RV *Investigator* Voyage Plan

Voyage #:	**IN2020_V06**
Version Number:	Final – 2.17
Voyage title:	Probing the Australian-Pacific Plate Boundary: Macquarie Ridge in 3-D
Mobilisation:	Hobart, Saturday 3 – Monday 5 October 2020
Depart:	Hobart, AM on Friday 9 October 2020
Return:	Hobart, 0800 Sunday 1 November 2020
Demobilisation:	Hobart, Sunday 1 November 2020
Voyage Manager:	Megan Hartog
Chief Scientist:	Prof Millard (Mike) Coffin
Affiliation:	IMAS/University of Tasmania
Principal Investigators:	Prof Hrvoje Tkalčić[1], Dr Caroline Eakin[1], Prof Nick Rawlinson[2], Prof Joann Stock[3]
Project name:	Same as voyage title
Affiliation:	[1]RSES/Australian National University
Affiliation:	[2]University of Cambridge
Affiliation:	[3]California Institute of Technology

Scientific objectives

The primary objectives of the voyage are to acquire passive seismological data that will enable us to:

1. Characterise the 3-D structure of the oceanic crust and sub-crustal lithosphere along the Macquarie Ridge Complex (MRC) with novel lithospheric seismic imaging. This includes teleseismic receiver function analysis, teleseismic and ambient noise tomography, joint inversion of receiver functions and ambient noise dispersion, shear wave splitting analysis, autocorrelation analysis, and enhancing of regional and teleseismic wavefield through array seismology.
2. Describe the structural, thermal, and compositional nature of the central MRC by applying a range of seismic imaging techniques to identify velocity anomalies in the crust and mantle. This is possible because 2-D or 3-D images of velocity anomalies in the crust and mantle may be interpreted as structural, thermal, or compositional variations.

These seismological objectives will be addressed by PIs Tkalčić, Eakin, and Rawlinson following instrument and data recovery scheduled by the MNF in 2021.

To achieve the above objectives, we will deploy ocean bottom seismometers (OBSs) around Macquarie Island, to be recovered in 2021.

The primary marine geophysical objectives of the voyage are to:

1. Define sites for OBS deployments in the vicinity of Macquarie Island using multibeam sonar and sub-bottom profiling data. Pending scheduled testing later this year, deployment parameters are tentatively in water depths ≥1000 m and on gentle seafloor slopes, ideally flat, but not to exceed 30°. Sediment cover is preferred over bare igneous rock for OBS deployment. Existing data around Macquarie Island are not of sufficient quality to define deployment sites.
2. Characterise the neotectonics, structure, and stratigraphy of the active Australian-Pacific plate boundary in the vicinity of Macquarie Island using multibeam sonar (both bathymetry and backscatter), sub-bottom profiling, gravity, and magnetics data. These data will also provide critical baseline information for benthic habitat mapping.

PIs Coffin and Stock will lead efforts to address these marine geophysical objectives.

Voyage objectives (Coffin, Tkalčić, Eakins, Rawlinson, Stock)

We will undertake multibeam sonar and sub-bottom profile data acquisition and interpretation in Macquarie Island region to identify suitable sites for deployment of OBSs and deploy 29 OBSs (17 AGOS and 12 CAS).

Lost time will be dealt with through reducing the size of the deployment survey areas and/or aborting one or more OBS deployments.

This project entails both marine geophysical data acquisition and deployment of ocean bottom seismometers. In more detail, below we describe the methods to be utilised at sea.

Multibeam bathymetry/backscatter: we will acquire multibeam/backscatter data in both the study area and during the transits. Anticipated water depths range from ~50 m to >6000 m, so the primary system will be the EM122, complemented by the EM710 in water depths less than ~1000 m. Track orientation in the study area will be along the strike of the Macquarie Ridge Complex, parallel to its axis, so as to maximise data acquisition efficiency and coverage. At an average speed of 10 kts, over the 9.6 days of acquisition in the study area, we will ensonify the seafloor along ~2,300 nautical miles of track. Near-real-time multibeam data will be utilised to create maps to identify optimal locations for OBS deployments, for which flat seafloor or shallow seafloor slopes are required, and to identify the active fault(s) marking the boundary between the Australian and Pacific tectonic plates. High-resolution multibeam bathymetry/backscatter data have not been acquired previously in the study area. Available bathymetry is either low-resolution side-scan sonar/bathymetry (Massell et al., 2000) or extremely low-resolution bathymetry calculated from satellite altimeter data (Smith & Sandwell, 1997), insufficient for OBS deployment site selection or for identification of active plate boundary faults.

Sub-bottom profiling: we will acquire SBP120 data continuously during the 9.6 days of multibeam/backscatter data acquisition along ~2,300 nautical miles of track. These near-real-time data will contribute to identifying the best locations for OBS deployments (e.g., presence of shallow sediment) and active faults (e.g., offsets/deformation of shallow sediment). Sub-bottom profiling data have not been acquired previously from the study area.

Single-beam and multi-beam water column echo-sounding: the EK60 and ME70 systems will be run throughout the entire voyage. The near-real-time data will reveal any acoustic plumes emanating from the seafloor; we will avoid deploying any OBSs in their vicinity, as they could be manifestations of active volcanism. No water column echo-sounding data have been acquired in the study area.

Passive seismology recording: The ship's crew and OBS technicians will deploy 29 OBSs around Macquarie Island for a time interval of ~12 months. The pool of 17 three-component ocean bottom seismometers, a multi-million-dollar investment of AuScope, are available with 12 months of recording capacity (at a recording rate of 100 samples per second). Their acquisition was part of the Australian Geophysical Observing System (AGOS), a government initiative funded through the Education Investment Fund. The 12 Chinese Academy of Sciences (CAS) OBSs also have 12 months of recording capacity. The AGOS and CAS OBSs can be safely installed to maximum depths of 6000 and 5000 m, respectively; slopes steeper than 30° must be avoided. Actual field implementation will depend on water depth, seafloor slope, and seafloor nature at each potential deployment location.

- **Array configuration:** We will use a spiral configuration in the southern section of the experiment and an X-shaped configuration in the northern part of the array (see Voyage Track figures). Smaller subsets of elements with favourable shape and element spacing can be designed to improve the observational capacity in a particular frequency range.
- **Earth imaging using passive seismology data:** Continuous waveform data in a digital format will be recorded over a time interval of approximately one year. During that time, typically about fifty moderate– to large–size earthquakes occur at different locations of the world. The elastic waves generated at earthquake loci propagate through the Earth's interior to the region of study and the ground motion gets recorded in form of the time series called seismograms. A class of study we propose here will enable us to use these recordings to gain a better understanding of the Earth beneath the region of study.

Gravity: gravity data will be acquired by the shipboard gravity meter during the entire voyage. Limited shipboard gravity data have been acquired in the study area; these data will help constrain the crustal and upper mantle structural objectives of the project.

Magnetics: magnetics data will be acquired by the towed magnetometer during all transits and all multibeam/sub-bottom profiling lines. Limited shipboard gravity data have been acquired in the study area; these data will help constrain the crustal and upper mantle structural objectives of the project.

ADCP: Multibeam and EK60/ME70 data take priority and precedence over ADCP data during multibeam/sub-bottom profile data acquisition, when ADCPs should be turned off. Current information is required for OBS deployments, so ADCPs will be turned on for these.

Voyage Objectives (MNF)

Personnel transfer from Macquarie Island

In partnership, the MNF and AAD are arranging for the transfer of two Macquarie Island expeditioners from the island via AAD's Inflatable Rubber Boat (IRB) to the *Investigator* for transport back to Hobart, toward the end of voyage upon the completion of science objectives. Depending on suitable weather windows, this transfer is tentatively scheduled to occur during the final phase of the voyage, upon completion of the mapping and OBS deployments in the NW quadrant. Weather conditions will be monitored and contact maintained with the Macquarie Island Station to identify a suitable weather window in this period.

AAD small vessel operations are restricted to the eastern side of the island. *Investigator* will station off the AAD base on the eastern side of the island at a distance of >500 m from shore (to satisfy biosecurity requirements) where the vessel will be met by the AAD IRB and the transfer will occur.

Operational Risk Management

No potentially high-risk work has been identified outside standard operations.

Media Activities

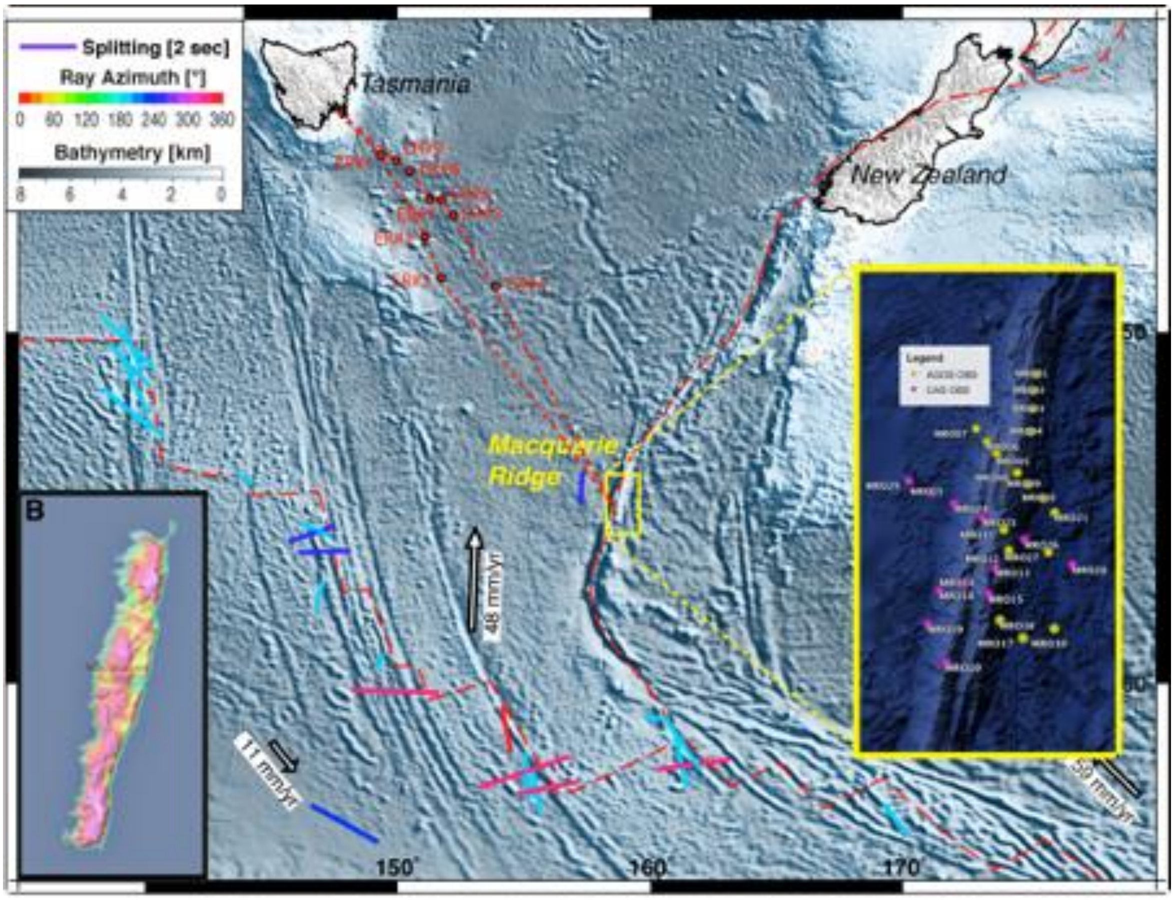
The MNF will seek to pursue opportunities that arise during the voyage to promote the science, scientists and ship, via conventional and social media channels, in consultation and/or collaboration with the relevant ship user.

Organisation	Activities	Timing	Responsible person
MNF	Media engagement for print story describing ship capabilities and current voyage highlights	Opportunistically	TBN
IMAS/UTAS	Chief Scientist undertaking interviews with networks to discuss science being undertaken	Pre-departure	Prof Mike Coffin
RSES/ANU	Principal Investigator undertaking interviews with networks to discuss science being undertaken	Pre-departure	Prof Hrvoje Tkalčić
IMAS/UTAS	A range of stories and blogs to be released	Throughout voyage	Prof Mike Coffin
RSES/ANU	A range of stories and blogs to be released	Throughout voyage	Prof Hrvoje Tkalčić and Dr Caroline Eakin
MNF	Post voyage media engagement on wharf apron with technical support personnel and Voyage Manager	Post Voyage	TBN
IMAS/UTAS	Post voyage media engagement	Post Voyage	Prof Mike Coffin
RSES/ANU	Post voyage media engagement	Post Voyage	Prof Hrvoje Tkalčić

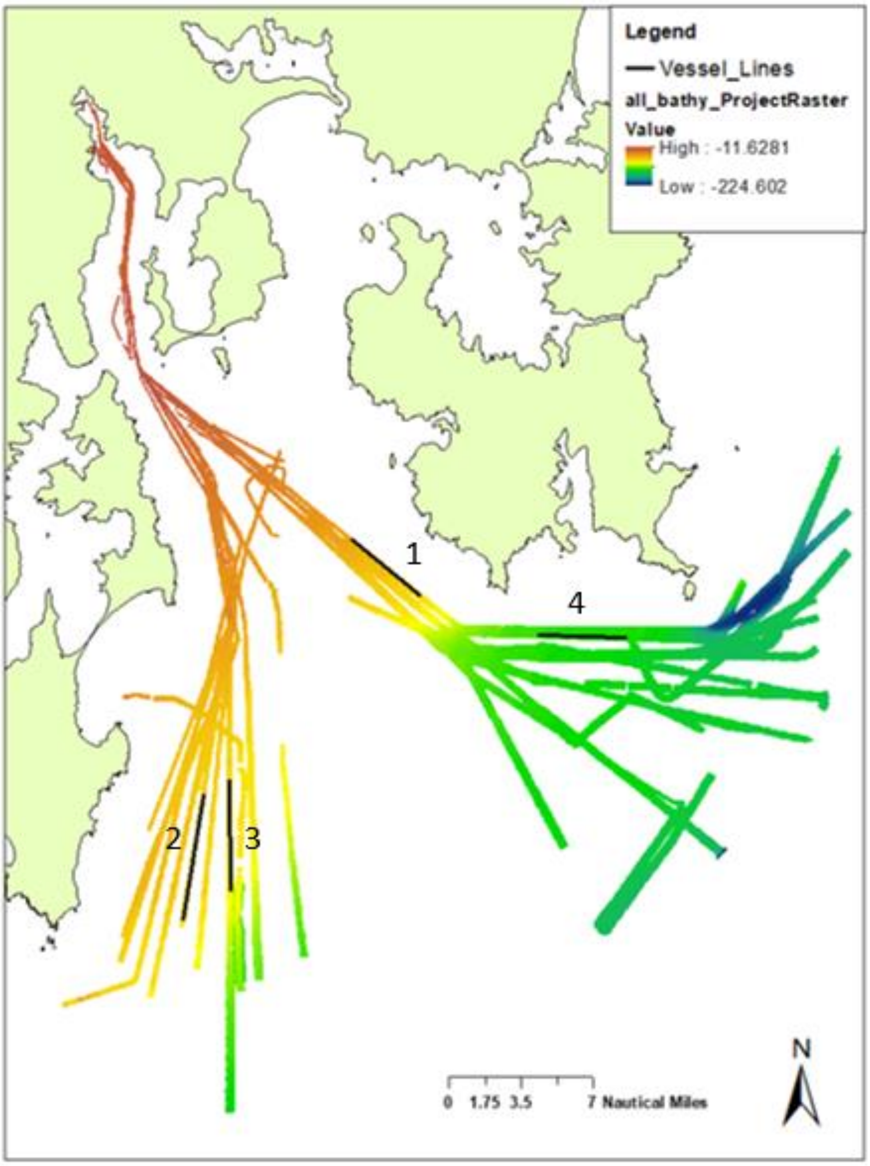
Overall activity plan including details for first 24 hours of voyage

The first 24 hours at sea will be entirely transit from Hobart to the mapping quadrant NE of Macquarie Island, which is a distance of ~815 nm. At 11 kts, the transit will take ~74 hours. During the transit we will test all underway acoustic and other geophysical systems to be used around the main Macquarie Island study area. During this transit, rehearsals will also occur for higher risk operations (i.e. OBS deployment and retrieval) with ASP deck and bridge crew, OBS technicians and MNF support staff in order to establish communication methods and roles.

Voyage track

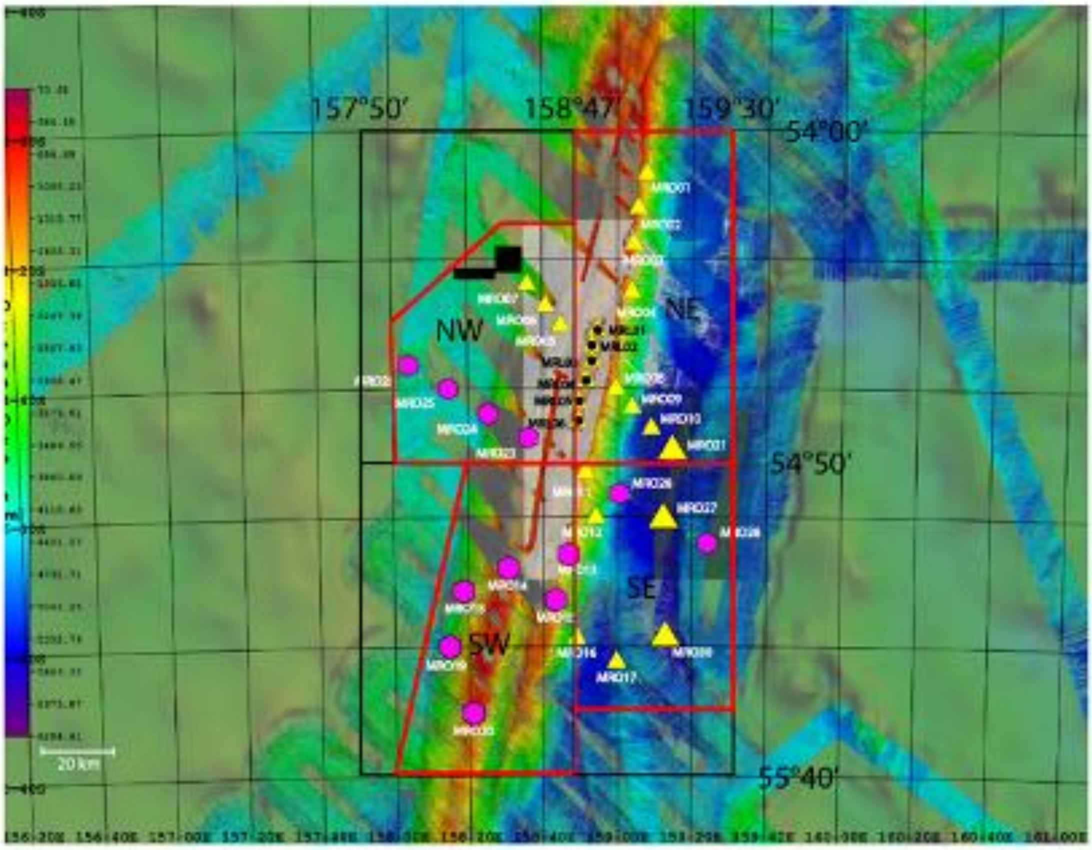


Voyage Track: Tectonic setting of the Macquarie Ridge Complex (MRC) and location of the proposed seafloor mapping, sub-bottom profiling, and seismometer deployment along the central MRC near Macquarie Island. Background bathymetry is from ETOPO1 and plate boundaries are outlined in red. RV *Investigator* ship track is indicated by bold red dashed line, Hobart–Macquarie study area–Hobart. Absolute plate motion vectors (white arrows) are from Argus et al (2011). Shear wave splitting results (coloured bars based on the azimuth between the earthquake and receiver according to the legend) from regional seismicity are overlain (Eakin et al, 2016). The length of the bar is scaled by delay time (a measure of the amount of splitting, or degree of seismic anisotropy). Bars of different colours often produce different splitting results (bar orientation and length) indicating azimuthal dependency and anisotropy that is more complex beneath ridge systems than most other tectonic settings. Inset: Macquarie Island.



Locations of backscatter calibration lines in Storm Bay. Departing Hobart, we will either repeat line 2 or line 3 (highlighted below).

Line	Start		End	
	Latitude	Longitude	Latitude	Longitude
1	-43° 11.935’	147° 37.513’	-43° 14.911	147° 42.601’
2	-43° 24.478’	147° 27.939’	-43° 30.632’	147° 26.618’
3	-43° 23.824’	147° 29.656’	-43° 28.37’	147° 29.713
4	-43° 16.541’	147° 50.1’	-43° 16.629’	147° 56.081



Zoomed-in ETOPO1 image of the MRC, including Macquarie Island, and the proposed area for multibeam/backscatter/sub-bottom profiler data acquisition encompassing the indicative sites for deployment of the ocean bottom seismometers (yellow triangles – AGOS; pink hexagons - CAS). Note an X-shaped sub-array in the northern section and a spiral-shaped sub-array in the southern section. The study area for multibeam/backscatter/sub-bottom profiler data acquisition and OBS deployment is sub-divided into 4 quadrants (NE, SE, SW, and NW) outlined in red. We will start at the NE quadrant and work clockwise, first mapping that quadrant, then deploying the OBS, and moving on to the next quadrant (see Waypoints, stations, and schedule).

Waypoints, stations, and schedule

Activity	OBS Site	Decimal Latitude	Decimal Longitude	Dist (nm)	Total Dist (nm)	GSM Depth (m)	Des-cent time (min)	Transit time (hrs)	Time at Site (hrs)	ETA Complete	Total Time (hrs)
Port Hobart		42°52.2'	147°21.00'							9/10/20 8:00	0.0
Storm Bay		43°19.8'	147°21.54'	28	28			2.51	0.00	9/10/20 10:30	2.5
Extinct Ridge #1		44°52.9'	149°10.11'	122	149			11.05	0.00	9/10/20 21:33	13.6
Extinct Ridge #2		47°15.1'	151°07.90'	164	313			14.93	0.00	10/10/20 12:29	28.5
Extinct Ridge #3		48°24.1'	151°41.08'	73	386			6.60	0.00	10/10/20 19:05	35.1
Transit to NE Quadrant (NW corner)		54°00'	158°47'	430	815			39.05	0.00	12/10/20 10:08	74.1
Mapping NE quadrant (finishing at SE corner)		54°50'	159°30'	743	1559			74.34	0.00	15/10/20 12:28	148.5
Transit to and deploy	MRO01	54°06.0'	159°08.40'	46	1605	-2200	60	4.58	3.75	15/10/20 20:48	156.8

Transit to and deploy	MRO02	54°11.4'	159°06.60'	6	1610	-1900	52	0.55	3.62	16/10/20 0:58	161.0
Transit to and deploy	MRO03	54°17.4'	159°06.00'	6	1616	-2300	63	0.60	3.80	16/10/20 5:22	165.4
Transit to and deploy	MRO04	54°24.6'	159°04.80'	7	1623	-2800	77	0.72	4.03	16/10/20 10:07	170.1
Transit to and deploy	MRO21	54°49.2'	159°15.60'	25	1649	-5200	142	2.54	5.12	16/10/20 17:47	177.8
Transit to and deploy	MRO10	54°45.0'	159°10.20'	5	1654	-5350	146	0.52	5.19	16/10/20 23:29	183.5
Transit to and deploy	MRO09	54°40.8'	159°03.00'	6	1660	-3280	90	0.59	4.24	17/10/20 4:20	188.3
Transit to and deploy	MRO08	54°37.2'	158°57.60'	5	1665	-890	24	0.48	3.16	17/10/20 7:58	192.0
Transit to SE Quadrant (NW corner)		54°50'	158°47'	14	1679			1.29	0.00	17/10/20 9:15	193.3
Mapping SE quadrant (finishing at SE corner)		55°30'	159°30'	584	2264			58.44	0.00	19/10/20 19:42	251.7
Transit to and deploy	MRO11	54°54.0'	158°50.40'	43	2306	-1630	45	4.26	3.49	20/10/20 3:27	259.5
Transit to and deploy	MRO12	55°00.0'	158°52.80'	6	2312	-2900	79	0.62	4.07	20/10/20 8:08	264.1
Transit to and deploy	MRO26	54°57.0'	159°00.60'	5	2318	-4250	71	0.54	3.93	20/10/20 12:36	268.6
Transit to and deploy	MRO27	55°00.6'	159°12.00'	7	2325	-5560	152	0.75	5.28	20/10/20 18:38	274.6
Transit to and deploy	MRO28	55°04.2'	159°23.40'	7	2333	-4650	78	0.75	4.04	20/10/20 23:26	279.4
Transit to and deploy	MRO30	55°21.6'	159°13.80'	18	2351	-5450	149	1.83	5.23	21/10/20 6:29	286.5
Transit to and deploy	MRO17	55°24.0'	158°58.80'	9	2360	-4880	133	0.89	4.97	21/10/20 12:21	292.4
Transit to and deploy	MRO16	55°19.2'	158°48.00'	8	2368	-3980	109	0.78	4.56	21/10/20 17:41	297.7
Transit to SW Quadrant (SE corner)		55°40'	158°47'	21	2389			1.90	0.00	21/10/20 19:35	299.6
Mapping SW quadrant (finishing at NW corner)		54°50'	158°20'	626	3014			62.55	0.00	24/10/20 10:08	362.1
Transit to and deploy	MRO15	55°12.0'	158°42.60'	26	3040	-700	12	2.56	2.94	24/10/20 15:39	367.7
Transit to and deploy	MRO20	55°30.0'	158°22.20'	21	3061	-1000	17	2.15	3.03	24/10/20 20:49	372.8
Transit to and deploy	MRO19	55°19.8'	158°13.80'	11	3072	-3300	55	1.13	3.67	25/10/20 1:37	377.6
Transit to and deploy	MRO18	55°10.8'	158°19.20'	10	3082	-2800	47	0.95	3.53	25/10/20 6:06	382.1
Transit to and deploy	MRO14	55°09.2'	158°30.1'	6	3088	-1350	23	0.65	3.13	25/10/20 9:52	385.9
Transit to and deploy	MRO13	55°04.8'	158°46.20'	10	3099	-1500	25	1.02	3.17	25/10/20 14:03	390.1
Transit to NW Quadrant (SE corner)		54°50'	158°47'	15	3113			1.35	0.00	25/10/20 15:24	391.4
Mapping NW quadrant (finishing at NNW corner)		54°15'	158°30'	489	3602			48.86	0.00	27/10/20 16:16	440.3
Transit to and deploy	MRO23	54°50.7'	158°40.2'	36	3638	-1075	18	3.60	3.05	27/10/20 22:55	446.9

Transit to and deploy	MRO24	54°46.2'	158°26.40'	9	3647	-3300	55	0.90	3.67	28/10/20 3:29	451.5
Transit to and deploy	MRO25	54°42.6'	158°15.00'	8	3655	-4100	68	0.75	3.89	28/10/20 8:07	456.1
Transit to and deploy	MRO29	54°39.0'	158°03.60'	8	3662	-3900	65	0.75	3.83	28/10/20 12:42	460.7
Transit to and deploy	MRO07	54°23.4'	158°37.20'	25	3687	-3300	90	2.51	4.25	28/10/20 19:28	467.5
Transit to and deploy	MRO06	54°27.6'	158°42.60'	5	3692	-1200	33	0.53	3.30	28/10/20 23:17	471.3
Transit to and deploy	MRO05	54°31.2'	158°47.4'	5	3697	-650	18	0.46	3.05	29/10/20 2:47	474.8
Transit MRO05 to Extinct Ridge #4		48°29.9'	153°28.66'	413	4110			37.51	0.00	30/10/20 16:18	512.3
Extinct Ridge #5		46°41.7'	152°10.00'	121	4230			10.97	0.00	31/10/20 3:16	523.3
Extinct Ridge #6		46°07.7'	151°37.87'	41	4271			3.69	0.00	31/10/20 6:58	527.0
Extinct Ridge #7		46°07.8'	151°14.75'	16	4287			1.46	0.00	31/10/20 8:26	528.4
Extinct Ridge #8		45°18.6'	150°24.21'	61	4348			5.52	0.00	31/10/20 13:57	534.0
Extinct Ridge #9		45°03.3'	149°51.92'	27	4375			2.50	0.00	31/10/20 16:26	536.4
Hobart		42°52.2'	147°21.00'	170	4546			15.50	0.00	1/11/20 7:56	551.9

Assumptions:			
Transit speed (kts)			11.0
Transit Speed in OBS study area (kts)			10.0
AGOS OBS descent rate (m/min)			36.6
CAS OBS descent rate (m/min)			60.0
Vessel positioning & OBS winch release (min)			15.0
Stability & system status check once OBS on seafloor (min)			30.0
Triangulation. Range to & circle the OBS site (min)			120

Notes for waypoint & time estimates: OBS descent times based on estimated ETOPO1 water depth and average descent rate of each instrument type (see assumptions above). Time at each OBS site (10^{th} column) includes time to position the vessel and release the OBS (15 mins), plus the estimated descent time, plus stability and status check once OBS hits seafloor (30 mins), plus triangulation to determine the location of the OBS on the seafloor (120 mins). This equates to 165 mins per OBS plus the descent time (dependent on water depth).

The five contingency days designated for this voyage have been incorporated into the science time shown in the table above. As a contingency, such as in the event of poor weather or equipment loss/failure, the size of the mapping area would be reduced and/or deployment/s of the additional 12 CAS OBSs would be aborted as necessary.

Deployment and Retrieval of OBSs

Deployment

Two methods are possible to deploy the OBSs: 1) release from the ship at the sea surface and 2) near-seafloor release after descent via wire or rope. The method used will be based upon prevailing weather and current conditions and onboard assessment of which method provides the greatest position accuracy and minimises deployment time.

The sea surface release method for deploying OBSs uses RV *Investigator*'s stern A-frame, sheave, and a light winch. A Dyneema rope is attached to the existing wire on the winch, run over the sheave, and attached to a quick-release fitting on the lifting point of the OBS. Two tag lines are attached to the OBS and are run around strong points to skilled operators. RV *Investigator* is oriented to allow for the calmest conditions at its stern. The OBS is lifted from the deck and deployed over the stern using the A-frame and lowered into the water, tag lines are released, and the pull cord on the quick release tugged to release the OBS. The OBS will then sink slowly to the seafloor. Checking the ballast and programming the OBS prior to deployment may take up to one hour. Positioning RV *Investigator* for the deployment may also take some time. The reason for using Dyneema rope is to reduce the risk of large heavy fittings (shackles, swivels, etc.) hitting and breaking OBS components.

The near-seafloor release method involves lowering the OBS to within a suitable distance of the seafloor using either the CTD wire (CTD winch) routed through the corer boom or the VS wire routed through either the corer boom or A-frame. An acoustic release and USBL transponder are attached to the wire or rope to enable tracking of the OBS through the water column and release at a depth proximate to the seafloor. This method provides the advantage of greater position accuracy (by minimizing the effects of currents on the landing location of the OBS) and may eliminate the need for triangulation.

Post-deployment Checks and Triangulation

Using the sea surface release method, once the OBS is descending to the seafloor, the acoustic transponder on the OBS is pinged from the ship, and a slant distance to the OBS is received. RV *Investigator*'s 12 kHz acoustic transponder system is anticipated to communicate with the OBS using coded messages. Alternatively, a portable 12 kHz transponder may be deployed in the water to communicate with the OBS. Once on the seafloor, the OBS is integrated for system status. An additional ~30 minutes after the OBS lands on the seafloor is required to ensure stability, centering, and system status. Once the systems are operating correctly, a triangulation procedure is undertaken to locate the OBS on the seafloor. This involves using the range function of the sonar transponder. Starting from the point from where the OBS was deployed, a circle of radius 1.5x water depth is plotted and three points on this circle, spaced 120° apart, are chosen. RV *Investigator* navigates to each of these points, and the RANGE command is used to measure the linear distance from the ship's position to the OBS. Once triangulation has been completed, RV *Investigator* can move to the next deployment location. As indicated above, the near-seafloor release method may eliminate the need for triangulation.

Retrieval

The retrieval process involves transiting to location directly above the OBS on the seafloor and either deploying the portable 12 kHz acoustic transponder or using RV *Investigator*'s 12 kHz acoustic transponder system, and then integrating the OBS. Once communication is established with the OBS, a coded message is sent to the OBS which releases its ballast, and the OBS begins its ascent to the surface. Once on the surface the unit is either observed floating or it is picked up on the vessel's AIS receiver. RV *Investigator* then transits to the OBS. The Dyneema rope, already run over the A-frame sheave, is attached to a retrieval hook with safety gate. A long pole is attached to the retrieval hook and the bridge maneuvers RV *Investigator* alongside the OBS. On the AGOS OBSs, the hook is set into either one of the 50 mm diameter retrieval holes along the main spine of the OBS or a lifting ring on the OBS spine. On the CAS OBSs, the hook is set into a lifting ring on the top of the OBS. The pole is removed from the hook and RV *Investigator* is maneuvered so that the OBS is at the stern of the vessel. The Dyneema rope is retrieved and while the OBS is still in the water, two snap hooks with tag lines are attached to the Dyneema rope. These snap hooks are allowed to slide down the

Dyneema rope until they lay on the OBS. These tag lines are then wound around strong points on the starboard and port sides of the RV *Investigator*. The OBS is then retrieved from the ocean. Tension is applied to these tag lines which reduces the potential swing of the OBS as it comes clear of the ocean. The deployment pallet is then placed on the rear deck under the A-frame, and the OBS is retrieved on deck and placed on the pallet.

A second method is to use a Man Overboard net. In heavy seas, this may be the only way to retrieve a OBS. This method will damage the AIS aerial on the AGOS OBS, but retrieval of the OBS and data is more important.

Time estimates

A general day-by-day summary is provided below.

Date	Time	Activity
Days 1- 4	3 days	Transit from Hobart to survey area (NE quadrant) via Extinct Ridge waypoints 1-3
Days 4 - 20	16 days	Four-phase multibeam sonar/sub-bottom profiler characterisation of and OBS deployment in red polygons (see Voyage Track). To exclude shallow (<50 m) waters surrounding Macquarie Island, Judge & Clerk Islets (6 nm north of Macquarie Island), and Bishop & Clerk Islets (18 nm south of Macquarie Island). Four phases are outlined below.
Days 4-7	3 days	Multibeam sonar/sub-bottom profiler characterisation of NE quadrant
Days 7-8	1.5 days	Deploy OBS in NE quadrant (MRO01, MRO02, MRO03, MRO04, MRO21, MRO10, MRO09, MRO08)
Days 8-11	2.5 days	Multibeam sonar/sub-bottom profiler characterisation of SE quadrant
Days 11-13	1.5 days	Deploy OBS in SE quadrant (MRO11, MRO12, MRO26, MRO27, MRO28, MRO30, MRO17, MRO16)
Days 13-16	2.5 days	Multibeam sonar/sub-bottom profiler characterisation of SW quadrant
Days 16-17	1.5 days	Deploy OBS in SW quadrant (MRO15, MRO20, MRO19, MRO18, MRO14, MRO13)
Days 17-19	2 days	Multibeam sonar/sub-bottom profiler characterisation of NW quadrant
Days 19-20	1.5 days	Deploy OBS in NW quadrant (MRO23, MRO24, MRO25, MRO29, MRO07, MRO06, MRO05)
Days 20-23	3 days	Transit back to Hobart via Extinct Ridge waypoints 4-9

Logistics of this project have been carefully considered. Overall, we will conduct 9-10 days of marine geophysical data acquisition, during which we will identify sites suitable for OBS deployment and delineate active plate boundary faults, in four phases. We have conservatively allocated six days, including transits, in four phases for deployment of the 29 OBSs, each of which takes three to five hours. As trialed during IN2015_E05 and detailed in the SWI, the OBSs will be deployed using the RV *Investigator*'s A-frame and a winch. In summary, the total of 16 days of science in the study area comprises 9-10 days of marine geophysical data acquisition and six days of OBS deployments. Detailed time estimates (hour-by-hour) are provided in the table under “Waypoints, stations, and schedule”.

Permits

Permits granted for this voyage are:

1. Permit numbers: PA2019-00085-1 and variation PA2019-00085-2 | Parks Australia | Department of the Environment and Energy: research and monitoring permit for Macquarie Island Marine Park Sanctuary Zone (IUCN Ia) and Habitat Protection Zone (IUCN IV) [n.b., This permit expires on 31 March 2022.]
2. Reference: 098661 | Tasmanian Parks and Wildlife Service | Department of Primary Industries, Parks, Water, and Environment | Macquarie Island Nature Reserve Access Authority [n.b., This permit expires on 1 November 2020.]

Appendix A

Scientific equipment and facilities provided by the Marine National Facility

Some equipment items on the list may not be available at the time of sailing. Applicants will be notified directly of any changes. Indicate what equipment and facilities you require from the Marine National Facility by placing an **X** in the relevant box.

(i) Standard laboratories and facilities

Name	Essential	Desirable	Notes/Comments
Aerosol Sampling Lab			
Air Chemistry Lab			
Preservation Lab			
Constant Temperature Lab			
Underway Seawater Analysis Laboratory			
GP Wet Lab (Dirty)	X		OBS preparations
GP Wet Lab (Clean)			
GP Dry Lab (Clean)	X		OBS preparations
Sheltered Science Area	X		OBS staging
Observation deck 07 level			
Walk in Freezer			
Blast Freezer			
Ultra-Low Temperature Freezer (-80^{0}C) X2			
Walk in Cool Room			
Salt water ice machine			

(ii) Specialised laboratory and facilities *(may require additional support)*

Name	Essential	Desirable	Notes/Comments
Modular Radiation Laboratory			
Modular Trace Metal Laboratory (TM1-blue)			
Modular Trace Metal Laboratory (TM2-white)			
Trace metal rosette and bottles			
Modular Hazchem Locker			
Deck incubators			
Stabilised Platform Container			
Clothing container	X		• The use of this container will be identified by MNF

(iii) Standard laboratory and sampling equipment

Name	Essential	Desirable	Notes/Comments
CTD - Seabird 911 with 36 Bottle Rosette			
CTD - Seabird 911 with 24 Bottle Rosette			
Lowered ADCP			
Sonardyne USBL System	X		
Milli-Q System			
Laboratory Incubators			
Heavy Duty Electronic Balance (80kg)			
Medium Duty Electronic Balance (15kg/5g resolution)			
Light Duty Electronic Balance (3kg/1g resolution)			
Surface Net (mouth area 1m^2)			
Bongo Net (not instrumented) ring diameter 485mm 0.018m^2			• 500 micron mesh only
Smith Mac grab			
Dissecting Microscopes (x4)			• Please specify number required

(iv) Specialised laboratory and sampling equipment

Name	Essential	Desirable	Notes/Comments *(These items may require additional MNF support staff)*
TRIAXUS – Underway Profiling CTD			
Desired towing profile:			
Additional instrumentation: (Please supply, make and model and datasheets. Also a contact person for discussion on integration.			
Continuous Plankton Recorder (CPR)			
Deep towed camera			
Piston Coring System			
Gravity Coring System			
Multi Corer			
Kasten Corer			
XBT System	X		• 2 per day provided
Trace Metal Rosette and bottles			
Sherman epibenthic sled			
Brenke Sled			
Rapid Cast SVP	X		•
Magnetometer	X		•
Drop Camera			•
Trace- metal in-situ pumps (x6)			• See non-MNF owned section below for additional 2 units
Rock Dredges			
EZ Net (maximum of 10 nets for depth stratified sampling. Mouth area of 1m^2)			• Please specify 335 micron, 500 micron, or 1,000 micron mesh
Rock saw			• Requires trained science personnel
Portable pot hauler			
Beam Trawl			
Pelagic trawl system (net, doors)			• Contact MNF to discuss net and mesh dimensions
Demersal trawl system (net, doors)			• Contact MNF to discuss net and mesh dimensions

(iv) Specialised laboratory and sampling equipment

Name	Essential	Desirable	Notes/Comments *(These items may require additional MNF support staff)*
MIDOC (multiple opening/closing codend system for pelagic trawl)			
Stern Ramp (please select exposed *OR* installed)	**Ramp Exposed**	**Deck covers installed**	
		X	
Trawl monitoring instrumentation (ITI) (2,000m depth limit)			
Radiosonde Receiver System			

(v) Equipment and sampling gear requiring external support *(may require additional support from applicants)*

Name	Essential	Desirable	
Seismic compressors			
Seismic acquisition system			

(vi) Underway systems

Acoustic Underway Systems

Name	Essential	Desirable	Notes/Comments
75kHz ADCP	X		At OBS deployment sites
150kHz ADCP	X		At OBS deployment sites
Multi Beam echo sounder EM122 12kHz (100m to full ocean depth)	X		
Multi Beam echo sounder EM710 70-100kHz (0-1000m approx.)	X		
Sub-Bottom Profiler SBP120	X		
Scientific Echo Sounders EK60 (6 bands, 18kHz-333kHz)	X		
Multibeam Scientific Echo Sounder ME70 (70-100 kHz)	X		
Omnidirectional Echo Sounder SH90			
Gravity Meter	X		

Atmospheric Underway Sensors

Name	Essential	Desirable	Notes/Comments
Nephelometer			
Multi Angle Absorption Photometer (MAAP)			
Scanning Mobility Particle Sizer (SMPS)			
Radon detector			
Ozone detector			
Condensation Particle Counter (CPC)			
Picarro spectrometer (analysis of $CO_2/CH_4/H_2O$)			
Aerodyne spectrometer (analysis of $N_2O/CO/H_2O$)			
Cloud Condensation Nuclei (CCN)			
Polarimetric Weather Radar			

Underway Seawater Systems and Instrumentation

Name	Essential	Desirable	Notes/Comments
Thermosalinograph	X		
Fluorometer			
Optode			
pCO2			

Seawater systems

Name	Essential	Desirable	Notes/Comments
Trace metal clean seawater supply			
Scientific clean seawater supplied to laboaratories			
Raw seawater available on deck and in laboratories.			

Non MNF Owned Equipment which may be accessed

Name	Essential	Desirable	
D & N Francis winch			• 13mm electro-optical cable
Box Corer			

Non MNF Owned Equipment which may be accessed

Name	Essential	Desirable	
UTAS In-Situ Pumps (x2)			
EM2040			• Shallow water multibeam echosounder system

Special Requests – MNF Scientific Equipment and Facilities

Videoconferencing needed for communication with shore-based PI Prof Nick Rawlinson.

Appendix B

User Supplied Equipment

Owner	Item name	Weight	Dimensions	Location on Vessel
AuScope/AGOS/ANU	Ocean Bottom Seismometers (x17)	236 kg each OBS (In-water weight: 15 kg)	Length: 1.470 m Width: 0.680 m Height: 0.566 m (0.760 m with aerial)	20 foot HiCube shipping container, re-designed inside. Rear deck inboard container slot
AuScope/AGOS/ANU	Cage pallet with spare ballast	800 kg	1150 x 1150 x 780 mm high	Secured on rear deck
AuScope/AGOS/ANU	OBS support frames (x4)	90 kg	1400 x 2308 x 950 mm high	To be removed from OBS container during voyage and secured on rear deck
CAS/Uni of Cambridge	Ocean Bottom Seismometers (x12), deck unit(x2), anchor(x13)	OBS(45Kg),deck unit(20Kg), anchor(20Kg) (In-water weight: 6 kg)	OBS & anchor (120*120*130cm); deck unit (80*50*40cm)	Secured on rear deck