Objectives and use of indicators in the Bering Sea/North Pacific

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To stimulate the discussion, the facilitator outlined issues that he thought might be useful to pursue. These were related to high level objectives, and to Bering Sea fishery objectives, both conceptual and operational. The latter of these includes indicators and reference points. He also highlighted the use of "contextual" indicators that could be used to monitor ecosystem state. The following is a summary of the discussion.

Issues

A number of overarching issues were identified by the group. The first was that, while the workshop terms of reference focused on an ecosystem approach to fisheries, there is a need to put this in the context of other human activities (*e.g.*, oil and gas exploration) through an overall ecosystem approach to management. This will require harmonization of the high-level objectives to ensure that all sectors are striving toward the same ends.

While there were fisheries management issues noted by the group (*e.g.*, abundance of Steller sea lions and crabs), in comparison with other jurisdictions (*e.g.*, Northwest Atlantic), fisheries management appears to be effective in regulating the effects of fishing. However, managers do not want surprises that might arise from productivity changes in the ecosystem. In a sense, the impact of the ecosystem on fisheries is the prime issue, not the other way around. Two ecosystem-level changes were mentioned – regime shifts involving ecosystem oscillation between "warm" and "cool" states and changes due to the regional effects of global climate change. Managers would like to know as much as possible about future ecosystem changes for planning. For instance, if the ecosystem was shifting from a primarily demersal-dominated to pelagic-dominated ecosystem, managers could initiate a review of pelagic fisheries management plans.

The state of the Bering Sea was felt to be quite different from that of the North Atlantic, where harvesting impacts on ecosystems have been, and continue to be, a concern. From this perspective, there is more utility in developing a suite of indicators that monitor broader ecosystem change than focusing on improvements to the current suite of fisheries performance indicators.

Objectives and indicators

The group considered that it would be useful to include a non-fisheries management objective in the determination of ecosystem state and the following objective was suggested:

"Determine the current state of the Bering Sea ecosystem to inform management decisions"

To achieve this objective, a suite of "contextual" indicators and reference points/directions would be needed to inform managers about the current state of the ecosystem and its probable future states. The contextual indicators typically require no immediate management action but they provide a context for the performance of indicators used in fisheries management.

The group considered this could be done through first developing conceptual model(s) of the Bering Sea ecosystem to summarize current understanding and hypotheses about the driving processes. Then, a suite of indicators would be chosen based upon this model(s) and would be used as an "ecosystem watch" by resource managers. It was considered essential to have an associated guidebook for PICES and NPFMC that would describe the background on the selection of the suite of indicators, describe the formulation of each indicator, and outline how the suite of them should be interpreted.

Regarding reporting, the group thought that formally separating the contextual and performance indicators in the *Ecosystem Considerations* appendix would facilitate demonstrating how each is used in management.

The group discussed how to improve the operational objectives, particularly focusing on the linkage between the contextual and performance indicators. This could be done by considering the influence of contextual indicators on the reference points/directions of particular operational objectives. Management decisions would then take this linkage into consideration.

The group ended by emphasizing the need for models that would be used in developing scenarios for managers which would describe potential ecosystem changes and modifications to management. A probabilistic-based, risk assessment approach will be a key element of this approach.

GROUP 2: Anne Hollowed (facilitator), Nicholas Bond, Clarence Pautzke, Bernard Megrey, Sarah Kruse, Gordon Kruse, Glen Jamieson, and Lisa Eisner

The group discussion began with a review of the objectives for monitoring ecosystem indicators. The group recommended adding an objective and modifying one objective:

- "*Assess ocean conditions and anthropogenic activities in an annual report on anomalies and their potential ecosystem impacts.*"
- Modify the statement on "*avoid seabird and marine mammal impacts*" to "*protect sensitive species*".

The first objective would link outcomes to indicators of the state of ocean conditions. The modification to the seabird and marine mammal objective would allow consideration of corals, and other species as well as assessment of status of sensitive species for reasons other than fishing impacts.

Objectives

The group identified the need to assess the overall goals and objectives for ecosystem management within national fisheries management authorities. In the United States, this would involve vetting the recommendations through the regional fisheries management councils. The group also pointed out that scientists are responsible for identifying unacceptable ecosystem properties. The group noted that, while defining "acceptable use" of the ecosystem is a social issue, the process would benefit from a description of the range of acceptable effects on the ecosystem. The group acknowledged that this step will be challenging for natural scientists because it will necessitate an examination of the accuracy of ecosystem forecasts. The accuracy of predictions will allow scientists to judge whether they are ready for use in defining acceptable levels of ecosystem impact. If ecosystem forecasts are reliable, social scientists would be able to present a better description of the expected societal outcomes. The group noted that defining acceptable social characteristics is difficult as well.

Recommendations for new research or monitoring

New funds are needed to collect and interpret ecosystem indicators. Funds should be used to focus on specific unfunded needs/activities and to take advantage of existing platforms of opportunity whenever possible. There is a compelling need to establish new process-oriented research focused on the processes influencing the frequency and intensity of species interactions. Standard census-type surveys are not designed to collect this type of information. One technique for establishing new process-oriented sampling would be to select locations for intense monitoring at meso-scales, both temporal (weeks) and spatial (kilometers). The sites could be visited frequently to capture the seasonal time scale of change. Moorings could be deployed to capture the very fine temporal scale of change in oceanography. Site selection should focus on one or more of the following criteria:

- regions of aggregation for several key species;
- habitats that are utilized by a large number of key species;
- regions that directly influence the fitness consequences for species utilizing the habitat (*e.g.*, nursery grounds);
- unique habitats that protect rare species that are directly tied to a specific habitat type.

Selection of locations could be based on outcomes of three dimensional bio-physical models coupled with ground-truthing by observation. The group noted that one key area might be the southern Bering Sea shelf where flow into the eastern Bering Sea is an important variable to monitor (see below).

Selection of regions based on the fitness consequences of ecosystem change could consider the location of fronts or spawning and nursery grounds. These features can control the degree of spatial overlap of predators, prey and the concentration of prey (fronts) or the dispersal of reproductive products across the Bering Sea (spawning and nursery grounds).
The following areas were recommended, based on their unique characteristics and their role in the production of living marine resources in the Bering Sea: Pribilof seal colonies, cod alley, and submarine canyons as regions of cross-shelf exchange.

The group noted the following to place-based regional research:
Advantages:
- Is cost effective;
- Solves the untenable problem of needing to sample everything everywhere.

Issue:
- Modeling is needed to translate observations at pulse points to an overall status of the ecosystem.

Review of indicators for objectives

Limit ecosystem impacts

We dismissed this topic because we felt that it was comparatively easy to select indicators of ecosystem impacts on fish, seabirds and marine mammals given existing monitoring programs for these species groups. Before managers decide to limit impacts they must first identify what are acceptable levels of impact. This is a difficult and complex scientific issue. We did note that our ability to assess the abundance of plankton and infauna and benthic epifauna is currently limited.

Indicators of food webs

The group felt that there should be some acknowledgement of the difficulty of managing food webs. It might be more appropriate to establish limits to ecosystem stress and then request input from society on the goals for management within the acceptable limits. For example, one might be able to establish a goal to avoid an ecosystem shift from a gadid-dominated system to one dominated by elasmobranchs.

Maintain trophic structure

The group noted that the approach of using trophic-level ratios and identification of appropriate reference points for this might be difficult to interpret. These indicators would be improved if efforts focused on data quality and monitoring of functional groups. The group also recommended a focus on:
- indicators of seasonal shifts,
- benthic infauna,
- cephalopods,
- benthic habitat-forming epifauna,
- habitat mapping,
- zooplankton abundance,
- pelagic fish species.

There is a need for more detailed information on species interactions.

The group discussed several analytical techniques for evaluating ecosystem properties. Among these, they noted that network analyses could be used to identify regions where a disproportionate ratio of energy concentrates at one of the key nodes. The group also recommended that analysts should conduct sensitivity analyses on food webs to inform of overfishing definitions.

Spatial management

Several recommendations for this element were discussed above. The group identified the following steps:

- Identify bio-regions;
- Review existing management areas to assess whether they match bio-regions;
- Use multi-beam and other technologies to assess habitat types (sand, mud, *etc.*);
- Determine corridors used by migratory species and evaluate migration pathways relative to the long-term norms;
- Determine the locations of spawning grounds.

Uncertainty

The use of ecosystem indicators in management is an effort to assess natural and anthropogenic impacts on ecosystems. Thus, the state of science is uncertain and thus, the advice to managers should include a clear description of the uncertainty associated with the indicators. The group recommended the following considerations when evaluating uncertainty:

- Develop scenarios to assess the implications of climate variability;
- Develop techniques to assess structural changes.

Key research issues lie in the identification of mechanisms linking growth, productivity, and vulnerability to survey species composition.

Governance

There is a need to distinguish between human and non-human impacts:

- Acknowledge that thresholds to human impacts can be controlled. Acknowledge that non-human changes require adaptation of control rules given the state of nature;
- Metrics exist, *e.g.*, average age of the fishers within a fleet, economic status, and education level. However, issues associated with a definition of acceptable societal attributes are almost as difficult as defining what is an acceptable ecosystem;
- Decision criteria must be defensible.

GROUP 3: Nathan Mantua (facilitator), Jake Rice, Suam Kim, Francis Wiese, Jason Link, Diana Evans, and Jennifer Boldt

Are there unique characteristics of the Bering Sea that would lead to a certain path or is it more appropriate to talk about general indicators for many ecosystems? There are indices that can be used for all ecosystems, but there are also ecosystem-specific indices. For example, North Atlantic fishing pressure outweighs climate signals whereas, in the Bering Sea, climate is more important than fishing. In the North Pacific, changes in carrying capacity are so large that strategic, long-term views and planning must consider the unstable nature of carrying capacity. There is a need, therefore, to have leading environmental indicators for the Bering Sea. Objectives must consider a temporal scale. If the concern is focused only on next year's fishery, climate indices may not be necessary, but if the concern is the status of the fishery over the longer term, then climate rises in importance.

The Bering Sea is unique because a large fishery has built up around a particular ecosystem state, which may present challenges for ecosystem indicators and objectives. There must be a framework to organize indicators and objectives, and indicators need to have clear functions. The Ecosystem Assessment (first section of the *Ecosystem Considerations* appendix) contains a framework that organizes indicators under three main objectives (maintain predator–prey relationships, diversity, and energy flow and balance), each with several sub-objectives. There are indices in the second and third sections of the *Ecosystem Considerations* appendix that are used to address these objectives. There are also indices in these two sections of the report that are not necessarily used to address these objectives.

It was suggested that indicators should be considered within a risk assessment framework. For example, the probability of various levels of stock productivity could be plotted as a function of the Pacific Decadal Oscillation (PDO), perhaps with a third axis that includes some measure of fishing (likelihood of an indicator as a function of environmental indicators). Despite the lack of an explanatory mechanism to support this correlation, it still may be useful to have a risk-based framework that encompasses what is known. The main concern is about an increasing risk of an undesirable change. When it occurs, it is necessary to understand whether the source was anthropogenic or whether the environment changed such that the likelihood of a good year-class decreased. A framework of this nature would help to identify key drivers for the processes of interest and allow us to choose a few appropriate indices. The framework could also provide NPFMC with advice such as "there is a 30 to 40% chance that there will be poor recruitment for the next 3 to 4 years." Knowledge of an ecosystem may not be sufficient to provide an accurate forecast, but information about the risk of these events may be valuable in meeting conservation goals.

With regard to thresholds, there is a need to focus on inflection points in the relationship between probability of a process (like production) and, for example, climate indicators. Predictions, in risk framework, can be used in developing and assessing future scenarios. Managers cannot influence environmental variables, but their strategy could look at the probability of productivity being high or low. Models can then incorporate a parameter to identify the current state. The less a system is understood, the more cautious we must be in perturbing it.

Concerning assessments of vulnerability, it will be important to build into the management process a means to avoid undesirable ecosystem states.

Process studies are important to improve management decisions, but how empirical and process studies can be linked to management is a difficult subject.

Recommendations

1. Driving ecosystem processes need to be identified and appropriate indicators selected.
2. Take an inventory of the status of indicators (*e.g.*, size, production, diversity, "canary" species, energy flow trophodynamics, habitat, physio-chemical regime) and map them to objectives.
3. Link selected indicators to see how they interact (correlative, mechanistic, *etc.*). Identify drivers *versus* responses and create relational type models.
4. Once relationships are established, identify key thresholds and appropriate levels.
5. Develop scenarios for risk assessment that assess the risks and benefits of different actions, given uncertainty.

What do you do when you are in a poor-productivity regime? How does it translate into a real suggestion to management? The advice for the first year might not result in a management action, but brings the subject to their attention and may provide a way of identifying important monitoring that needs to be done. This can also help provide an advanced "heads-up" to management and the public, if presented to the Council before there is a problem; it gives people a chance to get caught up on research, and have a dialogue.

GROUP 4: George Hunt (facilitator), Patricia Livingston (rapporteur), Villy Christensen, Elizabeth Fulton, James Ianelli, Vladimir Radchenko, and Akihiko Yatsu

Objectives

What do you want to indicate?

The group initially focused its discussion on objectives by talking about the state of the North Pacific and how its health might be measured. It soon became evident that there needed to be a clear, quantifiable definition of "ecosystem health". Only then could indicators of this ecosystem quality be identified. Likewise, the objective of maintaining the structure and function of marine ecosystems was described as difficult to quantitatively defend because the natural degree of variation in ecosystem properties is so poorly known that the significance of observed change is hard to interpret. The difficulties in defining "acceptable state" were also discussed. In some cases, it was recognized that it might be easier to define what states might need to be avoided, as opposed to defining an optimum or acceptable ecosystem state. Thus, it would be desirable to avoid reducing the abundance of a species, significantly reducing a species' range, or causing unacceptable levels of eutrophication such that the risk of its extinction is increased substantially. In some cases, there are strategic processes in place that alter management for habitat and protected species such as Essential Fish Habitat (EFH) protection measures and Endangered Species Act (ESA) consultations.

The group agreed that it is difficult to have a scientific definition of what is acceptable and/or what is not because the issue of acceptability is one of human values. For example, the Bering Sea was once home to an ecosystem that had many great whales, many Pacific ocean perch (*Sebastes alutus*) and few walleye pollock (*Theragra chalcogramma*). An unanswered question is whether the current state, with fewer great whales and Pacific ocean perch and many walleye pollock, is due to natural or human effects. If the current state (which some will consider desirable) is due to top-down effects of fishing on the Bering Sea ecosystem, then perhaps it would return to the old system if these top-down controls were reduced. The return of a large biomass of whales will likely change the Bering Sea. It is entirely possible that the two potential objectives, restoring great whales and maintaining the existing ecosystem, are incompatible. Tradeoffs between diametrically opposed goals might need to be made.

Short-term *versus* long-term objectives

How to use the indicator

The group discussed the differences between strategic and tactical indicators. Tactical indicators are for measuring immediate, short-term management responses, such as estimated stock biomass. Tactical objectives from other regions include those that support age structure of key species. For example, indicators measuring rockfish abundance and catch in space and time could be used to guide management decisions. Strategic indicators might be those that are context setting, such as changes in the productivity or biomass of lower trophic-level organisms, or trends in the Steller sea lion population or salmon bycatch. Management action does not follow immediately upon changes in these, but information on their trajectories might provide context for future management actions.

Strategic indicators of future ecosystem response ("sentinels of climate change") depend on the past being a good predictor of the future. If climate variability, at a variety of temporal scales, causes the rules by which ecosystems function to change, then the use of these longer-term predictors becomes problematic. A possible avenue of approach is to identify and understand the responses of key processes to climate variability. Indicators based on these processes could potentially have greater predictive power than those just based on species distributions or abundances. If species are to be useful as sentinels of change, *e.g.*, northern fur seals and winter-spawning flatfish, then there is a need to calibrate their responses to changes in ecosystem function.

Some measures of ecosystem-level effects of fishing could include changes in the trophic levels of the catch, size structure changes, piscivore-to-planktivore ratios, habitat changes or changes in productivity. Some objectives might be related to optimizing yield, in which case the 2 million metric ton yield cap in the eastern Bering Sea is an important threshold. It was recognized that there are tradeoffs in achieving multispecies maximum sustainable yield (MSY) because single species MSY cannot be achieved simultaneously due to predator–prey interactions between managed species. Species value might be one of the criteria used to determine which species catches should be optimized. The group considered economic–ecosystem indicators as a topic of potential interest. Would it be useful to learn about the mean profit level of the total catch? A shift from more to less valuable species could indicate ecosystem change.

Overall, there is a general lack of science-based advice about limits and thresholds at higher organizational levels. Thus, it is important to focus on development of objectives and measures relating to higher level changes, such as food web changes, ecosystem-level productivity, or multispecies MSY considerations. Ultimately, it should be management objectives and explicit societal goals that drive the indicators and determine how they are to be used.

Spatial scale

The group discussed the appropriate spatial scale for the system to be monitored. The broad classifications used to define large marine ecosystems were seen to be too coarse for some of the purposes under consideration in the southeastern Bering Sea, but there was recognition that a reef by reef scale is too fine. There was thus considerable interest in identifying practical eco-regions or bio-regions at intermediate spatial scales. For example, Australian bioregions have been defined based on multivariate biological/ physical/geological properties. The Australian objective is to maintain spatial diversity, and the policy has been to close off 15% of the habitat in each bioregion. It was recognized that stakeholders may need to be involved in these decisions.

Overview

There was some agreement that existing structures/processes are in place to protect species. The outstanding scientific issues include the need to focus on indicators that identify food web changes, ecosystem productivity, and multi-species MSY *versus* single species. Strategic indicators of future response to climate shifts will require a better understanding of ecosystem processes and how these are affected by climate variability. Food web constraints limit achieving certain societal goals for an ecosystem. Considering stakeholder input, tradeoffs will need to be made in designing objectives that meet human needs without impacting ecosystem function.