Professor Anthony J. Richardson
Mathematical Ecologist (UQ/CSIRO)

Research interests in HABs
My main interests in HABs are in whether they are increasing because of anthropogenic impacts, and how predictable blooms are from environmental drivers.

Background
BSc in Mathematics and Zoology (UQ)
BSc in Zoology (UQ)
PhD in plankton ecology and modelling, University of Cape Town (South Africa)

Relevant Experience
- I lead the IMOS AusCPR sub-facility
- I lead the IMOS NRS phytoplankton sub-facility
- Our lab counts phytoplankton samples for commercial partners

Selected HAB projects


In your experience what will be the most challenging part for achieving HABS forecasting and how do you think your research can play a part in overcoming this challenge?

HABs are a coastal phenomenon and most of the focus of IMOS is in blue water. Many HAB species occur in the open ocean, but bloom in near-shore areas. A huge challenge is how to integrate information from oceanic and estuarine observations.
Environmental influences on the development of harmful algal blooms

Scott Condie, Gustaaf Hallegraeff, Brian Hatfield

Experience across a diverse range of marine and freshwater systems indicates that environmental conditions can have a major influence on the development of harmful algal blooms (Hallegraeff et al., 1995; Bormans & Condie, 1998; Weise et al., 2002; Anderson et al., 2012; Yamamoto et al., 2013). As part of a broader FRDC funded project, we are currently investigating the influences of wind, rainfall, river discharge and oceanography on the development of *Alexandrium tamarense* blooms off eastern Tasmania.

Preliminary results suggest that bloom events in 2012, 2015 and 2016 may be correlated with rainfall and associated river discharge, and possibly offshore oceanography. While a range of environmental processes can potentially interact with *A. tamarense* ecology, stratification appears to be a strong underlying driver for bloom formation. This hypothesis is consistent with observations elsewhere (Anderson et al., 2012; Yamamoto et al., 2013) and theoretical ideas suggesting that the stability associated with a stratified water column can provide dinoflagellate species with a significant competitive advantage (Condie & Bormans, 1997).

Other research we are undertaking with potential implications for harmful algal blooms includes development of modelling tools for exploring the impacts of changed nutrient loads on water quality in southern Tasmanian coastal waters.


Karen has experience modelling phytoplankton blooms around Australia, including the toxic dinoflagellate Gymnodinium in the Huon and D'Entrecasteaux. Gymnodinium is interesting in that it has the capability to migrate vertically throughout the water column which increases its access to deep nutrients and surface light allowing faster growth rates and large accumulations of biomass in the stratified and recirculating Huon estuary. Models are a good way to articulate hypothesis about system dynamics leading to HAB occurrence, however key observations are needed to constrain uncertainty. Observations such as phyto- and zoo-plankton species composition, nutrient levels, water column attenuation, species specific size and growth rates, rates of plankton sinking, swimming and/or ex-cystment, trigger factors and timing of any vertical migration or ex-cystment, grazing and mortality rates, including virus activity.

Monika has recently arrived from Europe and has experience in in-situ optical and remote sensing observations of the toxic blue green algae Nodularia found in the Baltic, but also in some Australian estuaries such as Gippsland. Nodularia fixes nitrogen and achieves high biomass in waters with elevated phosphorous load. These blooms form characteristic surface slicks which can be positively identified in remote sensing images.
**Biotic drivers: understanding impacts on healthy communities that precede bloom formation**

Dr Martin Ostrowski  
Deputy Director Macquarie University Marine Research Centre

Other contributors:  
Assoc. Prof Federico Lauro (NTU/SCELSE Singapore)  
Dr Mark Brown (UNSW)  
Assoc. Prof Justin Seymour (UTS)  
Distinguished Professor Ian Paulsen (MQU)  
Dr Pascal Craw (CSIRO, Hobart)  
Dr Lev Bodrossy (CSIRO, Hobart)

Microorganisms in marine environments are normal and naturally occurring. They are both drivers of, and sensitive indicators of, ecosystem health. Understanding both how blooms arise and decline requires an integrated understanding of bloom dynamics based on bottom-up and top-down factors. This includes understanding the rapid succession of physical, chemical and community effects that precede HAB development. HABs exploit niches vacated by healthy marine microbiota. The key to accurate forecasting lies in identifying sensitive indicators that probe the impacts of grazers, viruses and anthropogenic stressors, such as discharge of waste, pesticides and industrial pollution on natural communities.

Preliminary results from the Australian Marine Microbiology Diversity Initiative show distinct communities of prokaryotic and eukaryotic phytoplankton at (sub)tropical and temperate reference sites along Australia’s coast. These communities include endemic, or seasonally abundant, species known to be associated with toxic blooms. Correlative studies suggest that nutrient dynamics can only partially explain HAB development at many locations worldwide, while biotic factors have received little attention.

Microbial communities are highly dynamic, the role of virus and phage and grazing, particularly by microbial protists has not been studied in any detail in Australia. Recent data collected by members of my research group indicate that mortality due to both grazing and viruses ranges from 22-80% of the microbial population along the east coast, every day. Comparison of NRS against adjacent harbors and impacted estuaries also show a distinct shift in the balance between heterotrophs and phototrophs in the community DNA that can only partially be explained by nutrients. These results suggest that factors that aren’t normally measured may play a significant role in perturbing the natural balance potentially leading to increased incidence of blooms.

“In your experience what will be the most challenging part for achieving HABS forecasting and how do you think your research can play a part in overcoming this challenge?”

HABS forecasting requires understanding the ecosystem factors that lead to bloom formation on relevant timescales to inform the selection of a panel of informative ecosystem-wide indicators. Two key research objectives underpin this work:
1. What constitutes a healthy marine microbiome, including a better understanding of the natural dynamics of grazers, viruses and prey, rather than simply taking snapshots of ‘standing stocks’

2. What changes occur when the chemical/physical/biotic balance is perturbed by anthropogenic or natural factors?

Translating this knowledge into sensitive indicators in our region requires higher frequency monitoring of selected at-risk ecosystems, e.g. using autonomous DNA samplers (SaFa) for metagenomics sampling with ancillary environmental data. This would allow us to extract relevant physical and biological (molecular) indicators, including toxin genes, from cross-correlations and shifted time series. DNA samplers could eventually be replaced with the next generation of in-situ real-time molecular/chemical monitors.

Much of this work is currently ongoing in linked local and international projects (listed below) and bioinformatics infrastructure already exists. However, IMOS infrastructure and other interested groups could help select appropriate monitoring sites and facilitate deployment of Autonomous DNA samplers which are due for delivery in 2016. Another alternative is to utilise citizen science microbial oceanography kits such as those deployed by <indigoVexpeditions.org> or Ocean Sampling Day to collect

**Related projects**

**AMMBI – BPA – IMOS  Marine Microbes**
Related activities include: Monthly NRS metagenomes to identify a core suite of molecular indicators suitable for the next generation of in-situ monitors. Establishing new coastal monitoring sites.

Related activities include: Modelling the costs and benefits of molecular processes at the single cell scale; Isolating phage and viruses of regional cyanobacteria and microbial phytoplankton; The first characterization of viral lysis rates and protist grazing rates on bacterial and phytoplankton communities

**Mapping and Modelling Australia’s Unseen Microbial Diversity: ARC DP Brown, Ostrowski, Bodrossy Beeman, Fuhrman.**
Related activities include: Providing the baseline for prokaryote and eukaryote community dynamics detailed with molecular and biochemical techniques. Blue water microbiomes provide context for coastal and estuarine processes.

**Identifying keystone microbes and planktonic guilds in Australia’s oceans.** ARC DP Brown, Seymour, Ostrowski, Bodrossy, Levine, Fuhrman.

**Understanding the viral composition of phytoplankton blooms in Singapore coastal waters**
Lauro et al. Viral isolation, forecast modelling, development of viral biocontrol of HABs
Dr Penelope Ajani, Chancellors Post Doctoral Fellow, Climate Change Cluster (C3),
University of Technology Sydney
http://www.uts.edu.au/staff/penelope.ajani

Research with respect to HABS

My research has focused on the evolution, ecology and biodiversity of phytoplankton
(including harmful algal bloom species) in south eastern Australia. I have collated and
published two compendiums of reported algal blooms in New South Wales (1890 to 2009)
and have recently published a review of eighty years of phytoplankton research in south
eastern Australia.

My research into harmful algal blooms includes a meta-analysis of the risk-taxa and risk-
zones of harmful algae in the oyster growing estuaries of New South Wales. I have
characterized (morphotaxonomy, molecular phylogeny, toxicity and distribution) species
belonging to the harmful diatom genus *Pseudo-nitzschia* (responsible for Amnesic Shellfish
Poisoning) in SE Australia and am currently working on a *Pseudo-nitzschia* probe, which
once fully developed, will provide an inexpensive screening test that will safeguard the
seafood industry from economic loss and protect the health of consumers from these toxic
algal outbreaks.

Using Australia’s longest and continuous phytoplankton and water quality data series from
the Hawkesbury River, I have undertaken mathematical modelling to identify key drivers
which underpin *Dinophysis* blooms (responsible for Diarrhetic Shellfish Poisoning) in this
estuary. Future work planned for this dataset includes modelling of other toxic species
(*Prorocentrum cordatum, Pseudo-nitzschia* etc), examining harmful species niche
partitioning and modelling to test resistant assemblage theories.

Another recent study was to collate the most up-to-date research on harmful algal species
and their potential risks relevant to the Hawkesbury River. This study included microalgal
species listed in the New South Wales Food Authority’s Marine Biotoxin Management Plan
(MBMP, 2015), the National Health and Medical Research Council (NHMRC) Guidelines
for Managing Risks in Recreational Waters (2008), and other species identified as being
present in the Hawkesbury River as a result of Hornsby Shire Council’s monitoring program.
Furthermore, species which have been identified in other areas of Australia which might pose
a threat to the east coast of Australia and/or the Hawkesbury River as a result of warmer
waters shifting south were also included in this study.

Using the sampling infrastructure provided through Australia’s Integrated Marine Observing
System, my research also has examined phytoplankton time series data from the long term
coastal monitoring station 8 km offshore from Sydney (Port Hacking 100m station). We have
also utilised IMOS phytoplankton and oceanographic data to establish an empirical basis for
Australia’s phytoplankton bioregions. We are also using IMOS data to examine the temporal
and spatial distribution of harmful algal species around Australia’s coastline as measured by
these coastal stations.
Some challenges I see to HAB prediction

- most HABs occur in estuaries in Australia (not coastal ocean)
- In NSW alone there are approximately 184 important estuaries, each being driven by a unique set of processes.
- little is known about life histories, physiological ecology and trophic interactions of HAB species in Australia
Dr Ruth Eriksen
Phytoplankton Ecologist (UTAS ACE CRC, Storm Bay, Southern Ocean Time Series)
Phytoplankton Analyst (CSIRO, National Reference Stations, AusCPR)

Research interests
My main interests in HAB species stem from my work as an ecotoxicologist, and experience in establishing a commercial laboratory for identification of marine and freshwater HAB species for the aquaculture industry. I have significant experience in the design of sediment and water quality studies for the salmon and oyster aquaculture industries, and time-dependent reporting requirements for regulatory and management purposes. I maintain an interest in QA/QC procedures associated with microscopy-based analysis of HAB species, contributing GLP and BP input into the ASQAAC (draft) Manual. More recently, my energies have been focused on improving taxonomic skills and competencies for a range of programs, including FRDC-funded baseline assessment of Storm Bay for the salmon industry, and continental-scale monitoring through the IMOS NRS and AusCPR programs.

Other interests include stakeholder engagement to develop timely, easily understood management plans, reports and prediction products, and assessment of impact of environmental conditions on phytoplankton community composition and seasonal cycles.

Background
Bachelor of Applied Science with Hons, Analytical Chemistry and Aquatic Biology (Deakin)
PhD, Marine Ecotoxicology (UTAS)

Relevant Experience
2000-2004 Manager, Algal Unit, Department of Primary Industry, Water & Environment, Tasmania
- Established Tasmania’s first commercial algal identification service for marine & freshwater HAB species, to meet the needs of Tasmanian Shellfish Quality Assurance Program, aquaculture industry, municipal and state waste water regulation, and health authorities.
- Approved NATA signatory for both marine & freshwater algae identification
- Establishment of ecotoxoicology testing facility for marine and freshwaters
- Overall quality assurance and quality control of results for the Algal Facility.
- Extensive development and documentation of biological, chemical & sampling methodologies, focusing on harmful algae.

2004-2007 Scientific Officer, Derwent Estuary Program
- Coordinated and managed ambient water quality monitoring and sediment water quality monitoring programs for industry, State government and local councils

2007-2010 Research Fellow Tasmanian Aquaculture and Fisheries Institute/IMAS
- Impacts of nutrient enrichment on sediment and water quality processes in the Derwent (ARC, CI D.J. Ross)
• Impacts of organic enrichment on sediment and water quality in Tasmanian salmonid industry (FRDC, CI C. Macleod)
• Impacts of copper anti-foulants on on sediment and water quality in Tasmanian salmonid industry (FRDC, CI C. Macleod)

2010-2014 Phytoplankton Taxonomist, Institute for Marine and Antarctic Studies

• Salmon Sub-program: Predicting marine currents, nutrients and plankton in the coastal waters of south eastern Tasmania in response to changing weather patterns (FRDC, CI Crawford)

2014-current Phytoplankton Ecologist, Institute for Marine and Antarctic Studies & ACE CRC

• Salmon Sub-program: Predicting marine currents, nutrients and plankton in the coastal waters of south eastern Tasmania in response to changing weather patterns (FRDC, CI Crawford)
• IMOS Southern Ocean Time Series phytoplankton community composition and environmental drivers (PI Trull)

Selected HAB training and projects

With funding from FRDC and Safefish, I travelled to Denmark in 2014 to participate in the IOC Taxonomic Workshop for Harmful Algae Identification, completing both identification and enumeration courses. Awarded the “Certificate of Proficiency in identification of Harmful Marine Microalgae” by IOC following examination. Prepared report for Safefish and FRDC on Best Practice in Enumeration of HAB species.

“Guidelines for Managing Cyanobacteria (Blue-Green Algae) Blooms in Sewage Treatment Lagoons” 2011, for Environment Division, Department of Environment, Parks, Heritage & the Arts


In your experience what will be the most challenging part for achieving HABS forecasting and how do you think your research can play a part in overcoming this challenge?

Stakes are high: human health is of the utmost importance, financial risks to growers are great, and the ability of industry, regulators and markets to respond to rapidly changing conditions and the level of risk is dependent on timely, accurate and reliable information. Prediction systems potentially form part of a battery of tools available to growers, managers and exporters to reduce risks to human health and the hard-won reputation of our high-value products. I want to contribute to improved models by understanding succession in marine phytoplankton communities and the environmental triggers via which HAB species transition from back-ground concentrations to biotoxin nightmares. I also bring a background of monitoring, analysis and reporting of HAB data based on LM techniques, and the requisite QA/QC protocols necessary for reliable data inputs.
Gustaaf Hallegraeff HAB projects 1986-2016

SEAFOOD QUALITY ASSURANCE. As a result of my work on the toxic PSP dinoflagellate Gymnodinium catenatum, in 1985 Tasmania was the first state in Australia to start monitoring for dinoflagellate toxins in shellfish. This was subsequently extended to Vic, SA, WA, Qld and led to the creation of the Australian Shellfish Quality Assurance Program (ASQAP). In 2012 Alexandrium tamarense toxic dinoflagellate problems caused the Tasmanian economy $23M in lost revenue, and -funded by a $600k Fishing Industry Development Corporation grant- I stepped up monitoring efforts by introducing antibody based rapid screen technologies (Neogen PST kit) which are currently undergoing international validation. In 1989 I coordinated a UNESCO training workshop on the toxic dinoflagellate Pyrodinium bahamense in the tropical Indo- West Pacific, and in 1996 I identified the fish-killing raphidophyte Chattonella marina in Australian waters and linked it to a major tuna aquaculture mortality event in South Australia ($45M loss).

BALLAST WATER BIOSECURITY . My detection of viable toxic dinoflagellate cysts in ships' ballast waters led in 1990 to the introduction in Australia of special ballast water quarantine regulations which ultimately in 2004 were adopted by the International Maritime Organisation (IMO) and will be internationally ratified in Sep 2017. To track down the overseas source populations of introduced toxic dinoflagellates, I pioneered the application of molecular markers, with Ph.D. students Chris Bolch, Miguel de Salas and Tae Guy Park. In collaboration with BHP shipping engineers Geoff Rigby and Alan Taylor, I pursued ballast water treatment and management options using resistant dinoflagellate cysts as a model organism.

INTERNATIONAL HAB COMMITTEE MEMBERSHIPS . (1) UNESCO group of international experts on Harmful Algal Blooms (since 1990), which led to editorship-in-chief of an authoritative Manual on Harmful Algal Blooms (UNESCO Monograph on Oceanographic Methodology 2003; the key text book for the HAB discipline). I am currently chairing for IOC-UNESCO a follow-up effort to produce Global Harmful Algal Bloom status reports; (2) Host of the 9th International Conference on Toxic Marine Phytoplankton in Hobart in Feb 2000, attended by 526 participants from 47 countries. I subsequently played a key role in all 8 follow up conferences in this series; (3) Vice-President of the International Society for the Study of Harmful Algae (ISSHA) of which I was a founding member. I currently serve on the editorial boards of the journals J. Applied Phycology and Harmful Algae, and in the past Phycologia and Journal of Phycology.

Top Ten HAB Publications


**Major HAB Grants**

2014-2017 600k FRDC Improved understanding of Tasmanian harmful algal blooms and biotoxin events to support Seafood Risk Assessment. Outcome: introduction of Neogen PST kits into Tasmania; AOAC validation. Continuing work on lobster and scallops PST.

2000-2015 1M ARC Understanding Fish Killing Mechanisms by Harmful Algal Blooms. Outcome: Fish kills are not due to known phycotoxins but due to fragile algal cells lysing to release free fatty acids and reactive oxygen species to produce lipid peroxidation products that damage fish gills. Implications: recently killed fish are suitable for human consumption. New ichthyotoxicity clay mopping strategies (applied eg. in Korea 2015). PhD Judi Marshall, Ben Mooney, Tae Gyu Park, Jorge Mardones, Andreas Seger.


2007-2010. 200k ARC Linkage. Genetic basis for saxitoxin production (with Shauna Murray, Brett Neilan)


HAB species in Storm Bay

Kerrie Swadling, Ruth Eriksen, Jason Beard, Christine Crawford.

We sampled 5 sites in Storm Bay from November 2009 to April 2015, on a monthly or bi-monthly schedule. Integrated water column samples for phytoplankton composition analysis were collected from the surface to 10m depth using a weighted Lund tube ("snake"). Samples were preserved in Lugol’s, concentrated using standard settling techniques and examined by phase contrast light microscopy (Leica DMLB2) in a Sedgewick-Rafter chamber. Temperature, salinity, fluorescence, and dissolved oxygen were profiled at each site using a Seabird SBE 19 plus CTD. Water samples were collected using an 8 L Niskin bottle from 0.5 – 1 m below the surface, at 10 m depth, and within 5 m of the seabed. NOx (nitrate + nitrite), phosphate, silicate and ammonium were measured at each site on each sampling occasion.

Sampling sites are shown on the map below. Note that site 9 (mouth of Frederick-Henry Bay) was not sampled for phytoplankton. Over 300 species/taxa were identified and the analysis of HAB species forms a small component of the larger project.

Example of data: *Pseudo-nitzschia* spp.
Peter Thompson  
Senior Principal Research Scientist  
Acting Research Director  
CSIRO Ocean and Atmosphere

Based on 40 years of experience I have some personal suggestions for making HAB science more quantitative.

1. Obtain more or better data.
   a. The largest single improvement would be to gain access to the existing monitoring of HABS around Australia. These data are NOT readily available and this is a major impediment to improved understanding of the HAB dynamics and trends. Consider South Australia where there are tens of sites sometimes monitored weekly. A similar situation exists in Tasmania. The data may need to amalgamated into regions to provide anonymity to individual businesses but this could be easily achieved. Gaining access to this resource through IMOS should be a priority for Australia.
   b. Other options for more or better data. A majority of the most toxic species are dinoflagellates. Their pigments are similar to most phytoplankton and there does not seem to be a simple method to detect these blooms using remote sensing (for discussion?). There are a number of groups around the world working on genetic techniques. These show real promise and there are some commercial products available. Reducing the total cost per sample (collection, processing etc.) is required to make this commercially viable in Australia. Various researchers/companies have developed in situ microscopes and flow cytometers but these remain very expensive to purchase and operate.

2. Predicting when and where
   a. For many years phytoplankton ecologists have felt that we should be able to build mechanistic models to predict annual dynamics of most species. Yes we can manage reasonable predictions of total biomass (often measured as chla). Yet models that successfully predict individual species are almost non-existent (for discussion?). So this remains an elusive dream for 99.99% of all species. The reasons for the slow progress are many including the large number of species (~ 30,000), only a few have studied for their basic responses to light, nutrients, and temperature. More complex ecological interactions (e.g. mixotrophy or selective grazing) remain largely in development.
   b. Statistical models may provide more predictive power sooner than mechanistic models. A relatively modest set of environmental conditions (e.g. the average insolation, temperature, nutrients, wind and depth) combined with knowledge of the presence or absence of a species should be enough to predict the likelihood of a bloom. This approach also allows us to predict the impacts of climate change on the likely phytoplankton community.
Lev Bodrossy

HABs associated work - Environmental genomics

Marine Microbes Project

In collaboration with IMOS and Bioplatforms Australia (and UNSW, UTS, MQ) we are building up a long term microbial oceanography observation database. The database consists of 16S/18S rRNA based observations of the microbial (bacteria, archaea and microeukaryotes) community structure. Samples are collected at monthly intervals at up to 6 depths at the 7 National Reference Stations of IMOS (green dots). Three stations (Maria Island, Port Hacking and North Stradbroke Island) have been sampled since July 2012. The other four NRSs joined in July 2015. In addition to the NRSs, we also sequence samples collected during voyages (purple dots) – these are used to improve the spatial resolution of the database.

The microbial community structure obtained is linked to a range of other observations (physical, chemical and other biological observations).

The Marine Microbes project has a more recent benthic/coastal component (in addition to the above “pelagic” component), looking at microbial communities in coastal habitats, primarily in sediments and on microalgal surfaces.

The long term observations at the NRSs in particular should enable us to analyse annual trends in the dynamics of algal species with HAB potential. Linking this to observations on the bacterial community and contextual chemical and physical observations could help to better understand potential drivers of HABs - and thus better predict their occurrences.
Remotely deployable autonomous devices for microbial oceanography

We are developing novel in-situ, remotely operated water sampling and analysis hardware for high spatial and temporal resolution microbial analysis:

SAFA – allows up to 24 samples to be collected over times up to several months. Samples are archived on board and analysed in the lab. Cost is in the region of $40,000. Remote triggering capability under development. Otherwise ready for deployment.

STAN – a low cost version of the SAFA capable of only one sample collection. The low cost allows many units to be deployed together or spread out across a wide area to offer flexibility in where and when samples are collected. Test deployment in progress, expected to be ready for deployment by December 2016.

MOBI – a research project to develop fully automated systems for sampling and molecular analysis of water samples for microbes. Analysis onboard is digital quantitative PCR, enabling the quantification of desired targets by “plugging in” a specific qPCR reaction. No price as yet, but target is $30k.
Martina A. Doblin  
Productive Coasts Research Program Leader, University of Technology Sydney: C3

Martina has broad knowledge of aquatic ecology, oceanography, environmental sensing technology, water resource management and biosecurity which she uses to tackle important questions in assessing ocean health and productivity; determining a national blue carbon budget (i.e., carbon captured and stored by oceans); and improving water quality and biosecurity.

PROFESSIONAL SERVICE

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<tr>
<th>Year</th>
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<tr>
<td>2014–</td>
<td>College of Experts, Australian Research Council, Biological Sciences and</td>
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<td></td>
<td>Biotechnology Panel</td>
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<td>2013–</td>
<td>Leader, NSW node for Integrated Marine Observing System (IMOS)</td>
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<td>2013–2015</td>
<td>Leader, Bio-optical Instrumentation and Observing Working Group (IMOS)</td>
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<td>2006–2010</td>
<td>Secretary, Australasian Society of Phycology and Aquatic Botany</td>
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<td>2009–</td>
<td>Scientific Advisory Committee member, Sydney Institute of Marine Science</td>
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HAB RESEARCH ACTIVITIES

- **US Department of Commerce**: Dr Doblin has made contributions to improving the understanding of the risk of bioinvasions, including toxin-producing algae, in the North American Great Lakes.
- **Water industry (Seqwater)**: Dr Doblin has contributed new knowledge of the processes regulating harmful algal blooms in water storages and estuaries, yielding an improved understanding of the ecology of toxin-producing algae (cyanobacteria, raphidophytes and dinoflagellates).
- **Australian biosecurity**: Dr Doblin’s research on ballast water management practices, risks on the spread of invasive species through recreational boating, and on techniques for detection has made important contributions to marine pest policy in Australia, with her expertise contributing to major policy documents and current surveillance activities.
- **Fisheries and aquaculture**: Dr Doblin is developing cost-effective optical techniques to detect algal blooms and estimate primary productivity in Australia’s coastal waters, a critical ecosystem service underpinning marine foodweb function and fisheries yields.
- **Range extension of tropical HABs**: Dr Doblin is using experimentation, observation and modelling techniques to examine the ecology of the causative organisms of ciguatera fish poisoning.

RELEVANT PUBLICATIONS


Hong Y, Burford, M.A., Udy, J., Doblin MA (2013), The cyanobacterium Cylindrospermopsis raciborskii is facilitated by copepod selective grazing. Harmful Algae 29:14–21


Please provide a 1 to 2 page summary of your research and activities as it relates to HABS:

Dr. Robert Johnson - I am a senior environmental scientist with the Australian Government’s Bureau of Meteorology. I have a background in Biological Oceanography and Remote Sensing.

I specialise in the development of regionally tuned models for environmental remote sensing. Recently I’ve worked on identifying specific types of phytoplankton, such as coccolithophorids, from space and on refining NASA’s global ocean colour models for use in the Southern Ocean and in the Australian coastal ocean.

I am currently the Bureau’s lead on the operational eReefs Great Barrier Reef ocean colour based Marine Water Quality and sea surface temperature based Coral Bleaching environmental monitoring systems. I’m part of the environmental intelligence section at the Bureau. We have a strong interest in environmental now-casting in the coastal marine environment and are currently developing forecasting capabilities in several regions of the Australian coastline. We focus on observing and forecasting ecological information in coastal marine ecosystems and their responses to environmental drivers and on communicating the resulting information and impacts to people, economies, governments, and communities.

The Bureau has a mandate to warn the Australian community of environmental hazards. Harmful Algae are an obvious candidate for an operational observing and forecasting service due to both the environmental and human hazard they present. I am attending these meetings to express the Bureau’s interest in the field of Harmful Algal Blooms and to build a partnership with this group to explore how we might lead this research into future operational services.
Experience in Harmful Algal Bloom research – Roger Proctor

Before coming to Australia in 2008 I used to run the “Modelling & Observations for Coastal Seas” research theme at Proudman Oceanographic Laboratory, Liverpool, UK (now National Oceanography Centre, Liverpool). A big part of this work was the development of pre-operational models for eventual operational implementation at the UK Met Office. We (in collaboration with Plymouth Marine Laboratory) developed a modelling system called POLCOMS (POL Coastal Ocean Modelling System) which consisted of 3-dimensional baroclinic hydrodynamics coupled with ERSEM (European Regional Seas Ecosystem Model), sediment transport and surface waves. This coupled system became the world’s first shelf seas ecosystem forecasting system when it became operational in 2007. This modelling system forecast hydodynamics (currents, sea surface heights, temperature and salinity) and ‘ecosystem’ parameters (nutrients (Phosphate, Nitrate/Nitrite, Silicate), oxygen, microbes, functional groups of phytoplankton and zooplankton) up to 5 days ahead.

Around the same time the European Union legislated a number of acts impacting on the water quality of EU waters (e.g. Marine Strategy Framework Directive, Bathing Waters Directive, Urban Waste Water Directive) which, together with international agreements such as the Oslo and Paris Convention’s (OSPAR) ‘Strategy to Combat Eutrophication’, required action from member states.

The importance of monitoring microbiological water quality within these regions was highlighted within the European Bathing Waters Directive (EU DIRECTIVE 2006/7/EC) which required all European agencies responsible for environmental issues to provide microbiological and bacterial water quality monitoring and forecasting of bathing waters by 2015. Following discussions with the UK Environment Agency, who had responsibility for monitoring bathing waters around the UK, I initiated a project called AlgaRisk, which looked to combine the forecasts of the operational POLCOMS with the Earth Observation products produced by the PML EO group with the aim of identifying the likelihood of Harmful Algal Blooms impacting on the UK coast.

After I left the UK this project ran for several years. The results of the project are described in Shutler et al, 2015, Computers & Geosciences 77, 87-96, “Operational monitoring and forecasting of bathing water quality through exploiting satellite Earth observation and models: the AlgaRisk demonstration service”. Here follows is a summary extracted from this publication.

AlgaRisk focussed its efforts on techniques to monitor and study high biomass harmful algal (microbiological) species that can potentially impact bathing waters (tourism) and marine life during the summer months. The term ‘harmful algal bloom’ (HAB) refers to the increase in density of microalgae leading to potentially or actual harmful effects. HAB forming species often occur naturally in the marine environment, but human activity is thought to play a role in their increasing occurrence (Hallegraeff, 2010, Journal of Phycology, 46, pp 220-235). For UK waters, the dinoflagellate Karenia mikimotoi is the high-biomass HAB species of most concern and it has previously been identified in harmful concentrations in other waters around the world. The frequency of the Karenia mikimotoi blooms appears to be increasing in European waters.

The AlgaRisk demonstration service was developed to provide a microbiological monitoring and forecast capability for dense algal blooms towards supporting the statutory obligations of bathing water regulatory agencies. AlgaRisk combined data from an operational hydrodynamic-ecosystem (physical-biological) model, at 6km resolution, with near-real time satellite Earth observations (EO), at 1km resolution (MODIS Aqua and AVHRR level 2 data). All of these data were made available via a dedicated web portal, where the end-user could access and visualise daily and historical data. The combination of the model and EO data were used to guide targeted in situ sampling and monitoring to verify specific algal species. The AlgaRisk ‘demonstration service’ was implemented pre-
operationally and exploited by agency staff between 2008 and 2010; the service continued (as a free to access service) until 2013. Throughout the demonstration study the data products were updated on a daily basis and automatically uploaded to the AlgaRisk web portal.

The MODIS level 2 EO data were used to produce three products. 1) Case 2 chlorophyll-a estimates were generated using an approach developed for waters within the English Channel and Bay of Biscay, estimating the coastal chlorophyll-a concentrations with zero bias and an $r^2$ of 0.7. 2) Maps of the likelihood of the phytoplankton species Karenia mikimotoi were generated with a correct classification rate of 86% with a false alarm rate of 0.01. 3) Maps of the location of potential high biomass blooms were generated with a correct classification rate of 68% with a false alarm rate of 0.24.

The satellite Earth observation data used within the AlgaRisk system provided a near-real time microbiological monitoring capability, and the model data provided a forecast capability. The nowcast model data provided a backup solution for monitoring if persistent cloud meant that no Earth observation data were available.
Dr Nick Hardman-Mountford
CSIRO

My research activities have been around phytoplankton detection algorithms at a whole of community level and understanding their ecological drivers, which is important for understanding HABs in the context of natural variability. Various publications below.

The biggest challenge will be forecasting events as (a) different HAB events seem driven by different environmental conditions and (b) we don’t measure enough of the system to always know what these are. So to come up with a predictive system, we need to tackle it on several fronts:

1) Understanding environmental drivers of HAB events
2) Improving space-time match-up of events in NRT modelling through data assimilation
3) Coupling observational early-warning indicators with models to improve predictions.

Some Publications:


Lesley Clementson

Research Group Leader – Temperate Coastal and Team Leader – Algal Ecology and Resources within CDM program within CSIRO Oceans and Atmosphere

Experience

For the past 20 years I have worked on the relationship between the environmental and bio-optical parameters and HAB formation. I have designed and led field work in projects concerned with HABs in southern Tasmanian waters and have worked closely with algal taxonomists to determine what relationships exist between in situ water column parameters and the HAB species present.

I manage the CSIRO Bio-analytical Facility and have the only validated method for pigment analysis in Australia. The Facility also routinely analyses the in situ bio-optical samples for most groups doing remote sensing/ocean colour validation in Australia. I have also developed a laboratory method to determine the phycocyanin concentration in water samples from inland systems where cyanobacterial blooms are present and pose a health risk to the public and I am currently implementing laboratory methods to determine the concentration of PSP toxins in water and shellfish samples.

Within the CSIRO Hobart site I am a co-manager of the Algal Facility which has both Biosecurity Containment (BC) level 5.2 and Physical Containment (PC) accreditation. I work closely with the staff of the Australian National Algae Culture Collection (ANACC) which is housed in the Algal facility and is home to several species/strains of HABs.

I am a member of the International Working Group for Phytoplankton Functional Type (PFT) Algorithm Development and lead the development of an international database of parameters (pigments, absorption coefficients, flow cytometry, algal counts etc) that are used for the comparison of the different algorithms.

Past HAB projects/reports


Keesing, J., Heine, J. (Eds.), 2006. Strategic Research Fund for the Marine Environment (SRFME): Final Report, December 2006. CSIRO, (senior author of section 3.2.3 and co-author of section 3.2.2).


“what will be the most challenging part for achieving HABS forecasting and how do you think your research can play a part in overcoming this challenge?”

The Aquaculture industry would benefit enormously, if we could forecast the likelihood of a HAB forming. I believe that only with archived data and current data of environmental - physical chemical and biological – conditions and algal species, together with species physiological knowledge from before during and after bloom formation can we determine possible relationships. In the past the formation of a bloom has often set off a sampling strategy to look at the “bloom”, but sampling during times of non-bloom activity is equally as important.
Dr Christopher John Stanley Bolch (Phytoplankton biologist IMAS-UTAS)

I am an algal biologist with expertise in culture, molecular systematics and diversity of marine and freshwater HAB species. My current research is increasingly focussed on 1) development of efficient cost-effective and specific detection systems for harmful algae in marine and freshwater systems; and 2) the complex interactions between the phytoplankton and microbial communities, a poorly understood but important driver of phytoplankton community dynamics and biogeochemical processes such as carbon and iron uptake/cycling.

Background
Undergraduate degree in microbiology (1983-1986); Hons and PhD in phycology (1999). Thirty years of experience in HAB-related research in Australia (CSIRO and UTAS) and the United Kingdom (Scottish Assoc. for Marine Science).

Relevant experience (1986-2016).

Taxonomy, molecular systematics and phylogeny of HAB species. Over the past 30 years my research has integrated classical and molecular approaches to the systematics, diversity, mating systems, lifecycles and phylogeny of HAB species. My work has resolved fundamental problems with species concepts/boundaries, developed new analytical tools for molecular identification and lifecycle analysis, and clarified cryptic-speciation in a number of genera (e.g. Gymnodinium, Pseudo-nitzschia, Alexandrium and Karenia/Takayama/Karlodinium, Dinophysis, Cryptoperidiniopsis), a completely new phylum, several new species, and improved the known distributions of toxic and harmful species in the Australasian region.

Global diversity, dispersal and biogeography of toxic dinoflagellates.

Biogeography is discipline of synthesis drawing on, and accurate species global distributions are essential for understanding global biogeographic patterns and distinguishing natural versus anthropogenic dispersal. My research pioneered the use of DNA fingerprinting and bacterial symbiont communities as tools to examine small-scale diversity and biogeography, establishing the high genetic and biochemical diversity of dinoflagellates at local (estuary-level) and regional (continental) scales.

Seafood biotoxins and HAB species detection.

While based in UK, I was the first to culture and identify both Pseudo-nitzschia seriata as the species responsible for widespread ASP in northern UK during the late 90s. Recently I cultured and conclusively identified Alexandrium fundyense as the species responsible for 2012 PST outbreak on Tasmania’s east coast, leading to FRDC-funded research with G. Hallegraeff examining the distribution, diversity and toxicity of Australian Alexandrium species. Water Industry research is also developing real-time in-situ detection networks for toxic cyanobacteria blooms in drinking and irrigation water- testing concepts/methods for future application to biotoxins in coastal waters.

Selected HAB Publications


Selected HAB-related research grants/projects

2014-17. FRDC. $600K. Improved understanding of Tasmanian harmful algal blooms and biotoxin events to support seafood risk assessment. (Hallegraeff & others).

2008-12. ARC-DP. $315 K. Polyketides as the conserved basis for diverse marine toxin synthesis. (with Neilan & Moffitt)


2001-03. ABRS. $90K. Molecular phylogeny and morpho-taxonomy of Australian gymnodinoid dinoflagellates. (with G Hallegraeff).


Challenges for HAB prediction
1. Cost/resources – 10s of millions required to gather sufficient data to inform and paramaterize models even for one species (e.g. Alexandrium/GOM).

2. Feasibility - HABs comprise >100 species from different genera/orders/classes of algae; with different environmental optima; >dozen different major phytoxins groups. Process-based prediction at species level is unrealistic due to the myriad of factors/interactions (plankton communities semi-chaotic systems? ) Feasible perhaps for coastal species where physical factors dominant given sufficient spatially relevant data and suitable physical scale of modelling?

3. Blooms of many species are inshore, estuary bound/driven processes. Can we realistically model every possible estuary/bay system? Simplified operational models (machine-learning?) and/or risk-based models may be achievable and also sufficient to inform management response.
Dr Andrew Fischer’s research focuses on understanding the interaction between physics and biology in the coastal ocean and estuaries. This work integrates observation from satellites, airborne sensors and in situ measurements from ships, autonomous underwater vehicles and moorings. By applying spatial and statistical approaches, this research focuses on understanding dynamic phenomena in rapidly changing coastal waters, in particular, the development of algal blooms and the transport and fate of land-based materials into the coastal ocean.

HABs are complex phenomena influenced by an interplay of biology and physics and driven by oceanographic processes/phenomena. Studies have shown that HAB inception, development and spread has been attributed to internal wave activity and nutrient transport across the shelf break (Ryan et al., 2005), nutrient transport across the land-sea interface (Fischer et al., 2014; Gibble and Kudela, 2014), persistence of frontal zones in upwelling shadows that lead to retention and stratification (Ryan et al., 2010) and interannual variation in cyst abundance (Anderson et al, 2014). The one thing that is clear is that the HAB events around the globe have different triggers and may be influenced by a complex combination synergistic oceanographic phenomena.

The challenge to understanding and describing HABS lies in acquiring data at appropriate spatial and temporal scales. This will require enabling multidisciplinary observations across sensors and platforms (e.g. satellites, mooring, AUVs, UAVs) at regional and sub-meso scales and across a variety of time scales. My collaborative, interdisciplinary research integrates observations from satellites, unmanned aerial vehicles (UAVs), autonomous underwater vehicles (AUVs), moorings and in situ measurements to describe HAB events. Advancing predictive skill is dependent upon understanding the physical and biological forcing underlying these complex phenomena.