Wendy Pyper

Modelling and statistics played key roles in developing and implementing the marine and freshwater Ecosystem Health Monitoring Programs. Peter Toscas and Bronwyn Harch of CSIRO will help to combine the two programs later this year.

Keeping trouble at bay

For the past 30 years, water quality measurements in Brisbane's Moreton Bay have tracked an increase in nutrients and sediments. When the Moreton Bay Study was initiated in 1994, sewage effluent, industrial discharges, and stormwater and catchment runoff were the main suspects.

To help understand how these factors influenced the overall health of the bay, scientists developed a conceptual model depicting their understanding of ecosystem processes. As no integrated study of Moreton Bay had been conducted, the model raised many questions about these processes and their interactions.

To fill these knowledge gaps, a series of 17 scientific tasks was initiated. They investigated issues such as the fate of sewage effluent, the reasons for turbidity in the Brisbane River, and the sediment and nutrient loads entering waterways.

Results of the research are embodied in the Water Quality Management Strategy, which addresses best practice standards and management actions for sewage treatment plants and industrial wastewater.

'The scientific tasks gave us a better understanding of the Moreton Bay system and, based on this new understanding, we received management commitments from stakeholders to improve the health of the system,' scientific coordinator, Dr Eva Abal, says.

'These commitments included upgrading sewage treatment plants to reduce nitrogen and phosphorus loads entering the bay and estuaries, and implementing wastewater improvement and recycling programs.'

As well as improving the understanding of ecosystem processes, the scientific tasks helped to identify chemical and biological indicators suitable for an Ecosystem Health Monitoring Program. This program allows stakeholders to assess the effectiveness of their management actions by measuring and reporting on indicators of bay and estuary health.

Tracing sewage sources

Marine plants such as seagrass, phytoplankton (microscopic algae), macroalgae (seaweed) and mangroves are useful indicators of bay and estuary health, as they allow scientists to trace sources of sewage nitrogen.

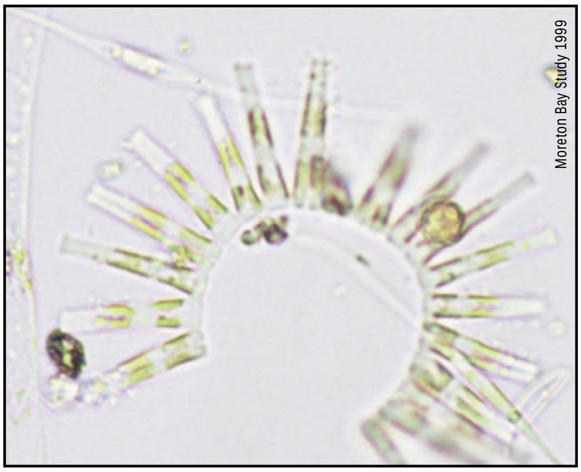
When sewage is discharged into urban waterways, it is enriched in the heavier nitrogen isotope, 15N. This is because biological processes, such as human digestion, tend to utilise the lighter 14N isotope, leaving more 15N in the solid waste (faecal matter) processed by sewage treatment plants. The relative proportion of

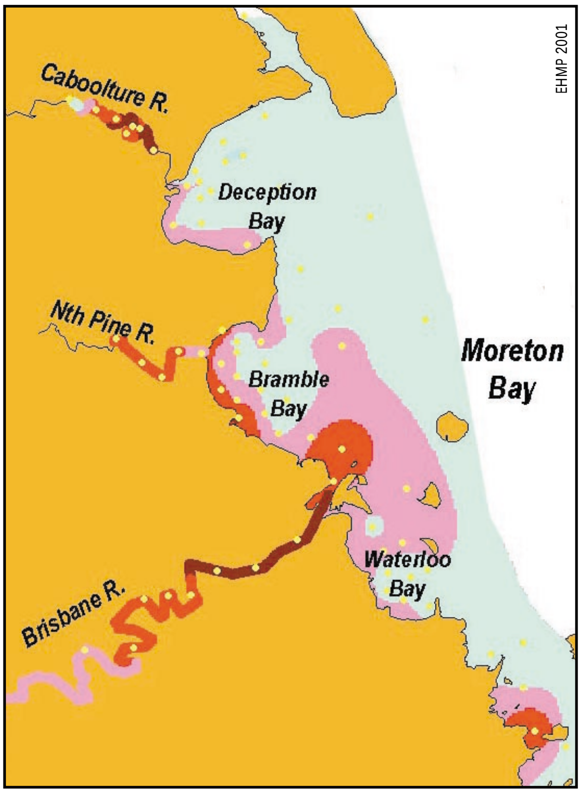
Results of the Ecosystem Health Monitoring Program are integrated into a yearly report card, which provides a grade for water quality and ecological health. The reports reflect the success of management actions and help scientists to reassess their understanding of the ecosystem.

these two isotopes in sewage discharge, compared with a world standard, is referred to as 'delta' 15N (∂15N). As plants incorporate nitrogen from the surrounding water column, the ∂15N signature in their tissues indicates the availability of processed (sewage) nitrogen.

As part of a scientific task entitled Design and Implementation of Baseline Monitoring, scientists from the University of Queensland, CSIRO, Southern Cross University and Queensland EPA looked at the proportion of 15N and 14N in macroalgae, seagrass and mangrove samples near sewage treatment plants. The results were used to map the source, extent and fate of sewage-derived nitrogen.

Recently, fish and oysters were found to reveal similar patterns of ∂15N, as they eat the marine plants that accumulate sewage nitrogen in their tissues, or animals that have eaten these plants. These indicators are being tested at northerly points of the monitoring zone.





Above right: Phytoplankton – diatoms, dinoflagellates, cyanobacteria and other flagellates – are measured to indicate light and nutrient limitation.

Right: Using a statistical model, CSIRO scientists can convert delta 15 nitrogen values, measured at 200 sites around the Bay, estuaries and rivers, into spatial maps showing predicted concentrations of sewage nitrogen throughout the study area. Sewage plumes around the mouths of the Pine and Brisbane Rivers are generally more extensive after rain, as this map produced after 2001

Plumes of sewage

For the Ecosystem Health Monitoring Program, ∂15N is measured twice a year at about 200 sites. The results are incorporated into sewage plume maps, produced by CSIRO scientists Tom Taranto and Peter Toscas. The maps are reproduced in quarterly newsletters and often reveal distinct plumes around the mouths of the Pine and Brisbane Rivers. However the extent of these plumes varies with the seasons and rainfall.

'The maps are used to get an idea of how pollution changes with time,' Toscas says. 'They reveal seasonal and temporal variations and help identify peak activity at different times of the year. So if councils know there's a pollution problem between say January and February, when there's lots of rain, they can put a management plan in action to minimise stormwater overflows and sewage input into the system at that time.'

Seagrass and phytoplankton

Marine plants can also be used to assess turbidity (light penetration) and nutrient limitation in the bay and estuaries.

For example, the relationship between the depth at which seagrass grows and turbidity provides a robust management and monitoring tool. University of Queensland marine botanist Ben Longstaff says seagrass needs about 30% surface light to survive. Logically then, as turbidity increases, the seagrass depth range decreases.

On the western side of Moreton Bay where pollution and turbidity is high, seagrass survives at depths of up to one metre. But in some parts of the bay, such as Bramble Bay and Deception Bay, seagrass beds have disappeared or are declining. On the eastern side of the bay, where the water is cleaner, lush seagrass beds grow at depths of up to three metres.

'By measuring seagrass depth twice a year, a long-term picture of changes in light availability across the bay can be obtained,' Longstaff says. 'These light changes are linked to turbidity in the water column, which is caused by resuspension of sediment through wave or tidal action, and sediment entering the bay.'

Phytoplankton (microscopic algae), which includes diatoms, dinoflagellates, cyanobacteria and other flagellates, can also be used to measure light and nutrient limitation.

Phytoplankton can use various forms of nitrogen and phosphorus for growth. These nutrients are abundant in the rivers and estuaries, leading to phytoplankton blooms and a decline in ecosystem health. On the eastern side of the bay, however, nutrients are generally limited and blooms are rare.

To assess the potential for phytoplankton blooms, water samples from 40 sites around the bay and estuaries are treated with nitrate, phosphate, ammonium, urea, no nutrients, or all four nutrients. The growth of phytoplankton in response to each treatment is determined daily by measuring the fluorescence of photosynthetic pigments.

A phytoplankton bloom in one of the sample bags offers a warning to avoid excess levels of that nutrient in that area. If a bloom occurs in the non-treated sample, turbidity is the factor controlling growth. Sediments in the sample would have settled to the bottom, enabling light to penetrate and the phytoplankton to use the available nutrients.

Mapping water quality

Other indicators used in the monitoring program include traditional water quality measures of turbidity, nitrogen, phosphorus, salinity, dissolved oxygen, temperature and chlorophyll *a*. Chlorophyll *a* – a photosynthetic pigment of plants – provides a measure of phytoplankton biomass, which in turn reflects nutrient and light availability.

These indicators are monitored monthly by the EPA which collects water samples from some 200 sites for analysis by Queensland Health laboratories. The results are mapped by CSIRO scientists Taranto and Toscas who use statistical models to estimate water quality indicator values between the sampled sites.

'Our maps show the predicted level of the nutrient or physical variable in the bay or river, because we can't sample every inch of the area. But we also provide a map that gives an idea of the uncertainty associated with those predictive values,' Toscas says.

'Councils can reduce the level of uncertainty by sampling more sites, but that gets expensive. So they need to understand the uncertainty first, and then decide if it warrants more sample sites.'

Results from the EHMP are integrated into a yearly report card, which provides a mark, from A to F, for water quality and ecological health. General comments are also provided. These reports provide stakeholders and their peers with a way to assess the effectiveness of their management actions and determine priorities for the future. They also help scientists to reassess their understanding of the ecosystem.

Wendy Pyper

Marine plants such as seagrass, phytoplankton, macroalgae and mangroves are useful indicators of bay and estuary health, as they can reveal the sources of sewage nitrogen.

Other organisations involved in the Moreton Bay Study were: Griffith University, Queensland University of Technology, Australian Geological Survey Organisation, Marine and Freshwater Research Institute, WBM/SKM Joint Venture and Parametrix Australia.

More about the monitoring program

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Model management for seagrasses

A COMPUTER-BASED model that predicts the effects of management actions on seagrass growth is the first in a suite of 'ecosystem component' models planned for Moreton Bay.

The model, developed by Francis Pantus of CSIRO Marine Research, is used to generate weekly maps of turbidity, nutrients, salinity and temperature across the bay. These are measured monthly as part of the Moreton Bay and Estuary Ecosystem Health Monitoring Program.

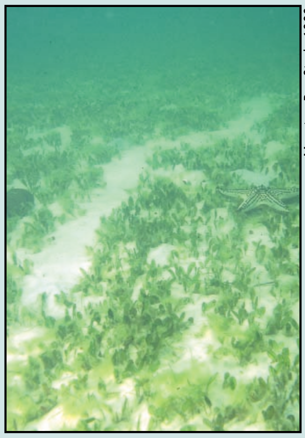
Light availability is one of the most important influences on seagrass growth and distribution.

'The amount of light that reaches the sea floor, where it is available for seagrass growth, depends on water depth (bathymetry), light penetration and the yearly daylight regime,' Pantus says. These three factors are combined in a 'light attenuation model', which determines the amount of light received weekly by seagrass beds in different parts of the bay.

Results from the light attenuation model feed into the main 'seagrass biomass' model, together with changing nutrient, salinity and temperature levels, and information on epiphytes (mainly microalgae), macroalgae (seaweed) and different seagrass species. 'Epiphytes and other critters that settle on seagrass compete for light,' Pantus says.

The model also accounts for the response of seagrasses to the prevailing environmental conditions.

Pantus says the model will help to evaluate the probable outcomes of different management scenarios. For example, it could predict the effect of improved turbidity on seagrass distribution.



Moreton Bay Study 1999

A dugong grazing trail in a seagrass bed. A model that evaluates the outcomes of management actions on seagrass beds is part of a dedicated campaign to address the loss of seagrasses in Moreton Bay.