FILE

I.O.S.

R.R.S. DISCOVERY
CRUISE 64

17 JULY – 13 AUGUST 1974

PHYSICAL OCEANOGRAPHY AND MARINE BIOLOGY OF THE EQUATORIAL ATLANTIC: PART OF GARP ATLANTIC TROPICAL EXPERIMENT (GATE) OCEANIC EQUATORIAL EXPERIMENT

CRUISE REPORT NO.13

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NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Physical Oceanography and Marine Biology of the Equatorial Atlantic: Part of GARP Atlantic Tropical Experiment (GATE) Oceanic Equatorial Experiment

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Institute of Oceanographic Sciences,
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EQUIPMENT AND AIMS

This cruise was part of the Global Atmospheric Programme Atlantic Tropical Experiment (GATE) Oceanic Equatorial Experiment. It was realised from the outset that as the time which could be spent near the Equator was so short, little could be learnt of the long term variability of the currents. Instruments had not yet been developed which could obtain rapid sampling of currents with high resolution suitable for short term work from on board ship. A new instrument, the Batfish, had however recently been acquired by the I.O.S. which could be used for surveying the near-surface temperature and salinity field. This is a towed body which, on command, undulates behind the ship, sampling conductivity, temperature and pressure using a Neil Brown C.T.D. The physical oceanography programme was planned around the use of this instrument (or, if it failed, lowered CTDs or STDs) complemented by a towed fish which measured the near-surface temperature and salinity, and supplemented by two moorings on 22.5°W, one at 3°N and the other near the core of the undercurrent*. The aim of the programme was to obtain three N-S sections across the undercurrent, to make some short period, high resolution, CTD studies near the core and at 3°N, and to maintain the two moorings for a period of about 20 days.

The aim of the biological programme was firstly to extend our observations on the structure of the vertical ecosystem into equatorial regions and secondly to examine the influence of the equatorial undercurrent on the depth distribution of migrant fauna, using mainly the Rectangular Midwater Trawling nets of one and eight square metres area (RMT 1+8) carrying a current meter to determine the speed and distance through the water and a depth sensor to help control them. The neuston net was used to sample surface species. The majority of trawls were planned to be made by day, but it was hoped to make some near-surface night-time trawls to study the diurnal vertical migration, and STD profiles to 2000 m to determine the physical properties.

*The exact positions of moorings and stations mentioned here and later are given in the station list, Appendix 1.

SUMMARY: TIMES AND POSITIONS*

Position	Time	Main Work Begun
Dep. Freetown, Sierra Leone	1030/17 July	On passage.
Arr. 3°N, 22°30'W	1150/20 July	Lay mooring (GATE mooring T1):IOS 171
Dep. 3°N, 22°30'W	1840/20 July	Begin Batfish/STD-CTD section. 1st run S.
Arr. 2°S, 22°30'W	2036/22 July	End Batfish/STD-CTD section. On passage. 1st run N.
Arr. Equatorial Undercurrent Core Area	0640/23 July	Lay mooring (GATE mooring T2) and begin Equatorial studies (IOS 172)
Dep. Equatorial Undercurrent Core Area	0625/29 July	On passage. 2nd run S.
Arr. 2°30'S, 22°30'W	1725/29 July	Begin Batfish section. 2nd run N.
Arr. 3°N, 22°30'W	1024/31 July	Begin studies at 3°N.
Dep. 3°N, 22°30'W	2313/3 Aug	Begin Batfish section. 3rd run S.
Arr. 2°30'S, 22°30'W	2237/5 Aug	End Batfish section. On passage. 3rd run N.
Arr. Equatorial Undercurrent Core Area	1450/6 Aug	Further Equatorial studies and recovery of mooring (GATE mooring T2). (IOS 172)
Dep. Equatorial Undercurrent Core Area	1323/8 Aug	On passage. Run N continued.
Arr. 3°N, 22°30'W	1400/9 Aug	Recover mooring (GATE mooring T1). (IOS 171)
Dep. 3°N, 22°30'W	2337/9 Aug	On passage.
Arr. Dakar	0945/13 Aug	

*A cruise chart is to be found at the end of this report.

NARRATIVE

'Discovery' departed Freetown 1030/17 July and laid course towards 3°N, 22°30'W.

Except for a little rain near the coast the weather during the whole cruise was good with wind force 4, broken cumulus, and an 8 foot swell from the SE continuing almost throughout. No part of the programme was delayed for bad weather, nor was the equipment put to any severe test.

The echo-sounder fish fibre glass housing was found to be fractured and was repaired. The boom on the forward end of the portside shelter deck was seized up, and so the fish was towed from the after boom, and echo-sounder watches begun. Moorey's ST profiling fish was put out at 1710/17 on the port bow. At 12 knots it lifted occasionally out of the water and so on 18th it was moved further aft onto the starboard side just forward of the electric winch. It continued to operate satisfactorily during the cruise. A restart of the cruise data collection by the computer was necessary early on 18th because of a course updating problem. During 17th the Batfish was prepared and tested inboard, and at 0930/18 it was launched for trials. The control and data acquisition systems worked well but problems (which continued until the beginning of August) were found in running the on-line temperature and salinity v depth plotting on the I.B.M. computer without faults or breaks in the plot.

The acoustic releases and command pinger for the first mooring were lowered on the hydrographic wire for tests on p.m./18, but the release failed to respond properly, and the tests were repeated on p.m./19 after a stop to pretension the mooring wire. The opportunity was also taken on 19th to test the midships winch and microcurrent meter.

A mooring was laid near 3°N, 22°30'W during 20 July and Batfish was lowered over the stern at 1919 in preparation for a section to the south, with temperature contouring being made by hand. However at 0600/21 control of the Batfish was suddenly lost and the fish was recovered. Some small quantities of jelly were found on the conductivity cell of the CTD, but the fish appeared mechanically sound. On closer inspection however sea water was found in the hydraulic servo control for the wings and a complete overhaul was begun. The N-S section was continued at half degree intervals from 1°30'N with STD (stn 8544) and then with CTD (stn 8545-8551). A stop was made to pretension the wire and to lower and test the acoustic release for the second mooring on p.m./22. It was clear from the isotherm contours and the surface ST profile that by 2°S the core of the undercurrent had been passed. Maximum surface salinity and minimum temperatures were found near 0°25'S and the 24°C and 14°C isotherms were most widely separated near this position. An area of level sea floor had been crossed at 0°21'S and a mooring (stn 8552) was laid near that position on a.m./23.

Trawling began at 1240/23 using RMT 1+8 and continued until sunset when a dhan buoy was laid as a navigational aid for CTD yo-yo series. An STD (stn 8553# 3) was made to 2000 m. Faults in both S and P channels developed during this profile and continued during the subsequent deep STD profiles in spite of efforts to detect their cause. A series of CTD profiles (stn 8554-8555) to 400 m (one to 1000 m) were made using the electric winch and contouring in real time using the Batfish software. It was obvious that strong current shear existed between 50 and 110 m for to keep the CTD wire vertical it was necessary to come ahead at 2-2.5 knots heading 110°. The surface drift as determined from satellite and DR, was generally westerly. Trawling continued in daylight on 24th and was followed by microcurrent meter trials. At 0030/25 the Batfish was again launched (Batfish 9) and after some careful control adjustments a series of 30 undulations were made on a course 290°. Daytime trawling and night-time Batfish runs (Batfish 10-11) were continued on the 25th-27th. The guided profiling current meter (GPCM) was tested on the evening of 27th and a series of 13 CTD profiles (stn 8561) made between 10 and 350 m. After making an STD profile to 2000 m, the dhan buoy was recovered and trawling was begun at 0900/28 and continued through the following night (stn 8562) until 0625/29 when course was set for 2°30'S, 22°30'W. On arrival at this position at 1725/29, further tests of the GPCM were made. The Batfish was launched at 1920/29 to begin a section on 22°30' to 3°N across the under-current.

Radio communication with 'Academic Kurchatov' (the communication ship for GATE Equatorial Experiment) was established on 30th and six hourly met. observations sent from 0000/25 and continued daily until 11 Aug.

The Batfish section was completed at 1023/31 July. Trawling began at 1106 near the mooring at 3°N being interrupted at sunset for further GPCM tests, but continuing for a half-night period until 0128/1 August. A CTD profile to 1000 m was followed by a series of 14 profiles to 250 m ending at 0742/1. During this period the transit sonar showed several undulations of the scattering layer, although the resolution was rather poor. Trawling continued after daybreak and continued for a second 'half-night period'. A notably large catch of Salpa cylindrica was made with the neuston net at 1345 as the ship passed through a narrow region of increasing temperature and salinity. After an STD (stn 8565# 7) the CTD was used on the electric winch to undulate between 22.5 and 15°C, approximately 60 to 130 m, to see whether or not the undulations in the scattering layer were related to density variations.

The surface drift to the NW was apparently much stronger than when the ship was at this position on 20 July, reaching 2 to 2.5 knots.

Trawling (stn 8567) continued during daylight on 2 Aug and at 1900 the GPCM was calibrated and a trial drop made to 300 m, before the Batfish was launched for a W to E section on 2°48'N (Batfish 13). The trawling programme at this position was completed on 3rd Aug and at 2304/3 the Batfish was again launched to begin a N-S section on 22°30'W. As the ship was some way to the W of this longitude a first leg to the E was made on 2°30'N before turning S at 0600/4. During the Batfish tow the opportunity was taken to remedy a short circuit on the 6 mm midships winch cable and to remove a section of the wire which contained some bad kinks.

Early on 5 Aug the conductivity cell on the Batfish CTD became fouled and the Batfish had to be recovered and relaunched. It was eventually recovered at 2°30'S at 2237/5. Course was laid to a position 15 miles E of the mooring where, at 1528/6, a dhan buoy was laid with a transponder hanging beneath it. The ship was hove to some 400 m from the buoy and maintained at a constant range and bearing whilst a series of 4 GPCM drops were made. During the final drop the dhan buoy came adrift and was recovered at 1954/6.

A trial lowering of the fluorometer pump and tube with weights attached was then made but abandoned when a tube connection broke.

The Batfish was launched at 2116/6 for a W-E-W run on 0°25'W (Batfish 16). The final two hours of the tow were made at a controlled constant depth (115 m), before the fish was recovered at 1426/7.

The dhan buoy with transponder was again laid and another GPCM drop made to 400 m at 1650/7, with the ship holding station on the dhan which was afterwards recovered.

The fluorometer was lowered with the STD for 4 profiles to 110 m (stn 8571). Again a tube connection parted, probably owing to the high drag of the water on the tube, but three profiles were successfully completed. Time was then available overnight for an additional deep trawl to collect samples before recovery of the Equatorial current meter mooring on 8 Aug.

At 0746/8 the ship was hove to some 2½ miles from the expected position in which the mooring was laid and transmission was begun to switch on the command pinger. There being no response, transmission to switch on the release pinger was begun at 0908 and continued as the ship approached and crossed the position of the mooring, but with no success. At 1046 however the buoyancy sphere was sighted on the surface about 1 mile to the east of the expected position and the mooring was recovered. Each of the current meters had suffered damage. The command pinger worked faultlessly when tested in the laboratory and it is assumed that abnormal transmission characteristics had accounted for its failure. The release pinger had an intermittent fault. All was recovered inboard at 1323/8 and a course laid for the mooring near 3°N.

At 0°45'N a series of neuston net trawls were begun through a region which had showed rapid changes in surface salinity and temperature in the previous N-S sections. Little change in the catches was found however and the series was terminated at 2329/8.

Engine room trouble delayed arrival at the mooring until early afternoon on 9 Aug. Again no response could be obtained from the command pinger but the release worked normally and a close approach was made before it was fired at 1622. The mooring was sighted immediately by the Netman, and recovered. The upper units were covered in barnacles and both current meters were damaged. The command pinger had an intermittent fault. All was recovered inboard at 1832/9.

Following three fluorometer-STD profiles (stn 8587), an STD was made to 2000 m. Unfortunately some of the data sampled by the computer was lost due to a failure of the electrical clock. At 2337/9 all was recovered and course laid for Dakar. There being time in hand, a deep water trawl was made on 10th (stn 8591) and a brief stop made on 12 Aug to recalibrate the GPCM. The ship berthed in Dakar at 0945/13.

MARINE PHYSICS

Moorings (S.A. Thorpe)

Moorings were laid at stations 8543 and 8552 (GATE T1 and T2).

The upper part of each mooring (supported by a submerged 4' sphere) was made up of 8 mm wire. This was connected by a short length of 6 mm wire to about 3000 m of 8 strand multiplait. Difficulties were encountered in laying the first mooring because of the unknown stretch characteristics of the multiplait (previously used in MODE) and because no more than 1000 m could be accommodated on the trawl winch at one time, and in consequence the upper current meter planned for mooring T1 had to be removed.

Neither command nor release pinger on T2 could be switched on during recovery but the release was fired and the mooring recovered about a mile east of its position. All three current meters sustained damage, the most serious being that the upper meter lost its rotor, apparently during launch. The lower meter had a broken universal joint. The magnetic tapes contained the expected volume of data which is at present being evaluated. The 6 mm wire was badly kinked on recovery.

The command pinger on T1 failed to switch on, but the release worked normally and only one pyro on the double modified Van Dorn release was fired when the ship had been manoeuvred close by. The buoyancy sphere and upper current meter both had a prolific growth of barnacles *Conchoderma virgatum*. Two had even grown under the Savonius rotor of the meter!

Both current meters had damaged universal joints which, like that damaged on T2, were made of nylon. The lower current meter had also a broken rotor and a bent steel rotor support. The 6 mm wire was again badly kinked and several tangles had to be untied in the upper 1000 m of multiplait as it was recovered. The current meters appear to have operated and it is not yet known when the damage occurred.

Guided Profiling Current Meter (A. Hall)

The first sea trials and calibration of the complete instrument were made during this cruise.

The instrument works on the principle of PROTAS (Simpson, J.H., 1972, Deep-Sea Res., 19, 331-336) but is designed to slide down a weighted 4 mm wire hanging from the ship. A neutrally buoyant vane at the lower end points in the direction of the relative current. The position of the vane is detected by an electrode system and once the vertical fall speed of the instrument is known, the relative horizontal velocity of the current may be determined. Vertical ship motion is removed by allowing the instrument to slide down the wire. The electronics are housed within an 8' long 7" diameter tube and recording of pressure, two channels which give the vane position, temperature and tube orientation are made internally twice a second. The fall speeds used were near 1 m s^{-1}. The instrument is switched on at about 15 m depth by a pressure switch and is switched off on contacting a magnet and sprung stop on the wire about 100 m above the 420 lb streamlined weight. The present pressure case is good to 400 m. The instrument is recovered by hauling in the wire on the electric winch.

Various electrical and minor mechanical problems, including a broken electrode, delayed the full calibration of the instrument until 2nd August, although several trial launch and recovery operations were made earlier to improve deck handling and to test the logger and electronics.

Further tests, including two free-falls to 300 m, were made on 3 Aug with encouraging results. On 6 Aug 13 calibration dips and 4 free-falls to 300 m were made with the ship holding station relative to a dhan buoy, using an acoustic transponder to measure range (stn 8569). The dhan buoy broke adrift shortly after the beginning of the last free-fall. Wire angles of about 10° were produced. Wire or tube vibration introduced spurious high frequency noise, but the change in tube orientation indicating a change from a westerly to an easterly drift below about 70 m was immediately obvious from the records. The vertical resolution of currents is expected to be about 10 m, but the results have not been fully worked up.

A final free-fall was made on 7 Aug (stn 8570) with the ship again holding station on a dhan buoy. Unfortunately a large zero shift was introduced, apparently due to a battery replacement, and part of the current record was lost. A final test on 12 Aug showed a recovery of the original zero position and calibration.

Microcurrent Meter (A. Hall)

This is an instrument carrying a Savonius rotor. The rotor carries a slotted disk which cuts a light path to a photoelectric cell, and the rotation of the rotor is monitored by the output of the cell. There is in addition a thermistor and pressure sensor on the instrument. The instrument is attached to the wire above a CTD or STD and signals are passed to the ship via a separate 12 core electrical cable.

Handling trials of the instrument were made during the cruise. The instrument itself functioned satisfactorily but the use of a separate cable makes the operation slow and only observations at fixed depths were possible. Furthermore the ship's motion made the analog record difficult to interpret.

STD/CTD (G.K. Morrison, G. Mardell)

Hardware

The new IOS version of the WHOI CTD has been used twice on trial cruises earlier this year. This cruise has seen it put into full operational use for the first time. It is an updated version of Neil Brown's prototype instrument which was used on the JASIN and MODE experiments on board Discovery.

The CTD was used in the Batfish during 11 tows totalling 160 hours of towed profiling to a maximum depth of about 400 metres, the longest tow lasting 39 hours. The same CTD electronics were transferred between the Batfish and a vertical profiling pressure case. 15 vertical casts were conducted to a maximum depth of 1000 metres.

Calibrations on the CTD were made using NIO type water bottles and reversing thermometers, which were most easily employed during the vertical casts, one bottle immediately above the instrument on the same wire and a second on a 10 metre strop to be triggered when the instrument returned to 10 metres before recovery. The start and finish of every Batfish tow was punctuated with a 10 m calibration, with the ship hove to and the instrument suspended at 10 metres a calibration bottle was taken amidships while the digital read-out of pressure, temperature and conductivity was recorded from the CTD deck unit. Although neither temperature nor conductivity channels were correct in absolute terms, both appeared to require linear correction with respect to temperature. The scatter in these calibrations was of the correct order to be largely attributable to the 0.01°C uncertainty in the water bottle temperatures. The CTD pressure sensor is temperature sensitive and in order to operate in gradients sometimes as great as 15°C in 50 metres temperature compensation is necessary (a 5 metre offset at the start of a station was usually reduced to about zero metres at the end of a station).

During the trial cruises noisy data had been traced to intermittent connections between the underwater unit circuit boards and the back plane wiring. The clamping of the boards devised before this cruise seems to have overcome this fault entirely.

The conductivity sensor has a small orifice and is therefore prone to fouling - usually displayed as a conductivity spike in the region of the scattering layer. After the first Batfish tow a more permanent jump was found to be attributable to a small prawn-like creature wedged in the sensor orifice. A later jump lasting several hours returned during recovery but was thought to be due to fouling as the remainder of the sensors were covered with a jelly-like substance after recovery. Some protection was given to the sensor by rotating the whole head so that the conductivity sensor was behind the slow response thermistor.

Processing and data logging

The data rate of the CTD system exceeds that which may be readily handled by the IBM 1800 shipboard system. A Hewlett-Packard 2100A (16K) minicomputer is the heart of the acquisition system; an IOS modified WHOI program was used to acquire, distribute and store the raw data at 31.25 scans/sec. All the acquired data was written in 'raw' form onto 9 track digital magnetic tape, one second spot values were passed to the IBM 1800 system for on line contouring and computed values of pressure, temperature, conductivity and salinity were typed out every minute on the 2100 system teleprinter. During vertical profiles the 2100 was also used to plot one second values of temperature and computed salinity against pressure.

Analogue outputs of pressure, temperature and conductivity were used to generate quick-look records of these variables, on a brush pen recorder, against time. When the instrument was incorporated in the Batfish the analogue pressure signal was used as the feedback in the pressure servo loop.

Except for the usual teething problems with some previously untried computer programs and a minor hardware failure in the teleprinter interface of the Hewlett-Packard computer this whole complex system has operated smoothly throughout the cruise.

STD system

The 9006 type instrument constructed from spare sensors and an IOS mixer unit/power supply was used for deep stations during the cruise (as the present CTD pressure case is only rated for 1000 m).

The STD was used for 13 vertical profiles, 4 of which were to 2000 metres. These four stations produced satisfactory data during the descents but after about 40 minutes on each station the salinity channel started giving spurious data returning to sensible values on the ascent. Towards the end of each station the depth period jumped by a fixed amount. As these problems only occurred on deep stations it is suspected that it is a thermal effect on the sensor packages. During 7 dips to 110 metres with the fluorometer the STD behaved very well.

Some problems were encountered with the STD suite of programs on the IBM 1800 but these were overcome (they were largely due to bad salinity data in the strong temperature gradient). After one STD station the conducting cable on the midships winch developed an electrical short about 600 metres from the inboard end. The cable had been wound onto the compensating winch. The offending section was removed and the remaining 3620 metres were wound back onto the winch with a steady tension of about 250 lbs applied using the parking brake on the electric winch.

Batfish (M. Carson)

The Batfish is an undulating towed body, used to carry the CTD described above. The undulations are achieved by turning the main depressing wing relative to the body. This is done by a hydraulic ram in the body, which is powered by a gear pump directly coupled to an impeller. The flow of oil to the ram is controlled by a Moog servo-valve, and this is fed from the Batfish deck unit.

During the trials on Cruise 62, we experienced oil leakage from the hydraulic system, and the oil was always contaminated with sea water. On bench test at Wormley, the lip-seal on the gear pump was found to be faulty, and it was replaced.

The first run on the present cruise (Batfish 7) was a short trial; leakage was insignificant. After 6 hrs of the first north-south run (Batfish 8), the servo-valve stuck, making the Batfish uncontrollable. Flushing the valve failed to clear the obstruction, so the system was stripped down for cleaning. There was no sign of corrosion in the servo-valve, but the shuttle seemed unduly tight in its bore, so this was dismantled and lapped. The reassembly and adjustment of the valve proved very difficult. It was necessary in the end to run the system with a large bias voltage to account for the imperfect mechanical adjustment.

The next four runs (Batfish 9-12) were completed satisfactorily, but oil loss was still high. Some of this loss may have been due to the extreme porosity of the pump body, which was allowing leakage past the face seal between the pump and the valve block. This porosity was sealed with epoxy resin, but leakage was still high. It seemed that the lip-seal, designed to keep sea water out of the pump, was not appropriate for keeping oil in. It was therefore supplemented by an O-ring running on the pump shaft, fitted in a plate bolted to the back face of the pump. This plate also carried a Nylatron bush, designed to relieve the pump bearing of the propeller shaft loads.

Following this modification runs 13-15 were completed with greatly reduced loss of oil, though this increased again on 16/17 due to wear on the O-ring. The oil was, however, being rapidly blackened, apparently by wear particles from the pump body. This was in turn caused by the worn pump bearing. The Nylatron bush was therefore replaced by phosphor-bronze and the shaft aligned to minimise rubbing.

Launch and recovery of the Batfish was performed without difficulty; the system has yet to be tried in rough weather. Only about 20 sections of fairing had to be replaced. The winch worked well, though the traversing gear was still too tight for its drive clutches and could not be used.*

Water bottles, reversing thermometers and S/T profiler (J. Moorey)

On 33 occasions up to 3 W/Bs were used for calibration. There was usually a 2 m and a 10 m W/B on a 4 mm wire. The 2 metre W/B was used to calibrate the S/T Profiler and the 10 metre W/B used to calibrate the CTD and/or STD. As well as the 2 and 10 metre W/Bs, a W/B was also attached to the wire just above the CTD or the STD and this W/B was reversed at selected depths. Of a total of 87 W/Bs attempted 81 were successful. The six failures were:-

Stn 8554 - the 2 m W/B had a faulty cam which had cracked and moved its position and failed to hold the frame latch. A new cam was fitted.

*Further details of Batfish runs are given in Appendix 2.

Stn 8558 - the operating lever of the 900 m W/B broke presumably when the messenger struck.

Stn 8563 - the messenger was sent down with 1015 m wire out but the unprotected thermometer (U3248, previously and since used successfully) gave a pressure of 341 db.

Stn 8564 - W/B has 0° to 12°C range thermometers but was reversed in water of about 12.90°C.

Stn 8566 - the 300 m W/B's two protected thermometers 2844 and 2845 recorded 12.83°C and 12.06°C respectively, and it seems possible that this W/B reversed prematurely while being lowered.

Batfish 16 launch - on the 10 m W/B No. 4 the operating lever (normally under the upper valve lever) was found to be above the operating valve lever when brought out of the water. This is inexplicable since it required the use of circlip pliers to put the operating lever back to its correct position.

Reversing thermometers

Pairs of thermometers were in good agreement and unprotected "pressures" looked reasonable. Thermometer 2855 failed twice in succession and was put aside.

Autolab Salinometer

One sample of a pair was measured one day and the duplicate usually one or two days later. The pairs look reasonable (but have not been mathematically checked). The ideal working temperature for the salinometer is about 22°C. The chemistry lab temperature was rising to 28°C. It was then found that the ventilators were not fully open. When opened the temperature came down to about 24°C but would occasionally go as high as 26°C, mainly due to a ventilator duct (from the galley?) passing through the lab. If "reasonable" temperatures are to be achieved then this duct needs to be lagged.

S/T Profiler

The fish was first towed using the neuston net boom on the fo'c's'le portside. However, in slightly rough weather the fish was occasionally surfacing. Another boom was rigged further off on the fo'c's'le on starboard side (leaving portside clear for neuston net) and at deck level. The fact that the boom is now 5 ft closer to the water and the diminished pitching at this point makes it an ideal towing position.

Although calibrated at I.O.S. two months previously the instrument recorded salinity 1.30‰ high and temperature 0.25°C high compared to W/B values. At the moment no reason can be given for the large salinity difference. At 1500 hrs on day 204* the salinity and temperature bridges were readjusted. A series of W/Bs after this gave the salinity correction as +0.13‰ S until

*Day 204 is 23 July

day 209 when the electrodes were brushed with detergent and the correction became +0.03‰ slowly increasing to +0.05‰ on day 221 when electrodes were again cleared. The chart record indicated that correction had reverted to +0.03‰ but no further W/B calibrations were made.

Summary	Salinity correction	Temperature correction
Start of leg until 1500 hrs day 204	-1.30‰	-0.25°C
1500 hrs day 204 - day 209	+0.13‰	-0.15°C
Day 209 - end of leg	+0.03 to +0.05‰	-0.20°C

Surface currents (G. Howe)

These surface currents are derived from satellite fixes and computed D.R.s relying on the ship's E.M. log. The port side log was used throughout in these calculations.

1st Run South 2046/20 July to 2054/22 July 3°N to 2°S on 22°30'W:- the currents on this run commenced at about 0.5 knots Easterly swinging through Southerly to Westerly at about 2°N and strengthening to a maximum of 1¾ knots Westerly by the end of the run at 2°S.

1st Run North 2054/22 July to Stn 8552 (GATE mooring T2), 2°S to 0°20'S:- the currents on this run were again Westerly about 1½ knots.

Work centred on 0°20'S 22°30'W Stn 8552 to 0406/29 July:- Currents in this area were about 0.75 knots. A change appeared to occur about mid-day on 26 July with the currents swinging from the W more to the NW.

2nd Run North 2034/29 July to 1024/31 July, 2°30'S to 3°N on 22°30'W:- the currents were again Westerly at the start about 1½ knots decreasing between 1°S and 2°N then increasing North of 2°N. A number of observations were lost in the middle of the run.

Area about 2°50'N, 23°W, 1024/31 July to 1814/3 August:- in general the currents were Northwesterly at 2 to 2.5 knots.

3rd Run South 0546/4 August to 2202/5 August, 2°30'N to 2°30'S on 22°30'W:- currents Westerly 2 knots down to about 1°N then decreasing to 1 knot swinging Southerly at the Equator and remaining so for the rest of the run.

3rd Run North 2202/5 August to 1554/6 August, 2°30'S to GATE mooring T2:- this run followed immediately after the previous run to the South and the change in the currents was marked. It would appear to indicate that our E.M. log reads slow and too much from starboard to port.

3rd Run North continued 1520/8 August to 0714/9 August, Equator to GATE mooring T1:- very strong Westerly currents experienced on this run nearly 3 knots Westerly. True value probably more like 2½ allowing for the log error.

(The scientists are grateful for the very helpful contribution made by Captain Howe in preparing this - and a more detailed - summary of currents).

BIOLOGY

Introduction (P. Foxton)

The aim of the biological programme was firstly to extend our observations on the structure of the vertical ecosystem into Equatorial regions and secondly to examine the influence of the Equatorial undercurrent on the depth distribution of the migrant fauna. Discrete depth sampling with the RMT 8+1 combination net was conducted at the Equatorial mooring position (26 hauls) to a depth of 2000 m, and at the northern mooring position (22 hauls) to a depth of 1000 m. Sampling was mainly restricted to daylight hours to integrate with the other work of the cruise but the upper 300 m was sampled by day and night at both positions so that conditions in the region of maximum undercurrent could be compared with those outside it. The RMT 8+1 and its ancillary net monitor system functioned perfectly and there were no operational failures. Hauls were standardised using the net flow indicator which proved essential in the rather exceptional conditions of current speed and direction experienced at the Equator. Vertical profiles of phytoplankton standing crop were obtained to 110 m depth using a pump and fluorometer system, while the comprehensive physical observations made with TSD, CTD and Batfish complement the biological sampling. In addition to the main sampling, surface collections and a series of neuston net hauls yielded rich and interesting catches and several hauls, including one from 3000-2000 m were made to collect material for experimental and other purposes.

The mesopelagic fauna was in general poor at both positions but rich catches occurred in the near surface layers. At the Equator salps, of which several species were swarming, chaetognaths, euphausiids and copepods were exceptionally rich and there was evidence of faunal stratification in association with the upper boundary of the undercurrent. The composition of the near surface fauna appeared to be similar at both positions but the biomass was clearly greatest at the Equator. While full details must await analysis of the catches the following notes of general interest are appended.

Siphonophora (P.R. Pugh)

Although large numbers of siphonophores have been caught during the cruise, particularly in the shallower depths, the species diversity has been quite low. The two vertical series of trawls, at the Equator and 3°N, have contrasted markedly in their populations of siphonophores, many more animals being present in the latter series, although in both cases the distribution of the mesopelagic species has generally been shallower than found further north, e.g. 30°N. The physonect siphonophores have tended to be the more interesting animals caught. Agalma okeni and Halistemma rubrum have predominated and several complete specimens of the former have been taken. The peculiar physonect, Athorybia rosacea has been quite common and has shown an interesting colour variation, tending to be yellowish in the deeper hauls (150-300 m) and a pinkish-purple colour closer to the surface, including an excellent specimen caught in a hand net at the surface. Whether this is a light/dark adaptation is not clear. Several complete and semi-complete specimens of Physophora hydrostatica have also been noted. Probably the most interesting siphonophore caught was of a new species of Bargmannia. Several nectophores were isolated from a deep haul (stn 8560#2, 2000-1510 m), but no other part of the specimen could be found. The nectophores are large in comparison with B. elongata and have large, wing-like lateral processes.

Physalia has been caught infrequently in the surface nets and all the specimens have been small. Larger specimens have, however, been sighted occasionally.

Pteropods and Heteropods (D. Shale)

A total examination of the animals present in the vertical series was not possible, but the most conspicuous were noted.

The major differences between the equatorial series and that at 3°N was the contrast in faunal composition, especially evident in the epiplanktonic thecosomes. The bathypelagic cosmopolitan forms, which show little or no vertical migration, such as Limacina helicoides and Clio polita were found in both areas. Relatively few of the superficial forms were found at the equator, these were Cavolinia uncinata, of which an unusually large number were found above 50 m during the day, Cavolinia tridentata and Diacria trispinosa. The pseudothecosome, Corolla sp., an infrequently caught specimen was found in moderate numbers above 100 m.

Samples from 3°N contained more species and larger numbers of pteropods. Diacria trispinosa occurred from 10 m down to 400 m during the day, and in the 300-400 m haul (8567 2) both formae - D. trispinosa trispinosa and D. trispinosa major occurred. Diacria quadridentata was found occasionally below 100 m. The commonest species was Cavolinia longirostris, which was found between 50 and 200 m.

The gymnosomatous pteropods were occasionally encountered but they were not identified.

The heteropods showed a similar species difference, more occurring at 3°N than at the equator. The commonest species were Pterotrachea coronata, Cardiapoda placenta and Carinaria lamarki, with large numbers of atlantids, especially at night. These molluscs are typically epiplanktonic and apart from the species differences, there was no obvious difference in their vertical distribution.

Euphausiids (A. de C. Baker)

At the southern (0°30'S) and northern (3°N) stations the species that were dominant were, with one exception, the same. They were:- *Euphausia americana*, *E. gibboides*, *E. tenera*, *Thysanopoda monacantha* and *T. tricuspidata*. *Stylocheiron carinatum* was very abundant in a narrow layer at the southern station but occurred only sporadically at the northern one.

The approximate vertical distributions of these species, based on a very brief examination of the samples, were as follows:-

0°30'S

	Day	Night
E. americana	50- 10 m (large numbers)	200-0 m
E. tenera	300-200 m	10-0 m and 100-50 m
E. gibboides	400-300 m	100-50 m
T. monacantha	few taken	200-50 m
T. tricuspidata	400-300 m (larvae consistently in 10-0 m day and night)	few taken
S. carinatum	100- 50 m	50-25 m

3°N

	Day	Night
E. americana	300-200 m	50-0 m
E. tenera	400-300 m	100-0 m but mostly in upper 10 m
E. gibboides	few taken	200-100 m
T. monacantha	500-400 m	200-100 m
T. tricuspidata	few taken	100-0 m

These figures indicate a somewhat deeper distribution at 3°N than at 0°30'S.

At 3°N the distribution in the upper 200 m during the day was more or less as expected with only larvae of *T. tricuspidata* and *E. tenera*, and larvae, adolescents and adults of *Stylocheiron spp.* present. At 0°30'S, however, there was a large population of adolescent and small, sexually mature, *E. americana* in the upper 50 m during the day, that is above the undercurrent. In the undercurrent itself (approximately 100-50 m) only one species, *S. carinatum*, occurred in significant numbers. From the daytime samples it looked as though the undercurrent might be acting as a barrier to downward movement of the E. americana, but the night observations showed that the 100-50 m layer was occupied by large numbers of E. gibboides, E. americana and T. monacantha.

Worth noting because of its size is a 63 mm female Thysanopoda cristata in the 400-300 m sample at stn 8567.

As found at 11°N in 1968 there was a relatively high incidence of parasitisation of euphausiids by the Dajid isopod Heterophryxus appendiculatus.

Observations were made on the synchronisation of the rotation of the eyes and photophores of euphausiids. Subjectively the amount of rotation was greatest in Stylocheiron abbreviatum and least in species of Thysanopoda.

Mysidacea (C.R. Hayes)

The equatorial undercurrent, which is a feature of the upper hundred or so metres of the water column in the area surveyed, would perhaps not be expected to have much effect on mysid distribution, since most mysids live at depths below five hundred metres migrating upwards at night only a little, most of the population lying between seven hundred and a thousand metres. This appears to be the case.

The mysid catches of both the series at the equator and at 3°N were small in numbers and similar in composition to each other. They resembled closely those taken at 11°N (stn 7824) though there the numbers had been larger. Species observed in the samples included Eucopia sculpticauda, E. unguiculata, E. grimaldii, Boreomysis microps, B. illigi, B. fragilis, Gnathophausia ingens, Chalaraspidum alatum and Euchaetomera typica. G. gracilis was conspicuous by its absence.

Care was taken to isolate and preserve separately any specimens of the rare C. alatum that were taken. Hopefully they will add to the limited knowledge available at present on this species and genus. In all ten specimens of it were recorded, the largest of these occurring in the deep final trawl of the cruise (stn 8591) between 2000 and 3000 metres. Unfortunately it was in a very damaged condition. The specimens of the infrequently taken B. fragilis were also caught in this trawl but again their condition was not very good.

They may also add to the information available on this species. In the upper four hundred metres Euchaetomera typica was the only observed mysid present (between 50 and 200 metres) apart from the even smaller species Siriella thompsonii taken in a series of neuston nets carried out over a dusk period.

Crustacean decapods (P. Foxton)

Species sampled were similar to those in previous collections from 11°N but abundance was very low. Acanthephyra kingsleyi and A. acanthitelsonis dominated the deeper catches while Sergestes diapontius was the most abundant shallow species. Several specimens of Amphionides occurred in the 1250-1000 m collection while larval Amphion were particularly numerous in 25-10 m samples. Among a sparse fauna sampled by the deep 3000-2000 m haul were Acanthephyra brevirostris and an undescribed Hymenodora that has been recorded previously from Bermuda and the eastern N. Atlantic.

Fishes (J.R. Badcock)

A cursory glance at the collections made at 3°N and ½°S suggests that a greater diversity of species exists in the more northerly area. The principal species, however, were common to both areas, although their relative abundances were often very different. Among the lantern fishes, for example, Benthosema suborbitale, Diogenichthys atlanticus and the various Diaphus species were better represented in the northern samples, whilst species such as Lampanyctus alatus were equally well sampled in both areas. Notolychnus valdiviae, common throughout large areas of the Atlantic, was the most abundant lantern fish at 3°N, but was not noted in the ½°S collections. The interspecific depth relations were as would be expected, and depths of capture were similar in the two areas. Cyclothone, numerically the best represented genus, contained only four species in the upper 1000 m. C. livida, so common in Discovery Atlantic collections from 11-28°N, was absent. Among the hatchet fishes, Sternoptyx was numerically best represented in both areas. 3 species of Argycopelecus were caught, A. affinis, A. sladeni and A. hemigymnus, but all in low numbers. Polyipnus, common off the tropical coast of West Africa and in the Caribbean, was absent. Aristostomias and Malacosteus were the most frequently caught "black" stomiatoids, which in general, were of low occurrence in the catches.

Of the lesser known fishes, Barbourisia rufa, Oneirodes Sp. A., Dolichopteryx and a couple of megalomycterid spp. are worthy of note.

Neuston (D. Shale)

Neuston sampling was irregular, with the exception of a dusk series of 15 hauls, taken in an area where fronts were known to occur, and it was hoped to cross one. However, only a small thermal change (0.2°C) was encountered during the four hours of sampling. The samples showed a typical nocturnal increase, especially in the numbers of fish. Myctophum punctatum and M. affine were the dominant species, with small Gonichthys coccoi and Astronesthes niger appearing in the latest samples. Of the invertebrates only the euphausiids showed a marked increase in numbers.

During routine sampling on the equator, large swarms of Glaucus atlanticus and Ianthina prolongata were seen from the ship. Samples of these were taken with both neuston and Oxfam nets: I. prolongata was found to have egg sacs attached to the bubble raft, but they were found to be in an early stage of development, no veligers being visible. Small specimens of Physalia and Porpita were occasionally taken and the ubiquitous Halobates micans occurred in every neuston sample.

Bioluminescence (P.J. Herring)

Observations have been made on Malacosteus, Aristostomias and Pachystomias, three genera with red-emitting light organs. The gross anatomy, pharmacological responses and chemical affinities of the organs have been investigated, and some material frozen for later analysis. Dark-adapted retinas of Malacosteus have been collected for visual pigment analysis. Luminescence of several species of angler fish and the argentinoids Opisthoproctus and Winteria has also been investigated, together with the collection of cultures of the luminescent bacteria from the latter two genera. Other work has involved the ocular photophores of cranchiid squids, the pharmacological responses of some amphipods and further recording of the luminescent responses of some myctophids. Material from a number of species has been fixed for light and electron microscopy (with K.H.).

Pigments (P.J. Herring)

Collections of Salpa cylindrica have been made for analysis of their blue carotenoprotein, and samples obtained of the characteristic red carotenoid pigments of the whale fishes Barbourisia and Rondeletia. Yellow fin tuna were obtained at Freetown for extraction and structural determination of tuna-xanthin.

Buoyancy of crustacean decapods (P. Foxton)

Experiments to determine the buoyancy balance sheet of Notostomus were performed on 8 specimens of N. gibbosus and N. robustus. Buoyancy measurements of other species including Acanthephyra acanthitelsonis, A. curtirostris, Systellaspis cristata, and Ephyrina sp. were made to provide comparative data.

Material resulting from these experiments was frozen for later analysis at the Marine Biological Association in collaboration with Professor E.J. Denton and Dr J. Gilpin-Brown.

Comparative anatomy of fish light-organs (K. Hansen)

Fish light-organs have been collected and fixed with the aim of making comparative studies of their ultrastructure. The work is in part a co-operation with Peter Herring and involves mainly the barbel-organs of Stomiatoids and Angler-fish light-organs. The cruise yielded good material of both groups in addition to valuable observations on fresh animals. The electron-microscopical work is done at the Institute of Comparative Anatomy, Copenhagen.

Fluorometry (P.R. Pugh)

The ship's sea water supply was connected into an Aminco fluorometer and the machine was adjusted to measure the near-surface fluorescence of the phytoplankton chlorophyll a. Profiles of the horizontal distribution of chlorophyll a were thus obtained throughout the cruise. The levels of pigment were very low at all times, averaging about 0.12-0.15 mg chlorophyll a/m^3.

As well as obtaining these horizontal profiles, vertical profiles of fluorescence down to 110 m were obtained with the aid of a submersible pump. 400 ft of 2" bore tubing were connected on the suction side of the pump and the inlet probe was attached to the TSD, thereby giving accurate measurements of these other parameters. The ship's IBM 1800 computer was used to sample all the data and to produce the fluorescence/depth profiles. Two sets of experiments were carried out along these lines, one at the equator (4 dips) and one at 3°N (3 dips). Both showed that there was very little change in the vertical distribution of chlorophyll a, but gave some indication of a slight concentration of the pigment, and thus phytoplankton, in the upper regions of the thermocline.

APPLIED ACOUSTICS (G. Phillips)

The Precision echo-sounder system used exclusively from Dakar to Freetown was the titanium element fish towed from the midships boom using the NIO Mk III electronics and beam steering unit. The hydraulically operated boom could not be used as it had seized up. There were no major problems and the system ran continuously for echo-sounding, net performance monitoring, acoustic ranging, and acoustic recovery systems. All net and mooring command instructions used the single element facility exclusively.

The two net monitors shared over 126 hours operation (49 hauls) between 3000 m and 10 m without failure. The fault discovered on one unit during Cruise 63 was repaired before the unit was used operationally. The one qualification to this performance was the thermal response of both pressure sensors. When used in or near the steep thermocline they required at least ten minutes to stabilise at an acceptable reading. This effect had not been obvious on previous cruises.

Wire tests of the acoustic command releases and beacons exposed faulty transducer windings. These were replaced, successfully retested and laid. On recovery, mooring B had a faulty release beacon but both pyro releases were successfully fired. Mooring A had a faulty command beacon but was located from approximately three miles using the release beacon. Recovery was achieved without needing to fire the second pyro release. Two command beacons were successfully tested for use on Cruise 65.

A transponder was designed and successfully used suspended 25 metres below a moored dhan buoy to achieve by acoustic means accurate short range station keeping. The two stations occupied were at acoustic ranges of 400 m and 780 m and were held to within 10 metres during runs.

The Kelvin Hughes transit sonar was used successfully in the vertical mode for observing scattering layer movement. Full gain had to be used at all times. Stratification was prominent during daylight but indistinct at night. Interpretation of wavelike structures seen was complicated by uncertainties in ship's relative speeds.

1800 Computer (F. Bilimoria, W.T.R. Slade)

The 1800 computer was used for the routine system functions of navigation, data acquisition of met. variables etc. and for the special systems TSD and Fluorometer, Guided Profiling Current Meter, Aanderaa Current Meter and Batfish/CTD probe.

A successful course update was not possible at the beginning of the cruise and this resulted in data recording beginning 36 hours after departure from Freetown. All other data was successfully recorded except TSD station no. 8590 when breaks occurred for short periods owing to a temporary clock failure.

Minor errors in the CDAT file caused some slight discrepancies in the navigation, but these have now been corrected using off-line programs in the laboratory.

On line plotting of selected isotherms and isohalines from the Batfish was accomplished for continuous periods of 10 hours after a series of tiresome problems had been overcome by means of both hard and software. Unfortunately, time did not allow the testing of modifications for longer periods.

The S.T. profiler and fluorometer were both connected and collected data successfully.

The 1816 typewriter jammed several times. A quick temporary fix was possible in general and permanent repair was effected before the end of the cruise.

Abbreviations used in Station List

RMT 1	1 m^2 Rectangular Midwater Trawl (0.33 mm mesh size)
	8 m^2 Rectangular Midwater Trawl (5 mm mesh size)
	These nets were used in combination.
NN	Neuston net
TSD	Temperature, salinity, depth probe
CTD	Conductivity, temperature, depth probe
WB 1	N.I.O. 1 litre reversing water bottle
MCM	Microcurrent meter
GPCM	Guided profiling current meter
Pump	Pump sampler
FL	Fluorometer

APPENDIX 1

STATION LIST

Stn.	Date 1974	Position Lat.	Position Long.	Gear	Depth (m)	CTD/STD/Fishing Time GMT	Remarks
8543	20/7	2°58.2'N	22°34.5'W	Mooring		All away 1732 Recovered 1832 9/8	CM at 59 & 182 m. GATE mooring no. T1. (IOS mooring 171)
8544	21/7	1°25.9'N 1°25.9'N	22°39.0'W 22°39.0'W	TSD WB 1	0- 500	1001-1039	WB at 2, 10 & 500 m.
8545	21/7	1° 0.1'N 1° 0.4'N	22°39.9'W 22°40.0'W	CTD WB 1	0- 500	1429-1516	WB at 2, 10 & 180 m.
8546	21/7	0°28.4'N 0°28.3'N	22°43.0'W 22°42.8'W	CTD WB 1	0- 500	1914-1943	WB at 2, 10 & 200 m.
8547	21/7	0° 3.2'S 0° 3.1'S	22°41.6'W 22°41.2'W	CTD WB 1	0- 500	2330-0001	WB at 2, 10 & 200 m.
8548	22/7	0°28.8'S 0°28.8'S	22°40.0'W 22°39.3'W	CTD WB 1	0- 500	0305-0345	WB at 2, 10 & 250 m.
8549	22/7	1° 0.4'S 1° 0.4'S	22°38.8'W 22°38.8'W	CTD WB 1	0- 500	0730-0806	WB at 2, 10 & 140 m.
8550	22/7	1°29.3'S 1°29.1'S	22°39.4'W 22°39.5'W	CTD WB 1	0- 500	1135-1207	WB at 2, 10 & 160 m.
8551	22/7	2° 0.2'S 2° 0.4'S	22°41.2'W 22°41.5'W	CTD WB 1	0- 500	1950-2026	WB at 2, 10 & 485 m.
8552	23/7	0°21.2'S	22°39.3'W	Mooring		All away 1115 Recovered 1323 8/8	CM at 116, 172 & 295 m. GATE mooring no. T2. (IOS mooring 172)
8553 1	23/7	0°21.2'S 0°21.0'S	22°28.5'W 22°23.2'W	RMT 1 RMT 8	505- 600	1313-1513 Day	Flow dist. 7.20 km.

Stn.	Date 1974	Position Lat.	Long.	Gear	Depth (m)	CTD/STD/Fishing Time GMT	Remarks
8553 2	23/7	0°20.6'S 0°19.7'S	22°20.7'W 22°15.2'W	RMT 1 RMT 8	605- 700	1622-1822 Day	Flow dist. 6.68 km.
8553 3	23/7	0°18.2'S 0°18.2'S	22°25.5'W 22°25.0'W	TSD WB 1	0-2000	2144-2355	Cable Fault - record good to ca. 1800 m.
8554	24/7	0°18.3'S 0°17.7'S	22°25.3'W 22°24.3'W	CTD (3 dips)	0- 400	0030-0237	WB at 10 & 355 m.
8555	24/7	0°18.4'S 0°17.8'S	22°26.0'W 22°24.3'W	CTD (7 dips)	0- 400(6) 0-1000(1)	0254-0745	WB at 2, 10 & 350 m.
8556 1	24/7	0°17.0'S 0°16.8'S	22°22.7'W 22°18.0'W	RMT 1 RMT 8	300- 405	0831-1031 Day	Flow dist. 7.16 km.
8556 2	24/7	0°18.5'S 0°20.7'S	22°12.8'W 22° 8.5'W	RMT 1 RMT 8	905-1000	1226-1426 Day	Flow dist. 7.70 km.
8556 3	24/7	0°22.0'S 0°23.4'S	22° 4.5'W 21°59.5'W	RMT 1 RMT 8	805- 900	1604-1804 Day	Flow dist. 7.96 km.
8557	24/7	0°20.2'S	22°26.7'W	MCM	0- 90	2249-2400	Abandoned, large wire angles.
8558 1	25/7	0° 9.8'S 0°11.8'S	22°52.8'W 22°48.3'W	RMT 1 RMT 8	700- 800	0839-1039 Day	Flow dist. 6.96 km.
8558 2	25/7	0°13.5'S 0°15.9'S	22°44.6'W 22°40.3'W	RMT 1 RMT 8	400- 500	1157-1357 Day	Flow dist. 8.29 km.
8558 3	25/7	0°16.6'S 0°18.7'S	22°38.7'W 22°34.3'W	RMT 1 RMT 8	203- 300	1438-1638 Day	Flow dist. 7.20 km.
8558 4	25/7	0°19.3'S 0°20.7'S	22°32.4'W 22°29.0'W	RMT 1 RMT 8	51- 102	1720-1820 Day	Flow dist. 3.65 km.

Stn.	Date 1974	Position Lat.	Position Long.	Gear	Depth (m)	CTD/STD/Fishing Time GMT	Remarks
8558 5	25/7	0°18.5'S 0°18.0'S	22°25.7'W 22°24.3'W	TSD WB 1	0-2000	1909-2058	WB at 10 m.
8559 1	26/7	0°11.8'S 0°12.6'S	22°54.7'W 22°52.2'W	RMT 1 RMT 8	105- 200	0909-1009 Day	Flow dist. 3.52 km.
8559 2	26/7	0°13.0'S 0°13.8'S	22°50.9'W 22°48.7'W	RMT 1 RMT 8	25- 52	1033-1133 Day	Flow dist. 3.65 km.
8559 3	26/7	0°14.1'S 0°14.7'S	22°48.0'W 22°46.0'W	RMT 1 RMT 8	10- 28	1151-1251 Day	Flow dist. 4.07 km.
8559 4	26/7	0°15.4'S 0°17.2'S	22°43.7'W 22°34.0'W	RMT 1 RMT 8	1250-1500	1404-1804 Day	Flow dist. 13.88 km.
8560 1	27/7	0° 5.8'N 0° 4.1'N	22°58.3'W 22°49.2'W	RMT 1 RMT 8	1005-1250	0907-1307 Day	Flow dist. 14.20 km.
8560 2	27/7	0° 3.1'N 0° 1.3'N	22°44.2'W 22°35.5'W	RMT 1 RMT 8	1510-2000	1507-1907 Day	Flow dist. 14.72 km.
8561	28/7	0°16.0'S 0°14.1'S	22°29.2'W 22°27.3'W	CTD (13 dips)	0- 350	0115-0530	WB at 10 & 240 m.
8562 1	28/7	0°13.2'S 0°13.0'S	22°26.9'W 22°26.2'W	TSD WB 1	0-2000	0559-0734	WB at 632 m.
8562 2	28/7	0°20.2'S 0°22.0'S	22°24.9'W 22°21.7'W	RMT 1 RMT 8	10-1000	0901-1018 Day	Oblique. Flow dist. 3.91 km.
8562 3	28/7	0°23.3'S 0°22.9'S	22°19.2'W 22°17.8'W	RMT 1	0- 10	1127-1227 Day	
8562 4	28/7	0°23.5'S 0°24.5'S	22°15.5'W 22°13.3'W	RMT 1 RMT 8	150- 205	1329-1429 Day	Flow dist. 3.38 km.

Stn.	Date 1974	Position Lat.	Position Long.	Gear	Depth (m)	CTD/STD/Fishing Time GMT	Remarks
8562 5	28/7	0°25.5'S 0°26.5'S	22°10.8'W 22° 7.9'W	RMT 1 RMT 8	100- 160	1528-1628 Day	Flow dist. 3.34 km.
8562 6	28/7	0°28.0'S 0°30.2'S	22° 4.7'W 21°59.0'W	RMT 1 RMT 8	805-1000	1742-1957 Day	Flow dist. 9.31 km.
8562 7	28/7	0°31.9'S 0°32.8'S	21°55.0'W 21°53.3'W	RMT 1 RMT 8	152- 200	2130-2230 Night	Flow dist. 3.38 km.
8562 8	28/7	0°33.4'S 0°34.3'S	21°51.7'W 21°48.9'W	RMT 1 RMT 8	102- 152	2308-0008 Night	Flow dist. 3.56 km.
8562 9	29/7	0°34.7'S 0°35.5'S	21°47.7'W 21°45.5'W	RMT 1 RMT 8	10- 33	0031-0131 Night	Flow dist. 4.50 km.
8562 10	29/7	0°34.7'S 0°35.1'S	21°47.7'W 21°46.5'W	RMT 1	0- 6	0033-0103 Night	
8562 11	29/7	0°36.2'S 0°37.1'S	21°43.7'W 21°41.2'W	RMT 1 RMT 8	25- 60	0211-0311 Night	Flow dist. 3.71 km.
8562 12	29/7	0°37.7'S 0°39.0'S	21°39.6'W 21°36.7'W	RMT 1 RMT 8	48- 104	0341-0442 Night	Flow dist. 3.80 km.
8562 13	29/7	0°39.7'S 0°41.0'S	21°35.3'W 21°32.7'W	RMT 1 RMT 8	200- 300	0512-0612 Night	Flow dist. 3.94 km.
8563 1	31/7	2°56.5'N 2°59.8'N	22°42.6'W 22°47.6'W	RMT 1 RMT 8	805- 900	1206-1406 Day	Flow dist. 9.09 km.
8563 2	31/7	3° 1.3'N 3° 3.6'N	22°52.0'W 22°56.4'W	RMT 1 RMT 8	905-1000	1546-1746 Day	Flow dist. 7.76 km.
8563 3	31/7	3° 7.3'N 3° 5.3'N	23° 1.3'W 23° 2.6'W	RMT 1 RMT 8	25- 50	2116-2216 Night	Flow dist. 3.70 km.

Stn.	Date 1974	Position Lat.	Position Long.	Gear	Depth (m)	CTD/STD/Fishing Time GMT	Remarks
8563 4	31/7	3° 4.7'N 3° 3.1'N	23° 2.8'W 23° 4.6'W	RMT 1 RMT 8	12- 25	2237-2337 Night	Flow dist. 3.76 km.
8563 5	31/7	3° 4.2'N 3° 3.4'N	23° 3.1'W 23° 4.1'W	RMT 1	0- 10	2250-2320 Night	Depth limit estimated.
8563 6	1/8	3° 1.9'N 2°59.7'N	23° 5.8'W 23° 7.4'W	RMT 1 RMT 8	44- 104	0018-0118 Night	Flow dist. 3.34 km.
8563 7	1/8	2°59.1'N 3° 0.1'N	23° 8.3'W 23° 8.8'W	CTD WB 1	0-1017	0154-0322	WB at 10 & 1017 m.
8564	1/8	3° 0.5'N 3° 4.0'N	23° 9.2'W 23°12.3'W	CTD (14 dips)	0- 250	0335-0745	WB at 2, 10 & 250 m.
8565 1	1/8	3° 3.1'N 2°59.2'N	23°14.3'W 23°18.4'W	RMT 1 RMT 8	700- 800	0845-1045 Day	Flow dist. 6.76 km.
8565 2	1/8	2°56.4'N 2°52.5'N	23°21.1'W 23°24.2'W	RMT 1 RMT 8	600- 705	1210-1410 Day	Flow dist. 7.56 km.
8565 3	1/8	2°50.3'N 2°45.7'N	23°25.7'W 23°27.9'W	RMT 1 RMT 8	400- 500	1511-1711 Day	Flow dist. 7.24 km.
8565 4	1/8	2°44.1'N 2°40.1'N	23°28.9'W 23°30.5'W	RMT 1 RMT 8	0-1000	1753-1910 Day	Oblique. Flow dist. 4.25 km.
8565 5	1/8	2°38.5'N 2°36.4'N	23°31.5'W 23°30.7'W	RMT 1 RMT 8	150- 200	2136-2236 Night	Flow dist. 3.43 km.
8565 6	1/8	2°35.2'N 2°33.3'N	23°30.2'W 23°29.4'W	RMT 1 RMT 8	104- 150	2311-0011 Night	Flow dist. 3.60 km.
8565 7	2/8	2°33.0'N 2°33.8'N	23°29.4'W 23°30.7'W	TSD WB 1	0-1000	0042-0220	WB at 10 & 920 m.

Stn.	Date 1974	Position Lat.	Position Long.	Gear	Depth (m)	CTD/STD/Fishing Time GMT	Remarks
8566	2/8	2°54.0'N 2°56.9'N	23°21.5'W 23°24.6'W	CTD (30 dips)		0447-0750	Between 22.5 & 15.0°C isotherms.
8567 1	2/8	2°56.8'N 2°53.9'N	23°27.5'W 23°29.8'W	RMT 1 RMT 8	505- 600	0835-1035 Day	Flow dist. 6.94 km.
8567 2	2/8	2°52.3'N 2°50.7'N	23°32.1'W 23°35.2'W	RMT 1 RMT 8	305- 400	1131-1331 Day	Flow dist. 7.88 km.
8567 3	2/8	2°50.1'N 2°48.5'N	23°35.6'W 23°36.1'W	RMT 1 RMT 8	150- 200	1431-1531 Day	Flow dist. 3.08 km.
8567 4	2/8	2°47.5'N 2°45.1'N	23°36.5'W 23°37.0'W	RMT 1 RMT 8	100- 180	1612-1712 Day	Flow dist. 3.70 km.
8567 5	2/8	2°44.1'N 2°40.7'N	23°36.8'W 23°35.6'W	RMT 1 RMT 8	23- 55	1737-1837 Day	Flow dist. 4.25 km.
8568 1	3/8	2°45.4'N 2°44.4'N	22°52.5'W 22°59.4'W	RMT 1 RMT 8	198- 306	0854-1054 Day	
8568 2	3/8	2°44.0'N 2°42.2'N	23° 0.4'W 23° 1.5'W	RMT 1 RMT 8	50- 103	1124-1224 Day	Flow dist. 3.29 km.
8568 3	3/8	2°41.7'N 2°40.6'N	23° 2.2'W 23° 3.3'W	RMT 1 RMT 8	10- 25	1303-1403 Day	Flow dist. 3.91 km.
8568 4	3/8	2°40.5'N 2°40.3'N	23° 3.5'W 23° 4.1'W	RMT 1	0- 11	1413-1443 Day	
8568 5	3/8	2°39.3'N 2°33.4'N	23° 5.3'W 23° 8.2'W	RMT 1 RMT 8	600- 800	1541-1830 Day	Flow dist. 9.76 km.
8568 6	3/8	2°34.6'N 2°32.8'N	23°10.1'W 23° 9.3'W	RMT 1 RMT 8	206- 300	2152-2252 Night	Flow dist. 3.03 km.

Stn.	Date 1974	Position Lat.	Position Long.	Gear	Depth (m)	CTD/STD/Fishing Time GMT	Remarks
8569	6/8	0°21.8'S	22°24.6'W	GPCM (4 dips)	0- 300	1608-1921	
8570	7/8	0°25.4'S	22°22.2'W	GPCM	0- 400	1650-1700	
8571 1	7/8	0°26.1'S 0°26.7'S	22°22.8'W 22°23.1'W	TSD Pump FL	0- 110	1818-1903 Dusk	
8571 2	7/8	0°26.7'S 0°27.2'S	22°23.1'W 22°23.3'W	TSD Pump FL	0- 110	1903-1943 Dusk	Piping detached at bottom of dip.
8571 3	7/8	0°27.6'S 0°28.0'S	22°24.0'W 22°24.1'W	TSD Pump FL	0- 110	2017-2052 Night	
8571 4	7/8	0°28.0'S 0°28.3'S	22°24.1'W 22°24.1'W	TSD Pump FL	0- 110	2052-2129 Night	
8572 1	7/8	0°29.9'S 0°33.6'S	22°23.2'W 22°18.8'W	RMT 1 RMT 8	605- 800	2238-0038 Night	Flow dist. 7.52 km.
8572 2	8/8	0°35.0'S 0°38.2'S	22°16.9'W 22°13.7'W	RMT 1 RMT 8	100- 300	0130-0330 Night	Flow dist. 7.64 km.
8573	8/8	0°46.3'N 0°47.1'N	22°42.1'W 22°42.2'W	NN	0- 0	1949-2001 Dusk	
8574	8/8	0°47.2'N 0°48.0'N	22°42.2'W 22°42.2'W	NN	0- 0	2003-2015 Dusk	
8575	8/8	0°48.2'N 0°49.0'N	22°42.2'W 22°42.2'W	NN	0- 0	2017-2029 Dusk	

Stn.	Date 1974	Position Lat.	Position Long.	Gear	Depth (m)	CTD/STD/Fishing Time GMT	Remarks
8576	8/8	0°49.0'N 0°49.9'N	22°42.2'W 22°42.3'W	NN	0- 0	2030-2042 Dusk	
8577	8/8	0°49.9'N 0°50.8'N	22°42.3'W 22°42.3'W	NN	0- 0	2044-2056 Night	
8578	8/8	0°50.7'N 0°51.6'N	22°42.3'W 22°42.4'W	NN	0- 0	2057-2109 Night	
8579	8/8	0°51.8'N 0°52.5'N	22°42.4'W 22°42.5'W	NN	0- 0	2111-2123 Night	
8580	8/8	0°52.7'N 0°53.4'N	22°42.5'W 22°42.5'W	NN	0- 0	2125-2137 Night	
8581	8/8	0°53.5'N 0°54.2'N	22°42.5'W 22°42.5'W	NN	0- 0	2139-2151 Night	
8582	8/8	0°54.3'N 0°55.0'N	22°42.5'W 22°42.6'W	NN	0- 0	2153-2205 Night	
8583	8/8	0°55.1'N 0°55.8'N	22°42.6'W 22°42.6'W	NN	0- 0	2207-2219 Night	
8584	8/8	0°55.9'N 0°56.6'N	22°42.6'W 22°42.5'W	NN	0- 0	2221-2233 Night	
8585	8/8	0°56.8'N 0°57.6'N	22°42.6'W 22°42.6'W	NN	0- 0	2235-2247 Night	
8586	8/8	0°57.8'N 0°58.6'N	22°42.6'W 22°42.6'W	NN	0- 0	2250-2302 Night	
8587	8/8	0°58.6'N 0°59.3'N	22°42.6'W 22°42.5'W	NN	0- 0	2303-2315 Night	

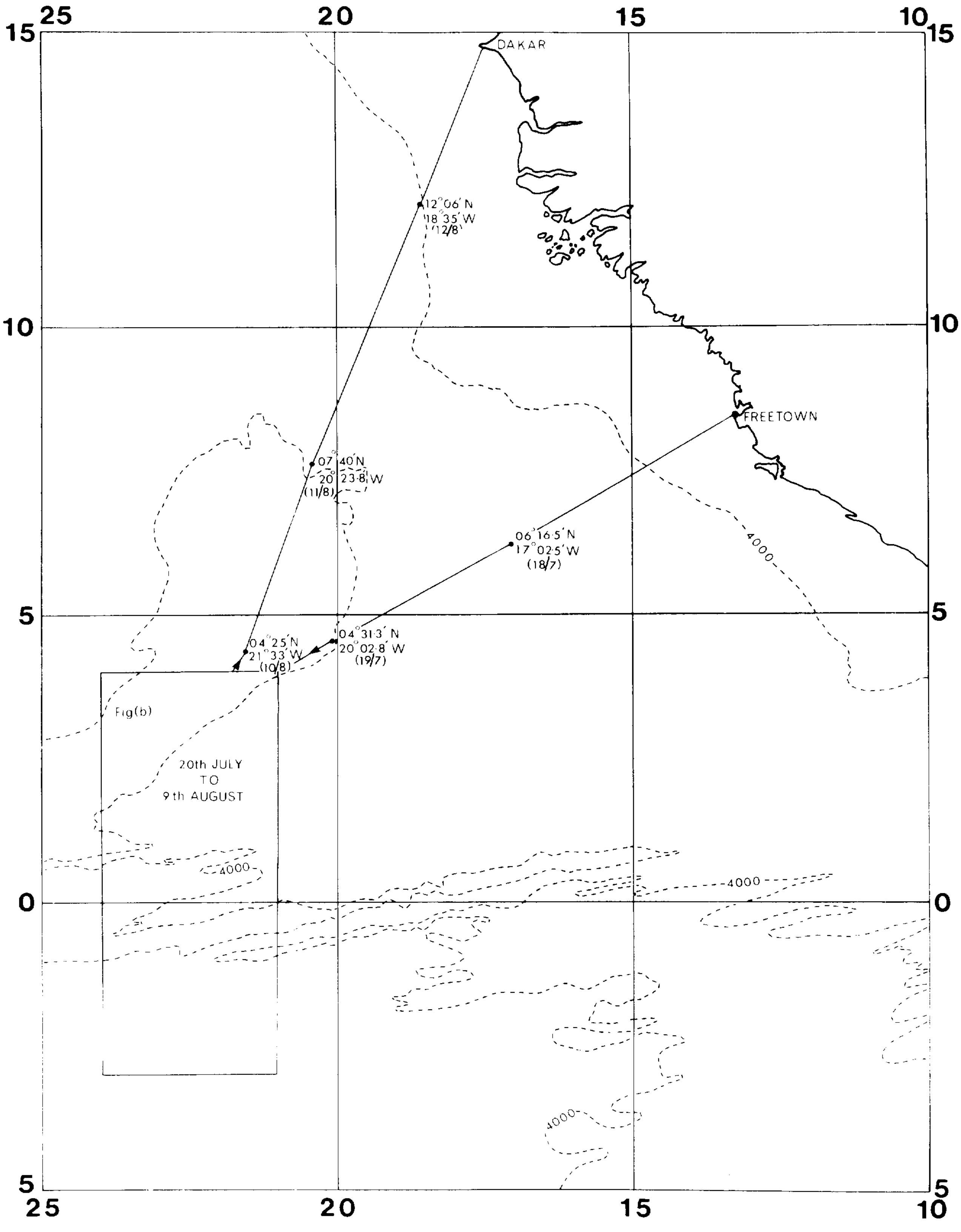
Stn.	Date 1974	Position Lat.	Position Long.	Gear	Depth (m)	CTD/STD/Fishing Time GMT	Remarks
8588	8/8	0°59.4'N 1° 0.0'N	22°42.5'W 22°42.4'W	NN	0- 0	2317-2329 Night	
8589 1	9/8	2°58.4'N 2°58.6'N	22°36.2'W 22°37.2'W	TSD Pump FL	0- 110	1908-1948 Dusk	
8589 2	9/8	2°58.6'N 2°58.4'N	22°37.2'W 22°38.2'W	TSD Pump FL	0- 110	1950-2033 Night	
8589 3	9/8	2°58.4'N 2°58.2'N	22°38.3'W 22°39.2'W	TSD Pump FL	0- 110	2035-2117 Night	
8590	9/8	2°58.3'N 2°58.1'N	22°39.7'W 22°41.4'W	TSD WB 1	0-2000	2137-2327	WB at 1900 & 10 m.
8591	10/8	4°26.2'N 4°21.7'N	21°46.1'W 21°37.8'W	RMT 1 RMT 8	2180-3000	1109-1530 Day	Flow dist. 16.43 km.

APPENDIX 2

POSITIONS OF BATFISH AT START AND END OF DATA COLLECTION RUNS

BATFISH RUN NO.	TIMES		POSITION	
	START	END	LATITUDE	LONGITUDE
7	1215-18/7	1516-18/7	6°15.5'N 6° 4.4'N	17° 3.9'W 17°22.9'W
8	0001-21/7	0601-21/7	2°38.0'N 1°48.4'N	22°34.3'W 22°37.0'W
9	0350-25/7	0706-25/7	0°15.9'S 0° 9.2'S	22°31.3'W 22°52.1'W
10	2249-25/7	0715-26/7	0°10.6'S 0° 9.9'S	22°28.1'W 22°57.4'W
11	2122-26/7	0647-27/7	0°29.5'S 0° 3.7'N	22°34.7'W 22°59.3'W
12	2207-29/7	0914-31/7	2°16.5'S 2°55.5'N	22°32.8'W 22°34.4'W
13	2302-2/8	0704-3/8	2°48.9'N 2°46.6'N	23°38.5'W 22°46.9'W
14	0027-4/8	0320-5/8	2°33.3'N 0°12.1'S	23° 6.5'W 22°27.3'W
15	0617-5/8	2121-5/8	0°22.0'S 2°35.5'S	22°29.2'W 22°27.0'W
16	2343-6/8	1119-7/8	0°26.6'S 0°23.9'S	22°14.0'W 21°59.5'W
17	1127-7/8	1327-7/8	0°23.9'S 0°23.5'S	22° 0.7'W 22°19.4'W

Batfish was in the water for 160½ hours during the cruise, giving 129 hours of recorded data during 544 controlled undulations at 31.25 samples per second.



CRUISE CHART (a) DISCOVERY CRUISE 64
NOON-DAY POSITIONS

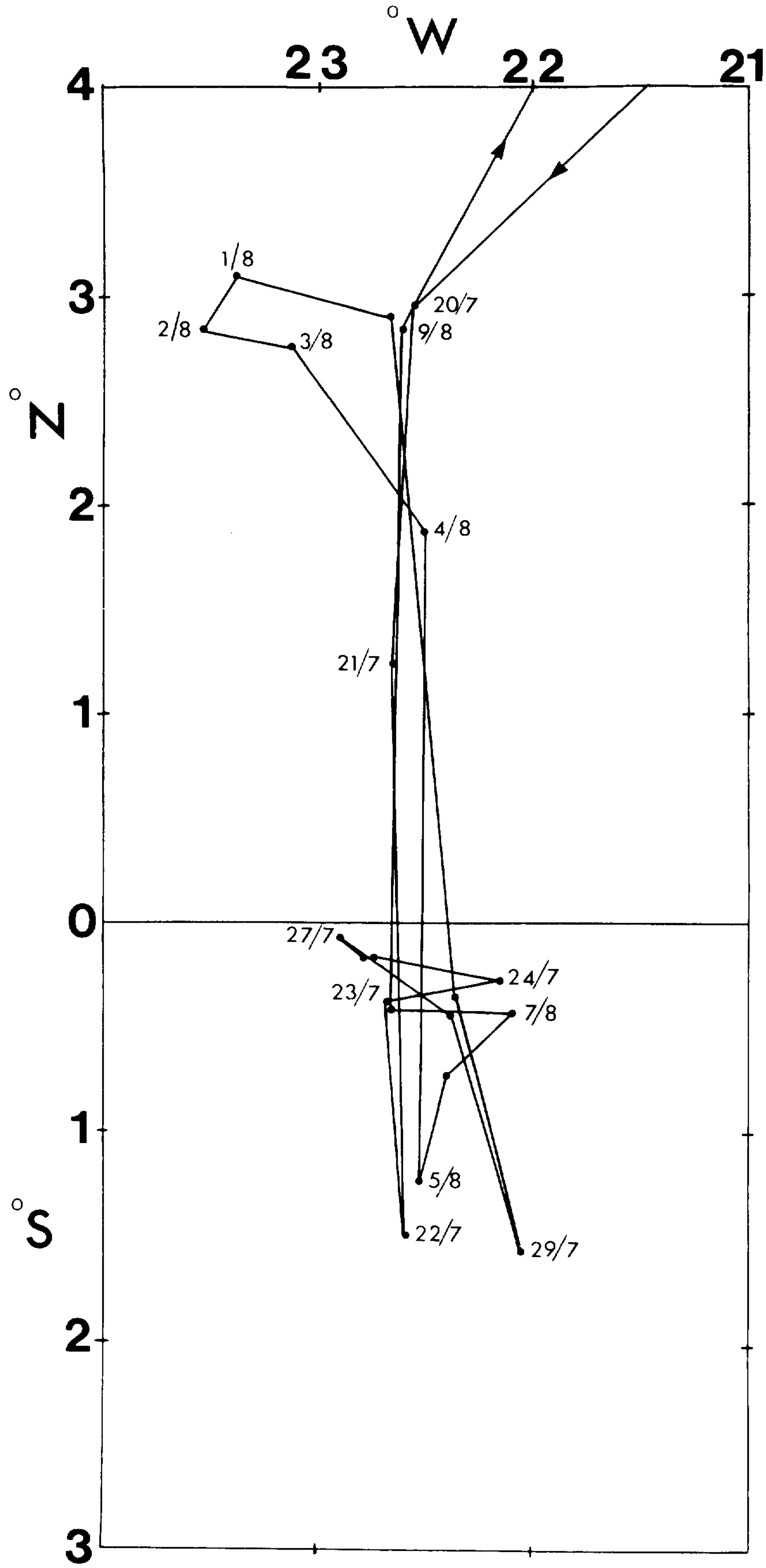


FIG (b)
DETAIL OF (a)
NOON-DAY POSITIONS

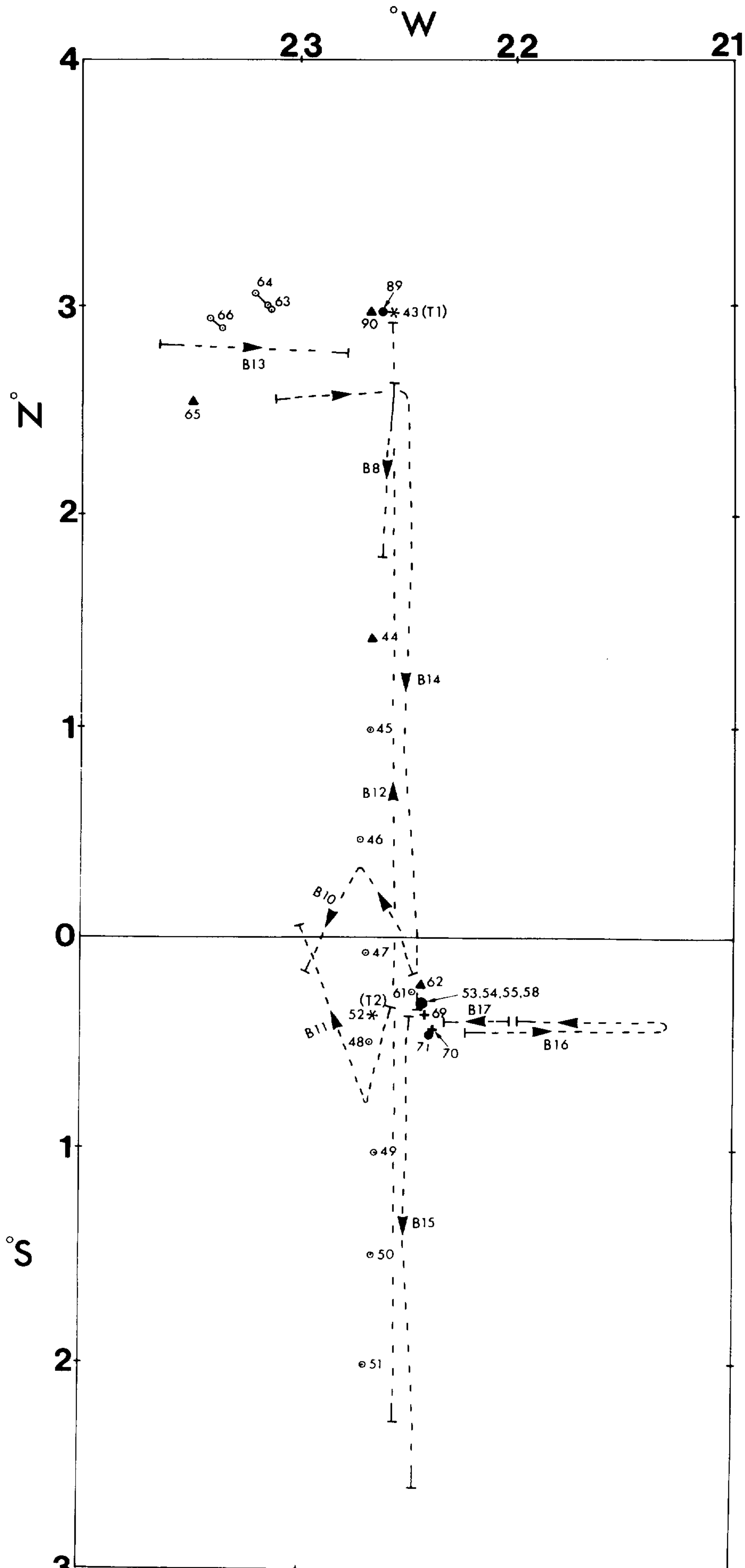


FIG (c) POSITIONS OF
MOORINGS * , TSD STATIONS ▲, CTD STATIONS ⊙, GPCM STATIONS +, TSD-FLOURIMETER STATIONS ●
AND THE EXTENT OF BATFISH DATA COLLECTION RUNS ⊢--⊣ (EXCEPT RUN 7).
STATION NUMBERS HAVE FIRST TWO DIGITS OMITTED. BATFISH RUNS ARE NUMBERED B8 ETC.