GUIDANCE ON THE FORMULATION OF CONSERVATION OBJECTIVES AND IDENTIFICATION OF INDICATORS, MONITORING PROTOCOLS AND STRATEGIES FOR BIOREGIONAL MARINE PROTECTED AREA NETWORKS

Figure 1. Fisheries and Oceans Canada's (DFO) six administrative regions.

Context

Canada has made various domestic and international commitments to establish a network of marine protected areas (MPAs) (e.g., World Summit on Sustainable Development, the Convention on Biological Diversity, Canadian Biodiversity Strategy). As the lead department on national MPA network planning, Fisheries and Oceans Canada (DFO) is working with federal, provincial and territorial partners to design and establish the Canadian network of MPAs in accordance to Decision IX/20 of the Convention on Biological Diversity (UNEP 2008). Development of Canada's MPA network is being guided by the 2011 National Framework for Canada's Network of Marine Protected Areas (Government of Canada 2011).

In 2009, Science provided general guidance regarding the design of MPA networks (DFO 2010). As the planning of MPA networks progresses, the priority is to define MPA network Conservation Objectives. Conservation Objectives are important components of a bioregional MPA network and to track progress on their achievement, network-level indicators and monitoring protocols and strategies are required.

This Science Advisory Report (SAR) is from the National Peer Review Process held October 3 to 5, 2012 in Montreal and provides science guidance for the development of measurable Conservation Objectives, and identification of indicators, monitoring protocols and strategies to evaluate the effectiveness of bioregional MPA networks in achieving their objectives. The advice provided in this SAR will allow for national consistency in the planning and implementation of bioregional MPA networks. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule.

SUMMARY

- Developing measurable Conservation Objectives and identifying the appropriate indicators, monitoring protocols and strategies to evaluate the effectiveness of MPA networks in achieving their Conservation Objectives are important steps in the establishment of bioregional marine protected area (MPA) networks.
- There are three commonly referenced levels of specificity for Conservation Objectives, going from the overarching Conservation Goals (e.g., National Network Goal 1, from the *National Framework for Canada's Network of Marine Protected Areas*), to the more specific Strategic Conservation Objectives and to the Operational Conservation Objectives.
- Operational Conservation Objectives (which are more specific and measurable) are emphasized in this paper, rather than 'higher level' Conservation Goals or Strategic Conservation Objectives. These Operational Objectives should describe the OUTCOMES expected if MPA network design and management are successful.
- Operational Conservation Objectives must address the concepts of: Biodiversity, Ecosystem Function, and Special Natural Features, which are the key components of the "conservation" goal (National Network Goal 1).
- The accepted design features of MPA networks, i.e., Replication, Connectivity among MPAs, and Representativity, should give a network a high likelihood of delivering the objectives set for it, and should be evaluated, but they are not Conservation Objectives in their own right.
- Guidance provided regarding the selection of indicators outlines the functions and properties of indicators, it suggests steps for their identification, and it also identifies links to the development of monitoring protocols and strategies. In the MPA and MPA network context, indicators are used to evaluate where the ecological system is with respect to achieving a particular objective. Failure to identify indicators that are relevant to their corresponding Operational Conservation Objectives could result in failure in the ability to evaluate the effectiveness of the MPA or the MPA network.
- Monitoring protocols describe the specific methodologies required for the monitoring while monitoring strategies are those avenues employed to undertake the monitoring protocols. Monitoring protocols and strategies are specific to the indicator in question, therefore, only general guiding principles are provided in the context of MPA networks. The importance of considering community-based monitoring is highlighted.
- Specific guidance on evaluating the effectiveness of MPA networks is premature, but must involve evaluation of both, whether Conservation Objectives have been met and whether design features have been adequately incorporated into the network.

BACKGROUND

Canada's *Oceans Act* (1996) assigns responsibility to the Minister of Fisheries and Oceans Canada (DFO) to lead and coordinate development and implementation of a national system of marine protected areas on behalf of the Government of Canada. In 2011, members of the Canadian Council of Fisheries and Aquaculture Ministers reviewed and approved in principle a *National Framework for Canada's Network of Marine Protected Areas* (Government of Canada 2011). The *National Framework* sets out overarching direction for the establishment of 13 nationally consistent bioregional networks of marine protected areas, composed of federal, provincial, and territorial MPAs. Canada has also committed to the establishment of a network of MPAs at a number of international fora, including the World Summit on Sustainable Development and the Convention on Biological Diversity (CBD) Conference of the Parties (COP) Decision VIII/24 (UNEP 2006). The CBD subsequently provided technical guidance on establishing MPA networks in the CBD-COP9 Decision IX/20 [Marine and Coastal Biodiversity] (UNEP 2008).

DFO Science has provided initial guidance to ensure national consistency in the implementation of these commitments, while allowing flexibility for adaptation to regional and local conditions. In 2009, Science provided advice on MPA networks including CBD design features in the Annexes from Decision IX/20 (scientific criteria in Annex I and scientific guidance in Annexes II and III), particularly at regional scales (DFO 2010). It was clear that as the policy discussion and implementation of MPA networks evolve, further Science advice would be required to address other implementation questions.

This Science Advisory Report is the next step in providing guidance for the planning of bioregional MPA networks, specifically guidance for the development of measurable Conservation Objectives, and identification of indicators, monitoring protocols and strategies to evaluate the effectiveness of the networks in achieving their objectives, and to ensure that they are conducted in a consistent manner while allowing for flexibility to adapt to regional and local conditions.

ANALYSIS

Guidance on Conservation Objectives

The current advice was based on a review of international practices in setting conservation objectives for MPA networks as well as previous domestic science advice on formulating Conservation Objectives in support of integrated management of Large Oceans Management Areas (LOMA) and regional experiences. To this end, the relationship of LOMAs and Integrated Oceans Management to MPA networks was explored to better understand the applicability of earlier science advice on conservation objectives that was developed in the LOMA context.

Integrated Ocean Management (IOM) at the LOMA level is tasked with planning a different set of objectives than is expected of MPA network planning. However, review of the guidance on setting Conservation Objectives for LOMAs developed in past Science Advisory Reports (SAR) and of lessons learned in applying the earlier guidance led the panel to conclude that although there is room for improvement as experience accumulates, the process for setting LOMA Conservation Objectives is generally working well and provides a good foundation for phrasing and formulating Conservation Objectives for MPA networks (see DFO 2007, 2008). The guidance also can help identify special natural features (e.g., Ecologically and Biologically Significant Areas) and specific species (e.g., Ecologically Significant Species) that should be considered in the network design process.

Conservation Objectives are those objectives that deal specifically with ecological outcomes. Past science advice in support of Integrated Management of LOMAs has stated that Conservation Objectives should describe desirable states of key components of a healthy ecosystem. Achieving the suite of Conservation Objectives should ensure a high likelihood that key structural and functional properties of the ecosystem have not suffered serious or irreversible harm. More specific past advice has stated that an "objective" has a measurable outcome that will be achieved in a specific timeframe to help accomplish a desired goal.

Considering the earlier advice in the context of MPAs and bioregional MPA networks, and the lessons learned from the LOMA process, the following advice is relevant for Conservation Objectives for MPA networks and their components:

- At the level of the bioregional MPA network, the first task is to set Conservation Objectives for ecosystem properties that describe the desired state that successful management should achieve. Specifically, Conservation Objectives should define the features and properties of the ecosystem that the MPA network, if successful, will contribute to protecting. It is expected that the Conservation Objectives of the component MPAs will be aligned with the Conservation Objectives of the MPA network.
- They should describe the desired state of features and properties of ecosystems, which may be either structural or functional (see Roff and Zacharias 2011). Although objectives for structural features and functional properties of MPAs and MPA networks are both legitimate on ecological grounds, in practice it is usually much easier to measure the state of structural features of ecosystems rather than the state of ecosystem functions. For these reasons, structural features are particularly valuable when linking Conservation Objectives to indicators for measuring progress towards their achievement.
- It may be appropriate to set Conservation Objectives for pressures as well as for ecosystem status, primarily to help managers design regulatory frameworks and management plans to achieve the Conservation Objectives. This can be useful, for example, when there is a well-established link between the level of the pressure and the status of the ecosystem features or properties of interest.

Conservation Objectives may be formed at a range of specificities, through a process referred to in DFO practice as “unpacking”[1] from general to specific. Although the degree of specificity is a continuum, there are three commonly referenced levels of specificity, going from the overarching Conservation Goals, to the more specific Strategic Conservation Objectives and to the Operational Conservation Objectives.

Goals (High-Level Conservation Objectives)

The highest, or *conceptual,* level of Conservation Objective is sometimes referred to as a **Goal**, which is the case for Canada’s MPA network. The *National Framework for Canada’s Network of Marine Protected Areas (*Government of Canada 2011) specifies three Goals for Canada’s MPA networks:

1. To provide long-term protection of marine biodiversity, ecosystem function and special natural features;
2. To support the conservation and management of Canada’s living marine resources and their habitats, and the socio-economic values and ecosystem services they provide; and,
3. To enhance public awareness and appreciation of Canada’s marine environments and rich maritime history and culture.

[1] Unpacking is the process of refining objectives to successively more specific levels (DFO 2001).

The National Framework is clear that Goals 2 and 3, regarding uses, are subordinate to Goal 1, about protection of biodiversity, ecosystem function, and special natural features. Goals 2 and 3 are only pursued under circumstances when their achievement does not jeopardize achievement of Goal 1. Therefore, this overarching Goal (National Network Goal 1) applies both as the Goal of the national program for MPA networks and to each bioregional network that is part of the national program. Because Goal 1 is the goal about conservation, for the remainder of this advice, it will be the focus of conclusions and recommendations. Reference to “the Goal” of MPA networks will be to National Network Goal 1 unless explicitly stated otherwise.

Strategic Conservation Objectives

Strategic Conservation Objectives are produced by unpacking the overarching Conservation Objectives (or conceptual Goals), to specify the desired state (healthy, protected, or conserved) of ecosystem features in order to have a high likelihood of achieving the overarching Conservation Goal. Strategic Conservation Objectives still reference general ecosystem properties, but describe the desired ecological outcome that has to be achieved for each specified property. The unpacking of a high-level Goal into Strategic Objectives may result in a set objective with multiple levels of specificity and all may still be Strategic Objectives; for example, unpacking “protect biodiversity” into “protect threatened and vulnerable species”, “protect species and habitats essential for key ecosystem functions” gives two Strategic Conservation Objectives. However, further unpacking “protect threatened and vulnerable species” into “protect a list of specific species considered threatened or vulnerable”, is still at the level of a Strategic Conservation Objective, as long as their status is described generally as “protected” or “conserved” or “healthy”.

Given the relationship between IOM and MPA networks, it is important that the Strategic Conservation Objectives of the MPA network function in coherence with the IOM objectives for the area in which the MPA network is designed. This would potentially make the MPA network a key tool in achieving the more encompassing IOM objectives, particularly the IOM objectives addressing conservation. As well, when considering how well the MPA network will achieve the Goals and Strategic Conservation Objectives set for the network, it is necessary to include the outcomes expected from other measures that play a role in the network (e.g., certain fisheries closures, etc.) as components of the outcomes expected of the network. This perspective brings a greater degree of flexibility into planning options for how to configure a network to achieve its Strategic Objectives and Goals. In addition, as part of the analysis of the applicability of earlier guidance on Conservation Objectives, which was developed in the IOM/LOMA context, to developing Conservation Objectives for MPA networks, it was concluded that the subset of all Objectives set at the LOMA scale that deal with biodiversity, ecosystem function or status of special natural features are good examples of Strategic Conservation Objectives for MPA networks.

Operational Conservation Objectives

Operational Conservation Objectives are more specific and measurable than Strategic Conservation Objectives described above. In the above example of unpacking the Strategic Objective of “protect threatened or vulnerable species”, Operational Conservation Objectives would specify parameters (such as abundance, area of distribution, biomass, or other factors relevant to viability of the species) for each threatened or vulnerable species identified through a Strategic Conservation Objective associated with protection. With Operational Conservation Objectives the unpacking process has reached a level of specificity that should directly guide the selection of suitable indicators and positioning of appropriate reference points. Consequently, Operational Conservation Objectives are needed to guide monitoring and evaluation of overall MPA network effectiveness, and the effectiveness of individual MPAs relative to their individual objectives.

Conservation Objectives and Design Features

Objectives describe the OUTCOMES expected to be achieved if MPA network design and management are successful. As described earlier, objectives can be set at many levels of specificity, through a process that usually starts with high-level, broad objectives and becomes progressively more specific.

The MPA network **Design Features** outlined and defined in CBD COP IX/20 are characteristics of the MPA network that are necessary in order for the network to have a high likelihood of delivering the objectives set for it. However, these **design features are not conservation objectives in their own right.** The design features have a **central and necessary role** in planning the MPA network and its component MPAs. They are important to the process of going from high-level objectives to specific ones. At the point when the planning process has tentatively arrived at a configuration of MPAs within the network, it will be important to evaluate the proposed network against the design criteria. If the proposed network fails to show the properties such as connectivity, representativity, and replication, or if any of the constituent MPAs may not be adequate or viable, then the network and respective MPAs may fail to realize the objectives that have been set. Hence the design features are a key part of the process of setting and planning to achieve objectives, but are not, *in themselves*, the source of conservation objectives.

Science advice specific to the design of MPA networks and its design features was provided in 2009 (DFO 2010). The following section deals with specific design features in the context of developing or achieving Conservation Objectives:

- **Connectivity** – Connectivity among MPAs and other sites which are part of the network is essential to allow MPA networks to achieve certain Conservation Objectives, particularly for protection of species with life history stages separated in space. There is a great deal of knowledge of oceanographic transport processes and animal movements that can and should be used in planning the spatial organization of MPAs and other sites that are part of MPA networks for such species. Nevertheless, the extent of realized connectivity cannot be assessed until after a network has been established, and the actual exchange of individuals among MPAs of the network and the ensuing conservation benefits to the relevant species are quantified. An important aspect of connectivity in MPA network design is that success of an MPA network to deliver outcomes dependant on more than one MPA hinges crucially on how human activities are managed in the areas between those MPAs. Consequently, IOM planning outside the MPAs in the network must take account of the outcomes being planned for within the network, if the network objectives that rely on connectivity are to be achieved.
- **Representativity –** This feature is particularly important for achieving MPA network objectives associated with protection of ecosystem functions. The relationships among representativity, scale, and potential benefits to protection of ecosystem functions are developed more fully in the Science Advisory Report on Representativity (DFO 2013).
- **Replication –** There is no universally appropriate level of replication. The degree of replication needed to achieve the MPA network Conservation Objectives will increase as the vulnerability

of ecosystem features and properties intended to be protected by the MPA network increases, and as threats to those ecosystem features and properties increase. These factors must be evaluated on a case by case basis for each network.

Reaching Operational Conservation Objectives in MPA Network Planning

Given the overarching Goal for bioregional MPA networks, Operational Conservation Objectives must specify the desired state of biodiversity, ecosystem functions, and special natural features in ways that are directly measured and evaluated. The numerical values for individual Operational Conservation Objectives will always be case-specific within MPAs and MPA networks. Nevertheless, for network planning to be nationally consistent, the case-specific objectives should reflect common biological properties for biodiversity components, ecosystem functions and status of special natural features.

General guidance on how to set Operational Conservation Objectives that are ecologically consistent across species or populations (as per the application illustrated below) with different biological traits is most fully developed in the Framework for the Application of Precaution that is part of the Sustainable Fisheries Framework. For example, in that framework for sustainable use of fish stocks, key population properties may include:

- the biomass below which recruitment is at risk of being impaired, which serves as the biological basis for Limit Reference Points;
- the biomass associated with a yield that meet the needs of harvesters, which serves as the biological basis for Target Reference Points; and
- the fishing mortality that on average will not lead to decline in a healthy stock, which serves as a basis for the Upper Removal Reference Point.

Each of these key properties represents a Strategic Objective, respectively:

- avoid allowing biomass to fall to levels that result in impaired recruitment (where, “maintaining stock productivity” may be a goal)
- keep biomass productive enough to allow sustainable harvests that meet social and economic objectives (where “contributing to Canadian prosperity” may be a goal); and
- keep fishing mortality low enough to avoid stock depletion (where “avoid overfishing” may be a goal).

These Strategic Objectives apply to most or all exploited fish populations. Thus, for each managed population (stock), a set of Operational Objectives is set with the objectives matching the biological and ecological requirements of the Strategic Objectives. Hence, the Operational Objectives may call for:

- the stock biomass to be maintained with a specified probability above the value of the stock biomass estimated to meet the biological requirements of a Limit Reference Point;
- the stock biomass to be maintained with a specified probability at the value of the stock biomass estimated to have the biological properties of the Target Reference Point; and

- fish mortality due to human pressures to be maintained with a specified probability below the value of fish mortality estimated to meet the biological requirements of the Upper Stock Reference Point.

As illustrated in this fisheries example, generic guidance on the properties required for Operational Objectives allows a consistent management framework to be applied to all exploited fish stocks. Similarly, as experience with MPA networks increases, it is possible that cases will emerge where the same ecological outcomes are desired from multiple MPAs or MPA networks. As such ecological outcomes emerge, guidance on consistent operational objectives can be provided.

The overarching Goal of MPA network planning is protection of biodiversity, ecosystem function, and special natural features; quite different from the overarching goal of sustainable use of fishery resources. That means the corresponding biological basis for consistent Operational Conservation Objectives will also be different, but in systematic ways. Although the example described above is not specific to MPA networks, it serves to illustrate the level of specificity needed in Operational Conservation Objectives.

Biodiversity

Operational Conservation Objectives should aim to protect areas and species that are at risk or inherently vulnerable. Operational Conservation Objectives should state that a feature will either be maintained (at a minimum, status should not worsen), or improved if the property is already depleted or degraded from past impacts of human activities. For example, if the Strategic Conservation Objective is for the stock status to be maintained, the Operational Conservation Objective would then specify the desired state to be maintained, the probability of keeping it there, and possibly the variance tolerance around the state. If the stock is depleted or degraded, the Operational Conservation Objective will specify the desired stock abundance that would be considered “recovery”, the probability of achieving it, and often the time frame in which recovery is expected. For species that are inherently vulnerable, a network Strategic Conservation Objective of “do all that is possible to contribute to species viability” may require specifying the necessary state of several ecological components within a network, each related to a different life history stage.

Conservation of biodiversity also requires being proactive, to protect intact/natural examples of the range of ecosystems, which may be important to recolonization. Operational Conservation Objectives for such natural areas should specify the size of key populations or habitats to ensure that the populations/areas in the MPA network are large enough for the ecosystems to function normally. The key populations that characterize the natural community will have a range of abundances that is considered healthy/natural for that community, and appropriate Operational Conservation Objectives will state that the populations should be kept within that range of natural variability. However, even if protection of biodiversity is being achieved, some populations will show declining trends in abundance for natural reasons. Because of this, Operational Conservation Objectives could include, for example, one that calls for ensuring that the proportion of declining indigenous species does not exceed the proportion observed during historical periods when biodiversity was not considered at risk from human pressures.

Ecosystem Function

Operational objectives for ecosystem functioning will require expert evaluations and often expensive monitoring to determine if the functions are performing normally. However, as noted in the Science Advisory Report on Representativity (DFO 2013), if ecosystems are functioning in ways typical for the area, the typical community patterns (e.g., distribution, predator-prey relationships, etc.), which are determined by those functions, would be expected. Quantitative Operational Conservation Objectives for the expected patterns can be set, as a reasonable basis for evaluating the success of the MPA network to protect ecosystem functioning. This approach requires that there be a good understanding of the linkages between ecological patterns and underlying functional processes.

Special Natural Features

Special natural features are exactly the ecological properties intended to be captured by the criteria for Ecologically and Biologically Significant Areas (EBSA) (DFO 2004, 2010; UNEP 2008), and Ecologically Significant Species and Community Properties (ESSCP) (DFO 2006). Past advice on setting Conservation Objectives for EBSAs and ESSCPs should be sufficient and appropriate guidance on setting operational Conservation Objectives for Special Natural Features.

Additional Considerations in Setting Conservation Objectives

Ecosystems vary for many natural reasons as well as due to impacts of human uses. Community characteristics at a given place vary between warm years and cold ones, or between El Niño years and non-El Niño years. The setting of Conservation Objectives at different levels, and evaluation of their achievement, must take these factors into account. The meeting did not evaluate which alternative ways to accommodate natural changes would be most efficient, but possibilities include setting different Operational Objectives for different environmental regimes, or taking advantage of extreme conditions to learn about the resilience of the ecosystem(s) being protected inside the MPA network. In any case, an MPA network cannot be expected to prevent ecosystems from being impacted by natural events; however, if successful, it should help buffer against such events and contribute to maintaining or restoring the resilience of those systems. Longer-term directional trends associated with climate change are important for MPA network planning but specific approaches for accommodating climate change were not addressed in this meeting. However, it is noted that there is value in using ecological classifications based on enduring features and that considerations need to be made across bioregional boundaries, which in turn highlights the importance of ensuring effective management in areas between MPAs and coordination of different objective setting processes.

When MPAs in an MPA network are expected to contribute to recovery of ecosystems or of their components that have been altered by impacts of past human uses, the most useful Operational Conservation Objectives should specify a time frame for recovery as well as desired state to be reached eventually. This issue proved complex in developing frameworks for recovery planning of species at risk, and will be complex in MPA network planning. Information was not available to provide advice on appropriate ways to set time-bounds for Operational Conservation Objectives for recovery of various types of ecosystem components, particularly degraded ecosystem functions, beyond noting that such bounds will depend on a number of ecological factors. More consideration of this issue is warranted.

Adaptive management is essential to good MPA network operations, and must include monitoring, periodic evaluation, and revisions to the MPA network management plans, which could include revisions to the MPA network configuration. However objectives are set, the MPA network planning and management processes must have the ability to revise objectives in response to evaluations of their performance, and changing conditions.

Guidance on the Identification of Indicators

Indicators are a widely used tool in rule-based Ecosystem Approach to Management (EAM) and could serve different purposes. It is recognized that over the last decade there has been much development regarding ecosystem indicators and their application, both domestically and internationally. Several frameworks have been suggested for the selection of indicators to evaluate the effects of anthropogenic activities on aquatic ecosystems (e.g., Rice and Rochet 2005; Shin *et al*. 2012; ICES 2012). These frameworks, as well as a review of international practices and domestic science advice and experiences with MPAs, were used to develop the following guidance for identifying and prioritizing indicators for Operational Conservation Objectives to assess MPA and MPA network performance (Figure 2).

For the purpose of this Science Advisory Report, an indicator is defined as a variable, pointer or index. Its fluctuation reveals key elements of a system. The position and trend of the indicator in relation to reference points or values indicate the present state and dynamics of the system. Indicators provide a bridge between objectives and actions (FAO 1999). In the context of MPAs and MPA Networks, each indicator needs to be relevant to its corresponding Operational Conservation Objective.

For an indicator to be useful in determining change there is a need for a point of comparison or reference point, which is a pre-determined value. This pre-determined value could be a target that reflects a desirable state, a limit in terms of unacceptable conditions or a risk tolerance value that would trigger management action. It is important that the selection of indicators and reference points be made based on objective grounds. In the MPA and MPA network context, indicators would be used for evaluating where the ecological system is with respect to achieving a particular objective, therefore, determining whether the indicator is at, below or above a reference point must be carried out with as much quantitative rigour as possible given the information available.

The identification, prioritization and selection of the appropriate indicators, and their reference points is scientifically complex. Moreover, failure to identify suitable and relevant indicators could result in failure in the ability to evaluate if the MPA or the MPA network is achieving its conservation objective(s). For these reasons, it is recommended that the process of identification and prioritization of indicators for monitoring be carried out by a team that includes the appropriate technical experts.

Functions of indicators in an MPA and MPA network context

Some of the important functions that indicators and their associated reference points may serve include:

- Measure progress towards management or conservation objectives;
- Evaluate the effectiveness of policies or management decisions;
- Assess effectiveness of the network (i.e., is it functioning as a network and providing ecological benefits beyond the sum of its parts?);

- Measure the overall state of ecosystem health in the MPA network, individual MPAs or of selected ecosystem sub-components;
- Measure the state of different ecosystem attributes at different spatial and temporal scales (e.g., biodiversity, resilience, ecosystem structure and function);
- Measure the strength of impacts of anthropogenic or environmental drivers of natural systems;
- Serve as the basis for and provide the inputs to formal (or informal) trade-off analyses of human pressures/activities occurring in MPAs or MPA networks as well as rule-based decision making to manage such human activities (e.g., an activity is reduced or stopped if a benchmark is approached);
- Effective communication and decision support tools; and,
- Educational tools to increase public awareness and also to increase the state of knowledge.

Properties of Indicators

Some of the properties that have been widely accepted as the necessary properties for an indicator to serve its function, and that are also equally applicable in the context of MPAs and MPA networks, include: theoretical basis, measurement, historical data, sensitivity, responsiveness, specificity, public awareness and cost effectiveness.

Steps for identifying indicators (Figure 1)

STEP 1: **Identify the Operational Conservation Objectives**. These should reflect the overarching National Network Goal, i.e., “To provide long-term protection of marine biodiversity, ecosystem function and special natural features”.

STEP 2: **Identify suitable indicators** to provide a measure for each of the Operational Conservation Objectives. Where possible indicators should have a pedigree, i.e., have been used and evaluated in other EAM studies; indicators may be drawn from other systems, the literature or local and traditional knowledge. Where possible, indicators should be consistent within an MPA network, and estimated from a coordinated monitoring process.

STEP 3: **Identify selection criteria**, based on the desirable properties of indicators (described above), to choose among the indicators identified in Step 2:

1. Theoretical basis – concepts are consistent with established theory;
2. Measurement – data used to estimate indicators should be easily and accurately measured;
3. Historical data – data from earlier time periods should be available, ideally with a time series of at least 10-20 years;
4. Sensitivity – the amount of change in indicator value corresponds to a change in the pressure (e.g., fishing, pollution);
5. Responsiveness – this includes the type of response (linear, non-linear, random) of the indicators to the pressure, the timeliness of the response and the signal to noise ratio, i.e.,

the data used to estimate the indicators should be measurable accurately enough that any change or trend in the indicator is greater than the variance in its measurement;

6. Specificity – indicators may be influenced by more than one pressure (e.g., fishing and temperature). How specific is the indicator to the pressure of concern? Can it be disentangled from other pressure (i.e., it is critical to know why an indicator is changing)?
7. Public awareness – should be easily understandable by non-scientists and clear to communicate; and,
8. Cost-Effectiveness – sampling, measuring, processing, analysing indicator data, and reporting assessment outcomes, should be feasible and within existing financial resources.

STEP 4: **Evaluate indicators** using criteria from Step 3 to narrow down the list of indicators. Given that no one indicator is likely to score well on all the criteria (i.e., have all the desirable properties), decisions need to be made on which are the most important properties for each indicator. The strategy for evaluating and selecting indicators may depend on the operational objective and the type of indicator: weights could be assigned to different properties and used to aid in indicator selection; alternatively, a suite of indicators may be selected to collectively encompass the full set of properties.

STEP 5: **Assess whether there is redundancy** within the suite of indicators using statistical techniques such as correlation analysis, multivariate analysis and mutual information analysis (Blanchard et al. 2010; Greenstreet et al. 2012). The objective is to reduce the suite of indicators to a parsimonious number. This ensures that all ecosystem attributes/properties are captured and avoids bias when synthesizing across indicators.

STEP 6: **Agree on the final suite of indicators** and cross-reference against the Operational Conservation Objectives. This would ensure that there is one or more suitable indicator(s) for each objective. Note there will be an iterative process through Steps 2 – 6.

STEP 7: **Estimate limit reference levels (unacceptable conditions) and target levels** for each indicator. The guidelines from the Working Group on the Ecosystem Effects of Fishing Activities (ICES 2012), recommend that “Quantitative thresholds are preferred over qualitative thresholds. Expert judgment thresholds should be avoided whenever possible and, when used, fully documented”. The feasibility of estimating quantitative limit and target reference levels depends on the type of indicator. For example, it may be possible to estimate reference levels for indicators of biodiversity or for single species, based on methods used in fish stock assessment and species at risk assessment. However, this is more challenging for indicators of ecosystem function. Alternative methods to estimate reference levels include the use of historical time series to identify acceptable and unacceptable values of the indicator or modelling the indicator values under extreme stress or in the absence of fishing.

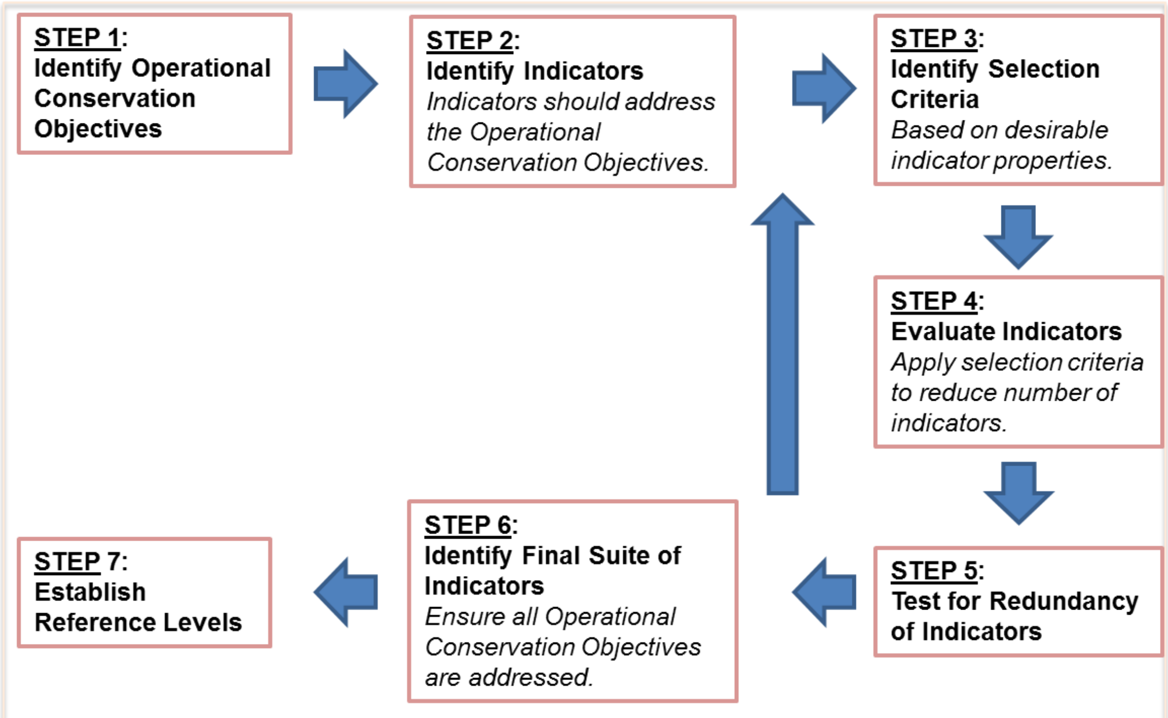

Figure 2. Framework for the selection of indicators to assess MPA and MPA network performance.

Other considerations and guiding principles when identifying indicators for MPAs and MPA networks

In addition to the above, the following are important considerations from the MPA and MPA network perspective:

- When possible, indicators should be monitored by non-invasive methods – causing neither harm nor disruption to the MPA's ecosystem or its components. This could be considered when prioritizing indicators, e.g., for indicators ranked as having equal merit on other considerations.
- Prioritize indicators that can be estimated in a coordinated and consistent fashion among jurisdictions, bioregions and internationally where appropriate.
- The timeframe necessary to detect change in an indicator, which will depend on the feature (generation time, response times) and the pressures, should be documented when the indicators are identified.
- It is advisable that the same indicator be used to assess similar objectives in more than one MPA or network to allow for comparisons at the network level (within a bioregion) or at the national level (between bioregions). If the same indicators are used in all MPAs within the network or a strategically selected subset of MPAs within the network, it would allow for data analyses at the network scale (e.g., an indicator of network function might be rates of recolonization of locally/regionally extirpated species that are presently isolated to one or two MPAs to other areas where they formerly occurred).

Guidance on the Development of Monitoring Protocols and Strategies

Because monitoring protocols and strategies are specific to the indicator selected for a particular Operational Conservation Objective, the following advice focuses on providing general guidance that would be applicable when developing monitoring protocols and strategies for MPA networks. The advice is based on the review of international practices with MPA networks, and domestic experiences with development of monitoring protocols and strategies for MPAs:

- Monitoring protocols describe the specific methodologies required for the monitoring activity such as equipment, techniques, quality control, timing, frequency, as well as analysis of data. Monitoring strategies are those avenues employed to undertake the monitoring protocols. For example, these may be carried out by DFO, other government agencies, academia, and community groups or by other opportunistic means. Community-based monitoring and citizen science should always be considered when developing monitoring protocols for MPAs and MPA networks.
- The scale and frequency of monitoring activities need to be considered when developing monitoring protocols and strategies (e.g., coarse or detailed monitoring). Previous experience also highlights the importance of regularly evaluating the efficacy of the indicators, monitoring protocols and the resulting indices as monitoring protocols may need to be revised based on the outcomes of these evaluations.
- To ensure that neither harm nor disruption is caused to the MPA's ecosystem or its components, non-invasive monitoring methods should be selected, where possible.
- Monitoring protocols and strategies for each indicator should be based on previous or on-going research efforts, where possible, to allow for comparison of results and efficient merging of datasets. However, their use will require explicit evaluation/interpretation to ensure applicability and accuracy. As well, natural variability should be considered as it could result in high uncertainty associated with all indicators. Monitoring protocols should be designed with this in mind as they need to provide sufficient statistical power to detect ecological changes large enough to be of concern for management.
- Ensure monitoring data are archived and accessible in relevant and established databases that are adequately maintained.
- Monitoring drivers and/or stressors of anthropogenic impacts (where this is necessary for the indicator) that affect the indicators must occur simultaneously so that any changes can be associated with causal factors. At a minimum, monitoring of abiotic parameters is essential.
- What happens within an MPA is not independent of what happens outside the MPA or the MPA network. The magnitude of the adverse impacts from unprotected areas, given that the magnitude of pressures may be less constrained outside the MPA, has the potential to also impact protected areas. Therefore, monitoring conducted solely within the bounds of MPAs may not be effective at signaling change. Linking monitoring activities within MPAs to research and monitoring in areas outside MPAs could increase effectiveness in detecting changes in the indicator in some cases (particularly for key migratory species).
- When developing monitoring protocols for indicators of Operational Conservation Objectives for pressures and when conducting monitoring and evaluation of the status of ecological properties themselves is not feasible, monitoring of a pressure could be a reasonable alternative, as long as there is a well-established link between the level of the pressure and the

status of the ecosystem properties of interest. For example, fishing pressure may be set at a low level to achieve conservation objectives.

Considerations Regarding Evaluation of the Effectiveness of the Network in Meeting its Conservation Objectives

While it is premature to provide specific guidance on evaluating the effectiveness of an MPA network, the following considerations are important during the planning stages of the bioregional MPA networks:

- Success of an MPA network will be demonstrated when a network is meeting its Conservation Objectives. In evaluating the effectiveness of the network, an important consideration would be to demonstrate that the network is doing more than the sum of its parts (the “value added” of a planned network over a collection or a set of randomly selected MPAs). An important consideration would be that the MPA network design features outlined in the CBD Annexes from Decision IX/20 are adequately incorporated into the network. Given MPA network design features, and the fact that individual MPAs will be designed to contribute to the goal of the network as a whole, if the network is adequately designed, success of individual MPAs will contribute to demonstrating the success of the network.
- It is important to understand what a particular component (an individual MPA) is contributing to the network, and what an Operational Conservation Objective is expected to show from the results of monitoring efforts. For example, if the goal is to achieve protection, then monitoring may not be expected to show improvement, only maintenance of components in *status quo*.
- Modelling could serve as an effective tool towards both design and evaluation of the effectiveness of MPAs and MPA networks, and should be further explored. For example, scenarios could be modelled to understand if indicators are sufficiently sensitive.
- Indicator data from both inside and outside MPAs and MPA networks, collected before and after their establishment, will improve the ability to measure MPA network effectiveness. As well, changes due to natural environmental changes should be considered.

OTHER CONSIDERATIONS

- Previous science advice on MPA networks (DFO 2010) highlighted the importance of understanding the role of MPAs and MPA networks relative to the roles of other management tools. These roles can be informed, and cooperatively decided upon, by the full range of policy and decision makers, and informed by the best available science. MPA network planning and design should consider the role of the various management tools that will contribute to the conservation and sustainable use of the ecosystems in which the networks occur and therefore will contribute to realizing the agreed-upon goal of providing long-term protection of biodiversity, ecosystem function and special natural features.
- As MPA networks are implemented at the bioregional level, monitoring must be considered to ensure a proper basis for evaluating whether the Conservation Objectives of a given MPA network are being achieved. It is recognized that, depending on the bioregion and the Operational Conservation Objective(s), the types and amounts of data or level of monitoring required to evaluate the effectiveness of a network in meeting its Conservation Objectives will vary.

- Information was not presently available to provide advice on appropriate ways to set time-bounds for operational objectives for recovery of various types of ecosystem components, particularly degraded ecosystem functions, beyond noting that such bounds will depend on a number of ecological factors. More consideration of this issue is warranted, particularly ensuring linkages with other ongoing research in DFO, such as the Aquatic Climate Change Adaptation Services Program (ACCASP), that may contribute to this topic and will inform future considerations.

SOURCES OF INFORMATION

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, national advisory meeting of 3-5 of October 2012 on *Guidance on the Formulation of Conservation Objectives and Identification of Indicators, Monitoring Protocols and Strategies for Bioregional Marine Protected Area Networks.* Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule.

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