I.O.S.

RRS DISCOVERY
CRUISE 168

23 JUNE – 7 AUGUST 1987

TROPHIC AND PHYSIOLOGICAL STUDIES OVER THE NORTH WEST AFRICAN SLOPE AND IN THE EASTERN NORTH ATLANTIC

CRUISE REPORT NO. 200
1987

INSTITUTE OF
OCEANOGRAPHIC SCIENCES
DEACON LABORATORY

NATURAL ENVIRONMENT RESEARCH COUNCIL

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RRS DISCOVERY

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Trophic and physiological studies over the North West African slope and in the eastern North Atlantic

Principal Scientist

P.J. Herring

1987

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ABSTRACT

Discovery Cruise 168 was a biological investigation of aspects of the distribution, feeding and physiology of oceanic organisms, working mainly in the Madeira and Cap Blanc areas of the eastern North Atlantic.

Leg 1 (Barry to Madeira; 23 June - 20 July 1987) was concerned with the distribution of echinoderms and near-bottom fishes and with the effects of lights on the capture efficiency of a midwater trawl. Sampling was carried out mainly in the Cap Blanc area.

Leg 2 (Madeira to Falmouth; 23 July - 7 August 1987) involved microbiological sampling and tests of a 25m² midwater trawl.

Physiological studies on vision, bioluminescence, muscle energetics, buoyancy and swimming of oceanic animals were undertaken on both Legs 1 and 2.

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Angel, Martin V.	" Biology	Leg 2
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Webb, Andrew T.	IOSDL Ocean Engineering	Legs 1 and 2
Wild, Roy A.	" Applied Physics	Legs 1 and 2
Withey, Stuart P.	" Applied Physics	Leg 2

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McCurry, R.	" " (leg 2)
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Attwell, M.A.	3rd Officer
Donaldson, B.	Radio Officer
O'Donnell, M.J.	Junior Radio Officer
Bennett, I.R.	Chief Engineer
Byrne, P.J.	2nd "
Anderson, J.E.	3rd "
Entwhistle, B.J.	4th "
Groody, W.E.	Electrical Engineer
Williams, F.S.	CPO deck
Harison, M.A.	PO
Carew, J.	Seaman
Hardy, S.A.	"
Marren, A.	"
Walker, D.J.	"
Richards, A.D.	"
Crabb, G.	"
Williams, R.L.	Cook/Steward
Welch, G.A.	Cook
Brown, L.	Steward
Chilcott, R.	"
Stanworth, D.J.	"
McKeown, J.	"

ITINERARY

Leg 1

Depart Barry 23 June - Arrive Funchal Madeira 20 July
(Stand off Funchal to embark additional scientific personnel : 29 June).

Leg 2

Depart Funchal Madeira 23 July - Arrive Falmouth, U.K. 7 August.

OBJECTIVES (AND GEAR)

1. To investigate the distribution of demersal fishes and their larvae on the West African slope (semi-balloon otter trawl; midwater trawls and near-bottom echosounder).
2. To study the distribution of echinoderms, particularly holothurians, at selected sites on the West African slope (Benthic sledge and multicorer).
3. To study the effects of lights on the capture efficiency of midwater nets (Midwater trawls with switched lights).
4. To investigate the physiology of oceanic animals, with particular reference to vision and bioluminescence (Midwater trawls with closing cod-end).
5. To investigate microbial interactions in near surface waters (CTD and water bottles).
6. To carry out horizontal and vertical profiles of bioluminescence and microzooplankton distributions (A.R.E. luminescence sensor and pump sampling).
7. To make initial trials of the RMT 25 system.

NARRATIVE

Discovery sailed from Barry at 1500hrs on 23rd June having received information that the Spanish authorities had not agreed to one of the requested working areas, north east of the Canary Isles. This necessitated some reappraisal of the cruise programme and it was decided that passage would be made to the Cap Blanc area for the main sampling effort on the first leg. Because of the changes in the cruise schedule that had occurred in recent weeks it had proved impossible for three scientists (Professors Land and Johnson and Dr. Nilsson) to meet the revised UK starting date; it had therefore been arranged to embark them at Madeira en route to Cap Blanc.

A general scientific meeting was held on 24/6 and rigging of the multiple RMT 8 system with controllable lights (RMT 8ML) was begun. The PES fish was deployed 25/6 and echo sounding began. On 26/6 the first trials of the light system were undertaken (Stn 11535) with tows at 800m. All the trials were successful, the lights switching as required. Problems were experienced with the starboard temperature controlled container and more refrigerant was requested in Funchal. On 27/6 a wire calibration of the light control monitor was undertaken and the CTD system tested. All aspects were functioning normally. A further RMT8ML test was successfully run (11536), during which the main trawl warp came off the sheave in the winch room and had to be relocated. On 28/6 a test was run of the new closing codend retractor system using the original codend (no. 1). The codend operated successfully but monitor problems prevented the net opening (11537). The vessel stood off Funchal harbour at 0900 29/6 and embarked the three additional scientists, and Miss L. Gouveia from the Funchal fisheries laboratory. Refrigerant for the container was obtained ashore and the vessel set sail for Cap Blanc at 1100 hrs. Station 11538 was fished in the evening for experimental animals. A meeting was held for the benefit of officers and crew a.m. 30/6 at which Dr. Herring, Professor Land and Mr Merrett gave a brief resume of the aims of the scientific programme. Damage to the PES fish was noted in the afternoon and it was brought inboard for repairs. It transpired that two of the three fish on board were defective, but one was subsequently repaired. During the day the otter trawl, sledge and multicorer were rigged. A ships safety committee meeting was held during the passage to Cap Blanc on 1/7. Dr Herring was present as scientific representative.

On arrival in the Cap Blanc area 2/7 an exploratory RMT1+8 was fished to determine the population densities at the depth (800m) selected for the light series (11539) and a sledge was fished in a depth of 2130m for the echinoid Pourtalesia (11540). Only a few were taken and the main constituent of the catch was the actinian Actinoscypha. The camera failed to operate. July 3rd was the 25th anniversary of the launch of 'Discovery' and a suitable celebration took place. A sledge at 600m (11541) caught more Actinoscypha and considerable quantities of mud, but no Ophiacantha which it was hoped would be present. No photographs were obtained. An otter trawl in 900m (11542) took 71kg of fish as well as many decapods (Glyphus) and other invertebrates. A deeper haul (4/7) in 1500m (11543) took a large catch of fish and holothurians.

The multicorer was deployed twice at the same position (11543#3) and took a successful set of cores on each occasion. During the first attempt to fish the multinet with near bottom echosounder (11545) the net failed to close but it operated satisfactorily on a subsequent trial (11546) and during three tows down to 11 metres off the bottom in 1300m of water (11547). These tows were aimed at capturing larvae of benthopelagic fishes but instead took many specimens of the very rare fish Leucobrotula. Further near bottom tows (6/7) yielded huge numbers of pelagic holothurians (11548) despite having to be fished in difficult sea conditions. A test run with the RMT1+8 system (11549) was done prior to the light tows and caught an exceptionally large siphonophore.

The light series of RMT8M nets commenced early a.m. on 7/7, each series of three nets fished with the light alternately 'on' or 'off' and each fished for 2 hrs in a northerly direction over the same course (start position 20°30'N 19°40'W). No account was taken of dawn and dusk periods and the nets were maintained at 800m$\pm$25m. The surface waters still showed strong signs of the high productivity associated with upwelling and the high turbidity would have prevented the penetration of any light from the surface to the fishing depth. All were assigned to Stn 11550, and of the 33 tows only one failure occurred, as the result of a failing battery. Large catches were taken throughout, particularly of fish, and included numerous ceratioids, Pachystomias, Aristostomias, and a variety of other stomiatoids and searsiids. Cyclothone livida was the most abundant single species. The series was completed a.m. 11/7.

Later in the day a pumping station with the submersible pump, CTD and in line A.R.E. bioluminescence sensor was carried out, taking 5min filter samples in every 10m between 10 and 90m (11551#1). Two RMT 8M series were fished for experimental material on the same day (11551#2-4, 11552#1-3) as well as a deep (1200-1300m) comparison with the 800m light series (11552#4). Nightly pump samples were initiated 12/7 (22552#5) followed by passage to 22°N 22°W for a deep OTSB14 tow (4500m). During the passage a short scientific meeting was held. The monitor trace on the OTSB14 was lost during the haul (11553) with 13000 m.w.o. but on hauling the net was seen to lift off the bottom at only 8500 m.w.o. A good varied catch was obtained including a large Histiobranchus and much clinker. Problems with the winch delayed the start of the haul by 1½ hrs. A pump station (11554) followed (13/7) and a multicorer dip (11555) at the same position as the OTSB14. No cores were obtained and the corer probably tilted on some obstacle. Closing cod-end materials hauls followed (11556, 11557) and then another pump station (11558). Passage northwards was made up the 22° meridian with closing cod-end tows for experimental animals at intervals and pump stations each night. Hauls 11559-11572 (17/7) were disappointingly small. A test of the new no. 2 codend was made 17/7 (11571) during which the vessel manoeuvered to avoid floating buoys and the net consequently sank to 2500m. The codend finally operated at 1150m (2112 m.w.o.). Later that afternoon the multinet (RMT1+8M) was rigged and deployed for filming purposes (11572). Following pump station 11573 (18/7) the midships winch wire was paid out to 4800m in order to eliminate some bad lays known to be present on the drum.

The poor RMT8 catches forced the decision to move northeast from the 22° meridian in an attempt to improve the volume of material obtained and course was set a.m. 18/7 for the Dragon seamount area, fishing enroute (11574-11578). As the last haul was being brought inboard the aft crane hydraulics failed in the derricking ram. As the fault could not be readily rectified the remainder of the scientific programme was abandoned and course made for Funchal, arriving 0900 20/7 local time. Crane repairs were later effected by ships and scientific engineers without recourse to shore assistance.

At Funchal, eleven of the scientific party left the vessel (Professors Johnston and Land, Drs Partridge and Nilsson, Miss Gouveia, and Messrs Merrett, Billett, Pascoe, Tate, Bonner and Bolwell). They were replaced by Drs Angel,

Campbell, Rainbow, Davenport, Huber and Arneson, Miss Shand and Miss Stirling and Messrs Antai, Brook and Withey. The scientific party received much hospitality from friends and colleagues in the Funchal Museum and Fisheries Department and were pleased to be able to reciprocate with the Captain and officers in hosting a reception on board on July 21st.

The vessel sailed on leg 2 1000 hrs 23/7 after problems concerning the cooled container had been largely solved by the engineers on board. Passage was made NW towards Ampere seamount and a brief scientific meeting held p.m. on 23rd. Sampling began 24/7 with a materials haul for Systellaspis debilis for Dr Rainbow (11579) followed by a CTD station. At the end of the station electronic problems in the midships winch were resolved by changing a circuit board. Further materials tows during the day (11581-11582) were followed by a CTD and pump station (11583). Work continued in the area until 22/7 (stations 11584-11596) during which time dense swarms of Meganyctiphanes were encountered near the surface at night. At one station (11590) the closing codend was badly damaged against the ship stern, but repairs were rapidly effected.

On 27/7 the RMT 25 (4.5mm mesh) and 8 jaw release was brought on deck for rigging and first deployed 28/7 on station 11602. It operated effectively and caught, inter alia, a magnificent specimen of Dolichopteryx. After two further RMT1+8 CCE tows for experimental animals (11603, 11604) passage was made towards 40°N 22°W with intervening RMT 1+8 CCE tows for experimental animals (11606, 11607, 11609), daily CTD dips with water bottle samples (11605, 11610) and a pump station (11608). The RMT 25 was deployed again on 30/7 at Stn 11611 but failed to fish when the closing bridle pulled out of the release gear jaws. A second attempt had a similar fate and its use was shelved, with an RMT 1+8 CCE (11612) completing the sampling on 30/7. A further large catch of Meganyctiphanes was obtained with the RMT 1+8 on 31/7 (11613), followed by a CTD (11614) and a second RMT 1+8 (11615). The RMT 25 was then deployed again (11616) with the masterlinks in the jaws, the bridles hung on them instead, and the original worn jaws replaced. Nevertheless the closing bridle still pulled out and further trials of the RMT 25 were abandoned in the face of deteriorating weather. An RMT 1+8 material haul (11617) ended 31/7 and was followed over the next two days by a continuing routine of CTDs in the morning (11619, 11624) and two material hauls by day and by night (11618, 11620, 11621, 11623, 11625,

11626) and a pump station (11622) on 1/8. Persistent NE winds and substantial swells made an early start towards Falmouth essential and the passage was begun after this station. A CTD (11628) and material tows (11627, 11629) on 3/8 were completed followed by a pump station (11630) and a CTD and water bottle station (11631) on the morning of 4/8. A comparative CTD station was carried out in the early afternoon of the same day (11632) and followed by a test of the RMT 25 with rebuilt jaws which worked successfully.

During this tow the closing bar bent somewhat but a further tow was carried out the following day, after a CTD station (11634); the RMT 25 opened successfully but the release ring hung up on the jaws and the net only closed at the surface. The closing bar was more severely deformed and no further tows were attempted with the gear. Two final RMT 1+8 tows were made on 5/8 (11636, 11637) followed by a final CTD station (11638) a.m. 6/8, just off the shelf edge. Passage was then made for Falmouth where Discovery docked at 0900/7th August.

Acknowledgements

The success of a research cruise is to a very large extent dependent upon the active collaboration between scientific, ship and planning personnel. It is therefore a pleasure to acknowledge the scientific debt owed to the officers and crew of RRS Discovery for their assistance and cooperation during the time at sea and to the RVS and IOS liaison personnel, especially Chris Adams and Arthur Fisher, for their efforts in smoothing the very difficult period prior to departure.

P.J.H.

SAMPLING GEAR

Nets

A variety of RMT nets and configurations were fished throughout the cruise. The rig used most frequently was the RMT 1+8 with a closing cod-end (CCE) on the RMT 8. This was fished on 54 occasions. A second CCE was used for the first time and after some initial problems, with ball valves not closing and a few other minor faults, it functioned well giving us two excellent units. The

reloadable retractors fitted to both CCEs for releasing the ball valves were totally reliable, working perfectly on every occasion, as did the acoustics. Some problems were experienced with the CCE hitting the stern of the ship as it came out of the water during recovery. This was overcome towards the end of the cruise by attaching a small drogue to the bucket ring by a 10m line.

The RMT 8 catch condition was found to be far better in nets with a fine mesh cod-end; accordingly a net of this type was fitted early in the cruise.

A series of hauls were made using three RMT 8s with a spot light fitted above the top bar, which could be switched on and off acoustically (see separate report).

The RMT 1+8 multinet with the near bottom echo sounder was fished 11 times on the African slope between 100 and 10 metres off the bottom during the first leg, with only one failure.

A new RMT 25 with a 4.5mm mesh was fished six times during the second leg. Unfortunately, due to problems with the 8 jaw release pulling out, only one of the first four hauls was successful. However, the net was brought to the surface open and appeared to set well with a good mouth angle using a total weight (including the bar) of 466Kg on the bottom bar. Modifications were made to the release which seemed to cure the pull out problem and one successful haul was made, although a bend developed in the closing bar. This worsened considerably on the final haul, probably partly due to the bridle ring hanging up on the drop arm and preventing the net from closing until it reached the surface. Further modifications are clearly necessary before the net can be regarded as fully effective, but the preliminary indications are that it obtains both larger catches and larger individuals than equivalent RMT 8 tows.

R.G.A.

Electronics

Telemetry

A variety of telemeters were used on cruise 168 for monitoring and control. One telemeter provided the additional capability of switching an underwater light on an RMT multinet. This function complemented the net opening/closing control and provided the required flexibility for a series of trawls. This telemeter suffered only a few minor component failures and was used for most of the cruise.

For several trawls, the necessity to fish close to the seabed with an RMT required the use of a separate telemeter containing a near-bottom echosounder (NBES) to provide an accurate "height off bottom" measurement.

The closing cod end, which requires a dedicated telemeter for its operation, was used extensively. Modifications to the device prior to the cruise included the incorporation of a solenoid retractor which, together with the telemeter, operated successfully throughout.

A telemeter was used on two benthic sledge trawls to monitor a variety of indicators and the operation of an IOS camera when sampling. On both trawls the camera control failed to operated properly. The fault was located to a latching relay unable to cope with the very fast, repetitive triggering of a mercury swith, leaving the relay in an undesired state. This was corrected for use on cruise 169. An additional fault on the frame counter was remedied and the flash sensor repositioned so that it looks directly into the flash head. A telemeter was attached to one door of an otter-trawl to monitor depth, temperature and angle of the door. The angle of the door provided a secondary indication (to the depth) that the trawl was on the seabed and sampling. A beacon was also attached to the IOS multicorer to provide near bottom indication.

CTD system

The CTD system consisting of shallow CTD, transmissometer, fluorometer, light meter, water bottle rosette, deck unit, digidata and BBC monitoring

package worked faultlessly throughout the cruise.

Bioluminescence

Continuous monitoring and logging of surface bioluminescence, conductivity and temperature was made available by the use of an A.R.E. system. The detectors were plumbed into the ship's non-toxic sea water supply and the results recorded on disc every minute. The use of a VDU and chart recorder provided a continuous display. Periodically the system was used to monitor water pumped via a hose attached to the CTD at depths down to 90 metres.

On the 2nd leg of the cruise a fluorometer was also plumbed into the non toxic sea water supply. This gave a continuous record of fluorescence, temperature and flow rate but after several days the system was damaged by a sea water leak.

Shipborne instruments

Three PES fish were loaded onboard at the beginning of the cruise (Nos 2, 5 and 10). After a week's deployment No. 5 fish developed a fault resulting from a damaged towing cable. No. 10 fish was checked through prior to deployment but also had a fault. On inspection this was found to be the transducer harness which was replaced with a spare. Finally, No. 2 fish was deployed and used for the rest of the cruise.

D.E.

BIOLOGICAL INVESTIGATIONS

Sampling programmes

Demersal fishes

Sampling to further the study of deep-sea demersal fish ecology followed two major aims. Semi-balloon otter trawling (OTSB14) for adults was carried out at 2 stations on the continental slope to the west of Cap Blanc (21°N) and 1 on the

abyssal plain in 22°N 22°W. The slope samples were taken at selected soundings to provide a maximum number of species common both to this region and the much studied Porcupine Seabight area to the north (49° 52°N, 11° 14°W). They yielded material for comparative reproductive and feeding investigations (the former in conjunction with Dr. S. Shackley of Swansea University) as well as for examination of possible racial differences between populations from the 2 areas. Half hour tows collected 71kg of demersal species at 930-840m soundings and 37kg at 1450-1505m. Catches were deep frozen immediately for laboratory examination ashore, but it was clear that the shallower sample was far less diverse than the highly speciose deeper catch and was strongly dominated by Nezumia species. In contrast, the 5½ hr tow on the abyssal plain caught 5.5kg of fish comprising 11 specimens of 6 species. The purpose of this tow was to obtain a preliminary comparison from a site near an upwelling region with samples previously taken, on the one hand in a relatively aseasonal area in mid-gyre (the Madeira Abyssal Plain), and on the other in a highly seasonal northern area (the Porcupine Abyssal Plain). The result suggested a closer affinity with the northern seasonal situation in the dominant species, but not in the biomass. It indicates a need for more intensive sampling to elucidate relationships among abyssal demersal fish assemblages and overlying productivity regimes.

The elusive early life-history stages of demersal slope-dwelling fishes were sought as the second aim of the programme, using the near-bottom echo sounder facility on the RMT 1+8 multinet. Ten successful samples were taken over the upper, middle and lower slope to the west of Cap Blanc, during which fishing was maintained largely in the 11-60m layer immediately above the bottom. While the catches contained a variety of juvenile demersal species, alevins of only bathygadine macrourids and alepocephalids were caught. The most noteworthy component of these samples came from mid-slope depths where 38 specimens of the parabrotulid, Leucobrotula adipata were taken in the 3 net series. This comprises a 5-fold increase in the total number of specimens of this species previously reported. A subsequent comparative tow at the same depth (1200-1300m), but over 3500m soundings, yielded no specimens of this species, suggesting that it is likely to be a component of the pseudoceanic ichthyofauna found only in slope regions.

N.R.M.

Echinoderms

Echinoderm feeding studies

Even though deposit-feeding echinoderms often dominate the deep-sea invertebrate megafauna and influence the structure of the rest of the benthic community through their feeding activities, little is known of their feeding biology. On this cruise it was intended to compare the intestine contents of echinoderms with samples of the superficial sediment taken from their locality. In particular, an investigation was intended into the importance of benthic foraminiferans in the nutrition of deposit-feeding species.

Megafaunal benthic invertebrates were collected from 5 stations sampled between 600 and 4500m off the coast of Mauritania and on the Cape Verde Abyssal Plain using an epibenthic sledge and an otter trawl. Sediment samples were taken at one of these stations (St. 11543, ca. 1500m) using a Multiple Corer for comparison of the superficial sediment with the intestine contents of the deposit-feeding holothurian Benthogone rosea. This holothurian dominates the benthic megafauna at mid-slope depths in many areas of the northeast Atlantic.

Unfortunately the corer failed to take a sample at 4500m (St. 11553). This was particularly disappointing since the trawl sample from this depth contained several deposit-feeding echinoderms with different feeding behaviours, including the asteroid Hyphalaster inermis and the holothurians Psychropotes semperiana, Deima validum, Pseudostichopus atlanticus and Paroriza prouhoi. The intestine contents taken from these species will be of limited value in the absence of sediment samples from this area.

The tentacles of several holothurian species were dissected and fixed in a 1:2 mixture of Osmium tetroxide and 4% Glutaraldehyde in Cacodylate buffer, for electron microscopy. It is hoped to be able to relate the fine structure of holothurian tentacles to the size and types of particles ingested.

Pelagic holothurians

Several RMT samples were taken within a few metres of the seabed off the

coast of northwest Africa. The deepest near-bottom RMT samples (St. 11548, ca. 2100m) contained over a thousand specimens of the pelagic holothurian Enypniastes diaphana. This species occurs throughout the benthopelagic zone in the northeast Atlantic below depths of about 1400m, but generally its abundance is very low. The present RMT samples and photographic evidence from previous cruises suggest that the benthopelagic zone off northwest Africa is a veritable "hot-bed" of these sea-cucumbers. The specimens collected by the RMT were much larger than those sampled previously by otter trawls off northwest Africa, indicating that Enypniastes diaphana may be synonymous with a larger, but similar species, E. eximia, found in the western Atlantic.

D.S.M.B.

Effect of lights on Multinet catches

The aim of this programme was to study the effect of an artificial light on the capture efficiency and selectivity of the RMT 8M.

The net used in this study is a modification of the IOS RMT 1+8 Multinet, with the RMT 1s removed and a new top bar fitted for the attachment of a deep sea lamp (VICON sealight) and a modified 12v lead-acid battery pack. This work is an extension of previous studies using open nets carried out from the MBA, Plymouth aboard RRS Challenger, but the RMT 8M allows much more accurate sampling of a discrete depth horizon than was previously possible.

A preliminary haul was carried out with the RMT 1+8 CCE in the area off Cap Blanc (Stn 11549), which from previous work is known to be a productive area subject to upwelling. 4 days were then set aside for continual comparative trawling in this area with the RMT 8ML (with lights). Efforts were made to reduce as many variables as possible during fishing i.e. towing from the same starting position (20°30'N, 19°40'W), on the same course, at the same speed for each tow, and maintaining the net in the 775-825m depth horizon for the 2 hour duration each net was fished. A flow meter fitted to the monitoring system allows correction for variations in the volume of water sampled by each net.

The net system was deployed 11 times during the 4 days, with only one minor problem, resulting in 31 catches for comparative purposes (16 with the light on

and 15 with the light off). The catches were sorted into the major taxa (fish, crustaceans, cephalopods and 'others') volumed and preserved. The fish were subsequently subdivided into Cyclothone spp. and other fishes. The small stomiatoid fishes of the genus Cyclothone were the dominant component of the fish fraction, at times over 50% by volume, and totalled over 41500 for the 31 catches ($\bar{x}$ = 1339). The resorting and counting was carried out with the help of Miss L. Gouveia, N.R. Merrett and J. Partridge, whom I thank for maintaining their good humour and enthusiasm throughout this arduous task. Four species of Cyclothone were identified, with C. livida being predominant (80%).

The 'other' fishes were also in large numbers for a net of this size, totalling 2361 ($\bar{x}$ 76.16), including at least 40 species.

The crustaceans were also numerous and diverse. The overall volumes show that slightly less were caught in nets with the light on than with it off, as was found during previous work of this nature, but the difference here is probably not significant. Observations on the catches suggest that there may be some significant changes in size of individuals and/or species caught with the light.

The cephalopods were not very numerous during the lights work, totalling 130 specimens from at least 15 genera. Some relatively rare species were obtained in very good condition. This collection will make a useful addition to the cephalopod material collected on previous cruises in the East Atlantic and held by MBA and IOS.

Table 1. Numbers and volumes of Cyclothone, 'other' fish and crustaceans. The figures for Cyclothone and 'other' fish were adjusted for each haul by dividing the observed figures by the number of flow units.

	Light ON		Light OFF	
	$\bar{x}$	s.d.	$\bar{x}$	s.d.
Cyclothone no.	18.20	6.06	12.18	4.10
Cyclothone ml.	2.95	1.02	1.89	0.77
Other fish no.	0.98	0.23	0.73	0.16
" " ml.	4.35	1.41	3.29	2.06
Crustaceans ml.	127.0	32.72	148.0	34.01

Table 2. Totals (no. or vol.) with lights on or off

	Light ON (n=15)	Light OFF (n=15)
Cyclothone no.	24938	15628
Other fish no.	1360	956
Crustaceans ml.	1820	2220
Cephalopoda no.	68	55
" ml.	521.5	759.0

Series 32 data (unpaired) omitted.

P.L.P.

Studies on vision

Visual pigments of deep sea fishes

The investigation of the visual pigments of deep sea fishes now spans a period of many decades. Relatively few species, however, have been examined by microspectrophotometry (msp), a technique which allows the measurement of visual pigment absorption spectra in situ in the outer segments of individual photoreceptors. Such measurements have confirmed that most mesopelagic and bathypelagic fishes have but one type of retinal photoreceptor. The outer segments of these cells contain visual pigments with absorption peaks

corresponding to the wavelengths of maximum light transmission of oceanic water. A few species, however, from a number of families, have now been shown to possess more than one class of rod-like photoreceptors which contain different visual pigments offset from the "usual" spectral position.

On leg 1 retinae were collected from deep sea fishes for msp at the University of Bristol Department of Zoology. 88 retinal samples were taken from some 40 mesopelagic and bathypelagic species. Fish were selected from RMT 8 multinet and RMT 8 CCE hauls that were brought on deck at night. Retinae were removed under dim red light and were 'preserved' either by a light glutaraldehyde treatment or by sucrose infusion and rapid freezing in an Arcton-12/dry ice slush.

Retinae were also taken from fish caught during daylight and were fixed in glutaraldehyde for later electron microscopy.

On leg 2 the sampling was continued, and fish from daytime hauls were also used if they were alive and could be dark-adapted for 1hr. In addition the retinae of fish from night-time neuston samples were prepared for msp. A total of 70 retinal samples were obtined from 46 species on leg 2. It is hoped that this survey will reveal the presence of multiple or 'unusual' visual pigments in deep sea fishes never before examined by msp. Such findings will then be related, as far as is possible, to the known ecology of these species and to their visual tasks in the light environment of the deep oceans.

J.P., J.S.

Eye structure in oceanic crustaceans

The optical structures in the compound eyes of several crustacean taxa were examined during the cruise. Much of the study involved experimental work on fresh eyes, but a large amount of material has also been preserved for later anatomical study.

One of the major surprises, discovered during the cruise, is that decapod shrimps of the genus Gennadas do not have the reflection superposition eye type characteristic of decapods, but instead they turned out to have the refraction

type of eye characteristic of euphausiids and mysids. The catches also offered a few other cases of "the wrong eye in the right animal". One apparently 'new' type of compound eye was found in a deep water hermit-crab but further studies of the collected material will need to be undertaken before conclusive results can be achieved.

Many crustaceans - hyperiid amphipods and larval shrimps in particular - have an eye design that minimises the apparent size of the eyes by confining pigmentation to a small core in the centre of the eye. A broad comparison of the special optics involved in these 'transparent' eyes has now been completed during the cruise.

Finally, the light gathering capacity and image quality was compared in the eyes of various shrimps, including decapods, euphausiids and mysids, from different depths in the sea. The result from this comparison requires some anatomical data before it can be completed, but it seems already clear that, in order to gain sensitivity, image quality is significantly sacrificed only in animals from very great depths.

D.E.N.

Eye movements in Pontellid copepods

The pontellids are large blue copepods with unusually well-developed eyes. In Pontella and Anomalocera the median ventral eye is particularly large, whereas in Labidocera the two dorsal eyes are enlarged. In the males of Labidocera these eyes are developed into long tubes, with a line of receptors at the bottom, aligned transverse to the body axis. G.H. Parker in 1895 commented that these animals moved their eye-cups through about 45° in the sagittal plane, which would mean that the row of receptors 'scans' back and forth, through the down-welling light if the animal is the right way up.

Video films of the eye movements of Labidocera were made to establish the range and temporal pattern of the activity, and to try to work out their role in the animal's life. There are two quite different kinds of movement: ones associated with movements of a light-source, and spontaneous scanning movements. If a light source is moved around an animal in a dish the eyes will track it

through the 45° arc over which they have mobility. Interestingly, the animal's tail can be driven up and down by the same movement; as the eyes look forwards the tail goes down and vice-versa. The effect of the tail movement in the open sea would be to keep the body at a constant - horizontal - angle to the light. The whole system is reminiscent of the same arrangement in euphausiids, which keeps the eye pointing upwards and the body level.

The scanning movements are lower amplitude (20°) fast fore-and-aft movements. These occur in distinct bouts of a minute or more, and the scanning rate varies from about 1 per second to a maximum of 3 per second. The eye cup is pulled backward rather slowly (200°/sec) and returns fast (450°/sec). It is concluded that these are searching movements. The sexual dimorphism suggests that the scans are concerned with the location of females by the males, against the background of downwelling light. One can imagine this to be effective in swarms where the animals are reasonably close to each other.

M.F.L.

Vision in hyperiid amphipods

Amphipods are a major constituent of the mid-water fauna, and have very well-developed compound eyes. These are often double, with an upward-pointing part covering a narrow angle and a wider angled part covering regions to the side and below the animal. The clearest division of this kind is in Phronima where the dorsal and ventral eyes are quite separate, but even in single-eyed species like Parapronoe the same division is evident.

The resolution of the eyes have been mapped in different parts of the visual fields of 10 species, to see how the animals sample their visual world. The technique is to locate the black 'Pseudopupil' in the eye, which indicates the local line-of-sight, and see how this moves as the animal is rotated. The main result is that in all species there is higher resolution in the upward direction. In Phronima and Phrosina it is 10 times greater upwards than downwards; in Parapronoe, Brachyscelus and Platyscelus the difference is more like 5 times; and in surface-living genera like Hyperia and Thamneus it is lower still. In Streetsia the resolution is very high dorsally in the anterior-posterior plane, but 10 times lower in the transverse plane, reflecting

the asymmetry of the eye. In many species the angular width of the high-acuity upper region is similar to the half-width of the down-welling intensity distribution - around 60°. However, in Phronima and Phrosina it is very much less, 5-10°, with inter-ommatidial angles as small as 1/4 of a degree, as low as in the most acute eyes of insects. If these animals are looking for food in the down-welling light, they must use an active scanning process to do so or they will miss a great deal.

I conclude that amphipods have two visual strategies, for dealing with dark objects in the downwelling light, and reflecting objects visible against the darkness below. The different optical organization of the dorsal and ventral eyes are related to differences in these tasks, and differences between species indicate different priorities between the two regions, probably related to diet and depth. Behavioural studies are needed to determine what amphipods actually do about what they see.

M.F.L.

Studies on bioluminescence

Luminescence of copepod crustaceans

The aim on the cruise was to investigate the nature of the luminescent system in a variety of luminescent copepod species, by working with live material and taking back fixed specimens for further analysis.

A number of luminescent species of copepod were obtained belonging to the genera Metridia, Pleuromamma (5 species), Gaussia (only a few specimens of G. princeps were caught at around 20°N), Lucicutia and Euaugaptilus. Most species were caught using the RMT 1+8 multinet combination fished at various depth profiles from 100-1500m. Some specimens, mainly the smaller Pleuromamma species (P. gracilis, P. piseki, P. borealis) were caught in the neuston net fished at night.

Animals isolated from the catch, after being identified, were either fixed immediately (in a glutaraldehyde cocktail) or maintained at 14°C in the constant temperature room until required. Work on live animals consisted of locating and

mapping out the position of luminous glands in each species using a compound fluorescence microscope (as the glands were autofluorescent under UV light). This was done to compare the distribution and gross morphology of glands between species.

Spectral studies of the fluorescence of the luminous material of metridinids, augaptilids and Oncaea have been made to compare with previously reported bioluminescence emission spectra and to investigate the possibility of energy transfer systems being involved.

Video recordings of the rapid alarm movements of luminous species have been made to estimate the rate of movement and effective Reynolds number at which the bioluminescent secretory responses may occur.

Extensive studies on the histology and microstructure of the luminous glands will be undertaken at UCNW on material collected and fixed on the cruise, using SEM, TEM, and light microscopy.

N.J.B., P.J.H.

Bioluminescent 'signatures'

For the first time at sea a new charge coupled device (CCD) spectrophotometer was used to measure the light emitted by bioluminescent organisms. The spectral composition of light from bioluminescent flashes was determined with an average spectral resolution of about 5nm; the time course of the flash was simultaneously followed with a temporal resolution of 30 msec. The objective of our studies is to determine the extent and sources of intraspecific variability in bioluminescence, and to determine whether organisms exhibit a recognizeable bioluminescent 'signature', that is, whether they can be identified by their light emission.

We recorded 140 flashes from 49 individuals of the euphausiid Meganyctiphanes norvegica, collected at night from 85-400m depth. These data will be used to analyze intraspecific variability. In addition, only the emissions of the ocular or abdominal photophores were measured for some flashes, allowing comparison of the output of different photophores. The data from M.

norvegica, along with 10 flashes from 3 individuals of Stylocheiron sp., will be added to our library of euphausiid signature data and used for interspecific comparisons.

Measurements were made of 162 flashes from 82 individual copepods collected from 660-1500m. At least eight species, including Disseta sp., Euaugaptilus magnus, Lucicutia grandis, Metridia princeps, Pleuromamma gracilis and P. xiphias, were represented. Most flashes were from Disseta sp., E. magnus and M. princeps; for these species sample sizes are sufficient for intraspecific analysis of varibility. Data from all the copepods will be used to examine interspecific variability.

Data were also collected from the siphonophores Vogtia glabra (5 individuals, 18 flashes) Maresearsia sp. (1 individual, 4 flashes), and V. spinosa (5 individuals, 12 flashes), two species of ctenophore (5 individuals, 29 flashes), the ostracod Conchoecia lophura (10 individuals, 16 flashes) and the fish Neonesthes capensis (1 individual, 6 flashes). As with the data from euphausiids and copepods, these data will be added to our signature library and be used to test the hypothesis that marine organisms can be identified from characteristics of their bioluminescent emissions.

M.E.H., A.C.A.

Biochemistry of oceanic bioluminescence

The long term aim of this programme is to use bioluminescence as a vehicle for studying biochemical evolution, and in particular to use it to unravel the molecular basis and development of threshold phenomena in cell activation and cell injury, together with their role in human disease.

The principal focus on the cruise was to identify the organisms utilizing an imidazolopyrazine as the chromophore in the chemiluminescent reaction responsible for light production. The biochemistry of these systems will then be compared using enzymological and recombinant DNA techniques. Systems having suitable characteristics for measuring chemical events inside mammalian cells will then be cloned and the cDNA or mRNA incorporated into human cells in situ. This will provide an intracellular bioluminescent indicator for monitoring the

chemistry of activation and injury in single living cells.

A highly sensitive and specific assay was established for quantifying luciferases utilizing coelenterazine (the imidazolopyrazine first identified in hydrozoan coelenterates) and for measuring coelenterazine itself in the fmol range (10^{-15}mol.). These assays provide a highly selective differentiation from the Vargula system which utilizes a different imidazolo pyrazine.

Coelenterazine was detected in several luminous decapods, copepods, ostracods, squid and fish. These include the hepatopancreas of Systellaspis (24.6 nmol/organ), Oplophorus (1.3nmol) Acanthephyra (0.85nmol) and a little in Hymenodora. It was not detected in Sergestes organs of Pesta. Detection in copepods was variable but was positive in species of Euaugaptilus, Pleuromamma, Lucicutia and Megacalanus, and in some non-luminous Pareuchaeta. Coelenterazine was also detected in the ostracod Conchoecia, Lampadena and other myctophids, possibly in Echiostoma and highly positive in the two squid Pterygioteuthis (46.1 nmol/animal) and Pyroteuthis (12.6nmol/animal). It was not detectable in the squid Bathothauma or the fishes Photostomias and Searsia.

Coelenterazine luciferase was highly active in hepatopancreas extracts of decapods: Hymenodora > Oplophorus > Systellaspis > Acanthephyra > Funchalia and the mysid Eucopia. Very high luciferase activity, with rapid kinetics, was detected in copepods E. periodosus > E. magnus > Heterorhabdus. The activity was detectable from one animal and >90% was in the swimming legs of Euangaptilus. The "luciferase" activity in non-luminous copepods was 2-3 orders of magnitude lower than in the luminous species. Some luciferase activity was also detected in the ostracods Conchoecia lophura and C. ametra.

The ostracod data raise the interesting possibilitiy that two different imidazolopyrazine luciferins may occur in the same order.

Future work

These experiments, together with material stored frozen, provide the basis for establishing which oceanic organisms use imidazolopyrazine luciferins and which do not. Careful quantification and characterization of the biochemistry

of these diverse systems will provide novel information into both the ecology of the deep sea, where chromophores or their precursors are obtained in the food chain, and the origin of chemical thresholds in biology, exemplified by living light.

A.K.C., P.J.H.

Spectral studies of fluorescence and reflectance

The fluorescence and/or reflectance of a number of luminous tissues and organs has been examined, in order to distinguish the extent to which the bioluminescence emission spectrum is determined by the reflectance characteristics of the organ. In some myctophid fishes reflectance is specular and near monochromatic, with peaks around 440nm, and must significantly affect the bioluminescent emission. In other (e.g. the decapod Oplophorus) the reflector has a broader spectral bandwidth. The spectral reflectance of the 'eyeshine' of a number of decapod and mysids has been examined. The typically golden eyeshine (max 550nm) is a characteristic of the superposition compound eyes of animals living in low ambient light conditions in the sea.

In vivo fluorescence spectra of a variety of bioluminescent tissues have been recorded, including the fishes Pachystomias, Aristostomias, Malacosteus and Searsia, decapods, ostracods, cephalopods anbd ophiuroids. The relationship of these data with the biluminescent emission spectra will be examined.

P.J.H.

Vertical and horizontal profiling of bioluminescence

It was hoped that a data set could be collected encompassing both vertical and horizontal profiles of bioluminescence encountered in the water mass covered by Cruise 168.

Vertical profiling was achieved on 14 stations by pumping water with a submersible pump from depths that were predetermined by the CTD. The range of depths examined was 10-90m and in addition to the profile, filter samples were taken of the water pumped over a five minute period at each depth. This should determine whether stimulable bioluminescence is correlated with the

microzooplankton composition at each depth, particularly the crustaceans.

Horizontal profiling was established by bleeding part of the ships sea water supply past a luminescence sensor. In both cases a photomultiplier tube was placed at 90° to the flow of water and the bioluminescence was recorded in the turbulence produced by a right angle in the flow path. The data was recorded in analogue chart form, digital on soft disc and in real time on a VDU.

There were problems with light leaks in both systems but these were readily overcome by simple solutions, such as black tape and black plastic bags. However, an electronics failure in the high-voltage PMT supply had to be repaired and was rectified by changing the power source.

A continuous horizontal profile was collected over the cruise track inocrporating more than 800 hours of data and initial results look encouraging.

D.M.T., P.J.H.

Associated studies

Muscle energetics in deep-sea fish

The aim of this study is to investigate the energetics of muscle contraction in a range of mesopelagic, baythypelagic and demersal deep-sea fish. In particular it seeks to test the hypothesis that a compromise is needed between the 'ideal' structural traits required for the adaptation of muscle proteins to high hydrostatic pressure and low temperature.

Skinned muscle fibres were prepared on board ship by freeze-drying small bundles of fibres which had been rapidly frozen in isopentane/liquid nitrogen (-159°C). In this condition the fibres are stable for several years at -20°C enabling sophisticated mechanical and biochemical experiments to be carried out in the UK. Other muscle samples were processed for electron microscopy and embedded in araldite. A total of 65 fish were sampled representing 11 pelagic and 10 demersal species inhabiting depths down to 4500m.

In the UK single fibre segments (typically 50μm diameter x 3mm length) will be isolated from the freeze-dried material. It is proposed to measure force

generation and the energy cost of contraction at a range of temperatures and hydrostatic pressures using a specially constructed pressure vessel. Measurements of force generation will be related to the cross-sectional area of myofibrils determined from electron micrographs. ATPase activity under force generating conditions will be measured by monitoring the production of nmolar quantities of ADP or creatine using High Performance Liquid Chromatography. Other experiments will investigate the possible role of myosin phosphosphorylation in modulating contractility during vertical migration. Information on the structural specialisations of deep-sea fish myosins will be obtained from studies of denaturation kinetics (temperature and urea) and by peptide mapping.

I.A.J.

Swimming and buoyancy studies

Objectives

In the light of experience on a previous cruise (140), it was proposed to study the swimming and buoyancy mechanisms of pelagic molluscs, particularly heteropods. It was also thought that an investigation of swimming in juvenile flying fish might be fruitful. A new type of high speed video camera was to be tested, and attempts made to construct density gradients at sea.

During the cruise heteropod molluscs were almost completely unavailable, so emphasis was shifted to the pteropods, particularly the gelatinous Desmopteryx and Cymbulium. In addition, opportunity was taken to study swimming in the ostracods Gigantocypris and Macrocypridina and a small swimming crab.

Finally, material was collected for members of staff of UCNW and the British Antarctic Survey.

Methods

A Panasonic F10 High Speed video camera and recorder was used.Despite the name, this type of camera does not record more than the normal 25 fields s-1. Instead a shutter system (SES) records information for only 0.001s during each

field - thereby avoiding blurring of images. The camera proved successful, but required high light intensities when the SES was switched on. Density determinations were carried out in a density gradient (5 x 5cm square section tube, 60cm high). The gradients were obtained by mixing diluted sea water and NaCl-augmented seawater supplied from two interconnected header tanks. On land this system gives substantially linear gradients, but gradients were very stable, being useable for several days. A novel calibration system, involving the withdrawal of droplets of water (via fine catheters) from various points in the gradient and measuring their salinity on a Goldberg refractometer, was quick and led to an accuracy equivalent to 1‰ (roughly 0.01 g ml-1).

Results

Pelagic molluscs: Swimming and density data were collected for species of gelatinous shelled and gymnosome pteropods. Only one species of heteropod was filmed. Analysis of videotape in the UK will yield descriptions of swimming mechanisms, velocity and acceleration data and a comparative account of the locomotory strategies of pteropods. The pseudotroch shape and composition of Cymbulium will be studied further at Menai Bridge.

Ostracods: Two ostracods were studied, the large, neutrally buoyant Gigantocypris and the smaller, dense Macrocypridina. Swimming was observed, the former species demonstrating high manoeuvrability, especially at low speeds. The spherical shape is stable because denser structures (e.g. gut and hepatopancreas) are situated ventrally. The tumbling locomotion reported for the species in the literature is anomalous, and is only shown at high temperatures. Macrocypridina demonstrates much faster swimming and greater acceleration. Its swimming speed is affected by temperature; animals cooled to 5°C did not swim, but resumed swimming when warmed to 10°C and became progressively faster at higher temperatures. Beyond 20°C their velocity declined again.

Swimming crab: A single specimen of an unidentified swimming crab was caught in a night neuston tow. Unlike most portunid crabs it did not swim with the 5th pair of limbs alone, but with all of the walking limbs.

Juvenile flying fish: About a dozen juveniles (drawn from 4-5 species) were collected and filmed. All swam with their pectoral fins expanded (like adults). A normal escape reaction produced an oblique swimming track towards the water surface, but the head did not break through the surface film. Occasional violent escapes involved jumping out of water, but this always involved a near vertical approach to the surface film (as had been predicted, since this minimizes the perimeter of the body on which surface tension acts); the juveniles have no ability to fly/glide in air.

Material for other workers

Much frozen material was collected for Dr. Andrew Clarke of BAS (for a comparative biochemical investigation of polar and tropical gelatinous animals, especially medusae).

A wide variety of deepwater pelagic fish were collected and preserved for gut parasites for Dr. Alan Probert of UCNW and a few species of Lepas were collected for Drs Hill and Holland of UCNW, as part of a comparative study of the biochemistry of prostaglandins in barnacles.

J.D.

Trace metals in oceanic crustaceans

The study of trace metals in oceanic crustaceans carried out on the second leg of Cruise 168 can be divided into three parts, viz: (a) an investigation of possible copper deficiency in the caridean decapod Systellaspis debilis, (b) collection of material to analyse possible geographical changes in trace metal concentrations of common oceanic crustaceans (in combination with P.S. Ridout and H.S.J. Roe, IOS), and (c) a study of the feeding biology of the stegocephalid amphipod Parandania boecki (in collaboration with Dr. P.G. Moore, Millport).

(A) Possible copper deficiency in Systellaspis debilis

Measurements of copper concentrations in specimens of S. debilis collected on earlier cruises (particularly Discovery Cruise 156) have shown a positive relationship between copper (Cu) concentration and body dry weight of the

decapods. Copper concentrations in juvenile Systellaspis deblis appear to be too low to meet theoretical copper requirements for the respiratory pigment haemocyanin in addition to enzyme needs, and preliminary measurements of body haemocyanin concentrations have confirmed a lack of the pigment in small specimens. Large S. debilis have copper and haemocyanin concentrations more typical of decapods. It is possible therefore that juvenile S. debilis are suffering from copper deficiency with the effect of limiting haemocyanin production, potentially affecting activity levels including the ability to undertake vertical migration.

(i) Laboratory copper accumulation experiments: The use of an RMT 8 with closing cod end allowed the collection of decapods in condition good enough to withstand a period of experimental handling, experiments being carried out in the temperature controlled container at 14°C. Systellaspis debilis, collected from c. 700m by day, were exposed to an increasing log series of dissolved added Cu concentrations (0 (control), 0.5, 5, 50 and 500 µg Cu l^{-1}) for up to 6 days. Survival in control and low Cu exposures was good, with clear copper toxic effects in the two highest exposures. Experimental specimens have been frozen individually for subsequent analysis of accumulated Cu concentrations. The juvenile S. debilis exposed to increased copper availability have thus been provided with a supply of copper for synthesis of haemocyanin, and body haemocyanin levels will also be measured.

(ii) Analyses of copper in Systellaspis debilis and vertical migration: Attempts were made on three consecutive nights to collect the portions of S. debilis populations either remaining at the depth occupied by day or migrating vertically to shallower waters, in order to investigate any possible differences in body copper and haemocyanin concentrations (particularly in juvenile specimens). In contrast to suggestions in the literature, it was found on each occasion that the whole population of S. debilis (juvenile and adult) had undertaken vertical migration, any apparent lack of copper and haemocyanin therefore not affecting the ability of the juveniles to migrate.

In addition samples of the hepatopancreas of adult Systellaspis deblis were fixed for electron microscopy with associated X-ray microanalysis.

(B) Geographical trends in crustacean trace metal concentrations

Collections were made of common oceanic crustaceans north from Madeira for analysis of body concentrations of trace metals such as arsenic, cadmium, chromium, cobalt, copper, iron, manganese, nickel, vanadium and zinc by either atomic absorption spectrophotometry or by plasma techniques. Emphasis has been placed on large samples of single species from individual catches, concentrating particularly on the decapods Acanthephyra purpurea, Gennadas valens and Systellaspis debilis, the euphausiid Meganyctiphanes norvegica and the hyperiid amphipod Parathemisto gaudichaudi.

(C) Feeding biology of the stegocephalid amphipod Parandania boecki

Stegocephalid amphipods are known to contain large crystals of ferritin in the gut caeca but little is known of the biology of any member of the family except Stegocephaloides christianiensis from the British continental shelf feeding on sea pens. The ferritin crystals result from an iron detoxification mechanism meeting the iron challenge from the iron-rich diet.

Nine specimens of P. boecki were collected from c. 800m using an RMT 8 with closing cod end. 3 were frozen for total body iron analysis. Dissected material provided caeca fixed for electron microscopy (glutaraldehyde with or without postosmication) and X-ray microanalysis of ferritin crystals, and gut contents fixed in formalin for light microscopical examination for nematocysts. On board, P. boecki was shown to be able to feed on species of the medusa Atolla, and subsequent analysis of the amphipod gut for the presence of porphyrins derived from the Atolla was positive. A similar clearly positive result for the presence of porphyrins in the gut of a newly captured P. boecki suggested that the amphipod may feed naturally on Atolla species, the only significant source of porphyrins available. Specimens of Atolla parva and A. wyvillei were frozen for the analysis and fixed for nematocyst identification.

P.S.R.

Microbial loop studies

Two studies were undertaken:

A. Vertical and horizontal distribution of bacterial and protozoan populations.

These were correlated with changes in phytoplankton abundance and the physical properties of the upper ocean (top 300m); profiles of bacterial production rates were also measured.

Daily (15) CTD casts were made to 300m. Normally these were made between 0830hr and 0930hr but on three occasions were between 1200 and 1400hr. Eight depths for sampling were selected from real time plots. Depths were chosen for biological features rather than constant fixed depths. (Depths chosen were normally 300m, 150m, three depths around the chlorophyll max., oxygen max., immediately below the thermocline and in the mixed layer). Surface and subsurface irradiance were measured during each CTD cast. From each of the eight bottles, samples were taken for analysis of bacterial numbers, bacterial production rate, microflagellate numbers and nutrients. Samples were taken from selected depths for protozoan counts, dominant phytoplankton and size fractionated chlorophyll analysis (0.2-1μm, 1-5μm, >5μm).

The CTD was calibrated with respect to salinity and chlorophyll. Preserved samples from selected depths were stored for further counting and SEM work.

B. Growth rates of, and predation pressure on, phytoplankton and bacteria at selected depths.

Three separate incubation experiments were carried out. All involved diluting seawater from a certain depth with seawater from the same depth, which had passed through a 0.2μm filter to remove all organisms. This reduced the number of predators in the incubations while increasing the nutrients available to each organism.

Exp (1) run 3 times, 27/7 - 28/7, 30/7-31/7, 2/8-3/8. (Stirling).

This gave information on the growth rate of, and grazing pressure on, bacteria and phytoplankton. For two of the experiments there is an indication of size selection on phytoplankton grazing by protozoans. The third gives an independent estimate of bacterial production.

Exp (2) run 3 times, 26/7-27/7, 29/7-30/7, 1/8-2/8 (Antai/Stirling).

This gave information on the growth rate of bacteria and an independent

estimate of bacterial production. Chlorophyll samples were taken to monitor phytoplankton growth. In the third experiment a comparison was made between water from the chlorophyll max. and the oxygen max. with respect to these measurements.

Exp (3) run once, 3/8 (Antai)

This gave information on bacterial production, growth rate, and the predation pressure on bacteria.

The CTD plots were used to identify the depth of the oxygen maximum. Water samples were then collected using 30L and 2½L Go Flo bottles from the forward winch.

M.S., E.A.

Filming activities

During leg 1 of the cruise filming was undertaken for two purposes. The first was to provide material, particularly of deep sea animals, for the three part BBC Natural History Unit series 'Atlantic Realm'. The second was to provide a record of the sampling activities and methods used during the cruise. Material that is not required for the Atlantic Realm programmes from each aspect will be available to IOS for educational and promotional use.

The major problems were keeping the animals alive and eliciting natural behaviour, and compromises were usually necessary. Despite the restrictions imposed by ship movement and vibration some excellent material has been obtained for both purposes. All filming was on 16mm colour negative film and shot mute.

S.B.

ABBREVIATIONS USED IN THE STATION LIST

RMT 1+8	Rectangular Midwater Trawl combination of $1m^2$ mouth area net of 330μm mesh (RMT 1) and $8m^2$ area net of 4.5mm mesh (RMT 8)
RMT 1+8M	Multiple RMT 1+8 with three pairs of nets
RMT 8ML	Multiple RMT 8 (with three nets and underwater spotlight)
OTSB14	Otter Trawl (semi-balloon)
BN1.5/3M	Bottom Net (benthic sledge) $1.5m^2$ mouth area incorporating 3 nets (2x4.5mm mesh, 1x330μm mesh)
SBN	Supra-Benthic Net (mouth area $0.5m^2$, mesh 330μm) mounted on the BN 1.5/3M
MC	IOS Multicorer (12 cores, 6cm diam.)
CCE	Acoustically operated Closing Cod End on RMT 8 net.
NBES	Near Bottom EchoSounder (used with RMT 1+8M)
CTD	Conductivity, Temperature, Depth probe. Routinely fitted with O_2 sensor, transmissometer, fluorometer and irradiance meter.
MS	General Oceanics Multisampler with 1.7l water bottles
W/B	Water bottles (30 litre Niskin and/or 2.5 litre Go Flo bottles)
PUMP	Zooplankton pump samples (330μm mesh filter) from selected depths.
BIOLUM	ARE Bioluminescence sensor in the pump flow line
CNR	Catch not retained
m.o.b.	Metres off the bottom (using NBES).

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11535# 1	26.vi	41°21.6'	12°00.7'	RMT8ML	825-775	1109-1209	3.73	Catch not retained (CNR)
		41°23.3'	12°02.2'	ON				
11535# 2	26.vi	41°23.3'	12°02.2'	RMT8ML	825-795	1209-1310	4.09	CNR
		41°24.8'	12°05.0'	OFF				
11535# 3	26.vi	41°24.8'	12°05.0'	RMT8ML	825-775	1310-1410	4.00	CNR
		41°26.3'	12°06.3'	ON				
11536# 1	27.vi	38°34.7'	13°40.6'	RMT8ML	825-775	1211-1311	3.10	CNR
		38°36.6'	13°40.3'	ON				
" # 2	27.vi	38°36.6'	13°40.3'	RMT8ML	800-700	1311-1410	3.51	CNR
		38°38.6'	13°40.0'	OFF				
" # 3	27.vi	38°38.6'	13°40.0'	RMT8ML	710-580	1410-1510	3.78	CNR
		38°40.9'	13°39.5'	ON				
11537# 1	28.vi			RMT1+8				Net failed to open
				CCE				CNR
11538# 1	29.vi	31°53.9'	16°55.2'	RMT1+8	725-480	2106-2206	3.69	CNR
		(at 2124Z)		CCE				
11539# 1	2.vii	21°02.9'	18°27.2'	RMT1+8	775-825	1009-1209	7.42	
		21°05.5'	18°23.6'	CCE				
11540# 1	2.vii	20°56.9'	18°12.0'	BN1.5/3M	2110-2130	1917-1953		
		20°57.0'	18°11.0'	SBN				
11541# 1	3.vii	20°31.3'	17°52.9'	BN1.5/3M	595-600	0936-0949		
		20°31.4'	17°53.0'	SBN				

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11542# 1	3.vii	20°41.1'	17°59.6'	OTSB14	840-930	1524-1557		
		20°39.1'	17°59.9'					
11543# 1	4.vii	20°29.2'	18°27.3'	OTSB14	1450-1505	0205-0253		
		20°30.2'	18°30.0'					
" # 2	4.vii	20°29.3'	18°27.6'	MC	1515	1000 (on bottom)		
" # 3	4.vii	20°28.9'	18°28.3'	MC	1590	1140 (on bottom)		
11544# 1	4.vii	20°35.5'	17°55.2'	RMT1+8M	490-640	1738-1839	3.37	100-17 metres off bottom
		20°36.8'	17°57.1'	NBES				
" # 2	4.vii	20°36.8'	17°57.1'	RMT1+8M	630-720	1839-1938	3.46	38-19 m.o.b.
		20°38.2'	17°59.1'	NBES				
" # 3	4.vii	20°38.2'	17°59.1'	RMT1+8M	720-810	1938-2039	3.91	11-34 m.o.b.
		20°39.1'	18°01.3'	NBES				
11545# 1	5.vii	20°39.3'	18°09.3'	RMT1+8M	1120-1350	0018-0236		Net failed to close
		20°47.0'	18°13.0'	NBES	(-0)			10-40 m.o.b.
11546# 1	5.vii	20°50.4'	18°10.8'	RMT1+8M	200-150	1343-1400	1.30	Trial of net monitor
		20°51.3'	18°10.9'	NBES				Nets 2 & 3 not fished CNR
11547# 1	5.vii	20°45.0'	18°03.7'	RMT1+8M	800-1190	1712-1812	4.05	To 52 m.o.b.
		20°47.1'	18°01.9'	NBES				
" # 2	5.vii	20°47.1'	18°01.9'	RMT1+8M	1190-1270	1812-1912	4.81	60-11 m.o.b.
		20°48.9'	18°00.5'	NBES				
" # 3	5.vii	20°48.9'	18°00.5'	RMT1+8M	1250-1290	1912-2012	4.14	40-11 m.o.b.
		20°50.9'	17°58.9'	NBES				
11548# 1	6.vii	20°52.5'	18°17.4'	RMT1+8M	2010-2180	0249-0412	5.22	11->100 m.o.b.
		20°54.1'	18°14.6'	NBES				

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
" # 2	6.vii	20°54.1'	18°14.6'	RMT1+8M	2080-2145	0412-0512	3.82	15-37 m.o.b.
		20°55.6'	18°13.1'	NBES				
" # 3	6.vii	20°55.6'	18°13.1'	RMT1+8M	2075-2090	0512-0612	3.64	11-42 m.o.b.
		20°57.1'	18°11.2'	NBES				
11549# 1	6.vii	20°32.2'	19°40.3'	RMT1+8	775-825	1909-2109	7.96	Test tow prior to light series
		20°36.7'	19°41.6'	CCE				
11550# 1	7.vii	20°22.4'	19°39.1'	RMT8ML	775-825	0140-0340	8.59	
		20°27.6'	19°38.3'	ON				
" # 2	7.vii	20°27.6'	19°38.3'	RMT8ML	775-825	0340-0540	9.00	
		20°32.7'	19°37.1'	OFF				
" # 3	7.vii	20°32.7'	19°37.1'	RMT8ML	775-825	0540-0740	9.09	
		20°37.9'	19°36.1'	ON				
" # 4	7.vii	20°20.9'	19°38.4'	RMT8ML	775-825	1132-1332	7.74	
		20°23.5'	19°34.4'	OFF				
" # 5	7.vii	20°23.5'	19°34.4'	RMT8ML	775-(825)	1332-1432	3.82	Battery failure in monitor,
		20°25.1'	19°32.9'	ON				1 hr tow only
" # 6	7.vii							Net 3 aborted
" # 7	7.vii	20°21.5'	19°39.3'	RMT8ML	775-830	1753-1953	7.02	
		20°25.8'	19°39.5'	OFF				
" # 8	7.vii	20°25.8'	19°39.5'	RMT8ML	775-825	1953-2153	6.97	
		20°30.6'	19°41.0'	ON				
" # 9	7.vii	20°30.6'	19°41.0'	RMT8ML	775-825	2153-2353	7.51	
		20°33.6'	19°41.6'	OFF				
" #10	8.vii	20°22.0'	19°39.7'	RMT8ML	775-825	0308-0508	8.68	
		20°27.6'	19°39.4'	ON				

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
" #11	8.vii	20°27.6'	19°39.4'	RMT8ML	775-825	0508-0712	9.22	
		20°33.3'	19°39.2'	OFF				
" #12	8.vii	20°33.3'	19°39.2'	RMT8ML	780-825	0712-0912	8.86	
		20°38.7'	19°38.5'	ON				
" #13	8.vii	20°22.6'	19°39.6'	RMT8ML	775-830	1314-1514	8.19	
		20°26.9'	19°36.9'	OFF				
" #14	8.vii	20°26.9'	19°36.9'	RMT8ML	775-825	1514-1714	7.96	
		20°31.3'	19°35.4'	ON				
" #15	8.vii	20°31.3'	19°35.4'	RMT8ML	775-830	1714-1914	7.38	
		20°35.7'	19°34.3'	OFF				
" #16	8.vii	20°21.9'	19°40.5'	RMT8ML	775-825	2242-0042	6.97	
		20°26.3'	19°41.2'	ON				
" #17	9.vii	20°26.3'	19°41.2'	RMT8ML	775-825	0042-0242	6.97	
		20°30.3'	19°42.0'	OFF				
" #18	9.vii	20°30.3'	19°42.0'	RMT8ML	775-825	0242-0442	7.20	
		20°34.6'	19°43.3'	ON				
" #19	9.vii	20°21.5'	19°40.0'	RMT8ML	775-825	0740-0940	6.93	
		20°26.5'	10°40.3'	OFF				
" #20	9.vii	20°26.5'	19°40.3'	RMT8ML	770-825	0940-1140	9.04	
		20°31.6'	19°40.4'	ON				
" #21	9.vii	20°31.6'	19°40.4'	RMT8ML	775-825	1140-1340	8.41	
		20°36.5'	19°40.4'	ON				
" #22	9.vii	20°23.3'	19°40.0'	RMT8ML	775-825	1712-1912	8.05	
		20°27.0'	19°38.7'	ON				

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
" #23	9.vii	20°27.0'	19°38.7'	RMT8ML	775-825	1912-2112	8.28	
		20°32.4'	19°38.1'	OFF				
" #24	9.vii	20°32.4'	19°38.1'	RMT8ML	775-825	2112-2312	8.23	
		20°37.5'	19°37.3'	ON				
" #25	10.vii	20°20.9'	19°39.5'	RMT8ML	775-825	0242-0442	6.79	
		20°25.0'	19°39.1'	OFF				
" #26	10.vii	20°25.0'	19°39.1'	RMT8ML	775-825	0442-0642	7.06	
		20°28.8'	19°39.3'	ON				
" #27	10.vii	20°28.8'	19°39.3'	RMT8ML	775-825	0642-0842	7.96	
		20°33.4'	19°39.9'	OFF				
" #28	10.vii	20°21.2'	19°39.5'	RMT8ML	775-840	1144-1344	6.84	
		20°25.5'	19°39.5'	ON				
" #29	10.vii	20°25.5'	19°39.5'	RMT8ML	775-825	1344-1544	7.38	
		20°29.6'	19°39.2'	OFF				
" #30	10.vii	20°29.6'	19°39.2'	RMT8ML	775-825	1544-1744	7.24	
		20°33.8'	19°39.1'	ON				
" #31	10.vii	20°20.4'	19°40.1'	RMT8ML	775-825	2358-0158	7.15	Net initially failed to open.
		20°25.7'	19°40.6'	OFF				Recovered and reset.
" #32	11.vii	20°25.7'	19°40.6'	RMT8ML	775-825	0158-0358	7.87	
		20°30.4'	19°41.1'	ON				
" #33	11.vii	20°30.4'	19°41.1'	RMT8ML	775-820	0358-0558	8.77	End of lights series
		20°35.3'	19°41.8'	OFF				

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11551# 1	11.vii	20°38.1'	19°43.3'	CTD PUMP	10-90	0825-1105		Samples at 10m intervals
		20°38.5'	19°46.8'	BIOLUM				
" # 2	11.vii	20°39.5'	19°47.6'	RMT8M	280-400	1139-1239	3.24	CNR
		20°42.4'	19°47.8'					
" # 3	11.vii	20°42.4'	19°47.8'	RMT8M	195-285	1239-1339	4.45	CNR
		20°45.1'	19°48.3'					
" # 4	11.vii	20°45.1'	19°48.3'	RMT8M	110-195	1339-1439	4.72	CNR
		20°47.6'	19°48.8'					
11552# 1	11.vii	20°45.4'	19°47.7'	RMT8M	195-300	1639-1739	4.09	CNR
		20°47.5'	19°47.9'					
" # 2	11.vii	20°47.5'	19°47.9'	RMT8M	100-200	1739-1839	4.23	CNR
		20°49.8'	19°48.2'					
" # 3	11.vii	20°49.8'	19°48.2'	RMT8M	15-100	1839-1939	4.09	CNR
		20°52.0'	19°48.5'					
" # 4	11.vii	20°55.5'	19°48.8'	RMT8M	1200-1300	2053-2253	7.33	Nets 2 and 3 not fished
		20°59.8'	19°49.3'					CNR
" # 5	12.vii	21°01.9'	19°49.7'	CTD PUMP	10-90	0010-0200		Samples at 10m intervals
		21°02.1'	19°50.8'	BIOLUM				
11553# 1	12.vii	22°16.5'	21°55.0'	OTSB14	4512-4535	1941-0103		Monitor trace lost on bottom
		22°26.8'	21°49.8'					13000 m.w.o.

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11554# 1	13.vii	22°31.5'	21°47.8'	CTD				
				PUMP	10-90	1500-0200		Samples at 10m intervals
		22°32.0'	21°48.8'	BIOLUM				
11555# 1	13.vii	22°19.8'	21°55.2'	MC	4568	1228(on bottom)		Cores not obtained
11556# 1	13.vii	22°29.3'	21°57.6'	RMT1+8	175-390	1630-1716	2.47	CNR
		22°30.7'	21°57.5'	CCE				
11557# 1	13.vii	22°44.1'	22°00.3'	RMT1+8	825-900	1946-2146	5.62	CNR
		22°47.5'	21°58.7'	CCE				
11558# 1	13.vii	22°48.4'	21°58.5'	CTD				
				PUMP	10-30	2306-0042		System failure after 3 samples
		22°48.4'	21°58.8'	BIOLUM				
11559# 1	14.vii	23°48.8'	22°05.6'	RMT1+8	95-420	0730-0930	7.47	CNR
		23°52.5'	22°06.6'	CCE				
11560# 1	14.vii	23°55.7'	22°06.2'	RMT1+8	110-400	1052-1252	6.97	CNR
		23°59.5'	22°06.4'	CCE				
11561# 1	14.vii	24°57.7'	21°55.8'	RMT1+8	625-820	1944-2144	6.97	CNR
		25°01.2'	21°53.4'	CCE				
11562# 1	14.vii	25°03.1'	21°53.4'	CTD				
				PUMP	5-90	2258-0056		Samples at 10m intervals
		25°03.5'	21°53.9'	BIOLUM				
11563# 1	15.vii	25°59.3'	21°59.4'	RMT1+8	600-800	0749-0949	7.33	CNR
		26°02.5'	21°58.5'	CCE				
11564# 1	15.vii	26°06.2'	21°55.3'	RMT1+8	400-580	1140-1340	7.20	CNR
		26°09.0'	21°52.1'	CCE				

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11565# 1	15.vii	26°44.2'	21°57.0'	RMT1+8	350-500	1933-2133	8.37	CNR
		26°48.0'	21°53.9'	CCE				
11566# 1	15.vii	26°49.5'	21°53.1'	CTD				
				PUMP	10-90	2325-0120		Samples at 10m intervals
		26°49.7'	21°54.3'	BIOLUM				
11567# 1	16.vii	27°48.2'	21°58.7'	RMT1+8	400-600	0740-0940	8.05	CNR
		27°52.6'	21°56.0'	CCE				
11568# 1	16.vii	27°56.2'	21°52.2'	RMT1+8	(0)-605-800	1148-1348	7.51	Hauled to surface to check net operation
		28°00.1'	21°49.1'	CCE				CNR
11569# 1	16.vii	28°36.4'	21°59.6'	RMT1+8	790-1000	2020-2220	7.96	CNR
		28°42.9'	22°00.1'	CCE				
11570# 1	16.vii	28°44.6'	21°59.7'	CTD				
				PUMP	10-90	2338-0118		Samples at 10m intervals
		28°45.3'	21°59.5'	BIOLUM				
11571# 1	17.vii	29°40.7'	22°01.7'	RMT1+8	1475->1600	0819-1116	10.93	Net sank rapidly well below calibration limit during tow
		29°48.0'	22°03.2'	CCE				CNR
11572# 1	17.vii	30°36.4'	22°03.0'	RMT1+8	25-400	1934-2134	8.50	Only net 2 fished
		30°41.4'	22°02.6'	CCE				CNR
11573# 1	17.vii	30°54.7'	22°02.1'	CTD				
				PUMP	10-90	2307-0048		Samples at 10m intervals
		30°54.8'	22°02.3'	BIOLUM				

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11574# 1	18.vii	31°47.1'	21°04.8'	RMT1+8	(50)-425-	1123-1323	5.53	Opened at 50m
		31°49.4'	21°02.9'	CCE	535			
11575# 1	18.vii	32°29.8'	20°13.6'	RMT1+8	670-825	2027-2227	6.97	CNR
		32°34.0'	20°13.4'	CCE				
11576# 1	18.vii	32°35.3'	20°13.1'	CTD				
				PUMP	10-90	2325-0057		Samples at 10m intervals
		32°35.4'	20°13.5'	BIOLUM				
11577# 1	19.vii	33°15.9'	19°19.8'	RMT1+8	300-400	0736-0936	7.69	CNR
		33°20.5'	19°19.7'	CCE				
11578# 1	19.vii	33°23.1'	19°18.5'	RMT1+8	200-300	1057-1258	6.21	CNR
		33°25.5'	19°14.8'	CCE				
11579# 1	24.vii	34°34.7'	12°58.5'	RMT1+8	535-630	0939-1139	6.93	CNR
		34°37.9'	12°55.8'	CCE				
11580# 1	24.vii	34°39.6'	12°55.0'	CTD	0-300	1241-1320		MS 300, 250, 100 & 10m
		34°39.5'	12°55.4'	MS				
11581# 1	24.vii	34°41.0'	12°55.3'	RMT1+8	660-800	1416-1617	6.43	CNR
		34°45.1'	12°55.2'	CCE				
11582# 1	24.vii	34°48.6'	13°17.9'	RMT1+8	825-1010	2025-2129	4.18	CNR
		34°50.8'	13°21.4'	CCE				
11583# 1	24.vii	34°52.4'	13°23.6'	CTD				
				PUMP	10-90	2328-0035		Samples at 10m intervals
		34°52.4'	13°24.3'	BIOLUM				
11584# 1	25.vii	34°53.0'	13°25.0'	RMT1+8	175-225	0116-0316	8.32	CNR
		34°56.7'	13°29.6'	CCE				

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11585# 1	25.vii	34°58.6'	13°31.7'	RMT1+8	250-325	0440-0650	8.73	CNR
		35°03.7'	13°34.6'	CCE				
11586# 1	25.vii	35°06.7'	13°36.6'	CTD	0-300	0830-0921		MS at 300, 250, 200, 120, 95,
		35°07.4'	13°36.3'	MS				60, 35 and 10m
11587# 1	25.vii	35°10.7'	13°35.0'	RMT1+8	725-865	1029-1229	8.46	CNR
		35°14.9'	13°34.1'	CCE				
11588# 1	25.vii	35°10.7'	13°34.3'	RMT1+8	710-870	1559-1759	7.06	CNR
		35°15.0'	13°31.5'	CCE				
11589# 1	25.vii	35°19.8'	13°28.7'	RMT1+8	1170-1225	2050-2250	6.57	CNR
		35°23.8'	13°26.6'	CCE				
11590# 1	26.vii	35°29.5'	13°22.0'	RMT1+8	90-115	0136-0306	5.35	Codend damaged on recovery
		35°31.7'	13°18.9'	CCE				CNR
11591# 1	26.vii	35°34.3'	13°15.5'	RMT1+8	630-710	0500-0700	7.42	CNR
		35°37.4'	13°11.7'	CCE				
11592# 1	26.vii	35°39.3'	13°08.6'	CTD				30l and GoFlo samples at 45m
				MS	0-300	0833-1038		MS at 300, 250, 200, 120, 90,
				W/B				70, 45 and 10m
11593# 1	26.vii	35°43.7'	13°07.9'	RMT1+8	1425-1550	1236-1536	12.46	CNR
		35°51.0'	13°07.6'	CCE				
11594# 1	26.vii	36°02.9'	13°26.6'	RMT1+8	175-225	1930-2130	6.12	CNR
		36°05.6'	13°22.2'	CCE				
11595# 1	26.vii	36°07.6'	13°19.6'	RMT1+8	750-850	2307-0107	7.42	CNR
		36°10.8'	13°15.2'	CCE				

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11596# 1	27.vii	36°12.5'	13°12.6'	RMT1+8	(0-)65-100	0235-0435	7.15	CNR. Net brought to surface
		36°15.2'	13°09.6'	CCE				to check operation
11597# 1	27.vii	36°27.8'	13°46.5°'	CTD	0-300	0836-0959		30l water bottles at 45m
				MS				MS at 300, 250, 200, 150,
				W/B				90, 55, 45 and 10m
11598# 1	27.vii	36°29.1'	13°46.5'	RMT1+8	1240-1500	1140-1440	8.41	CNR
		36°30.7'	13°40.6'	CCE				
11599# 1	27.vii	36°32.2'	14°42.2'	RMT1+8	620-700	2115-2310	8.01	CNR
		36°32.9'	14°42.9'	CCE				
11600# 1	28.vii	36°38.0'	14°49.2'	CTD				
				PUMP	10-90	0042-0150		Samples at 10m intervals
				BIOLUM				
11601# 1	28.vii	37°01.9'	15°56.2'	CTD	0-300	0911-0936		MS at 300, 250, 200, 150,
				MS				80, 50, 35 and 10m
11602# 1	28.vii	36°43.6'	16°05.6'	RMT25	(0-)630-	1354-1615		CNR
		36°47.7'	16°03.5'		690			
11603# 1	18.vii	37°59.9'	16°29.1'	RMT1+8	500-600	2036-2236	8.10	CNR
		37°04.4'	16°31.8'	CCE				
11604# 1	28.vii	37°06.6'	16°33.4'	RMT1+8	125-200	2351-0151	7.96	CNR
		37°09.9'	16°36.5'	CCE				
11605# 1	29.vii	37°40.1'	17°48.7'	CTD				30l and GoFlo samples at 38m
				MS	0-200	0841-0937		MS at 200, 150, 90, 80, 55, 38
				W/B				26 and 15m

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11606# 1	29.vii	37°44.0'	17°51.9'	RMT1+8	875-1100	1133-1433	13.00	CNR
		37°51.6'	17°53.6'	CCE				
11607# 1	29.vii	38°12.2'	18°34.7'	RMT1+8	300-400	2137-2307	5.85	CNR
		38°14.6'	18°32.8'	CCE				
11608# 1	30.vii	38°16.5'	18°33.4'	CTD				
				PUMP	10-90	0021-0129		Samples at 10m intervals
				BIOLUM				
11609# 1	30.vii	38°17.5'	18°34.3'	RMT1+8	475-1150	0223-0350	5.35	Oblique tow
		38°22.0'	18°34.7'	CCE				CNR
11610# 1	30.vii	38°38.9'	19°15.4'	CTD				30l WB at 28m
				MS	0-300	0838-0931		MS at 300, 150, 90, 70, 45,
				W/B				28, 24 and 10m
11611# 1	30.vii	38°42.7'	19°14.8'	RMT25	925-1010	1121-1421	13.72	Net failed to fish
		38°49.8'	19°12.1'					
11612# 1	30.vii	39°02.7'	19°09.9'	RMT1+8	1250-1500	2139-0039	12.37	CNR
		39°09.4'	19°14.3'	CCE				
11613# 1	31.vii	39°13.1'	19°16.1'	RMT1+8	50-150	0225-0425	9.31	CNR
		39°18.7'	19°14.3'	CCE				
11614# 1	31.vii	39°27.9'	19°56.4'	CTD	0-300	0850-0940		MS at 300, 150, 85, 62, 45
				MS				37, 30 and 10m
11615# 1	31.vii	39°28.9'	19°56.7'	RMT1+8	750-950	1048-1248	6.97	CNR
		39°32.0'	19°57.3'	CCE				
11616# 1	31.vii	39°36.8'	20°03.2'	RMT25	0-600	1548-1618		Net closed prematurely CNR

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11617# 1	31.vii	39°44.2'	20°10.4'	RMT1+8	1325-1500	2058-2358	9.85	CNR
		39°49.6'	20°15.2'	CCE				
11618# 1	1.viii	39°52.0'	20°15.7'	RMT1+8	85-150	0140-1340	7.55	CNR
		39°55.7'	20°15.1'	CCE				
11619# 1	1.viii	39°58.1'	21°10.9'	CTD				GoFlo samples at 50 and 85m
				MS	0-300	0842-0934		MS at 300, 150, 100, 85,
				W/B				65, 50, 40 and 10m
11620# 1	1.viii	40°01.6'	21°10.8'	RMT1+8	775-885	1115-1315	8.23	CNR
		40°06.0'	21°14.0'	CCE				
11621# 1	1.viii	40°10.5'	21°17.5'	RMT1+8	685-790	1542-1712	5.53	CNR
		40°14.4'	21°18.1'	CCE				
11622# 1	1.viii	40°45.8'	20°35.1'	CTD				
				PUMP	10-90	2328-0038		Samples at 10m intervals
				BIOLUM				
11623# 1	2.viii	40°48.6'	20°36.1'	RMT1+8	125-400	0143-0355	11.20	CNR
		40°54.4'	20°36.4'	CCE				
11624# 1	2.viii	41°15.5'	20°08.8'	CTD				30l and GoFlo samples at 55m
				MS	0-300	0847-0944		MS at 300, 150, 120, 85, 70
				W/B				65, 55, 45 and 10m
11625# 1	2.viii	41°18.8'	20°09.2'	RMT1+8	1000-1200	1140-1340	7.42	CNR
		41°23.2'	20°10.1'	CCE				
11626# 1	2.viii	41°25.4'	20°11.5'	RMT1+8	25-250	1535-1635	3.64	CNR
		41°27.1'	20°12.1'	CCE				

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11627# 1	3.viii	43°00.7'	17°53.3'	RMT1+8	195-400	0932-1132	8.10	CNR
		43°03.5'	17°55.9'	CCE				
11628# 1	3.viii	43°05.5'	17°57.2'	CTD				30l samples at 43m
				MS	0-300	1221-1310		MS at 300, 150, 70, 55, 42,
				W/B				35 and 10m
11629#1	3.viii	43°09.0'	17°59.2'	RMT1+8	450-600	1431-1639	9.49	CNR
		43°14.4'	18°07.0'	CCE				
11630# 1	3.viii	43°47.9'	17°04.9'	CTD				
				PUMP	10-90	2327-0036		Samples at 10m intervals
				BIOLUM				
11631# 1	4.viii	44°31.4'	15°40.8'	CTD	0-300	0838-0920		MS at 300, 150, 90, 60, 37,
				MS				33 and 10m
11632# 1	4.viii	45°00.5'	14°50.4'	CTD	0-300	1407-1430		Comparison with 11631
11633# 1	4.viii	45°01.6'	14°50.0'	RMT25	0-190	1517-1618		Test of system: CNR
		45°05.9'	14°51.2'					
11634# 1	5.viii	46°44.0'	11°49.1'	CTD	0-300	0834-0924		MS at 300, 150, 70, 50,
				MS				45 and 25m
11635# 1	5.viii	46°46.4'	11°45.5'	RMT25	(0-)980-	1101-1401	12.82	Net failed to close
		46°47.0'	11°34.5'		825			Catch retained
11636# 1	5.viii	46°43.3'	11°28.3'	RMT1+8	300-220	1654-1754	3.37	CNR
		46°43.4'	11°25.3'					

Station series	Date 1987	Latitude (Start/finish) N	Longitude W	Gear	Depth (m)	Fishing time (GMT)	Flow Dist. KM	Remarks
11637# 1	5.viii	46°43.7' 46°43.6'	11°21.8' 11°17.6'	RMT1+8	775-825	1907-2004	4.18	CNR
11638# 1	6.viii	47°56.8'	09°03.1'	CTD MS	0-200	0829-0854		MS at 50m

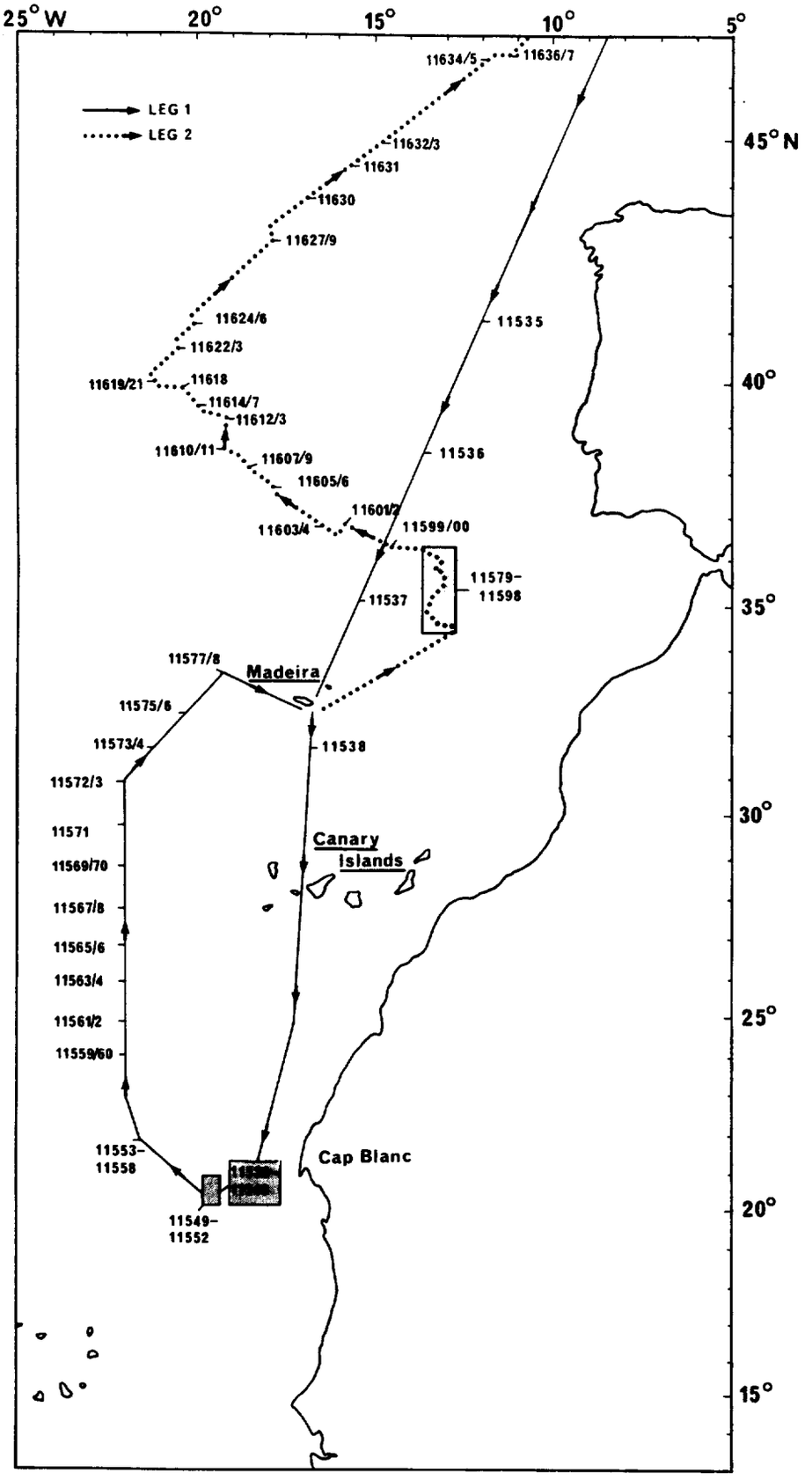

Fig 1 DISCOVERY Cruise 168 track chart
JUNE 23 - AUGUST 7 1987