NATIONAL INSTITUTE OF OCEANOGRAPHY
Wormley, Godalming, Surrey.

R.R.S. DISCOVERY
CRUISE 18 REPORT

JULY - AUGUST 1967

PHYSIOLOGY AND BIOLOGICAL GEAR TRIALS

N.I.O. CRUISE REPORT SERIES: CR.18

CONTENTS

SCIENTIFIC PERSONNEL

Mr. M.V. Angel	N.I.O. (left in Teneriffe)
Mr. J. Badcock	N.I.O.
Mr. A. de C. Baker	N.I.O.
Mr. J. Blaxter	Aberdeen University
Miss K. Chidgey	N.I.O.
Dr. M.R. Clarke	N.I.O. (Scientist in Charge)
Mr. P.M. David	N.I.O. (Joined in Teneriffe)
Prof. E.J. Denton, F.R.S.	Bristol University and M.B.A.
Mr. B. Ellis	N.I.O.
Dr. J.B. Gilpin-Brown	M.B.A.
Dr. P. Herring	N.I.O.
Mr. N. Macleod	N.I.O.
Mr. N. Moss	N.I.O.
Miss N. Naftel	N.I.O.
Mr. B. Page	N.I.O.
Mr. D. Pugh	Cambridge University (Joined in Teneriffe)
Dr. B.L. Roberts	M.B.A.
Dr. D. Sandeman	St. Andrew's Marine Laboratory (Joined in Teneriffe)
Mr. C. Wardle	Marine Laboratory, Aberdeen.
Mr. F.J. Warren	M.B.A.
Miss F.J. Whish	M.B.A.
Mr. R. Wild	N.I.O.

ABBREVIATIONS

EMT	Engel's Midwater Trawl
IKMT	Isaacs-Kidd Midwater Trawl
N113	Net with mouth = 1 sq. m.
NF70	Plankton net used obliquely (N70B) or vertically (N70V)
NN	Neuston net
FRN 30	Free rise net with mouth = 30 ft. diameter
W/B	Water bottles (used for hydrographic sampling)
BT	Bathythermograph
Acoustic CDB	Acoustic catch dividing bucket
PES	Precision echo sounder
TMT1	Tucker Midwater Trawl with a sampling area of 1 sq. m.
TMT1 X 2	As above but with 2 nets one above the other.
TMT8	Tucker Midwater Trawl with a sampling area of 8 sq. m.
TMT90	Tucker Midwater Trawl with a sampling area of 90 sq. m.
DTP	Depth telemetering pinger
BLL	Longline with hooks on bottom

PRINCIPAL OBJECTS

The main aims of the cruise may be conveniently grouped under the headings gear trials, ecological work and physiological work. While the N.I.O. personnel were principally concerned with gear trials, some ecological and physiological work was carried out by them. The visiting physiologists were concerned with both the study of very specialised examples of physiological mechanisms and also the relationship between various functional properties of animals and their distribution.

More specifically the aims were:-

1. Trials of four new types of net with comparisons between these and nets previously used. New nets are the TMT1, an opening and closing net (it is also used with two similar nets one above the other, TMT1 X 2); the TMT8, another opening and closing net; the TMT90 and the free rise net (FRN). Trials were also carried out with net cod ends instead of the orthodox buckets.

2. Trials with a bottom longline (B.L.L.).

3. Trials of two depth telemetering pingers and some new N.I.O. shearpin hydrostatic releases.

4. Trials of the acoustic C.D.B.

5. Trials of the Echo ranging camera.

6. Sampling off Morocco and Fuerteventura to find any marked differences in faunal composition between this and previous years.

7. Bottom longlining to investigate the bottom fish in depths of 800 - 1500 m. off Fuerteventura and to evaluate the method for further work.

8. A study of the buoyancy of marine animals.

9. A study of the eyes and photophores of fish and squids.

10. A study of the survival of fish after capture.

ITINERARY

"Discovery" sailed from Plymouth at 2200 hours 14/7/67 and after several runs over the measured mile to calibrate the E.M. log, proceeded to Falmouth for fuel. At 1300 hours 15/7/67 the ship sailed from Falmouth. The PES fish was lowered at 1635 hours but this did not function and it was replaced by the spare PES fish at 2041 hours the same day. During the passage South to Fuerteventura a number of stations were completed to calibrate or test fishing gear and to provide animals for the physiologists to test their instruments. During the passage south to 36°N 10°W two IKMT's and calibrations of the CDB and both DTPs (Depth telemetering pinger) were carried out at about 46°N 7°W. A TMT8 (Tucker Midwater trawl) was used at 42°41'N 10°W and the TMT90 was used at 38°41'N 10°02'W and 36°N, 10°W. The ship then proceeded to the Moroccan shelf to undertake a brief survey for comparison with the work done in 1966 (Cruise 15). To this end five TMT8's were completed and a brief echo sounding survey of the shelf edge was made; in addition, flowmeters and a DTP were calibrated and a large NN was used. Upon leaving the Moroccan shelf at 2015 hours 21/7/67 the ship proceeded direct to the south east of Fuerteventura where work has been carried out in two previous years.

In this sheltered region off Fuerteventura work was carried out continuously between 1455 hours 23/7/67 and 1150 hours 7/8/67 and consisted of 18 TMT8s, 8 TMT90s, 2 TMT1 X 2s, 3 IKMTs, 10 EMTs, 4 N113 X 3s, 6 N113 X 2s, 3 N113s, 6 NH and LH stations, 5 BLL's, a FRN30 and numerous NN hauls in addition to a W/B series to 1000 m, a BT, photometer measurements to 100 m, and tests with the echo-ranging camera, the camera for observing animals under pressure, the acoustic C.D.B. and the DTP. Upon leaving Fuerteventura at 1200 hours 7/8/67, course was set to Teneriffe. En route, a deep series of NF70 V's was done at 28°28'N, 15°20'W and Santa Cruz was entered at 0700 hours 8/8/67.

The ship sailed from Santa Cruz, Teneriffe at 0700 hours 10/8/67 and returned to the Fuerteventura region. Work commenced again at 2010 hours 10/8/67 and included 9 TMT8s, 7 EMTs, 2 IKMTs, 3 BLL's as well as further tests with the cameras before the ship sailed for Plymouth at 1005 hours 16/8/67.

While on passage to Plymouth 4 geophysical stations were carried out for Mr. D. Pugh of Cambridge at 31°42.7'N 15°00.6'W; 39°32.0'N 15°00'W; 43°36.0'N, 15°47.0'W and 45°13'N, 12°35'W (Stations 6444, 6446, 6448 and 6449). In addition TMT8's were carried out at 32°15.0'N, 15°00'W (Station 6445) 39°35.0'N, 15°05.0'W (Station 6447) and 45°13.0'N, 12°35'W (Station 6450). The ship reached Plymouth 2300 hours 23/8/67.

SCIENTIFIC PROJECTS

1. Tucker Midwater Trawl (TMT) Series of Nets
(A. de C. Baker and M.R. Clarke)

Several nets similar to one devised by Tucker of San Diego have been made and were tried on this cruise.

a) TMT1 X 2 (A. de C. Baker and M.R. Clarke)

This consisted of 2 meter nets carried between the same side wires so that the lower bar of the top one formed the upper bar of the lower one. This net was tried on three occasions to see what difficulties there may be if several such nets were used one above the other. So far, only the euphausiids have been counted in one of these hauls. 90 were found in the upper net and 140 in the lower. The difference between these was largely in the number of the more active species and could be explained in terms of downward avoiding movements of larger animals.

b) TMT8 (M.R. Clarke and A. de C. Baker)

This net is about the same size as an IKMT but has fine mesh for the purpose of catching euphausiids and can be opened and closed at the mouth. The net was used 35 times but the opening and closing gear was only used 4 times effectively.

From the hauls done it is clear that the net catches a very wide size range of animals from the largest normally caught in an IKMT down to large copepods and chaetognaths. However, catches contain fewer of the larger animals than those of the IKMT. As one would expect, the volumes of the TMT8 catches are considerably greater than comparative IKMT hauls (twice the volume) because of the fine netting.

Condition of the catches is similar to that of IKMT catches when a metal bucket is used on the TMT8.

The euphausiid catches taken by the TMT8 are of the order of 1,000's and sometimes 10,000's compared with 100's taken by the N113. The size range of euphausiids taken is sufficient for the net to sample adults of all species but finer mesh nets would have to be used for quantitative work on early larvae.

The net proved very easy to handle from R.R.S. "Discovery", was stable in the water and registered loads of less than one ton. The opening and closing was achieved by using hydrostatic shearpin releases. The use of these depended on knowing the depth accurately while towing and trouble with the depth telemetering pinger resulted in them not opening or premature closure on several occasions, while leakage of one of the release gears prevented the net from opening on two occasions. However, the actual method of opening and closing proved quite effective and little leakage into the closed net appears to take place.

The net depth to wire out is about 1:2 down to about 500 m. depth but gets better the deeper the haul and the deepest haul of 1400 m. was attained with 2100 m. of wire out.

c) TMT90 (M.R. Clarke)

9 trials with this large net have shown that handling is not unduly difficult and it is possible to use a large trawl from a single warp without imposing very large loads on the warp. The trials have indicated some improvements to the gear and a new net could be even easier to handle.

The catches of this net were extremely encouraging as they included squid and fish larger than any taken in the B.C.M.T. and the condition of the catches was very good, many animals being still alive when brought inboard. The volume of the catches averaged the same as for the EMT taken in the same place during this cruise (about 5 ml/min).

2. Cod ends and buckets (M.R. Clarke and A. de C. Baker)

After trials with net cod ends and buckets at the NPL flume at Feltham the TMT nets were fitted with a net cod end having a large filtration area relative to the entrance from the net. These were tried during most of the trawls and comparisons were made between these and the orthodox metal buckets. There is little doubt that animals were abraided by the netting and were generally in better condition in the buckets. It seems that large catches tend to be in better condition than small ones when the netting cod ends are used, presumably due to a greater protection from the netting towards the centre of the catch.

3. Free rise net (FRN) (M.R. Clarke)

The 30 feet diameter FRN was lost on the first occasion it was used so that no assessment of its value for sampling can be made. The new net ring proved much easier to assemble than the one used in 1966.

4. Bottom longlining (M.R. Clarke)

Bottom longlines were used on eight occasions off Fuerteventura in depths of 930 - 1600 m. During the first two attempts the line did not lie along the bottom and only a single fish (Aphanopus carbo) was caught. In all later hauls (932 - 1520 m.) a little more weight was used and catches varied between 7 and 19 fish per haul. The six successful hauls caught a total of 73 fish on 287 hooks. Thus, about 25% of the hooks caught fish; 42% of the hooks lost their bait and 5% of the hooks were lost. Only 29% of the hooks remained with bait on and of these 32% had been chewed or bitten.

The fish were identified as 29 Centroscymnus coelolepis, 4 Etmopterus spinax, 8 Deania, 1 Lepidorhinus, 7 Scymnodon, 2 Raia longirostra, 1 Aphanopus carbo, 7 ? Mora, 2 Macrurids, 3 Synaphobranchus, 1 "fish" and 8 "fish heads". A rare squid, Tetronychoteuthis sp. was found in the stomach of one of the small sharks.

This should prove a most useful method for studying the animals living close to the bottom particularly in the "canyons" associated with oceanic islands.

5. Engel's Midwater Trawl (M.R. Clarke)

17 hauls were made with the EMT but the catches were much smaller

(averaging less than one sixth) than at the same place in November 1966 (Cruise 15). Again a number of very interesting animals were caught but the condition was certainly not as good as animals caught with the TMT90.

6. Echo-ranging camera (B. Page)

This consists of the standard N.I.O. Deep Sea Underwater Camera with a modified triggering system. The standard camera is usually triggered by a bottom weight when being used for photography or by a baited paternoster when being used to photograph midwater fish.

The echo-ranging system provides a trigger to the camera whenever an object of sufficient size is in range in the field of view of the camera. This is achieved by having a 67 KHz echo sounder transducer mounted on the same framework as the camera so that both camera and echo sounder view a common cone of water. The transducer is a line and cone device with a beam angle of about 10°, it transmits 0.2 mS pulses of 67 kc/s at a repetition rate of 10 p.p.s. the power output being 200 W. The same transducer is used for both transmission and reception and after being amplified the received signals are passed to a range gate which may be set to pass only those signals which correspond to objects within a 5 ft. section of water in the field of the camera. This 5 ft. section may be set to be at any range from the camera between 5 and 20 ft. The signal then passes from the range gate to a level detector which will produce a trigger to the camera if the signal is above the predetermined level.

The first attempts at using the echo-ranging camera were thwarted by a number of faults, such as failure of the slip ring gear on the winch and power loss down the long cables used. However, it was eventually used on one occasion at depths between 10 and 100 m. but as no echoes were seen it was decided to arrange targets on the next dip so that some idea of the signal levels which would be obtained from various animals could be ascertained. The targets used were:- Spirula, Cyclothone and Decapods; large echoes were received in each case but it is thought that these echoes were largely due to air trapped in the mesh of the bag used to hold the fish.

Unfortunately the failure of the flash tubes prevented any further camera dips since the spares carried had been used on other equipment.

7. Camera for observing animals under pressure (P. Herring)

Preliminary tests with live animals lowered on a vertical wire and photographed at various depths with a modified underwater camera have showed that this method of obtaining information on the behavioural responses of animals at different pressures can yield useful information in the case of the larger crustacea, but is unlikely to be as effective for fish or squid. The problems to be overcome are partly optical, in that without additional lenses only large animals provide pictures of sufficient clarity, and partly interpretive, but the use of short bursts of ciné film instead of single exposures would obviate these.

8. Depth telemetering pinger and hydrostatic releases (M.R. Clarke)

The DTPs proved rather unreliable during the cruise mainly due to leads which leaked at low pressures. Such unreliability reduced the effectiveness of the hydrostatic shearpin releases because it is essential to know the depth of the net during fishing in order to operate the opening and closing releases at the right time.

Trials of the hydrostatic releases showed that brass shearpins were much more reliable than silver solder shearpins and in six trials one size of brass pin sheared at 480, 488 and 477 m. and another sheared at 652, 647 and 637 m; a range of less than 3% of the depth.

9. Conditions off the Moroccan Shelf (M.R. Clarke)

A 24 hour visit was made to the Moroccan shelf area previously studied on cruise 15 in 1966. TMT hauls were made over the shelf, the slope and in deep water just off the slope. As in 1966, they again showed a great sparcity of plankton. This was remarkable in view of the presence of larger organisms in the area; echo traces showed fish shoals, trawlers were operating in the region and a concentration of Mola was passed through, (average of one was passed every minute for 40 minutes). As in 1966 there was a scattering layer just above the bottom between 90 and 200 fathoms and irregular discontinuities were present on the water surface.

10. Conditions off Fuerteventura (M.R. Clarke)

The water conditions were rather different from previous years at Fuerteventura. The water varied from the dark green of more inshore water to the clearer and more blue oceanic water. Both colours were in patches and indistinct discontinuities were regularly seen. Nets were regularly covered in green slime which was not noticed previously and the EMT hauls contained about one sixth of the catch by volume of the 1966 visit to the area.

Temperature/salinity curves and salinity and temperature profiles down to 1000 m. suggest a distinct water mass, possibly Mediterranean water, was present at a depth of 600 - 800 m. during this cruise but was absent during the late Autumn of 1965 and 1966. The bottom here was only 1200 m. and this may have caused Mediterranean water to be rather shallower than usual elsewhere. Surface salinity and temperature were lower than previously encountered in this region.

While towing nets strong currents were encountered. From a comparison of the distances covered according to land fixes and the distances recorded by the E/M log there was a surface current running from the North East probably caused by the generally North wind. Nets fished South West to North East (i.e. against the surface current) tended to go deeper; therefore it seems likely that there was a deep current from the South West.

11. Chaetognaths (P.M. David and Miss K. Chidgey)

The main aim of the work done on this group has been in trying to obtain a series of mature stages of the so-called *Eukrohnia bathypelagica* Alvarino 1963, for histological investigation of the ovaries. The specimens which have been assigned to this species could well be suspected to be late mature and spent forms of *E. hamata*. Alvarino, in her published description of this species, shows the earliest developmental stage of the ovary as a small coiled body, which has previously been described as the final remnant of the spent ovary of E. hamata. Only 10 specimens with coiled ovaries have been collected in the various hauls on this present cruise, but about 50 specimens with ovaries in the elongated form have been collected.

These specimens and other chaetognath material have been preserved in a range of fixatives with the object of determining which is best for subsequent histological work on this group.

Several species have been kept alive for varying periods in temperature controlled tanks. The forms with a thick body wall such as S. planctonis have been the most resilient and have remained alive for periods up to 40 hours, whereas those similar in form to S. hexaptera have only remained alive for periods up to 18 hours.

Observations of the movements and pigmentation of live chaetognaths have been made, the most interesting of which was a brownish black pigmentation in the gut of S. planctonis which has not been described in any literature on this species.

12. Euphausiids (A. de C. Baker)

The euphausiid fauna off Fuerteventura consisted of the species previously found during the SOND cruise and thecruise in October 1966, the most notable features being the earlier stage of development of larvae and the consequent reduction in the size of catches in terms of volume.

Moulting

Three specimens of Euphausia hemigibba moulted during the first 24 hours in cold tanks and survived for a further period of 2 days.

Reproduction

Specimens of various species were fixed for histological work on spermatophores and to show the musculature of the copulatory organ.

A swarm of Meganyctiphanes norvegica

At 0200 hours on 21st August at 43°38'N, 15°36'W the engine room filters became choked with large numbers of M. norvegica causing the engines to be switched off due to overheating. The specimens were retained and a rough estimate of numbers made. Both at 0200 and again at 0400 approximately 9,000 were collected. No estimates can be made of the density in the water since accurate times at which the blocking started and finished are not available, nor is it possible to determine any rates of flow through the filters. A neuston net was fished for 12 minutes at 0300 hours but no Meganyctiphanes were taken. The inlet to the engine room is at approximately 16 ft. depth but it is not known whether the lack of Meganyctiphanes in the NN was due to their being well below the surface or to the net being fished between two swarms. No luminescence was visible at the surface at 0300 hours.

The swarm(s) consists largely of fully grown or nearly fully grown specimens but includes a small proportion of adolescents.

13. Decapod development (P. Herring)

Work involving the rearing of the eggs of a number of species of bathypelagic decapod crustacea has had considerable success in that live larvae have been obtained from the eggs of the commoner species reared in vitro, and the larvae have been maintained through up to three months, providing confirmatory evidence for the postulated early developmental stages of Acanthephyra purpurea, Oplophorus grimaldii and Systellaspis debilis. A detailed examination of the embryonic development and hatching processes of Acanthephyra purpurea has been undertaken.

Preliminary attempts have been made to evaluate the efficacy of antibiotics and of ultra-violet sterilised and artificial seawaters in the maintenance of oceanic plankton in the laboratory.

14. Cephalopods (M.R. Clarke)

These were not sorted on board. Rather fewer were caught relative to effort than on previous occasions at Fuerteventura. The TMT90 caught fewer of the smaller squids than did the EMT but seemed to catch as many of the larger squids such as Todarodes sagittatus. Small squid were observed flying during daylight on several days and these were probably Ommastrephes caroli which was the commonest species encountered at the surface at night.

Tetronychoteuthis was found in the stomach of a Centroscymmus coelolepis (Portuguese shark) taken on a bottom line. Beaks of this rarely caught squid are common in stomachs of sperm whales caught off Durban.

15. Fish (J. Badcock)

The few stations off Morocco allowed little scope for comparison of species with those caught off Fuerteventura, although the abundance of the hatchet fish Argyropelecus olfersi off Morocco and its absence off Fuerteventura was very obvious.

The fish catches, compared with cruise 15, were generally small, and the dominant group, the myctophids, were fairly immemorable apart from a large Lampanyctus crocodilus of S.L. 168 mm. Diaphus rafinesquei and Lampanyctus pusillus appeared to be amongst the more abundant of the myctophids, and quite a high proportion of the latter species were infected by parasitic copepods. Gonichthys coccoi was the commonest myctophid caught in the NN night hauls, but was not apparent in any type of day net. However, a complete vertical distribution daytime series was not carried out. Symbolophorus veranyi and Ceratoscopelus maderensis were also occasionally caught in the NN.

Of the other fish stomiatoids were not over numerous, apart from Cyclothone, and there was a complete absence of Idiacanthus females until after the Tenerife port call, although a few males, c S.L. 35 mm, were caught before this. Malacosteids appeared to be among the more commonly caught stomiatoids. Six examples of Argyripnus atlanticus were brought up in a 230 - (0)m TMT8 haul, in the Fuerteventura bay, which according to the D.T.P. went within 40 m. of the bottom (Station 6374). A deal fish was brought up in the first EMT haul (Station 6404), and the final EMT yielded a fine brotulid from 480 - (0) m. Several evermanellids were caught during the cruise, including Evermanella indica, and E. sicaria. Chiasmodon was common, and one which was caught had an extremely distended belly. The stomach was opened and a Lampadena sp., bent double, was revealed. Originally this prey was c 2/3rds the length of its predator, which had a S.L. 145 mm. A particularly fine Saccopharynx was caught in the N113 from 1050 - (0) m. in a night haul at the Oceanic Station 6445 near Madeira.

Generally the fish were in a reasonable condition, but the fish in the best condition were brought up in nets using a metal bucket.

The few bottom longlines made yielded promising results. The majority of fish hooked were squalid sharks, of which five fenera were represented, namely Centroscymnus, Scymnodon, Deania, Centrophorus (Lepidorhinus) and Etmopterus. 2 large rays were also caught, and also a number of teleosts including Aphanopus carbo, a macrurid, 2 deep sea eels, and Mora. From seven lines (50 hooks apiece) some 46 squalid sharks were caught. The gut contents of the squalid sharks were examined but most of these were found to be empty. In several cases the stomach contained the heads of mora-like fish, some of which had definitely been hooked already. The cephalopod Tetronychoteuthis was found in the stomachs of two Centroscymmus coelolepis, and some decapods were found in the spiral valve of the same.

Many surface fish were seen. Several sharks were reported, but only one was identified, as a hammer head, whilst underway from Morocco to Fuerteventura. On this stretch, forty-one Mola mola were observed in as many minutes. Around Fuerteventura large numbers of flying fish were seen, of which one flew on board.

Measurements of the jelly sheath thickness around Chauliodus danae, C. sloani and Stomias boa were made. Some Myctophid swimbladders were fixed, and a number of myctophids were deep frozen for further work.

16. Zooplankton pigments (P. Herring)

The pigmentation of the isopod Idothea metallica has been studied for comparison with that of two littoral species of the same genus, and a quantity of material has been deep-frozen for subsequent detailed analysis of the carotenoid constituents.

Considerable material has been collected for later analysis of the carotenoid and carotenoprotein pigments of the eggs of several species of bathypelagic decapod crustacea, and a number of horizontal hauls at several depths to 1000 m. have been made for determination of the depth distribution of carotenoid pigments in the smaller zooplankton, and its correlation with ambient light intensities.

17. Amphipod bioluminescence (P. Herring and B. Roberts)

Work has continued on bioluminescence of species of Scinidae, with particular emphasis upon electrophysiological experiments. Most such work has been carried out upon Scina crassicornis, and in this species flashing is obtained in response to electrical stimulation at physiological levels. Light production is synchronous with the stimuli, and has a latent period of about 20 msec. Individual flashes have a total duration of about 60 msec., show summation at stimulus frequencies between 10 and 100 per second, and the responses are clearly neural in origin. Continuous light production in moribund animals following brief electrical stimulation suggests the possibility of inhibitory control also obtaining in healthy animals.

Electrical stimulation of a number of different species of Scina and Acanthoscina has invariably elicited luminescence, and it seems probable that this phenomenon obtains in all the species of Scinidae.

Examination of live animals under ultra-violet light has shown that the sites of luminescence are usually fluorescent, in keeping with reports of the fluorescence of luciferin in a number of other bioluminescent systems.

Material has been fixed for light and electron microscopic study of the light organs involved.

18. Survival of Fish (J.H.S. Blaxter, C.S. Wardle and B.L. Roberts)

I. Post-mortems and survival

The main nets (TMT, EMT, IKMT) did not produce many fish in good condition, the TMT90 and IKMT being the best. At an early stage in the cruise some possible causes of death were considered, apart from the more obvious ones such as abrasion and similar physical damage.

a) Embolisms and swimbladder

Clear cases of embolisms were only seen in one Argyropelecus and two line-caught Mora. They do not seem a common cause of death. Air-filled swimbladders were either swollen or ruptured and the fish floating. Some specimens which were still active under these conditions should have responded to re-pressurising had the pressure vessel been available. Withdrawl of air by hypodermic is probably too risky without a detailed knowledge of the anatomy within the body cavity. No cases of emphysema (interstitial gas) were seen.

b) Osmotic imbalance

Freezing point depressions of blood samples which were measured on board were very low (-1.2 to -1.5°C) suggesting dehydration. Many others await analysis ashore. Imbalance then seems to be a contributory cause of death. Holding fish in 50% sea water delayed death appreciably compared with controls (but did not permit any revival).

c) Respiratory failure

Fish are almost certainly pinned against the net during capture and are unable to open the operculum. This may be a reason why the netting cod-ends did not improve survival. Many fish examined on deck had hearts beating and may be considered as potential material for resuscitation. Passing water over the gills showed a hint of promise in restoring respiratory reflexes. Due to the time taken to do this manually its success as a technique can only be evaluated after the development of suitable apparatus.

d) Temperature shock

Catches from deep water were kept at 10°C but the modified cod-end for bringing the catch up in sub-thermocline water was not ready in time for the cruise.

e) It is well-known that fish suffer stress effects on capture. Techniques for assessing this are still being developed and were not used on board. They would require some fish in rather better condition than those available, and must include experiments on the physiology of tank adaptation.

f) The use of anaesthetics as tranquillisers was not carried far because of the generally poor condition of the fish. With surface fish caught by the neuston net it was clear that the concentration suitable for both long-term and short-term immersion was very critical.

g) Other temperature and pressure effects. Examination of the blood of mesopelagic and surface fish showed that the former had very low haematocrit values (3 - 10%) with extremely rapid sedimentation of the red blood cells. This led to a programme of sampling which occupied much of the cruise.

II. Relationship between metabolism, activity and certain physiological features

Low haematocrits and rapid sedimentation of the red blood cells suggested that a lowering of the plasma viscosity at the high temperatures and low pressures near the surface could have a marked effect on cardiac output and oxygen availability, so accelerating death. Indeed these factors could well limit vertical migration and even at greater depths have an influence on metabolism and activity and might also be related to the watery flesh and diffuse muscle structure of many deep-sea fish. To try and relate these aspects of the blood to the consistency of the muscles and high water content of the body generally a number of individuals from both mesopelagic and surface species were sampled in detail, as shown below:-

(i) Haematocrit and blood smear.

(ii) Sedimentation rates of red blood cells at different temperatures in selected species.

(iii) Viscosity of plasma at different temperatures, using an improvised "falling-sphere" viscometer, in selected species.

(iv) Wet and dry weight.

(v) Heart weight.

(vi) Freezing point depression of blood and muscle fluid.

(vii) Histology of muscle, especially ratio of red : white muscle and general muscle texture.

(viii) Histology of the kidney, especially of the distal tubules to relate to wateriness of the tissues.

Considerable effects of temperature on viscosity and sedimentation were measured on board and related to final haematocrit values, both in mesopelagic and surface species. The remaining material will be worked on ashore.

19. Eyes of fish and squid

(i) Dark-light adaptation (J.H.S. Blaxter)

Whether mesopelagic fish, many of which have a pure rod retina, can light-adapt is of interest when considering light as limiting vertical range. The eyes of about 20 species were fixed after light-and-dark-adaptation for a later histological examination of the retinal masking pigments. A further three species were held at different light intensities to determine the light level at which the pigment movements, if any, take place. One light station was done to obtain a measure of underwater light conditions in the area worked. This gave an attenuation coefficient of 0.045.

(ii) On the lenses from the eyes of fish and squid (E.J. Denton & F.J. Warren)

It had previously been shown that the absorption spectra of the visual pigments of oceanic animals change greatly with depth; on this cruise this work was extended by a study of the lenses from the eyes of fish and squid.

It was shown that there are very great differences between different fishes and squid in the absorption of light in the blue and ultra-violet. In general, the lenses of animals which live near the surface in bright light absorb the ultra-violet very markedly whereas the deeper living animals, which live always in dim light, have lenses which are transparent down to about 310 mu. These differences are particularly great in the oceanic squid for which the absorption of light by the lenses range from that of the bright yellow lenses of the flying squid Onychoteuthis banksi which absorb light heavily up to about 430 mu to the lenses of the deep living squid, such as Chiroteuthis veranyi, which transmit light down to 310 mu. The most surprising finding was that both Calliteuthis meleagroteuthis and Histioteuthis bonelli had one lens like those of Onychoteuthis and one lens like those of Chiroteuthis. In both of the former species one eye is very much larger than the other and the lens of this eye is bright yellow in colour. This yellow colour is entirely confined to the outer layers of the lens which contain a pigment absorbing heavily between 440 and 320 mu. The inner layers of the lens are transparent to the near ultra-violet It seems certain therefore that in small animals the lenses of these squid are almost identical in their spectral absorbing properties and like those of the deep-living squid. Later in life one eye becomes much larger than the other and adapted for surface conditions. The large eye is unusual in shape, and its lens has a ratio of focal length to radius much greater than the 2.6 (Mattheison's ratio) found for almost all squid and fish lenses.

It was also shown on lenses from the eyes of the large fish Mora and Centroscymnus that the fish lens is virtually free from chromatic aberration in the near ultra-violet. This is quite unlike the human lens which has very serious chromatic aberration even in the blue. It is usually considered that terrestrial animals absorb ultra-violet to diminish the effects of chromatic aberration; this clearly cannot be true of the fish.

(iii) Eye lenses (C. Wardle)

Lenses from many of the named species caught during the cruise were collected for N. Wilkins, Marine Laboratory, Aberdeen, who will examine by electrophoresis the species specific pattern of their protein composition.

20. The Photophores of Argyropelecus (E.J. Denton, J.B. Gilpin-Brown & B.L. Roberts).

As a continuation of earlier work in Plymouth on the reflecting layers of fishes, a study was made of the organisation of the photophores of Argyropelecus.

It is generally thought that many of the photophores on the ventral surfaces of deep sea fish are used to match the light falling on the fish from above and so make them invisible when viewed from below. On the present cruise, it was shown that the light distribution from such photophores in three species of Argyropelecus was decided by the special properties of the reflecting tubes down which the light is projected.

The outer surfaces of these tubes are usually half-silvered, containing platelets consisting of piles of broad guanine crystals. Sometimes there are two layers of such crystals, differing in their spectral reflecting properties, and set at different angles with respect to the surfaces on which they lie.

The inner reflecting surfaces of these tubes are always made of densely-packed long thin crystals whose long axes run dorso-ventrally. When light, from the photogenic source above, strikes such a surface it is reflected specularly, i.e. with the angle of incidence equal to the angle of reflection, but, as we might expect from a system which consists effectively of many small mirrors whose surfaces are parallel to one another only in the dorso-ventral plane, the light is spread towards the head and tail of the fish.

Most of these reflecting tubes are wedge-shaped and so light travelling along them is reflected backwards and forwards between their inner and outer surfaces. Every time light strikes the outer surface of these tubes a certain fraction is transmitted, but with each double reflection the residual light is turned more dorsally, i.e. towards the surface of the sea. The photophores are arranged in groups, differing in the way in which they distribute light. These groups must certainly act in unison, since they have a common photogenic mass enclosed in a highly reflecting wall with openings leading to all the photophores of a group. This reflecting wall itself has very interesting directional reflecting properties.

In this ingenious way it would certainly be possible for the fish to match the external light distribution for all possible angles of viewing.

21. <u>On the buoyancy of Spirula spirula</u>
<u>(E.J. Denton & J.B. Gilpin-Brown).</u>

The shell of <u>Spirula</u> is closely related to those of <u>Sepia</u>, <u>Nautilus</u> and the fossil cephalopods. <u>Spirula</u> lives, however, at much greater depths than <u>Nautilus</u> or <u>Sepia</u>, yet, like them, the gas inside the shell is at less than atmospheric pressure.

Relatively large numbers of <u>Spirula</u> were caught in a position off Fuerteventura at which they were <u>known</u> (from previous cruises of "Discovery") to be plentiful. The work was almost exclusively directed to a study of the mechanism by which liquid is pumped in and out of the chambered shell so as to give the animal buoyancy.

There was only a small difference in strength between the shells of very young and of mature animals and they all imploded at depths of around 1,700 metres.

The distribution of liquid between the chambers of the shell was studied in young and mature animals. Because "Discovery" was so very steady it proved possible to dissect shells from animals only a few mm. long and to extract liquid from shells with only three chambers. It was shown that the chambers of young animals are, apart from the one most recently formed, completely dry. In the young animal it proved possible to follow the course of events which take place when a new chamber is formed. Such a chamber is at first full of liquid iso-osmotic with sea water but the concentration of salts falls to about one-fifth of that of sea water before the appearance of a small bubble indicates the formation of a gas space. Clearly, the salts are pumped out of the chamber before the water. In the shells of mature animals the pattern of liquid distribution is entirely different, liquid is now found only in the oldest chambers. When such chambers are completely filled with liquid the concentration of salts is often very close to that of sea water.

Almost all the animals which were brought to the surface were found to be less dense than sea water and it was shown that in such animals the liquid in the siphuncle is sometimes markedly hypo-osmotic to sea water. We should expect this if the change in depth had disturbed a balance between the hydrostatic and 'osmotic' forces involved in controlling the liquid content of the shells.

Very little liquid is pushed into a shell (whether the animal is alive or dead) when the animal is subjected to high hydrostatic pressures for a few hours. The chambers must therefore be rather impermeable to liquid, or else valved against its entry.

These experiments give strong support to the hypothesis that all the living cephalopods with chambered shells control the buoyancy of their shells in the same way. These experiments on "Discovery" have, because of the special anatomy and depth range of Spirula, given information about the mechanism controlling buoyancy which it would otherwise have been very difficult, or impossible, to obtain.

22. On squid using ammonia to give buoyancy
(E.J. Deonton & J.B. Gilpin-Brown & M.R. Clarke).

It had previously been shown (with T.I. Shaw) that the cranchid squid brings itself close to neutral buoyancy by having a coelomic cavity, of volume often equal to two thirds that of the whole animal, filled with a solution which is oso-osmotic with sea water but containing mostly ammonium chloride instead of sodium chloride. Other cephalopods have fairly high concentrations of excretory ammonia in their renal sacs but in the cranchids the ammonia secreting mechanism is not only present in an extreme form, and so of interest to physiologists, but the whole behaviour of the animal is decided by its possessing such a buoyancy arrangement.

On the present cruise it was shown that similar accumulations of ammonia (concentrations close to half molar) are used to give buoyancy by squid of the families Histioteuthidae, Chirotheuthidae and the Octopoteuthidae. In these families the high concentrations of ammonia are not confined to the coelomic cavities, but are spread (apparently in discrete tissues) throughout the body. The behaviour and posture of these squid must be determined by the way in which ammonia is distributed throughout their bodies. In Helicocranchia, for example, the distribution is such that it must normally swim head downwards, in Chiroteuthis the arms are very buoyant so that it must normally hang head upwards, and in Calliteuthis ammonia is so well distributed throughout the body that applications of very small forces will enable it to maintain any attitude.

These results, together with those on Eryoneicus, show that ammonia is very much more widely used for buoyancy than had previously been thought and that a study of the mechanism of its secretion is of very great interest.

23. On the buoyancy of the larva of Eryoneicus
(J.B. Gilpin-Brown & Miss J.F. Whish)

The living larva of the crustacean Eryoneicus is approximately neutrally buoyant in sea water. If the liquid, which is found within its body cavity is drained from the animal, it then sinks. The liquid must therefore be less dense than sea water and, like the coelomic liquids of the cranchid squid, it contains very high concentrations of ammonium and is very acid.

This is the first example of a crustacean using high concentrations of ammonium ions in its body fluids to give buoyancy.

24. Material for electron microscopy (Miss J.F. Whish)

A good deal of material in connection with the various lines of work undertaken on this cruise was fixed and embedded aboard "Discovery" for later electron microscopy.

25. Lipids of fish (C. Wardle)

Total lipid from the livers of 4 species of Squalidae were collected by solvent extraction. The lipid metabolic chains of Squalus acanthias have already been studied. The large livers of the deep sea squalids are similar and the preserved oils will be analysed and compared. The strucutre and secretion of the liver cells will be studied from frozen sections.

Total lipid from Gonostoma elongatum, G. denudatum and Chauliodus will be analysed and compared.

26. The testes of Squalidae (C. Wardle)

Six species of Squalidae from deep water caught by line were sampled. The testes of Squalus acanthias has been found to give information of previous maturity and the time of mating. The testes of the six species will be examined with the hope of revealing features of their biology.

The sites of steroid synthetic enzymes will also be examined and compared by histochemical technique on frozen sections.

The semen of the Squalidae has been found to contain high concentrations of steroid hormones and the enzymes for their synthesis.

27. Macrourids; parasitic copepods (J.H.S. Blaxter)

About 40 macrourid larvae from various hauls were collected for Dr. P.A. Orkin at Aberdeen University and parasitic copepods from Myctophids for Dr. Z. Kabata at Nanaimo.

Conventions in Report Station List

Sounding: Corrected depth in metres;
Minimum and maximum depths recorded if continuous soundings were taken;
Figures in ( ) are approximate.

Times: Local time on a 24 hour system.
Overall starting and finishing times for a station are given.

Sampling: Abbreviations used are given on page 1.
Hydrographic W/B's used in $carbon^{14}$ analysis are indicated by (C^{14}).
N70 nets fitted with a flow-meter are indicated by NF70.
V, B or H following a net abbreviation indicate vertical, oblique or horizontal hauls.
NP(600) = phytoplankton net.

Figures in ( ) preceeding a gear abbreviation indicate the number of samples or observations made with the gear at that station and the depth following is the maximum depth sampled. Where more than one net was used on one warp [ ] are used.

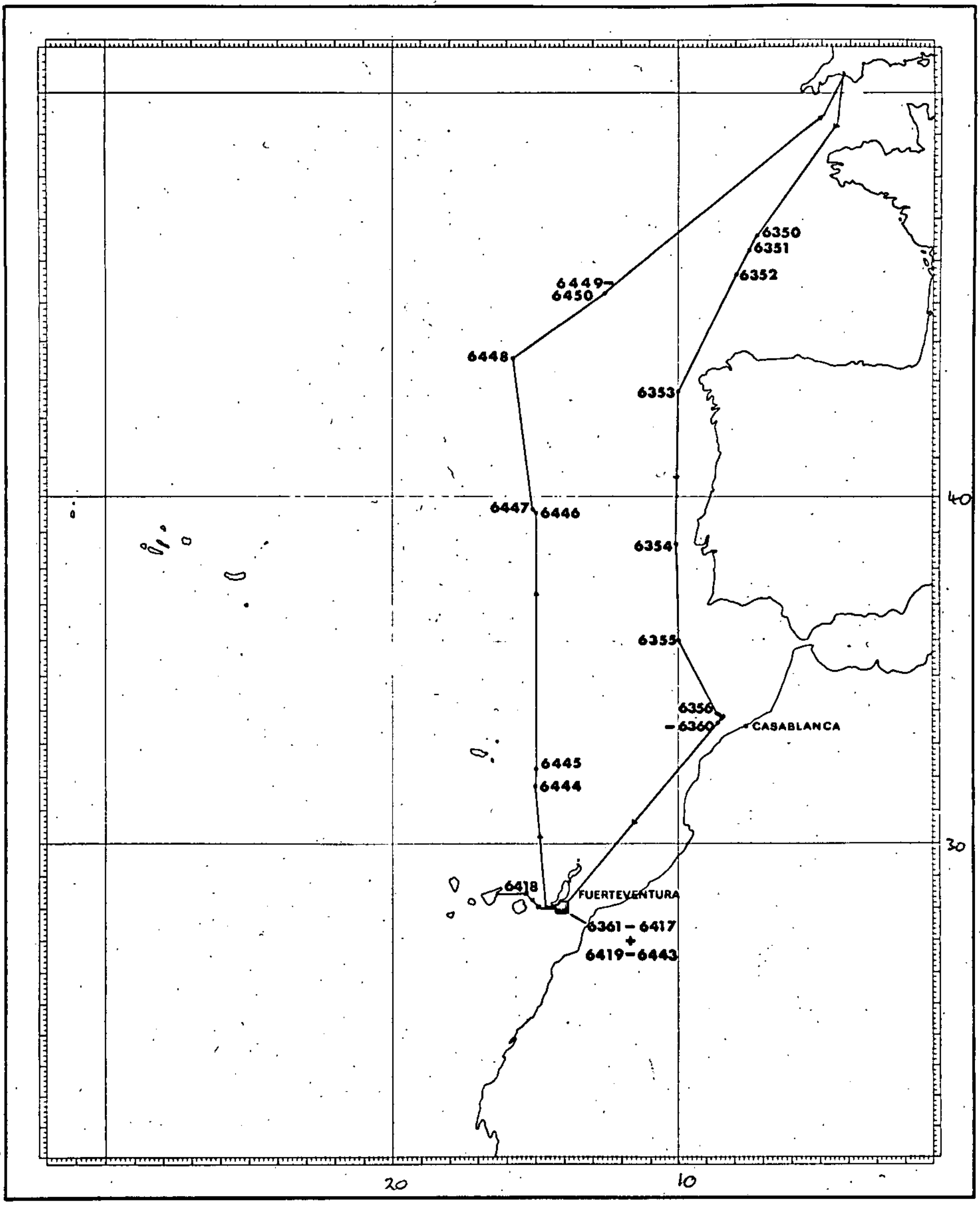
Stn.	Position Lat. N.	Long W.	Date (1967)	Sounding	Times	Sampling programme
6350	46°37'	07°16'	16/7	4616	1030-1230	(2) pinger to 1000 m. Acoustic bucket to 600 m. T.D.M.
6351	46°14' 46°03'	07°32' 07°45'	16/7	4817	1525-1930	IKMTB to 1000 m.
6352	45°40'	07°58'	16/7 - 17/7	-	2223 -0012	IKMTH to 200 m.
6353	42°41'	10°00.5'	17/7	-	2116-2245	TMT8 to 100 m.
6354	38°41.5'	10°02'	18/7 - 19/7	-	2100 -0200	TMT90 to 540 m.
6355	36°00'	10°00'	19/7 - 20/7	-	2045 -0140	TMT90 to 400 m.
6356	33°55'	08°40'	20/7 - 21/7	-	2010 -0307	(6) WB to (800) m. TMT8 DTP to 800 m. NN.
6357	33°55'	08°40'	21/7	-	0340-0800	TMT8 to 820 m.
6358	33°49.5'	08°23'	21/7	162	0933-1110	TMT8 to (180) m.
6359	33°49.5'	08°23'	21/7	426	1153-1505	TMT8 to 280 m.
6360	33°37.5'	08°34'	21/7	-	1644-2015	TMT8 to 600 m.
6361	28°13.5'	13°51'	23/7 - 24/7	1548	1455 -0023	(2) TMT8 to 720 m. IKMT to 840 m.
6362	28°07'	14°03.9'	24/7	-	0300-0500	NH
6363	28°05'	14°05'	24/7	-	0627-1850	(4) /N113H X 37 to 1000 m.
6364	28°00'	14°10'	24/7 - 25/7	-	2108 -0011	TMT90 to 340 m.
6365	28°00.7'	14°09'	25/7	772	0100-0400	TMT90 to 225 m.
6366	28°08'	14°02'	25/7	-	0405-0920	TMT90 to 395 m.
6367	28°04'	14°08.2'	25/7	-	0950-1608	TMT90 to (600) m.
6368	28°08'	14°08'	25/7	700	1650-2145	BLL.
6369	28°06'	14°08'	25/7	-	2231-2400	(2) W/B 7.5 to 400 m. NH.
6370	28°06'	14°10'	26/7	-	0033-0330	TMT8 to 220 m.
6371	28°07'	14°03'	26/7	-	0343-0641	TMT8 to 200 m.
6372	28°08'	13°59'	26/7	(1315)	0704-0804	TMT8 to 630 m.

Stn.	Position Lat. N.	Long W.	Date (1967)	Sounding	Times	Sampling programme
6373	28°02'	14°12'	26/7	-	1147-1930	/TMT8 + N113H/ to 1250 m.
6374	28°09'	14°04'	26/7 - 27/7	-	2112 -0008	TMT8 to 230 m.
6375	28°07.5'	14°10.5'	27/7	-	0105-0315	WB 7.5 to 400 m. NH.
6376	28°05'	14°08'	27/7	-	0404-0515	/N113H X 2/ to 50 m. NNL.
6377	28°05'	14°10'	27/7	-	0949-1356	TMT90 to 610 m.
6378	28°05'	14°06'	27/7	-	1358-1850	TMT90 to 610 m.
6379	28°07'	13°57'	27/7	1128	1852-2340	TMT90 to (300) m.
6380	28°08.5'	13°51.5'	28/7	-	0050-0556	TMT90 to 200 m.
6381	28°05'	14°10'	28/7	(1503)	0739-1750	(5) /N113H X 2/ to 900 m. /N113H X 3/ to 900 m.
6382	28°08'	14°51'	28/7	-	2100-2201	W/B 7.5 to 400 m.
6383	28°08'	14°51'	28/7 - 29/7	-	2230 -0818	NH. (2) /TMT1 X 2/ to 200 m.
6384	28°07'	14°03'	29/7	-	0951-1309	TMT8 to 700 m.
6385	28°07'	13°59'	29/7	-	1350-1739	TMT8 to 1100 m.
6386	28°07'	14°10'	29/7	-	1906-2205	TMT8 to 410 m.
6388	28°07'	14°05'	30/7	-	0906-1410	TMT8 to 700 m.
6389	28°05'	13°55'	30/7	1242	1425-1838	TMT8 to 975 m.
6390	28°07'	14°10'	30/7	-	2158-2351	TMT8 to 175 m.
6391	28°07'	14°06'	31/7	-	0012-(0200)	IKMT to 190 m.
6392	28°06.5'	14°06.5'	31/7	-	0210-0405	TMT8 to 165 m.
6393	28°07'	14°07'	31/7	-	0413-0610	IKMT to 180 m.
6394	28°05'	14°12'	31/7	(1298)	0624-1323	TMT8 to 1250 m.
6395	28°06'	14°07'	31/7 1/8	-	2030 -2205	FRN30 U/C to 100 m.
6396	28°06'	14°07'	1/8 - 2/8	1405	2300 -0130	U/C to 10 m. NH.
6397	28°06'	14°09'	2/8	-	0212-0900	TMT8 to 790 m.
6398	28°06'	14°03'	2/8	1274	1040-1610	BLL

Stn.	Lat. N.	Long W.	Date (1967)	Sounding	Times	Sampling programme
6399	28°07'	14°04'	2/8 - 3/8	-	1640 -1115	BLL
6400	28°07'	14°06'	2/8 - 3/8	-	1927 -0035	BLL
6401	28°07'	14°06'	3/8	-	0120-0345	U/C to 100 m.
6402	28°06'	14°09'	3/8	1259	0418-1400	BLL
6403	28°06'	14°10'	3/8	-	0600-0645	W/B 7.5 to 400 m. BT.
6404	28°07'	14°07'	3/8	-	1530-2200	EMT to 500 m.
6405	28°08'	13°56'	3/8 - 4/8	-	2215 -0615	EMT to (100) m.
6406	28°04'	14°11'	4/8	-	0643-1218	EMT to 500 m.
6407	28°04'	14°00'	4/8	-	1242-1921	EMT to 160 m.
6408	27°50'	13°59'	4/8 - 5/8	-	1933 -0230	EMT to 180 m.
6409	27°51'	14°23'	5/8	-	0318-0930	EMT to 205 m.
6410	28°02'	14°11'	5/8	-	0945-1602	EMT to 530 m.
6411	28°05'	14°01'	5/8	-	1615-2245	EMT to 470 m.
6412	28°00'	14°04'	5/8 - 6/8	-	2307 -0420	EMT to 270 m.
6413	27°51'	14°17'	6/8	-	0445-1635	EMT to 420 m.
6414	28°01'	14°10'	6/8	-	1138-1843	EMT to 1400 m.
6415	28°04'	14°09'	7/8	-	0045-0334	(15) W/B to 1000 m. Camera for observing animals under pressure to 560 m.
6416	28°06'	14°07'	7/8	-	0540-0610	Photometer
6417	28°05'	14°08'	7/8	-	0721-1150	TMT8 to 850 m.
6418	28°28'	15°20'	7/8 - 8/8	-	1935 -0245	(4) N70V to 4000 m.
6419	28°07'	14°09'	10/8 - 11/8	-	2029 -0115	TMT8 to 205 m.
6420	28°03'	14°01'	11/8	-	0140-0530	(6) W/B 7.5 to 350 m. NH. LH.
6421	28°06'	14°08'	11/8	752	0932-1550	EMT to 650 m.

Stn.	Position Lat. N.	Long W.	Date (1967)	Sounding	Times	Sampling programme
6422	28°06'	14°00'	11/8	633	1620-2018	EMT to 515 m.
6423	28°08'	13°52'	11/8 - 12/8	-	2035 -0140	EMT to 128 m.
6424	28°04'	14°09'	12/8	-	0154-0625	EMT to 190 m.
6425	27°54'	14°19'	12/8	957	0845-1555	TMT8 to 970 m.
6426	28°04'	14°11'	12/8	-	1609-1957	TMT8 to 630 m.
6427	28°07'	14°04'	12/8	-	2006-2238	TMT8 to 185 m.
6428	28°07'	13°59'	12/8	-	2253-0130	IKMT to 175 m.
6429	28°07'	13°52'	13/8	-	0153-0530	IKMT to 390 m.
6430	28°07'	14°04'	13/8	-	0540-0910	TMT8 to 300 m.
6431	28°04'	14°13'	13/8	1562	0935-1955	BLL
6432	28°07'	14°07'	13/8	1260	1231-2248	BLL
6433	28°06'	14°08'	13/8	-	1400-1635	"Spirula on vertical wire for buoyancy tests".
6434	28°08'	14°07'	13/8 14/8	1151	2355 -0105	BLL
6435	28°06'	14°09'	14/8	-	0137-0710	(6) W/B 7.5 to 400 m. "Spirula on vertical wire for buoyancy tests".
6436	28°06'	14°08'	14/8	-	1519-1925	TMT8 to 815 m.
6437	28°07'	14°09'	14/8 - 15/8	-	2102 -0100	TMT8 to 905 m.
6438	28°06'	13°52'	15/8	-	0109-0400	TMT8 to 135 m.
6439	28°06'	13°51'	15/8	1503	0412-0823	TMT8 to 570 m.
6440	28°07'	13°59'	15/8	-	1135-1759	EMT to (350) m.
6441	27°55'	13°57'	15/8 - 16/8	-	1836 -0100	EMT to 240 m.
6442	27°59'	14°15'	16/8	-	0135-(0800)	EMT to 480 m.
6443	28°04'	14°03'	16/8	-	0912-1021	(12) W/B 7.5 to 400 m.
6444	31°43'	15°01'	17/8	4394	1350-1625	Bottom temperature probe.
6445	32°15'	15°00'	17/8 - 18/8	-	2032 -0221	[TMT8 + N113H] to 1050 m.
6446	39°32'	15°00'	19/8	5348	1800-2035	Bottom temperature probe.

Stn.	Position Lat. N.	Long W.	Date (1967)	Sounding	Times	Sampling programme
6447	39°35'	15°05'	19/8 20/8	-	2106 -0120	TMT8 to 860 m.
6448	43°36'	15°47'	20/8 21/8	5686	2240 -0120	(5) W/B 7.5 to 100 m. Bottom temperature probe.
6449	45°13'	12°35'	21/8	4817	1800-2022	Bottom temperature probe.
6450	45°13'	12°35'	21/8 - 22/8	-	2044 --0713	(2) TMT8 to 500 m. (3) [TMT 1 X 2] to 300 m. NH.



6350
6351
6352
6449–
6450
6448
6353
6447
6446
6354
6355
6356
–6360
CASABLANCA
6445
6444
6418
FUERTEVENTURA
6361 – 6417
+
6419–6443
40
30
20
10