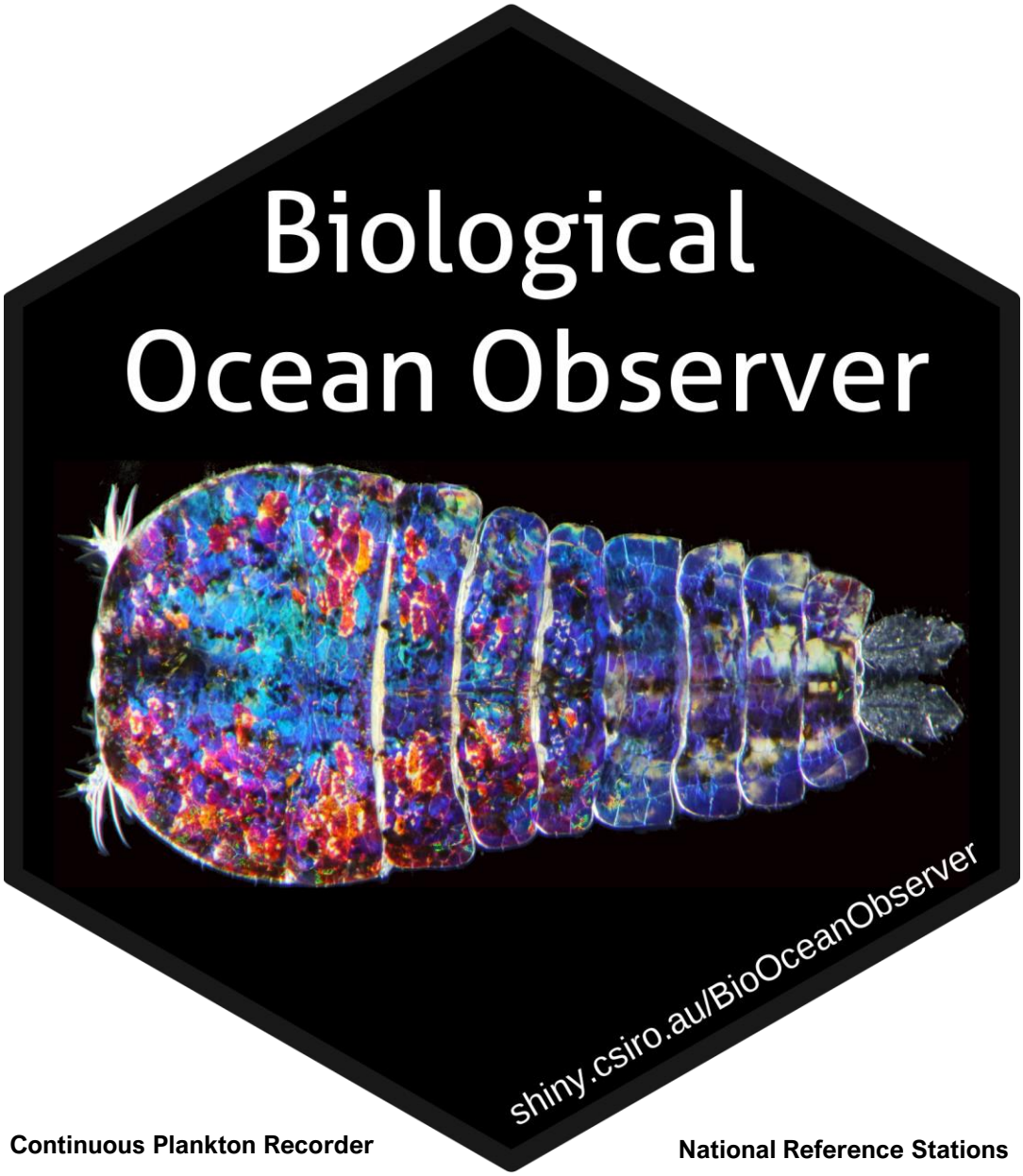
Issue 15
March 2024

IMOS Integrated Marine Observing System

IMOS

Australian Plankton Survey



Continuous Plankton Recorder

33,516 Phytoplankton Colour Index segments counted
7,689 zooplankton segments counted
11,153 phytoplankton segments counted

167,580 nautical miles towed
213 trips processed

941,495 zooplankton counted
174,876 phytoplankton counted

National Reference Stations

990 zooplankton samples counted
999 biomass samples completed
909 phytoplankton samples counted

644,372 zooplankton counted
394,674 phytoplankton counted

It is great that I can write an introduction to our newsletter and get to highlight that our plankton time series have now been going for 15 years. It's quite a milestone! Most time series end within a couple of years of being established. I'd like to thank the Integrated Marine Observing System (IMOS), CSIRO, and our collaborators for their continued support. The IMOS time series are the longest running plankton program in Australia and one of the longest in the Southern Hemisphere.

This milestone could not have been reached without the continued commitment of the IMOS-CSIRO plankton team. After 15 years working on the same two projects (the Australian Continuous Plankton Recorder survey (AusCPR) and the National Reference Stations plankton sampling), it can be challenging to maintain motivation. The team has remained motivated by continually striving to achieve best practice. For example, in terms of improving our taxonomic identification, the team has continued to undertake taxonomic training to hone their skills, develop taxonomic sheets and lucid keys to standardise our identification and make them freely available to other scientists globally, and build image databases to improve taxonomy. The team has also been busy in other science areas related to plankton, including involvement in field trips and cruises, contributing to ecosystem assessment reports, analysing data, continually improving the plankton database, and writing scientific papers. In my experience, there are few plankton parataxonomists in the world who can identify both phytoplankton and zooplankton to species – and even fewer who can do this from samples collected from a range of sampling devices, including CPRs, bottles and net samples. I continue to be impressed with the taxonomic expertise, motivation and professionalism of the team.

A challenge over recent times at CSIRO is that all plankton team members have been pulled onto non-plankton related projects. This is because our team has a lot of field and lab expertise that is in high demand at CSIRO. This has challenged continued delivery of our plankton work. We recently had a full-day team-building exercise at the UQ Atrium in the city. This was excellent for us to re-invigorate our camaraderie and to speak directly about what is working and what we need to improve. In response to feedback, we have modified the way we allocate samples to be counted, which has increased transparency and team communication. Although running a long-term time series means we need to keep our counting methods relatively unchanged, we continue striving to improve our procedures that support our counting.

I would like to take this opportunity to highlight some of our recent papers. These have been across a spectrum of different areas related to plankton. One of the main ways that our plankton data and expertise is used is to support modelling efforts. Tyler Rohr – focusing on how zooplankton are parameterised in biogeochemical models – has produced two papers. In Rohr et al. (2022), they provided recommendations on the functional form of zooplankton grazing relationships and their parameterisation in biogeochemical models. In Rohr et al. (2023), they compared outputs from 11 Earth System Models that included zooplankton. They found that the largest source of uncertainty in their representation of the marine carbon cycle – critical to estimating how hot the Earth will be in the future – was zooplankton grazing, which had >3 times larger uncertainty than that of net primary production. This revelation highlights that there needs to be more effort in robustly modelling zooplankton. A paper by Coleen Petrik and co-authors was the first paper to assess how well zooplankton biomass was estimated in Earth System Models (these are the models used by the IPCC) agrees with observations, including those from our IMOS plankton data (Petrik et al. 2022). Although they found that most models were able to reasonably simulate the large regional variations in mesozooplankton biomass globally, there was huge discrepancies in some areas, and the authors called for more data on zooplankton biomass from around the world for model validation.
Lastly, Ryan Heneghan and colleagues used an ecosystem model to investigate zooplankton communities globally and found that under climate change., future oceans favour food webs increasingly dominated by carnivorous (chaetognaths, jellyfish and carnivorous copepods) and gelatinous filter-feeding zooplankton (larvaceans and salps) at the expense of omnivorous copepods and euphausiids (Heneghan et al. 2023).

I would like to highlight the fieldwork in the Indian Ocean by Claire Davies. Claire was part of the second International Indian Ocean Expedition in 2019, which repeated a transect along 110°E that was traversed in the 1960s. A series of papers have now been published, with Claire involved in several of them. These papers analysed plankton communities over the broad-range of latitudes of the transect, and focused on: highlighting the key role of mixotrophs in the zooplankton community (Davies et al. 2022); identifying species of the genus *Tripos* that were indicators of water masses (Anderson et al. 2022); describing the importance of microbial biomass, production and grazing in the region (Landry et al. 2022); and investigating the low temperature sensitivity of picophytoplankton (Landry et al. 2022).

On the taxonomic front, we continue to work with our long-term collaborator, Gustaaf Hallegraeff, who has now retired from the University of Tasmania. Ruth Eriksen and Claire Davies collaborated with Gustaaf to describe the distributions of many key dinoflagellate genera – including *Dinophysis*, *Phalacroma*, *Metaphalacroma*, *Pseudophalacroma*, *Ornithocercus*, *Histioneis*, *Parahistioneis*, *Histiophysis*, and *Amphisolenia* – based on our plankton database, which contains 9,350 records of these genera from 1938–2019. This work will help improve our Quality Control of dinoflagellate identification.

We continue to explore new sampling techniques to supplement and fill in gaps in our microscopy work. Tina Berry and co-authors showed that DNA metabarcoding data is a powerful approach for investigating the biodiversity of zooplankton, detecting many more taxa than are possible with microscopy (Berry et al. 2023). It was also clear from this work that there are gaps in the utility of molecular approaches, particularly in terms of deriving robust measures of abundance, which is relatively straight-forward using net samples and microscopy. We have also been collaborating with Luigi Vezzulli from Italy, who uses molecular approaches on formalin-preserved CPR samples. This work found that the bacterium *Vibrio* (found on copepods, which are the carrier for the human disease of cholera) and other bacteria on the Great Barrier Reef increased during and after the 2016 El Niño and intense marine heatwave (Doni et al. 2023). It was clear from these collaborations with molecular biologists that there are strengths – and some weaknesses – of all techniques we use to describe plankton communities.

I would also like to highlight a paper involving long-term changes in Harmful Algal Blooms (HABs) in the Bohai Sea (China) that Ruth Eriksen played a key role in (Li et al. 2022). These authors found marked shifts in the representative HAB-forming microalgae, from dinoflagellates before 2000 (e.g., *Noctiluca scintillans*, *Tripos furca* and *Prorocentrum cordatum*), to haptophytes from 2000–2009 (particularly *Phaeocystis globosa*), and pelagophytes after 2009 (particularly *Aureococcus anophagefferens*). These community changes were accompanied by greater phytoplankton species richness, a decrease in cell-size, and an increase in negative impacts on people. These long-term changes in HABs were linked with the combined effects of climate change, eutrophication and mariculture development.

Finally, we have written a couple of plankton-focused reviews recently. One from Laura Lilly, a visiting Fullbrigh Scholar to our lab. She was working on pyrosomes and wrote an informative review on this neglected group (Lilly et al. 2023). They found that Pyrosomes – particularly *Pyrosoma atlanticum* – form blooms in high productivity waters below 18°C and use variable-depth diel vertical migration to adapt to a range of temperatures. We were also involved in a global review of key responses of zooplankton to ocean warming, including shifts in phenology, range, and body size, and assessed the implications for the biological carbon pump and interactions with higher trophic levels (Ratnaraj et al. 2023). We highlighted key geographic gaps in monitoring coverage, and discussed an integrated sampling approach combining traditional and novel techniques to improve zooplankton observation for the benefit of monitoring zooplankton populations and modelling future scenarios under global changes.

Last thing from me – the plankton team is gearing up for attending the ICES/PICES Zooplankton Production Symposium in March 2024 in Hobart. We are busily preparing talks and posters, and are looking forward to meeting plankton researchers from around the world!

Enjoy the newsletter.

Anthony

References

Anderson MPBC, **Davies CH**, **Eriksen RS** (2022). Latitudinal variation, and potential ecological indicator species, in the dinoflagellate genus Tripos along 110° E in the south-east Indian Ocean. *Deep Sea Research Part II: Topical Studies in Oceanography* 203: 105150. https://doi.org/10.1016/j.dsr2.2022.105150

Berry TE, Coghlan ML, Saunders BJ, Jarman S, Power M, **Richardson AJ**, **Davies C**, Berry O, Bunce M (2023) A 3-year plankton DNA metabarcoding survey reveals marine biodiversity patterns in Australian coastal waters. *Diversity and Distributions* 29: 862-878. https://doi.org/10.1111/ddi.13699

Davies CH, Beckley LE, **Richardson AJ** (2022) Copepods and mixotrophic Rhizaria dominate zooplankton abundances in the oligotrophic Indian Ocean. *Deep Sea Research Part II* 202: 105136. 11 pp. https://doi.org/10.1016/j.dsr2.2022.105136

Doni L, Oliveri C, Lasa A, di Cesare A, Losaaso C, Martinez-Urtaza J, **Coman F**, **Richardson AJ**, Vezzulli L (2023) Large-scale impact of the 2016 Marine Heatwave on the plankton-associated microbial communities of the Great Barrier Reef (Australia). *Marine Pollution Bulletin* 188: 1-10. https://doi.org/10.1016/j.marpolbul.2023.114685

Hallegraeff GM, **Eriksen RS**, **Davies CH**, **Uribe-Palomino J** (2022) Marine planktonic dinophysoid planktonic dinoflagellates (order Dinophysales): 60 years of species-level distributions in Australian waters. *Australian Systematic Botany* 35 (6): 469-500. https://doi.org/10.1071/SB21023

Heneghan RF, Everett JD, Blanchard JL, Sykes P, **Richardson AJ** (2023) Climate-driven zooplankton shifts cause large-scale declines in food quality for fish. *Nature Climate Change* 13: 470-477. https://doi.org/10.1038/s41558-023-01630-7

Landry MR, Hood RR, **Davies CH**, Selph KE, Antoine D, Carl MC (2022) Microbial community biomass, production and grazing along 110°E in the eastern Indian Ocean. *Deep Sea Research Part II: Topical Studies in Oceanography 202*: 105134. https://doi.org/10.1016/j.dsr2.2022.105134

Landry MR, Selph KE, Hood RR, **Davies CH**, Beckley LE (2022). Low temperature sensitivity of picophytoplankton P:B ratios and growth rates across a natural 10°C temperature gradient in the oligotrophic Indian Ocean. *Limnology and Oceanography Letters* 7 (2): 112-121. https://doi.org/10.1002/lol2.10224

Li X-Y, Yu R-C, **Richardson AJ**, Sun C, **Eriksen R**, Kong F-Z, Zhou Z-X, Geng H-X, Zhang Q-C, Zhou M-J (2023) Impacts of multiple stress triggered dramatic changes in harmful algal blooms in the Bohai Sea. *Harmful Algae* 121: 102370. 11 pp. https://doi.org/10.1016/j.hal.2022.102370

Lilly L, Everett JD, Suthers IM, Richardson AJ (2023) A global review of pyrosomes: Shedding light on the ocean's elusive "fire-bodies". *Limnology and Oceanography Letters* 8: 812-829. https://doi.org/10.1002/lol2.10350

Petrik CM, Luo JY, Heneghan RF, Everett JD, Harrison CS, **Richardson AJ** (2022) Assessment and constraint of mesozooplankton in CMIP6 Earth system models. *Global Biogeochemical Cycles 36*, e2022GB007367. 25 pp. https://doi.org/10.1029/2022GB007367

Ratnarajah L, Abu-Alhaija R, Atkinson A, Batten S, Bax NJ, Bernard K, Canonico G, Cornils A, Everett JD, Grigoratou M, Ishak NHA, Johns D, Lombard F, Muxagata E, Ostle C, Pitois S, **Richardson AJ**, Schmidt K, Stemmann L, Swadling KM, Yang G, Yebra L (2023) Monitoring and modelling marine zooplankton in a changing climate. *Nature Communications* 14(564): 1-17. https://doi.org/10.1038/s41467-023-36241-5

Rohr T, **Richardson AJ**, Lenton A, Shadwick E, Chamberlain M (2022) Recommendations for the formulation of grazing in marine biogeochemical and ecosystem models. *Progress in Oceanography* 208(102878). 27 pp. https://doi.org/10.1016/j.pocean.2022.102878

Rohr T, **Richardson AJ**, Lenton A, Shadwick E, Chamberlain M (2023) Zooplankton grazing is the largest source of uncertainty in marine carbon cycling in CMIP6 IPCC. *Communications Earth & Environment* 4(212). 22 pp. https://doi.org/10.1038/s43247-023-00871-w

Anthony Richardson

Position: Leader IMOS Australian Plankton Survey
Location: CSIRO, Brisbane, Queensland

I manage the CPR project, I help secure funding, guide research directions, develop relationships with other plankton surveys, and support and develop CPR staff. My research interests are marine climate change ecology, plankton ecology, pelagic ecosystem dynamics, and ecosystem modelling. In my spare time I love to spend time with my family.

Anita Slotwinski

Position: Plankton Biologist
Location: CSIRO, Brisbane, Queensland

I analyse CPR & NRS plankton samples. I also manage the project website, communication materials, the zooplankton species reference collection and contribute to developing Australian taxonomic material. My research interests are in marine plankton ecology, environmental change and species response. I also enjoy photomicroscopy and expanding our photographic catalogue of Australian zooplankton.

Claire Davies

Position: Plankton Biologist
Location: CSIRO, Hobart, Tasmania

My job includes identifying and counting CPR and NRS samples. I also manage the NRS and CPR databases, and am a boat driver for SE NRS sampling. My research interests include plankton ecology, climate change impacts and the feeding dynamics between zooplankton and megafauna. In my spare time I spend as much time in and out of the water as possible.

Felicity McEnnulty

Position: Plankton Biologist Location: CSIRO, Hobart, Tasmania

I analyse CPR and NRS samples, am involved in data collation and quality control and contributing to publications and presentations. My research interests include plankton ecology, deep-sea invertebrates, introduced marine species and Antarctic marine invertebrates and fishes.

Frank Coman

Position: Deputy Leader
Location: CSIRO, Brisbane, Queensland

My role involves liaising with ships that tow the CPR, the management of the North Stradbroke Island NRS sampling, zooplankton sorting of IMOS NRS samples, and plankton analysis of CPR samples. I am interested in plankton biology and ecology, climate change impacts on marine ecosystems and aquaculture. In my spare time I play sport, enjoy fishing, camping and photographing Australian wildlife.

Julian Uribe-Palomino

Position: Plankton Biologist
Location: CSIRO, Brisbane, Queensland

My role involves analyses of plankton samples, operational tasks, data collection and quality control and contributing to publications and presentations. I am interested in biological oceanography, environmental modelling, biogeography, remote sensing and GIS.

Karl Forcey

Position: Technical Officer
Location CSIRO, Brisbane, Queensland

I am helping the survey by working on the integration of marine instrumentation to CPR projects, data recovery and quality control, maintenance and repair of CPR units and technical advice. My research interests include underwater video systems, oceanographic instrumentation and AUV's gliders and other emerging technologies.

Luke Brokensha

Position: Phytoplankton Biologist Location Australian Antarctic Division, Hobart

I am a phytoplankton taxonomist with the Institute for Marine and Antarctic Studies. My research is focused on the CPR program for the Southern Ocean (SO-CPR), funded by IMOS. This program samples the plankton found in the surface waters between the Australian and Antarctic continents, and my role focuses on phytoplankton taxonomy. The data set covers the last 30 years and is continuously growing in temporal and spatial scope. With this rich data set, we are able to track and map trends and changes to plankton communities through time and assess the impacts of climate change on the Southern Ocean.

Mark Tonks

Position: Experimental Scientist
Location: CSIRO, Brisbane, Queensland

My tasks include liaising with shipping companies, including owners, agents and crew to ensure that CPR sampling is maintained, and counting NRS and CPR zooplankton samples. I also have a coxswain's certificate and drive our research vessel to the NRS site where I then assist with plankton and water sampling. My research interests include plankton ecology, bycatch sustainability and fish and crustacean ecology. I also enjoy playing a variety of sports.

Ruth Eriksen

Position: Plankton Biologist
Location CSIRO, Hobart, Tasmania

I analyse CPR and NRS samples, and am involved in data collation and quality control and contributing to publications and presentations. My research interests are phytoplankton ecology and taxonomy, phytoplankton physiology and response to contaminants, tintinnid ciliates and temperate and sub-Antarctic phytoplankton community dynamics.

Sarah Pausina

Position: Plankton Biologist
Location CSIRO, Brisbane, Queensland

I work in the lab analysing plankton samples from Australian waters and contribute to the reference material we use for taxon identification. Occasionally you'll find me in the field helping with sample collection. Broadly, my background is in marine ecology, and I am particularly interested in zooplankton dynamics and water quality.

Wayne Rochester

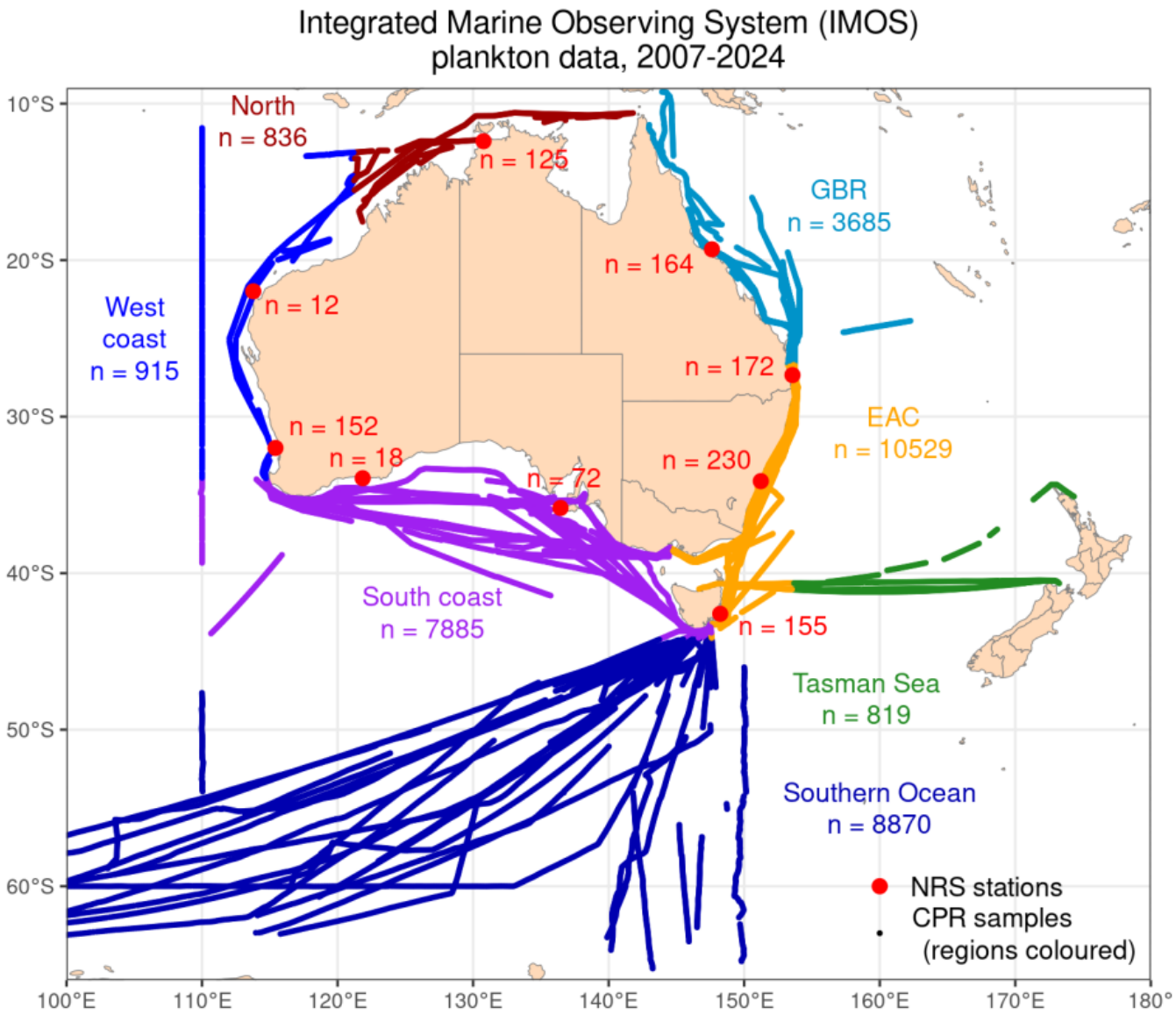
Position: Quantitative Ecologist
Location CSIRO, Brisbane, Queensland

I help the survey by the analysis of plankton data for ecosystem health assessment. My research interests are quantitative ecology, spatial ecology and natural resource management.

The EAC route is towed quarterly from Brisbane to Melbourne and follows the southward-flowing warm-water East Australia Current. This region is forecast to warm more this century than anywhere else in the Southern Hemisphere .

The National Reference Stations are sampled monthly.

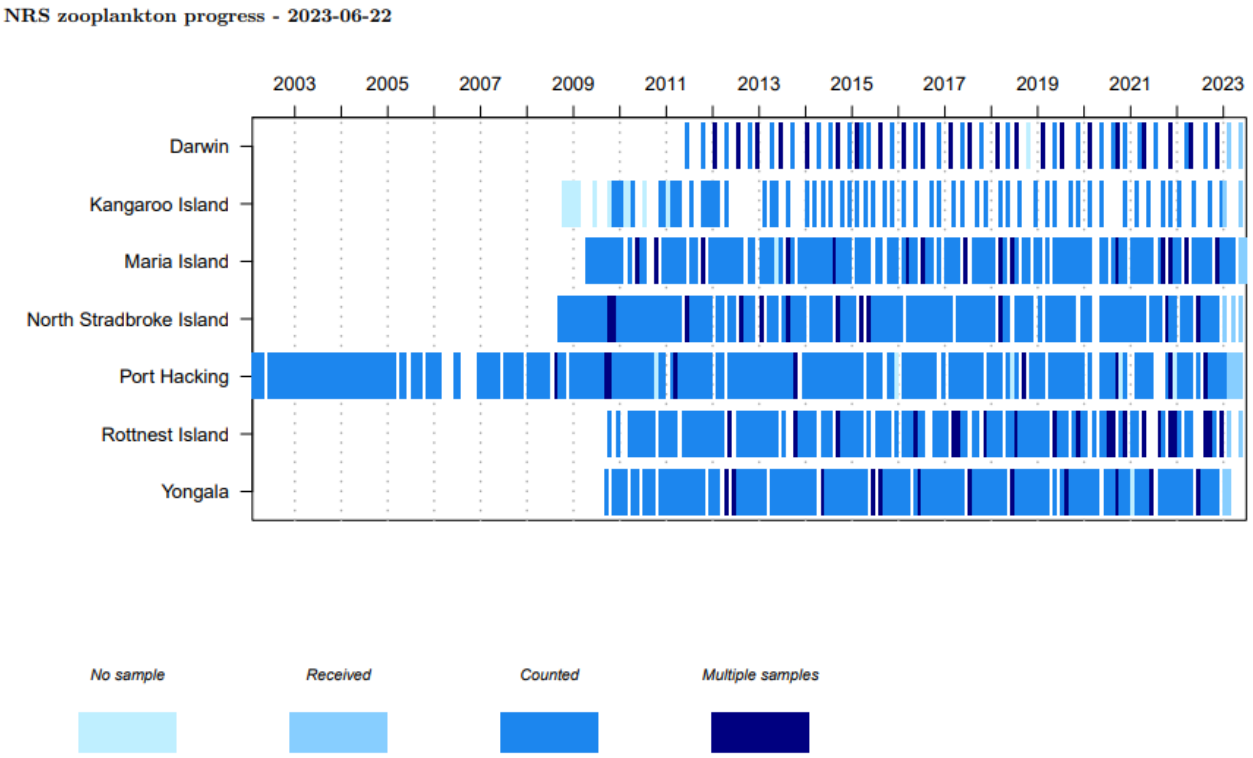
The Great Barrier Reef (GBR) route is towed seasonally from Gladstone to Cairns in the GBR lagoon. Long-term observations on the GBR, such as those by the CPR, help support management of a healthy reef.



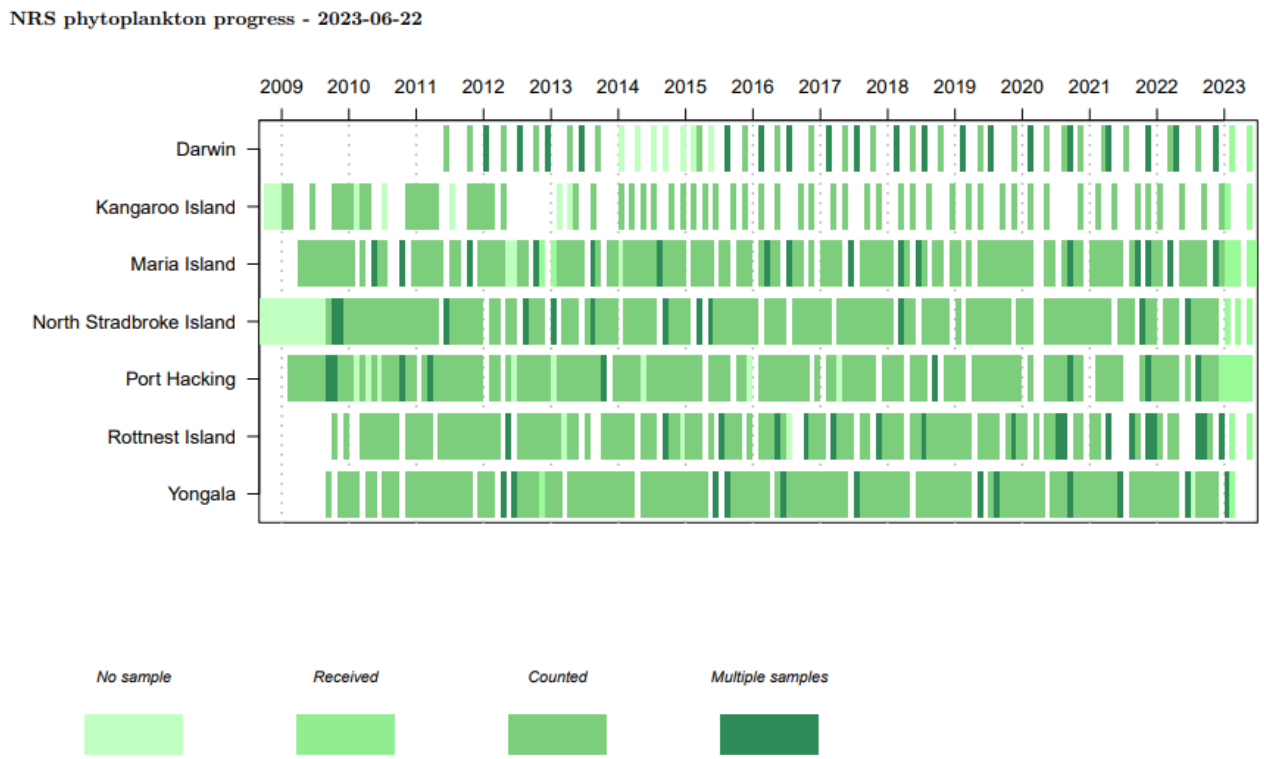
The route from Melbourne to Adelaide is one of our longest-running routes and traverses the productive upwelling waters of the Bonney upwelling system.

Our Southern Ocean routes are towed in collaboration with the SCAR SO-CPR Survey based at the AAD. Together with the EAC route, the Southern Ocean sampling provides an almost continuous transect running from warm tropical to polar waters.

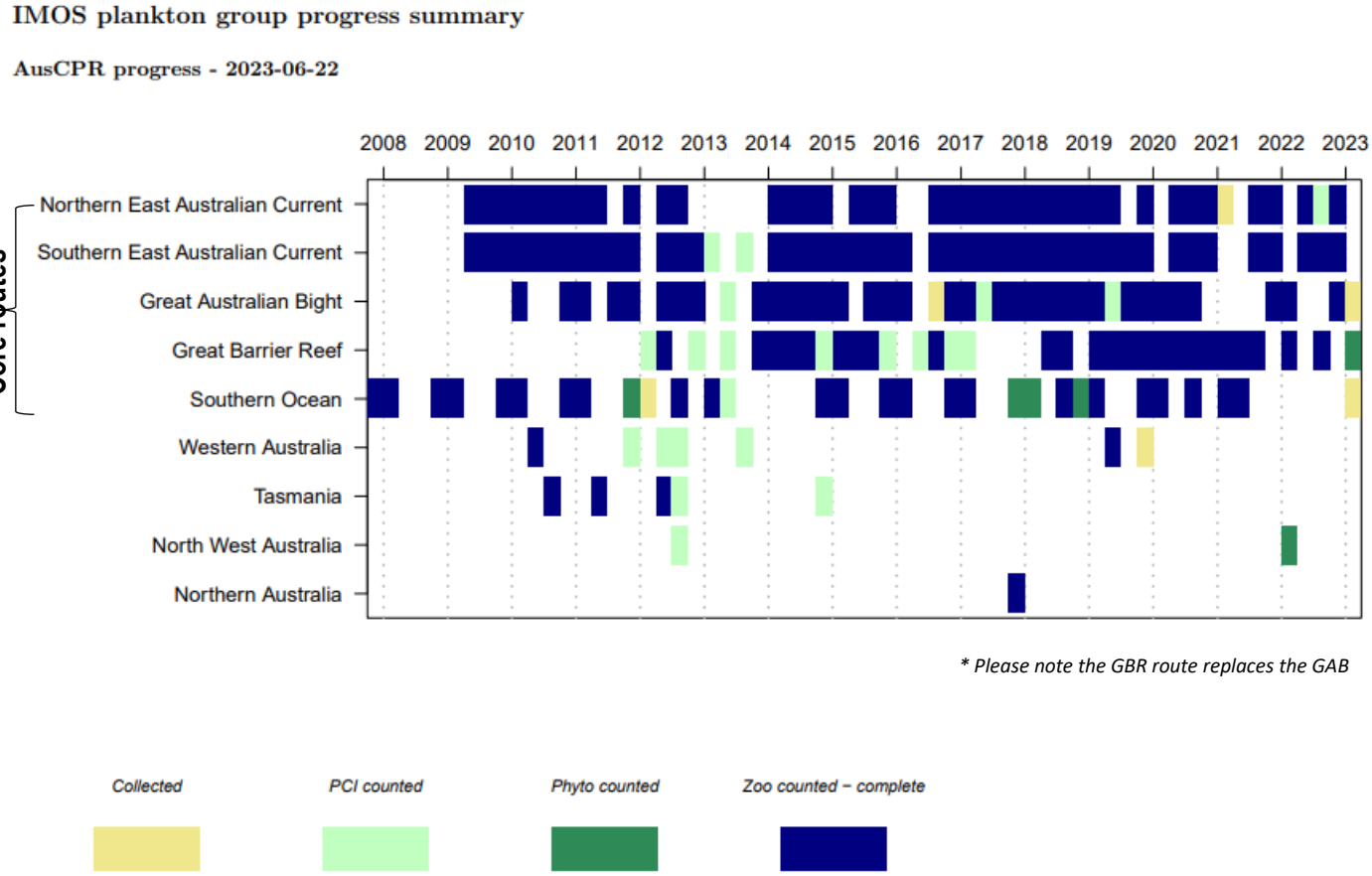
Progress in our National Reference Stations Zooplankton Sampling and Counting



Progress in our National Reference Stations Phytoplankton Sampling and Counting



Progress in Australian Continuous Plankton Recorder Sampling and Counting



** Please note the GBR route replaces the GAB*

MEET THE SHIPS WORKING WITH US

SHIP NAME	OPERATOR	LENGTH	DEAD WEIGHT
MV Tonsberg	Wallenius Wilhelmsen	265 m	41820 tonnes
MV Salome	Wallenius Wilhelmsen	265 m	43878 tonnes
RTM Wakmatha	Rio Tinto Shipping	236 m	89605 tonnes

Images: MV Tonsberg (Dexter), MV Salome (Mick Prendergast), RTM Wakmatha (all from www.marinetraffic.com). Thank you to all the ship operators that are working with us.

SHIPPING UPDATE

Mark Tonks

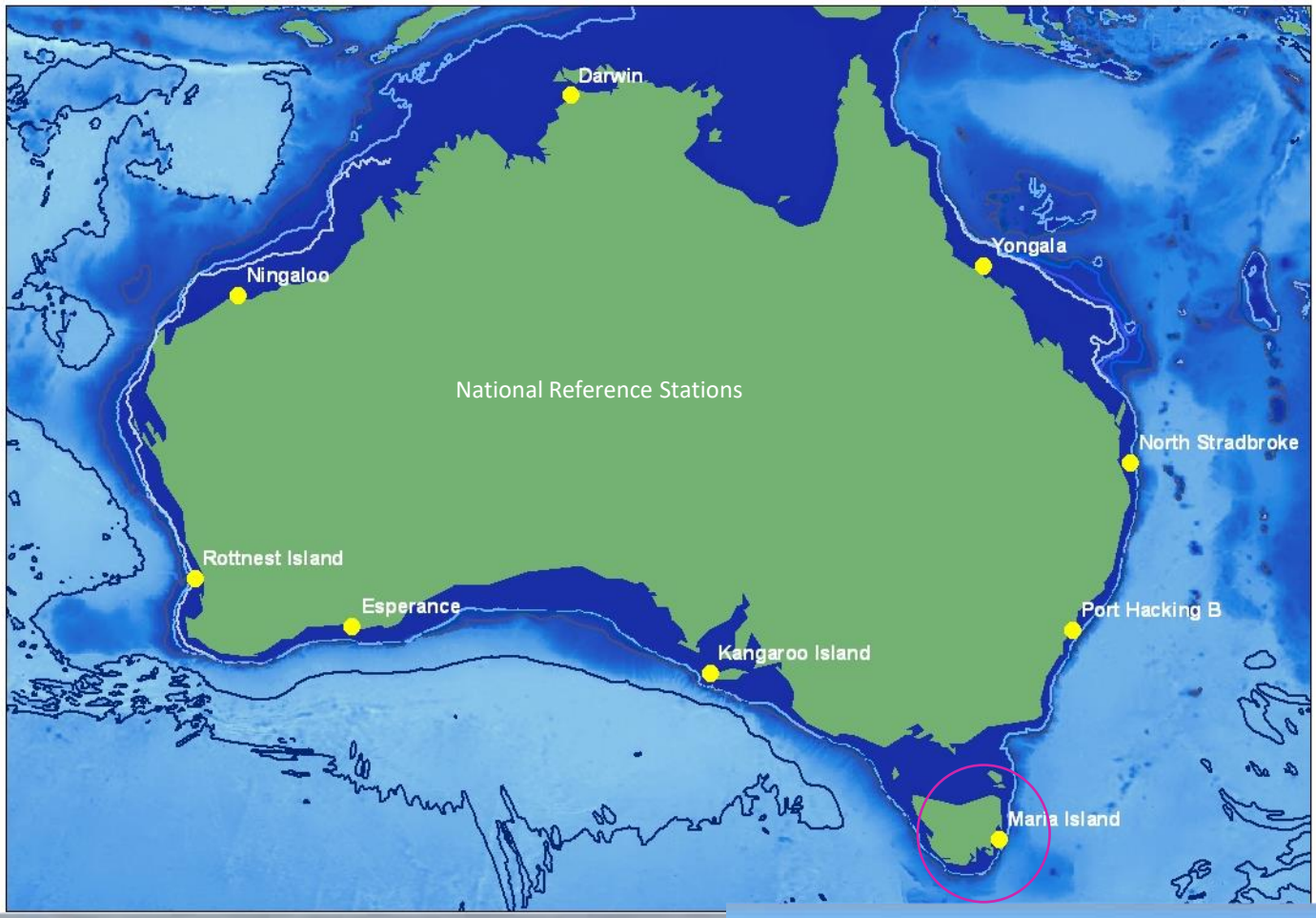
The Wallenius Wilhelmsen (WW) ships, *Tonsberg* and *Salome,* are currently towing CPRs through eastern and southeastern Australian coastal waters between the ports of Brisbane, Port Kembla and Melbourne. Recent changes in shipping demand and supply have changed shipping routes over the past six months and they currently do not visit Adelaide or Fremantle ports. Further, there are berthing delays at ports of up to three weeks, which creates some minor logistical issues related to sample return for analysis. Despite these disruptions, both vessels have now completed a combined 100 CPR tows covering >36,000 nautical miles. Since our last newsletter, several WW staff who were key in initially supporting and facilitating CPR tows from these vessels, have moved on from their positions. We wish Captain Sunil Dhowan (previous Head of Port & Cargo Operations, Oceania) and Captain Roman Rossa (previous Brisbane Port Operations Manager) the best in their future endeavours. Despite these personnel changes, we continue to be well supported by the current shipping agents and crews of the ships involved.

The Rio Tinto ship, *RTM Wakmatha,* continues to tow CRPs along the inner Great Barrier Reef between Cairns and Gladstone. This ship travels regularly between Weipa and Gladstone, carrying bauxite for alumina refineries in Gladstone. Since their initial CPR tow in June 2018, a further 16 tows been completed up until June 2023. In total, over 6000 nautical miles have been sampled. Due to the ship going into dry dock for a major refit in Singapore (Sept 2022), we were unable to collect samples for the second half of 2022. CPR sampling recommenced early in 2023. We thank Rio Tinto and the *Wakmatha* crew, particularly Chief Officer's Robert Spencer-James, Jack Miller, Nick Harvey and Michael Bender for their assistance.

In May 2023, summary reports were sent to both Wallenius Wilhelmsen and Rio Tinto to highlight their contributions to the Australian Continuous Plankton Recorder Survey thus far. These reports provided information of the number of tows and nautical miles sampled for each vessel. Further, seasonal biological data from each tow, such as the Phytoplankton Colour Index (a proxy for phytoplankton abundance) and plankton biomass were plotted. Information on some of the abundant phytoplankton and zooplankton was also provided.

The RTM *Wakmatha* bosun filling the CPR cassette with preservative after CPR tow completed. Image: *Wakmatha* crew.

IN THE FIELD – NATIONAL REFERENCE STATIONS SAMPLING

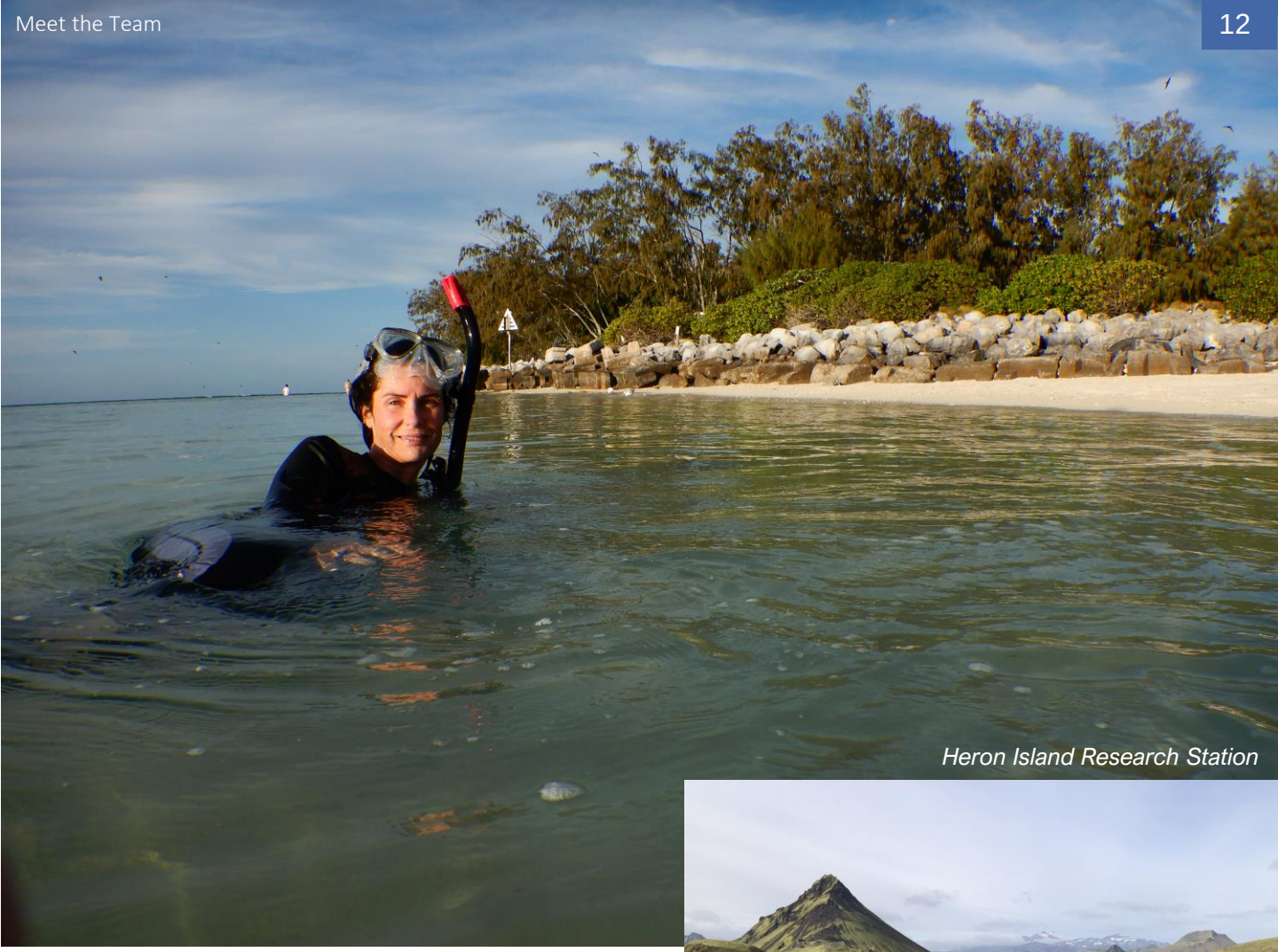


Images from the field at the Maria Island National Reference Station.

Maria Island National Reference Station, 2022.
Images: Julie Janssens

A plankton sample collected at the Maria Island National Reference Station.

Maria Island National Reference Station, 2022.
Images: Julie Janssens



Heron Island Research Station

Laugavegur Trail, Iceland

SARAH PAUSINA IN THE PLANKTON TEAM

Position: Zooplankton Biologist 2021-2023

Location: CSIRO Plankton Ecology Lab, Brisbane

I have a Bachelor of Science from The University of Auckland and a Master of Applied Science in Tropical Ecology and Fisheries Biology from James Cook University. I have spent the years since working across a variety of fields in freshwater and marine environments, from sustainable fishing in New Zealand and the Philippines to water quality improvement for Moreton Bay here in south-east Queensland. More recently, I have been involved in paleolimnological research using plankton preserved in sediment profiles to examine ecological regime shifts in response to human disturbance. I also have a passion for sharing knowledge with the next generation and can occasionally be found at Moreton Bay Research Station leading Science Camps.

Contributing to the multi-decadal time series of the nation's coastal seas as a plankton biologist under the Integrated Marine Observing System with the CSIRO team fulfills my primary interest in the ecological health of coastal systems. The expertise and resources within the lab and broader IMOS teams are world class, and I am gratefully extending my knowledge in analytical and monitoring techniques. I am fortunate to have this opportunity, it is rewarding work that informs research into ocean and climate variability and associated ecosystem responses.

I love the ocean, so I take every opportunity to spend my spare time surfing and diving. I also love hiking, and recently walked the stunning Laugavegur Trail in Iceland.

WELCOME LUKE BROKENSHA TO THE PLANKTON TEAM

Position: Phytoplankton Taxonomist, University of Tasmania 2023 - ongoing

Location: Australian Antarctic Division, Hobart

I have recently been employed by the University of Tasmania as a phytoplankton taxonomist. I am a visiting scientist within the Antarctic Division and CSIRO and will conduct my taxonomic analysis at the AAD. My role is to analyse and identify the phytoplankton found on the CPR silks returned from voyages in the Southern Ocean.

I obtained my Bachelor of Science in Marine Biology at Flinders University in South Australia and have collected experience in a varied array of work fields since. I am currently finalising my MSc in Marine and Antarctic Science through the Institute for Marine and Antarctic Studies (IMAS), specialising in the connection between deep sea krill and the Antarctic ice shelf. My studies have allowed me to sharpen my microscopy skills, with electron and light microscopy constituting a large portion of my current research.

Previously, I have spent many years working in wilderness therapy and as a wilderness guide – here in Australia and in Canada. I have also worked as an Environmental Science Instructor for a marine biology institution in the Bay of Fundy, on the east coast of Canada.

I started my taxonomic work at AAD under the guidance of Dr. Fiona Scott, with added assistance and support from the AusCPR team based at CSIRO. The training proved invaluable, and my taxonomic knowledge increased daily. I am eager to contribute to the pre-existing image database and hope also to use my Scanning Electron Microscopy (SEM) knowledge to add detailed images to these databases. I understand the importance of long-term spatial and temporal data sets for analysis and look forward to adding to the already rich Southern Ocean CPR phytoplankton database.

MAKING OUR DATA FAIR

Claire Davies

" There is a lot of emphasis now on data being **FAIR** - **F**indable, **A**ccessible, **I**nteroperable, and **R**eusable. IMOS has adopted these principles and has encouraged the Australian Marine Science community to do the same".

There is a lot of emphasis now on data being FAIR – **F**indable, **A**ccessible, **I**nteroperable, and **R**eusable. IMOS has adopted these principles and has encouraged the Australian Marine Science community to do the same. In 2022, the plankton data team, Marg Miller, Steve Edgar and me, along with the Australian Ocean Data Network team (AODN including Marty Hidas and Leo Laiolo) completed a project to ensure plankton data was available in easy-to-use data products. Pre-wrangled data is now available for all the NRS and CPR plankton data and the NRS oceanographic variables. These are now Findable and Accessible from many places:

- Wrangled data products can be downloaded in .csv format from the AODN portal (https://portal.aodn.org.au/)
- As the raw .csv files sent harvested from CSIRO (http://imos-data.s3-website-ap-southeast-2.amazonaws.com/#IMOS/BGC_DB/harvested_from_CSIRO/)
- Products can be accessed directly through AODN geoserver, search files under layer preview (https://www.cmar.csiro.au/geoserver/web/)
- As visualisable and downloadable code and plots from the IMOS Biological Ocean Observer (https://shiny.csiro.au/BioOceanObserver/)
- As data that is accessible and able to be wrangled yourself through planktonr (https://github.com/PlanktonTeam/planktonr)

All these products have full metadata records available through the AODN portal that reports the data provenance and lineage.

GOOS has also launched the BioEco portal recently and the AusCPR and IMOS National Reference Stations monthly biogeochemical sampling have already been added to the Portal, along with 580 other monitoring programmes. Check it out here – https://bioeco.goosocean.org/.

IMOS BIOLOGICAL OCEAN OBSERVER AND *PLANKTONR*

Claire Davies

Building on the improved data management, Claire, Ant and Jason Everett secured funding as part of one of the New Tech Proving projects to improve data visualisation of IMOS biological data. We have designed and developed an R-Shiny app – the IMOS Biological Ocean Observer – and an R package – *planktonr* – that will bring the biological data to life at your fingertips. To interact with the IMOS Biological Ocean Observer, you will not need to be an R user, just curious about plankton. By selecting options from drop-down boxes and filters, you will be able to see visualisations, such as time series of important indices, and download the code, the plot and/or the data used to create the graphic. All the NRS and CPR data are integrated with physical and chemical parameters behind the scenes, so the biological response to physical parameters can be explored, graphed and downloaded. There will also be examples packaged as vignettes, which can be downloaded and used by teachers to guide learning on biological ecosystems and coding practices. If this does not give you quite what you need, then install *planktonr* and use our ready-made functions to access the data directly from the AODN, and wrangle and plot to suit your project requirements. Using these tools makes all our work Interoperable and Reproducible, thus helping to fulfil FAIR requirements.

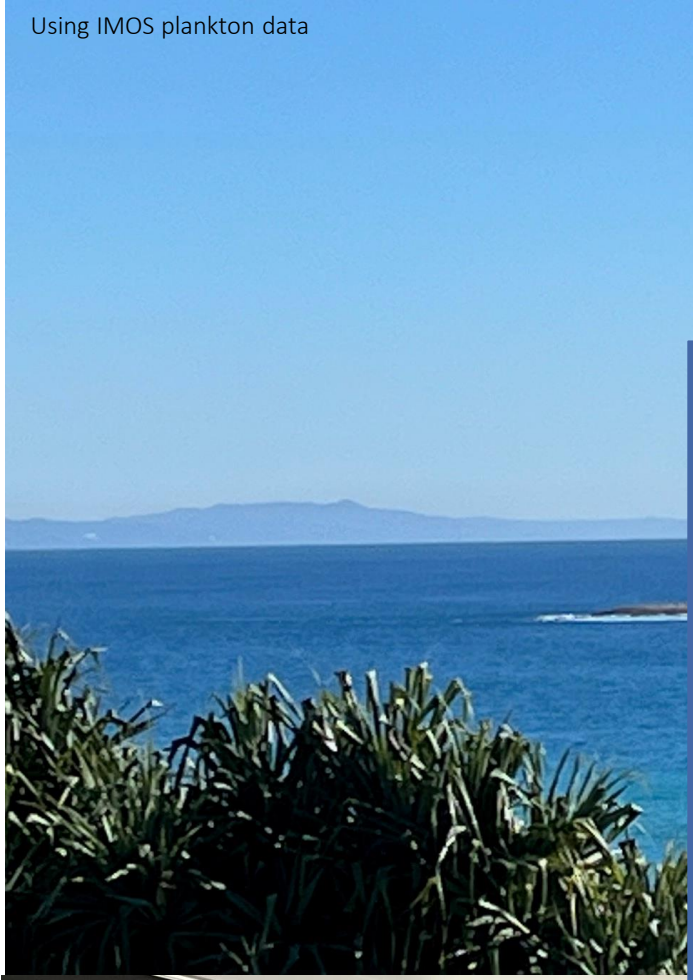
IMOS and Bioplatforms Australia also secured Australian Research Data Council (ARDC) funding for a project to bring the molecular data from the NRS stations and other projects into the visualisation space. Justin Seymour and Martin Ostrowski from UTS, Mark Brown from the University of Newcastle, and Sophie Mazard from Bioplatforms Australia, will be working with us to provide analysis ready molecular data for integration into the IMOS Biological Ocean Observer.

These are exciting projects and were designed with your feedback in mind. The major aim is to make IMOS biological data more readily accessible to all so that a broader audience can interact with the data. The raw data will remain available for those with niche requirements that are not covered through BOO and, as always, we will be available to provide support and advice to anyone using our data. Thanks to IMOS and the AODN for supporting us, together we can increase our impact.
If you use this app in any publication, please cite as:

'Davies, Claire H., Everett, Jason D., Ord, Louise (2022) IMOS Biological Ocean Observer - Shiny APP. v3. CSIRO. Service Collection. *http://hdl.handle.net/102.100.100/447365?index=1*.

All of the analysis and plotting contained in the application are powered by the *planktonr* package: Everett Jason D., Davies Claire H. (2022). planktonr: Analysis and visualisation of plankton data. R package version 0.1.1.0000, *https://github.com/PlanktonTeam/planktonr*.

IMOS Integrated Marine Observing System



OCEAN HACK 2022 WEEK WITH NICK MORTIMER

Claire Davies

Ocean Hack Week is a global online hackathon that took place through synchronous 3-hour periods per day and asynchronous collaboration. The workshop was covered by 6 satellite events in the US Northeast, US Northwest, US Southwest, Australia, Brazil and Spain. The Australian event was held on Stradbroke Island, where coders tried hard to not get distracted by the ocean view and frolicking whales. It was organised by Nick Mortimer (CSIRO, WA), who has been developing notebooks for managing big data in the cloud environment, and Claire went along to help.

The idea behind the week is to turn up with some tricky, big data problem that warrants time from some experienced and enthusiastic coders. With support from other participants, these ideas become projects, participants split up into groups, and work on solving the issues raised. Participants are encouraged to interact across time zones and geographical locations. To get discussions and ideas started, some seminars were also presented on coding techniques that apply to big data, with versions in R and python provided.

Seminars can be watched live if the time zone is applicable to you or your satellite group can watch the recordings at a more convenient time. Topics covered included Xarray, data access, data visualisation and machine learning. Some of the popular project ideas were ENSO prediction using Deep Learning, Kerchunk! Bless you, Extreme events/anomaly detection, Clusters in profiles of nutrients and correlation with phytoplankton communities, and unsupervised classification of flow cytometry time series data.

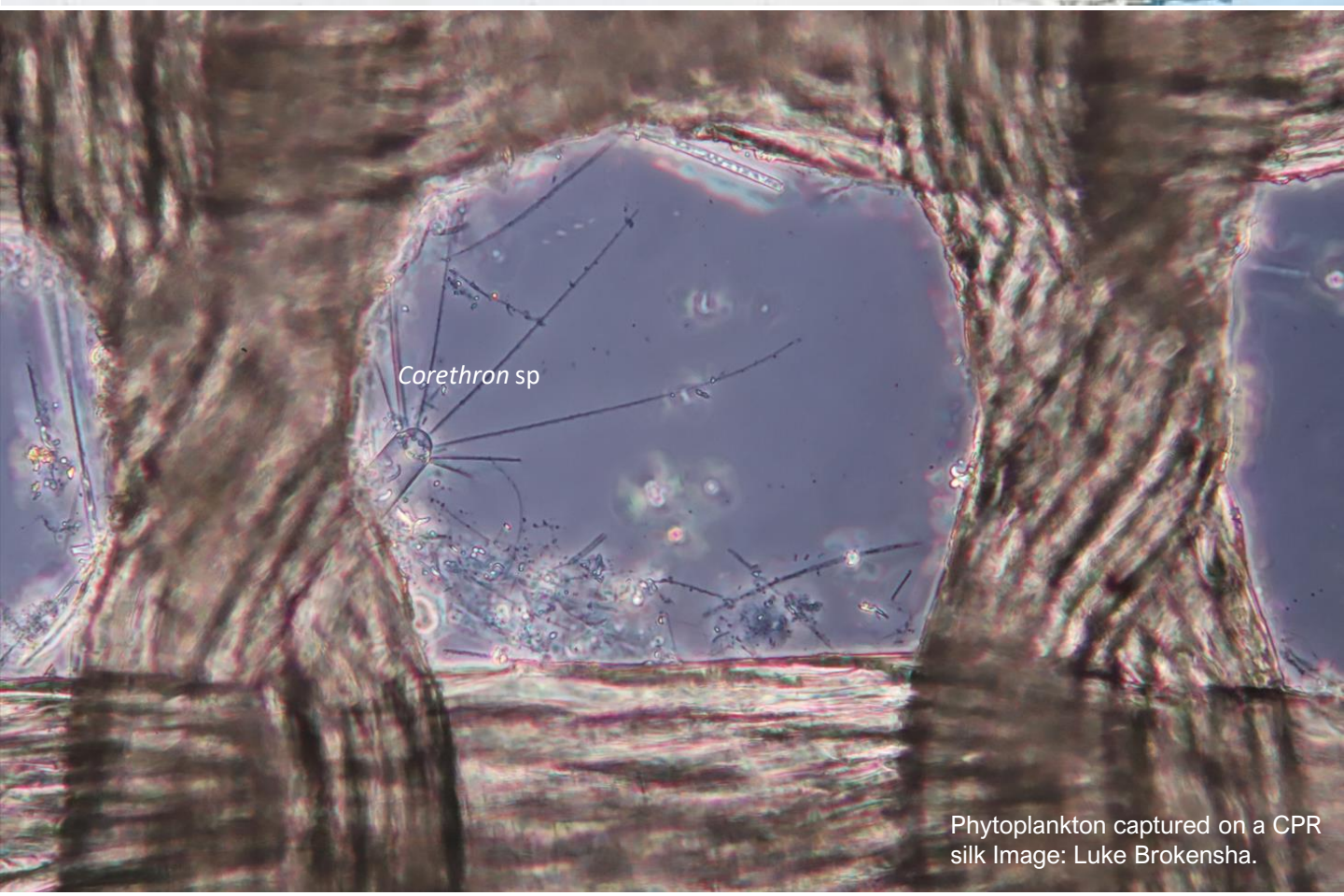
Find out more and look out for events in your area: https://oceanhackweek.org/index.html

FROM THE HOBART PLANKTON LAB

Luke Brokensha

The Southern Ocean CPR program is moving along smoothly, with the final silks from the TEMPO voyage currently being counted. On completion of these silks, outstanding tows from the 2019 ENRICH voyage, and 2019/2020 voyages will be counted to bring the SO-CPR up to date with current voyages. Long-term SO-CPR data is currently being analysed and used for various upcoming publications and reports, with more information on these to follow when they have reached completion.

Map: https://www.cmar.csiro.au/data/trawler/survey_details.cfm?survey=IN2019%5FV01



Phytoplankton captured on a CPR silk Image: Luke Brokensha.

FROM THE HOBART PLANKTON LAB continued...

Felicity McEnnulty

The Hobart lab have been busy counting samples of phytoplankton and zooplankton from the IMOS National Reference Stations, as well as data entry and QAQC. Sampling at the Maria Island National Reference station continued throughout 2021-2023, with samples collected from 12 sampling trips in 2021, 11 sampling trips in 2022, and 10 sampling trips in 2023.

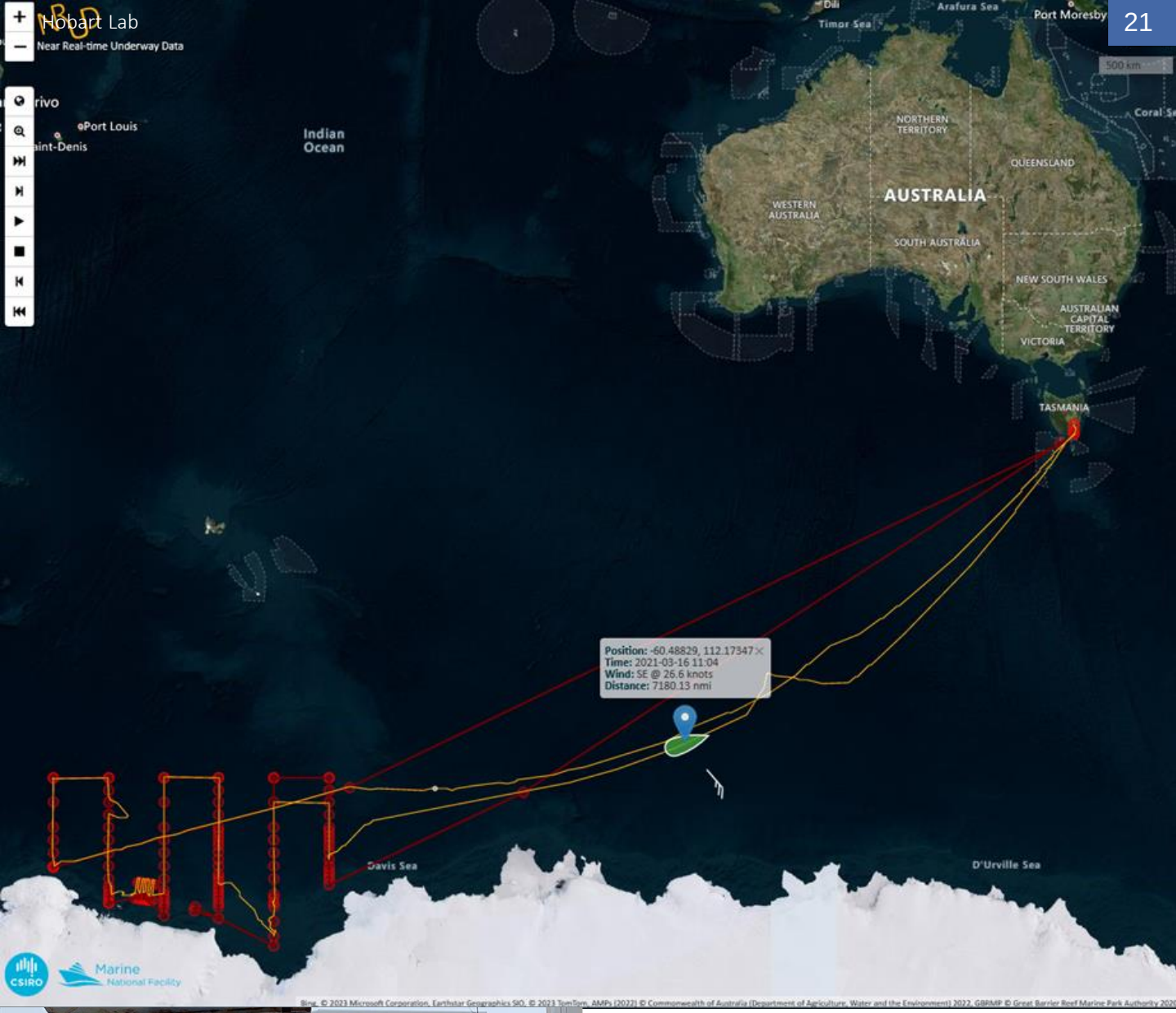
We have also worked on CPR samples from several sources including those collected by Claire in January to March 2022 on the BLOOFINZ-IO voyage RR2201 on the *RV Roger Revelle* led by Michael Landry of Scripps Institution of Oceanography at the University of California.

The Marine National Facility (MNF) has continued to collect samples for us on *RV Investigator*. The annual Southern Ocean Times Series (SOTS) mooring voyage tows the CPR for us on one of the voyage legs. The CSIRO Hobart workshop also made up a trolley to move the (very heavy) CPR around. The mooring at the SOTS was also changed over, and this time-series provides Ruth with samples collected during the previous 12 months.

Screen shot of the vessel track of *RV Investigator* during IN2021_V02. The CPR was towed on the steam northbound from the SOTS mooring to Hobart in April 2021 (credit: https://mnf.csiro.au/). Our plankton sample code HOSO20210415-01.

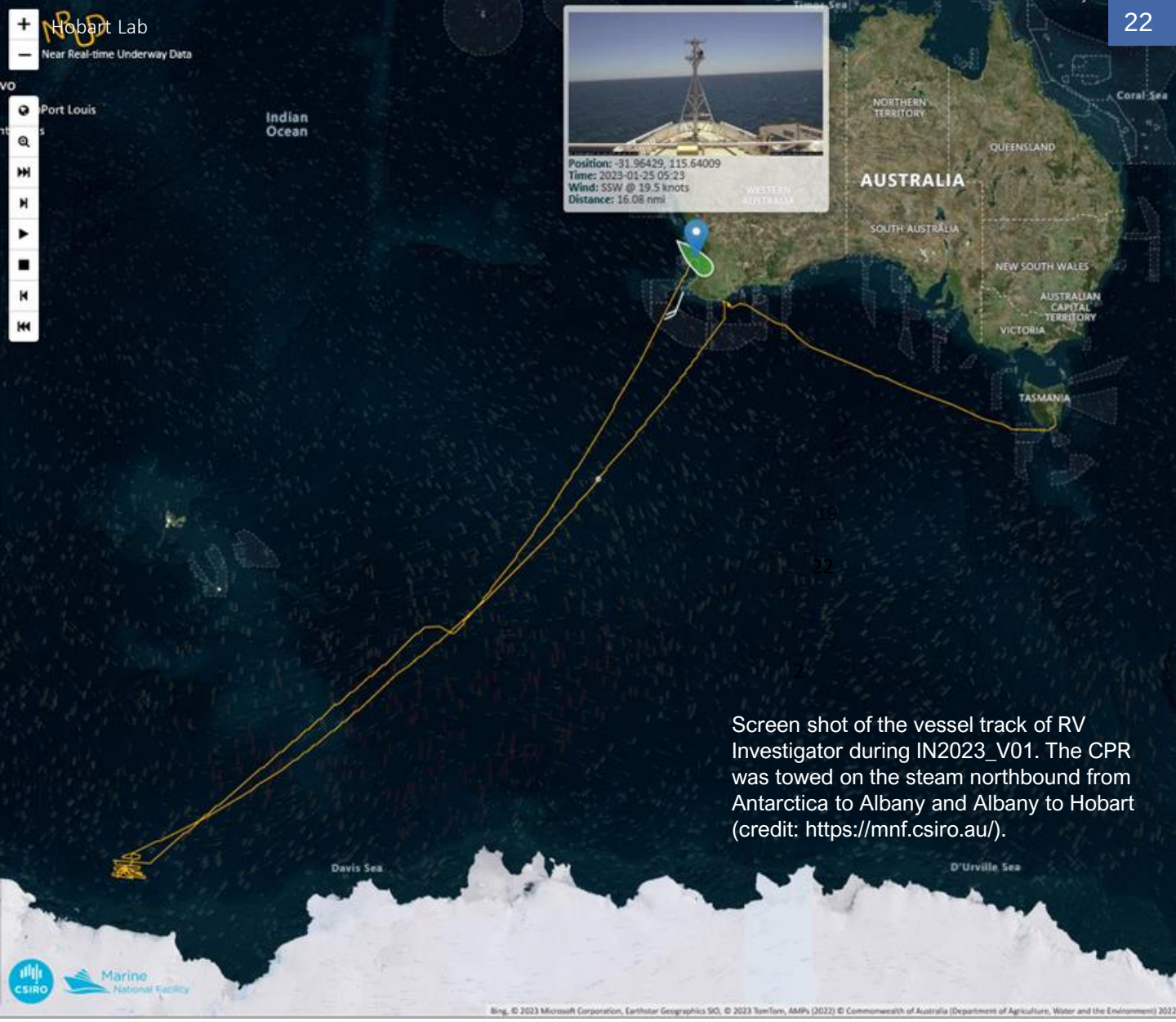
The MNF CPR on its custom-built trolley ready to be lifted on to the RV Investigator.

Since the retirement of the Antarctic icebreaker, RSV Aurora Australis, the Australian Antarctic Division has charted the RV Investigator for the summer research voyages IN2021_V01 (TEMPO) and IN2023_V01 (Geoscience Australia lead). Sampling using the AAD CPR, they have provided us with CPR plankton samples from the Southern Ocean north of 47 degrees south. The TEMPO voyage also passed the SOTS station and they kindly collected additional surface samples for Ruth as they passed the site. We look forward to receiving CPR samples collected by the new Antarctic vessel: RV Nuyina once it starts the science research program in the coming summer.



Above: Screen shot of the vessel track (yellow) of RV Investigator during IN2021_V01. The CPR was towed from Hobart to Antarctica in January on the steam south and from Antarctica to Hobart in March on the return journey (credit: https://mnf.csiro.au/).

Left: AAD deployment of CPR on TEMPO voyage credit: J Melvin (AAD).



Screen shot of the vessel track of RV Investigator during IN2023_V01. The CPR was towed on the steam northbound from Antarctica to Albany and Albany to Hobart (credit: https://mnf.csiro.au/).

Fiona Scott, our collaborator who was working on the routine phytoplankton analysis of Southern Ocean CPR silks based at the Australian Antarctic Division, finished in September 2022. She has left us with a large collection of identified images, which are a great help for us going forward and we miss her expertise around the lab and in meetings. Before leaving, Fiona worked with Luke Brokensha, who is now doing the phytoplankton identification on the AAD CPR silks.

In the lab, we have had the student Kaya Baxter and his assistant Yasandi Athapaththu settling phytoplankton samples taken off the Hobart wharf. They are examining them under the microscope for key species for Kaya's PhD.

In March 2021, we participated online in the Lucid and Fact Sheet Fusion training (postponed due to covid) which was held on site at QBP with external trainers.

In July 2022, Claire, Ruth, Felicity travelled to Brisbane to attend an R-course at the University, and plankton group face-to-face meetings, the first since 2020. Claire and Felicity attended the final Advanced Online R Workshops held by Bill Venables. We thank Bill Venables for his valuable input and advice on R over the years.

CSIRO has switched to an electronic safety system online HSE portal, so we have been busy converting all our risk assessments, safe working instructions and updating chemical inventories for the laboratories and field work.

Claire has spent a lot of time working on getting the plankton data out into the world, including: developing the Oceans Observing Project including a shiny app and R package with Jason Everett, working with the AODN on the Plankton data visualisation project to produce data products and developing a project to use products from ZooScan data.

Claire participated in Ocean Hack Week in August 2022. Ruth attended the IOC Training Course on Harmful Microalgae in Denmark in October 2022. Claire along with Frank and Julian attended the IMOS QC summit in Sydney in March 2023.

Ruth and Anthony have been busy working with the Chinese Academy of Science project – using underwater imaging technology to provide high temporal resolution images of plankton. As part of our interest in utilising Machine Learning and automated techniques for quantifying plankton, Ruth and Julian went to Perth in March 2023 for a Labs Of The Future project with Joanna Strzelecki. This project is using FlowCam (an automated instrument combining flow cytometry and imaging) to acquire phytoplankton images, which are then processed using Machine Learning approaches. We are working with Chris Jackett from NCMI to explore rapid processing of large image-based datasets and providing critical taxonomic ground-truthing for these new methods.

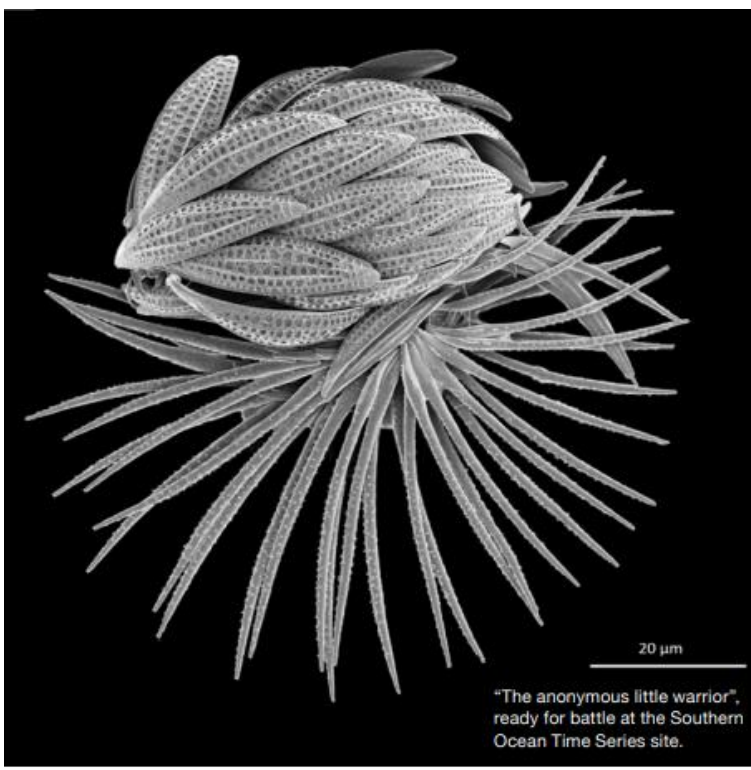
Claire and Ruth worked collaboratively on many papers with taxonomists, modellers and students on phytoplankton (*Tripos, Dinophysis*) and zooplankton, including 3 in a special journal issue for the IIOE voyage. Ruth co-edited the book: Advances in Phytoplankton Ecology that was published in December 2021. One of the chapters includes contributions from Anthony Richardson and Rowena Stern and colleagues from the MBA in the UK, describing the value of the CPR archive in unravelling the molecular diversity of *Emiliania huxleyi* and the genus *Pseudo-nitzschia*."

Ruth has been teaching the Advanced Phytoplankton Taxonomy unit to post-graduate students at the University of Tasmania. She uses a lot of images from the IMOS samples, particularly focusing on light and scanning electron microscopy approaches to taxonomy. Anusya Willis (NCMI) also teaches and presents molecular approaches to taxonomy so students can see the intersection between traditional and modern approaches.

Ruth has been busy on the SEM and won a the Micropaleontological Society 2022 image competition (right). The winning image and article can be viewed on page 14 of the IMOS Marine Matters May 2023 newsletter.

Another notable achievement for one of our team members was recognition of Claires's 15 years of service with CSIRO working on plankton.

Claire will be in IN2023_V05 for the month of July 2023 sampling plankton in the south-east fisheries off SE Australia.



Right: "The anonymous little warrior" was submitted to the Micropaleontological Society 2022 image competition by Ruth Eriksen, CSIRO, winning first prize. Image taken at the Central Science Laboratory, University of Tasmania. Source here.

FROM THE BRISBANE PLANKTON LAB

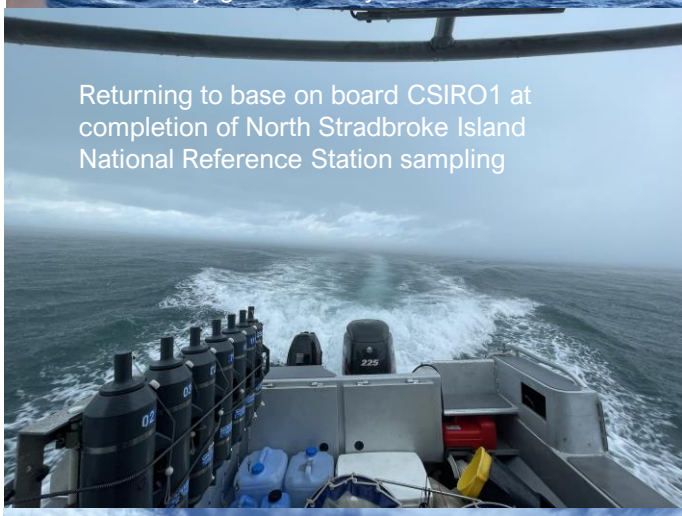
Frank Coman

During the last 2 years, the working situation has returned to be somewhat like pre-2020, despite a small number of occasions when staff were requested not to be on site. Many staff in our project team and others have returned to regularly working in the office at the Queensland Biosciences Precinct laboratories, and Anthony has also returned to face-to-face teaching at the University of Queensland. There have, however, been some changes for our team over this period. Anita took time off for maternity leave, returning in June 2022. We were able to recruit Sarah Pausina to a term position to assist us with counting and laboratory work for part of the time Anita was on leave, and after her return. Sarah has worked in and around our labs as a student with Anthony, and began working with our team on a term position from January-October 2022. We were then able to extend her term through until June 2023. Another notable achievement for one of our team members was recognition of Mark's 20 years of service with CSIRO.

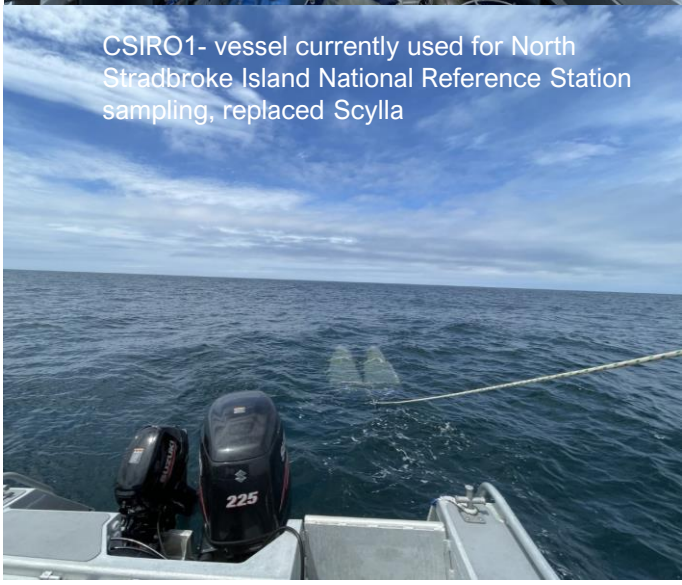
The IMOS work, which supports most of the plankton monitoring work we do, has continued successfully. The National Reference Stations sampling (right middle and bottom) and counting has returned to normal operations, and the same is mostly true for the continuous plankton recorder projects but been a few disruptions to shipping due to the continuing impacts on manufacturing and distribution.

Both the Wallenius Wilhelmsen ships, the *Salome* (top right), and the *Tonsberg* continued to collect samples between Brisbane and Adelaide for us. Throughout the 2021 and 2022 there were 9 voyages, which travelled along the east coast between Brisbane and Melbourne, and on 2 of these voyages, samples were also collected between Melbourne and Adelaide. Twice during this period, the sample collection was undertaken in a northerly direction (rather than the usual southern direction) due to changes in the normal routes of the ships. A big thanks goes out to the ship's crews, the port staff in Brisbane, Melbourne and Perth, and the staff from the Perth CSIRO office who assisted us in collecting the samples and getting the equipment onto and off the ship. The Rio Tinto ship, *Wakmatha*, also managed to continue collecting samples along the Great Barrier Reef between Cairns and Gladstone, with samples being collected for us on 6 voyages in 2021 and 2022. The ship was unavailable at the end of 2022 to go into dry dock but returned to service at the beginning of 2023.

RV Roger Revelle- ship used for Indian Ocean voyage In January 2022



Returning to base on board CSIRO1 at completion of North Stradbroke Island National Reference Station sampling



CSIRO1- vessel currently used for North Stradbroke Island National Reference Station sampling, replaced Scylla

Claire preparing cassette for deployment on RV Roger Revelle voyage in January 2022

Claire retrieving sample from zooplankton net drop deployment on Roger Revelle voyage in January 2022

Sampling at the North Stradbroke Island National Reference station continued throughout 2021 and 2022 with samples collected from 11 sampling trips in 2021 and 10 sampling trips in 2022. Unfavourable weather conditions were the cause of the sampling months we did miss. There was a significant change to our sampling in March 2021 after the loss the Scylla, the vessel we had been using since 2009. We are now using a slightly smaller vessel, the CSIRO 1, which is capable, but which can be a bit of a tight fit to get all the sampling equipment on board. As with recent years Mark Tonks, Julian Uribe-Palomino, Steve Edgar and Frank continue to be the regular crew on the sampling trips. We did however receive plenty of help from other staff and students who joined us on sampling when the regulars were not available. Thank you to Steve Margaret Miller, Sarah Pausina, Rob Kenyon, Anthony Richardson, Karl Forcey and Tim Vance for their assistance over the last 2 years.

Team members from Brisbane have continued to support several other projects, particularly with field work. Mark Tonks participated in the Northern Prawn Fishery (NPF) survey in the Gulf of Carpentaria both 2021 and 2022. Julian and Mark 3 weeks on Orpheus Island in 2022 as part of the EcoRRAP reef restoration projects. Mark, Julian and Frank also participated in field work on Heron Island in both 2021 and 2022 and also a coral identification course in July 2021. Mark and Frank also both spent time on Queensland's southeast coast as part of the effects of trawling project. In early 2022 staff from Brisbane also assisted with getting continuous plankton recorder and net sampling equipment to the Darwin to be used on the RV Revelle voyage, led Michael Landry, that Claire participated in off Northwest Australia.

A plan for training on developing Lucid keys had to be postponed in 2020, but in March 2021 the training was able to go ahead on site at QBP with external trainers, with staff from Hobart dialling in. With travelling becoming a bit less restricted Claire, Ruth, Felicity, Jason and Chaojiao were able to travel to Brisbane in July 2022. The main reason for travel was to attend an R-course at the University, but it also enabled our first face-to-face meetings with our non-Brisbane colleagues since 2020.

Anthony has continued to have students working with our data or visiting our laboratories to collect their own data or learn techniques. Arthur Blanluet, from France and Sandra Neubert, from Germany, have both recently been working on model projects using our data. Alyson Theseira visited our laboratories to collect water samples from the North Stradbroke Island NRS station for her PhD work, and Hannah Molony has visited our laboratories for two periods to discuss methods and learn techniques for her PhD on Mantas at the Maldives.

Although we have mainly been able to return to work as normal there are still some challenges to overcome because of ingoing influences from 2020. We have, however, continued to meet our IMOS objectives and also assist with other projects being run from the CSIRO laboratories in Brisbane.

SOE REPORT

Jason Everett

In late 2021, the CSIRO Plankton Team, along with valued colleagues, contributed to 5 expert assessments to the Marine Environment Chapter of the Australian State of the Environment Report which was released in 2022. These expert assessments covered 1) oceanic water quality (Doblin et al. 2021), 2) harmful algal blooms (Hallegraeff et al. 2021), the 3) neritic (nearshore) (Richardson et al. 2021a) and 4) epipelagic (offshore) plankton community (Richardson et al. 2021b), and 5) secondary productivity (zooplankton) (Richardson et al. 2021c). The data underlying the assessments were collected by the CSIRO Plankton Team as part of the Integrated Marine Observing System's (IMOS) National Reference Station (NRS) sampling and Continuous Plankton Recorder (CPR) transects. As experts in each of the above topics, members of the CSIRO Plankton Team were invited to contribute brief assessments that were then peer reviewed, edited, and harmonised to produce the final Marine Environment chapter. In addition to providing analysis for the 2021 State of the Environment, we developed tools and code that is reproducible and can be levereaged for use in future marine assesments. The original assessments are available online and the final State of the Environment Report can be found here: https://soe.dcceew.gov.au/marine/introduction

Doblin, Martina ; Everett, Jason ; Davies, Claire (2021): 2021 State of the Environment Report Marine Chapter – Expert Assessment – State and Trend – Water clarity (turbidity, transparency and colour). Department of Agriculture, Water and the Environment (DAWE). https://doi.org/10.26198/3KG0-WC48

Hallegraeff, Gustaaf ; Davies, Claire ; Eriksen, Ruth ; Everett, Jason ; Rochester, Wayne ; Richardson, Anthony (2021): 2021 State of the Environment Report Marine Chapter – Expert Assessment – State and Trend – Harmful algal blooms. Department of Agriculture, Water and the Environment (DAWE). https://doi.org/10.26198/WH7W-CM22

Richardson, Anthony ; Everett, Jason ; Davies, Claire (2021a): 2021 State of the Environment Report Marine Chapter – Expert Assessment – State and Trend – Water column – epipelagic (0-200 m, off-shelf). Department of Agriculture, Water and the Environment (DAWE). https://doi.org/10.26198/GMA2-PV88

Richardson, Anthony ; Everett, Jason ; Davies, Claire (2021b): 2021 State of the Environment Report Marine Chapter – Expert Assessment – State and Trend – Water column – epipelagic (0-200 m, off-shelf). Department of Agriculture, Water and the Environment (DAWE).dataset. https://doi.org/10.26198/GMA2-PV88

Richardson, Anthony ; Everett, Jason ; Davies, Claire ; Rochester, Wayne (2021c): 2021 State of the Environment Report Marine Chapter – Expert Assessment – State and Trend – Secondary production (zooplankton). Department of Agriculture, Water and the Environment (DAWE). https://doi.org/10.26198/2rsb-x342

RECENT PAPERS

Here is a list of new papers the Team has either led or been involved in since the last newsletter. It is so rewarding for us to see the data we collect being used in so many different capacities.

IMOS PUBLICATIONS

Berry TE, Coghlan ML, Saunders BJ, Jarman S, Power M, **Richardson AJ**, Davies C, Berry O, Bunce M (2023) A 3-year plankton DNA metabarcoding survey reveals marine biodiversity patterns in Australian coastal waters. *Diversity and Distributions* 29: 862-878

Boss, Emmanuel; Waite, Anya; Trull, Tom; Batten, Sonia; Richardson, Anthony; Muller-Karger, Frank. Recommendations for Plankton Measurements on Ocean SITES Moorings With Relevance to Other Observing Sites. Frontiers in Marine Science. 2022; 9(929436):1-16.
https://doi.org/10.3389/fmars.2022.929436

Castro-Cera, L, Vega-Diaz, D, Eriksen, R, Leblanc, K and Hallegraeff, G M. (2022) "New observations on the rare tropical dinoflagellates *Tripos lanceolatus* (Kofoid) F.Gómez and *Tripos schroeteri* (B.Schröder) F.Gómez from the Colombian Caribbean, South Pacific and Indian Ocean" Botanica Marina, vol. 66, no. 1, 2023, pp. 67-72. https://doi.org/10.1515/bot-2022-0050

Davies, Claire; Beckley, Lynnath; Richardson, Anthony. Copepods and mixotrophic Rhizaria dominate zooplankton abundances in the oligotrophic Indian Ocean. Deep-Sea Research Part II: Topical Studies in Oceanography. 2022; 202:105136.
https://doi.org/10.1016/j.dsr2.2022.105136

Doni L, Oliveri C, Lasa A, di Cesare A, Losaaso C, Martinez-Urtaza J, Coman F, **Richardson AJ**, Vezzulli L (2023) Large-scale impact of the 2016 Marine Heatwave on the plankton-associated microbial communities of the Great Barrier Reef (Australia). *Marine Pollution Bulletin* 188: 1-10

Everett, Jason; Eriksen, Ruth; Coman, Frank; Jateff, Emily; Richardson, Anthony. IMOS Plankton Team contributes to the Australian National Maritime Museum. IMOS Marine Matters. 2022; 37:11-12

Grigoratou, Maria; Richardson, Anthony; Everett, Jason; O'Brien, Todd. The MBON plankton workshops: "Plankton ecosystem function, biodiversity, and forecasting -research requirements and applications". Limnology and Oceanography Bulletin. 2022; 31(1):22-26.
https://doi.org/10.1002/lob.10479

Hallegraeff, Gustaaf; Davies, Claire; Eriksen, Ruth; Everett, Jason; Rochester, Wayne; Richardson, Anthony. 2021 State of the Environment Report Marine Chapter – Expert Assessment – State and Trend – Harmful algal blooms. Canberra: Department of Agriculture, Water and the Environment (DAWE); 2022. csiro:EP2022-3754. https://doi.org/10.26198/WH7W-CM22

Hallegraeff, Gustaaf M.; Eriksen, Ruth S.; Davies, Claire H.; Uribe Palomino, Julian. Marine planktonic dinophysoid dinoflagellates (order Dinophysales): 60 years of species-level distributions in Australian waters. Australian Systematic Botany. 2022; 35(6):31.
https://doi.org/10.1071/SB21023

Hernandez, Andres S. Rigual; Sierro, Francisco; Flores, Jose; Trull, Tom; Rodrigues, Teresa; Martrat, Belen; et al. Influence of environmental variability and *Emiliania huxleyi* ecotypes on alkenone-derived temperature reconstructions in the subantarctic Southern Ocean. Science of the Total Environment. 2022; 812:Article 152474.
https://doi.org/10.1016/j.scitotenv.2021.152474

Petrik, Colleen; Luo, Jessica; Heneghan, Ryan; Everett, Jason; Harrison, Cheryl; Richardson, Anthony. Assessment and constraint of mesozooplankton in CMIP6 Earth System Models. Global Biogeochemical Cycles. 2022; 36:1-25. https://doi.org/10.1029/2022GB007367

Shadwick, Elizabeth; Hernandez, Andres S. Rigual; Eriksen, Ruth; Jansen, Pete; Davies, Di; Wynn-Edwards, Cathryn; *et al*. New decadal scale changes in Southern Ocean biogeochemistry, and the potential impact on pH-sensitive planktonic organisms. Ocean Observing Supplement. 2022; 34(4):14-15. https://doi.org/10.5670/oceanog.2021.supplement.02-06

Richardson, Anthony; Everett, Jason; Davies, Claire; Matis, Paloma; Suthers, Iain. 2021 State of the Environment Report Marine Chapter – Expert Assessment – State and Trend – Water column – neritic (0-200 m, on-shelf). Canberra: Department of Agriculture, Water and the Environment (DAWE); 2022. csiro:EP2022-3800. https://doi.org/10.26198/GFRJ-0729

Richardson, Anthony; Everett, Jason; Davies, Claire. 2021 State of the Environment Report Marine Chapter – Expert Assessment – State and Trend – Water column – epipelagic (0-200 m, off-shelf). Canberra: Department of Agriculture, Water and the Environment (DAWE); 2022. csiro:EP2022-3799. https://doi.org/10.26198/GMA2-PV88

Richardson, Anthony; Everett, Jason; Davies, Claire; Rochester, Wayne. 2021 State of the Environment Report Marine Chapter – Expert Assessment – State and Trend – Secondary production (zooplankton). Canberra: Department of Agriculture, Water and the Environment (DAWE); 2022. csiro:EP2022-3792. https://doi.org/10.26198/2rsb-x342

OTHER PUBLICATIONS

Anderson, Madeline; Davies, Claire; Eriksen, Ruth. Latitudinal variation, and indicator species, in the Dinoflagellate genus Tripos along the 110°E line in the south-east Indian Ocean . Deep-Sea Research Part II: Topical Studies in Oceanography. 2022. 10. https://doi.org/10.1016/j.dsr2.2022.105150

Andrzejaczek, S; Lucas, TCD; Richardson, Anthony; Armstrong, Amelia; Dudgeon, Christine; Couturier, Lydie; *et al*. Diving into the vertical dimension of elasmobranch movement ecology. Science Advances. 2022; 8:1-19. https://doi.org/10.1126/sciadv.abo1754

Buenafe, Kristine; Everett, Jason; Dunn, Daniel; Mercer, James; Suthers, Iain; Schilling, Hayden; *et al*. A global, historical database of tuna, billfish, and saury larval distributions. Scientific Data. 2022; 9:1-9. https://doi.org/10.1038/s41597-022-01528-7

Buenafe KCV, Dunn DC, Everett JD, Brito-Morales I, Schoeman DS, Hanson JO, Dabalà A, Neubert S, Cannicci S, **Richardson AJ** (2023) A metric-based framework for climate-smart conservation planning. *Ecological Applications.* e2852, 29 pp.

Brito, Isaac; Schoeman, David; Klein, Carissa; Everett, Jason; Dunn, Daniel; Molinos, Jorge Garcia; et al. Towards climate-smart, three-dimensional protected areas for biodiversity conservation in the high seas. Nature Climate Change. 2022; 12:402-407.
https://doi.org/10.1038/s41558-022-01323-7

Da Silva, Ricardo, White, Camille, Bowman, John, Bodrossy, Lev, Bissett, Andrew, Revill, Andy, Eriksen, Ruth and Ross, Jeff. Network and machine learning analyses of estuarine microbial communities along a freshwater-marine mixed gradient. Estuarine, Coastal and Shelf Science, 2022 Record Identifier: csiro:EP2022-1339 https://doi.org/10.1016/j.ecss.2022.108026

Eriksen, R.S. Stunning and rare image from the Southern Ocean Time Series wins photographic prize. Marine Matters. 2023. 14. https://imos.org.au/fileadmin/user_upload/shared/IMOS_General/documents/newsletters/IMOS_Marine_Matters_issue_39_WEB.pdf

Grutter, Alexandra; Nishikawa, Natsumi; Uribe Palomino, Julian; Richardson, Anthony.
Cleaner fish *Labroides dimidiatus* presence does not indirectly affect demersal zooplankton. Frontiers in Marine Science. 2022; 9:117. https://doi.org/10.3389/fmars.2022.812989

Halpern BS et al. and 116 co-authors including **Richardson AJ** (2023) Priorities for synthesis research in ecology and environmental science. *Ecosphere* 14(1): e4342. https://doi.org/10.1002/ecs2.4342

Heneghan RF, Everett JD, Blanchard JL, Sykes P, **Richardson AJ** (2023) Climate-driven zooplankton shifts cause large-scale declines in food quality for fish. *Nature Climate Change* 13 pp. https://doi.org/10.1038/s41558-023-01630-7

Jaspers C, Everett JD, Hopcroft RR, Lombard F, López-Urrutia A, Kiørboe T, **Richardson AJ** (in press, 5/5/2023) Gelatinous larvacean zooplankton can enhance trophic transfer and carbon sequestration. *TREE*. 14 pp.
https://doi.org/10.1016/j.tree.2023.05.005

Landry, Michael; Hood, Raleigh; Davies, Claire; Selph, Karen; Beckley, Lynnath; Carl, Mika; *et al*. Microbial community biomass, production and grazing along 110°E in the eastern Indian Ocean. Deep-Sea Research Part II: Topical Studies in Oceanography. 2022. 16.
https://doi.org/10.1016/j.dsr2.2022.105134

Lawson, Chris; Dudgeon, Christine; Richardson, Anthony; Broadhurst, Matt; Bennett, Mike. Flexibility for fuelling reproduction in a pelagic ray (*Mobula eregoodoo*) suggested by bioenergetic modelling. Journal of Fish Biology. 2022; 100:1-10.
https://doi.org/10.1111/jfb.14995

Lilly L, Everett JD, Suthers IM, **Richardson AJ** (in press, 24/7/2023) A global review of pyrosomes: shedding light on the ocean's elusive 'fire-bodies'. *Limnology and Oceanography Letters.*

Menesch J, Godde C, Venables W, Renard D, **Richardson AJ**, Cobelli O, Waha K (in press, 12/12/2022) Agricultural diversification for crop yield stability: a smallholder adaptation strategy to climate variability in Ethiopia. *Regional Environmental Change*. https://doi.org/10.1007/s10113-022-02021-y

Ratnarajah L, Abu-Alhaija R, Atkinson A, Batten S, Bax NJ, Bernard K, Canonico G, Cornils A, Everett JD, Grigoratou M, Ishak NHA, Johns D, Lombard F, Muxagata E, Ostle C, Pitois S, **Richardson AJ**, Schmidt K, Stemmann L, Swadling KM, Yang G, Yebra L (2023) Monitoring and modelling marine zooplankton in a changing climate. *Nature Communications* 14(564): 1-17.
https://doi.org/10.1038/s41467-023-36241-5

Continued on last page 43...

PLANKTON IN THE INDIAN OCEAN

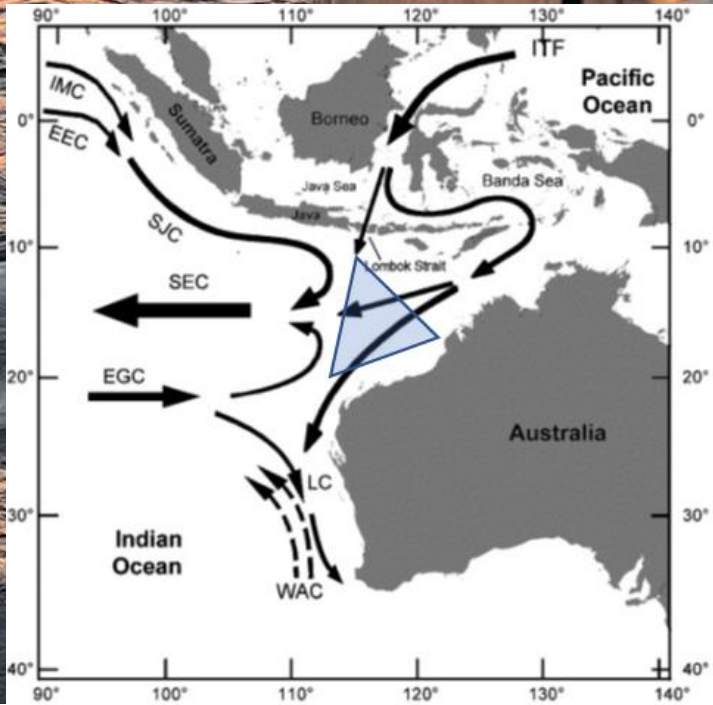
Claire Davies

Following on from the success of the IIOE II RV Investigator voyage, IN2019_V03, in the Indian Ocean led by Lynnath Beckley (Murdoch University) in 2019, Claire was invited to participate in another IIOE II endorsed voyage, BLOOFINZ-IO. This voyage was led by Michael Landry of Scripps Institution of Oceanography at the University of California and was on R/V Roger Revelle, cruise RR2201, in February 2022. The voyage was primarily funded by the US National Science Foundation, project BLOOFINZ-IO (Bluefin Larvae in Oligotrophic Ocean Foodwebs, Investigations of Nutrients to Zooplankton) and set out to investigate the physical, chemical and biological characteristics of the Eastern Indian Ocean. This voyage brought together a highly diverse range of scientists from 8 US institutions and 8 institutions across Australia, Spain, France, China and New Zealand.

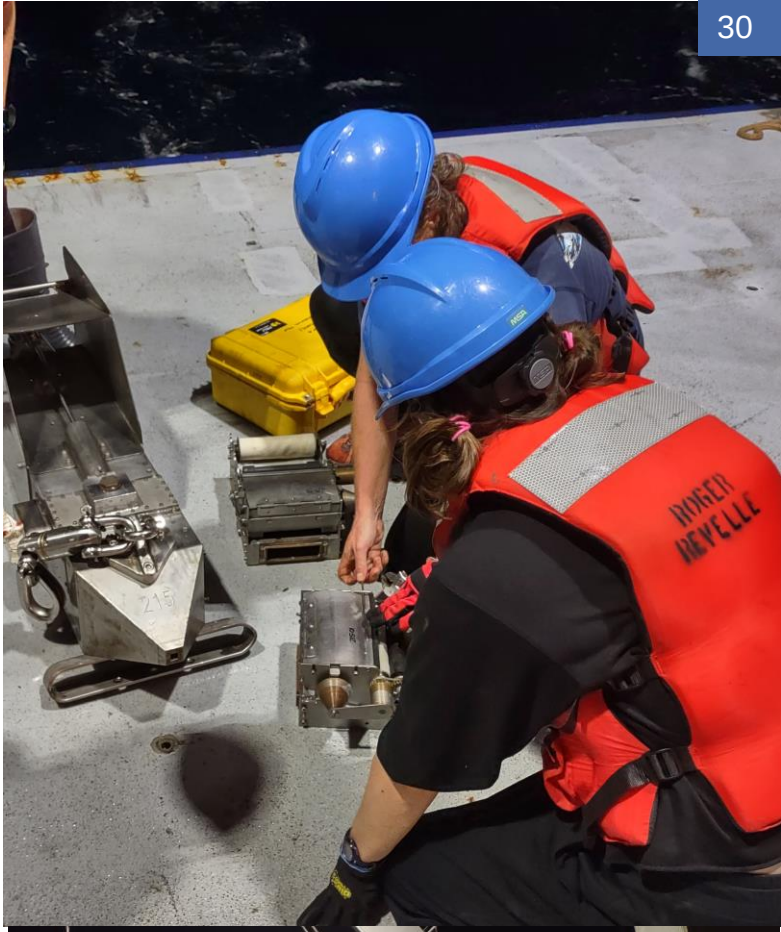
The voyage focused strongly on the oceanography of this oligotrophic region especially in relation to Southern Bluefin Tuna (SBT), the eastern Indian Ocean being an important spawning area for the species. SBT is a highly valued top predator that migrates thousands of kilometres to spawn in this region.

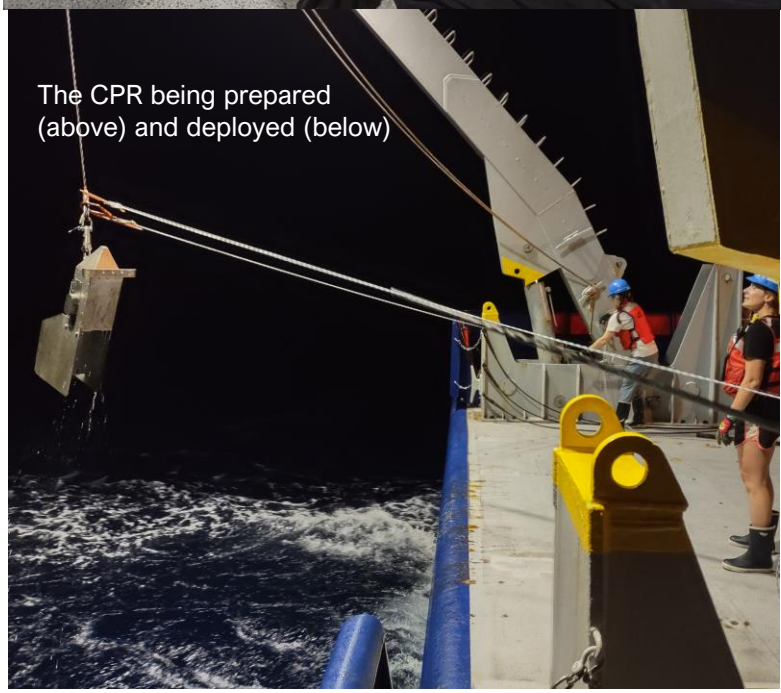
The main aims of the voyage were to determine:

- the main source of nitrogen nutrients to the system (deep mixing vs nitrogen fixation);
- the magnitude, variability and controls of primary production;
- the biomass, composition and trophic structure of the lower (planktonic) food web;
- the pathways and rates of trophic transfer;
- the export of particulate C and N to the deep sea; and
- the abundance, feeding, growth and survival rates of tuna larvae, their dependencies on specific food-web pathways and their potential vulnerabilities to climate change



Many different sampling techniques were employed to answer these questions. Claire took a Continuous Plankton Recorder on board, a first for the Revelle, and several tows were completed along the Northern and North-west coasts of Australia and out in open water further West. A region where we have very little data and is generally under-sampled. She also deployed the IMOS NRS drop net at the sampling stations which were part of process studies across mesoscale features, eddies, and physical structures identified in the region. We repeatedly sampled the same water for integrated euphotic-zone assessments of community composition, biomass structure, stable isotopes, nutrients, nitrate uptake, N fixation, primary production, phytoplankton growth, micro- and mesozooplankton grazing, passive and active (diel migrant) export, and larval feeding, growth and survival. The compositional data from our sampling informs us how the food environment changes spatially relative to features and is important for understanding of food availability and trophic processes that support the larval tuna and more generally an understanding of planktonic food webs in oligotrophic waters. Theories are changing on the food web dynamics in oligotrophic environments and this data can also be used to further understand the impact of larvaceans and salps and mixotrophs that, by different mechanisms, can shunt energy more efficiently through the food web. Plankton sampling from the previous voyage, IN2019_V03, along the 110°E transect where similar experiments were run supported the hypothesis that mixotrophy was an important behaviour in this region. Claire virtually presented this work from IN2019_V03 at the International Indian Ocean Science Conference in March 2022 on her return from the BLOOFINZ-IO voyage.





The CPR being prepared (above) and deployed (below)

Publications from IN2019_V03

(Anderson *et al.*, 2022; Davies *et al.*, 2022; Landry *et al.*, 2022a; Landry *et al.*, 2022b) (Landry *et al.*, 2020)
4 of these publications featured in a special issue in Deep Sea Research Part II: Topical Studies in Oceanography under the section title "Revisiting 110°E in the Second International Indian Ocean Expedition". Edited by Lynnath Beckley, Raleigh Hood, Peter Thompson.
Anderson, M.P.B.C., Davies, C.H., Eriksen, R.S., 2022. Latitudinal variation, and potential ecological indicator species, in the dinoflagellate genus Tripos along 110°E in the south-east Indian Ocean. Deep Sea Research Part II: Topical Studies in Oceanography 203, 105150.

Davies, C.H., Beckley, L.E., Richardson, A.J., 2022. Copepods and mixotrophic Rhizaria dominate zooplankton abundances in the oligotrophic Indian Ocean. Deep Sea Research Part II: Topical Studies in Oceanography 202, 105136.

Landry, M.R., Hood, R.R., Davies, C.H., 2020. Mesozooplankton biomass and temperature-enhanced grazing along a 110°E transect in the eastern Indian Ocean. Marine Ecology Progress Series 649, 1-19.

Landry, M.R., Hood, R.R., Davies, C.H., Selph, K.E., Antoine, D., Carl, M.C., Beckley, L.E., 2022a. Microbial community biomass, production and grazing along 110°E in the eastern Indian Ocean. Deep Sea Research Part II: Topical Studies in Oceanography 202, 105134.

Landry, M.R., Selph, K.E., Hood, R.R., Davies, C.H., Beckley, L.E., 2022b. Low temperature sensitivity of picophytoplankton P: B ratios and growth rates across a natural 10°C temperature gradient in the oligotrophic Indian Ocean. Limnology and Oceanography Letters 7 (2), 112-121.

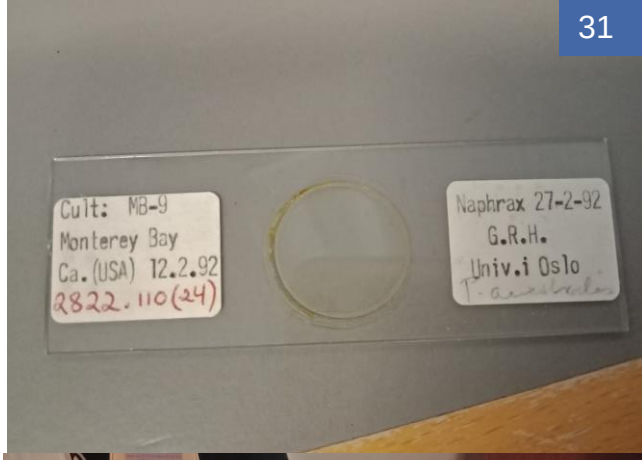
IOC HARMFUL ALGAL BLOOM TAXONOMIC TRAINING IN DENMARK

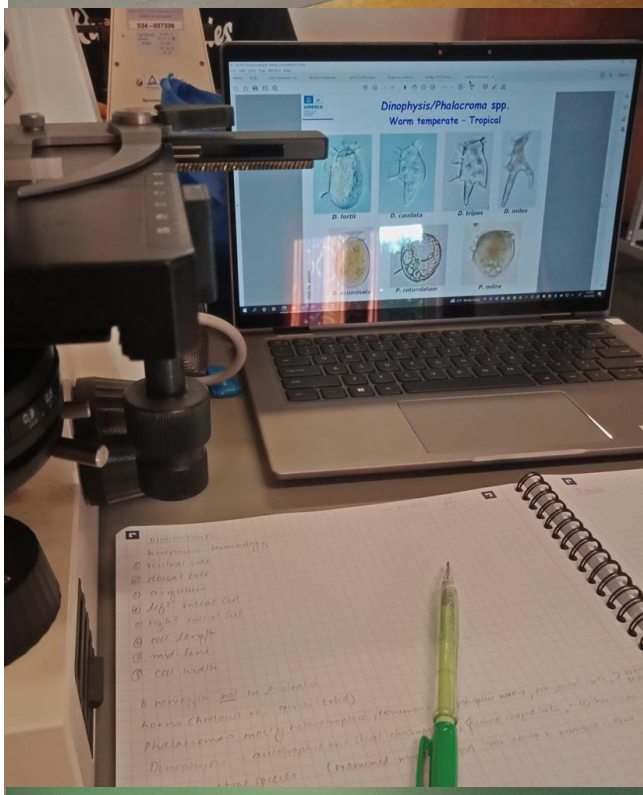
Ruth Eriksen

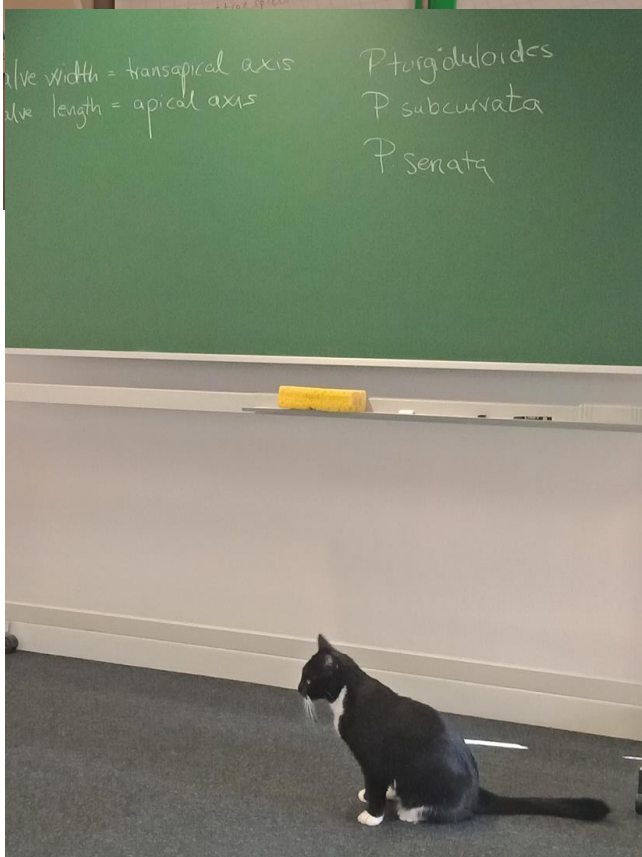
In October 2022, I travelled to Hillerød, Denmark to complete the practical component of the Intergovernmental Oceanographic Commission (IOC) of UNESCO training course '*Certificate of Proficiency in Identification of Harmful Marine Microalgae*'. The course included 100 hours of teaching, divided into two parts. Part 1 of the course was an internet-based teaching programme while Part 2 was a practical microscopy course in species identification. The online component consisted of 11 modules each with a short introductory text and a (long!) list of additional reading, covering all the major taxonomic groups of harmful algae. The on-line modules were delivered by Dr Jacob Larsen from the University of Copenhagen, over several time zones. It was pleasing to see a number of participants from the Phytoplankton Ecology Unit, Department of Water and Environment, WA in our group of 18!

The courses are traditionally offered every year, but COVID restrictions meant the on-line component was completed in 2021, and it wasn't until late 2022 that the face-to-face component could be realised. The residential workshop in Hillerød focused on practical aspects and limitations of identification of harmful algal species, with particular reference to the 'IOC Taxonomic Reference List on Toxic Plankton Algae'. Dr Jacob Larsen and Dr Santi Fraga delivered lectures (in Spanish and English!) each morning and then we spent each afternoon on the microscopes looking at culture and preserved samples from all around the world. The most valuable aspect for me was integration of molecular data into the taxonomic review of several difficult groups, with a fabulous primer on interpreting genetic data-streams by Professor Nina Lundholm. Examining slides prepared by the legendary Professor Grethe Rytter Hasle was also memorable. The lectures and practicals culminated in a 3-hour microscopy exam, one of the most intense assessments I have ever experienced. The lectures were often attended by the resident cat, who also soothed many nerves during the exam.

The course was incredibly in understanding and appreciating the realities of HAB identification using light microscopy – this method is not perfect but it is so integrated into routine monitoring programs, and published taxonomic descriptions that it is critical to maintain this skill-set, even as we move towards better, affordable and routine discrimination with genetic approaches. The bulk of the course content is delivered by retired experts, a testament to their commitment and willingness to sharing their accumulated wisdom.







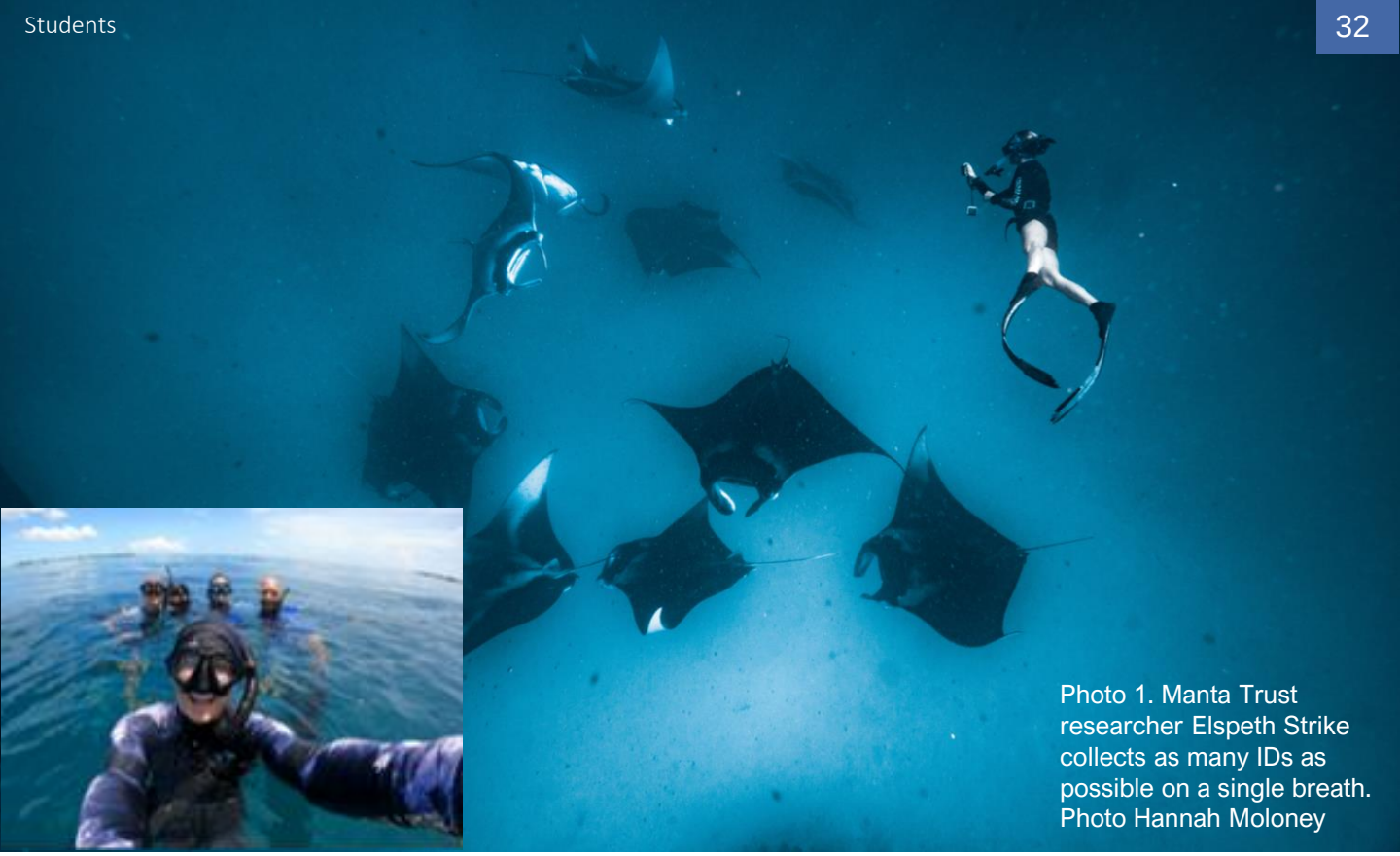


Photo 1. Manta Trust researcher Elspeth Strike collects as many IDs as possible on a single breath. Photo Hannah Moloney

GROUND TRUTHING BACKSCATTER OF MANTA RAYS AND ZOOPLANKTON BIOMASS ON ADCP's Hannah Moloney

Hanifaru Bay in the Maldives turns into a melting pot for large megafauna. Reef manta rays (*Mobula alfredi*) aggregate to feast on the plankton soup that results from the perfect recipe of prevailing winds, currents, tides and moon phases. This unsuspecting small reef inlet the size of a football pitch hosts the world's largest aggregation of these threatened filter feeders. While the ephemeral hotspot lasts, mantas race around with their unfurled cephalic fins and mouths agape scooping up zooplankton predominantly consisting of copepods, chaetognaths, shrimp-like animals, salps and crab zoea. Snorkelers watch from above in disbelief. Finding yourself surrounded by the organised chaos created by 150 large flying carpets (some the size of a flat VW Beetle car) is nothing less than surreal! (Photo 1).

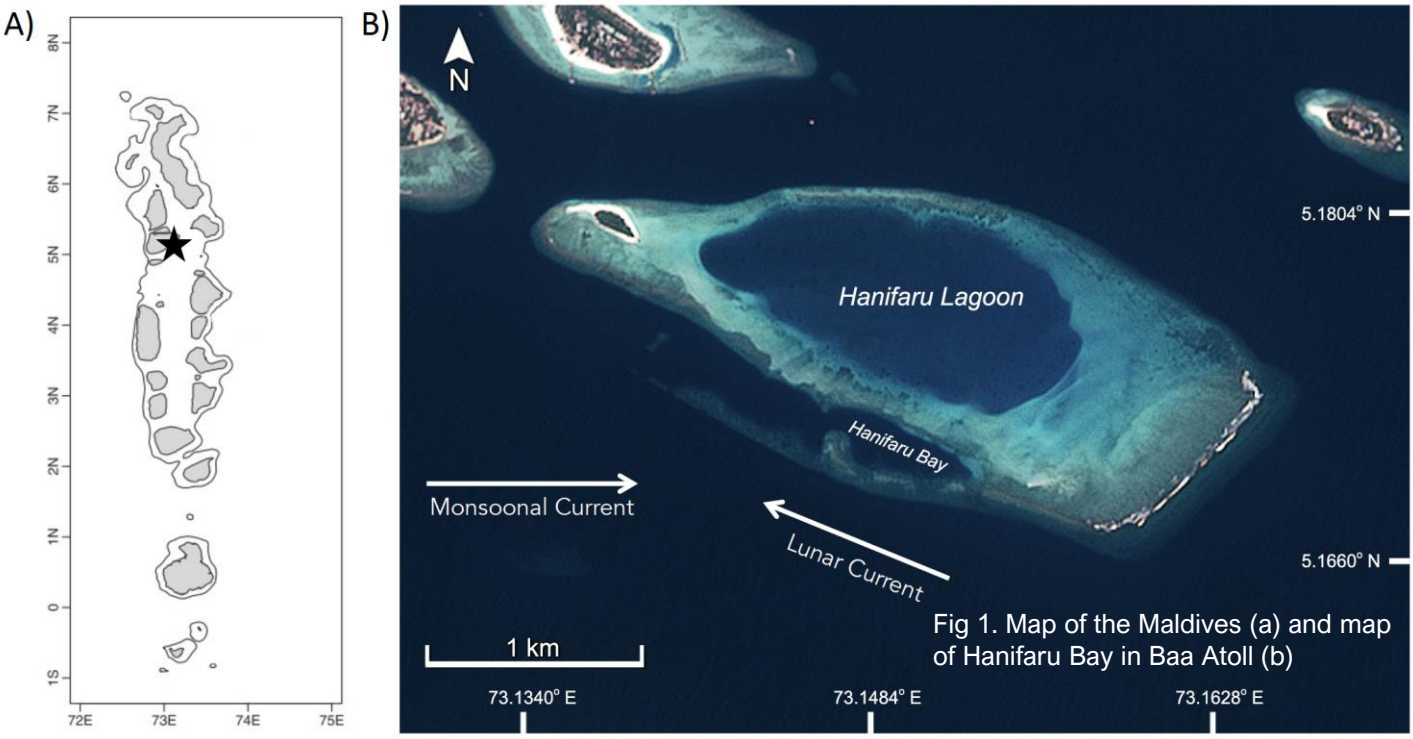


Fig 1. Map of the Maldives (a) and map of Hanifaru Bay in Baa Atoll (b)

But how and why do the prevailing currents and changes in water properties promote the concentration of zooplankton and ultimately manta rays in Hanifaru Bay. Last year we set out to investigate what exactly is the perfect recipe for mass feeding manta rays in Hanifaru Bay. Lead by Plymouth University's Dr. Phil Hosegood, a project combining biological sciences with physical oceanography was launched in Baa Atoll. This study aims to monitor the physical oceanographic conditions that are driving manta ray behaviour and zooplankton availability in and around Hanifaru Bay (Fig 1). We used a combination of zooplankton sampling, aerial surveys, manta ray photo-ID and oceanography equipment to address these large overarching questions.

To understand circulation and the role of currents in Baa Atoll, we deployed 2 x signature 500 moorings at 50metres in the channels and 2 x signature 1000 Acoustic Doppler Current Profilers (ADCPs) tripods at 15metres in Hanifaru Bay (Photo 2). The ADCP's use sound to survey the water column to resolve currents (water movement, temperature and velocity). We also mapped the bathymetry of the bay using multibeam surveys.

As part of my PhD, I aim to ground-truth the backscatter on the ADCP echosounder by measuring zooplankton biomass and composition, and identifying manta rays. To validate the ADCPs high resolution (3mm bins) single frequency (1000kHz) echosounder mode, I have collected in-situ zooplankton tows and remote videos. This site is UNESCO World Heritage and has many regulations to protect manta rays from the impacts of tourism, which also eliminates the prospect of more traditional plankton sampling methods like boat-based net tows.

Using nothing but a single breath and some long free-diving fins, I collected zooplankton samples at varying depths carrying a hand-towed net (Photo 3). This also meant I could target a range of high and low zooplankton biomass. Remote videos collected using weighted GoPro's will be used to ground-truth large shapes in the echogram (Fig 2) to real-time manta sightings. Preliminary data visualisations suggest that DVI inside the Atoll may be occurring with the zooplankton hugging the seafloor in the early hours. A major concern of working with acoustics in a shallow bay is the interference from sediment and bubbles at the surface. However, with currents moving at 2-3cm per second in a clockwise eddy, sediment is unlikely to cause a huge issue in the analysis and the backscatter we are seeing is likely to be clouds of zooplankton. These eddy's may even influence some of the group feeding strategies employed by manta rays such as cyclone feeding (Photo 4).

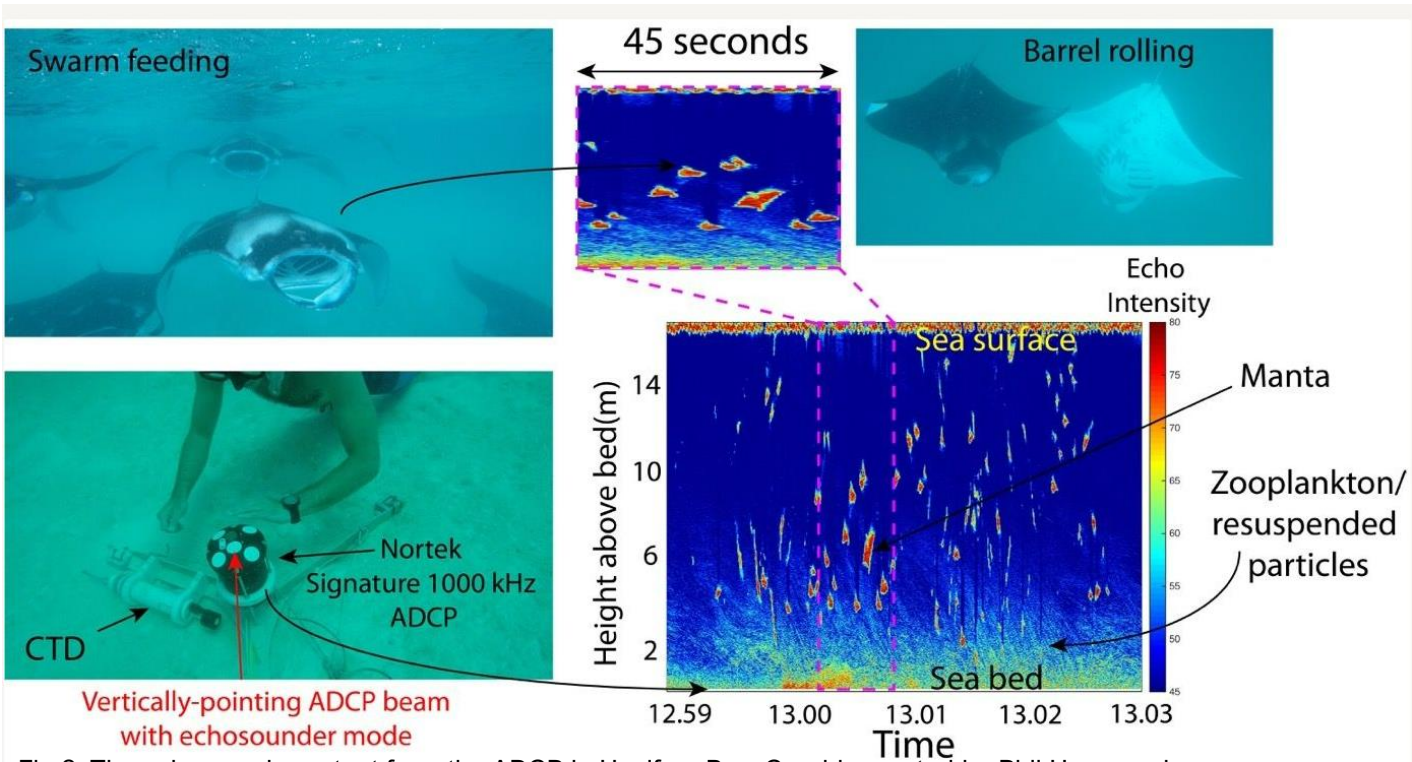


Fig 2. The echosounder output from the ADCP in Hanifaru Bay. Graphic created by Phil Hosegood

Photo 2. ADCP tripod deployment in Hanifaru Bay. Photo Sophie Owsianka

Photo 4. Drone photo of cyclone feeding manta rays in Hanifaru Bay. Photo Simon Hilbourne

Photo 5. Chain feeding manta rays with their mouths agape making the gill rakers visible. Photo Hannah Moloney

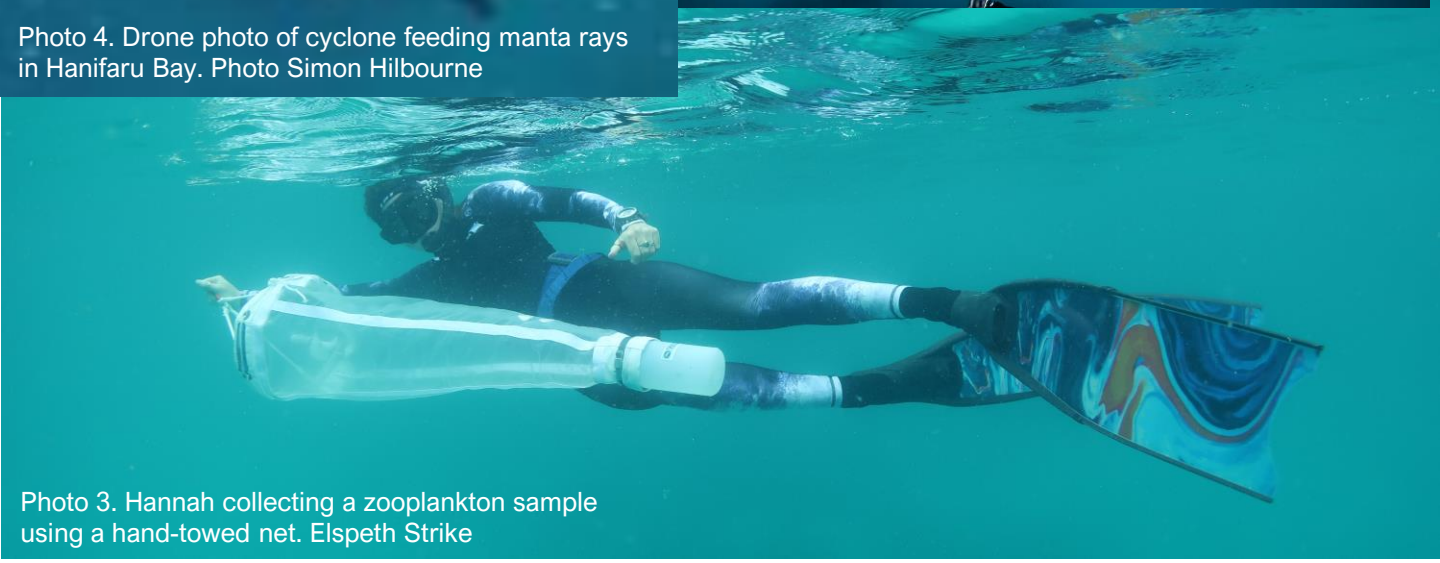


Photo 3. Hannah collecting a zooplankton sample using a hand-towed net. Elspeth Strike

With the intensity of systems such as El Nino increasing, it is more important than ever to understand what drives these natural systems. A changing climate threatens to decrease zooplankton biomass and affect the availability of food for manta rays and other planktivores. This study will help us to understand what drives the worlds largest feeding aggregation of reef manta rays and how we can aid conservation efforts into the future protecting the habitats that they call home and the food they call dinner (Photos 5).

Written by Hannah Moloney, PhD researcher at the University of the Sunshine Coast and Principal Collaborator at Manta Trust. This study is in collaboration with Plymouth University, University of the Sunshine Coast, CSIRO Australia, University of Queensland, EPA Maldives, Biosphere Reserve Maldives, Four Seasons Resorts and Manta Trust.

RESCUING A HISTORICAL ICHTHYOPLANKTON GOLDMINE

By Kristine Camille Buenafe

The Nishikawa dataset[1] contains the largest (based on 63,017 tows), near-global, historical data (1956-1981) on larval distributions of fish species (Figure 1). It has a 1º spatial resolution and contains data on 18 mainly commercial pelagic taxa of the families Scrombridae, Xiphiidae, Istiophoridae, Scombrolabracidae, and Scomberosocidae. Portions of this dataset have been used in fisheries reports[2] and in an analysis of seven tuna species with a 5º resolution[3], but the digitized data were not publicly available. In our newly published paper in Nature Scientific Data, *A global, historical database of tuna, billfish, and saury larval distributions*[4] (https://doi.org/10.1038/s41597-022-01528-7), we digitized all 72 seasonal larvae distribution maps in the Nishikawa dataset.

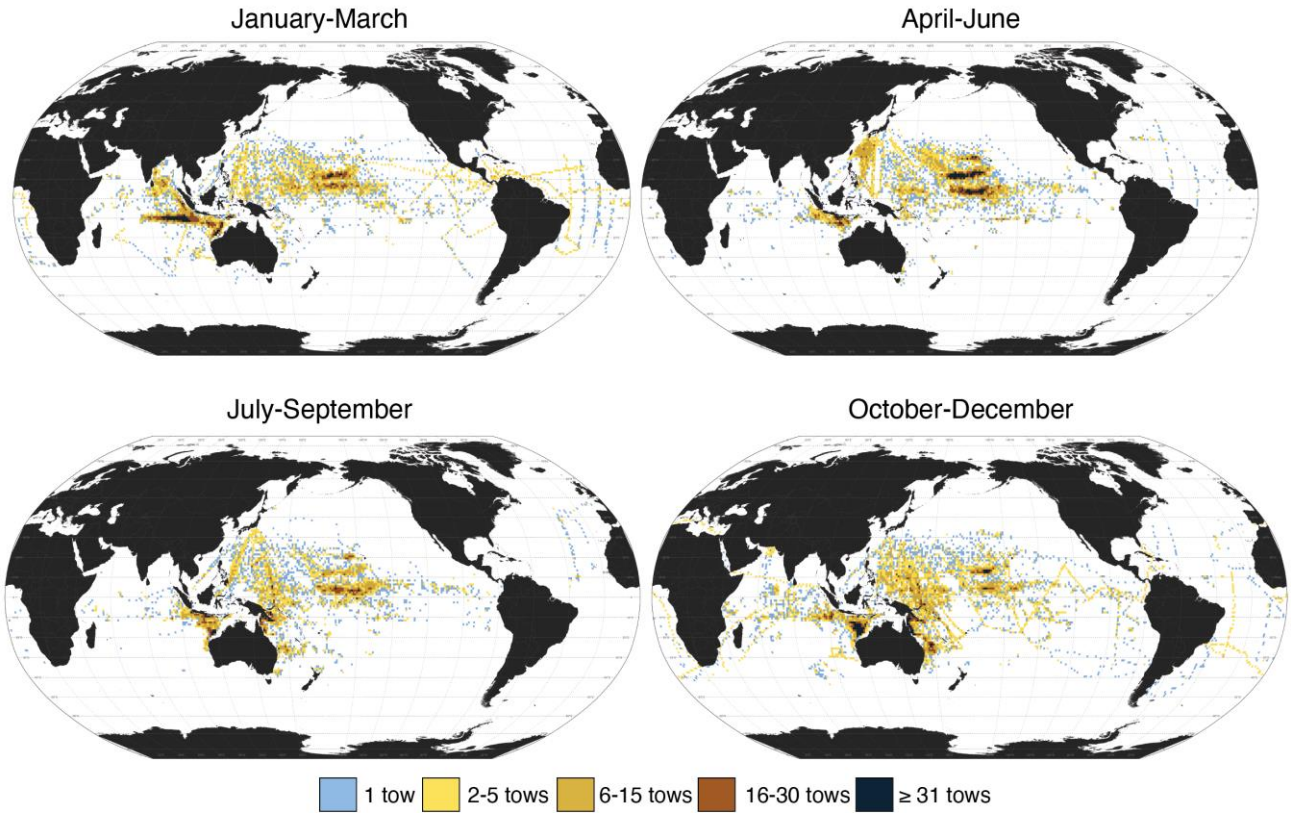


Figure 1. Seasonal towing effort map. Seasonal 1ºx1º maps of towing effort in terms of number of tows, with seasons (1956-1981) represented in ranges of months: 1) January-March; 2) April-June; 3) July-September; and 4) October-December.

The digitization process was started by James Mercer, Iain Suthers, Anthony Richardson, Jason Everett, Hayden Schilling, and Charlie Hinchliffe in 2018-2019 for 4 out of the 18 species. During my MSc, I continued this process, digitizing the remaining 14 species in the Nishikawa dataset. Unfortunately, optical character recognition technology could not be used because of the poor quality of the copy and the warped pages, so the digitization process was performed manually. Digitized maps were checked against the originals (Figure 2).

a.

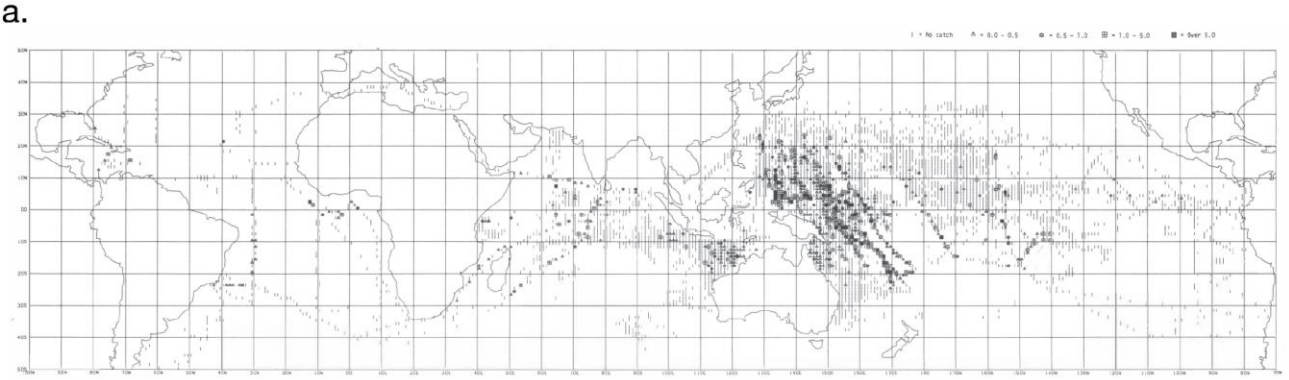


Fig. 52. Skipjack, *Katsuwonus pelamis* (October—December). カツオ（10—12月）

b.

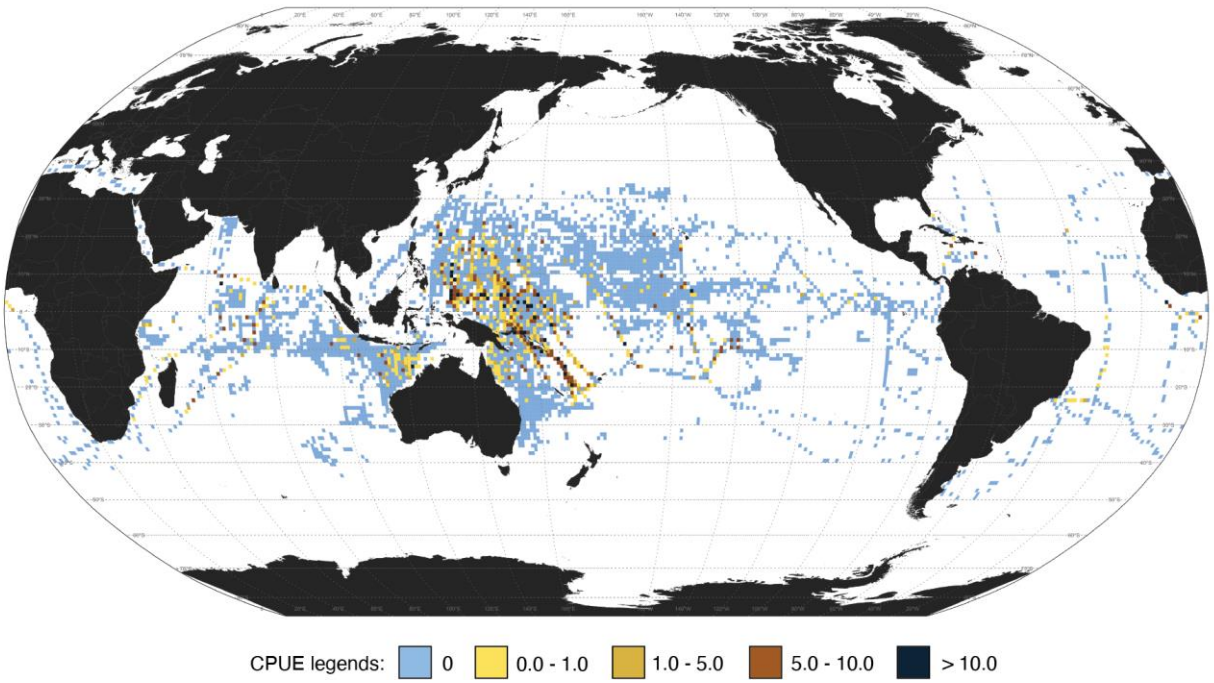


Figure 2. Side-by-side of seasonal map of skipjack tuna for October-December: a) the original chart from Nishikawa et al. (1985); and the b) the digitized map.

The dataset contains ichthyoplankton data collected between 50ºN-50ºS in the Pacific, Indian, and Atlantic Oceans. Sampling was biased towards the Western Pacific, primarily because the surveys were carried out by Japanese government institutions surveying tuna longline grounds. Because data were collected by different organizations and in a range of different ways, data on individual tows are not available. The seasonal larval abundance for each species was standardized to catch per unit effort (CPUE) or the number of larvae per 1,000 m^3 water strained (see Figure 3 for yellowfin tuna).

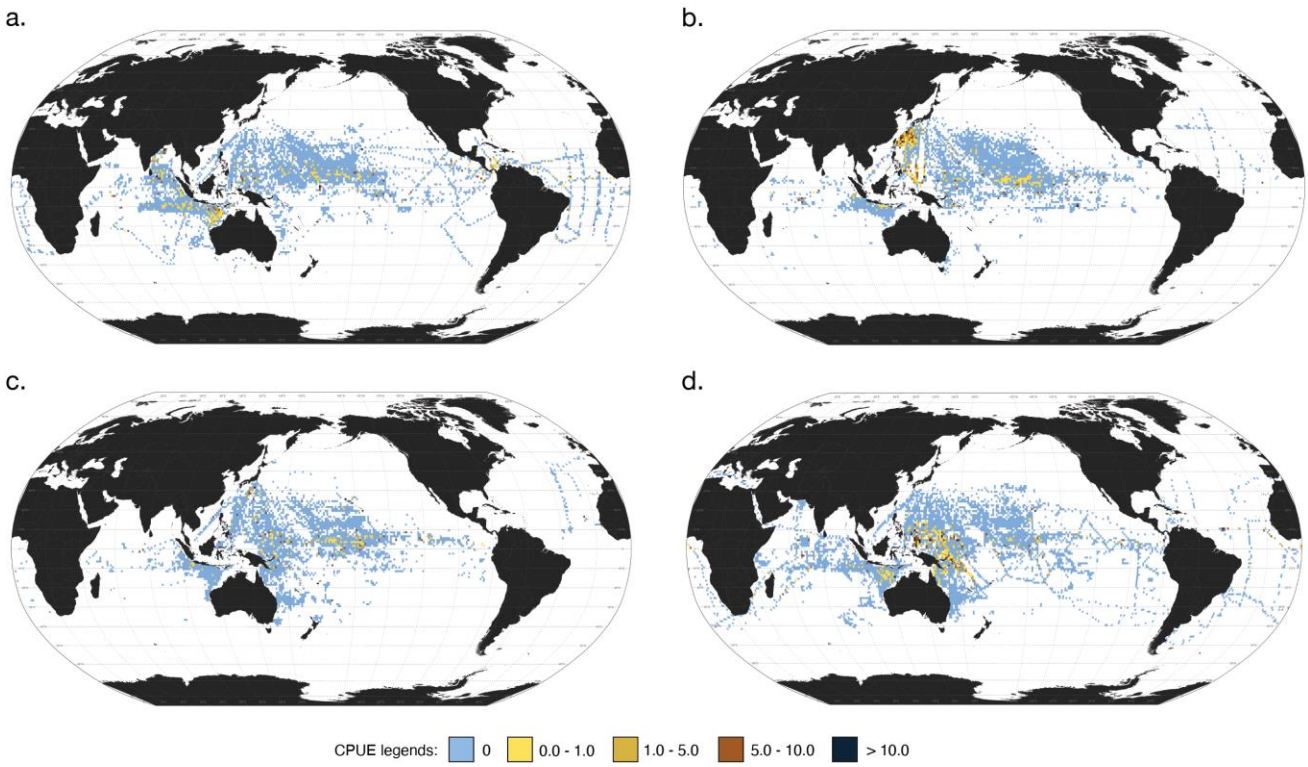
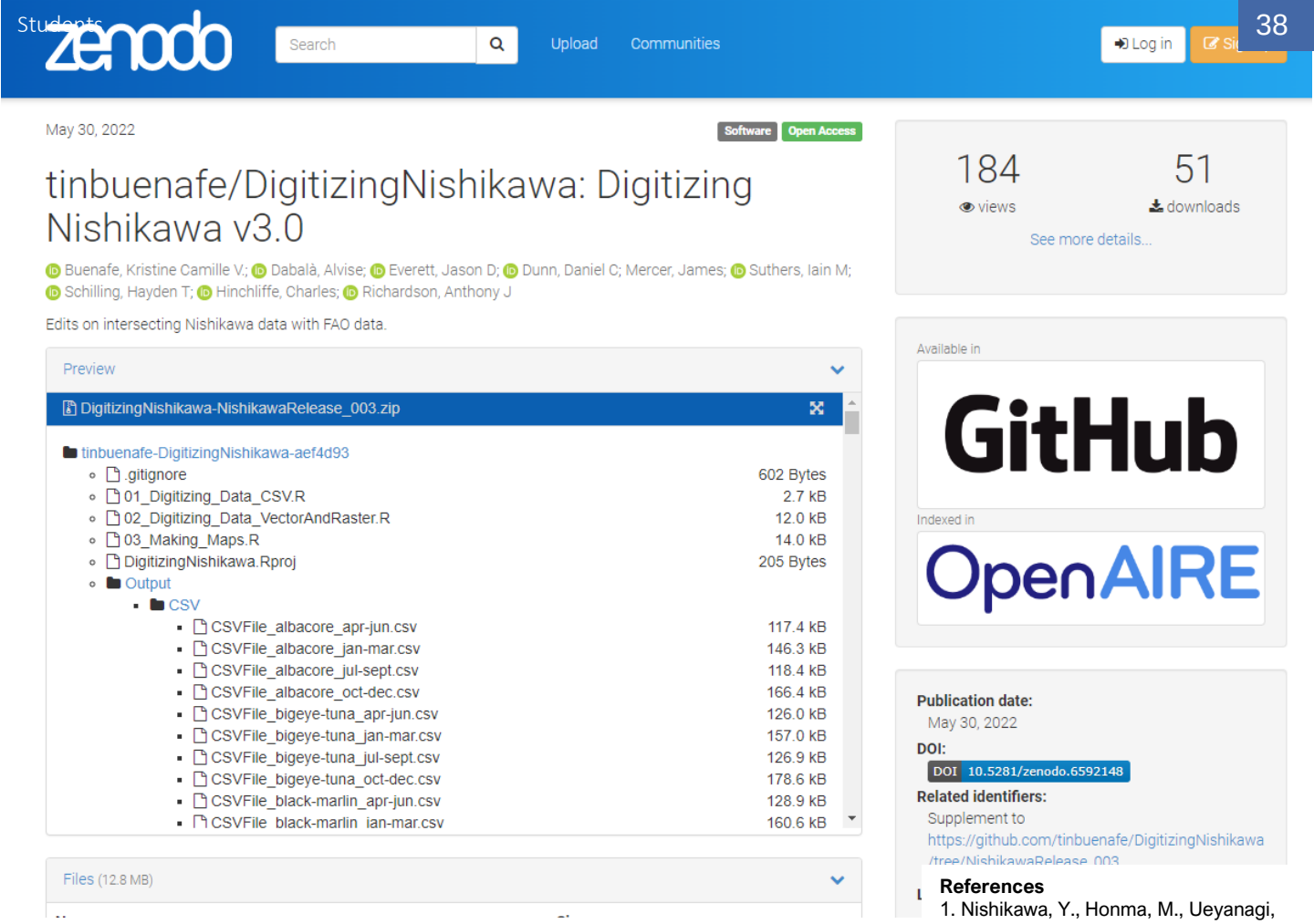


Figure 3. Seasonal larval distribution maps of yellowfin tuna. a) January-March; b) April-June; c) July-September; and d) October-December. Catch per unit effort (CPUE) for each grid cell is expressed in number of larvae·1,000 m^{-3}.



The dataset contains ichthyoplankton data collected between 50ºN-50ºS in the Pacific, Indian, and Atlantic Oceans. Sampling was biased towards the Western Pacific, primarily because the surveys were carried out by Japanese government institutions surveying tuna longline grounds. Because data were collected by different organizations and in a range of different ways, data on individual tows are not available. The seasonal larval abundance for each species was standardized to catch per unit effort (CPUE) or the number of larvae per 1,000 m^3 water strained (see Figure 3 for yellowfin tuna).

We provide the digitized data in three different file formats (delimited text, raster, and vector) which can be freely accessed here[5]: https://doi.org/10.5281/zenodo.6592148. We hope that making what is probably the largest near-global larval dataset publicly available will encourage its extensive future use in novel ways.

Based on the digitized Nishikawa dataset, I developed Generalized Additive Models (GAMs) for skipjack tuna, yellowfin tuna, albacore, and swordfish during my MSc with Anthony Richardson, Jason Everett, and Daniel Dunn. The GAMs allowed us to identify key spawning areas and a suite of environmental drivers. These larvae distribution maps of 4 key species informed where conservation-sensitive, climate-smart fisheries closures can be placed in the Pacific Ocean's Areas Beyond National Jurisdiction (ABNJ) based on a spatial prioritization. My master's thesis work further emphasized the dataset's importance, especially in marine spatial planning. Spawning hotspots can be used as focal areas for marine protected area networks in the high seas. The hotspots could also be used to inform the establishment of conservation-sensitive fisheries closures that can count towards conservation targets, which are known as other effective area-based conservation measures (OECMs)[6-8]. We hope that the Nishikawa data can be used to bridge fisheries management and conservation efforts[7].

References

1. Nishikawa, Y., Honma, M., Ueyanagi, S., & Kikawa, S. Average Distribution of Larvae of Oceanic Species of Scombroid Fishes, 1956-1981. (Far Seas Fisheries Research Laboratory, 1985).
2. Kiyofuji, H. & Ochi, D. *Proposal of alternative spatial structure for skipjack stock assessment in the WCPO.* (WCPFC, 2016).
3. Reglero, P., Tittensor, D., Álvarez-Berastegui, D., Aparicio-González, A., & Worm, B. Worldwide distributions of tuna larvae: revisiting hypotheses on environmental requirements for spawning habitats. *Mar. Ecol. Proj. Ser.* **501,** 207-224 (2014).
4. Buenafe, K.C.V., Everett, J.D., Dunn, D.C. et al. A global, historical database of tuna, billfish, and saury larval distributions. **Sci Data** 9, 423 (2022). https://doi.org/10.1038/s41597-022-01528-7
5. Buenafe, K.C.V., Dabalà, A., Everett, J.D., Dunn, D.C., Mercer, J., Suthers, I.M., Schilling, H.T., Hinchliffe, C., & Richardson, A.J. tinbuenafe/DigitizingNishikawa: Digitizing_Nishikawa (NishikawaRelease_003). *Zenodo* https://doi.org/10.5281/zenodo.6592148 (2022).
6. CBD. *Protected areas and other effective area-based conservation measures (Decision 14/8).* https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-08-en.pdf (2018).
7. Gurney, G.G. *et al.* Biodiversity needs every tool in the box: use OECMs. *Nature* **595,** 646-649 (2021).
8. Hiltz, E., Fuller, S., & Mitchell, J. Disko Fan Conservation Area: a Canadian case study. *Parks* **24,** 17-30 (2018).

TEMPORAL AND SPATIAL VARIATION IN ZOOPLANKTON AND ITS DRIVERS IN AUSTRALIAN WATERS

Marc Koh

Zooplankton are one of the ocean's sentinels of change. They serve as the sensitive indicators of environmental change, as well as important food sources for many of our beloved macro and megafauna. To understand how the physical and chemical state of our oceans affect zooplankton abundance and communities is an important part of predicting how these abiotic drivers may affect the higher trophic levels of the marine food web, and ultimately, us.

For my Honours thesis, data from the IMOS National Reference Stations (NRS) was used to assess changes in zooplankton biomass and copepod community structure spatially and temporally. This can be done on a local and continental scale due to the strategic positioning of the NRS, allowing for an overview of zooplankton communities in Australian waters. We hypothesised that temperate regions would have a larger biomass that would see more variation interannually and seasonally as compared to tropical and sub-tropical regions. We had also hypothesised that climate oscillations would only have impacts at specific stations, particularly those that are situated on the Australian east coast. With respect to copepod communities, we hypothesised that there would be substantial variation driven by temperature between each site, with smaller warm water species dominating northern sites.

Using a generalised linear model, we assess how zooplankton biomass has changed over the last decade, and with season, Sea Surface Temperature, Salinity, Chlorophyll *a*, and El-Nino Southern Oscillation, around Australia and at individual sites. Copepod communities were assessed using non-metric Multidimensional Scaling with Permutational Analyses of Variance, and Indicator Species Analyses to find species that are "indicative" of sites, seasons, and other categorical variables.

As our oceans change, it is pertinent to understand how marine life adapt and change with them. I am excited for the results of this project to contribute to our understanding of drivers of Australia's zooplankton, as well as the wider knowledge of plankton. I'd like to thank my supervisors, Helen Bostock and Anthony Richardson, for their continuous support, patience, and guidance. I would also like to thank the plankton team at CSIRO Environment, without their hard work, this project would not be possible. Lastly, I would like to particularly thank Julian Uribe-Palomino for introducing me to the world of plankton and inspiring my love for copepods.

Monstrilloid copepod female

FIRST BARCODE SEQUENCES FROM AUSTRALIAN MONSTRILLOID COPEPODS

Julian Uribe Palomino

Liang Kang Marc Koh delivered an oral presentation on Monstrilloid copepods at the SCOR (*Scientific Committee on Oceanic Research*) MetaZooGene Symposium 2022, as part of the ICES (*International Council for the Exploration of the Sea*) Annual Science Conference 2022. This research summarised preliminary results of genetic barcoding (COI) monstrilloid specimens from two geographically separated coastal areas of Australia: Coral Bay -WA (Indian Ocean) and the Southern part of the Great Barrier Reef (GBR) (Pacific Ocean). This work supports the importance of molecular evidence as a tool towards the validation of monstrilloid species and demonstrates the need for a suitable reference library that can be used for future biodiversity and environmental assessments.

This research has been possible thanks to the collaboration with: Cynthia Riginos, Ilha Byrne, Iva Popovic from the University of Queensland, Stephanie Venables from the Marine Megafauna Foundation and Sharon Appleyard and Julian Uribe-Palomino from CSIRO.

DIGITAL KEYS TO THE CALANOID COPEPODS BY DR JANET BRADFORD-GRIEVE

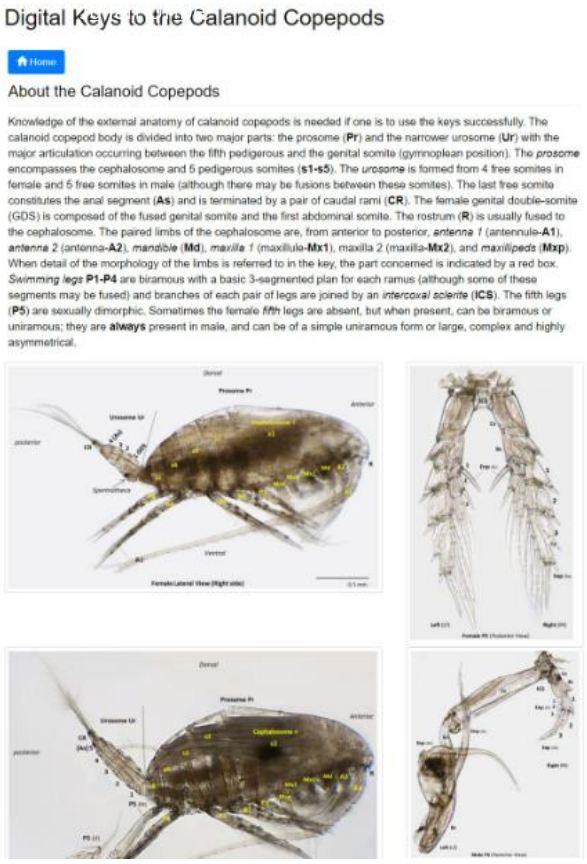
Julian Uribe Palomino

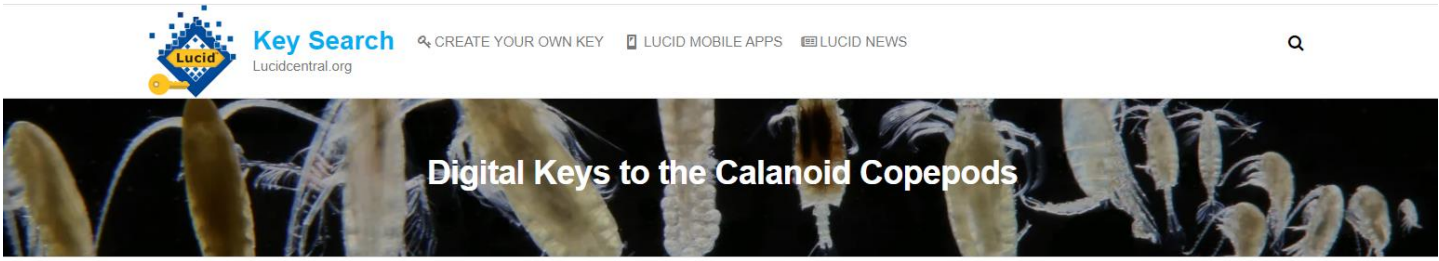
The traditional approach to the taxonomic identification of organisms is usually dichotomous keys, which are not always easy to navigate and limit the number of options available for the identification of the specimen based on the number of features and the terminology used by the Author of the key.

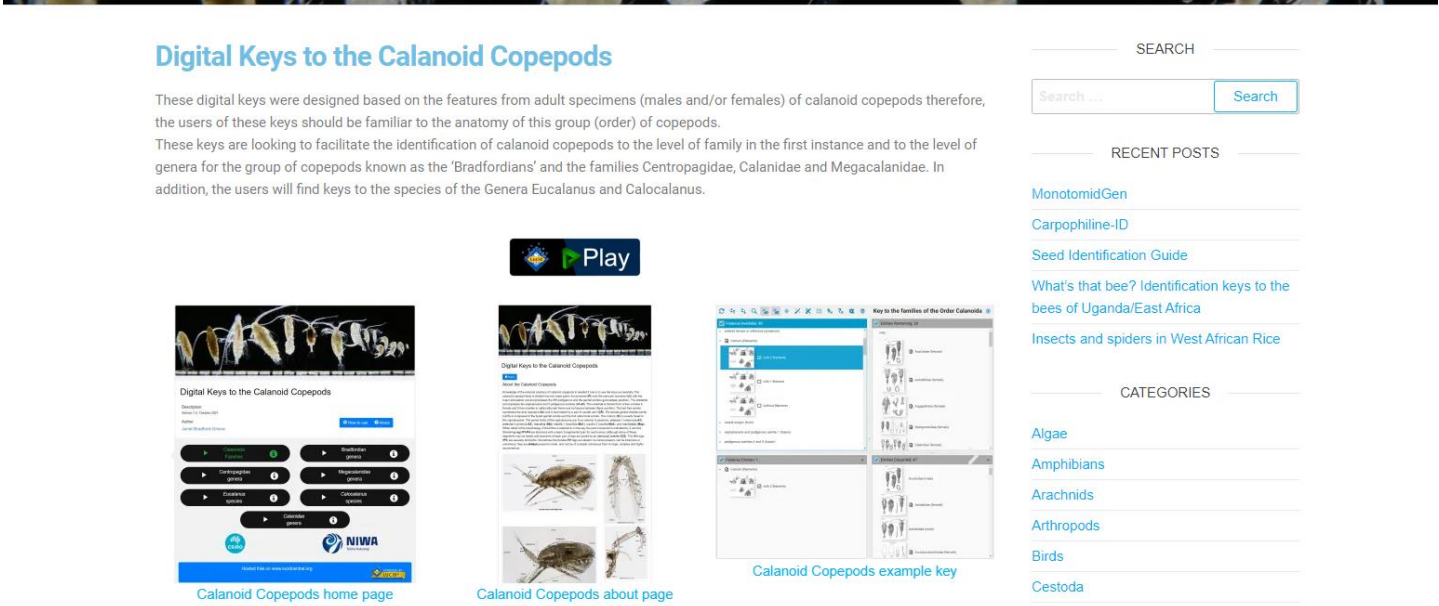
On the other hand, Lucid keys are a flexible and dynamic digital platform that allows the users to select from two or more morphological features with the purpose of getting the most suitable identification of a specimen. The morphological features can contain text and images that can clarify terminology used to describe these features and ease the understanding of the specimen's morphology and facilitates the decision-making process when selecting one or multiple options.

The digital keys built by Dr Janet Bradford-Grieve during her professional career are a valuable resource to help researchers and students identify calanoid specimens to the level of family and, certain specimens, to the level of genus or species in a more dynamic way than using traditional dichotomous keys.

These keys are now available, through the collaboration between CSIRO, NIWA and Dr Bradford-Grieve, at the Lucid central website. Click in the link below to start playing with them: https://keys.lucidcentral.org/search/calanoid-copepods/



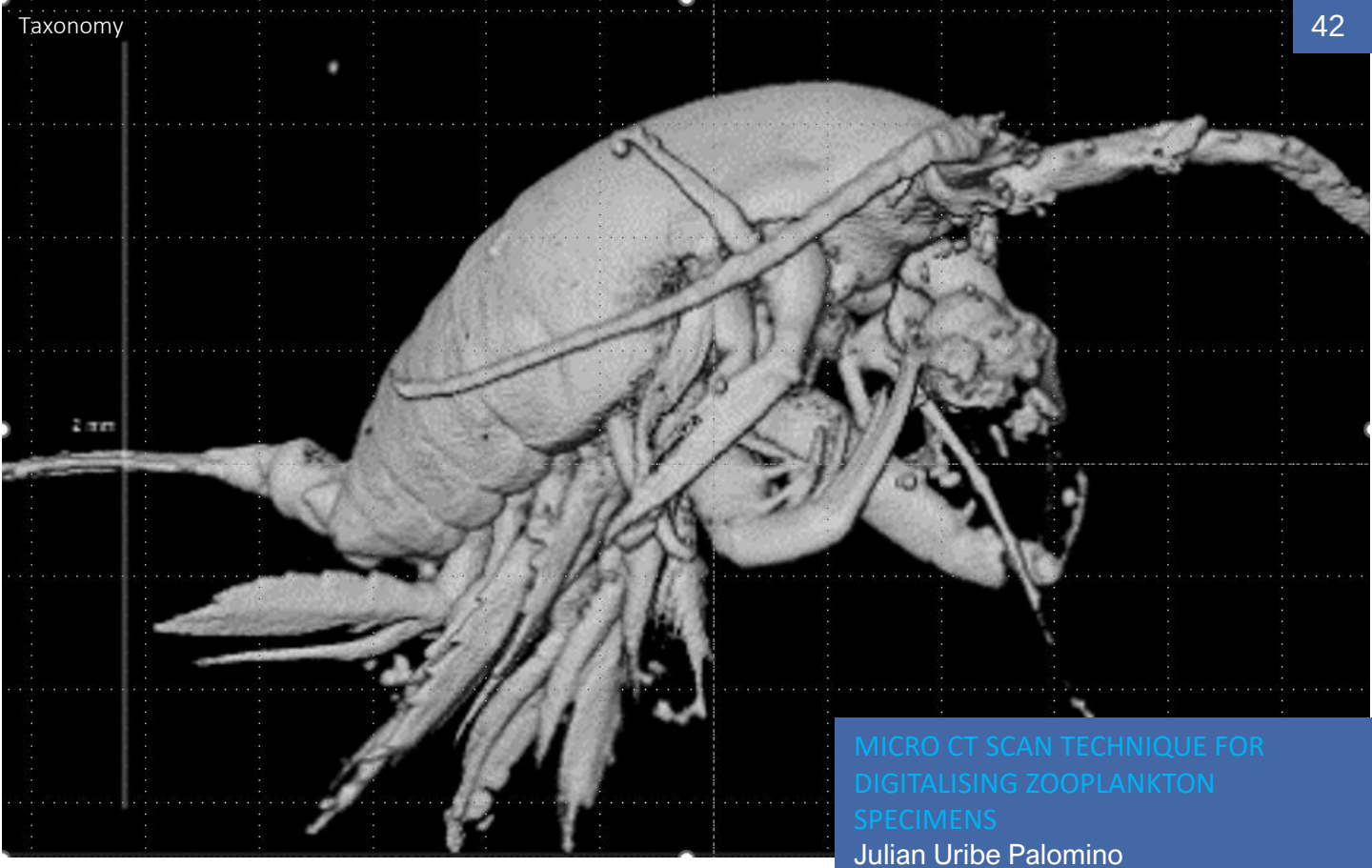




Calanoid Copepods home page

Calanoid Copepods about page

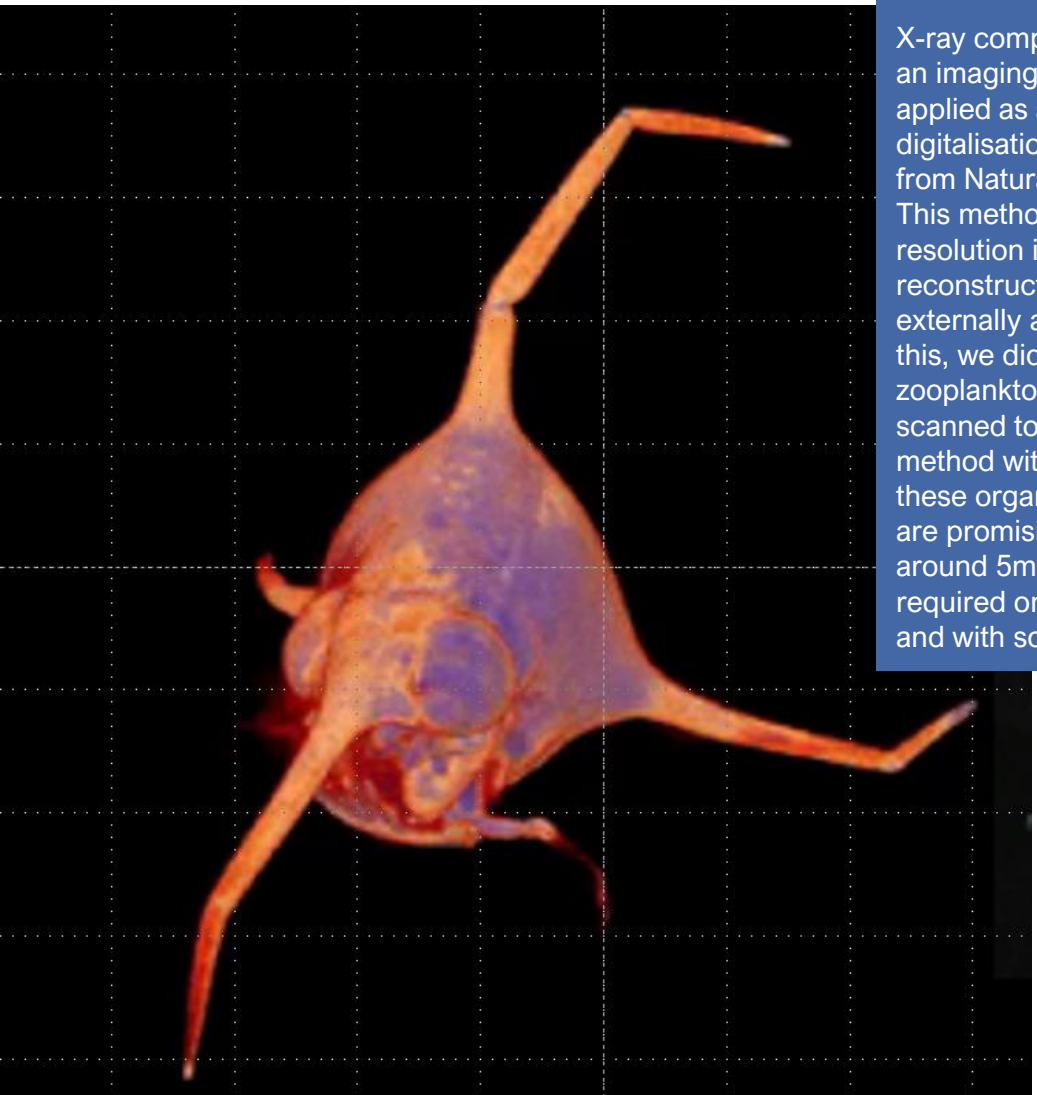
Calanoid Copepods example key



MICRO CT SCAN TECHNIQUE FOR DIGITALISING ZOOPLANKTON SPECIMENS

Julian Uribe Palomino

X-ray computed tomography (XCT) is an imaging technique that now is being applied as a novel method for digitalisation of small to large specimens from Natural Collections from Museums. This method produces very high-resolution imagery, allowing the reconstruction of the specimen's body externally and internally. Having in mind this, we did a small trial getting a few zooplankton specimens micro-CT scanned to test the limitation of the method with the type of body and size of these organisms. Preliminary results are promising for solid specimens around 5mm however, more testing is required on animals smaller than 2mm and with soft bodies.



Above: Image of a *Candacia* calanoid copepod.

Left: Crab zoea larvae 3D model after image reconstruction.

RECENT PAPERS

...Continued from page 27.

Rohr, Tyler; Shadwick, Elizabeth; Lenton, Andrew; Richardson, Anthony. Recommendations for the Formulation of Grazing in Marine Biogeochemical and Ecosystem Models. Progress in Oceanography. 2022; 208:27. https://doi.org/10.1016/j.pocean.2022.102878

Rohr T, **Richardson AJ**, Lenton A, Shadwick E, Chamberlain M (2023) Zooplankton grazing is the largest source of uncertainty in marine carbon cycling in CMIP6 IPCC. *Communications Earth & Environment.*

Schoeman DS, Sen-Gupta A, Harrison CS, Everett JD, Brito-Morales I, Hannah L, Bopp L, Roehrdanz P, **Richardson AJ** (in press, 12/4/2023). Demystifying global climate models for use in the life sciences. *TREE*

Sun, Chaojiao; J. Hobday, Alistair; Condie, Scott; Baird, Mark; Eveson, Paige; Hartog, Jason; *et al*. Ecological forecasting and operational information systems support sustainable ocean management. Forecasting. 2022; 4:1051-1079. https://doi.org/10.3390/forecast4040057

Suthers, Iain; Hinchliffe, Charles; Falster, Daniel; Richardson, Anthony; Everett, Jason. The Mortality/Growth ratio of larval fish and the slope of the zooplankton size-spectrum. Fish and Fisheries. 2022; 23:750-757. https://doi.org/10.1111/faf.12633

Weldrick, C.M, **Eriksen, R.S**., King, S., Swadling, K. Rivers of brine in Antarctic sea ice provide a home for tiny organisms. Frontiers for Young Minds

Womersley, Freya; Richardson, Anthony; Duarte, Carlos; Sims, David. Global collision-risk hotspots of marine traffic and the world's largest fish, the whale shark. Proceedings of the National Academy of Sciences of the United States of America. 2022; 119(20):1-10. https://doi.org/10.1073/pnas.2117440119

NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

Australia's Integrated Marine Observing System (IMOS) is enabled by the National Collaborative Research Infrastructure Strategy (NCRIS). It is operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent. **www.imos.org.au**

IMOS Integrated Marine Observing System

PRINCIPAL PARTICIPANTS

University of Tasmania (Lead Agent) · Australian Government · Australian Institute of Marine Science · Australian Government Bureau of Meteorology · CSIRO · Government of South Australia · SARDI · The University of Western Australia · sims sydney institute of marine science · UTS · The University of Sydney · Macquarie University · UNSW Sydney

SIMS is a partnership involving four universities.

ASSOCIATE PARTICIPANTS

Curtin University · Australian Government Department of Climate Change, Energy, the Environment and Water Australian Antarctic Division · Australian Antarctic Program · Deakin University · The University of Melbourne

IMOS thanks the many other organisations who partner with us, providing co-investment, funding and operational support, including investment from the Tasmanian, Western Australian and Queensland State Governments.

IMOS acknowledges the Traditional Custodians and Elders of the land and sea on which we work and observe and recognise their unique connection to land and sea. We pay our respects to Aboriginal and Torres Strait Islander peoples past and present.

We invite people to explore our plankton data further: https://shiny.csiro.au/BioOceanObserver/

Follow us on social media for up to date national and international plankton news, plankton images and videos, free educational resources and stunning plankton posters!
Search IMOS Australian Plankton Survey or go to https://www.facebook.com/imosaustralianplanktonsurvey

Visit the AusCPR website
Australian Plankton Survey: IMOS.org.au

Visit the NRS website National Reference Stations: IMOS.org.au

IMOS Australian Plankton Survey Leader - Professor Anthony J. Richardson
Anthony.Richardson@csiro.au

Newsletter - Anita Slotwinski
Anita.Slotwinski@csiro.au