National Oceanography Centre, Southampton
Cruise Report No. 66
RRS *Discovery* Cruise DY108-109

6 SEPTEMBER – 2 OCTOBER 2019

CLASS – Climate-linked Atlantic System Science
Darwin Mounds Marine Protected Area habitat monitoring,
BioCAM - first equipment trials
BLT- Recipes: pilot study

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ABSTRACT

DY108/109 was a combined expedition, integrating a series of scientific and technological objectives related to three different projects. The main study area was the Darwin Mounds Marine Protected Area, an area of small cold-water coral mounds in the Northern Rockall Trough, discovered by NOC scientists in 1998 and protected from bottom contact fisheries (mainly bottom trawling) since 2003.

As part of the NERC CLASS programme (Climate-Linked Atlantic Sector Science), the aim was to assess the status of the coral mounds, in order to identify and quantify any long-term changes to this deep-sea habitat. The mounds were surveyed with the Autosub6000 AUV (sidescan sonar), the HyBIS video platform and a series of targeted boxcores, repeating a first round of monitoring efforts undertaken in 2011 (expedition JC060). In addition, two settlement experiments deployed in 2011 were recovered on board.

The second aim of the cruise was to demonstrate and test the latest innovation in survey technology as a potential new method for monitoring this type of seafloor habitat. The new BioCam system, a combined stereo camera and double laser line scanner integrated in the Autosub6000, was developed under the NERC Oceanids Marine Sensor Capital programme. BioCam enabled millimetre-resolution 3D colour reconstructions of the seabed over areas that are an order of magnitude larger than typically covered with conventional visual methods (~30ha/day). This type of technology will revolutionise marine habitat monitoring in the future, both in terms of area covered and level of information obtained.

In addition to these habitat mapping and monitoring activities in the Darwin Mound area, DY108/109 also supported two oceanographic studies of the Rockall Trough. For the NERC-funded project BLT-Recipes, two 24h CTD stations were occupied on the Irish margin, as pilot study to support further work in 2020 and 2021. For the oceanographic part of the CLASS programme, a number of single CTD casts were taken along the “Ellett Line”, while the turn-around of a lander with upward-looking ADCP was attempted. Unfortunately, investigation with the HyBIS platform confirmed that the lander was severely damaged and could not be recovered.

Despite some time lost to weather and unfortunate equipment malfunctioning, the expedition was a success, with 10 HyBIS dives completed (76h seabed video), two sidescan sonar surveys repeated, 20 successful boxcores taken, sieved an analysed on board, one mooring deployed and 48 CTD casts completed. Most of all, the BioCam system performed excellently, staightaway from its first deployment, and acquired two dense grid survey datasets covering ~60ha in total.

KEYWORDS

Cold-water coral, BioCam, CLASS, Marine Protected Area, Darwin Mounds, monitoring, habitat mapping, Autosub6000, AUV, Rockall Trough, Ellett Line, OSNAP, turbulent mixing

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Contents

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1.1. SCIENTIFIC PERSONNEL

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James	Strong	NOC	Habitat mapper/watch leader
Noelie	Benoist	NOC	Biologist
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Jose	Cappelletto	USoton	BioCAM team
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Rachel	Marlow	NMF-MARS	Autosub
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Stewart	Mackay	Master
Philip	Gauld	Chief Officer
Declan	Morrow	2nd Officer
Simon	Willcox	3rd Officer
Gary	McCoy	Chief Engineer
Edin	Silajdzic	2nd Engineer
Gavin	Nicholson	3rd Engineer
Dean	Clements	3rd Engineer
Charles	Fisher	ETO
Graham	Bullimore	Purser
Stephen	Smith	Chief Petty Officer - Scientific

Stuart	Cook	Chief Petty Officer - Deck
Christopher	Peppin	Petty Officer - Deck
Brian	Conteh	Engine Room Petty Officer
Gary	Crabb	Seaman Grade 1A
David	MacKenzie	Seaman Grade 1A
Ryan	Paris	Seaman Grade 1A
Derek	Mackay	Seaman Grade 1A
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Christopher	Keighley	Chef
Jane	Bradbury	Steward
Denzil	Williams	Assistant Steward

2. ITINERARY

Departure Southampton: 6 September 2019, time: 07:20 BST
Arrival Southampton: 2 October 2019, time: 14:15 BST

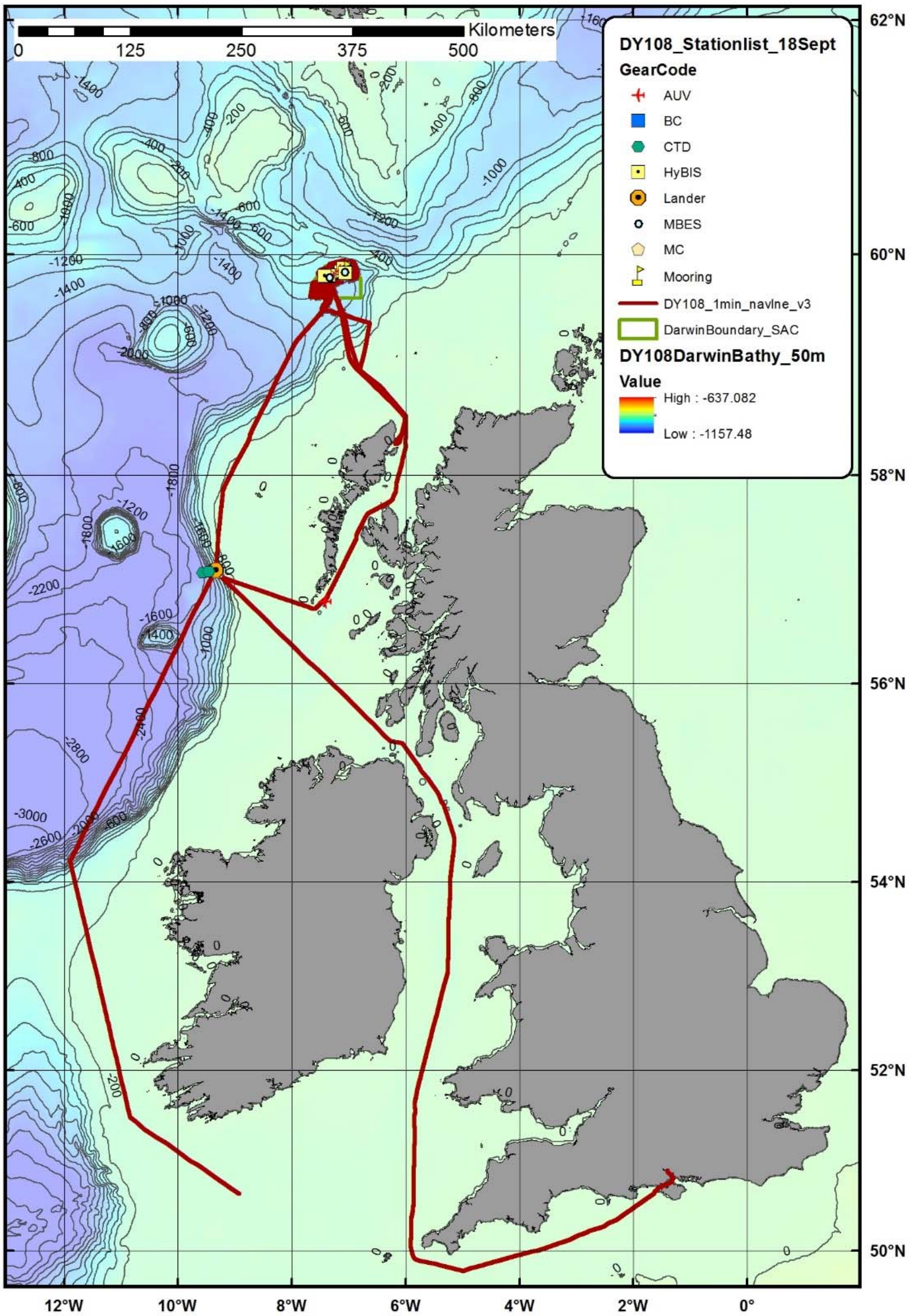

Fig. 2.1 Cruise track chart

3. BACKGROUND AND SCIENTIFIC RATIONALE

Expedition DY108-109 combined research activities for three major NERC projects: the National Capability Programme CLASS, the project BioCAM, part of the OCEANIDS programme, and the NERC-NSF joint project BLT-Recipes.

3.1. CLASS programme: sustained observations and technological development

CLASS (Climate Linked Atlantic Sector Science; https://projects.noc.ac.uk/class/) is the National Capability Single Sector Marine Research Programme funded by NERC for the period 2018-2023. It aims to deliver the knowledge and understanding of the Atlantic Ocean system that society needs to make evidence-based decisions regarding ocean management. CLASS will address key knowledge gaps in the understanding of ocean variability, climate regulation and ocean services, and will assess how the ocean will evolve as a result of climate change and intensified human exploitation.

CLASS is being delivered through the combination of an Atlantic focussed science programme, and a series of activities that underpin Marine Science within the UK: sustained ocean observations in the Atlantic, world class model development, and state of the art technology.

The objective behind the CLASS sustained ocean observations is to create and expand multi-decadal records of ocean parameters that provide insights in the temporal evolution of the Atlantic, from the surface to the seafloor, and from the coast to the deep sea. The programme includes a number of repeat transects across the Atlantic, a number of fixed-point water column observatories, and a number of repeat seafloor & habitat monitoring sites. The latter include sites from the shelf (Western Channel Observatory, Haig Fras Marine Conservation Zone), slope (Darwin Mounds Marine Protected Area, Whittard Canyon & Canyons Marine Conservation Zone) and abyssal plain (Porcupine Abyssal Plain), which will be surveyed on a regular basis (yearly for the WCO and PAP, every 3 years for Haig Fras, every 5 years for Whittard Canyon and every 8 years for the Darwin Mounds).

As part of the science programme within CLASS, the results of those repeat surveys will be used to create an improved understanding of the role and impact of abrupt seafloor disturbances on benthic communities, including their resilience and recovery; looking both at natural and anthropogenic disturbance events. The impact of human activities in the marine environment is extensive and increasing, as countries around the world develop their blue economies. Direct impacts, such as fishing, drilling, mining or the construction of seafloor installations, can have long-term effects on benthic communities, exceeding the natural levels of variability and disturbance those communities are adapted to. However, because direct impacts are often related to specific events or pressures, direct impacts are often manageable through marine spatial planning, such as the designation of fishery closures or establishment Marine Protected Areas. Correct information and knowledge about the long-term evolution and/or recovery of benthic systems following major disturbances hence is paramount to support effective marine spatial planning.

The work during DY108-109 covered two aspects of the CLASS programme: the repeat observation of the status of the Darwin Mounds MPA, and the servicing of one of the essential landers measuring the overturning in the Rockall Trough.

3.1.1. Darwin Mounds *(Brian Bett, Hayley Hinchen, Veerle Huvenne)*

The Darwin Mounds Marine Protected Area (MPA) lies at the north end of the Rockall Trough located approximately 160 km north west of Cape Wrath, Scotland, with depths ranging between 710-1129m. The site is an extensive area of sandy mounds, each of which is capped with multiple thickets of various species of cold-water coral. Each of the mounds is approximately 100m in diameter and 5m high, and distinguished by a 'tail' feature visible on sidescan sonar imagery. Hundreds of mounds lie within the site boundary, but two particularly dense fields of mounds are present to the north east and north west limit of the area (Bett, 2001).

Finding of the Darwin Mounds site (1998)

The story begins on board RV *Colonel Templer* in May 1998[1], with that vessel engaged in a wide area survey of the deep waters of the UK Atlantic Margin, in particular those areas being licensed for deep-water oil exploration, known as the 17th round Tranches (Masson & Jacobs, 1999). The survey was being carried out with NOC's Towed Ocean Bottom Instrument (TOBI), a deep towed sidescan sonar vehicle fitted with a 30 kHz sonar array and a 7.5 kHz sub-bottom profiler. Through Monday 25 to Sunday 31 May 1998, the TOBI vehicle completed four survey lines, the northern ends of which covered the area now known as the *Darwin Mounds*.

At around the same time, the RRS *Charles Darwin*[2] was setting sail from Fairlie to begin phase two of the same wide area survey (Bett, 1999). The two cruises were staggered in time to allow the team onboard the RV *Colonel Templer* to complete a preliminary TOBI map and send an interpretation to the team on the RRS *Charles Darwin* that would guide their seabed sampling and photography efforts. The TOBI science team, led by Doug Masson and Colin Jacobs, reported "individual targets … the profiler shows them to be positive relief features of 2-5 m in height and around 200 m in diameter. They occur at about 1,000 m water depth. Our preliminary interpretation is that they are likely to be biogenic mounds or small mud volcanoes".

Their description continued "region is punctuated by a large number of discrete high backscatter targets, centred approximately on 59° 42.0' N 07° 26.0' W; most are a few to tens of metres in diameter … the strength of the backscatter suggests that they are some form of hard material and may be biogenic mounds … In the extreme north of the area, we mapped a number of 'Haloed' features - circular to subcircular areas of high acoustic backscatter with areas of moderately high backscatter forming ellipses in an apparent down-current (alongslope) direction ... The central part of each target shows small shadows on their far sides indicating that they have some relief" (Figs. 3.1 & 3.2).

Finding coral in the Darwin Mounds West Field (1998)

The team onboard RRS *Charles Darwin*, led by Brian Bett, arrived in the area on Wednesday 3 June, and were able to locate seabed mound targets on the ship's fitted 10 kHz echo sounder. The following

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[1] All data and survey results presented herein were acquired during a wide area survey project undertaken in 1998 on behalf of the Atlantic Frontier Environmental Network (AFEN). AFEN comprises: Agip (UK) Ltd., Amerada Hess Ltd., Amoco (UK) Exploration Company Limited, ARCO British Ltd., BG E&P Ltd., BP Exploration Operating Company Ltd., Chevron U.K. Ltd., Conoco (U.K.) Ltd., Deminex UK Oil and Gas Limited, Elf Exploration UK plc., Enterprise Oil plc., Esso Exploration and Production UK Ltd., Fina Exploration Ltd., Marathon Oil UK Ltd., Mobil North Sea Ltd., Phillips Petroleum Company U.K. Ltd., Saga Petroleum Ltd., Shell U.K. Exploration and Production , Statoil Ltd., Texaco Britain Ltd., Total Oil Marine plc., Joint Nature Conservation Committee, Fisheries Research Services, and the Department of Trade and Industry.

day, Thursday 4 June, the NOC Wide-Angle Seabed Photography (WASP) vehicle was deployed (station 54565#1) and towed across two mounds "Video shows areas of rippled sand, what appear to be *'miniature terraced hillsides'*, and at one point on each mound occurrences of coral". On Saturday 6 June, WASP was deployed (stn 54569#1) in the vicinity of a mound and the video shows "dense populations of xenophyophores". WASP is deployed again (stn 54574#1) "During the run two mound tops are covered on the echo sounder. This run produces the best video yet, which confirms that WASP ran over two mound top features" (i.e. *Lophelia pertusa*, now classified as *Desmophyllum pertusum*, colonies were seen on both mounds).

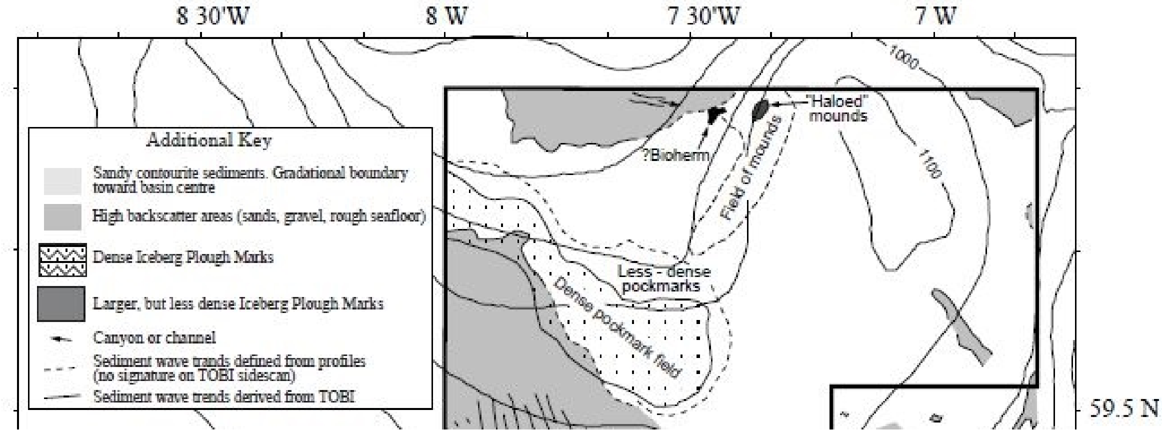

Fig. 3.1 Preliminary interpretation of TOBI sidescan sonar survey from RV Colonel Templer*, note the "Haloed" mounds, the area now known as the* Darwin Mounds *West Field.*

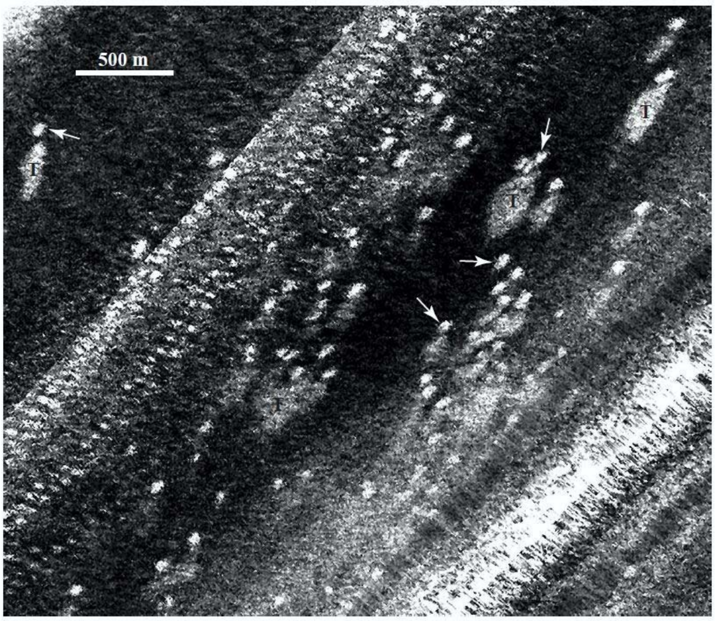

Fig. 3.2 Example of TOBI sidescan sonar image from RV Colonel Templer *showing mounds (arrowed) and tails (T) in the area now known as the* Darwin Mounds *West Field.*

The RRS *Charles Darwin* cruise report concludes that "observations made around the seabed mounds of the 'haloed mounds' region suggest that appreciable biological zonation may attend these features ... aggregations of coral colonies and xenophyophores appear to be associated with the mounds". It was at around this time that the term '*Darwin Mounds*' came in to use. The link between the ship and the mounds continued in the following two years.

Finding coral in the Darwin Mounds East Field (1999)

In 1999, the RRS *Charles Darwin* returned to the area, with a team led by Brian Bett and Colin Jacobs engaged in another wide area survey of the deep waters of the UK Atlantic Margin as part of the DTI's (now BEIS) Strategic Environmental Assessment process (Bett & Jacobs, 2007) [2]. This enabled a brief visit to the area now known as the Darwin Mounds East Field. On Sunday 15 August, "Echo sounding confirms presence of seabed mounds of a similar character to the *'Darwin Mounds'*. WASP is then deployed at Site A as station 55002#1 … Video shows corals and xenphyophores as expected, though the ground does appear a little different to the *'Darwin Mounds'* sites previously studied … A new field of 'tailed' mounds … with associated colonies of the coral *Lophelia pertusa* [*Desmophyllum pertusum*] and populations of the giant protozoan *Syringammina fragilissima* … Depth c. 1050 m … Presence of a number of cobbles and rocks marks the ground as a little different from the western Darwin Mound field".

Finding coral in the Darwin Mounds Mini Field ("pocket mounds" 2000)

In the year 2000, the RRS *Charles Darwin* was back again (Bett, 2007) [3], making an unusual rendezvous at sea with the RRS *Discovery* (III) in the *Darwin Mounds* West Field area on Sunday 23 July. RRS *Discovery* had been on site since 9 July, with a team led by Paul Tyler (University of Southampton) engaged in the first full science cruise to the *Darwin Mounds* area. The ships parted to continue their respective operations, with the RRS *Charles Darwin* returning to the area on Monday 31 July to investigate the *Darwin Mounds* 'mini-field', an apparently isolated pocket of *Darwin Mounds* to the north of the East Field that were imaged during a TOBI survey in 1999[4]. The WASP vehicle was deployed (Site WTS8; stn. 55254#1) "footage obtained … shows the expected presence of *Lophelia* [*Desmophyllum*] and xenophyophores, but also appears to show evidence of trawl damage to the coral communities". An observation that the work onboard RRS *Discovery* (III) was to expand on.

Starting the detailed science of the Darwin Mounds (2000)

The RRS *Discovery* (III) visit to the *Darwin Mounds* in the year 2000 represented the start of detailed scientific investigations at the site (Bett et al., 2001). This effort was funded by NERC, with additional support from two European Union funded programmes, ACES[5] and ECOMOUND[6]. The programme of work encompassed: seabed photography using the NOC SHRIMP (Seafloor High Resolution IMaging Platform) vehicle and *Bathysnap* time-lapse camera system, biological seabed sampling (multiple corer, box corer, Agassiz trawl), geological seabed sampling (piston corer, giant gravity corer), seabed imaging by high frequency (100 and 410 kHz) sidescan sonar, and oceanographic observation by CTD and moored current meters. This detailed investigation, together with the earlier surveys, resulted in

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[2] All data and survey results presented herein were acquired during a wide area survey project undertaken in 1999 on behalf of the UK Department of Trade and Industry. The project was carried out as a joint venture between the George Deacon and Challenger Divisions of the Southampton Oceanography Centre and was managed by Geotek Ltd.

[3] The primary survey data presented herein were acquired during a wide area survey project undertaken in 2000 on behalf of the UK Department of Trade and Industry. The project was carried out as a joint venture between the George Deacon and Challenger Divisions of the Southampton Oceanography Centre and was managed by Geotek Ltd.

[4] RRS Charles Darwin cruise 119A, Principal Scientist Douglas Masson

[5] EU 5th Framework project "Atlantic Ecosystem Study", contract number EVK3-CT-1999-00008

[6] EU 5th Framework project "Environmental Controls on Carbonate Mound Formation" contract number EVK3-1999-00061

numerous scientific publications, most notably Bett (2001), Masson *et al*. (2003) and Wheeler *et al*. (2005).

Bett (2001) provides the first formal publication of the name "Darwin Mounds" and an initial assessment of the comparative ecology of mounds, tails, and the background sedimentary environment, noting the apparent association of *Lophelia pertusa* [*Desmophyllum pertusum*] colonies with mounds, and abundant *Syringammina fragilissima* populations with the mounds and their tails. Masson *et al.* (2003) gives a detailed account of the mounds, the wider seafloor environment, and their potential mechanism of formation, and serves as a synthesis of the 1998-2000 studies. Wheeler *et al.* (2005) revealed that in 2000 the Darwin Mounds had already been impacted by commercial demersal trawling activities, with near-complete destruction of some mounds.

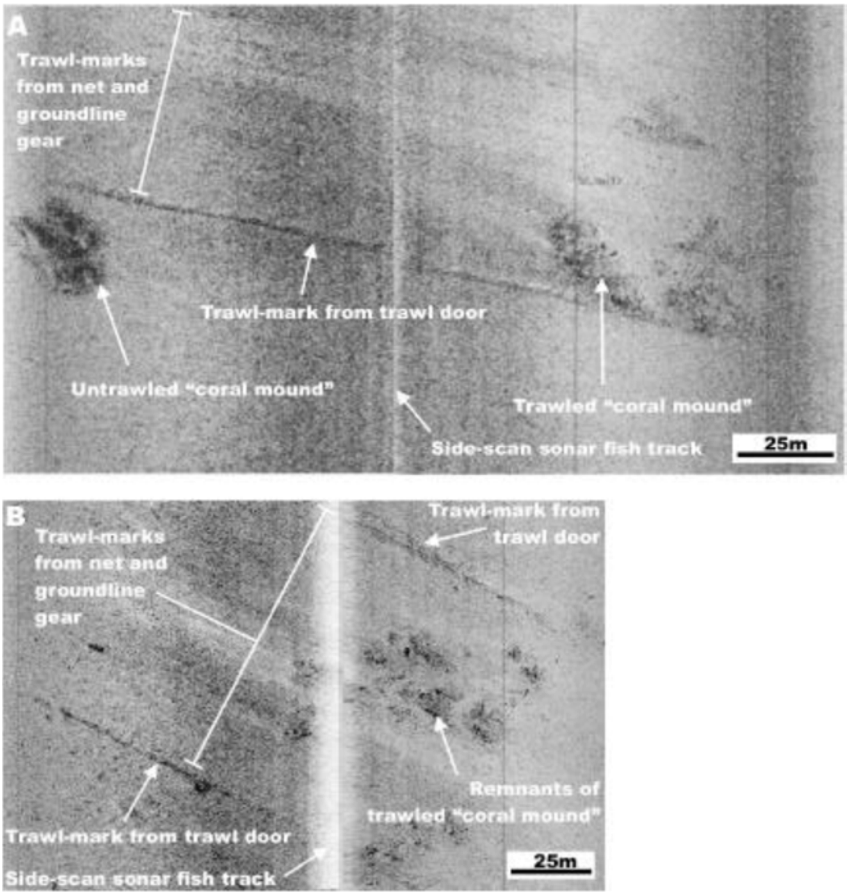


Fig. 3.3 Sidescan sonar imagery illustrating the appearance of a "healthy" coral mound vs. trawled coral mounds. From Wheeler et al. (2005). Dark tones represent high acoustic backscatter

The UK's first deep-water marine protected area

Cold-water corals are considered to form vulnerable marine ecosystems that require protection (UNGA, 2006), and deep-water reefs may be specifically protected under Annex I of the EC Habitats Directive[7]. The high-resolution sidescan sonar and video data that illustrated impacts from bottom trawling in the *Darwin Mounds* were therefore of concern. Those observations, together with the fact that at the time of their discovery, the *Darwin Mounds* were the only example of *Lophelia* [*Desmophyllum*] colonies growing on sandy rather than rocky substrata, were important in driving the

[7] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, O.J. L206, 22.07.92

development of a conservation policy. This was not entirely straightforward (see timeline table below). It started with an emergency closure of the area under the EU Common Fisheries Policy in August 2003, that was made permanent in March 2004 (De Santo & Jones, 2007). The *Darwin Mounds* then became the UK's first offshore MPA, and were subsequently designated as a Special Area of Conservation under the EC Habitats Directive on 17 December 2015. The implementation of these protection measures is managed by the UK's Joint Nature Conservation Committee (JNCC) and Marine Scotland. Unfortunately, evidence from VMS data seemed to suggest that trawling pressure directly before the fisheries closure was high, particularly in the Eastern Darwin Mounds (Davies *et al*., 2007).

Timeline of Darwin Mounds MPA Designation

1998 May	Discovery of the Darwin Mounds
1999 Nov	The "Greenpeace Judgment", UK required to extend Habitats Directive offshore
1999	JNCC begin identifying offshore Natura 2000 sites (Johnston et al., 2001)
2000 Jul	Darwin Mounds revisited, trawling damage detected
2000 Jul	European Commission (EC) requested ICES to provide advice on cold-water corals
2001 early	UK Secretary of State commits to protecting Darwin Mounds as an MPA
2002 May	WWF-UK Report on a Darwin Mounds Special Area of Conservation (Gubbay et al., 2002)
2002 Oct	UK approaches EC regarding protecting Darwin Mounds
2003 Jan	Revised Common Fisheries Policy (CFP) Regulation 2371/2002 – a mechanism for emergency closure
2003 Jun	UK requests action under CFP Regulation 2371/2002
2003 Aug	**Emergency closure** (Regulation 1475/2003)
2003 Sep	Proposal for permanent Regulation submitted
2004 Feb	Emergency closure extended six months (Regulation 263/2004)
2004 Mar	**Closure made permanent** (Regulation 602/2004)
2015 Dec	**Designation of The Darwin Mounds Special Area of Conservation**

Darwin Mounds protection today

The coral thickets qualify as Annex I Reef according to the European Commission interpretation. The occurrence of *Lophelia pertusa* reef as thickets capping sandy mounds is believed to be unique due to the particular geological processes which formed the mounds and the fact that the coral is growing on sand rather than a hard substratum (Masson et al, 2003). The number of thickets vary per mound and may be between one and several metres wide and high.

As well as the designated cold water coral reef feature, the sandy mounds also support significant populations of the xenophyophore *Syringammina fragilissima*, which is a Vulnerable Marine Ecosystem (VME) indicator species that occurs in particularly high densities on the mounds and the tails (Bett, 2001; Hughes & Gooday, 2004). The individual reefs on each mound provide a habitat for various species of larger invertebrates such as sponges and brisingiid starfish.

Continuing the detailed science of the Darwin Mounds (2011)

Following the initial research described above, the Darwin Mounds were not investigated for several years. Only eleven years later, in May 2011, a new visit took place during expedition JC060 on board the RRS *James Cook* (Huvenne, 2011). The cruise was part of the NERC MAREMAP programme, and was also funded by the ERC Starting Grant project CODEMAP (Grant no 258482), with additional support from JNCC and the Lenfest Ocean Program. New technologies were deployed to investigate the coral mounds: the Autosub6000 Autonomous Underwater Vehicle (AUV) was used to produce detailed multibeam and high-resolution sidescan sonar maps of sections of both the Eastern and Western Darwin Mounds, and a commercial inspection class ROV provided imaging capability. The dataset also included a series of boxcores and two piston cores that sampled the entire thickness of two mounds. The analysis of these datasets (Huvenne *et al*., 2016; Victorero *et al*., 2016) taught us that:

- There is a reasonable compliance with the fisheries closure and MPA designation, although occasional violation still occurs. A few trawl marks were observed in the sidescan sonar data, but the density reduced by ~90%.
- The cold-water coral habitat has a low resilience and recovery potential. Heavily impacted areas showed very little recovery and no re-growth, eight years after their protection.
- The precautionary principle and swift development of conservation measures are very important for a successful conservation strategy. The Western Darwin Mounds had received less trawling impact before the closure, and the rapid designation of the MPA meant at least that part of the coral ecosystem was successfully protected. It maintained the same level of live coral occurrence as encountered in 2000.
- Mound initiation started in the early Holocene, with rapid mound development between 10 and 9.7ka BP, and further phases of vibrant coral growth around 8.8ka BP, 6.5 ka BP and 3.4 ka BP. After that, coral growth declined, probably as a result of changing current regimes and a reduced food input towards the corals.
- The use of autonomous and robotic vehicles was key in obtaining the detailed results, and will become the method of choice for future monitoring of deep-sea conservation areas.

A further expedition on board the RRS *James Cook* took place in the area in June 2015 (JC136 – DeepLinks expedition, Howell &Taylor, (2016)). However, the visibility at the seabed was so heavily impacted by the presence of phytodetritus (arrival of the spring bloom), that no reliable imagery work could be carried out.

Extending the detailed science of the Darwin Mounds (2019)

Since the last detailed survey, another eight years have passed, which means the MPA has been closed to bottom contact fisheries for 16 years now. Hence the main aim of the CLASS work during DY108/109 is to assess the status of the Darwin Mounds MPA in terms of coral cover, coral health and community composition.

3.1.2. OSNAP/Ellett Line *(Sam Jones)*

The Scottish Continental Slope Current is a swift, narrow boundary current flowing north along the continental slope of the Rockall Trough, NE Atlantic (Booth & Ellett, 1983). It is found typically between 1000m and 250m depth, with its core along the 500m depth contour. The current contains the warmest and saltiest water flowing northward across this latitude in the sub-polar gyre. Although the net transport of the current is small, because the temperature and salinity are much larger than the average between Scotland and Greenland it is important for the net heat and freshwater fluxes in the subpolar gyre.

The CLASS project is trying to continuously monitor the current as part of the international OSNAP and CLASS programmes whose goal is to try and quantify the role of the subpolar gyre Atlantic overturning circulation in the World's climate. This work is a continuation of a long time series started by David J Ellett, who established a hydrographic transect across the Rockall Trough, that has been monitored on a close to annual basis since 1975 (Holliday et al., 2000; Johnson et al., 2010).

The aim of DY108/109 with regard to the "Ellett Line" part of the CLASS programme is the recovery of a benthic lander system that has been out on the continental slope for one year, and the deployment of an identical new system for the coming year. The landers were built to measure the strength, structure and variability of the Scottish Continental Slope Current.

3.2. BioCam *(Blair Thornton & BioCam team)*

BioCam is a seafloor imaging system being developed at the University of Southampton under NERC's Oceanids Marine Sensor Capital program, grant number NE/P020887/1 (2017 to 2021). BioCam enables millimetre resolution 3D colour reconstruction of the seafloor from high altitudes of between 5-8 m off the seafloor. This is significantly higher than conventional colour imaging systems that typically need to operate at 2-3 m off the seafloor. The increased swath (6-10 m instead of 2-3 m), and ability to image from safer altitudes using faster moving vehicles (1m/s instead of 0.2 m/s) allows BioCam to achieve area coverage rates of up to 40,000 m^2/hour for a single swath transect, which is more than an order of magnitude higher than conventional visual survey methods.

DY108/109 is the first expedition to deploy the new BioCam system, and the first where this type of technology is integrated into the Autosub6000. The main goal is system testing, but at the same time the team aims to map significant proportions of the Darwin Mounds MPA, in a variety of survey patterns, to evaluate the use of this technology for MPA monitoring and assessment.

3.3. BLT Recipes *(Alberto Naveira Garabato, Eleanor Frajka-Williams)*

Since the seminal work of Walter Munk in the 1960s (Garrett & Munk, 1972), oceanographers have believed that the upwelling of cold, abyssal waters that regulates the deep ocean's ability to sequester heat and carbon for decades to millennia (thereby shaping Earth's climate) is driven by centimetre-scale turbulent mixing associated with breaking waves in the ocean interior. Measurements of deep-ocean turbulence over the last two decades, however, starkly contest this scenario, and instead suggest that mixing by breaking waves drives *downwelling* of abyssal waters. Inspired by this conundrum, recent theoretical investigations have developed a tantalising alternative view of the role of mixing in sustaining deep-ocean upwelling. In this new view, upwelling is driven by highly localised turbulence within thin (typically tens of metres thick) layers near the seafloor, known collectively as the bottom boundary layer.

BLT Recipes (Bottom-Boundary Layer Turbulence and Abyssal Recipes; NERC grant NE/S001433/1) seeks to test this emergent new paradigm of ocean mixing, whereby deep-ocean upwelling is primarily driven by bottom boundary layer turbulence instead of by breaking internal waves in the ocean interior - as has been held over the last four decades. The project will do this by: (i) measuring the net mixing and upwelling in a deep-ocean basin through the release of a chemical tracer (SF5CF3); (ii) measuring the contribution of interior processes to mixing and upwelling in the basin with ship-deployed turbulence profilers; (iii) measuring the contribution of bottom boundary layer processes to mixing and upwelling in the basin with specialised moorings and the release of a chemical dye (fluorescein); and (iv) evaluating the relative roles of interior and boundary processes in determining basin-scale mixing and upwelling with a high-resolution numerical model grounded on the observations from (i)-(iii).

The deep-ocean basin in which the experiment will be conducted is the Rockall Trough (RT), in the Northeast Atlantic. The RT is an optimal choice because of its easy accessibility from western Europe, moderate depth (which facilitates frequent sampling with ship-deployed instrumentation), modest mean and eddy flows (which prevent an overly rapid and widespread dispersion of the tracer), and notable tidally-induced deep-ocean turbulence (which generates readily measurable signals of turbulent mixing).

The project is an international collaboration between U.K. investigators (Prof. Alberto Naveira Garabato and Dr. Eleanor Frajka-Williams from the University of Southampton, and Dr. Marie-Jose Messias from the University of Exeter) and U.S. investigators (Prof. Raffaele Ferrari from the Massachusetts Institute of Technology, Dr. Kurt Polzin and Dr. James Ledwell from the Woods Hole Oceanographic Institution, and Prof. Matthew Alford and Dr. Gunnar Voet from the Scripps Institution of Oceanography). It will entail research vessels and instrumentation from both countries.

The fieldwork for BLT-Recipes will start in earnest in summer 2020, however cruise DY108/109 provided the unique opportunity to obtain pilot data in the Rockall Trough. Based on a number of 24h CTD casts, planning of the further activities and expeditions for BLT-Recipes will be improved significantly.

4. OBJECTIVES

4.1. Cruise aims for CLASS

4.1.1. Darwin Mounds re-visit

The overall DY108/109 cruise aim for the CLASS programme was to identify and quantify any potential changes to the habitats and benthic communities in the Darwin Mounds MPA over the last 20 years.

The specific objectives were to:

- Re-map the Eastern and Western Darwin Mounds using AUV sidescan sonar to evaluate trawling intensity & mound extent
- Re-run the ROV video transects from 2011 to study community composition, biomass and distribution
- Video, and if possible recover, marker bouys with settling plates left in 2011 to evaluate colonisation & connectivity
- Deploy a short mooring with sediment trap, CTD and ADCP to quantify physical environment and disturbance regime

Furthermore, the team supported the following collaborative work:

- Boxcoring on/off mound for macrofauna studies (UEdin)
- Megacoring inside/outside MPA for meiofauna studies (NOC/OBE)
- Collection of coral samples for connectivity studies (UPlymouth, UEssex)
- Collection of voucher specimens for taxonomic ID (if possible)

4.1.2. Ellett Line

The overall aim of the CLASS programme with regard to the long-term observations along the Ellett Line is to measure the strength, structure and variability of the Scottish Continental Slope Current.

The specific objectives during DY108/109 were:

- Recover trawl-resistant RTADCP Lander
- Download ADCP Data
- Refurbish lander
- Redeploy or deploy the new, spare lander instead

Additional objectives were:

- CTD profile at lander site
- CTD profiles at other EEL stations

4.2. Cruise aims for BioCam

The DY108/109 expedition represents the first sea trials of BioCam, and the first attempt to collect continuous cover dense grid maps using Autosub6000. The objectives for BioCam can be split into engineering (E) and scientific (S):

- E1: Verify TRL8 (Technology readiness Level 8) of BioCam on Autosub6000 through successful collection of datasets from 1000 m depth at Darwin mounds.
- E2: Collect data for further engineering development of methods to
    a. improve colour and dimensional accuracy of reconstructions and AUV localization estimates

b. automatically classify imagery by topic and develop query algorithms to help understand broader scale spatial patterns,
c. automatically segment features within an image frame

- S1: Collect data regarding the multihectare scale area cover of cold-water coral (GOOS EOV) impact on local ecology
- S2: Collect multihectare scale revisitable dense grid imagery suitable for temporal monitoring on future expeditions
- S3: Upload imagery and metadata to community wide open access, web-based annotation platforms such as Squidle+

4.3. Cruise aims for BLT

BLT Recipes seeks to test an emergent new paradigm of ocean mixing, whereby deep-ocean upwelling is primarily driven by bottom boundary layer turbulence instead of by breaking internal waves in the ocean interior. To support the cruise planning for the 2020 season under the BLT-Recipes project, the DY108/109 aims were:

Specific objectives:

- 24hour yoyo CTD station inside canyon
- 24hour yoyo CTD station outside canyon

Additional work:

- additional individual CTD casts in the canyon

5. NARRATIVE

Thursday 5 September 2019

Final day of mobilisation. All scientists arrived by lunchtime, and the last pieces of equipment, including the equipment brought down by van from Edinburgh, loaded on board. Science meeting at 14:30BST, followed by Safety Briefing and ship familiarisation at 15:40BST. Final unpacking and securing equipment, ready to sail in the early morning.

Friday 6 September 2019

Fair weather, but strong winds, up to Force 6-7 at times, calming down to Force 4 by the evening.

Shore leave finished at 06:00BST, and by 06:45BST the gangplank was taken on board. The ship left the quayside at 07:15BST, and a smooth transit followed for the rest of the day. The EM122 and EM710 multibeam systems were switched on when entering the West Solent, and ran for the rest of the day. The rest of the equipment was set up and prepared. A safety drill with muster took place at 16:00BST.

Saturday 7 September 2019

Fair weather with moderate winds, Force 4, sea state slight (3)

Clocks changed to GMT at 02:00BST. We passed Land's End overnight, and turned north towards the Irish Sea, continuing the transit for the rest of the day. Further equipment was set up and tested, and science introductions presented to colleagues and the ship's crew.

Sunday 8 September 2019

Fair weather with moderate winds, Force 3, increasing to 5 in the evening. Sea state smooth to slight (2-3)

The transit continued smoothly, and the team started to gear up for the first deployments and recoveries of the cruise the next day. At 19:45z the ship was stopped shortly to lower the dropkeel in order to be prepared for the lander recovery the next morning.

Monday 9 September 2019

Partly cloudy with moderate winds, Force 5, sea state moderate (4)

We continued the transit to the ADCP lander site throughout the night (Cruise RV Armstrong AR30-04, mooring number AR30-04-RTADCP1), and arrived at the waypoint 1.5nm SSE of the nominal lander site shortly after 05:00z. Steaming towards the lander site, the release was pinged and an answer received at 05:17z. This was repeated with as we were approaching the lander site, indicating that the lander was still in the right place. However, at the same time an unnamed fishing vessel was spotted, that was on a direct course towards the lander site. Attempts to contact the vessel were made, but no response received. Eventually the vessel changed course slightly, but it was decided safest to wait until this trawler had passed, before the release was triggered (07:11z). Although both releases were triggered and reported they were open, the lander did not appear to come up. Further attempts were made, but at 07:40z the lander was considered stuck on the seafloor and it was decided to leave the lander site.

The ship was moved 0.5nm to the west, for a short dip of the AUV to test its buoyancy. After that we moved to WP004, 1nm SSE of the Ellett mooring at 1800m water depth, for the first CTD of the cruise (DY108-001-CTD01). The CTD was in the water at 09:46z, and reached the deepest point (1780m) at 10:24z. On the way up, water was collected at 1100m, while two USBL beacons and a set of acoustic releases were tested as well). The instrument was back on deck at 11:30z.

We then moved back to the lander location, with the aim to inspect the instrument on the seabed with the HyBIS vehicle (DY108-002-HyBIS50). HyBIS was in the water at 13:30z, and descended to the seabed normally, when at 13:58z, at 423m depth, the lights dimmed and camera connections failed. The HV switch tripped and the vehicle was powered off, and it was brought back on board at 14:22z. No immediate fault was found with the vehicle (it ran well on the deck lead), suggesting a fault in the umbilical or power supply. The issue would require several hours to get fixed, hence we gave up on the idea to inspect the lander with HyBIS, and decided to deploy the new lander at a location 500m NNW along the 750m contour (DY108-003-ADCP01).

The acoustic release was fixed to the slings, and the whole package was lifted off the deck at 15:43z. However, as it was lowered into the water, the floatation with ADCP disconnected and floated free from the concrete base plate. The plate was lifted back on board 16:13z, after which the skilful deck crew recovered the floatation unit and brought this on deck as well (16:47z).

To finish the work for the day, a yoyo CTD cast was added to the programme (DY108-004-CTD02_03), mainly to pressure test the housing of one of the BioCAM lasers, as a potential microcrack had been spotted earlier in the day, which had to be tested before real deployment. The CTD was in the water at 18:25z and lowered & lifted two times, before being recovered on deck at 20:05z.

After this operation we set sail for Mingulay, to run a calibration mission with BioCAM on the Autosub in sheltered waters.

Tuesday 10 September 2019

Overcast with increasing winds from Force 5-7, sea state 3, increasing throughout the day to 5, occasionally 6

We arrived at the Mingulay site just before 4am. The team carried out the last pre-dive checks and toolbox talks, and Autosub was launched at 06:41z (DY108-005-AUV150). The system carried out its calibration mission exactly as planned, and we followed the vehicle on the USBL for the duration of the mission. Autosub was back at the surface by 09:45z, and back on deck by 10:27z. By that time, the wind had picked up, and the sea state started to pick up as well. Everything was secured on deck and we started our transit to the Darwin Mounds. With the wind and tide pushing the ship forward, we made very good speed in the Minch. Traveling north of Lewis was a little more challenging.

Wednesday 11 September 2019

Partly cloudy with strong winds , Force 5-6, sea state 5

We arrived at the Western Darwin Mounds at 09:00z, and set up the ship for a CTD. After assessing the weather conditions, it was decided that the sea state was workable for deployments midships from the starboard side, but not for AUV deployments. The first station of the day (DY108-006-CTD04) was a CTD, also to obtain a sound velocity profile. The CTD was deployed at 09:45z, and recovered by 10:10z. We then moved to a mound position where we attempted to take a boxcore for macrofauna studies. Our first attempt (DY108-007-BC01, in water 12:00z, back on deck 13:14z) was not successful: the core did not trigger. For the second attempt (DY108-008-BC08, in water 13:36z, back on deck 14:40z), the trigger wire was extended a bit and the core was lowered a little faster. Some material was recovered, but it was partly washed out. The core was sieved nonetheless, mainly as background information. A third attempt (DY108-009-BC03, in the water 15:13z, back on deck 16:16z) was considered successful, considering the type of material that we were trying to core (coral rubble in a coarse, sorted sand matrix). Once the boxcore was secured on deck, the ship went on transit to the Eastern Darwin Mounds for our first HyBIS dive (DY108-010-HyBIS51). The EM122 multibeam system and SBP120 sub-bottom profiler were kept running during all operations, but data was only recorded during transits. This approach was followed as much as possible for the next days, although

occasionally data recording was not switched off on station, or the systems developed a fault and had to be re-started.
The HyBIS vehicle was deployed at 19:07z, and reached the seabed at 20:12z. We repeated the ROV dive JC060-117-ROV26, and inspected one of the marker bouys deployed on the seabed in 2011. HyBIS was operated using the active heave compensation on the winch, which improved the quality of the footage massively.

Thursday 12 September 2019

Partly cloudy with a few showers. Strong winds, force 5-6, sea state 5

The HyBIS dive continued smoothly until 02:07z, and the vehicle was back on deck at 02:52z.The ship then transited back to the Western Darwin Mounds to continue the boxcore work there. The first boxcore (DY108-011-BC04) was deployed at 04:48z, and was back on deck by 05:48z with a successful sample. The second boxcore (DY108-012-BC05) was deployed at 06:20z, and came on deck at 07:17z. After that we moved back to the Eastern Darwin Mounds for a third boxcore (DY108-013-BC06), in the water at 09:41z, back on deck at 10:51z. At that moment the weather had improved enough to consider an Autosub deployment, and after some discussion and consultation of the weather charts, it was decided to move back to the Western Darwin Mounds and deploy Autosub for its first science mission (DY108-014-AUV151). This mission aimed to re-survey the high-resolution sidescan sonar mosaic of the Western Darwin Mounds, but also included two hours of additional calibration runs for BioCAM. The transit to the Western Darwin Mounds took longer than expected, as the ship had to sail into the weather, but we managed to come onto station shortly after 12:45z. Autosub was released at 13:25z, and started to dive at 13:32z. We followed the vehicle on the USBL until it reached the seabed, by which time it had drifted ~500m from the waypoint in a south-southwesterly direction (~210°). Attempts were made to communicate with the vehicle, and to update its positional information, but no communication link could be established. Eventually the vehicle's programmed waiting pattern timed out, and it started the mission at 15:45z, however with a ~500m offset compared to the planned location.
From that point we stopped following the vehicle on the USBL, and prepared for the next activity: a HyBIS dive (DY108-015-HyBIS52) to recover one of the marker buoys left in the Western Darwin Mounds during JC060 (JC060-030-Mark02). The system was in the water at 17:32z, and back on deck by 19:27z after a successful mission: the 3.5m-long marker buoy was collected and brought on deck for sampling of the encrusting fauna. During the HyBIS dive, we also kept tracking the AUV on the USBL system, and could see the vehicle pass by at ca. 1km distance.
With the marker buoy safely on deck, we moved back to the Eastern Darwin Mounds to pick up a similar system there (DY108-016-HyBIS54, old station number: JC060-050-Mark04). HyBIS was in the water at 21:21z, picked up the mooring at 22:38z, and was back on deck with the ~5m long package at 23:26z. This mooring had two settling plates fixed to it at 1 and 2 m above the seabed, but unfortunately the upper plate came off during recovery. However, the rest of the package was densely encrusted with a variety of fauna, including cold-water corals, which provided ample opportunities for sampling.
With those two rescue dives under our belt, HyBIS was reconfigured back to its normal video surveying mode, ready for a next deployment. This took up some time, and left us with too little time for another dive before the change of watch. Hence the ship slowly migrated to the first boxcore station ready for deployment in the morning.

Friday 13 September 2019

Changeable with heavy showers, strong winds, force 6 occasionally up to 7, sea state 5 occasionally up to 6

When the coring team came on watch at 4am, conditions had deteriorated, to the point that the boxcoring operations were called off. As the conditions did not improve during the early morning, it was decided to go back to the Western Darwin Mounds and follow Autosub on the last section of its mission, to obtain a better navigation correction. The transit back to the west was slow and uncomfortable, as we were going into the seas, but we arrived well in time to see the vehicle finish its last lines of BioCAM calibrations before leaving the seabed at 11:18z. It came to the surface at 11:53z, but was quite far away from the ship, and although occasionally a Wifi connection could be established, and regular Iridium positions came through, it took ~45 mins and a series of ship moves before the vehicle was spotted in the water. At that moment, the sea state was still too rough for recovery (wave heights around 4 m, occasionally more), and it was decided to delay the operation, as the weather was predicted to improve. The vehicle was left drifting at the surface, and the ship kept following it, until by ~15:30z it was decided to start the recovery. The vehicle was grappled by 16:19z, and was successfully recovered by 16:29z. Data download started immediately, and showed the mission had been a success.
By then the wind started to pick up, and given the predictions of a storm with wave heights of 7-10m, we turned south and sailed back to the Minch to sit out the adverse weather. Swells were already building to such extent that the course of the ship had to be chosen carefully, and the planned multibeam survey along a line parallel to the transit taken on Wednesday 11 Sept into the Darwin Mounds had to be given up. The EM122 system was still kept running and recording, to obtain opportunistic data along the transit.

Saturday 14 September 2019

Stormy weather with rain showers, strong winds, force 8 up to 9. Sea state in Broad Bay (off Stornaway) 3 to 4, calming down during the day

The ship arrived into Broad Bay at breakfast time, and sheltered for the rest of the day. The EM122 multibeam system was switched off once the ship was in the bay. The science team used the time to process the first Autosub data, and a few colleagues presented their work at the daily science meeting in the afternoon.

Sunday 15 September 2019

Partly cloudy with sunny spells, still strong winds up to force 7. Sea state in Broad Bay 3, in Rockall Trough 5 through transit

Following a quiet night in Broad Bay, the ship set sail at 09:23z on course for the Darwin Mounds once again, with the aim to arrive there before 4am the next day. The early start gave the vessel the chance to choose a course and speed that would minimise the discomfort during the transit. Following the compulsory hour of cetacean watch, the EM122 and EM710 multibeam systems, together with the SBP120 sub-bottom profiler were switched on to record data during the transit. However, the sea state was still quite rough, severely affecting the quality of the acoustic data. Despite the conditions, the ship made good progress and we approached the Darwin Mounds working area earlier than expected.

Monday 16 September 2019

Partly cloudy with sunny spells, winds easing to force 5, increasing again to 6-7 in the late afternoon. Sea state easing from 5 to 4, picking up shortly again in the early evening.

We arrived at the Western Darwin Mounds at ~01:30z, but decided to wait for the swell to come down a little before deploying the CTD (DY108-017-CTD05). The system was in the water by 03:02z and back on deck by 04:02z. We downloaded the data and extracted the sound velocity profile in order to update the USBL and echosounder systems. The next operation was an Autosub deployment (DY108-

018-AUV152) with the BioCAM system, aiming to create a dense grid over a section of the Western Darwin Mounds. After the usual pre-dive checks, the AUV was deployed at 06:39z, and started diving at 06:50z. The vehicle was tracked on the USBL and on the tracklink system until it was close to the bottom, but like the previous dive, communications were lost just before it reached the working altitude. Again this meant that no update on position could be sent, and the drift that had occurred during descent could not be corrected. However, this time we had deployed the vehicle 'upstream' of the target waypoint, estimating the expected offset based on the ship-board ADCP recordings. As a result, the Autosub started its mission only ~60m away from the waypoint, which was an acceptable offset. We still had to wait for the vehicle waiting pattern to time out, so it was not before ~09:12z that the actual mission started. Just after that moment, at 09:18z, also the USBL connection with the AUV was lost. Bar a few uncertain pings immediately after that, no further positional information was transmitted and the connection was not restored for the rest of the mission.
We did trust that the vehicle was well underway, so moved to our first boxcore location for the day. The boxcoring operations stayed in the Western Darwin Mounds, with the aim to potentially obtain a few USBL fixes from Autosub, which would improve the Kalman filtering of the navigation. Three boxcores were taken over the course of the day (DY108-019-BC07, DY108-020-BC08 and DY108-021-BC09), all in tail features. The operations started at 10:20z, and cores came on deck at 11:25z, 13:16z and 15:25z. With that last core on deck, the ship was repositioned for the next HyBIS dive (DY108-022-HyBIS54). The vehicle was deployed in worsening conditions at 16:50z, with the bridge reporting some difficulties keeping position against strong winds and surface currents. On the descent, the Scorpio camera failed shortly, but it could be restarted and a good signal was received before the system reached the seafloor. Initially it was difficult to manoeuvre the HyBIS along the correct track, because of the strong currents at depth, but the conditions became better as the night went on.

Tuesday 17 September 2019

Partly cloudy with moderate winds, force 3-4. Sea state coming down from rough to moderate, 5-4.

HyBIS was brought on deck by 02:54z, with the aim to reposition the ship back to the Autosub survey area in an attempt to re-establish USBL connection. However, by 03:30z a flashing light was observed at the surface, and it turned out that the vehicle had sent a first Iridium message at 03:23z. This meant that no end-of-survey USBL position was obtained. The ship then approached the AUV, but it was decided to wait with recovery until first light. Upon investigation it could be concluded that the system had completed its mission correctly, and that the initial time estimates had been slightly wrong.
The recovery operation was started shortly before 06:00z, and by 06:15z the vehicle was back on board. However, the conditions were still quite rough, and the recovery was not easy. The mission was very successful, though, with a full BioCAM photo dataset recovered.
Once Autosub was back on board, we repositioned for a series of boxcores in the Western Darwin Mounds. (DY108-023-BC10, DY108-024-BC11, DY108-025-BC12, DY108-026-BC13). The first core was in the water at 08:16z, and the coring operations finished by 14:43z. After that we repositioned for a new HyBIS dive (DY108-027-HyBIS55), repeating ROV transect 5 from JC060. The vehicle was deployed at 16:29z.

Wednesday 18 September 2019

Mostly sunny with light winds, force 3. Sea state slight to moderate, 3-4

HyBIS continued its operation smoothly till it had to be recovered, and was back on deck by 03:03z. The ship then moved back to the Eastern Darwin Mounds for a couple of boxcores (DY108-028-BC14 and DY108-029-BC15), before the AUV would be launched. The core was deployed at 04:35z and back on deck at 05:40z, before being redeployed at 06:12z and being back on deck by 07:10z.

Then it was time for the next Autosub mission (DY108-030-AUV153). With an uncertain weather forecast, and the assessment that the last two recoveries had been borderline, it was decided to collect the most important dataset first. Given the good results with the BioCAM the day before, another BioCAM dense grid was planned, this time over the Eastern Darwin Mounds. The vehicle was in the water by 09:01z, and travelled as planned to the seabed. During the descent, it was tracked successfully using both the USBL and Tracklink systems. However, once at the bottom, the Tracklink once again lost communications. By that time Autosub had drifted over 400m to the NNW of the foreseen starting waypoint. In an attempt to restore communications, the ship was manoeuvred right over the vehicle, and all shipboard acoustic systems were switched off. Eventually also the power setting on the Tracklink was increased, and a message could be sent to the AUV, which was received just in time for it to make it to the waypoint before the waiting time-out. We followed the system for a while with the USBL to check it was following the correct path, and kept recording USBL positions for the duration of the subsequent boxcoring operations. Two more boxcores were taken in the Eastern Darwin Mounds (DY108-031-BC16 and DY108-032-BC17), with the operations starting at 12:07z and finishing at ca. 15:00z. We then re-positioned for the HyBIS dive of the night (DY108-033-HyBIS56), which was repeating JC060 ROV dive 25. The system was in the water at 16:17z, and apart from the video surveying of the seafloor habitats, it also carried out an inspection of the second marker buoy left in the Eastern Darwin Mound area. Unfortunately some of the video recordings failed or became corrupted, and only the Scorpio stills of the marker bouy were saved.

Thursday 19 September 2019

Overcast with light to moderate winds, force 4, sea state slight, 3.

HyBIS came on deck at 03:04z, allowing the ship to reposition for the first boxcore of the day (DY108-034-BC18). On the way, we picked up USBL signals from Autosub again, providing more tie-points for the navigation corrections that the BioCAM team apply to their data. The boxcore was deployed at 04:17z and recovered at 05:21z. The ETA for Autosub was 07:00z, but given the previous experience, no further boxcoring was planned before the AUV recovery, to allow good navigation data to be collected before recovery. However, this time Autosub took a little longer than planned, and it only came to the surface around 08:30z. It was captured by 09:25z, and on deck by 09:35z. Again it had collected a full BioCAM dataset.

With these data on board, we set off for the Western Darwin Mounds again, in order to complete the boxcore series there. At 11:15z, the first core was deployed (DY108-035-BC19), but it came on deck at 12:19z with only a small sample from one of the mounds. A second core (DY108-036-BC20) was deployed in a tail at 13:32z, and brought a good core on deck at 14:29z. It was decided that there was too little time after that to take any further cores before the HyBIS dive of the night, so the ship slowly made its way to the start point of the HyBIS dive (DY108-037-HyBIS57). There we had to wait until the HyBIS team were on shift (16:00z) before deploying. By 16:25z the system was in the water, for another dive in the Western Darwin Mounds. We repeated part of the JC060 ROV06 transect, but also spent some time in an attempt to find the whale fall that the BioCAM team had found in their dataset. Unfortunately their navigation correction calculations were still running, and there was some uncertainty about the position of the whale fall. We checked out several positions, also using the scanning sonar on HyBIS, but could not find the carcass. Towards the end of the dive some new mounds were inspected, at the same time providing imagery for cross-correlation with the BioCAM data.

Friday 20 September 2019

Sunny weather with light to moderate winds, force 5. Sea state slight to moderate, 3-4.

HyBIS was back on deck at 02:46z. We then repositioned to the last mound boxcore site in the Western Darwin Mounds to try once again to obtain a good core there (DY108-038-BC21). The core was deployed at 04:07, and back on deck at 05:07, but again did not provide a full sample. It was sieved and stored nonetheless.

The next operation was an Autosub deployment over the Eastern Darwin Mounds, in order to re-survey the area with high-resolution sidescan sonar, but during the pre-dive checks no wifi communication with the vehicle could be established. The error required more investigation, and after some debate the mission was delayed till the afternoon. Instead we moved back to one of the mounds that was boxcored before, to try to obtain a megacore there for meiofauna studies. Three attempts were made (DY108-039-MC01, DY108-040-MC02 and DY108-041-M03), but none of them were successful. The second deployment did bring up some fossil coral fragments which were bagged and stored for dating. The coring operations lasted from 09:01z till 12:55z. By that time the error on Autosub had been isolated, investigated and repaired, and the ship moved back to the AUV start position.

However, during the pre-dive checks before the mission, it was established that the batteries had emptied a little too much to allow a 24h mission, so an hour was spent on re-charging. After that, it became clear that the Iridium beacon did not respond. The spare beacon was mounted, but did not respond either, so this issue had to be resolved before the AUV could be deployed. This took a considerable amount of time, but eventually the spare beacon did activate, and the mission was scheduled (DY108-042-AUV154). Autosub was deployed at 16:20z, but then had a fault on the Phins IMU. This is a vital part of the control system, so the mission was cancelled and Autosub was brought back on board at 17:02z. After this we gave up on further AUV deployments for the day: the AUV team was fully out of hours and the real cause for the errors had not yet been established, so it was decided to analyse the problem in the morning and attempt a mission around lunchtime.

We then moved to the HyBIS site for the evening (DY108-043-HyBIS58): the repeat of a WASP video transect from 1999, over a small 'pocket' of mounds north of the main Eastern Darwin Mounds. In 1999, quite a lot of live coral had been found there, and we wanted to check if any of it had survived. HyBIS was deployed at 18:00z, and upon arrival at the seafloor at 18:32z we immediately found an extensive patch of live coral. Along the dive large patches with large colonies of live *Lophelia* and *Madrepora* were found, together with a diverse associated community and the inevitable marine litter. The video transect also passed over several barchans dunes.

Saturday 21 September 2019

Sunny with light to moderate winds, force 4. Sea state slight to moderate, 4 coming down to 3.

As always, HyBIS came back on deck at 02:50z. From there, we started a dedicated multibeam survey with the EM122 multibeam system (DY108-044_MBES01), mapping the wider N Rockall Trough over & around the Western & Eastern Darwin Mound provinces. Multibeam data were collected during JC060, but they were collected under adverse weather conditions, and were of poor quality. The survey continued until 13:30z, after which we went full speed to the start point of the AUV mission (DY108-045-AUV155). We had monitored the system all morning to detect the cause of the problem with the Phins IMU, however the fault had not re-occurred. It was then decided to deploy Autosub but keep watch over her for the whole mission. Autosub went through its pre-dive checks successfully, and was deployed at 15:13z for a sidescan sonar mission over the Eastern Darwin Mounds. We followed the track with the ship through the night.

Sunday 22 September 2019

Sunny, calm weather with light to moderate winds, force 4. Sea state slight, 3.

Autosub performed well throughout the night, but the monitoring continued for the rest of the mission, and this did pay off, because when the vehicle finished the sidescan sonar part of the mission (14:05z), it started to behave erratically. The AUV team was alerted, and the vehicle was followed on the USBL system as it started to come to the surface. As soon as it surfaced, the ship was put in position for recovery, and the AUV was back on board at 15:33z. Investigations later showed that the vehicle had made contact with the seabed, before the collision avoidance system dictated it to come up. The fault was due to an error in the ADCP and the loss of bottom lock.
With the AUV on board, the vessel repositioned for a HyBIS dive in the Western Darwin Mounds (DY108-046-HyBIS59). This dive finished off the repeat of JC060 dive ROV06, and added the investigation of some new mounds that were the target of the AUV mission. HyBIS was deployed at 16:58z and carried out its dive smoothly for the rest of the night.

Monday 23 September 2019
Overcast with low clouds, dense fog in the afternoon and heavy rain showers in the evening. Moderate winds, force 4-5, sea state slight, 4 calming down to 3.
HyBIS was recovered at 02:16z, and the ship was slowly repositioned to the chosen location for the deployment of a short mooring. Before the mooring package went into the water, a calibration CTD was carried out (DY108-047-CTD06). The instrument was in the water at 05:02z and back on deck at 06:20z. Apart from the typical CTD package, the frame also carried three microcat CTDs (of which two would be chosen for the mooring), a USBL beacon from the BioCAM team, and a large number of polystyrene cups to be shrunk under pressure. Once back on deck, the microcat CTDs were checked, and the two systems with most robust values were chosen for the mooring (DY108-048-MR01). They were quickly attached to the mooring string, and the deployment operation started at 07:36z with the deployment of the floatation. By 08:01z the anchor was lifted over the side and the mooring string sank to the seabed. We carried out a triangulation operation to confirm the exact deployment position, which finished at 09:50z. From there we had planned a multibeam survey (DY108-049-MBES02), but it took the ship an hour to get going, mainly because of a miscommunication with the ship's engineering team carrying out maintenance tasks. Eventually, at 10:48z, the survey started, but it could only last till 12:30z, as we had scheduled the next AUV deployment at that time. The AUV team had been busy working on the ADCP problem from the night before, but eventually it was a dense fog that made us delay the Autosub deployment with another day. As alternative programme we deployed the megacore twice on a mound in the Western Darwin Mounds (DY108-050-MC04 and DY108-051-MC05), starting at 13:33z and finishing at 15:47z, but neither of the deployments were successful. It appeared that also the mounds in the Western Darwin Mounds are too hard to core.
With the corer back on deck, the ship went on transit to the Eastern Darwin Mounds for the last HyBIS dive there (DY108-052-HyBIS60), repeating JC060 tracks ROV02 and 03, and exploring an area with an unusual signature on the sidescan sonar maps.

Tuesday 24 September 2019
Slightly overcast, with sunny spells and moderate winds, force 4, occasionally 5. Sea state slight to moderate, 3 to 4
HyBIS came on board at 02:35z, after which we started another multibeam survey (DY108-053-MBES03). The ship started the transit at 03:03z, and started the actual survey at 03:55z. We continued surveying until 11:31z, when we had to return to the Western Darwin Mounds for the next AUV deployment (DY108-054-AUV156). We arrived on station at 12:27z.
In the meantime Autosub had been fitted with the spare ADCP system, and all checks on deck had been completed successfully. The system was deployed at 13:36z; the mission started with a test run for the new ADCP. The vehicle was programmed to surface again to allow data download, and it was

spotted at 15:04z. It started diving again at 15:25z, this time for the real science mission, another dense grid with BioCAM covering part of the Western Darwin Mounds. When it reached the seafloor, an updated start position was transmitted to the vehicle. However, the positional offsets were not estimated correctly, and another correction had to be sent. Unfortunately, the vehicle failed to pick up this second command, even after several attempts. Eventually the waiting pattern timed out, and the mission was carried out with an offset of ca. 65 m to the south.
We continued to track the vehicle for a while at the seabed, before setting of for the last HyBIS dive in the Darwin Mound area. Communications through the Tracklink system continued, and seemed to indicate that the BioCAM system may not have recorded any photographs. However, by the time this was established, a dense fog had come up again, and it was decided to leave the AUV doing the programmed mission, hoping that the error sat with the Tracklink communication rather than with the BioCAM.
Eventually (at ~18:15z) we slowly moved to the start position of the HyBIS dive (DY108-055-HyBIS61). The vehicle was deployed at 19:32z, and reached the seabed at 20:06z. An error in the georeferencing of the OFOP underlay map meant that the planned track was not followed for the first hour, however, as this was an exploratory dive, no essential data was lost. Corrections were made in time to enable the rest of the dive to take place along the planned line.

Wednesday 25 September 2019

Overcast with moderate to strong winds, force 5, occasionally 7. Increasing sea state, 4.
HyBIS was brought on deck by 02:39z, after which the ship was scheduled to check on the Autosub's USBL position. A miscommunication regarding the waypoint at which this check had to happen resulted in an hour's delay, but eventually Autosub was found in the area where it was supposed to be, and the USBL positions confirmed it was working along the correct track. At 05:02z, we then started another multibeam survey with the EM122 (DY108-056-MBES04), mapping the south-eastern part of the MPA. The weather was deteriorating, though, and the data quality was less than the day before. We finished the survey at 13:28z and transferred to the end-point of the AUV mission. Although the ETA for the vehicle at the surface was 15:30, by the time we arrived at the waypoint (~14:30z), Autosub was already on its way up. It reached the surface at 14:44z, and was recovered on deck by 15:54z. Unfortunately it very quickly became apparent that the BioCAM had not collected any photographs. Further investigation the next day revealed that one of the cables connecting BioCAM with the main Autosub system must have failed under pressure during the second descent. The system did come back online during the ascent, but the break in communication meant that the BioCAM did not receive the 'start' command, and hence did not record any images.
Unfortunately, our time in the Darwin Mound area was up, so we went on transit back to the lander site as soon as Autosub was secured on deck. The aim was to carry out the HyBIS dive that we had planned at the start of the cruise, but that had been cut short because of a problem with the vehicle.

Thursday 26 September 2019

Partly cloudy with light to moderate winds, force 4. Sea state calming down to 3.
While the sea state had come down throughout the night, the ship did encounter some strong currents, and a speed of 10kn could not be maintained for most of the transit. Problems with the Autopilot system on the bridge (which had affected the ship from the start of the cruise) also meant the ship slowed down below optimal speed. Hence our arrival at the OSNAP ADCP lander site was delayed by 3 hours. Still, by 13:45z HyBIS was deployed (DY108-057-HyBIS62) for the investigation of the SAMS ADCP lander. The vehicle was at the seabed by 14:28z, and within 15 mins the lander was found, thanks to the forward scanning sonar. The frame was completely silted over, the dome that was to protect the ADCP was ripped off and the ADCP and gimbal system were pulled out of the frame.

Trawlmarks all around, visible on the forward looking sonar, showed the most likely cause of this destruction. We used HyBIS to collect detailed visual evidence, and discussed potential ways of recovery. However, after evaluation, it was decided that there was too much risk and not enough time to attempt a recovery of the system with HyBIS. Hence the position of the lander was recorded, and then HyBIS was brought on deck by 15:42z, so we could continue the transit to the BLT CTD sites.

Friday 27 September 2019

Partly cloudy, good visibility, moderate to strong winds, force 5. Sea state moderate, 4.

The transit continued at an average speed of 8.4kn. We arrived at the first BLT CTD site (DY108-058-CTD07_27), ~1800 m depth inside the submarine canyon, at ~15:30z. The CTD was deployed at 15:50z, and was lowered and raised repeatedly in a continuous operation for 24h.

Saturday 28 September 2019

Partly cloudy, calm weather, light to moderate winds, force 4. Sea state slight, 3.

We continued the 24h CTD work until 16:39z. Around 08:00z the altimeter of the CTD showed some errors, and some of the CTDs were not lowered as close to the seabed as others (target altitude was ~5-7m). However, after two more cycles the altimeter partly recovered, and the work could be continued as normal.

Once on deck, the CTD was serviced (altimeter swopped out, LADCP data downloaded and battery pack swopped out). The data download took much longer than anticipated, so the start of the second 24h CTD (DY108-059-CTD28-34) was delayed until 20:18z. This 24h yoyo cast targeted the canyon rim, at ca. 1400m water depth.

Sunday 29 September 2019

Partly cloudy with occasional showers, light to moderate winds calming down from force 4 to force 2. Sea state slight, 2-3.

CTD work continued throughout the night. However, at 03:43z the CTD unexpectedly made contact with the seabed. It appeared that too much cable had been paid out, because the winch system did not stop automatically at the requested length of wire out. An estimated 15m of wire was deposited on the seafloor. It was carefully winched back up, followed by the CTD itself, and the whole system was brought on deck at 04:24z. All components of the CTD and winch were inspected thoroughly, but luckily no major damage had occurred, and it was decided to deploy the system again for the rest of the 24h slot (DY108-060-CTD35-48). The instrument was back in the water at 05:26z, and continued its operation until 19:52z, when it was brought back on deck.

With that, we finished science operations, and once the equipment was safely secured on deck, the ship set sail to Southampton.

Monday 30 September 2019

Overcast with regular rain showers, strong winds up to force 8. Sea state moderate, 4.

As the transit continued, the science and technical teams started to pack up the equipment, and wrote the necessary sections for this cruise report. Data was backed up and initial analyses completed.

Tuesday 1 October 2019

Partly cloudy with occasional showers. Strong winds easing, force 7 to 5. Sea state moderate to rough, 4-5.

Clocks went forward to GMT overnight, while the transit continued. The ship made good speed, and the rest of the transit progressed well.

Wednesday 2 October 2019

Partly cloudy with occasional showers. Winds had eased, and sea state as well

The transit continued as before, and we picked up the pilot at the agreed time (12:30 BST). We docked in Empress Dock at 14:15 BST, and started the demob immediately.

6. METHODS AND INITIAL RESULTS

6.1. Acoustic mapping & profiling *(Tim Le Bas, Catherine Wardell)*

6.1.1. Shipboard Multibeam Systems: EM122 and EM710

RRS Discovery has two multibeam echosounders, a Kongsberg EM122 (12kHz) and a Kongsberg EM710 (70kHz). Both the systems are hull mounted. Before these systems were started, 1 hour of cetacean watch was done from the vantage point of the bridge, and at no time in that hour were cetaceans observed. The system was then started. Sound Velocity profiles were calculated from CTD profiles and entered into the systems. Most of the cruise was in deep water (>200m) and thus the EM122 was used more frequently. The EM710 was used for times in shallow water such as The Solent (during passage) and The Minch (when sheltering from bad weather).

The EM122 was set to DEEP and to have equidistant sampling. Some depth filters were applied during acquisition as the system often lost lock on the seafloor signal without this. The offsets, lever arms and calibration values, listed in Figs. 7.38 & 7.39 were already inserted into the acquisition system (SIS) from the previous trials cruise DY107.

Processing of the bathymetry data was done using CARIS HIPS and SIPS v9.1 and using a vessel file of zero offsets and no attitude corrections. A "Polpred" correction tide file was applied for the EM122 data, though being a deep water system it was assumed 1% depth errors were considerably higher than tidal range of 1.5m. The data were quite noisy but easily edited by the swath and subset editors. Bad weather did affect the data quality and at times made the data unusable.

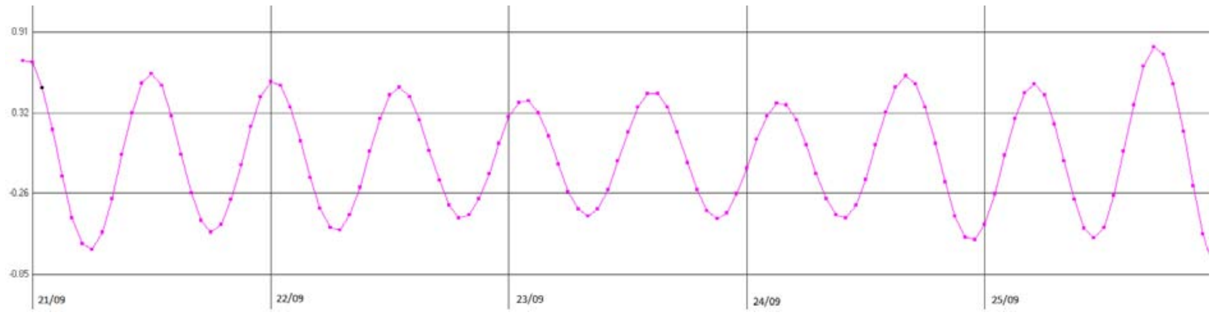


Fig. 6.1 - Tidal data for Darwin Mounds area for period of multibeam data collection

In the region of the Darwin mounds 4 dedicated periods of time were given to EM122 multibeam survey (Table 6.1) and added to some transit lines between waypoints for a near full coverage map.

Table 6.1 – Dedicated multibeam surveys in the Darwin Mounds area

	Multibeam Start	Multibeam End	Duration (hours)
1	2019-09-21 03:29:10	2019-09-21 13:38:21	10:09:11
2	2019-09-23 10:48:33	2019-09-23 12:29:52	01:41:19
3	2019-09-24 03:02:36	2019-09-24 12:12:53	09:10:17
4	2019-09-25 05:01:41	2019-09-25 17:44:09	12:42:28
		Total	33:43:15

Bathymetry grids were made at 100m, 50m and 25m resolution using the CUBE method (IHO S44 Order 2 and using Density and locale). A small amount of interpolation was required to fill small gaps due to poor data, caused by weather. The mounds themselves were not visible on the bathymetry map due to their minimal height in comparison with the error in multibeam depth. Vertical error was estimated to be 5-10 metres (1%).

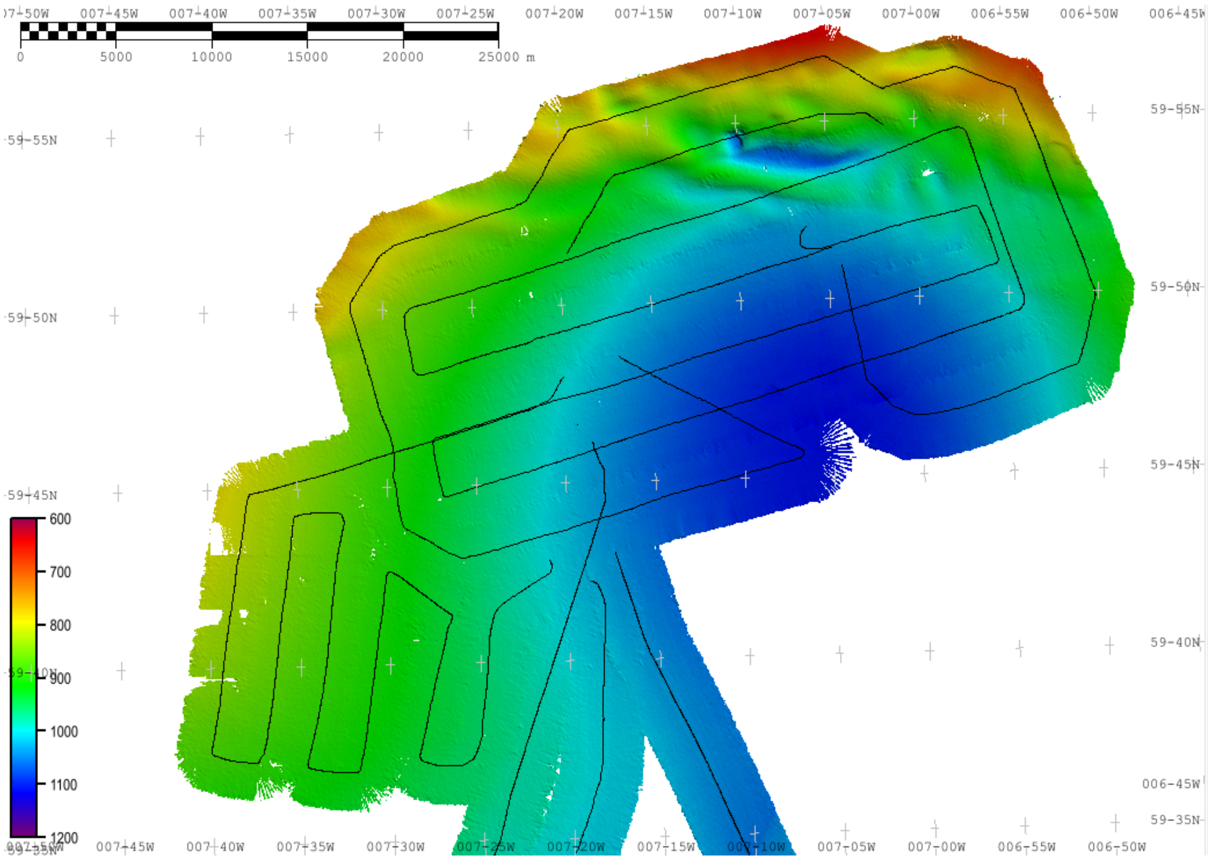


Fig. 6.2 - Darwin Mounds area bathymetry and ship tracklines used for data acquisition.

Multibeam backscatter processing was done in FMGT v7.8.3 Build 1022. As the ship was leaving Southampton the system recorded data very near to the backscatter calibration patch of western Solent (Roche et al., 2018).

Table 6.2 Calibrated backscatter values for the seafloor calibration patch in the W Solent

FMGT processing	Mean Backscatter	Standard Deviation of Backscatter	Frequency kHz
Discovery EM122	-26.9dB	3.5dB	12
Discovery EM710	-15.3dB	2.7dB	70
Calibration Value (Belgica MBES system)	-16.3dB	1.8dB	300

In the area of the Darwin Mounds the EM122 multibeam data was also processed in FMGT to a resolution of 5m. The data was considerably affected by poor weather and consequent aeration under the hull. The resulting mosaic was of poor quality but did seem, in places, to show some correlation with the mound features. The data was attempted to be put through the PRISM software for more controlled processing, but it was found that data format (.all) was not compatible with the "Replay" procedure previously used and so could not be read.

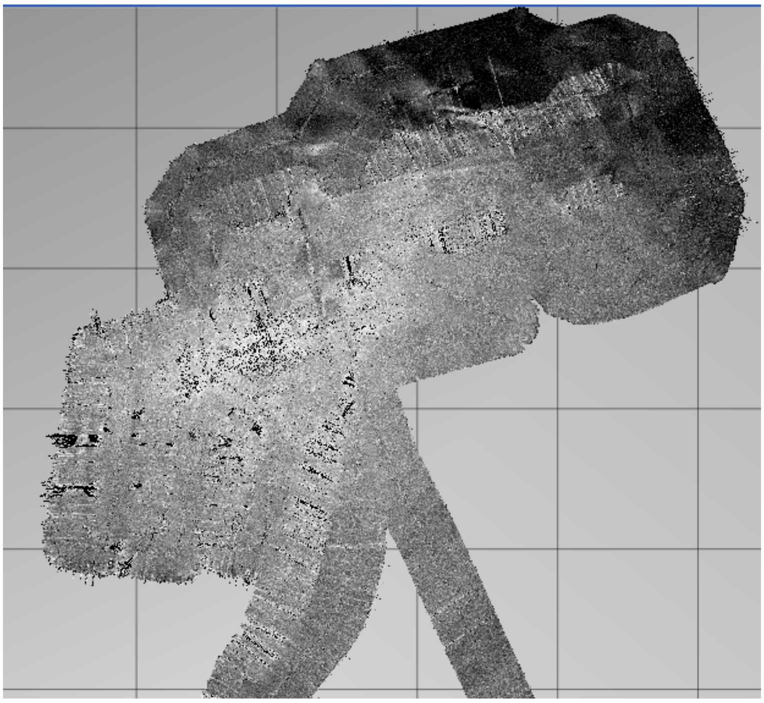


Fig. 6.3 - Backscatter mosaic for Darwin Mounds area. Pixel resolution was 5m

6.1.2. Shipboard SBP System

RRS Discovery has a Sub-Bottom Profiling system as part of the EM122. The system was used periodically. We recorded 148 raw files and converted in 216 segy automatically. No further processing was carried out on the SBP data.

6.1.3. Autosub 6000 Sidescan

The Autosub 6000 system had two dedicated sidescan missions (Table 6.3).

Table 6.3 Overview of the Autosub6000 sidescan sonar missions

	Data Start	Data End	Height (Altitude)	Line Spacing	Area name	Range setting	Total Length
M151	Thu Sep 12 15:44:45	Fri Sep 13 09:01:00	15m	200m	West Darwin Mounds	300m	68.5km
M155	Sat Sep 21 16:33:53	Sun Sep 22 14:02:41	15m	180m	East Darwin Mounds	150m	88.4km

Processing of the sidescan imagery was approached in two ways (compare Fig. 6.4):

- SonarWiz (v7.0)
- PRISM (v4.0)

Sonarwiz processing

Initially the JSF files were imported into SonarWiz but it was discovered that some of the files had gaps or had missing data, and thus these files were put through the **SalvageCorruptZeroes.exe** program. The first file however had a channel count of 0 (instead of 2) and still could not be read.

Conversion to XTF format can be done in three ways:

1. **Discover.exe**, the EdgeTech data replay software. This has the advantages that the user can see each file's imagery on the screen as it is converted but it is slow due to each file having to be loaded individually one by one.
2. **JSF2XTF.exe** This has an advantage that it can do all the files in a single command.
3. **JSFFileConverter.exe** This is similar to JSF2XTF.exe as it has no graphical output but is time-consuming due to each file having to be loaded individually by the user one by one, but is quicker than Discover.exe

The files had the Autosub6000 navigation embedded, of where the system thought it was located. If a better navigation file was available the data could be updated using **NavInjectorPro .exe** (V6, part of the SonarWiz capability).

The import facility in SonarWiz will take both JSF and XTF formatted data but as some data would not be imported in JSF format, XTF format imports were used. A UTM zone of 29N was chosen. Advanced settings options for XTF format were: Turn off Min-Max Amplitude, and using 4096 samples.

When imported into SonarWiz the first task is to calculate the slant-range correction and use Bottom Tracking. The Bottom Track variables were: Blanking 1 Duration 20 Threshold 5, Port Sync, Port and Starboard. Next an EGN (Empirical Gain Normalisation) was built using all files and then applied to the first file. Range was reduced to 120m on both sides and then using the file manager used to make all the other files to be like the first file.

Initially the polarity of the output is white is low backscatter and black is high backscatter. The viewing setting of data overlap were Root Mean Square and drawing mode High resolution. Export of the mosaic is suggested to be done on the standard output as a project Geo-image in 8 bit Erdas Imagine format. Output resolution was chosen to be 0.2m. On import to ArcGIS the polarity of the imagery was reversed so that weak backscatter was dark and strong backscatter was light.

The resulting mosaics are likely to be misplaced due to an incorrect start location but this was corrected by using georeferencing of the new mosaic to the 2011 mosaics which had themselves been georeferenced to match the ROV interpretation from previous cruises.

PRISM processing

High frequency (410kHz) sidescan data was downloaded from the Autosub disks in the .jsf format. These .jsf files were converted into XTF format using the Edgetech Discover 4200 MP 2.03 software; this allowed viewing of the data during conversion. Any files not converted successfully were repaired in SalvageCorruptZeroes.exe software. The settings for replay were set at High Freq: Gain 30dB and TVG 11dB/100m. The XTF format files were then converted into PRISM format (.cdf) using the program reson2prism.

As listed in Table 6.3, two Autosub dives were undertaken collecting sidescan sonar data. For dive M151 the range of the sonar was set to 300m whilst for dive M155 the range was 150m. Due to this variance the data from each dive was treated slightly differently. For both dives the data was averaged and subsampled by a factor of 5. For dive M151 the data files were given 3000 samples per side whilst for dive M155 2500 samples per side were used. The PRISM commands.cfg file contained the following commands:

mrgnav_inertia -i %1 -o %0 -u 0 -r 0.0,0.0 -n navfile.veh_nav
widealt -i %1 -o %0 -p
tobslr -i %1 -o %0 -r0.0576 , res # high freq 110m 6 Hz subsamp 5
edge16 -i %1 -o %0 -m
shade_tobi -i %1 -o %0 -n 1000
filter -i %1 -o %0 -b 1,351 -h -v 1,5000
filter -i %2 -o %0 -b 21,351 -l -v 1,5000
wtcombo -i %2 , %1 -o %0 -c 1,1
restorehdr_tobi -i %1 -h %5
widealt -i %2 -o %0 -h -l 500

Bottom tracking was conducted in PRISM, setting the water column threshold and starting altitude of each file. This was viewed and checked before the navigation was imported from corrected BioCam navigation for dive M151 or extracted from the .cdf files which contain the embedded Autosub navigation for dive M155. A map was created fitting the survey boundaries using the mapcreate function in PRISM. The function prismrange was then used to insert the data and navigation into this map at a resolution of 0.2m. The final map was viewed in ArcMap to check for navigational consistencies and data quality. Due to an incorrect start position the final mosaic is likely incorrectly positioned and so pre-existing data was used to georeference this.

6.1.4. Autosub 6000 SBP

The sub bottom profiler data was collected using the Edgetech 4200 mounted on Autosub 6000 for dives M151 and M155 only. The system was set to 2-16kHz with a 16ms sweep, and was used at an altitude of 15m.

Preliminary data processing was conducted in order to visualise the profiles. The Edgetech software collects the SBP data in .jsf format, this was converted to .sgy format using the programme *jsf2segy* in a Linux environment. I

nput: Edgetech .jsf file, output (-o) .sgy file, options used: -a use the analytic (correlated) sub bottom data rather than the raw data.

The SeisUnix command was then used to visualise the data:

segyread tape=input file.sgy endian=0 | segyclean | sugain epow=5 | sushift tmin=0 tmax=0.3 | supsimage perc=98 > output file.ps

The data was also input into the SonarWiz software. The software allows easy viewing of the sub-bottom profiler data when doing bottom tracking (Figs. 6.5 & 6.6). Once returned to shore alternative software will be used to input the corrected navigation and Autosub altitude to the SBP data.

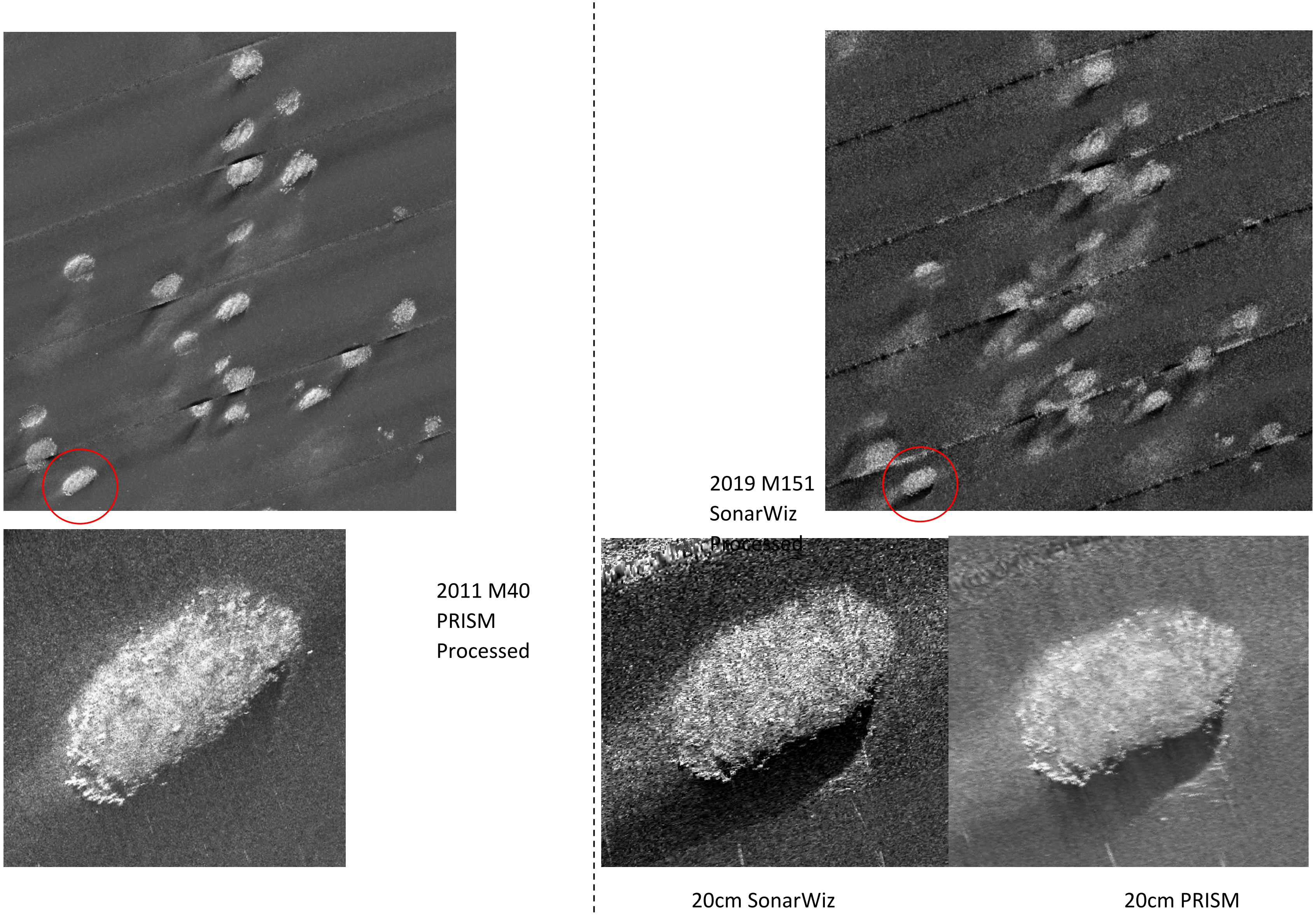


Fig. 6.4 Comparison of 2011 and 2019 Autosub6000 EdgeTech sidescan sonar data, processed using different software systems.PRISM provides sharper results

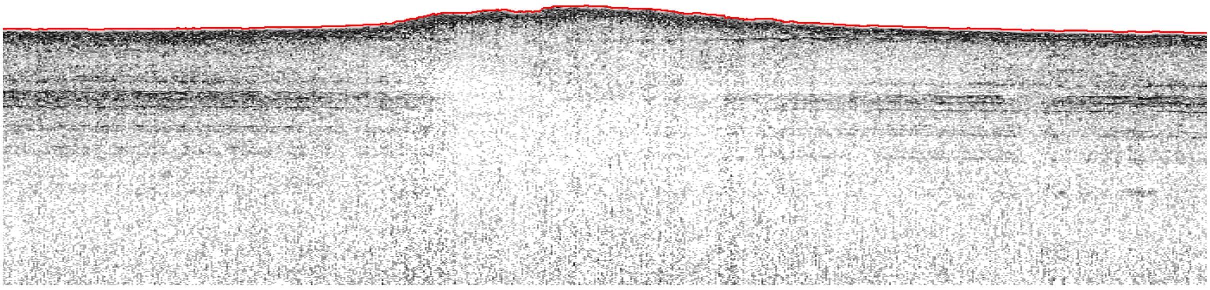


Fig. 6.5 - Sub-bottom profile from East Darwin Mounds area showing a mound. Note the remnant horizontal horizon in line with the seabed under the mound.

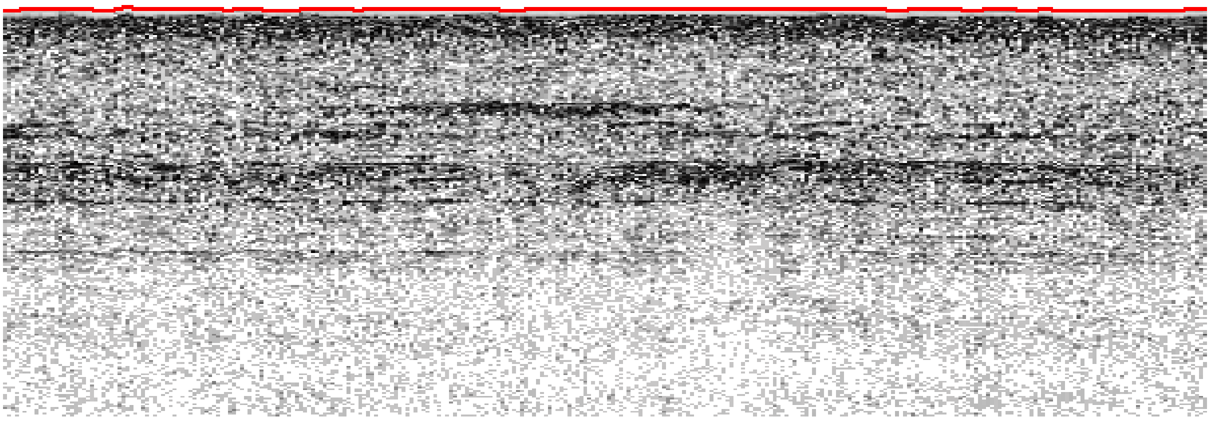


Fig. 6.6 - Sub-bottom profile from East Darwin Mounds area showing a strong reflector about 2m below the seabed surface.

6.2. BioCAM-based mapping *(Blair Thornton, Adrian Bodenmann, Miquel Massot, Jose Cappelletto, Takaki Yamada, David Stanley)*

6.2.1. Description of the device

6.2.1.1. BioCam

BioCam (see specification Table 6.4) is a visual mapping system that collects data for generating 3D reconstructions of the seafloor along the trajectory of an underwater vehicle. The device consists of a stereo camera and logging unit, two line lasers, two LED strobes and two strobe driver bottles. The laser, strobes and cameras are mounted downward looking with an unobstructed view to the seafloor from an altitude of between 4 to 10 meters. A reed switch and a magnet are used for arming the sheet lasers.

Table 6.4: BioCam specifications

Mass	39.6 kg (in air) 17.2 kg (in water)
Power	48 V, 0.8 A (typ.) 1.5 A (peak)
Depth rating	3000 m
Mapping altitude	4 to 10 m
Maximum surge velocity@6m	1.5 m/s
Baseline between camera and laser/strobe	Ideal: 1.5 to 2.0 m (Minimum: 1.0 m)
Swath at 6m	Swath: 8.4 m
Resolution at 6m	3 mm/pixel
Laser wavelength and power	525 nm, 1 W (class 4)
Laser safety switch	Magnetic reed switch

6.2.1.2. Integration on Autosub6000

BioCam was integrated to the underside of Autosub6000 as shown in Fig. 6.7 using a bespoke mounting setup (designed by Richard Austin-Berry, MARS). There is one strobe at the front and one at the back of the vehicle in order to evenly illuminate the images that the camera pair in the main housing acquire. There is a sheet laser at the front and one at the back, with the laser line aligned perpendicular to the direction of motion. A reed switch at the end of a cable is mounted on top of Autosub6000 and a magnet is installed next to it. The reed switch interrupts the power supply to the lasers when the magnet is removed. The magnet is attached to the recovery line, so that the magnet is separated from the reed switch during recovery (designed by Owain Shepperd, MARS). While the laser is normally also disabled through a software watchdog before recovery, this adds an additional layer of safety to guarantee that the laser is turned off during recovery of the AUV.

BioCam is connected to Autosub6000 via a power and Ethernet cable through which Autosub6000 sends the commands for starting and stopping of the data acquisition (command interface implemented Rachel Marlow, MARS). BioCam also sends information including in which data acquisition mode it currently is and how many images have been collected to Autosub6000, which forwards that information via the acoustic modem to the ship (health status monitoring interface developed by Adrian Bodenmann, UoS).

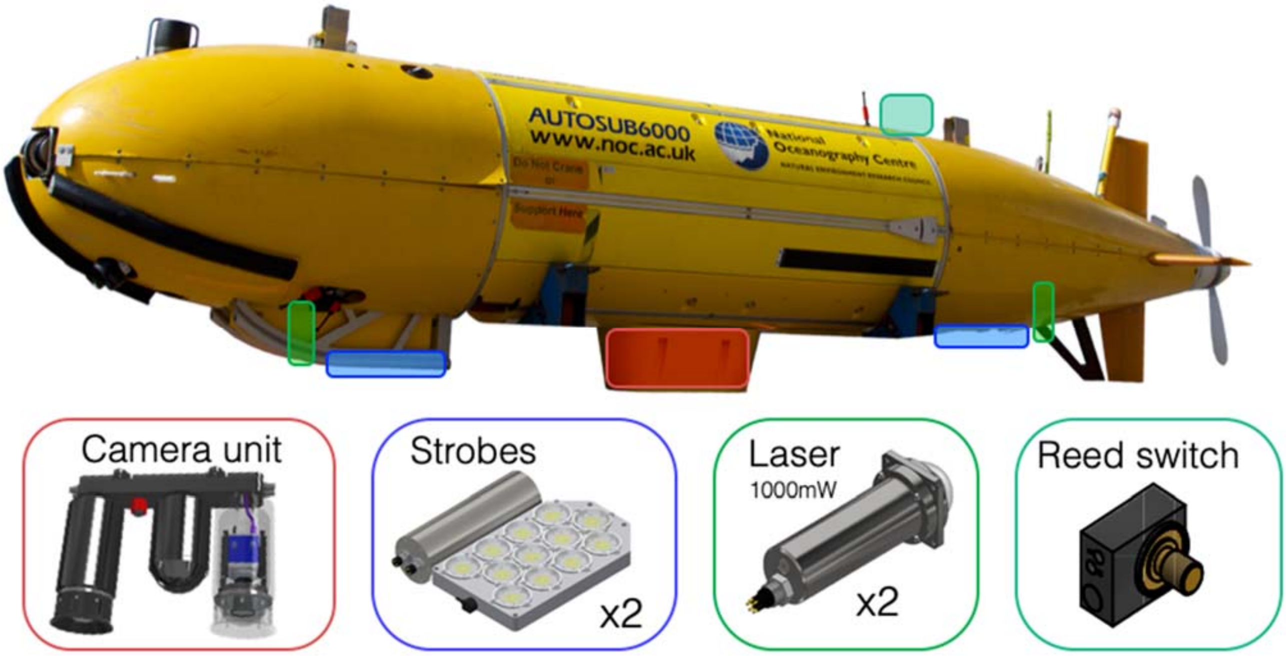


Fig. 6.7 BioCam components mounted on Autosub6000

6.2.2. Method to collect data

6.2.2.1. **Settings for BioCam**

The typical dive phases for a BioCam and Autosub6000 mapping survey are shown in Fig. 6.8.

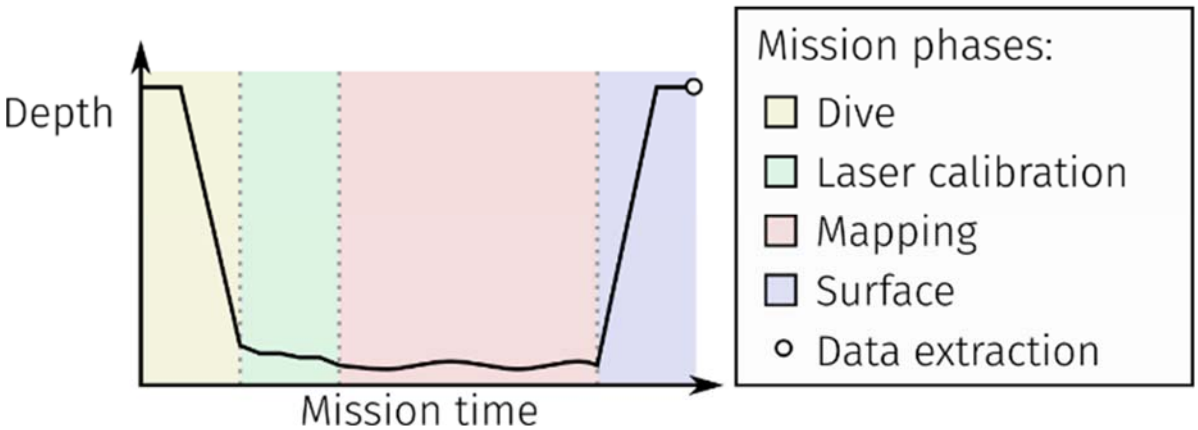


Fig. 6.8: Typical mission phases for BioCam mounted on Autosub6000.

These operations consist of the following sequences:

- Dive: the AUV dives nose-down to a target altitude.
- Laser calibration: during the last portion of descent, both cameras and lasers are triggered to gather imagery at varying depths for a posterior laser plane calibration.
- Mapping: the main portion of the dive is a waypoint following mission at a controlled speed and altitude, gathering strobed and laser images.
- Surface: the AUV comes back to the surface and BioCam stops collecting images.
- Data extraction: once the AUV is on deck, BioCam is connected to the ship network to download its data on a network storage.

The parameters for BioCam / Autosub6000 missions are summarized in Table 6.5.

Table 6.5: Mission parameters for BioCam and Autosub6000

AUV speed	1 m/s
AUV altitude	5 to 6 m
Strobe frequency	0.3 Hz
Strobe duration	7 ms
Laser frequency (mapping)	10 Hz
Laser Frequency (laser calibration)	2 Hz
Laser duration	7 ms
Camera shutter speed	10 ms

6.2.2.2. **Workflow**

Raw images of laser line profiles and colour stereo imagery of the seafloor are captured together with navigation data from the AUV's DVL (velocity), IMU (attitude) and pressure (depth) sensors and USBL measurements of position from the vessel. The information is fused to extract colour and shape information about the seafloor and generate dimensionally accurate 3d reconstructions (Fig. 6.9). Prior to mapping, the raw information collected are corrected for measurement artefacts. The raw imagery is corrected for the wavelength dependent attenuation of light through water and uneven distribution of light from the strobes. The dead-reckoned navigational data of the AUV suffers from unbounded error drift as velocity measurements are integrated to estimate position. To overcome this, the information is fused together with the USBL position fixes, which have a high level of uncertainty but their uncertainty is bounded.

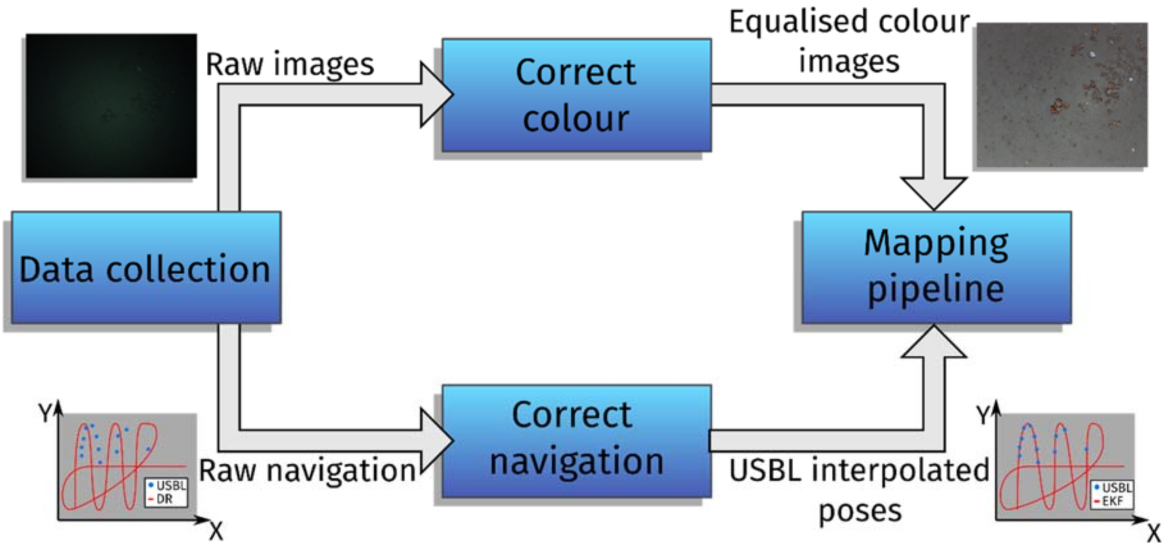


Fig. 6.9 Processing workflow after data collection. The images are colour corrected and the navigation fused to feed a mapping pipeline.

6.2.2.3. **Data processing**

Correction of colour

The parameters of a physics-based model of light attenuation with distance, as measured by the altitude readings of the DVL, are estimated using a regression across the different colour channels measured by BioCam. This is carried out for every pixel in the imagery for each of the dives, since water quality, which affects these parameters, is expected to vary between dives. Using this model, colour data that would be observed without the presence of the water is estimated. To compensate for wide-angle lenses introducing vignette effects (darkening of the edges) and unevenly lit scenes, a grey-world assumption is imposed for each pixel across the entire dataset. This allows evenly lit scenes with the correct relative colour balance to be generated (Fig. 6.10). Camera calibrations are also applied to undistort images, though the distortion with the domed pressure windows used on BioCam's cameras is relatively small, even before applying the calibration.

Fig. 6.10 Example images from the correct colour process.

Correction of navigation

Raw navigation data of internal sensor readings and USBL readings are fused using an Extended Kalman Filter to generate more accurate navigation estimates (Fig. 6.11). This takes into account the position and orientation probability distribution of the vehicle based on the measurement updates. This navigation solution gives position estimates for when each raw image was captured.

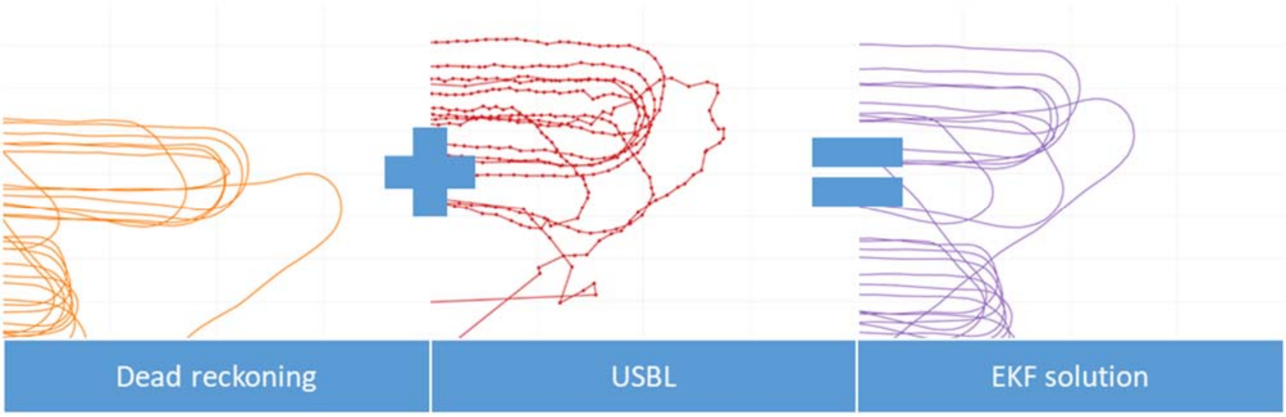


Fig. 6.11 Example data from the correct navigation process.

Laser mapping pipeline

The algorithm described in Bodenmann et al. (2017) is used to generate texture-mapped 3D reconstructions based on images of the laser line profiles and the strobed colour images of the seafloor (Fig. 6.12). Images of laser lines and their respective vehicle poses are processed to extract depth information of the seabed at high lateral and vertical resolution, which is used to form a dense point cloud of the seabed's bathymetry from which a 3D mesh is then produced. Colour data and its associated vehicle poses are combined with the mesh to produce fully 3D, coloured, visual maps of the seabed.

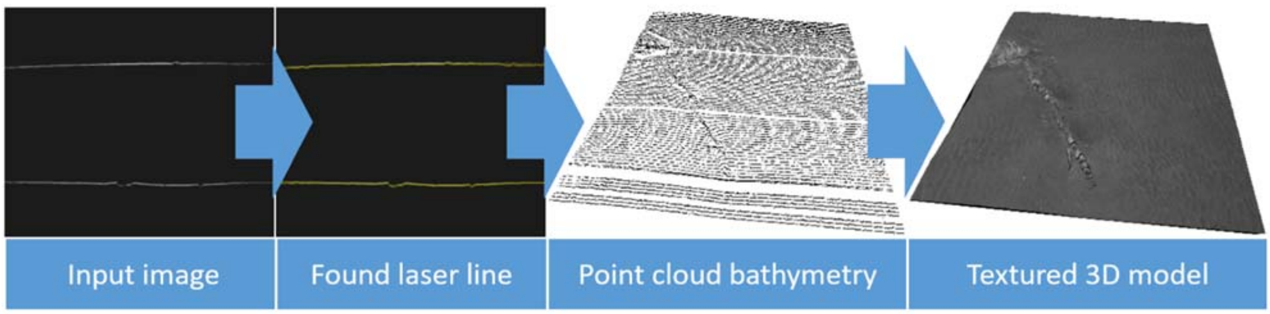
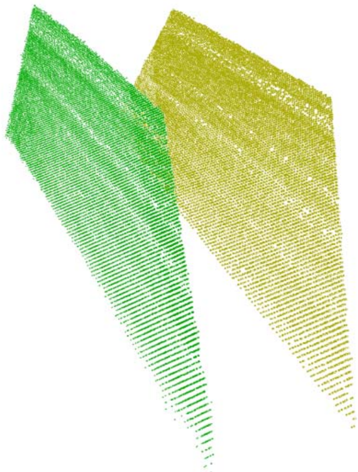


Fig. 6.12 Example images from the mapping pipeline.

On one of the first dives, the system was calibrated to obtain the laser plane equations with respect to BioCam. The calibration procedure consists of acquiring stereo images of the laser line projection from different altitudes. The laser lines are detected in both camera images and triangulated to form two point clouds, one for each laser. Fig. 6.13 shows the point clouds corresponding to the two laser planes. Using a least squares algorithm, the plane equations that best fit the point clouds are determined. The laser plane equations determined based on the data collected during Autosub6000 dive M151 are



$$0.5138x - 0.007583y - 0.010614z - 0.8578 = 0$$

$$0.5546x + 0.023958y - 0.007533z + 0.8317 = 0$$

Fig. 6.13 Results of laser plane calibration. The two laser planes have been correctly detected and its 3D points shown with respect to BioCam coordinate frame.

Stereo mapping pipeline

The algorithm described in Johnson-Roberson et al. (2010) is used to build texture-mapped 3D reconstructions based on strobed stereo pairs. Stereo matches between the images of a stereo pair as shown in Fig. 6.14 are used to generate a 3D reconstruction of the scene. Matches between images of overlapping transects are also used in a SLAM algorithm to improve the navigation solution. Finally, all the points are aggregated into a texture-mapped 3D model of the entire mapped area.

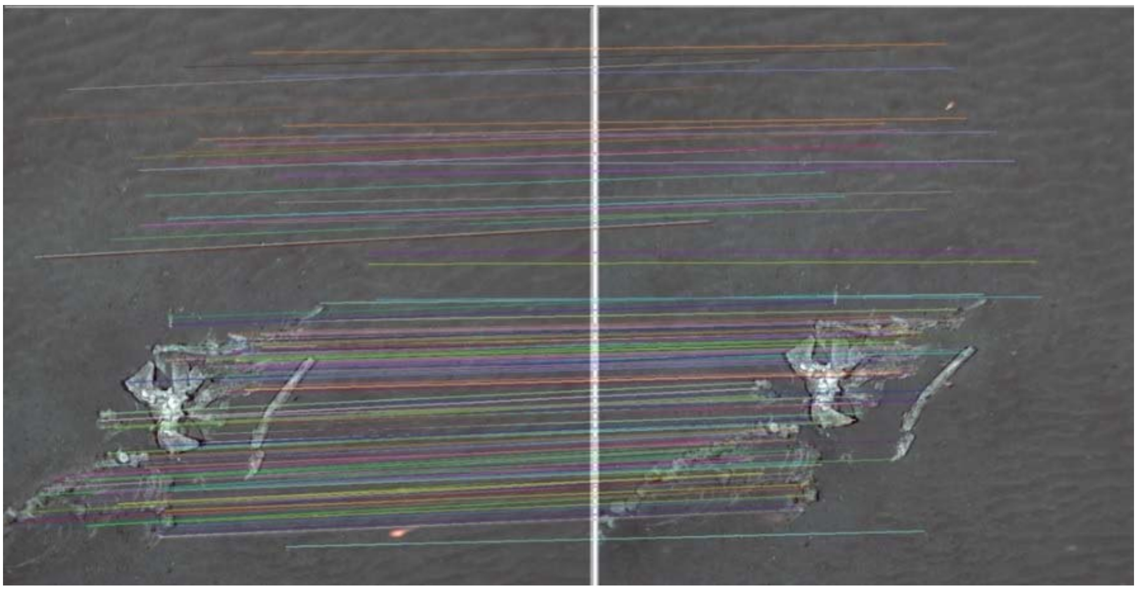


Figure 6.14 Matches detected in a stereo pair of a whale fall

6.2.3. Autosub6000 dives with BioCam

M150: System tests dive

A 2-hour system test was performed at Mingulay reef to confirm manoeuvrability of Autosub6000 with BioCam as it was the first time this setup has been used, and to confirm that there was no interference between BioCam and the side scan sonar.

Table 6.6 M150 dive data

Site	Mingulay Reef		Mission	M150
Ship (deploy/recovery)	In water		On deck	
Date / Time	10/09/2019	06:41:00	10/09/2019	10:27:00
Coordinates (LAT/LON)	56°47.995 N	7°24.839 W	-	-
BioCam (mapping)	Start		End	
Date / Time	10/09/2019	07:11:09	10/09/2019	09:33:28
Coordinates (LAT/LON)	56°48.0749 N	7°24.6848 W	56°48.2166 N	7°25.0130 W
Water depth	206 m		210 m	

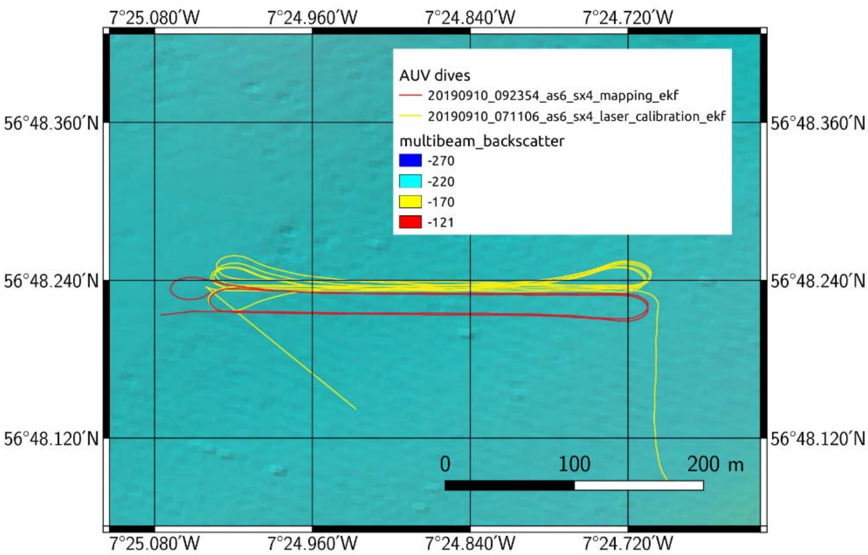


Fig. 6.15 Trajectory for dive M150

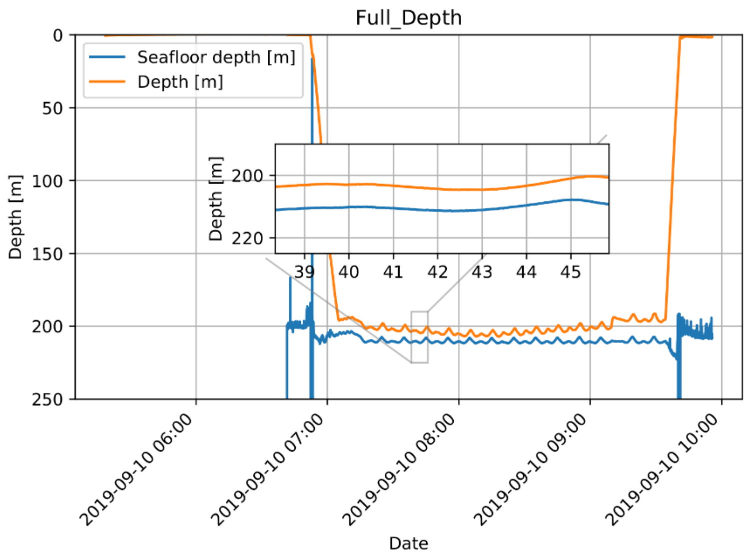


Fig. 6.16 Depth profile for dive M150

M151: Calibration dive

Calibration data was collected following a side scan survey mission at the WDM. The dive consisted in stereo imagery collection of the dual laser line projections from altitudes between 10 to 5 m to determine the precise position and orientation of the laser planes. After this, a mapping test was performed to determine the optimal altitude for data collection. The dual laser planes determined from this dive are used in subsequent data analysis when generating laser bathymetry, and the illumination levels indicated that an altitude of 5 m would be most suitable for future dives.

Table 6.7 M151 dive data

Site	Darwin Mounds (West)		Mission	M151
Ship (deploy/recovery)	In water		On deck	
Date / Time	12/09/2019	13:08:00	13/09/2019	16:29:00
Coordinates (LAT/LON)	59°48.772 N	7°20.0495 W	59°46.6958 N	7°18.3166 W
BioCam (mapping)	Start		End	
Date / Time	13/09/2019	10:13:48	13/09/2019	11:15:34
Coordinates (LAT/LON)	59°49.0020 N	7°22.2424 W	59°48.9932 N	7°22.2190 W
Water depth	989 m		1034 m	

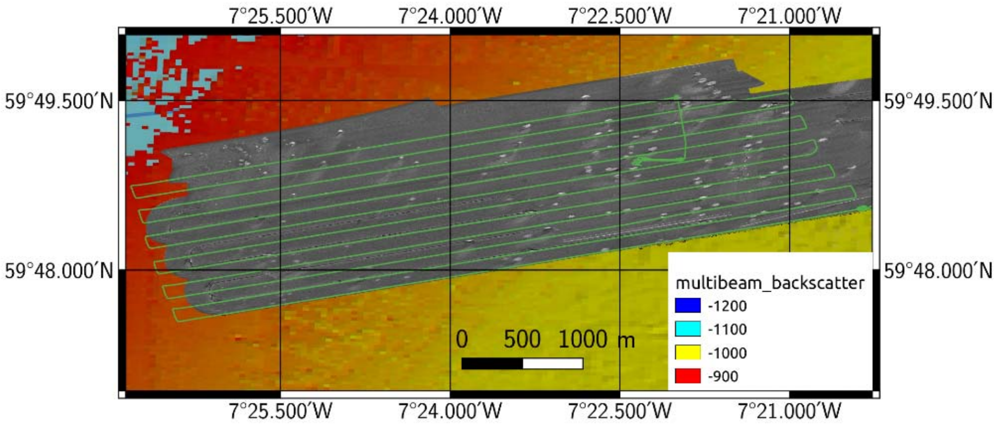


Fig. 6.17 Trajectory for dive M151

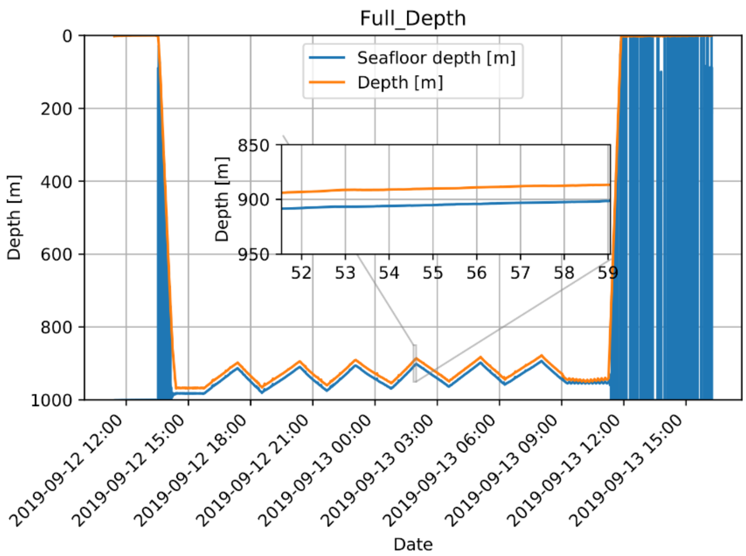


Fig. 6.18 Depth profile for dive M151

M152: Dense grid survey

A 24 h survey was carried out to generate dense grid imagery of a 900 m by 320 m area (29 hectares) in the WDM, covering a total distance of 75.9 km. The survey transects consisted of 80 x 900 m long north-south transects at 4 m spacing mapped from 5 m altitude with 2 cross track lines to improve navigational estimates using visual slam. The waypoints generated followed a modified Zamboni pattern so that the minimum turning circle diameter was set to 32 m, and the vehicle forward velocity was set to 1.2 m/s. Altitude tracking was performed using the altitude range of the Autosub6000's ADCP and the obstacle avoidance sonar on Autosub6000 was not used.

M152 Preliminary outputs

The dive succeeded in collecting millimetre resolution 3D imagery of the targeted region. Data consists of 20,663 strobe illuminated stereo pairs and 605,118 dual laser bathymetry images. A whale carcass was also discovered in the north west corner of the mapped area.

In terms of vehicle performance, the vehicle had difficulties maintaining altitude over the mounds using only its ADCP range. Fluctuations in vehicle velocity are also observed due to bottom currents. The high quality of imagery obtained led to a decision that images could be taken from 6 m altitude in future dives.

Table 6.8 M152 dive data

Site	Darwin Mounds (West)		Mission	M152
Ship (deploy/recovery)	In water		On deck	
Date / Time	16/09/2019	06:39:00	17/09/2019	06:15:00
Coordinates (LAT/LON)	59°48.8725 N	7°21.2556 W	59°48.0975 N	7°21.3423 W
BioCam (mapping)	Start		End	
Date / Time	16/09/2019	09:05:07	17/09/2019	02:51:52
Coordinates (LAT/LON)	59°48.8420 N	7°21.2969 W	59°48.5484 N	7°21.6007 W
Water depth	971 m		986 m	

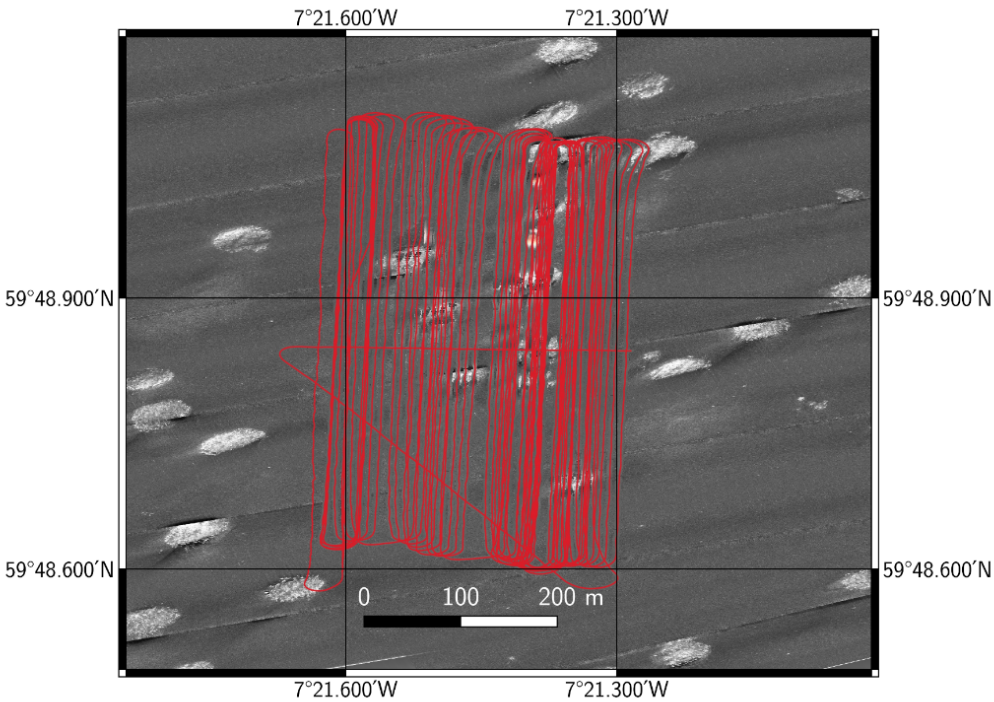


Fig. 6.19 Trajectory for dive M152

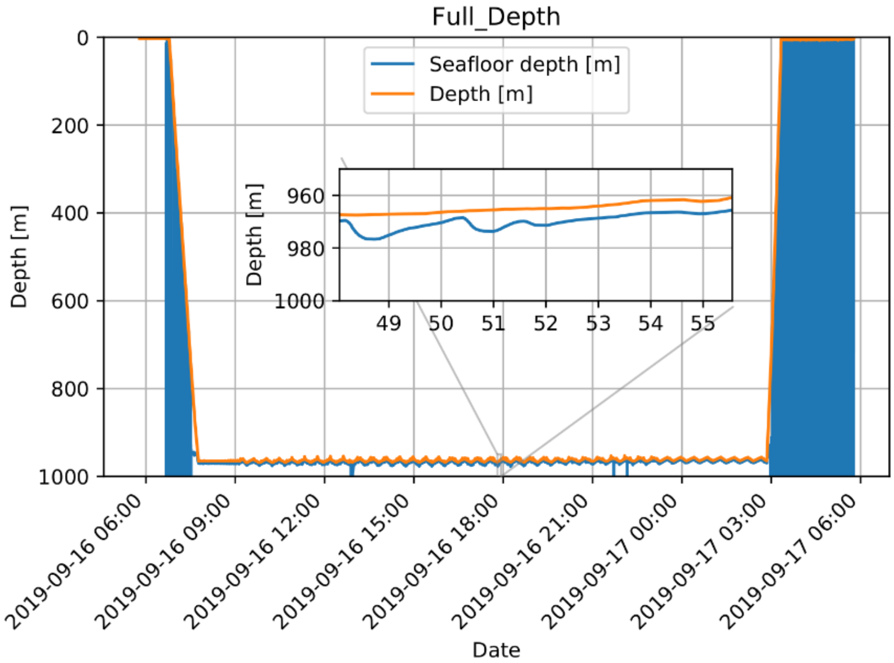


Fig. 6.20 Depth profile for dive M152

M153: Dense grid survey

A 24 h survey was carried out to generate dense grid imagery of a 900 m by 370 m area (33 hectares) in the EDM, covering a total distance of 89.8 km. The survey transects consisted of 94 x 900 m long east-west transects mapped from 6 m altitude, with the same line spacing, cross track lines and Zamboni pattern and velocity as the previous dive. Altitude tracking was performed using the altitude range of the AUV's ADCP.

M153 Preliminary outputs

The dive succeeded in collecting 24,943 strobe illuminated stereo pairs and 723,138 dual laser bathymetry images. The increased altitude did not solve the problem of bottom tracking and so it was decided that the transects should be aligned with the major axis of the mounds to minimize the steepness of slopes encountered in future dives. The currents were stronger in the EDM resulting in large fluctuations in vehicle velocity, and the turbidity resulted in degradation of image quality, and so it was decided that future missions should be run at 5 m altitude.

Table 6.9 M153 dive data

Site	Darwin Mounds (West)		Mission	M153
Ship (deploy/recovery)	In water		On deck	
Date / Time	18/09/2019	09:01:00	19/09/19	09:35:00
Coordinates (LAT/LON)	59°59.299	7°4.452	59°51.39	7°4.75
BioCam (mapping)	Start		End	
Date / Time	18/09/2019	10:53:41	19/09/2019	08:08:18
Coordinates (LAT/LON)	59°51.317 2N	7°4.5324 W	59°51.1224 N	7°4.1605 W
Water depth	1042 m		1049 m	

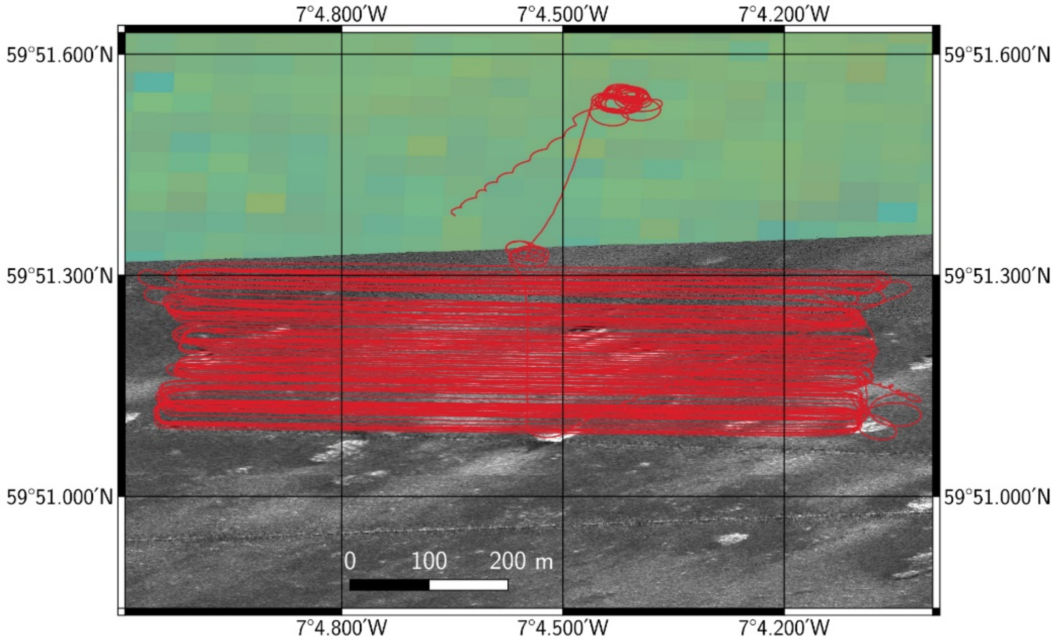


Fig. 6.21 Trajectory for dive M153

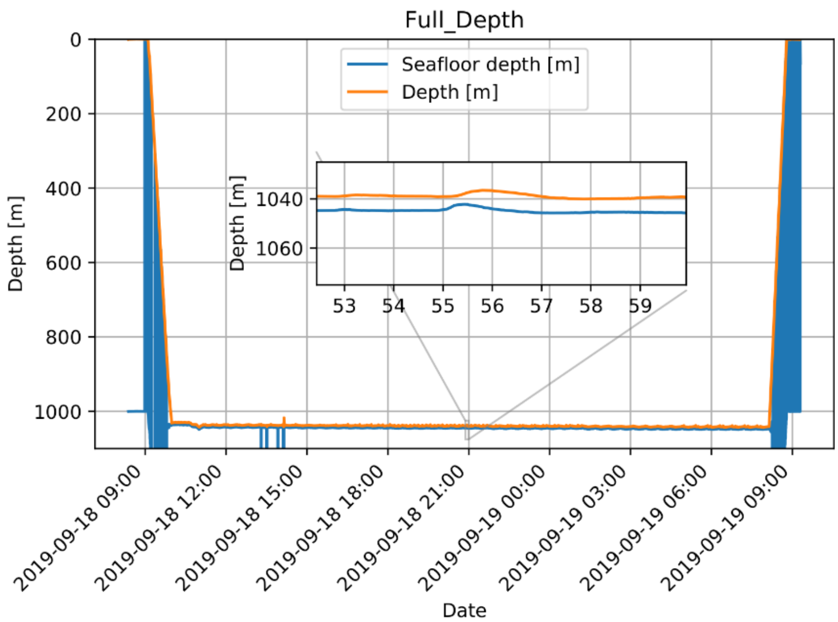


Fig. 6.22 Depth profile for dive M153

M155: System tests dive

A short test mission was planned at the end of a 24 h side scan mission to test different strobe durations on image quality. This consisted of 5 x 900 m long transects at 15, 10, 6, 5, 4 m altitude. Unfortunately, shortly after completing the side scan survey during this mission, the AUV's ADCP failed resulting in a loss of bottom lock and recovery of the vehicle.

Table 6.10 M155 dive data

Site	Darwin Mounds		Mission	M155
Ship (deploy/recovery)	In water		On deck	
Date / Time	21/09/2019	15:04:00	22/09/2019	15:39:00
Coordinates (LAT/LON)	59°51.3694 N	7°9.569 W	59°50.889 N	7°8.375 W
BioCam (mapping)	Start		End	
Date / Time	22/09/2019	14:06:32	22/09/2019	14:55:18
Coordinates (LAT/LON)	59°50.1370 N	7°9.3660 W	59°50.1464 N	7°9.3438 W
Water depth	1041 m		1063 m	

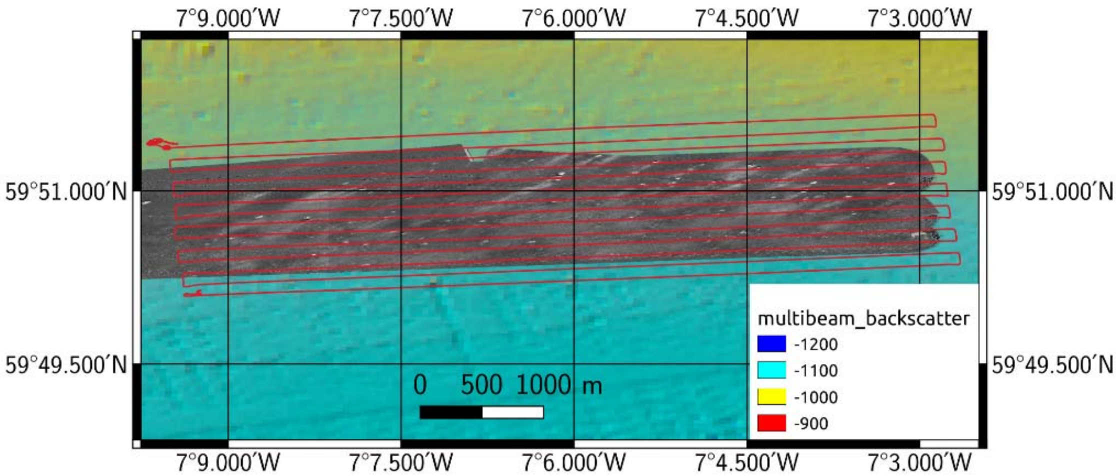


Fig. 6.23 Trajectory for dive M155

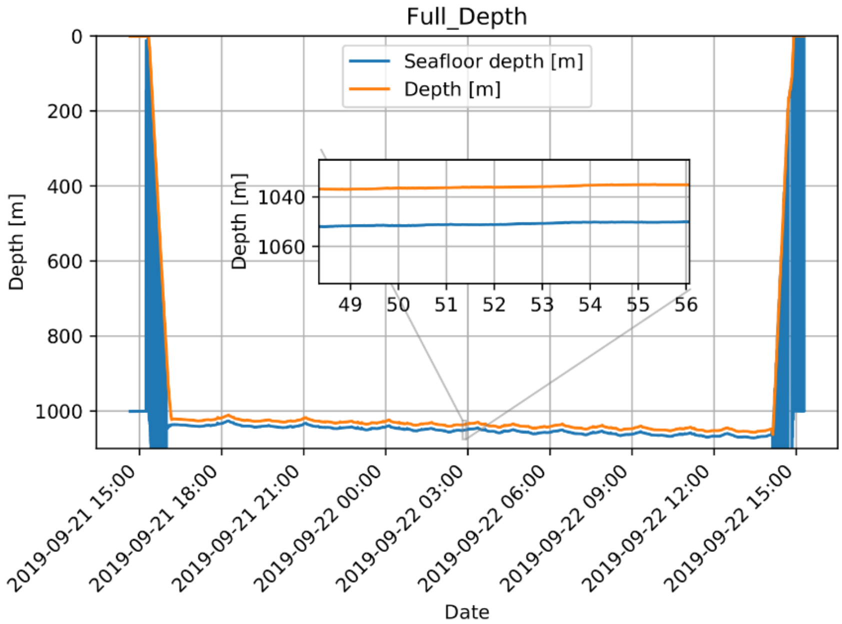


Fig. 6.24 Depth profile for dive M155

M156: Dense grid survey

A 24 h survey was carried out to generate dense grid imagery of a 74 0m by 450 m area (33 hectares) in the WDM, covering a total distance of 90.0 km. The survey transects consisted of 114 x 750 m long diagonal transects mapped from 5 m altitude, with the same line spacing, cross track lines and Zamboni pattern and velocity as the previous dive. The diagonal transects were aligned with the major axis of the mounds to minimize the slope encountered by the AUV.

M156 Preliminary outputs

Failure of a communication cable between Autsub6000 and BioCam meant that the start data acquisition command could not be sent to BioCam to start its observations. The health status monitor system on BioCam that is forwarded via the Autosub6000's modem had alerted the team to abnormal behaviour during the dive. On discussion with the PSOs and MARS team, it was decided not to abort and recover under the circumstance due to the unreliable acoustic communication with the AUV, and the fact that the deployment was late in the shift hours for the teams involved. It was also considered that the health status reporting could be at fault (although it had been reliable on the previous dive) and there was a risk of potentially aborting a successful mission.

Analysis of the mission logs on BioCam indicate that there was an ethernet cable failure between BioCam and the Autosub6000 that prevented the mission start command being sent to BioCam. As a result, no imagery could be obtained. Regarding the vehicle motion, the gentler slopes meant that more accurate altitude keeping was achieved. Analysis of the recorded obstacle avoidance data are inconclusive regarding the effect of 150 m range horizon following using the obstacle avoidance, however, early indications are that this would not cause the same undulating effects seen at lower altitudes of 2 m in past expeditions.

Table 6.11 M156 dive data

Site	Darwin Mounds		Mission	M156
Ship (deploy/recovery)	In water		On deck	
Date / Time	24/09/2019	13:30:00	25/09/2019	15:54:00
Coordinates (LAT/LON)	59°49.426 N	7°21.631 W	59°49.85 N	7°22.666 W
BioCam (mapping)	Start		End	
Date / Time	-	-	-	-
Coordinates (LAT/LON)	-	-	-	-
Water depth	958 m		941 m	

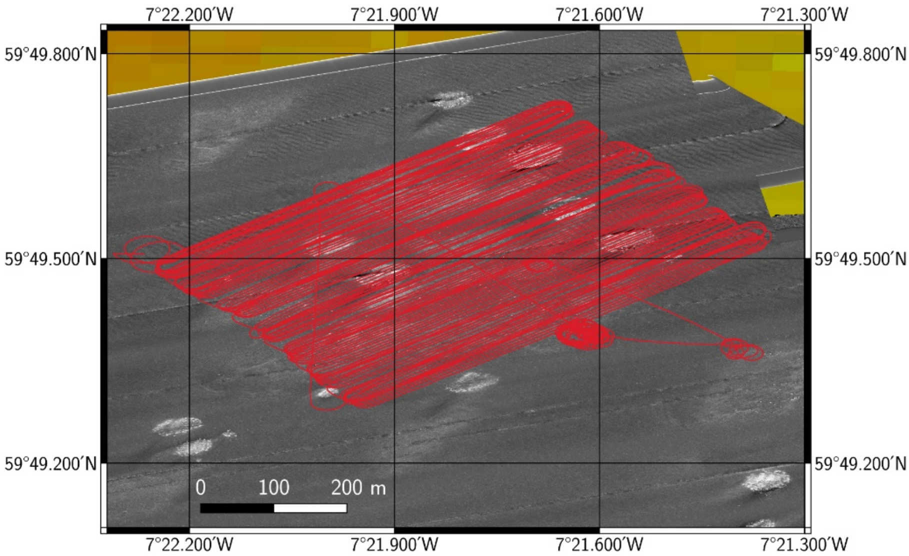


Fig. 6.25 Trajectory for dive M156

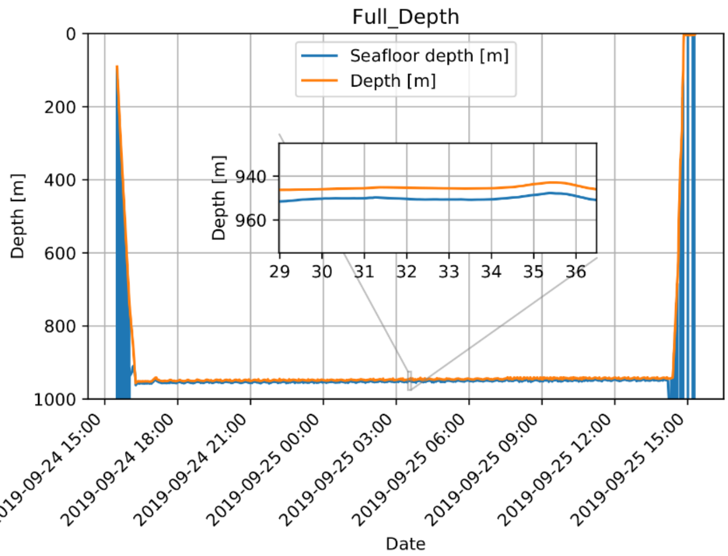


Fig. 6.26 Depth profile for dive M156

6.2.4. Results

The overall numbers of data collection are summarized in the following table:

Table 6.12 Summary of collected data

Dive	M150	M151	M152	M153	M155	M156	Total
Stereo pairs	2678	2392	42,558	50,850	1896	0	100,374
Laser lines	106,042	103,984	1,210,490	1,446,284	45,482	0	2,912,282
Area mapped (hectares)	1	1	29	33	0	0	64
Area cover rate (m^2/h)			16,300	15,500			

6.2.4.1. Three dimensional reconstructions

Stereo and Structure from motion 3D reconstructions

The ACFR stereo pipeline was used to generate 3D reconstructions of the dense grid survey carried out during M152. The map measures 29 hectares, with edge lengths of 900m and 320m, providing broader scale context regarding the distribution of coral and habitats around the 10 mounds covered in the survey area. The details show some of the features that were mapped during the dive.

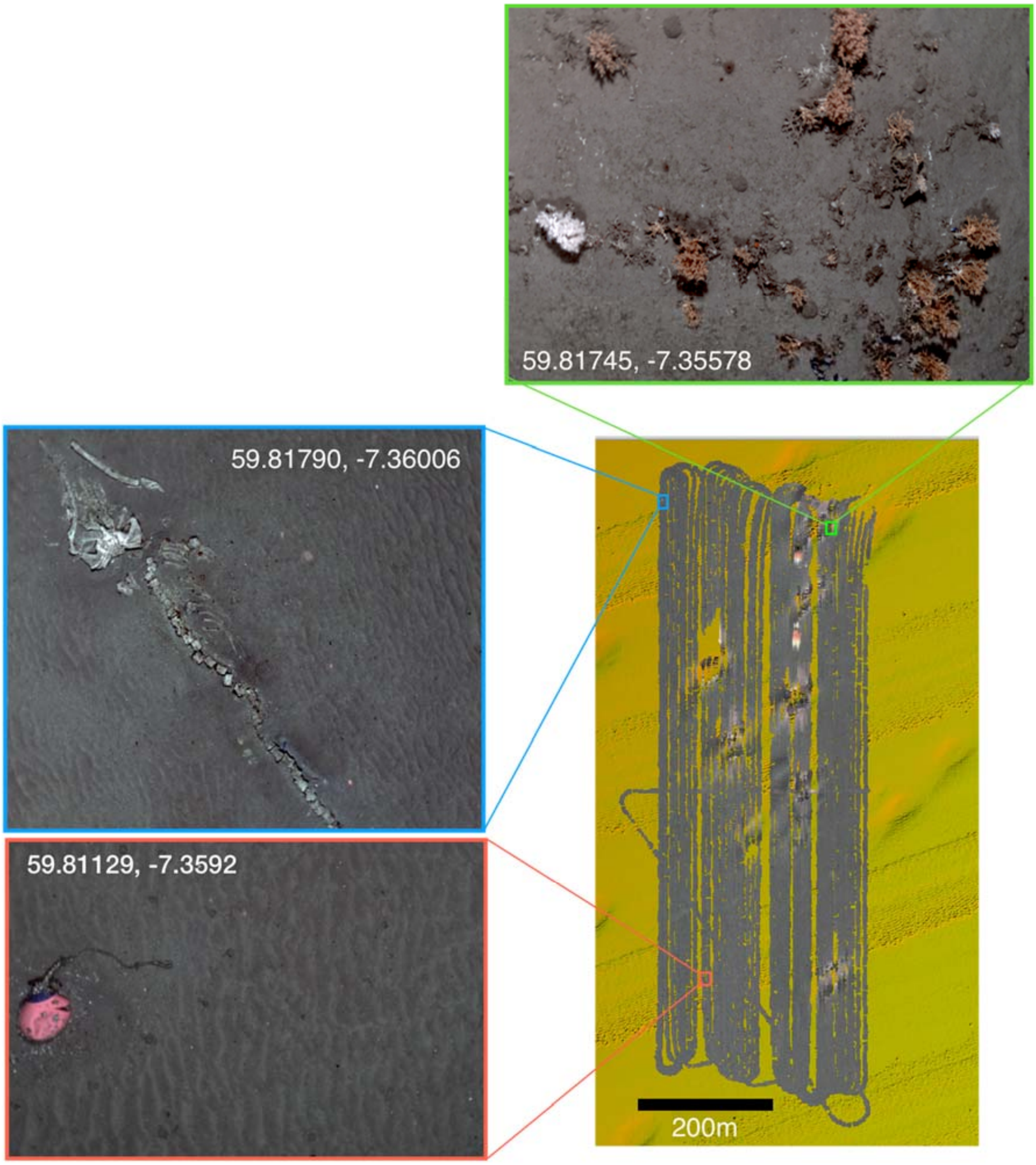


Fig. 6.27 3D reconstruction generated from M152 data

Laser reconstruction

The area around the whale fall (59.8179, -7.3601, depth 956m) that was captured during the M152 dive was reconstructed using the laser scanning pipeline, and the resulting 3D reconstruction is shown in Fig. 6.28. The reconstruction shows that the length of the skeleton is 7.51m, the widest part of the skull is 1.03m and the highest protrusion above the seafloor measures 0.26m

Fig. 6.28 3D reconstructed of the whale carcass using laser scanning bathymetry.

6.2.4.2. **Structure from motion**

By applying Structure from Motion (SfM) using commercially available software (Agisoft Metashape from https://www.agisoft.com/) to several subsets of undistorted colour and greyscale images, it was possible to obtain detailed 3D reconstructions of the whale carcass (Fig. 6.29) and some coral patches (Fig. 6.30).

Fig. 6.29 3D reconstruction of whale carcass using SfM.

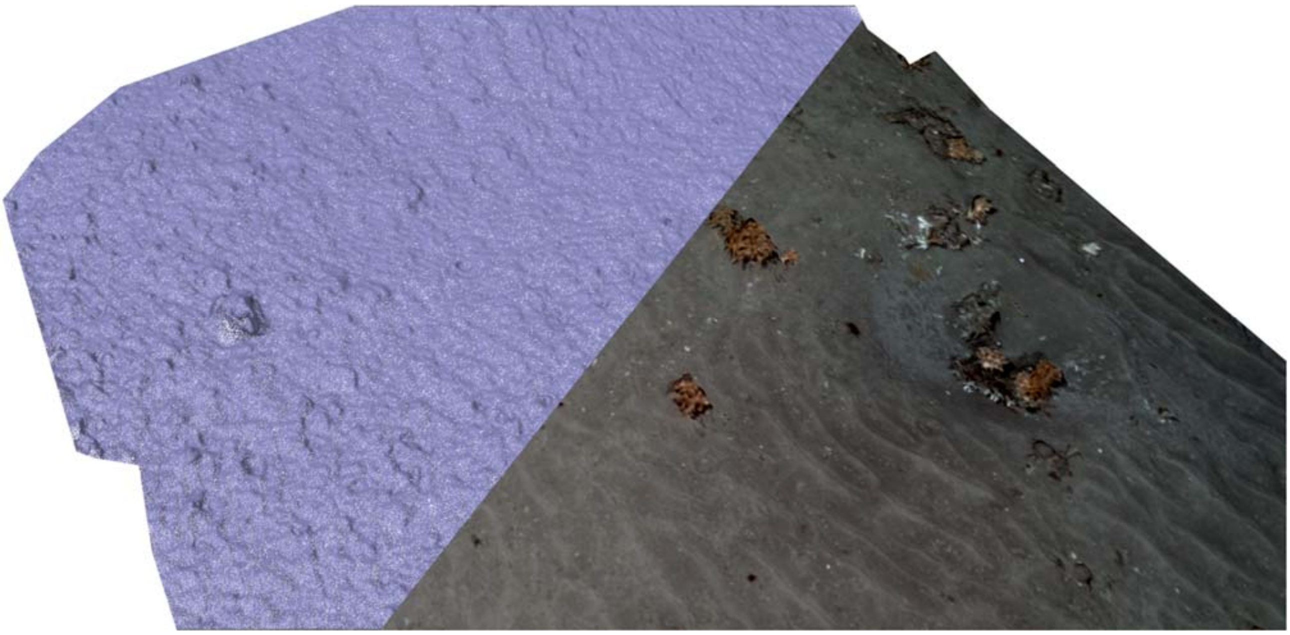


Fig. 6.30 3D reconstruction at the base of a coral mound located at 59.8139 -7.357. The left side shows the mesh generated from the imagery and the right side shows the texture map overlayed onto the mesh.

6.2.4.3. **Results of unsupervised clustering and image query**

The broad scale distribution of habitats on the seafloor was characterised using an unsupervised clustering algorithm currently being developed at the University of Southampton (Yamada et al., in preparation). The algorithm uses a deep-convolutional neural network to learn representative features from each image dataset. The learnt features are used to:
organise entire datasets into similar classes, or topics
enable specific images to be queried based on their similarity index.

Unlike supervised learning methods, this approach does not require human labelled training data, which form a major limitation for supervised approaches. It instead relies on features that are intrinsic to the image dataset itself, allowing broad scale spatial patterns to be identified within expedition relevant time frames. While the clustering separates images into similar regions and can highlight spatial patterns, the ability to query the dataset by presenting the algorithm with a series of images showing specific features of interest allows humans to look for spatial patterns in a more targeted way. The criteria used by the algorithm are the same as that used for clustering, and so require no human labelled training data.

Fig. 6.31 shows the 21,279 colour images collected during the M152 dive organised according to the topic, and the t-distribution Stocastic Neighbourhood Embedding (t-SNE) feature space generated that has been extracted from the data and used as a basis for clustering and image queries. The topics identified are meaningful to human experts, and broadly align with rippled sand (blue, light blue, orange, green, beige), xenophyophores (lime green, red), and coral (pink, purple). The vast majority of images show rippled sand, highlighting the fact that spatially discretising the survey area would not provide a representative overview of each habitat that exists at this site. Fig. 6.32 shows the spatial distribution of these classes alongside a series of representative summaries for each image topic identified by the algorithm.

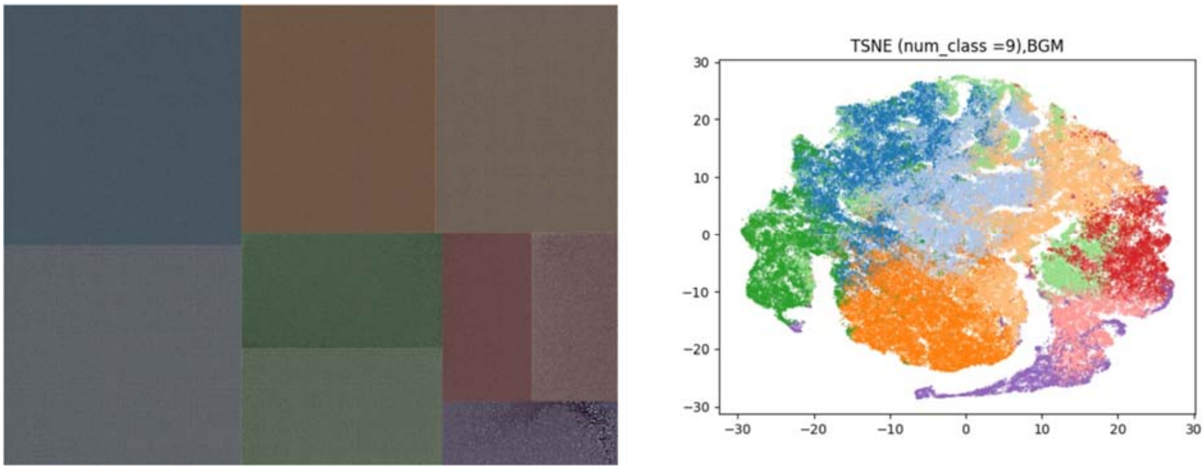


Fig. 6.31 Images taken during the expedition organised by unsupervised topic class (left), and the corresponding t-SNE feature space showing the different topics (right)

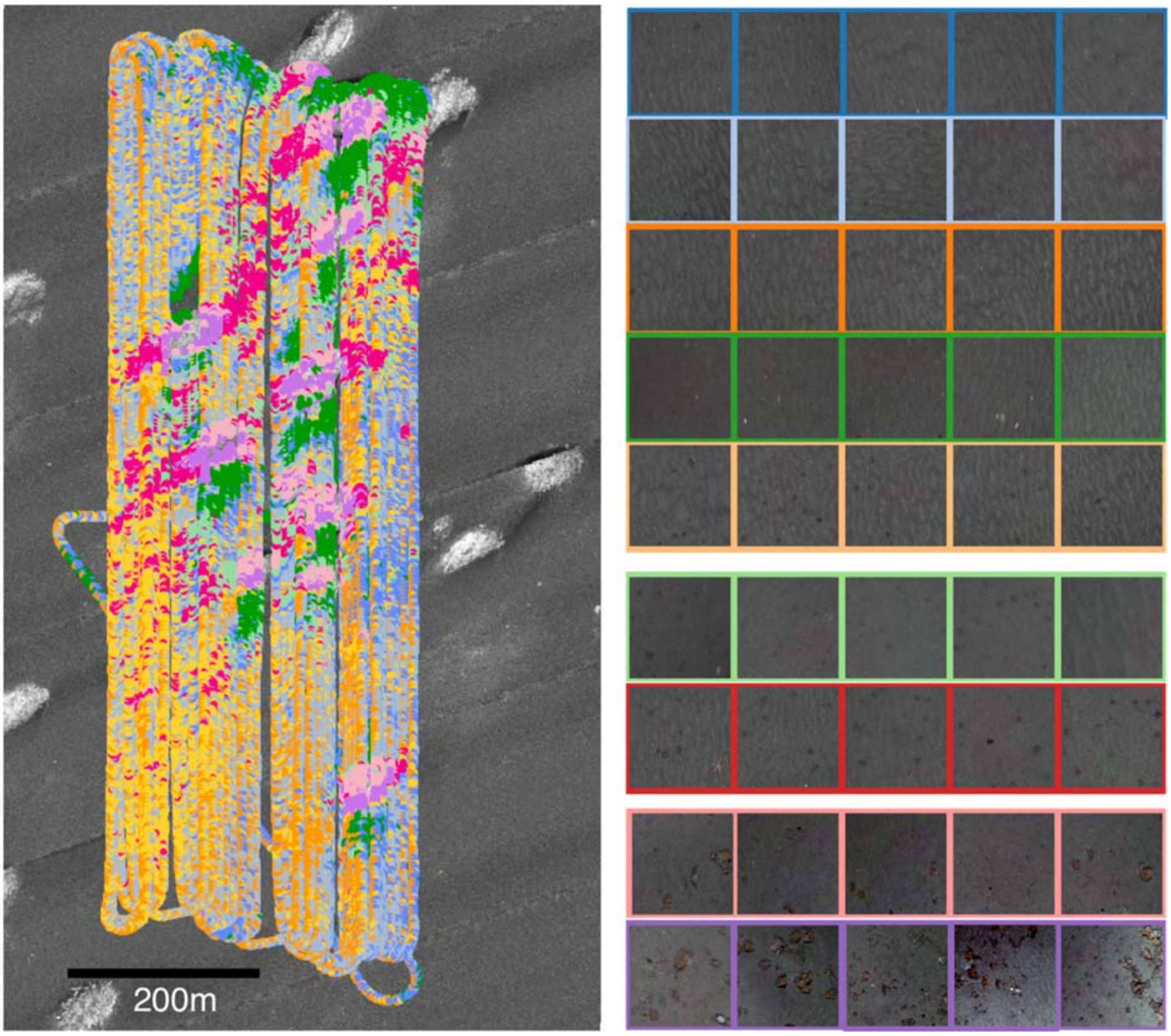


Fig. 6.32 Spatial distribution of the different topics identified by the unsupervised clustering algorithm(left), and representative summaries (right) where the corresponding colours in Fig. 6.31 have been used.

While this representation provides an effective method to rapidly summarise the multihectare scale spatial distributions seen in the imagery, a more targeted basis for analysis can be achieved using the same feature space to query specific images of interest. Fig. 6.33 shows the results of a query search for an image showing live coral. The image matrix in the centre of the figure organises other images in the dataset by their similarity to the query images, going from top left to right, and then top to bottom. The image on the right shows the spatial distribution of similar looking images, where yellow shows images that are most similar.

Fig. 6.34 shows the distribution of images similar in appearance to a) live cold-water-coral, b) coral fragments, c) densely distributed xenophyophores and d) sparsely distributed xenophyophores. The query images, detailed excerpts and maps cover the entire range of spatial scales observed from just under 10 mm^2 to several tens of hectares, equivalent to the scale of a single blade of grass going up to multiple football stadiums. The cold-water corals are found mainly at the base and slopes of the mounds, with coral fragments found on the mounds and forming long tails in the northeast to southwest direction. Xenophyophores are found at the base of the mounds, following the tails with a higher density near to the mounds, and lower density found further away from their base.

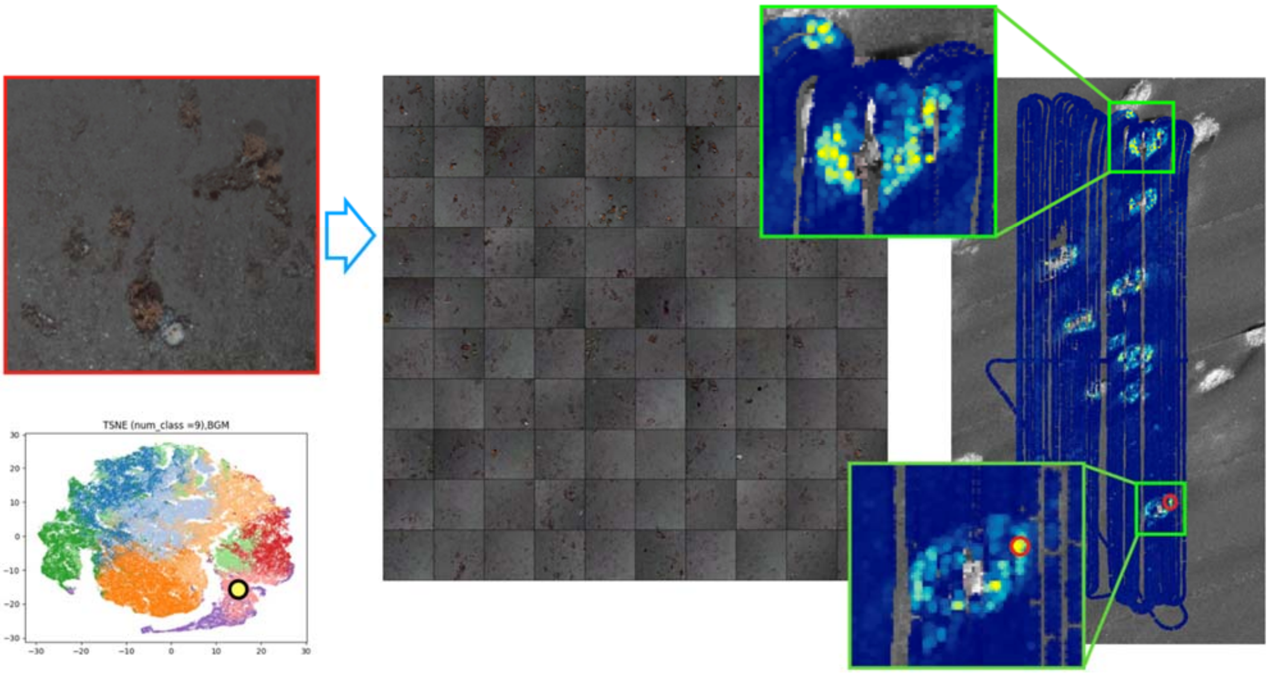


Fig. 6.33 Results of a query search for coral. The red circle identifies the image that was used as a query. The yellow colour in the spatial representation indicates the presence of similar images.

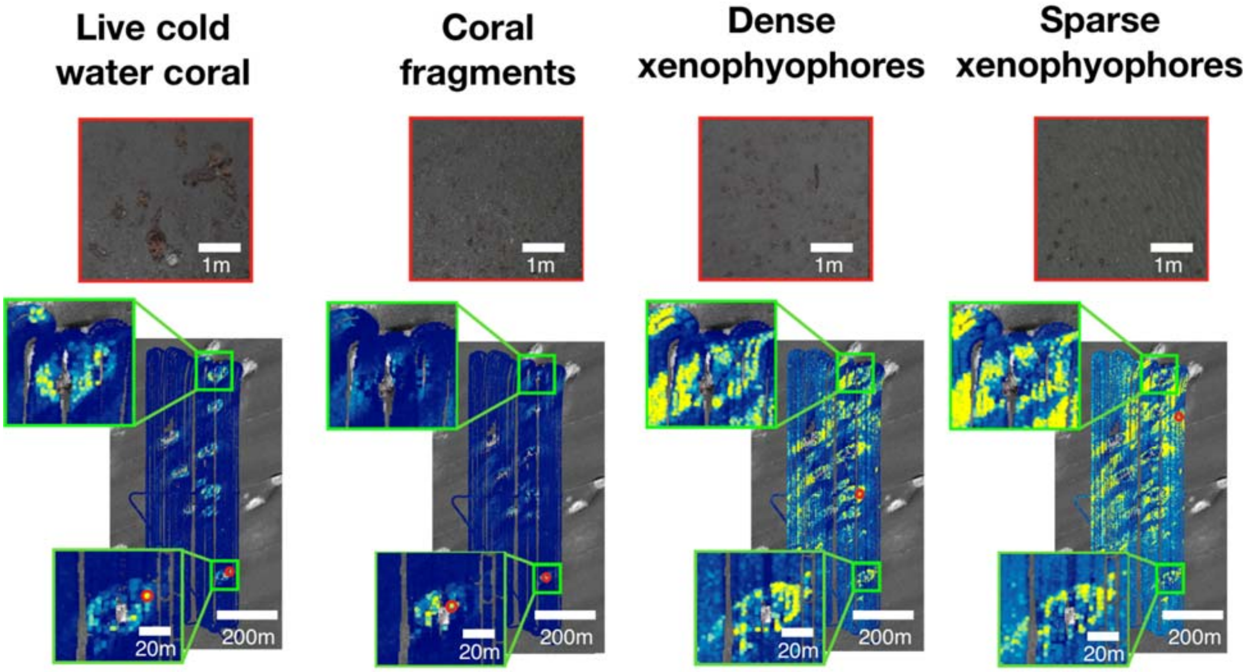


Fig. 6.34 Panels show respectively, cold-water coral, coral fragments, densely distributed xenophyophores, sparsely distributed xenophyophores together with their query images.

6.2.4.4. **Open access via Squidle+**

Imagery collected using BioCam during this expedition will be made publicly available through Squidle+ (http//soi.squidle.org), a web-based image annotation platform, under campaign dy108-109_nerc_oceanids_class.

6.2.5. Conclusion and future recommendations

The engineering objectives for the BioCam project have been successfully achieved.

- Autosub6000 mounted BioCam has demonstrated TRL8 performance through successful collection of scientifically meaningful datasets from 1000 m depth at the Darwin Mounds.

  Over the deployments, the device demonstrated robust performance of both its hardware and software systems and succeeded in collecting 45,606 strobe illuminated stereo pair images of the seafloor and 1,349,127 dual laser bathymetry lines, corresponding to 5830 million points of millimetre resolution 3D information. The platform and sensor were operationally reliable, with safety mechanisms to automatically turn off lasers in the event of any abnormality through a software watchdog and use of a magnetic kill switch removed as part of the recovery procedure, allowing for safe operation of the device.

  The mission failsafe procedure and health status monitoring capabilities were effective during the dives. In the final dive, where there was a pressure failure of the commercial communication cable between BioCam and Autosub6000, BioCam's health status signal successfully alerted the operating teams to an abnormality through Autosub6000's acoustic communication during the mission, although the decision made was not to abort the mission.

The Autosub6000 and RRS Discovery navigational logs were successfully integrated into BioCam's data processing pipelines, allowing datasets collected to be processed and reconstructions produced and machine-based interpretations to be conducted effectively during the expedition. This contributed to the discovery and accurate localization of a previously unknown whale carcass within the WDM survey area. The discovery was featured by the BBC news during the expedition (see section 6.7). 3D reconstructions of the observed scenes also informed strategies for improved data collection using the Autosub6000 during the expedition.

- Autosub6000 is capable of accurate bottom tracking at an altitude of 5 m in the terrains found at the Darwin Mounds and collecting continuous cover dense grid datasets by using a modified Zamboni pattern with a minimum turn diameter of 30 m. AUV transects should be aligned with the major axis of the mounds (or any other protruding features) as much as possible to minimize the slopes encountered during the dive.

  The impact of using Autosub6000's 150m range forward looking obstacle avoidance sonar during high altitude imaging using BioCam remains unclear. Early indications from the data collected suggest that the undulating effects reported in missions at lower altitude are less likely to happen. However, the tests conducted here without actually performing obstacle avoidance remain inconclusive, and future tests should be carried out to verify horizon tracking obstacle avoidance impact on data quality. For areas with bathymetry similar to the Darwin Mounds (i.e. mainly flat with 5m high peaks of 100m diameter), the indication is that safe missions are possible without the obstacle avoidance provided the AUV tracklines are aligned with the most gently slope.

  Maintaining a 30 m diameter turning circle (natural minimum turning of Autosub6000) allows usable image data to be collected for the entire length of a transect. While initial missions were designed to allow for a 150 m overshoot either side of the observation area, this was found not to be necessary, and the overshoot needs only to be the length of the turn radius in terrains encountered at the Darwin Mounds.

  An average area coverage rate of 15,900 m^2/h was achieved during dense grid surveys. This is lower than the maximum possible (40,000 m^2/h) with single swath transect surveys due to the overlap required between adjacent survey lines to collect dense grid surveys. However, the mapping rate still represents an order of magnitude increase in area covered compared to conventional ROV and hover capable AUV seafloor imaging surveys.

- The data collected during this expedition is suitable for future engineering development of methods to improve colour and dimensional accuracy of reconstructions and AUV localization estimates, and automated feature segmentation. Topic-based unsupervised classification and query algorithms run during the expedition demonstrate how these methods can be used to identify broader scale patterns and highlight interesting scenes in the data.

The following scientific objectives have been achieved.

- Multi-hectare scale 3D imagery of cold-water corals and the surrounding local ecology has been successfully collected using BioCam. The preliminary data and information products produced during the expedition illustrate spatial distribution patterns of the coral around the mounds over scales that are significantly larger than a single image frame.

- The size of the surveyed areas is in the order of several hundreds of metres along each axis. This is significantly larger than the uncertainty associated with underwater localization, indicating that exactly overlapping image datasets can be obtained for future repeat observations and quantitative temporal studies in future expeditions.

- The datasets collected have been processed and made ready to upload onto the web based open access annotation platform Squidle+ to allow members of the scientific community to analyse its results. This was carried out during the expedition and was limited only by internet bandwidth to upload the data from the ship. Ships with significantly faster internet connections are available, demonstrating that data with its associated metadata can be disseminated to the broader scientific community during an ongoing expedition.

The habitat maps and classes derived from BioCam data may have potential implications for monitoring. The following points should be considered in this context.

- Structuring analysis: Derived habitat classes may be useful for grouping physical seafloor samples or imagery. It is necessary to explore the potential for:
    - Making comparisons of measurements made in across different habitat types.
    - Targeting labelling efforts to allow for balanced treatment across different habitat types, especially in cases where the spatial coverage of individual habitats is different.
    - Use of query functions to focus efforts for more detailed studies on specific groups of species or habitats of interest.

- Planning observations: The analysis and visualisation of spatial patterns can be robustly carried out during expedition relevant time frames (from same day to a week). This may be useful for making more targeted sampling efforts, for example, by making more evenly balanced observations across different habitat types.

- Repeat monitoring: Traditionally, co-registered visual observations have been limited to time-lapse images and point wise measurements with a small footprint of several metres. Repeat observations with BioCam have the potential to make co-registered visual observations that can be direct comparisons over multi-hectare spatial scales.

- Multi-resolution analysis: The millimetre order resolution observations made by BioCam cover a larger area than traditional imaging surveys, but at the same time, sacrifice some resolution compared to sub-millimetre resolution imagery obtained by ROVs and hover capable platforms.
    - The implications of resolution on observable features, and area cover, on statistical robustness when computing the types of ecological variable used in monitoring should be studied.
    - The resolution and visual context of BioCam imagery can be used to ground truth inferences made from AUV side scan and multibeam surveys, which cover larger areas at lower resolutions (tens of centimetres to metres). The correlation between

overlapping measurements made by these approaches may be useful to study how habitats can be robustly inferred over regional scales.

6.3. Megafauna community study from seabed observations *(Nils Piechaud, Guillem Corbera, James Strong, Brian Bett)*

The 'Hydraulic Benthic Interactive Sampler' (HyBIS) is a modular, versatile, towed robotic underwater vehicle (RUV) capable of reaching depths of 6000 metres, developed and operated by the NOC (see also section 7.2). Controlled via fibre optic cable connected to the ship, HyBIS is equipped with two cameras (HD Scorpio and a low resolution 'tooling' camera) and a forward-facing sonar. The main module consists of the steering unit represented by two propellers as well as the energy supply, the cameras, the light, the hydraulic systems and the telemetry. Depending on the sampling requirements, different modules can be mounted under the main module.

In contrast to a conventional remotely operated vehicle (ROV), HyBIS is not neutrally buoyant. Both the descent and the ascent of the HyBIS, as well as the operating depth are controlled from the ship through the fibre optic cable. Therefore, HyBIS can deploy and recover a net load up to 700 kg (sampling equipment and sampling material), which is several times the payload of an ROV.

HyBIS navigation is through USBL (Sonardyne Ranger), and is visualised in real-time on the OFOP software (Ocean Floor Observation Protocol). The software also provides the opportunity to annotate and log the video in real time.

During DY108, a total of 11 HyBIS dives were successfully completed. Dives 51, 53, 54, 56 and 60 were conducted at Darwin Mounds East. Dives 52, 55, 57, 58, 59 and 61 were performed at Darwin Mounds West. A brief summary of each dive is provided below.

6.3.1. Dive 51: Darwin Mounds East (1050 – 1058 m; moderate visibility and current strength)

Objective of the dive: repeat the historical track collected during 2011 and find the settlement panel mooring.

The majority of the substrata at this station was a silty sand lacking surface ripples (Fig. 6.35a and b). The sandy substratum, and areas in the lee side of coral mounds, contained numerous Xenophyopores (approximately 2-3 ind per m^2). Squid, cutthroat eels (Synaphobranchidae) and gelatinous zooplankton appeared abundant in the water column. Epifaunal species, in approximate order of decreasing abundance, included pencil and fine-spined urchins (Echinoidea), brittlestars (Ophiuroids), Hexactinellid sponges, anemones (mainly Cerianthids) and squat lobsters (Galatheoids). The HyBIS track crossed five substantial mounds (Fig. 6.36). Coral mounds were covered in small coral rubble pieces with little live coral (only small colonies of both *Madrepora oculata* and *Lophelia pertusa* – see Fig. 6.37). The coral colonies were occasionally accompanied by the hexactinellid sponge *Aphrocallistes* sp., a taxon known to be associated to cold-water coral mounds. Marine litter was relatively infrequent and composed of plastic bags, bottles and small sections of fishing net. The North Atlantic codling (*Lepidion eques*) was common in areas containing coral. Chimera (probably *Chimaera monstrosa*) were occasionally observed both on sand and on coral mounds. The mooring with settlement panels was successfully located and logged for later retrieval.

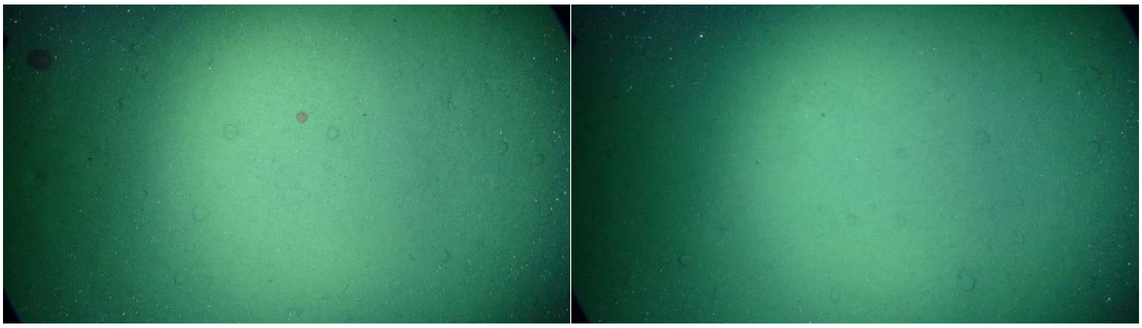


Fig. 6.35a and b. Typical sandy substratum with abundant Xenophyopores observed in HyBIS dive 51.

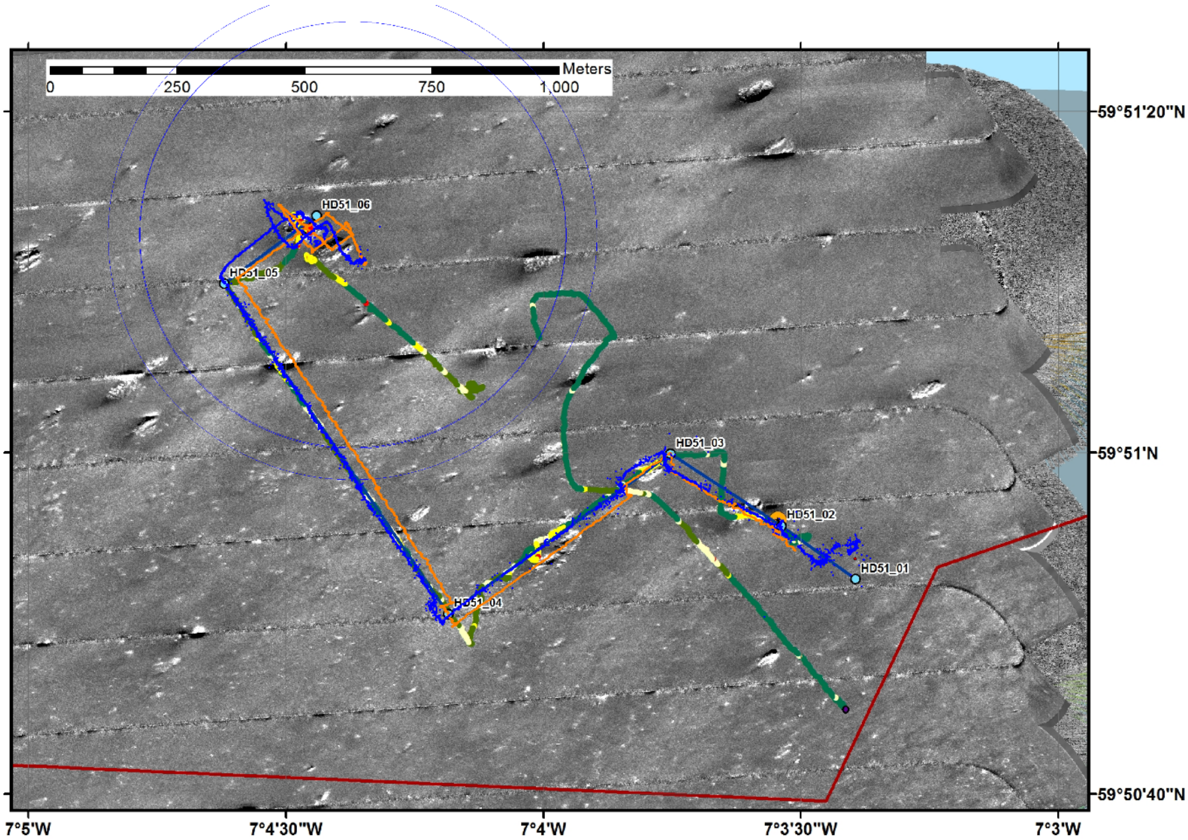


Fig. 6.36 Final OFOP map showing the tracks of the ship (orange) and HyBIS (blue) for dive 51. The historical track is colour-coded; dark green for sand with Xenophyopores, green for sand with pebbles and light green for just sand, yellow for coral rubble and red for live coral. The other colour coded track represents the 2011 version of track 60.

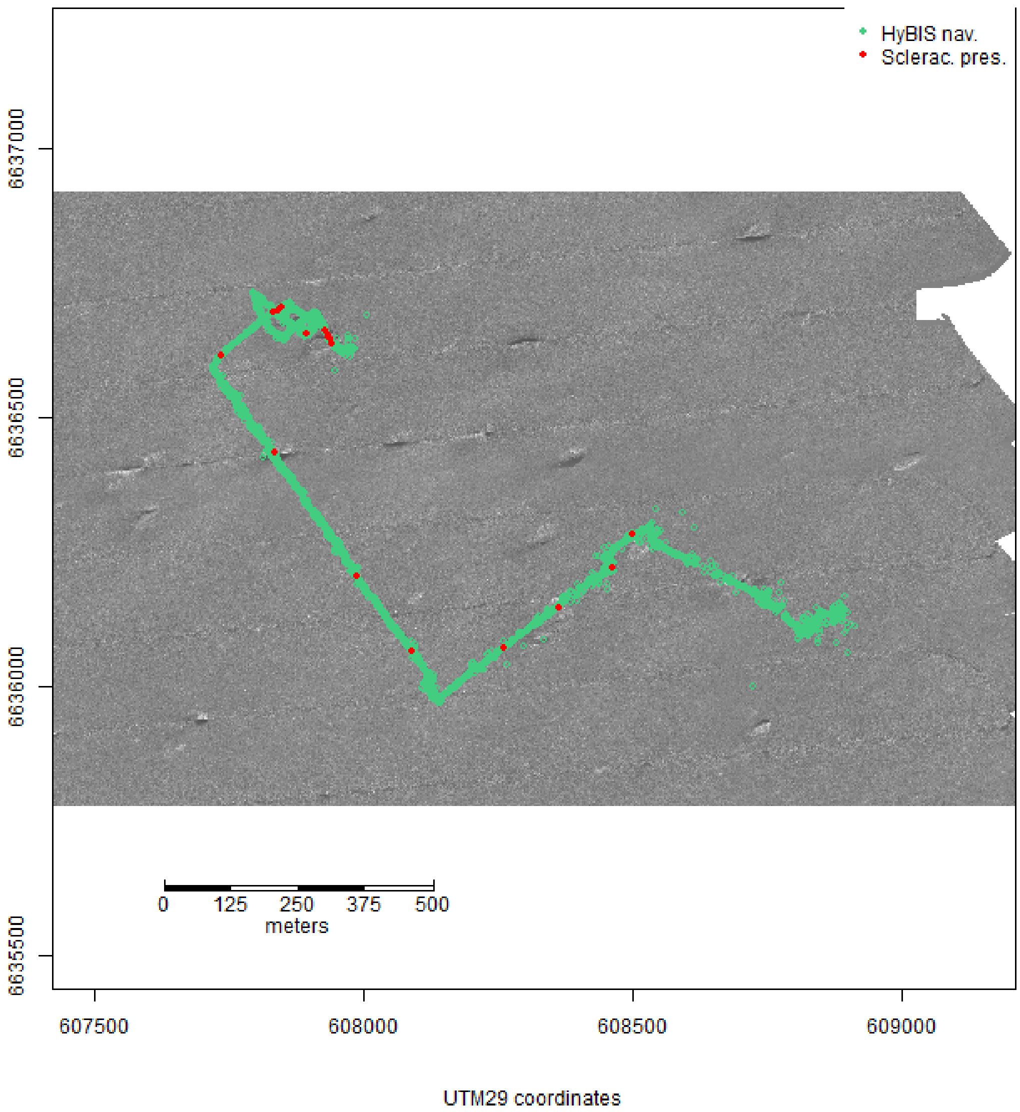


Fig. 6.37 The distribution of live colonial scleractinian coral observations (Madrepora oculata and Lophelia pertusa), shown as red points, along the route of HyBIS dive 51 (light green points).

6.3.2. Dive 52: Darwin Mounds West (969 m; moderately poor visibility and high current speeds - spring tide)

Objective of the dive: recover one of the settlement panel moorings (59° 48.829 N 7° 21.609W)

HyBIS was used to successfully recover the settlement panel mooring deployed in 2011. A full description of the mooring and its biofouling community can be found in Section 6.5.

6.3.3. Dive 53: Darwin Mounds East (952 m; moderately poor visibility and high current speeds - spring tide)

Objective of the dive: recover the second mooring with settlement panels (59° 50.932 N 7° 3.538 W).

HyBIS was used to successfully recover the settlement panel mooring deployed in 2011. A full description of the mooring and its biofouling community can be found in Section 6.5.

6.3.4. Dive 54: Darwin Mounds West (945 – 965 m; moderately poor visibility and high current speeds - spring tide)

Objective of the dive: repeat ROV track collected in 2011.

The majority of the transect was a sandy substratum with distinct areas of straight, sinuous and surface ripples, although areas lacking ripples were also observed. A short patchy turf was often associated with sandy areas lacking surface texture, which was assumed to be abundant polychaete tube worm tubes. Squid, cutthroat eels (Synaphobranchidae) and gelatinous zooplankton appeared abundant in the water column. Epifaunal species, in approximate order of decreasing abundance, included tube-dwelling anemones (Cerianthids) and epifaunal anemones (including the Venus fly trap anemone *Phelliactis* sp.), brittlestars (Ophiuroidea), pencil and fine-spined urchins (Echinoidea), starfish (Asteroidae); gorgonians (Gorgonacea), sponges and squat lobsters (Galatheoids).

The HyBIS track crossed four substantial coral mounds (Fig. 6.38), which were covered in a moderate amount of small to medium sized coral colonies (Figs. 6.39 and 6.40). *Madrepora oculata* appeared to be more abundant than *Lophelia pertusa* on the coral mounds. The coral colonies were occasionally accompanied by the hexactinellid sponge *Aphrocallistes* sp., a taxon known to be associated to cold-water coral mounds. Marine litter was encountered on several of the mounds and included plastic debris and fishing gear (Fig. 6.39b). Fish, such as the North Atlantic codling (*Lepidion eques*) and the roundnose grenadier (*Coryphaenoides rupestris*) were common in areas containing coral. Chimera (probably *Chimaera monstrosa*) were occasionally observed both on sand and on coral mounds.

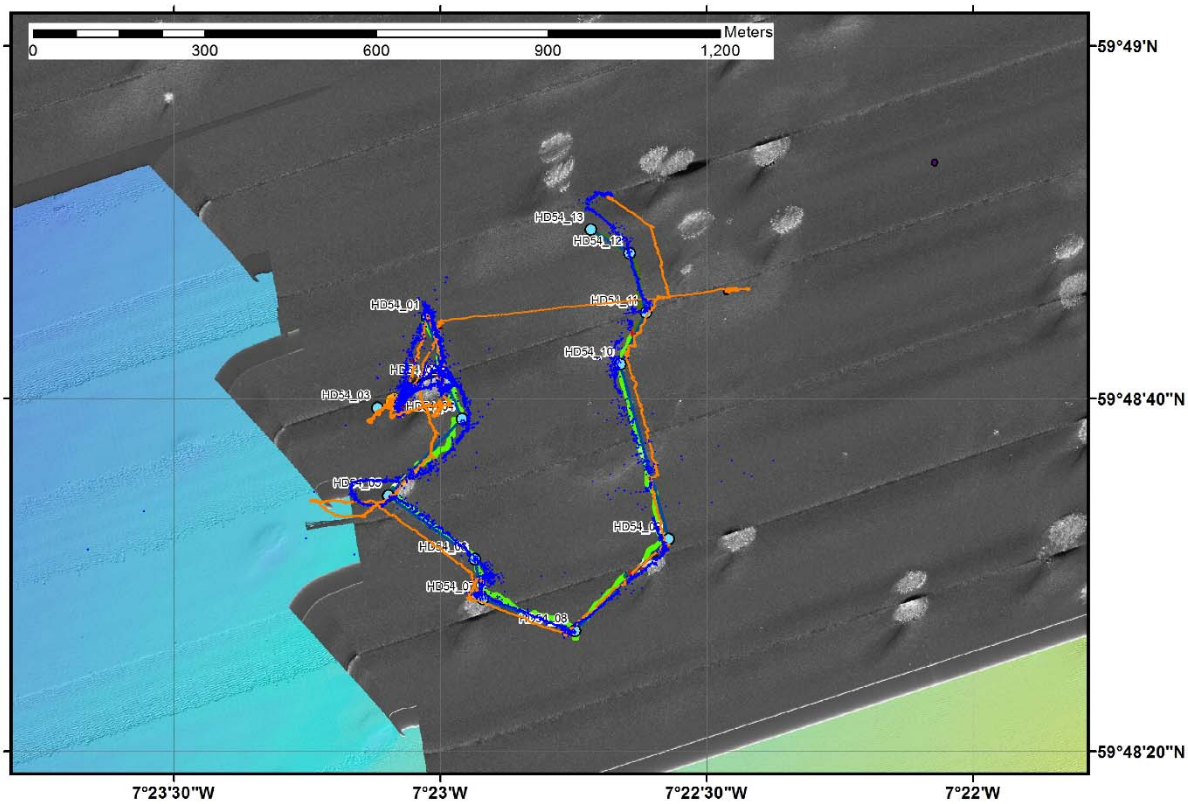


Fig. 6. 38 Final OFOP map showing the tracks of the ship (orange) and HyBIS (blue) for dive 54. The historical track is colour-coded; dark green for sand with Xenophyopores, green for sand with pebbles and light green for just sand, yellow for coral rubble and red for live coral.

Fig. 5.39a and b. Moderate sized colony of coral (left) and a similar colony with fouled fishing gear from HyBIS dive 54.

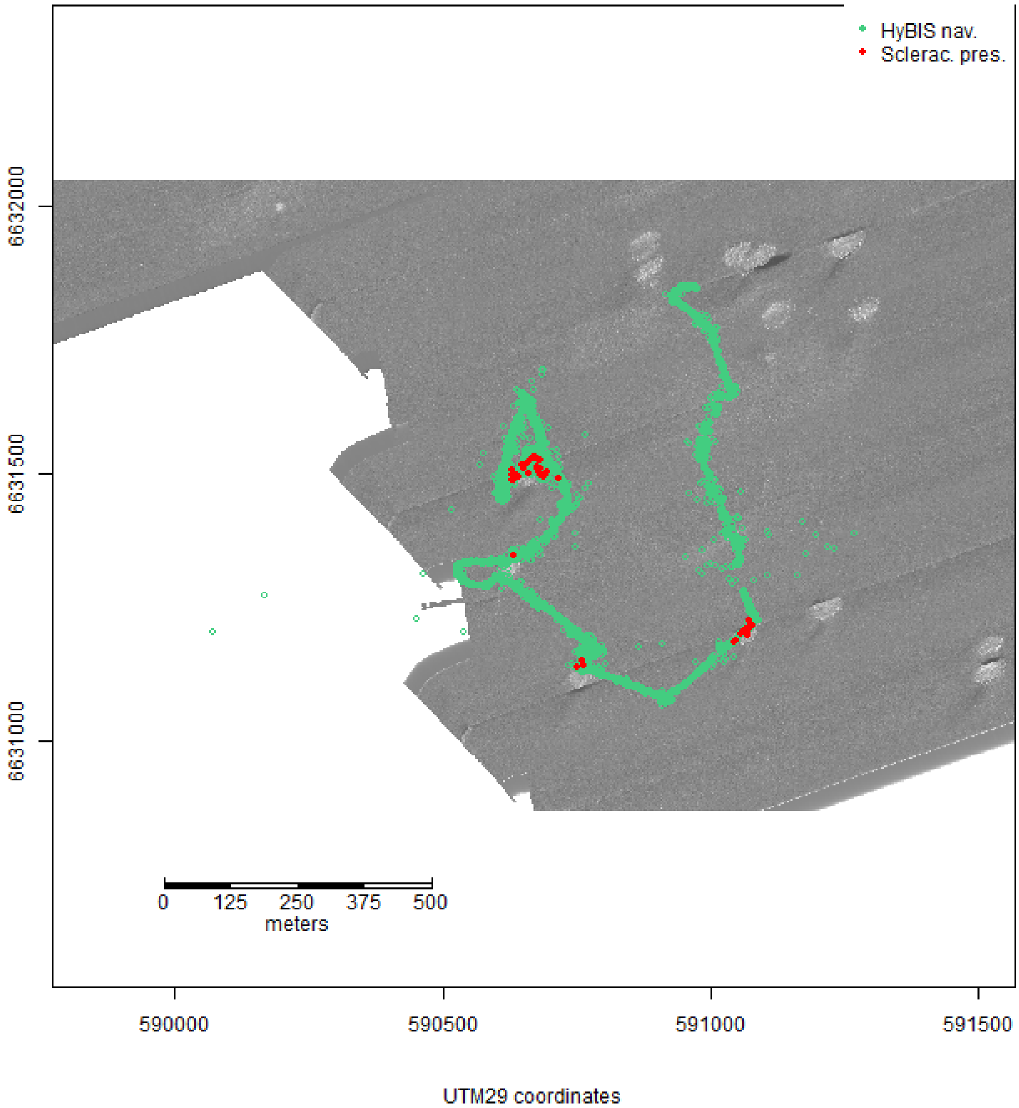


Fig. 6.40 The distribution of live colonial scleractinian coral observations (Madrepora oculata and Lophelia pertusa), shown as red points, along the route of HyBIS dive 54 (light green points).

6.3.5. Dive 55: Darwin Mounds West (963 – 971 m; moderately poor visibility and high current speeds - spring tide)

Objective of the dive: repeat ROV track collected in 2011.

The majority of the transect was dominated by a sandy substratum, often with a discontinuous or lobate pattern suggesting localised increases in hydrodynamic energy. The rest of the sandy substratum lacked surface texture but did have substantial densities of small polychaete tubeworms. Xenophyopores were moderately abundant on both rippled and featureless areas. As with all HyBIS stations on the Darwin Mounds, squid and cutthroat eels (Synaphobranchidae) were abundant. Epifaunal species, in approximate order of decreasing abundance, included brittlestars and starfish (Ophiuroidea and Asteroidae), pencil and fine-spined urchins (Echinoidea), tube-dwelling anemones (Cerianthids), gorgonians (Gorgonacea), sponges and hermit crabs with shells covered in Epizoanthids. A large sponge of the genus *Geodia* was also observed during this dive, a not very common taxon in this region.

The HyBIS track crossed three coral mounds and passed over the flanks of four other mounds (Fig. 6.41). Small and large pieces of coral rubble were present on the top of the mounds (Figs. 6.42 and 6.43). Coral mounds were also covered in a moderate amount of medium and occasionally large sized coral colonies (comprised mainly of *Madrepora oculata* and some *Lophelia pertusa*). The coral colonies were occasionally accompanied by the hexactinellid sponge *Aphrocallistes* sp., a taxon known to be associated to cold-water coral mounds. Marine litter was encountered on several of the mounds and included plastic debris and a tin can. The North Atlantic codling (*Lepidion eques*) was common in areas containing coral whereas the roundnose grenadier (*Coryphaenoides rupestris*) was less frequently seen. Chimera (*Chimaera monstrosa*) were occasionally observed mainly on sand and occasionally near coral mounds.

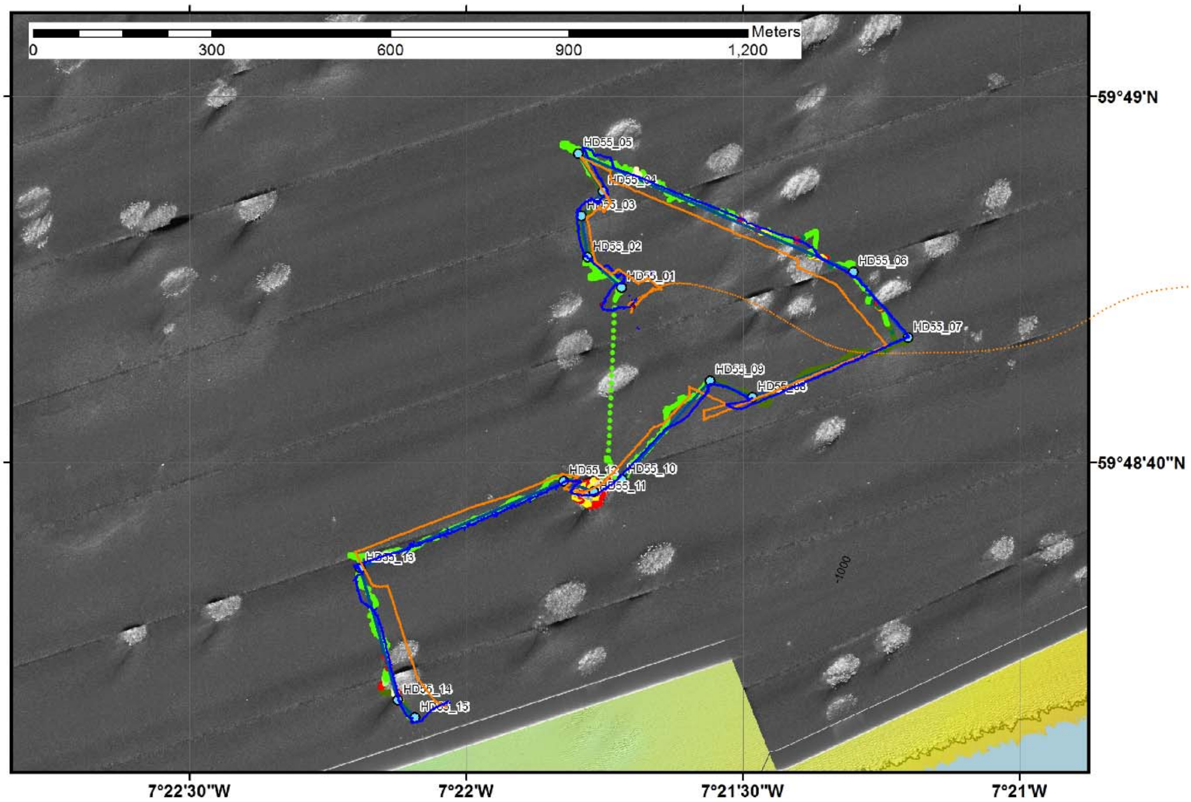


Fig. 6.41 Final OFOP map showing the tracks of the ship (orange) and HyBIS (blue) for dive 55. The historical track is colour-coded; dark green for sand with Xenophyopores, green for sand with pebbles and light green for just sand, yellow for coral rubble and red for live coral.

Fig. 6.42. Sparse coral colonies on a mound during dive 55.

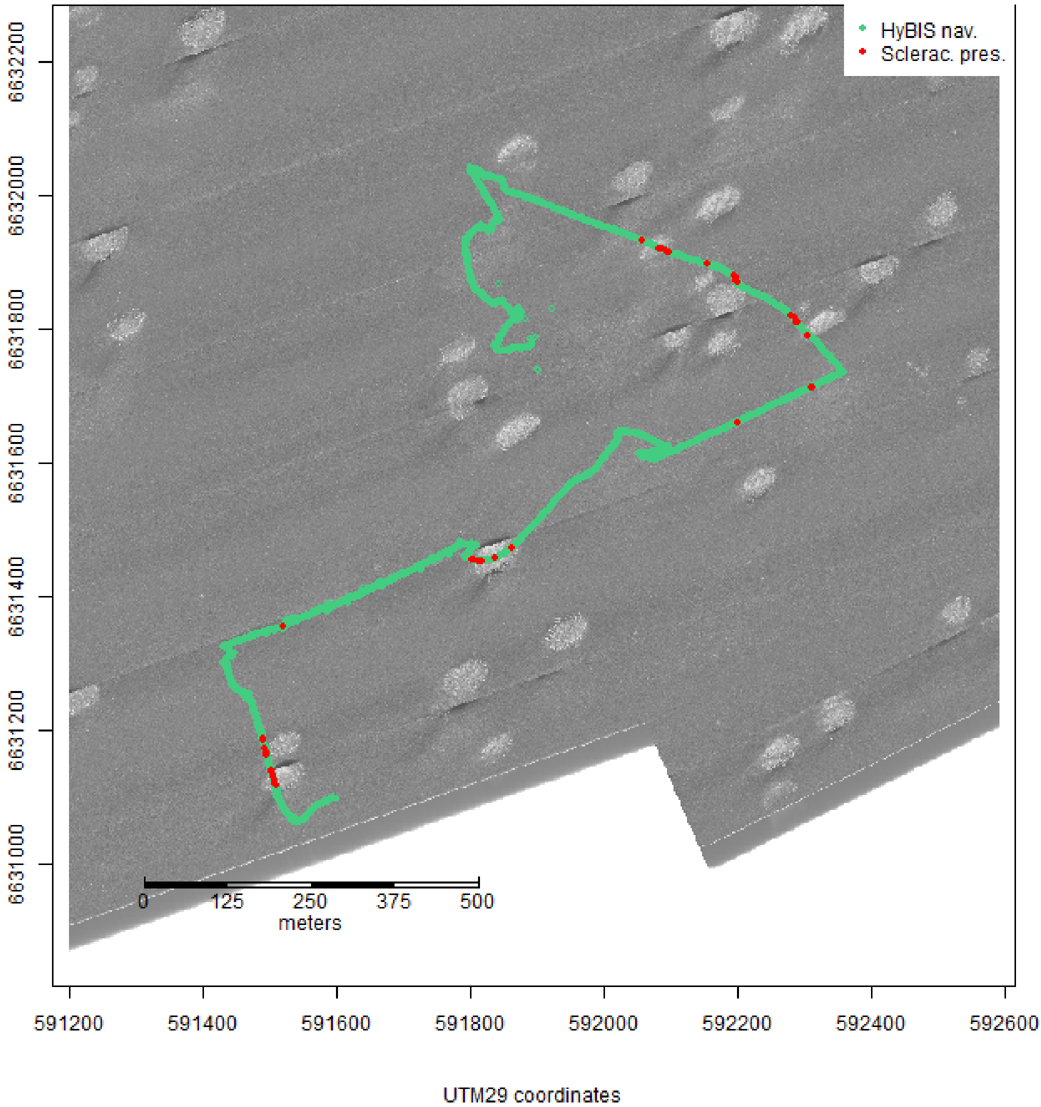


Fig. 6.43 The distribution of live coral observations (Madrepora oculata and Lophelia pertusa), shown as red points, along the route of HyBIS dive 55 (light green points). The presence of living coral a few meters away from the mound structures represented in the side-scan sonar might indicate a positional inaccuracy of the latter.

6.3.6. Dive 56: Darwin Mounds East (1045 – 1058 m; moderate visibility)

Objective of the dive: repeat ROV track collected in 2011.

The majority of the substratum on this dive was a silty sand mostly lacking surface ripples. Numerous Xenophyopores were present on the sandy substratum and densities increased markedly in the lee side of coral mounds. Squid and cutthroat eels (Synaphobranchidae) were abundant throughout the dive. Epifaunal species, in approximate order of decreasing abundance, included tube-dwelling anemones (Cerianthids), brittlestars (Ophiuroidea), fine-spined urchins (Echinoidea), sea cucumbers (Stichopodidae) and gorgonians (Gorgonacea). An isolated specimen of the genus *Pheronema* was also observed during this dive. Aggregations of this species are considered vulnerable marine ecosystems (VME).

The HyBIS track crossed nine mounds (Fig. 6.44). Coral mounds were covered in small coral rubble pieces with only a low density of small colonies of both *Madrepora oculata* and *Lophelia pertusa* (Fig. 6.45 and 6.46). The coral colonies were occasionally accompanied by the hexactinellid sponge *Aphrocallistes* sp., a taxon known to be associated to cold-water coral mounds. Marine litter, which was relatively infrequent when compared with Darwin Mounds West, included plastic debris and fishing gear. The North Atlantic codling (*Lepidion eques*) was common in areas containing coral and large accumulations of larger rubble. Chimera (*Chimaera monstrosa*) were occasionally observed both on sand and on coral mounds.

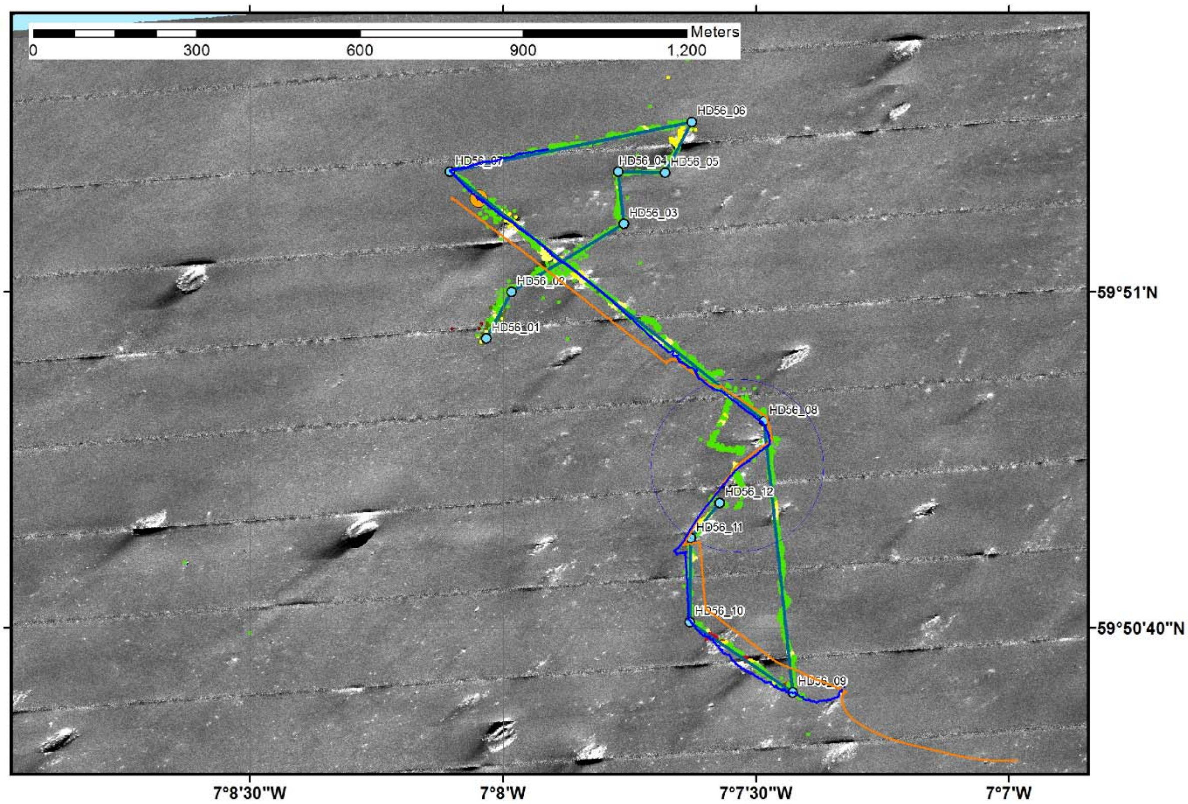


Fig. 6.44 Final OFOP map showing the tracks of the ship (orange) and HyBIS (blue) for dive 56. The light blue line is the planned transect line for the HyBIS dive. The historical track is colour-coded; dark green for sand with Xenophyopores, green for sand with pebbles and light green for just sand, yellow for coral rubble and red for live coral.

Fig. 6.45 Typical summit of a coral mound during dive 56 at Darwin Mounds East.

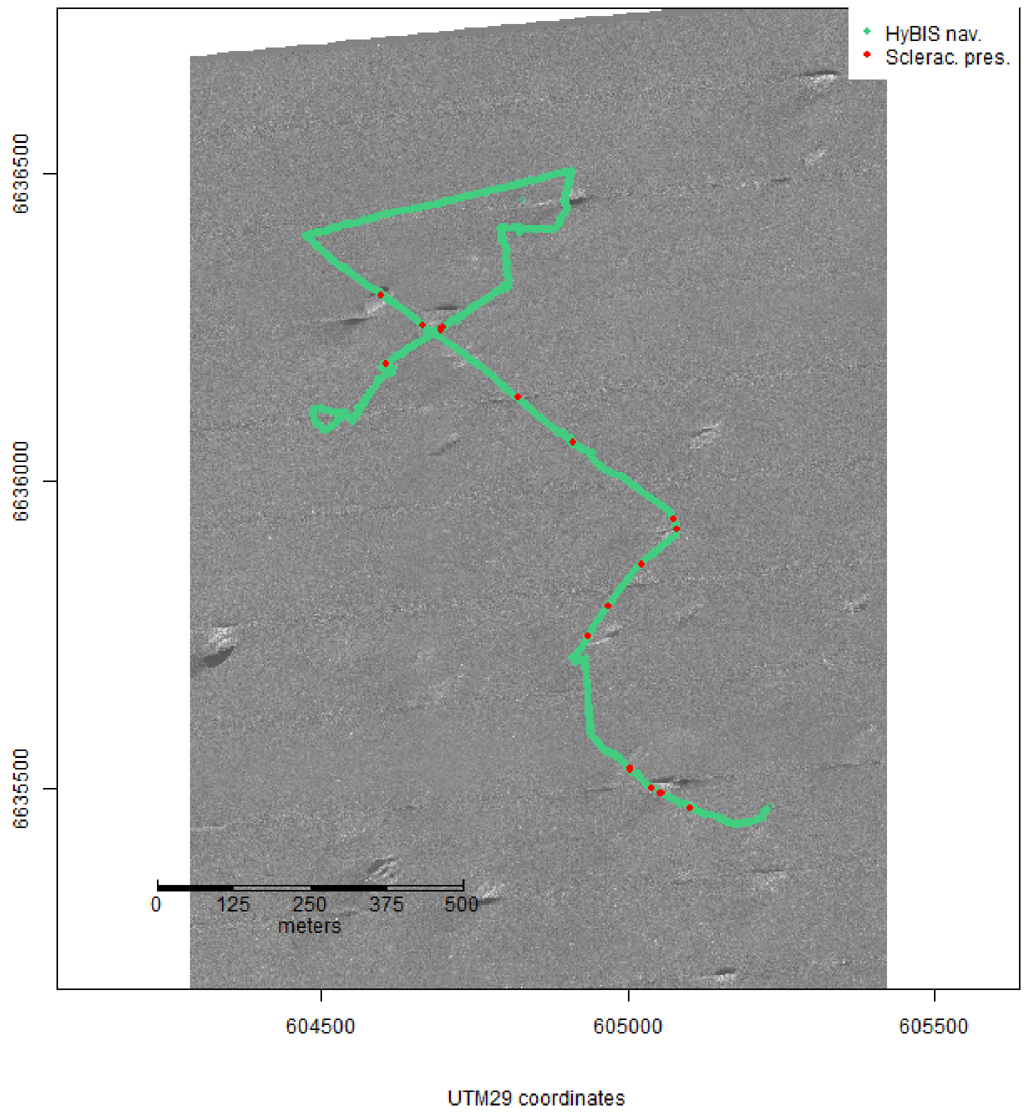


Fig. 6.46 The distribution of live coral observations (Madrepora oculata and Lophelia pertusa), shown as red points, along the route of HyBIS dive 56 (light green points).

6.3.7. Dive 57: Darwin Mounds West (958 – 973 m; moderate visibility)

Objective of the dive: repeat ROV track collected in 2011 and look for a whale carcass previously detected during a Biocam mission using Autosu6000.

The majority of the transect was over a sandy, rippled substratum with fewer Xenophyopores than observed in other stations. As per the entire Darwin Mounds area, squid and cutthroat eels (Synaphobranchidae) were abundant throughout the dive. Epifaunal species on sand, in approximate order of decreasing abundance, included pencil and fine-spined urchins (Echinoidea), tube-dwelling anemones (Cerianthids), brittlestars and starfish (Ophiuroidea and Asteroidae) and sea cucumbers (Stichopodidae).

The HyBIS track crossed five mounds (Fig. 6.47). Both *Madrepora oculata* and *Lophelia pertusa* were present on most mounds (Fig. 6.48). Some mounds had what appeared to be high densities of echiurans, generally in the surroundings of the coral colonies (Fig. 6.49). A small, isolated stand of coral was also found within a sand plain (identified as a small, bright spot on an acoustic image). The coral colonies were occasionally accompanied by the hexactinellid sponge *Aphrocallistes* sp., a taxon known to be associated to cold-water coral mounds. Litter was present at almost all of the significant concentrations of coral (Fig. 6.50a and b) and typically comprised of plastic packaging. The North Atlantic codling (*Lepidion eques*) was common in areas containing coral. Chimera (*Chimera monstrosa*) were occasionally observed both on sand and on coral mounds. The same HyBIS dive was used to locate the whale fall observed in the Autosub/BioCam mission. As such, only half of the historical track was repeated, i.e. waypoints 1 – 6 completed.

Despite the intense efforts from the scientist team and HyBIS technicians the whale carcass could not be spotted during this dive.

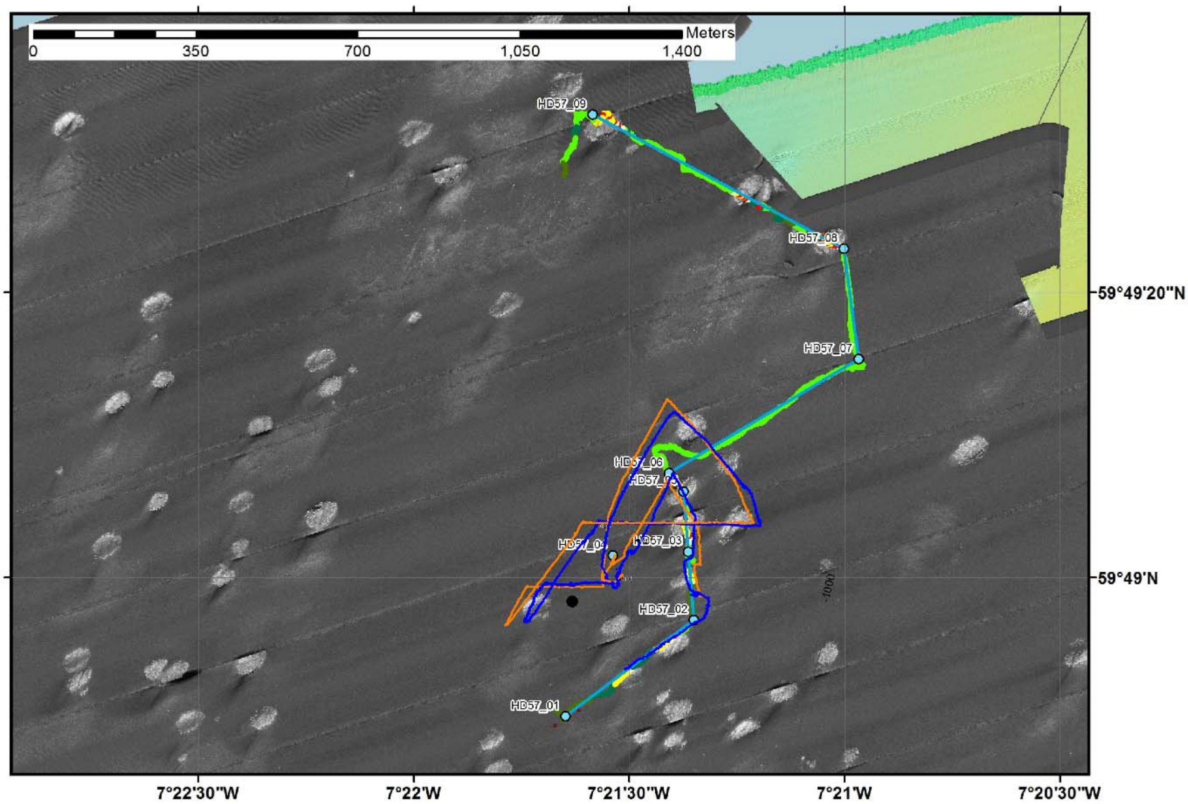


Fig. 6.47 Final OFOP map showing the tracks of the ship (orange) and HyBIS (blue) for dive 57. The light blue line is the planned transect line for the HyBIS dive. The historical track is colour-coded; dark green for sand with Xenophyopores, green for sand with pebbles and light green for just sand, yellow for coral rubble and red for live coral.

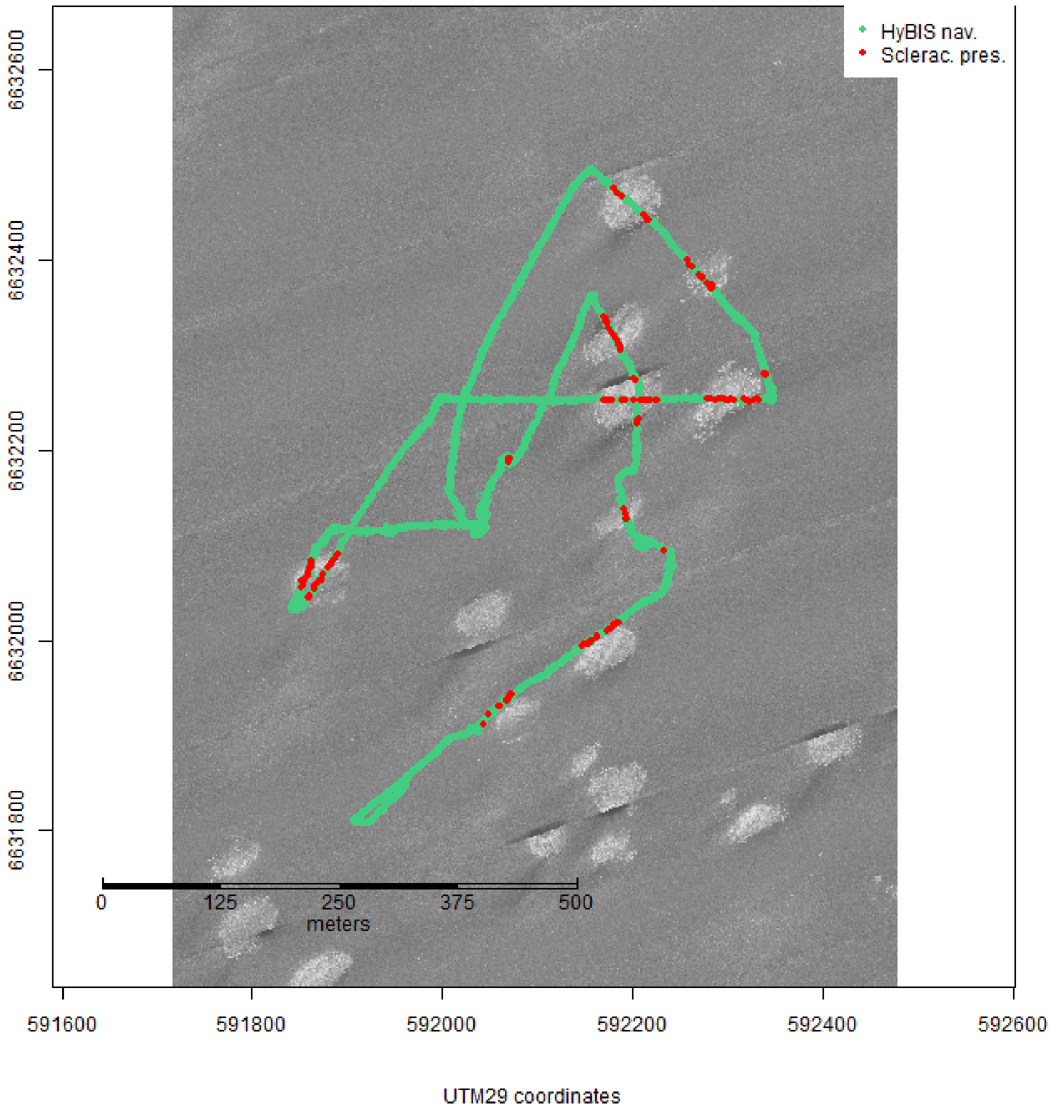


Fig. 6.48 The distribution of live coral observations (Madrepora oculata and Lophelia pertusa), shown as red points, along the route of HyBIS dive 57 (light green points).

Fig. 6.49 High density of spoon worms (echiurans) on top of a coral mound during dive 57.

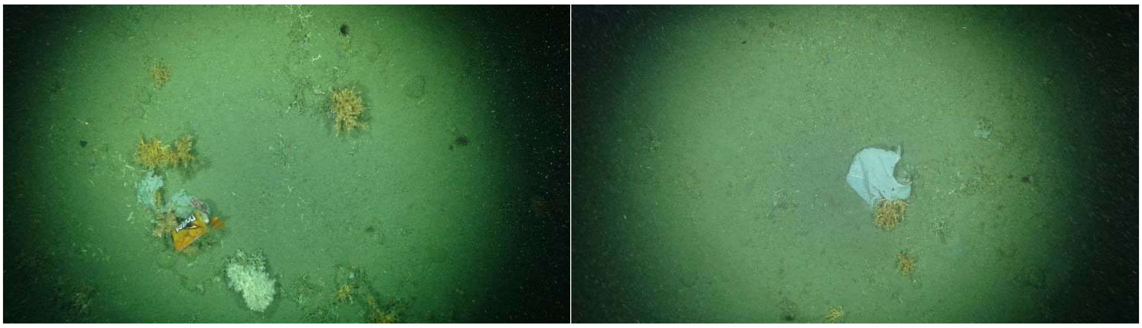


Fig. 6.50a and b. Branded plastic litter seen during dive 57 (left) and more plastic litter during the same dive (right).

6.3.8. Dive 58: North of Darwin Mounds West (965 - 980 m; moderate currents and visibility)

Objective of the dive: repeat the historical WASP track (southern transect moving east) and examine new mounds (northern transect moving west).

This site was previously examined with the WASP drop-down system in 1999 (Fig. 6.51). This station has distinct coral mounds and extensive areas of sparse coral (Fig. 6.52). During the southern part of the transect, the sand substratum had a significant topping of gravel but with no surface rippling. Unlike both Darwin Mounds East and West, there was a general absence of Xenophyopores with some sporadic individuals. Epifaunal species, in approximate order of decreasing abundance, included pencil and fine-spined urchins (Echinoidea), tube-dwelling anemones (Cerianthids), gorgonians (Gorgonacea), brittlestars and starfish (Ophiuroidea and Asteroidae), sea cucumbers (Stichopodidae) and various sponges.

The northern transect (running east to west) ran over and between some large and densely colonised mounds (Fig. 6.52). Generally, *M. oculata* appeared to be more abundant than *L. pertusa*. The coral colonies were occasionally accompanied by the hexactinellid sponge *Aphrocallistes* sp., a taxon known to be associated to cold-water coral mounds. Sand running between these mounds occasionally formed channels of heavily rippled sand, often with extreme sharp boundaries between ripple and unrippled sand (Fig. 6.53a). Some of these sedimentary features could be part of a larger structure, such as barchan dunes. These features might be related to faster currents nearer the Wyville Thomson Ridge or occasional overflow of cold arctic water over this ridge. Coral density and height superficially appeared to be greater here than elsewhere in the West (Fig. 6.53b). Besides the coral colonies located on the mounds, some off-mound sparse coral aggregations were observed, one of them being of a considerable size (approximately 3 – 4 m across and more than a meter tall) (Fig. 6.53c). The North Atlantic codling (*Lepidion eques*) was common in areas containing coral. Chimera (*Chimaera monstrosa*) were occasionally observed both on sand and on coral mounds. Marine litter, typically plastic debris (Fig. 6.54a) was frequently encountered and especially abundant within stands of dense coral. A large fishing net, approximately 30 – 40 m long, was found attached to a small, but surprisingly healthy, coral outcrop (Fig. 6.54b). The net was sparsely covered with barnacles and coral could be seen growing through the net mesh. The HyBIS video track roughly corresponded to the TOBI acoustic image (the acoustic image was perhaps shifted north north-west by 70 - 100 m).

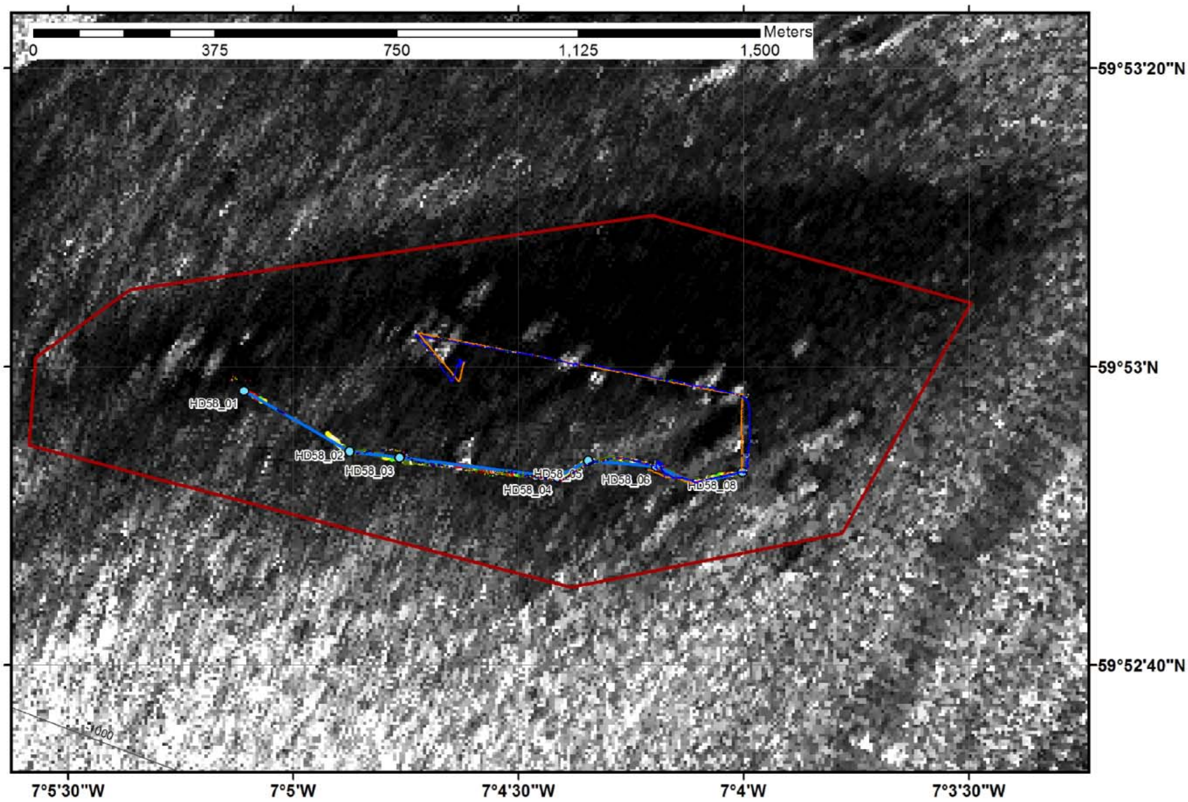


Fig. 6.51 Final OFOP map showing the tracks of the ship (orange) and HyBIS (blue) for dive 58. The light blue line is the planned transect line for the HyBIS dive. The historical track is colour-coded; dark green for sand with Xenophyopores, green for sand with pebbles and light green for just sand, yellow for coral rubble and red for live coral.

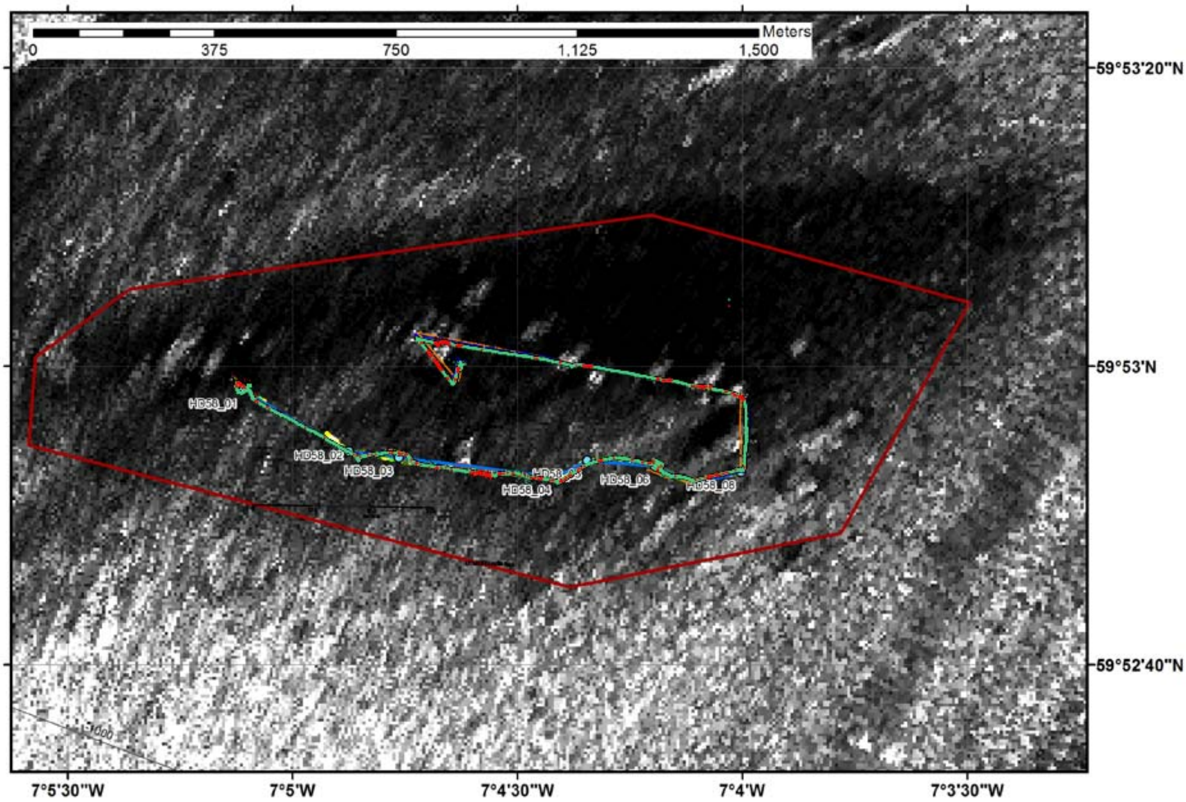


Fig. 6.52 The distribution of live coral observations (Madrepora oculata and Lophelia pertusa), shown as red points, along the route of HyBIS dive 58 (light green points).

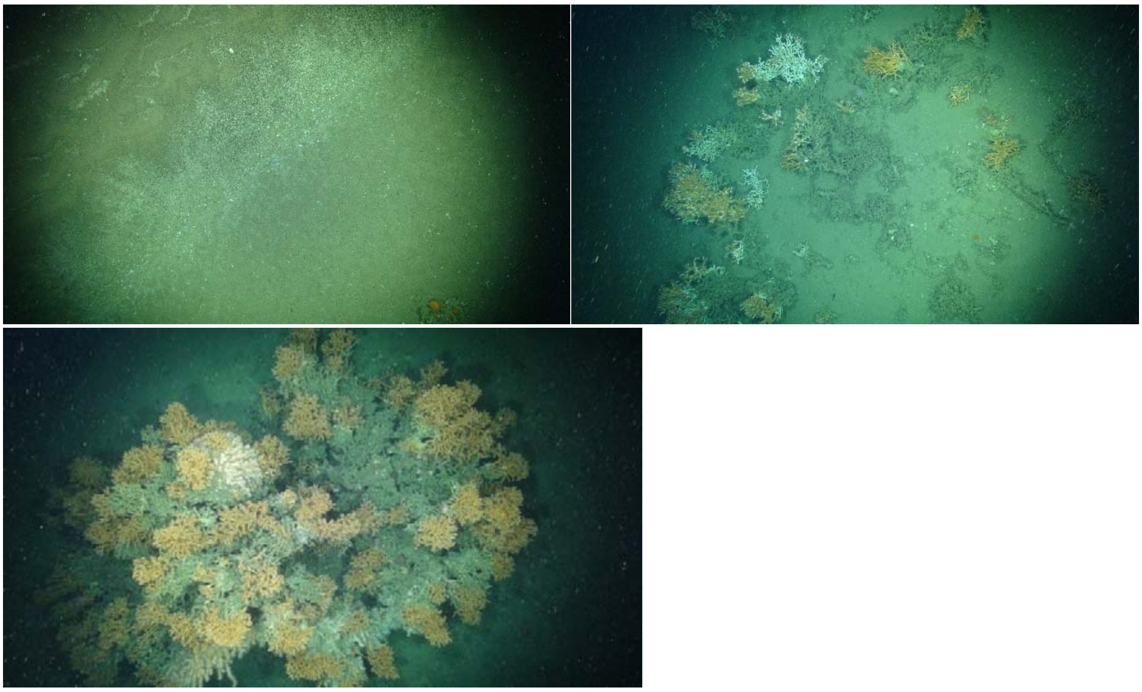


Fig. 6.53a, b and c. A distinct boundary between untextured sand and ribbons of heavily rippled sand that runs between coral mounds during the northern ad hoc transect (left) and a typical coral mound from the same area (right). Large off-mound aggregation of M. oculata with some patches of L. pertusa (down).

Fig. 6.54a and b. Plastic or fabric litter caught on coral (left) and part of the fishing gear (59° 53.00320 N 007° 4.37176 W) caught on coral along the northern ad hoc transect.

6.3.9. Dive 59: North of Darwin Mounds West (943 - 961 m; moderate to high visibility)

Objective of the dive: repeat ROV track collected in 2011 and examine new mounds north of the transect.

The majority of the transect was on a sandy substratum, with some areas having an undulatory (rippled) surface. Although heterogeneous, there was a moderate density of Xenophyopores on both the sand and on some coral mounds. Further north, the sandy substratum started to form into megaripples – these features were obvious in the existing sidescan sonar data and in the forward-facing sonar on HyBIS but not in the camera footage. Dense fields of small, polychaete tubeworms/amphipod tubes were often associated with areas of featureless sand. Squid and cutthroat eels (Synaphobranchidae) were abundant throughout the dive. Epifaunal species associated with the sand, in approximate order of decreasing abundance, included tube-dwelling anemones (Cerianthids), pencil (*Cidaris cidaris*) and fine-spined urchins (Echinoidea), brittlestars and starfish (Ophiuroidea and Asteroidae) and squat lobsters (galatheoids). Chimera (*Chimaera monstrosa*) were occasionally observed more over sandy substrata.

The planned track crossed eight coral mounds (Fig. 6.55). Mounds typically had a low to medium density of small to medium sized coral patches (Fig. 6.56). The majority of the live coral on the mounds was dominated by *M. oculata* (both orange and white morphs) with smaller quantities of *L. pertusa*. Sponges and gorgonians were frequently present with the live coral. The coral colonies were occasionally accompanied by the hexactinellid sponge *Aphrocallistes* sp., a taxon known to be associated to cold-water coral mounds. Epifaunal species associated with the coral included Brisingida starfish (large aggregation of these asteroids on one of the mounds) (Fig. 6.57), large anemones, spoon worms (Echiurians) and crinoids. As per most mounds in the West, marine litter such as plastic sheeting, fishing gear and bottles was present on numerous coral mounds. The North Atlantic codling (*Lepidion eques*) was common in areas containing coral, whereas the roundnose grenadier (*Coryphaenoides rupestris*) was only occasionally sighted.

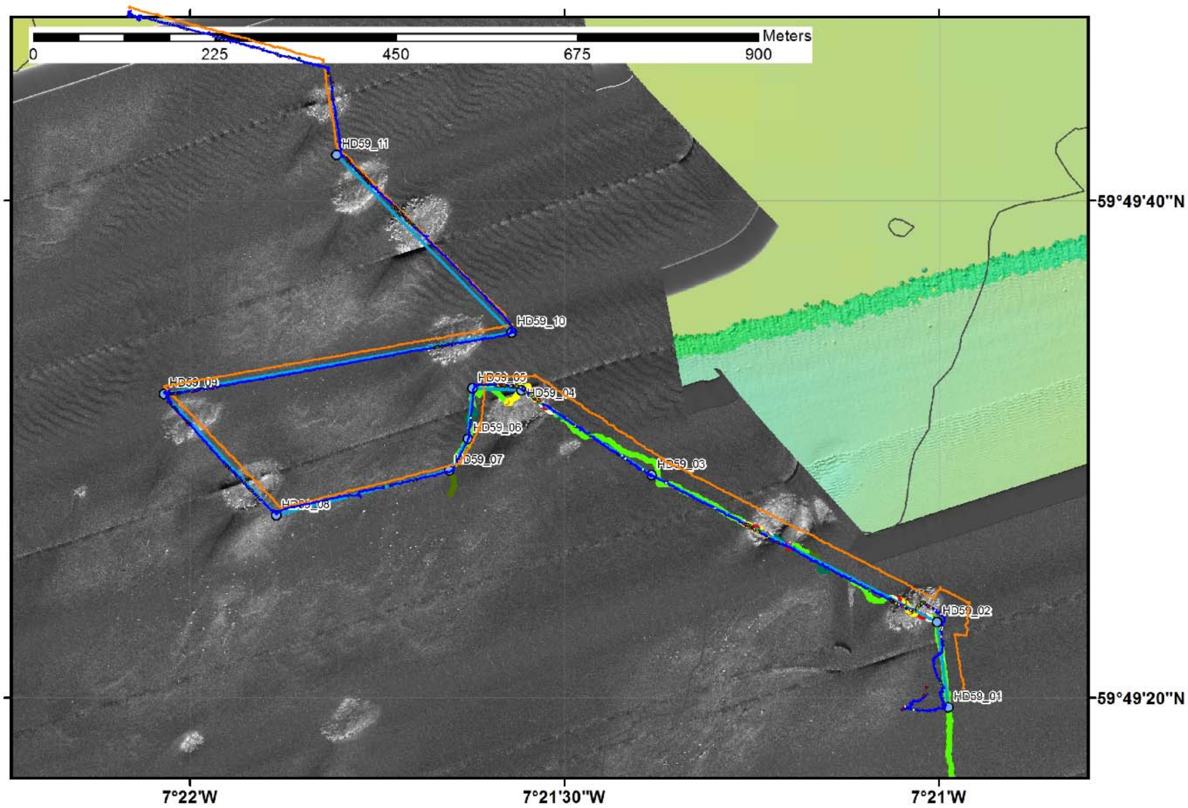


Fig. 6.55 Final OFOP map showing the tracks of the ship (orange) and HyBIS (blue) for dive 59. The light blue line is the planned transect line for the HyBIS dive. The historical track is colour-coded; dark green for sand with Xenophyopores, green for sand with pebbles and light green for just sand, yellow for coral rubble and red for live coral.

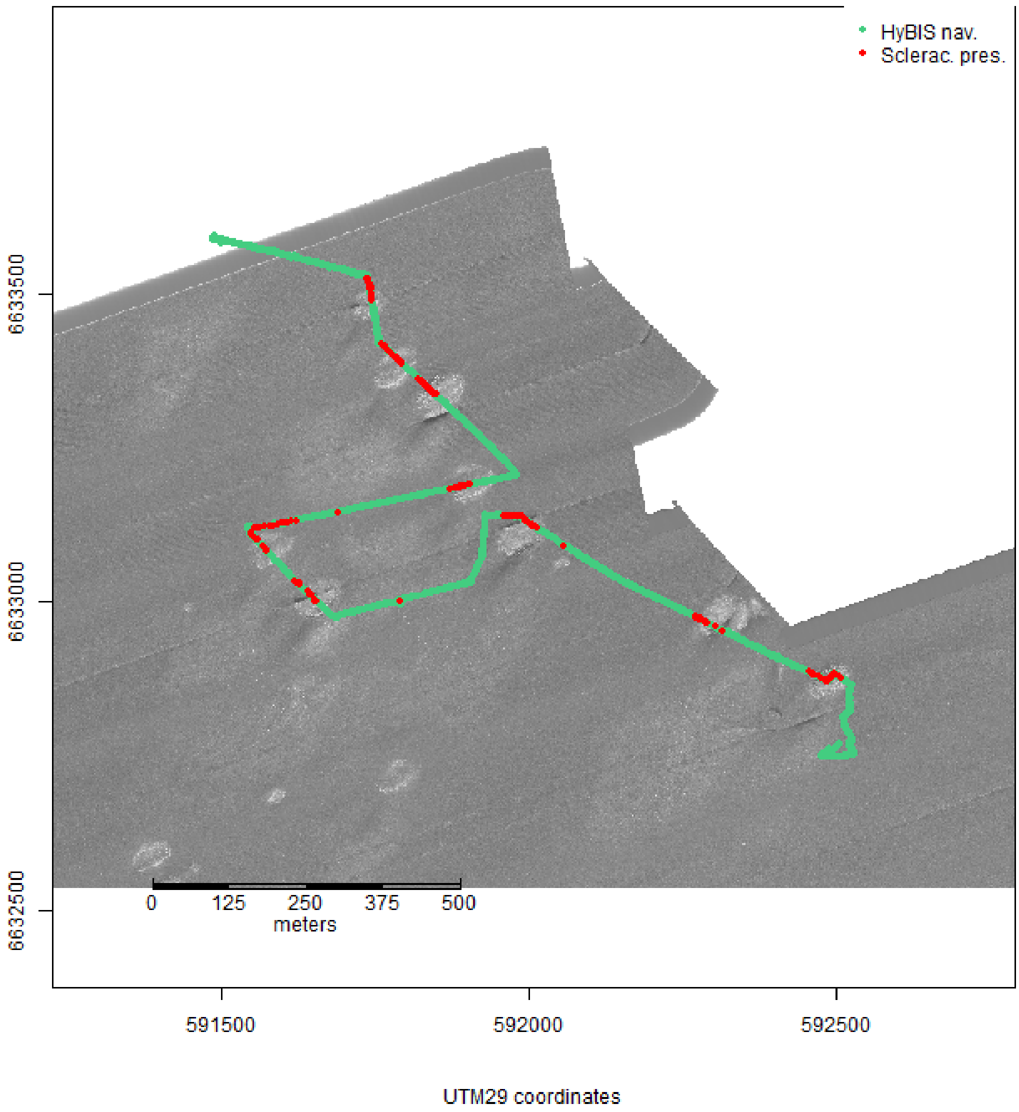


Fig. 6.56 The distribution of live coral observations (Madrepora oculata and Lophelia pertusa), shown as red points, along the route of HyBIS dive 59 (light green points).

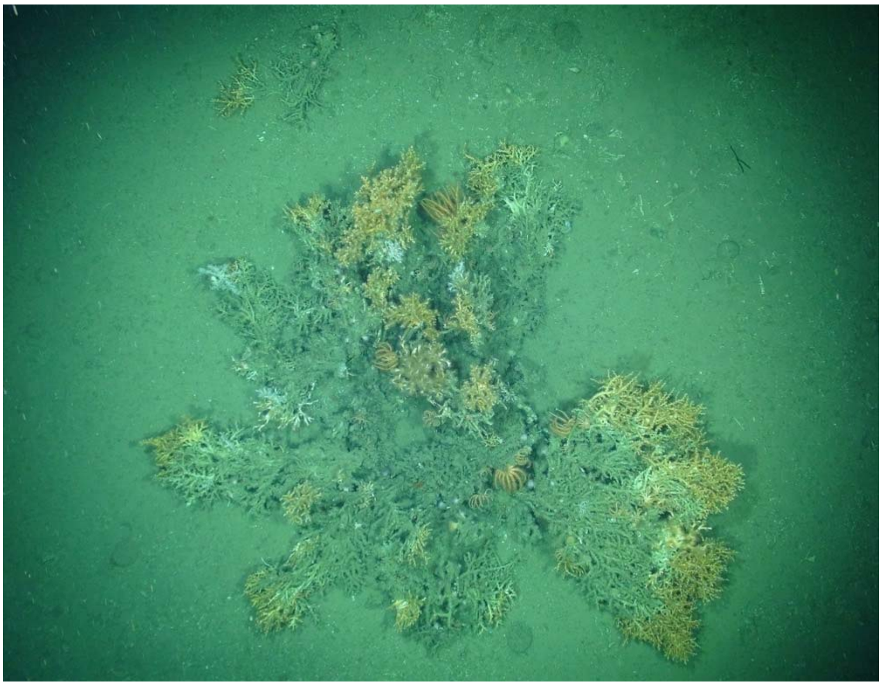


Fig. 6.57 Unusual abundance of Brisingida in an on-mound coral patch.

6.3.10. Dive 60: North of Darwin Mounds East (1048 - 1060 m, moderate to high visibility)

Objective of the dive: repeat ROV track collected in 2011 and examine a new area south of the transect.

The majority of the transect was on a sandy substratum lacking surface texture. Xenophyopores were common throughout the dive although their abundance did decline on coral mounds. Dense fields of small, polychaete tubeworms /amphipod tubes were often associated with areas of untextured sand. As per all HyBIS dives, squids were common and cutthroat eels (Synaphobranchidae) abundant throughout the dive. Epifaunal species associated with the sand, in approximate order of decreasing abundance: tube-dwelling anemones (Cerianthids), brittlestars and starfish (Ophiuroidea and Asteroidae), pencil (*Cidaris cidaris*) and fine-spined urchins (Echinoidea), and squat lobsters (galatheoids). Approximately 4-5 seapens were also encountered during the dive.

During the descent, a large elasmobranch (possibly *Lamna nasus*) appeared in both of the HyBIS cameras. Chimera (*Chimaera monstrosa*) were occasionally observed over sandy substrata. A large monkfish (*Lophius piscatorius*) was also observed on the seabed during the dive.

The planned track crossed about seven significant coral mounds (Fig. 6.58). Mounds were similar to other mounds in the area with large quantities of coral rubble and gravel but little live coral (Fig. 6.59). Live colonies were typically small and comprised of *M. oculata* with smaller quantities of *L. pertusa*. Due to the lack of live coral, epifaunal species associated with the coral were not particularly common or diverse but did include gorgonians, brisingida starfish, large anemones, spoon worms (Echiurians) and crinoids. Marine litter, such as plastic sheeting, fishing gear and plastic bottles, were present on the coral mounds. The North Atlantic codling (*Lepidion eques*) was common in areas containing coral and higher densities of coral rubble.

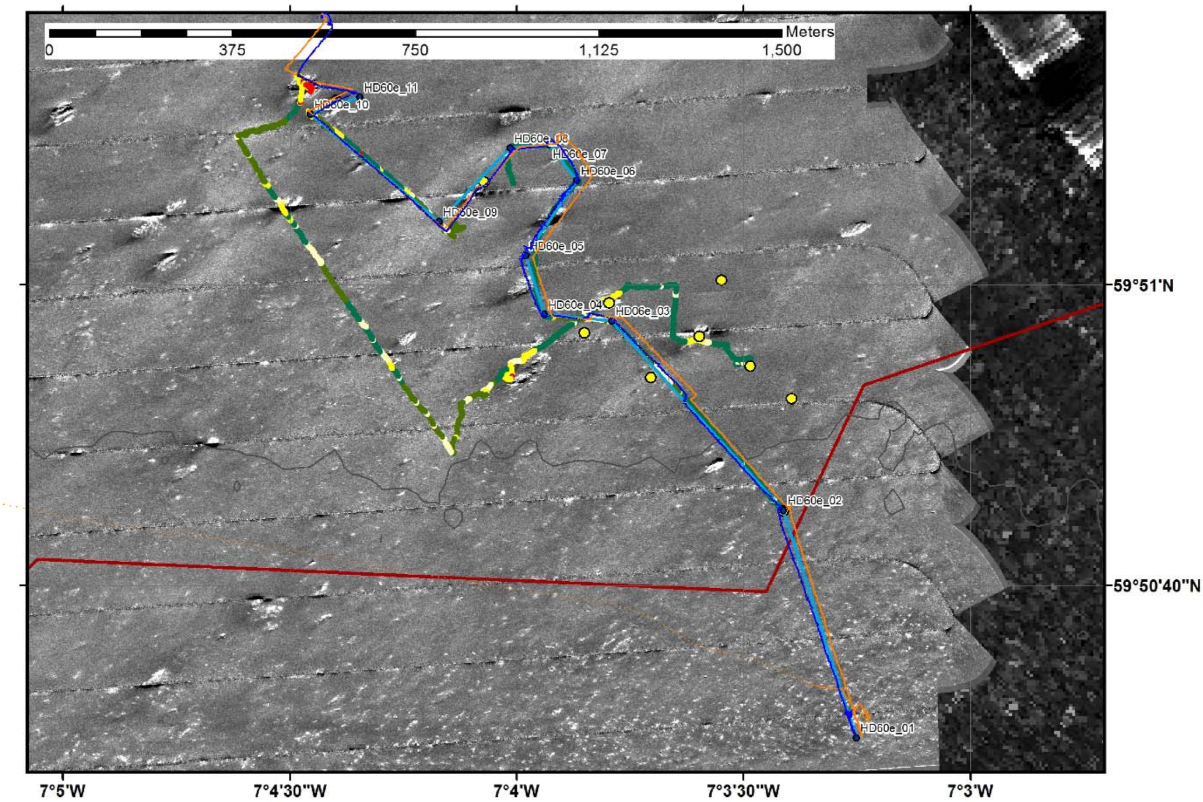


Fig. 6.58 Final OFOP map showing the tracks of the ship (orange) and HyBIS (blue) for dive 60. The light blue line is the planned transect line for the HyBIS dive. The historical track is colour-coded; dark green for sand with Xenophyopores, green for sand with pebbles and light green for just sand, yellow for coral rubble and red for live coral.

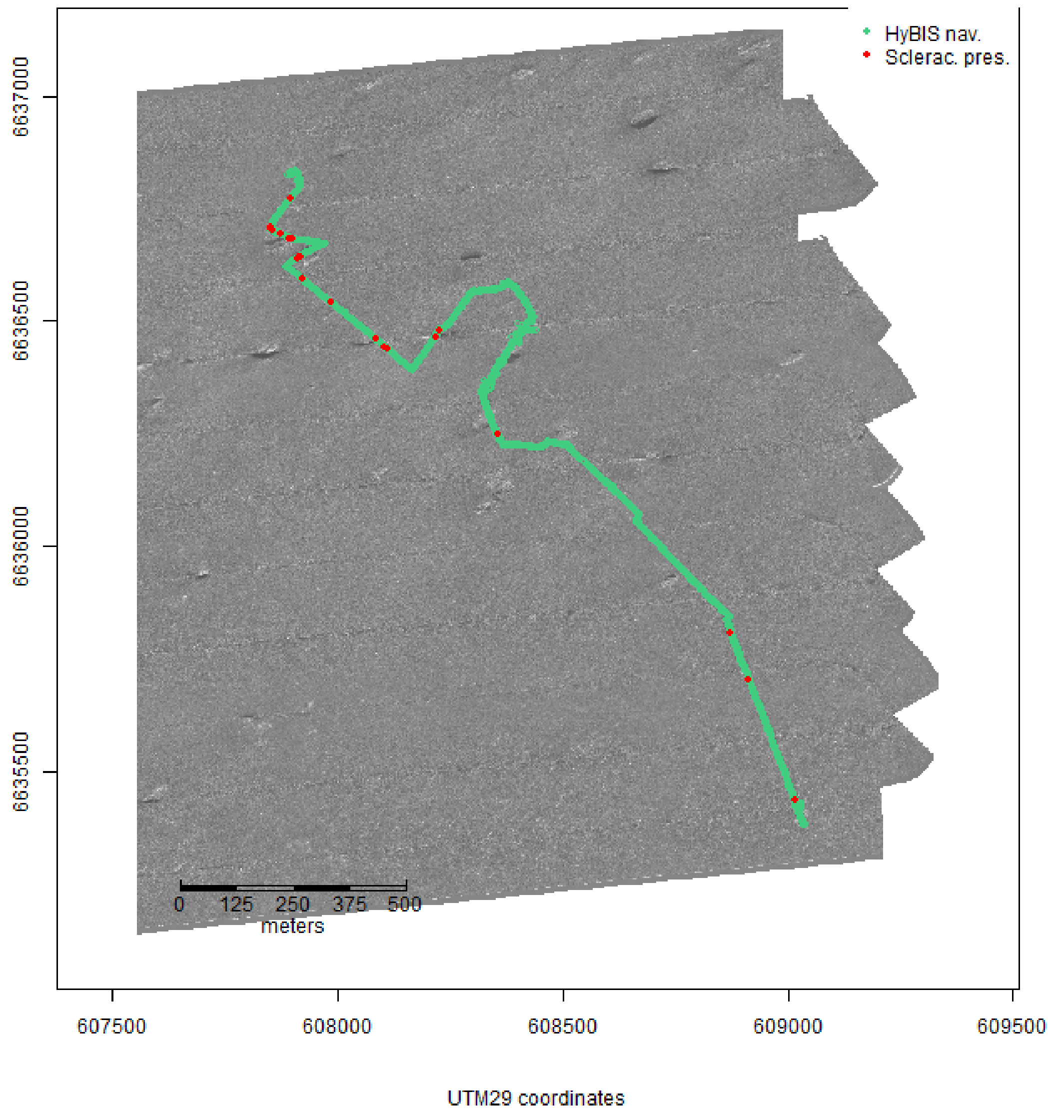


Fig. 6.59 The distribution of live coral observations (Madrepora oculata and Lophelia pertusa), shown as red points, along the route of HyBIS dive 60 (light green points).

6.3.11. Dive 61: North of Darwin Mounds West (902 - 924 m; moderate to high visibility)

Objective of the dive: Investigate new area to the west of the areas surveyed in 2011.

The majority of the dive crossed a sandy substratum, with most areas having an undulating, rippled surface. The density of Xenophyopores was much lower on sand with textured surfaces and on coral mounds. Although patchy, small tube dwelling amphipods or polychaetes were common on almost all sandy substrata, although densities were lower on textured sand surfaces. Squids and cutthroat eels (Synaphobranchidae) were abundant throughout the dive. Epifaunal species associated with the sand, in approximate order of decreasing abundance, included pencil (*Cidaris cidaris*) and fine-spined urchins (Echinoidea), brittlestars and starfish (Ophiuroidea and Asteroidae), tube-dwelling anemones (Cerianthids) and squat lobsters (Galatheoids). Chimera (*Chimaera monstrosa*) were occasionally observed over sandy substrata.

The planned track crossed nine small and medium-sized coral mounds (Fig. 6.60). The majority of the mounds during the first two-thirds of the dive were covered in high concentrations of coral gravel and rubble, with only occasional patches of small colonies (more often *M. oculata* than *L. pertusa*). Many of these mounds looked heavily abraded and superficially similar to those seen at Darwin Mounds East. Later in the dive mounds did have a greater density of live coral, and many of the colonies were larger than seen earlier in the transect (Fig. 6.61). Epifaunal species associated with the coral included sponges, gorgonians (Gorgonacea), various anemones, spoon worms (Echiurians) and crinoids. As per most mounds in the West, marine litter such as plastic sheeting, fishing gear and bottles were present. The North Atlantic codling (*Lepidion eques*) was common in areas containing coral rubble and live coral. The roundnose grenadier (*Coryphaenoides rupestris*) was only sighted occasionally during the dive.

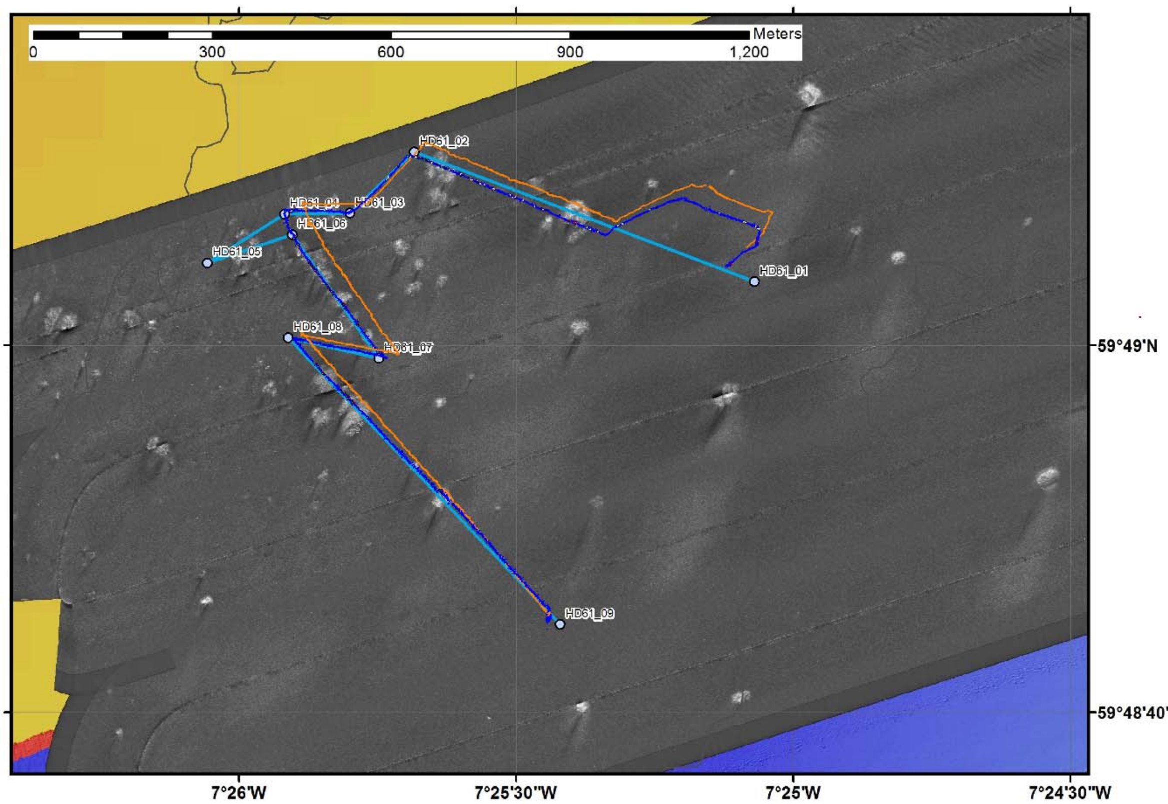


Fig. 6.60 Final OFOP map showing the tracks of the ship (orange) and HyBIS (blue) for dive 61. The light blue line is the planned transect line for the HyBIS dive.

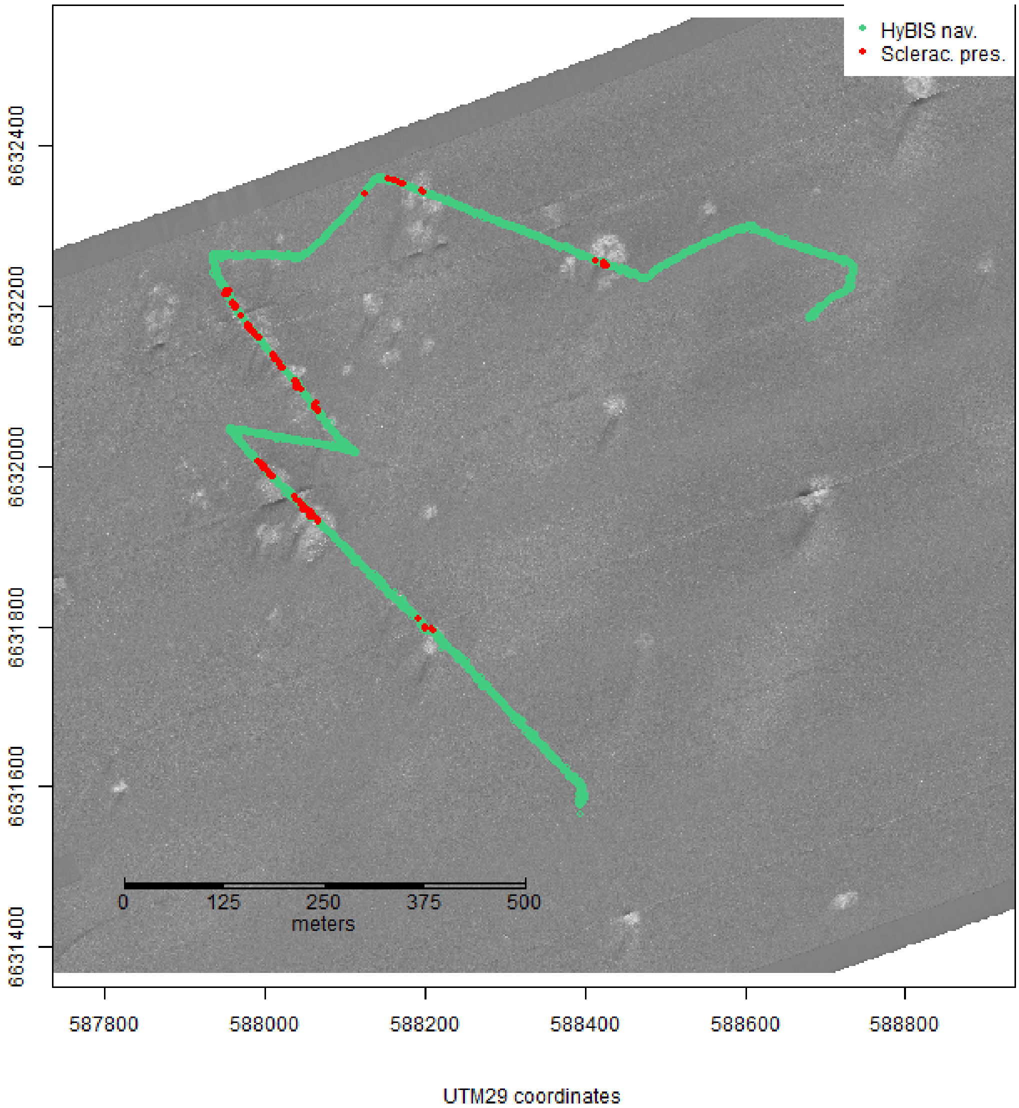


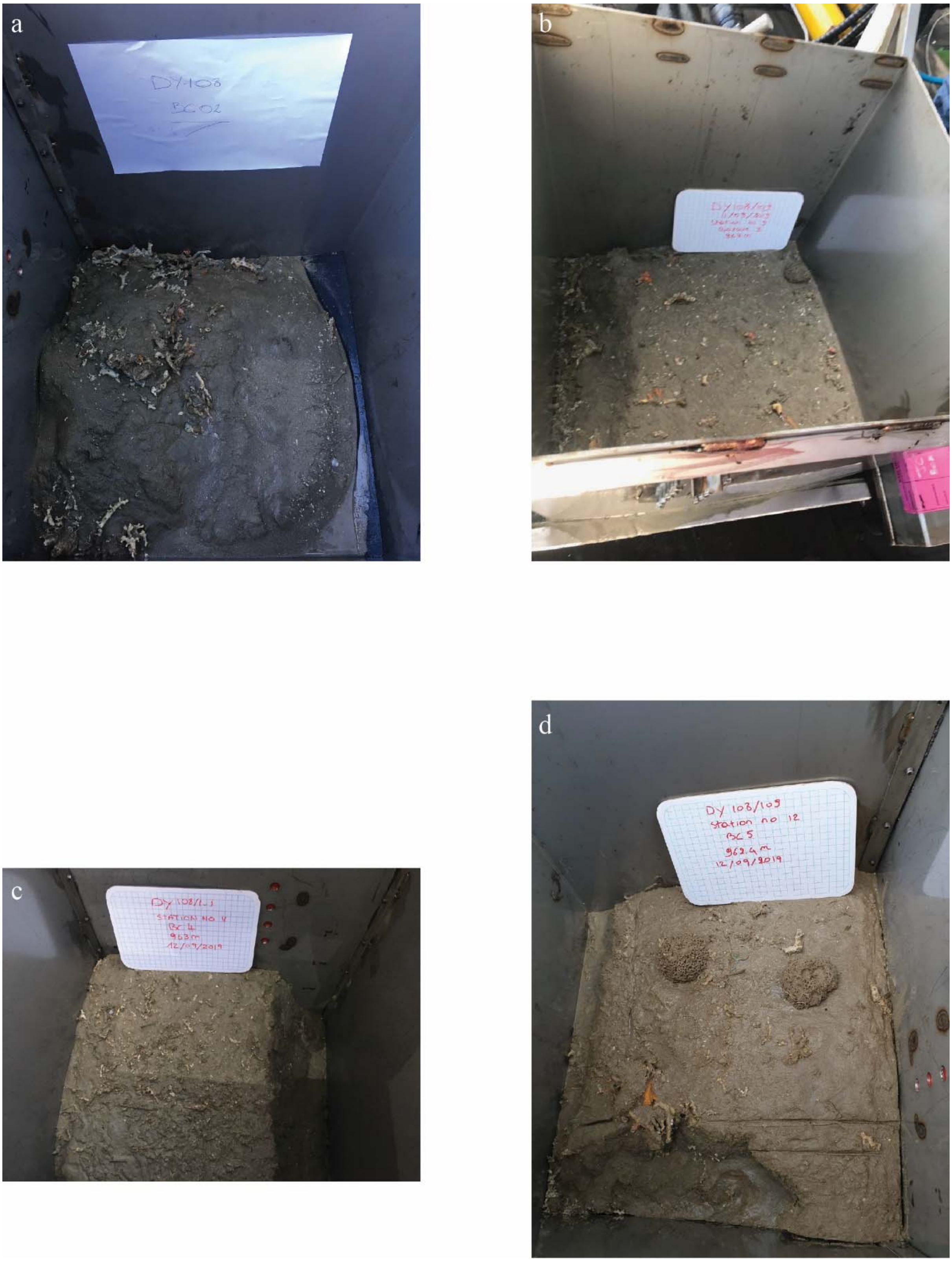
Fig. 6.61 The distribution of live coral observations (Madrepora oculata and Lophelia pertusa), shown as red points, along the route of HyBIS dive 61 (light green points).

6.4. **Macrofauna community study from boxcores** *(Laurence De Clippele, Laura Duran Suja)*

Twenty-one boxcore deployments were carried out in the west and east Darwin Mound area in an attempt to obtain large-volume samples of mound and tail sediments of trawled and untrawled areas to analyse the macrofaunal biodiversity. The corer used was the NOC NMFD stainless steel, USNEL-type 0.25m^2 boxcorer (see Section 7.3.1). It was rigged and operated with the penetration limit removed. The mound samples were all insufficiently cohesive to support the water in the box once in air. Consequently, these samples were subject to wash-out. Tail samples on the other hand were able to retain the water and were subject to minor wash-out. The “intact” areas of the recovered sediment of the mound samples were sampled in a quantitative matter, i.e. the dimensions were measured and this known surface area was then sieved on a 500 micron mesh, with the resultant residue fixed and preserved in borax buffered 3.7% seawater formaldehyde. 15 boxcores were classified as successful, four as partly and two did not trigger (Fig. 6.62 and 6.63, Table 6.13).

After allowing the samples to fix for 2-5 days in the borax buffered 3.7% seawater formaldehyde, the samples were washed and identified to family level using a ZEISS Stemi 305 stereo microscope. After identification the samples were transferred into glass vials on 75% Industrial Methylated Spirit (IMS).

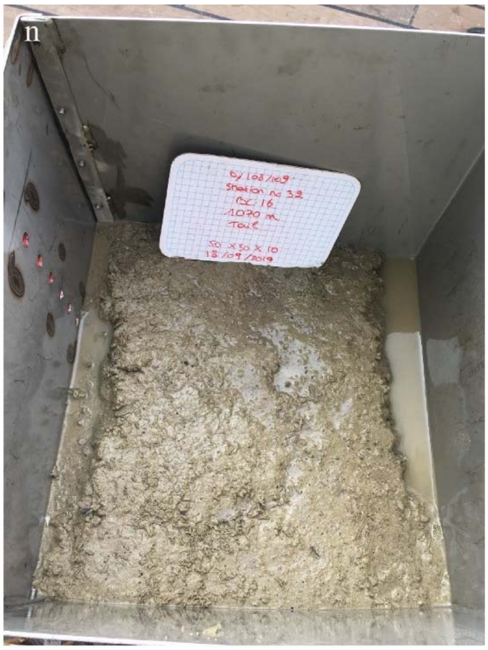
These samples were taken on behalf of Prof J Murray Roberts and Dr Lea-Anne Henry, from the University of Edinburgh, to serve as a comparison to a similar set of samples collected from the Darwin Mounds area during the 2000 RRS Discovery cruise 248 (Bett et al, 2001) and 2011 RRS James Cook cruise 060 (Huvenne, 2011). A comparison analyses of the tails versus the mound associated biodiversity will also be conducted.


a
DY-108
BC02
b
c
BC 4
953m
12/09/2019
d
Dy 108/109
station no 12
BC 5
962.4 m
12/09/2019


e
DY108/109
Station no 13
1053 m
12/08/2019
30x60x10
f
g
DY108/109
Station no 20
BC 8
960 m
Tail
50x50x10
h


i
DY 108/109
Station no 23
BC 10
1065 m
mound
18 x 50 x 10
17/09/2019
j
DY 108/109
Station no 24
BC 11
1005 m
mound
22 x 31 x 10
17/09/2019
k
DY 108/109
Station no 26
BC 13
1002 m
mound
x x 10
17/09/2019
l


m
DY 108/109
Station no 29
BC 15
1050 m
50 x 50 x 10
18/09/2019


n
DY 108/109
Station no 32
BC 16
1070 m
50 x 50 x 10
18/09/2019


o
DY 108/109
Station no 32
BC 17
1053 m
37 x 20 x 10
18/09/2019


p
DY 108/109
Station no 35
BC 18
1053 m
50 x 50 x 10
19/09/2019

Fig 6.62 Photographs of boxcore surface upon recovery: (a) DY108/109_ST8_BC2; (b) DY108/109_ST9_BC3; (c) DY108/109_ST11_BC4; (d) DY108/109_ST12_BC5; (e) DY108/109_ST13_BC6 whiteboard is missing "BC6"; (f) DY108/109_ST19_BC7; (g) DY108/109_ST20_BC8; (h) DY108/109_ST21_BC9; (i) DY108/109_ST23_BC10; (j) DY108/109_ST24_BC11; (k) DY108/109_ST26_BC13; (l) DY108/109_ST28_BC14; (m) DY108/109_ST29_BC15; (n) DY108/109_ST31_BC16 whiteboard station location should be "31"; (o) DY108/109_ST32_BC17 habitat type on whiteboard should be "mound"; (p) DY108/109_ST34_BC18 Station number on whiteboard should be "34"; (q) DY108/109_ST35_BC19; (r) DY108/109_ST36_BC20; (s) DY108/109_ST38_BC21

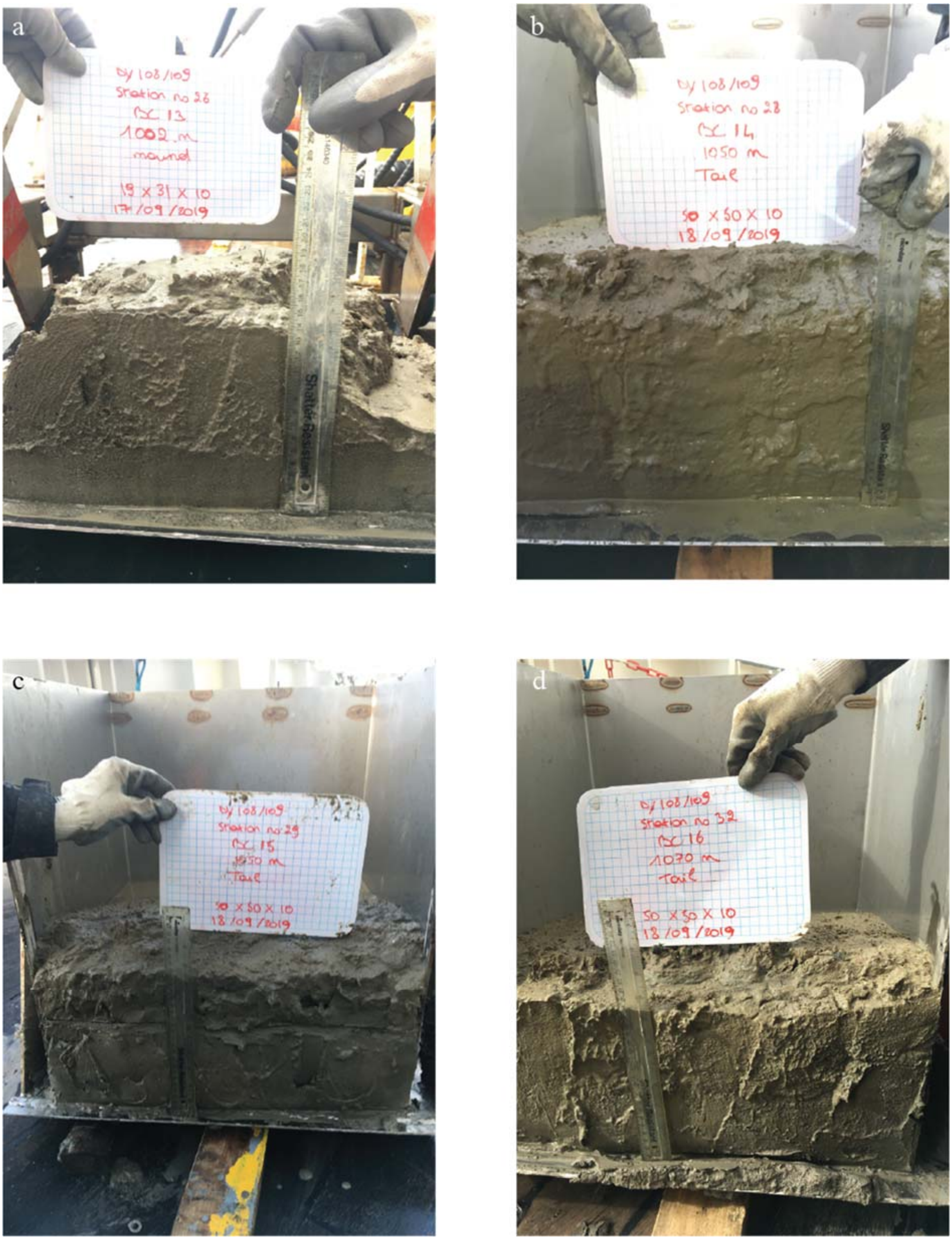

a
DY 108/109
Station no 28
BC 13
1002 m
mound
19 x 31 x 10
17/09/2019
b
DY 108/109
Station no 28
BC 14
1050 m
Tail
50 x 50 x 10
18/09/2019
c
DY 108/109
Station no 29
BC 15
1050 m
Tail
50 x 50 x 10
18/09/2019
d
DY 108/109
Station no 32
BC 16
1070 m
Tail
50 x 50 x 10
18/09/2019

Fig 6.63 Photographs of boxcore profiles: (a) DY108/109_ST26_BC13 (b) DY108/109_ST28_BC14 (c) DY108/109_ST29_BC15 (d) DY108/109_ST31_BC16 whiteboard station location should be "31" (e) DY108/109_ST32_BC17 habitat type on whiteboard should be "mound" (f) DY108/109_ST34_BC18 Station number on whiteboard should be "34" (g) DY108/109_ST36_BC20

Table 6.13 Overview of boxcores taken during the cruise.

SAMPLE NR	Date	Location	Habitat	Station	BC no.	Success	Depth (m)	Dimensions (cm)	Sediment type detail	Time	USBL Lat degrees	USBL Lat Minutes	USBL Lon degrees	USBL Lon Minutes	Estimated family
DY108/109_ST7_BC1	11/09/2019	WDM	mound	7	1	no	966	NA	NA	12:36	59	48.74	7	21.744	
DY108/109_ST2_BC2	11/09/2019	WDM	mound	8	2	medium	964	50x25x10	sand with coral rubble (15%)	14:12	59	48.75	7	21.719	54
DY108/109_ST9_BC3	11/09/2019	WDM	mound	9	3	yes	968	41x35x10	sand with coral rubble (25%)	15:48	59	48.748	7	21.712	62
DY108/109_ST11_BC4	12/09/2019	WDM	mound	11	4	yes	963.5	35x35x10	sand with coral rubble (35%)	05:21	59	49.103	7	21.372	24
DY108/109_ST12_BC5	12/09/2019	WDM	mound	12	5	yes	962.4	35x35x10	muddy (10%) sand (90%) with coral rubble (35%)	06:52	59	49.3892	7	21.0288	38
DY108/109_ST13_BC6	12/09/2019	EDM	just next to mound	13	6	medium	1053	30x40x10	Gravelly sand	10:18	59	50.98126	7	3.82663	20
DY108/109_ST19_BC7	16/09/2019	WDM	tail	19	7	yes	975	50x50x10	sandy (20%) mud (80%)	10:58	59	49:31187	7	21.2818	15
DY108/109_ST20_BC8	16/09/2019	WDM	tail	20	8	yes	957	50x50x10	sandy (20%) mud (80%)	12:47	59	49.2308	7	21.8687	11
DY108/109_ST21_BC9	16/09/2019	WDM	tail	21	9	yes	1456	50x50x10	sandy (20%) mud (80%)	14:56	59	49.7554	7	21.4977	15
DY108/109_ST23_BC10	17/09/2019	EDM	background	23	10	yes	1057	18x50x10	Gravelly sand	08:57	59	50.9661	7	3.8359	NA
DY108/109_ST24_BC11	17/09/2019	EDM	just next to mound	24	11	yes	1055	22x31x10	Gravelly sand	10:54	59	50.636	7	7.5785	14
DY108/109_ST25_BC12	17/09/2019	EDM	mound	25	12	no	1062.5	NA	NA	12:52	59	51.034	7	7.9049	
DY108/109_ST26_BC13	17/09/2019	EDM	just next to mound	26	13	yes	1052	19x31x10	Gravelly sand	14:13	59	51.0334	7	7.9239	8
DY108/109_ST28_BC14	18/09/2019	EDM	tail	28	14	yes	1052	50x50x10	sand	05:11	59	50.9992	7	8.0092	12
DY108/109_ST29_BC15	18/09/2019	EDM	tail	29	15	yes	1057	50x50x10	muddy (20%) sand (80%)	06:39	59	50.7135	7	8.3476	11
DY108/109_ST31_BC16	18/09/2019	EDM	tail	31	16	yes	1050	50x50x10	gravely sand	12:38	59	50.9422	7	3.8744	16
DY108/109_ST32_BC17	18/09/2019	EDM	just next to mound	32	17	yes	1053	37x20x10	gravelly sand with a few coral rubble pieces (1%)	14:15	59	50.953	7	3.6312	19
DY108/109_ST34_BC18	19/09/2019	EDM	tail	34	18	yes	1053	50x50x50	gravelly muddy (15%) sand with coral rubble pieces (3%)	04:52	59	50.9057	7	3.6984	24
DY108/109_ST35_BC19	19/09/2019	WDM	mound	35	19	medium	953	19.5x23x10	sand with coral rubble (15%)	11:54	59	48.82409	7	22.51364	26
DY108/109_ST36_BC20	19/09/2019	WDM	tail	36	20	yes	952	50x50x10	mud (20%) sand (80%)	14:01	59	48.8159	7	22.80049	11
DY108/109_ST38_BC21	20/09/2019	WDM	mound	38	21	medium	951	9x16x10	sand with one piece of rubble	04:42	59	48.8247	7	22.5341	NA

6.5. Settling experiment *(James Strong)*

Four small moorings were deployed in the Darwin Mounds during expedition JC060 in 2011, to mark the start of ROV dives and provide a clear point to return to (Huvenne, 2011). Two of the four moorings, those placed in the Eastern Darwin Mounds, also carried two settlement panels. Each mooring had a steel plate anchor and a spherical glass buoy encased in two hemispherical plastic shells. The height of the buoy above the ballast varied between moorings. Moorings were fitted with settlement panels at 1 m and 2 m above the seabed. Settlement panels were concrete roof tiles that were drilled and attached to the moorings with cable ties. The objective of the deployments was to establish whether the settlement of *Desmophyllum pertusum* (nom. nov *Lophelia pertusa*) (Linnaeus, 1758) was occurring at either site.

On initial inspection during DY108-109 with HyBIS, it was apparent that each of the buoys had accumulated a substantial amount of biofouling. HyBIS video footage revealed the presence of multiple coral species, including *L. pertusa*, on the buoys. As such, the decision was taken to recover one mooring from both East and West Darwin Mounds for further inspection (Section 6.5.2) and to leave the remaining moorings for future study (Section 6.5.3).

6.5.1. Recovered settlement moorings

The two moorings (Table 6.14) were recovered with the HyBIS remote underwater vehicle. The HyBIS frame was modified to include a snap-carabiner, mounted on a pole and attached to the HyBIS frame with a lifting strop. Care was taken not to disturb the mooring excessively during the recovery. Close up video observations were collected before the ascent should the mooring be lost on recovery (Darwin Mounds West buoy - Figures 6.64a and 6.64b; Darwin Mounds East buoy - Figures 6.65a and 6.65b).

Table 6.14 Details of the settlement moorings at Darwin Mounds East and West.

	Darwin Mounds West	Darwin Mounds East
Original station numbers	JC060-30-Mark-02	JC060-50-Mark-04
Deployed	16/05/2011 21:46	21/05/2011 23:00
HyBIS dive	52	53
Recovered to deck	12/09/2019 ~ 19:21	12/09/2019 ~23:25
Depth	968 m	1058 m
Position	59° 48.86417 N 007° 21.54315 W	59° 50.93434 N 007° 3.53917 W
Buoy height above the seabed	6 m	4.5 m
Settlement panels	N/A	1 m and 2 m above seabed (2 m panel lost on recovery)
Moorings remaining in place	1	1

6.5.1.1. **Visual inspection of the recovered moorings *in situ***

The ballast weight was not colonised whilst the mooring rope was covered in a dense hydroid turf. The buoys at both sites were predominantly covered in large barnacles as well as a variety of mobile epifaunal species such as urchins (Echinoidea), hermit crabs (Paguroidea), gastropods (Gastropoda), brittlestars (Ophiuroides) and shrimp (*Pandalus* sp.) - much of this was lost during the ascent.

Fig. 6.64 a & b Darwin Mounds West buoy on seabed (left) and close-up of buoy during ascent (right).

Fig. 6.65 a & b. Darwin Mounds East buoy on seabed showing the location of the two settlement panels near the base of the mooring (left) and close-up of buoy during ascent (right).

6.5.1.2. **On-deck observations of the mooring from Darwin Mounds West**

The buoy was completely covered in biofouling and several of the mobile epifaunal species were still attached to the buoy (i.e. urchins and numerous brittlestars). Barnacles dominated the buoy in terms of both cover and biomass (Fig. 6.66, Fig. 6.67a). Noteworthy members of the biofouling community included:

- Four colonies of *L. pertusa* attached to the buoy - each colony was between 25 - 95 mm in height and contained multiple polyps. Colonies were mostly growing on barnacle plates.
- Numerous individual *Desmophyllum* sp. polyps were interspersed through the barnacle cover (Fig. 6.67b).
- Many small orange, Chlamys-like species, pectinids were scattered over the barnacle encrustment .
- Ophiuroids were abundant across the surface of the buoy (approximately in the low to mid hundreds).
- Polychaete worms were frequent within the interstitial spaces between barnacles.
- Several small soft coral colonies were also present on the buoy (Fig. 6.67c).
- The mooring rope was also colonised, although sparsely, with barnacles, individual *Desmophyllum* polyps, hydroids and small, soft corals.

Fig. 6.66 Photomosaic of the mooring buoy deployed at Darwin Mounds West.

Fig. 6.67a, b and c. Close-up of a barnacles with Desmophyllum sp. (top), Desmophyllum sp. (middle), and soft coral (bottom).

The following samples were collected from the mooring:

- four colonies of *L. pertusa* (Fig. 6.68a and b) in ethanol;
- seven individual *Desmophyllum* sp. polyps (Fig. 6.69a, b and c) in ethanol;
- a one-eighth sub-sample of the total biofouling on the buoy (in ethanol);
- a pseudo-settlement panel sample (an area of 659 $cm^{2)}$ from the buoy surface, lower half (in ethanol); and

- all remaining fouling was frozen for weighing back at NOC.

Fig. 6.68a and b. Example images of L. pertusa on the Darwin Mounds West mooring.

Fig. 6.69a, b and c. Example images of the Desmophyllum sp. polyps on the Darwin Mounds West mooring.

6.5.1.3. **On-deck observations of the settlement panel mooring from Darwin Mounds East**

The buoy was again completely in barnacles (Fig. 6.70). Several urchins, as well as numerous ophiuroids, were still occupying the buoy following the ascent. The settlement panel 2 m above the seabed was lost during the recovery process. Noteworthy members of the biofouling community included:

- One small colony of *L. pertusa* was attached to the buoy - the colony was attached to a barnacle plate.
- One very small colony of *L. pertusa* (one polyp colony) attached to the settlement panel but growing on a barnacle plate. The settlement panel had a significant uncolonised area.
- Numerous smaller *Desmophyllum* sp. polyps were interspersed throughout the barnacle cover.
- Many small orange pectinids were scattered over the barnacle encrustment.
- Ophiuroids were abundant across the surface of the buoy (approximately in the low to mid hundreds).

- Polychaete worms were frequent within the interstitial spaces between barnacles.
- The blue rope attached to the mooring rope was also colonised, although sparsely, with barnacles, individual *Desmophyllum* polyps, hydroids and small bivalves.

Fig. 6.70 Biofouling on the two halves of the Darwin Mounds East mooring buoy - the width of the buoy (from point A to point B) is 494 mm.

The following samples were collected from the mooring:

- one colony of *L. pertusa* (in ethanol);
- the entire settlement panel (in ethanol);
- a one-eighth sub-sample of the buoy biofouling (in ethanol);
- a pseudo-settlement panel sample (an area of 659 $cm^{2)}$ from the buoy surface (in ethanol); and
- all remaining fouling was frozen for weighing back at NOC.

Laboratory analysis required on return to NOC:

- Identification of the species present on each buoy.
- Enumeration and weighing of the biofouling species.
- Coral samples to be weighed, measured and dispatched for genetic sampling.
- Careful examination of the samples for smaller colonies of coral missed on deck.

6.5.2. *In situ* observations of the settlement panel moorings remaining in place

The mooring remaining in place at Darwin Mounds West was inspected during HyBIS dive 54 (16/09/2019). The mooring lacked settlement panels and was estimated to be 4 m in height. The plate anchor was not colonised but the mooring rope was colonised by hydroids and some barnacles. The buoy was completely covered in feeding barnacles (Fig. 6.71) and looked superficially the same as the recovered buoy. A possible *Lophelia pertusa* colony was also apparent on the buoy. Additional taxa on the buoy included sea anemones and large tufts of hydroid.

The mooring remaining in place at Darwin Mounds East was inspected during HyBIS dive 56 (18/09/2019). The mooring lacked settlement panels and was estimated to be 4.5 m in height. The plate anchor was surrounded by debris from the mooring (probably detached barnacles). One of the detached settlement panels could be seen resting against the anchor and appeared to be colonised by barnacles. A basket star (*Gorgonocephalus* sp.) was attached to the bottom of the mooring rope. The rest of the mooring rope was colonised by a small number of barnacles, hydroids and a Venus fly trap anemone (*Phelliactis* sp.). The buoy was again completely covered in barnacles (Fig. 6.72). Based on a superficial inspection of the camera footage, no hard corals were apparent on the buoy. Unfortunately, the video recording of this buoy was lost – only the Scorpio downward pictures were recorded.

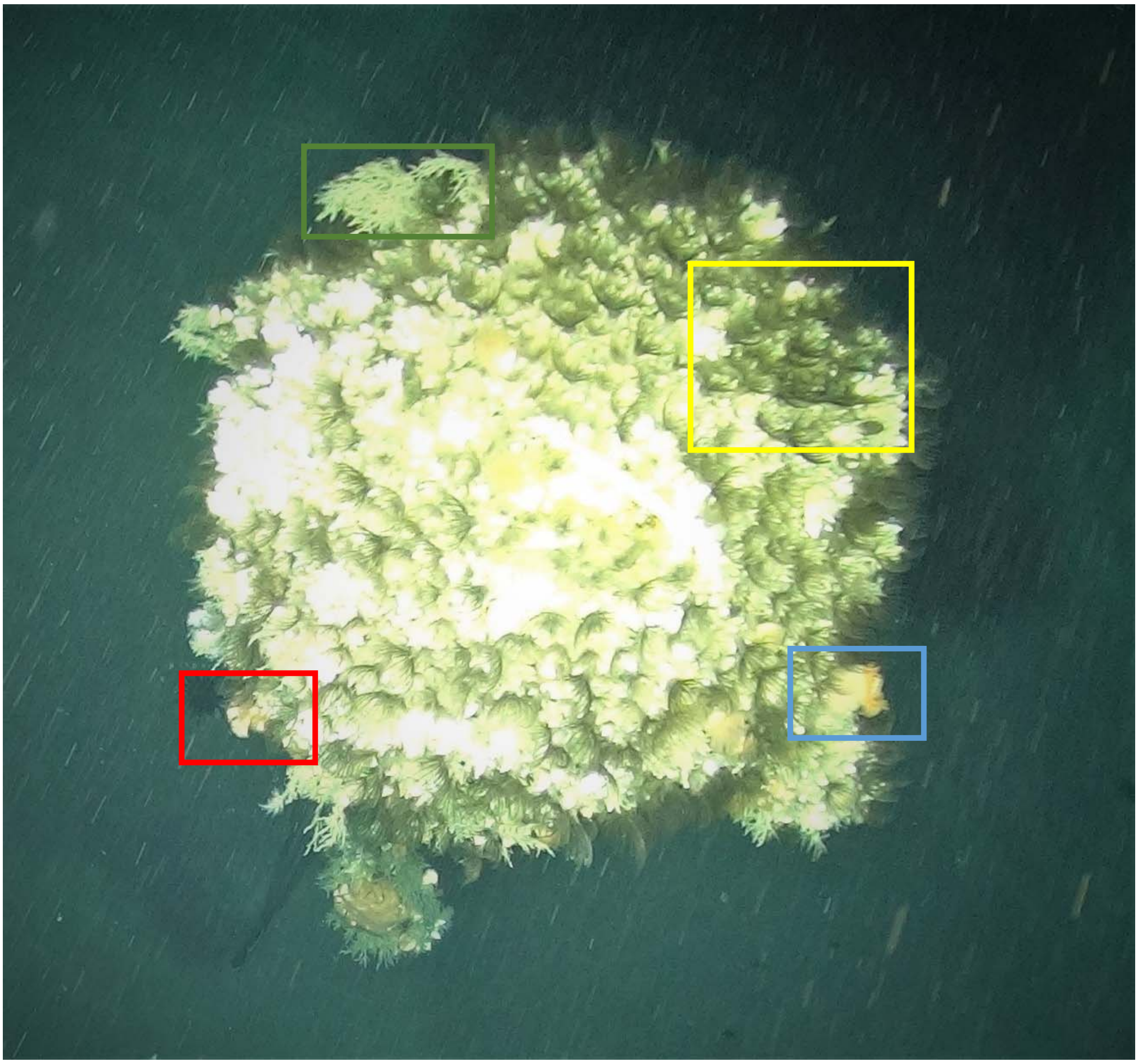


Fig. 6.71 Scorpio downward photographs of the Darwin Mounds West settlement buoy that remained in-place. The red box highlights a possible Lophelia colony. The blue box surrounds a sea anemone. The yellow box shows an area of filtering barnacles. The green box encompasses large tufts of hydroid.

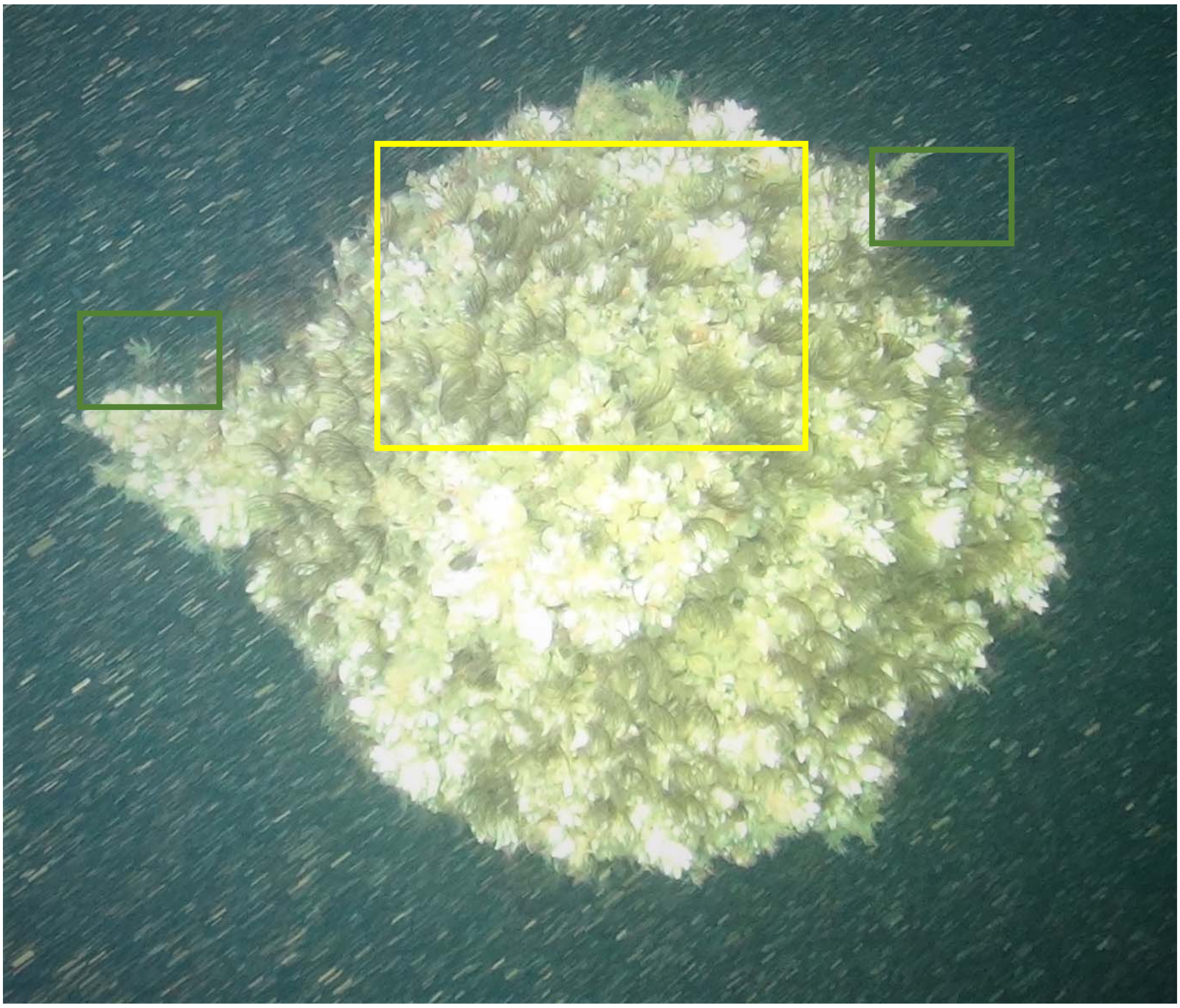


Fig. 6.72 Scorpio downward photographs of the Darwin Mounds East settlement buoy that remained in place. The yellow box shows an area of filtering barnacles. The green boxes encompass large tufts of hydroid.

6.5.3. Initial impressions of the fouling growth present at both sites

- More hard coral colonies were present on the moorings located in Darwin Mounds West when compared with Darwin Mounds East. Western moorings were also shorter than those in the East.
- The biofouling community consisted of attached and, interestingly, many large and numerous mobile epifaunal species - it is likely that these species also settled on the buoy rather than migrated up the mooring rope.
- Coral colonies were typically growing on barnacle plates suggesting the surviving colonies settled sometime after the barnacles i.e. less than 8 years ago.
- Coral growth is moderately rapid in the West with one colony having grown close to 10 cm in length in 8 years (or less as is more likely considering corals were attached to barnacle plates).
- It is possible that the high abundance of mobile epifauna is maintained by large quantities of pseudo-faeces produced by the barnacles and bivalves.

- It is not clear whether the coral settlement and growth on the buoys is enhanced by: (i) the elevation above the seabed, and consequently an increase in current speed and food availability; (ii) isolation from seafloor predators and sedimentary processes (burial and scour); and/or (iii) the reduction of taphonomically induced mortalities of settling larvae on cleaner buoy surfaces.

6.5.4. Deployment of new settlement experiment

Following the successful recovery of the JC060 moorings, and the unexpectedly high colonisation rates, it was decided that further settlement experiments should be carried out to investigate following questions:

- Given the high colonisation in eight years, what is the level of settlement/colonisation after 1 year?
- Do corals settle preferentially on barnacle plates rather than directly on the plastic shells of the marker buoys?
- What is the effect of height above the seabed?

In order to obtain some pilot data to answer these questions, the plastic shells of the mooring were cleaned, and attached at two different heights to the oceanographic mooring that was deployed in the Eastern Darwin Mounds (see Section 7.5). The inside of the shells was cleaned with a ligh soap, while the outside was just scraped clean, leaving some biological residue from the barnacles as biological settlement surface.

6.6. Water column study from CTDs, ADCP, mooring, sediment trap and lander

(Sam Jones, Brian Bett)

Oceanographic measurements during DY108/109 consisted of CTD casts (with LADCP), continuous measurements with the ship-board ADCPs, a mooring deployment and the attempt to recover & deploy a lander frame with upward-looking ADCP.

6.6.1. Shipboard ADCP measurements

RRS Discovery is fitted with RD Instruments 75kHz and 150 kHz Ocean Surveyor ADCPs. The instruments are mounted in the ship's hull in a forward–aft configuration, approximately 6 m below the waterline.

Positional and attitude information is provided via a PosMV multi-receiver GPS attitude sensor. Discovery now uses UHDAS (University of Hawaii Data Acquisition System), which in turn employs CODAS (Common Ocean Data Access System database) to construct a dataset of averaged, Earth referenced ocean velocities. The root folder for the VM-ADCP data (raw and processed) is in the following folder in the ship's data archive:

Ship_Fitted_Scientific_Systems\Acoustics\ADCP-UHDAS.

The UHDAS GUI is used to configure the ADCP and perform velocity mapping to the reference frame of the vessel. Bottom tracking was disabled for the cruise as the work areas were in waters too deep for it to be effective.

Vessel mounted ADCP data were recorded throughout DY108 with the exception of the long transits at the beginning and end of the cruise. In general, the ADCP systems worked well throughout the cruise, though suffered from a daily mid-water column reduction in signal strength which might be linked to zooplankton diurnal vertical migration. As a rule of thumb, the 150 kHz instrument has a lower range but better resolution than the 75 kHz insrument. Typical ranges achieved by the instruments were as follows:

OS75 broadband: 180 m
OS75 narrowband: 400 m
OS150 broadband: 100 m
OS150 narrowband: 180 m

RDI OS150 Setup

Narrowband Mode:	ON
NB Number of Bins:	40
NB Bin length (m):	8.0
NB Blanking (m):	4.0
Broadband mode:	ON
BB Number of Bins:	80
BB Bin length (m):	4.0
BB Blanking (m):	4.0
Bottom Tracking:	OFF
BT Max Depth (m):	500.0
TP min ping time (s):	01.10
Trigger in,out [,timeout]:	0,0

RDI OS75 Setup

Narrowband Mode:	ON
NB Number of Bins:	60
NB Bin length (m):	16.0
NB Blanking (m):	8.0
Broadband mode:	ON
BB Number of Bins:	45
BB Bin length (m):	8.0
BB Blanking (m):	8.0
Bottom Tracking:	OFF
BT Max Depth (m):	1000.0
TP min ping time (s):	01.80
Trigger in,out [,timeout]:	0,0

Accessing the processed data in the UHDAS file structure

The VM-ADCP data processed by UHDAS are automatally output and stored in the ship's archive in the folder:

Ship_Fitted_Scientific_Systems\Acoustics\ADCP-UHDAS\proc\os75nb\contour (e.g. for 75 kHz narrowband data).

This contains temporally averaged and gridded data, which has been referenced to Earth coordinates (ship velocities removed). The UHDAS user's guide (https://currents.soest.hawaii.edu/docs/adcp_doc/adcp_data/adcp_access/READING/MATLAB/GETMAT/index.html) provides the following information for reading these data files into Matlab:

1. You will probably want the matlab program load_getmat.m (available for download from the webpage above).

2. Identify the location of the files generated by getmat.m. For example, a modern UHDAS installation writes files in contour/allbins_*.mat. You can see the live processing directory and access the allbins*.mat files by looking at the shared data directory and following the example in the next step.

3. If the location of the getmat output is uhdas_data/km1001c/proc/os38nb/contour then load the files with matlab as follows:

data = load_getmat('uhdas_data/km1001c/proc/os38nb/contour/allbins_');
% DO apply the editing mask:
u = data.u . data.nanmask;*
v = data.v . data.nanmask;*

4. Variable names are documented with "help load_getmat".

Example data plots

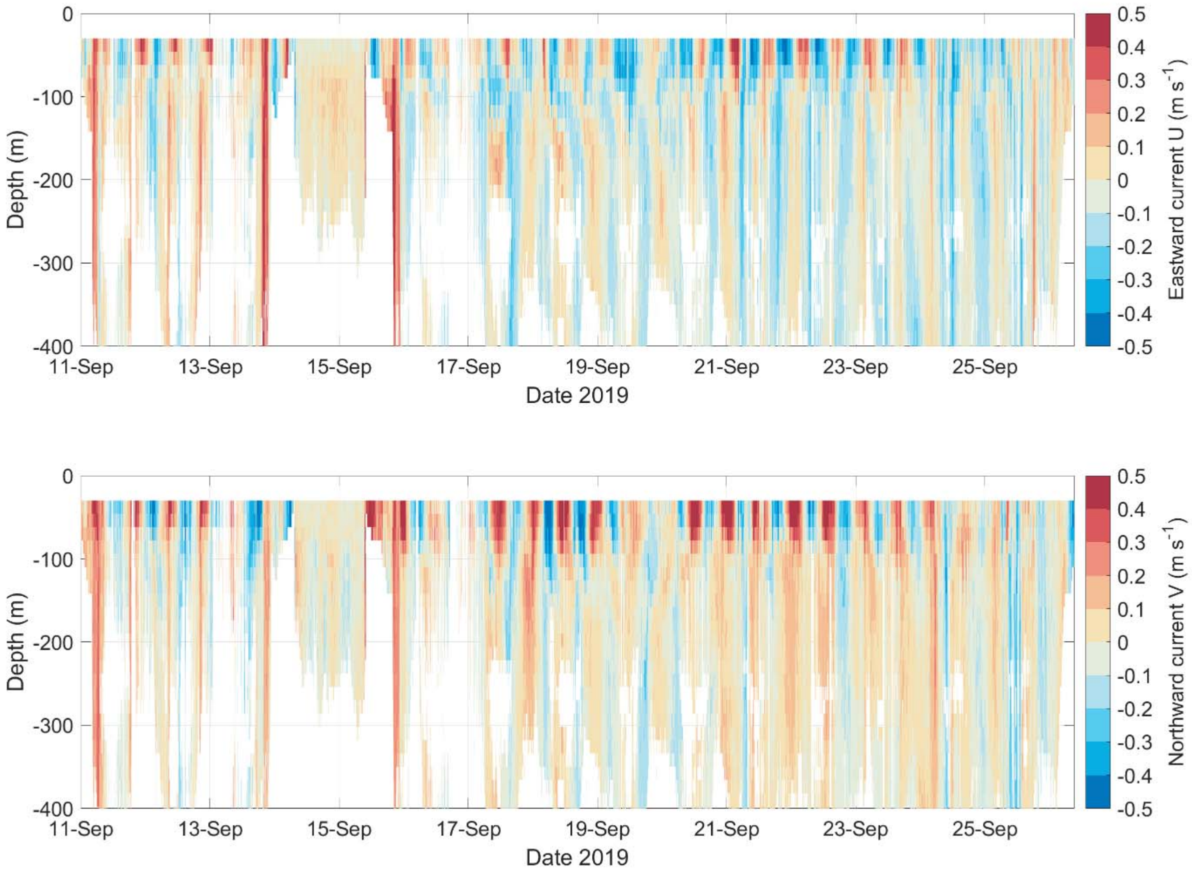


Fig. 6.73 U (eastward) and V (northward) currents recorded by the 75 kHz vessel-mounted ADCP in narrowband mode. The time interval shown approximately covers the occupation of the Darwin Mounts study areas. Note the period between the 14th and 16th September when the ship moved to an anchorage in the Outer Hebrides to avoid a storm.

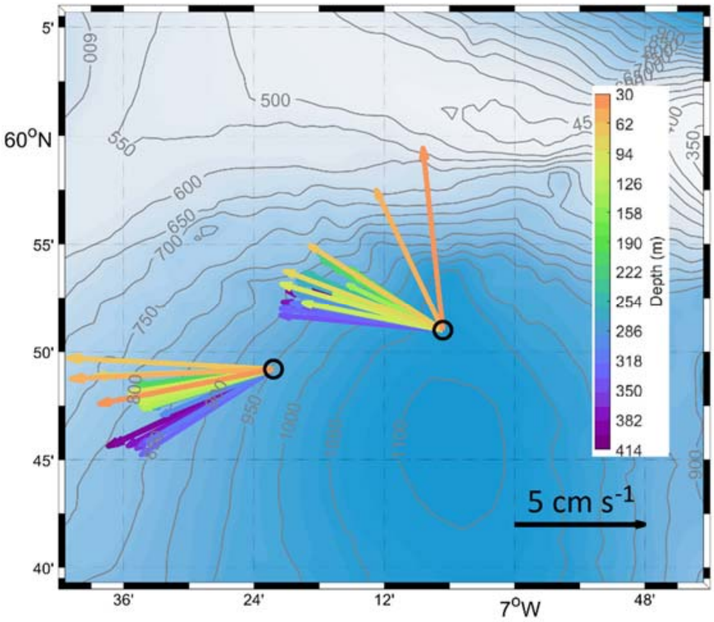


Fig. 6.74 Stick vectors of temporally averaged currents by depth for the two study sites in the Darwin Mounds region. Note that the stick vectors only extend to the range of the ADCP, not the full water column. Each location average is constructed from numerous occupations between 11th September and 26th September. Data from 75 kHz vessel-mounted ADCP in narrowband mode.

6.6.2. Water column structure in the Darwin Mounds

Three CTD profiles were collected in the Darwin Mound area (Fig. 6.75), in order to obtain sound velocity profiles for the acoustic systems in addition to information about the environmental conditions around the coral mounds. The lower portion of the profiles is plotted in Fig. 6.76, and the water column characteristics are summarised in Table 6.15.

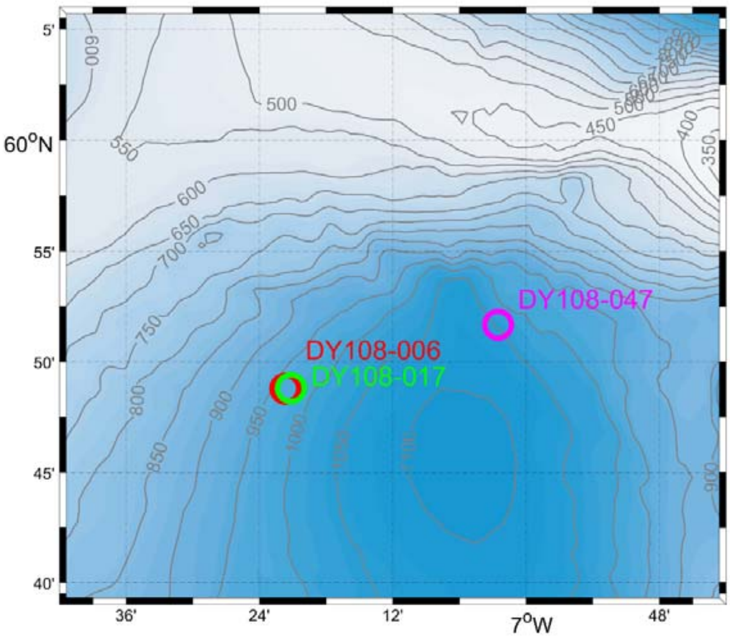


Fig. 6.75 CTD locations in Darwin Mounts study region during DY108

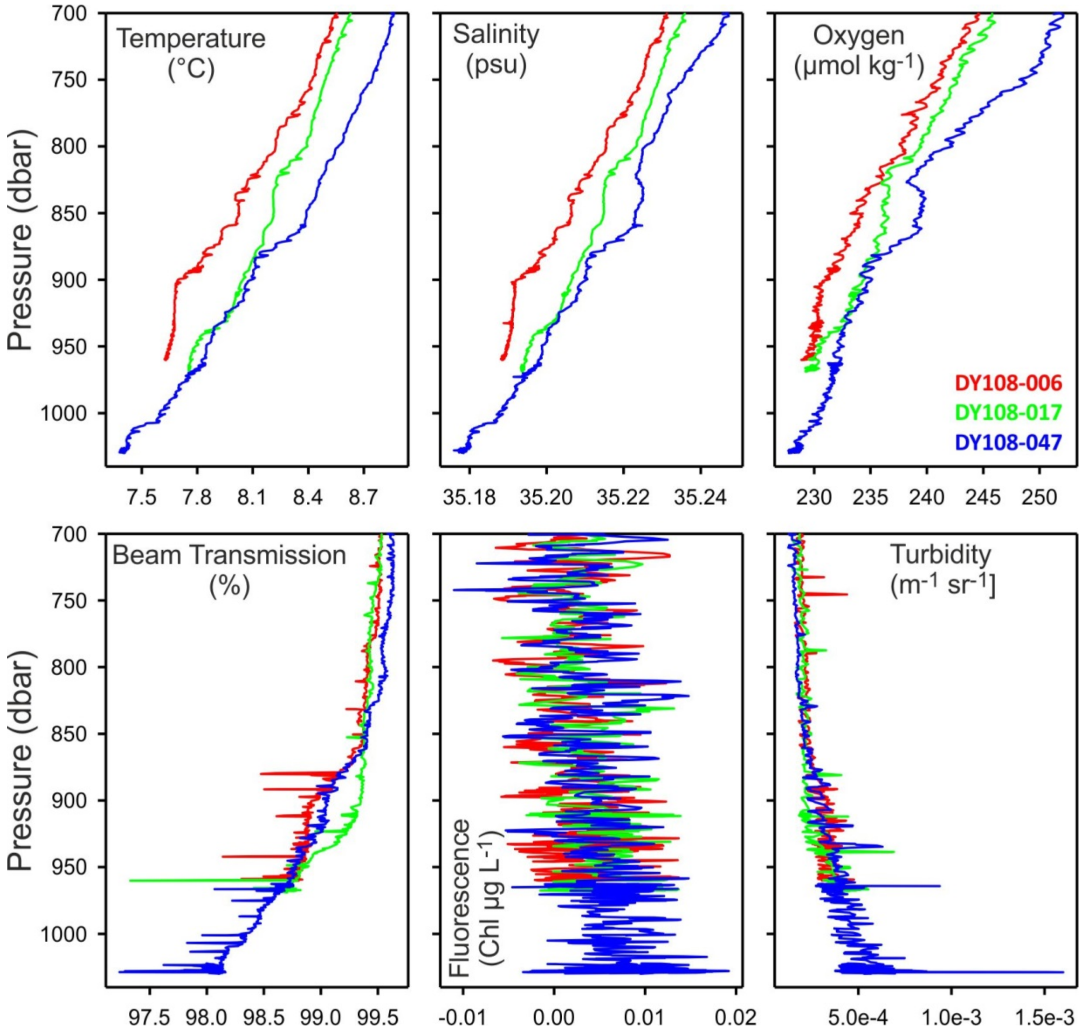


Fig. 6.75 Plots of downcast CTD profiles for the three casts made in the Darwin Mounds area (West Field, DY108-006, 017; East Field, DY108-047)

Table 6.15 Benthic boundary layer water properties as determined by CTD deployments. The data presented are statistical summaries of the downcast data logged while the CTD package was at an altitude of < 20 metres above bottom.

Variable	Statistic	DY108-006 West Field	DY108-017 West Field	DY108-047 East Field
Pressure (db)	Median	958.4	966.6	1027.8
	Interquartile range	1.3	1.4	1.1
	Minimum	955.1	959.5	1020.6
	Maximum	960.2	969.0	1030.0
Altitude (m)	Median	14.61	9.45	10.36
	Interquartile range	0.59	0.65	0.53
	Minimum	13.84	8.31	9.50
	Maximum	19.47	19.15	19.71
Temperature (ITS-90, °C)	Median	7.631	7.757	7.403
	Interquartile range	0.003	0.003	0.010
	Minimum	7.624	7.753	7.380
	Maximum	7.647	7.776	7.435
Salinity (PSU)	Median	35.1886	35.1938	35.1783
	Interquartile range	0.0003	0.0003	0.0006
	Minimum	35.1881	35.1933	35.1759
	Maximum	35.1896	35.1948	35.1803
Oxygen (µmol kg^{-1})	Median	229.6	229.8	228.3
	Interquartile range	0.3	0.3	0.3
	Minimum	228.9	229.2	227.7
	Maximum	230.1	230.4	229.0
Fluorescence (Chl, µg L^{-1}) × 10^{-3}	Median	5.3	6.4	8.1
	Interquartile range	4.1	3.8	4.7
	Minimum	-2.1	-1.5	-3.4
	Maximum	13.7	13.7	19.2
Beam Transmission (%)	Median	98.77	98.70	98.06
	Interquartile range	0.03	0.06	0.06
	Minimum	98.30	97.33	97.23
	Maximum	98.84	98.82	98.16
Turbidity (m^{-1} sr^{-1}) × 10^{-4}	Median	3.15	3.73	4.75
	Interquartile range	0.29	0.50	0.71
	Minimum	2.83	3.07	3.76
	Maximum	4.76	5.54	15.97

Plotting CTD data in T-S space shows a nearly straight mixing line between North Atlantic Water (carried in the European Slope Current) and Modified North Atlantic Water or some other mid-depth water mass in the Faroe-Shetland Channel (Fig. 6.76). This would seem to indicate some residual effect from sporadic overflow episodes, perhaps the overflowed water remains stagnant in the centre of the basin and mixes away gradually. An alternative explanation, although unlikely, would be that there is some southern deep-water source which could explain this.

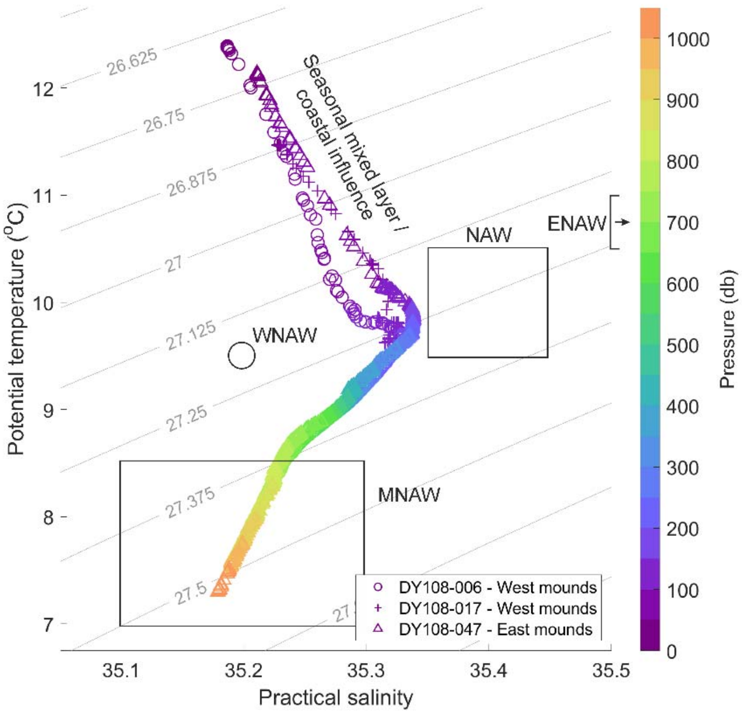


Fig. 6.76 Temperature–salinity plot for the three CTD stations in the Darwin Mounts region. The T-S properties of local water masses are overlaid, based on the definitions by Johnson et al. (2013) and McKenna et al. (2016). See map in Fig. 6.77 for a schematic of the pathways of the water masses highlighted.

Apart from the CTDs in the Darwin Mound area, the first CTD cast (DY108-001) was performed just next to the location of one of the large moorings of the CLASS Ellett Line (see next section), two more CTD casts were taken between the ADCP lander and this mooring (DY108-004), and two 24-hour yoyo CTDs were carried out in a submarine canyon on the Irish Rockall Margin, for the BLT-Recipes project (DY108-058 to 060). All CTD casts carried the LADCP (see section 7.5 for technical details). During the second 24-hour yoyo CTD, the instrument frame touched the seabed, and the CTD had to be brought on board for an hour to be checked over. The system turned out to be unharmed, and the yoyo CTD was continued. Initial data visualisation indicated unusual water column structures with clearly different water masses.

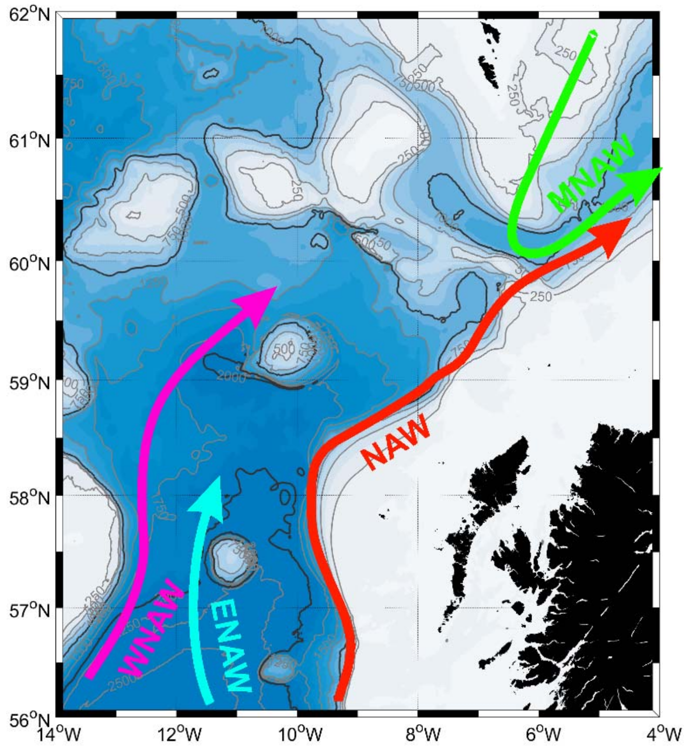


Fig. 6.77 Flow pathways of water masses referred to in Figure 2. WNAW = Western North Atlantic central Water, carried in North Atlantic Current; ENAW = Eastern North Atlantic Water, enters Rockall Trough from south; NAW = North Atlantic Water, carried from Bay of Biscay region in Shelf edge current; MNAW = Modified North Atlantic Water, circulates at mid depth in Faroe-Shetland Channel.

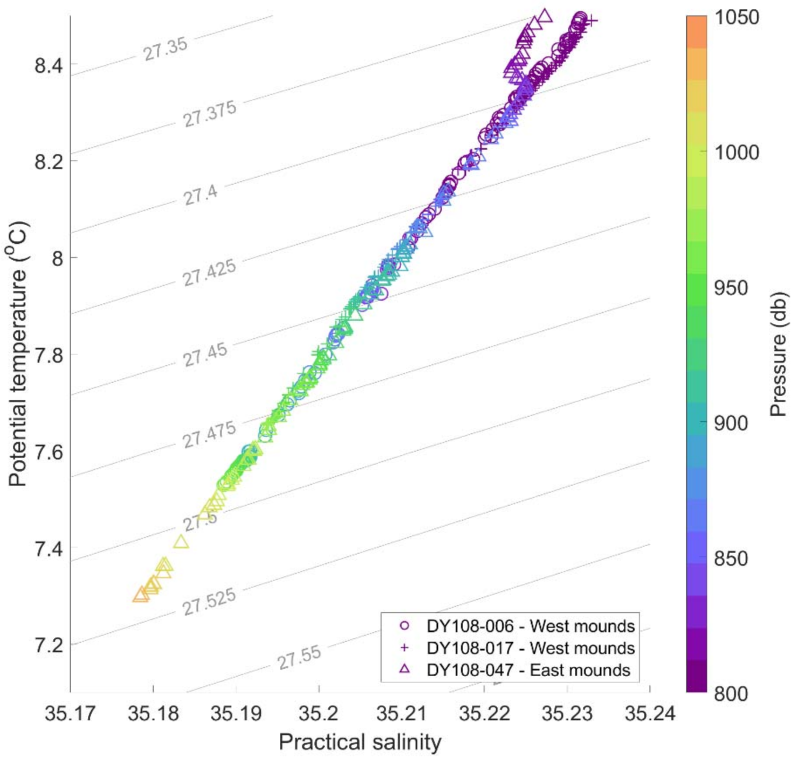


Fig. 6.78 Zoomed portion of temperature-salinity plot, showing only the water deeper than 800 m.

6.6.3. OSNAP ADCP lander

6.6.3.1. **Attempted AL500 lander pickup**

We began pinging near expected location and planned to follow a spiral search pattern outward which would allow some coverage up and down slope in the limited time available. We arrived two km south of RTADCP1 on the 750 m contour on 9 September, and began pinging at 05:19. Response was almost immediate, initially ranging at 2166 m. Subsequent ranging placed it in the same location it was deployed, minimum range from the drop keel was 741 m. We then held station for two hours to allow a fishing trawler to leave the area. Both releases were successfully fired at 07:20 but caused no change in range. We moved off to conduct a CTD at EB1 (35 minutes steam) and returned around 13:00. Further ranging to the releases demonstrated that the lander hadn't moved during this interval.

An attempt was made to launch the NOC HyBIS system with cameras to assess the state and position of the lander on the seabed. However, lowering was aborted at 400 m due to a loss of all telemetry on the HyBIS which was later traced to an onboard power failure. There was no time to repair the HyBIS that day, so the investigation was aborted.

6.6.3.2. **AL500 lander deployment and retrieval**

The new lander assembly to be deployed on DY108 was comprised of a new concrete base supplied by the AL500 manufacturer, refurbished buoyancy and gimbal assembly (also built by the AL500 manufacturer) and a new aluminium pad built by an external fabricator.

The onboard acoustic release was armed, tightened and checked, then the buoyancy unit was assembled onto the structure on 8th September. We decided to program and power-on the ADCP at 5 pm on the 8th September due to a combination of calm sea, dry weather and lack of deck activity. This meant that programming and connecting the battery and dummy comms plug was done without time pressure. The ADCP was also set to flash for 24 hours to ensure it was sampling at the rate expected.

The ADCP battery cable has male connectors at both ends and there is a significant risk of a short-circuit on the metal frame if it is first connected to the battery and left loose. We found that the cable can be first connected to the gimballed ADCP by chocking the gimbal up and reaching inside, then connected to the battery by reaching into the Iridium beacon hole on the buoyancy, thereby eliminating short-circuit risk. Arrows were painted on the buoyancy pointing to the lifting eyes which tend to sit underwater during recovery. The protective dome for the ADCP was missing on this lander, so we hoped to use the dome from the recovered lander. In the event, there was no recovery so we decided to proceed with the exposed ADCP.

The deployment method was similar to that used in previous AL500 deployments, with glass spheres fitted above the lifting gear to keep the bridle under tension on the seabed prior to release (Fig. 6.79).

The lander was lifted off the deck at 15:42 and quickly manoeuvred over the water. It was in the water at 15:45. Lowering was briefly delayed as a handling line had become wrapped around the lander. It was then lowered gently as the ship's heave was creating slack in the winch cables. At about 15:50 the onboard lander release mechanism failed, allowing the buoyancy to prematurely separate and drift away. Reviewing a video of the deployment shows that it survived numerous heaves of the ship before it failed, but that this probably contributed to the release failure.

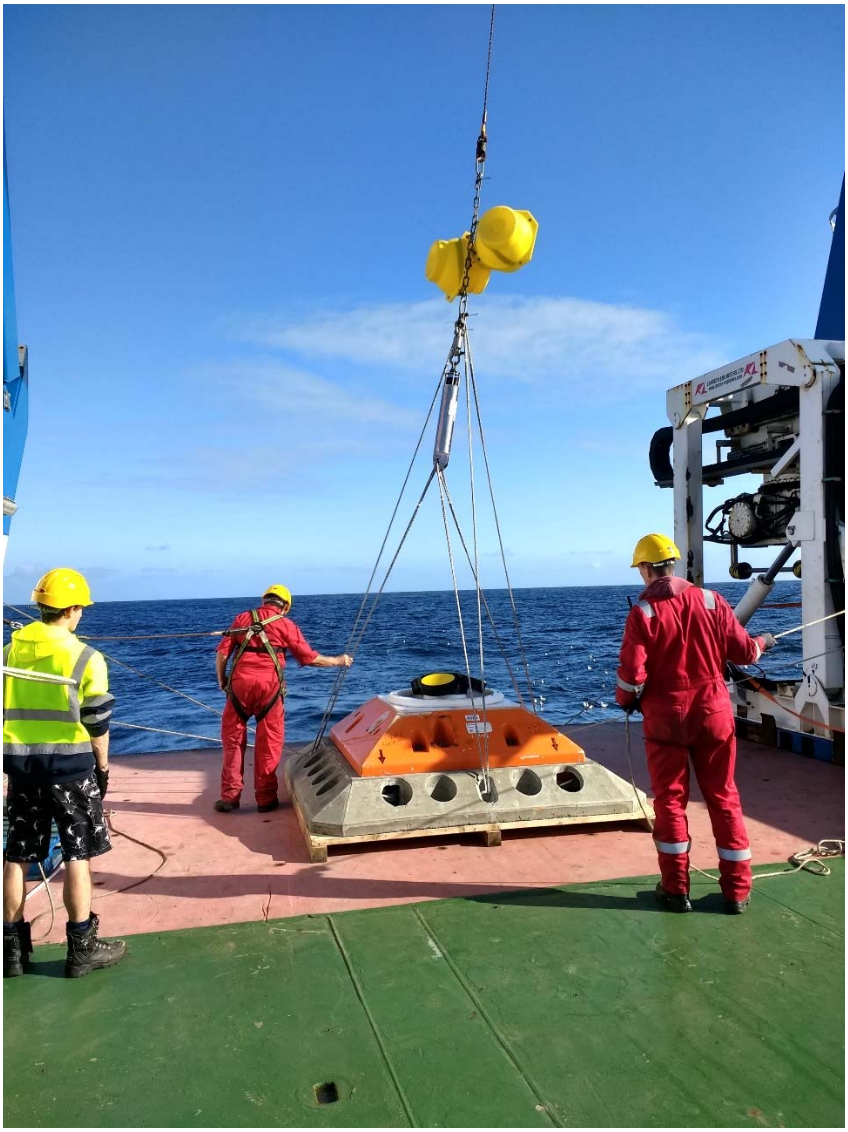


Fig. 6.79 Prior to deployment, showing layout of lifting bridles.

The concrete base (which would not normally have to be lifted back on deck) was manoeuvred carefully out of the water and secured on both sides to stop it swinging (Fig. 6.80). It wasbBack on deck at 16:13. The lander package was brought alongside the ship and hooked with a telescopic pole on one of its lifting eyes. It was lifted by one eye and was back on deck at 16:47.

Fig. 6.80 Retrieval of the buoyancy and aluminium pan

A preliminary investigation suggests that nothing failed structurally in the release mechanism. It appears that a combination of play in the release mechanism, and an altered latch geometry, which was necessitated by differences between the new aluminium pan and the manufacturer's version, made the latch less secure (Fig. 6.81). It is likely that it would hold the static force of the buoyancy but that the dynamic snatching forces on deployment contributed to its failure to stay latched under tension.

Fig. 6.81 Armed release from side

6.6.3.3. **ADCP lander HyBIS survey on 26/09/2019**

Towards the end of DY108 there was an opportunity to return to the ADCP lander site and conduct a survey with the HyBIS to try to ascertain the cause of its failure to surface. The lander was located relatively quickly using the HyBIS's forward scanning sonar less than 10 m away from the predicted location based on its deployment triangulation conducted on AR30 in 2018.

The camera survey revealed extensive trawl damage, with the ADCP and its gimbal separated from the lander's structure and lying beside it, but with the ADCP battery cable still connected (Figs. 6.82 & 6.83). This damage alone would not have prevented the lander from surfacing; however, the main structure was also buried beneath a thick layer of sediment. This presumably was heavy enough to counteract the ~200 kg of positive buoyancy supplied by the syntactic foam and keep the lander on the seabed. It is possible that future trawl activity will cause the lander to release and float to the surface as both acoustic releases successfully fired. The Iridium system and light may still be functional, but the ADCP and its acquired data will almost certainly be lost, as the weak point in the battery cable (the plastic connector at its termination) will likely fail on the ascent or shortly after.

Fig. 6.82 ADCP lander deployed on AR30 cruise in 2018. Imaged by HyBIS in September 2019 after it failed to surface and was found to have been damaged and partially buried by trawl activity.

Fig. 6.83 Close-up of damaged gimbal and ADCP head

6.6.4. Darwin Mounds long-term mooring (DY108-048)

Recovery information

Position:	59° 51.672´ N 007° 02.631´ W (triangulated)
Water depth:	1028 m (corrected)
Release:	s/n 2330, ARM 1B89, REL 1B55
Last bottle closes:	12:00 6 October 2020
Instrumentation:	ADCP, 21-bottle sediment trap, 2 × MicroCAT
Samples:	21 × formaldehyde preserved (caps with NOC MG); 3 × hard hat colonization surfaces (e.g. Teledyne Benthos 17” standard ribbed single shell) – containers / preservatives / protocols needed

General mooring arrangement

The mooring comprised a pick-up float (12” glass), buoyancy pack (3 × 17” glass), MicroCAT, 44” syntactic sphere carrying: light, argos, and downward ADCP, 21-bottle sediment trap, 2 × colonization hard hat, MicroCAT, 1 × colonization hard hat, acoustic release, and 1000 kg chain clump anchor (Fig. 6.84).

The mooring was deployed buoyancy first, towed to nominal position and let go. The achieved location of the mooring was estimated by triangulation from three points c. 0.5 nm from the intended target location. The intention is for the mooring to be in place for ~one year.

Sediment trap preserving fluid

- 19 L deep seawater (CTD DY108-001; 1000 m)
- 100 g NaCl
- 1 L c. 38% formaldehyde solution
- 5 g sodium tetraborate

The preserving fluid was made up as per the recipe above; seawater and salt were mixed and left for a few days; formaldehyde and borax were mixed and left for a few days; hypersaline seawater and buffered formaldehyde were mixed and left a few days. Trap bottles were filled near-full and fitted to the carousel and left a couple of days (aided clearance of bubbles), then topped-up using the trap “fill program”. Archive sample retained as blank (NOC MG).

Sediment trap programming

The sediment trap carousel system was programmed (Table 6.16) to rotate one unit every 18-days from 12:00 UTC 25 September 2019, i.e. first bottle opens at that time. The last bottle is scheduled to close at 12:00 UTC 6 October 2020. Trap programming and schedule were as follows:

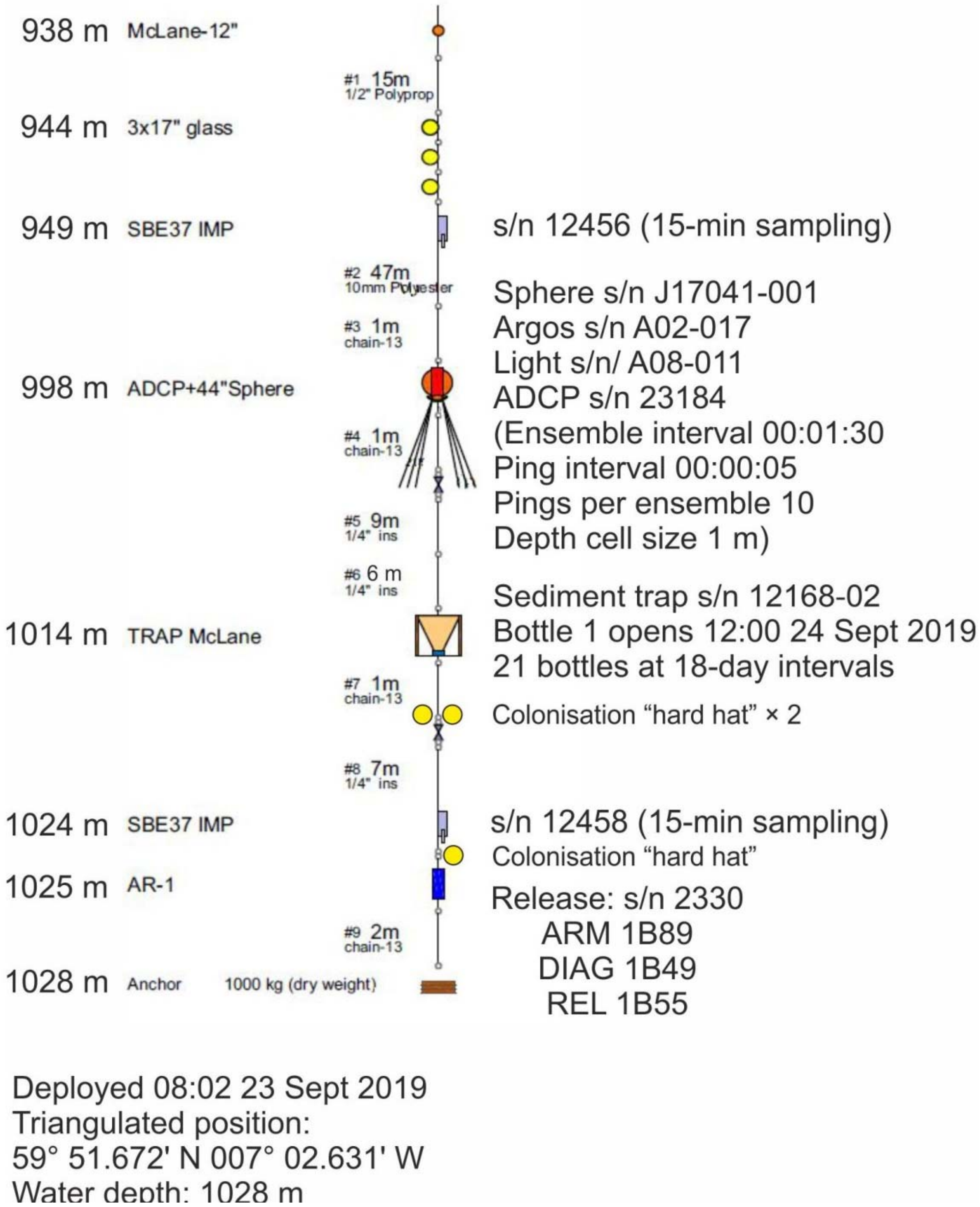


Fig. 6.84 Darwin Mounds long-term mooring as deployed (DY108-048)

Keystroke log

```
 Is the rotator aligned to the
 open hole (Yes/No) [N] ? y

 Clock reads 09/22/2019 15:29:57
 Change time & date (Yes/No) [N] ? n

 Existing deployment data file will be
 erased.  Continue (Yes/No) [N] ? y

 Enter new deployment schedule (Yes/No) [N]
? n

 Schedule Verification

 Event   1 of  22 = 09/24/2019 12:00:00
 Event   2 of  22 = 10/12/2019 12:00:00
 Event   3 of  22 = 10/30/2019 12:00:00
 Event   4 of  22 = 11/17/2019 12:00:00
 Event   5 of  22 = 12/05/2019 12:00:00
 Event   6 of  22 = 12/23/2019 12:00:00
 Event   7 of  22 = 01/10/2020 12:00:00
 Event   8 of  22 = 01/28/2020 12:00:00
 Event   9 of  22 = 02/15/2020 12:00:00
 Event  10 of  22 = 03/04/2020 12:00:00
 Event  11 of  22 = 03/22/2020 12:00:00
 Event  12 of  22 = 04/09/2020 12:00:00
 Event  13 of  22 = 04/27/2020 12:00:00
 Event  14 of  22 = 05/15/2020 12:00:00
 Event  15 of  22 = 06/02/2020 12:00:00
 Event  16 of  22 = 06/20/2020 12:00:00
 Event  17 of  22 = 07/08/2020 12:00:00
 Event  18 of  22 = 07/26/2020 12:00:00
 Event  19 of  22 = 08/13/2020 12:00:00
 Event  20 of  22 = 08/31/2020 12:00:00
 Event  21 of  22 = 09/18/2020 12:00:00
 Event  22 of  22 = 10/06/2020 12:00:00

 Modify an event  (Yes/No) [N] ? n
 Current Header reads:

 DY108

 Do you want a different header (Yes/No)
[N] ? n

 System status:

 09/22/2019 15:31:32 18.7 Vb 18 øC  aligned

 Caution:  Deployment will overwrite the
           EEPROM data backup cache.

 Proceed with the deployment (Yes/No)? y

  >>> Remove communication cable and <<<
        >>> attach dummy plug. <<<
 >>> Sediment trap is ready to deploy. <<<

 <09/22/2019 15:31:46> Waiting for Event 01
    of 22 @ 09/24/2019 12:00:00

 09/22/2019 15:31:48 Sleeping . . .
```

Table 6.16 Sediment trap schedule as programmed

Action	UK Date		US Date
0	24/09/2019 12:00		09/24/2019 12:00
1	12/10/2019 12:00		10/12/2019 12:00
2	30/10/2019 12:00		10/30/2019 12:00
3	17/11/2019 12:00		11/17/2019 12:00
4	05/12/2019 12:00		12/05/2019 12:00
5	23/12/2019 12:00		12/23/2019 12:00
6	10/01/2020 12:00		01/10/2020 12:00
7	28/01/2020 12:00		01/28/2020 12:00
8	15/02/2020 12:00		02/15/2020 12:00
9	04/03/2020 12:00		03/04/2020 12:00
10	22/03/2020 12:00		03/22/2020 12:00
11	09/04/2020 12:00		04/09/2020 12:00
12	27/04/2020 12:00		04/27/2020 12:00
13	15/05/2020 12:00		05/15/2020 12:00
14	02/06/2020 12:00		06/02/2020 12:00
15	20/06/2020 12:00		06/20/2020 12:00
16	08/07/2020 12:00		07/08/2020 12:00
17	26/07/2020 12:00		07/26/2020 12:00
18	13/08/2020 12:00		08/13/2020 12:00
19	31/08/2020 12:00		08/31/2020 12:00
20	18/09/2020 12:00		09/18/2020 12:00
21	06/10/2020 12:00		10/06/2020 12:00

(Action 0 opens bottle 1, Action 1 closes bottle 1and opens bottle 2 etc. etc.)

Acoustic Doppler current profiler set-up

A 600 kHz ADCP in downward-looking orientation was set-up to the following specification:

- Duration: 365 days
- Ensemble interval: 00:01:30
- Ping interval: 00:00:05
- Pings per ensemble: 10
- Depth cell size: 1 m (30 m range)

MicroCAT sensors

The mooring was fitted with two MicroCATS (Sea-Bird Scientific SBE 37-SM) carrying temperature, conductivity, and pressure sensors. One MicroCAT (s/n 12456) was located at c. 79 mab (949 m) and the other (s/n 124558) was located at c. 4 mab (1024 m). The MicroCATs, sampling at 10-second intervals, were tested on CTD deployment DY108-047, carried out in the near vicinity of the intended mooring location, immediately prior to the mooring deployment (Table 6.17). During the up-cast of the CTD, 5-minute stops were made at four depths (1014, 945, 101, and 36 m) to provide cross-calibration data. Following standard processing, the CTD and MicroCAT data were summarized to median and 95% non-parametric confidence intervals for the periods of the stops. The resultant data and plots (Fig. 6.85) suggested that both MicroCATs were performing well.

For the mooring deployment (DY108-048), MicroCAT sampling interval was set to 15-minutes.

Colonization panels

The mooring was fitted with three colonization panels, two located at c. 11 mab (1017 m) and one located at c. 4 mab (1024 m). Each panel is a single shell of a Teledyne Benthos 17” standard ribbed ‘hard hat’. These shells were recovered during the cruise as marker buoy originally emplaced during RRS *James Cook* cruise 060 (see original cruise report, and section 6.5 in this report). The heavy biofouling was roughly cleaned from the outer surface of the shell, and the essentially clean inner surfaces given a basic wash prior to their redeployment on the mooring (DY108-048).

Table 6.17 CTD and Microcat data from “calibration stops” on up cast of DY108-047; median value (95% CI) during stop

	CTD hand log					**CTD data**							
	Depth (m)	**Time**	**Temp**	**Sal**	**Con**	**Pressure (db)**		**Temperature (ITS-90, °C)**		**Conductivity (mS cm^{-1})**		**Salinity (PSU)**	
1	36 m	06:14	11.9	35.279	40.164	36.3	(36.2, 36.3)	11.8857	(11.8850, 11.8862)	40.1303	(40.1297, 40.1306)	35.2204	(35.2204, 35.2204)
2	101 m	06:06	10	35.325	38.469	102.1	(102.1, 102.1)	10.0232	(10.0232, 10.0234)	38.4734	(38.4733, 38.4735)	35.3229	(35.3228, 35.3229)
3	945 m	05:43	7.9	35.2	36.71	956.0	(956.0, 956.0)	7.8755	(7.8754, 7.8757)	36.7056	(36.7055, 36.7058)	35.1988	(35.1988, 35.1988)
4	1014 m	05:34	7.7	35.179	36.279	1027.9	(1027.9, 1028.0)	7.4029	(7.4027, 7.4029)	36.2773	(36.2772, 36.2774)	35.1783	(35.1782, 35.1783)
						Depth (m)							
	Microcat s/n 12456					34.2	(34.0, 34.5)	11.8871	(11.8836, 11.8960)	40.1296	(40.1257, 40.1375)	35.2180	(35.2175, 35.2187)
						99.9	(99.8, 100.2)	10.0242	(10.0209, 10.0266)	38.4705	(38.4684, 38.4737)	35.3203	(35.3200, 35.3207)
						943.4	(943.2, 943.5)	7.8767	(7.8746, 7.8798)	36.7033	(36.7018, 36.7073)	35.1964	(35.1962, 35.1967)
						1014.3	(1014.1, 1014.6)	7.4033	(7.3993, 7.4054)	36.2743	(36.2711, 36.2759)	35.1752	(35.1750, 35.1755)
	Microcat s/n 12458					34.6	(34.3, 34.8)	11.8853	(11.8836, 11.8947)	40.1306	(40.1286, 40.1397)	35.2209	(35.2203, 35.2214)
						99.8	(99.7, 100.0)	10.0263	(10.0236, 10.0294)	38.4758	(38.4736, 38.4778)	35.3227	(35.3224, 35.3235)
						943.2	(942.9, 943.6)	7.8789	(7.8762, 7.8839)	36.7067	(36.7050, 36.7129)	35.1987	(35.1984, 35.1988)
						1014.3	(1014.1, 1014.7)	7.4054	(7.4014, 7.4087)	36.2782	(36.2752, 36.2820)	35.1778	(35.1776, 35.1780)

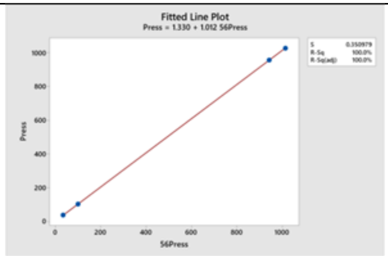
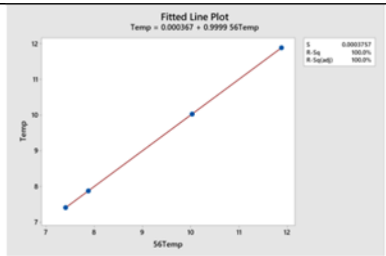
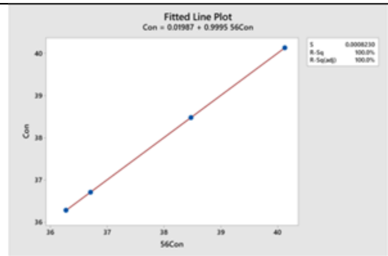
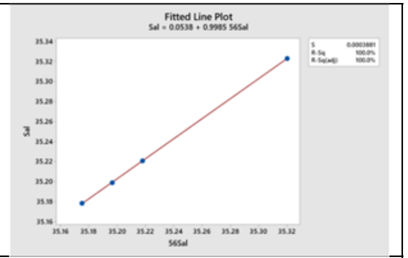
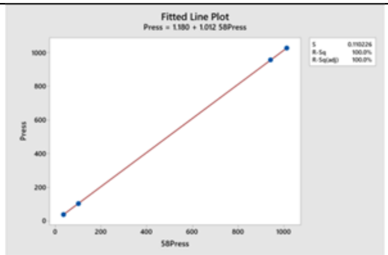
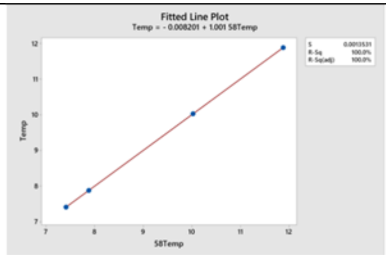
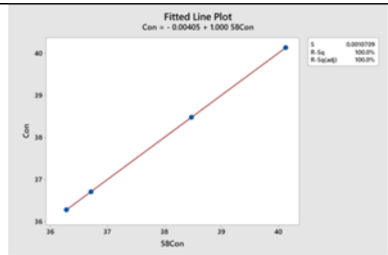
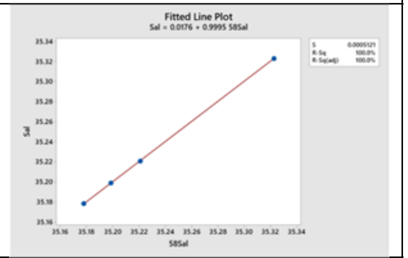
Microcat s/n 12456				
	CTD pressure vs Microcat depth	CTD vs Microcat temperature	CTD vs Microcat conductivity	CTD vs Microcat salinity
Microcat s/n 12458				
	CTD pressure vs Microcat depth	CTD vs Microcat temperature	CTD vs Microcat conductivity	CTD vs Microcat salinity

Fig. 6.85 Cross-calibrations of CTD and MicroCAT data

6.7. Outreach activities *(Larissa Macedo, Loïc Van Audenhaege)*

During the DY108/109 cruise, outreach practice was performed through social media. The scientists were well engaged with content sharing and media coverage. Information about daily activities on the cruise was shared via Twitter and the blog page on the following addresses:

- @CLASS_UKRI - (https://twitter.com/CLASS_UKRI)
- CLASS blog - (https://projects.noc.ac.uk/class/blog)

Larissa Macedo and Loïc Van Audenhaege were responsible for tweeting and posting on the blog, under the supervision of Veerle Huvenne.

The account @CLASS_UKRI tweeted an average of two tweets/day. All content was linked to twitter accounts and hashtags of the research bodies and partners i.e. SAMS (@ScotMarineInst), JNCC (@JNCC_UK), University of Southampton (@unisouthampton), University of Edinburgh (@EdinburghUni), NOC (@NOCnews) and BioCam (#BioCam) and the study site #Darwinmounds. Usually, tweets were posted with a type of visual content which included images and videos of the equipment, scientists in action and the findings from HyBIS HD camera. The scientists on board were also active on media sharing. Around eight scientists tweeted from their personal accounts making use of the aforementioned names and hashtags.

The statistical data collected with Twitter Analytics shows that the content shared on @CLASS_UKRI account earned around 57.1K impressions since the start of the cruise. The number of profile visits and impressions has increased by 56.3% and 360.3%, respectively (Fig. 6.86):

Fig. 6.86 Data from 01/10/2019. Source: Twitter

Until the 1st of October, 2019, our top tweets earned around 4.990 impressions (Fig. 6.87):

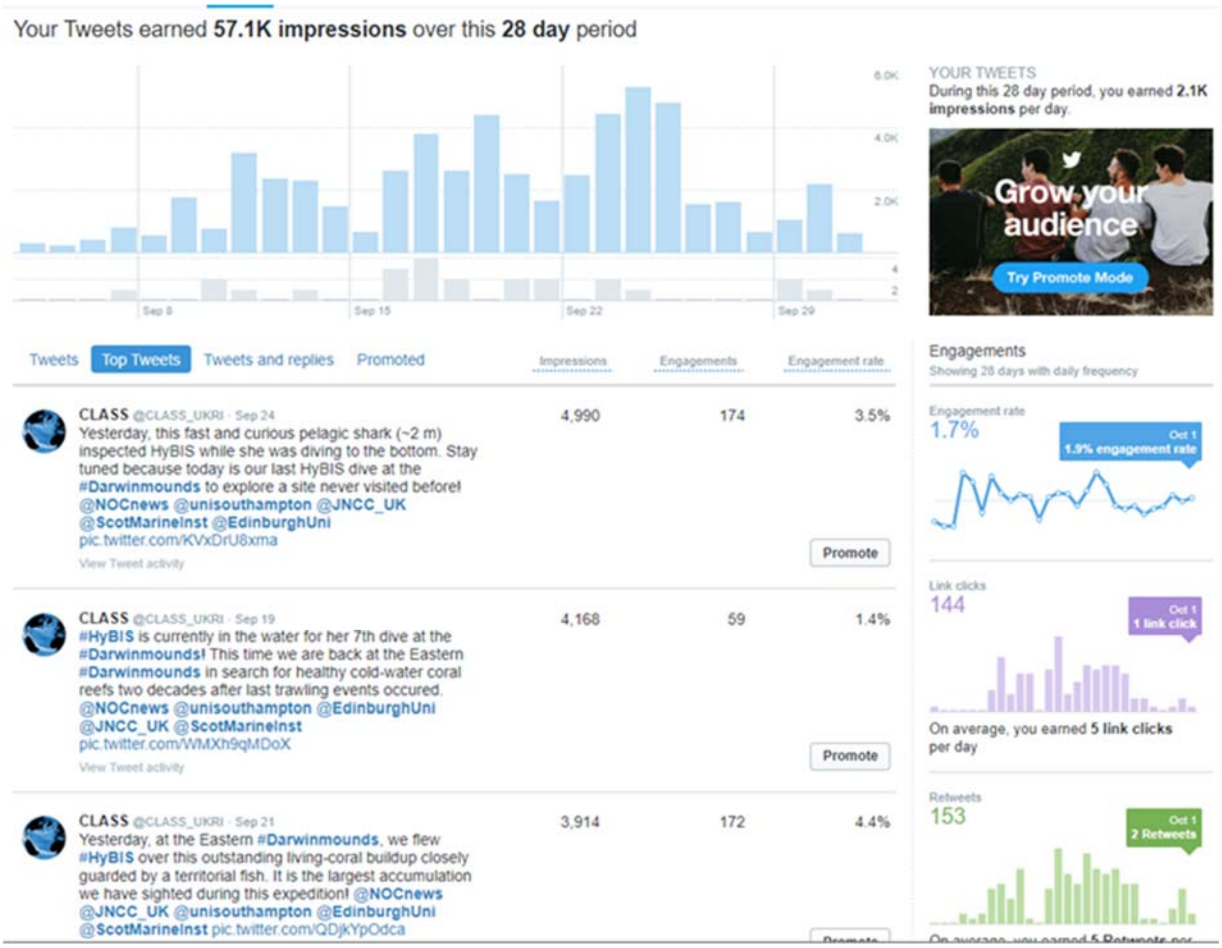
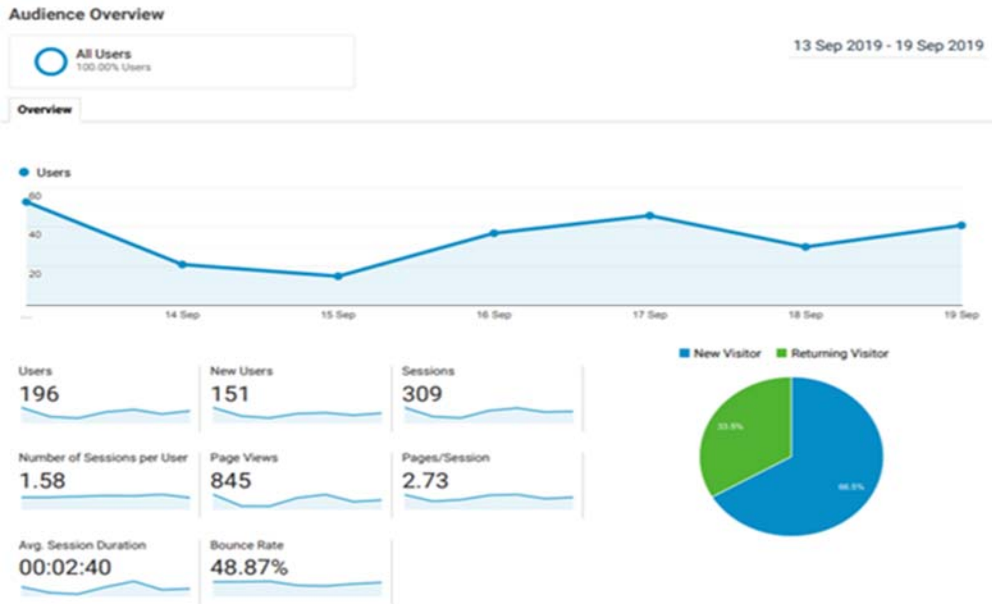


Fig. 6.87 Data from 01/10/2019. Source: Twitter

As for the blog, there was a commitment to post at least twice a week. The posts covered different activities that were carried out during the cruise. Usually, it contained information about the Darwin Mounds, equipment, weather forecast, methods, and general research activities. The aim was to give an idea about daily research routine and life at sea to compose a story related coherently by the different posts. All posts were followed by visual content within the context of the blog.

Since the start of the DY108/09 cruise, the website statistics showed an increase in new users by 66,5%. Around 44.5% of the users are concentrated in the UK and 29% are from the USA. The blog has reached other countries such as France (6.63%), Belgium (3.37%), Canada, Australia, Denmark, Spain (Fig. 6.88).



	Language	Users	% Users
1.	en-gb	97	49.49%
2.	en-us	57	29.08%
3.	fr-fr	13	6.63%
4.	nl-be	7	3.57%
5.	ca-es	2	1.02%
6.	de	2	1.02%
7.	de-de	2	1.02%
8.	en-au	2	1.02%
9.	es-es	2	1.02%
10.	fr	2	1.02%

Fig. 6.88 Website interaction statistics for the CLASS project cruise website during the second week of the cruise

The overall results of outreach activities were positive. As can be seen from the statistical data, the social media engagement was considered high and the actions attracted new users and impressions to the project's results.

The expedition story had also an impact on the news media as the BBC wrote five press articles for the section "UK/Scotland/Highlands & Islands" and the Times in Scotland wrote one article. See links below:

- https://www.bbc.co.uk/news/uk-scotland-highlands-islands-49606937
- https://www.bbc.co.uk/news/uk-scotland-highlands-islands-49727181
- https://www.bbc.co.uk/news/uk-scotland-highlands-islands-49753440
- (https://www.thetimes.co.uk/article/protected-coral-reef-is-blighted-by-plastic-waste-03k85j63v

In addition, several posts contained an hyperlink to a 3D model of some organism (e.g. *Desmophyllum dianthus*) and scientific features (e.g. the buoy recovered). High-resolution 3D models are easy to make and do not require powerful hardware (phone`s camera and a basic computer, software: Meshroom (opensource) or Agisoft). SketchFab was used for 3D data visualization. This outreach tool is in our opinion a good way to enable people to interact with our scientific work and to show what we do for a non-specialised audience.

Outreach recommendation for future expeditions:

● Before an expedition, we recommend that most of the scientific accounts post an update regarding the preparation of the cruise by uploading teaser-like posts. This would help to already build up a more solid and earlier audience prior to the expedition.

● Twitter can spread tweets very quickly but, it is mainly used by a specific public. The use of Instagram and Facebook could be a way to reach better a "more general" audience. Facebook could be a way to update people with more detailed stories than Twitter, while Instagram is useful to share visual content through the "Story" feature. It is necessary to mention that Instagram does not allow to share hyperlinks (if account <1000 followers). Finally, the National Oceanography Centre is active on Instagram and on Facebook and these accounts could be useful to share the project account prior to the start of the expedition.

● Finally, as the expedition can be sometimes repetitive, it is necessary to think of plans B in terms of outreach (e.g. "How is the life at Sea", "Who is involved in the running of an expedition (i.e. focussing on the cooks, technicians, engineers, navigation crew)"). Furthermore, it could be a great idea to define a more recreative post concept that will be related once a week. For example, a quiz every Sunday (e.g. "What is this animal?") or a "Fun-fact" Sunday post, etc.

7. EQUIPMENT & SAMPLING REPORTS

7.1. Autosub6000 Cruise Report

Operational Team : Phil Bagley, Rachel Marlow, Owain Shepherd, Richard Austin-Berry, Eoin O'Hobain

7.1.1. Autosub 6000 Cruise Summary

The Autosub 6000 was deployed on 7 missions (1 abandoned), providing Sidescan and Biocam survey data as well as delivering the standard suite of science data throughout (Table 7.1). The Biocam operated successfully in all but the last deployment where the cable between the Logger tube and the Biocam appeared to have failed under pressure preventing Autosub UDP data reaching the Biocam. One mission (M154) was abandoned soon after deployment. The Phins unit within the Autosub Inertia Navigation System hung and was not responding to motion or heading changes. The Autosub was recovered back to deck successfully. During M155, after successfully completing a 90km side scan survey the ADCP (used for bottom tracking) failed just after the start of Biocam element of the mission. The vehicle ascended to the safe depth and the mission was aborted. The ADCP unit was replaced and the vehicle successfully operated during the following final mission.

Table 7.1 Overview of Autosub missions for DY108/109

Mission	Survey Time	Distance Travelled	Maximum Depth
M150	4 hrs 36 mins	12.7 km	206.6 m
M151	23 hrs 43 mins	93.5 km	968.3 m
M152	23 hrs 59 mins	90.3 km	965.8 m
M153	24 hrs 55 mins	90.2 km	1043.7 m
M154	(mission abandoned)	-	-
M155	25 hrs 1 min	97 km	1063.3 m
M156	26 hrs 8 mins	92.9 km	952.8 m
Total	**5 days 21 hrs 40 mins**	**476.6 km**	**-**

Fig. 7. 1 Owain & Richard recovering the Autosub after Mission M156

Mission 150

The AUV was launched and dived successfully. The AUV was monitored via the Ships USBL and the Linkquest throughout the mission, a navigation offset was not sent and the vehicle sent on its way. The vehicle surfaced a little ahead of schedule in the expected location and was recovered back on deck without incident in increasingly freshening winds. Initial analysis of data indicated a successful mission.

Mission 151

The AUV was launched and dived successfully. The AUV was monitored via the Ships USBL at the start of the dive. We were unable to set the mission navigation offset due to poor Linquest communication. The navigational offset at the start was (Autosub was located):

- 459m south of the starting waypoint
- 265m West of the starting waypoint.

The mission was completed as expected. The vehicle surfaced a little ahead of schedule in the expected location. Due to higher sea state than forecast we did not immediately recovery the Autosub and stood by for approximately 4 hours. The weather conditions had improved slightly but conditions were still difficult for the recovery. Autosub was recovered back on deck without incident due the skill of Owain and Richard, the officers on the Bridge and the deck crew. Initial analysis of data indicated a successful mission, with embedded Edgetech navigational data and good Biocam imagery. To improve lighting for future missions the Biocam team may increase the intensity of the LED flashes.

Mission 152

Dense Grid Biocam survey of Western Darwin Mounds. Test New Biocam lighting configurations. The vehicle successfully dived, however the USBL stopped working during the descent. The Linquest acoustic telemetry also failed to communicate with the vehicle once the vehicle reduced its pitch as it approached the sea floor. This is similar to the situation on M151. Biocam work successfully. LED drivers were modified to run at higher voltage, creating a brighter flash.

Mission 153

AUV successfully dived and was followed on the Ships USBL and the LinkQuest Fish until the AUV moved into 'WaitAtAlt' mode where the LinkQuest communication dropped out. Ship repositioned over vehicle and LinkQuest Fish was set to high power, this enabled intermittent comms with AUV meaning it was possible to send the required navigation offset. The AUV then continued the mission and surfaced about 90 minutes later than expected. Initial analysis suggests that a number of survey lines overran the expected duration and timed out potentially due to strong seabed currents. The data also shows that the vehicle hit the seabed although there is no visible damage to the AUV. The AUV was successfully recovered.

Mission 154

The vehicle was successfully launched but once in the water no heading change was observed in the mission commander. The vehicle was recovered before starting the mission. Later analysis showed the Phins unit within the Autosub's Inertial Navigation System had hung, and vehicle motion was not being measured or recorded. This situation may occur when the Phins does not successfully complete it's alignment phase. Alignment has two phases:

Course alignment when the Phins unit should be kept as still as possible

Fine alignment when the Phins should experience moderate motion.

This can be difficult to achieve on a ship and deployment procedures were updated to confirm correct Phins operation before relese into the water.

Mission 155

Successful Edge tech mission. However, just after the Biocam section of the dive started the Autosub lost bottom lock and dived and hit the seabed. It aborted the mission and ascended to near the safe depth of 160m (note a safe depth of 100m was programmed, unclear why the Autosub did not achieve this depth. However strong surface currents were present at the time and may have influenced Autosub dynamic performance). The mission was aborted via the Linquest system on the acoustic fish and the vehicle surfaced 50m from the ship. Recovered on board safely. Later analysis showed the Autosub lost bottom lock because the ADCP had failed. The Autosub then dived to try to reacquire the seabed, causing the collision with the seabed. Post mission the ADCP was removed and bench tested where it was conformed both beams 2 & 4 were no longer working.

Mission 156

The new ADCP was tested successfully by performing a dive to 900m to obtain DVL bottom lock and run two test lines. The vehicle then ascended back to the surface again and paused where data was offloaded to check ADCP performance. All appeared correct and so the vehicle was sent on the remaining Biocam mission. The vehicle performed correctly and we saw a better altitude tracking performance than on earlier dives (Fig. 7.2). The vehicle surfaced as expected and was recovered successfully under demanding conditions. The Biocam did not collect any data. Initial analysis suggests the cable between the Biocam and the logger failing under pressure at 900m at the start of the Biocam mission. Then working again at 300m on the ascent after the Biocam mission. Although power was still being supplied the Biocam did not receive any UDP messages from Autosub. Post mission analysis of the Logger tube data showed UDP messages around the Autosub vehicle were working as normal. Therefore, the cable between the Biocam and the logger is suspect.

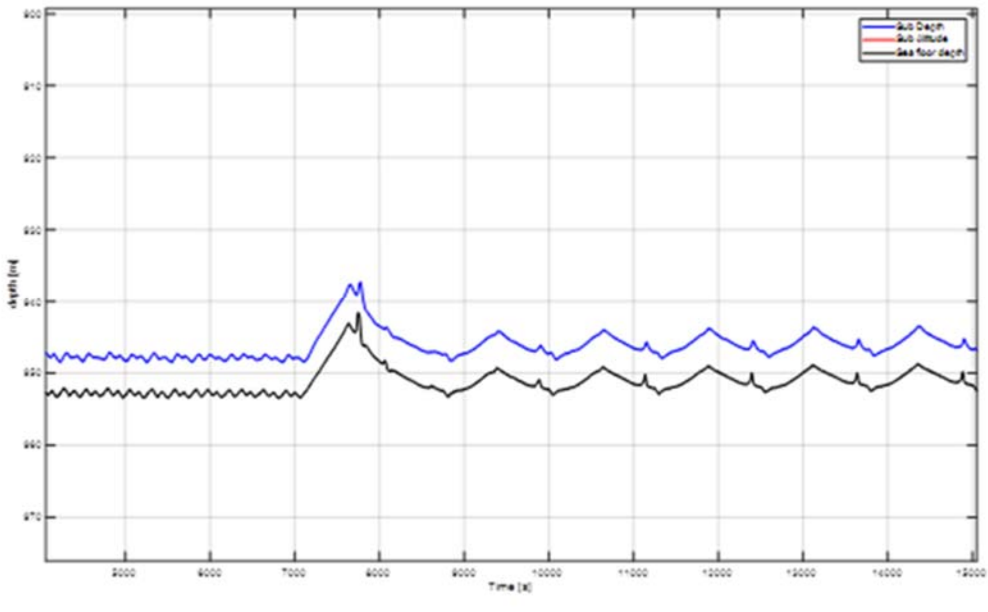
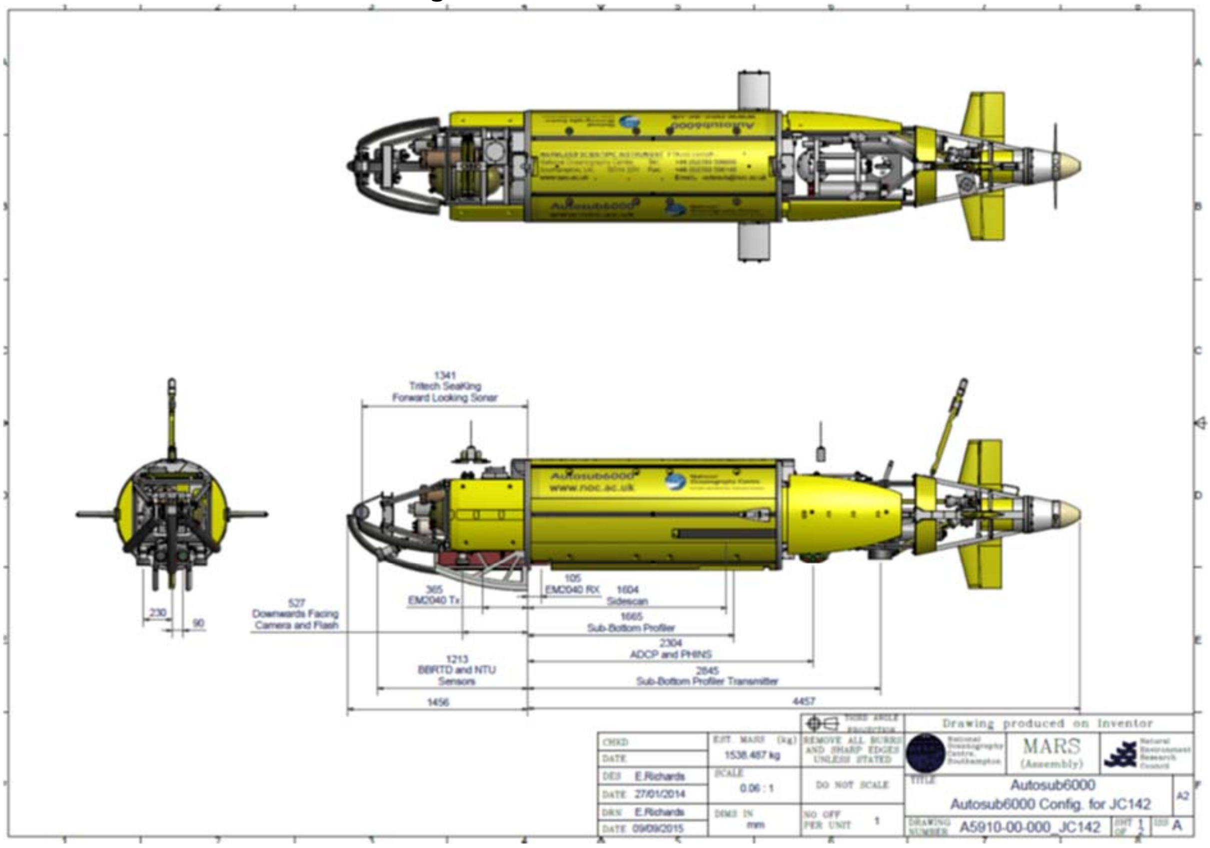


Fig. 7.2 Autosub bottom tracking (Track at Altitude command) during M156

7.1.2. AUV Standard Sensor Configuration



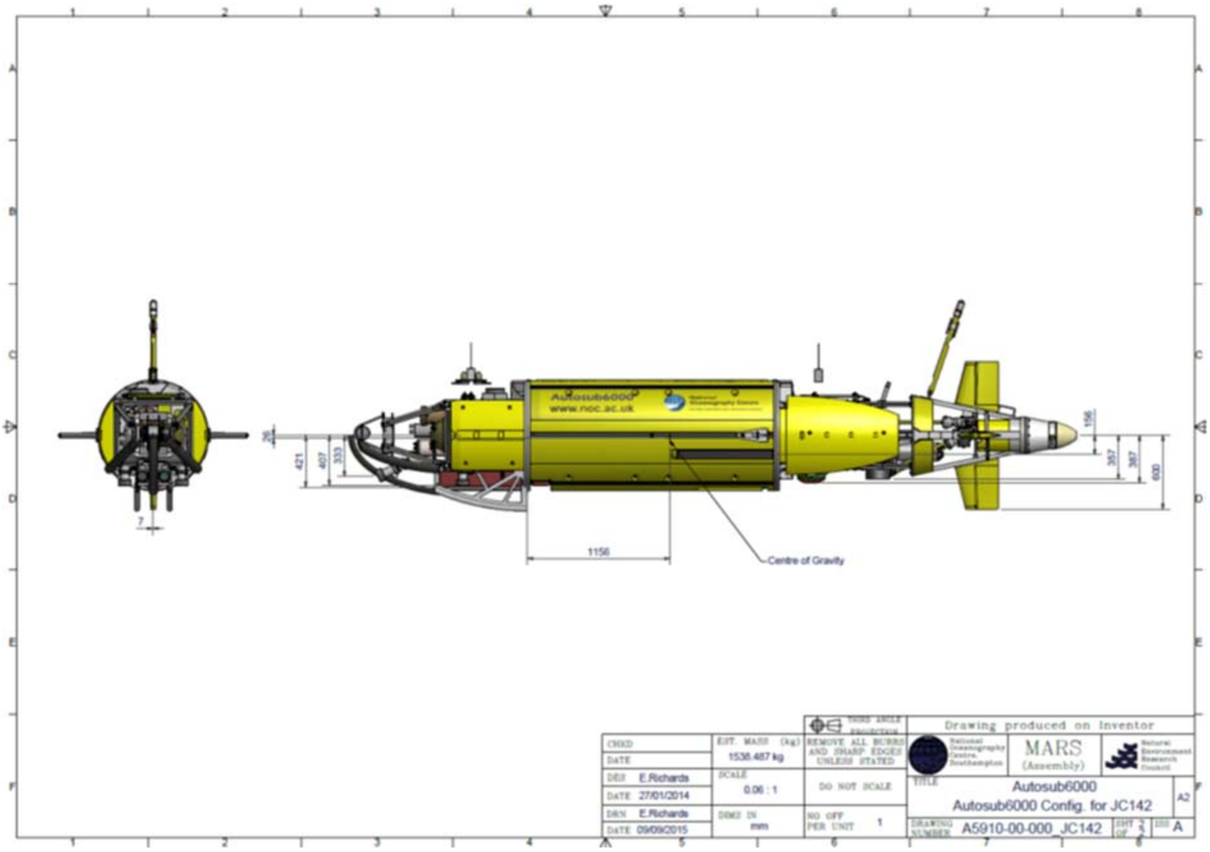


Fig. 7.3 Autosub standard configuration

7.1.3. AUV Biocam Configuration

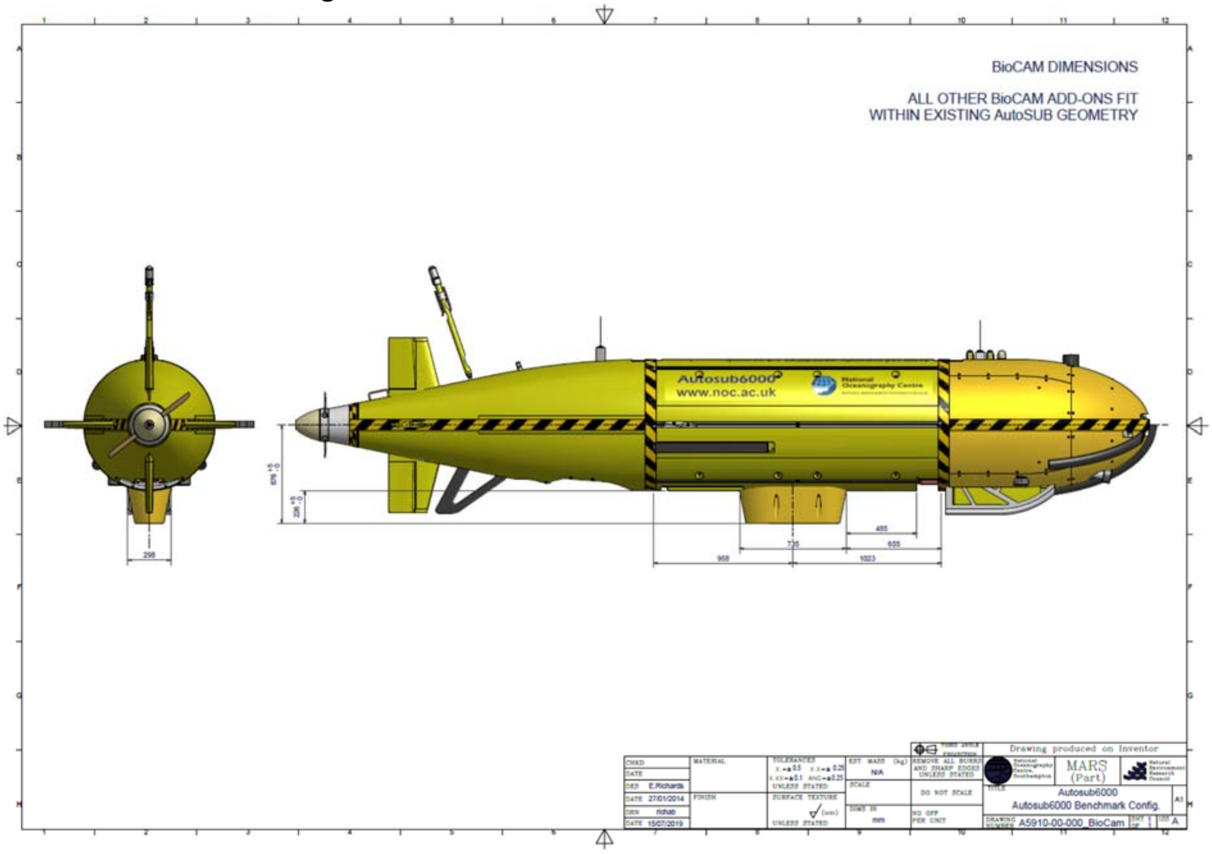


Fig. 7.4 Adjusted Autosub configuration to accommodate the BioCam system

7.1.4. Mission M150 Summary

Campaign **:** DY108/9 ***Mission No.*** **:** M150

Operating Area **:** Mingulay

Objectives

Biocam calibration mission, plus short sidescan sonar lines at end of mission to determine performance of systems operating together.

Mission Plan

Mission to calibrate the Biocam aboard the Autosub 6000

- Initial dive to depth followed by Biocam laser calibration lines at 10m, 9m, 8m, 7m, 6m, and 5m.
- Followed by a further Biocam data acquisition lines starting at 5m and increasing in altitude back to 10m in 1m steps.
- Final phase of edge Tech survey lines at 15m altitude with Biocam off, then a further Edge Tech line with Biocam on to determine Autosubs capability to drive both systems and determine if any interference was present.

Table 7.2 Vehicle Configuration and sensors used for M150

Sensors used	***Sub configuration***
1) RDI workhorse ADCP 300kHz downwards. 2) PHINS INS 3) Seabird 9+ CTD with dual CT sensors 4) EM2040 multi-beam (not used on this mission) 5) EdgeTech 2200-M 120-425kHz side scan and 2-16kHz sub-bottom profiler (not used on this mission) 6) 1 x colour downwards camera and flash (not used on this mission) 7) 1 x colour forward camera and flash (not used on this mission) 8) Tritech Seaking obstacle avoidance sonar 9) Sonardyne G6 USBL Transponder 10) Biocam, two flash panels and two Class 4 lasers	1) Rear winglets set at 6º pitched downwards. 2) Autosub 6k recovery line retention system with nylon springer lines 3) 16.9kg positive buoyancy. 4) 6 x new battery packs. 5) New Autosub6000 launch and recovery system (LARS)

Table 7.3 Mission Conditions for M150

	Start of Mission	***End of Mission***
Time [logger]	05:18:40 10/09/2019	09:55:35 10/09/2019
Position [GPS]	N56:48.096 W7:24.662	N56:48.254 W7:25.045
Sea state	2	3
Wind speed	15 knots	30 knots
Battery Voltage (pack)	49.75 Volts	48.41 Volts

Table 7.4 Mission Statistics for M150

Total Mission duration	4 hrs 36 mins	***Time on seabed surveying***	2 hrs 21 mins
Avg. descent speed	0.27 m/s	***Avg. ascent speed***	0.48 m/s
Mean ground speed at bottom	0.76 m/s	***Distance travelled***	12.7 km
Mean motor power	246.7 W	***Maximum Depth***	206.6 m
Approximate useful vertical images	-	***Approximate useful forward images***	-

Useful images are based on survey time between 2m and 4m altitude with a picture rate of 1000 ms.

The AUV was launched and dived successfully. The AUV was monitored via the Ships USBL and the Linkquest throughout the mission, a navigation offset was not sent and the vehicle sent on its way. The vehicle surfaced a little ahead of schedule in the expected location and was recovered back on deck without incident in increasingly freshening winds.

Initial analysis of data indicated a successful mission.

All systems appeared to operate successfully. Edge tech navigation data not found by Sonarwiz. However, this was working during test dives in ballast tank prior to cruise. Edge Tech systems appears to be receiving and interoperating navigational data correctly.

Table 7.5 Sensor Data Quality for M150

EM2040 – not used during this mission
CTD, DO -
Seaking sonar – Data present, not analysed
Magnetometer – Data present, not analysed
ADCP – Data present (DVL operated correctly)
Side-Scan Sonar (425kHz) – Data files present, not yet analysed
Side-Scan Sonar (120kHz) –
Sub bottom profiler – Data files present not yet analysed
AESA Cameras – not used during this mission

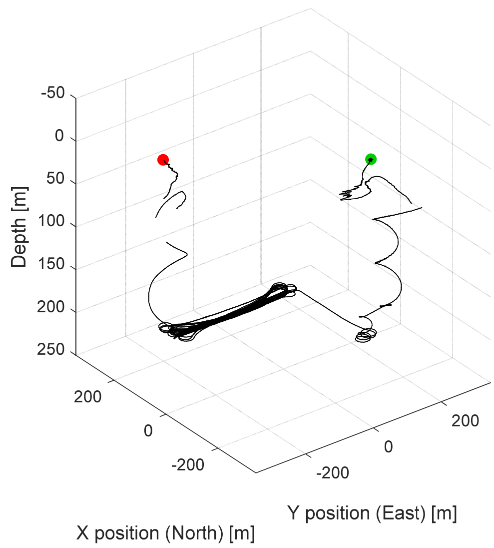


Fig. 7.5 3D Vehicle track for M150

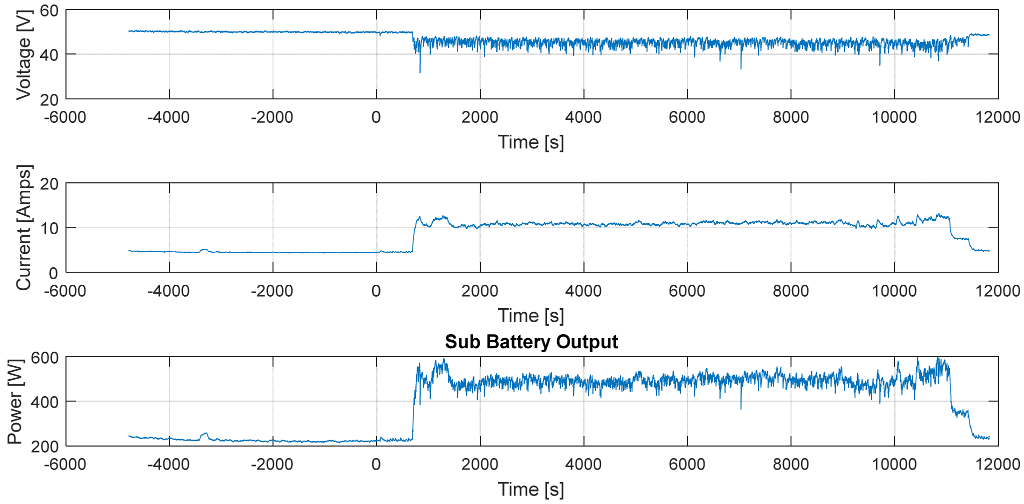


Fig. 7.6 Mission Power Usage for M150

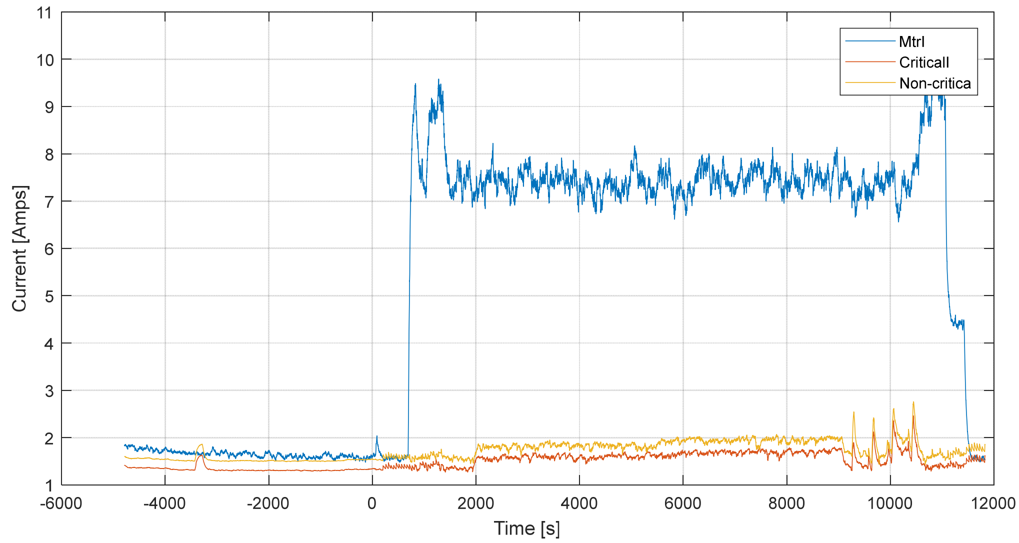


Fig. 7.7 Current analysis for M150

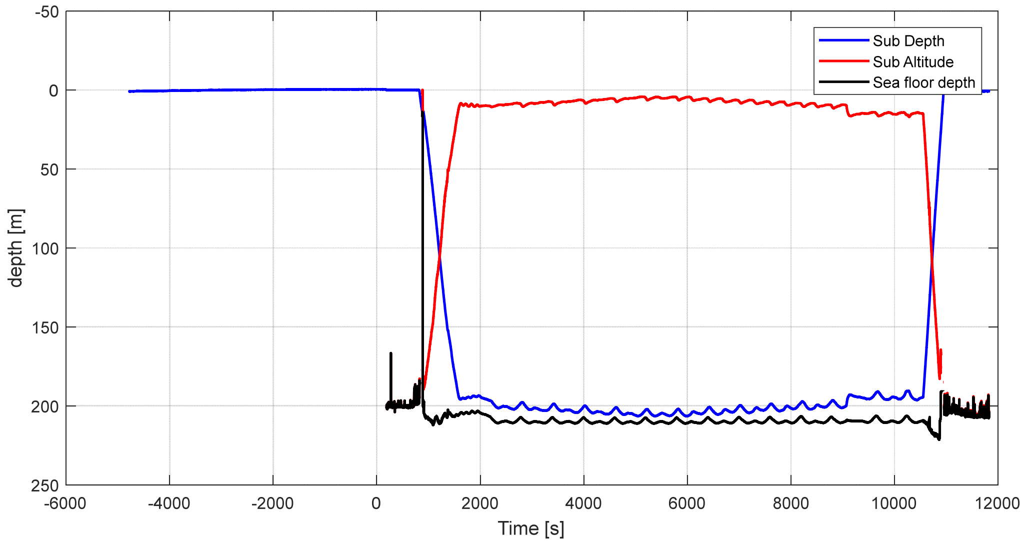


Fig. 7.8 Altitude tracking for M150

7.1.5. Mission M151 Summary

Campaign **:** DY108/9 ***Mission No.*** **:** M151

Operating Area **:** Darwin Mounds (West)

Mission Objectives & Description

Repeat 2011 sidescan survey of theWestern Darwin mounds trawl damaged coral field to determine if the area is improving. At the end of this survey repeat the Biocam calibration runs of M150 (poor visibility during M150 necessitates re-running the calibration).

Mission Plan

Sparse Edge Tech grid over eastern Darwin Mounds coral field. !5m altitude, high resolution side scan survey. Then repeat the Biocam laser calibration survey of M150 i.e.:

- Initial dive to depth followed by Biocam laser calibration lines at 10m, 9m, 8m, 7m, 6m, and 5m.
- Followed by a further Biocam data acquisition lines starting at 5m and increasing in altitude back to 10m in 1m steps.
- Final phase of edge Tech survey lines at 15m altitude with Biocam off, then a further Edge Tech line with Biocam on to determine Autosubs capability to drive both systems and determine if any interference was present.

Table 7.6 Vehicle Configuration and sensors used for M151

Sensors used	***Sub configuration***
11) RDI workhorse ADCP 300kHz downwards. 12) PHINS INS 13) Seabird 9+ CTD with dual CT sensors 14) EM2040 multi-beam (not used on this mission) 15) EdgeTech 2200-M 120-425kHz side scan and 2-16kHz sub-bottom profiler (not used on this mission) 16) 1 x colour downwards camera and flash (not used on this mission) 17) 1 x colour forward camera and flash (not used on this mission) 18) Tritech Seaking obstacle avoidance sonar 19) Sonardyne G6 USBL Transponder 20) Biocam, two flash panels and two Class 4 lasers	6) Rear winglets set at 6º pitched downwards. 7) Autosub 6k recovery line retention system with nylon springer lines 8) 16.9kg positive buoyancy. 9) 6 x new battery packs. 10) New Autosub6000 launch and recovery system (LARS)

Table 7.7 Mission Conditions for M151

	Start of Mission	***End of Mission***
Time [logger]	12-Sep-2019 13:20:11	13-Sep-2019 13:02:39
Position [GPS]	N59:48.723 W7:20.052	N59:49.207 W7:21.964
Sea state	3	4 to 5
Wind speed	20 knots	30 knots
Battery Voltage (pack)	48.0 Volts	43.6 Volts

Table 7.8 Mission Statistics for M151

Total Mission duration	23 hrs 42 mins	***Time on seabed surveying***	20 hrs 53 mins
Avg. descent speed	0.32 m/s	***Avg. ascent speed***	0.43 m/s
Mean ground speed at bottom	1.01 m/s	***Distance travelled***	93.5 km
Mean motor power	320.4 W	***Maximum Depth***	968.3 m
Approximate useful vertical images	-	***Approximate useful forward images***	-

Useful images are based on survey time between 2m and 4m altitude with a picture rate of 1000 ms.

The AUV was launched and dived successfully. The AUV was monitored via the Ships USBL at the start of the dive. We were unable to set the mission navigation offset due to poor Linquest communication. The navigational offset at the start was (Autosub was located):

- 459m south of the starting waypoint
- 265m West of the starting waypoint.

The mission was completed as expected. The vehicle surfaced a little ahead of schedule in the expected location. Due to higher sea state than forecast we did not immediately recovery the Autosub and stood by for approximately 4 hours. The weather conditions had improved slightly but conditions were still difficult for the recovery. Autosub was recovered back on deck without incident.

Initial analysis of data indicated a successful mission, with embedded Edgetech navigational data and good Biocam imagery. To improve lighting for future missions the Biocam team may increase the intensity of the LED flashes.

All systems appeared to operate successfully. Edge Tech data had embedded navigational data this time (manually auto record the edge tech during pre-mission setup). The Biocam appeared to operate correctly but the image intensity was less than expected. LED intensity will be increased before the next mission.

Table 7.9 Sensor Data Quality for M151

EM2040 – not used during this mission
CTD, DO -
Seaking sonar – Data present, not analysed
Magnetometer – Data present, not analysed
ADCP – Data present (DVL operated correctly)
Side-Scan Sonar (425kHz) – Data files present, not yet analysed
Side-Scan Sonar (120kHz) –
Sub bottom profiler – Data files present not yet analysed
AESA Cameras – not used during this mission

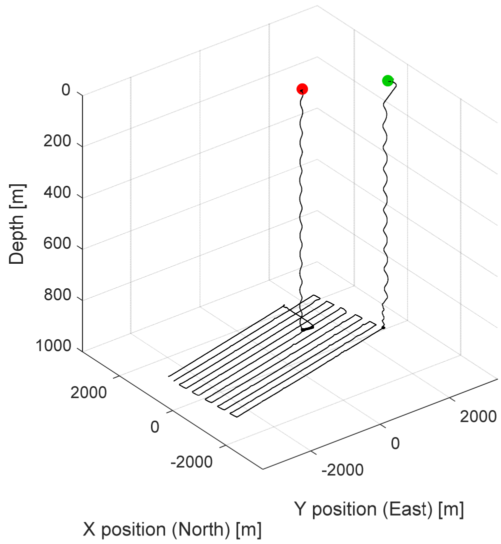


Fig. 7.9   3D Vehicle track for M151

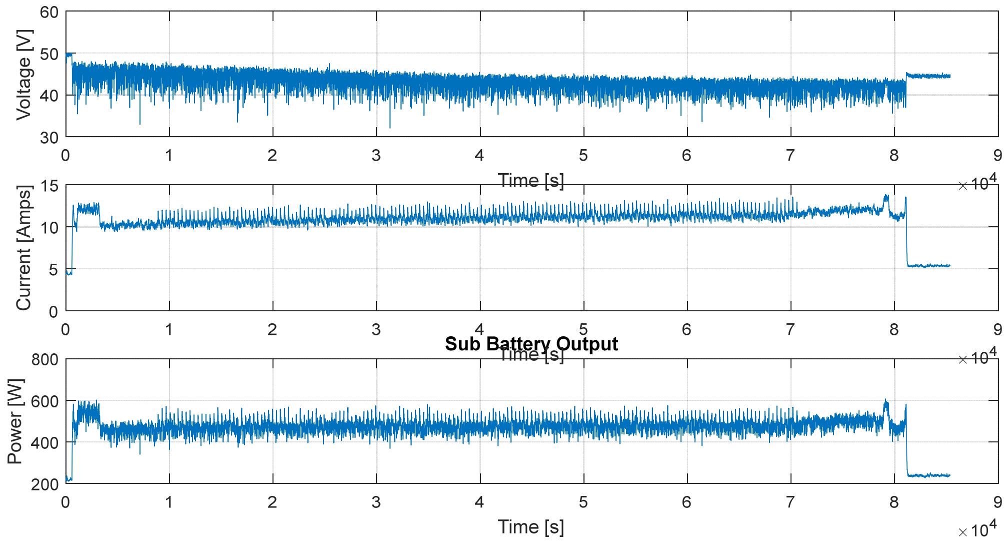


Fig. 7.10 Mission Power Usage

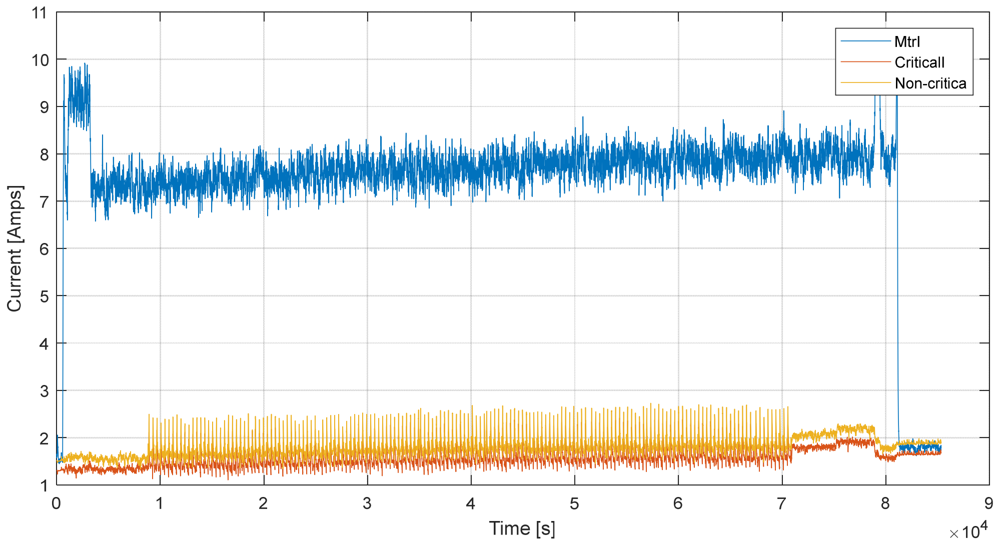


Fig. 7.11 Current analysis for M151

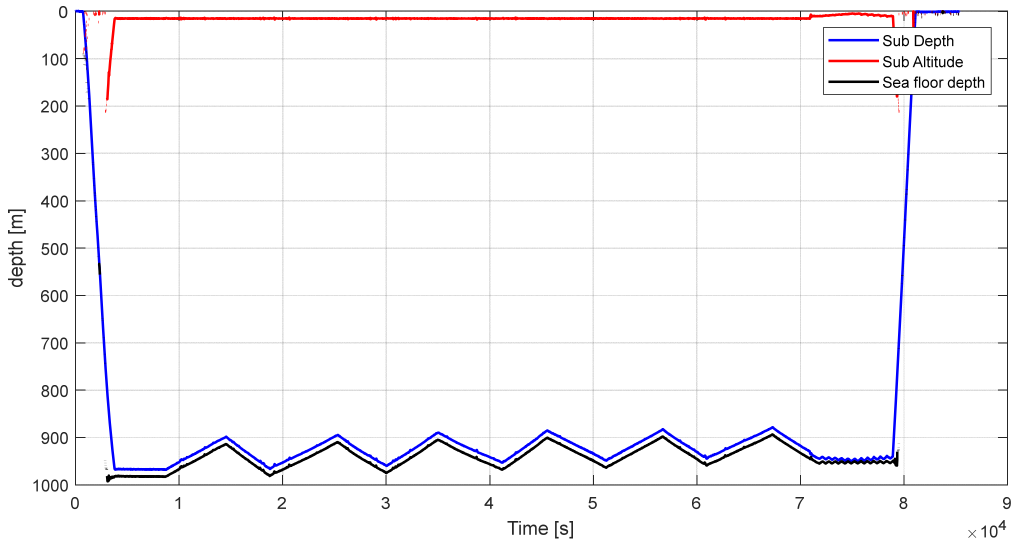


Fig. 7.12 Altitude Tracking for M151

7.1.6. Mission M152 Summary

Campaign **:** DY108/9 ***Mission No.*** **:** M152

Operating Area **:** Darwin Mounds (West)

Mission Objectives & Description

Dense Grid Biocam survey of Western Darwin Mounds. Repeating survey of the pervious EdgeTech survey. Test New Biocam lighting configurations.

Mission Plan

Biocam Dense grid over the region of the previously Edge Tech surveyed Darwin Mounds (West). Using Zamboni waypoints to give a spacing of 5 meters between lines.

Table 7.10 Vehicle Configuration and sensors used for M152

Sensors used	***Sub configuration***
21) RDI workhorse ADCP 300kHz downwards. 22) PHINS INS 23) Seabird 9+ CTD with dual CT sensors 24) EM2040 multi-beam 25) EdgeTech 2200-M 120-425kHz side scan and 2-16kHz sub-bottom profiler (not used on this mission) 26) 1 x colour downwards camera and flash (not used on this mission) 27) 1 x colour forward camera and flash (not used on this mission) 28) Tritech Seaking obstacle avoidance sonar 29) Sonardyne G6 USBL Transponder 30) Biocam, two flash panels and two Class 4 lasers	11) Rear winglets set at 6º pitched downwards. 12) Autosub 6k recovery line retention system with nylon springer lines 13) 16.9kg positive buoyancy. 14) 6 x new battery packs. 15) New Autosub6000 launch and recovery system (LARS)

Table 7.11 Mission Conditions for M152

	Start of Mission	***End of Mission***
Time [logger]	16-Sep-2019 05:46:53	17-Sep-2019 05:46:05
Position [GPS]	N59:48.860 W7:21.136	N59:48.437 W7:21.504
Sea state	3	3
Wind speed	25 knots	20 knots
Battery Voltage (pack)	49.61 [V]	44.76 V]

Table 7.12 Mission Statistics for M152

Total Mission duration	23 hrs 59 mins (or 86352.2 seconds)	***Time on seabed surveying***	19 hrs 8 mins
Avg. descent speed	0.278 m/s	***Avg. ascent speed***	0.531 m/s
Mean ground speed at bottom	0.92 [m/s]	***Distance travelled***	90.3 [km]
Mean motor power	309.7 [W]	***Maximum Depth***	965.8 [m]
Approximate useful vertical images	n/a	***Approximate useful forward images***	n/a

Useful images are based on survey time between 2m and 4m altitude with a picture rate of 1000 ms.

Table 7.13 Sensor Data Quality for M152

EM2040 – Not used during this mission
CTD, DO – Data Ok
Seaking sonar – Data Ok
Magnetometer – Data Ok
ADCP – Data Ok
Side-Scan Sonar (425kHz) – Not used
Side-Scan Sonar (120kHz) – Not sued
Sub bottom profiler – Not Used
AESA Cameras – Not Used

Successful Dive. USBL died on the dive down. Acoustic failed at sea floor similar to M151.

Biocam worked. LED drivers were modified to run at higher voltage, creating a brighter flash.

Acoustic Modem (TrackLink) failed to communicate when circling at 150m altitude.

USBL stopped working 1 hours and 30 minutes into the mission. This was due to the battery failing to charge. Issue with USBL not accepting charge. Seen this issue previously on DY94.

Mission plan overestimated the time need to complete the mission. Sub returned 2hrs and 30 minutes earlier than expected.

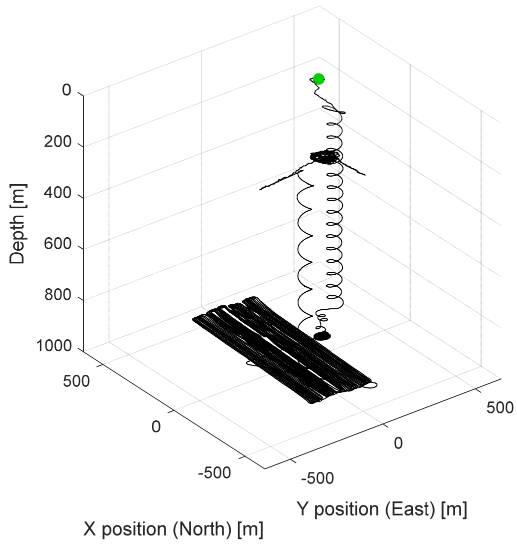


Fig. 13 3D Vehicle track for M152

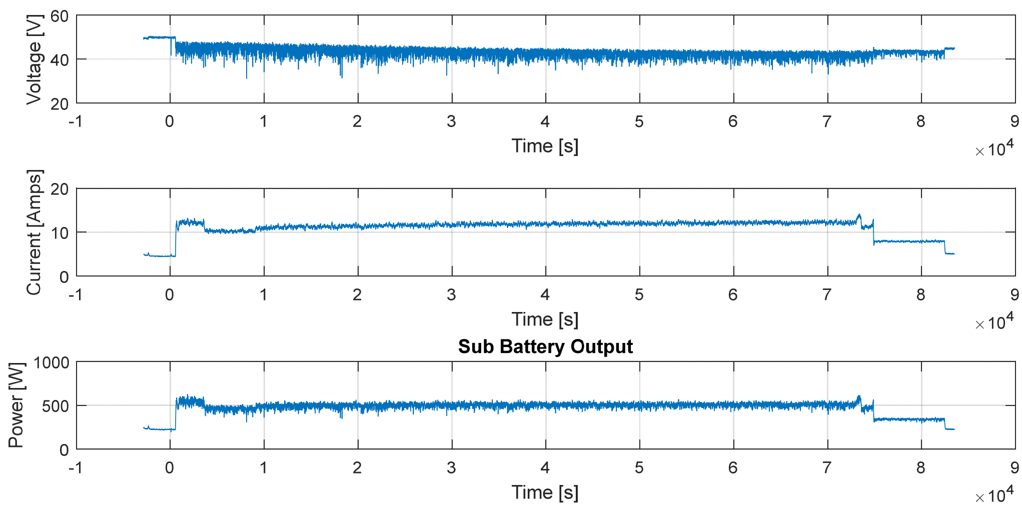


Fig. 7.14 Mission Power Usage

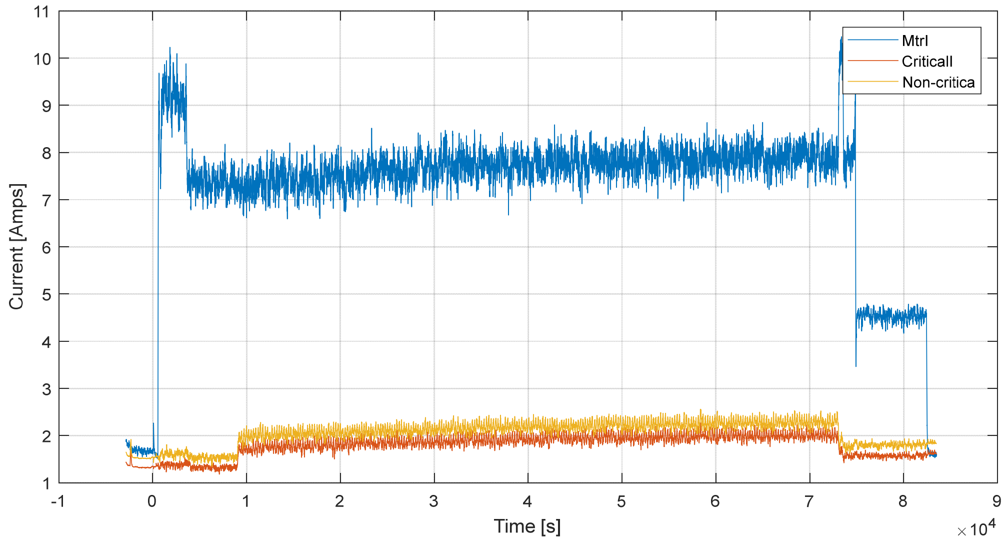


Fig. 7.15 Current Analysis

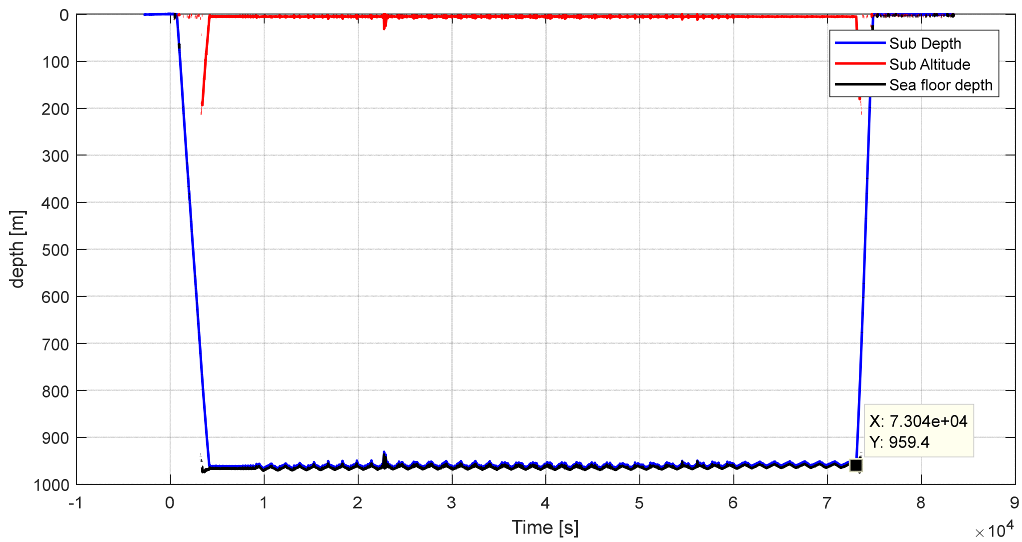


Fig. 7.16 Altitude tracking for M152

7.1.7. Mission M153 Summary

Campaign : DY108 ***Mission No.*** : M153

Operating Area : Darwin Mounds

Mission Objectives & Description

2nd BioCam survey at 6m of the eastern Darwin Mounds.

Mission Plan

- Deck Test for all suitable systems
- Fast dive to 950m then more gentle until ADCP contact made with bottom
- Circle and wait for position offset from the Acoustics or timeout
- Start BioCam/EM2040/Edgetech then run survey.
- Return to surface potter until we arrive to pick it up.

Table 7.14 Vehicle Configuration and sensors used for M153

Sensors used	***Sub configuration***
31) RDI workhorse ADCP 300kHz downwards. 32) PHINS INS 33) Seabird 9+ CTD with dual CT sensors 34) EM2040 multi-beam 35) EdgeTech 2200-M 120-425kHz side scan and 2-16kHz sub-bottom profiler (not used on this mission) 36) 1 x colour downwards camera and flash (not used on this mission) 37) 1 x colour forward camera and flash (not used on this mission) 38) Tritech Seaking obstacle avoidance sonar 39) Sonardyne G6 USBL Transponder	16) Rear winglets set at 6º pitched downwards. 17) Autosub 6k recovery line retention system with nylon springer lines 18) 14.2kg positive buoyancy. 19) 6 x new battery packs. 20) New Autosub6000 launch and recovery system (LARS)

Table 7.15 Mission Conditions for M153

	Start of Mission	***End of Mission***
Time [logger]	18-Sep-2019 08:22:43	19-Sep-2019 09:18:00
Position [GPS]	N59:51.327 W7:4.592	N59:51.283 W7:4.384
Sea state	1.5m	1.5m
Wind speed	15kn	15 kn
Battery Voltage (pack)	49.95 [V]	44.21 [V]

Table 7.16 Mission Statistics for M153

Total Mission duration	24 hrs 55 mins	***Time on seabed surveying***	
Avg. descent speed		***Avg. ascent speed***	
Mean ground speed at bottom	1.01 [m/s]	***Distance travelled***	90.2 [km]
Mean motor power	323.1 [W]	***Maximum Depth***	1043.7 [m]
Navigation Offset Applied	Move 370m south and 120m west		

Mission completed successfully: AUV successfully dived and was followed on the Ships USBL and the LinkQuest Fish until the AUV moved into 'WaitAtAlt' mode where the LinkQuest communication dropped out. Ship repositioned over vehicle and LinkQuest Fish was set to high power, this enabled intermittent comms with AUV meaning it was possible to send the required navigation offset. The AUV then continued the mission and surfaced about 90 minutes later than expected, it is expected that this is because of the currents, a number of lines can be seen to be timing out. The data also shows that the vehicle potentially hit the seabed although there is no visible damage to the AUV. The AUV was successfully recovered.

Linkquest - Same fault as previous missions, when AUV moves into 'WaitAtAlt' it is not possible to communicate with the AUV.

Tritech – From inspection of the Tritech node and data it appears that the Tritech head is not functioning.

Depth – Inspection of the data shows that the vehicle depth sensor is reading less than that of the CTD. The code on the lonworks node suggests that the latitude should be taken into consideration when making the depth calculation, this had been updated earlier in the cruise but will update again to see if this rectifies the issue.

Table 7.17 Sensor Data Quality for M153

EM2040 – N/A

CTD, DO - Ok

Seaking sonar – Data collected

Magnetometer – Ok

ADCP – Ok

Side-Scan Sonar (425kHz) – N/A

Side-Scan Sonar (120kHz) – N/A

Sub bottom profiler – N/A

AESA Cameras – N/A

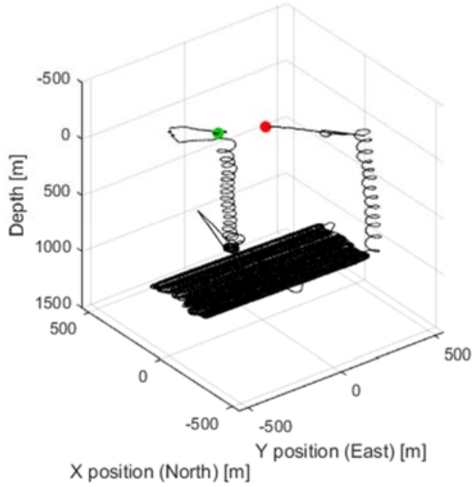


Fig. 7.17 3D Vehicle track for M153

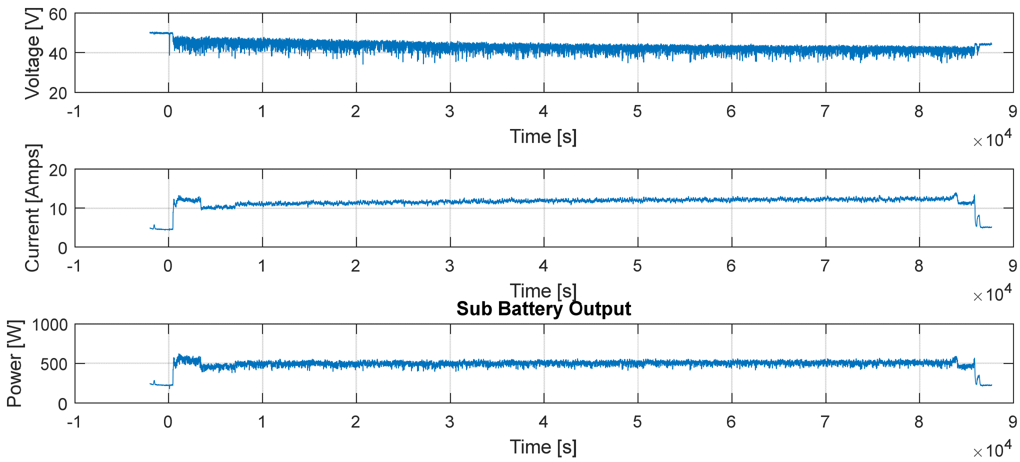


Fig. 7.18 Battery voltage measured at the motor node for M153

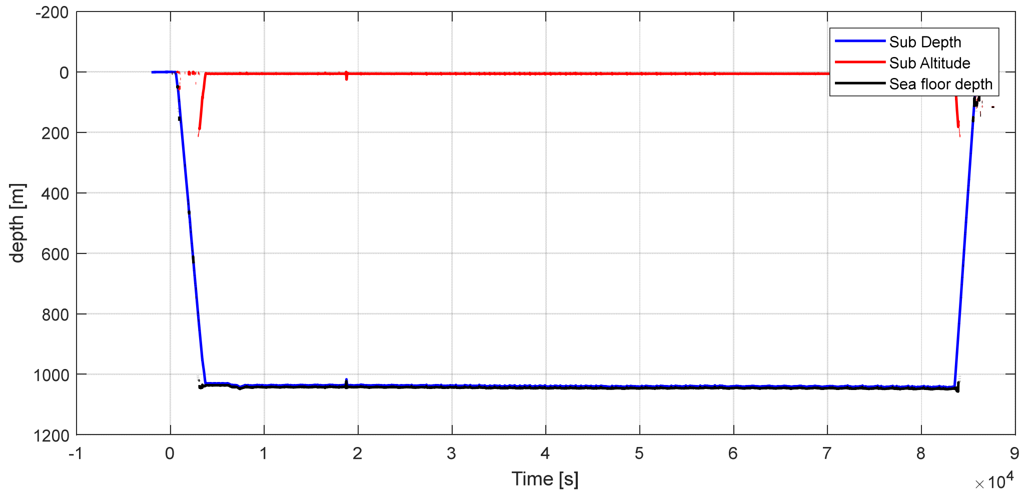


Fig. 7.19 Altitude tracking for M153

7.1.8. Mission M154 Summary

Campaign **:** DY108 ***Mission No.*** **:** M154

Operating Area **:** Darwin Mounds

Mission Objectives & Description

Run Edgetech survey of Eastern Darwin mounds followed by a short BioCam survey.

Table 7.18 Vehicle Configuration and sensors used for M154

Sensors used	***Sub configuration***
40) RDI workhorse ADCP 300kHz downwards. 41) PHINS INS 42) Seabird 9+ CTD with dual CT sensors 43) EM2040 multi-beam 44) EdgeTech 2200-M 120-425kHz side scan and 2-16kHz sub-bottom profiler (not used on this mission) 45) 1 x colour downwards camera and flash (not used on this mission) 46) 1 x colour forward camera and flash (not used on this mission) 47) Tritech Seaking obstacle avoidance sonar 48) Sonardyne G6 USBL Transponder	21) Rear winglets set at 6º pitched downwards. 22) Autosub 6k recovery line retention system with nylon springer lines 23) 16.8kg positive buoyancy. 24) 6 x new battery packs. 25) New Autosub6000 launch and recovery system (LARS)

Table 7.19 Mission Conditions for M154

	Start of Mission	***End of Mission***
Time [logger]	20-Sep-2019 14:34:43	20-Sep-2019 17:10:53
Position [GPS]	N59:51.411 W7:9.554	N59:51.246 W7:9.406
Sea state	1.5m	1.5m
Wind speed	12kn	12kn
Battery Voltage (pack)		

The vehicle was successfully launched but once in the water it was noticed that the heading from the INS was not changing and the mission was abandoned.

- The heading from the INS appeared to have frozen, it was possible this was occurring on deck but was not noticed until the vehicle was in the water and had made a dramatic shift in its orientation.

7.1.9. Mission M155 Summary

Campaign **:** DY108/9 ***Mission No.*** **:** M155

Operating Area **:** Darwin Mounds (East)

Mission Objectives & Description

Perform a sidescan sonar survey over the east Darwin mounds area previously surveyed in 2011. The purpose is to compare sidescan images from the two surveys to determine if the site has improved since 2011. At the end of the survey complete a short Biocam survey.

Mission Plan

Edge Tech survey over the east Darwin mounds coral reef field. A repeat of the survey carried out in 2011, to determine the extent of recovery. After the edge tech survey a short Biocam mission with Edge tech still operating at depths from 15m to 4m

Table 7.20 Vehicle Configuration and sensors used for M155

Sensors used	***Sub configuration***
49) RDI workhorse ADCP 300kHz downwards. 50) PHINS INS 51) Seabird 9+ CTD with dual CT sensors 52) EM2040 multi-beam (not used on this mission) 53) EdgeTech 2200-M 120-425kHz side scan and 2-16kHz sub-bottom profiler 54) 1 x colour downwards camera and flash (not used on this mission) 55) 1 x colour forward camera and flash (not used on this mission) 56) Tritech Seaking obstacle avoidance sonar 57) Sonardyne G6 USBL Transponder 58) Biocam, two flash panels and two Class 4 lasers	26) Rear winglets set at 6º pitched downwards. 27) Autosub 6k recovery line retention system with nylon springer lines 28) 16.9kg positive buoyancy. 29) 6 x new battery packs. 30) New Autosub6000 launch and recovery system (LARS)

Table 7.21 Mission Conditions for M155

	Start of Mission	***End of Mission***
Time [logger]	21-Sep-2019 14:39:20	22-Sep-2019 15:40:39
Position [GPS]	N59:51.406 W7:9.501	N59:50.965 W7:8.309
Sea state	2	3
Wind speed	12 knots	20 knots
Battery Voltage (pack)	49.69 [V]	44.24 [V]

Table 7.22 Mission Statistics for M155

Total Mission duration	25 hrs 1 mins	***Time on seabed surveying***	22 hrs 0mins
Avg. descent speed	0.34 m/s	***Avg. ascent speed***	0.39 m/s
Mean ground speed at bottom	1.02 [m/s]	***Distance travelled***	97 [km]
Mean motor power	315.9 [W]	***Maximum Depth***	1063.3 [m]
Approximate useful vertical images	n/a	***Approximate useful forward images***	n/a

Successful Edge tech mission. However, just after the Biocam section of the dive started the Autosub lost bottom lock and dived and hit the seabed. It aborted the mission and ascended to near the safe depth of 160m (note a safe depth of 100m was programmed, unclear why the Autosub did not achieve this depth). The mission was aborted via the Linquest system on the acoustic fish and the vehicle surfaced 50m from the ship. Recovered on board safely. Later analysis showed the Autosub lost bottom lock because the ADCP had failed. The Autosub then dived to try to reacquire the seabed, causing the collision with the seabed. Post mission the ADCP was removed and bench tested where it was conformed both beams 2 & 4 were not longer working.

Successful EdgeTech mission, however loss of bottom lock just after the start of the Biocam section of the mission resulted in the Autosub pitching downwards and colliding with the sea floor. The Autosub then returned to close to the safe depth at which point the mission was aborted via the Linquest acoustic system,

- The Autosub did not return exactly to the safe depth. Aurtosub circled and pottered at 160m rather than the configured 100m

- Bottom lock was lost due to an ADCP failure. Post mission analysis of the ADCP (removed from the Navigation tube) showed beam 2 and 4 were not working

- We do not have a full understanding of what happened after the collision with the seabed. The vehicle did return to somewhere near the safe depth, however post mission analysis showed all mission script commands after the collision were actioned but then then skipped over rapidly (within a few minutes rather than the 2 to 3 hours programmed). We are unclear whether this is normal behaviour.

Table 7.23 Sensor Data Quality for M155

EM2040 – Not used during this mission
CTD, DO – Questionable data, depth data poor quality requires investigation.
Seaking sonar – Data Ok
Magnetometer – Data Ok
ADCP – Data Ok
Side-Scan Sonar (425kHz) – Data OK
Side-Scan Sonar (120kHz) – Not sued
Sub bottom profiler – Data Ok
AESA Cameras – Not Used

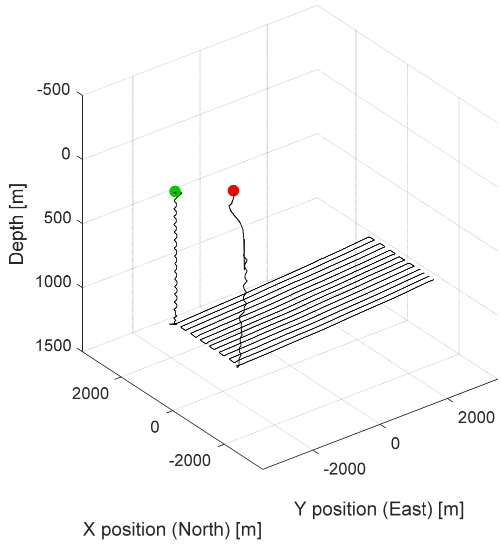


Fig. 7.20   3D Vehicle track for M155

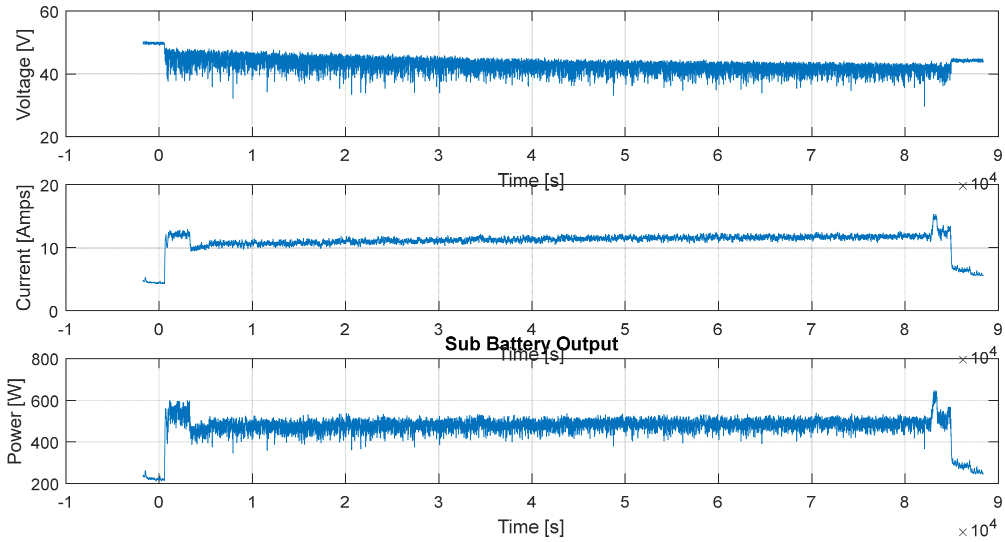


Fig. 7.21 Mission Power Usage for M155

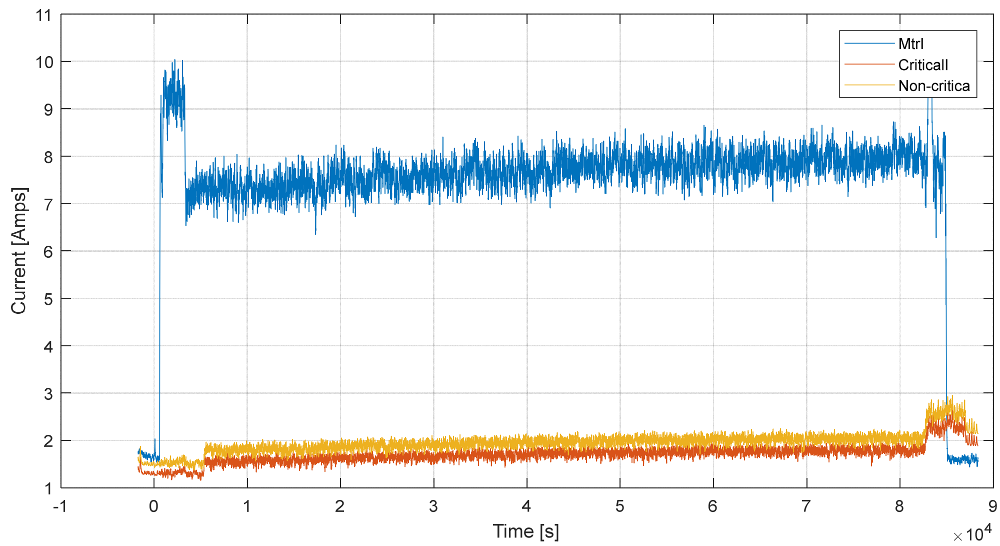


Fig. 7.22 Current Analysis for M155

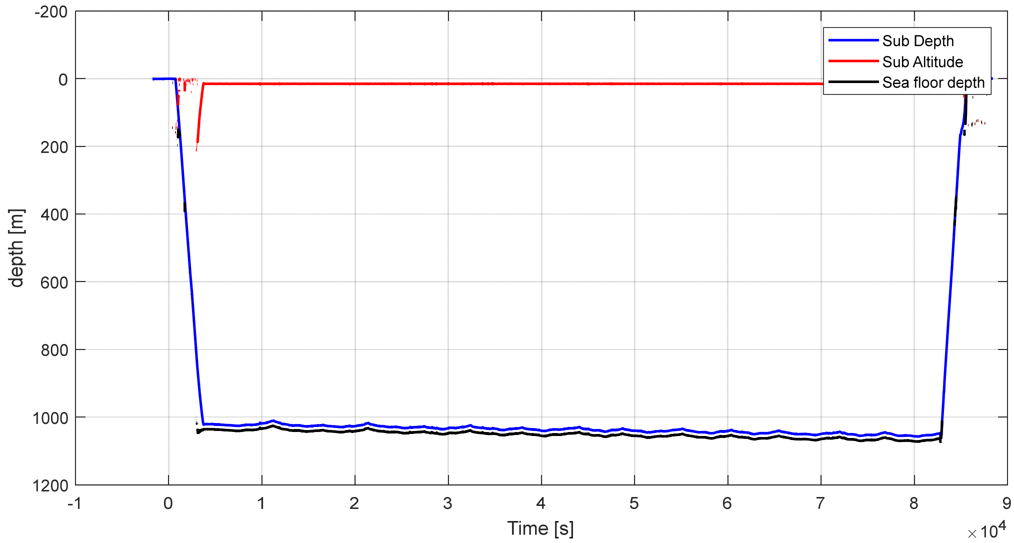


Fig. 7.23 Altitude Tracking for M155

7.1.10. Mission M156 Summary

Campaign **:** DY108/9 ***Mission No.*** **:** M156

Operating Area **:** Darwin Mounds (West)

Mission Objectives & Description

Test dive to check new ADCP followed by a Biocam dense grid survey of the Western Darwin mounds coral reef site. This area was side scanned previously on this cruise and the dense grid hopes to highlight key coral mounds within the area.

Mission Plan

Perform a test dive to check operation of the newly installed, and then carry out a dense grid Biocam survey over the previously side scanned area to pick out key features.

Table 7.24 Vehicle Configuration and sensors used for M156

Sensors used	***Sub configuration***
59) RDI workhorse ADCP 300kHz downwards. 60) PHINS INS 61) Seabird 9+ CTD with dual CT sensors 62) EM2040 multi-beam (not used on this mission) 63) EdgeTech 2200-M 120-425kHz side scan and 2-16kHz sub-bottom profiler (not used on this mission) 64) 1 x colour downwards camera and flash (not used on this mission) 65) 1 x colour forward camera and flash (not used on this mission) 66) Tritech Seaking obstacle avoidance sonar 67) Sonardyne G6 USBL Transponder 68) Biocam, two flash panels and two Class 4 lasers	31) Rear winglets set at 6º pitched downwards. 32) Autosub 6k recovery line retention system with nylon springer lines 33) 16.9kg positive buoyancy. 34) 6 x new battery packs. 35) New Autosub6000 launch and recovery system (LARS)

Table 7.25 Mission Conditions for M156

	Start of Mission	***End of Mission***
Time [logger]	24-Sep-2019 13:01:37	25-Sep-2019 15:17:41
Position [GPS]	N59:49.454 W7:21.677	N59:49.708 W7:22.520
Sea state	2	4
Wind speed	20 knots	30 knots
Battery Voltage (pack)	49.93 [V]	44.09 [V]

Table 7.26 Mission Statistics for M156

Total Mission duration	26 hrs 08 mins	***Time on seabed surveying***	21 hrs 58 mins
Avg. descent speed	0.38 m/s	***Avg. ascent speed***	0.41 m/s
Mean ground speed at bottom	1.07 [m/s]	***Distance travelled***	92.9 [km]
Mean motor power		***Maximum Depth***	952.8 [m]
Approximate useful vertical images	n/a	***Approximate useful forward images***	n/a

The new ADCP was tested successfully by performing a dive to 900m to obtain DVL bottom lock and run two test lines. The vehicle then ascended back to the surface again and paused where data was offloaded to check ADCP performance. All appeared correct and so the vehicle was sent on the remaining Biocam mission. The vehicle performed correctly and we saw a better altitude tracking performance than on earlier dives. The vehicle surfaced as expected and was recovered successfully under demanding conditions.

The Biocam did not collect any data. Initial analysis suggests the cable between the Biocam and the logger failing under pressure at 900m at the start of the Biocam mission. Then working again at 300m on the ascent after the Biocam mission. Although power was still being supplied the Biocam did nor receive any UDP messages from Autosub. Post mission analysis of the Logger tube data showed UDP messages around the Autosub vehicle were working as normal. Therefore, the cable between the Biocam and the logger is suspect.

Table 7.27 Sensor Data Quality for M156

EM2040 – Not used during this mission
CTD, DO – Data Ok, although a delay accrues during the mission so data does not align correctly at the end of the mission
Seaking sonar – Data Ok
Magnetometer – Data Ok
ADCP – Data Ok
Side-Scan Sonar (425kHz) – Not used
Side-Scan Sonar (120kHz) – Not sued
Sub bottom profiler – Data Ok
AESA Cameras – Not Used
Biocam – No data due to Biocam cable failing under pressure

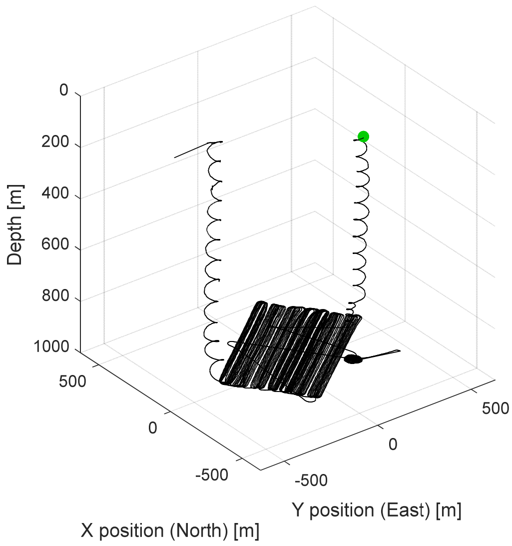


Fig. 7.24 3D Vehicle track for M156

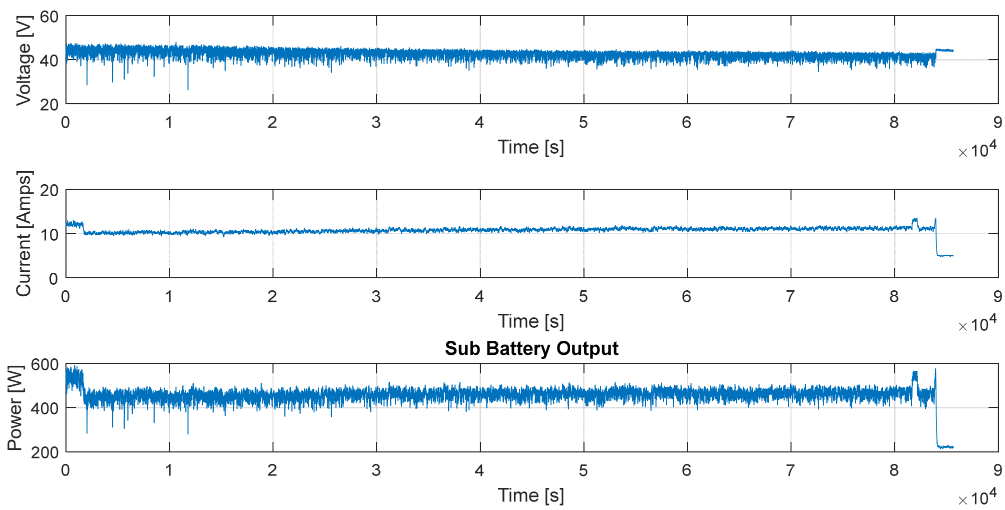


Fig. 7.25 Mission Power Usage for M156

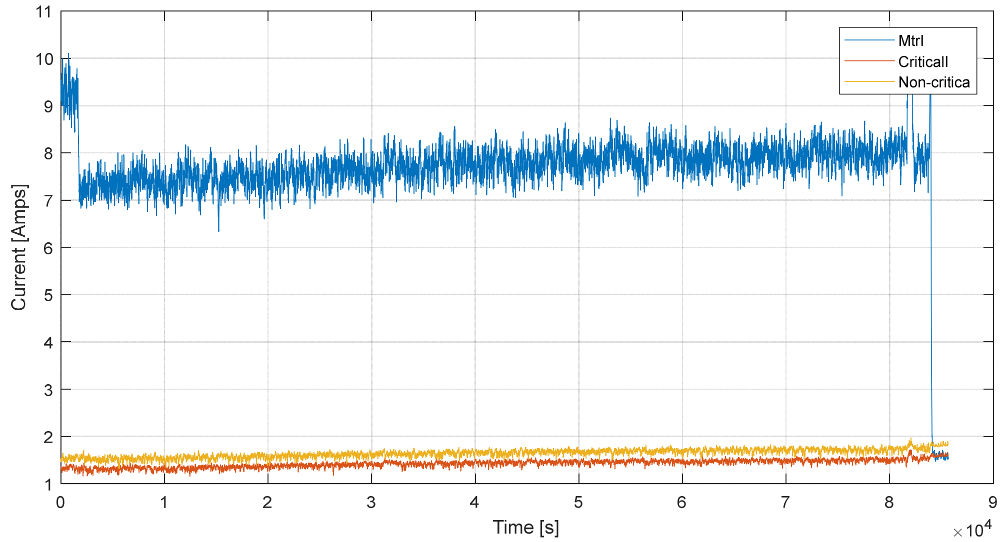


Fig. 7.26 Current Analysis for M156

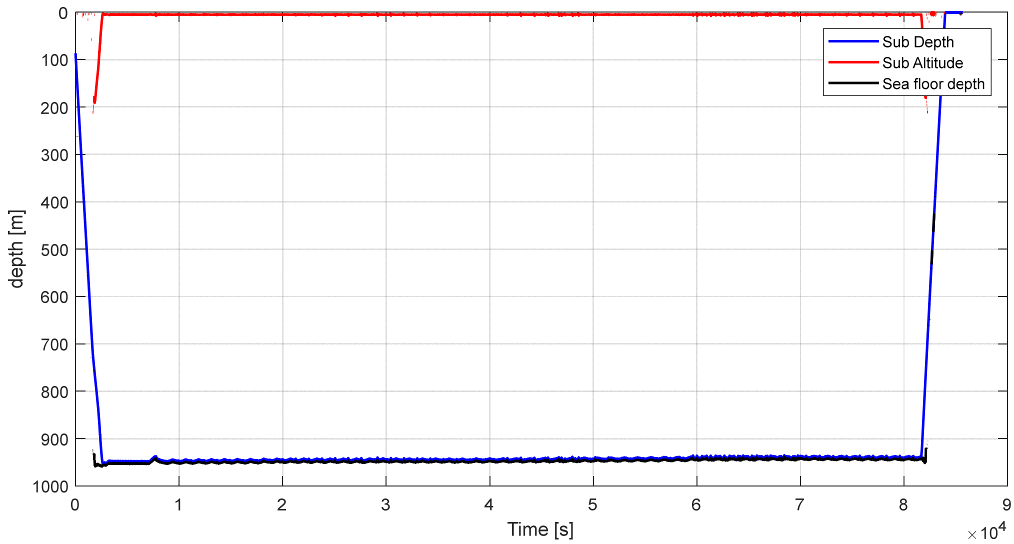


Fig. 7.27 Altitude Tracking for M156

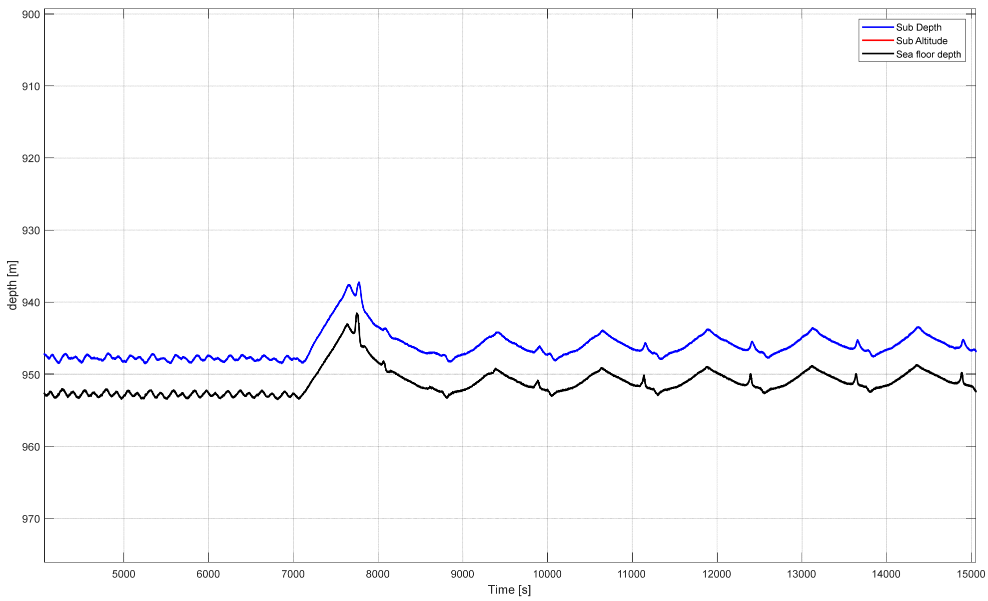


Fig. 7.28 Improved Altitude tracking performance for M156

7.2. HyBIS System Cruise Report

Operational Team: Dave Turner, Russell Locke & Emre Mutlu

Fig. 7.29 HyBIS on deck

7.2.1. Cruise Outline

HyBIS was used during DY108 for HD video and stills survey of the Darwin Mounds.

7.2.2. Stats

No. of dives DY108 (Dive nos. HY50 to HY62)	13
Water Depths	755m – 1072m
Total time at seabed or survey depth:	75:50 hrs
HyBIS total time in water:	90:46 hrs
Total Video (Apple ProRes 422)	HD 4.17 TB
	PAL 3.84 TB
Scorpio Images	26845 images – 102.2 GB

Master #1 Lacie Raid unit SER# NL4104NZ will be installed in the NOC media room for BODC to archive and provide access for scientists post cruise.

Backup #1 Lacie Raid unit SER# NL41042D will be retained by the ROV team until BODC have archived the Master unit.

7.2.3. Mobilisation

NOC Southampton: 2nd September to 5th September 2019

The mobilisation of Hybis in preparation for DY108 was conducted by the whole of the ROV team.

The HYBIS monitors and control rack were assembled in the first bay (furthest forward) of the main lab, with the winch operator's CLAM and CCTV monitors mounted at the end of the bench. The HYBIS power supply unit was mounted on top of the portable table, inside of the High Voltage Cage. The HYBIS team were given responsibility of the HV cage key and the Chief Engineer kept the key to the key cabinet also kept inside the cage.

An Evergrip termination was still connected to the deep tow cable following the previous (trials) cruise. After electrical testing, new fibre optic tails were spliced onto the cable. The results of the electrical and optical testing are shown below:

Optical readings were taken from the Main Lab Junction box to the terminated end of the Deep Tow.

	1310 nm	1550 nm
Red	-11.15dB	-9.50dB
Black	-11.37dB	-10.82dB
Grey	-11.12dB	-10.50dB

OTDR readings:

	1310 nm	1550 nm
Red	9.91 km xxxdB Loss	9.91 km xxxdB Loss
Black	9.91 km 6.7dB Loss	9.91 km 5.6dB Loss
Grey	9.9 km 5.8dB loss	9.9 km xxxdB Loss

The termination was then connected to HYBIS with the red fibre used for telemetry and the black fibre used for the Scorpio camera. The vehicle was then tested using the 240V deck lead followed by the HV supply and all functions worked correctly.

The electrical conductor readings were taken from the Deep Tow junction box in the winch room to the terminated end of the Deep Tow.

Table 7.28 – RRS Discovery deep tow cable test results

Continuity of Conductors & Earth	Test Results Ω
L1 – L2	92.6
L1 – L3	92.1
L2 – L3	92.0
L1 – Earth	47.4
L2 – Earth	47.3
L3 – Earth	47.2
Insulation Resistance Test	**Test Results (GΩ)**
L1 – L2	3.27
L1 – L3	4.46
L2 – L3	3.47
L1 – Earth	2.59
L2 – Earth	3.00
L3 – Earth	2.53

7.2.4. De-Mobilisation

The HyBIS system was prepared for demobilisation during the transit back to NOC Southampton. The vehicle was stripped of lights and sensors and the cages were packed so that the HyBIS system was ready to be lifted off the ship.
During the de-mobilisation another deep tow wire inspection was made and the fibre optic power values were recorded on the IMS system. The Evergrip termination was cut off and returned to the NOC ROV Hangar S1/55 for service and storage.

7.2.5. Deep Tow Cable

7.2.5.1. Umbilical Termination

During DY108, HyBis was the only piece of equipment attached to the deep tow cable underneath the hydraboom, so no wire swapping was required.

There is now a working fusion splicing kit, OTDR, optical power meters and associated tools and consumables on board the Discovery, located in aluminium boxes in the technician's lab.

Suggestions/Recommendations

- Re-test the umbilical cable during the de-mob. Remove Evergrip termination from the umbilical and return to ROV hangar for refurbishment.

7.2.5.2. **Active Heave Compensation**

The Active Heave Compensation (AHC) of the deep tow cable was tested during the Discovery trials cruise, which took place just before DY108. During testing, the main problem with the AHC was identified and fixed.

The AHC was used on dive HY51 of DY108 during weather that would have normally produced poor video footage, due to the large sea state. The water depth at the work site was 1046m and the AHC was turned on at a depth of 900m. The AHC compensated well for the heave of the ship and HyBIS maintained a constant altitude off the sea bed (± ~0.5m) providing stable video footage and reducing the constant winch adjustments that are normally required. The data provided by the winch console showed that the maximum heave compensation during the dive was 6.43m with the average compensation being 2.19m.

The AHC was subsequently used for every HyBIS dive and improved the image stability and video quality substantially.

7.2.5.3. **High Voltage Operations**

As with previous cruises, the HV operations were discussed and agreed with the Chief Engineer and the ETO prior to sailing. The key to the HV cage key remained in the possession of the HyBIS HV appointed person for the duration of the trip. The HV was turned on at 110m depth, which allowed just one stop during descent and was also the depth that the Active Heave Compensation (AHC) could be turned on.
During recovery, the power to HyBIS was turned off at 100m depth and the bridge was notified when this was done so that HyBIS could be recovered to deck.
A permit to work/Isolation certificate was filled out to show that the vehicle was isolated and HV probes were used each time the HV JB was opened.

After the last HyBIS dive, the system was isolated and an isolation certificate was completed. The system was then inspected by the Chief Engineer and ETO.

Suggestions/Recommendations

- The HV cage on the ship should be modified so that the front panel does not need to be dismantled each time when the HV portable system and table is installed and removed.
- It would be highly recommended that the 230V supply in the HV cage be changed to a switched socket for isolation and lockout/tag out purposes.

7.2.6. HyBIS System

During DY108 the HyBIS vehicle was stowed inside the hangar aft of the CTD slot. It was sat on a pallet and moved out under the hydra-boom prior to each launch. When deploying from this position and when the sampling module was attached (Dive HY50) it was found that the height between the Evergrip and the first set of rollers was not sufficient to allow any floats to be attached to the wire, without first opening the bulwark doors. During dive HY50 it was decided to put all five floats onto the wire when HyBIS was approximately 12m under the surface.

The associated HyBIS spares boxes and consumables were stowed in cages in the main hangar. Deck testing was achieved using the 240V AC deck lead plugged into a socket in the hanger. The deep tow cable was not removed from the vehicle during DY108 so during deck testing, communications were done using the deep tow fibres.

7.2.6.1. **Vehicle**

7.2.6.1.1 Hydraulic System

The only hydraulic function used on DY108 was the camera tilt.

Suggestions/Recommendations

- Flush and replace hydraulic oil before next HyBIS cruise.

7.2.6.1.2 Thrusters

The thrusters were used significantly during DY108 and worked well. Small oil leak on starboard thruster.

Suggestions/Recommendations

- Drain all thrusters. Strip and check for signs of wear.
- Fix oil leak on starboard thruster

7.2.6.1.3 Modules

7.2.6.1.3.1 Sampling

The sampling module was mobilised for DY108 and attached to Hybis for the first dive (HY50), which was to be a reconnaissance and possible recovery of a lander. Unfortunately, due to the cable failure described, the dive was aborted and the sampling module was not used again during the cruise.

7.2.6.1.3.2 Downward video

The downward video frame was used for all but one of the dives during DY108. It was modified to accommodate an extension pole, grapple hook and lifting strop for the recovery of the marker buoys (HY52 & HY53).

7.2.6.1.3.3 Grab module

Not mobilised for this cruise.

7.2.6.1.4 Cameras

Two Super Scorpio HD cameras were made available for DY108 from the Isis ROV equipment. Unit Serial# SSC102 was mounted onto HyBIS for the duration of the trip.
During dive HY54-power-up and after two days of HyBIS not being used, the Super Scorpio camera would not come to life. The power was cycled several times and it could be seen from the fibre optic rattler that the camera was sending a signal to topside. After approximately five minutes, and a final power cycle, the camera came to life but had lost all of its internal set-up parameters. Unit SSC102 was the camera that had just been returned from having its internal battery replaced, but it appears that the repair was unsuccessful.

It was noticed during dives HY54 and HY55 that the Delrin shroud of the Super Scorpio camera could be seen at the corners of the image. The shroud was adjusted during HY56 pre-dive by rotating until it disappeared from the field of view.

During DY108 white balancing was not required as this was done by post processing of the video and images.

The download of images was done with a laptop and a power supply in the hanger.

Two Bowtech PAL cameras were available as part of the HyBIS equipment. During the first pre-dive of the trip it was noticed that the upward looking camera image was distorted and the display was cutting in and out. To test the cables the cameras were swapped over but the problem remained with the same camera unit ruling out a problem with the camera leads. The faulty camera was dismantled and it was suspected that the internal wiring might be suffering from dry joints. The internal wiring was replaced and the camera reassembled but the same display problem was seen. The problem may lie in the actual camera unit. For the rest of DY108 HyBIS was operated with one PAL camera and no spare.

Suggestions/Recommendations

- Look into purchasing replacement HyBIS Bowtech PAL camera
- Contact Insite Pacific and seek advice concerning failure of Super Scorpio internal battery

7.2.6.1.4.1 Super Scorpio Specs:

HD: 1920 x 1080 / (50P), **50i,** 25p

12.3 MEGA-PIXEL quality for Ultra-High Definition (4672 x 2628-pixel) Still Images

Sensor: Exmor Back-illuminated CMOS 1/2.88" (6.2mm)

10X Optical Zoom Lens (26.3mm - 263mm in 35mm format)

Focal Distance= f= 3.8mm – 38mm

Aperture: F1.8 - F9.6

64GB Internal Flash Memory

On recovery deck download of images (Ethernet deck cable)

7.2.6.1.5 Lights

During video transect dives, three Cathx Aphos lights were pointed downwards to illuminate the Scorpio camera and two DSPL Lumos LED lights faced forwards for the PAL tooling camera.

Suggestions/Recommendations

- Return Cathyx lights to ISIS spares container and DSPL Lumos LED lights to MPUS spares.

7.2.6.1.6 Scaling Lasers

Two NOC lasers were used for DY108 with two spares. The lasers worked well for the duration of the cruise.

Suggestions/Recommendations

- Check lasers for damage and replace seals as part of their routine maintenance.

7.2.6.1.7 Valeport VA500 Pressure / Altimeter transducer

The pressure/altimeter transducer worked well for most of DY108 and proved very useful to the winch driver during bottom operations.

During dive HY57 the altimeter did not return a signal to the GUI PC for a short period of time. The signal then re-appeared of its own accord.

During dive HY58, altimeter cut out again for 5 minutes, then came back to life of its own accord. During the last four HyBIS dives, no further problems with the altimeter were observed.

7.2.6.1.8 Tritech Sonar

The HyBIS 4000m Tritech sonar was used throughout DY108 and worked successfully for the duration of the cruise. It proved to be very useful during the location of the marker buoys and lander. It also imaged the mounds and the bedforms (sandwaves, ripples) very well

Suggestions/Recommendations

- Develop a method to record the forward sonar data for later re-play/analysis

7.2.6.1.9 Compass

The Xsense MTi-30 AHRS compass worked well during DY108. The compass offset was set to zero as per previous cruise (DY103) and this seemed to correctly reflect the vehicles movements during video transects.

Suggestions/Recommendations

- Remove the -25 degree offset built into the GUI software.

7.2.6.1.10 Vehicle cabling

During the first HyBIS dive (HY50) the vehicle powered up and worked correctly to a depth of approximately 250m at which point the power to the vehicle was lost and HyBIS was recovered.

At first, it was thought that the umbilical had failed as the vehicle still powered up using the deck lead. Continuity and insulation Resistance checks were made on the cable but the test results looked okay and were similar to the values obtained during the mobilisation.

The fault was eventually traced to the 240V power lead from the transformer to the high power tube. On visual inspection the cable had a tight 90° bend and when tested it was found to be faulty.

The cable was replaced and when the transformer overload was re-set, the vehicle powered up successfully again.

7.2.6.2. **Lab Setup and Rack Mount Case**

The rack unit and lab set-up was identical to that of HyBIS cruise DY094 & DY103.

7.2.6.2.1 Mini HP GUI Machine

The GUI PC was used to run the Labview status displays for HyBIS.

7.2.6.2.2 Mini HP OFOP Machine

The OFOP PC and monitor were used to run the OFOP software. A second monitor was provided for science logging of ocean floor observations.

7.2.6.2.3 AJA KiPro video recorders

Two AJA Rackmounted KiPro units were used to record video. The Top unit was assigned to the Scorpio HD camera. The lower unit was connected to the 720P50 quad which was connected to the PAL tooling camera. The copying of the KiPro disks to the Lacie units was done by the HyBIS team.

During dive HY56 the PAL KiPro Unit Stopped recording of own accord. The unit then locked up and would not mount formatted solid state drive unit. When viewed on the Mac-Mini, the .mov file on that particular 250Gb drive unit was corrupt and could not be viewed. Afterwards it was noticed that that particular drive unit would not click/lock into the KiPro deck and could be removed without using the release button. It was believed that the unit might have not been fully engaged and somehow created a corrupt file. A spare 250Gb drive unit was installed and the old drive unit was labelled faulty. No further KiPro issues occurred.

7.2.6.2.4 HD Video Overlay

The new modified HYBIS video overlay worked well during DY108 with no freezing or crashes.

7.2.6.3. **Football Floats**

The football floats were not required for the majority of the cruise and were only used when the sampling module was attached to HyBIS during dive HY50.

It should be noted that when deploying HyBIS using the hydra-boom, there is not sufficient height above the Evergrip termination to attach floats prior to deployment.

Suggestions/Recommendations

- Modify HyBIS deployment procedure to describe the number of floats and their positions when deploying HyBIS with the Hydra-boom on the RRS Discovery.

7.2.6.4. **Sonardyne Beacon**

One of the ROV Sonardyne WMT beacons (2709) was used for each HyBIS deployment on DY108. Generally, the beacon tracked well apart from just one dive (HY54) where connection was intermittent and there was larger than normal error in the vehicle position. It was noted that the ship was also struggling to hold position due to the weather during the dive, so the problems with tracking were put down to the environmental conditions at that time.

The beacon was removed from the vehicle after each dive and connected to the charger and HyBIS laptop in preparation for the next dive.

7.2.7. HyBIS specific operations

7.2.7.1. **Marker Buoy Recoveries - Dives HY52 & HY53**

Several marker buoys were placed on the seabed during a previous visit to the Darwin Mounds. It was believed that two of the markers might interfere with the operation of the AUV during DY108 and after a visual inspection of one of the markers during HyBIS dive HY51 it was decided to try and recover them.

HyBIS was rigged for the recovery by attaching a strop to the central aluminium channel of the video module. An aluminium pole was also attached to the channel, which protruded approximately 1.5m out the front of the vehicle. A master link and snap hook were attached to the end of the strop which was then run along the length of the pole and secured in place with cable-ties (See Fig. 7.30).

During both dives, the position of the markers was located with the Tritech Super Sea-King scanning sonar, and the ship was manoeuvred towards that position. The Active Heave Compensation (AHC) was turned on during the HyBIS descent and this helped enormously with the stability of the vehicle during the marker buoy recoveries. When visual contact was made with the markers, HyBIS was manoeuvred so that the snap hook caught around the rope, just below the marker buoy. The winch driver then hauled on the deep tow, to take the weight of the buoy on the hook so that it detached itself from the aluminium pole and swung underneath the HyBIS vehicle.

As HyBIS was recovered to deck, the weight of the marker buoy was taken by the rex-roth winch, so that HyBIS could be detached from the package and landed on deck. The marker buoy was then also recovered to deck.

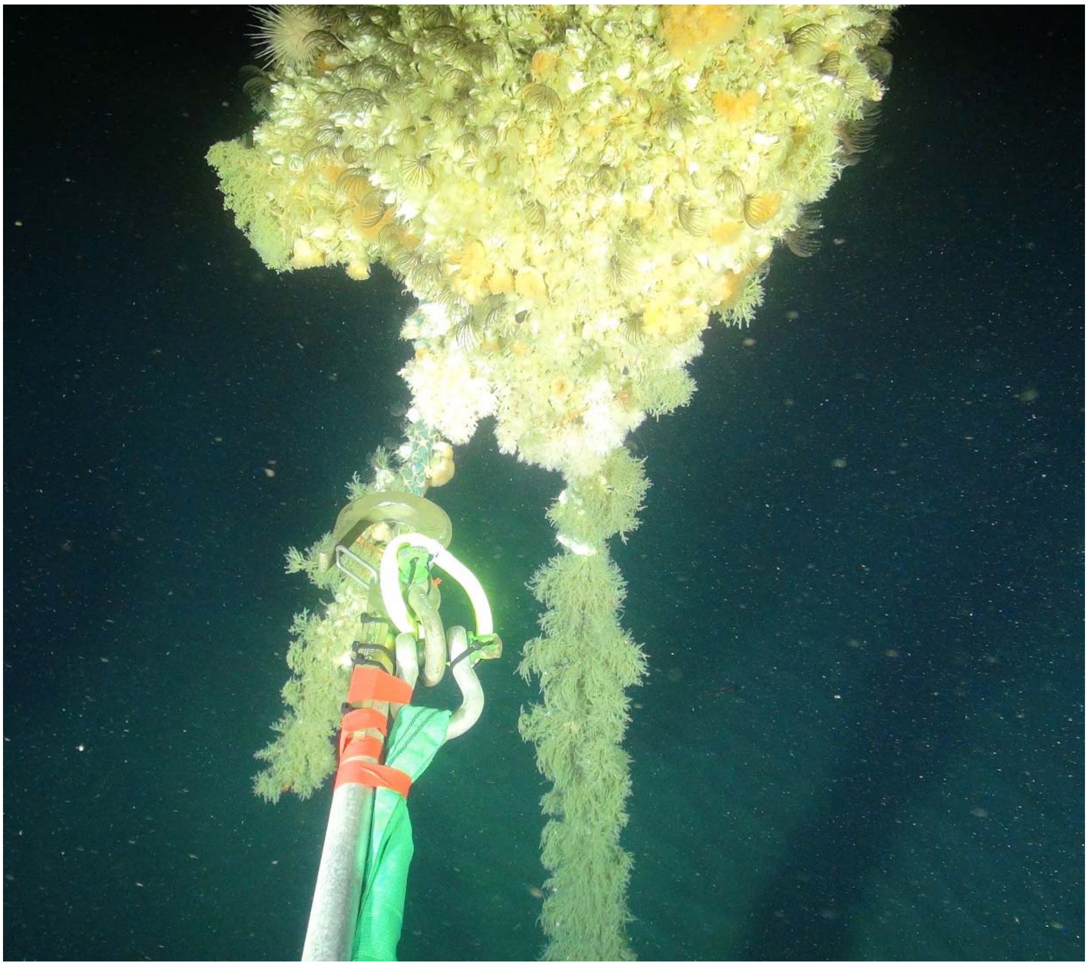


Fig. 7.30 - Photo showing marker buoy and snap hook arrangement.

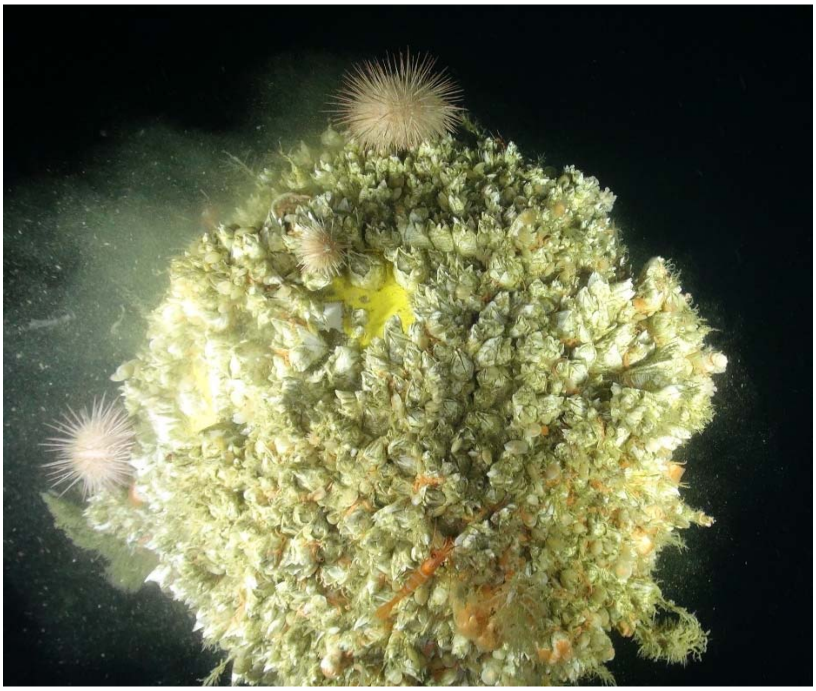


Fig. 7.31 - Photo showing ecology attached to glass sphere.

7.2.7.2. **Lander Inspection - Dive HY62**

Dive HY62 was the last HyBIS dive of DY108 and was the video inspection of a lander that had been released and could still be ranged, but had not come to the surface.

The ship was positioned close to the estimated position of the lander and HyBIS was lowered to the seabed. A target was observed straight away using the Tritech forward scanning sonar and was within a range of 50m. The ship was then manoeuvred towards the target until it came into view on the video display.

The lander appeared to be covered with silt and the ADCP had been ripped off and lay close by, still attached to the power cable (Figs. 7.32 & 7.33).

Fig. 7.32 - Photo showing silt covered lander with detached ADCP.

Fig. 7.33 - Photo showing close up of detached ADCP.

It was not possible to make a recovery attempt with the video inspection set-up of HyBIS and it was discussed whether HyBIS should be recovered and re-deployed with the sample module and manipulator arm, but there was not enough time left in the schedule to attempt it. The video did however provide good information on the state of the lander and the fact that it was probably damaged by a passing trawl.

7.2.7.3. **HyBIS Dive Hr Summary**

Dive 1 09/09/2019

Station 02	HY50	GMT	Difference between times			
	In Water	13:30:00	Hr			
	Seabed	13:58:00	Hr	00:28:00	In Water Time	00:52:00
	Off Seabed	13:59:00	Hr	00:01:00	On Bottom Time	00:01:00
	On Surface	14:22:00	Hr	00:23:00		

Dive aborted at 350m due to power fault

Dive 2 11/09/2019

Station 10	HY51	GMT	Difference between times			
	In Water	19:10:00	Hr			
	Seabed	19:59:00	Hr	00:49:00	In Water Time	07:40:00
	Off Seabed	02:07:00	Hr	06:08:00	On Bottom Time	06:08:00
	On Surface	02:50:00	Hr	00:43:00		

Dive 3	12/09/2019					
Station 15	HY52	GMT	Difference between times			
	In Water	17:32:00	Hr			
	Seabed	18:01:00	Hr	00:29:00	In Water Time	01:55:00
	Off Seabed	18:40:00	Hr	00:39:00	On Bottom Time	00:39:00
	On Surface	19:27:00	Hr	00:47:00		

Dive 4	12/09/2019					
Station 16	HY53	GMT	Difference between times			
	In Water	21:22:00	Hr			
	Seabed	21:58:00	Hr	00:36:00	In Water Time	02:04:00
	Off Seabed	22:38:00	Hr	00:40:00	On Bottom Time	00:40:00
	On Surface	23:26:00	Hr	00:48:00		

Dive 5	16/09/2019					
Station 22	HY54	GMT	Difference between times			
	In Water	16:50:00	Hr			
	Seabed	17:49:00	Hr	00:59:00	In Water Time	10:04:00
	Off Seabed	02:20:00	Hr	08:31:00	On Bottom Time	08:31:00
	On Surface	02:54:00	Hr	00:34:00		

Dive 6	17/09/2019					
Station 27	HY55	GMT	Difference between times			
	In Water	16:28:00	Hr			
	Seabed	17:06:00	Hr	00:38:00	In Water Time	10:35:00
	Off Seabed	02:34:00	Hr	09:28:00	On Bottom Time	09:28:00
	On Surface	03:03:00	Hr	00:29:00		

Dive 7	18/09/2019					
Station 33	HY56	GMT	Difference between times			
	In Water	16:18:00	Hr			
	Seabed	16:53:00	Hr	00:35:00	In Water Time	10:46:00
	Off Seabed	02:32:00	Hr	09:39:00	On Bottom Time	09:39:00
	On Surface	03:04:00	Hr	00:32:00		

Dive 8	19/09/2019					
Station 37	HY57	GMT	Difference between times			
	In Water	16:25:00	Hr			
	Seabed	16:56:00	Hr	00:31:00	In Water Time	10:22:00
	Off Seabed	02:19:00	Hr	09:23:00	On Bottom Time	09:23:00
	On Surface	02:47:00	Hr	00:28:00		

Dive 9 20/09/2019

Station 43	HY58	GMT	Difference between times			
	In Water	17:58:00	Hr			
	Seabed	18:32:00	Hr	00:34:00	In Water Time	08:52:00
	Off Seabed	02:23:00	Hr	07:51:00	On Bottom Time	07:51:00
	On Surface	02:50:00	Hr	00:27:00		

Dive 10 22/09/2019

Station 46	HY59	GMT	Difference between times			
	In Water	16:58:00	Hr			
	Seabed	17:31:00	Hr	00:33:00	In Water Time	09:20:00
	Off Seabed	01:48:00	Hr	08:17:00	On Bottom Time	08:17:00
	On Surface	02:18:00	Hr	00:30:00		

Dive 11 23/09/2019

Station 52	HY60	GMT	Difference between times			
	In Water	17:16:00	Hr			
	Seabed	17:49:00	Hr	00:33:00	In Water Time	09:20:00
	Off Seabed	02:06:00	Hr	08:17:00	On Bottom Time	08:17:00
	On Surface	02:36:00	Hr	00:30:00		

Dive 12 24/09/2019

Station 55	HY61	GMT	Difference between times			
	In Water	19:32:00	Hr			
	Seabed	20:06:00	Hr	00:34:00	In Water Time	07:08:00
	Off Seabed	02:15:00	Hr	06:09:00	On Bottom Time	06:09:00
	On Surface	02:40:00	Hr	00:25:00		

Dive 13 24/09/2019

Station 57	HY62	GMT	Difference between times			
	In Water	13:56:00	Hr			
	Seabed	14:28:00	Hr	00:32:00	In Water Time	01:48:00
	Off Seabed	15:15:00	Hr	00:47:00	On Bottom Time	00:47:00
	On Surface	15:44:00	Hr	00:29:00		

Total Water Time (Days}	3.781944444
Total Bottom Time (Days)	3.159722222
Total Water Time (Hrs)	90:46:00
Total Bottom Time (Hrs)	75:50:00

7.2.8. HyBIS Media Data

		Scorpio Video	Pal Video	Stills:	Files	Data
HY50		0.0	0.0		0	0.0
HY51		387.0	365.2		2156	8.4
HY52		77.2	72.9		237	0.8
HY53		90.7	85.1		258	0.8
HY54		462.0	437.0		2980	10.7
HY55		527.7	495.7		3382	13.0
HY56		441.5	366.6		3445	13.7
HY57		517.3	483.4		3352	12.1
HY58		438.1	398.2		2805	12.5
HY59		460.5	422.2		2967	10.9
HY60		457.1	422.3		2783	10.7
HY61		348.1	319.8		2200	7.7
HY62		66.3	61.4		280	0.9
	GB	4273.5	3929.8		26845	102.2
	TB	4.17	3.84			0.10

Total storage used (GB)	8305.480
Total storage used (TB)	8.111

7.3. Coring

Operational Team: Richard Phipps, with help from Brian Bett

7.3.1. Boxcorer

The corer used (Fig. 7.34) was a NOC NMF supplied stainless steel United States Naval Electronics Laboratory (USNEL) Mk 2-type spade box corer, having a nominal 50 × 50 cm (0.25 m^2) seabed sampling aperture (see e.g. Gage & Bett, 2005; Narayanaswamy et al., 2016). The corer was rigged and operated in conventional fashion, with the penetration limiting stops having been removed prior to the first deployment. Note that to maximise sampling performance, the core box was specifically ground to a fine profile match with the spade sealing surface, and the supernatant draining mechanism and opening side of the box were sealed closed during pre-cruise preparation. The corer was operated in conjunction with a Sonardyne Wideband Sub-Mini 6 Plus USBL transponder that was clamped to the coring warp 50 m above the corer. Typically, the corer was lowered to c. 50 m above the seabed at a maximum of 0.8 ms^{-1}, if required the ship was then repositioned in an attempt to move the corer closer to the intended seafloor target point, the final pay out speed was 0.5 ms^{-1}, with a c. 5 m wire over-run on bottom contact, and immediate hauling at 0.3 ms^{-1}, and subsequent recovery at maximum 0.8 ms^{-1}. Pull-out tension typically reflected seabed habitat type: mounds averaged 1.5 T (1.4-1.9 T), tails averaged 2.9 T (1.6-4.5 T). See separate account of samples retained.

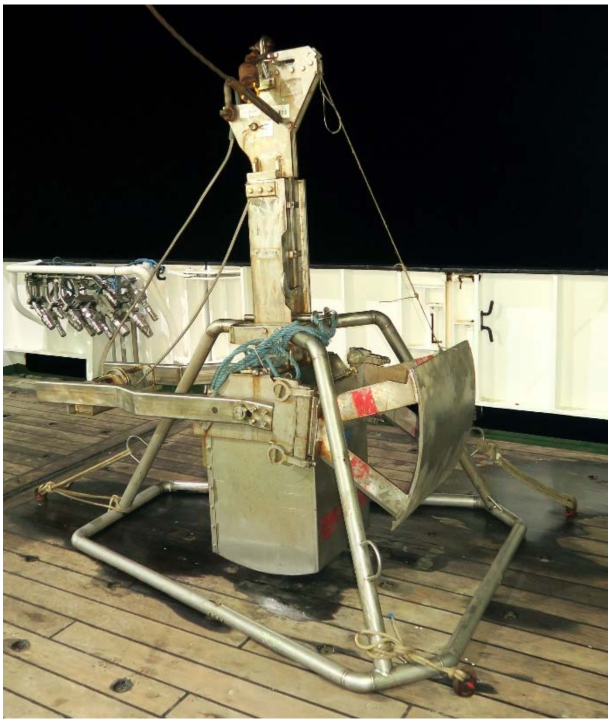


Fig. 7.34 Boxcorer on deck

7.3.2. Megacorer

The corer used (Fig. 7.35) was a NOC NMF supplied Bowers & Connelly Megacorer (see e.g. Gage & Bett, 2005) with extended protective frame and three additional layers of ballast lead sheet. In all cases during the present cruise the corer was rigged in MgC02+2 format (2 × 10 cm ID coring units, and 2 × 59 mm ID coring units) and deployed in conventional fashion. The corer was operated in conjunction with a Sonardyne Wideband Sub-Mini 6 Plus USBL transponder that was clamped to the coring warp 50 m above the corer. Typically, the corer was lower to c. 50 m above the seabed at a maximum of 0.8 ms^{-1}, if required the ship was then repositioned in an attempt to move the corer closer to the intended seafloor target point, the final pay out speed was 0.4 ms^{-1}, with a c. 5 m wire over-run on bottom contact, a 1-minute wait period, then hauling at 0.3 ms^{-1}, and subsequent recovery at maximum 0.8 ms^{-1}. The corer was deployed on five occasions, each on a mound target. No sediment samples were recovered. Coral fragments were retained dry from deployment DY108-040; coral fragments were retained dry from deployments DY108-050 & 051 from the same mound target; and a polychaete and an amphipod were also retained from deployment DY108-051, and preserved in ethanol.

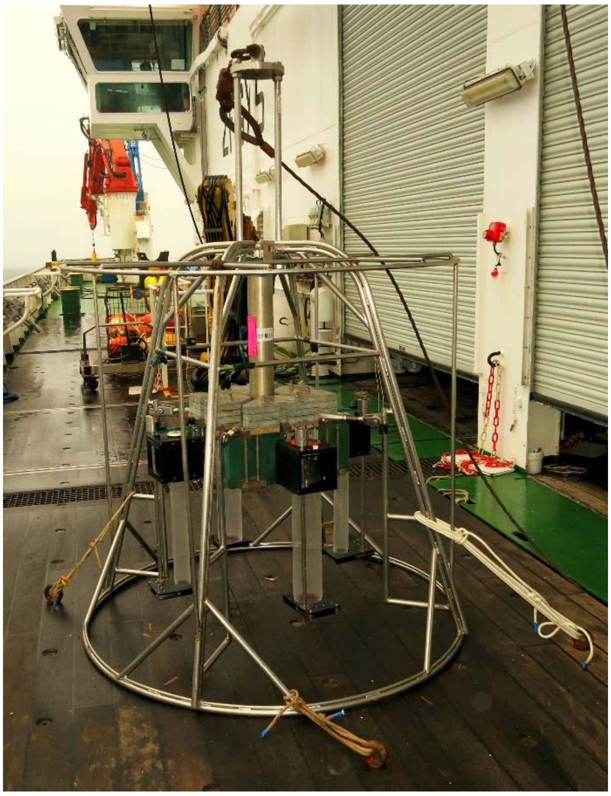


Fig. 7.35 Megacorer on deck

7.4. CTD

Operational Team: Jeff Benson, Billy Platt

7.4.1. CTD system configurations

1) One CTD system was prepared. The water sampling arrangement was a 24-way stainless steel frame system (s/n SBE CTD6), and the initial sensor configuration was as follows:

Sea-Bird 9plus underwater unit, s/n 09P-77801-1182
Sea-Bird 3P temperature sensor, s/n 03P-4814, Frequency 1 (primary)
Sea-Bird 4C conductivity sensor, s/n 04C-2165, Frequency 2 (primary)
Digiquartz temperature compensated pressure sensor, s/n 129735 Frequency 3
Sea-Bird 3P temperature sensor, s/n 03P-4816, Frequency 4 (secondary)
Sea-Bird 4C conductivity sensor, s/n 04C-3258, Frequency 5 (secondary)
Sea-Bird 5T submersible pump, s/n 05T-3086, (primary)
Sea-Bird 5T submersible pump, s/n 05T-3090, (secondary)
Sea-Bird 32 Carousel 24 position pylon, s/n 32-60380-0805
Sea-Bird 11plus deck unit, s/n 11P-24680-0589 (main)
Sea-Bird 11plus deck unit, s/n 11P-34173-0676 (back-up logging)

2) The auxiliary input initial sensor configuration was as follows:

Sea-Bird 43 dissolved oxygen sensor, s/n 43-1882 (V0) (primary)
Sea-Bird 43 dissolved oxygen sensor, s/n 43-2818 (V1) (secondary)
Chelsea Aquatracka MKIII fluorometer, s/n 88-2615-126 (V2)
Benthos PSA-916T altimeter, s/n 62679 (V3)
Biospherical QCP-2350-HP DWIRR PAR sensor, s/n 70510 (V4)
Biospherical QCP-2350-HP UWIRR PAR sensor, s/n 70520 (V5)
WETLabs BBRTD light scattering sensor, s/n BBRTD-5466 (V6)
WETLabs C-Star 25cm path transmissometer, s/n CST-1654DR (V7)

3) Other sensors & instruments:

TRDI Workhorse Monitor 300kHz Downward-looking LADCP, s/n 1855
TRDI Workhorse Monitor 300kHz Downward-looking LADCP, s/n 4275
NOCS Workhorse LADCP battery pack pressure case, s/n WH007
OTE 10L water samplers, s/n's 1B through 24B
MDS titanium CTD swivel, s/n 1246-1

4) Sea-Bird 9*plus* configuration file DY108_1182_SS.xmlcon was used for the stainless steel frame CTD casts 001 – 003. Sea-Bird 9*plus* configuration file DY108_1182_1940_SS.xmlcon was used for the stainless steel frame CTD casts 004 – 048.

5) The spare water sampling arrangement was a 24-way stainless steel frame system (s/n SBE CTD1). The spare sensors were as follows:

Sea-Bird 9plus underwater unit, s/n 09P-54047-0943
Sea-Bird 3P temperature sensor, s/n 03P-4381, 03P-4383 and 03P-4593
Sea-Bird 4C conductivity sensor, s/n 04C-2450, 04C-2571 and 04C-2580
Digiquartz temperature compensated pressure sensor, s/n 110557

Sea-Bird 5T submersible pump, s/n 05T-6320, 05T-6916 and 05T-7515
Sea-Bird 32 Carousel 24 position pylon, s/n 32-34173-0493

6) The spare auxiliary input initial sensor configuration was as follows:

Sea-Bird 43 dissolved oxygen sensor, s/n 43-1940
Chelsea Aquatracka MKIII fluorometer, s/n 88-2050-095 and 88-2960-163
Benthos PSA-916T altimeter, s/n 59494
WETLabs BBRTD light scattering sensor, s/n BBRTD-759R and BBRTD-1055
WETLabs C-Star 25cm path transmissometer, s/n CST-1718TR and CST-1837TR

7) Spare sensors & instruments:

TRDI Workhorse Monitor 300kHz LADCP, s/n 12369, 13329, 15288 and 23444
NOCS Workhorse LADCP battery pack pressure case, s/n WH006T and WH008T
OTE 10L water samplers, s/n's 1A through 24A
MDS titanium CTD swivel, s/n 1253-2

Changes to instrument suite: 43-1940 replaced 43-1882 for casts 004-048. PAR sensor s/n 70520 removed from frame for casts 005-006 to test BioCam USBL modem. LADCP battery pack s/n WH006T replaced s/n WH007 for the second series of 24 hour CTD yo-yo's, as the original battery pack required more than 3 hours of re-charging.

Total number of casts - 48
Casts deeper than 2000m - 0
Deepest cast - 1785m

7.4.2. Technical detail report

7.4.2.1. S/S CTD on CTD1 with titanium CTD swivel

CTD wire 1 was inspected before the start of DY107 and re-terminated at the sea cable end. The sea cable end was terminated with the normal S&M CTD termination; it was load tested by following the standard procedure of being pulled at 0.5T, 1.0T, 1.5T and 2.0T. The termination assembly was held for 5 minutes at each and re-torqued between each. It had a 'megger' value of >1000 MOhms and internal resistance of 70.1 Ohms post-cruise. The termination was tested at the start of DY108 and it had a 'megger' value of >1000 MOhms and internal resistance of 69.7 Ohms. This remained for the duration of the cruise.

Casts 001 was a cast to 1600m to check termination electrical integrity, test other instruments (acoustic releases and USBL beacons), to obtain water for the sediment trap mooring, and to check sensor performance. At the beginning of the down cast the primary oxygen sensor exhibited noise and drift, along with erratic readings, compared to the secondary oxygen, and was subsequently checked on deck post-deployment and flushing. The readings were not similar enough to confirm the sensor was functioning properly. The primary oxygen sensor was left in place for casts 002 & 003 (mini-yoyo), and exhibited identical problems. Prior to cast 004 the cable was replaced for deck tests, and no change was observed. Thus s/n 43-1882 was then replaced with s/n 43-1940.

Deployments 005 to 006 did not have the Biospherical UWIRR sensor, as it was removed to test the BioCam USBL modem. (The power supply provided for the USBL was not sufficiently depth rated to test the modem to greater than 1000m.) The Sea-Bird 9P underwater unit was used to supply +9 to +28V required for the modem.

During cast 020 the altimeter began to display signs of intermittent cable failure, as the height off bottom was fixed at approximately 9m on the downcast, until a range of 7 to 8m was actually reached. As this was during the first 24 hour BLT CTD yo-yo series, the bottom was well known from previous deployments, and reaching the target range of less than 10m off the bottom was attainable. The altimeter cable was replaced at the end of the first series of yo-yo deployments, cast 026, and began to read correctly until cast 032, when the same symptoms reappeared.

The secondary conductivity sensor started to give “noisy” readings at 1350m depth during the downcast on 027, and continued through cast 034. As the measurements were consistent with the overall trend of the primary sensor, the cause of the “noise” was suspected to be biofouling.

During deployment 034 the CTD frame made contact with the bottom. (A separate report provides these details.) After recovery to deck, prior to cast 035, the altimeter cable was replaced, and the secondary conductivity sensor cleaned and flushed. These remedies worked until cast 041, when the secondary conductivity again became “noisy”. The altimeter also resumed not working correctly at a range of 10m from the bottom. The BBRTD showed “spikes” from 300m through the thermocline, during upcasts, from deployment 042.

Only one titanium CTD swivel was used with the CTD frame, and it was refurbished MDS titanium CTD swivel s/n 1246-1; no problems or oil leaks observed.

7.4.2.2. **LADCP**

Two different pairs of command files were used during the cruise; one provided by RSMAS for the single deployments, and the other provided by BAS for the 24 hour yo-yo deployments. An explanation of the BAS command file set is attached in Appendix B.

Deployment of the Slave instrument on DY108_006s resulted in 4 separate files. The first file, DY108_006s, stopped recording approximately 20 minutes before the Master file of DY108_006m. The next three Slave files all stopped and started sequentially, and were named DY108_006a_s, DY108_006b_s and DY108_006c_s. None of these three files appear to have any meaningful data.

At the finish of the first 24 hour CTD yo-yo series, the Slave LADCP recorded for only a few minutes. The command files were checked again for any errors or missing characters prior to re-deployment for the second 24 hour yo-yo. Both instruments worked correctly for the entire second series, which indicates a possible intermittent connection within the LADCP Star cable on the CTD frame as the cause of the non-recording of data to the Slave instrument.

7.4.2.3. **AUTOSAL**

A Guildline 8400B, s/n 65764, was installed in the Salinometer Room as the main instrument for salinity analysis. The Autosal set point was 21C, and samples were processed according to WOCE cruise guidelines: The salinometer was standardized at the beginning of the first set of samples, and checked

with an additional standard analysed prior to setting the RS. Once standardized the Autosal was not adjusted for the duration of sampling.
A standard was analysed after each crate of samples to monitor & record drift (second standard analysed after sample 24, third standard analysed after sample 48, etc).
Standards were labeled sequentially and increasing, beginning with number 9000. Standard deviation set to 0.00002. 2.5 crates of salinity samples were analysed, with 7 bottles of standard used to monitor the instrument drift. The electronic standby value after the standardisation was stable at 6132 to 6136 for the duration of the cruise.The spare salinometer, s/n 68426, was not used.

7.4.3. Configuration files

Stainless CTD frame:

Casts 001 – 003
Date: 09/06/2019
Instrument configuration file: C:\Users\sandm\Documents\Cruises\DY108_109\Seasave Setup Files\DY108_1182_SS.xmlcon
Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus Firmware Version < 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : PC
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature
Serial number : 03P-4814
Calibrated on : 14 June 2018
G : 4.30111327e-003
H : 6.24737110e-004
I : 1.86297758e-005
J : 1.29851757e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity
Serial number : 04C-2165
Calibrated on : 23 August 2017
G : -9.76338109e+000
H : 1.34212964e+000
I : -2.03325982e-003
J : 2.01310127e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC
Serial number : 129735
Calibrated on : 3 November 2017
C1 : -6.064446e+004
C2 : 6.966022e-002
C3 : 1.971200e-002
D1 : 2.882500e-002
D2 : 0.000000e+000
T1 : 3.029594e+001
T2 : -6.713680e-005
T3 : 4.165390e-006
T4 : 0.000000e+000
T5 : 0.000000e+000
Slope : 0.99982000
Offset : -1.48930
AD590M : 1.279180e-002
AD590B : -8.821250e+000

4) Frequency 3, Temperature, 2
Serial number : 03P-4816
Calibrated on : 23 August 2017
G : 4.30497192e-003
H : 6.34223731e-004
I : 2.17264599e-005
J : 2.02839765e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2
Serial number : 04C-3258
Calibrated on : 25 August 2017
G : -1.06581670e+001
H : 1.36071859e+000
I : 1.30128231e-004
J : 6.09502147e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43
Serial number : 43-1882
Calibrated on : 21 July 2018
Equation : Sea-Bird
Soc : 4.84100e-001
Offset : -4.91000e-001
A : -4.34740e-003
B : 2.09570e-004
C : -3.16150e-060
E : 3.60000e-002
Tau20 : 1.23000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Oxygen, SBE 43, 2
Serial number : 43-2818
Calibrated on : 24 August 2017
Equation : Sea-Bird
Soc : 4.65400e-001
Offset : -4.98300e-001
A : -4.41050e-003
B : 2.34710e-004
C : -3.56300e-006
E : 3.60000e-002
Tau20 : 1.38000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

8) A/D voltage 2, Fluorometer, Chelsea Aqua 3
Serial number : 88-2615-126
Calibrated on : 16 August 2018
VB : 0.593340
V1 : 2.105980
Vacetone : 0.756140
Scale factor : 1.000000
Slope : 1.000000
Offset : 0.000000

9) A/D voltage 3, Altimeter
Serial number : 62679
Calibrated on : 14 Janusry 2014
Scale factor : 15.000
Offset : 0.000

10) A/D voltage 4, PAR/Irradiance, Biospherical/Licor
Serial number : 70510
Calibrated on : 27 June 2019
M : 1.00000000
B : 0.00000000
Calibration constant : 20300000000.00000000
Multiplier : 1.00000000
Offset : -0.05009162

11) A/D voltage 5, PAR/Irradiance, Biospherical/Licor, 2
Serial number : 70520
Calibrated on : 27 June 2019
M : 1.00000000
B : 0.00000000
Calibration constant : 19900000000.00000000
Multiplier : 1.00000000
Offset : -0.05148773

12) A/D voltage 6, Transmissometer, WET Labs C-Star
Serial number : CST-1654DR
Calibrated on : 7 April 2017
M : 21.1627
B : -0.1550

Path length : 0.250

13) A/D voltage 7, OBS, WET Labs, ECO-BB
Serial number : BBRTD-5466
Calibrated on : 4 February 2019
ScaleFactor : 0.003307
Dark output : 0.051000

Scan length : 41

Casts 004 – 048
Date: 09/10/2019
Instrument configuration file: C:\Users\sandm\Documents\Cruises\DY108_109\Seasave Setup Files\DY108_1182_1940.xmlcon

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus Firmware Version < 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : PC
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature
Serial number : 03P-4814
Calibrated on : 14 June 2018
G : 4.30111327e-003
H : 6.24737110e-004
I : 1.86297758e-005
J : 1.29851757e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity
Serial number : 04C-2165
Calibrated on : 23 August 2017
G : -9.76338109e+000
H : 1.34212964e+000
I : -2.03325982e-003
J : 2.01310127e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC
Serial number : 129735
Calibrated on : 3 November 2017
C1 : -6.064446e+004
C2 : 6.966022e-002

C3 : 1.971200e-002
D1 : 2.882500e-002
D2 : 0.000000e+000
T1 : 3.029594e+001
T2 : -6.713680e-005
T3 : 4.165390e-006
T4 : 0.000000e+000
T5 : 0.000000e+000
Slope : 0.99982000
Offset : -1.48930
AD590M : 1.279180e-002
AD590B : -8.821250e+000

4) Frequency 3, Temperature, 2
Serial number : 03P-4816
Calibrated on : 23 August 2017
G : 4.30497192e-003
H : 6.34223731e-004
I : 2.17264599e-005
J : 2.02839765e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2
Serial number : 04C-3258
Calibrated on : 25 August 2017
G : -1.06581670e+001
H : 1.36071859e+000
I : 1.30128231e-004
J : 6.09502147e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43
Serial number : 43-1940
Calibrated on : 21 July 2018
Equation : Sea-Bird
Soc : 5.30300e-001
Offset : -4.97000e-001
A : -3.46500e-003
B : 1.95130e-004
C : -3.33540e-006
E : 3.60000e-002
Tau20 : 1.33000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Oxygen, SBE 43, 2
Serial number : 43-2818
Calibrated on : 24 August 2017
Equation : Sea-Bird

Soc : 4.65400e-001
Offset : -4.98300e-001
A : -4.41050e-003
B : 2.34710e-004
C : -3.56300e-006
E : 3.60000e-002
Tau20 : 1.38000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

8) A/D voltage 2, Fluorometer, Chelsea Aqua 3
Serial number : 88-2615-126
Calibrated on : 16 August 2018
VB : 0.593340
V1 : 2.105980
Vacetone : 0.756140
Scale factor : 1.000000
Slope : 1.000000
Offset : 0.000000

9) A/D voltage 3, Altimeter
Serial number : 62679
Calibrated on : 14 Janusry 2014
Scale factor : 15.000
Offset : 0.000

10) A/D voltage 4, PAR/Irradiance, Biospherical/Licor
Serial number : 70510
Calibrated on : 27 June 2019
M : 1.00000000
B : 0.00000000
Calibration constant : 20300000000.00000000
Multiplier : 1.00000000
Offset : -0.05009162

11) A/D voltage 5, PAR/Irradiance, Biospherical/Licor, 2
Serial number : 70520
Calibrated on : 27 June 2019
M : 1.00000000
B : 0.00000000
Calibration constant : 19900000000.00000000
Multiplier : 1.00000000
Offset : -0.05148773

12) A/D voltage 6, Transmissometer, WET Labs C-Star
Serial number : CST-1654DR
Calibrated on : 7 April 2017
M : 21.1627
B : -0.1550
Path length : 0.250

13) A/D voltage 7, OBS, WET Labs, ECO-BB
Serial number : BBRTD-5466
Calibrated on : 4 February 2019

ScaleFactor : 0.003307
Dark output : 0.051000
Scan length : 41

LADCP script files:

Casts 001 – 006 (RSMAS)

Master:

```
WV250          ; ambiguity velocity [cm/s]
WN25           ; number of depth cells; NBP0402
WS1000         ; bin size [cm]; NBP0402: WS1000
WF0            ; blank after transmit [cm]; NBP0402
WB1            ; narrow bandwidth mode
EZ0011101      ; Sensor source: (NBP0402: EZ0111111)
EX00100        ; coordinate transformation: (NBP0402: 11111)
WP1            ; single-ping ensembles; NBP0402: WP3 most of the time
TP 00:00.90    ; time between pings; NBP0402
TE 00:00:01.50 ; time per ensemble
CF11101        ; Flow control:
SM1            ; set to master
SA011          ; send pulse before ensemble
SW5500         ; master waits .5500 s after sending sync pulse
RNmast_
CK             ; keep params as user defaults (across power failures)
W?
T?
CS
```

Slave:

```
WV250          ; ambiguity velocity [cm/s]
WN25           ; number of depth cells; NBP0402
WS1000         ; bin size [cm]; NBP0402: WS1000
WF800          ; blank after transmit [cm]; NBP0402
WB1            ; narrow bandwidth mode
EZ0011101      ; Sensor source: (NBP0402: EZ0111111)
EX00100        ; coordinate transformation: (NBP0402: 11111)
WP1            ; single-ping ensembles; NBP0402: WP3 most of the time
TP 00:00.00    ; time between pings; NBP0402
TE 00:00:01.50 ; time per ensemble
CF11101        ; Flow control:
SM2            ; set to slave
SA011          ; waits for pulse before ensemble
ST120          ; waits 120s for ma-signal before running single^M
RNslav_
CK             ; keep params as user defaults (across power failures)
W?
T?
CS
```

Casts 007 – 048 (CTD yo-yo series) BAS

Master:
CR1
RN DY108
WM15
TC2
LP1
TB 00:00:02.80
TE 00:00:01.30
TP 00:00.00
LN25
LS0800
LF0
LW1
LV400
SM1
SA011
SB0
SW5500
SI0
EZ0011101
EX00100
CF11101
CK
CS

Slave:
CR1
RN DY108
WM15
LP1
TP 00:00.00
TE 00:00:00.00
LN25
LS0800
LF0
WB1
LW1
LV400
SM2
SA011
SB0
EZ0011101
EX00100
CF11101
CK
CS
$I

7.4.4. SENSOR INFORMATION

7.4.4.1. CTD

SHIP: RRS DISCOVERY	CRUISE: DY108/109

FORWARDING INSTRUCTIONS / ADDITIONAL INFORMATION:
Stainless steel 24-way CTD frame

Checked By: J. Benson	DATE: 6th September 2019

Instrument / Sensor	Manufacturer/ Model	Serial Number	Channel	Casts Used
Primary CTD deck unit	SBE 11plus	11P-24680-0589	n/a	All casts
CTD Underwater Unit	SBE 9plus	09P-77801-1182	n/a	All stainless casts
Stainless steel 24-way frame	NOCS	SBE CTD 6	n/a	All stainless casts
Primary Temperature Sensor	SBE 3P	03P-4814	F0	All stainless casts
Primary Conductivity Sensor	SBE 4C	04C-2165	F1	All stainless casts
Digiquartz Pressure sensor	Paroscientific	129735	F2	All stainless casts
Secondary Temperature Sensor	SBE 3P	03P-4816	F3	All stainless casts
Secondary Conductivity Sensor	SBE 4C	04C-3258	F4	All stainless casts
Primary Pump	SBE 5T	05T-3086	n/a	All stainless casts
Secondary Pump	SBE 5T	05T-3090	n/a	All stainless casts
24-way Carousel	SBE 32	32-60380-0805	n/a	All stainless casts
Primary Dissolved Oxygen Sensor	SBE 43	43-1882	V0	Casts 001-003
Primary Dissolved Oxygen Sensor	SBE 43	43-1940	V0	Casts 004-048
Secondary Dissolved Oxygen Sensor	SBE 43	43-2818	V1	All stainless casts
Fluorimeter	CTG Aquatracka III	88-2615-126	V2	All stainless casts
Altimeter	Benthos PSA-916T	62679	V3	All stainless casts
DWIRR PAR	Biospherical QCP-2350-HP	70510	V4	All stainless casts

IWIRR PAR	Biospherical QCP-2350-HP	70520	V5	All stainless casts except 005-006
Backscatter	WETLabs BBRTD	BBRTD-5466	V6	All stainless casts
Transmissometer	WETLabs C-Star	CST-1654DR	V7	All stainless casts
Downward-looking 300kHz Monitor LADCP	TRDI	1855	n/a	All stainless casts
Upward-looking 300kHz Monitor LADCP	TRDI	4275	n/a	All stainless casts
LADCP battery pack	NOCS	WH007	n/a	Casts 001-026
LADCP battery pack	NOCS	WH007 6T	n/a	Casts 027-048
10L Water Samplers	Ocean Test Equipment	1B-24B	n/a	All stainless casts

7.4.4.2. **Lowered Acoustic Doppler Current Profiler (LADCP) –** ***Instrument and Configuration***

For all CTD casts, two RDI 300kHz Workhorse LADCP units were fitted to the CTD frame one in a downward-looking orientation the other upward-looking. Each LADCP was configured to have 25 x 8 m bins, a 0 m blank-to-surface, one ping per ensemble, and two ensembles per burst in narrowband mode. Data were collected in beam coordinates.

Parameter Description:

WM15 water mode 15 (LADCP)
TC2 ensembles per burst
LP1 pings per ensemble
TB 00:00:02.80 time per burst
TE 00:00:01.30 time per ensemble
TP 00:00.00 time between pings
LN25 number of depth cells
LS0800 bin size [cm]
LF0 blank after transmit [cm]
LW1 narrow bandwidth LADCP mode
LV400 ambiguity velocity [cm/s]
SB0 disable hardware-break detection on Channel B (ICN118)
EZ0011101 Sensor source: - manual speed of sound (EC)- manual depth of transducer (ED = 0 [dm]) - measured heading (EH) - measured pitch (EP) - measured roll (ER) - manual salinity (ES = 35 [psu]) - measured temperature (ET)
EX00100 Coordinate transformation: - radial beam coordinates (2 bits) - use pitch/roll (not used for beam coords?) - no 3-beam solutions – no bin mapping
CF11101 Flow control: - automatic ensemble cycling (next ens when ready) -automatic ping cycling (ping when ready) - binary data output- disable serial output - enable data recorder

7.5. Mooring

Operational Team: Billy Platt

The mooring, as described in section 6.6.4 was deployed over the aft end of the Discovery by hand and is as per the mooring diagram in Fig. 6.84. After triangulation the final position of the mooring was confirmed to be 59 deg 51.672 N, 007 deg 02.631 W.

Prior to deployment the Ixsea release was tested down to a depth of 1800m and worked correctly.

7.5.1. SBE37

The SBE 37's were attached to the CTD for a test dip to ensure that they were working fine. The data was checked by the science party, compared to the CTD data and deemed to be good. Both were setup for deployment using the following commands.

```
datetime=MMDDYYYYHHMMSS
outputformat=3
txrealtime=n
outputsal=y
sampleinterval=900
samplenumber=0
samplenumber=0
startdatetime=startnow
qs
```

7.5.2. ADCP 600KHz Workhorse Sentinel

Sn 23184 fitted downward looking in a 44" syntactic sphere, Sn J17041-001 along with Light Sn A08-011 and Argos Sn A02-017.

Downlooking 600 kHz ADCP

Duration: 365 days
Ensemble interval: 00:01:30
Ping interval 00:00:05
Pings per ensemble: 10
Depth cell size: 1 m (30 m range)

7.5.3. Sediment trap

Sn 12168-02
21 bottle trap programmed with the science party as described in Section 6.6.4.

7.5.4. Instrument Log

SBE 37's

ds
SBE37SM-RS232 v4.1 SERIAL NO. 12456 23 Sep 2019 07:16:30
vMain = 13.14, vLith = 2.97
samplenumber = 0, free = 559240
logging
sample interval = 900 seconds
data format = converted engineering

```
transmit real-time = no
sync mode = no
pump installed = yes, minimum conductivity frequency = 3073.6
<Executed/>

ds
SBE37SM-RS232 v4.1  SERIAL NO. 12458  23 Sep 2019 07:17:29
vMain = 13.36, vLith =  3.00
samplenumber = 0, free = 559240
not logging, stop command
sample interval = 900 seconds
data format = converted engineering
transmit real-time = no
sync mode = no
pump installed = yes, minimum conductivity frequency = 3110.7
<Executed/>
startnow
<!--start logging at = 23 Sep 2019 07:32:47, sample interval = 900 seconds-->
<Executed/>
ds
SBE37SM-RS232 v4.1  SERIAL NO. 12458  23 Sep 2019 07:17:48
vMain = 13.35, vLith =  3.00
samplenumber = 0, free = 559240
logging
sample interval = 900 seconds
data format = converted engineering
transmit real-time = no
sync mode = no
pump installed = yes, minimum conductivity frequency = 3110.7
<Executed/>
```

ADCP

```
CR1
CF11101
EA0
EB0
ED0
ES35
EX11111
EZ1111101
WA50
WB0
WD111100000
WF88
WN29
WP10
WS100
WV175
```

TE00:01:30.00
TP00:09.00
TF19/09/23 07:00:00
CK
CS
;
;Instrument = Workhorse Sentinel
;Frequency = 614400
;Water Profile = YES
;Bottom Track = NO
;High Res. Modes = NO
;High Rate Pinging = NO
;Shallow Bottom Mode= NO
;Wave Gauge = NO
;Lowered ADCP = NO
;Ice Track = NO
;Surface Track = NO
;Beam angle = 20
;Temperature = 5.00
;Deployment hours = 9600.00
;Battery packs = 2
;Automatic TP = YES
;Memory size [MB] = 3900
;Saved Screen = 2
;
;Consequences generated by PlanADCP version 2.06:
;First cell range = 2.10 m
;Last cell range = 30.10 m
;Max range = 42.01 m
;Standard deviation = 2.21 cm/s
;Ensemble size = 734 bytes
;Storage required = 268.80 MB (281856000 bytes)
;Power usage = 829.88 Wh
;Battery usage = 1.8
;
; WARNINGS AND CAUTIONS:
; Advanced settings have been changed.

Sediment trap

Schedule Verification

Event 1 of 22 = 09/24/2019 12:00:00
Event 2 of 22 = 10/12/2019 12:00:00
Event 3 of 22 = 10/30/2019 12:00:00
Event 4 of 22 = 11/17/2019 12:00:00
Event 5 of 22 = 12/05/2019 12:00:00
Event 6 of 22 = 12/23/2019 12:00:00
Event 7 of 22 = 01/10/2020 12:00:00

Event 8 of 22 = 01/28/2020 12:00:00
Event 9 of 22 = 02/15/2020 12:00:00
Event 10 of 22 = 03/04/2020 12:00:00
Event 11 of 22 = 03/22/2020 12:00:00
Event 12 of 22 = 04/09/2020 12:00:00
Event 13 of 22 = 04/27/2020 12:00:00
Event 14 of 22 = 05/15/2020 12:00:00
Event 15 of 22 = 06/02/2020 12:00:00
Event 16 of 22 = 06/20/2020 12:00:00
Press any key to continue.
Event 17 of 22 = 07/08/2020 12:00:00
Event 18 of 22 = 07/26/2020 12:00:00
Event 19 of 22 = 08/13/2020 12:00:00
Event 20 of 22 = 08/31/2020 12:00:00
Event 21 of 22 = 09/18/2020 12:00:00
Event 22 of 22 = 10/06/2020 12:00:00

09/22/2019 15:31:32 18.7 Vb 18 øC aligned

7.6. Ship-fitted Systems

Operational team: Martin Bridger

7.6.1. Scientific Computer Systems

7.6.1.1. **Acquisition**

Network drives were set up on the on-board file server; firstly a read-only drive of the ship's instruments data ('current_cruise') and a second drive ('Public') for the scientific party. Both drives have been backed up on external disks, and have been provided to the co-chief scientists of the cruise. The data back-ups have also been transferred to the British Oceanographic Data Centre (BODC) who will archive the cruise data for NERC, and who will make the data available to interested scientists (following agreement by the cruise PIs).

Data was logged by the Techsas 5.11 data acquisition system. The system creates NetCDF and ASCII output data files located in the below 'TechSAS' directory. The format of the data files is given per instrument in the "Data Description" directory:

Cruise Disk Location: ***'DY108/Cruise_Documentation/Data_Description_Documents/'*** ***'DY108/Ship_Fitted_Scientific_Systems/TechSAS'***

The Ship-fitted instruments that were logged are listed in Table 7.30.

The NMF 'RVDAS' raw data logger also records raw data streams as a backup/QC option to the primary Techsas logger. These raw ASCII files are located in the below cruise directory:

Cruise Disk Location: ***'DY108/Ship_Fitted_Scientific_Systems/RVDAS'***

Data was additionally logged into the legacy RVS Level-C format.

There are ASCII dumps of all the Level-C streams included on the data disk in the directory:

Cruise Disk Location: ***'DY108/Ship_Fitted_Scientific_Systems /Level-C/Enterprise-pro_data*/ascii/'**

Table 7.30 Ship-fitted instrumentation and logging status for DY108/109

Manufacturer	Model	Function/data types	Logged? (Y/N)	Comments
Meinberg	M300	GPS network time server (NTP)	N	Not logged but feeds times to other systems
Applanix	POS MV320 V5	DGPS and attitude	Y	Secondary DGPS
C-Nav	3050	DGPS and DGNSS	Y	Primary DGPS Logged
Kongsberg Seatex	Seapath 330	DGPS and attitude	Y	No attitude logged, only position
iXSea	PHINSIII	Inertial Navigation System	N	
Sonardyne	Fusion USBL	USBL	Y	
Sperry Marine		Ship gyrocompasses x 3	Y	
Kongsberg Maritime	Simrad EA640	Single beam echo sounder (hull)	Y	
Kongsberg Maritime	Simrad EM122	Multibeam echo sounder (deep)	Y	
Kongsberg Maritime	Simrad EM710	Multibeam echo sounder (shallow)	Y	
Kongsberg Maritime	Simrad SBP120	Sub bottom profiler	Y	
Kongsberg Maritime	Simrad EK60	Scientific echo sounder (fisheries)	N	
NMFSS	CLAM	CLAM system winch log	Y	
NMFSS	Surfmet	Meteorology suite	Y	
NMFSS	Surfmet	Surface hydrography suite	Y	
		Skipper log (ship's velocity)	Y	
OceanWaveS GmbH	WaMoS II	Wave Radar	N	
Teledyne RD Instruments	Ocean Observer 75 kHz	VM-ADCP	Y	
Teledyne RD Instruments	Ocean Observer 150 kHz	VM-ADCP	Y	
Microg Lacoste	Air-Sea System II	Gravity	N	

7.6.1.1.1 Main Acquisition Period

Techsas logging for 'DY108' commenced **on 06/09/2019** whilst alongside in Southampton. RVDAS logging commenced 10:28 on 05/09/2019.

All logging was concluded upon arrival in Southampton 2nd October 2019.

7.6.1.1.2 Events/Data Losses

No known data losses occurred.

7.6.1.2. **Communications**

7.6.1.2.1 Internet provision

Satellite Communications were provided with both the Vsat and Fleet Broadband (FBB) systems. The Vsat had a guaranteed speed of 1.5 Mbps, bursts greater than this when there is space on the satellite, and unlimited data. The FBB had a maximum un-guaranteed speed of 256 kbps with a fair use policy that equates to 15 GB of data a month. There was solid service throughout, interrupted with a few mast blockages.

7.6.1.2.2 Email provision

Email communications were provided primarily through user email clients and web-browser clients.

7.6.2. Instrumentation

7.6.2.1. **Marine Mammal Protection**

All acoustic instruments were operated in accordance with JNCC / NERC Marine Mammal protection guidelines. To ensure compliance, a member of the science party (H.Hinchen from JNCC), who had attended the necessary training, was involved in all acoustic operations. They also offered guidance to avoid any detrimental effect on the marine life due to inappropriate use of acoustic equipment.

7.6.2.2. **Coordinate reference Datum**

The common coordinate reference was defined by the Parker Maritime survey (2013) as:

1. The reference plane is parallel with the main deck abeam (transversely) and with the baseline (keel) fore- and aft-ways (longitudinally).
2. Datum (X = 0, Y = 0, Z = 0) used in all systems is that of the coordinate reference system 2 with CRP at CG.

Multibeam

The Kongsberg axes reference conventions are (see Fig. 7.36) as follows:

1. X positive forward,
2. Y positive starboard,
3. Z positive downward.

The roll reference is set to follow the convention of Applanix PosMV.

The translations and rotations provided by the Applanix PosMV Primary scientific position and attitude system have the following convention:

1. Roll positive port up,
2. Pitch positive bow up,
3. Heading true,
4. Heave positive up.

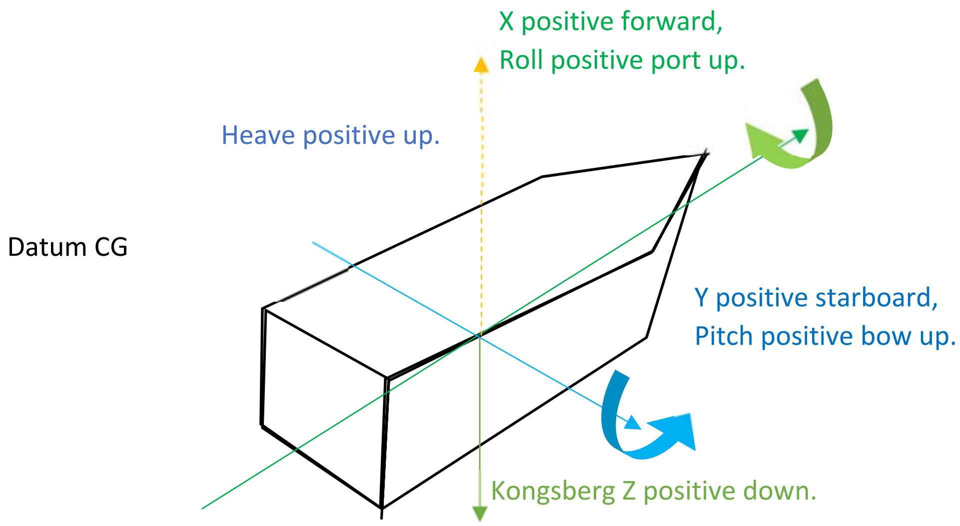


Fig. 7.36 Conventions used for position and attitude.

7.6.2.3. **Position and Attitude**

GPS and attitude measurement systems were run throughout the cruise.

7.6.2.3.1 Applanix POSMV

The ***Applanix POSMV*** system is the vessel's primary scientific GPS system, outputting the position of the ship's common reference point in the gravity meter room (Refer to Parker Report, 2013 – Enclosure 3/Coordinate System 2). The POSMV is available to be sent to all scientific systems and is repeated around the vessel. The position fixes, attitude and gyro data are logged to the Techsas system.

<u>The POSMV was the position and attitude source used by the EM122/EM710 as appropriate during this cruise.</u>

7.6.2.3.2 Kongsberg Seapath 330

The ***Kongsberg Seapath 300*** system is the vessel's secondary GPS system. It provides an input to the Gravity meter due to the POSMV not having vessel course available in its RMC NMEA message. Position fixes and attitude data is logged to the Techsas system.

Due to faults with the Seapath developed on the previous cruise resulting in occasional large HDOP values, data from this system should be treated with caution.

7.6.2.3.3 C-NAV 3050

The ***CNav 3050*** GPS system is a differential correction service. It provides the Applanix POSMV system with RTCM DGPS corrections (greater than 1m accuracy). The position fixes data are logged to the Techsas system.

7.6.2.3.4 Fugro Seastar 9205

The **Fugro Seastar 9205** GPS system is a differential correction service. It provides the Seapath system with RTCM DGPS corrections. Fugro NMEA output messages are logged to the Techsas system.

7.6.2.4. **Meteorology and sea surface monitoring package**

The NMF Surfmet system was run throughout the cruise, excepting times for cleaning, entering and leaving port, and whilst alongside. Please see the separate information sheet for details of the sensors used and whether calibrations values have been applied:

> *'DY108_Surfmet_sensor_information_sheet.docx'*
> Cruise Disk Location: ***'DY108/Ship_Fitted_Scientific_Systems/Surfmet/'***

Seawater is taken in at a depth of 5.5m, and pump rate was 20,000ml/min (pre-debubbler), 1750 ml/min (instrumentation).

The Surfmet system is comprised of (see also Table 7.31 and Fig. 7.37):

1. Hull water inlet temperature probe (SBE38).
2. Sampling board conductivity, temperature salinity sensor (SBE45).
3. Sampling board transmissometer (CST).
4. Sampling board fluorometer (WS3S)
5. Met platform temperature and humidity probe (HMP45).
6. Met platform port and starboard ambient light sensors (PAR, TIR).
7. Met platform atmospheric pressure sensor (PTB110).
8. Met platform anemometer (Windsonic).

Table 7.31 details of fitted sensors on the Surfmet system during DY108/109

Manufacturer	Sensor	Serial No	Comments	Calibration applied?	Last calibration (DD/MM/YY)
AML	Micro-X Surface SV	10377/203551	Drop Keel SV	Y	03/04/2019
Skye	PAR SKE510	28560	Starboard	N	01/05/2018
Skye	PAR SKE510	48927	Port	N	30/01/2018
Kipp & Zonen	TIR CM6B	994132	Starboard	N	18/10/2018
Kipp & Zonen	TIR CM6B	973134	Port	N	18/10/2018
Gill	Windsonic Option 3	10280018	Starboard Inv: 250006705	N	N/A (tested 28/09/2015)
Vaisala	HMP155 Temp./Hum.	N1211119	260004820	N	22/10/2018
Vailsala	PTB210 Air Pres.	N093256	260004687	N	19/10/2018
Wet Labs	WS3S Fluorimeter	WS3S-134		N	24/10/2018
Wet Labs	CST Transmissometer	CST-1852PR		N	19/03/2018
Sea-Bird	SBE45 TSG	4548881-0230	Installed 05/09/2019	N	27/06/2019
Sea-Bird	SBE38 Temperature	3854115-0487	Installed 05/09/2019	N	26/06/2019

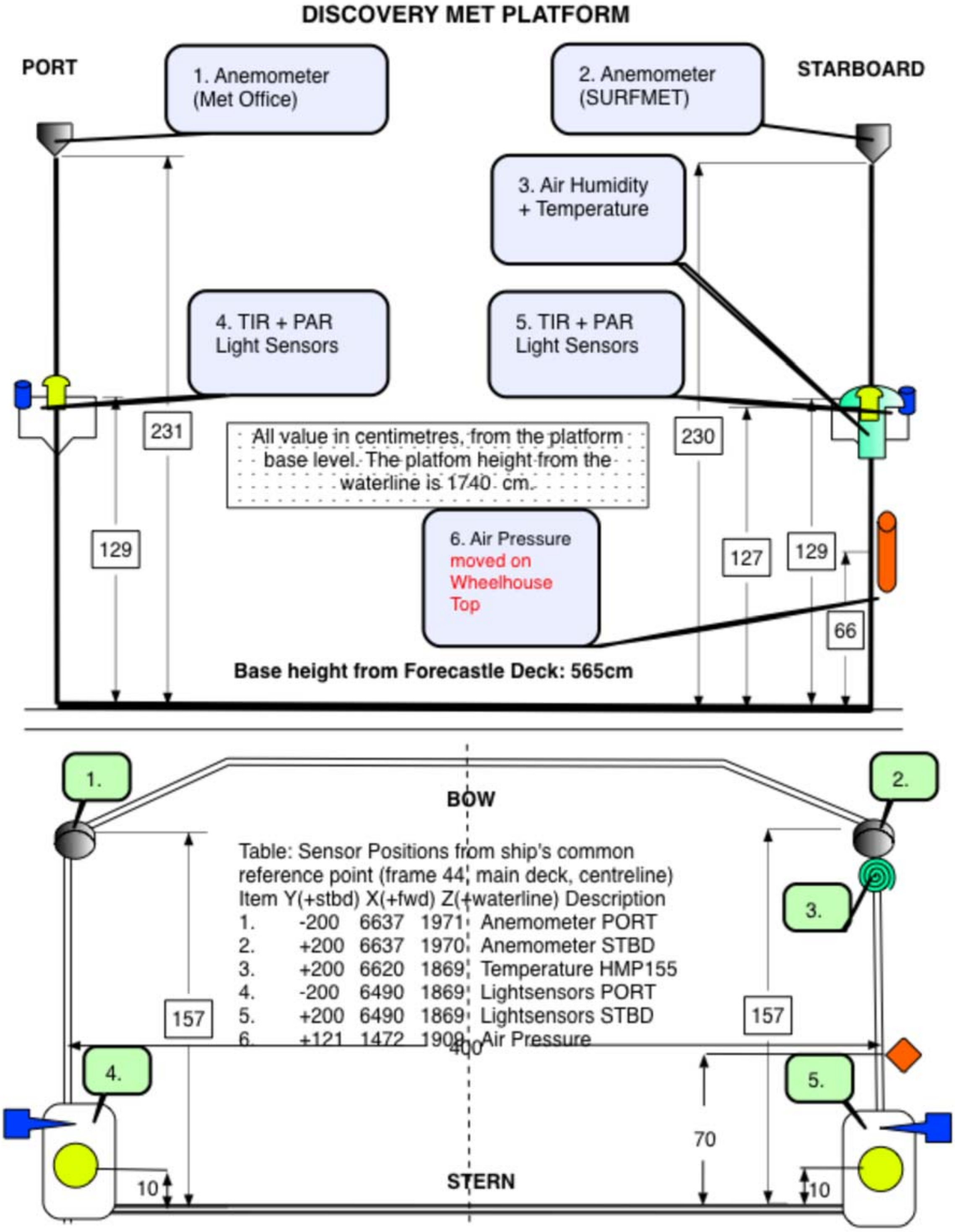


Fig. 7.37 Configuration of the DY108 Met Platform

Instrument calibration sheets are included in the directory:

Cruise Disk Location:
'DY108/ Ship_Fitted_Scientific_Systems/Surfmet/SurfMet_Calibration_sheets/'

7.6.2.4.1 Underway TSG Data

Table 7.32 Overview of water samples taken from the Surfmet package

Crate	Bottle	Date	Time start	Time end	TSG salinity
4	97	2019-09-16	15:39:00	15:39:00	35.223929
4	98	2019-09-16	15:39:00	15:40:00	35.223929
4	99	2019-09-17	13:22:00	13:23:00	35.202884
4	100	2019-09-17	13:22:00	13:23:00	35.202884
4	101	2019-09-20	08:54:00	08:55:00	35.196755
4	102	2019-09-20	08:54:00	08:55:00	35.196755
4	103	2019-09-22	08:58:00	08:59:00	35.203968
4	104	2019-09-22	08:58:00	08:59:00	35.203968
4	105	2019-09-23	08:25:00	08:26:00	35.190874
4	106	2019-09-23	08:25:00	08:26:00	35.190874
4	111	2019-09-25	11:10:00	11:11:00	35.188768
4	112	2019-09-25	11:10:00	11:11:00	35.188768
4	107	2019-09-26	13:23:00	13:24:00	35.156802
4	108	2019-09-26	13:23:00	13:24:00	35.156802
4	109	2019-09-27	11:12:00	11:13:00	35.209274
4	110	2019-09-27	11:12:00	11:13:00	35.209274

The collected water samples were measured for salinity using a Guildline Autosal 8400B salinometer. These results and a comparison with SBE45 TSG salinity values (averaged over 30 seconds before sample and 30 seconds after sample) are in the directory below:

Cruise Disk Location: ***'DY108/Ship_Fitted_Scientific_Systems/Surfmet/tsg_salinities'***

7.6.2.5. **Drop Keel Sound Velocity Sensor**

The surface Sound Velocity (SV) sensor (AML SmartSV) mounted on the drop keel was used throughout providing SV data to the EM122/EM710. The port drop keel remained flush with the hull for the duration of the cruise.

7.6.2.6. **Kongsberg EA640 10 & 12 kHz Single-beam**

The EA640 single-beam echo-sounder was run throughout the cruise. Both 12 and 10kHz were used. Pulse parameters were altered during the cruise in response to changing depth. This depth was used as the input for the CLAM (Cable Logging and Measurement) during deployment activities.

The system used a constant sound velocity of 1500 ms^{-1} throughout the water column to allow it to be corrected for sound velocity in post processing if required. Salinity (35 PSU) and Temperature (10degreeC) and Conditions (salt water) were also left as constant values for the cruise duration.

Kongsberg *.raw files (~100MB file size) and *.xyz files are logged and depths were logged to Techsas, Level-C and RVDAS.

7.6.2.7. **Kongsberg SBP120 Sub Bottom Profiler**

This system was run during the cruise, both RAW and SEGY formats were recorded (see also Section 6.1).

Cruise Disk Location: ***'DY108/Ship_Fitted_Scientific_Systems/Acoustics/*****SBP120**

7.6.2.8. **ADCP OS75KHz (RDI Teledyne).**

The RDI Teledyne Ocean Surveyor 75KHz ADCP was configured as per DY107 trials cruise. It was run continuously, controlled, and logged by UHDAS. During the passage to the work area both systems were set to bottom track. Once enough bottom track data was collected, they were switched to hybrid Wideband/Narrowband mode.

Cruise Disk Location: ***'DY108/Ship_Fitted_Scientific_Systems/Acoustics/*****ADCP-UHDAS**

Data Feeds

- GGA (Ship Position) and VTG (Ship Speed) was provided by the Applanix POS-MV.
- Heading and Tilt was provided by the iXSea PHINS MRU (PRDID NMEA message).

7.6.2.9. **ADCP OS150KHz (RDI Teledyne).**

The RDI Teledyne Ocean Surveyor 150KHz ADCP was configured as per DY107 trials. It was run continuously, controlled, and logged by UHDAS. During the passage to the work area both systems were set to bottom track. Once enough bottom track data was collected, they were switched to hybrid Wideband/Narrowband mode.

Cruise Disk Location: ***'DY108/Ship_Fitted_Scientific_Systems/Acoustics/*****ADCP-UHDAS**

Data Feeds

- GGA (Ship Position) and VTG (Ship Speed) was provided by the Applanix POS-MV.
- Heading and Tilt was provided by the iXSea PHINS MRU (PRDID NMEA message).

7.6.2.10. **Kongsberg EM122 Multibeam Echo Sounder**

The EM122 multibeam echo sounder was run throughout the cruise. The position and attitude data were supplied from the Applanix PosMV and True Heave *.ath file are logged to allow for inclusion during reprocessing.

Sound velocity profiles were obtained from CTD casts using the Chen and Millero formula as this is the most appropriate for shelf work <1000m (Ref. Valeport) and compares very well against the Midas SVP profile (ref. DY100). These were entered into SIS after converting the files using the SVP editor.

Figs. 7.38 & 7.39 show the system installation configuration. The values are from the ships Parker survey report, which is included on the data disk.

Location offset (m)

	Forward (X)	Starboard (Y)	Downward (Z)
Pos, COM1:	0.00	0.00	0.00
Pos, COM3:	0.00	0.00	0.00
Pos, COM4/UDP2:	0.00	0.00	0.00
TX Transducer:	39.910	0.885	7.426
RX Transducer:	35.219	-0.005	7.438
Attitude 1, COM2/UDP5:	0.00	0.00	0.00
Attitude 2, COM3/UDP6:	0.00	0.00	0.00
Waterline:			1.34

Fig. 7.38 – EM122 transducer locations

Offset angles (deg.)

	Roll	Pitch	Heading
TX Transducer:	0.07	0.15	0.05
RX Transducer:	0.05	0.37	359.98
Attitude 1, COM2/UDP5:	-0.10	0.00	-0.85
Attitude 2, COM3/UDP6:	0.00	0.00	0.00
Stand-alone Heading:			0.00

Fig. 7.39 – EM122 transducer offsets

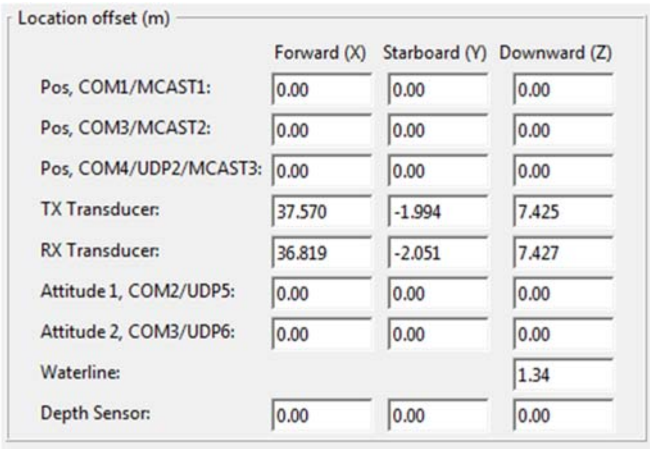
Cruise Disk Location: ***'DY108/Ship_Fitted_Scientific_Systems/Acoustics*** **/EM122/'**

7.6.2.11. **Kongsberg EM710 Multibeam Echo Sounder**

The EM710 multibeam echo sounder was used during shallow water surveys, e.g. during transits. The position and attitude data was supplied from the Applanix PosMV and True Heave *.ath file are logged to allow for inclusion during reprocessing.

Sound velocity profiles were obtained from CTD casts, and entered into SIS after converting the files using the SVP editor.

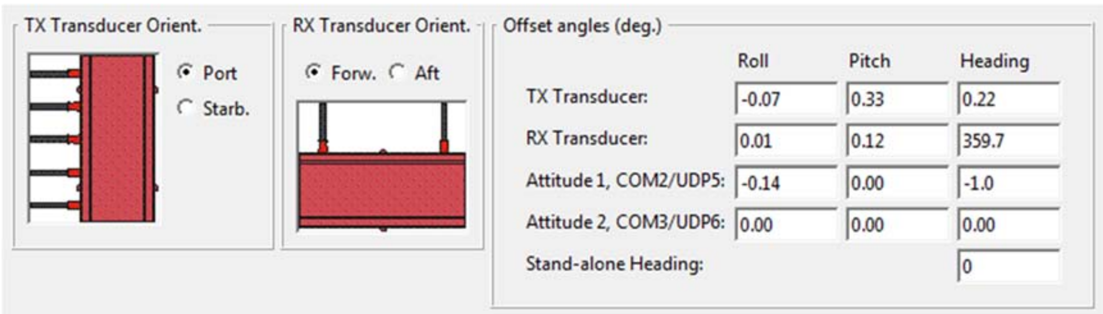
Figs. 7.40 & 7.41 show the system installation configuration. The values are from the ships Parker survey report, which is included on the data disk.



Location offset (m)

	Forward (X)	Starboard (Y)	Downward (Z)
Pos, COM1/MCAST1:	0.00	0.00	0.00
Pos, COM3/MCAST2:	0.00	0.00	0.00
Pos, COM4/UDP2/MCAST3:	0.00	0.00	0.00
TX Transducer:	37.570	-1.994	7.425
RX Transducer:	36.819	-2.051	7.427
Attitude 1, COM2/UDP5:	0.00	0.00	0.00
Attitude 2, COM3/UDP6:	0.00	0.00	0.00
Waterline:			1.34
Depth Sensor:	0.00	0.00	0.00

Fig. 7.40 – EM710 transducer locations



Offset angles (deg.)

	Roll	Pitch	Heading
TX Transducer:	-0.07	0.33	0.22
RX Transducer:	0.01	0.12	359.7
Attitude 1, COM2/UDP5:	-0.14	0.00	-1.0
Attitude 2, COM3/UDP6:	0.00	0.00	0.00
Stand-alone Heading:			0

Fig. 7.41 – EM710 transducer offsets

Cruise Disk Location:
'DY108/Ship_Fitted_Scientific_Systems/Acoustics **/EM710/'**

7.6.2.12. **Multibeam CARIS Processing**

Processing using CARIS HIPS&SIPS was undertaken by the scientific party, and is explained in Section 6.1.

7.6.2.13. **Sound velocity profiles**

Cruise Disk Location: ***'DY108/Ship_Fitted_Scientific_Systems/Acoustics/*****Sound_Velocity_Profiles/**

7.6.2.14. **Sonardyne USBL**

The starboard head was used as this gave the widest angular range. The calibration offsets were entered into System 1 (USBL1 on Blackbox) and this was used throughout the cruise.

System 1 : Port pole : Pitch=0.489, roll=0.187, heading=0.345

System 2 : Starboard pole : Pitch=0.262, roll=0.129, heading=0.761

USBL beacons used:

SandM WMT beacon was used for Autosub missions. Its address was changed to 3004, and power set to maximum to make it the same as SSS beacon 3003. After several long deployments, and being charged between deployments, the AUV team returned the beacon with a flat battery. This exhibited similar charging issues that befell our WMTs earlier this year, except it was still possible to communicate with the beacon. Swapping batteries with our known good (new) spare, did not work, and the beacon reported that the battery was only about 10% charged. During charging, the brown disk (thermal fuse possibly?) got very hot. The software reported temperatures in excess of 30C while the beacon was on the bench in pieces, with battery connected but not actually fitted in the unit.

SandM are going to have to send their beacon back to Sonardyne for evaluation.

WMT 3003 was used for the remainder of Autosub missions without problems.

Both WSM beacons were used for coring QsY2 was used mainly.

Both WSM beacons were used alternately for 2 x 24 hour Yoyo deployment, swapping the beacon between deployments. The WSM beacons worked well throughout.

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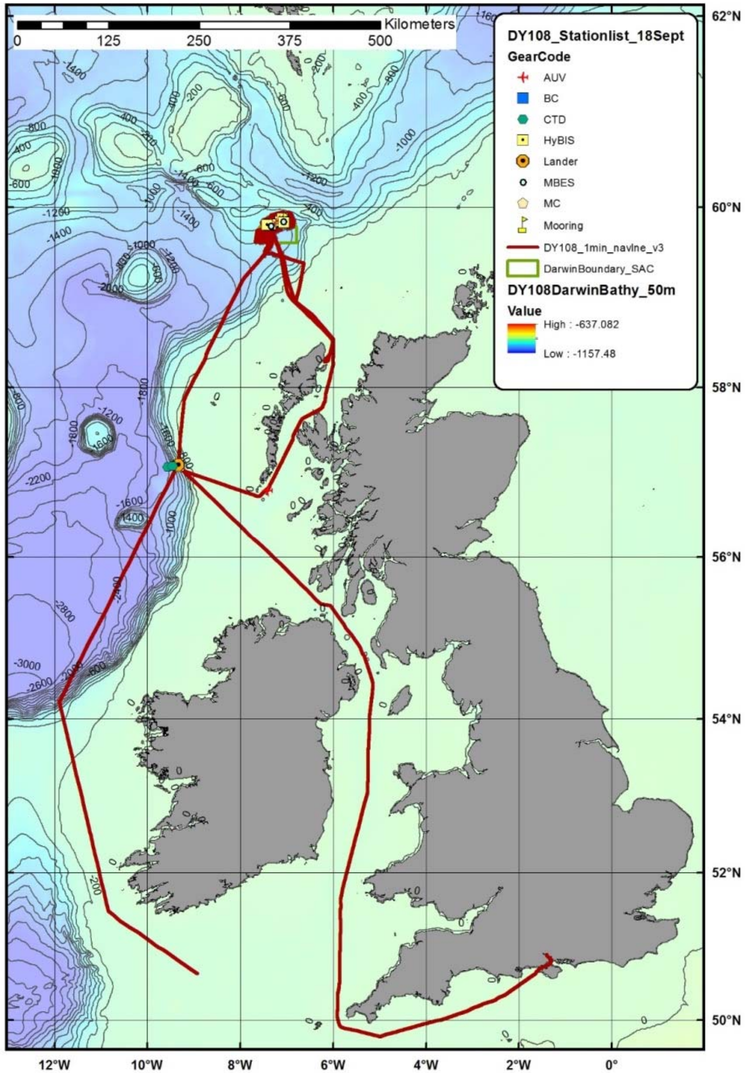
9. STATION LIST

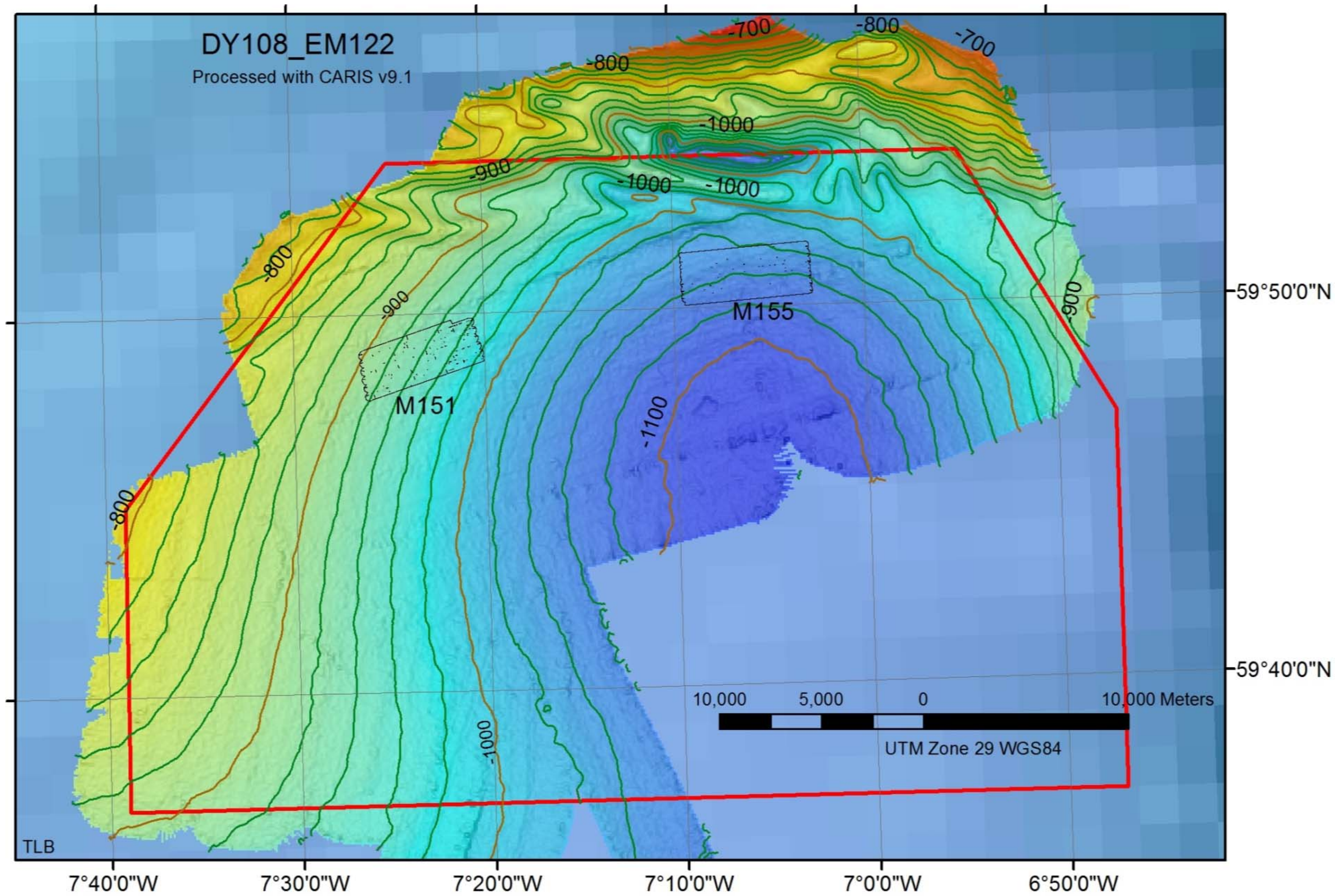
Site	Final sample number	JDay (Start	Start Dat	Start Time GMT	Start Lat Degr	Start Lat Min N	Start Long Degr W	Start Long Min V	Start Waterd epth mete	JDa	End Date	End Time GMT	End Lat Deg	End L	End Long Deg	End L	End waterd epth mete	Comments	Recipient
OSNAP Lander	DY108-001-CTD/CTD01	**252**	09/09/2019	**09:46:00**	57	5.0000	009	33.3910	1804	**252**	09/09/2019	**11:30:00**	57	5.0000	009	33.3910	1804	Water sample collected at 1100 m depth for sediment trap #7-10. #2 is leaking.	-
OSNAP Lander	DY108-002-HyBIS/Hy50	**252**	09/09/2019	**13:30:00**	57	5.8400	009	20.0350	743	**252**	09/09/2019	**14:22:00**	57	5.8410	009	20.0100	743	Camera and light failed - cancelled.	-
OSNAP Lander	DY108-003-Lander/Lander01	**252**	09/09/2019	**15:45:00**	57	6.1100	009	20.1510	750	**252**	09/09/2019	**16:47:00**	57	5.7835	009	99.3380		Ballast detached from lander, all components recovered - failed to deploy.	SAMS
OSNAP Lander	DY108-004-CTD/CTD02_03	**252**	09/09/2019	**18:23:00**	57	5.3615	009	27.3156	1587	**252**	09/09/2019	**20:05:00**	57	5.3608	009	27.3155	1586	Included test of laser housing for biocam.	-
Mingulay Reef	DY108-005-AUV/AsubM150	**253**	10/09/2019	**06:41:00**	56	47.9950	007	24.8390	206	**253**	10/09/2019	**20:27:00**	56	48.2540	007	25.0450		Asub6000 + BioCam test.	-
Darwin mounds	DY108-006-CTD/CTD04	**254**	11/09/2019	**09:45:00**	59	48.7910	007	21.6990	966	**254**	11/09/2019	**10:10:00**	59	48.7940	007	21.6720	966	-	-
Darwin mounds (W	DY108-007-BC/BC01	**254**	11/09/2019	**12:36:00**	59	48.7400	007	21.7440	965									Fail - did not trigger.	UEdin
Darwin mounds (W	DY108-008-BC/BC02	**254**	11/09/2019	**14:12:00**	59	48.7500	007	21.7190	964									50 x 25 x 10 cm. Partially washed out.	UEdin
Darwin mounds (W	DY108-009-BC/BC03	**254**	11/09/2019	**15:48:00**	59	48.7480	007	21.7120	968									41 x 35 x 10 cm.	UEdin
Darwin mounds (Ea	DY108-010-HyBIS/Hy51	**254**	11/09/2019	**19:07:00**	59	50.8952	007	3.3969	1058	**255**	12/09/2019	**02:52:00**	59	51.1841	007	4.3472	1050	Exploring mound after reaching WP06.	-
Darwin mounds (W	DY108-011-BC/BC04	**255**	12/09/2019	**05:21:00**	59	49.1030	007	21.3720	963									35 x 35 x 10 cm. 0445 on hold; bowthrust problem. On Bottom 10 m away afrom target.	UEdin
Darwin mounds (W	DY108-012-BC/BC05	**255**	12/09/2019	**06:52:00**	59	49.3892	007	21.0288	962									35 x 35 x 10 cm.	UEdin
Darwin mounds (Ea	DY108-013-BC/BC06	**255**	12/09/2019	**10:15:00**	59	50.9813	007	3.8266	1053									30 x 40 x 10 cm. Beacon at 60 m cable.	UEdin
Darwin mounds	DY108-014-AUV/AsubM151	**255**	12/09/2019	**13:08:00**	59	48.7720	007	20.0495	989	**255**	12/09/2019	**16:29:00**	59	46.6958	007	18.3166	1034	Whale bones discovered. ☆	-
Darwin mounds (W	DY108-015-HyBIS/Hy52	**255**	12/09/2019	**17:29:00**	59	48.8290	007	21.6080	969	**255**	12/09/2019	**19:27:00**	59	48.8290	007	21.6080	969	JC060 morring1 was collected. Further notes scanned. Samples taken. ☺ 3D Darwin Planet model created.	NOCS
Darwin mounds (Ea	DY108-016-HyBIS/Hy53	**255**	12/09/2019	**21:19:00**	59	50.9220	007	3.4350	1058	**255**	12/09/2019	**23:26:00**	59	50.9342	007	3.5166	1054	JC060 morring2 was collected. Further notes scanned. Samples taken. One settlement plate recovered from 1 m above seabed; plate at 2 m altitude above seabed lost during recovery.	NOCS
Darwin mounds (W	DY108-017-CTD/CTD05	**259**	16/09/2019	**03:02:00**	59	48.8189	007	21.1626	974	**259**	16/09/2019	**04:02:00**	59	48.8190	007	21.1950		Cast at 955 m water depth.	-
Darwin mounds (W	DY108-018-AUV/AsubM152	**259**	16/09/2019	**06:39:00**	59	48.8725	007	21.2556	971	**260**	17/09/2019	**06:15:00**	59	48.0975	007	21.3423	986	Flashing light at surface 03:30, first iridium received 03:23	-
Darwin mounds (W	DY108-019-BC/BC07	**259**	16/09/2019	**10:58:00**	59	49.3119	007	21.2818	975									50 x 50 x 10 cm.	UEdin
Darwin mounds (W	DY108-020-BC/BC08	**259**	16/09/2019	**12:47:00**	59	49.2308	007	21.8687	957									50 x 50 x 10 cm - from mound tail.	UEdin
Darwin mounds (W	DY108-021-BC/BC09	**259**	16/09/2019	**14:56:00**	59	48.7554	007	22.4977	955									50 x 50 x 10 cm.	UEdin
Darwin mounds (W	DY108-022-HyBIS/Hy54	**259**	16/09/2019	**16:48:00**	59	48.7334	007	23.0022	945	**260**	17/09/2019	**02:54:00**	59	48.8554	007	22.6827	957	JC060 marker buoy seen.	-
Darwin mounds (Ea	DY108-023-BC/BC10	**260**	17/09/2019	**08:57:00**	59	50.9661	007	3.8359	1057									18 x 50 x 10 cm.	UEdin
Darwin mounds (Ea	DY108-024-BC/BC11	**260**	17/09/2019	**10:54:00**	59	50.6360	007	7.5785	1005									22 x 31 x 10 cm.	UEdin
Darwin mounds (Ea	DY108-025-BC/BC12	**260**	17/09/2019	**12:52:00**	59	51.0340	007	7.9049	1013									Fail.	UEdin
Darwin mounds (Ea	DY108-026-BC/BC13	**260**	17/09/2019	**14:13:00**	59	51.0334	007	7.9239	1002									19 x 31 x 10 cm.	UEdin
Darwin mounds (W	DY108-027-HyBIS/HY55	**260**	17/09/2019	**16:29:00**	59	48.8080	007	21.6990	961	**261**	18/09/2019	**03:03:00**	59	48.4447	007	22.0367	966	All waypoints reached, missing their data records on logsheet	-
Darwin mounds (Ea	DY108-028-BC/BC14	**261**	18/09/2019	**05:11:00**	59	50.9992	007	8.0092	1002									50 x 50 x 10 cm.	UEdin
Darwin mounds (Ea	DY108-029-BC/BC15	**261**	18/09/2019	**06:39:00**	59	50.7135	007	8.3476	1057									50 x 50 x 10 cm.	UEdin
Darwin mounds	DY108-030-AUV/AsubM153	**261**	18/09/2019	**09:01:00**	59	59.2990	007	4.4520	1050	**262**	19/09/2019	**09:35:00**	59	51.3900	007	4.7500	1049	Asub6000 + BioCam.	-
Darwin mounds (Ea	DY108-031-BC/BC16	**261**	18/09/2019	**12:38:00**	59	50.9422	007	3.8744	1056									50 x 50 x 10 cm.	UEdin
Darwin mounds (Ea	DY108-032-BC/BC17	**261**	18/09/2019	**14:15:00**	59	50.9530	007	3.6312	1053									37 x 20 x 10 cm.	UEdin
Darwin mounds (Ea	DY108-033-HyBIS/HY56	**261**	18/09/2019	**16:17:00**	59	50.9682	007	8.0417	1049	**262**	19/09/2019	**03:04:00**	59	50.6020	007	7.3240	1065	20:30-22:15 tapes not recording (i.e. c. 01:30 not recording).	-
Darwin mounds (Ea	DY108-034-BC/BC18	**262**	19/09/2019	**04:52:00**	59	50.9057	007	3.6244	1053									50 x 50 x 10 cm.	UEdin
Darwin mounds (W	DY108-035-BC/BC19	**262**	19/09/2019	**11:54:00**	59	48.8374	007	22.5136	953									19.5 x 23 x 10 cm. Small sandy sample with coral rubbles.	UEdin
Darwin mounds (W	DY108-036-BC/BC20	**262**	19/09/2019	**14:01:00**	59	48.8159	007	22.8005	952									50 x 50 x 10 cm.	UEdin

Site	Final sample number	JDay (Start)	Start Date	Start Time GMT	Start Lat Degr N	Start Lat Min N	Start Long Degr W	Start Long Min W	Start Waterdepth meter	JDay	End Date	End Time GMT	End Lat Degr	End Lat I	End Long Degr	End Long	End waterdepth meter	Comments	Recipient
Darwin mounds (W	DY108-037-HyBIS/Hy57	262	19/09/2019	16:25:00	59	48.8444	007	21.6172	970	263	20/09/2019	02:46:00	59	49.0020	007	21.5180	964	20:38 tape change, reboot system, cameras off. Did not reset HD57_04. 21:36 heading to mound located B270 D70 m (next to whale block). 22:37 Mound was <...> heading to <...> transect (HD57_04). 23:30 heading to mounds located at east of HD57_04, heading north from HD57_03.	-
Darwin mounds (W	DY108-038-BC/BC21	263	20/09/2019	04:42:00	59	48.8247	007	22.5341	951									9 x 16 x 10 cm. Very small volume of sediment recovered.	-
Darwin mounds	DY108-039-MC/MC01	263	20/09/2019	09:45:00	59	51.0331	007	7.8845	1053									Fail (2 small + 2 large).	-
Darwin mounds	DY108-040-MC/MC02	263	20/09/2019	11:00:00	59	51.0358	007	7.8955	1052									Fail (2 small + 2 large) - opportunistic small quantity of coral fragments for dating analysis.	NOCS
Darwin mounds	DY108-041-MC/MC03	263	20/09/2019	12:14:00	59	51.0318	007	7.9064	1052									Fail (2 small + 2 large).	-
Darwin mounds (Ea	DY108-042-AUV/AsubM154	263	20/09/2019	16:14:00	59	51.3688	007	9.5549		263	20/09/2019	17:02:00	59	51.3688	007	9.5549		Fail - dive cancelled due to heading not updating.	-
Darwin mounds (Ea	DY108-043-HyBIS/Hy58	263	20/09/2019	17:58:00	59	52.9848	007	5.0986	968	264	21/09/2019	02:50:00	59	53.0043	007	4.6213	970	Did not dive through HD58_01; survey the surroundings. ~2100 first tape change. Finished transect surveyed by WASP in 2000. Headed north for further exploration.	-
Darwin mounds	DY108-044-MBES/EM122_01	264	21/09/2019	03:29:00	59	51.6588	007	6.5994	1036	264	21/09/2019	13:34:00	59	48.9000	007	22.5000	950	65/65, 7-10 kts. Pilot whales spotted at 1100.	-
Darwin mounds (Ea	DY108-045-AUV/AsubM155	264	21/09/2019	15:04:00	59	51.3694	007	9.5690	1041	265	22/09/2019	15:39:00	59	50.8890	007	8.3750	1063	100 m displacement starting halfway through 1st line, following 2nd line back on track. ~1405 EOL-EOS sidescan system coming up.	-
Darwin mounds (W	DY108-046-HyBIS/Hy59	265	22/09/2019	16:58:00	59	49.3417	007	021	967	266	23/09/2019	02:16:00	59	47.7566	007	22.0799	945	-	-
Darwin mounds (Ea	DY108-047-CTD/CTD06	266	23/09/2019	05:00:00	59	51.6883	007	2.5204	1034	266	23/09/2019	06:20:00	59	51.6844	007	2.5245	1034	CTD + 3x microcats + 1 trial USBL beacon.	-
Darwin mounds (Ea	DY108-048-Mooring/Mooring	266	23/09/2019	07:36:00	59	51.8220	007	2.9980	1027									Triangulated to 59° 51.672 N 7° 2.631 W. 3 settlement panels: 1 above release, 2 under sediment trap.	-
Darwin mounds	DY108-049-MBES/EM122_02	266	23/09/2019	10:48:00	59	51.8220	007	2.9980	1027	266	23/09/2019	12:30:00	59	51.3600	007	19.7400	935	Broke off early to go to Autosub dive site.	-
Darwin mounds	DY108-050-MC/MC04	266	23/09/2019	14:09:00	59	49.3972	007	21.0321	963									Fail (2 small + 2 large) - opportunistic coral fragments for dating analysis.	NOCS
Darwin mounds	DY108-051-MC/MC05	266	23/09/2019	15:18:00	59	49.3937	007	21.0275	963									Fail (2 small + 2 large) - opportunistic coral fragments for dating analysis; ★ 1 amphipod, 1 worm, few tube worms.	NOCS
Darwin mounds	DY108-052-HyBIS/Hy60	266	23/09/2019	17:15:00	59	50.5309	007	3.2527	1023	267	24/09/2019	02:35:00	59	51.2995	007	4.4284	1048	-	-
Darwin mounds	DY108-053-MBES/EM122_03	267	24/09/2019	03:03:00	59	50.9040	007	4.2594	1061	267	24/09/2019	12:27:00	59	45.4800	007	7.0800	1111	-	-
Darwin mounds	DY108-054-AUV/Asub156	267	24/09/2019	13:30:00	59	49.4260	007	21.6310	958	268	25/09/2019	15:54:00	59	49.8500	007	22.6660	941	-	-
Darwin mounds	DY108-055-HyBIS/Hy61	267	24/09/2019	19:30:00	59	49.0790	007	25.1100	917	268	25/09/2019	02:39:00	59	48.7565	007	25.4405	922	Transect was updated to start at a different WP. HD61_04 and HD61_06 not logged.	-
Darwin mounds	DY108-056-MBES/EM122_04	268	25/09/2019	05:02:00	59	47.9400	007	20.0400	999	268	25/09/2019	13:28:00	59	42.9000	007	21.0600	1001	Poor weather conditions.	-
OSNAP Lander	DY108-057-HyBIS/Hy62	269	26/09/2019	13:55:00	59	5.8732	009	20.0639	750	269	26/09/2019	15:42:00	59	5.8180	009	20.0820	731	Lander found; covered in sediment; ADCP detached from base.	-
Irish Margin	DY108-058-CTD/CTD07_26	270	27/09/2019	15:52:00	54	12.9709	011	53.5667	1793	271	28/09/2019	16:37:00	54	12.9683	011	53.5639	1797	24-h CTD; cast 07 to 26. Altimeter seems off 1630. 22 water samples collected.	-
Irish Margin	DY108-059-CTD/CTD27_34	271	28/09/2019	20:19:00	54	13.8618	011	52.6178	1391	272	29/09/2019	04:24:00	54	13.5579	011	52.6348	1393	24-h CTD (1/2); cast 27 to 34. CTD hit the seabed at 0343; brought back to deck for check up.	-
Irish Margin	DY108-060-CTD/CTD35_48	272	29/09/2019	05:27:00	54	13.5583	011	52.6300	1392	272	29/09/2019	19:52:00	54	13.5586	011	52.6256	1391	24-h CTD (2/2); cast 35 to 48.	-

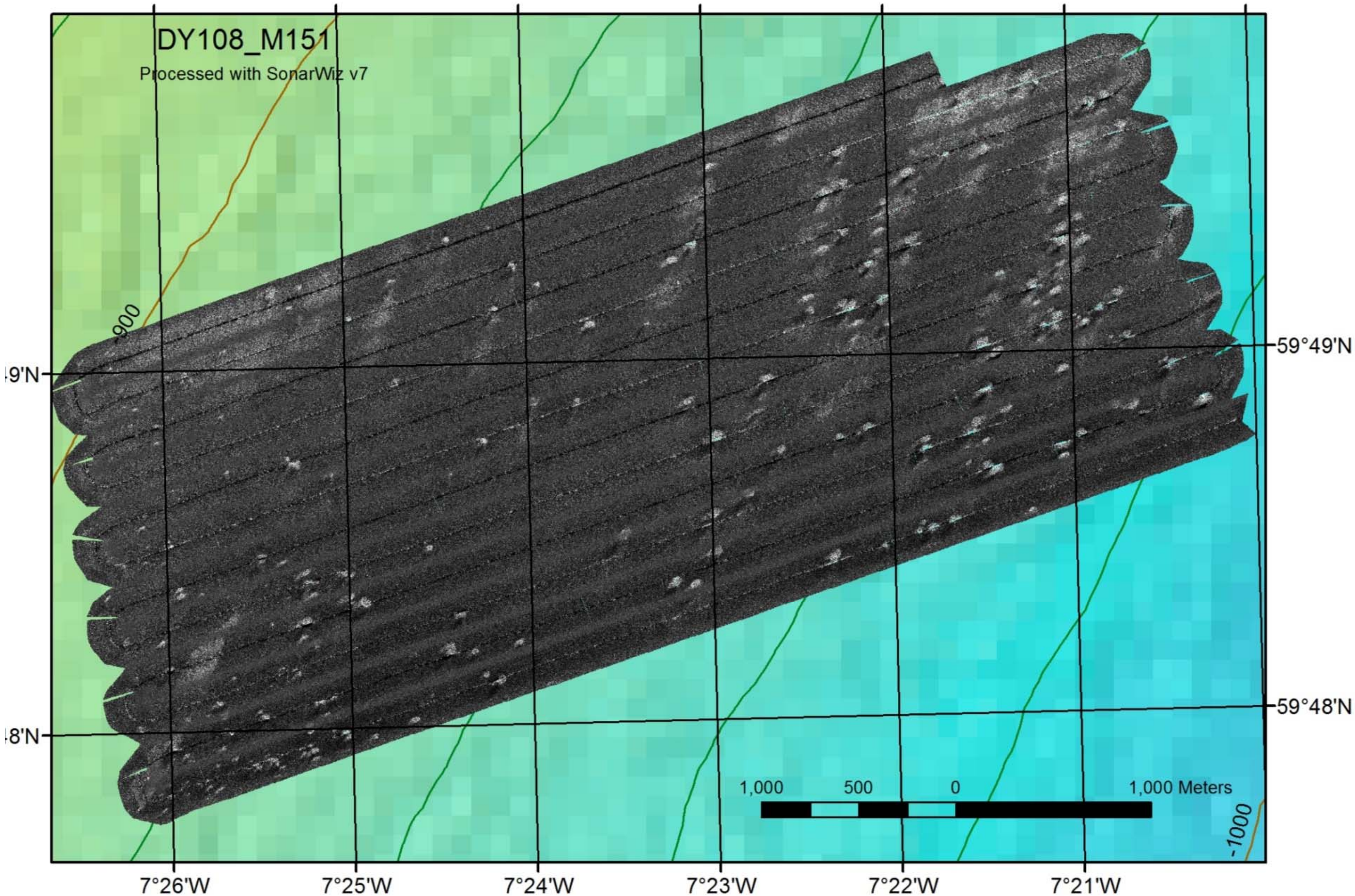
10. MAPS

General cruise track:

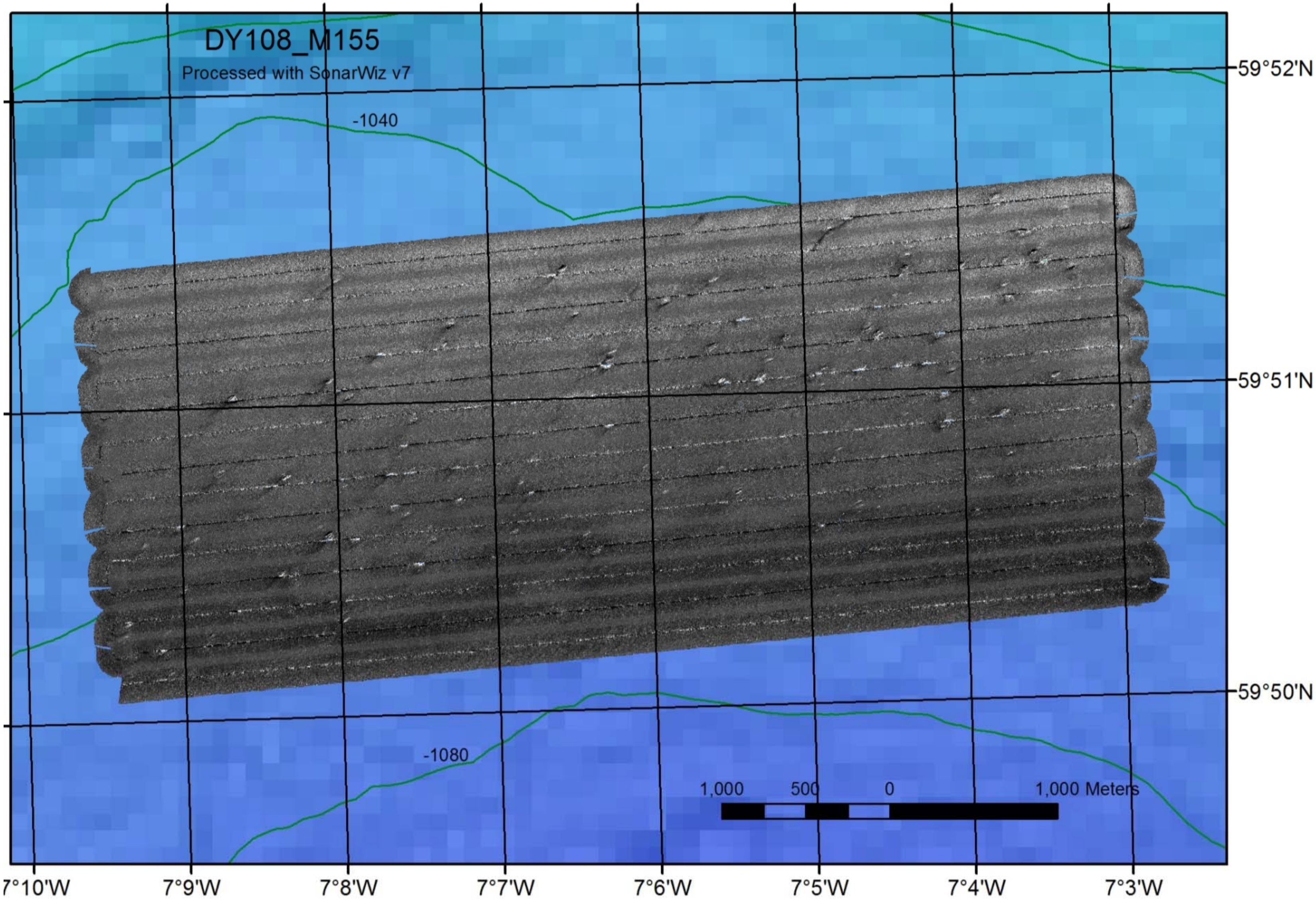




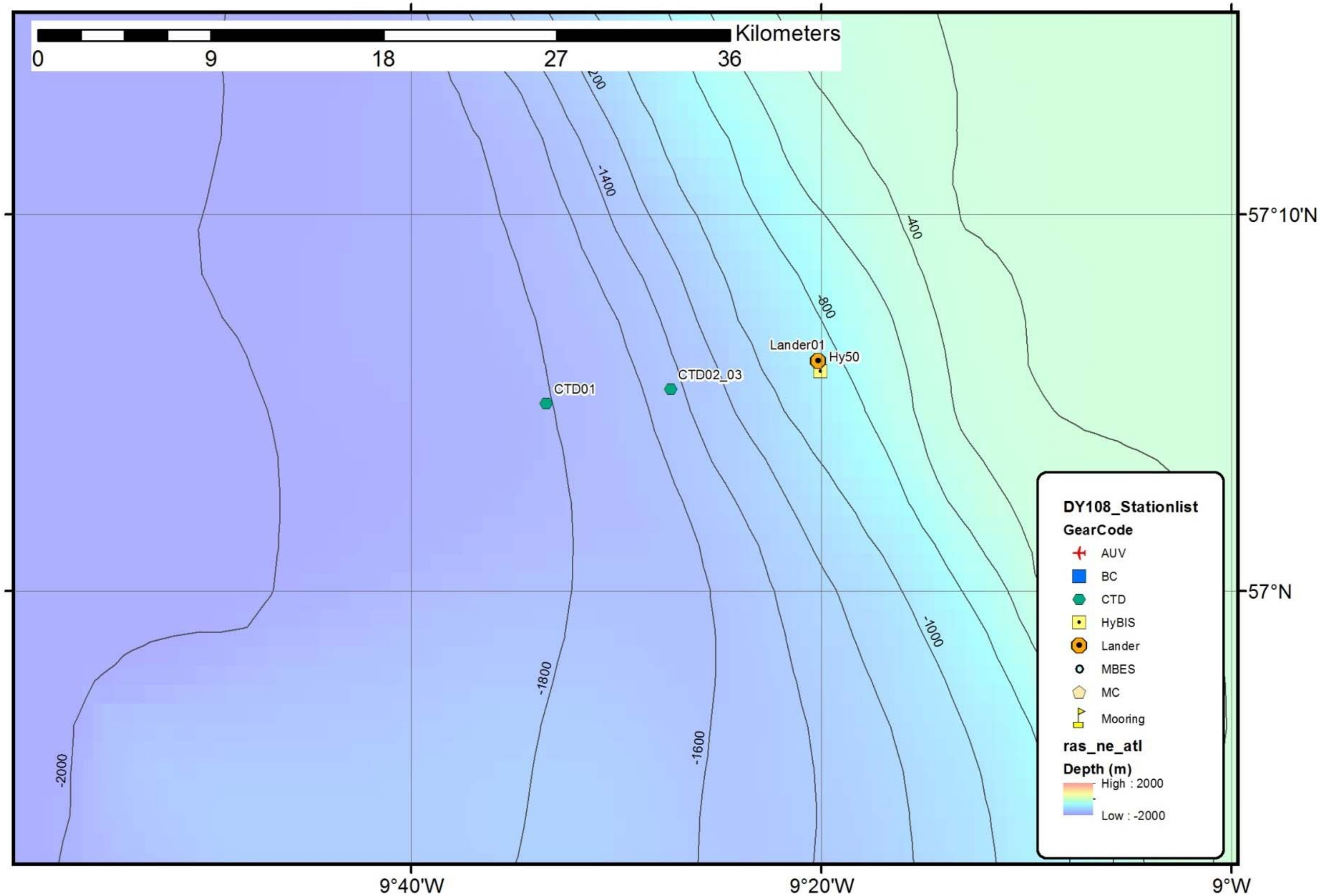
New shipboard bathymetry data collected in the Darwin Mounds area



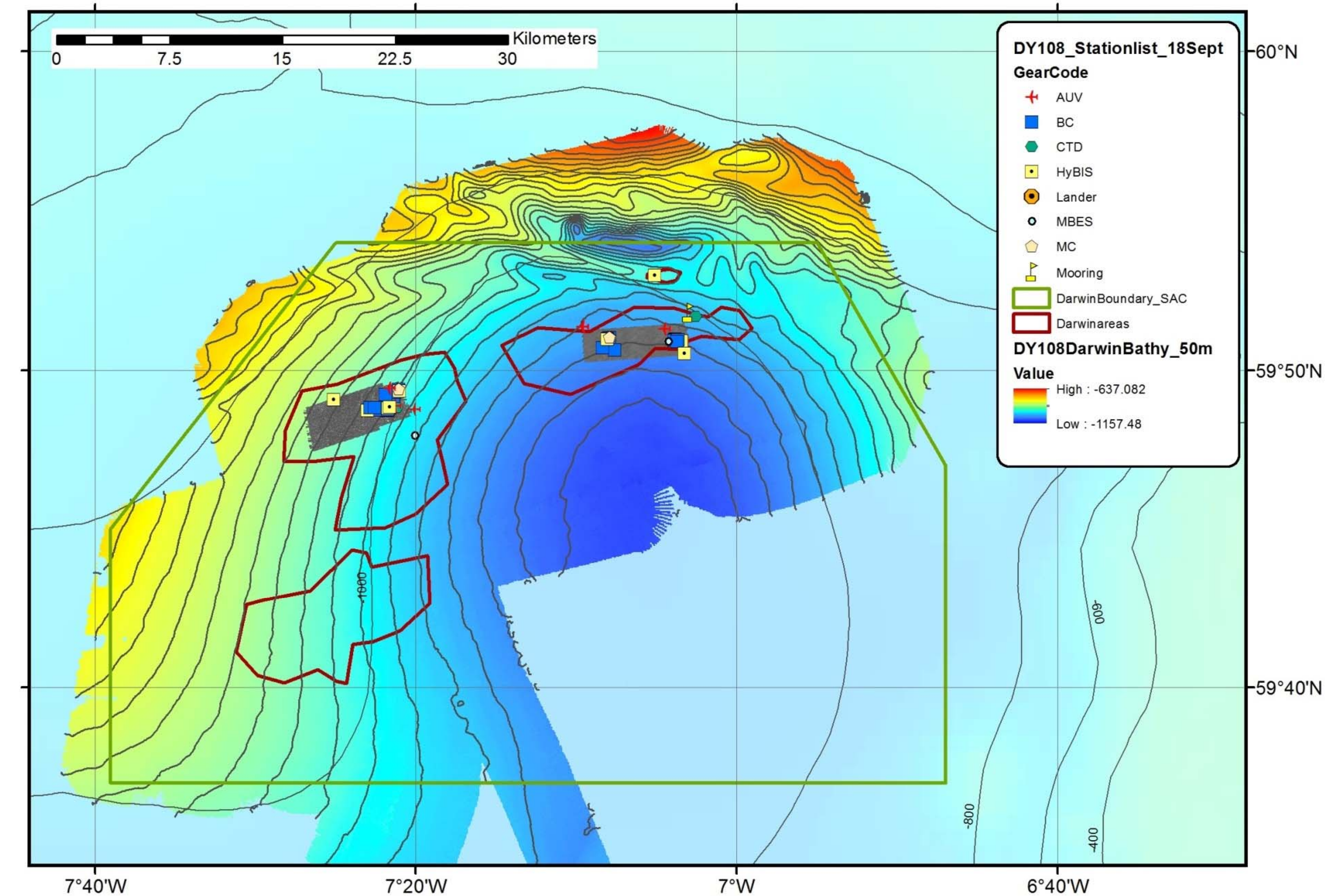
Processed new sidescan sonar data of the Western Darwin Mounds



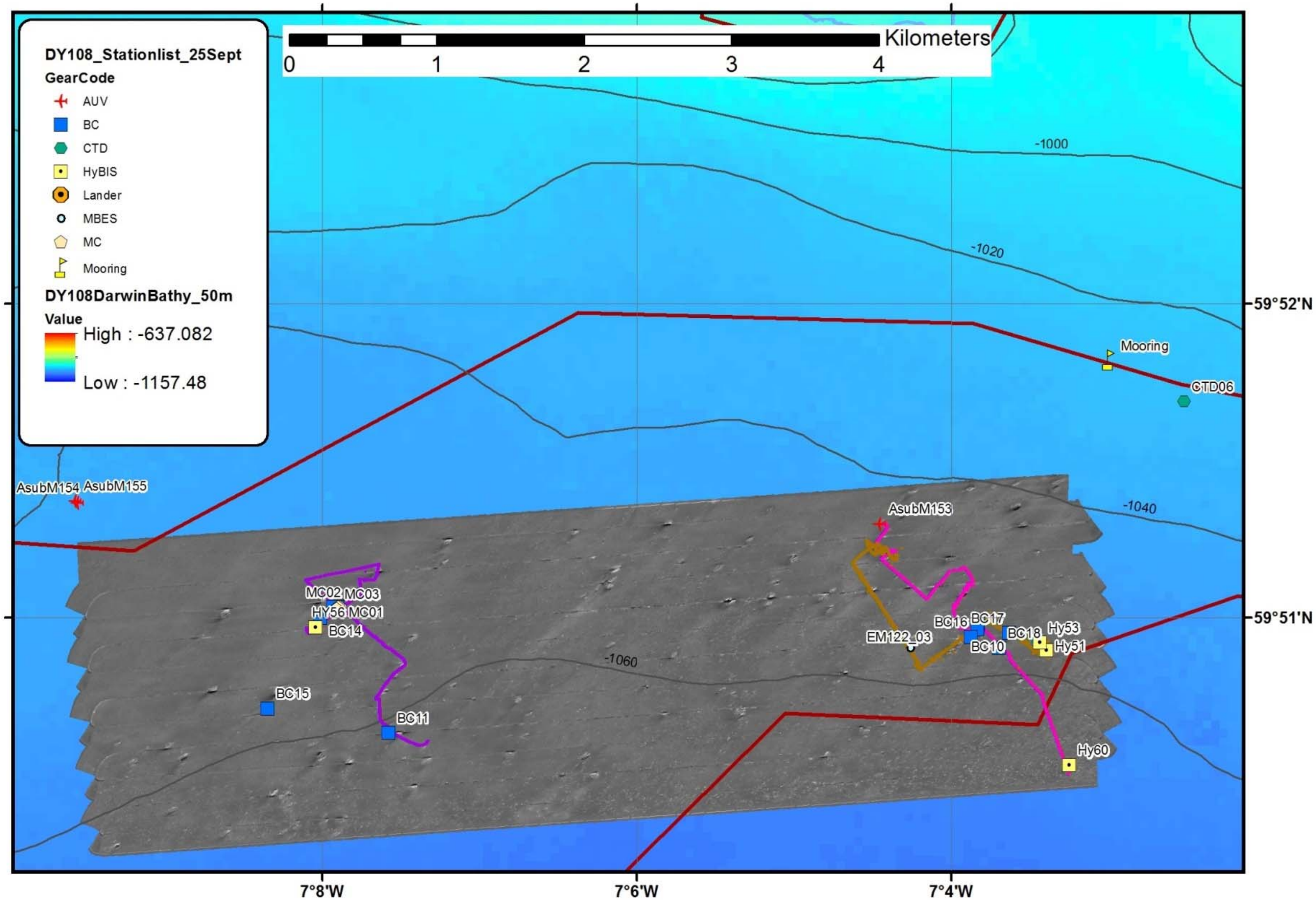
Processed new sidescan sonar data for the Eastern Darwin Mounds



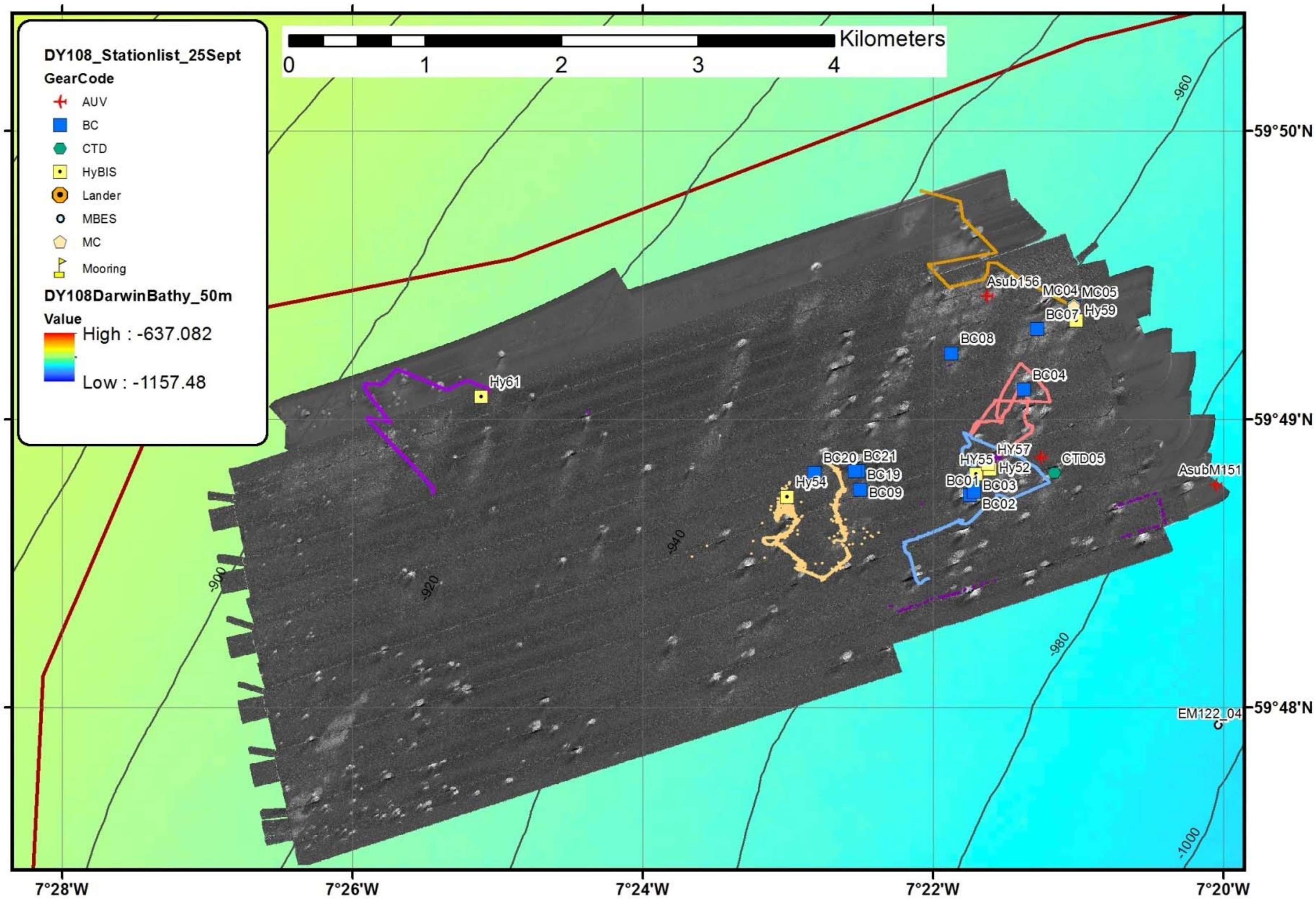
DY108/109 station locations for CLASS Ellett Line work



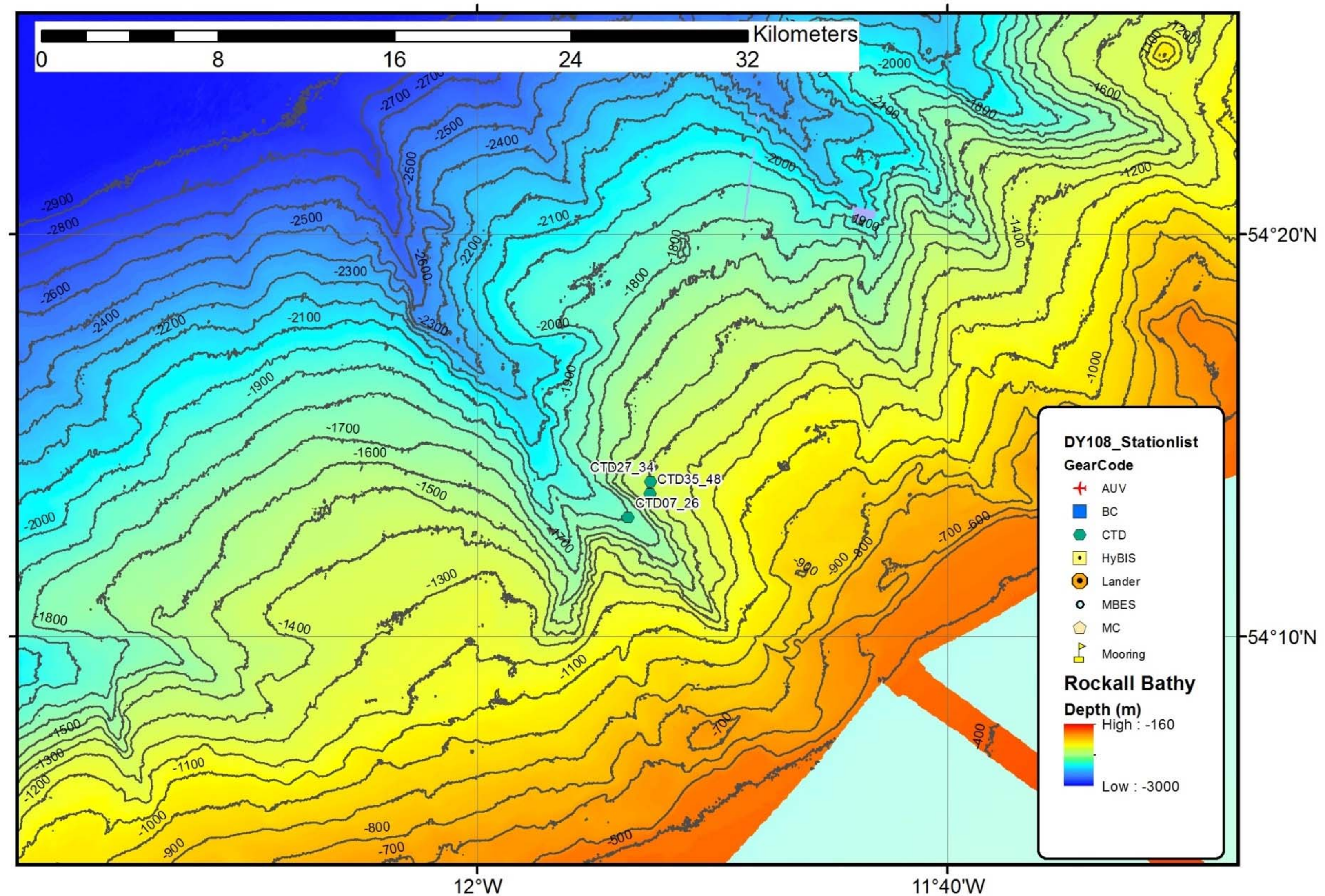
DY108/109 Stations in the Darwin Mound area



Stations and HyBIS dive tracks in the Eastern Darwin Mounds, over AUV sidescan sonar data from JC060



Stations and HyBIS dive tracks in the Western Darwin Mounds, over AUV sidescan sonar data from the current cruise (front) and from JC060 (background)



CTD stations for BLT-Recipes. Background bathymetry provided by INFOMAR programme