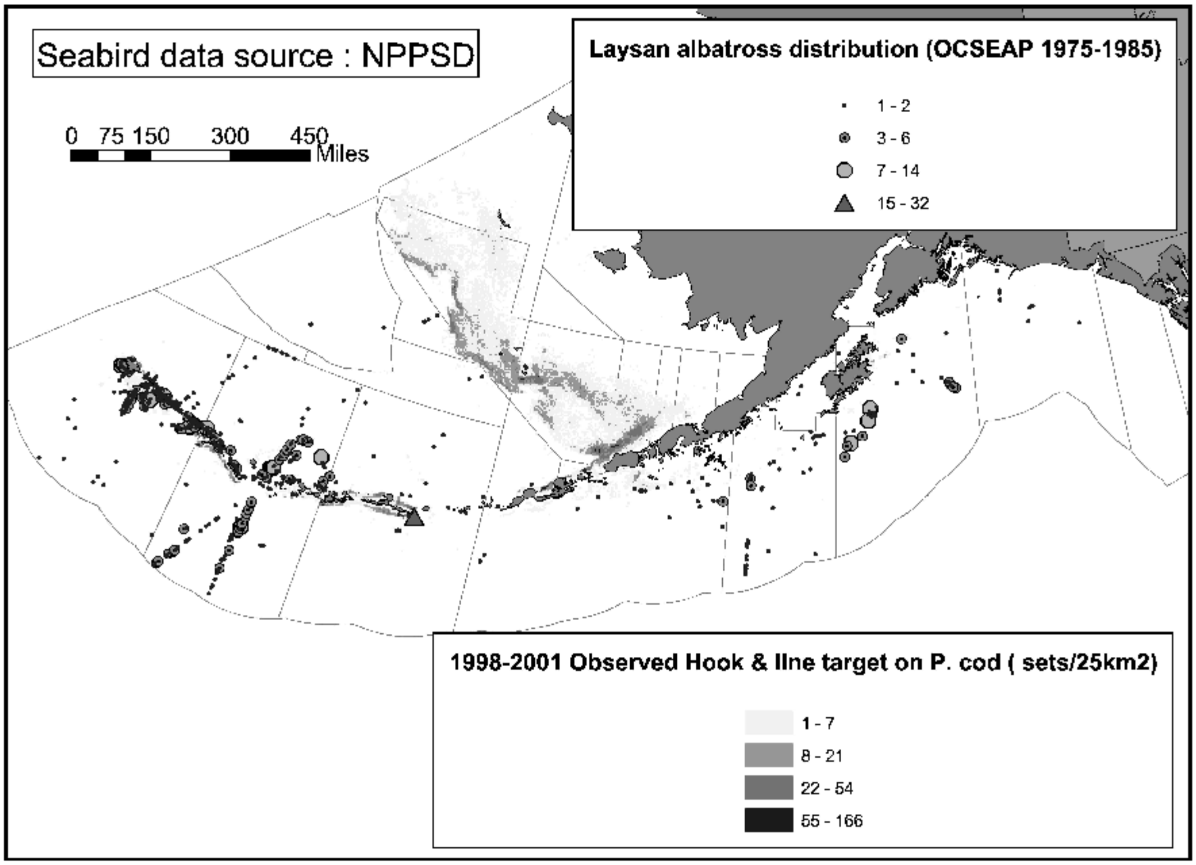


Figure 11: Distribution of Laysan albatross in Alaska, as determined from boat-based surveys conducted between 1975-1985. Data are a subset of the North Pacific Pelagic Seabird Database, under development by the USGS/BRD and USFWS in Anchorage, AK. Hook-and -line fishery target on Pacific cod using observer data from 1998-2001 is also displayed.

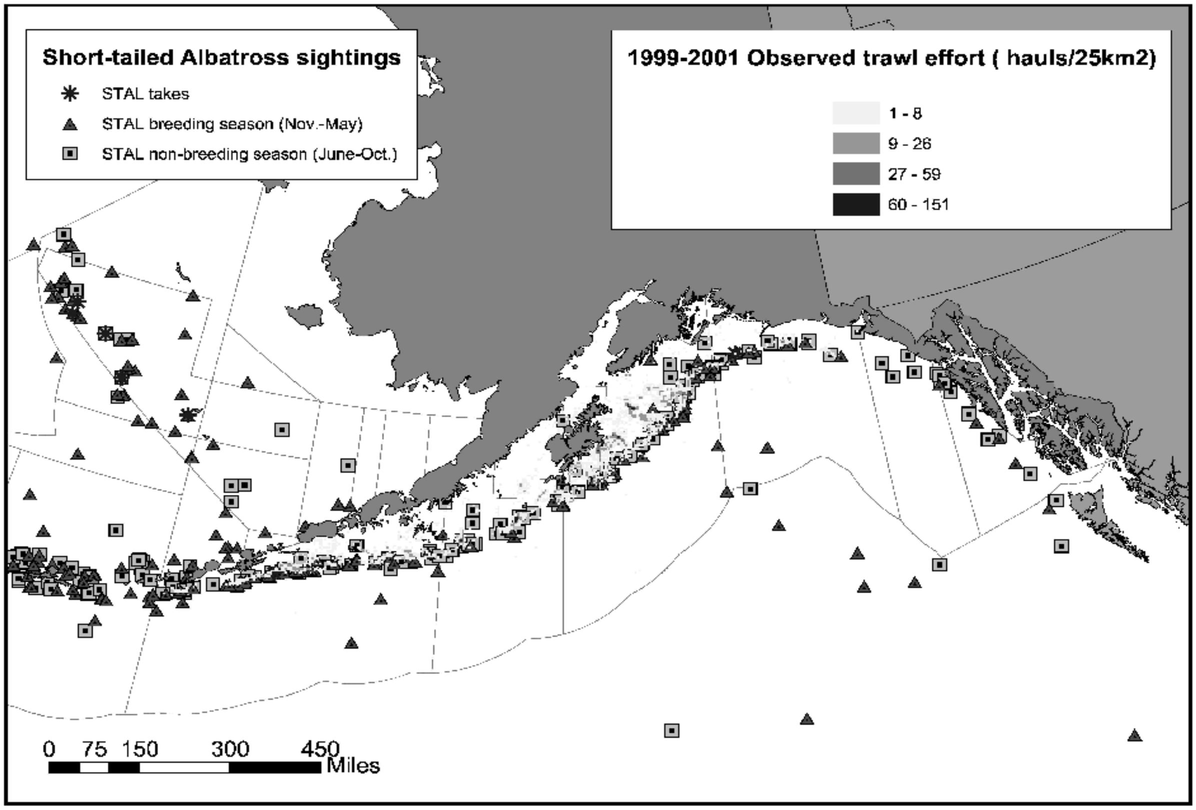


Figure 12: Short-tailed albatross (STAL) sightings (by breeding season and take locations) in the BSAI in relationship to the 1998-2001 observed hook and line Pacific cod fishery effort (sets/25 km^2).

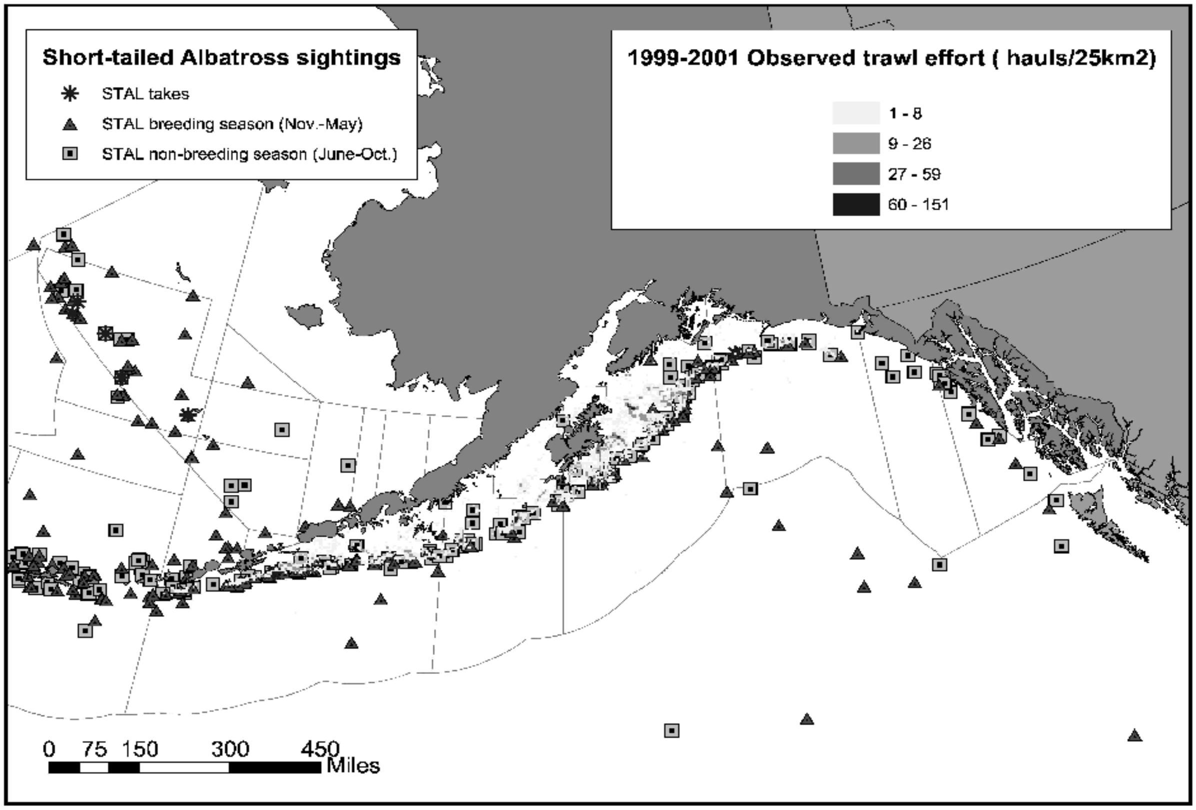


Figure 13: Short-tailed albatross (STAL) sightings (by breeding season and take locations) in the GOA in relationship to the 1998-2001 observed trawl fishery effort (hauls/25 km^2).

Incidental Catch of Seabirds in Fishing Gear

Seabirds are caught incidentally in all types of fishing operations (Jones and DeGange 1988). In a coastal drift gillnet fishery in Washington state, sea state and time of day were significant predictors of seabird bycatch rates, indicating that visibility or maneuverability, as well as feeding behaviors, may affect susceptibility of birds (Melvin, Parrish *et al.* 1999). In a demersal trawl fishery for hake off of southern Africa, the distribution of some seabird species was affected by trawling activity (Ryan and Moloney, 1988). This effect would depend on the species foraging behaviors and patterns. Generally, species with large radii of attraction were influenced by trawling activity and trawler offal comprised a large part of the diet. Species with small radii of attraction were less influenced and trawler offal comprised a minimal part of their diet. In Southern Ocean longline fisheries, the incidental catch of wandering albatrosses is likely to depend on the space and time overlap of the albatross population and fishing effort (Tuck, Polacheck *et al* 2001). This will be a function of the sex of the birds, age, breeding status, and the particular population under consideration. In groundfish fisheries off Alaska, longlines account for most of the seabird incidental catch. Trawls also take some seabirds, primarily those that feed beneath the surface on prey in the water column. Pots occasionally take diving seabirds. Some birds also are injured or killed by striking the vessel superstructure or gear while flying in the vicinity. In a two-year study on the effectiveness of seabird avoidance measures on the incidental take of seabirds in demersal longline fisheries off Alaska, results indicated that "year" (ie inter-annual differences) significantly affected both seabird attack and incidental catch rates (Melvin *et al* 2001). Spatial factors ("region") explained a large amount of deviation in attack rate and was the most significant variable explaining the incidental catch rate.

Monitoring Seabird Incidental Catch and Seabird/Fishery Interactions and Incidental Catch Estimation Procedures

Data collection regarding seabird/fishery interactions by NMFS in the groundfish fisheries began in 1990 and was expanded during the 1993, 1997, 1999 and 2000 seasons.

A report using 1993-1997 data from the longline fishery describes seabird incidental catch estimation methods and procedures developed by USFWS, in consultation with NMFS (Stehn, Rivera *et al.* 2001). Similar methods and procedures were developed by NMFS and used to calculate preliminary estimates using 1993-1999 data for all groundfish fisheries (NMFS 2001a). Standard statistical procedures ("separate ratio estimators" of stratified random sampling; Cochran 1977) for estimating a population total from a sample were used. NMFS calculated rates and estimates for all seabird species or species groups in each stratum of all gears, statistical fishing areas, regions (BSAI or GOA), vessel types (processors, motherships, and catcher_only vessels), time periods (annual or each of 13 four-week periods in a year) for each year from 1993 to 1999. As requested by USFWS, the following eleven groups of seabirds were chosen for analysis: short-tailed albatross, black-footed albatross, Laysan albatross, unidentified albatross, fulmars, gulls, shearwaters, unidentified tubenoses (procellarids), alcids, other bird species, and unidentified seabirds (those not identified to one of the other ten groups).

Incidental catch estimates were based on the number of seabirds by species in samples from observed hauls and the total commercial fish catch as estimated by the NMFS blend program. The NMFS method utilized two measures of fishing effort: total tons of groundfish catch per haul or set for the trawl fishery (NMFS blend program), and the number of hooks or pots per set for both the longline and pot fisheries (estimated for the unobserved fishery in the NMFS blend program using the average number of hooks or pots, respectively, in the observed fishery). The NMFS Observer Program NORPAC database records the weight of the catch by species in the species composition samples and the estimated weight of the entire catch (all species combined) in the whole haul or set. NORPAC also records the number of hooks or pots in the sample and the estimated number of total hooks or pots in the whole set. The number of observed birds in a species composition sample per effort (tons or hooks or pots) of that sample was used to extrapolate the number of seabirds to the whole haul or set, and similarly upwards to the whole fishery, including the unobserved effort.

On trawl vessels only, observers may use any one of three different sample sizes of groundfish catch to monitor bycatch of birds in a haul. Observers are currently advised to use the largest of the three sample sizes whenever possible However, observers do not record the sample size choice for monitored hauls which have no observable seabird bycatch. Thus, it has been necessary to calculate two alternative sets of estimates of seabird bycatch for trawlers based on the smallest (ALT1) and largest (ALT2) sizes of sampling effort recorded for fish species (see "low" and "high" estimates in Table 11). In each of these two alternative calculation methods, a "separate ratio estimator" was used to bind the results of the catch ratios and variances of data from the three different sample sizes into arbitrary equal samples which were then inflated upwards to the total catch effort of the NMFS blend program. Although, it is not known with certainty which of the 2 sets of estimates is more accurate, the probable level of seabird bycatch on trawl vessels during the 1990s lies somewhere between the 2 sets of estimates.

The unobserved weight of fish was calculated by subtracting the known weight of sampled fish on observed hauls from the estimated total weight of fish (all hauls). The estimated total number of birds caught was the sum of observed birds in the catch and the estimated unobserved birds. For each species or species group in a stratum, the number of unobserved birds was estimated by multiplying the ratio of the number of observed birds of that species or species group caught per unit of effort of sampled groundfish from observed hauls times the total estimated effort of groundfish caught in unobserved hauls. Incidental catch estimates from each stratum were summed to yield total estimates for statistical fishing areas and regions. No estimates were made for those few strata in the NMFS blend program which consisted only of data from unobserved vessels; in this regard the estimates are conservative.

Both the catch rate of birds (number of birds per weight of fish, or birds per 1,000 hooks) and the catch rate of fish (total weight of all fish species per hook/pot/net) were assumed to be equal for observed and unobserved hauls of the same gear, area, and time period. These assumptions may not hold, not necessarily because the presence of the observer may change the fishing practices of the skipper or crew, but rather because, for some other operational reason, the smaller (unobserved) vessels may have different catch rates than the large or mid-sized vessels. The constant catch rates for birds and/or fish among vessel size categories are untested and critical assumptions. If different catch rates do exist for different vessel size categories, then the average area catch rates and the estimates of the total seabird incidental catch number may be overestimated or underestimated.

In the NMFS analysis of 1993 to 2001 observer data, only three of the albatross taken were identified as a short-tailed albatross (and all from the BSAI region). Of the albatross taken, not all were identified. This analysis of 1993 to 2001 data resulted in an average estimate of one short-tailed albatross being taken annually in the BSAI groundfish hook-and-line fishery and zero short-tailed albatross being estimated taken annually in the GOA groundfish hook-and-line fishery. The incidental take limit established in the USFWS biological opinions on the effects of the hook-and-line fisheries on the short-tailed albatross is based on the actual reported takes and not on extrapolated estimated takes.

Based on estimates of seabirds observed taken in groundfish fisheries from 1989 to 1993, 85 percent of the total seabird bycatch was caught in the BSAI, and 15 percent in the GOA. Longline gear accounted for 90 percent of the total seabird bycatch, trawls for 9 percent, and pots 1 percent. (Wohl *et al.* 1995). NMFS analysis of 1997 to 2001 observer data indicates similar patterns as those seen in the 1989 to 1993 data (Figure 14). Depending on which trawl estimate is used, longline gear accounted for 94 (or 65) percent of the total average annual seabird incidental catch, trawl gear for 6 (or 35) percent and pot gear for less than 1 percent. The higher percentage of trawl incidental catch coincides with the higher trawl estimate displayed in Table 11. Based on the average annual estimates of seabirds observed taken in groundfish longline fisheries from 1993 to 2001, 93 percent of the longline seabird bycatch was caught in the BSAI, and 7 percent in the GOA (Table 10). Also of note, the bycatch rates in the BSAI are approximately 4 times higher than in the GOA (Table 10).

Incidental Catch in Longlines

Longlines catch surface-feeding seabirds that consume invertebrate prey which resemble bait. During setting of the line seabirds are hooked as they attempt to capture the bait. Birds that habitually scavenge floating material from the sea surface are also susceptible to being hooked on longlines (Brothers 1991, Alexander *et al.* 1997, Brothers, Cooper *et al.* 1999). Recent studies have implicated longline fishing in these population declines of albatross species. A model was developed for assessing the effects of longlining on wandering albatross populations at South Georgia and Crozet Islands in the Southern Ocean. The model results suggest that the marked decline in both populations, and subsequent recovery of the Crozet Islands population, can be explained by the tuna longline incidental catch (Tuck, Polacheck et al 2001). Longline fishing is considered the most recent and potentially most serious global threat faced by albatrosses and other procellariiforme taxa (Brothers *et al.* 1999a). Effects of the incidental catch in longline fisheries off Alaska of albatross and other seabirds at the population level are uncertain (Melvin et al 2001). With the exception of the short-tailed albatross, data on the number, size and geographic extent and mixing of seabird populations are poorly understood. Seabird mortality in Alaska longline fisheries represents only a portion of the fishing mortality that occurs, particularly with the albatrosses. The endangered short-tailed albatross population is currently increasing, the total population estimated at about 1600 to 1700. Mortality of black-footed and Laysan albatrosses occurs in both Alaskan and Hawaiian longline fisheries and may be assumed to occur in other North Pacific longline fisheries conducted by Japan, Taiwan, Korea, Russia, and China (Brothers *et al.* 1999b). See section 4.7.1 for a discussion of the potential cumulative impacts of North Pacific longline fisheries on the black-footed albatross (NMFS 2001b).

Estimates of the annual seabird incidental catch for the Alaska groundfish fisheries, based on 1993 to 2001 data, indicate that approximately 15,400 seabirds are taken annually in the combined BSAI and GOA groundfish fisheries (14,400 in the BSAI; 1,000 in the GOA) at the average annual rates of 0.09 and 0.01 birds per 1,000 hooks in the BSAI and in the GOA, respectively (Table 10).

Of the estimated 14,400 seabirds that are incidentally caught in the BSAI, the species composition is: 60 percent fulmars, 19 percent gull species, 12 percent unidentified seabirds, 4 percent albatross species, 3 percent shearwater species, and 2 percent ‘all other’ species (Table 8).

Of the estimated 1,000 seabirds that are incidentally caught in the GOA, the species composition is: 46 percent fulmars, 35 percent albatrosses, 11 percent gull species, 4 percent unidentified seabirds, 3 percent shearwater species, and less than 1 percent ‘all other’ species (Table 9, Figure 15). Five endangered short-tailed albatrosses were reported caught in the longline fishery since reliable observer reports began in 1990: two in 1995, one in 1996, and two in 1998, and all in the BSAI. Both of the birds caught in 1995 were in the vicinity of Unimak Pass and were taken outside the observers' statistical samples; the bird caught in 1996 was near the Pribilof Islands in an observer's sample; the two short-tails taken in 1998 were in observers’ samples.

It is difficult at this time to make valid comparisons of bird bycatch rates between regions. We cannot discern if the differences between the BSAI and GOA estimated bycatch rates are due to the vastly different levels of fishing effort in each region, the different types of vessels used in each region (‘small’ catcher vessel in GOA, ‘large’ catcher-processor in BSAI), different distribution and abundance of birds, etc. An analysis of covariance would allow for a valid statistical comparison of the regional bycatch rates.

Table 10. Annual Estimates, by Area, of Total Fishery Effort, Total Numbers and Bycatch Rates of Seabirds Taken in Longline Fisheries. Values in Parentheses are 95% Confidence Bounds.

Year	**Effort (No. of Hooks in 1,000s)**	**No. of Birds**	**Bycatch Rate No. of Birds per 1,000 Hooks**	**Percent of Hooks Observed**
Bering Sea and Aleutian Islands				
1993	123,232	7,975 (6981-8968)	0.06	24.5
1994	134,954	10,633 (9604-11662)	0.08	24.5
1995	141,779	19,214 (17853-20576)	0.14	24.2
1996	141,810	8,480 (7594-9366)	0.06	23.8
1997	176,534	18,063 (16491-19634)	0.10	22.6
1998	175,530	24,592 (22769-26415)	0.14	23.5
1999	157,319	12,409 (10940-13877)	0.08	25.0
2000	192,994	18,154 (16,562-19,746)	0.09	22.8
2001	226,186	9,992 (9,027-10,958)	0.04	21.0
Average Annual Estimates				
1993–1996	135,444	11,576 (11034-12117)	0.09	24.5
1997-2001	185,725	16,642 (15,966-17,318)	0.09	22.8
1993-2001	163,377	14,390 (13,344-14,836)	0.09	23.3
Gulf of Alaska				
1993	56,300	1,309 (1056-1563)	0.02	10.2
1994	49,452	532 (397-668)	0.01	4.9
1995	42,357	1,519 (1302-1736)	0.04	12.7
1996	33,195	1,631 (1203-2059)	0.05	10.8
1997	28,047	514 (338-689)	0.02	10.0
1998	29,399	1,495 (792-2198)	0.05	8.1
1999	31,895	1,093 (812-1375)	0.03	8.6
2000	35,345	742 (392-1,032)	0.02	6.5
2001	34,216	512 (311-713)	0.01	7.8
Average Annual Estimates				
1993–1996	45,326	1,248 (1108-1388)	0.03	9.5
1997-2001	31,780	871 (696-1,047)	0.03	8.1
1993-2001	37,801	1,039 (923-1,154)	0.03	8.8

Table 11. Range of Estimates of Total Incidental Catch of Seabirds by Species or Species Groups[a] in the Combined Bering Sea and Aleutian Islands and Gulf of Alaska Trawl Fisheries, 1997–2001

Year	Actual Number Taken[b]	Estimate Range[c]	STAL	BFAL	LAAL	NOFU	Gull	SHWR	Unid. Tubenoses	Alcid	Other	Unid. ALB	Unid. Seabird	Total
1997	55	low	0	0	80	75	0	77	0	115	0	0	181	528
		high	0	0	149	343	0	662	0	115	0	0	1074	2343
1998	45	low	0	0	134	93	1590	856	1	110	3	0	8	2794
		high	0	0	341	2617	708	1238	163	543	2494	0	1035	9138
1999	154	low	0	0	8	446	0	82	0	664	0	0	17	1218
		high	0	0	27	7810	0	812	0	730	85	0	663	10,187
2000	101	low	0	0	0	298	37	10	2	1	0	0	60	407
		high	0	0	0	9,432	114	3,034	155	182	0	0	480	13,397
2001	141	low	0	0	8	323	4	329	9	1	3	0	65	741
		high	0	0	150	9,255	288	887	863	68	297	0	681	12,488
Average Annual Estimate														
1997-2001	na	low	0	0	46	274	326	271	2	178	1	0	66	1,138
		high	0	0	133	5,891	222	1,327	236	340	575	0	787	9,511

Notes: [a] See the species and species groups footnoted in Table 8.

[b] Actual number taken is the total number of seabirds recorded dead in the observed hauls.

[c] The high and low estimates result from different methodologies used by observers to sample the haul. "Low" from effort data of observed hauls based on largest sample unit actually used by observers for fish species monitoring ("whole sample approach"). "High" from effort data of observed hauls based on smallest sample unit actually used by observers for fish species monitoring ("basket sample approach").

Table 12. Estimated Total Incidental Catch of Seabirds by Species or Species Groups[a] in the Combined Bering Sea and Aleutian Islands and Gulf of Alaska Pot Fisheries, 1993–2001. Values in parentheses are 95% confidence bounds.

Year	Actual Number Taken [b]	STAL	BFAL	LAAL	NOFU	Gull	SHWR	Unid. Tubenoses	Alcid	Other	Unid. ALB	Unid. Seabird	Total
1993	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	6	0	0	0	9 (2-23)	3 (1-10)	7 (1-20)	0	19 (2-55)	0	0	0	39 (6-79)
1996	9	0	0	0	80 (7-174)	0	0	2 (1-6)	0	0	0	7 (1-19)	89 (9-183)
1997	4	0	0	0	14 (3-29)	0	0	0	9 (1-26)	0	0	0	23 (4-46)
1998	2	0	0	0	19 (1-54)	15 (1-44)	0	0	0	0	0	0	33 (2-79)
1999	47	0	0	0	166 (71-261)	0	9 (1-26)	14 (5-28)	0	0	0	0	189 (91-286)
2000	1	0	0	0	0	0	0	0	0	0	0	42 (1-22)	42 (1-22)
2001	3	0	0	0	13 (2-33)	3 (1-8)	0	0	0	0	0	0	16 (3-36)
Average Annual Estimate													
1993–1996	na	0	0	0	22 (2-46)	1 (0-3)	2 (0-5)	1 (0-2)	5 (0-14)	0	0	2 (0-5)	32 (6-58)
1997-2001	na	0	0	0	42 (21-64)	4 (0-10)	2 (0-6)	3 (1-6)	2 (0-6)	0	0	8 (0-25)	61 (33-88)
1993-2001	na	0	0	0	33 (17-49)	2 (0-6)	2 (0-5)	2 (0-4)	3 (0-8)	0	0	5 (0-15)	48 (28-67)

Notes:

[a] See the species and species groups footnoted in Table 8.

[b] Actual number taken is the total number of seabirds recorded dead in the observed hauls.

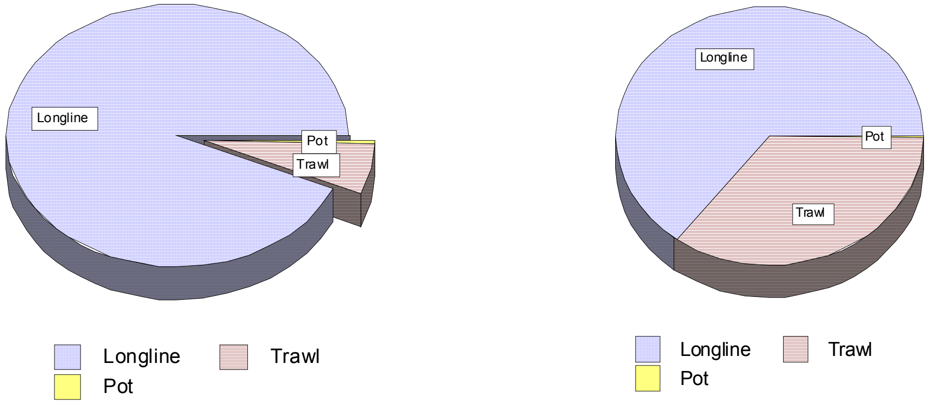


Fig. 14. Average Annual Estimate of Number of Seabirds Taken by Gear Type, 1997-2001. Estimates Differ Based on Trawl Sampling Methodology Used.

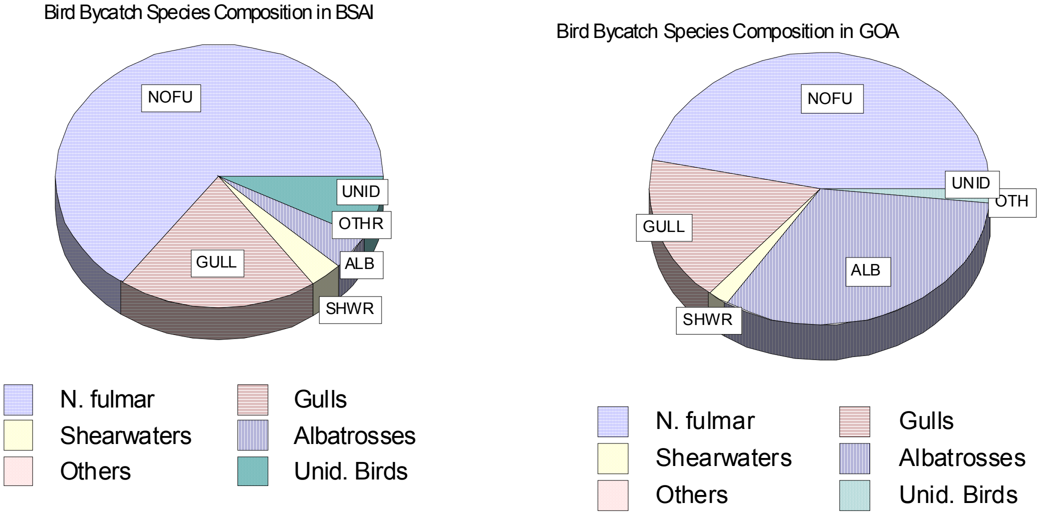


Fig 15. Relative Species Composition of Seabird Incidental Catch in the Longline Fisheries, BSAI (left) and GOA (right). Average annual estimates, 1997-2001.

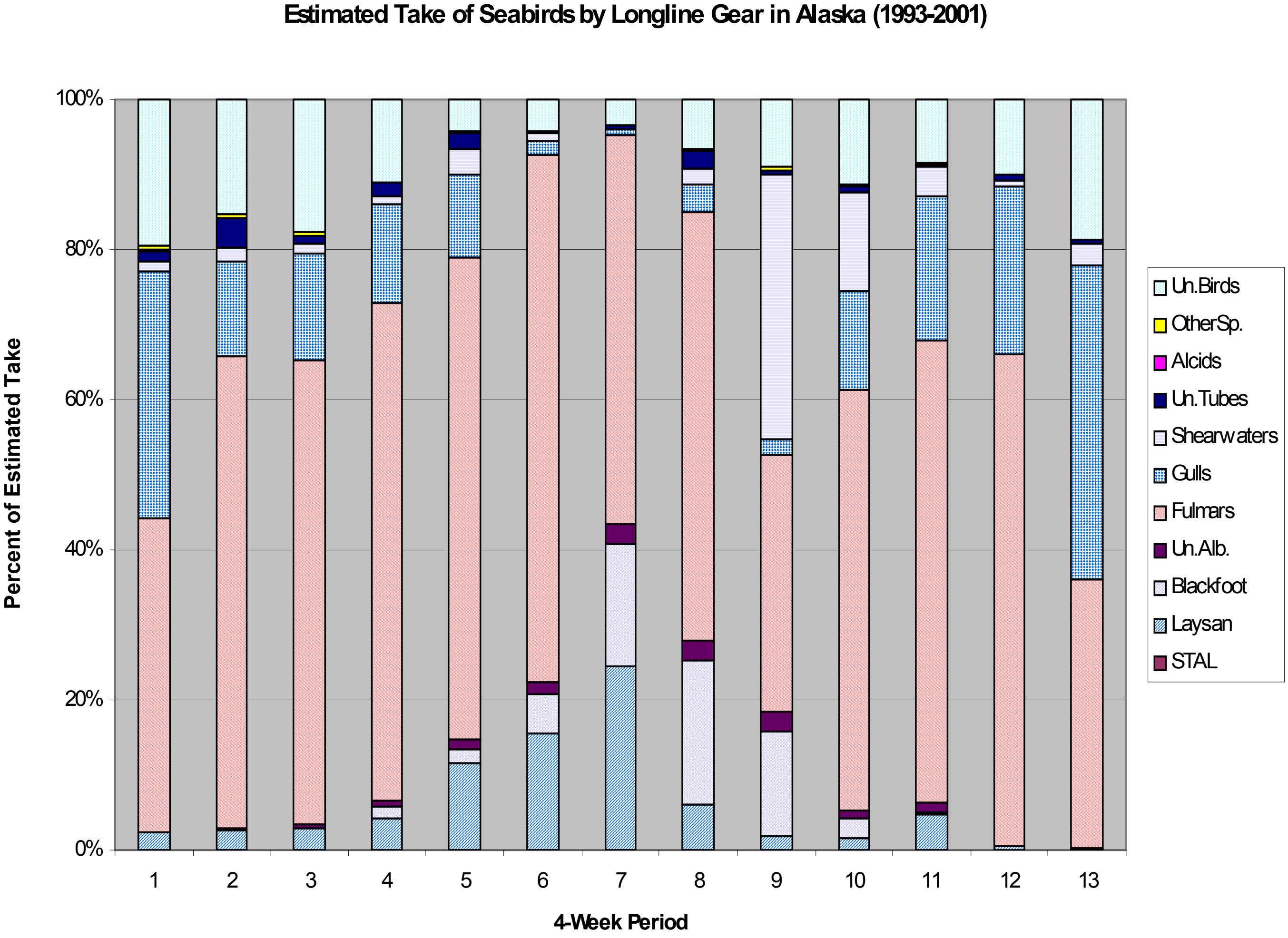


Figure 16: Cumulative Estimated Seabird Incidental Catch in Longline Fisheries in Alaska, by Species Group, by 4-Week Periods, 1993-2001.

Efforts to Reduce Seabird Incidental Catch in Longline Fisheries

The NMFS Alaska Region has been involved with ongoing efforts to reduce seabird bycatch in the longline fisheries off Alaska since the early 1990s. Efforts have included: collection of bycatch data via onboard observers; outreach and education to the fishing fleet and other stakeholders; coordination with the USFWS and full compliance with requirements of biological opinions issued under the ESA; requiring the use of seabird avoidance measures by vessel operators in longline fisheries off Alaska; research on the effectiveness of such measures; implementation of the United States' *National Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries* (NPOA); and international coordination with scientists, fishery managers, and organizations involved with these issues in other parts of the world. Participants from the NMFS Alaska Region, the Council, USFWS, fishermen, and researchers will join others in attending the *Second International Fishers Forum* in November 2002. The primary mission of the forum is to convene an international meeting of fishermen to address possible solutions to incidental catch of sea turtles and seabirds by longline fishing gear. Additional details of these Alaska Region efforts are available in several documents cited here (NMFS 1998, 1999, 2001a, 2001c, 2001d).

The NPOA contains several action elements, one which pertains to reporting. The NPOA states that "NMFS, in collaboration with the appropriate [Regional Fishery Management] Councils and in consultation with USFWS, will prepare an annual report on the status of seabird mortality for each longline fishery, including assessment information, mitigation measures, and research efforts. USFWS will also provide regionally-based seabird population status information that will be included in the annual reports. The reports will be submitted annually as part of the Stock Assessment and Fishery Evaluation (SAFE) Report that is already provided on an annual basis by NMFS and made widely available. Such annual reports will be compiled and incorporated into NMFS' biennial status report to FAO on its implementation of the *Code of Conduct for Responsible Fisheries*." The information contained within this seabird section of the "Ecosystem Considerations for 2003" hereby serves to fulfill the Alaska Region's requirements for annual NPOA reporting.

Mitigation Measures

NMFS required hook-and-line vessels fishing for groundfish in the BSAI and GOA and federally permitted hook-and-line vessels fishing for groundfish in Alaskan waters adjacent to the BSAI and GOA, to employ specified seabird avoidance measures to reduce seabird incidental catch and incidental seabird mortality in 1997 (62 FR 23176, April 29, 1997). Measures were necessary to mitigate hook-and-line fishery interactions with the short-tailed albatross and other seabird species. Prior to 1997, measures were not required, but anecdotal information suggests that some vessel operators may have used mitigation measures voluntarily. NMFS required seabird avoidance measures to be used by vessels fishing for Pacific halibut in U.S. Exclusive Economic Zone (EEZ) waters off Alaska the following year (63 FR 11161, March 6, 1998).

By regulation, all vessel operators using hook-and-line gear to fish for groundfish and Pacific halibut must conduct fishing operations as follows:

1. Use baited hooks that sink as soon as they are put in the water.
2. Discharge offal in a manner that distracts seabirds from baited hooks (if discharged at all during the setting or hauling of gear).
3. Make every reasonable effort to ensure that birds brought on board alive are released alive. In addition, all applicable hook-and-line vessels at or more than 26-ft length overall, must employ *one or more* of the next four measures.
4. Set gear at night (during hours specified in regulation).
5. Tow a streamer line or lines during deployment of gear to prevent birds from taking hooks.
6. Tow a buoy, board, stick, or other device during deployment of gear at a distance appropriate to prevent birds from taking hooks.
7. Deploy hooks underwater through a lining tube at a depth sufficient to prevent birds from settling on hooks during the deployment of gear.

Fishermen currently are provided some flexibility in choice of options in that they can select the most appropriate and practicable methods for their vessel size, fishery, and fishing operations and conditions.

In October 2001, Washington Sea Grant Program (WSGP) presented research results, recommendations, and its final report "*Solutions to Seabird Bycatch in Alaska's Demersal Longline Fisheries*" (available at http://www.wsg.washington.edu/pubs/seabirds/seabirdpaper.html) to the Council and NMFS. The Council took initial action at this meeting and final action at its December 2001 meeting.

For complete details of the research, results, and recommendations, see the WSGP final report. In summary, the WSGP research program compared seabird incidental take mitigation strategies over 2 years (1999 and 2000) in 2 major Alaska demersal longline fisheries: the Individual Fishing Quota (IFQ) fishery in the GOA and Aleutian Islands for sablefish and halibut and the Bering Sea catcher-processor longline fishery for Pacific cod. A key feature of the program was an industry-agency-academic collaboration to identify possible deterrents and test them on active fishing vessels under typical fishing conditions. The avoidance measures tested were: paired streamer lines, single streamer lines, weighted groundline, line shooter, lining tube, and a combination of paired streamer lines and weighted groundline. Experimentally rigorous tests of seabird avoidance measures on the local abundance, attack rate, and hooking rate of seabirds in both fisheries were conducted on vessels over 60 ft (18.3 m) LOA. On vessels this size (larger vessels), paired streamer lines of specified performance and material standards were found to successfully reduce seabird incidental take in all years, regions, and fleets (88 percent to 100 percent relative to controls with no deterrent). Single streamer lines of specified performance and material standards were slightly less effective than paired streamer lines, reducing seabird incidental take by 96 percent and 71 percent in the sablefish and cod fisheries, respectively. This study represents the largest of its kind in the world with over 1.2 million hooks being set in the sablefish fishery and over 6.3 million hooks being set in the cod fishery component of the 2-year research program.

The Council's recommendations to NMFS for revised seabird avoidance measures are:

- Vessels over 55 ft (16.8 m) LOA using hook-and-line gear in the EEZ would be required to use paired streamer lines of specified performance and materials standards.
- Vessels over 26 ft (7.9 m) LOA to 55 ft (16.8 m) LOA using hook-and-line gear would be required to use less stringent measures such as a buoy bag line or single streamer line—each with its own specified performance and materials standards. The requirement would depend upon fishing location ['Inside' or EEZ, where 'Inside' is Prince William Sound (NMFS Area 649), Southeast Inside District (NMFS Area 659), and state waters of Cook Inlet], vessel type (if masts, poles, or rigging are on vessel), and gear type (if snap gear is used).
- The performance and material standards for measures required on smaller vessels would be guidelines for an interim one-year period, at which time they would become required.
- Directed discharge (through chutes, pipes, or other similar devices suited for purpose of offal discharge) of residual bait or offal from the stern of the vessel while setting gear would be prohibited.
- Prior to offal discharge, embedded hooks would be removed from offal.
- A Seabird Avoidance Plan would be required onboard the vessel.
- Vessels less than or equal to 32 ft (9.8 m) LOA fishing for halibut in IPHC Area 4E within 0 to 3 miles of shore would be exempt from seabird avoidance measures.
- Vessels less than or equal to 26 ft (7.9 m) LOA would continue to be exempt from seabird avoidance measures.

The proposed seabird avoidance measures would apply to the operators of vessels using hook-and-line gear for:

- Pacific halibut in the IFQ and Community Development Quota (CDQ) management programs (0 to 200 nm),
- IFQ sablefish in EEZ waters (3 to 200 nm) and waters of the State of Alaska (0 to 3 nm), except waters of Prince William Sound and areas in which sablefish fishing is managed under a State of Alaska limited entry program (Clarence Strait, Chatham Strait), and
- Groundfish (except IFQ sablefish) with hook-and-line gear in the U.S. EEZ waters off Alaska (3-200 nm).

At its March 2002 meeting, the Alaska Board of Fisheries (Board) approved a Board-generated proposal that will change state groundfish regulations to parallel federal regulations governing seabird avoidance measure requirements for operators in hook-and-line fisheries. NMFS is currently promulgating regulations based on these Council recommendations.

Incidental Catch in Trawls

Trawls primarily catch seabirds that dive for their prey. This probably occurs as the trawl is being retrieved rather than while it is actively fishing. A few birds may also be caught as they are attempting to scavenge fish or detritus at the surface during retrieval. The species composition of seabird incidental catch in observed trawl hauls is currently available for 1993 through 2001. The principal bird species reported in trawl hauls were northern fulmars, gulls, shearwaters, and alcids. Small numbers of other species also were caught. NMFS analysis of 1993 to 2001 observer data indicates that trawl gear accounted for 6 to 35 percent of the total average annual seabird bycatch in the BSAI and GOA groundfish fisheries combined, depending on the trawl sampling methodology used (Figure 14).

Onboard observations of birds (including Laysan albatrosses) colliding with the trawl transducer wires (sometimes called third wire) have been made. These wires are typically deployed from the stern of midwater trawl vessels fishing for pollock and carry the transducer net sounder cable down to the head of the trawl net. Any birds killed by such collisions would most likely not be recorded in the observers' sampling of the trawl haul in that it is unlikely that such dead birds would make their way into the trawl net. NMFS is investigating the extent of use of trawl third wires in the trawl fleet and additional details of the bird/vessel interactions. Solutions may be as simple as hanging streamers from the third wire or trawl gantry (Balogh, USFWS; N. Smith, New Zealand Ministry of Fisheries pers. comm.). See the 'Vessel Strike' section below for additional information about this bird/trawl interaction.

Vessel Strikes

Striking of vessels by birds in flight is reported by observers, and their observations from 1993 - 2000 have recently been put in an Observer Notes Database (USFWS, Anchorage). The bird-strike data are preliminary and have not been analyzed statistically, but some quantitative summaries can be made. Of the over 2600 observation records (which include albatross sightings, vessel strikes, rare seabird observations, effectiveness of mitigation devices, etc.) there are 537 reports of birds found on the vessel, or birds striking the vessel or rigging. The records include 79 species or species groups and involve over 5,300 birds. Of these, 136 records are definitive reports of birds striking the vessel (n = 101), the rigging (n = 19), or specifically striking the 'third wire' on trawl gear (n = 16). The third wire incidents involved 79 birds, mainly fulmars and Laysan albatross, with approximately 90% mortality. The main species involved in vessel strikes were northern fulmars, Laysan albatross, storm petrels, and crested auklets, and for all vessel strikes, almost half of the birds were killed or injured.

Details on the location, time of day, or weather condition are mostly incomplete, pending the merging of observations via their cruise number and haul number to the NORPAC database. For the limited number of records that included such observations, most of the bird-vessel interactions (n= 224) occurred at night (63%) and where weather was recorded (n = 53), it was usually snowing (83%), with some occurring during rain (10%) or fog (7%). Birds are especially prone to strike vessels during storms or foggy conditions when bright deck lights are on, which can disorient them. The proximity of the vessels to seabird colonies during the breeding season is also a factor (USFWS, V. Byrd pers. com).

Incidents of vessel strikes were most frequent for fulmars (564 birds in 38 incidents), Laysan albatross (21 birds in 15 incidents), or petrel species (631 birds in 19 incidents), but the total number of birds involved was greatest for crested auklets (1,305 birds in 7 incidents). Another species with few events but large numbers of birds was the sooty shearwater (526 birds in 6 incidents). Crested auklets appear to be particularly susceptible to collisions; in winter of 1977 an estimated 6,000 crested auklets were attracted to lights and collided with a fishing vessel near Kodiak Island, and in 1964 in the central

Aleutians, approximately 1,100 crested auklets were attracted to deck lights on a processor and collided with structures on the vessel (Dick and Donaldson 1978).

Many trawl vessels deploy a cable ("third wire") from the vessel to the trawl net monitoring device. Seabird mortality resulting from interactions with the third wire has been documented, but is not directly monitored by groundfish observers. Therefore, the temporal and spatial distribution of seabird mortalities or injuries by species is unknown. NMFS's Alaska Fisheries Science Center is currently pursuing contractual arrangements for a study that would use video technology to evaluate the feasibility of detecting and identifying interactions of seabirds with the trawl third wire during trawl fishing operations.

Research Initiatives and Additional Research Needs

In 1999 and 2000, the WSGP compared seabird bycatch mitigation strategies in 2 major Alaska demersal longline fisheries: the GOA and AI IFQ fishery for sablefish and halibut and the BS catcher-processor longline fishery for Pacific cod. Researchers conducted experimentally rigorous tests of seabird bycatch deterrents on the local abundance, attack rate, and hooking rate of seabirds in both fisheries. The goal was to identify mitigation devices that significantly reduced seabird bycatch with no loss of target catch or increase in the bycatch of other organisms. Control sets with no deterrent established a baseline and allowed exploration of seabird interaction with longline gear as a function of temporal and spatial variation, physical factors such as wind and sea state, and fishery practices (Melvin et al 2001). A key feature of this program was an industry-agency-academic collaboration to identify possible deterrents and test them on active fishing vessels under typical fishing conditions. At its December 2001 meeting, the Council made recommendations to NMFS for changes to the existing regulations based on the WSGP research. NMFS is currently promulgating changes to the existing regulations. See the previous section on "mitigation measures" for additional details as well as the WSGP final report (Melvin et al 2001).

Section 4.3.4 of the Alaska Groundfish Fisheries DPSEIS included several research and/or analysis needs identified by scientists currently researching seabirds in the BSAI and GOA ecosystem (NMFS, 2001a). As the information gaps are filled, the view of how seabirds are affected by fisheries may change. Some additional research and analysis needs identified in SSC comments on the DPSEIS, in the *Draft: Bering Sea Ecosystem Research Plan* (AFSC, 1998) and by other seabird scientists are:

- Quantitative models to help evaluate the potential population-level impact of fisheries-related seabird mortality, particularly for those seabirds species that are killed in high numbers (e.g. northern fulmar), for abundant species (e.g. sooty shearwater and short-tailed shearwater, Laysan's albatross), and for less abundant species of concern (black-footed albatross).

- For many species, the potential impact of bycatch mortality needs to be assessed at the colony level. That is, are particular colonies more susceptible to bycatch impacts because of the temporal and spatial distribution of fisheries?

- Quantitative models to help evaluate the potential population-level impacts from the availability of fishery discards and offal, particularly on juvenile birds.

- Research and analysis to ascertain how much benefit seabirds of the North Pacific derive from discards and offal and to then balance that with the adverse impacts associated with the incidental take of seabirds in fishing gear as a result of vessels attracting birds via the processing wastes and offal that are discharged.

- In varying the timing of fishing effort, there may be some effects on the value to seabirds of the discards and offal that result from the fishing activity. Discards in times when the seabirds have high energy demands or when naturally available food is hard to obtain may be more valuable to the seabirds than would be true in times of plentiful prey. A question that should be explored is whether pulsed fishing saturates the ability of the seabirds to take advantage of the waste produced.

- Compilation of pelagic (at-sea) data on distribution of seabirds in Alaska and elsewhere in the North Pacific. Such data on the pelagic distribution and abundance of seabirds is critical for addressing questions such as raised in this analysis on seabirds and could be used to assess the potential interactions between commercial fisheries and seabirds (e.g. longlines and albatrosses).

- Satellite telemetry studies on the short-tailed albatross, a rare and endangered species, to accurately identify spatial and temporal distribution patterns in the BSAI and GOA, particularly as they intersect with commercial fishing activity and the potential for interactions.

- Investigate the extent of use of trawl third wires in the trawl fleet, evaluate the extent to which seabirds interact with this third wire, and if necessary, pursue the development and/or identification of practical and effective methods and devices to reduce seabird interactions with trawl vessels equipped with trawl third wires.

- Conduct a more detailed analysis of multi-year data sets of seabird bycatch to include factors such as: spatial and temporal factors for both fishing effort and seabird distribution, vessel type, effectiveness of seabird deterrent devices.

- Develop and support a minimal program to piggyback marine bird observations on suitable monitoring platforms (e.g. ADF&G, IPHC, and NMFS longline surveys; research cruises).

- Examine the temporal and spatial scale of marine bird aggregations with respect to ephemeral and stable oceanographic features and prey aggregations.

- Use telemetry and standard ship transect methods to define (horizontally and vertically) seabird apex predator feeding areas both in the Being Sea during summer and in areas outside the Bering Sea that may be visited seasonally and to define the relationship of feeding areas to principal fishing areas. Identify and quantify food items used by seabirds in these areas of overlap.

- Expand collection and sysnthesis of data on seabird diet to include fall through spring months, and for all seasons, examine regional patterns of prey use and trends over time.

- Cooperative gear research on commercial fishing vessels to evaluate effective methods for setting longlines underwater to prevent access by seabirds. Methods could include: underwater setting chutes, lining tubes, line-weighting.

In 2001 and 2002, steps were taken to address many of these research gaps by way of a congressional funding initiative. In both years, Congress allocated $575,000 to the USFWS–Office of Migratory Bird Management to reduce the impact of seabird bycatch in Alaska fisheries. Studies and contracts, implemented in FY01 and FY02, addressed the following:

1. *Demographics and Productivity of Albatrosses at Their Breeding Sites*
Recent declines in black-footed albatross, and the high bycatch rate of Laysan albatross, require more sophisticated analyses and modeling of potential population-level effects from incidental catch in groundfish fisheries. Analysis of long-term data from the Northern Hawaiian Islands breeding sites was initiated with this funding. Additionally, a banding database will be completed this year, with the goal of assisting demographics and modeling efforts.

2. Demographics of Albatrosses and Fulmars Caught in Alaska Longline Fisheries

The NMFS North Pacific Groundfish Observer Program began collecting albatross and fulmar carcasses from birds caught in longline fisheries from the BSAI, to be shipped to the University of Alaska, Fairbanks. The UAF Museum has been processing the carcasses to obtain demographic information such as age and sex, as well as body size, condition and other mensural characteristics. Salvaged tissue samples will be sent to USGS/BRD and University of Washington researchers to conduct genetic analyses. Genetic studies may identify colony or region of origin, and together with the demographic information, assist modeling to determine whether population-level effects occur. The project will extend in 2003 to include the GOA region. To date, over 80 carcasses have been processed.

Funds also supported a pilot satellite telemetry project on fulmars (presented in this report). This will eventually determine where fulmars forage throughout the year, to alert fishers of high density fulmar regions and better understand population dynamics.

3. Short-tailed Albatross Satellite Telemetry Tracking and Data Analysis

A joint U.S.-Japan initiative was implemented to determine the occurrence and marine habitat use of the endangered Short-tailed albatross in the Bering Sea and North Pacific. In 2001 and 2002 birds were tagged at Torishima Island, Japan, and a contract was established to fund analysis of albatross distribution and marine habitat use of tagged birds. Information will alert fishers of albatross high-use areas, and will benefit efforts to enhance albatross population recovery and delisting.

4. Pelagic Seabird Database

All agencies identify the need for a comprehensive database on offshore distribution and abundance of waterbirds in Alaska. Over three decades of various types of surveys need to be standardized and synthesized, but could answer basic questions such as where the birds are, when are they present and how many are there. The database will eventually be available to agency and industry groups via a website, to provide fishers with locations of high density seabird areas to promote bycatch avoidance and efficiency in fishing.

Work began on the development of the North Pacific Pelagic Seabird Database, via a contract with the USGS/BRD, in cooperation with USFWS, NMFS, and MMS. Preliminary results from this effort include the at-sea distribution maps of selected seabirds subject to incidental catch in the fisheries, which have been incorporated into this chapter section. As the database is completed and updated, it will assist analysis of additional aspects of seabird distribution, such as long-term temporal and spatial changes.

5. *Educational Video for Fishers*

A contract was established with the Washington Sea Grant Program, University of Washington, to develop a video for fishers, to alert them to the problem of seabird bycatch, methods to reduce bycatch, and instruction on the deployment of bycatch avoidance devices. Footage of fishing operations and streamer deployment have been made, and work has begun on the production of the video.

6. *Fishery Observer Bird Observation Report*

The NMFS North Pacific Groundfish Observer Program contributes incidental information on seabird sightings and seabird-related incidents to the USFWS. The information, while valuable, was not in an easily accessible database. This project entered the observations into a database to make them accessible and quantifiable to all user groups. The main entries of interest include albatross sightings, vessel strikes, rare seabird observations, and notes on effectiveness of mitigation devices. Preliminary results, some of which have been included in this report, assisted in the development of new Seabird Daily Log data sheets. The observer records will be merged with the NORPAC database to complete information such as location and weather for each record.

7. *Test Of A Prototype Weighted Sink Line*

To continue the search for more universally practical, cost effective and efficient methods, this project tests the effectiveness of integrated weight groundlines as a seabird bycatch deterrent in longline fisheries. The Washington Sea Grant Program conducted field tests in Alaska in 2002 on 4 types of lines under different boat sizes and configurations, and will make results available to all parties. Preliminary results indicated that weighted groundlines could be cost-effective and successful at reducing incidental take of birds.

8. *Test Bycatch Reduction Devices On Small Vessels*

Paired streamer lines, properly deployed, are effective in reducing seabird bycatch, but tests conducted between 1999 and 2000 were based on vessels > 55 ft. This project studied the effectiveness of performance and material standards for small vessels to reduce seabird bycatch. In a cooperative study between USFWS and Washington Sea Grant, field work was completed in June 2002 and a final report on the results will be made available in October 2002, to assist NMFS and the Council in defining regulatory actions.

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Ecosystem or Community Indicators and Modeling Results

Ecosystem Analysis of the Pribilof Archipelago

Contributed by Lorenzo Ciannelli, FOCI, University of Washington

In spite of absence of clear geographical boundaries, the biological features of the water adjacent the Pribilof Islands are distinct from the rest of the Bering Sea. In this study we attempted to identify the boundary of the Pribilof ecosystem using energetic arguments. In particular, the boundary was defined as the one that accommodates most of the energetics requirements of the species residing within the system (i.e. balance between predation and production). We constructed a mass-balance ecosystem model representative of the period from 1990-2000, and applied it to progressively larger concentric areas around the Pribilof Islands. Results indicated that the species community residing around the Pribilof reached the highest balance between predator demand and prey production within a circular area of 100 nautical miles radius from the center of the archipelago. Groups that played a major role in defining the extent of the boundary were the "central place foragers" (CPF), and particularly fur seals, due to the long foraging trips typical of these animals. Our findings can be useful in understanding the role of the Pribilof ecosystem both as a juvenile pollock nursery area and as an ecosystem nested within the larger Bering Sea. Further, our study and the methodology implied have potential applicability in setting the limits of marine reserves meant to protect CPF.

Introduction

The Pribilof Archipelago, in the Bering Sea is composed of two major islands, St. Paul and St. George, and two minor islands, Walrus and Otter Islands. Despite the absence of defined physical boundaries, the area around these islands may be ecologically bounded from the rest of the Bering Sea. A favorable combinations of physical events (Stabeno *et al.* 1999a, Flint *et al.*, In press) makes the waters around the Pribilof Islands among the most productive of the Bering Sea (Cooney and Coyle, 1982; Coyle and Cooney 1993; Flint *et al.*, In press). High production around the Pribilofs likely permeates higher up in the trophic web, both in the benthic and pelagic systems, and contributes to create further biological distinction of the Pribilof region from the rest of the Bering Sea. In this paper we address the problem of spatially-defining the Pribilof Archipelago ecosystem. From an energetic perspective, an ecosystem is defined as an area within which the energy flow is balanced (Odum, 1969). Hence, we define the Pribilof ecosystem boundary as the smallest area within which prey availability is in balance with predator demand. The energy balance between predator demand and prey availability is estimated using a mass-balance analysis on different geographic scales, each representative of a progressively larger concentric region with the Pribilof Archipelago at its center.

Mass-balance model description

The model used to balance the energy flow within a community was ECOPATH (Polovina, 1984; Christensen and Pauly, 1992; Christensen *et al.*, 2000), distributed by the Fisheries Centre at the University of British Columbia, BC, Canada (www.ecopath.org). Henceforth we just reiterate few model characteristics relevant to this study. Ecopath is a static mass-balance model that describes the flow of energy in a trophic web. Assuming a mass balance and a steady-state, the production from a trophic group *i*, is partitioned among predation, export (*Ex*) and other losses:

$$PB_i B_i EE_i = Ex_i - \sum_1^n DC_{ji} QB_j B_j \qquad (1)$$

where *PB* and *QB* is the mass specific production and consumption rates, *DC* is the diet composition matrix and *EE* is the ecotrophic efficiency.

In Ecopath the total mortality fraction of a group (Z) is composed of a predation mortality (M2), fishing mortality (F) and "other mortality" (M0) due to diseases or senescence. For each group, the three sources of mortality are derived as follows:

$$M2_i = \frac{\sum_j Q_{ji}}{B_i},$$

$$F_i = \frac{H_i}{B_i}, \text{ where } H_i \text{ is harvest on group } i,$$

$$M0_i = (1 - EE_i)Z_i.$$

Moreover, for each group, M2 is further partitioned among all predators that feed on it, in proportion to the quantity consumed (Christensen *et al.*, 2000).

In this application of Ecopath, Equation 2 is solved for EE, and the input parameters for each trophic group included in the food web are PB (y^{-1}), QB (y^{-1}), B (MT km^{-2} y^{-1}), and diet (DC) expressed as weight percentage. If group production does not exceed the amount predated upon or removed, then the EE will be less than or equal to 1. However, if production is lower than predation or removal, then the EE will be higher than 1, in proportion to the amount needed to fulfill the excess lost.

Trophic groups and parameters

A total of 39 trophic groups plus two detritus pools (benthic and pelagic) have been included in our Ecopath representation of the Pribilof Islands food web (Table 1). A description of how we estimated the biomass, physiological rates (PB and QB) and diet of all trophic groups is presented in the Ciannelli (2002).

Table 1. List of trophic groups included in food web analysis, with respective trophic level (TL), production to biomass rate (P/B, year-1), consumption to biomass rate (Q/B, year-1), and biomass (B, MT km-2). The biomass is shown for each system (50 NM, 100 NM, 150 NM) simulated.

Trophic group				Biomass (MT km-2)		
	TL	P/B	Q/B	50NM	100NM	150NM
Phytoplankton	1	111.00		36.220	36.220	36.220
Pelagic detritus	1					
Benthic detritus	1					
Protozoa	1.9	72.00	144.00	10.00	10.00	10.00
Bacterioplankton	2	150.00	300.00	11.08	11.08	11.08
Crabs	2	1.16	5.09	1.78	1.48	1.27
Infauna	2	1.97	12.00	22.45	17.94	13.80
Microzooplankton	2.4	9.00	27.00	25.00	25.00	25.00
Mesozooplankton	2.4	9.00	27.00	25.74	25.74	25.74
Macrozooplankton	2.5	2.70	9.00	16.60	16.60	16.60
Epibenthic	2.6	1.58	5.78	6.99	5.81	4.39
Small jellies	2.7	7.00	23.00	50.00	50.00	50.00
Agonidae	3.1	0.40	2.56	0.13	0.07	0.05
Small flatfishes	3.1	0.40	2.97	8.12	7.05	5.47
Chaetognaths	3.4	1.35	3.87	25.05	25.05	25.05
Forage fishes	3.4	1.00	7.00	<0.01	5.00	10.00
Mesopelagic fishes	3.5	1.57	7.83	<0.01	1.48	2.20
Liparidae	3.5	0.60	2.49	<0.01	0.05	0.05
Zoarcidae	3.5	0.60	2.49	0.06	0.23	0.28
Juvenile gadids	3.6	6.97	20.23	3.56	3.28	3.08

Rockfish	3.6	0.16	3.10	0.08	1.24	2.77
Adult pollock	3.8	0.50	4.16	15.60	11.66	8.56
Squids	3.9	3.20	10.67	1.00	2.00	3.50
Large jellies	3.9	1.50	3.00	15.00	16.00	19.00
Sculpins	3.9	0.40	2.56	0.98	0.61	0.48
Skates	4	0.40	2.56	1.04	1.03	1.11
Adult cod	4.1	0.50	4.16	2.42	1.86	1.43
Thick-billed murres	4.1	0.97	18.04	0.05	0.01	0.01
Large flatfishes	4.2	0.40	2.92	2.83	2.99	3.03
Grenadier	4.2	0.40	2.49	<0.01	12.87	13.83
Stellar sealions	4.2	0.06	27.04	<0.01	<0.01	<0.01
Sablefish	4.4	0.40	2.49	<0.01	0.13	0.20
Black-legged kittiwakes	4.4	0.80	51.76	<0.01	<0.01	<0.01
Puffins	4.4	0.80	11.79	<0.01	<0.01	<0.01
Common murre	4.5	1.09	17.03	0.02	<0.01	<0.01
Red-legged kittiwakes	4.5	0.80	51.76	<0.01	<0.01	<0.01
Red-faced cormorant	4.5	0.80	9.45	<0.01	<0.01	<0.01
Harbor seals	4.5	0.06	19.44	<0.01	<0.01	<0.01
Sleeper sharks	4.6	0.40	2.56	<0.01	0.07	0.17
Dall porpoises	4.6	0.06	28.01	<0.01	<0.01	<0.01
Fur seals	4.7	0.06	19.96	1.30	0.32	0.14

Simulation scheme

We estimated the energy balance of three trophic webs, each representative of a species assemblage at increasing distances from the Pribilof Islands during the decade 1990-2000. The area of the three simulated systems were assumed those of circles, with radii of 50 (50 NM system), 100 (100 NM system) and 150 (150 NM system) nautical miles from a point located at approximately the center of the Pribilof Archipelago (57^{o} 00.00' N, 170^{o} 00.00' W) (Fig. 1). Within each system, the balance between predator demand and prey availability was measured by the EE of the prey (i.e., EE>1 indicated that more prey biomass was removed than produced). Moreover, the mortality fractions of groups with EE > 1 (henceforth overtaxed groups) were partitioned among its component Z and M2, to further investigate reasons leading to unbalance. To evaluate the overall degree of energy balance within each system we defined a unique metric, EB, from the sum of the EE's of the overtaxed groups only:

$$EB = \sum_{k=1}^{m} EE_k$$

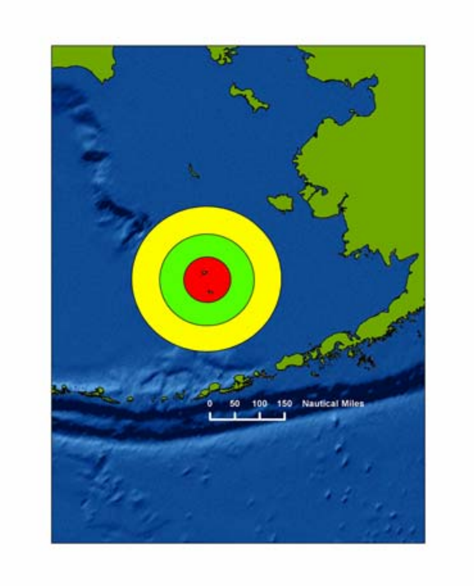

Figure 1. Simulated areas in food web analysis around the Pribilof Archipelago. Each area has a circular shape with radius of 50 (red circle), 100 (green circle) and 150 (yellow circle) nautical miles from a point located at approximately the center of the Pribilof Archipelago (57^{o} 00'.00 N, 170^{o} 00'.00 W).

where *m* is the number of overtaxed groups within a simulated system. Using a Monte-Carlo re-sampling approach, we assessed the error of EB estimates from 1,000 model runs generated by random combinations of input parameters sampled from pre-specified uniform distributions. The parameter distributions used in the error analysis were representative of the uncertainty in the initial parameter estimate (Ciannelli, 2002).

Results

Within the 50 NM system, many species were in energetic imbalance, as suggested by their high EE (Table 2). Trophic groups with highest EE were mesopelagic fish (EE = 2,209.98) and shelf forage fish (EE = 1,757.68) (Table 2). Other trophic groups that had EE higher than one were zoarcidae, adult pollock, agonids, juvenile gadids, squids, macrozooplankton, microzooplankton, crabs and protozoa (Table 2). Fur seals caused more than 52% and 56% of the total predation mortality of the mesopelagic and shelf forage fishes, respectively (Fig. 2). Increasing the system boundary from 50 to 100 nautical miles drastically reduced the energetic imbalance of mesopelagic and shelf forage fishes. Their respective EE dropped to 6.27 and to 1.25 (Table 2). A further increase of the system boundary, from 100 to 150 NM resulted in a further energetic balance of mesopelagic fishes, forage fishes, and squids, albeit to a much smaller degree (6.27 to 4.85 mesopelagic fishes, 1.25 to 0.63 forage, 2.13 to 1.16 squids) than that observed from the 50 to the 100 NM system. Moreover, an even larger number of trophic groups further increased their EE in the 150 NM simulation with respect to the 100 NM simulation (Table 2).

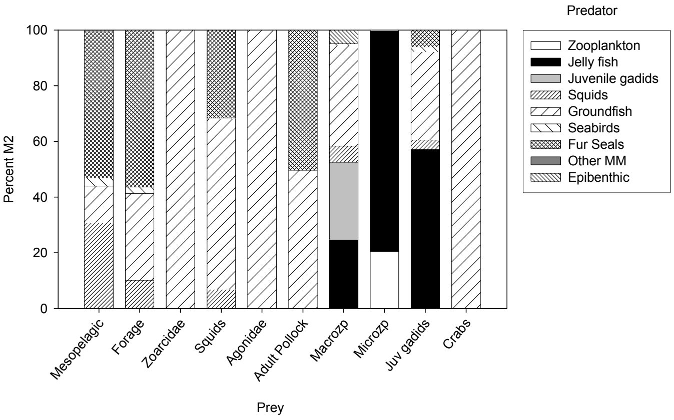

Figure 2. Partitioning of predation mortality (M2) of all groups with EE > 1 in the 50 NM ecosystem simulation. Prey groups are indicated in the x-axis and predator groups are indicated by the color code legend (Zooplankton = mcro-, meso- and macro-zooplanton; Other MM = marine mammals other than fur seals; Macrozp = macrozooplankton; Microzp = microzooplankton; Juv gadids = juvenile gadids).

The estimated average EB for each system, resulting from the Monte Carlo model run under parameter uncertainty, was 5,779.76 (standard deviation 3,273.53) for the 50 NM boundary, 23.59 (8.98) for the 100 NM system and 25.45 (8.38) for the 150 NM system. All EB values were significantly different from each other (P<0.001).

Table 2. Results of ecotrophic efficiency (EE) for all trophic groups and systems (50NM, 100NM, 150NM) simulated. Groups with EE>1 are in bold.

Group name	Ecotrophic Efficiency		
	50 NM	100 NM	150 NM
Phytoplankton	0.30	0.30	0.30
Pelagic detritus	0.81	0.81	0.82
Benthic detritus	0.25	0.21	0.17
Protozoa	**1.02**	**1.02**	**1.02**
Bacterioplankton	0.90	0.90	0.90
Crabs	**1.24**	**1.41**	**1.52**
Infauna	0.90	0.90	0.90
Microzooplankton	**1.29**	**1.29**	**1.29**
Mesozooplankton	0.70	0.83	0.96
Macrozooplankton	**1.86**	**2.08**	**2.39**
Epibenthic	0.63	**1.43**	**1.98**
Small jellies	0.01	0.01	0.02
Agonidae	**3.44**	**2.11**	**2.68**
Small flatfishes	0.36	0.28	0.46
Chaetognaths	0.35	0.32	0.30
Forage fishes	**1757.68**	**1.25**	0.63
Mesopelagic fishes	**2209.98**	**6.27**	**4.85**
Liparidae	0.16	0.16	0.16
Zoarcidae	**16.28**	**47.26**	**43.17**
Juvenile gadids	**1.27**	**1.35**	**1.60**
Rockfish	0.19	0.02	0.02
Adult pollock	**3.15**	**2.25**	**2.46**
Squids	**4.88**	**2.13**	**1.16**
Large jellies	0.00	0.00	0.00
Sculpins	0.69	0.71	0.70
Skates	0.04	0.06	0.03
Adult cod	0.66	0.35	0.27
Thick-billed murres	0.00	0.00	0.00
Large flatfishes	0.84	0.74	0.71
Grenadier	0.62	0.62	0.62
Stellar sealions	0.00	0.00	0.00
Sablefish	0.00	0.00	0.00
Black-legged kittiwakes	0.00	0.00	0.00
Puffins	0.00	0.00	0.00
Common murre	0.00	0.00	0.00
Red-legged kittiwakes	0.00	0.00	0.00
Red-faced cormorant	0.00	0.00	0.00
Harbor seals	0.00	0.00	0.00
Sleeper sharks	0.00	0.00	0.00
Dall porpoises	0.00	0.00	0.00
Fur seals	0.03	0.03	0.03

Discussion

Our analysis showed that the predatory demand of the species community residing within 50 nautical miles from the center of the Pribilof Islands was unsustainable, given the available prey biomass and production. However, an enlargement of the ecosystem boundary brought the predator community toward a better energetic balance with their prey. This was shown by a progressive reduction of the EE of key prey groups as the system increased its boundary (Table 2), coupled with a reduction of whole-system EB. Key prey species in defining the community energetic balance were the mesopelagic fishes and the shelf forage fishes, and key predator species were the Central Place Foragers (CPF) and in particular, fur seals.

The achievement of energetic balance between predator demand and prey availability, however, did not progress steadily as the system increased its boundary. This was shown by a large decrease in EE of key forage species from the 50 to the 100 NM system, followed by a rather smaller decrease from the 100 to the 150 system (Table 2), and by an initial (from 50 to 100 NM) large decrease of system EB followed by a slight increase in the 150 NM system. Thus, while the Pribilof system gained energetic balance upon an initial boundary enlargement, a continuous enlargement did not result in further balance, but rather brought the system toward new imbalances. Supposedly, as the system got larger, besides including more prey and spreading CPF predation pressure over a broader area, higher biomass of non-CPF predators also was incorporated within its boundary. This result would indicate that the Pribilof ecosystem boundary couldn't grow indefinitely, further corroborating the assumption of a real functional distinction of the Pribilof area from the rest of the Eastern Bering Sea. Based on the above evidence, we conclude that the 100 NM simulation yielded a more realistic representation of a balanced community than either the 50 or the 150 NM simulations. Hence we infer that during the 1990-2000 decade the Pribilof ecosystem boundary was closer to the 100 NM radius, than it was to either the 150 or the 50 NM radius.

In this study it was found that fur seals can exert a massive predatory impact on the Pribilof system, especially within a narrow region around the Islands. However, fur seals as well as other apex predators can be seen as important production boosters of the system. These animals bring enormous amount of organic matter back in the nearshore waters of the Pribilofs, releasing it in the form of feces, dead bodies or excretion (i.e. detritus). The released necromass will be decomposed in nutrients and recycled back into the system, particularly in near-shore waters where mixing and recycling potential are very high (Stabeno *et al*., 1999). In that regard, the apex predators of the Pribilof ecosystem, and particularly fur seals, can be compared to farmers in terrestrial systems. By fertilizing the soil, farmers enhance production and increase the harvest. Likewise, by bringing biomass in nearshore waters, fur seals augment the productivity around the Pribilofs. Ironically, if fur seals did not reside on the Pribilofs and did not impact the prey community as they actually do, the productivity of the system could be considerably reduced. From the ecosystem simulation around the Pribilof (Table 2) it is evident that within the 100 NM boundary there is both an excess of primary and detritus production (EE = 0.30 and 0.21 respectively), and part of the excess biomass can be advected to adjacent areas.

In summary, our study shows that energetic arguments at the community level can be used to define the constraints that spatially define aquatic systems that are not otherwise bounded from adjacent areas. Our study and the methodology implied have potential applicability in setting the limits of marine reserves meant to protect CPF. This is a topic of paramount relevance particularly for the Bering Sea and Gulf of Alaska regions where local populations of many CPF have been declining during the last 20-30 years.

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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 Joe Terry

The retention and sale of crab, halibut, herring, and salmon generally is prohibited in the groundfish fishery; therefore, these are referred to as prohibited species. The prohibition was imposed to reduce the catch or bycatch of these species in the groundfish fishery. A variety of other management measures have been used to control the bycatch of these species and data from the groundfish observer program have been used to estimate the bycatch of these species and the bycatch mortality of halibut. Most of the groundfish catch and prohibited species bycatch is taken with trawl gear.

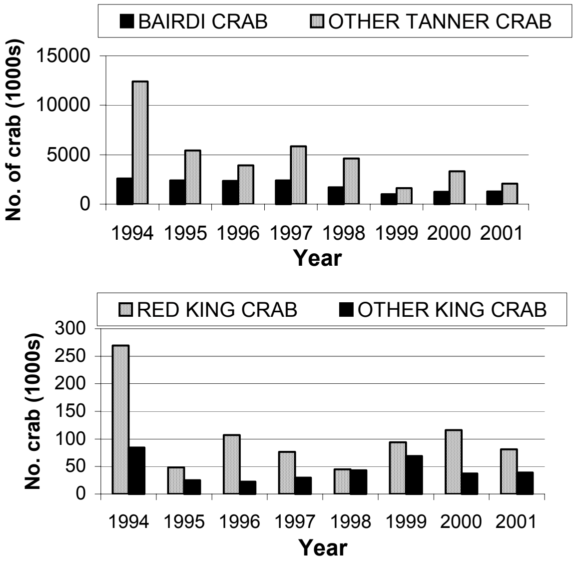

Figure 1.--Tanner and king crab bycatch in groundfish fisheries off Alaska, 1994-2001.

The implementation of the halibut and sablefish IFQ programs in 1995 allowed for the retention of halibut in the hook and line groundfish fishery and effectively addressed an important part of the halibut bycatch problem in that fishery, but it also made it very difficult to differentiate between halibut catch and bycatch for part of the hook and line groundfish fishery. Therefore, the estimates of halibut bycatch mortality either for the hook and line fishery or for the groundfish fishery as a whole are not comparable before and after 1995.

Estimates of the bycatch of prohibited species other than halibut and estimates of halibut bycatch mortality are presented in Figures 1-2. Halibut bycatch is managed and monitored in terms of bycatch mortality instead of simply in terms of bycatch. This is done to provide an incentive for fishermen to increase the survival rate of halibut that are discarded. The survival rates for discarded salmon and herring are thought to approach zero and there is substantial uncertainty concerning the

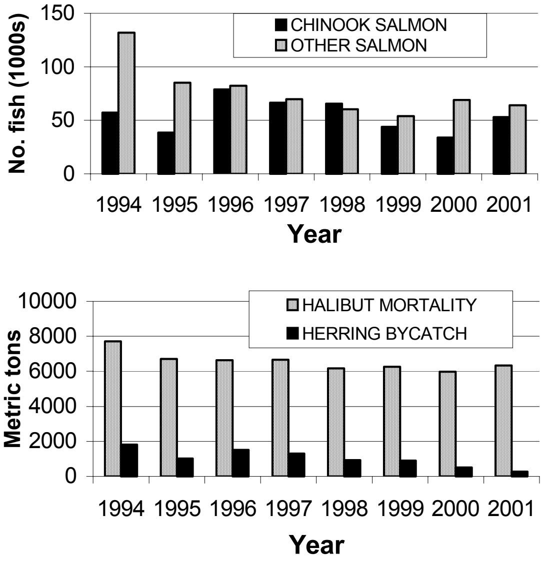

Figure 2. Bycatch of salmon, halibut, and herring in the groundfish fisheries off Alaska, 1994-2001.

survival rates for discarded crab. Currently, the limited ability to control or measure survival rates for the other prohibited species makes it impracticable to manage and monitor their bycatch in terms of bycatch mortality.

Time trends in groundfish discards

Contributed by Joe Terry, Alaska Fisheries Science Center

The amount of managed groundfish species discarded in Federally-managed groundfish fisheries dropped in 1998 compared to the amounts discarded in 1994-97 (Figure 1). The aggregate discard rate in each area dropped below 10% of the total groundfish catch. The substantial decreases in these discard rates are explained by the reductions in the discard rates for pollock and Pacific cod. Regulations that prohibit discards of these two species were implemented in 1998. Discards in the Gulf of Alaska have increased somewhat since 1998 but are still lower than amounts observed in 1997, prior to the implementation of the improved retention regulations. It should be noted that although the blend estimates are the best available estimates of discards, these estimates are not necessarily accurate because they are based on visual observations of observers rather than data from direct sampling.

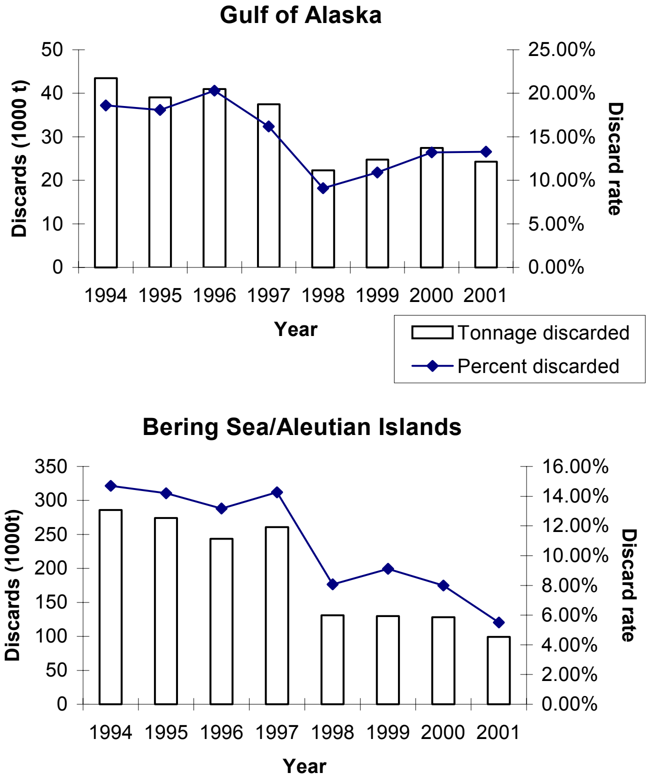

Figure 1. Total biomass and percent of total catch biomass of managed groundfish discarded in the GOA and BS/AI areas 1994-2001. (Includes only catch counted against Federal TACS.)

Time Trends in Non-Target Species Bycatch and Discards (not yet updated for 2002)

By Sarah Gaichas and Pat Livingston, Alaska Fisheries Science Center

In addition to prohibited species and target species catches, groundfish fisheries also catch and discard non-target species (Figure 1). There are three main categories of non-target species: forage (gunnels, lanternfish, sandfish, sandlance, smelts, sticheids, euphausiids), non-specified species (anemones, benthic invertebrates, birds, coral, crabs, echinoderm, grenadier, jellyfish, seapen/whip, shrimp, sponge, starfish, tunicates), and other species (dogfish, octopus, salmon shark, sculpin, shark, skates, sleepershark, squid).

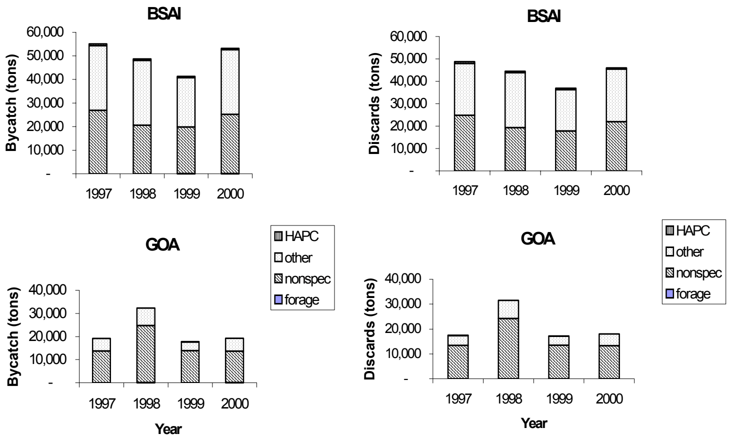

Figure 1. Bycatch and discard estimates of non-target species in the BSAI and GOA areas by groundfish fisheries.

In the BSAI most bycatch and discard consisted of species in the non-specified and other categories. Dominant species groups were jellyfish, grenadier, starfish, and skates. Nonspecified species comprised the majority of the bycatch and discard in the GOA and grenadier was the dominant group. Other non-target species caught in the GOA were primarily skates. HAPC biota bycatch estimates are presented in Figure 1 but are too small relative to the other non-target bycatch sources to be seen. HAPC biota bycatch estimates range from about 550-750 t in the BSAI and 25-35 t in the GOA. Most bycatch of all these non-target species is discarded.

These non-target species discard estimates are very similar in amount to the discards of target species in the GOA. Bering Sea discard amounts of non-target species are more than double the non-target species discards in the GOA but are less than one-third of the discard amount of target species in the BSAI (see section above on groundfish discards). As noted above in the groundfish discard estimate section, it should be noted that although the blend estimates are the best available estimates of discards, these estimates are not necessarily accurate because they are based on visual observations of observers rather than data from direct sampling.

Ecosystem Goal: Maintain and Restore Fish Habitats

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

Contributed by Cathy Coon, NPFMC

Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut) (Table 1, Figure 1). 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 1. 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 2000 and 2001. For 2001, over 90,000 nmi of the EEZ off Alaska was closed to trawling year-round. Additionally 40,00 nmi were closed on a seasonal basis. State waters (0-3nm) are also closed to bottom trawling in most areas.

Figure 4. Groundfish closures in Alaska's Exclusive Economic Zone

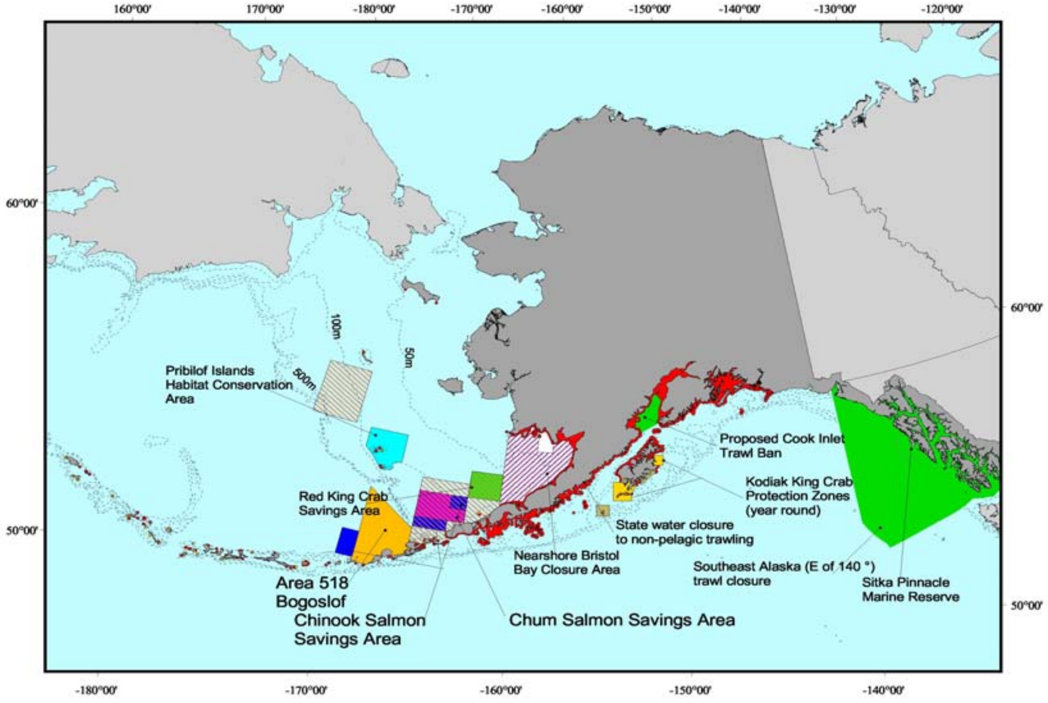

Table 1. Time series of groundfish trawl closure areas in the BSAI and GOA, 1995-2002

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
	CSSA	8/1-8/31	5,000 nm^2	re-closed if 42,000 chum salmon in bycatch
	CHSSA	trigger	9,000 nm^2	closed if 48,000 Chinook salmon bycatch
	HSA	trigger	30,000 nm^2	closed to specified fisheries when trigger reached
	Zone 1	trigger	30,000 nm^2	closed to specified fisheries when trigger reached
	Zone 2	trigger	50,000 nm^2	closed to specified fisheries when trigger reached
	Pribilofs	year-round	7,000 nm^2	established in 1995
	RKCSA	year-round	4,000 nm^2	established in 1995; pelagic trawling allowed
	Walrus Islands	5/1-9/30	900 nm^2	12 mile no-fishing zones around 3 haul-outs
	SSL Rookeries	seasonal ext.	5,100 nm^2	20 mile extensions around 8 rookeries

1996 Same closures in effect as 1995
1997 Same closure in effect as 1995 and 1996, with two additions:

Bristol Bay	year-round	19,000 nm^2	expanded area 512 closure
COBLZ	trigger	90,000 nm^2	closed to specified fisheries when trigger reached

1998 same closures in effect as in 1995, 1996, and 1997

1999 same closure in effect as in 1995, 1996, 1997 and 1998

2000 same closure in effect as in 1995, 1996, 1997 ,1998 and 1999
with additions of 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 29,000 nm^2
Mackerel Restrictions

2001 same closure in effect as in 1995, 1996, 1997 ,1998 and 1999, 2000
with additions of 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 29,000 nm^2
Mackerel Restrictions

2002 same closure in effect as in 1995, 1996, 1997 ,1998 and 1999, 2000, 2001
with additions of 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 29,000 nm^2
Mackerel Restrictions

Gulf of Alaska

Year	Location	Season	Area size	Notes
1995	Kodiak	year-round	1,000 nm^2	red king crab closures, 1987
	Kodiak	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 around 14 rookeries
	SSL Rookeries	seasonal ext,	1,900 nm^2	20 mile extensions around 3 rookeries
1996	same closures in effect as in 1995			
1997	same closures as in 1995 and 1996			
1998	same closures as in 1995, 1996 and 1997, with one addition:			
	Southeast trawl	year-round	52,600 nm^2	adopted as part of the license limitation program (11,929 nm^2 area on the shelf)
1999	same closures as in 1995, 1996, 1997 and 1998, with two additions:			
	Sitka Pinnacles Marine reserve	year-round	3.1 nm^2	Closure to all commercial gear
	Sea Lion haulouts			
2000	same closures as in 1995, 1996, 1997, 1998 and 1999			
	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*	
2001	same closures as in 1995, 1996, 1997, 1998 and 1999, 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*	
2002	same closures as in 1995, 1996, 1997, 1998 and 1999, 2000, 2001			
	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*	

CSSA= chum salmon savings area
CHSSA= Chinook salmon savings area
RKCSA = red king crab savings area
HSA = herring savings area
SSL= Steller sea lion
COBLZ= c. opilio bycatch limitation zone

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

Contributed by Cathy Coon, NPFMC

This fishery is prosecuted with stationary lines, onto which baited hooks are attached. Gear components include the anchors, groundline, gangions, and hooks. The fishery is prosecuted with both catcher vessels and freezer longliners. The amount of effort (as measured by the number of sets) in longline fisheries is used as an indicator for target species distribution as well as for understanding habitat effects. Figures 1-3 show the spatial patterns and intensity of longline effort, 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) as well as changes in markets and increased bycatch rates of non-target species.

Bering Sea

For the period 1998-2001, there were a total of 65,286 observed longline sets in the Bering Sea fisheries. Spatial patterns of fishing effort were summarized on a 5km^2 grid (Figure 1). 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, as well as 521-533. This fishery occurs mainly for Pacific cod, Greenland turbot, and sablefish.

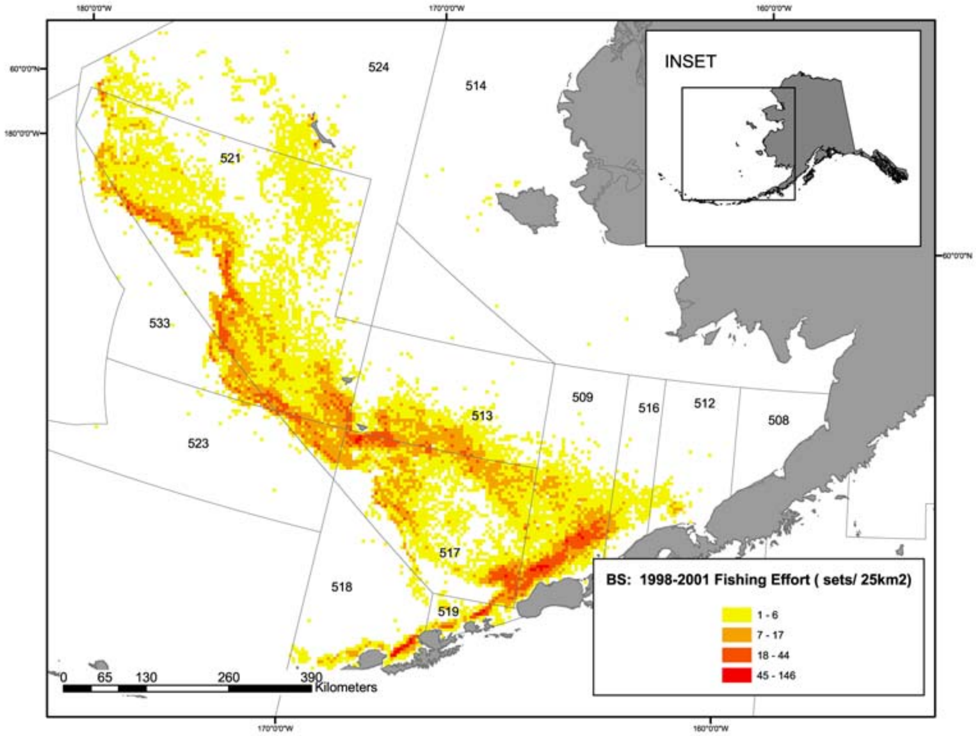

Figure 1. Spatial location and density of hook & line (longline) effort in the Bering Sea 1998-2001.

Aleutian Islands

For the period 1998-2001 there were 13,462 observed hook and line sets in the Aleutian Islands. The spatial pattern of this effort is dispersed over a wide area. Patterns of high fishing effort are dispersed along the shelf edge (Figure 2).

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.

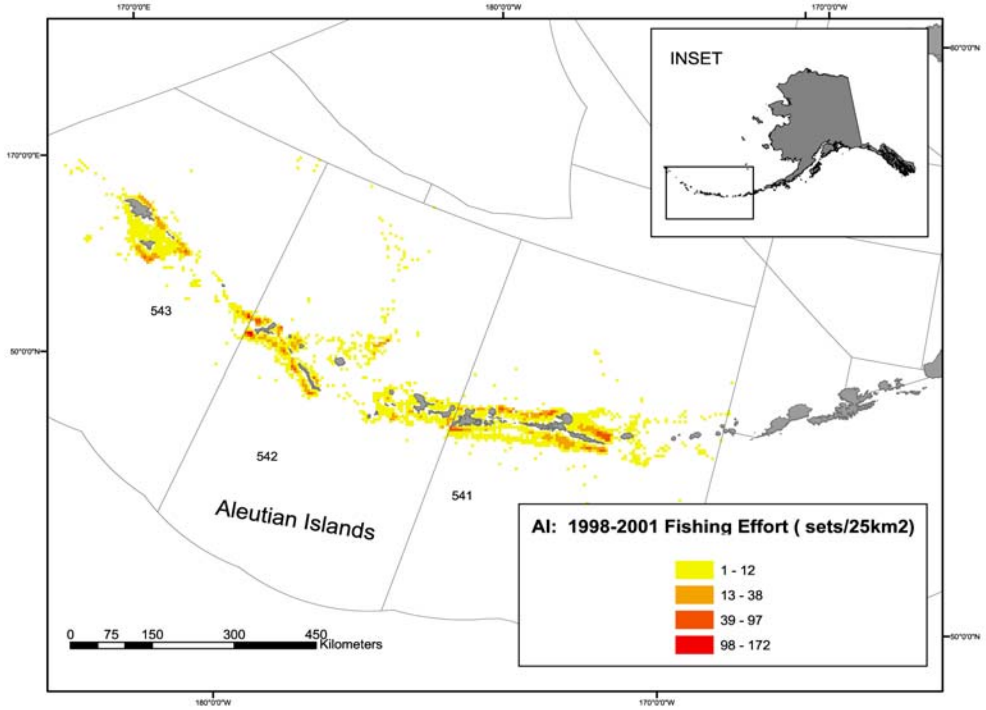

Figure 2. Spatial location and density of hook & line effort in the Aleutian Islands, 1998-2001.

Gulf of Alaska

For the period 1998-2001 there were 7,139 observed hook and line sets in the Gulf of Alaska. Patterns of high fishing effort are dispersed along the shelf (Figure 3). The predominant hook and line fisheries in the Gulf are composed of sablefish and Pacific cod. Southeast Alaska includes a demersal rockfish fishery dominated by yelloweye rockfish (90%), with lesser catches 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 number of vessels, reduced crowding, gear conflicts and gear loss, and increased efficiency. The cod longline fishery generally occurs in 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.

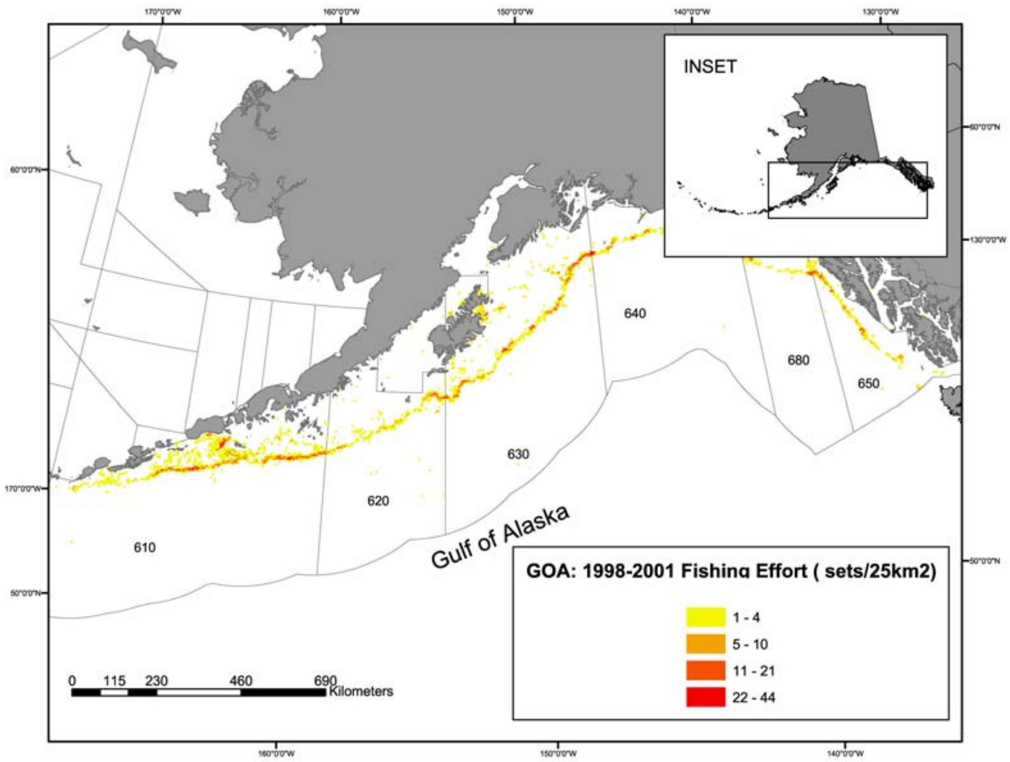

Figure 3. Spatial location and density of hook & line effort in the Gulf of Alaska, 1998-2001.

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

Contributed by Cathy Coon, NPFMC

The amount of effort (as measured by the number of days fished) in bottom trawl fisheries is used as one indicator for benthic habitat effects. Effort in the bottom trawl fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 1. In general, bottom trawl effort in the Gulf of Alaska and Aleutian Islands has declined as pollock and Pacific cod TACs have been reduced. Effort in the Bering Sea has remained relatively stable from 1991 through 1997, peaked in 1997, then declined. Fluctuations in fishing effort track well with overall landing of primary bottom trawl target species; namely flatfish and to a lesser extent pollock and cod. Since 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. Figures 2-4 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 fishing closure areas (i.e. Steller sea lion protection measures) as well as changes in markets and increased bycatch rates of non-target species. The magnitude of the Bering Sea trawl fisheries are twice as large in terms of effort than both the Aleutian Islands and Gulf of Alaska combined.

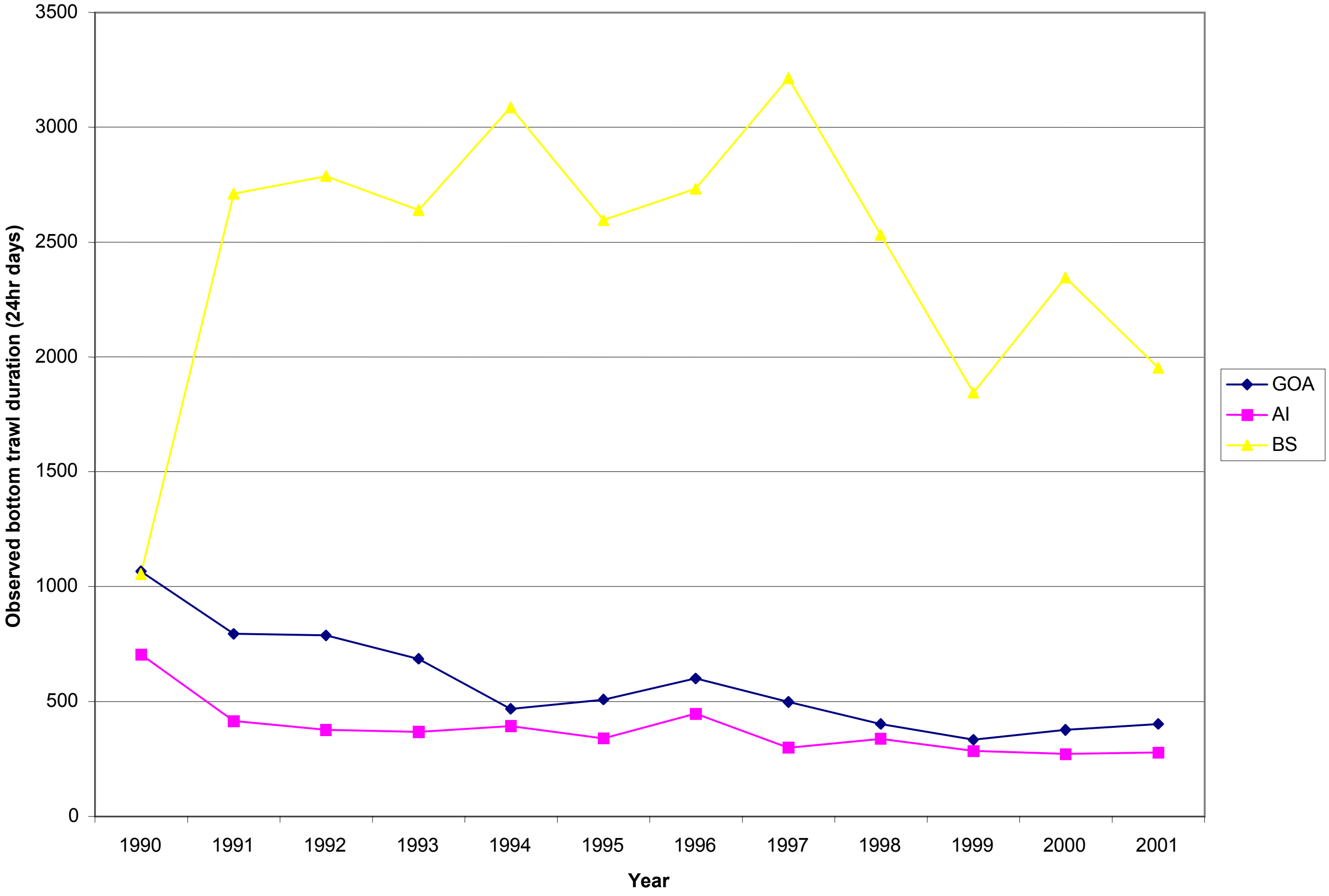

Figure 5. Estimated bottom trawl time in the Gulf of Alaska, Bering Sea, and Aleutian Islands during 1990-2001.

Bering Sea

For the period 1990-2001, there were a total of 240,347 observed bottom trawl sets in the Bering Sea fisheries. During 1999, trawl effort consisted of 14,631 sets which was the low for the 10-year period. Spatial patterns of fishing effort were summarized on a 5km2 grid (Figure 2). 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.

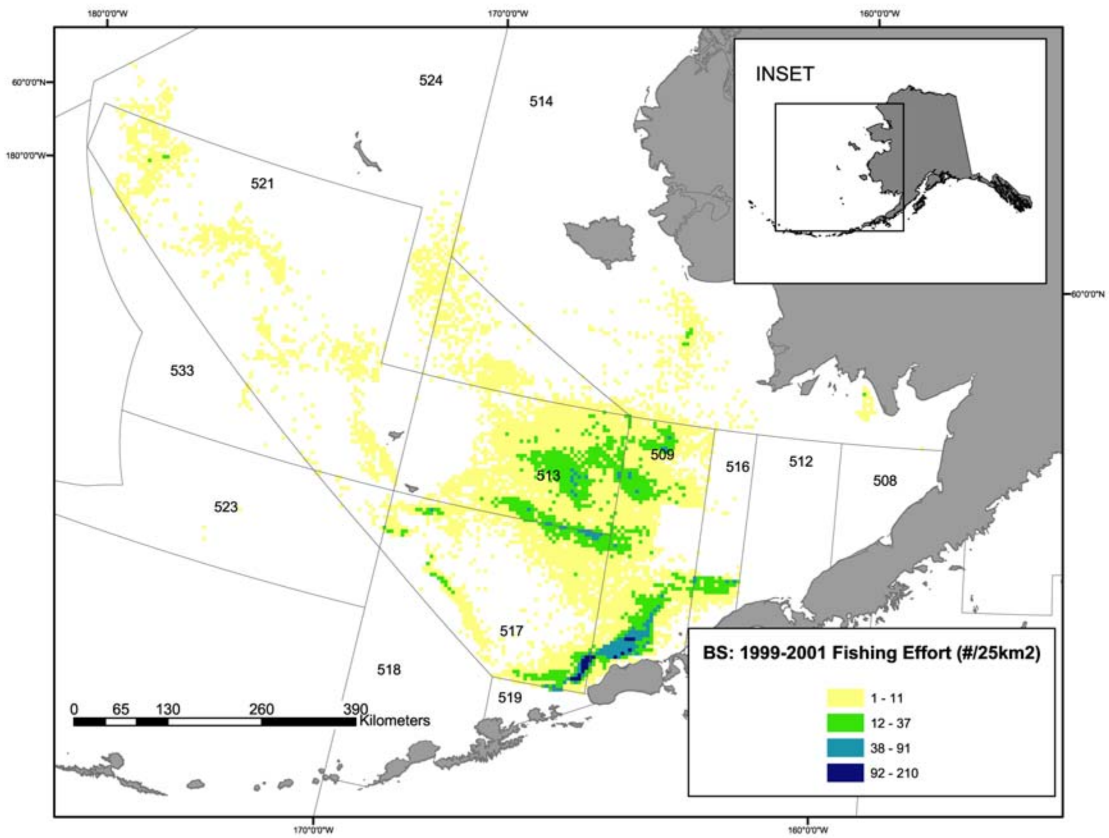

Figure 6. Spatial location and density of bottom trawl effort in the Bering Sea 1999-2001.

Aleutian Islands

For the period 1990-2001 there were 43,585 observed bottom trawl sets in the Aleutian Islands. The spatial pattern of this effort is dispersed over a wide area. During 2000, the amount of trawl effort was 2,583 sets, which was the low for the 10-year period. Patterns of high fishing effort are dispersed along the shelf edge (Figure 3). The primary catch in these areas was pollock, Pacific cod, and Atka mackerel. Catch of Pacific Ocean perch by bottom trawls was also high in earlier years.

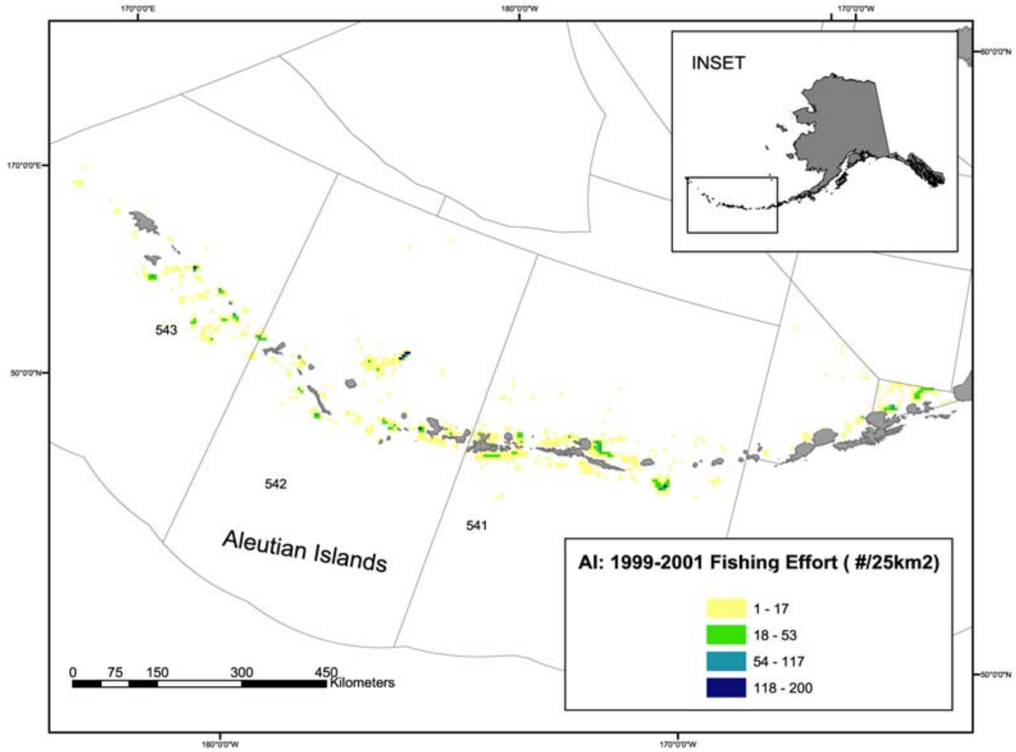

Figure 7. Spatial location and density of bottom trawl effort in the Aleutian Islands, 1999-2001.

Gulf of Alaska

For the period 1990-2001 there were 68,436 observed bottom trawl sets in the Gulf of Alaska. The spatial pattern of this effort is much more dispersed than in the Bering Sea region. During 2000, the amount of observed trawl effort was 3,443 sets. Patterns of high fishing effort are dispersed along the shelf edge with high pockets of effort near Chirikof, Cape Barnabus, Cape Chiniak and Marmot Flats (Figure 4). Primary catch in these areas was pollock, 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.

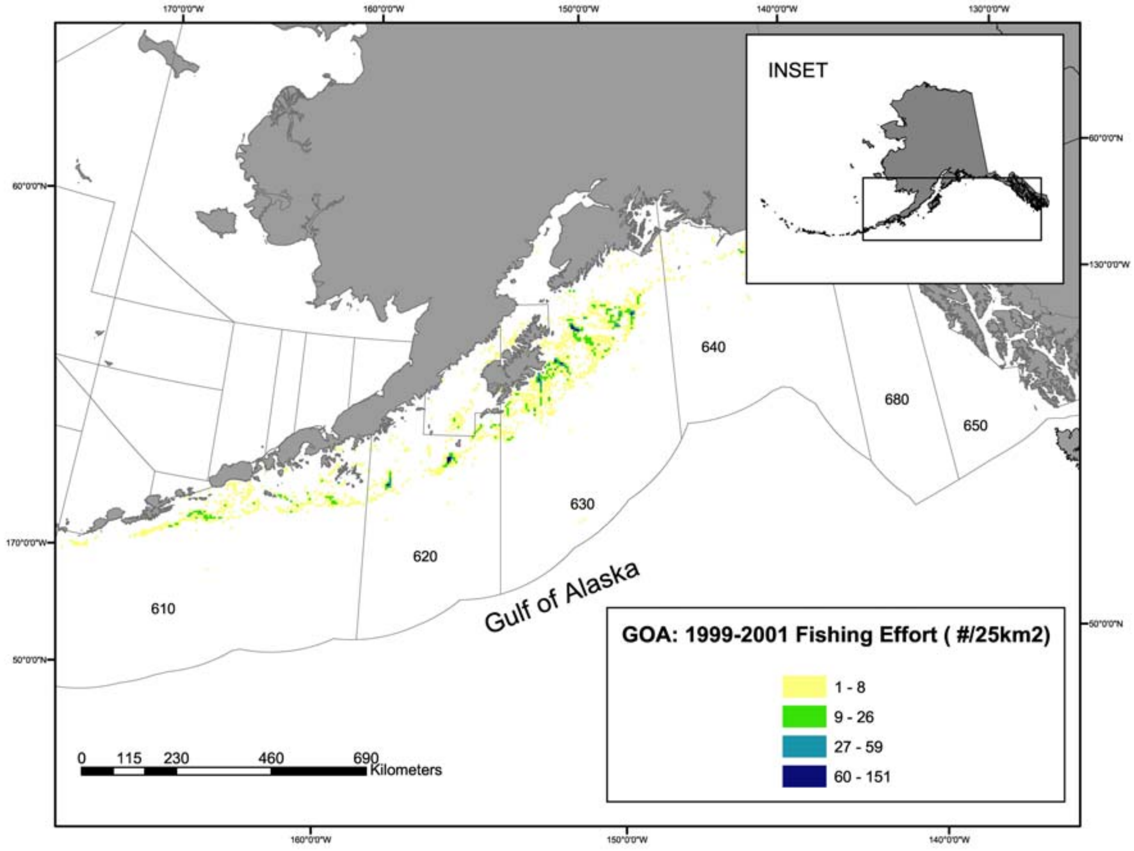

Figure 8. Spatial location and density of observed bottom trawl effort in the Gulf of Alaska, 1999-2001.

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

Contributed by Gregg Rosenkranz, Alaska Department of Fish and Game

A dredge fishery for weathervane scallops (*Patinopecten caurinus*) is prosecuted off the coast of Alaska in 3 main areas: the eastern Gulf of Alaska (GOA) between Cape Fairweather and Cape St. Elias (Fig 1); around Kodiak Island (Fig. 2); and the eastern Bering Sea (Fig. 3). The majority of effort each year occurs in the regions fished during the 2001/2002 season (Figs. 1–3), with some interannual variability in extent and intensity (Fig. 4). Smaller fishing areas off the Shumagin Islands near Sand Point and around Umnak Island were not opened during the 2001/2002 season due to concerns about localized depletion of scallops. Scallop fishing is permitted in some areas of the Aleutian Islands west of 170° W, but effort is rare.

Participation in the Alaska scallop fishery is restricted to 9 vessels by a license limitation program (LLP) implemented in 2001. Inception of the LLP led to cooperative harvesting arrangements that have further reduced the number of vessels in the fishery and increased the duration of the fishing season, i.e., effort occurs in the same areas but is spread over a longer time period. Fishing in all areas is closed by regulation between February 16 and June 30 each year, and many parts of the coast are closed to dredging year round (see map pg. 172 of 2002 Ecosystem Considerations document).

The New Bedford offshore scallop dredge is used by all vessels in the fishery. Seven LLP vessels are allowed to fish two 4.6 m (15 foot) dredges, while 2 others are restricted to a single 1.8 m (6 foot) dredge. Towing speeds are 2.1–2.6 m/s (4–5 nautical miles/hr), and a typical tow with two 15 foot dredges sweeps 7–8 hectares of bottom. Studies from the east coast indicate that habitat effects of scallop dredging vary with bottom type. Video stock assessment work by the Alaska Department of Fish and Game around Kodiak and in the eastern GOA have shown predominately mud and silt sediments in scallop fishing areas.

Vessels fishing for scallops in Alaska waters outside Cook Inlet are required to carry onboard observers on all trips. Observers monitor bycatch and haul composition as well as collecting biological data on scallops. Vessel operator logbooks that are part of the observer program provided the data for the accompanying figures.

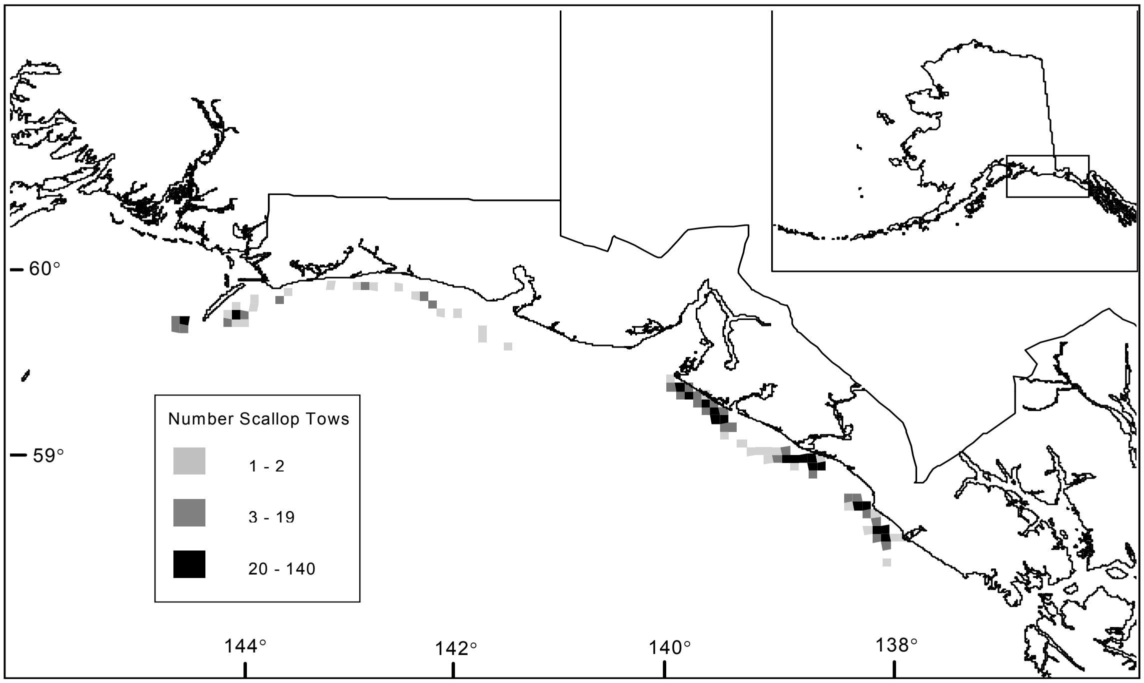

Figure 1. Scallop fishing effort in the eastern Gulf of Alaska summarized over a 5 × 5 km grid, 2001/2002 season.

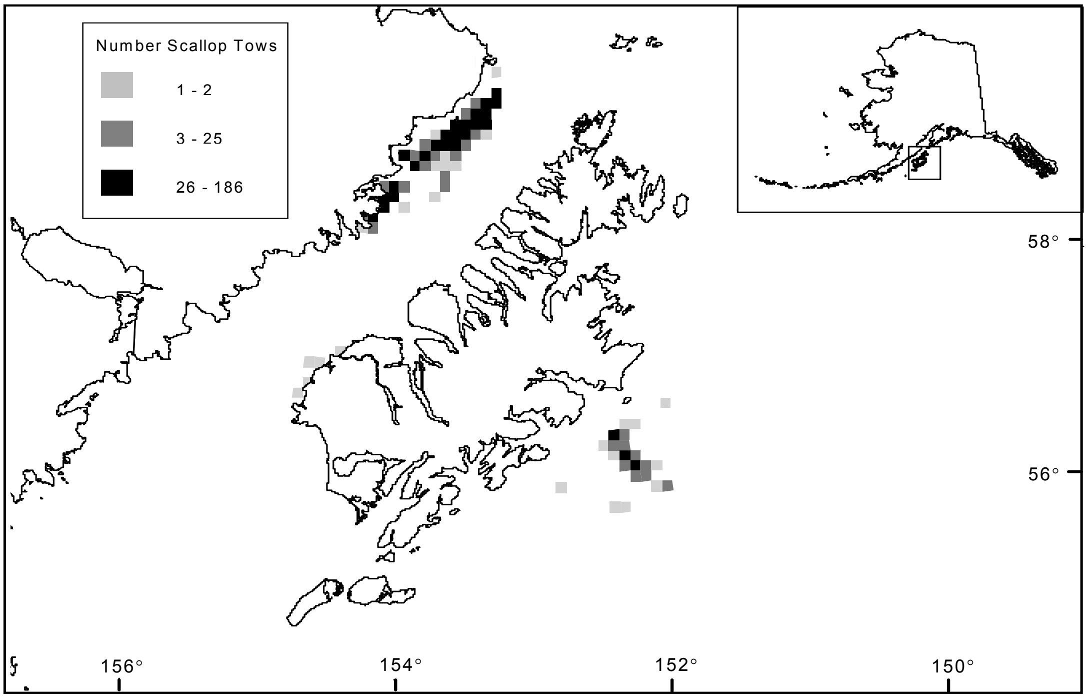

Figure 3. Scallop fishing effort in the Bering Sea summarized over a 5 × 5 km grid, 2001/2002 season.

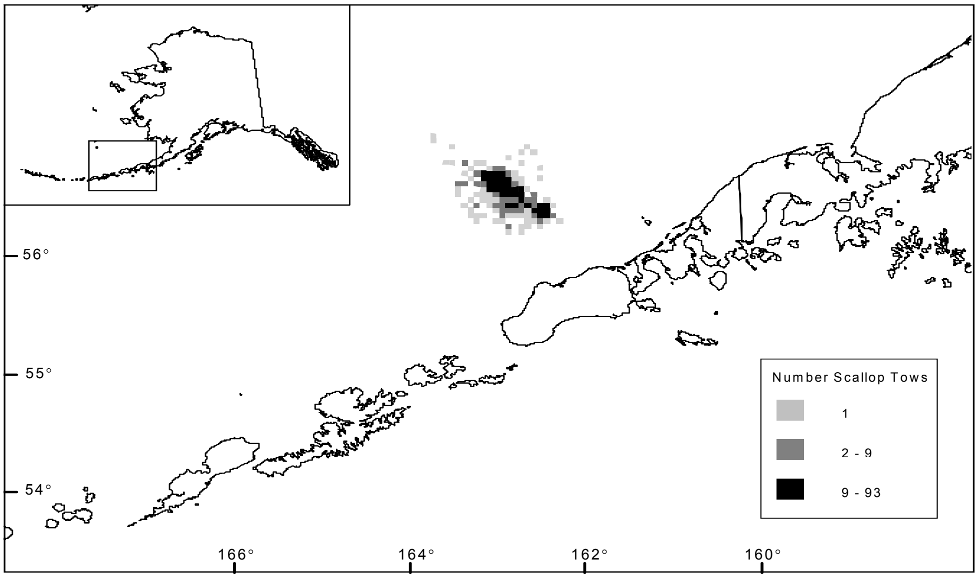

Figure 2. Scallop fishing effort in the Kodiak area summarized over a 5 × 5 km grid, 2001/2002 season.

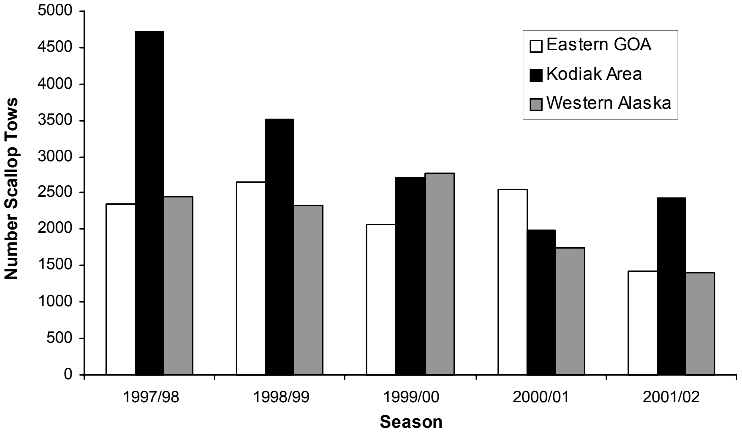

Figure 4. Number of scallop tows by area, 1997/1998 – 2001/2002 seasons. Western Alaska includes the Bering Sea, Shumagin Islands and Umnak Island

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

Trophic level of the catch

Contributed by Pat Livingston, Alaska Fisheries Science Center

To determine whether North Pacific fisheries were "fishing-down" the food web, the total catch, trophic level of the catch, and Pauly's (2001) Fishery Is Balanced (FIB) Index in the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska areas were determined. Total catch levels and composition for the three regions show the dominance of walleye pollock in the catch from around the 1970's to at least the early 1990's. Other dominant species groups in the catch were rockfish prior to the 1970's in the Aleutian Islands and the Gulf of Alaska, and Atka mackerel in the 1990's in the Aleutian Islands. All these species are primarily zooplankton consumers and thus show alternation of similar trophic level species in the catch rather than a removal of a top-level predator and subsequent targetting of a lower trophic level prey.

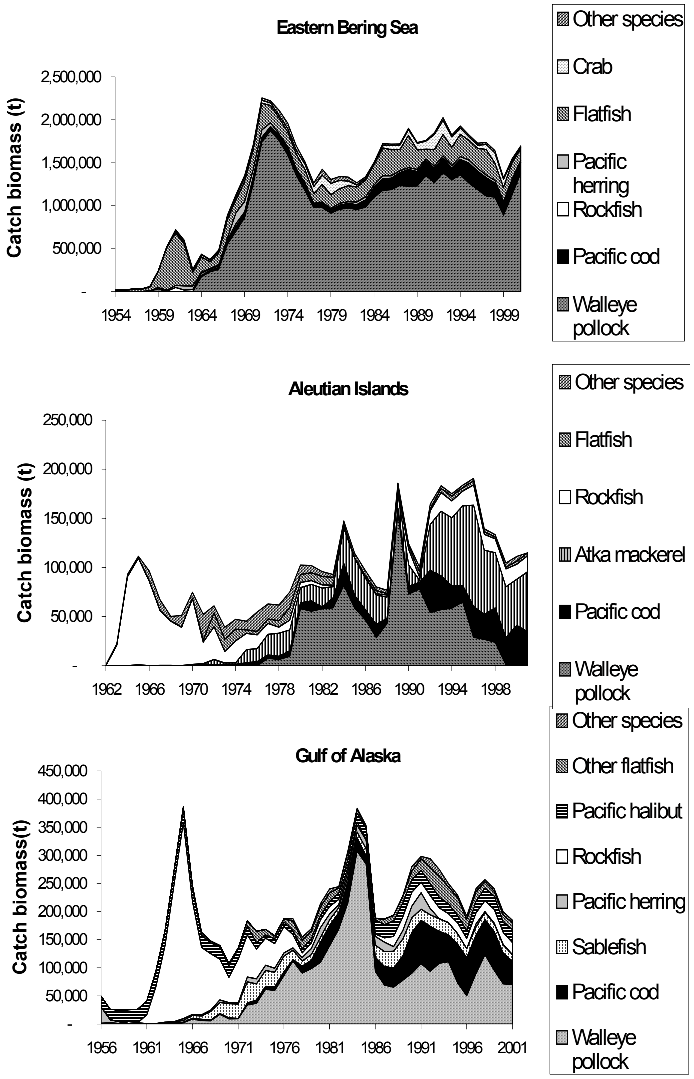

Figure 1. Total catch biomass (except salmon) in the EBS, GOA, and AI through 2001.

The trophic level of each species in the catch was obtained from published accounts of diet for non-groundfish species and from the food habits data base of the Alaska Fisheries Science Center for groundfish species. Trophic level (e.g., 1 for phytoplankton, 2 for consumers of primary production, 3 for consumers of secondary production, etc.) of the total catch was determined by weighting the trophic level of each species in the catch by the proportion (by weight) of that species in the total catch and summing the weighted trophic levels in each year. Stability in the trophic level of the total fish and invertebrate catches in the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska (Figure 2) are another indication 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 1960's in all areas, the trophic level of the catch has been high and stable over the last 25 years. This result is consistent with the previous analysis of Livingston et al. (1999) that described the lack of a fishing-down effect in the eastern Bering Sea.

Pauly et al. (2000) noted the possibility that trophic level catch trends may be a reflection of deliberate choice and not of a fishing down the food web effect.

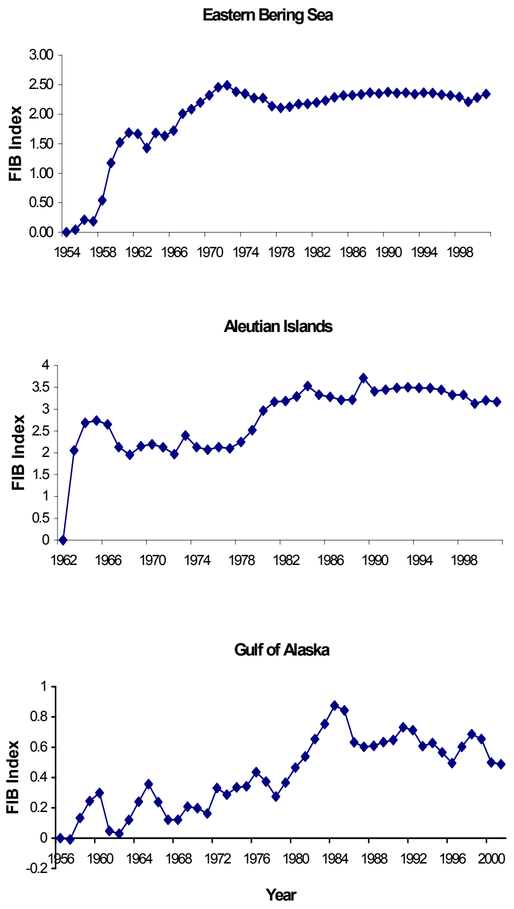

Figure 3. FIB Index values for the EBS, AI, and GOA through 2001.

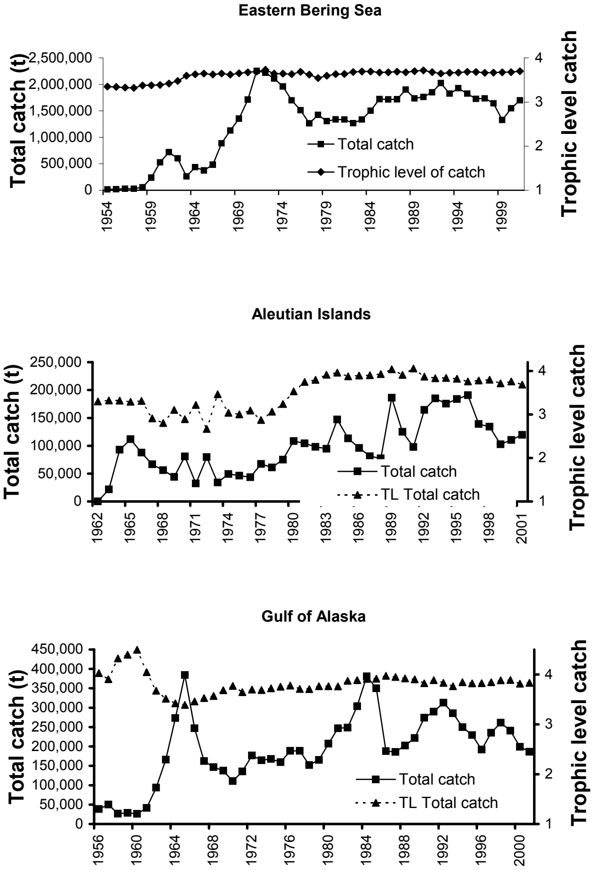

Figure 2. Total catch (groundfish, herring shellfish, and halibut) and trophic level of total catch in the EBS/AI and GOA through 2001.

Thus, they propose a new index that declines only when catches do not increase as expected when moving down the food web. The FIB index for any year *i* in a series is defined by

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

Where Y is the catch biomass, TL the mean trophic level in the catch, TE the transfer efficiency of energy from one trophic level to the next (assumed = 0.1), and 0 is the baseline year. In this case the baseline year used was the initial year of the time series. The FIB index for each Alaskan region was calculated (Figure 3) 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.

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Livingston, P.A., L-L. Low, and R.J. Marasco. 1999. Eastern Bering Sea ecosystem trends. p. 140-162. In: Sherman, K. and Q. Tang (eds) Large Marine Ecosystems of the Pacific Rim: Assessment, Sustainability, and Management. Blackwell Science, Inc. Malden, MA. 465p.

Pauly, D., V. Christensen, and C. Walters. 2000. Ecopath, Ecosim, and Ecospace as tools for evaluating ecosystem impact of fisheries. ICES J. Mar. Sci. 57:697-706.

Status of groundfish, crab, salmon and scallop stocks

Updated by Pat Livingston, Alaska Fisheries Science Center

Table 1 summarizes the status of Alaskan groundfish, crab, salmon and scallop stocks managed under federal fishery plans in 2001 from the April 2002 NMFS report to Congress available on the web at: http://www.nmfs.noaa.gov/sfa/reg_svcs/statusostocks/Status02.pdf

Although only two stocks are considered in the overfished category (Bering Sea Tanner crab and St. Matthew Island Blue king crab), rebuilding plans for three crab stocks are presently in place because Bering Sea snow crab is still rebuilding. There are no groundfish stocks in the overfished category, the status of a large proportion of the stocks or unknown. In 2000, most (85%) of the unknown status stocks comprised <1% of the landings. There are 43 stocks that are defined as major stocks for which overfished status is unknown (19 GOA Groundfish, 10 BSAI Groundfish, 14 BSAI crab).

Table 1. Status of groundfish and crab stocks managed under federal fishery management plans off Alaska, 2001.

Number of Stocks by Overfished Category

FMP	Overfished	Not Overfished	Unknown	Total
GOA Groundfish	0	9	93	102
BSAI Groundfish	0	13	100	113
Crab	2	4	14	20
Salmon	0	5	0	5
Scallop	0	1	0	1

Ecosystem Goal: Humans are part of Ecosystems

Fishing overcapacity programs

Updated by Jessica Gharrett, NMFS Alaska Regional Office and Ron Felthoven, AFSC

Overcapacity, wherein there are too many vessels to harvest the limited 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 has developed several programs to address overcapacity in the Alaskan fisheries. For most groundfish and crab species and for scallops, management programs limit the number of harvesting vessels that may be deployed off Alaska. In contrast, Halibut and fixed gear sablefish fisheries are managed under an Individual Fishing Quota (IFQ) program, which, rather than limiting harvesting vessels, grants Quota Share holders the privilege of harvesting a specified percentage of the Total Allowable Catch (TAC) each year.

Congress, too, has provided statutory tools to help relieve overcapitalization. The American Fisheries Act (AFA) retired and limits 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. And, a program to retire licenses, vessels, and vessel histories from the BSAI crab fisheries is authorized and is under development by NMFS.

Moratorium on New Vessels

A moratorium on new vessel entry into the federally managed groundfish and crab fisheries was implemented 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 of the time the program was sunsetted, December 31, 1999. In addition to limiting the number of vessels the moratorium also restricted each vessel's length. Vessels that were less than 125' length overall could only be increased to 120 percent of their

length on June 24, 1992, or up to 125', whichever is less; vessels that were 125' or longer could not increase their length. Increasing a vessel's length could add harvesting capacity without increasing the number of vessels.

License Limitation Program (LLP)

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 are tightening the LLP program and include additional restrictions on vessel numbers, and fishery crossovers; and limit participation in the non-trawl BSAI Pacific cod fisheries. Based on preliminary estimates of qualified vessels, the LLP should reduce the number of vessels eligible to participate in the Bering Sea/Aleutian Islands (BSAI) crab fisheries by more than 60% (down to approx. 283 licenses) as compared with the vessel moratorium. The number of vessels predicted to be eligible for groundfish licenses (N = 2,000) is slightly greater than the number that held moratorium permits (while the LLP carries stricter qualification standards, many moratorium permits were never claimed). However, the LLP is more restrictive in terms of the areas a vessel can fish and the types of gear it can deploy. Also important to note is that the vast majority of the vessels qualifying for the LLP are longline vessels less than 60', and they are only eligible to participate in Gulf of Alaska fisheries. These vessels have typically had relatively small catch histories in past years.

Crab Buyback

A statutory change to the MSA, for which regulations are under development, authorizes an industry-funded buyback program for the crab fisheries. This program will permanently retire vessels, LLP licenses, and vessel histories. The program is subject to an industry referendum in which a majority of participants must approve the proposed effort reduction and debt retirement burden.

Sablefish and Halibut Individual Fishing Quotas (IFQs)

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 passed an IFQ program for both the halibut and fixed gear sablefish fisheries. These programs were initiated in 1995. After implementation, the fisheries changed from a short pulse fishery to one that extends over several months. IFQs have allowed participants to better match fishing capacity with the amount of fish they are allowed to harvest during a year. In recent years the numbers of vessels and persons have declined, even as the TACs have been increasing. A total of 4,830 persons were initially issued halibut Quota Share (QS) and 1,052 were initially issued sablefish QS. As of the end of 2000, 3,541 persons held halibut QS and 875 held sablefish QS. Vessels landing halibut declined from 3,450 in 1994 to 1,568 (IFQ fishery) at the end of 2000; and catcher vessels landing sablefish declined from 1,139 in 1994 to 416 (IFQ fishery) in 2000.

American Fisheries Act (AFA)

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 inception of the AFA, 21 catcher/processors and 112 catcher vessels qualified, or were specifically identified, as being 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 is comprised of 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 A/B season and six chose not to fish during the C/D season. This pattern continued in 2000 and 2001 when 4 and 3 catcher/processors were idle in the A/B season, respectively. FIve of the catcher/processors were idle in both 2000 and 2001 for the C/D season. Vessel size of participating vessels has ranged from 201- 376 ft LOA.

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 and twenty catcher vessels to deliver pollock to these three motherships. In 1998, 31 vessels landed greater than 10 mt of pollock to be processed by offshore motherships. In 1999, the number of catcher vessels delivering to motherships dropped to 27. In 2000, the first year in which a cooperative was operating in the mothership sector, that number dropped again to 19 catcher vessels and was the same for 2001.

In 1998, there were 107 inshore catcher vessels that delivered greater 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), and remained at that level in 2001.

Finally, it should be noted that the AFA also restricts eligible vessels from shifting their effort into other fisheries. “Sideboard” measures, as they have become known, 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 be increased to better compete in those fisheries.

Groundfish fleet composition

Contributed by Joe Terry, Alaska Fisheries Science Center

The Groundfish Fleet

Fishing vessels participating in the groundfish fisheries in the EEZ 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 1993. They both increased in 1994 and then decreased annually through 1998 before increasing again in both 1999 and 2000. The total number of vessels was about 1,500 in 1993, peaked at almost 1,700 in 1994, decreased to less than 1,300 in 1998, and returned to more than 1,376 in 2001 (Figure 1). Hook and line vessels accounted for about 1,200 and 1,012 of these vessels in 1993 and 2001, respectively. The number of vessels using trawl gear has tended to decrease, during this seven-year period it decreased from 282 to 241 vessels. During the same period, the number of vessels using pot gear increased from 117 to 222.

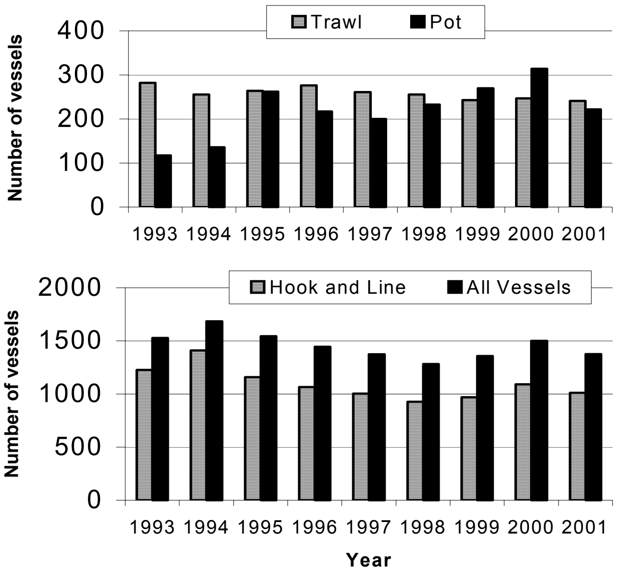

Figure 1.--Number of vessels participating in the groundfish fisheries in the EEZ off Alaska by gear type, 1993-2001.