Tracking nitrogen from the paddock to the reef—
a case study from the Great Barrier Reef

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The Great Barrier Reef Region

- Largest coral reef system in the world
- >3000 reefs; 2,200 km long;
- 350,000 km²
- Adjacent catchment dominated by extensive grazing systems.
- Small areas of cropping close to the coast, in higher rainfall areas. (intensive sugarcane, horticulture and bananas, extensive grains)
GBR under pressure

Fishing

Coastal Development

Increased ship traffic

Run off

Increasing temperature

Ocean acidification

Crown-of-thorns starfish

Cyclones & Storms
Coral bleaching
2016 Coral bleaching event

IMOS 14-day Mosaic: SST Anomaly
12 April 2016 GBR region

Far North (offshore)
26% dead
Range*: 11-35% dead

North
67% dead
Range*: 47-83% dead

Central
6% dead
Range*: 2-17% dead

South
1% dead

*upper and lower quartiles
The GBR catchment to reef connection

Exposure to runoff from broad-scale land use is a key pressure for the ecosystems of the GBR

Loads have increased: Sediment (3-5 x), Nitrogen (2-6 x), Phosphorus (2-9 x) + herbicides
3 main N sources

- Upwelling
- River inflows
- N-fixation

Salinity: 20 PSU to 30 PSU
The marine N-cycle

Source: Virginia Coast Reserve Long-Term Ecological Research project
Coral bleaching & nutrients

Breakdown of symbiosis:

• Too much heat
• Too much light
• Too much N
  – Increased zooxanthellae density
  – N/P imbalance
  – Too much organic carbon, triggering higher N-fixation on corals

Wooldridge et al. in press. Marine Pollution Bulletin
Outbreaks of the Crown-of-Thorns seastar (CoTS) & nutrients
Enhanced food availability for CoTS larvae

“Nutrient Hypothesis” - A numbers game:
Higher survival of larvae due to increased food availability

Likely in combination with:
• Hydrodynamic conditions that retain larvae
• Reduced predators
• Increasing temperature

Reefs condition & nutrients

- High nutrients, High sediments
- Low nutrients, Low sediments
Inshore seaweeds benefit from higher nutrient availability

Net photosynthesis (µmol O₂ h⁻¹ g DW⁻¹)

- **Sargassum baccularia**
- **Padina tenuis**
- **Turbinaria ornata**
- **Chlorodesmis fastigiata**

- **Control**
- **10 µM N**
- **1 µM P**
- **10 µM N + 1 µM P**

Recovery of reefs after disturbance

*Water quality is an important factor*

- moderate algal growth, mainly turfs
- coral recruitment & growth
  \[\rightarrow\] Recovery

- enhanced algal growth
- coral recruitment reduced
- coral/algal competition
  \[\rightarrow\] slow or no recovery, reduced diversity
Regional variability in loads, pre- and post-development

- Large regional variation in predevelopment loads.
- Anthropogenic activity has increased loads substantially.
- Largest relative increases in regions where predevelopment loads were quite low.

Sources of N in loads entering the GBR.

- There are 3 dominant sources of N.
- Grazing and sugarcane cropping are the dominant agricultural land uses in terms of N loads.
- The 3rd ranked source (stream bank erosion) is linked to development and loss of riparian vegetation.
- The constituent N forms from each source are quite different, and are the product of the N inputs and the loss processes in each system.
Are these N constituents what left the field (i.e. do we know what we are trying to manage?).

- Loads modelling calibrated against end of catchment loads monitoring.
- A series of N transformations and losses can occur between paddock and river mouth.
- These can result in DIN enrichment, as well as lower N loads.
- Residence times will have a major impact on these processes.
The form and pathway of N loss will determine water quality impact and the effectiveness of management strategies

- Denitrification losses will have no **direct** water quality impact
- The proportions of PN and DIN will influence the zone of impact (inshore v outer reef).
- Minimizing runoff will reduce PN loads but not necessarily DIN.

An example from *sugarcane*, comparing measured runoff losses at block scale and modelled loads at end-of-catchment.
Monitoring suggests leaching and lateral movement are a major DIN source in sugar catchments.

~10-15% of Fitzroy DIN load in base flow (grazing)

50-60% of Tully DIN load in base flow (cane, bananas)

These transformation processes don’t stop at the river mouth

Reducing DIN loads may seem a logical first step to reducing the biologically active N loads. However, the risks posed by labile organic N cannot be ignored.
Minimizing N losses from grazing systems – controlling erosion...

Hillslope/sheet erosion

- Managed by retaining groundcover
- A focus of grazing BMP programs
- Only delivers ~ 20% of total sediment

Gully erosion

- Intensive remediation/stabilization
- A focus of on ground activity
- Delivers ~ 80% of total sediment

Extensive areas vs. Small, defined areas

Where to focus?

The map and chart illustrate the proportion of grazing total N loads for various regions. The chart shows:

- **Cape York Region**: Approximately 0.5% of total N loads.
- **Wet Tropics Region**: Approximately 10% of total N loads.
- **Burdekin Region**: Approximately 20% of total N loads.
- **Mackay Whitsunday Region**: Approximately 1% of total N loads.
- **Fitzroy Region**: Approximately 25% of total N loads.
- **Burnett Mary Region**: Approximately 10% of total N loads.

The map highlights the regions with the highest proportion of N loads, indicating where to focus efforts.
N enrichment ratios will help focus activity on soil types with greatest N delivery risk

• Bioavailable nutrient levels in surface soil varied widely between soil types

• Enrichment ratios (sediment/soil) also varied widely
Labile N in the fine sediment fraction represents the greatest water quality risk to the outer reef

For fine (<10um) sediment:

- Sub-surface sediment contributes most of PN load (90% in this eg. – Wilkinson et al. 2015)
- Surface sediment contributes significantly more mineralisable N than its load proportion
- Management intervention must consider both hillslope and streambank/gully erosion processes

Wilkinson et al. (2015); Burton et al. (2015); Bartley et al. (in press).
Minimizing N losses from sugarcane - managing surplus N.....

An example for an 80 t/ha cane crop in the wet tropics
Urea and the current N surplus

With no environmental losses, growers could reduce conventional N rates by ~40 kg N/ha and still meet crop demand in this example.
The reality - losses to the environment can be high and crop N supply may become suboptimal.

Environmental losses remove the option to safely reduce N rates. In high loss situations, increasing N rates can be a reasonable risk management strategy!
Improved fertilizer technology will break this nexus

- Environmental losses halved
- Adequate N for crop demand maintained, even in high loss environments
- Fertilizer N rates can safely be rationalized to match crop productivity zones
Conclusions

• Elevated bioavailable N in the GBR lagoon is affecting ecosystem health, and process level understanding of the ecological mechanisms is developing rapidly
• The major sources of anthropogenic N are the grazing and sugar industries
• Changed management practices are reducing loads, but not far enough or fast enough.
• Management interventions to limit N loads may not be the same as for sediments and pesticides
• Enhanced efficiency fertilizers offer solutions in sugar
• Climate variability and the feasibility of increased management intensity in extensive grazing systems remain challenging
• Climate change remains the biggest threat to the longer term health of the Great Barrier Reef
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