## Matching objectives with indicators

**Ian Perry (facilitator),** Jake Rice, Glen Jamison, Francis Weise, Anne Hollowed (rapporteur), Suam Kim, and Akihiko Yatsu

### Objectives

The group began by reviewing the high-level objectives for ecosystem-based management in the eastern Bering Sea (and North Pacific) as defined by several management agencies for these regions, and summarized by Belgrano *et al.* (this report):

- Protect ecosystem structure, functioning, and key processes (including diversity and habitats);
- Account for food web interactions;
- Manage regionally;
- Incorporate precaution into decisions;
- Integrate broad societal goals; and
- Acknowledge multiple, external influences, including climate.

The group noted that most of the objectives were not true objectives (many are "directions" to improve management), and that all could be folded under objectives 1 and 5 as overarching (but very general) objectives. The group decided that to spend time discussing these high-level goals was not useful for the following reasons:

- These objectives will be established by governmental agencies with broader input than the members of this group;
- Most governmental institutions have already established high-level objectives; and
- The goals are so broad and general that scientists cannot offer meaningful scientific advice on them.

It was also noted that objective 5 in its current form is inappropriate for the activity of this workshop because integration of societal goals is not necessarily important to conservation. For example, it was pointed out that governments (generally) cannot be sued for failing to maintain high levels of walleye pollock, however, they can be sued for failing to prevent the pollock stock from falling into an overfished state. A key point for the group was that the integration of societal goals comes once the boundaries of conservation have been identified – it is the role of scientists to determine and articulate these conservation boundaries. Identifying conservation objectives is the core of science and, although not "easy", methods are being developed to achieve this task. Socio-economic objectives need to be better defined, and by a larger constituency than scientists; once this has been done then scientists can identify ecological means to move towards these socio-economic objectives. Therefore, a 3-step procedure was envisaged:

1. scientific identification of conservation limits;
2. articulation of socio-economic objectives; and then
3. scientific identification of means to move towards socio-economic goals.

The North Pacific Fishery Management Council (NPFMC) should play a central role in identifying socio-economic objectives for the ecosystems discussed here.

Legislative language typically sets objectives to "avoid a certain state". With ecosystems, however, this type of language should be broadened to include terminology such as "maintain the ability for ecosystems to recover from perturbation". Such an objective could then be dissected into the knowledge, *e.g.*, biodiversity and a natural mix of species and age groups that maintain resilience, and the actions required to achieve this objective.

### Indicators

The group discussed the difference between contextual and management indicators. Contextual (or "audit") indicators provide background context, and may index conditions over which humans have no direct control. Management (or "control") indicators report on conditions over which humans have some direct control; they could be used to monitor the results of management actions. Several issues were noted for indicators:

- Most tend to index current conditions rather than predict a future state;
- There are unresolved issues of how well indicators might perform between different "regimes", or whether they may exist at all, *e.g.*, whether sea ice will be an important indicator in a future (warm) Bering Sea.

The existence of vague objectives makes identification of effective indicators particularly difficult, if not impossible. It would be useful for stakeholders to clearly define their goals to evaluate how conservation and stake holder goals match, and to enable scientists to define management actions to increase the likelihood of achieving these goals. However, in the Bering Sea where fishing mortality is tightly controlled, the ability for managers to engineer an ecosystem to achieve a societal goal may be limited due to uncertainties of ecosystem productivity.

Characteristics of good indicators include (*e.g.*, Rice and Rochet, 2005):

- Forecast: Indicators should be able to consistently predict a particular phenomenon.
- Sensitivity analysis: Given an objective and a list of potential indicators and the processes that may impede or accelerate progress towards achieving the objective, evaluate which indicators are most sensitive to threats.
- Is it measurable? What is the cost of collection?
- What is the ease with which you can communicate the criterion?
- Can you link the indicator to a management action?
- The indicators must be able to withstand scrutiny when it is used for decision making, particularly when the decision may result in reduced access to resources.

The group noted that there are a few cases in which an ecosystem indicator has been used by management to limit fisheries activities, *e.g.*,

- Kittiwake fledging success has been used to control sand eel fisheries in the North Sea.
- Harvest control rules for Pacific sardine fisheries are conditional on temperature at Scripps Pier. However, the temperature has never dropped to a level at which reductions in fishing mortality have been implemented.

Lessons could be learned by examining societal responses to the use of such indicators in a management context.

**DPSIR approach**

The Driver-Pressure-State-Impact-Response (DPSIR) framework has become increasingly useful for determining ultimate drivers, indicators, and responses of environmental systems to stressors. The ICES community has been exploring this framework in an assessment of the key pressures of human activities on marine ecosystems (*e.g.*, Table 7). A schematic flowchart of how such a DPSIR approach might be integrated into issues of indicators and objectives has been developed (Fig. 19). At present, scientists in the Bering Sea–North Pacific regions have good sets of indicators for Pressures and State, but poor indicators for their Impacts. In addition, the Response to these Drivers, Pressures and Impacts need to depend on the desired (and stated) objectives for the ecosystem.

**Risk assessment**

There are often multiple pathways leading from objectives to indicators; risk assessment is a formal tool which can help to choose among these various pathways (*i.e.*, given the knowledge available and uncertainties, which pathway might be expected to achieve the desired result). The group recognized that it may not be practical at present to do risk assessments on whole ecosystems. At present, a more practical question is to ask, "Will activity *A* do harm to specific key parts of the ecosystem?"

The group noted that there are techniques for assessing the risk of specific management decisions. Regional fisheries management councils should evaluate what level of risk is acceptable. To do this, scientists must provide an evaluation of the risk to ecosystem function by a particular activity. This requires assessment of the cumulative effects of past and present activities. While this can be done qualitatively, developing a probabilistic representation of this surface is likely to be difficult. Too broad a surface may give clients and fisheries managers a sense of security that the system is more resilient (less responsive) to management actions than may be true.

**Table 7** The relationship between activities in the North Sea and the mechanisms through which they exert pressure on the marine ecosystem. From ICES Working Group Report 2006, WGECO, Table 4.4.3.1.

| | **Activity** | Aquaculture | Climate change | Dredging | Oil & Gas | Renewable energy | Aggregate extraction | Fisheries | Recreation | Military | Research | Shipping | Land-based discharges & emissions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| **Pressure** | | | | | | | | | | | | | |
| Physical | Substratum loss | | | ■ | ■ | ■ | ■ | ■ | | | ■ | | |
| | Smothering | ■ | | ■ | ■ | ■ | ■ | ■ | | | ■ | | ■ |
| | Change in suspended sediment | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | | ■ |
| | Change in water flow rate | ■ | ■ | | ■ | ■ | ■ | ■ | | | ■ | | ■ |
| | Change in temperature | | ■ | | ? | | | | | | | ?Ballast | ■ |
| | Change in turbidity | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | | ■ |
| | Change in sound field | | ? | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| | Change in light regime | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | | ■ |
| | Visual presence | ■ | | | ■ | ■ | | ■ | ■ | | ■ | | |
| | Abrasion/ physical disturbance | ■ | | ■ | ■ | ■ | ■ | ■ | | | ■ | | |
| Chemical | Synthetic compound contamination | ■ | | ■ | ■ | | ? | | | ? | | ■ | ■ |
| | Heavy metal contamination | | | ■ | ■ | | ■ | ■ | | ■ | ■ | ■ | ■ |
| | Hydrocarbon contamination | | | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Radionuclide contamination | | | ■ | ■ | | ■ | ■ | | ■ | ■ | | ■ |
| | Changes in nutrient levels | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | | ■ | | ■ |
| | Changes in salinity | | ■ | | | | | | | | | ■ | ■ |
| | Changes in oxygenation | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | | ■ |
| Biological | Introduction of microbial pathogens/ parasites | ■ | ■ | | | | | ■ | ■ | ■ | ■ | ■ | ■ |
| | Introduction of non-native species & GMOs | ■ | ■ | | ■ | | | ■ | ■ | ■ | ■ | ■ | |
| | Selective extraction of species | ■ | | | | | | ■ | ■ | | ■ | | |

Shading indicates an existing mechanism for a particular activity, while '?' indicates a potential mechanism.

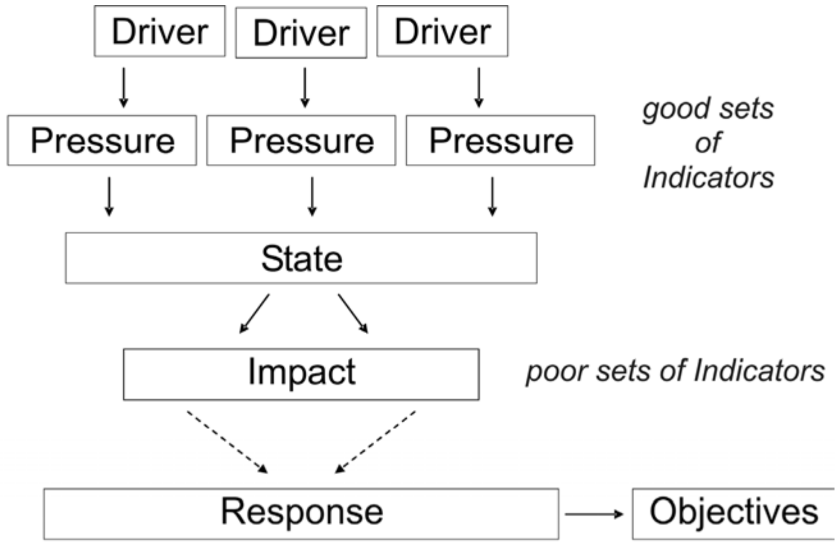


**Fig. 19** Schematic that matches indicators to objectives using a DPSIR approach.

## Recommendations

1. The integration of societal goals should occur once the boundaries of conservation have been identified – it is the role of scientists to determine and articulate these conservation boundaries. A 3-step procedure is recommended to develop objectives for ecosystem-based management of particular systems:
   - scientific identification of conservation limits;
   - articulation of socio-economic objectives (not exclusively by scientists); and then
   - scientific identification of means to move towards socio-economic goals.

   Regional fisheries management councils, such as NPFMC, should play a central role in identifying socio-economic objectives for the ecosystems considered in this workshop.

2. Selection of indicators is a signal detection exercise. Scientists in the PICES region should develop formal evaluation criteria and perform the evaluation (see Rice and Rochet, 2005). Scientific standards must be high but this should not deter forecasting as failures in prediction are often informative.

3. Consider the Driver-Pressure-State-Impact-Response (DPSIR) framework as a tool to evaluate human and climate drivers of changes in marine ecosystems, how these might be adequately indexed (*e.g.*, considering "contextual" and "control" indicators), and how they relate to management actions and decisions.

4. Risk assessment techniques must be developed and included in evaluating appropriate response pathways from indicators to action and in how they relate to objectives.

## References

Belgrano, A., Boldt, J., Livingston, P. and Napp, J. 2006. Toward ecosystem-based management for the oceans: A perspective for the fisheries in the Bering Sea. (This report)

ICES. 2006. Working Group on Ecosystems (WGECO) report.

Rice, J.A. and Rochet, M.-J. 2005. A framework for selecting a suite of indicators for fisheries management. *ICES J. Mar. Sci.* **62**: 516–527.