

North Pacific Fishery Management Council

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July 20, 2012

Mr. William Michaels
Fisheries Service, Office of Science and Technology
1315 East-West Highway, F/ST4
Silver Springs, MD 20910

Dear Bill:

At its meeting in June 2012, the Council adopted its Five-Year Research Priorities Plan for 2012-2016 based on recommendations from the Scientific and Statistical Committee (Attachment 1). The Council identified its research priorities as those activities that are the most important for the conservation and management of fisheries in the Gulf of Alaska, Aleutian Islands and the eastern Bering Sea. The priorities focus on four broad themes: (1) fisheries; (2) fisheries interactions; (3) habitat; and (4) other areas of research necessary for management purposes. The priorities have been further separated into two categories: Immediate Concerns and Ongoing Needs.

I wanted to bring these research priorities to your attention, and hope they will be considered in your research planning process.

Sincerely,



Chris Oliver
Executive Director

Cc: William Chappell, Dr. Doug DeMaster, Ms. Molly McCammon, Dr. Jim Balsiger,
Dr. Arthur Nowwell, Dr. Ussif Rashid Sumaila, Dr. Cynthia Suchman,
Dr. Michael Castellini, Ms. Cora Campbell, Dr. Phil Mundy, Robert Foy,
Ms. Nancy Byrd, Dr. Tara Riemer-Jones.

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Council's Five-Year Research Priorities: 2012 through 2016 (as approved in June 2012)

The NPFMC has identified priorities for research in the next 1 to 5 years as those activities that are the most important for the conservation and management of fisheries in the Gulf of Alaska, Aleutian Islands, eastern Bering Sea, and the Arctic. This listing of priorities has two purposes: 1) to meet the requirements of the revised Magnuson-Stevens Act for the Councils to identify research that is needed in the next 5 years, and 2) to provide guidance on research priorities to the research community and to funding agencies.

The research priorities are separated into two categories: **Immediate Concerns** and **Ongoing Needs**. **Immediate Concerns** include research activities that must be addressed to satisfy federal requirements and to meet pressing fishery management and ecosystem issues related to fishery management. Within these categories, we have indicated those Research Priorities for which **Research is Underway**. These are Research Priorities for which NPRB grants have been awarded or for which it is known that one or more other agencies have undertaken the recommended research. These priorities will remain on the list until the recommended research is complete and evaluated in terms of its meeting the Research Priority that had been listed. **Ongoing Needs** include research to advance the Council's fisheries management goals as defined in the Groundfish PSEIS, other strategic documents of the Council (i.e., FMPs, AI FEP, and EFH, crab, salmon PSC, and other EISs) and NMFS. **Ongoing Needs** include efforts on which the assessment models depend for their annual updates. For example, without the survey information, the annual process of setting ABCs and OFLs for the managed stocks would be compromised. The Council sees these efforts as needed on an ongoing basis, and constituting the time series on which management is based. It should be recognized that research in these categories is being conducted or may be conducted through Federal, State of Alaska, North Pacific Research Board, and other funding sources.

Five-Year Research Priorities: 2012-2016

Immediate Concerns

I. Fisheries

A. Fish and Fisheries Monitoring

1. Non-recovering stocks. A pressing issue is why certain stocks have declined and failed to recover as anticipated (e.g., Pribilof Island blue king crab, Adak red king crab). Research into all life history components, including predation by groundfish on juvenile crab in near-shore areas, is needed to identify population bottlenecks, an aspect that is critically needed to develop and implement rebuilding plans.
2. Improvements are needed for catch accounting by sex and size for crab (genetic samples) in non-directed fisheries with high bycatch or PSCrates, particularly for blue king crab in the Pacific cod pot fishery in the Pribilof Islands.

3. Develop methods for reliable estimation of total removals (e.g., surveys, poorly observed fisheries) to meet requirements of total removals under ACLs. Improve species identification, by both processors and observers, for priority species within species complexes in catches. Methods that quantify and correct for misidentifications are desired.
4. There is a need to characterize the spatial distribution of male snow crab relative to reproductive output of females in the middle domain of the EBS shelf (partially underway)
5. Genetic and crab movement research for Blue King crab to evaluate determination if Blue King crab bycatch is comprised of Pribilof Island Blue King crab, Saint Mathews Blue King crab, or other Blue King crab stocks

B. Stock Assessment

1. Improve handling mortality rate estimates for crab and scallops. For crab, improved understanding on the post-release mortality rate of discarded crab from directed and non-directed crab pot fisheries and principal groundfish (trawl, pot, and hook and line) fisheries is required. The magnitude of post-release mortality is an essential parameter in the determination of total annual catch used to evaluate overfishing in stock assessment and projection modeling. For example, assess discard mortality rates of Tanner crab by size, month, sex, and fishery type. For scallops, conduct field studies to estimate scallop discard mortality (specifically the relationship between capture, release condition, and survival of scallops). (crab studies are partially underway: *Chionocetes* RAMP study)
2. Develop biomass indices for lowest tier species (Tier 5 for crab, Tier 6 for groundfish), such as sharks, and conduct net efficiency studies for spiny dogfish. Explore alternative methodologies for Tier 5 and 6 stocks, such as length-based methods or biomass dynamics models.
3. Owing to the lack of fishery-independent surveys for scallops, there is a need for analyses of fishery CPUE and observer data for use in assessing fishery performance and stock assessment. For instance, sharp declines in CPUE have occurred in some areas, such as Kayak Island and Alaska Peninsula, prompting concerns about local depletion. Additional new techniques may be desirable in regions with data-poor stocks.
4. New information and data are needed that would inform our understanding of the spawner - recruit relationship for groundfish and crab with sufficient precision to project year-class strength (e.g., Tanner crab, GOA pollock, sablefish, halibut). (Underway)
5. Conduct studies to determine stock structure and potential spatial management for BSAI pollock (e.g., movement).
6. Conduct district-wide surveys for demersal shelf rockfish in Southeast Alaska on an annual, biennial, or triennial basis.
7. Conduct a tagging study of red king crab in the region north of Bristol Bay to assess the movement between this region and the Bristol Bay registration area. Similar work on blue king crab in Bristol Bay relative to the Pribilof Islands is needed.
8. Research is needed on the vertical distribution of Pacific cod relative to the EBS bottom trawl and comparisons between the EBS and GOA trawl gear. (Underway).
9. Develop Pacific cod stock assessment for the Aleutian Islands region.
10. Tagging studies of Aleutian Islands Pacific cod and Atka mackerel are needed to create models of short-term movement of fish relative to critical habitat (tagging for Atka mackerel partly underway).

11. Studies are needed to validate and improve age determination methods for Pacific cod, Pacific sleeper sharks, and spiny dogfish. Conventional tagging studies of young of the year and/or one-year old Pacific cod would be useful in this regard (partially underway for cod and dogfish).

12. Maintain the core data from the eastern Bering Sea needed to support a diverse suite of models used to support the integrated ecosystem assessment program for the Bering Sea. Core data include inputs for single- or multi-species management strategy evaluations, food web, and coupled biophysical end-to-end ecosystem models (e.g. biophysical moorings, stomach data, zooplankton, age 0 surveys).

C. Fishery Management

1. Develop a research program that will facilitate evaluation of salmon (both Chinook and non-Chinook) PSC mitigation measures in the BSAI and GOA. This includes updated estimates of the amounts reasonably necessary for subsistence, timing of runs and openings relative to subsistence requirements, and access to cost data for the commercial pollock and salmon industries so that impacts on profits (not gross revenues) can be calculated.

2. Improve the resolution of Chinook and chum salmon genetic stock identification methods (e.g., baseline development, marker development), improve precision of salmon run size estimates in western Alaska, and initiate investigations of biotic and abiotic factors influencing natural mortality rate during ocean migration in the GOA and BSAI. (baseline development is nearing completion, more work on Cook Inlet Chinook and chums is needed)

3. Develop improved catch monitoring methods of fishery interactions including direct and alternative options (e.g., electronic logbooks, video monitoring), particularly on smaller groundfish, halibut, and commercially guided recreational fishing vessels, as well as an assessment of feasibility for small vessels. Investigate factors that affect angler demand in the guided angler sector of the halibut fishery resulting from regulatory changes or general economic conditions.(Underway)

4. Develop bioeconomic models with explicit age- or size-structured population dynamics for BSAI and GOA groundfish fisheries to estimate maximum economic yield and other bioeconomic reference points under uncertainty.

5. Research the benefits and costs of halibut and halibut PSC utilization in different fishing sectors. For halibut and other PSC and bycatch species, conduct research to better identify where regulations restrict the utilization of fish from its intended use and evaluate how changes in existing regulations would affect different sectors and fisheries. (partially underway)

6. Initiate/continue research on developing and evaluating thresholds for ecosystem indicators, including ecosystem-level management strategy evaluation.

II. Fisheries Interactions

A. Protected species

1. Studies of the localized interactions between fisheries and protected species, such as interactions between Steller sea lions and commercial fish species in the Central and Western Aleutian Islands (particularly areas 541, 542, 543), are needed. These studies should be conducted at appropriate spatial and temporal scales with an emphasis on seasonal prey fields, diet, and movement of sea lions and their prey.

2. Assess age- and size-specific vital rates (i.e., reproduction and survival) of Steller sea lions in the western and central Aleutians at sufficient frequency to track population dynamics in the western DPS.

3. Assess possible indirect effects of fisheries removals via periodic health assessments, indices of body condition, survival of pups and juveniles, and pup-non pup ratios of Steller sea lions in the eastern DPS.
4. Quantify killer whale predation of Steller sea lions, particularly in the western and central Aleutian Islands.
5. Develop new methods to estimate sea lion abundance, such as the use of unmanned aerial vehicles, which could increase the probability of acquiring abundance estimates in remote areas. (underway)
6. Assess the impact of the displacement of the groundfish fleet due to Steller sea lions protection measures on the prey availability, foraging ecology, diet, movements, and vital rates for Northern fur seals (partially underway).
7. Assess the extent and impact of seabird incidental takes in fisheries on bird populations, and develop methods to reduce seabird incidental takes, particularly of protected species, such as short-tailed albatross.
8. Determine potential impacts of fishing activities on North Pacific right whales and the Eastern North Pacific blue whales in the GOA, particularly in identified critical (NPRW) or essential (NPBW) habitat.

III. Habitats

A. Evaluate habitats of particular concern:

1. Assess whether Bering Sea canyons are habitats of particular concern, by assessing the distribution and prevalence of coral and sponge habitat, and comparing marine communities within and above the canyon areas, including mid-level and apex predators to neighboring shelf/slope ecosystems. (partially underway)

B. Baseline Habitat Assessment

1. Dynamic ecosystem and environmental changes in the northern Bering Sea and Arctic are occurring on a pace not observed in recorded time. In response to the new Arctic FMP, assessment of the current baseline conditions and trophic interactions is imperative. This effort, while of great scientific importance, should not supplant the regular surveys in the BSAI and GOA, which are of critical importance to science and management. (partially underway)

C. Fishing Effects on Habitat

1. Research is needed on the effects of trawling on the distribution of breeding and ovigerous female red king crab and subsequent recruitment. Relevant studies include effects of potential habitat modifications on the distribution of females, particularly in near-shore areas of southwest Bristol Bay (partially underway), and environmental effects (e.g., trawling overlap in warm vs. cold years). Retrospective studies, the use of pop-up tags to identify larval release locations, and larval advection using Regional Ocean Modeling System would help address this need.
2. Impact of bottom trawl fisheries on invertebrate abundance and species composition in benthic habitats, especially as might be relevant to the foraging ecology of walrus (candidate species for listing under ESA), but also bearded seals (ESA determination due in July), and gray whales.

Ongoing Needs

I. Fisheries

A. Fish and Fishery Monitoring

1. Continuation of State and Federal annual and biennial surveys in the GOA, AI, and EBS, including BASIS surveys and crab pot surveys, is a critical aspect of fishery management off Alaska. It is important to give priority to these surveys, in light of recent federal budgets in which funding may not be sufficient to conduct these surveys. Loss of funding for days at sea for NOAA ships jeopardizes these programs. These surveys provide baseline distribution, abundance, and life history data that form the foundation for stock assessments and the development of ecosystem approaches to management. *Although an ongoing need, these surveys are considered the highest priority research activity, contributing to assessment of commercial groundfish and crab fisheries off Alaska.*

2. Conduct routine subsistence use, fish, crab, and oceanographic surveys of the northern Bering Sea and Arctic Ocean. These surveys will become increasingly important under ongoing warming ocean temperatures because range expansions of harvested fishery resources may occur. If range expansions or shifts occur, data will be needed to adjust standard survey time series for availability.

3. Explore alternative approaches to the triennial ADF&G Aleutian Islands golden king crab pot survey to acquire fishery-independent abundance data on stock distribution and recruitment, including the potential for future cooperative research efforts with industry.

4. Continue and expand cooperative research efforts to supplement existing surveys to provide seasonal or species-specific information for use in improved assessment and management. The SSC places a high priority on studies that provide data to assess seasonal diets and movements of fish and shellfish, for use in studies of species interactions in spatially explicit stock assessments.

5. The HAPC action for skate egg case concentration sites included two recommendations that the Council suggested should be addressed during the annual research priority discussion: (a) skate egg case concentrations should be monitored every 2 to 3 years using non-invasive research design, such as in situ observation; and (b) skate conservation and skate egg concentration areas remain a priority for EFH and HAPC management and within Council and NMFS research plans.

6. For groundfish in general, and rockfish in particular, continue and expand research on trawlable and untrawlable habitat to improve resource assessment surveys. For example, improved surveys, such as hydro-acoustic surveys, are needed to better assess pelagic rockfish species that are found in untrawlable habitat or are semi-pelagic species, such as northern and dusky rockfish.

7. Studies are needed to evaluate effects of the environment on survey catchability. For groundfish and crabs, studies are needed on catchability, as it directly bears on estimates of the stock size for setting of catch quotas. Research to refine the estimates of survey catchability, q , used to infer absolute, rather than relative, abundance would substantially improve the quality of management advice. Particular emphasis should be placed on Tanner crab, because of recent trends in stock status, and on fishery and fishing gear selectivity for Aleutian Island golden king crab to improve the stock assessment model.

8. Continue research on the design and implementation of appropriate survey analysis techniques, to aid the Council in assessing species (e.g., some crabs and rockfish) that exhibit patchy distributions and, thus, may not be adequately represented (either over- or under-estimated) in the annual or biennial groundfish surveys.

9. Advance research towards developing a quantitative female reproductive index for the surveyed BSAI crab stocks. Research is needed on mating, fecundity, fertilization rates, and, for snow and Tanner crab, sperm reserves and biennial spawning, to develop annual indices of fertilized egg production that can be incorporated into the stock assessment process and to model the effects of sex ratios, stock distribution, and environmental change on stock productivity. Priority stocks for study are eastern Bering Sea snow and Tanner crab and Bristol Bay red king crab. (Ongoing for snow crab and red king crab)
10. Expand existing efforts to collect maturity scans during fisheries that target spawning fish (e.g., pollock). Time series of maturity at age should be collected to facilitate the assessment of the effects of density-dependence and environmental conditions on maturity.
11. Identification and recovery of archived data (e.g., historical agency groundfish and shellfish surveys) should be pursued. Investigate integrating these data into stock and ecosystem assessments.
12. There is a need for fishery-independent surveys of scallops on major fishing grounds, e.g., Yakutat, other areas.
13. Develop a long-term survey capability for forage fish (partially underway).

C. Stock Assessment

1. Acquire basic life history information needed for stock assessment and bycatch/PSC management of data-poor stocks, such as scallops, sharks, skates, sculpins, octopus, grenadiers, squid, and blue king crab (Bering Sea), golden king crabs (Aleutian Islands), and red king crab (Norton Sound). Specifically, information is needed on natural mortality, growth, size at maturity, and other basic indicators of stock production/productivity). For octopus, there is particular need for estimates of mortality and abundance, including verification of the cod consumption-based approach. Tagging studies would provide information on growth and movement of scallops and growth and absolute abundance estimates for golden king crab.
2. Improve estimates of natural mortality (M) for several stocks, including Pacific cod and BSAI crab stocks. **Develop and validate aging methods for crabs to improve estimates of M, including improved independent estimates of stage-specific M (e.g., large red king crab in Norton Sound).**
3. Studies are needed to validate and improve age determination methods for Pacific cod, Pacific sleeper sharks, and spiny dogfish. (partially underway for Pacific cod and spiny dogfish)
4. Evaluate the assessment and management implications of hybridization of snow and Tanner crabs.
5. Quantify the effects of historical climate variability and climate change on recruitment and growth, and develop standard environmental scenarios for present and future variability based on observed patterns. There is also a clear need for information that covers a wider range of seasons than is presently available.
6. There is a need for the development of projection models to evaluate the performance of different management strategies relative to the Council's goals for ecosystem approaches to management. Projection models are also needed to forecast seasonal and climate related shifts in the spatial distribution and abundance of commercial fish and shellfish. (partially underway)
7. To identify stock boundaries, expanded studies are needed in the areas of genetics, mark-recapture, reproductive biology, larval distribution, and advection.

8. Develop spatially explicit stock assessment models, where appropriate. High priority species for spatially explicit models include: snow crab, walleye pollock, Pacific cod, sablefish, yellowfin sole, rock sole, arrowtooth flounder, Pacific ocean perch, black spotted rockfish, roughey rockfish, and Atka mackerel. (partially underway for some species)

9. Genetic studies to provide information on sources and sinks for scallop larvae are needed to improve our understanding of the rate of larval exchange between scallop beds. Age-structured models for scallop assessment are also needed.

10. Conduct multivariate analysis of bycatch data from the scallop observer program (haul composition data) to estimate abundance and trends of benthic communities on scallop beds and computerized image processing to facilitate scallop stock assessments from camera sled.(CamSled) data.

D. Fishery Management

1. Refine methods to incorporate uncertainty into harvest strategies for groundfish for ACL estimation. Continue existing management strategy evaluations at the stock level. (underway)
2. Conduct studies documenting the subsistence harvest patterns, norms, and quantities in communities that depend upon resources that may be affected by Council action.
3. Examine interactions between coastal communities and commercial fisheries (e.g., subsistence-commercial linkages, adaptations to changes in resource use, economic opportunities for coastal communities).
4. Evaluate the effectiveness (e.g., potential for overharvest or unnecessarily limiting other fisheries) of setting ABC and OFL levels for data-poor stocks (Tier 5 and 6 for groundfish and Tiers 4 and 5 for crab, e.g., squid, octopus, shark, sculpins, other flatfish, other rockfish, skates, grenadier, and crab). Research is needed to refine the basis for setting gamma for Tier 4 crab stocks. (partially underway)
5. Conduct retrospective analyses to assess the impact of Chinook salmon PSC measures on the BSAI pollock fishery. Analyses should include an evaluation of the magnitude and distribution of economic effects of salmon avoidance measures for the Bering Sea pollock fishery. In this case, it is important to understand how pollock harvesters have adapted their behavior to avoid Chinook and “other” salmon, under various economic and environmental conditions and incentive mechanisms.
6. Develop forecasting tools that incorporate ecosystem indicators into single or multispecies stock assessments, to conduct management strategy evaluations under differing assumptions regarding climate and market demands. Standardization of “future scenarios” will help to promote comparability of model outputs.
7. Development of an ongoing database of product inventories (and trade volume and prices) for principal shellfish, groundfish, Pacific halibut, and salmon harvested by U.S. fisheries in the North Pacific and eastern Bering Sea.
8. Analyze current determinants of ex vessel, wholesale, international, and retail demand for principal seafood products from the GOA and BSAI.
9. Conduct pre- and post-implementation studies of the benefits and costs, and their distribution, associated with changes in management regimes (e.g., changes in product markets, characteristics of quota share markets, changes in distribution of ownership, changes in crew compensation) as a consequence of the introduction of dedicated access privileges in the halibut/sablefish, AFA pollock, and BSAI crab fisheries. “Benefits and costs” include both economic and social dimensions.

10. Conduct prospective analyses of the robustness and resilience of alternative management strategies under varying environmental and ecological conditions.
11. Conduct prospective and retrospective analyses of changes in the spatial and temporal distribution of fishing effort, in response to management actions (e.g., time/area closures, marine reserves, PSC and other bycatch restrictions, co-ops, IFQs).
12. Develop a framework for collection of economic information on commercial, recreational, and charter fishing, as well as fish processing, to meet the requirements of the MSFCMA sections 303(a)(5, 9, 13), 303(b)(6), and 303A.
13. Continue to evaluate the economic effects from crab rationalization programs on coastal communities. This includes understanding economic impacts (both direct and indirect) and how the impacts are distributed among communities and economic sectors.
14. Improve estimation of fishery interactions (including catch) with marine mammals (e.g., state managed gillnet fisheries), seabirds, and non-target groundfish (e.g., sharks, skates), and protected species.

II. Fisheries Interactions

A. Protected Species Interactions

1. Economic, social, and cultural valuation research on protected species (i.e., non-market consumptive use, passive use, non-consumptive use), particularly in the Arctic.
2. Foraging ecology and vital rate studies of Steller sea lions in the Gulf of Alaska, Russian Far East, and Commander Islands, including at-sea tracking of older animals, and diet composition of sea lions throughout the region. Emphasis should be placed on the use of methods that allow population abundance estimates to be directly compared between Russia and Alaska.
3. Linkages between fishery-induced disturbance or local prey depletion for northern fur seals in the Pribilof Islands region. (underway)
4. Gear modifications and fishing practices to reduce bycatch and, particularly, PSC (e.g., salmon and crab). (partly underway)
5. Studies of sperm whale depredation of catch in long-line fisheries and surveys to improve the quality of long-line fish abundance estimates. (underway)
6. Monitor interactions between fishing fleet and protected seabirds, particularly, in Aleutian Islands and the eastern Bering Sea shelf edge where numbers of albatross have increased.
7. Assess the potential for increased interactions between protected species (i.e., large whales and post-breeding/migrating seabirds) and fishing efforts in essential habitats, in particular throughout migratory routes, and with respect to changes in fish stock distribution and/or expansion into Arctic waters.

B. Bycatch/PSC Issues

1. There is a need to analyze the effects of recent Council actions on bycatch and PSC, including:
 - a. interaction among PSC reduction initiatives (e.g., halibut, salmon)
 - b. quantifying the effects of PSC reduction in groundfish fisheries to the target fisheries (e.g., charter and commercial halibut fisheries, salmon fisheries)

- c. Research approaches to create bycatch and PSC reduction incentives.

III. Habitat

A. Habitat Mapping

1. Improved habitat maps (especially benthic habitats) are required to identify essential fish habitat and distributions of various substrates and habitat types, including habitat-forming biota, infauna, and epifauna in the GOA, BS, and Arctic. (partially underway)
2. Develop a GIS relational database for habitat, including development of a historical time series of the spatial intensity of interactions between commercial fisheries and habitat. Such time series are needed to evaluate the impacts of changes in fishing effort and type on EFH. Assess the extent of the distribution of *Primnoa* corals and skate egg case concentration sites in the GOA, and conduct routine monitoring of these areas.

B. Function of Habitat

1. Research is needed on the role of habitat in fish population dynamics, fish production (growth, reproduction), and ecosystem processes. Such research will improve the capability to identify and protect important habitats (including essential fish habitat and habitat areas of particular concern); help design effective habitat restoration efforts; improve the design and management of marine protected areas; improve fishery-independent population surveys; and improve stock assessments. Studies are needed to evaluate relationships between, and functional importance of, habitat-forming living substrates to juvenile and adult age classes of commercially important species and their preferred prey (forage fish). (partially ongoing)
2. Establish a scientific research and monitoring program to understand the degree to which impacts (habitat, benthic infauna, etc.) have been reduced within habitat closure areas, and to understand how benthic habitat recovery of key species is occurring. (This the objective of the EFH research approach for the Council FMPs).

IV. Other Areas of Research Necessary for Management

A. Ecosystem indicator development and maintenance.

1. Climatic indicators

- a) Develop a multivariate index of the climate forcing of the Bering Sea shelf. Three biologically significant avenues for climate index predictions include advection, setup for primary production, and partitioning of habitat with oceanographic fronts and temperature preferences.
- b) Develop bottom and water column temperature database for use in EBS, GOA, and AI stock assessments.
- c) Maintain sea ice formation and retreat index for the EBS.

2. Lower trophic level community production data

- a. Collect and maintain primary production time series in the EBS, AI, GOA, and Arctic; particularly in relationship to key climate and oceanographic variables.
- b. Collect and maintain zooplankton biomass and community composition time series in the eastern Bering Sea. Develop, collect, and maintain time series of zooplankton biomass and community composition for the GOA, AI, and Arctic.

- c. Collect and maintain data on forage fish community composition and abundance in the Bering Sea, GOA, AI, and Arctic.
 - d. Collect and maintain time-series data on the community composition, production and biomass of benthic invertebrate and vertebrate fauna.
3. Develop methods for incorporating ecosystem indicators into stock assessments and ecosystem assessments. Specifically:
 - a. Maintain indicator-based ecosystem assessment for EBS.
 - b. Develop indicator-based ecosystem assessments for AI (in progress), GOA, and Arctic.
 - c. Develop stock-specific ecosystem indicators and incorporate into stock assessments. (in progress)
 4. Develop methodologies to monitor for new/emerging diseases among exploited species and higher trophic levels.
 5. Assess the impact of increases in recovering whale populations (e.g. gray, humpback, and fin) on lower trophic level energy pathways.
 6. Ecosystem indicator synthesis research.
 7. Continue and expand cooperative research efforts to supplement existing at-sea surveys that provide seasonal, species-specific information on upper trophic levels (seabirds and marine mammals). Updated surveys to monitor distribution and abundance of seabirds and marine mammals are needed to assess impacts of fisheries on apex predators, improve the usefulness of apex predators as ecosystem indicators, and to improve ecosystem management.
 8. Initiate and expand non-market valuation research of habitat, ecosystem services, and passive use considerations.
 9. Assess the relative importance of non-commercially exploited species (invertebrates, fish, marine mammals, and seabirds) to human communities, particularly in Arctic.

B. Research on Environmental Influences on Ecosystem Processes

1. Climate variability: monitor and understand how changes in ocean conditions influence managed species.
 - a) Maintain moorings. Development and maintenance of indices of the timing and extent of the spring bloom is a high priority. For this, maintenance of moorings, especially M-2, is essential. (underway)
 - b) Monitor seasonal sea ice extent and thickness: If recent changes in ice cover and temperatures in the Bering Sea persist, these may have profound effects on marine communities.
 - c) Measure and monitor fish composition: Evaluate existing data sets (bottom trawl surveys, acoustic trawl surveys, and BASIS surveys) to quantify changes in relative species composition of commercial and non-commercial species, identify and map assemblages, and monitor changes in the distribution of individual species and assemblages. Additional monitoring may be necessary in the Aleutian Islands, northern Bering Sea, and areas of the Gulf of Alaska.
 - d) Assess the movement of fish to understand the spatial importance of predator-prey interactions in response to environmental variability.
2. Improve understanding of ocean acidification and its effects on managed species

- a) Collect and maintain time series of ocean pH in the major water masses off Alaska. (partially underway)
 - b) Assess whether changes in pH would affect managed species, upper level predators, and lower trophic levels. (partially underway for some species)
3. Species' responses to multiple environmental stressors
- a) Laboratory studies are needed to assess the synergistic effects of ocean acidification, oil, dispersants, and changes in temperature on productivity of marine species.
 - b) Monitor contaminant flux and loads in lower and higher trophic levels, and assess potential for impact on vital rates.
- C. Basic research on trophic interactions
- 1. Collect, analyze, and monitor diet information (species, biomass, energetics), from seasons in addition to summer, to assess spatial and temporal changes in predator-prey interactions, including marine mammals and seabirds. The diet information should be collected on the appropriate spatial scales for key predators and prey to determine how food webs may be changing in response to shifts in the range of crab and groundfish.
 - 2. Ecosystem structure studies: Studies are needed on the implications of food web interactions of global warming, ocean acidification, and selective fishing. For instance, studies are needed to evaluate differential exploitation of some components of the ecosystem (e.g., Pacific cod, pollock, and crab) relative to others (e.g., arrowtooth flounder).
 - 3. In the last decade, many whale populations (e.g., gray, humpback, and fin) have increased dramatically, after being depleted by whaling. These increases in abundance have the potential to alter lower trophic level energy pathways in the region. In addition, we should investigate potential impacts to other upper trophic level groups (i.e., pinnipeds, seabirds, large predatory fish).
- D. Ecosystem Modeling
- 1. Modeling studies of ecosystem productivity in different regions (EBS, GOA and AI).