IMOS

marinematters

Integrated **Marine Observing** System

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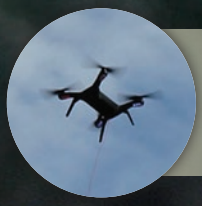
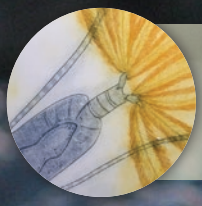
Latest bioacoustic tracks from FV *Antarctic Discovery* provide unique data to IMOS



Using autonomous drones to improve data quality for High-Frequency Ocean radars



Artist Diane Masters inspired by plankton in her current exhibition

Tough love for elephant seal pups

A recent study examined how female elephant seals adjust their expenditure with respect to prevailing environmental conditions, and demonstrates that seal mothers give more to their pup when conditions are favourable and less when they are poor.

Ben Arthur, CSIRO

director's corner

Welcome to the first edition of Marine Matters for 2017. As we enter another year, all of our eyes are looking up and beyond 'next Xmas'. The big goal for IMOS in 2017 is securing long-term support for our sustained observing system and national data network.

IMOS only exists because of funding provided as a priority capability under the National Collaborative Research Infrastructure Strategy (NCRIS). The combination of long-term funding for NCRIS and a priority in the area of marine environment is required to sustain the IMOS marine observing and data management infrastructure. As previously reported, the future prospects are currently very good.

Australian Government has made an ongoing commitment to NCRIS and announced decadal funding of $1.5 billion under the National Innovation and Science Agenda (NISA). A new National Research Infrastructure Roadmap is being developed to guide this and related investment.

The National Research Infrastructure Roadmap is all but finalised as Marine Matters goes to press. IMOS was well represented in the Draft National Research Infrastructure Roadmap, and we have no reason to believe this will be any less so in the final version. Once the final Roadmap is submitted to Australian Government, their response will inform an investment planning process to fully release the ten-year, $150 million per annum funding for priority NCRIS capabilities.

This suggests that even in a best-case scenario, it will take a little more time before IMOS actually has secure, long-term funding in place. NCRIS funding for IMOS is only committed to 30 June 2017, and we are now expecting an interim extension while the Roadmap and investment plan process is designed and implemented. Our users and stakeholders, operating institutions, operational partners, research partners, co-investors, and international collaborators continue to absorb a range of associated risks in the interim. Their ongoing support speaks volumes for the power of IMOS as a national collaboration with global reach, established and sustained through NCRIS.

The stories featured in Marine Matters provide tangible evidence of these collaborations in action. They demonstrate national leadership, international significance, and regional relevance. They showcase high quality science, research for policy and management, and research with operational impact. We hope you enjoy reading this edition.

Tim Moltmann

NEWS

National IMOS community gathers in WA for annual meeting

Each year the IMOS community from across Australia gets together to review the previous year, share achievements and challenges and collectively look to the future. This February, the eleventh annual IMOS meeting was held in Perth at the University of Western Australia.

Chaired by IMOS Director, Tim Moltmann, this year's meeting was organised around three themes; Signal to noise – extracting value from datasets and time series, Operational oceanography, and Marine extremes. The final day focussed on IMOS performance – assessment and improvement.

Mr Moltmann was appreciative of all the time and energy participants put into the Annual Planning Meeting and was happy with its outcomes.

"Our reflections at the Board meeting on Thursday afternoon and Friday morning were very positive. "It was particularly useful to have senior industry representatives in attendance to share their perspectives and priorities regarding marine observations," said Mr Moltmann.

As part of the Operational oceanography theme, Steve Buchan from RPS Metocean and Jan Flynn from Shell Australia presented.

They spoke about gaps and requirements from the perspectives of a metocean service provider and an offshore energy company. Thermal structure, biofouling, bottom boundary layers, tropical cyclone forecasting, swell, surface currents, and ocean renewables were all discussed.

Warrick Glynn, IMOS

Representatives of the national IMOS community listen to a colleague at the Annual Planning Meeting in Perth.

The possibility of access to industry data, leveraging the Defence Department's hydrographic data acquisition program, and improving bathymetry, was also a topic of discussion during this theme.

The need to focus on understanding user needs and how these needs evolve and change came up in a number of discussions. It was widely accepted that IMOS should continue to look for opportunities to underpin more synthesis products, as many end-users of data are seeking marine and climate information in accessible applications or packages such as IMOS *OceanCurrent*.

The series of talks on marine extremes highlighted some excellent work going on around Australia, and the important role that IMOS observations are playing. Known gaps in tropical fluxes and spatial coverage across the north were highlighted. The importance of relating findings back to forecast skill, and opportunities to improve it, was a key point raised.

Access to data collections and their use came up regularly throughout the meeting. An update on the Australian Ocean Data Network's status and priorities was presented. A number of developments to this online resource have occurred over the past year and these were outlined. There was some discussion of tailoring the presentation of data to the various segments of the market, from expert users to those who only want data products.

On the final day of the meeting, the United States Consul General to WA, Rachel Cooke, called in to meet with meeting participants. Tim Moltmann and Chair of the IMOS Board, Ian Poiner, discussed the functions and challenges of IMOS and its linkages with the USA with Ms Cooke. IMOS facility leaders and others from the IMOS community also joined the discussion, providing their particular perspectives and discussing their groups' contributions to marine observing in Australia.

Key messages in the IMOS Five Year Plan were highlighted during the meeting. Participants agreed on the importance of planning for future growth, notwithstanding ongoing short-term uncertainty with respect to core funding. The Five-Year Plan sets out the need for a step change increase in access to autonomous vehicles, and vessel-independent capability to observe in remote regions. IMOS will need to establish processes over the next year or so to prepare for success on these fronts.

Representatives of the national IMOS community will meet again in February 2018 in Hobart, Tasmania.

Presentations given at the meeting can be accessed via the **agenda of the 11th IMOS Annual Planning Meeting**.

Warrick Glynn, IMOS

US Consul General to WA, Rachel Cooke, visited the IMOS meeting. Ms Cooke is pictured here with Chair of the IMOS Board, Ian Poiner (left) and IMOS Director, Tim Moltmann (right).

Inspired by plankton

ARTIST **DIANE MASTERS**

Have you ever thought of what the microscopic, drifting, primary producers that the ocean is teeming with have done for you? These are the phytoplankton, and they are grazed by animals known as zooplankton. All ocean life and we humans, depend on plankton because they are the start of the food chain.

Plankton dominates the biomass of the oceans. Phytoplankton perform nearly half of the photosynthesis on Earth, fixing carbon dioxide and producing half of the oxygen we breathe. The most common zooplankton, the copepods, outnumber insects as the most abundant animals on Earth. The abundance and success of all marine life is dependent on the health of the plankton. They are our oceanic “canaries in the coal mine”. Plankton also impacts human health directly. Some phytoplankton species are toxic and form large harmful algal blooms, contaminating shellfish and causing poisoning and death in humans. Some zooplankton are venomous, such as the box jellyfish and Irukandji species, causing severe pain and death and beach closures in Northern Australia.

In her current exhibition, artist Diane Masters has been inspired to create stunning artwork of plankton. She collaborated with Claire Davies and Dr Ruth Eriksen who work in the IMOS Australian Plankton Survey sub-facility.

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 Ruth and Claire continued to send Di photos of all the especially beautiful planktons they saw in the samples. Di worked over two years to complete the amazing set of etchings through the aquatint process in the exhibition.

An important part of the IMOS biological observing is the work we do on plankton. IMOS plankton observations come from monthly water sampling at our seven National Reference Stations. One of the these is located off Maria Island, where we have 70 years of historical data to build on. The others are off Sydney, Brisbane, Townsville, Darwin, Perth, and Adelaide. IMOS also collects plankton with Continuous Plankton Recorders,

very robust instruments towed behind ships of opportunity that capture plankton between silks.

All of these samples come back to labs in Brisbane and Hobart where they are identified and counted and turned into datasets that can be used to understand distribution and abundance of species, and how this is varying and changing through time. Vitally important to understanding the state of our marine ecosystems.

IMOS Director, Tim Moltmann introduced the exhibition in Hobart at the Institute of Marine and Antarctic Studies Gallery on Wednesday 1st of February, and Christine Milne officially opened the exhibition.

"The IMOS plankton observations represents a big effort, involving a lot of planning and preparation, time at sea, time in the lab peering down microscopes, work on databases and data analysis. But in talking to the people that do this work you realise they are also motivated by the sheer beauty of these tiny plants and animals, and the wonder of what they do," says Mr Moltmann.

"It's this beauty and wonder that I'm sure has captured Di Masters' imagination as an artist."

"As publicly funded scientists we must take responsibility for communicating our work to the public. This glorious partnership between science and art is a great way to do that."

Undercurrent by Diane Masters is in the IMAS exhibition space at our Waterfront Building from 1 February until 30 March 2017.

Tim Moltmann, Diane Masters, Christine Milne and David Masters at the exhibition.

Claire Davies, Diane Masters and Dr Ruth Eriksen collaborated on the project.

International ocean science leader visits Hobart

Dr Vladimir Ryabinin, Executive Secretary of the Intergovernmental Oceanographic Commission (IOC) of UNESCO, visited Hobart in early February.

Based in Paris, Dr Ryabinin leads the IOC in its efforts to promote international cooperation in ocean science and to coordinate programmes in research, services and capacity-building. These programmes include the Global Ocean Observing System (GOOS).

The trip to Hobart was a detour in a busy schedule involving meetings in Canberra and Melbourne, followed by an international Indian Ocean meeting in Perth. However, Dr Ryabinin said he was very happy to make the journey, describing Hobart as 'a capital of oceanography' that is well known and respected in the international arena.

The visit was hosted by Tim Moltmann, IMOS Director and Chair of the GOOS Regional Alliance Council, and John Gunn, CEO of the Australian Institute of Marine Science and Co-Chair of the GOOS Steering Committee. It involved meetings at CSIRO and the University of Tasmania with Australian scientists holding senior positions on international committees and other bodies relevant to IOC.

"We really appreciated the fact that Dr Ryabinin took the time to come to Hobart and meet with us face to face" said Mr Moltmann. "What shone through in our discussions is the fact that so many global frameworks are now in place that provide pathways for ocean science to have real and lasting societal impact."

"These cover sustainable development, climate change, disaster risk reduction and biodiversity beyond areas of national jurisdiction. This is exciting for our national marine science community with its focus on driving the development of Australia's blue economy."

Dr Ryabinin was accompanied by Dr Ray Canterford from the Bureau of Meteorology, who is Australia's national representative to IOC-UNESCO. This visit was also useful in discussing how the national marine science community can better support Dr Canterford in representing Australia at the IOC.

Marian Wiltshire, IMOS

Dr Ray Canterford, Bureau of Meteorology, Dr Vladimir Ryabinin, Executive Secretary of the IOC and IMOS Director Tim Moltmann during their visit to Hobart.

Head of South African coastal observation visits IMOS office during Antarctic circumnavigation

IMOS hosted a visit by Dr Tommy Bornman from the South African Environmental Observation Network (SAEON). He is on the Cape Town to Hobart leg of the Swiss Polar Institute Antarctic circumpolar expedition (ACE) which arrived in Hobart in January.

Dr Bornman leads the Coastal (Elwandle) Node of SAEON, which is mandated to undertake long-term monitoring and research on South Africa's coastal zone.

Dr Bornman gave a presentation in the IMAS lecture theatre on the work of SAEON and its plans for developing research infrastructure in South Africa. He was keen to meet with IMOS staff to discuss issues of mutual interest to our two organisations and to share experiences of developing a national marine observation capability.

One of the areas of particular interest to SAEON is data management and access, an area in which IMOS has considerable experience. SAEON is also planning to expand its coastal observation infrastructure to include moorings that transmit data in real-time. Again, this is an area where IMOS can share its experience.

IMOS can learn from SAEON too, as it undertakes a successful national educational outreach program. Although not mandated to run an education program, IMOS is interested in such outreach activities as they help to develop the next generation of marine scientists, data managers and other related professionals.

The Swiss Polar Institute's ACE journey has now completed its first leg, having arrived in Hobart. As part of his presentation, Dr Bornman showed a video of highlights of the journey so far, from South Africa to Tasmania.

ACE participants are conducting a number of research projects along the way and while in Hobart, many are networking with others who share their professional interests.

Warrick Glynn, IMOS

Dr Tommy Bornman (right) with Tim Moltmann at the IMOS office in Hobart.

2015/16 Annual Highlights document published

It was a big year for IMOS, being the tenth year of operation for our national collaboration.

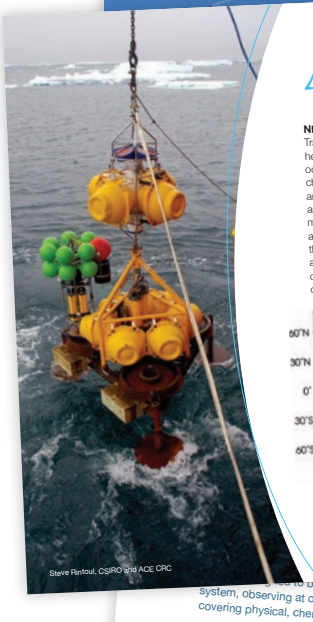
This Annual Highlights document covers the tenth year of IMOS operation. A related document entitled “From Observations to Impact” has been prepared to celebrate the first decade of IMOS. However, we believe it is also important to continue the Annual Highlights series so as to provide accountability for the 2015-16 year.

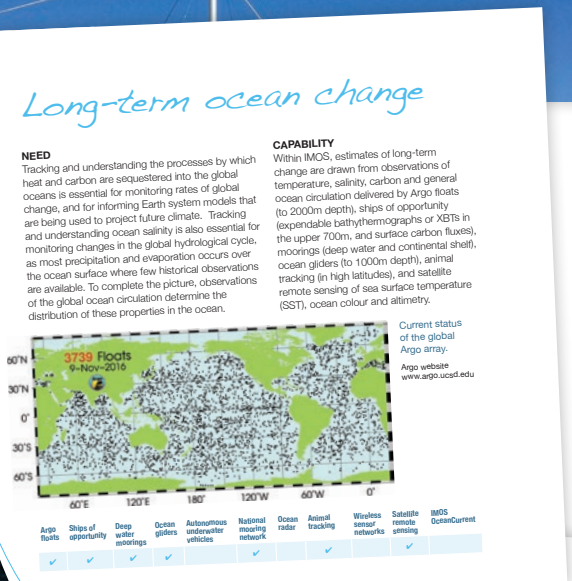
Consistent with previous years, 2015-16 Impacts are reported against each of the five major research themes that unify IMOS science plans and related observations i.e.

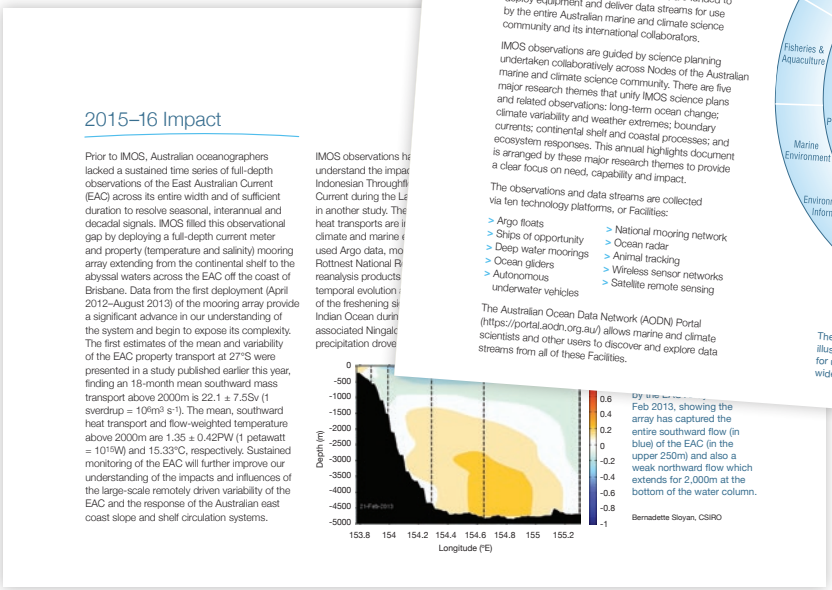
- Long-term ocean change
- Climate variability and weather extremes
- Boundary currents
- Continental shelf and coastal processes, and
- Ecosystem responses.

IMOS Director, Tim Moltmann says, “the value of systematic and sustained observing, integrated across scales and variables, can be clearly seen in the 2015-16 Impacts.”

We hope you enjoy reading this IMOS Annual Highlights document for 2015-16.







NSW-IMOS announces leadership change

Following a meeting on 11 January, the New South Wales node of IMOS (NSW-IMOS) announced that Justin Seymour, from the University of Technology Sydney (UTS) will take over leadership of the node. Tim Ingleton from the NSW Office of Environment and Heritage will remain as the Deputy Leader.

Martina Doblin, from UTS and the Sydney Institute of Marine Science (SIMS), has stepped down as leader after several years in the position.

IMOS Director, Tim Moltmann, acknowledged the important contribution Dr Doblin has made in her leadership of the NSW-IMOS node.

"IMOS has benefited greatly from Martina's leadership," said Mr Moltmann.

"We thank her for that contribution, and hope to keep her engaged through our work at the nexus of ocean optics, remote sensing and microbial ecology."

This change completes a refresh of the NSW-IMOS leadership, with Robin Robertson from the Australian Defence Force Academy (ADFA) and the University of New South Wales (UNSW) stepping down as Deputy Leader late last year. We also acknowledge and thank Robin.

As a large, diverse and dispersed community, IMOS relies on a series of integrated Nodes to develop relevant science plans to guide its activities.

There are six nodes of IMOS, covering Australia's shelf and coastal seas, as well as the surrounding open ocean.

Each of the nodes contributes to a National Science and Implementation Plan with input from many, many researchers from across the Australian marine and climate science community. The Plan represents a major body of work that will continue to evolve over the life of IMOS, in response to national needs and global trends. IMOS can only work in this way because we have excellent scientists within the community who are prepared to dedicate the time and effort required to lead our Nodes.

Mr Moltmann welcomes Justin Seymour to the position of Node leader and looks forward to a productive relationship.

"Justin's appointment is very timely," he said. "His area of expertise is in microbial oceanography, which is an important strategic direction for IMOS. We think he's a great fit."

"Justin's appointment is very timely. His area of expertise is in microbial oceanography, which is an important strategic direction for IMOS. We think he is a great fit."

Ships of Opportunity:

Latest bioacoustic tracks from FV *Antarctic Discovery* provided unique data to IMOS

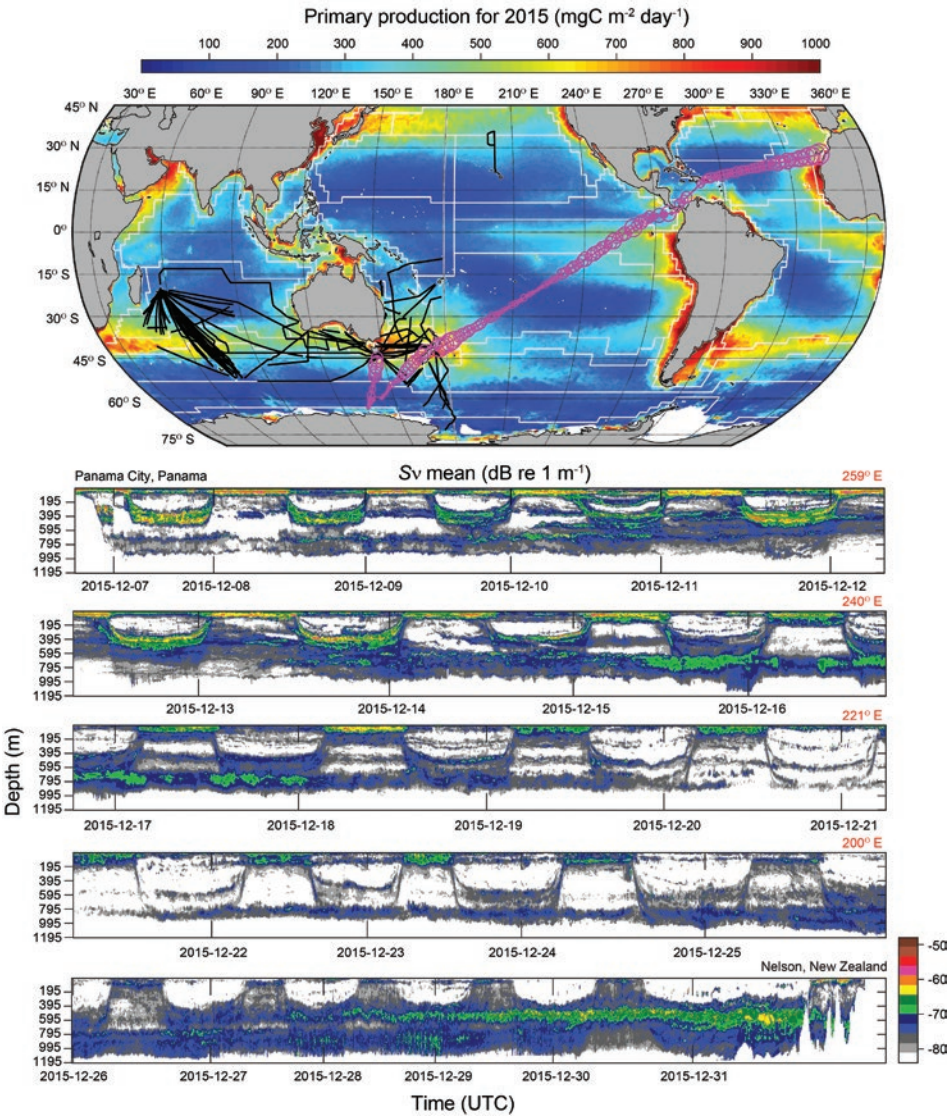
WRITTEN BY: HARIS KUNNATH AND RUDY KLOSER, CSIRO

The Australian Longline vessel *Antarctic Discovery*.

Since July 2010, the IMOS Bio-Acoustic Ships of Opportunity (BASOOP) sub-facility has been delivering calibrated (now multi-frequency) water column acoustic data to characterize ocean basin scale distribution and seasonal behaviour of mid-trophic level organisms. At present, 17 vessels are participating in the BASOOP program. Between 2010 and 2017 300,786 km of data were collected and processed (see Figure at right). The resulting acoustic *snapshots* of mid-trophic (macro-zooplankton and micronekton) communities are combined with established ocean observing systems to fill the *dark hole* in our understanding of marine ecosystems and support their sustainable management.

As a part of the existing industry collaboration, the Australian Longline Pty Ltd fishing vessel *Antarctic Discovery* successfully recorded 38 kHz acoustic data during its delivery voyage. The hull-mounted echosounder has been calibrated recently that enabled us to publish this vast data set across the oceanic basins (Figure at right) including Atlantic (7077 km), Pacific (11798 km), and Southern Ocean (6307 km). The processed acoustic backscatter maps reveal large-scale spatio-temporal patterns in pelagic sound scattering layers and diel vertical migration. The diel vertical migration (referred to as the largest daily migration of animals on earth) contribute substantially to the *biological pump* and regulate the primary production involved in the marine biogeochemical cycles.

The mesopelagic fish communities living in the twilight zone of the ocean (200–1000 m depth) have been identified as one of the least investigated components of the open ocean ecosystem. The mesopelagic fish communities are readily detectable using echosounders and in the ocean the transmitted acoustic signals uncover a principal deep scattering layer (DSL), evidencing its interrelationship with the open ocean fish biomass and primary production (Figure below, note net primary production is derived from satellite ocean colour and averaged for the year 2015). With a current stock estimate of ~1,000 million tons, mesopelagic fish likely dominate the total biomass of fish in the ocean. However, the actual biomass is still unquantified and researchers have indicated that the real abundance could be at least 10 times higher than previously assumed. To bridge the gap, IMOS BASOOP program offers the prospect of acquiring new data, novel insights and delving into new research challenges for the sustainable management of our oceans.



The lower mesopelagic (400–800 m depth) area backscatter strength variation (magenta circles) along the *Antarctic Discovery* voyage transect, superimposed on a satellite-derived map of net primary productivity (averaged for the year 2015) and the Longhurst oceanic biogeographical provinces (white lines). The bottom panels display the echogram along the vessel transit covering the Pacific Ocean from Panama to New Zealand, revealing broad transitions between the Longhurst provinces. The center part of the south Pacific (25oS 220oE) highlight oligotrophic regions with low predicted productivity (blue), which is observed in general by the low mesopelagic (400–800 m depth) backscatter strength (small magenta circles).

Deep Water Moorings:
International link bears fruit

The Southern Ocean Carbon Processes (SOCarP) project – consisting of two sediment traps, one acoustic Doppler current profiler (ADCP), two rotor current meters (RCM) and three MicroCATs (measures conductivity and temperature) – has reported that it successfully deployed a sediment trap mooring at 40°S 58.5°E on 13 January.

The deployment was from the SA Agulhas as a part of its current Southern Ocean expedition. The mooring is programmed for two years although it may be retrieved next year.

Some time ago Tom Trull (IMOS Deep Water Moorings Facility) assisted the project by sending information to Dr P. V. Bhaskar from the Indian National Centre for Antarctic and Ocean Research (NCAOR) and later meeting with him at his lab and mooring shop in Hobart.

Tom hopes to explore the possibility of expanded links with NCAOR for both Southern Ocean moorings and BioArgo efforts.

Ocean Gliders:
A new paper and video series teaches analysis and visualisation of ocean glider data

A new paper has been published in the journal 'Oceanography' on the use of 'Glider scope' a software package developed for the analysis and visualisation of ocean glider data.

The paper was developed as a hands-on activity with example data sets and video tutorials for ease of use. The activity and exercises were tested through the University of Western Australia ENVE 4615 Physical Oceanography undergraduate class.

Reference: Hanson, C.E., L.M. Woo, P.G. Thomson, and C.B. Pattiaratchi. 2016. Observing the ocean with gliders: Techniques for data visualization and analysis. Oceanography 30(2), **https://doi.org/10.5670/oceanog.2017.210**.

See the first video tutorial on YouTube.

Also, Gliderscope version 6 has been released – it is now uploaded onto the IMOS website including an updated user manual. **http://imos.org.au/gliderscope.html**

Ocean Gliders:
Industry collaboration doubles the data collection capacity of Australia's Slocum glider fleet

A new paper has been published A successful partnership between IMOS Ocean Gliders Facility in Perth and local company 'Master Instruments' has significantly improved the efficiency of Slocum glider missions – at no extra cost.

Glider missions are restricted in duration due to battery life and this presents two major issues. Firstly, the amount of data that can be gathered during any single mission depends on how long the glider can stay in the water, and secondly, operational effort and expense is increased with each recovery and deployment.

In a collaboration with **Master Instruments**, the team at the IMOS Ocean gliders facility set out to address these two issues. Together, they developed an innovative rechargeable battery pack that is likely to double the amount of data that can be collected by the glider fleet each year without any additional expense.

IMOS Ocean Gliders Facility Operations Manager, Mr Dennis Stanley, who is based at the Oceans Institute at the University of Western Australia, explained the benefits of the new rechargeable battery packs.

"Firstly, the increased battery capacity means that longer missions involving significantly more data collection days (DCDs) are possible," said Mr Stanley.

"The old single-use battery packs constrained us to a maximum of about three weeks at sea, and longer missions would have required us to turn some sensors off to conserve power.

"Four weeks at sea with full data collection every day is now very doable so we can observe specific ocean events over longer time periods," he said.

Powered by one of the new battery packs, Slocum glider U239 set a new IMOS ocean gliders endurance record of 30 continuous DCDs with relative ease. A recent Two Rocks mission was on track for 34 days but completed its science objectives early so was recovered.

Warrick Glynn, IMOS.

IMOS Ocean Gliders Facility Operations Manager, Mr Dennis Stanley, in the Ocean Glider Facility Laboratory

"The second major advantage of using these new batteries is it takes fewer missions to collect the same amount of data and that means less operational time and less expense," said Mr Stanley.

In addition to the longer missions and less operational effort, the new batteries can be recharged from mains power, without needing access to sophisticated lab facilities. Gliders can now be turned around within 24 hours if required, more or less on-site, even along relatively remote parts of coastline.

Previously it could take weeks or even months to refurbish gliders after a deployment, because replacing the single-use battery would also necessitate re-ballasting, re-calibrating the compass and other instruments as well as overland transport of the gliders to labs across the country, sometimes even internationally. In 2016 Unit 239 completed two Bonney Upwelling missions in South Australia, being recovered, charged, driven back to the start and redeployed 48 hours later. After completing the second, record endurance 30 day mission, this unit travelled by truck to NSW and completed two more missions before being returned to the lab for a major service. This saved a remarkable six transits of the continent by truck and weeks of lab time.

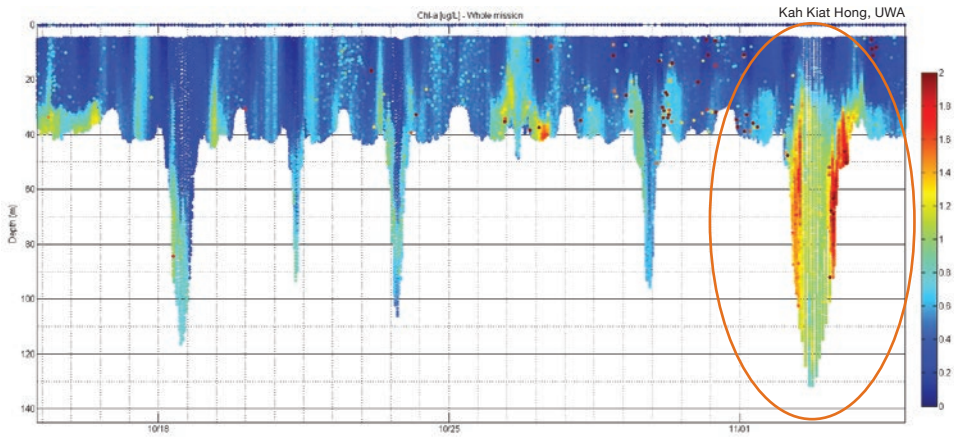
Other efficiencies are also becoming apparent. Unexpectedly short missions – such as a recent deployment on the Two Rocks transect that required an emergency recovery on the 9th day because a shark bite destroyed the glider-mounted CTD – would previously have wasted an entire single-use battery with little data to show for it. Using a rechargeable battery pack means data collection can be resumed much more quickly than before, without such wastage.

Having effectively doubled the capacity for the Slocum glider fleet to deliver ocean observations, this successful research-industry collaboration is looking at the possibility of further innovation. Newer Slocum gliders can theoretically take an even larger battery pack so there are plans to take advantage of this to further increase the duration of glider missions.

Second generation batteries, currently being developed, are based on lithium technologies and will stay charged

UWA

Slocum glider at sea



Sub-surface chlorophyll bloom observed during the extended Data collection. This would have been missed with the old single-use battery packs.

even longer. Innovations include a redesigned battery case to accept multiple sizes of battery and the possibility of external charging capability which will further decrease handling and turn-around time of the glider.

Daniel Rutkowski, a technical designer with Master Instruments, has enjoyed a long and rewarding relationship with the IMOS Ocean Gliders Facility.

"It's been a great opportunity for us to be able to work on something so cutting-edge, and to be able to assist an Australian organisation.

"Transporting lithium batteries internationally has its challenges and therefore additional cost, so it makes perfect sense to manufacture these locally," said Mr Rutkowski.

Greater mission duration, however, does present new challenges. Longer time at sea increases the likelihood of sensor biofouling in some regions. In warmer water biofouling of sensors limits effective mission length to 25–30 days. This is still a work in progress.

Mr Stanley said he is keen to continue working with industry partners to make sure the IMOS ocean glider fleet is delivering the best possible ocean glider data for Australia.

This article is based on text originally written by Suzanne Long, Turn the Tide Pty Ltd.

National Mooring Network:

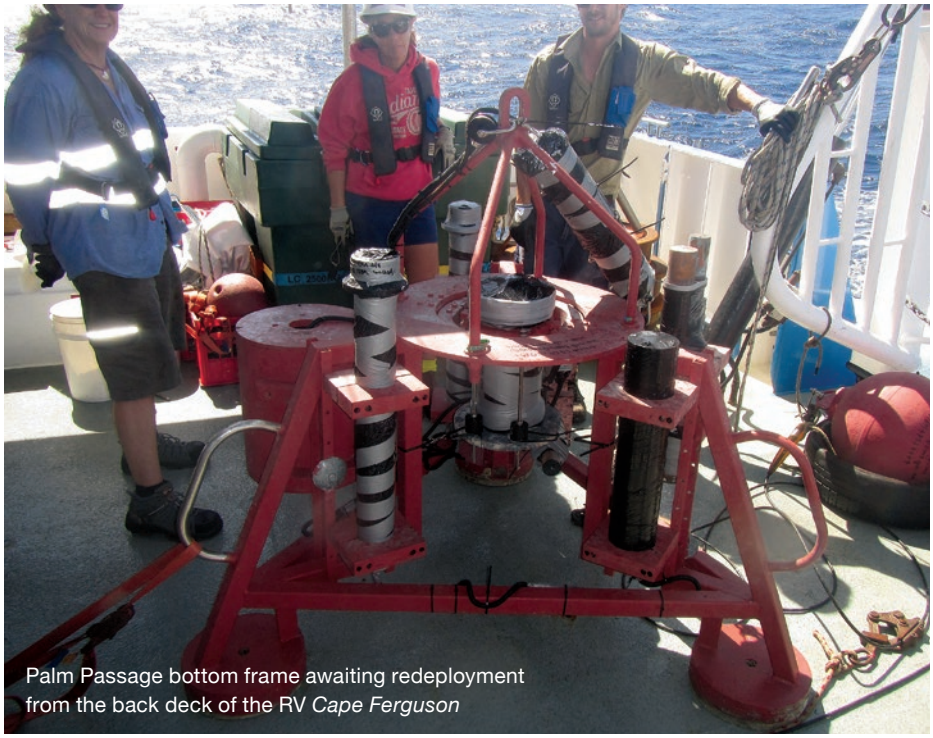
Intrusive upwelling in the central Great Barrier Reef

The central Great Barrier Reef (GBR) has an open reef matrix along the outer-shelf compared to the north and south to the north and south which presents more as a true barrier. Reef passages allow the exchange of water between the continental shelf and the Coral Sea. During the summer months, cool water is uplifted over the slope and flows onto the shelf along the seafloor. These periods of bottom cooling are termed "intrusions" as they are not reflected in the surface temperature.

These intrusions are important as they influence the thermal structure of waters over the shelf. The near-bottom cooling can potentially provide relief for the shelf's benthic marine ecosystems from the impacts of strong summertime warming and marine heat waves.

Intrusive upwelling induces cross-shelf changes in nutrient supply for reef communities from the shelf-edge to the lagoon. The upwelled water entrains nutrients providing an important source for the Central GBR continental shelf and can enhance biological productivity.

Research by a team of scientists at the Australian Institute of Marine Science led by Dr Jessica Benthuysen was published recently in the ***Journal of Geophysical Research: Oceans***, and examined cool, salty bottom intrusions in the Central GBR. The study aimed to characterise their seasonal occurrence, the intensity of bottom cooling and duration, and to determine the physical mechanisms causing them.



Craig Steinberg, AIMS

Palm Passage bottom frame awaiting redeployment from the back deck of the RV *Cape Ferguson*

The research identified the intrusions using six years of mooring observations from the IMOS mooring in the Palm Passage and linked them to fluctuations in the winds and source waters over the slope. A complementary analysis using a regional hydrodynamic *eReefs* model for the Great Barrier Reef further revealed the roles of winds and density field in forcing the shelf circulation during intrusion events.

The research identified 64 intrusion events, which predominantly occurred from October to March including the wet season. During an event the outer-shelf's near-bottom temperature decreased by 1-3°C typically over 1 week. The near-bottom salinity tended to increase, while near-surface changes did not reflect these tendencies. The hydrodynamic model revealed widespread cooling along the seafloor concentrated through the reef passages. During intrusion events, isotherms tended to uplift over the continental slope and onto the shelf and the East Australian Current intensified poleward. While wind fluctuations played a major role in controlling the along-shelf currents, the model results indicated that a concurrent topographically induced circulation can assist the onshore spread of cool water.

Palm Passage mooring surface buoy

Craig Steinberg, AIMS

Ocean Radar:

Using autonomous drones to improve data quality for High-Frequency Ocean radars

WRITTEN BY: SIMONE COSOLI, Ocean Radar Facility Leader – JIM PETTIGREW, Ocean Radar Technical Officer

The effective operation of the SeaSonde High-Frequency (HF) radars managed by the IMOS Ocean Radar Facility requires a frequent, accurate and repeated calibration of the receiver antennas and their pattern. The antenna pattern can change over time due, for instance, to hardware problems or changes in the local environment surrounding the receive element. Far from being a problem, changes in the environment can be accounted for with proper calibration, thus frequently repeated calibrations are essential for ensuring that high-quality surface current measurements are collected.

Over the past years, the Ocean Radar Facility has adopted the standard calibration procedure recommended by the system manufacturer: a boat carrying a signal source, or transponder, tracks a semicircular path at a distance ranging between 1 to 2 km offshore at a constant speed not exceeding 2 m/s, under the ideal conditions of flat sea and no or light winds. While these are common conditions in closed seas, rough sea states, severe winds, submerged reefs and dangerous currents, as well as the remote launch locations for the boats, severely limit the calibration opportunities in Australia and represent dangerous conditions to boat operators and the Ocean Radar Facility staff.

Other calibration procedures have been developed recently to overcome these difficulties, including semi-automatic calibration approaches that exploit the radar echoes from ships of opportunity of appropriate size (such as tankers or container ships). This approach has proven to be very effective in the San Francisco Bay area, and a cost-benefit analysis for the IMOS Ocean Radars suggested that the budget usually allocated to the conventional boat-based calibration would have easily covered the capital costs required to upgrade the SeaSonde radar systems to this technology. However, shipping lanes offshore from the Western Australia systems are prevalently located on the outer edges of the radar operating ranges; consequently, an unambiguous identification of the ship echoes is potentially subject to significant biases due to the poor signal-to-noise ratio constraints.

The IMOS Ocean Radar Facility is now making use of a cutting-edge technology developed by Eduardo Romero, an HF radar technician at University of California at Santa Barbara, Marine Science Institute, in which a commercial-type quadcopter ("drone") available at any hobby shop carries a compact signal source, in replacement of the more conventional type transponder, at a 300 m distance from the receive antenna. The calibration procedure is similar to the boat calibration, but faster, more effective and significantly safer for the operators: a mission is programmed and waypoints are uploaded to the drone's internal GPS; the drone takes off, heads to the arc's starting point and follows very accurately the loaded track; once the calibration is finished, it returns to its launching platform. Even in its autonomy, the drone is continuously under the operator's control, and the mission can be interrupted at any time if problems arise, telemetry is lost or the battery level drops below 50%. In this case, the drone returns following the shortest path to its launching position.

Processing of calibration files and GPS tracks is then almost instantaneous, and a full calibration file can be generated in less than 30 minutes with minimum system downtime.

From a cost-benefit perspective, this methodology has reduced calibration costs well above any expectation. During a recent maintenance visit at the Bonney Coast systems, for instance, a total of 6 missions were performed with a 100% success rate at less than 1 / 10th of the budget normally allocated for the calibration purposes, again minimizing system downtime.

Calibrations at this site had been a priority for the Ocean Radar facility for a long time: several attempts had been made over the past three years, with most of them frustrated by severe weather conditions, dangerous sea states or failing transponders. The most recent calibrations performed at this node will now allow the reprocessing and the quality-control of historical data, as well as the output of calibrated and quality-controlled observations in near real-time.

Calibration is also very important for the WERA phased-array radar systems, and as such the Ocean Radar team is now investigating the possibility of extending and adapting the drone calibration to the entire radar network across Australia, with the added benefit of cost-effectiveness and greater safety for the technical staff.

Louise Adams, IMAS

The small quadcopter used for the calibration of the receive antenna at Nora Creina (SA) SeaSonde radar station is taking off and heading to the first waypoint.

Animal Tracking:

Tough love for elephant seal pups

A recent study examined how female elephant seals adjust their expenditure with respect to prevailing environmental conditions, and demonstrates that seal mothers give more to their pup when conditions are favourable and less when they are poor.

The size of offspring is an important indicator of maternal size and allocation, offspring fitness and ultimately population growth, with larger offspring typically having higher survival rates. Obviously, higher survival confers greater potential fitness on mothers that will persist into future generations.

Southern elephant seals are a particularly good model species for investigating differences in maternal expenditure in offspring because: (i) they are highly sexually dimorphic, in extreme cases breeding males weigh up to 10 times the mass of breeding females, with the biggest males siring the most offspring; (ii) they are one of the most polygynous of all mammals and consequently lifetime reproductive output varies not only between sexes but particularly among individual males; (iii) they are capital breeders, with breeding females relying solely on energy reserves accumulated prior to breeding during their brief 24-day nursing period so that expenditure is not entangled with foraging efficiency and (iv) they live in the biologically heterogeneous environment, the Southern Ocean, which has highly variable resources.

The study, led by Dr Clive McMahon of the Sydney Institute of Marine Sciences, the Institute of Marine and Antarctic Studies and the Marine Predator Research Group at Macquarie University, quantified maternal size and pup size at birth and weaning for 342 elephant seal mothers at Macquarie Island. The study was conducted over 11 years of contrasting sea-ice and Southern Annular Mode values, both indices of the resources available to mother seals. The study also used tracking data from 94 adult females tracked between 1994-2016 (some of which is IMOS seal tracking data) to describe the spatial context of mother's core foraging areas.

Overall large females weaned male pups that weighed 17kg more than female pups. Maternal condition varied by as much as 59kg among years, and was positively related to Southern Annular Mode, and negatively to maximum sea-ice extent.

Importantly, the study demonstrated that when conditions are favourable that small and medium sized mothers weaned relatively larger male pups, with this effect less apparent for larger mothers. This is because there is a non-liner relationship between pup size at weaning and survival. In fact, pup survival declines above a threshold weaning mass, so there is potentially a cost if the largest females produced overly large pups.

In conclusion, the study suggests that elephant seal mothers appear to adjust their reproductive effort according to prevailing environmental conditions, which thereby enhances their lifetime reproductive success.

The full paper is available online through **Wiley Online Library**.

McMahon, C. R., Harcourt, R. G., Burton, H. R., Daniel, O. and Hindell, M. A. (2017), Seal mothers expend more on offspring under favourable conditions and less when resources are limited. *J Anim Ecol*, 86: 359–370. doi:10.1111/1365-2656.12611

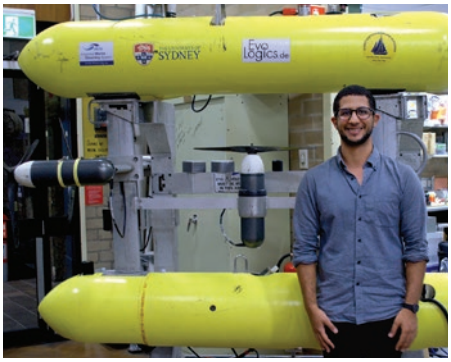
Ben Arthur, CSIRO

Postgraduate Student | **Nader Boutros**

PROJECT TITLE:

High resolution spatial surveys of demersal fish and their habitat using autonomous underwater vehicles

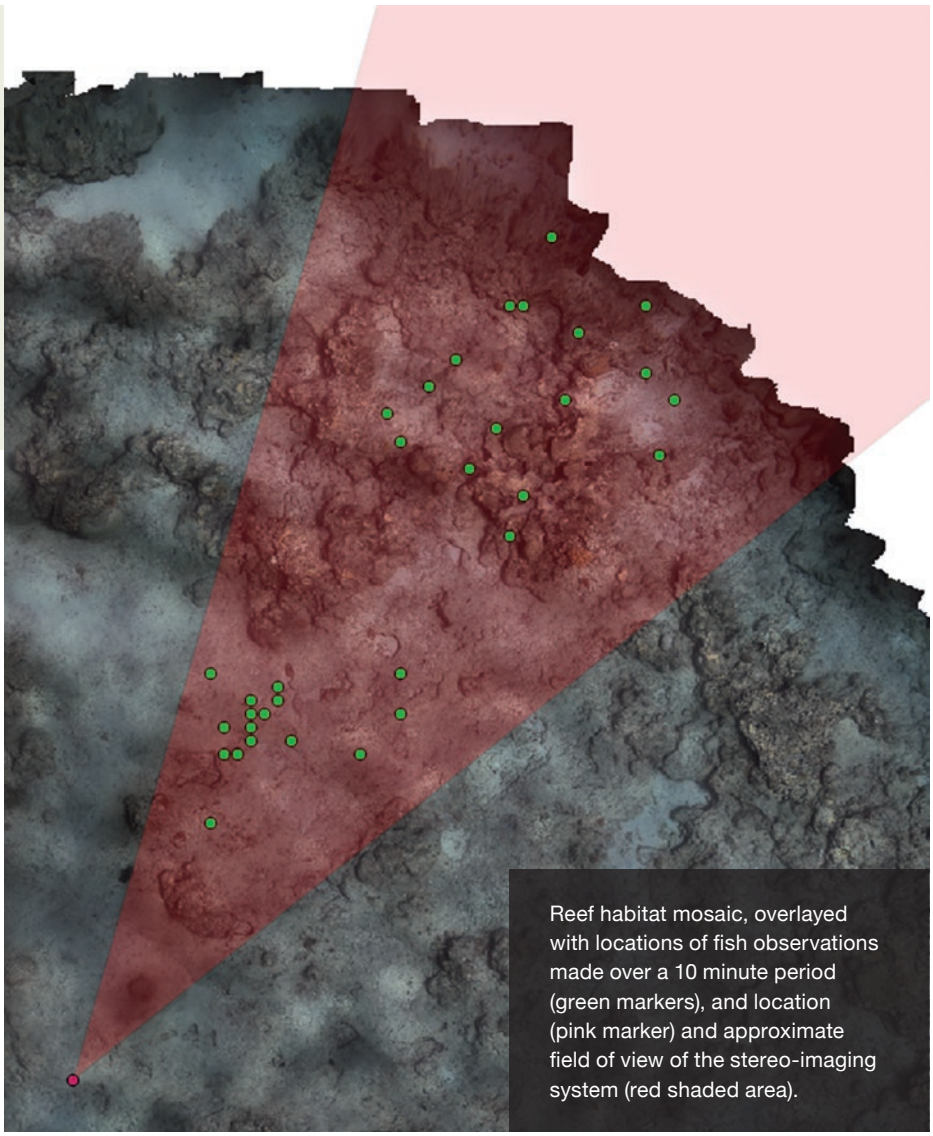
Australian Centre for Field Robotics, University of Sydney



Reef environments are characterised by a complex diversity of abiotic structures and habitat forming organisms. Habitat factors can impact the abundance and distribution of fish (e.g. Ferrari et al. 2016), however it can be difficult to observe this relationship at smaller scales, for example within an individual reef. A comprehensive understanding of the link between fish and habitat can guide ecological management and assist in planning and monitoring of marine protected areas (Curley et al. 2002).

The autonomous underwater vehicles (AUVs) operated by the Australian Centre for Field Robotics are designed to generate high resolution, 3-dimensional reconstructions of benthic habitats. The data generated by these vehicles enables researchers to analyse the spatial distributions of physical and biological habitat features at fine spatial scales. Nader's project aims to use the mapping and localisation capabilities of AUVs to observe the spatial distributions of reef fish within their habitat.

Testing of a preliminary survey technique was conducted at Lizard Island, on the northern Great Barrier Reef. A diver operated mapping system, equipped with a similar sensor suite to the IMOS AUV Sirius, was used to generate a 3D seafloor reconstruction of an area of reef. Fish were observed within this surveyed area using a stereo-imaging system, allowing their position on the reef to be recorded. Fish positions were then overlayed onto the habitat map (see figure above).



Reef habitat mosaic, overlayed with locations of fish observations made over a 10 minute period (green markers), and location (pink marker) and approximate field of view of the stereo-imaging system (red shaded area).

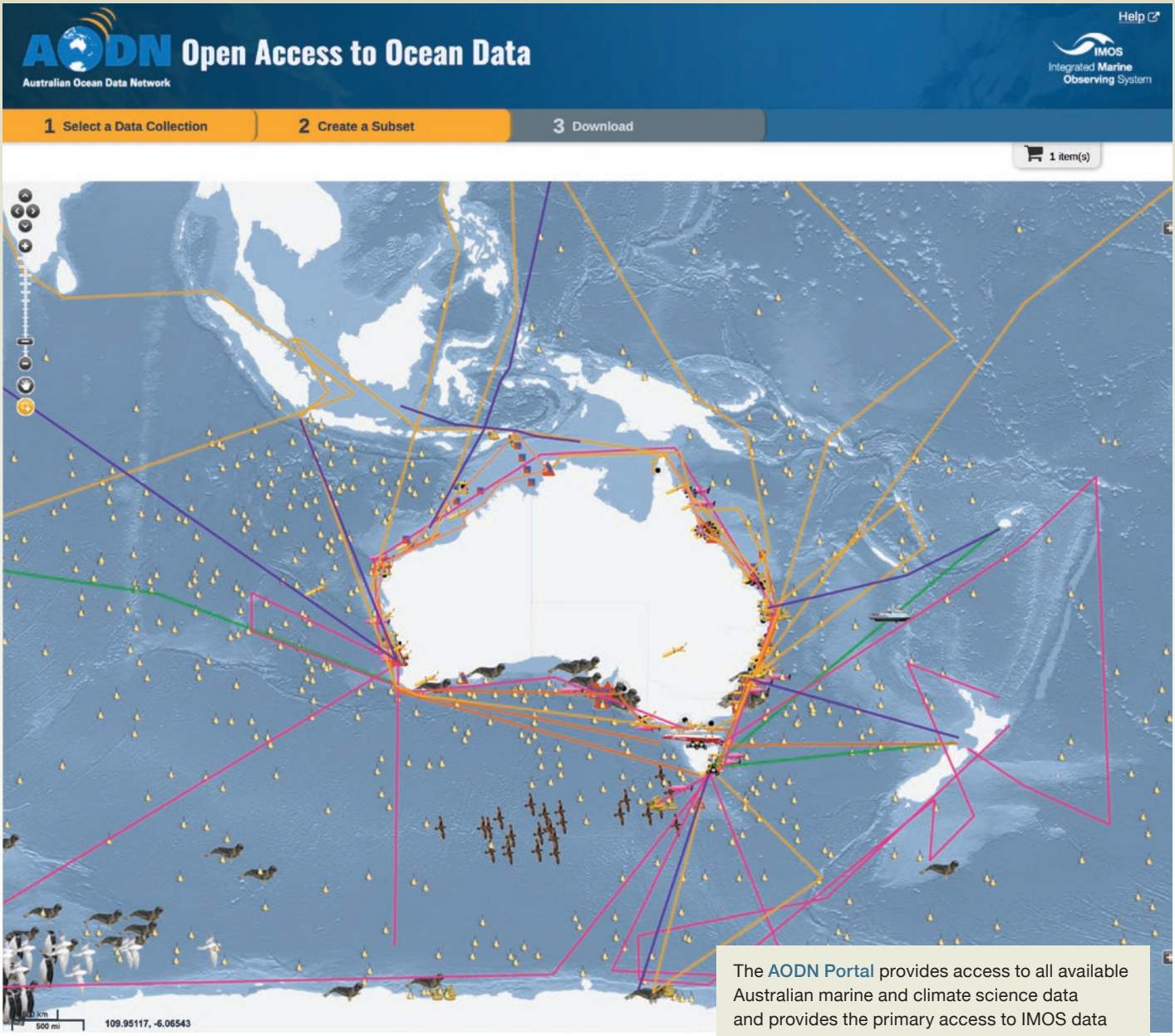
Physical habitat characteristics (e.g. rugosity; Friedman et al. 2012) can be estimated directly from the seafloor reconstruction, and the mosaic can be paired with in-situ coral identification to model the interaction between habitat diversity and fish assemblage structure. These habitat variables can then be used to characterise the areas of the reef where fish were observed, allowing for a more directed way of observing habitat preferences in fish.

Supporting references:

Curley, B.G., Kingsford, M.J. and Gillander, B.M. 2002. Spatial and habitat-related patterns of temporal reef fish assemblages: Implications for the design of Marine Protected Areas. Marine and Freshwater Research, 58(3):1197-1210.

Ferrari, R., Bryson, M., Bridge, T., Hustache, J., Williams, S.B., Byrne, M. and Figueira, W. 2016. Quantifying the response of structural complexity andcommunity composition to environmental change in marine communities. Global Change Biology, 22(5):1965–1975.

Friedman, A., Pizarro, O., Williams, S.B. and Johnson-Robertson, M. 2012. Multi-scale measures of rugosity, slope and aspect from benthic stereo image reconstructions. Plos ONE, 7(12).



The AODN Portal provides access to all available Australian marine and climate science data and provides the primary access to IMOS data including access to the IMOS metadata.

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IMOS

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