INTRODUCTION

Aquatic food-webs' ecology: old and new challenges

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Looking up "aquatic food web" on Google provides a dizzying array of eclectic sites and information (and disinformation!) to choose from. However, even within this morass it is clear that aquatic food-web research has expanded greatly over the last couple of decades, and includes a wide array of studies from both theoretical and empirical perspectives. This book attempts to bring together and synthesize some of the most recent perspectives on aquatic food-web research, with a particular emphasis on integrating that knowledge within an ecosystem framework.

It is interesting to look back at the pioneering work of Sir Alister Hardy in the early 1920s at Lowestoft Fisheries Laboratory. Hardy studied the feeding relationship of the North Sea herring with planktonic assemblages by looking at the species distribution patterns in an attempt to provide better insights for the stock assessment of the North Sea fisheries. If we take a look in his food-web scheme (Figure 1), it is interesting to note that he considered species diversity in both phytoplankton and zooplankton, and also specified body-size data for the different organisms in the food web. Thus, it appears that already almost 100 years ago the concept of constructing and drawing links among diverse species at multiple trophic levels in a network-like fashion was in the mind of many aquatic researchers.

In following decades, researchers began to consider links between food-web complexity and ecological community stability. The classic, and still contentious MacArthur hypothesis that "Stability increases as the number of link increase" (1955) gave rise to studies such as that by Paine (1966) that linked latitudinal gradients in aquatic species diversity, food-web complexity, and community stability.

Following that early MacArthur hypothesis, we find it timely to also ask, *How complex are aquatic food webs?*

The first book on theoretical food-web ecology was written by May (1973), followed by Cohen (1978). Since then, Pimm (1982) and Polis and Winemiller (1996) have revisited some of the ideas proposed by May and Cohen and discussed them in different contexts, and trophic flow models have been proposed and used widely for aquatic and particularly marine ecosystems (e.g. Wulff et al. 1989; Christensen and Pauly 1993). However, recent advances in ecosystem network analysis (e.g. Ulanowicz 1996, 1997; Ulanowicz and Abarca-Arenas 1997) and the network structure of food webs (e.g. Williams and Martinez 2000; Dunne et al. 2002*a,b*; Williams et al. 2002) in relation to ecosystem dynamics, function, and stability clearly set the path for a new, complementary research agenda in food-web analysis. These and many other studies suggest that a new synthesis of available information is necessary. This new synthesis is giving rise to novel basic research that generalizes across habitats and scales, for example, the discovery of universal scaling relations in food-web structure (Garlaschelli et al. 2003), and is also underpinning new approaches and priorities for whole-ecosystem conservation and management, particularly in marine systems.

Aquatic food-web research is also moving beyond an exclusive focus on taxa from phytoplankton to fish. A new look at the role that marine microbes

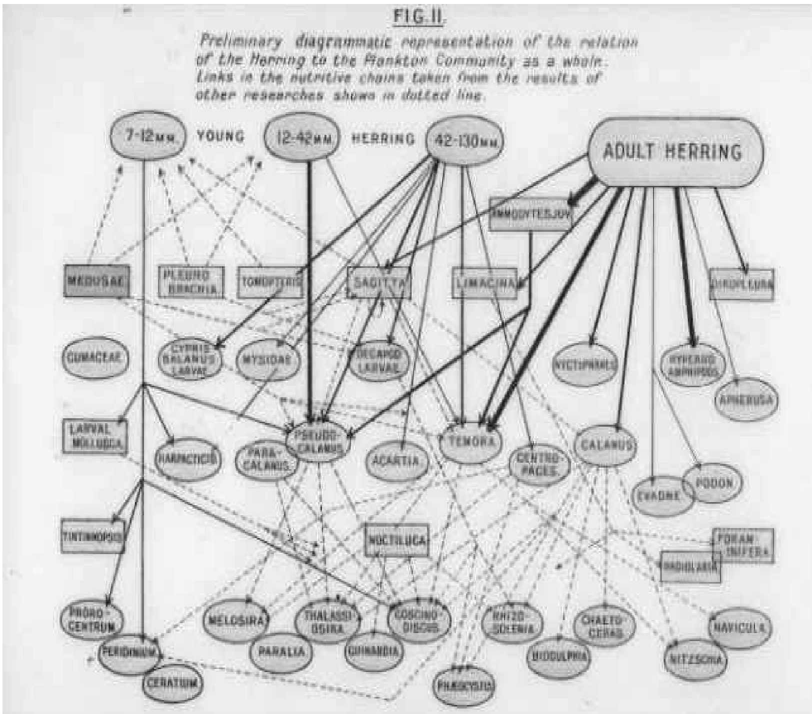

Figure 1 The food web of herring *Clupea harengus* Hardy (1924). From *Parables of Sea & Sky—The life, work and art of Sir Alister Hardy F. R. S.* Courtesy of SAHFOS—The CPR Survey, Plymouth, UK.

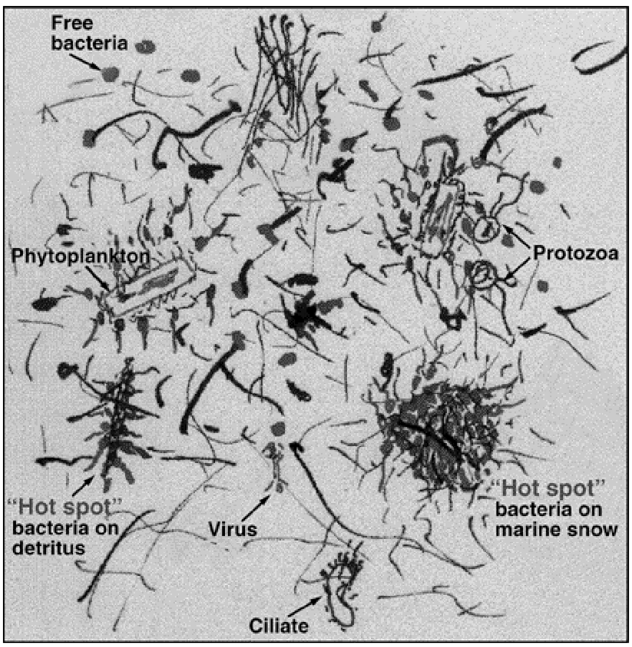

Figure 2 The microbial loop: impressionist version. A bacteria-eye view of the ocean's euphotic layer. Seawater is an organic matter continuum, a gel of tangled polymers with embedded strings, sheets, and bundles of fibrils and particles, including living organisms, as "hotspots." Bacteria (red) acting on marine snow (black) or algae (green) can control sedimentation and primary productivity; diverse microniches (hotspots) can support high bacterial diversity. (Azam, F. 1998. Microbial control of oceanic carbon flux: the plot thickens. *Science* **280**: 694–696.) (See Plate1)

play in the global ocean (Azam and Worden 2004) suggests that oceanic ecosystems can be characterized as a complex dynamic molecular network. The role of microbial food webs (Figure 2—see also, Plate 1—Azam 1998) needs to be considered to understand the nonlinearities underlying the relationship between the pelagic and benthic domains.

Emerging challenges in aquatic food-web research include integrating genomic, biogeochemical, environmental, and economic data in a modeling effort that will elucidate the mechanisms governing the ecosystem dynamics across temporal and spatial scales at different levels of organization and across the whole variety of species diversity, including humans. Aquatic food webs may provide a particularly useful empirical framework for developing and testing an information theory of ecology that will take into account the complex network of interactions among biotic and abiotic components of ecosystems.

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