SOME CONCEPTS IN MARINE ECOSYSTEMS FROM A FISHERIES PERSPECTIVE

Global fish production is apparently leveling off at record levels while remaining a very important component of the world's food supply. Fish represent more than 15 percent of the total animal protein consumed by people globally, and the *first* sale of those fish in the market – from boat to dock - is an $81 billion industry annually. By any measure, we should understand how this valuable resource is influenced by environmental change and our own actions.

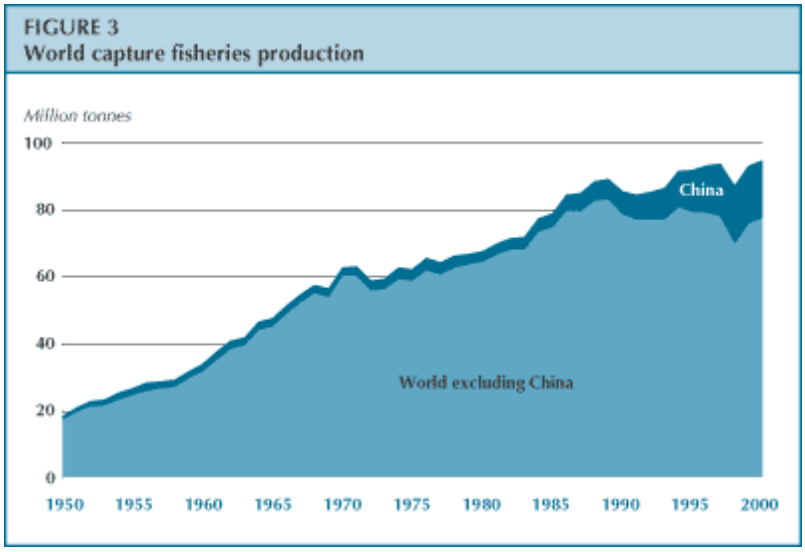


Figure 1. Global fish production not including aquaculture. Note the leveling off in the late 1980s and 1990s. Data from Food and Agriculture Organization.

Fish populations are an integral part of a system that includes everything from the physics of ocean currents to people and societies. Historically, we've managed fish populations as single species – just cod or just flounder – and almost always in isolation from the system in which they exist. In recent years, however, there has been a growing awareness that traditional approaches to managing fisheries are incomplete and partially unsuccessful. Sustainable use of living aquatic resources must consider both the impacts of the ecosystem on the living resources, and the impacts of the fishery on the ecosystem. It is critical that these resources be viewed as an integrated system.

In many countries, including the United States, we are moving toward this more holistic approach to fisheries management. Our national legislation now mandates that we take an 'ecosystem approach' to fisheries problems. Clearly, this is an improvement, but we need to develop new ways of thinking to meet these legal requirements and do a better job managing our coastal resources.

We are calling for an 'ecosystem approach', but what is an ecosystem (Fig. 2)? The term 'ecosystem' dates back to Tansley in 1935 and arose in the context of terrestrial systems. One recent definition of 'ecosystem' is *"a spatially explicit unit of the earth that includes all of the organisms, along with all the components of the abiotic environment within it's boundaries."* (Likens 1992). This implies consideration of an enormous range of possibilities: water, light, currents, detritus, hundreds or thousands of organisms ranging from viruses to whales – and people.

This definition, as well as some of the examples used below, is very nice and tidy. We're using very simplified concepts to illustrate a few main points. What's hidden here is the variability and confounding interactions that typify ecological systems. The real situation is actually incredibly complex. For example, Jason Link of the NOAA Northeast Fisheries Science Center in Woods Hole describes the 'food web' for the Northwest Atlantic Ocean as a "bird's nest" of interactions (Fig. 3). His food web has 75 highly interconnected components ranging from detritus (Fig. 3; Box Number 1) up to people (Fig 3; Circle 75).

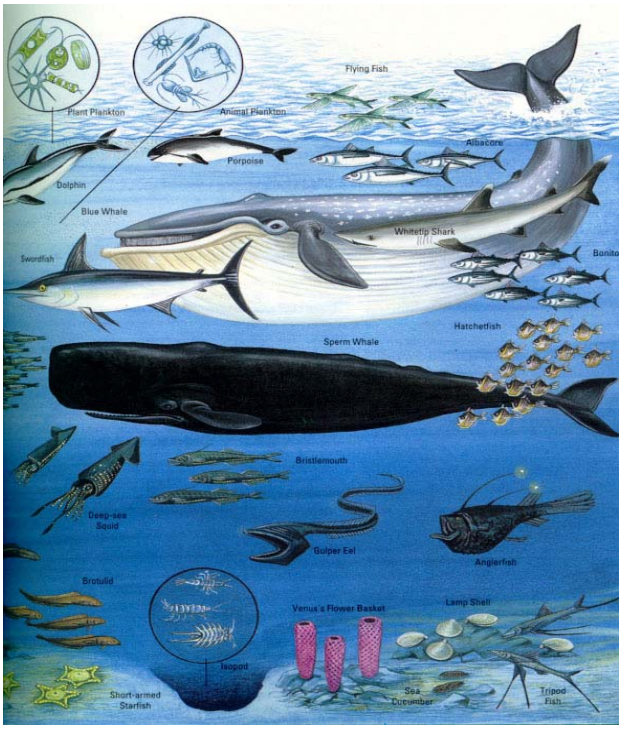


Fig. 2 A very much simplified depiction of an 'ecosystem' which is clearly focused on the more apparent biological components.

Some important questions about ecosystems might be along the lines of

- Which species are most critical?
- What are the causes of change in the system?
- Which ecological processes are most sensitive to change?
- Can fishing have an impact on the way the system functions?

Answers to these questions can come from understanding how energy flows through the system, and what controls it. That is the basic point of this review.

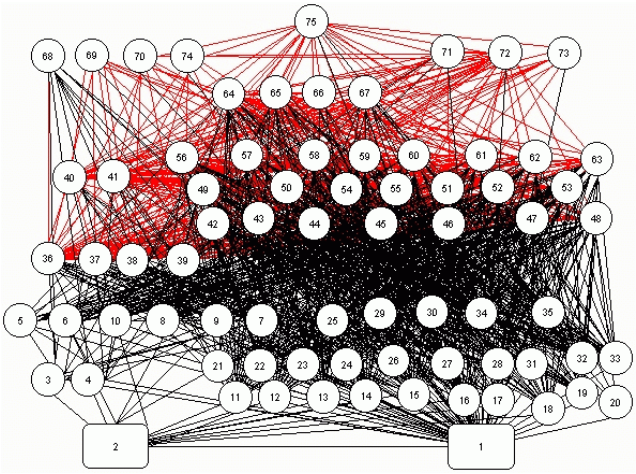


Fig. 3 Link's food web for the NW Atlantic Continental Shelf. The web is strongly interconnected, linkages between groups change in time and most species feed opportunistically at more than one trophic level. **http://www.nefsc.noaa.gov/pbio/fwdp/projects.htm** for more information.

Box 1 – *Definitions…*

Ecosystem: A spatially explicit unit of the earth that includes all of the organisms, along with all the components of the abiotic environment within its boundaries.

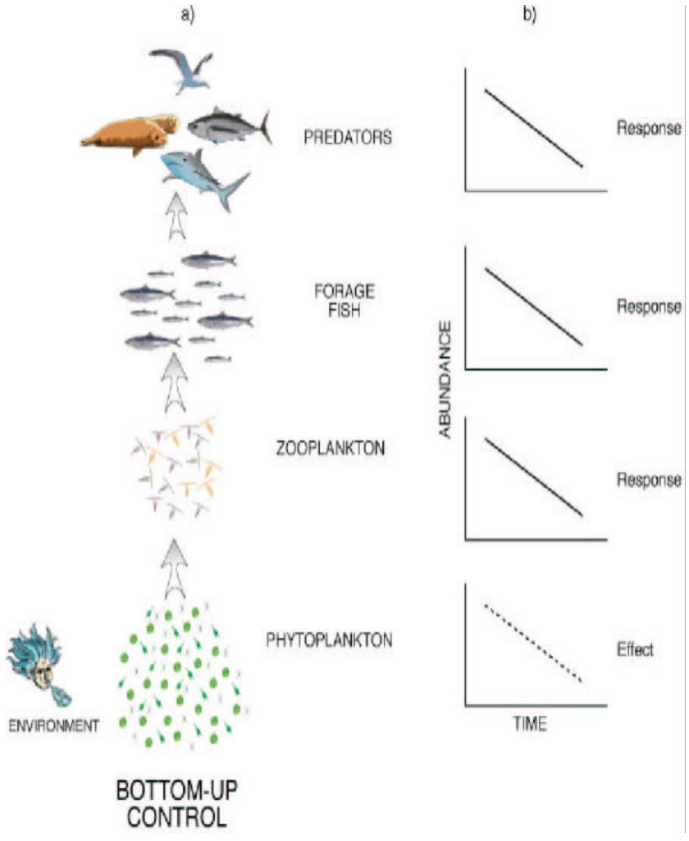
Food Chain: A highly simplified, linear sequence of organisms in which each is food for the next member in the sequence.

Food Web: A schematic representation of the feeding interactions in a community.

Trophic Level: The nutritional position occupied by an organism in a food chain or food web; e.g., primary producers (plants - phytoplankton), primary consumers (herbivores – zooplankton), secondary consumers (carnivores - 'forage fish'), tertiary consumers (predators – cod, sharks), etc.

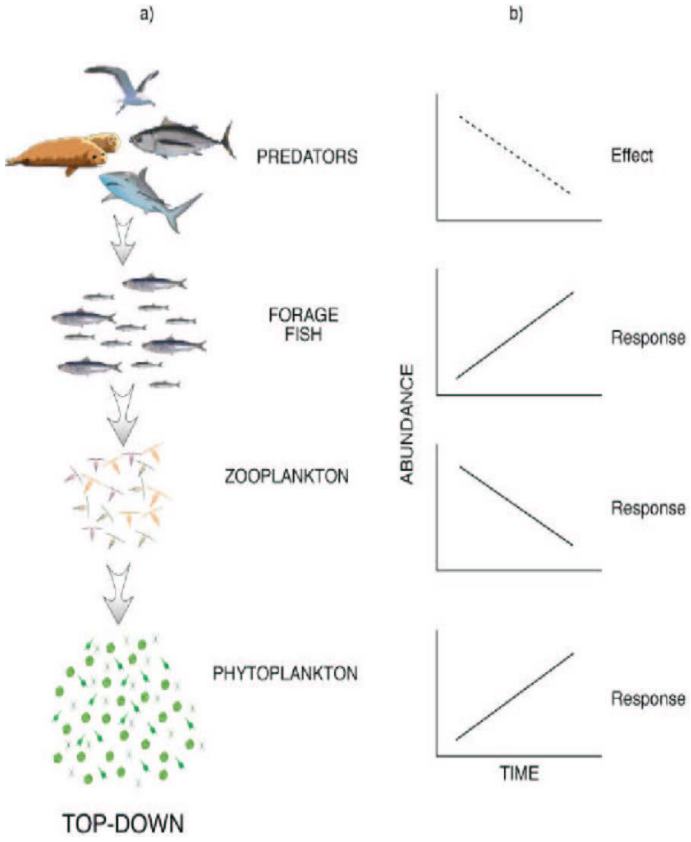
Three general descriptions of controls on energy flow through a system are made below: *Bottom-up*, *Top-Down* and *Wasp-Waisted*. Each description will use the same simplified food chain and will discuss the role of environmental forcings.

Bottom-up control: One way to think about ecosystems is from the bottom-up. That is, processes influencing the very bottom of the food web – the primary producers – drive the overall system. In the figure on this page, we have a cartoon which we can use to highlight some important concepts.



The first column shows a food chain with a series of organisms. At the very bottom are the primary producers (phytoplankton), next are primary consumers (zooplankton), then secondary consumers (forage fish) and at the top are upper-level consumers (predators). The 'environment' (which could be wind, temperature, etc.) affects the base of the chain – at the level of the primary producers. Increases or decreases in wind speed, for instance, can create an environment less favorable for phytoplankton resulting in a decline through time (second column). This reduced abundance is projected **up** the food chain and results in declines at each trophic level.

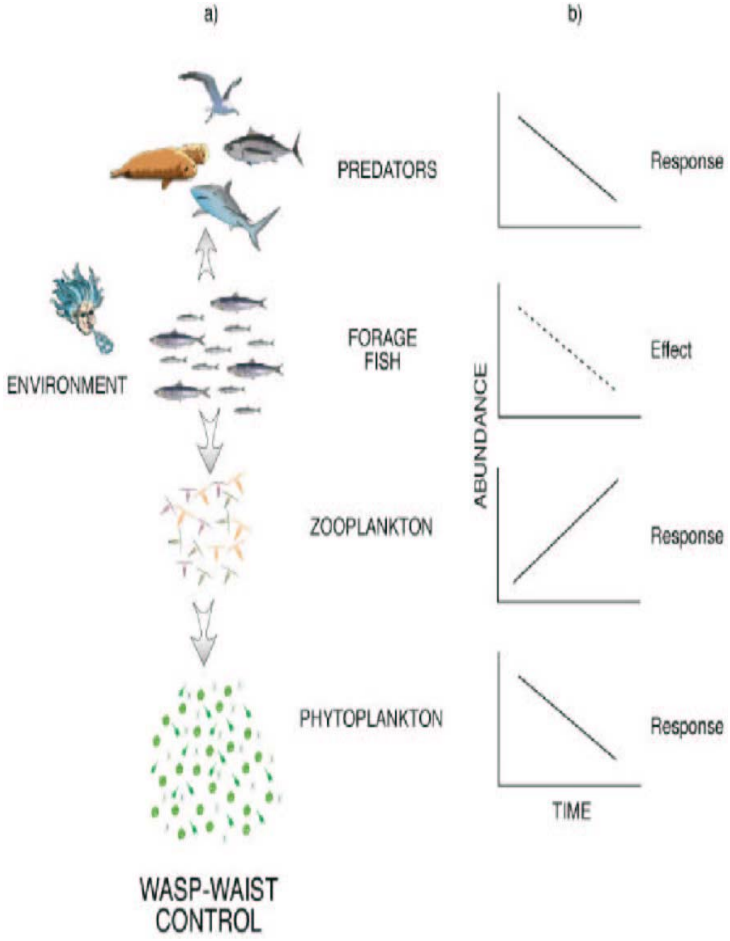
Top-down control: Another way to think about these systems is from the top down. In these situations, upper trophic level organisms – predators - exert an influence on the food chain through their feeding activity.



Because predation is such a large factor in aquatic systems, being larger is beneficial – fewer things can eat you, it makes some sense to think that removal of predatory fish can influence other components of the system.

Under top-down controls, increases or decreases in predator abundance – caused by fishing or ecological interactions – result in changes moving **down** the food chain. Fewer predators would reduce predation on forage fish and their numbers would increase. More forage fish would increase predation on zooplankton. Fewer zooplankton would reduce grazing pressure on primary producers.

Wasp-waisted control: The last point to make here is that under certain situations, changes in one trophic level can affect groups **above** and **below** that trophic level. Usually, this wasp-waist in the trophic structure is composed of just one or a few species of small planktivorous fish (sardine or anchovy). Increases or decreases in these fish might be related to very large scale ocean-atmosphere processes such as the Pacific Decadal Oscillation or, some argue, to enormous fishing pressure.



Using the figure to the right, changes in environmental conditions (or intense fishing pressure on small pelagic species – e.g. the sardine fishery) may directly cause a decline in a particular species of forgage fish. **Up** the food chain we see a decline in the predators populations that were dependent on that species. **Down** the food chain, there might be an increase in zooplankton abundance and a resulting decrease in primary producers.

As you can see, there several different ways to think about how an ecosystem might work and each has it's place. The main point of all of the above is that ecosystem approaches to fisheries management require us to use concepts like food webs. The interactions between the members of the web can be quite subtle, enormously complicated and often involve strong environmental forcings. So when you think of fishing, which might target particular species, think also of how removal of that species might impact the food web in which it is embedded.

Box 2 – *Questions…*

- Define Ecosystem, Food Chain, Food Web, or Trophic Level.
- Draw a schematic of Top-Down (Bottom-Up) Control and describe the interactions.
- What are some of the problems associated with concepts like 'foodwebs'? (See Link's food web and his website.)