NOAA Coastal Ocean Program

Fiscal Year 1998 Implementation Plan

for

SOUTHEAST BERING SEA CARRYING CAPACITY

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I. Introduction

A. Background

The Bering Sea ecosystem is among the most productive of high-latitude seas, with large biomasses of fishes, birds and mammals. This productivity is important to the U.S. economy. Fish and shellfish constitute almost 5% of the world and 40% of the U.S. fisheries harvest. Walleye pollock (*Theragra chalcogramma*), salmon, halibut, and crab generate over 2 billion dollars each year in fisheries revenue and provide a major source of protein. At present, some Bering Sea fisheries, such as pollock, appear not to be overexploited, although there have been major changes in abundance over the last thirty years. Populations of several species, such as king crab and Greenland turbot, however, are at near historical lows. The collapse of the New England cod fishery, perhaps due to over-exploitation, has called attention to potential human impacts on the Bering Sea.

The 1970s and the 1980s were marked by dramatic changes in abundance for many groups of upper-trophic level species. Populations of some piscivorous seabirds, such as murres and kittiwakes, underwent significant declines. Similarly, estimates of Steller sea lions and northern fur seals showed a declining trend, particularly in the 1980s. Biomass of adult pollock decreased during the 1970s, increased in the 1980s, and has approached a median value in the 1990s. These upper-trophic level predators all use juvenile pollock as a food source. We do not understand the fragility of the present state of the ecosystem. Pollock, however, plays a singularly important role, and its population historically has varied over a wide range.

The relative importance of natural cycles and exploitation in explaining variability in abundance is a key management issue for the Bering Sea. In addition to perturbations created by human activities, environmental factors are seldom stable and are subject to large scale fluctuations. For example, the production of new organic matter, which provides the basis for exploitable fish populations and all other higher trophic level animals, is greatly affected by environmental factors. Also, during summer 1997, there occurred anomalies in the physical environment that perturbed productivity on the Bering Sea shelf. These anomalies were accompanied by a never-before-reported bloom of coccolithophorid phytoplankton, massive die-offs of seabirds, and a commercial failure of the Bristol Bay salmon fishery. Research is needed to understand variation in new production and other elements of the ecosystem dynamics of the vast Bering Sea shelf that supports such high productivity.

Southeast Bering Sea Carrying Capacity (SEBSCC) supports studies of the Bering Sea ecosystem. SEBSCC's conceptual model proposes that juvenile pollock are a nodal species in the ecosystem in utilizing the high primary and secondary productivity and providing food for the pelagic upper trophic level species, including adult pollock. By nodal, we imply that a large fraction of the system energy flow passes through this species population. We focus on pollock in terms of their linkages to other species. We seek to understand interspecific overlaps in feeding habits through various stages of life history, including energy flow into and out of the pollock population. We want to identify synchronized increases or decreases in biomass at different trophic levels that may indicate the co-influence of factors. Project researchers will study change in distribution and intensity of secondary productivity as a basis for change in year-

class strength. The project will examine pollock as a key to the large scale changes in productivity of the Bering Sea over the last three decades. As an abundant resource, pollock provides an important measure of the health of the ecosystem.

Build Sustainable Fisheries is the first goal listed in the Strategic Plan of the National Oceanic and Atmospheric Administration (NOAA). SEBSCC meets the requirement of the Advance Fisheries Prediction element of the Strategic Plan: The Bering Sea is a major ecosystem and economic resource where there is a large year-to-year pollock recruitment and upper-trophic level variability which is not well understood. SEBSCC's management structure is a proven NOAA-academic-international partnership, effective in providing scientific leadership and subsequent transition to management. Information from SEBSCC will contribute toward the work of the North Pacific Fishery Management Council (NPFMC) and International Convention on Conservation and Management of Pollock Resources in the Central Bering Sea. Results will increase understanding of the response of the pollock population to changes in environmental conditions, and will allow evaluation of alternate management approaches taking into account such responses. Results from indicial models relating to short-term forecast of pollock recruitment will be incorporated into stock assessments used by the Alaska Fisheries Science Center (AFSC) to recommend allowable biological catch (ABC) estimates to the Council. Other research results involving factors influencing horizontal and vertical distribution of juvenile pollock to upper trophic level predators would assist Council decisions regarding restriction of fishing around marine mammal rookery areas. The NPFMC is attempting to move in the direction of ecosystem management, and information provided by SEBSCC will expedite this effort by improving knowledge of the role of pollock in the SE Bering Sea ecosystem. Focus on the response of the system, and in particular juvenile pollock, to changes in forcing will provide a context for management in a changing environment.

B. Goal

SEBSCC's goal is to increase understanding of the southeastern Bering Sea ecosystem, to document the role of juvenile pollock and factors that affect their survival, and to develop and test annual indices of pre-recruit (age-1) abundance.

C. Objectives

SEBSCC has scientific and programmatic objectives. Scientific objectives are to

1. investigate influences of climate variability on the Bering Sea ecosystem,
2. determine what limits population growth on the Bering Sea shelf,
3. identify effects of oceanographic conditions on biological distributions, and
4. understand environmental influences on primary and secondary production regimes.

Scientific pursuits use four approaches -- modeling, monitoring, process-oriented studies and, retrospective analysis -- to examine biophysical domains, juvenile pollock productivity, and relationships between them and the ecosystem of the southeastern Bering Sea. SEBSCC engages agencies, groups, and investigators with broad ecological interest in the southeast Bering Sea. This team for the research cycle lasting from 1996 through 1998 is investigating the ecology of juvenile pollock and sources and fate of nutrients in the southeastern Bering Sea. Following review by the Technical Advisory Committee in early 1998, SEBSCC will modify its objectives

as necessary and recruit a science team for the second research cycle. Scientific communication is achieved through monthly principal investigator meetings, Senior Investigators Council meetings, working group meetings, and the SEBSCC Home Page at http://www.pmel.noaa.gov/sebscc/.

Programmatic objectives are to insure that SEBSCC

1. supports a specific goal to provide critical knowledge needed for formulating policy and management of resources of the southeast Bering Sea ecosystem;
2. builds partnerships and encourages multidisciplinary cooperative efforts among research scientists within the academic community, NOAA, and other agencies interested in the SE Bering Sea; and
3. provides an open process in establishing research objectives and proposal selection to foster quality and diversity.

II. FY 1997 Annual Report

A. Progress

SEBSCC had four objectives for the fiscal year:

1. continue modeling, monitoring, and retrospective studies begun in FY 1996, and begin process studies,
2. coordinate field activities for 1997 and 1998,
3. conduct the first full year of field studies, and
4. assemble a research council.

These objectives were attained by the following approaches:

For modeling, SEBSCC implemented coupling of a regional circulation model with a 2-D global model; configured the Bering Sea IBM model with region-specific parameters, and completed a multispecies virtual population analysis of the eastern Bering Sea for input to a spatial model of upper-trophic level interactions. In continuing environmental monitoring, the project acquired and analyzed satellite images to compile an eddy census; processed 1996 monitoring data; surveyed juvenile pollock, pollock prey and sea birds; and began index identification. During FY 1997, continued retrospective studies investigated coring for deposited sediments from coastal embayments; compiled an inventory of and began sectioning seal teeth; developed a conceptual model of relationships between pollock recruitment and biophysical correlates; and located, collated, processed and analyzed atmospheric, cold pool and productivity data. This year saw the start of process-oriented components of SEBSCC. The project sampled and processed sinking organic matter, phytoplankton, and zooplankton; collected nutrient samples; identified a mesoscale eddy, then tracked and observed it with drifters and optical instruments; obtained, incubated, sampled, and preserved pollock eggs; analyzed historical distributions of juvenile pollock and associated zooplankton samples; parameterized a bioenergetics model of age-0 pollock; and developed and tested an algorithm to distinguish juvenile pollock from plankton in hydroacoustic data.

Coordination of field activities is critical so that SEBSCC can observe the ecosystem of the southeastern Bering Sea at crucial times during the year. In summer 1996, first-round project

researchers were queried for field requirements needed to support their research. A draft schedule for cruises during FY 1997 and 1998 was created from investigators' submissions and discussed at the first SEBSCC PI meeting on October 15, 1996, in Nanaimo, British Columbia. SEBSCC managers and meeting participants developed a strategy to address field activities. Field operations focus on deployment and recovery of instrumentation and in situ monitoring of physical and biological ocean conditions during the period of productivity from spring through early fall. SEBSCC uses about 100 to 120 sea days each year aboard two or more research ships, principally the NOAA Ship *Miller Freeman*, UNOLS Vessel *Wecoma*, and, cooperatively, the Japanese Fisheries Research Ship *Oshoro Maru*. The scenario for the first research cycle divides ship time into about 8 to 10 distinct cruises, from February through September. The first and last cruises are used to deploy and recover moorings, ice permitting, in regional habitats of the southeastern Bering Sea shelf. Early spring cruises determine seasonal aspects of ocean circulation and biology in anticipation of the spring bloom, and sample spawning pollock to obtain eggs for incubation studies on the effect of sea temperature and larval development. In late spring, the spring bloom is peaking and the seasonal ice pack has generally receded. Surface moorings are deployed in habitat areas and nutrient-phytoplankton-zooplankton sampling takes place there. Over the summer, additional monitoring tracks the temporal and spatial partitioning of the season's productivity. In late summer and early fall, field sampling focuses on the Pribilof Island habitat, an important region for juvenile pollock. Because juveniles are an important food item for upper level predators, sea bird and marine mammal observations are also made during Pribilof cruises. A final cruise in late September recovers moorings. Process studies are conducted on a piggy-back basis during appropriate times. In June 1998, a NOAA P-3 research aircraft will augment observations of primary productivity. At the time of this report, SEBSCC had not been able to secure ship support for the fall 1998 work at the Pribilof Islands and to recover moorings.

A significant accomplishment of 1997 was the execution of the first full-year field program. During cruises to the Bering Sea from February through September, SEBSCC not only monitored and sampled the environment in support of its projects, but also documented the environmental variability that led to a rare bloom of coccolithophorids on the shelf, a large die-off of migratory sea birds, and a commercial failure of the Bristol Bay salmon fishery. In FY 1997, project personnel participated in 12 cruises aboard three ships for a total of 152 sea days. Unfortunately, equipment from moored platforms and one platform itself was lost during the year and will jeopardize SEBSCC's ability to monitor the ecosystem effectively.

Fiscal year 1997 also saw the establishment of a Senior Research Council (SINCO). SINCO provides scientific leadership, integration, and communication among project principal investigators. The council has six members, one for each scientific approach (modeling, monitoring, lower- and upper-trophic level studies, retrospective analysis) and one member-at-large, who are responsible for maintaining contact within disciplines defined by scientific approach. SINCO meetings are held about every half year.

B. Scientific Accomplishments and Other Outcomes

SEBSCC's scientific program began its second year by continuing modeling, monitoring, and retrospective analysis and beginning process studies. Funded investigators and their projects are listed in Appendix 1. Scientific accomplishments are detailed by approach below.

Modeling

SEBSCC modelers expanded the original rigid-lid Bering Sea circulation model to include seasonal variability of the flows through passes at the edges of the model domain, and developed regional free-surface and global wind- and tidal-driven models. Development of the global Spectral Element Ocean Model (SEOM) and regional S-Coordinate Rutgers University Model (SCRUM) has focused on four areas: 1) appropriate grids for SEOM and SCRUM; 2) wind-driven runs of SEOM in two-layer mode, and further development of a three-dimensional version of the model; 3) tidal simulations of the Bering Sea using SCRUM; and 4) implementation of coupling between SEOM and SCRUM.

Much of the structure of SEBSCC's individual-based model (IBM) is the same as the IBM configured for Gulf of Alaska pollock. Progress has been made in extending the model, in adapting parts of the model to the Bering Sea, and in collecting parameters specific to the region. The juvenile stage module has been revised and extended based on recent information on this stage from the Bering Sea. A major extension to the IBM has been the addition of a mortality component. Parameters specific to the Bering Sea which are being incorporated into the IBM include: 1) spawning times, locations and depths, 2) low-temperature egg development rates, 3) low-temperature larval metabolic rates and Q10, 4) depth distributions of different life stages, 5) bioenergetics and consumption parameters for the juvenile stage, 6) an algorithm to predict the hours of feeding of juveniles, and 7) an algorithm to predict the depth of juveniles.

The goal of upper trophic level modeling is to develop a forward projection model of predators on juvenile pollock. Multispecies virtual population analysis (MSVPA), a retrospective method, is a useful step for obtaining more realistic estimates of numbers-at-age and natural mortality for juvenile fish, particularly pollock. Juvenile pollock abundance in the forward projection model will be derived, at least initially, from MSVPA outputs. SEBSCC completed parameterizing the MSVPA model for the eastern Bering Sea. The MSVPA model includes the following species as predators: pollock, Pacific cod, Greenland turbot, yellowfin sole, arrowtooth flounder, and northern fur seal. Prey species are pollock, Pacific cod, Greenland turbot, yellowfin sole, rock sole, and Pacific herring. The modeled time period is 1979 to 1995, and results show that most predation mortality for the prey species in the model occurs on juveniles that have not yet recruited to the fishery. Model estimates of population abundance for exploited ages of each prey species are similar to those provided by single species models. However, abundance estimates of juveniles, particularly pollock, are substantially larger than estimates from single-species models. Pollock was the main prey species consumed by MSVPA predators, and cannibalism constituted the majority of the predation mortality of age-0 fish. The dominant predators on age-1 pollock included adult pollock, Pacific cod, arrowtooth flounder, and northern fur seals. In some years, Pacific cod consumed the largest biomass of pollock prey relative to other predators. However, most of the biomass of pollock consumed by cod tended to be from older pollock.

Monitoring

A one-year component used existing satellite altimeter measurements of sea surface height (SSH) in the Bering Sea to catalog the distribution and variability of mesoscale eddy-like features in the space-time domain. Maps of SSH variability in the Bering Sea indicate that eddy-like activity along the shelf break region of the basin is greater than that which occurs in the basin. The region of principal interest is the shelf break region in the central Bering Sea, a region of high primary productivity along which flows the Bering Slope Current (BSC). Altimeter data sets reveal mesoscale features near the shelf break region that propagate both along the shelf break and away from the shelf break. The features that are observed to propagate along the shelf break are interpreted to be topographic planetary waves, whereas the mesoscale features that are observed to propagate into the central Aleutian Basin are interpreted to be baroclinic planetary waves. The topographic planetary waves have a representative wavelength of about 100 km and period of about 2 months. These waves are most developed in the spring and early summer months. The baroclinic planetary waves are characterized by wavelengths of hundreds of kilometers and periods of hundreds of days. There is evidence for dispersion of these latter waves as representative wavelengths and periods increase as the waves propagate away from the shelf break. Very little eddy activity, coherent with that occurring seaward of the shelf break, is observed on the continental shelf. The occurrence of short wavelength (tens of kilometers) phenomena in the basin during the autumn and early winter months suggest that stratification of the upper waters in the Bering Sea is strongest at this time.

Progress was made on monitoring biophysical features of the ecosystem and developing indices of survival-potential of young pollock using the observations. Biophysical monitoring of the shelf and slope region was conducted during winter, summer, and fall comprising: 1) hydrography from stations in the vicinity of Unimak Pass and from stations which span the Aleutian North Slope Current (ANSC) and BSC; 2) hydrography across the shelf and along the 80-m isobath, and nutrient chemistry and plankton biomass at clusters of stations along those transects; and 3) hydrography, nutrient chemistry and plankton biomass along four transects radiating from the Pribilof Islands. Observations of water properties and nutrients from the vicinity of Unimak Pass provided the basis for characterization of flow onto the southeastern shelf from both the Alaska Coastal Current via the pass itself and from the slope water flowing along the north side of the Aleutian Island chain. Given the limited definition in both time and space provided by the monitoring scheme, it appears that the flow of slope water onto the shelf via Bering Canyon provides a more consistent source of nutrients than does the flow through Unimak Pass. Observations of temperature and salinity versus depth were collected six times from the slope/shelf CTD transect. Preliminary analysis of these data revealed that in spring 1997, transport in both the ANSC and the BSC was unusually large. Sections from both currents showed transports greater than 6×10^6 m^3 s^{-1} whereas transport is typically 2-4 $\times 10^6$ m^3 s^{-1}. Moored current records from the ANSC revealed a strong consistent flow, supporting the inference that flow in the ANSC was steady this year. Whether the enhanced strength of these currents affects shelf/slope exchange is not known; however, it is vital for understanding the shelf ecosystem. For the first time, time series of water properties, current and acoustic backscatter were obtained during the fall evolution from two layers to mixed conditions over the middle shelf. Preliminary analysis reveals that well-mixed conditions did not occur until late in November 1996. Because there are no other observations of this phenomenon, we cannot say how representative the timing is. The transition from two layers to mixed may be a factor in

replenishment of nutrients. The climatological, baroclinic flow eastward across the shelf from the vicinity of the Pribilof Islands likely does not exist when the water column is mixed. The later into the fall that this feature can transport nutrients, the greater the supply for the following spring. The global atmospheric phenomenon that resulted in an El Niño at the equator also caused marked changes in the southeastern Bering Sea. Vast numbers of marine birds died this summer and salmon returns were far below expected. As with the El Niño, departures from the typical climatology were not marked during winter, but became greatly different by early summer. Sea ice conditions exhibited average coverage, latitudinal extent and time of melt-back. Satellite remote sensing provides the following sequence of sea surface temperature conditions over much of the southeastern Bering sea shelf: in early May temperatures were slightly below normal (~0.0 to -1.0°C), by mid-June the anomaly was strongly positive (2.0-2.5°C above normal) and persisted through August, decreasing to < 1.0°C by mid-September. These changes resulted from local heat exchange with the atmosphere rather than advection of water from the Pacific Ocean. Two factors contributed to an unusually strong and widespread stratification of the middle and inner shelf regions. Cloud cover was less than usual, with the resulting strong insolation adding to sea surface warming, and the shelf was characterized by extremely calm wind conditions during the spring and summer. This resulted in an early phytoplankton bloom, depletion of nitrogenous nutrients and subsequent settling of the bloom in early May. During the summer, a large portion of the shelf water had high reflectance as a result of a coccolithophorid bloom (high light extinction, but low levels of chlorophyll or particulate organic carbon). SEBSCC may also have observed a shift in the zooplankton community relative to other years, with a decrease in copepods and an increase in pteropods. The temporal and spatial extent of the bloom is being examined using *in situ* and satellite-image data. Further examination of our plankton and juvenile fish samples will reveal if and how this anomalous bloom affected the food web and the diets and condition of juvenile pollock. The opaque waters may also have affected foraging of the resident seabirds and been partly responsible for high mortality of adult birds observed this summer. In 1997, the numbers of foraging seabirds recorded south of St. George Island appeared reduced compared with records from the 1980s. This may have reflected a shift in foraging grounds. Preliminary inspection of data from the 1980s suggested that the numbers and foraging activity of piscivorous seabirds changed between years in which reproductive success of birds on St. George differed. In 1987, a year in which seabirds had low reproductive success, considerable numbers of birds foraged to the southwest of St. George Island. In contrast, in 1988, a year in which reproductive success was high, more birds were observed foraging, and more birds foraged to the southeast of St. George Island, over the head of the Pribilof Canyon. The reduction in the numbers of birds south of the Pribilof Islands in 1997 may indicate a shift in the local availability of forage fish. Results from the collaborating National Science Foundation (NSF) study of the Inner Front near Nunivak Island revealed that the front there was not as well developed as previously reported. The water in the coastal domain was more stratified than typical because unusually weak winds were not able to mix the water column. This may have effectively shut-down inner front dynamics which normally supply nutrients to the upper layer. The extent of nutrient depletion north of St. Paul, south of St. George Island and across the outer shelf between the Pribilof Islands and Unimak Pass was noticeable. Likewise, preliminary estimates of biomass of chlorophyll were lower than expected. Equipment from moored platforms and one platform itself was lost during 1996/97. This is the first large loss since we began our Bering Sea research programs funded by the Coastal Ocean Program starting in 1991. In 1997, due to equipment failures, we were unable to accomplish our

planned deployment of acoustic Doppler current profilers at sites south of the Pribilofs. These data were to have supplied a continuous time-series of currents and zooplankton backscatter, a proxy for zooplankton biomass.

Lower trophic level processes

Isotopic and biomarker composition of sinking organic matter is used to indicate food web structure. The temporal variation of the quantity and composition of sinking particles depends on interactions among weather, climate, and geographic location over the shelf. Moored sediment traps are being used to examine temporal variability, on time scales of weeks to years, in the source and quantity of sinking particles. A swimmer (zooplankton)-excluding trap designed to minimize trapping efficiency artifacts was chosen for this study. The sediment trap samples will be analyzed for carbon and nitrogen stable isotope composition. The stable isotope composition of sinking particles is expected to reflect the rate of photosynthesis, extent of nutrient depletion, and the trophic level of animals supplying particulate matter to the trap. The sediment trap samples will also be analyzed for wax esters, triacylglycerols, and sterols: lipid biomarkers which allow identification of plant and animal sources of trapped material. Stable isotope and lipid composition of zooplankton and phytoplankton samples collected near the mooring sites are being determined to facilitate source identification. Two traps were deployed in late April 1997, at sites M2 (56° 53' N, 164° 02' W) and M3 (56° 04' N, 166° 20' W), and recovered in late September 1997. The M3 trap was significantly damaged during the bad-weather recovery. That trap contained no usable samples, apparently because of a motor failure. Eleven samples, collected at intervals of 1 or 2 weeks, were recovered from the M2 trap. A third sediment trap, funded through a cooperating Arctic Research Initiative (ARI) project, was deployed at site M2 in late September 1997; this trap will collect samples at biweekly to monthly intervals during the winter and early spring. Phytoplankton and zooplankton samples were collected at five stations near each of the sites M2, M3, and M4 (57° 52' N, 169° 12' W) during June 1997, and subsamples of single zooplankton species were sorted from these samples. Zooplankton samples were also collected near the mooring sites during September 1996 and April 1997. Bad weather prevented sampling during September 1997. The analysis of plankton samples for stable isotope and lipid composition is in progress.

Another lower trophic level approach was to use measurements of near-surface optical properties to determine and compare the mean concentrations and temporal variability of surface chlorophyll within and outside at least one mesoscale eddy. This variability was to be related to the relevant physics associated with the eddy. During operations in the Bering Sea, 11 - 26 June 1997, SEBSCC collected the necessary measurements of biological and optical properties of surface waters. In early May 1997, an eddy was identified using altimeter data, and on May 13 a satellite-tracked drifter was deployed within the eddy. This drifter along with the altimeter data was then used to trace the eddy until June 10, when the process study began. The study was divided into two parts: the first lasted from June 10-15. During this time we deployed four satellite-tracked drifters (two within the eddy, one at the edge and one outside the eddy). Each drifter measured and telemetered its position, ocean temperature and color. In addition we conducted CTD and nutrient casts to 1500 m and made optical measurements inside and outside the eddy. After completion of other research on the shelf, we returned to the eddy on June 23 and made observations for another three days. We deployed another color drifter in the eddy and one to the south along the Alaskan Peninsula. This was a large (~100 km diameter) eddy that

originated from an instability in the BSC. Transport within the eddy was ~$6x10^6$ m^3 s^{-1}, approximately the same transport that was observed in the BSC during the spring. The eddy was asymmetric with highest speeds observed near the shelf break. Maximum rotational velocities within the eddy exceeded 40 cm s^{-1}. While the eddy weakened during the end of summer, the three drifters deployed within the eddy were still there as of September 20, 1997. The eddy moved slowly (~1 cm s^{-1}) to the southwest between June and September. During the first four days at the eddy, its baroclinic structure extended to >1500 m, but when we returned on June 23, there was little organized structure below 1000 m. This was likely a result of the eddy brushing against the shelf break. Measured solar radiation in seven wavebands between 411 and 700 nanometers (nm), including the wavebands corresponding to the SeaWiFS sensor, was converted to records of photosynthetically available radiation, useful for biological models. A tethered radiometer buoy was used to measure upwelling radiance and downwelling solar irradiance in 13 wavebands between 323 and 700 nm. We have results for 80 5-min intervals during which surface chlorophyll was measured and samples were taken for measurement of spectral absorption by particulates and dissolved organic matter (DOM). The data are appropriate for developing algorithms for estimating chlorophyll and DOM from ocean color as measured by drifters, moorings, aircraft, and, if the sky is clear, satellites. Solar-stimulated chlorophyll fluorescence at 683 nm was measured by the radiometer, and algorithms will be developed. Reflectance spectra from the cruise show clearly the biologically-determined optical variability associated with the eddy. We see blue water to the west of the eddy, high-chlorophyll waters near the edges, and lower-chlorophyll water near the middle.

Another objective of lower-trophic studies is to determine the sources and distribution of nutrients in the southeast Bering Sea with respect to physical processes and to determine the utilization and regeneration of nutrients with respect to primary production and recycling biological processes. This year nutrient samples for nitrate, nitrite, ammonium, phosphate and silicate were collected during SEBSCC cruises in collaboration with physical and biological sampling. Most nutrient samples were analyzed fresh onboard ship so that analysis results could be used to guide the sampling depths in transects and time series stations. Some nutrient samples collected at the beginning and end of the cruise period during mooring deployment and retrieval were frozen due to funding limitations. Additional analyses for urea and DON were performed on all nutrients from productivity casts. Phytoplankton pigments samples were also collected to obtain profiles of phytoplankton biomass and to calibrate fluorescence sensors on the CTD and underway surface fluorometer. Multiple samplings of transects and time series stations allow estimates of advective and diffusive inputs of nutrients to the shelf areas and an estimate of phytoplankton nutrient uptake in collaboration with isotope uptake studies. Additional nutrient samples were also analyzed in collaboration with collaborating deep Bering Sea and inner shelf studies in order to provide a better estimate of the interactions with these areas on the SEBSCC boundaries. The distributions of nutrients observed indicated that enrichment processes were smaller than previously observed with a probable cause of weaker advective transport and/or stronger stratification. Major biological productivity uptake of nutrients occurred before the May cruise so that nutrient depletion of the water column on the outer shelf and middle was significant. The depletion of nutrients below the pycnocline that occurred later in the summer was interpreted as uptake by deep phytoplankton productivity and nutrients were not replenished by typical physical processes.

Upper trophic level processes

Pollock eggs were obtained northwest of Unimak Island near the 100 m shelf contour on April 1, 1997. Fertilized eggs were incubated at -1, 0, 2, and 4°C, the last temperature having both a dark and diel treatment (14 hr light/10 hr dark). Egg mortality was high for the first two weeks which may have been the result of immaturity of the adult pollock; however, mortality dropped to negligible levels, leaving enough eggs to allow sampling during the incubation period and to adequately document 50% hatch in all treatments except those incubated at -1°C. Development of embryos was normal for all temperatures except -1°C. At that lowest temperature, gross abnormalities included malformation of the tail and the absence of eyes. The pattern of hatch was similar for all eggs incubated under constant dark conditions: 50% hatch of eggs occurred approximately midway through the period of time required for all eggs to hatch. However, hatching of eggs incubated under diel light was delayed; 50% hatch occurred after 90% of the hatching period had elapsed.

For later life stage pollock studies using midwater trawl observations from September 1994 and 1995, SEBSCC examined abundance, distribution, and size composition of age-0 pollock in relation to the physical oceanography and biology of the structural front along a transect north of St. Paul Island. The frontal region occurred 12-20 km offshore during both years, but the thermocline was much shallower in 1995 (25 m) than in 1994 (45 m). The isothermal (<8°C) inner domain had low chlorophyll, and relatively low, small (>153 μm) and large (>505 μm) zooplankton concentrations. The highest chlorophyll and small zooplankton concentrations occurred at the front and were lower both inshore and farther offshore of the front. Large zooplankton (mainly euphausiids and cnidarians) were most abundant in the stratified offshore waters. By number, age-0 pollock dominated the catches of midwater trawls (>99% and >95% in 1994 and 1995, respectively). Overall, however, large medusae dominated the total biomass. Age-0 pollock densities were the highest at the front or inshore of the front. Age-0 pollock densities averaged about three times higher in 1994 than in 1995. Age-0 pollock were significantly smaller in 1994 inshore and at the front (mean = 43.4 and 44.6 mm, respectively) than in 1995 (52.2 and 51.7 mm). Dietary composition, feeding intensity, and condition index of age-0 pollock were examined for variations related to time of day, location, size of predator, and year. Stomach contents of pollock collected at a hydrographic front near the Pribilof Islands during September 1994 through 1996 were compared with those from pollock collected on either side of the front. Diets were dominated in all regions by small zooplankton, mainly copepods, pteropods, euphausiids, and chaetognaths, but fish and some epibenthic crustaceans were also consumed. Copepods and pteropods dominated the diet in all years and areas by number but the diet was more mixed by weight with chaetognaths, euphausiids, and fish (smaller pollock) also being important. Copepods were more abundant in the diet during the day. No significant day/night differences in weight composition were noted. Stomach fullness was highly variable by year and habitat and no significant differences were observed. Stomach fullness peaked at around sunset for fish <50 mm and at night for the larger fish, implying that feeding chronology changed with ontogeny. Age-0 pollock condition factor (Fulton's K) varied from 0.45 to 1.20 (mean = 0.767 ± 0.09 (SD)). Year was not found to be an important factor in determining condition although the location with respect to the front was important.

SEBSCC's final upper trophic level process study developed and evaluated a method for distinguishing fish from plankton using multi-frequency acoustic data (38, 120 and 200 kHz). This has never been done before in a rigorous, quantitative fashion. Data (including acoustic,

CTD, bird observations, surface temperature, salinity and fluorescence) are being processed and combined for three years of Bering Sea surveys. Those data will be examined and tested for relationships between survey variables using nonparametric regression and other spatial statistical methods. Image processing methods have been successfully used to identify fish schools and shoals (looser aggregations or layers) from 38 kHz acoustic backscatter images. The fish shoals have relatively high backscatter and consist, in the backscatter images, of contiguous pixels of elevated backscatter. Plankton are characterized by lower backscatter than fish, generally larger patches than fish schools, and increased backscatter strength with higher frequency (especially between 120 and 200 kHz). Generally, plankton are not visible at 38 kHz in the data. Once the fish shoals or plankton patches have been identified in the images, a connected component algorithm produces location information of the centroid of each patch, backscatter information (maximum, minimum and average dB, total energy and variance in backscatter energy) and size information (width and length, location of points along the boundary, area, and perimeter). The school and patch data are subjected to further visualization and statistical analysis to convert location in the image of each patch to latitude and longitude, to compute bottom depth under each patch centroid, and to determine the time of each patch encounter (by interpolation from the starting and ending time of each image). Environmental information, such as the temperature of the patch center is estimated by interpolation of CTD data onto each patch location. Finally, distance to each school (patch) from the start of the transect is computed by converting latitude and longitude distance from the start of the transect to a meter distance. This allows us to standardize the plankton and fish data, which are based on acoustic images collected by different vessels (though one closely followed the other, they were not in the same place at the same time). The ability to do this emphasizes the importance of georeferencing to future data collection by vessels operating in coordination. In order to be able to examine both the acoustic data by transect and the supporting data, as well as to allow development and evaluation of methods interactively, we developed an acoustic data viewer. The viewer 1) provides user flexibility in choice of what to view and how to view it; 2) allows overlaying of data and observations; 3) permits exploration and observation of relationships between variables; 4) enables description and testing of algorithms; and 5) can compare data sets at different frequencies or different years. From preliminary results we suspect that much of the observed backscatter may be due to small plankton (copepods 3-4 mm in length), which were found in very high densities in many of the plankton tows. We suspect that jellyfish may, because of buoyancy regulation, aggregate at density discontinuities, and occur in distinct thin horizontal layers that may be visible in the echograms. Both visual perusal of the data and results from morphological identification of fish shoals (layers) and plankton patches indicate that the area covered by both layers and plankton can be substantial.

Retrospective studies

The SEBSCC component that determines natural scales of variability from analysis of bottom cores considered drilling in two sites bordering the southeastern Bering Sea. The first was at Herendeen Bay, near Port Moller on the Alaskan Peninsula; the second was at Skan Bay, Unalaska Island in the Aleutians. Preliminary gravity cores collected from Herendeen Bay indicated that it is not a good site for sampling. Although there is clearly an anoxic basin in the bay, there was little evidence of preserved fish scales in the samples. Cruise scheduling did not

permit drilling in Skan Bay during 1997. However, an existing, unanalyzed bottom core from Skan Bay has been located at the University of Alaska and will be examined in 1998.

Changing physical characteristics of apex predators may provide a proxy for long-term forage fish abundance and distribution. Female northern fur seals make several day-long foraging trips from their breeding islands, periodically returning to nurse their pups. Variability in the duration and total number of trips females complete before weaning their pups likely reflects changes in prey availability in the Bering Sea during July-November. When prey is abundant, females presumably make shorter trips and therefore more total trips before weaning. The number of foraging trips made by female northern fur seals while rearing their pups can be estimated by counting growth lines in their offspring's teeth. The goal of this project is to reconstruct a long-term time series on the mean number of trips made by female fur seals by examining teeth collected since the late 1940's on St. Paul Island. This data set would then serve as an index of prey availability to fur seals over several decades. Our first step is to establish whether there is a link between abundance of the current primary prey of fur seals in the Bering Sea, juvenile pollock, and the number of foraging trips recorded in teeth. We began by limiting our analysis to years when juvenile pollock abundance was estimated using both bottom trawl and hydroacoustic surveys. These surveys have been conducted triennially beginning in 1979. Teeth from northern fur seals were available for four of these years, and a sample from each year is currently being analyzed. Thirty teeth are being analyzed from each year excepting 1982 when 20 teeth from 2-year-olds and 20 from 3-year-olds will be analyzed to determine whether age at death of the sampled fur seals influences the estimated mean number of nursing lines. The teeth are sectioned and the number of lines estimated independently by two researchers. Sections of poor quality in which nursing lines cannot be counted are replaced until required sample sizes are achieved. Currently, all the teeth have been sectioned and read. We are now beginning the process of analyzing the nursing line data along with estimates of juvenile pollock abundance.

In investigating relationships between pollock recruitment and the environment, a working conceptual model of pollock survival was adapted from a similar model developed for Gulf of Alaska pollock. The model can be termed a switch or survival gauntlet model in that it represents successive conditions or switches that must be realized for fish to survive. Each switch has a conditional probability of being set for survival or mortality. The probability is subject to spatial and temporal variability. For example, a "hatch switch" could be dependent on water temperature that varies in space and time. Switches can act on individuals, cohorts, or populations. This model has a type of dynamic termed supply-dependent, multiple-life-stage control. In the working conceptual model, most mortality takes place in the juvenile life stage, although mortality during the larval life stage could be important in some years. Two factors have been suggested as important mechanisms in regulating pollock year-class strength. These are predation, primarily cannibalism of juvenile pollock by adult pollock, and environmental factors. Predation on pollock is greatest in the first and second year of life. It has been suggested that the intensity of cannibalism is primarily a function of the degree of spatial separation of adults and juveniles. Environmental factors enter the model through their impact on spatial separation. Wind drift influences the distribution of animals prior to the juvenile life stage. The strength of vertical stratification of the water column during the juvenile life stage is also important. SEBSCC's hypothesis is that strong year classes result when planktonic stages are transported shoreward and away from adults by near surface currents in spring (warm years). In cold years, winds reduce the effect of this mechanism, and juvenile utilization of inshore

regions is more limited. This results in similar distribution patterns of adults and juveniles, potential for more cannibalism, hence a weak year class. Even when adult and juvenile life stages coincide, stratification of the water column can effectively separate adults from juveniles. This "switch" works in opposition to the wind-drift switch. Wind mixing (turbulence) can influence year-class strength by affecting the ability of first feeding larvae to feed successfully. Its influence is mainly restricted to yolk sac larvae and first feeding life stages. Climatic factors, such as atmospheric circulation dynamics that determine frequency and trajectory of storms, wind direction and intensity, ice extent and water temperature, can affect all life stages of pollock. The spawner-recruit relationship for eastern Bering Sea pollock reflects a moderate density dependence between the spawning stocks and recruitment, with reduced survival of recruits at high levels of adult abundance. Cannibalism is presumed to be the mechanism underlying density dependence. Outliers in the spawner-recruit relationship are associated with warm years. Warm years are characterized by strong shoreward wind drift, subsequent high spatial separation of adults and juveniles, low rates of cannibalism, and good recruitment. In these years, density-dependent (cannibalism) mechanisms are not in effect. Spawner-recruit data that fit established relationships are associated with cold years. Cold years are characterized by weak shoreward wind drift and subsequent low spatial separation between adults and juveniles, high rates of cannibalism, and poor to average recruitment. In cold years, the cold pool temperature tends to alter distributions of both adult and juveniles tending to enhance coincidence. Thus, in cold years, density-dependent (cannibalism) mechanisms are important. There is also a correlation with temperature that may result from variation in the intensity of the Aleutian Low at a one year lag, which suggests that environmental effects are exerted, not in the first few months of life, but rather at later juvenile stages. Other biophysical processes important to pollock recruitment (i.e., ice and spring bloom dynamics) are under examination but not yet included in the conceptual model.

To address the hypothesis that the cold pool affects distribution of walleye pollock, 5571 stations spanning the years 1966-1996 were assembled. Time series of 25-50 years length were located, collected, collated, and processed through 1995, including: wind data, air temperature, sea-surface temperature, weekly percent ice cover, seasonal sea ice index, temperature and salinity profiles of the Bering Sea shelf, primary productivity data, sea-level pressure, Southern Oscillation Index, atmospheric forcing data, Sitka air temperature, and distribution data for arrowtooth flounder, yellowfin sole, Pacific cod, and pollock (age-1, age-2, age-3 and older). SEBSCC found that in the late 1970s there was a regime shift, or step, in the climate of the north Pacific causing, among many other things, a 5% reduction in ice cover in the eastern Bering Sea. Analyses of monthly mean northern hemisphere sea level pressure for winters (December through March) for 1947-96 were compared with monthly mean ice cover for 1952-96, as well as with the Southern Oscillation Index (SOI). Before the regime shift, below normal ice cover was typically associated with El Niño conditions which caused the Aleutian low to move eastward of normal, driving warm Pacific air over the Bering Sea. Conversely, above normal ice cover was associated with La Niña conditions which are accompanied by the Aleutian low moving westward of normal allowing higher pressure and colder conditions to move over the region. However, since the regime shift, this correlation of ice with both the Aleutian low movement and with the SOI has reversed. Before the regime shift, the occurrence of El Niño and La Niña conditions was about even. Since the regime shift, El Niño conditions are about three times more prevalent.

C. Applications from Funded Projects

Publications

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Brodeur, R., 1997: FOCI ecosystem-related juvenile pollock studies. PFMC Ecosystem Workshop, Seattle, January.

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Brodeur, R., 1996: Habitat differences in frontal regions around the Pribilof Islands and their importance to juvenile pollock survival. FOCI Seminar, NOAA, Seattle, WA, October 31.

Brodeur, R., 1996: In situ observations of the association between juvenile fishes and scyphomedusae in the Bering Sea. International Symposium on the Role of Forage Fishes in Marine Ecosystems, Anchorage, AK, November.

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Worldwide Web Presentations:

SEBSCC has published information on the World Wide Web that is located at address http://www.pmel.noaa/sebscc/. Research updates, notices of meetings, a publication list, personnel rosters, and addresses of related web sites are included in SEBSCC's offering.

Besides programmatic news, SEBSCC has underwritten development of a Bering Sea and North Pacific Ocean Theme Page at http://www.pmel.noaa.gov/bering/. This theme page serves as a common source for research activities pertaining to the Bering Sea and North Pacific Ocean. It supports multiple program interests based on the physical, chemical, biological and fisheries oceanography of this unique geographic area. This resource is intended to serve as a reference point for the numerous programs and investigators working in this area.

Also under development for SEBSCC and other researchers is a Bering Sea Biophysical Metadatabase (http://www.pmel.noaa.gov/bering/mdb/) that will be an on-line tool to locate data holdings that pertain to SEBSCC's interests.

Collaborations:

SEBSCC is a unique administrative partnership between a state university and two federal agencies. These partners are the University of Alaska Fairbanks, the AFSC of the National Marine Fisheries Service (NMFS), and the Pacific Marine Environmental Laboratory (PMEL) of

the Office of Oceanic and Atmospheric Research (OAR). SEBSCC's research team blends the talents of scientists from five universities -- University of Alaska Fairbanks, University of California Irvine, University of Washington, Rutgers University, University of Texas at Austin -- and two federal agencies (NMFS, OAR).

National collaboration is attained through cooperative research with other NOAA Bering Sea programs -- NMFS Bering Sea stock assessment, Fisheries-Oceanography Coordinated Investigations (FOCI), and Arctic Research Initiative (ARI) -- and with the NSF's Inner Front Study. International collaboration with Japanese and Korean scientists established under NOAA Coastal Ocean Program's Bering Sea FOCI are continuing with SEBSCC. Planning meetings with Japanese scientists were held during October 1996. Project scientists took part in a research cruise aboard the Japanese fishery research vessel *Oshoro Maru* from July 18 to August 2. Accomplishments included a pollock survey of the eastern Bering Sea shelf and St. Lawrence shelf using CTD, bottom trawl, NORPAC net, larval net, and juvenile beam trawl.

III. FY 1998 Implementation Plan

A. Background

SEBSCC's goal is to study the southeastern Bering Sea ecosystem and the role of juvenile pollock in it, including the factors that affect their survival. A product to be developed and tested from this study is a set of annual indices of pre-recruit (age-1) abundance. The time scale for attaining these results is five years.

In its first year (FY 1996), SEBSCC defined its scientific goals, assembled a project management team and a technical advisory committee, recruited a research staff for 1996-1998, and began retrospective, modeling, and monitoring efforts. In its second year, SEBSCC continued the modeling, monitoring and retrospective research begun in year one, and added ecological research components that use the fourth approach: process-oriented studies. FY 1997 brought the first complete realization of SEBSCC's annual field program. During the year, a Senior Investigators Council (SINCO) was added to the administrative/scientific team. SINCO will provide a forum for exchange of information on the multidisciplinary aspects of the Bering Sea. Continuity of the council will foster extensive cross-disciplinary cooperation and help coordinate SEBSCC's role in the Bering Sea with other projects supported through ARI, NSF, PICES, GLOBEC, Bering Sea Impacts Study (BESIS) and Bering Sea Ecosystem Study.

B. Objectives for FY 1998

The project has four objectives for the coming year:

1. Complete modeling, monitoring, and retrospective studies begun in FY 1996 and process studies begun in FY 1997.
2. Prepare for the second research cycle (1999-2001).
3. Begin synthesis of ecosystem dynamics.
4. Progress in determining index of pre-recruit pollock abundance.

C. Approach

SEBSCC proposes the following approaches to meet this coming year's objectives. These approaches also serve as milestones for the project. The target deliverable dates are at the end of the fiscal year's quarter shown in parentheses.

- Conduct a workshop of SEBSCC principal investigators to review status of the program and discuss gaps in knowledge that can be addressed by SEBSCC's second research cycle (1999-2001). (1Q)
- Convene a meeting of SEBSCC project managers and technical advisors to discuss project redirection in preparation for the second research phase (1999-2001). (1Q)
- Conduct a mooring cruise to the Bering Sea shelf. (2Q)
- Conduct additional cruises to observe ecosystem dynamics associated with the spring bloom of phytoplankton. (3Q)
- Select SEBSCC proposals for the second research phase. (3Q)

- Contrast the environment of the Bering Sea shelf and slope from observations made during 1996, 1997, and 1998 to understand the strong interannual variability in the ecosystem. (4Q)
- Use SEBSCC model simulations to compare circulation, its effect on pollock survival, and upper-trophic-level interactions in the southeastern Bering Sea for warm and cold years to determine the influence of interannual variability in the ecosystem, and provide results of SEBSCC biophysical models. (4Q)

Specific goals that relate to completion of first-cycle research are addressed by SEBSCC's scientific approaches:

Modeling
- compare circulation in a cold versus a warm year in the SE Bering Sea, using the combined global (Spectral Element Ocean Model) and regional (S-Coordinate Rutgers University Model) circulation models
- complete a working 1-dimensional IBM of pollock for the Bering Sea that is coupled with the circulation model, and run the coupled model for two years that vary in physical conditions
- complete initial parameterization of growth, feeding, and migration submodels and examine model predictions under different climate regimes
- continue environmental monitoring by processing 1997 data, surveying the biophysical environment from moorings and platforms, and beginning index identification

Monitoring
- process 1997 data; survey juvenile pollock, pollock prey and predators; continue index identification

Lower trophic level processes
- sample and process sinking organic matter, phytoplankton, zooplankton
- collect nutrient samples, deploy moored in situ nitrate sensor

Upper trophic level processes
- analyze juvenile pollock and associated zooplankton samples; complete bioenergetics model
- generate hypotheses abut how biological aggregations interact with fronts and predators

Retrospective studies
- analyze core of deposited sediments from Skan Bay
- relate growth rings on fur seal teeth to interannual fluctuation in pollock abundance
- explore correlative relationships between pollock recruitment and biophysical parameters
- process and analyze atmospheric, cold pool and productivity data

D. Proposed Budget

The third year (FY 1998) of funding for SEBSCC is proposed to be $948.5K. Long range budgeting is discussed in Section III. The FY 1998 budget is divided into two parts: Research and Management. Project Management ($44.8K) will provide for PMT activities, a principal investigators' meeting, a council meeting, communications (including WWW development), and announcement of opportunity for, and selection of, round-two proposals. Research contracts

($903.7K) support the final year of round-one research in retrospective studies, modeling, monitoring, and process-oriented studies of lower and upper trophic levels. FY 1998 awards to research staff are shown in Appendix 2. The following table shows a general SEBSCC budget for FY 1998.

SEBSCC FY 1998 General Budget

Research	*$903.7K*
Modeling	$126.2K
Monitoring	$267.2K
Lower-trophic studies	$173.6K
Upper-trophic studies	$196.3K
Retrospective analysis	$140.4K
Project Management	*$44.8K*
PI Meeting	$15.0K
TAC Meeting	$10.0K
Communications	$15.0K
Research Council	$4.8K
TOTAL	*$948.5K*

IV. Outlook

A. Annual Steps

FY 1998 is the final year of SEBSCC's first research cycle. During the research cycle, SEBSCC conducts annual workshops of investigators to facilitate exchange and synthesis of scientific results, to promote formation of small working groups, and to facilitate planning of scientific operations. As the first cycle comes to a close, the PMT with the guidance of the TAC will refocus scientific objectives and the mix of investigations, as necessary. A second Announcement of Opportunity will be developed for fiscal years 1999-2000.

Intermediate, first research cycle products include a regional model of southeastern Bering Sea circulation with output to an individual-based model of pollock, and a spatial model of upper-trophic level interactions in the eastern Bering Sea. From satellite altimetry analysis we have a census of eddy-like features. Analysis will indicate dynamics responsible for eddy generation, evolution and influence on exchange of properties and material between the Bering Sea basin and shelf. Effects of local enhancement of primary productivity on higher trophic levels will be better understood. Reproductive processes on the shelf occur at a variety of temperatures from year to year, depending on long and short-term climate. SEBSCC has examined development of pollock eggs at water temperatures spanning the expected range;

results from this study will help regulate the individual-based model of pollock and shed light on temporal and spatial synchrony in the ecosystem. Other expected first-cycle results are determination of scales of variability in the coastal marine ecosystem from analysis of deposited sediments, historical changes in prey availability to upper trophic level predators as determined by seal foraging records, and effects of interannual climate fluctuations on pollock abundance through control of oceanographic conditions. To support data collection, SEBSCC deploys biophysical platforms measuring a suite of atmospheric, oceanic, and biological information, and conducts cruises phased with important events in the ecosystem such as the spring bloom.

Over its six-year lifetime, SEBSCC will provide information to help assess resources of the Bering Sea. Synthesis of information from two research cycles will be used to quantify ecosystem concerns. An ecosystem focus will be the role of juvenile pollock in the Bering Sea, both as a consumer of energy from the bottom of the food chain and as a source of food to apex predators and other pollock. SEBSCC will develop an index of juvenile pollock abundance based on measurable ecosystem characteristics documented by retrospective studies and by data from biophysical platforms and annual spring through fall cruises. Steps to develop the index are data collection, exploratory hypothesis testing, and development and testing of the index. In the final field year, 2001, cruises and moorings will be used to validate the index.

The SEBSCC budget stipulated initial year (FY 1996) funds of $0.5M and level funding of $1.0M from 1997 through 2000. In 2001, to include minimal field operations, project funding will ramp down to $0.7M, followed by $0.3M in 2002 for final synthesis. Inflation provides an additional downward financial ramp over the life of the project. We exploit that ramp by procuring capital equipment for monitoring at the start of the project, then shift to process studies, leading to synthesis, evaluation and validation, and information dissemination. The following timeline presents a schedule of major program elements for the duration of SEBSCC. FY 2002, not shown in the timeline, will be a final year of synthesis.

SEBSCC Timetable of Major Program Elements

	FISCAL YEAR					
	96	97	98	99	00	01
Workshop	*	*	*	*	*	*
Proposal Cycle	*		*			
Exploratory Hypothesis Testing	I ---------- I					
Develop Survival Index		I ---------- I				
Validate Survival Index				I ---------- I		
Synthesis				I ---------- >		
Measurement Program						
Biophysical Platforms	I -- I	I -- I	I ---I	I---I	I -- I	I -- I
Larval Ecology Cruises	I I	I I	I I	I-I	I I	I I
Juvenile Ecology Cruises	I I	I I	I-I	I I	I I	I-I

B. Collaborative Planning

SEBSCC is a highly leveraged program. It works collaboratively with ongoing efforts by other NMFS programs examining pollock resources and ecology of the Bering Sea (fishery acoustics group, stock assessment group, and Marine Mammal Protection Act Studies), programs at the University and State of Alaska, EPA, Shelikof Strait FOCI, Japan Far Seas Fisheries Laboratory, Ocean Research Institute of Tokyo University, Faculty of Fisheries, Hokkaido University, the Japanese Marine Science and Technology Center, Tokai University in Sapporo, Tohoku National Fisheries Institute, Korean Ocean Research and Development Institute and the Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences. SEBSCC cooperates with other Bering Sea ecosystem programs such as ARI and NSF Inner Fronts Study. We also coordinate with inhabitants of St. Paul Island. Marine mammalogists from the AFSC, ornithologists from the University of California-Irvine, and bioacousticians from the Southwest Fisheries Science Center and Scripps Institute of Oceanography collaborate on ecosystem studies as begun by a sister project, Bering Sea FOCI, and continued by SEBSCC. Researchers at NESDIS collaborate on remote sensing of ocean color. Japanese and SEBSCC researchers coordinate Japanese summer cruises in the eastern Bering Sea. When combined with NOAA cruises, this will allow several larval cohorts to be followed through their period of maximum mortality. There is ongoing University of Alaska Fairbanks and Hokkaido University collaboration on climate change and Bering Sea productivity. Japanese researchers (JAMSTEC) also are cooperating with University of Alaska scientists in research on the northern Bering Sea and Chukchi Seas in consort with Russian participants, and are providing financial support for

ship time. SEBSCC is considered a component of the PICES-GLOBEC Climate Change and Carrying Capacity (CCCC) Program.

C. Projected Resource Issues

For FY 1998, SEBSCC has planned 70 sea days aboard the NOAA Ship *Miller Freeman* during February, April, and May; and 62 days aboard the UNOLS Ship *Wecoma* during April, May, and June. The *Miller Freeman* is not available for the crucial fall cruises to the Pribilof Islands and for mooring recoveries. We are trying to find alternate vessels. The project will require similar ship time in 1999 aboard the *Miller Freeman* and a Class I vessel. Cruises need to coincide with ecosystem events such as the spring bloom and with larval and juvenile life stages of pollock.

Appendix 1. SEBSCC Investigators Funded during FY 1997

Investigator	Institution	Project title	FY97 award ($K)	Total award ($K)	Thru
Hinckley, Sarah, and Megrey, Bern	NOAA/AFSC	Individual-based modeling of walleye pollock in the southeast Bering Sea			1998
Hermann, Al	University of Washington				1998
Livingston, Pat and Hinckley, Sarah	NOAA/AFSC	A spatial model of upper-trophic level interactions in the Bering Sea			1998
Hermann, Al	University of Washington	Circulation modeling for the SE Bering Sea			1998
Stabeno, Phyllis	NOAA/PMEL				1998
Haidvogel, Dale	Rutgers University				1998
Musgrave, David	University of Alaska Fairbanks				1998
Schumacher, Jim and Stabeno, Phyllis	NOAA/PMEL	Monitoring and development of biophysical indices of the southeastern Bering Sea			1998
Brodeur, Ric and Napp, Jeff	NOAA/AFSC				1998
Hunt, George	University of California Irvine				1998
Cullen, John and Davis, Richard	Dalhousie Univ. (contract)				1998
Okkonen, Steve	University of Alaska Fairbanks	Altimetric census of mesoscale eddy-like features in the Bering Sea			1997

Whitledge, Terry	University of Texas at Austin	Origin and dynamics of nutrients on the southeast Bering Sea shelf	1998
Henrichs, Susan	University of Alaska Fairbanks	Isotopic and biomarker composition of sinking organic matter in the SE Bering Sea: indicators of food web structure	1998
Stabeno, Phyllis	NOAA/PMEL	Optical measurements in the southeast Bering Sea	1998
Swartzman, Gordie	University of Washington	High-resolution acoustic and juvenile pollock retrospective data analysis	1998
Brodeur, Ric	NOAA/AFSC		1998
Brodeur, Ric and Napp, Jeff	NOAA/AFSC	Habitat differences in frontal regions around the Pribilof Islands	1998
Doyle, Miriam	University of Washington		1998
Francis, Robert	University of Washington		1998
Blood, Debbie	NOAA/AFSC	Low-temperature incubation of pollock eggs	1998
Francis, Robert	University of Washington	Natural scales of variability in coastal marine ecosystems	1998
Loughlin, Tom	NOAA/AFSC	Historical trends in the number of foraging trips by lactating northern fur seals	1998
Niebauer, Joe	University of Alaska Fairbanks	The role of atmospheric forcing on the “cold pool” and ecosystem dynamics the Bering Sea shelf: a retrospective study	1998
Bond, Nick and Wyllie-Echeverria, Tina	University of Washington		1998
Megrey, Bern and Wespestad, Vidar	NOAA/AFSC	Retrospective investigation into relationships between pollock recruitment and biophysical correlates	1998

Appendix 2. SEBSCC Investigators Funded during FY 1998

Investigator	Institution	Project title	FY98 award ($K)	Total award ($K)	Thru
Hinckley, Sarah, and Megrey, Bern	NOAA/AFSC	Individual-based modeling of walleye pollock in the southeast Bering Sea			1998
Hermann, Al	University of Washington				1998
Livingston, Pat and Hinckley, Sarah	NOAA/AFSC	A spatial model of upper-trophic level interactions in the Bering Sea			1998
Hermann, Al	University of Washington	Circulation modeling for the SE Bering Sea			1998
Stabeno, Phyllis	NOAA/PMEL				1998
Haidvogel, Dale	Rutgers University				1998
Musgrave, David	University of Alaska Fairbanks				1998
Schumacher, Jim and Stabeno, Phyllis	NOAA/PMEL	Monitoring and development of biophysical indices of the southeastern Bering Sea			1998
Brodeur, Ric and Napp, Jeff	NOAA/AFSC				1998
Hunt, George	University of California Irvine				1998
Cullen, John and Davis, Richard	Dalhousie Univ. (contract)				1998
Whitledge, Terry	University of Texas at Austin	Investigation of the origin and dynamics of nutrients on the southeast Bering Sea shelf in relation to dominant physical and biological processes			1998

Henrichs, Susan	University of Alaska Fairbanks	Isotopic and biomarker composition of sinking organic matter in the southeast Bering Sea: indicators of food web structure	1998
Stabeno, Phyllis	NOAA/PMEL	Using optical measurements to explore the influence of mesoscale eddies on the interaction of lower and higher trophic levels in the southeast Bering Sea	1998
Swartzman, Gordie	University of Washington	High-resolution acoustic and juvenile pollock retrospective data analysis	1998
Brodeur, Ric	NOAA/AFSC		1998
Brodeur, Ric and Napp, Jeff	NOAA/AFSC	Habitat differences in frontal regions around the Pribilof Islands and their importance to juvenile pollock growth and survival in the Bering Sea	1998
Doyle, Miriam	University of Washington		1998
Francis, Robert	University of Washington		1998
Blood, Debbie	NOAA/AFSC	Low-temperature incubation of walleye pollock eggs from the southeast Bering Sea region	1998
Francis, Bob	University of Washington	Natural scales of variability in coastal marine ecosystems of the eastern Bering Sea	1998
Loughlin, Tom	NOAA/AFSC	Historical trends in the number of foraging trips made by lactating northern fur seals	1998
Niebauer, Joe	University of Alaska Fairbanks	The role of atmospheric forcing on the “cold pool” and ecosystem dynamics the Bering Sea shelf: a retrospective study	1998
Bond, Nick and Wyllie-Echeverria, Tina	University of Washington		1998

Megrey, Bern and Wespestad, Vidar	NOAA/AFSC	A retrospective investigation into relationships between southeast Bering Sea pollock recruitment and biophysical correlates	1998

Appendix 3. Personnel

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