# what corals eat

Organisms divide into two main groups based on how they obtain food: Autotrophs take inorganic materials (like carbon, nitrogen, phosphorus) and use light or chemical energy to produce their nutritive organic molecules (like sugars). Heterotrophs feed on or use the products of other organisms to obtain their nutritive organic needs. Corals are heterotrophs with a twist! Most reef building corals (hermatypes) and many non-reef building corals (ahermatypes) have a symbiotic relationship with various dinoflagellate algae called zooxanthellae. The zooxanthellae use sunlight to photosynthesize food for themselves and for the polyp and at the same time the polyps also directly feed on other micro and macro fauna in the water making them polytrophic (or mixotrophic).

## SUNLIGHT and ZOOXANTHELLAE

The waters around coral reefs generally have extremely low levels of nutrient sources primarily due to fierce competition for these nutrients by the numerous species found there. A successful strategy in this environment would be to utilize a resource that is not generally limited and in tropical waters that resource is sunlight. Adequate sunlight makes having zooxanthellae a net benefit to the coral: the cost of keeping them is negated by their useable photosynthates. This explains why corals respond to their environment like plants: they need sunlight and are normally found in clear, shallow waters. Corals that contain zooxanthellae include most of the stony corals (hermatypic), corallimorths, and Caribbean gorgonians; over half the soft corals, about half the zooanthids; a couple shallow water Pacific gorgonians, and the Millepora genus of hydrocoral.

Zooxanthellae are dinoflagellate photosynthetic algae (a plant) living in coral (an animal) tissues. In exchange for the coral providing them with a protected place to live and some compounds they need for photosynthesis (water, carbon dioxide) the algae in turn give the coral oxygen, glucose and other photosynthates it uses for respiration and other metabolic functions. Research has found that zooxanthellae can deliver up to 100% of the daily required *energy budget* for corals. But the majority of these photosynthates are carbon rich and nitrogen poor and nitrogen is an essential for protein synthesis, growth, repair and sexual reproduction. So while calcification and other processes use the energy provided by the zooxanthellae these other needs are not met and feeding on other foods like phytoplankton, zooplankton, bacteria, detritus and other organic matter provides nitrogen, amino acids, vitamins, phosphates, lipids, (long chain Omega-3 fatty acids), and other essential elements needed by corals.

Each coral species depends in varying degrees on all sources with some more on one thing than another. That all corals with zooxanthellae are entirely autotrophic and require only "light" to meet their growth needs is a false assumption. Continuing research shows that all corals rely on and / or take advantage of a number of food sources in the water column including phytoplankton, zooplankton, bacteria, and particulate organic matter making them polytrophic; they acquire their energy, growth, and reproductive needs from multiple sources.

> The heterotrophic nutritional activities of reef corals, as observed both in the field and in the laboratory, include the following: (1) specialized carnivorous feeding, primarily on zooplankton, facilitated by ciliated currents and mucus, direct transfer of prey to the mouth by the tentacles, or extracoelenteric feeding by the mesenterial filaments; (2) un-specialized detritus feeding, involving the use of a wide range of organic matter of animal and perhaps of bacterial origin; (3) direct utilization of dissolved or colloidal organic matter as suggested by the uptake of amino acids by the epidermis and by the ultrastructural, histochemical and physiological features of the free cell border.[1]

Zooxanthellae are initially acquired either from the water column (broadcast spawning corals), or from the parent polyp (brooding corals). Coral polyps keep various amounts of zooxanthellae in their tissues responding to different environmental and metabolic conditions. They will release some at times and acquire more from the water column at other times to control growth and reproduction. Stressed corals may expel their zooxanthellae giving the coral a white or bleached appearance and if it looses too much of its zooxanthellae it will die. Zooxanthellae are also responsible for the colors seen in many stony corals.

## PHYTOPLANKTON

The name derives from the Greek words phyton (plant) and planktos (errant, wanderer, drifter). They are photosynthesizing microscopic organisms living in fresh and salt water environments and are mainly unicellular algae and cyanobacteria but can also be bacteria or members of the Protist kingdom (protozoans, most algae, diatoms, oomycetes, and the slime molds). Important members include diatoms, cyanobacteria, dinoflagellates and coccolithophores. Dinoflagellates have a complex shell and a whip-like tail (flagella) they use to move through the water. Diatoms have rigid shells made from interlocking parts and no flagella relying on ocean currents to move through the water. Coccolithophores have calcium carbonate plates or scales. Cyanobacteria are the blue-green algae.

Phytoplankton start most (if not all) of marine food chains by using chlorophyll to convert sunlight, carbon dioxide, and inorganic nutrients (nitrates, phosphates, sulfur) to produce oxygen and sugars needed for energy and growth. They are the major source of primary production in the ocean; they fill the upper 200m of oceanic waters which cover over 70% of the earth's surface[2]. In the end, almost all visible ocean life is supported in some way by phytoplankton. Phytoplankton is subdivided by size with the majority falling in the picoplankton and nanoplankton divisions:

| **PLANKTON SIZE DIVISIONS** | | |
|---|---|---|
| **DIVISION** | **EXAMPLES (listing both Phytoplankton and zooplankton)** | **SIZES** |
| Femtoplankton | marine viruses | < 0.2 μm |
| Picoplankton | Chrysophyta, small eukaryotic protists; bacteria | 0.2 – 2μm |
| Nanoplankton | Pyrrophyta, Chrysophyta, Chlorophyta, Xanthophyta, and small eukartotic protists, diatoms, flagellates | 2 – 20μm |
| Microplankton | Ciliates, Copepod and other crustacean nauplii, Foraminiferans, juvenile metazoans, Rotifers | 20 – 200μm |
| Mesoplankton | Chaetognaths, Cladocera, Copepods, Euphausids, Heteropoda, Medusae, Metazoans, Ostracoda, Pteropods, Tunicata; larval and post larval crustaceans | .2 – 2mm |
| Macroplankton | Cephalopods, Ctenophores, Chaetognaths, Doliolids, Euphausids, Medusae, Myctophids, Pteropods, Pyrosomes, Salps, Sergestids | 2 – 20mm |
| Megaplankton | Cephalopods, Ctenophores, Jellyfish, Pyrosomes, Salps, Scyphozoans, Thalacians (Gelatinous plankton) | > 20mm |

They are a food source for soft corals, clams, feather duster worms, tunicates, copepods, sponges, invertebrate larvae, and other filter feeders that may be in your live rock. They are to a lesser degree a food source for stony corals as these are not well adapted to sieve or filter feeding like soft corals. Phytoplankton and bacteria are also the primary food source for zooplankton.

If you intend to provide phytoplankton to your reef or other marine tank you will find phytoplankton products or supplements that have either living or dead cells. Both have their pros and cons. Live phytoplankton cultures are available but care must be taken in storing, without preservatives they can go bad causing fouling and other problems. They are also the most expensive option . There are cryo-preserved products that are less expensive and equally nutritious, again provided it is stored correctly and contains a diversity of species and sizes. Downsides are the algae are dead and if not eaten can decompose and affect water quality ; because they are concentrated, overfeeding is easy; and they need to be stored frozen. Dried phytoplankton products can provide a good nutritional profile, are easy to store but don't have the particle size range and obtaining best results requires attention to mixing directions. Liquid phytoplankton supplements are a preserved product, easy to store and feed but overall efficacy and cost effectiveness in reef tanks is questionable.

## ZOOPLANKTON

The name comes from from Greek zoon (animal) and planktos (errant, wanderer, drifter). This group includes primarily small protozoans and metazoans, ciliates, copepods, amphipods, tintinnids, and some of the eggs and larvae of larger animals (fish, crustaceans, annelids). Zooplankton are larger than phytoplankton and are the primary diet of many marine and reef organisms; stony corals rely heavily on zooplankton capture to meet their energy needs. Zooplankton also consume significant amounts of phytoplankton, bacterioplankton and other zooplankton. The copepods are the largest fraction of total zooplankton and along with amphipods are the primary consumers of the larger phytoplankton (especially nanoplankton) size classes.

Zooplankton are classified based on size (like phytoplankton, see table) and / or developmental stage (see below). The majority are demersal, migrating vertically from the reef benthos (deep, dark region) up into the water column generally at night. Copepods and mysids compose the majority of zooplankton available to coral reefs.

| OTHER ZOOPLANKTON DIVISIONS | |
|---|---|
| **DIVISION** | **EXAMPLES** |
| Meroplankton | Larvae that eventually change into worms, mollusks, crustaceans, coral, echinoderms, fishes, or insects |
| Holoplankton | Chaetognaths, Copepods, Larvaceans, Pteropods, and Siphonophores |
| Demersal | Living at or near the bottom of a body of water |
| Pelagic | Living in the water column of open seas and oceans |

Some corals feed during day hours or day and night but most feed at night, when zooplankton is more abundant. Tentacle extension can occur for a number of reasons though: food capture, competition, or to expose zooxanthellae in the tentacles to light. In most instances corals with transparent (no zooxanthellae) tentacles are night feeders but in reef aquariums corals fed during the day many of the normally night-feeding corals will extend to feed. Whether this off-time feeding is deleterious for exclusive night feeding corals is difficult to say.

That different species gain different amounts of energy from various sources has been pretty well established. The amount a coral depends on zooplankton varies from slight to total dependence depending on species. The idea that small polyp stony (SPS) corals depend mostly on light, and require less food than large polyp stony (LPS) corals is untrue. A study of the capture rate of an equivalent biomass of two corals, the LPS Montastraea cavernosa and SPS Madracis mirabilis, showed the capture rate of the SPS coral was 36 times greater[3]

Plankton (phytoplankton and zooplankton) is abundant on a reef, and a vital and constantly available food source for corals and other reef inhabitants. There various sources you can employ to feed your corals: Commercially available products that mimic zooplankton, frozen mysid shrimp; shredded or blended raw seafood; culturing Artemia, Daphnia, and Gammarus is fairly easy to do; and having a refugium with a deep sand or mud bed. There are many opinions on how much, how often, and how to best feed your reef tank. Reading and some experimentation will help you determine what is best for your tank.

## DISSOLVED ORGANIC MATTER (DOM)

Dissolved organic matter contains various elements: Dissolved organic nitrogen, DON, which includes amino acids and urea and dissolved organic carbon, DOC, which includes carbohydrates. All of these molecules are taken up by corals. Observation on natural coral reefs show the coral's urea uptake is much greater than nitrate, a possible adaptation to the urea producing fish found on the reef.. Scientists also found that urea and amino acids are more actively taken up during the day and may be integral to building the organic matrix that aids the formation of aragonite crystals, increasing the density and strength of the coral skeleton. Other evidence of uptake is observed in reef and marine tanks with noticed polyp expansion after feeding plankton or plankton supplements containing dissolved organics.

## DISSOLVED INORGANIC MATTER (DIM)

Corals uptake both macro-elements such as calcium, magnesium, bicarbonates and potassium; gases such as oxygen and carbon dioxide, and trace elements such as iodine, phosphorus, and iron. Macro-elements important in calcification are often added to reef tanks and aquariums by adding calcium hydroxide (Ca(OH)2 or kalkwasser) via a calcium reactor, Balling method, or dosing. Trace elements are those found in seawater in minute concentrations. The table below is an overview of main elements and compounds found in seawater and utilized by corals. Some elements (like copper, zinc, and chromium) can prove highly toxic to corals and other invertebrates in the wrong quantity but are still needed (such as zinc) for life sustaining chemical reactions. Supplementing metals should be done with much care.

| **Macro Elements in Seawater (in ppt)** | | **Trace Elements in Seawater (in ppm)** | | **Trace Elements (in ppb)** | |
|---|---|---|---|---|---|
| Oxygen (O) | 857.8 | Bromine (Br) | 65 | Nitrogen (N) | 300 (includes nitrate) |
| Hydrogen (H) | 107.2 | Strontium (Sr) | 8 | Lithium (Li) | 170 |
| Chlorine (Cl) | 18.98 | Boron (B) | 4 | Phosphorus (P) | 70 (includes phosphate) |
| Sodium (Na) | 10.556 | Silicon (Si) | 3 | Iodine (I) | 50 |
| Sulfate ($SO_4^{2-}$)* | 2.649 | Fluorine (Fl) | 1 | Zinc (Zn) | 10 |
| Magnesium (Mg) | 1.272 | | | Iron (Fe) | 10 |
| Potassium (K) | 0.38 | | | Aluminum (Al) | 10 |

| | | | | |
|---|---|---|---|---|
| Bicarbonate ($HCO_3^-$)* | 0.14 | | Manganese (Mn) | 2 |
| | | | Lead (Pb) | 0.04 |
| | | | Mercury (Hg) | 0.03 |
| | | | Gold (Au) | 0.000004 |

** Bicarbonate and sulfate are not elements but molecules that are included due to their importance*

## PARTICULATE ORGANIC MATTER (POM)

This source comes primarily from the remains, secretions and excretions of living organisms and has many names: detritus, reef snow, marine snow, flocculent, and suspended organic matter (SOM). In the sediments found on coral reefs, it is primarily from dead algae, bacteria, mucus, and feces and contains bacteria, protozoa, excrement, micro algae, microscopic invertebrates and organics. In aquaria it comes from fish feces, coral mucus, worm castings, uneaten foods, algal remnants, crustacean molts, and other debris. It is used by microbes (microalgae, cyanobacteria, bacteria), eaten by detritivores (fish, crustaceans, corals, and others), incorporated into sediments, exported, and regenerated. Coral mucus serves double duty: as a growth medium for marine microbes on the surface of corals and as a primary contributor to particulate aggregates of detritus that provide food for corals and other particulate filter feeders.

All studied corals feed to some extent on POM and it can be the primary food source of some corals supplying over 100% of carbon and nitrogen requirements depending on the availability of other types of living plankton. Soft corals (Octocorallia), zooanthids (Zoantharia), stony corals (Scleractinia), and mushrooms (Corallimorpharia), all accept detritus as food and can, in some cases, be provided with over 100% of their carbon and nitrogen requirements by this resource alone. As with all things, too much can prove detrimental and too much sediment or suspended matter can block sunlight and suffocate corals. There are many particulate food sources commercially available that can provide a reasonable substitution for particulate organic material. Ones that tend to remain in suspension easily are more able to provide easy access to the food by filter feeding animals, including corals.

## BACTERIA

Coral consume bacteria in a number of ways: They can use their mucus and epithelial cilia to snare and consume attached and pelagic bacteria. Some (like Turbinaria species) use cilia to form their mucus into webs which they cast out like a net into the water column to capture bacteria and other particulate matter. The cilia then pull the net back to the colony where polyps consume the catch. Bacteria provide carbon and nitrogen for the polyp and are an important source of phosphorous and other elements for the zooxanthellae.

Bacteria are found in very high diversity and biomass on coral reefs, on coral surfaces, and in marine environments. Bacterial levels in reef aquariums are largely unmeasured but are likely to be similar to wild communities and it can be expected that aquarium corals are likely obtaining significant amounts of energy by consuming bacteria on detrital aggregates, in the water column, and grown on their surfaces (*see POM*).

### References & Additional Reading

[1]p257; Reef Corals: Autrotrophs or Heterotrophs? Thomas F. Goreau, Nora I Goreau, and C.M. Yonge:
http://globalcoral.org/Corals%20Heterotrophs%20or%20Autotrophs.pd
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