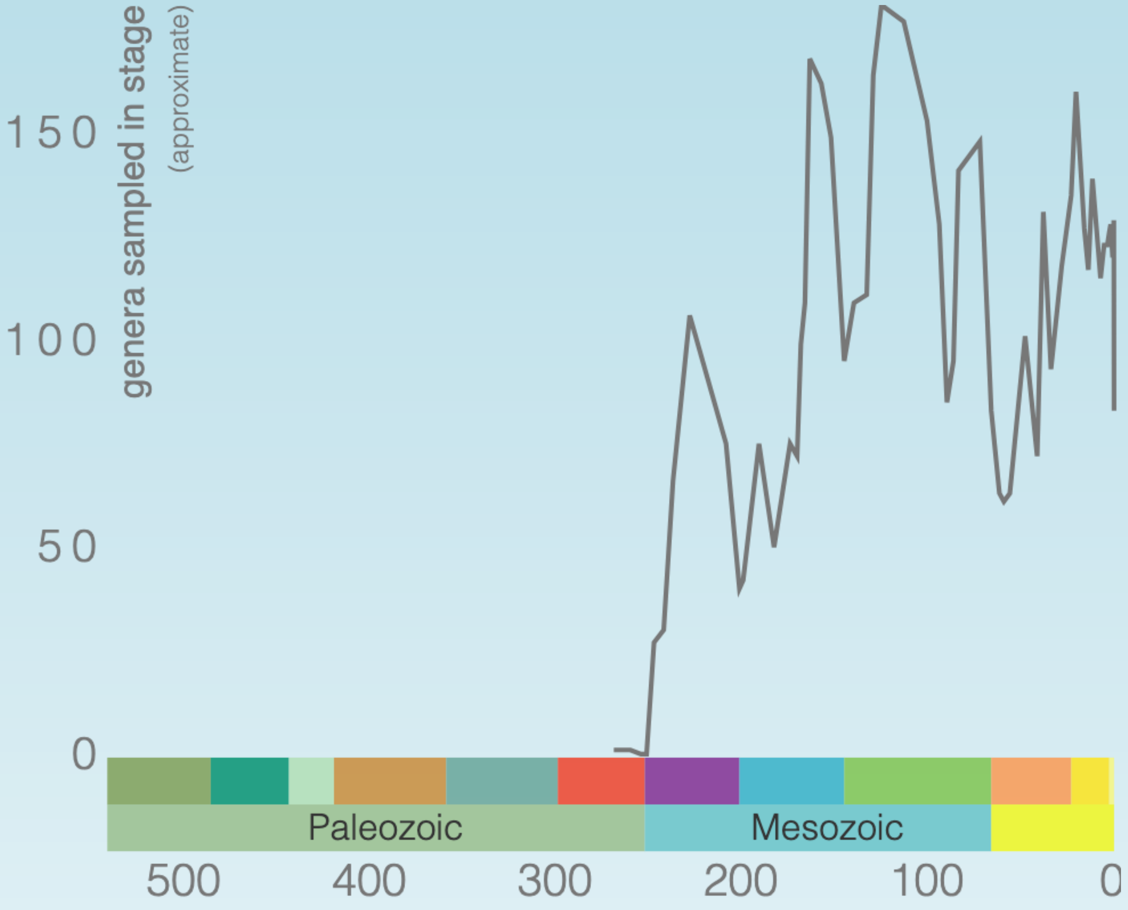
Nutrient Availability and Metabolism Affect the Stability of Coral–Symbiodiniaceae Symbioses

LUKE A. MORRIS , CHRISTIAN R. VOOLSTRA, KATE M. QUIGLEY, DAVID G. BOURNE AND LINE K. BAY

Journal Club 27/5
Xamin Luca

Coral reef systems

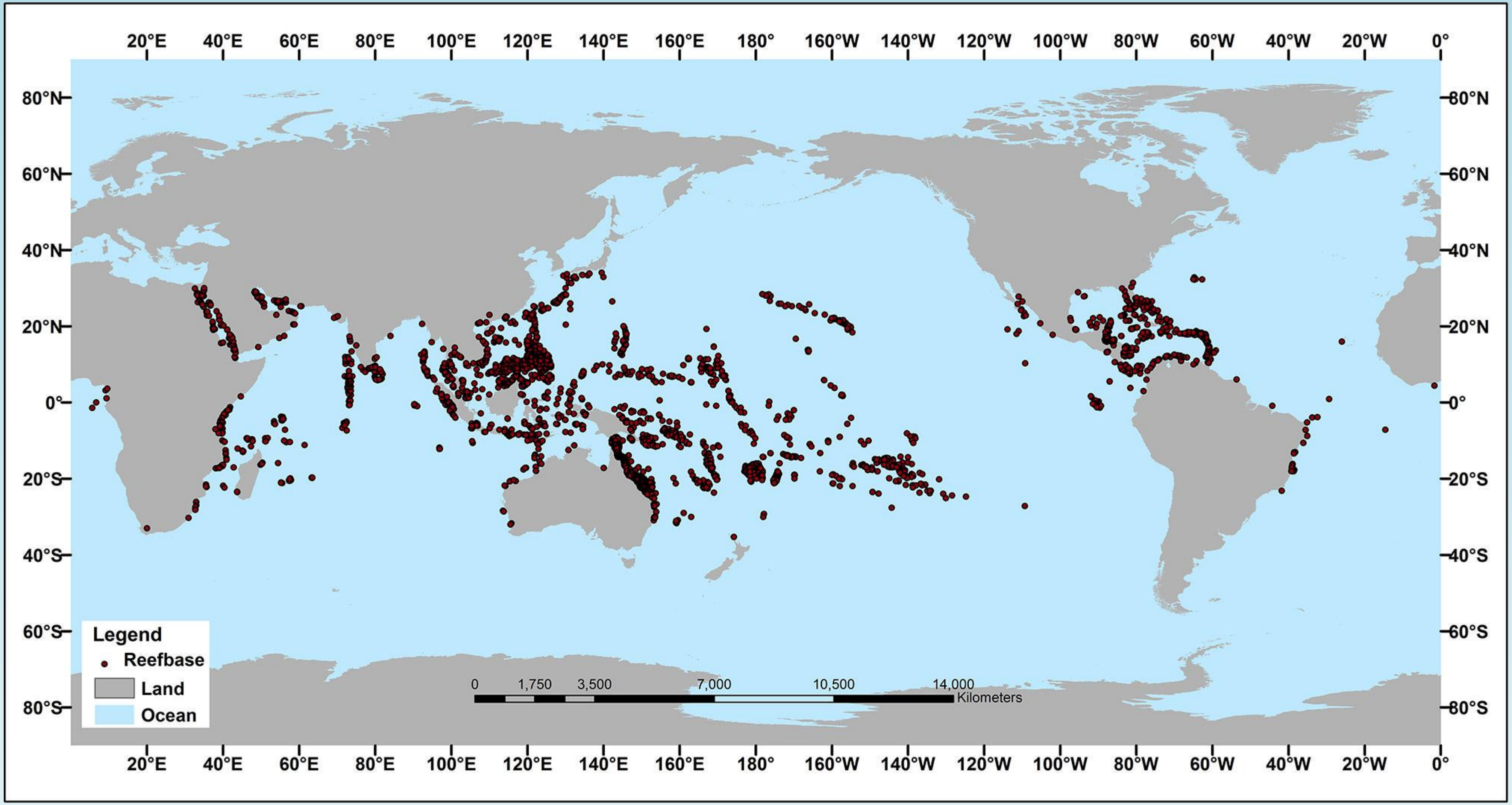
Tropical scleractinian corals

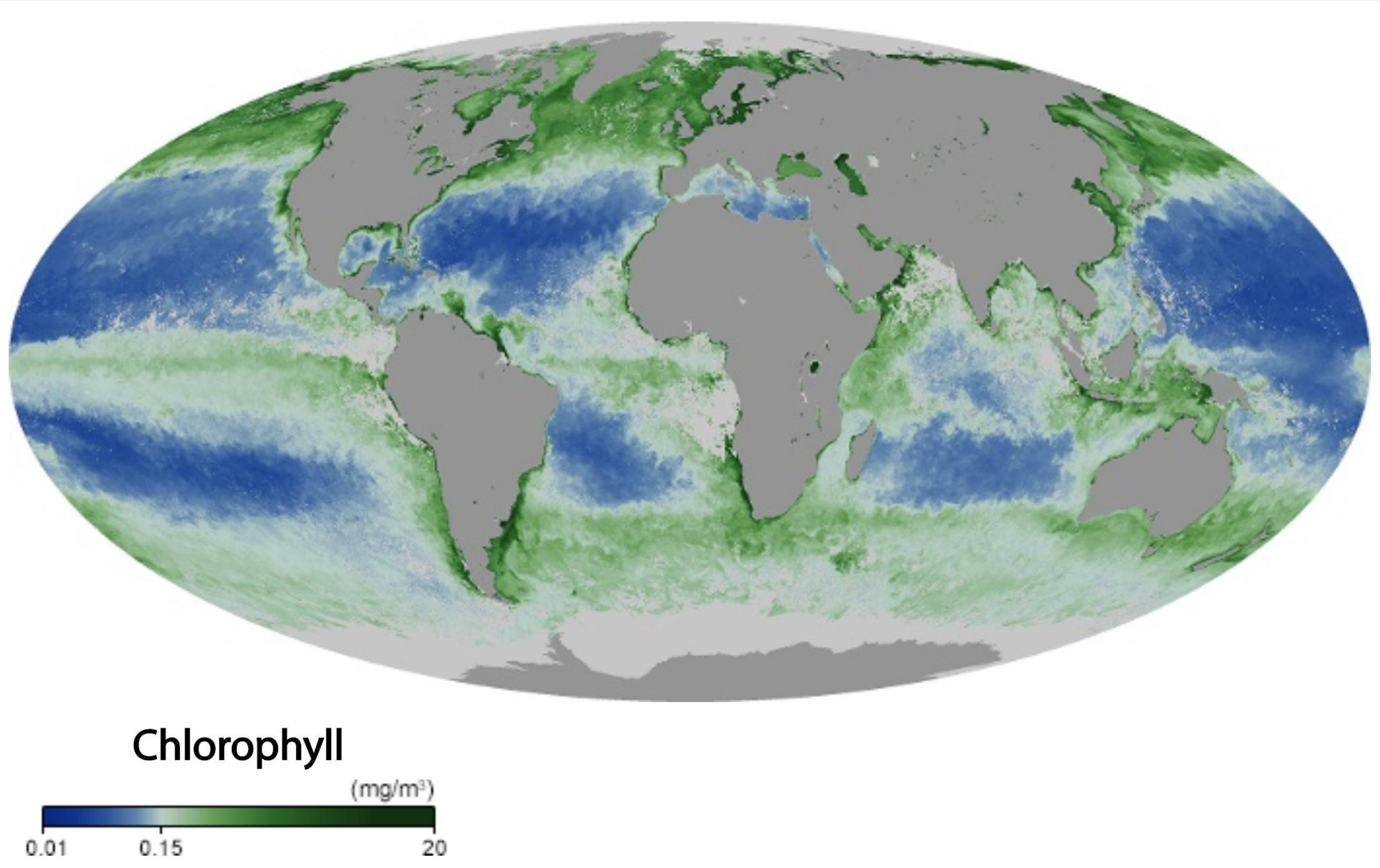


Scleractinia includes the "true corals" or "stony corals," which are represented today by about 1500 extant species.
Scleractinians first appeared in the early Middle Triassic and have been the dominant (though not exclusive) reef-building organisms over the past 240 million years.

The reefs built by modern scleractinian corals are Earth's most biodiverse marine ecosystems and provide numerous valuable services to human societies.

Map showing the modern distribution of scleractinian coral reefs around the world. Image by NOAA (public domain).





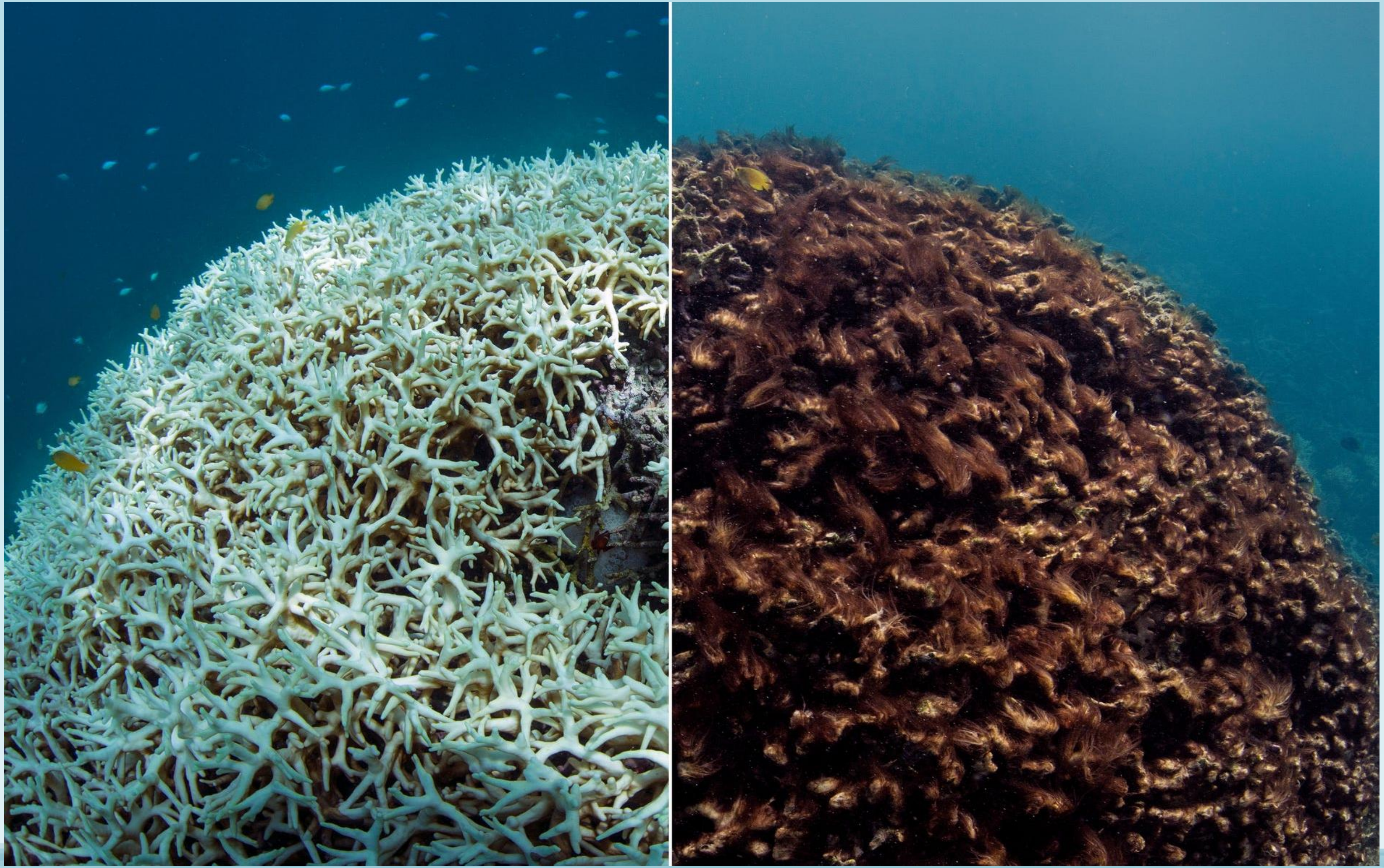
Global marine cholorophyll levels during September 2019. Image source: NASA (public domain).

Reef-building scleractinian corals prefer areas that are **low** in nutrients. One reason for this is that high nutrient levels can greatly accelerate the growth of algae that can very quickly cover and overwhelm corals.

Coral Reefs under Anthropogenic Stress

- **Coral bleaching** is a stress response to **elevated heat and light** levels, where corals lose their algal symbionts.
- Coral reefs are also impacted by local stressors, which **reduce water quality** and have the potential to interact with warming to increase coral bleaching susceptibility.
- Changes in land use adjacent to reefs can result in primary nutrient enrichment
- Climate change also influences marine biogeochemistry at a global scale, where increased storm activity intensifies enrichment events through riverine flux and water column mixing

Coral bleaching

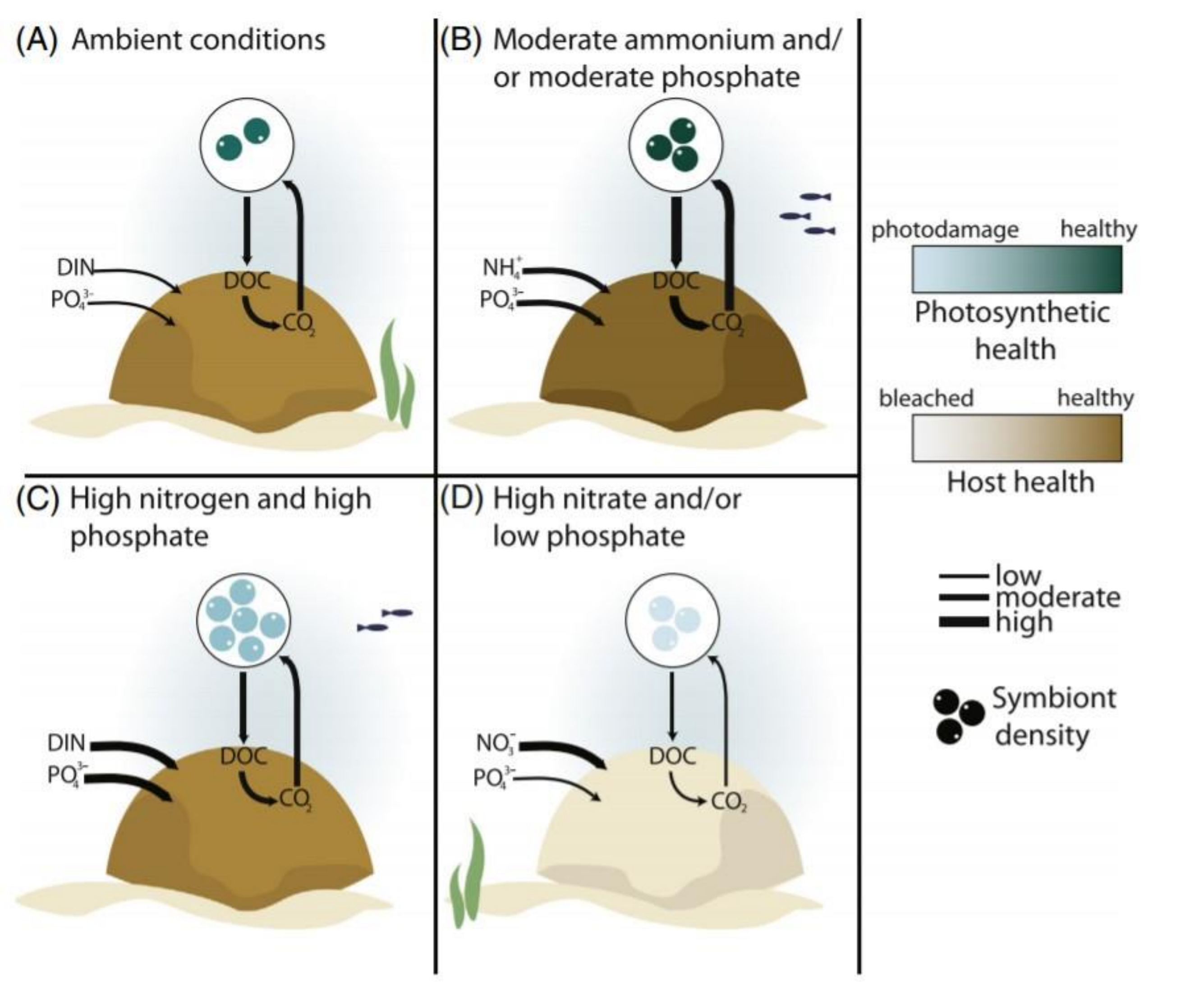


Maintenance and Breakdown of the Coral–Symbiodiniaceae Symbiosis

- Tight nutrient recycling within the symbiosis provides the algal symbionts with respiratory CO_2 and nitrogenous waste products, and in exchange the coral host receives photosynthetically fixed carbon.
- The internal nutrient metabolism and external nutrient environment should be considered, in addition to photo-oxidative stress, when predicting the response of corals to thermal stress.
- Temperature increases could shift the algal symbiont populations from mutualism to parasitism. At elevated temperatures, the contribution of the symbionts to the carbon metabolism of the symbiosis is decreasing, due to reduced photosynthate translocation and/or increased host metabolism.

The Impacts of Nutrient Availability on Coral Health and Thermal Tolerance

- Laboratory studies have clearly linked declines in coral holobiont health to specific nutrient sources and the ratios they occur in
- **Ammonium** (NH_4^+) is derived from metabolic processes of the coral host and other reef organisms and is the preferred inorganic nitrogen source of the algal symbionts.
- **Nitrate** (NO_3^-) produced from anthropogenic sources is less favoured, perhaps because its utilization diverts electrons away from photosynthesis.
- **Phosphate** (PO_4^{3-}) is supplied through a mixture of natural and anthropogenic sources, mostly favourable.



<u>Particulate food and moderate levels of ammonium and phosphate tend to benefit coral holobiont health and increase thermal tolerance, whereas nitrate negatively impacts the coral holobiont and reduces thermal tolerance unless accompanied by phosphorus</u>

Symbiodiniaceae Growth Rates and Coral Thermal Tolerance

- Ammonium stimulates photosynthesis and allows the algal symbionts to maintain photoprotective pigmentation and carbon translocation to the host under thermal stress.
- Nutrient enrichment of ammonium, nitrate, and phosphate induced and/or enhanced a range of coral diseases related to microbial disbiosis
- Increased nitrate assimilation, due to external enrichment and/or thermal stress, encourages symbiont parasitism, where the algal symbionts pass the energetic costs of nitrate utilization onto the coral host.

Phosphorus Stabilizes the Coral–Symbiodiniaceae Symbiosis

- Without an adequate supply of phosphate, coral holobionts that are enriched with nitrate can suffer reduced health.
- A lack of phosphorus limits the synthesis and maintenance of crucial molecules for cellular growth, including phospholipids and DNA, which could therefore inhibit cell division in both coral hosts and the algal symbionts
- High N:P ratios inhibit DNA repair in corals during thermal stress. Under the high N:P condition, severe competition for phosphorus can occur where the algal symbionts become parasitic, retain nutrients, and potentially sequester ATP from their hosts. In response, the coral host may digest its symbiont population to recuperate lost nutrients

Metabolic Compatibility and Coral recovery

- Coral holobionts containing high-performance ‘generalist’ algal symbionts often outperform more ‘specialized’ stress-tolerant symbionts in terms of key traits such as photosynthesis and host growth
- A moderate increased nitrogen availability per symbiont following bleaching can promote recovery of corals with stress-tolerant types

Phenotypic Plasticity in Nutrient Metabolism

- Acclimation to elevated and variable temperatures prior to acute thermal stress reduces the severity of coral bleaching.
- Acclimation to high variable temperature may help coral hosts to resist bleaching by invoking metabolic processes which act to maintain their symbionts in a mutualistic state. Due to this, <u>inshore reefs are often resistant to bleaching, despite their exposure to elevated and variable nutrient and temperature conditions relative to offshore reefs.</u>
- Evolved thermal tolerance of corals in oligotrophic regions, such as the Red Sea, may be highly sensitive to even minor increases in nutrient availability.

Concluding remarks

- The coral–Symbiodiniaceae relationship is primarily a trophic mutualism and therefore the <u>stability of this symbiosis is dependent on the balance and exchange of nutrients in response to environmental conditions</u>
- Bleaching is attributed to changes to autotrophic carbon metabolism, which depend on nutrient form and ratio.

Living scleractinian corals on the Great Barrier Reef, Queensland, Australia.