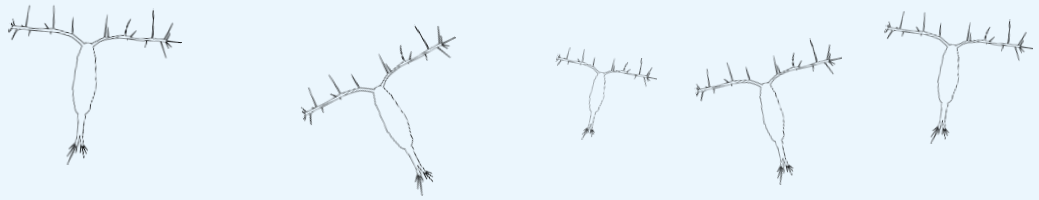
IMOS Integrated Marine Observing System

Issue 10
March
2017

IMOS Australian Plankton Survey Newsletter - 2016

The Australian Continuous Plankton Recorder Survey & National Reference Stations



Directors report

One of the key breakthroughs this past year has been establishing a strong relationship with the shipping company Wallenius Wilhelmsen Logistics (WWL). We rely on the good will of shipping companies to tow our Continuous Plankton Recorders (CPRs) free-of-charge. Previously we have had to use several different vessels from different companies to sample routes from Brisbane to Perth, but now we have the one vessel the Wilhelmsen Tonsberg doing the entire route. We have also installed a towing point to a second WWL vessel Wallenius Salome so that we have a back-up if the MV Tonsberg changes routes. Well done Tonka and Frank for making this happen!

To keep up with the hundreds of samples coming in each month and to drive down our cost per observation, we have streamlined many of our procedures, including our counting protocol. To ensure there was minimal effect on data quality, we conducted an extensive simulation analysis which showed almost no change in abundance estimates and very little change in diversity estimates derived from CPR and NRS samples. These changes have dropped our counting time by 20% with virtually no change in the data. I would like to acknowledge the hard work of the Team – Frank, Claire, Anita, Mark, Julian, Felicity and Ruth – over the past year to catch up with much of our counting backlog, especially through the redundancy turmoil at CSIRO. I would also like to thank IMOS for their continued support and we will endeavor to keep producing high quality, species-level plankton data as affordably as possible.

Over the past year we have also contributed to IMOS ZOOM Task Team (Zooplankton Ocean Observations and Modelling), which is striving for greater assessment of zooplankton in models. There is generally very little assessment of zooplankton in models and getting this trophic level right is critical for correctly estimating the conversion of primary production into fish. As part of ZOOM, Felicity has worked closely with the research community to assemble nearly 15,000 zooplankton biomass observations, which will be used to create a gridded product for modellers (see page 9). The ZOOM Task Team has also written a perspectives paper, led adeptly by Dr Jason Everett, that seeks to bridge the gap between modellers and observationalists by describing different types of models for observationalists, and by describing various types of zooplankton data for modellers. The paper also provides a blueprint for model assessment of zooplankton, through data wrangling that transforms observations to be more similar to model output, and through the use of observation models that transform model outputs to be more like observations. ZOOM will build on the relationships forged and the methods developed in its first year to incorporate more plankton in models through several case studies around Australia.

The IMOS Plankton Laboratory has continued to support several collaborators this past year. Dr Micheli Duarte de Paula Costa has helped with identification of fish larvae for the National Ichthyoplankton Monitoring and Observing (NIMO) at the IMOS NRS, Boer Bao helped develop rapid counting protocols for the cyanobacterium *Trichodesmium* from net samples at the IMOS NRS, Leslie Braberry and Chloe Jahakodey have used ZOOSCAN to measure zooplankton size spectra for IMOS NRS and these data will soon be posted on the AODN, Jose Gutierrez investigated the impact of ENSO on plankton from the tropical Pacific (see page 19),

IMOS is a national collaborative research infrastructure supported by Australian Government. It is led by University of Tasmania in partnership with the Australian marine & climate Science community.

NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

UTAS

Sarah Pausina has investigated the impact of floods on plankton in SE Queensland, Sophie Sabarot developed plankton indicators using IMOS zooplankton data (see page 21), and Chloe Jahakodey showed that climate change is likely to lead to smaller zooplankton in the future (see page . Thanks to all the Team but especially to Julian for supporting the students so ably!

I would also like to highlight the production of the Australian Phytoplankton database, which collates 3,765,032 presence records from around Australia over the past 60 years (see page 11). There are 46 authors from 23 organizations including universities, government research agencies, state and local councils and private companies. A great way to bring the community together. Well done Claire!

Finally, I'd like to highlight the growing number of ecosystem assessments both nationally (e.g. State of Environment) and globally (IPCC Assessment Reports, IPBES, UN World Ocean Assessments) that are being undertaken and the role that plankton can play. Plankton provide important baselines of the productivity in our oceans and provide sensitive indicators of environmental health and climate change. There is a great opportunity for IMOS and the plankton time series data it produces – now approaching 10 years in length – to contribute to these assessments. This will be an exciting space for the IMOS Plankton Team to contribute to this year and for years to come.

Best wishes
Anthony

Visit the AusCPR website at
http://imos.org.au/auscpr.html

Visit the NRS website at
http://imos.org.au/anmnnrs.html

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Further team contact details can be located at
http://imos.org.au/cpr_staff.html

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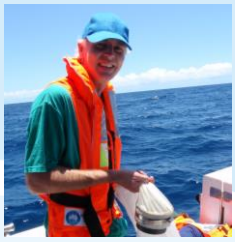
Anthony Richardson
Position: Leader IMOS Australian Plankton Survey
Location: CSIRO, Brisbane, Queensland
I manage the CPR project, I help secure funding, guide research directions, develop relationships with other plankton surveys, and support and develop CPR staff. My research interests are marine climate change ecology, plankton ecology, pelagic ecosystem dynamics, and ecosystem modelling. In my spare time I love to spend time with my family.



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.

Claire Davies
Position: Plankton Biologist
Location: CSIRO, Brisbane, Queensland
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.

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.

Anita Slotwinski
Position: Plankton Biologist
Location: CSIRO, Brisbane, Queensland
I analyse CPR & NRS samples. I also manage the project website, communication materials, and the zooplankton species reference collection. My research interests are in marine plankton ecology, environmental change and species response and photomicroscopy. In my spare time I enjoy time with family & friends, photography, gardening and exploring nature.

Mark Tonks
Position: Plankton Biologist
Location: CSIRO, Brisbane, Queensland
My tasks include counting CPR & NRS samples, and management of project procedure manuals. I have worked for CSIRO for 19 years and spend 60% of my time working on plankton. My research interests include plankton ecology, bycatch sustainability and fish and crustacean ecology. I also enjoy playing a variety of sports including hockey, touch football and cricket.

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.

Ruth Eriksen
Position: Plankton Biologist
Location CSIRO, Hobart, Queensland
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.

James McLaughlin
Position: Marine Biologist/ Biogeochemist
Location: CSIRO, Floreat, Western Australia
My job is helping to expand the survey into WA waters and the analysis of phyto- and zooplankton samples. I have been with CSIRO for 5 years and work 10% of my time with AusCPR. My research interests include marine phytoplankton dynamics and ecology, benthic and pelagic primary production, and ocean acidification. I enjoy spending time with my family, travelling and keeping tropical aquarium fish.

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.

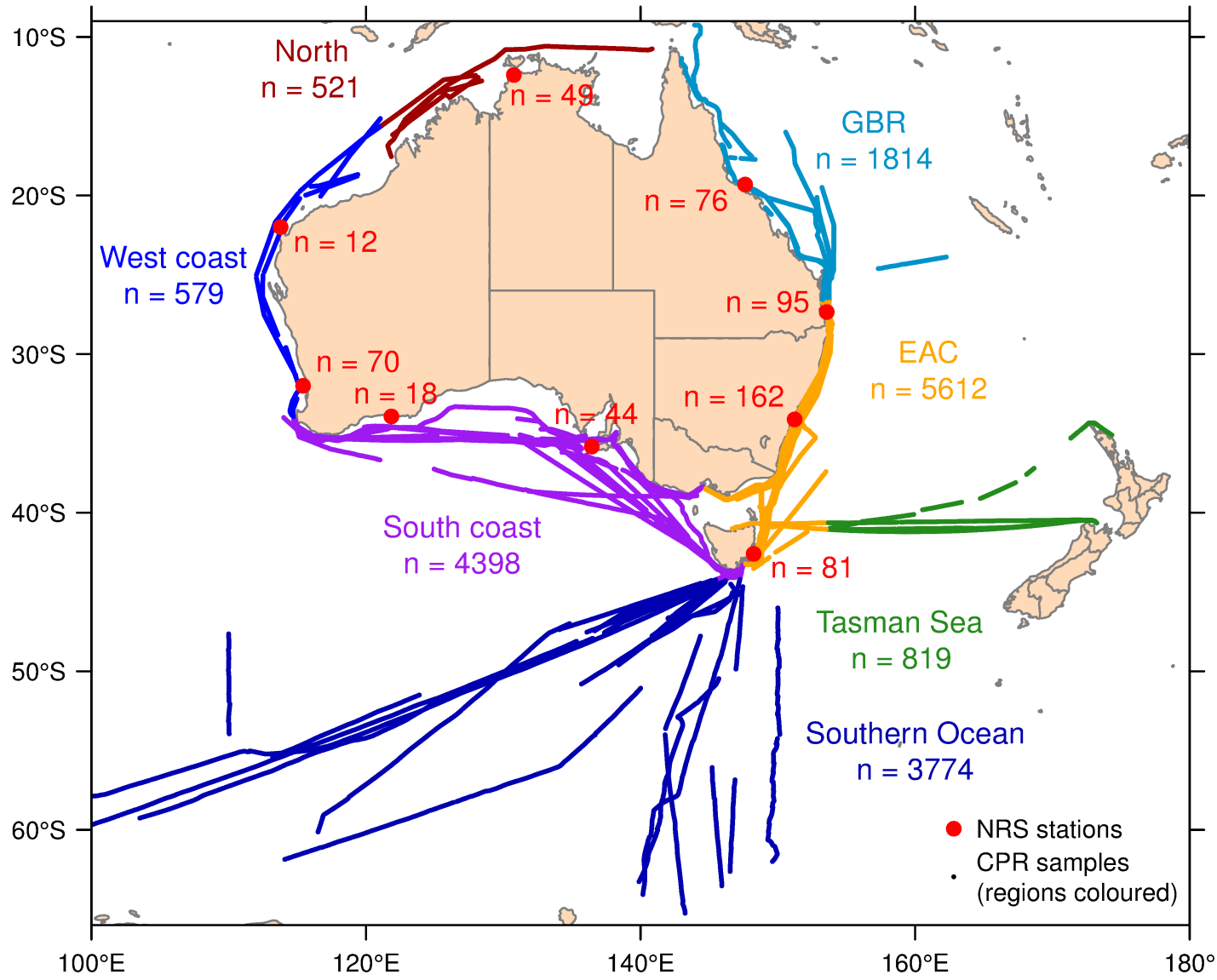
Karl Forcey
Position: Technical Officer
Location CSIRO, Brisbane, Queensland
I am helping the survey by working on the integration of marine instrumentation to CPR projects, data recovery and quality control, maintenance and repair of CPR units and technical advice. My research interests include underwater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

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 than anywhere else in the Southern Hemisphere this century.

The **NRS** we sampled approximately monthly.

The **Tasman Sea route** is towed annually and extends from Burnie, Tasmania to Nelson, New Zealand. This is an important area for fisheries and our survey links in with the IMOS Bioacoustic Facility.

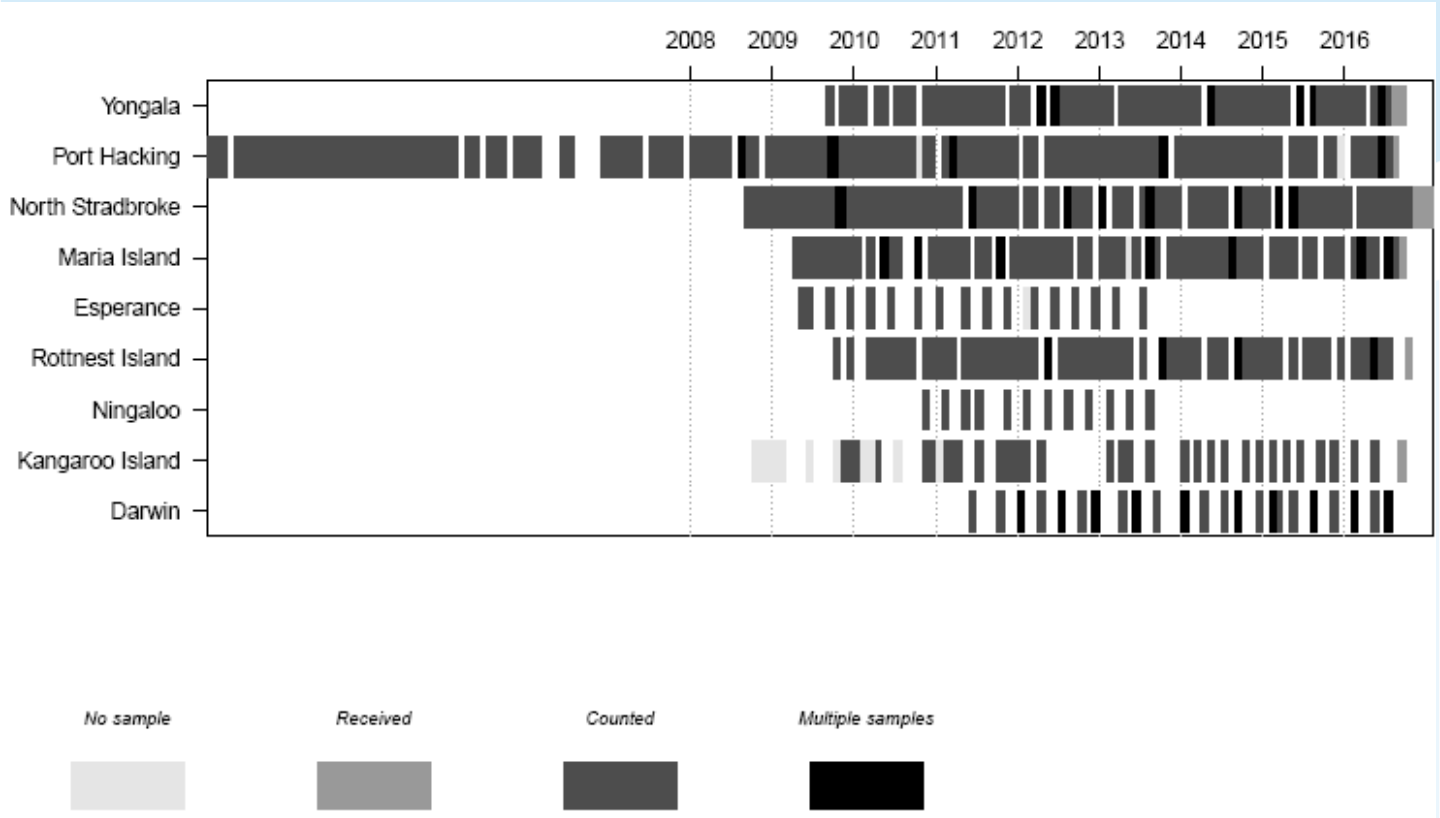
Integrated Marine Observing System (IMOS) plankton data, 2007–2016



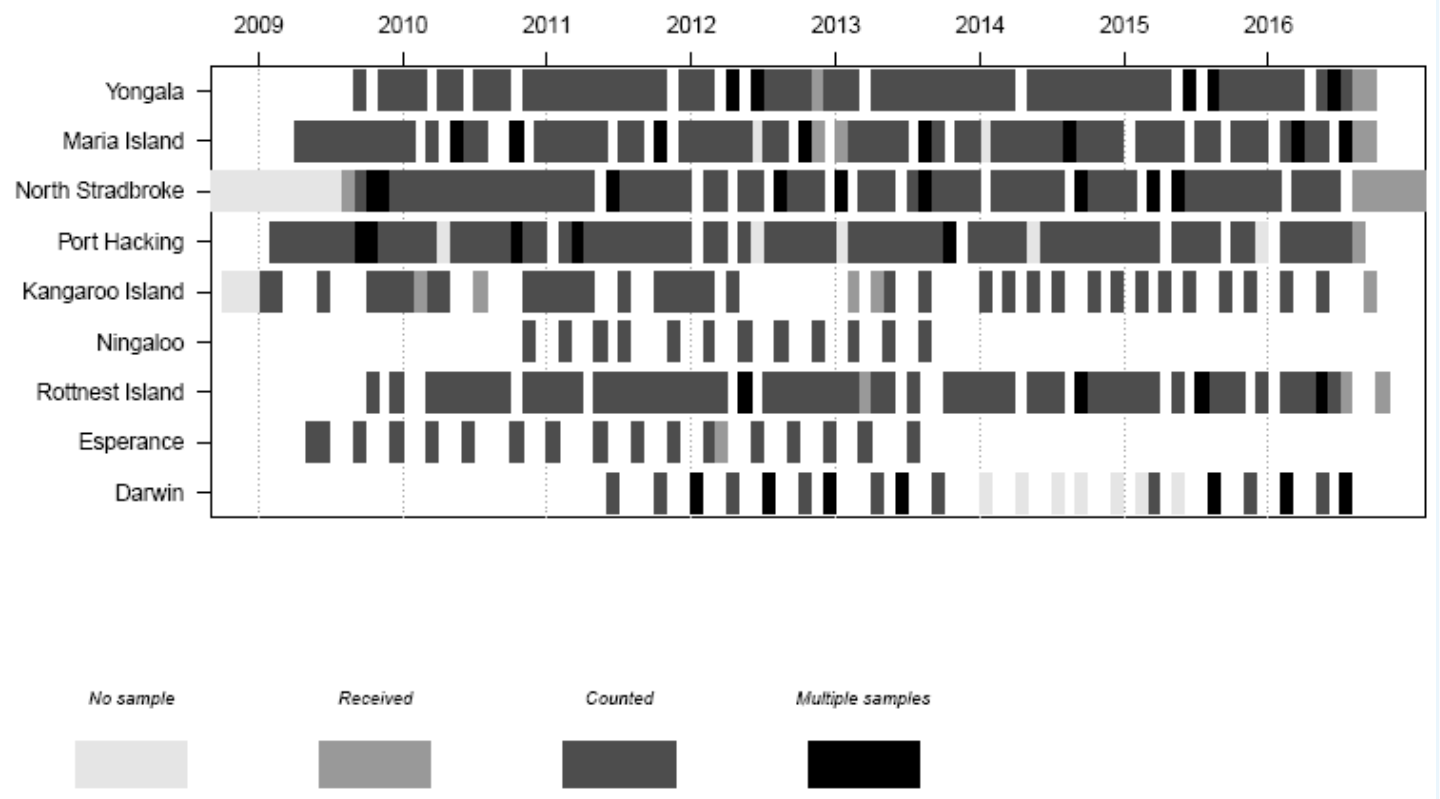
The **South Coast route** is towed quarterly from Melbourne to Fremantle. This route passes through a region of high endemism and is partly funded by the energy company BP.

The **Southern Ocean routes** below Australia are conducted by the SCAR SO-CPR Survey through the AAD and NIPR Japan, in conjunction with the AusCPR. Together with the EAC route, the Southern Ocean sampling provides an almost continuous transect running from warm tropical to polar waters.

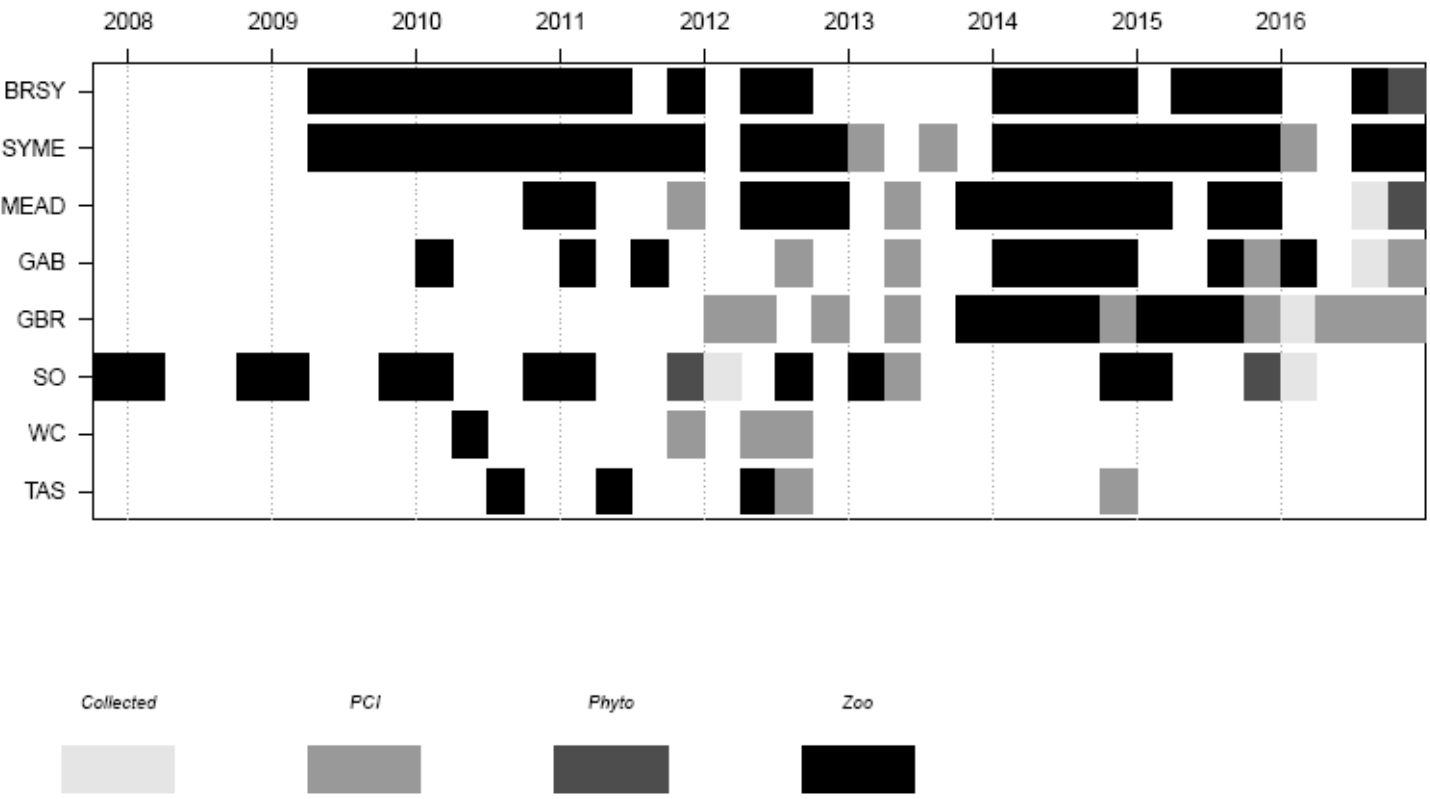
National Reference Stations Zooplankton Progress 30-1-2017



National Reference Stations Phytoplankton Progress 30-1-2017



Australian Continuous Plankton Recorder Progress 30-1-2017



Shipping

Mark Tonks

Over the last few years It has been challenging finding long-term ships to tow the CPR because many ships have short-term contracts servicing a particular route. However since our last newsletter in late 2015 we've had some exciting news. We've received a significant boost to long term plankton sampling from Brisbane, south and across the Great Australian Bight to Fremantle. This is a key sampling region for the IMOS Australian Plankton Survey. In mid-2016, we established a strong working relationship with Wallenius Wilhelmsen Logistics (WWL) and are currently towing Continuous Plankton Recorders (CPRs) on two of their vessels, the *Tonsberg* and its sister ship the *Salome*. Both of these vessels are 265 m long 'roll on roll off' vehicle carriers.

Above: The *Tonsberg*.

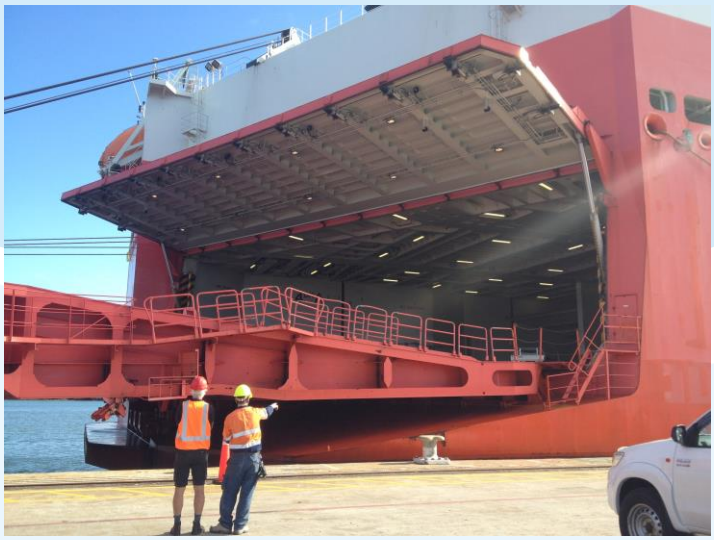
Above: The CPR being towed for the first time on the *Tonsberg*.

We originally approached the company in mid-2015 and while they were extremely supportive of the program we determined that the configuration on their mooring deck would not support the attachment of a traditional tow point. As a result we sort other short term options with other companies. However, after we exhausted these options we again approached WWL with an alternative tow point configuration which was based on designs supplied by SAHFOS for similar vessels. This alternative configuration was a 'swinging arm tow point' which fastens to the outside of the vessel and swings out to deploy the CPR away from the vessel. However, we couldn't proceed with this design as restrictions

…apply for attaching external structures on vessels transiting through the Panama Canal. Thankfully the Master of the *Tonsberg* came up with an innovative idea – the 'push out tow point' (pictured to the right below), which can be retracted within the outer boundaries of the vessel. The tow point was designed and constructed at sea by the crew and inspected by the Brisbane plankton team when the ship arrived in port. In late July 2016, the *Tonsberg* began towing the CPR from Brisbane to Port Kembla. The same tow point design was then manufactured in Brisbane by the Stella Marine Group and set up on the *Salome* a few months later. To date we've had three successful tows from these vessels in 2016 and a fourth tow to be performed in March 2017. We are extremely grateful to the owners, agents and crews associated with WWL for their support. We would particularly like to thank Sunil Dhowan, Roman Rossa and Patrick Lobo (WWL) and Richard Silver, Piotr Zapiec and James Stevens (Stella Marine Group) for their assistance.

CPR sampling in the inner Great Barrier Reef region between the ports of Gladstone, Townville and Cairns continue to be supported by the Kweichow from Swire Shipping. This vessel samples this region every 2.5 months and recently collected samples in early February, 2017.

Above: Welder from Stella Marine Group (Brisbane) attaching the 'push out tow point' on the *Salome.*



Above: The *Tonsberg;* stern of the ship.

Above: Frank Coman and Karl Forcey (CSIRO) showing the CPR to *Salome* crew.

Above: Chief Engineer (*Tonsberg*) explaining to Richard Silver (Stella Marine Group) how the 'push out tow point' was manufactured and how it functions.

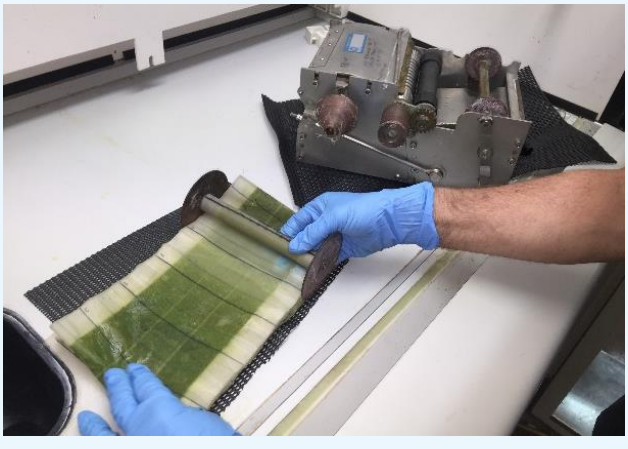
Precious cargo on the Investigator

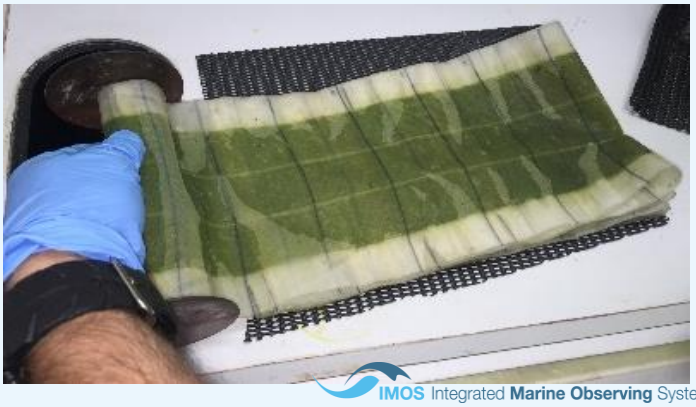
Julian Uribe-Palomino

One of our precious Continuous Plankton Recorders CPR was towed by the CSRIO research vessel, Investigator, from Hobart to Sydney on the 27th - 28th of August. The trip covered a 772 km transect. The silk contained in the CPR showed an amazing phytoplankton bloom attributed to a tiny but very prolific diatom called *Thallassiosira* spp. This bloom is consistent to what has been observed in this area during spring. On the 19th of September of 2016, the IMOS-CSIRO Plankton team, collected the silk from the Investigator for further analysis at the laboratory. Results of this tow can be viewed at the IMOS data portal soon.

Above : *Investigator* moored at Hobart.

Above, below, right : Mark Tonks and Frank Coman removing CPR silks from cassettes on board the *Investigator*.





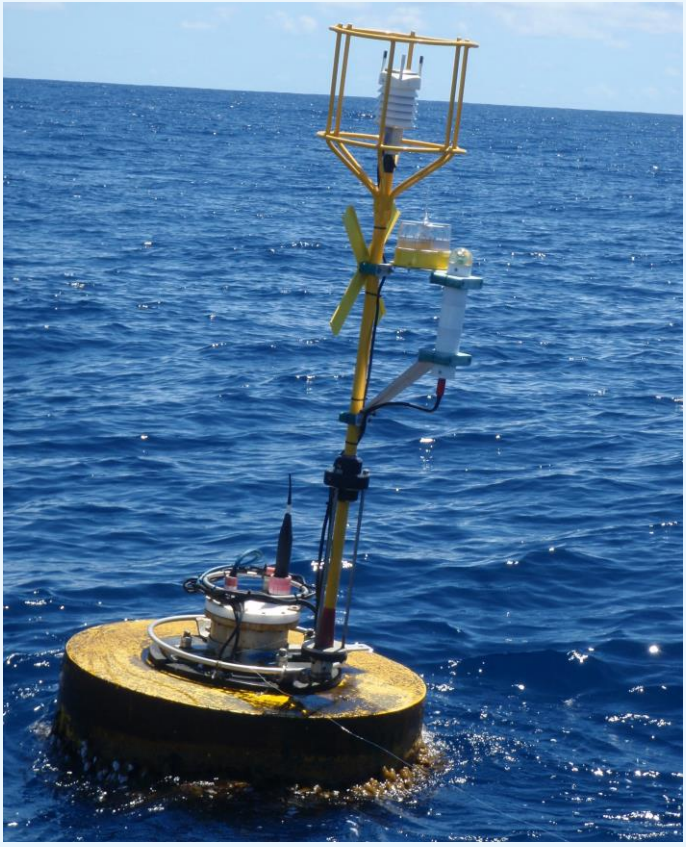
Update from Queensland

Frank Coman

The main focus of staff at the Brisbane laboratory continues to be collecting and analysing samples from both AusCPR and the National Reference Stations (NRS).

In September 2016 Emma Sommerville from the IMOS head office visited our laboratory with Natalie Toon to get a better feel for how we actually produce our data. In that month we also visited the Investigator while it was berthed in Brisbane to collect samples and provide supplies to collect further plankton samples. Throughout the year staff from Brisbane also travelled to various workshops and to meet with ships, and this stories are covered in more detail elsewhere in this newsletter.

Once again there have been quite a few students and visitors working in our laboratory over the last year; a few of their projects will described more fully elsewhere in this newsletter, but as a quick summary we have had several international visitors; Sophie Sabarot from France was completing an internship in Australia and was looking at how plankton communities varied with water temperature; Ainhoa Bernal was visiting from Spain and was investigating the diet of planktivorous fish (particularly mictophids or lanternfish); Chhaya Chaudhary from New Zealand and Jose Guiterra from Colombia were both here working with Anthony on their PhDs. We have also had a number of people volunteer their time in the laboratory including Boer Bao and Larissa Perez who both worked on *Trichodesmium* counting in NRS samples and Rena Ono, Leslie Braberry and Chloe Jayakody who assisted with the size spectrum measurements of the NRS zooplankton size distributions using the zooscan. Chloe has more recently returned to work on an undergraduate research subject, for which she has been investigating whether there is a detectable change in size of *Temora turbinata* from samples collected at different latitudes. Ryan Downie, from CSIRO Hobart, spent some time in our laboratory using Zooscan as part of an Indian Ocean project, and Kate Burgess and Chris Rohner have also spent time in the laboratory working on their PhD projects investigating the lives of plankton feeding elasmobranchs from around the world.



Above : NSI Mooring.

Sampling at the National Reference station at North Stradbroke Island has continued successfully. Since July 2015 we have only missed one month of sampling in February 2016 due to bad weather. While Mark Tonks, Julian Uribe-Palomino and I continue to be the regular crew, Kinam Salee has been helping out regularly, particularly when Mark is not available to skipper the boat and we have also received plenty of help from other staff and students who have been visiting the laboratory and. There have been some slight updates to the ichthyoplankton sampling procedure in the last year. In March 2016 we began sampling at a shallower station (30 m depth) slightly closer to shore than the mooring, and in May 2016 we began collecting a second sample at the mooring site, which is preserved in ethanol for genetic analysis. The ichthyoplankton samples are collected with a 500 µm mesh net and when fresh have provided some excellent opportunities for Julian to obtain some great microscope images.

Australian Zooplankton BIOMASS Database

Felicity McEnnulty

I have been collating zooplankton biomass data from Australian waters into a database and will produce a paper similar to the zooplankton abundance and phytoplankton abundance papers published in the last few years.

If you would like to contribute, please contact Felicity at Felicity.McEnnulty@csiro.au

Update from Tasmania

Felicity McEnnulty

It has been a busy 2016 in the lab in Hobart for us identifying NRS phytoplankton samples from all the stations, NRS zooplankton from Maria Island as well as phytoplankton and zooplankton from CPR samples from various AusCPR routes and from SOCPR samples provided by the Australian Antarctic Division samples from Tasmania down to 47° South.

RV Investigator has towed the CPR for us in August up the East Coast of Australia during a transit from Hobart to Sydney. The guys in Brisbane collected it and had a tour of the ship – Julian has photos of a very green silk and reloading the cassette on the ship – see page 8.

We have been involved in tutorials educating other IMOS members on uploading BCG data into the database. Ruth has investigated some image stacking software and her and Julian have produced some amazing images – see page 25. Claire published the paper on the Australian Phytoplankton Database - see page 11. Claire has also participated in field sampling at the NRS Maria Island site – see images to the right. Anthony, Claire and Felicity participated in the ZOOM workshop mid-February 2016. Claire and Ruth provided images and contributed to the art exhibition “Undercurrent” by Diane Masters in Feb 2017 – see page 13.

Erin McCosker submitted her MSc thesis, titled “Influence of oceanographic conditions on coastal zooplankton assemblages at three IMOS National Reference Stations in Western Australia” in November. She was supervised principally by Professor Lynnath Beckley at Murdoch University and co-supervised by Claire. This study uses the IMOS National Reference Station zooplankton and water quality data to provide the first detailed comparison of zooplankton assemblages in the northwest, southwest and southern shelf waters of Western Australia, and enhances understanding of the processes influencing zooplankton distribution and structure.

Above : Dion Frampton collecting a NRS plankton sample off Maria Island, TAS.

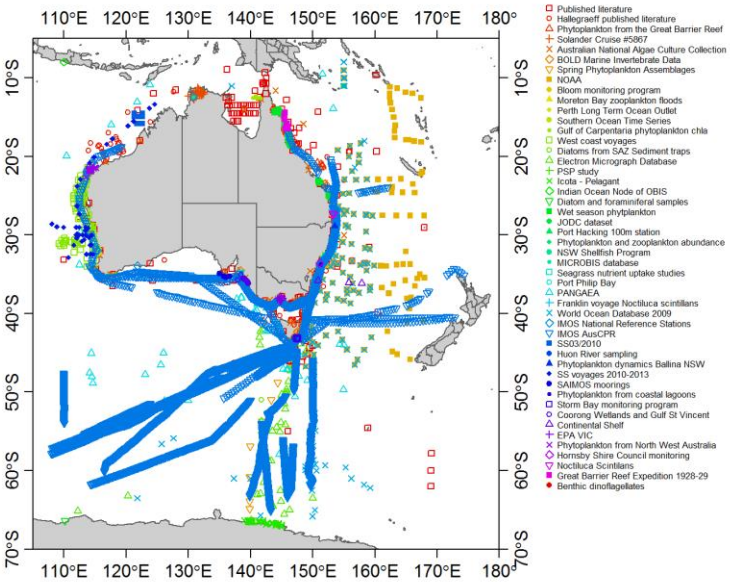
Above : NRS plankton sample collected off Maria Island, TAS.

Above : Kendall Sherrin collecting water samples from niskin bottles, whilst NRS sampling off Maria Island.

Using the Australian Phytoplankton Database

Claire Davies

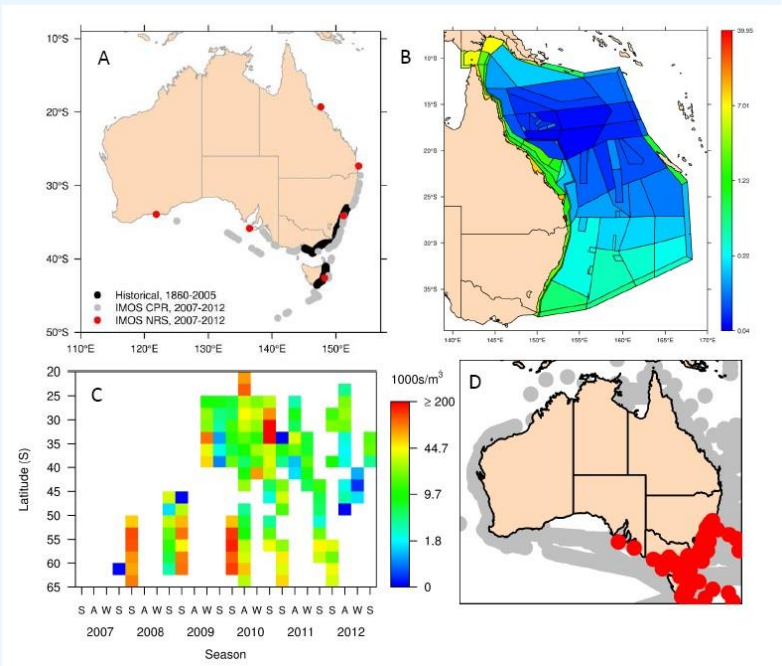
The Australian phytoplankton community published a collation of all the available phytoplankton data from the Australian region in Nature – Scientific Data in June 2016. This was the culmination of several years work, over 50 collaborators and 94 projects. The distribution of samples can be seen on the map to the right. The data ranges from 1844 to the current day. Some of the projects are ongoing so the database will continue to grow over time.



Above : Phytoplankton data from the Australian region.

There are many ways in which you can use the data. Some examples of what we have done (see below right), are showing the range extension of *Noctiluca scintillans* from around the Port Hacking area, along the east and south coasts and into Antarctic waters over the past 150 years by comparing historical data to the continuous plankton recorder data; using the diatom abundance from the continuous plankton recorder data and satellite chlorophyll function type analysis to parameterise an ecosystem model (Atlantis); investigating diatom diversity by latitude from the Continuous Plankton Recorder data; and mapping the distribution of potentially harmful algal bloom species, e.g. *Dinophysis tripos,* using data from many sources. Other examples of ways to use the data can be seen in Plankton 2015.

This is a complementary database to the Australian Zooplankton Database that we published in Ecology in 2014. Many projects have data in both databases and can be joined together using the project_id identifiers that download with the data. As an example of using data from both databases we are currently involved in a project with the eReefs modelling team at CSIRO who are using the zooplankton and phytoplankton count data from the Yongala and North Stradbroke reference stations to validate, and test the sensitivity of, the eReefs model with observational data.



Above : Examples of phytoplankton data use.

Data are freely available through the AODN, the direct link to access the data is: https://portal.aodn.org.au/search?uuid=75f4f1fc-bee3-4498-ab71-aa1ab29ab2c0.

Uptake of our data is really important to us, if you require more information to use our data please contact us at imos-plankton@csiro.au.

Chlorophyll *a* and a zooplankton biomass databases will soon also be made available through the AODN. Anyone out there with Chlorophyll or zooplankton biomass data from Australian waters, get in touch via imos-plankton@csiro.au.

Plankton team participate in the 3rd international workshop on symbiotic copepoda

Julian Uribe-Palomino

The international workshop on symbiotic copepoda or IWOSC was organised by James Cook University and the Australian society for Parasitology and held at Heron Island Research Station.

IWOSC was an opportunity to meet local and international specialists and students who have been doing research related to parasitic copepods and isopods from a variety of places including New Caledonia, South East Coast of America, South Africa and Australian waters.

The plankton team presented a summary of the study of the plankton community from Australian marine waters, linked to the AusCPR and NRS, projects supported by IMOS and CSIRO.

The workshop provided the guidance and training required to collect and process marine organisms from diverse taxa for the purpose of finding parasitic copepods and isopods. This work was carried out via practical sessions and master classes that covered general information and specific information from each of the groups studied at the workshop.

The collected organisms were identified and catalogued before delivery to the Queensland Museum.

Additional information about IWOSC can be found here.

Left to right: Nico Smit, Niel Bruce, Danny Tang, Rony Huys, Julianne Passarelli, Geoff Boxshall and Kate Hutson

Above: Julian Uribe-Palomino presenting IMOS plankton research at the symbiotic copepod workshop.

Dr Geoff Boxshall visited our lab at the Eco-Sciences precinct

Julian Uribe-Palomino

In July 2016, Dr Geoff Boxshall, one of the world experts in the description and classification of marine copepods from the Natural History Museum in London, visited the plankton team at CSIRO in Brisbane. He is the author of several publications that cover the biology, evolution, ecology and systematics of copepods worldwide.

Many of his studies are focused on the description and identification of parasitic organisms such as the Tantulocarids, a very particular group of parasites which were discovered and described by Geoff. Geoff was also a member of the steering committee of the World Register of Marine Species WoRMS for several years until October 2016.

The plankton team had the opportunity to talk to Geoff about the importance of the plankton research we perform in Australian marine waters. We explained the processing of samples collected by the CPR and NRS.

Geoff took the opportunity to congratulate the Plankton Team for the work we perform in Australia. He also presented a talk at the Ecosciences library about the diversity of copepods.

Undercurrent – Plankton Art Exhibition

IMAS Gallery, Castray Esplanade, Hobart
2nd Feb until 31st March 2017

The collaboration began when Claire moved to Hobart and met up with long-time friend and dive buddy, Diane Masters. Diane Masters is a visual artist based in Hobart, Tasmania. She works as a painter, printmaker and installation artist. Over coffee Di asked Claire exactly what it was she did at work. She knew what plankton was but had no idea of the scale that the word plankton encompasses. Claire invited Di to the lab and showed her some planktons under the microscope and some of the photos that our team had taken. Di was immediately enthralled and the seed of Undercurrent was sown. Di's previous works had come under the theme of 'Drifting', through migration, cultural shift and a nomadic sense of belonging crossing elemental landscapes. Plankton fitted directly into that space. Ruth's love of plankton and enthusiasm quickly saw her become part of the project as we continued to send Di photos of all the especially beautiful planktons we saw in our samples. Di worked over two years to complete the amazing set of etchings through the aquatint process in the exhibition.

Opening night was a huge success with over 100 people visiting the gallery, all refreshed through the generosity of AMSA and Truckle and Co. Tim Moltmann give a speech about the importance of plankton within the umbrella of IMOS and the critical role plankton plays within the oceans. Christine Milne officially opened the exhibition by highlighting that these brilliant works have been produced through the collaboration of not just art and science, but between friends. The exhibition remains in place for 2 months.

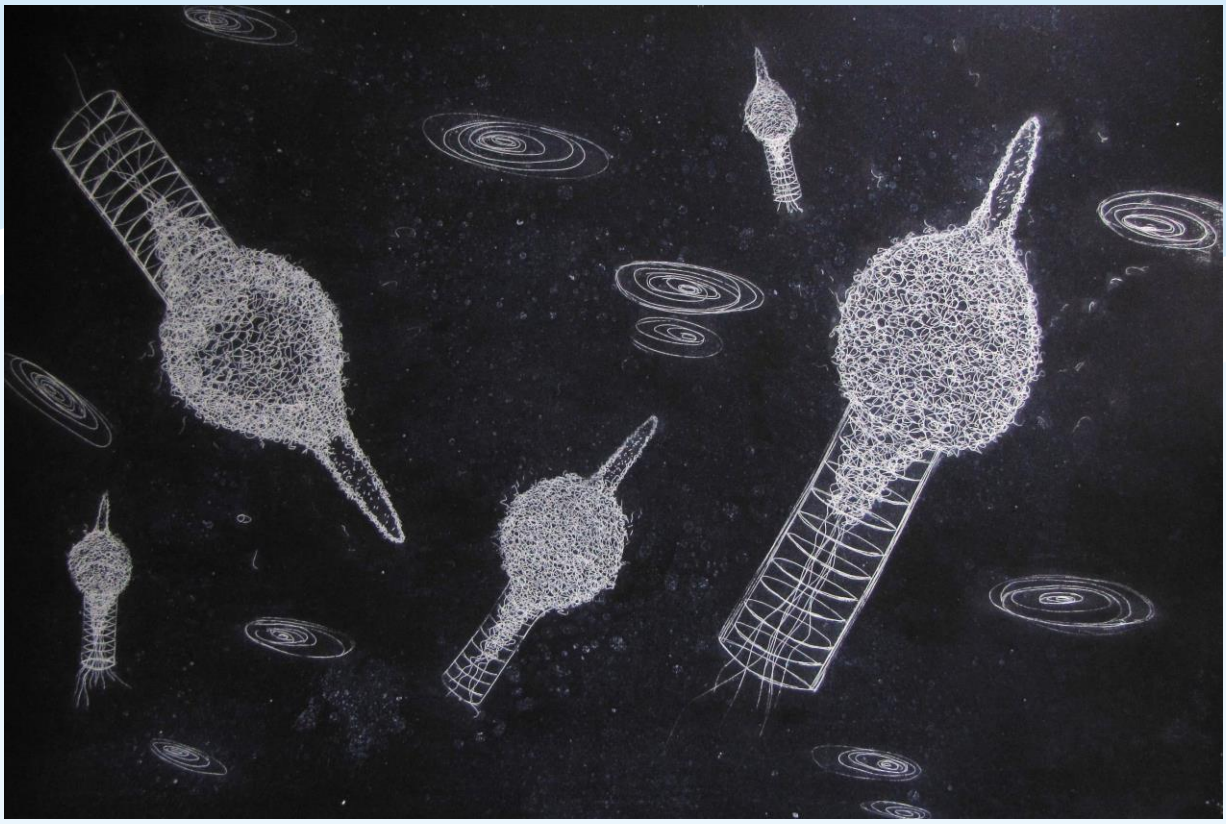
Congratulations to Di for showing off plankton in this unique and educational exhibition.

Above left: Claire Davies, Diane Masters and Ruth Eriksen working on Undercurrent pieces.

Above right: Claire Davies and Ruth Eriksen hold an Undercurrent print.

Far left: Christine Milne officially opens the exhibition.

Left: IMOS director Tim Moltmann.



Above: Tintinnid *Codonellopsis orthoceras.*

Above: Copepod *Paracalanus aculeatus.*

Above: Tintinnids – vases and minarets.

Above: Tim Moltmann, Diane Masters, Christine Milne and MC of the event David Masters.

Above: The enthusiastic plankton crowd.

How do big, tropical filter-feeders cope with a sparse and patchy prey environment?

Dr Chris Rohner – Marine Megafauna Foundation

Many of the largest planktivores, such as baleen whales, travel to the poles to feed. This makes sense as they find highly productive waters there in summer and feeding efficiency is high. For tropical fishes, such a seasonal migration is not an option, because they cannot regulate their body temperature and the high latitudes would be too cold for them. These large planktivores, specifically whale sharks, manta and mobula rays, need to find enough food in the warmer waters, where plankton is sparse and patchily distributed. So what are their feeding strategies?

I spent the last few years investigating the feeding ecology of whale sharks, mantas and mobula rays and regularly visited the Zooplankton Lab at CSIRO, Brisbane, to conduct lab work and learn all things plankton from the team here. We took three approaches to find out what these megafauna species eat.

First, we collected zooplankton when whale sharks were feeding and also when they were not and compared those samples in terms of taxonomy, biomass and size structure. This work took me to Mafia Island in Tanzania, where whale sharks aggregate and are often seen feeding at the surface. We found that whale sharks there target dense patches of large sergestid shrimps, with biomass estimates being 10 times higher in feeding samples than in background samples. By comparing these results with information from other whale shark and manta feeding sites, we found that the taxonomic composition is not important, but that they feed in high biomass patches, and that their preferred prey is usually comparatively large. Pushing a dinner-table sized mouth through the water costs a lot of energy, so it makes sense that the sharks only feed when biomass is high.

Second, we wanted a longer-term view on their diet and used fatty acid and stable isotope analyses to gain time-integrated dietary information. This study took me to Lady Elliot Island in Australia, where we collected small biopsies from free-swimming mantas and analysed the lipids in their tissue. Although this was a bit like a detective approach, we could show that mantas and whale sharks don't only eat surface zooplankton during the day – the stuff we see them do all the time. Instead, they also likely feed on emergent zooplankton and on mesopelagic prey. Vertically migrating prey from deep water may be important when they travel away from the coast, as open ocean surface waters are generally low in zooplankton biomass.

The most recent diet study that is currently underway was to take a direct approach and examine stomach contents of these animals. This was perhaps the trickiest method yet, as whale sharks and mantas sink when they die, so finding dead specimens is quite rare. Further, it is unethical to catch these threatened species and use lethal scientific methods. We got the chance eventually in the Philippines, where mobula rays and mantas are caught in a targeted fishery and the local community allowed us to collect some samples of their catch. Some stomach contents were difficult to identify because you are basically looking at a digested soup, so the expertise of the team in Brisbane was needed to identify some of the prey items from fragments of legs or eyes etc. Early calorific results indicate that these rays ingest a lot of food in one go and then may undergo a period of starvation until they find the next dense prey patch.

Overall, we learnt that large filter-feeders in warm water have a more varied diet that previously thought, feeding at the surface during the day, but also at other times and elsewhere in the water column. They feed in high biomass prey patches, often comprised of large zooplankton, such as sergestids, mysids or euphausiids. And they may use a boom-and-bust approach to make the most of an abundant prey source when it is available.

Whale shark images
by Chris Rohner.

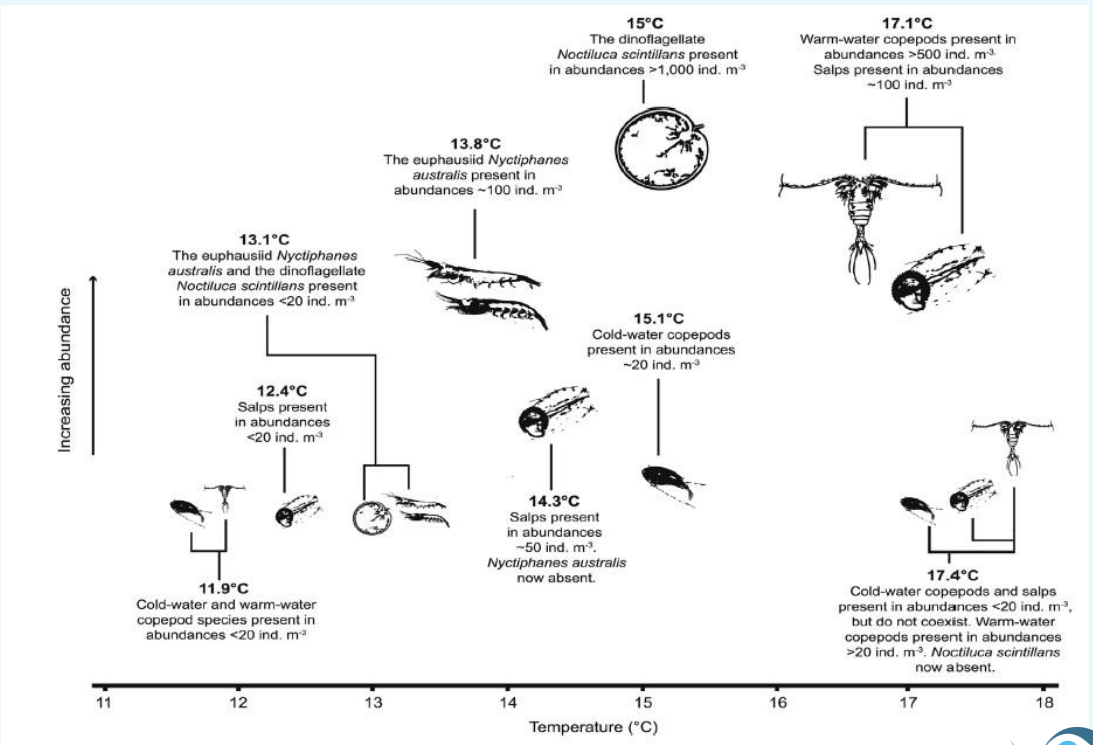
Zooplankton responses to increasing sea surface temperatures in the south-eastern Australia global marine hotspot

Paige Kelly

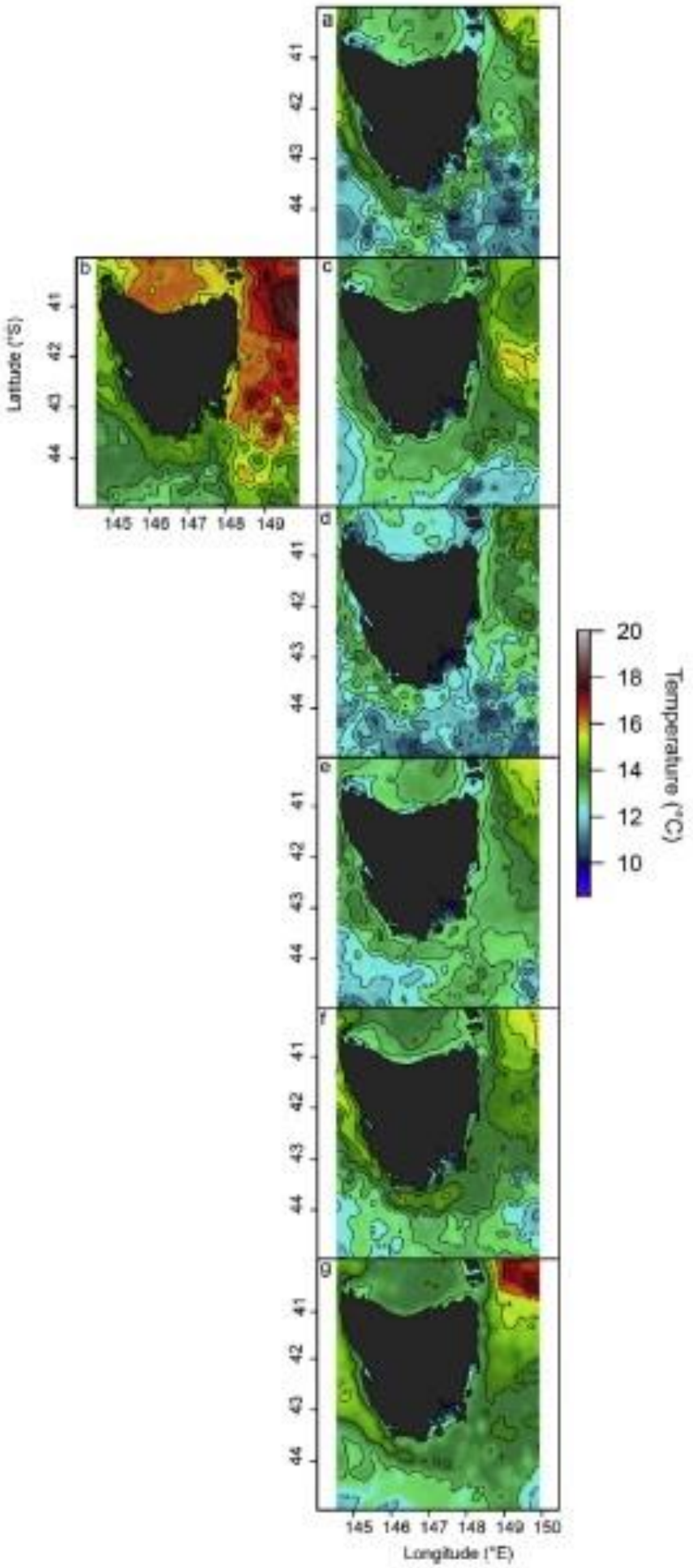
Although the waters off Southern Tasmania are just a small piece of the blue planet, oceanographic and biological changes in this region may provide highly valuable information concerning how our global marine ecosystems are responding to a changing climate. Here, a southerly extension of the East Australian Current (EAC) has been attributed to sea surface temperatures increasing at a rate more than double the global trend. This rapid change makes these waters an ideal study site for identifying biological responses to increasing temperatures, such as species' range expansions. So, which marine taxonomic group can provide us with an indication of how ecosystems are responding to such stressors? It is again another small, but highly significant feature of the ocean that might give us the answers we need.

Zooplankton are the free-floating primary consumers of marine ecosystems. Their dependency on ocean currents for transportation, and short life cycles, means that they are highly sensitive to fluctuations in the ocean's climate, and are robust biological indicators of oceanographic change. This work, recently published in Estuarine, Coastal and Shelf Science, identified temperature-driven changes in the zooplankton community in the waters off Maria Island 42° S, 148° E, using a combination of IMOS National Reference Station and historical zooplankton abundance and community composition data. The Maria Island zooplankton community was found to be responding to increasing temperatures through relocation, long-term increases in warm-water species and size-based shift in the species composition. Results from this study suggest that the extended influence of warm EAC water into autumn and winter months at Maria Island has induced a shift towards a zooplankton community dominated year-round by small (~1-2 mm), warm-water copepods, including *Acartia tranteri* and *Temora turbinata*. In recent years (2009-2014), the abundance of the larger (10-17 mm), cold-water euphausiid *Nyctiphanes australis* has been limited by these warm-water injections, and has not been present when temperatures exceed 15° C.

To identify and monitor how Australian marine ecosystems are responding to changes in the marine environment, a repeated sampling regime, such as that undertaken across the IMOS National Reference Network, is vital. Additional years of IMOS zooplankton data will confirm whether the observed trends are part of a long-term ecosystem regime shift, which may adversely affect pelagic fish species. A continuation of the discussed size-based trend would disadvantage a number of commercially fished species that prey upon large zooplanktors, such as Jack mackeral *(Trachurus declivis)* and skipjack tuna *(Katsuwonus pelamis)*. Trends revealed in this study have applications for local fisheries management and can provide much needed insight into how global ecosystems may respond to intensifying Western boundary currents.



Left: Temperature-abundance trends in a number of cold and warm-water zooplankton, at Maria Island from 2009 to 2014. Temperature is the average temperature of the upper 50 m of the water column.



Left: Aqua MODIS composite SST (9 km resolution) during July 2009 (a), May 2010 (b), July 2011 (d), July 2012 (e), July 2013 (f), July 2014 (g).

What has been the ecological response of the oceanic zooplankton from the Colombian Pacific Basin to climate variability between 2003-2012

José Manuel Gutierrez Salcedo

José Gutierrez -Salcedo is a PhD student at the National University of Colombia. He did a short internship with the CSIRO Plankton team group in 2016. José is a museum curator of the invertebrate collections of the Makuriwa Museum (INVEMAR-Santa Marta, Colombia), he also studies the marine biodiversity of Colombia and currently is doing his doctoral studies of tropical Zooplankton. Mr. Gutierrez became part of the research team of the Makuriwa Museum in 2007 where he specialised in invertebrate organisms; crustaceans and zooplankton are his areas of expertise.

Above: Jose Gutierrez. PhD Student Universidad Nacional de Colombia.

In the last decades, the climate has changed drastically, and plankton have had to adapt quickly to avoid extinction. Scientists have found three main adaptations to the new climate variability: migration, change in phenology and change in size. For the third adaptation, scientists have found evidence to corroborate that temperature is the trigger. The effect of the temperature on organisms, populations and community are the following: when the temperature increases, the organism size decreases, the abundance of the populations increases, and in the communities, the proportions of the small species and juveniles increase. Only the change in size of the organism has been evaluated directly with the copepod group. The change in population abundance and community proportions, the evaluation has been evaluated indirectly. Furthermore, in all cases these studies were conducted in coastal temperate areas.

The goal of my PhD thesis is try to answer the following question: What has been the ecological response of the oceanic zooplankton from the Colombian Pacific Basin to the climate variability between 2004-2012?

The idea is to evaluate if the tropical oceanic zooplankton has the same adaptations in terms of a change in size as those found in the temperate areas. For this, I will use the samples that were collected in the Pacific Colombian Ocean -82/-84° W, -2/5° N during March and September between 2004-2012. I found temperature differences of 7° C during this sampling period, with the temperature average of the first 50m of depth.

I will select 10 species that represent the different functional groups (eg. big carnivorous like chaetognaths). For each species, I will count and measure a minimum of 25 adult organisms by sample and I will find the abundance with the filtered volume. Furthermore, I will digitalize with a scanner each sample to find the size structure.

I will correlate this biological data with the oceanic temperature of each sample point, and with the El Niño/La Niña period, to try to answer the main question and contribute new information to tropical areas.

Above: Jose Gutierrez collecting samples at the NSI National Reference Station, helping to process samples at the humid laboratory of CSIRO at Manly-Brisbane.

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Lantern fish from the Indian Ocean and their planktonic diet

Ainhoa Bernal Bajo

During my stay at CSIRO's Zooplankton Laboratory in Brisbane I have been in charge of the revision of mesopelagic fish species from the Southern Indian Ocean. They were collected and analysed to the lowest taxonomic level, and frozen during a survey performed from Jakarta (Indonesia) to Port Louise (Mauritius) (PROJECT GCP/INT/003/NOR). They were then transferred to 5% formalin-buffered seawater prior to dissection. Mesopelagic fishes were collected with a Pelagic Trawl usually within the first 100 m of the water column at night, where the strongest acoustic layers corresponded with the highest densities of fish and zooplankton. The main objective of the analysis of fish in the laboratory has been to analyse gut contents to further determine, statistically, if there are feeding differences within each species, interspecifically, and between specimens collected under the southern Indian Ocean gyre influence and outside it. An additional goal for the survey was to determine the presence of plastic particles in the fish guts (as it is suggested that plastic debris may concentrate in the gyre). In more recent times, the concern on the small particles derived from the breakage of macroplastics and on their effects and dispersal in the ocean, is growing.

Once in the laboratory, after double checking the species / genus of the recognizable specimens, three of the most abundant species of the Indian Ocean were selected for diet analysis (*Ceratoscopelus warmingii, Diaphus effulgens and Symbolophorus evermanni*). This involved the identification of prey items to the lowest taxonomic level and the measurement of prey body length and width, when possible, to investigate predator-prey relationships. The gut contents of 200 juveniles and adults were examined and prey items identified under a microscope up to 1600x (Leica M165C). Prior to dissection, the following measurements were recorded to the nearest 0.01 mm: Standard Length (SL), Lower Jaw Length (LJL), Mouth Width (MW) and Eye Diameter (ED). MW, LJL and ED were used to establish allometric relationships with SL.

Most of the identified prey were copepods, mainly calanoids, whose identification was assisted in many cases by the experienced and specialised Zooplankton Team at CSIRO. In some cases small pieces of plastic debris were identified and measured to report their presence and origin. The data will be compared with data on the distribution, composition and abundance of micro- and macrozooplankton species collected during the same survey (which are being analysed in South Africa) to determine feeding selectivity indexes for the mesopelagic fish species and other ecological relationships that are important for understanding the functioning of pelagic and abyssal communities in this widely unexplored ocean. The relevance of the research expedition underlies the fact it is the second scientific expedition (Second International Indian Ocean Expedition) conducted after the first one fifty years ago.

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Above: Ainhoa Bernal examining a plankton sample.

Above: Lantern fish with plastic in gut contents.

Application of the Community Temperature Index on marine copepods

Sophie Sabarot, MSc in Aquatic Ecosystem Dynamics (France) Supervisor: Professor Anthony Richardson

My project was based on the application of a thermal indicator called the Community Temperature Index (CTI) to marine copepods around Australia. Data were obtained from the 9 National Reference Station (NRS) and from the Continuous Plankton Recorder (CPR) between 2011 and 2016. The CTI was developed by *Devictor et al.* in (2008) and allows us to measure the rate of change in community composition in response to temperature change. It is based on the Species Temperature Index (STI), which represents the long-term average temperature experienced by individuals of a species over its entire range. Until now, it was mainly applied to terrestrial organisms such as birds and butterflies. However, *Stuart-Smith et al.* (2015) used this index on reef fish and invertebrates. In this study, the STI was estimated as the median of the abundance to avoid having a skewed mean value for the coldest and warmest species.

The results show an overall linear relationship between the CTI and the Sea Surface Temperature (SST) with a slight step pattern for the CPR data (*Figure 1*).

However, the climatology analyses showed that CTI poorly tracked the changes in local temperatures for the NRS. The main reason may be that some abundant and cosmopolitan species are dominating and dampening the CTI signal. This finding means that this index lacks precision when applied on short spatial scale, such as the NRS.

So we chose to select warm and cold-water indicator species that meet specific criteria. First, the species has to be common - we set a benchmark of occurring in 30% of NRS samples or 10% of AusCPR samples. We also defined that a species STI had to be greater than 1°C away from the mean temperature at the particular station. And finally that the species has a narrow temperature preference (low standard deviation) (*Figure 2*).

This work shows that the indicator species approach worked better than CTI in tracking temperature changes. The mean abundance of warm indicator species is keeping pace with the changes in local temperature with peaks occurring at the same period in summer (*Figure 3*). Therefore, using the STI of selected indicators is interesting to track the changes in community composition against the climate change. Finally, this is the first time that this method has been applied on short-lived organisms such as marine copepods.

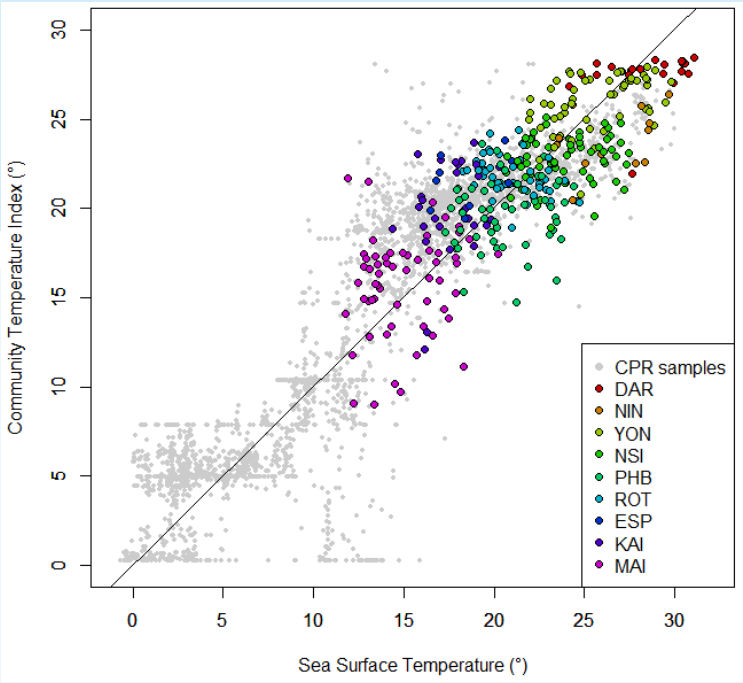


Figure 1. Overall CTI values plotted against SST.

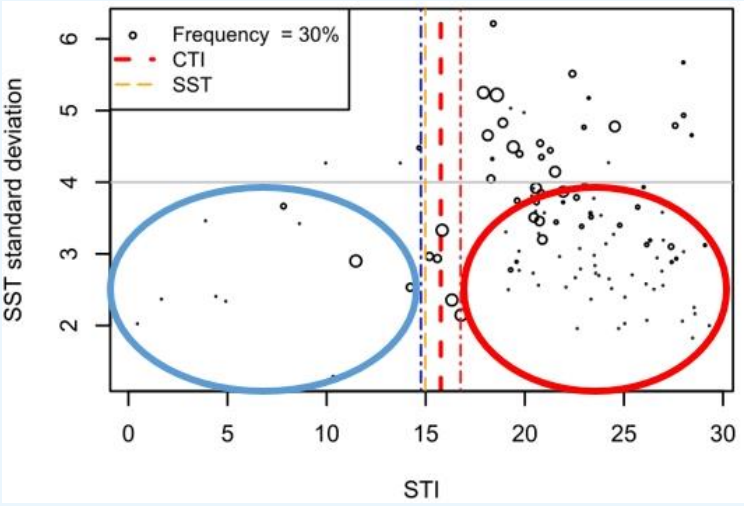


Figure 2. Selection of cold and warm indicator species (e.g. Maria Island).

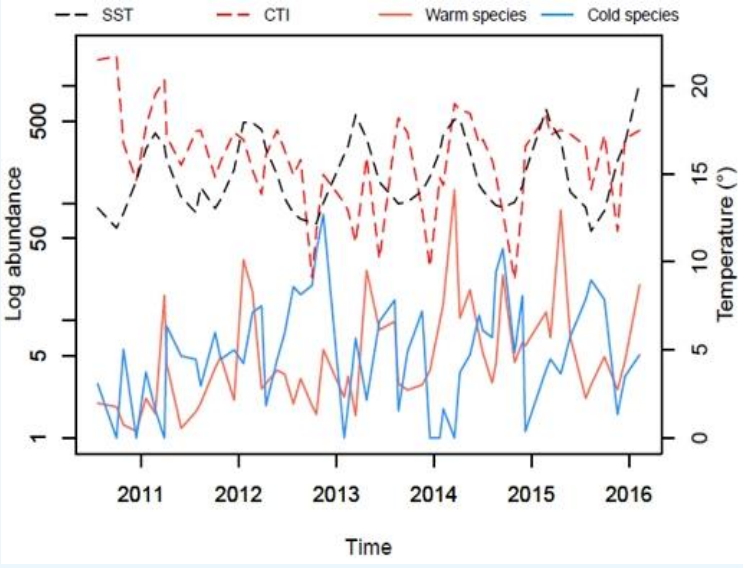


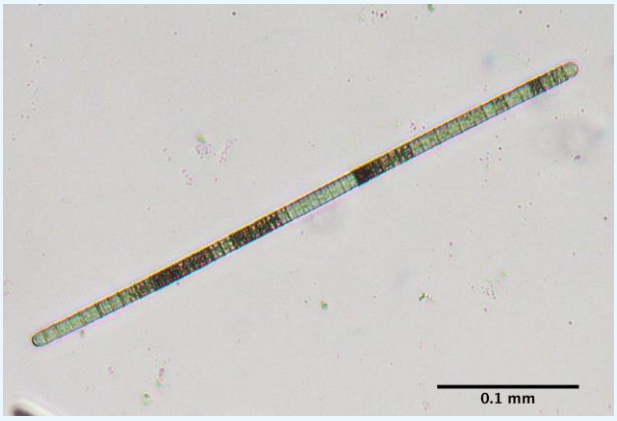
Figure 3. Time series of the mean abundance of indicator species with the monthly CTI and SST (e.g. Maria Island).

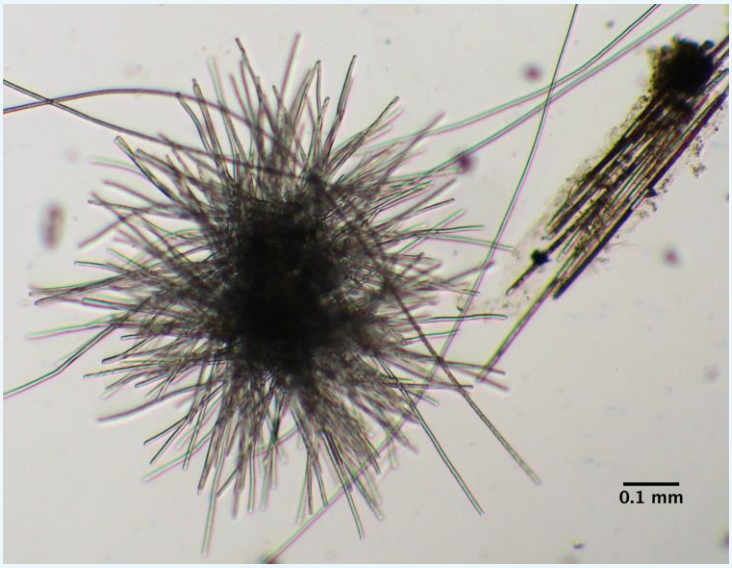
Trichodesmium Project

Boer Bao

I have recently completed a BSc (Hons) degree on isolation, identification and characterisation of microalgae for food and feed applications at the University of Queensland. Over the last 2 months, I have been working as a volunteer for the Australian Plankton Survey group at CSIRO Oceans and Atmosphere, supervised by Anthony Richardson and Julian Uribe-Palomino. The *Trichodesmium* project focuses on developing a fast and accurate method for quantifying these cyanobacteria in Australian waters. This is particularly important because *Trichodesmium* are major 'nitrogen fixers' in marine ecosystems. They can take nitrogen gas from air and convert it into biologically usable forms of nitrogen such as ammonium and nitrogen oxides. In order to quantify them, I have identified *Trichodesmium* filaments and collected quantity data using the samples from the National Reference Stations (NRS) of Yongala, North Stradbroke Island and Darwin from 2012 to 2016 following the counting methods that Larissa Perez established. The preliminary results show that the number of filaments counted after the first minute can be used to accurately estimate the count for the whole sample. Further, the Trichodesmium estimates we now obtain from the net samples are much better than those from bottle samples, which is the standard way of collecting phytoplankton.

Above: *Trichodesmium* bloom off the Great Barrier Reef (source: wikipedia).





Above: *Trichodesmium*, from NRS Yongala, QLD.
Right: *Trichodesmium,* from Great Barrier Reef, QLD.
Images: Boer Bao.

Global Biodiversity Patterns

Chhaya Chaudhary, University of Aukland

I am a PhD scholar from the University of Auckland and working on the distribution of marine species diversity patterns across latitudes, and reasons behind the diversity dip near the equator. I visited CSIRO (15 July, 2016 – 15 September, 2016) to work with Professor Anthony Richardson. He has helped me a lot in building Generalized Additive models (GAMs) on R interface. These GAMs are a great tool in understanding the influence of sampling efforts, and environmental variables such as, temperature and continental shelf, on the latitudinal gradients of species diversity. I was a new bee in working on R and Anthony's guidance was a great support. Apart from this, I had a wonderful time with the team (Julian, Mark, and Frank) on board. It was my first experience in the sea and had a lot to learn about sampling techniques they use. I really enjoyed my time in CSIRO and the friendly culture there.

Master Class of Zooplankton at Ecosciences Precinct

Julian Uribe-Palomino

Some of the students that visit our research group as part of their undergraduate, post-graduate or professional research, carry out studies on plankton data but they never have the opportunity to appreciate the diversity in size, shape and general variety of the plankton organisms. For some of these students this was the first time they have used a microscope and seen 'real' creatures that make up a part of their daily work.

Last August 2016 on the 26th, I directed a master class of marine zooplankton identification in our lab at the Eco-Science Precinct in Brisbane, to help close the gap between the 'real organisms' and provide connectivity with the scientific names that researchers use in their data. The aim of this short practical session was to understand the main differences between the diverse groups of free-living copepods and also to learn identification skills using a microscope. In addition to this very important group of micro-crustaceans, we covered some of the most common groups of the zooplankton community such as: gelatinous plankton, polychaete worms, molluscs, cladocerans, decapod larvae, echinoderms and fish larvae.

Some of our interns have had the opportunity to participate in field trips to North Stradbroke Island, IMOS-National Reference Station. This is an important part of their professional training as it allows for participation in the sample collection that generates the data used in their research. We explained the different devices and the types of information collected. The students also learn to get information such as: wind speed and direction; secchi disk measurements and they participate in the collection of water samples from standard depths with niskin bottles, collection of zooplankton samples and fish larvae tows.

Attendees: Boer Bao (James Cook University), Chloe Jayakody and Leslie Braberry (The University of Queensland), Chhaya Chauhary (Auckland University- New Zealand), Sophie Sabarot (Universite De Pau Et Des Pays De L'Adour- France), and Larissa Perez (Universidade Federal Fluminense, Brazil).

From the Plankton Lab to A-Star

Julian Uribe-Palomino

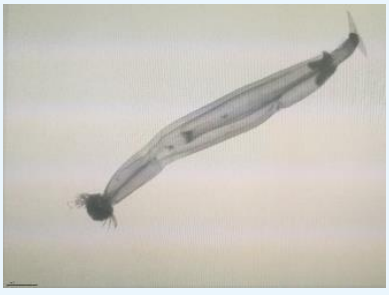
Rena Ono is a Japanese student who did a short internship with the Plankton team during December 2015- January 2016. Rena focused her internship on producing size spectrum data from a device called "The ZooScan". This piece of technology has been specially designed to scan liquid samples such as the IMOS National Reference Station samples we collect. Rena learnt very quickly to obtain high resolution ZooScan pictures and also learnt to process them with software that classifies each entity into a zooplankton category such as: copepod, chaetognath, mollusc, egg, fish larva and other planktonic groups. Rena went back to Japan and wrote us a letter:

"Last month, I held an event about studying abroad in my Uni with my mates who experienced study in other countries. We mainly did a presentation for students who are interested in studying abroad. Some teachers also came to the event. After finishing the presentation, a dean praised my presentation and gave me a great chance. It was that he wanted me to go to Singapore (A*STAR) with a scholarship and make a good connection to local students because my university is going to start an exchange program with A*STAR from next spring. (It means that he needed a student who can be a trial student for that program before it starts). A*STAR is a famous science centre in the world and Singapore is one of the countries which I love! So, I decided to study there before graduation with the scholarship (from Dec to Feb).

I am planning to study Molecular Biology. It is a totally new field for me that may be useful for my future job, a researcher of cosmetics. I really want to say THANK YOU because CSIRO gave me the marvellous experience and you confidence to try everything which I am interested in! So, I am enjoying the last year of uni."

Above: Rena helping to prepare niskin bottles on a NRS sampling trip.

Above: ZooScan.



Above: A chaetognath scanned by ZooScan.

Right: A plankton sample processed by ZooScan.

Hitch-hikers Guide to the Oceans

Ruth Eriksen and Julian Uribe-Palomino

Phytoplankton have intriguing ecological niches and can form unique symbiotic or epiphytic relationships with a range of other marine organisms. Diatoms may either play host to hitch-hiking organisms, or catch a ride themselves. The diatoms may simply need a suitable substrate to settle on, but in some cases appear to have been specially selected by their hosts. We include here a summary of some of the fantastic associations we have observed in samples from the NRS and AusCPR.

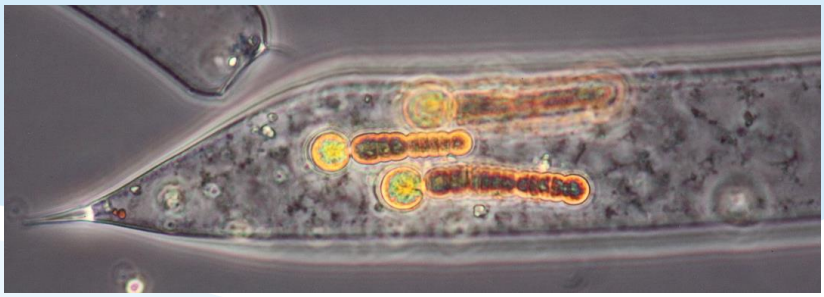


Figure 1: The centric diatom *Rhizosolenia cf clevei* with the cyanobacteria *Richelia intracellularis*.

Figure 1 shows the diatom *Rhizosolenia clevei* forming a symbiotic association with the cyanobacteria, *Richelia intracellularis.* This cyanobacteria is also known to form associations with other species of *Rhizosolenia,* as well as *Hemialus, Chaetoceros* and *Bacteriastrum.* We observe this association in warmer waters, with records from Yongala, Rottnest and Stradbroke Island. *Chaetoceros coarctacus* is often seen supporting groups of epibiont ciliates (*Vorticella*) at Rottnest Island and Kangaroo Island (Figure 2). The consortium between the colonial stramenopile *Solenicola setigera* and the chain forming diatom *Leptocylindrus mediterraneus* is very intriguing (Figure 3). Latest research suggests this is not a parasitic relationship, but a mutual symbiosis.

Figure 2a): *Chaetoceros coarctatus* and b) the epibiont *Vorticella oceanica*.

The stunning diatom *Coscinodiscus gigas* was observed at Yongala and North Stradbroke, playing host to large numbers of ciliates (Figure 4). Diatoms may themselves seek appropriate substrate, and Figure 5 shows small pennate diatoms settling on a small piece of debris from Rottnest Island. Equally stunning, is the diatom *Proboscia alata*, observed at Yongala with a heavy burden of colonial ciliates (Figure 6a) and North Stradbroke Island (Figure 7a). Figure 7b shows solitary ciliates on the diatom *Odontella sinensis*, observed at North Stradbroke and Morton Bay. Also in Moreton Bay, *Palmerina ostenfeldii* hosts a living ciliate within the cell structure, and is the subject of current detailed taxonomic studies by Julian and Gustaaf Hallegraeff (Figure 8a, b).

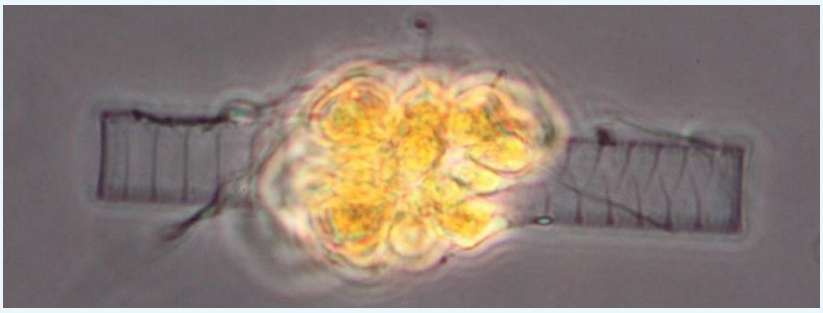


Figure 3: Diatom *Leptocylindrus mediterraneus* with the strameopile *Solenicola setigera*.

Equally fascinating is the rarer observations of diatoms forming epiphytic communities on some species of copepods. Figure 9 shows dense communities of pennate diatoms (xx) on the calanoid copepod *Candacia* from North Stradbroke Island.

Figure 4: *Coscinodiscus gigas* with ciliates.

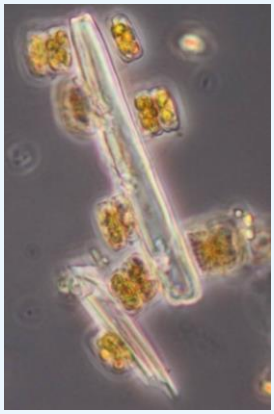


Figure 5: Small centric diatoms attached to debris substrate, Rottnest Island.

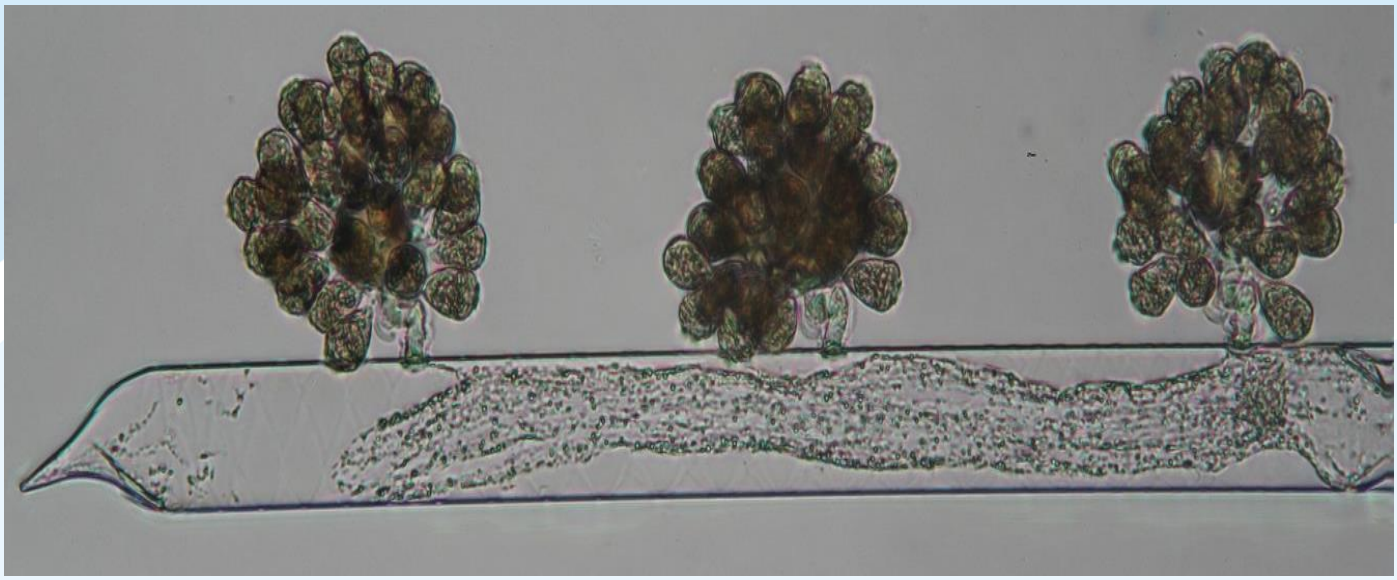


Figure 6a: Proboscia alata with colonial ciliates.

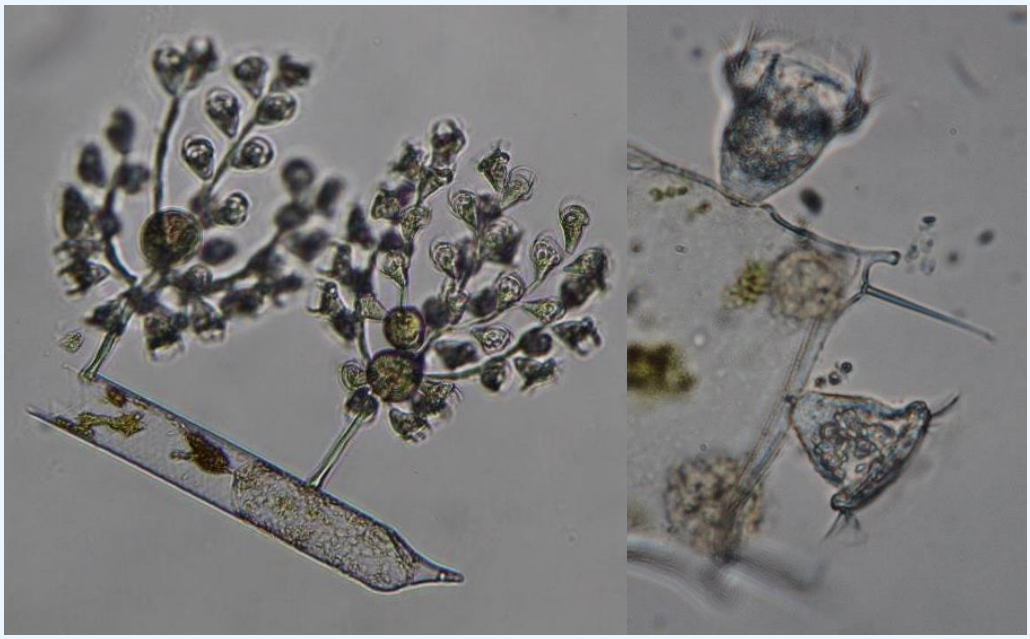


Figure 7a: detail of colonial ciliates on Proboscia, and b: *Odontella sinensis*.

Figure 9: Pennate diatoms on the copepod Candacia.

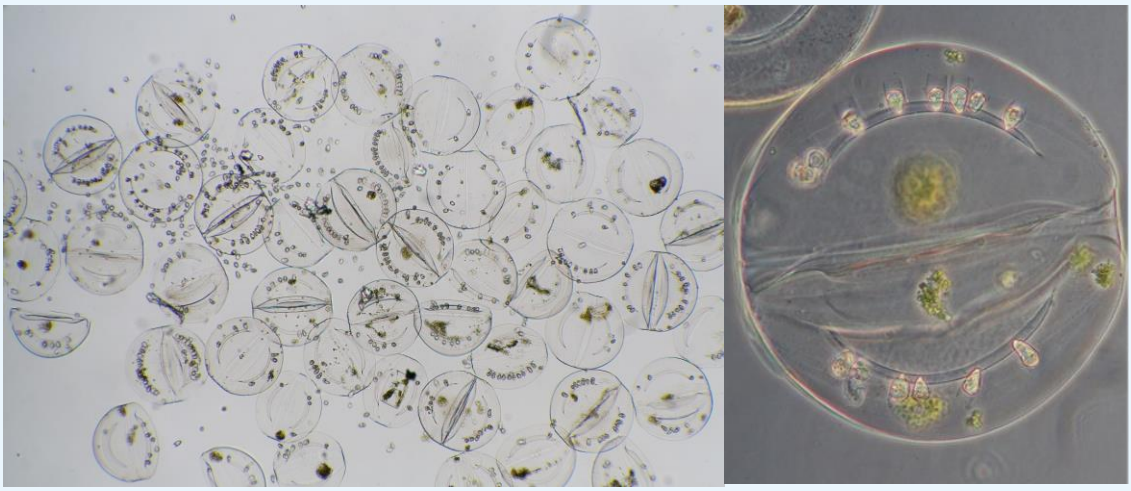


Figure 8: *Palmerina ostenfeldii*, and it's previously undiscovered ciliate.