RV *Investigator* Voyage Summary

Voyage #:	**IN2017_C01**		
Voyage title:	GAB deep water geological and benthic ecology program		
Mobilisation:	Hobart, Monday, 10 April 2017		
Depart:	Hobart, 0900 Tuesday, 11 April 2017		
Return:	Hobart, 0800 Friday, 28 April 2017		
Demobilisation:	Hobart, Friday, 28 April 2017		
Voyage Manager:	Tegan Sime	Contact details:	(insert details)
Chief Scientist:	Dr Asrar Talukder		
Affiliation:	CSIRO Energy	Contact details:	Asrar.talukder@csiro.au
Principal Investigators:	Alan Williams, Charlotte Stalvies, Andrew Ross		
Project name:	Great Australian Bight Deepwater Marine Program		
Affiliation:	CSIRO	Contact details:	Andrew.ross@csiro.au

Scientific objectives

The Great Australian Bight (GAB) represents a unique cold water carbonate margin with a large sedimentary depositional sequence. Whilst recent voyages have begun to reveal the nature and complexity of both the deep water geology and biology the basin, especially along the continental and abyssal slopes, significant knowledge gaps remain

The Ceduna sub-basin is the product of rifting followed by the subsequent Southern Ocean seafloor spreading between Australia and Antarctica. The rifting created a narrow seaway between Australia and Antarctica, which was initially filled by two large deltaic super sequences (represented by the Tiger and Hammerhead super sequences respectively). Decreased sediment supply followed this period, during which commencement of fast seafloor spreading led to the initiation of widespread igneous activity and the development of a large number of volcanoes across the basin. Subsequent low sedimentation rates combined with continued subsidence have created the current modern deep water Ceduna sub-basin geomorphology. Key knowledge gaps in the understanding of the fundamental geology of the Ceduna sub-basin include:

1. Sedimentary facies and paleo environment

The deltaic sedimentary super sequences of the Great Australian Bight were deposited at high latitudes at critical periods within the Cretaceous hothouse period. They thus record information about paleo-environmental conditions which can be used to inform our understanding of global paleo-environmental records. Rock dredging during prior voyages in the GAB (IN2015_C01, SS01/2007) successfully recovered samples from both the Tiger and Hammerhead super sequences, however, large gaps remain in our understanding about the formation of these sedimentary sequences and the paleo-environment of deposition. Spatially precise sampling of outcropping rocks from these intervals, from the abyssal slope and within canyons, will permit the paleo-environments of deposition to be characterised, and placed in context with global paleo-environmental records.

Whilst the Great Australian Bight has been regarded as a passive continental margin environment with low sedimentation rates, data from recent voyages and historical 3D seismic surveys reveal a complex seafloor shaped by active sedimentary processes that have occurred throughout the Tertiary sedimentary sequence and recent geological history. These processes include mass transport deposits (turbidite and debrite flows) on the continental slope. We aim to improve understanding of the nature of these processes and the timing of their occurrence; this is important in determining the dynamic factors influencing the geomorphology and ecology of the deep water margin of southern Australia.

2. Identification and sampling of potential seeps

Many of areas of potential seepage (hydrocarbon and other fluids) visited during the IN2015_C01 voyage in the GAB were determined not to be areas of seepage, however a large number of potential sites of seepage remain to be characterised. Further study of these areas will be used to describe subsurface fluid processes and chemical and biological coupling between the geosphere, seafloor and overlying hydrosphere in the GAB.

3. Basin and benthic biodiversity and distribution

The GAB is a region of high endemism and whilst the majority of seabed terrains across the deep continental slope are thought to be predominantly calcareous oozes, the geological targets described above represent areas of hard substrates with localised current regimes or chemosynthetic energy source in the case of seeps. The objective of this aspect of the study is to describe the composition, abundance and distributions of benthic fauna in these areas to define aspects of diversity community structure, endemism and functional ecology.

Voyage objectives

The voyage objectives are built around three main scientific objectives:

1. The benthic characterisation and sampling outcropping sedimentary rocks to aid understanding of modern seabed erosional mechanisms, sedimentary processes and paleoenvironmental reconstruction.
2. Benthic characterisation and sampling in areas of potential seepage to determine if fluid escape is occurring and the nature of the fluids and their relationship to the benthic fauna in these areas.
3. Sampling of benthic fauna over a large geographic area to establish deep water community structure and function and augment understandings gained from recent IN2015_C01 and IN2015_C02 voyages.

Benthic characterisation of outcrop rocks and sampling of benthic fauna carry higher weight than that of the seep characterisation. The voyage plan includes more planned operations in each target area than can be achieved within the time allocations for the survey. Each of these target areas are ranked based on their importance in delivering on the scientific objectives.

The survey will use a hierarchical design comprising seafloor mapping prior to seafloor sampling and limited water column characterisation.

Seafloor mapping and water column characterisation

1. Hull mounted acoustic characterisation of the water column and seafloor over the target areas of interest. This activity will comprise the use of MBES, water column acoustic backscatter, single beam echo sounder, sub-bottom profiler and ADCP to determine processes occurring in the water column and map the seafloor and shallow subsurface geology.
2. Seafloor characterisation from the surface will be complemented with a limited number of tow camera to obtain video transects across the target area seafloor and overlying near bottom waters.

Seafloor and water column sampling

A number of sampling operations will be undertaken to describe the seafloor geology and benthic biota. Each sampling operation will differ dependant on sampling target, primarily based on substrate composition. For the soft substrate targets there will be a focus on grab samples whilst for the harder substrate types the focus will be on dredging. Sampling will be by:

1. Deployment of grab sampler to sample the surface sediment infauna, microbiology, hydrocarbon chemistry and physical properties.
2. Use of a beam trawl or Sherman sled to collect samples of benthic macro fauna over target areas.

3. Use of rock dredges to collects lithified sediments for description and detailed chemical analysis.
4. Limited collections of water column profile data including CTD, chemical sensor readings and associated water samples

Piggy-back projects

Title: Bio Argo float deployment in the Great Australian Bight

Principle Investigator: Dr Nick Hardman-Mountford

Scientific and voyage objectives

Our objective is to deploy two (2) Bio-Argo profiling floats and two (2) Argo floats to provide autonomous measurements of bio-optical and biogeochemical properties of the GAB for improving satellite remote sensing estimates of productivity and characterising the biogeochemistry of the region.

CSIRO will provide the four (4) floats, two (2) of these floats will be equipped with CTD and bio-optical sensors to measure a range of parameters: T, S, dissolved oxygen, chl fluorescence, backscattering (4 wavelengths), nitrate, upwelling radiance and down welling irradiance (4 wavelengths). Floats will be deployed at stations within Australian waters along the ship's route of transit (estimate stations OR21 and OR11). Deployment of the floats can be undertaken from the A-frame off the rear deck or by two people using a rope and manhandling the float over the stern. Once deployed, the floats will descend to depth and start their pre-programmed cycle of profiling and data collection, with data transmitted via Iridium satellites.

During each Bio-Argo float deployment a CTD profile and water samples to 1000m are also required to characterise the water at time of deployment for salts, pigment, nutrient and dissolved oxygen concentrations. Additional sensors to be included on the CTD include chlorophyll fluorometer, backscattering meter, beam transmissometer, dissolved oxygen sensor and deep SUNA/ISIS nitrate sensor. We will provide the backscattering meter as this is not available through the MNF equipment pool. Water samples will be analysed on board where possible or filtered and chemically fixed otherwise (e.g. pigments) according to standard operating procedures. We anticipate each deployment station taking 3 hours.

Time implications are limited to the time required to deploy the Argo floats and an associated CTD deployment. Deployments will take place within the area of operations with limited or no deviation from the planned route.

Results

- **The benthic characterisation and sampling outcropping sedimentary rocks**

Achieved: Approximately 1.28 tons of materials (sedimentary rocks) collected from the four targeted sites. Before each of the sampling operations, additional swath mapping was undertaken to permit precise targeting of the sampling locations. Samples were collected from previously un-sampled geological sequences, which will help complete the sequence stratigraphic framework that describes the formation of the basin from Late Cretaceous to Palaeocene.

- **Benthic characterisation and sampling in areas of potential seepage**

Achieved: During the voyage several areas of potential seepage were characterised acoustically. Several interesting water column and seafloor features were identified, which warranted further investigation with chemical sensors and the collection of water and sediment samples. Data processing and sample analysis is ongoing to ascertain the nature of these features.

- **Sampling of benthic fauna over a large geographic area**

Achieved: A total of over 200 taxa of benthic megafauna (invertebrates and fishes) were collected from 10 successful beam trawls in depths from 2750 to 5030 m. This represents the deepest systematic collection of benthic fauna in Australian waters. These data complement previous deep-sea collections taken from RV Investigator in 2015, mostly in 200-3000 m depths. In addition, seabed video imagery was collected along 3 transects over two volcanic seamounts in the Great Australian Bight Commonwealth Marine Reserve. Again, these data complement those taken in 2015 from a range of seabed habitat types including other seamounts. Collectively, the faunal collections and image data will enable the first characterisation of benthic fauna over the full depth range of the deep-sea within the Australian jurisdiction (~200-5000 m).

Voyage Narrative

The voyage targeted six sites of investigation over the 18 day voyage period within the Great Australian Bight from 129-136° East. During this period which included the transits to and from Hobart, 5,058 km was travelled with 8,950 km^2 of seafloor and water column mapped using multibeam sonar. During the voyage swath mapping revealed the seabed morphology and character of several submarine canyons that cross cut the continental and abyssal slopes. The collection of this data will enhance our understanding of the sedimentation, erosion and transport mechanisms occurring in the deep water Great Australian Bight.

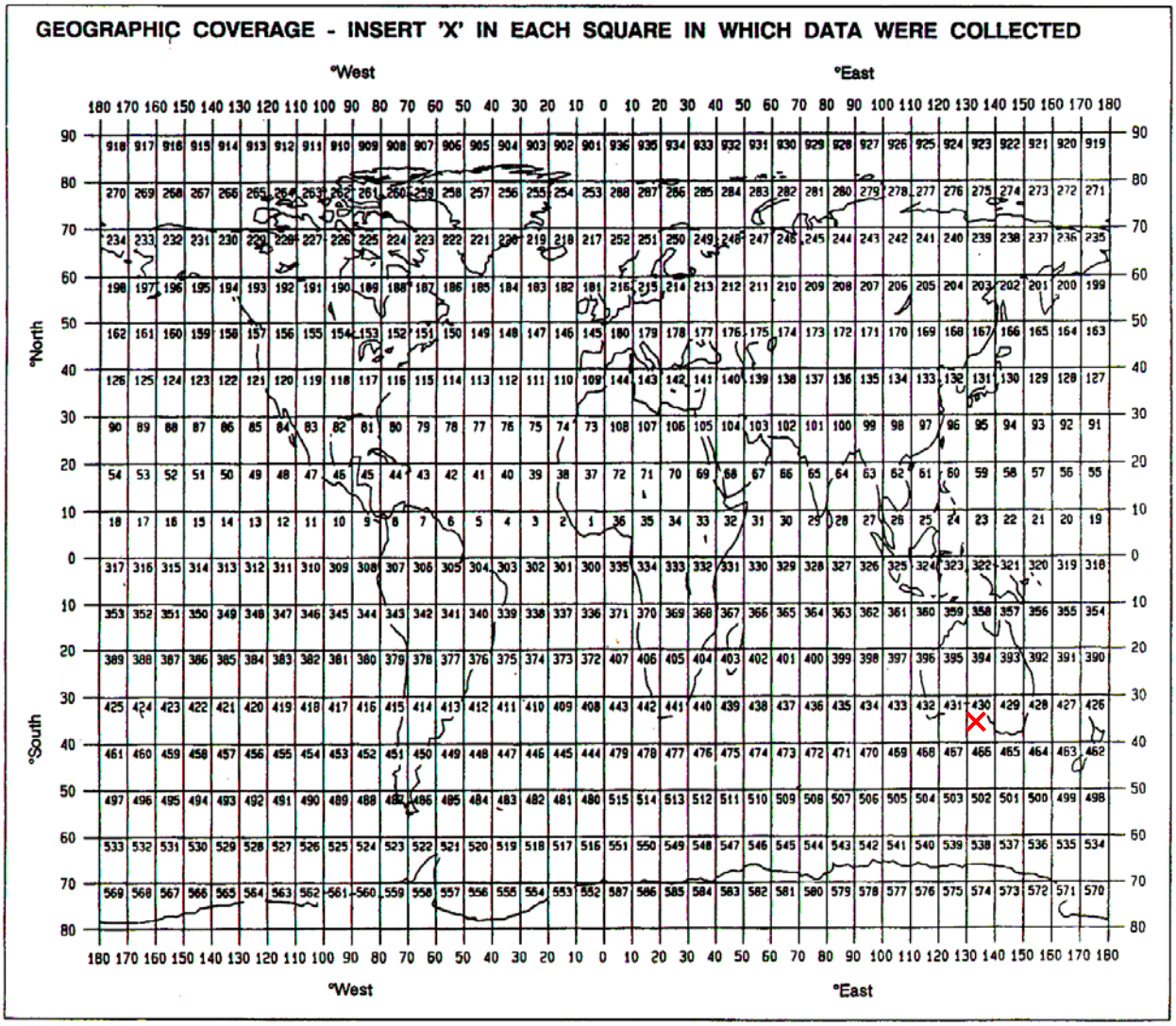
In order to collect samples during the voyage, several different types of instrumentation were deployed from the RV Investigator. These equipment included water column profiling instrumentation (Augmented CTD system with additional acoustic and chemical sensors) and seafloor sampling instruments (beam trawls, rock dredges, grab and towed camera). The equipment deployments were undertaken in water depths ranging from 135 m to 5560 m, including the deepest beam trawl deployment for biological sampling ever undertaken either in Australia or worldwide at the water depth of 5080 m.

The large scientific crew complement from three research organisations from across Australia (Australian Museum, Museum Victoria, and the University of Western Australia) was able to process, describe and archive samples on board. Approximately 1.28 tons of rocks and sediments were recovered and 34 kg of biological materials comprising 3238 specimens from 208 taxonomic units were also collected. The weather conditions were optimal during the whole voyage and the planned work program was carried out in full.

Summary

The IN2017_C01 voyage was the fourth and final voyage of the CSIRO's Great Australian Bight Deepwater Marine Program. The main objective of this voyage was to augment our understanding of the ultra-deep water of the Great Australian Bight. This voyage collected data and samples are essential to provide a more holistic understanding of the deep water geology and ecology of the region and complement other samples and data collected throughout the rest of the program. The data and samples collected during the voyage comprise again a large addition to the scientific understanding of the geological processes that have shaped this deep water environment and the benthic habitat and communities that currently reside there. The voyage was highly successful with all the voyage objectives met. Whilst data and samples continue to be processed and analysed, outcomes from this voyage will become a large publically accessible data set, leading to new insights into the region and scientific publications in high impact journals.

Marsden Squares



Moorings, bottom mounted gear and drifting systems

Four Argo Floats were deployed at differing longitudes across the survey area.

Item No	PI See page above	APPROXIMATE POSITION						DATA TYPE	DESCRIPTION
		LATITUDE			LONGITUDE				
		deg	min	N/S	deg	min	E/W		
1	NH-M	-40	17.199262	S	139	30.124529	E	H10, H11, D06	Deployed on 12/04/2017 at 11:37:07 PM.
2	NH-M	-39	12.097778	S	137	30.547520	E	H10, H11, D06	Deployed on 13/04/2017 at 9:06:41 AM
3	NH-M	-35	35.729658	S	131	44.936265	E	H10, H11, D06	Deployed on 17/04/2017 at 10:13:17 AM
4	NH-M	-34	27.089476	S	129	53.335318	E	H10, H11, D06	Deployed on 22/04/2017 at 12:47:45 PM

Summary of Measurements and samples taken

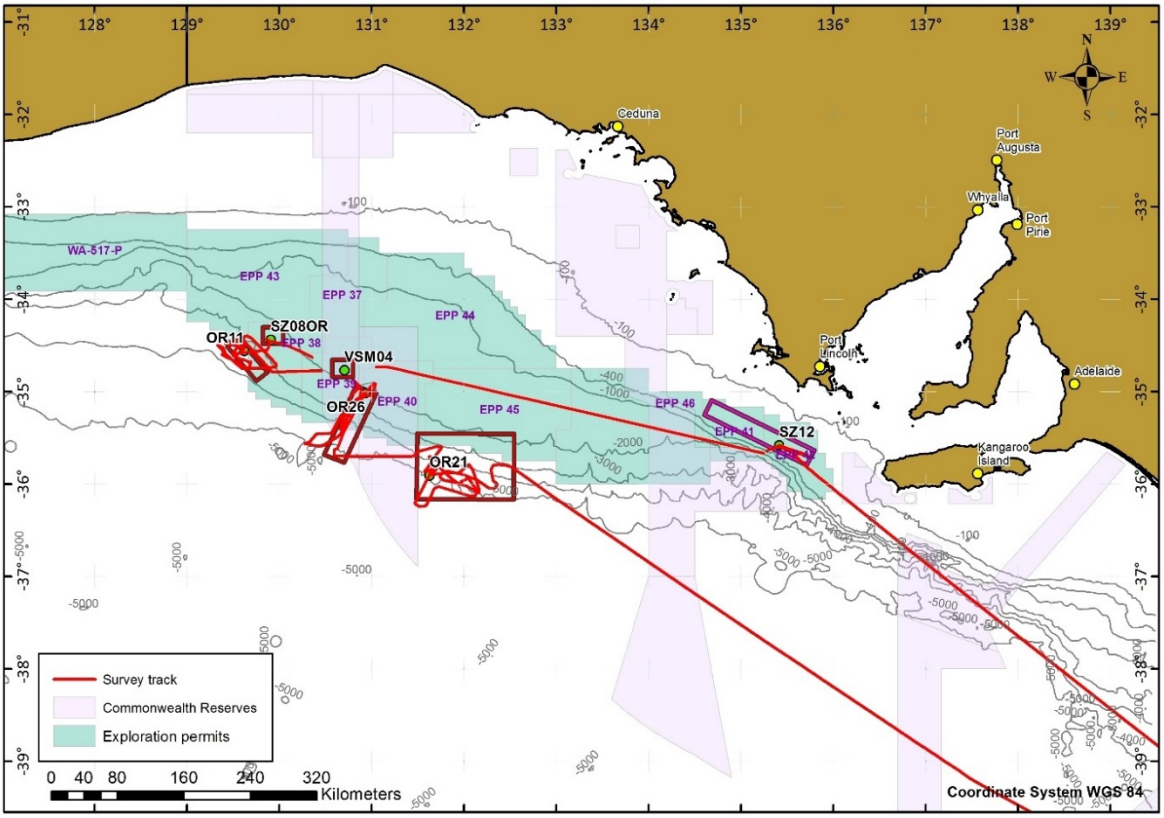
CAST_ID	CAST_TYPE	ROCK WEIGHT (KG)	CORE RECOVERY (M)	FISH (G)	INVERTEBRATES (G)	DESCRIPTION
BEAMT_175	Beam Trawl	17.26		438	710	Collection of geology and biological specimens from towed gear.
BEAMT_178	Beam Trawl	11.106		9764	1510	Collection of geology and biological specimens from towed gear
BEAMT_179	Beam Trawl	4.756		5810	1230	Collection of geology and biological specimens from towed gear
BEAMT_182	Beam Trawl	64.372		37	1856	Collection of geology and biological specimens from towed gear
BEAMT_188	Beam Trawl			37	1856	Collection of biological specimens from towed gear
BEAMT_189	Beam Trawl				548	Collection of biological specimens from towed gear
BEAMT_192	Beam Trawl	0.795			418	Collection of geology and biological specimens from towed gear
BEAMT_197	Beam Trawl	0.216		331	2991	Collection of geology and biological specimens from towed gear
BEAMT_198	Beam Trawl	28.55		370	1348	Collection of geology and biological specimens from towed gear
BEAMT_207	Beam Trawl	0.02			1730	Collection of geology and biological specimens from towed gear
BEAMT_208	Beam Trawl	0.049			0	Collection of geology and biological specimens from towed gear
CTD_180	CTD					Vertical profile data. Analysis planned = Chlorophyll: HDM: Isotopes: Metals: Nutrients: PAHs, Biomarkers for 18 samples
CTD_200	CTD					Vertical profile data. Analysis planned = Chlorophyll: HDM: Isotopes: Metals: Nutrients: PAHs, Biomarkers s for 18 samples
CTD_210	CTD					Vertical profile data. Analysis planned = Chlorophyll: HDM: Isotopes: Metals: Nutrients: PAHs, Biomarkers for 12 samples
CTD_211	CTD					Vertical profile data. Analysis planned = BTEX / Volatile Organics: Metals: Nutrients: PAHs, Biomarkers for 15 samples
CTD_213	CTD					Vertical profile data. Analysis planned = BTEX / Volatile Organics: Metals: Nutrients: PAHs, Biomarkers for 15 samples
CTD_215	CTD					Vertical profile data. Analysis planned = BTEX / Volatile Organics: Metals: Nutrients: PAHs, Biomarkers for 15 samples
DRDGE_173	Dredge	6.279				Collection of Geological specimens from towed gear
DRDGE_174	DRDGE	147.504				Collection of Geological specimens from towed gear
DRDGE_176	DRDGE	42.38				Collection of Geological specimens from towed gear
DRDGE_177	DRDGE	1.416				Collection of Geological specimens from towed gear
DRDGE_183	DRDGE	85.62			5	Collection of Geological and Biology specimens from towed gear
DRDGE_184	DRDGE	25.361				Collection of Geological specimens from towed gear
DRDGE_186	DRDGE	18.31			1	Collection of Geological and Biology specimens from towed gear
DRDGE_187	DRDGE	3.37			1	Collection of Geological and Biology specimens from towed gear
DRDGE_193	DRDGE	60.99			9	Collection of Geological and Biology specimens from towed gear
DRDGE_195	DRDGE	381.53			8	Collection of Geological and Biology specimens from towed gear
DRDGE_196	DRDGE	406.15				Collection of Geological specimens from towed gear

CAST_ID	CAST_TYPE	ROCK WEIGHT (KG)	CORE RECOVERY (M)	FISH (G)	INVERTEBRATES (G)	DESCRIPTION
DRDGE_199	DRDGE	72.12			11	Collection of Geological and Biology specimens from towed gear
SMG_212	Grab				31	Collection of Geological and Biology specimens from lowered gear
SMG_214	Grab				11	Collection of Geological and Biology specimens from lowered gear
SMG_216	Grab				23	Collection of Geological and Biology specimens from lowered gear
TCAM_204	TCAM					Collection of video from towed gear
TCAM_206	TCAM					Collection of geological specimens from towed gear. Analysis planned = HDM: Foraminifera for 3 samples
TCAM_209	TCAM					Collection of video from towed gear

Curation Report

Item #	DESCRIPTION
1.	All raw voyage data will be stored by the MNF with a duplicate copy retained by the CS for further analysis and interpretation.
2.	Analytical data collected during the course of the survey will be stored by CSIRO until post survey data processing is complete, after which the data will be made available to AODN and the National Geological Data repository.
3.	Biological taxonomic samples: All samples were preserved in Ethanol or Formalin and stored at ambient conditions, depending on taxa samples will be publically accessible through the various organisations responsible for their curation (CSIRO, South Australian Museum, Museum of Victoria, Australian Museum).
4.	Biological microbial samples: All samples will be preserved at -80^{o}C before destructive testing.
5.	Sediment samples: All samples to be initially stored at CSIRO in order to undertake subsampling for more detailed analysis. After which the samples stored, at ambient conditions, cold store or freezer at the Geoscience Australia publically accessible government geological sample repository.

Track Chart


Survey track
Commonwealth Reserves
Exploration permits
0 40 80 160 240 320
Kilometers
Coordinate System WGS 84
Ceduna
Port Augusta
Whyalla
Port Pirie
Port Lincoln
Adelaide
Kangaroo Island
WA-517-P
EPP 43
EPP 37
EPP 44
EPP 38
EPP 39
EPP 40
EPP 45
EPP 46
EPP 41
SZ08OR
OR11
VSM04
OR26
OR21
SZ12

Personnel List

	Name	Organisation	Role
1.	Tegan Sime	CSIRO MNF	Voyage Manager
2.	Ben Baldwinson	CSIRO MNF	SIT Support
3.	Will Ponsonby	CSIRO MNF	SIT Support
4.	Bernadette Heaney	CSIRO MNF	GSM Support
5.	Frances Cooke	CSIRO MNF	GSM Support
6.	Karl Malakoff	CSIRO MNF	DAP Support
7.	Peter Shanks	CSIRO MNF	DAP Support
8.	Cassie Schwanger	CSIRO MNF	Hydrochemistry Support
9.	Asrar Talukder	CSIRO Energy	Chief Scientist
10.	Alan Williams	CSIRO O&A	Shift lead
11.	Christine Trefry	CSIRO Energy	Data manager
12.	Charlotte Stalvies	CSIRO Energy	Geology sampling lead
13.	Emanuelle Frery	CSIRO Energy	Geology sampling
14.	Richard Kempton	CSIRO Energy	Geology sampling
15.	Lionel Esteban	CSIRO Energy	Geology sampling
16.	Louise Russell Cargill	Volunteer student	Geology sampling
17.	Thomas Tam	CSIRO Energy - student	Geology – Sub-bottom profiler/sampling
18.	Mark Green	CSIRO O&A	Logistics (bio + geo)
19.	Candice Untied	CSIRO O&A- student	Biology sample lead + data
20.	Maylene Loo	Contractor	Biology sample lead + data
21.	Karen Gowlett-Holmes	CSIRO O&A	Taxonomy + photography
22.	Emily Armstrong	CSIRO O&A- student	Tissues
23.	Kate Naughton	Museum Victoria	Microbiology
24.	Ken Graham	Aus Museum (AMRI)	Taxonomy - fish
25.	David Staples	Museum Victoria	Taxonomy - invertebrates
26.	Lisa Goudie	Contractor	Taxonomy - invertebrates
27.	Kelly Merrin	Museum Victoria	Taxonomy - invertebrates
28.	Francesco Criscione	Aust Museum (AMRI)	Taxonomy - invertebrates
29.	Anna Murray	Aust Museum (AMRI)	Taxonomy - invertebrates
30.	Nick Mortimer	CSIRO O&A	Electronics (sensors and Argo float deployment)
31.	Scott Foster	CSIRO Data61	Biology sampling

Marine Crew

Name	Role
Gurmukh Nagra	Master
Brendan Eakin	Chief Mate
Andrew Roebuck	Second Mate
James Hokin	Third Mate
Chris Minness	Chief Engineer
Mark Ellicott	First Engineer
Michael Sinclair	Second Engineer
Damian Wright	Third Engineer
John Curran	Electrical Engineer
Gary Hall	Chief Caterer
Kyra Lade	Caterer
Keith Shepherd	Chief Cook
Adrian Hughes	Cook
Graham McDougall	Chief Integrated Rating
Paul Langford	Integrated Rating
James Hogg	Integrated Rating
Dennis Bassi	Integrated Rating
Daniel Morse	Integrated Rating
Mathew Schmierer	Integrated Rating
Roderick Langham	Integrated Rating

Signature

Your name	Asrar Talukder
Title	Chief Scientist
Signature	Asrar Talukder
Date:	12 June 2017

Additional figures and documents

Appendix A CSR/ROSCOP Parameter CodeS

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