Session A3
End-to-End Marine Food Webs

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The consequences of global change for plant and animal communities can be direct and/or indirect. Indirect effects are likely to be complex, with many possible responses and different degrees of response to different combinations of factors. Perturbations can propagate both up and down a food web hierarchy, affecting living organisms and feeding back to biogeochemical cycles. Marine food webs should be considered from end to end (from viruses to top predators) as integrated systems within changing physical and chemical environments. Although marine food webs are essentially continuous systems, research has been fragmented among different scientific communities, tending to focus on either the low trophic levels (phytoplankton and the microbial food web), intermediate trophic levels (zooplankton and fish), or high trophic levels (top predators). Through studying end to end marine food webs, it should be possible to quantify the flows of energy and cycling of materials in marine ecosystems on global scales, to characterize ecosystem responses to external forcing, and to understand the causes and consequences of changes in biodiversity. This session was organised to provide an opportunity to share information about processes involved in end to end marine food webs, and to raise issues that should be considered in future research activities.

PRESENTATIONS

Bridging gaps by weaving marine food webs from end to end. ***Coleen Moloney***, Zoology Department and MA-RE Institute, University of Cape Town, South Africa.

Looking at the end-to-end food web through copepod Neocalanus. ***Hiroaki Saito***, Tohoku National. Fisheries Research Institute, Shiogama, Japan.

Benguela food webs in relation to global change. ***Lynne Shannon***, Marine and Coastal Management, Cape Town,, South Africa.

DISCUSSION

The discussion was structured around the question:
What are the key issues in marine food webs under global change that need to be addressed?
A number of points were raised during the session, and these have been combined subsequently under five main issues below.

Issue 1. Varying element ratios

Food web models exist that use different "currencies" to track flows of materials. Conversions are usually employed to relate flows between models with different currencies. It is not clear how sensitive the model results are to stoichiometric assumptions. Conversions can be straightforward in high trophic levels, but can be very difficult in low trophic levels.

Issue 2. Linking processes at different scales

Food web models are critical for understanding energy flows from the primary producers. With NPZD models, there can be problems with closure terms for the zooplankton. When one introduces higher trophic levels and nutrients to models, one is often considering the cycling of materials, and the top predators might not be considered top predators any longer. It was also highlighted that there is still

poor understanding of how physical oceanography affects biogeochemistry, because of scale problems. Similarly, feedback loops in food webs are still not understood well enough. It was also stated that deterministic understanding may not be sufficient, and it should be considered whether to include stochasticity in models. There is a need to learn how to deal with temporal and spatial scale problems when integrating models of lower trophic levels (plankton) and traditional food web models (fish/top predators). It is possibly useful to start with "simple" systems, such as oceanic pelagic systems. Climate change can cause collapse of fish populations, and a question was asked how this possibility could be addressed in long-term forecasts of fisheries options. With respect to fisheries, there is also a need to link management to likely changes in markets.

Issue 3. Stability/variability and resilience of food webs

The question was asked whether variable ecosystems respond differently to change than more stable systems. For example, the Benguela is a variable system in which species appear to show high adaptive potential. In contrast, in the NW Atlantic off Canada, overfishing under environmental change appears to have caused a collapse of the system, with subsequent changes in population characteristics contributing to non-recovery. With regard to variability, there was a question about whether niches change over time, or whether species replace one another in the same niche. Niches are a flexible concept and may well change over time, and this needs to be considered in models. In addition, populations that are seemingly replacing one another can have different spatial requirements (e.g. sardine vs. anchovy in the Benguela), and it might be useful to model habitat requirements/ characteristics along with trophic interactions. The timing of the onset of certain events might be at least as important as changes in the magnitude of drivers/ pressures.

Issue 4. Food web models

There is a continued need for detailed models (ecosystem-specific) but also a need for comparisons among ecosystems. Simplified models might be required for the global scale, but how complex is simple? Are order-of-magnitude, descriptive comparisons good enough? It was also suggested that one framework might be required rather than several linked models. However, the key to comparisons is the realisation that all models are simplifications of reality, and models need objectives to be meaningful. If models are built with different objectives, they are not comparable. Indeed, models with comparable objectives but different structures might still not be comparable. This needs to be considered very carefully at the onset of all comparative/ integrative work. One possibility might be to use one model framework in different systems, and learn more about the systems when finding out why the model might work well in one system but not in another.

Issue 5. Semantics and paradigms

There was some discussion about whether the term "end-to-end" food webs is useful, as there is a perception that it describes something new, whereas much of the discussion was suggesting that the concept is more about integrating studies of marine food webs. Another important question asked was whether there are first order ecosystem issues that unite food web studies globally. For example, issues like *what controls the regeneration of carbon in the ocean?* or *what is the efficiency of the biological pump on the global scale?* It was emphasized that there is a continued need for baseline studies; we still need to understand mechanisms in order to predict. It might be useful to also consider pathways that to date are less well researched, such as mesopelagic fishes as predators.