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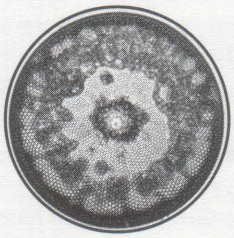
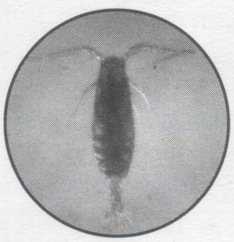
The Pelagic Food Web in Estuaries

Doreen M. Monteleone
Darcy J. Lonsdale
Marine Sciences Research Center

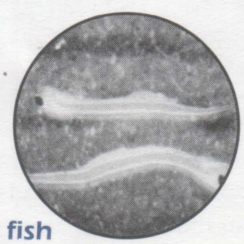
Figure 1 Not to scale



A. Phytoplankton



B. Zooplankton



C. Larval fish

Introduction

Food webs exist in every ecosystem, though the organisms in the various ecosystems may be very different. For example, on land insects eat grass, toads eat insects, snakes eat toads, and hawks eat snakes. In aquatic systems, food webs consist of aquatic plants and animals, and in nearshore regions, there are often terrestrial plant components, as well.

In aquatic systems—bays, estuaries, oceans, and lakes— zooplankton eat phytoplankton, small fish and larval fish eat zooplankton, and some larger fish eat the smaller fish. In all of these examples, plants, whether single celled or multicellular, represent the basic food supply on which the remainder of the food chain ultimately depends.

An example of this simplified feeding relationship, or food chain, is shown in Figure 1. But in nature, any food chain is just a small part of a more realistic, complex set of relationships, called a food web (Figure 2). This Bulletin addresses the food web in estuaries—places where salt water and fresh water

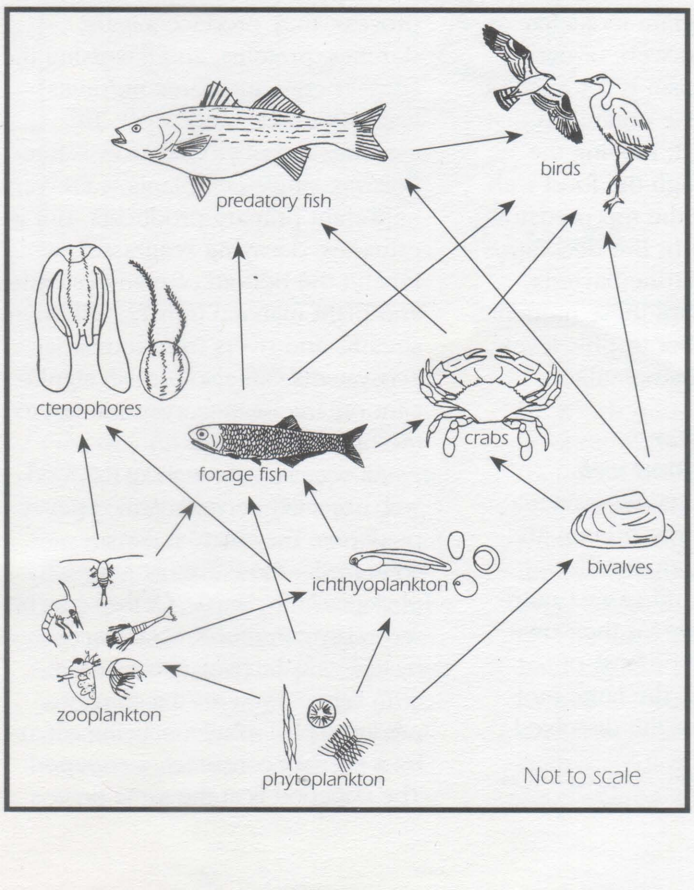


Figure 2 **A simplistic estuarine food web**

meet and mix, such as mouths of rivers—and its focus will be on the pelagic organisms, those living in the water column.

Trophic levels and energy flow

Producers, consumers, and decomposers.

A food chain is a conceptual framework to describe the transfer of matter and energy between organisms and consists of trophic levels, or feeding levels. These levels are distinctly linear—each higher level acquires energy from the previous level.

The food web concept, on the other hand, is more representative of the real-life situation and shows a less distinct hierarchy in energy transfer. In the food web, as shown in Figure 2, the arrows indicate the direction of the energy flow[1]: from the producer, or organism being eaten, to its consumer. Since an organism may be consumed by more than one consumer, the food web diagram looks like an interconnected web, or net.

Each organism is a source of energy for those organisms that will consume it, moving the nutrients through the food web until reaching the top predators, such as bluefish. But decomposers, such as marine bacteria, eventually return these nutrients, tied up in higher trophic levels, back to the phytoplankton.

Energy transfer through the food web

When organisms die, bacteria break down large protein and fat molecules into smaller components, and extract nutrients and energy for their own growth. In the process of breaking down the large molecules, some of the dissolved nutrients are released directly into the sea water. The consumers of bacteria, the protozoa, as well as larger zooplankton, also release dissolved nutrients into the sea water, where they are free to be absorbed by the aquatic plants. Thus the nutrients are cycled and recycled through the food web.

No organism is 100% efficient in energy transfer, so there is an unavoidable loss of energy in consuming food. Energy gained from consuming food is also used by the organism to carry out its life processes. Thus, the total amount of energy transferred up through the food web is less at each successive level.

In general, the decrease of energy available at each level means that less biomass can be supported at each successive level. Consequently, the total number of individuals of top predators is generally less than the number of smaller organisms at lower levels of the food web.

Primary and secondary producers and consumers

Energy to fuel a food web comes from photosynthesizing organisms—chlorophyll-containing plants. In this process, they produce sugars, starches, proteins, and fats using the sun's energy, inorganic nutrients, carbon dioxide, and water. In estuaries the phytoplankton —free-floating, single-cell plants— are very important primary producers. But in estuaries, decaying seagrasses, which inhabit the bottom of many estuaries, and plant material transported down streams and rivers from terrestrial ecosystems can also furnish significant organic matter, contributing to the base of the web.

All organisms throughout this food web ultimately depend on the primary producers. They may be primary consumers—those that consume phytoplankton directly. Or they may be secondary consumers, obtaining energy by ingesting the primary consumers.

In Figure 2 you see the primary producer, phytoplankton, being eaten by a primary consumer, a copepod. The copepod is at the same time, a secondary producer for the ctenophore, which is a secondary consumer. Some organisms can be both primary and secondary consumers. For example, as shown in this figure, fish larvae consume both phytoplankton and zooplankton.

Herbivores, carnivores, and omnivores

Zooplankton are very small marine animals, and although Figure 2 shows them only consuming phytoplankton, many of them, in fact, will consume the larval stages of their own or other zooplankton. If they only consume phytoplankton, as some zooplankton do, they are called herbivores. If they eat both plants and animals, they are called omnivores. If they eat only other animals, they are called carnivores.

The food web in Great South Bay

Great South Bay on the south shore of Long Island is an estuary, which traditionally has been heavily fished for clams and a variety of finfish. The bay is quite shallow, with an average depth of only 1.3 m (4.25 ft). It is a temperate estuary whose waters undergo a seasonal temperature cycle, ranging from less than 0° C in January and February to over 25° C in July and August. Salinity in the bay averages 24-30 parts per thousand (open seawater is approximately 35 parts per thousand and fresh water is 0 parts per thousand).

The seasonal variability of phytoplankton

Generally in estuaries, the biomass (the standing crop, or weight per area) of phytoplankton tends to be highest in the spring. Rates of photosynthesis, and thus primary productivity (weight per area per time), which are closely correlated with water temperature and sunlight, are highest in the summer and lowest in winter. The size and composition (number of species and their abundance) of the phytoplankton community in this bay varies throughout the year. As an aid to

[1]Energy flow can also be thought of as nutrition moving from the prey to predator.

studying the dynamics of pelagic food webs, scientists divide phytoplankton into categories based on size.

Throughout much of the year, the majority of the phytoplankton is made up of smaller nanoplankton (plankton less than 20 microns in diameter), on the order of 5 microns or less. While the nanoplankton dominates year round, during the summer, larger dinoflagellates (phytoplankton having two flagella used for locomotion, Figure 3)* may also be important. Diatoms (phytoplankton, ranging in size from 4 to 220 microns,without flagella, and with a cell wall composed of silica Figure 1A) are more abundant during colder months.

Many of the larger zooplankton, such as species of the genus*Acartia* (Figure 1B) cannot efficiently feed on

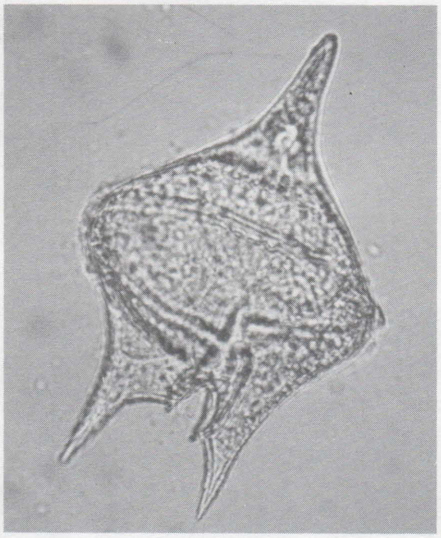
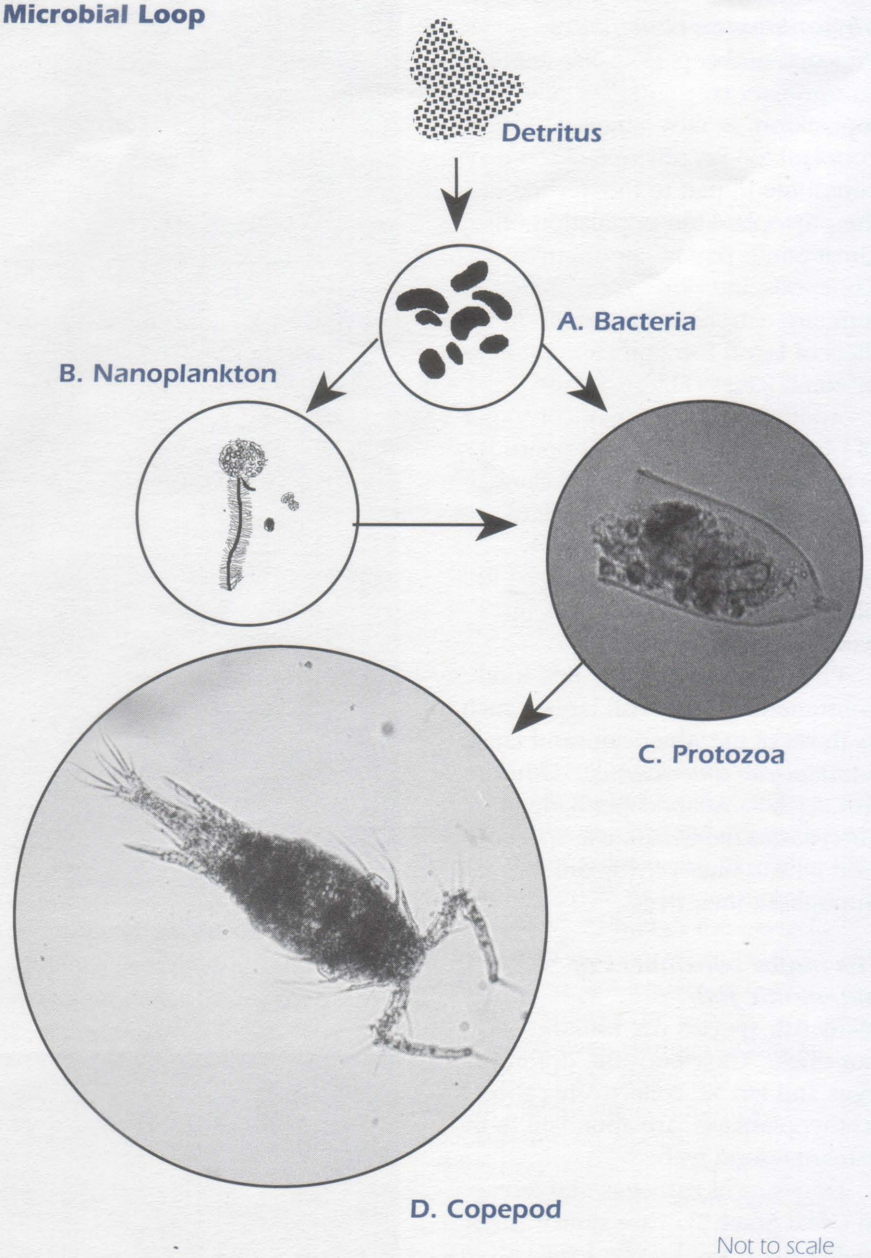


Figure 3. Dinoflagellate
** Flagella not visible in this photo.*

such small phytoplankton cells as the small nanoplankton(Figure 4B). Their sieve-like appendages very efficiently capture particles greater than 5 microns, while the smaller, nanoplankton may pass through.

But smaller zooplankton, such as protozoa, (Figure 4C), do feed efficiently on the nanoplankton, as well as on the even smaller marine bacteria. Thus, the protozoa may be particularly important in transferring energy up the food web.

Figure 4
Microbial Loop



The microbial loop
Protozoa (about 2 to 200 microns long) and copepods (approximately 50 microns to 1.5 millimeters long) are the most abundant members of the zooplankton community. The transfer of energy, accomplished by protozoa consuming nanoplankton and bacteria, and then by the larger zooplankton consuming the protozoa, is called the microbial loop—an energy transfer through the microbes (Figure 4).

The microbial loop is the channel by which nutrients from the decomposition of dead plants and animals (detritus) flow to the zooplankton community via bacteria. Nutrients from the smallest primary producers, the nanoplankton, flow through the protozoa to the larger zooplankton.

The microbial loop concept may help explain why Great South Bay, as well as many other estuarine ecosystems in the world, can support such abundant populations of zooplankton and fish larvae.

The major phytoplankton consumers

Protozoa and copepods are important primary consumers of phytoplankton. In fact, grazing by zooplankton on phytoplankton may contribute in part to the decline in the phytoplankton population of Great South Bay in late summer. Copepods and other zooplankton, in turn, are extremely important in the diets of larval fish and ctenophores, or comb jellies (Figure 5).

Another major primary consumer of phytoplankton in Great South Bay is the bottom-dwelling hard clam (*Mercenaria mercenaria*). Hard clams are filter feeders, actively pumping water through siphons to filter out food particles, predominantly phytoplankton.

Phytoplankton are the first food consumed by some fish larvae, such as those of the American sand lance (*Ammodytes americanus*). Other fish, such as Atlantic menhaden (*Brevoortia tyrannus*), use specialized gills to filter phytoplankton throughout their lives.

The major consumers of planktonic fish

Many fish species use estuaries as nurseries. Their buoyant, drifting eggs and larvae, collectively called ichthyoplankton, are abundant in the estuarine food web.

Densities of fish eggs and larvae in Great South Bay are similar to, or higher than, any known for East Coast estuaries in the U.S. Eggs or larvae from 23 species of fish have been identified in plankton samples collected from Great South Bay. The samples included early life stages of important forage fish species such as bay anchovy (*Anchoa mitchelii*) (Figure 6); American sand lance (*Ammodytes americanus*); Atlantic silverside (*Menidia menidia*); and Atlantic menhaden (*Brevoortia tyrannus*).

Eggs or larvae of fish species important to recreational fishers that are found in the bay include weakfish (*Cynoscion regalis*); winter

Figure 5. Comb Jelly

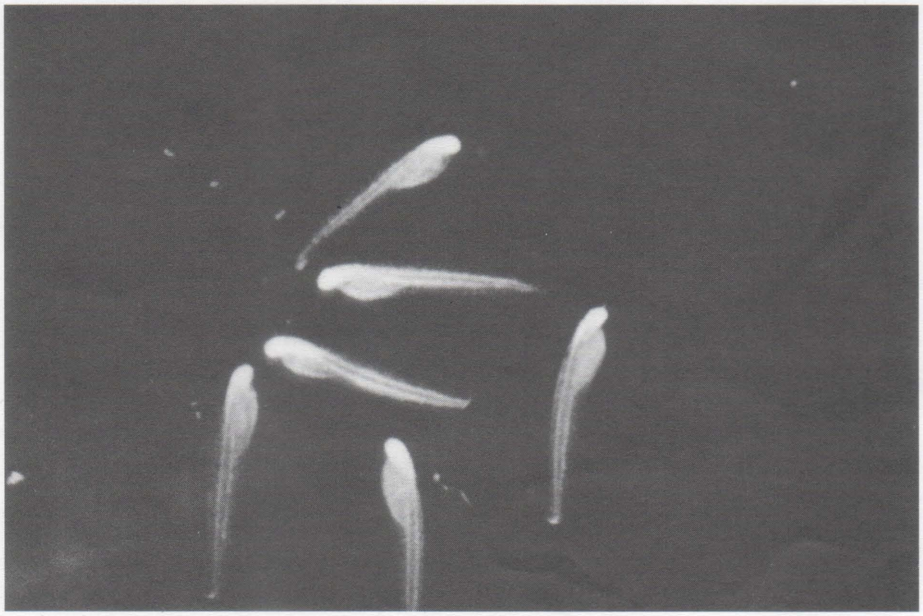


Figure 6. Bay Anchovy Larvae

flounder *Pleuronectes americanus*); blackfish, or tautog (*Tautoga onitis*); Atlantic mackerel (*Scomber scombrus*); cunner (*Tautogolabrus adspersus*); and puffer (*Sphoeroides maculatus*).

Fish spawning peaks occur twice a year in Great South Bay. The first peak occurs in winter and early spring, and the second in late spring to early summer. The second spawning in Great South Bay is dominated by bay anchovy, during which time densities of their eggs can exceed one per liter, or approximately 300 billion eggs in the entire bay on any given day during peak spawning. Both spawning peaks are coincident with peaks in phytoplankton and zooplankton production.

Less than 1% of fish eggs spawned will reach maturity. Most of the eggs and larvae become the prey of larger fish (sometimes via cannibalism by the adults of the same species), gelatinous zooplankton such as ctenophores, or even relatively large zooplankters, such as amphipods. At all stages, however, from egg to adult, fish provide food for several trophic levels in the food web (Figure 2).

The major zooplankton consumers

Ctenophores are important predators of zooplankton and ichthyoplankton. They are so voracious that they can cause a rapid demise of their food supply, especially copepods.

Pleurobrachia pileus (sea gooseberry) and *Mnemiopsis leidyi* (comb jelly) are the two most abundant ctenophores found in Great South Bay. *Pleurobrachia pileus* prefers cold water and is abundant in the spring and early summer and again in October. This comb jelly enters the bay from the ocean through Fire Island Inlet. *Mnemiopsis leidyi* is most abundant in the late summer and early fall, from August through mid November, reaching extremely high population densities from relatively few individuals that overwinter in the bay.

Population densities of *M. leidyi* and *P. pileus* are thought to depend more on food availability, primarily copepods, and water temperature than on predation pressure. Predators on these ctenophores in this region are minimal, but include fish such as the ocean sunfish (*Mola mola*) and other ctenophores such as *Beroe sp.* (another comb jelly).

Field studies show that copepods, in turn, are usually abundant only when the ctenophore densities are low. In Great South Bay, the dominant spawning peaks of fishes also do not co-occur with peak abundances of the two ctenophore predators.

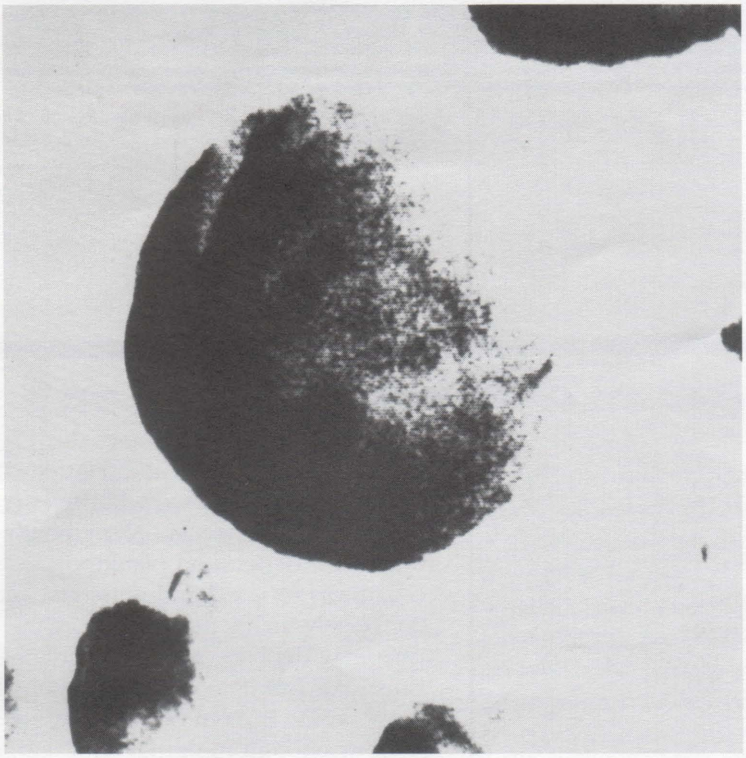


Figure 7. Brown Tide Alga (magnified 30,000 times)

The "brown tide" effects on the food web

During 1985 and 1986 a plankton sampling program was undertaken coincident with the first outbreaks of the brown tide phytoplankter, *Aureococcus anophagefferens* (Figure 7; see Bulletin on Brown Tide, Vol. I, No.1). The brown tide reached unprecedented densities of more than a billion cells per liter in Great South Bay, as well as several other local bays.

This small alga (2 to 3 microns in diameter) was so dense that it gave the bay water a distinctive brown coloration; hence, its name, the "brown tide." Although the impact of the brown tide organism on the food web was not known at the time, the results of the survey showed that even during the bloom of the brown tide there was a thriving planktonic community, especially the copepods.

However, other animals in the food web, such as the scallops suffered severe impacts from the brown tide, as was discussed in the previous Bulletin and Update (January 1991). Apparently, the presence of the "brown tide" cells caused the scallops to stop feeding, suggesting that this phytoplankton species may have toxic properties.

For other phytoplankton consumers, such as the copepods and some fish larvae, the brown tide may not have had a detrimental effect because it is such a small algae, and thus not efficiently grazed. It may also be that protozoa thrived during the brown tide, providing food for the larger zooplankton in the near absence of other phytoplankton sources.

Conclusions

While this Bulletin addresses the planktonic food web, the benthic (bottom dwelling) food web is also linked to the plankton. Many benthic organisms depend on planktonic organisms for food and nutrients, and conversely, many planktonic organisms may depend on benthic organisms. For example, seagrasses, which grow on the bottom of bays that are shallow enough to permit light penetration to the bottom, provide nutrients and refuge from predators for planktonic and benthic organisms.

The Great South Bay is often referred to as one of the most productive bays on the east coast; that is, it supports a large biomass of organisms, partly because it is shallow throughout. This permits nutrients to be constantly mixed from top to bottom. But this high productivity is also a result of nutrient enrichment, from land runoff and groundwater seepage. Nutrient enrichment that leads to phytoplankton blooms is called *eutrophication.*

Eutrophication in some nearshore waters may have serious consequences for both benthic and planktonic organisms, as is the case in the summer in the western Long Island Sound (See Hypoxia Bulletin Vol.1, No. 4). But while nutrient enrichment may not always cause large, problematic phytoplankton blooms, marine ecologists are nevertheless concerned about it causing chronic below bloom-level phytoplankton growth. Even this concentration of phytoplankton may reduce light levels enough to impact seagrasses on the bottom, such as the eelgrass that populates many estuaries, including Great South Bay.

Suggested reading

Duguay, L. E., D. M. Monteleone and C. E. Quaglietta. 1989. Abundance and distribution of zooplankton and ichthyoplankton in Great South Bay, New York, during the brown tide outbreaks of 1985 and 1986. Novel Phytoplankton Blooms. Coastal and Estuarine Studies 35: 599-623.

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The Great South Bay. 1991. Schubel, J.R., Bell, T.M., Carter, H.H., eds. State University of New York Press, Albany.107 pp.

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