Methodologies to monitor ecosystem-wide structural change

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Recognizing that the protection of ecosystem structure and functioning (including diversity and habitat) is an integral part of ecosystem-based fisheries management (EBFM), methodologies to monitor structural changes are a key component of any approach to EBFM. We defined structural changes as:

- changes in relative species composition of any faunal assemblage (based on abundances of individual species, functional groups, or trophic groups);
- changes in species richness, evenness, and/or diversity of faunal assemblages;
- changes in size composition (within or across species);
- changes in habitat type and/or quantity;
- changes in spatial distribution of individual species or species groups.

Methodologies for monitoring structural changes require (1) suitable indicators that can be measured at different points in time, typically on an annual basis, and (2) graphical or statistical methods to examine whether the resulting time series display patterns that may indicate a structural change.

The group's assessment of some of the most promising and useful indicators included indicators from four broad classes.

1. Abundance or biomass of "key" taxa. Commercial fish species and many seabirds and marine mammals are already being monitored closely and status and trend information is published annually. There are, however, clear gaps in our ability to monitor lower trophic-level species that could serve as early indicators of changes in bottom-up forcing and prey availability such as phytoplankton abundance (Chl *a*) and productivity, zooplankton abundance and productivity, abundance of lower trophic level benthos, and abundance of forage fish.

2. Trophodynamic indicators include simple ratios such as pelagic *versus* benthic biomass that were felt to be most useful, easy to interpret, and readily obtained from existing data. Other existing indicators such as the trophic level of the catch and the "Fishing in Balance (FiB)" indicator are currently being computed on an annual basis, but lack clearly defined reference points. Other promising indicators that could be monitored include the community condition factor, the trophic level of the community (based on survey data) relative to the trophic level of the catch, and diet-based indicators of the relative abundance of forage fishes.

3. Size-based indicators have proven useful in many systems and include the mean length (or weight) in the community, slope and intercept of length (or weight) spectra, and the proportion of "large" fish in the community.

4. Diversity indicators were not considered to be particularly useful without further examination of the diversity–productivity relationship. However, the related methodology of constructing abundance/biomass curves was felt to offer a more promising approach as an indicator of "stressed" communities.

The above indicators are largely measures of states rather than rates. Rate indicators are likely to be more sensitive to changes, but are more difficult to measure. Most of the indicators are univariate or aggregate measures derived from survey data. Many other indicators could be derived from multivariate analyses of existing time series or from ecosystem models. However, such indicators are often more difficult to interpret and may be more suitable as a research tool rather than a routine monitoring tool.

To detect structural changes in any indicator time series requires methods to distinguish "normal" fluctuations of a stationary time series from "anomalies" such as one-time events, long-term trends, and gradual or abrupt changes in the mean or variance of a series. Statistical methods for detecting specific deviations from stationarity are available and need to be applied to existing indictor series.