

Pelagic Ecology

THE PELAGIC ENVIRONMENT

The oceans can be divided into a number of distinct environments. The most basic division is between the pelagic (open ocean) and the benthic (sea floor) regions. This week's lab will focus on the pelagic realm, which encompasses the whole water column, from the surface to great depths, and is arguably the largest ecosystem on the planet. The pelagic zone can be further subdivided into ecological zones based on depth: the **epipelagic** (≈ 0 -200m), the **mesopelagic** (≈ 200 -1000m), the **bathypelagic** (≈ 1000 -4000m), and the **abyssopelagic** region (≈ 4000 to 6000m) (see Fig. 1). Areas deeper than 6000m are called **hadal** regions - while they account for the deepest regions on the planet's oceans, they compose a very small fraction of the total oceanic environment (for example, the Mariana trench is a hadal environment). The largest concentrations of biomass are located in the epipelagic and mesopelagic depths. The epipelagic realm is usually not light limited, and therefore supports primary production by phytoplankton. Below the epipelagic realm, organisms must operate in near-darkness. As most food webs in the ocean are supported at the base by photosynthesis, this is not surprising.

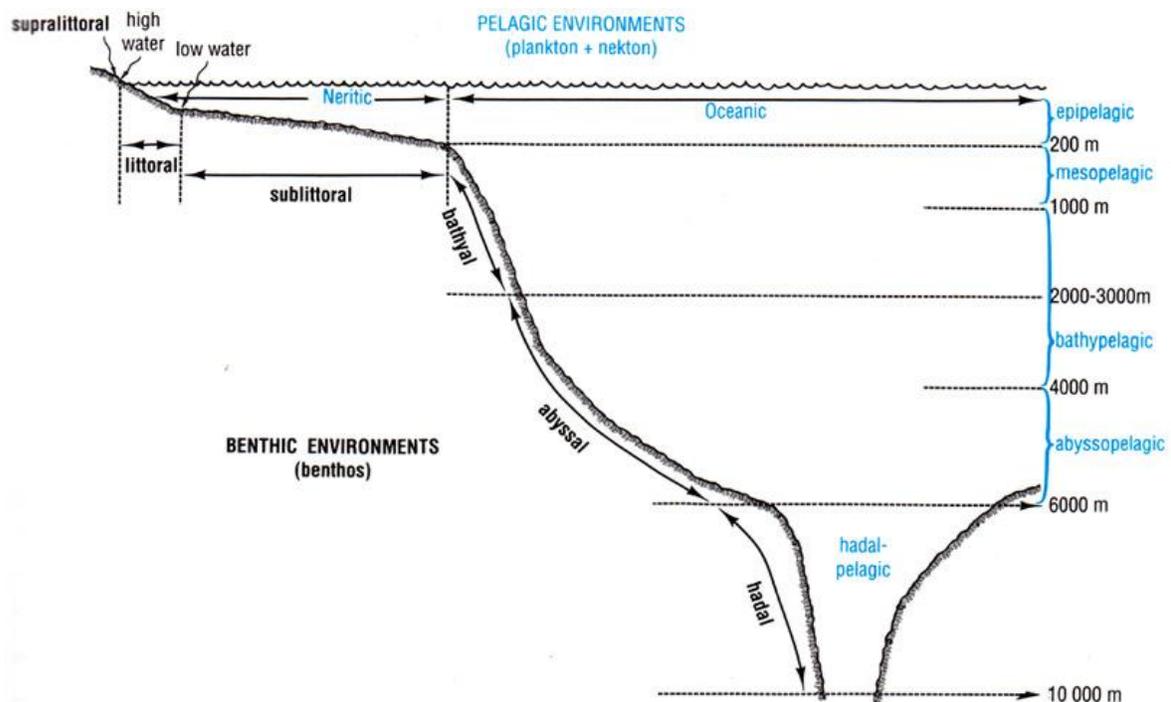


Fig. 1: Ecological divisions of the open ocean. Pelagic divisions are marked in blue.

The pelagic environment is home to two basic groups of marine organisms. The first group consists of the **plankton** (Greek for “wandering”) which is appropriate because they possess little power to ‘swim’ any significant distance, and are thus passively transported by ocean currents. Planktonic plants are known as **phytoplankton**, and planktonic animals are known as **zooplankton** (e.g. jellyfish, small crustaceans, pelagic snails, etc.). The second group of pelagic marine organisms are the free-swimming **nekton**, including marine mammals, fish, squid, and some larger crustaceans.

For now we will focus on the nekton, and particularly those of the epi- and mesopelagic zones.

ADAPTATIONS OF PELAGIC ORGANISMS

All organisms must be adapted to the unique environments in which they are found, and to accomplish three major objectives with the greatest possible success: finding food, avoiding predators, and reproducing. Some aspects of the pelagic environment pose special challenges that have led to unique adaptations for the organisms that live there. First, the pelagic habitat is **‘three-dimensional’**—organisms must be able to move (and preferably see) in all directions. Second, there are **no solid substrates** to provide refuge. For these reasons, superior swimming ability is an important means of survival for many large fishes such as tuna, helping them to capture prey and avoid predators. Indeed, many pelagic fishes are migratory, covering vast distances of the open ocean in search of food. These types of fish are streamlined, with thick bodies and heavy musculature.

Various forms of camouflage are common in pelagic organisms. Fishes in the epipelagic realm are generally **countershaded**, so their bodies show a color gradient from dark on the dorsal surface to light on the ventral surface. This type of coloration makes them difficult to see, both from above and below. Others are silvery, helping them to reflect sunlight near the surface, and blend in with the surrounding waters.



Fig. 2: (Left) Red ctenophore, difficult to see at depth. (middle) Deep-water squid of the genus *Histiototeuthis*, also red, and covered with photophores (right) the great white shark (*Carcharodon carcharias*) exhibits counter-shading with a dark top side (dorsal surface) and a lighter stomach (ventral surface).

Mesopelagic organisms, which live in deeper, darker waters, use different forms of camouflage. Being black or red in color can help make an organism difficult to spot (Fig. 2). Recall from the physics and chemistry section that red is the first color to attenuate in the water column, so if you are a red animal, you are essentially invisible because there is no red light to bounce off of you! For the same reason, being black absorbs all kinds of light, making you less visible as well. Many mesopelagic fish and

squids have **photophores** used for **counterillumination**, which works in the same way as countershading. Photophores are light producing organs capable of matching the intensity and color of the light from the surface, helping to obscure the organism's silhouette (Fig. 3). Above 400m the light from the surface becomes too intense for counterilluminating organisms to match, so their vertical distributions are limited to below 400m in the daytime. All these adaptations to avoid being seen can have a negative impact on the ability to attract mates. Some mesopelagic fish have lights on their tails called sternchasers, which advertise them to members of the same species and opposite sex (Fig. 3, top). Photophores are usually arranged in species-specific patterns, making the organism easy to identify.



Fig. 3: Two mesopelagic fish of the class Myctophidae (commonly called lanternfish). (Top) Sternchasers are visible on the top and bottom of the tail, which are bioluminescent and can be flashed to confuse potential predators, as well as attract mates. (Bottom) A row of photophores is visible along the ventral edge of this specimen, and can be used for *counterillumination*.

Low light levels in the mesopelagic zone can make it difficult to spot prey. Many fish use photophores mounted on the ends of fins or dangling projections that act as lures to bring prey in close where the fish can attack them. Mesopelagic organisms can also have modified **tubular eyes** with increased sensitivity to light and enhanced depth perception. Many have eyes 2-5 times larger than normal, which are sometimes set at upward-looking angles, maximizing the ability to look for shadows cast by other animals. In addition, some kinds of fish use photophores for 'headlights;' *Malacosteus* uses red headlamps to detect red prey while most animals at depth cannot see red light. This is partially due to the fact that most animals have reduced eyes because light is minimal in the deep ocean.

DIEL VERTICAL MIGRATION

Many organisms in the mesopelagic realm such as fish, shrimp, and squid, undergo a **diel vertical migration**. This migration happens daily, and includes roughly 50% of mesopelagic organisms. At dusk, mesopelagic animals migrate from depth (~500-1000m) to the surface to feed in the zone of increased primary production. In the pre-dawn hours, they migrate back to depth, where they can better hide from visually-oriented predators such as tunas. Most vertically migrating fishes have **gas bladders** that store gases and help make the fish neutrally buoyant at any depth. Some researchers believe that diel vertical migration developed as a means of escaping predation by surface predators, such as tuna. This predation pressure by tuna is an example of **top-down control**, in which top predators control the functioning of the ecosystem. Alternatively,

vertical migration may have evolved simply because there is not sufficient food at mesopelagic depths to support the organisms that live there, and they must return to the photic zone to take advantage of higher levels of primary production. In addition, by feeding in warmer water at the surface, and then returning to the colder waters at depth to digest food, energy is conserved because metabolic rates are slower at low temperatures. This theory is an example of **bottom-up control**, in which the structure of the ecosystem results from pressure at the lowest levels of the food chain (i.e. phytoplankton).

THE PELAGIC FOOD WEB

A **food web** is a representation of the transfer of energy and organic materials through various trophic levels of marine organisms (Fig. 4). Each **trophic level** is composed of organisms that obtain their energy in a similar manner. The foundation of any food web is the group known as **primary producers**—photosynthetic organisms that produce organic material using the sun’s energy. The primary producers of the pelagic food web are the phytoplankton. Herbivorous species of zooplankton that feed on phytoplankton are known as **primary consumers**. All subsequent trophic levels, composed of carnivorous zooplankton, fishes and other predators, are **secondary consumers, tertiary consumers**, and so on. The number of links in the food web can vary, but this number has an important impact on the abundance of higher predators that can be supported by an ecosystem.

As mentioned above, the food web consists of organic material contained in various trophic levels. When organisms from one link in the web feed on those at another link, they obtain energy and organic nutrients from their prey. However, the transfer of energy and organic material from prey to predator is not very efficient. For this reason, only a fraction of the energy and material contained in the living organisms at one trophic level is actually transferred into living tissue at the next level. That fraction (usually around 10-15%) is known as the **ecological transfer efficiency**. If the transfer efficiency is 10%, that means 90% of the organic material in one trophic level is *not* passed on to the level above. Thus, the more trophic levels organic material must pass through from primary producers to top predators, the less “efficient” the transfer and the larger the primary producer level must be to support the top predators.

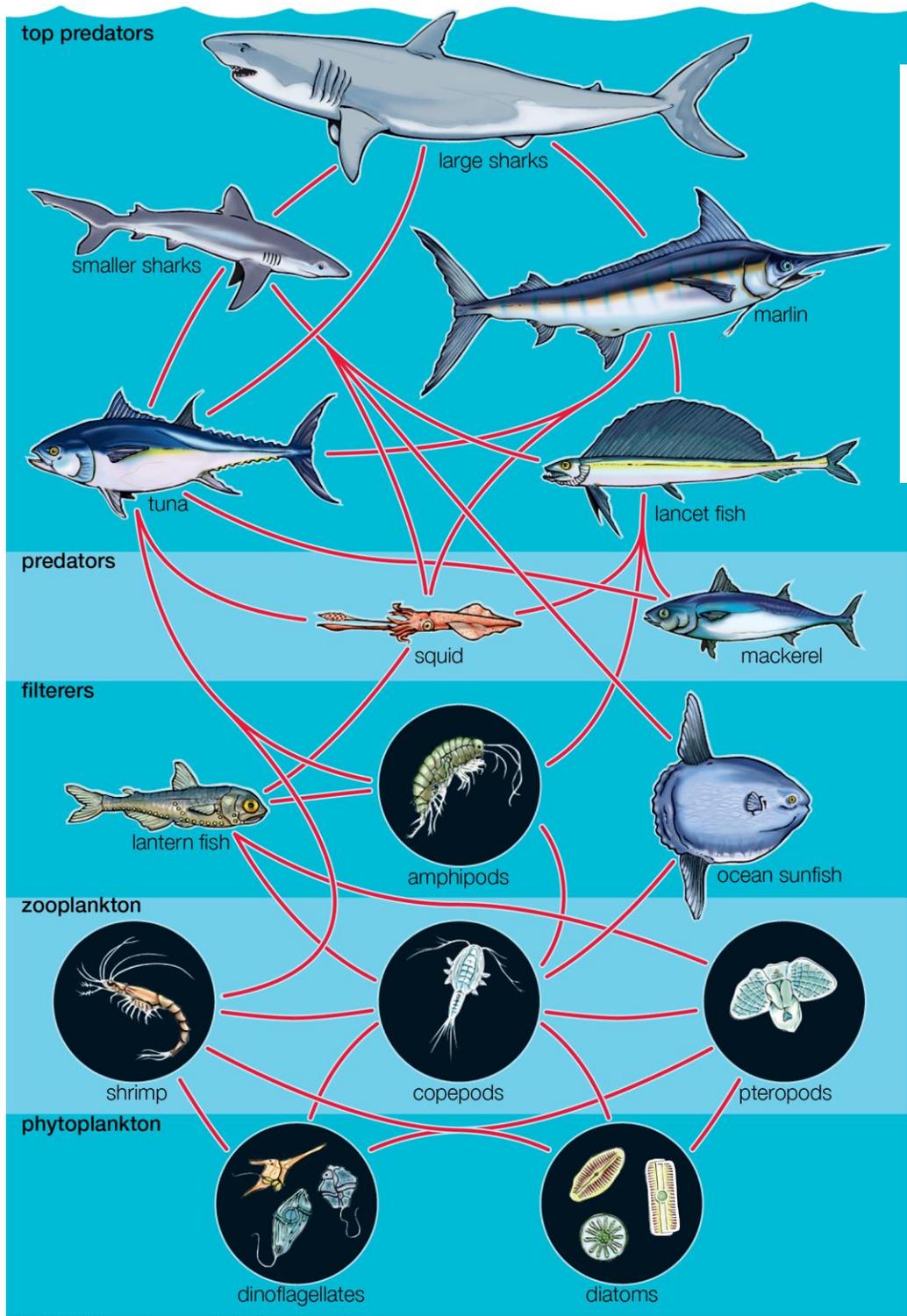


Fig. 4: Example of a typical pelagic food web from Hawaiian waters. The Hawaiian food web is relatively short and 'efficient', making it possible for large top predators such as sharks, tuna, and billfish to be easily supported by the lower trophic levels.

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