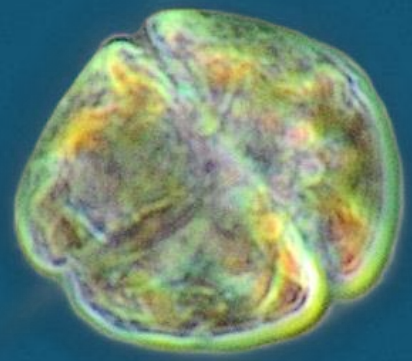
Harmful Algal Blooms



Global context and significance
Overview of 2025 *Karenia* bloom

Guiding questions and context

Christopher Bolch
2nd to 3rd June 2026

OFFICE FOR ALGAL BLOOM RESEARCH

Government of South Australia
Department of Primary Industries and Regions

SARDI SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Australian Government

- **Red Tide – particular type of visible water discolouration**
  - Very high conc. (>10^7 cells litre), usually dinoflagellates concentrated via wind, tide, currents
  - red/brown pigment – Peridinin

Diseases and conditions caused by eating seafood contaminated with algal toxins

Accessible link: www.cdc.gov/habs/illness-symptoms-marine.html#contaminated-seafood

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

Disease or Condition

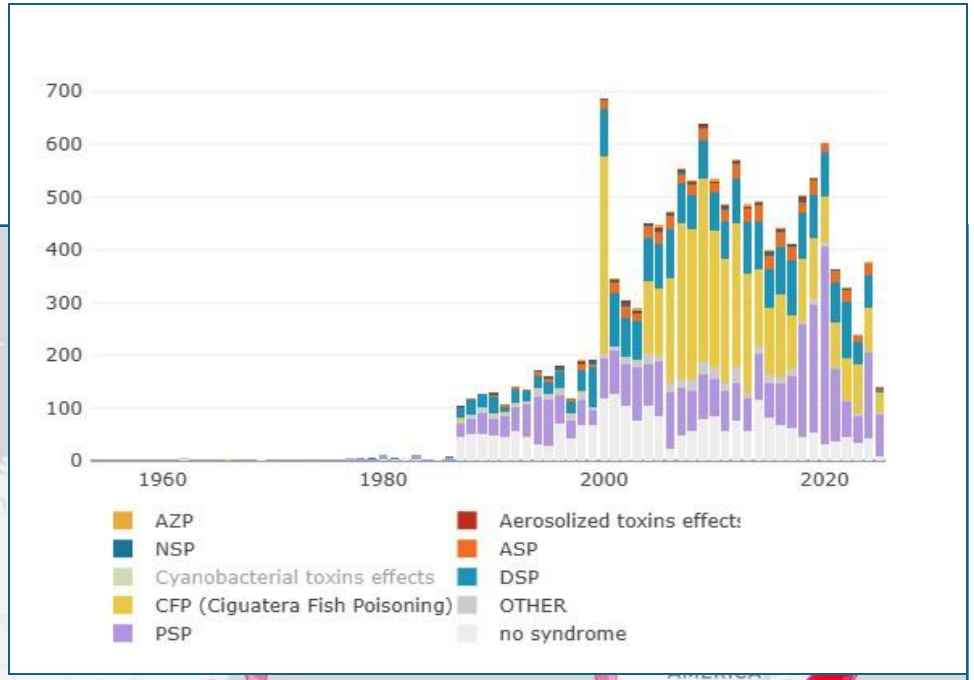
	Ciguatera fish poisoning (CFP)	Neurotoxic shellfish poisoning (NSP)	Paralytic shellfish poisoning (PSP)	Domoic acid poisoning and amnesic shellfish poisoning (ASP)	Diarrheic shellfish poisoning (DSP)	Azaspiracid shellfish poisoning (AZP)	Fish kills & marine fauna kills
Toxin-producing organism	Dinoflagellates: *Gambierdiscus toxicus*, possibly others	Dinoflagellates: *Karenia brevis* and other *Karenia* species	Dinoflagellates: *Gymonodinium catenatum*, *Pyrodinium bahamense*, *Alexandrium* species	Diatoms: *Pseudo-nitzchia* species	Dinoflagellates: *Dinophysis* species, *Prorocentrum lima*	Dinoflagellates: *Prorocentrum* species	Dinoflagellates *Karenia* spp. Raphidophytes Prymnesiophytes
Toxin(s)	Ciguatoxins, Maitotoxin, Scaritoxin	Brevetoxins	Saxitoxins	Domoic acid	Okadaic acid	Azaspiracid	**Various toxins** *Brevetoxins, Karlotoxins. Brevsulcanal, prymnesins, leadbeaterins, ROS/toxic lipids*
Foods likely to be contaminated	Reef fish such as barracuda, grouper, red snapper, and amberjack	Shellfish, primarily mussels, oysters, scallops	Shellfish, primarily scallops, mussels, clams, oysters, and cockles, Some fish and crabs	Shellfish, primarily scallops, mussels, clams, oysters, Possibly some fish species	Shellfish, primarily scallops, mussels, clams, oysters	Shellfish	
Short-term symptoms	Nausea, Vomiting, Diarrhea, Stomach pain	Nausea, Vomiting, Diarrhea, Stomach pain, Numbness of lips, tongue, and throat, Dizziness	Nausea, Vomiting, Diarrhea, Shortness of breath, Irregular heartbeat, Numbness of mouth and lips, Weakness	Nausea, Vomiting, Diarrhea, Stomach pain, Shortness of breath, Irregular heartbeat, Abnormal hot and cold sensations, Memory loss, Disorientation, Seizures, Possibly coma	Nausea, Vomiting, Diarrhea, Stomach pain, Possibly chills, Headache, Fever	Nausea, Vomiting, Diarrhea, Stomach pain	**Various symptoms depending on species** Agitation , disorientation, gill mucus production loss of movement/locomotion Morbidity / Death
Long-term symptoms	Abnormal hot and cold sensations, Pain, Weakness, Low blood pressure	Unknown	Unknown	Possibly amnesia	Unknown	Unknown	
Treatment	Supportive care (treatment of symptoms), Possibly IV mannitol	Supportive care	Supportive care, Possibly respiratory support	Supportive care, especially for older people and those with kidney disease	Supportive care	Supportive care	

Department of Primary Industries and Regions · Research and Development Institute · Australian Government

Global significance of HABs

HABs are global

- Several hundred bloom events/yr
- Under-reported in some regions
- Frequency increasing ?



Records through human history

- Indigenous knowledge and taboos
  - Local native taboo against eating shellfish when sea is bioluminescent
  - 1793 British Columbia, Captain George Vancouver, 4 crew affected by PSP
- The Bible – the three plagues
  - Moses "*struck the water of the Nile, and all the water was changed into blood*." (Exodus 7:14 to 23)

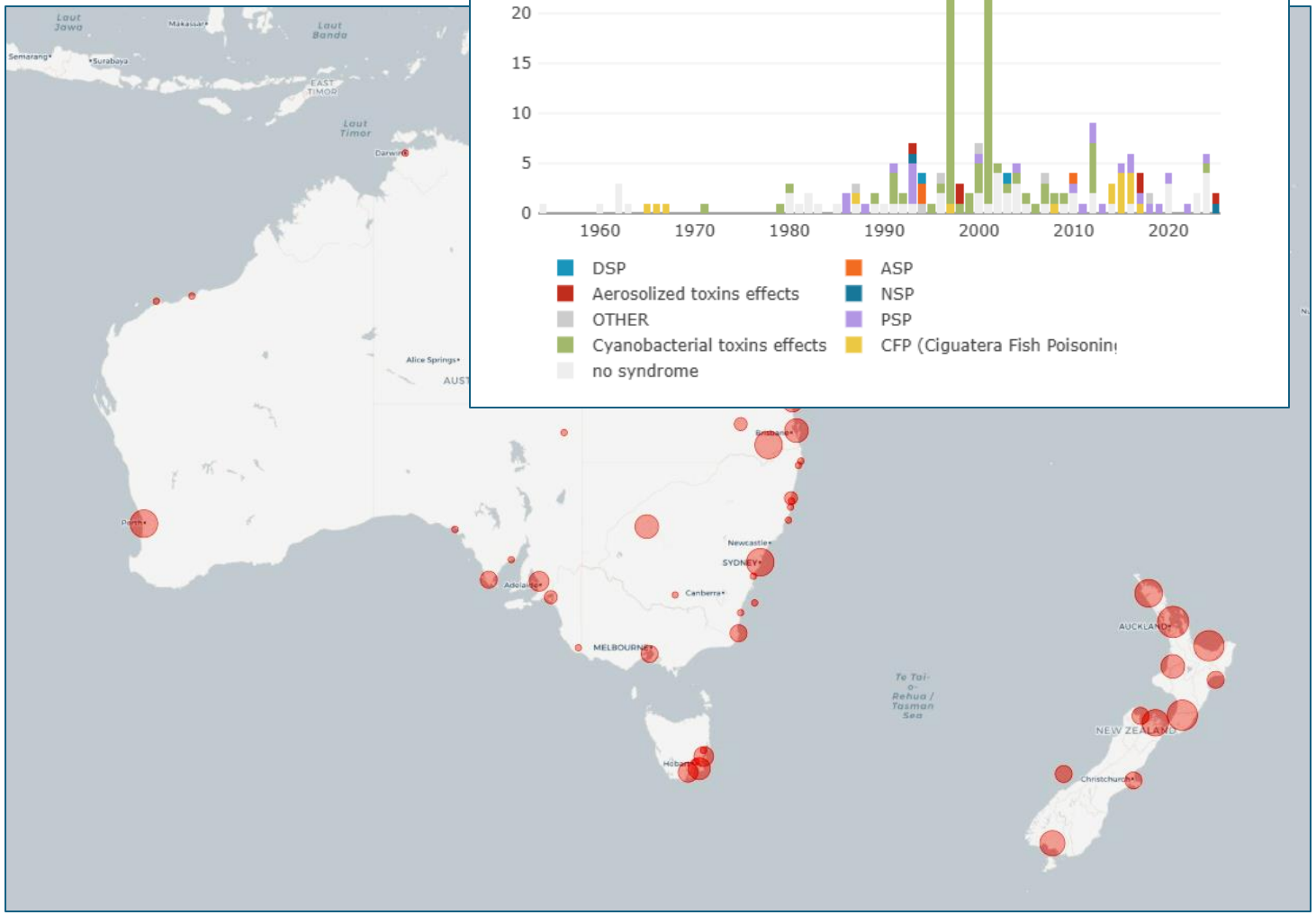
HABs in Australasia

Not a new phenomenon in Australia

- *Noctiluca* red-tides in NSW back to 1860s (sea sparkle)
- PSP detected in1935 from wild mussels (Le Messurier 1935)

HABs regularly recorded from the 50s, reports increasing from 1980s

- Increased scientific scrutiny
- Increasing intensive cultivation of seafood



Karenia HABs

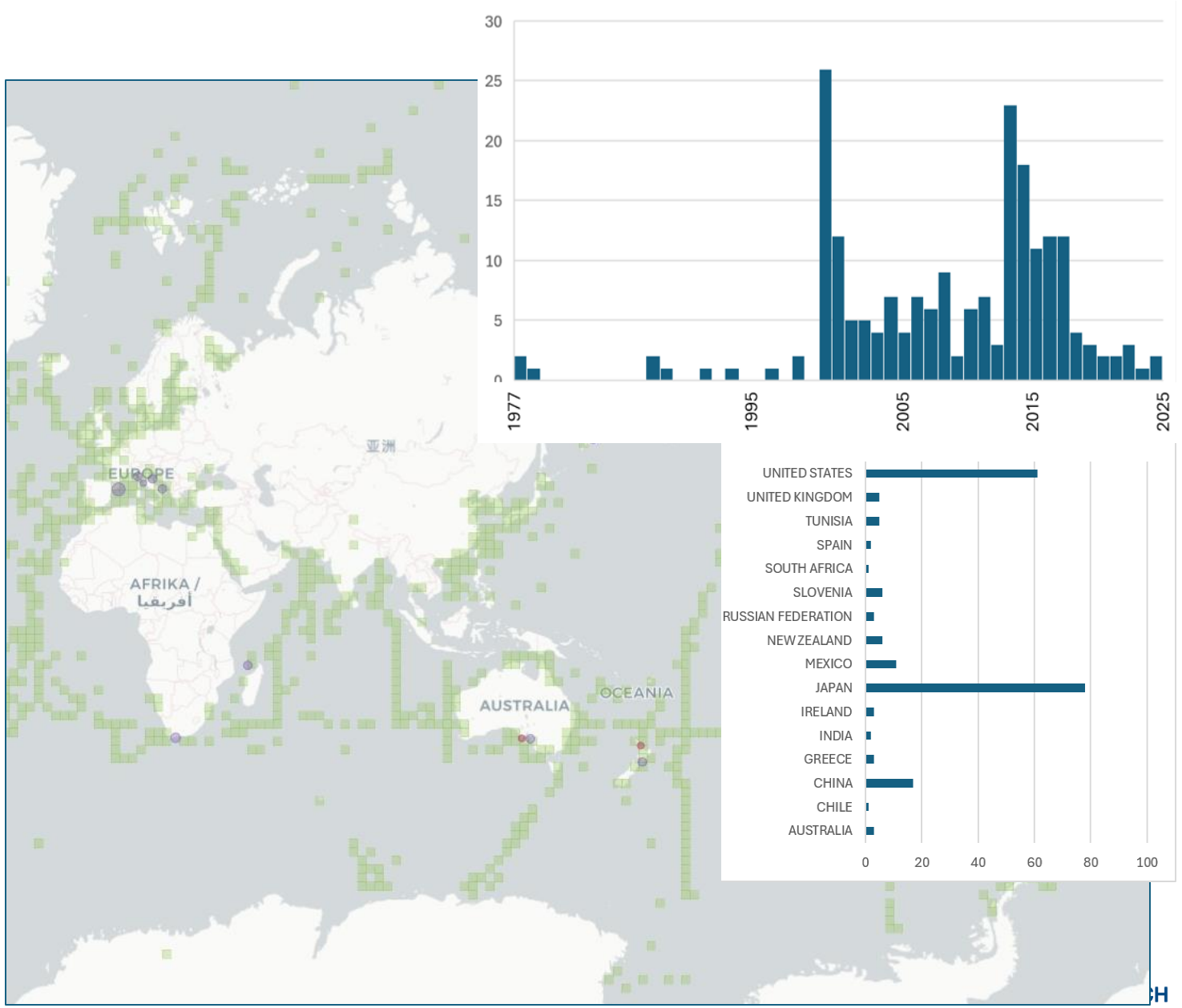
Not a new phenomenon

- Gulf of Mexico “Gymnodinium breve” blooms and NSP recorded for over 300 years
- “Red-water” and human respiratory symptoms as early as 1528 (Magana et al. 2003)

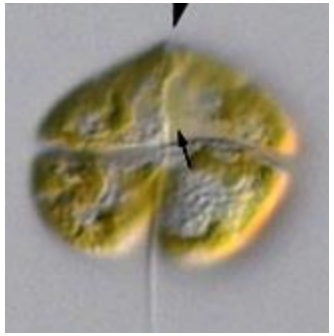
Karenia species are common and widespread throughout the world’s oceans

Karenia HABs are a global problem

- Increasing intensive cultivation of sea-caged finfish since 1970s
- Increasing understanding of *Karenia* diversity and toxicology from the 90s



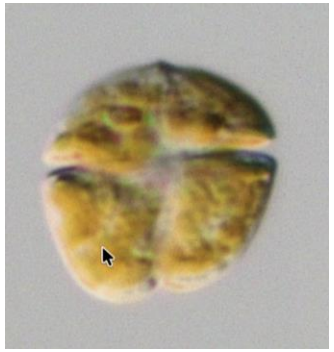
Genus *Karenia* : many species in Australasia



papilionacea

mikimotoi

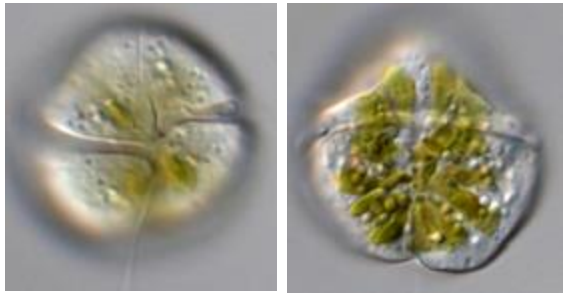
brevisulcata



cristata

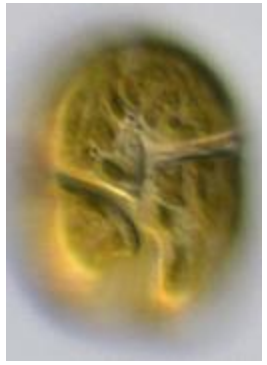
Not yet detected in Australia

K. brevis
K. concordia
K. bicuneiformis
K. hui
K. longicanalis (Grp 2, 3)
K. selliformis (Grp 1, 2)

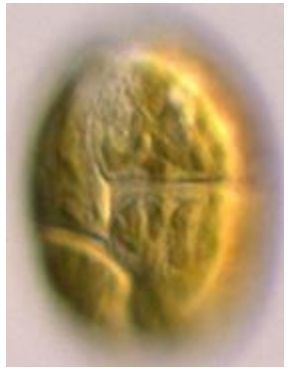


asterichroma

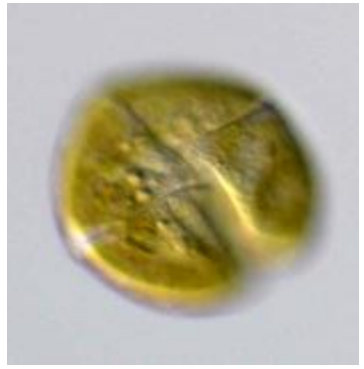
longicanalis (Grp 1)



Karenia sp. PB1



Karenia sp. PB2



Karenia sp. PB3

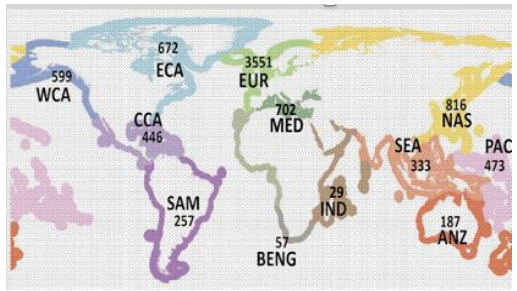
Images: Miguel de Salas and Christopher Bolch

Are HABs increasing?

- **When corrected for increasing scrutiny and sampling effort**
  - **No uniform trend** for all HABs, across all regions
  - Nor should it be expected

- **Climate change??**
  - Expect different effects in different climate zones for each species/toxin type
  - Tropical – temperate shifts

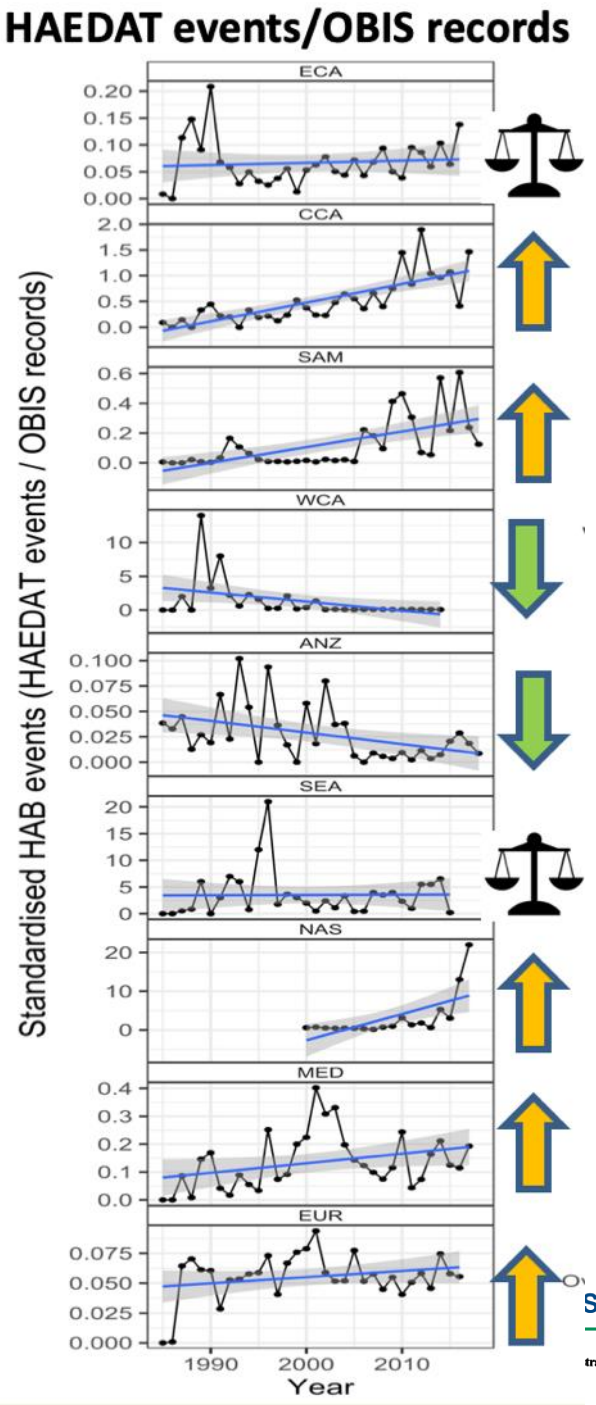
35,000 microalgae; 200 HABs



Slide & data courtesy of
Prof. Gustaaf Hallegraeff

HAEDAT
HARMFUL ALGAE EVENT DATABASE

OBIS OCEAN BIODIVERSITY INFORMATION SYSTEM



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The 2025 *Karenia* bloom

- Early March – surfers reporting respiratory symptoms
- Initial ID of *Karenia mikimotoi*
- Brevetoxins (BTX) detected in shellfish
- First time BTX detected in Australia
- One of first instances of BTX from *Karenia* outside the SE USA.
- More than 20 000 km^2 affected
- Millions of marine animals killed and >550 species affected
- Human respiratory symptoms widespread

A catastrophic marine mortality event caused by a complex algal bloom including the novel brevetoxin producer, *Karenia cristata* (Dinophyceae)

Shauna A. Murray, Christopher J S Bolch, Steve Brett, Cheong Xin Chan, Mark Doubell, Hazel Farrell, Greta Gaiani, Hannah Greenhough, Gustaaf Hallegraeff, Tamsyne Smith Harding, D.Tim Harwood, Robert G. Hatfield, Neil MacDonald, Ian Moody, Hugo Bastos de Oliveira, Lesley Rhodes, Andrew Selwood, Justin Seymour, Nachshon Siboni, Anastasiia Snigirova, Nikola Streiber, Anne Rolton, Clinton Wilkinson, Kirsty Smith

doi: https://doi.org/10.1101/2025.10.31.685766

Abstract | Full Text | Info/History | Metrics | Preview PDF

Abstract

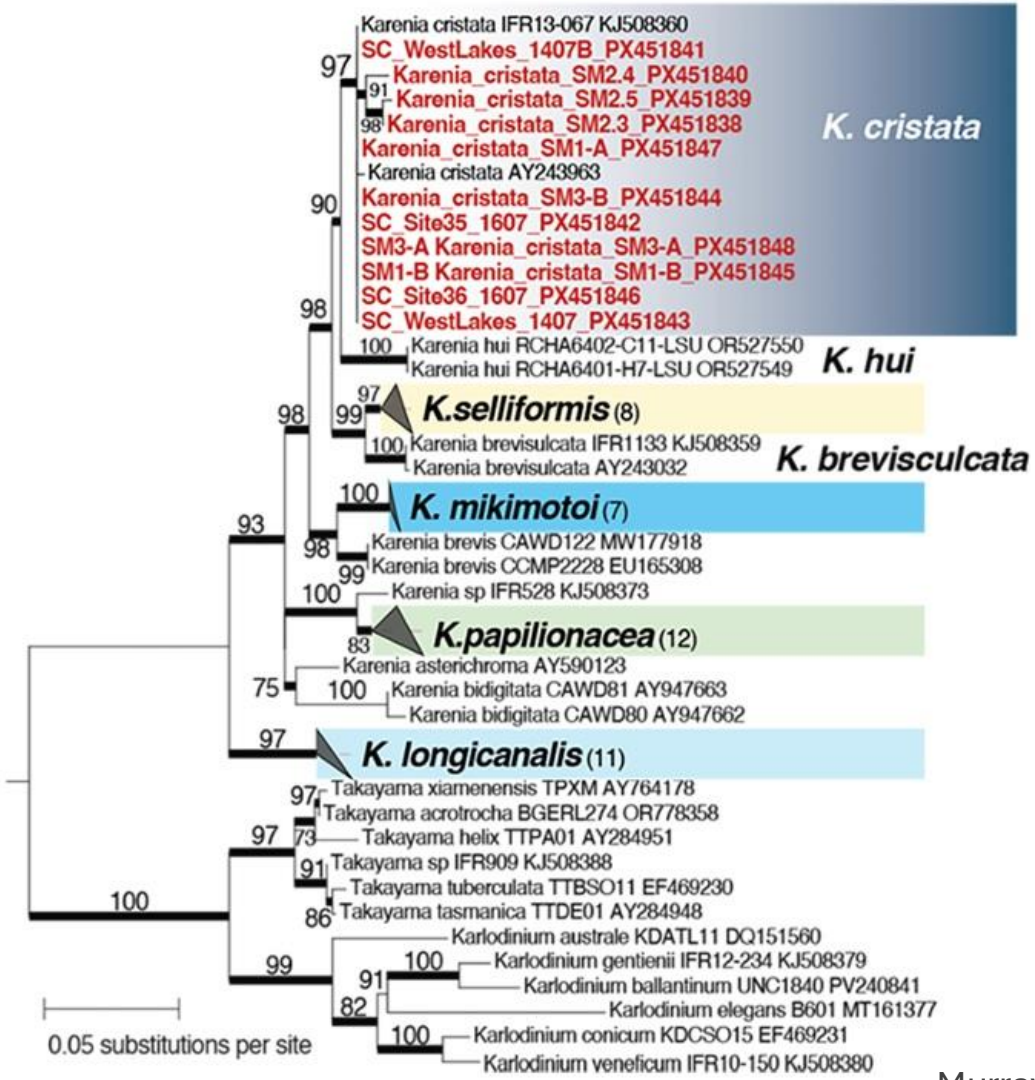
Harmful algal blooms of *Karenia brevis* (Dinophyceae) are a global anomaly, occurring in one location worldwide, causing severe marine and acute human impacts via brevetoxins (BTX). During 2025 an unprecedented, currently ongoing, mass marine mortality occurred in South Australia, across an area of ~20,000 km^2, persisting for >6 months, resulting in the deaths of ~10^6 marine animals of >550 taxa, with human health impacts. Using custom metabarcoding, long-read sequencing and targeted quantitative PCR, we characterized the microalgal assemblage. *Karenia cristata* dominated over the sampling area, in an assemblage with four other *Karenia* species with varied abundances spatially and temporally. High abundances of *K. cristata* appeared in the austral autumn, and hydrodynamic processes appear to have entrained cells coastward in the semi-enclosed seas. We isolated the species and characterized it using light and electron microscopy, liquid chromatography mass spectrometry and a toxicity assay. We show for the first time that the rare and little known *K. cristata* produces significant BTX with a profile (BTX 2, 3, B5), differing from *K. brevis*, with toxicological effects. These findings reveal a novel, significant BTX-producing *Karenia*, which considering its substantial detrimental marine ecosystem impacts, is an emerging international threat with unknown consequences in changing

Murray et al. 2026 (in press)

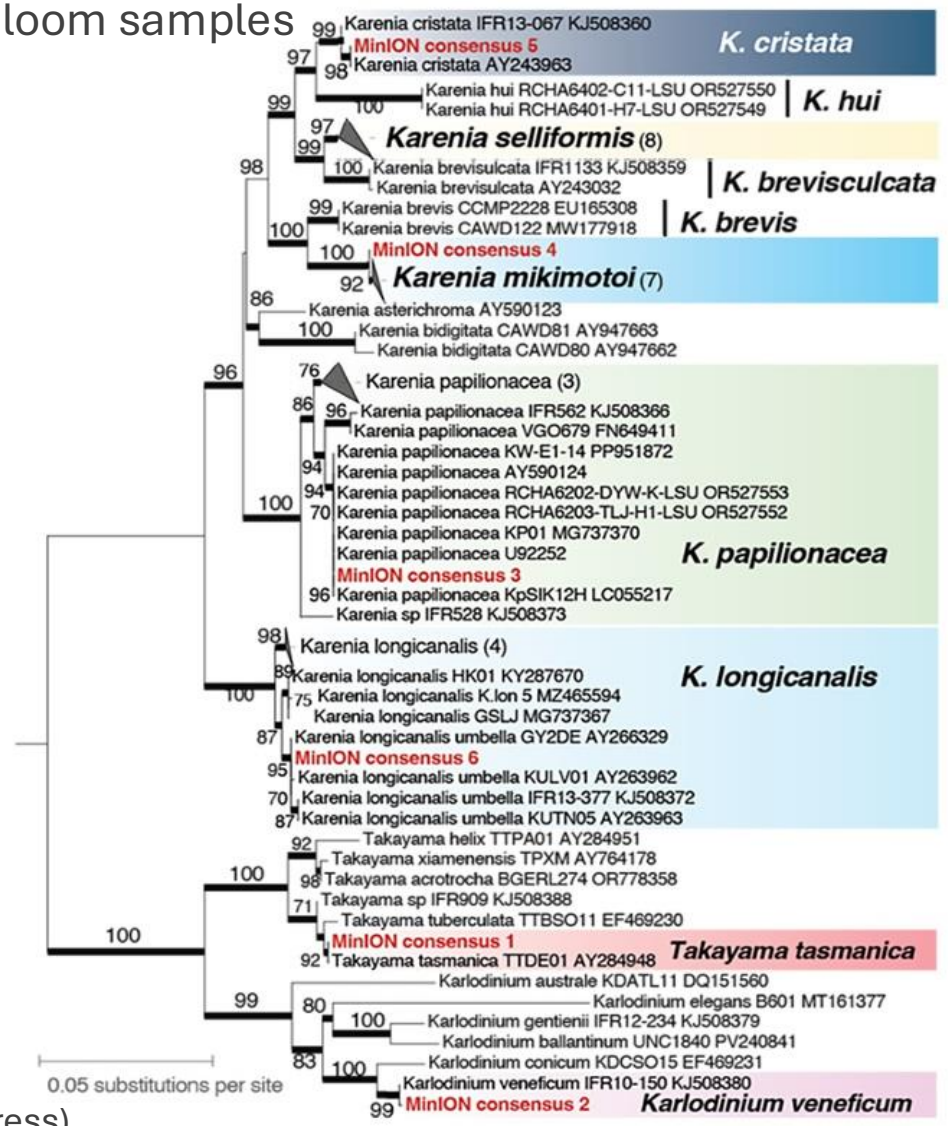
Images S. Brett, G. Hallegraeff & C. Bolch

Molecular analyses confirm bloom species conposition

DNA sequencing from lab cultures

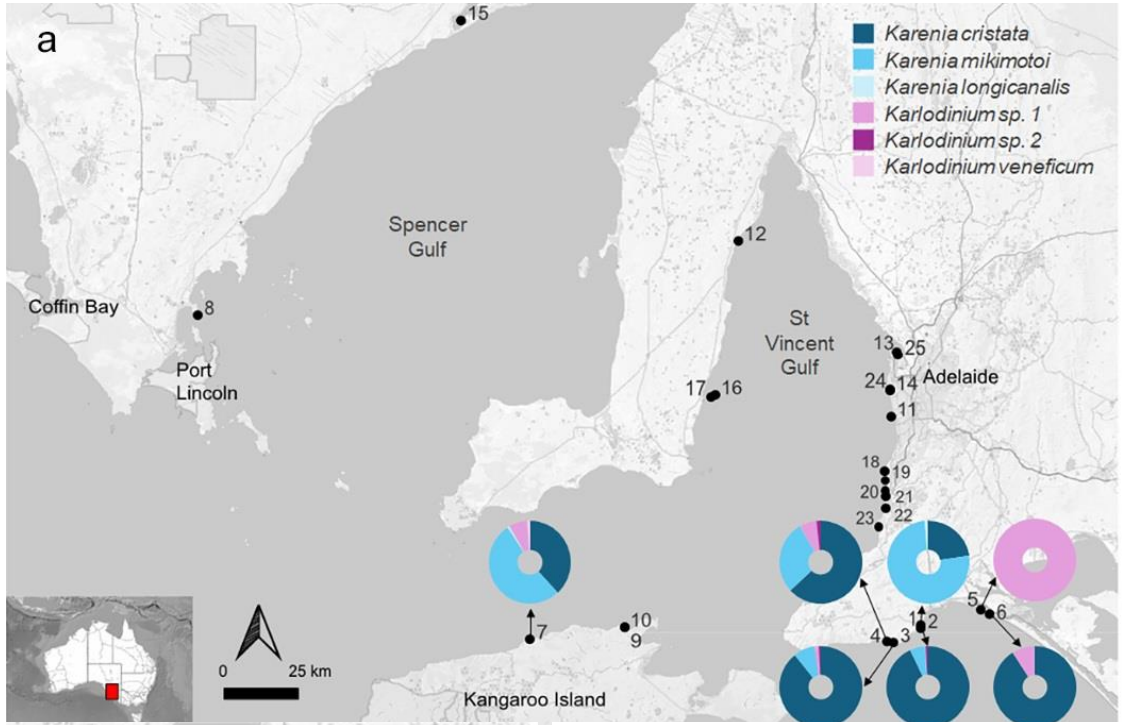


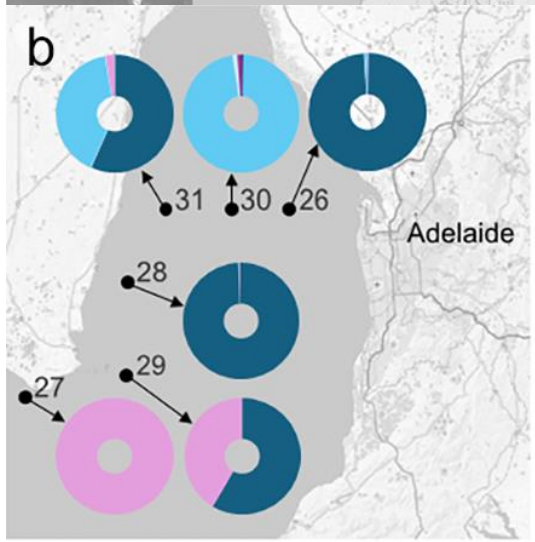
High-throughput sequencing ONP Minion) of bloom samples

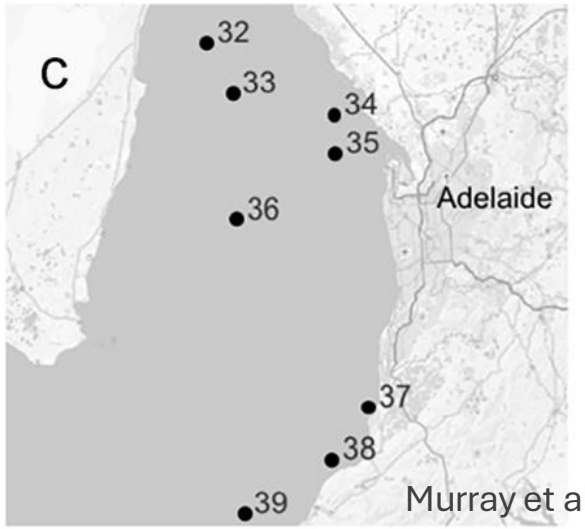


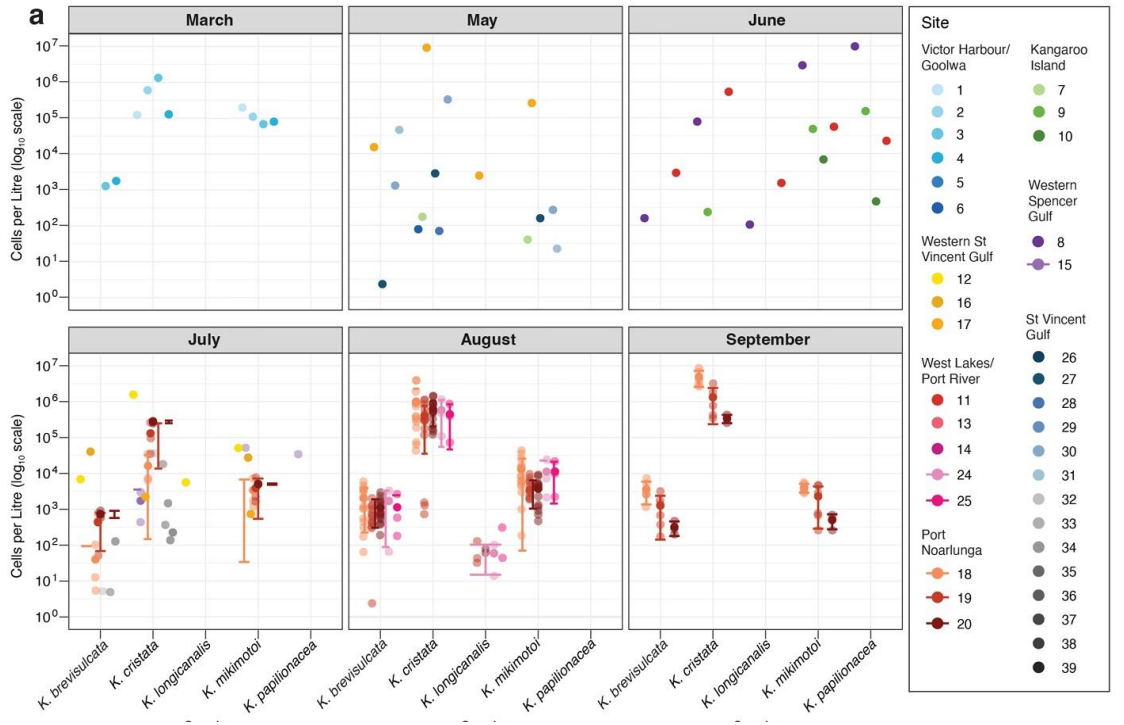
Murray et al. 2026 (in press)

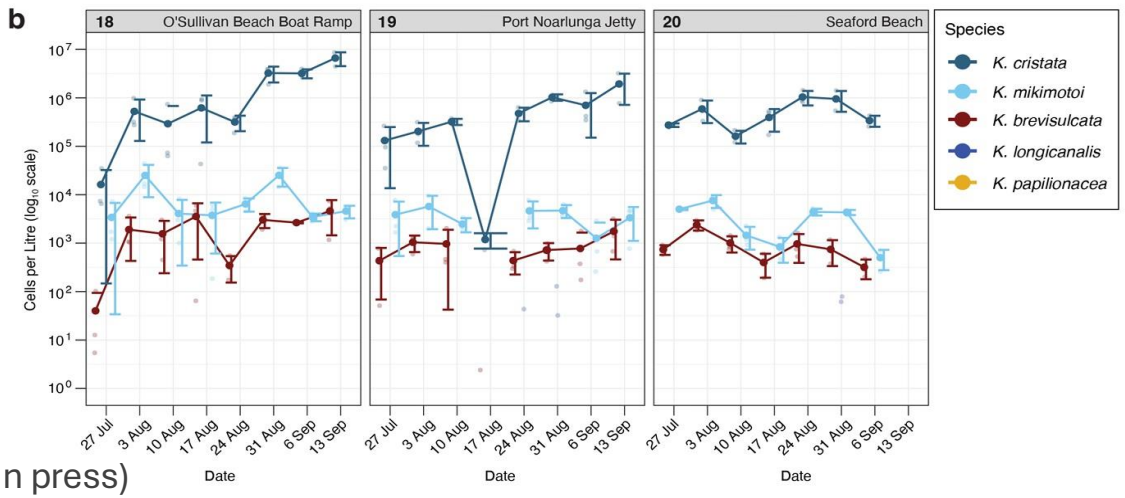
A complex and dynamic mix of species (qPCR)







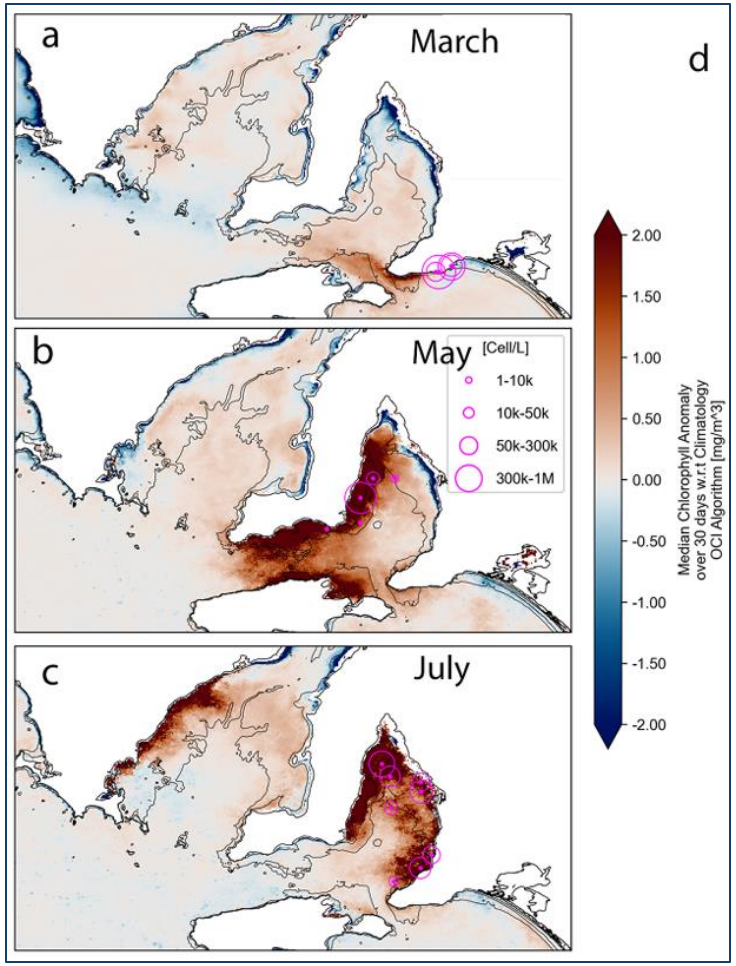


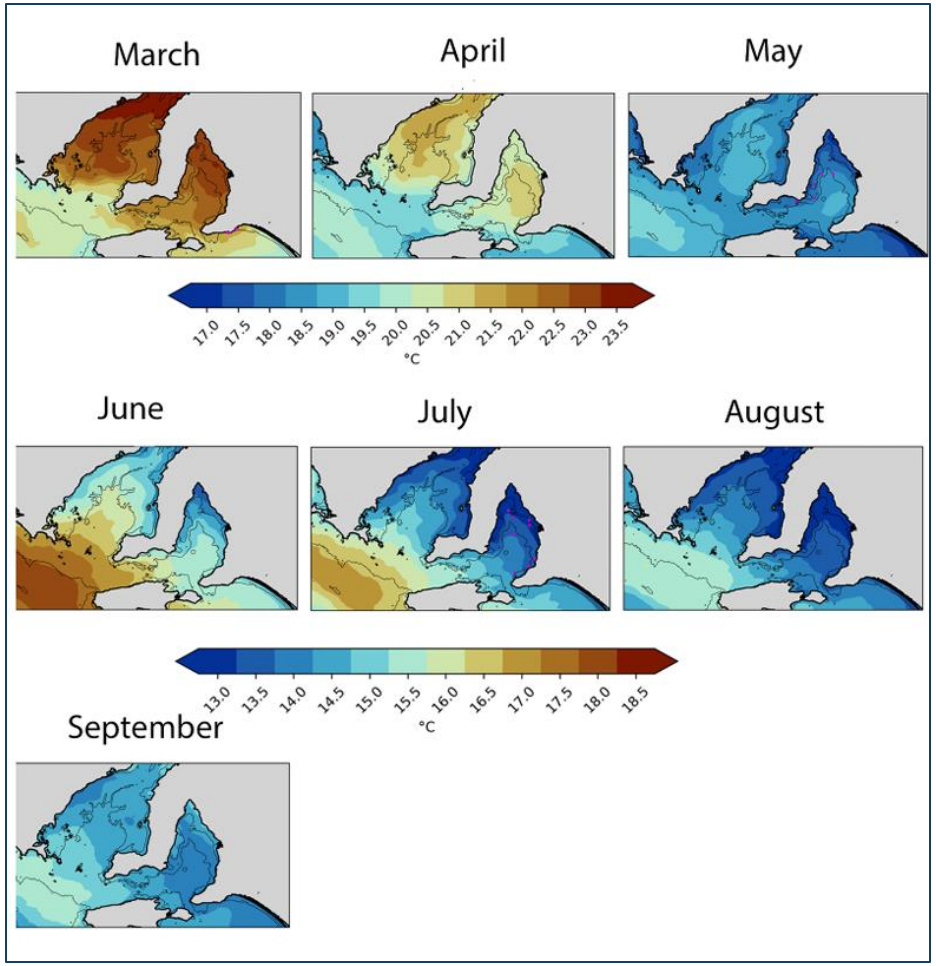


Murray et al. 2026 (in press)

Satellite imagery: larger-scale patterns

- **Sea surface Chl-a**
  - Chl-a conc.
  - Chl-a anomoly
- **Sea Surface temperature (SST)**
  - Temperature
  - SST anomoly





Murray et al. 2026 (in press)

Where do apparently new HABs come from?

Two main ideas often raised :

- **Marine introduction or bioinvasion?**
  - Species not-endemic and was accidentally introduced or transported from elsewhere

OR

- **Endemic but cryptic (rare, not detected) and recently stimulated by:**
  - **Climate change?** Increasing global temperatures may create or increase the seasonal bloom windows
  - **Ocean Acidification?** rising dissolved CO_2 may stimulate growth and toxicity of *Karenia*
  - **Unusual combination of local conditions?**
    - More to come from Prof. Simon Goldsworthy

Can we ever know why a bloom happens?

Determining where, when & why is almost always difficult:

1. **Detection is usually weeks to months after inception**
   - When dense enough to be visible
   - When negative effects are evident (discolouration, foam, dead sealife etc)
2. **For coastal HABs, the origin may be many hundreds of miles away or offshore**
   - Sampling the right place at the right time is incredibly unlikely
3. **Post-hoc investigation reliant on:**
   - Opportunist/archived samples and data collected for other reasons
   - Correlative reasoning (what was different about that year/month, compared to previously ?)
   - Modelling ocean currents, weather, algal growth, biogeochemical parameters
   - Understanding particular biological and ecological characteristics of the organism

Are HABs predictable?

Near-casting and forecasting may be possible (ie. now vs next week)

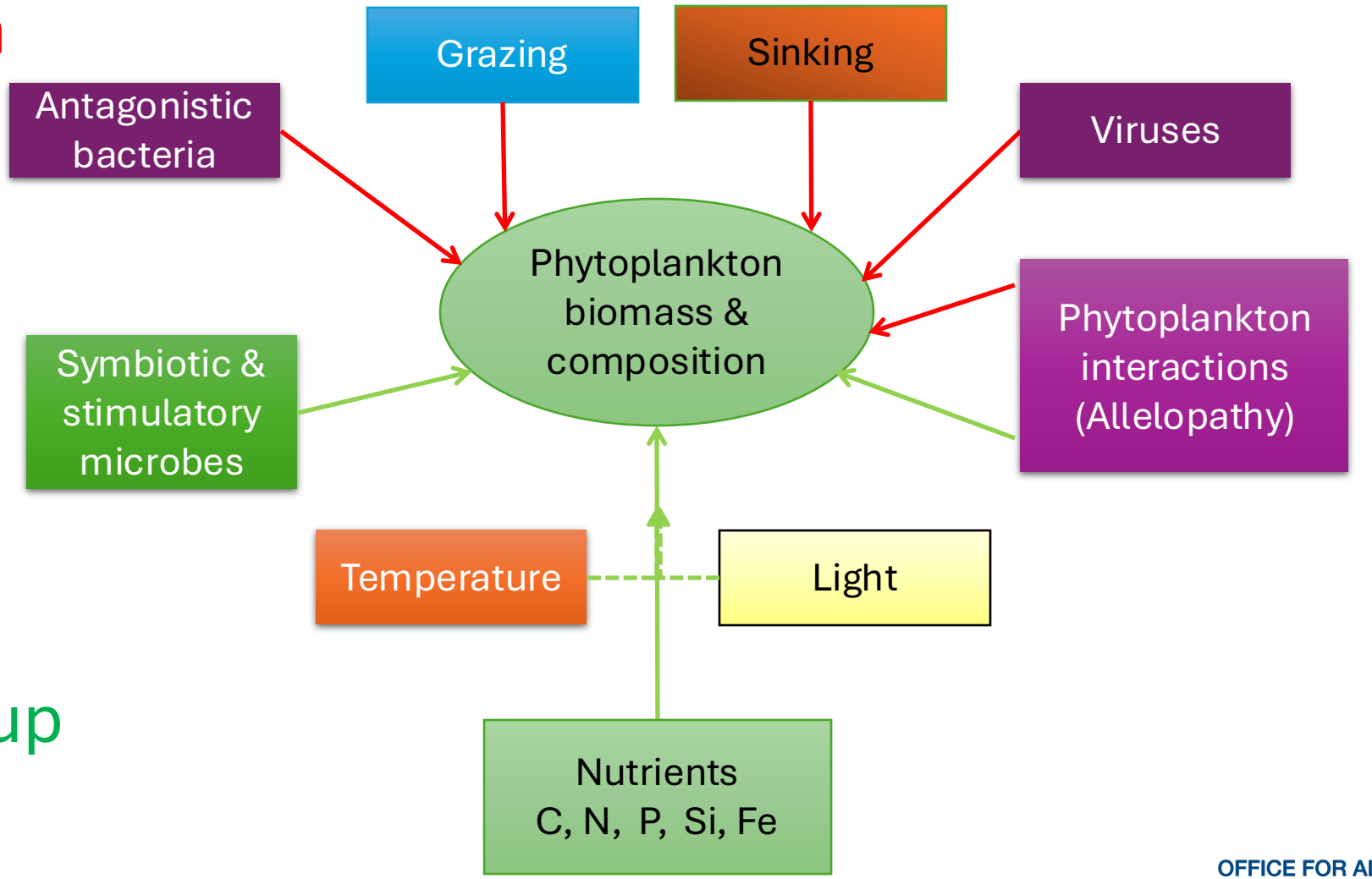
- Real-time *in-situ* data monitoring, satellite imagery (more to come from Mark D)
- Accurately parameterised and integrated oceanographic/biological models

Capacity for long-term prediction is currently limited by:

- Limitations of modelling/prediction of major forcing factors
  - E.g. Weather for 7-10 days, increasingly uncertain out to 30 days and beyond
- Weak ecological understanding of how planktonic communities operate at species level
  - Why that species, at that time/location? Why not another ?

Phytoplankton growth: conceptual model

Top - down



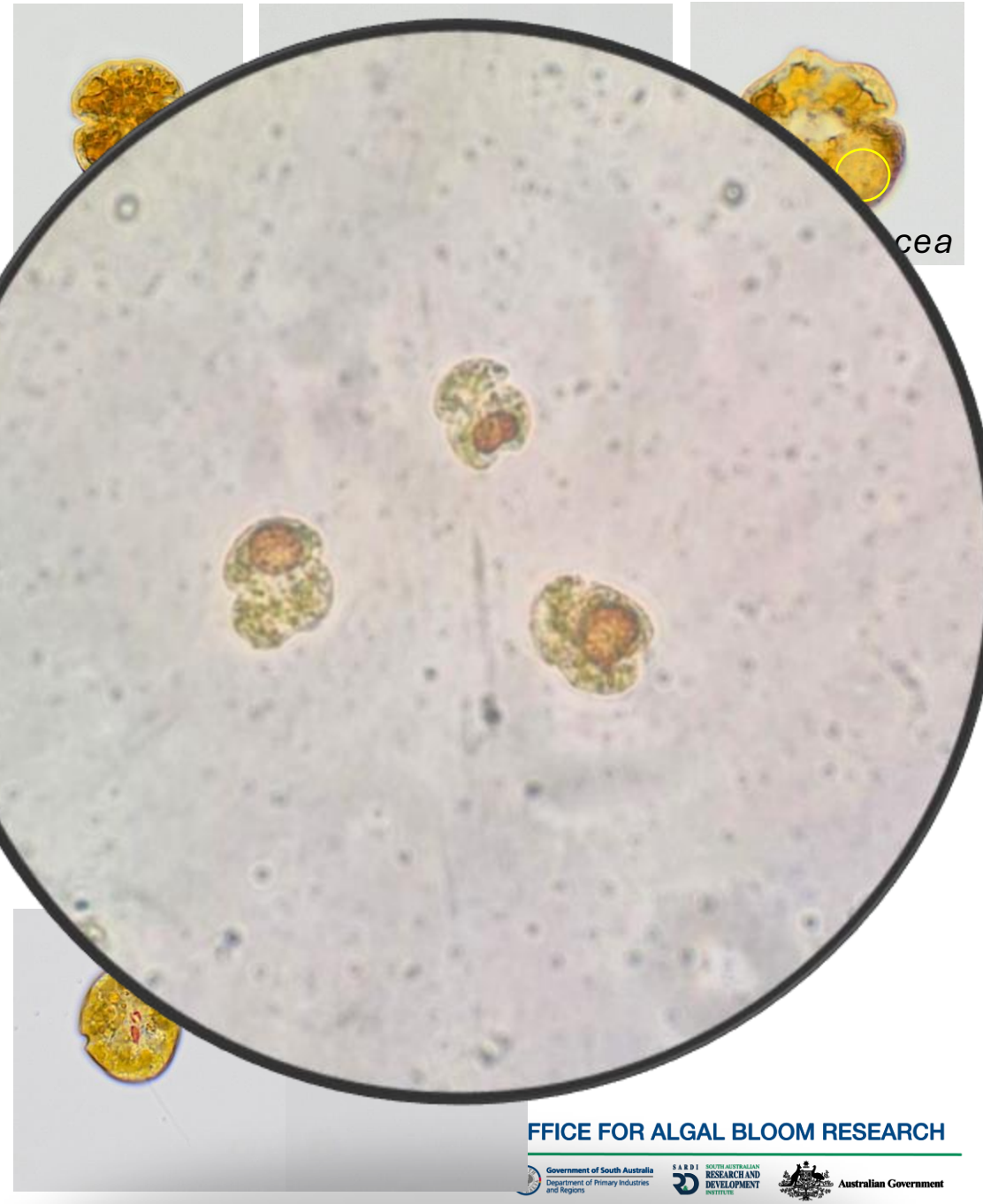
Bottom - up

What has Chris been doing ?

- **Boston Bay *Karenia mikimotoi* bloom**
  - Documenting unknown *Karenia* spp.
  - Establishing cultures (circa 100 isolates to date
  - single-cell PCRs to confirm species identities

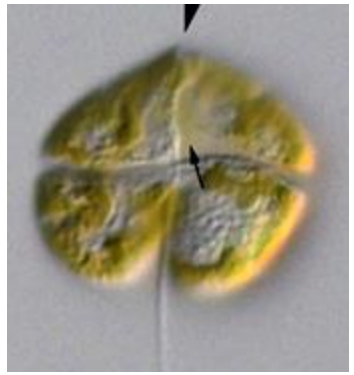
- **Advice on HAB species identity**
  - Looking out for *K. cristata*
  - *Karenia* species in HAB survey samples.
  - Informal training of taxonomic analysts

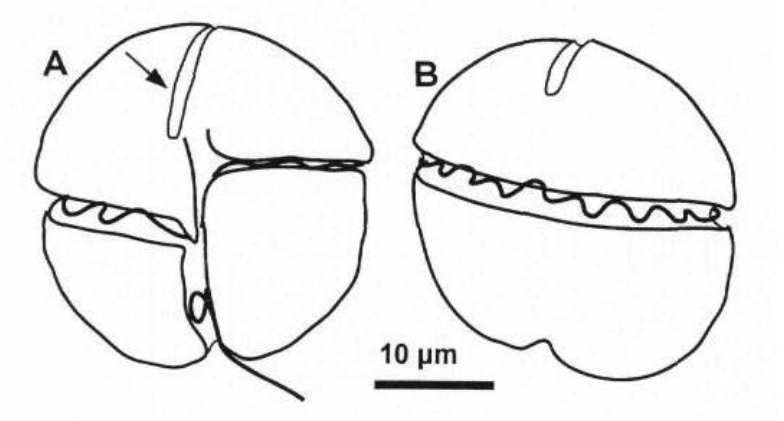
- **Inman River bloom and fish deaths**
  - Dinoflagellate *Kryptoperidinium* sp. identified
  - Confirmation of ID awaiting further DNA sequencing data.



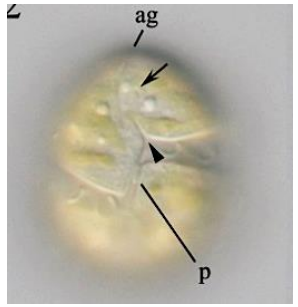
Karenia and related genera

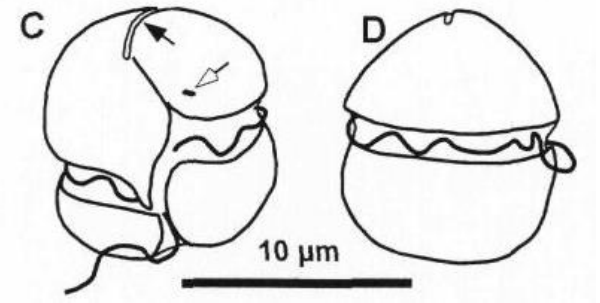
- ***Karenia***
  - straight apical groove



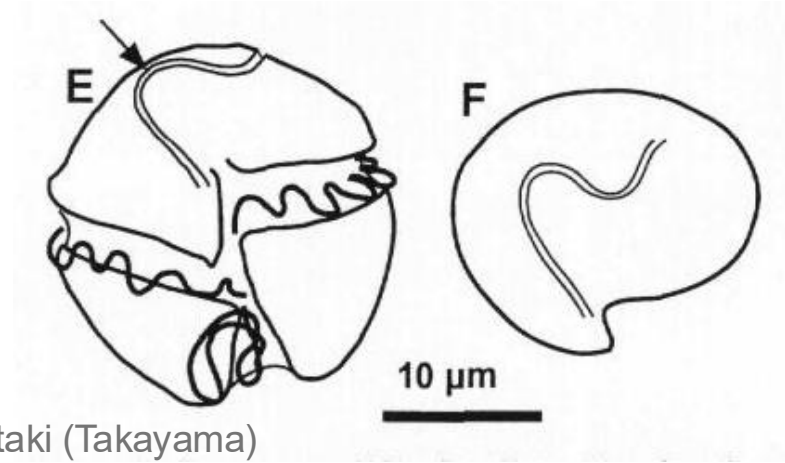


- ***Karlodinium***
  - Short apical groove
  - Ventral pore
  - Diff. cell structure





- ***Takayama***
  - Sigmoid apical groove



Images: Dr Miguel de Salas; Dr Mitsunori Iwataki (Takayama)

What are algal cultures?

- **Single or multiple species of algae maintained or grown in a container**
  Provide requirements for growth/reproduction

- **Contained, controlled and flexible experimental systems**
  - Less complex, less confounding variables
  - Enable comparison of different species under a set of common conditions
  - Independently or co-culture (competition)

- **Simplified biological models**
  - Able to test/verify hypotheses about how the more complex real-world works

Why are cultures important ?

Critical to understand how species respond to it's environment.

Without cultures it is difficult to:

- **Verify source/identity and toxicity**
  - Recognise, react and manage future HAB/toxic events
  - Understand variations in toxicity and impacts on marine fauna/flora and human health
- **Establish environmental tolerances, ecological preference, and rate dynamics**
  - To parameterise algal growth models
  - Underpin development of bloom prediction tools
- **Test competing hypotheses explaining bloom initiation, maintenance and decline**
  - How do *K. cristata blooms* establish and maintain community dominance for such long periods?
- **Test feasibility of control/mitigation measures**