Institute of
Oceanographic Sciences
Deacon Laboratory

RRS Discovery Cruise 194

04 Aug - 02 Sep 1990

Comparative benthic biology at 31°N 20°W (Madeira Abyssal Plain) and associated midwater studies

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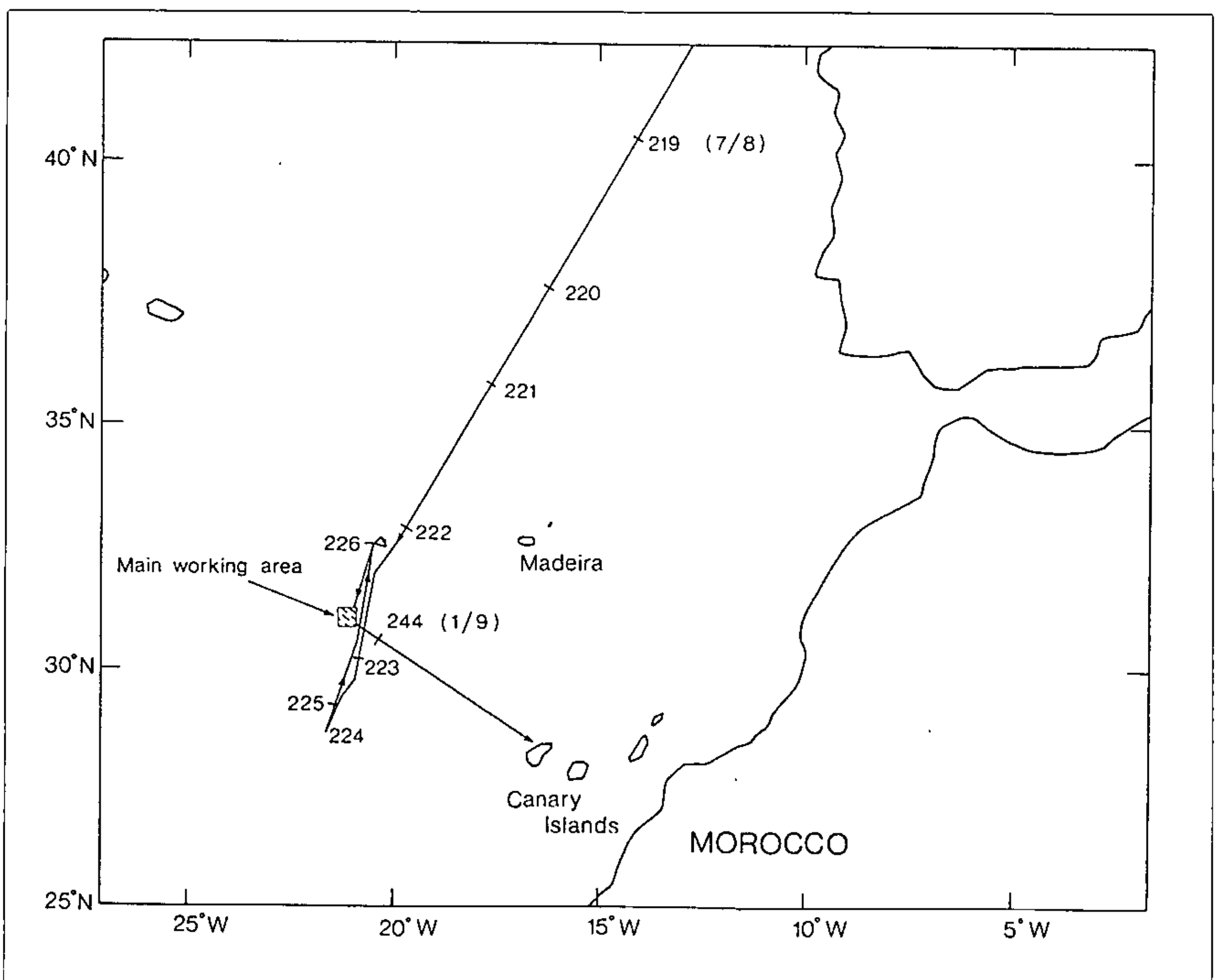

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CRUISE REPORT NO. 219

RRS DISCOVERY CRUISE 194
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Comparative benthic biology at 31°N 20°W (Madeira Abyssal Plain) and associated midwater studies

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ABSTRACT

Discovery cruise 194 had two major objectives. The first was the detailed study of the benthic biology of a southerly station for comparison with the northerly site (48°50'N 16°30'W) sampled at a similar season in 1989 on *Discovery* cruise 185. In the event the intended area was found to be so extensively affected by recent turbidites that the direct comparison of the two sites on climatic grounds was less practicable than anticipated. Nevertheless the assessment of the effects of the turbidite cover on the fauna is in itself of great interest.

The second objective was to study the distribution and movements of epibenthic fishes (esp. macrourids) by means of a pop-up vehicle with camera, hydrophone and baited acoustic tags. To this end ten successful deployments were made and a number of fishes tracked for long periods.

The main sampling programme involved: (a) spade box corer and multiple corer sampling for meiofaunal and macrofaunal analysis and determination of small-scale patterns; (b) sledge hauls for macrofaunal and megafaunal abundance; (c) otter trawls for demersal fish populations and other megafauna; (d) pop-up camera deployments (Bathysnap) for surface activity and scavenger assembly; (e) CTD and multisampler dips for water column analysis; (f) midwater trawls for physiological studies and the effects of lights on nets.

Additional experimental incubations of the sediment samples included studies of the changes in their organic geochemistry and associated bacterial populations.

KEYWORDS

ATLANTIC(NE)
ATTRACTING TECHNIQUES
BACTERIA
BAITED CAMERAS
BENTHOS
BOX CORER
DEMERSAL FISH
DISCOVERY/RRS - cruise(1990)(194)
EPIBENTHIC SLEDGE
GEOCHEMISTRY
LIGHT
MACROFAUNA
MADEIRA ABYSSAL PLAIN
MEGAFAUNA
MEIOFAUNA
MIDWATER TRAWLS
MULTICORER
OTTER TRAWL
PHYSIOLOGY
SONIC TAGS
TURBIDITES

ISSUING ORGANISATION

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HOLT, J.M.	3rd Engineer
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LEWIS, E.F.	Seaman
HEBSON, H.R.	Seaman
SPROUL, B.	Motorman
HEALY, A.	Motorman
BAILEY, G.	Motorman
PERRY, C.K.	Cook Steward
McAULIFFE, A.	Cook
ROUTLEDGE, A.	2nd Steward
ELLIOTT, C.	Steward
SMITH, S.	Steward
BALDWIN-WHITE, L.	Steward

ITINERARY

Depart Barry, South Wales - 4 August

Arrive Tenerife, Santa Cruz - 2 September

OBJECTIVES

1. To measure the benthic biomass at an appropriate site with little seasonal change near 31°N 20°W, and its distribution between different taxonomic, functional and size categories, for comparison with similar data from a site at 48°50'N 16°30'W sampled in 1989 and subject to substantial deep winter mixing.

2. To monitor the behaviour and movements of macrourid fishes using a pop-up vehicle baited with ingestible acoustic tags.

3. To study aspects of the physiology of midwater animals and in particular the reactions of crustaceans to illuminated trawls.

NARRATIVE

R.R.S. *Discovery* sailed from Barry at 0800 hr on Saturday August 4th, having loaded the equipment for cruises 194 and 195 over the previous two days. The scientific party had joined the ship at 1500 hr on Friday 3/8. Passage was made south, towards the intended sampling area, with echo-sounding watches commencing at 0900 hr 5/8. The first few days were devoted largely to gear rigging and testing, including a test deployment of the Aberdeen University Deep Ocean Submersible (AUDOS) on 7/8. The first station (12164), on the same day, was a CTD and acoustic release test. Passage south continued until 9/8 when two CTD casts and further release tests were undertaken (Stn 12165).

Results obtained by IOSDL geologists earlier in 1990, using the Towed Ocean Bottom Instrument (TOBI), had indicated that the site originally chosen for the main sampling programme (31°00'N 20°00'W) was subject to considerable turbidite cover. The presence of this turbidite cover would make a direct biological comparison between the two sites difficult to interpret. An alternative southerly site at 28°40'N 21°40'W (with appropriate bathymetry and topography) was therefore provisionally selected for comparison with the northerly station sampled on *Discovery* cruise 185 in 1989.

It was decided to take a set of multiple core samples at 32°00'N 20°33'W, some 150 miles northwest of this revised main site. These samples were to provide information about this position as a possible alternative site if it was later found that the revised main site was also seriously affected by turbidite cover. Six cores were obtained (12166) but they indicated clearly that the upper layers were turbidite deposits. During this station delays of several hours were caused by problems with both the alternator and the winch itself.

Passage was then made south and another multiple corer sample was taken at 0500/11/08, which achieved 12 good cores, but with turbidite overlay. Course was therefore made to the revised main site at 28° 40'N 21°40'W. A valve leak on the Schat davit was repaired during the passage. At this position AUDOS was deployed for the first time (12168 #1) and recovered the following day (12/8). Pictures of fish taking the bait were obtained but problems with the hydrophone and scanner prevented any tracking. During the deployment the RMT1+8 system was used to obtain experimental material at depths between 425 and 695 m (12168 #2, #3, #4) and a further multiple corer deployment provided 11 core samples, still containing turbidites (as indicated by the texture, colour and composition of the top layer of sediment) (12168 #5). A CTD with acoustic trials was deployed to 4000m (#6) early on 12/8.

Station 12169 comprised another multiple corer which demonstrated continued turbidite cover. An RMT1+8M deployment for experimental material (12170 #1, #2, #3) and the AUDOS recovery completed the station work for 12/8. The apparently uniform turbidite cover prompted urgent reappraisal of the potential benthic site, including telephone consultation with IOSDL geologists familiar with the area. Following these discussions it was decided to return north to 32°40'N, 20°30'W to look for an acceptably undisturbed site.

Passage was made to the area, arriving late 13/8 and station work (12171) began with the deployment of AUDOS (#1), followed by a multiple corer (#2) which collected six cores, and an RMT1+8M from 300m to 600m. Station 12172 #1 was a multiple corer deployment up the slope at a depth of 4705m and finally obtained 4 cores lacking the turbidite overlay. The topography of the area was not suitable for the main work site, so, after a CTD and transponder test, and the recovery of AUDOS, passage was made to a main site at 31°05'N 21°10'W (Fig. 1). Although this is still a turbidite-dominated region, it is in TOBI run 1 and the topography is suitable for all the sampling gears. A survey on a spiral grid pattern was carried out on the approach run.

Work at this site (12174) commenced with a CTD (#1) and an AUDOS deployment, and followed with an RMT1+8M series of hauls (#3, #4, #5) to help decide appropriate depths for the subsequent repeat series of hauls with lights. On 16/8 two multiple corer samples were obtained (#6 & #7) for experimental incubations to investigate the biogeochemical consequences of bacterial activities. A further multiple corer sample was taken later (#10), and two box cores (#9 & #11). The better of these two had a remarkable subsurface fluidity quite unlike the texture of the overlaying material. A similar condition was found in several subsequent deployments, and is thought to result from core impact pressures on the coarse material near the bottom of the turbidite. A Bathysnap was deployed (#8) to be recovered at the end of the cruise. Proceedings on 17/8 began with trials of the acoustically controlled lights on the RMT8M system, which operated successfully, and followed with recovery of AUDOS. Good pictures of large macrourids and an eel were obtained and fishes were tracked for 15 hours within the area. 12 excellent cores were taken by the multiple corer (#15) and another good box core (#16) was achieved prior to deploying AUDOS. A single RMT8 haul for experimental material was then fished (#18).

It was decided to postpone the series of "lights" hauls for 24 hours in order to fish an OTSB14 otter trawl. It was hoped that this would provide holothurian gut contents suitable for bacterial incubations for comparison with the sediment samples taken earlier. In the event the pinger on the trawl failed on deployment and the net had to be fished blind. A small sample of epibenthic animals was obtained but none of the desired holothurians. The trawl (#19) took up most of 18/8 and was followed by a baited Bathysnap deployment ("Bathysnack", 12174 #20).

A series of night RMT8 tows at 200m, with and without a light on the net, was begun with #21, #22 & #23 on 18th/19th August. This was followed on 19/8 by two successful multiple corer samples and one disturbed box core when the doors failed to close properly. A fifth AUDOS deployment (#27) included an upper hydrophone in the float rack. Further overnight light RMT8s were followed by an OTSB14 (#31) on which the pinger worked perfectly but much of the catch was hung up in the net and lost as it was being brought aboard. After the next set of light tows AUDOS was recovered somewhat sooner than expected as the soluble Mg link had parted and the vehicle was waiting at the surface when *Discovery* returned for it.

Between recovery and redeployment of AUDOS two box cores and a multiple core were taken (#35-#37) and a CTD employed to collect water samples from 30m for grazing experiments. A fault in the light system on the RMTs (#40-#42) was traced to a connector and rectified. Later in the day (22/8) a good box core was obtained and the new version of the benthic sledge deployed for the first time (#44). Unfortunately no odometer trace was achieved and the very small catch suggested that it had spent little time fishing on the bottom. A series of neuston nets (#45-#48) were fished to examine the potential food for seabirds which were extremely sparse in the area.

The three overnight light hauls (#49-#51) began slightly late and the last one was reduced to $1^1/_2$ hours duration to ensure total darkness throughout. During the day (23/8) a full set of multiple cores and an excellent box core were obtained and AUDOS deployed again. The series of light tows were completed with #55-#57, making 15 tows in all. On 24/8 a slightly disturbed box core was taken (#60) and a CTD with downwelling irradiance sensor was lowered to 240 m. An attempt to fish the benthic sledge (#62) was abandoned after it had twice overturned soon after launch and there had been a two hour power failure on the winch. A second Bathysnack, with a transponder, was laid on the sea-bed with the camera set for a 9 minute frame interval (#64). This was followed by a multiple corer and a series of three RMT8s, this time incorporating a flashing light. AUDOS was recovered on the morning of 25/8 and succeeded by a box core and a benthic sledge (#70). The latter produced a very small catch with considerable quantities of clinker. AUDOS was deployed for the 8th time later the same day.

The first use of the RMT1+8 with the closing codend (#73) was successful at 800m, and was repeated later 26/8 with a deeper tow at 1000 m which captured *inter alia* a very large *Bathothauma*. An OTSB14 (#77) ran from early afternoon 26/8 to the morning of 27/8. This produced a good catch of decapod crustaceans and a few fish (including a very large specimen of the anglerfish *Gigantactis*) but only one holothurian. The importance of holothurians at the northerly station is clearly not reflected at this site.

AUDOS #8 was recovered at noon 27/8, somewhat delayed by the close approach of a merchant vessel. It was followed by an RMT 1+8 with closing codend (#78) which was terminated early because of a monitor fault. A box corer and multiple corer were followed early on 28/8 by the deployment of AUDOS #9, another RMT, a box corer and a CTD for experimental work on bacteria (#84). Four attempts were then made to fish a benthic sledge, but it was aborted when it turned over on each launch. A multiple corer was deployed instead and followed by an RMT. A brief scientific meeting was held in the early afternoon to assess the achievements to date and to assign the priorities for the remaining period.

On 29/8 a multiple corer and a box corer were separated by the recovery of AUDOS #9, and trials of the benthic sledge's stability followed. These were encouraging, and a sledge was finally launched in the afternoon (#90), albeit at the third attempt. It was recovered early the next morning (30/8) but returned with all the nets, including the suprabenthic net, full of sediment. During the subsequent clean-up operation AUDOS #10 was deployed and RMT and multiple core samples were obtained later. A Telex message was received from RVS giving notification of very recent Senegalese demands for observers on cruise 195. It was decided that the timing and costs were quite unreasonable and that it would therefore be appropriate to avoid their waters during 195.

Both Bathysnack and Bathysnap were successfully recovered around noon 30/8 and both provided an interesting photographic record of the working site and its associated fauna. The day ended with a multiple corer and an RMT (#95). An attempt was made to deploy a photosledge over the previous sledge track but this was thwarted by consistent instability of the vehicle. A deep RMT was fished instead, but failed to open as a result of incomplete adjustment of the release gear before deployment. Meanwhile AUDOS #10 had popped up unexpectedly early and was recovered 0900 hrs 31/8. A shallow CTD (#98) was used to acquire water samples for experimental purposes and a deep (to 2300m) RMT fished. Increasing wind and swell made recovery harder and caused the RMT1 net to tear at the tail, with the resulting loss of the codend bucket. The final station of the cruise (12175 #1) involved the deployment of a longterm Bathysnap (with an associated piece of wood) which is intended to be recovered in 1991 and has a frame rate of 5 per day.

Passage was then made to Santa Cruz, Tenerife, arriving on Sunday morning September 2nd, where most of the scientific party disembarked. Only the PSO and two RVS technicians remained on board for cruise 195.

PJH

PROJECT AND EQUIPMENT REPORTS

Benthic Biology

Cruise 194 was the second sampling opportunity within the IOSDL Laboratory Research Programme 4. LRP4 is based on the comparison of the benthic communities at two abyssal localities in the north-eastern Atlantic overlain by contrasting physical and biological conditions in the water column. These contrasting conditions are expected to result in differences in both the amount and the temporal distribution of the supply of organic matter to the sea-floor. One of the two localities, on the Porcupine Abyssal Plain at 48°50'N 16°30'W, was sampled extensively during *Discovery* cruise 185 in August 1989. This region is characterised by deep (>500m) winter mixing, high surface productivity and a strong seasonal signal in the supply of organic matter to the deeper layers. A second site, scheduled to be sampled during cruise 194, was originally selected as 31°N 20°W on the Madeira Rise. This site is at a similar depth to the northern locality, but is known to be overlain by a water column with a much shallower (<150m) depth of winter mixing, a lower level of surface productivity and an assumed much less marked seasonal input to the benthos. However, during the months leading up to the cruise new data suggested that this locality was not a good choice for the achievement of the objectives of LRP4. First, in January 1990, data obtained with the IOSDL Towed Ocean Bottom Instrument (TOBI) revealed benthic features suggesting that 31°N 20°W is in the path or one or more recent turbidites derived from the channel between Madeira and the Canaries. Second, cores obtained during a Dutch cruise in April 1990 revealed the existence of a surficial turbidite in the region which was aged by IOSDL chemists as between 200 and 500 years (P.E. Weaver, pers. comm.). In view of the known relatively low rates of benthic recolonisation at abyssal depths, the effects on the sea-floor communities of such a recent major disturbance event might still be evident and could mask the more subtle consequences of the water-column characteristics to be studied under LRP4. Consequently, the initial intention during cruise 194 was to find an area on the Madeira Rise unaffected by recent turbidites.

The IOSDL geologists had expressed the view that the turbidite would not extend over a very wide latitudinal range and that its influence probably would not reach as far south as c. 29°30'N. However, during the early part of cruise 194 a series of multiple corer drops (Stns 12166 to 12172) revealed the presence at depths of 4800+m of the presumed recent turbidite from at least 32°30'N to 29°12'N, with a similar, but possibly distinct, turbidite being encountered some 20n.m. further south at 28°50'N. Turbidites were not present at 4600m at 32°37'N (12173), but at this depth the bottom topography was unsuitable for the envisaged sampling programme.

Having by now expended more than four days in an unsuccessful quest for a turbidite-free region, and having once more consulted the IOSDL geologists, we concluded that we were unlikely to find such a region in this general area. Accordingly, it was deemed necessary to make the best of an unsatisfactory situation and to devote the cruise to a study of the benthic community in a recent turbidite area, even though this would limit the relevance of the results to the stated aims of LRP4. The chosen study area was centred on 31°05'N 21°10'W, in the path of one of the TOBI runs referred to above and therefore in a region for which there is already a considerable amount of information about the turbidite. In working this station (12174) the box corer and multiple corer were deployed as close as practicable to the station central position. Deployed moorings, Bathysnap and the AUDOS rig, were positioned some distance (generally 5-10 n.m.) away from the central position, while the towed benthic gears, the OTSB and the epibenthic sledge, were fished in order to sample as close as possible to the central position (Fig. 2), but clear of the moorings.

A key requirement of the LRP4 programme is an accurate knowledge of the positions of the samples, including the towed gears. Cruise 194 provided a second opportunity to test an acoustic navigation system being developed at IOSDL to tackle this difficult problem. Unfortunately, as detailed in the gear reports, these trials were unsuccessful.

ALR

Spade box corer

The spade box corer is the best available gear for obtaining samples of small macrofaunal organisms (size range 250-1000μm) and the only means of collecting larger burrowing organisms. Undisturbed cores with intact surface layers are necessary for size-spectrum analysis and the vertical distribution of organisms within the sediment.

The gear was deployed 14 times (Table 1). It operated satisfactorily on all occasions, and suffered none of the unfortunate breakages and pretriggering which had plagued attempts to use it on Cruise 185. Ten cores were suitable for full analysis. The remaining 4 cores were damaged to a greater or lesser extent, usually having suffered lateral compression, displacement of sediment, and destruction of some or all of the surface. Dynamometer readings during bottom contact, penetration and pull-out showed considerable variation. Normal wire tension just prior to bottom contact was about 2.2 tonnes. Peak tension at pull-out ranged from 2.6 to 4.2 tonnes, and settled to 2.5-2.6 tonnes once the corer was clear of the bottom. Peak pull-out tension correlated with the condition of the resultant core. Tensions in excess of 3.5 tonnes invariably produced good cores, and those above about 2.9 tonnes often did, but lower tensions usually resulted in a damaged core. All damaged cores suffered from some degree of lateral compression, suggesting a non-vertical entry of the corer into the sediment or non-vertical pull at pull-out. A probable cause for this problem was the displacement of the ship by a significant but irregular westerly set experienced during much of the time spent at the main work station.

Each good core was photographed and a brief description made of the surface colour, texture and features. Komoki and other foraminifers were common on the surface of most cores, and examples were removed and set aside for future study. Two coring tubes (57mm i.d.) were driven vertically into the box core to obtain subsamples for meiofaunal analysis and for sedimentological and granulometric studies. A subjective summary was made of the relative resistance to penetration of each core tube. In the absence of any piston device, core compression was monitored during tube emplacement. The box core was cut into 6 layers (0-1, 1-3, 3-5, 5-10, 10-15, 15-20cm). Down to 10cm, sediment from each layer was sieved on 1000, 500, 300 and 250μm meshes, and below 10cm on 1000 and 500μm meshes only. The use of 300 and 250μm meshes for the upper layers should ensure comparability with both American and French macrofaunal analyses. Residues were fixed in 10% buffered formalin. The 0-10 and 10-20cm layers of 2 of the damaged cores were sieved on a 1000μm mesh for larger macrofauna. The remaining two box cores were discarded although one was subsampled for geochemical analysis before disposal. Brief descriptive notes were taken on the appearance, texture and consistency of the whole of each box core, based on information obtained during emplacement of the subsample tubes, cutting out the sieved layers, and the subsequent removal of the sediment deeper than 20cm. The subsample cores were removed to the cold room. Subsequently, the meiofauna core was cut into putative 0-1, 1-2, 2-3, 3-4, 4-5, 5-10, 10-15 and 15-20cm layers using compaction data obtained during emplacement. Sediment was fixed unsieved in buffered 10% formalin.

Box core surfaces were very soft, creamy buff-grey in colour, and showed little evidence of major individual bioturbation events. Burrows 5-8mm in diameter were present on some surfaces. In one case, surface openings led down into a U-shaped burrow penetrating 130mm into the sediment and inhabited by an 80mm long polychaete. Komoki and other foraminifers were common on most core surfaces, and patchy drifts of dead debris from these organisms were present to a varying extent. Small amounts of brownish flocculent material were found on some cores. It bore some resemblance to phytodetritus, and suggested that some cores at least had suffered only very minimal disturbance.

Penetration of the box corer ranged from 32 to 51.5cm (mean 41.5cm). Cores showed some degree of overall similarity, but also much individual variation. The top 2-5cm consisted of very soft creamy buff-grey sediment of very fine texture and containing few foraminifers. This is thought to represent the oxidised layer. Below this, the sediment tended to become more compact, greyer in colour, and coarser grained. The bottom of this layer, 13-43cm below the surface, was marked in many cases by a coarse well-sorted layer consisting largely of foraminifers, and represented the bottom of the 200-500 year old turbidite which covers this area. Cross-banded layering could be seen in some cores towards the bottom of the recent turbidite, but above the coarsest deposits. In 6 of the cores a fluidized layer occurred, usually centred about 20cm below the surface. This is presumed to be an artefact of box penetration. Below the recent turbidite, the sediment was firm to very hard, usually very sticky, tinged orange or pink in colour, and contained few foraminifers. This layer was 10cm or more thick, and represented Holocene pelagic sedimentation. In some cores where the overlying layers were relatively thin, these pelagic sediments were underlain by a dark 'pepper and salt' layer, very rich in mineral grains and with some foraminifers. This well sorted layer may represent the very extensive turbidite which occurred at the end of the last glaciation (c. 11000 years B.P.).

Sieved residues from the box core layers were very small in most cases, indicating uniformly fine sediments. Only in those cores where the bottom of the recent turbidite lay above or close below the 20cm horizon were residues larger. No microscopic examination of sieved residues was undertaken on the ship, but animals appeared to be very sparse in >1mm fractions, with numbers at least an order of magnitude less than was found at the EC station (48°50'N 16°30'W).

MHT, BJB

Multiple corer

The twenty-one deployments (Table 2) fell into two phases. During the first phase (deployments 1-10) the corer was beset with problems and yielded a full set of twelve samples on only one occasion (12174#6). Various measures were taken in order to improve the performance. From the second deployment (12167#1) onwards, only tubes which projected a uniform distance (about 1cm) above the top ring were used. Three extra bungee loops were installed in positions 6,7 and 11 from deployment 5 onwards to test whether extra pressure on the top lids would improve core retention. For deployment 7 only, the nut closing the end of the hydraulic damper was removed so that the hydraulic piston, and hence the coring head, would descend more rapidly. None of these modifications made any perceptible difference.

From deployment 8 onwards two extra lead weights (16kg) were attached to the sliding frame to increase sediment penetration. The addition of these extra weights was apparently beneficial since it was followed by the recovery of two good sets of samples (12174#6,7). However, the most obvious and lasting improvement in performance followed the fitting of new core catcher arms. These were made of grey polypropylene and replaced the original white polypropylene arms which had become bent during several years usage. The new arms fitted accurately and firmly below the core tubes and their installation was almost certainly responsible for the near perfect performance of the gear during the remaining deployments (11-21).

The corer returned a total of 201 usable cores which were sampled for a wide variety of purposes. During its first seven deployments (Stns 12166-12169, 12171-12173) the corer was used principally to survey the distribution and thickness of the turbidite deposit. In each case, several cores were chilled and frozen and additional cores, when available, were subsampled and preserved in formalin. The final 14 deployments were carried out at Stn 12174 (Table 3). The upper 5mm of sediment was removed from the first two sets, homogenised and used in an experiment to investigate the effects of microbial degradation of organic matter on sediment geochemistry. Nine core sets were subsampled according to a standard protocol: at least 2 were frozen for chemical investigations; 1 was chilled for granulometric analysis; 3 were sliced into 1cm thick layers down to either 5cm or 15cm and preserved in formalin for foraminiferal and nematode studies (Gooday, J. Lambshead (Natural History Museum)); two were sliced down to 5cm or 15cm and preserved in alcohol for foraminiferal studies (J. Murray (University of Southampton)); four syringe subsamples were taken from the remaining three cores for foraminiferal and nematode studies (Gooday, Lambshead; a small subsample of sediment from one of these cores will be used for fractal analysis by Prof. J. Lawton, (Imperial College, Univ. of London)). The upper 1cm of sediment from each core of two sample sets (#65, 79) was preserved in formalin for a study of small-scale variability among foraminiferal populations (Gooday). Two syringe subsamples were taken from each core of another set (#86) for a study of intra- vs inter-core variability among nematode populations (Lambshead).

Any large, epibenthic foraminifers visible on the core surfaces were removed and preserved separately (see below).

AJG, SK

Large Agglutinated Rhizopods

As on *Discovery* cruise 185, large, agglutinated rhizopods noticed on the surfaces of box and multiple-corer samples were removed and preserved separately. The most obvious foraminifer was a species with a finely agglutinated test which resembled a small, flexible tree extending 10-15mm above the sediment surface. This arborescent morphology is typical of suspension feeding foraminifers. Thirteen specimens occurred in 122 multiple corer samples from Stn 12174 (density = 42.6 individuals per m^2) and 30 specimens occurred in 11 box-cores (density = 10.9 individual per m^2). The apparently lower density in box-cores probably reflects the fact that specimens were much less visible when flattened against the drained surface of a box-core than when projecting into the water overlying a multiple-corer sample.

A second, smaller upstanding organism was much less common. It resembled a mushroom, consisting of a short stalk a few mm long, giving rise to a discoidal structure supported by bifurcating branches of the stalk. This organism is probably a foraminifer although its morphology is very unusual. A total of 9 specimens occurred in the core samples (density in box-cores = 2.2 per m^2; density in multiple cores = 9.8 per m^2). However, it was not noticed until the eighth box-core (12174#53) and may have been overlooked in previous samples.

Other epibenthic or shallow infaunal foraminifers visible on core surfaces included short, branched, flat-lying, stick-like tests and komokiacean mudballs, mainly specimens of the genus *Edgertonia*. A number of rhizopods which occurred at the northern LRP4 site (*Discovery* cruise 185, Stn 11908; 48°50'N, 16°30'W) were notably absent. These included the komokiaceans *Rhizammina algaeformis* and *Lana* and xenophyophores (large agglutinated rhizopods, possibly related to foraminifers). The latter seem to be associated with areas of high food supply and sloped topography. Their absence at Stn 12174 is not surprising therefore.

AJG, SK

Nanobiota and phytodetritus

The nanobiota (organisms, mainly protozoans, in the 2-42μm size range) of deep-sea, fine grained sediments have proved difficult to study because of the problems involved in separating the organisms from sediment grains and the apparent sparsity of the fauna. Several methods were tried, without success, during an earlier cruise (*Discovery* 185). During the present cruise an attempt was made to observe nanobiota using a new procedure devised by Bak and Nieuwland (1989) for intertidal muds. This method involves the following steps: (i) a small volume (0.2ml) of surface sediment is suspended in 20ml of 0.2μm filtered seawater in a test tube and left to stand for 30 minutes; (ii) 5ml of the supernatant (taken from the centre of the tube) is transferred to another tube and DAPI solution added to give a final DAPI concentration of 0.5μg per ml; (iii) after staining for 15 minutes the suspension is vacuum filtered over a 0.2μm millepore laser-etched filter; (iv) the filter is mounted in UV inert immersion oil and examined under the epifluorescence microscope. It proved to be particularly important to use a very dilute sediment suspension in order to avoid overloading the filter with sediment and thereby obscuring any nanofaunal organisms that might be present.

Sediment from two multiple-corer deployments (Stns 12166, 12174#93) was examined using this technique. Virtually nothing resembling a nanofaunal organism was seen on the filters apart from very occasional oval structures, each containing a more strongly fluorescent body (?nucleus), which may possibly have been flagellates. This experience strengthens the impression gained during *Discovery* cruise 185 that a considerable investment of time, both at sea and in the laboratory, will be necessary if any progress is to be made with the nanobiota.

Brownish material was often present as scattered patches on the surfaces of multiple corer samples. Occasionally, this material formed lumps which were sufficiently coherent to be removed intact, mounted on slides in glycerol, and examined under the epifluorescence microscope. These lumps contained planktonic elements (diatoms, planktonic foraminifers, crustacean moults, cyanobacteria) and presumably were a form of phytodetritus. One aggregate contained an indeterminate live benthic foraminifer which had ingested cyanobacteria.

AJG

Bacterial studies

Objectives.

1) To collect samples of both sediment and coretop water from the multiple corer for bacterial counts. These samples to be preserved for Dr. J. Patching, Galway, for comparison with the samples from cruise 185 at the Northern LRP4 station.

2) To develop methodology for determination of rates of uptake of ^{3}HThymidine (^{3}HTdr) in deep sea sediments, as a method for estimating bacterial productivity for comparison with euphotic zone studies.

3) To monitor changes in bacterial activity (^{3}HTdr uptake) and numbers in sediment incubated at *in situ* temperature and pressure, for comparison with concomitant changes in the organic chemistry and structure of the sediment.

4) To monitor bacterial and chemical changes in the gut contents of holothurians known to contain bacteria in their gut epithelium, and those without epithelial bacteria, for a comparison with the changes observed in the sediment alone.

5) To measure community bacterivory in the euphotic zone.

6) To measure the total carbon content of a natural oceanic bacterial population in collaboration with Dr. H. Kennedy, UCNW Bangor.

Benthic studies

1) Bacterial abundance: Sediment and core top water samples were preserved in 1% glutaraldehyde. Duplicate samples were collected from these stations for intercalibration. In addition, several box cores were sampled for bacterial abundance.

2) Bacterial productivity: At three separate multiple core stations the sediments were assayed for bacterial productivity. Two different methods of purification of the labelled DNA were compared. For each determination, a time course of five separate incubations was analysed. The incubations were carried out in pressure vessels at *in situ* temperature and pressure.

3) Long term changes in sediments: From two stations longer term incubations were carried out to monitor changes in bacterial productivity, bacterial numbers and chemical changes over a period of 14 days. The productivity of bacteria in these samples was measured at 0, 2, 4 and 14 days. Samples were preserved for bacterial cell counts, and frozen for the analysis of changes in the organic chemistry of the samples during the incubations.

4) Bacteriology and chemistry of gut contents: The gut contents of certain echinoderms were preserved from two sledge deployments for bacterial cell counts. The animals sampled were;

12174 #31	2	*Hyphalaster inermis*
	2	*Molpadia blakeii*
	1	*Pseudostichopus* sp.
12174 #77	2	*Hyphalaster inermis*
	1	*Styracaster* sp.

Water column studies

1) Two successful grazing experiments were carried out using water collected with the CTD rosette sampler.

One included an analysis to determine the fate of the labelled thymidine. Purification of the cold trichloroacetic acid insoluble material, using the Robart and Wicks method, allows us to determine into which macromolecules the label has been incorporated.

The second was a combination of a time course of thymidine uptake, changes in cell numbers and Robart and Wicks purification. This represents the most comprehensive test yet of the modified dilution experiment used for the measurement of community bacterivory.

2) Contamination from the ship's smoke stack meant that it was impossible to measure bacterial carbon in the after container. This type of measurement would need to be carried out in a laminar flow hood. The feasibility of such a study, however, was investigated by looking at cell counts before and after the two levels of filtration. Water will be collected on the homeward leg for filtration and freezing at Wormley. The samples can be subsequently analysed at UCNW.

Problems

Objectives 2 - 4 were severely restricted by the loss of the scintillation counter before sailing. This loss meant that any analysis of ^{3}HTdr uptake on board was impossible. The development of a protocol for the determination of bacterial production in deep sea sediments therefore required more options to be covered, with a consequent 5 fold increase in the workload for these experiments. The experiments involving the measurement of thymidine uptake in the water column were less affected as the protocol for shallow water column studies is already established.

Objective 4 was limited by the lack of echinoderm material collected during the cruise, a result of the low densities of megabenthos in this region. Temperature variations within the constant temperature container could have presented problems but were buffered by the insulation properties of the pressure vessels.

Station activities (12174)

Sediment Bacterial Abundance

multiple corer: #6, #7, #24, #26, #36, #52, #88, #93, #94.

box corer: #9, #53, #74.

Bacterial Productivity

multiple corer: #6, #7, #93.

Long term changes in sediments

multiple corer: #6, #7.

Gut content chemistry and bacteriology

OTSB : #31, #77.

Community bacterivory

CTD : #38, #61, #84.

MWS

Organic geochemistry of deep sea sediments

Background

The work carried out on Cruise 194 forms part of a collaborative effort with the IOS programme LRP4. This project aims to compare the processes of degradation and utilisation of organic matter (OM) by bacteria and megafauna in deep sea sediments from high and low latitude sites in the northern Atlantic Ocean. Samples from Cruise 185 (Porcupine Abyssal Plain) have been analysed at Liverpool University. These include sediment core (multiple corer) and holothurian gut contents. Initial results for the sediment cores show that OM in the relatively rich surface (5mm) layers is degraded very rapidly. The high abundance of bacterial biological markers suggest that microbial processes are probably of great importance. However, as yet, there is very little understanding of the influence of larger organisms e.g. holothurians, asteroids etc.

Aims

(1) To collect multiple core and box core sediment samples from the low latitude site chosen for LRP4, in order to compare the nature and degradation of OM with the northern site.

(2) To carry out incubation experiments of fresh sediment samples under ambient temperature and pressure conditions in order to assess the rates of degradation of OM by bacteria.

(3) To collect animal gut contents for comparison with sedimentary material and if possible to carry out incubation experiments of these gut contents in parallel with the sedimentary experiments. These experiments would attempt to assess qualitatively and quantitatively the nature of OM utilised by the animals, and the rates of OM degradation in their guts relative to the sediments.

Samples collected

The site chosen for this study (see other reports) turned out to be less than ideal, because of the extensive recent turbidite which covers the area. This facies varies in nature and in thickness; it tends to be well sorted, fining to the top, and overlies highly disturbed pelagic sediments. The surface 1-2mm of all multiple core samples showed some evidence of renewed pelagic sedimentation. The turbidite is assumed to have been deposited at ca. 200-500 yrs B.P.

The most southerly site appeared somewhat different. Although a turbidite was also present, it was much thicker, and was overlain by 3-4mm of pelagic sediment. A redox boundary was also evident in the pale turbidite layer. It was assumed that this flow was somewhat older than that seen at the northern sites.

Ten multiple core samples were taken:

12167#1	29°30.3'N 21°15.6'W	4846m	
12168#5	28°49.3'N 21°35.1'W	4845m	
12169#1	29°12.5'N 21°25.0'W	4848m	
12174#15	31°05.5'N 21°10.8'W	4938m	
12174#24	31°05.4'N 21°09.9'W	4950m	
12174#36	31°06.7'N 21°10.3'W	4932m (2 cores)	
12174#52	31°05.3'N 21°10.2'W	4942m	
12174#88	31°05.5'N 21°10.2'W	4942m	
12174#93	31°05.1'N 21°10.1'W	4946m	
12174#94	31°05.1'N 21°10.3'W	4947m	

In addition, two cores were taken from a box-core sample:

12174#69   31°04.8'N 21°10.6'W   4947m

These were taken (1) to give deeper sampling than the multiple cores and (2) to obtain a section through a black layer of apparent volcanic origin.

In addition, animal gut contents were collected for organic geochemistry from specimens taken by two OTSB trawls:

12174#31   4914-4938m

Hyphalaster inermis	7	
Molpadia blakei	1	Samples from foregut, posterior intestine & 2 general gut samples
Pseudostichopus sp.	1	Samples from body cavity, stomach & posterior intestine
Styracaster sp.	1	

12174#77   4945-4962m

Hyphalaster inermis	10
Styracaster sp.	2

Unfortunately, as a result of the paucity of holothurian specimens, no incubation experiments were possible with gut contents. Asteroids are unsuitable, since it is impossible to tell how long the sediment has spent in the gut before dissection.

Sediment incubation experiments

Sediment incubation experiments were set up in order to investigate the degradation of OM by sedimentary bacteria in the deep ocean. Originally the experiments were to be carried out on pelagic sediments, in order to compare the southern and northern sites in LRP4. Unfortunately, because of the turbidite problem (see above), this was not possible. Nevertheless, the incubations were carried out for comparison with asteroid gut contents.

Sediment samples for the incubations were collected using the IOS multiple corer (drops 12174#6, #7). Two separate drops were made, in order to be able to carry out duplicate experiments. The cores (12 and 8 in total, respectively), were taken immediately to the cold room (2.5-4°C), and the top 5mm removed using a brass cutter. A sample from each core was taken by D. Roberts (Queens University) for fixing. For the incubation experiments, the 5mm sections were combined and mixed in a clean glass beaker. 40ml of the slurry was then placed in each of 5 polythene bags (0, 2, 4, and 14 days + 14 day control) which were sealed, and then pressurised at ambient pressure (500 bar). The 0 day bag was immediately frozen to -70°C. The 14 day control was incubated with formalin (1ml). In each case, the samples have been split for organic analysis (Liverpool), and for bacterial population and activity; the latter experiments will be carried out by M. Stirling (IOSDL).

Summary

Despite the overall problems of Cruise 194 with respect to LRP4, the sampling programme was successful. The sediment incubation experiments will give an indication of the viability of carrying out such experiments, and hopefully these will be developed for a more intensive programme at the northern site in 1991/92. Core samples should give information on the variability of the nature of OM in the turbidite throughout the sampled sites.

GAW

Epibenthic sledge

The epibenthic sledge was launched 6 times, but only on three occasions did the sledge reach the sea bed in its correct orientation and take a sample. Two samples were taken with the Mk I sledge, with a mesh of 4mm, and one sample was obtained with the Mk III sledge, with a mesh of 1mm. Both sledges were fitted with a cutting edge that sliced the top few centimetres of sediment, and with wire mesh plates of the appropriate size placed on the sides and top of the frame.

The cutting edge was of moderate success. A greater proportion of the sample was of infaunal animals, but the strain gauge kept leaping intermittently from 2.3 tonnes to 3.0 tonnes, suggesting that the sledge was digging itself deeper into the sediment. This was borne out by mud collected in the fine mesh nets which had a consistency similar to that found at about 10cm depth in the box corer samples.

Many of the photographs were obscured by mud clouds which may indicate either that the sledge was sampling inefficiently, or merely reflect the very soupy nature of the surface sediment.

The two catches from the coarse mesh Mk I sledge were exceedingly small, even in comparison with samples taken on the Madeira Abyssal Plain in previous years. Bivalves (mostly *Abra profundorum*) dominated the catches, which also included porcellanasterid asteroids (*Hyphalaster inermis*, *Styracaster* spp.), gastropods, annelids, isopods (*Storthyngura*), and natant decapods. The small fish *Bathymicrops* was also present and the samples were notable for a considerable amount of clinker and pumice. One sample had a bamboo shoot colonized by boring bivalves.

The single fine mesh epibenthic sledge haul was very successful. The nets were so full of mud that it took a great deal of effort, accompanied by a cacophony of ripping sounds, to get the nets inboard. Fortunately it had been decided to have three nets of equal mesh (rather than a large single net) for increased filtration and ease of handling, and to fit handling lines to the cod ends to facilitate their retrieval. Both ideas proved invaluable in recovering these samples. About 150 litres of mud was sieved, with much hilarity, all for a faunal sample of about 15ml. Most of the sample appeared to be of Wormley origin, largely composed of birch seeds accumulated during outside storage of the sledge system!

DSMB

Otter trawling

The OTSB was fished three times during cruise 194. During the first of these (12174#19) the pinger failed shortly after deployment and the gear was therefore fished blind. The small catch was dominated by midwater contaminants, benthic organisms being restricted to the few fish, including a bathypteroid and a large *Histiobranchus*, and several specimens of the benthopelagic decapod *Plesiopenaeus*.

The second haul appeared to proceed without any significant problems. However, during recovery the catch became hung up in front of the cod-end, possibly because the lazy-line was slightly too short, and at least half was lost. The remaining catch was rather disappointing, including about 19 fish, 2 rattail species together with 4 bathypteroids and about 12 ipnopids. Echinoderms were the most abundant invertebrates, though several species of decapod, including *Plesiopenaeus*, were present.

During the third otter trawl (12174#77) the pinger traces were lost when the gear neared the bottom. The catch was dominated by the decapods *Plesiopenaeus* and *Bentheogenemma* but also included bathypteroid and macrourid fish and a large anglerfish (*Gigantactis*). The other invertebrates present were again mainly echinoderms.

ALR

Echinoderm studies

This work is part of ongoing research investigating nutrient resource partitioning and bacterial associates in deep-sea holothurians in collaboration with D.S.M. Billett and the LRP4 programme (IOSDL). Additional areas of interest include heavy metal levels and genetic variation in holothurians and, in collaboration with N.R. Merrett (BMNH), genetic variation in rattails. Material for these latter studies was required for comparison with extensive samples collected at the northern site during *Discovery* cruise 185 (1989).

Major objectives during the cruise were to:

1) Acquire additional preserved tentacle and gut material for functional and analytical studies.

2) Collect frozen tissue samples from holothurians for metal analysis and electrophoresis.

3) Collect frozen liver and muscle samples and preserved stomachs from rattails.

4) Conduct incubation experiments on surface sediments and holothurian gut contents in collaboration with D.S.M. Billett and M.W. Stirling (IOSDL) and G.A. Wolff (Liverpool University).

Most of these objectives met with limited success only because of the dearth of holothurians and the required fish samples.

Tentacle, gut, body wall and muscle samples from 7 specimens of holothurians have been fixed or frozen for follow-up work (Table 4). In addition, tissue and gut samples have been preserved from *Hyphalaster inermis* and *Styracaster* sp. since these were the most abundant megabenthic surface deposit-feeders available. Samples include dorsal and ventral body wall and cribriform organs; these tissues will be screened for bacterial associates. The quality of fixation is likely to be a major problem with much of this material as specimens were subjected to relatively long periods in surface waters at approximately 24°C (cf bottom temp 2-3°C) where autolysis would be accelerated.

Liver and muscle samples from fifteen specimens of fish taken in three OTSB hauls were frozen at -70°C. Approximately a third of these were rattails. Replicate liver (for DNA and racial studies) and muscle (for racial studies) will be analysed at BMNH and QUB respectively.

Surface deposits from two deployments of the multiple corer provided enough material for a replicated incubation at ambient temperature and pressure. The objective of this experiment is to follow changes with time in bacteria, other biota and the chemistry of uningested sediments for comparison with gut samples from surface-deposit feeders. No suitable animal material was available in time to initiate a parallel incubation with gut sediments. However experimental techniques have been developed to make this feasible in the future.

DR

Underwater photography

The four IOS underwater camera units, two mark IVs for use with the epibenthic sledge and two mark Vs for use with Bathysnap, all worked satisfactorily throughout the cruise.

One mark V unit (P5 01) was deployed on a Bathysnap for 14 days and produced consistently good results with Ektachrome 200 film. The camera was also used on the long Bathysnap deployment (12175#1). The other mark V camera (P5A 04) which was deployed on two successive Bathysnack deployments, one for

$4^{1}/_{2}$ days (12174#20) and one for 6 days (12174#64), also produced good results with Ektachrome 200. However, the data back on this second camera was incorrectly set and the LEDs were over-exposed and difficult to read.

The mark IV cameras employed with the epibenthic sledge also performed well with both FP4 and Ektachrome 200 film. However, the nature of the seafloor and the consequent difficulty in fishing the sledges resulted in many frames being obscured by disturbed mud.

ALR

Bathysnap

In total four Bathysnap deployments were made during this cruise. Two were deployed in the normal configuration; the other two were baited and are subsequently referred to as Bathysnacks.

New Mk V cameras were used in all four deployments, with the focal distance set to 1.5m, the aperture set to f8 and loaded with 30m of Ektachrome 200 ASA film. Buoyancy was similar in all cases: four 18" spheres main, two additional 18" spheres higher on the rig, plus a smaller lazy-line sphere.

Table 5 summarises the four deployments and three recoveries made during the cruise, giving details of: series number, position, depth and times for arrival on bottom and subsequent release. The table also includes data on the variable aspects of each deployment: payload, transponder or recording current meter (RCM), and frame interval.

The first Bathysnap deployment had a duration of 14 days, with the camera on the bottom for approximately 338 hours. On retrieval two short lengths of film from the end of the deployment were developed aboard ship. These indicated that the camera had functioned well, but there was no evidence of faunal presence or activity. The remainder of the film was developed and an initial examination performed on return to IOSDL. This examination confirmed the conclusions reached onboard.

The second Bathysnap was prepared for a long deployment with a proposed duration of approximately one year. It is worth noting that the camera used in this deployment does not have a light-tight cover; on recovery the pressure case should therefore only be opened in a darkroom. (Dr. D. Roberts, QUB, attached two small blocks of wood to the frame of this Bathysnap to investigate possible colonization.)

The two Bathysnacks deployed were baited with mackerel well-wrapped in muslin. The bait was attached to the end of a short pole which projected from the frame to approximately the centre of the field of view. On retrieval the baits were examined by M.H. Thurston (IOSDL) who was able to recover substantial numbers of amphipods from the muslin and what remained of the mackerel carcasses.

Film from the Bathysnacks indicated that the baiting had been very successful. Fish, large prawns and amphipods were present in a great many of the frames. These data are currently being analysed (A.L. Rice, IOSDL) and although complete in themselves will also serve as a useful comparison with the AUDOS work carried out during the cruise.

Few problems were encountered in the operation, deployment or recovery of the cameras. Most significantly the RCM on Bathysnack 1 was, on recovery, found to be fouled by the short strop connecting it to the camera frame. It is believed that this occurred during deployment as a result of the buoyancy-first launch. The RCM may have initially descended faster than the camera frame. When the mooring then straightened under tension a bight of the connecting strop may then have looped round the vane of the RCM. Future deployments should consider ballast-first launches, particularly when a heavy payload is included just above the camera frame. (The only other problem encountered was the deterioration of two of the buoyancy spheres, IOSDL 33062 and IOSDL 33078, during the Bathysnap 1 deployment, these were replaced prior to Bathysnap 2 deployment.)

BJB

Movements of deep-sea benthic fish

This work formed part of a study supported by NERC grant no. GR3/6611. The aim was to compare the population density and foraging behaviour of scavenging benthic fishes at two different locations in the North Atlantic. A relatively productive northern station had been studied previously on *Discovery* cruise 185 in 1989 and the aim of this cruise was to carry out complementary studies at a less productive southerly station.

The experimental protocol was based on deployment of a pop-up vehicle, AUDOS (Aberdeen University Deep Ocean Submersible). A standard bait of mackerel with acoustic transmitters embedded in small baited "haggises" was deployed on the sea floor beneath the vehicle within view of a downward-looking photographic camera. In the films, any scavengers can be observed arriving at the baits, ingesting transmitters and finally departing from view. Those fish that ingest transmitters can be tracked using two acoustic receiving systems on board the vehicle, ATEX and SCATEX. ATEX used omnidirectional hydrophones and SCATEX incorporates a scanner which detects fish direction. The vehicle also carries an electromagnetic current meter.

Ten deployments with AUDOS were planned and ten were achieved, each with approximately 30h duration on the sea floor. A steady rhythm of recovery and redeployment of AUDOS was maintained with no loss of time through weather or ship's problems. We are grateful to all our colleagues and all the ship's company in enabling us to achieve our target. A vital component of any pop-up vehicle is the release mechanism. The IOS type acoustic releases ably operated by G.J.R. Phillips of IOSDL worked perfectly with no malfunction. On four deployments the vehicle surfaced prematurely set free by the soluble magnesium back-up release. These early pop-ups gave us useful information on time delays of different magnesium releases.

It was evident in view of a combination of disturbance to the sea floor and low surface primary production that the study area would be very food-sparse as far as fish are concerned. This was to provide a more extreme contrast with our northern station than we had expected. In photographs developed on board ship we observed a variety of fish attracted to our baits including grenadiers, synaphobranchid eels and ophidioids. All baits had been consumed by the end of the 30h experimental period on the sea floor. In total 16 fish were tracked using the ATEX and SCATEX systems. All of these fish moved out of the 1km range of the acoustic tracking system within 30h of ingesting the transmitters indicating an active foraging mode of life. Results of this cruise have shown that, as in the Pacific Ocean, even in very food-sparse environments scavenging fishes rapidly detect, consume and disperse organic matter reaching the sea floor.

IGP, JDA, PB

Acoustic equipment

Acoustic releases

Three IOS and two RVS CR200 units were overhauled for the two IOS Bathysnap rigs and the Aberdeen AUDOS rig. They were all tested before use to a depth of 4500m, attached to the CTD frame.

Bathysnap was deployed for 14 days and used 2 pyroreleases; it was then deployed, again using 2 pyros, for recovery sometime in 1991. Bathysnack was deployed for 5 and then 6 days each using one pyro and one retractor.

AUDOS was deployed on ten occasions each of about 30 hours duration, using one pyro and one retractor. It was allowed to return by use of a corrodable link on 4 occasions; the pyros and retractors used on these deployments were reused, but separately with a fresh partner.

Two retractors operated with such force that external and internal components were damaged; operation is ambient pressure assisted. All the retractors that had been stored with the bottom spring assembly attached had to be disassembled and a ridge of plastic removed. This ridge has been proved to delay release by periods from a few minutes to five years and tends to build up over a period of a few weeks when under tension.

GRJP

Acoustic navigation

The IOSDL benthic biology project LRP4 requires the accurate navigation of both its towed and vertically deployed sampling gears relative to a seabed transponder array. The towed samplers (sledge, trawls) present the major technical challenge as they operate at depths of 5000 m and require towing warps of up 12500m length. Launch thus takes place many miles from the sampling site in order that the gear may reach the bottom at the appropriate position.

A potentially successful strategy has been evolved and equipment designed and built. However, problems in two key areas conspired to prevent any useful work being carried out on this cruise:

1. To achieve the long horizontal ranges between towed unit and seabed array we rely on running an inefficient acoustic transducer (which nevertheless has good horizontal directionality) at very high power

levels. A fault in the circuit layout of the sea unit power amplifier disguised the fact that the components were operating beyond their acceptable limits. No satisfactory alternative could be produced with the components available on board.

2. It had been intended to use a low noise amplifier and a low loss beam steering unit originally designed as part of an advanced PES unit. However, in the absence of this system, and with the additional complication of the sea unit noted above, no usable results could be achieved. The beam steering unit that was available only steers fore and aft and loses over half the directional gain as a consequence of its circuitry.

GRJP

Simrad Precision Echosounder

This system is potentially the Research Vessel Fleet's standard deep water echosounder for the next decade. This summer I have sailed both with the system currently fitted to the *Darwin* and with that on the *Discovery* and am helping RVS to evaluate them for general purpose oceanographic work.

As a deep water echosounder they are very good but this is only part of their role. On most cruises the echosounder is required to assist the sampling programme by monitoring active acoustic units attached to the sampling gear. These units vary from simple 'precision pingers', attached to vertically deployed equipment such as corers and CTDs, to the considerably more sophisticated systems used to monitor towed nets and camera systems. All depend on the standard deep sea echosounder for successful operation. Not only are these units a major part of NERC's benthic sampling armoury but they are also widely used internationally in a similar way.

The Simrad is designed to optimise the quality of a wide range of reflected signals in a wide variety of situations. This enables the targetted reflectors to be identified by their individual reflection characteristics in a wide variety of propagation conditions. The system is a thinly disguised, very sophisticated fish finder. All the sophistication is in the software; it is very difficult to override and is easily confused by the presence of active acoustic units.

My overall conclusion is that the system could be made to suit NERC's applications. This requires two criteria to be satisfied.

1. The system must be able to echosound while locked to the active units repetition rate; this is currently only possible in 'external trigger mode' with the disadvantages of unremovable time varied gain, the need for an external trigger source, and the software spending variable amounts of time hunting for something it can interpret as an echo. The totally passive 'pinger mode' installed in the *Darwin*'s unit is not the solution.

2. It must be possible to read both the depth and any active units information accurately and independently of the digitisation; this is currently impossible to do on either ship's systems. The current scale generated on both systems is provided by uniform intensity lines which become unreadable at five metre

spacing and too inaccurate at wider spacing; they are also currently tied to the American standard of 800 fathoms per second and are independent of sound velocity input on both systems. The solution could be the use of colour or density highlighting as with the current PES, or (preferably) the use of an active cursor such as the Poseidon Technology waterfall display. The use of an expansion window is not an adequate solution by itself.

I am still dubious about the printer's ability to run 24 hours a day for 300 days a year as the current hard copy machines do; the unit on *Darwin* ran for 12 days or so without problem but the unit on *Discovery* stopped after about 5 days. It would be sensible to add access to the predigitisation analogue signal, suitably buffered. This would allow any of the current facsimile machines to be used for high resolution hard copy (including the current PES Mk 3 units). It would also allow easy access to underwater signals for those of us in NERC with more unusual requirements.

GRJP

Midwater trawling and lights on nets.

A total of 46 sets of rectangular midwater trawl samples were taken during the cruise. Of these 12 were RMT 1+8M (multinet) samples, deriving from four deployments of this net system with its three pairs of nets. No problems arose with the system and the catches were largely for physiological material. A consistent feature of these and later tows was the abundance of *Pyrosoma* in the water, at depth by day and in the upper 100m or so at night.

Following the multinet sampling, the RMT1 nets were removed and the system rerigged with three RMT8 nets only. A Seacon Viking 12v 55 watt underwater lamp was mounted on the top bar. This was powered by a pressure-balanced 60 amp hour car battery suspended below it. An I.O.S. telemeter provided a means of controlling independently the operation of both the lamp and the net release from the ship by acoustic command. This was used to study the effects of illuminating the net on the catches of actively migrating species of crustaceans, particularly decapod shrimps.

One series was carried out at 250m, but it was decided from previous tows that 200m would be likely to provide larger numbers of decapods for better statistical analysis. One set of three nets was fished on each of six consecutive nights, with the light alternately on and off within each trio. Each net was fished at 200m +/- 25m for a duration of two hours between approximately 2200 and 0400 GMT (respectively some 1.5-2 hours after sunset and before dawn). On two occasions the light failed on the illuminated net of the trio, once resulting from the failure of the battery and once from a connector failure. A total of nine "dark" and seven "light" tows were therefore achieved. Catch volumes of crustaceans with the lights "on" were almost invariably lower than with lights "off", indicating some degree of avoidance. A similar result was obtained with the preliminary trial series at 250m.

An additional facility built into the telemeter enabled the lamp to operate in a flashing mode, at a frequency of approximately 2 Hz. A single series of three nets was fished, again at 200m, using this capability. The catch volume in the light "off" net was significantly greater than in the two adjacent light "on" nets.

The overall results indicate a degree of avoidance of the illuminated net by migrant crustaceans, in qualitative agreement with previous work in the same area by M.R. Clarke and his colleagues.

The RMT 1+8 system was fished as a single pair of nets on nine subsequent occasions, seven of them with the closing cod-end on the RMT8. The closing cod-end has an independent telemeter mounted on it which provides the activation for an IOS autoretractor controlling the valve closure. The system performed well but range limitations restrict its depth of operation to about 1100m. The two signals indicating valve closure rarely appeared but this was a mechanical problem of the magnetic switches, as the codend failed to close only on the one occasion when the cod-end liner trapped the upper ball valve.

PJH, DE

Bioluminescence and reflectance studies

Observations on the bioluminescence and fluorescence spectra of the light-emitting organs of a wide variety of animals were made in conjunction with the midwater trawling programme. The measurements indicated a significant difference in the two spectra in almost all photophores. This suggests that energy transfer to fluorescent proteins, such as is known to occur in some coastal coelenterates, plays little part in determining the bioluminescent emission spectra of most oceanic animals. However, the fluorescence emission spectra of e.g. the postorbital photophores of a variety of stomiatoid fishes were sufficiently similar to suggest that in each case the fluorescence derives from the same luciferin or its oxidation product.

The bioluminescence kinetics of a number of species were recorded directly, with particular examples being the ceratioid *Linophryne* and the stomiatoid *Astronesthes*. Escas from three ceratioids, including that of *Linophryne*, were frozen for subsequent investigation of the identities of their luminous bacteria. Additional samples of luminous tissue were removed from fish, squid and crustaceans for later laboratory analysis of their luminescence chemistry.

Reflectance measurements were made on the individual photophores of several species of fish, particularly myctophids, to determine whether the spectral characteristics of the bioluminescence are significantly modified by the reflector system. All had relatively narrow bandwidth reflectance, typical of multi-layer specular reflection systems, and probably limit the bandwidth of emitted bioluminescence to some degree.

Additional reflectance measurements on the lateral regions of the bodies of a variety of decapod and mysid crustaceans were made with a scanning monochromator and diffusing sphere. In each case the red pigmentation was significantly reflective only at wavelengths greater than 600nm and over the blue-green region from 450-550nm the animals are essentially non-reflective. The presence of brown or purple pigments in certain species (e.g. *Notostomus* and *Eucopia*) merely shifted the maximal reflectance to even longer wavelengths but had no effect on the low reflectance in blue-green light.

PJH

Trace metals in crustaceans

As part of an ongoing study into the significance of concentrations of essential and non-essential metals in crustaceans, it was considered of interest to extend further the available knowledge of metal concentrations in a variety of oceanic crustaceans. The specific objectives therefore were to collect a large number of specimens of several deep sea malacostracan crustaceans, particularly decapods, for the subsequent analysis for heavy metals including copper, zinc and cadmium in order to define geographical variation and individual size effects.

During cruise 194 over 500 specimens were taken at a variety of depths from a series of sites by means of various arrangements of an RMT system of nets, often with a closing cod end. The crustaceans were identified with assistance from P.J. Herring, rinsed in double-distilled water and frozen in individual polythene bags for transport back to the UK (and later analysis).

In all five penaeid decapod and seven carid decapod species were taken, in addition to three mysid species and several euphausiid species. At many sites samples were taken in sufficient numbers for detailed analyses of body size/metal concentration relationships within a single species, separate from any possible effects of geographical variation. This was particularly true of the carid *Acanthephyra purpurea*.

The collection of live *Systellaspis debilis* allowed the ship-board exposure of captured prawns to a range of dissolved copper concentrations (within the range 0.13 to 56.2μg Cu l^{-1}) for up to 8 days. Subsequent copper analysis of the exposed prawns will shed additional light on the mode of regulation of body copper in oceanic crustaceans.

Several deep trawls (with a closing cod end) collected individuals of the gammarid amphipod *Parandania* spp. which were frozen subsequently for metal analysis. This is part of a study of iron-rich crystals in the gut caeca of stegocephalid amphipods with P.G. Moore (Millport) and P.S. Rainbow (QMC, Univ. of London).

The opportunity was taken throughout the cruise to collect specimens of both hyperiid and gammarid amphipods for ultrastructural comparative studies of the relationship between their mouthparts (hence mode of feeding) and their ventral and posterior caeca. I am grateful to M.H. Thurston for much needed assistance with the identification of many of the hyperiid amphipods.

JMW

Cephalopod enzyme analysis

Cephalopods were collected on cruise 194 in order to compare the electrophoretic patterns of mantle enzymes with those previously investigated in coastal species. A total of sixty-seven individual cephalopods, representing nine of the twenty four known families of oceanic (oegopsid) squid, two families of octopod and one species of cuttlefish, were caught during the course of the cruise (Table 6).

All animals were caught in configurations of the RMT8 nets, with the exception of five larger mastigoteuthids (one species) which were caught on two separate occasions in the otter trawl and in the benthic sled.

Upon recovery animals were identified as completely as possible and a sample of mantle tissue removed. The mantle tissue was then immediately frozen to -70°C in order to preserve the enzyme activity.

The samples collected on this cruise have greatly increased the diversity of cephalopod material available for genetic analysis and have provided an invaluable opportunity to study animals in superb, and even live, condition.

AB

Ornithological observations

A total of 224 routine ten-minute bird observations were made during the cruise, as and when other duties permitted. This represents a mean of 8.1 day^{-1} (range 5-13). In addition, casual sightings were listed. In all 11 species were identified positively, but with the exceptions noted below, most were single sightings only.

The cruise fell naturally into four parts; the passage out to the general area of operations south and west of Madeira, a period of 5 days spent between 28°N and 33°N attempting to locate a suitable work site, 17 days at and around the main station position at 31°05'N 21°10'W and the passage to Tenerife.

Observations commenced on 5 August west of Ushant. Few birds were seen on the outward passage, and such as were, occurred at the Biscayan shelf break and close to the Galicia Bank where a number of Cory's shearwaters (*Calonectris diomedea*) were recorded, and NW of Madeira.

The period 10-14 August produced very few birds. Only 9 observations out of 48 were positive (19%) and no observations produced more than a single individual. Six of the sightings were Bulwer's petrels (*Bulweria bulwerii*).

The main station was occupied from 15 to 31 August. Birds were very sparse initially; none was seen during the first 29 observation periods, and only 2 in 68 (3%) up to and including 24 August. Thereafter, 34 of 59 (68%) of observations were positive. This resulted largely from the passage south of Greater shearwaters (*Puffinus gravis*). All birds seen were flying on courses of 150°-190° ie 90°-140° off the near constant NE-ENE winds. The maximum number of birds seen during a single observation was 23 on the evening of 30 August.

This corresponds to 60 birds crossing a 1km baseline at right angles to the flight path every hour. During the same period several small parties of terns, presumably Arctic terns (*Sterna paradisaea*) were seen heading south.

Nothing of note was seen on passage to Tenerife.

MHT

SUMMARY AND CONCLUSIONS

The cruise duration of 29 days proved adequate for the bulk of the sampling programme initially proposed as well as the necessary passage time (Table 7). The vessel covered 2352nm on passage and a total of 464 hours on station. Only 4.4hr of station time were lost through shipboard gear failures, and no time was lost to bad weather. The search for an appropriate sampling site, and the decision that the core samples were of highest priority, meant that the intended near-bottom RMT tows could not be fitted into the programme.

The extensive turbidite cover over the whole area studied makes comparisons with the northern site less easy to interpret. Although this comparison was the primary objective, the study of this turbidite-affected area will in itself be of great interest as no similar area has been examined from this point of view or with the equivalent geological background information now available for this site.

The sampling programme demonstrated the practicability of meshing together the requirements of different, but complementary, prime objectives. The catches of both the benthic and midwater sampling programmes reflected the paucity of this oceanic gyral area, in marked contrast to the northerly station, but similar to that experienced in the Great Meteor East region in 1985. The experimental and subsampling activities highlighted the essential need on biological cruises for controlled environment facilities and adequate cold storage.

PJH

ACKNOWLEDGEMENTS

The successful outcome of this cruise owes much to the help and encouragement of the Master and ship's company throughout. It is a pleasure to acknowledge their skilled and willing assistance at all times. The effective achievement of a gruelling sampling programme also reflects credit on the technical support from RVS, both on board and prior to the cruise, in the maintenance of the ship's equipment.

Table 1. Station 12174 spade box cores

Series no.	Maximum penetration (cm)	Bottom of recent turbidite (cm)	Top of dark layer (cm)	Full sieving protocol observed	Subcores taken Meio-fauna	Granul-ometry
9	45	c.35		+		+
11	35	c.25	c.32	+	+	+
16	49	37		+		+
25	37	?	c.32			
35	33	27		+	+	+
37	30	?	26			+
43	41.5	22	38	+	+	+
53	45.5	27		+	+	+
60	32	13		+	+	+
69	50	?19				
74	42	?17	39			
80	45	27		+	+	+
83	51.5	43		+	+	+
89	44.5	30		+	+	+

Table 2. Multiple corer deployments

Deployment	Station/Series	Depth (m)	Usable cores retained	Length (mm)	Remarks
1	12166#1	4825	6	130-155	
2	12167#1	4846	8	140-160	
3	12168#5	4845	10	340-360	
4	12169#1	4848	6	110-140	
5	12171#2	4860	4	100-130	
6	12172#1	4705	4	85-110	
7	12173#1	4618	4	30-80	No turbidite
8	12174#6	4958	12	160-200	Microbial degradation experiment
9	12174#7	4953	10	140-180	Microbial degradation experiment
10	12174#10	4942	7	300-400	
11	12175#15	4936	12	190-200	Set of new core catchers fitted
12	12174#24	4950	11	180-190	
13	12174#26	4947	12	290-320	
14	12174#36	4932	12	100-120	
15	12174#52	4942	12	300-340	
16	12174#65	4942	12	150-170	Complete set of core tops taken
17	12174#79	4947	12	140-155	Complete set of core tops taken
18	12174#86	4937	12	100-130	Complete set of syringe subsamples taken
19	12174#88	4942	12	340-395	
20	12174#93	4946	12	250-265	
21	12174#94	4947	11	120-135	

Table 3. Fate of multiple corer samples at Stn 12174

Series	Formalin			Alcohol		Syringe Subsamples			
	0-15cm[1]	0-5cm[2]	0-1cm	0-5cm[2]	0-15cm[3]	Forams	Nematodes	Frozen	Chilled
10	-	1	1	1	-	-	1	-	-
15	1	1	-	1	1	2	1	2	1
24	1	1	-	1	1	2	1	2	1
26	1	1	-	1	1	2	1	3	1
36	1	2	-	-	1	2	1	4	1
52	1	2	-	-	1	2	1	4	1
65	1	2	8	-	1	-	-	-	-
79	1	2	8	-	1	-	-	-	-
86	-	-	-	-	-	-	12	-	-
88	1	2	-	1	1	2	1	2	1
93	1	2	-	1	1	2	1	2	1
94	1	2	-	1	1	2	1	2	1

[1] sliced into 1cm layers down to 15cm

[2] sliced into 1cm layers down to 5cm

[3] sliced into 1cm layers down to 5cm, then 5-10cm, 10-15cm

Table 4. List of echinoderm samples collected

	n	Gut	Tentacles SEM	Tentacles TEM	Body Wall	Crib. org	Muscle	Body Wall
		Fixed					Frozen	
Holothurians								
Pseudostichopus sp.	1	+	+	+	+	-	+	+
Psychropotes semperiana	3	+	+	+	+	-	+	+
Molpadia blakei	2	+	+	+	+	-	+	+
Enypniastes sp.	1	-	+	+	-	-	-	-
Asteroids								
Hyphalaster inermis	5	+	-	-	+	+	-	-
Styracaster sp.	2	-	-	-	+	+	-	-

Table 5. Details of baited (Bathysnack) and unbaited Bathysnap pop-up camera systems deployed on *Discovery* cruise 194

Gear	Station No.	Latitude (°N)	Longitude (°W)	Depth (m)	Payload	Interval (mins)	On bottom (Day no-GMT)	Released (Day no-GMT)
BSNAP	12174#8	31°05.50'	21°12.69'	4950	transp.	18	228-1102	242-1349
BSNAP	12175#1	31°05.01'	21°10.09'	4944	RCM	288	242-2011	To be recovered
BSNACK	12174#20	31°07.63'	21°09.01'	4941	RCM	4.5	230-2113	235-1247
BSNACK	12174#64	31°03.82'	21°13.18'	4943	transp.	9	236-2048	242-1304

Table 6. Classification of cephalopod material frozen for electrophoretic study

<u>ORDER TEUTHOIDEA (SQUID)</u>

Sub-Order Oegopsida (Oceanic squid)

Family	Species	No.
CYCLOTEUTHIDAE	*Discoteuthis*	1
ENOPLOTEUTHIDAE	*Pterygioteuthis*	1
	Pyroteuthis	11
CRANCHIIDAE	*Bathothauma lyromma*	5
	Helicocranchia	1
HISTIOTEUTHIDAE	*Histioteuthis*	14
CTENOPTERYGIDAE	*Ctenopteryx sicula*	1
MASTIGOTEUTHIDAE	*Mastigoteuthis*	14
OMMASTREPHIDAE	*Todarodes sagittatus*	2
CHIROTEUTHIDAE	*Chiroteuthis*	1
NEOTEUTHIDAE	*Neoteuthis*	1

<u>ORDER OCTOPODA (OCTOPUS)</u>

Sub-Order Incirrata (Typical Octopuses)

BOLITAENIDAE	*Japatella diaphana*	8
	Bolitaena microcotyla	1
ARGONAUTIDAE	*Argonauta hians*	3

<u>ORDER SEPIOIDEA (CUTTLE FISH)</u>

Sub-Order Spirulina

SPIRULIDAE	*Spirula spirula*	2

Table 7. Summary sampling programme on Cruise 194

AUDOS deployments	10
Bathysnap	2
Bathysnack	2
Multiple corer	21
Spade box corer	14
Epibenthic sledge	6
Otter trawl	3
RMT1+8	14
RMT8L	25
RMT1+8 with closing cod-end	7
Neuston nets	8
CTD dips	11
Total stations	123

Gear codes used in station list

CTD	Conductivity, temperature, depth probe
LMD	Photodiode light meter
MS	Rosette multisampler
MLT.CORER	Multiple corer
BOX COR	Spade box corer
AUDOS	Aberdeen University Deep Ocean Submersible mooring
BSNAP	Bathysnap camera mooring
BSNACK	Bathysnack baited camera mooring
BN1.5/C	Epibenthic sledge with camera
BN1.5/P	Photosledge
OTSB14	Semi-balloon otter trawl
NN	Neuston net
RMT1	1m^2 rectangular midwater trawl
RMT8	8m^2 rectangular midwater trawl
RMT1M	Multiple 1m^2 rectangular midwater trawl
RMT8M	Multiple 8m^2 rectangular midwater trawl
RMT8ML	Multiple 8m^2 rectangular midwater trawl with lights
RMT8MLF	Multiple 8m^2 rectangular midwater trawl with flashing lights
CCE	Closing cod end

STN.	DATE 1990	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12164	7/ 8	39 57.3N	14 35.8W	MS	0-4913	1815-2136	3 bottles at 200m	
# 1		39 57.2N	14 33.7W	CTD		Day		
12165	9/ 8	34 33.2N	18 41.2W	MS	0- 50	0840-0847	Bottles at 50, 30 and 10m	
# 1		34 33.1N	18 41.2W	CTD		Day		
12165	9/ 8	34 33.6N	18 41.2W	MS	0-4851	0856-1324	No bottles; acoustic gear trials	
# 2		34 31.1N	18 40.3W	CTD		Day		
12166	10/ 8	32 0.7N	20 32.8W	MLT.CORER	4825-4825	1158-1200	6 successful cores only	4825
# 1		32 0.8N	20 32.8W			Day		
12167	11/ 8	29 30.3N	21 15.7W	MLT.CORER	4846-4846	0646-0648	12 short cores, 10 good	4846
# 1		29 30.3N	21 15.7W			Dawn		
12168	11/ 8	28 42.3N	21 36.3W	AUDOS	4856-4856	1653-1728	Descent 0.79m/s, ascent 0.87m/s	4856
# 1	12/ 8	28 42.5N	21 36.2W					
12168	11/ 8	28 43.7N	21 36.9W	RMT1M/1	425- 510	1704-1800	Gash haul	
# 2		28 45.3N	21 36.9W	RMT8M/1		Day	Flow Dist. 2.563 km.	
12168	11/ 8	28 45.3N	21 36.9W	RMT1M/2	492- 595	1800-1900	Gash haul	
# 3		28 46.9N	21 37.9W	RMT8M/2		Day	Flow Dist. 3.100 km.	
12168	11/ 8	28 46.9N	21 37.9W	RMT1M/3	595- 695	1900-2000	Gash haul	
# 4		28 48.7N	21 37.2W	RMT8M/3		Dusk	Flow Dist. 2.920 km.	
12168	11/ 8	28 49.4N	21 35.2W	MLT.CORER	4845-4845	2246-2249	11 long cores	4845
# 5		28 49.4N	21 35.2W			Night		
12168	12/ 8	28 49.6N	21 35.7W	MS	0-3890	0056-0321	No bottles; acoustic gear trials	
# 6		28 49.6N	21 36.9W	CTD		Night		

STN.	DATE 1990	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12169	12/ 8	29 12.6N	21 25.5W	MLT.CORER	4848-4848	0826-0828	8 short cores	4848
# 1		29 12.6N	21 25.5W			Day		
12170	12/ 8	29 2.9N	21 28.4W	RMT1M/1	800- 920	1219-1320	Gash haul	
# 1		29 0.8N	21 29.3W	RMT8M/1		Day	Flow Dist. 3.999 km.	
12170	12/ 8	29 0.8N	21 29.3W	RMT1M/2	705- 800	1320-1419	Gash haul	
# 2		28 58.8N	21 30.2W	RMT8M/2		Day	Flow Dist. 3.910 km.	
12170	12/ 8	28 58.8N	21 30.2W	RMT1M/3	610- 705	1419-1519	Gash haul	
# 3		28 56.7N	21 31.2W	RMT8M/3		Day	Flow Dist. 4.000 km.	
12171	14/ 8	32 39.8N	20 30.6W	AUDOS	4917-4917	0030-0001	Descent 0.83m/s, ascent 0.84m/s	4917
# 1	15/ 8	32 40.6N	20 31.6W					
12171	14/ 8	32 39.7N	20 28.2W	MLT.CORER	4860-4860	0138-0140	6 short cores	4860
# 2		32 39.7N	20 28.2W			Night		
12171	14/ 8	32 40.9N	20 27.9W	RMT1M/1	310- 400	0352-0454	Gash haul, RMT1 & 8 liners reversed	
# 3		32 43.7N	20 26.4W	RMT8M/1		Night	Flow Dist. 3.998 km.	
12171	14/ 8	32 43.7N	20 26.4W	RMT1M/2	400- 500	0454-0553	Gash haul, RMT1 & 8 liners reversed	
# 4		32 45.3N	20 24.8W	RMT8M/2		Night	Flow Dist. 4.270 km.	
12171	14/ 8	32 45.3N	20 24.8W	RMT1M/3	480- 585	0553-0653	Gash haul, RMT 1 & 8 liners reversed	
# 5		32 47.4N	20 23.2W	RMT8M/3		Dawn	Flow Dist. 4.315 km.	
12172	14/ 8	32 31.7N	20 23.3W	MLT.CORER	4705-4705	1331-1334	4 short cores only	4705
# 1		32 31.8N	20 23.3W			Day		
12172	14/ 8	32 32.2N	20 23.2W	MS	0-4422	1538-1829	Bottles at 200, 120, 40, 28 and 10m	
# 2		32 33.5N	20 21.2W	CTD		Day		

STN.	DATE 1990	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12173	14/ 8	32 37.2N	20 16.9W	MLT.CORER	4618-4618	2109-2110	4 very short cores only	4618
# 1		32 37.3N	20 16.9W			Night		
12174	15/ 8	31 16.3N	21 7.9W	MS	0-4718	1708-1948	Bottles at 90, 45 and 10m	
# 1		31 16.7N	21 7.0W	CTD		Day		
12174	15/ 8	31 15.9N	21 6.4W	AUDOS	4922-4922	2213-0500	Descent 0.84m/s, ascent 0.79m/s	4922
# 2	17/ 8	31 15.8N	21 6.5W					
12174	15/ 8	31 10.4N	21 9.0W	RMT1M/1	245- 295	2157-2258	RMT1 codends badly twisted, no catch	
# 3		31 7.9N	21 9.2W	RMT8M/1		Night	Flow Dist. 3.909 km.	
12174	15/ 8	31 7.9N	21 9.2W	RMT1M/2	295- 355	2258-2356	RMT1 codends badly twisted, no catch	
# 4		31 5.6N	21 9.9W	RMT8M/2		Night	Flow Dist. 4.136 km.	
12174	15/ 8	31 5.6N	21 9.9W	RMT1M/3	205- 250	2356-0056	RMT1 codends badly twisted, no catch	
# 5	16/ 8	31 3.0N	21 10.8W	RMT8M/3		Night	Flow Dist. 4.810 km.	
12174	16/ 8	31 4.6N	21 10.3W	MLT.CORER	4958-4958	0327-0330	12 cores	4958
# 6		31 4.6N	21 10.3W			Night		
12174	16/ 8	31 5.7N	21 11.4W	MLT.CORER	4953-4953	0654-0657	9 cores	4953
# 7		31 5.8N	21 11.4W			Dawn		
12174	16/ 8	31 5.5N	21 12.7W	BSNAP	4950-4950	1102-1349	Descent 0.84m/s, ascent 1.02m/s	4950
# 8	30/ 8	31 5.2N	21 13.1W					
12174	16/ 8	31 7.2N	21 14.3W	BOX CORER	4958-4958	1333-1336	Good core	4958
# 9		31 7.2N	21 15.0W			Day		
12174	16/ 8	31 6.7N	21 12.7W	MLT.CORER	4942-4942	1724-1727	7 poor cores	4942
#10		31 6.7N	21 12.7W			Day		

STN.	DATE 1990	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12174	16/ 8	31 4.4N	21 10.3W	BOX CORER	4936-4936	2139-2142	40cm core disturbed along one side	4936
#11		31 4.3N	21 10.3W			Night		
12174	17/ 8	31 4.8N	21 9.6W	RMT8ML/1	223- 278	0033-0134	Trial haul, light on	
#12		31 6.5N	21 8.3W			Night	Flow Dist. 3.819 km.	
12174	17/ 8	31 6.5N	21 8.3W	RMT8ML/2	220- 265	0134-0233	Trial haul, light off	
#13		31 8.2N	21 6.3W			Night	Flow Dist. 4.090 km.	
12174	17/ 8	31 8.2N	21 6.3W	RMT8ML/3	240- 275	0233-0334	Trial haul, light on	
#14		31 10.6N	21 4.6W			Night	Flow Dist. 4.089 km.	
12174	17/ 8	31 5.6N	21 10.2W	MLT.CORER	4938-4938	1105-1108	12 excellent cores	4938
#15		31 5.6N	21 10.2W			Day		
12174	17/ 8	31 4.9N	21 9.4W	BOX CORER	4947-4947	1428-1429	Good core	4947
#16		31 4.9N	21 9.4W			Day		
12174	17/ 8	31 13.3N	21 5.7W	AUDOS	4912-4912	2155-0534	Descent 0.83m/s, ascent 0.77m/s	4912
#17	19/ 8	31 13.3N	21 5.7W					
12174	17/ 8	31 13.9N	21 4.8W	RMT8ML/1	129- 172	2127-2226	Lights not used, gash haul	
#18		31 11.7N	21 5.7W			Night	Flow Dist. 4.731 km.	
12174	18/ 8	31 4.4N	21 19.2W	OTSB14	4942-4958	0800-1150	Pinger failed, times and depths est.	
#19		31 14.5N	21 10.9W			Day		
12174	18/ 8	31 7.6N	21 10.0W	BSNACK	4941-4941	2113-1247	Descent 0.88m/s, ascent 0.96m/s	4941
#20	23/ 8	31 7.8N	21 8.4W					
12174	18/ 8	31 5.6N	21 9.3W	RMT8ML/1	175- 225	2204-0004	Light off	
#21	19/ 8	31 9.4N	21 6.3W			Night	Flow Dist. 8.000 km.	

STN.	DATE 1990	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12174	19/ 8	31 9.4N	21 6.3W	RMT8ML/2	185- 205	0004-0205	Light on	
#22		31 13.2N	21 3.9W			Night	Flow Dist. 8.359 km.	
12174	19/ 8	31 13.2N	21 3.9W	RMT8ML/3	175- 225	0205-0405	Light off	
#23		31 17.1N	21 0.2W			Night	Flow Dist. 8.585 km.	
12174	19/ 8	31 5.4N	21 9.9W	MLT.CORER	4950-4950	1147-1149	12 cores, 2 slightly disturbed	4950
#24		31 5.4N	21 9.9W			Day		
12174	19/ 8	31 4.3N	21 9.6W	BOX CORER	4938-4938	1454-1456	Core disturbed, sample discarded	4938
#25		31 4.3N	21 9.6W			Day		
12174	19/ 8	31 4.7N	21 9.2W	MLT.CORER	4947-4947	1808-1811	12 good cores	4947
#26		31 4.7N	21 9.2W			Day		
12174	19/ 8	31 3.2N	21 11.4W	AUDOS	4942-4942	2235-	Descent 0.85m/s, premature pop-up	4942
#27								
12174	19/ 8	31 5.9N	21 9.9W	RMT8ML/1	185- 230	2214-0014	Light on	
#28	20/ 8	31 9.9N	21 6.8W			Night	Flow Dist. 8.675 km.	
12174	20/ 8	31 9.9N	21 6.8W	RMT8ML/2	195- 205	0014-0214	Light off	
#29		31 13.6N	21 3.4W			Night	Flow Dist. 8.495 km.	
12174	20/ 8	31 13.6N	21 3.4W	RMT8ML/3	175- 225	0214-0411	Light on	
#30		31 17.3N	21 0.1W			Night	Flow Dist. 8.632 km.	
12174	20/ 8	31 14.9N	21 7.5W	OTSB14	4914-4938	1149-1450	Part of catch lost during recovery	
#31		31 9.3N	21 14.5W			Day		
12174	20/ 8	31 5.2N	21 10.2W	RMT8ML/1	175- 220	2207-0007	Light off	
#32	21/ 8	31 8.8N	21 6.4W			Night	Flow Dist. 8.585 km.	

STN.	DATE 1990	POSITION LAT.	POSITION LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12174	21/ 8	31 8.8N	21 6.4W	RMT8ML/2	180- 220	0007-0207	Light on	
#33		31 12.2N	21 2.8W			Night	Flow Dist. 8.315 km.	
12174	21/ 8	31 12.2N	21 2.8W	RMT8ML/3	175- 225	0207-0407	Light off	
#34		31 15.4N	20 59.4W			Night	Flow Dist. 7.910 km.	
12174	21/ 8	31 5.7N	21 10.2W	BOX CORER	4942-4942	0925-0927	Acceptable core	4942
#35		31 5.7N	21 10.2W			Day		
12174	21/ 8	31 6.8N	21 10.3W	MLT.CORER	4932-4932	1237-1239	12 short cores	4932
#36		31 6.8N	21 10.3W			Day		
12174	21/ 8	31 7.5N	21 10.8W	BOX CORER	4943-4943	1545-1546	Bottomed twice, badly damaged core	4943
#37		31 7.5N	21 10.8W			Day		
12174	21/ 8	31 7.5N	21 10.8W	MS	0- 10	1540-1545	4 bottles at 10m	
#38		31 7.5N	21 10.8W	CTD		Day		
12174	21/ 8	31 3.3N	21 14.9W	AUDOS	4947-4947	2027-0400	Descent 0.83m/s, release c.04:00 23/7	4947
#39	23/ 8							
12174	21/ 8	31 4.5N	21 10.7W	RMT8ML/1	180- 225	2210-0010	Light failed, catch discarded	
#40	22/ 8	31 8.4N	21 8.5W			Night	Flow Dist. 7.370 km.	
12174	22/ 8	31 8.4N	21 8.5W	RMT8ML/2	175- 220	0010-0210	Light assumed off	
#41		31 12.5N	21 6.5W			Night	Flow Dist. 7.865 km.	
12174	22/ 8	31 12.5N	21 6.5W	RMT8ML/3	175- 220	0210-0410	Light assumed off	
#42		31 16.3N	21 3.5W			Night	Flow Dist. 7.730 km.	
12174	22/ 8	31 5.3N	21 10.9W	BOX CORER	4947-4947	0746-0747	Reasonable core	4947
#43		31 5.3N	21 11.0W			Dawn		

STN.	DATE 1990	POSITION LAT.	POSITION LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12174	22/ 8	31 7.6N	21 14.4W	BN1.5/5C	4961-4961	1539-1634	No odometer	4961
#44		31 8.8N	21 13.6W			Day		
12174	22/ 8	31 5.0N	21 16.5W	NN	0- 0	1400-1430		
#45		31 6.5N	21 15.6W			Day		
12174	22/ 8	31 6.2N	21 15.5W	NN	0- 0	1434-1504		
#46		31 7.1N	21 14.7W			Day		
12174	22/ 8	31 4.7N	21 12.0W	NN	0- 0	2256-2326		
#47		31 5.1N	21 10.6W			Night		
12174	22/ 8	31 5.2N	21 10.5W	NN	0- 0	2329-2359		
#48		31 6.3N	21 10.0W			Night		
12174	22/ 8	31 4.8N	21 10.8W	RMT8ML/1	180- 220	2315-0115	Light on	
#49	23/ 8	31 8.9N	21 8.6W			Night	Flow Dist. 7.730 km.	
12174	23/ 8	31 8.9N	21 8.6W	RMT8ML/2	180- 220	0115-0315	Light off	
#50		31 13.2N	21 6.4W			Night	Flow Dist. 7.640 km.	
12174	23/ 8	31 13.2N	21 6.4W	RMT8ML/3	175- 220	0315-0445	Light on	
#51		31 16.3N	21 4.9W			Night	Flow Dist. 6.360 km.	
12174	23/ 8	31 5.4N	21 10.2W	MLT.CORER	4942-4942	1054-1056	12 long cores	4942
#52		31 5.4N	21 10.2W			Day		
12174	23/ 8	31 5.2N	21 10.2W	BOX CORER	4945-4945	1703-1705	Excellent core	4945
#53		31 5.2N	21 10.3W			Day		
12174	23/ 8	31 11.9N	21 10.2W	AUDOS	4907-4907	2151-	Descent 0.90m/s, release c.04:30 23/7	4907
#54								

STN.	DATE 1990	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12174	23/ 8	31 5.5N	21 9.2W	RMT8ML/1	180- 225	2205-0005	Light on	
#55	24/ 8	31 9.2N	21 6.6W			Night	Flow Dist. 7.370 km.	
12174	24/ 8	31 9.2N	21 6.6W	RMT8ML/2	185- 220	0005-0205	Light off	
#56		31 12.7N	21 2.5W			Night	Flow Dist. 7.730 km.	
12174	24/ 8	31 12.7N	21 2.5W	RMT8ML/3	175- 205	0205-0405	Light on	
#57		31 16.5N	20 58.8W			Night	Flow Dist. 8.405 km.	
12174	23/ 8	31 7.0N	21 7.8W	NN	0- 0	2259-2329		
#58		31 7.9N	21 7.0W			Night		
12174	23/ 8	31 8.2N	21 6.7W	NN	0- 0	2340-0010		
#59	24/ 8	31 9.2N	21 5.9W			Night		
12174	24/ 8	31 5.6N	21 10.0W	BOX CORER	4947-4947	0807-0809	Good core	4947
#60		31 5.6N	21 10.0W			Day		
12174	24/ 8	31 6.0N	21 10.0W	MS	0- 240	1036-1051	4 bottles at 10m	
#61		31 6.0N	21 10.0W	CTD		Day		
				LMD				
12174	24/ 8	31 2.8N	21 19.9W	BN1.5/5C	0- 0	1334-1624	Net turned over, haul aborted	
#62		31 8.3N	21 13.0W			Day		
12174	24/ 8	31 6.7N	21 14.8W	NN	0- 0	1529-1559		
#63		31 7.6N	21 13.8W			Day		
12174	24/ 8	31 3.8N	21 13.2W	BSNACK	4943-4943	2048-1559	Descent 0.93m/s, ascent 1.02m/s	4943
#64		31 7.6N	21 13.8W					
12174	24/ 8	31 4.3N	21 10.4W	MLT.CORER	4942-4942	2146-2149	12 shortish cores	4942
#65		31 4.3N	21 10.4W			Night		

STN.	DATE 1990	POSITION LAT.	POSITION LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12174	24/ 8	31 4.5N	21 11.0W	RMT8MLF/1	175- 225	2340-0110	Light on	
#66	25/ 8	31 6.5N	21 7.0W			Night	Flow Dist. 4.605 km.	
12174	25/ 8	31 6.5N	21 7.0W	RMT8MLF/2	180- 225	0110-0240	Light off	
#67		31 8.5N	21 3.8W			Night	Flow Dist. 5.325 km.	
12174	25/ 8	31 8.5N	21 3.8W	RMT8MLF/3	180- 225	0240-0410	Light on	
#68		31 10.7N	21 0.4W			Night	Flow Dist. 6.045 km.	
12174	25/ 8	31 4.9N	21 10.6W	BOX CORER	4947-4947	1022-1023	Core badly disturbed	4947
#69		31 4.9N	21 10.6W			Day		
12174	25/ 8	31 6.4N	21 16.6W	BN1.5/5C	4953-4958	1752-1923	Odometer distance run 1774m	
#70		31 8.7N	21 14.9W			Day		
12174	26/ 8	31 15.3N	21 10.8W	AUDOS	4927-4927	0101-0850	Descent 0.87m/s, ascent 0.75m/s	4927
#71	27/ 8	31 15.8N	21 11.0W					
12174	25/ 8	31 15.2N	21 10.9W	MS	0- 200	2346-0016	All bottles at 200m	
#72	26/ 8	31 15.3N	21 11.0W	CTD		Night		
12174	26/ 8	31 17.8N	21 9.4W	CCE	660- 800	0147-0247		
#73		31 19.7N	21 8.1W	RMT1		Night	Flow Dist. 3.370 km.	
				RMT8				
12174	26/ 8	31 5.4N	21 10.5W	BOX CORER	4950-4950	0718-0720	Core oblique and badly compressed	4950
#74		31 5.4N	21 10.5W			Day		
12174	26/ 8	31 8.4N	21 9.6W	CCE	905-1000	1036-1150	CCE closing problem	
#75		31 10.8N	21 8.3W	RMT1		Day	Flow Dist. 3.853 km.	
				RMT8				
12174	26/ 8	31 9.9N	21 8.8W	NN	0- 0	1123-1153		
#76		31 11.0N	21 8.2W			Day		

STN.	DATE 1990	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12174	26/ 8	31 4.4N	21 20.5W	OTSB14	4945-4962	2014-0044	Traces lost, fished blind	
#77	27/ 8	31 15.2N	21 16.9W			Night		
12174	27/ 8	31 13.7N	21 9.5W	CCE	1025-1180	1358-1438	CCE failed to close	
#78		31 12.0N	21 9.5W	RMT1		Day	Flow Dist. 2.576 km.	
				RMT8				
12174	27/ 8	31 4.9N	21 10.6W	MLT.CORER	4947-4947	1817-1819	12 good, but short cores	4947
#79		31 4.9N	21 10.6W			Day		
12174	27/ 8	31 5.2N	21 10.2W	BOX CORER	4942-4942	2223-2226	Good core	4942
#80		31 5.2N	21 10.2W			Night		
12174	28/ 8	31 7.4N	21 9.4W	AUDOS	4947-4947	0249-0549	Descent 0.87m/s, ascent 0.74m/s	4947
#81	29/ 8	31 6.6N	21 9.6W					
12174	28/ 8	31 9.2N	21 7.3W	CCE	1070-1210	0233-0333		
#82		31 11.0N	21 5.2W	RMT1		Night	Flow Dist. 3.280 km.	
				RMT8				
12174	28/ 8	31 5.5N	21 10.4W	BOX CORER	4941-4941	0854-0855	Good core	4941
#83		31 5.5N	21 10.4W			Day		
12174	28/ 8	31 5.5N	21 10.4W	MS	0- 10	0828-0837	Bottles at 10m	
#84		31 5.5N	21 10.4W	CTD		Night		
12174	28/ 8	30 58.8N	21 20.1W	BN1.5/P	0- 0	1214-	Turned over four times, haul aborted	
#85						Day		
12174	28/ 8	31 5.5N	21 9.0W	MLT.CORER	4937-4937	1728-1731	12 short cores	4937
#86		31 5.5N	21 8.9W			Day		
12174	28/ 8	31 8.1N	21 7.5W	CCE	1085-1205	2138-2300		
#87		31 10.7N	21 6.3W	RMT1		Night	Flow Dist. 3.891 km.	
				RMT8				

STN.	DATE 1990	POSITION LAT.	POSITION LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12174	29/ 8	31 5.5N	21 10.2W	MLT.CORER	4942-4942	0338-0341	12 cores	4942
#88		31 5.5N	21 10.2W			Night		
12174	29/ 8	31 5.3N	21 10.4W	BOX CORER	4947-4947	1046-1047	Good core	4947
#89		31 5.3N	21 10.4W			Day		
12174	29/ 8	31 2.5N	21 13.7W	BN1.5/5C	4942-4945	1921-2044	c1.2m3 of mud, some lost	
#90		31 5.0N	21 11.4W			Dusk		
12174	30/ 8	31 9.2N	21 8.0W	AUDOS	4942-4942	0406-	Descent 0.83m/s, premature pop-up	4942
#91								
12174	30/ 8	31 12.3N	21 5.7W	CCE	860-1110	0502-0602		
#92		31 15.0N	21 3.5W	RMT1		Night	Flow Dist. 4.180 km.	
				RMT8				
12174	30/ 8	31 5.2N	21 10.2W	MLT.CORER	4946-4946	1046-1049	12 cores	4946
#93		31 5.2N	21 10.2W			Day		
12174	30/ 8	31 5.1N	21 10.3W	MLT.CORER	4947-4947	1814-1817	12 short cores	4947
#94		31 5.1N	21 10.4W			Day		
12174	30/ 8	31 6.5N	21 9.5W	CCE	800-1010	2048-2200		
#95		31 8.2N	21 7.2W	RMT1		Night	Flow Dist. 4.080 km.	
				RMT8				
12174	31/ 8	30 55.9N	21 23.7W	BN1.5/5C	0- 0	0118-	Turned over four times, haul aborted	
#96						Night		
12174	31/ 8	31 0.5N	21 16.8W	RMT1	1775-2000	0436-0606	Gash haul	
#97		31 2.6N	21 13.7W	RMT8		Night	Flow Dist. 5.190 km.	
12174	31/ 8	31 9.7N	21 8.4W	MS	0- 200	0918-0932	4 bottles at 200m, 4 at 10m	
#98		31 9.8N	21 8.3W	CTD		Day		
				LMD				

STN.	DATE 1990	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
12174	31/ 8	31 13.0N	21 4.3W	RMT1	1900-2300	1125-1327	Gash haul, RMT1 bucket torn off	
#99		31 14.9N	20 59.9W	RMT8		Day	Flow Dist. 8.740 km.	
12175	31/ 8	31 6.0N	21 10.9W	BSNAP	4944-4944	2011-	Long-term, recovery planned for 1991	4944
# 1								

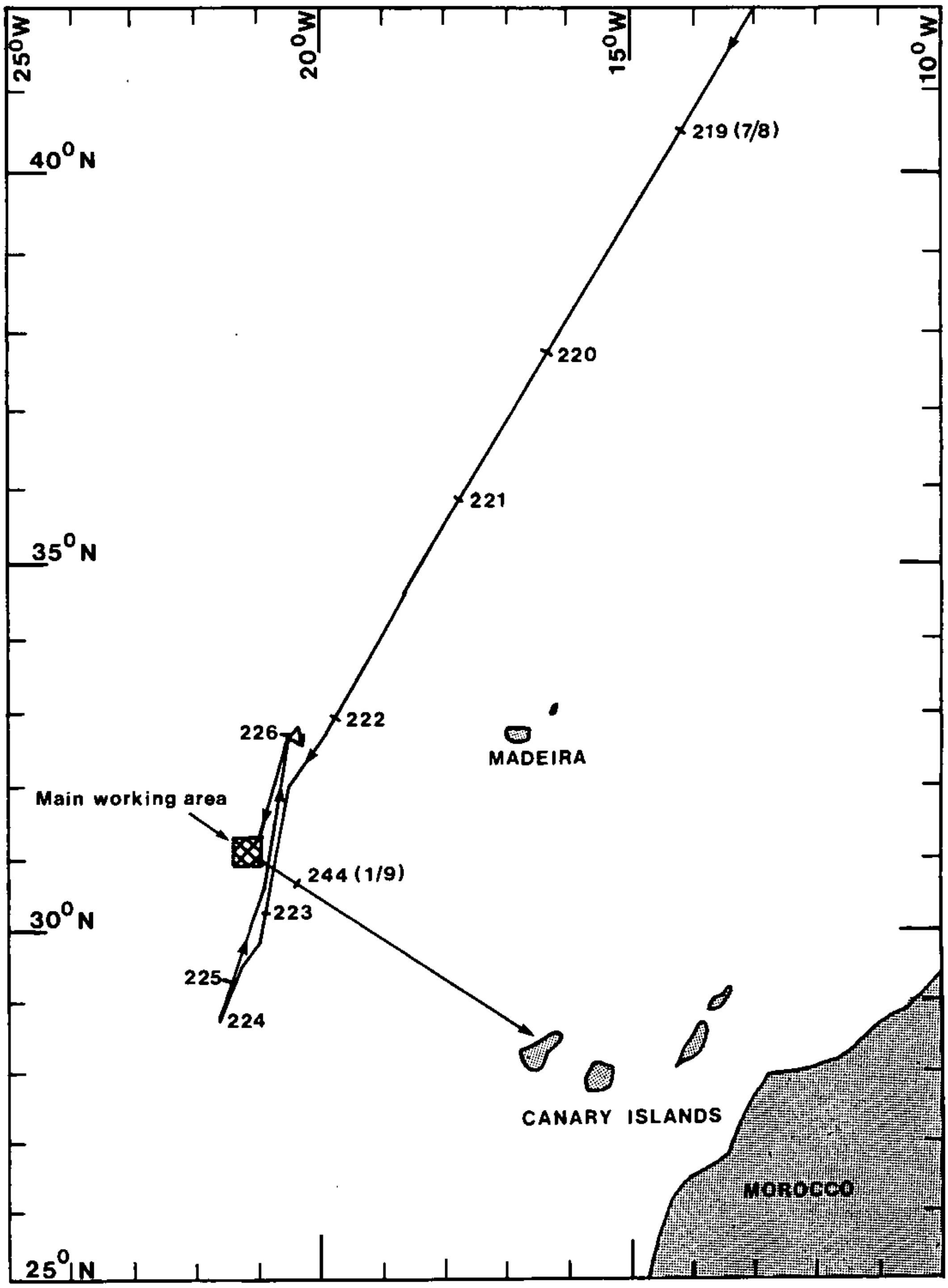

Figure 1. Track chart of *Discovery* cruise 194. The box marks the main working area. The position at the start of each day is indicated by the Julian day numbers.

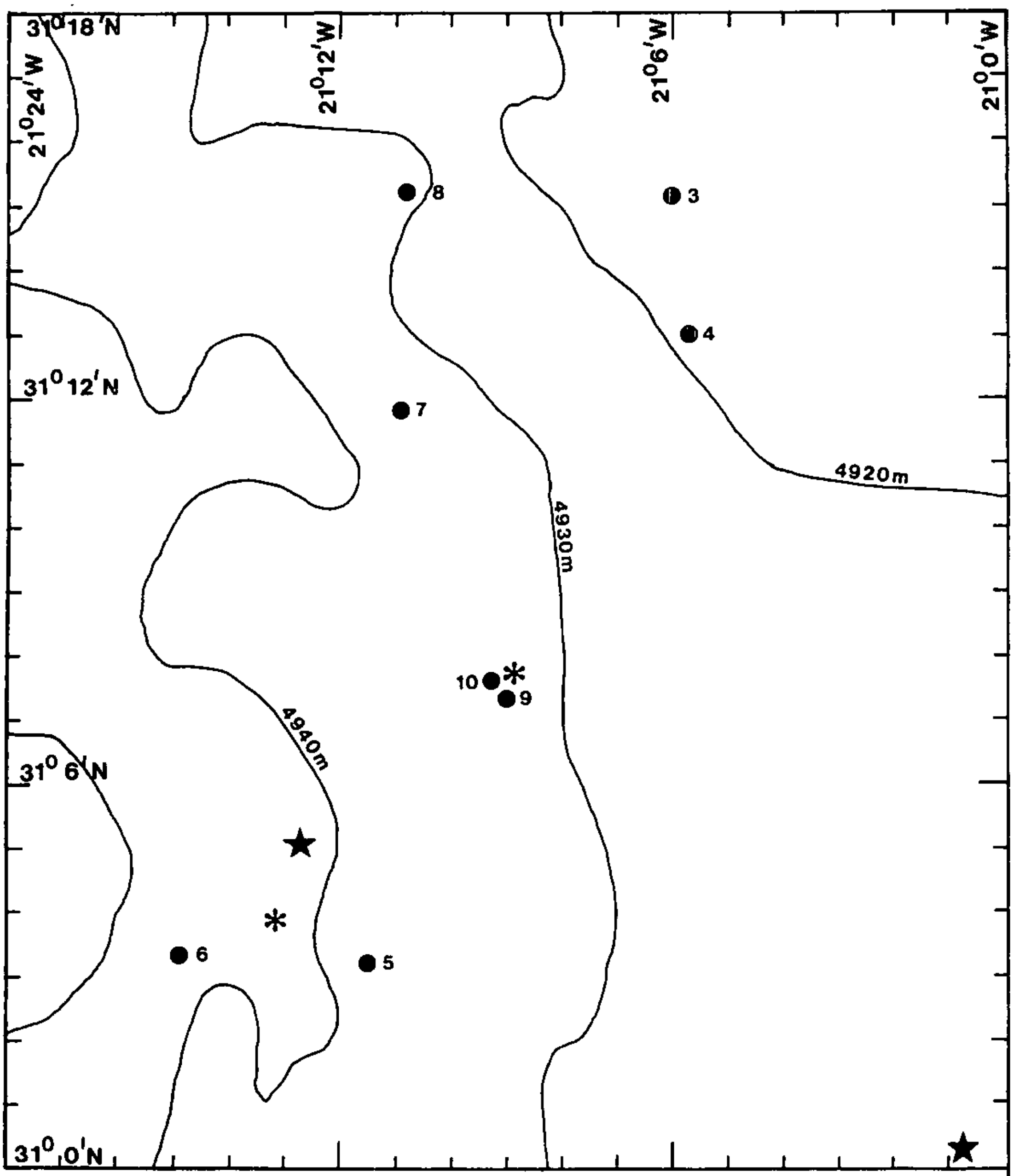

Figure 2. Bathymetry of the main working area and the positions of AUDOS deployments 3-10 (dots), Bathysnap (stars), and bathysnack (asterisks). AUDOS deployments 1 and 2 were, respectively, south and north of this area.

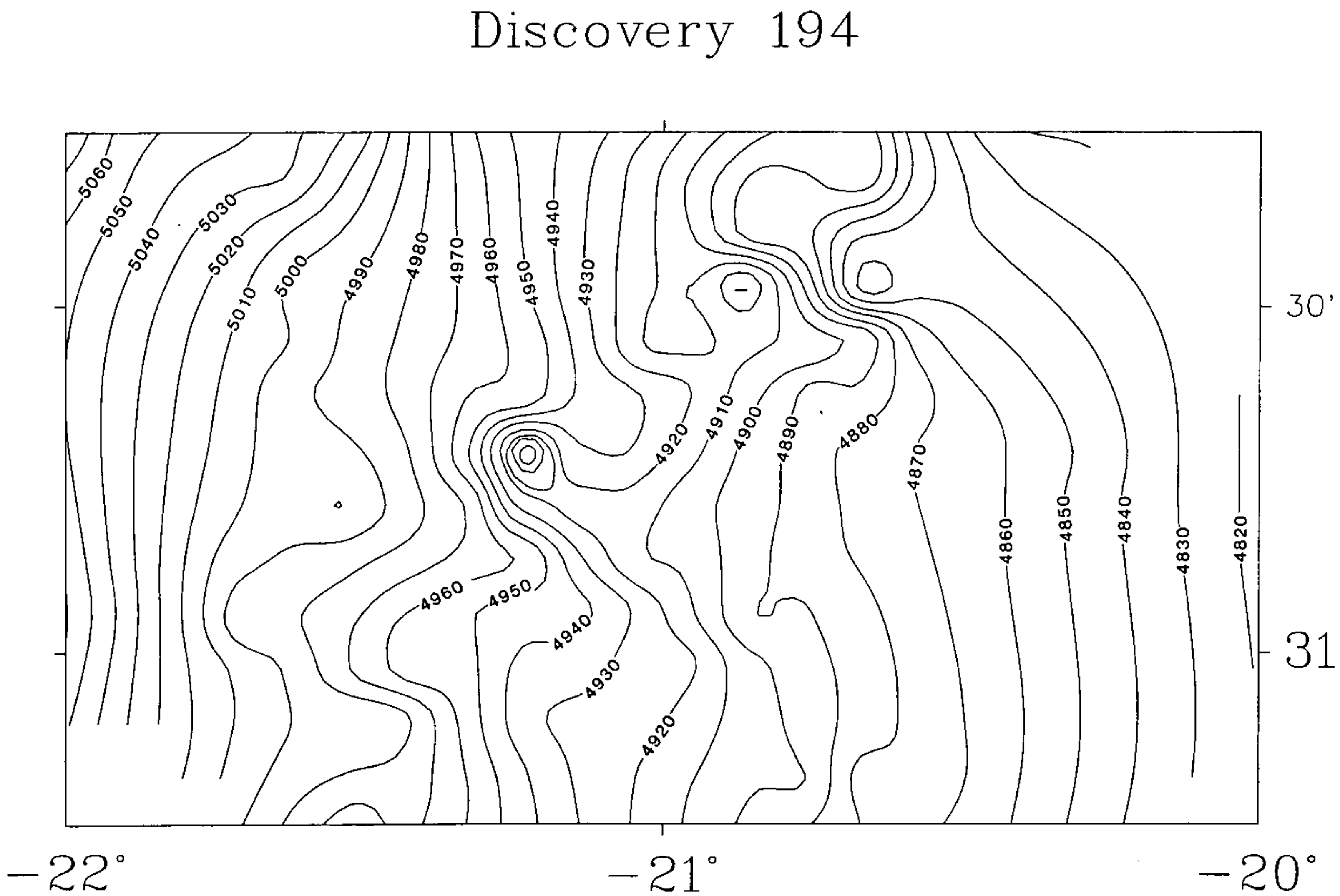

Figure 3. Preliminary computer-generated chart of bathymetry in the main work area (Station 12174)