Food web

Contributed by: Stuart Pimm

Publication year: 2014

A diagram depicting those organisms that eat other organisms in the same ecosystem. In some cases, the organisms may already be dead. Thus, a food web is a network of energy flows in and out of the ecosystem of interest. Such flows can be very large, and some ecosystems depend almost entirely on energy that is imported. A food chain is one particular route through a food web.

A food web helps depict how an ecosystem is structured and functions. Most published food webs omit predation on minor species, the quantities of food consumed, the temporal variation of the flows, and many other details.

Example

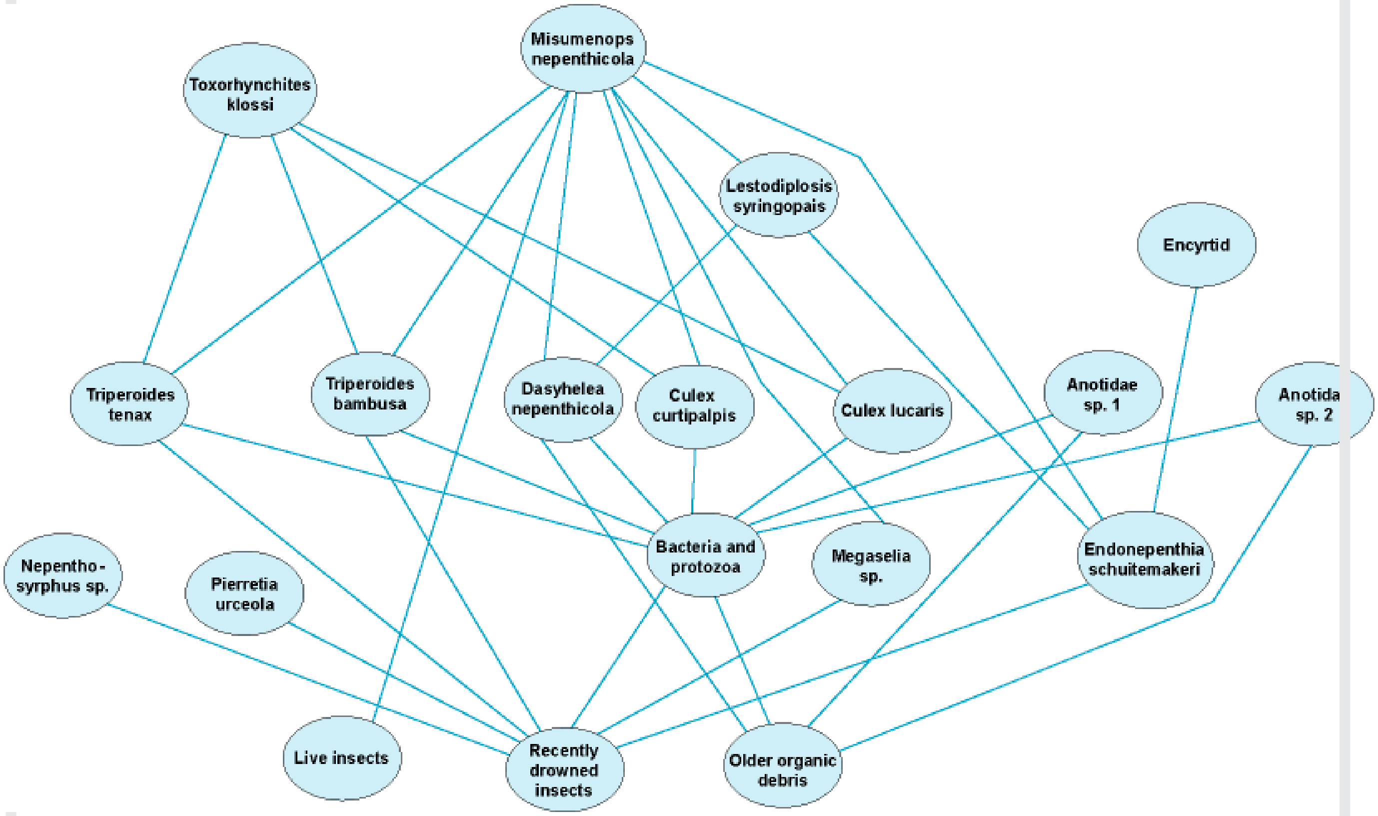
Pitcher plants (belonging to the family Nepenthaceae) are tropical species with a structure that holds water into which insects fall and drown. The plant gains nutrients from the decaying insects. Many other species thrive in these tiny ponds, grabbing the energy from the decaying insects before the plant can do so (see **illustration**).

At the base of the food web in the pitcher plant are drowning insects, dead insects, and older organic debris. Some of the species that feed on the decaying material have predators; others do not. In addition, some species may receive energy from more than one level. One predator, a spider (genus *Misumenops*), feeds on another predator, a fly (*Lestodiplosis*), and both these species feed on another fly (*Endonepenthia*). Thus, species are not always arranged into neat, clear food chains.

Food chains

Along a simple food chain, A eats B, B eats C, and so on. For example, the energy that plants capture from the sun during photosynthesis may end up in the tissues of a hawk. It gets there via a bird that the hawk has eaten, the insects that were eaten by the bird, and the plants on which the insects fed. Each stage of the food chain is called a trophic level. More generally, the trophic levels are separated into producers (the plants), herbivores or primary consumers (the insects), carnivores or secondary consumers (the bird), and top carnivores or tertiary consumers (the hawk).

Food chains may involve parasites as well as predators. The lice feeding in the feathers of the hawk are yet another trophic level. When decaying vegetation, dead animals, or both are the energy sources, the food chains are described as detrital.



Food web of the insects found in the pitcher plant *Nepenthes albomarginata* in West Malaysia. Each line represents a trophic linkage; predators are higher in the web than their prey.

Patterns

Food webs have a long history in ecology, including C. Darwin's famous description of a "tangled bank" at the end of *Origin of Species*. This analogy to tangles implies that even when food webs ignore some details, they demonstrate how complex nature can be. This complexity raises questions: First, are food web patterns simply random, or is there a pattern to their tangles? Second, what are the consequences of these patterns for the dynamics of the ecosystem?

Food chains are usually short. The shortest food chains have two levels. For example, in the illustration there are the drowning insects in the water, and the spider *Misumenops*. The longest chains have five levels [old organic debris, the bacteria and protozoa that feed on it, two species of *Culex* (mosquitoes), *Dasyhelea* (biting midges), and *Misumenops*]. One way to describe and simplify various food chains is to count the most common number of levels from the top to the bottom of the web. Thus, although *Misumenops* sits atop chains of length two and five, the most common chains in the web are those of length three, which is quite typical. Most food chains are three or four trophic levels long (if parasites are excluded), though there are longer ones.

Energetics

There are several possible explanations for why food chains are generally short. The first involves energy. In many ecosystems there are more plants than insects, more insects than insectivorous birds, and more insectivorous birds than hawks. These ecological pyramids reflect an underlying energetic constraint. The first law of thermodynamics states that when energy is converted from one form to another the amount of energy remains constant. An approximate statement of the second law is that the amount of useful energy decreases at each conversion. When insects eat plants, they convert energy locked in plant tissues into insect tissue. Yet, they pay an energetic cost in doing so. Mammals and birds pay an even greater cost. Only about 1% of the energy of the food consumed goes to produce new tissues. The rest is lost as heat, both for warmth and as a by-product of the conversion process. *See also:* ECOLOGICAL ENERGETICS.

Thus, between each trophic level, much of the energy is lost as heat. As the energy passes up the food chain, there is less and less to go around. There may not be enough energy to support a viable population of a species at trophic level five or higher.

This energy flow hypothesis is widely supported, but it is also criticized because it predicts that food chains should be shorter in energetically poor ecosystems such as a bleak arctic tundra or extreme deserts. These systems often have food chains similar in length to energetically more productive systems.

Recovery from disaster

Another hypothesis about the shortness of food chains has to do with how quickly particular species recover from environmental disasters. For example, in a lake with phytoplankton, zooplankton, and fish, when the phytoplankton decline the zooplankton will also decline, followed by the fish. The phytoplankton may recover but will remain at low levels, kept there by the zooplankton. At least transiently, the zooplankton may reach higher than normal levels because the fish, their predators, are still scarce. The phytoplankton will not completely recover until all the species in the food chain have recovered. Mathematical models can expand such arguments. These models show that the longer a food chain, the longer it will take its constituent species to recover from perturbations. (The phytoplankton could recover quickly in the example if they were the only trophic level.) Species atop very long food chains may not recover before the next disaster. Such arguments predict that food chains will be longer when environmental disasters are rare, short when they are common, and will not necessarily be related to the amount of energy entering the system.

Consequences for species dynamics

The number of trophic levels a food web contains will determine what happens when an ecosystem is subjected to a short, sharp shock—for example, when a large number of individuals of one species are killed by a natural disaster or an incident of human-made pollution—and how quickly the system will recover.

The food web will also influence what happens if the abundance of a species is permanently reduced (perhaps because of harvesting) or increased (perhaps by increasing an essential nutrient for a plant). For example, the population of a fertilized plant species may not expand because herbivores consume the increased plant production, and then the more numerous herbivores may be consumed by their predators, and so on up the food chain.

Some species have redundant roles in an ecosystem so that their loss will not seriously impair the system's dynamics. Therefore, the loss of such species from an ecosystem will not have a substantial effect on ecosystem function. The alternative hypothesis is that more diverse ecosystems could have a greater chance of containing species that survive or that can even thrive during a disturbance that kills off other species. Highly connected and simple food webs differ in their responses to disturbances, so once again the structure of food webs makes a difference. *See also:* ECOLOGICAL COMMUNITIES; ECOSYSTEM; POPULATION ECOLOGY.

Stuart Pimm

Bibliography

S. R. Carpenter, *Complex Interactions in Lake Communities*, 1988

J. E. Cohen, F. Briand, and C. M. Newman, *Community Food Webs*, 1990

S. L. Pimm, *Food Webs*, 1982

S. L. Pimm, J. H. Lawton, and J. E. Cohen, Food web patterns and their consequences, *Nature*, 350:669–674, 1991 **DOI:** **http://doi.org/10.1038/350669a0**

Additional Readings

U. Brose, Body-mass constraints on foraging behaviour determine population and food-web dynamics, *Funct. Ecol.*, 24(1):28–34, 2010 DOI: http://doi.org/10.1111/j.1365-2435.2009.01618.x

J. C. Moore and P. C. de Ruiter, *Energetic Food Webs: An Analysis of Real and Model Ecosystems*, Oxford University Press, Oxford, UK, 2012

P. Ory et al., Pelagic food web patterns: Do they modulate virus and nanoflagellate effects on picoplankton during the phytoplankton spring bloom?, *Environ. Microbiol.*, 12(1):2755–2772, 2010
DOI: http://doi.org/10.1111/j.1462-2920.2010.02243.x