Marine Biodiversity Hub

National Environmental Science Programme

Wessel Marine Park Post-Survey Report for IN2019T02

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Project D4 - Expanding our spatial knowledge of marine biodiversity to support future best-practice reviews

July 2020

Milestone 11 – Research Plan V6

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ISBN 978-1-925848-84-7

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Citation

Przeslawski R, Beaman R, Fava L, Nichol S, Woehler E, Yule C (2020). Wessel Marine Park: Post-Survey Report for INV2019T02. Report to the National Environmental Science Program, Marine Biodiversity Hub. *Geoscience Australia.*

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EXECUTIVE SUMMARY

Australia has established the world's largest network of marine protected areas and is now tasked with managing this vast and valuable resource. However, the lack of information in many marine parks about the seafloor and associated biota may hinder effective monitoring. One such area is the Wessel Marine Park in northern Australia, which is regarded as a biodiversity hotspot and culturally significant, but is also one of the most data-poor marine parks within the North Network. This project collected data to map the seafloor and characterise habitats of targeted areas within the Wessel Marine Park, providing crucial baseline information to better understand and manage this marine park, including those sites sacred to local indigenous communities.

This survey has uncovered a unique filter feeding community in the Wessel Marine Park that appears to be associated with a deep hole and scour feature containing high concentrations of nutrients.

The Wessel Marine Park project acquired multibeam data adjacent to that previously collected in 2005, as well as concurrent sub-bottom profile data. We also mapped a small grid to the south of this area over a possible raised geomorphic feature as indicated on the hydrographic chart. Four 1500 m video transects were undertaken across a range of geomorphic features and depth gradients, and two CTD (Conductivity, Temperature, Depth) casts were made, one at the deepest part of the study area and one at consistent shelf depths for the area. In addition, seabirds were surveyed during daylight hours throughout the Wessel Marine Park as part of Supplementary Project 3 during this survey.

Key results were as follows:

- A total of 142 individual seabirds was recorded within the Wessel Marine Park, and all but one of these were Crested Terns (*Sterna bergii*). No marine mammals were recorded within the Wessel Marine Park.
- Approximately 16 km^2 of new mapping to the west of the 2005 grid showed the full extent of the prominent tidally-scoured hole and surrounding shelf.
- A remapped strip of the 2005 study area to evaluate bedform stability found negligible change in position and form.
- The sub-bottom profiles revealed that the northern channel has a dynamic morphology that is dependent on the deposition and erosion of younger sediment, while the southern channel consists of infilled sediment and is likely to be more stable
- The benthic environment in the study area was highly turbid with strong currents, and associated imagery can therefore only be used for habitat classification, coarse morphospecies identification, or defining broad biological communities.
- Suspension feeders including fan sponges (e.g. *Ianthella* spp.), sea fans (e.g. *Mopsella* spp.), and barrel sponges (e.g. *Xestospongia* spp.) were locally abundant on the edge and rocky slope of the hole. These sponge and octocoral gardens provided habitat for other animals such as crinoids and fish.
- The CTD deployed on the shelf recorded vertical stratification at 35 m, with abrupt decreases in oxygen and temperature. The CTD deployed over the hole feature showed some decrease in oxygen and temperature at 20 m, with another stratification at 50 m.

This survey revealed a localised band of high biodiversity linked to a unique and culturally important geomorphological feature in the otherwise uniform seascape prevalent in the Wessel Marine Park. Our findings help contribute to an understanding of the values of a northern marine park, including an inventory of communities and habitats as well as potential relationships to geomorphic features and culturally important sites. This has national significance to the implementation of the northern marine park management plan, as well as informing future monitoring programs in northern Australia.

1.1 Background and Rationale for Survey

As anthropogenic impacts on the marine environment continue to increase, marine protected areas are becoming increasingly important for the management of natural resources (McCauley et al. 2015). In July 2018, the Australian Government implemented management plans for the Australian Marine Parks (AMP) Network, the largest network of marine protected areas in the world (Cochrane 2016). These management plans identify conservation values for the AMP network, at regional and park-specific level. For many parks, however, detailed information on conservation values and the natural assets under protection is lacking. We therefore have little baseline information for many of the marine environments against which to measure the effectiveness of the protection that these parks are intended to provide. This is particularly the case for deeper waters and areas off remote coasts. In northern Australia, the marine parks include some of the most data-poor parks, with the great majority of biological data collected from shallow waters (e.g. Stuart-Smith et al. 2017; Miller et al. 2017). The importance of environmental baselines is being increasingly recognised (Bruno et al. 2014), but when little environmental or biological information is available, it is challenging to develop and assess appropriate management strategies for marine protected areas.

The Northern Marine Parks are the most data-poor, with just a small proportion of national high-resolution bathymetric data located in northern Australia (Figure 1). Biological data are also depauperate in this region, with a noticeable national gap in imagery deployments and comparatively few biological observations (Figure 2). Similarly, very little is known about broad patterns in the seabird distribution across the region. The Gulf of Carpentaria region is believed to be relatively depauperate for seabirds, due largely to its shallow, well-mixed water and low productivity. The presence of suitable nesting habitat could be expected to increase seabird abundances and diversities closer to shore (see Chatto (2001) for known seabird breeding sites from the area).

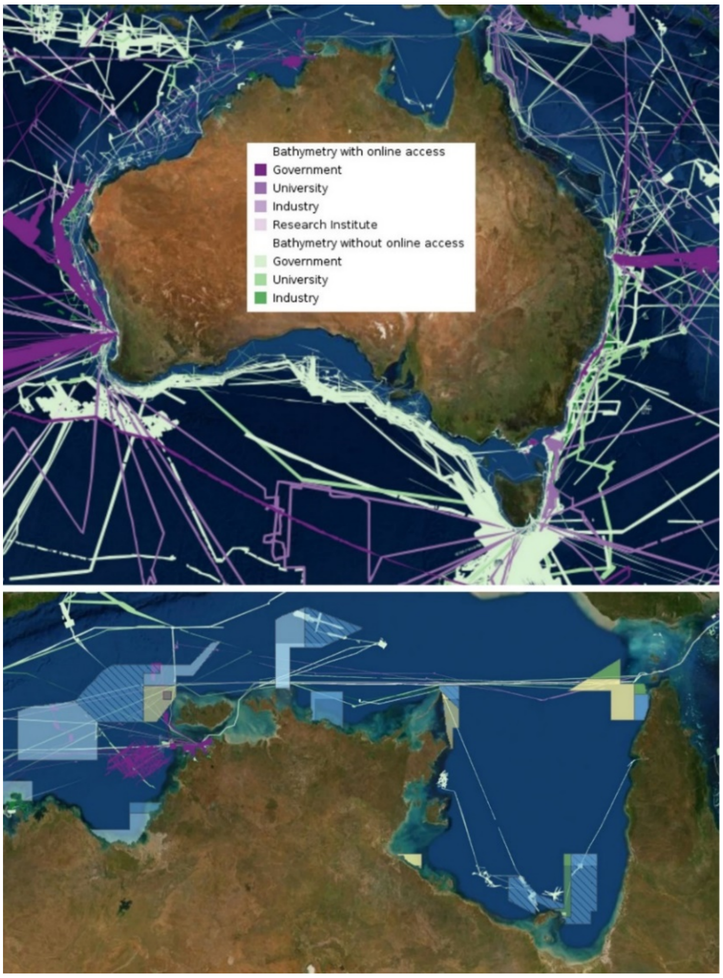

Figure 1 Bathymetry holdings from AusSeabed as of March 2020 showing national coverage (top panel) and coverage overlaid on the northern Australian Marine Parks (bottom panel)

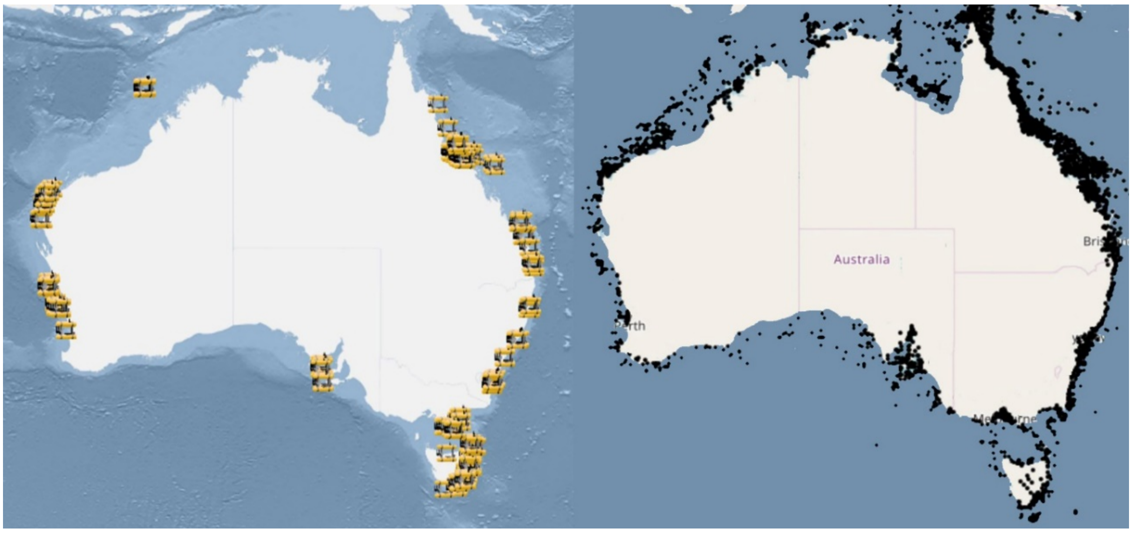

Figure 2 Maps of autonomous underwater vehicle (AUV) deployments in Australia (left, from AODN portal) and species occurrences of sponges (right, from Atlas of Living Australia). AODN and ALA portals were accessed in March 2020.

The North Marine Parks Network are also of key interest for indigenous engagement. The marine parks are managed by Parks Australia under the *North Marine Parks Network Management Plan 2018* (the Plan), which came into effect on 1 July 2018. The Plan seeks to protect and conserve the marine environment, including the cultural values of the marine parks. Cultural values are defined as living and cultural heritage, Indigenous beliefs, practices and obligations for country, places of cultural significance and cultural heritage sites. There is a particularly strong linkage to sea country in the north of Australia, and Parks Australia is working with Traditional Owners and ranger groups to better understand the cultural values of the North Marine Parks Network. This is in recognition of, and respect for, the ongoing cultural responsibilities of Indigenous people to care for sea country, and in support of providing multiple benefits for Traditional Owners.

In addition to targeted mapping or sampling scientific surveys, opportunistic data collection is a practical way to accumulate datasets over time, thereby allowing the characterisation of a defined marine environment. This can be done through vessel transits, piggyback projects, industry partnerships, citizen science, and indigenous engagement, and is an increasingly popular approach to cost-effectively building the information and datasets for Australia's large marine estate.

1.2 Australian Marine Park Context

The Wessel Marine Park is located off the remote coast of northern Australia, adjacent to Cape Wessel and the surrounding archipelago. The Park covers an area of 5908 km^2, and most of the Marine Park encompasses depths between 15 and 70 m. There is a tidally scoured hole on the northeast boundary of the Park that goes to depths of 110m.

The *North Marine Parks Network Management Plan 2018,* identifies the region as significant because it contains habitats, species and ecological communities associated with the Northern Shelf, including the Gulf of Carpentaria basin, a key ecological feature valued for its regional importance for biodiversity and aggregations of marine life. The Wessel Marine Park and its surrounding waters adjacent to the Wessel Islands are considered a biodiversity hotspot, thought to support a number of endemic species, as well as a variety of unique sponge and coral communities (Director of National Parks, 2018).

The Wessel Marine Park overlaps, and is adjacent to, three Indigenous Protected Areas (IPAs): Marthakal, Dhimurru and Laynhapuy. These IPAs reflect the aspirations of Traditional Owners to manage and care for the sea country that they are so strongly connected to, through the work of local Indigenous ranger groups. Due to these strong connections to the Wessel Marine Park, it is important for Parks Australia to better understand, and therefore better manage, the park's natural and cultural values. This understanding is being progressed through a project with the three ranger groups to engage with Traditional Owners and to map the cultural values of the marine park.

Despite its presumed significance, only 2.6% of the Wessel Marine Park seabed has been mapped in detail. There are raised geomorphic features in the park that may support rich invertebrate and fish assemblages as has been found elsewhere in the North Marine Bioregion (Heyward et al. 1997, Przeslawski et al. 2015), but the extent and detailed morphology of these features remain unknown. It is possible that these features are drowned reefs, similar in age and origin to relict reefs mapped in the southern Gulf of Carpentaria (Harris et al. 2008). Testing of this hypothesis will be possible using high resolution bathymetry data, seabed samples and underwater imagery. A previous transit voyage with the Marine National Facility (SS2012t07) found sponge assemblages in the Wessel Marine Park region were significantly different those found in a marine park to the west (Przeslawski et al. 2015), but it remains unknown if this applied to other taxonomic groups or more broadly to habitats.

1.3 Aims and Objectives

This project aimed to collect and analyse valuable environmental baseline information in a data-poor marine park. Specifically, we used a combination of multibeam sonar, sub-bottom profiles, and towed imagery to map the seafloor and characterise seafloor habitats and biological assemblages of an area in the north-west of the Wessel Marine Park and adjacent area. Collected data were combined with the limited data collected from previous surveys to begin to test assumptions about the marine park drawn from the 2018 management plan, namely that Wessel Marine Park i) includes some of the most diverse environments in the North Marine Region; ii) includes some of the most species-rich environments in the North Marine Region; iii) supports a number of endemic species; and iv) acts as a transition point for sessile invertebrate and fish species.

The primary planned methods to be applied were multibeam sonar and towed imagery, but during the transit survey, we opportunistically acquired other key datasets as part of other projects, namely seabird and marine mammal observations, and CTD profiles.

Results from this study will inform implementation plans, including monitoring programs, as well as zoning assessments. In particular, this study will expand the currently limited species inventory from the region; contribute to an assessment of the significance of raised geomorphic features in the park; and identify geomorphic features, habitats, or communities of interest.

1.4 Survey Area

The study area centres on a deep hole feature northeast of the northernmost island in the Wessel archipelago which has been the focus of two previous surveys (Table 1). This feature overlaps the marine park and was chosen because it was located adjacent to the planned transit route, had been partially mapped during a previous survey, and is likely one of the most significant geological features in the northern Wessel Marine Park. The deep hole and surrounding shelf was first mapped in 2005 (Harris et al. 2006) who characterised it as a "…tidally-scoured depression on the seafloor located directly north of Cape Wessel, at the northern end of the Wessel Islands….. Tidal scour is suggested by the closed bathymetric contours and the curved shape of the depression which is aligned with the main orientation of tidal flow across the area." The western edge of the depression was not fully mapped during this earlier survey.

Przeslawski et al. (2013) used an observation-class ROV (Class I in Monk et al. (2020)) and benthic sled samples to describe this area. Despite low-quality imagery, they found that the shelf immediately surrounding the deep hole had a high diversity of sponges and octocorals, while the deep hole was likely "…covered with muddy gravel and scattered sessile and sedentary invertebrates, of which crinoids dominate. The hole also supports skates and numerous small demersal fish." This earlier study recommended that future surveys deploy more appropriate imagery systems to handle the strong currents in the region, as the small ROV was often unable to reach the bottom due to the strong currents (Przeslawski et al. 2013).

Table 1 Recent surveys to the study area

Survey	Vessel	Date	Data[1]	Reference
GA276	*RV Southern Surveyor*	April 2005	Multibeam, SBP, CTD (1), grab (1), towed video (1)	Harris et al (2007)
SS2012T07	*RV Southern Surveyor*	October 2012	ROV video (3), benthic sled (3)	Przeslawski et al. (2013)
INV2019T02	*RV Investigator*	October 2019	Multibeam, SBP, CTD (2),	Current report

The current survey (INV2019T02) acquired multibeam data adjacent to that collected in 2005 (Harris et al. 2007), as well as concurrent sub-bottom profile data. Four video transects were undertaken across a range of geomorphic features and depth gradients (Figure 3). Two CTD casts were made, one at the deepest part of the study area and one at consistent shelf depths for the area (Figure 3).

[1] Includes only data collected around the study area, not the entire survey. Parentheses indicate number of deployments.

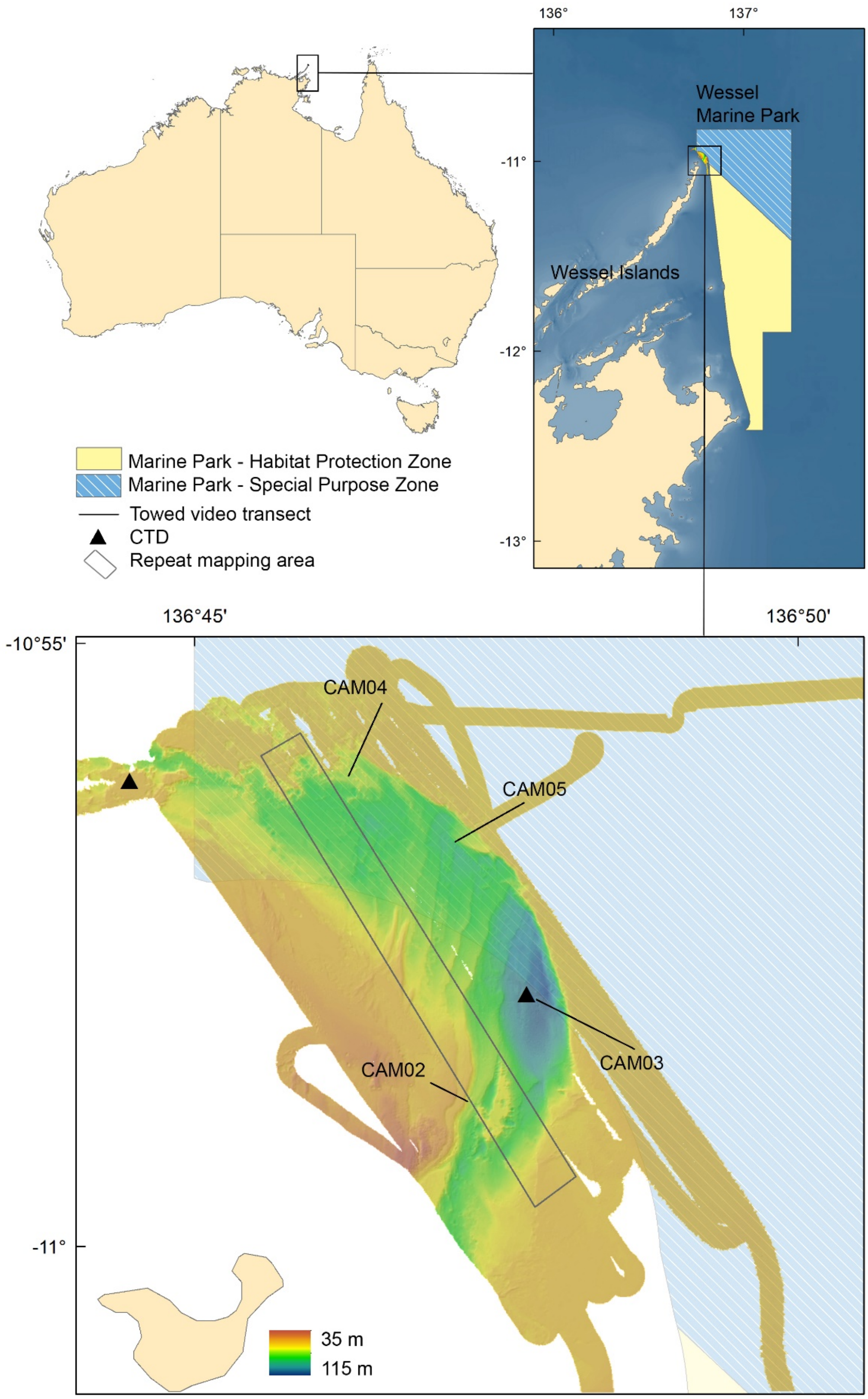

Figure 3 Study area of the current survey showing the location within Wessel Marine Park [right panel] and survey operations (CTD, towed video) overlaid on bathymetry [bottom panel].

2. METHODS

2.1 Multibeam

The R.V. *Investigator's* Kongsberg EM710 multibeam sonar system (70-100 kHz) was used to acquire bathymetry and backscatter data in the study area. Mapping was designed to acquire 100 percent coverage of the survey area, with ~10% overlap between survey lines. A rapidCAST sound velocity probe (i.e. moving velocity profiler) was conducted about once every line of mapping to account for the dynamic oceanographic environment in the region. Onboard technicians from the Marine National Facility processed the multibeam data and gridded to a resolution of 10 m. The final bathymetric grids are available through AusSeabed (www.ausseabed.gov.au).

2.2 Sub-Bottom Profiles

The R.V. *Investigator's* sub-bottom profiler (SBP) acquisition system (2-8 kHz) was used for high-resolution imaging of geological features down to 40m below the seafloor (e.g. to detect Quaternary strata, buried palaeochannels, slumps and slides). One of the benefits of using the SBP in tandem with bathymetry data is that we can analyse the reflected signal to determine the general composition of the seafloor (e.g. unconsolidated sediment vs. rock).

The SBP produces high-resolution data that can quickly become unmanageable. To best manage the data, we implemented a strategy to reduce file sizes and redundancy. The SBP data were segmented into hourly intervals to reduce the individual file size and to easily remove data that may have errors. Each segment/line was run through a script that performed processing to clean up the data, converting the onboard navigation from Latitude and Longitude to the UTM zone we were in (UTM53S) and auto-picked the seafloor so a 250 millisecond window was exported from the seafloor rather than the entire water column. A corresponding timing delay was added so that the SBP data maintained its depth when viewed in profile. The SBP data were then imported into OpendTect, a program that displays seismic and surface data in 3D space, where it could be analysed.

The bathymetry data that were collected at the same time as the SBP data were also imported into OpendTect. Importing the bathymetry data required a depth-time conversion as the vertical unit is in metres whereas the SBP data are in milliseconds. The equation to convert depth into time is $d = Vt/2$ where t is time in milliseconds, d is depth of the water column in metres, V is the velocity of sound in water in metres per millisecond and the 2 is to convert the depth into two-way travel time. The velocity of sound in water was determined to be 1.53 metres per millisecond on average according to the SBP system. The resulting OpendTect 3D model of SBP profiles effectively linked the seafloor topography to the seafloor subsurface. Integrating the SBP and bathymetry data into the one 3D model provided more geological context for both datasets.

2.3 Towed Imagery

Towed imagery transects were selected using seabed mapping from multibeam operations. Towed imagery operations followed national protocols (Carroll et al. 2018, Przeslawski et al. 2019), with the exception that the recommended downward-facing stills camera was substituted with the forward-facing stills camera on the vessel's deep-tow system.

Underwater imagery was acquired with the Marine National Facility's Deep-Towed Camera system (Figure 4) which includes the following features (Marine National Facility 2019):

- Cannon 1DX DSLR – remote viewing and control, usually used for still image acquisition
- Cannon C300 HD cinema camera – live HDSDI video steam and recording
- Hitachi PAL forward camera
- Deep Sea Power & Light floodlights – remote controlled
- Kongsberg-Mesotech 500m range altimeter
- SBE37 – live CTD data acquisition and monitoring
- 2 x Deep Sea Power & Light size reference lasers (10 cm spacing)
- USBL positioning system

Due to high turbidity and strong currents, the Cannon 1DX DSLR was the only suitable camera for this project, as the others could not produce a visual of the seafloor.

Figure 4 Towed video system (left) and operations room (right) of the R.V. *Investigator* during deployment

The camera was towed for approximately 1000 m at 1 – 1.5 knots (~30 minutes) along geomorphic and depth gradients of the seafloor, with the exception of CAM02 which was aborted after 600 m due to concerns the camera was at risk of collision due to low visibility and rocky outcrops (Appendix A). Video was live-streamed to the operations room (Figure 4) where it was annotated to broad habitat classification to identify transition zones. Annotation was done using the shipboard event logger which paired USBL data with one of seven broad habitat categories, thus providing a geo-referenced transect of habitat transitions. The habitat categories were modified from Przeslawski et al (2013) and are defined in Table 2. A total of four transects were annotated onboard (Table 3).

Table 2 Habitat classifications used during real-time video annotation in the Wessel study area

Biodiversity / Complexity	Category	Description
Low ↓	*Barren flat*	There was little or no evidence of faunal activity or bedforms.
	Barren rippled.	There was little or no evidence of faunal activity, but bedforms such as ripples were visible.
	Bioturbated	There were few or no animals observed, but the seafloor was bioturbated with burrows, tracks and other evidence of faunal activity.
	Scattered epifauna	The seafloor has low epifaunal cover, with few if any large habitat-forming taxa.
	Mixed patches	There are locally abundant patches of sponges, octocorals and other habitat-forming taxa, usually on scattered rocks or outcrops.
High	*Mixed gardens*	The seafloor supports moderately dense coverage of sponges and octocorals, with high abundances of other taxa.
	Other/unknown	The habitat is other than that described above, or the seafloor is not visible.

Table 3 Location and depth of imagery transects

	Transect start			Transect end		
Station	Lat	Long	Depth	Lat	Long	Depth
CAM02	-10.9774	136.7826	-65.56	-10.9799	136.7877	-68.82
CAM03	-10.9727	136.8107	-63.69	-10.9659	136.7972	-110.73
CAM04	-10.925	136.7758	-62.99	-10.935	136.7712	-75.87
CAM05	-10.9387	136.7954	-62.78	-10.9441	136.786	-84.81

2.4 Seabird & Marine Mammal Observations

Seabird and marine mammal observations were undertaken continuously from before sunrise to sunset during the entire IN2012T02 survey as per established international protocols (Woehler et al. 2010). For the purposes of this report, we confined observations to the Wessel Marine Park. A team of three observers was present on board for the voyage. Observations were conducted from Deck 7 on the R.V. *Investigator*, approximately 25 m above sea level. All seabirds within a 300 m forward arc from the bow to the side of the ship with least glare were recorded, with details of species, behaviours and numbers recorded in real time on a dedicated data collection portal connected to the vessel's underway data system. All marine mammals within a 1 km radius were recorded in a similar manner. All seabirds and marine mammals seen beyond these bounds were recorded in the system as 'out of zone' records.

2.5 CTD

The Marine National Facility's CTD (Figure 5) was deployed at two sites in the study area to profile conductivity (salinity), temperature, and depth of the water column. These sites were chosen to identify potential differences in vertical mixing within the deep hole feature and outside of it (Figure 3).

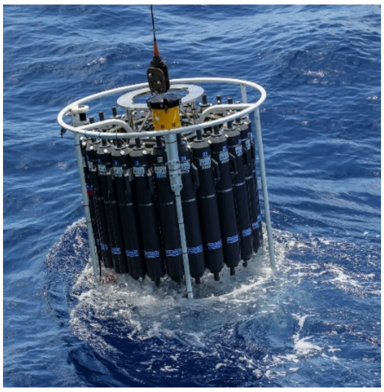

Figure 5 CTD being deployed from the R.V. *Investigator.* Photo credit Chris La Rosa.

3. RESULTS AND PRELIMINARY INTERPRETATIONS

3.1 Seabed Features

Multibeam mapping and SBP profiles of the hole feature revealed four geological classes: basement rock in the southeast corner, in-filled paleochannels in the south, shifting bedforms at the southern end of the channel, and a scree slope at the scarp edge. The rest of the surrounding area in the Wessel Marine Park is likely to be marine sediment plains.

3.1.1 Geomorphic features

We completed approximately 16 km^2 of new mapping to the west of the 2005 grid. This new mapping data showed the full extent of the prominent tidally-scoured hole mapped by Harris et al. (2006). The hole extends 3 km along a north-south alignment, is up to 1 km wide and reaches a maximum depth of ~108 m. Along its western edge, the perimeter of the hole is a well-defined break in slope at approximately 80 m water depth. A scarp that rises 40 m from the base of the hole to 60 m water depth defines the eastern perimeter. This scarp continues a further 3 km beyond the northern end of the hole (Figure 6). At the 10 m resolution of the bathymetry grid, the floor of the hole appears smooth and flat. Observations from the towed video also indicate the substrate within the hole was dominantly unconsolidated sediments, while the inner rim of the hole was hard rock.

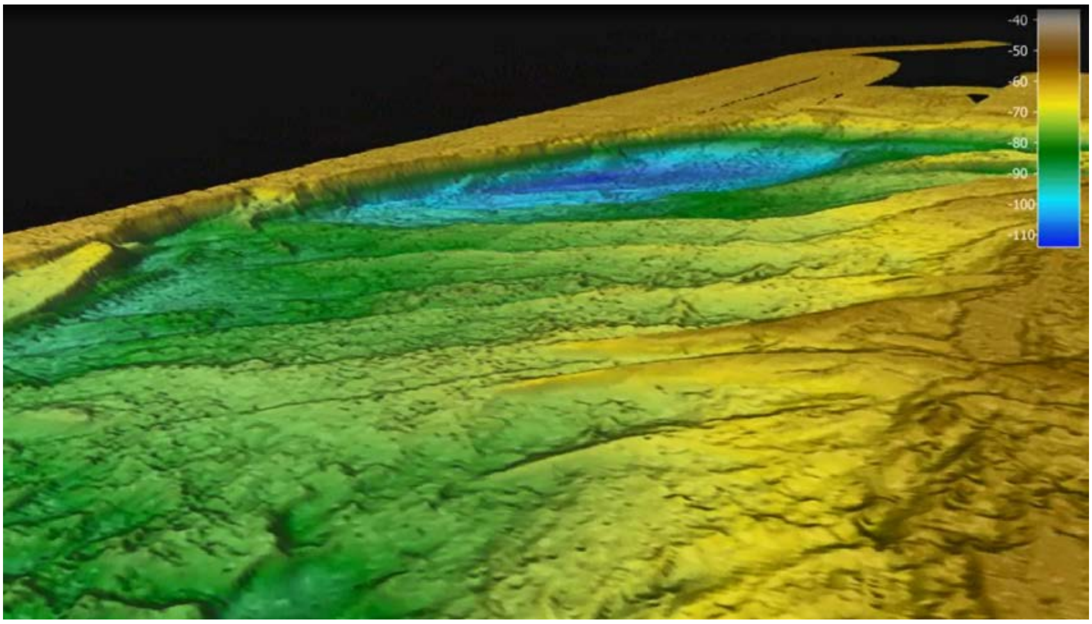

Figure 6 Screenshot from a fly-through showing the scour feature and deep hole bounded by a 40 m high scarp along its eastern perimeter.

To the west of the deep hole, the seabed is characterised by a series of stepped terraces that rise to a platform at a water depth of approximately 50 m. The terraced platform extends to the northwest forming the edge to a broad and shallow depression that is bound to the east by the scarp noted above. A distinctive feature of the depression is a series of linear ridges that extend up to 2 km across the depression. The ridge crests are up to 5 m above the adjacent seabed, are 200-300 m apart and sit in water depths of approximately 80 m. In profile, the ridges are asymmetric with steeper sides facing southeast, but they become less well defined toward their northern ends.

We remapped a strip of the 2005 study area to evaluate bedform stability across these ridge features and found negligible change in position and form (Figure 7). It is therefore likely that these ridges are relict (inactive) sedimentary bedforms that formed at a lower sea level during the late Pleistocene to early Holocene (ca. 12,000 – 8,000 yrs before present). It is also possible that the ridges are (partly) lithified (cemented) and therefore stable, at least under the modern hydrodynamic regime of this area.

To the north of the depression and ridges, the seabed is irregular, with flat and hard seabed dissected by numerous shallow pits and depressions. Similarly, the area to the south of the deep hole is characterised by a locally irregular seabed with a mix of raised hardground and small pits and depressions.

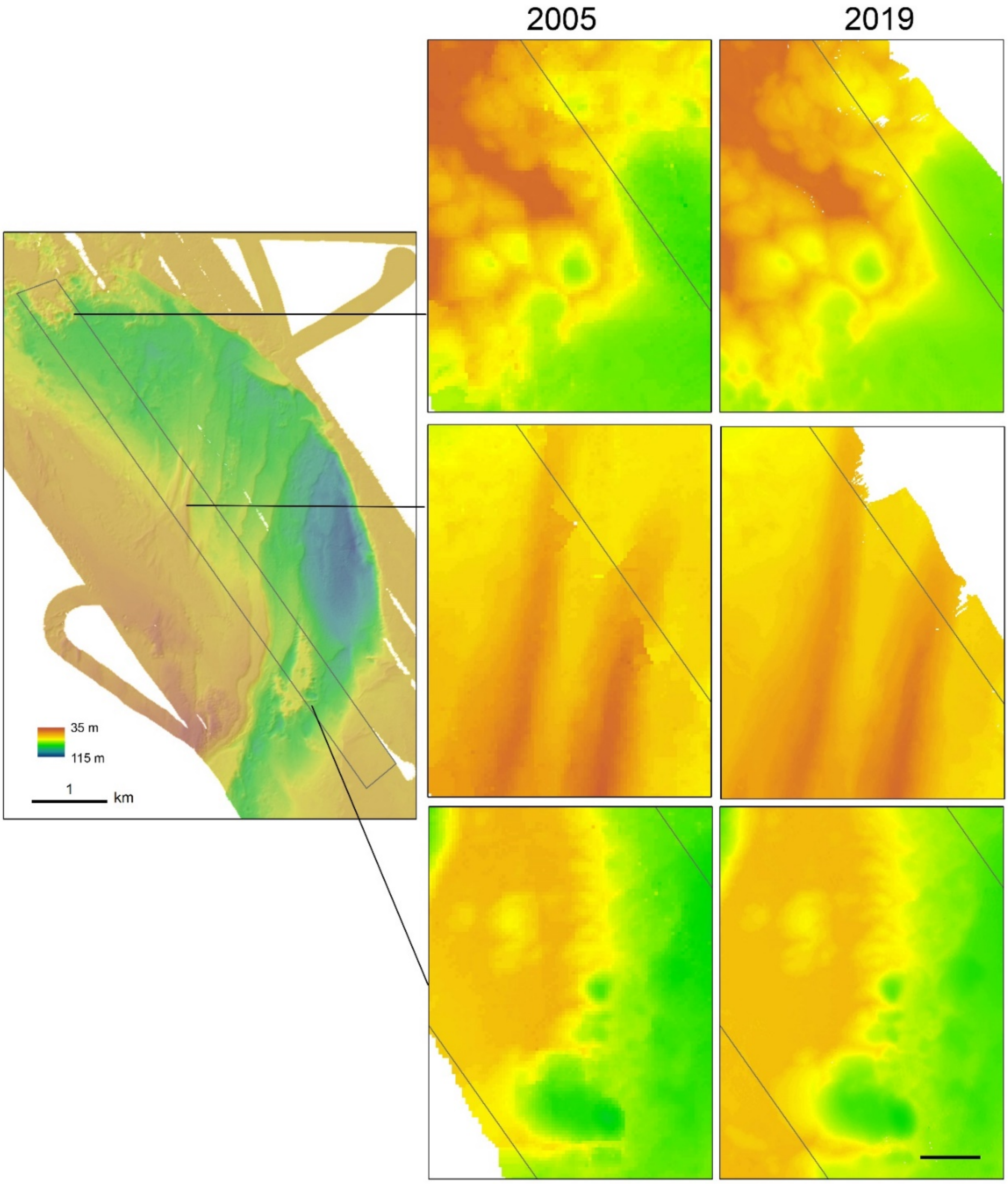

Figure 7 Remapped area (in grey rectangle), showing bathymetry from 2005 and 2019.

3.1.2 Sub-seabed structure

Sub-bottom profile data complement the bathymetry data by providing information to characterise the structure of sub-seabed geology of the survey area within Wessel Marine Park (Figure 8). We interpret two stratigraphic units from the SBP profiles acquired within the survey area. Unit 1 is the most extensive and is characterised by a strong (high amplitude) seabed reflector and absence of sub-surface reflectors (Figure 9). We interpret this as a lithified sedimentary unit, of likely Pleistocene age. Unit 2 sits on top of the Pleistocene unit, with the contact marking a clear unconformity (erosion surface). This upper unit is characterised by a strong seabed reflector with local depressions (pockmarks?) and a package of strong, conformable reflectors that form a broad concave to horizontal geometry. These properties indicate the material is sedimentary, with surface depressions evidence for localised scouring (erosion) by tidal currents. The surface SBP reflector closely matches with the bathymetry, which provides a high degree of confidence for these interpretations.

As described in section 3.1.1, the mapped area of Wessel Marine Park is characterised by a broad depression, or channel, leading into a deep hole. The SBP data has revealed that the northern and southern channels are quite different. The southern channel is incised into partially truncated Pleistocene unit that is infilled by ~30 m thickness of younger sediment (Figure 8c). The southwestern end of this channel has no infill but as it approaches the deep hole to the northeast, the truncation and infill increases. The centre of the channel has an area of shallow seabed made of unconsolidated sediment that divides the channel in two (Figure 8d). The edges of the Southern Channel are made of the hard Pleistocene unit and active seafloor erosion causes scouring of the softer young sediment, leaving a high in the centre.

In contrast, the northern channel is incised into the Pleistocene unit that is not truncated (Figure 8e). The northern edge is made of younger sediment that is deposited on a relatively flat surface (Figure 8f). Thus, the northern channel has a dynamic morphology that is dependent on the deposition and erosion of younger sediment whereas the southern channel consists of infilled sediment and likely to be more stable (Figure 8g).

The deep hole of the Wessel Marine Park (Figure 8h) shares characteristics with the channels that merge into it. Like the southern channel, the southern extent of the deep hole is truncated and partially infilled by young sediment and is bound by the harder Pleistocene unit. The southern extent is also deeper which is indicative of stronger seafloor currents. The northern extent of the deep hole, similar to the northern channel, has a flatter Pleistocene surface with ~10 m of younger sediment deposited on top. The differing properties of these channels and deep hole contribute to the unique seafloor morphology of the Wessel Marine Park.

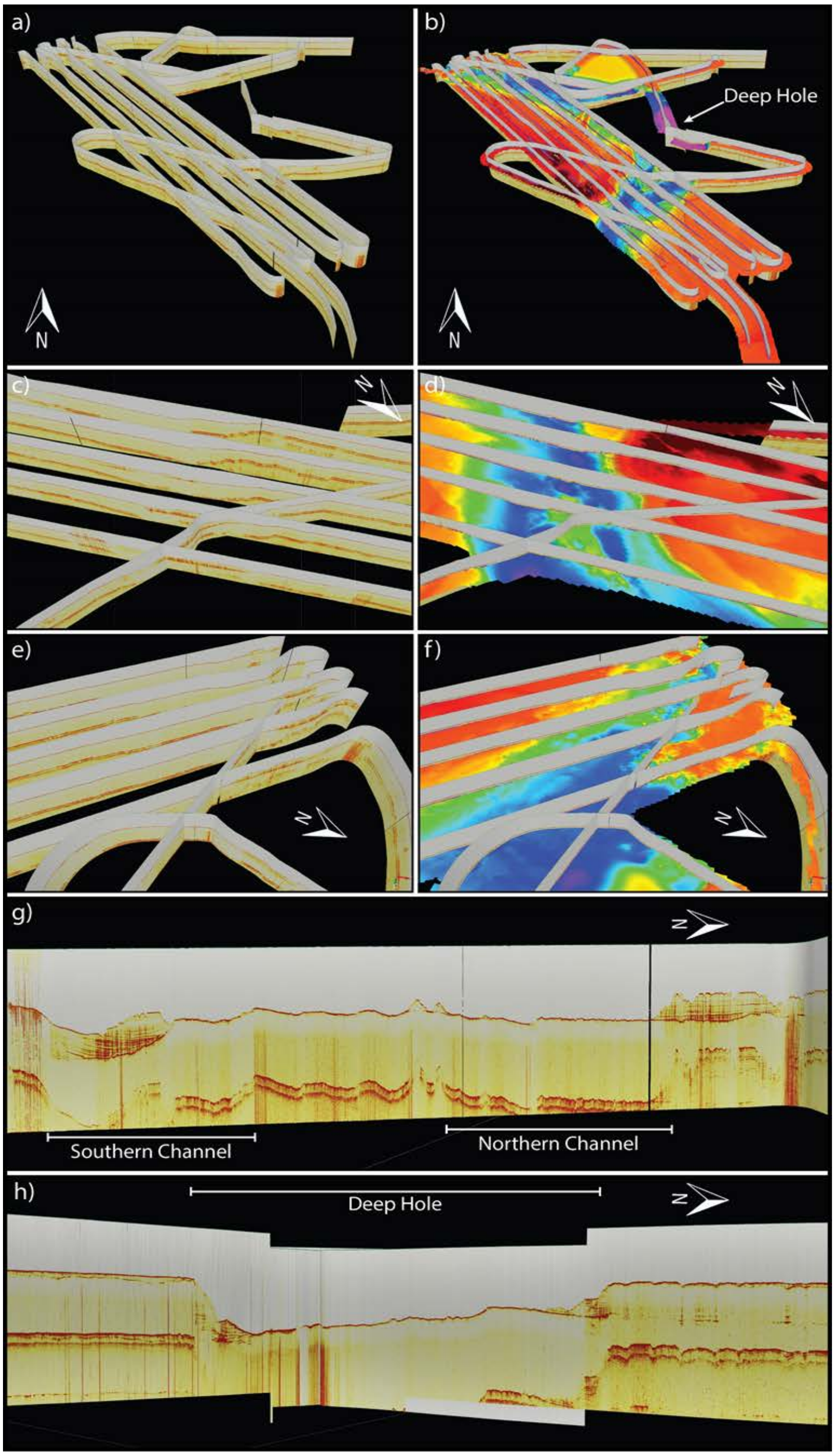

Figure 8: Sub-bottom profile (SBP) images integrated with bathymetry of the Wessel Marine Park, showing: (a) All SBP profiles in overview; (b) SBP profiles and bathymetry; (c) SBP profiles, southern channel; (d) bathymetry and SBP profiles, southern channel; (e) SBP profiles, northern channel; (f) bathymetry and SBP profiles, northern channel;(g) SBP profile across both channels; (h) SBP profile across the deep hole.

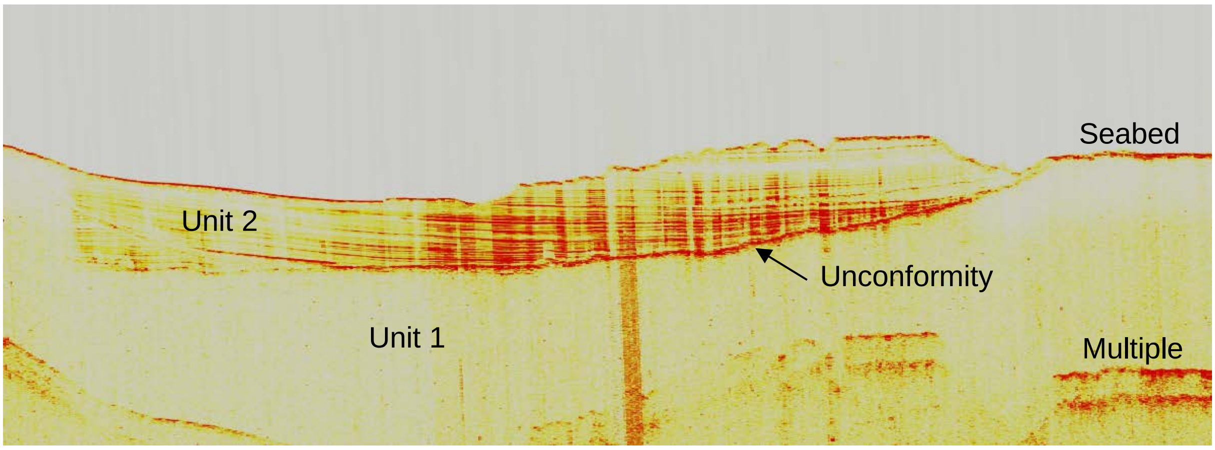

Figure 9 Subset of SBP data from the southern channel, with stratigraphic units and surfaces labelled. The multiple is an artefact of the seabed 'echo' within the SBP data.

3.2 Biological Communities

3.2.1 Epifaunal Communities

The benthic environment in the study area was highly turbid with strong currents, and associated imagery can therefore be only used for habitat classification, coarse morphospecies identification, or defining broad biological communities. Nonetheless, it was clear that suspension feeders including fan sponges (e.g. *Ianthella* spp.), sea fans (e.g. *Mopsella* spp.), and barrel sponges (e.g. *Xestospongia* spp.) were locally abundant on the edge and rocky slope of the hole. These sponge and octocoral gardens provided habitat for other animals such as crinoids and fish. The bottom of the deep hole showed scattered fish, as well as a highly localised dense population of brittle stars. In contrast, the flat terraces around the hole supported only scattered small epifauna, such as hydroids, ascidians, and sponges. Qualitative assessments of each video transect are in Appendix A.

There were no areas classified as barren, and there were only a few images classified as bioturbated, mostly along the area of sediment accumulation in the northern part of the deep hole (CAM04, Figure 10). The majority of all transects were classified as low to moderate densities of epifauna (i.e. scattered epifauna, mixed patches). Within each of the four transects, annotations indicated localised segments of higher biodiversity (i.e. mixed gardens or mixed patches):

- The shortened transect in the southwest of the study area (CAM02) had relatively homogenous geomorphology across the edge of the stepped terraces and a moderate depth range (50-67 m) which was reflected in sporadic areas of moderate biodiversity (i.e. mixed patches) (Figure 10);
- The easternmost transect (CAM03) included the largest depth gradient (63 – 114 m), traversing the shelf, scarp and the deep hole. There was very clear pattern of increasing biodiversity towards the edge of the shelf and the slope (Figure 10). An almost continuous transect distance of > 200 m supported moderate – high densities of habitat-forming epifauna (i.e. mixed gardens) (Figure 11a,b). At the bottom of the hole, only scattered

epifauna were observed (Figure 10), including localised high abundances of brittlestars (Figure 11c);

- The northernmost transect (CAM04) traversed a gradual downward slope (63 – 76 m). The start of the transect was difficult to annotate due to poor quality imagery (see Appendix A), but eventually we observed scattered epifauna and mixed patches throughout most of the transect (Figure 11e). There were areas of low biodiversity (i.e. bioturbated) towards the deeper part of the transect (Figure 11f).
- The northeast transect across the terrace (CAM05) spanned a moderate depth range (63 – 83 m) and showed similar patterns to that observed in CAM03 but with a much smaller segment of high epifaunal biodiversity. Scattered epifauna were most common on the terrace, transitioning to mixed patches closer to the terrace edge (Figure 11d), followed by a narrow band of mixed gardens. Habitats abruptly reverted to scattered epifauna beyond the scarp (Figure 10).

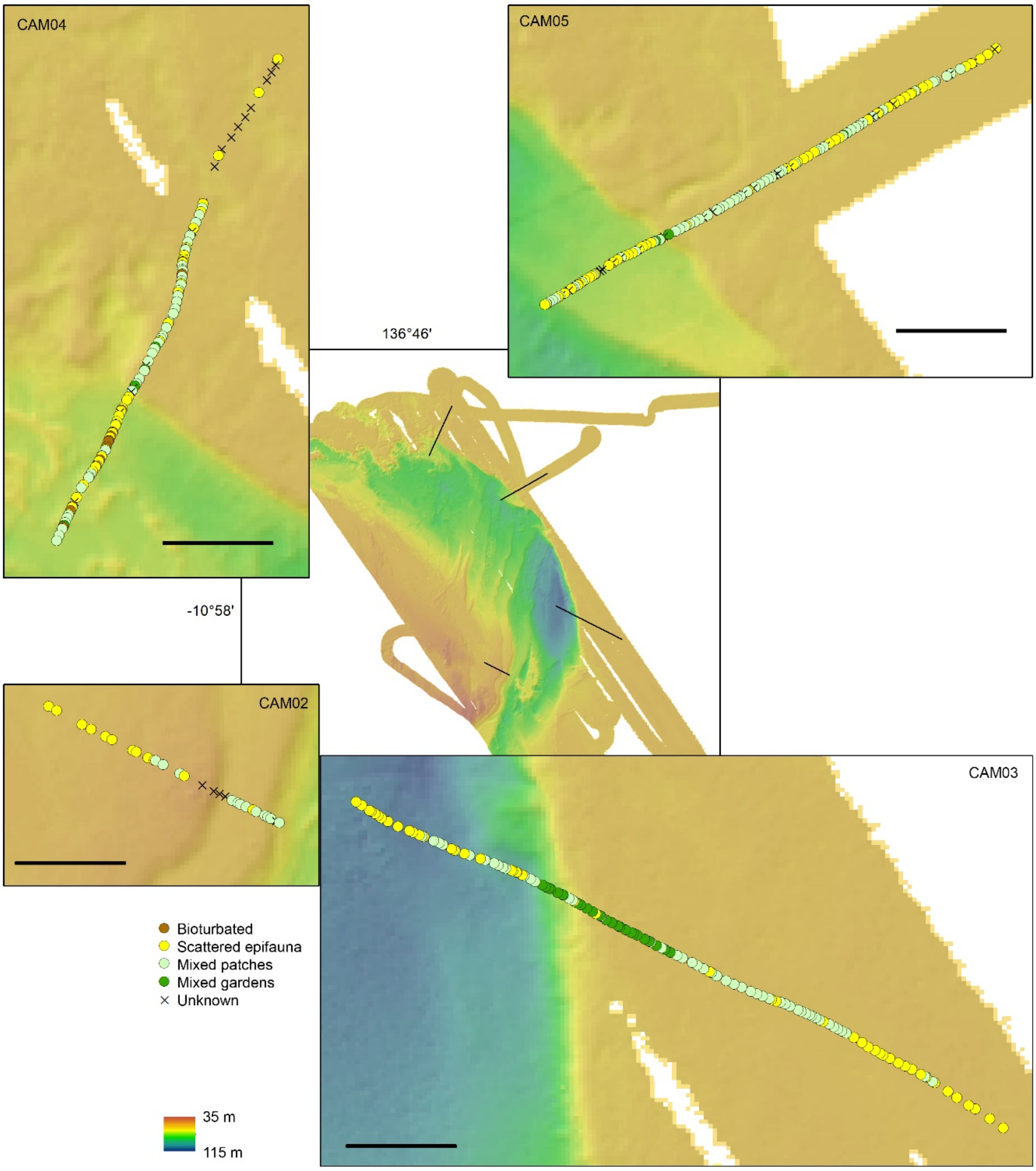

Figure 10 Towed video transects undertaken in the study area [centre panel], with habitat annotations overlaid [outer panels] showing transition zones and areas of higher benthic biodiversity (green dots). Scale bars on outer panels represent 200 m.

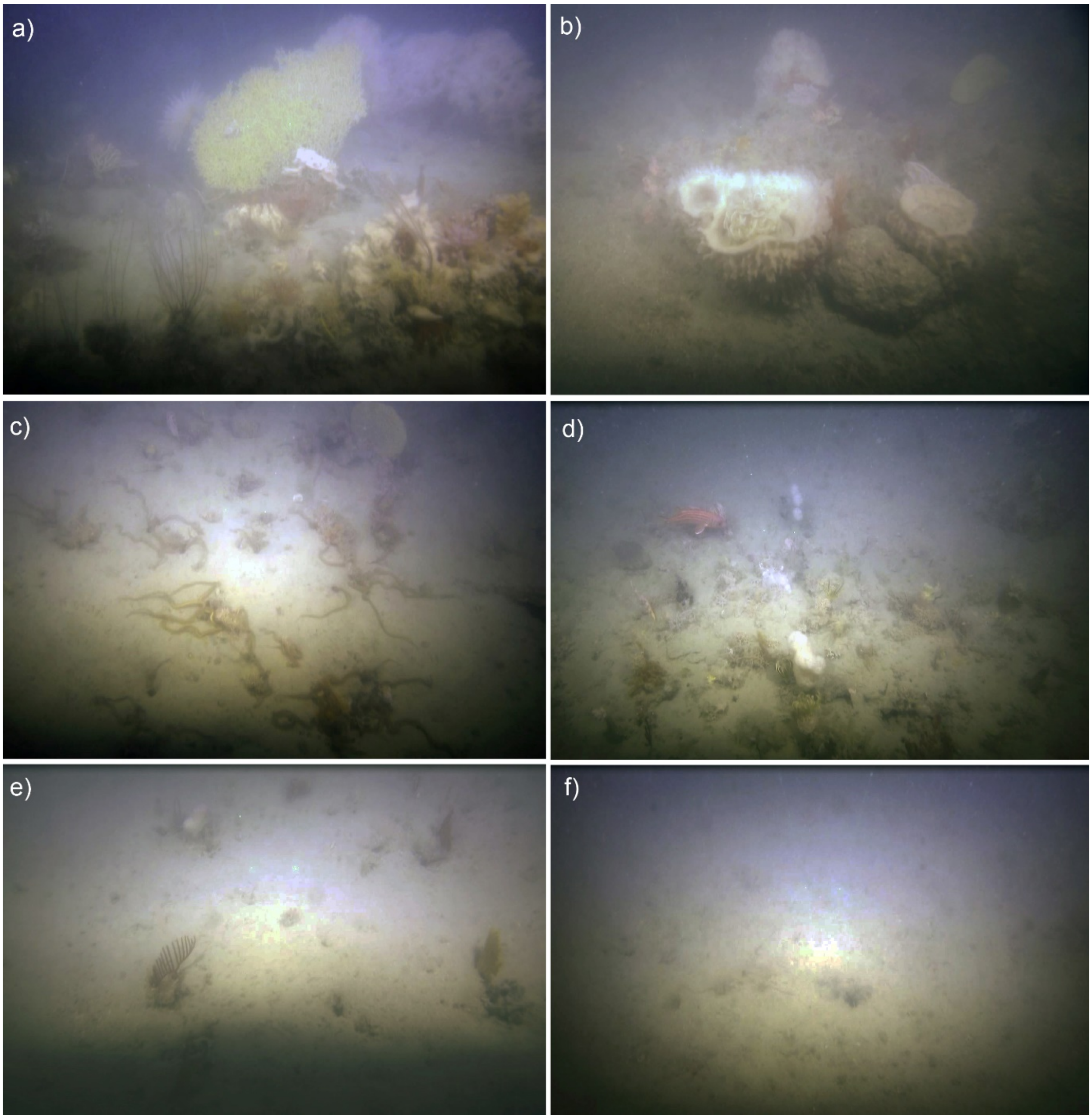

Figure 11 Images of representative habitats from towed video transects: a) mixed gardens with orange gorgonian *(Mopsella* sp.) from CAM03; b) mixed gardens with barrel sponges (*Xestospongia testudinaria)* and associated fauna from CAM03; c) high densities of brittlestars from CAM03; d) mixed patches of sessile fauna including fish at CAM05; e) scattered epifauna at CAM04; and f) bioturbated habitat at CAM04.

These results support those from Przeslawski (2013) who noted large sessile invertebrates on the shelf around the deep hole feature, but found none within the feature. The lack of larger sessile invertebrates in the hole and surrounding scour feature may be due to the predominately unconsolidated sediment combined with high disturbance limiting settlement on all but the largest rocks. The current study yields further insight into this area by revealing that representative habitat and communities on the surrounding shelf are also not likely to support patches or gardens of habitat-forming epifauna.

3.2.2 Seabird & marine mammal observations

A total of 142 individual seabirds from two species was recorded within the Wessel Marine National Park Zone (MNPZ) and Wessel Multiple Use Zone (MUZ) on 11 October 2019 (Figure 12). The two species of seabirds recorded were Crested Tern (*Sterna bergii*, 141 individuals) (Figure 11) and Bridled Tern (*S. anaethetus*, 1 individual). No marine mammals were recorded within the Wessel MNPZ and MUZ during the voyage. There are no known records of Crested and Bridled Tern breeding colonies from the Wessel Islands (Chatto 2001), so the source colonies of the terns observed are unknown.

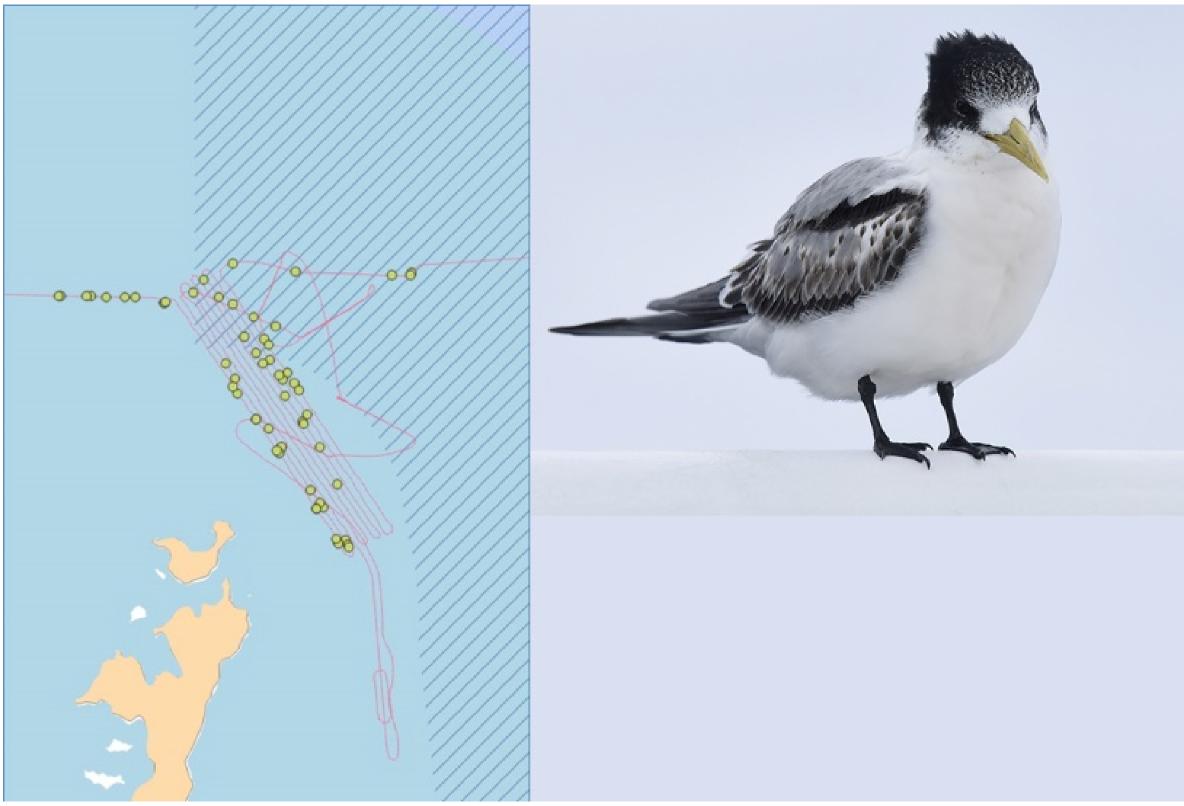

Figure 12 Map [left] showing the locations of seabirds (yellow circles) observed within and adjacent to the Wessel Marine National Park Zone and Wessel Multiple Use Zone on 11 October 2019 from RV Investigator. The cruise track is shown as a thin red line, and the Wessel Marine park is shown by diagonal blue lines. Almost all observations were of the Crested Tern [right].

The observations of seabirds and marine mammals collected during IN2019T02 provide contemporary data on the distribution and abundance of species within the northern Australian bioregion, including within marine parks. Many of these species are listed under the EPBC Act 1999 and will contribute to a species inventory for marine management. Analyses underway into feeding associations and species assemblages will complement studies elsewhere, enabling assessments of the representativeness of the processes observed and the species involved. It is likely that the results will parallel those from previous studies, reinforcing the role of behavioural interactions as a key driver of ecosystem processes in tropical waters.

3.3 Oceanographic Data

The CTD deployed on the shelf recorded vertical stratification at 35 m, with abrupt decreases in oxygen and temperature. In contrast, the CTD deployed over the deep hole feature showed some decrease in oxygen and temperature at 20 m, with another stratification at 50 m, corresponding with the depth of the surrounding shelf (Figure 13). Salinity remained similar among both sites and all depths (Figure 13).

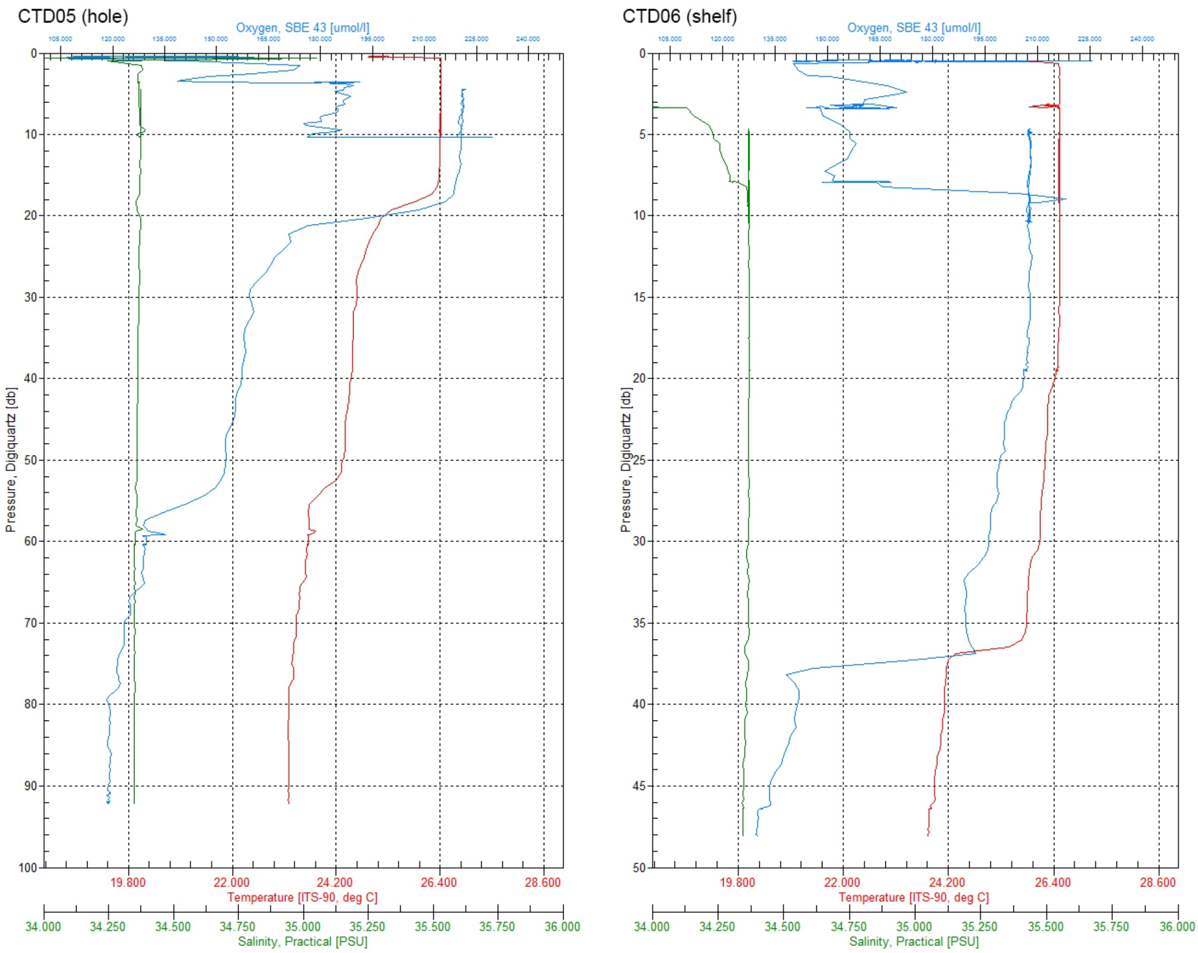

Figure 13 CTD data from the two casts deployed in the Wessel study area over the deep hole feature [left] and the surrounding shelf [right]

4. CONCLUSIONS & FUTURE WORK

4.1 Assessment of Towed Imagery

The shelf waters of Northern Australia are recognised as a region of high turbidity, and it may be the area in the current study has even higher localised turbidity. This is supported by a previous CTD cast that showed the highest suspended sediments in surface (0.0125 grams per litre) and near-bottom water (0.0144 grams per litre) in the deep hole compared to sites in the Gulf of Carpentaria (Harris et al. 2006).

The poor quality of the towed imagery from this survey highlighted the challenges of monitoring our northern marine parks. Although we were able to identify broad habitat and community types, the turbidity of the region precludes identification of animals at anything other than the coarsest resolution. Future research in the area should explore alternative methods, such as acoustic cameras, as well as different lighting systems and orientations of towed systems deployed over varying tidal conditions. Surveys from the Ocean Shoals Marine Park to the west of the Wessel indicate that downward-facing still images may represent the best quality imagery from the region with its turbidity and strong currents (Nichol et al 2013, Bridge et al. 2020).

4.2 Environmental Summary

This survey confirmed the presences of a deep hole feature surrounded by a tidally scoured seafloor bounded by a steep rugose slope which is likely a unique feature in the otherwise uniform seascape prevalent in the Wessel Marine Park. The geological processes that shaped this feature can be inferred from the bathymetry, backscatter and sub-bottom profiles.

To the north and south of the deep hole feature, on the surrounding flat plain, the seafloor is irregular, with a relatively flat and hard seabed dissected by numerous shallow pits and depressions. The southern extent of the deep hole is a broad depression of channel which truncates the Pleistocene surface and was partially infilled with younger sediment that appears to be actively eroding, likely through tidal scour. The central part of the deep hole feature has a thin veneer of soft sediments overlying hard rock which presents as a steep scarp forming the western rim of the hole. A scree slope of loose rubble is located against this steep scarp. The northern extent of the deep hole is a broad depression or channel with less sediment infill compared to the southern part of the hole. The Pleistocene basement is overall deepening towards the north in keeping with the general gradient of the shelf.

The southern rock area likely became exposed during the last sea level fall. As sea level rose at the last glacial maxima, sediment infilled the entire valley in layers. Very likely, tidal scour processes have (and continue to be actively) removing these older sediments, exposing the deep hole to a hard rock Pleistocene surface or leaving areas of remnant eroded soft sediment deposits lying on this Pleistocene surface, with the southern part being most actively eroded to the original Pleistocene basement rock. Over geological time, the channel will likely widen.

The rocky slope and edge immediately surrounding the deep hole form a band of high biodiversity, with higher densities and diversity of sessile invertebrates here than in the deep hole and surrounding shelf. Benthic cover increased across the flat platform and closer to the edge of the hole, with many large sponges and octocorals observed. The steeper sides of the hole had the highest benthic cover with numerous boulders covered in colourful sponges. CTD casts indicated variations in ocean currents over the deep hole and scour feature which may bring high concentrations of nutrients to support the suspension-feeders prevalent along the slope and shelf rim.

The observations of feeding terns within the Wessel Marine Park from RV Investigator may be indicative of unknown breeding colonies in the area. Crested Terns were observed to dive onto small fish brought to the surface by foraging Tuna (*Thunnus* spp). The absence of marine mammals is somewhat surprising, but given the relatively brief period spent inside the Wessel Marine Park, may be an artefact of limited survey effort.

4.3 Management Plans

Due to the poor quality of the imagery and limited time to undertake towed operations, we were unable to definitively test the original assumptions drawn from the 2018 marine management plan (Section 1.3). The turbidity and strong currents of the area are a challenge that future management plans will have to consider in respect to monitoring (i.e. how do we assess status and trends if we can't clearly observe something?).

Nonetheless, we did identify a localised band of high biodiversity linked to a unique and culturally important geomorphological feature in the Wessel Marine Park. Despite limitations testing these original assumptions, the baseline marine environmental knowledge produced by this survey is fundamental to better address sustainable management objectives in the Wessel Marine Park.

4.4 Indigenous Engagement

This survey highlighted the benefits of collaborating with the Traditional Owners of sea country. As part of authorising a permit for this survey work, Parks Australia consulted with Traditional Owners of Wessel Marine Park via the local ranger groups in March 2019. Given the location of the survey site, the Marthakal Ranger group were particularly involved and facilitated engagement with Traditional Owners for the site, both during the survey and upon the vessel's arrival into Darwin. In Darwin, Traditional Owners were invited onboard the vessel and shown footage from the deep towed camera as it traversed the scoured underwater geological feature. The importance of the sacred site was acknowledged, as was the delight to see the underwater imagery. Approval was granted to share the footage not only amongst the scientific community but to the interested media as well.

Through healthy country and IPA management plans, ranger groups and Traditional Owners articulate their aspirations to work collaboratively or in partnership with organisations on marine science in their sea country. In the future, where appropriate, Traditional Owners, or rangers may be interested in partaking in voyages and scientific surveys over their sea country. Future surveys in the Wessel Marine Park and surrounding region now have an excellent opportunity to collaborate with the local indigenous groups, incorporating their knowledge of sea country into survey design and data interpretation. Further, Traditional Owners of sea country where marine research has taken place, have expressed an interest in hearing back about results once the research findings are finalised.

4.5 Conclusion

This study helps contribute to an understanding of the values of a northern marine park, including an inventory of communities and habitats as well as potential relationships to geomorphic features and culturally important sites. In addition, this survey has further highlighted the challenges of collecting seafloor images from environments with high turbidity and strong currents. Overall, baseline environmental knowledge acquired from this study has national significance to the implementation of the northern marine park management plan, as well as informing future monitoring programs in northern Australia.

5. ACKNOWLEDGEMENTS

We are extremely grateful to the crew of the R.V. *Investigator* and to our fellow scientists and teachers that shared the journey with us. We are particularly grateful to Amy Nau (Marine National Facility) for her expertise with onboard processing of multibeam data and Zhi Huang (GA) for producing the bathymetric grids used in this study. This research was supported by a grant of sea time on RV Investigator from the CSIRO Marine National Facility. This work was partly funded by the Marine Biodiversity Hub, a collaborative partnership supported through funding from the Australian Government's National Environmental Science Program (NESP). NESP Marine Biodiversity Hub partners include the University of Tasmania; CSIRO, Geoscience Australia, Australian Institute of Marine Science, Museums Victoria, Charles Darwin University, the University of Western Australia, Integrated Marine Observing System, NSW Office of Environment and Heritage, NSW Department of Primary Industries. R Przeslawski and S Nichol publish with permission of the CEO of Geoscience Australia.

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APPENDIX A – QUALITATIVE SUMMARY OF VIDEO TRANSECTS

Video transects area publicly accessible via the Australian Marine Imagery Collection hosted by the National Computing Infrastructure (NCI): http://dap.nci.org.au/thredds/remoteCatalogService?catalog=http://dapds00.nci.org.au/thredds/catalog/fk1/catalog.xml. Imagery from the current survey is located in a folder titled 'INV2019_T02_Wessel'.

CAM01

We did not deploy a camera at this location because mapping revealed an error in the hydrographic chart. The seafloor was flat.

CAM02

High turbidity and strong currents. Forward-facing video didn't show anything so operator was flying blind. Downward-facing video showed moderate densities of massive sponges and gorgonians with some mobile fauna (prawns, fish). Rocky outcrops were interspersed in habitat, with sessile invertebrates growing on them. Likely Xestospongia and Mopsella. Ended after 600 m with a few breaks where camera was too far off bottom to see anything.

CAM03

Slower speed and less turbidity meant the downward-facing video here was clearer than CAM02, but forward-facing video was still unusable. There were scattered epifauna and mixed patches of sponges and octocorals on the shelf. As we approached the edge of the terrace, the epifauna became denser until there were gardens of sponges and octocorals. The edge of the hole feature was quite rocky, more graduand covered in sponges and other sessile invertebrates, including many xestosponges. The bottom of the hole had mixed patches of smaller sessile invertebrates, with only a few gorgonians and barrel sponges and small rocks interspersed throughout the bottom. As we approached the deepest part of the hole, epifauna became even more sparse with an accumulation of fine sediments and very high localised densities of brittlestars.

CAM04

Some initial issues annotating as crew change meant we were looking at forward-facing video which didn't perform well. Scattered epifauna and mixed patches of sponges, octocorals and ascidians throughout the transect, with some indication that sessile invertebrates increased in density down the slow. There were higher densities of barrel sponges in the deeper part of the transect, interspersed with almost barren bits with signs of bioturbation. There were some rocky bits throughout the transect.

CAM05

Video stopped recording for ~5 min during middle of transect (around transition). Start of transect on shelf was flat, muddy, with scattered epifauna and fish. As we approached the hole feature, epifauna increased in density with barrel sponges and larger gorgonians appearing. When the seafloor sloped down, there were more rocks and higher density of sessile invertebrates. The deeper end of the transect had scattered rocks and low densities of gorgonians, ascidians, and sponges. There was a rocky overhang towards the end of the transect. This tow had more fish than any of the others, including several larger red fish, a school of razorfish, and some small squid.

APPENDIX B – LICENSES AND PERMITS

Permit Number PA2019-00006-1

Permitted Activity Scientific Research – using multibeam sonar and towed underwater video camera systems for establishing environmental baselines for Wessel Marine Park for sections 354-354A of the Environment Protection and Biodiversity Conservation Act 1999 and regulation 12.10 of the Environment Protection and Biodiversity Conservation Regulations 2000.

Marine Park/s Wessel Marine Park

Permit Area Special Purpose Zone Habitat Protection Zone as specified in the North Marine Parks Network Management Plan 2018 for the Wessel Marine Park available at the Federal Register of Legislation.

Commencement Date 1 October 2019

Expiry Date 31 October 2019

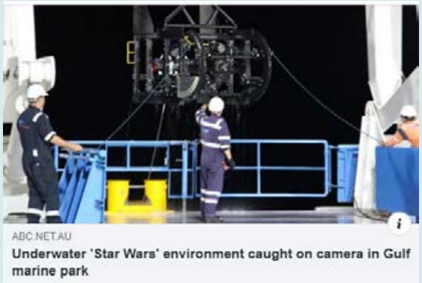
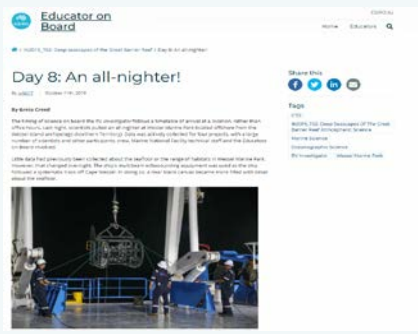
Permittee Organisation: Geoscience Australia Address: Corner of Hindmarsh Ave and Jerrabomberra Ave, Symonston ACT 2609 Phone: 026249 9111 Email: clientservices@ga.gov.au

Permittee Representative Name: Dr Rachel Przeslawski Position: Marine Ecologist Organisation: Geoscience Australia Address: Corner of Hindmarsh Ave and Jerrabomberra Ave, Symonston ACT 2609 Phone: 0262499101 Email: rachel.przeslawski@ga.gov.au

Nominated Vessel/s Name: RV Investigator / Registration number: IMO9616888 Type: Monohull research vessel / Capacity: 60 persons Length: 93.9 m / Tonnage: 6082 (gross)

Activity Conditions This permit is subject to the following activity specific conditions to 1. The Permitted Activity must be undertaken in accordance with the attached application (Schedule 1), except where inconsistent with this permit. PA2019-00006-1 reduce impacts on marine park values. Scientific Research 2. The Permittee must ensure only the following equipment is used: i. multibeam sonar and towed underwater video camera systems

APPENDIX C – MEDIA

Type	Source	URL	Screenshot
News article	ABC	https://www.abc.net.au/news/2019-10-21/csiro-gulf-sea-floor-mapping-science-underwater-world-discovered/11621084	
News video	ABC	https://www.youtube.com/watch?v=C1aBgjtEfbA	
Blog	CSIRO	https://research.csiro.au/educator-on-board/day-6-women-wessel-and-weird-stuff/	
Blog	CSIRO	https://research.csiro.au/educator-on-board/day-8-an-all-nighter/	
Social media posts	GA, Parks Australia, NESP Marine Hub	www.facebook.com www.twitter.com	

www.nespmarine.edu.au

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