RV *Investigator* Voyage Summary

Voyage #:	**IN2017_T01**		
Voyage title:	Natural iron fertilisation of oceans around Australia: linking terrestrial dust and bushfires to marine biogeochemistry		
Mobilisation:	N/A		
Depart:	Sydney, 2000 Sunday, 24 September 2017		
Return:	Broome, 1300 Sunday, 08 October 2017		
Demobilisation:	N/A		
Voyage Manager:	Hugh Barker	**Contact details:**	Hugh.barker@csiro.au
Chief Scientist:	Andrew Bowie		
Affiliation:	UTAS	**Contact details:**	andrew.bowie@utas.edu.au
Principal Investigator:	Katherine Walters		
Project name:	Exploring different science communication strategies for engaging the public in marine science		
Affiliation:	Griffith University	**Contact details:**	katie.walters@griffithuni.edu.au
Principal Investigator:	Ryan Beemer		
Project name:	Interdisciplinary characterisation of the macro-mechanical behaviour of offshore sediments from Northern Australia		
Affiliation:	UWA	**Contact details:**	ryan.beemer@uwa.edu.au
Principal Investigator:	Vicki Stavropoulos & Ben Arthur		
Project name:	CSIRO Educator on Board		
Affiliation:	CSIRO	**Contact details:**	vicki.stavropoulos@csiro.au
Principal Investigator:	David Steinberg		
Project name:	Macumba Wreck		
Affiliation:	Department of Tourism and Culture, Northern Territory	**Contact details:**	david.steinberg@nt.gov.au
Principal Investigator:	Eric Woehler		
Project name:	Spatial and Temporal Variability in the Distribution and Abundance of Seabirds		
Affiliation:	BirdLife Australia UTAS	Contact details:	Eric.Woehler@utas.edu.au

The Chief Scientist

Associate Professor Andrew Bowie is a Chemical Oceanographer. His research investigates the biogeochemistry of trace elements in the ocean, with projects addressing key research questions related to atmospheric dust deposition and solubilities, ocean iron fertilisation, physico-chemical speciation of trace elements and their isotopes, and the role of ocean dynamics on chemical and biological marine processes. His research outcomes are focused on assessment of trace element control of ocean productivity, ocean carbon sequestration and expanding our knowledge of marine geochemical processes. His research is supported by the Antarctic Climate and Ecosystems CRC (ACE CRC), the Australian Research Council (ARC), and several national and international collaborative grants. Andrew has provided leadership of international chemical oceanography research expeditions, is a co-chair of the Scientific Steering Committee of the 'GEOTRACES' program (an international study of the global marine biogeochemical cycles of trace elements and their isotopes).

Scientific objectives

Natural iron fertilisation of the oceans around Australia: linking terrestrial dust and bushfires to marine biogeochemistry

Oceans play a vital role in Earth's climate through the control of atmospheric CO2. An important component of this system is the iron cycle, in which iron-rich aerosols are transported from land via atmosphere to ocean. Iron is a key micronutrient for marine phytoplankton, the scarcity of which controls essential biogeochemical processes. This project will facilitate an integrated ship-based atmospheric observational program for trace elements in oceans around Australia. During the voyages, we will sample and conduct experiments on atmospheric particles containing terrestrial dust, bushfire smoke and anthropogenic emissions that are transported from Australia to its surrounding oceans. This will provide the critical information on atmospheric iron supply for ocean fertility and health, providing the science for predicting a key factor in the future impact of the oceans on climate. The project supports the training and research of two postgraduate PhD students from IMAS-UTAS.

Voyage objectives

Transit Objective

The main objective of this transit voyage is to move the vessel from Sydney to Broome prior to IN2017_V05. The objectives listed below are complementary with the transit.

1. Natural iron fertilisation of the oceans around Australia: linking terrestrial dust and bushfires to marine biogeochemistry – Chief Scientist, Dr Andrew Bowie

We will install an atmospheric sampling system for the clean collection of particles in the ship's aerosol lab. This system consists of vacuum pumps (Thomas Sheboygan 2107CD18), flow meters (DiTGM ML-2500) and filtration systems (Savillex PFA). The manifold is connected to air intake lines fed from the sampling nozzle located ~10 m above sea level on the foremast at the bow of the vessel. Samples will be collected on filters housed in 47 mm filtration holders located within a laminar flow hood (AirClean Systems) to avoid contamination. The system is controlled by automated sector control switch (pump controller) to ensure the system only samples 'clean' air from the forward sector (nominally between 270o port and 90o starboard), avoiding air impacted by the ship's exhaust. The system is capable of running up to 4 flow lines in parallel, to enable replicate sampling or to sample for different parameters using different filters on different lines. A newer more sophisticated version of this aerosol sampling system (including PM1, PM2.5, and TSP size selective inlets) is being developed at CSIRO and should be ready for installation on RV Investigator in the latter part of 2017.

Samples will be collected on a range of different filter types (polycarbonate, Whatman-41, cellulose, Teflon) suitable for different analytical needs. Filters will be changed approximately daily, depending on the aerosol loading, flow rates and amount of time the air inlet is in a suitable 'clean' air sector and sampling takes place. The sector sampling switch records the date/times and waypoints when the wind is 'in sector'. A range of procedural and field exposure blanks will be collected at sea, as well as preliminary leaching and dissolution experiments. Sampled filters will be stored frozen and returned to the shore-based laboratory for further experiments and analyses.

We will also opportunistically collect event-based clean rainwater samples using either a polyethylene funnel and collection bottle (when conditions allow), to quantify the trace metal deposition in the 'bulk' and 'precipitate-only' fractions. Ideally samples would be collected on upper and forward decks, either above the bridge or at the bow when heading into the wind.

The project also requests access to the RV Investigator trace metal clean underway supply system (preferably the outlet in the clean wet lab which has been designed for clean filtration and sampling in the laminar flow hood). This will enable us to correlate the atmospheric flux of trace elements with the surface in-water concentrations. Surface seawater will also be used for leaching and dissolution experiments on the collected atmospheric particles.

Our sampled aerosols will include terrestrial dust, processed soils, particles generated through biomass burning and industrial processes, and marine aerosols. Analyses and lab-based experiments will provide observations on 'bulk' measurements of micronutrient trace elements (including iron), their solubility in fresh and saline waters (Buck et al., 2006; Mackie et al., 2006; Baker and Jickells, 2006), their processing during long-range transport and cycling (Sedwick et al., 2008), and their bioavailability to marine phytoplankton. Isotopic tracers (radon-222, $\delta\delta$56Fe) and back-trajectories will be used to differentiate the source, fetch and air type.

Results

All voyage objectives were completed satisfactorily for the Primary Project and five piggyback projects.

The transit trip IN2017_T01 traversed from Sydney (departed 2000 Sunday, 24 September 2017) to Broome (arrived 1300 Sunday, 08 October 2017). The primary scientific objective of the transit voyage was to undertake studies of natural iron fertilisation of the oceans. A suite of aerosol samples was collected for the analysis of trace elements in atmospheric particles. In addition, rain water was sampled during selected precipitation events. The voyage allowed an UTAS-IMAS PhD student to continue research on her project, and she deployed methodologies and equipment to study the atmospheric deposition of trace elements at sea. This work contributed to a wider integrated ship-and land-based atmospheric observational program for trace elements in oceans around Australia.

Voyage Narrative

The relatively short transit voyage was enjoyed by all on-board, with good sailing conditions. Overall the voyage was highly successful, meeting stated objectives safely, with good interactions between the diverse project teams.

Summary

Satisfactory completion of all voyage objectives. RV *Investigator* is an excellent platform for science.

2. Principle Investigator, Katie Walters

Objectives and brief narrative of voyage

Modified after discussion with Chief Investigator (on board): To investigate the nature of exchange between marine scientists and the public, and discern strategic points for intervention for increasing the mutual beneficial nature of this exchange.

Transit voyage IN2017_T01 provided ideal circumstances for the collection of data from the on-board scientists, as their scientific duties were not overwhelming them and they had the space and time to share their thoughts and insights.

Scientific objectives

The objective of this voyage was the collection of information from marine scientists in Australia relating to how they view their role in society, what makes a good marine scientist, what makes for “good” and “bad” science communication, what they believe the public thinks of them and their work, and what they think the public don’t know about marine science/scientists, that they *should* know.

Voyage objectives

Modified after discussion with Chief Investigator (on board): To conduct interviews with marine scientists on board RV Investigator regarding their role in society, and the perceptions of the public.

Results

Semi-structured interviews were conducted with a range of scientists, scientific staff, and science facilitators, both from MNF and from the scientists on board. Interviews ranged from 30-60 minutes long and covered topics including the scientists' initial attraction to science, the qualities which make a good scientist, their belief of the public perception of their work, their own perceptions of good and bad science communication strategies, and priorities for public education about marine science.

Voyage Narrative

The initial days of the voyage were spent learning about the ship, the facilities of the ship, the roles of scientific personnel and understanding the responsibilities their roles might entail. Subsequent voyage time was spent interviewing scientists, encoding their responses, and building an initial understanding of where the scientific personnel aboard IN2017_T01 "fit" in the greater pool of marine science and scientists interviewed as part of a broader PhD study. Additional activities included participation in the mechanical collection of data for Beemer (collection of sediment using box corers), an important experience of marine science as practiced.

Summary

This experience was invaluable for providing access to Australian marine scientists working in a quite unique set of circumstances, who displayed a range of responses to the questions of interest to this researcher (see above). This data has been de-identified according to ethics requirements, and will be analysed as part of a broader study of marine scientists in Australia and made available as published research.

An additional outcome was the discernment of the group of scientists at work on diverse projects in unique circumstances on IN2017-T01 as displaying collaborative investigation and mutual exchange which fostered creativity and innovation. This scientific culture may prove a model in new, challenging global conditions which require urgent attention and innovation (such as those posed by climate change). This topic is likely to be explored in articles resulting from the collection of the above data.

3. Principle Investigator – Ryan Beemer

Objectives and brief narrative of voyage

The aims of the calcareous sediment collection from offshore North Australia is to: 1) Study the impact of calcareous sediment taxonomy on the soils behaviour, this could help engineers understand the unusual mechanical properties of these sediments 2) Characterise the mechanical behaviour of offshore sediments from Northern Australia for public consumption by research engineers and scientist so the data can be used to study submarine landslides and foundations for offshore energy infrastructure

Data curation:

- Sediment samples will be made available by the Centre for Offshore Foundation Systems at the University of Western Australia through its webpage. The webpage will be updated after initial

categorising and segregation of samples for completion of the scientific objectives of this voyage.

- All data collected from on-shore laboratory testing of the sediments will be publicly curated on The University of Western Australia Research Repository: http://www.library.uwa.edu.au/repository

Scientific objectives

The behaviour of offshore sediments under load is very important to understand from an engineering prospective. It will dictate whether a submarine slope will fail and result in a tsunami. It will also determine the size of anchors needed to secure a renewable energy infrastructure. In spite of this importance very little public data on the mechanical properties of offshore Northern Australian soil is available to researchers. This project aims to collect and study the geotechnical behaviour of offshore soils in Northern Australia and make it available to the public. It will provide valuable data for researchers trying to understand and predict submarine landslides and for engineers researching anchoring systems for renewable energy systems.

We propose collecting three box cores, with the Octopus box corer (Currently on board), at three different locations along the transit route. Our goal is to collect samples with high quantities of benthic or planktonic foraminifera with the specific goal of understand how the variation in the soils bio geology impacts their mechanical properties. This should be easily achieved across the majority of Northern and North West Australia.

Our plan is to sample at one site North of Tiwi Islands/ Bathurst Island and one site in the Browse Basin (possible two sites if time prevails).

Voyage objectives

Box Core Samples Collected						
Location	**Latitude**	**Longitude**	**Water Depth**	**Time**	**Date**	**Samples**
			(m)	**(UTC)**	**(UTC)**	**(#)**
Tiwi Island	-11.11	130.70	32.4	1635	05/10/17	2
Browse Basin 1	-13.33	124.41	137.3	0330	06/12/17	3
Browse Basin 2	-13.60	123.04	373.7	1330	06/10/17	4
Browse Basin 3	-14.22	122.46	361.4	1730	06/10/17	6

4. Principle Investigator, Dr Ben Arthur

The Educator on Board program has a number of national benefits. These include; updating the STEM content knowledge of participating teachers with contemporary research, facilitating the demonstration of real-world STEM in Australian classrooms, an experience to draw on to inspire and inform students about career options in the marine sector, and the delivery of STEM education resources that are available to all Australian teachers.

This opportunity provided a unique professional development program to two Australian STEM teachers who are currently producing curriculum resources based on the voyage research (sea bird distributions, and the link between physical and biological scales in the ocean, respectively), which will be shared with all Australian teachers.

5. Principle Investigator – Dr David Steinberg

The *Macumba*, was a 2,500-ton merchant ship sunk in Northern Territory waters in a Japanese air attack on the 6 August 1943. There were three casualties. Despite early detection soon after its sinking, the wreck site had not successfully been located since WWII.

The Macumba is considered a significant historic shipwreck. It is a monument to our wartime past, and is the grave of one crew member (two others dying of their injuries after rescue). The site has considerable archaeological research potential, and has likely evolved into a rich marine habitat.

A search area was developed based on historic information and past searches. The voyage consisted of a methodical search of the sea floor using remote sensing tools. Once detected the team switched to site recording using remote sensing tools and a drop camera.

As a result of this voyage, we have finally located one of the most significant wartime wrecks of the Northern Territory. It ends a five year search for this significant historic shipwreck. With its discovery we can turn to mapping, research, conservation and site management. The voyage also resulted in the first recording of the site, providing invaluable information about the nature of the wreck, its layout, level of integrity and also crucial site environment information such as depth.

6. Principle Investigator – Dr Eric Woehler

Scientific objectives

The project seeks to quantify the distribution and abundance of seabirds at sea around Australia using standardised seabird survey protocols. One or two dedicated observers will collect real-time data on seabirds observed within 300m transect during daylight hours while the vessel is underway. Incidental observations will be collected while the vessel is stationary (e.g. CTD stations) or while the vessel is deploying/recovering moorings. The data collected will be compatible with previous seabird at sea surveys conducted around Australia and farther south, allowing for analyses and assessments to be extended by the current surveys. The distribution of seabirds at sea is strongly linked with oceanographic features such as convergences that concentrate prey at densities that allow for efficient foraging by seabirds. Our surveys on the voyage will link with oceanographic investigations to identify the types and strengths of oceanographic features at which we observe different species of seabirds that utilise different methods of feeding (surface seizing, diving etc.). No dedicated ship time is required for the seabird surveys. Surveys are conducted by observers while the vessel is underway during daylight hours.

Results

- Extensive new spatial records for Flesh-footed Shearwaters from the Arafura Sea and northeast Timor Sea, some 15° farther north than previously recorded, with other species' distributions also extended,

- More than 30 records of predatory fish – seabird feeding interactions, not previously published for these species in Australia, with a manuscript and data analyses started during voyage, and
- Probable sightings of two pods of Australian Snubfin Dolphins.

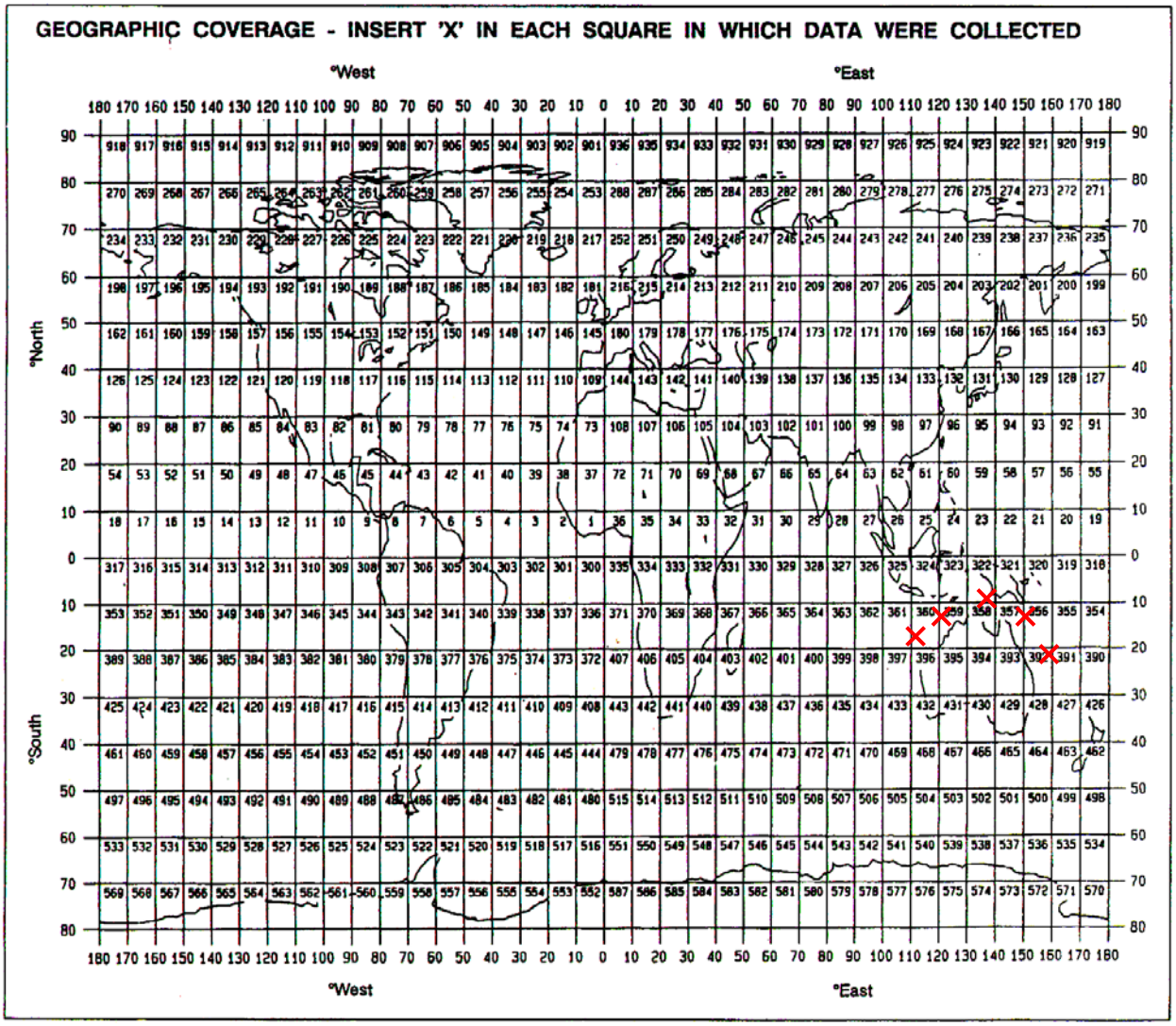
Voyage Narrative

The project was significantly assisted by Dr Ben Arthur and Ms Frances Cooke, both of whom made substantial contributions to the observations and real-time data analyses for the predatory fish interactions manuscript; their assistance, contributions and involvement are acknowledged with sincere thanks.

Summary

Dr Eric Woehler undertook seabird observations while the vessel was underway from approximately 15 minutes before sunrise to sunset each day throughout the cruise. More than 6000 seabirds of 20 species were recorded. In addition, observations of four species of marine mammals were also recorded.

Marsden Squares



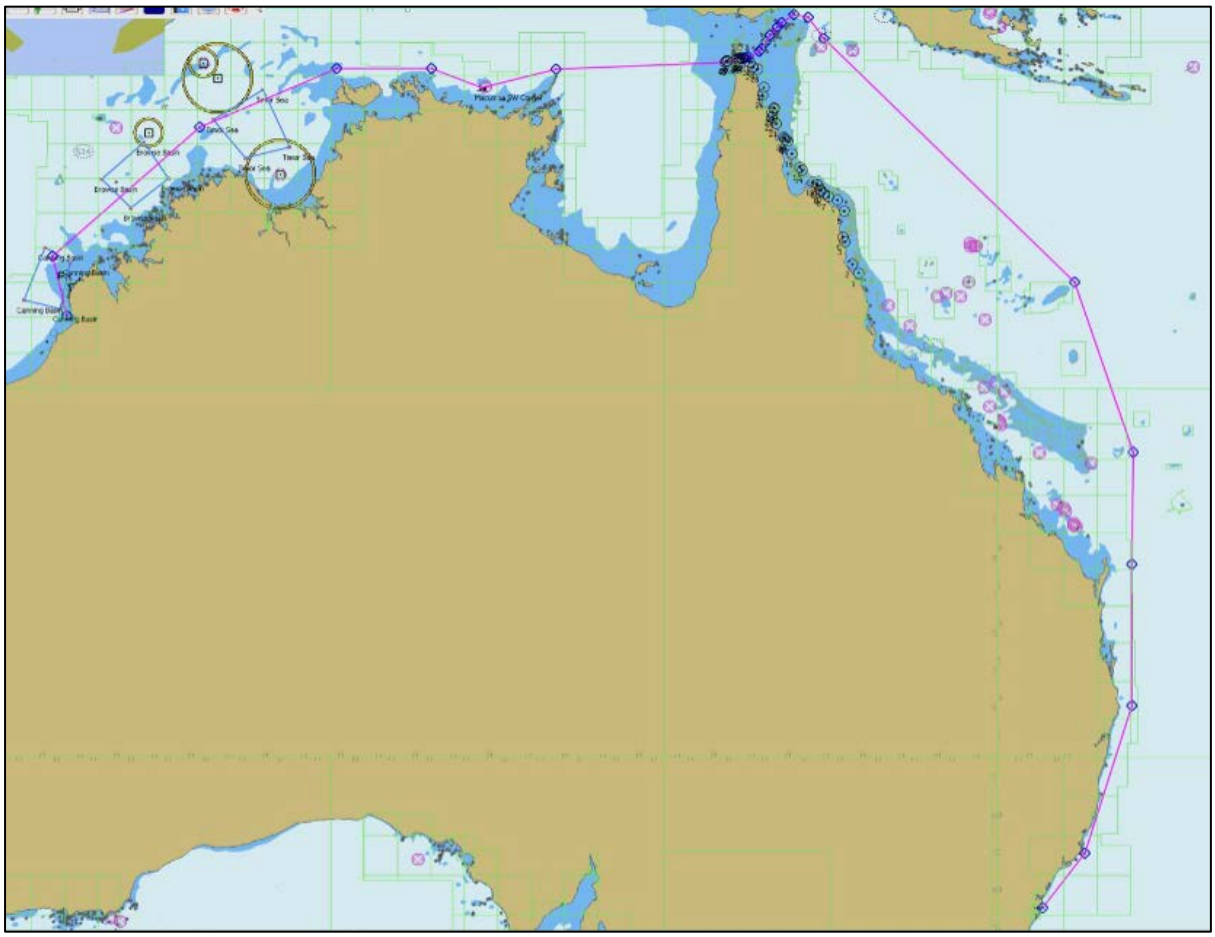
Summary of Measurements and Samples taken

Item No.	PI	NO	UNITS	DATA TYPE	DESCRIPTION
1.	Beemer	15	Cores	G04	Samples were collected with the 240W x 240L x 550H box core sampler. Sampling occurred at: 1. (-11.11, 130.70) in 32.4 m of water depth 2. (-13.33, 124.41) in 137.3 m of water depth 3. (-13.60, 123.04) in 373.7 m of water depth 4. (-14.22, 122.46) in 361.4 m of water depth On shore analysis of the samples will performed at the Centre for Offshore Foundations Systems, Geotechnical Testing Laboratory at the University of Western Australia. A full geotechnical analysis of the mechanical properties (carbonate content, density, friction angle, compressibility…) of the samples are planned on the sample including a geological identification of microfacies in the samples.
2.	Bowie	14	Sample filters	M71	Aerosol trace elements and nutrients
3.	Bowie	17	Seawater	H30	Underway trace metal seawater samples
4.	Bowie	3	Rainwater	M71	Precipitation events

Curation Report

Item #	DESCRIPTION
1.	Archived at UWA
2.	Archived by IMAS-UTAS, GEOTRACES GDAC
3.	Archived by IMAS-UTAS, GEOTRACES GDAC
4.	Archived by IMAS-UTAS, GEOTRACES GDAC

Track Chart



Personnel List

	Name	Role	Organisation
1.	Hugh Barker	Voyage Manager	CSIRO MNF
2.	Aaron Tyndall	SIT Support	CSIRO MNF
3.	Will Ponsonby	SIT Support	CSIRO MNF
4.	Stuart Edwards	GSM Support	CSIRO MNF
5.	Amy Nau	GSM Support	CSIRO MNF
6.	Frances Cooke	GSM Support	CSIRO MNF
7.	Steve Van Graas	DAP Support	CSIRO MNF
8.	Pamela Brodie	DAP Support	CSIRO MNF
9.	Cassie Schwanger	Hydrochemistry Support	CSIRO MNF
10.	Linda Gaskell	MNF Research Assistant	CSIRO MNF
11.	Morgane Perron	Research Support	UTAS
12.	Eric Woehler	Principle Investigator	UTAS
13.	Katie Walters	Principle Investigator	Griffith University
14.	Ben Arthur	Education and Outreach	CSIRO MNF
15.	Jesse Hawley	Communications	CSIRO
16.	Christian Halverson	Teacher	Department of Education – New South Wales
17.	Chantelle Cook	Teacher	Department of Education – Western Australia

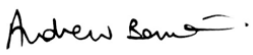
Marine Crew

Name	Role
John Highton	Master
Gurmukh Nagra	1st Mate
Brendan Eakin	2nd Mate
Thomas Watson	3rd Mate
Christopher Minness	Chief Engineer
Samuel Benson	1st Engineer
Michael Sinclair	2nd Engineer
Damien Wright	3rd Engineer
John Curran	Electrician/ Engineer
Graham McDougall	CIR
James Hogg	IR 1
Paul Langford	IR 2
Roderick Langham	IR 3
Dennis Bassi	IR 4
Peter Taylor	IR 5
Daniel Morse	IR 6
Gary Hall	Chief Caterer
Adrian Hughes	Chief Cook
Andrew Goss	2nd Cook
Emma Lade	2nd Caterer
Lachlan Poole	TIR

Acknowledgements

We are grateful to the MNF and ASP for ship access prior to the mobilisation day, and for excellent support at sea. We thank the directors of the MNF, ACE CRC and IMAS for support of the primary scientific activity, which was funded by the Australian Research Council.

Signature

Your name	A/Prof Andrew Bowie
Title	Chief Scientist
Signature	
Date:	27 October 2017

List of additional figures and documents

Attach any numbered and titled figures here. Delete section if not applicable.

Appendix A CSR/ROSCOP Parameter CodeS

Appendix B Photographs. Please refer to four blogs entries during the voyage at: https://blog.csiro.au/investigator/

Appendix A - CSR/ROSCOP Parameter CodeS

	METEOROLOGY
M01	Upper air observations
M02	Incident radiation
M05	Occasional standard measurements
M06	Routine standard measurements
M71	Atmospheric chemistry
M90	Other meteorological measurements

	PHYSICAL OCEANOGRAPHY
H71	Surface measurements underway (T,S)
H13	Bathythermograph
H09	Water bottle stations
H10	CTD stations
H11	Subsurface measurements underway (T,S)
H72	Thermistor chain
H16	Transparency (eg transmissometer)
H17	Optics (eg underwater light levels)
H73	Geochemical tracers (eg freons)
D01	Current meters
D71	Current profiler (eg ADCP)
D03	Currents measured from ship drift
D04	GEK
D05	Surface drifters/drifting buoys

	MARINE BIOLOGY/FISHERIES
B01	Primary productivity
B02	Phytoplankton pigments (eg chlorophyll, fluorescence)
B71	Particulate organic matter (inc POC, PON)
B06	Dissolved organic matter (inc DOC)
B72	Biochemical measurements (eg lipids, amino acids)
B73	Sediment traps
B08	Phytoplankton
B09	Zooplankton
B03	Seston
B10	Neuston
B11	Nekton
B13	Eggs & larvae
B07	Pelagic bacteria/micro-organisms
B16	Benthic bacteria/micro-organisms
B17	Phytobenthos
B18	Zoobenthos
B25	Birds
B26	Mammals & reptiles
B14	Pelagic fish
B19	Demersal fish
B20	Molluscs
B21	Crustaceans

D06	Neutrally buoyant floats
D09	Sea level (incl. Bottom pressure & inverted echosounder)
D72	Instrumented wave measurements
D90	Other physical oceanographic measurements

	CHEMICAL OCEANOGRAPHY
H21	Oxygen
H74	Carbon dioxide
H33	Other dissolved gases
H22	Phosphate
H23	Total - P
H24	Nitrate
H25	Nitrite
H75	Total - N
H76	Ammonia
H26	Silicate
H27	Alkalinity
H28	PH
H30	Trace elements
H31	Radioactivity
H32	Isotopes
H90	Other chemical oceanographic measurements

B28	Acoustic reflection on marine organisms
B37	Taggings
B64	Gear research
B65	Exploratory fishing
B90	Other biological/fisheries measurements

	MARINE GEOLOGY/GEOPHYSICS
G01	Dredge
G02	Grab
G03	Core - rock
G04	Core - soft bottom
G08	Bottom photography
G71	In-situ seafloor measurement/sampling
G72	Geophysical measurements made at depth
G73	Single-beam echosounding
G74	Multi-beam echosounding
G24	Long/short range side scan sonar
G75	Single channel seismic reflection
G76	Multichannel seismic reflection
G26	Seismic refraction
G27	Gravity measurements
G28	Magnetic measurements
G90	Other geological/geophysical measurements

	MARINE CONTAMINANTS/POLLUTION
P01	Suspended matter
P02	Trace metals
P03	Petroleum residues
P04	Chlorinated hydrocarbons
P05	Other dissolved substances
P12	Bottom deposits
P13	Contaminants in organisms
P90	Other contaminant measurements