Habitat Status Report on Ecosystem Objectives

Background

In 2001, the Department of Fisheries and Oceans (DFO) conducted a National Workshop on Objectives and Indicators for Ecosystem-based Management (the "Dunsmuir meeting"). That meeting adopted three conceptual ecosystem objectives, and identified ten components of those objectives. The Workshop also concluded that to make those conceptual objectives and their components useful in integrated management, they would have to be "unpacked".

The notion of "unpacking" is an activity of breaking down the high level concepts in the conceptual objectives and components into terms of increasing specificity, until the terms represent properties of the ecosystem which can be measured and monitored. The practical or "operational" objectives are then statements which specify a measurable property of the ecosystem, and the quantitative state of that property which management is trying to achieve. For example, an operational objective unpacked from the conceptual component "Maintain species within the bounds of historic variability" might be to "Maintain smooth-cheeked sculpin between 10 million and 80 million fish (as estimated from the annual surveys of Scotia Bank)".

The conceptual objectives and their components were carried forward by the national working group on Ecosystem Objectives and endorsed by DFO as the starting point for setting operational ecosystem objectives. However when pilot integrated management projects began to undertake unpacking exercises, participants encountered difficulties applying consistent interpretations of many of the terms in the conceptual objectives and components. Therefore a meeting was held to develop guidelines for interpreting the scientific terms during the unpacking exercise.

Figure 1: Map of Canada

Introduction

The conceptual ecosystem objectives adopted by DFO are:

- to conserve enough components (ecosystems, species, populations, etc.) so as to maintain the natural resilience of the ecosystem.
- to conserve each component of the ecosystem so that it can play its historic role in the food web
- to conserve the physical and chemical properties of the ecosystem;

whereas the components are:

A. to maintain communities within bounds of natural variability
B. to maintain species within bounds of natural variability
C. to maintain populations within bounds of natural variability
D. to maintain primary production within historic bounds of natural variability
E. to maintain trophic structure so that individual species/stage can play their historical role in the food web

F. to maintain mean generation times of populations within bounds of natural variability
G. to conserve critical landscape and bottomscape features
H. to conserve water column properties
I. to conserve water quality
J. to conserve biota quality

In order to keep the generality of the overall conceptual objectives, it is expected that there will be a number of operational objectives associated with each conceptual objective. One of the challenges of an objectives-based approach to integrated ecosystem management is to keep that number tractably small while having the suite of operational objectives cover the conceptual components of the ecosystem adequately.

Habitat Concern

Many of the terms in the conceptual objectives and components are open to multiple interpretations when being applied or unpacked. These guidelines are intended to assist those unpacking the higher level objectives and components to interpret the scientific terms consistently.

These guidelines represent the results of a first attempt to make the terminology more explicit. Further improvements will be made over time, as experience with using them in unpacking exercises accumulates. Experience may show that they are incomplete (fail to address situations which are encountered) or even misleading (guide users to poor choices). However, they represent the best guidelines that could be developed with the information currently available, and were thought to provide useful guidance in trial exercises.

Management Context for the Guidelines

In applying these Guidelines a number of other points about the setting of ecosystem objectives need to be kept in mind. These include:

Objectives-based integrated management following an ecosystem approach requires that objectives be set not just for properties of marine ecosystems, but also of social, economic, and cultural benefits resulting from human activities in those ecosystems. This report deals only with the setting of ecosystem objectives. The conceptual social, economic, and cultural objectives have not been specified and processes to facilitate setting these objectives need to be developed. These processes may need guidelines as well, but different experts would be required to facilitate those activities.

There are two types of ecosystem objectives; objectives to prevent harm to ecosystems and their components, and objectives to achieve desired states of these systems and components. Both former types of objectives can be set on the basis of ecological knowledge. However, the latter type of objectives also require identifying the desired state of the ecosystem, which is a value-driven activity that follows from setting the social, cultural, and economic objectives for the system. Thus ecological knowledge alone is not sufficient for the setting of objectives to obtain desired ecosystem states.

Scientific and technical experts play a central role in developing ecosystem objectives. All the participants in the governance system of an area may share in setting the social, cultural and ecosystem objectives. Scientific experts have an advisory role in setting these objectives, through specifying the conditions necessary for various uses to be sustainable. For example, if objectives for profits and jobs from a fishery were set, fisheries scientists could advise on the size of the stock necessary to produce yields large enough to provide those benefits on a sustainable basis.

When suites of ecological and social, cultural, and economic objectives are being set, it is essential that they be reviewed as a package, to ensure that they are mutually inter-compatible. In particular, activities necessary to achieve all the desired social and economic uses of marine ecosystems may not be

possible without violating ecosystem objectives set to protect ecosystem components from harm. In such cases, it is necessary to revise the social and economic objectives, to ensure that the ecological conservation-based objectives are not compromised.

Suites of ecosystem objectives have to consider together, once they have been set, to ensure that as a group they cover important parts of the marine ecosystem adequately. They also have to be evaluated relative to expected major threats, to ensure that the suite includes operational objectives for ecosystem properties expected to be exposed and sensitive to them. It is also necessary to consider in advance how the operational objectives will be used to assist in management of cumulative impacts as well as activity-specific impacts.

Ecosystem objectives can be set for any ecosystem property. However in an integrated management context, ecosystem objectives are particularly useful when they are specified for ecosystem properties which can be measured directly, and are under direct management control. Operational objectives for properties which can only be measured indirectly are harder to evaluate and interpret in management or ecological contexts. Operational objectives for properties that management cannot influence effectively often may not provide guidance on appropriate management actions to address discrepancies between the reference point and the state of the ecosystem as measured by the indicator.

Considerations in Developing the Guidelines

In setting operational Ecosystem Objectives (EOs), it is very difficult to find phrasings which are neither recursive nor circular. The phrases “sustainable”, “healthy”, and “responsible” are used without explicit definitions in various Guidelines, but also without the circularity of defining them as conditions of the ecosystem when well-chosen objectives would be met. These terms have technical meanings in the scientific literature on conservation and development, but the technical meanings are generally consistent with the common interpretations of the terms. Together, the terms refer to uses (sustainable), states (healthy), and human activities (responsible) present in ecosystems which may not have been in their pristine condition, but which were not a condition where, with hindsight, remediation was needed.

Within that context, there are several overall points of guidance for those setting EOs. These are not specific to any single conceptual objective but should be kept in mind when unpacking any of them.

- Generally, those setting EOs and their operational components (e,g, reference points), should consider data and information covering as wide a time period as possible, and encompass periods when, with current knowledge, the ecosystem would be considered healthy.

- We lack time series of data for many ecosystem properties for which EOs may need to be set. Even where data series exist, most come from recent decades at best, and from times when human activities had already altered the ecosystem in important ways. Therefore our time series may limit artificially what we perceive are the natural state or bounds of natural variation. Given the repeated occurrence of the phrase “within bounds of natural variability” in the conceptual objectives and components, this limitation may have some uncomfortable implications for making the conceptual objectives operational.

- Those managing human activities in marine ecosystems have an obligation to try to evaluate management actions intended to achieve individual ecosystem objectives with regard to the impacts of those actions on the other ecosystem properties addressed in these Guidelines, and in the *Report of the National*

Workshop on Objectives and Indicators for Ecosystem-based Management.

- These Guidelines are necessarily presented individually, but should be considered as a suite which functions together. Several Guidelines may have to be applied in developing a suite of operational Ecosystem Objectives. Ecosystem Objectives cannot be accepted just because they meet one Guideline of interest, if they violate other guidelines in this list. Likewise, the cumulative effects of multiple activities, which may not be simply additive, need to be considered in setting Ecosystem Objectives and in developing management measures to achieve them.

- Nothing in this document is intended to preclude the conduct of well designed scientific research intended to improve our knowledge and provide a better scientific basis for Ecosystem Objectives and management.

- When setting Ecosystem Objectives intended to address perceived problems, it is important to consider root causes, and not just symptoms. Work to improve understanding of those root causes should be a priority.

Guidelines

A. Mean generation time

1. When considering mean generation time, the dependence of reproductive potential (fecundity, maturity, other relevant factors) on age needs to be considered, not just age structure of the population alone.

Points in need of future development - Although objectives could be set for mean generation time of many species, and not just those targeted by a fishery (or directly impacted by some other mortality source), there is insufficient knowledge to determine whether the individual objectives would be *different* (as opposed to just more numerous) in a multispecies context than in a sequence of single-species objectives for mean generation time. This needs to be explored further.

B. Bounds of natural variability

2. In determining the bounds of natural variability, to the extent allowed by the information available, trend should be differentiated from “variability”.

3. To interpret “natural variability”, it is important to look for common patterns (technically “cross-correlations”) of variation among species, and between species and both anthropogenic and environmental forcers.

4. Consider the best sources of information regarding long time period (technically “lower frequency”) components of variation. The multi-year to decadal scale variation of the major oceanographic features in the system are also relevant to interpreting “natural variability”. When there is important long-term pattern to the environmental forcers, generally Ecosystem Objectives should guide management to keep variability within the bounds of the current regime. In such cases Ecosystem Objectives should also guide management to respond swiftly to signs of regime change.

5. The sampling has to be representative in space of the expected variation, and will usually be best considered on scales of 10’s of km or larger.

Points in need of future development - Current knowledge of bounds of natural variability is inadequate to provide clear direction with regard to several important concepts that must be applied when setting operational Ecosystem Objectives. Nonetheless the concepts are important to interpreting and applying historic data in setting Ecosystem Objectives, and need to be addressed explicitly. Key points include:

- What role the variability itself plays in ecosystem structure and function

- The degree to which preserving structural ecosystem components (for example, biomasses and numbers of species) inherently preserves functional components (for example feeding and competitive linkages and energy flows) as well

- The proper ways to measure "natural variability" in ways that would allow comparison across diverse properties of ecosystem (for example, across weather, oceanography, behaviours of animals, abundances of short and long-lived species).

C. Historic role in the food web

This phrase is not expected to be a basis for operational objectives in most circumstances for several reasons, including:

- Management control over the food web as a whole is very weak, so it is hard to know the best way to move a food web towards a specific state,

- Knowledge of historical states of the food web is poor (so it is hard to characterise quantitatively what "healthy" states were like),

- Knowledge of stability of historic states even poorer (so it is hard to characterise future "desirable" states in ways which make it possible to achieve and then stay within them).

There may be objectives set that are based on food-web characteristics, but reference to historic conditions of the web are unlikely to be helpful. Historical information may help identify the desired direction of change in a system, but generally would not be used to identify a particular state that operational Ecosystem Objectives should be trying to restore.

D. Trophic structure

Setting Ecosystem Objectives for aspects of trophic structure presupposes that trophic data are available, which will often not be the case. It is particularly important to improve our data and knowledge of trophic relationships. However, even where data are weak, the importance of trophic structure to ecosystem structure and function means that proxies should be sought when Ecosystem Objectives are being set for human activities likely to alter trophic structure substantially. Technical experts should consider for each case whether size composition data, trophic data from other systems, or other alternatives would provide the best source of background information for setting the Ecosystem Objectives.

6. In general, extra care should be taken to ensure important fodder species (mid-trophic-level species like capelin and euphausiids, which are used intensively by top predators when the fodder species is abundant) are not reduced below historically average values.

7. The consequences of management manipulations of trophic systems are highly unpredictable. Therefore, only under conditions of exceptionally good understanding would there be a scientific basis for forming Ecosystem Objectives which might lead to planned major reductions of predators with the intent of producing specific benefits to populations lower in the food web.

8. Because the consequences of management manipulations of trophic systems are highly unpredictable, Ecosystem Objectives should not knowingly guide management to allow actions that substantially alter the ratio of different trophic levels in the food web or size classes in the size composition of the web.

9. These guidelines should be applied on spatial scales large enough that population dynamics processes are likely to dominate over extrinsic factors such as migration. (That is, Ecosystem Objectives to maintain particular trophic structures on very local scales are likely

to be impossible to achieve, because the presence and abundance of many of the species may be determined by factors acting on much larger spatial scales.)

10. It is particularly important to coordinate the setting of Ecosystem Objectives for trophic structure with the setting of Ecosystem Objectives for communities.

Points in need of future development - Food webs are complex and even in knowledge-rich systems ability to predict specific consequences of management actions or environmental factors influencing the trophic structure will be limited. However, our knowledge of trophic relationships is very weak for most marine systems, and better information would improve our understanding of at least general consequences of perturbations to food webs.

E. Primary Productivity

Primary production, although fundamental to ecosystem processes, is not usually going to be a source of specific operational Ecosystems Objectives for management. There can be valid concerns about quantities (amount and rates of production) and quality (primarily species composition) of primary production, usually on local scales. The concerns could reflect problems with either excessive or depleted primary production, with a variety of possible causes including excessive nutrient loading, diminished light penetration, etc. These concerns are important, but could usually be addressed effectively with ecosystem objectives regarding properties of water quality, species abundances, or community composition. Additional specific ecosystem objectives for primary production would be of limited value as a basis for management. However it is important to review the suite of ecosystem objectives, once developed, to ensure that if they are achieved, primary productivity would not be left at risk.

F. Resilience

Resilience of ecosystems is very important, but it is not under direct management control and not directly measurable – although indirect measures do exist. Therefore resilience itself is not recommended as something to be captured directly in ecosystem objectives. However, as with Primary Productivity, other Ecosystem Objectives need to be evaluated individually and as a suite, relative to their implications for ecosystem resilience. Moreover, resilience of ecosystems provides another justification for ensuring that management is aware of and responsive to the ecosystem stresses caused by natural and anthropogenic factors. To protect ecosystem resilience, the cumulative effects of both natural and human stresses on ecosystems need to recognised and accommodated in management. It should be further noted that there is not a simple and direct relationship between “resilience” and “perturbation” of an ecosystem. Ecosystems can be “resilient” in states considered to be unhealthy, and inconsistent with many other Ecosystem Objectives for the system, and not very “resilient” in states that may be considered highly desirable for achieving many Ecosystem Objectives related to social, economic, and even ecological goals

G. Habitat – Physical/Chemical

For the purpose of these guidelines, habitat is defined broadly to include the physical and chemical features required by living organisms to carry out their life process. Physical habitat includes abiotic (e.g., geomorphological) and biotic (e.g. kelp beds) structural components as well forces or energies (e.g., currents, temperature).

11. Structural habitat features may be usefully addressed in Ecosystem Objectives for their own right, without having to demonstrate the features serve an important biological function.

12. Where biological functions of structural habitat features are known, those should be given prominence in setting Ecosystem Objectives.

13. Away from coastal influences, it is unlikely to be helpful to management to set Ecosystem Objectives with regard to

perturbations of natural characteristics of the water column (for example, for salinity, stratification, or light penetration).

14. Ice may be an exception to Guideline (13), as a number of human activities could alter ice cover in ways that could have wide consequences for marine ecosystems. Understanding of these potential problems is limited at present, but extra caution may be warranted in the case of ice cover, where specific Ecosystem Objectives might be valuable in some contexts.

15. Away from coastal influences, introduction of foreign materials (e.g. oil spills), forces (e.g. ice-breaking), and energies (including noise) to the water column may be addressed usefully by Ecosystem Objectives to the extent that the introduced materials, forces, or energies pose a risk of detrimental effects on the ecosystems. The phrasing "materials, forces, and energies" is intended to be broadly inclusive of the many ways that human activities may alter natural systems by pollution, extracting or disturbing sediments, etc.

16. In areas where coastal influences on water column or seabed properties are expected to be prominent, Ecosystem Objectives can and should address the likely impacts and important habitat features. These will play a particularly important role in integrated coastal management.

17. In setting Ecosystem Objectives for the pathogen levels and for physical and chemical properties of water quality or seafloor substrates, levels of deleterious or bio-accumulating substances that may become a problem should be addressed explicitly. This provides a direct link between major sources of pollution and management based on ecosystem objectives.

18. Ecosystem Objectives may be set for contaminant (defined broadly, to include endocrine disruptors, pathogens, etc, as well as toxic chemicals) levels in the water column, to keep these at levels which pose low risk to ecosystem components. However, separate Ecosystem Objectives can be set for levels of these substances in the tissues of organisms, which would reflect concerns for human consumption or for accumulation in the food chain. These Ecosystem Objectives can be set without necessarily demonstrating deleterious population-level impacts of the substances on ecosystem components.

H. Communities

"Community" is a term with a broad and loose application in ecology, and can be used appropriately on geographic scales from a few km to thousands of kms. Hence, as a precondition for setting any Ecosystem Objectives relating to Communities, it is necessary to have a clear and consistent description of the community for which the Ecosystem Objective is expected to provide protection or benefits. This description should highlight any emergent properties of that community which are considered to be of special ecological importance. These are properties of the community like stability, resilience, connectivity, and diversity, which are considered to be a consequence of the interactions among the individual parts of the community, and not just the aggregate sum of the parts.

19. In setting Ecosystem Objectives for community properties, it is necessary to think broadly about the meaning of ecological community at the scale specific to the management objectives. However, because many species in a community may have their population dynamics determined at larger or smaller scales than the community of concern, it is often necessary to consider communities at larger and smaller scales of relevant ecological processes as well.

20. Ecosystem Objectives can be set directly for the emergent properties of the community which are of special value. However, in practice such objectives are often of limited use in guiding management actions, because these properties usually are not under direct management control and often can only be measured indirectly, if at all.

21. To the extent that species which are diagnostic of the important community properties, or sensitive to perturbations of those properties, exist and can be identified, then the structural aspects of communities are often best addressed through setting Ecosystem Objectives for those species.

22. To the extent that spatial patterns which are diagnostic of the important functional community properties, or sensitive to perturbations of those properties, exist and can be identified, then the functional aspects of communities are often best addressed through setting Ecosystem Objectives that preserve the spatial pattern of the community, and particularly address preventing fragmentation.

23. Knowledge of the causes and robustness of the structural and functional properties of communities is particularly limited, which makes it hard to set operational Ecosystem Objectives for those properties directly. However, there could be some role in management for Ecosystem Objectives intended to prevent major changes in the relative abundance or distribution of species and habitat features in the community, with the expectation that preventing such changes at least reduce the risk of harm to structural and functional community properties. In these cases, however, attention should be given to ensuring that the Ecosystem Objectives can be clearly linked to management actions with known consequences, so the populations can be maintained with high certainty.

24. It is particularly important to coordinate the setting of Ecosystem Objectives for communities with the setting of EOs for trophic structure.

I. Species

25. It is legitimate to set Ecosystem Objectives for all types of marine species regardless of their commercial value. Species with special status in the Species-at-Risk Act warrant special attention but a species does not have to be at risk to warrant inclusion in an Ecosystem Objective.

26. When particular threats are known or expected to occur in an area for which Ecosystem Objectives are being set, it is reasonable to set Ecosystem Objectives for the species most vulnerable and sensitive to that threat.

27. It is legitimate and sometimes necessary to set Ecosystem Objectives for different life history stages of a species, or for particularly important factors which contribute to a species' life history, such as migration routes or spawning aggregations.

28. Exotic or invasive species are not covered by the intrinsic value provision (25). Where the risk of detrimental impacts on native species or communities is considered high, there is justification for Ecosystem Objectives to manage aggressively to deter the establishment of invasive species.

29. Ecosystem Objectives setting high standards of scientific understanding for intentional introductions and transfers are also warranted.

30. If Ecosystem Objectives are to be set for intentionally reducing a species' abundance significantly, the evidence of serious and widespread harm needs to be very strong, such as with harmful

algal blooms. In such cases there also needs to be a good understanding of the consequence of the management actions taken to achieve the EO.

J. Populations

31. Where experts identify population structure below the level of the species, the Guidelines for Species apply at those units as well.

32. Size, sex ratio, and possible age distribution within a population are important components of population demongraphy. Where particular threats to such properties are known or expected to occur, they should be covered by Ecosystem Objectives in addition to Objectives to do with abundance alone.

Considerations in Applying These Guidelines

Management based on operational Ecosystem Objectives will have many characteristics of Objectives-based management within narrower disciplines. This will include identifying appropriate indicators and reference points for management. These selections will address all the usual concerns about data availability and quality, monitoring capacity, effectiveness of management control, and degree of stakeholder and industry support for the various alternatives. However when working in a broader ecosystem approach to management, these Guidelines invite some additional considerations. These include:

1. Ecosystems can show large, fairly abrupt, and sometimes unwelcome changes in state, that are difficult foresee. Monitoring needs to be vigilant for signs of such changes. Management needs to keep the risk of such changes in mind when setting and pursuing Ecosystem Objectives, and be able to respond rapidly to signs of such changes.

2. Given the difficulty in determining bounds of natural variability and several other ecosystem properties, it is important to explore the conditions, if any, under which information from one area (or part of an ecosystem) can be applied to other areas.

3. For many of the ecosystem properties captured by, or served by, Ecosystem Objectives, models are an essential tool for gaining understanding and advising management. The scientific advisors on management need to develop and test such models much more extensively. Because there are many unresolved questions about the causes of important ecosystem structural and functional properties, it is important to explore a variety of ecosystem model which make different assumptions about how the ecosystem dynamics work. Management actions which are predicted to have similar consequences by models making very different assumptions are likely to be more robust, and a sounder basis for action.

4. Management in an ecosystem approach will have to operate at multiple spatial scales from the sub-population scale up to very large scales. There is very limited understanding of how ecosystem properties and management consequences scale up and down. This area needs more study, and management need to be cautious in making assumptions about consequences and interactions of management actions which pursue Ecosystem Objectives on several scales.

Sources of Uncertainty

Essentially all aspects of pursuing Ecosystem Objectives in an ecosystem approach to management will have to deal with greater uncertainty than single-species and single-factor management. All the sources of uncertainty in such management carry over into the larger ecosystem approach, and uncertainty is amplified by a number of factors. These include:

- Need to address many more species and habitat features, not just those which are the main targets of the human activities.
- Need to address many more human activities simultaneously, as well and their interactions, the effects of natural variation on these uses and the cumulative impacts of these activities and forcers.
- Limited knowledge of linkages and relationships among the ecosystem components, and how they are affected by environmental variation.
- Limited knowledge of the contributions of the various species, habitat features, and their linkages and relationships to the higher-order ecosystem properties like stability, diversity, resilience, etc.
- Limited understanding of second order (indirect) impacts of manipulating individual ecosystem components.

A large number of research needs were identified during development of the Guidelines. Areas of particular focus included work to improve understanding of community structure and function, patterns of natural variability, trophic structure, resilience, and habitat features and linkages.

Conclusions

The conceptual Ecosystem Objectives developed at the workshop in March 2001 provide a high-level basis for taking a more integrated ecosystem approach to management. However they require substantial interpretation in order to unpack them to a degree of specificity where they provide useful support for management. Consistent interpretation of the terminology has been difficult and controversial.

To assist in more consistent interpretation of the conceptual objectives, 32 Guidelines have been developed, addressing ten terms, in addition to several overall guidelines for general purpose. These guidelines are proposed for exploratory use and testing, but there is insufficient knowledge of how ecosystems are structured and function and how human activities affect ecosystem properties, to be confident that they will always guide users to the best choices of Ecosystem Objectives. However the Guidelines reflect consensus of substantial expert knowledge, and there is some confidence that their application will at least improve performance relative to practice without any Guidelines.

Applying the Guidelines in developing operational Ecosystem Objectives for integrated management of human activities in marine ecosystems is expected to form an important part of moving management to a more comprehensive ecosystem approach. However, much more research is required to address major sources of uncertainty in ecosystem structural and functional properties, and the ways that human activities affect these properties. Such research, along with the experience of applying these Guidelines in programs to develop Ecosystem Objectives for pilot integrated management projects, will lead to revisions and improvements to the Guidelines in future.

References

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