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Cruise Report No. 04

RRS *James Cook* Cruise 60

09 MAY-12 JUN 2011

Benthic habitats and the impact of human activities in Rockall Trough, on Rockall Bank and in Hatton Basin

Principal Scientist

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2011

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ABSTRACT

The main aim of cruise JC060 was to carry out habitat mapping work in selected areas of the Rockall Trough, Rockall Bank and Hatton Basin in order to assess the status of different benthic habitats in relation to human activities, especially deep-sea bottom trawling. The cruise included a revisit of the Darwin Mound cold-water coral reefs, discovered in 1998 and protected in 2003, and an assessment of the status of two fisheries closure areas on Rockall Bank. In addition, two pilot studies of a more geological nature were carried out as well: one was targeting a Polygonal Fault System in the Hatton Basin, potentially linked to fluid flow, while the other focused on the history of the Rockall Bank Mass Flow.

The tools used to achieve these objectives included the Autosub6000 Autonomous Underwater Vehicle (AUV), newly equipped with an EdgeTech dual frequency high-resolution sidescan sonar plus chirp profiler and a monochrome stills camera, a commercial inspection class ROV, and more traditional equipment including piston-, mega- and boxcore, CTD and shipborne multibeam (EM120 and EM710).

Although the unsettled weather hampered the operations to a certain extent (including a forced return to the shelter of the Minches, resulting in an ad hoc survey of the E Shiant Bank), the cruise was a success, with 88h of ROV footage & photography collected, 125km^2 of seabed mapped at high resolution (metre to centimetre-scale) by the Autosub6000, 400km^2 mapped with the EM710 on Rockall Bank, and 52 coring operations for geological and biological studies.

The first results of the cruise stress again the importance of a sound management of the marine realm, including the deep ocean, and underline the continuous need for detailed information and high-resolution data to underpin such management.

KEYWORDS

Habitat mapping, Autosub6000, AUV, ROV, Darwin Mounds, Rockall Trough, Rockall Bank, Hatton Basin, polygonal faults

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I

ITINERARY

Departure Govan (Glasgow): 9 May 2011
Arrival Govan (Glasgow): 12 June 2011

BACKGROUND AND SCIENTIFIC RATIONALE

1. Recovery of the Darwin coral mounds since protection from trawling in 2003

The Darwin Mounds are a field of small cold-water coral mounds or patches, each up to 75 m in diameter and 5 m high, which occur at about 1000 m water depth in the northern Rockall Trough, NW of the UK. They were discovered in 1998 (Masson et al, 2003) and initial sidescan sonar maps revealed over 300 mound features in the area. They also revealed that several mounds had been badly damaged by deep-sea trawling (Wheeler et al., 2005). Those observations eventually resulted in the closure of the Darwin Mound area to bottom trawling, first under EU emergency legislation (August 2003, based on the Common Fisheries Policy), later under a permanent measure (March 2004). The UK government is currently in the process of converting these regulations into UK national legislation, and has submitted the Darwin Mounds as one of the first candidate UK deep-water Special Areas of Conservation (cSACs) to the EU (under the Habitats Directive). However, there are indications of increased trawling activity in the area immediately before the emergency closure in 2003 (Davies et al., 2007), and the current state of the mounds is unknown, as no new seabed observations have been made since the initial discovery cruises in 1998 and 2000.

The Darwin Mounds are developed on the upstream flank of a large sediment drift body, while an extensive field of pockmarks are found on the downstream flank. It is still not clear if both sets of features may be related, e.g. representing different outcomes of fluid expulsion from the seabed (Masson et al., 2003; Huvenne et al., 2009). Detailed chirp profiles, recorded simultaneously with the sidescan sonar and/or multibeam surveys, are necessary to give insight in the structure of the sub-seafloor stratigraphy and to illustrate any potential fluid flow pathways. The seismic data should be groundtruthed with well-placed piston cores.

2. Environmental controls on cold-water coral growth on steep topography

Until now, cold-water corals have mainly been studied in reef-like settings where the interplay between current regime, sediment dynamics and food availability determine the coral habitat structure, abundance and reef-building potential (e.g. Mienis et al., 2009; Huvenne et al., 2005). However, there are other sites of significant coral occurrence in UK deep waters; Rockall Bank is key among these (Davies et al., 2006). Here, corals have been reported from steep or even near-vertical slopes where the controlling factors may have different limits, setting different constraints on the occurrence of these filter feeders. For example, frequent downslope sediment flows may seriously limit the areas available for colonisation. Vertical ecosystems have hardly been studied in the deep-sea so far, as they are impossible to sample with traditional 'over the side' equipment. The use of new tools such as ROVs and AUVs gives us the chance to look at these ecosystems in more detail than ever before, and allows us to answer questions about the corals' environmental niche.

Predictive Modelling of Species Distribution

To map the likely occurrence of vulnerable marine ecosystems (VMEs) in the deep sea, a number of spatial models have been created at the University of Plymouth. Based on previous video transects, where these habitats were encountered, the abiotic conditions were recorded and input into the models which base their predictions on factors such as slope, water mass, and depth. Generalised Linear Models (GLMs), Generalised Additive Models (GAMs) and the software Maxent are used to model the distribution of habitats such as cold water coral reefs, patchy cold water coral colonies, and deep water coral gardens (Howell et al., subm.). However, further ground-truthing is necessary, to refine the current models, to create new predictions for areas that were not mapped before and to build new models predicting the distribution of different habitats such as aggregations of the sponge *Pheronema carpenteri* or the xenophyophore *Syringammina fragilissima*.

3. Fluid seepage from polygonal faults

Sub-seafloor polygonal faulting is a widespread phenomenon affecting sedimentary basins worldwide (Cartwright et al, 2003). It is commonly believed that polygonal faulting is the result of sediment contraction and fluid expulsion, although the process behind the fluid expulsion is still under debate (syneresis, residual shear strength faulting, density inversion or gravitational collapse – see Cartwright et al. (2003) for a recent review). If, as suspected, active fluid expulsion is responsible for these features, then the composition and flux of this fluid will have a substantial impact on our understanding of the global ocean geochemical budget and carbon cycle. Recent investigations of the Hatton Bank have revealed an unprecedented region of polygonal structures that are, uniquely, exposed at the sea floor. Subsequent analysis of pre-existing seismic data reveals that these polygons occur within most of the Hatton Basin. They affect the top 500 to 700 m of sediments and are the first seabed polygons of this size and clarity to be observed (Berndt et al., 2006). The fact that polygonal deformation in the Hatton Basin reaches the seabed suggests that the formation of the polygons is ongoing. Possible carbonate crusts seen in seabed video footage suggest that fluid flow may also be occurring at the present day.

Hence this site forms a unique location to provide new constraints on the different proposed hypotheses for the development of polygonal faults. Constraining the processes of fluid flow through these structures will affect our understanding of slope stability, the marine component of the carbon cycle, and hydrocarbon reservoir integrity. If the expelled fluids transport significant amounts of carbon (as suggested by possible carbonate crusts seen in preliminary seabed video footage), the focusing of these fluids may sustain chemosynthetic benthic ecosystems. Sustainable management of such ecosystems depends on our understanding of their distribution and drivers. In addition, because the amount of expelled fluids may be extensive and even small concentrations of carbon within the expelled fluids would result in large total fluxes, the carbon flux from these systems could have an impact on models of the North Atlantic's carbon cycle, biogeochemistry and predictions for climate change.

4. Fisheries impacts on Hatton and Rockall Bank

The deep-water banks north-west of the UK are well-known fishing grounds for an international fishing fleet (e.g. Durán-Muñoz et al., 2009). A large proportion of this fishing activity is based on deep-sea trawling, which is one of the most destructive fishing methods world-wide. As the importance of ecosystem-based management is increasing, and the idea of deep-water Marine Protected Areas is becoming more common, there is an urgent need for a status assessment of the various benthic habitats in those areas. The resulting conclusions will support future conservation measures, and will form the basis of a monitoring strategy for deep-water trawled areas.

Rockall Bank cSAC

Rockall Bank is situated in the North East Atlantic, 400 km west of the Outer Hebrides. It is approximately 450 kilometres in length and 200 kilometres wide (Howell *et al* 2009). Depth ranges from over 1000m at the base of the Rockall Bank, to 200m across much of the top. On account of their sheer size, oceanic banks such as Rockall cause the deviation of ocean currents along their flanks. This facilitates the colonization of habitat-forming corals which depend on a consistent supply of current-transported organic matter and zooplankton (Freiwald *et al* 2004).

The North West area of the Rockall Bank is covered in a layer of fine sediment, gravel, cobbles and boulders of glacial origin, some of which is shaped into characteristic 'ploughmark' formations by icebergs during the last ice age. These iceberg ploughmarks are a variant of stony reef and consist of lines of cobbles and boulders with a sediment-filled furrow between (Howell *et al* 2010). The designation of Special Areas of Conservation (SACs) to protect stony reef is required under Annex 1 of the Habitats Directive (92/43/EEC). The associated biological communities are dependent on the mixed sediment and stony substratum, rather than on the underlying bedrock. Notable species include sessile fauna such as the erect bryozoan *Reteporella* sp., the solitary coral *Caryophyllia* sp, serpulid worms and many types of sponge including globose, tubular, cup and encrusting varieties. Squat lobsters (*Munida rugosa*), sea cucumbers (*Stichopus tremulus*) and the bluemouth red fish (*Helicolenus dactylopterus)* are also present (Howell *et al* 2010). *(JNCC SAC SAD)*

In 2005, ICES recommended a closure to dermersal fishing activities under EC Regulation No 40/2008 and NEAFC Recommendation IX-2008. Measures for the fisheries closure were to be enforced for the period 1 January 2007 – 31 December 2009, however this has now been extended (Recommendation IX– 2007 to NEAFC).

In 2010, the area was submitted to the EU as a Special Area of Conservation by the Joint Nature Conservation Committee (JNCC) due to the presence of stony reef. Justification for the site relied on information on the distribution of cold water corals and stony reef in the area, including data gathered by JNCC and Marine Scotland Science from 2005 to 2009. Furthermore, fishermen's records of cold water coral occurrences and suspected reef locations supplied by the Scottish Fisheries Federation and J. Hall-Spencer (pers. comm.) were also considered. The Conservation Objective for NW Rockall Bank cSAC is to restore the site to favourable condition.

The boundary of the cSAC and the fisheries closure are not aligned. In 2011, proposals to align the fishery closure area to the cSAC boundary were submitted to NEAFC through ICES working groups.

Rockall Bank Haddock Box

Following fishing survey-based indices showing a decline in the haddock fish population since 1995 and a stock historical low in 2002, the Rockall Haddock box was closed to the following demersal fishing activities; bottom trawling and fishing with static gear, including bottom set gillnets and longlines. The area is located partly in North East Atlantic Fisheries Commission (NEAFC) area and partly in EU waters. The NEAFC area has been closed since 2001 and the EU area has been closed since 2002.

The following revised coordinates became binding January 2010 (boundaries are modified according to new data providing more scientific evidence on the distribution of Haddock):

- 57° 00' N, 15° 00' W
- 57° 00' N, 14° 00' W
- 56° 30' N, 14° 00' W
- 56° 30' N, 15° 00' W

The purpose of the box is to protect juvenile haddock and to improve the selection pattern of haddock. NEAFC contracting parties, which include EU members, Denmark (in respect of the Faroe Islands & Greenland), Iceland, Norway and the Russian Federation are to take appropriate measures to ensure measures are adhered to within the fishery closure areas and to report new discoveries of cold water corals.

Preliminary analysis by ICES members suggests that the exploitation has decreased since the enforcement of the box. However no quantitative studies have been conducted to show the effects of the Haddock Box. Since the closure, the abundance of Haddock has increased but it has been recommended that the closures be renewed.

OBJECTIVES

The objectives of this cruise were:

- To investigate the different benthic biotopes listed above, including the physical environment and faunal communities
- To identify the extent of human impacts on those habitats, especially from deep-sea trawling activities
- To illustrate the effect of protection measures in the area.
- To investigate the formation of polygonal fault systems, and the potential association with fluid flow processes.

The cruise was related to and supported by the NERC MAREMAP programme, the EC FP7 IP HERMIONE (grant agreement n° 226354) and the ERC Starting Grant project CODEMAP. Additional funding to support the ROV work was obtained from the Joint Nature Conservation Committee (JNCC) and the Lenfest Ocean Program/PEW Foundation.

NARRATIVE

Sunday 8 May 2011 (JD 128)
Scientific party arrives on vessel and attends safety briefing in the afternoon. Technical team is already on board as a result of the mobilisation during the previous days. Mobilisation continues with delivery of the Hybis vehicle & connection to the deck deep-tow winch, further installation of the Autosub6000 vehicle and set-up of the Commercial Lynx ROV (SAAB-Seaeye, delivered by Hallin Marine).

Monday 9 May 2011 (JD129)
Sailed at 10.20 (0920z) from Govan, with moderate weather. It became clear that a connecting cable was missing for the ROV, and it was decided to arrange for a boat transfer in Ullapool the next day. At the same time a spare part for the ship side (kitchen equipment) would be picked up. A science meeting was held at 13.00 (1200z) and a boat drill at 16.15 (1515z).

Tuesday 10 May 2011(JD 130)
Passage was continued through the Minch, under moderately to strong winds from the SE. Installation of equipment continued, and a first daily science meeting was held at 16.00 (1500z) We arrived in Ullapool at 17.08 (1608z), and after the Caledonian ferry cleared the port at 17.20 (1620z), the MOB boat was launched to pick up the parcels. All were back on board by 19.00 (1800z), and the James Cook set sail for the first WayPoint of the cruise, the test site for the ROV and Autosub6000. At 20.00 (1900z) the PSO and R. Wynn gave a general presentation about the cruise and the wildlife that could be expected.

Wednesday 11 May 2011 (JD 131)
Clocks were put back with one hour at 02.00 (0100z), to ensure the ship's time was in line with the times we will log for the stations. At 0440z we arrived at the first waypoint, the target area for the ROV and AUV tests. A short reconnaissance survey was carried out with the EM710 shipboard

multibeam and SBP120. This was completed by 0628z, and followed by an ROV deployment. The ship was repositioned and all safety procedures were double-checked. At 0658z the ROV was deployed (Station JC060-001-ROV01) with the wideband and super sub-mini USBL beacons strapped to the vehicle and TMS for testing. The seabed was reached at 0709z, and a range of tests were carried out (cameras, arm etc.). All ROV tests were successful, and the super sub-mini beacons connected well with the Standard USBL head. The wideband beacon did not respond, but the reason for this was identified upon recovery. However, the Big USBL head did not establish connection with any of the beacons.
At 0830z the ROV was back on deck. Because Autosub was not ready for testing by that time, the passage towards the Darwin Mounds was resumed (including logging of EM120, EM710 and SBP120).
We arrived at the Darwin Mounds, WP2, at 1420z. The first deployment consisted of a CTD dip (JC060-002-CTD01), including the SVP and the wideband and Compatt5 USBL beacons for further testing. Despite initial spooling problems with the winch (due to a software reinstallation), the CTD deployment went smoothly. The USBL testing gave mixed results: the beacons worked well with the Standard Head, but the Big Head was still problematic. The CTD was back on deck at 1642z, and the new sound velocity profile was uploaded into the Kongsberg system.
Following this, we set off towards the first megacore site for Uni Aberdeen (WP3). We decided to carry out a multibeam survey underway, using the EM120 (JC060-003-SWATH01). We started the survey at 1708z and finished at 2038z. The first megacore carried 4 coring tubes (JC060-004-MC01) and was 100% successful. The core was in the water at 2046z and back on deck at 2133z. For the second megacore 2 more tubes were added (JC060-005-MC02), which again gave 100% success, and sufficient sediment for the first incubation experiment to be set up. We left the site at 2304z for a further swath survey (JC060-006-SWATH02).

Thursday 12 May 2011 (JC132)
The swath survey continued successfully until 0520z. The preparation of Autosub for launch took a little longer, so swathing was contiuned until 0705z. We were on station for the Autosub launch at 0738z, but last minute pre-dive checks indicated a problem with one of the Argos beacons. This was attended to, and by 0953z, Autosub finally was in the water (JC060-007-AUV37). The communications fish was deployed at 1020z, and the mission was started at 1045z. However, the instrument dived with the wrong heading, and the mission was aborted. Autosub was back at the surface at 1105z, and the fault was rectified through WiFi communication. Autosub dived again at 1152z. We tracked the vehicle down to the seabed, where it performed a number of test operations. It left the seabed at 1525z, arriving at the surface at 1545z. It was safely on deck by 1607z. Some of the tests were successful, while others were not. The new EdgeTech chirp profiler seemed not to have collected any consistent data, while the collision avoidance system seemed to have triggered the vehicle into diving upwards much more than necessary. One of the batteries failed. The Autosub team set out to correct the errors and to prepare the vehicle for the next dive on Friday afternoon. In the meantime we took a successful 8-tube Megacore at 750m waterdepth for the University of Aberdeen (JC060-008-MC03), out at 1855z, on deck at 1951z. This was followed by a swath survey (JC060-009-SWATH03) to finish the survey broken off this morning.

Friday 13 May 2011 (JC133)
We finished the swath survey at 0432z, and arrived at the first piston core site of the day at 0500z (JC060-010-PC01, 6m recovery). The core was in the water by 0552z and back on deck by 0726z. The next piston core (JC060-011-PC02, 6.5m recovery) was in the water at 0847z and back on deck at 0948z. Both cores contained large sections of glacigenic mud, overlain by 20 to 30 cm of contourite sand.
The next operation was the first ROV dive in the Darwin Mound area (JC060-012-ROV02), targeting the eastern mound field. It was decided to limit the dive to one video transect and a test of the new

biobox. The bathymetry collected by Autosub during its test mission formed the background for this operation. We arrived at the ROV station at 1144z, the ROV was in the water at 1200z and on the seabed by 1237z. The video quality again was fairly good, but the biobox, carried by the ROV in the manipulator, meant the ROV had to stay quite far off the seabed. Sampling did not appear very straightforward, but the ROV team managed to take a number of coral samples. Unfortunately only 2 or 3 occurrences of live coral were spotted during the entire dive – it appears as if the coral communities have not recovered after having been trawled >10 years ago. On the other hand, a high density of Xenophyophores was seen, and a large number of other species including sea urchins and sponges. A few pieces of litter were also present on the seabed.
The ROV left the seabed at 1534z and was recovered by 1635z. The next operation then was the deployment of Autosub (JC060-013-AUV38) in the western mound field (WP23). We arrived on station at 1825z, and Autosub was in the water by 1848z. After tracking it to the seabed and recording its navigation tie-in box, we left the vehicle at 2103z to WP26 for the next 8-tube megacore for the University of Aberdeen (JC060-014-MC04), at 950m waterdepth. The core was in the water by 2210z and on deck by 2328z, but only brought 6.5 cm of sand in one of the tubes. It was decided to try the site again. The second core (JC060-015-MC05) was in the water at 2341z.

Saturday 14 May 2011 (JC134)
The megacore was retrieved on deck at 0058z, but again was unsuccessful. It was decided to give up the station and move on to the next item planned, which was another piston core in the area of the sandy contourite (JC060-016-PC03, WP24). We arrived on station at 0328z, had the core in the water by 0415z and had it back on deck by 0555z. It was very successful again, recovering 6.30m. It consisted again of glacigenic mud, overlain by 20cm of contourite sands. No sign of the thick sandy contourite section recovered in D248 core 44 closeby. We then moved back to the Autosub site to check if the vehicle was performing as planned. Communication was established at 0646z, and all was normal. We could continue the programme without problem, and steamed back to the eastern mound field to deploy the ROV for a video survey (JC060-17-ROV03). The vehicle was in the water at 0854z, at the seabed by 0855z, at the end of the track by 1209z and back on board at 1249z. We came across 3 coral mounds, but hardly any live coral was found, and broken coral pieces were scattered everywhere. There were a lot of other species visible in the video, though. With the ROV on board we steamed off for the rendez-vous with Autosub. However, upon arrival, Autosub appeared to be in mid-water, circling a fair distance away from its planned waypoint. It did perform the planned navigation box, but at ~450m water depth instead of ~900m depth. In the end it was decided to make it drop its weights, and the vehicle came up to the surface (1611z), to be recovered at 1658z. A thorough investigation was carried out to find the cause of the unusual behaviour, and a number of faults were repaired. Unfortunately one of the batteries discharged beyond recovery, which will have repercussions on maximum mission lengths. With Autosub back on board safe and well, we steamed off for the next piston core (JC060-18-PC04, in water 1733z, on bottom 1750z, on deck 1816z). With 6.7m recovery, a successful core again, but very similar to the previous ones: only 27cm of sandy contourite on the top.
The piston core was followed by a second attempt to obtain a megacore at 950m depth for the incubation experiments of a Aberdeen University. A station further west was chosen, but upon arrival it appeared that the GEBCO bathymetry was not fully accurate and we had to travel another 6 miles further south to find the correct depth. The core (JC060-019-MC08, out 2233z, on bottom 2311z, on deck 2348z) was 100% successful, and allowed the scientists from Uni Aberdeen to set up their last experiment. While carrying out this coring work, we processed the first bathymetric dataset from the Autosub mission, and used this to plan the next ROV dive. The video-survey plan is created using stratified random sampling: 3 types of environment will be surveyed: mounds, tail features and background sediment. 20 mounds (out of the 129 in the western map) and 10 tails were chosen randomly, and 100m transects with random heading were created across them. We also randomly created 20 centre points in the backscatter area and created 100m transects over

them. Video survey trajectories were then created by connecting those randomised transects in the shortest possible way.

Sunday 15 May 2011 (JC135)
We started the day steaming to the next ROV dive site (JC060-020-ROV04). The vehicle was in the water at 0318z and on the seabed at 0345z. The transect lead across several mounds, some of which appeared to have been trawled (as indicated by the large number of small coral pieces) while others had larger coral frameworks. There was live coral on most of the mounds, in varying amounts & densities. The ROV left the seabed at 0858z and was on deck by 0929z. We then returned to the eastern mound field with the aim to core a mound. First attempt was by piston core (JC060-021-PC05, at site 1042z, in water 1107z, on bottom 1154z, on deck 1231z). The core was placed with high precision, using the USBL beacon and placing the centre of the ship's DP system on the starboard gantry. Still, unfortunately, we missed the target and instead retrieved the normal contouritic sand overlying glacigenic mud. In a second attempt we used the boxcore and tried to position the core even more precisely (JC060-022-BX01, WP55, in water: 1407z, on bottom: 1442z, on deck: 1512z). The core did retrieve a partly washed sample, again of the sandy contourite – but including one of the Xenophyophores which have been observed in high abundance on the mounds & surroundings. The sample was halved, and the intact half was sieved and stored for macrofauna analysis at Heriot-Watt University in Edinburgh. A second boxcore was attempted (WP56, JC060-023-BX02, in: 1559z, on bottom: 1653, on deck: 1722z), but again the contourite was sampled rather than a mound.
By that time Autosub was near to ready for deployment, and by 2013z the system was in the water. After navigation tie-in, it started its seabed mission (JC060-024-AUV39) at 2209z. Leaving Autosub to its mission, we returned to the western mound field for a boxcore, trying to obtain a sample from a mound (JC060-025-BX03, in water: 2345z).

Monday 16 May 2011 (JC136)
The boxcore reached the seabed at 0020z, and was back on deck by 0048z. Unfortunately, it was washed out. Time for another ROV dive then (JC060-026-ROV05). The vehicle was in the water by 0129z, on the seabed by 0158z and carried out a video transect across mounds, tails and background sediment. At the end of the survey (0715z) the ROV was returned to the TMS, and moved to a mound observed earlier on on the transect for some detailed photography (0741z till 0901z). Unfortunately the video data from this transect was not recorded on tape, but it provided very good photography. The ROV was back on deck at 0935z.
Having the ROV secured on deck, we steamed off for the rendez-vous with Autosub. We arrived a little early: the system still had to finish its last line, which was followed by the navigation tie-in box. After the magnetometer calibration was finished, the ascent command was given, and Autosub was at the surface by 1312z. It was on deck by 1404z.
The Autosub recovery was followed by a spell of boxcoring. The first core (JC060-028-BX04, WP74, in: 1527z, bottom: 1557z, deck: 1625z) brought up a sample that was washed on one side. It was decided to keep the undisturbed half of the core for Heriot-Watt University. The next core (JC060-029-BX05, WP75, in: 1730z, bottom: 1805z, on deck: 1835z) was unsuccessful. The sample was mainly washed out and there was no evidence of coral. Hence the core was discarded.
Before carrying out any further operations in the area, we decided to deploy 2 marker moorings on the seabed. They will be left there, and will form indicators of where we have been working, which should support future monitoring work. The first marker (JC060-029-MARK01, yellow) was in the water by 1921z and released at 2003z, using precision positioning with the Compatt5 USBL beacon. The second marker (JC060-030-MARK02, white), was in the water at 2103z and on the bottom at 2146z. As a next step we now planned to identify these beacons on the seabed using the ROV. However, due to a problem with the tether, the ROV deployment was delayed, and two more boxcore attempts at WP75 were carried out. (JC060-031-BX06, in: 2241z, bottom: 2313z, on deck

2342z; JC060-032-BX07, in: 2352z, bottom: 0033z, on deck: 0102z). Unfortunately, both attempts failed.

Tuesday 17 May 2011 (JC137)

By 0220z finally the ROV was put in the water, but it developed a power fault and was taken out almost immediately. A second attempt was carried out at 0257z, and finally upon the third attempt (0319z) the ROV could be launched properly and descended to the seabed. Some extra checks were carried out at a depth of 500m and at 20m off the seabed (0345z). The first task for this survey (JC060-033-ROV06) was to locate the white marker bouy, which was found more or less immediately. From there a video transect was carried out and the ROV left the seabed at 0958z. It was back on board by 1032z. With deteriorating weather predicted, we now carried out a set of cores, targeting mounds that had shown a large proportion of dead coral on the video data. The first boxcore (JC060-034-BX08, WP93, on station: 1044z, in water: 1107z, on bottom: 1149z, on deck: 1215z) had a partial recovery, and was sieved & stored for qualitative analysis. As the site proved to contain coral, we decided to take a piston core, in an attempt to obtain a core section through a mound (JC060-035-PC06, WP93, in: 1305z, on bottom: 1413z, on deck: 1458z). The core was successful, with 4.5m recovery, of which at least 3 to 3.5m contains coral fragments in a sandy matrix. The lowermost part of the core again contained the regionally typical glacigenic mud. Because of the coral content, the core will need to be frozen and split with a rocksaw to avoid dragging coral fragments through the stratigraphy with the cheese-wire. In addition, the sandy matrix contained a lot of water, so we decided to freeze the core straightaway, to avoid the slushing water in rough seas destroying the stratigraphy. This meant that the core was cut into shorter sections than usual, to allow storage in the -80 chest freezer.

Following this success, we tried the boxcore again at the same location (JC060-036-BX08, WP93, in: 1537z, on bottom: 1621z, on deck: 1649z), and this time it was successful. A further boxcore was taken at WP94 (JC060-037-BX09, in: 1739z, on bottom: 1804z, on deck 1834z), again successful. Similarly, as the site proved to be a coral-bearing mound, we took a second piston core (JC060-038-PC07, in 1934z, on bottom: 2004z, on deck: 2041z), again successful(~6m). The core was treated like the previous one, cut into 1m sections, and the coral-containing sections were placed in the -80 freezer. Finally, we obtained another boxcore at this location (JC060-039-BX10, in: 2124z, on bottom: 2158z, on deck: 2227z), with success. This was our last operation before we left the study area to seek shelter east of the Isle of Lewis as heavy weather with 8m waves was predicted for the next 36 hours.

Wednesday 18 May 2011 (JC138)

We sailed towards Lewis through the night and arrived in Broad Bay by 1020z. It became clear that we would have to shelter for a considerable amount of time, hence our partners in the MAREMAP programme were contacted to ask for potential study sites in the northern Minches. This would allow us to spend our time in a more constructive way rather than just waiting for the weather to blow over. A few suggestions were brought forward by JNCC and by BGS, and it was decided to carry out an SBP and multibeam survey in the Bay of Stornoway the next morning. In the meantime the delivery of a spare transformer coil for the Hybis vehicle to Ullapool was also arranged for.

Thursday 19 May 2011 (JD139)

We left Broad Bay at 0600z to steam towards the survey site in the Bay of Stornoway. We ran 2 crossing lines over BGS borehole BH78/4 (JC060-040-SWATH04, start: 0809z, end: 1152z), using the EM710 and SBP120. We also recorded a reciprocal line for calibration purposes. Once the survey was finished, we set sail for Ullapool (1246z), to pick up the transformer part for Hybis. We arrived in Ullapool at 1630z and left by 1830z, sailing towards the northern end of East Shiant Bank to carry out a multibeam survey with the EM710 again (JC060-042-SWATH05). This would form the basis for an ROV dive the next day, as requested by Scottish Natural Heritage via JNCC. At the start of the survey we first deployed an XBT to obtain a sound velocity profile (JC060-041-XBT01, at 2024z)

Friday 20 May 2011 (JD140)

We continued the EM710 survey until 1017z, with very good results, especially for the backscatter. Based on this dataset, we chose 3 short transects, 600 to 700m each, to groundtruth the different backscatter types with the ROV. The dives (JC060-043-ROV07, in: 1042z, bottom: 1047z, off: 1222z, on deck: 1226z; JC060-044-ROV08, in: 1310z, bottom: 1316z, off: 1440z, on deck: 1450z; JC060-045-ROV09, on station: 1532z, in: 1550z, bottom: 1556z, deck: 1710z) crossed grounds from bioturbated mud with *Nephrops*, over sandy grounds to gravel and boulders with attached filter feeders. The different habitats correlated very well with the multibeam backscatter intensity.
After the last dive we went back to multibeam surveying (JC060-046-SWATH06, start: 1726z).

Saturday 21 May 2011 (JD150)

The swath survey continued until 0425z, when we broke up to move back to the Darwin Mounds. The EM710 kept recording until 0700z, when we pulled up the drop keel. We attempted to collect data during the further transit over the shelf, but by 0854z both the multibeam and SBP120 data were of such bad quality that it did no longer make sense to record data.
We arrived at the eastern Darwin Mounds at 1816z, and started work with an XBT (JC060-047-XBT02). Next we deployed a boxcore on a mound which appeared trawled in the sidescan sonar dataset from D248 in 2000 (JC060-048-BX11, WP131, on station: 1819z, in: 1820z, on bottom: 1914z, on deck: 1943z). The core was partly successful and half of it was sieved for Heriot-Watt Uni. As next operation we deployed 2 more marker bouys (JC060-049-MARK03, WP132, grey, in: 2015z, released: 2109z; JC060-050-MARK04, WP133, black, in: 2219z, released: 2300z). We added 2 settling plates (based on terracotta roof tiles) to each of them, at a height of 0.5 and 1m above the bottom.

Sunday 22 May 2011 (JD151)

With the bouys deployed, we steamed on to the western mound field again, to deploy the Autosub for a high resolution sidescan sonar survey of the same area we had obtained multibeam and low-res sidescan sonar data from before (JC060-051-AUV40). The vehicle was in the water by 0120z and was followed to the seabed for its navigation tie-in. Once that was completed, we sailed back to the eastern mounds for an ROV video survey, starting from one of the marker bouys (JC060-052-ROV10, on site: 0410z, in: 0427z, on deck: 0442z). However, the system encountered technical problems that could not be repaired instantaneously, and the ROV dive thad to be given up. As alternative, we reverted to boxcoring. The first site (WP150) needed two attempts as the core did not trigger correctly on the first deployment (JC060-053-BX12, on station: 0625z, in water: 0634z, on bottom: 0724z, on deck: 0755z; JC060-054-BX13, on station: 0841z, in water: 0846z, on seabed: 0926z, on deck: 0955z). We then moved to WP151, one of the largest and strongest backscattering mounds in the eastern mound field, and deployed the boxcore again (JC060-055-BX14, on station: 1021z, in: 1029z, on bottom: 1113z, on deck: 1140z). Unfortunately the core was not successful: most of the sediments had washed out by the time it reached the surface. A few pieces of dead coral were left, and one large piece was kept for further study (coral species and age). We decided to try to core this mound with the piston core, to look at the history of mound build-up, but as the technicians were building up the core and preparing for deployment, the weather deteriorated rapidly, with the wind picking up to gusts of 45kn. All operations were stopped out of safety considerations, and the ship was put head in the wind, slowly travelling into the direction of the Autosub rendez-vous. At the peak of this short storm, wind gusts up to 63kn were measured, and a very confused sea state developed. However, the storm disappeared nearly as quickly as it had started, and although 3 hours later than planned, we managed to meet up with Autosub at the predicted location. By the time we arrived, the vehicle had surfaced already, and was easily spotted (2144z) in the reducing evening light thanks to its 2 flashing strobe lights. The scientific team helped the crew on the bridge to keep the vehicle in sight until the sea had calmed down sufficiently for the recovery (0020z).

Monday 23 May 2011 (JD143)
Autosub was back on deck by 0100z. As the sea state had calmed down enough, the next operation on the programme was another attempt at ROV video surveying in the eastern mound field (JC060-056-ROV11). The engineers had spent several hours the day before to repair the problem with the wich slip-ring and the vehicle was ready to go. The ROV was in the water by 0308z and at the seabed by 0405z. However, there was too much heave on the ship, transferred down to the TMS, to work safely. In addition, there was a very strong current at the seabed (as also experienced earlier while positioning the boxcores with the USBL system), and the dive was abandoned. It took the pilot nearly one hour to park the ROV back into the TMS garage, and it was 0556z by the time the system was back on deck.
As alternative we reverted back to coring, starting with the piston core at WP151 which we did not manage to take the day before (JC060-057-PC08, on station: 0633z, in: 0642z, on bottom: 0729z, on deck: 0820z). However, also the piston core at this location failed: some coral fragments were retrieved and stored for dating, but the sediment washed out. We decided to move to a different mound (WP152) and try again with the boxcore (JC060-058-BX15, on station: 0855z, in: 0902z, on bottom: 0935z, on deck: 1003z), but also this core was largely washed out. It showed how much coarser the sediments in the eastern mound field are compared to the western field.
With this last boxcore on board, it was again decided to give up furhter operations because of deteriorating weather conditions. Although more work could be done in the Darwin Mound area, it was decided to move to the next study area (Hatton Basin) while the weather was unworkable, and to start work there as soon as possible. We were on transit from 1021z.

Tuesday 24 May 2011 (JD144)
The passage to Hatton Basin continued for the entire day. At first, the ship was heading in a west-northwesterly direction to create the safest course possible, avoiding the worst weather. At 1100z, the course was adapted to west-southwest, heading for the study site in Hatton Basin more directly.

Wednesday 25 May 2011 (JD145)
We arrived at WP154 in Hatton Basin at 0920z, and used the EM120/SBP120 to verify existing bathymetry data from the area to find the right location for coring and CTD work. The main aim was to study a triple junction between 3 polygonal faults, using piston core, megacore and CTD. By 1313z we had located a suitable triple junction, and were on station for the first CTD, including an SVP (JC060-059-CTD02, in: 1343z, bottom: 1424z, on deck: 1528z). Once on deck, the niskin bottles were subsampled for methane and Dissolved Inorganic Carbon (DIC). The CTD was followed by a piston core (JC060-060-PC09, WP158, in: 1605z, on bottom: 1646z, on deck: 1736z) at the same location. We recovered 8.7m of core, which were split in 50cm sections in order to be analysed in the glove bag.
Next, we deployed Autosub again for a mission of multibeam bathymetry and high-resolution sidescan sonar recordings over a triple junction and part of a polygon (JC060-061-AUV41, WP159, on station: 1825z, in: 1917z, navigated and on its way: 2118z). Unfortunately, the sea state was still too rough to carry out an ROV dive, so we resorted to EM120 surveying (JC060-062-SWATH05). But also here the sea state caused difficult conditions, and no useful heading could be found on which both reciprocal survey directions would give good data. Instead data was recorded in one direction only.

Thursday 26 May 2011 (JD146)
We broke off the EM120 survey at 0919z, to add in a piston core to the programme before picking up Autosub. The core (JC060-063-PC10, WP177, on station: 1011z, in: 1031z, on bottom: 1105z, on deck: 1158z) was located at the centre of the polygon, and was a great success: 13.5m of core for

geochemical analysis. The stratigraphy was very similar to PC09: a sequence of darker and lighter deposits, probably representing colder and warmer stages, with a lot of bioturbation. While positioning this core, we alreay tracked the Autosub on the USBL system. It turned out that the vehicle was running late on its track, hence it was decided to cut the mission short with an hour, to allow enough time for ROV surveying later. At 1310z, Autosub was at the surface and by 1344z it was on deck. We immediately proceeded to deploy the ROV on a transect across the triple junction and across the first piston core site (JC060-064-ROV12, on station: 1421z, in: 1425z, out: 1550z). Unfortunately, when the system arrived at the seabed, there was a problem with the spooling of the tether, and the ROV had to be brought up again. The problem was solved fairly quickly, and at 1557z the vehicle was back in the water (JC060-065-ROV13: in: 1557z, bottom: 1631z, off: 2059z, deck: 2143z). The short delay had given us the time to process the first bathymetry data from Autosub Mission 41, and the videosurvey transect was adapted slightly to look at a number of features identified on the bathymetry. Two potential pockmarks were investigated, the first one turning out to be a large dropstone with associated scour mark, the second one indeed being a pockmark with a large number of boulders and gravel at the bottom. No indication of active seepage was seen (bubbles, shimmering water, bacterial mats), but the sediment drape on the boulders was very limited, which suggested potential recent flow. The rest of the transect was fairly homogeneous, although a depth zonation could be seen in the benthic communities. After crossing the triple junction twice, it was decided to bring the ROV on board and relocate to a different feature identified on the bathymetry data. A short dive was carried out there (JC060-066-ROV14, in: 2227z, bottom: 2300z, off: 0000z, on deck: 0046z), focussing on a large and enigmatic rock with associated fauna (octopus, *Lophelia* coral, wolffish). The setting and shape (large number of circular holes) of the rock were puzzling, and detailed investigation of the video & photo data will be necessary to identify its origin and role.

Friday 27 May 2011 (JD 147)

After the ROV was recovered, we set out to piston core the pockmark discovered during ROV dive 13. However, by the time the ship was in position and the core was rigged up, the weather conditions had deteriorated, and the operation was delayed by 2 hours. By 0328z the ship was back on station, and the core could be taken (JC060-067-PC11, in: 0351z, bottom: 0436, deck: 0517z). It was successful, and recovered 3.6m of sediment, including a layer of small gravel pieces at the top. A CTD was taken at the same location (JC060-068-CTD03, in: 0636z, bottom: 0731z, deck: 0820z). This was followed by a Megacore at WP158, the first piston core & CTD site of yesterday (JC060-069-Mega07, in: 0845z, on bottom: 0927z, deck: 1001z). Also the second core site from yesterday (WP177) was complemented with a CTD (JC060-070-CTD04, in: 1054z, bottom: 1154z, deck: 1225z) and a megacore. The latter had to be repeated as not enough sediment was recovered in the tubes to provide a sensible geochemical profile in the shallow seafloor (JC060-071-Mega08, in: 1258z, bottom: 1340z, deck: 1419z; JC060-072-Mega09, in: 1432z, bottom: 1511z, deck: 1547z). By that time the weather conditions and sea state had deteriorated to a level that made over-the-side work quite difficult. With worse weather to come, it was decided to stop the work in the Hatton Basin and to move on to the next study area, Rockall Bank. We started our transit at 1647z

Saturday 28 May 2011 (JD148)

The transit continued until ca 0834z in the morning, the ship travelling with the sea. At that point we had already passed the study area, so the ship turned back into the wind and slowly hoved towards the first waypoint. However, the sea state was still too severe for any work to be carried out (up to 6m swell), and the scientific team had to stay on standby until 1900z, when work restarted with an SBP120 line to identify 3 piston coring sites across the Rockall Bank Mass Flow headwall scarp (studied by the Irish representative from the Universiy College Cork). Unfortunately the course with heading 215° caused too many bubbles under the hull, and the data was of such poor quality that it was decided to travel to the northern end of the line and run the geophysical survey in the opposite

direction. By 2029z we then turned to a heading of 152°, which produced good data. The survey finished at 2231z, when the first coring site was reached.
The first piston core (JC060-073-PC12, on station: 2224z, in: 2301z, on bottom: 2335z, deck: 0011z) used a 9m barrel, and failed. The corer sheared at the junction between the 6 and 3m barrel.

Sunday 29 May 2011 (JD149)
It was decided to try coring the same site again with a 6m barrel. Unfortunately, again, the core cutter sheared off and the core was unsuccessful (JC060-074-PC13, in: 0122z, bottom: 0157z, deck: 0243z), although there was again a 3.7T pull-out, indicating the corer had gone into the sediment. The next core was rigged up, but before it could be deployed the windspeed increased considerably and the weather situation was considered unsuitable for further piston coring. Again the ship hoved to, avoiding the worst of the weather. By 1141z the situation had ameliorated enough to start the transit back to the next point of work. It was decided to avoid piston coring for a while, and to try collecting megacore samples inside and outside of the Haddock Box protected area, for macrofauna analysis carried out at the University of Aberdeen.
The first station was reached at 1615z, but the deployment of the megacore was stopped immediately because of a problem with the winch. The ship's engineers tended to the problem immediately, but by 1830z no solution was found, so it was decided to return to piston coring (using the plasma rope instead of the metal coring wire). A different site was chosen compared to this morning, and a 12m barrel was rigged (JC060-075-PC14, on station: 2036z, in water: 2051z, on bottom: 2121z, on deck: 2154z). Unfortunately, also this site proved difficult, and the barrel came back bent. A short core section of 0.5m was rescued, containing Holocene sand overlying muddier sediments with dropstones.
As the coring wire was still not repaired, and the sea state was still too high to carry out any ROV work, we resorted to multibeam mapping of an area crossing the boundary of the Haddock Box protected area, to prepare for a potential AUV mission tomorrow (JC060-076-Swath06, start: 2358z, end: 1209z).

Monday 30 May 2011 (JD 150)
The EM710 swath survey continued throughout the morning, as the engineers tended to the winch problem, while the coring techs devised an alternative method for megacoring, using the plasma wire. By lunchtime, however, the winch problem was solved in a sense: using parts of the plasma winch, the winches driving the coring wire and CTD wire were repaired. As things stand for the moment, the plasma wire will no longer be required throughout the cruise, and we reverted fully back to the traditional steel wire. This was immediately used for a megacore (JC060-077-MC10, WP199, on startion: 1336z, in: 1356z, bottom: 1417z, deck: 1437z), at ca. 500m water depth inside the Haddock Box. However, the core came back empty, with only a few pieces of shell debris and coarse sand stuck to the frame. A second attempt (JC060-078-MC11, WP197, station: 1524z, in: 1535z, seabed: 1555z, deck: 1619z) gave the same result, and a third deployment confirmed our impression that the seabed in this area is too coarse for megacoring (JC060-079-MC12, WP198, station: 1658z, in: 1700z, seabed: 1719z, deck: 1739z).
The next operation on the list was another mission for Autosub, crossing the boundary of the protected area (JC060-080-AUV42, launched: 2006z). Once the navigation tie-in was carried out, we returned to coring for the University of Aberdeen, in a last attempt to gather samples for macrofauna analysis, this time using the boxcore. However, the first boxcore (JC060-081-BX15, WP199, in: 2319z, seabed: 2339z, deck: 2356z) failed.

Tuesday 31 May 2011 (JD151)
Two more boxcoring attempts were undertaken (JC060-082-BX16, WP197, in: 0045z, seabed: 0107z, deck: 0126z and JC060-083-BX17, WP198, in: 0213z, seabed: 0233z, deck: 0253z), but they did not bring back anything better than a washed out sample of coarse sand and shell hash. It was decided

to give up on the sampling for macrofauna in this area, and we steamed back to the Autosub rendez-vous point. Upon arrival (0552z), Autosub was contacted without problem, and the vehicle was on deck by 0700z. By that time the sea state had calmed down to such extent that we could deploy the ROV for a short dive to groundtruth the high-resolution sidescan sonar that Autosub had collected (although by that time the data was still downloading from the AUV, so the ROV dive track had to be chosen randomly). We decided to first groundtruth the seabed inside the Haddock Box, hoping for a further chance of a second ROV dive outside the box later on. Dive 15 (JC060-084-ROV15, station: 0745z, in: 0750, seabed: 0801z, off: 0946z, deck: 1006z) showed us a sandy seabed with glacial dropstones of all sizes, inhabited by urchins, hermit crabs carrying anemones, a variety of fish species and holothurians. Unfortunately, several of the holothurians appeared damaged, and evidence of broken cold-water corals was seen. Later on today, once the sidescan sonar data was processed, it became clear that trawling continues in the area, both inside and outside the Haddock box.

However, the wind picked up to speeds exceeding 30kn, and further ROV operations were put on hold. We waited in the area for a potential weather window later on that day, but by 1545z it became clear that the conditions would not get much better within the foreseable future. The weather forecast predicted even more gales and a 5 to 6 m high swell, so we decided to use that time period for passage to the northern side of the Rockall Bank, the next area where we planned to work.

Wednesday 01 June 2011 (JD152)

We arrived at the N Rockall Bank at 0036z and started an EM710 survey of an area within the Fisheries closure straightaway (JC060-085-Swath07). To obtain reasonable quality data in both survey directions, we offset the swath lines by 45° from the overall direction of the swell, which resulted in E-W directed lines. The survey carried on until 2013z, when we prepared to deploy Autosub (JC060-086-AUV43). The vehicle was in the water by 2127z, and was followed to the seabed for the usual navigation tie-in. Once we were happy with its movements and performance, we moved to a second survey area on the N Rockall Bank, just outside the Fisheries closure, but within a section proposed for further protection by JNCC. There we started a second EM710 survey (JC060-087-Swath08) at 2355z.

Thursday 02 June 2011 (JD153)

The swath survey carried on until the morning, although it was suspended shortly at 0407z, when the ship appeared to have snagged a longline (probably on the dropkeel). By 0418z the line was successfully shaken off, and the survey continued, although with avoidance of the area where fishing gear was spotted. No further incidents occurred until the end of survey at 1125z, when we came on station to pick up Autosub. Although the weather conditions were fairly rough (4m wave height, up to 30kn wind speeds), the recovery went fairly smooth. The vehicle was at the surface at 1250z and was on deck by 1328z.

However, the weather conditions were still too rough to deploy the ROV, hence we resorted back to multibeam surveying, this time of a third area, in slightly deeper water, again on the edge of the Fisheries closure, in an area where JNCC suggests to extend the protection. We started the survey at 1545z (JC060-088-Swath09), but suspended the swath work shortly for a CTD and SVP (JC060-089-CTD05, WP219, in:1709z, bottom: 1729z, deck: 1752z), before carrying on with the swath.

Friday 03 June 2011 (JD154)

We carried on gathering bathymetry data until 0526z, when we repositioned to deploy Autosub in the area (JC060-090-AUV44). We arrived on station at 0554z, and after the last safety checks, Autosub was in the water at 0614z. We followed it to the seabed, carried out the navigation correction, and finally left it for its mission at 0742z.

Next operation on the schedule was a set of ROV dives to ground-truth the Autosub sidescan sonar data from Mission 43. However, upon arrival on station (0921z), the ship encountered a problem with the azimuth thruster, and all operations were put on hold until this was repaired. Unfortunately, a thorough investigation showed that the azimuth thruster could not be repaired during the cruise. This poses a serious limitation to the operations, especially with the ROV and AUV, with regard to weather and sea state. But luckily, the weather improved throughout the day, and after some tests the captain was happy to carry out the ROV operations using the DP system with the other thrusters & propellors of the ship. This meant that by 1243z, the ROV was in the water (JC060-091-ROV16, seabed: 1254z, off: 1522z, deck: 1545z) for a very informative dive. We encountered large cold-water coral colonies in between the boulders and sand fields of the iceberg ploughmarks that are so characteristic for this area. The colonies seemed in good state and no evidence for trawling was seen. The thickets had a distinctly assymetric appearance with live coral on the southern side and dead coral on the northern side, indicating that the coral grows towards a food source that is brought in from the south. There were a large number of juvenile fish, plus some large adult specimens (ling). The dive was shortened a little to allow a second dive to sample the coral (JC060-092-ROV17, in: 1639z, seabed: 1647z, deck: 1748z). The ROV took a number of samples of dead coral from the northern side of coral thickets, in an attempt to date the thickets, and took one colony of live coral from the southern side. The samples were placed in the sample box, but on the ascent of the ROV, the box was ripped of its handle by the swell, and all samples were lost.
Following this negative result, we decided to limit further work in this area to video surveying, and a short dive was added with this respect (JC060-93-ROV18, in: 1832z, seabed: 1841z, off: 1955z, deck: 2005z). We then sailed off at full speed to meet up with Autosub. We arrived just in time when Autosub finished its work. The command to surface was given, and the AUV was spotted at 2148z. The vehicle was on board by 2213z after a smooth recovery, despite the lack of the azimuth thruster.

Saturday 4 June 2011 (JD155)
With Autosub back on board, we went back to EM710 mapping (JC060-094-Swath10, start: 0028z, end: 0646z), this time focussing on the shallower area forming the eastern boundary of the fisheries closure area, expanding the area we surveyed two nights ago. The survey finished when the ship repositioned for the next Autosub deployment (JC060-095-AUV45, on station: 0648z, in: 0717z). This was again followed by ROV work in the boundary area to the west of the fisheries closure (JC060-096-ROV19, station: 1033z, in: 1045z, seabed: 1055z, off: 1329z, deck: 1343z). A second dive was carried out in the area immediately after the first one (JC060-097-ROV20, on station: 1407z, in: 1425z, seabed: 1435z, off: 2016z, deck: 2029z). Both dives showed a very different seabed compared to yesterday, with a lot of broken coral in between patches of gravelly sand and boulders, scarred by trawlmarks.
Once the second dive was finished, it was time to head off again to pick up Autosub. The vehicle was at the surface at 2330z, and was on board at 0030z.

Sunday 5 June 2011 (JD156)
By now we are getting into a routine of Autosub deployments, ROV dives and swathing, and today was no different. With Autosub back on board, we set out to fill the gap between two areas of EM710 swath recorded before (central fisheries closure area and eastern edge) (JC060-098-Swath11, start: 0057z, end: 0849). This was followed by another Autosub mission, back in the western area, however this time focussed on a technical test for the CODEMAP project (JC060-099-AUV46). The aim is to collect data of the same patches several times with the high-res and low-res sidescan and the multibeam, under different angles of incidence, and to see if automated image analysis techniques would classify the seabed differently between the different passes. Ideally it shouldn't, as the seabed will not change significantly within the time-span of the mission, so this procedure should test the sensitivity of the classification algorithms.

The ROV work that followed was also slightly different: it focussed on the steep cliffs on the NE edge of Rockall Bank. Two transects were laid out to test predictive habitat models produced by the University of Plymouth. The first dive (JC060-100-ROV21, station: 1343z, in: 1345z, seabed: 1417z, off: 1600z, surface: 1624z, back in water: 1628z, off: 1831z, deck: 1852z) started at ca. 830m depth and slowly worked its way up the steep flank of the bank. At a water depth of ca. 625 (in the middle of an area of very abundant coral growth) a technical fault was encountered, and the ROV needed to be brought up to the surface to reset the camera. It was brought back to the seabed shortly after and the transect was resumed. The second dive (JC060-101-ROV22, in: 1917z, seabed: 1938z, off: 2100z, deck: 2121z) targeted the same cliff, slightly further to the south-east. The models did not indicated this area as having a high probability of coral growth, but large amounts of coral were encountered nonetheless. Once the ROV was on deck, we sailed back again to the Autosub station.

Monday 6 June 2011 (JD157)

Autosub was at the surface at 0023z and on board by 0054z. The rest of the night was filled again with EM710 survey (JC060-102-Swath13, start: 0109z, end: 0503z), finishing off the survey we set out the day before. At that stage, the sea state had come down to 2, and it was decided to test the HyBIS vehicle (JC060-103_Hybis1). For most of the cruise, there have been problems with the HyBIS transformer, but by now the team had re-wired the light circuit to it, and were ready for a wet test. We were on station at 0519z, and HyBIS was in the water at 0616z. It reached the seabed by 0630z, and carried out a video transect until 0802z. The system worked well and no major problems were encountered, except for the fact that in 200m water depth all the heave was transferred directly to the vehicle, which caused some difficulties in keeping the seabed in focus. Also sampling was rather difficult because of this effect. HyBIS was back on deck by 0812z.

We immediately moved to the next ground-truthing site, which we inspected with the ROV (JC060-104-ROV23, station: 0836z, in: 0856z, seabed: 0901z, off: 1459z, deck: 1512z). The 6-hour dive took us across bedrock, gravel & boulders, sand patches and finally over some very rich cold-water coral 'shrubberies'. We decided to bring up the vehicle and to repositon to another area of coral growth to sample some live and dead coral (JC060-105-ROV24, station: 1528z, in: 1540z, seabed: 1551z, off: 1643z, deck: 1659z). Ben Boorman had constructed a new sampling device, this time based on a laundry bag. With a little difficulty, the system worked, and the ROV sampled several pieces of live and dead coral. The live samples were stored in ethanol for genetic analyses, and the dead coral fragments will be dated with ^{14}C. By the time this dive was finihsed, weather conditions were deteriorating again, and we left the Rockall Bank on our way back to the Darwin Mounds. On the way out there we planned a swath and SBP survey over George Bligh Bank to support GEBCO (JC060-106-Swath13, start: 1707z, end: 2205z), but this meant sailing straight into the weather. The data quality was non-existent, and it was decided to give up this survey and sail straight to the Darwin Mounds.

Tuesday 7 June 2011 (JD158)

The entire day was spent on passage to the Darwin Mounds, the course directly into the weather making progress slow and difficult

Wednesday 8 June 2011 (JD159)

Passage towards the Darwin Mounds continued until well into the afternoon, when we reached the western boundary of the protected area. We restarted the scientific work with a couple of megacores in this area, just inside the fisheries closure zone. The cores will be used by the University of Aberdeen to compare macrofauna infauna communities inside and outside the protected area. This study was originally planned for the 'Haddock box' on Rockall Bank, but the coarseness of the substrate in that area prevented us from mega- and boxcoring, and the study was relocated to the Darwin Mounds. Two core deployments were carried out (JC060-107-MC13, in: 1719z, seabed:

1748z, deck: 1813z; JC060-108-MC14, in: 1835z, seabed: 1904z, deck: 1930z). Both were successful (7/8), and the top 10 cm was sieved in 2 sections on a 250 micron sieve and stored in formalin.
From there we sailed straight through to the eastern Darwin Mound field to deploy the Autosub for a high-resolution mission (JC060-109-AUV47, in: 2151z, out: 2334z). However, when the command was given for the vehicle to dive, it developed a fault with the actuator of the stern plane, and the dive had to be given up. With Autosub back on board, we moved on to an ROV dive.

Thursday 9 June 2011 (JD160)
The ROV was in the water shortly after midnight (JC060-110-ROV25, in: 0034z, seabed: 0104z, off: 0925z, surface: 1004z), and a long transect was carried out in the eastern Darwin Mound field, groundtruthing several mounds and tails. The transect also passed by one of the marker bouys left out there earlier on in the cruise. Most of the coral mounds appeared dead, with large amounts of coral fragments and dead coral.
With the ROV back on board, we deployed Autosub again for a slightly altered mission (JC060-111-AUV48). This then gave us time to collect more megacores for the University of Aberdeen. Four megacores were collected back to back (JC060-112-MC15, station: 1421z, in: 1437z, seabed: 1506z, deck: 1535z; JC060-113-MC16, in: 1709z, seabed: 1735z, deck: 1758z; JC060-114-MC17, in: 1816z, seabed: 1842z, deck: 1906z; JC060-115-MC18, in: 1924z, seabed: 1954z, deck: 2019z). Each core carried 8 tubes, which all came back with a >30cm sample.
After this megacore 'frenzy', we went back to the western Darwin Mounds, to take one more piston core through a mound (JC060-116-PC14, in: 2230z, deck: 2336z). Unfortunately the winch guiding the piston core cradle failed, and the core could not be deployed. It was decided to leave the station and head for the Autosub recovery point.

Friday 10 June 2011 (JD161)
Autosub reached the surface at 0218z, and was on deck by 0311z. We then moved on to the last station of the cruise, another ROV ground-truthing transect (JC060-117-ROV26, in: 0405z, seabed: 0435, off: 0910z, deck: 0945z). Again the transect started at one of the marker bouys, and worked its way across an area with lots of scattered coral, mound and non-mound related.
Once the ROV was on deck and secured, we set sail for the Minch and ultimately for Govan.

Saturday 11 June 2011 (JD162)
The clocks were moved forward to BST overnight. The entire day was spent on passage to Govan under favourable weather conditions. The scientific team used the day to pack all equipment and samples, clean all the labs and back up all data.

Sunday 12 June 2011 (JD163)
Further passage to Govan. We picked up the pilot at 06.00 (0500z), and docked in Govan at 08.30 (0730z).

EQUIPMENT and SAMPLING REPORTS

1. Autosub6000

1.1. Mission Summary
There were a total of 10 successful science missions. 123 km^2 were surveyed over a period of 173 hours with a combination of LF (120 kHz) , HF (410 kHz) Sidescan, EM2000 multibeam and a digital mono stills camera.

For each mission, the navigation was tied in at the start using the range only navigation technique. When in bottom tracking range the AUV executed a square course of 250 m (for shallower missions) or 500 m side (deeper missions), while we tracked its range from the ship using the Linkquest USBL system, and simultaneously tracking the AUV position to the ship. In most cases, the navigation correction so obtained was transmitted directly to the AUV; hence the navigation data used in these missions was already corrected.

Table 1.1. below is a record of the navigation corrections which were measured, and whether they were applied in the mission. Table 2 is a general summary of all the missions.

Table 1.2. is a general summary of the Autosub6000 missions on JC060.

Table 1.1 . Record of Range Only Navigation (RoN) corrections.

#	Range only Nav (RoN) correction at the start. East , North (m)	Whether corrected at start of mission	RoN at end of mission. Or USBL check This is not sent to the AUV, hence is not in the navigation file. East North (m).
37	-30 , 50 m	No. Data poor quality because ship was long way off the waypoint (> 1 km).	No – short mission.
38	-	No correction at mission time. RoN failed due to problem logging ships data.	No . AUV mission aborted due to depth control fault.
39	184.9 , 192.4	Yes	-16, -38
40	125.9, 5.5	Yes	No , Navigation box missed due to weather conditions
41	82.6, 56.8	Yes	No
42	32.9, -23.0	Yes	No
43	37.0, 13.0	Yes	No
44	-12.3, 16.0	Yes	No
45	-17.1, 20.1	Yes	No
46	16.2, 35.9	Yes	No
47	NA	Abortive mission	No
48	-6.0, 217.2	Yes	No

Table 1.2. Autosub6000 Missions Summary

#	Start date & time [GMT]	Duration Hrs	Loc.	Start	Max Depth [m]	km travelled surveying	Survey Mode	Area Surveyed [km^2]	Notes on mission
37	12/05/2011 11:39	3.8	EDM	59.8678 N 7.0580 W	1036	n/a	n/a	n/a	Initial shakedown test mission. On first attempt at dive the AUV headed off in the wrong direction – rudder installed incorrectly. Noise affecting the obstacle avoidance caused erratic depth control. Tail lifting lines had come out before recovery.
38	13/05/2011 19:13	22.8	WDM	59.8143 N 7.3806 W	943	83.3	EM2000 LFSSS	14.4	Sternplane failure near the end of mission causing large depth excursions
39	15/05/2011 20:01	17.2	EDM	59.8502 N 7.1151 W	1015	66.6	EM2000 LFSSS	25.2	Multibeam and side scan survey of the Darwin mounds.
40	22/05/2011 01:30	19.8	WDM	59.8252 N 7.3995 W	969	79.9	EM2000 HFSSS	15.5	The AUV ran out of power while circling at the end of the mission dropping abort weights and then surfaced.
41	25/05/2011 19:03	17.9	PFA	58.1747 N 16.4458 W	1163	77.3	EM2000 HFSSS	16.8	AUV ran out of energy and aborted during surfacing
42	30/05/2011 19:55	10.5	RB	56.6689 N 14.0124 W	405	43	HFSSS	6.9	Concerns that one battery was not discharging caused us to reduce the mission length. In practice the battery functioned normally.
43	01/06/2011 21:15	15.6	RB	57.9669 N 13.9982 W	219	69	HFSSS	12.0	All ok.
44	03/06/2011 06:38	15.0	RB	58.0863 N 14.1754 W	319	68.9	HFSSS	12.0	All ok.
45	04/06/2011 07:02	16.5	RB	57.8504 N 13.9704 W	179	70.7	HFSSS	13.0	All ok.
46	05/06/2011 09:26	15.6	RB	58.0708 N 14.1790 W	322	60.7	EM2000 HFSSS	n/a	Hires SS, camera and multibeam evaluation mission for the CODEMAP project.
47	08/06/2011 21:59	0.8	EDM	59.8430 N 7.0442 W	789	N/A mission was terminated	HFSSS	N/A mission was terminated	The mission was terminated due to the control plane failing in a similar fashion to Mission 38.
48	09/06/2011 10:16	17.2	EDM	59.8491 N 7.1143 W	1053	65.7	HFSSS	10.8	All ok.

1.2. Autosub6000 Data Descriptions

Table 1.3. is a data description of the comma separated data files for the low rate Autosub6000 navigation and sensor data. The file has a single row header of the variable names, and then the data in comma separated columns.

Table 1.3. Data description for the Autosub6000 'M0xx_ScienceData.CSV'

Variable	**Units**	**Description**
Date		Date of record to nearest day
Time		Time of record to the nearest second
ExcelTime	days	Time as defined by Excel. Days since 1/1/1900 (imports directly into excel date: time).
Seconds		Seconds since first record in file.
Latitude	Deg	AUV Latitude
Longitude	Deg	AUV Longitude
depth	m	AUV Depth
Altitude	m	AUV altitude above the seafloor. Max ADCP range ~200m. Values of 1000m mean out of range of the seafloor
Roll	Rad	AUV roll. Using the yaw/pitch/roll Euler angle sequence
Pitch	Rad	AUV pitch. Using the yaw/pitch/roll Euler angle sequence
Heading	Rad	AUV heading. Using the yaw/pitch/roll Euler angle sequence
WaterSpeed	m/s	AUV speed through the water determined from the ADCP bins
GroundSpeed	m/s	AUV speed over the ground determined from the DVL
MagX	microTesla	Magnetometer raw X-value reading
MagY	microTesla	Magnetometer raw Y-value reading
MagZ	microTesla	Magnetometer raw Z-value reading
Temperature	°C	Magnetometer temperature
MagX_cal	microTesla	Magnetometer calibrated X-value reading
MagY_cal	microTesla	Magnetometer calibrated Y-value reading
MagZ_cal	microTesla	Magnetometer calibrated Z-value reading
T1	°C	CTD Temperature 1
T2	°C	CTD Temperature 2
C1		CTD Conductivity 1
C2		CTD Conductivity 2
Depth	m	CTD depth
DO	V	CTD – Dissolved oxygen reading
LSS	V	CTD – Light scattering sensor reading
EH	V	CTD – EH Sensor reading
rho1	Kg/m^3	CTD – Calculated density1 using the seabird program
rho2	Kg/m^3	CTD – Calculated density2 using the seabird program
Pres	Pa	CTD – Pressure
S1		CTD – Salinity1
S2		CTD – Salinity2
pTmp1	°C	CTD – Potential temperature1
pTmp2	°C	CTD – Potential temperature2
CorMg0	none	Correlation magnitude for bottom track
Inten0	0.24dB	Beam 1 signal intensity
Veast0	mm/sec	Side velocity bin for bottom track. In AUV frame of reference. If AUV is moving to port, then this number is positive
Vnorth0	mm/sec	Forward velocity in AUV frame. Forward motion produces a negative value for this

Vdown0	mm/sec	Down velocity. AUV motion down produce negative result.
Verr0	mm/sec	Error velocity.
ADCPVersion	none	Version number
ADCPRev	none	Revision
HeadBias	0.01 deg	Always 0
NumWatPings	none	Number of water pings per ensemble. Always 1.
CellSize	Cm	Cell size in cm. (e.g. 800).
BlankSize	cm	Blanking period in cm.
NumCells	none	Number of water track cells
MinThresh	none	
HeadAlign	0.01 deg	Heading align (critical to navigation)
Salinity	sal_units	Fixed salinity for ADCP sound velocity correction (e.g. 35).
SoundSpeed	m/sec	Speed of Sound that the ADCP calculates at zero depth (T and S correction only)
ADCPTemp	°C	Temperature measured at the ADCP head
Inten3_1	0.24dB	Beam 3 signal intensity
Inten1	0.24dB	Beam 1 signal intensity
Veast1	mm/sec	Side velocity bin 1. In AUV frame of reference. If AUV is moving to port, then this number is positive
Vnorth1	mm/sec	Forward velocity in AUV frame. Forward motion produces a negative value for this
Vdown1	mm/sec	Down velocity. AUV motion down produce negative result.
Verr1	mm/sec	Error velocity.

Each ADCP bin has its own : Inten3_**Y**, Inten**Y**, Veast**Y**, Vnorth**Y**, Vdown**Y**, Verr**Y** where **Y** is the bin number . There are 15 bins in the ADCP configuration for JC060.

1.3. Autosub6000 Camera system and Image Meta data file Description.

Table 1.4. is general information on the Autosub6000 mono digital camera and flash system.
Table 1.5. contains meta data for all the images for the mission v". It will load into excel automatically as comma separate variables. '.csv' .

Table 1.4. General information for Autosub6000 Camera and Images:

Camera	
Type	Prosilica GE1380
Sensor	Sony ICX625 mono CCD
Pixels	1360 x 1024.
Pixel Spacing	6.45 µm
Imager Size	8.77 mm x 6.60 mm
Size of seabed Pixel	Altitude (m) *0.0645 (with flat port – assumed 1.33 water magnification))
Size of Seabed frame (long side)	Altitude (m) * 0.864 (with flat port)
Position	2 m ahead of vehicle centre
Lens	75 mm , *f*1.8 Navitar
Camera Mount Angle	Inclined aft at 14 degrees to vertical. Optimised for 15 m altitude (image short axis is reduced in length by 3%)
Frame rate	Once per 20 seconds.
Frame format: Archive	16 bit tiff (raw)
Processed images	8 bit tiff processed with removal of constant averaged

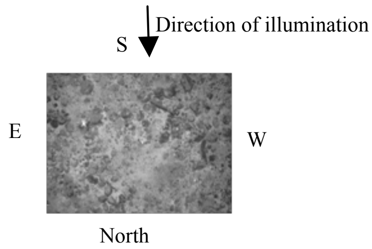
	backscatter frame, application of adaptive histogram equalisation (contrast enhancement and flattening of illumination), and 2 D wiener filter (noise reduction)
Geometry of the stored frames. When the AUV is travelling due north, the frame is :	
Flash	
Type	Canon 580
Zoom setting	105 mm (full) (with flat port)
Manufacturer Claimed guide number	58 m (@ 100 ISO equivalent).
Input electrical energy	50 Joules
Position	2 m aft of AUV centre

Table 1.5. Fields for imageData.csv. This file contains meta data for all the images for the mission v". It will load into excel automatically as comma separate variables. '.csv' .

FIELD	DESCRIPTION
Time	Time of frame in excel format (days since 1900). Just format the imported data as date time.
GoodFrame	Is 1 for an altitude <22 m (assumed good frame). Is 0 otherwise
MeanPixel	The mean pixel amplitude for each frame *before any contrast enhancement of filtering.* 3.6 counts corresponds to one detected electron. The photon efficiency is 0.6 at 450 nm.
Altitude_m	Altitude of AUV in m. Is set to 'NaN' if no data (> 180 m altitude)
AUVdepth_m	AUV depth in m.
WaterDepth_m	The water depth is AUV depth plus AUV altitude. (NaN if no valid
Latitude_deg	The decimal Latitude in degrees
Longitude_deg	The decimal Longitude in degrees
Pitch_deg	AUV pitch (positive is nose up) in degrees
Roll_deg	Roll (positive is starboard down)
Heading_deg	Heading (positive clockwise from north)
Frame_Filename	The Frame Filename. The Filename is e.g. *8bit_bsremoved31052011_071654.tiff.* The number in the filename is the time (Autosub logger time) that the frame was taken. In format: ddmmyyy_hhmmss

Following recovery of the AUV and its data, a Matlab script calculates a backscatter frame from up to 40 frames where the altitude is > 30 m and < 200 m. It then removes this frame from all the frames, applies an adaptive histogram for contrast stretching and flattening of illumination, and finally a Weiner 2 D noise filter, before scaling and saving the data to a 8 bit tiff.

1.4. Sonar devices installed on Autosub6000

This was the first occasion that the Edgetech 2200- FS sub bottom profiler with sidescan option had been used on Autosub6000.

The system consists of a dual 120 kHz, 410 kHz sidescan system, with a 2 to 15 kHz sub bottom profiler. The one way beam width is reported to be 0.3 degree for the 410 kHz, and 0.8 degree for the 120 kHz.

Mission 37 tests proved that the Edgetech sidescan system and the EM2000 cannot be simultaneously operated in mutually asynchronous mode due to interference between the SS and Multibeam. We arranged for subsequent missions that these operated in mutually exclusive mode, the operation of each controlled via mission script commands.
The high frequency sidescan proved to be the most useful for the requirements of the science missions, with its ability to distinguish coral mounds and trawl marks. For most missions, this was run at a repetition rate of 6 Hz (maximum possible range of 125 m). In practice the range obtained was 90 to 125 m depending on the type of terrain (flat sedimented giving minimum range).
The EM2000 multibeam returned a surprisingly large 410 m swath width when flying at 100 m altitude. This corresponds to a total angular width of 128 degrees, which is 8 degrees higher than specification. This needs investigating. This is presumably due to a configuration setting.

1.5. Subbottom profiler performance on Autosub Missions 37 to 48

For Missions 37 to 40 inclusive, both the transmitter and receiver arrays for Edgetech sub bottom profiler were installed in the free flooded tail section of the AUV, requiring the sound to pass through a 3 mm thick glass fibre reinforced plastic panel.
The system was set up with a 2 to 15 kHz , 0.005 second pulse. The results from this arrangement were disappointing (Fig. 1.1. left hand trace), with low signal/noise and for the later missions, three changes were made:

1) The receive transducers were moved from the tail section to an open position under the AUV syntactic foam centre section. The transducer spacing port to starboard was 50 cm. The centre of the receive array was 120 cm forward of the transmitter transducer. The problems which could arise from the non co-location of the receiver and transmitter array acoustic centres were appreciated, but back of envelope calculations suggested that the problems resulting from the receive array directivity should not be excessive, and in any case, there was no other location option, and it was considered imperative to try something to improve the very poor signal / noise.
2) A hole was cut below the transmit transducer (covered with plastic tape). Of all the mitigations, this is thought least likely to have had an effect on the system signal / noise.
3) That the system was transmitting at full power was checked. No evidence could be found that the system had not been transmitting at full power, and it was thought likely that it was. Information regarding the system set up is recorded in the Edgetech system data files, but we do not have, at the moment, the software to read this information.

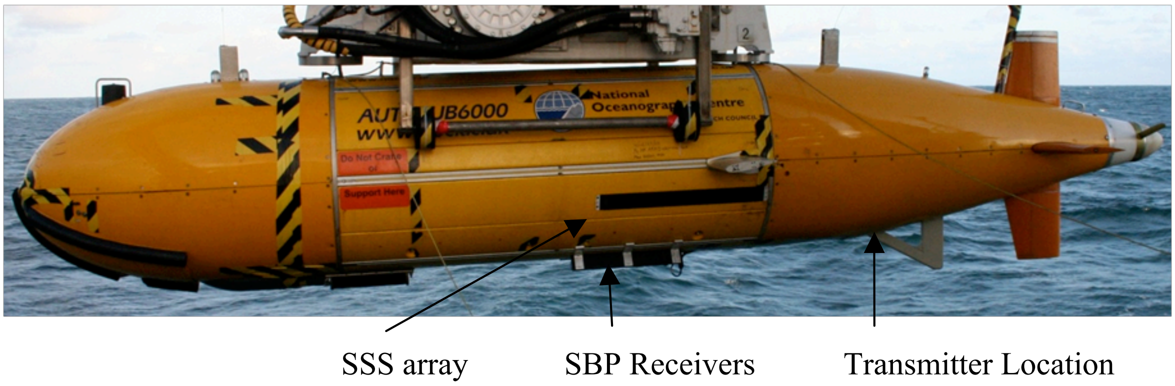


Figure 1.1. The Side Scan Sonar and Sub Bottom Profiler array positions on Autosub6000

The results showed a dramatic improvement, in both the signal level and the noise level. Figure 1.2. contains before and after figures for SBP results of similar types of seabed, before and after the changes were made.

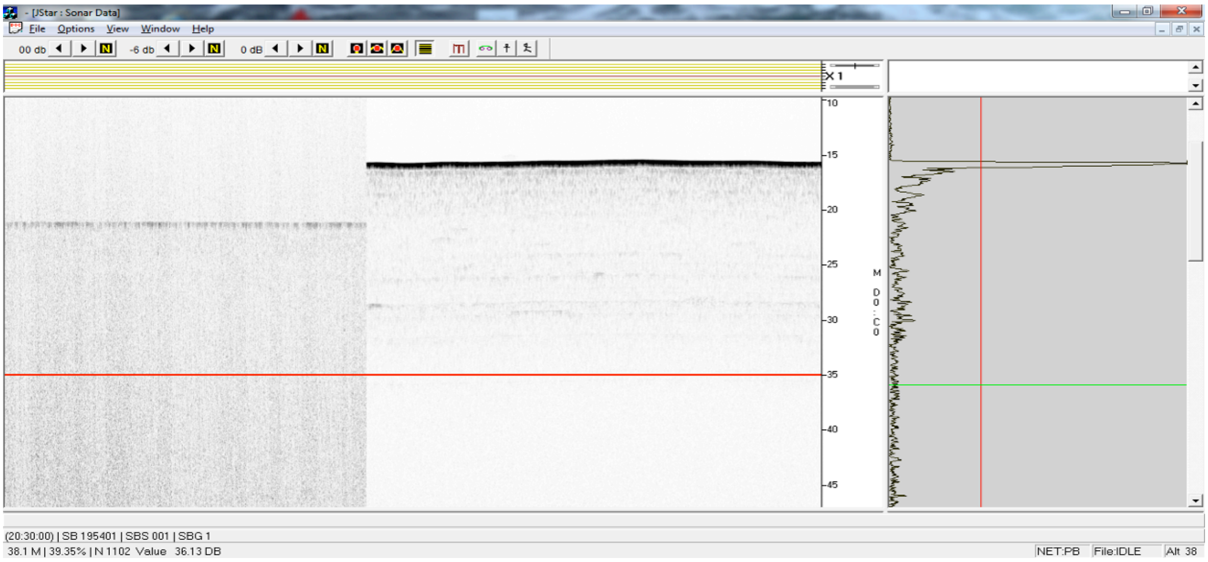


Figure 1.2. Before and after plots. 1st half of plot is from mission 41 (before changes), 2nd for mission 48. The Survey areas are very similar. Vertical scale is metres. Playback gain settings are identical.

Table 1.6. Before and after comparison for the Edgetech SBP system on Autosub6000. The noise level was ~ 16 dB less after moving the hydrophones. The signal level was 10 dB higher. The range vs distance loss for the seabed signal is assumed to be 20 log(R)

Mission	***Area***	***Flying Altitude***	***Noise at 15 m range***	***Seabed signal***	***Signal corrected to 20 m***	***Signal/ Noise (comparative)***
41	Hatton Basin	20 m	15 dB	32 dB	32 dB	17 dB
48	Darwin Mounds	15 m	-1 dB	45 dB	42.5 dB	43.5 dB

Recommendations for use of the Edgetech SBP on Autosub.

- Use as long a pulse as possible given the water depth.
  Suggested pulse length (ms) < Altitude (m) (this gives 33 % margin).
- Site the receive transducers external to the rear section. It would be ideal to mount theses into the centre section syntactic foam.

Sonar.ini setting for Edgetech Systems on Autosub6000 JC060

```
; Explanation of this file can be found in Sonar.txt ion the Edgetech Documentation.
; Config for M41. All raw data logging disabled by changing NCHAN entries and
; commenting out the [SUBnIOx] sections where n is subsystem and x is the
; IO channel section.

[Main]
NETWORK_QUEUE_SIZE=5000
Config=ATAPI_SBSS
;CompressNet=1
AutoEther=0

;===========================================

[SUB0]
TriggerMask=1                 ; Trig A INput
TriggerOutLength=30000
;NCHAN=1                      ;Processed data only
NCHAN=2                       ;Includes raw data loggin
OneWindowForEntireSubsystem=1
```

```
[Sub0IO1]
MFDataSource=0
DACChan=-2
ADCChan=0
DATA_TYPE=2
DATA_NETWORK=0

[SUB1]
TriggerMask=1
;AutoPulseMode=1
NCHAN=2
;NCHAN=4 includes 2 channels of raw data logging
OneWindowForEntireSubsystem=1
PING_TRIGGER=2
TriggerSystem=0

[SUB1IO2]
;MFDataSource=0
;ADCChan=8
;DATA_TYPE=2
;DATA_NETWORK=0

[SUB1IO3]
;MFDataSource=1
;DACChan=-2
;ADCChan=9
;DATA_TYPE=2
;DATA_NETWORK=0

[SUB2]
TriggerMask=1
TriggerOutLength=30000
;AutoPulseMode=1
NCHAN=2
;NCHAN=4 includes 2 channels of raw data logging


OneWindowForEntireSubsystem=1
PING_TRIGGER=2
TriggerSystem=0

[SUB2IO2]
;MFDataSource=0
;ADCChan=12
;DATA_TYPE=2
;DATA_NETWORK=0

[SUB2IO3]
;MFDataSource=1
;DACChan=-2
;ADCChan=13
;DATA_TYPE=2
;DATA_NETWORK=0

[DSP0]
;TimeSyncMask=2


[File] - Store and Forward

PrimaryDrive=E:
BaseName=\DATA\DATA
MaxFileSize=500
MaxFileTime=900
FileQueueSize=5000
```

1.6. Autosub Sensor Configuration

The sensor suite fitted to Autosub6000 is listed in Table 1.7. Figures 1.3 to 1.12. show the installation of the CTs, Oxygen, Eh, camera and flash, multi beam, side scan and sub bottom profiler. Each CT assembly was mounted on the inside of the nose panel with a 40mm (i.e. short) length of tube plumbing the water outside the vehicle to the temperature sensor (Fig. 1.3.).

The magnetometer was mounted fore/aft on top of the nose frame using plastic Tie Wraps, tape, cradles and screws to minimise the magnetic fields in the immediate vicinity of the instrument (Fig. 1.4.).

The Edgetech sub bottom profiler (SBP) was mounted in the tail section with the transmitter and receivers initially transmitting/receiving through the GRP panel. Early missions showed difficulties with the data and after Mission 41, a hole was cut in the panel beneath the transmitter and the receivers were mounted outside the vehicle on the centre section (Fig. 1.11, 1.12.).

Table 1.7. Autosub sensor suite for JC0060

Description	Part No.	Source	Serial No.
CTD Port Temp	90565	Sea Bird	03P5009
CTD Port Cond'	90468	Sea Bird	043499
CTD Stbd Temp	90465	Sea Bird	03P5071
CTD Stbd Cond	90468	Sea Bird	043566
Oxygen sensor	90599.2	Sea Bird	431582
CTD Pump Port	90544	Sea Bird	055125
CTD Pump Port	90544	Sea Bird	055238
CTD Logger	90538.042	Sea Bird	09P52764-0930
EH Sensor		Ko-ichi Nakamura	
Magnetometer		Applied Physics Inc. (NOCS-USL integration)	
Light Scattering Sensor (LSS)		Sea Point	
300 kHz ADCP		RDI-Teledyne	
Depth sensor	NOC dwg No A5952	Digiquartz Inc.	
Camera	GE1380	Prosilica Inc. (NOCS-USL integration of Camera and Flash gun).	
Flash	Canon 580	Canon (NOCS-USL integration)	
Multibeam	EM2000	Kongsberg	
Side scan, Sub bottom profiler	2200 –M	Edgetech	

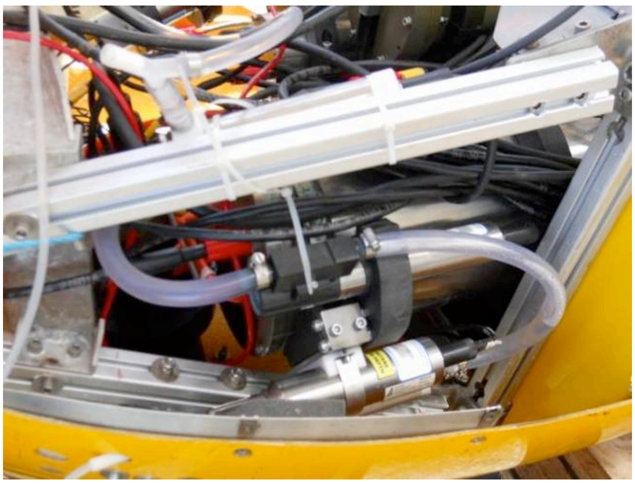


Fig. 1.3. Port CT (mounted below the panel split line) and Oxygen sensor uppermost

Fig. 1.4. Magnetometer mounted on top of nose frame, avoiding magnetic materials where possible. Shown here across the vehicle, moved 90 degrees in line with vehicle and to port side before cruise to reduce magnetic effect of the Argos batteries (just in shot at bottom RH corner)

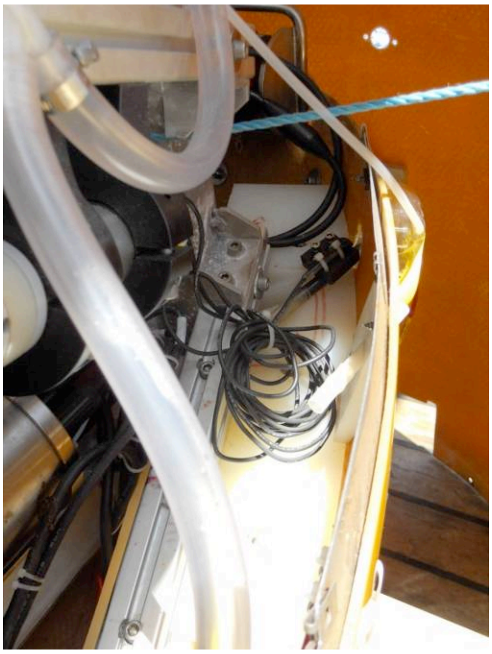


Fig. 1.5. EH sensor on starboard side protruding through panel

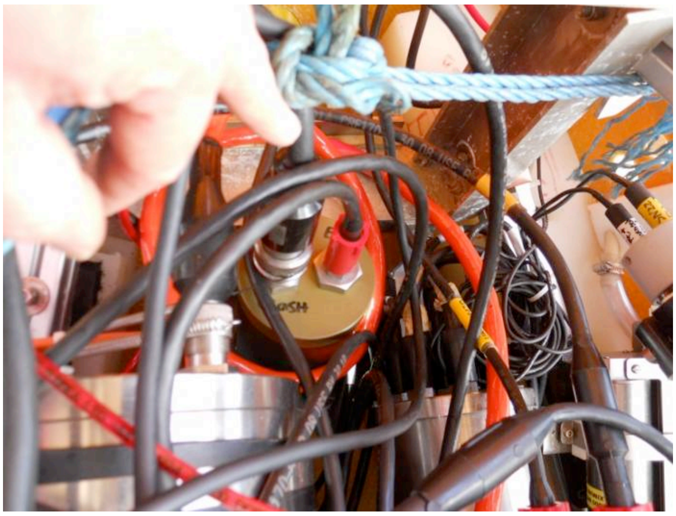


Fig. 1.6. Looking down into the nose section at the camera unit (at end of finger)

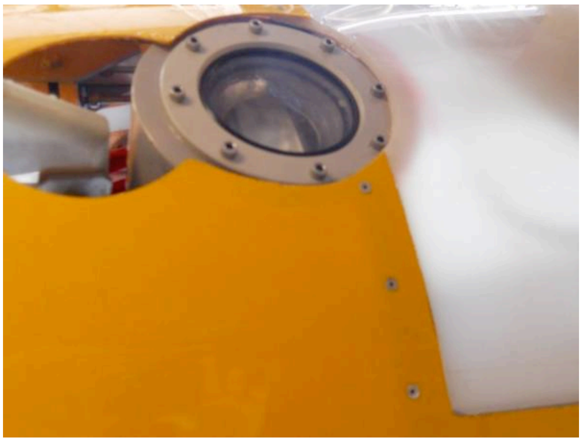


Fig. 1.7. Looking upwards at the flash unit in the tail section

Fig. 1.8. EM2000 Multibeam mounted beneath nose panel

Fig. 1.9. Edgetech electronics mounted in the tail

Fig. 1.10. Edgetech Side Scan inset into the centre buoyancy blocks just below the winglets

Fig. 1.11. Looking up at the tail section, 'bumble bee' tape covers the aperture cut after mission 41 for the sub bottom profiler transmitter

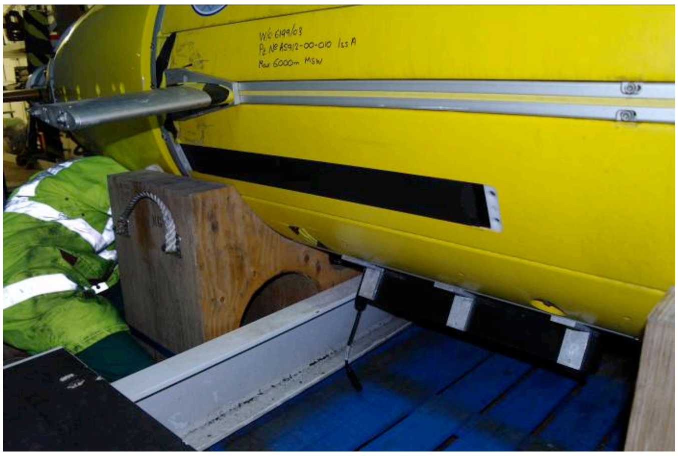


Fig. 1.12. Sub bottom profiler receivers (bottom of photo) mounted outside vehicle after mission 41

1.7. Launch and recovery

The new Lawson Engineering Ltd gantry was used for the first time, mounted on the aft deck toward the port side. The equipment performed well and launch and recoveries were without drama. The system seems more robust than the MKII with much less twisting of the head system, and an absence of disturbing noises. Issues with overly sensitive winch speed controls need dealing with before the next cruise.

Fig. 1.13. The Autosub6000 MKII L&R system installed on the aft deck of the RRS James Cook.

Steve McPhail, Peter Stevenson, Miles Pebody and Maaten Furlong

2. Geophysical data processing

Eight types of sonar data were processed, cleaned and mosaiced:

1. Autosub EM2000 Multibeam Bathymetry (111 beams)
2. Autosub EM2000 Multibeam Backscatter (200kHz)

3. Autosub Edgetech Low frequency Sidescan (120kHz)
4. Autosub Edgetech High frequency Sidescan (410kHz)
5. RRS James Cook EM120 Multibeam bathymetry (101 beams)
6. RRS James Cook EM120 Multibeam backscatter (12kHz)
7. RRS James Cook EM710 Multibeam bathymetry (400 beams)
8. RRS James Cook EM710 Multibeam backscatter (70-100kHz)

Processing was mainly done in CARIS HIPS v7.0 and PRISM v4.0. PRISM programs and scripts are shown in italics and for fuller information see the PRISM manual (Le Bas, 2004). Many of the scripts however have been created, improved or updated since this date and for these help and usage parameters are available on-line.

Not all systems were run at the same time and thus the table below should assist:

Table 2.1. Overview of shipboard and Autosub-based bathymetry, backscatter and sidescan sonar surveys

Area	EM2000 Bathy	EM2000 Backs	Edge Low	Edge High	EM120 Bathy	EM120 Backs	EM710 Bathy	EM710 Backs
Test							✓ (10m)	✓
Darwin Mounds					✓ (50m)	✗ poor		
M37	✓ (1m)	✓ (1m)	✗					
M38	✓ (2m)	✓ (1m)	✗					
SNH survey							✓ (2m)	✓ (2m)
BGS survey							✓	✓
M39	✓ (2m)	✓ (50cm)	✓ (50cm)					
M40				✓ (20cm)				
Hatton					✓ (50m)	✗ poor		
M41	✓ (2m)	✓ (50cm)		✓ (50cm) (2cm)				
Rockall (east)							✓ (20m)	✗ (2m)
M42				✓ (20cm)				
Rockall north							✓ (10m)	✓ (2m)
Rockall mid							✓ (10m)	✓ (2m)
Rockall NW							✓ (10m)	✓ (2m)
M43				✓ (50cm)				
M44				✓				

				(50cm)				
M45				✓ (50cm)				
M46 (repeatability)			✓	✓				
M48				✓ (50cm) (5cm)				

2.1. Autosub EM2000 Multibeam Bathymetry (111 beams)

A project was created for each area and data imported in CARIS HIPS. Initially zero tidal correction was used. A sound velocity profile was input but the software was unable to cope with AUV depth and was therefore not used. The data was gridded using a BASE (Bathymetry Associated with Statistical Error) grid of 1 or 2m. Editing of the data for attitude, navigation and swath errors was done on the raw data, with 3D editing on geographical surface subset. The data was generally of good quality, with little noise. However, cross cutting tracks showed an offset of a couple of metres. This was assumed to be tidal variation and a graph was constructed of differences in height over time, which gave a reasonable tidal curve (e.g. for mission M39 below) and this was applied

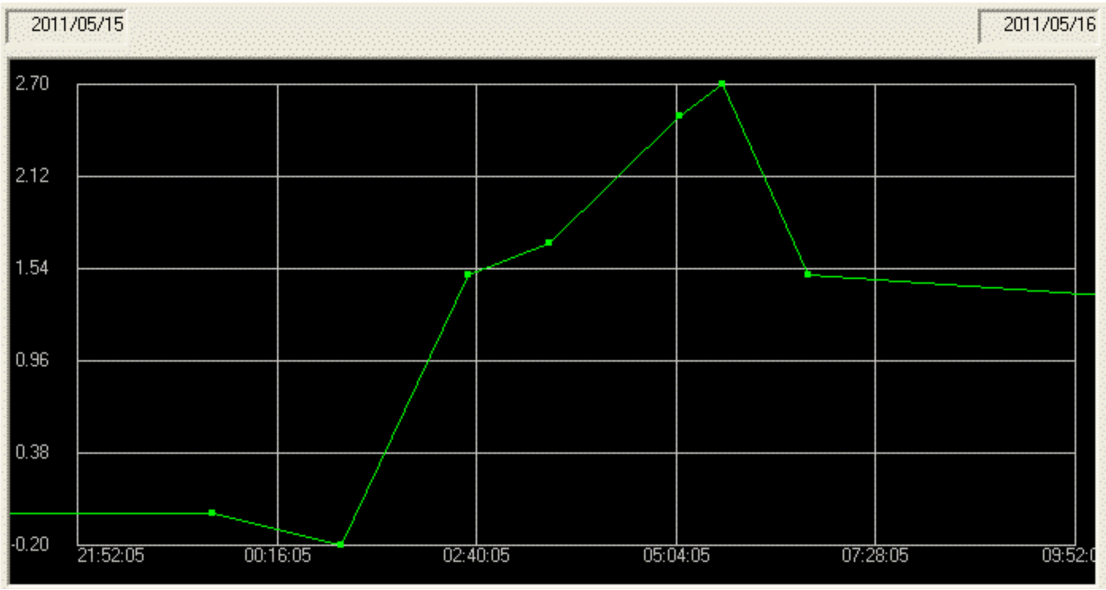


Fig. 2.1. Tidal correction curve for Autosub Mission 39. Base level is relative to one point and not to LAT.

2.2. Autosub EM2000 Multibeam Backscatter (200kHz)

Processing of the Multibeam backscatter was done in PRISM. Transfer of data to PRISM was done via the Neptune replay system which converts the Raw.all files to Proc format which can be read by PRISM. Unfortunately the internal names in the Raw.all files were set to a single value and thus conversion to proc produced the same filenames for every file, i.e. overwriting them. Therefore each file had to be converted individually to proc and then to CDF (PRISM format).

Navigation was extracted from the CDF files (*do_make_nav*), and the map areas chosen with overlapping edges (*maptile*). Sonar processing and geometrical correction used a 45º course deviation factor for segments and either 1m or 50cm resolution. Overlap of coverage was eliminated by direction priority and range location parameters (*prismrange*). Processing commands were:

mrgnav -i %1 -o %0 -n navfile.nav -l 0,0
filter -i %1 -o %0 -b 1,21 -z -v 130,255
filter -i %1 -o %0 -b 1,301 -h -v 130,255
filter -i %2 -o %0 -b 31,301 -L -v 130,255
wtcombo -i %2 , %1 -o %0 -c 1,1 -a -128
restorehdr -i %1 -h %5
resol -i %2 -o %0 -r res -a
shade -i %1 -o %0 -n 128 -t 1,254

Results were collated in ERDAS Imagine and mosaiced into a single image. Overlapping map edges were feathered and thus removed minor radiometric differences which are otherwise visible to the human eye. Overall position of the resulting grid could be biased according to Autosub positioning offsets.

2.3. Autosub Edgetech Low frequency Sidescan (120kHz)

This was a new source of data. Data was slowly downloaded from the Autosub disks, typically taking about 6 hours per dive to download (about 2 minutes for 100Mb). The data files contain the low and high frequency sidescan data as well as the chirp sub-bottom profiler. The Edgetech Discover 4200-FS software was used to convert the .jsf format data into XTF format. This has the advantage of viewing the data whilst being converted. Occasionally the data conversion would pause for several minutes for no apparent reason and either then continue processing or jump to another file. Jumps in data were later found to be present and it is assumed that there is a data corruption in the original datafile, possibly missing bytes in the data structure.

Conversion of the sidescan is tempered by the gains set on the video display and thus were set to:
Low Freq: Gain 11dB TVG 1dB/100m
Low Freq: Gain 8dB TVG 5dB/100m (M46 onwards)

The XTF data were then converted into PRISM format (CDF) using the *reson2prism* program. The original data have a sample rate of 3.456cm but as the ping rate was 2Hz (75cm) the data were averaged and subsampled by a factor of 5 to 17.28cm. Initially data files were given 4000 samples per side but later reduced to 2250 to reduce unnecessarily large filesizes.

Navigation was obtained separately from Autosub data files. It was found that there was a drift and offset of the Edgetech clock relative to the Autosub clock which had to be corrected. It could be calculated from start and end times or from matching features on the seafloor as seen by the sidescan imagery. Vehicle heading was not recorded in the data and thus track heading was used and swath direction was calculated to be perpendicular to this value. Vehicle altitude was also not available and was therefore measured from the first return (*do_alt*).

Sonar processing and geometrical correction used a 45º course deviation factor for segments and a 50cm resolution. Overlap of coverage was eliminated by direction priority and range location parameters (*prismrange*). Processing commands were:

```
mrgnav_inertia -i %1 -o %0 -u 0 -r 0.0,0.0 -n navfile.veh_nav
tobslr -i %1 -o %0 -r0.1728 , res #  400 range
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
lowpass2b2 -i %2 -o %0
restorehdr_tobi -i %1 -h %3
widealt -i %2 -o %0 -h -l 500
```

Results were collated in ERDAS Imagine and mosaiced into a single image. Overlapping map edges were feathered and thus removed minor radiometric differences which are otherwise visible to the human eye. The final mosaic was of very good quality for the resolution. Some interference from the ADCP(?) is visible at ranges beyond 100m but does not affect much of the data, and may be able to be removed with further investigation as it is symmetrical on both sides of the imagery.

2.4. Autosub Edgetech High frequency Sidescan (410kHz)

As mentioned previously in the Low frequency section these data were converted via the Discover 4200-FS software, though the gains used were:

High Freq: Gain 30dB TVG 7dB/100m
High Freq: Gain 25dB TVG 15dB/100m (M44 onwards)

The XTF data were then converted into PRISM format (CDF) using the *reson2prism* program. The original data have a sample rate of 1.152cm but as the ping rate was 6Hz (25cm) the data were averaged and subsampled by a factor of 5 to 5.76cm. Initially data files were given 4000 samples per side but later reduced to 2250 to reduce unnecessarily large filesizes.

```
addnav -i %1 -o %0 -s 4.0
widealt -i %1 -o %0 -p
tobslr -i %1 -o %0 -r0.0576 , res #  high freq 110m 6 Hz subsamp 5
mrgnav_inertia -i %1 -o %0 -u 0 -r 0.0,0.0 -n navfile.veh_nav
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
```

Results were collated in ERDAS Imagine and mosaiced into a single image. Overlapping map edges were feathered and thus removed minor radiometric differences which are otherwise visible to the human eye. The final mosaic was of excellent quality for the resolution. Many shadows were seen and thus vertical height of features can be calculated.

Much of the imagery was processed at 50cm resolution for speed of processing but the data could be processed at a much higher resolution. A small test area was processed at 2cm resolution. This gave good results though only showed slightly more detail. Typically at 50cm resolution the processing took about 1 hour and gave a 100Mb image where as at 20cm this took 4 hours and produced a 400Mb image. It is suggested that small "chosen" areas 250m by 250m are processed at 5cm resolution using the factor 5 subsampled and averaged raw imagery to its fullest potential.

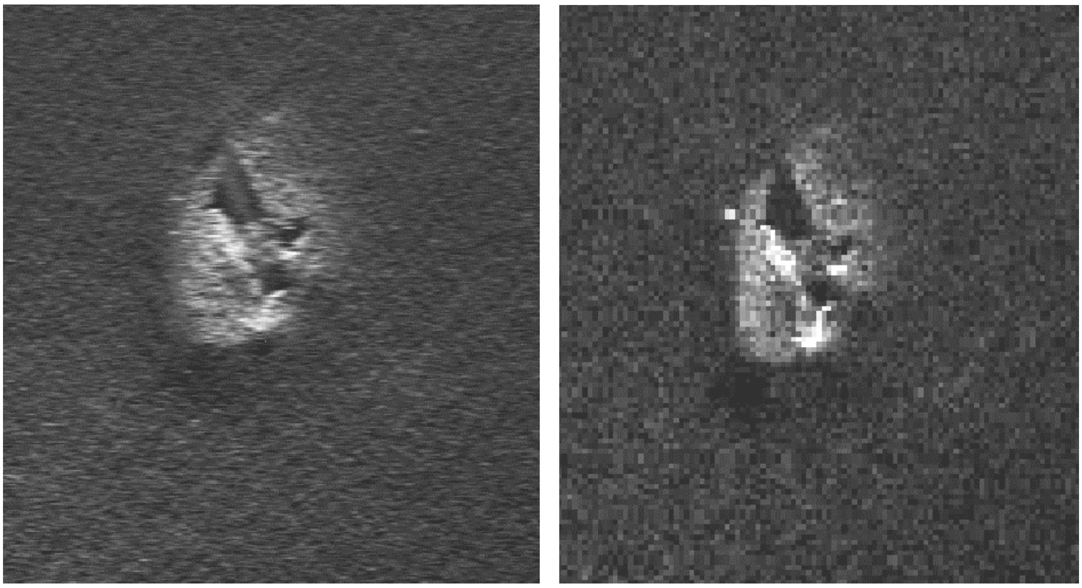


Fig. 2.2. Autosub High frequency sidescan sonar imagery processed at 2cm resolution and compared with 50cm resolution imagery . Feature is a large boulder about 10 metres long, 3.5 metres wide and 1.2 metres high

2.5. RRS James Cook EM120 Multibeam bathymetry (111 beams)

Processing was carried out in CARIS HIPS v7.0. A zero tidal correction was used. A sound velocity profile was input, and the data were gridded using a BASE (Bathymetry Associated with Statistical Error) grid of 50m. Editing of the data for attitude, navigation and swath errors was done on the raw data, followed by 3D editing on the surface subset. The data were generally of only moderate quality, with much noise and attitude induced variation.

2.6. RRS James Cook EM120 Multibeam backscatter (12kHz)

Processing of the Multibeam backscatter was carried out in PRISM. Transfer of data to PRISM was done via the Neptune replay system which converts the Raw.all files to Proc format which can be read by PRISM and converted to CDF (PRISM format).

Navigation was extracted from the CDF files (*do_make_nav*), and the map areas chosen with overlapping edges (*maptile*). Sonar processing and geometrical correction used a 15º course deviation factor for segments and a 25m resolution. Overlap of coverage was eliminated by direction priority and range location parameters (*prismrange*). Processing commands were:

mrgnav -i %1 -o %0 -n navfile.nav -l 0,0
filter -i %1 -o %0 -b 1,21 -z -v 130,255
filter -i %1 -o %0 -b 1,301 -h -v 130,255
filter -i %2 -o %0 -b 31,301 -L -v 130,255
wtcombo -i %2 , %1 -o %0 -c 1,1 -a -128
restorehdr -i %1 -h %5
resol -i %2 -o %0 -r res

shade -i %1 -o %0 -n 128 -t 1,254

Results were collated in ERDAS Imagine and mosaiced into a single image. Overlapping map edges were feathered and thus removed minor radiometric differences which are otherwise visible to the human eye. Only poor results were seen and of virtually no value due to too much movement and noise in the watercolumn or under the ship.

2.7. *RRS James Cook EM710 Multibeam bathymetry (400 beams)*

Processing was carried out in CARIS HIPS v7.0. A zero tidal correction was used. A sound velocity profile was input, and the data were gridded using a BASE (Bathymetry Associated with Statistical Error) grid of usually 10m. Editing of the data for attitude, navigation and swath errors was done on the raw data, followed by 3D editing on the surface subset. The data was of variable quality, which was very dependent on seastate and steered track. Tracks with headings about 45º from the seastate proved the best. In really poor weather the data was unusable.

2.8. *RRS James Cook EM710 Multibeam backscatter (70-100kHz)*

Processing of the Multibeam backscatter was done in PRISM. Transfer of data to PRISM was done via the Neptune replay system which converts the Raw.all files to Proc format which can be read by PRISM and converted to CDF (PRISM format).

Navigation was extracted from the CDF files (*do_make_nav*), and the map areas chosen with overlapping edges (*maptile*). Sonar processing and geometrical correction used a 15º course deviation factor for segments and a 2m resolution. Overlap of coverage was eliminated by direction priority and range location parameters (*prismrange*). Processing commands were:

mrgnav -i %1 -o %0 -n navfile.nav -l 0,0
filter -i %1 -o %0 -b 1,21 -z -v 130,255
filter -i %1 -o %0 -b 1,301 -h -v 130,255
filter -i %2 -o %0 -b 31,301 -L -v 130,255
wtcombo -i %2 , %1 -o %0 -c 1,1 -a -128
restorehdr -i %1 -h %5
resol -i %2 -o %0 -r res -a
shade -i %1 -o %0 -n 128 -t 1,254

Results were collated in ERDAS Imagine and mosaiced into a single image. Overlapping map edges were feathered and thus removed minor radiometric differences which are otherwise visible to the human eye. Results were generally good.

2.9. *Autosub EdgeTech Chirp profiler*

The sub bottom profiler data was collected using the Edgetech 2200 mounted on Autosub 6000. The system records in .jsf format which has separate channels for envelope, analytic and raw data. The envelope and analytic data are correlated and corrected for spherical spreading within the EdgeTech system. No processing is applied to the raw data in the system and they are sampled at twice the rate of the analytic and raw data.
For missions 37 through 41, the data were extremely noisy, and the only well imaged reflector was the seabed. Before mission 42, the Edgetech system was re-positioned within Autosub, improving the signal to noise ratio.
For missions 42 and higher, a 5 ms source, sweeping from 2.0 to 15.0 kHz, was output at a ping rate of 6 Hz. The sub travelled at ~5.0 km/hr, giving a trace spacing of 24 cm. Each trace is 158 ms long with sample rates of 0.46 µs and 0.23 µs for the envelope/analytic and

real data respectively. The penetration was variable due to the different seabed morphology. Maximum penetration of 30 ms or 22 m was seen at eastern Darwin mounds; in the Rockall bank area penetration was up to 5 ms or 4 m.
Real data were extracted from the analytic channel of the .jsf files with the freeware jsf2segy (Tom O'Brian, 2005) and input into ProMAX. The data for missions 37 through 41 were not processed in ProMAX. An attempt was made to deconvolve the data for these missions, but poor results were attained due to contamination by noise. The data for missions 42 and higher were deconvolved and static corrected to sea level within ProMAX. To assign the Autosub navigation to the data, the time of each ping was extrapolated from start time of data recording using the ping rate. Navigation data (x,y,z) were then imported into ProMAX and used to calculate a static correction, Δt, for each trace.

$$\Delta t = 2*1500*z^{-1}$$

Tim Le Bas and Becky Cook

3. Lynx ROV

3.1. Summary

A total of 26 Dives, equal to 100hrs operation were completed during this cruise. For each dive a single, standard definition video source was recorded on DVCAM tapes and data from the ROV mounted bathymetric unit captured to text file. Post-dive, images were downloaded from the digital stills camera and together with digitised tapes, all data were backed up to hard disk.

3.2. Equipment

Equipment supplied under contract from Hallin Marine included a SeaEye Lynx ROV equipped with manipulator tool skid, Kongsberg OE14-208 digital stills camera (+ spare) with 4GB storage, Kongsberg OE14-366 colour zoom camera, bathymetric unit and altimeter (Tritech SK700). In support of this a launch and recovery system (LARS), a spares container and a control container were installed on deck (port side). Supplied from NMFSS Deep Platforms: 2 crates of 6 push cores, and two 5mW red scaling lasers plus mounting bracket (2 mating whips made by Hallin Marine to specification).

3.3. Configuration

ROV operations were conducted at the aft forward port side (Usual Isis ROV position). The single 20' control container was positioned in the dual deck level container slot, and powered from the Isis 125A 3 phase hangar supply with a ship supplied connector. The 10' spares container was positioned just aft of the LARS.
During mobalisation a bed plate for the LARS was constructed with welded steel members utilising the Isis LARS side plates. It was successfully load tested before sailing. Water cooling for the winch was fed from a hangar supply.
Shipboard Avocent system cables were run from the ship to the control van to provide display and control of the Sonardyne navigation and a coaxial cable patched through to the main lab for video feed from the ROV colour zoom camera. Additionally a telephone line and network connection were installed. A supersub mini transponder was attached to both the ROV and TMS for each dive.
The Kongsberg colour zoom and digital stills cameras were mounted on the ROV pan and tilt unit with a light strobe fixed to one side, angled for optimum seabed illumination. Fixed by a 10cm spacing bracket the red lasers were piggy-backed onto the stills camera. The altimeter was attached at the vehicle front end 300mm up from the base of the ROV.

3.4. Operations

Prior to sailing the system was tested in the dock and balance trimmed with lead weights. A cable for operation of the altimeter was missing and later collected and fitted when calling into Ullapool enroute to the worksite.

After each dive the digital camera images were downloaded to a laptop via a USB deck interface box. It was found after the dock test that the laptop would not recognise the camera USB interface so the camera was replaced with the spare which was used for the rest of the cruise. Images from the faulty camera were extracted by opening the housing and removing the memory card. This could be read on an NMFSS computer with integrated card reader. To switch from operation mode (RS232) to download mode (USB) required the use of a remote control aimed at the receiver through the camera viewport. Due to the close proximity of the zoom camera which had the same viewport control to switch between RS232 and long line drive, care was taken not to inadvertently change both camera settings.

A Bio sample box was constructed for intended sampling operations, designed as a 'handbag' with lockable lid for the ROV to carry around with the rope attached to the manipulator jaw. Its first operation had an element of success but it proved difficult to close the lid with the limited manipulator dexterity. For its 2nd operation partitions and an extra lid lock mechanism were attached. This proved successful but during recovery the box handles broke, dumping the box and samples back to the seabed. Following this, a new design comprising a linen bag with plastic collar and draw string was physically attached to the front of the ROV toolsled, the arc of the rigid manipulator crossing the bag opening. This proved successful with both a number of dead and live coral specimens collected.

Technical problems were few and mainly related to the winch and TMS. After a number of dives ran into problems due to Ground Fault indications, the winch junction box was removed and it was found that the cable-fed Copex protection jacket was broken, exposing the cables. This was repaired but on subsequent dives similar problems occurred. The system was stripped down again and this time the inboard side of the slip ring cable protection within the drum had the same problem. Arcing could be heard when power was applied. The slipring was completely removed and damaged cables repaired with armouring cut back and reininstated. This problem was due to an oversize slipring being factory inserted with non-suited cable glands for the space provided. To prevent further damage to the repaired cables the slipring was partially reinserted and stood off on extension rods – a temporary solution which required careful monitoring for all subsequent dives. Similarly care of the winch level wind required regular manual adjustment during recovery operations.

A damaged tether was replaced at an early stage of operations running with the spare without problems for the rest of the cruise. Occasionally problems were encountered recoiling the tether with the TMS bailing arm, possibly due to mud on the tether reducing the tension of friction grip rollers. These were all checked and adjusted and subsequently performed ok.

During one dive inadvertent operation of the control van gas level detection switch caused a complete power down. System power was quickly restored, however, the ROV colour zoom camera reverted to its longline mode and could only be reset by recovering to the ship's rail and using the remote through its viewport.

Poor weather conditions were prevailing during the cruise with one dive being aborted soon after reaching the seabed due to the difficulty garaging the ROV in the TMS. Despite the officer of the watch optimizing the ships orientation to minimize pitch and roll on many occasions garaging the ROV proved difficult. An insurance limit of 30 Knt winds and a short swell of more than a few metres limited the use of the system far more than a live boating solution may have done.

Fig. 3.1. Compilation of photographs illustrating the set-up and use of the Lynx ROV

3.5. Technical evaluation

The SeaEye Lynx combined with the TMS is a compact system, easy to deploy and operate and it copes well with strong current conditions. It performed well during the cruise, although several shortcomings were highlighted during cruise operations.

This eyeball system has limited manipulator dexterity and sample storage. In addition, it has a negatively bouyant tether which potentially could cause damage and snagging in survey / transect mode. The weather window is severly reduced due to the limitation of recovering the ROV into its garage. It lacks payload to carry a Doppler sonar to provide steady automated transect speed, and subsequently navigation accuracies are only related to the acoustic navigation. Similarly its light weight flux gate compass is less accurate than a fibre optic equivalent producing a relatively non-stable heading biased by strong currents.

The control van displays were of poor quality quickly creating pilot fatigue, the patched display in the lab providing a far superior image. Seating in the control van was poor, with chairs unadjustable and unfixed and cramped conditions when scientists joined the van.

David Edge and Kelly Screen

4. Video surveying & photography

In total, 26 ROV dives were carried out (see overview table). Although some dives were aimed at testing the equipment or sampling the seabed, the majority of dives were dedicated to video surveying. During video transects, the camera settings were kept as constant as possible, with the colour zoom camera fully zoomed out and both colour & stills cameras pointing downwards as much as possible. Laser pointers, set at 10cm distance, give an indication of scale. In between dedicated video transects, mostly when waypoints were reached, a more 'explorative' way of surveying was used to obtain a better overview of the local geomorphology and of the coral colonies (distribution, morphology, setting).

Video transects were chosen according to a number of objectives:

- *Stratified random sampling within the Darwin Mounds* with the aim of groundtruthing a range of habitats. Originally, the plan was to identify trawled and untrawled mounds, tails & background sediment from the backscatter and sidescan sonar data, and carry out a number (10) of randomly placed transects in each habitat type. However, time- and resolution-constraints meant that the trawling impact could not be identified immediately from the first maps obtained with Autosub (backscatter and LowRes sidescan), hence it was decided to limit the habitats to 'mound', 'tail' and 'background'. The centre points of the mounds and tail features were digitised in both the Eastern and Western mound field. Twenty mounds and 10 tails were randomly chosen in each field, and 20 more random points (representing the background) were created in each area. 100m transects with random heading were constructed across all of these centre points (within ArcGIS). ROV dives were then planned trying to connect a maximum number of these 100m transects, although in neither of the 2 areas all transects could be surveyed due to a lack of time.
- *Dedicated ground-truthing of features identified on the bathymetry & backscatter maps in the Hatton Basin*. Due to the weather situation, only 12h of ROV operations were possible in the Hatton Basin. Hence the dives were focussed very much on a number of pockmarks/dropstones identified from the Autosub bathymetry, and on a transect across a triple junction and polygonal fault (taking in two piston core locations).
- *Ground-truthing of high-res sidescan sonar maps on Rockall Bank*: ROV dives in the NW Rockall Trough Fisheries Closure Area generally consisted of long straight transects, crossing a maximum of habitats as identified from the Autosub sidescan maps. In some cases the sidescan sonar map was not ready by the time the ROV started the dive, hence the transect was chosen based on the EM710 bathymetry and backscatter.
- *Evaluation of predictive models for Lophelia pertusa*: the 2 ROV transects on the E Rockall Bank cliffs were chosen in locations where the models had either predicted coral gardens, or predicted an absence of coral gardens.

Site	Final sample number	J Day	Start Date	Start Time GMT	Start Lat		Start Long		Start Depth	End Date	End Time GMT	End Lat		End Long		End Depth	Comments	Photos
shelf trial	JC060_001_ROV01	131	11/05/2011	06:58:00	59	25.06	6	16.15	158	11/05/2011	08:30:00	59	25.06	6	16.18	161	ROV test dive	IMG_5636 11/05/2011 – IMG_5700 11/05/2011 (65 files)
darwin mounds	JC060_012_ROV02	133	13/05/2011	12:00:00	59	51.04	7	4.163	1048	13/05/2011	16:24:00	59	51.183	7	4.509	1045		IMG_4654 13/05/2011 17:37 – IMG_4832 13/05/2011 19:48 179 files NOTE: File timestamp are UTC+5h
darwin mounds	JC060_017_ROV3	134	14/05/2011	08:54:00	59	50.753	7	3.437	1059	15/05/2011	12:49:00	59	51.131	7	3.985	1045		IMG_4801 14/05/2011 09:36 – IMG_5060 14/05/2011 12:11 (260 files)
darwin mounds	JC060_020_ROV04	135	15/05/2011	03:45:00	59	48.177	7	23.088	944	15/05/2011	08:58:00	59	48.834	7	22.769	945		IMG_5061 15/5/2011 03:43 - IMG_5493 15/05/2011 08:54 (433 files)
darwin mounds	JC060_026_ROV05	136	16/05/2011	01:58:00	29	48.426	7	22.075	960	16/05/2011	09:01:00	59	48.652	7	21.84	959		IMG_5494 16/05/2011 01:54 - IMG_6263 16/05/2011 08:56
darwin mounds	JC060_033_ROV06	137	17/05/2011	04:13:00	59	48.866	7	21.626	960	17/05/2011	09:48:00	59	49.49	7	21.708			IMG_6265 17/05/2011 04:01 - IMG_6814 17/05/2011 09:56 (550 files)
Minches	JC060_043_ROV07	140	20/05/2011	10:20:00	58	4.957	5	58.602	89	20/05/2011	12:22:00	58	4.994	5	59.101	66		IMG_6815 20/05/2011 10:53 - IMG_6957 20/05/2011 12:20 (183 files)
Minches	JC060_044_ROV08	140	20/05/2011	13:16:00	58	3.672	5	56.713	75	20/05/2011	14:40:00	58	3.671	5	57.481	67		IMG_6958 20/05/2011 13:18 - IMG_7118 20/05/2011 14:38 (161 files)
Minches	JC060_045_ROV09	140	20/05/2011	15:32:00	58	0.429167	5	53.707	91	20/05/2011	17:03:00	58	1.63	5	54.253	82		IMG_7119 20/05/2011 15:56 - IMG_7283 20/05/2011 17:03 (165 files)
darwin mounds	JC060_052_ROV10	142	22/05/2011	04:27:00	59	50.952	7	8.051	1052	22/05/2011	08:13:00	59	50.957	7	8.038	1052	failed	
darwin mounds	JC060_056_ROV11	143	23/05/2011	03:08:00	59	50.958	7	8.055	1051	23/05/2011	05:56:00	59	50.982	7	7.976		no data - too much heave on TMS	
Hatton Basin	JC060_064_ROV12	146	26/05/2011	14:25:00	58	10.766	16	27.381	1177	26/05/2011	15:50:00	58	10.766	16	27.431		failed due to TMS problem	
Hatton Basin	JC060_065_ROV13	146	26/05/2011	15:57:00	58	10.773	16	27.439	1176	26/05/2011	21:43:00	58	10.605	16	28.028			IMG_7302 26/05/2011 16:31 - IMG_7840 26/05/2011 20:58 (539 files)
Hatton Basin	JC060_066_ROV14	146	26/05/2011	22:27:00	58	11.085	16	25.313	1186	27/05/2011	00:46:00	58	11.023	16	25.313			IMG_7842 26/05/2011 22:59 - IMG_7987 26/05/2011 23:57 (146 files)
Haddock Box	JC060_084_ROV15	151	31/05/2011	7:50:00	56	39.166	14	2.116	379	31/05/2011	10:06:00	56	39.5	14	2.83			JC060-084: IMG_7989 31/05/2011 08:00 - IMG_8191 31/05/2011 09:44 (203 files)
NW Rockall Bank	JC060_091_ROV16	154	03/06/2011	12:43:00	57	57.101	13	58.702	214	03/06/2011	15:45:00	57	57.575	13	58.475			IMG_8194 03/06/2011 12:53 - IMG_8485 03/06/2011 15:27 (292 files)
NW Rockall Bank	JC060_092_ROV17	154	03/06/2011	16:39:00	57	57.384	13	58.739	217	03/06/2011	17:48:00	57	57.384	13	58.712			IMG_8486 03/06/2011 16:45 - IMG_8558 03/06/2011 17:32 (73 files)
NW Rockall Bank	JC060_093_ROV18	154	03/06/2011	18:32:00	57	57.677	14	0.504	223	03/06/2011	20:05:00	57	57.826	14	0.083			IMG_8559 03/06/2011 18:41 - IMG_8731 03/06/2011 19:54 (173 files)
NW Rockall Bank	JC060_096_ROV19	155	04/06/2011	10:45:00	58	5.475	14	11.929	327	04/06/2011	13:43:00	58	4.993	14	11.21			IMG_8733 04/06/2011 10:55 - IMG_8988 04/06/2011 13:23 (256 files)

NW Rockall Bank	JC060_097_ROV20	155	04/06/2011	14:25:00	58	4.158	14	10.712	295	04/06/2011	20:29:00	58	4.704	14	8.697			IMG_8989 04/06/2011 14:34 - IMG_9739 04/06/2011 20:18 (751 files)
NE Rockall Bank	JC060_100_ROV21	156	05/06/2011	13:45:00	58	16.207	13	36.108	805	05/06/2011	18:52:00	58	15.918	13	36.603			IMG_9743 05/06/2011 14:02 - IMG_0249 05/06/2011 18:31 (406 files) ** IMPORTANT NOTE ** Power outage during JC060-100-ROV dive caused a reset to still camera frame numbering. Date and time stamp on the image files is correct throughout. File names run: IMG_9741 to IMG_9900 then IMG_0001 to IMG_249
NE Rockall Bank	JC060_101_ROV22	156	05/06/2011	19:17:00	58	15.593	13	35.483	721	05/06/2011	21:21:00	58	15.604	13	35.975			IMG_0250 05/06/2011 19:40 - IMG_0502 05/06/2011 20:59 (253 files)
NW Rockall Bank	JC060_104_ROV23	157	06/06/2011	08:56:00	57	50.35	13	58.612	180	06/06/2011	14:59:00	57	50.859	14	0.321			IMG_0504 06/06/2011 09:02 - IMG_1353 06/06/2011 14:57 (850 files)
NW Rockall Bank	JC060_105_ROV24	157	06/06/2011	15:40:00	57	51.475	14	0.427	189	06/06/2011	16:59:00	57	51.464	14	0.408			IMG_1354 06/06/2011 15:19 - IMG_1385 06/06/2011 16:07 (32 files)
Darwin mounds	JC060_110_ROV25	160	09/06/2011	00:34:00	59	50.976	7	8.038	1050	09/06/2011	10:04:00	59	51.092	7	7.971			IMG_1387 09/06/2011 01:03 - IMG_2192 09/06/2011 09:26 (806 files)
Darwin Mounds	JC060_117_ROV26	161	10/06/2011	04:05:00	59	50.899	7	3.506	1051	10/06/2011	09:45:00	59	51.217	7	4.444			IMG_2194 10/06/2011 04:35 - IMG_2652 10/06/2011 09:08 (459 files)

Fig. 4.1. Megabenthos and demersal fish of the Darwin Mounds (945-1055m)

Fig. 4.2. Megabenthos and demersal fish of the Darwin Mounds (945-1055m)

Fig. 4.3. Megabenthos and demersal fish of the Darwin Mounds (945-1055m)

Fig. 4.4. Megabenthos and demersal fish of Shiant Bank (60-90m)

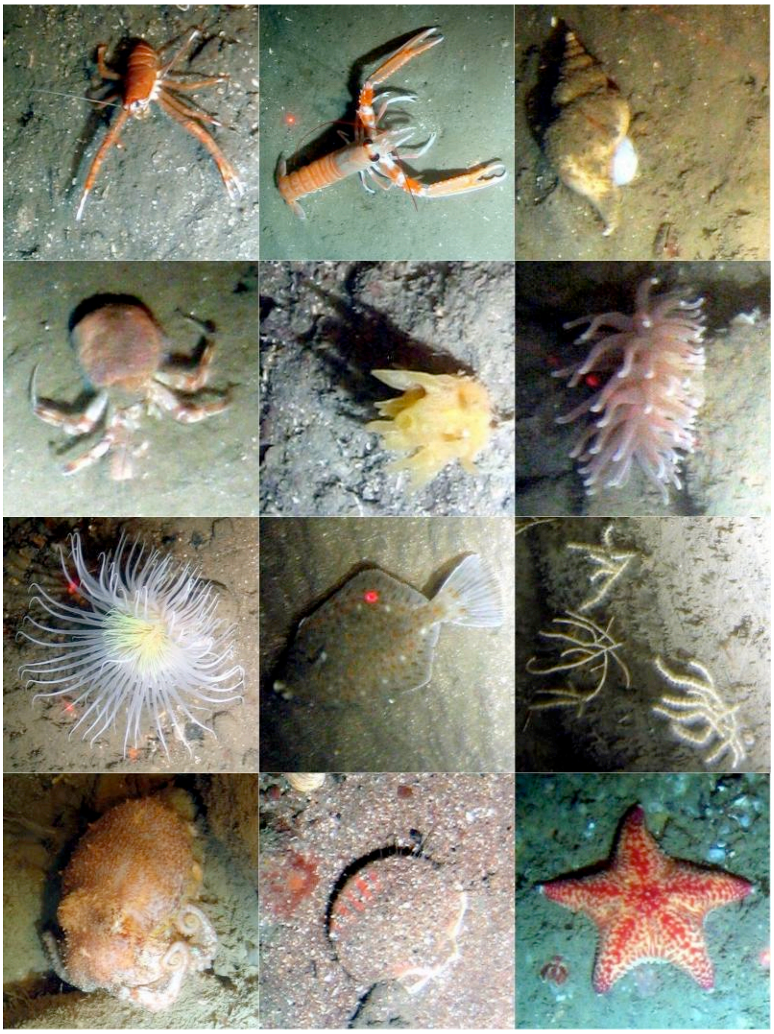


Fig. 4.5. Megabenthos and demersal fish of Shiant Bank (60-90m)

Fig. 4.6. Megabenthos and demersal fish of Hatton-Rockall Basin (1175-1225m)

Fig. 4.7. Megabenthos and demersal fish of Hatton-Rockall Basin (1175-1225m)

Fig. 4.8. Megabenthos and demersal fish of Rockall Bank, Haddock Box (350-380m)

Fig. 4.9. Megabenthos and demersal fish of Rockall Bank, northern shoulder (180-325m)

Fig. 4.10. Megabenthos and demersal fish of Rockall Bank, northern shoulder (180-325m)

Fig. 4.11. Megabenthos and demersal fish of Rockall Bank, northern shoulder (180-325m)

Fig. 4.12. Megabenthos and demersal fish of Rockall Bank, NE flank (500-800m)

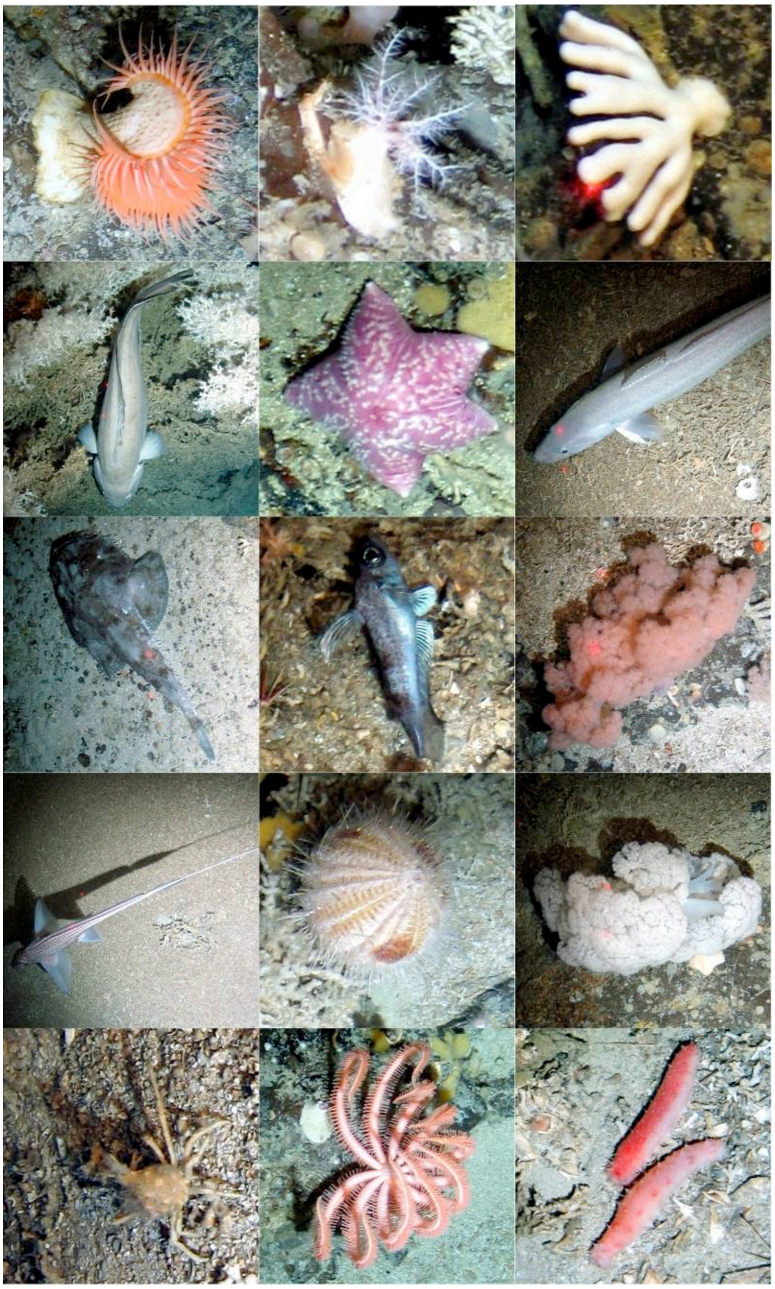


Fig. 4.13. Megabenthos and demersal fish of Rockall Bank, NE flank (500-800m)

Brian Bett & Veerle Huvenne

5. Hybis

5.1. Introduction
The HyBIS vehicle is a robotic underwater vehicle (RUV) capable of 6000m depth operations. Its modular design allows for a command module comprising a power and electronics pod with telemetry and controls, thrusters and hydraulic actuators. The sampling modules comprise a bucket grab (0.4 cubic metres) and a tool sledge with sample tray and 5-function manipulator arm.

5.2. Deployment on JC060
On JC060, the ship's deeptow winch was out of use, which meant we had to position HyBIS on the aft deck for deployment through the stern gantry and use a portable winch with 4km of deep-tow cable. This was far from ideal as the pitch of the RRS James Cook, even in a slight swell, meant that the vehicle would heave by several metres with a frequency of 0.1 Hz. This limited the operational weather window to sea state 3 or below, which only occurred during a few days throughout the 5 week voyage.

5.3. Sampling modules
The tool sledge was a new module, prepared in time for this cruise and designed to collect coral and rock samples, as well as taking push cores. Before departure, the vehicle was fully serviced and tested on our low voltage (110V) power supply unit, and the new tool sled was included in the tests. All compensation circuits and oils had been changed, motors, cameras, lights and hydraulic valve packs serviced. A new stainless steel shackle had been purchased (with accompanying certification). The sampling grab had also been serviced, with a dent taken out of the cutting edges to ensure a sealed closure. The grab was to be used in place of box cores for bulk sampling of the mega-fauna in gritty substrates.

5.4. Faults
Unfortunately, the vehicle was found to have an electrical fault, early on in the cruise, when supplied by the high volts (HV) transformer. There was no fault apparent when the vehicle was supplied by our 110V deck transformer. Following lengthy investigations, the fault was traced to faulty transformers on the vehicle itself. The vehicle transformer comprises two toroids in series, stepping down from 1500Vac to 110v ac. A new toroid was ordered from the manufacturers (Hydro-Lek) and collected from Ullapool whilst the ship sheltered from a gale.

After testing the toroids while connected to the vehicle (using a break-out cable from the main power harness and observing the waveform on an oscilloscope) it was found that one or both toroids were suffering from magnetically saturated cores (Figures 1 and 2). This was attributed to a design flaw in which the toroids were unbalanced by the current load supplying the lighting whips (2kW). On removing the toroids, the compensation oil in the transformer pod was found to be black and hence contaminated with carbon residues. The transformers were cleaned for 3 days in WD40 and the compensation oil changed for a silicone oil. One of the toroids tested was found to be especially prone to magnetic saturation and so was swapped for the new toroid. We also rewired all services on the vehicle to 220V, thus avoiding any future unbalancing of the transformers (we had available 4 x 250V, 150W lamps for the lighting whips). The reassembled vehicle was then tested on deck and found to be operational when supplied with HV.

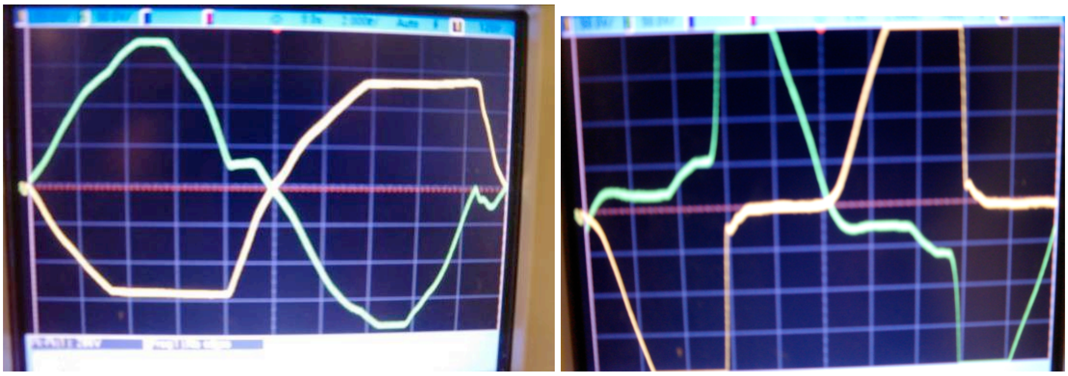


Fig. 5.1a (above left) example of low voltage output from HyBIS transformers when attached to vehicle with only a hotel service load.
Fig. 5.1b (above right) example of same with 350W of lighting loaded on one of the toroids. Note the asymmetric waveforms indicating possible core saturation.

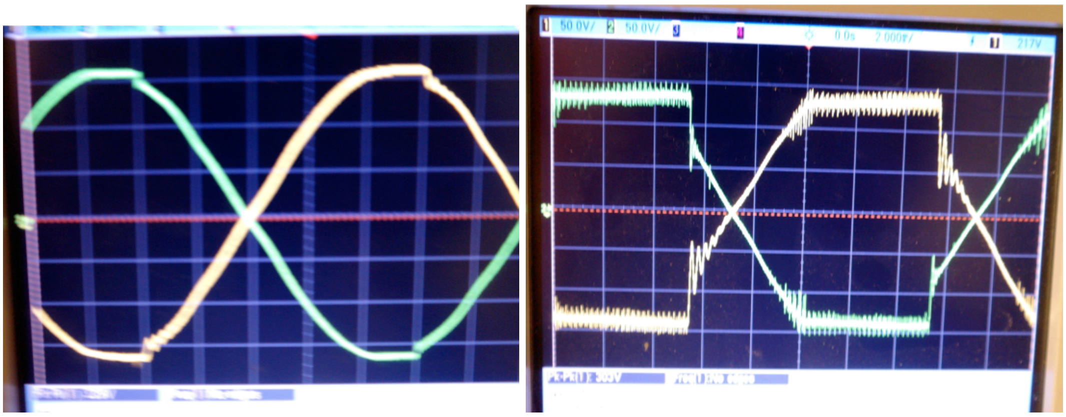


Fig. 5.2a (above left) example of low voltage output from HyBIS 110V deck transformers when attached to vehicle with only a hotel service load.
Fig. 5.2b (above right) example of same with 3kW of hydraulic pumps running. Note the symmetry of the waveforms indicating correct transformer function.

5.5. Dive

A dive was made on Rockall Bank to a depth of 200m (Station JC060_103). The sea state was 2 or 3. The dive initially involved landing on the bottom where a 1kg rock sample was taken and stowed in the sample tray with ease. This was followed by a 500m-long survey. The lower-powered lamps made for relatively low levels of illumination compared to our usual arrangement. This, however, will be corrected once we have installed higher-powered lamps (250W versions are available, although we might also consider implementing HID lamps). The heave was still excessive and caused problems with disturbance of the substrate and difficulties when landing. At the end of the 90-minute survey, we landed again, but bounced three times. This resulted in communications drop-outs, possibly due to snatch-loads on the deep-tow cable and possible fibre-optic termination damage. The dive was terminated and the vehicle returned to the surface where the sample was removed and the vehicle secured.

Note: The depth sensor on the vehicle has always been noisy, with erratic oscillations of ±100m. On scoping the A to D input on the 'SeaEye' board, the channel was found to be noisy with variable voltage. A 4.5nF capacitor was inserted across the sensor input (ground and 1-5Vdc sensor signal). This reduced the low-frequency noise by 90%. However, on the dive, the pressure indication did not change from 0m. This will have to be reviewed and the true cause of the noise found and removed. We suspect the noise is from either the sensor supply voltage or the ground reference voltage.

Acknowledgements
I would like to thank Steve McPhail for his assistance throughout the diagnosis of the fault on HyBIS, also Hydro-Lek for their prompt (overnight) delivery of a new toroid to Ullapool, and to Dave Edge for the high-voltage work during the cruise.

Bramley Murton

6. Piston coring

A modified NIOZ piston corer with a 1.5 tonne head weight mounted on a barrel array of 6-21 m was used for all deployments. A small 1 m-long trigger core was deployed on the end of the trigger arm and chain. Most cores were cut into 1.5 m sections, although those recovered from the Hatton-Rockall Basin site were cut into 0.5 m sections to aid with geochemical sampling, and the cores containing coral fragments were cut at 1 m intervals to allow storage in the -80° freezer. Split cores were divided into working and archive halves, visually logged and photographed (with the exception of cores from coral mounds which were left un-split and were frozen to aid later splitting).

6.1. Darwin Mounds

Summary

The first four cores in this area (010, 011, 016 and 018) were targeting an area of the mound province where previous coring (D248, see Huvenne et al., 2009) had recovered an interesting sandy contourite record. Sediment recovery was good, at 60-70%. All four cores contained a thin (20-30 cm) layer of Holocene muddy sand contourite overlying several metres of glacial mud containing scattered small black dropstones and shell fragments. The boundary between the two units was typically gradational, with the muddy sand contourite being upward-coarsening. The absence of any significant sandy contourite sequence suggests that the previous core had actually hit a mound.

The next four cores (021, 035, 038 and 057) were targeting coral mounds and adjacent mound tails. Three cores recovered good samples that were not split as they contained coral rubble and were therefore retained for subsequent freezing and splitting. The fourth core failed to retain a sample, but contained fragments of dead coral in the core catcher.

Fig. 6.1. Core photo of piston core JC060-010; note the dropstone in section 1 and the patchy sulphide staining most obvious in sections 3-5.

<u>JC060-010</u>
Corer at seabed: 0629 hrs on day 133
Location: 59°49.445 N / 07°22.541 W
Water depth: 938 m
Pullout: 2.2 tonnes
Corer length: 9 m
Recovery: 5.95 m (5 sections; no trigger core)

Core contains 27 cm of disturbed Holocene muddy sand overlying 5.6 m of structureless, bioturbated, grey-brown glacial mud containing scattered small (<5 mm) black dropstones and shell fragments. Patches of black sulphide staining throughout.

<u>JC060-011</u>
Corer at seabed: 0916 hrs on day 133
Location: 59°48.976 N / 07°22.562 W
Water depth: 949 m
Pullout: 2.55 tonnes
Corer length: 9 m
Recovery: 6.7 m (5 sections; no trigger core)

Core contains 20 cm of upward-coarsening Holocene muddy sand contourite overlying 6.5 m of structureless, bioturbated, grey-brown glacial mud containing scattered small (<5-10 mm) black dropstones and shell fragments. One dropstone of 35 mm diameter noted in section 1. Patches of black sulphide staining throughout.

<u>JC060-016</u>
Corer at seabed: 0442 hrs on day 134
Location: 59°50.586 N / 07°20.050 W
Water depth: 948 m
Pullout: 2.67 tonnes
Corer length: 9 m
Recovery: 6.25 m (5 sections; no trigger core)

Core contains 20-25 cm of upward-coarsening Holocene muddy sand contourite overlying 6.05 m of structureless, bioturbated, grey-brown glacial mud containing scattered small (<20 mm) black dropstones and shell fragments. Patches of black sulphide staining throughout.

<u>JC060-018</u>
Corer at seabed: 1816 hrs on day 134
Location: 59°49.149 N / 07°21.892 W
Water depth: 953 m
Pullout: 2.31 tonnes
Corer length: 9 m
Recovery: 6.7 m (5 sections; no trigger core)

Core contains 25 cm of upward-coarsening Holocene muddy sand contourite overlying 6.45 m of structureless, bioturbated, grey-brown glacial mud containing scattered small (<10 mm) black dropstones and shell fragments. Patches of black sulphide staining throughout.

<u>JC060-021</u>
Corer at seabed: 1154 hrs on day 135
Location: 59°50.882 N / 07°03.659 W
Water depth: 1054 m
Pullout: 2.67 tonnes
Corer length: 9 m
Recovery: unknown (core not split – missed the coral mound, but core retained whole for study of oxygenation effects on ITRAX measurements)

<u>JC060-035</u>
Corer at seabed: 1413 hrs on day 137
Location: 59°49.398 N / 07°21.038 W
Water depth: 956 m
Pullout: 2.63 tonnes
Corer length: 9 m
Recovery: unknown (core not split - retained whole for freezing)

<u>JC060-038</u>
Corer at seabed: 2004 hrs on day 137
Location: 59°49.104 N / 07°21.378 W
Water depth: 961 m
Pullout: 2.53 tonnes
Corer length: 9 m
Recovery: unknown (core not split - retained whole for freezing)

<u>JC060-057</u>
Corer at seabed: 0729 hrs on day 143
Location: 59°51.005 N / 07°08.618 W
Water depth: 1047 m
Pullout: 2.4 tonnes
Corer length: 9 m
Recovery: 0 m (sediment washed out – dead coral fragments in catcher)

6.2. Hatton-Rockall Basin

<u>Summary</u>

The first core (060) in this area of polygonal faults targeted smooth seafloor in a topographic low, representing the fault zone. The second core (063) targeted pitted, burrowed seafloor on a broad, flat topographic high between faulted areas. The third core (067) targeted a small pockmark filled with large black boulders and cobbles. All three cores recovered sediment, with a particularly good sequence of cold- and warm-period hemipelagic units recovered in cores 060 and 063. All three cores can be correlated based on the position and character of these units. An initial chrono-stratigraphy, based on visual characteristics and correlations, suggest that the white ooze at the base of the longest core (063) goes back to Oxygen Isotope Stage 13 at ~0.5 Ma. Hemipelagic sedimentation rates during warm periods are in the order of 2-3 cm/kyrs. There are no obvious indications for fluid flow, but geochemical staining and banding due to oxidation processes is prevalent.

Fig. 6.2. Core photo of piston core JC060-060 showing alternating dark (cold period) and pale (warm period) hemipelagic units

<u>JC060-060</u>

Corer at seabed: 1646 hrs on day 145
Location: 58°10.431 N / 16°27.421 W
Water depth: 1188 m
Pullout: 2.8 tonnes
Corer length: 12 m
Recovery: 8.7 m (18 sections + trigger core)

Core contains alternating series of structureless hemipelagic units, representing gradual switches from warm (interglacial) to cold (glacial) periods. Cold periods represented by dark brown or grey muddy silt intervals containing scattered small (<5 mm) black dropstones and shell fragments. Occasional larger dropstones up to 25 mm, one of which is granitic. Warm periods represented by pale grey, brown or white carbonate-rich silty mud hemipelagites or stiff oozes. Boundaries between these two facies are typically gradational. Core variably bioturbated throughout with Planolites-type burrows and rare Zoophycos burrows. Small blackish sulphide streaks scattered in patches throughout core, together with intermittent horizontal green/purple geochemical bands. Small (<30 mm) fluid- or gas-filled voids in sections 17 and 18 surrounded by blackish purple staining. Possible thin normally graded fine *sand turbidite in section 8 at 66-70 cm, and thin foram-rich turbidite at 0-3 cm in section 13. Note core top compressed (boundary at 8 cm in piston core corresponds to boundary at 28 cm in trigger core) but rest of core is good quality. Thin layer of oxidized mud at top of trigger and piston core indicates complete recovery of surface.*

JC060-063
Corer at seabed: 1105 hrs on day 146
Location: 58°09.653 N / 16°26.450 W
Water depth: 1172 m
Pullout: 2.9 tonnes
Corer length: 21 m
Recovery: 13.3 m (22 sections; no trigger core)

Core contains alternating series of structureless hemipelagic units, representing gradual switches from warm (interglacial) to cold (glacial) periods. Cold periods represented by dark brown or grey muddy silt intervals containing scattered small (<5 mm) black dropstones and shell/carbon fragments. Warm periods represented by pale grey, brown or white carbonate-rich silty mud hemipelagites or stiff oozes. Boundaries between these two facies are typically gradational, although pale units are slightly more silt-rich than in core 060, probably due to more intense bioturbation and mixing in of glacial material. Core variably bioturbated throughout with Planolites-type burrows, rare Zoophycos burrows and rare large crustacean burrows (corresponding to a more burrowed pitted seafloor observed on ROV video at this site). Strange hair-like fibres at 110-120 cm in white ooze in section 6 probably sponge spicules. Small blackish sulphide streask scattered in patches throughout core, together with intermittent horizontal green/purple geochemical bands. Elongate (<100 mm) fluid- or gas-filled void in section 19 surrounded by blackish purple staining. Thin, sharp-based, normally-graded, fine sand ash layer in section 10 at 33-37 cm, and thin foram-rich turbidite at 85-90 cm in section 11. Thin layer of oxidized mud at top of core indicates complete recovery of surface.

JC060-067
Corer at seabed: 0436 hrs on day 147
Location: 58°10.619 N / 16°27.273 W
Water depth: 1184 m
Pullout: 2.2 tonnes
Corer length: 9 m
Recovery: 3.6 m (8 sections + trigger core)

Core top contains very disturbed pale grey-brown silty mud containing several basaltic dropstones up to 30 mm across. This corresponds to a zone at 30-40 cm in the trigger core, suggesting the top of the piston core has been lost. Remainder of core contains alternating series of structureless hemipelagic units, representing gradual switches from warm (interglacial) to cold (glacial) periods. Cold periods represented by dark brown or grey muddy silt intervals containing scattered small (<3 mm) black dropstones and shell/carbon fragments. Warm periods represented by pale grey, brown or white carbonate-rich silty mud hemipelagites or stiff oozes. Boundaries between these two facies are typically gradational. Core variably bioturbated throughout with Planolites-type burrows and rare Zoophycos burrows. Small blackish sulphide streask scattered in patches throughout core, together with intermittent horizontal green/purple geochemical bands. Base of core compressed.

6.3. *Rockall Bank Mass Flow Scarps – Pilot study*

The area of extensive scarring on the Rockall Bank related to the Rockall Bank Mass Flow (RBMF) was reached on the 28th May. The aim of our work in this area was to carry out a pilot study of the RBMF headwall area, before further work is planned in this area. The morphology of the area has a staircase appearance with glide planes cutting into different stratigraphic levels (Elliott et al., 2010). Turbidite deposits are found in the deep Rockall Trough further downslope that are believed to be linked to the scarps on the Rockall Bank (Georgiopoulou et al., in press). It has been suggested that the slide took place progressively, i.e. the oldest scarp is the uppermost and further collapsing took place progressively downslope (Elliott et al., 2010). However, this hypothesis can be questioned.

There were three objectives in surveying this area: a) To generate a more accurate age for the RBMF as the current dating (ca 15 ka) is believed to be ambiguous (Elliott et al, 2010); b) to test the model of a progressive slide; and c) to acquire sedimentary record from the source area of the slide to compare with the turbidite deposits found in the basin.

Three piston core sites were programmed in this area based on the Irish National Seabed Survey (INSS) bathymetric dataset. A short EM120 and SBP120 survey was carried out across the three sites in order to assess the sediment type and amend the core positions accordingly. The first core site (JC060-073) was at 1069 m water depth attempting to core through to the glide plane. A 9-m barrel was set up. The corer sheared at the top of the 3m section. The same site was attempted with a 6-m barrel set-up (JC060-074), which failed too, this time with the cutter having been sheared of. In both cases high pull-out values were recorded which suggests that the corer penetrated the seabed and substrate but was sheared during pull-out. The decision was made to abandon the site and move to the next one upslope which was targeting debrite deposits where they appeared to be thinning out on the sub-bottom profile. The site (JC060-075) was at 870 m water depth and a 12-m core set-up was used. The barrel was retrieved bent but a 49 cm core was recovered containing a layer of possibly debritic coarse sand overlying finer grey laminated sand, which may have been overlying glacial mud (1 cm of dark grey mud at the bottom of the core containing a drop-stone).

Due to the damage already caused by the sediments in this area, the third site (the shallowest) was not attempted as it was decided that piston coring is not effective in this area.

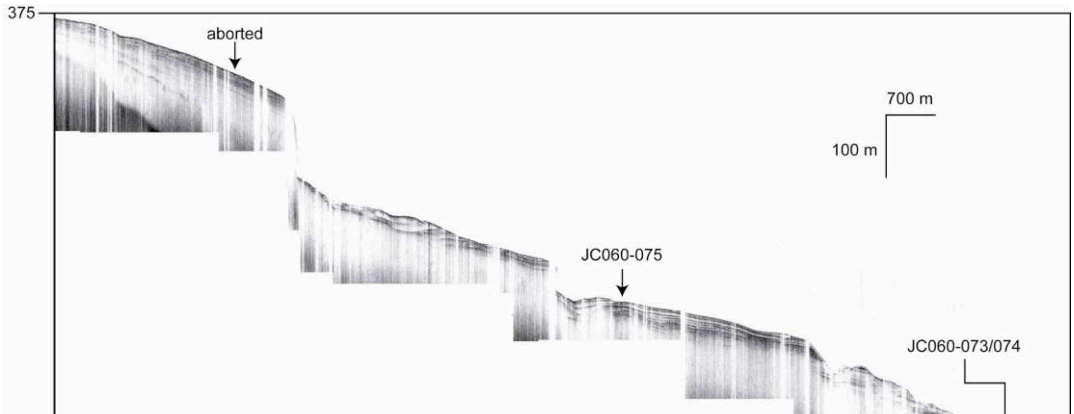


Fig. 6.3. SBP120 profile across the headwall area of the RBMF, indicating the coring stations attempted during JC060

Core descriptions

Three attempts were made to core areas where slide material thinned and/or onlapped, allowing deeper layers to be targeted. The first two attempts at the same site both failed to recover sediment, although the pullout suggests the corer penetrated the seabed. In both cases the bottom of the corer sheared off during the pullout. It is likely that the seafloor sediments here were either very stiff or comprised a mixed mud-sand debrite, as this would lead to high friction on pullout. The third core recovered a small amount of sediment but the lower section was bent.

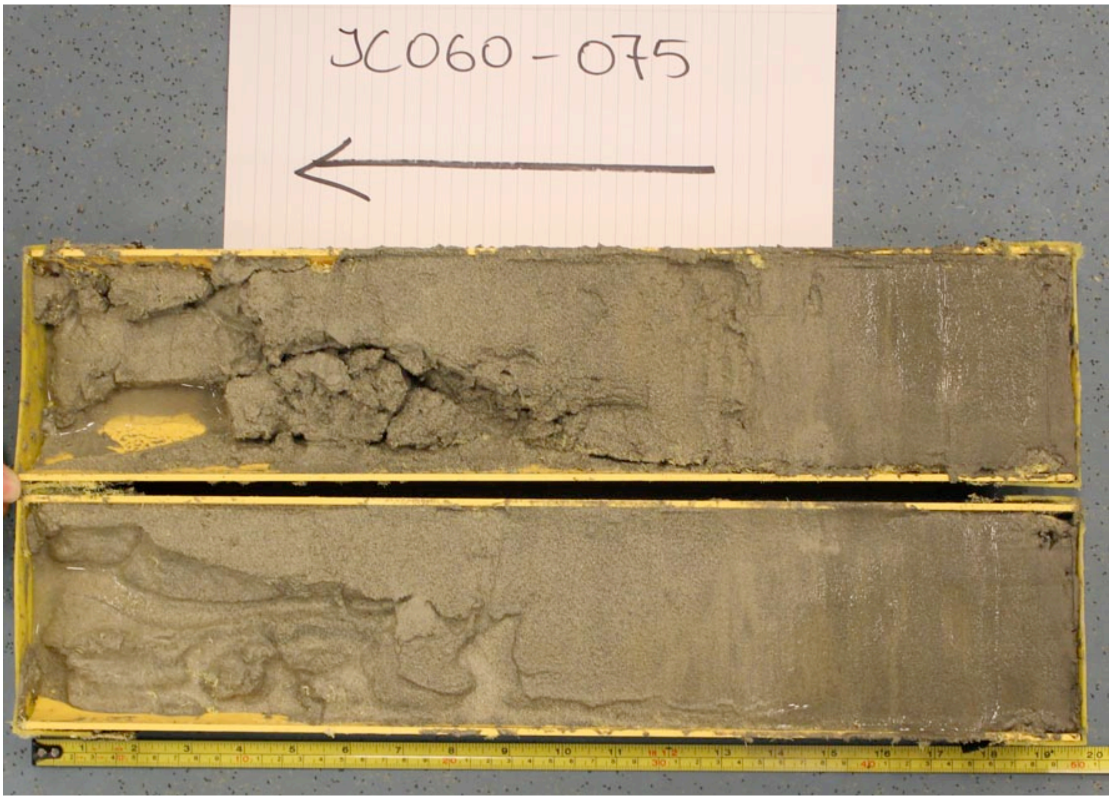


Fig. 6.4. Core photo of piston core JC060-075 showing disturbed sand overlying darker glacial mud at base.

JC060-073

Corer at seabed: 2335 hrs on day 148

Location: 56°38.545 N / 13°43.422 W

Water depth: 1069 m

Pullout: 3.7 tonnes

Corer length: 9 m

Recovery: 0 m (corer sheared off at top of lower 3 m barrel)

JC060-074

Corer at seabed: 0157 hrs on day 149

Location: 56°38.559 N / 13°43.415 W

Water depth: 1066 m

Pullout: 3.72 tonnes

Corer length: 6 m

Recovery: 0 m (core cutter sheared off)

JC060-075
Corer at seabed: 2121 hrs on day 149
Location: 56°39.822 N / 13°49.005 W
Water depth: 870 m
Pullout: 2.46 tonnes
Corer length: 12 m
Recovery: 0.5 m (bent corer)

Core contains 40 cm of disturbed grey-brown sand overlying a few cm of dark grey-brown glacial mud containing small (<2 mm) black dropstones. The boundary between the two units is apparently gradational, suggesting that the top sand is probably in situ Holocene sandy contourite. The core catcher contained shelly gravel.

Russell Wynn, Aggeliki Georgiopoulou & Jez Evans

7. Geochemistry

7.1. Pore Fluids

Pore fluids were extracted from sediment cores, collected at the polygonal fault structures (PFS's) in the Hatton-Rockall Basin, in one of two ways: either by extruding or splitting cores and squeezing the sediment in a gas press under nitrogen in an enclosed glove bag, or by using rhizons filters pushed directly into the sediment, either through the core liner of un-split cores, or into split core sections in the glove bag. Part of the aims of this cruise was to test and compare these two methods. As well as pore fluids, samples were taken for methane and porosity analysis. In general, the rhizons filters recovered a larger volume (~10ml) of pore fluids than the press (~4ml) and proved to be a much more accessible method of pore water extraction.

Once the pore fluids were obtained (usually 4-10ml volume) sub-samples were taken for major and trace metals analysis (ICP), anions (IC), alkalinity, pH, H_2S, silica, nutrients and isotopes (C and O). Alkalinity was measured onboard by titration, while the other analyses will be carried out on-shore at NOC.

7.2. Alkalinity analyses

Pore fluid alkalinity was measured on board by titration.

Reagents:

32mg methyl red was mixed with 1.19ml 0.1M NaOH solution and dissolved in 80ml ethanol. 10mg methylene blue was dissolved in 10ml of ethanol. 4.8ml of the blue solution and 80ml of the red solution are mixed to make a green indicator solution. 0.05M HCl solution was accurately made from CONVOL 1M HCl solution. IAPSO standard seawater solution (certified alkalinity of 2,325 mmol/l) was used as a calibration standard.

Titration procedure:

1ml sample plus approximately 4ml milli-Q water were pipetted into a pear shaped flask. Nitrogen gas was bubbled into the flask to aid mixing and to remove H_2S or CO_2 produced during the reaction. 40µl green indictor was added, then 0.05M HCl was titrated until the solution changed to a stable, pale pink colour. The volume of HCl added is used to calculate the alkalinity of the sample.

7.3. Methodology for water column geochemistry

Water collected by CTD was sub-sampled for methane and DIC (dissolved inorganic carbon) analysis. Methane samples were collected in blood bags which had been purged with nitrogen gas to remove oxygen. As much gas as possible was removed before the sample bag was capped. DIC samples were collected in 250ml glass bottles with glass stoppers. Both methane and DIC sample were poisoned with saturated mercuric chloride solution to preserve them. An oxygen profile was also obtained from a probe on the CTD, along with temperature and salinity.

Belinda Alker

8. Onboard stable isotope labelling incubation experiment: the effect of organic matter flux quantity on sediment "priming".

Rationale: Coastal and continental slope sediments are responsible for 80 % of the global benthic mineralization. The balance between degradation and preservation of organic matter (OM) in these sediments is thus of primary importance to the global C cycle. Priming effects (PE), i.e. changes in the decomposition of refractory (=old) OM following inputs of labile (=fresh) OM, have the potential to alter the C budget in marine sediments but their occurrence and magnitude is not well understood. The purpose of this experiment is to study priming effects in continental slope sediments in relation to the magnitude of fresh OM deposition and depth.

Materials & Methods: Three stations along a depth gradient were sampled using a Megacorer (Table 8.1). The top 3 cm from all cores collected per station were pooled and sediment was homogenized. The preparation of sediment slurries for incubation took place in a temperature-controlled room at 8°C. 20 ml of sediment was transferred into 125 ml amber glass septum incubation vials. Each vial was then added 20 ml of filtered (0.7 mm GF/F) bottom water and a pre-weighed amount of freeze-dried ^{13}C-labeled diatoms (*Thalassiosira rotula*). After algae addition, the vials were sealed and purged with a gas mixture of 80% N_2: 20% O_2 for 5 min to remove CO_2 from the headspace.

Table 8.1. List of stations where sediment for the incubation experiment was collected.

Station JC060	Equipment used	Date	Latitude	Longitude	Depth	Sample description
004	Megacorer 4 cores	11.05.2011	59°57.641	07°41.778	558	Shallow station: sediment from stations 004 and 005 was combined.
005	Megacorer 6 cores	11.05.2011	59°57.639	07°41.779	558	
008	Megacorer 8 cores	12.05.2011	59°49.950	07°35.996	741	Mid-depth station
019	Megacorer 8 cores	14.05.2011	59°34.063	07°37.350	945	Deep station

The amount of algae added in the vials was based on 3 quantity treatments: low, medium and high, each corresponding to 5%, 20% and 50% of the annual organic carbon flux in each station. Vials without algae addition were used as controls. The fate of the labeled material was followed for 21 days with sampling intervals after 7 and 14 days. The starting conditions were determined using vials that were sampled just after preparation (Time 0). Due to destructive sampling (see below), different vials were prepared for each sampling interval with 3 replicates per treatment (2 replicates for Time 0 sampling only). The number of vials per station amounted to 44: 3 sampling times (7, 14, 21) x 4 levels (control, low, medium, high quantity) x 3 replicates = 36 + 8 vials for Time 0 (4 levels x 2 replicates). The total of 132 vials were incubated at 8-9^{o}C and were manually shaken daily.

Each vial was sampled for

a) Total CO_2 and $^{13}CO_2$ concentration in the headspace and overlying water. The gas and water samples were stored at 8^{o}C and will be analysed on a Thermo Finnigan GASBENCH II Isotope Ratio Mass Spectrometer (IRMS) on return. These measurements will provide data on total and diatom-derived OM respiration.
b) Molecular/phylogenetic analysis. 2 ml of sediment from each vial were stored into eppendorfs at -80^{o}C. These samples will be used for terminal restriction fragment length polymorphism (T-RFLP) analysis to study changes in the composition of the microbial community during fresh OM processing.
c) Phospholipid fatty acids (PLFA) and sediment characteristics. The remaining sediment was frozen at -20^{o}C and will be freeze-dried on return for analysis of PLFA, sedimentary OC content, bulk sediment δ^{13}C, C/N and chl a. The abundance and isotopic signature of PLFA will be determined on a CG-c-IRMS on return. This analysis will provide information on changes in the microbial community biomass and composition during the incubation as well as the diatom-derived carbon that is incorporated into bacterial biomass. The OC content, C/N ratio and δ^{13}C signature of bulk sediment will be measured using an elemental analyser-IRMS following acidification with HCl.

Evina Gontikaki & Niels Jobstvogt

9. Effect of trawling on the macrofaunal community at the Rockall Bank (haddock box).

Rationale: The upper deep-sea slope is the main target of industrial trawlers fishing for valuable deep-sea fish species throughout the world. Negative effects of bottom trawling on the macrofaunal communities in the deep seabed have been related mainly to habitat smothering, burial of burrows and mortality caused by fishing gear. However, to our knowledge no quantification of the impact of trawling on benthic slope communities has been undertaken. This project aims at providing information on the recovery potential of the macrobenthic fauna inside the Haddock Box at the eastern slope of the Rockall Bank. The protected area has been closed to fisheries since 2001 and the species diversity of the macrofauna inhabiting the soft substrate is expected to show signs of recovery compared to the fishing area outside the Haddock Box.

Materials & methods: Five stations each, inside and outside the fishing closure on a 500 m depth contour (488 – 501 m), have been targeted for macrofaunal samples using a megacorer and box corer. The megacorer was armed with eight cylinders per haul. Both corers failed to take samples probably due to very coarse sediment at this depth contour (for station coordinates see table 9.2). The sampling was therefore ended after six unsuccessful sampling attempts.

Table 9.1. List of coring stations inside the haddock box

Station	Latitude	Longitude	Depth	Gear	No. of cores
JC060-077 (WP 199)	56° 34.298	14° 06.7742	498	Megacorer	FAILED
JC060-078 (WP 197)	56° 32.8466	14° 09.2609	488	Megacorer	FAILED
JC060-079 (WP 198)	56° 31.2372	14° 11.3282	501	Megacorer	FAILED
JC060-081 (WP 199)	56°34.295	14° 06.776	497	Box corer	FAILED
JC060-082 (WP 197)	56° 32.8477	14° 09.2654	486	Box corer	FAILED
JC060-083 (WP 198)	56° 31.241	14° 11.349	499	Box corer	FAILED

Due to the difficulties in sampling at Rockall Bank, the decision was made to conduct this study in the Darwin Mounds protected area. In total, 6 stations were sampled around the 800 m contour (769 – 823 m; 3 inside, 3 outside the fisheries closure), one megacorer deployment per station (Table 3). The upper 10cm of the cores were sliced into 0-5 cm and 5-10 cm layers. The two layers of the eight core samples per haul were pooled and sieved on a 250µm sieve. Afterwards they were preserved in 20% formalin (with seawater and borax added). For analyses of grain size and organic content a 20 ml sample of each haul was taken with a cut-off 20 ml syringe of one of the cores and frozen at -20°C.

Table 9.2. List of coring stations inside and outside the Darwin Mounts protected area.

Station	Latitude	Longitude	Depth	Gear	No. of cores	Location
JC060-107	59° 47.0328	07° 34.727	815	Megacorer §08	7	INSIDE
JC060-108	59° 47.354	07° 34.158	816	Megacorer §08	7	INSIDE
JC060-112	59° 47.575	07° 33.516	823	Megacorer §08	8	INSIDE
JC060-113	59° 41.905	07° 47.462	773	Megacorer §08	8	OUTSIDE
JC060-114	59° 41.904	07° 48.126	771	Megacorer §08	8	OUTSIDE
JC060-115	59° 41.892	07° 48.906	769	Megacorer §08	8	OUTSIDE

Niels Jobstvogt & Evina Gontikaki

10. <u>Further biological sampling for macrofauna and megafauna</u>

10.1. Darwin Mounds – boxcore – macrobenthos samples

Sixteen boxcore deployments were carried out in the Darwin Mound area, in an attempt to obtain large-volume samples of trawled and untrawled mound sediments to analyse the macrofaunal biodiversity. The corer used was the NOC NMFD stainless steel, USNEL-type, 0.25m^2 boxcorer. It was rigged and operated in conventional manner (penetration limit removed following first deployment). Rather as expected, none of the boxcore deployments in the Darwin Mounds area recovered a sample with top water retained, the short (c. 15cm) sandy sediment column recovered being insufficiently cohesive to support the water depth in the box once in air. Consequently, all samples were subject to wash-out. Relatively "intact" areas of the recovered sediment were sampled in a quantitative manner (see Fig. 8.1.), i.e. a known surface area, and sieved on a 500 micron mesh, with the resultant residue fixed and preserved in borax buffered 4% seawater formaldehyde. Nine boxcore deployments were (partly) successful, the other cores were discarded (too much wash-out) or did not trigger (see overview table).

These samples were collected on behalf of Dr J. Murray Roberts, Heriot-Watt University, to serve as a comparison to a similar set of samples collected from the Darwin Mounds area during RRS *Discovery* cruise 248 (Bett et al., 2001).

St No	Gear No	Final sample number	JDay	Date	Time GMT	Lat		Long		Lat	Long	depth	ship or USBL	Comments	Storage	Recipient
22	BC01	JC060_022_BC01	135	15/05/2011	14:42:00	59	50.882	7	3.644	59.84803	-7.06073	1051	usbl	15 cm core, top 10 cm of half box (0.125 m2) sieved for macrobenthos (500 um)	2 x 5 l buckets plus Xeno in smaller bucket	HW Uni
23	BC02	JC060_023_BC02	135	15/05/2011	16:53:00	59	50.96	7	3.957	59.84933	-7.06595	1052	usbl	top 10 cm of half box (0.125 m2) sieved for macrobenthos (500 um)	2 x 5 l bucket	HW Uni
25	BC03	JC060_025_BC03	136	16/05/2011	00:20:00	59	48.543	7	22.504	59.80905	-7.37507	952	ship	no recovery		
27	BC04	JC060_027_BC04	136	16/05/2011	15:57:00	59	48.65	7	21.78	59.81083	-7.363	968	usbl	0.075 x 10 cm thick sample sieved at 500 um for macrobenthos	2 x 5 l bucket	HW Uni
28	BC05	JC060_028_BC05	136	16/05/2011	18:05:00	59	48.47	7	22.122	59.80783	-7.3687	970	usbl	failed		
31	BC06	JC060_031_BC06	136	16/05/2011	23:13:00	59	48.471	7	22.134	59.80785	-7.3689	956	usbl	failed		
32	BC07	JC060_032_BC07	137	17/05/2011	00:33:00	59	48.474	7	22.14	59.8079	-7.369	957	usbl	failed		
34	BC08	JC060_034_BC08	137	17/05/2011	11:49:00	59	49.398	7	21.047	59.8233	-7.35078	955	usbl	qualitative sample retained, sieved on 500um	1 x 5 l bucket	HW Uni
36	BC09	JC060_036_BC09	137	17/05/2011	16:21:00	59	49.397	7	21.048	59.82328	-7.3508	965	usbl	0.125 m2 x 10 cm thick sample sieved at 500 um for macrobenthos	2 x 5 l bucket	HW Uni
37	BC10	JC060_037_BC10	137	17/05/2011	18:08:00	59	49.11	7	21.372	59.8185	-7.3562	963	usbl	0.1 m2 x 10 cm thick sample sieved at 500 um for macrobenthos	2 x 5 l bucket	HW Uni

39	BC11	JC060_039_BC11	137	17/05/ 2011	21:58:00	59	49.108	7	21.388	59.81847	-7.35647	967	usbl	0.1 m2 x 10 cm thick sample sieved at 500 um for macrobenthos	2 x 5 l bucket	HW Uni
48	BC12	JC060_048_BC12	141	21/05/ 2011	19:14:00	59	51.029	7	7.891	59.85048	-7.13152	1056	usbl	0.1 m2 x 10 cm thick sample sieved at 500 um for macrobenthos	2 x 5 l bucket, plus surface coral in small bucket for dating	HW Uni
53	BC13	JC060_053_BC13	142	22/05/ 2011	07:24:00	59	50.651	7	7.571	59.84418	-7.12618	1059	usbl	failed	one large fragment of coral retained for dating	NOC
54	BC14	JC060_054_BC14	142	22/05/ 2011	09:26:00	59	50.648	7	7.564	59.84413	-7.12607	1060	usbl	succesful core with dead coral and xeno, 0.0625m2 x 10cm sieved on 500 um	1 x 5 l bucket, 2 large fragments of coral retained for dating	HW Uni/NOC
55	BC15	JC060_055_BC15	142	22/05/ 2011	11:13:00	59	51.002	7	8.621	59.85003	-7.14368	1047	usbl	failed		
58	BC16	JC060_058_BC16	143	23/05/ 2011	09:35:00	59	51.059	7	7.967	59.85098	-7.13278	1050	usbl	washed out, some large coral fragments		

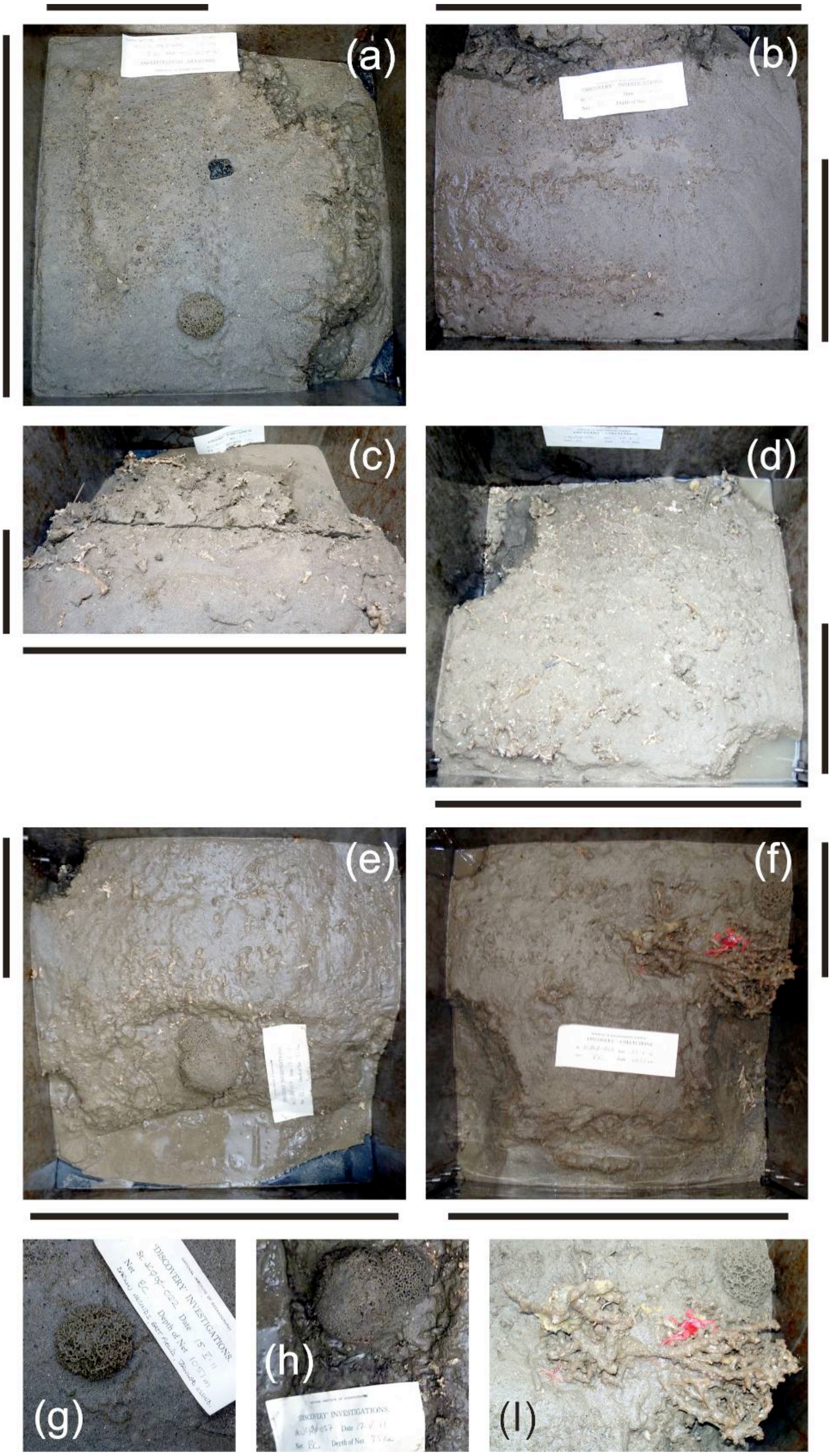


Fig. 10.1. Boxcore surface photographs. (a) JC060-022-BC; (b) -023-; (c) -027-; (d) -036-; (e) -037-; (f) -048-. Surface details: (g) JC060-022-BC, Xenophyophore (Syringammina fragilissima); (h) -037-, Xenophyophores (Syringammina fragilissima), budding?; (i) -048-, Xenophyophore (Syringammina fragilissima) and coral debris with epifauna. Side bars on (a)-(f) indicate areas sampled.

10.2.Darwin Mounds – other samples

JC060-012: Coral remnants (plastic bag, dry sample) Discovery Collections, NOC; c/o Dr Tammy Horton, NOC)

JC060-019: Holothurioidea, from incubation experiment (alive after 21-days) (small glass vial, 4% formaldehyde) (Dr David Billett, NOC)

JC060-027: Coral remnants (plastic bag, dry sample) Discovery Collections, NOC; c/o Dr Tammy Horton, NOC)

JC060-027: Echiura (500ml bucket, 4% formaldehyde) (*Discovery Collections*, NOC; c/o Dr Tammy Horton, NOC)

JC060-048: Amphipoda (?*Ampelisca*) (burrow photographs, see bjb_fig_2) (squat 250ml plastic jar, 4% formaldehyde) (Dr Tammy Horton, NOC)

JC060-054: Coral remnants (500ml bucket, dry sample) Discovery Collections, NOC; c/o Dr Tammy Horton, NOC)

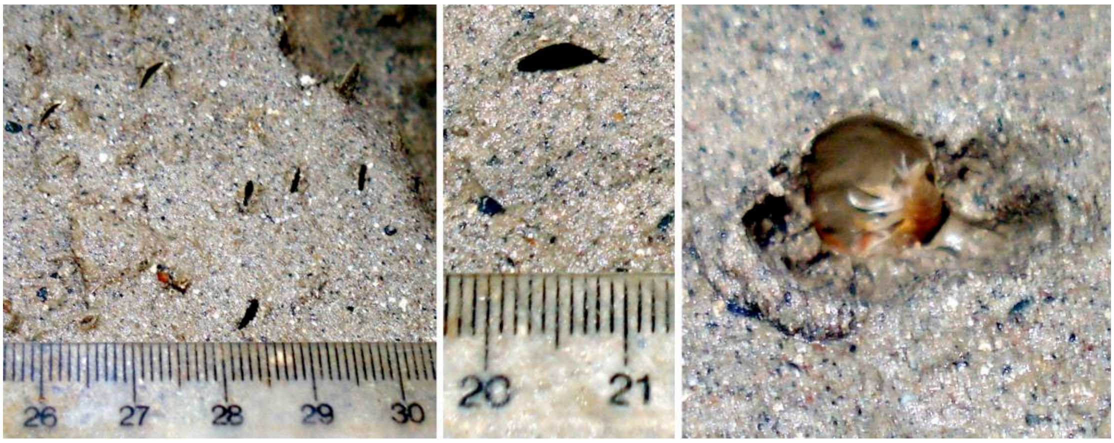


Fig. 10.2. JC060-048 box core surface detail showing amphipod burrows and partially excavated amiphod in situ.

10.3.Hatton Basin – megacore – meiobenthos samples

JC060-069: core A 12.32cm^2 0-5cm (500ml plastic jar) (*Discovery Collections*, NOC; c/o Dr Tammy Horton, NOC)

JC060-069: core B 12.32cm^2 0-5cm (500ml plastic jar) (*Discovery Collections*, NOC; c/o Dr Tammy Horton, NOC)

JC060-072: core A 12.32cm^2 0-5cm (500ml plastic jar) (*Discovery Collections*, NOC; c/o Dr Tammy Horton, NOC)

JC060-072: core B 12.32cm^2 0-5cm (500ml plastic jar) (*Discovery Collections*, NOC; c/o Dr Tammy Horton, NOC)

NOC OBE/MG Megacorer, 10cm ID tubes, sub-cored with cut off syringes (2 per Megacore tube) of 2.8cm ID, 0-5cm horizon, giving total sample of 12.32cm^2, fixed and preserved in borax buffered 4% seawater formaldehyde. Collected speculatively against possibility of fluid-flow influenced fauna in the region.

10.4.Rockall Bank

JC060-105 (Southern Boundary Area): *Lophelia pertusa* polyp samples for genetic analysis (500ml plastic jar, laboratory reagent grade absolute ethanol) (*Discovery Collections*, NOC; c/o Dr Tammy Horton, NOC)

JC060-105 (Southern Boundary Area): Coral remnants (plastic bag, dry sample) (*Discovery Collections*, NOC; c/o Dr Tammy Horton, NOC)

Brian Bett

11. Ship systems

11.1. GPS

All GPS units worked well during this cruise with no reported problems.

11.2. USBL – Ultra Short Baseline

Brief Description of Operations

Due to a fault with the Big Head (Transceiver model 8023), USBL operations were conducted solely with the Standard USBL Head (transceiver Model 8021) for the duration of JC060. The Standard USBL Head was replaced just before the cruise, as it had developed a fault a few months before as well.

USBL Tracking was used on the following systems

- Autosub
- Hallin ROV
- Hallin TMS
- Mega Core
- Piston Core
- Box core
- CTD
- Moorings Deployment

In total over 100 USBL equipped deployments occurred during JC060

Lack of Calibration

During JC060 the Standard head was not calibrated and operated in the UNCALIBRATED state it was delivered from the factory. During the large number of deployments we found that the transceiver appeared to give good positional values with a high degree of repeatability on subsequent ROV dives or coring operations. Where possible the position data from the USBL system was cross-referenced with the data acquired from the Autosub telemetry system which showed very good comparisons. Measuring the position of the beacon on the equipment and comparing it with wire-out from the winch system we had roughly 0.2m depth accuracy. Furthermore, in the relatively shallow depths we were operating in, errors would have been minimal.

Beacons

Fig. 11.1. SMBA Box corer had a super sub mini mounted on the frame which gave good returns

Fig. 11.2. The TMS was routinely equipped with two USBL Beacons, 12 and the new wideband super sub mini. Both beacons are shown in this image

File/Data Deliverables in Ranger – Com Port Generated
Due to problems with the 'Fusion' USBL software, the more basic 'Ranger' package had to be used. This presented us with a number of limitations.

In Fusion one is able to track multiple beacons and save each vehicle's co-ordinates in a separate log file. This feature is not available in Ranger and each vehicle's position is sent to the same file as well as to our TECHSAS data logger with no vehicle identifier field to distinguish which vehicle the position came from. The propriety "Acoustic Log File" generated by the Ranger software includes all beacons in a single file, although they are identified by their name (highlighted in bold) e.g :

*TPDR,20:16:50.033,**MoorRelease**,5,244276,3,20:16:49.876,1.528,0.207,186.086,0,1.0,604517.42,6636356.67,19.04,0,0.0,0.0,0.0,0.0,0.0*

However, in this file positions of beacons are given as Northings/Eastings, which is not ideally suited for our purposes. The fields recorded in the Acoustic Log file for transponders are:

- TPDR
- tick
- name
- index
- fix
- flag
- time

- pitch
- roll
- bearing
- residual
- quality
- east
- north
- depth
- const
- x_angle
- y_angle,
- debug1
- debug2
- debug3

However, during JC060 we rarely had more than one "system" in the water that required tracking at any given time. Hence the position of the system in use at that moment could be recorded correctly within the TECHSAS files. Whilst operating the ROV we were usually a good number of kilometres away from any Autosub survey which made tracking the AUV impossible. On one instance we deployed a piston core whilst tracking Autosub, but this was a one-off scenario. During ROV operations we frequently operated with two beacons on the TMS and one on the ROV. However, the beacons on the TMS were disabled in Ranger from outputting individual positions to the reports and were only used to show the pilots where the TMS was in relation to the ROV and ship – hence the USBL positions in the TECHSAS files were limited to the ROV positions.

However, even when disabled from outputting to reports (i.e the text based reports given below and the output to TECHSAS) the position of the beacons are still logged in the acoustic log file, albeit in Northings & Eastings (UTM coordinates, spheroid WGS84, Zone 28N or 29N depending on the study area).

11.3. SBP120 – Sub Bottom Profiler

System Specification

Frequency Sweep Range	2.5 to 7khz
Number of Beams per Ping	Maximum 11
Maximum Ping rate	4Hz
Beamwidth	4Khz (along x across)
Transmit	3/6/12 x 35 degrees
Recive	80 x 3/6/12 degrees

General Operation

The SBP was extensively used throughout JC060. Data quality was dependant on weather conditions (see below). However, the system preformed well and produced some high quality data.

Operational Settings

High Speed Transit– 7-10kts

Source Power: -10-20db depending on depth
Pulse Form: Hyperbolic Chirp Up
Beam Width TX/RX: Normal/Wide 10

Survey Speed – Shallow Water – 100-300m Rockall
Source Power: -20-25db
Pulse Form: Hyperbolic Chirp Up
Beam Width TX/RX: Normal

Survey Speed – Deep Water – 1000m Darwin Mounds
Source Power: -10db
Pulse Form: Hyperbolic Chirp Up
Beam Width TX/RX: Normal

Motion Data
It was noted on more than one occasion that motion data (pitch) was visible in the displayed data. Screenshots of the problem were forwarded to Kongsberg who are investigating the problem.

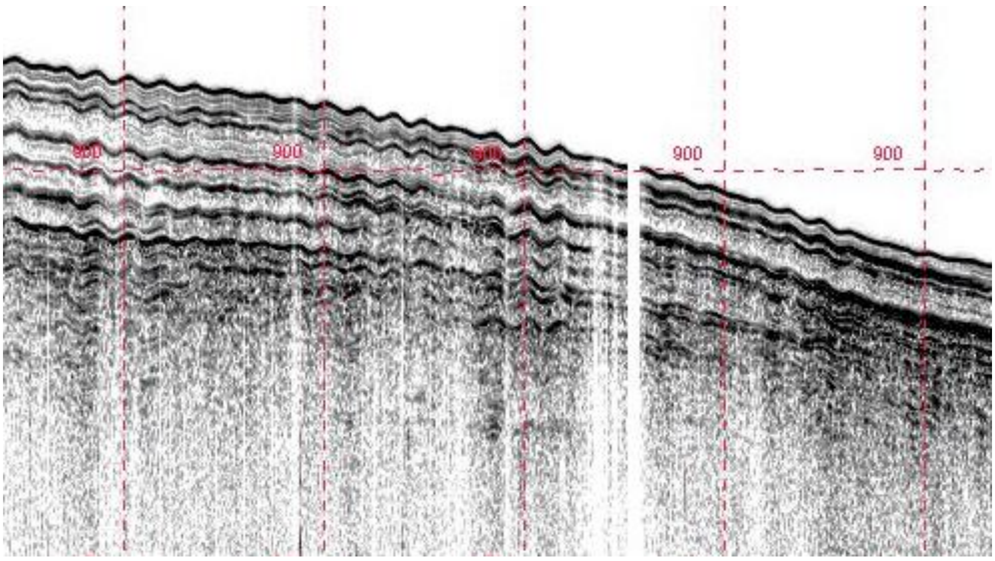


Fig. 11.3. Example of SBP120 data affected by swell conditions

Surveys/Data Logging
During the cruise all data was logged in
JC060[DAT TIME]_002.seg
BGS-JC060-Storn_022.seg
JC060-transittoHatton-[DATE TIME]_003.seg
Hatton0057-156_002.seg
Rockall_149_DATETIME_001.seg

11.4. EM120 – Deep Water Multibeam
The EM120 was used at sites > 450m. However, as the majority of the surveys were conducted in water depths < 350m the EM710 was predominantly used. Banding was still a considerable issue on this cruise. A Kongsberg engineer will be visiting the vessel in Glasgow and conducting a number of tests on the EM120 system to try and remove this issue. All on-board processing was conducted by the scientific party (see sections 2.5. and 2.6.).

Surveys Conducted
JC060_1 – All data from this cruise were logged in this survey

11.5. EM710 – Shallow Water Multibeam

The EM710 was used to conduct a large number of surveys throughout the cruise, and all processing was carried out by the scientific party (see sections 2.7. and 2.8.). When swathing from Glasgow to Ullapool it was noted that the drop keel offsets were for the drop keel extended and not flush with the hull. This mistake was communicated to the scientists and corrected by TLB in post processing.

Surveys Conducted

JC060_131
JC060_Clyde_Survey
JC060_Rockall
JC060_BGS
Survey_To_Darwin

11.6. EA500

Operated well throughout the cruise with no reported issues

11.7. Sound Velocity

XBTs

Two XBTs were deployed during the cruise, which worked without problems. However, the XBT probes were found to be several years out of date and produced incorrect profiles when compared with SVPs deployed in the same area. It was decided to discontinue use of XBTs.

SVPs

Valeport XXX was used throughout JC060. SVPs were taken at stations 2, 49, 59 and 89 and both raw and processed files are included on the end-of-cruise disk. All profiles were correct and loaded into the Em120, Em710, Ea600 and USBL with times noted in the Event Log/Watch Sheets

Leighton Rolley

12. Wildlife observations

Week one: 9-15 May

The initial passage north through the Sea of the Hebrides and The Minch on 10 May produced most of the commoner seabirds, including 140 Puffins, a few Great and Arctic Skuas, a pod of at least 10 Common Dolphins, and single Collared Dove and Willow Warbler on deck dodging the blustery showers. A brief port call in Ullapool produced a distant Great Northern Diver and a scatter of smart Black Guillemots in Loch Broom.

Fig. 12.1. Common Dolphins accompanying the ship through The Minch

On 11 May we were on transit to our work area over the Darwin Mounds, about 150 km NNW of Lewis. Timed hourly counts consistently produced 100-250 birds per hour, mostly Fulmars, Gannets and Kittiwakes with smaller numbers of Manx Shearwaters, Great Skuas, Black-headed Gulls, Lesser Black-backed Gulls, Arctic Terns and Puffins.

Fig. 12.2. Adult Gannet

Fig. 12.3. Great Skua

The first few days of work (12-15 May) in the Darwin Mounds area at ~1000m water depth produced a northwards passage of 24 Pomarine Skuas and smaller numbers of Great and Arctic Skuas. Most of the Pomarine Skuas were in ones and twos, with no sign of the large flocks seen passing the Outer Hebrides at the same time (presumably because of the lack of a focussing effect).

Fig. 12.4. Pomarine Skua

There was also a steady northwards passage of Arctic Terns and Puffins, with occasional Manx Shearwaters and a single migrant Shag. Hundreds of Fulmars aggregated around the ship each day, including occasional intermediate and dark morph birds. Smaller numbers of large gulls and Kittiwakes were also attracted to the vessel, which in turn attracted regular close fly-bys from photogenic Pomarine Skuas.

Fig. 12.5. Curious Fulmars investigating Autosub6000, our Autonomous Underwater Vehicle

Fig. 12.6. Intermediate-morph Fulmar and Autosub6000

Migrant land birds on deck included Swallow, Wheatear, Meadow Pipit, White Wagtail and Blackcap, while a Turnstone circled the ship for a couple of minutes one morning. The two Wheatears, a male and a female, arrived independently on deck on 12 May, and both looked exhausted and in poor condition. Later that day they were seen huddled close together on top of a container, and the next morning the female was picked up dead. The wing length of 101 mm confirmed that this was a Greenland race bird, and the lack of body fat indicated it had probably been over the water for some time.

Fig. 12.7. Close-up of male Greenland Wheatear on deck

Fig. 12.8. Later in the day the male and female were seen huddled together for warmth

The first offshore sighting of cetaceans came on 15 May, with a mixed group of about 100 Long-finned Pilot Whales and White-sided Dolphins around the ship for most of the day.

Fig. 12.9. Part of a large pod of Pilot Whales

Fig. 12.10. Spy-hopping juvenile Pilot Whale checking out the ship (

Fig. 12. 11. White-sided Dolphins and Fulmar

Week two: 16-22 May

Work continued in the Darwin Mounds area from 16-17 May. The highlight was two Iceland Gulls (a first-summer and a third-summer), mixed in with a large flock of Fulmars and Gulls around the ship on 17 May. Two adult Long-tailed Skuas passed northwards overhead while the Iceland Gulls were being photographed, and a Blue Fulmar was picked out from the flock.

Fig. 12.12. First-summer Iceland Gull

Fig. 12.13. Third-summer Iceland Gull

Fig. 12.14. Adult Long-tailed Skua

Fig. 12.15. Dark-morph 'Blue' Fulmar

Pomarine Skuas also continued moving north, with ten seen including one dark phase bird. Also of note were three Leach's Storm Petrels, one European Storm Petrel, at least 40 Puffins, and small numbers of Manx Shearwater, Great Skua, Arctic Skua and Arctic Tern. The only land bird migrants were Purple Sandpiper (which was later found dead) and White

Wagtail, while a distant view of at least five Pilot Whales on 16 May could have related to some of the animals seen the previous day.

Fig. 12.16. Purple Sandpiper: this exhausted bird drowned when flushed off deck and was later seen being pecked at in the water by hungry Fulmars

Bad weather on 18 May saw the ship retreating back to The Minch, where another Pomarine Skua, two Red-throated Divers, a Swallow and a pod of 5-10 Common Dolphins were seen. On 21 May the wind eased and the ship headed back out to the Darwin Mounds, with the passage north producing four Long-tailed Skuas and one Pomarine Skua heading north, as well as a European Storm Petrel and a total of 11 Whimbrel over.

On the shelf the density of birds was reasonably consistent (130-250 birds per hour) but rapidly increased in deep water on the continental slope, with many hundreds of Fulmars, Gannets, Kittiwakes and other common seabirds. A lone Swallow visited the main lab for a few hours and later left of its own accord, but was sadly found dead on deck the following day.

Fig. 12.17. Exhausted Swallow roosting in the main lab; sadly this bird was found dead on the outer deck on the following day

Week three: 23-29 May

Bad weather saw us heading westwards to the next work area, and on 25 May we started work in Hatton-Rockall Basin about 550 km west of Lewis. Seabird sightings on that day included a 2nd-summer Iceland Gull, two Pomarine Skuas (including one dark phase bird) and four Arctic Terns. More surprising was a flock of three Great Northern Divers flying west, presumably heading for Greenland.

Fig. 12.18. Second-summer Iceland Gull

Fig. 12.19. Pomarine Skua

Fig. 12.19. Pomarine Skua harassing Lesser Black-backed Gull

The following day saw two 1st-summer Glaucous Gulls and a first-summer Iceland Gull accompanying the Lesser Black-backed Gulls around the ship. A pale adult Pomarine Skua and a Blue Fulmar were also seen amongst the commoner seabirds.

Fig. 12.20. First-summer Glaucous Gull

The only land bird migrants were two Common Redpolls on board on 27 May. Their size and plumage indicated that they were of one of the northwest races, presumably en route to Iceland or Greenland.

Fig. 12.21. Northwest Common Redpoll, presumably heading for Iceland or Greenland

Further stormy weather on 28 May saw us relocating to the eastern part of Rockall Bank, about 330 km west of Barra. The following day an adult Sabine's Gull was attracted to food discards behind the ship.

Fig. 12.22. Adult Sabine's Gull

Week four: 30 May-5 June

The ship continued to operate in the East Rockall Bank area on 30-31 May, despite the ongoing bad weather. Another one or two adult Sabine's Gulls were seen, together with a moulting Sooty Shearwater and a Leach's Storm Petrel. A brief visit from a Common Redpoll on 30th presumably related to a new bird, as it is unlikely that the birds from 27th could have survived on board for three days.

Fig. 12.23. Sooty Shearwater; note the obvious wing moult

Sightings made on North Rockall Bank between 1 and 5 June included a pale adult Pomarine Skua (2nd), an adult Long-tailed Skua moving north (5th), and small numbers of European Storm Petrels, Manx Shearwaters, Great Skuas, Arctic Skuas, Arctic Terns, Guillemots and Puffins. A Wheatear briefly visited the ship (5th), on which date two pods of Pilot Whales totalling 25+ animals and an associated pod of at least 20 unidentified dolphins were seen.

Week five: 6-12 June

A pale adult Pomarine Skua was seen on 6 June on North Rockall Bank, and a small arrival of late migrant land birds included Wheatear, Meadow Pipit and two Swallows. A further spell of bad weather on 7-8 June saw the ship relocate back to the Darwin Mounds work area. On 9 June two Fin Whales spent an hour in the vicinity of the ship, and a Dunlin flew over.

Fig. 12.24. Fin Whale on a pre-dive roll, showing the falcate dorsal fin

The following day (10 June) the ship was again visited by an inquisitive pod of Pilot Whales, this time numbering at least 20 and including several calves. A Collared Dove on deck in the morning remained on board as we began our passage back to port in the evening. It was joined by another bird with both preening on the after deck as we rounded the Butt of Lewis.

Fig. 12.25. Pilot Whales; note the small calf


Fig. 12.26. Collared Dove

The final day of passage (11 June) through the North Channel in calm seas produced good numbers of commoner seabirds and a fly-over Whimbrel and Curlew.

Russell Wynn

RESULTS

1. **Darwin Mounds**

Combining the results from the Autosub mapping missions, ROV dives, boxcore recoveries and piston cores, the following preliminary conclusions can be drawn about the status of the Darwin Mound area:

- Based on a quick comparison of 410kHz sidescan sonar data from 2000 (Wheeler et al., 2008) and the new high-resolution maps of the same frequency, it appears that the number of trawl tracks has decreased significantly (Fig. 1.1.). It is not yet clear if the few trawl marks found in the JC060 surveys are remnants of old tracks, or if they are more recent. A re-positioning of the old data will be necessary before such conclusions can be drawn. However, the reduction in trawl marks on the seafloor seems to indicate that the fisheries closure is fairly well respected.

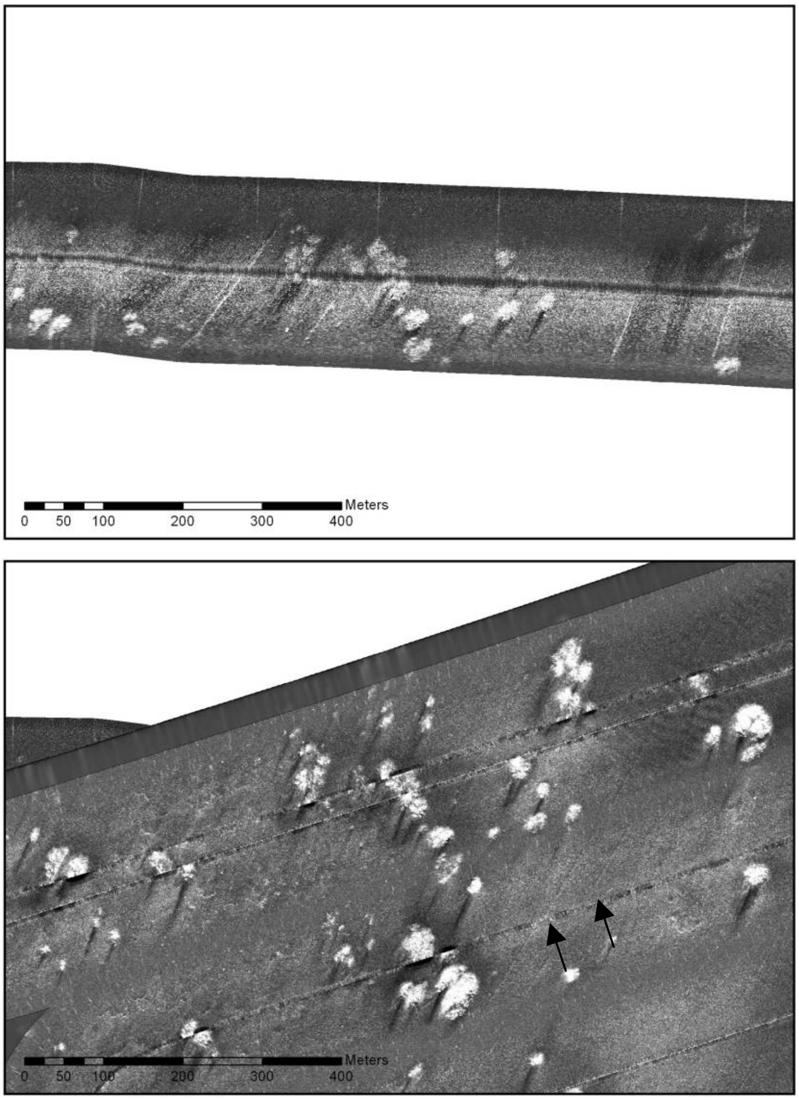


Fig. 1.1. 410kHz sidescan sonar record from the 2000 survey (courtesy NOCS and University College Cork) showing numerous trawl marks (top). The same area mapped during JC060 has only one set of parallel trawl marks (bottom)

- On the other hand, the Darwin Mounds are still mainly covered with dead coral. Especially in the Eastern Darwin Mound region, very little live coral was observed. The situation seems better in the Western Darwin Mounds, where larger colonies (>50cm high) were found. We also observed a number of colonies that appear to have continued growing even after the corals were dislocated or knocked over (Fig. 1.2.). This seems to suggest that a certain amount of regrowth is happening. However, no obvious signs of recolonisation (new colonies based on larval settlement) were observed. It is possible that the resolution of the camera systems was not sufficient to identify this, although no new coral growth was seen in any of the boxcores either. Perhaps 8 years of protection is too short for a recolonisation to take place, or perhaps no adequate larval input has happened/is possible to the region. It is also possible that the environmental conditions for the corals are marginal in this area, and recolonisation will be difficult. Further research and monitoring will be essential to answer these questions. However, despite the limited amount of live coral, the Darwin Mounds are reefs nonetheless, providing a habitat for a large community of associated fauna.

Fig. 1.2. Coral fragment in the Western Darwin Mounds that appears to have been knocked over but continued to grow.

- A clear difference was noted between Eastern & Western Darwin Mounds, in terms of current regime (which affects the substratum availability), associated fauna (e.g. Echiurans in the Western Darwin Mounds, but not in the Eastern field), and the percentage live Scleractinians.
- Despite the protection from bottom fishing activities, the Darwin Mounds are still impacted by human activities. A large amount of litter was encountered on the seabed (e.g. Fig. 1.3.), while more invisible human impacts such as global change and ocean acidification most probably will leave their traces on the area as well.

Fig. 1.3. Litter in the Western Darwin Mounds

- Considering the number of unanswered questions and the ongoing requirement for sustainable management, there is a strong need for further monitoring. The marker bouys left on the seabed will help with such activities in the near future.

Veerle Huvenne

2. Hatton Basin

The Rockall-Hatton PFS (Polygonal Fault System), with its surface expression and subsurface fault structures was targeted for reconnaissance using a suite of surface multibeam echosounding and sub-bottom profiling (SBP), low-altitude high-resolution swath bathymetry and sidescan imagery (via an AUV), ROV video inspection surveys, CTDs, piston and mega coring. The objective was to test whether there was any expression of fluid flow from the sub-seafloor into the overlying water column.

The reconnaissance survey was centred on 58°28'30"N, 16°26'30"W in a water depth of 1165m (Fig. 2.1). Following a multibeam and SBP survey, we chose sampling sites where the PFS's apparently breached the sea floor: these included a triple junction, a well defined single PFS trace and the centre of a polygon for comparison. An AUV (Autosub 6000) survey was also made over the area containing a triple junction, a PFS fault trace and a polygon centre.

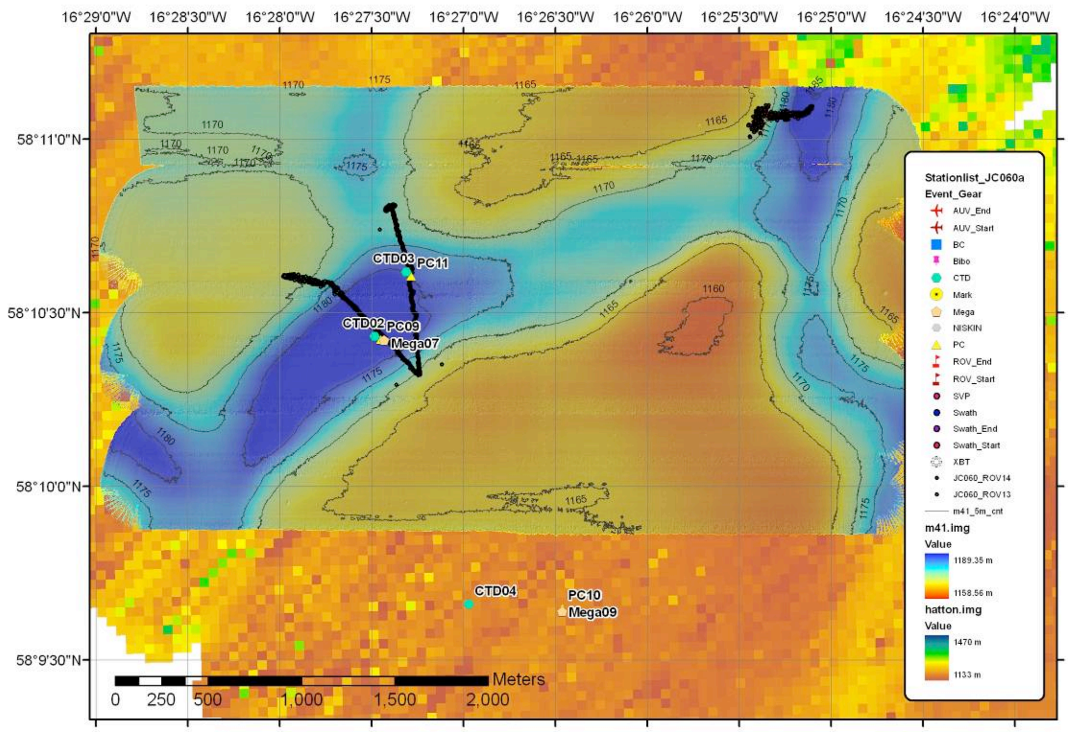
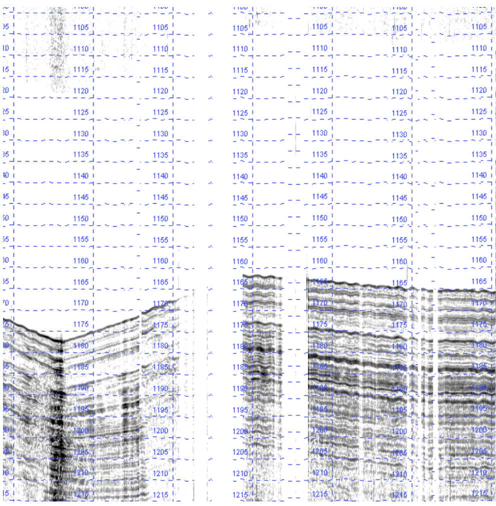


Fig. 2.1. Location map of survey and sampling work in Hatton Basin

SBP images obtained several tens of metres of penetration into the underlying substrate. Some PFS's stopped 5 to 10m short of the surface whilst others breached the surface. A variety of PFS styles were detected, some as single fault planes that emerged at the centre of 'V'-shaped troughs between polygons (Fig. 2.2), whilst others were either offset towards one of the inward-facing slopes of the troughs (Fig. 2.3) or presented as a double fault structure in a 'U'-shaped trough (Fig. 2.4). In some places, blanking of the underlying strata on the SBP may indicate intergranular gas occupying pore spaces in the upper 20m-30m of the trough sediments (Fig. 2.4).



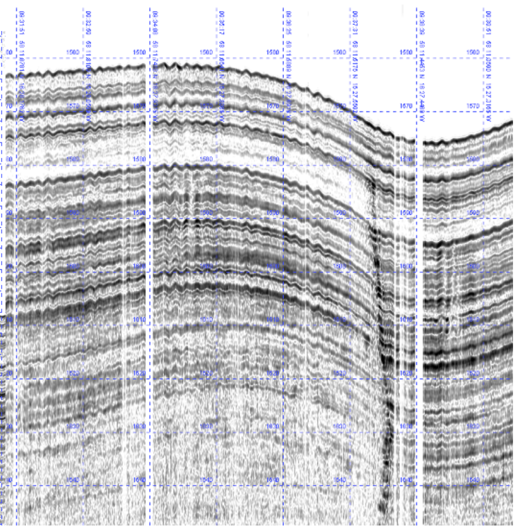


Fig. 2.2. (above left) showing an SBP image of a 'V'-shaped inter-polygonal trough hosting a centrally located fault trace and underlying vertically oriented fault.
Fig. 2.3. (above right) showing an SBP image of an asymmetric 'U'-shaped inter-polygonal trough hosting an offset fault trace and underlying steeply inclined oriented fault.

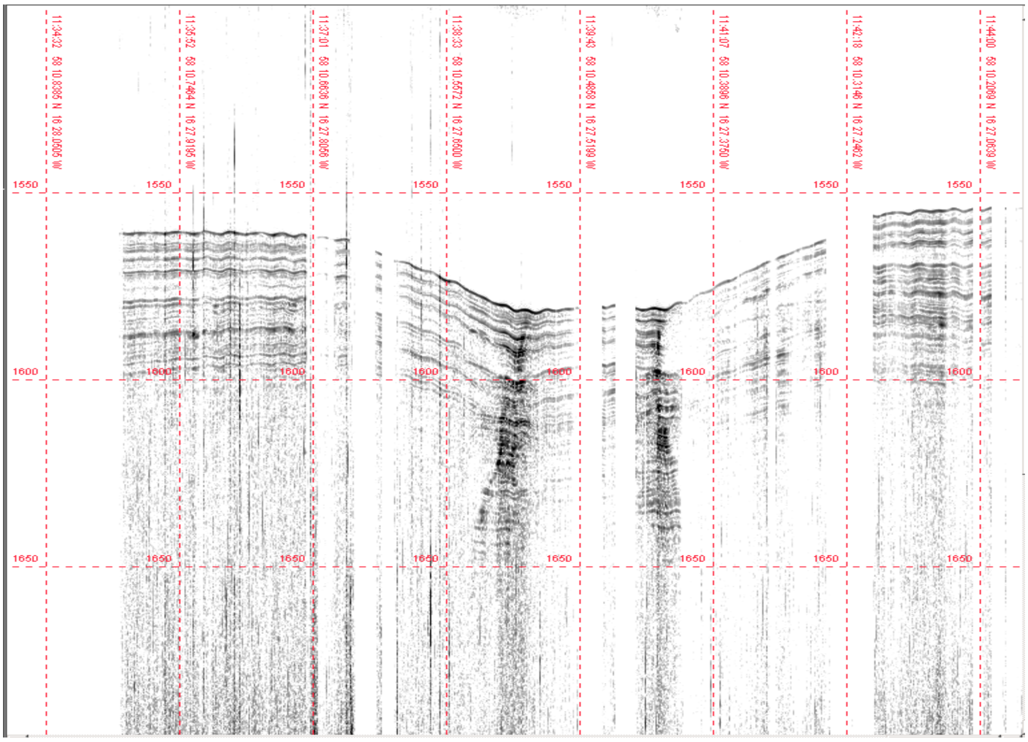


Fig. 2.4. (above) showing an SBP image of a ‘U’-shaped inter-polygonal trough hosting two centrally located fault traces and underlying steeply inclined outward-facing faults. Note to the right of the right-hand fault, a section of the substrata is ‘blanked’, despite the sea floor reflector being imaged, indicating the possible presence of intergranular free gas.

The piston core sampling was carried out with USBL navigation giving a precision of ±10m and an accuracy of ±5m (see Equipment reports, par. 6.2). These same stations were occupied by CTD casts and multi-cores. None of the cores showed any visible sign of fluid flow (no authigenic carbonates, gas bubbles or pipe structures) and comprised up to 4 or 5 glacial-interglacial sequences. Similarly, mega cores recoverd the top 50cm including seawater/sediment interfaces. All cores were sampled for fluids, including the seawater interface from the megacores. Pore waters were extracted with a decreasing depth interval frequency with increasing depth (see geochemical methods section) and all fluids preserved for methane, anions, trace metals, alkalinity and pH analyses. Sub cores were taken for methane, porosity and grain size (including XRD mineralogy) analyses.

The CTD casts showed a variable water structure with decreasing temperature and salinity (T & S) towards the bottom typical for the North Atlantic. A notable change was the gradient in T & S in the lowermost 20m, especially in the PFS troughs where T and S declined more rapidly than the 500m water column gradient above the troughs. This was also apparent from the Autosub6000 CTD data, which showed negative T anomalies in the troughs after correcting for the background T & S gradient. The Autosub6000 sensor data did not show any anomalies in Eh or optical backscatter as the sensors were compromised by bio-fauling during the dive. However, the high-resolution multibeam data did show scattered pock-marks around the edges of the inter-polygon troughs. These were up to 10m in diameter and 5 - 10m deep. Some had elevated centres similar to a central high with a peripheral moat.

Two ROV surveys were carried out in the area (Fig. 2.1.). The first one was aimed at the groundtruthing of one triple junction, and included a full transect of the fault trace that was cored before plus the crossing of two pockmarks. The second dive was a short mission to a large pockmark with positive feature identified from the AUV bathymetry.

The first pock-mark was found to be a large drop stone with a peripheral erosional trench. The drop-stone was rich in sessile fauna. The second pock-mark was found to be covered in its centre by large boulders and rubble. Neither showed any evidence for fluid flow, except perhaps the latter, which had black staining to the upper surfaces of the boulders indicative of reducing conditions (Fig. 2.5). The last pock-mark proved the exception and was floored by a large and disrupted slab of *insitu* authigenic carbonate. This dark-coloured, horizontally layered yet massive lithology was undercut by erosion where its thickness of at least 500 to 1000mm was observed. Again, there were blackened stains to the rock indicative of reducing conditions. Fauna were both abundant and richly diverse relative to the sparsely populated surrounding sea floor.

No evidence was seen on the ROV dive for fluid flow, or even any surficial expression of the fault traces we could see breaching the sea floor on the SBP. This may mean that fluid escape is currently either too slow, or not present, to be seen. However, the geochemical profiles of the pore waters will be a more reliable test for slow advective fluid discharge, especially if by porous permeable migration rather than discreet channels.

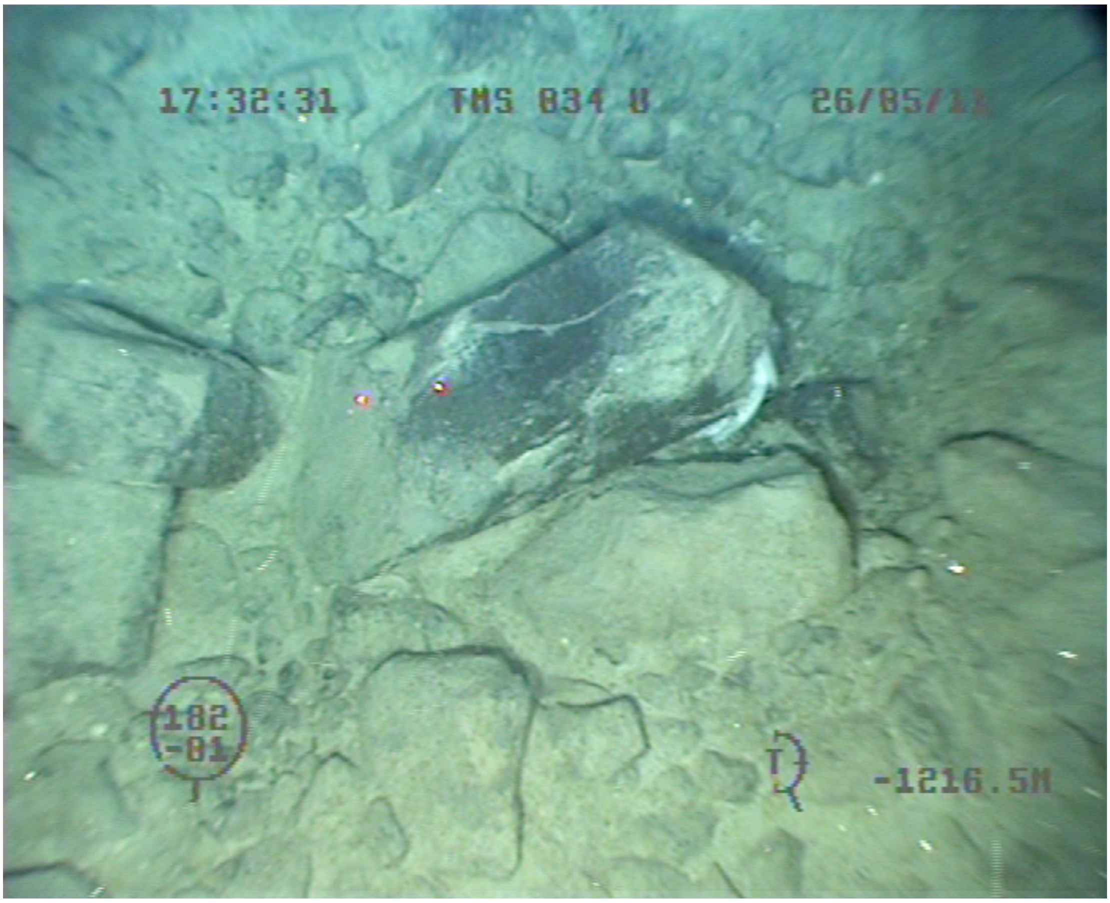


Fig. 2.5. Second pock-mark explored by ROV at the Hatton-Rockall PFS showing black staining (reduction) on top of the larger boulders indicative of recent/active fluid flow.

Bramley Murton

3. Rockall Bank

In total, 5 sub-areas were studied on Rockall Bank, as listed in Table 3.1 below (see also maps in Appendix).

Table 5.1. Survey areas and methods at Rockall Bank

Survey area	Description	Methods
1	Inside both the NW Rockall Bank cSAC and the NEAFC fisheries closure	• EM710 bathymetry and backscatter • Autosub 6000 high resolution side scan • 3 ROV dives (1 to collect samples – which were lost)
2	Western box inside the NW Rockall Bank cSAC but not inside the NEAFC fisheries closure	• EM710 bathymetry and backscatter • Autosub 6000 high resolution side scan • 2 ROV dives
3	Eastern box inside the NW Rockall Bank cSAC but not inside the NEAFC fisheries closure	• EM710 bathymetry and backscatter • Autosub 6000 high resolution side scan • 2 ROV dives, last one to sample live & dead coral
4	NE flank of Rockall Bank	• 2 ROV dives
5	Haddock Box	• EM710 bathymetry and backscatter • Autosub 6000 high resolution sidescan • 1 ROV dive inside the Haddock box

Live coral was found in survey areas 1, 3 and 4. Dead coral or coral rubble was found in survey area 2 and a small amount in area 5. The high resolution sidescan from Autosub6000 was used to plan the ROV dives. Areas of possible coral were identified in the sidescan sonar images and targeted in the subsequent ROV dives. The most extensive patches of reef were found on the western edge of survey area 3 which is not currently included in the NEAFC fisheries closure. Three large cold water coral reefs averaging about 10m in length and 4m in height were found in this area, providing further evidence that this area should be included in the fisheries closure (Fig. 3.1). The coral reefs in area 1 were smaller, but were much more numerous, again supporting the Fisheries Closure and cSAC.

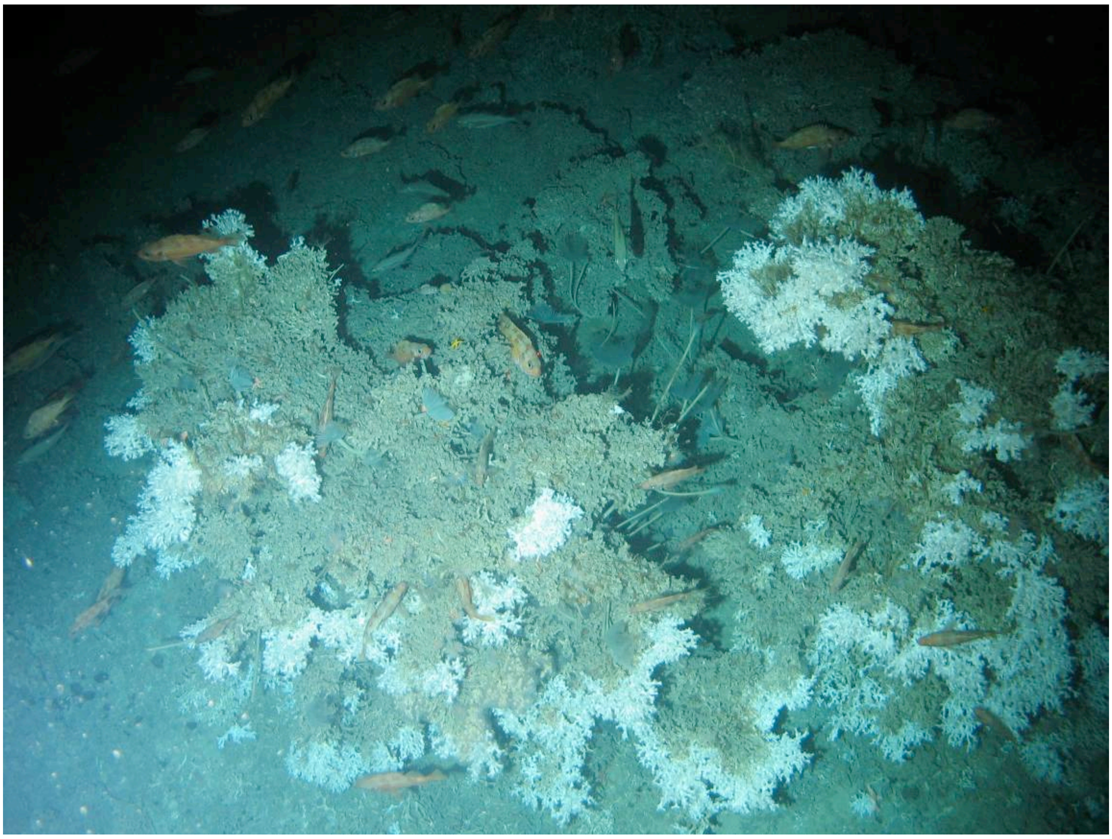


Fig. 3.1. Coral reefs with associated fauna in study area 3 on NW Rockall Bank

The reconnaissance dives in area 4 provided footage of rich coral communities and potential 'coral gardens'. The results indicate that more, focussed research is necessary towards these steep topographies and cliff habitats.

The JC060 work in the Haddock Box area provided evidence that trawling still occurs both within and outside the Fisheries Closure (Fig. 3.2). The ROV footage provided observations of high abundances of red urchins (*Echinus*), flatfish, some coral rubble and sea cucumbers.

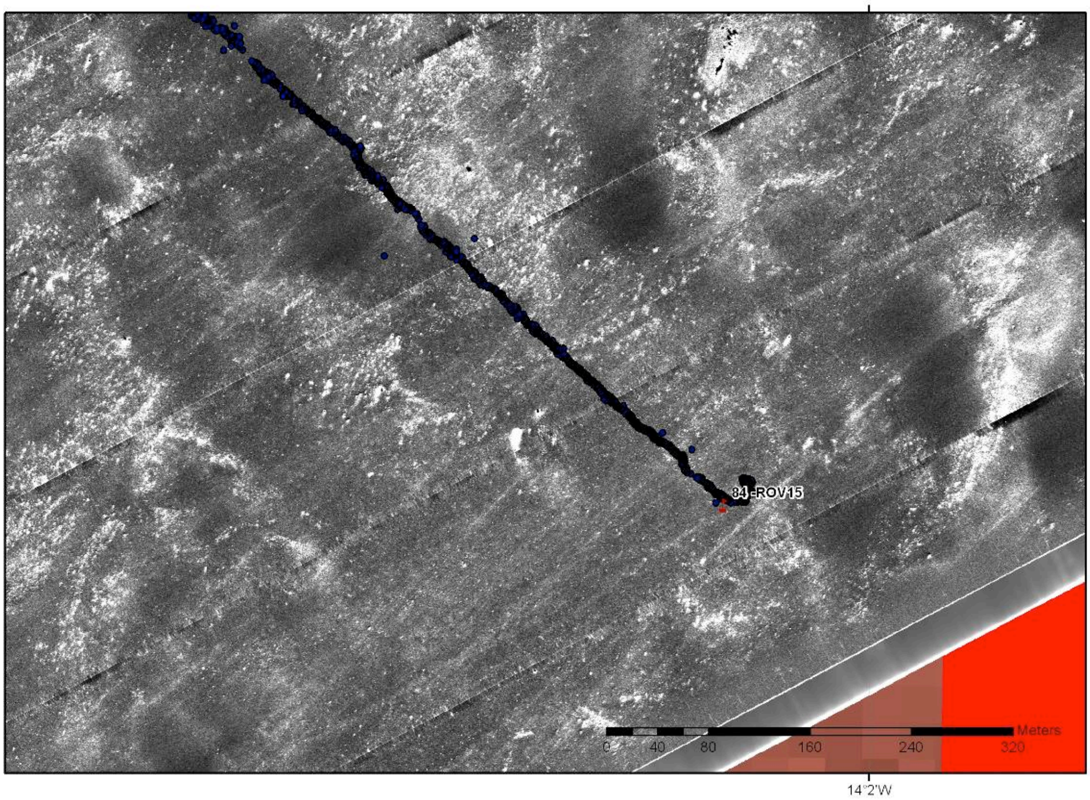


Fig. 3.2. Autosub6000 sidescan sonar imagery from the western part of Mission 42 (inside the Haddock Box). See main map section in Appendix for location. The sidescan data shows a large number of trawl tracks in an area which we later on crossed during ROV Dive15 (station JC060_84).

Fionnuala McBreen and Sophie Elliot

REFERENCES

Berndt, C., Jacobs, C., Gay, A., Hitchen, K., and Long, D.. 2006. Km-scale polygonal seafloor depressions in the Hatton Basin: New clues on the origin of polygonal fault systems, EGU General Assembly: Vienna, Austria.

Bett, B.J., Billet, D.S.M., Masson, D.G. and Tyler, P.A., 2001. RRS Discovery cruise 248 - A multidisciplinary study of the environment and ecology of deep-water coral ecosystems and associated seabed facies and features (The Darwin Mounds, Porcupine Bank and Porcupine Seabigth). 36, Southampton Oceanography Centre.

Cartwright, J.A., James, D. and Bolton, A., 2003. The genesis of polygonal fault systems. In: P. Van Rensbergen, R.R. Hillis, A. Maltman and C.K. Morley (Editors), Subsurface sediment mobilisation. Geological Society London, pp. 223-243

Davies, A.J., Narayanaswamy, B.E., Hughes, D.J. & Roberts, J.M., 2006. An Introduction to the Benthic Ecology of the Rockall - Hatton Area (SEA 7). Department of Business Enterprise and Regulatory Reform, London. (www.offshore-sea.org.uk/consultations/SEA_7/).

Davies, A.J., Roberts, J.M. and Hall-Spencer, J., 2007. Preserving deep-sea natural heritage: emerging issues in offshore conservation and management. Biological conservation, 138: 299-312.doi: 10.1016/j.biocon.2007.05.011

Durán Muñoz, P., Sayago-Gil, M., Christobo, J., Parra, S., Serrano, A., Díaz del Rio, V., Patrocinio, T., Sacau, M., Murillo, F.J., Palomino, D. and Fernández-Salas, L.M., 2009. Seabed mapping for selecting cold-water coral protection areas on Hatton Bank, Northeast Atlantic. Ices Journal of Marine Science, 66(9): 2013-2025.DOI: 10.1093/icesjms/fsp170

Elliot, G.M., Shannon, P.M., Haughton, P.D.W. and Øvrebø, L.K., 2010. The Rockall Bank Mass Flow: collapse of a moated contourite drift onlapping the eastern flank of Rockall Bank, west of Ireland. Marine and Petroleum Geology, 27: 92-107.doi: 10.1016/j.marpetgeo.2009.07.006

Freiwald, A., Fosså, J.H., Grehan, A., Koslow, T. and Roberts, J.M., 2004. Cold-water coral reefs; out of sight - no longer out of mind, UNEP-WCMC, Cambridge.

Georgiopoulou, A., Benetti, S., Shannon, P.M., Haughton, P.D.W., McCarron, S., in press. Gravity flow deposits in the deep Rockall Trough, Northeast Atlantic. In: Y. Yamada, K. Kawamura, K. Ikehara, Y. Ogawa, D. Mosher, J. Chaytor, M. Strasser, (Eds), Advances in Natural and Technological Hazards Research, Submarine Mass Movements and their Consequences, 4th Edition, Springer.

Howell, K.L., Davies, J.S. and Narayanaswamy, B.E., 2010. Identifying deep-sea megafaunal epibenthic assemblages for use in habitat mapping and marine protected area network design. Journal of the Marine Biological Association of the United Kingdom, 90(1): 33-68

Howell, K.L., Holt, R., Pulido Endrino, I, Stewart, H. (submitted) When the species is also a habitat: comparing the predictively modelled distributions of Lophelia pertusa and the reef habitat it forms. Biological Conservation

Huvenne, V.A.I., Beyer, A., de Haas, H., Dekindt, K., Henriet, J.P., Kozachenko, M., Olu-Le Roy, K., Wheeler, A.J. and the TOBI/Pelagia 197 and CARACOLE cruise participants, 2005. The seabed appearance of different coral bank provinces in the Porcupine Seabight, NE Atlantic : results from sidescan sonar and ROV seabed mapping. In: A. Freiwald and J.M. Roberts (Editors), Cold-water corals and ecosystems. Springer-Verlag, Heidelberg, pp. 535-569

Huvenne, V.A.I., Masson, D.G. and Wheeler, A.J., 2009. Sediment dynamics of a sandy contourite: the sedimentary context of the Darwin cold-water coral mounds, Northern Rockall Trough. International Journal of Earth Sciences, 98(4): 865-884.doi: 10.1007/s00531-008-0312-5

Masson, D.G., Bett, B.J., Billett, D.S.M., Jacobs, C.L., Wheeler, A.J. and Wynn, R.B., 2003. The origin of deep-water, coral-topped mounds in the northern Rockall Trough, Northeast Atlantic. Marine Geology, 194: 159-180

Mienis, F., de Stigter, H.C., de Haas, H. and van Weering, T.C.E., 2009. Near-bed particle deposition and resuspension in a cold-water coral mound area at the Southwest Rockall Trough margin, NE Atlantic. Deep-Sea Research I, 56(6): 1026-1038.doi:10.1016/j.dsr.2009.01.006

Wheeler, A.J., Bett, B.J., Billet, D.S.M., Masson, D.G. and Mayor, D., 2005. The impact of demersal trawling on NE Atlantic deep-water coral habitats: the case of the Darwin Mounds, UK. In: P.W. Barnes and J.P. Thomas (Editors), Benthic habitats and the effects of fishing. America Fisheries Society, Bethesda, Maryland, pp. 807-817

Wheeler, A.J., Kozachenko, M., Masson, D.G. and Huvenne, V.A.I., 2008. Influence of benthic sediment transport on cold-water coral bank morphology and growth: the example of the Darwin Mounds, NE Atlantic. Sedimentology, 55, 1875-1887. doi: 10.1111/j.1365-3091.2008.00970

APPENDIX 1 – JC060 Station List

	needs updating with USBL position	yellow: missing information	green: entries not on Sample Log sheets - derived from	purple: entries that have been corrected and hence diff	blue: entries taken from bridge log

Cruise	Site	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 Water depth meter	Equip depth	ship or USBL position	End Date	End Time GMT	End Lat Degr	End Lat Min	End Long Degr	End Long Min	End water depth meter	Comments	Recipient
JC060	shelf trial	JC060_001_ROV01	131	11/05/2011	06:58:00	59	25.060	6	16.150	158		ship	11/05/2011	08:30:00	59	25.060	6	16.180	161	ROV test dive	
JC060	darwin mound	JC060_002_CTD01	131	11/05/2011	14:30:00	59	47.513	7	10.475	1087	1081	ship	11/05/2011	16:42:00	59	47.580	7	10.470			
		JC060_002_SVP01	131	11/05/2011	14:30:00	59	47.513	7	10.475	1087	1081	ship	11/05/2011	16:42:00	59	47.580	7	10.470			
		JC060_002_CTD01/n01	131	11/05/2011	15:34:00	59	47.580	7	10.470	1087	1081	ship									
		JC060_002_CTD01/n02	131	11/05/2011	15:34:00	59	47.580	7	10.470	1087	1081	ship									
		JC060_002_CTD01/n03	131	11/05/2011	15:35:00	59	47.580	7	10.470	1087	1081	ship									
		JC060_002_CTD01/n04	131	11/05/2011	15:35:00	59	47.580	7	10.470	1087	1081	ship									
		JC060_002_CTD01/n05	131	11/05/2011	16:07:00	59	47.580	7	10.470	1087	548	ship									
		JC060_002_CTD01/n06	131	11/05/2011	16:08:00	59	47.580	7	10.470	1087	548	ship									
		JC060_002_CTD01/n07	131	11/05/2011	16:09:00	59	47.580	7	10.470	1087	548	ship									
		JC060_002_CTD01/n08	131	11/05/2011	16:10:00	59	47.580	7	10.470	1087	548	ship									
JC060	darwin mounds	JC060_003_Swath01	131	11/05/2011	16:11:00	59	47.580	7	10.620	1096		ship	11/05/2011	00:00:00	59	57.640	7	41.638	556		
JC060	darwin mounds	JC060_004_Mega01/c01	131	11/05/2011	21:12:00	59	57.641	7	41.778	560	560	ship								total 40 cm; upper 5-6 cm gravelly sand, grades to mud below	Gontikaki
		JC060_004_Mega01/c02	131	11/05/2011	21:12:00	59	57.641	7	41.778	560	560	ship								total 40 cm; upper 5-6 cm gravelly sand, grades to mud below	Gontikaki
		JC060_004_Mega01/c03	131	11/05/2011	21:12:00	59	57.641	7	41.778	560	560	ship								total 39 cm; upper 5-6 cm gravelly sand, grades to mud below	Gontikaki
		JC060_004_Mega01/c04	131	11/05/2011	21:12:00	59	57.641	7	41.778	560	560	ship								total 39 cm; upper 5-6 cm gravelly sand, grades to mud below	Gontikaki
JC060	darwin mounds	JC060_005_Mega02/c01	131	11/05/2011	22:19:00	59	57.639	7	41.779	560	560	ship								total 48 cm, upper sediments coarse sand	Gontikaki
		JC060_005_Mega02/c02	131	11/05/2011	22:19:00	59	57.639	7	41.779	560	560	ship								total 45 cm, upper sediment sand	Gontikaki
		JC060_005_Mega02/c03	131	11/05/2011	22:19:00	59	57.639	7	41.779	560	560	ship								total 38 cm, upper 6 cm coarse sand	Gontikaki
		JC060_005_Mega02/c04	131	11/05/2011	22:19:00	59	57.639	7	41.779	560	560	ship								total 37 cm, upper layer coarse sand	Gontikaki
		JC060_005_Mega02/c05	131	11/05/2011	22:19:00	59	57.639	7	41.779	560	560	ship								total 41 cm, upper layer coarse sand	Gontikaki
		JC060_005_Mega02/c06	131	11/05/2011	22:19:00	59	57.639	7	41.779	560	560	ship								total 47 cm, upper layer coarse sand and gravel	Gontikaki
JC060	darwin mounds	JC060_006_Swath02	131	11/05/2011	23:04:00	59	57.245	7	40.923	554		ship	12/05/2011	05:17:00	59	48.703	7	12.241	1051		
JC060	darwin mounds	JC060_007_AUV37	132	12/05/2011	09:53:00	59	51.221	7	4.154	1051		ship	12/05/2011	16:07:00	59	51.002	7	3.729	1051	Autosub mission 37	
JC060	darwin mounds	JC060_008_Mega03/c01	132	12/05/2011	19:24:00	59	49.950	7	35.996	741	741	ship								total 39 cm, upper 6 cm layer of sand, pea gravel with epifauna	Gontikaki
		JC060_008_Mega03/c02	132	12/05/2011	19:24:00	59	49.950	7	35.996	741	741	ship								total 39 cm, upper 6 cm layer of sand, pea gravel with epifauna	Gontikaki
		JC060_008_Mega03/c03	132	12/05/2011	19:24:00	59	49.950	7	35.996	741	741	ship								total 39 cm, upper 6 cm layer of sand, pea gravel with epifauna	Gontikaki
		JC060_008_Mega03/c04	132	12/05/2011	19:24:00	59	49.950	7	35.996	741	741	ship								total 39 cm, upper 6 cm layer of sand, pea gravel with epifauna	Gontikaki
		JC060_008_Mega03/c05	132	12/05/2011	19:24:00	59	49.950	7	35.996	741	741	ship								total 39 cm, upper 6 cm layer of sand, pea gravel with epifauna	Gontikaki
		JC060_008_Mega03/c06	132	12/05/2011	19:24:00	59	49.950	7	35.996	741	741	ship								total 39 cm, upper 6 cm layer of sand, pea gravel with epifauna	Gontikaki
		JC060_008_Mega03/c07	132	12/05/2011	19:24:00	59	49.950	7	35.996	741	741	ship								total 38 cm, upper 6 cm layer of sand, pea gravel with epifauna	Gontikaki
		JC060_008_Mega03/c08	132	12/05/2011	19:24:00	59	49.950	7	35.996	741	741	ship								total 39 cm, upper 6 cm layer of sand, pea gravel with epifauna	Gontikaki
JC060	darwin mounds	JC060_009_Swath03	132	12/05/2011	21:01:00	59	49.131	7	29.907	850		ship	13/05/2011	04:32:00	59	48.063	7	19.127	1004		
JC060	darwin mounds	JC060_010_PC01	133	13/05/2011	06:29:00	59	49.445	7	22.541	938	938	usbl								core length 6.95 m	
JC060	darwin mounds	JC060_011_PC02	133	13/05/2011	09:16:00	59	48.976	7	22.562	949	949	usbl								core length 6.58 m	
JC060	darwin mounds	JC060_012_ROV02	133	13/05/2011	12:00:00	59	51.040	7	4.163	1048	1048	ship	13/05/2011	16:24:00	59	51.183	7	4.509	1045		
		JC060_012_ROV02/bibo1	133	13/05/2011	15:06:00	59	51.192	7	4.444	1045		usbl									
JC060	darwin mounds	JC060_013_AUV38	133	13/05/2011	18:48:00	59	48.931	7	23.028	945		ship	14/05/2011	16:58:00	59	48.516	7	22.503	954	Autosub mission 38	
JC060	darwin mounds	JC060_014_Mega04/c01	133	13/05/2011	22:58:00	59	41.529	7	28.618	920	920	ship								failed	
		JC060_014_Mega04/c02	133	13/05/2011	22:58:00	59	41.529	7	28.618	920	920	ship								failed	
		JC060_014_Mega04/c03	133	13/05/2011	22:58:00	59	41.529	7	28.618	920	920	ship								failed	
		JC060_014_Mega04/c04	133	13/05/2011	22:58:00	59	41.529	7	28.618	920	920	ship								failed	
		JC060_014_Mega04/c05	133	13/05/2011	22:58:00	59	41.529	7	28.618	920	920	ship								failed	
		JC060_014_Mega04/c06	133	13/05/2011	22:58:00	59	41.529	7	28.618	920	920	ship								failed	
		JC060_014_Mega04/c07	133	13/05/2011	22:58:00	59	41.529	7	28.618	920	920	ship								failed	
		JC060_014_Mega04/c08	133	13/05/2011	22:58:00	59	41.529	7	28.618	920	920	ship								failed	

JC060	darwin mounds	JC060_015_Mega05/c01	134	14/05/2011	00:20:00	59	41.520	7	28.620	920	920	ship								failed	
		JC060_015_Mega05/c02	134	14/05/2011	00:20:00	59	41.520	7	28.620	920	920	ship								failed	
		JC060_015_Mega05/c03	134	14/05/2011	00:20:00	59	41.520	7	28.620	920	920	ship								failed	
		JC060_015_Mega05/c04	134	14/05/2011	00:20:00	59	41.520	7	28.620	920	920	ship								failed	
		JC060_015_Mega05/c05	134	14/05/2011	00:20:00	59	41.520	7	28.620	920	920	ship								failed	
		JC060_015_Mega05/c06	134	14/05/2011	00:20:00	59	41.520	7	28.620	920	920	ship								failed	
		JC060_015_Mega05/c07	134	14/05/2011	00:20:00	59	41.520	7	28.620	920	920	ship								failed	
		JC060_015_Mega05/c08	134	14/05/2011	00:20:00	59	41.520	7	28.620	920	920	ship								failed	
JC060	darwin mounds	JC060_016_PC03	134	14/05/2011	04:42:00	59	50.586	7	20.050	948	948	ship								core length 6.17 m	
JC060	darwin mounds	JC060_017_ROV3	134	14/05/2011	08:54:00	59	50.753	7	3.437	1059		ship	15/05/2011	12:49:00	59	51.131	7	3.985	1045		
JC060	darwin mounds	JC060_018_PC04	134	14/05/2011	18:16:00	59	49.149	7	21.892	951	951	ship								core length 6.67 m	
JC060	darwin mounds	JC060_019_Mega06/c01	134	14/05/2011	23:11:00	59	34.063	7	37.350	945	945	ship								core length 41 cm, no distinct sand top	
		JC060_019_Mega06/c02	134	14/05/2011	23:11:00	59	34.063	7	37.350	945	945	ship								core length 42 cm, no distinct sand top	
		JC060_019_Mega06/c03	134	14/05/2011	23:11:00	59	34.063	7	37.350	945	945	ship								core length 42 cm, no distinct sand top	
		JC060_019_Mega06/c04	134	14/05/2011	23:11:00	59	34.063	7	37.350	945	945	ship								core length 42 cm, no distinct sand top	
		JC060_019_Mega06/c05	134	14/05/2011	23:11:00	59	34.063	7	37.350	945	945	ship								core length 42 cm, no distinct sand top	
		JC060_019_Mega06/c06	134	14/05/2011	23:11:00	59	34.063	7	37.350	945	945	ship								core length 44 cm, no distinct sand top	
		JC060_019_Mega06/c07	134	14/05/2011	23:11:00	59	34.063	7	37.350	945	945	ship								core length 42 cm, no distinct sand top	
		JC060_019_Mega06/c08	134	14/05/2011	23:11:00	59	34.063	7	37.350	945	945	ship								core length 43 cm, no distinct sand top	
JC060	darwin mounds	JC060_020_ROV04	135	15/05/2011	03:45:00	59	48.177	7	23.088	944		ship	15/05/2011	08:58:00	59	48.834	7	22.769	945		
JC060	darwin mounds	JC060_021_PC05	135	15/05/2011	11:54:00	59	50.882	7	3.659	1054	1054	usbl								core length 6.66 m	
JC060	darwin mounds	JC060_022_BC01	135	15/05/2011	14:42:00	59	50.882	7	3.644	1051	1051	usbl								15 cm core, half box (0.125 m2) sieved for macrobenthos (500 um)	HW Uni
JC060	darwin mounds	JC060_023_BC02	135	15/05/2011	16:53:00	59	50.960	7	3.957	1052	1052	usbl								top 10 cm of half box (0.125 m2) sieved for macrobenthos (500 um	HW Uni
JC060	darwin mounds	JC060_024_AUV39	135	15/05/2011	20:13:00	59	50.988	7	6.948	1052		ship	16/05/2011	13:12:00	59	50.417	7	6.881		Autosub mission 39	
JC060	darwin mounds	JC060_025_BC03	136	16/05/2011	00:20:00	59	48.543	7	22.504	952	952	ship								no recovery	
JC060	darwin mounds	JC060_026_ROV05	136	16/05/2011	01:58:00	59	48.426	7	22.075	960		ship	16/05/2011	09:01:00	59	48.652	7	21.840	959		
JC060	darwin mounds	JC060_027_BC04	136	16/05/2011	15:57:00	59	48.650	7	21.780	962	968	usbl								0.075 x 10 cm thick sample sieved at 500 um for macrobenthos	HW Uni
JC060	darwin mounds	JC060_028_BC05	136	16/05/2011	18:05:00	59	48.470	7	22.122	970	970	usbl								failed	
JC060	darwin mounds	JC060_029_Mark01	136	16/05/2011	20:03:00	59	48.663	7	23.082	944	944	usbl								tethered glass sphere marker for future repeat ROV survey	
JC060	darwin mounds	JC060_030_Mark02	136	16/05/2011	21:46:00	59	48.870	7	21.546	961	961	usbl								tethered glass sphere marker for future repeat ROV survey	
JC060	darwin mounds	JC060_031_BC06	136	16/05/2011	23:13:00	59	48.471	7	22.134	956	956	usbl								failed	
JC060	darwin mounds	JC060_032_BC07	137	17/05/2011	00:33:00	59	48.474	7	22.140	957	957	usbl								failed	
JC060	darwin mounds	JC060_033_ROV06	137	17/05/2011	04:13:00	59	48.866	7	21.626	960		ship	17/05/2011	09:48:00	59	49.490	7	21.708			
JC060	darwin mounds	JC060_034_BC08	137	17/05/2011	11:49:00	59	49.398	7	21.047	955	955	usbl									
JC060	darwin mounds	JC060_035_PC06	137	17/05/2011	14:13:00	59	49.398	7	21.038	956	956	usbl								frozen, not split, core length 3.7 m	
JC060	darwin mounds	JC060_036_BC09	137	17/05/2011	16:21:00	59	49.397	7	21.048	958	965	usbl								0.125 m2 x 10 cm thick sample sieved at 500 um for macrobentho	HW Uni
JC060	darwin mounds	JC060_037_BC10	137	17/05/2011	18:08:00	59	49.110	7	21.372	963	963	usbl								0.1 m2 x 10 cm thick sample sieved at 500 um for macrobenthos	HW Uni
JC060	darwin mounds	JC060_038_PC07	137	17/05/2011	20:04:00	59	49.104	7	21.378	961	961	usbl								not split, core length 7.79 m	
JC060	darwin mounds	JC060_039_BC11	137	17/05/2011	21:58:00	59	49.108	7	21.388	967	967	usbl								0.1 m2 x 10 cm thick sample sieved at 500 um for macrobenthos	HW Uni
JC060	Stornoway Bay	JC060_040_Swath04	139	19/05/2011	08:09:00	58	9.553	6	15.233	50		ship	19/05/2011	11:52:00	58	9.821	6	14.616	48	EM710, SPB120	
JC060	Minches	JC060_041_XBT	139	19/05/2011	20:24:00	58	0.301	5	51.486	96		ship								T7 probe	
JC060	Minches	JC060_042_Swath05	139	19/05/2011	20:45:00	58	0.511	5	51.890	82		ship	20/05/2011	10:17:00	58	4.959	5	58.637	88	EM710, SPB120	
JC060	Minches	JC060_043_ROV07	140	20/05/2011	10:20:00	58	4.957	5	58.602	89		ship	20/05/2011	12:22:00	58	4.994	5	59.101	66		
JC060	Minches	JC060_044_ROV08	140	20/05/2011	13:16:00	58	3.672	5	56.713	75		ship	20/05/2011	14:40:00	58	3.671	5	57.481	67		
JC060	Minches	JC060_045_ROV09	140	20/05/2011	15:32:00	58	0.429	5	53.707	91		ship	20/05/2011	17:03:00	58	1.630	5	54.253	82		
JC060	Minches	JC060_046_Swath06	140	20/05/2011	17:26:00	58	0.388	5	54.061	82		ship	21/05/2011	08:54:00	58	27.265	6	5.940		EM710, SPB120	
JC060	darwin mounds	JC060_047_XBT2	141	21/05/2011	18:16:00	59	51.037	7	7.090	1049		ship								failed	
JC060	darwin mounds	JC060_048_BC12	141	21/05/2011	19:14:00	59	51.029	7	7.891	1056	1056	usbl								0.1 m2 x 10 cm thick sample sieved at 500 um for macrobenthos	
JC060	darwin mounds	JC060_049_Mark03	141	21/05/2011	21:09:00	59	51.090	7	8.052	1036		usbl								tethered glass sphere marker for future repeat ROV survey	
		JC060_049_SVP3	141	21/05/2011	21:09:00	59	51.090	7	8.052	1036		usbl								SVP mounted on acoustic release frame	
JC060	darwin mounds	JC060_050_Mark04	141	21/05/2011	23:00:00	59	50.936	7	3.542	1030		usbl								tethered glass sphere marker for future repeat ROV survey	
JC060	darwin mounds	JC060_051_AUV40	142	22/05/2011	01:20:00	59	49.457	7	24.123	923		ship	23/05/2011	01:00:00	59	50.037	7	22.014		delayed recovery - bad weather; Autosub mission 40	
JC060	darwin mounds	JC060_052_ROV10	142	22/05/2011	04:27:00	59	50.952	7	8.051	1052		ship	22/05/2011	08:13:00	59	50.957	7	8.038	1052	failed	
JC060	darwin mounds	JC060_053_BC13	142	22/05/2011	07:24:00	59	50.651	7	7.571	1059	1059	usbl								failed	
JC060	darwin mounds	JC060_054_BC14	142	22/05/2011	09:26:00	59	50.648	7	7.564	1060	1060	usbl								succesful core with dead coral and xeno	
JC060	darwin mounds	JC060_055_BC15	142	22/05/2011	11:13:00	59	51.002	7	8.621	1047	1047	usbl								failed	
JC060	darwin mounds	JC060_056_ROV11	143	23/05/2011	03:08:00	59	50.958	7	8.055	1051		ship	23/05/2011	05:56:00	59	50.982	7	7.976		no data - too much heave on TMS	
JC060	darwin mounds	JC060_057_PC08	143	23/05/2011	07:29:00	59	51.005	7	8.618	1047	1047	usbl								failed	
JC060	darwin mounds	JC060_058_BC16	143	23/05/2011	09:35:00	59	51.059	7	7.967	1050	1050	usbl								washed out, some large coral fragments	

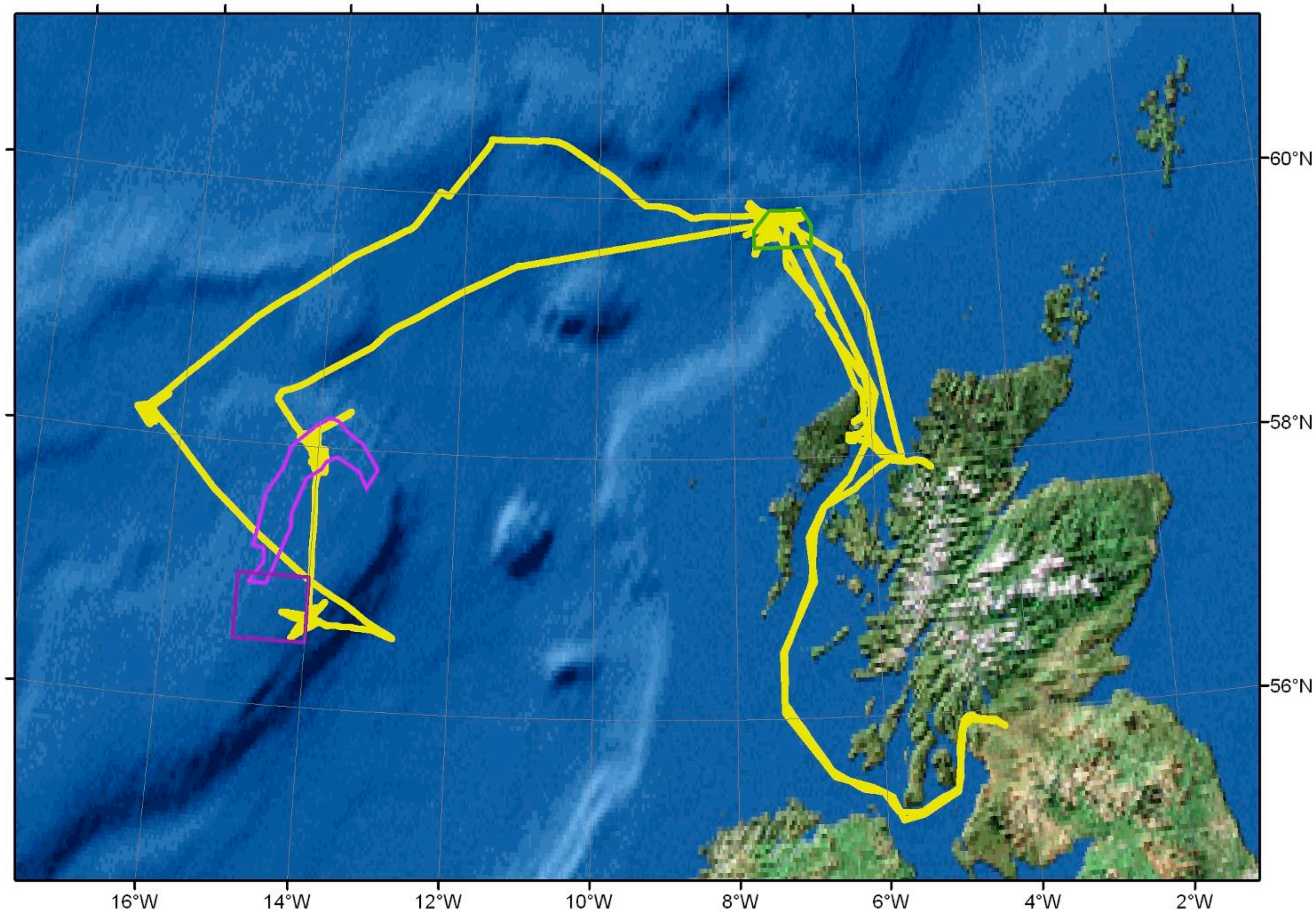
JC060	Hatton_Rockall	JC060_059_CTD02	145	25/05/2011	13:13:00	58	10.431	16	27.483	1188		ship	25/05/2011	15:28:00	58	10.425	16	27.438		20 water bottles fired, 2 leaked	
		JC060_059_SVP03	145	25/05/2011	13:13:00	58	10.431	16	27.483	1188		ship	25/05/2011	15:28:00	58	10.425	16	27.438			
		JC060_059_CTD01/n01	145	25/05/2011	14:24:00	58	10.431	16	27.483	1169		ship									
		JC060_059_CTD01/n04	145	25/05/2011	14:31:00	58	10.431	16	27.483	1145		ship									
		JC060_059_CTD01/n07	145	25/05/2011	14:35:00	58	10.431	16	27.483	1126		ship									
		JC060_059_CTD01/n10	145	25/05/2011	14:39:00	58	10.431	16	27.483	1098		ship									
		JC060_059_CTD01/n12	145	25/05/2011	14:44:00	58	10.431	16	27.483	1067		ship									
		JC060_059_CTD01/n14	145	25/05/2011	14:52:00	58	10.431	16	27.483	859		ship									
		JC060_059_CTD01/n16	145	25/05/2011	15:05:00	58	10.431	16	27.483	452		ship									
JC060	Hatton_Rockall	JC060_060_PC09	145	25/05/2011	16:46:00	58	10.431	16	27.421	1188	1188	usbl								8.7 m core	
JC060	Hatton_Rockall	JC060_061_AUV41	145	25/05/2011	19:17:00	58	10.661	16	26.756	1179		ship	26/05/2011	13:44:00	58	10.305	16	25.158		Autpsub mission 41	
JC060	Hatton_Rockall	JC060_062_Swath05	145	25/05/2011	23:05:00	58	18.242	16	13.181	1211		ship	26/05/2011	09:19:00	58	11.262	16	38.387			
JC060	Hatton_Rockall	JC060_063_PC10	146	26/05/2011	11:05:00	58	9.653	16	26.450	1172	1172	usbl								13.36 m core	
JC060	Hatton_Rockall	JC060_064_ROV12	146	26/05/2011	14:25:00	58	10.766	16	27.381	1177		ship	26/05/2011	15:50:00	58	10.766	16	27.431		failed due to TMS problem	
JC060	Hatton_Rockall	JC060_065_ROV13	146	26/05/2011	15:57:00	58	10.773	16	27.439	1176		ship	26/05/2011	21:43:00	58	10.605	16	28.028			
JC060	Hatton_Rockall	JC060_066_ROV14	146	26/05/2011	22:27:00	58	11.085	16	25.313	1186		ship	27/05/2011	00:46:00	58	11.023	16	25.313			
JC060	Hatton_Rockall	JC060_067_PC11	147	27/05/2011	4:36:00	58	10.619	16	27.273	1184	1184	usbl									
JC060	Hatton_Rockall	JC060_068_CTD03	147	27/05/2011	6:36:00	58	10.617	16	27.309	1184		ship	27/05/2011	08:20:00	58	10.602	16	27.306			
		JC060_068_CTD03/n01	147	27/05/2011	8:35:00	58	10.617	16	27.309	1170		ship								geochemistry	
		JC060_068_CTD03/n02	147	27/05/2011	8:40:00	58	10.617	16	27.309	1155		ship								geochemistry	
		JC060_068_CTD03/n03	147	27/05/2011	8:47:00	58	10.617	16	27.309	1147		ship								geochemistry	
		JC060_068_CTD03/n04	147	27/05/2011	8:55:00	58	10.617	16	27.309	1126		ship								geochemistry	
		JC060_068_CTD03/n05	147	27/05/2011	9:00:00	58	10.617	16	27.309	1076		ship								geochemistry	
		JC060_068_CTD03/n06	147	27/05/2011	9:11:00	58	10.617	16	27.309	976		ship								geochemistry	
		JC060_068_CTD03/n07	147	27/05/2011	9:25:00	58	10.617	16	27.309	500		ship								geochemistry	
JC060	Hatton_Rockall	JC060_069_Mega07/c01	147	27/05/2011	9:27:00	58	10.423	16	27.430	1189	1189	usbl								geochemistry, core length 23 cm	
		JC060_069_Mega07/c02	147	27/05/2011	9:27:00	58	10.423	16	27.430	1189	1189	usbl								geology, core length 23cm	
		JC060_069_Mega07/c03	147	27/05/2011	9:27:00	58	10.423	16	27.430	1189	1189	usbl								geology, core length 23cm	
		JC060_069_Mega07/c04	147	27/05/2011	9:27:00	58	10.423	16	27.430	1189	1189	usbl								biology, core length 23 cm	
		JC060_069_Mega07/c05	147	27/05/2011	9:27:00	58	10.423	16	27.430	1189	1189	usbl								biology, core length 23 cm	
JC060	Hatton_Rockall	JC060_070_CTD04	147	27/05/2011	10:54:00	58	9.660	16	26.970	1168		ship	27/05/2011	12:25:00	58	9.656	16	26.466			
		JC060_070_CTD04/n01	147	27/05/2011	11:38:00	58	9.660	16	26.970	1158		ship								geochemistry	
		JC060_070_CTD04/n04	147	27/05/2011	11:42:00	58	9.660	16	26.970	1138		ship								geochemistry	
		JC060_070_CTD04/n07	147	27/05/2011	11:45:00	58	9.660	16	26.970	1124		ship								geochemistry	
		JC060_070_CTD04/n10	147	27/05/2011	11:49:00	58	9.660	16	26.970	1067		ship								geochemistry	
		JC060_070_CTD04/n12	147	27/05/2011	11:54:00	58	9.660	16	26.970	998		ship								geochemistry	
		JC060_070_CTD04/n14	147	27/05/2011	12:04:00	58	9.660	16	26.970	749		ship								geochemistry	
		JC060_070_CTD04/n19	147	27/05/2011	12:14:00	58	9.660	16	26.970	401		ship								geochemistry	
JC060	Hatton_Rockall	JC060_071_Mega08	147	27/05/2011	13:40:00	58	9.659	16	26.467	1168	1168	usbl								poor recovery - discarded	
JC060	Hatton_Rockall	JC060_072_Mega09/c01	147	27/05/2011	15:11:00	58	9.659	16	26.467	1173	1173	usbl								core length 23 cm, biology	
		JC060_072_Mega09/c02	147	27/05/2011	15:11:00	58	9.659	16	26.467	1173	1173	usbl								core length 23 cm, biology	
		JC060_072_Mega09/c03	147	27/05/2011	15:11:00	58	9.659	16	26.467	1173	1173	usbl								core length 23 cm, geochemistry	
		JC060_072_Mega09/c04	147	27/05/2011	15:11:00	58	9.659	16	26.467	1173	1173	usbl								core length 23 cm, geochemistry	
		JC060_072_Mega09/c05	147	27/05/2011	15:11:00	58	9.659	16	26.467	1173	1173	usbl								core length 23 cm, geology	
		JC060_072_Mega09/c06	147	27/05/2011	15:11:00	58	9.659	16	26.467	1173	1173	usbl								core length 23 cm, geology	
JC060	E Rockall slope	JC060_073_PC12	148	28/05/2011	23:35:00	56	38.545	13	43.422	1069	1069	ship								failed - bottom core barrel lost/usbl failed	
JC060	E Rockall slope	JC060_074_PC13	149	29/05/2011	1:57:00	56	38.559	13	43.415	1066	1066	usbl								failed -core cutter lost	
JC060	E Rockall slope	JC060_075_PC14	149	29/05/2011	21:21:00	56	39.822	13	49.005	836	836	usbl								0.5 m core	
JC060	E Rockall slope	JC060_076_Swath06	149	29/05/2011	23:58:00	56	36.484	14	2.649	519		ship	30/05/2011	12:06:00	56	38.302	14	4.212			
JC060	E Rockall slope	JC060_077_Mega10	150	30/05/2011	14:17:00	56	34.298	14	6.774	498	498	usbl								no recovery	
JC060	E Rockall slope	JC060_078_Mega11	150	30/05/2011	15:55:00	56	32.847	14	9.261	487	487	usbl								no recovery	
JC060	E Rockall slope	JC060_079_Mega12	150	30/05/2011	17:19:00	56	31.237	14	11.328	511	511	usbl								no recovery	
JC060	E Rockall slope	JC060_080_AUV42	150	30/05/2011	20:06:00	56	40.171	14	0.930	363		ship	31/05/2011	07:00:00	56	40.125	14	0.102			
JC060	E Rockall slope	JC060_081_BC17	150	30/05/2011	23:39:00	56	34.295	14	6.776	497	497	usbl								no recovery	
JC060	E Rockall slope	JC060_082_BC18	151	31/05/2011	1:07:00	56	32.848	14	9.265	486	486	usbl								no recovery	
JC060	E Rockall slope	JC060_083_BC19	151	31/05/2011	2:33:00	56	31.241	14	11.349	499	499	usbl								no recovery	

JC060	E Rockall slope	JC060_084_ROV15	151	31/05/2011	7:50:00	56	39.166	14	2.116	379		ship	31/05/2011	10:06:00	56	39.500	14	2.830			
JC060	NW Rockall Bank	JC060_085_Swath07	152	01/06/2011	0:36:00	57	58.923	13	53.955	210		ship	01/06/2011	20:13:00	57	56.008	14	4.328		EM710 + SBP120	
JC060	NW Rockall Bank	JC060_086_AUV43	152	01/06/2011	21:27:00	57	57.977	13	59.946	223		ship	02/06/2011	13:28:00	57	57.410	13	59.609			
JC060	NW Rockall Bank	JC060_087_Swath08	152	01/06/2011	23:55:00	57	51.972	14	0.500	195		ship	02/06/2011	11:25:00	57	57.913	13	59.839		EM710 + SBP120	
JC060	NW Rockall Bank	JC060_088_Swath09	153	02/06/2011	15:45:00	58	5.889	14	6.966	280		ship	03/06/2011	05:26:00	58	3.084	14	6.489		EM710 + SBP120	
JC060	NW Rockall Bank	JC060_089_CTD	153	02/06/2011	17:09:00	58	5.729	14	15.959	366		ship	02/06/2011	17:52:00	58	5.693	14	15.869			
		JC060_089_SVP	153	02/06/2011	17:09:00	58	5.729	14	15.959	366		ship	02/06/2011	17:52:00	58	5.693	14	15.869			
JC060	NW Rockall Bank	JC060_090_AUV44	154	03/06/2011	05:54:00	58	5.047	14	10.761	302		ship	03/06/2011	22:13:00	58	4.926	14	10.409			
JC060	NW Rockall Bank	JC060_091_ROV16	154	03/06/2011	12:43:00	57	57.101	13	58.702	214		ship	03/06/2011	15:45:00	57	57.575	13	58.475			
JC060	NW Rockall Bank	JC060_092_ROV17	154	03/06/2011	16:39:00	57	57.384	13	58.739	217		ship	03/06/2011	17:48:00	57	57.384	13	58.712			
JC060	NW Rockall Bank	JC060_093_ROV18	154	03/06/2011	18:32:00	57	57.677	14	0.504	223		ship	03/06/2011	20:05:00	57	57.826	14	0.083			
JC060	NW Rockall Bank	JC060_094_Swath10	155	04/06/2011	00:28:00	57	50.082	14	0.604	186		ship	04/06/2011	00:28:00	57	51.040	13	58.239		EM710 + SBP120	
JC060	NW Rockall Bank	JC060_095_AUV45	155	04/06/2011	06:48:00	57	51.109	13	58.327	184		ship	05/06/2011	00:30:00	57	50.671	13	57.566			
JC060	NW Rockall Bank	JC060_096_ROV19	155	04/06/2011	10:45:00	58	5.475	14	11.929	327		ship	04/06/2011	13:43:00	58	4.993	14	11.210			
JC060	NW Rockall Bank	JC060_097_ROV20	155	04/06/2011	14:25:00	58	4.158	14	10.712	295		ship	04/06/2011	20:29:00	58	4.704	14	8.697			
JC060	NW Rockall Bank	JC060_098_Swath11	156	05/06/2011	00:57:00	57	50.914	13	59.883	188		ship	05/06/2011	07:36:00	57	54.729	14	1.655		EM710 + SBP120	
JC060	NW Rockall Bank	JC060_099_AUV46	156	05/06/2011	08:53:00	58	4.271	14	10.899	297		ship	06/062011	00:54:00	58	4.042	14	10.605			
JC060	NE Rockall Bank	JC060_100_ROV21	156	05/06/2011	13:45:00	58	16.207	13	36.108	805		ship	05/06/2011	18:52:00	58	15.918	13	36.603			
JC060	NE Rockall Bank	JC060_101_ROV22	156	05/06/2011	19:17:00	58	15.593	13	35.483	721		ship	05/06/2011	21:21:00	58	15.604	13	35.975			
JC060	NW Rockall Bank	JC060_102_Swath12	157	06/06/2011	01:09:00	58	3.518	14	10.960	282		ship	06/06/2011	05:03:00	57	51.417	13	59.678		EM710 + SBP210	
JC060	NW Rockall Bank	JC060_103_Hybis1	157	06/06/2011	06:16:00	57	51.250	13	56.350	180		ship	06/06/2011	08:12:00	57	51.206	13	56.906			
JC060	NW Rockall Bank	JC060_104_ROV23	157	06/06/2011	08:56:00	57	50.350	13	58.612	180		ship	06/06/2011	14:59:00	57	50.859	14	0.321			
JC060	NW Rockall Bank	JC060_105_ROV24	157	06/06/2011	15:40:00	57	51.475	14	0.427	189		ship	06/06/2011	16:59:00	57	51.464	14	0.408			
JC060	N Rockall Bank	JC060_106_Swath106	157	06/06/2011	17:07:00	57	51.740	14	0.844	189		ship	06/06/2011	22:05:00	58	23.907	14	35.366			
JC060	Darwin mounds	JC060_107_Mega13/c01	159	08/06/2011	17:48:00	59	47.033	7	34.727	815		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_107_Mega13/c02	159	08/06/2011	17:48:00	59	47.033	7	34.727	815		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_107_Mega13/c03	159	08/06/2011	17:48:00	59	47.033	7	34.727	815		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_107_Mega13/c04	159	08/06/2011	17:48:00	59	47.033	7	34.727	815		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_107_Mega13/c05	159	08/06/2011	17:48:00	59	47.033	7	34.727	815		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_107_Mega13/c06	159	08/06/2011	17:48:00	59	47.033	7	34.727	815		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_107_Mega13/c07	159	08/06/2011	17:48:00	59	47.033	7	34.727	815		usbl								core length 39 cm, seived for biology (Aberdeen)	
JC060	Darwin mounds	JC060_108_Mega14/c01	159	08/06/2011	19:04:00	59	47.354	7	34.158	816		usbl								core length 39 cm, seived for biology (Aberdeen)	
		JC060_108_Mega14/c02	159	08/06/2011	19:04:00	59	47.354	7	34.158	816		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_108_Mega14/c03	159	08/06/2011	19:04:00	59	47.354	7	34.158	816		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_108_Mega14/c04	159	08/06/2011	19:04:00	59	47.354	7	34.158	816		usbl								core length 39 cm, seived for biology (Aberdeen)	
		JC060_108_Mega14/c05	159	08/06/2011	19:04:00	59	47.354	7	34.158	816		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_108_Mega14/c06	159	08/06/2011	19:04:00	59	47.354	7	34.158	816		usbl								core length 39 cm, seived for biology (Aberdeen)	
		JC060_108_Mega14/c07	159	08/06/2011	19:04:00	59	47.354	7	34.158	816		usbl								core length 39 cm, seived for biology (Aberdeen)	
JC060	Darwin mounds	JC060_109_AUV47	159	08/06/2011	21:51:00	59	50.599	7	2.690	628		ship	08/06/2011	23:34:00	59	50.768	7	2.672		technical failure	
JC060	Darwin mounds	JC060_110_ROV25	160	09/06/2011	00:34:00	59	50.976	7	8.038	1050		ship	09/06/2011	10:04:00	59	51.092	7	7.971			
JC060	darwin mounds	JC060_111_AUV48	160	09/06/2011	10:56:00	59	50.588	7	3.144	1057		ship	10/06/2011	03:11:00	59	51.632	7	9.076			
JC060	darwin mounds	JC060_112_Mega15/c01	160	09/06/2011	14:21:00	59	47.575	7	33.516	823		ship								core length 32 cm, seived for biology (Aberdeen)	
		JC060_112_Mega15/c02	160	09/06/2011	14:21:00	59	47.575	7	33.516	823		ship								core length 32 cm, seived for biology (Aberdeen)	
		JC060_112_Mega15/c03	160	09/06/2011	14:21:00	59	47.575	7	33.516	823		ship								core length 32 cm, seived for biology (Aberdeen)	
		JC060_112_Mega15/c04	160	09/06/2011	14:21:00	59	47.575	7	33.516	823		ship								core length 32 cm, seived for biology (Aberdeen)	
		JC060_112_Mega15/c05	160	09/06/2011	14:21:00	59	47.575	7	33.516	823		ship								core length 20 cm, seived for biology (Aberdeen)	
		JC060_112_Mega15/c06	160	09/06/2011	14:21:00	59	47.575	7	33.516	823		ship								core length 32 cm, seived for biology (Aberdeen)	
		JC060_112_Mega15/c07	160	09/06/2011	14:21:00	59	47.575	7	33.516	823		ship								core length 32 cm, seived for biology (Aberdeen)	
		JC060_112_Mega15/c08	160	09/06/2011	14:21:00	59	47.575	7	33.516	823		ship								core length 31 cm, seived for biology (Aberdeen)	
JC060	darwin mounds	JC060_113_Mega16/c01	160	09/06/2011	17:35:00	59	41.905	7	47.467	773		ship								core length 38 cm, seived for biology (Aberdeen)	
		JC060_113_Mega16/c02	160	09/06/2011	17:35:00	59	41.905	7	47.467	773		ship								core length 38 cm, seived for biology (Aberdeen)	
		JC060_113_Mega16/c03	160	09/06/2011	17:35:00	59	41.905	7	47.467	773		ship								core length 38 cm, seived for biology (Aberdeen)	
		JC060_113_Mega16/c04	160	09/06/2011	17:35:00	59	41.905	7	47.467	773		ship								core length 38 cm, seived for biology (Aberdeen)	
		JC060_113_Mega16/c05	160	09/06/2011	17:35:00	59	41.905	7	47.467	773		ship								core length 39 cm, seived for biology (Aberdeen)	
		JC060_113_Mega16/c06	160	09/06/2011	17:35:00	59	41.905	7	47.467	773		ship								core length 38 cm, seived for biology (Aberdeen)	
		JC060_113_Mega16/c07	160	09/06/2011	17:35:00	59	41.905	7	47.467	773		ship								core length 38 cm, seived for biology (Aberdeen)	
		JC060_113_Mega16/c08	160	09/06/2011	17:35:00	59	41.905	7	47.467	773		ship								core length 37 cm, seived for biology (Aberdeen)	

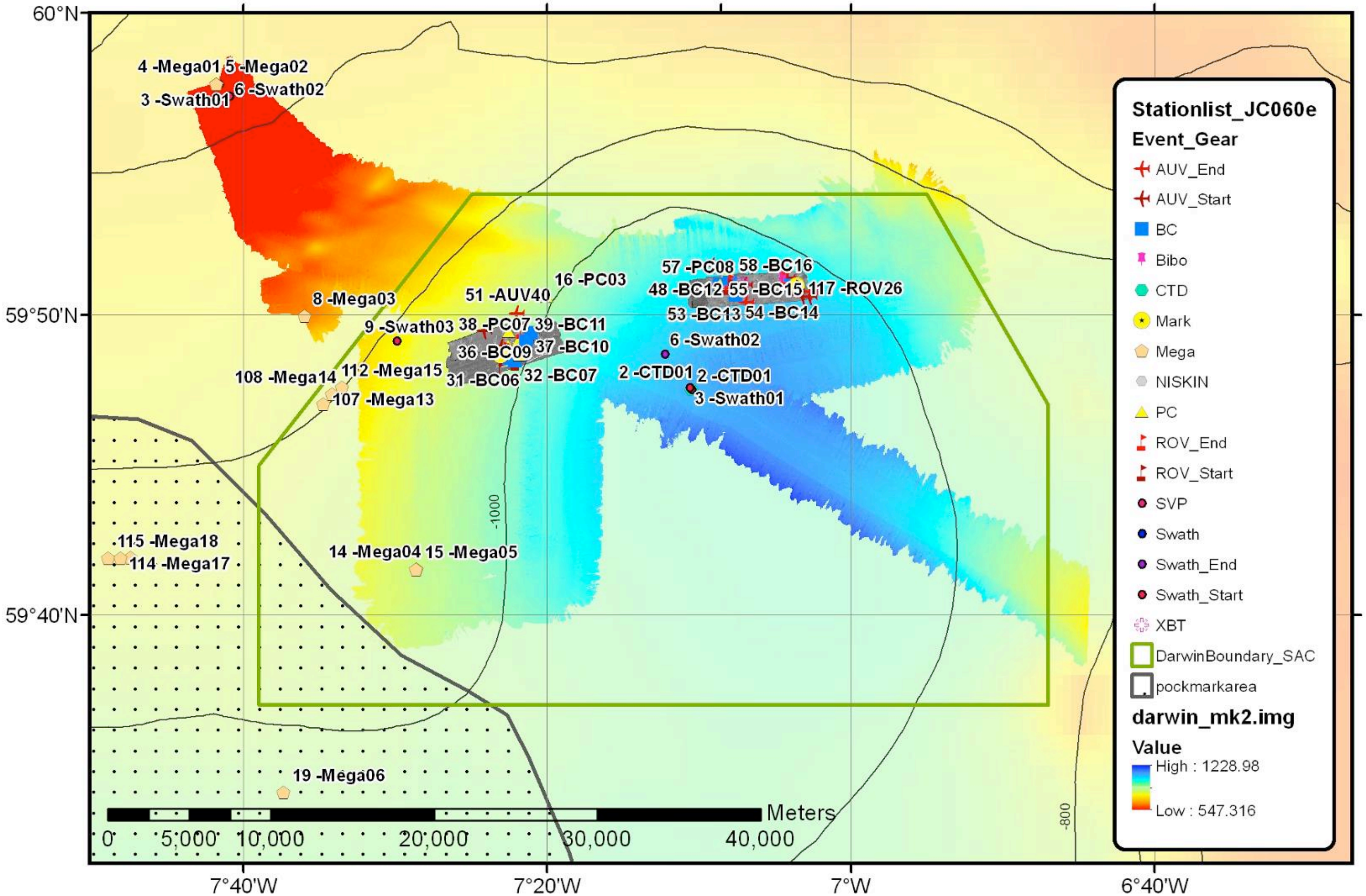
JC060	darwin mounds	JC060_114_Mega17/c01	160	09/06/2011	18:42:00	59	41.904	7	48.126	771		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_114_Mega17/c02	160	09/06/2011	18:42:00	59	41.904	7	48.126	771		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_114_Mega17/c03	160	09/06/2011	18:42:00	59	41.904	7	48.126	771		usbl								core length 40 cm, seived for biology (Aberdeen)	
		JC060_114_Mega17/c04	160	09/06/2011	18:42:00	59	41.904	7	48.126	771		usbl								core length 39 cm, seived for biology (Aberdeen)	
		JC060_114_Mega17/c05	160	09/06/2011	18:42:00	59	41.904	7	48.126	771		usbl								core length 37 cm, seived for biology (Aberdeen)	
		JC060_114_Mega17/c06	160	09/06/2011	18:42:00	59	41.904	7	48.126	771		usbl								core length 41 cm, seived for biology (Aberdeen)	
		JC060_114_Mega17/c07	160	09/06/2011	18:42:00	59	41.904	7	48.126	771		usbl								core length 39 cm, seived for biology (Aberdeen)	
		JC060_114_Mega17/c08	160	09/06/2011	18:42:00	59	41.904	7	48.126	771		usbl								core length 39 cm, seived for biology (Aberdeen)	
JC060	darwin mounds	JC060_115_Mega18/c01	160	09/06/2011	19:54:00	59	41.892	7	48.906	769		usbl								core length 38 cm, seived for biology (Aberdeen)	
		JC060_115_Mega18/c02	160	09/06/2011	19:54:00	59	41.892	7	48.906	769		usbl								core length 37 cm, seived for biology (Aberdeen)	
		JC060_115_Mega18/c03	160	09/06/2011	19:54:00	59	41.892	7	48.906	769		usbl								core length 39 cm, seived for biology (Aberdeen)	
		JC060_115_Mega18/c04	160	09/06/2011	19:54:00	59	41.892	7	48.906	769		usbl								core length 39 cm, seived for biology (Aberdeen)	
		JC060_115_Mega18/c05	160	09/06/2011	19:54:00	59	41.892	7	48.906	769		usbl								core length 39 cm, seived for biology (Aberdeen)	
		JC060_115_Mega18/c06	160	09/06/2011	19:54:00	59	41.892	7	48.906	769		usbl								core length 39 cm, seived for biology (Aberdeen)	
		JC060_115_Mega18/c07	160	09/06/2011	19:54:00	59	41.892	7	48.906	769		usbl								core length 35 cm, seived for biology (Aberdeen)	
		JC060_115_Mega18/c08	160	09/06/2011	19:54:00	59	41.892	7	48.906	769		usbl								core length 38 cm, seived for biology (Aberdeen)	
JC060	Darwin Mounds	JC060_116_PC15	160	09/06/2011	22:30:00	59	48.655	7	21.779	960		ship								technical failure, no recovery	
JC060	Darwin Mounds	JC060_117_ROV26	161	10/06/2011	04:05:00	59	50.899	7	3.506	1051		ship	10/06/2011	09:45:00	59	51.217	7	4.444			

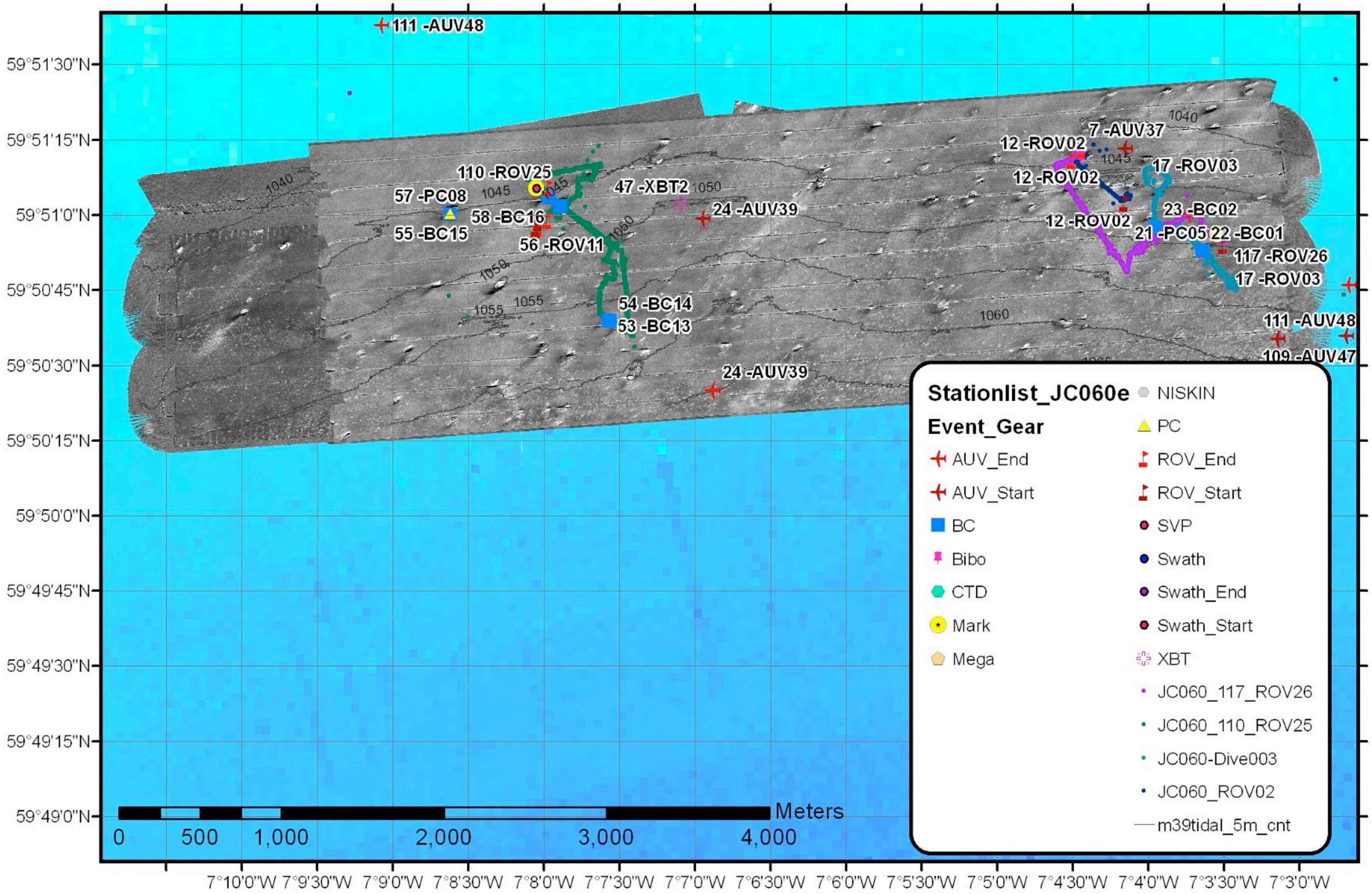
APPENDIX 2 – JC060 Maps

General cruise track:

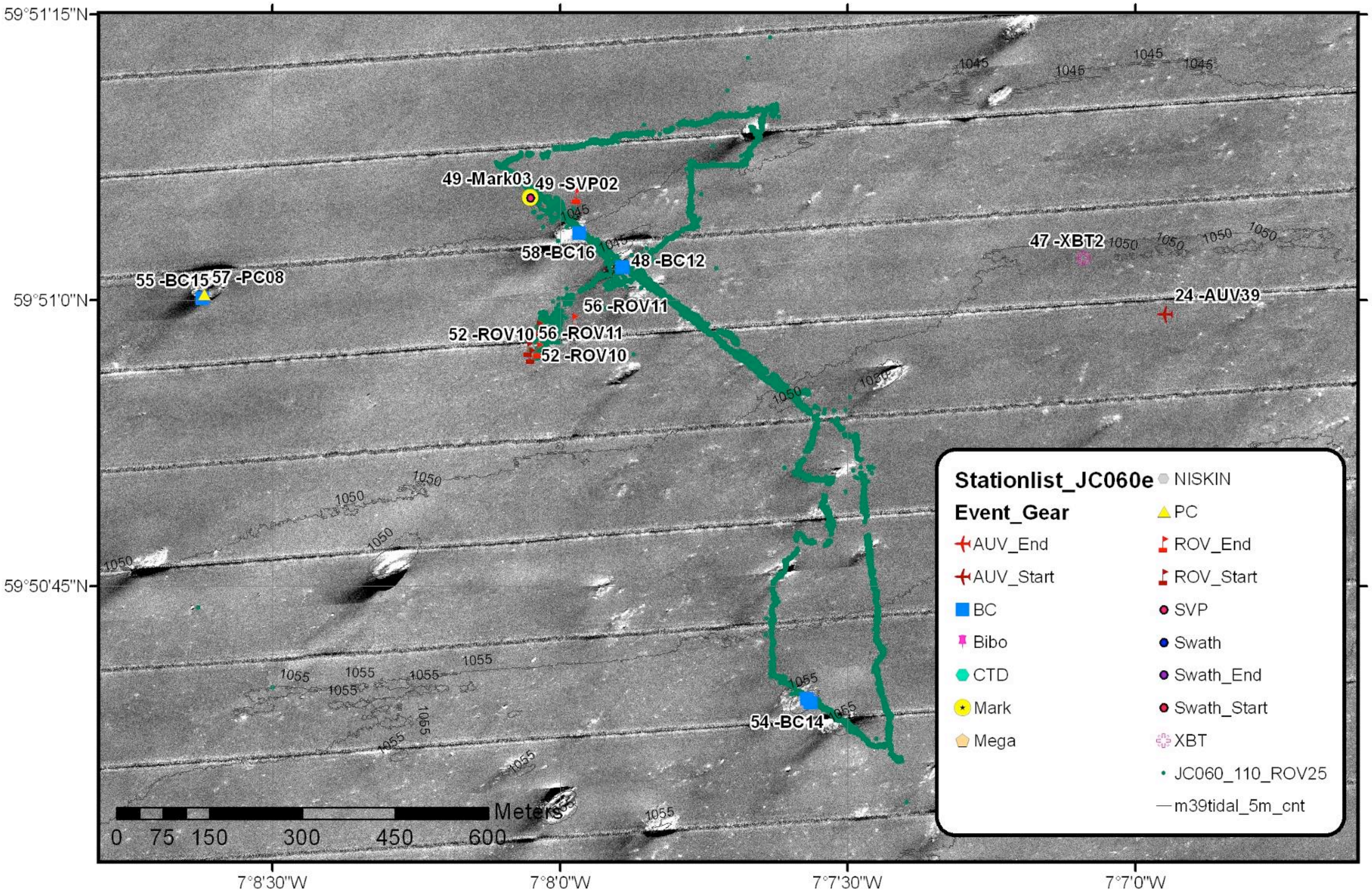


Darwin Mound area:

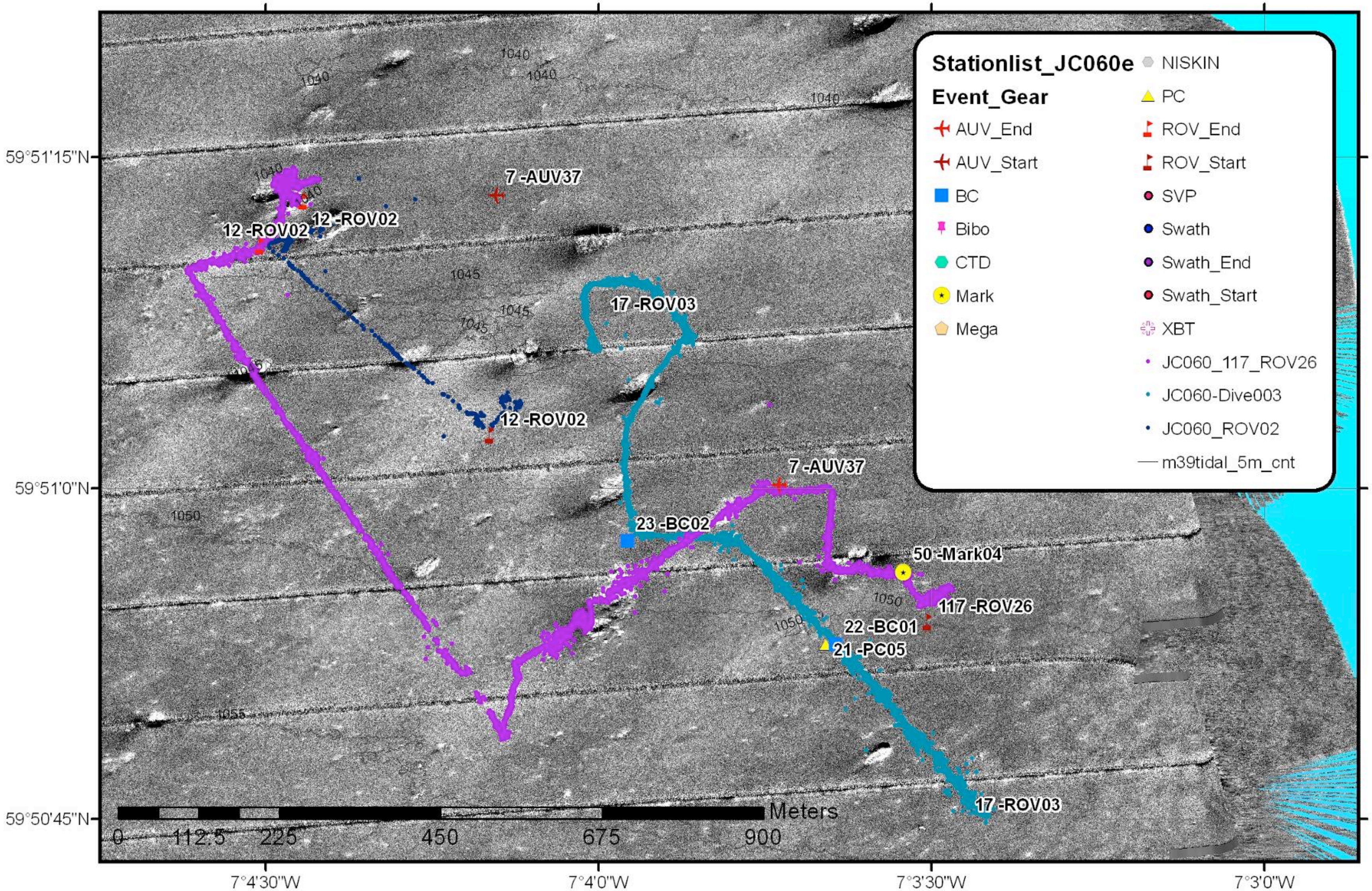


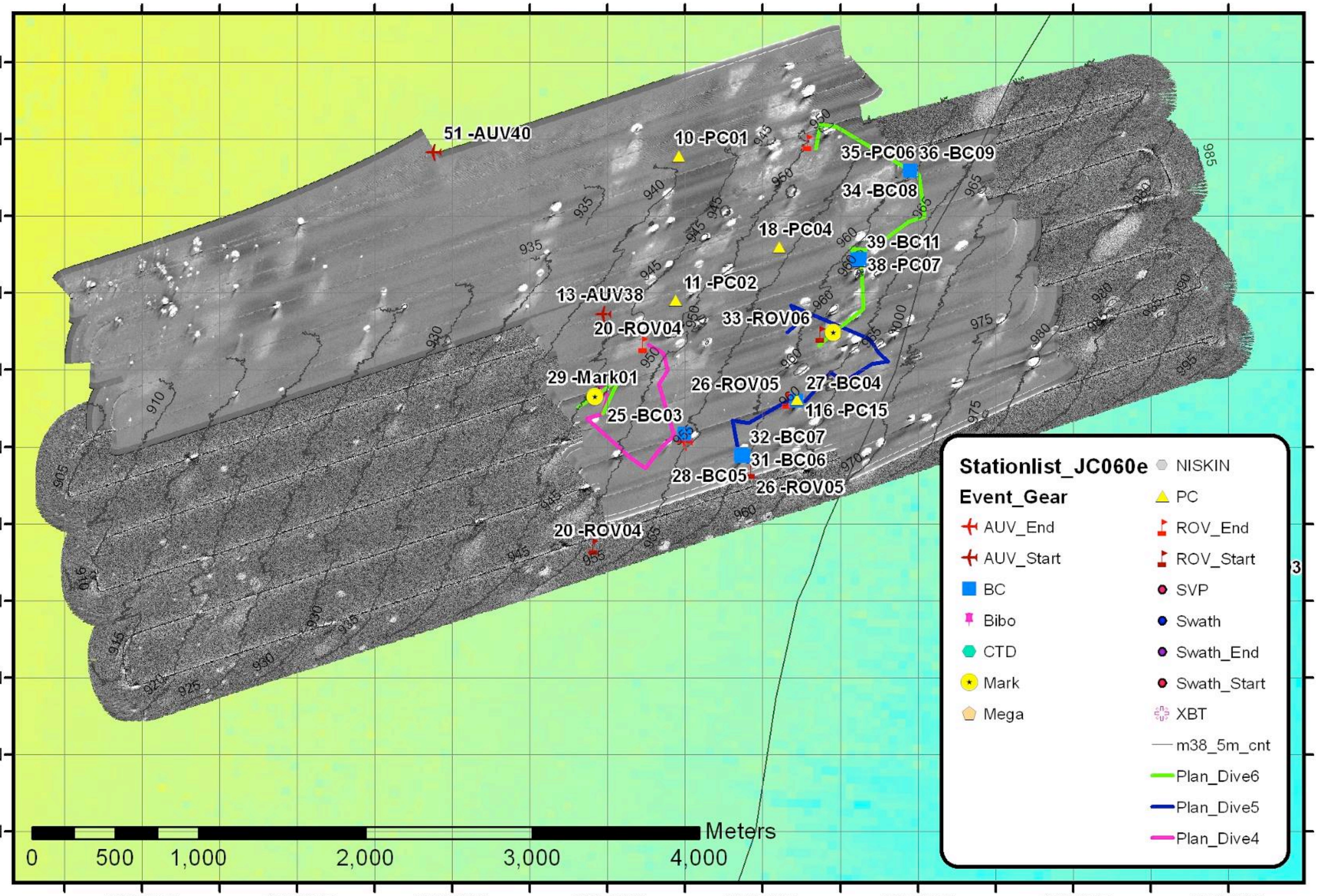


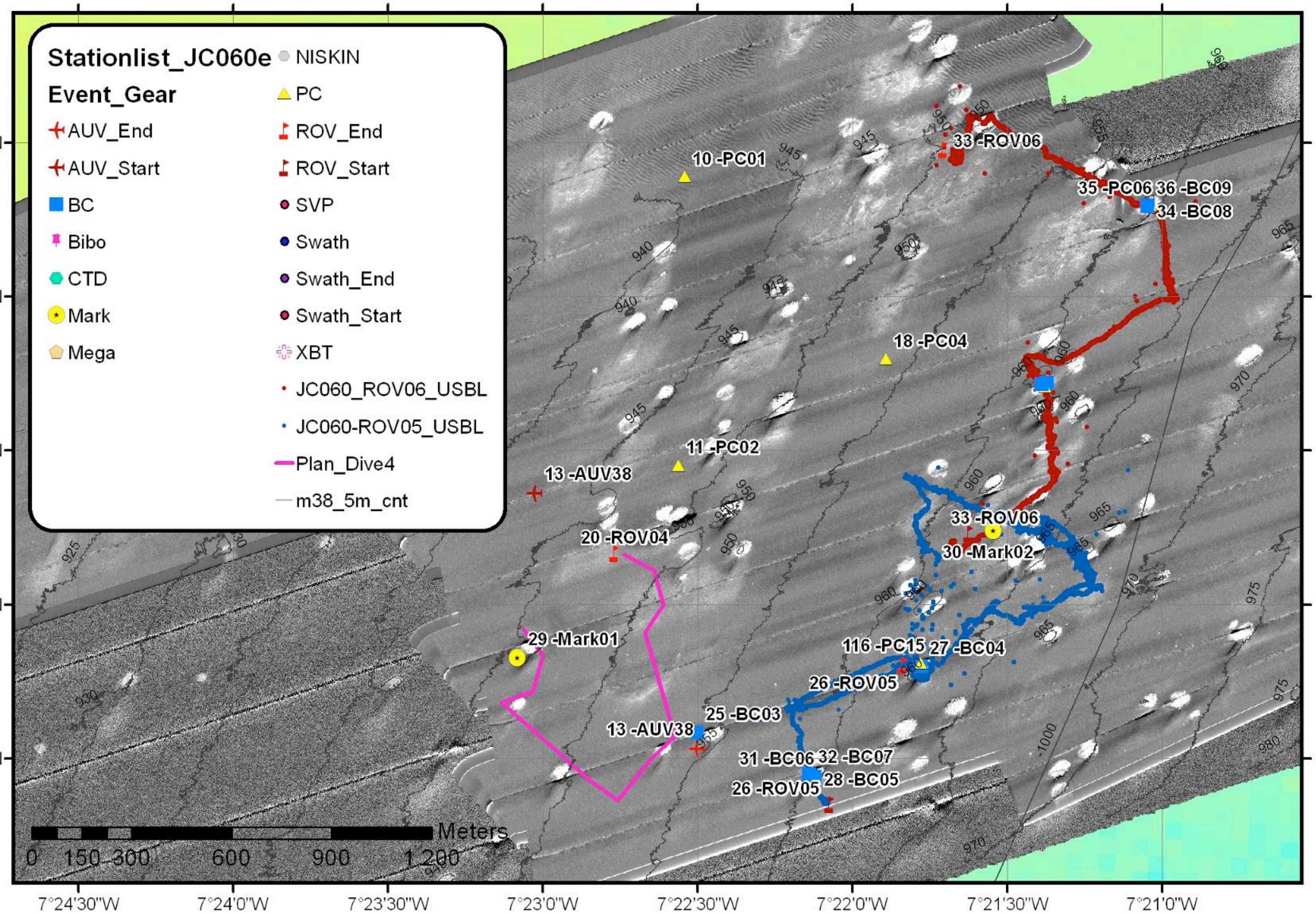
111 -AUV48
7 -AUV37
12 -ROV02
12 -ROV02
12 -ROV02
17 -ROV03
17 -ROV03
110 -ROV25
47 -XBT2
57 -PC08
58 -BC16
55 -BC15
56 -ROV11
24 -AUV39
23 -BC02
21 -PC05
22 -BC01
117 -ROV26
54 -BC14
53 -BC13
111 -AUV48
109 -AUV47
24 -AUV39
1040
1045
1050
1055
1060
59°51'30"N
59°51'15"N
59°51'0"N
59°50'45"N
59°50'30"N
59°50'15"N
59°50'0"N
59°49'45"N
59°49'30"N
59°49'15"N
59°49'0"N
7°10'0"W 7°9'30"W 7°9'0"W 7°8'30"W 7°8'0"W 7°7'30"W 7°7'0"W 7°6'30"W 7°6'0"W 7°5'30"W 7°5'0"W 7°4'30"W 7°4'0"W 7°3'30"W 7°3'0"W
0 500 1,000 2,000 3,000 4,000 Meters
Stationlist_JC060e
Event_Gear
AUV_End
AUV_Start
BC
Bibo
CTD
Mark
Mega
NISKIN
PC
ROV_End
ROV_Start
SVP
Swath
Swath_End
Swath_Start
XBT
JC060_117_ROV26
JC060_110_ROV25
JC060-Dive003
JC060_ROV02
m39tidal_5m_cnt



59°51'15"N
59°51'0"N
59°50'45"N
7°8'30"W
7°8'0"W
7°7'30"W
7°7'0"W
49 -Mark03
49 -SVP02
58 -BC16
48 -BC12
55 -BC15
57 -PC08
56 -ROV11
52 -ROV10
56 -ROV11
52 -ROV10
47 -XBT2
24 -AUV39
54 -BC14
1045
1050
1055
0 75 150 300 450 600
Meters
Stationlist_JC060e
Event_Gear
AUV_End
AUV_Start
BC
Bibo
CTD
Mark
Mega
NISKIN
PC
ROV_End
ROV_Start
SVP
Swath
Swath_End
Swath_Start
XBT
JC060_110_ROV25
m39tidal_5m_cnt

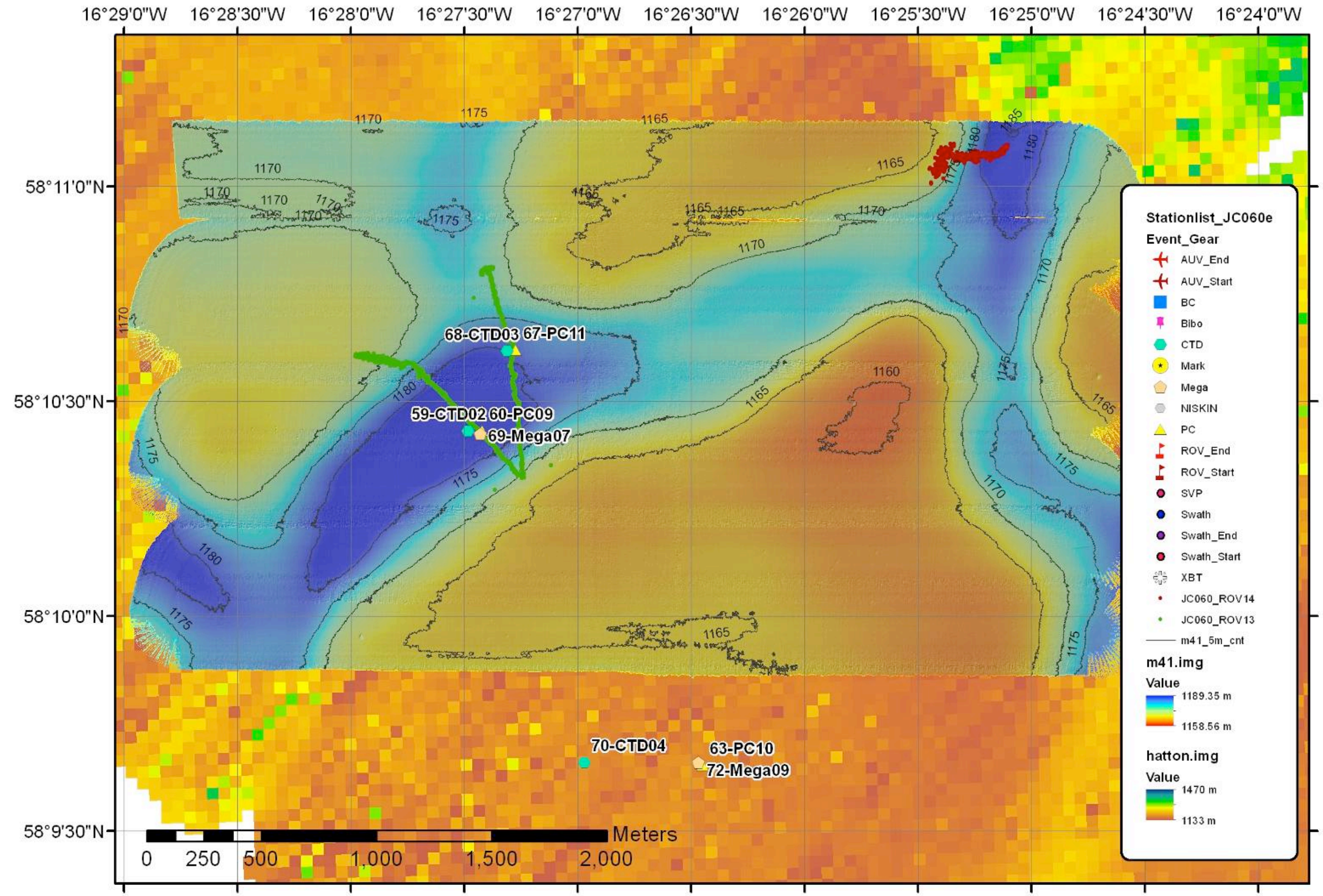

Stationlist_JC060e
Event_Gear
AUV_End
AUV_Start
BC
Bibo
CTD
Mark
Mega
NISKIN
PC
ROV_End
ROV_Start
SVP
Swath
Swath_End
Swath_Start
XBT
JC060_117_ROV26
JC060-Dive003
JC060_ROV02
m39tidal_5m_cnt
7 -AUV37
12 -ROV02
17 -ROV03
23 -BC02
50 -Mark04
117 -ROV26
22 -BC01
21 -PC05
Meters
0
112.5
225
450
675
900
59°51'15"N
59°51'0"N
59°50'45"N
7°4'30"W
7°4'0"W
7°3'30"W
7°3'0"W


Stationlist_JC060e
Event_Gear
AUV_End
AUV_Start
BC
Bibo
CTD
Mark
Mega
NISKIN
PC
ROV_End
ROV_Start
SVP
Swath
Swath_End
Swath_Start
XBT
m38_5m_cnt
Plan_Dive6
Plan_Dive5
Plan_Dive4
51 -AUV40
10 -PC01
35 -PC06
36 -BC09
34 -BC08
18 -PC04
39 -BC11
38 -PC07
11 -PC02
13 -AUV38
20 -ROV04
33 -ROV06
29 -Mark01
26 -ROV05
27 -BC04
116 -PC15
25 -BC03
32 -BC07
31 -BC06
28 -BC05
26 -ROV05
20 -ROV04
59°49'45"N
59°49'30"N
59°49'15"N
59°49'0"N
59°48'45"N
59°48'30"N
59°48'15"N
59°48'0"N
59°47'45"N
59°47'30"N
59°47'15"N
7°26'0"W
7°25'0"W
7°24'0"W
7°23'0"W
7°22'0"W
7°21'0"W
7°20'0"W
7°19'0"W
0
500
1,000
2,000
3,000
4,000
Meters

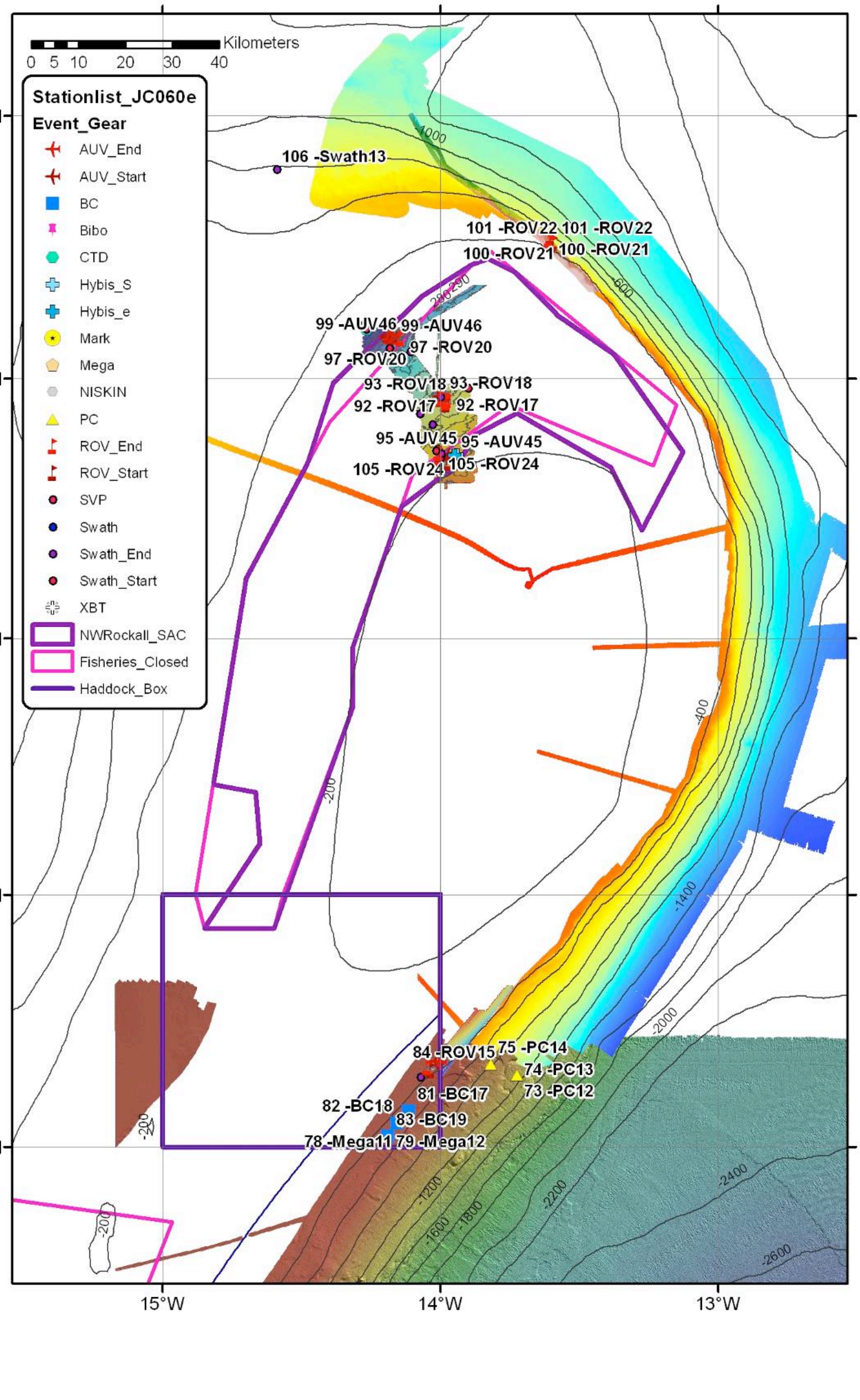


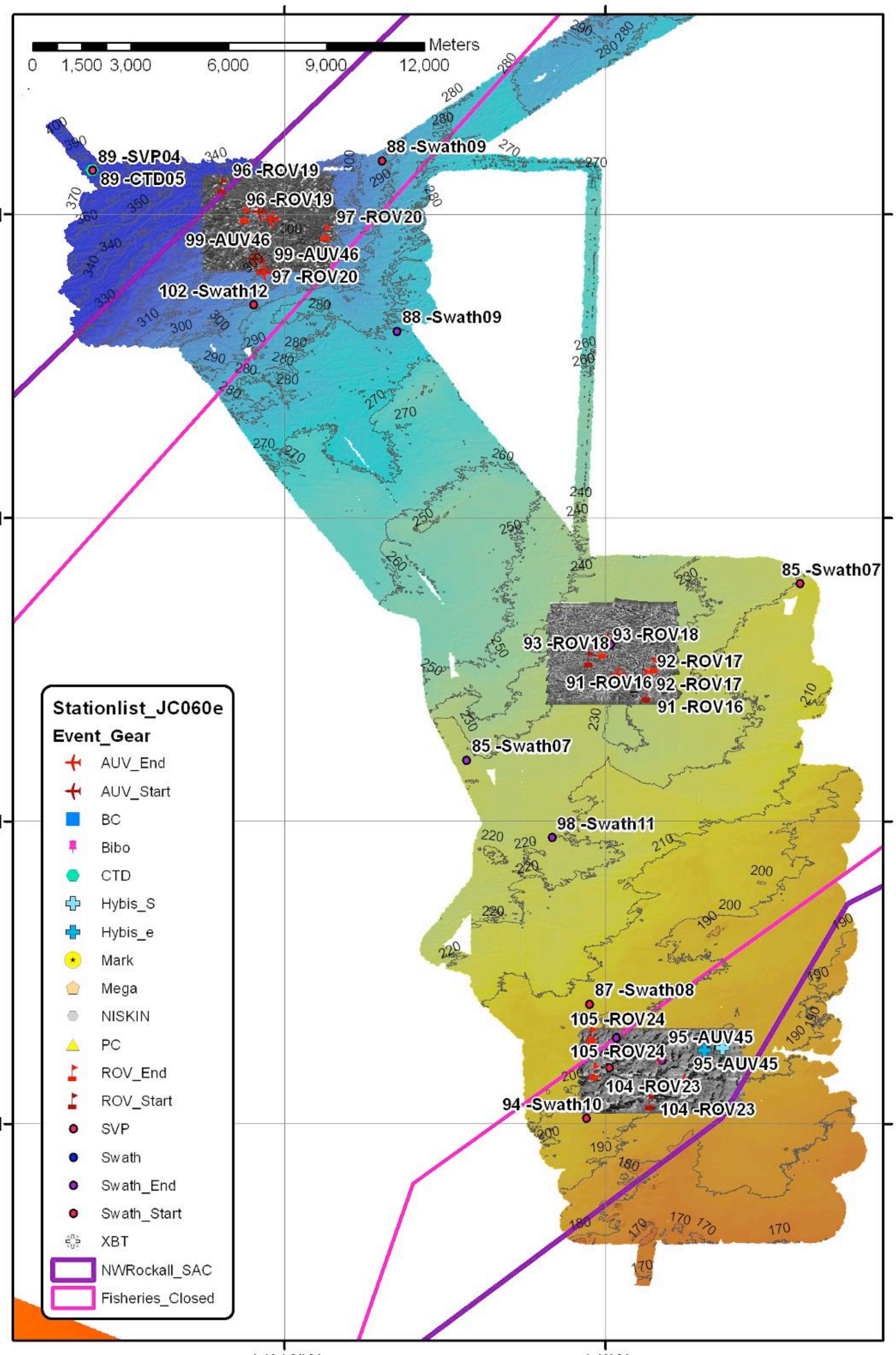
Stationlist_JC060e
Event_Gear
AUV_End
AUV_Start
BC
Bibo
CTD
Mark
Mega
NISKIN
PC
ROV_End
ROV_Start
SVP
Swath
Swath_End
Swath_Start
XBT
JC060_ROV06_USBL
JC060-ROV05_USBL
Plan_Dive4
m38_5m_cnt
59°49'30"N
59°49'15"N
59°49'0"N
59°48'45"N
59°48'30"N
7°24'30"W
7°24'0"W
7°23'30"W
7°23'0"W
7°22'30"W
7°22'0"W
7°21'30"W
7°21'0"W
10 -PC01
33 -ROV06
35 -PC06 36 -BC09
34 -BC08
18 -PC04
11 -PC02
13 -AUV38
20 -ROV04
33 -ROV06
30 -Mark02
29 -Mark01
116 -PC15 27 -BC04
26 -ROV05
25 -BC03
13 -AUV38
31 -BC06 32 -BC07
28 -BC05
26 -ROV05
Meters
0 150 300 600 900 1,200

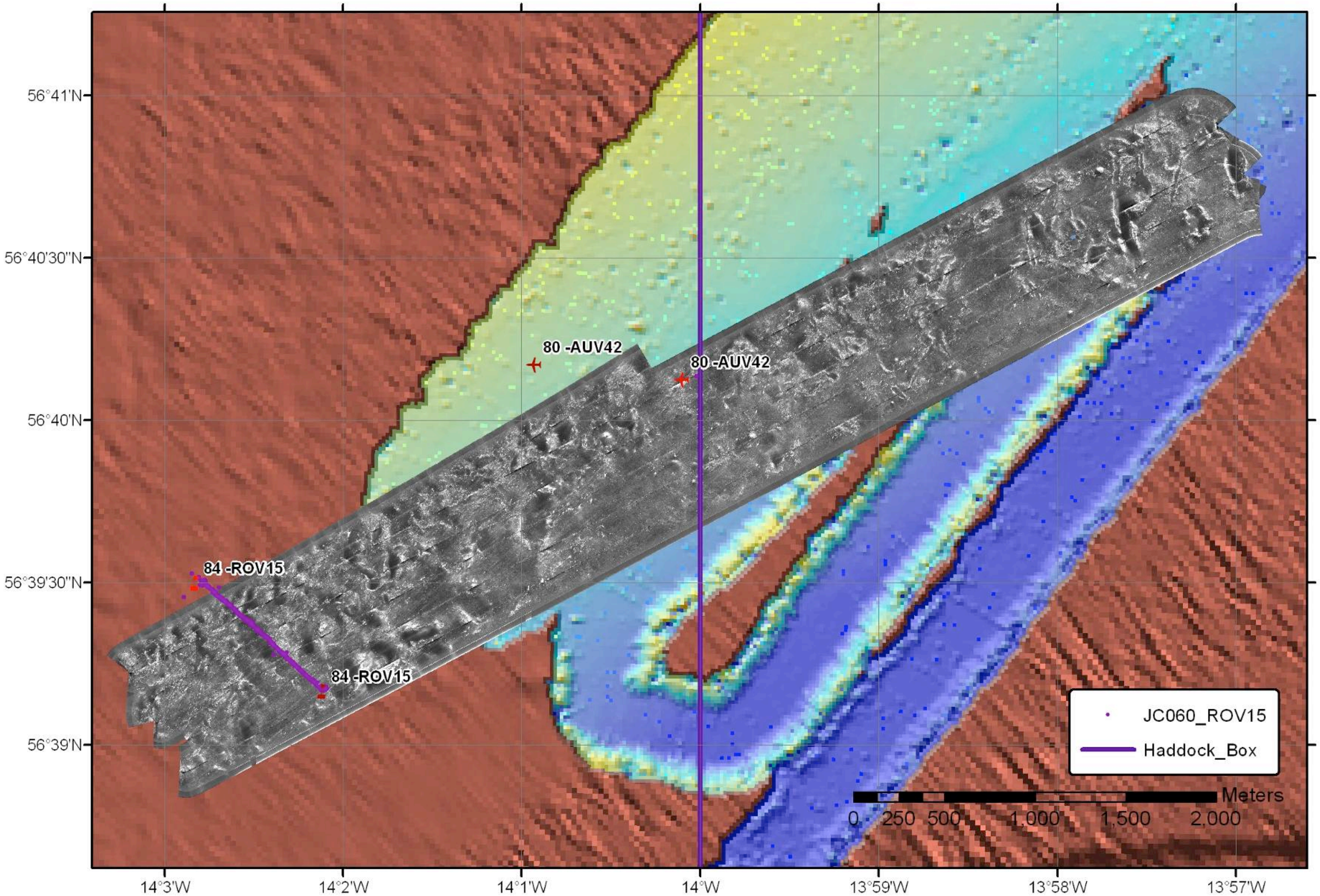
Hatton Basin:

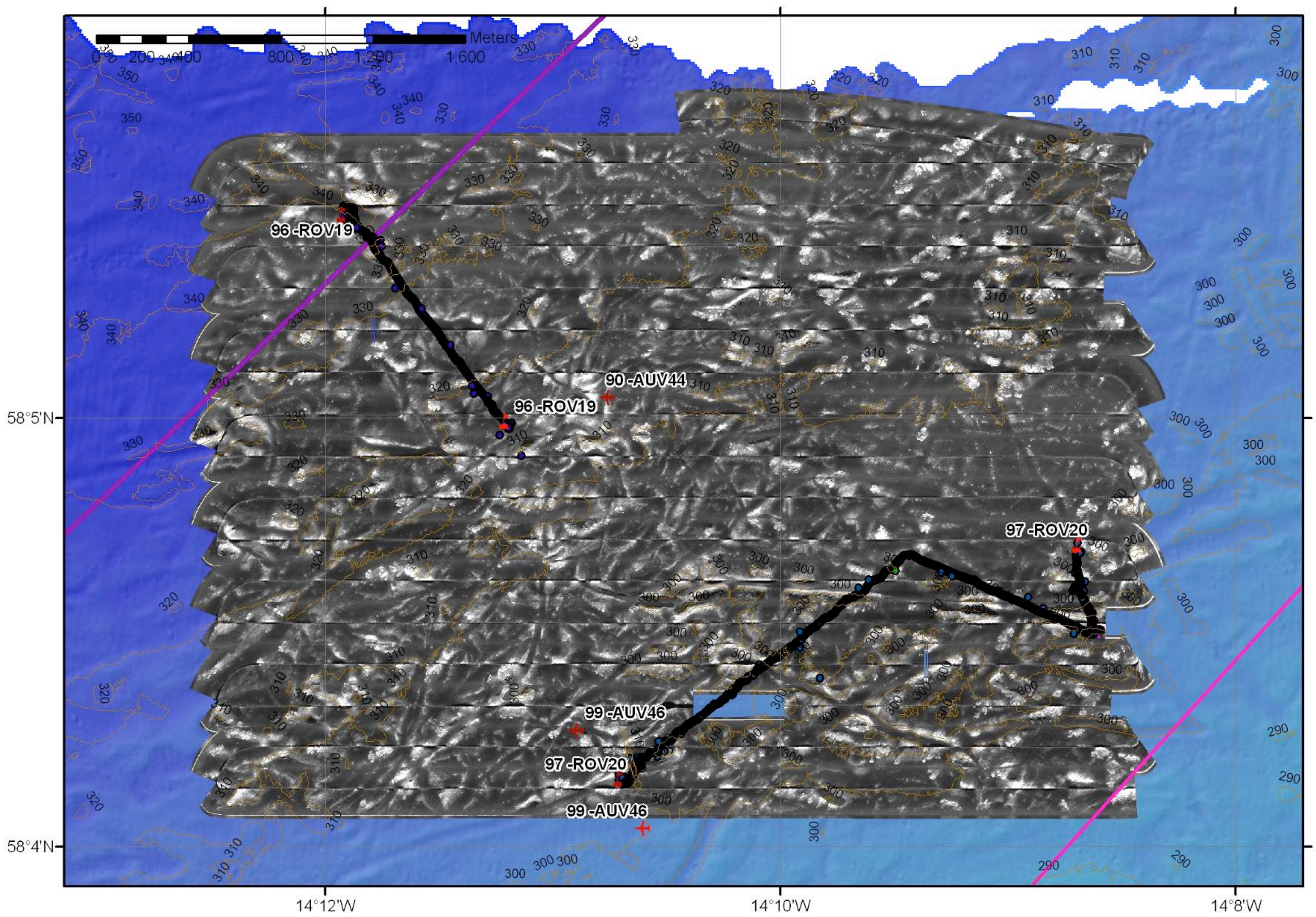


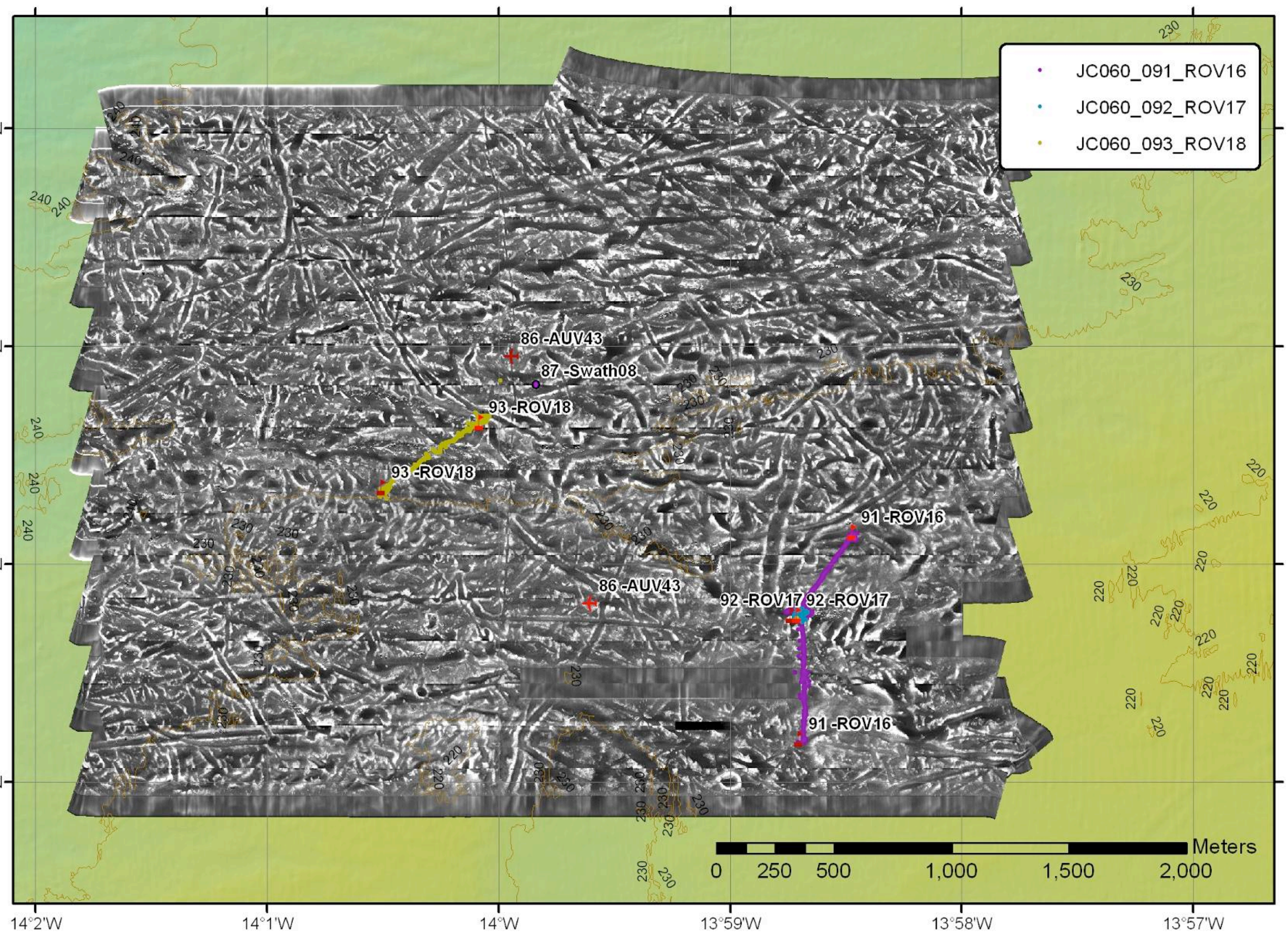
Rockall Bank:

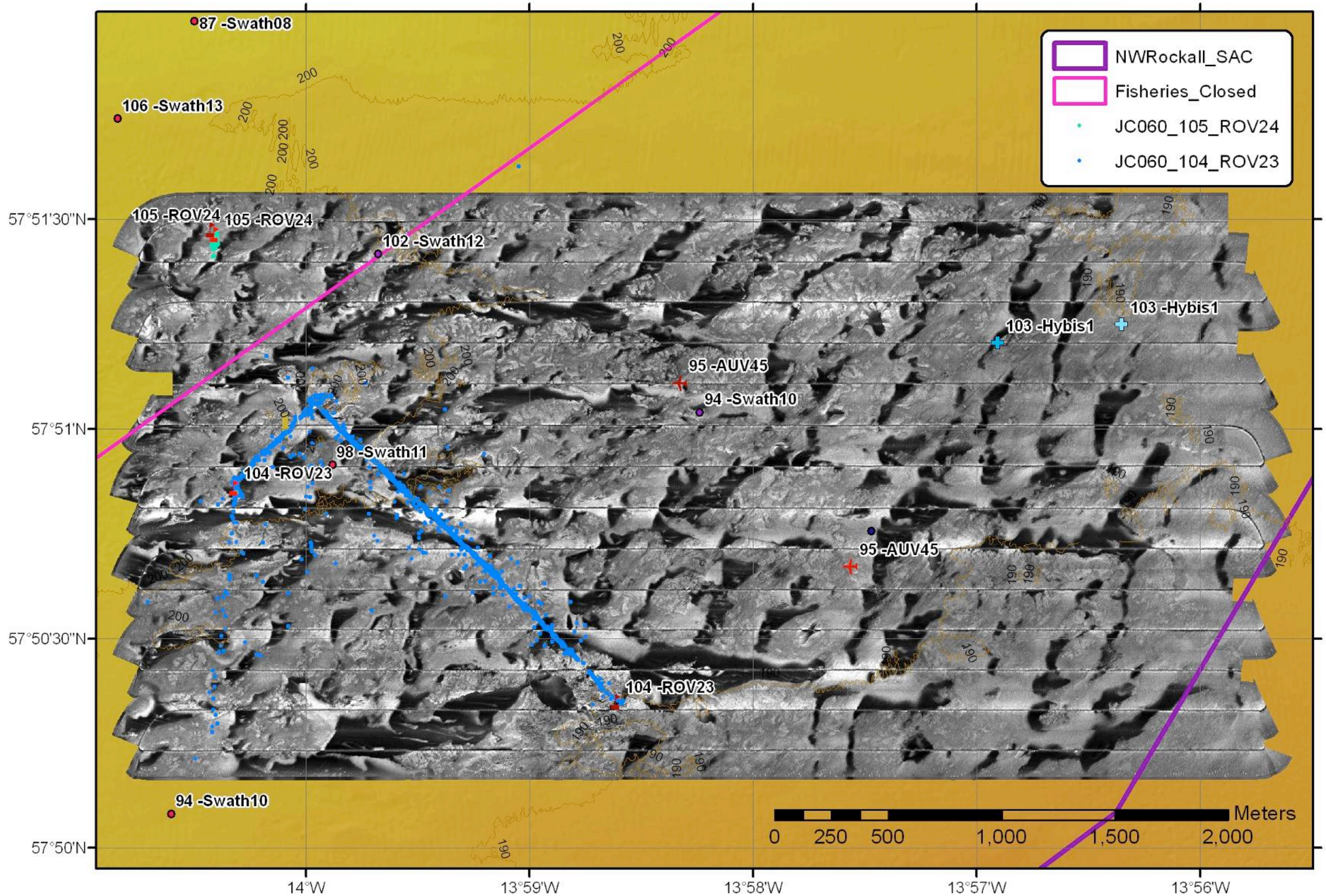



Meters
0
1,500
3,000
6,000
9,000
12,000
58°5'N
58°N
57°55'N
57°50'N
14°10'W
14°W
89 -SVP04
89 -CTD05
96 -ROV19
96 -ROV19
97 -ROV20
99 -AUV46
99 -AUV46
97 -ROV20
102 -Swath12
88 -Swath09
88 -Swath09
85 -Swath07
93 -ROV18
93 -ROV18
92 -ROV17
91 -ROV16
92 -ROV17
91 -ROV16
85 -Swath07
98 -Swath11
87 -Swath08
105 -ROV24
105 -ROV24
95 -AUV45
95 -AUV45
104 -ROV23
104 -ROV23
94 -Swath10
Stationlist_JC060e
Event_Gear
AUV_End
AUV_Start
BC
Bibo
CTD
Hybis_S
Hybis_e
Mark
Mega
NISKIN
PC
ROV_End
ROV_Start
SVP
Swath
Swath_End
Swath_Start
XBT
NWRockall_SAC
Fisheries_Closed


56°41'N
56°40'30"N
56°40'N
56°39'30"N
56°39'N
14°3'W
14°2'W
14°1'W
14°W
13°59'W
13°58'W
13°57'W
80 -AUV42
80 -AUV42
84 -ROV15
84 -ROV15
JC060_ROV15
Haddock_Box
Meters
0 250 500 1,000 1,500 2,000


0 200 400 800 1,200 1,600
Meters
96 -ROV19
96 -ROV19
90 -AUV44
97 -ROV20
99 -AUV46
97 -ROV20
99 -AUV46
58°5'N
58°4'N
14°12'W
14°10'W
14°8'W


JC060_091_ROV16
JC060_092_ROV17
JC060_093_ROV18
86 -AUV43
87 -Swath08
93 -ROV18
93 -ROV18
91 -ROV16
86 -AUV43
92 -ROV17
92 -ROV17
91 -ROV16
57°58'30"N
57°58'N
57°57'30"N
57°57'N
14°2'W
14°1'W
14°W
13°59'W
13°58'W
13°57'W
0
250
500
1,000
1,500
2,000
Meters



NWRockall_SAC
Fisheries_Closed
JC060_105_ROV24
JC060_104_ROV23
87 -Swath08
106 -Swath13
105 -ROV24
105 -ROV24
102 -Swath12
103 -Hybis1
103 -Hybis1
95 -AUV45
94 -Swath10
98 -Swath11
104 -ROV23
95 -AUV45
104 -ROV23
94 -Swath10
Meters
0
250
500
1,000
1,500
2,000
57°51'30"N
57°51'N
57°50'30"N
57°50'N
14°W
13°59'W
13°58'W
13°57'W
13°56'W

East Shiant Bank: