Workshop on Ocean Biology Observatories

Mestre Italy, 16-18 September

Working Group Report: **Observational approaches to changes in trophic structures**

Executive summary:

The function and resilience of an ecosystem depends on the strength and versatility of the trophic links. Changes in tropic structure that have been broadly identified as having major energy transfer and biogeochemical impacts. E.g. 1) Changes in planktonic and benthic primary producers (e.g., HABs, macroalgae) that have major impacts on grazers and higher trophic levels, including man (i.e. toxicity). 2) changes in planktonic grazers, away from crustacean/fish to gelatinous zooplankton, with major implications for secondary grazers and carnivores. 3) Top-down impacts, such as overfishing on carnivorous and/or zooplanktivorous fishes (sardines and anchovies off Namibia), which have led to cascading effects on the food web as well as biogeochemical cycling.

To detect the ecological impact of currently observed global changes, it is necessary to measure on a global scale. Large scale monitoring is important, with large scale measurements bounded by point process studies and observing systems that introduce process and time-scale contexts to the global scale. Existing and future locations and time-series data should be identified as benchmark sites critical to the detection of change, its roots, and its likely causes and outcomes.

The objective of this working group was to integrate detection, characterization and quantification of changes in trophic structure in large scale ocean observation programs. Observing and monitoring marine ecosystems structure and energy flux variations poses a particular challenge for modern ecology. No instruments exist for direct measures, and indirect methods are commonly expensive, effort consuming, and system specific.

In order to capture trophic structure and change, the ideal scenario would be to measure energy flow, biomass, density and biodiversity across spatial and temporal scales, globally. Ecosystem modeling is considered essential, and methods to integrate observed data into current and future models and vice/versa should be considered important. Comparable metrics and associated uncertainties should be produced from observational and modeling studies.

In the context of global observing systems to approach this task, basic core measurements across observing systems would be biomass and distribution information on primary producers, primary consumers and secondary consumers. Current technology exists that are feasible to include in global scale observation programmes, integrating temporal and spatial scales, these include Sea-surface colour, fluorimetry, optical imagery, active and passive acoustics and tagging that could be cost-effective across large numbers of observing systems. Resulting observations, combined with physical and chemical data will detect trophic structure and changes at local, regional and global scales as well as challenge and validate ecological models.

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Work-group discussions:

The objective of this working group was to integrate detection, characterization and quantification of changes in trophic structure in large scale ocean observation programs. By way of specific examples and their impacts on trophic structure, we discussed ways to include methods and approaches for determining trophic changes, their impacts on food web dynamics, fluxes of carbon, nutrients and energy in marine ecosystems. It is important to consider environmental (including natural-climatic and human) impacts on trophic structure in the context of physical forcings, biogeochemical cycling, biodiversity and overall water quality and habitat conditions/change in the context of conservation of matter and energy. These are essential ingredients of an observational component dealing with changes in trophic structure, especially if such a component is to be included in larger scale, comprehensive monitoring and modeling efforts as part of ocean biological observatories.

One focus of this discussion group was to provide documentable examples of changes in tropic structure that have been broadly identified as having major trophic transfer and biogeochemical impacts. These include: 1) Changes in planktonic and benthic primary producers (e.g., HABs, macroalgae) that have major impacts on grazers and higher trophic levels, including man (i.e. toxicity). 2) changes in planktonic grazers, away from crustacean to gelatinous zooplankton, with major implications for secondary grazers and carnivores. 3) Top-down impacts, such as overfishing on carnivorous and/or zooplanktivorous fishes (sardines and anchovies off Namibia), which have led to cascading effects on the food web as well as biogeochemical cycling. .

There have been many advances in the detection, characterization (species, functional groups, and communities) and quantification of key species and communities mediating these changes. These include acoustic, optical (e.g., laser, fluorescence, bioluminescence), molecular (e.g. real-time PCR, chip technology) electrochemical detection and characterization techniques, remote sensing (aircraft and satellite-based systems, lidar), and "low tech" but potentially powerful and highly useful techniques such as bycatch analysis. Furthermore, conceptual and technical advances in modeling have opened up avenues for incorporating the effects of environmental factors on trophic structure change and the impacts such change has on biodiversity and food web function, primary production (photoautotrophy vs. chemoautotrophy) and secondary production dynamics (i.e. food availability and fisheries), biogeochemical fluxes and the fate of carbon, limiting nutrients (N, P), water quality (e.g. HAB outbreaks) and habitat condition (e.g. hypoxia, anoxia, loss of biodiversity).

Key questions the group was asked to consider:

- Background and context for observing approaches related to trophic structure.
- Need for systemic long term measurements over large scales.
- What are the priority observations to address trophic structure?
- Where should the observations be made and at what frequency and duration?
- Observational technologies now available and on the horizon, and gaps in available sensors to address the need.

Additionally, the organizers asked the working groups to consider these two additional topics:

- Funding and practicality.

- Important ecosystem attributes we need to bring to forefront: things that this group might think of that others might not.

Background and context for observing approaches related to trophic structure.

Mapping is important to develop some idea of the size of the system under consideration, the migratory habits or movement patterns of ecosystem members, and their interaction with different predators and prey in different times and places. The group felt that energy biomass exchange with the benthic environment, and the contribution of chemosynthetic bacteria should not ignored. We noted that oxygen minimum zones and similar 'undesirable' environmental states in fact have their own fauna and are productive in ways that need to be accounted for.

Certain taxa and trophy relations pose special problems. Scavengers are often difficult to discriminate from top predators using stable isotope measures.

We felt that models based on species composition, trophic functional groups or organism size would all work, as long as there was a quantitative expression of biomass or energy produced and consumed.

Need for systemic long term measurements over large scales.

The group agreed that large scale monitoring was important, but also noted the value of lab studies or studies of relatively bounded ecosystems as a way of developing some key quantitative relationships for trophic models. Having said that, the group also noted that time series data for key benchmark sites are critical to the detection of change, its roots, and its likely causes and outcomes.

What are the priority observations to address trophic structure?

Some members felt that models based on a key nutrient or key species were not useful because of the potential for other species to be released from competition or immigrate in a changing ecosystem. It was not clear if all concurred and we lacked the time and expertise to discuss in more detail. However we all agreed that quantitative models were necessary for trophic modeling; that lists of species or qualitative relationships between trophic functional groups was not sufficient.

The group also discussed the issue of data archival, management and service of data products. We like the practice within the physical/ chemical community of making standard data like temperature and salinity immediately available and felt that values like nitrogen or carbon ought to be treated the same way: common enough measures, useful to all, especially when merged with other standardized data from around the world.

Where should the observations be made and at what frequency and duration?

As noted in other sections of this report, we decided that large scale long term observations were necessary to generate time series for detecting and tracking change on global or large ecosystem scales. We also suggested selective supplemental observations of key species, unique or relatively bounded ecosystems. We noted that low diversity within a trophic functional group was a cause for extraordinary concern and should be a criterion for selecting a species or multiple species for more focused study. We also noted that trophic flow under such circumstance is highly sensitive to the life cycle of the 'bottleneck", species, causing trophic flow in the ecosystem to track the life history characteristics of these pivotal species. We also noted that some life stages may be more sensitive to physical parameters, such as water temperature and that these pivotal stages might be the most appealing to people contemplating joint physical and biological models. However, generally speaking the group had mixed feelings about the value of identifying 'hotspots' of trophic importance, given how little we understand about what makes good indicators of such productivity and how frequently such productivity depends on physical and biological processes outside the ecosystem under consideration.

Observational technologies now available and on the horizon, and gaps in available sensors to address the need.

The group agreed to focus on primary producers and primary consumers for technologies that are now available and readily usable with traditional physical and chemical sampling in GOOS. Fluorimetry for assessing primary production and active acoustics were recommended as our first choice for useful trophic data incorporated into the larger GOOS plan.

Stable isotope sampling was not considered sufficiently mature technologically, nor was it considered well calibrated in terms of its biological significance. We believe this and similar spectral analysis tools could be very useful but are not candidates for immediate adoption. We also felt that fatty acid analysis holds great promise, though it too is not available commercially and there are some unresolved issues about scientific interpretation of conservation of fatty acid chains from prey versus addition fatty acid metabolic pathways within the organism.

Genomics was considered an exciting technological field for assessing community composition, but did bring much value to trophic models because it indicates variety of genetic material in the community, not the energy or biomass tied up in a species or group.

Sampling tools for higher trophic levels may well differ from sampling for primary producers and consumers. The group discussed uses of LIDAR, tags on animals, research trawling for fish, radar for birds and other tools that might work best for larger, higher trophy level members. The group felt limited in its expertise in this topic and focused primary on the traditional primary production and consumption categories. Microplankton, viruses and bacteria were also not discussed in great depth. We felt that these trophic categories, particularly the large top consumer category, might be better addressed by some of our other working groups. We also felt that removal experiments might be useful in some cases to test models. We also noted the ongoing value of traditional methods like gut contents analysis.

As noted in the other sections we felt that trophic models needed to be quantitative and meet basic physical laws for conservation of mass and energy. We noted that the climate change community has a well developed process for testing, modifying and ranking models, often running data through 10 20 or more models to assess their relative performance. We felt this was useful approach for trophic models too, since many functional relationships and community components are still not well documented or understood.

Funding and practicality.

Selection of topics and trophic relationships that are associated with key indicators change important to humans; fisheries, protected seabirds for example. Ideally these would be fairly well developed models with good data sets to illustrate for the physical ocean science community what we like to see when things are working well in a trophic model.

The group felt that commercial fluorimetry sensors and active acoustic plankton profilers would be useful, relatively inexpensive sensors to incorporate into moorings, drifters, underwater vehicles carrying physical and chemical sensors. The combined data on pH, dissolved nitrogen, phosphorus, oxygen and other chemical data should provide useful datasets for trophic system modeling. (recognizing that microplankton and top predators will need to be assessed by other methods to complete the picture.)

We recommended that the simple data we proposed for collection (fluorimetry and active acoustics) be archived with other standard ocean data and made available for open use as soon as possible. We did not feel sufficiently expert in this area to make recommendations about data standards, necessary metadata, calibration protocols or archival systems.

Important ecosystem attributes we need to bring to forefront: things that this group might think of that others might not.

The group concurred that trophic analysis called for quantitative data about biomass and energy transfer. A list of species or an inventory of trophic functional groups would not be sufficient to support useful, meaningful trophic models. The question was raised in large group discussion that perhaps “pristine” ecosystems should receive priority of study. We did not think that that was a useful characterization, because there is probably no marine ecosystem on earth that is unperturbed, of affected by perturbations outside the ecosystem. Reductions in sharks and large predatory fishes, and the dramatic reduction of many marine mammals illustrate out thinking on this. We did agree that there are probably less disturbed ecosystems than other comparable sites, and that these might make good focal study sites if coupled with a comparable highly disrupted ecosystem. The Antarctic, Azores and Palmyra were cited as examples of minimally disturbed ecosystems.

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