Northeast Fisheries Science Center Reference Document 06-06

Report of the GoMA GOOS Workshop on Objectives of Ecosystem Based Fisheries Management in the Gulf of Maine Area
Woods Hole, Massachusetts
11-13 May 2004

by

Stratis Gavaris, Wendy Gabriel,
and Thomas Noji, Co-Chairs

April 2006

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Background

The Global Ocean Observing System (GOOS) is an international programme preparing a permanent global framework of observations, modeling and analyses of ocean variables needed to support operational ocean services. The goals of GOOS are:

- To serve the marine data and information needs of humanity for the efficient, safe, rational and responsible use and protection of the marine environment, and for climate prediction and coastal management, especially in matters requiring information beyond that which individual national observing systems can efficiently provide, and which enable smaller and less-developed nations to participate and gain benefit.
- To establish an international system to provide the required coordination and sharing of data and products that otherwise would not be possible.

The ICES Steering Group on the GOOS was established in 1997 with the focus of its early deliberations being the coordination of collection and reporting of measurements pertaining to operational fisheries oceanography. It was noted in the initial SGGOOS planning document that the challenge for the fisheries research and management community is to assemble, assess and use environmental data within the annual fish stock assessment cycle. SGGOOS subsequently promoted regional GOOS Pilot Projects in the north Atlantic.

Significant progress is being made in developing a GOOS regional alliance between Canada and the USA through the development of a pilot project for the Gulf of Maine area, GoMA GOOS. A draft project proposal has been completed and task teams are being formed to address technical issues such as data sharing protocols, data product development, etc. It was anticipated that the project would start in 2003/2004, run for five years and would be funded primarily from internal resources from the major players – Fisheries and Oceans Canada and the USA National Marine Fisheries Service. Several planning meetings for GoMA GOOS have already occurred but this workshop was the first working meeting.

There are conflicting multiple uses of the Gulf ecosystem; including fisheries, oil and gas, aquaculture, waste disposal, eco-tourism, marine transportation, and recreation. Changes in international and national legal instruments have created a regime shift in the management of ocean activities; from *ad hoc* consideration of sectoral issues within relatively narrow conservation constraints, to integrated management of multiple ocean uses within the context of broad ecosystem objectives. The United States and Canada are grappling with the technical challenges of implementing ecosystem-based fisheries management (EBFM) in a practical manner. The GoMA GOOS project places particular emphasis on fisheries use of the ecosystem and initial efforts will focus on needs for managing fisheries, but will be approached from the perspective of the broad ecosystem objectives.

Contemporary fisheries management plans are complex and have evolved to include a greater range of emerging concerns. The impact of overexploitation on target species was the focus during the 1970s and 80s, followed by attention to incidental mortality on non-target species in the 1990s and now to disturbance of ecosystem structure and function. The conservation objectives, maintaining productivity, preserving diversity and protecting habitat, are important for securing viable and sustainable fisheries into the future. Scientific evaluations have formed the basis for development of strategies to achieve the conservation objectives and of tactics to implement the strategies. Following the historical evolution of emerging concerns, much of that scientific evaluation has concentrated on exploitation strategies for maintaining productivity. The purpose of this workshop was to identify the relevant monitoring required to address strategies of practical relevance to fisheries management planning with respect to the full scope of ecosystem conservation objectives.

The GoMA GOOS project has four main objectives:

- Evaluate the observation and monitoring system, and its coordination, of the Gulf of Maine Area (NAFO Div 4X-5) in relation to diverse indicators required for 'integrated management', with particular emphasis on fisheries.
- Develop an information support system for management.
- Undertake research on the inter-relationships of indicators of diversity, productivity, and habitat.
- Develop a seasonal forecast model of the Gulf of Maine and adjacent marine areas. Incorporate oceanographic models for the Gulf of Maine Area into climate change models of the North Atlantic.

One approach for undertaking the work implied by these objectives would be to catalogue potentially useful ocean observations that could serve as indicators in EBFM. A disadvantage of such an approach is that effort and resources may be expended planning for the collection and reporting of indicators that are poorly, or even not at all, linked to the strategies of the EBFM. The approach taken at the workshop was to identify the decision support requirements by evaluating the conservation objectives and associated strategies of EBFM and subsequently developing pertinent indicators. The resulting EBFM framework could serve as a guide for project activities.

Defining the Context for this Workshop

The Gulf of Maine Global Ocean Observing System (GoMA GOOS) is intended to provide monitoring capacity and address information needs to support Ecosystem-Based Fisheries Management (EBFM) in the region. The Gulf of Maine Council is developing a suite of indicators to characterize the State of the Gulf. Contacts should be developed within the Gulf of Maine Council so that the two groups' efforts are complementary. The focus of the Census of Marine Life program in the region is broader than monitoring, but GoMA GOOS can meet the monitoring needs of that program.

In the broader GOOS context, this group considered the formation of a regional alliance. The formation of a regional alliance would represent a formal commitment to management, a long-term observation network, and conformation to GOOS principles such as data exchanges.

Terminology

Objectives are generally considered to be broad aspirations for management programs. For example, a suite of conservation objectives could entail conservation of biodiversity, productivity and habitat. Objectives focus on managing ocean use, rather than managing ecosystems. Of the multiple components of ocean use, fisheries is the focus of the GoMA GOOS program, rather than other social and economic components of ocean use. In the context of fisheries management, objectives would be to ensure that fishing does not cause an unacceptable reduction in biodiversity, productivity, and habitat.

High level conceptual objectives, stating the broad aspirations and policies, are translated into operational strategies, defined by indicators and reference points. An objective of fisheries management planning in the Gulf of Maine area might be to ensure that fishing does not cause reductions in the productivity of the harvested resources. The strategies define "what" will be done to achieve the objectives. For example, a strategy that can be employed to contribute towards achievement of the conservation of productivity is to keep fishing mortality rates moderate.

The process of developing strategies to achieve the conservation objectives involves restating the objectives with greater specificity at each step until the outcome constitutes the equivalent of a phrase that includes a management action, a measurable performance indicator, and a reference point for that performance indicator. The performance indicator is prescribed by the strategy and tracks the quantity that the strategy is aimed at affecting. A reference point for a performance indicator is a guidepost for decision making. Often it is a threshold that delineates a boundary between acceptable and unacceptable states of the performance indicator. Reference points are derived and updated using various supporting metrics with relationships that describe our understanding of ecosystem and fishery dynamics.

We have identified three major categories of indicators:

- Performance indicators reflect the performance of the management system, not the performance of the ecosystem. Performance indicators relate to human pressures that can be managed.
- Supporting indicators are variables that are used in developing a reference point or evaluating system status, but may not be directly related to human pressures that can be managed. Changes in supporting indicators (e.g., environmental variables) may modify the reference point. These indicators may be:
    - High frequency, reflecting annual dynamic processes, for example; or
    - Low frequency, reflecting longer term processes.
- Contextual or presumptive indicators are quantities of interest with no currently proven link to or effect on a reference point, but which may eventually be found to be influential. These indicators may be objects of research efforts, and may be considered candidate supporting indicators.

The difference between these indicator types can be illustrated using traditional single-species fishery management indicators and reference points. Fishing mortality rate is an example of a performance indicator: it reflects a human pressure which is intended to be controlled by the management process. Stock biomass is an example of a supporting indicator: it cannot be directly controlled by management, but it is used in the development and implementation of control rules and reference points, and is also used to evaluate stock status.

The North Atlantic Oscillation (NAO) index may be an example of a conceptual or presumptive indicator: although the underlying environmental process may affect stock productivity over time, and hence the reference fishing mortality rate, the linkages or mechanisms have yet to be demonstrated. Nonetheless, it is desirable to continue to monitor this indicator, as it may have future explanatory power.

Oceanographic features in general are known to be important influences on productivity, but we often do not understand how they will affect reference points. In cases where credible hypotheses exist or linkages to reference points are clear, an environmental indicator could be considered qualitatively as a supporting indicator. For example, if temperature were to decrease, one would expect a decrease in growth rate, which would imply a decline in an F-based reference point related to fisheries yield. In other cases, it is simply desirable to track environmental changes over time to evaluate whether the environment is changing from a biogeographic perspective, because the Gulf of Maine is a transition zone for several species groups. In still other cases, changes in oceanographic features could modify ecosystem elements. For example, a change in stratification characteristics would change the distribution of nutrients in the water column, potentially changing the pelagic/benthic structure of the system. Environmental changes may affect every sector's management approach, as human behavior within the sector may need to be modified in the face of environmental change.

Management measures are regulatory actions that occur at the sector level (e.g., fishery use of the ecosystem).

Proposed Strategies, Performance Indicators, Supporting Indicators

The principal outcome of the workshop was development of an Ecosystem-Based Fisheries Management framework to serve as a guide for project activities. The background discussions are summarized in the Appendix. The framework was structured according to the following template:

Objective

Sub-objective

- Strategy
    - {**performance indicator**: *reference point supporting indicators*}

This framework is designed to be consistent with the traditional single-species approach, but to move from single-species reference points to ecosystem analogs. The core currency remains production, although now production is viewed from a whole system perspective rather than from single species perspective. The largest difference in this framework is probably in the scope of tradeoffs to be evaluated by managers. Tradeoffs must now be considered among sectors, e.g., among petroleum, aquaculture, and groundfish fishery sectors.

The development of conservation objectives will drive plans for each sector, and plans for each component within that sector. Not all issues will be relevant in every sector. If a national objective is the conservation of the diversity of benthic communities, then the groundfish fishery and gas and oil sectors will address this issue, while marine transportation may not (with the possible exception of species introductions via ballast water). After individual sectors have established plans to address the issue, then those plans should be pulled from the component sectors and reviewed for consistency and cumulative effects. In the example of conservation of diversity of benthic communities, area of disturbance may be an indicator. Both the groundfish fishery and gas and oil sectors contribute to the area of disturbance. Thus, the indicators may have a hierarchical structure: a within-sector component and an among-sector aggregate.

The draft EBFM framework developed at the workshop follows.

Biodiversity

Biotopes/seascapes

- Limit disturbance of seascapes/biotopes within Gulf of Maine
  - {**% area and frequency disturbed per unit time**: *habitat / biome / seascape map, vulnerability of habitat to specific gears, geographic pattern of physical disturbance, recovery rate of disturbed biomes/seascapes, identify biomes/seascapes, relative importance of spawning grounds as a factor in achieving MSY*}

Species

- Limit incidental mortality on species of concern including loggerhead and leatherback turtles, harbor porpoise, Atlantic salmon, cusk (Cdn), coastal and offshore sharks, and whales.
  - {**bycatch**: }
- Limit incidental mortality on non-target species
  - {**% bycatch** or **absolute bycatch** or **bycatch mortality rate**: }
- Minimize spread and impact of invasive species
  - {**change in species distribution**: }

Populations

- Maintain components of (target species, such as Atlantic herring, Gulf of Maine cod)
  - {**% component biomass** or **number of viable components**: }

Productivity

Primary Production

- N/A

Community productivity

- Preserve sufficient biomass of forage species (including herring, krill, mackerel, sand lance, and squids) for higher level predators
  - {**Landings/Consumption of aggregate forage species by predators**: *biomass prey, human and natural removal of prey, biomass predator, composition of diet, consumptive demand, temperature*}
- Limit biomass removals from any trophic level with respect to trophic demands of next higher level
  - {**catch at trophic level $_i$/demand at trophic level $_{i+1}$**: *biomass of trophic levels, human and natural removal of prey, composition of diet, consumptive demand, trophic transfer efficiencies, temperature*}
- Limit total biomass removals within system production capacity
  - {**total catch biomass**: *production of trophic levels, human and natural removal of prey, composition of diet, consumptive demand, trophic transfer efficiencies, temperature*}
- Adjust fishing mortalities to address biomass tradeoffs and multispecies interactions (e.g. silver hake vs. cod)
  - {**fishing mortality**: *socio-economic considerations*}

Population

- Keep fishing mortality moderate
  - {**fishing mortality**: *biomass, weight at age, fishery exploitation pattern at age, maturity at age*}
- Promote rebuilding when biomass low

  - {**biomass change**: }
- Prevent fishing when biomass below threshold
  - {**biomass**: }
- Maintain population at biomass optimum yield (OY)
  - {**biomass**: }
- Manage size/age/sex of capture
  - {**% size/age/sex in catch per unit time**: }
- Prevent disturbance during spawning
  - {**effort in spawning areas**: }
- Minimize discarding
  - {**% discarded catch per unit time**: }

Habitat

Bottom

- Limit disturbance to nursery grounds, spawning grounds, and benthic communities
  - {**% area and frequency disturbed per unit time**: *habitat / biome map, vulnerability of habitat to specific gears, geographic pattern of physical disturbance, recovery rate of disturbed habitats, identify nursery grounds, relative importance of nursery ground as a factor in achieving MSY*}
- Limit disturbance to structural complexity, e.g. corals, of physical environment
  - {**% area and frequency disturbed per unit time**: *habitat / biome map, vulnerability of habitat to specific gears, geographic pattern of physical disturbance, recovery rate of disturbed habitats, distribution of structurally complex habitats such as corals*}

Water Column

- Minimize loss of gear and ghost fishing (long lines, nets)
  - {**rate of encounter with lost gear; amount of lost gear**: *type of gear, density of lost gear, incidental mortality caused by lost gear, biodegradability of gear*}
- Reduce/control noise level and frequencies with respect to species of risk, e.g. marine mammals
  - {**distribution of species of risk relative to distribution of the disturbance including sonar and engine noise**: *sound frequency and intensity of disturbance relative to ambient background*}

Other issues

- Inclusion of effects of climate variability/climate change on management decisions/actions/monitoring
  - Open ocean {volume transport; heat; salinity; freshwater; nutrients; zooplankton; micronekton; }
  - Land/ocean{river discharge; nutrient discharge; contaminants}
  - Atmosphere/Ocean fluxes {evaporation/precipitation balance; CO2, contaminants}
  - Internal indicators {upper vs. deep waters: heat content; salt content upper - deep; stratification; winter mixing: nutrients in surface water; spring bloom timing, concentration, composition; overwintering zooplankton: *Calanus finmarchicus*; community structure of zooplankton; seasonal characterization of production cycle; }
- Monitor turbidity of upper mixed layer

- Monitor meteorological events, which can trigger phytoplankton blooms
- Track impact of predation by top predators (seal populations)
- Monitor quality and availability of zooplankton food supply
- Monitor quality and availability of phytoplankton food supply
- Consider alteration of physical structure and sediment-water chemistry due to resuspension of sediment
- Maintain genetic diversity (of targeted species, such as prevention of selective removal of faster growing individuals)

Framework Evaluation

There are two aspects of the framework that require evaluation:

1. Are the strategies effectively implemented by the management measures?
2. Are the conservation objectives being achieved by the strategies?

Evaluation of the effectiveness of management measures for implementing the strategies is accomplished by regular monitoring of the performance indicators relative to the respective reference points.

Evaluation of the appropriateness of strategies for achieving the conservation objectives can be done less frequently, but periodically, when demographic and/or environmental supporting indicators are updated or when refinements to the models describing the ecosystem dynamics have been developed. While considerable progress in establishing strategies may be achieved with analytical and/or empirical models, e.g. fishery productivity models, more complex situations with interactions among the suite of management measures in a plan may require application of management strategy evaluation techniques through simulation.

Next Steps

These strategies must be mapped into current legislation of both countries. In those contexts, details must be added. For example, definitions of biodiversity must be resolved (e.g., number of species vs. relative abundance) and desirable (vs. unacceptable) states identified.

A common USA/Canada framework is required to support individual management and legislative requirements. Consistency is needed because a measure on one “side” affects opportunities on the other. Although the management tactics may differ between the two countries, it would be preferable to adopt the same strategies. At this point, there is only a consistent strategy on the exploitation of some target species. Consistent strategies need to be developed for bycatch species, corals, and other elements. Strategies must be tempered with pragmatism in terms of what can be regulated, however.

Four tasks were identified for first consideration and follow-up.

1. Develop the indicators pertinent to the “other issues” (Lead: K. Frank, G. Harrison, J. Link).
    a. Review area-level indicators and identify “other-issue” indicators.
    b. Once indicators are determined, compare data available to support those indicators to data needed to support those indicators. Identify gaps.
    c. Determine whether data collection systems require enhancement or replacement.

2. Develop the indicators pertinent to “bottom habitat” conservation objectives (Lead: T. Noji, V. Kostylev).

    a. Review indicators and develop indicators as needed.
    b. Compare data available to support indicators to data needed to support those indicators. Identify gaps.
    c. Determine whether data collection systems require enhancement or replacement.

(Some elements, such as underwater noise, require feedback as to whether they are in fact issues which require indicators.)

This represents a valuable opportunity to consider broader perspectives (e.g., with respect to habitat). Supporting indicators and associated data streams also require identification.

3. Summarize the data integration situation by reporting on what is already happening and where the gaps are in data products, linking these to the EBFM framework.
    a. Identify what integration has already been accomplished.
    b. Identify what integration has been planned but remains to be accomplished.
    c. Identify what integration remains to be planned, including what other elements need to be included.

Summarization of data streams may be necessary to organize information for decision-making processes, and that organization scheme requires identification. Additional personnel may be required to incorporate external data sets that are not part of existing on-going data streams. Membership in this group should include Gulf of Maine Ocean Data Partnership members (e.g, David Mountain).

4. Consider the merits of using a “pilot” fishery, e.g. herring versus a suite of fisheries for implementation and evaluation of the framework approach. This task may be started later.
    a. Simulate the use of this approach in practical management. Modify an existing management plan to include indicators and develop reference points and decision rules for management plan. Focus on one fishery, and issues that need to be addressed. Identify stumbling blocks and improvements.

    b. Attempt to integrate more than one plan, if possible.

Simulations of these approaches would enable evaluation. A mechanism for dealing with cumulative impacts of multiple plans (fishing, oil and gas, aquaculture) is required.

5. Formally submit GOMA GOOS to IOC as a Shelf Seas pilot (action M. Sinclair and J. Boreman).

It was anticipated that the groups addressing tasks 1 and 2 could report back by early January 2005.

Appendix: Background Discussions of Alternatives

The workshop focused on incorporating ecosystem considerations by extending the existing fisheries management plan structure because it was considered more pragmatic and more likely to be received favorably by stakeholders. Nevertheless, a variety of alternative management structures and models should be evaluated in terms of potential advantages and disadvantages compared to the ecosystem analog of single-species reference points, implemented in separate management plans.

One alternative to this approach would be the development of a single Gulf of Maine management plan, which would be a higher risk approach than the two national schemes under the status quo. It would require parallel effort for tractability. It would be based on a nested hierarchy, with a single overarching plan consistently implemented by sectors. Implications for fleet sectors would still apply.

A different alternative would be a more aggregate approach with higher level objectives and less species complexity. This would avoid potentially overwhelming complexity of simultaneously managing multiple species individually. The management time frame would be decadal rather than annual. If species co-varied, management goals would include aggregate stability.
Under this approach, for example, a TAC would be developed for a group of economically and ecologically similar species, rather than maintaining individual TACs for cod and haddock, for example. This approach depends on the functionality of taxonomic and economic groupings. It would require ecological and economic substitutability within species aggregations, which is not always the case, however.

Conceptual Model Approach

Under this approach, traditional models are extended to incorporate explicit effects of fishing on carrying capacity (through habitat effects); effects of tradeoffs between and among species (including trophic interactions); and effects of environmental changes on productivity. An intermediate level of complexity is desirable for model usage by fishery managers. Although complex mechanistic details could be added to these models, the cost is an increase in uncertainty, because measurement of complex key parameters is difficult and uncertain. Results of models will not be used to find a single best solution to a specified problem under certain assumptions and model structures (optimization); but rather to find a “good enough” solution (satisficing).

Biodiversity is maintained under this approach by identifying the most vulnerable components of the system and understanding their dynamics, in order to maintain all components of the system. This “weak link” approach may be applied through protection of more vulnerable life history stages, for example. In order to preserve ecosystem structure, these stages may require protection first.

Habitat effects in this context are considered in terms of how changes in fishing effort affects system productivity, e.g., how is carrying capacity affected by changing fishing effort.

Research on complex systems (e.g., on emergent properties and the hierarchical structure of the system) is required. Emergent properties such as total production of the system may be related to trophic diversity rather than production by individual species.

Because ecosystems change over time, the stability implied by “maintenance” or “restoration” may be artificial. Component indicators are expected to change over time. Thus, although there will be indicators and reference points within sector plans that are explicit for sector management, it is also desirable to tract broader indicators within an area (even though the implications of these changing indicators may be unknown at the time).

Empirical Approach

Within a system, there may be bounding conditions which dictate long-term limits, and shorter-term indicators which are appropriate for informing tactics from year to year. There are a suite of indicators which should be detectable, sensitive to change, and reflective of processes within the system. Candidate indicators could be incorporated into control rules to reflect caution or concerns. For example, the proportion of biomass contributed by pelagic fish could be categorized into three categories: when pelagic biomass is very high, target predators may be missing; when pelagic biomass is very low, the forage base may be missing; when pelagic biomass is intermediate, there is less concern about the system. For each of these categories, management actions may be prescribed, e.g., reduce F on target predators, reduce F on forage species, maintain F, respectively. Candidate indicators could include the proportion of total biomass composed of flatfish species, the percentage of biomass at higher trophic levels, the aggregate biomass of piscivores compared to benthivores and planktivores, the mean number of trophic links per species, the number of cycles in the trophic network, the number of scavengers, the volume of jellyfish and the area of living hard coral.

Indicators should be established as a function of fishing mortality rate relative to other perturbations. Indicators may serve as a proxy for fishing pressure, and if fishing mortality were measured, the indicator should corroborate measured patterns in fishing mortality. However, changes in trophic structure, for example, may not be due entirely to fishing mortality. Proxies may be required to reflect second order effects. For example, although fishing mortality estimates may be possible for target species, they may not be possible for non-target species. The drivers that affect these response variables need to be well-understood. For example, changes in mean length or biomass spectrum may arise from changes in fishing mortality rate and/or changes in recruitment.

Combination of Model and Empirical Approaches

In general, a two track approach is desirable, consisting of a) conceptual/analytic models in a form familiar to managers, and b) representation of change over time, indicating that a fundamental change to the system is occurring. In the former track, the model indicates how to change fishing mortality rate to change the system. In the latter track, indicators of overall system change signal that some management action is needed.

Habitat-Related Issues

Habitat types must be related to productivity of fish, and must be prioritized with respect to effects on productivity. Otherwise, in the context of defining Essential Fish Habitat, the entire shelf area would be included. Temporal aspects also become important. For example, nursery areas may not be occupied year-round. Habitats may be classified in terms of relative vulnerability to physical disturbance and relative recovery rates once disturbed. A vulnerable habitat that recovers from disturbance quickly may be more resilient than a less-vulnerable habitat that recovers more slowly once disturbed. Classifications based on grain size may also be valuable in the literature.

The terms “seascape” and “biome” require definition. Benthic communities are considered part of the seascape/biome, but there are specific benthic communities that would be dealt with as habitat (e.g., coral). It is important to consider both the habitat and biome perspectives.

Within the water column, habitat issues include effectiveness and degradation rates of ghost gear, and the attendant mortality inflicted by ghost gear. Anthropogenic underwater noise may affect marine mammals and fish, and monitoring systems should include noise, in terms of frequency and intensity with respect to ambient levels.

Other Observations

Although GOOS implementation plans currently specify 36 regional variables, a regional alliance may select new variables. Formal weighting protocols exist to inform variable selection. We have taken a different weighting approach, however, based first on indicator identification and then on variables to support those indicators. Weighting may also reflect needs associated with international agreements and national legally mandated needs. GOOS Report 125 (IOC Document Series 1183) should be reviewed with an eye to how GoMA GOOS would contribute to that process.

The Gulf of Maine area requires spatial definition in terms of e.g., northern and southern limits.

The process should include identification of ecosystem properties that need to be preserved.

Related to indicators and ocean modeling, basin scale models have been developed based on Argo float monitoring systems which could serve as input to shelf seas models. Funding is required (approximately $100K total?) to unify basin scale and shelf scale models. In this region, the GoMOOS shelf sea model could benefit from incorporation of basin scale and atmospheric forcing. Results could provide input to the indicator groups.

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