Marine Ecosystems

Eye in the sky: tracking harmful algal blooms with satellite remote sensing

***Hoe Chang, Ken Richardson, Michael Uddstrom**, and **Matt Pinkerton** combined ground observations and satellite remote sensing to track algal blooms on the northeast coast of New Zealand in 2002.*

Microalgae are tiny, free-floating marine plants. They are the ocean's primary producers and form the basis of marine food webs. When conditions are right (for example, optimal light, favourable water temperatures, plentiful nutrients), these microscopic algae can grow rapidly and build up to very high concentrations in a matter of days. This population explosion is commonly referred to as an algal bloom.

Most blooms are harmless and contribute to ocean primary productivity, but a few algal species can be harmful. The build-up of these species, known as a harmful algal bloom (HAB), can damage marine ecosystems and communities. Toxins produced by these harmful species sometimes kill a wide range of marine life, and can lead to illness and death in humans. Shellfish contaminated by harmful species cannot be harvested, and this has negative consequences for the aquaculture industry.

Photo: Miriam Godfrey

The dramatic appearance of a 'red tide' algal bloom at Leigh, near Cape Rodney.

Since the 1993 major toxic shellfish events in New Zealand, shellfish industries and the government regulatory authorities conduct regular monitoring. Water samples are tested for HAB species and shellfish collected from discrete sites are screened for toxicity.

The view from space

Microalgae absorb sunlight for photosynthesis through photo-pigments such as chlorophyll. As algal biomass increases, the colour of the deep ocean under clear skies changes from blue to green because the chlorophyll pigments absorb blue light. Variations in the particular combination of photo-pigments between species can cause other subtle changes in water colour, giving it a hint of red, brown, or cream. The build-up of photo-pigments in the ocean can be detected using satellite-borne ocean-colour sensors such as SeaWiFS (the Sea-viewing Wide Field-of-view Sensor). Ocean-colour satellites measure the intensity of several different colours of light emerging from the sea, giving valuable information about the development and trajectory of blooms over a very large area in real time.

Sea surface temperature (SST) data from space satellites add another dimension to our understanding of the relationships between physical environment and onset of algal bloom events. SSTs are derived from infrared (or thermal) emissions from the ocean surface; the data let us form a high-resolution, synoptic (snapshot) view of upper-ocean structure in real time. At NIWA we have an archive of these data that extends from 1993 to the present.

The 2002 HAB events

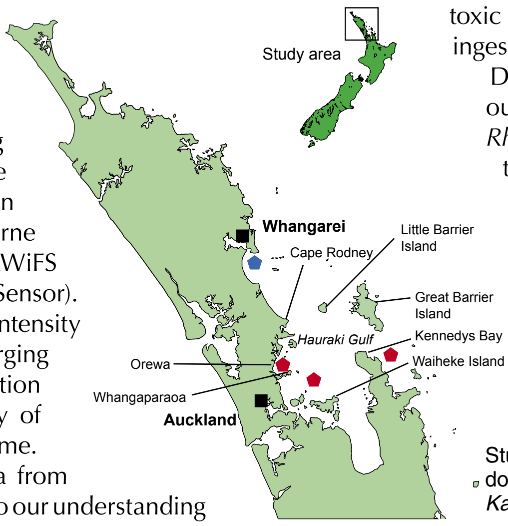
When several huge HABs occurred in New Zealand waters in October 2002, NIWA scientists used satellite data to track the events. Most importantly, we also made shipboard measurements to identify the dominant species and provide further information about environmental conditions during bloom events.

From the water: identifying the culprits

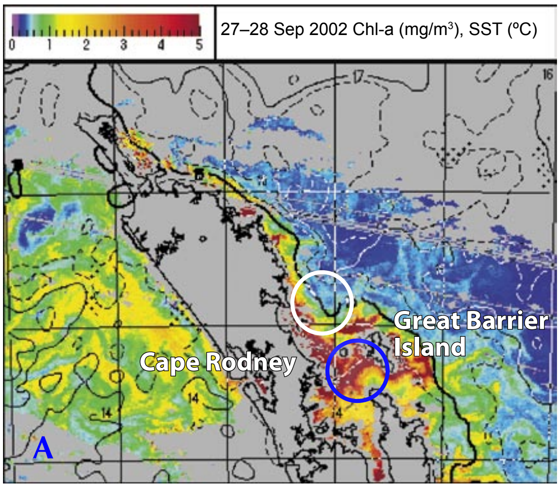
In the Hauraki Gulf during October 2002, tens of thousands of dead fish washed up on beaches at Orewa and Whangaparaoa, north of Auckland. Around the same time, a large number of abalone was reported dead at a marine farm in Kennedys Bay on the eastern coast of Coromandel Peninsula outside the Hauraki Gulf. In all these locations we detected high concentrations of *Karenia* species, including a newly described species, *K. concordia*.

Members of the public also reported several patches of red surface discoloration. We found that most of these visible blooms were dominated by *Noctiluca scintillans*, a harmless, non-photosynthetic dinoflagellate species of alga. *Noctiluca* was not immune to the October 2002 toxic outbreaks, and the organisms died after ingesting cells of *Karenia* species.

During the same period, there were blooms outside the Hauraki Gulf dominated by *Rhizosolenia* (diatoms) and *Noctiluca*, but in this case we detected no *Karenia* species. Healthy *Noctiluca* cells were discovered in the region, feeding mainly on diatoms and the larvae of several marine organisms, with a small number feeding on cysts from *Alexandrium* cf. *catenella*, an algal species that produces paralytic shellfish poison.

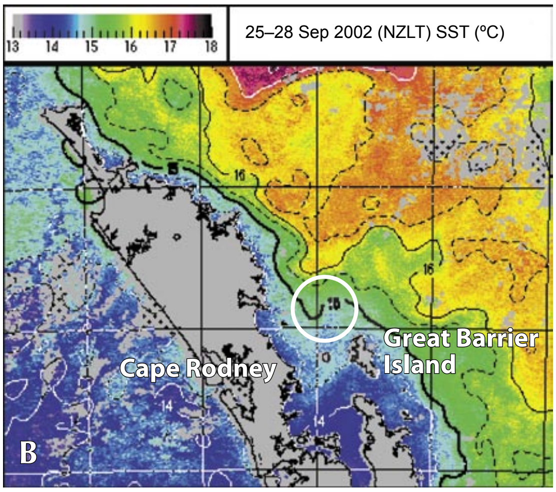


Study area and sampling locations. The coloured dots show where blooms were dominated by *Karenia* (red dots) and *Rhizosolenia* (blue dot).



A. Ocean colour image, overlaid with SST isotherms. (The bold black isotherm is 15°C.) The colour indicates chlorophyll *a*, with the greatest concentration (5 mg per m^3) at the red end of the scale. The blue ring marks the entrance of Hauraki Gulf where the chlorophyll concentrations were greatest and the white ring marks the lowest concentrations.

B. Sea surface temperature. The white ring marks a tongue of warm water intruding into the colder inshore waters of the Hauraki Gulf. Note that the tongue corresponds to the low-chlorophyll patch in map A.



From the sky: satellite observations

Ocean colour

Ocean colour images from September to December 2002 showed the build-up of several patches of high-chlorophyll water along the North Island northeast coast. In the Hauraki Gulf, the build-up apparently started in late September. Map A (above) shows elevated chlorophyll concentrations covering a large area stretching from Waiheke Island inside the Hauraki Gulf to Little Barrier Island at the entrance in the north. Between early and mid October, this high-chlorophyll patch of water coincided with areas where bloom proportion of harmful *Karenia* species and marine life kills were reported, providing some evidence about the extent of this bloom in the Gulf. Although *Noctiluca scintillans* also bloomed simultaneously with *Karenia* species, its lack of chlorophyll makes it difficult to see from space.

Sea surface temperature

SST data retrieved from the US National Space Administration for the same period provide some insight into the physical environment before the initiation of the HABs. In the late winter of 2002, signs of strong upwelling and deep mixing were observed to extend from the open coastline to the entrance of Hauraki Gulf. At this point no bloom was observed. As seasonal warming progressed, upwelled water inshore started to stabilise. From September onwards, SSTs derived from the satellite showed 'tongues' of relatively warm surface waters intruding into the cold, presumably nutrient-rich, nearshore waters close to the entrance of Hauraki Gulf (see map B). We hypothesise that *Karenia* species originating in offshore water were introduced as seed stock during an incursion into this nutrient-rich coastal region, thereby initiating the 2002 HAB at the entrance of the Gulf.

Potential applications

This study indicates that, in combination with sea-truthing, ocean-colour and sea-surface-temperature data from satellites can be used to continuously monitor bloom events over large areas. The combination of ground and space observations provides much more information than fixed-point monitoring, and is particularly useful for understanding bloom formation and movement over large areas of coastline.

We are currently trying to determine whether it is possible to use the information from satellite observations to distinguish bloom events by colour. This is a difficult task, usually impossible for most individual species, but worth pursuing for taxonomic groups of species, since it would significantly improve bloom-monitoring capability and provide additional information for studies of algal dynamics over large areas. W&A

Further reading

Chang, F.H.; Ryan, K. (2004). *Karenia concordia* sp. nov. (Gymnodiniales, Dinophyceae), a new nonthecate dinoflagellate isolated from the New Zealand northeast coast during the 2002 harmful algal bloom events. *Phycologia 43*: 552–562.

Useful links

SeaWiFS: oceancolor.gsfc.nasa.gov/SeaWiFS

NOAA HAB forecast system: www.noaanews.noaa.gov/stories2004/s2323.htm

Dr Hoe Chang's work focuses on biodiversity, biosecurity, biotechnology, and ocean ecosystems. Dr Ken Richardson, Dr Michael Uddstrom, and Dr Matt Pinkerton are remote-sensing scientists. The authors all work at NIWA in Wellington.

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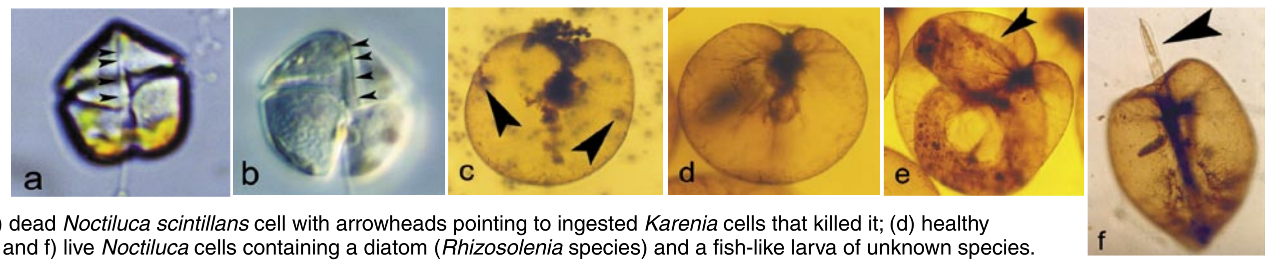

Viewed through the microscope: (a and b) *Karenia concordia* cell (ventral view and dorsal view) with arrowheads marking the characteristic apical groove; (c) dead *Noctiluca scintillans* cell with arrowheads pointing to ingested *Karenia* cells that killed it; (d) healthy *Noctiluca* cell; (e and f) live *Noctiluca* cells containing a diatom (*Rhizosolenia* species) and a fish-like larva of unknown species.

Photos: Hoe Chang