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Coral Reefs and Eutrophication

Noga Stambler
Department of Life Sciences, Bar-Ilan University, Ramat Gan 52900, Israel
Fax: 972 3 535 1824

Coral reefs are found in oligotrophic waters, which are poor in nutrients such as nitrogen, phosphate, and possibly iron. In spite of this, coral reefs exhibit high gross primary productivity rates. They thrive in oligotrophic conditions because of the symbiotic relationship between corals and dinoflagellate algae (zooxanthellae) embedded in the coral tissue. In their mutualistic symbiosis, the zooxanthellae contribute their photosynthetic capability as the basis for the metabolic energy of the whole association, and eventually of a great part of the entire reef ecosystem.

Corals are adapted to nutrient-poor environments and can take up, retain, and recycle both dissolved inorganic and organic nutrients. Animal metabolism and zooplankton digestion by the host are the main source of nutrients for the zooxanthellae. Nutrients as dissolved inorganic compounds, are available also to the algae from the sea.

The population density of algae is controlled by nitrogen and carbon limitation. The coral host keeps the algal growth rate far from its maximum, as compared to growth rates in culture, and thereby ensures a supply of carbon translocated from the zooxanthellae. Additions of ammonium cause an increase in algal populations, and decreased translocation of carbon to the host (Dubinsky *et al.*, 1990; Stambler *et al.*, 1991; Stambler, 1998).

There are three major ways by which increased nutrient supply may adversely affect corals and entire reefs (Dubinsky and Stambler, 1996).

A. Increase in phytoplankton populations in the waters surrounding the reef. Any increase in nutrient availability in oligotrophic waters invariably results in considerable increases in phytoplankton standing stocks, and thus an increase in chlorophyll *a* occurs, resulting in a decrease in the light available to the underlying corals.

B. The increase in available essential nutrient annuls increases seaweed growth. The onset of eutrophication removes the competitive advantage normally held by zooxanthellate coelenterates and opens the substratum to invasion by the much faster growing seaweed, which now settle on any vacated substratum patch, dead coral, or even on wounds of living colonies. Overgrown by algae, eventual death of corals results from the combination of shading of the colonies severely curtailing photosynthesis of the zooxanthellae, nighttime depletion of oxygen due to impeded circulation, and evolution of toxic hydrogen sulfide from the decaying algae and anoxic sediment. In the Gulf of Aqaba, upwelling of nutrient have resulted in overgrowth and smothering of the coral reef by the green seaweed *Enteromorpha* sp. and thus the death of the corals.

C. The increase in nutrients may affect the relationship between the zooxanthellae and the coral.

I. The algae show significantly reduced photosynthetic rates due to carbon limitation in the super dense, multilayered algal population. The photosynthetic rates of nutrient enriched colonies of *Stylophora pistillata* increased compared to unenriched controls. However, there was a considerable decrease in photosynthesis per cell as zooxanthellae density increased. The coral growth rate was reduced.

Table 1: Effect ammonium enrichment on the corals *Stylophora pistillata* and *Pocillopora damicornis* (Dubinsky *et al.*, 1990; Stambler *et al.*, 1991).

Treatment	Areal chl a mg chl *a* cm^{-2}	Cellular chl *a* pg chl $cell^{-1}$	Area cell cell cm^{-2}
***S. pistillata* (Red Sea)**			
Control	1.82	3.00	6×10^5
N-enrichment	6.98	4.25	1.65×10^6
***P. damicornis* (Hawaii)**			
Control	1.40	7.714	1.96×10^5
N-enrichment	18.00	6.593	2.61×10^6

II. The increased algal population respires a larger share of the total, photosynthetically acquired carbon. The coral *Stylophora pistillata* from the Red Sea responded to enrichment with ammonium or ammonium + phosphate, mostly by increasing algal density. This was also found in colonies of *Pocillopora damicornis* from Hawaii (Table 1). An increase in algal density represents a breakdown of the balance between the host and the algae and results in decreased growth rate of the coral.

III. The zooxanthellae retain a much higher fraction of photosynthate, rather than translocating it to the animal. The zooxanthellae, while N-limited, have no use for most of the abundant photosynthate (C) they produce in excess of their own respiratory requirements, and the excess up to 95% is translocated to the host. Once supplied with additional nutrients, either as inorganic compounds such as ammonium and phosphate, or via zooplankton consumption by the host animal, the zooxanthellae retain most of their photosynthate, which they now utilize for synthesis of their own biomass.

The decrease in the contribution of each alga to the energy budget of the colony may have led to the observed decrease in the growth rate of the colony under nutrient enrichment conditions. Under increasing densities of algae resulting from nutrient enrichment, the algae may become CO_2-limited and may compete with the animal for carbon for calcification (Dubinsky *et al.*, 1990).

Coral reefs, on a local and regional scale, are exposed to many anthropogenic stressors, the main one being eutrophication. Nutrient enrichment can introduce an imbalance in the exchange of nutrients between the zooxanthellae and the host coral, reduces light penetration to the reef due to nutrient stimulated phytoplankton growth, and the most harmful of all, may bring about proliferation of seaweed. The latter rapidly outgrow, smother and eventually replace, the slow-growing coral reef, adapted to cope with the low nutrient concentrations typical to tropical seas

References

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