Synoptic Scale Monitoring Supports the Coral Reef Eutrophication Threshold Model

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Impacts of Eutrophication [1,2,3,4]

- Eutrophication (i.e. increased fertility/nutrients N&P) of GBR lagoon reduces water transparency, inhibits the reestablishment of damaged corals by reducing recruitment and promoting the growth of algae, soft corals and other filter feeders (e.g. sponges, bivalves)
- Eutrophication contributes to initial coral damage/loss by:
  - promoting the growth and spread of corallavoires (e.g. crown of thorns starfish and probably *Drupella* spp.)
  - promoting the growth of heterotrophs (e.g. bacteria, ciliates) that cause/promote coral diseases
  - reducing calcification rates and causing a weakening of the coral structure
- Eutrophication[2,7,12] changes planktonic community structure and higher trophic levels (e.g. promotion of growth of jellyfish and crown of thorns starfish)
- The reef destruction by eutrophication leads to a reduction in fish diversity and population size

Synoptic Scale Monitoring [5]

- Synoptic scale monitoring of chlorophyll *a* (Chl *a*) using field measurements and satellite imagery provides information on the causes and the extent of impacts of eutrophication.
- Much of the increased fertility can be attributed directly to increased loads of nutrients (e.g. nitrogen, N and phosphorus, P) exported via discharges from coastal developments (urban, industrial, agricultural)[1,2,12].
- In addition the activity of nitrogen fixing bacteria and cyanobacteria (e.g *Trichodesmium* spp.), which are contributing to the problem[2,3] by fixing substantial loads of "new" nitrogen, can also be monitored to some extent using satellite imagery.

Conclusions

- Many of the impacted regions are characterised by annual mean Chl *a* concentrations exceeding the upper bound of the suggested eutrophication threshold concentrations[1,2,3] (ETC-Chl a ~0.2-0.5 µg l^{-1}) or the recently defined[13] Trigger Levels (TL-Chl a ~0.4-0.45 µg l^{-1}) ; the wide extent of values >0.3 µg l^{-1} suggests a chronic level of eutrophication exists in most of the GBR lagoon.
- In the impacted regions many reefs are showing signs of low resilience to disturbance and hence are degraded (Plates 1-4)[1,2,3], whereas those in regions where annual mean Chl *a* values are in the lower range of the proposed ETC-Chl *a* (i.e. 0.2-0.3 µg l^{-1}) show little evidence of degradation over the past century (Plate 5).
- Phosphorus discharges are particularly important because elevated P concentrations not only promote algal growth but also promote higher N_2 fixation rates and reduced calcification rates[3,6].
- ***We conclude that eutrophication is a principal cause of the ~40%-60% loss of hard coral cover that has occurred in most regions of the GBR over the past century.***

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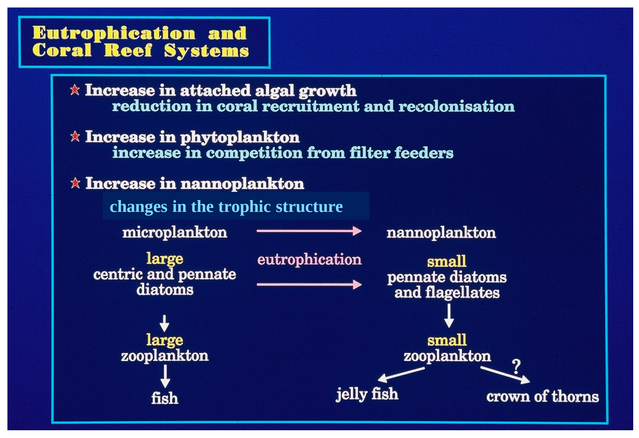
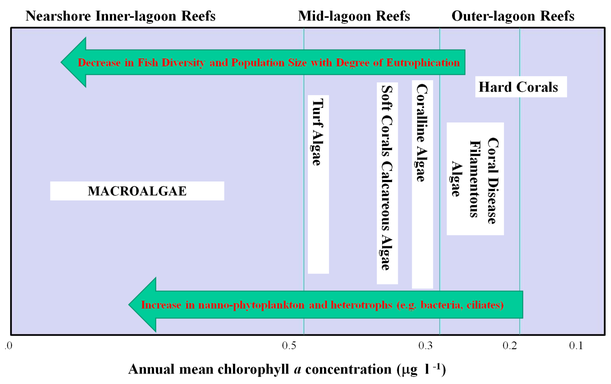


Plate 1. Stone Is. Dead overgrown reef 1993 Vs flourishing high diversity coral reef 1897[9]



"Bottom-up" scenario—Changes to bottom-type, plankton and fish populations with Chl *a* concentration (i.e. degree of eutrophication) across GBR lagoon

Impacts of Eutrophication

Replacement of hard corals with algae, soft corals and other filter feeders

Promotion of growth and spread of crown of thorns starfish, Drupella spp. and Jellyfish

Promotion of coral diseases

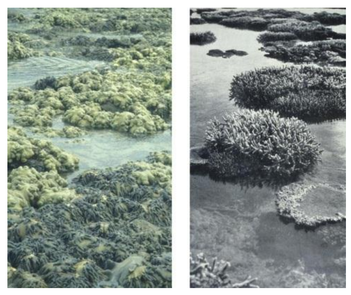
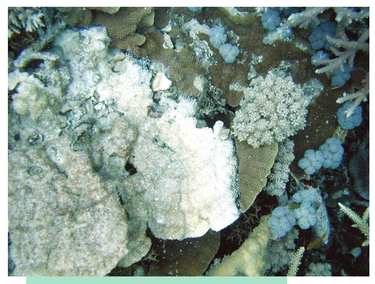


Plate 2. Low Is. Dead overgrown reef 1993 Vs coral dominated reef 1929[15]

Crown of Thorns starfish[8]

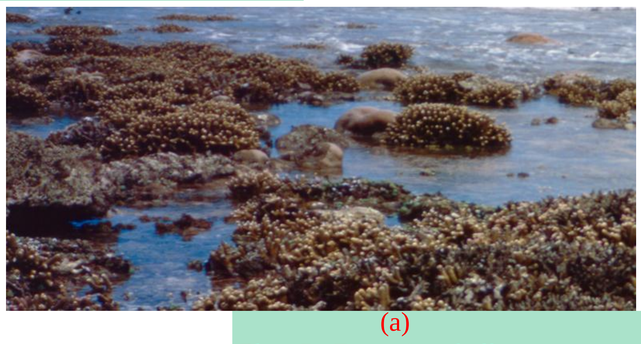


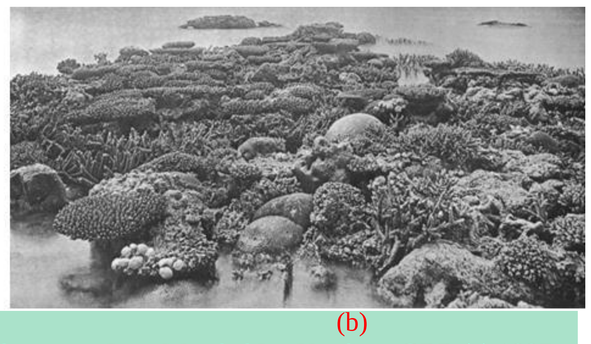
Black Band Disease [8]

Plate 3. Macroalgal overgrowth of coral Pt Douglas

Box Jellyfish [11]

Plate 4. Coral disease and algal overgrowth





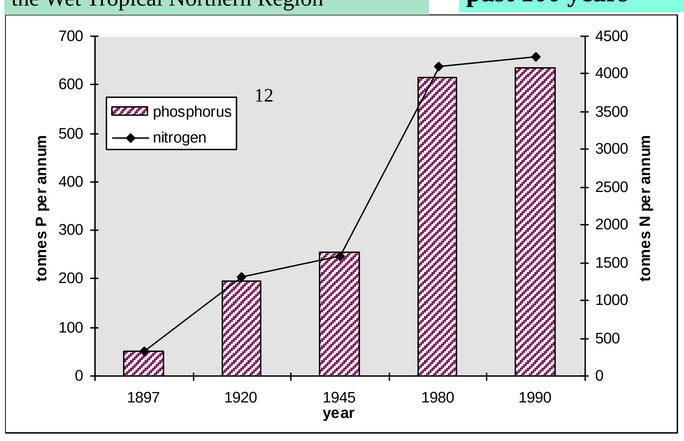
(a) (b)

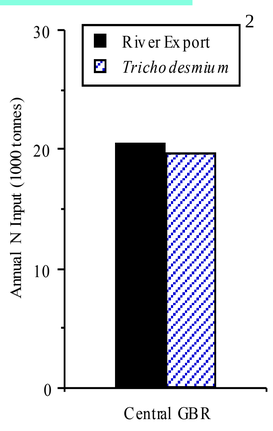
Plate 5. Extensive shallow-water coral cover at Low Wooded Is., Northern GBR (a) 1997 and (b) 1897[9]. Corals here are bathed in low Chl a waters (~0.25 µg l^{-1}) and exhibit a high degree of resilience

Sources of Nutrients

Loads of nutrients in run-off from developed catchments, sewage discharges and N_2 fixation (e.g. *Trichodesmium*) have all increased over past 100 years

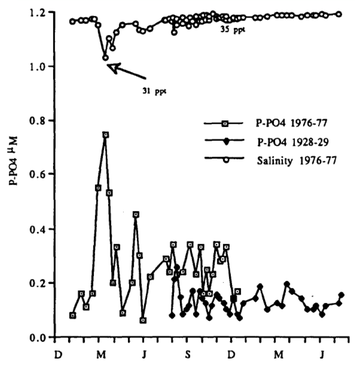
Export of nutrients from cultivated land in the Wet Tropical Northern Region



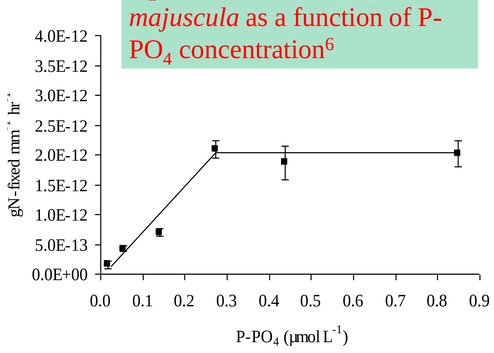


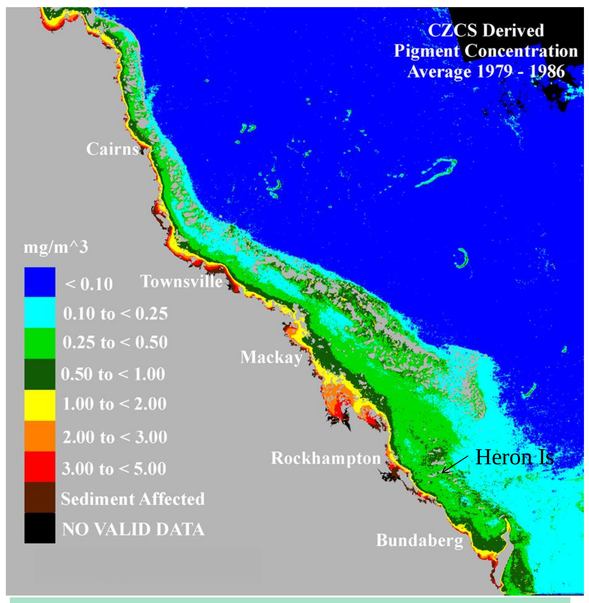
Importance of Phosphorus Discharges

Comparison of variation of $P\text{-}PO_4$ in mid-lagoon off Townsville 1976-77 with that 3ME off Low Isles 1928-29[3]

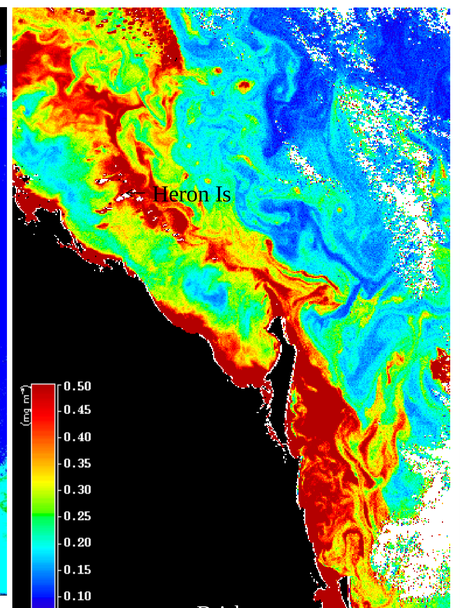


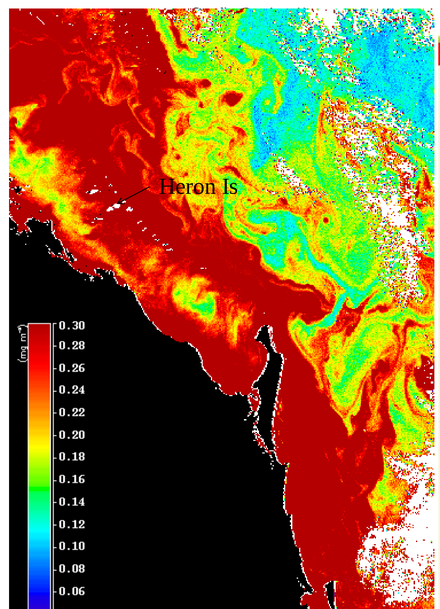
N_2 fixation rate of *Lyngbya majuscula* as a function of $P\text{-}PO_4$ concentration[6]



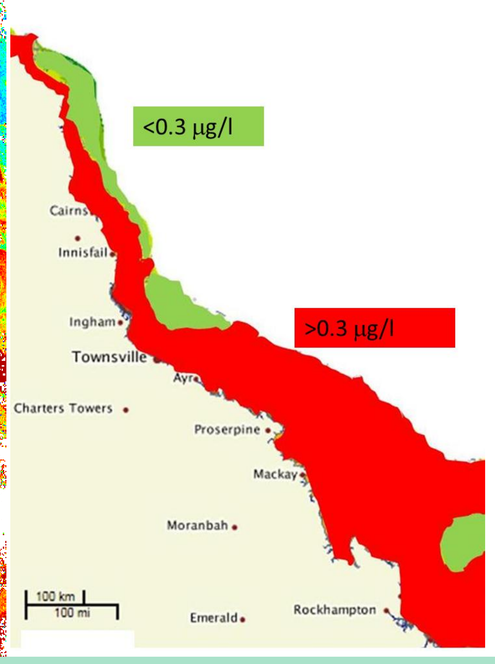


Average of all CZCS[14] satellite images 1979-86 showing relatively high phytoplankton concentrations occur over most of GBR lagoon.

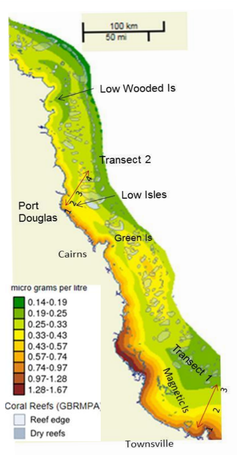




SeaWIFS[14] satellite data showing extent of chlorophyll *a* variations with respect to upper and lower ETC-Chl-*a* ranges



Extent of regions with Chl a >0.3 µg l^{-1} and hence subject to chronic effects of eutrophication (based on AIMS data[10]).



Long-term averages of Chl *a* in field-collected samples[10] in Northern and Central GBR lagoon