APPENDIX C

Ecosystem Considerations
for 2002

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

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November 2001

ECOSYSTEM CONSIDERATIONS –2002
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INDICATOR SUMMARY

The following table is an initial attempt at summarizing some of the indicators contained in this document. Eventually, the document will contain a more complete set of indicators and an evaluation of the meaning of the observed changes. For example, the habitat section is presently missing information on time series trends of fishing effort by non-trawl gear types and more information from NMFS trawl surveys could be used to provide information on population trends of non-target species. Also missing is status and trend information for other managed resources such as crab, herring, and salmon. Future evaluations will provide an assessment of whether the observed change was beneficial, detrimental, or neutral with respect to a particular ecosystem issue.

INDICATOR	OBSERVATION	INTERPRETATION	EVALUATION
Physical oceanography			
North Pacific Index	Sea level pressure averaged for Jan.-Feb, Near neutral slightly negative for the last few years	No major atmospheric support for the PDO shift	
Arctic Oscillation Index	Shift to negative	When negative it supports a stronger Aleutian low, helps drive a positive PDO pattern	
Pacific Decadal Oscillation	Cool coastal pattern in GOA since 1998	Indicates shift in PDO to neutral or negative phase	
GOA Temperature Anomaly	1deg less negative than May 2000	2001 not as cold as 2000	
EBS summer temperature	Bottom temperatures were generally warmer and surface temperatures were colder than average	No marked changes in fish distribution were noted	
GOA summer temperature	Bottom temperatures in 2001 appeared above average	Bottom temperature at depths 50-150 did not track PDO trend this year	
EBS sea ice extent	Strong southerly winds kept sea ice northward of 60N	Low ice year, kept middle shelf bottom temperatures warmer	
Papa Trajectory Index	Surface water circulation in the eastern Gulf of Alaska still appears to be in the northward mode	Stronger northerly drift pattern of Subarctic current	
Habitat			
Groundfish bottom trawling effort in GOA	Bottom trawl time in 2000 was similar to 1998-99 and lower than 1990-1997	Less trawling on bottom	
Groundfish bottom trawling effort in EBS	Bottom trawl time increased in 2000 relative to 1999	More trawling on bottom though still less than 1991-98	
Groundfish bottom trawling effort in AI	Slightly lower in 2000, generally decreasing trend since 1990	Less trawling on bottom	
Area closed to trawling	More area closed in 2000 compared with 1999	Less trawling on bottom in certain areas though may concentrate trawling in other areas	
HAPC biota bycatch by all gears	Estimated at 560 t for BSAI and 32 t for GOA in 2000	Lower in BSAI than 1997-98, about constant in GOA since 1997	

INDICATOR	OBSERVATION	INTERPRETATION	EVALUATION
Target Groundfish			
Total biomass EBS/AI	Total about same in 2000 as in 1999, pollock dominant	Relatively high total biomass since around 1981	
Total catch EBS	Total catch about same in 2000 as in 1999, pollock dominant	Catch biomass about same from 1984-2000	
Total catch AI	Total catch declining since about 1996, Atka mackerel dominant	Total catch returning to lower levels	
Total biomass GOA	Declining abundance since 1982, arrowtooth dominant	Relatively low total biomass compared to peak in 1982	
Total catch GOA	Total catch lower in 2000 than 1999	Total catch similar from 1985-present	
Groundfish discards	Slightly increasing rates in 2000 relative to 1999 but still lower than 1997	Slightly more target species discarding, may not be significantly different from 1999	
GOA recruitment	Groundfish recruitment in 1990s is mostly below average for age structured stocks, except POP	Groundfish recruitment is low in 1990's	
EBS recruitment	Some above average recruitment in early 1990s, mostly below average	Groundfish recruitment is low in mid-late 1990's	
Groundfish fleet	Total number of vessels actually fishing increased in 2000 relative to 1999 (121 were H&L, 43 pot, 8 trawl)	More groundfish fishing vessels	
Forage			
Forage bycatch EBS	72 t in 2000,32-49t in 97-99, mostly smelts	Higher smelt catch rates in 2000	
Forage bycatch GOA	125 t in 2000, higher than 1999 (30t) but similar to 1998, 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	

INDICATOR	OBSERVATION	INTERPRETATION	EVALUATION
Other species			
Spiny dogfish	Observer bycatch rates show mixed trends by area in GOA	Both increasing and decreasing catch rates observed over time by area	
Spiny dogfish	IPHC bycatch rates since 97 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, large increases noted in Kodiak region	
Salmon shark	Highest bycatch rates in Kodiak region	Similar catch rates in recent years	
EBS jellyfish	Large increases in 2000 relative to 1999, biomass increased since 1990	High jellyfish biomass	
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	
Prohibited species bycatch	Halibut mortality, herring , other kind crab, chinook salmon bycatch decreased in 2000, Bairdi, opilio, other salmon increased in 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	

INDICATOR	OBSERVATION	INTERPRETATION	EVALUATION
Marine mammals			
Alaskan western stock pup counts	2000 and 2001 counts from Seguam to PWS were similar to 1998	Annual decrease of about 8%/yr since 1990	
Alaskan western stock sea lion counts	2000 non-pup counts were lower than 1998	Continued decline in non-pup portion of population	
Alaskan eastern stock sea lion counts	Overall increase from 1990-2000 was 29.3%	Stable or slightly increasing	
Northern fur seal pup counts	Non significant change on St Paul from 1999 to 2000, significant change on St. George from 1999 to 2000	Overall small decline since 1990	
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	1999 BSAI longline bycatch is lower than 1998, 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	

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 report provides updates and new information to supplement the original report. The original 1995 report presented a compendium of general information on the Bering Sea, Aleutian Island, and Gulf of Alaska ecosystems as well as a general discussion of ecosystem-based management. The 1996 Ecosystem Considerations report 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 report 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 report 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 Chapter 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 documents 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.

WHAT'S NEW IN ECOSYSTEM-BASED MANAGEMENT?

Summary of the Canadian National Workshop on Objectives and Indicators for Ecosystem Based Management

Contributed by Patricia Livingston, Alaska Fisheries Science Center

This workshop was held 27 February-2 March, 2001 in Sidney, British Columbia. The Canadian Department of Fisheries and Oceans (DFO) sponsored this workshop to identify ecosystem-level objectives, with associated indicators and reference points that could be used in managing ocean activities. Participants included DFO scientists, fisheries managers, ocean managers, and habitat managers. Invited experts from other Canadian government departments and academia along with scientists from other nations attended the workshop. Alaska Fisheries Science Center scientist Pat Livingston was invited to attend and relate the Alaskan experiences with regard to ecosystem-based fisheries management and the development of the ecosystem considerations document that accompanies Alaskan groundfish stock assessment advice to fishery managers. The full report of the workshop by Jamieson and O'Boyle (2001) can be obtained at:
http://www.dfo-mpo.gc.ca/CSAS/CSAS/Proceedings/2001/PRO2001_09e.pdf

The workshop identified conservation of species and habitats as the overarching objective. Subobjectives relating to biodiversity, productivity, and the physical and chemical properties of the ecosystem were then defined and a nesting system was devised under each subobjective to obtain objectives at a level that were suitable for operational management. For each of these nested components, a suite of biological properties or characteristics was defined and example indicators and reference points were suggested. For example, under the biodiversity subobjective, maintaining communities within bounds of natural variability was defined as a component. One characteristic of this might be trophic level balance and several indicators related to this characteristic might be slope of the size spectrum, Fishery is Balanced Index (FIB), effective number of species within trophic level, and abundance of keystone species. Reference points for these indicators could not be defined at the workshop but it was thought that reference points relating to these might be based on an undisturbed system. The operational objective would be to maintain these indicators relative to some reference point including a specified risk tolerance and desired value for the indicator.

It was clear that further work on these indicators and reference points would be required at both national and regional levels in Canada. Defining these reference points in most require further research. In some cases this might mean obtaining longer time series of observations to understand levels of natural variability. However, in the absence of well-defined reference points, practical means for moving forward with respect to ecosystem-based management in the short term still need to be devised.

Several assessment frameworks were presented that allowed evaluation of progress against several objectives simultaneously. The two main integrative frameworks discussed were the Index of Biological Integrity (IBI) and the Traffic Light Approach (TLA). The IBI approach integrates indicators at the individual, population, community, and ecosystem levels. Each indicator at a particular site is given a score relative to an undisturbed reference site, all scores are added together to produce the IBI for a given location. One cited advantage of the approach is that it is more likely to detect environmental impacts than one indicator species that may only be sensitive to one type of perturbation and not to others. Further work on testing robustness of this index is required to better understand the miss and false alarm rates, which some have suggested are high. Additionally, there are many difficulties in marine areas in locating and defining undisturbed reference sites and conditions. Finally, its use of intercorrelated indicators might make it more sensitive to certain changes and not to others thus making its utility to managers somewhat uncertain.

The Traffic Light Approach (TLA) is a data-based method for integrating resource status that was first proposed by Caddy (1999) for data-poor fish stock assessment situations. The approach designates cut-point for indicator values that place a particular index into positive (green), intermediate (yellow), or negative (red) categories that is very similar to the semi-quantitative approach used in Environmental Impact Analysis. All indicators are shown and summaries are presented that are either a weighted average or a model-based result from the composite. It was noted at the workshop that color coding habitat management schemes have already been in place in some areas for a decade. TLA has been used in Canada for Newfoundland shrimp (Koeller et al. 2000) and Maritimes groundfish assessments where indicator results are linked to a pre-negotiated set of management actions. Further work on this approach is planned in Canada during 2001. It seems to have promise in situations where quantitative ecosystem-based reference points are undefined. An expert workshop for comparison of the IBI and TLA approaches was recommended for fall 2001 along with pilot sites for testing different assessment frameworks.

References

Caddy, J.F. 1999. Deciding on precautionary management measures for a stock based on a suite of limit reference points (LRPs) as a basis for a multi-LRP harvest law. NAFO Sci. Coun. Studies, 32: 55-68.

Jamieson, G. and R. O'Boyle. 2001. Proceedings of the National Workshop on Objectives and Indicators for Ecosystem Based Management. Canada Department of Fisheries and Oceans, Science Advisory Secretariat, Proceedings Series 2001/09. 140p.

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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 reflects that new understanding.

Physical Environment

Empirical Evidence for a 1998/1999 North Pacific Regime Shift

Contributed by N.J. Mantua (1) and S.R. Hare (2)
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(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.

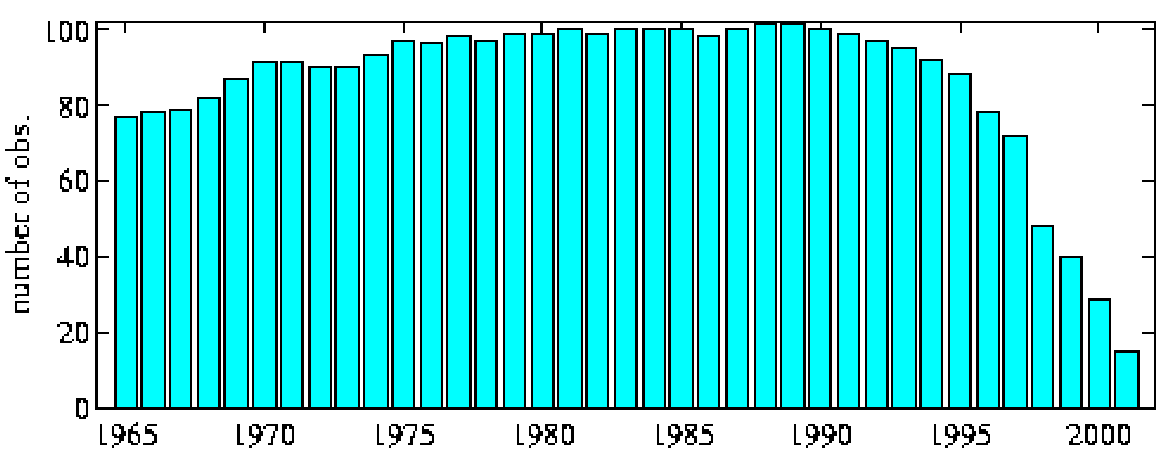

Figure 1. Number of observations in each year. Note that the data available for 1998-2001 is quite limited, with almost no fishery data in our matrix.

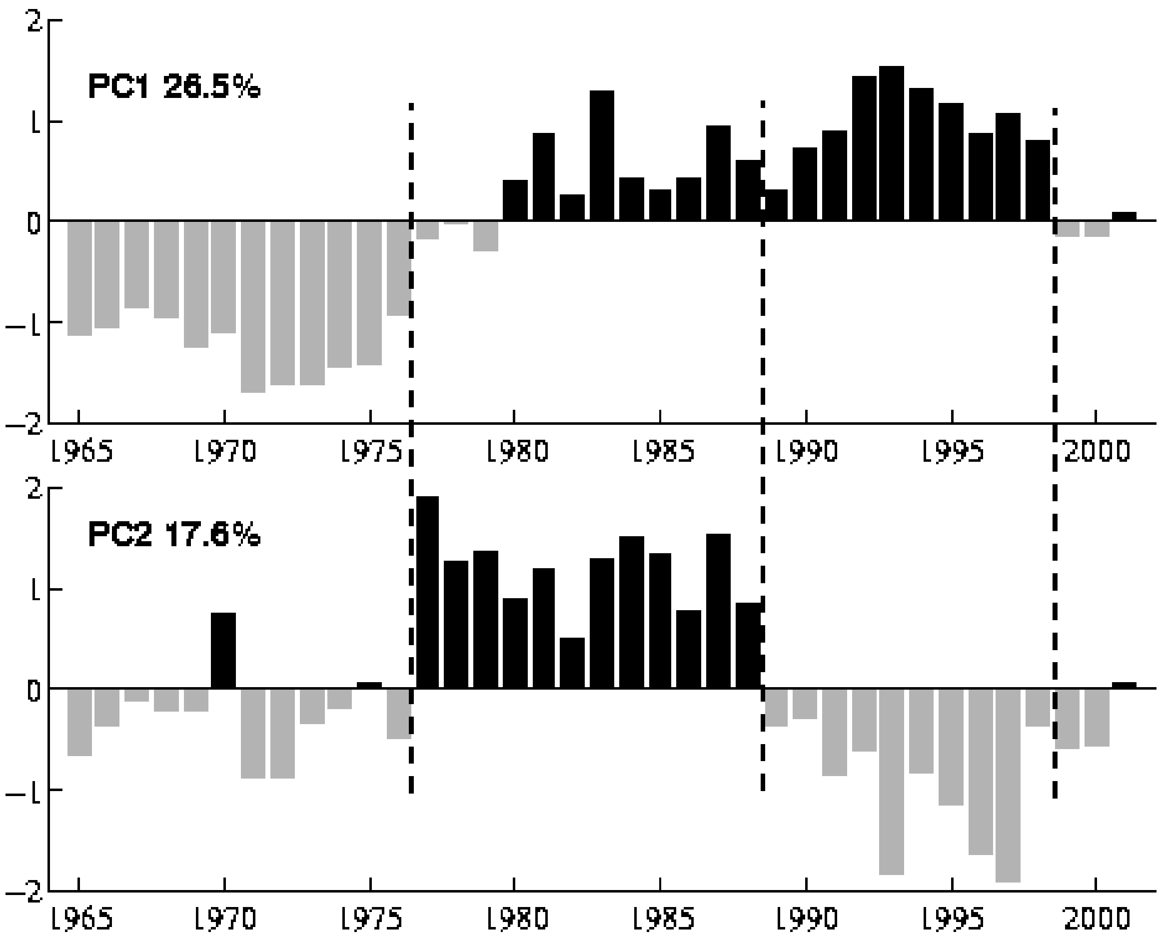

Figure 2. The first two principal component scores from a principal component analysis of the 100 environmental time series. The scores are normalized time series and vertical bars are shown before the data points for 1977, 1989, and 1999.

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.

References

Hare, S.R. and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47: 103-146.

Ecosystem Indicators and Trends Used by FOCI

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 (2001) 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 – 2001

Recent indicators suggest that it is difficult to determine climate trends for the North Pacific region over the next several years.

La Niña conditions in 1998-1999 cooled the coastal waters of the Pacific Northwest and Gulf of Alaska. The persistence of this cool coastal pattern is shown as a change in sign of the Pacific Decadal Oscillation from positive to negative (Figure 1, bottom) after 1998. The May 2001 map of sea surface temperature anomalies shown in Figure 2 represents the negative phase of the PDO. Note the cool coastal waters and warmer waters in the central Pacific.

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.

There is growing biological evidence that there was a regime shift in the North Pacific after 1998 that was of similar magnitude as the major 1976 regime shift. Record salmon catches were recorded off of Oregon that were as high as during the 1930s. However, the climate indices are not as strong an indicator of a continued, new regime. The cold temperature anomaly in the Gulf of Alaska in 2001 is weaker by 1° than the anomaly in May 2000. The PDO index itself has moved toward neutral. A strong (deep) Aleutian Low sea level pressure pattern helps to drive the positive PDO pattern. The strength of the Aleutian Low is given by the NP (North Pacific) index as the top curve in Figure 1. The NP has been near neutral or slightly negative over the last several years indicating no major atmospheric support for the PDO shift. The Arctic Oscillation (Figure 1 middle) in its positive phase helped to slightly weaken the Aleutian Low in the 1990s compared to the 1980s. The AO has gone negative which supports a stronger Aleutian Low.

In the past years, strong PDOs have resulted in apparent north-south distributions of abundant salmon returns. Interestingly in 2001, some salmon returns in Southeast Alaska are also at high levels. The more neutral PDO that we are experiencing may have brought a relaxation of the out-of-phase character of Alaska vs. west coast productivity. The relation of productivity to climate may also be experiencing lags of several years. All of these factors contribute to uncertainty for the near future.

Thus, there is conflicting evidence about the state of the North Pacific. Biological evidence remains indicative of a 1998 regime shift, while the climate data are neutral. There is no compelling data to choose whether the negative phase of the PDO will continue over the next five years or that the shift that occurred in the late 1990s will revert back to the positive phase of the 1980s.

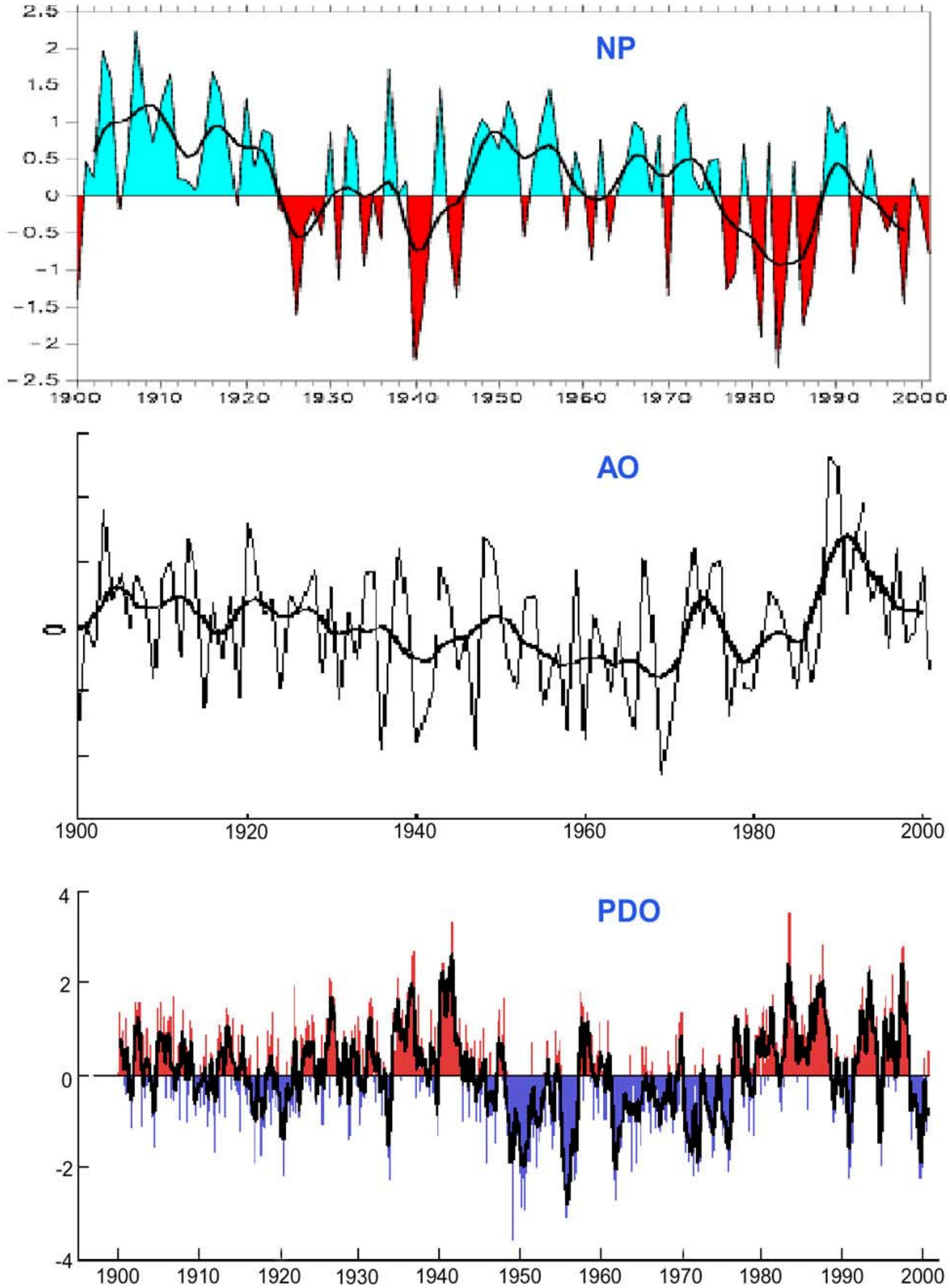

Figure 1. Top: The North Pacific Index (NPI) from 1900 through 2001 is the sea-level pressure averaged for January through February. **Middle:** Monthly and smoothed (black line) relative values of the Arctic Oscillation (AO) index, 1900-2001. **Bottom:** Monthly and smoothed (black line) values of the Pacific Decadal Oscillation (PDO) index, 1900-2001 (updated from Mantua et al. 1997).

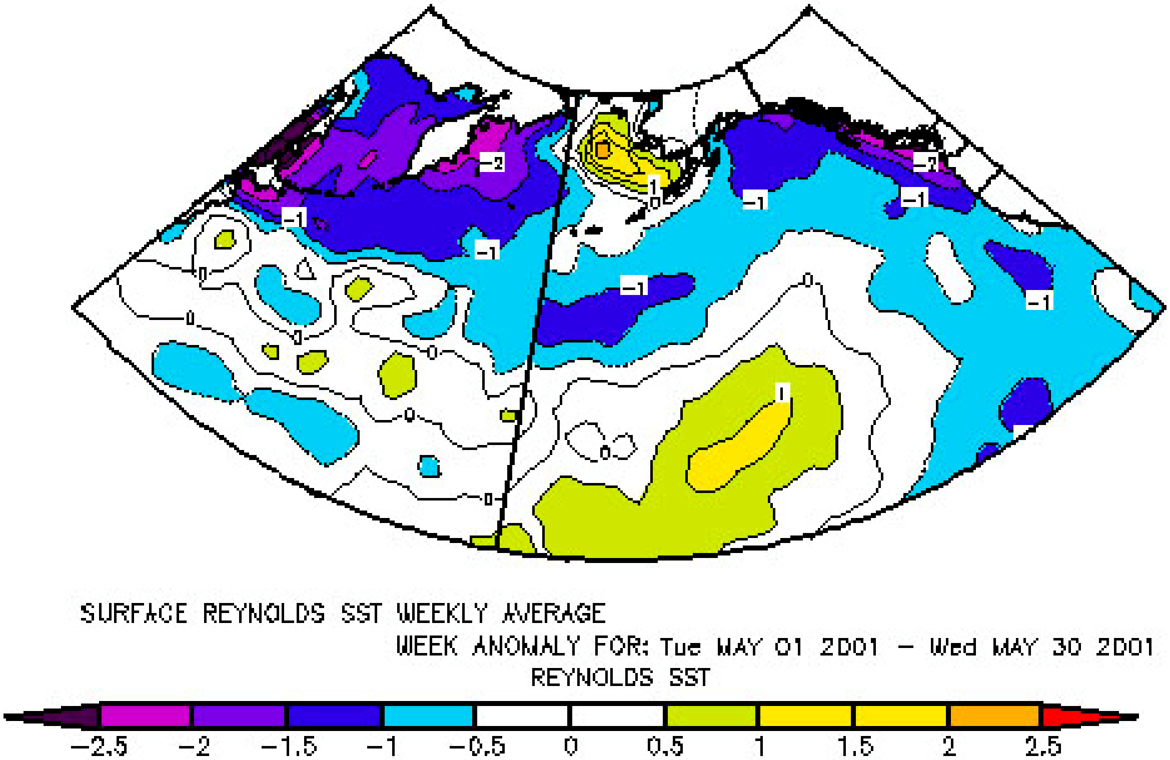

Figure 2. The pattern of sea surface temperature anomalies for May 2001 shows a diminishing of the strong negative phase seen at the same time one year ago.

WESTERN GULF OF ALASKA

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 3. 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. The past two years have seen increasing survival potential.

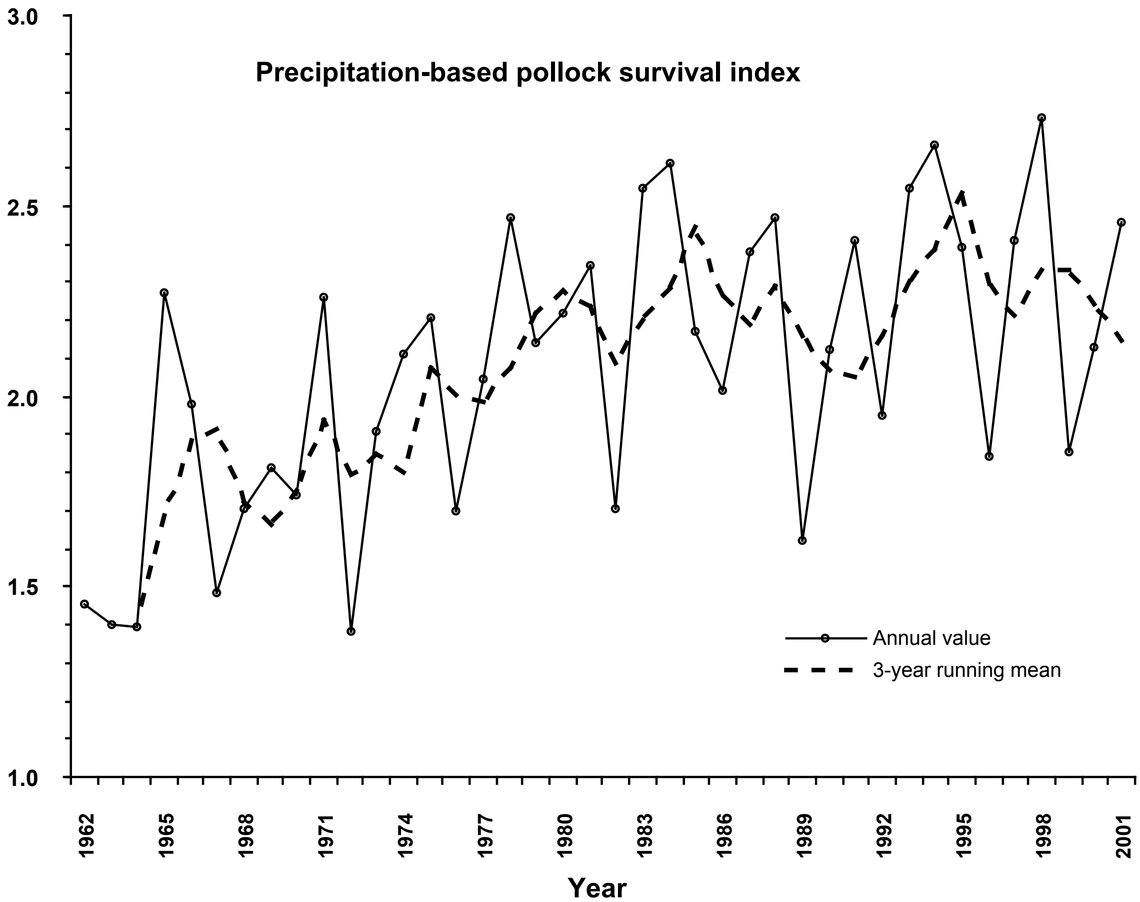

Figure 3. Index of pollock survival potential based on measured precipitation at Kodiak from 1962 through 2001. The solid line shows annual values of the index; the dashed line is the 3-year running mean.

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. 4) 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 four January through June periods (1998-2001). This may be further evidence that the North Pacific climate regime has shifted in the past few years.

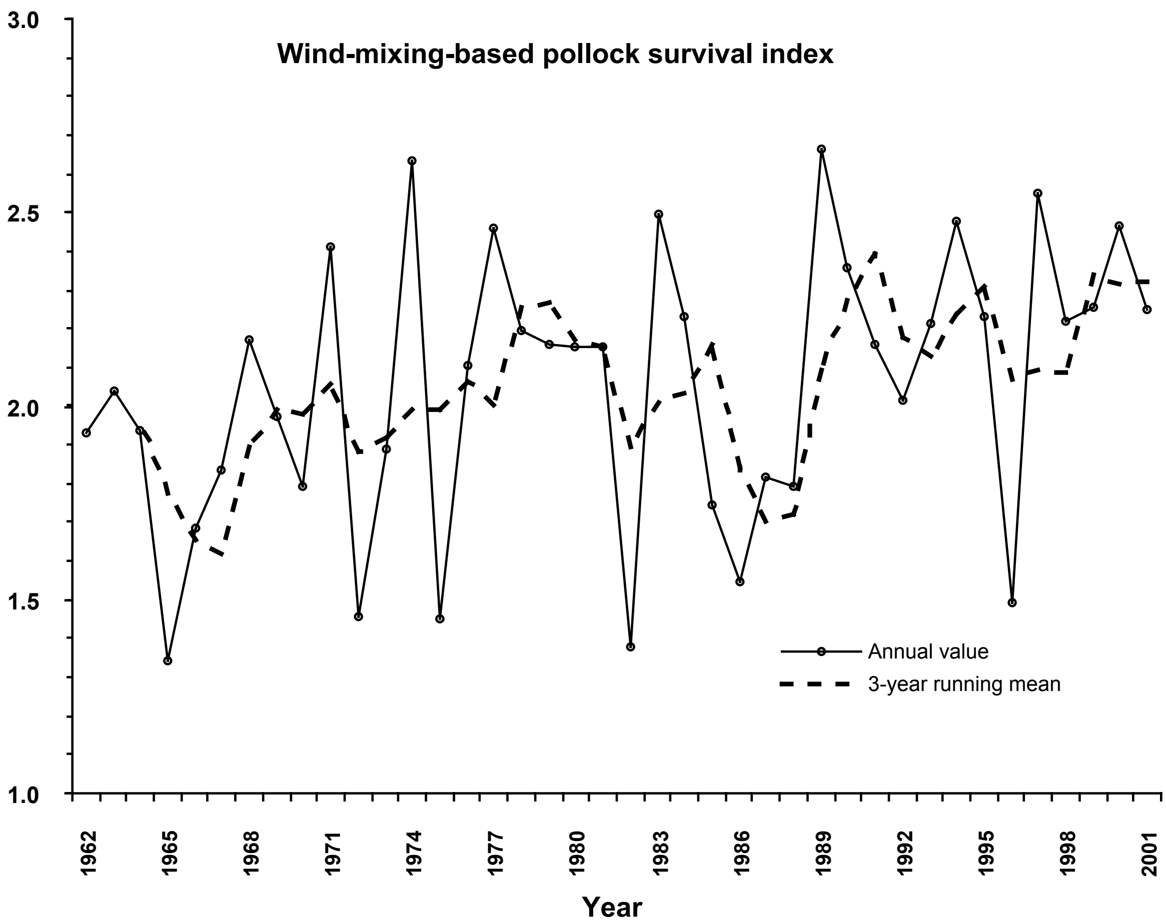

Figure 4. Index of pollock survival potential based on estimated wind mixing energy at a location south of Shelikof Strait from 1962 through 2001. The solid line shows annual values of the index; the dashed line is the 3-year running mean.

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 5 are from October 18. Each red line represents the track of the drift buoy for the past 5 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.

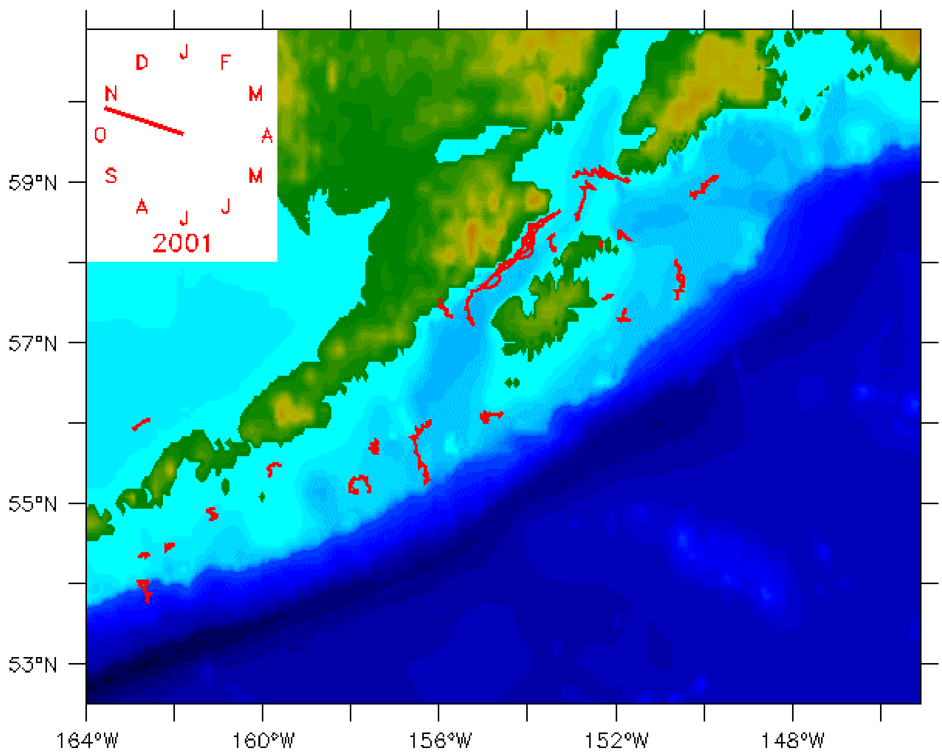

Figure 5. Tracks of satellite-tracked drifters for the period October 14-18, 2001, show sluggish flow on the shelf, except for within Shelikof Strait.

EASTERN BERING SEA

Sea ice extent and timing

The extent and timing of seasonal sea ice over the Bering Sea shelf plays an important role, 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 Sea. Following the regime shift at the end of the 1970s, the Bering Sea 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 6 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.

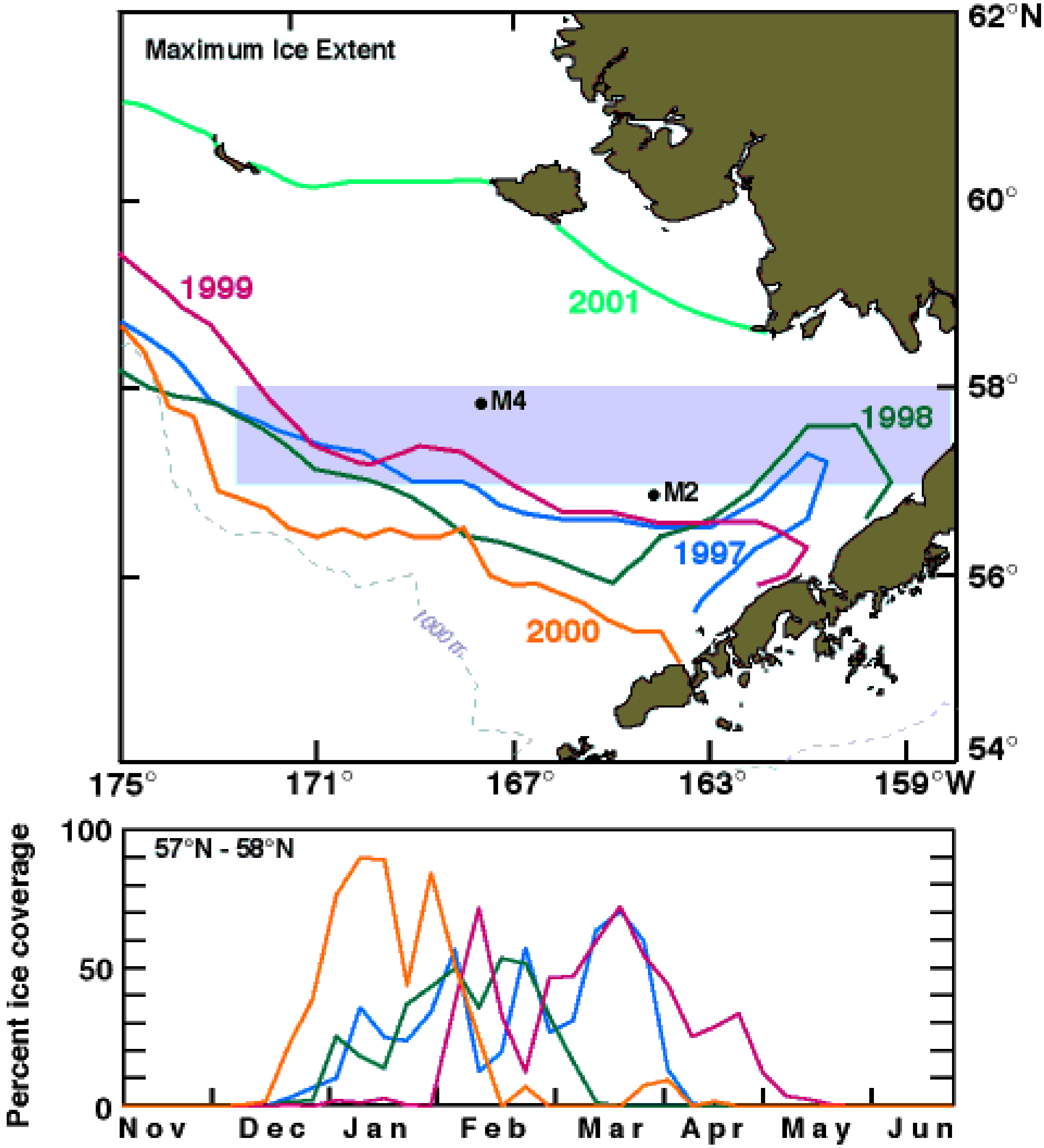

Figure 6. Top: Maximum ice extent during the period 1997-2001. **Bottom:** Weekly percent ice cover of the area indicated by the shaded box in the top figure (57° N – 58°N) for the same 5-year period.

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. 7) 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. 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.

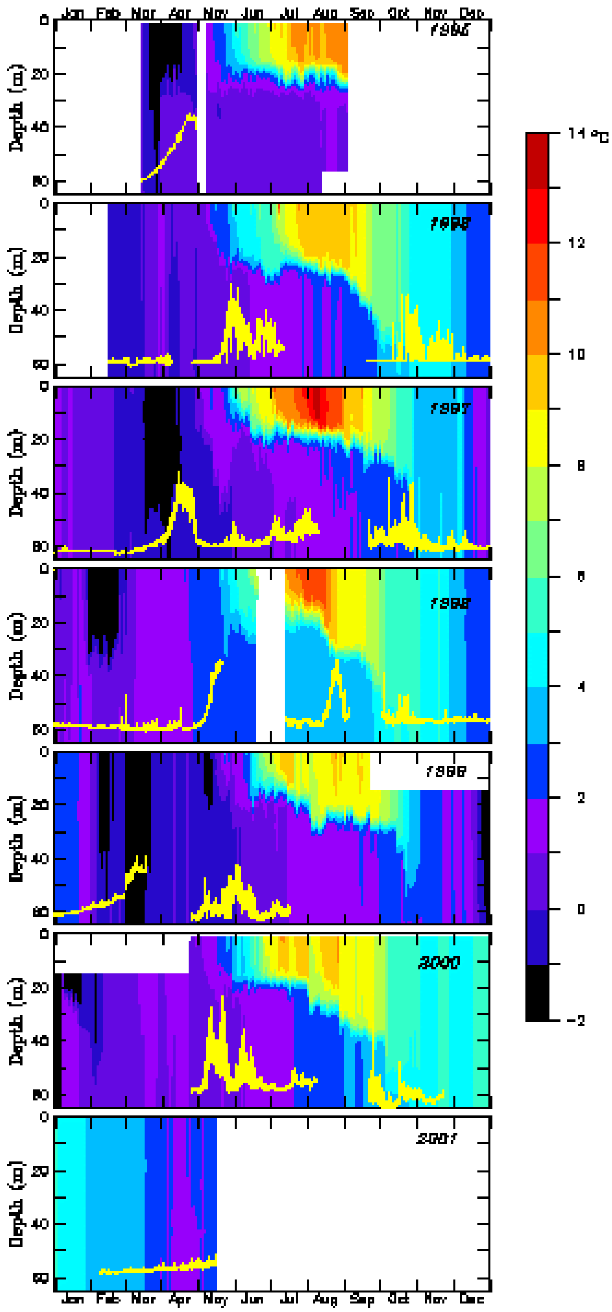

Figure 7. Ocean temperature (°C) as a function of depth (m) and time (month of year) and fluorescence as a function of time measured at mooring site 2 during 1995 through 2001.

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.

Ocean Surface Currents

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

Ocean surface current modeling has contributed to our understanding of the year-to-year variability in movements, survival, and spatial overlap with predators of larval fish in the eastern Bering Sea (Wespestad et al., 1999). Now, you can either update this study for yourself or create your own ocean-variability studies with the new version of the "Ocean Surface CURrent Simulator" (OSCURS) newly available on the World Wide Web. To run this numerical model just pick your own inputs: 1) a longitude-latitude start-point on the graphic chart of the North Pacific Ocean and Bering Sea; 2) any start-day (0000Z) from January, 1967 to July, 2001 (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 a chart is produced that shows the vectors of daily water movement strung together in a red trajectory line giving you the net drift of water from the start-point. These simulation experiments can now be run by the general public on the World Wide Web by connecting to the NOAA-NMFS-Pacific Fisheries Environmental Lab's (PFEL) home page, **http://www.pfeg.noaa.gov,** and clicking on "OSCURS."

Development of OSCURS was motivated by the need in fisheries research for indices that describe variability in ocean surface currents. Recognition of historical patterns in this synthetic, but calibrated, time-series data provides some limited forecasting value from the probable reoccurrence of these patterns. These synthetic data, derived through empirical modeling and calibration, provide insights that 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 (1967-2001) 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 for comparison with fisheries data at a particular location. See the information article on the NOAA-NMFS-AFSC-REFM OSCURS web page http://www.refm.noaa.gov/docs/oscurs/Default.htm, Information on the OSCURS Model, for a summary of experiments that have already been run. 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 (updated with data from the new OSCURS for 2001). To create the data series, OSCURS was run 100 times starting at Ocean Station Papa (50º N, 145º W) on each December first for 90 days for each year from 1901 to 2000 (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.

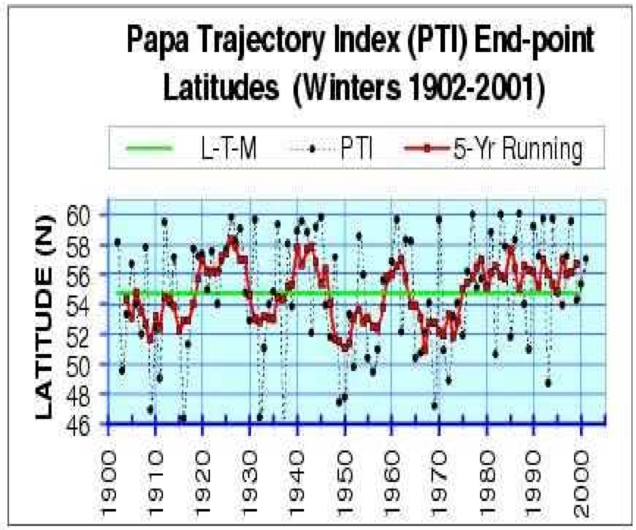

Figure 1. Annual long-term mean, and 5-year running mean values of the PAPA Trajectory Index (PTI) time-series from winter 1902-2001. Large dots are annual values of latitude of the end points of 90-day trajectories started at PAPA (50ºN, 145ºW) each December, 1, 1901, 2000. The straight line at about 55ºN is the mean latitude of the series. The oscillating thick line connecting the squares is the 5-year running means.

To reveal decadal fluctuations in the oceanic current structure relative to the long-term mean latitude (green horizontal line at 54.74º N), the trajectories were smoothed in time with a 5-year running 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 35 years and continuing (1964-1999). The drift from Ocean Weather Station Papa has fluctuated between north and south modes about every 23 years over the last century. The drift pattern is presently in the northern mode and the shift from north to south modes appears to be overdue or at least the longest oscillation this century. (The time-series includes 5-yr running means that include the winter 2001 calculations.)

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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.

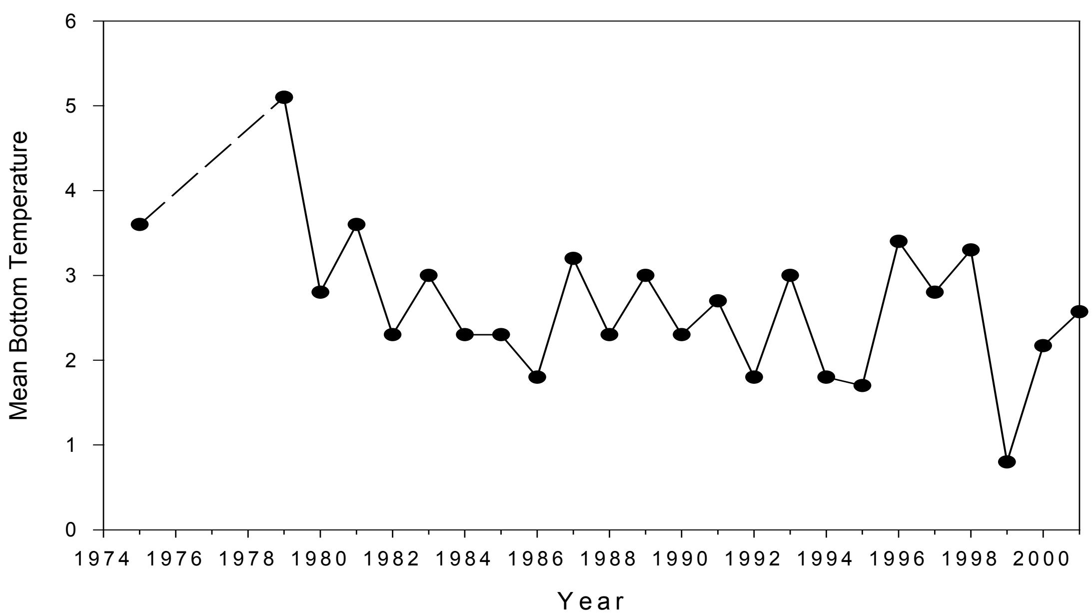
Summer bottom and surface temperatures- Eastern Bering Sea

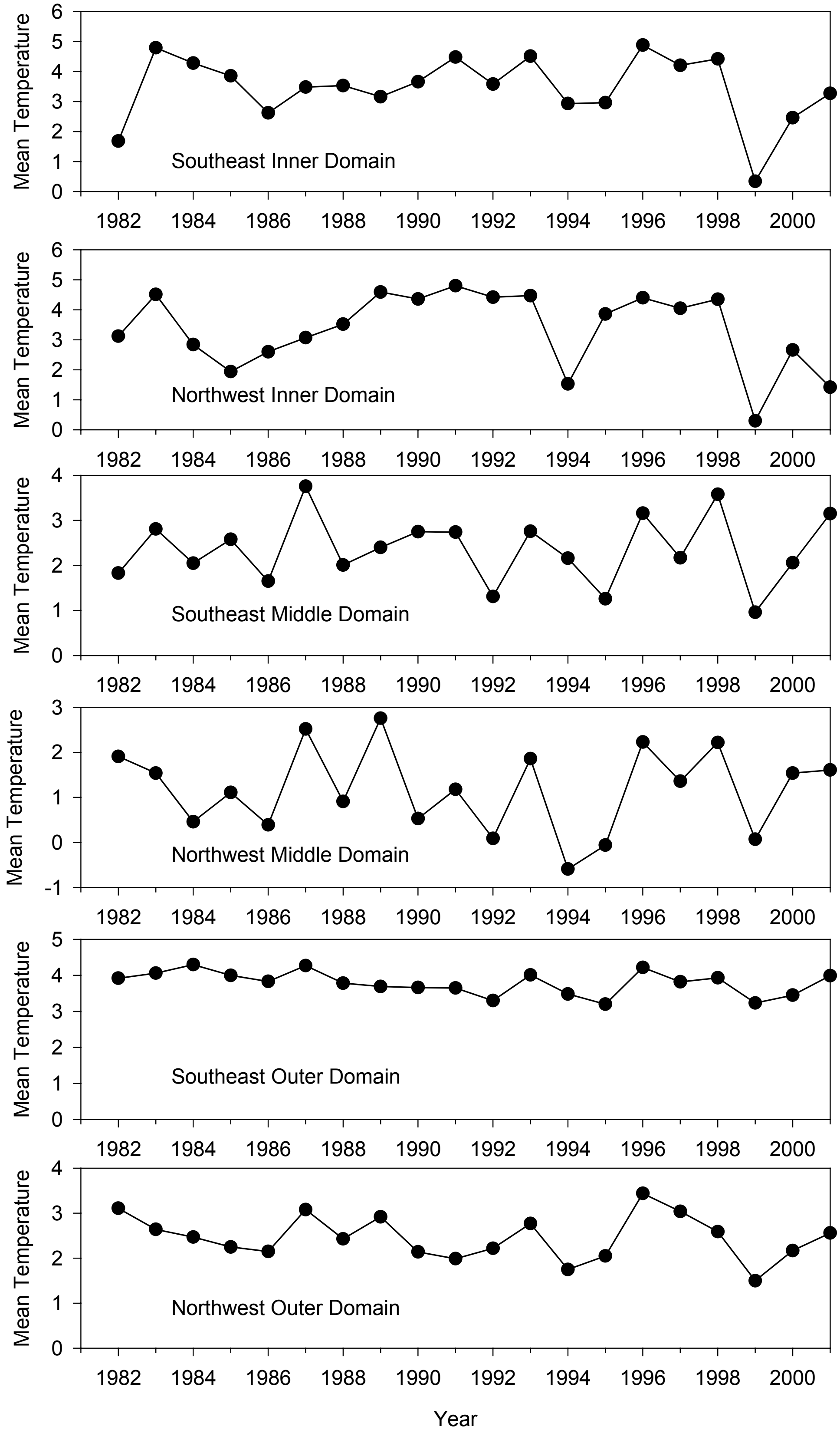
Contributed by Gary Walters, Alaska Fisheries Science Center

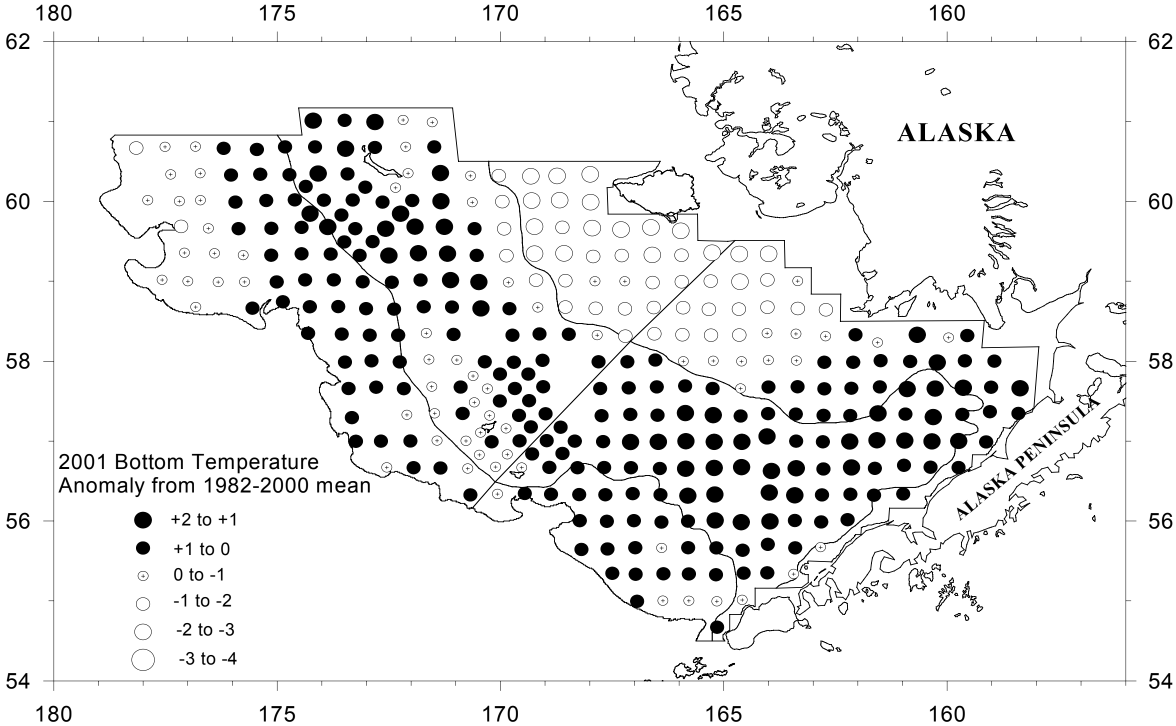
The annual AFSC bottom trawl survey for 2001 was started on 29 May, 2001, returning to near the 1 June start time typical of the 1982-1998 time series. During the previous two years (1999,2000) the time was approximately 2 weeks earlier. The marked event that may have had the most to do with temperature distributions however, was the lack of winter ice cover over the southeast Bering Sea. As a result, bottom temperatures were warmer in the middle regime and colder in the northwest inner and outer regimes than the overall mean from the time series. Surface temperatures were generally colder throughout than the overall time series mean.

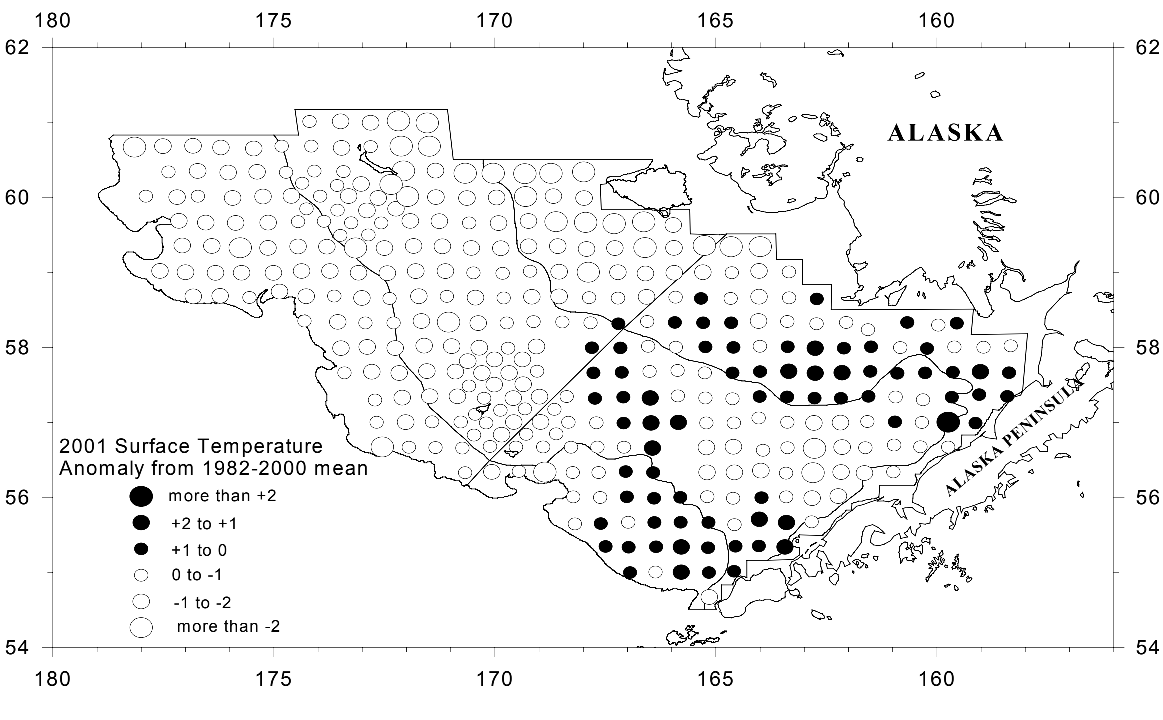
The average bottom temperature was 2.57^{O}C, slightly above the long term mean of 2.43^{O}C. The average surface temperature was 5.80^{O}C, below the long term mean of 6.63^{O}C.

There were no marked changes in distribution of fishes during this survey.




Mean Temperature
Southeast Inner Domain
Northwest Inner Domain
Southeast Middle Domain
Northwest Middle Domain
Southeast Outer Domain
Northwest Outer Domain
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
Year


180
175
170
165
160
62
60
58
56
54
ALASKA
ALASKA PENINSULA
2001 Bottom Temperature
Anomaly from 1982-2000 mean
+2 to +1
+1 to 0
0 to -1
-1 to -2
-2 to -3
-3 to -4


180
175
170
165
160
62
60
58
56
54
ALASKA
ALASKA PENINSULA
2001 Surface Temperature
Anomaly from 1982-2000 mean
more than +2
+2 to +1
+1 to 0
0 to -1
-1 to -2
more than -2

Gulf of Alaska Survey Bottom Temperature Analysis

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.

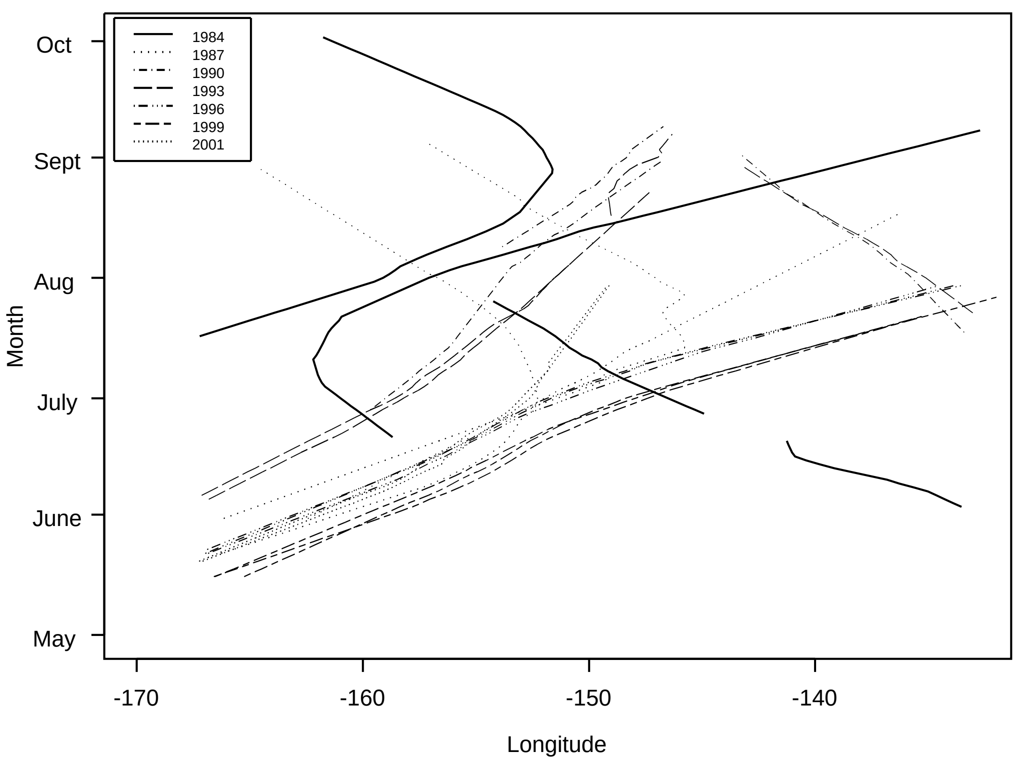


Figure 2. GOA survey data collection by longitude and date.

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.

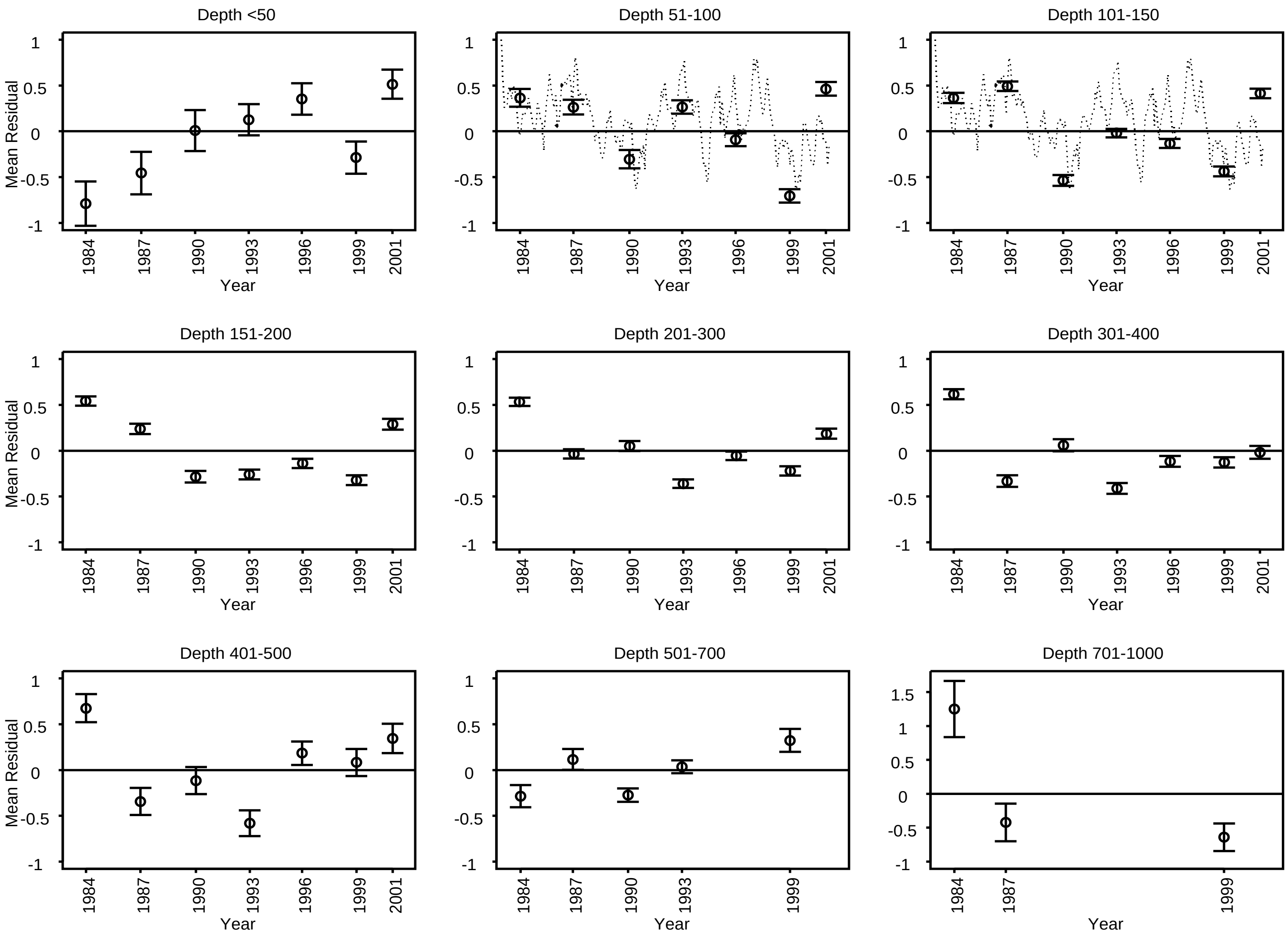


Figure 3. Mean temperature anomalies plotted by year within each depth stratum. Dotted line represents Pacific Decadal Oscillation index. Note expanded scale in 701-1000 m plot.

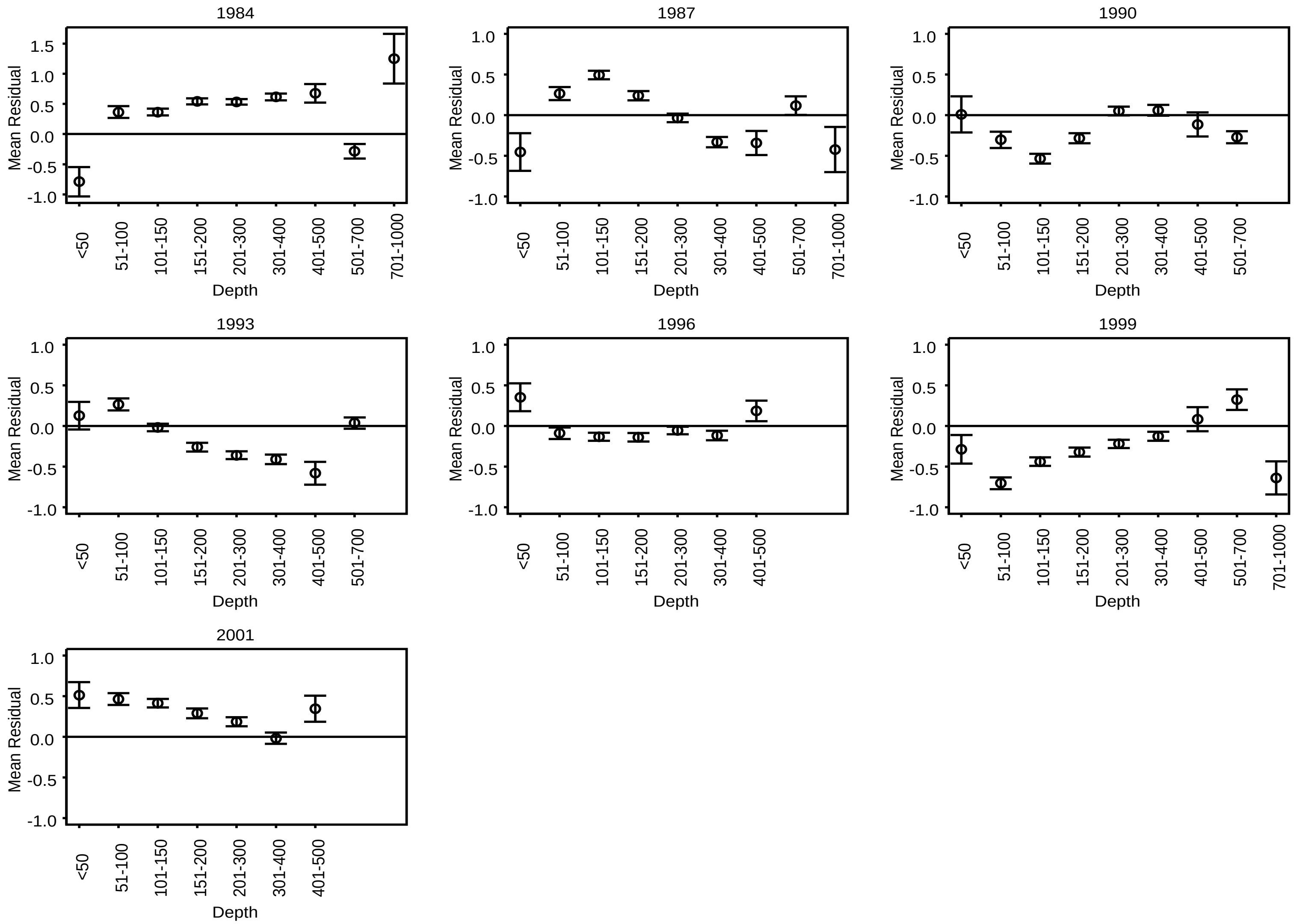


Figure 4. Mean temperature anomolies plotted by depth stratum within each year. Note expanded scale in 1984 plot.

Habitat

Indices of contaminant levels in sediments, groundfish and their prey.

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

The main harmful algal species in Alaska is the dinoflagellate *Alexandrium* that causes paralytic shellfish poisoning (PSP). PSP events have been documented as long ago as 1799 when Baranof crew members ate tainted blue mussels. Although PSP events have been documented mostly in summer, spring and autumn events have also occurred. PSP events affect shellfish and crab harvesting and expansion in Alaska (NWFSC 2000). In September, 2000 there was a fish kill around Kodiak that was tested for the presence of harmful algal species. More recent PSP events have been reported in January, 2001 around Kodiak Island.

References

Northwest Fisheries Science Center(NWFSC). 2000. Red Tides: West coast newsletter on marine biotoxins and harmful algal blooms. Available from the NWFSC web site (http://www.nwfsc.noaa.gov./hab).

Progress Report on Essential Fish Habitat Research

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

Several EFH projects were continued this year (see project reports below).

Project:	**Identification and Characterization of Atka Mackerel (Pleurogrammus monopterygius) Reproductive Habitat**
Period:	2001
Region/Office:	Alaska Fisheries Science Center, Seattle, WA

Participants: Bob Lauth, Scott McEntire, and Lowell Fritz

The basic biology of Atka mackerel has been poorly studied despite its commercial value and importance as a key forage species for the endangered Steller sea lion and other marine piscivores. During the summer and early fall, behavior and migration patterns of adult Atka mackerel presumably change because of spawning. Russian research suggests that Atka mackerel migrate to nesting areas where females deposit their eggs onto rocky substrate and males fertilize the demersal egg clusters and remain over the nests to guard the embryos. Off the Kamchatka Peninsula, Russian research divers have reported the maximum depth for Atka mackerel nesting is 32 m. Over the past several years, our researchers in the central Aleutian Islands have observed similar nesting behaviors in the nearshore areas, although there is much more to learn about the temporality of nesting and its spatial coverage across the entire Aleutian Island chain. Our research has shown a similar lower depth limit for nesting, however, we believe the 32 m depth limit may be an artifact of the depth limitations imposed by SCUBA and a lack of appropriate rocky substrate below 32 m in the vicinity of the study sites where nests have been observed. Evidence from other recent investigations using archival tags and trawling suggests that spawning and nesting in rocky habitat occurs to depths down to 120 m. If true, the essential habitat required for Atka mackerel nesting covers a much greater area than previously thought.

To date, our investigation of Atka mackerel nesting habitat has been limited to a small area near Finch Cove on Seguam Island using a drop camera, time-lapse cameras and SCUBA. We plan to continue using *in situ* time-lapse camera deployments at these specific sites for recording the temporal variation in the utilization of the nesting habitat during courtship, spawning and guarding. We suspect that nesting areas are more widespread in the central and western Aleutian Islands, that nests occur deeper than 32 m, and that peak nesting occurs in late August and early September. High vesssel charter costs and time-consuming dive operations limit our ability to search over large areas where nesting may take place. To expand our capabilities for searching, verifying, and quantifying Atka mackerel reproductive, we decided it was necessary to explore the use of a more effective sampling tool.

During 2001, we developed the Quadrat Underwater Assessment Drop Camera (QUADCAM). The new camera will enable us to quickly search for new nesting areas in nearshore regions with rough bottom, kelp and high current using an inflatable skiff as the research platform. Larger research vessels cannot venture into these nearshore areas. The camera system is capable of discerning embryo masses on a rocky substrate and measuring a fixed area for estimating embryo mass density and quantifying habitat types. The QUADCAM system consists of a bottom resistant tripod frame, high-resolution-progressive-scan digital video camcorder with high frequency strobes, 1000 m aluminum pressure case with water corrected optics, live feed ultra-low light camera with 250 m of cable, GPS overlay, and a data logger for measuring depth, temperature, and light. During the late summer/early fall of 2002, we plan to work in conjunction with the U.S. Fish and Wildlife's research vessel *Tiglax* to use the QUADCAM for documenting the spatial distribution of nesting areas and density of embryo masses in different parts of the central and western Aleutian Islands.

Project: **Nearshore Habitat Utilization by Rockfish and Other Species**
Period: 2001
Region/Office: Alaska Fisheries Science Center, Auke Bay Laboratory
Participants: Scott Johnson and John Thedinga

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 Southeast 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 Southeast 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.

Patterns in the distribution, habitat, and behavior of rockfish (*Sebastes* spp.) were examined with a remotely operated vehicle (ROV) in coastal waters <90 m deep of Southeast Alaska from 1998 to 2001. We made 616 observations (~4800 fish) representing 14 species in 208 ROV dives at 37 sites. Species identified were black, canary, china, copper, dusky, harlequin, Puget Sound, quillback, redstripe, rosethorn, silvergray, tiger, yelloweye, and yellowtail rockfish. Quillback and dusky rockfish were the most widely distributed species and found at 22 and 17 sites, respectively. China and harlequin rockfish were the least widely distributed species and found at only 1 site each. Species richness, based on number of species observed, was greater at sites on or near the outer coast than at sites in more inside, sheltered waters. Most (>75%) observations of rockfish were over complex bottoms of boulder and rock or in vertical bedrock wall habitats. Few rockfish were observed over soft bottoms with no relief. Median depth of observations was ≤30 m for black, copper, dusky, and yellowtail rockfish and >30 m for all other species. Median temperature of observations ranged from 6.1° C for harlequin rockfish to 9.4° C for black rockfish. Size of fish observed ranged from 10 to 60 cm; fish size was positively correlated ($P \leq 0.036$) with depth for dusky, quillback, and yelloweye rockfish. Species often observed alone were china (67%), copper (46%), quillback (46%), and rosethorn (43%) rockfish. Most (≥70%) observations of harlequin, Puget Sound, silvergray, tiger, and yelloweye rockfish were in mixed species assemblages. When first observed, the behavior of most rockfish species was swimming or hovering. Notable exceptions were china, harlequin, rosethorn, and tiger rockfish; 33-57% were resting on bottom or in a hole or crevice. Nearshore waters of Southeast Alaska are utilized by at least 14 species of rockfish, many of commercial, sport, and subsistence value. Knowledge of the distribution and habitat of nearshore rockfishes will help managers protect coastal habitats at risk to human activities.

In 2001, a long-term study was initiated to monitor 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 were sampled for fish assemblages with a beach seine and area of each meadow was measured by GPS. Other habitat parameters measured included eelgrass stem density and biomass, and sediments were collected for baseline contaminant analysis. Each of these sites will be sampled annually over the next several years. Sites were located from inside to outside waters of

Southeast Alaska. Eelgrass meadows support high biodiversity and provide important habitat for juvenile rockfish and other species. At least 49 species of fish are known to use eelgrass meadows in Southeast Alaska.

Characterization of nearshore fish assemblages and habitat is also providing valuable information on available prey to Steller sea lions in Southeast 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 Southeast Alaska. Thus, in conjunction with satellite tagging of sea lions and scat surveys, our nearshore studies will help provide a complete picture of where sea lions forage, what prey is available, and what they consume.

Project:	**Essential Fish Habitat Evaluation in Southeast Alaska Estuaries**
Period:	2001
Region/Office:	Alaska Fisheries Science Center, Auke Bay Lab
Participants:	Mitch Lorenz, Dean Courtney, and K Koski

The purpose of this project was to develop and test fish habitat classification and habitat use models to allow inventory and EFH evaluation of Alaska estuaries. The Alaska Essential Fish Habitat (EFH) Planning Team determined that estuaries adjacent to rapidly developing coastal areas were "habitat areas of particular concern" (HAPC). In other regions NMFS research has identified estuaries as critical fish habitat, particularly for the non-adult stages of species that are most often missing from stock assessment and EFH evaluations in Alaska. In Alaska, however, little is known about how much estuary exists and even less is known about how estuarine habitat is used by species managed by NPFMC

Current EFH definitions for many Federally managed fish species in the Alaska Region are so general and have such broad coverage as to be of little use in consultations. Inability to do consultations could jeopardize findings that NMFS has met the requirements of the EFH mandates in the MSFCMA. Since 1998, scientists at Auke Bay Laboratory have been developing methods to assess and monitor HAPCs and evaluate EFH in nearshore areas. This research has been designed to improve NMFS ability to assess and evaluate not only nearshore but also offshore fish habitat.

The overall objectives were to develop a fish habitat classification system and essential fish habitat models for estuarine areas of Southeast Alaska utilizing the following tasks:

- Develop a classification system to delineate EFH in estuarine areas of Southeast Alaska from existing data sources (e.g., nautical charts, National Wetlands Inventory, ACOE Permit database) and remote sensing sources (e.g., aerial photography, satellite imagery).
- Compile and integrate fish abundance and environmental data from throughout the Southeast Alaska area with the classification system to produce a GIS for EFH evaluations in regional estuaries.

- Develop models to help monitor and predict the effects of coastal development on EFH and to identify nearshore HAPCs.

In 1999 and 2000, fish abundance and habitat characteristics were evaluated in the estuarine wetlands of the Mendenhall Wetlands State Game Refuge near Juneau. This research indicated that Alaska estuarine wetlands provide diverse habitat for important FMP species and also produce food organisms used by such species. Estuaries provide a critical physiological staging area for salmon during migration between salt and fresh water. Salmon and other important FMP and forage species (e.g., yellowfin sole, rock sole, starry flounder, sand lance, herring, capelin, eulachon, and many invertebrates) are also plentiful in coastal wetlands associated with estuaries (Table 1). Patterns of spatial and temporal habitat use, relative abundance, and feeding life stages of several FMP species that use estuarine wetlands have been demonstrated, however, links between estuarine habitat and abundance and distribution of fish are not well understood. A GIS was developed by integrating the field data with existing maps, nautical charts, and remote imagery. An experimental EFH classification system was then developed from that GIS.

In 2001 EFH data was collected in two additional estuaries in northern Southeast Alaska. Fish habitat was classified during fish abundance surveys and was mapped during GPS ground surveys. That data will be integrated into a GIS and evaluated with the experimental classification system developed in 1999-2000. The classification system will be adjusted to provide consistency between the various sites.

In 2001 a contractor has been hired to map estuarine areas in Southeast Alaska from available satellite and photographic imagery and from National Wetlands Inventory and NOAA chart data. The contractor will also work with ABL scientists to refine the experimental EFH classification system for spatial analysis and mapping. Future funding from the Essential Fish Habitat program will be necessary to continue this work.

TABLE 1. Species Captured in EFH Sampling in the Mendenhall Wetlands

Species	**Percent of Total Catch**	**Species**	**Percent of Total Catch**
Pacific herring	44%	Sturgeon poacher	<1%
Chum salmon	16%	Flathead sole	<1%
Coho salmon	6%	Capelin	<1%
Starry flounder	6%	Gunnel	<1%
Halibut	5%	Sockeye salmon	<1%
Cottids	5%	Cutthrout trout	<1%
Pacific sand lance	5%	Steelhead trout	<1%
Yellowfin sole	5%	Greenling	<1%
Dolly varden	2%	Dungeness crab	<1%
Rock sole	1%	Bay pipefish	<1%
Chinook salmon	1%	Snailfish	<1%
3-spined stickleback	<1%	Sand fish	<1%

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 sea floor 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.

Habitat evaluation of major fishing grounds Principal investigators Robert Stone, Jeffrey Fujioka, and Jonathan Heifetz (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 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.

The objective of the study is to characterize bottom habitat in or near heavily fished rockfish grounds to understand whether habitats in current fishing grounds are vulnerable to ongoing fishing activities. Habitat that may be most vulnerable to bottom trawling is believed to occur on rough, hard, or steep bottom, often on shelf areas near the slope. Rockfish are typically found on or near rough bottom, based on the type of gear used by trawlers targeting rockfish. Vulnerable habitat in soft bottom areas such as sea whip beds are being investigated in other AFSC studies.

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 noted on the flatter grounds where perhaps the relatively level bottom does not induce door gouging and there is a lack of boulders to be turned over or dragged. The substrate was a poorly sorted mix of silt, sand, shell and gravel with an occasional boulder. The most common sessile epifauna were crinoids, small non-burrowing sea anemones, glass sponges, stylasterid corals and two species of brittlestars. Occasional large boulders 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.

Evidence of trawling was quite evident on one slope site where there were boulders turned over or dragged. The uneven bottom perhaps induced gouging by the trawl doors. The bottom was mostly small boulders, cobble, and gravel. Presently there does not appear to be much habitat in these areas that would can be damaged by trawl impacts. Whether this is the result of past trawl activity is unclear.

Large boulders were observed at the lightly fished site toward the middle of the Bank, perhaps contributing to its lightly fished condition. From a preliminary superficial look at the video tapes, the "lightly fished" sites did not have markedly more or larger benthos or greater species diversity. Any comparison of the lightly fished site with other sites would be confounded by location and habitat differences and the possible unobserved fishing in this area.

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.

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 characterized. The objective of this study is to map limited areas of the Alaska EEZ for geomorphic/geologic characterization using state-of-the-art technology. During summer of 2001, approximately 900 km^2 of sea floor in the vicinity of the commercial fishing grounds of Portlock Bank were mapped using a high-resolution multibeam echosounder that included coregistered backscatter data. Survey depths ranged from less than 100 m to about 750 m.

An additional mapping survey was conducted in cooperation with the Alaska Department of Fish and Game off Cape Ommaney in southeast Alaska. The purpose of the survey was to map habitat features in the vicinity of colonies of red-tree coral (*Primnoa willeyi*). The area mapped is characterized as an irregular seabed with mixed sediments (mostly sand and gravel) and high-relief rocky outcrops and pinnacles. Depths at the survey site ranged from approximately 150 m - 300 m. The survey covered approximately 180 km^2 of seafloor during two days of surveying. A small part of this area was previously surveyed with a submersible. Combined with submersible observations this mapping will allow habitat and geological characterization and classification of the areas.

Trawl impact studies in the Eastern Bering Sea Principal Investigator - Robert A. McConnaughey (RACE Division, Alaska Fisheries Science Center)

The trawl impact study in 2001 was conducted to experimentally investigate possible adverse effects of bottom trawls on a soft-bottom community in the eastern Bering Sea and to evaluate a state of the art side scan sonar and swath bathymetry system for exploration of benthic habitats. Whereas earlier work focused on chronic effects of trawling, the present study is a more process oriented look at short-term effects and recovery. The 155' trawler *F/V Ocean Explorer* was chartered and all scientific systems were successfully implemented, 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 30 May-1 June gear trials in Puget Sound. During the 15 June-15 July Alaska cruise, biological, physical and chemical characteristics of the seabed were randomly sampled in six experimental-control corridor pairs (Fig. 1). Individual corridors were 20.9 km long and 100 m wide, representing the long-term average tow for commercial bottom trawls in the study area. Biological sampling consisted of 15 min research trawls for epifauna (n=72 total) and 0.1 m^2 van Veen grab samples for infauna (n=144 total at 2 per epifauna site). At each infauna sampling site, a second grab sample (n=144 total) was collected for characterizing carbon and nitrogen levels in surficial sediments, as well as grain size properties. Sampling effort in experimental and control corridors was equally divided before and after fishing in the experimental units with a commercial bottom trawl (NETS 91/140 Aleutian cod combination). Experimental corridors were fished four times with bottom trawl gear while no-fishing was performed on the controls. Each of the experimental and control corridors was also surveyed twice using a Klein 5410 side scan sonar system.

Preliminary observations indicate a very diverse epifaunal community (approximately 90 distinct taxa) on very-fine olive-gray sand at 60 m depth. The sea floor appears to be brushed smooth in the preliminary 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, with at least some areas of the seafloor resembling the surface of a soccer ball with marbled coloration. Significant numbers of derelict king crab pots were encountered and there is preliminary evidence of extensive feeding by walrus, which involved the presence of bottom furrows and large numbers of intact but empty bivalve shells that is consistent with what is know about walrus feeding behavior in the area. Two conspicuous as yet unidentified targets were also encountered. A more detailed characterization of the area will be possible once laboratory processing and analysis of the sonar, epifauna, infauna and sediment data are completed.

The new NOAA Ocean Exploration program supported use of a Klein 5410 interferometric side scan sonar system. This fully-digital multibeam system produces co-registered backscatter and swath bathymetry with four side scan beams and one interferometric beam each on the port and starboard sides of the towfish. At this time, there are only three prototype Klein 5410 systems in existence (France, Japan, U.S.). Side scan backscatter images contain quantitative information about the sediment type and general roughness of the seabed, while swath bathymetry enables direct measurements of small vertical features on the seabed. Both types of information are important when investigating relationships between geological features, benthic biota and fishing gear disturbance. In addition to data collection for an analysis of change due to trawling, additional objectives of the deployment were evaluations of advanced remote-sensing technology for future broad-scale sea floor mapping expeditions and the feasibility of using ships of opportunity for this purpose. Approximately 950 line-km of seabed were successfully sampled with the system and protocols were developed for implementing state of the art side scan sonar and navigation technology on a chartered commercial fishing vessel.

Plans for proposed research in 2002 have two objectives. First, the trawl effects study will continue with recovery assessments in all six experimental-control corridor pairs. The full biological and geophysical sampling regime will be used to characterize changes that have occurred after a one-year recovery period. Using a Before-After-Control-Impact ("BACI") experimental design, baseline information on natural variability in control corridors will be statistically factored out of the recovery responses observed in the experimentally-trawled areas. The experimental design will accommodate one additional series of epifauna sampling and multiple years of grab sampling after 2002. The second objective for the 2002 field operations is to use the Klein sonar system for high-resolution reconnaissance mapping of the Bristol Bay seabed. These surveys are intended to detect boundaries between distinct texture-bedform classes of seabed, rather than synoptic mapping which is impractical for large areas.

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.

Analyses completed indicate that: 1) trawling intensity in this area, although high for the GOA, is relatively low compared to other areas worldwide, and 2) effects on the sedimentary and biogeochemical features of the seafloor and infauna community structure from present levels of bottom trawling were subtle and no clear patterns were detectible. Although epifaunal community structure analyses are incomplete, a clear positive relationship between total epifaunal biomass and sea whip abundance is apparent. This relationship indicates that sea whip habitat may have increased productivity. Recent studies in the Bering Sea have shown a similar functional relationship for sea whip habitat.

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 sea floor 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 sea floor 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.

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

Detailed knowledge of sea floor 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. A recently completed study demonstrated that the *QTC View* seabed classification system (Quester Tangent Corporation, Sidney, B.C.; QTC) is capable of background data acquisition during routine survey operations. Subsequently, nearly 8 million digitized echo returns from the seafloor were collected along a 9,000 nm trackline in the eastern Bering Sea during a hydroacoustic fishery survey by the *Miller Freeman* (cruise MF 99-09, June-August 1999). Data were simultaneously collected at two frequencies (38 and 120 kHz) and analyses are continuing 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 covering the entire Bering Sea shelf. 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 that are rich in sediment character. 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 strikes a balance between high information content (i.e., many classes) and high confidence in the assigned class (e.g., if only one class).

Collaborative research with the QTC during 2001 was focused on refining statistical processes and developing a fully objective procedure for identifying the optimum classification scheme. At each frequency, six combinations of two pre-processing parameters known to affect classification results were evaluated: (1) echo stacking (or averaging) to improve signal to noise and (2) reference depth, used to compensate for beam spreading and depth-related effects. After each PCA using the full data sets, a new application of Bayesian Information Theory was applied to guide the clustering process and a statistical measure of distance was used to rank the results. 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 were used for these 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. Based on this analysis, the optimal number of classes was 18 at 38 kHz and 25 at 120 kHz. The higher number of classes at 120 kHz is to be expected based on greater theoretical sensitivity to surface features including benthic biota. Data visualization was enhanced with a color scheme that assigned similar colors to acoustically similar classes. In order to use the full data sets for clustering, we will be investigating use of simulated annealing in 2002, which is a technique for efficiently identifying global minima. Automating the full analytical process would enable seabed classification and mapping over very large areas on a routine basis.

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. The 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.

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 2001. Two sites established in July 1999 were revisited during Cruise 01-11 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 two previous years. A third study site was established in Kelp Bay, Baranof Island 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). Cobbles were collected with recently established colonies (solitary polyps) and these are being reared in laboratory aquaria. Careful monitoring for asexual budding in these young colonies will provide valuable information on gorgonian growth patterns and rates.

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

Results of the aforementioned study (Freese, in press) 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, will be monitored on an opportunistic 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 addition, we plan to remove pieces of a known size from certain of these specimens to obtain information related to rates of regeneration of the sponge bodies. A second community of sponges located in the vicinity of Benjamin Is., Lynn Canal, Alaska, will also be tagged, measured, and monitored, beginning in November 2001.

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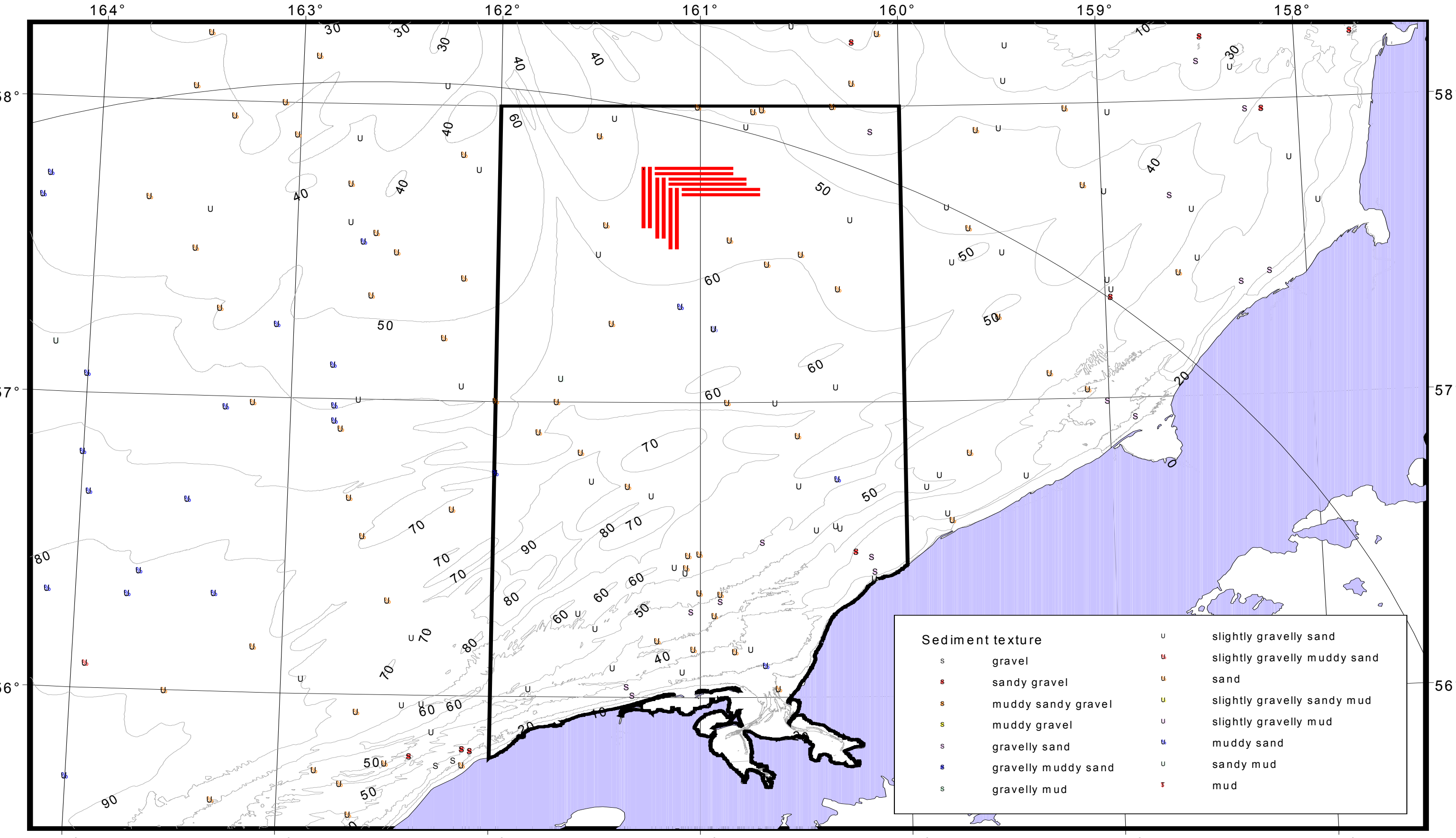

Figure 1. Location of research corridors with the Crab and Halibut Protection Zone 1 in the Bristol Bay area of the eastern Bering Sea. Six experimental-control corridor pairs were sampled during the summer 2001 cruise. Depths in meters and sediment textures are indicated, as well as an arc indicating the advertised 180 nm broadcast radius for the U.S. Coast Guard differential GPS beacon located at Cold Bay, Alaska.

Zooplankton, Chlorophyll and Nutrients

Contributed by FOCI
NO NEW INFORMATION

Forage Fish

FOCI Research on Early Life History of Capelin

Contributed by Miriam Doyle, University of Washington

Ichthyoplankton surveys have been conducted by the Alaska Fisheries Science Center (AFSC) in the northeast Gulf of Alaska (GOA) from 1977 to the present, primarily during spring. Time series data (1977-1998) from these cruises indicate that a peak in capelin (*Mallotus villosus*) larval abundance occurs in late summer and early autumn (September-October) on the continental shelf. Capelin larvae occur in the plankton throughout the rest of the year in low numbers, with a minimum March-May. The most intensive seasonal collections of larvae were made during a 17-month period from 1977-1979, within 4 Kodiak Island, AK, bays and over the adjacent continental shelf and slope. More extensive analyses of these data concur with observed long-term patterns of abundance on the shelf and also indicate a summer peak (July-August) in larval abundance in Kodiak bays. Spatial patterns in abundance and size distribution of larvae suggest that the smallest individuals are advected from beaches where they were spawned. Subsequent to this seaward movement, larvae may be subject to mixing processes on the shelf south of Kodiak Island where current direction is variable. Diel variation in abundance indicates that larvae (mostly >20 mm SL) undergo a nocturnal migration to the surface. Results from this study provide new information on the early life history of capelin in the vicinity of Kodiak Island, during a period of high adult abundance that has been linked to a cold phase in the oceanographic environment of the GOA. Our observations form the basis for future studies of early life history patterns for capelin in GOA and are particularly relevant for comparisons with other investigations conducted during the warm water or transitional phases of the oscillating oceanographic regimes in this region.

Bering Sea Juvenile Walleye Pollock

Contributed by Ric Brodeur, Northwest Fisheries Science Center

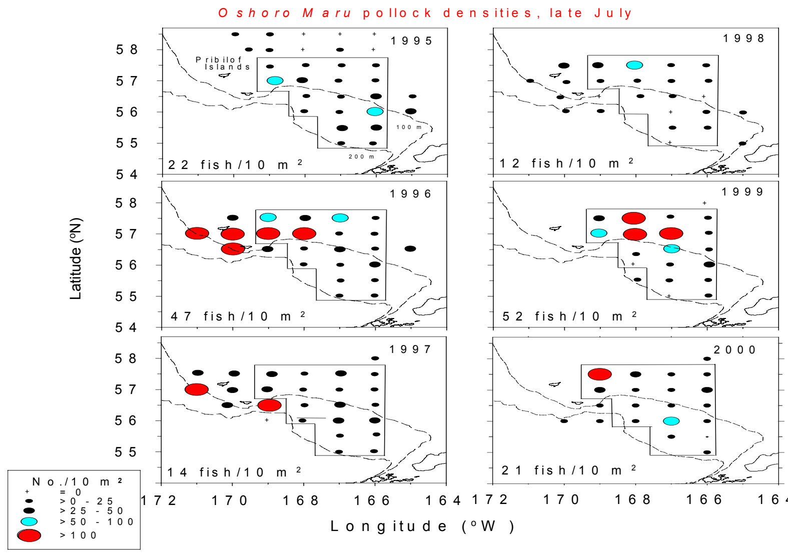

Figure 1. Densities of age-0 walleye pollock sampled in summer on the Oshoru Maru, 1995-2000. Number at the bottom of each panel indicates the density inside the outlined standard sampling area.

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.

Groundfish Biomass and Recruitment Trends

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.

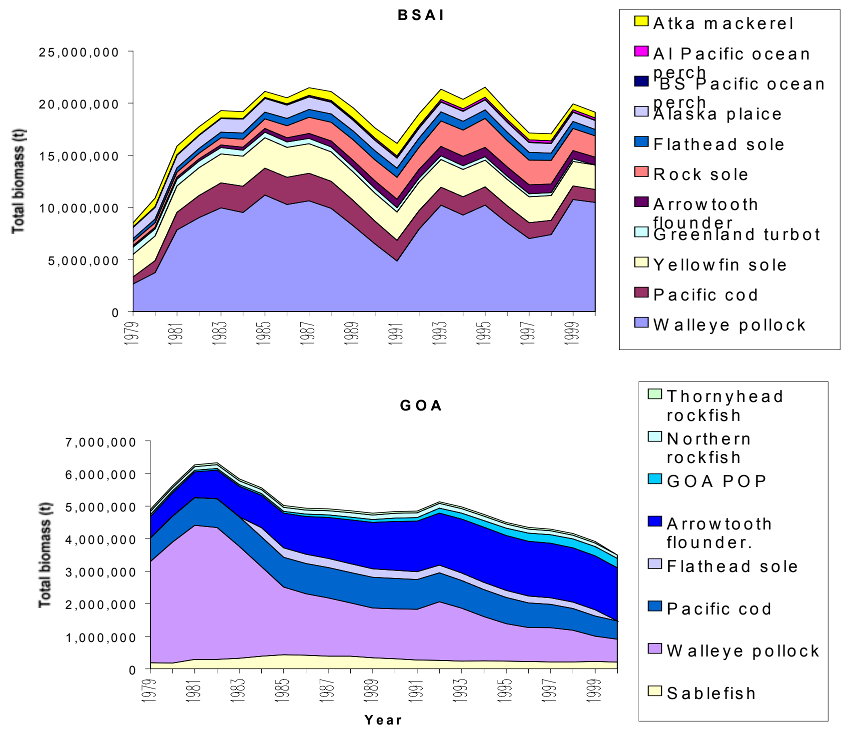

Figure 1. Groundfish biomass trends in the BSAI and GOA from 1979 to 2000, as determined from age-structured models of the Alaska Fisheries Science Center reported by NPFMC (2000a,b).

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).

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.

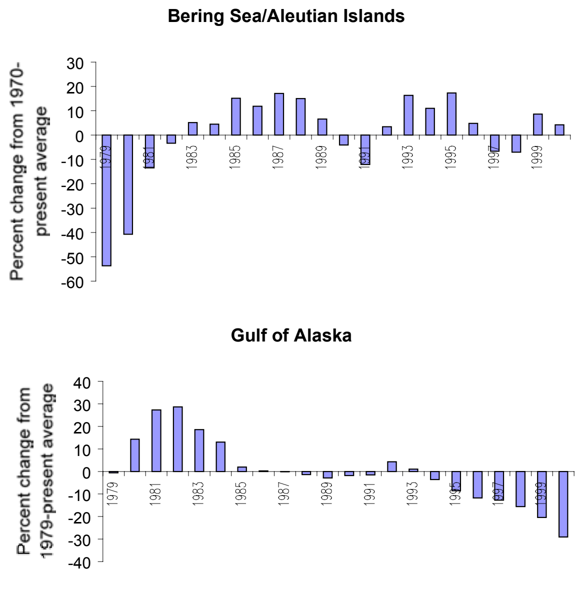

Figure 2. Total biomass trends (percent change from time series average) for BSAI and GOA groundfish assessed by age-structured models of the Alaska Fisheries Science Center, 1979-2000.

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.

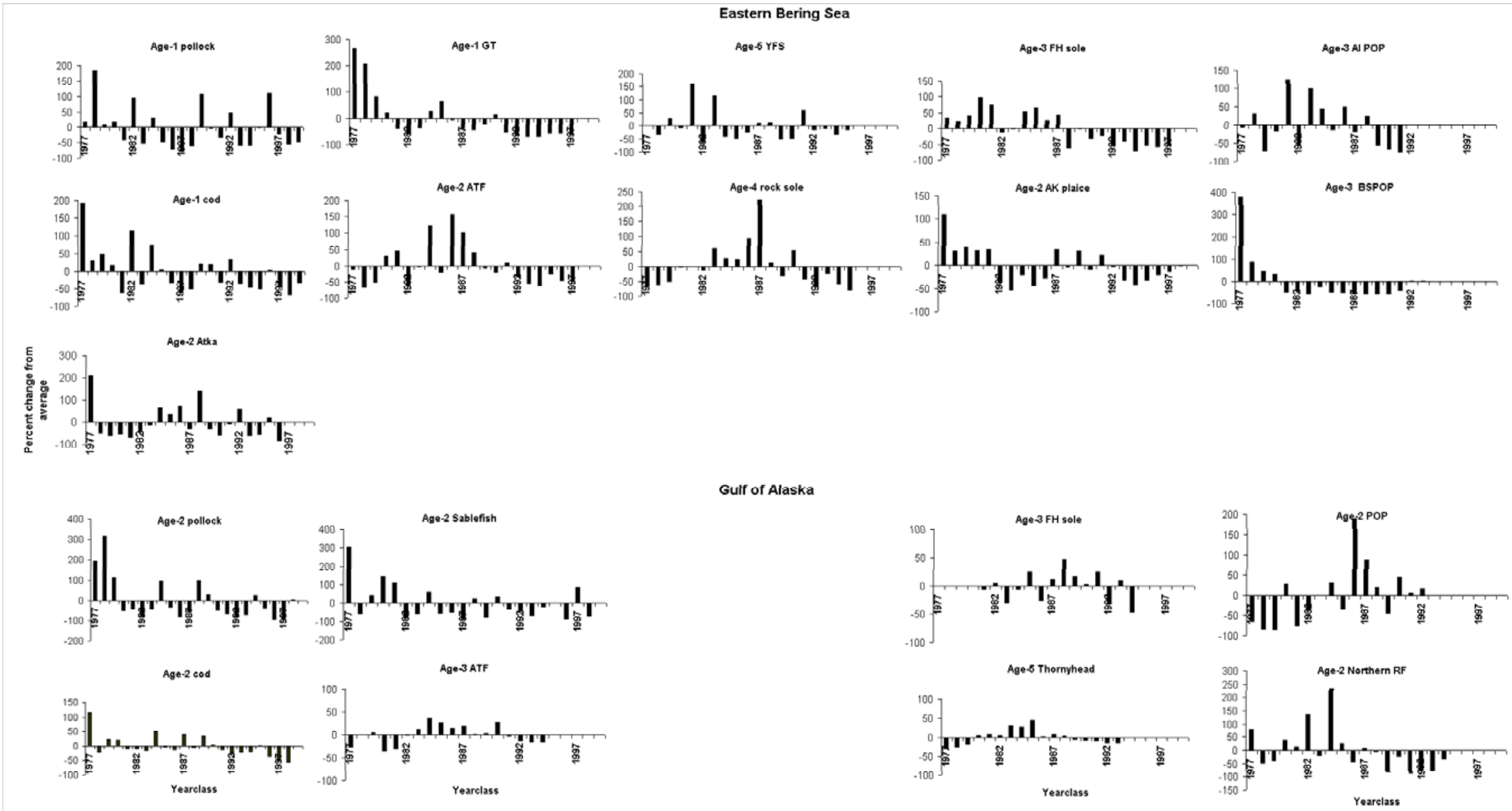

Figure 3. Groundfish recruitment trends (percent change from the 1977-present average) as determined from the age structure models of the Alaska Fisheries Science Center reported in NPFMC (2000a, b).

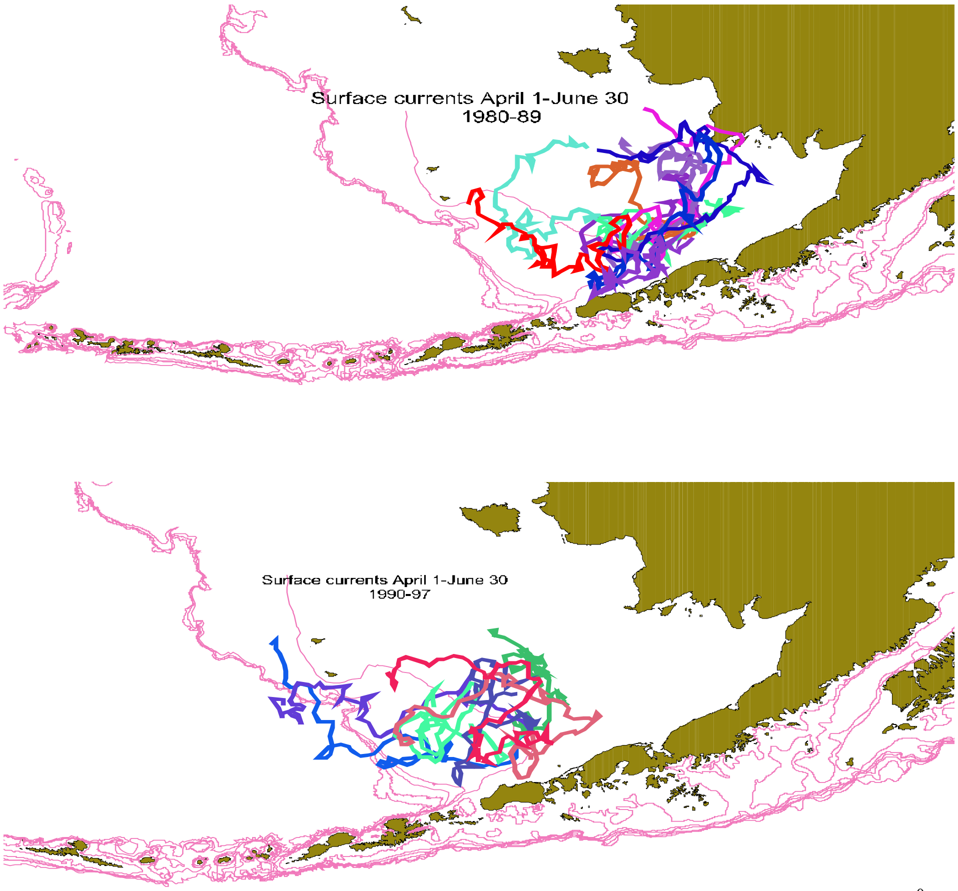

Figure 4.—OSCURS (Ocean Surface Current Simulation Model) trajectories from starting point 56^0 N, 164^0 W from April 1-May 31 for the 1980s (upper panel) and 1990-1996 (lower panel).

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Historical Abundance Trends from Bottom Trawl Data

By Liz Conners, Anne Hollowed, and Eric Brown, Alaska Fisheries Science Center

We conducted a 40-year retrospective study of catch biomass and species composition from bottom trawl surveys in the southeast Bering Sea (BS) and Gulf of Alaska (GOA). The study (Conners, Hollowed, and Brown 2001) looks at differences in catch between subareas within each region, and at changes in trawl catch over a period that includes substantial changes in climate, fish harvest, and management strategies.

Methods

The NMFS RaceBase database includes trawl data from 1961 through 2000. Over this period, surveys were conducted by several different agencies using variations on a 400-mesh Eastern trawl net and Nor'Eastern net. In the 1960's and 70's major surveys were conducted by the International Pacific Halibut Commission (IPHC). NMFS conducted crab and groundfish surveys during the 1970's and began annual surveys of the Bering Sea shelf and triennial surveys in the GOA in the early 1980's. While the earlier data include variations in gear, vessels, and methodology, gear comparison studies (vonSzalay & Brown in press, Wilderbuer, Kappenman and Gunderson 1998, Munro 1998) allow the combination of data from the different net types onto an approximately common scale of catch weight / area trawled. Study areas approximately 200 km by 200 km were selected in each region (BS, Western GOA, and Central GOA) to include areas with the best spatial and temporal coverage. This scale represents a finer spatial resolution than the basin-wide estimates used for stock assessments, and trends noted are for the selected area only, rather than the entire basin. Selection criteria were applied to limit the analysis to valid summer season trawl data, and the catch weight in each haul was tabulated for a number of species and taxonomic groups. The resulting coverage includes ≥20 hauls in most sites and years. We used a robust trawl survey indicator (TSI) of median CPUE based on the delta distribution (Pennington 1983) to track changes over time, calculated as:

$$TSI_{(year,site)} = \text{Sample Geometric Mean of non-zero hauls} \times \text{Percentage of non-zero hauls}$$

Approximate 95% confidence intervals for the median were calculated from all data using a robust nonparametric procedure based on order statistics (Gilbert 1987).

Results – Bering Sea

Time series for three sites on the southeastern Bering Sea shelf (Figure 1) show substantial changes over the last 40 years. All three sites show major shifts in both demersal fish and benthic invertebrates beginning around 1980 (Figure 2a,b,c). The biggest changes are increases in biomass of walleye pollock, Pacific cod, rock sole, and non-crab benthic invertebrates. There are substantial shifts in local biomass of gadids over time, which may be related to changes in climate. Pollock and cod show low biomass during the cold period of 1971-76, but increased biomass following the climate "regime shift" in 1976-77. A very high pollock biomass in the 1980's is a result of strong year classes during the "warm" period of 1977-85. These stocks also show a general decrease in biomass following the "correction" to more moderate temperatures in 1989-92. In the 1990's gadid biomass is annually variable and slightly smaller than in the 1980's, but still substantially greater than was observed in the 1960's and early 70's.

Some flatfish species show steep biomass increases that represent a geographic range expansion into Bristol Bay and the northern parts of the shelf (rock sole) and/or an overall increase in abundance (arrowtooth flounder). Both of these changes are most pronounced in the mid-1980's and 1990's. These shifts may be related to climate-driven changes in on-shelf advection (Wilderbuer et al 2001). A striking change also occurs in the biomass of benthic invertebrates other than crabs, beginning around 1980 and continuing through the 1990's. The increased biomass of this group includes increases across several taxa (echinoderms, mollusks, sponges, and ascidians). While early data on these taxa are incomplete, surveys after 1973 should include the correct weight of invertebrates caught, even where species identifications were not made. This result suggests a substantial shift in the benthic community, with possible effects throughout the benthic/demersal food web. Taken together, the concurrent changes over several different species and groups suggest a substantial re-arrangement of the shelf ecosystem.

Results – Gulf of Alaska

The five study sites selected in the Central and Western GOA show substantial variation in species composition and catch biomass (Figure 3a,b), which reflects the spatial variability in habitat and bottom conditions that exists in these regions. Sites with the closest proximity and similar habitat (Chirikof and Kodiak, Outer PWS and Yakutat) show the greatest similarity of species composition and time trends, but the full range of east-west variation in catch is apparent. An important feature of the GOA results is that they do *NOT* show the same patterns of increase in gadid biomass and benthic invertebrates seen in the Bering Sea. Invertebrate catch at all five GOA sites represents only a fraction of the total biomass, and does not show substantial changes over time. The data do suggest differences in both catch biomass and species composition from the 1961-62 survey to more recent years, even when the TS Index is adjusted for gear differences. Most sites also show differences between survey catches during the coldest years (1971-76), the warmest years (1977-88), and the most recent intermediate period (1989-2000). Changes in productivity of the GOA may be more strongly related to shorter-scale El Nino events than the decadal temperature shift (Hollowed, Hare, and Wooster 1998).

Trends in walleye pollock biomass from bottom trawl data differ from those in estimates of total pollock biomass for the GOA. Pacific cod is commonly the dominant roundfish species in trawl catches in the western Gulf, with sablefish becoming important in the central Gulf, and rockfish in the east. With the exception of Pacific ocean perch, all of the current commercially important species had low biomass in the 1961-62 surveys. Flatfish show substantial differences in species composition from west (Sanak) to east (Yakutat), with rock sole and halibut important components in the western Gulf, gradually replaced by flathead sole, rex sole, and Dover sole in the east. Arrowtooth flounder is present at all sites even in the earliest data, but this species shows a strong increase in biomass at Chirikof and Kodiak from 1984-1990. Our sites in the central GOA show the greatest difference in overall catch between 1970-76, 1977-88, and 1989-2000. Sites furthest east and west show less variation in catch over time, both in species composition and biomass.

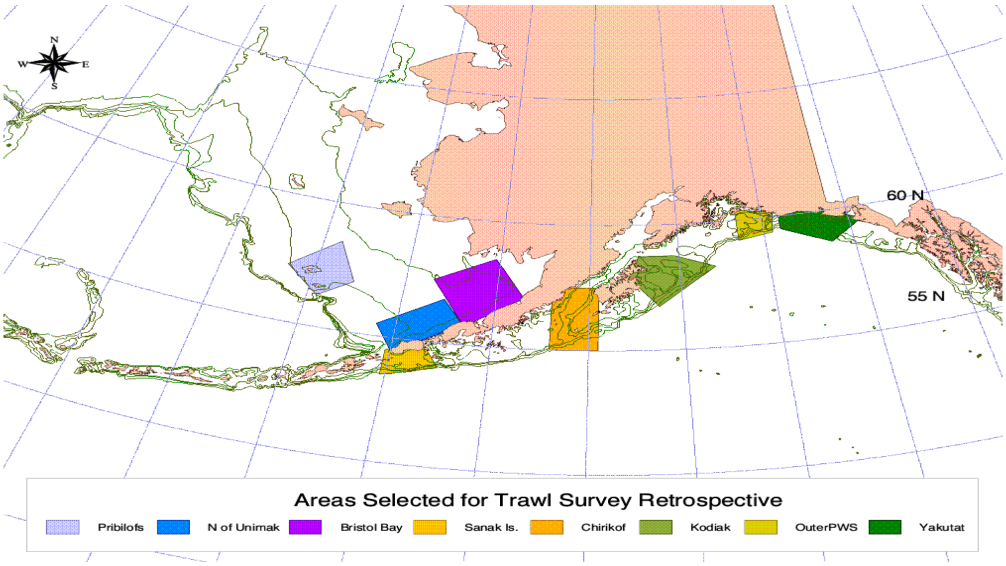

Figure 1. Selected study sites for time-series analysis of bottom trawl catch data.

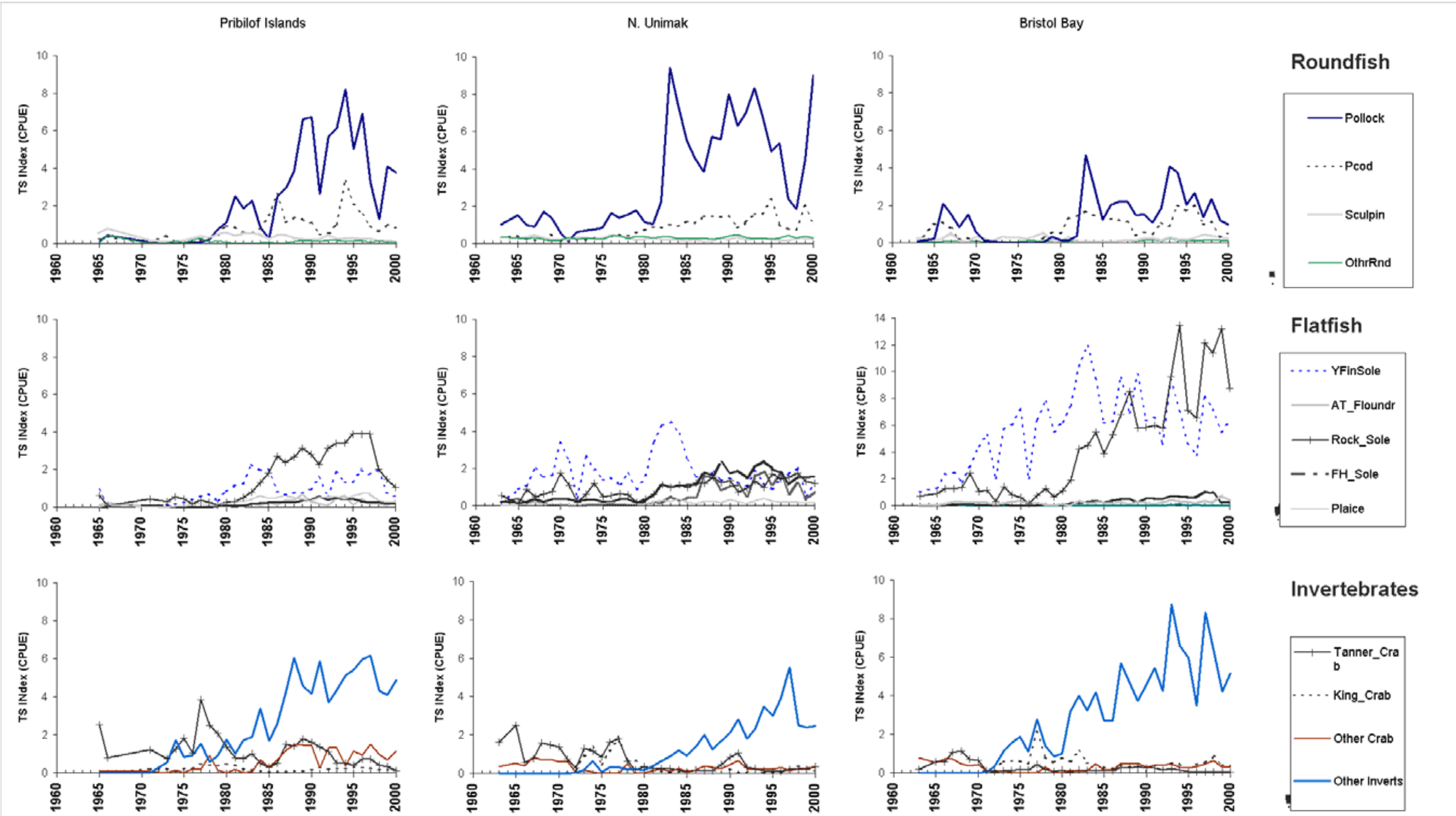

Figure 2. Trends in bottom trawl catch biomass for sites in the southeast Bering Sea: near the Pribilof Islands, North of Unimak Island and Bristol Bay.

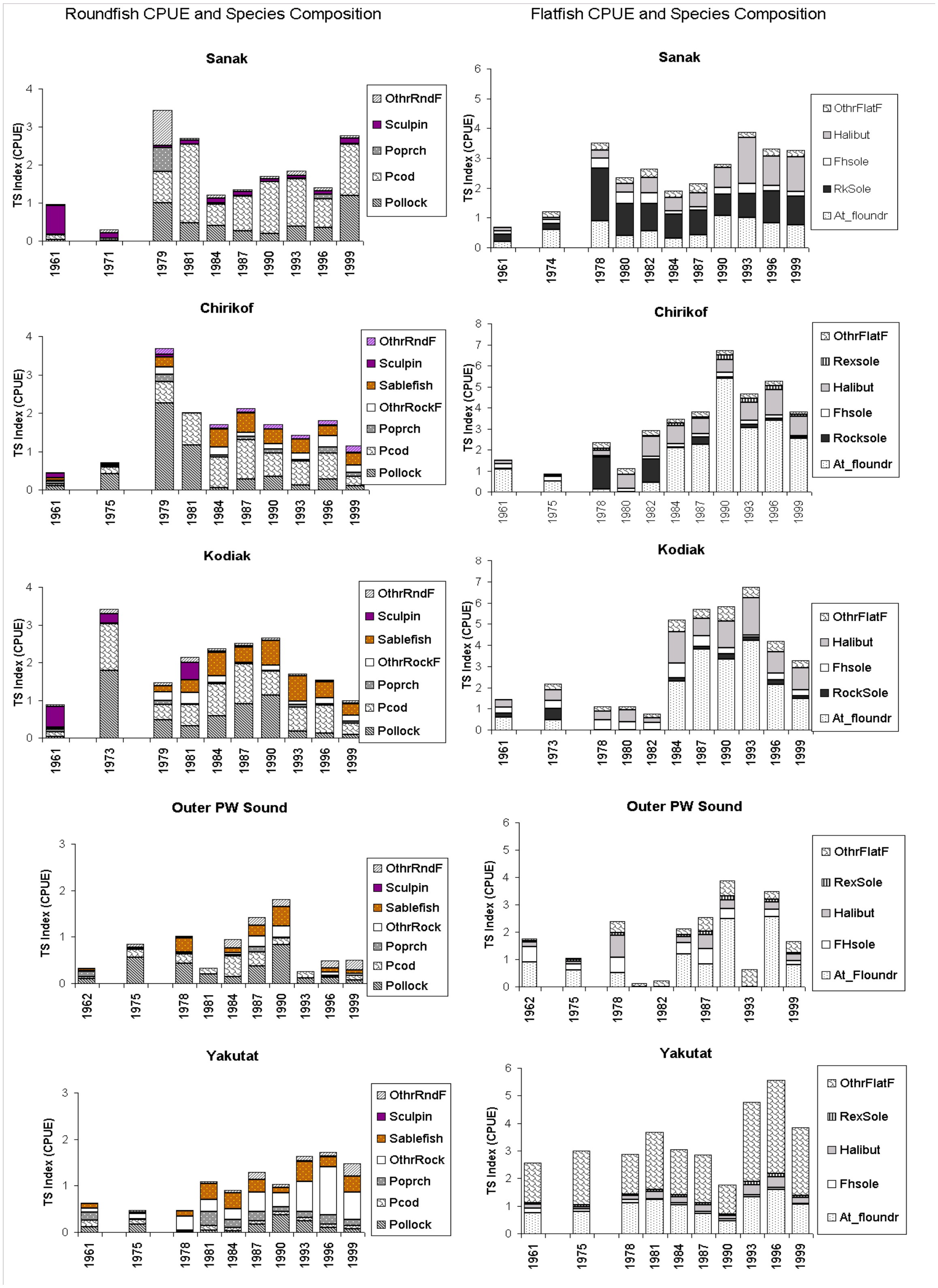

Figure 3. Site-to-site differences in species composition and biomass from GOA bottom trawl surveys.

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Other Species

Sharks and shark bycatch in Alaska State and Federal waters

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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^{o}N-65^{o}N latitudeon the western side and from 23^{o}N-65^{o}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^{o}C to 15^{o}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^{o}N to70^{o}N in the western Pacific and from 25^{o}N to 70^{o}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^{o}C and 4.1^{o}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^{o}N-65^{o}N in the western Pacific and 30^{o}N-65^{o}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^{o}C to 18^{o}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^{o}C to 11^{o}C in smaller specimens and up to 13.6^{o}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^{o}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).

<u>NMFS GOA Area 630</u>

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.

<u>NMFS GOA Area 640</u>

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.

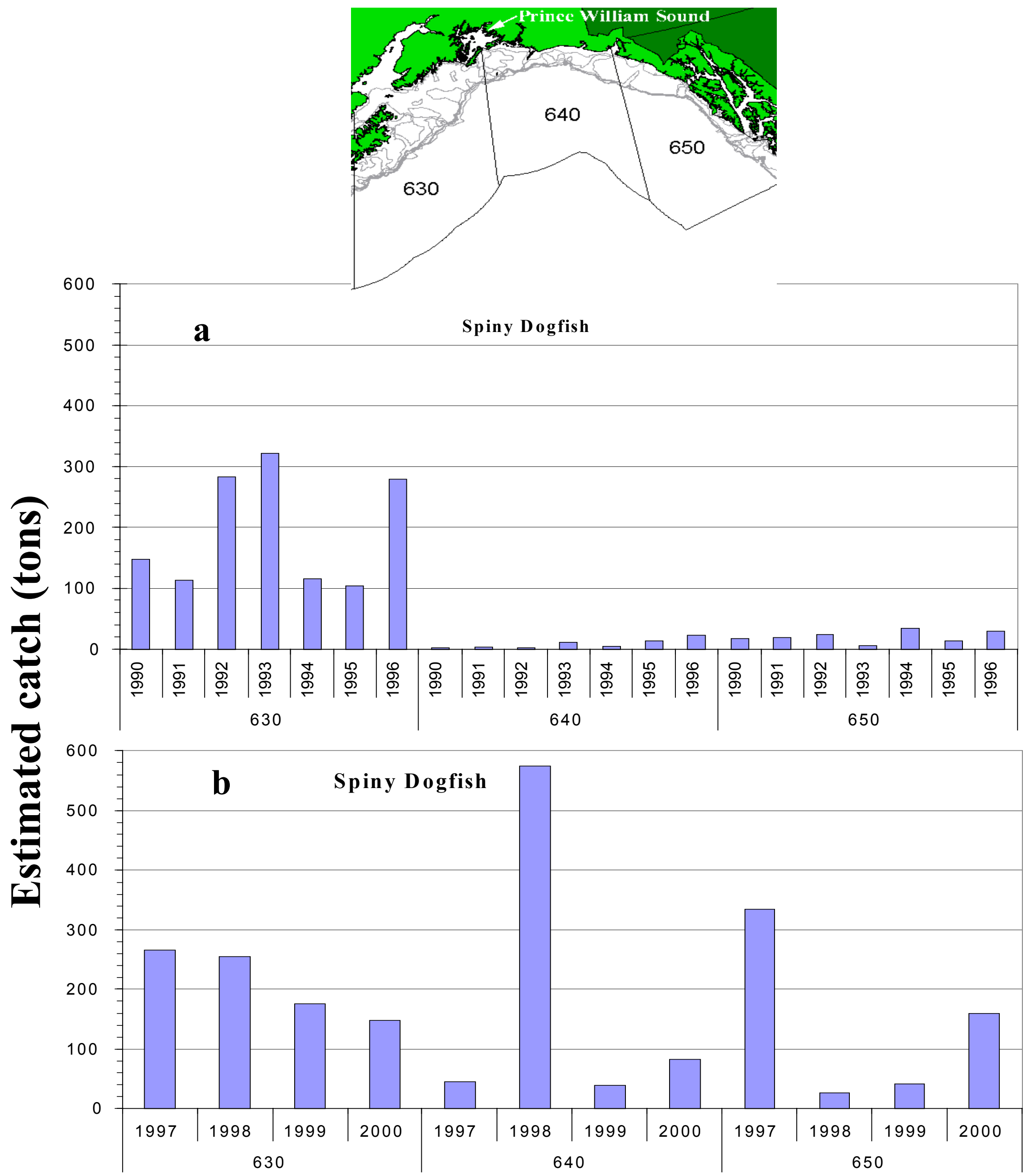

Figure 1. Spiny dogfish bycatch in the central GOA (from the NMFS Observer Program).

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.

<u>ADF&G and IPHC PWS Areas</u>

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).

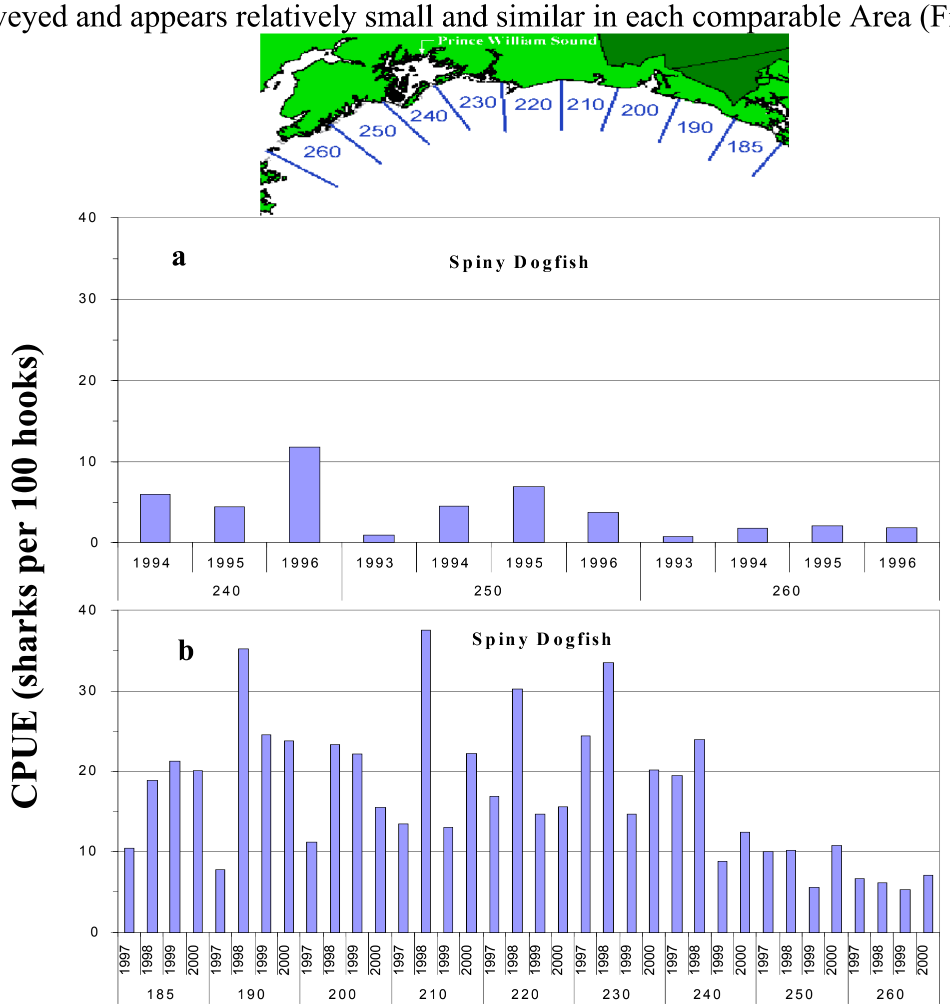

Figure 2. Spiny dogfish bycatch in the central GOA (from the IPHC).

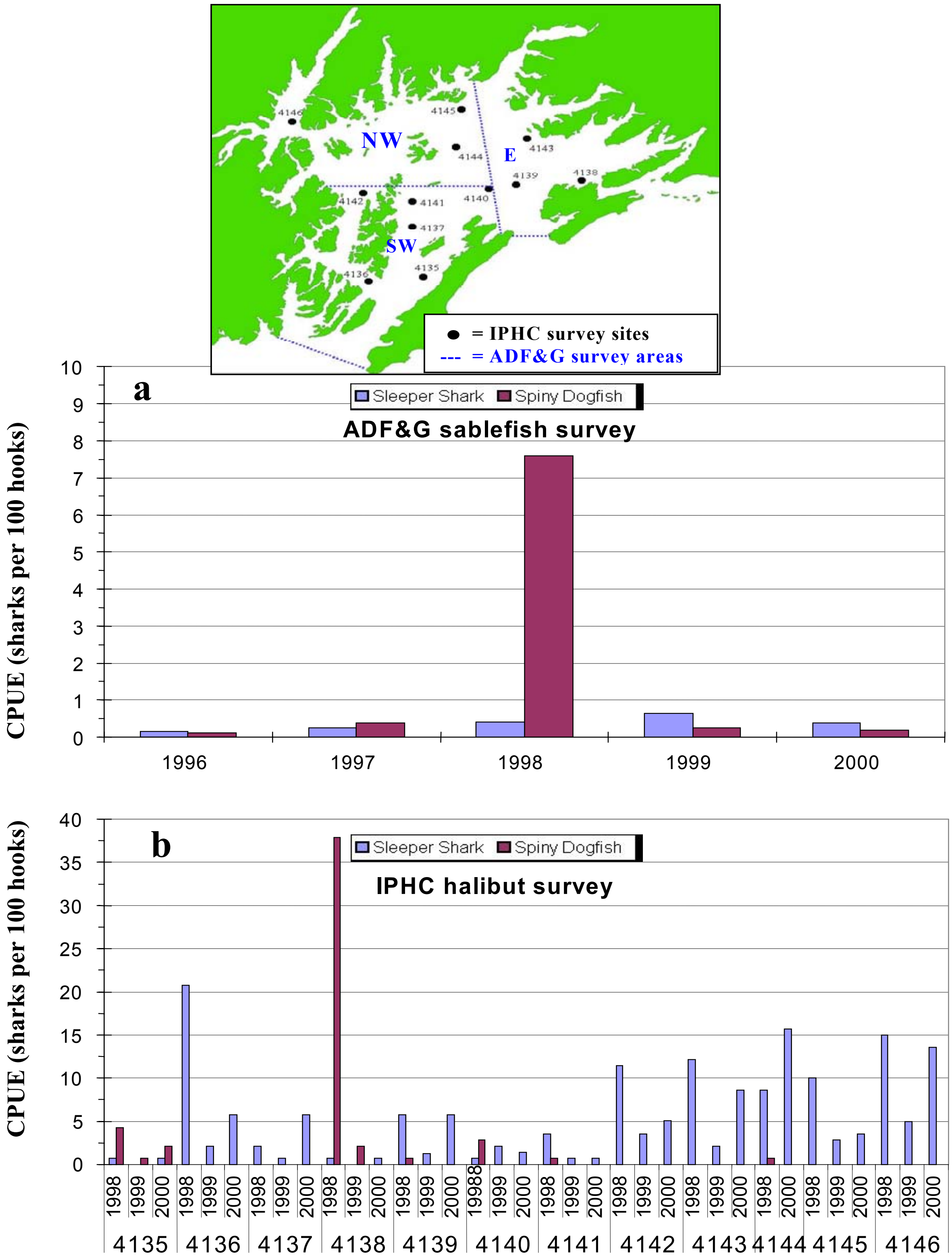

Figure 3. Spiny dogfish and sleeper shark bycatch from PWS. a) ADF&G data b)IPHC data.

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).

<u>GOA and PWS data</u> 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).

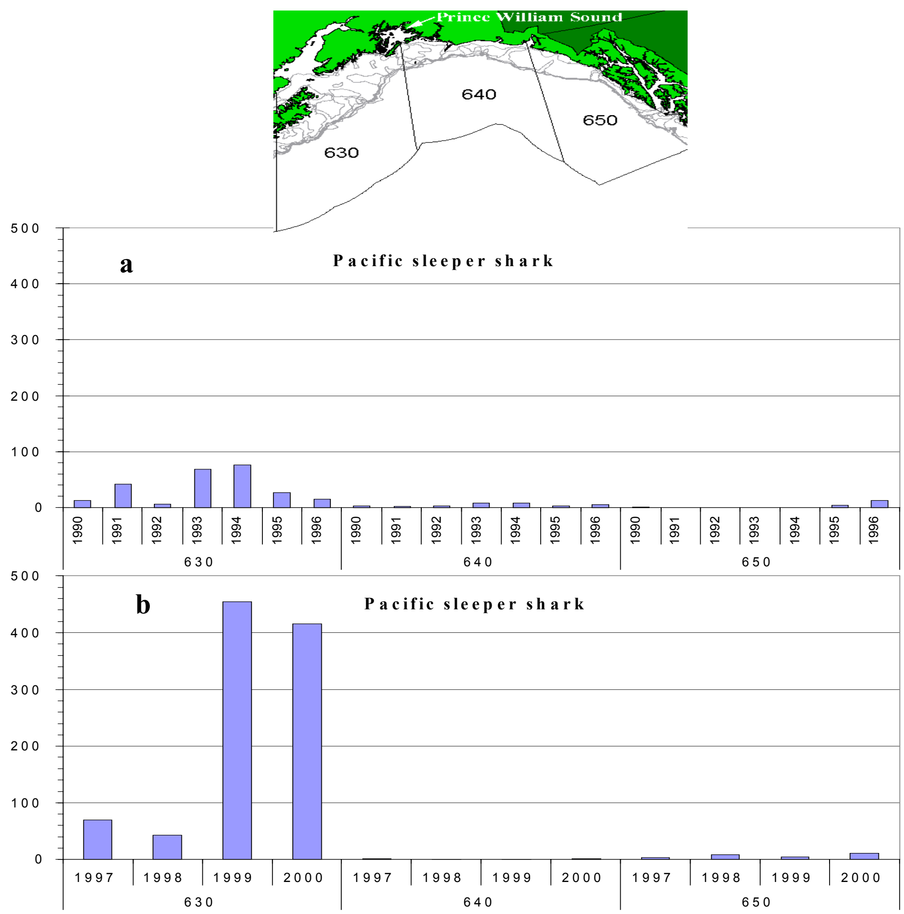

Figure 4. Pacific sleeper shark bycatch in the central GOA (from the NMFS Observer Program).

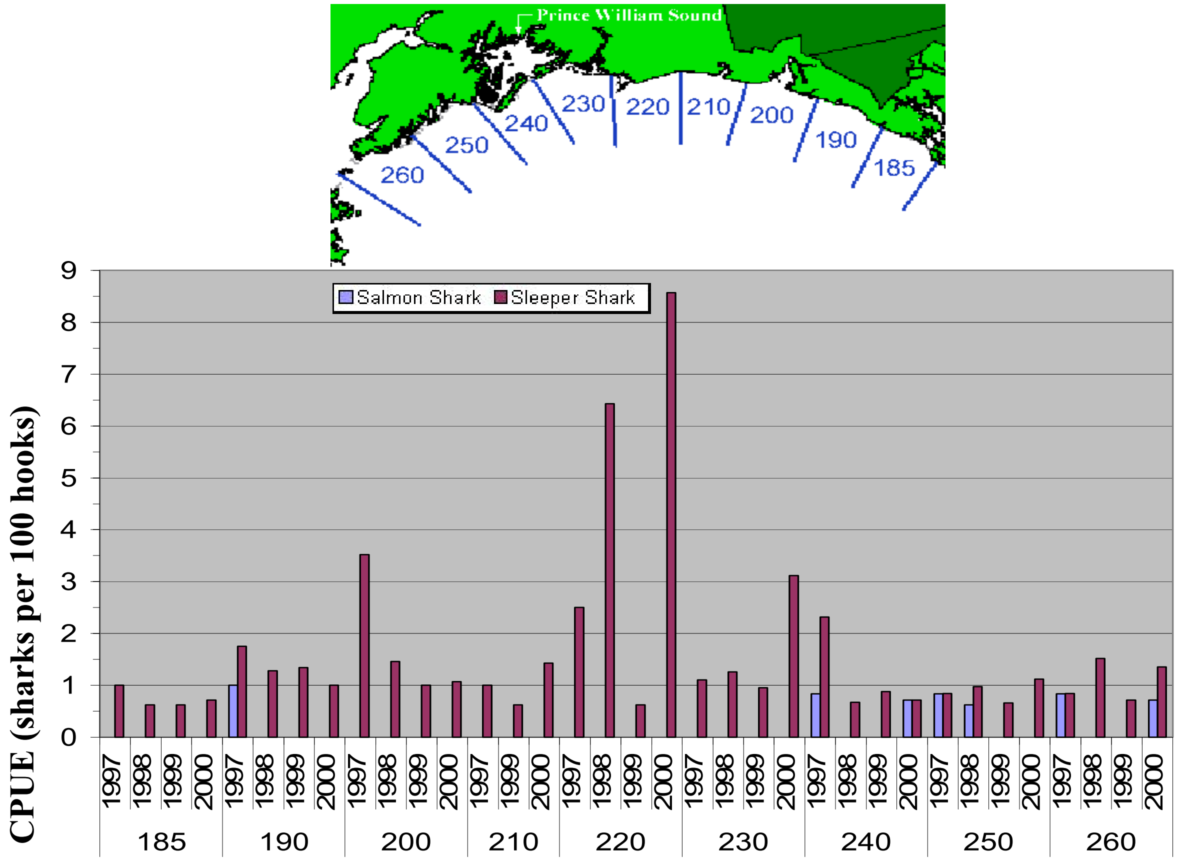

Figure 5. Sleeper and salmon shark bycatch in the central GOA (from the IPHC).

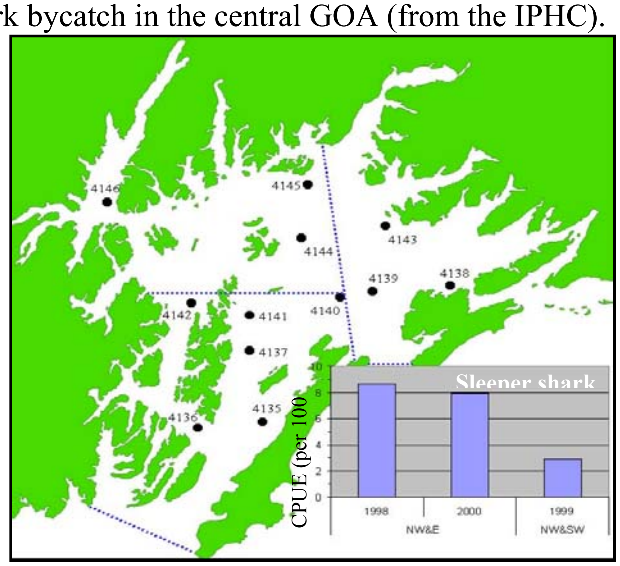

Figure 6. IPHC areas encompassed by ADF&G areas with comparative CPUE chart (see text).

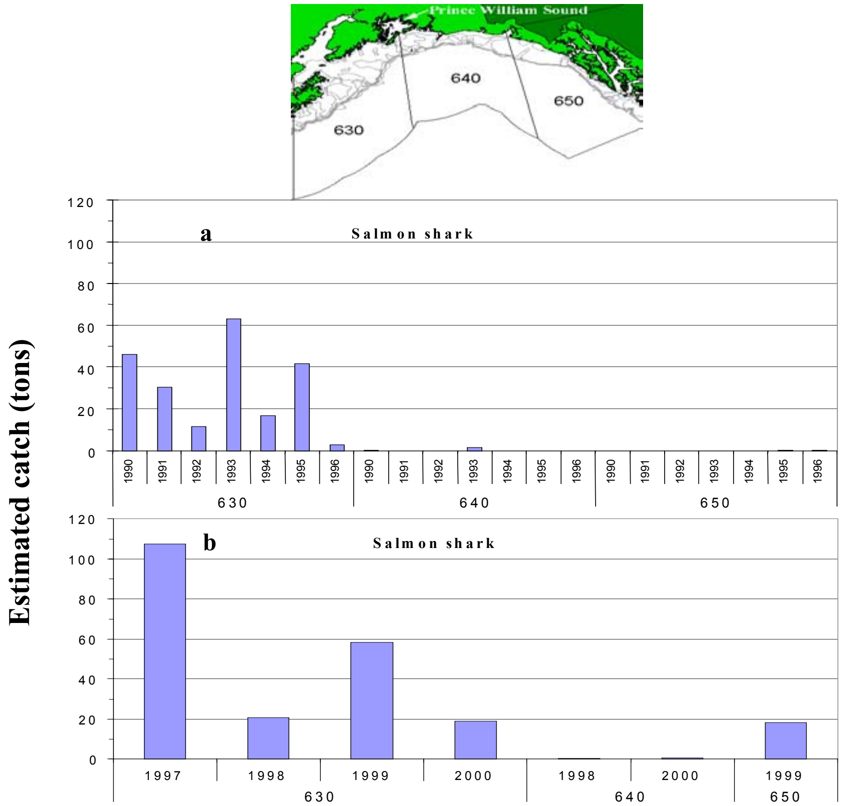

Figure 7. Salmon shark bycatch in the central GOA (from the NMFS Observer Program).

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.).

<u>Shark bycatch in other Areas not included in this report</u>

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.

I thank Sarah Gaichas, Bill Bechtol, Scott Meyer, Charlie Trowbridge, Heather Gilroy, Aaron Ranta, Paul Anderson, Jim Blackburn, Pat Livingston and Jane DiCosimo for sharing bycatch data, their time on the phone, numerous e-mails and comments on this draft.

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Benthic Communities and Non-target fish species

Gulf of Alaska

ADF&G Large Mesh Survey

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 contiguous 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.

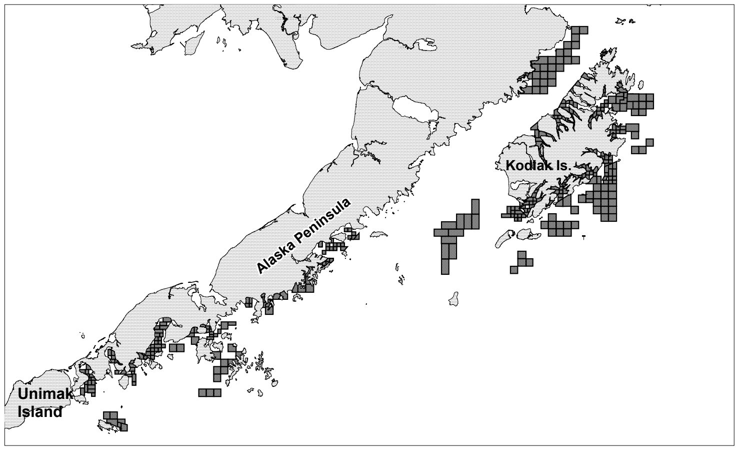

Figure 1. Stations fished during the 2001 ADF&G trawl survey, one haul per station.

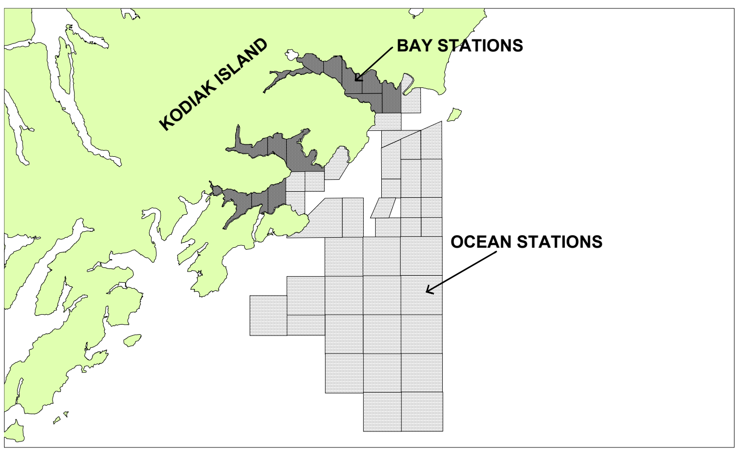

Figure 2. Adjoining trawl stations on the east side of Kodiak Island used to characterize nearshore and offshore ecosystem trends.

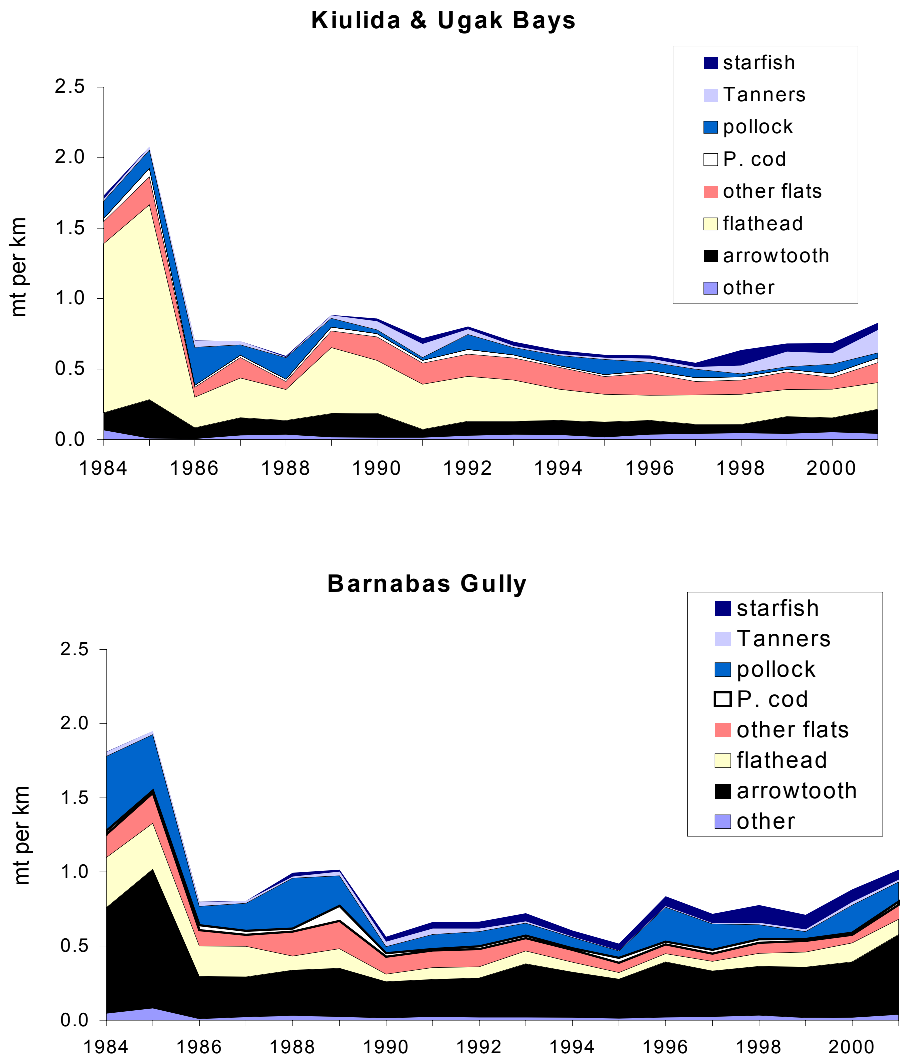

Figure 3. Metric tons per kilometer caught during the ADF&G large mesh trawl survey from adjacent areas off the east side of Kodiak Island.

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Eastern Bering Sea

Jellyfish
Contributed by Ric Brodeur, Northwest Fisheries Science Center

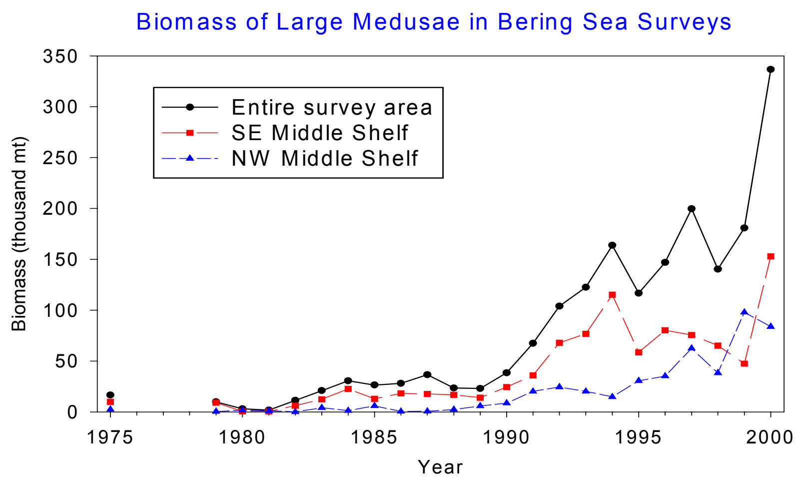

Figure 1. Index of large medusae biomass during summer in the eastern Bering Sea from the NMFS bottom trawl survey.

The time series of jellyfish caught as by-catch in the annual Bering Sea bottom trawl survey was updated for 2000 (Figure 1). The trend for increasing abundance that began around 1989 reported by Brodeur et al. (1999) continued and in fact, the 2000 catch was by far the highest of the series. The overall area biomass index for 2000 is 336,673 t and the catch in the NW Middle Shelf Domain is 83,818 t and in the SE Middle Shelf Domain is 152,835 t. The increase is almost entirely the result of one huge catch (over 2000 kg). This is the largest single station catch by far in the time series and when it is removed, the biomass estimate drops by a third down to about 224,000 t and the 95% confidence limits include the 1999 estimate. The 6 largest catches (300-2000 kg) were all in inner Bristol Bay right near the 50 m contour. In previous years, the highest catches of jellyfish were within the Middle Shelf Domain in deeper waters.

Marine Mammals

By NMFS National Marine Mammal Lab Staff

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). Brief descriptions of the range, habitat, diet, abundance, and population status for species thought to potentially have the most significant interactions with commercial fisheries because of direct takes or diet overlap were provided in the Ecosystem Considerations chapter 2001. Below is an update of recent analyses of diet, population trends, and management measures taken to address interactions with commercial fisheries for two of these significant species, Steller sea lions and northern fur seals. More information on Alaska marine mammal stock assessments can be found at the following web location where the draft 2001 Alaska Marine Mammal Stock Assessment report can be found:
http://www.nmfs.noaa.gov/prot_res/PR2/Stock_Assessment_Program/sars.html#Overview

The draft 2001 report contains updated information for Steller sea lion, northern fur seal, spotted seal, bearded seal, ringed seal, ribbon seal, Cook Inlet beluga whale, resident killer whale, humpback whale, fin whale, minke whale, and bowhead whale.

Pinnipedia

The Otariidae, or eared seals (Steller sea lion and northern fur seals) are among three families of pinnipeds represented in the management areas. While Steller sea lions and northern fur seals are just two among a number of North Pacific apex predators that have undergone dramatic population declines since the mid-1970's, they are the only ones for which recently updated population and life history information is currently available.

Steller sea lion (*Eumetopias jubatus*)

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 in rookeries on relatively remote islands, rocks, and reefs. Females generally return to rookeries where they were born to give birth to a single pup and mate (Alaska Sea Grant 1993, Calkins and Pitcher 1982, Loughlin et al. 1984). 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 generally are weaned before the next breeding season, but it is not unusual for a female to nurse her offspring for a year or more. 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 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.

Observations of Steller sea lions at sea suggest that large groups usually consist of females of all ages and subadult males; adult males sometimes occur in those groups but are usually found individually. On land, all ages and both sexes occur in large aggregations during the nonbreeding season. Breeding season aggregations are segregated by sexual/territorial status. Steller's sea lions are not known to migrate, but they do disperse widely at times of the year other than the breeding season. For example, sea lions marked as pups in the Kuril Islands (Russia) have been sighted near Yokohama, Japan (more than 350 km away) and in China's Yellow Sea (over 750 km away), and pups marked near Kodiak, Alaska, have been sighted in British Columbia, Canada (about 1,700 km distant). 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 and, as a general rule, return to their island of birth to breed as adults. Rates of change for Alaskan stocks are shown in Tables 1 and 2.

Table 1.-- Annual trends and standard errors of the numbers of non-pup Steller sea lions in Alaska, 1991-2000. Trends were statistically significant ($P < 0.05$) for the western stock as a whole and separately in the eastern and central Gulf of Alaska and the central and western Aleutian Islands. (See Figure on the following page for interpretation of geographic regions listed here.)

Region	Annual trend (%)	SE (%)	t value	Pr(>|t|)
Eastern Gulf of Alaska	-9.98	1.19	-8.414	<0.001
Central Gulf of Alaska	-8.27	0.72	-11.451	<0.001
Western Gulf of Alaska	-2.26	0.95	-2.373	0.064
Eastern Aleutian Islands	-1.73	1.10	-1.568	0.192
Central Aleutian Islands	-3.14	1.00	-3.139	0.035
Western Aleutian Islands	-8.66	1.75	-4.942	0.008
Total Western stock	-5.03	0.25	-20.390	<0.001
Southeastern Alaska	1.72	0.96	1.801	0.147

Source: Loughlin, T. and York, A. E. in press. An Accounting of the Sources of Steller Sea Lion, Eumetopias jubatus, Mortality. Marine Fisheries Review.

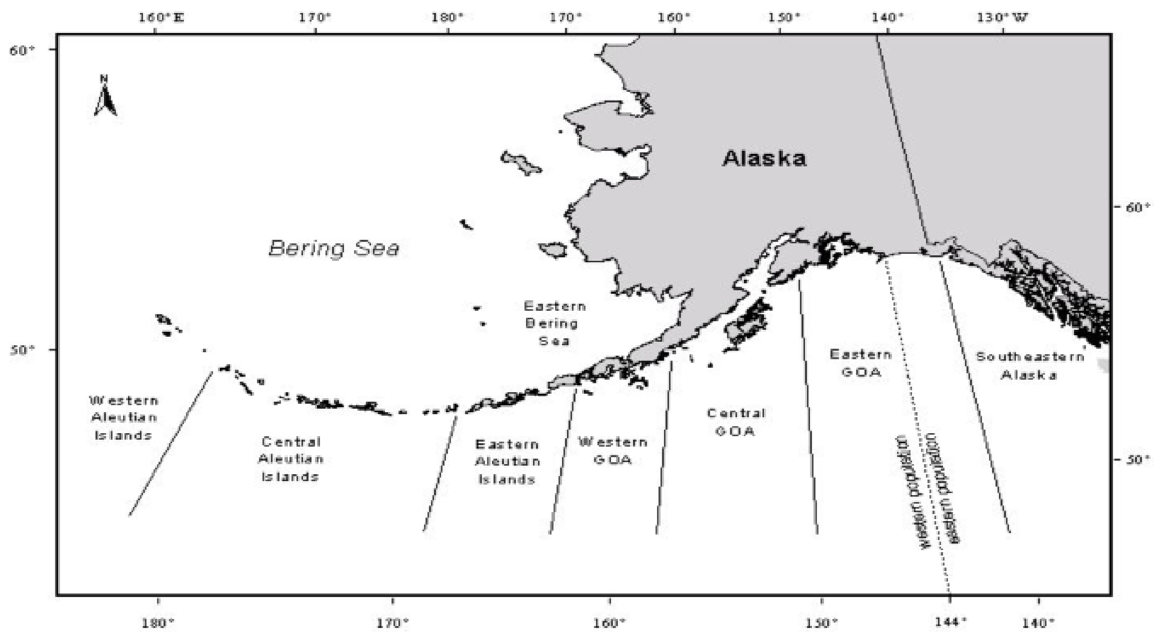

Figure – Standard sea lion survey regions.

Table 2.—Counts of adult and juvenile (non-pup) Steller sea lions observed at **ALL SURVEYED ROOKERY AND HAUL-OUT SITES** in seven subareas of Alaska during June and July aerial surveys from 1991 to 2000, including overall percent change between the count for each year and the count for 2000.

	Gulf of Alaska			Aleutian Islands			Kenai to Kiska (n=227)	Western stock (n=264)
Year	Eastern (n=25)	Central (n=55)	Western (n=37)	Eastern (n=54)	Central (n=81)	Western (n=12)		
1991	4,812 (-53%)	7,715 (-39%)	5,341 (-14%)	5,291 (- 6%)	8,966 (-22%)	4,923 (-66%)	27,313 (-22.0%)	37,048 (-31.9%)
1992	4,360 (-48%)	7,330 (-36%)	5,502 (-17%)	5,715 (-13%)	8,307 (-16%)	4,533 (-64%)	26,854 (-20.7%)	35,747 (-29.4%)
1994	3,997 (-43%)	6,795 (-31%)	5,719 (-20%)	6,055 (-17%)	7,426 (- 6%)	3,369 (-51%)	25,995 (-18.1%)	33,361 (-24.4%)
1996	2,586 (-12%)	5,751 (-18%)	5,724 (-20%)	5,969 (-16%)	7,181 (- 2%)	3,411 (-52%)	24,625 (-13.5%)	30,622 (-17.6%)
1998	2,072[1] (+10%)	4,971 (- 5%)	5,855 (-22%)	5,803 (-14%)	7,689 (- 9%)	2,867 (-42%)	24,318 (-12.4%)	29,257 (-13.8%)
2000	2,274	4,711	4,577	5,000	7,013	1,652	21,301	25,227

[1] 1999 counts for the eastern Gulf of Alaska.

Population – Western Stock

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, although this still included a patchwork of regional counts and surveys. 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).

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). Trend sites are those rookeries and haul-out sites surveyed consistently from the mid 1980s to the present, thus allowing analysis of population trends on a decadal scale. Trend sites include about 75% of animals observed in recent surveys (Strick *et al.*, 1997; Sease *et al.*, 1999; Sease and Loughlin, 1999; Sease *et al.*, 2001). At 82 rookery and haul-out trend sites in the Western Stock, the population of non-pups has declines at ~5% (SE=0.3%) per year since 1991 while the eastern stock has increased but not at a significant rate (1.78%, SE=1%) (Table 1).

In the last decade that decline rates have not been uniform across space – the population is declining sharply at more than 8% per year in the standard sea lion survey areas of the EGOA, CGOA, and WAI and is declining at lesser rates (1.7-3.1% per year) in the WGOA, EAI, and CAI (Table 1 and see associated Figure for interpretation of the regions mentioned here, which differ from groundfish fishery management regions).

In most years, pups within the Western Stock in Alaska have been counted only at selected rookeries, and on an alternating schedule to minimize potential cumulative effects of disturbance. Range-wide survey efforts included pup counts at virtually all Western Stock rookeries in Alaska in 1998, and all except the Near Islands in the western Aleutian Islands in 1994 (Strick *et al.*, 1997; Sease and Loughlin, 1999). Pup counts in the western stock in Alaska (excluding the western Aleutian Islands) declined by 19.0% from 1994 to 1998. In the western Aleutian Islands, pup numbers declined 18% from 1997 to 1998, the only years for which comprehensive comparison is possible. Recent pup counts on sample rookeries in 2000 and 2001 from Seguam Island to Prince William Sound were similar in magnitude to those conducted in 1998 (NMFS NMML data, unpublished).

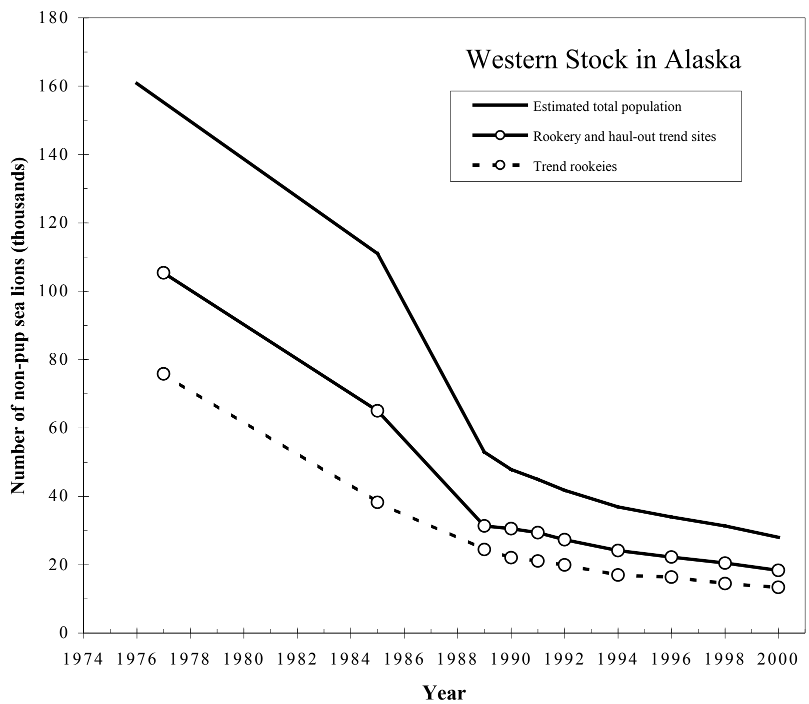

Figure 1. Steller sea lion western stock population trends, 1976-2000.

Population – Eastern Stock

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, even though numbers of non-pup sea lions (adults and juveniles combined) in Southeast Alaska increased by about 16% from 1985 to 1989, or by an average of 3.5% to 4.0% per year. 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). The Steller Sea Lion Recovery Team employed a different set of index, or "trend," sites for monitoring population status (NMFS, 1992b; NMFS, 1995a). Counts of non-pup sea lion at SE Alaska trend sites increased 1.7% (SE=1%) per year during 1991-2000. This increase is not statistically significant (P=0.15) (Table 1). Despite differences in individual index sites or model type (e.g., based on counts of pups versus non-pups), the conclusion is that numbers of Steller sea lions in Southeast Alaska are stable or increasing slightly.

Steller sea lions in Southeast Alaska are not an isolated stock, as demonstrated by genetic data and by the movement of branded and tagged animals from Southeast Alaska to British Columbia and Washington (Raum-Suryan *et al.*, submitted). The number of non-pup sea lions in British Columbia is similar to the number in southeast Alaska, and increasing by about 2.5% per year during the last decade. Numbers of pups in British Columbia have increased by about 1.5% per year during the same time (personal communication from P. Olesiuk, Pacific Biological Laboratory, Nanaimo, British Columbia, V9R 5K6). Counts of Steller sea lions in Oregon and northern California have been stable during recent decades at about a third as many animals as in either British Columbia or Southeast Alaska. Numbers in central and southern California have been small, but decreasing at about 4.5% - 5.0% per year since 1982 or as much as 10% per year since 1990 (NMFS, 1995a; Calkins *et al.*, 1999; Ferrero *et al.*, 2000, Angliss *et al.*, 2001). Despite the observed declines in southern and central California, the Eastern Stock as a whole is stable or increasing slowly. Historical trends of various regional components of the Western and Eastern stocks are shown below in Figure 2.

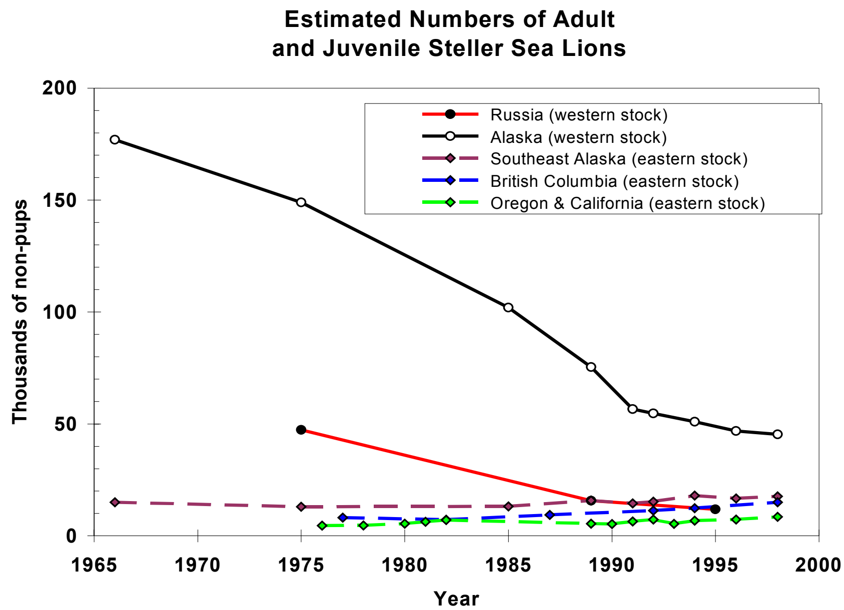

Figure 2. Historical trends of regional components of Steller sea lions.

Steller Sea Lion Diet, Western Stock – Current[1]

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. The interpretation of predator diet through the use of scat was first developed for terrestrial studies and has been adapted for use in marine mammal trophic studies over the past two decades. Scat is a reliable tool for monitoring seasonal and temporal trends in predator diets without the need to euthanize the animal. 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).

[1]*Discussion of current diet trends in the western stock of Steller sea lions is based on a recently submitted draft publication (Sinclair and Zeppelin, submitted) and should not be cited without permission from the authors.*

The most recent analysis of Steller sea lion diet compares trends in prey species consumption between summer and winter, when juveniles are first learning to forage on their own. (Sinclair and Zeppelin, submitted). Summer collections represent primarily the diet of adult females, while winter collections represent a mix of all ages and sexes. Steller sea lion scats were collected (1990-1998) from 31 rookeries (May-September) and 31 haulout sites (December-April) across the U.S. range of the Western Stock resulting in a sample of 3,762 scats with identifiable prey remains. As is typical in marine mammal diet studies prey remains were identified to the lowest possible taxon using museum reference specimens. The relative importance of each prey species was based on their frequency of occurrence (FO).

Steller sea lions eat a broad range of prey that vary in adult body size from approximately 10-80 cm in body length. Prey remains in Sinclair and Zeppelin (submitted) were primarily from late stage juveniles and adults. Frequency of occurrence values combined across years, seasons, and sites 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 on certain islands 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 where the FO of prey were most similar were identified using Principal Components and Agglomerative Hierarchical Cluster Analysis (Ward, 1963; Ramsey and Schafer, 1996) resulting in regions of diet similarity. These newly defined diet regions were used to compare regional and seasonal differences in prey. The diet divisions closely paralleled those defined as metapopulations based on patterns in population decline by York *et al.* (1996) suggesting that diet and decline are linked (Figure 3). Region 1 is an area of slow decline, region 2 contains a mixture of trends from slow decline to stable or increasing, region 3 is stable or increasing, and region 4 is primarily declining slowly.

Chi-square analysis demonstrated significantly ($P = 0.01$) strong seasonal patterns in diet within each of the defined diet regions (island groupings as defined by cluster analysis). Pacific cod FO was significantly larger in winter in every region. Salmon FO was 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 was significantly lower in winter. Atka mackerel was 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 was not significantly different between seasons in any Region. Irish lord FO was generally higher in winter than in summer and though rarely occurring during summer and not included in Chi-square analysis, sandfish and snailfish have relatively high occurrences during the winter across all regions (Figure 4).

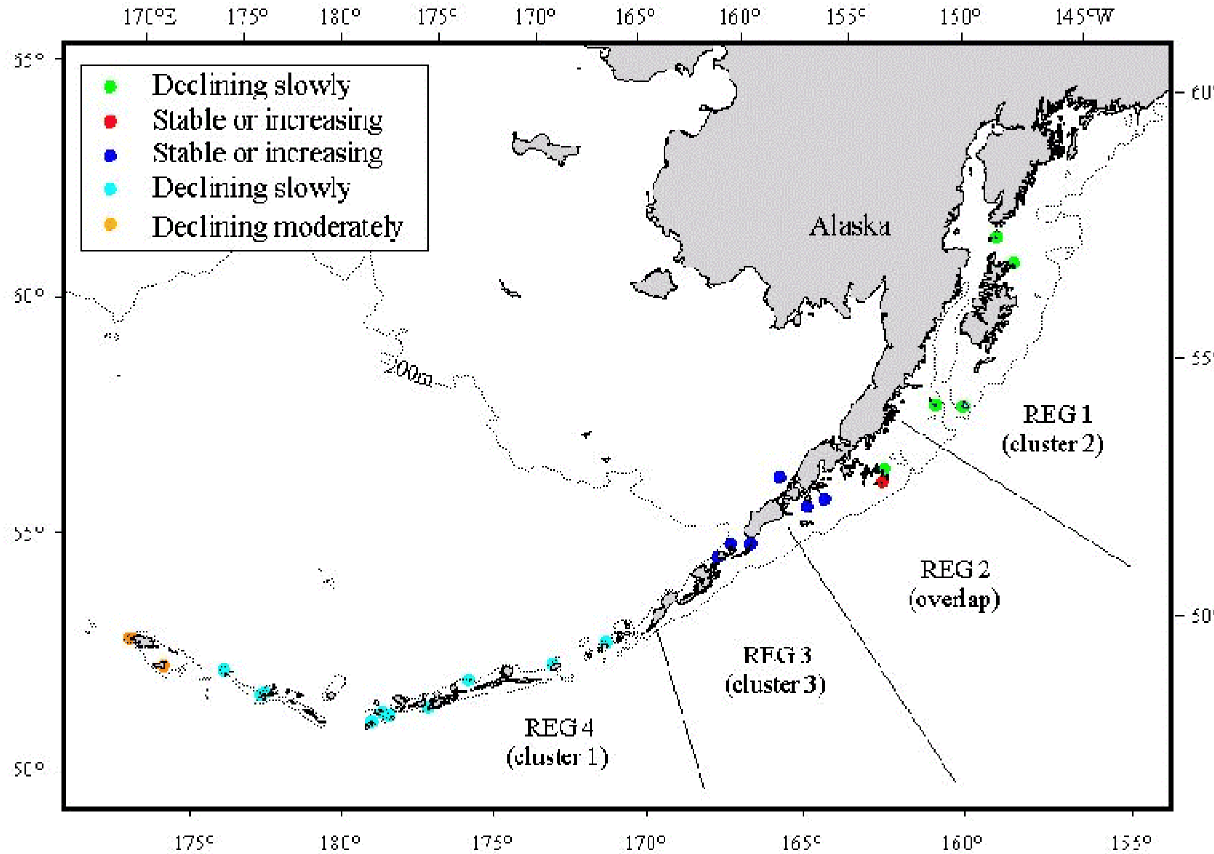

Figure 3. Steller sea lion diet divisions in relation to population trends (1989-1994; York et al. 1996) (Sinclair and Zeppelin, submitted). The two notations for stable or increasing trends represent trend counts for different blocks of time.

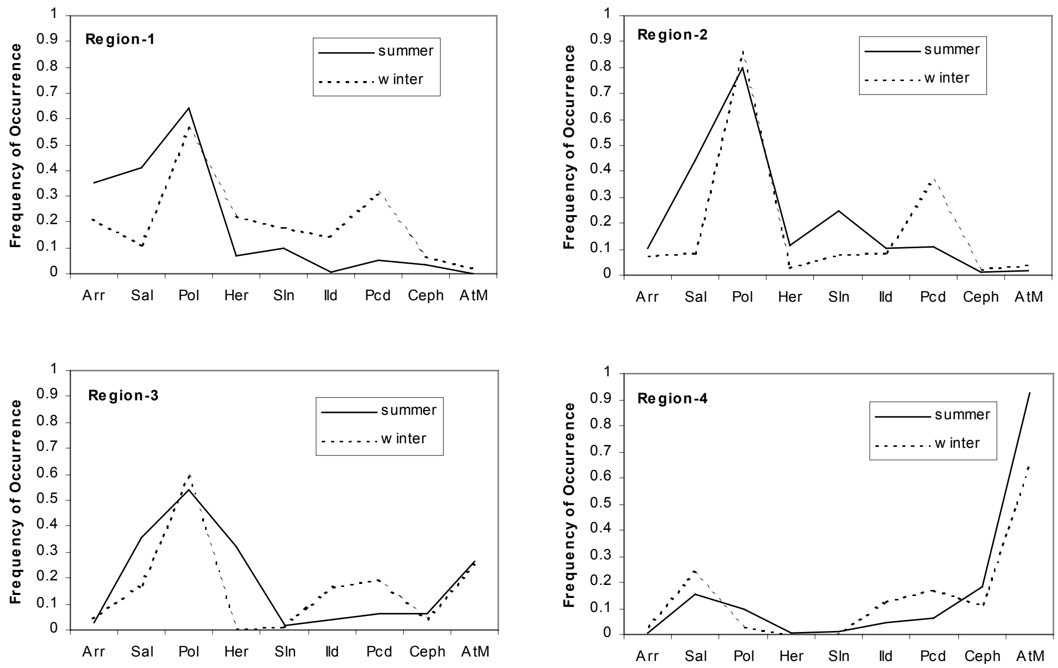

Figure 4. Frequency of occurrence of prey items occurring in Steller sea lion scats, in all regions and seasons, 1990-1998 (Sinclair and Zeppelin, submitted).

Diet diversity, calculated using Shannon's index of diversity (Ludwig and Reynolds, 1988), indicated that 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 in this study. In the midst of precipitous population declines range wide among the western stock (Loughlin *et al.*, 1992), Amak Island was among 5 other rookeries identified by York *et al.* (1996) that demonstrated persistently stable or increasing population counts: Amak, Akun, Akutan, Chernabura, Clubbing, Ugamak. The York *et al.* (1996) temporal model for extinction of the western stock predicted that in the face of extinction of all other sites, these six would remain viable. All of these sites fall within Regions 2 and 3 as defined in this study, regions of highest diversity and greatest overlap in prey matrices between regions in this study (Figure 3). Implications of the importance of diversity in otariid diet (Merrick *et al.*, 1997; Sinclair *et al.*, 1994), though difficult to measure, will 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.

Based on the patterns in prey consumption presented in this (Sinclair and Zeppelin, submitted) and earlier studies (Fiscus and Baines, 1966; Pitcher, 1981; Calkins, 1998), Steller sea lions specialize on particular prey throughout the water column in the epipelagic (herring), demersal (arrowtooth flounder), and semi-demersal (pollock, Atka mackerel) zones. While the size of prey consumed undoubtedly varies with the age and sex of sea lion sampled, the remains of primary prey represented in this study are largely from adult fish (Zeppelin *et al.*, in prep). The seasonal and regional patterns in prey consumption by Steller sea lions presented in this study, along with known distributions of their primary prey, indicate that Steller sea lions target prey when they are densely schooled in spawning aggregation nearshore (over or near the continental shelf) or along oceanographic boundary zones. This 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.

The close parallel of these data (Sinclair and Zeppelin, submitted) 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.

<u>Steller sea lion diet, Western Stock – historical</u>

In terms of the species of fish eaten by Steller sea lions, recent diet work (Sinclair and Zeppelin, submitted) compares most closely with studies conducted since the mid-1970s. In studies conducted along the range of the western stock between 1958 and 1969, pollock were completely absent from Steller diet (Mathisen *et al.*, 1962; Thorsteinson and Lensink, 1962; Tikhomirov, 1964; Fiscus and Baines, 1966). The high occurrence of pollock in Sinclair and Zeppelin (submitted) this study is comparable to diet studies conducted since 1975 (Calkins, 1998; Frost and Lowry, 1986; Merrick *et al.*, 1997[2]; Pitcher, 1981) and possibly prior to the 1950s when Imler and Sarber (1947) reported pollock in 2 stomachs collected near Kodiak Island in 1945-1946. Sinclair and Zeppelin (submitted) also highlight the importance of Pacific cod in Steller diet during the winter months. Prior to this work, relatively few papers have focused on winter diet, so it is difficult to assess whether consumption of Pacific cod by Steller sea lions is a recent trend. Pacific cod was a top prey item in Calkins (1998) Bering Sea winter collections, and in stomachs collected in winter in the Gulf of Alaska 1973-1975 (Pitcher 1981). Overall, the most common prey items in studies prior to the mid-1970s included: capelin (*Mallotus villosus*), sand lance, cephalopods, herring, greenlings (Hexagrammidae), rockfishes, and smelts. Capelin, which was important in Steller diet through the 1970s (Fiscus and Baines, 1966; Pitcher, 1981), do not have an occurrence greater than 5% in recent studies. Salmon were present in early studies, but not at the frequencies found 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. Cephalopods were among the top prey items found in Steller sea lion stomachs in many early studies (Mathisen *et al.*, 1962; Pitcher, 1981; Thorsteinson and Lensink, 1962), sometimes ranking as the most frequently occurring prey item

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[2]Merrick *et al.* 1997 was based on portions of the 1990-1993 dataset incorporated into Sinclair and Zeppelin (submitted).

(Fiscus and Baines, 1966). Cephalopod occurrence in Sinclair and Zeppelin (submitted) 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. The difference in cephalopod values between recent scat and historical stomach based 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 content, and therefore energy density, varies 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.

Based on satellite telemetry studies, the available data suggest two types of foraging patterns: 1) foraging around rookeries and haulout sites that is crucial for adult females with pups, pups, and juveniles and 2) foraging that may occur over much larger areas where these and other animals may range to find the optimal foraging conditions once they are no longer tied to rookeries and haulout sites for reproductive or survival purposes.

The foraging patterns of adult females vary seasonally. Trip duration for females with young pups in summer is approximately 18 to 25 hours, trip length averages 17 km, and they dive approximately 4.7 hours per day. In winter, females may still have a dependent pup, but a mean trip duration is about 200 hours, with a mean trip length of about 130 km, and they dive about 5.3 hours per day (Merrick and Loughlin 1997). Loughlin *et al.*, (unpublished) described three types of movements for young sea lions, long-range trips (greater than 8 miles and greater than 20 hours), short-range trips (less than 8 miles and less than 20 hours), and transits to other sites. Transits began as early as 7 months of age, occurred more often after 9 months of age and ranged between 3.5 – 245 miles. Long-range trips started around 9 months of age and occurred most frequently at around the time of weaning while short-range trips happened almost daily (.9 trips/day, n = 426 trips). Estimated home ranges are 320 km^2 for adult females in summer, about 47,600 km^2 (with large variation) for adult females, and 9,200 km^2 for winter yearlings in winter (Merrick and Loughlin 1997).

Compared to some other pinnipeds, Steller sea lions tend to make relatively shallow dives, with few dives recorded to depths greater than 250 m. 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 72 m (Merrick and Loughlin 1997; Swain and Calkins 1997). The rate at which they develop diving skills and begin to dive to greater depths or take prey at greater depths is unknown, but probably occurs rapidly after weaning to take advantage of otherwise unavailable prey resources.

Northern fur seal (*Callorhinus ursinus*)

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 (NMFS unpublished data[1]). 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

Northern fur seals were listed as depleted under the MMPA in 1988 because population levels had declined to less than 50% of levels observed in the late 1950s 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).

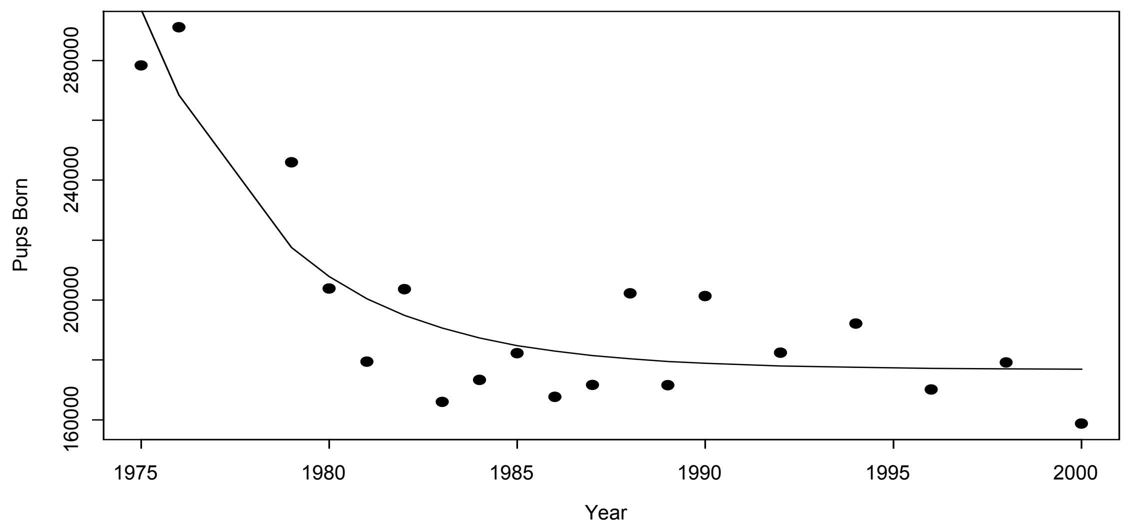
Northern fur seal abundance varies by season. During the breeding season, approximately 74% of the worldwide population of northern fur seals is found on the Pribilof Islands, with the remaining animals spread throughout the North Pacific Ocean. Of the seals in U.S. waters outside the Pribilof Islands, 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.

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*. 2000) 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 (41%) from 1975-2000 was much less than the loss on St. George Island (67%) during the same time period (Figure 5).

The most recent of pup production estimate for the Pribilof Islands was conducted in August of 2000 (NMML unpublished data). An estimated 158,736 (SE = 17248) pups were born on St. Paul Island and 20 176 (SE = 271) on St. George Island. These numbers do not include Sea Lion Rock, a small reef just off St. Paul; the last census occurred there in 1994 and registered about 12,000 pups born. On St. Paul, pup numbers declined 11.4% since the previous census, but the decline was not statistically significant due to the high SE for the 2000 estimate. The estimate of the number of pups born is the smallest pup production figure recorded since 1921. There is evidence that the pup production on St. Paul Island is declining at a small rate: since 1990, pup numbers have decreased at 1.9% (SE = 0.59%, $P = 0.03$). On St. George, pup numbers declined 8.7% since the previous census. This decline was statistically significant ($P < 0.001$). The 2000 estimate for St. George Island is the smallest since 1917. However, there is no indication of a

[1]D. DeMaster, "Personal Communication," National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115.

statistically significant decline since 1990, as on St. Paul. When data are combined for the two islands, since St. Paul numbers dominate those from St. George, there is evidence of a small, but statistically significant decline since 1990 of 1.8% (SE = 0.45%, P < 0.01). The most recent estimate of the number of fur seals in the eastern Pacific stock is approximately 983,918 (Angliss *et al*. 2001).



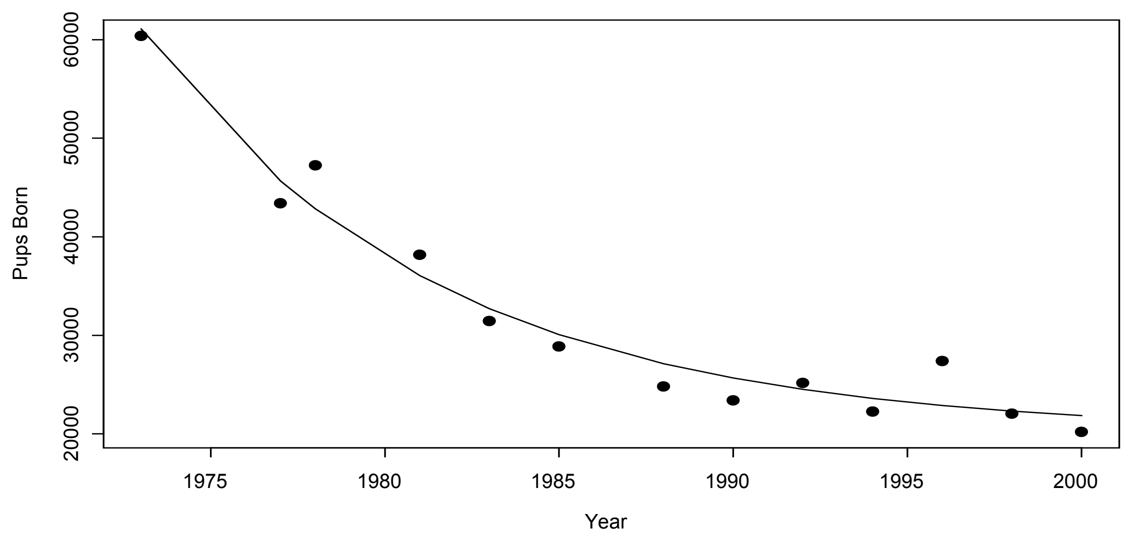


Figure 5. Points represent the numbers of northern fur seal pups born on St. Paul Island (top) and St. George Island (bottom, Alaska. The line represents the fitted negative exponential model.

Prey and Foraging Behavior

During the breeding and pup rearing season (June - October), female fur seals are central place foragers commuting to marine foraging areas between nursing visits on shore (Gentry 1998). 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 (NMFS unpublished data[1]). 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).

Satellite telemetry studies have shown that 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. Meta-home range areas were calculated as the 95% fixed kernel home range (Worton 1989) from the pooled locations for females from each area following the methods in Robson (2001). Using satellite telemetry locations for lactating females, discrete foraging areas for females from southwest St. Paul Island, northeast St. Paul Island and St. George Island were shown in 1995-96. Little overlap occurs between sites relative to the size of the overall meta-home range (Figure 6). Previous studies have also shown differences in dive patterns among individual females that can be 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 328 ft (100 m), while female fur seals foraging off-shelf dive to shallow depths (less than 328 ft).

[1]Ibid.

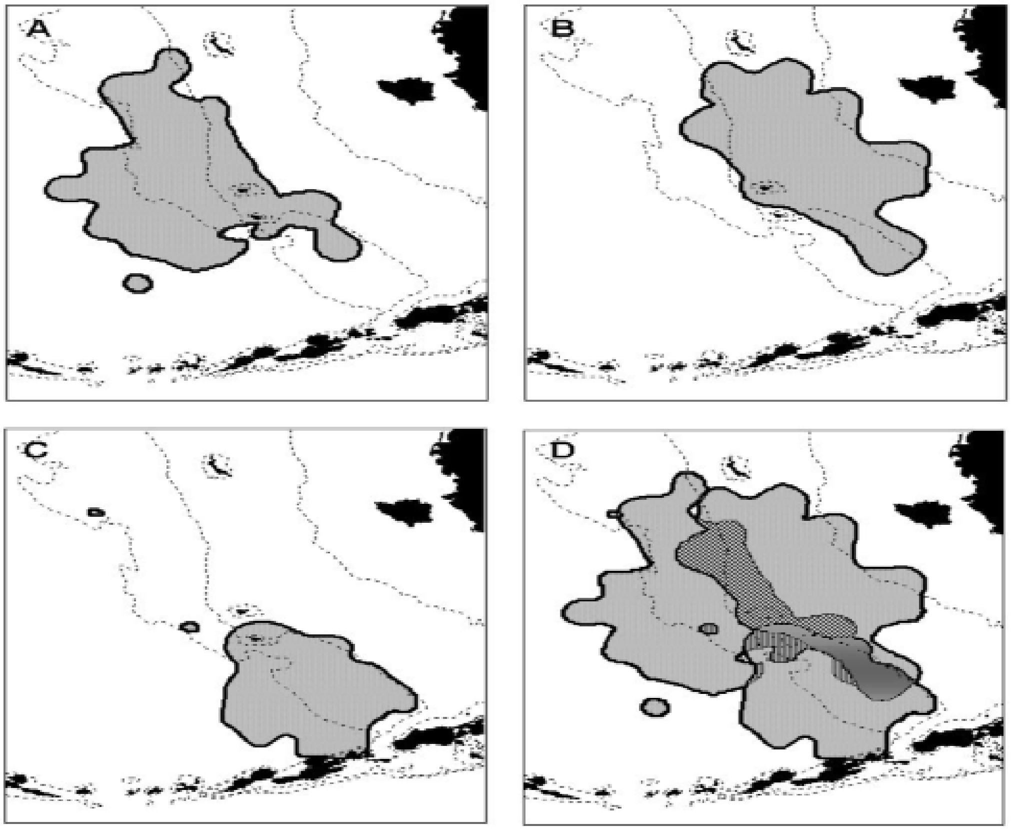


Figure 6. Meta-home ranges for lactating northern fur seals from St. Paul and St. George Islands. Panels (A) southwest St. Paul Island, (B) northeast St. Paul Island and (C) St. George Island. Panel D shows the zone of overlap between combinations of sites.

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 .

Based on diet studies conducted since the early pelagic collections (Sinclair *et al*. 1994; Sinclair *et al*. 1996; 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, while the age and size of pollock eaten by adult female fur seals has decreased from predominantly adult sized fish to age-0 and age-1 juveniles. 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).

Gastrointestinal contents of 73 northern fur seals collected from the Bering Sea in 1981 (n=7), 1982 (n=43), and 1985 (n=43) indicated consumption of nearly 100% fish (1981), 88% fish and 12% squid (1982), and 88% fish and 12% squid (1985) (Sinclair et al. 1994). Analysis of these data showed that pollock and squid were the most frequently eaten prey in the EBS, and that a positive correlation exists between pollock year-class strength and the frequency of pollock in fur seal diets (Sinclair et al. 1994). Sinclair et al. (1994) concluded that adult female northern fur seals are size-selective mid-water feeders during the summer and fall in the EBS. Since 1987, studies of northern fur seal diet have been based on fecal samples (scats). A comparative study of adult female fur seal diet based on the current method of scat analysis vs. stomach content analysis from the 1980s collections (Sinclair et al. 1996) demonstrated that walleye pollock represented 79% of all prey for all years combined in gastrointestinal tracts, and 78% of the total prey in fecal samples. The frequency of occurrence of pollock in all years averaged 82% in gastrointestinal tracts and 76% in fecal samples (Sinclair et al. 1996).

Based on the pelagic collections in the 1970s, annual food consumption by the northern fur seal population in the eastern Bering Sea was 432.4×10^3 mt, of which 289.7×10^3 mt represented fish species. Of the total annual fish consumption, commercial groundfish comprised 56%, which was an estimated 0.7% of the standing biomass of commercial groundfish consumed (i.e., by all predators combined) annually in the eastern Bering Sea (Perez and McAlister 1993). Based on data collected in the 1980s, 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.

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. None of the marine mammal incidental mortality estimates for Alaskan groundfish fisheries exceed the Potential Biological Removals (PBRs) (Hill and DeMaster 1999); therefore, those interactions are not expected to have large ecosystem consequences.

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. Such interactions may limit foraging success through localized depletion, dis-aggregation of prey or disturbance of the predator itself. Compounding the problem of identifying competitive interactions is the fact that biological effects of fisheries may be indistinguishable from changes in community structure or prey availability that might occur naturally. The relative impact of fisheries perturbations compared to broad, regional events such as climatic shifts are uncertain, but given the potential importance of localized prey availability for foraging marine mammals, they warrant close consideration.

Lowry (1982) developed qualitative criteria for determining the likelihood and severity of

biological interactions between fisheries and marine mammal species in the Bering Sea. His criteria were based on marine mammal diet, focusing on species consumed, prey size composition, feeding strategy, and the importance of the Bering Sea as a foraging area. This approach is applicable for adjacent waters such as the GOA because many of the same marine mammals found in the Bering Sea are found there as well, with diets comparable to those of their conspecifics. Based on Lowry's (1982) Bering Sea assessment, three pinniped species (northern fur seal, harbor seal, and Steller sea lion) had the greatest potential for adverse ecological interactions with commercial fisheries. All of these species have also undergone major declines in abundance over the past 30 years (Loughlin et al. 1992, NMFS 1993a, Pitcher 1990).
NMFS has used similar criteria to assess the extent of overlap between commercial fisheries and Steller sea lions.

Possible ecological interactions between marine mammals and commercial fisheries can be illustrated using the Steller sea lion case. Steller sea lions have a diverse diet composed primarily of pelagic or semidemersal schooling fish such as walleye pollock, Atka mackerel, Pacific cod, capelin, Pacific herring, and Pacific salmon, most of which are commercially exploited (Calkins and Pitcher 1982, Lowry 1982). Merrick and Calkins (1995) suggested that the diet diversity differed from area to area and Sinclair and Zeppelin (submitted) demonstrated that, among the Western Stock, diversity was highest where the population was most stable. Steller sea lion scat samples collected from 1990-1998 indicate that pollock is the primary prey in the GOA and eastern Aleutian Islands, while Atka mackerel assumes the dominant role from the central Aleutian Islands, westward (Sinclair and Zeppelin, submitted). Pacific cod is also well represented in sea lion scats collected in the GOA and eastern Aleutians. Such prey preferences on commercially harvested species represent overlaps that could be expected to result in competition, particularly where fisheries operate in important foraging areas. Attempts to correlate time series of sea lion abundances on rookeries with nearby removals of pollock by fisheries have not provided insight on the correlations between fisheries activity and sea lion declines (Alaska Sea Grant 1993, Ferrero and Fritz 1994, Loughlin and Merrick 1989). Data on either the available prey base or on Steller sea lion's response to potential changes in prey availability have not been collected in sufficiently fine levels of resolution to facilitate more thorough analyses.

The selectivities of the fishery and sea lions for various sizes of pollock suggests that at some level, competition exists every year a fishery occurs (Loughlin and Nelson 1986). Overall, sea lions are capable of consuming all sizes of pollock, and appear to utilize whatever sizes are present in the foraging areas. The fishery may be somewhat more size selective than sea lions, because it generally targets and retains pollock greater than 30 cm in length (Wespestad and Dawson 1992). Smaller fish are caught by the fishery roughly in proportion to their abundance (Fritz 1996). On average (based on 1979 to 1998 data), about 4% of the total population of 2-3 year-old pollock (20-35 cm in length) were caught each year by fisheries in the eastern Bering Sea, and about 2% in the GOA, but very few 0-1 year-old pollock have been caught.

Limited data available on feeding behavior from the early 1980s in the Kodiak Archipelago suggest that adult Steller sea lions ate sizes of pollock nearly in proportion to their abundance (Figure 7), while juvenile sea lions preferred pollock <30 cm in length (Merrick and Calkins 1996). Juvenile sea lion prey preferences from other years or locations are not available and the extent to which they consume larger fish is unknown. However, both adult and juvenile Steller sea lions forage in areas designated as critical habitat in the Bering Sea and Aleutian Islands where almost 70% of the pollock trawl fishery (total pollock catch from critical habitat of almost 850,000 mt) occurred as recently as 1995 (Fritz and Ferrero 1998). Most of this critical habitat catch of pollock occurred during the roe fishery in January-March (45% of the annual total), when 80% or more of the harvest often came from these sensitive areas. However, since 1999, catches of pollock from eastern Bering Sea critical habitat have been capped by season, and the Aleutian Islands region has been completely closed to the pollock fishery, as part of the Revised Final Reasonable and Prudent Alternatives (RFRPA) to mitigate jeopardy and adverse modification. This has had the result of reducing the annual percentage removals from BSAI critical habitat to under 40% and the catch to approximately 350,000 mt. These actions have not entirely eliminated competition for prey between pollock fisheries and Steller sea lions in critical habitats, but may have reduced it.

A potential mechanism by which marine mammals may be disadvantaged by competition with commercial fisheries for food resources is localized depletion of prey. Whereas the overall abundance of prey across the entire Bering Sea or GOA may not be affected by fishing activity, reduction in local abundance, or dispersion of schools 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.

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. As previously noted, Atka mackerel is a major item in the diet of Steller sea lions, particularly in the 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 (1997a) 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. Spatial as well as temporal Atka mackerel fishery dispersion measures enacted in 1999 consisted of a 4-year time schedule for reducing to 40% the proportion of Atka mackerel catch taken from critical habitat, as well as splitting the annual TAC into two seasons (beginning in January and September). These actions both reduced the catches from critical habitat and the likelihood of creating localized depletions of sea lion prey.

In the ESA Section 7 Biological Opinion on the authorization of the walleye pollock fisheries in the BSAI and GOA (NMFS, Alaska Region, 1998), NMFS investigated more fully the potential for competitive interactions between Steller sea lions and the pollock fisheries. The questions regarding competitive interactions that were used to guide this analysis were:

1. Is the fished species a significant sea lion prey?
2. Are the sizes of fish eaten by sea lions and caught by fisheries similar?
3. Are the depths at which the fish are caught by sea lions and fisheries similar?
4. Are there significant temporal and spatial overlaps in feeding and fishing distributions?
5. Is there evidence of disproportionate harvest rates or localized depletions of prey in sea lion

feeding areas?

For Steller sea lion/pollock fishery interactions, NMFS concluded that the answer to each of these questions was "yes", and proposed reasonable and prudent alternatives (RPAs) to modify the fishery to reduce the competitive interactions. NMFS demonstrated that since the late 1970s, the pollock fisheries in the GOA and BSAI had caught increasing amounts and proportions of total catch from critical habitat. Furthermore, in the eastern Bering Sea, comparisons of fishery and survey information revealed disproportionately high catch rates of pollock from sea lion critical habitats in the summer and fall. This suggested that the fishery could be reducing the prey available to sea lions and thus, jeopardizing their recovery. RPAs for the pollock fisheries in the GOA and BSAI consisted of more temporal and spatial dispersion of the pollock fishery, reduced catches of pollock in sea lion critical habitat, and creation of pollock trawl exclusion zones around sea lion haulouts.

Steller sea lions may also interact with the Pacific cod fishery, much as in the case of pollock. Pacific cod is a significant sea lion prey, the size range of cod harvested and the depths fished overlap with Steller sea lion foraging habits. Furthermore, a large proportion of the catch is taken from critical habitat during winter (when sea lion prey availability and foraging ability is thought to most sensitive). Analysis of the Pacific cod fishery and the seasonal distribution of the species is warranted to determine the likelihood and severity of such interactions.

Recent discussion has suggested that prey quality may be as important to the health and survival of marine mammals, notably Steller sea lions, as is prey quantity and the role of localized depletion. The present dominance of pollock over more nutritionally superior forage fish such as herring, capelin, and cod could compromise sea lion health (Alverson 1992). Changes in blood parameters have been noted in harbor seal studies when different prey are consumed (Thompson et al. In press) and changes in Steller sea lion and other pinniped blood parameters may be linked to their nutritional plane (Rea and Mioskowski 1997, Zento-Savin et al. 1997). However, captive studies have shown that Steller sea lions obtain a larger portion of ingested energy from numerous small meals than from fewer large ones, suggesting that prey distribution is an important factor in sea lion nutrition (Rosen and Trites 1997). Additional studies are needed to clarify the importance of prey quality in contributing to the current population dynamics of Steller sea lions.

Disturbance from either vessel traffic or fishing activities may also be a disadvantage to marine mammals, particularly foraging Steller sea lions. 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). Hydroacoustic observation of the effects of trawling on Pacific whiting school structure in Puget Sound, Washington suggest that while the school deforms and has a "hole" in it due to the removal of fish and their avoidance of the gear, its structure returns relatively quickly (on the order of 10 minutes) to a pre-trawling condition (Nunnallee 1991). Preliminary results on the effects of the noise produced by a single vessel (no trawl in the water) on pollock school structure suggests that the fish may move down and to either side of the vessel, but return to the undisturbed structure within minutes of the vessel passage (C. Wilson, NMFS, AFSC, personal communication). Neither study, however, documents the effects of repeated trawling by many vessels over several days or weeks on fish school structure, nor the possible impact on prey availability to Steller sea lions.

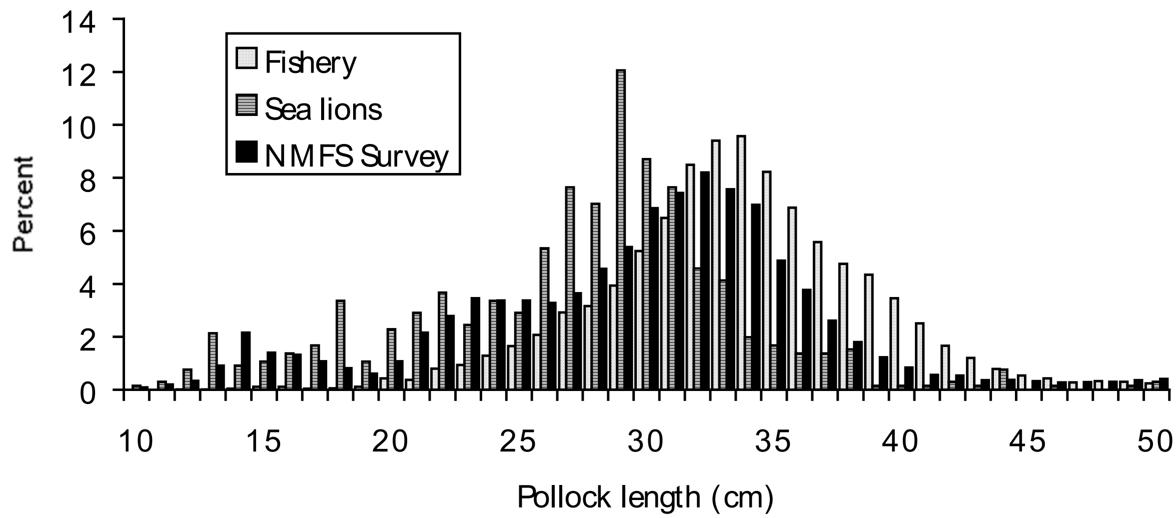


Figure 7. Percent size frequency of walleye pollock in the fishery, consumed by sea lions, and observed in the NMFS survey in the early 1980s.

Influence of environmental and climatic change on Steller sea lions

From 1940-1941 an intense Aleutian Low was observed over the BSAI, and GOA, this was followed from December 1976 to May 1977 with an even more intense Aleutian Low. During this latter period, most of the North Pacific Ocean was dominated by this low pressure system which signaled a change in the climatic regime of the BSAI, and GOA (NRC, 1996). The system shifted from a "cold" regime to a "warm" regime that persisted for several years. Since 1983, the GOA and Bering Sea have undergone different temperature changes. Sea surface temperatures in the GOA were generally above normal and those in the Bering Sea were below normal. The temperature differences between the two bodies of water have jumped from about 1.1° C to about 1.9° C. Recent evidence now indicates that another regime shift occurred in the North Pacific in 1989 (NRC, 1996).

Most scientists agree that the 1976/77 regime shift dramatically changed environmental conditions in the BSAI and GOA (Benson and Trites, 2000). However, there is considerable disagreement on how and to what degree these environmental factors may have affected both fish and marine mammal populations. Productivity of the Bering Sea was high from 1947 to 1976, reached a peak in 1966, and declined from 1966 to 1997. Some authors suggest that the regime shift changed the composition of the fish community and reduced the overall biomass of fish by about 50 percent (Merrick *et al.,* 1995; Piatt and Anderson, 1996). Other authors suggest that the regime shift favored some species over others, in part because of a few years of very large recruitment and overall increased biomass (Beamish, 1993; Hollowed and Wooster, 1995; Wyllie-Echeverria and Wooster, 1998).

Many competing factors have contributed to the ecosystem in which Steller sea lions now depend (Pauly *et al.*, 1998). However, the important question is whether the diet of Steller sea lions was adversely affected by the regime shift. Specifically, the question has been raised as to whether the increase in pollock abundance is now contributing to the decline of Steller sea lions. From the information available, it seems reasonable to conclude that gadids (i.e., pollock and Pacific cod) were abundant before the regime shift, and that sea lions relied upon them for food before the decline. Therefore, it is unlikely that a change in the structure of the ecosystem, resulting in a dominance of gadids is the sole cause of the current decline.

Shima *et al.* (2000), looked at the GOA and three other ecosystems which contained pinniped populations, similar commercial harvest histories, environmental oscillations, and commercial fishing activity. Of the four ecosystems only the GOA pinniped population (Steller sea lions) were decreasing in abundance. They hypothesized that the larger size and restricted foraging habitat of Steller sea lions, especially for juveniles that forage mostly in the upper water column close to land, may make them more vulnerable than other pinnipeds to changes in prey availability. They further reasoned that because of the behavior of juveniles and nursing females, the entire biomass of fish in the GOA might not be available to them. This would make them much more susceptible to spatial and temporal changes in prey, especially during the critical winter time period (Shima *et. al.*, 2000).

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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 their 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 of seabird colony locations, short-tailed albatross (*Phoebastria albatrus*) observation locations, movement of satellite-tagged northern fulmars (*Fulmarus glacialis*), and at-sea distribution of several seabird species relative to fishing effort; 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.

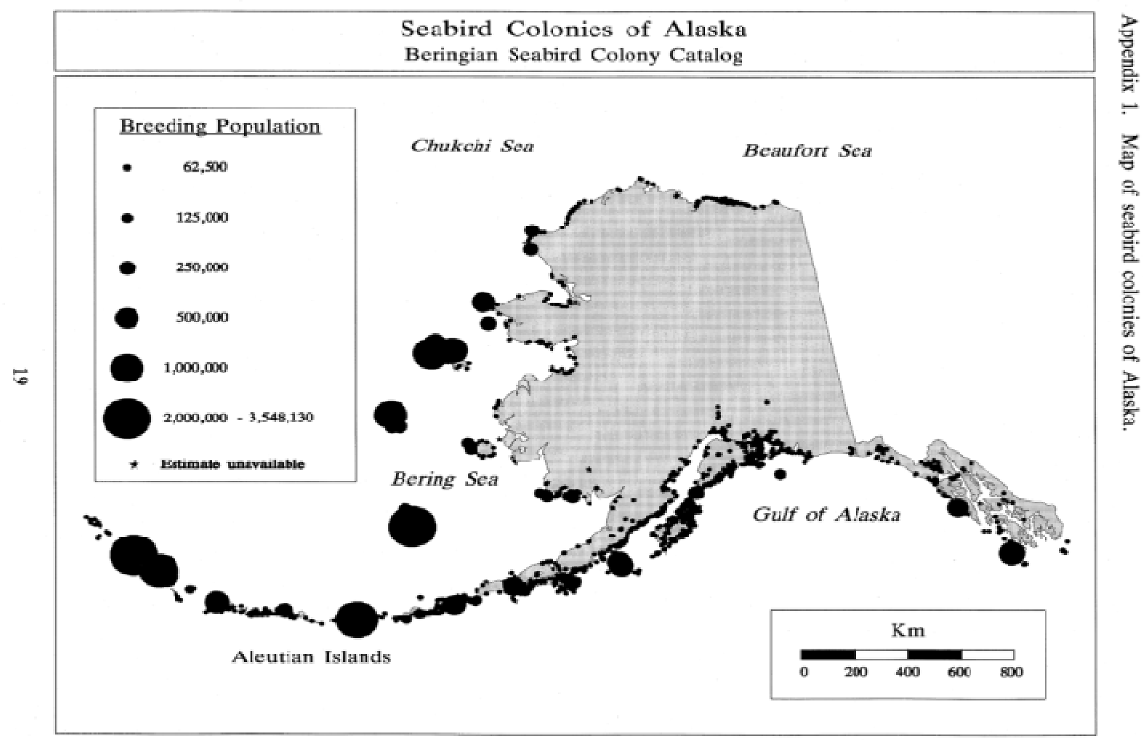


Figure 1. Seabird Colonies of Alaska. Beringian Seabird Colony Catalog, 2000. USFWS.

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,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 leucorrhoa*)	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	1,500	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

- Source of population data for colonial seabirds that breed in coastal colonies: modified from USFWS 1998. Eastimates are minima, especially for storm-petrels, auklets, and puffins.
- 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 $\leq 10^3$.
- 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).
- Sources of diet data: see species accounts in text.
- 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.
- 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 fulmars, cormorants, glaucous-winged gulls, kittiwakes, murres and for storm-petrels, and tufted puffins (Table 3). Trends are known for a few small areas of the state for pigeon guillemots, murrelets, auklets, and terns (Table 4). Trends are unknown at present for other species [jaegers, most auklets, and horned puffins; (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

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 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. 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 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 oceanographic 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 et al. 2000, Roby 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). 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.

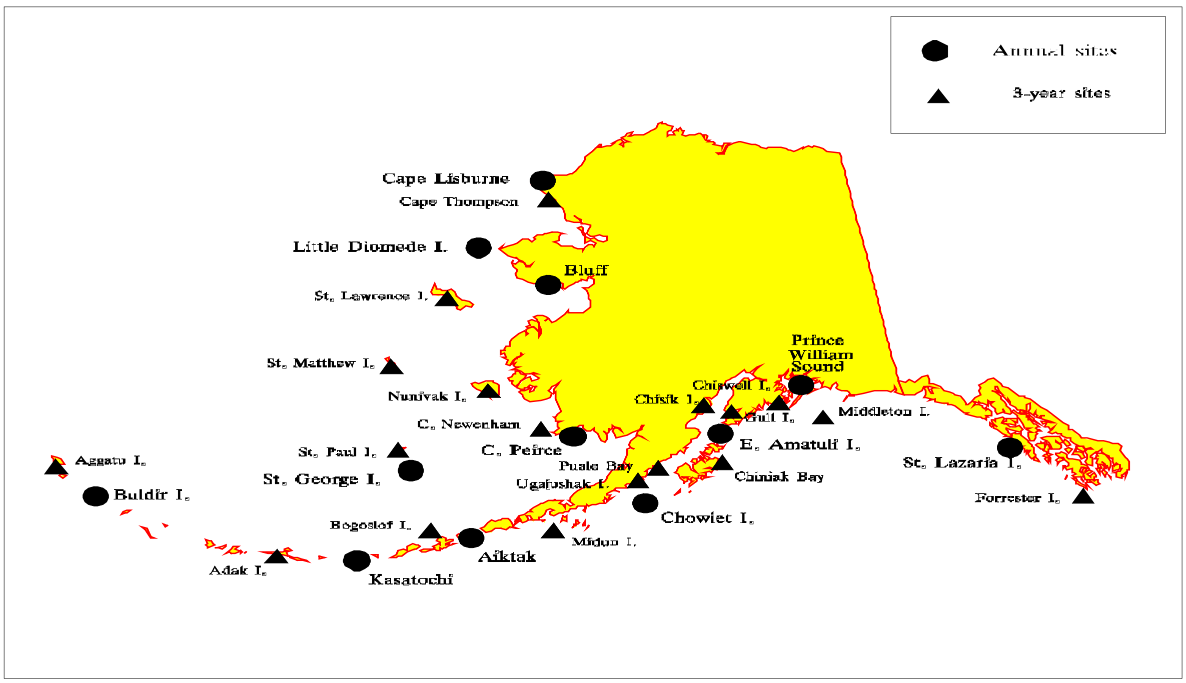


Figure 2. Location of seabird colony sites in Alaska monitored by the U.S. Fish and Wildlife Service and the USGS Biological Research Division. Some sites are monitored annually (circles), while others are monitored on three-year rotation (triangles).

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 or 2001. (Data from Shawn Stephensen, USFWS, Anchorage, and John Piatt, USGS/BRD, Anchorage, unpublished data).

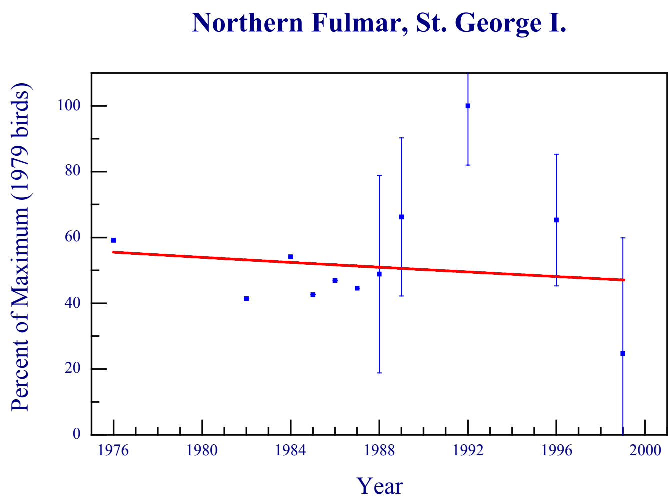
Site	Arctic Tern & Aleutian Tern	Pigeon Guillemot	Marbled Murrelet	Kittlitz's Murrelet
Prince William Sound	-	-	-	-
eastern Kodiak Island	-	0	?	?
Glacier Bay, SEAK	0	-	-	-

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). Overall, 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 et al. 2000). Tufted puffins and storm petrels were more abundant than average in the SE Bering Sea, but kittiwakes and murres declined.

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 will be censused by Alaska Maritime National Wildlife Refuge biologists in 2002, which will help determine whether this decline is a significant trend. 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.



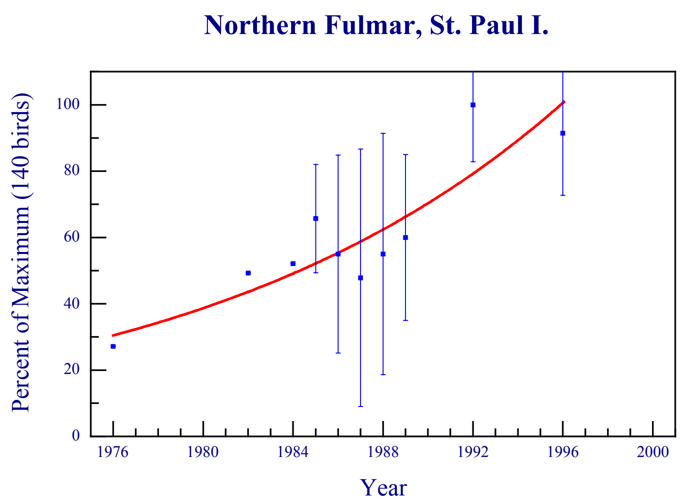


Fig. 3. Population trends of northern fulmars in the Pribilof Islands, based on plot counts on St. George I., 1976 - 1999 (Top) and St. Paul I., 1976 - 1996 (Bottom). Percent of Maximum is based on the number of birds on the study plots only. The majority of the estimated 80,000 fulmars on the Pribilof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

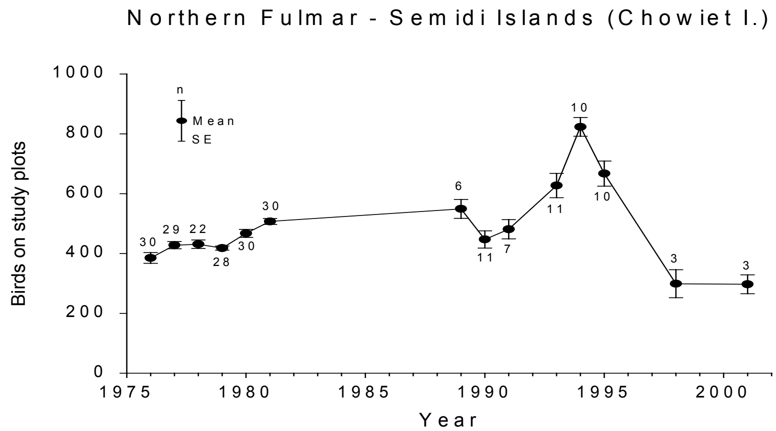


Figure 4. Population trends of northern fulmar on Chowiet Island, based on plot counts taken during summer, 1975 - 2001. (Unpublished data and graphic provided by Scott Hatch, USGS/BRD, Anchorage).

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, through a USFWS funding initiative to the USGS/BRD, in cooperation with the NMFS North Pacific Groundfish Observer Program. 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).

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).

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.

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 et al. 2000). 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 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 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). Additionally, although overall consumption of fish biomass by seabirds is estimated at < 4 % (Livingston 1993), 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). 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 relationship between fisheries effort and seabird colonies, we overlaid 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 7), 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 1998-2000), 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 7. 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. Geroge Island fulmar breeding population is relative 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.

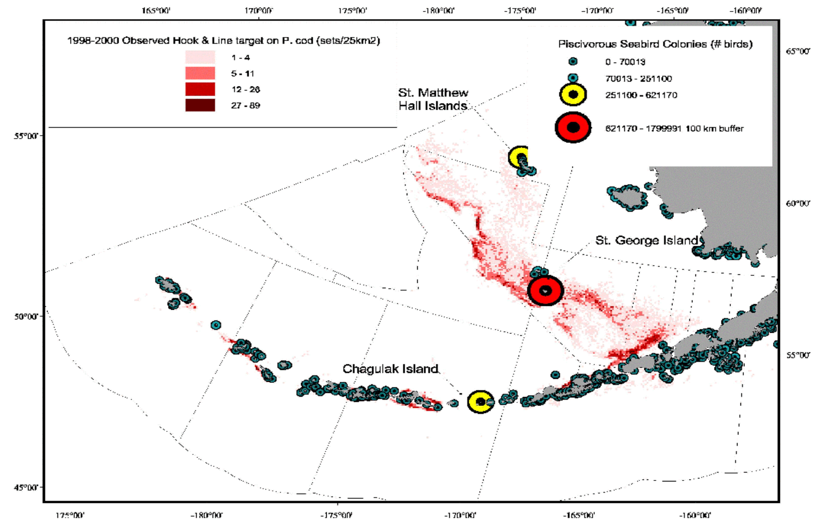


Figure 5. Location and relative size of seabird colonies (counting piscivorous birds only) in Alaska, relative to the 1999 observed trawl effort (hauls / 25 km^2).

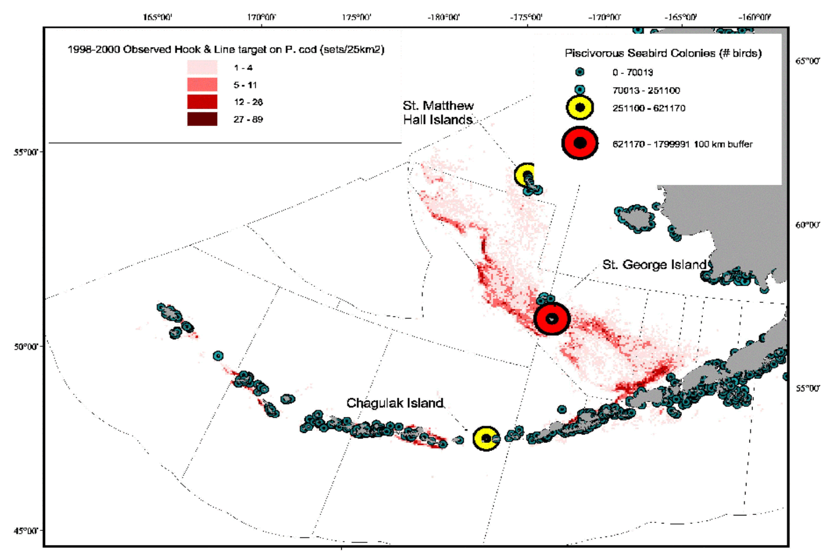


Figure 6. Location and relative size of seabird colonies (counting piscivorous birds only) in the Bering Sea/Aleutian Islands region of Alaska, relative to the 1998-2000 observed hook and line Pacific cod fishery effort (sets / 25 km^2).

Satellite Telemetry Tracking of Fulmars. – A more precise and current example of fulmar foraging from a colony was provided by satellite telemetry tracking of two northern fulmars captured on St. George Island (Scott Hatch, USGS/BRD, Anchorage, AK, unpublished data). These two birds, which laid eggs but did not complete nesting in 2001, were captured and harnessed with the satellite package on 17 June 2001; one bird died of unknown causes between 3-10 October and the other, last recorded in mid-October, continues to transmit signals. Both 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 overlap extensively with the 1998-2000 longline fishery effort (Figure 7). The surviving bird traveled to the northern GOA in early October. This pilot study demonstrates potential 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 seasons or regions.

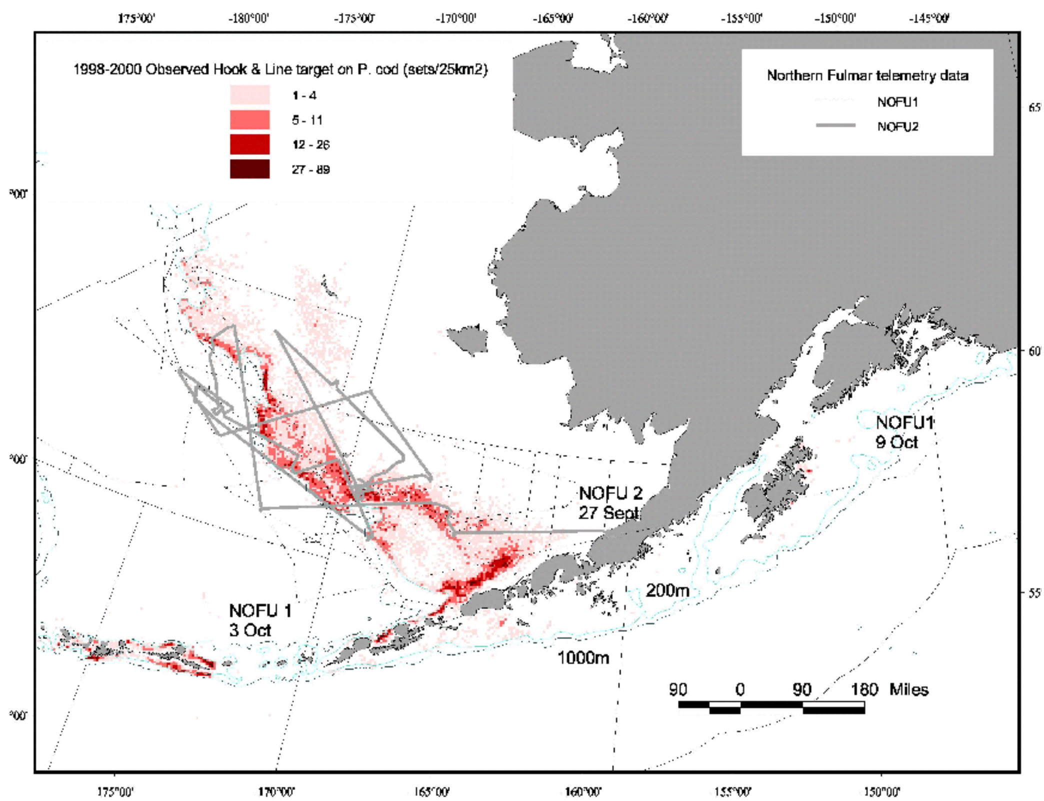


Fig. 7 Locations and track lines of two northern fulmars equipped with satellite telemetry packages. The birds were tagged at St. George Island in the Pribilofs in June 2001, and signals were transmitted every six days. Fulmar No.2 died between 3 - 10 October on the Alaska Peninsula. (Unpublished telemetry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

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).

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.

Table 8. Estimated Total Incidental Catch of Seabirds by Species or Species Groups[a] in Bering Sea and Aleutian Islands Longline Fisheries, 1993–1999. Values in Parentheses are 95% Confidence Bounds.

Year	Actual Number Taken[b]	STAL	BFAL	LAAL	NFUL	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 (10940-13877)
Average Annual Estimate													
1993-1996		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)
1997-1999		3 (0-6)	12 (4-20)	782 (653-912)	12,329 (11455-13203)	3,125 (2818-3432)	626 (540-713)	201 (109-293)	19 (9-29)	34 (17-51)	6 (1-12)	1,217 (1025-1410)	18,354 (17414-19294)
1993-1999		2 (0-4)	24 (15-34)	568 (499-636)	8,762 (8317-9207)	2,486 (2303-2670)	491 (431-551)	206 (152-260)	18 (8-28)	29 (19-40)	78 (53-103)	1,817 (1644-1940)	14,481 (13973-14989)

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, NFUL – 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, 2001).
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 1999. 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, 1993–1999. Values in Parentheses are 95% Confidence Bounds.

Year	Actual Number Taken[b]	STAL	BFAL	LAAL	NFUL	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)
Average Annual Estimate													
1993-1996		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)
1997-1999		0	191 (79-302)	153 (89-217)	501 (288-715)	153 (76-229)	24 (8-40)	0	0	2 (0-7)	1 (0-4)	9 (1-19)	1,034 (775-1293)
1993-1999		0	215 (158-272)	139 (106-172)	540 (429-651)	107 (63-152)	30 (19-41)	1 (0-3)	0	2 (0-4)	56 (41-71)	66 (47-86)	1,156 (1019-1293)

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
NFUL – 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, 2001).

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 1999. 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.

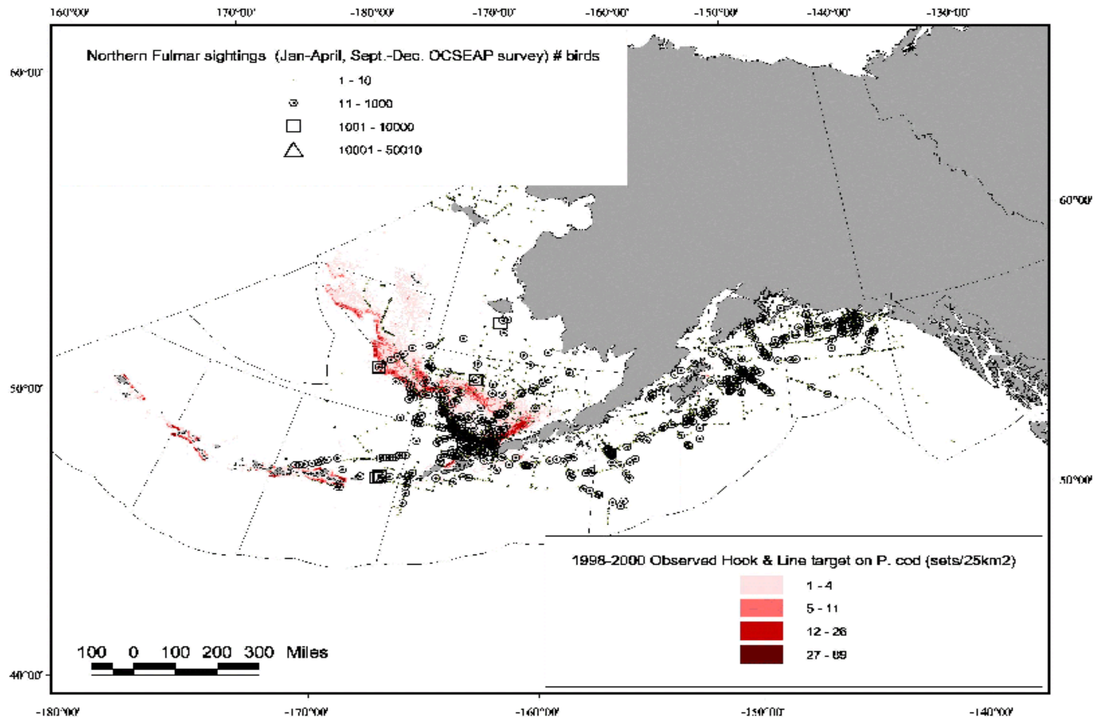


Fig. 8 Distribution of northern fulmars at sea in Alaska, as determined from boat-based surveys conducted between 1975-1985. Data are a subset of the North Pacific Pelagic Seabird Database, under development by the USGS/BRD and USFWS in Anchorage, AK.

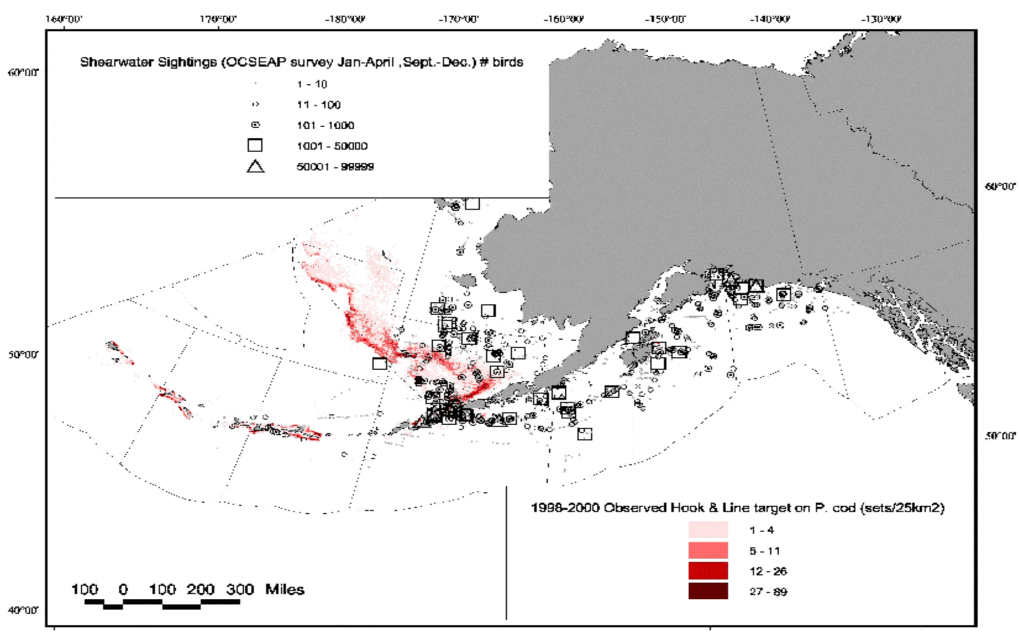


Fig. 9 Distribution of shearwaters (primarily sooty and short-tailed ssp) at sea in Alaska, as determined from boat-based surveys conducted between 1975-1985. Data are a subset of the North Pacific Pelagic Seabird Database, under development by the USGS/BRD and USFWS in Anchorage, AK.

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). However, 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.

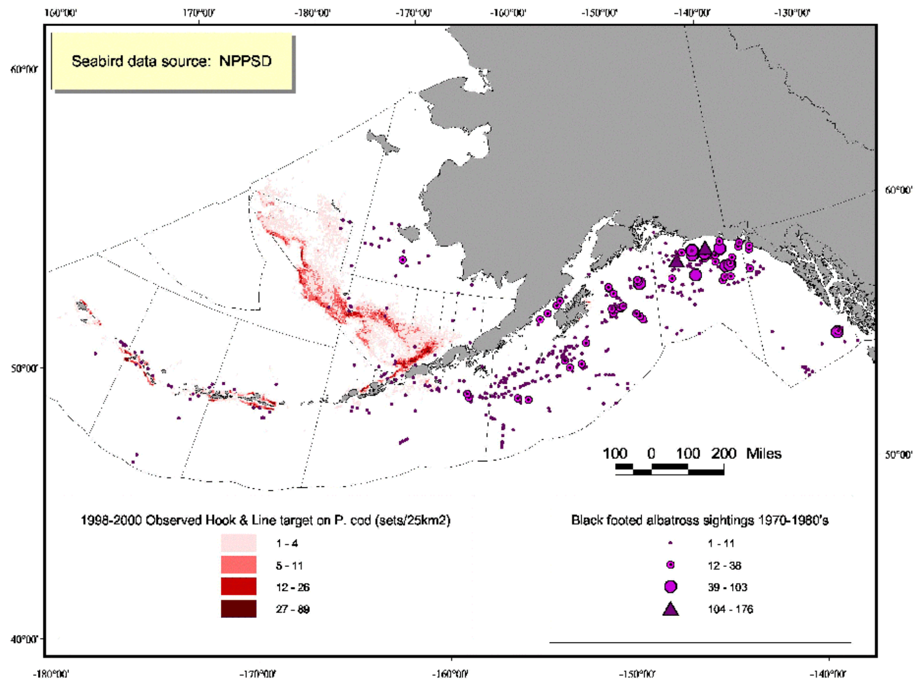


Fig. 10 Distribution of black-footed albatross in Alaska, as determined from boat-based surveys conducted between 1975-1985. Data are a subset of the North Pacific Pelagic Seabird Database, under development by the USGS/BRD and USFWS in Anchorage, AK.

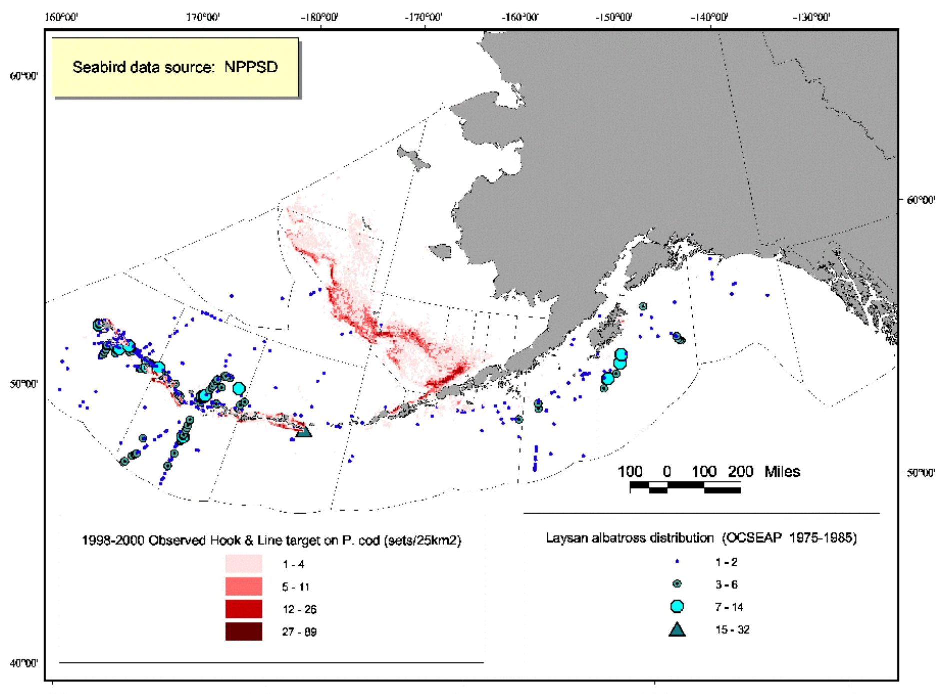


Fig. 11 Distribution of Laysan albatross in Alaska, as determined from boat-based surveys conducted between 1975-1985. Data are a subset of the North Pacific Pelagic Seabird Database, under development by the USGS/BRD and USFWS in Anchorage, AK.

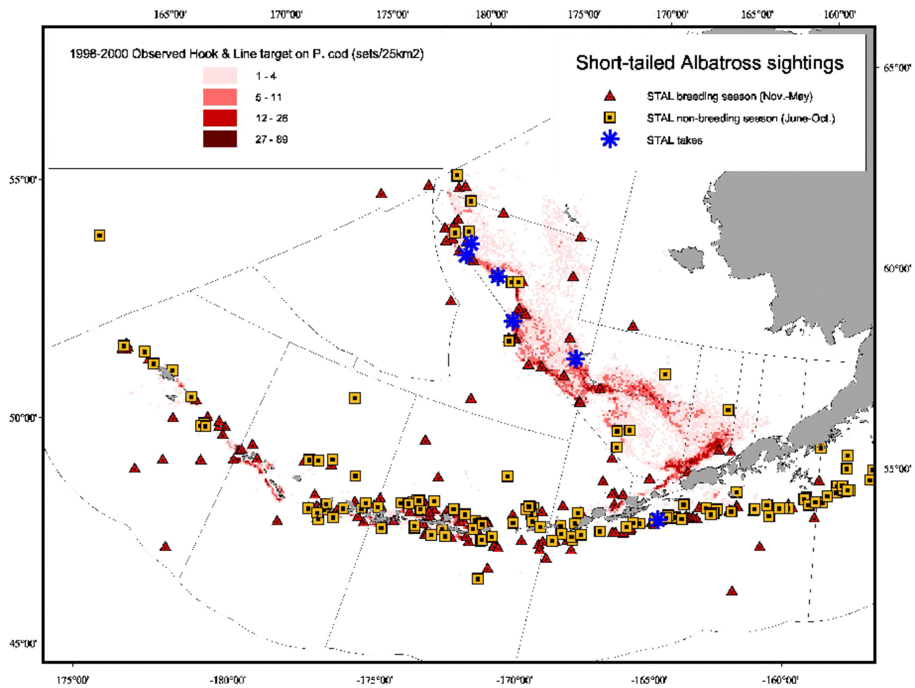


Fig. 12 Short-tailed albatross (STAL) sightings (by breeding season and take locations) in the BSAI in relationship to the 1998-2000 observed hook and line Pacific cod fishery effort (sets / 25 km^2).

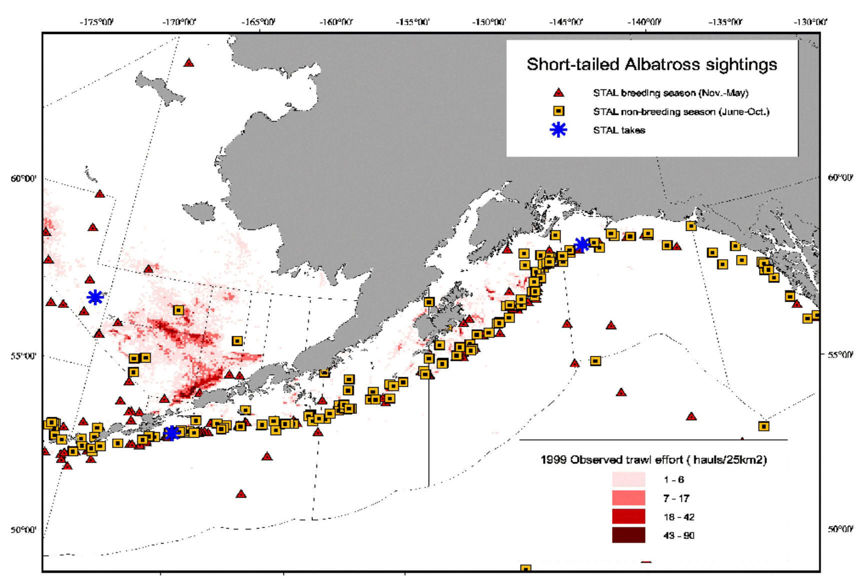


Fig. 13 Short-tailed albatross (STAL) sightings (by breeding season and take locations) in the GOA, relative to the 1999 observed trawl effort (hauls/25km2).

Bycatch of Seabirds in Fishing Gear

Seabirds are caught incidentally in all types of fishing operations (Jones and DeGange 1988) (Figure 14). 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 groundfish fisheries, longlines account for most seabird bycatch (Table 10, Figures 15-16). Trawls also take some seabirds, primarily those that feed beneath the surface on prey in the water column (Table 11). Pots occasionally take diving seabirds (Table 12). Some birds also are injured or killed by striking the vessel superstructure or gear while flying in the vicinity.

Monitoring Seabird Bycatch and Seabird/Fishery Interactions and Bycatch 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 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.

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
Average Annual Estimates				
1993–1996	135,444	11,576 (11034-12117)	0.09	24.5
1997–1999	169,814	18,354 (17414-19294)	0.11	23.7
1993–1999	150,174	14,481 (13973-14989)	0.10	24.2
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
Average Annual Estimates				
1993–1996	45,326	1,248 (1108-1388)	0.03	9.5
1997–1999	29,780	1,034 (775-1293)	0.03	9.3
1993–1999	38,663	1,156 (1019-1293)	0.03	8.9

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, 1997–1999

Year	Actual Number Taken[b]	Estimate Range[c]	STAL	BFAL	LAAL	NFUL	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
Average Annual Estimate														
1997–1999		low	0	0	74	205	530	338	0	296	2	0	69	1514
		high	0	0	172	3590	236	904	54	482	860	0	924	7223

Notes: [a]See the species and species groups footnoted in Table 3.5-6.
[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.

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, 1993–1999. Values in parentheses are 95% confidence bounds.

Year	Actual Number Taken [b]	STAL	BFAL	LAAL	NFUL	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)
Average Annual Estimate													
1993–1996		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)
1997–1999		0	0	0	66 (32-101)	5 (0-15)	3 (0-9)	5 (1-10)	3 (0-9)	0	0	0	82 (45-119)
1993–1999		0	0	0	41 (21-61)	3 (0-7)	2 (0-6)	2 (0-5)	4 (0-10)	0	0	1 (0-3)	53 (31-75)

Notes: [a]See the species and species groups footnoted in Table 3.5-6.
[b]Actual number taken is the total number of seabirds recorded dead in the observed hauls.

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 that 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. Bycatch 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 1999 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 1999 data resulted in an average estimate of two 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 1999 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 92 (or 73) percent of the total average annual seabird bycatch, trawl gear for 7 (or 26) percent and pot gear for less than 1 percent. The higher percentage of trawl bycatch 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 1999, 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 3 times higher than in the GOA (Table 10).

Bycatch on 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. Longline fishing is considered the most recent and potentially most serious global threat faced by albatrosses and other procellariiforme taxa (Brothers *et al.* 1999a). Seabird mortality in Alaska longline fisheries represents only a portion of the fishing mortality that occurs, particularly with the albatrosses. 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 bycatch for the Alaska groundfish fisheries, based on 1993 to 1999 data, indicate that approximately 16,000 seabirds are taken annually in the combined BSAI and GOA groundfish fisheries (14,500 in the BSAI; 1,200 in the GOA) at the average annual rates of 0.10 and 0.03 birds per 1,000 hooks in the BSAI and in the GOA, respectively (Table 10).

Of the estimated 14,500 seabirds that are incidentally caught in the BSAI, the species composition is: 61 percent fulmars, 17 percent gull species, 12 percent unidentified seabirds, 5 percent albatross species, 3 percent shearwater species, and 2 percent 'all other' species (Figure 15).

Of the estimated 1,200 seabirds that are incidentally caught in the GOA, the species composition is: 47 percent fulmars, 35 percent albatrosses, 9 percent gull species, 6 percent unidentified seabirds, 3 percent shearwater species, and less than 1 percent 'all other' species (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.

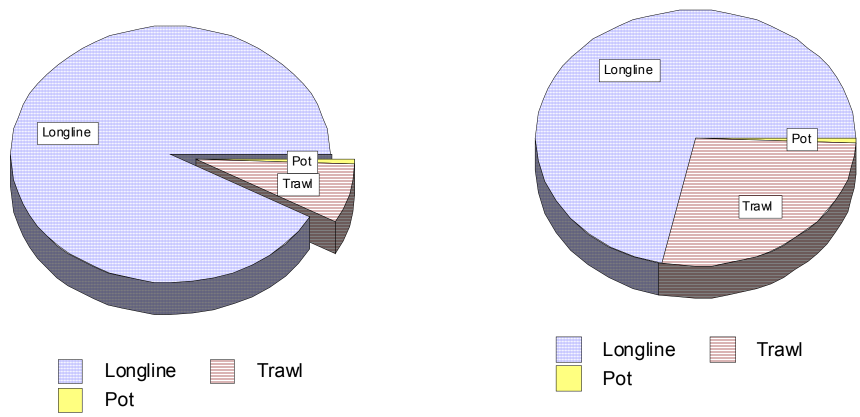


Fig. 14. Average Annual Estimate of Number of Seabirds Taken by Gear Type, 1997-1999. Estimates Differ Based on Trawl Sampling Methodology Used.

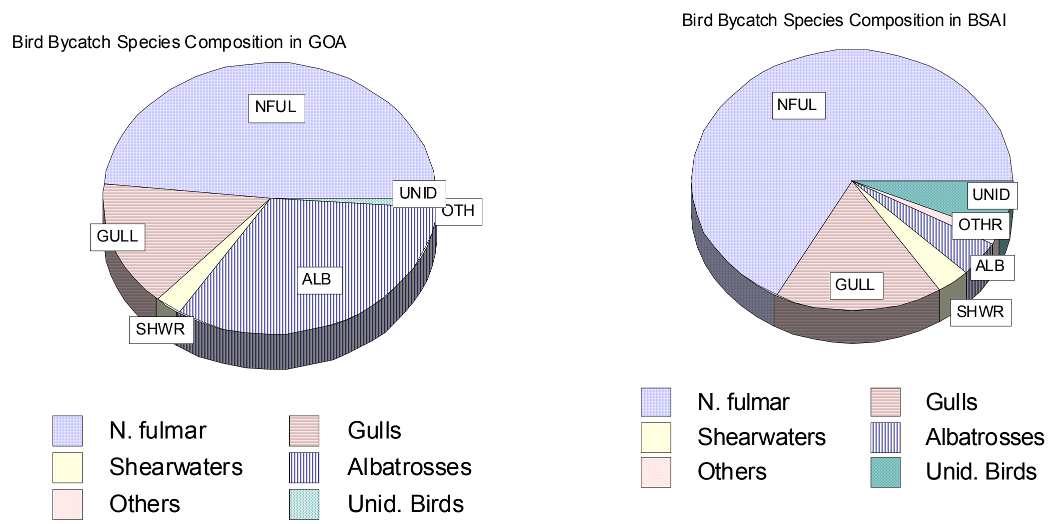


Fig 15. Relative Species Composition of Bird Bycatch in the Longline Fisheries, BSAI (right) and GOA (left). Average annual estimates, 1997-1999.

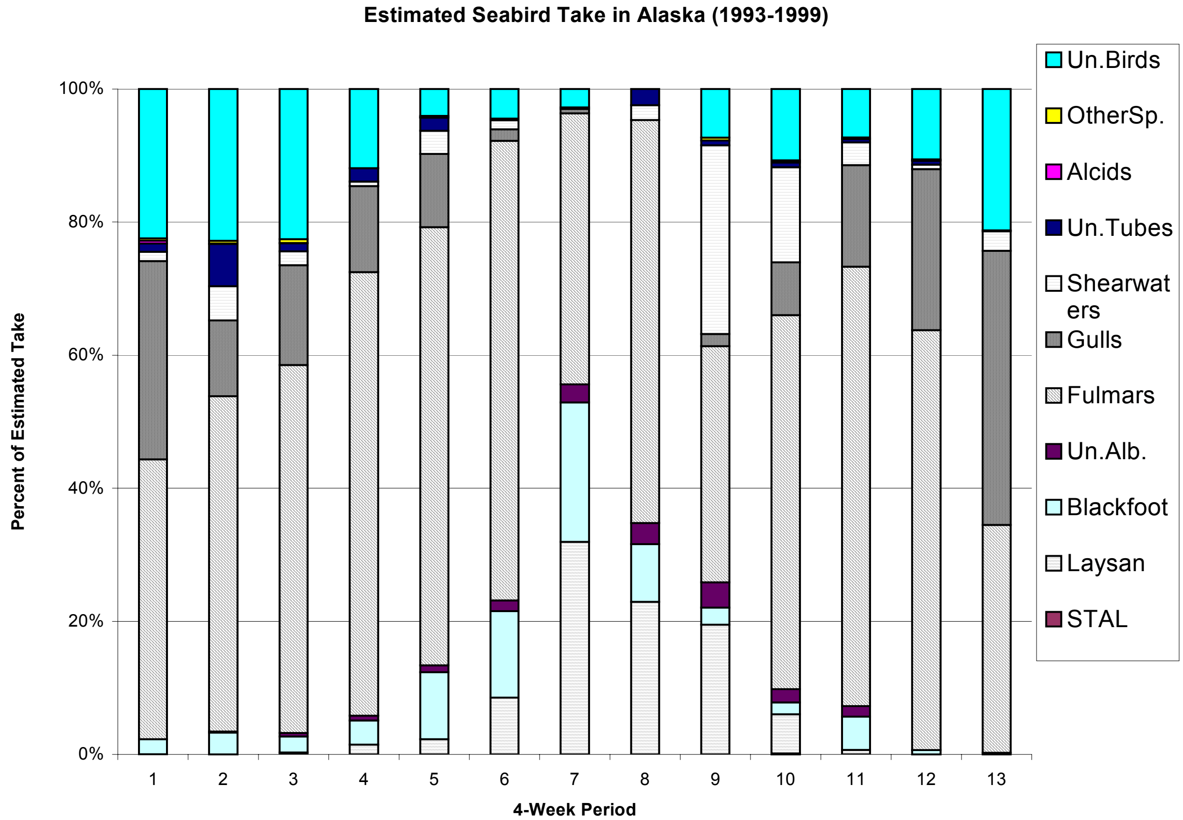


Fig 16 Cumulative Estimated Seabird Bycatch in Longline Fisheries in Alaska, by Species Group, by 4-Week Periods, 1993-1999.

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.

Efforts to Reduce Seabird Bycatch 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. 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 that 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 2002" hereby serves to fulfill the Alaska Region's requirements for annual NPOA reporting.

<u>Mitigation Measures</u>

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. At the October 2001 meeting of the North Pacific Fishery Management Council (Council), Washington Sea Grant Program (WSGP) researchers presented results from a 2-year scientific study evaluating the effectiveness of the seabird avoidance measures currently in use. The WSGP final report made four basic types of recommendations to the Council and NMFS: 1) proposed changes to existing regulations, 2) optional actions that could be included in a comprehensive seabird bycatch reduction program and that are non-regulatory in nature (education and outreach and gear suggestions), 3) suggestions for future research, and 4) gear, methods, and operations which should not be allowed as seabird avoidance measures. The regulatory recommendations call for the use of paired streamer lines with standards for performance and construction of the streamer lines and include some suggested guidelines to assist fishers in achieving some of the standards that would be required in regulation. See the 'research' section below, plus all components are more fully described in the WSGP final report (Melvin et al 2001). The Council is also considering an alternative that proposes some variations of requirements for small vessels and is scheduled to take final action on revisions to seabird avoidance regulations at its December 2001 meeting.

Bycatch 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 bycatch in observed trawl hauls is currently available for 1993 through 1999. The principal bird species reported in trawl hauls were alcids, northern fulmars, and gulls. Small numbers of other species also were caught. NMFS analysis of 1993 to 1999 observer data indicates that trawl gear accounted for 7 to 26 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.).

Vessel Strikes

Striking of vessels by birds in flight is reported by observers, but bird-strike data have not been analyzed statistically. Some birds that strike vessels fly away without injury, but some are injured or killed. Bird strikes are probably most numerous during the night; 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). Collisons of large numbers of birds occasionally occurs as in the case of where approximately 6,000 crested auklets which were attracted to lights and collided with a fishing vessel near Kodiak Island during the winter of 1977 or in the central Aleutians in 1964 when approximate1y 1,100 crested aukets attracted to deck lights on a processor and collided with structures on the vessel (Dick and Donaldson 1978). Species that most commonly strike vessels include storm-petrels, auklets, and shearwaters.

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. The Council will take final action at its December 2001 meeting to make changes to the existing regulations based on the WSGP recommendations. 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 and by other seabird scientists are:

1. 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).

2. 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?

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

4. 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.

5. 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.

6. 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).

7. 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.

8. Investigate the extent of use of trawl third wires in the trawl fleet 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.

In 2001, steps were taken to address many of these research gaps by way of a congressional funding initiative. 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 in progress in 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 supported. 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 will obtain albatross and fulmar carcasses from the BSAI, to be shipped to the University of Alaska, Fairbanks. The UAF Museum will process 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. If successful, the project will extend another year and include the GOA region.

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. 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.

5. *Outreach Plan and Video for Fishers*
A contract was established with the Washington Sea Grant Program, University of Washington, to develop a comprehensive outreach program and 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.

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, needs to be entered into an accessible database. This project will create the database and enter observer notes 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. Results will guide improvement of the Seabird Daily Log data sheet used by observers.

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Ecosystem or Community Indicators and Modeling Results

Present and Past Ecosystem Observations – Local and Traditional Knowledge

Alaska Natives have the experience of thousands of years of observations on various aspects of the ecosystems of the North Pacific. Although Western science strives to achieve such a long term perspective, it presently resides with those who have inhabited these regions and used the resources for subsistence over the years. The Alaska Native community is working to join their collective knowledge together on the ecosystems of the North Pacific. Similarly, local observations are presently being made by other resource users and attempts are being made to collect and summarize that information in an organized fashion. Below are some summaries of these observations

Historical Accounts of Ecosystem Change in the Eastern Aleutians
Contributed by Glenn Merrill
NO UPDATE THIS YEAR

Multispecies Forecasting of the Effects of Fishing and Climate

Contributed by Jesus Jurado-Molina, University of Washington and Pat Livingston, Alaska Fisheries Science Center

Commercially important groundfish populations in the eastern Bering Sea are connected to each other through the food web and act either as predators, prey, or both in the system. Some species, such as walleye pollock (*Theragra chalcogramma*), are dominant in terms of biomass and may also dominate the trophic dynamics. In addition to having different trophic roles, the recruitment patterns of these species are variable and may be related to climate forcing on either inter-annual or inter-decadal time scales. We examined the possible future effects of four levels of fishing mortality ($F_{30\%}$, $F_{40\%}$, $F_{50\%}$ and no fishing) on trophically-linked species under two different scenarios of future climate regimes using both single-species and multi-species forecasting models of the eastern Bering Sea.

The eight-species system developed in the multispecies virtual population analysis (MSVPA) of the eastern Bering Sea by Livingston and Jurado-Molina (2000) was used. Four species, walleye pollock (Theragra chalcogramma), Pacific cod (Gadus macrocephalus), Greenland turbot (Reinhardtius hippoglossoides) and yellowfin sole (Pleuronectes asper) played the role of both predator and prey. Two species, rock sole (Lepidopsetta bilineata) and Pacific herring (Clupea pallasi), were considered only as prey. Two species, arrowtooth flounder (Atheresthes stomias) and northern fur seal (Callorhinus ursinus), were considered "other predators", whose populations are not estimated within the model but are provided externally from other sources. The multi-species forecast model includes predation interactions and uses as input the predator-prey suitabilities which were derived from MSVPA.

Monte Carlo simulations for each level of fishing mortality and each assumption on mean recruitment level associated with each regime shift were performed using the single-species and multi-species forecasting models. We took a simple approach for recruitment by assuming that the climate regime shift produced a change in the variability and mean level of this parameter. Two hypotheses were examined. One hypothesis was that the eastern Bering Sea is still responding to the 1977 climate regime and the second hypothesis was that the species are responding to a possible new regime shift that occurred in 1989. Mean and variance in recruitment for each species used in the forecast models were calculated from historical recruitment estimates corresponding to a particular regime-shift. The ratio of spawning biomass in the forecast of year 2015 relative to the starting year of 1998 was used as indicator of performance. The temporal trend of the median spawning biomass ratio of pollock was also tracked in the long-term.

In the single-species context, fishing mortality in conjunction with the regime shift assumption were the most important factors driving the dynamics of the species. The regime shift assumption produced important effects in only three species in a single-species context. The three species; Pacific cod, Greenland turbot and rock sole, were the species in which the regime shift assumption changed the mean (Pacific cod and rock sole) or had a larger change in the variance of recruitment (Greenland turbot). The observed changes in SSB ratios of these species were a direct result of the changes in recruitment assumptions for the two regime shift scenarios. Thus, forecasts of single-species dynamics can be influenced if regime shifts changes in recruitment can be estimated and incorporated into the projections.

In the multi-species scenario, the results showed greater complexity. Fishing was an important factor driving the dynamics of all species. An increase in fishing mortality produced a decrease in the mean spawning biomass in the majority of the species. For Pacific herring, in which fishing mortality was held constant at the 20% harvest rate policy presently used in its management, an opposite trend was observed. This tendency was due to predation interactions. As the fishing mortality of Pacific herring predators increased, their abundance decreased, producing a reduction in Pacific herring predation mortality and thus an increase in its mean SSB ratio. This shows how fishing changes on predator populations in combination with predation interactions have the potential to cause unintended changes in prey populations.

The cumulative frequency distributions of some species' SSB ratios were also affected by predation. Within a no-fishing scenario, the single-species simulation of both assumptions of climate regime shift suggested an increase in the spawning biomass of most species. Different results were seen in the multi-species forecasts, which included predation interactions. For walleye pollock, the multi-species no-fishing simulation suggested an increase in the SSB ratio in the medium-term projections. However, this increase was smaller than the multi-species simulations of the $F_{40\%}$ and $F_{50\%}$ levels of fishing mortality. These differences are due to the cannibalistic interactions that increase the complexity of the dynamics of walleye pollock.

If predation interactions are taken into account in models of walleye pollock, the absence of fishing mortality produces an increase in the survival of adult walleye pollock and consequently an increase in the predation mortality of juvenile pollock. This result is also seen in our simulations (Figure 1), in which the initial effect of a no-fishing regime on pollock in the multi-species forecast is a strong build-up of adult biomass and the depression of juvenile pollock biomass. Therefore, results of the multi-species forecast suggest that cannibalism is an important factor influencing the amplitude and frequency of biomass oscillations in walleye pollock in this model. The lack of an explicit stock-recruitment function in generating recruitment values in this model is also likely responsible for the strong depression of juveniles at high adult walleye pollock stock sizes. Future refinements for this model should include derivation of functional stock-recruitment relationships for walleye pollock under different climate regimes. However, there are not yet enough historical observations of stock and recruitment to derive these for different climate regimes.

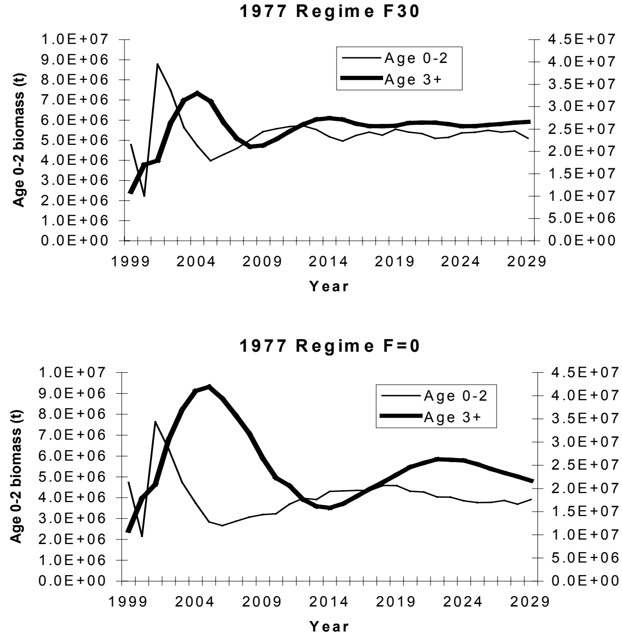

Figure 1. Median biomass trajectories of walleye pollock juveniles (age 0-2) and adults (age 3+) from the multispecies scenario of the 1977 regime shift under two levels of fishing ($F_{30\%}$ - top and F=0 – bottom)

For rock sole, predation interactions were also important. The multi-species forecast of the no-fishing level under the 1989 regime shift assumption predicted a decreasing spawning biomass ratio compared with the no-fishing scenario under the 1977 regime shift assumption, which predicted an increasing biomass ratio. The decreasing trend of the spawning biomass ratio is likely due to increased predation mortality caused by an increase in the population of rock sole's predators (walleye pollock and Pacific cod) when fishing is stopped, together with the reduced recruitment in rock sole assumed under the 1989 regime relative to the 1977 regime. The single species forecast for rock sole under the 1989 regime shift scenario predicted an increased SSB trend. Thus, predation interactions can influence not only the magnitude of population change but also the direction of change.

The displacement of the frequency distributions produced by the different combination of assumptions of climate regime and fishing mortality in the single-species and multi-species forecasts produced an overlap of some cumulative frequency distributions of the SSB ratio of some species such as Pacific cod and rock sole. In the case of Pacific cod, a more conservative policy ($F_{40\%}$) under recruitment assumptions of a 1989 regime shift could produce similar effects to those produced by a less-conservative policy ($F_{30\%}$) under the assumptions of the 1977 regime shift in the medium-term (Figure 2).

In the case of walleye pollock there was overlap among scenarios in the cumulative frequency distributions in both the medium-term and the long-term multi-species projections. In this species, the addition of strong cannibalistic interactions in combination with fishing and changes in recruitment variability produce oscillations in the medium-term that have a different amplitude and frequency for each scenario. There is overlap at various short and long time intervals of the median biomass estimates from different scenarios. Discriminating among environment, predation and fishing effects on this species will continue to be a challenge. Similarly, the design of multi-species or ecosystem-based management strategies that attempt to balance human and predator needs for walleye pollock are complicated by these cannibalistic interactions that are confounded with fishing and environmental factors.

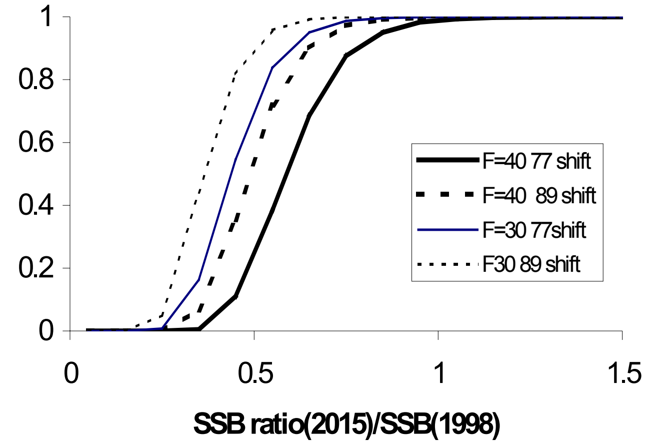

Figure 2. Cumulative distributions of the spawning biomass (SSB) ratio of Pacific cod relative to 1998 estimated with two levels of fishing mortality ($F_{30\%}$ and $F_{40\%}$) and two assumptions of climate regime shift in the single species forecast.

In summary, the effects of fishing, predation interactions and climate could be considered similar because they produce changes in the SSB ratios of species of the same order of magnitude. The effect of fishing is always to reduce the biomass of the target species in single-species forecasts. On the other hand, the effects of predation and fishing in multi-species forecasts cannot be generalized and depend on the species, the complexity and magnitude of the predation interactions and the species= position in the food web and its response to climate variability.

The MSVPA and the multi-species forecast models are a first step in taking a more holistic approach in providing advice for fisheries management. However, some aspects in this approach can be improved. The incorporation of climate regime shifts in the model will require a better understanding of the mechanisms involving changes in physical environment and their effects on recruitment success during a particular climate regime. The recognition of the 1977 regime shift was made in the early 1990=s and there is a belief that that event was not exceptional but the latest in a sequence of regime shifts (Hare and Mantua, 2000). Therefore it is necessary to develop a reliable way to identify regime shifts based on biological and/or physical indices. Monitoring these indices in the North Pacific and the Bering Sea ecosystems might allow for an earlier identification of regime shifts.

This identification, in combination with a sufficient number of stock and recruitment data points in different regimes, will allow a more detailed functional specification of recruitment of the Ricker or Beverton-Holt form for each regime shift. Long-term monitoring is required in order to recognize and quantify the effects of regime shifts on marine ecosystems. This recognition and the improved understanding of the influence of multi-species interactions will help resource management better adapt to current or future environmental conditions.

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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.

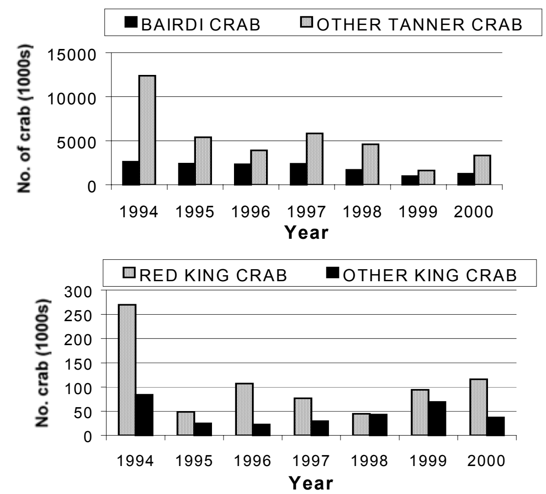

Figure 1.--Tanner and king crab bycatch in groundfish fisheries off Alaska, 1994-2000.

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.

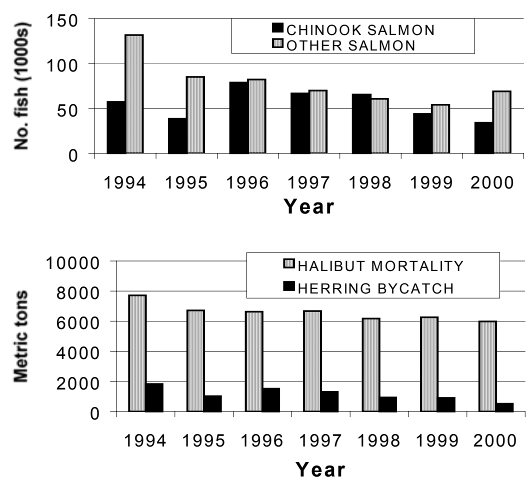

Figure 2. Bycatch of salmon, halibut, and herring in the groundfish fisheries off Alaska, 1994-2000.

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 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 both areas 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.

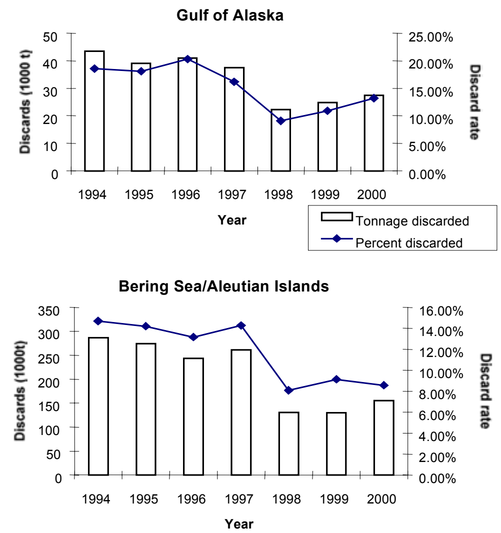

Figure 1. Total biomass and percent of total catch biomass of managed groundfish discarded in the GOA and BS/AI areass 1994-2000. (Includes only catch counted against Federal TACs.)

Time Trends in Non-Target Species Bycatch and Discards

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).

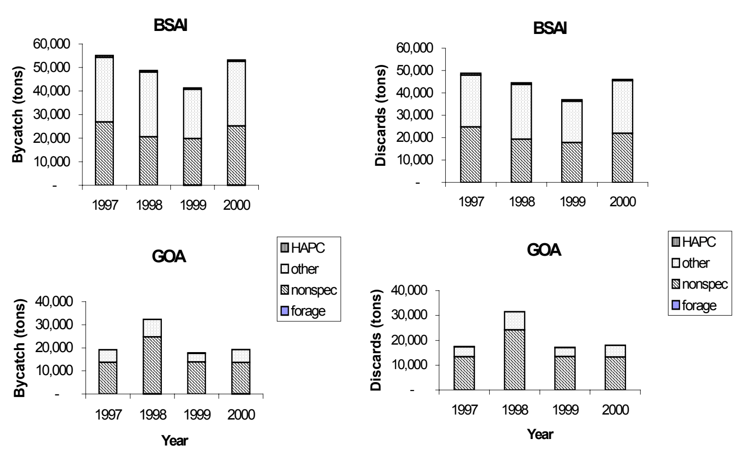

Figure 1. Bycatch and discard estimates of non-target species in the BSAI and GOA areas by groundfish fisheries.

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 prhibited species (i.e., salmon, crab, herring and halibut) (Table 1, Figure 1). Some of the closures are in effect year-round while others are only 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 stock of Steller sea lion began in 1999 with some simple restrictions based on rookery and haulout locations, to specific fishery restrictions in 2000 and 2001. For 2001, over 90,000 nmi of the EEZ off Alaska was closed to trawling year-round. Additionally, 40,000 nmi were closed on a seasonal basis. State waters (0-3nmi) are also closed to bottom trawling in most areas.

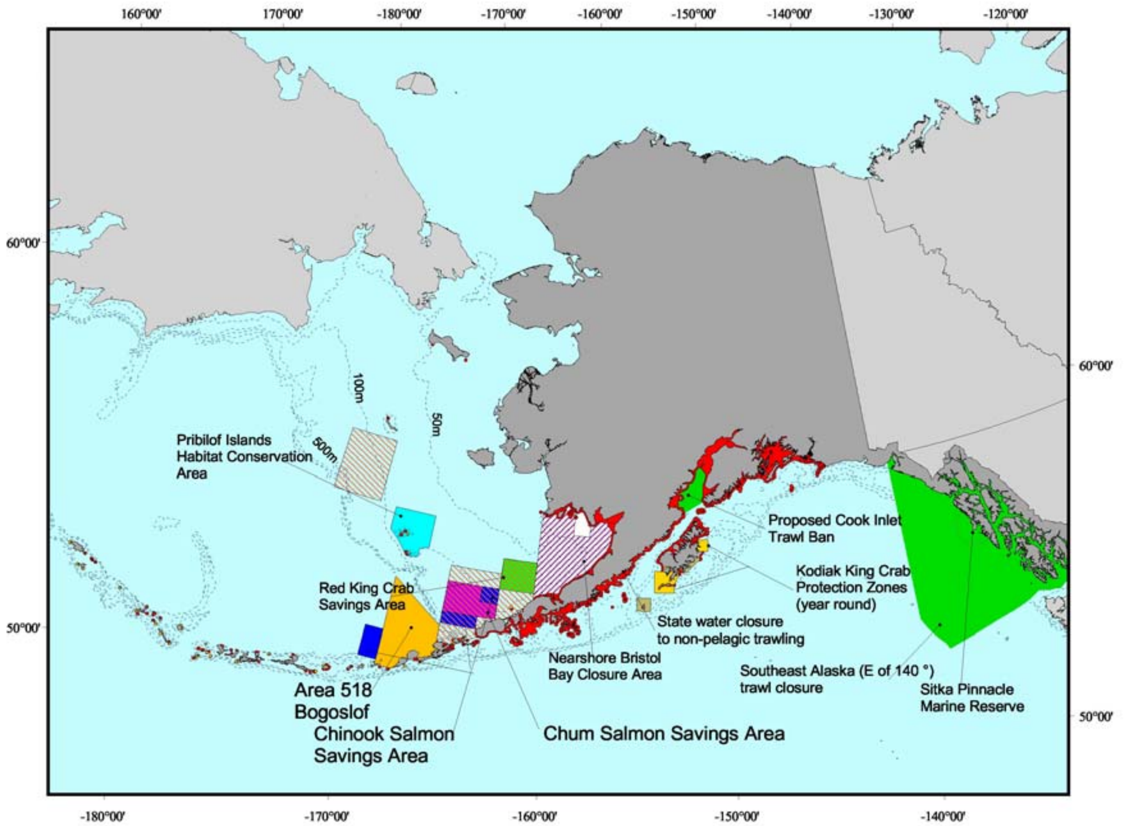

Figure 5. Groundfish closures in Alaska's Exclusive Economic Zone

CSSA= chum salmon savings area

CHSSA= Chinook salmon savings area
RKCSA = red king crab savings area
HSA = herring savings area
SSL= Steller sea lion

Table 1. Time series of groundfish trawl closure areas in the BSAI and GOA, 1995-2001

Bering Sea/ Aleutian Islands

Year	Location	Season	Area size	Notes
1995	Area 512	year-round	8,000 nm2	closure in place since 1987
	Area 516	3/15-6/15	4,000 nm2	closure in place since 1987
	CSSA	8/1-8/31	5,000 nm2	re-closed if 42,000 chum salmon in bycatch
	CHSSA	trigger	9,000 nm2	closed if 48,000 Chinook salmon bycatch
	HSA	trigger	30,000 nm2	closed to specified fisheries when trigger reached
	Zone 1	trigger	30,000 nm2	closed to specified fisheries when trigger reached
	Zone 2	trigger	50,000 nm2	closed to specified fisheries when trigger reached
	Pribilofs	year-round	7,000 nm2	established in 1995
	RKCSA	year-round	4,000 nm2	established in 1995; pelagic trawling allowed
	Walrus Islands	5/1-9/30	900 nm2	12 mile no-fishing zones around 3 haul-outs
	SSL Rookeries	seasonal ext.	5,100 nm2	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 nm2	expanded area 512 closure
	COBLZ	trigger	90,000 nm2	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
with additions of Steller Sea Lion protections
Pollock haulout trawl exclusion zones for EBS, AI, GOA
Summer
Year-round
Winter
A-Season
CHCVOA

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 nm2*
No trawl (Jan-June)14,800 nm2*
No Trawl Atka 29,000 nm2
mackerel Restrictions

Gulf of Alaska

Year	Location	Season	Area size	Notes
1995	Kodiak	year-round	1,000 nm2	red king crab closures, 1987
	Kodiak	2/15-6/15	500 nm2	red king crab closures, 1987
	SSL Rookeries	year-round	3,000 nm2	10 mile no-trawl zones around 14 rookeries
	SSL Rookeries	seasonal ext,	1900 nm2	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 nm2 adopted as part of the license limitation program
(11,929 nm2 area on the shelf)

1999 same closures as in 1995, 1996, 1997 and 1998, with two additions:
with additions of Steller sea lion protections
Pollock haulout trawl exclusion zones for EBS, AI, GOA
Summer
Year-round
Winter

Sitka Pinnacles
Marine reserve year-round 3.1 nm2 Closure to all commercial gear

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 nm2*
No trawl (Jan-June)14,800 nm2*

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 an indicator for 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. Fluctuation in fishing effort track well with overall landings 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.

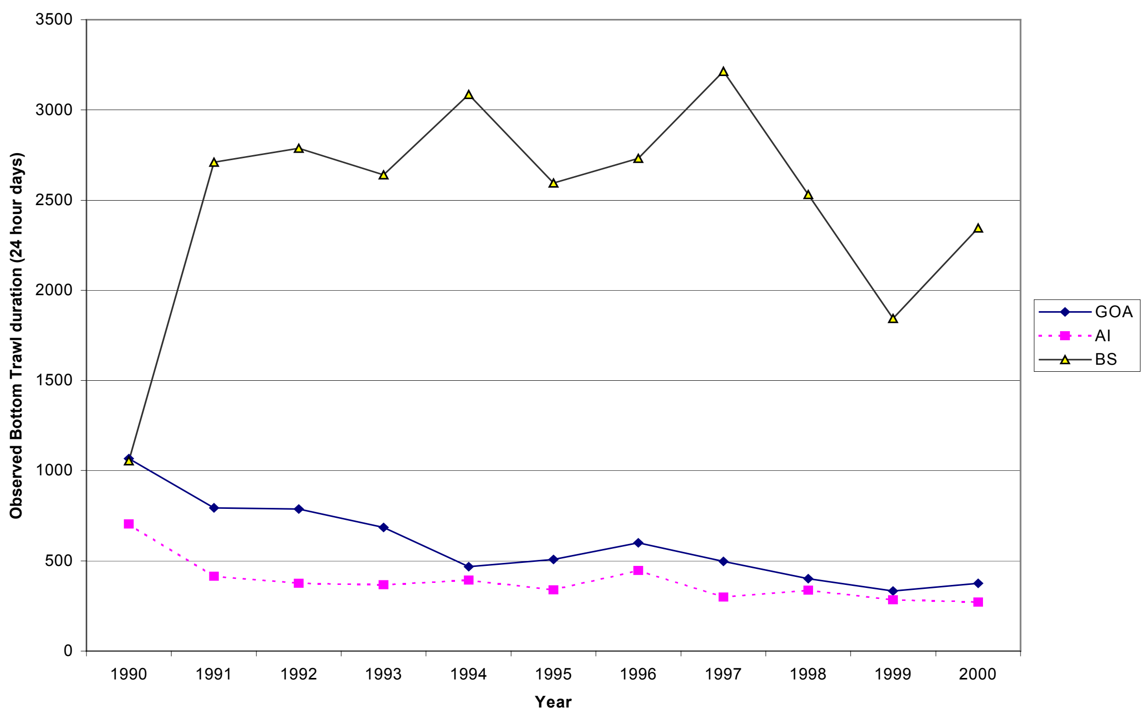

Figure 1. Estimated bottom trawl time in the Gulf of Alaska, Bering Sea, and Aleutian Islands from 1990-2000.

Bering Sea
For the period 1990-2000, there were a total of 227,749 observed bottom trawls 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.

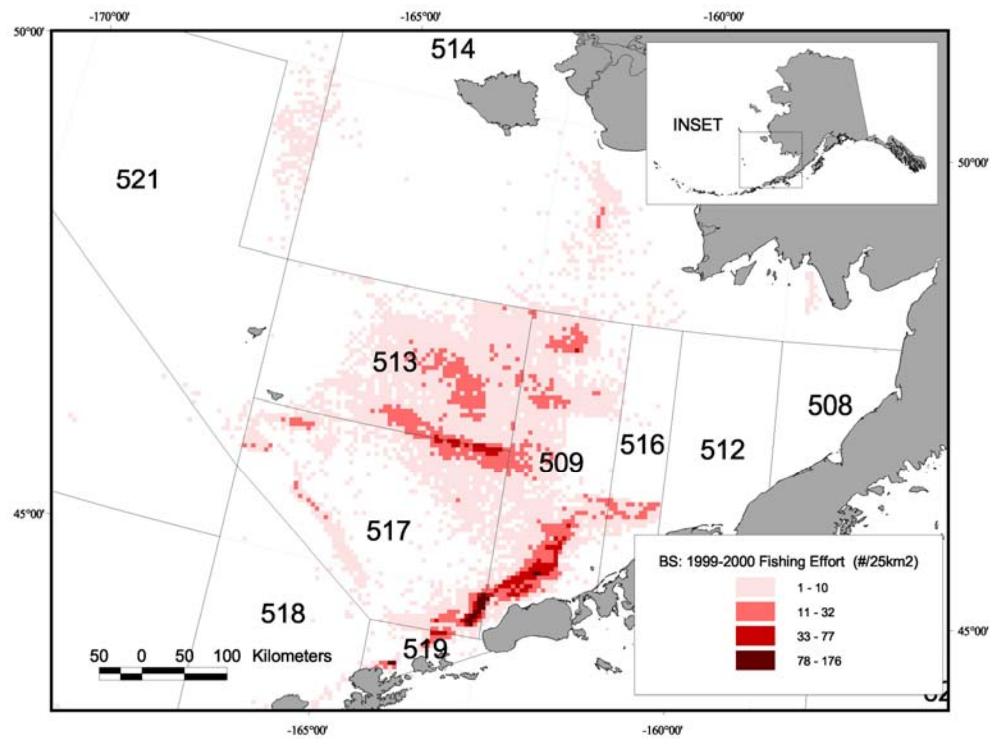

Figure 2. Spatial location and density of bottom trawl effort in the Bering Sea 1999-2000.

Aleutian Islands
For the period 1990-2000 there were 40,952 observed bottom trawls 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. Areas 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.

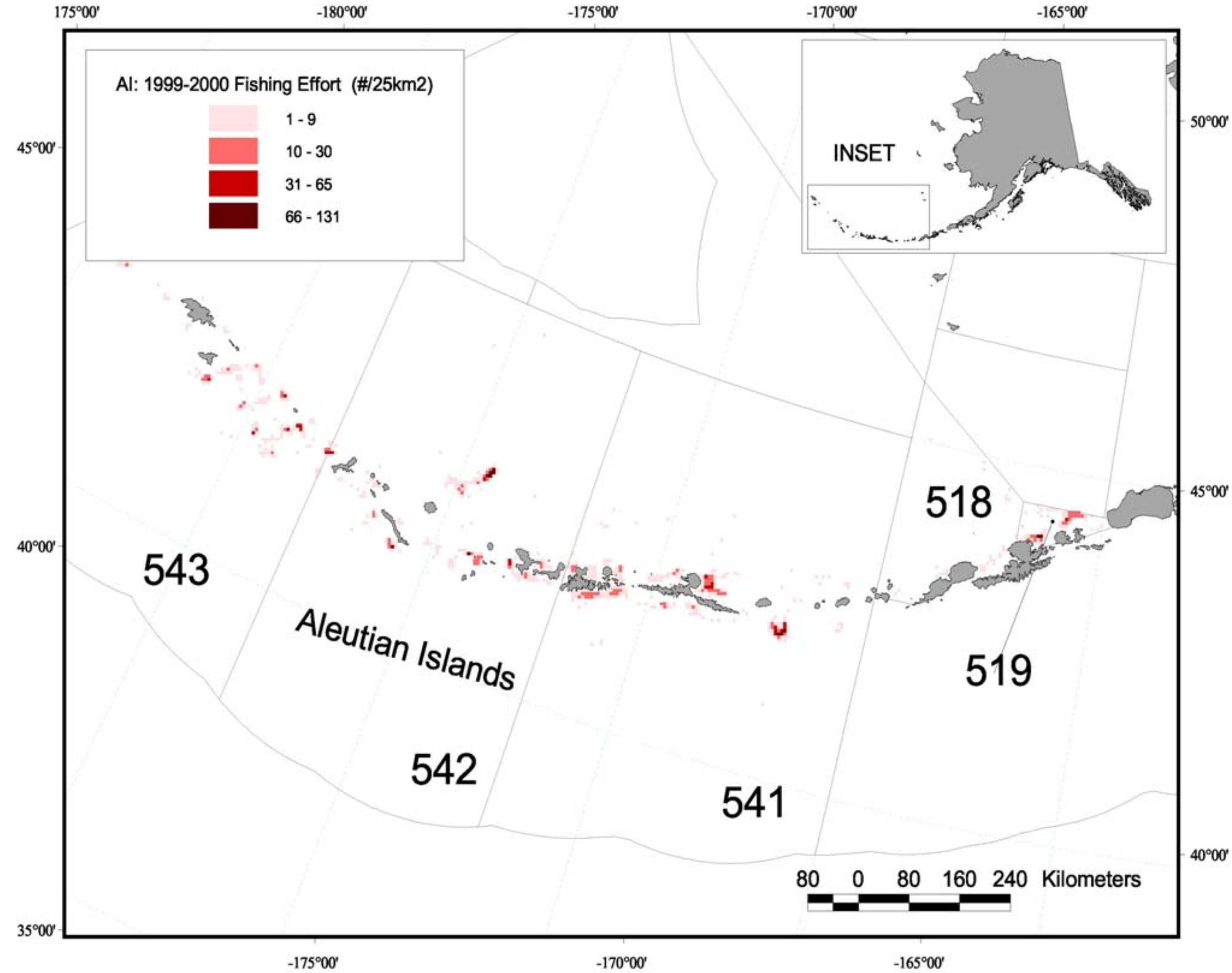

Figure 3. Spatial location and density of bottom trawl effort in the Aleutian Islands, 1999-2000.

Gulf of Alaska

For the period 1990-2000 there were 64,948 observed bottom trawls 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 trawl effort was 3,443 sets. Areas of high fishing effort are dispersed along the shelf edge with high pockets of effort near Chirikof Is., Cape Barnabus, Cape Chiniak and Marmot Flats. 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.

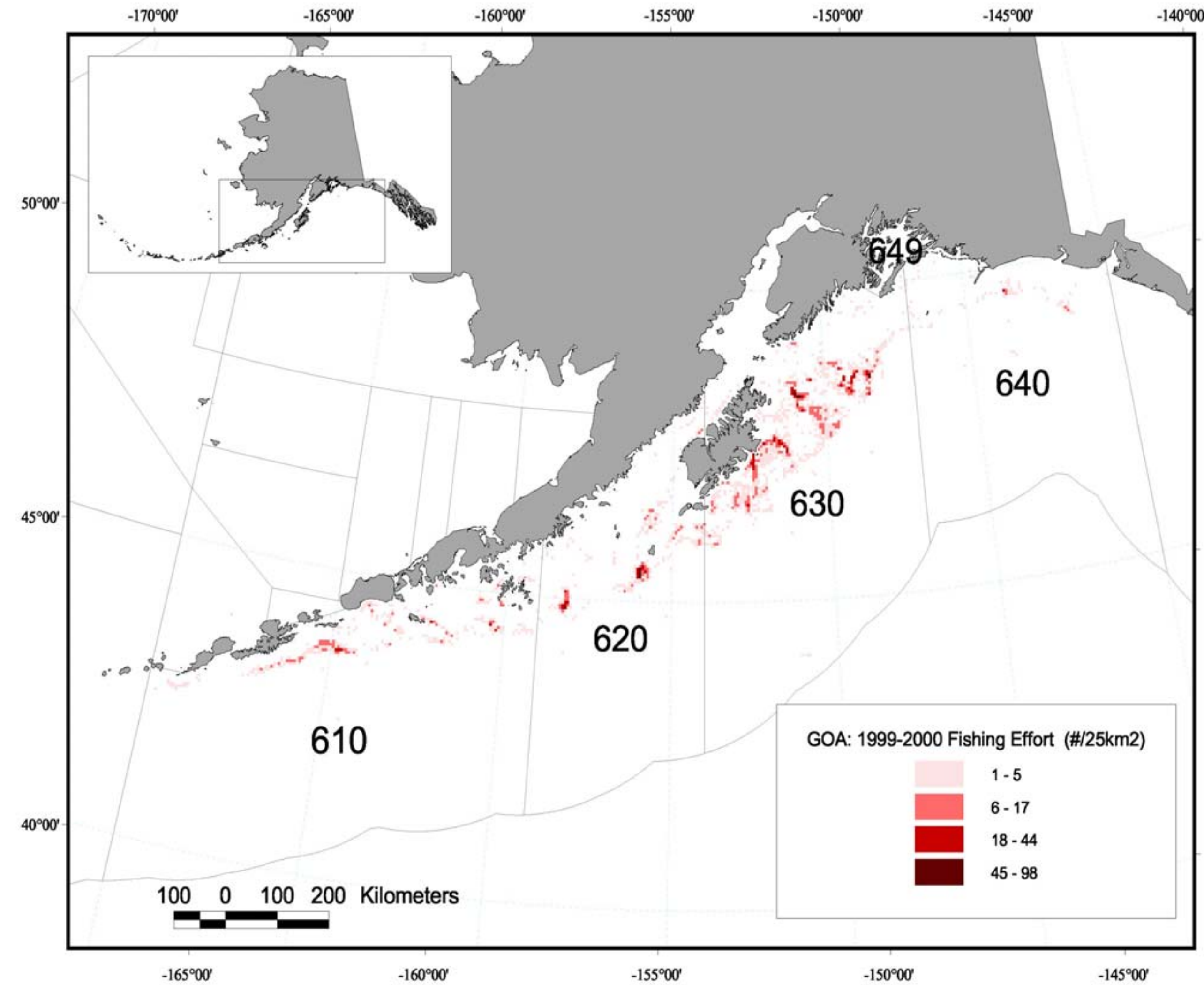

Figure 4. Spatial location and density of bottom trawl effort in the Gulf of Alaska, 1999-2000.

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.

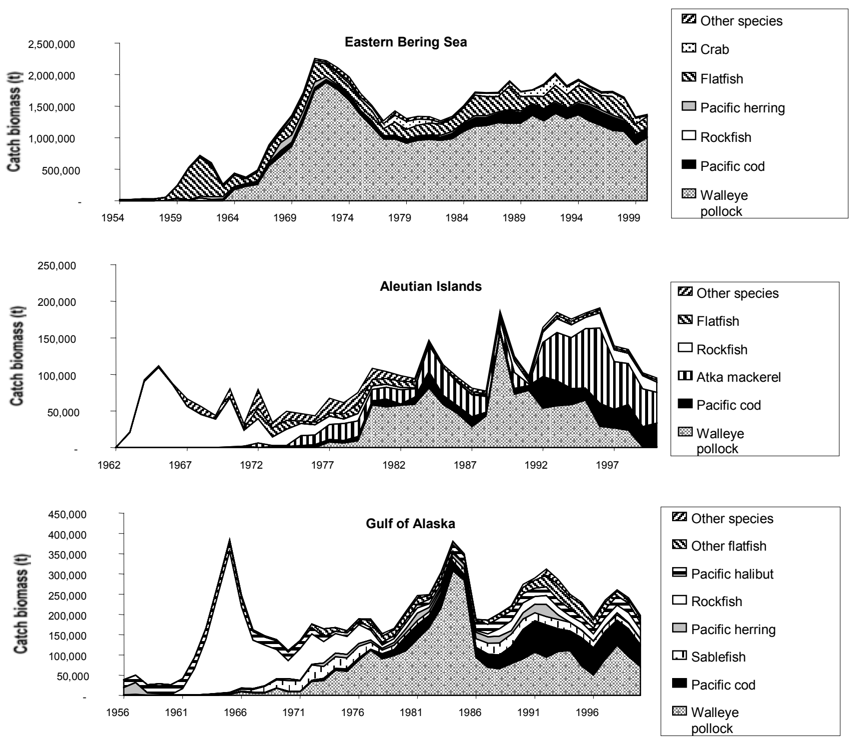

Figure 1. Total catch biomass (except salmon) in the EBS, GOA, and AI through 2000.

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.

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. 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

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

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.

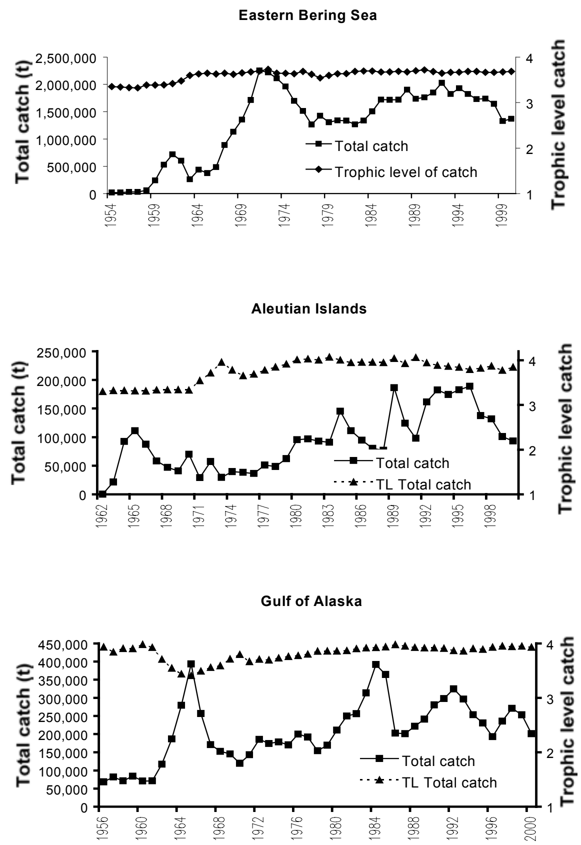

Figure 2. Total catch (groundfish, herring shellfish, and halibut) and trophic level of total catch in the EBS/AI and GOA through 2000.

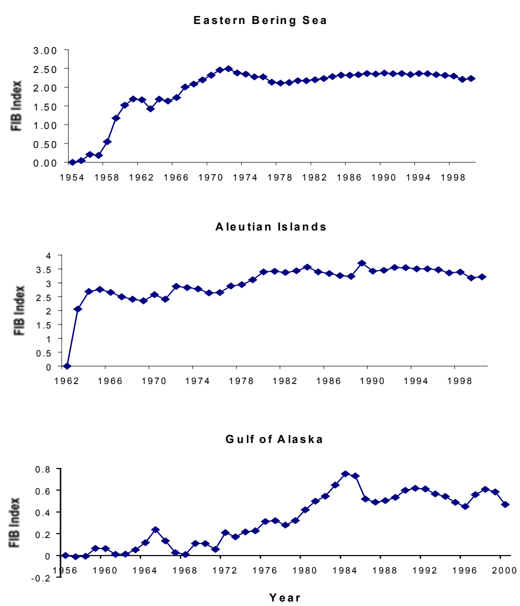

Figure 3. FIB index values for the EBS, AI, and GOA through 2000.

References

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 2000 from the January 2001 NMFS report to Congress available on the web at:
http://www.nmfs.noaa.gov/sfa/Status%20of%20Fisheries%202000.pdf. Although only two stocks are considered in the overfished category, 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. Most (85%) of the unknown status stocks comprise <1% of the landings. There are 43 stocks that are defined as major stocks for which overfished status is unknown.

Table 1. Status of groundfish and crab stocks managed under federal fishery management plans off Alaska, 2000.

Number of Stocks by Overfished Category

FMP	Overfished	Not Overfished	Unknown	Total
Groundfish	0	21	197	218
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

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 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 fisheries. Groundfish and crab management programs generally limit the number of vessels that are allowed to fish off Alaska. In addition, halibut and fixed gear sablefish are managed under an Individual Fishing Quota (IFQ) program, which does not limit the number of vessels, but instead, grants permission to Quota Share holders to harvest a specified percentage of the Total Allowable Catch (TAC) each year. Specific programs are reviewed below.

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 would, if and when implemented, tighten the LLP program and include additional restrictions on vessel numbers, and fishery crossovers; and limit participation in the BSAI Pacific cod fisheries. A statutory change to the MSA, for which regulations are under development, authorized a joint publicly- and industry-funded license buyback program for the crab fisheries and further gear and species endorsement restrictions for the groundfish 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) compared to the current vessel moratorium. The number of vessels predicted to be eligible for groundfish licenses (N = 2,435) is slightly greater than the number currently holding moratorium permits (while the LLP carried stricter qualification standards, many moratorium permits were never claimed). However, the LLP will be 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.

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 present, 21 catcher/processors and 112 catcher vessels qualify and are permitted under the AFA. Nine large capacity catcher/processors were retired from the fishery by the AFA. Under the fishery cooperative structure now in place, not all 21 eligible catcher/processors fished during the 1999 late winter and early spring pollock seasons. In 1999, five of the 21 catcher/processors authorized to fish under the AFA chose not to fish during the A/B season and six chose not to fish during the C/D season. This pattern continued in the 2000 fishery when 15 catcher/processors harvested pollock. Vessel size ranged from 201- 376 ft LOA.

The AFA authorizes seven catcher vessels to deliver to catcher/processors. These seven catcher vessels participated in the 1998 fishery and traditionally delivered the majority of their pollock to catcher/processors. Under the AFA, these seven catcher vessles were allocated 8.5 percent of the catcher/processor directed fishery offshore allocation. In 1999, these seven vessels formed a cooperative (High Seas Catchers' Cooperative, (HSCC)) and since that time, they have leased much of their TAC allocation for pollock to catcher/processors. 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 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.

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), and again decreased in the 2000 roe fishery (91 vessels).

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 1,500 in 2000 (Figure 1). Hook and line vessels accounted for about 1,200 and 1,100 of these vessels in 1993 and 2000, respectively. The number of vessels using trawl gear has tended to decrease, during this seven year period it decreased from 282 to 250 vessels. During the same period, the number of vessels using pot gear increased from 117 to 314.

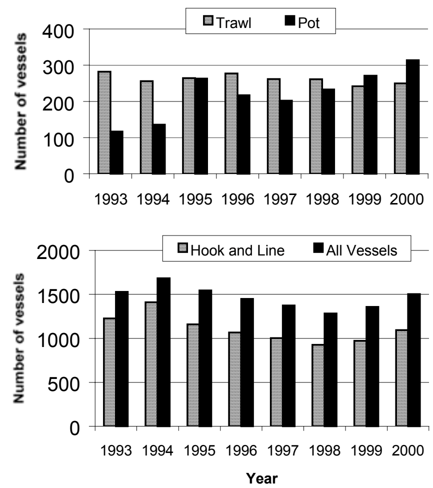

Figure 1.--Number of vessels participating in the groundfish fisheries in the EEZ off Alaska by gear type, 1993-2000.