

ASSESSMENT OF MEAN TROPHIC LEVEL AND PREY – PREDATOR RELATIONSHIP

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Abstract: Predator–prey relationships and trophic levels are indicators of community structure, and are important for monitoring ecosystem changes. Mammals colonized the marine environment on seven separate occasions, which resulted in differences in species' physiology, morphology and behavior. It is likely that these changes have had a major effect upon predator–prey relationships and trophic position. The trophic level of an organism is the position it occupies in a food chain.

Keywords: Predator-prey, Trophic level, Colonized, Ecosystem.

Introduction

The trophic level of an organism is the position it occupies in a food chain. The word trophic derives from the Greek (trope) referring to food or feeding. A food chain represents a succession of organisms that eat another organism and are, in turn, eaten themselves. The number of steps an organism is from the start of the chain is a measure of its trophic level. Food chains start at trophic level 1 with primary producers such as plants, move to herbivores at level 2, and predators at level 3 and typically finish with carnivores or apex predators at level 4 or 5. The path along the chain can form a one-way flow, or a food "web." Ecological communities with higher biodiversity form more complex trophic paths.

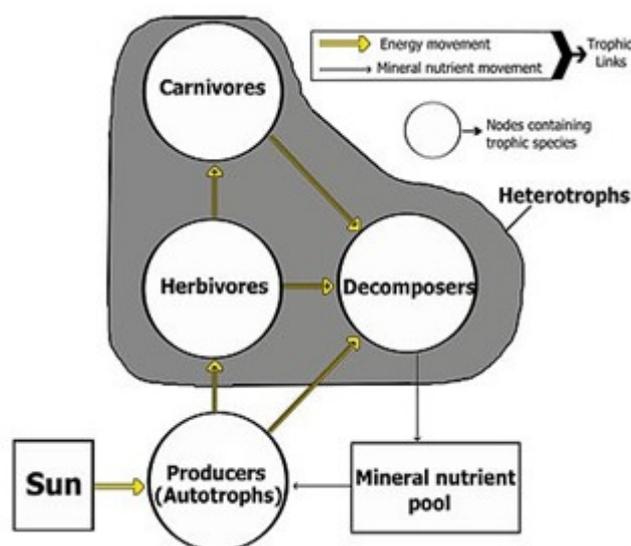
The three basic ways organisms get food are as producers, consumers and decomposers.

1. Producers (autotrophs) are typically plants or algae. Plants and algae do not usually eat other organisms, but pull nutrients from the soil or the ocean and manufacture their own food using photosynthesis. For this reason, they are called primary producers. In this way, it is energy from the sun that usually powers the base of the food chain. An exception occurs in deep-sea hydrothermal ecosystems, where there is no sunlight. Here primary producers manufacture food through a process called chemosynthesis.

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2. **Consumers** (heterotrophs) are animals which cannot manufacture their own food and need to consume other organisms. Animal that eat primary producers (like plants) are called herbivores. Animals that eat other animals are called carnivores, and animals that eat both plant and other animals are called omnivores.

3. **Decomposers** (Detritivores) break down dead plant and animal material and wastes and release it again as energy and nutrients into the ecosystem for recycling. Decomposers, such as bacteria and fungi (mushrooms), feed on waste and dead matter, converting it into inorganic chemicals that can be recycled as mineral nutrients for plants to use again.



Trophic levels can be represented by numbers, starting at level 1 with plants. Further trophic levels are numbered subsequently according to how far the organism is along the food chain.

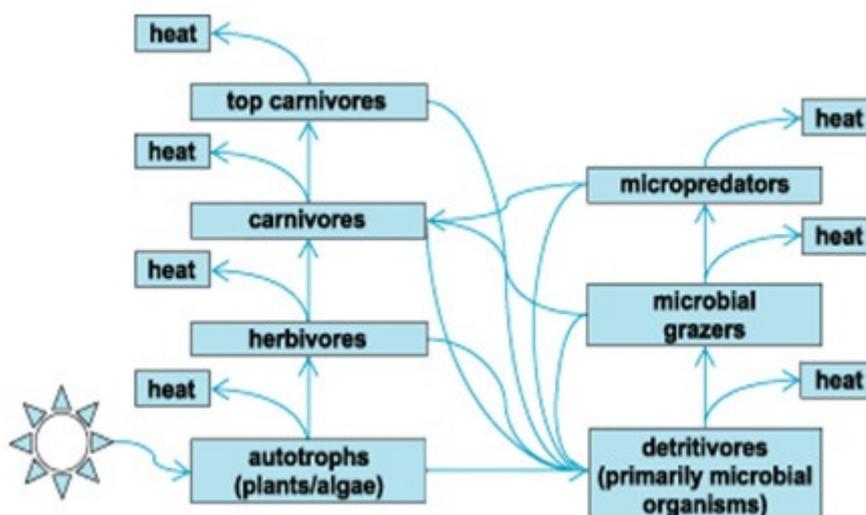
Level 1: Plants and algae make their own food and are called primary producers.

Level 2: Herbivores eat plants and are called primary consumers.

Level 3: Carnivores which eat herbivores are called secondary consumers.

Level 4: Carnivores which eat other carnivores are called tertiary consumers.

Level 5: Apex predators which have no predators are at the top of the food chain.



In real world ecosystems, there is more than one food chain for most organisms, since most organisms eat more than one kind of food or are eaten by more than one type of predator. A diagram which sets out the intricate network of intersecting and overlapping food chains for an ecosystem is called its food web. Decomposers are often left off food webs, but if included, they mark the end of a food chain. Thus food chains start with primary producers and end with decay and decomposers. Since decomposers recycle nutrients, leaving them so they can be reused by primary producers, they are sometimes regarded as occupying their own trophic level.

Biomass Transfer Efficiency

Generally, each trophic level relates to the one below it by absorbing some of the energy it consumes, and in this way can be regarded as resting on, or supported by the next lower trophic level. Food chains can be diagrammed to illustrate the amount of energy that moves from one feeding level to the next in a food chain. This is called an energy pyramid. The energy transferred between levels can also be thought of as approximating to a transfer in biomass, so energy pyramids can also be viewed as biomass pyramids, picturing the amount of biomass that results at higher levels from biomass consumed at lower levels. The efficiency with which energy or biomass is transferred from one trophic level to the next is called the ecological efficiency. Consumers at each level convert on average only about 10 percent of the chemical energy in their food to their own organic tissue. For this reason, food chains rarely extend for more than 5 or 6 levels. At the lowest trophic level (the bottom of the food chain), plants convert about one percent of the sunlight they receive into chemical energy. It follows from this that the total energy originally present in the incident sunlight that is finally embodied in a tertiary consumer is about 0.001 %.

Fractional Trophic Level

Food webs largely define ecosystems, and the trophic levels define the position of organisms within the webs. But these trophic levels are not always simple integers, because organisms often feed at more than one trophic level. For example, some carnivores also eat plants, and some plants are carnivores. A large carnivore may eat both smaller carnivores and herbivores; the bobcat eats rabbits, but the mountain lion eats both bobcats and rabbits. Animals can also eat each other; the bullfrog eats crayfish and crayfish eat young bullfrogs. The feeding habits of a juvenile animal, and consequently its trophic level, can change as it grows up. The fisheries scientist Daniel Pauly sets the values of trophic levels to one in plants and detritus, two in herbivores and detritivores (primary consumers), three in secondary consumers, and so on. The definition of the trophic level, TL, for any consumer species i is:

$$TL_i = 1 + \sum_j (TL_j \cdot DC_{ij})$$

Where, TL_i is the fractional trophic level of the prey j , and DC_{ij} represents the fraction of j in the diet of i . In the case of marine ecosystems, the trophic level of most fish and other marine consumers takes value between 2.0 and 5.0. The upper value, 5.0, is unusual, even for large fish, though it occurs in apex predators of marine mammals, such as polar bears and killer whales.

Mean Trophic Level

The mean trophic level is calculated by assigning each fish or invertebrate species a number based on its trophic level. The trophic level is a measure of the position of an organism in a food web, starting at level 1 with primary producers, such as phytoplankton and seaweed, then moving through the primary consumers at level 2 that eat the primary producers to the secondary consumers at level 3 that eat the primary consumers, and so on. In marine environments, trophic levels range from two to five for the apex predators. The mean trophic level can then be calculated for fishery catches by averaging trophic levels for the overall catch using the datasets for commercial fish landings.

In fisheries, the mean trophic level for the fisheries catch across an entire area or ecosystem is calculated for year y as:

$$TL_y = \frac{\sum_i (TL_i \cdot Y_{iy})}{\sum_i Y_{iy}}$$

Where: Y_{iy} is the catch of the species or group i in year y , and TL_i is the fractional trophic level for species i as defined above. It was once believed that fish at higher trophic levels

usually have a higher economic value; resulting in overfishing at the higher trophic levels. Earlier reports found precipitous declines in mean trophic level of fisheries catch, in a process known as fishing down the food web. However, more recent work finds no relation between economic value and trophic level; and that mean trophic levels in catches, surveys and stock assessments have not in fact declined, suggesting that fishing down the food web is not a global phenomenon.

Overfishing occurs when fishing activities reduce fish stocks below an acceptable level. This can occur in any body of water from a pond to the oceans. Ultimately overfishing can lead to resource depletion in cases of subsidised fishing, low biological growth rates and critical low biomass levels (e.g. by critical depensation growth properties). For example, overfishing of sharks has led to the upset of entire marine ecosystems.

Generally, a fishery is an entity engaged in raising and/or harvesting fish, which is determined by some authority to be a fishery. According to the FAO, a fishery is typically defined in terms of the "people involved, species or type of fish, area of water or seabed, method of fishing, class of boats, and purpose of the activities or a combination of the foregoing features". The definition often includes a combination of fish and fishers in a region, the latter fishing for similar species with similar gear types. A fishery may involve the capture of wild fish or raising fish through fish farming or aquaculture. Directly or indirectly, the livelihood of over 500 million people in developing countries depends on fisheries and aquaculture. Overfishing, including the taking of fish beyond sustainable levels, is reducing fish stocks and employment in many world regions.

The Ecology of Fishing Down

Ecologically, the decline in the mean trophic level is explained by the relationship between the size of the fish captured and their trophic level. The trophic level of fishes usually increases with their size, and fishing tends to selectively capture the larger fishes. This applies both between species as well as within species. When the fishing is intense, the relative abundance of the larger fish positioned high in the food chain is reduced. Consequently, over time, small fishes start to dominate the fisheries catches, and the mean trophic level of the catches declines. Recently the market value of small forage fishes and invertebrates, which have low trophic levels, has sharply increased to the point where they can be considered to be subsidizing fishing down. Daniel Pauly has suggested a framework for the ecological impacts fishing down can have on marine ecosystems. The framework distinguishes three phases:

1. **Pristine** – the first phase. Pristine environments are the states ocean ecosystem was in before fishing made strong impacts. Some outlier areas of the South Pacific may still be pristine. For most of the world what these pristine states may have been can only be inferred from archeological data, historical accounts and anecdotes. In pristine ocean environments, the biomasses of the large predator fish are 10 to 100 times greater than their present biomass. This implies a large supporting biomass of small prey fishes and invertebrates. On the seafloor, the benthos is dominated by deposit feeders which prevent resuspension of sediments, and filter feeders which keep the phytoplankton down. Thus the water column tends to be oligotrophic, free of both suspended particles and of the nutrients that leach from them.
2. **Exploited** – the second phase. Exploited is the phase we are currently in. It is characterized by declines in the biomass of large predator fish, declines in the diversity, size and trophic level of captured fish, and declines in the benthos. Bottom trawlers progressively destroy the biogenic structures built over many years on the seafloor by the filter and detritus feeders.
3. **Fully degraded** – the third phase. The dead zone is the biological endpoint of a fully degraded marine ecosystem. The dead zone is a zone with excessive nutrients in the water column, resulting in the depletion of oxygen and the elimination of multicellular organisms. The abundant detritus and marine snow is processed by bacteria rather than by the benthic animals.

Farming Up The Webs

While the mean trophic level in wild fisheries has been decreasing, the mean trophic level amongst farmed fish has been increasing.

Production trends across different trophic levels in the Mediterranean		
Herbivores	Intermediate predators	Top-level predators
The production of bivalves, such as mussels and oysters, increased from about 2,000 tonnes in 1970 to 100,000 tonnes in 2004	The mariculture of species such as sea bream increased from 20 tonnes in 1983 to 140,000 tonnes in 2004	The production of the bluefin tuna has gone from almost zero in 1986 to 30,000 tonnes by 2005

As an example, the table above shows trends in the trophic levels of fish farmed in the Mediterranean. However, the farming of bluefin tuna is restricted to a fattening process. Juvenile tuna are captured from the wild and put in pens for fattening. Wild stocks of bluefin are now threatened, and the fisheries scientist Konstantios Stergiou and colleagues argue that

the "fact that the capacity of tuna farms greatly exceeds the total allowable catch indicates lack of conservation planning in development of the tuna-fattening industry, which, ideally, should have been linked to fisheries management policies, and may lead to illegal fishing." Much of the fish suitable for direct human consumption is being used to grow higher trophic level fish to indulge a relatively small group of affluent consumers.

Prey – Predator Relationship

Actually, it's more like eat and be eaten for most organisms. While plants and some bacteria can make their own food, other organisms must eat living things to survive. This makes them predators. You might not think of a grass-munching cow as much of a predator, but cows are indeed the predators of their grass prey.

Of course, the cows themselves are prey to other animals, like humans and coyotes. Now we have a simple food chain, with grass plants making food at the bottom, cows as middle predators, and then humans and coyotes as "top predators." While predators usually kill their prey to eat them, parasites live on or in their prey (called a host), nibbling or sucking tiny bits so the host survives, nourishing them for many meals to come. Almost all organisms play host to parasites throughout their entire lifetimes.

To succeed at the evolutionary game, organisms must eat but not be eaten. As a result, in predator-prey (and parasite-host) relationships, something called coevolution can often occur: when one of them develops a new offense or defense, the other must develop a counter-weapon to survive. Typical ocean forage fish are small, silvery schooling oily fish such as herring, anchovies and menhaden, and other small, schooling baitfish like capelin, smelts, sand lance, halfbeaks, Pollock, butterfish and juvenile rockfish disambiguation needed. Herrings are a preeminent forage fish, often marketed as sardines or pilchards.

The term "forage fish" is a term used in fisheries, and is applied also to forage species that are not true fish, but play a significant role as prey for predators. Thus invertebrates such as squid and shrimp are also referred to as "forage fish". Even the tiny shrimp-like creatures called krill, small enough to be eaten by other forage fish, yet large enough to eat the same zooplankton as forage fish, are often classified as "forage fish".

Forage fish feed on plankton. When they are eaten by larger predators, they transfer this energy from the bottom of the food chain to the top and in this way are the central links between trophic levels. Forage fish are usually filter feeders, meaning that they feed by straining suspended matter and food particles from water. They usually travel in large, slow moving, tightly packed schools with their mouths open. They are typically omnivorous. Their

diet is usually based primarily on zooplankton, although, since they are omnivorous, they also take in some phytoplankton.

Young forage fish, such as herring, mostly feed on phytoplankton and as they mature they start to consume larger organisms. Older herrings feed on zooplankton, tiny animals that are found in oceanic surface waters, and fish larvae and fry (recently-hatched fish). Copepods and other tiny crustaceans are common zooplankton eaten by forage fish. During daylight, many forage fish stay in the safety of deep water, feeding at the surface only at night when there is less chance of predation. They swim with their mouths open, filtering plankton from the water as it passes through their gills.

Ocean halfbeaks are omnivores which feed on algae, plankton, marine plants like seagrass, invertebrates like pteropods and crustaceans and smaller fishes. Some tropical species feed on animals during the day and plants at night, while others alternate summer carnivore with winter herbivore. They are in turn eaten by billfish, mackerel, and sharks.

Symbiosis

Symbiosis refers to two species that have a close relationship with each other. The relationship can be mutuality, when both species benefit from the relationship, commensalistic, when one species benefits and the other is unaffected, and parasitistic, when one species benefits, and the other is harmed.

An example of commensalism occurs between the hawkfish and fire coral. Thanks to their large, skinless pectoral fins, hawkfish can perch on fire corals without harm. Fire corals are not true corals, but are hydrozoans possessing stinging cells called nematocysts which would normally prevent close contact. The protection fire corals offer hawkfish means the hawkfish has the high ground of the reef, and can safely survey its surroundings like a hawk. Hawkfish usually stay motionless, but dart out and grab crustaceans and other small invertebrates as they pass by. They are mostly solitary, although some species form pairs and share a head of coral.

There is a mutuality relationship between sea anemones and clownfish. This gives the sea anemones a second line of defence. They are guarded by fiercely territorial clownfish, who are also immune to the anemone toxins. To get their meal, butterfly fish must get past these protective clownfish who, although smaller, are not intimidated. An anemone without its clownfish will quickly be eaten by butterfly fish. In return, the anemones provide the clownfish protection from their predators, who are not immune to anemone stings. As a

further benefit to the anemone, waste ammonia from the clownfish feed symbiotic algae found in the anemone's tentacles.

Different Predator – Prey Relationships On The Reef

1. Giant triton (snail) -> Crown-of-thorns starfish -> Hard coral

One of the few predators of the crown-of-thorns starfish, the giant triton (*Charoniatritonis*) has evolved a tolerance to the starfish's toxins. Unfortunately, tritons can no longer keep starfish populations in check since they've been overharvested for their beautiful shells. With too few tritons on the reef, crown-of-thorns starfish populations can explode, jeopardizing the living coral that makes up reefs.

Covered with long, venomous spikes, the crown-of-thorns starfish (*Acanthaster planci*) is a voracious feeder that can eat living corals because of a unique adaptation: a wax-digesting enzyme system. Populations of the starfish were once kept low by a few key predators, namely the giant triton. Since humans decimated giant triton populations, crown-of-thorns starfish outbreaks periodically kill vast expanses of hard coral. Hard corals have evolved to have large amounts of a wax (cetyl palmitate) in their tissues. Very few predators can digest the wax, which has allowed corals to flourish and produce massive reefs. Recently, epidemic populations of one predator -- the crown-of-thorns starfish -- have done extensive damage to many reef regions. Armies of grazing starfish leave a wake of destruction in their path, killing up to 95 percent of the hard corals in an area.

2. Tiger shark -> Green sea turtle

Lurking around the edges of reefs during the day, tiger sharks (*Galeocerdocuvier*) have evolved as highly aggressive "top" predators that grow at least 25 feet long. They detect prey using an array of finely tuned senses, including electrical current detection. Rows of razor-sharp teeth and powerful jaws allow them to crack through even the thick carapace (shell) of full-grown sea turtles. One common defense against predators is a protective covering, such as a shell. Another is to flee the predator. During its evolution, the green sea turtle (*Cheloniemydas*) sacrificed speed in favor of a thick, heavy shell (carapace). The carapace acts as armor, protecting the turtle's body from the sharp teeth of predators. But some, like the tiger shark, are powerful enough to bite right through the carapace and kill the turtle.

3. Sea slug -> Sea sponge

Many sea sponges, like anemones, use toxins to repel would-be predators. Some species of sea slugs, however, such as *Platydorisscabra*, have evolved immunity against the toxins of specific sponge families (in this case, *Microcionidae*). This adaptation benefits the slugs in

two ways. First, they don't have to compete with many other organisms for the sponges. The sea slugs can also concentrate the sponge toxins to foil their own predators -- at least until the slugs' predators also evolve immunity to the toxins. Sea sponges, such as those of the Microcionidae family, have escaped predation by all but a few species because they produce foul-tasting and sometimes toxic compounds. These compounds evolved as chemical weapons for use against other sponges, as well as against fouling organisms (creatures that grow on top of other creatures, thus decreasing their fitness) -- their defensive function was just a lucky side effect. But some predators, such as sea slugs, have evolved resistance to the toxins and even use those toxins against their own predators.

4. Barracuda -> Parrotfish -> Benthic algae

Barracuda (*Sphyraena* spp.) are fierce predatory fish that patrol outer reef areas in large schools. Like many predators, they have evolved as extremely fast swimmers, with streamlined, torpedo-like bodies. And they are efficient killers, using conical, razor-sharp teeth to quickly rip prey to shreds. In addition, they are resistant to the toxin found in the bodies of many of their prey, such as parrotfish. Named for their bright colors and beak-like mouths, parrotfish (*Scaridae* family.) are large herbivores that graze on the algae growing atop hard corals. Using their beaks and two pairs of crushing jaws, parrotfish are marvelously adapted for crunching and pulverizing chunks of algae-coated coral. They digest the algae and excrete the coral as fine sand. Unfortunately, they are poorly equipped to defend themselves against predators, such as barracuda, but some find protection by schooling with better-armored fish.

Algae occur in a kaleidoscope of forms and colors on the reef, but they have one main function: turning solar energy into food. Thus they are called "primary producers." Without them, the reef would quickly become a lifeless moonscape. One important algal group, benthic (bottom-dwelling) algae, rapidly grows over dead coral and other inert objects, providing a grazing yard for herbivores, such as parrotfish.

5. Saddled butterflyfish -> Sea anemone

Saddled butterflyfish (*Chaetodon* spp.) seem to flutter, rather than swim, above the algae-covered coral they commonly graze on. Their gentle disposition disappears, however, in the presence of another favorite food: sea anemones. When feeding, the butterflyfish turn into vicious predators, darting in to rip off the anemones' fleshy tentacles. Having evolved resistance to the anemones' toxins, they need only get past clownfish guards to pick off a delicious meal. Packed with miniature toxin-loaded harpoons (nematocysts), the tentacles of

sea anemones provide an excellent deterrent against almost all would-be predators. Saddled butterfly fish, though, have evolved resistance to the toxins and apparently relish the tentacles. Still, to grab a meal, the butterfly fish must get past the anemones' second line of defense: zealous clownfish guards.

6. Reef heron -> Fish fry

Reef herons (*Egretta sacra*), unlike true seabirds, live onshore year-round. While seabirds hunt far out beyond the reef, reef herons fish along the cay and reef flat. They have evolved to hunt during low tide, allowing them to wade the shallows. With excellent eyesight and marksman-like aim, they expertly spear fish fry, adult fish, and crustacean prey from beneath the water's surface. Silvery schools of many species of juvenile fish (called fish fry) find some refuge from the intense predation of outer reef zones by living near the shoreline. But they can't let down their guard completely. While feeding on benthic algae and floating microscopic communities of plants and animals, they are easily visible from above the water's surface and often fall prey to hunting reef herons.

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