A Pathway for Conducting Ecosystem Research

by Mike Sigler

Successfully addressing the preeminent challenges of fish, seabird, and marine mammal management in Alaska demands an ecosystem approach to research. Our understanding of why Bering Sea pollock recruitment fell during 2002-05 grew from research in the Bering Sea on oceanography, zooplankton, and fish energetics. Untangling the causes of the Steller sea lion decline in the Gulf of Alaska and Aleutian Islands in the 1980s and '90s resulted from studies of their prey and predators and the competitive effects of fishing. Such ecosystem research has informed management decisions in Alaska and, for example, resulted in a reduction of catch quotas during 2008-10 for the Bering Sea pollock fishery (the largest volume fishery in the United States) based in part on our understanding of why Bering Sea pollock recruitment had declined earlier in the decade. Similarly, special protection areas established in the 1990s in identified Steller sea lion habitat have restricted when and where pollock and other groundfish fisheries in Alaska may occur with the twin goals of continuing harvest while leaving sufficient prey to end the Steller sea lion population decline.

An ecosystem approach to fisheries and marine mammal management is part of NOAA's mandate to manage ecologically related species (fishes, crabs, seals, sea lions, and whales). As part of this mandate, NOAA's management of fisheries in Alaska includes catch shares, marine protected areas and non-trawl zones, caps on total groundfish landings, fisheries closures once target and non-target species quotas are reached, and a ban on forage fish fisheries (other than herring). In the high Arctic (Chukchi and Beaufort Seas), NOAA has set a zero quota through implementation of an Arctic Fishery Management Plan, where no fisheries for groundfish or crab will be considered until proper assessments are in place.

Alaska has been a pioneer of ecosystem research in agency science. NOAA's Fisheries Oceanography Cooperative Investigations (FOCI), established in the 1980s, brought Pacific Marine Environmental Laboratory oceanographers and Alaska Fisheries Science Center (AFSC) fish biologists together. Beginning in the 1990s, the ecosystems considerations chapter of the North Pacific Groundfish annual stock assessment report brought ecosystem information into the stock assessment process.

In keeping with the ecosystem approach to research, the AFSC formed the Habitat and Ecological Processes Research (HEPR) program in 2005 to facilitate interdisciplinary research in habitat and marine ecology. The HEPR program was organized as a non-traditional program (consisting of one person) based on the idea that a non-hierarchical approach to research was more flexible and that groups of AFSC staff would be identified as necessary to address specific research issues. (A traditional agency approach is hierarchical and based on a separate, permanent "ecosystems research team" structure.)

The following article describes ecosystem research through the lens of the HEPR program experience and examines one pathway for conducting ecosystem research. My goal was to address the following questions: What are the requirements for worthwhile ecosystem research? What approaches work? What are some examples? How many people contribute? What are the lessons learned?

Requirements for ecosystem research

Derive ecosystem research from major legal mandates - The first requirement for NOAA's ecosystem research is fundamental: that it be derived from major legal mandates, in particular the Magnuson-Stevens Reauthorization Act (MSRA), the Marine Mammal Protection Act (MMPA), and the Endangered Species Act (ESA). For example, stock assessments determine sustainable catch quotas for fish and crab fisheries and potential biological removals for marine mammals. These activities meet MSRA and MMPA mandates, respectively, through monitoring and assessment of changes in fish, crab, and marine mammal abundance. In turn, understanding abundance changes through ecosystem research also meets these legal mandates. As mentioned in the introduction, ecosystem research provided understanding of why Bering Sea pollock recruitment fell during 2002-05 and was applied to justify reduced quotas for the Bering Sea pollock fishery during 2008-10.

Ecosystem research by nature is general. Thus, vague goals like "utilizing cutting edge science" or "developing an integrated ecosystem research portfolio," though well intentioned, invite an unfocused approach driven by the disciplines and expertise present during planning. Having linkages to legal mandates provides a focus as well as a tool for determining specific research goals to address. For example, understanding the abundance decline of northern fur seals at the Pribilof Islands (MMPA mandate) requires studies of pup mortality, female fecundity, oceanography, and prey availability (ecosystem research).

Guide ecosystem research with a research plan - Besides relevance to major legal mandates, ecosystem research also must address specific hypotheses, because a general study of the ecosystem will be impracticably expensive. A focused, problem-specific, regional approach guided by a research plan is necessary. The research plan identifies research hypotheses or priorities and provides a shared agreement for research direction. The research plan also should include a process for synthesizing results. Creating a good research plan consists of three steps: 1) gather a multidisciplinary team to draft a science plan; 2) complete review by other scientists; and 3) complete review by scientific administrators.

Scientists outside the planning group and scientific administrators should review the proposed research plan in order to prioritize projects and verify that sufficient personnel, ships, and lab facilities are available for conducting the work. The purpose of the

Figure 1. The Bering Sea Project has about one hundred principal investigators (PI). Shown here are the participants at the March 2011 PI meeting in Anchorage, Alaska. The Bering Sea Project has contributed nearly 30 publications and another 24 publications have been accepted for the first special issue of the Bering Sea Project to be published in Deep Sea Research (Pt. II).

reviews also is to ensure that the proposed research is coherent, hypothesis driven, and meets NOAA legal mandates. Though the review process can be challenging because of funding limits and disagreements over priorities and research approach, the effort is worthwhile and improves the plan and subsequent research.

Build ecosystem research on existing monitoring - Ecosystem research is by its nature integrated and overlapping. Classifying research into "ecosystem" and "non-ecosystem" contradicts the linkage premise of ecosystems; ecosystem research is nonexclusive and overarches many activities including single-species studies and mandates. Ecosystem research does not have to be separated and identified as distinct from other research activities. For example, a large ecosystem study, the Bering Sea Project (*bsierp.nprb.org*), was funded by the National Science Foundation (NSF) and the North Pacific Research Board (NPRB), and fieldwork was conducted in the Bering Sea during 2007-10. A critical part of this ecosystem study was routine annual monitoring conducted by NOAA and U.S. Fish and Wildlife Service (FWS).

Establish shared goals - Conducting ecosystem research requires teamwork and invariably includes different talents and personalities working side by side. Fundamental to successful teamwork is a shared set of goals, which in science is a well-defined set of research hypotheses or priorities. If the group agrees on shared goals, then all team members have an accepted end point to work towards (addressing the research hypotheses).

A second need is for a structure that promotes communication and the grass roots nature of science (the individual scientist). In the Bering Sea Project, short (<1 hr) monthly calls provide progress updates and often promote collaboration and motivation. The calls also catch many details that would have been missed otherwise. In addition, principal investigator (PI) meetings held annually (Fig. 1) are structured to emphasize the hypotheses as a study framework; study progress is explicitly evaluated vis-a-vis the hypotheses at each PI meeting.

Identifying the benefits of collaboration also motivates people to work together toward shared goals. Working together provides more understanding of ecological mechanisms than working alone. For example, a traditional seabird study might focus on seabird fledging success and then in a regression analysis relate these results to sea ice extent and discuss possible mechanisms to explain variation in fledging success. A collaborative study adds project components that explicitly examine these mechanisms. For example, a collaborative study might add research on prey, oceanography, seabird densities at sea, and seabird flight paths with this information collected by oceanographers and fish, seabird, and zooplankton biologists. The additional prey and oceanography information help define which mechanisms explain fledging success. Likewise, the fish biologists gather information within their discipline and also gain information on predators and oceanography.

Establish inclusive and collaborative program leadership - Sharing program leadership strengthens collaborations and helps ingrain shared goals. This can be as simple as varying which PI represents the group in presenting research to outside audiences. This approach also helps to share credit. For more complex studies with many PIs, lead PIs can be identified for project components. The lead PIs are responsible for organizing a project component and providing leadership at a local level. Finally, a steering committee facilitates and guides the group. This can be an ad hoc group or a formal steering committee such as the one that guides the Bering Sea Project and for 5 years now has encouraged, cajoled, and communicated the benefits of working together.

Program leadership occurs through facilitation instilled with a strong sense of purpose, along with grassroots participation, shared goals, and widely shared credit. A good starting point is a draft plan which then is modified and elaborated based on group input and discussion. When meeting in a group, ask each person to speak to an issue so that each person's viewpoint is heard. This approach works particularly well if some group members are quiet while others are dominant, or if the issue is difficult and people are coming from different perspectives. After discussion, if consensus seems apparent, sum up and ask if everyone agrees (or if anyone disagrees, depending on how strong the consensus appears). If unsure of consensus, sum up the choices and ask people, yes or no, to state their choice. These lessons have proved successful in leading and facilitating ecosystem research.

Approaches to ecosystem research

Ecosystem research can consist of a fully integrated study or a series of related projects that address a research plan. A fully integrated study explicitly integrates projects with clear links between projects, feeding information back and forth. For example, in the Bering Sea Project, ichthyoplankton, zooplankton, phytoplankton, and physical oceanography projects form a working whole necessary to understand mechanisms affecting walleye pollock, Pacific cod, and arrowtooth flounder recruitment. An integrated project is actively managed to maintain integration and accordingly is more labor intensive.

In contrast, ecosystem research also may consist of a series of individual projects not explicitly linked yet each meeting research plan priorities. An example of this approach is NOAA's Essential Fish Habitat (EFH) research in Alaska. This EFH research follows a research plan, however, PIs conduct individual studies. While these studies must address EFH research priorities, the studies are not explicitly linked. The challenge then is integration, which is led by the focus of the research plan objectives. There is less need for active management because projects are not explicitly linked, thus, integration is less labor intensive. Management of the research still occurs in several ways including 1) clear communication of projects, their breadth, and whether they are complementary; and 2) periodic review of how well recent research collectively has addressed research priorities.

The HEPR program consists of four research areas: the Bering Sea Project, Loss of Sea Ice, Ocean Acidification, and Essential Fish Habitat. Each research area has a research plan. In the following sections, I address three questions. How were these research areas organized? How did they run? And how did they follow a pathway for ecosystem research?

Bering Sea Project – As stated earlier, NOAA participation in ecosystem research requires that the study goals must meet legal mandates. The Bering Sea Project (*bsierp.nprb.org*) is a large ecosystem study which meets legal mandates of both NOAA and FWS by including upper trophic level focal species managed by NOAA (pollock, cod, arrowtooth flounder, northern fur seal, humpback whale, fin whale) or by FWS (walrus, thick-billed murre, black-legged kittiwake). The study focuses on understanding abundance changes by examining the food web (trophic interactions) as well as its spatial heterogeneity (location). In addressing these upper trophic level species, many other disciplines are brought to bear such as physical, biological, and chemical oceanography, fisheries acoustics, and modeling.

A fully integrated research plan was proposed to the North Pacific Research Board (NPRB) for the Bering Sea Project. The proposal was complex with five major hypotheses and about 20 projects. The proposal was written by a multidisciplinary group of scientists and reviewed and prioritized by other scientists (the HEPR team) and administrators (the AFSC Board of Directors). In putting together the proposal, it was difficult to fit all of the objectives into the budget; the proposal started with approximately $26M in studies for a $14M budget. Ultimately some who contributed to the proposal development were cut during the internal review or external NPRB review. Although difficult, the reviews helped focus the proposal. Science plans by the funding organizations provided some guidance but were fairly general and did not dictate, for example, specific hypotheses to address. The external review process was complicated as NPRB balanced PI creativity and interpretation with NPRB intent. The NPRB also modified the proposal, and the National Science Foundation (NSF) funded additional individual projects. The final integration (before the work started) was led by a science steering committee which focused on hypotheses from the first PI meeting. We have continued this focus on hypotheses throughout the project. Now that fieldwork is complete and we are in the synthesis and reporting phase, the final step is a comparison (the 'road map') of planned and completed publications to the study hypotheses to ensure that the original study hypotheses are addressed.

A critical part of this ecosystem study was routine annual monitoring conducted by NOAA and FWS. The within-year process studies funded by NSF and NPRB intentionally built upon the existing NOAA and FWS monitoring and only together formed an integrated ecosystem research study. Long-term monitoring is recognized as a necessary tool for gauging ecosystem response to climate change. The annual monitoring also functioned as an among-year process study of the response of the Bering Sea ecosystem to annual fluctuations in climate. For example, the Bering Sea experienced a run of warm (2001-05) and then cold (2007-10) years; the contrasting ecosystem response significantly added to our understanding of the Bering Sea ecosystem. In fact, most research under stock assessments (in the long run) supports the understanding of ecosystem processes, with the single-species focus for assessment providing considerable information for ecosystem studies. For example, our understanding of spatial shifts of Bering Sea fish populations in response to temperature has depended on analysis of data from stock assessment-related monitoring, primarily the eastern Bering Sea shelf bottom trawl survey. Furthermore, building upon existing research or monitoring can be a cost-effective approach to ecosystem research.

Figure 2. Essential Fish Habitat research has contributed over 40 publications since 2005. Both nearshore (pictured here) and offshore research is conducted.

New synthesis ideas may emerge over the course of the project. One approach is to reserve time or funds to support emergent ideas. For the Bering Sea Project, NPRB planned a 2-year synthesis effort whereas NSF planned a 1-year synthesis effort followed by a separate synthesis competition. The NPRB approach was less flexible to respond to emerging synthesis ideas because no funds were reserved for this purpose. The NSF approach led to concerns over who was in and who was out in the separate synthesis competition. A viable approach may be a marriage of the planned 2-year synthesis effort and the reservation of some funds for synthesis (e.g., travel funds).

Essential Fish Habitat – An EFH research plan has guided EFH research since 2007 (Fig. 2). Individual PIs lead projects that address research plan priorities. The EFH research plan was prepared by a group of about 25 scientists in 2005. The group included habitat, stock assessment, and marine mammal scientists, and habitat managers. The draft was reviewed by other scientists (the HEPR team), scientific administrators (the AFSC Board of Directors) and habitat managers (the NMFS Alaska Regional Office), and a revision was approved in 2006. Since then, a midstream evaluation of research progress was conducted in 2008 and a plan review in 2011.

The research priorities of the 2006 EFH plan were broad and provided a large umbrella for EFH studies to fit under. The revised plan has focused on narrowing these priorities and promoting integration of research results. EFH research studies during the last 5 years, while advancing understanding of EFH on a broad front, have not collectively addressed some basic needs of EFH knowledge in Alaska. In particular, habitats most important for sustaining Alaska's productive fisheries have not been defined mostly due to funding limitations and the vast size of marine habitats in Alaska. The purpose of the EFH research plan revision is to focus EFH research so that the results 1) can be applied to broad scales; 2) can consider effects on animal density, growth, and survival and not just presence-absence; and 3) are matched to available (though limited) habitat type information for Alaska. Check back in 5 years on EFH research progress.

The EFH research review process is the most traditional and formal of the HEPR research areas. EFH research is a competitive process where PIs compete for funds through a request for proposals each fall. A group of scientists (the HEPR team) reviews proposals and provides science ratings. Habitat managers (NMFS Alaska Regional Office) and the HEPR program leader determine management priority of proposals. Only projects with a science rating of 'good' or better normally are recommended for funding regardless of their management priority. The HEPR team provides written feedback to each PI so that unfunded proposals can be improved and resubmitted the next year.

Ocean Acidification – The AFSC Ocean Acidification Research Plan was published in 2008. Individual PIs lead projects that address research plan objectives; PIs do not formally compete for funds as for EFH research. Proposed studies are reviewed by a group of scientists (the HEPR team) and scientific administrators (the AFSC Board). Ocean acidification is more collaborative but not fully integrated (intermediate to the approach of the EFH projects and the Bering Sea Project). Some projects are integrated; for example AFSC biologists, chemists, and economists study ocean acidification effects on king crab and conduct species-specific experiments, test water and tissue chemistry, and incorporate laboratory results into bioeconomic models to forecast future crab abundance (Fig. 3).

Principal Investigators each year discuss research plans with other AFSC researchers, as well as researchers at the Northwest and Northeast Fisheries Science Centers, to ensure that temperate water research is complementary. The PIs from these three Science Centers also discuss research techniques through periodic calls approximately every other month. The AFSC's ocean acidification planning effort largely preceded development of the NOAA Ocean Acidification Plan and provided a substantial contribution to the NOAA plan. Funded research began in 2010. The AFSC effort is shifting from 1-year to 3-year project plans with more oversight by a new NOAA Ocean Acidification Program Office.

Figure 3. Red king crab is a focal species for ocean acidification research because of its commercial value and the calcium carbonate that stiffens its exoskeleton. Ocean acidification experiments are integrated with water and tissue chemistry and bioeconomic modeling in order to forecast future crab abundance.

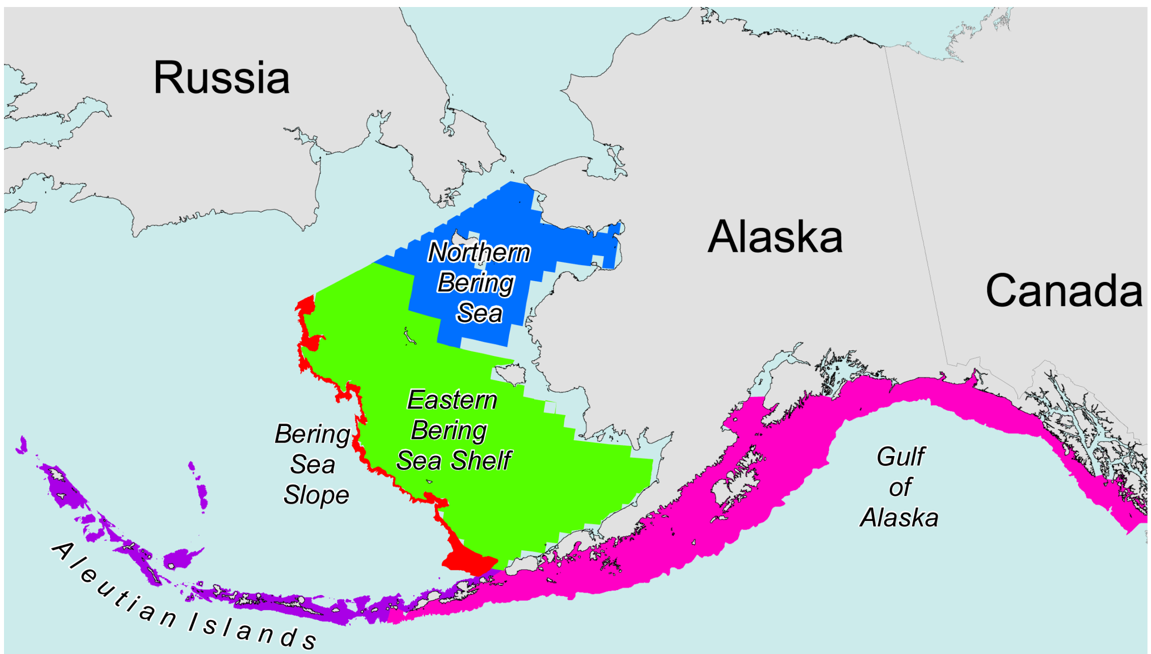

Figure 4. The northern Bering Sea was surveyed by standard bottom trawl survey methods for the first time in about 20 years in 2010 using Loss of Sea Ice funding.

Loss of Sea Ice – A requirement of ecosystem research is that the research must address specific hypotheses. The first HEPR program plan was the Loss of Sea Ice Plan which described possible monitoring and process studies to understand effects of loss of sea ice on ice-influenced seas off Alaska (Bering, Chukchi, and Beaufort Seas). The plan was successful in that it led to development of the Bering Sea Project study plan and surveys of the northern Bering (complete) (Fig. 4), Chukchi (planned) and Beaufort (complete) Seas. However, the total budget was large (several million dollars), and the plan was incomplete because only limited guidance was provided on which research to conduct. It took about 2 more years and further thought by many people for loss of sea ice research to mature and priorities to be identified. This maturation occurred through writing the hypothesis-driven Bering Sea Project proposal and funding justifications for loss of sea ice research.

The AFSC Loss of Sea Ice Research Plan was published in 2007. Individual PIs lead projects that address research plan objectives. The research area (as evolved) is collaborative (PIs work together), and PIs do not formally compete for funds as for EFH research. The research focuses on monitoring ice seal abundance in the Bering, Chukchi, and Beaufort Seas and fish and crab abundance in the northern Bering and Chukchi Seas. Proposed studies for 2010-14 were reviewed by a group of scientists (the HEPR team) and scientific administrators (AFSC Board of Directors). Funded research began in 2010.

It takes a village

Since the start of the HEPR program in 2005, 17 people have served on the HEPR team, and 50 people have participated in HEPR-related science planning.

HEPR Team Members	HEPR Work Group Members		
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Acknowledgements

I thank Michael Cameron, Craig Faunce, Tom Helser, Henry Huntington, Ben Laurel, Mandy Lindeberg, Tom Van Pelt, and Francis Wiese; their reviews and discussions helped me to focus this article.

Lessons learned

The HEPR experience with implementing ecosystem research has brought forward five basic lessons:

- Derive ecosystem research from major legal mandates
- Guide ecosystem research with a research plan
- Build ecosystem research on existing monitoring
- Establish shared goals
- Establish inclusive and collaborative program leadership

Additional Reading

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