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CRUISE REPORT No. 8

RRS *DISCOVERY* CRUISE 224, Leg 2
30 DEC 1996 - 17 JAN 1997

Biological and physical investigations in the region of the Almeria-Oran Front (western Mediterranean)

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1997

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ABSTRACT

The purpose of *Discovery* Cruise 224, Leg 2, was to continue the physical and biological surveys previously undertaken during Leg 1 as part of the EEC MAST OMEGA Project; and to undertake comparisons of the western Mediterranean macrozooplankton and micronekton communities on either side of the Almeria-Oran Front.

The sampling programme consisted of: 1) Fine scale SeaSoar surveys, at the beginning and end of the leg, to investigate the changes in the structure of the Almeria-Oran frontal system, and to establish the sites for biological sampling. 2) Investigations of the day and night depth distribution, throughout the water column, of the macroplankton and micronekton communities, by means of a vertically stratified series of RMT1+8M net deployments, at two sites on either side of the Almeria-Oran Front. This was largely successful, but bad weather prevented any near-bottom tows being carried out at one of the sites. 3) Investigations of the near-surface cross-frontal distribution of macrozooplankton and micronekton, again using the RMT1+8M net system. 4) Observations on the patterns of acoustic backscatter, using the shipborne ADCP and towed EK500 systems, throughout the cruise and to relate these with data from the biological sampling; with additional 'sea-truthing' from Longhurst-Hardy Plankton Recorder deployments.

In addition studies were made on the bioluminescent characteristics of the interesting examples of the pelagic fauna.

KEYWORDS

ADCP, ALMERIA-ORAN FRONT, BIODIVERSITY, BIOLUMINESCENCE, BIOMASS, CHAETOGNATHS, CHLORPHYLL, CRUSTACEAN, *DISCOVERY*/RRS, CRUISE 224 LEG 2 1996-97, EK500 (GOLDFISH), HYDROGRAPHY, ICHTHYOPLANKTON, LADCP, LONGHURST HARDY PLANKTON RECORDER, MACROPLANKTON, MICRONEKTON, OMEGA, RMT, SEASOAR, VERTICAL MIGRATION

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Depart Cartagena, Spain 30th December 1996 - Arrive Cartagena 17th January 1997

OBJECTIVES

1. To carry out two fine-scale SeaSoar surveys, one at the beginning and one at the end of the leg, to study the Almeria-Oran Front to the east of the Alboran Sea. These studies will further the objectives of the first leg of the cruise, and will form part of the research for the MAST III funded project OMEGA. The data from the first survey will be used to establish, relative to the front, the two main stations for the biological investigations.

2. To carry out total water column biological sampling programmes, using the RMT1+8M net system, at two stations on either side of the Almeria-Oran Front, in order to:-

   a) To establish how the depth distribution of the specific communities of macroplankton and micronekton, and their standing crop, compare with those in the Atlantic and western Mediterranean.

   b) To establish to what extent the deep-water communities are linked to production in the near-surface layers and to what extent they are determined by the physical circulation.

   c) To provide information concerning the origins and continuing development of biodiversity in the western Mediterranean, by investigating how faunistic links with the Atlantic are being maintained by the inflows, and whether there is local speciation.

4. To carry out additional RMT1+8M net sampling across the Almeria-Oran Front.

5. To validate and cross-calibrate the various shipborne bioacoustic sensors by targeted sampling using the Longhurst Hardy Plankton Recorder.

NARRATIVE (FIGURE 1)

RRS *Discovery* sailed from Cartagena at 0900 GMT on Monday 30th December and course was set for the start point (36°45.8'N 1°55'W) of the first SeaSoar survey. This survey was planned to be a slightly curtailed (legs c-j) version of the fine-scale surveys carried out during the first leg of the cruise. During the passage the opportunity was taken to calibrate the shipborne ADCP.

At c. 1800Z the EK500 and PES fishes were deployed, and the launch of the SeaSoar commenced (St. 13063). Course was then set for the first leg of the fine scale SeaSoar survey (see Figure 2). The SeaSoar survey continued over the next 2.8 days, and meanwhile, during the New Year's Eve festivities the old year was rung out by the oldest person aboard (Martin Angel) and the new one rung in by the youngest (Sophie Fielding). The survey took a little longer than expected as occasionally the ship's speed was reduced due to the blustery weather conditions, which were to recur throughout the cruise. During the survey it became evident that the Almeria-Oran Front had broken down and that there was a widespread eastward flow of superficial Atlantic water across the survey area. This was in marked contrast to the results of the last survey on the first leg of the cruise, when the front was present and the Atlantic waters were slightly warmer. Recovery of the SeaSoar was commenced at c. 1400Z on 2nd January. During the recovery it was discovered that a large quantity of long-line, including hooks, had fouled the cable at about its mid length. This all had to be laboriously removed. Approximately 60 m of fairing had either been stripped off or damaged, and subsequently removed during recovery. The fouling of the cable was almost certainly the reason why, during the latter part of the survey, there was a reduction in the maximum depth to which the SeaSoar dived.

After the SeaSoar and EK500 had been recovered, the ship steamed to the first of two main sampling sites. This first site (St. 13064) was centred on 36°45'N, 01°W were the waters were of Mediterranean origin. A full depth CTD was carried out whilst the aft deck was rearranged in preparation for netting. Then the RMT1+8M netting commenced with a night-time set of hauls between 500 and 200 m. The intention was to fish a day and night series of hauls down to 1100 m, thereby encompassing the range in which diel vertical migration of the macroplankton/micronekton might be found, and a further series of time-independent hauls at deeper depths. The new G96 monitor was used for these nets and it appeared to work properly. The catches were larger than had been expected. A second set of night-time nets was completed successfully, but toward the end of this deployment the weather conditions, as previously experienced during the SeaSoar survey, began to change rapidly for the worse, with winds gusting up to 45 knots, such that the recovery of the nets was carried out with some caution. The ship then steamed back to a suitable launch position, but the gale to strong gale winds meant that fishing was too dangerous. The ship, thus, remained hove to for the remainder of the day and the following night, during which time the winds gusted up to 55 knots.

By the morning of the 4th January the weather had improved dramatically, but the launch of the nets was delayed until 1100Z in order to allow the sea state to settle down. Because of the shortness of daylight hours, which only allowed c. 7.5 hours of fishing, it was only possible to carry out one day-time series of hauls. After this a shallow (0-200 m)

CTD cast was made in order to collect chlorophyll samples to calibrate the SeaSoar fluorometer, which had been incorporated into the CTD system.

Problems with the net monitors now began to appear. The G96 monitor began to fail during the last of the next night-time series of hauls, resulting in an inability to close the nets. Fortunately, the 50-0 m depth range was being fished and so the nets were recovered in an open state, but without any loss or contamination of the catch. The monitor was examined and the fault apparently cured, so that it was used again for the next deployment. The first nets opened normally, but they failed to close at depth so that the haul was aborted. Eventually, all the nets were closed at c. 50 m depth, just before recovery. The G96 monitor was now replaced by the "Black lead" one; but this failed as soon as it hit the water, and so the nets were again recovered.

The third "White lead" monitor was now brought into service and this worked successfully for several deployments. However, the flow meter now began to give problems. At first this appeared to be due to a leaky cable, but ultimately it was found that there was a definite fault with the meter itself, and so the whole unit was replaced. Two successful day-time deployments were carried out on 5th January in very calm weather conditions. However, as the first night-time nets were about to be launched a squall hit the ship with a heavy inundation of virtually horizontal rain. This quickly passed and it appeared save to launch the nets. However, the weather began to deteriorate again, with the wind gusting to 40-45 knots. In addition, there problems with the engines that meant that a steady speed could not be maintained. Thus after the first net had been fished the Master called for the haul to be aborted. The nets were recovered and fishing abandoned for the remainder of the night.

By the morning (6th January) the weather had again improved and the day-time series of hauls, in the top 1100 m of the water column, completed. Time then allowed the 1700-1100 depth range to be sampled, over 200 m horizons, before the night-time series was completed with a final tow. Because of the unpredictable changes in weather, that had already lost us over a day and a half in sampling time, it was decided to steam toward other site (c. 36°05'N 01°40'W), where superficial Atlantic water should be present. On leaving the first site (7th January), the LHPR was launched and fished for the next 2.5 hours. The weak salinity front that appeared, from the SeaSoar survey, to be all that remained of the Almeria-Oran front was then located. Two sets of RMT1+8M hauls (St. 13065#1-6) at fixed depths (c. 250 m by day and c. 150 m by night) were then fished through this front again using the G96 monitor. Problems were encountered during the second deployment which appeared to be cured by simply switching the monitor off and on again.

Passage to the second main sampling site was then continued and shortly before midnight a very marked salinity and temperature front was crossed. Thus it appeared that the Almeria-Oran front had re-established itself, and the weak salinity front that had been sampled early was probably only a vestige of the previous break-up of the front.

Once at the second sampling site, there were two unsuccessful launches of the nets because the traces from the G96 monitor kept on locking on to each other, and switching the monitor off and on failed to cure this. The "White lead" monitor was, thus, brought back into service, and the series of day and night sampling (St. 13066) with the RMT1+8M nets commenced. However, further problems were set to plague us. During the first day-time deployment the second net refused to close at depth, and so the haul had to be abandoned, with just the first net samples being retained. In addition, the weather and sea state were now rapidly deteriorating. It soon became apparent that netting was out of the question and so we steamed to the site position and carried out a brief CTD (0-746 m), again with the purpose of calibrating the SeaSoar fluorometer. A lull in the weather then allowed a full depth CTD cast to be made. The first CTD showed a very peculiar thermoclinal structure in the fluorescence, but part of this had already been eroded by the time the second cast was made. Constant winds of c. 40+ knots meant that fishing was impossible; and the opportunity was take to celebrate the mid-point of the cruise! The weather remained inclement throughout most of the next day (9th January), but in the evening it began to improve and it appeared that fishing could recommence.

The 10th January was a disaster for fishing. Two night launches, with different monitors, had to be aborted as the nets would not open or close. Eventually, a fault was found in the cable to the release gear. In addition it was thought that there might be a fault in the release gear itself and so this too was changed. While these faults were traced the LHPR was launched at 0830Z into a flat calm sea. The RMT1+8M nets were then launched, using the "Black lead" monitor as the "White lead" one appeared to be misbehaving. Although the nets appeared to fish correctly, on recovery it was discovered that all the catch was in the third net. It was presumed that three of the bridles must have pulled out from the release gear, and on closer inspection it was discovered that there was a fault in the drive cam. The original release gear was re-instated and a test launch was carried out to run the nets through and make sure that they had opened correctly. No fault was found and so the nets were fully launched for a successful night haul.

The RMT1+8M system now worked almost perfectly for the remaining nine deployments carried out at the second main sampling site, and no further time was lost to the weather. Only one problem occurred when the batteries in the release gear gone down, but this did not result in any loss of sample. There was sufficient time available for one set of near-bottom tows. It was hoped that the new G96 monitor could be used, so that the new altimeter could be tested out. However, it was obviously malfunctioning and so the "White lead" monitor was used. The old Near Bottom Echo Sounder, despite its limited range, worked well and the haul was successful, although there was very little in the catches.

The remainder of the night of the 13th January was spent doing a small-scale survey of the Almeria-Oran front, which now manifested itself as a sharp change in salinity, but with little temperature change. Four sets of hauls (Sts. 13067-8), two by day and two by night, were then fished through this front at fixed depths (c. 150 and 225 m by day, and c. 100 and 60 m at night). Course was then set for the start of the second fine-scale SeaSoar survey, which was commenced at c. 0800Z on the 14th January. Shortly after launch an unusually high strain on the cable was noted, and shortly thereafter the Master informed us that he had been warned to keep away from naval submarines that were exercising in the area. Whether this was a coincidence or not remains a mystery. The survey continued until c. 2000 on the 16th January, with time constraints meaning that there had to be a short curtailment of the final leg. Meanwhile the catering staff produced a magnificent meal in honour of Dr. Martin Angel as he is shortly to retire and this was his last cruise.

Despite the loss of almost 70 hours of sampling time to bad weather, with a further day lost to equipment failures, the overall objectives of the cruise were successfully achieved. Such success depends on a great deal of collaboration and co-operation not only between the participating scientists, but also with the ship's personnel. The latter were outstanding and it is a great pleasure to express my thanks to the Master, the Officers, and the crew for their considerable contribution to the success of the cruise.

PRP

SCIENTIFIC INVESTIGATIONS

Physical Measurements

In addition to the deployments of SeaSoar and the lowered CTD system (see below) a variety of shipborne equipment was used. High spatial resolution measurements were made, using the ship's non-toxic sea water supply, of temperature, salinity, chlorophyll *a* fluorescence and light transmittance. The hull mounted ADCP was used to determine water velocity profiles in the upper part of the water column and to make qualitative assessments of the distribution and diel vertical migrations of the macrozooplankton and micronekton. In addition, the towed multi-frequency EK500 system enabled quantitative acoustic measurements of size class abundance.

SeaSoar Surveys.

Two SeaSoar surveys were carried out and covered a shortened version of the fine scale surveys undertaken during the first leg of the cruise. Conductivity, temperature, depth, chlorophyll *a* fluorescence, optical back-scatter, light and 0.25 to 3 mm particle concentrations, using an optical plankton recorder, were measured with an effective along-track resolution of c. 4 km. The equipment performed without fault, but towards the end of the first survey, the maximum depth obtainable was reduced to 250 metres. On recovery, a large bunch of longline and hooks was found wrapped around the middle section of the tow cable and fairing. About 60 metres of fairing was missing and/or damaged; the latter being removed during recovery. The second survey was completed without problems, and depths of 300 metres obtained. Opportunity was taken during this leg, to remove the last few bugs from the SeaSoar control software.

Superficial Atlantic water enters the Alboran Sea through the Straits of Gibraltar, and then circulates around in a system of two gyres before forming the Algerian Current. The eastern boundary of the eastern gyre forms the Almeria-Oran Front. Within this gyre relatively warm and fresh (salinity < 36.7 psu) water overlies cooler saltier Levantine Water (salinity >38.4 psu). Between these is a transitional layer, approximately 150 m deep, that to the east of the front reaches to the surface. The resulting large horizontal density gradient across the front results in a strong (> 1 ms^{-1}) geostrophic flow along the front.

During both legs of the cruise the surface signature of the Almeria-Oran Front became more diffuse, possibly as a result of the inclement weather causing an increased buoyancy loss and increased vertical mixing of the surface layers. This was immediately apparent from the near-surface measurements made by the thermosalinograph (Figures 2 and 3). There were indications during the Survey at the start of the leg that the eastern gyre had almost broken down and that water flow was direct into the Algerian current. Absolute water velocity vectors from the VM-ADCP showed strong vertical shear in the upper 150 m of the water column (Figures 4 and 5) and an absence of a along-front jet below this depth. All the fine scale surveys indicate that the position of the Almeria-Oran Front is very variable, on a time scale of hours/days, as is apparent from the VM-ADCP current vectors (Figures 4 and 5). North and east of the front the current vectors showed regions of mesoscale eddy-like re-circulation. These vectors also show that there was a strong horizontal shear on the eastern side of the Almeria-Oran Front current.

JS, PRP

CTD Operations

Four CTD stations were occupied; two shallow and two to full depth. The Lowered Acoustic Doppler Current Profiler (LADCP) was used on the two full depth. Water bottle samples were taken for calibration purposes. The fluorometer from the SeaSoar was mounted on the CTD frame in place of the original instrument for the last two casts, for calibration purposes. All equipment performed without fault during these casts.

The two deep casts were carried out at each of the biological sampling stations on either side of the Almeria-Oran Front (Figures 6 and 7). Below c. 500 m the depth profiles of temperature and salinity were virtually identical at the two sites. At the station (13064) (Figure 6) on the Mediterranean side of the Almeria-Oran Front there was a very narrow (c. 50 m deep) top mixed layer were the temperature was c. 12.8°C. The thermocline extended to a depth of c. 130 m, below which there was a slight temperature inversion followed by a gradual decline to a temperature of 12.79°C. Salinity increased from a surface value of 37.74 psu to a deep value of 38.44 psu.

At the station on the Atlantic side of the front (13066) (Figure 7) the top mixed layer was deeper (c. 90 m), warmer (16.24°C) and fresher (salinity 36.66 psu). There was a shelf in the thermocline, between c. 150 and 180 m. Below the thermocline there was a similar, but smaller, temperature inversion and below this the temperature and salinity values were virtually identical to those at the other station.

JS, PRP

Data Processing

In general data were processed in the same manner as in leg 1 (see cruise report for first leg of *Discovery* Cr. 224). Consequently, except where different methods were used, only a brief description follows.

SeaSoar

Data were read into PSTAR format every four hours. After a nominal calibration, spikes were removed and salinity edited for offsets caused by fouling of the conductivity cell. The one-second data were then appended and gridded by averaging into cells of length four kilometres and depth four metres. A further calibration was performed for the first of the two surveys. Salinity data were extracted from the gridded file at 5 metres. These data were merged with the salinity data from the thermosalinograph. The salinity difference is shown in Figure 8. Spikes originate from the uncertain time difference between the two measurements: thermosalinograph measurements are made from the ships 'non-toxic' supply, SeaSoar measurements are made some distance behind the ship. Taking the difference, when the salinity is less than 36.7 psu., gives a mean salinity difference of -0.0062 (i.e. the SeaSoar salinity is higher than the TSG by 0.0062 psu) with a standard deviation of 0.0021. This will be compared with the data in the noisy region using a student-t test. This value has been used to correct the SeaSoar data from the survey.

Data from the second survey have as yet not been completely edited. One major fouling event complicated this procedure; the salinity remaining offset for over three hours.

Optical Plankton data were read and processed as on the first leg. Some data were accidentally deleted near the end of the cruise because the PC software generates file names containing a number that cycles from 01 to 99. Once the files returned to 01, it was not clear which had been processed.

SA, MH

Acoustic Doppler Current Profiler

Data from the ADCP were read in every 12 hours. After correcting the timebase for the PC clock drift, velocities relative to a layer around 200 metres were calculated. Because of the strong surface signature of the front, plots of the relative currents were directly comparable to those of absolute velocity calculated using differential GPS during the previous leg.

For the first survey, two minute absolute velocities were calculated in the usual manner: correcting for gyro errors using gyro and Ashtech 3DGPS data; merging with velocities derived from GPS navigation data. Without differential GPS, careful editing of the ships velocity was required (see below). The resulting absolute velocities were smoothed with a 20 minute moving filter (the data at 14 and 102m are shown in Figures 4 and 5). No significant differences were observed by changing from a rectangular to a triangular filter. A shorter filter may be possible.

SA

Navigation

Ashtech 3DGPS and gyro data were processed in 12 hour sections corresponding to the ADCP data. They were merged on time and then an Ashtech-gyro heading difference calculated at the full data resolution of one second. All records that had data outside an acceptable range of a single variable were then deleted. The criteria used were:

pitch	-6	+6	degrees
roll	-10	+10	degrees
brms	0	0.06	
mrms	0	0.007	
attf	-0.5	0.5	
a-ghdg	-3	+3	degrees

Pitch, roll and a-ghdg were then viewed as histograms and further editing performed as appropriate. All data were averaged to two minute intervals to correspond to the ADCP data. The heading correction was finally edited graphically as a function of time to remove outliers and poor data on or near a change of heading.

Positional data were derived from the RVS 'bestnav' process. However to calculate ship's speed over the ground for use with ADCP data, GPS data were used directly. In the absence of differential GPS, careful filtering of the data was required. First, velocity was calculated from latitude, longitude and time. Velocity spikes were found using a median filter, excluding data where a single east or north velocity value was 40 cm/s larger than the surrounding four records. After interpolation in order to preserve the timebase, the one-second data were smoothed. A number of different filters were tested. They included 5-minute, 10-minute and 20-minute filters, each using a rectangular and a triangular mask.

SA

Thermosalinograph (TSG)

TSG data were processed in 12 hour sections, merged with 'bestnav' navigation and averaged to two minute intervals. These data were used extensively in locating the position of the front. Seawater samples were taken from the ship's 'non-toxic' supply every hour during the SeaSoar surveys and every four hours at other periods. These were used to calibrate the instrument.

Data from the first survey were calibrated by performing a linear regression between TSG and bottle salinities. This regression line was then used to correct the two-minute data:

Corrected salinity = -0.08699 + (0.99672 * (TSG salinity))

SA

Salinometry

Salinity samples taken for TSG and CTD calibration were analysed using an onboard Guildline Autosal 8400A. A model 8400 was also available, but was not used. The instrument proved reliable and stable except for a short period during the middle of the cruise when two standard sea water samples taken at the beginning and end of a set of 24 samples differed by 0.00015 units (equivalent to about 0.003 psu). For a short time this difference continued to increase. Eventually running more standards through it revealed a gradual drift back to higher values. After resting the machine for 24 hours values returned to normal. There is some evidence to suggest that a small piece of glass (from a standard sea water ampoule) or plastic (from one of the pipes) was transmitted through the cell. The instrument continued reliably from this point.

IW, MH, SA

PEXEC software

PEXEC software was installed and command scripts developed at the beginning of the first leg. These were used largely without modification on the second leg. One problem arose which was associated with the change of year. The routine to convert between RVS and PSTAR formats, 'datapup', takes the first time in the RVS file as a reference point, using the start of the corresponding year as the reference time in the output PSTAR file. Because RVS files were first written to in 1996 on the previous leg, PSTAR files were created with time in seconds from 1st January 1996 as their time variable. This could cause large truncation errors. No problems have yet been encountered however. Backups of important 'user' directories on the Unix systems were made to 8 mm cartridge tape at irregular intervals during the cruise. Data were archived to erasable optical disk.

SA

Meteorological data

One sonic anemometer and various slow sampling instruments ('meanmet') were left from the first leg. These were checked regularly and the slow data processed and plotted daily.

SA

CTD

Four CTD deployments were made during the second leg. These were read in and a nominal calibrations applied. The processing involves specifying an eight character name for each CTD, but the ship's naming convention allows for a cast number and sequence number.

Consequently, the CTDs were processed using the following numbers:

Processed name	Station no.
ctd13063	13064#1
ctd13064	13064#11
ctd13065	13066#7
ctd13066	13066#8

Salinity samples were taken from each of the 12 Niskin bottles on the 24 position rosette, in odd numbered positions. Standard processing was used to merge the resulting salinity data with information from the CTD. The route proved to be messy and required a lot of trial and error. For example, times of bottle firings contained in the RVS file 'bottles' were often incomplete because of buffering, so the RVS program 'listit' was used instead of 'datapup' to acquire these data.

SA

EK500

The SIMRAD EK500 system comprises a fish mounted three transducer assembly (Goldfish), winch system and deck unit. The fish was deployed for the duration of both the SeaSoar surveys, and for the majority of the time in between when biological sampling was being carried out. The fish was removed from the water whenever steaming at speed greater than 10 knots was required. When hove to the depth of the deployed fish was approximately 12 metres, and this decreased to c. 8 metres when steaming at 8 knots. Several of the brackets that stop the fairing from sliding along the towing cable broke free from the cable on deployment and should probably be replaced with a more flexible variety. The fish also takes a long time to fill and drain, placing unnecessary strain on the cable whilst the fish sits on the surface. Additional drain holes would remedy the situation. The configuration of the deck unit remained the same as that used during the first leg of the cruise. Data from the 38, 120 and 200 kHz transducers are broadcast, by the deck unit, over an ethernet whence it is intercepted by a Sun workstation. The script ekexec0 was run with the arguments 2008 and 2019 that decoded the messages from the deck unit and created binary files of 2 hours duration. The latter were archived. Some preliminary processing was performed on the files collected during the first SeaSoar survey, the binary files were converted into PSTAR format using ekexec1.ts and ekexec1.sv. The sections were plotted and showed strong diel migratory characteristics for all three frequencies over the entire frontal area. Whilst fishing nets the 38 kHz data showed the first band of backscatter rising from the depths to be primarily due to hatchet fish. Some interesting horizontal banding was apparent on the morning of 15th January, when the 'shelf break' just North of Algeria was being approached. This banding also appeared on the shipboard ADCP and the 12 kHz echosounder.

MH

Lowered Acoustic Doppler Current Profiler (LADCP)

The (LADCP) was used on the two full depth CTD casts using the same set-up as previously employed on D223 (see relevant cruise report) and the first leg of D224. Data were transferred from the ADCP onto a Dell PC where initial stages of setting up the CODAS database were performed prior to archiving the data onto optical disk. A brief look at the data from the two casts using BBLIST showed them to be coherent with values for both water velocities and acoustic backscatter. The latter was extracted from the instruments downloaded binary file using BBLIST in batch mode. The data from the previous leg also were extracted in this way for completeness. These were also stored onto optical disk.

MH

Computing

Level A's

log_chf	MkII - serial smp
gyro	MkII - serial smp
gps_4000	MkII - serial smp
gps_ash	MkII - serial smp
surflog	PC based - serial smp
grhomet	PC based - serial smp
sbwr	PC based - UDP message
echo	MkII - serial smp
seasoar	MkII(vme) - ethernet smp
ctd_12c	MkII(vme) - ethernet smp
adcp	PC based - serial message

Level A's not mentioned below performed without mishap or were normal in operation.

Gps_ash - The Ashteck attitude sensing system suffered from poor satellite coverage at certain times of the day.

Surflog - Continues to suffer from a software bug affecting to format of its time data (see cruise report from previous leg).

SeaSoar - A hardware error caused repeated resets on a few occasions. Few data were lost due to the vigilance of the watchkeepers.

Level B. - Only two minor failures occurred with no data loss.

Level C. - The majority of data processing was performed using the "PSTAR" suite of programs.

RL

Biology

Chlorophyll Analyses

Water samples were analysed for their chlorophyll and phaeopigment content to calibrate the CTD fluorometer, the TSG fluorometer and consequently the SeaSoar (following the recommendation from the previous cruise that the SeaSoar fluorometer be calibrated with the TSG one).

CTD chlorophyll samples were taken at 5, 50, 100 and 200m depth at every station, with a further sample taken at the chlorophyll maximum. Underway samples were taken hourly whenever SeaSoar was deployed. These were drawn from the non-toxic sea water supply that fed the TSG fluorometer.

Samples were drawn into blacked out 2.5l Nalgene bottles, which were rinsed twice prior to filling to 1 litre. Immediately three 100 ml aliquots measured out using a cut off plastic volumetric flask (rinsed in sample) were filtered through 2 Whatman GF/F 25 mm diameter filters at low pressure (<6 mm Hg).Filtering was carried out in reduced lighting, with the bottle annexe lights off, and a black plastic bin liner covering the filtration gear. The samples were placed in individually numbered glass vials and immediately transferred to -20^{0}C in the dark. A problem arose in this phase of the procedure at the beginning of the cruise, as filtering pressure was initially erratic and high. This was caused by one of the filtering columns being partially blocked. This was cleared by soaking it in hydrochloric acid overnight.

20 ml of acetone was added to batches of 50 frozen samples daily (whenever possible) from an Anachem 25 ml adjustable autodispenser, to extract the chlorophyll. They were then replaced in the freezer for a further 22 to 24 hours. After this period smaller batches of 10 samples were warmed to room temperature in a dark water bath before the fluorescence was measured in a Turner Designs Fluorometer (model 10-000R, serial no. 00859). Then 3 drops of 10% hydrochloric acid were added to the sample and the fluorescence remeasured.

The fluorometer was calibrated using standard chlorophyll solutions. These were made from a primary standard (1 mg Sigma chlorophyll *a* pellet dissolved in 1 litre acetone), whose exact chlorophyll concentration was ascertained from its absorbance measured before and after acidification at 665 and 750 nm wavelengths using a Pye

Unicam SP6-500 spectrophotometer. Secondary standards (dilutions of the primary) were used to calibrate the fluorometer over the expected range of chlorophyll concentrations.

Chlorophyll and phaeopigment concentrations were calculated using the equations from the JGOFS protocols (1994) and the resulting values were imported into PSTAR as tab delimited text files.

Equations

1 ° standard concentration:

$$\text{Chlorophyll a (mg m-3)} = \frac{26.7(665b-665a)v}{l}$$

$$\text{Phaeopigments (mg m-3)} = \frac{26.7((1.7*665a)-665b)v}{l}$$

where: 665b = Absorbance at 665 nm before acidification.

665a = Absorbance at 665 nm after acidification.

v = Volume of extract (ml)

l = path length of cuvette (cm)

Sample concentrations

Chlorophyll a (mg m-3) = FD*(Fm/(Fm-1))*(Fb-Fa))*(v/V)

Phaeopigments (mg m^{-3}) = FD*(Fm/(Fm-1))*((2.2*Fb)-Fa)*(v/V)

where: FD = Chlorophyll Standard concentration / Chlorophyll standard Fluorescence before acidification.

Fb, Fa = Fluorescence value before and after acidification of sample.

Fm = Fb/Fa from standard chlorophyll solution.

v = Volume of 90% acetone used in extraction (ml).

V = Volume of seawater filtered (ml).

Samples were taken in the above manner during the first SeaSoar survey and all CTD casts. The SeaSoar fluorometer was mounted on the CTD frame for several casts to allow a direct calibration through the subsurface chlorophyll maximum.

Possible areas of error in the methodology were a) filtering leakages, b) imprecise measurements of sample volume in the cut off volumetric flask, and c) any discrepancies in adding acetone (e.g. volume and % of acetone). The Turner fluorometer was affected by the motion of the ship (an observation also noted on D223), and the normal readable accuracy of three significant figures was reduced. It is probable that the orientation of the fluorometer should be changed from port/starboard to fore/aft to reduce the effect of rolling, and an overhaul of the machine in case any parts are loose and subject to motion. It was also noted that over the duration of the cruise the sensitivity of the fluorometer seemed to be decreasing. It is probable that the sensitivity could be restored if the fluorometer was cleaned.

SF

RMT - Acoustic Equipment

The RMT acoustic equipment consisted of three RMT monitors, two old units and one new; three deck units, one Mk 3, one Mk 4 and one Mk 5. There was also a computer to act as a waterfall display.

The two monitors functioned correctly, although the near-bottom echo-sounder on the Black Lead one had an intermittent fault that could not be traced. The new unit was used initially, but was withdrawn when it appeared not to be responding to acoustic commands. Its sensitivity was increased and the unit re-deployed, but it developed a fault that was subsequently traced to the cpu card. The card will have to be returned to the manufacturer. An intermittent fault on the main release gear was also observed later in the cruise, which may have had the effect of making the monitor appear insensitive.

The Mk 5 deck unit required some adjustment at first, to increase receiver sensitivity. There is little reverberation on the output signal, unlike the Mk 3. This means that the trace is very thin, often less than 1 pixel on the 640 x 480 resolution available on the waterfall display. This makes the interpretation of the traces, in particular the flow, a problem. Lack of a thermal recorder, which has much finer resolution, exacerbated this. Otherwise the Mk 5 operated the monitors to the deepest depth ranges reached during the cruise.

Discovery now has a beam-steering unit installed as standard equipment. The standard wiring allows the SIMRAD echo-sounder to be switched between the PES fish and the hull. The fish is wired through the beam-steering unit. In order to use the waterfall display the output from the beam-steering unit was taken to the deck unit, leaving the echo-sounder permanently switched to "hull". This allowed reception and transmission through the deck unit without the need for the operator to unplug anything. A thermal line-scan recorder was not provided.

DW

RMT - Release Gears

Both 4-Jaw releases were provided for this cruise in bench working condition. The first operated successfully for most of the cruise, there being one failure when the battery pack went down. Late in the cruise this release gear locked up on the bench but had no failures in the water. A full strip down is required to find this possible, intermittent fault. The second release gear was used as a replacement, but failed on the first deployment; three bridles having ripped out before the gear was triggered. This meant that all the catch was in the third net. Calm weather deployments had occurred without mishap on previous cruises. However, close examination revealed that there was a problem with the drive cam, which meant that none of the release arms engaged properly. A new cam and drive shaft will be made and fitted, and the relevant drawings modified.

BB

LHPR (Longhurst Hardy Plankton Recorder).

The LHPR (from George Deacon Division, SOC) is a vehicle towed in a V-shaped profile from the surface to approximately 400m and back to the surface. Because of the light aluminium frame and polypropylene tail fin, a 45 kg depressor weight is attached to the underside front, and a drogue streams from the back to assist stability. A nose channels water through a 280µm mesh net to the cod-end. The latter contains 2 spools of gauze which wind round every 2 minutes sandwiching each sample of plankton, thus allowing semi-discrete sampling.

The LHPR was run in "logging" mode. This permits a maximum time of 180 minutes in the water (the data holding capacity of the sensor cylinder before overwriting), including deployment and recovery. Thus, erring on the side of caution, tows were limited to approximately two and a half hours. A delay of 6 minutes before the first wind on of gauze was added to allow time for deployment. Deployment of the LHPR was from the main A frame on the aft deck using the main towing warp. 20m of wire was initially payed out at the start of each haul and the LHPR held there to allow one wind on of the gauze. The wire was then payed out at 30m per minute until the LHPR was at an estimated depth of around 400m. This was equated as 1200m wire out (i.e. depth = wire out/3). The LHPR was then held at that depth for 5-10 minutes, before hauling in at 30m per minute. On the up haul several depths of interest (shown by anomalies in ADCP backscatter) were stopped at and sampled for a further 5-10 minutes. On retrieval the double roll of gauze containing the sandwiched zooplankton was preserved in 4% formaldehyde.

Two hauls were carried out, one at each of the main sampling. A slight problem occurred with the second haul. As a result of the light weight of the equipment and a reasonably heavy swell it was not possible to pay out 1200m of wire within the allotted two and half hours. Wire pay out was stopped at 900m and the LHPR brought back. The depth achieved was c. 350m.

SF

RMT Sampling

Day and night profiles of RMT(1+8)M samples were collected to a depth of 1100m at two stations - one in typical Mediterranean water, the other where Atlantic inflow water occupied the upper 150m or so of the water column. A few hauls were also collected from even greater depths to confirm the absence of any specific bathypelagic and abyssopelagic fauna in the Mediterranean as reported in the literature. Samples were also collected at selected shallow depths across the region of the Almeria-Oran front that marks the interface between the inflow water and typical Mediterranean surface water. At the time of sampling there was little expression of the front in surface temperature, but salinity showed a substantial change of 0.75 psu. The volumes of water filtered by the nets are given in Table 1.

Biomasses of the hauls were estimated by measuring the displacement volumes (Table 1). These measurements implied that the overall standing crops of both macroplankton and micronekton were slightly higher in the water column influenced by the Atlantic inflow water. However, the standing crop in the upper 200m was lower in the Atlantic water - at night this seems to have resulted from the halocline at the base of the inflow water halting the upward migration of some of the specimens, although none of the individual species seemed to be limited by this feature.

The composition of the catches showed no obvious specific differences. Diversity was low, especially in the deeper hauls where it was confirmed that the maximum in species richness observed in Atlantic profiles was absent from these Mediterranean profiles. Catches in the upper 300m were highly gelatinous, containing larger quantities of siphonophores, particularly *Abylopsis tetragona*, a large heteropod species, and the pteropod *Cymbulia.* There were also some salps including a rugose, pink-coloured species of *Pyrosoma*. There were some minor differences in the vertical distributional ranges of the dominant species at the two stations. For example, the hatchet fish *Argyropelecus hemigymnus* occurred at 200-400m by day in the Atlantic water, whereas in the Mediterranean water it was 100m deeper. However diel vertical migrations resulted in the night-time ranges being very similar. In contrast the daytime range of the common *Gennadas* species was 100m deeper in the Atlantic water station, but at both stations it was migrating up into the top of the main thermocline at 70m. *Cyclothone braueri* was most abundant at depths of 300-500m at both stations and another species became the more abundant at >600m. *Eucopia unguiculata*, represented only by small specimens, was undertaking slight vertical migrations at both stations, extending the ceiling of their range from 500m to 300m. In the deeper samples large *Chauliodus* sp., *Acanthephyra* spp. (including *A. eximia*) and large specimens of *Pasiphaea multidentata* were in evidence.

A notable feature of the RMT 1 samples was the almost total absence of living copepods in the catches from depths >600m. Copepods contributed very little to the total biomasses caught, and most specimens consisted of decaying corpses or empty carapaces. This absence of what is usually the dominant component of the macroplankton, while being inexplicable in itself, may be a major causal factor in the absence of a bathypelagic fauna.

MVA

TABLE 1

Volumes of water filtered and biovolumes of RMT1 and RMT8 catches.

			RMT1		RMT8	
Station		Depth Range (m)	Volume filtered (m^3)	Biovolume (mls)	Volume filtered (m^3)	Biovolume (mls)
13064	2	395-500	2389	116	25214	400
	3	300-395	2156	96	25129	420
	4	200-300	1976	126	19865	450
	5	650-800	2075	30	20631	130
	6	600-700	2037	22	23774	160
	7	500-600	2399	44	24763	155
	8	400-500	2708	168	32607	860
	9	295-400	2486	110	30346	1010
	10	199-295	2642	94	27822	240
	12	92-216	2389	108	25214	720
	13	50-105	2586	184	31995	900
	14	0-50	3220	386	37950	1400
	16	700-800	2361	36	24542	230
	17	600-700	1800	56	20744	230
	18	500-600	2160	44	21943	270
	19	100-200	2074	4	26976	160
	20	50-100	2100	30	24750	105
	21	0-50	2100	80	24750	250
	22	975-1175	4433	19	52250	160
	23	1000-1100	2486	7	26951	320

Table 1 (Continued)

Station	#	Depth Range (m)	RMT1 Volume filtered (m^3)	RMT1 Biovolume (mls)	RMT8 Volume filtered (m^3)	RMT8 Biovolume (mls)
	24	895-1000	2412	13	29175	170
	25	790-900	2634	24	27838	150
	26	1500-1710	5483	18	68263	85
	27	1300-1500	5359	11	67404	120
	28	1100-1305	5630	17	60128	115
	29	898-1000	4044	18	51566	300
	30	805-898	4041	18	51009	230
13065	1	242-254	1852	64	22349	1180
	2	251-260	2996	155	36965	260
	3	246-260	2542	127	26535	230
	4	136-170	1636	132	18372	760
	5	143-159	2722	266	32639	1170
	6	150-160	2388	201	24628	1190
13066	1	395-510	2116	98	21174	440
	2	300-395	1874	108	21604	460
	3	205-300	2342	117	24079	2350
	4	705-800	2608	28	29585	240
	13	700-810	2116	36	21174	220
	14	605-700	2266	39	26995	205
	15	500-605	2542	60	26535	220
	16	1005-1105	3572	17	37644	130
	17	905-1005	3315	36	39282	155
	18	800-905	3453	18	35400	170
	19	600-700	2155	51	21576	250
	20	500-600	2087	60	24460	315
	21	400-500	2451	148	25397	605
	22	100-205	2608	72	29585	135
	23	50-100	2654	23	33217	80
	24	0-50	2780	126	29778	115

Table 1 (Continued)

Station	#	Depth Range (m)	RMT1 Volume filtered (m^3)	RMT1 Biovolume (mls)	RMT8 Volume filtered (m^3)	RMT8 Biovolume (mls)
	25	100-200	2144	109	21553	750
	26	60-100	3142	58	38847	385
	27	5-60	2770	370	29597	640
	28	1512-1710	4598	3	47556	170
	29	1300-1512	3761	13	45709	145
	30	1095-1300	3938	15	41775	105
	31	300-400	2766	170	38502	1350
	32	200-300	2706	140	34278	1150
	33	995-1100	2771	2	37215	210
	34	900-995	2714	13	34476	280
	35	800-905	2778	18	29785	140
	36	230-1905	4839	-	51779	390
	37	1895-1940	2486	-	30346	-
	38	1920-2005	2676	-	28266	-
13067	1	125-170	2077	58	27454	150
	2	140-160	2384	50	29030	155
	3	150-165	2603	45	27314	105
13068	1	210-235	1537	39	18555	290
	2	210-235	1943	50	24060	570
	3	220-240	1993	48	21022	180
	4	80-110	2030	105	26767	1020
	5	100-110	2542	73	31454	600
	7	60-60	1842	90	25805	1000
	8	60-60	3322	150	40927	1300
	9	60-60	2812	145	30014	1250

Bioluminescence studies

The spectral characteristics of two aspects of photophore structure and physiology were examined, namely their reflectance and fluorescence. Reflectance is determined by the particular reflectors associated with the photophore. In some species these appear silvery, i.e. reflecting all wavelengths, while in others they are almost monochromatic, usually blue or blue-green. Specimens of several species of myctophid were examined and photophore reflectance measured. In *Diaphus* the reflector is clear blue, with a narrow spectral bandwidth, peaking at about 480 nm. In others, such as *Ceratoscopelus*, the reflectors are silvery with no marked maxima. Blue reflectors in *Diaphus* are restricted to those directed ventrally and presumably involved in counter-illumination; its forward and laterally directed ones have silver reflectors. In the squid *Abralia* the photophores are of at least three kinds and two of these appear green and blue respectively in bright light. Measurements indicate the green reflecting photophores also have a blue component, whereas the blue ones lack the green element. Both are very narrow bandwidth, indicating that they are interference reflectors. This species produces both blue and green bioluminescence, and the reflectors are probably key elements in determining the spectral output from particular photophores.

Many bioluminescent tissues are intensely fluorescent; this may derive from luciferin or oxyluciferin fluorescence, or from an additional fluor in systems where energy transfer occurs. Measurements from several myctophid, squid and crustacean photophores showed considerable similarity in the fluorescence emission spectra, indicating that they all probably utilise the same luciferin (known to be coelenterazine in some related species). No candidate fluors for energy transfer were identified and it is likely that all the species investigated have a blue or blue-green bioluminescence.

Photophores from both squid and fish were fixed for subsequent morphological study.

PJH

Ichthyoplankton

The purpose of the project was to study the specific composition of ichthyoplankton communities on either side of the Almeria-Oran frontal system. At the same time, the vertical distribution of fish larvae with relation to the physical structure of the water column and their possible vertical migrations will be determined.

During the cruise, fish larvae, eggs and some juveniles were sorted from the all the preserved samples collected by the RMT1 nets fished between 800 m and the surface (Table 2). Occasionally, some larvae were removed from the RMT8 samples before they were fixed. Fish larvae were sorted from the whole sample as their abundance was, in

TABLE 2

Number of juveniles, larvae and eggs of fish sorted from the samples at the two main stations.

St. 12664 (Mediterranean water)

Depth Range (m)	Day #	juv.	larvae	eggs	Night #	juv.	larvae	eggs
0-50	21	1	185	61	14	189 (1)	2 (9*)	62
50-100	20	40	28	26	13	7	161	
100-200	19	1	1	14	12	13	34	72
200-300	10	25	19	17	4	19 (56)	28 (1)	
300-400	9	114		5	3	64		
400-500	8	54			2	64		
500-600	18	39	1	1	7	124		
600-700	17	38			6	62		
700-800	16	72		1	5			

St. 13066 (Atlantic water)

Depth	Day #	juv.	larvae	eggs	Night #	juv.	larvae	eggs
0-50	24		419 (6)	43	27	27	99	54
50-100	23		130	19	26	8	81	36
100-200	22	4	74	29	25	10	9	48
200-300	32	19	3	4	3			
300-400	31	123	1	2	2			
400-500	21				1		1	2
500-600	20		2	7	15			
600-700	19				14			
700-800	4				13			

RMT8 numbers in brackets

* 2 leptocephalus + 7 flat fish larvae

general, quite low. Juveniles were sorted from a subsample. All were counted onboard and will be identified in Barcelona at the Instituto de Ciencias del Mar. In general, fish larvae were mainly collected between 100 m depth and the surface. The vertical distribution of juveniles was more extensive, extending to deeper levels. The majority of specimens belonged to species of mesopelagic fish, e.g. various species of the Myctophidae (*Myctophum punctatum*, *Notoscopelus* sp., *Lampanyctus* sp.) and other species such as *Cyclothone braueri* and *Argyropelecus hemigymnus*. Nevertheless, at the station located on the Atlantic side of the front, larvae of shelf species, such as Clupeoids and Gadoids, were also collected.

AS

Chaetognaths

Specimens of chaetognaths were sorted from the RMT1+8M samples to enable two projects to be carried out. Firstly, specimens were needed so that a comparison could be made of the intraspecific genetic differences in chaetognaths collected at the two stations on either side of the Almeria-Oran front. Specimens of *Sagitta lyra* (about 800), *S. hexaptera* (about 20) and *S. enflata* (about 50) were sorted from the fresh RMT8 material and frozen at -50°C. In addition, about 200 specimens of *S. lyra* were fixed in methanol for comparative analyses to see whether it is possible to use specimens preserved in this way for genetic analysis and, if so, to establish the differences in results between the two methods of fixation.

Preliminary observations showed that mainly adult *Sagitta lyra*, with very few specimens of *S. hexaptera*, occurred on either side of the front. *S. enflata* was seen only on the Atlantic (south-western) side of the front in the RMT8 samples. However, the greater number of species and specimens in the RMT-1 samples showed that *S. enflata* also occurred on the Mediterranean (north-eastern) side of the front. Other species found included *S. decipiens, S. minima*, and *S. bipunctata*, in addition to *S.lyra* and *S. hexaptera.*

The second project is concerned with the vertical distribution of chaetognaths on either side of the Almeria-Oran front, and in the frontal region itself. Chaetognaths will be sorted from both the formalin preserved RMT8 and RMT1 samples and will be qualitatively and quantitatively analysed. Preliminary sorting of some of the RMT8 samples showed the main depth distributional range of *S. lyra* at St. 13064 (Mediterranean water) lay between 500 and 600 m, both by day and by night. At St. 13066 (superficial Atlantic water) the depth range was 400-500m, again for both day and night samples.

AP-B & MH

Euphausiids

Two projects will be undertaken with reference to the euphausiid material collected during the cruise. Firstly, the vertical distributions of all species of Euphausiaceae at the two stations on either side of the Almeria-Oran front will be analysed and compared.

Secondly, the stomach contents (quantity and, if possible, quality) of these euphausiids will be analysed in order to determine the time of day and depth at which feeding occurs.

During the cruise, euphausiids were sorted from many of the RMT8 samples (either the whole or a subsample). Preliminary results show the presence of, at least, *Euphausia krohni, E. hemigibba, Nematoscelis megalops, Thysanopoda aequalis, Stylocheiron maximum, Stylocheiron* sp. (*longicorne* ?), and *Meganyctiphanes norvegica.* Overall, *E. krohni* (epipelagic) and *N. megalops* (mesopelagic) were the dominant species. At St. 13064 (Mediterranean water), the number of euphausiids in the samples decreases considerably below 1000 m at night, and below 800 m during the day. In both cases the deeper populations mainly consisted of *N. megalops*, and there were no indications of the presence of bathypelagic euphausiid species. At St. 13066 (Atlantic water), although not yet completely sorted, this decline in numbers appeared to begin from 800 m downwards - at least during the night. Only a few specimens of *M. norvegica* were found in the samples from both the main stations; but it appeared to be quite abundant in the upper 200 m during the night at St. 13068, where sampling was carried out in the region of the Almeria-Oran front..

M VAN C

Sixty four specimens of *Meganyctiphanes norvegica* were sorted from the RMT8 samples collected at St. 13068, where the nets were fished at fixed depths across the Almeria-Oran Front. These specimens will be used, by the staff of Prof. Bruno Battaglia of Padova, to study the genetic structure of this species in the Alboran Sea.

PL

Mysids and Copepods

Specimens of the mysid *Eucopia unguiculata* were sorted from the fresh samples and preserved in glutaraldehyde. Transmission and scanning electron microscopy will be used to make observations on the gut as part of a comparative study of the guts of Mysids.

Calanoid copepods were also sorted from the samples and preserved for scanning electron and photo microscopic studies of their external and internal female genitalia. These observations will contribute toward a functional and phylogenetic study of the genitalia in different families of copepods.

CC

An aliquot, containing at least 100 copepods, was removed from every RMT1 sample, after preservation. The volumes of these aliquots are given in Table 3. The material will be used to study the vertical distribution, diel migrations, and biomass of the specific copepod populations.

PL

TABLE 3

Volumes of aliquots removed from RMT1 samples for analyses of copepods.

Station	#	Depth Range (m)	Aliquot Volume (mls)	Volume of jar (mls)	% of total
13064	2	395-500	4.2	1000	0.42
	3	300-395	6.8	900	0.76
	4	200-300	4.8	900	0.53
	5	650-800	33.2	900	3.69
	6	600-700	36.1	900	4.01
	7	500-600	11.2	900	1.24
	8	400-500	7.9	1000	0.79
	9	295-400	10.1	900	1.12
	10	199-295	4.1	900	0.46
	12	92-216	8.0	900	0.89
	13	50-105	8.0	1500	0.53
	14	0-50	7.6	2600	0.29
	16	700-800	36.7	400	9.18
	17	600-700	34.7	400	8.68
	18	500-600	12.1	400	3.03
	19	100-200	44.2	400	11.05
	20	50-100	17.7	400	4.43
	21	0-50	2.6	400	0.65
	22	975-1175	28.2	400	7.43
	23	1000-1100	45.0	400	11.25
	24	895-1000	30.1	400	7.53
	25	790-900	21.8	400	5.45
	26	1500-1710	32.6	400	8.15
	27	1300-1500	22.6	400	5.64
	28	1100-1305	17.3	400	4.33
	29	898-1000	18.9	370	5.11
	30	805-898	29.1	370	7.86
13065	1	242-254	2.9	450	0.64
	2	251-260	1.7	900	0.19
	3	246-260	2.7	900	0.3
	4	136-170	7.0	900	0.78
	5	143-159	8.8	2600	0.34
	6	150-160	8.3	2600	0.32
13066	1	395-510	5.1	900	0.57
	2	300-395	2.6	900	0.29
	3	205-300	5.1	1450	0.35
	4	705-800	35.2	450	8.80
	13	700-810	48.3	900	5.37
	14	605-700	22.7	900	2.52
	15	500-605	33.1	900	3.68
	16	1005-1105	21.9	340	6.44
	17	905-1005	9.0	355	2.54
	18	800-905	13.9	370	3.76
	19	600-700	22.8	400	5.70
	20	500-600	18.5	900	2.06
	21	400-500	9.3	900	1.03

Table 3 (Continued)

Station	#	Depth Range (m)	Aliquot Volume (mls)	Volume of jar (mls)	% of total
	22	100-205	2.5	400	0.63
	23	50-100	7.7	400	1.93
	24	0-50	3.5	950	0.39
	25	100-200	4.8	900	0.53
	26	60-100	8.4	900	0.93
	27	5-60	6.9	1500	0.46
	28	1512-1710	65.4	400	16.35
	29	1300-1512	19.1	400	4.78
	30	1095-1300	14.0	400	3.50
	31	300-400	4.3	900	0.48
	32	200-300	1.9	900	0.21
	33	995-1100	68.1	400	17.03
	34	900-995	24.9	400	6023
	35	800-905	37.7	400	9.43
13067	1	125-170	2.4	400	0.60
	2	140-160	2.3	400	0.58
	3	150-165	2.7	400	0.68
13068	1	210-235	5.2	400	1.30
	2	210-235	3.9	400	1.03
	3	220-240	5.5	400	1.38
	4	80-110	7.6	900	0.84
	5	100-110	10.9	900	1.21
	7	60-60	6.5	900	0.77
	8	60-60	4.2	900	0.47
	9	60-60	7.2	900	0.80

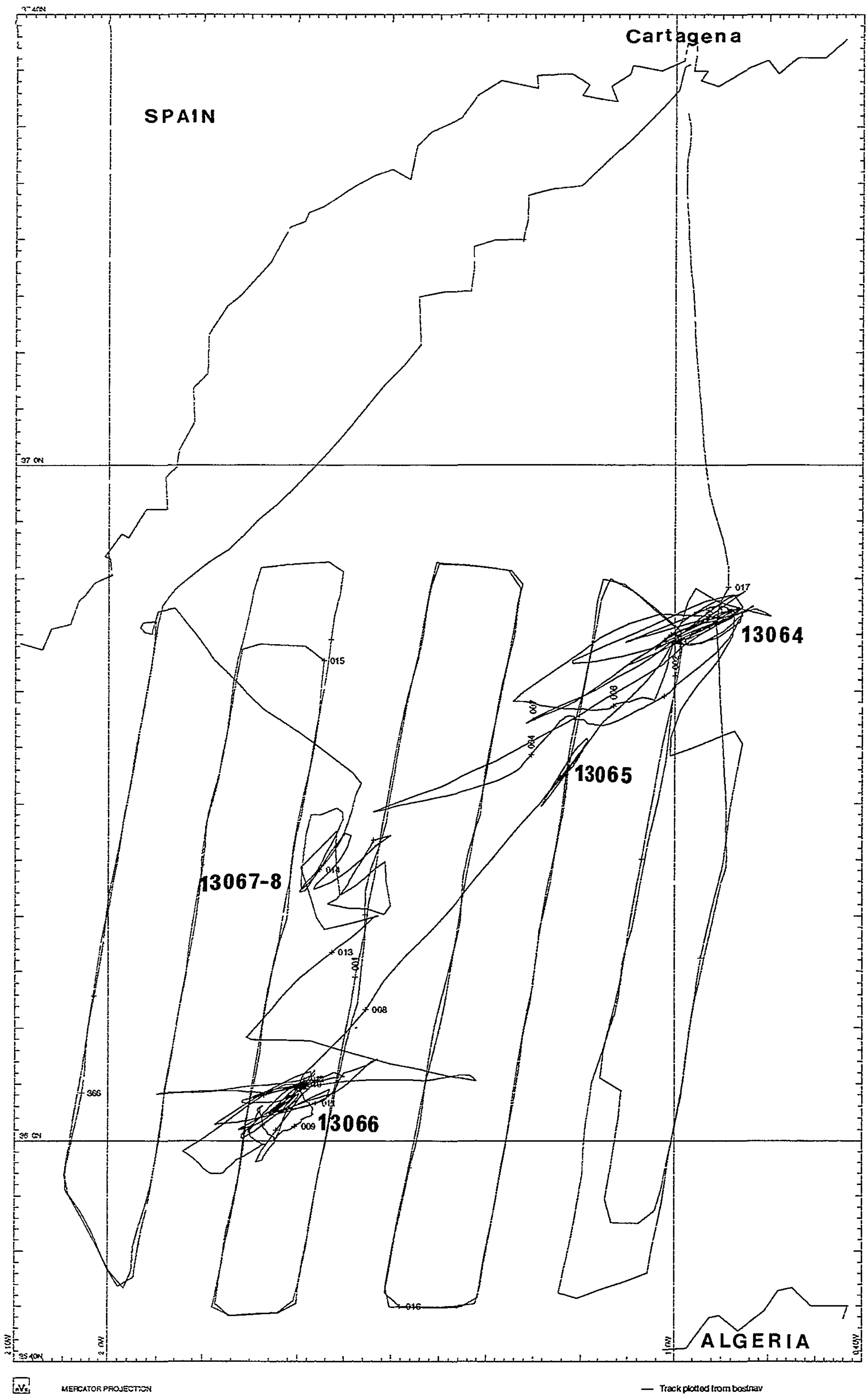


Figure 1. Track chart for *Discovery* Cruise 224, leg 2, 30 Dec 1966 to 17 Jan 1977.

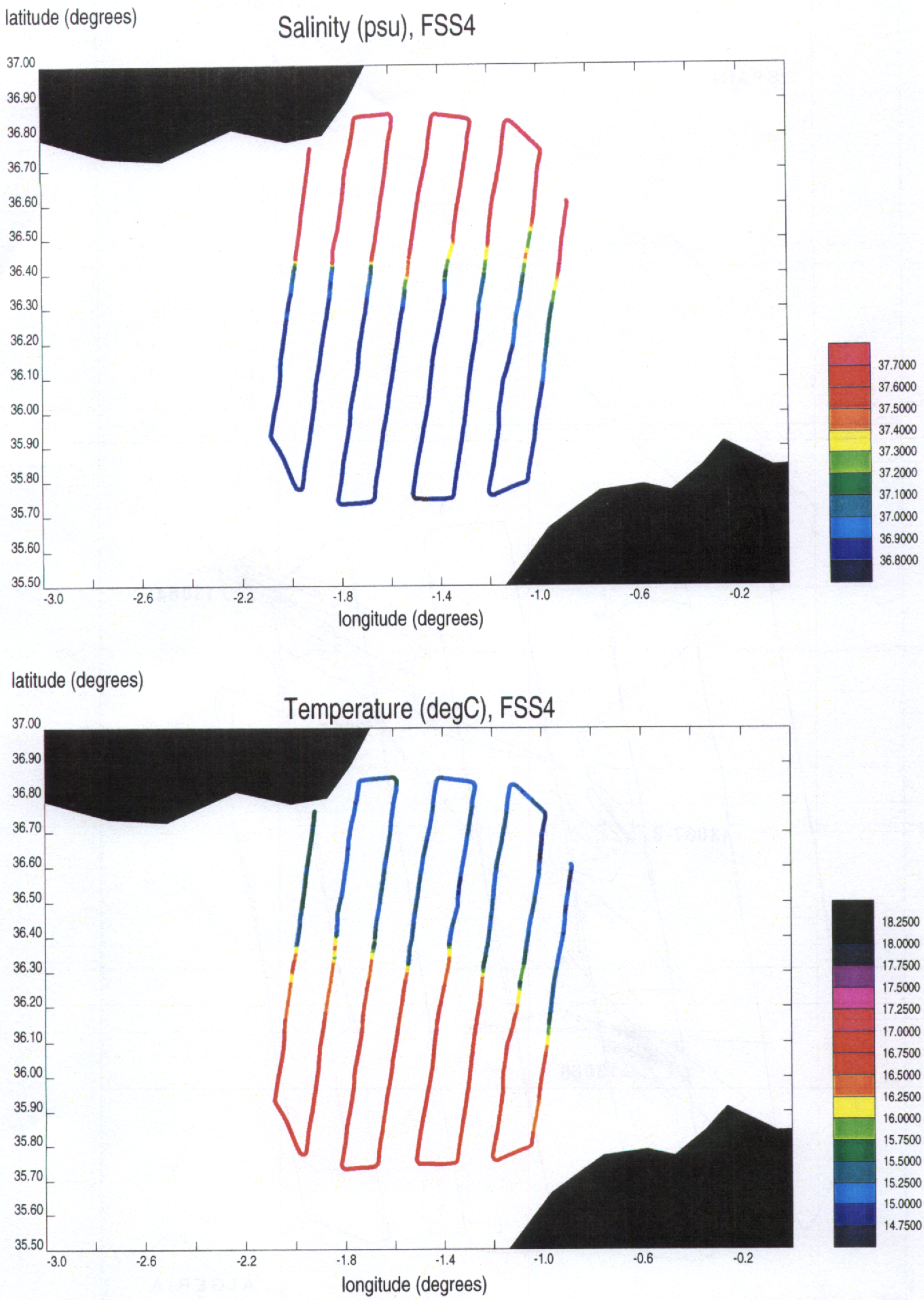


Figure 2. Near-surface profiles of salinity and temperature recorded by the shipborne thermosalinograph during the fine-scale SeaSoar survey (FSS4) at the start of *Discovery* Cr. 224 leg 2.

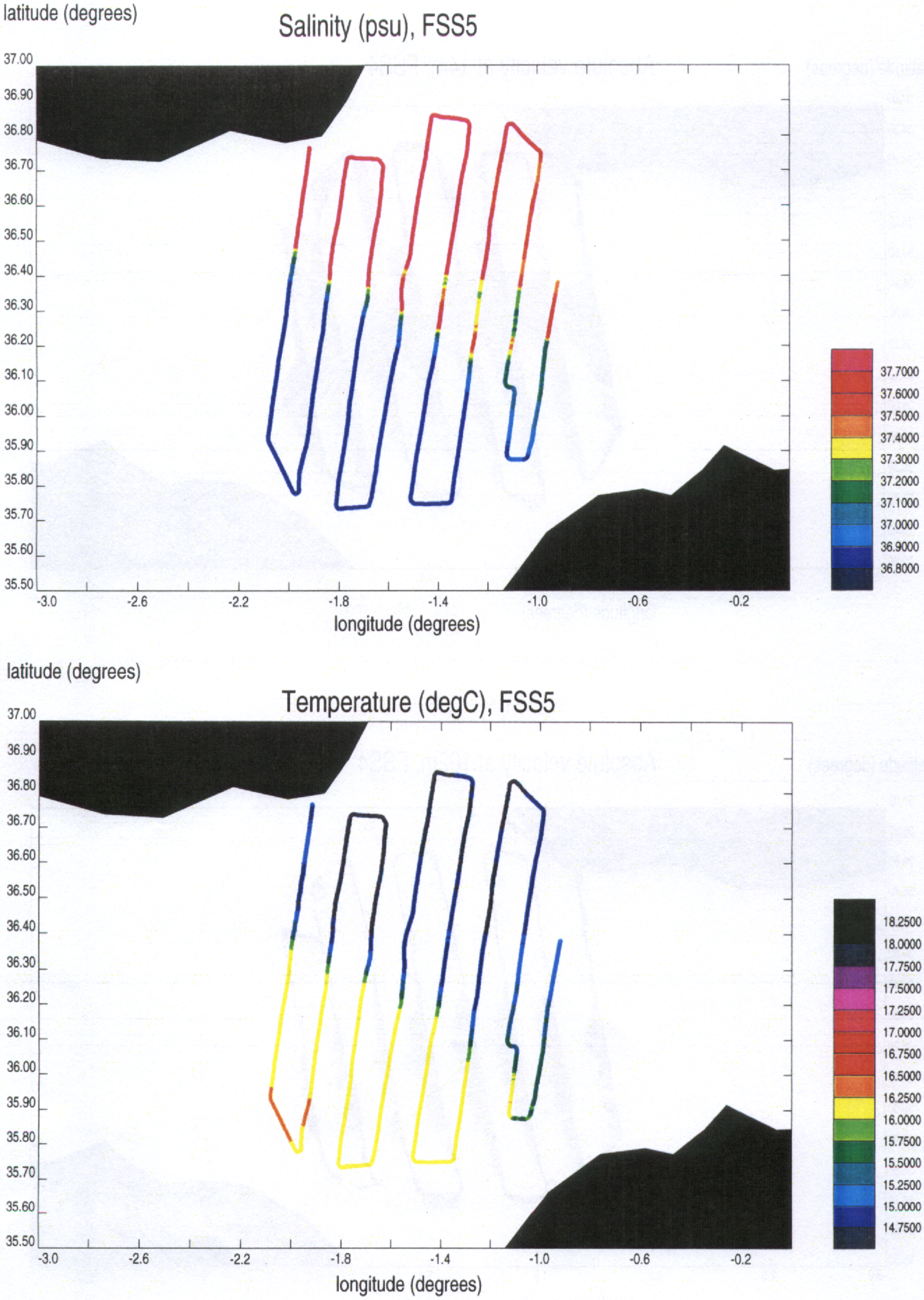
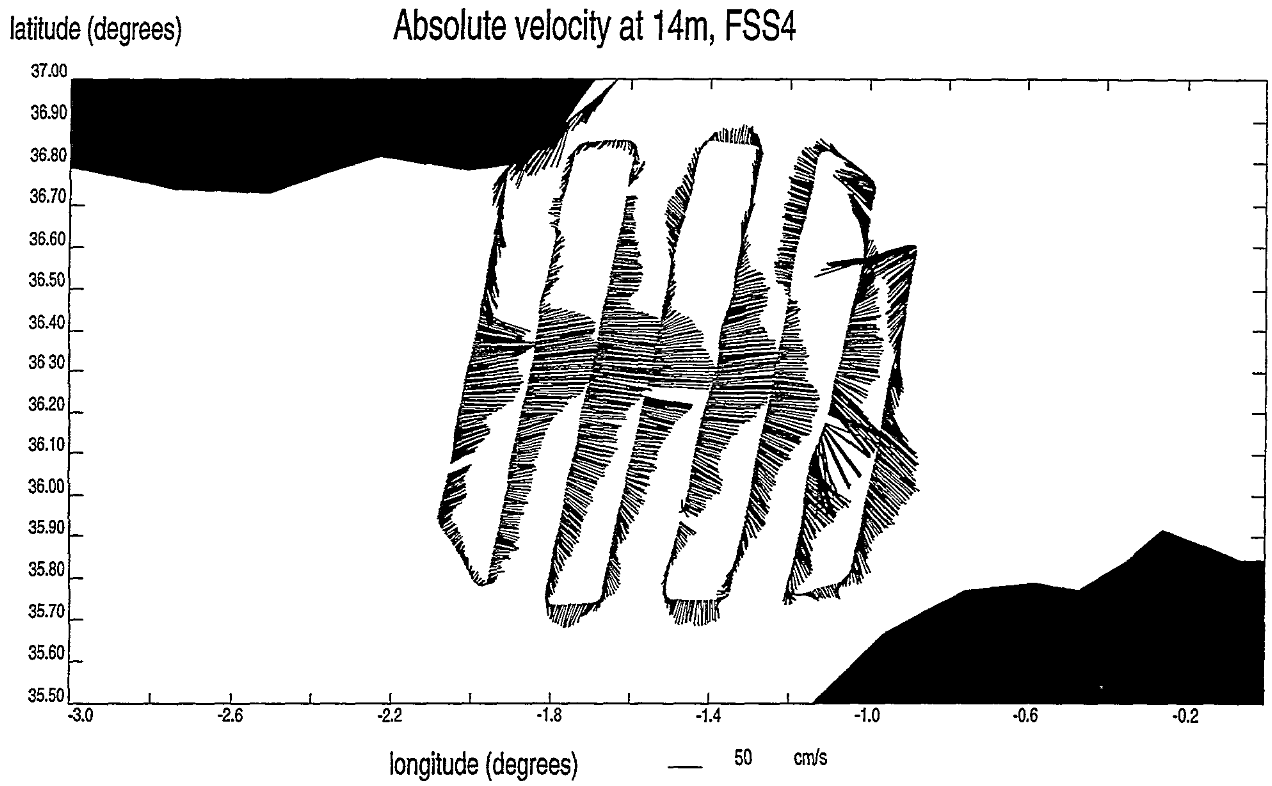


Figure 3. Near-surface profiles of salinity and temperature recorded by the shipborne thermosalinograh during the fine-scale SeaSoar survey (FSS5) at the end of *Discovery* Cr. 224 leg 2.



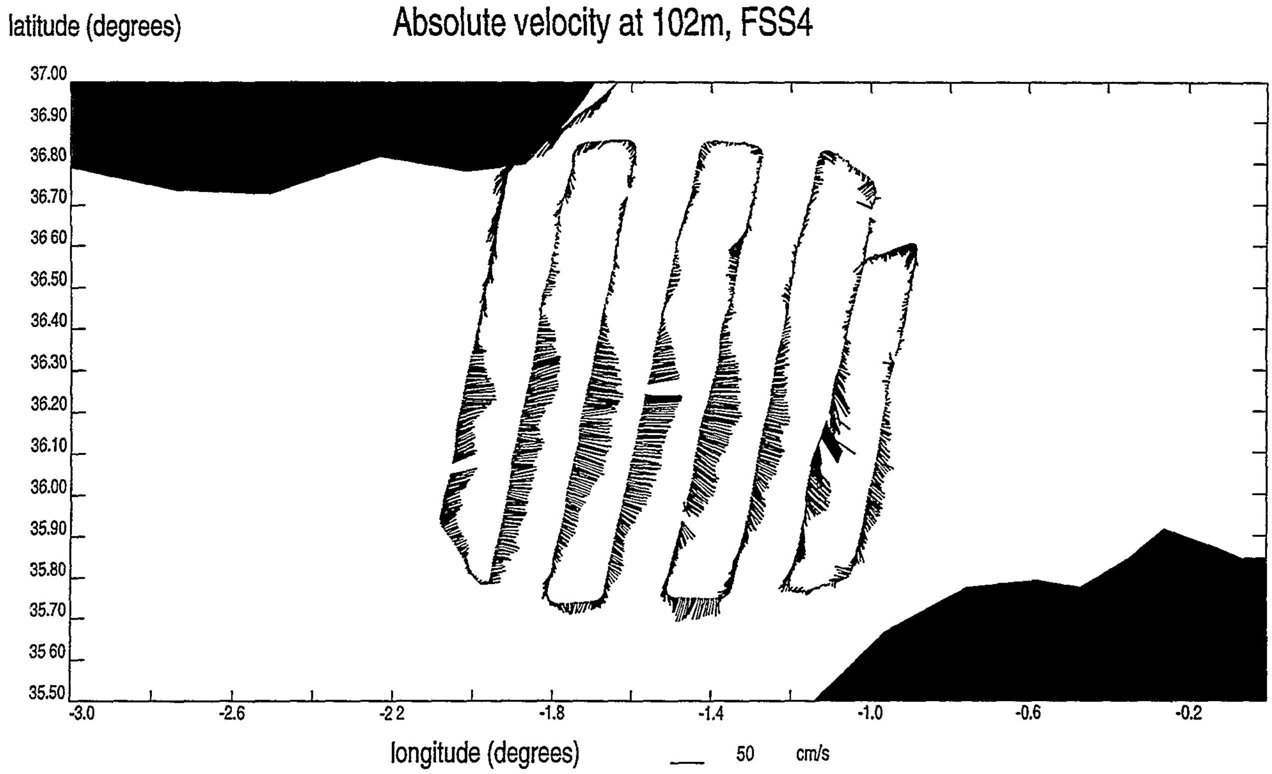
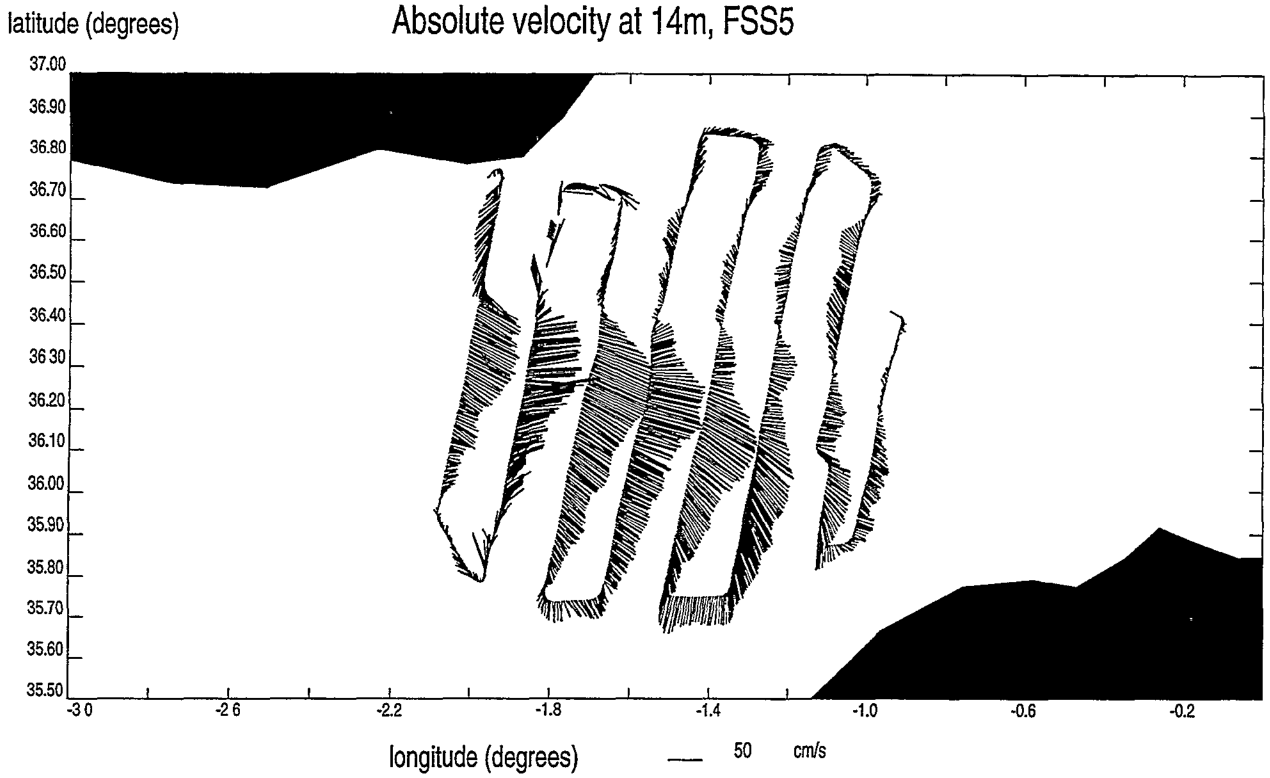


Figure 4. VM-ADCP current vectors at 14 and 102 m for the fine-scale SeaSoar survey (FSS4) at the start of *Discovery* Cr. 224 leg 2.



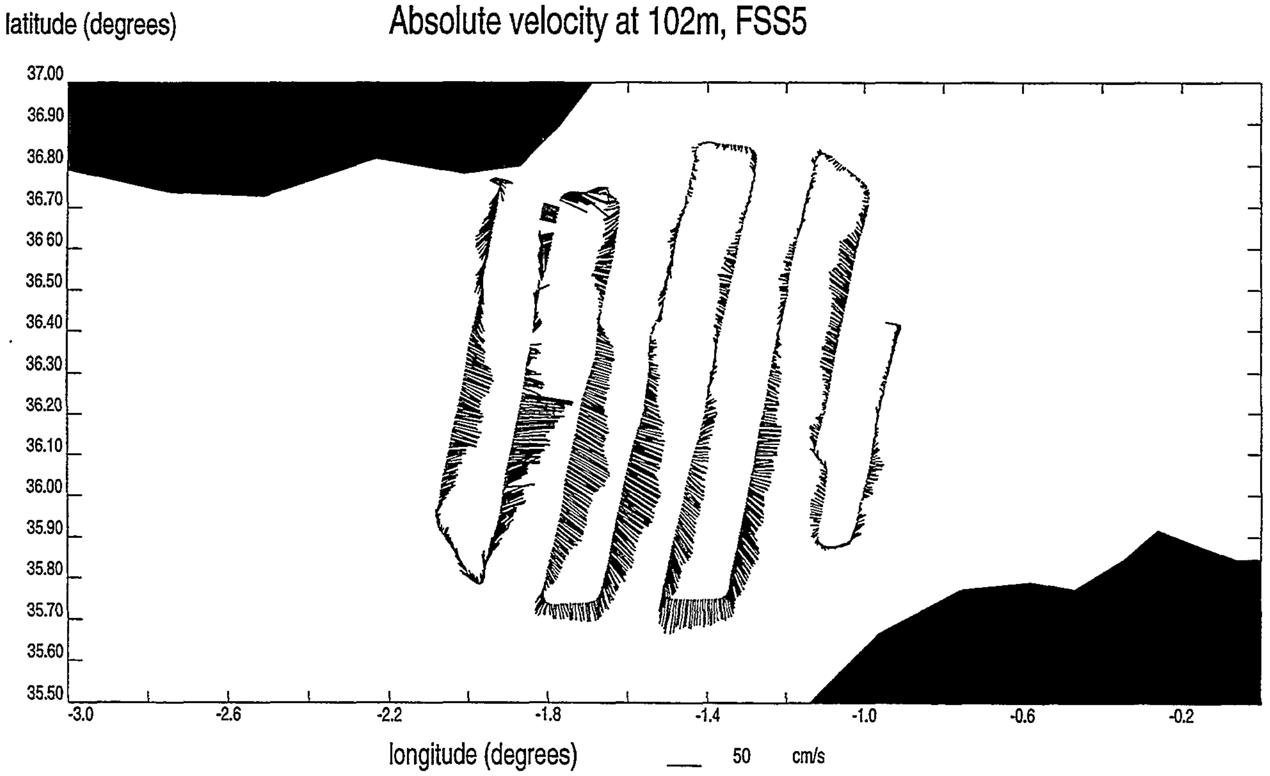


Figure 5. VM-ADCP current vectors at 14 and 102 m for the fine-scale SeaSoar survey (FSS5) at the end of *Discovery* Cr. 224 leg 2.

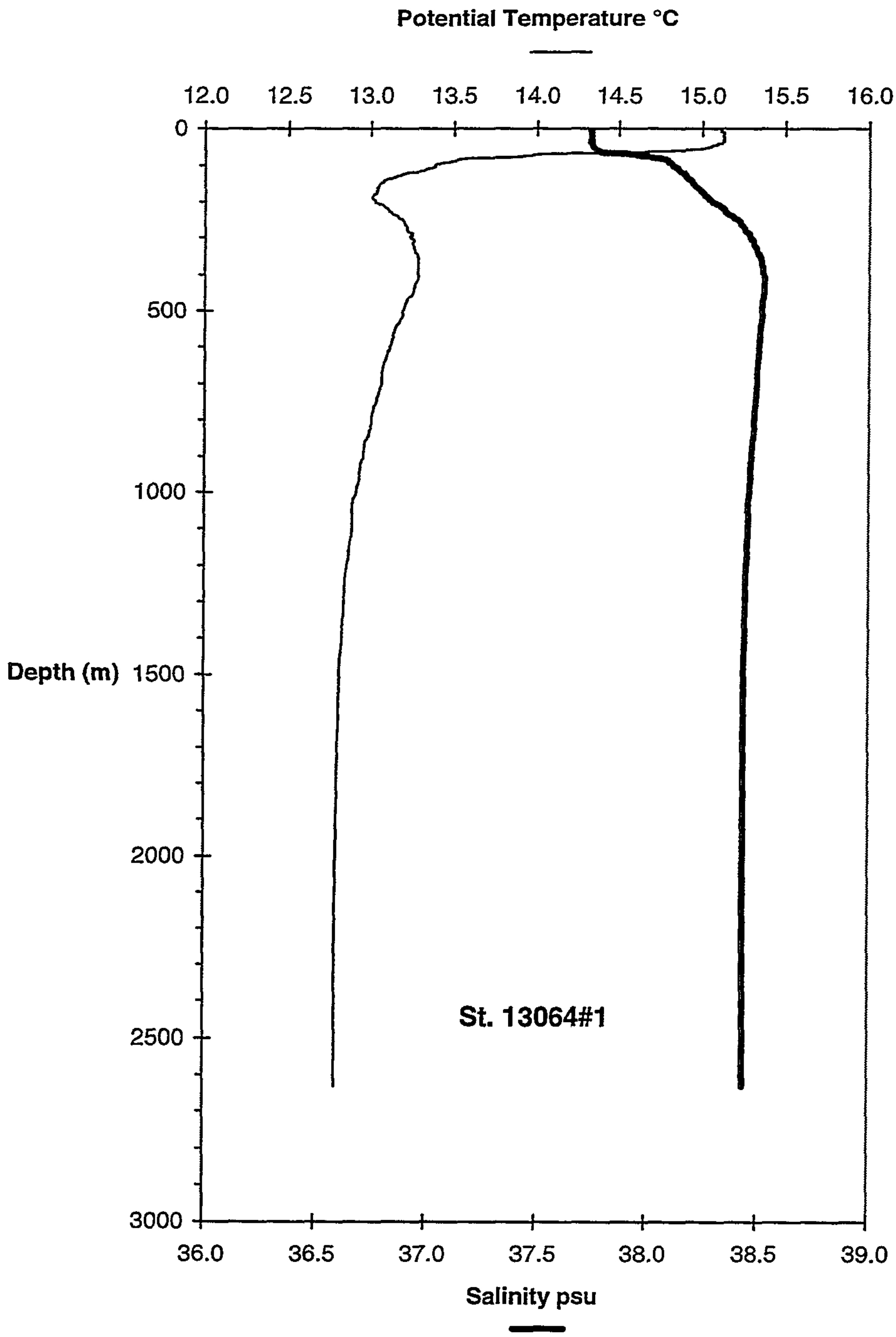


Figure 6. Temperature and salinity profiles at the station (13064) on the Mediterranean side of the Almeria-Oran Front.

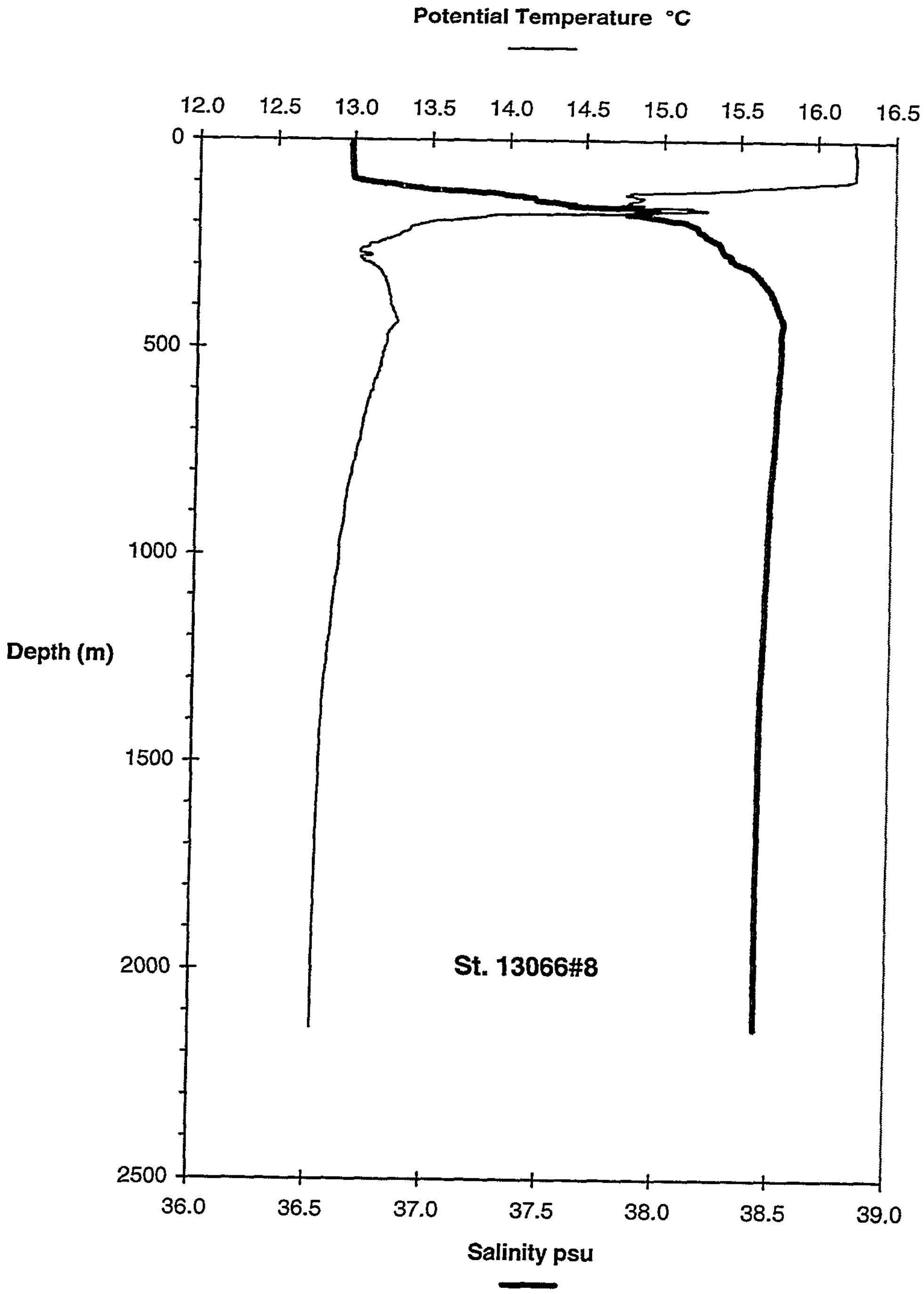


Figure 7. Temperature and salinity profiles at the station (13066) on the Atlantic side of the Almeria-Oran Front.

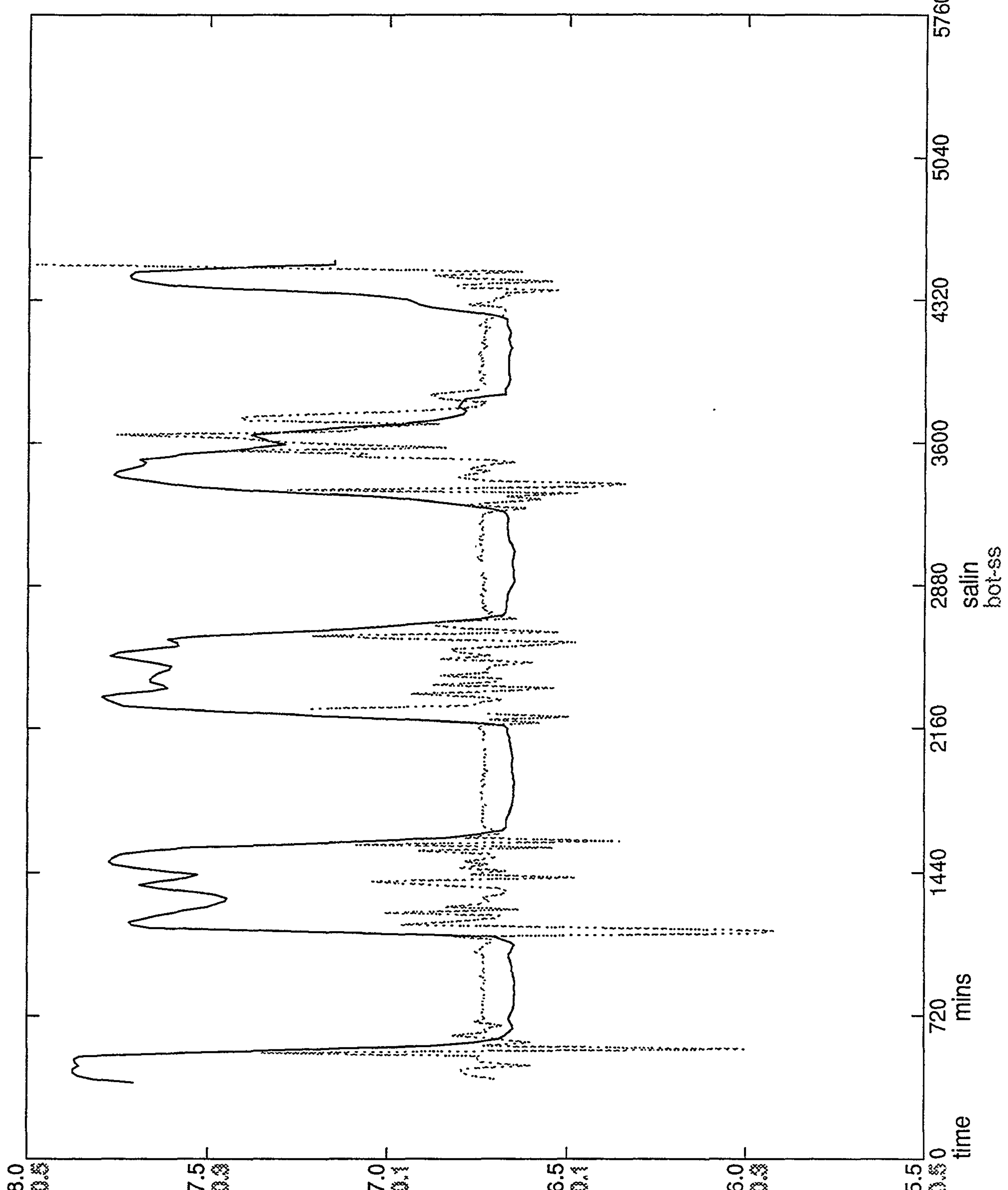


Figure 8. SeaSoar and Thermosalinograph-SeaSoar salinity values.

GEAR ABBREVIATIONS USED IN STATION LISTING

CTD	Conductivity-Temperature-Depth Probe
LHPR	Longhurst-Hardy Plankton Sampler
MS	Rosette Multisampler (Water Bottle)
NBES	Near-Bottom Echo Sounder
RMT1+8M	Rectangular Midwater Trawl, having 3 pairs of nets with nominal; mouth openings of $1m^2$ (RMT1, mesh size 0.33 mm) and $8m^2$ (RMT8, mesh size 4.5 mm).
SEASOAR	SeaSoar Towed Undulator
TRANSM	Transmissometer
UFL	Underwater Fluorometer

STN.	DATE 1997	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
13063 # 0	30/12 2/ 1	36 42.2N 36 34.7N	1 55.7W 0 58.5W	SEASOAR	0- 340	1857-1534	Long-line wrapped round fairing.	
13064 # 1	2/ 1	36 46.8N 36 47.0N	0 54.0W 0 54.1W	CTD MS TRANSM UFL	0-2558	1733-1939	WB @ standard depths	2568
13064 # 2	2/ 1	36 46.6N 36 45.8N	0 56.0W 0 57.9W	RMT1M/1 RMT8M/1	395- 500	2037-2137 Night	MED Station - New Monitor Flow Dist. 2.785 km.	
13064 # 3	2/ 1	36 45.8N 36 45.2N	0 57.9W 0 59.8W	RMT1M/2 RMT8M/2	300- 395	2137-2241 Night	Flow Dist. 2.605 km.	
13064 # 4	2/ 1	36 45.2N 36 44.5N	0 59.8W 1 1.0W	RMT1M/3 RMT8M/3	200- 300	2241-2341 Night	Flow Dist. 2.020 km.	
13064 # 5	3/ 1	36 46.8N 36 45.9N	0 53.8W 0 55.5W	RMT1M/1 RMT8M/1	650- 800	0150-0250 Night	Flow Dist. 2.226 km.	
13064 # 6	3/ 1	36 45.9N 36 45.1N	0 55.5W 0 57.1W	RMT1M/2 RMT8M/2	600- 700	0250-0350 Night	Flow Dist. 2.470 km.	
13064 # 7	3/ 1	36 45.1N 36 44.6N	0 57.1W 0 58.8W	RMT1M/3 RMT8M/3	500- 600	0350-0450 Night	Flow Dist. 2.718 km.	
13064 # 8	4/ 1	36 46.9N 36 45.9N	0 57.6W 1 0.3W	RMT1M/1 RMT8M/1	400- 500	1155-1255 Day	Flow Dist. 3.820 km.	
13064 # 9	4/ 1	36 45.9N 36 45.2N	1 0.3W 1 2.5W	RMT1M/2 RMT8M/2	295- 400	1255-1355 Day	Flow Dist. 3.505 km.	
13064 #10	4/ 1	36 45.2N 36 44.5N	1 2.5W 1 4.6W	RMT1M/3 RMT8M/3	199- 295	1355-1455 Day	Flow Dist. 3.370 km.	
13064 #11	4/ 1	36 46.6N 36 47.2N	0 54.0W 0 53.2W	CTD MS TRANSM UFL	0- 200	1628-1720 Day	WB for SeaSoar UFL calib.	2609
13064 #12	4/ 1	36 47.1N 36 46.2N	0 53.8W 0 55.5W	RMT1M/1 RMT8M/1	92- 216	1826-1926 Night	Flow Dist. 2.785 km.	

STN.	DATE 1997	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
13064	4/ 1	36 46.2N	0 55.5W	RMT1M/2	50- 105	1926-2026		
#13		36 45.4N	0 57.5W	RMT8M/2		Night	Flow Dist. 3.888 km.	
13064	4/ 1	36 45.4N	0 57.5W	RMT1M/3	0- 50	2026-2135	No flow. Monitor and flowmeter problems	
#14		36 44.3N	0 59.9W	RMT8M/3		Night		
13064	5/ 1	36 44.9N	0 58.7W	RMT1M/1	50-1105	0042-0415	Net failed to close 'til hauled to 50m.	
#15		36 42.5N	1 11.0W	RMT8M/1		Night		
13064	5/ 1	36 47.3N	0 57.0W	RMT1M/1	700- 800	0941-1042	White lead monitor	
#16		36 46.3N	0 58.8W	RMT8M/1		Day	Flow Dist. 2.694 km.	
13064	5/ 1	36 46.3N	0 58.8W	RMT1M/2	600- 700	1042-1140		
#17		36 45.3N	0 59.9W	RMT8M/2		Day	Flow Dist. 2.110 km.	
13064	5/ 1	36 45.3N	0 59.9W	RMT1M/3	500- 600	1140-1240		
#18		36 44.3N	1 1.4W	RMT8M/3		Day	Flow Dist. 2.290 km.	
13064	5/ 1	36 44.2N	1 1.0W	RMT1M/1	100- 200	1347-1432	Flow inaccurate	
#19		36 45.3N	0 57.9W	RMT8M/1		Day	Flow Dist. 3.293 km.	
13064	5/ 1	36 45.3N	0 57.9W	RMT1M/2	50- 100	1432-1517	Flow meter failure.	
#20		36 46.3N	0 54.8W	RMT8M/2		Day		
13064	5/ 1	36 46.3N	0 54.8W	RMT1M/3	0- 50	1517-1602	Flow meter failure.	
#21		36 47.1N	0 52.1W	RMT8M/3		Day		
13064	5/ 1	36 43.9N	1 0.3W	RMT1M/1	975-1175	1945-2120	Haul aborted. No flow	
#22		36 39.5N	1 2.0W	RMT8M/1		Night		
13064	6/ 1	36 46.0N	0 56.7W	RMT1M/1	1000-1100	1004-1104		
#23		36 45.4N	0 59.0W	RMT8M/1		Day	Flow Dist. 3.010 km.	
13064	6/ 1	36 45.4N	0 59.0W	RMT1M/2	895-1000	1104-1204		
#24		36 44.4N	1 1.3W	RMT8M/2		Day	Flow Dist. 3.280 km.	
13064	6/ 1	36 44.4N	1 1.3W	RMT1M/3	790- 900	1204-1303		
#25		36 43.4N	1 3.3W	RMT8M/3		Day	Flow Dist. 3.461 km.	
13064	6/ 1	36 46.1N	0 56.9W	RMT1M/1	1500-1710	1721-1921		
#26		36 43.4N	1 3.1W	RMT8M/1		Dusk	Flow Dist. 8.135 km.	

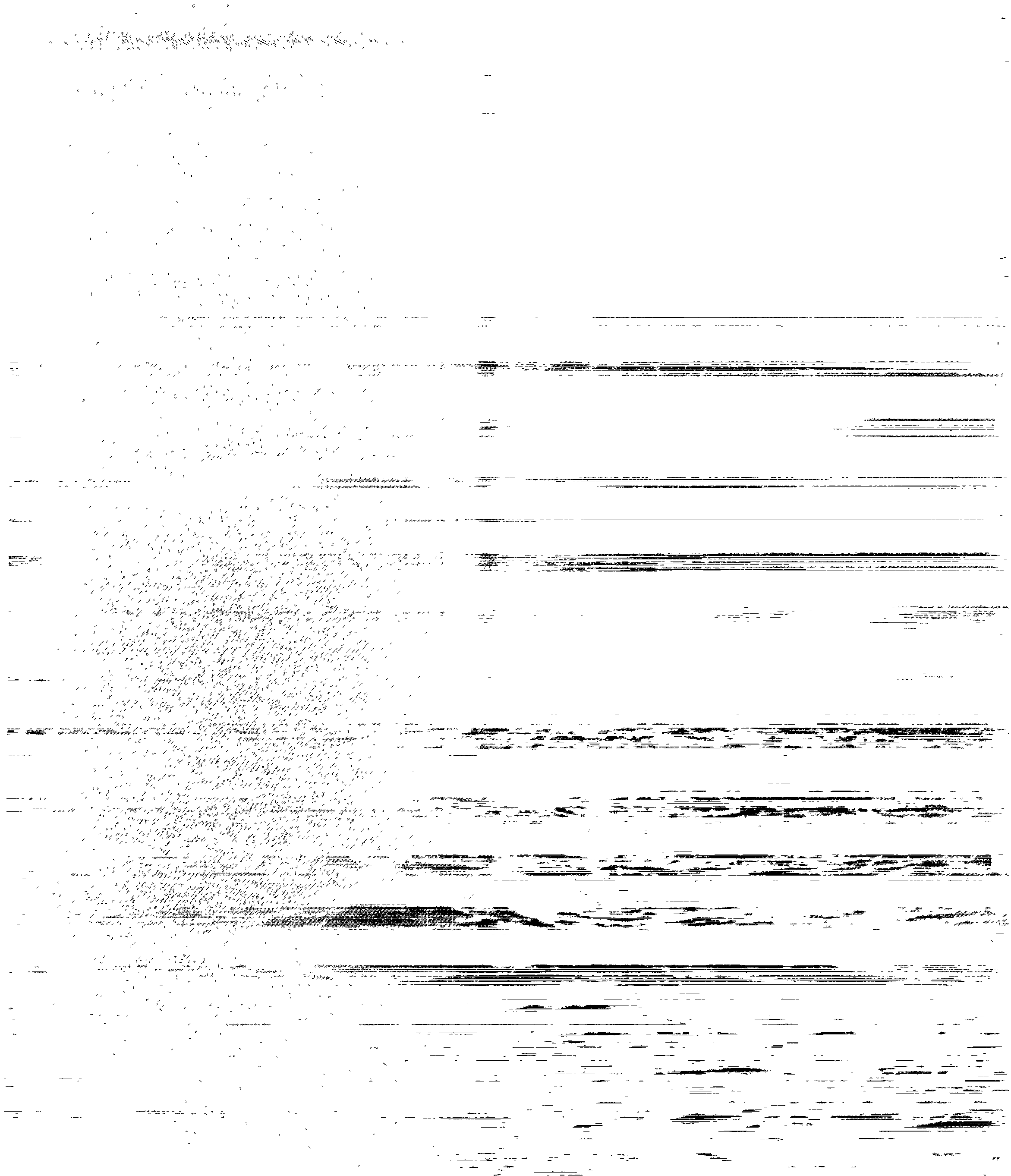
STN.	DATE 1997	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
13064 #27	6/ 1	36 43.4N 36 40.3N	1 3.1W 1 8.2W	RMT1M/2 RMT8M/2	1300-1500	1921-2121 Night	Flow Dist. 8.945 km.	
13064 #28	6/ 1	36 40.3N 36 37.8N	1 8.2W 1 14.0W	RMT1M/3 RMT8M/3	1100-1305	2121-2323 Night	Flow Dist. 8.448 km.	
13064 #29	7/ 1	36 42.6N 36 45.2N	1 3.2W 0 58.9W	RMT1M/1 RMT8M/1	898-1000	0313-0441 Night	Flow Dist. 6.225 km.	
13064 #30	7/ 1	36 45.2N 36 48.1N	0 58.9W 0 54.5W	RMT1M/2 RMT8M/2	805- 898	0441-0611 Night	Flow Dist. 6.945 km.	
13064 #31	7/ 1	36 44.6N 36 37.2N	1 0.1W 1 7.7W	LHPR	0- 409	0831-1107 Day		
13065 # 1	7/ 1	36 34.7N 36 33.4N	1 10.0W 1 11.0W	RMT1M/1 RMT8M/1	242- 254	1314-1355 Day	Cross-frontal tows. Flow Dist. 2.621 km.	
13065 # 2	7/ 1	36 33.4N 36 31.4N	1 11.0W 1 12.7W	RMT1M/2 RMT8M/2	251- 260	1355-1505 Day	Cross-frontal tows. Flow Dist. 4.442 km.	
13065 # 3	7/ 1	36 31.4N 36 29.9N	1 12.7W 1 13.9W	RMT1M/3 RMT8M/3	246- 260	1505-1605 Day	Cross-frontal tows. Flow Dist. 3.055 km.	
13065 # 4	7/ 1	36 34.4N 36 33.5N	1 10.1W 1 10.8W	RMT1M/1 RMT8M/1	136- 170	1831-1909 Night	Cross-frontal tows. Flow Dist. 2.083 km.	
13065 # 5	7/ 1	36 33.5N 36 31.9N	1 10.8W 1 12.7W	RMT1M/2 RMT8M/2	143- 159	1909-2019 Night	Cross-frontal tows. Flow Dist. 3.587 km.	
13065 # 6	7/ 1	36 31.9N 36 30.4N	1 12.7W 1 14.0W	RMT1M/3 RMT8M/3	150- 160	2019-2119 Night	Cross-frontal tows. Monitor problems. Flow Dist. 2.695 km.	
13066 # 1	8/ 1	36 3.6N 36 2.6N	1 40.8W 1 42.2W	RMT1M/1 RMT8M/1	395- 510	0302-0402 Night	Atl. Station. White lead monitor. Flow Dist. 2.290 km.	
13066 # 2	8/ 1	36 2.6N 36 1.7N	1 42.2W 1 43.7W	RMT1M/2 RMT8M/2	300- 395	0402-0502 Night	Flow Dist. 2.200 km.	
13066 # 3	8/ 1	36 1.7N 36 1.0N	1 43.7W 1 45.9W	RMT1M/3 RMT8M/3	205- 300	0502-0602 Night	Flow Dist. 2.605 km.	
13066 # 4	8/ 1	36 2.9N 36 0.7N	1 40.9W 1 42.0W	RMT1M/1 RMT8M/1	705- 800	0817-0917 Day	Flow Dist. 3.370 km.	

STN.	DATE 1997	POSITION LAT.	POSITION LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
13066 # 5	8/ 1	36 0.7N 35 58.1N	1 42.0W 1 44.1W	RMT1M/2 RMT8M/2	100- 705	0917-1107 Day	Net failed to close. Haul aborted.	
13066 # 6	8/ 1	35 58.1N 35 58.1N	1 44.1W 1 44.1W	RMT1M/3 RMT8M/3	96- 100	1107-1110 Day	Net not fished.	
13066 # 7	8/ 1	36 4.2N 36 4.5N	1 39.5W 1 38.9W	CTD MS TRANSM UFL	0- 746	1231-1338 Day	WB for SeaSoar UFL calib.	2103
13066 # 8	8/ 1	36 5.1N 36 4.4N	1 40.5W 1 39.9W	CTD MS TRANSM UFL	0-2093	1639-1822 Day	WB @ standard depths.	2103
13066 # 9	10/ 1	36 4.8N 36 0.4N	1 40.0W 1 45.9W	LHPR	0- 350	0848-1108 Day		
13066 #10	10/ 1	36 2.4N 36 3.5N	1 42.0W 1 38.6W	RMT1M/1 RMT8M/1	600- 700	1228-1328 Day	Only Net3 fished. Catches combined. Flow Dist. 4.630 km.	
13066 #11	10/ 1	36 3.5N 36 4.5N	1 38.6W 1 35.5W	RMT1M/2 RMT8M/2	515- 600	1328-1429 Day	Only Net3 fished. Catches combined. Flow Dist. 4.719 km.	
13066 #12	10/ 1	36 4.5N 36 6.1N	1 35.5W 1 33.3W	RMT1M/3 RMT8M/3	400- 515	1429-1528 Day	Only Net3 fished. Catches combined. Flow Dist. 4.045 km.	
13066 #13	10/ 1	36 4.1N 36 3.3N	1 36.4W 1 37.9W	RMT1M/1 RMT8M/1	700- 810	1831-1931 Night	Flow Dist. 2.290 km.	
13066 #14	10/ 1	36 3.3N 36 2.8N	1 37.9W 1 40.1W	RMT1M/2 RMT8M/2	605- 700	1931-2031 Night	Flow Dist. 2.920 km.	
13066 #15	10/ 1	36 2.8N 36 2.6N	1 40.1W 1 42.3W	RMT1M/3 RMT8M/3	500- 605	2031-2131 Night	Flow Dist. 3.055 km.	
13066 #16	11/ 1	36 3.2N 36 2.4N	1 38.3W 1 41.9W	RMT1M/1 RMT8M/1	1005-1105	0005-0135 Night	Flow Dist. 4.155 km.	

STN.	DATE 1997	POSITION LAT.	POSITION LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
13066	11/ 1	36 2.4N	1 41.9W	RMT1M/2	905-1005	0135-0305		
#17		36 1.8N	1 45.1W	RMT8M/2		Night	Flow Dist. 4.200 km.	
13066	11/ 1	36 1.8N	1 45.1W	RMT1M/3	800- 905	0305-0435		
#18		36 1.5N	1 48.2W	RMT8M/3		Night	Flow Dist. 3.795 km.	
13066	11/ 1	36 4.6N	1 39.3W	RMT1M/1	600- 700	0817-0918		
#19		36 3.7N	1 41.1W	RMT8M/1		Day	Flow Dist. 2.334 km.	
13066	11/ 1	36 3.7N	1 41.1W	RMT1M/2	500- 600	0918-1018		
#20		36 3.3N	1 43.1W	RMT8M/2		Day	Flow Dist. 2.560 km.	
13066	11/ 1	36 3.3N	1 43.1W	RMT1M/3	400- 500	1018-1118		
#21		36 3.2N	1 45.6W	RMT8M/3		Day	Flow Dist. 2.830 km.	
13066	11/ 1	36 5.0N	1 39.4W	RMT1M/1	100- 205	1255-1355		
#22		36 4.7N	1 41.3W	RMT8M/1		Day	Flow Dist. 3.370 km.	
13066	11/ 1	36 4.7N	1 41.3W	RMT1M/2	50- 100	1355-1455		
#23		36 4.4N	1 42.9W	RMT8M/2		Day	Flow Dist. 4.270 km.	
13066	11/ 1	36 4.4N	1 42.9W	RMT1M/3	0- 50	1455-1555		
#24		36 3.9N	1 44.5W	RMT8M/3		Day	Flow Dist. 4.495 km.	
13066	11/ 1	36 5.4N	1 37.7W	RMT1M/1	100- 200	1819-1919		
#25		36 4.6N	1 38.9W	RMT8M/1		Night	Flow Dist. 2.335 km.	
13066	11/ 1	36 4.6N	1 38.9W	RMT1M/2	60- 100	1919-2032		
#26		36 3.5N	1 40.2W	RMT8M/2		Night	Flow Dist. 4.709 km.	
13066	11/ 1	36 3.5N	1 40.2W	RMT1M/3	5- 60	2032-2132		
#27		36 2.6N	1 41.5W	RMT8M/3		Night	Flow Dist. 4.180 km.	
13066	12/ 1	36 5.2N	1 40.2W	RMT1M/1	1512-1710	0025-0225		
#28		36 4.8N	1 45.3W	RMT8M/1		Night	Flow Dist. 5.210 km.	
13066	12/ 1	36 4.8N	1 45.3W	RMT1M/2	1300-1512	0225-0357		
#29		36 4.3N	1 49.5W	RMT8M/2		Night	Flow Dist. 5.211 km.	

STN.	DATE 1997	POSITION LAT.	POSITION LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
13066	12/ 1	36 4.3N	1 49.5W	RMT1M/3	1095-1300	0357-0524		
#30		36 4.2N	1 53.6W	RMT8M/3		Night	Flow Dist. 5.373 km.	
13066	12/ 1	36 4.2N	1 43.7W	RMT1M/1	300- 400	0823-0923		
#31		36 4.7N	1 40.1W	RMT8M/1		Day	Flow Dist. 4.900 km.	
13066	12/ 1	36 4.7N	1 40.1W	RMT1M/2	200- 300	0923-1023		
#32		36 5.5N	1 36.6W	RMT8M/2		Day	Flow Dist. 4.810 km.	
13066	12/ 1	36 5.2N	1 35.4W	RMT1M/1	995-1100	1303-1403		
#33		36 5.4N	1 31.7W	RMT8M/1		Day	Flow Dist. 4.630 km.	
13066	12/ 1	36 5.4N	1 31.7W	RMT1M/2	900- 995	1403-1503		
#34		36 5.4N	1 28.1W	RMT8M/2		Day	Flow Dist. 4.990 km.	
13066	12/ 1	36 5.4N	1 28.1W	RMT1M/3	800- 905	1503-1603		
#35		36 5.5N	1 24.8W	RMT8M/3		Day	Flow Dist. 4.630 km.	
13066	12/ 1	36 9.9N	1 44.5W	RMT1M/1	230-1905	2012-2211	Oblique tow.	
#36		36 14.0N	1 40.3W	RMT8M/1		Night	Flow Dist. 5.751 km.	
13066	12/ 1	36 14.0N	1 40.3W	RMT1M/2	1895-1940	2211-2311	60-35 mob.	
#37		36 15.5N	1 38.1W	RMT8M/2		Night	Flow Dist. 3.505 km.	
				NBES				
13066	12/ 1	36 15.5N	1 38.1W	RMT1M/3	1920-2005	2311-0011	>60-35 mob.	
#38	13/ 1	36 17.0N	1 35.9W	RMT8M/3		Night	Flow Dist. 3.505 km.	
				NBES				
13067	13/ 1	36 21.4N	1 36.0W	RMT1M/1	125- 170	0911-0956	Cross-frontal tows.	
# 1		36 23.0N	1 34.5W	RMT8M/1		Day	Flow Dist. 3.383 km.	
13067	13/ 1	36 23.0N	1 34.5W	RMT1M/2	140- 160	0956-1054	Cross-frontal tows.	
# 2		36 24.8N	1 33.2W	RMT8M/2		Day	Flow Dist. 3.327 km.	
13067	13/ 1	36 24.8N	1 33.2W	RMT1M/3	150- 165	1054-1154	Cross-frontal tows.	
# 3		36 26.5N	1 32.0W	RMT8M/3		Day	Flow Dist. 3.235 km.	
13068	13/ 1	36 23.0N	1 37.8W	RMT1M/1	210- 235	1408-1442	Cross-frontal tows.	
# 1		36 24.0N	1 36.5W	RMT8M/1		Day	Flow Dist. 2.177 km.	

STN.	DATE 1997	POSITION LAT.	LONG.	GEAR	DEPTH (M)	TIMES GMT	COMMENT	MEAN SOUND. (M)
13068	13/ 1	36 24.0N	1 36.5W	RMT1M/2	210- 235	1442-1527	Cross-frontal tows.	
# 2		36 25.5N	1 35.1W	RMT8M/2		Day	Flow Dist. 2.933 km.	
13068	13/ 1	36 25.5N	1 35.1W	RMT1M/3	220- 240	1527-1612	Cross-frontal tows.	
# 3		36 27.0N	1 34.3W	RMT8M/3		Day	Flow Dist. 2.573 km.	
13068	13/ 1	36 22.8N	1 39.2W	RMT1M/1	80- 110	1815-1859	Cross-frontal tows.	
# 4		36 24.4N	1 37.7W	RMT8M/1		Night	Flow Dist. 3.293 km.	
13068	13/ 1	36 24.4N	1 37.7W	RMT1M/2	100- 110	1859-1958	Cross-frontal tows.	
# 5		36 26.4N	1 36.4W	RMT8M/2		Night	Flow Dist. 3.821 km.	
13068	13/ 1	36 26.4N	1 36.4W	RMT1M/3	95- 115	1958-2058	Nets closed prematurely. No catch	
# 6		36 28.5N	1 35.2W	RMT8M/3		Night		
13068	13/ 1	36 17.1N	1 27.6W	RMT1M/1	60- 60	2324-0004	Cross-frontal tows. Depths approx.	
# 7	14/ 1	36 24.3N	1 37.5W	RMT8M/1		Night	Flow Dist. 3.297 km.	
13068	14/ 1	36 24.3N	1 37.5W	RMT1M/2	60- 60	0004-0122	Cross-frontal tows. Depths approx.	
# 8		36 27.7N	1 34.9W	RMT8M/2		Night	Flow Dist. 4.885 km.	
13068	14/ 1	36 27.7N	1 34.9W	RMT1M/3	60- 60	0122-0223	Cross-frontal tows. Depths approx.	
# 9		36 30.5N	1 33.9W	RMT8M/3		Night	Flow Dist. 4.179 km.	
13069	14/ 1	36 45.8N	1 56.8W	SEASOAR	0- 290	0810-2018	SeaSoar Survey 2.	
# 0	16/ 1	36 24.6N	0 54.5W					



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