AGENDA B-5
FEBRUARY 1997

MEMORANDUM

TO: Council, SSC and AP Members

FROM: Clarence G. Pautzke
Executive Director

DATE: January 28, 1997

SUBJECT: Ecosystem Committee Report

ESTIMATED TIME
5 HOURS
(for all A/B items)

ACTION REQUIRED

Receive Report from Ecosystem Committee and Provide Further Direction as Necessary.

BACKGROUND

The Council established its Ecosystem Committee in June 1996 to explore approaches to incorporating and disseminating additional ecological information and providing guidance to the Council on policy matters. Committee members include Dave Fluharty (chair), Linda Behnken, Robin Samuelsen, Chris Blackburn, and Kristen Stahl-Johnson. The Committee has formally met twice thus far, first in Sitka (September 1996) and then in Seattle (January 1997). The committee also plans to meet informally during each Council meeting week to get public feedback. An informal session is scheduled for Thurday night, February 6.

In January 1997, the NPFMC's Ecosystem Committee met for a two-day workshop in Seattle. The workshop was put on by the Alaska Fisheries Science Center, National Marine Fisheries Service, and coordinated by Patricia Livingston. Draft minutes from this meeting will be made available during the Council meeting. Committee chairman Dave Fluharty will provide a summary of ecosystem committee activities.

Functions of the Ecosystem Committee

1. Provide a platform for education on ecosystem topics.
2. Obtain additional information on N. Pacific ecosystem.
3. Develop working definition for ecosystem-based management in context of NPFMC.
4. Develop policies for ecosystem-based management.
5. Provide advice.

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DRAFT

Summary of Anchorage Meetings on Essential Fish Habitat Guidelines

Public meetings were held in Anchorage during the evenings of February 5, 6, 7 to discuss proposed essential fish habitat (EFH) guidelines. This a brief summary of the discussion and recommendations.

There was general concern among fishing industry representatives and fishermen about how EFH guidelines would be applied to protect EFH from potential fishing impacts. Some felt that it the intent of EFH was directed at shutting down certain fisheries, and hence the guidelines were non-neutral and raise questions of fairness. Therefore, it was suggested that **the preamble for the proposed rule should clarify that the intent of the regulations is to describe, identify, and conserve EFH, not to preclude fishing activity in that habitat, but to refine our ability to manage that fishing activity by taking into account our increasing knowledge and understanding of the importance of habitat.**

Most people felt that **defining and mapping essential fish habitat would be useful to the Councils for effective fisheries management.** The North Pacific Fishery Management Councils (NPFMC) existing policy on habitat, adopted in 1988, has guided these actions and is very similar to the EFH policy proposed by the National Marine Fisheries Service. The NPFMC's habitat policy statement is:

> Recognizing that all species are dependent on the quantity and quality of their essential habitats, it is the policy of the North Pacific Fishery Management Council to: conserve, restore, and maintain habitats upon which commercial, recreational and subsistence marine fisheries depend, to increase their extent and to improve their productive capacity for the benefit of present and future generations. (For purposed of this policy, habitat is defined to include all those things physical, chemical, and biological that are necessary to the productivity of the species being managed.)

In the North Pacific, the focus has been on protecting critical or sensitive habitats from potential impacts. For example, over 15,000 square nautical miles of the North Pacific has been closed to fishing with bottom trawls to protect sensitive king crab habitat. **It was recommended that the guidelines need to be clarified with respect to areas already protected.**

One benefit of mapping EFH using GIS is that is will be useful to track habitat use over time. It may be difficult, however, to generate accurate EFH maps for species covered under the NPFMC's fishery management plans (FMPs). Habitat data are very limited for commercially exploited fish species, and virtually unknown for many other fish species, invertebrates, and plants in the North Pacific. **It was suggested that a good first step to understanding what data are available would be to construct an information matrix table.** Data collection is not necessary to implement EFH regulations; maps would be generated from existing information when available for that species or life stage.

There was a great amount of concern expressed about additional funding for habitat research and administration. The guidelines provide a hierarchical approach to obtaining additional information on EFH, yet our information base may increase only slowly with current funding levels and limits on FTEs. **It was suggested that more funding should be made available for research on EFH and potential impacts of fishing on EFH.** It would also be helpful if the guidelines could specify, or at least estimate, the level of effort that would be needed to generate EFH maps. Because this isn't a new data collection, but simply a summary of existing information, perhaps only one day per species may be needed.

The FMP for the Bering Sea and Aleutian Islands region groundfish fishery applies to all species of fish and invertebrates not covered under another FMP (e.g., salmon and crab). The Bering Sea supports about 300 species of fishes and an unknown abundance of molluscs, crustaceans, and other forms of marine animal and plant life that is defined as fish under the Magnuson-Stevens Act. Only about 20 fish species are targeted by commercial fisheries; other species are managed as prohibited species, other species, or non-specified species that include things such as anenomones and jellyfish. **It was recommended that the guidelines establish what species would require EFH determinations.**

As defined in section 3(10) of the Magnuson-Stevens Act, EFH is "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity". The proposed guidelines define the word "necessary" in this case as the habitat required to support a managed species or assemblage at a *target production level* reflecting conscientious stewardship (p. 2). The guidelines further establish that "the minimum threshold for determining the target production of a species or assemblage should be that level necessary to maintain at least the current reproductive capacity of the population so that the *maximum sustainable yield* (MSY) can be attained"(p. 5). It should be pointed out that the only stock in the North Pacific for which biomass that produces MSY has been estimated is eastern Bering Sea walleye pollock (B_{msy} = 6 million mt). Many of those attending the meetings felt that the language regarding target production levels should be replaced by a more useful concept in guiding the Councils actions relative to habitat. One suggestion was to **define "necessary" as the habitat required to protect the sustainability, within the known range of natural variability, of fisheries and the biological integrity and diversity associated with those fisheries.**

Further, "EFH is to be determined based on the target production level that supports the *maximum societal benefit* of a species, including harvest, and will always be greater than the critical habitat for any managed species listed as threatened or endangered under the Endangered Species Act" (p. 5) **It would be difficult at best to define "maximum societal benefits of each species". Therefore, those attending the meetings suggested deleting this concept from the guidelines.** The Council process seeks to attain these benefits through achieving optimum yield.

The guidelines are vague as to how EFH should be protected and about what constitutes "an activity that is likely to substantially affect the habitat" (p.4). **It was suggested that the guidelines should prioritize where to focus efforts to protect and restore habitats.** For example, efforts should concentrate on sensitive EFH (such as coral reefs and sea grass beds) or on overfished and depleted species. The NPFMC's habitat policy defines significant activities and policies, and they include those that:

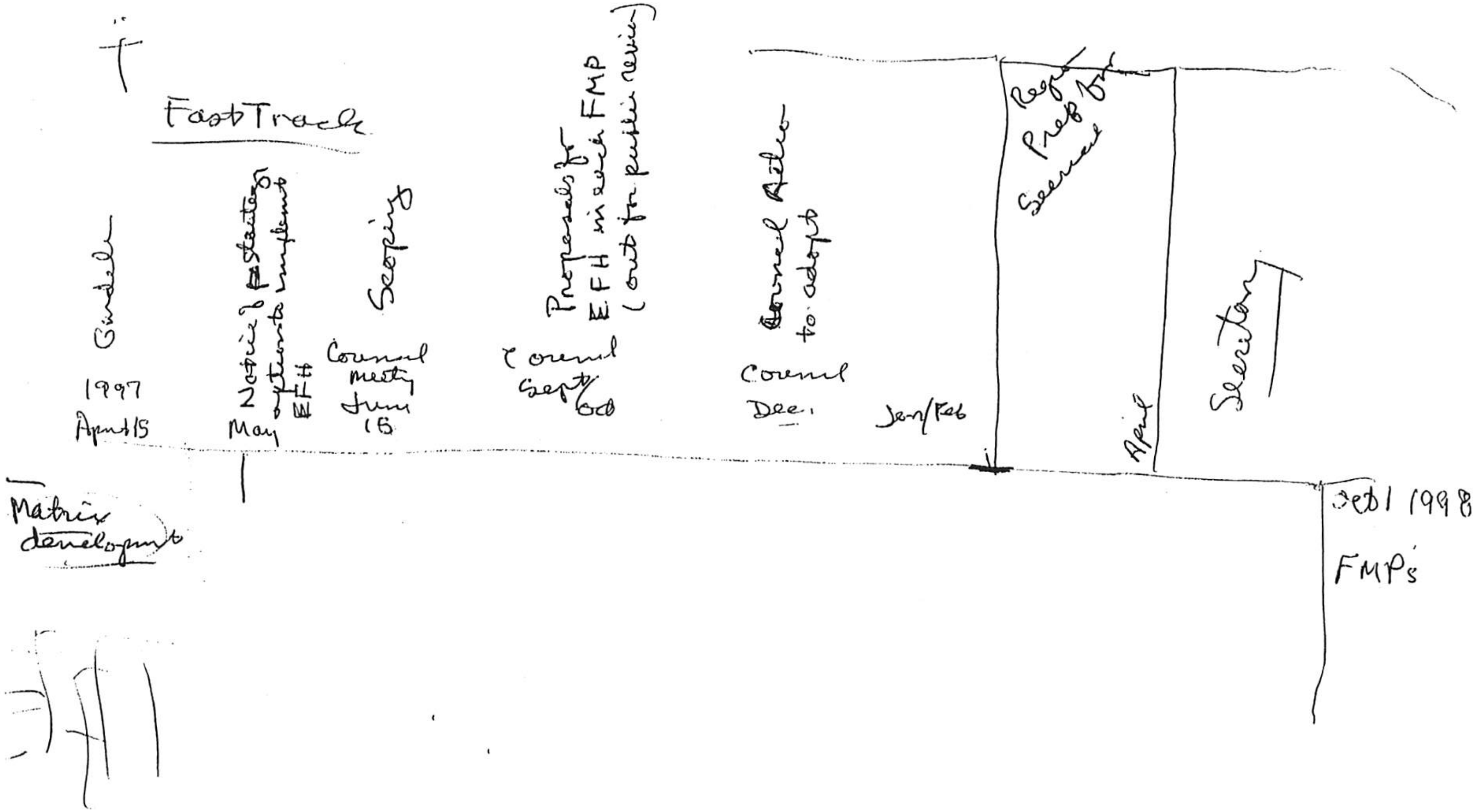
1. may directly affect fisheries habitat for which the Council has a management or research interest.
2. Could affect habitat important to species managed under the MFCMA, or habitat important to species upon which managed species are dependent for food.
3. May be precedent-setting, highly controversial, or proposed in unique or critical habitat areas.
4. Could have a substantial indirect impact on water circulation patterns, nutrient production and export, saltwater intrusion, freshwater inflow, availability of nursery areas, migration corridors, and overwintering areas, etc.
5. Could result in released of toxic or otherwise hazardous wastes.

Concern was expressed that the only actions that could be taken to protect EFH by the Council related to fishing activities within the EEZ. It was recommended that **guidance be provided for implementation by states to address EFH within state waters.**

The Magnuson-Stevens Act authorizes the Councils to comment on and make recommendations concerning any activity that my affect habitat of any fishery, and requires comment on activities that are likely to substantially affect the habitat of an anadromous fishery. **The guidelines should indicate how the comment process is to be accomplished.** Will NMFS make the decision on what activities meet this criteria and inform the Council, or will the Council's make this determination?

The possibility of combining the NMFS public review period on EFH determination with the Council public review period and public hearing was discussed. It appears that an unnecessary duplication of effort may occur when there is limited time available. **It was suggested that NMFS consider using the Council process for public review and comment.** One possible timeline for public review and actions on EFH regulations is shown in the attached figure. **A determination needs to be made as to whether EFH regulations can be achieved for all FMPs in one amendment package.** Combining amendments may reduce staff time required. It should also be spelled out who will prepare the EFH amendment package; staff from Council, NMFS, or States?

At this time, these comments are only applicable to the advance notice of proposed rulemaking. **Further recommendations and comments may be made after publication of the proposed rule in March.**


Fast Track
1997
April 15
May
Scoping
Council meeting June 16
Proposals for EFH in each FMP (out for public review)
Council Sept/Oct
Council Action to adopt
Council Dec.
Jan/Feb
April
Secretary
Sept 1998
FMP's
Matrix development

AGENDA B-5
February 1997
Supplemental

Ecosystem Committee Report to the North Pacific Fishery Management Council

February 1997

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DRAFT Minutes of the Ecosystem Committee Meeting January 23-24, 1997
The Alaska Fisheries Science Center Workshop on Ecosystem Research

Background

The NPFMC's Ecosystem Committee was formally established by the Council in June 1996 following a recommendation by the Scientific and Statistical Committee (SSC). The SSC suggested that this group be charged with exploring approaches to incorporating and disseminating additional ecological information and providing guidance to the Council on policy matters. The Committees first met in Sitka on September 1996 to discuss the role and objectives of the committee. Most attendees agreed that the committee could serve as an educational forum and that the committee could interact with the plan teams as well as provide advice to the Council. The committee could also stimulate specific ecosystem related research projects and direction with regard to specific population goals for species covered in the fishery management plans.

Functions of the NPFMC Ecosystem Committee and Some Examples of Work in Progress

① Provide a platform for education on ecosystem topics
- ✔ AFSC workshop and program review
- ✔ bibliography of ecosystem literature
- ✔ interaction with other agencies, groups

② Obtain additional information on N. Pacific ecosystem
- ✔ traditional knowledge and wisdom
- ✔ local knowledge and fisheries data

③ Develop working definition for ecosystem management in context of NPFMC
- ✔ review other management schemes
- ✔ proposed definition for discussion

④ Develop policies for ecosystem-based management
- ✔ draft policy similar to habitat policy

⑤ Provide advice
- ✔ research priorities, adaptive management, habitat
- ✔ Magnuson-Stevens Act mandates

Ecosystem Research Workshop

In January 1997, the NPFMC's Ecosystem Committee met for a two day workshop in Seattle. The workshop was put on by the Alaska Fisheries Science Center, National Marine Fisheries Service, and coordinated by Patricia Livingston. Committee members Dave Fluharty, Chris Blackburn, and Kristen Stahl-Johnson were present (Robin Samuelson and Linda Behnken had prior commitments), along with approximately 50 people who attended at least one day of the workshop. The meeting was conducted based on the attached agenda. A brief summary of each report is provided below. Copies of presentation overheads are available from the Council office.

What Constitutes an Ecosystem? Pat Livingston (AFSC) provided an overview of ecosystem definitions, important elements and processes, and the concept of ecosystem health. Bodkin (1990) defines an ecosystem as "a set of interacting species and their local, non-biological environment, functioning together to sustain life". Structural elements of an ecosystem include inorganic substances (C, N, CO2, H2O, etc.), organic substances (proteins, carbohydrates, lipids, etc.), climate regime (temperature, rainfall, etc.), producers (green plants), consumers (animals), and decomposers (bacteria, fungi, protozoa). Functional elements of ecosystems include energy flow circuits, food chains, diversity in time and space, nutrient cycles, development and evolution, and feedback control mechanisms (cybernetics). She discussed the dichotomy between this system-level view of ecosystems and the population-community approach to ecosystem study. The current strategy in ecosystem research is to integrate the two approaches by studying not only the processes influencing the distribution and abundance of organisms and the interactions among organisms but also to study the interactions between organisms and their role in transformation and flux of energy and matter. Studying population and community ecology is an essential aspect of ecosystem research. Ecosystem health as a concept was discussed. The concept is useful because it provides a focus for examining human activity and its effect on ecosystems. Defining ecosystem health is difficult, however, especially in systems such as the eastern Bering Sea where it is difficult to separate natural variability from human-induced changes. We are still in the early stages of attempting to find reliable indicators of ecosystem health. This effort may require monitoring of key ecosystem attributes.

Biodiversity, its definititions and importance, were also discussed. Measurement of diversity and its changes requires regional scale research and monitoring. Because both perturbed and natural ecosystems are now present, efforts to maintain and restore biodiversity need to consider the value and stability of existing ecosystems.

The focus of current ecosystem-related research efforts is to study ecosystems at a variety of levels: population, community, and system levels. Depending on the questions being asked, this requires examination of processes at a variety of time and space scales, determination of key information on important populations, emphasis on trophic interactions, and understanding the effects of human activities. Presently, much attention is being given to examining the effects of physical factors on biological processes and spatial distributions of key marine species.

Fisheries-Oceanography Coordinated Investigations (FOCI) Rick Brodeur (AFSC) reviewed research investigations conducted under the FOCI program. FOCI was established in 1984 to gain an understanding of recruitment mechanisms of walleye pollock. The initial studies focused on pollock reccruitment in the Shelikof Strait population of the GOA with an aim to understanding the physical and biological process which affect survival. Studies were conducted to determine spatial distribution of spawners and eggs, vertical distributions and mortality of the various life stages, trophic interactions, and finally development of biophysical models and management advice via stock projections. The Bering Sea FOCI program began in 1991 and focuses on stock structure and recruitment of walleye pollock in the Bering Sea. Many of the studies conducted in the GOA were continued in the BS but several new studies were initiated, including those on stock structure and onshore transport of eggs and larvae. Studies have examined differential survival of eggs and larvae over the Bering Sea slope and shelf, noting a coincidence of high concentration of larvae in eddies.

Rick also reported on the Southeast Bering Sea Carrying Capacity (SEBSCC) research program, which was established in 1996 and will run through the year 2001. A major research project under the SEBSCC program is to examine the distribution and ecology of juvenile pollock near tidal fronts at the Pribilof Islands. The presence of these fronts, which contain high densities of juvenile pollock and their predators in some years, may have impacts on juvenile pollock survival. Underwater examination by ROV indicated that juvenile pollock were associated with jellyfish, which may provide shelter for these pollock during the day and hence enhance survival. Results were also presented on another SEBSCC project which examined the distribution and species and habitat associations of forage fish, including juvenile pollock, in the Bering Sea from Russian and NMFS surveys going back to 1982. The overall distribution and diversity of forage fish available in various locations was contrasted between warm and cold years on the eastern Bering Sea shelf.

Pinniped Research Program Tom Loughlin (NMML) gave the group an overview of research conducted to understand declines of Steller sea lions and northern fur seals. Research on Steller sea lions has included foraging and food habit studies, physiology studies, prey surveys, and studies of other possible impacts (disease, contaminants, reproductive failure, predation, etc.). The decline of Stellers is chronic and widespread, and it appears that juvenile survival is the primary problem. Possible causes of the decline could be emigration, predation, harvest, pollution, disease, takes in fisheries, or changes in prey availability. Careful evaluation of these possible causes suggests that changes in prey availability is perhaps the biggest culprit. Food habit studies have indicated that diet has changed during the course of the decline by becoming more simplified and more focused on pollock or Atka mackerel. Primary prey are either small (<30 cm) midwater schooling fish or various small demersal fishes. Juvenile diets appear more restricted that adults, and diet diversity is directly correlated with the amount of sea lion decline. That is, the largest declines have occurred in areas with fewer prey species available. Stellers now rely primarily on pollock, rather than other higher energy foods such as capelin. Studies using telemetry (satellite transmitters) have shown that young-of-the-year Steller sea lions do not range very far for food, and have limited diving capacity (<50 m). Hence, prey availability near rookeries and haulouts may be very important for survival.

Northern fur seal is another species of concern and focus of considerable research. The northern fur seal population began to decline in the mid-1970's for reasons that are not apparent. The two main breeding islands have shown different trends, with St. Paul Island showing stable pup production since the early 1980's, whereas the St. George Island pup production continued to decline until only recently. A new population of fur seals was established at Bogoslof Island in 1983 and has grown rapidly. Studies have focused on various aspects of the northern fur seal in relationship to its pelagic ecosystem. Foraging behavior studies using satellite transmitters have shown that these animals range far in search of food. Two typical diving patterns have been found for foraging behavior of lactating female fur seals. Shallow divers dive to 20-75 m at night feeding on pelagic prey. Deep divers dive 75-150 m throughout the day and night feeding near the shelf bottom. Many females combine these patterns when moving from deep to shallow water. Interestingly, fur seals from St Paul appear to forage to the north and west, while those from St. George forage to the south and east of the island. Scat analysis indicates that juvenile pollock is the most common prey of fur seals from St. Paul. Fur seals from St. George consume a combination of pollock and squid.

The 1994 amendments to the Marine Mammal Protection Act provided for a Bering Sea Ecosystem Study Plan, which will provide for increased involvement of Alaska natives into ecological research. Once funded, research may begin in 1998.

<u>Seabird Status and Research</u> Vivian Mendenhall (USFWS) reviewed the status of seabirds and the importance of prey availability to seabird survival. In general, fish eating seabird populations in the Bering Sea are stable, following a decline of several species (red-legged and black-legged kittiwakes, thick-billed murres) through the early 1980's. Most seabird populations are limited by prey availability near nesting sites, particularly for those seabirds that are surface feeders. Some birds are able to make long forays (e.g., thick billed murres forage out to 100 km), whereas others remain closer to land in search of prey. Prey availability depends on fish stock size, local sea conditions (surface temperature, upwelling, etc.), and distribution. Energy content of forage fish varies greatly (20 fold), with myctophids and eulachon having the highest energy density, and cod and pollock the lowest. Hence, pollock may be unable to sustain successful breeding of some seabird species (except puffins). Effects of forage fluctuations on seabird populations vary with seabird species, depending on its foraging strategy, breeding strategy, and adaptability. Threats to seabirds include oil spills, logging (old growth required for murrelet nesting), predators (foxes, rats), tourism disturbance, bycatch in fishing gear, fishery waste discharges (may increase some populations of competitors or predators), and localized fishery removals of prey. Several research projects are ongoing to help understand seabird ecology. The Seabird, Marine Mammal, and Oceanography Coordinated Investigations (SMMOCI) project is examining the relationship of seabird population trends to forage fish biomass near colonies. The Alaska Predator Ecosystem Experiment (APEX) project is examining the relationship of seabird populations in the northern Gulf of Alaska to the availability of forage fish, including the influences of oceanography, forage fish selection by birds, and fish carcass composition. The PICES-GLOBEC International Program on Climate Change and Carrying Capacity project is international and multi disciplinary in nature.

<u>Habitat Research</u> Bob McConnaughey (AFSC) provided an overview of some habitat research being conducted by the AFSC. Habitat can be considered as the biotic-abiotic interface. This view is a composite of several terms including habitat (physical locality), ecological niche (environmental conditions), and biotope (location plus environmental conditions suitable for particular species). A few general principles underlie much of habitat (actually *biotope*) research: (1) a single species is not ubiquitous, thus habitat is restrictive; (2) a species is not uniformly distributed throughout its area of occurrence, thus habitat quality varies; and (3) there is significant temporal variability in habitat quality and location. In general, fish abundance reflects habitat quality. Because fish are able to select habitat, the best habitat is occupied first and at the highest density, while marginal areas are eventually occupied in response to crowding. As such, relative abundance is a reasonable first approximation of habitat quality. Current research includes environmental data collection, habitat characterization, environmental impacts of fishing, and analysis of community ecology. New technology (acoustic bottom typing, laser line systems and GIS) may allow for much improved data collection and analysis. Acoustic bottom typing enables passive collection of sea floor attributes during fishing and/or survey operations. Laser line systems

function much like a towed camera system but it is useable in somewhat more turbid conditions. Habitat characterization research has focused on identifying limits and preferences of fish species, incorporating the effects of population size and describing associations with surface sediments. An investigation into the environmental impacts of bottom trawling in the Bering Sea was initiated last year. Comparison of heavily fished and unfished areas in Bristol Bay will assess chronic exposure effects. Experimental trawling in unfished areas in 1997 and beyond will provide information on acute exposure effects and the recovery process will be monitored. These studies will enable resource managers to evaluate the efficacy of time-area closures in soft-bottom areas. Similar studies are being conducted in harder bottom areas of the Gulf of Alaska using a submersible and video assessment technology. Additional planned studies include a retrospective analysis for the Gulf and a field study of trawl impacts in gorgonian coral habitat in the Aleutians. Potential changes in Bering Sea community ecology will be examined by comparing current fish assemblages with those identified in an earlier (1982) study. Various habitat research bottlenecks were discussed. These include the limited seasonal coverage of data collection, the general paucity of environmental data, frequently inconsistent data formats and potentially high data processing costs (e.g., infauna and video). There are additional resource constraints related to manpower and short-term funding cycles.

<u>Essential Fish Habitat</u> Cindy Hartmann (NMFS) briefed the group on Magnuson-Stevens Act requirements regarding essential fish habitat (EFH). As defined under the Act, EFH is "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity". NMFS has developed a framework for guidelines to describe, identify, conserve, and enhance EFH. Comments on the Proposed Rule are due February 12, 1997. As proposed, EFH is the amount of habitat necessary to maintain a managed species at a target production level (note: default=MSY). EFH will be defined for each life history stage and will be presented in the FMP in the form of text, tables, and maps. Information used to determine EFH will be based on a hierarchical approach depending on data availability.

<u>**Proposed hierarchical approach to EFH.**</u>
Level 1. Presence/absence data
Level 2. Habitat-related densities of species
Level 3. Habitat-related growth, reproduction, or survival rates by habitat
Level 4. Production rates by habitat

<u>Resource Ecology and Ecosystem Modeling</u> Pat Livingston (AFSC) briefed the group on resource ecology and ecosystem modeling activities underway at the Science Center. Food habits data are collected from the dominant groundfish species in the eastern Bering Sea, Gulf of Alaska and Aleutian Islands regions. This sampling provides information on geographic distribution of prey, prey size composition, and diet composition by season, size, and sex. Geographic information may be particularly valuable when survey data are limited (e.g., capelin). These data are used to estimate the impacts of groundfish predation on species that are important to fish, birds, marine mammals, and fisheries. Information generated from single species can be brought together into a multispecies synthesis, giving estimates of diet similarity and habitat use by species, time series of groundfish predation mortality, marine mammal and seabird consumption, and providing insights into food web interactions and ecosystem change indicators. Pat has found that the food web in the Bering Sea has some differences from the Gulf of Alaska food web. For example, although walleye pollock are a dominant component of each system, pollock are highly cannibalistic in the BS, but not in the GOA. In general, the pelagic portion of the food webs the Bering Sea, Gulf of Alaska, and Aleutian Islands is relatively separate from the demersal, inshore food webs. Multispecies modeling provides both retrospective information (predation mortality, recruitment estimates, historical biomass levels, etc.) and projections into the future (long-term effects of fishing strategies such as mesh size changes on multiple species or differential exploitation rates, effects of environmental change, and a guide to future research directions). Data gaps for multispecies forecast modeling include: information on the seasonal distribution, movements, and diet of groundfish.

<u>Incorporating Predation and Climatic Effects into Stock Assessments</u> Anne Hollowed (AFSC) provided an overview of incorporating predation and environmental information into stock assessment modeling. Food habit research provides information on daily rations, size, age and weight of prey, and annual estimates of

consumption. Predators are incorporated into the assessment by modeling them as fisheries. For GOA pollock, studies have shown that arrowtooth flounder tend to be selective for age 1 pollock, and sea lions are selective for age 2+ pollock, whereas halibut tend to eat older pollock (3+). There is annual variability in the age composition of pollock consumed by predators, because of fluctuations in year class strength of pollock. This information coupled with information on the time series of predator abundance can then be used to estimate age specific mortality of pollock due to predation by various predators. Additional research on recruitment process of GOA pollock with the FOCI program has also proven to be useful in stock assessments. Information on environmental conditions during each early life history stage (eggs, larvae, juveniles) can be scored and tallied to provide fairly accurate predictions of year-class strength. Simulation modeling of the GOA pollock stock using stochastic recruitment at age 3 has provided estimation of probabilities of falling below threshold (defined as 20% of the unfished spawner biomass). The element of risk can thus explicitly incorporated into the plan teams ABC recommendation, as was the case in 1993.

Incorporating Ecological Information into Stock Assessment and Management Advice Lowell Fritz (AFSC) reviewed how oceanographic information is being incorporated into projections of Eastern Bering Sea (EBS) pollock recruitment, and analysis of fishery and Steller sea lion interactions. Pollock year-class size is variable in the EBS. In general, recruitment has been reduced at very high stock sizes. One hypothesis is that because pollock are cannibalistic in the EBS, large year-classes result when there is a high degree of spatial separation between adults and juveniles. There does appear to be some relationship between spatial separation and year-class strength, and this separation appears to be linked to larval drift. Computer models indicate that surface flows during April-July of years producing large pollock year-classes (1978, 1982, and 1989) pushed larvae into the inner and middle shelf areas of northern Bristol Bay, and away from the adult population on the outer shelf. Small year classes are produced when larvae are not greatly dispersed away from outer shelf spawning areas. This technique provides insights into year-class strength well before it can be estimated by trawl survey data.

A review of fishery data has yielded insights into temporal-spatial considerations for fishery and Steller sea lion interactions. Trawl exclusion zones were established in 1992 around sea lion rookeries along the Aleutian Islands and Alaska Peninsula. Combined with the closure of the Bogoslof area to conserve Donut hole pollock, there was a significant redistribution of effort onto the Bering Sea shelf area north of Unimak Island, which contains critical habitat for Steller sea lions. The amount of pollock taken within critical habitat has increased since the mid-1980's, such that almost 70% of the total BSAI pollock catch was taken from these areas in 1995. Another study examined localized depletion of Atka mackerel in the Aleutian Islands. The fishery takes place in very small discrete areas, most of which are within the 20 nm critical habitat areas around Steller sea lion rookeries and haulouts. Analysis of fishery catch-per-unit-effort (CPUE) data indicate that localized depletion of Atka mackerel, a major food source for sea lions, can occur in these areas. These types of analyses are useful to managers considering ways to mitigate possible impacts of fisheries on Steller sea lions and refine previous management actions.

Overview of Ecosystem-Based Management Principles Dave Witherell (NPFMC) provided a brief overview of the literature on marine ecosystem-based management. As defined by the Ecological Society of America, ecosystem management is "management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function". In more general terms, ecosystem-based management is shorthand for a more holistic approach, which focuses more on maintaining system integrity rather than maximizing extraction of certain resources.

A number of management measures previously adopted by the Council encompass ecosystem-based management principles (e.g., establishing a 2 million mt optimum yield cap, spatial and temporal allocation of groundfish harvest, incorporation of risk aversion and uncertainty, establishment of no-trawl zones, etc.). Since 1984, the Council's #1 comprehensive management goal (NPFMC 12/7/84) is to conserve fishery resources, maintain habitats, and give full consideration for interactions with other elements of the ecosystem. The Council has also had a comprehensive policy on habitat since 1988. The objectives of this policy are to maintain the current quantity and productive capacity of habitats, and restore and rehabilitate any habitats previously degraded.

The principles and elements of ecosystem management were identified in five published papers (Grumbine 1994, USFWS 1994, Mangle et al. 1995, Christiansen et al. 1996, Larkin 1996). The concept of ecosystem-based management includes the elements of sustainability, goals, ecological models and understanding, complexity, dynamic character, context and scale, adaptability, and humans as ecosystem components. A working definition for ecosystem-based management in the context of the North Pacific Fishery Management Council was proposed and discussed in the workshop group. The working definition, as revised, is shown in the adjacent box; additional changes may be made in the future.

Working Definition for Ecosystem-Based Management in the Context of the NPFMC - January 1997

Definition: Ecosystem-based management, as defined by the NPFMC, is a strategy to regulate human activity towards maintaining long-term system sustainability (within the range of natural variability as we understand it) of the North Pacific, covering the Gulf of Alaska, the Eastern and Western Bering Sea, and the Aleutian Islands region.

Objective: Provide future generations the opportunities and resources we enjoy today.

Principles:
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 of resources for human consumption and non-extractive uses.
4. Maintain the concept that humans are components of the ecosystem.

Guidelines:
1. Integrate ecosystem-based management through interactive partnerships with other agencies, stakeholders, and public.
2. Utilize sound ecological models as an aid in understanding the structure, function, and dynamics of the ecosystem.
3. Utilize research and monitoring to test ecosystem approaches.
4. Use precaution when faced with uncertainties to minimize risk; management decisions should err on the side of resource conservation.

Understanding:
1. Human population growth and consequent demand for resources is inconsistent with resource sustainability.
2. Ecosystem-based management requires time scales that transcend human lifetimes.
3. Ecosystems are open, interconnected, complex, and dynamic; they transcend management boundaries.

Other Discussion

The group discussed the proposed essential fish habitat (EFH) guidelines. It was noted that the definition of EFH was habitat required for target production levels; many thought this was extremely vague and highly discretionary. Some present were concerned that this is another unfunded mandate, that will take staff time away from other, more useful projects. Additional funding should be made available if this is a priority project. As a way to save time and money, it was suggested that as a first step, a matrix of presence/absence of information be constructed. Such an information matrix table could have life history stage as columns, with each row a separate species. A simple check would indicate if the information was already available. It was felt that this table would help identify where data were available that could be subsequently analyzed and where data were lacking and new research is needed. It could also serve as a basis for setting priorities and new funding initiatives. It was suggested that critical habitat was more important than essential habitat, as these might be more discrete areas for managers to identify and protect. Another thought was that identifying "sensitive habitat" more vulnerable to impacts (attached invertebrates and plants) might be more useful than essential fish habitat for individual fish species. Another suggestion was to use existing closure areas as first approximation of critical habitat for herring, red king crab, hair crab, and halibut. One could also consider the "threats" and define what is the risk. NMFS staff is planning an informal session to discuss proposed EFH guidelines on the evening of February 5.

It was agreed that the ecosystem committee should meet on an informal basis during Council meetings to generate additional discussion and public involvement. An informal meeting of the Ecosystem Committee has been scheduled for 7 pm on Thursday, February 6 at the Anchorage Hilton Hotel. The group expressed its appreciation to Pat Livingston for coordinating an excellent workshop, and to all the speakers for their presentations.

Attendance List:

Dave Fluharty (committee chair)
Chris Blackburn (committee member)
Kristen Stahl-Johnson (committee member)
Dave Witherell (staff)
Gordon Kruse (advisor)
Pat Livingston (workshop coordinator)
Clarence Pautzke
Doug DeMaster
Warren Wooster
Tamra Faris
Lowell Fritz
Chuck Fowler
Ole Mathisen
Richard Brodeur
Sue Hills
Hal Weeks
Richard Ferrero
Bob McConnaughey
Vivian Mendenhall
Andrew Trites
Lennie Gorsuch
Ken Adams
Eric Swenson
Jerry Brennan
Gordon Blue
Richard Merrick
Dan Nichol
John Roos
Jude Hensler
Connie Sathre
Ann Hollowed
Ed Casillas
Dan Waldeck
Gretchen Harrington
Michiyo Shima
Craig Rose
Tiana Honkalehto
Fred Munson
Jeff Fujioka
Sandra Lowe
Loh-lee Loh
Jim Ianelli
Tom Wilderbuer
Tom Loughlin
Ross Anderson
John Field
Eric Weissmen
Mark Weissmen
Rich Marasco

~5 unidentified persons

Note: Please contact Dave Witherell (NPFMC staff) if you wish to obtain additional information, ecosystem-based management bibliography, or copies of presentation overheads. The Ecosystem Committee is seeking information and informal advice on how to obtain traditional ecological knowledge and wisdom as well as the experience and insights of local persons and other fishermen. Please submit these suggestions in writing to Dave W.

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[additional contributions are appreciated]

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Proposed Agenda
Overview of Ecosystem-related Research at AFSC
January 23-24, 1997
NOAA/WRC 7600 Sand Point Way NE, Seattle, WA - Bldg 4, Room 1055

Day 1:

A. OVERVIEW

9:00- 9:20 Introduction and goals (Marasco, Fluharty)
Review of agenda (Livingston)

9:20- 10:15 What constitutes an ecosystem- definitions, important elements, processes and the concept of health. (Livingston)

10:15- 10:30 Break

B. AFSC, AKR, USFWS Ecosystem-related programs: program overview, key ecosystem components and processes studied, research gaps, and current/potential links to fishery management

10:30-11:30 RACE - FOCI (physically-driven, bottom-up approach to predicting pollock recruitment) (Brodeur)

11:30-12:30 Lunch

12:30- 1:30 NMML- Pinniped research program (role of top predators, understanding population declines) (Loughlin)

1:30 - 2:30 U.S. Fish and Wildlife Service - Summary of seabird research (biology, conservation concerns, ecosystem-related research efforts) (Mendenhall)

2:30 - 2:45 Break

2:45 - 3:45 ABL& RACE - Habitat research (effects of fishing, defining habitat types) (McConnaughey)

3:45 - 4:45 AKR - Framework for the Description, Identification, Conservation, and Enhancement of Essential Fish Habitat (Hartmann)

Day 2:

8:30 - 9:30 REFM - Resource ecology and ecosystem modelling (trophic interactions, multispecies models) (Livingston)

9:30 - 9:45 Break

9:45 -10:45 REFM - Stock assessments (incorporating climate effects, predation, etc. into stock assessments - GOA pollock examples) (Hollowed)

10:45-11:45 REFM - Stock assessments (incorporating ecological information into stock assessments and other management advice, eg., buffer zones, bycatch reduction) (Fritz)

11:45- 1:00 Lunch

C. Ecosystem management

1:00 - 2:00 Overview of various proposed/current ecosystem management schemes (Witherell)

2:00 - 5:00 OPEN DISCUSSION

(15 January 1997)

BERING SEA ECOSYSTEM STUDY PLAN

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INTRODUCTION

The 1994 Amendments to the Marine Mammal Protection Act (MMPA) added Section 110(d)(1) requiring the Secretary of Commerce (Secretary), in consultation with the Secretary of Interior, the Marine Mammal Commission, the State of Alaska, and Alaska Native Organizations (ANOs) to undertake a scientific research program to monitor the health and stability of the Bering Sea ecosystem. The research program was to resolve uncertainties concerning the causes of population declines in marine mammals, sea birds, and other living resources of that marine ecosystem. The amendments further required that the program address research recommendations developed by previous workshops on the Bering Sea and that it include research on subsistence uses of such resources and ways to provide for the continued opportunity for such uses. The Secretary was directed to utilize, where appropriate, traditional local knowledge in the conduct of the research.

Section 110(d)(1) of the MMPA, as enacted by the 1994 Amendments, is intended to establish a new approach to conducting research and monitoring for marine resources. By placing the emphasis on the study of the entire ecosystem, Congress signaled its intent to move away from single species research. The goal of the Amendments was to use the Bering Sea Ecosystem Program as a test case for ecosystem-based studies.

The provisions of section 110(d)(1) were intended to establish a new precedent for cooperative research between federal agencies and Alaska Natives and other residents of Bering Sea coastal communities. Congress recognized that local residents can provide significant valuable information to research programs, and that they should be provided with an active role in any long-term research and monitoring program. Accordingly, Congress required that research on the Bering Sea Ecosystem Program be carried out, to the maximum extent, in Alaska and the Bering Sea region.

In addition, Congress specified that the research and monitoring itself should be carried out, where appropriate, by qualified Alaska Native Organizations. Congress recognized the value of having such work undertaken by Alaska Native Organizations representing the peoples who have historically inhabited the Bering Sea region. The end result of this coordinated program is intended to be a model of cooperation between federal agencies, state agencies, academia, Alaska Natives, and residents of the Bering Sea region. The benefits of such an approach is expected to be not only better research and more careful monitoring, but also improved cooperation between federal officials and residents of coastal communities. This strong relationship is expected to not only improve the nature and the quality of the research conducted, but also provide the basis for a more effective and cooperative long-term management program to maintain and enhance the ecological, economic, subsistence, cultural, and social values of the Bering Sea.

The unique features of the Bering Sea contribute to its position as one of the most productive ecosystems in the world. The Bering Sea is at least a seasonal home to some of the largest marine mammal, bird, fish, and invertebrate populations among the world's seas. The North Pacific

Ocean and Bering Sea are not only some of the most productive ocean regions in the world, they also support many of the world's largest populations of groundfish, salmon, and crabs. Large-scale commercial fisheries for groundfish in Alaskan waters were developed and dominated by foreign fleets from the early 1950s until the Magnuson Fishery Conservation and Management Act (MFCMA) was passed in 1976. The domestic groundfish fishery in the Bering Sea, Aleutian Islands, and Gulf of Alaska that developed as a result of the MFCMA's passage is now a major industry with 1992 landings totaling almost 2 million mt generating ex-vessel revenues of over $600 million. When the landings and values generated by fisheries for Pacific halibut (Hippoglossus stenolepis; 1991 landings of 34,400 mt worth $110 million), crabs (1992 landings of 170,000 mt worth $305 million), and salmon (Onchorhynchus spp.; 1992 landings of 314,200 mt worth $575 million) are also considered, the commercial fisheries off Alaska generate billions of dollars each year, as well as millions of metric tons of protein for the world. Recent catches of various fishery resources off Alaska are summarized in NMFS (1993). A summary of published descriptions of the physical and biological attributes of the Bering Sea can be found in numerous publications (e.g., Hood and Calder 1981; Hood and Kelley 1974; NRC 1996).

Equally important are the many other values of the Bering Sea ecosystem. The resources of the Bering Sea, for example, have since time immemorial provided for the subsistence needs of residents of the Bering Sea region. Food, clothing, cultural artifacts, handicraft items, and economically valuable products have been taken from the Bering Sea for thousands of years by the Native inhabitants of the Bering Sea coast. These subsistence resources remain essential to the livelihood of Alaska Natives and other residents of Bering Sea coastal communities. The fate of these resources is inextricably tied to the utilization of them for commercial fishery and other purposes. Hence, the Bering Sea Ecosystem Plan is to put the evaluation of impacts on subsistence resources on an equal plane with other resources.

In addition to subsistence, The Bering Sea also provides important aesthetic, conservation, and environmental values. This region is one of the most scenic and inspirational ecosystems on the planet. It is the location of several national parks and national wildlife refuges. It contains abundant fish, wildlife, and bird populations which are the basis for a burgeoning recreational and ecotourist industry. These also are values deserving protection. The protection of these values is as dependent upon ecosystem dynamics as the highly prized economic, commercial, and subsistence resources of the region, and the Bering Sea Ecosystem Plan will address them as well.

Finally, The Bering Sea ecosystem, and the living marine resources which serve as its constituent elements, have intrinsic value in and of themselves. The extraordinarily productive Bering Sea ecosystem is unique. Nowhere else on earth can such an extraordinary assemblage of marine mammals, seabirds, and fish species be found together in a dynamic relationship that plays a vital role in the lives of the residents of the region. The unique attributes of the Bering Sea ecosystem are deserving of protection and study in and of themselves.

The declines in some seabirds and marine mammals in the Bering Sea are significant and have resulted in the listing of Steller sea lions (Eumetopias jubatus) as threatened pursuant to the U.S.

Endangered Species Act (ESA) and the designation of northern fur seals (Callorhinus ursinus) as depleted under the MMPA. Declines in piscivorous sea birds (e.g., murres and kittiwakes) on some Bering Sea islands has evoked discussions of their status relative to the ESA. The uncertainties mentioned above have been discussed at length in many reports and workshops and are summarized in Appendix I -- Review of past volumes, symposia and workshops. Participants at a 1991 workshop on "Is it food?" concluded that food was the limiting factor in most of the observed declines of sea birds and marine mammals. However, examination of the population declines in the context of the entire Bering Sea results in the paradox that most monitored stocks of groundfish species (principal prey of declining marine mammal and bird stocks) are healthy, exploited at comparatively low levels, and seem to be sufficiently abundant to provide adequate nourishment to the declining stocks. Because of these uncertainties, a broad, ecosystem-based approach to the Bering Sea is needed to elucidate the underlying causes of the declines.

The U.S. Department of State and National Research Council (NRC 1996) recently established a Committee on the Bering Sea Ecosystem and charged it with (1) evaluating the environmental factors and ecological relationships that control the Bering Sea food web, (2) evaluating the probable cause and effects of observed population fluctuations, (3) estimating historical population dynamics of marine mammals and birds, and commercially important species, (4) evaluating historical records of commercial fisheries, and (5) evaluating the relationship between biological resources and subsistence cultures of indigenous people. Results of the study are complex and difficult to summarize here; it is recommended that the reader consult the study for further evaluation. However, some of the recommendations for research and management within the NRC report are relevant to the present Bering Sea Ecosystem Study Plan (BSESP). These include the recommendation to (1) improve coordination of the many institutions and groups, (2) adopt a broader ecosystem perspective for both scientific research and management of Bering Sea resources, (3) conduct research on the structure of the ecosystem (emphasizing the cause of pollock population dynamics and the role of sea ice in structuring the ecosystem), and (4) broaden the distribution of fishing effort in space and time, especially for pollock.

Each of the earlier workshops, planning documents, and research programs summarized in Appendix I had in some form as one (or more) of its primary research recommendations the commencement, continuation and/or expansion of biological and oceanographic surveys to obtain information on distribution, age structure, population dynamics and feeding ecology of fish (with an emphasis on non-commercial forage species), marine mammals, and seabirds to overlay on an improved understanding of the dynamics of the physical environment and its links to primary production. Such broad scale ecosystem studies can be structured from the bottom-up (oceanographic physico-chemical processes affecting primary and secondary production, and eventually upper level predators), or from the top-down.

Ice cover and the accompanying formation of cold bottom water exerts an important influence on distributions of fishes over both the western (Radchenko and Sobolevskiy 1993) and the eastern shelf (Bulatov 1989; Ohtani and Azumaya 1995; Wyllie-Echeverria 1995) of the Bering Sea. A hypothesis exists that during cold years the spatial domain of age-1 pollock over the shelf is minimal (a behavioral response to temperature) and increased densities of these fish result in enhanced take by predators (Ohtani and Azumaya 1995). Cold winters with extensive ice cover, however, provide conditions that can lead to a more primary production over a shorter period of time (Niebauer et al. 1995). This could enhance success of first feeding pollock larvae and lead to a strong year class.

Examples of bottom-up ecosystem studies include Bering Sea FOCI (A in Appendix I), which specifically addresses recruitment processes of pollock, PICES' research plan for the Bering Sea (F in Appendix I), which is broader and more inclusive than FOCI, and the outline of ecosystem research topics in the program development plan published by NMFS (C in Appendix I). The other workshops outlined in B, D, and E (in Appendix I) were convened primarily to discuss recent observed declines in upper trophic level marine mammals and birds. While participants in these workshops recognized that environmental and oceanographic processes are integrally linked with responses of apex predators (c.f. El Niño), most of the studies they recommended were top-down in structure. Bottom-up programs generally have the disadvantage that they may require more years of basic data-gathering surveys than top-down programs to amass enough data to gain an understanding of a portion of the ecosystem. Furthermore, since most of the concern regarding the Bering Sea ecosystem comes from the suite of species encompassing the upper trophic levels (most commercial fish, marine mammals and birds), it may make more sense to begin detailed studies at this level. However, the principal advantage that bottom-up studies have over top-down ones is that the oceanographic processes and primary production underlying the entire ecosystem are investigated in greatest detail first, and information on successive trophic levels are added as layers upon it, yielding a more fundamental understanding of the entire ecosystem.

All living marine organisms are part of biologically and environmentally linked species groups which comprise a marine ecosystem. Stocks within a marine ecosystem fluctuate considerably and in many cases change over periods of decades and usually involve a change in dominance of one species over another. These natural fluctuations are further influenced by environmental processes and ecological perturbations, as well as by the direct influence of fisheries, habitat alterations, and pollution. Consequently, more attention needs to be focused on all factors governing variation in population abundance and the affects of these fluctuations on ecosystem function.

Just as most species are not harvested in isolation, they cannot be managed in isolation. The manager must understand inter-species relationships to manage interrelated fisheries and the systems in which they occur. This includes understanding the nature of normal variations in abundance of individual stocks. Assessment of these factors is dependent upon having a well structured and integrated research program that is directed at generating knowledge about biological, oceanographic, and economic processes associated with living marine resources. The interrelationships that exist between these processes requires that a holistic approach be taken in examining them.

A holistic approach to research monitoring and management of living marine resources is now feasible because of advances in technology and systems modeling methods. These technological advances, along with the long history of local, traditional knowledge in Alaska, facilitate a shift in living marine resource program efforts toward a multi-species/ecosystem approach.

Such an approach is planned for the BSESP with the intention to coordinate and integrate this study with two parallel studies planned for the Bering Sea. The first, the Southeast Bering Sea Carrying Capacity study (SEBSCC), is a collaborative effort coordinated by the University of Alaska, Pacific Marine Environmental Laboratory (NOAA), and NMFS. Goals of the SEBSCC study are to (1) increase understanding of the southeastern Bering Sea, (2) document the role of juvenile pollock by examining the factors that affect their survival, and (3) develop and test annual indices which reflect the status and vitality of the ecosystem, including a measure of juvenile abundance. Specific study proposals were being evaluated during the period of the BSESP development.

The second is a joint research plan between the North Pacific Marine Science Organization (PICES) and GLOBEC International to study processes underlying Climate Change and the Carrying Capacity (the Four C's) of the North Pacific of which the Bering Sea is a regional, basin scale component. U.S. GLOBEC is presently considering which areas, the Bering Sea or the Gulf of Alaska, to solicit proposals for possible studies in the future.

A significant effort will be made in the implementation of the BSESP to incorporate and utilize results from these (and past) studies and not to fund studies which are redundant to other efforts. For instance, studies into the factors affecting walleye pollock recruitment are vital to understanding the Bering Sea ecosystem and must be an integral component of the BSESP. However, these studies need not be specifically addressed in the BSESP since they are the focus of the SEBSCC study. Similarly, many of the studies to assess physical oceanography and the relationship between environmental factors and primary and secondary production will likely be completed under the auspices of PICES CCCC.

One of the significant differences between the BSESP (and the BSIS Program) and other research efforts will be the inclusion of traditional ecological knowledge and wisdom (TEKW) into the study plan. It is envisioned that this information will be vital to the development of hypotheses to be tested in specific studies discussed below.

The Bering Sea Ecosystem Program will coordinate two interrelated research tracks: The Alaska Native component; and a component that involves standard scientific studies. While these two tracks may function independently to some extent, they will be part of a single, unified plan that will give equal importance and support to the two components.

With respect to the Native component, there will be two ways in which ANOs participate. First, the Alaska Native community will coordinate among its own people to develop their own research and monitoring plan that addresses the objectives of the overall Bering Sea ecosystem study. Initially, the Alaska Native coastal communities of the Bering Sea will focus their efforts on formalizing a communication process between the communities, and develop the environmental parameters to be observed and exchanged. For example, efforts will be made to assess the technological and financial feasibility of establishing a computerized communication network and bulletin board focused first on the Alaskan side of the Bering Sea, then Bering Sea-wide. In addition, principles, processes, and protocols will be developed for the gathering and use of TEKW. TEKW is that body of knowledge, ways of knowing and understanding the environment gained by traditional processes established by Alaska Natives. It may involve knowledge, history and experience from past generations orally transferred, and/or actual experience and information gained from and validated by the collective understanding of a community. The Native component of the overall plan will establish a framework and protocols for the development and use of TEKW, so that it can be directly incorporated into the substantive tasks of the Native and standard scientific components of the Bering Sea study. The use of TEKW will be one of the distinguishing features of the Bering Sea ecosystem study.

With assistance from scientists, the communities will construct a framework and the parameters for monitoring in the Bering Sea by coastal participants. It is envisioned that the focus of any monitoring and information exchange shall be on the possible causes for declines of various higher trophic species in the Bering Sea, local observations of activities or conditions which may aid in research and management, and the identification of any events or activities which may affect human health and the viability of the subsistence way of life and coastal cultures. The goal of the monitoring and information exchange between coastal communities shall be to establish a unique and invaluable database which can assist the communities in their advocacy for the Bering Sea and coastal cultures, as well as to assist the government agencies in better targeting their research and management efforts.

Research and monitoring by Alaska Natives will be designed and conducted by Alaska Natives will be designed and conducted by local peoples of the Bering Sea according to the Native view of the world, although the communities may consult with scientists and managers. This effort to gather and use TEKW will have its own system of validation and be considered independent of the work conducted by other researchers. It is envisioned that the Native community will establish a team of independent scientific advisors to assist the coastal communities in responding to proposals for research and management by government agencies.

The second component will be for qualified ANOs to participate directly in the standard research efforts by conducting appropriate studies and other activities of the federal agencies. As noted above, Congress has indicated that such research should be conducted to the maximum extent in the Bering Sea region and that contracts and other arrangements should be made with ANOs to undertake such work. There are a variety of ANOs that can play an integral and productive role in this research, and their services will be utilized by the appropriate federal agencies carrying out their duties under the plan.

OBJECTIVES OF THE BERING SEA ECOSYSTEM STUDY PLAN

As noted above, The Bering Sea Ecosystem Research and Monitoring Program is intended to serve the dual purpose of establishing a new approach to the study of living marine resources that does not focus on single-species approaches, and developing a collaborative research approach between agency scientists and residents of coastal communities. It is hoped that the results of this research program will ultimately lead to improved management actions as well. Ultimately, the purpose of this research is not simply to gather information and conduct studies for their own sake. As requested for many years by residents of the Bering Sea region, a new management approach is needed for this region that puts a focus on ecosystem relationships and ensures the long-term viability of the entire region. The ultimate objectives of this research program, therefore, is to provide the basis for identifying and evaluating better and more effective approaches to manage Bering Sea resources for their long-term productivity and continued sustainability for the full range of values reflected by this unique environment.

1. To provide information, including TEKW, that will contribute to monitoring the health and maintaining biodiversity of the Bering Sea ecosystem.

2. To monitor key components of the Bering Sea ecosystem.

3. To investigate potential causes of depletion of major taxa of marine mammals, seabirds, and other living resources of the Bering Sea ecosystem.

4. To conduct research and monitoring efforts in conjunction with ANOs, government and academic research institutions, independent researchers, and citizens.

5. To use TEKW, other long term databases, and workshop recommendations in the pursuit of research and monitoring goals.

6. To serve as a platform for recommending management alternatives.

Inherent in these objectives, and all studies conducted under the auspices of this plan, are the following suggestions.

- The studies should address questions that can be answered and that are relevant to the problem.

- The overall effort should include monitoring studies as well as hypothesis testing.

- The Plan and its studies should involve the qualified government and private sector entities, as well as non-profit entities and academic institutions, regardless of legislative responsibilities and jurisdiction. As required by section 110(d)(1), qualified Alaska Native Organizations will be included as an integral part of this Plan and its studies.

- All studies should provide opportunities for training of Alaska natives, other minorities, and interested citizens with the ultimate goal of these citizens being responsible for the conduct of monitoring natural resource utilization.

(the following section may be deleted after review by ANOs and inclusion of their text)

The following principles were adopted in May 1993 by the Alaska Federation of Natives Board of Directors to enhance the involvement of natives in ecosystem research, and will be considered in the development of the Plan.

1. Protect the sacred knowledge and cultural/intellectual property of native people.

2. Hire and train native people to assist in the study.

3. Use native language whenever English is the second language.

4. Guarantee confidentiality of surveys and sensitive material.

5. Include native viewpoints in the final study.

6. Acknowledge the contributions of native resource people.

7. Inform the Native Research Committee in a summary and in non-technical language of the major findings of the study.

8. Provide copies of reports to the local library.

PRIMARY ISSUES AND QUESTIONS PERTAINING TO THE BERING SEA ECOSYSTEM STUDY PLAN

The following issues and questions are based on key scientific questions and unmet research needs, particularly those concerning marine mammals and birds, identified at the November 2-3, 1995 workshop in Anchorage and by previous related workshops and panels. The narrative of the step-down outline in Appendix II includes detail on all elements of a research plan for the Bering Sea. However, many of those elements are already being addressed by existing research programs or are being proposed for research under the SEBSCC. The research plan contained here focuses on research questions and activities that would be complementary to existing and proposed research programs in the Bering Sea. In addition, this research plan will include research on subsistence use of resources and incorporate TEKW, as appropriate, into the conduct of the research. Monitoring the health and stability of the Bering Sea ecosystem has been specified in the MMPA amendment as a component of this research program. As other research programs have recognized, a balanced ecosystem research effort requires research activities in all of the following areas: retrospective analysis, development of numerical models, ecosystem process studies, and monitoring.

The main scientific issue behind the development of this research plan is to explain the causes of population declines, particularly of marine mammals and sea birds, in the Bering Sea. Although marine mammal and sea bird research is currently being conducted in the Bering Sea by NMFS, USFWS, NBS, ADFG, University of Alaska, and others, there are critical gaps in the research effort. There is a lack of information on key life history parameters, seasonal distribution, foraging areas, bioenergetics, and ecosystem processes involving marine mammals and sea birds. Key scientific questions and research activities required to address the questions constitute the research plan. These questions provide the necessary focus to collect information that is most important in dealing with the main scientific issue.

The key scientific questions include those related to physics, habitat, ecosystem, marine mammals and sea birds, fisheries and trophic interactions, and ANOs concerns.

Habitat

- How have toxic substances and industrial waste affected marine mammals and sea birds and habitat of special biological significance to them?

- How important is the near-shore zone to marine mammals and sea birds and have there been changes (natural or human-induced) in this zone that have affected them?

Ecosystem

- How do bottom-up processes, such as climate and its relationship to primary and secondary production, affect marine mammal and sea bird populations?

- How important are top-down processes (e.g., predation and competition) involving marine mammals and sea birds in structuring the Bering Sea ecosystem?

- How does sea ice and its related biophysical processes affect the ecosystem both top-down and bottom-up?

Marine mammals and sea birds

- What changes have occurred and are occurring in the biological characteristics (such as growth, size/age at maturity, distribution, abundance, survival, and reproductive success) of marine mammal and sea bird populations?

- What factors induce change in biological characteristics (such as growth, size/age at maturity, distribution, abundance, survival, and reproductive success) of marine mammals and sea birds?

Fisheries and trophic interactions

- What are the effects of commercial fishing (such as the removal of fish biomass, return of discards and offal to the sea, pulse fishing, trawl exclusion zones, and the impact of fishing gear on the sea floor and its associated fauna) on marine mammal and sea bird populations?

- What changes have occurred and are occurring in the biological characteristics (such as growth, size/age at maturity, distribution, abundance, survival, and reproductive success) of marine mammal and sea bird prey and competitors?

- What factors induce change in biological characteristics (such as growth, size/age at maturity, distribution, abundance, survival, and reproductive success) of marine mammal and sea bird prey and competitors?

ANOs concerns

- What are the historical and current subsistence uses of Bering Sea resources, particularly marine mammals and sea birds, and how can these be sustained?

- How can the use of TEKW be institutionalized by the Alaska Native community and shared between member communities, researchers, and managers?

The key research activities required to address the above questions include retrospective analysis of existing information, development of numerical models of various aspects of the ecosystem, experimental studies (field or laboratory) designed to gain information on ecosystem processes, and monitoring of important physical and biological parameters.

Retrospective analysis

- Retrospective analysis of existing information, particularly TEKW, on nearshore habitat changes in the Bering Sea and the use of this zone by marine mammals and sea birds.

- Retrospective analysis of existing information on population dynamics and spatial distribution of marine mammals, sea birds, commercially important species, and fishing removals of the Bering Sea, their interrelationships and factors contributing to their fluctuations.

- Retrospective analysis on the subsistence use of Bering Sea resources.

Modeling

- Develop models of the fate of contaminants from military bases and industrial sites.
- Develop models of marine mammal and sea bird population responses to fishing removals of prey.
- Develop spatially-explicit models of marine mammal and sea bird foraging demand, migration, and bioenergetics that could be linked to physical circulation models, larval and juvenile pollock models, and other upper trophic level models of the Bering Sea.

Process

- Perform electronic tagging experiments on marine mammals and sea birds to determine how their behavior (foraging depth, trip duration and distance, etc.) is related to the physical and biological environment.
- Develop an experimental approach to the manipulation of no-fishing zones, particularly around pinniped rookeries.
- Develop an institutionalized process in which information, observations, and experiences about the environment can be shared between the member communities of the Bering Sea on a formalized basis.
- Determine how marine mammals and sea birds foraging behavior responds to changes in prey abundance and availability.
- Develop alternate methods of population survey for cetaceans and more northerly populations of marine mammals.
- Develop appropriate indices for monitoring changes in health and condition of marine mammals and sea birds at the individual and population levels.
- Develop improved techniques for capture, restraint, marking, and monitoring of individual birds and mammals to improve information needed for monitoring.

Monitoring

- Monitor contaminant levels in key habitats of marine mammals and sea birds.
- Monitor contaminant levels in marine mammals, sea birds, and their key prey.
- Seasonally monitor marine mammal and sea bird abundance, life history characteristics, diet,

and other important biological variables at key index sites.

- Seasonally monitor physical environmental variables and primary and secondary production at key index sites of marine mammals and sea birds.

- Seasonally monitor marine mammal and sea bird prey and competitor abundance, life history characteristics, and diet at key index sites.

- Monitor subsistence use of Bering Sea resources.

- Monitor sea bird and marine mammal abundance/attraction to fishing vessels and consumption of fishery discards and offal by birds and mammals.

- Monitor population trends of scavenging sea birds.

- Estimate sea bird mortality induced through fisheries via continued use of NMFS observer program.

STEP-DOWN OUTLINE OF THE BERING SEA ECOSYSTEM STUDY PLAN

See Appendix II for the narrative for the step-down outline. Letters following each item designate a suggested priority for accomplishment, where H = high, M = medium, and L = low priority. (to be assigned later)

1. <u>Identify Major Perturbations and Influences</u>

2. <u>Identify Habitat of Special Biological Significance</u>.
   21. Identify current and historical use areas.
   22. Determine seasonal use patterns.
   23. Document effects of disturbance caused by human activities.
      231. Toxic substances.
         2311. Heavy metals.
         2312. Persistent organic pollutants (POPs).
         2313. Radionuclides.
      232. Commercial fishing operations
         2321. Concentrated fishing around rookeries.
         2322. Return of fishery discards and fish processing offal to the sea.
         2323. Effect of fishing gear on the bottom and bottom animals.

3. <u>Investigate physical and chemical processes of importance to primary and secondary production</u>.

31. Gather Climate information, including:
    311. Wind fields.
    312. Temperature and atmospheric pressure.
    313. Rainfall.
    314. Freshwater discharge.
    315. Ice.
32. Gather physical oceanographic information, including:
    321. Processes and patterns, i.e., upwelling, eddy and circulation structures, tidal and swell characteristics, wave height and intensity.
    322. Larger system influences, one or two scales beyond local influences, i.e., major currents, hemispheric and oceanwide.
    323. Seasonal thermo-haline characteristics, including fronts, ice-edge, thermocline and cold-pool.
33. Gather information on nutrients.
    331. Nutrient field structure.
    332. Nutrient dynamics.

4. <u>Investigate biological processes</u>.
  41. Primary production.
  42. Secondary production and grazing impact.
    421. Zooplankton.
    422. Bacteriozooplankton and microzooplankton.
  43. Upper trophic levels.
    431. Marine birds.
      4311. Population assessment (abundance and distribution).
      4312. Population indices.
        43121. Mortality.
        43122. Reproduction.
        43123. Health and Condition.
      4313. Characteristics of diet.
      4314. Predator-prey relationships.
    432. Marine mammals.
      4321. Population assessment (abundance and distribution).
      4322. Population indices.
        43221. Mortality and reproduction.
        43222. Health and condition.
      4323. Characteristics of diet.
      4324. Predator-prey relationships.
    433. Mammal and bird prey species.
      4331. Population assessment (abundance and distribution).
      4332. Population life history parameters.
        43321. Mortality.
        43322. Reproduction.

43323. Health and condition.
4333. Characteristics of diet.
4334. Predator-prey relationships.
434. Marine mammal and bird competitors.
4341. Population assessment (abundance and distribution).
4342. Population life history parameters.
43421. Mortality.
43422. Reproduction.
43423. Health and condition.
4343. Characteristics of diet.
4344. Predator-prey relationships.

5. Incorporate Traditional ecological knowledge and wisdom (TEKW)

6. Model the Bering Sea ecosystem.

7. Integrate and evaluate studies annually.

IMPLEMENTATION OF THE PLAN

including data management

(to be completed after meeting with ANOs)

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Appendix I

REVIEW OF PAST VOLUMES, WORKSHOPS, AND SYMPOSIA

The published proceedings of the volumes, workshops, symposia, and the NMFS program development plan for ecosystem monitoring and fisheries management provide both a conceptual framework for a comprehensive research program and direction for specific areas of study. The following provides an overview, in chronological order, of some of the more relevant documents, as well as a summary of their recommendations.

A. Proceedings of the workshop on walleye pollock and its ecosystem in the eastern Bering Sea, May 2-4, 1983. NOAA Technical Memorandum NMFS F/NWC-62 (D. Ito, ed.), U.S. Dept. Commerce., NOAA, NMFS, Seattle, WA 98115, August 1984.

In 1981, an Ecosystem Working Group was formed at the Northwest and Alaska Fisheries Science Center of NMFS to encourage researchers to conduct their analyses in an ecosystem context, to enhance communication among researchers in various disciplines, and to promote examination of the functional interrelationships of ecosystem components. One of the first recommendations of the group was to convene a pollock ecosystem review workshop to develop conceptual models of the biophysical and fisheries systems and to identify gaps in understanding and existing data. Workshop participants noted the coordinated fishery/oceanographic research begun two years earlier in the Gulf of Alaska (NMFS' Alaska Fisheries Science Center and the NOAA's Pacific Marine Environmental Laboratory Fisheries Oceanography Coordinated Investigations, or FOCI) and suggested that a similar program begin in the Bering Sea to gain greater understanding of the role of biological and physical factors in pollock population dynamics. The oceanographic portion of Bering Sea FOCI began 5 years later in 1989, while the biological/fisheries component began in 1994.

B. Proceedings of the workshop on biological interactions among marine mammals and commercial fisheries in the southeastern Bering Sea, October 18-21, 1983, Anchorage, AK. Alaska Sea Grant Report 84-1, University of Alaska, Fairbanks, Alaska 99775, April 1984.

This report documents the discussion of workshop participants, convened by Alaska Sea Grant, on the interactions between marine mammals and four types of fisheries in the southeastern Bering Sea: groundfish, herring, salmon, and shellfish. The objectives of each group were to: 1) identify marine mammal species that are known to be or could be affected by the fishery; 2) indicate the nature and probable significance of the interactions; 3) determine whether existing data, models and research/monitoring programs were sufficient to predict, detect, and mitigate any possible adverse effects of interactions on marine mammals, the exploited species, or the fishery; 4) identify any critical data gaps; 5) suggest how critical data gaps could be filled; and 6) rank research needs in order of priority. High priority research needs of each of the groups were: feeding ecology of marine mammals; distribution (both geographically and with depth) and diet of marine mammals by area, season, age and sex; and population dynamics and factors affecting recruitment and distribution (seasonal and geographic) of both exploited and non-commercial prey species. Recommended methods of obtaining data on feeding ecology of marine mammals included tagging/tracking studies and analyses of stomach contents, scats and teeth to determine what is being eaten where and by whom, and oceanographic and biological surveys to determine the abundance, distribution and species composition of the prey available to marine mammals at the same times and locations.

C. National Marine Fisheries Service program development plan for ecosystems monitoring and fisheries management, NMFS, Washington, DC, September 14, 1987.

This plan provides a discussion of the general considerations involved in the development and implementation of broad-scale ecosystem programs. Although written from a national perspective, the contents are relevant to a program tailored specifically for the Bering Sea. The plan includes descriptions of the underlying justifications for such programs, a template for program structure, and program management considerations. An appendix includes an outline of ecosystem research topics and data needs, which was used as a framework for the construction of the Bering Sea Ecosystem Study Components section of the present document. Much of the step-down outline below was adapted from the NMFS Plan.

D. Conference on Shared Living Resources of the Bering Sea Region, June 6-8, 1990, Fairbanks, Alaska. Counsel on Environmental Quality (R. Townsend).

Summary not available as of January 15, 1997.

E. Uncertainties and research needs regarding the Bering Sea and Antarctic marine ecosystems, December 12-13, 1990, Seattle, WA. U.S. Dept. Commerce., Natl. Tech. Info. Serv. PB91-201731 (Swartzman, G. L., and R. J. Hofman), Springfield, VA 22161, July 1991.

This workshop was convened by the Marine Mammal Commission (MMC), in consultation with NMFS and Alaska Sea Grant, to: (1) identify critical uncertainties concerning the causes and possible relationships among the observed declines in various marine mammal and seabird populations in the Bering Sea over the previous 20 years, (2) identify the research that would be required to resolve the uncertainties; and (3) determine how experience in the Bering Sea/Gulf of Alaska and the Antarctic might be used to improve research planning and resource management in both area. Uncertainties in understanding and recommendations for research were listed for marine mammals, seabirds, fish and fisheries, and oceanography and primary production. Principal research recommendations for the first three biological components were improvements in techniques for estimating vital rates (e.g., size, mortality, births, energy flow) of populations (particularly for cetaceans, seabirds and some fish stocks, and in areas outside the Bering Sea for seasonal migrants), greater understanding of their seasonal distributions, and studies specifically designed to investigate the specific effects of fisheries on prey availability and population dynamics of fish and other species in upper trophic levels (including non-commercial species). With regard to Bering Sea oceanography and primary production, workshop participants recommended the establishment of a long-term monitoring program of primary, secondary and benthic production, as well as environmental parameters at a series of stations located on cross-shelf and slope transects in at least the western and northern Bering Sea. Participants also recommended that a formal or *ad hoc* working group, like CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources) in the Antarctic, be established to plan and coordinate results of resource-related research in the Bering Sea and Gulf of Alaska.

F. Is it food? Addressing marine mammal and seabird declines, March 11-14, 1991, Fairbanks, AK. Alaska Sea Grant College Program Report AK-SG-93-01, University of Alaska, Fairbanks, AK, 99775, 1993.

The emphasis of this workshop organized by Alaska Sea Grant was to attempt to answer the dual questions of: Is food availability the key to declining marine mammal and seabird populations in the northern Gulf of Alaska and Bering sea?; and if so, What are the causes of reduced food availability (oceanographic/environmental changes, or human activities, principally fishing)? While workshop participants agreed that changes in quality and quantity of prey were most likely major contributors to observed declines in marine mammal and seabird population sizes, no consensus was reached on the factor(s) responsible for such changes. Structured similarly to the workshop summarized in D above, the workshop subgroups recommended research in feeding ecology of marine mammals and seabirds, with specific attempts to ensure the availability of small or young fish as prey, improvements in methods and funding for studies to monitor species demographics (e.g., population size, age structure, vital rates), initiation of studies on distribution, population dynamics and nutritional value of non-commercial prey species, and expansion (seasonally and geographically) of pre-recruit surveys of commercial species (e.g. pollock).

G. North Pacific Marine Science Organization (PICES), Bering Sea Working Group meetings, 1993-94 (latest in July 1994, Seattle, WA, A. V. Tyler, Chair).

PICES represents an international effort of countries bordering the North Pacific Ocean and Bering Sea to coordinate and plan scientific research to better manage the living marine resources of the region. The organization is loosely patterned after the ICES (International Council for Exploration the Sea) in the North Atlantic, and to a lesser degree, CCAMLR. The Bering Sea Working Group of PICES met recently and proposed a series of research questions that it considered important for understanding environmental and ecosystem function in the Bering Sea. The questions, organized into major ecosystem components, were predicated on group consensus on three points: (1) the abundance of animals in the Bering Sea fluctuates widely in time; (2) organisms live in both physical and biotic environments, and both warrant integrated study; and

(3) comparative studies of the Bering Sea and other boreal ecosystems could provide significant insights. The major ecosystem components and research topics identified by the group are:

- Biology of predator-prey relations - assessment surveys of non-commercial fish and cephalopods, identification of nodal species and investigations of their population dynamics and distribution, specific effects of commercial fisheries on the Bering Sea food web, particularly upper trophic levels (marine mammals and birds).

- Deep Bering Sea basin waters - sources, residence time, lateral and vertical fluxes of nutrients and anthropogenic materials (e.g., radionucleotides, chlorinated and organic hydrocarbons), biological and physical interactions with shelf waters

- Influence of ice formation on Bering Sea productivity - effects of annual variation in southern location of ice edge on primary production regime (timing, magnitude, duration, and intensity of spring bloom), role of ice edge over the entire south to north retreat, examination of recurrent polynyas in the northern Bering Sea.

- Decadal scale environmental changes - mechanisms, magnitude, and effects of decadal/centennial scale variability in atmospheric and oceanic conditions on biological communities.

H. Long-Term Databases

Long-term research has been conducted annually on critical aspects of physical, geological, and biological elements of the Bering Sea Ecosystem by individuals and institutions independent of formal international working groups. For example, a recent project named Processes and Resources of the Bering Sea Shelf (PROBES) was established at the University of Alaska. Other projects are housed at institutions including the Alaska Department of Fish and Game, the National Marine Fisheries Service, the University of Alaska, the University of California at Irvine, and the United States Fish and Wildlife Service. Annual monitoring efforts have been conducted, in some cases, for over 50 years and represent a tremendous resource of baseline data for on-going research.

I. Report on the Workshop on Enhancing Methods for Locating, Accessing and Integrating Population and Environmental Data Related to Marine Resources in Alaska. 1992

The primary goals of this workshop were to:

- Identify the data types critical to the conservation of marine mammals and other marine resources in Alaska, and the organization collecting and maintaining those data.

- Determine how these data can be made available to other individuals and agencies.
- Describe current geographic information systems (GIS) used by different groups.
- Determine and recommend actions to develop a common or coordinated GIS or other data networks.

The workshop was held as a result of the findings of a 1992 study contracted by the Marine Mammal Commission entitled "Assessment and possible use of a cooperative/coordinated GIS to facilitate access to, and integration and analysis of, data bearing upon the conservation of marine mammals in Alaska." The study results suggested that the development of a coordinated GIS would enhance the efficiency and utility of existing databases presently maintained independently by various agencies and organizations.

J. The Bering Sea Ecosystem, Committee on the Bering Sea Ecosystem, Polar Research Board, Commission of Geosciences, Environment, and Resources, National Research Council. February 1996. 324 pp.

Concerned about the future of the Bering Sea ecosystem, The U.S. Department of State asked the National Research Council (NRC) to study the available scientific and technical information on the Bering Sea ecosystem, focusing particularly, on environmental factors that influence natural variability in populations of marine mammals, seabirds, and fish. To respond to the charge, the NRC's Polar Research Board established the Committee on the Bering Sea Ecosystem. The charge to the study committee was to review and evaluate:

- Environmental factors and ecological relationships that control the Bering Sea ecosystem, including atmospheric and ocean circulation patterns, biological production pathways, and energy transfer within the food web.
- The life history, distribution, and population dynamics of commercially important species, with special emphasis on species that migrate through international waters or into the United States or Russian exclusive economic zones; and the probable causes and effects of their population fluctuations.
- Estimates of historical population dynamics of marine mammals, seabirds, and commercially important species of the Bering Sea, their interrelationships, their current status, and the factors contributing to their population fluctuations.
- The historical records of the commercial fisheries of the Bering Sea.
- The relationship between the biological resources of the Bering Sea and (a) subsistence cultures and economies of indigenous peoples, (b) commercial fisheries and other users, and

(c) the assemblage of organisms that constitute the biological component of the Bering Sea ecosystem.

The study resulted in a printed report available from the National Academy Press. The report concludes with a summary of gaps in knowledge and recommendations for research and management of Bering Sea resources.

K. Planning Workshop for Southeast Bering Sea Carrying Capacity, Battelle Seattle Conference Center, Seattle, WA, November 1995. 51 pp.

This planning workshop was convened to develop a request for proposals (RFP) to implement a study to be funded by NOAA's Coastal Ocean Program Ecosystem Study in the southeastern Bering Sea. The conceptual model for the study proposes that juvenile walleye pollock are a nodal species in the Bering Sea ecosystem in utilizing high primary and secondary productivity and providing food for the pelagic upper trophic level species, including adult pollock. The studies intend to examine pollock in terms of linkages to other species. The specific goals of the study are to document the role of juvenile pollock in the eastern Bering Sea ecosystem, to examine the factors which affect their survival, and to test annual indices of pre-recruit abundance. The planning workshop further developed hypotheses to be addressed in the RFP by potential investigators and resulted in a final plan for the study. Specific proposals addressing these hypotheses were submitted and reviewed during early 1996.

Appendix II.

NARRATIVE OF THE STEP-DOWN OUTLINE

1. Identify Major Perturbations and Influences

Physical processes such as coastal erosion and ice conditions could influence habitat quality and size for different marine organisms in the Bering Sea. Polling local villages would assist in the identification of changes in habitat or distribution of marine organisms.

Human effects identified as possible sources of major perturbations and influences were: toxic substances found at military sites, waste from industrial sites (mines and nuclear plants), and commercial fishing operations which remove fish biomass, return discard and fish processing offal to the system, and impact bottom fauna through trawling.

2. Identify Habitat of Special Biological Significance.

The near-shore zone (intertidal/subtidal) was identified during working group discussions as needing additional attention. Feeding zones around marine mammal and bird rookeries and marine mammal haulout sites are especially critical. Depending on season and species these zones could be quite extensive.

21. Identify current and historical use areas. Substantial data exist on distribution at sea of northern fur seals and some marine bird species. Retrospective data analysis should be performed to identify historical use areas and possible time trends in the location or size of those areas .

22. Determine seasonal use patterns. Many gaps exist in seasonal use patterns of habitat use. Monitoring schemes need to be developed to determine these patterns.

23. Document effects of disturbance caused by human activities.

231. Toxic substances. Levels of toxic substances in the Bering Sea and their effects on the ecosystem are poorly understood. This section will address all toxic substances which impact the Bering Sea Ecosystem, including anthropogenic and natural sources. It follows the general outline of the eight-nation Arctic Monitoring and Assessment Programme (AMAP) report. High Priority

2311. Heavy metals. All heavy metals should be studied, but particularly those targeted by AMAP - Cd, Cu, Hg, Pb, Zn, Cr, Ni, As, Se, Al, V, Fe, Li. It has also been recommended that Hg and Se be investigated and reviewed simultaneously due to the prophylactic effect of Se to Hg toxicity. Likewise the impact of Cd on the increased uptake of some Persistent Organic Pollutants (POPs) needs to be investigated. There may also be synergistic effects from exposure to multiple heavy metals, or metals in concert with POPs or other environmental stressors. High priority.

2312. POPs. This study should focus on the POPs targeted by AMAP, including PAH, Planar PCBs, total PCB, DDT/DDE/DDD, HCH, HCB, Chlordane, Dieldrin, Toxaphene, Dioxins/PCDD, Dibenzofuran/PCDF and Mirex. Lindane (g-HCH) may also be present in high concentrations. An expanded sampling network should be established to meet AMAP requirements. In addition, more effort should be focused on ecosystem fate and effects of these chemicals. High priority.

2313. Radionuclides. AMAP targeted items include Gross gamma, Gross beta Cs137, Cs134, Sr90, Te99 and Pb210. Studies should include Russian, U.S. and other sources and their fates and effects in the ecosystem. High priority.

232. Commercial fishing operations

2321. Concentrated fishing around rookeries. The NRC report (1996) concluded that the concentrated fishing for pollock in some places probably reduces the availability of food for marine mammals and birds. Development of an adaptive management strategy that involves an experimental approach to the manipulation of no-fishing zones, particularly around rookeries, would be important.

2322. Return of fishery discards and fish processing offal to the sea. Analysis of the current amounts of discard and fish processing offal being returned to the sea by NMFS indicated that amounts of offal being returned were substantially larger than discard amounts. Most offal and discards appear to be from walleye pollock. Examination of groundfish predator diets indicated that offal was consumed by the same species that also were regular predators on pollock. This is an indication that normal energy pathways are not necessarily being disrupted by the current practices of returning discards and offal to the sea. Research conducted on scavenging birds in the North Sea, however, indicated the possibility that discards and offal could result in increasing population size of scavenger populations. More research is required on scavenging bird populations in the Bering Sea, including monitoring of population trends and observing bird densities and offal and discard consumption around fishing boats and processing operations.

2323. Effect of fishing gear on the bottom and bottom animals. Current research on the effect of fishing gear on bottom and bottom-dwelling animals shows that most long-term effects from mechanical disturbance on the bottom tend to be in deeper waters. Mortality of bottom-dwelling animals by fishing gear is most important for longer lived animals such as clams. More research on the effects of fishing gear on the bottom need to be done specifically in the Bering Sea. Critical to this research effort is obtaining information on the current state of the benthic community of animals inside and outside of no-trawl zones.

3. Investigate physical and chemical processes of importance to primary and secondary production.

31. Gather climate information.

311. Wind fields. Wind fields are measured adequately over much of the Bering Sea through a network of shore-based meteorological stations and through ship-board observations. However, if process studies involving wind speed are conducted, more spatially and temporally intense measurements would be necessary. Medium priority.

312. Temperature and atmospheric pressure. Both of these parameters are adequately measured for monitoring purposes, but not for process studies. Low priority.

313. Rainfall. Rainfall is adequately measured. Low priority.

314. Freshwater discharge. Freshwater discharge is monitored adequately in the US through a network of gauges stationed at major rivers draining into the Bering Sea. Information from the Russian side, which may be important, is sparse. High priority to get Russian data.

315. Ice. Ice formation and melting are important processes controlling Bering Sea primary and secondary production and influencing marine populations. To understand ice processes better, routine monitoring of radiation, albedo, and characteristics such as thickness, extent and rate of melting of the ice pack are required. Radiation measurements can be made from a network of sites on Bering Sea islands and on board ships. Albedo can be measured via airplanes or by remote sensing, but the extent of current albedo observations is unknown. Ice thickness, extent, formation and melting rate can be measured through a combination of remote and in situ observations, some of which are available. None of these parameters are adequately monitored at present. Radiation and albedo measurements are of low priority, while understanding ice characteristics is of high priority.

32. Gather physical oceanographic information.

321. Processes and patterns, i.e., upwelling, eddy and circulation structures, tidal and swell characteristics, wave height and intensity. Biomass yields at higher trophic levels in the Bering Sea ecosystem are intimately linked to nutrient fluxes and their attendant primary and secondary production. Waters of the Bering Slope Current bathe the upper slope and shelf break with relatively warm saline nutrient rich water. Eddies provide one mechanism that results in a flux of nutrients onto the shelf. In spring, large numbers of pollock larvae and other plankton are associated with eddies over the slope. Other processes contribute to fluxes onto the shelf. Regardless of mechanism, one central result is a highly productive "Green Belt" and associated higher trophic level populations along the shelf edge. Candidates for monitoring the behavior of the Bering Slope Current include moored instruments, synthetic aperture RADAR (SAR), satellite altimetry, and satellite tracked buoys. A better understanding of dynamics, however, would

permit refinement of techniques mentioned above, and development of other monitoring strategies. Toward this goal, it is paramount to have a circulation model whose domain includes the Bering Sea and some of the adjacent North Pacific Ocean. Once such a model is able to reliably simulate observations, it could be used to provide a monitoring tool while assimilating actual observations. The priority for research on these processes and for model development is high.

322. Larger system influences, one or two scales beyond local influences, i.e., major currents, hemispheric and oceanwide. These far-field forcing functions, mostly from outside the Bering Sea proper, can have significant influence on processes within the ecosystem. These features are adequately understood, but further research is needed to determine their specific effects on the ecosystem. High priority.

323. Seasonal thermo-haline characteristics, including fronts, ice-edge, thermocline and cold-pool. These features are extremely important to Bering Sea ecosystem processes. Knowledge of these features and their effects on production and behavior of marine populations is not well understood. The processes responsible for the nutrient flux at both the shelf break (Green Belt) and inner (structural) front have not been determined, nor have the related biophysical mechanisms that make these features the focus of marine mammal, fish, bird activity. Research, particularly of the inner front (both around the Pribilof Islands and throughout the southeastern shelf from the vicinity of Unimak Pass to Nunivak Island) is required to understand the role of this feature in the ecosystem. Routine monitoring is also necessary to elucidate the temporal and spatial behavior of the fronts. High priority.

33. Gather information on nutrients.

331. Nutrient field structure. Nutrient field structure is of significant importance to understanding primary and secondary production processes. While the link between nutrient field structure and production is understood, more data would be required for process studies. High priority.

332. Nutrient dynamics. Same as nutrient field structure.

4. Investigate biological processes.

41. Primary production. Investigate phytoplankton spatial distribution, its relation to the physical and chemical environment, and annual seasonal cycles and interannual variability. These measurements should include species and size composition, numbers and biomass, and primary production. High priority.

42. Secondary production and grazing impact.

421. Zooplankton. Investigate zooplankton spatial distribution, relation to physical environment, annual seasonal cycles and interannual variability of following the parameters: dominant species, populations numbers and biomass trophic structure of zooplankton communities, grazing impact and secondary production. High priority.

422. Bacteriozooplankton and microzooplankton. Conduct studies to assess numbers, spatial distribution of biomass, temporal variability, and their role in pelagic energy transfer. Low priority.

43. Upper trophic levels.

431. Marine birds.

4311. Population assessment (abundance and distribution). The Bering Sea Ecosystem supports a wide variety of seabirds and several species of sea ducks. Data on abundance and distribution of marine bird species were minimal prior to initiation of Outer Continental Shelf Environmental Assessment Program (OCSEAP) studies in 1975. Since then, research efforts by U.S. Fish and Wildlife Service (USFWS), Minerals Management Service (MMS), National Biological Service (NBS), National Park Service (NPS), University of Alaska at Fairbanks (UAF), University of California at Irvine (UCI), Alaska Department of Fish and Game (ADF&G), and others have provided more information. Studies have concentrated on summer distribution and abundance, and on the more accessible, cliff-nesting species. However, there is little information on winter distribution of marine birds (e.g., murres, guillemots, fulmars and eiders) in the Bering Sea.

The principal sites where breeding seabirds have been monitored in the Bering Sea are at the Pribilof Islands (St.George and St. Paul), and at Cape Peirce and Bluff in Norton Sound. Monitoring at these sites, supported by OCSEAP, USFWS, MMS and UAF, has been conducted most years since 1976; colonies at Cape Peirce and at Bluff have been monitored annually since 1984. Colonies at Little Diomede, St. Matthew, St. Lawrence, Round (ADF&G), Walrus and Nunivak islands, and Cape Newenham have been monitored irregularly since 1976. Data have been gathered every 2 to 5 years since 1974 at the Aleutian Islands colonies on Buldir and Agattu islands, and less frequently at Bogoslof and Aiktak islands. A cooperative ecosystem study (USFWS, NBS, NMFS, and UAF) began in 1995 on Aiktak Island to assess characteristics of the nearshore marine environment that support marine mammals and seabirds in the area. In 1995, data were gathered by USFWS at seven sites designated as annual monitoring sites in the USFWS's Bering Sea/Aleutian Islands Ecosystem Plan (Bluff, St. George, St. Paul, Cape Peirce, Aiktak, Kasatochi/Koniuji, and Buldir).

Pelagic distribution and abundance of marine birds has been monitored intermittently in the Bering Sea. Aerial and shipboard surveys were conducted in the mid-1970s as part of OCSEAP by USFWS and MMS, and more detailed offshore research since then has characterized local foraging areas of birds in association with prey concentrations and oceanography. The offshore work has been accomplished by UCI near the Pribilof Islands and by USFWS and NBS near St. Lawrence Island and the Aleutian Islands. The NBS maintains a data base containing information on the pelagic distribution and abundance of seabirds in the Bering Sea.

In recent years, there has been concern over declining populations of eiders; spectacled eiders were listed as a threatened species in 1993, and a proposal has been published to list the Alaska breeding population of Steller's eiders as threatened. Spectacled eiders are being studied on their breeding grounds on the Yukon-Kuskokwim Delta by NBS; USFWS has conducted aerial surveys for molting and wintering spectacled eiders in the Bering Sea since 1993; and USFWS and NBS have conducted surveys and studies of Steller's eiders on the Alaska Peninsula.

USFWS maintains the Alaska Seabird Colony Catalog, a long-term computerized database containing breeding distribution and population data of seabird colonies. USFWS is also working with the Institute of Biological Problems of the North in Magadan, Russia, to include Russian seabird colony information, and is planning a circumpolar seabird database as part of the Convention on Arctic Flora and Fauna.

4312. Population indices.

43121. Mortality. Subsistence harvest of some species of seabirds is important in villages of the Aleutian Islands and the Bering and Chukchi seas. Eggs of some species of seabirds are harvested and adults taken in western and northwestern Alaska. Information on species of seabirds harvested for subsistence purposes may be adequate, but there are few data on the numbers taken. Although subsistence harvest of seabirds is generally thought to have no adverse impact on populations, there is little evidence to support that conclusion. Subsistence use surveys of seabirds have not been done in most coastal villages. Recommended strategies: 1) determine the species and numbers of seabirds used for subsistence purposes 2) determine the importance of seabird subsistence harvests to Alaska natives 3) monitor or restrict subsistence harvest at specific colonies where seabirds are declining.

Today, more Alaskan seabirds are killed annually during commercial fishing operations in the North Pacific Ocean than by all other human activities in Alaska combined. The major causes of seabird mortality are entrapment in fishing gear, drowning due to bird strikes on structural features of fishing vessels, and shooting of birds around vessels. Some seabird populations in the western Aleutians might have declined as a result of fishing mortality in foreign salmon driftnet fisheries which are now banned. Trawl netting, currently in use for several fisheries in the Bering Sea, entangles fewer birds than gillnets. Long-line fisheries can cause large scale mortality for surface feeding species such as albatrosses and shearwaters. Large numbers of birds die from colliding with brightly lit vessels during storms or at night particularly in the snail, crab, and cod fisheries of the Bering Sea. Most of these operations are conducted in darkness, and vessels employ bright lights to aid in pot setting and retrieval. Large numbers of birds (mostly nocturnal species) can be attracted to the lights or disoriented by them, especially in stormy weather. Recommended strategies: 1) Estimate the incidental mortality of seabirds in foreign and domestic fisheries through continued use of the NMFS observer program and 2) determine the effect of light attraction mortality by using NMFS observers.

Oil and fuel spills can cause wide-spread mortality of seabirds within the spill zone.

43122. Reproduction. Seabirds have been studied at several colonies in the Bering sea. However, annual monitoring of productivity has occurred at only 3 sites since the late 1980's (St. George, Buldir, and Cape Peirce). There are two basic methods for monitoring productivity of seabirds: short-term and intensive site visits. Short-term visits usually consist of an early and a late visit to a colony. The measurement parameter obtained from this method is usually number of chicks fledged per nest attempt for the species monitored. The intensive visit method involves having a crew monitor the species of interest every few days throughout the breeding season. Because of the greater effort to collect data researchers are able to suggest at what point in the reproductive cycle birds failed (nest building, laying, hatching, fledgling, etc...). Recommended strategies: 1) Establish a series of annual monitoring sites to track productivity and other parameters of seabirds at strategically located colonies throughout the Bering Sea to better understand ecosystem processes. Colonies include: Bluff, St. George, Buldir, Kasatochi/Koniuji, Aiktak, and Cape Peirce. 2) Establish a series of bi or tri-annual sites to monitor productivity and other parameters of seabirds. These sites would be used to calibrate data obtained at annual sites and to determine if observed values at annual sites were isolated events restricted in extent or more widespread. Suggested sites include: St. Matthew, St. Paul, Agattu, Adak, Bogoslof.

43123. Health and Condition. Various measures may be used singly and in combination to evaluate the condition of seabirds. Although not widely used, indices such as body weight (normalized for size) and egg sizes between years can offer some insight into the relative health among years of seabird populations. Condition of individuals will affect their survival and reproductive output which in turn will influence population status and trend. Recommended strategies: 1) Collect data at annually monitored seabird colonies to calculate various condition indices. 2) Estimate survival rates of seabirds to assess relative health between years.

4313. Characteristics of diet. Most information on seabird diets in the region of the Bering Sea has been obtained in the last 25 years. Japanese investigators examined stomach contents of birds salvaged from driftnet fisheries in the early 1970's, much information was generated during the OCSEAP in the mid to late 1970's, and intermittent sampling that builds upon the OCSEAP database has continued to the present time through the efforts of various federal, academic, and foreign organizations including the USFWS, MMS, NBS, Russian Academy of Sciences, University of Alaska Fairbanks, University of California, and others. The principal species targeted in these studies have been murres, kittiwakes, and planktivorous auklets. Most sampling has been conducted during summer and consists of collections of adults or regurgitated chick meals at or near the breeding colonies. In the Aleutian Islands, the nestling diets of tufted puffins have also been monitored in recent years by sampling the foods delivered to chicks as whole prey items.

The main sampling locations for seabird diets in the Bering Sea include St. Lawrence Island, Bluff, and St. Matthew Island in the northern sector and, in the southeast, the Pribilof Islands and Cape Peirce. Work has been conducted at Bogoslof Island and Aiktak Island in the eastern Aleutians as well as Buldir Island and Agattu Island in the far western Aleutian Islands. Russian scientists have conducted limited sampling in the Commander Islands group. In addition to these colony-based studies, Japanese workers conducted offshore investigations of murres diets in the southeastern and northwestern portions of the Bering Sea during the 1970's, and University of California researchers sampled auklets from pelagic waters of the northern Bering Sea in the 1980's.

The combined result of these efforts is that it is now possible to characterize the summer diets of a few key species of seabirds in the Bering Sea, with particular reference to geographic and interannual variation. The geographic scope of ongoing work is minimal, however, with most effort during 1995 being conducted at just two Aleutian sites (Aiktak Island and Buldir Island). Taxonomically, the sampling scheme employed in the past remains generally appropriate for future work, because it includes fish-eating and planktivorous species, as well as surface feeders and divers. Both contrasts are thought to be important aspects of seabird feeding ecology in the Bering Sea. Future efforts should include sampling in winter wherever possible, because this important data gap occurs at the time of year when populations may be most limited by food availability. Above all, what is needed is a systematic program of **annual** sampling of seabird diets in conjunction with population and productivity monitoring at strategic locations, e.g., St. Lawrence Island, St. Matthew Island, the Pribilof Islands, Cape Peirce, and selected islands in the Aleutian chain. A properly designed program will serve the dual purpose of addressing current conservation issues for particular populations of seabirds, and will also take advantage of birds as cost-effective samplers of prey distribution and abundance. For example, efficient and nonconsumptive techniques are available for sampling puffin diets, providing vital information on the composition of forage fish communities that is difficult to obtain by any other means.

4314. Predator-prey relationships. Prior work has shown that some piscivorous seabirds in the Bering Sea consume substantial amounts of walleye pollock, which also support a major commercial harvest. In light of declines in seabird numbers observed at some colonies since the mid 1970's--similar, if less dramatic, to the declines of certain pinnipeds--the major issue debated today concerns the nature of competitive relationships involving seabirds, pinnipeds, pollock, and humans. One view is that commercial fisheries are inimical to seabirds and pinnipeds because they reduce the availability of pollock and other prey to these consumers. The alternative view is that an historically large biomass of pollock has, over the last couple of decades, competed heavily with seabirds and pinnipeds for alternative prey and/or has displaced those prey through competitive interactions at early life stages of the fish. The management implications of these views are diametrically opposed. If the latter interpretation is correct, existing fisheries may benefit seabirds and pinnipeds by reducing competition for preferred prey species such as sandlance, capelin, herring, and myctophids. In other words, without the fisheries, the adverse trends in seabirds and pinnipeds might be worse. At another level, the issue can be debated whether the wholesale removal of large quantities of fish biomass from the ocean can reasonably be accomplished without causing untoward, if poorly understood, effects on a host of higher consumers besides man.

Ongoing work relevant to this issue from a seabird perspective is limited to the study of bird foraging or population parameters at a few colonies, intermittent sampling of groundfish food habits--important work that should be continued and intensified--and the compilation and analysis of applicable fisheries data (stock assessment surveys, fishery catch statistics). Much of the information required for seabird biologists to resolve the major management issues concerning this group of consumers will be gathered by workers in other disciplines. Priorities for an expanded program of marine ecological research in the Bering Sea would include: (1) information on the distribution, abundance, and trends of forage species including sandlance, capelin, herring, and myctophids, (2) information on species interactions (competition, predation, behavior) between large predatory fish (e.g., pollock, arrowtooth flounder, halibut, salmon) and forage species, and (3) evaluation of the relative roles of fishing pressure and natural environmental variation in determining the composition of marine fish stocks.

432. Marine mammals.

4321. Population Assessment (abundance and distribution). Twenty-five species of marine mammals seasonally inhabit the Bering Sea. Sixteen of these inhabit the Bering Sea shelf during either winter (bowhead whales, beluga whales, polar bears, walruses, bearded , ringed, spotted and ribbon seals) or summer (gray whales, northern fur seals, fin, minke, humpback, and killer whales, Dall and harbor porpoises). Sea otters, Steller sea lions, and harbor seals reside over the southern part of the continental shelf year-round.

Decreasing population levels among harbor seals, fur seals, and Steller sea lions in the Bering Sea have focused attention on diet and the potential competition between marine mammals and commercial fisheries. In contrast to the declining numbers of these species, increases in the number of fin, humpback, minke, and killer whales have been reported. This information is not based on population estimates, but on observations in the vicinity of the Pribilof Islands. Increased sightings of killer whales in the Bristol Bay and humpback whales in the southeastern Bering Sea have also been reported. Since marine mammals are often transient residents in the Bering Sea, population counts of a given species conducted in other parts of the North Pacific range are often directly applicable to Bering Sea population levels. For some species, especially for those inhabiting the more northerly reaches of the Bering (and the Chukchi) such as walruses and ice seals (e.g. bearded, spotted, and ribbon seals), population surveys only have been conducted at long intervals or intermittently. Population surveys have never been conducted for some species or population stocks (e.g. the Bering-eastern Chukchi polar bear stock). In virtually all cases the data for these more northerly species are insufficient for describing population size accurately, or are so imprecise as to be useless for monitoring population status and trends.

Monitoring of marine mammal distribution and abundance in the Bering Sea has been conducted by a myriad of agencies and research groups. During the 1970s and to a lesser extent in the

1980s, many studies collection population related data were conducted under the auspices of OCSEAP and the MMS. Currently most work is being conducted by federal agencies having management jurisdiction for the particular species. In some cases, such as for Steller seal lions and harbor seals, population assessment studies are carried out by both NMFS and by appropriated funds to the ADF&G. Population monitoring of several pinniped species (fur seals, harbor seals and Steller sea lions) and sea otters in the Aleutian Islands, has traditionally been accomplished through aerial surveys focused on a single species and supplemented with counts by ground based observers. For some species, counts of a cohort (i.e. pup counts) have provided a useful index of population status and trend. At the current time the best available approach for determining population status and distribution of ice seals is the use of aerial surveys coupled with satellite telemetry, an expensive and time consuming process. The same approach has been determined to be so costly for walrus that the USFWS has begun to investigate the potential for using ground counts of walrus in Bristol Bay as a index of population status and trend. A combined aerial survey - ice breaker approach has been recommended as the assessment approach for polar bears in the northern Bering - eastern Chukchi Sea.

Localized aerial and vessel surveys have been used to monitor beluga whale population status along disjunct regions of western Alaska. Population assessment and monitoring for pelagic cetaceans is problematic.

4322. Population indices. Surveys of marine mammal population abundance are inherently costly, logistically difficult, and often imprecise. These problems have generated a need for alternative approaches, or indices, for evaluation of population status. Indices that may be of value for assessing population status include mortality and reproductive rates, and various measures of health and physical condition of individual members of a population. Utility of such indices will depend on variation among populations known to differ in status (e.g., increasing, stable or decreasing) and ease of measurement.

43221. Mortality and reproduction. Mortality and reproductive rates in a population may be influenced by various factors, including age, sex and environmental conditions and, if monitored over time or in populations under varying circumstances, may reflect change in population status. Sources of mortality include harvest, incidental takes, and natural causes including predation, starvation, disease and advanced age. Rates of mortality typically vary greatly by age class, with young and old individuals experiencing higher mortality. In many large mammals, males typically experience higher mortality rates than females.

Age and sex-specific mortality and reproductive data historically have been inferred from harvested animals. However, declining harvests and the few numbers of species presently harvested limit the value of this method. Additionally, harvest records are subject to biases in the composition of animals relative to the total population. Data have also been obtained subsequent to major mortality events (such as occurred for sea otters following the 1989 Exxon Valdez oil spill) which provide a large and perhaps unbiased sample of carcasses from which age distributions and reproductive information can be obtained.

Mortality rates of juveniles (dependent or recently weaned) may be a sensitive index of population status. Studies of Steller sea lions have identified increased mortality of juveniles as a major factor in population declines, whereas adult survival rates have apparently remained stable. Studies of juvenile sea otters have also determined that mortality rates vary significantly among populations and over time, with less variation detected among populations in mortality rates of adult otters.

Monitoring natural mortalities (e.g., collection of beach-cast carcasses) to determine the distribution of ages at death can provide information on population status. However, collection of a sufficient sample of carcasses may be logistically difficult and require many years of effort for detection of change.

Pupping rates and/or pup mortality potentially reflect conditions to which females are subjected throughout the period of breeding and gestation. Data from sea otters, however, indicate that reproductive rates remain high in populations of differing status, while juvenile mortality rates may vary dramatically. Age at first reproduction (or age at sexual maturity), which is expected to be later in individuals experiencing less favorable environmental conditions, may prove to be a more sensitive index than reproductive rate of mature females.

For species that attend rookeries, counts of pups and monitoring their survival at rookeries will provide indices of reproduction and early mortality rates. Studies to estimate pup counts and survival rates at specific rookeries are ongoing for Steller sea lions, northern fur seals, and harbor seals.

Further development of techniques for marking and monitoring individuals are needed to improve capabilities for measurement of age-specific mortality and reproductive rates. VHF radio-transmitters are of limited use in remote areas or when individual animals may range over large areas, and require labor-intensive monitoring of animals. Satellite transmitters are a more appropriate package for some marine mammals, but problems with cost, capture and restraint, as well as difficulties in attachment, have limited their use in long-term monitoring. Recent work in sea birds has demonstrated that internal satellite transmitters (with an external antenna) are feasible; such packages should be evaluated for application in marine mammal studies.

43222. Health and Condition. Because the general health and physical condition of individuals in the population presumably will relate to mortality and reproductive rates, indices of health or condition measured at the individual level offer potential as alternative criteria for evaluating population status. A variety of morphometric, physiological and biochemical indicators of individual health and condition have been examined in mammalian species with the ultimate objective of inferring the condition of the larger population. For marine mammals, age-specific growth rates, body morphometrics, body composition (generally indicated by body fat content), blood chemistry and hematology, and immune function are being evaluated as indices of population status. Biomarkers of exposure to contaminants are also being examined. Generally, age of the individual must be estimated for meaningful interpretation of data, particularly when measuring animal condition. Studies to address the value of health and condition indices are ongoing in harbor seals, sea lions, walrus, and sea otters, and include exploratory data collection on a variety of physiological and biochemical parameters.

Collection of data on individual health and condition requires suitable methods for capture and restraint of animals; however, for most marine mammals, further research is needed to develop safe, reliable handling methods.

4323. Characteristics of diet. Marine mammals of the Bering Sea (and Gulf of Alaska) feed on a wide array of other marine organisms at several trophic levels. Individual species show considerable dietary specialization, and their feeding patterns may vary by geographical region, time of year, gender, and age class.

With the exception of bearded seals and walruses that eat large amounts of clams, pinnipeds feed mostly on fishes, cephalopods (squids and octopuses), and crustaceans (principally shrimps). Squids form a major component of the diet of northern fur seals, while fishes are most important for Steller sea lions and harbor seals. Fishes commonly eaten by pinnipeds include members of the cod family (walleye pollock, Pacific cod, arctic cod, and saffron cod), smelt family (capelin, eulachon, and rainbow smelt), herring, sand lance, Atka mackerel, and myctophids.

Toothed whales feed primarily on fishes and cephalopods with the species eaten varying with the predator's abilities and the habitats used for feeding. Beaked whales and sperm whales feed mostly on deep water species. Dall's porpoise feed mostly in mid-water, while harbor porpoise and belugas often feed in the nearshore zone. The killer whale is unique in that it feeds on other marine mammals, in addition to fishes and cephalopods.

Of the baleen whales, gray whales are unusual in that they eat principally benthic crustaceans. All other baleen whales feed on zooplankton, and some also eat fishes such as juvenile pollock and herring. Right whales and bowhead whales feed almost exclusively on plankton (copepods and euphausiids), while fishes make up a substantial portion of the diet of minke, fin, and humpback whales.

4324. Predator-prey relationships. The relationship between marine mammals and their prey is poorly understood. Dietary studies, based on scats and stomachs, have shed some light on the types and size of prey consumed in the wild. Other insights into where and how marine mammals feed have come from micro computers attached to the animals. This is, however, but the start of understanding predator prey dynamics.

Many questions are waiting to be answered. For example, what happens to prey populations when predators are removed or reduced in number? How are predator populations affected if prey populations are exploited by other predators? How do predators and prey co-exist? Do marine mammals control prey populations? How do marine mammals respond to an increase in prey? How do marine mammal diets change when prey are abundant as opposed to when they are scarce? Do changes in diet reflect changes in prey abundance?

Some of these questions can only be answered by experimentally removing marine mammals from the ecosystem (which is unlikely to ever be permitted) and observing the response of the ecosystem. Others can be answered by assessing marine mammal diets at the same time that the abundance and dynamics of the prey are assessed. A third, and cost effective approach, is to describe the interactions between predator and prey using simple mathematical models.

Fisheries management needs to incorporate predator-prey dynamics. Yet it is going to take time to understand the predator-prey dynamics associated with marine mammals. Captive studies with marine mammals can yield considerable information about dietary choice and the abilities of animals to handle prey of different types and sizes. Diet and foraging studies need to continue in the wild. At the same time, considerable effort will have to be spent to grasp the dynamics of potential prey and their inter-relationships with other components of the food web. Without such information it will not be possible to prioritize or assess the predictions made by the mathematical models that are developed.

433. <u>Mammal and bird prey.</u>

4331. <u>Population Assessment (abundance and distribution).</u> Key prey species of marine mammals and birds in the eastern Bering Sea and Aleutian Islands regions include juvenile walleye pollock, Pacific herring, Atka mackerel, capelin, sand lance, myctophids, euphausiids, clams, sea urchins, squid and octopus. With the exception of the first three prey species, there has been little directed research effort in recent years to assess the abundance of these prey groups.

Population assessment of walleye pollock is focused primarily on adults (age 3 and older) while marine mammals and birds rely heavily on younger (ages 0-2) pollock for prey. Systematic bottom trawl surveys of the eastern Bering Sea shelf (conducted annually by NMFS) show the summer distribution patterns of adults and also give some idea of the summer distribution of age 1 pollock. Although a winter spawning survey on walleye pollock in the Bogoslof Island area is conducted, there is currently no systematic survey of pollock during seasons other than summer. A small-scale survey of juvenile pollock around frontal regions of the Pribilof Islands has been conducted in the summers of 1994 and 1995 by NMFS. The purpose of these surveys was to understand the physical and biological processes influencing juvenile pollock distribution. Final results and interpretation of the surveys are not yet available..

Pacific herring abundance estimates are mainly from ADF&G aerial spawning surveys in inshore areas in spring. It is believed that herring move to offshore areas near the shelf break of the eastern Bering Sea for overwintering but there are no quantitative data available on adult distribution during non-spawning periods or on the distribution and abundance of juveniles during any period.

Atka mackerel are primarily located in the Aleutian Islands region and abundance estimates are from triennial NMFS bottom trawl surveys conducted in the summer. The schooling behavior of this species, as well as its lack of a swim bladder, make it difficult to survey with trawls or hydro acoustics. Furthermore, factors which would greatly affect local Atka mackerel distributions (and realized survey abundance estimates) are spawning and male nest-guarding behaviors on seasonal time-scales, and tidal currents on daily time scales. Because bottom trawl surveys have not been designed to account for the species' behaviors, data on absolute abundance and seasonal distributions is limited.

The population abundances of the remaining prey species (capelin, sand lance, myctophids, euphausiids, clams, urchins, squid and octopus) are not currently being directly assessed. Some idea of sea urchin abundance might be obtained from NMFS summer trawl survey data but these surveys do not trawl shallow inshore areas of the Bering Sea which might be more important foraging areas for marine mammal and bird predators of urchins. A general idea of capelin distribution in the Bering Sea has been obtained by examining occurrence in NMFS bottom trawl surveys and in fisheries catches. However, quantitative information on abundance and seasonal distribution is lacking. It is known that myctophids and many squid species inhabit the slope region of the Bering Sea. However, virtually no quantitative information exists on distribution and abundance of sand lance, myctophids, euphausiids, squid, and octopus in the eastern Bering Sea. Clam abundance was assessed during the OCSEAP program in the late 1970's but recent data on abundance is lacking.

4332. Population life history parameters

43321. Mortality. The primary source of mortality for juvenile pollock appears to be predation by other marine animals including adult pollock, other groundfish species, marine mammals, and birds. Most data on juvenile pollock mortality through predation are obtained during summer using food habits information from the various predators. More seasonal food habits information is required from these predators to better estimate predation mortality of juvenile pollock throughout the year.

Sources of natural mortality for Atka mackerel include predation by arrowtooth flounder, Pacific halibut, Pacific cod, marine mammals, and marine birds. A directed fishery for Atka mackerel has also been conducted since the late 1970's. An estimate of the instantaneous natural mortality rate of 0.3 yr^{-1} has been used in recent Atka mackerel stock assessments, published by the North Pacific Fishery Management Council. Fishing mortality rates since 1977 have been fairly low, ranging from 0.02 yr^{-1} to 0.12 yr^{-1}.

Natural mortality rates for herring in the eastern Bering Sea have been estimated using various methods which utilize relationships between other life history parameters and natural mortality. These methods have produced a wide range of natural mortality estimates from 0.1 to 0.57 yr^{-1}. Subsistence and commercial fishing on herring is conducted in the eastern Bering Sea with targeted commercial removals of around 20% of spawning population size.

There is little directed commercial fishing on the remaining mammal and bird prey species (capelin, sand lance, myctophids, euphausiids, clams, urchins, squid and octopus). Natural mortality of these prey species has not been quantitatively determined for the eastern Bering Sea region.

43322. Reproduction. Reproductive biology of walleye pollock has been evaluated and significant differences have been found in the fecundity of spawners in the Aleutian Basin and spawners of the slope and shelf regions of the eastern Bering Sea. There may be a link between food supply and the realized length-at-age and the resulting fecundity of walleye pollock. There are also differences in time of spawning of pollock in different areas of the eastern Bering Sea. More research is needed to determine the fate and location of spawning products from the different spawning aggregations and their eventual contribution to the adult population. There is evidence of a Ricker-shape spawner-recruit curve (i.e., a curve with a downward trend in recruitment at higher spawning stock sizes). The shape of this spawner-recruit relationship is strongly linked to the cannibalistic tendencies of adults.

Herring spawn in inshore areas of the Bering Sea during spring with the largest spawning aggregation occurring in the Togiak area. There are data on age-specific maturity rates and fecundity of eastern Bering Sea herring. The main changes in size specific fecundity appear to be related to changes in the growth rate which affects age of maturation and weight-at-age.

Atka mackerel move inshore to shallow, rocky areas with high current to spawn. Females deposit egg masses in nests, which are fertilized, guarded and aerated by males for about 40 days until the eggs hatch. Peak spawning is from July through October in Alaskan waters. Female maturity at length and age have been determined for Aleutian Islands Atka mackerel and fecundity is currently being studied by NMFS.

Fecundity of capelin in the Bering Sea was assessed by a short-term study completed in 1977. Mean fecundity was determined to be 16,000 ova per female, about half the fecundity of Atlantic capelin. Spawning in Alaskan waters occurs in late May and June in the Togiak area.

Very little quantitative information is available on reproduction and fecundity of the other marine mammal and bird prey species (sand lance, myctophids, euphausiids, clams, urchins, squid, and octopus).

43323. Health and condition. Indices such as weight-at-age and fecundity-at-age can be measured to show the status of growth and reproduction for individuals in each of the populations. These indices should be performed on an annual basis. Weight-at-age information is available for adult walleye pollock but weight-at-age and fecundity at age information across time is mostly lacking for juvenile pollock and the other marine mammal and bird prey species (Atka mackerel, capelin, sand lance, myctophids, euphausiids, clams, squid, and octopus).

Important index sites for monitoring health and condition of mammal and bird prey species have been identified: Pribilof Islands, Bristol Bay, Unimak Pass, St. Lawrence Island, Buldir Island, and Kasatochi Island.

Monitoring studies of key prey species could be conducted at the following index sites in the winter (W,w) and/or summer (S,s). Capital letters for seasons indicate important site for study for that species or species group, while lower-case letters indicate a site of lesser importance.:

	Index Sites					
Key Prey	Pribilofs	Bristol Bay	Unimak Pass	St. Lawrence I.	Buldir	Kasatochi
Juv. Pollock	W,S	s	W,S	W,S		W
Atka mackerel			W,S		W,S	W,S
Herring	W,S	S	S	S		
Capelin	W,S	S	s	S		
Sand lance	s			S	S	
Myctophids	W,S					W,S
W,S						
Euphausiid	W,S		W,S	W,S	W,S	W,S
Clams		W,S		W,S		
Squid	W,S		W,S		W,S	W,S
Octopus	W,S	W,S	W,S		W,S	W,S

4333. Characteristics of diet. Diet of walleye pollock in the eastern Bering Sea has been studied extensively, particularly during summer. Small pollock rely heavily on copepods while larger pollock consume mainly copepods, euphausiids, and juvenile pollock. Seasonal variation in diet has been generally characterized with copepod consumption being highest in spring and cannibalism rates higher in fall and winter. However, better quantitative seasonal diet information is needed particularly with respect to juvenile diet and ration and adult cannibalism.

Atka mackerel diet has been studied mainly during summer. They feed on euphausiids, copepods, and larvaceans in the Aleutian Islands area and have also been documented as consumers of juvenile pollock. Herring, capelin, and sand lance are considered to be primarily zooplankton feeders with copepods being a primary prey. Myctophids rely heavily on copepods and euphausiids for food. Euphausiids consume phytoplankton and copepods. Clams are benthic filter-feeders, consuming mainly detritus. Squid and octopus have a more varied diet consisting largely of fish and other invertebrates. More seasonal and interannual information on variation of diet and ration is required for all these species.

4334. Predator-prey relationships. The prey species listed in the table above are not only important prey to marine mammal and birds in the eastern Bering Sea but they are also important prey to many groundfish species. Juvenile pollock is an important prey item for adult walleye pollock, arrowtooth flounder, Greenland turbot, Pacific cod, Pacific halibut, and flathead sole. Atka mackerel is consumed by Pacific halibut, arrowtooth flounder, and Pacific cod in the Aleutian Islands area. Herring occurs seasonally in the diet of some groundfish species. Although capelin is an important prey of groundfish in the Gulf of Alaska, it is not found in appreciable quantities in eastern Bering Sea groundfish diets. Myctophids are consumed by piscivorous fish in slope waters, including walleye pollock, arrowtooth flounder, and Greenland turbot. Euphausiids are an important prey for many groundfish species such as walleye pollock arrowtooth flounder, Atka mackerel, and flathead sole. Squid are consumed by Greenland turbot and arrowtooth flounder. There is a large small-mouthed flounder biomass on the eastern Bering Sea shelf, consisting mainly of yellowfin sole, rock sole, and Alaska plaice, and clams are a part of their diet. Crab also consume clams.

Commercial fishing occurs on adult walleye pollock, although some juveniles are also taken. It has been hypothesized that fisheries can disrupt predator/prey interactions by depleting prey in localized areas but the effectiveness of trawl exclusion zones has yet to be determined. Atka mackerel and herring are also subject to fishing removals and the fisheries could be considered as competitors with marine mammal and bird species that consume Atka mackerel and herring. Commercial fishing operations also have the potential to promote aggregations of scavengers, which can include birds and marine mammals. It is currently unknown whether scavenger populations significantly benefit from commercial fishing operations in the eastern Bering Sea.

434. Marine mammal and bird competitors.

4341. Population Assessment (abundance and distribution). The following species have been identified as competitors with marine mammals and birds for common prey: walleye pollock, Atka mackerel, arrowtooth flounder, Greenland turbot, Pacific halibut, Pacific cod, salmon, yellowfin sole, rock sole, crab, other flatfish. Walleye pollock and Atka mackerel have already been addressed in the section of marine mammal and bird prey species.

Estimates of summer abundance and distribution on the eastern Bering Sea shelf are available from the annual NMFS bottom trawl surveys for arrowtooth flounder, Greenland turbot, Pacific halibut, Pacific cod, yellowfin sole, crab, and other flatfish. Species such as Greenland turbot and arrowtooth flounder, however, have a large proportion of population biomass on the slope, which has been assessed on a triennial basis. Yellowfin sole and rock sole have most of their biomass in the inner and middle shelf regions of the shelf while Pacific cod biomass is more broadly distributed. Salmon are seasonal migrants through the Bering Sea shelf and run sizes are usually estimated from catches using some fixed escapement factor. Although it is believed that most of these species have seasonal changes in their geographic distribution, quantitative data are lacking. In general, most species are believed to move further offshore during winter and move inshore in summer.

4342. Population life history parameters.

43421. Mortality. There are natural and fishing mortality rate estimates for most of the groundfish species. These estimates are revised on an annual basis by NMFS stock assessment biologists. The International Pacific Halibut Commission biologists also revise mortality estimates for Pacific halibut on an annual basis. Natural mortality coefficients (M) are generally assumed to be constant over age and time (at least for the exploitable parts of each stock) while fishing mortality rate estimates are usually age and year-specific. There are many difficulties in estimating age specific crab mortality rates, mainly due to difficulty in determining crab population age composition. Natural mortality rates for juvenile fish and crab are largely unknown and require more research attention.

43422. Reproduction. Timing and areas of spawning are generally known for groundfish and crab species. Various levels of detail, however, are available about size/age relationships of fecundity and maturity. Little is known about the maturity and fecundity by age of Greenland turbot in the eastern Bering Sea although these relationships have been estimated for Greenland turbot in the Atlantic. One fecundity study on Greenland turbot in the Bering Sea from 1982 is available. Average and median ages at maturity along with some data on number of eggs produced by size of female are known for Pacific halibut. Size and age at maturity of yellowfin sole in the eastern Bering Sea was estimated from data taken in 1992 and 1993. Fecundity estimates of yellowfin sole in the eastern Bering Sea are currently being performed. Size and age at maturity of Pacific cod has been estimated for the eastern Bering Sea, and fecundity estimates have been made on stocks in other areas. Studies are currently underway to estimate fecundity of arrowtooth flounder in the Gulf of Alaska. New information on size at maturity for rock sole is now being evaluated and Russian scientists have previously estimated fecundity at size in the Bering Sea. Size at maturity has been determined for the main crab species in the eastern Bering Sea (red king crab, and Chionoecetes bairdi and C. opilio). Fecundity of red king crab as a function of carapace width is an approximately linear relationship.

43423. Health and condition. Indices such as weight-at-age and fecundity-at-age across time can be measured to show the status of growth and reproduction of each species. Development of such indices across time will require annual monitoring of these parameters, which is currently not being performed.

Monitoring studies of competitor fish species could be conducted at the following index sites in the winter (W,w) and/or summer (S,s). Capital letters for seasons indicate important site for study for that species or species group, while lower-case letters indicate a site of lesser importance.:

Competitors	Index Sites Pribilofs	Bristol Bay	Unimak Pass	St. Lawrence I.	Buldir	Kasatochi
Pollock	W,S		W,S	w,S		W
Atka mackerel			w,s		W,S	W,S
Arrowtooth fl.	W,S		W,S	W,S	W,S	W,S
Greenland turb.	W,S		W,S		W,S	W,S
Halibut	W,S	S	S	S		
Cod	W,S	S	W,S	S	W,S	W,S
Salmon		S	S			
Yellowfin sole	S	S		S		
Rock sole	S	W	W			
Crab	W,S	W,S		w,s	w,s	w,s
Other flatfish	S	S	s	S		

4343. Characteristics of diet. Annual collections of groundfish stomachs have been made during the NMFS summer bottom trawl surveys on the eastern Bering Sea shelf since 1984 and two years of groundfish stomach content data are available from the triennial slope survey. Crab diet has been reported mainly from data taken during the OCSEAP program period of the late 1970's to early 1980's. Recent stomach content data from salmon on the eastern Bering Sea shelf are not available. Greenland turbot consumes squid and walleye pollock. Arrowtooth flounder preys on squid, herring euphausiids, eelpouts, and walleye pollock. Pacific cod and halibut feed on similar prey, consuming walleye pollock, eelpouts, snow and tanner crabs, hermit crabs, and yellowfin sole. Yellowfin sole, rock sole, and crab are inshore benthic infauna feeders and may consume clams, echiuran worms, and polychaete worms. Quantitative seasonal diet information is lacking for most of these species.

4344. Predator-prey relationships. These species are not only important competitors for food resources with marine mammal and birds in the eastern Bering Sea but some species, notably walleye pollock and Atka mackerel, are also important prey. Understanding predator/prey dynamics in both the pelagic and benthic realms may require more regular monitoring of primary and secondary production and the fate of that production across time. Seasonal monitoring of groundfish, mammal, and bird populations, their diets, and the abundance of their common prey are also key to improving our knowledge of the strength of competitive interactions. Refinement of techniques on determination of carbon and nitrogen stable isotope ratios in marine animals may also elucidate position in the food chain and carbon sources utilized.

Although commercial fisheries have the potential to compete with marine mammals and birds for prey, currently only the Atka mackerel fishery has been identified as a potential direct competitor with marine mammals and birds. Most commercial fishing operations in the eastern Bering Sea target adult groundfish such as walleye pollock, cod, and flatfish that are competitors with marine mammals and birds for common prey.

5. Incorporate Traditional ecological knowledge and wisdom (TEKW)

--to be completed with input from ANOs.--

6. Model the Bering Sea ecosystem

The BSESP must utilize ecosystem-based models which incorporate TEKW in their formulation and direction. These models will more effectively direct research and data collection for a better understanding of the physical, ecological, and human systems surrounding the Bering Sea ecosystem. Ecosystem modeling will provide a conceptual framework for increasing our understanding of the environmental reality/complexity of the living marine resources. Natural species groupings and ecological units will also provide the data base for multi-species investigations and management. Such models should include, at the least:

- Models that will help develop indices of production related to variable environmental processes.

- An analysis of the causative interactions between climatic processes, human induced factors, and subsequent ecological effects, and the population processes of individual species, and

- Development of ecosystem models, as well as management oriented environment-dependent single-species and multi species models.

PICES Scientific Report No. 4 1996, Report of the PICES-GLOBEC International Program on Climate Change and Carrying Capacity, includes a science plan which recommends the development of numerical and ecosystem process studies based on modeling. The report recommends a variety of foodweb formulations, one-dimensional mixed layer models, and other more complex models. By reference to that report, studies and models recommended there are suggested for the BSESP, where appropriate.

7. Integrate and evaluate studies annually.

An important component to the success of the BSESP is the integration of results from studies resulting from this plan as well as those from the many institutions conducting studies outside this plan. As suggested by the National Research Council Report (NRC 1996), each management and research institution should be reviewed to determine:

- the geographic area and the resources/activities under its purview.
- its basic operational procedures and the source and level of funding.
- any links between it and other organizations in research, planning, or operations.

Inherent in these reviews is the view that studies conducted under the BSESP are not completed in isolation to other endeavors and that results from all studies must be integrated and evaluated separately and together.

Concomitant to these reviews is the need to integrate data management and use. Data gathered as a result of BSESP studies should be available to investigators conducting studies under the GLOBEC CCCC umbrella and the SEBSCC effort. PICES Technical Committee on Data Exchange is addressing the issue of data management and exchange and the need to work closely with the National Oceanographic Data Centers (NODCs) of the region. Principal investigators working under the BSESP must also coordinate their data gathering and dissemination in a manner that will be optimal (useable and understood) for all researchers and users, including Alaska Native Organizations.

Appendix III.

HISTORY OF BERING SEA ECOSYSTEM STUDY PLAN DEVELOPMENT

April 1994 -- Congress includes section 110(d)(1) of the MMPA requiring the Department of Commerce to develop a Bering Sea Ecosystem Study Plan.

September 1995 -- Draft Plan reviewed within NMFS;.

January 1995 -- NMFS distributes draft Plan to interested parties.

March-April 1995 -- NMFS receives comments on draft Plan.

November 1995 -- NMFS sponsored public workshop to develop and revise Plan

March 1996 -- Revised Plan completed and reviewed within NMFS.

April 1996 -- NOAA and ANOs meet to develop strategy and mechanism to blend scientific and native plans into one plan (the BSESP).

? 1996 -- Final Bering Sea Ecosystem Study Plan sent to government and legislative representatives with proposed dollar amounts and lead agencies/ANOs for specific studies.