Cruise Report

# R/V ENDEAVOR Cruise 262 to Georges Bank


23 February - 10 March 1995

**Acknowledgements**

We gratefully acknowledge the very able assistance provided by the Officers, Crew, and Marine Technician of the R/V ENDEAVOR. Their professional expertise and willingness to apply it to special problems that arose during the cruise, made it possible to accomplish nearly all of our research goals and objectives.

This report was prepared by Cabell Davis, Scott Gallager, Bob Campbell, Dian Gifford, Stephan Plourde, Jeff Van Keuren, and Ed Dever with assistance from others in the scientific party. This cruise was sponsored by the National Science Foundation.

## TABLE OF CONTENTS

## Purpose of the Cruise

The overall goal of the U.S. GLOBEC Georges Bank Program is to determine how population dynamics interacts with physical processes in controlling the abundance of key animal species on the bank, namely cod and haddock and the dominant spring copepods *Calanus* and *Pseudocalanus*. The program consists of several components including field and laboratory studies for estimating population structure and vital rates as well as modeling and retrospective analyses to synthesize the empirical information. The field program is in its first major sampling year and is focussing on how the development of vernal physical stratification affects the population dynamics of the target species. The field program involves process cruises to experimentally measure the vital rates and fine-scale vertical migration behaviors in relation to the physical properties of the water column, and broad-scale cruises to map the distribution of physical and biological properties of the Bank. The process cruises were further divided into those focusing on the larval cod and haddock and those focusing primarily on *Calanus* and *Pseudocalanus*.

The present cruise aboard the R/V ENDEAVOR was the second in a series of five zooplankton process cruises spaced at roughly monthly intervals. Our purpose was primarily to determine the vital rates and vertical migration behaviors of *Calanus* and *Pseudocalanus* in relation to local circulation and hydrography. We also conducted studies of the feeding of cod larvae on protozoans and copepod nauplii. Our effort focused on zooplankton in the feeding environment of larval cod and haddock. The vital rate and behavioral information provided by our process cruises together with the larger-scale context of population distribution provided by the broadscale cruises will be incorporated into models of biological-physical processes controlling population dynamics of these species. Our specific objectives were:

(1) to measure vital rates including feeding, birth, development, and growth rates of *Calanus finmarchicus* and *Pseudocalanus* spp. while following a drogue in the vicinity of a larval fish patch (as determined by the broadscale cruises) and in the well mixed area of the bank.

(2) to measure the fine-scale (cm) vertical and horizontal distributions of these species in relation to hydrography and other planktonic and particulate matter.

(3) to map the local velocity fields using an Acoustic Doppler Current Profiler (ADCP).

(4) to conduct a hydrographic section across the southern flank of the Bank and a Video Plankton Recorder transect across the entire bank.

(5) to collect live individuals of *Calanus* for laboratory studies.

(6) to measure the ultraviolet and visible light fields in the study area

The work primarily involved experimental studies while station-keeping near a drifter. Transect studies consisted of CTD/hydrography and VPR. The ship's ADCP unit was used to make continuous measurements of the water current profile under the ship, in order to construct the local current fields at each site. These data will be used to help in the interpretation of all the other observations made on the cruise.

Two principal sites were occupied, one on the northeast peak and one in the mixed area (Figure 1; the complete cruise track is shown in Figure 2). Station #1 was chosen based on information from the previous broadscale cruise which found high concentrations of gadoid eggs on the northeast peak of the bank. Broadscale station #27 was chosen as the location to deploy our first ARGOS/GPS drifter since it was within the gadoid egg patch but far enough away from the bank edge that the drifter would not be carried off the bank. Station #2 was chosen in the mixed area to be at the long-term crest mooring site. Station #3 was chosen as a re-visit of the ARGOS drifter left at the northeast peak. A priority was assigned to each of the major cruise activities so that in event of worse-than-expected weather, the most relevant work could be completed. The highest priority was given to station #1, where the gadoid eggs were observed, followed in terms of priority by station #2, the hydrographic transect, station #3, the cross-bank VPR transect, and the Great South Channel station. Weather limitations during the cruise sometimes resulted in a curtailed sampling schedule where only a CTD profile was possible. On the 5th day of the cruise, a detailed schedule was prepared and followed with modifications for the remainder of the cruise (Appendix I). A formal log of the sampling events (with correct times and locations) is given in Appendix II.

**Cruise Narrative**

***Days 1 - 3 (2/23/95-2/25/95):*** The R/V ENDEAVOR left Narragansett Rhode Island at 0950 hrs on 23 Feb 1995. We steamed to within about 40 km of the first station (located at the standard Broadscale Station #27 on the Northeast Peak). This station was chosen based on observations, made during the previous broadscale survey (EN261), of high concentrations of gadoid eggs in this region. While steaming to the 1st station during the first night (Feb 23-24), the cook became very ill and, by morning, had to be taken to the hospital via a U.S. Coast Guard rescue helicopter (around 0700). The ship had already turned around (about 0330) and was steaming toward Woods Hole. It was agreed that a replacement cook was essential, so we continued steaming towards Woods Hole to acquire one. Since we could not reach port before dark, the captain decided to slow the ship down to a more comfortable ride and to reach port by morning light. We docked at Woods Hole at 0630 and had to wait until noon for the tide to slacken before departure. While in port, the cook, Dan Butler, came aboard, the air conditioner in the special purposed lab was fixed by a repair man, and a test deployment of VPR was made to examine an electrical interference problem. All repairs were made and at 1200 we left Woods Hole and steamed back to the station at the Northeast Peak.

***Day 4 (2/26/95):*** We reached station around 0600 and deployed the GPS drifter (drifter ID # 7234) at 0700 as planned. We then started the sequence of drifter station sampling activity to be done as outlined in the following Table:

**Table I. Activity Schedule for Drifter Stations**

0700 Arrive station and deploy drifter

*-----Repeat this loop for three days (except VPR for 2 days)------*

0800 MOCNESS
Pump (note: on all pump casts, the pump was attached to the CTD)
CTD full/hydro - water collection for experiments
Deploy Gallager et al drifters
Net tows to collect live animals for experiments
Optics cast
1100 Start VPR tow
1700 End VPR tow
Retrieve Gallager et al drifters
2000 MOCNESS
Pump
CTD/Hydro
2300 Start VPR tow
0500 End VPR tow

---

Due to several unforeseen complications this schedule could not be followed on Day 4 (Feb 26). The GPS information from the drifter could not be determined in real time. The position data output from the serial port of the GONIO Model 400 Deck Unit was not decipherable (by the maker of the drifter), but we could obtain relative bearing both from the serial port and the deck box display. The radar reflector on the drifter could not be seen on the bridge's radar scope. Initially, we had to rely on visual sightings and relative bearing to follow the drifter. Craig Lewis began deciphering the code from the GONIO using instructions in the manual.

An initial CTD cast was made to collect water for Gallager et al.'s cod feeding experiments. Fish larvae were added to experimental bottles containing natural seawater and seawater supplemented with cultured protozoans and/or nauplii. The bottles will be deployed on a drifter for in situ incubation experiment. After the CTD cast, a MOCNESS tow was made. The temperature reading on the MOCNESS was not working, and it took Jan Zelag about a half hour to solve the problem. In addition, the GPS input to the MOCNESS was not working initially Jan Zelag switched serial lines coming to the MOCNESS computer. Due to a problem with the switch, the A-frame was not working and it took 45 minutes to fix it. After the MOCNESS tow, we attempted to steam back to the drifter to make a pump cast, but we could not find the drifter for about an hour and decided to make the pump cast anyway. During the pump cast the drifter was observed about 200 m off the port bow at around 1030. Note that for all pump casts, the pump was attached to the CTD. Following the pump cast, a full hydro CTD cast was made. Due to a problem with the bottles on the CTD rosette, a second cast to collect more water for experiments was delayed, and the Gallager et al drifters were deployed about 1130 h. A second CTD cast to collect water for experiments then was made followed by a net haul for live animals. During this haul, a net was ripped and the haul had to be repeated. After the net haul a light cast was made. We then steamed back to Gallager's drifter and searched from there for the main (Durbin) drifter. We found the drifter about 1430 h using Craig Lewis's program which decodes the information from the GONIO box.

We then made a one hour surface tow using the VPR (VPR 1) while keeping the drifter in sight, and at the end of the tow we attempted to attach one of Gallager's high-flyers to the Durbin drifter since the one already attached to the drifter was too small to be seen on the radar scope. The ship drifted over the drogue and the line connecting the drifter to the drogue became lodged underneath the ship along the starboard side of the fantail. We finally had to cut the line and moved the ship forward with the main propeller, and the drifter/drogue became dislodged. The propeller had chopped up the drogue as we found a piece of it floating on the surface shortly thereafter. We were able to retrieve the drifter (drifter ID # 7234) which had sustained damage to its GPS antenna. After retrieval, we steamed back and recovered the Gallager drifter and then launched another GPS drifter (drifter ID # 7200), this time using one of Gallager's high-flyers rather than the smaller one of the Durbin group. We completed this launch at about 2000. Bob

Campbell decided not to conduct the MOCNESS or pump cast and no live animal tows were made, since his group had to finish setting up their molting experiments. Dian Gifford made a second CTD cast around 2030. A VPR tow was made from 2230-0120 (VPR 2). The armor of the VPR tow cable became tangled during the tow, and we held the VPR at 20-30 m while the tangle was cut off and the severed strands of the cable armor taped down. While the cable was being repaired, we lost the pressure reading on the VPR.

***Day 5 (2/27/95):*** A MOCNESS tow, pump cast, CTD, and Gallager drifter release, went according to the schedule in Table I. The Gallager drifter was released within 100 m of the GPS drifter. The CTD rosette electronics did not work properly and the bottles for the hydro samples did not trip; a second test CTD cast was made around 1100 and none of the bottles could be tripped. Live net tows and a light cast were made, after which Jan Zelag worked on the CTD problem. The same cable and block were used for the CTD, live tows and light casts, because the block usually used for the live tows and light casts was ashore being repaired. This situation meant that the CTD problem could not be examined until after the live tows and light casts were made. After the live tows and light casts, we steamed back to the GPS drifter which had separated from the Gallager drifter by several hundred meters. After consulting with Sea Scan Inc. via INMARSAT, we replaced the pressure sensor board in the MOCNESS electronics can on the VPR. A 2-hour VPR towyo was made while circling the drifter starting at 1420 (VPR 3). After the VPR tow, Gallager's drifters were retrieved using the crane boom. The CTD had problems with the slip rings - Jan Zelag worked on the cable wiring problem including reterminating the cable and by 0730 the following morning was able to conduct a test cast. Since the CTD cable was under repair, no pump cast or CTD was done at night. During the VPR tow around 1430, it was noticed that the GPS drifter (drifter ID # 7200) was not transmitting its position to the ship. We decided to try to attach our third GPS drifter (drifter ID # 7201) to the GPS drifter/high-flyer array already in the water, but gale force winds came up quickly and we had to suspend all operations. Thus night time MOCNESS and VPR tows were not done.

***Day 6 (2/28/95):*** By 0000, the gale had abated enough to attach the drifter (drifter ID # 7201) to the one already in the water; and the new drifter was attached around 0050. Jan Zelag conducted a test CTD cast at 0800 and all but two bottles tripped. A MOCNESS tow was made around 0830 followed by a pump, Gallager drifter deployment, live net hauls, and light cast. A VPR towyo was made around the drifter until about 1130-1630 (VPR 4). The Gallager et al drifter was retrieved around 1700. The MOCNESS, pump, and CTD then were deployed followed by a VPR towyo near the drifter starting at 2145 (VPR 5). The drifter had not be seen since 2000 h but was relocated by the captain around 2200. Drifter positions from the GONIO via Lewis' decoding program seemed to be off by a few tenths of a nautical mile perhaps due to time lags. Lewis worked on projecting drifter positions from new GPS fixes received from the GONIO every half hour. The drifter transmitted to the ship every 90 s, but new GPS fixes were obtained by the drifter only on the half hour.

***Day 7 (3/1/1995):*** The VPR towyo (VPR 5) ended at 0130 due to an electrical short in an underwater cable connector which was subsequently repaired. A MOCNESS tow was made around 0800, but the nets did not trip properly, so another MOCNESS tow made. During preparation for the pump cast the CTD cable jumped the sheave and became lodged. The cable had to be cut and reterminated. The pump cast was cancelled, and a CTD/hydro cast was made around 1330, followed by live net tows and a light cast. A VPR towyo was made from 1500-1640, circling around the GPS drifter at 0.5 nautical mile radius towing at 3 knots (VPR 6). After the VPR was aboard we attempted to find Gallager's drifter but had difficulty doing so. After about 1.5 hours the drifter was found and recovered using the crane off the starboard side. A MOCNESS tow was made at 2015 followed by a pump cast at 2100, a CTD cast at 2130, and a VPR towyo (VPR 7) at 2300.

***Day 8 (3/2/1995):*** The VPR towyo ended at 0430 after circling the drogue about 5 times at a distance of about 1 km. We lost sight of the drifter and spent several hours trying to find it. GPS fixes from the drifter via the GONIO box and Craig Lewis' decipher/projection program were used to relocate the drifter. The high-flyer was sighted first and was retrieved at 0920, but it had become detached from the drifter and drogue. To find the drifter/drogue, the ship steamed along Lewis's projected GPS drifter path, and the drifter was sighted directly ahead of the ship. The drifter and drogue were brought on board at 1015. The older, non-functioning drifter (#7200) was removed from the array, and data from the working drifter (#7201) was downloaded to the ship's PC (the one used for the CTD). The drifter then was reassembled, attached to a new drogue (we used the large 2 m diameter ones), and to the high-flyer. The ship steamed to the position the drifter would have been at 1130 had it remained in the water, as projected by Lewis's program. The drifter/drogue/high-flyer then was redeployed at that location at 1130. The drogue was launched off the port stern, then, in rapid succession, the GPS/ARGOS drifter followed by the high-flyer which was rolled off the gunwale. This operation was recorded on video tape as were various other launch/retrieval operations during the cruise. The Gallager et al cod incubation drifter then was launched off the stern (under the A-frame) within 100 m of the GPS drifter. A CTD cast was made at 1220 followed by 2 live tows. No light cast, pump, MOCNESS, or VPR deployments could be made due to rough seas. The ship returned next to the drifter. At 1835 the Gallager et al drifter was retrieved in rough seas. A pump cast was made around 2000, but it was still too rough for MOCNESS and VPR. No live tows were made since sufficient numbers of animals for crest area experiments were obtained from the daytime live tow. We left for the crest mooring site at 2054.

***Day 9 (3/3/1995):*** Arrived crest station at 0530 and hove to until first sampling at 0800. We did a MOCNESS tow next to the crest mooring at 0830 followed by a pump, CTD, live tow, and optics cast. At 1100, the Gallager et al drifter was deployed near the crest mooring. An intercalibration between the CTD, VPR (VPR 8), and MOCNESS was attempted at 1120 in the sequence outlined in Table II:

## Table II. CTD/VPR/MOCNESS INTERCALIBRATION SEQUENCE

Launch CTD

***While steaming at 1+ knots:***

Launch MOCNESS
Leave CTD and MOCNESS in water for 1/2 hr at 1+ knots

Retrieve MOCNESS, leaving CTD in water

Launch VPR
Leave VPR and CTD in water for 1/2 hr

Slow ship speed and retrieve CTD

Resume 1+ knot ship speed

Launch MOCNESS
Tow MOCNESS and VPR at surface for 25 minutes hr tripping nets at 5 minute intervals and using all 5 nets.

Retrieve MOCNESS
Retrieve VPR

The CTD was deployed first but on attempting to launch the MOCNESS, the hydraulic line burst on the MOCNESS winch and it took several hours to fix it. Starting at 1420, the intercalibration was performed as shown in Table II was completed at 1730. By that time, we had to retrieve the Gallager et al drifter, so no daytime VPR tow was made. We began looking for the drifter at 1750 but did not find it until 2200. Since 12 h had passed, the drifter had completed one tidal ellipse and had been set 4 nautical miles to the SSW of the crest mooring. We then steamed back to the crest mooring and made a pump/CTD cast at 2250 followed by a VPR tow (VPR 9) at 2330.

***Day 10 (3/4/1995):*** The VPR tow (VPR 9) consisted of several short transect lines made near the crest mooring to attempt to map out plankton distributions, but no obvious horizontal or vertical variability was observed. A number of 5 mm long tear-drop shaped objects were observed in the video at a concentration of about 1/ml, but they had not been seen in the net tows. A bucket sample was taken, and these organisms were observed to be light-brown hollow multicellular sacs. The sacs were very fragile and were easily destroyed by probing them, which accounts for their not being seen in the net tows. The VPR tow (VPR 9) ended at 0355, and we hove-to by the crest mooring until daytime sampling began. At 0820 a MOCNESS was done followed by a pump, CTD, Gallager drifter launch, 2 live net hauls, and a light cast. A 2-km grid was sampled with the VPR (VPR 10) around the Gallager et al drifter from 1250 - 1530. The drifter was retrieved at 1645 after which we returned to the crest mooring. At 2000 a MOCNESS tow was made, but there was a problem with a bent net bar and the tow was repeated at 2100, followed by a pump cast at 2130. The Gallager et al. high-flyer was launched at 2320 so that a 1 nautical mile VPR grid could be done centered on the drifter. The VPR (VPR 11) was deployed at 2330.

***Day 11 (3/5/1995):*** Near the completion of the VPR grid (0410), the tow cable jumped the sheave in the towing block and we ended the tow. No damage was done. The drifter was retrieved at 0510. A MOCNESS tow was made at 0820 followed by a pump, CTD, and light cast. At 1000, we steamed towards the start of the hydro transect and reached the first station at 1230. For the 12+ hour hydrographic transect, a watch was posted for two 6 hour shifts (1300-1900: Dever, Absher, Hunt-vonHerbing, Zelag; 1900-0200: Dever, Zelag, Brown, Vankeruen). The CTD cast was made at the first station on the transect at 1236. Rough seas (4-5 m wave height, 15-20 m/s wind) reduced our steaming speed between stations to 6 knots (3 m/s, streaming time between stations was about 40 min). CTD casts were made at the second and third stations along the transect at 1336 and 1438, respectively. At the next station, the stratification array (ST 2), a light cast was made at 1600 followed by a CTD cast at 1630. The latter was yoyoed for 1 hour, next to the mooring for sensor calibration of the moored instrumentation. On the last yoyo, bottles were tripped for water collection. It was too rough to

do a MOCNESS, pump, or live tow at this station. CTD cast 10 of this transect was made at 2400.

***Day 12 (3/6/1995):*** At the 12th CTD station, a live tow and a MOCNESS tow were made at 0215 and 0300, respectively. An additional station was added to the end of the transect, since the shelf-slope front was further off the bank than expected. The last (13th) CTD cast was made at 0440. Rather than steam directly back to the drifter at the northeast peak, to save steaming time, we decided to conduct the first half of the X-bank VPR towyo (VPR 12). From the halfway point of this X-bank transect, we planned to steam 20 miles to the northeast peak drifter station. So from the end of the CTD transect, we steamed ENE to the start of the first half of the cross-bank VPR towyo transect. The added CTD station on the hydro transect together with heavy fog, which slowed our steaming speed, delayed our arrival at the start of the VPR transect. Upon arrival, we first made a light cast. By this time the winds had become weak, and we waited two hours for the seas to settle down. We took on more ballast and commenced the 1st half of the cross-bank VPR towyo (VPR 12) at 1400. Despite towing the VPR in the trough of the still large swells, the extra ballast made the ship quite stable. At 1540, the VPR hooked into a lobster line, which we dragged to the surface, cut, spliced, and released intact. This operation only took a few minutes. During this 14-hour towyo, we received the latest ARGOS fix (from 3/5/95 at 0900) by FAX from Jim Bisgani and Peter Garrahan on the GPS drifter we had left at drifter station #1. This fix showed that the drifter had moved about 20 miles to the southwest over a 2 1/2 day period and was located near the halfway point of X-bank VPR transect. We began receiving ARGOS transmissions from the drifter as we neared the end of the first half of the VPR transect. These incoming data (deciphered by Craig Lewis) revealed that the drifter was not receiving GPS data, thus the position data were not being transmitted to the ship.

***Day 13 (3/7/1995):*** At 0400, we ended the 1st half of the VPR transect (VPR 12) near the location of the ARGOS fixes we had received from Bisagni and started searching for the drifter. We used the radio direction finder on the GONIO (although it was somewhat erratic) to locate the drifter and Craig Lewis spotted it 200 m off the starboard side at 0700. It had a broken GPS antenna. We stayed by the drifter and commenced station activities at 0830. A MOCNESS tow was made first followed by a pump cast, CTD, Gallager drifter deployment, and two live tows. We then retrieved the GPS drifter with attached drogue because we were concerned that it might sink. A light cast was made at 1120 followed by another CTD at 1145. A 1-nautical mile VPR grid (VPR 13) was done around the Gallager drifter (not drogued) from 1300-1800. After this VPR tow, the drifter was retrieved at 1830, the cod larvae containers removed, and the drifter redeployed at 1840. At 2000, a MOCNESS tow was made, followed by a pump cast, CTD, and another VPR grid (VPR 14) around the drifter at 2140.

***Day 14 (3/8/1995):*** The nearly completed VPR grid ended at 0140 due to an electrical short. The drifter was brought aboard at 0218 after having drifted nearly 10 miles to the north. We then steamed SW to the start of the 2nd half of the X-bank VPR transect. An electrical short was

found to be located somewhere between the winch slip rings and the end of the tow cable entering the VPR. The wiring was switched and the system ran fine. The VPR (VPR 15) was launched for the 2nd half of the X-bank transect at 0600 and was towyoed for 10 hours to the end of the transect. At this station (station #4), a light cast was made at 1607 followed by two live tows for Stephan Plourde, a pump, and a CTD. A surface MOCNESS tow was made to collect $5x10^5$ live *Calanus finmarchicus* for Ann Durbin, but too few were obtained. The standard MOCNESS tow then was made, and this tow was used to look for any potential layers of *Calanus*
for a further live collection. A third MOCNESS tow was made, towyoing the system between 10 and 50 m. At 2200 we steamed for the start of the Great South Channel VPR transect. Since the weather forecast was not good, we decided steam to an intermediate way point (broadscale standard station # 35) and, at that point, reassess whether to turn to the SE to the start of the VPR transect (at $41^{o}$ 27.5' N $68^{o}$ 27.0' W) or to continue west to the Gulf of Maine station (broadscale standard station #38). Weather conditions deteriorated so that the VPR transect could not be made, and we steamed directly to the Gulf of Maine station, arriving there at 0800. At this station, the gale was still in force, and we decided only to conduct live net tows. We had one hour to make these tows in order to arrive at Woods Hole by the tide at 1600. We had wanted to go to Woods Hole to off-load the VPR equipment. We left the station at 0900 steaming for Woods Hole, but we soon learned that the Woods Hole port was full and could not accommodate us. We then steamed for Narragansett. Since we now had more time, we stopped to make some more live net tows, because not enough live *Calanus finmarchicus* had been collected previously. We were about 4 miles from the Gulf of Maine station. We started steaming for Narragansett at 1130.

## Individual Reports

**Hydrography** (E. Dever)

1. Introduction

The second GLOBEC process cruise of 1995 took place from February 23 to March 10. This cruise summary covers aspects of CTD operations at the three drifter stations, hydrographic line A, and the Georges Basin and Great South Channel stations occupied during EN262.

The two persons most responsible for CTD operations were Ed Dever (PO student at WHOI) and Jan Zelag (marine technician at URI). The remainder of this report is divided into three sections. Section 2 describes the equipment used and sampling protocols. Section 3 is a day by day cruise narrative describing the stations occupied, problems encountered etc., and section 4 is a preliminary comparison of the CTD observations to previous cruise (EN260) observations along line A and general commentary about drifter site CTD stations.

2. Equipment and Salt Sampling Procedures

Hydrographic data were collected using a Neil Brown Mk V CTD with transmissometer, oxygen sensor, and fluorometer. A twelve bottle rosette with 9 to 11 attached GO-FLO bottles was used to collect water samples for salinity calibration chlorophylls and other purposes. Bottles for salinity calibrations were generally collected near the surface and bottom. Salinity samples were run on board using a Guildline Autosal provided by George Knapp of WHOI. Samples for chlorophyll analysis and other purposes, when collected, were generally taken at bottom, surface, and 20 m depths.

During this cruise two types of CTD casts were done, a conventional cast for water collection and T, S profiles, and a pump cast for Ted Durbin's group. For the conventional casts the CTD was lowered/raised at 40 m/min at stations 1 and 3 and 30 m/min at station 2 where the depth was quite shallow (< 40 m). For the pump casts the CTD was lowered at 20 m/min and raised at 4 m/min. Generally no bottles were tripped at stations 1 and 3 during the pump casts. Because station 2 was very well mixed, I felt the slower lowering speed of the pump cast did not affect the T, S profiles and the pump down cast could also be used as the hydrographic cast if no water collection at intermediate depths was required. In this report, cast numbers appended by a (p) indicate pump casts. Hydrographic profiles were generally obtained twice a day at each of the drifter sites usually around 0900 and 2100.

Unfortunately no post processing of the CTD samples was performed at sea as the computer hard disk drive with post processing software crashed during the beginning of post processing.

3. Cruise Narrative for Hydrography

Note that all times given in the following narrative are local. Universal Time (UT) is 5 hours later than local (EST). This narrative is meant as a general overview of CTD work; specific information about each station can be found on the CTD station sheets.

February 26:
Station 1 was reached at approximately 0630, and the GPS drifter was deployed on the northeast flank near 41 58' N, 66 42' W. Water depth at this location was near 72 m. CTD cast 001 was made at about 0730. The water column was slightly stratified at this time and location with cool fresh water (4.58 C, 32.81 psu at 10 m) underlain by slightly warmer saltier water (4.65 C, 32.83 psu at 60 m). We tripped all 10 bottles to sample the bottom, 20 m depth, and surface. Several bottles (7,8,9) came up empty though they tripped on the rosette. This problem also occurred during other casts. Apparently the GO-FLO's aren't opening at shallow depths. Salts were taken at 0, 20, and 63 m. Though a slight stratification existed through the water column, they should all be useful for salt calibration as no strong halocline was evident. Continued on with CTD casts 002(p), 003, 004, and 005. Noticed problems with bottles tripping on casts 001, 003, 005. On cast 005, we got a software error ("buffer filled") at the end of the upcast. Computer froze up and we could not end cast with CTRL F10. We then had to reboot the computer. This caused the loss of the .btl and .edt files for the upcast. Given the weak stratification, Jan felt we could go ahead and run the salts for this cast using the raw data files to check salinity at the bottle depths noted in the CTD log, however we may want to exclude them from a determination of the post cruise calibration.

Weather conditions today were highly favorable to cooling (65% rel hum, T_a = -3.5 C, T_s = 4.5 C, winds around 15 knots) and later profiles show evidence of being slightly unstably stratified.

February 27:
We continued at station 1 with CTD casts 006(p), 007, and 008. Bottles were again troublesome. Along with the mechanical problems of bottles not opening at depth, we began having problems with bottles not tripping beginning at cast 007. This second problem was caused by an intermittent short in the end termination on 007 which became total on 008. CTD signals were not affected, but no current was getting down the wire to trip the bottles. Jan re-did the end termination on the night of February 27.

February 28:
We continued again at station 1 with CTD's 009, 010(p), 011(p), and 012. Conditions today were not particularly favorable to cooling (near 100% humidity, T_a > T_s). We got hit by a rain shower in the mid morning. Later in the day the VPR crew noticed a very shallow surface layer (1 m) with lower fluorescence and slightly higher temperature (0.01--0.03 C). This is

shallower than the CTD with rosette can reliably measure. Perhaps it would be interesting to bring along a SeaCat to lower by hand to check out similar near surface features.

March 1:
Continued again with station 1. Attempted a morning pump station, but the wire jumped the block just as the CTD was deployed. Jan had to reterminate and we were ready to go by 1320. We ended up doing casts 013, 014(p), and 015. Cabell notes that in VPR tracks around the drifter some horizontal variability (0.10 C, 0.1 psu) is evident. When variation occurs it happens rapidly (one or two up and down tows) rather than gradually across the transect. This is in line with typical variability between CTD casts. It's possible that the surface drifter has found a weak front with convergence, but further interpretation is best done after the VPR crew plots up their data in 3-D.

March 2:
Rough weather meant morning pump station, optics cast, and VPR called off. Continued at station 1 with casts 016, 017(p). Water was well mixed at this time and weather was still relatively rough so I decided to use evening pump (017(p)) as hydrographic station as well. I continued this practice at station 2 as the site was well mixed there as well. The pump hose is attached to the top of the rosette frame and no pumping is done on the downcast, so the only issue is the lowering speed of 20 m/min. I decided to continue using the pump data for the T, S profile at station 2, as the water column was well mixed. Cast 017(p) is the last cast at station 1. By now the drifter is near 41 45' N, 66 46' W at a depth of 69 m and has drifted about 13 miles south and 3 miles west of its deployment location.

March 3:
Begin station 2, the crest mooring site (41 25' N 67 33' W). The depth here is around 40 m with large (5--10 and occasionally 15(!) m) sand waves. Calmer and partly sunny today. We did CTD casts 018(p), 019, 020, 021, 022, and 023(p) today. On CTD 019 the CTD probably touched bottom with no apparent ill affects. Casts 020, 021, and 022 were near surface (10 m) tows done at 1.5--2 knots for CTD/MOCNESS and CTD/VPR intercalibration purposes. Cast 020 was an abortive first attempt at CTD/MOCNESS intercalibration. Winch 2 (used to lower the MOC) busted a hydraulic line which delayed us for a couple hours. Cast 021 was the CTD/MOC intercalibration tow and 022 was the CTD/VPR intercalibration tow. All data for these tows was written into downcast files. Bottles were tripped at the end of cast 022 as an ultimate check of CTD and VPR salinities. At first glance it appears CTD salinities are higher than both VPR and MOC salinities by 0.07--0.1 psu. This bears further checking out.

March 4:
Continued at station 2 with casts 024(p), 025, and 026(p). Partly cloudy and fairly calm with similar air and sea temperatures. Jan ran the first batch of salts at night.

March 5 and early morning March 6:
Began at station 2 with casts 027(p) and 028. CTD 028 was the last at station 2 (41 26' N 67 34' W). Drifted about one mile northwest in the two days we were here. Began steaming to hydrographic transect A (CTD casts 029--048) about 1030 and arrived there (41 09.2' N 67 46.8' W) at 1230. Began A with marginal conditions (seas 8--10', wind around 30 knots). Deployed CTD with one and later two tag lines, used snap hook to recover CTD. GO-FLO bottles again had trouble opening at depth at shallow stations (A-1, and A-2). Rather than do A-4, we stopped at mooring site ST2, about a mile away along the A transect. We did a one hour yo-yo cast at ST2, tripping bottles on the last upcast. These yo-yo casts collected 8 profiles in one hour near ST2. We continued on to station A-12 and I decided to extend the line 4 nm further to A-13 as surface temperature was only 7 C at A-12. Surface temperature jumped to 16 C at A-13. Ended transect shortly after 0500 March 6.

March 6:
Towed VPR to station 3 (northeast flank GPS drifter site), no CTD stations except early morning end of transect A (above). Jan ran second batch of salts.

March 7:
Arrived station 3 (northeast flank) and picked up GPS drifter as its antennae were damaged. Drifter position in morning was approximately 41 43' N 67 00' W with a depth of 64 m; hence the drifter went 2 miles south, 12 miles west since we left it on March 2. Did CTD's 049(p), 050, 051, 052(p), and 053. Cast 053 was the last cast at the Station 3 northeast flank drifter site.

March 8:
Finished VPR transect across Georges Bank and did CTD casts 054(p) and 055 in Georges Basin.

March 9:
Did CTD casts 056(p) and 057 in Great South Channel.

4. Interpretation

Conditions at drifter station 1 (northeast flank, 70 m depth) were often nearly well mixed (gradients often near 0.01 in T and S) with temperatures between 4.48 and 4.65 and salinities between 32.75 and 32.83 from cast to cast. As noted in section 3, this variability is similar to that observed by the VPR and is probably an indicator of short scale ( ~1 km) spatial variability rather than temporal variability. These temperatures and salinities fall within historical winter values on the northeast flank (Flagg, in Georges Bank volume).

As at station 1, conditions at drifter station 2 (crest site, near 40 m depth) were often nearly well mixed (gradients often near 0.01 in T and S) with temperatures between 5.04 and 5.14 and

salinities very near 33.39. Temperature and salinity fall within historical winter values on central Georges Bank (Flagg, in Georges Bank volume).

Returning to the drifter at station 3, it had drifted west to the winter fishing grounds from the northeast flank and was now on the border between the northeast flank and central Georges bank regions as defined by Flagg. Depth shallowed to around 60 m with 5 m sand waves common. Temperature at station 3 varied between 4.38 and 4.41 and salinity varied between 32.83 and 32.84. Though the water surrounding the drifter was cooler now, its salinity was quite similar to that at station 1.

Hydrographic section A can be compared with a nearly identical section obtained during EN260 (GLOBEC mooring deployment cruise January 29 -- February 6, 1995). In the month between EN260 section A and EN262 section A several changes occurred most notably:

1. Cooling within the 80 m isobath

Typical temperatures within the 80 m isobath during EN260 ranged from 6.4 to 7 C with salinities from 33.05 to 33.2. During EN262 temperatures ranged from 5.0 to 5.2 and salinities ranged from 33.00 to 33.30.

2. Near surface expression of shelf/slope front moving offshore
During EN260 the shelf slope front was strong and relatively narrow. Its near bottom expression was between A line stations A-8 and A-9 (40 45' N and 40 41.6' N) and its surface expression was between stations A-9 and A-10 (40 41.6' N and 40 38.1' N). During EN262 the near bottom expression became evident between A-8 and A-9 (though the gradient was not as sharp as that during EN260); however the surface expression of the shelf slope front didn't become evident until stations A-12 and A-13 (an extra station added on to resolve the shelf slope front.

### 3.2 Copepod development, growth, and vertical distribution:

Zooplankton Abundance, Physiological Condition, and Growth Rates
(E. Durbin, A. Durbin, R. Campbell, D. Avery, and G. Teegarden)

Objectives:

(1) To determine the abundance and stage composition of the target zooplankton species (Calanus finmarchicus and Pseudocalanus spp.) at the proposed drifter locations on Georges Bank and at several off-bank stations.

(2) To determine the size (length, carbon and nitrogen) and condition (condition factor and RNA/DNA ratio) of Calanus finmarchicus over the bank.

(3) To correlate growth and development rates of Calanus finmarchicus copepodite stages and egg production rates of adult females with RNA/DNA ratios in ship board incubations, and compare these results with the RNA/DNA ratios of field collected copepods to estimate growth rate in the field.

(4) To determine if growth and development rates of Calanus finmarchicus copepodite stages are food limited on Georges Bank.

Zooplankton were collected twice each day at the drifter locations. A 1 m2 MOCNESS equipped with 150 um mesh nets was used and sampled between the following depth intervals: 0-bottom, bottom-100m, 100-40m, 40-15m and 15m-surface. In addition, a plankton pump equipped with 50 um mesh nets, which quantitatively retains all of the nauplii of the target copepod species, was used and sampled the same depth intervals. There did not appear to be any difference in the copepod species composition at both drifter sites (northeast peak and crest regions). Calanus finmarchicus, Pseudocalanus spp. and Centropages typicus were all present in good numbers. All stages of Calanus were present from nauplii through adult. MOCNESS tows were also made in the slope water southeast of Georges Bank and in Georges Basin.

Calanus finmarchicus N5 through adult were routinely collected with live net hauls (150 um and 300 um) for size (length, carbon and nitrogen) and condition (condition factor and RNA/DNA ratio) measurements. Copepod images were recorded with a video system for later length measurements and then placed in either a tin boat and dried over desiccant for carbon and nitrogen analysis or put into cryotubes and frozen in liquid nitrogen for RNA/DNA determinations.

Experiments were conducted on board ship to determine the relationship between RNA/DNA ratio and growth and development rate of Calanus finmarchicus copepodites, and whether growth was food limited. Copepodites of a specific stage were sorted from the live tow under a dissecting microscope (exp1, C2; exp 2, 3, 4, C3; and exp 5, C4) and incubated in 8 l polycarbonate bottles filled with ambient surface water or ambient water enriched with phytoplankton cultures (Tetraselmis sp. and Thalassiosira weissflogii), and placed in a water bath cooled with surface water. Two ambient bottles and two enriched bottles (exp 2 and 3 only) with between 30 and 45 copepodites in each bottle, depending on stage, were used in each experiment. Initial measurements were taken for size and condition and the final measurements of size and condition (noting any molting that had occurred) were made after a two day incubation.

The mean number of copepods molting to the next stage during the two day incubation was 17% and ranged between 9% and 28% for all experiments combined. Preliminary results

show that there was no difference between the ambient and enriched treatments suggesting that development rate was not food limited at this time on the bank. Also, there did not appear to be any significant difference in development rates between copepods in the northeast peak region and those on the crest.

In addition, size and condition measurements were made on individual adult female Calanus for which individual egg production measurements, and in some copepods, state of gonad maturation had been determined by Stephane Plourde. These measurements were made on copepods collected from different regions on the bank.

Phytoplankton tows were taken with a 35 micron mesh net at the two drifter stations, off the southern flank at the start of the VPR transect, and at the Great South Channel. On bank diatom flora were consistent in diversity and abundance, dominated by Thalassionema spp., Chaetoceros spp., Thalassiosira spp., and Coscinodiscus spp.; many other genera were present in lesser numbers. Dinoflagellates comprised Ceratium spp., which were numerically dominant, Dinophysis spp., and Protoperidinium spp., and possibly an unidentified gonyaulacoid. One interesting feature noted at the southern flank station was the strong numerical dominance by the diatom Pseudonitzschia; diatoms of this genus can produce domoic acid, responsible for amniesic shellfish poisoning. This diatom was not identified to species however, so no conclusions can be drawn at this time. Although >35 micron phytoplankton were abundant on the bank and off the southern flank, they were very sparse at the Great South Channel.

### 3.3 Copepod Feeding

Ingestion of Phytoplankton, Nanozooplankton and Microzooplankton by *Calanus finmarchicus* (Dian Gifford and Mike Sieracki)

Our objectives on EN262 were (1) to measure ingestion rates of *Calanus finmarchicus* on phytoplankton, nanozooplankton and microzooplankton and (2) to characterize the potential prey field of *C. finmarchicus* and larval cod by determining the vertical distribution, numerical abundance and biomass of size fractionated chlorophyll a, nanozooplankton and microzooplankton.

We performed feeding experiments at two drifter stations. Station 1, located on the northeast peak of the bank, was occupied for 5 days, and Station 2, located on the bank crest, was occupied for 3 days. Ingestion rates by *C. finmarchicus* life history stages C2, C3, C4, C5, and adult

female were measured at Station 1. Ingestion rates of stages C4, C5 and adult female were measured at Station 2.

To characterize the copepod's potential prey field, we collected samples for size fractionated chlorophyll, nanozooplankton and microzooplankton from Go-flo bottles in conjunction with CTD casts at the two drifter stations. Preliminary examination of bulk seawater indicates that aloricate ciliates were abundant at both stations. Tintinnid ciliates were present, but rare. Large diatoms were abundant, and included *Coscinodiscus* and *Chaetoceros* species. The colonial forms, *Phaeocystis pouchetii* and *Chaetoceros socialis* were present but not abundant. In general, chlorophyll > 20 um contributed at least 60% of the total chlorophyll at both drifter stations, with chlorophyll 5-20 um at low levels and chlorophyll < 5 um accounting for the balance. Total chlorophyll levels at the crest station were approximately twice as high as those at the northeast peak station. All samples for phytoplankton, nanozooplankton and microzooplankton will be analyzed ashore by a combination of inverted microscopy and image-analyzed epifluorescence microscopy.

Ancillary activities included collection and preliminary isolation of *Chaetoceros* spp. for Carl Boyd of Dalhousie University. A University of Rhode Island graduate student, Erica Absher, accompanied our group to satisfy her cruise requirement for the Graduate School of Oceanography.

### 3.4 Copepod egg production:

Egg production of dominant copepods species on Georges Bank.
(S. Plourde & J.A. Runge)

Objectives:

(1) Measure egg production rates of dominant copepod species
(2) Establish a reproductive index of the *Calanus finmarchicus* females population
(3) Measure egg viability of *C. finmarchicus*
(4) Compare egg production, mortality and recruitment rates of dominant species on different location of the Bank

Methods

Egg production. See END259 cruise report.

Egg viability

Egg viability of *C. finmarchicus* was evaluated concurrently with egg production experiments. We measured egg viability with 2 different methods: hatching % and chemical staining of egg DNA with Trypan Blue.

Hatching method was performed as followed. During the first egg count, 50 eggs were gently pipetted in 4 20-ml scintillation vials filled with 1um filtered sea water (FSW)(10 eggs $f^{-1}$ $vial^{-1}$). Thus, each vial contained eggs of the same 5 different females. Eggs were incubated at 8 C in 12:12 light/dark cycle. After 3 days, unhatched eggs and nauplii were preserved in 4% buffered formalin for later enumeration.

Trypan Blue were used to develop a more quicker and easier method to measure egg viability. During each egg production experiments, egg counted were pooled in 2 large petri dishes filled with FSW and kept at experimental conditions until end of 24 h experiments. After last egg count, c.a. 50 eggs of each petri dish were gently transferred into 3 20-ml scintillation vials. We took care to pipette less water possible during these manipulation. Eggs were immersed in 1-ml of Trypan Blue during 2 min. After, eggs were rinsed in FSW and preserved in 4% buffered formalin. Dead eggs were dark colored as stainer is able to pass through dead cell membranes. Viable eggs were uncolored or slightly blue.

Results and Discussion

A total of 20 experiments were made, 8 with *C. finmarchicus*, and 6 with both *Pseudocalanus* spp. and *Centropages typicus*. Females of these 3 species were the most abundant during this cruise.

We observed no noticeable differences in egg production for *C. finmarchicus* between STA01,03 (Northeast Peak) and the station on Crest of the Bank, STA02. At both sites, females laid eggs at rates ranged c.a. 42-48 eggs $f^{-1}$ $d^{-1}$ and with a mean clutch size of c.a. 42-52. The spawning frequency was typically >0.80. At a station made along the Hydro Line (STA12) where egg production wasn't measured, the proportion of females population ready to produce eggs was lower, as evaluated by a quick examination of states of gonad development.

No results are already available for *Pseudocalanus* spp. and *C. typicus* as eggs and females have been preserved and will be counted later. Nevertheless, some observations were made during animals were sorted. Proportion of *Pseudocalanus* spp. bearing eggs sac was higher at STA02 and at revisited STA03 at the end of the cruise than at STA01. Also, females were most abundant at the Bank Crest (STA02). *C. typicus* females showed, in high proportion, mature gonads which suggest high egg production rates at all stations visited.

Eight egg viability experiments with *C. finmarchicus* were achieved during the cruise. Even though samples have to be analyzed, I was able to roughly evaluate the proportion of "bizarre" eggs (brownish color, deformed etc...). At all stations, less than 8% of eggs laid were considered to be non-viable. It is interesting to note that some individuals produced more than 50% of "bizarre" eggs. These assessments were made <8 h after eggs were released, which represented a small fraction of the time needed to hatch at *in situ* temperature.

### 3.5 Copepod vertical migration and micro-meso-scale distributions of plankton

Video Plankton Recorder Sampling of micro-mesoscale plankton distributions
(Cabell Davis, Scott Gallager, Phil Alatalo, Craig Lewis, Mark Benfield)

The goal of the VPR sampling during the process cruises is to measure the micro-finescale distributions of *Calanus* and *Pseudocalanus* together with other plankton and seston in relation to physical properties of the water column over similar scales. Comparative day/night sampling of these variables will provide insights into the vertical migration behavior of the plankton. These data will help us understand the physical and biological mechanisms controlling patch formation in plankton, and will provide insights into the role of vernal stratification in concentrating these organisms, which serve as food for larval fish (eg. cod and haddock).

The sampling design involved slowly towyoing the VPR in a 2 km square grid centered on the drifter. In this way, both the finescale vertical and horizontal distributions of plankton, seston, and hydrography in the vicinity of the drifter could be determined. The VPR (Davis et al, 1992a,b) was configured with two cameras set at two different magnifications and viewing concentric volumes. The high magnification camera had a field of view of 5.8w x 4.8h mm and the low magnification camera had a field of view of 37w x 27h mm. The video from the underwater unit was transmitted to the ship via fiber optic cable and was recorded on board the ship using broadcast quality SONY BETACAM SP Recorders and 90-minute tapes (Model 55). The video also was fed into and image processor and SUN workstation to extract in-focus subimages and store them to disk. The VPR also contained a MOCNESS sensor package which included SeaBird temperature and conductivity sensors, a pressure sensor, a SeaTech fluorometer and transmissometer, an angle indicator, and a flowmeter. These ancillary data were recorded to computer hard disk on shipboard 2 times per second.

In general, the cruise was highly successful in terms of VPR sampling. Fifteen good VPR tows were made (Figs. 3-16). However, on the way home, the ship's vibrations cause the workstation hard-disk to crash and we lost data from tows 2, 5 and 7. All other data had been backed up on the PC. In all, seven stations were sampled at the Northeast Peak drifter (station 1), four at the mixed area site (station 2), two additional ones upon returning to the NE Peak drifter, and a 22-

hour cross-bank towyo (Figs. 3-16). In the beginning of the cruise, we ran through a series of hurdles with equipment problems, but none of these were insurmountable, and did not deter us from our sampling objectives. After this initial bout of difficulty, the VPR worked perfectly and was quite robust, providing excellent *in situ* images of plankton and seston. Several hundred thousand images of plankton were obtained and will be analyzed in the laboratory.

*Calanus* and *Pseudocalanus* were observed to be the dominant copepods at all sites on the bank. *Calanus* occurred in surprisingly high concentrations in the well mixed area. We also observed higher concentrations of the chaetognath *Sagitta elegans* than we had ever seen before with the VPR. At the northeast peak drifter site, we also found hydroid polyps which are usually characteristic of the well mixed area.

At the well-mixed site, we found very high concentrations (up to 1/ml) of an unidentified tear-drop shaped organism (about 2-7 mm long) that appeared to be dividing. These organisms were not observed in the net tows. Microscopic examination of a carefully collected surface bucket sample confirmed their high concentration and revealed that they were cellular sacs which were brown in color but did not fluoresce. None of the scientists on board could identify them. These sacs were delicate and would be destroyed in passage through a Niskin or GOFLO stopcock valve.

Another interesting observation was a lens of shelf water overlying the Slope Water at the start of the cross-bank VPR transect. This shelf water contained extremely high concentrations of algal mats consisting of chain forming (rod-shaped) diatoms, which appeared to be *Thalassiosira* or perhaps *Rhizosolenia*. This bloom continued onto the southern flank bank. Fluorescence values were >3 volts in this bloom.

As usual, the most numerous category observed at all stations was marine snow. Direct observation of the ocean at these scales reveals that copepods and even the diatoms are a small fraction of the total particulate concentration. Since most of this particulate matter is delicate, our view of the planktonic environment as determined by net, pump, and bottle sampling is greatly biased towards the more robust organisms such as copepods and phytoplankton.

### 3.6 Larval cod feeding:

The Importance of Microzooplankton in the Diet of Newly Hatched Cod Larvae.
(Scott Gallager, Ione Hunt von Herbing, Linda Davis, Phil Alatalo)

Objectives:

1) To quantify differential grazing by cod larvae from newly hatched to 10 days post-hatch on natural assemblages of microzooplankton (protozoans) and net plankton (copepod nauplii) collected from the surface and the pycnocline, where present.
2) To determine growth and survival rates of larvae fed prey assemblages collected at different depths.
3) To characterize seasonal changes in the potential prey field for newly hatched cod larvae with respect to prey motility patterns and the prey size spectrum.

Hypotheses:

1) Newly hatched cod larvae will feed exclusively on small soft-bodied protozoans in preference to the larger copepods nauplii until the yolk-sac is fully absorbed and the mouth and gut has fully developed.
2) Ingestion of protozoans before yolk-sac absorption leads to greater survival through 10 days post-hatch,
3) The microzooplankton assemblage will be both quantitatively and qualitatively different between the surface and the pycnocline and thus will influence larval cod grazing and growth differentially.
4) Prey capture success by larval cod depends on prey size and prey motility patterns: prey with consistent swimming patterns will be captured more readily compared with prey which jump randomly.

Methods

Cod Embryos
To test these hypothesis, we conducted eight experiments at sea to determine grazing rates of cod larvae exposed to water collected non-destructively from various locations in the water column. Cod eggs were spawned and fertilized in the laboratory one to two weeks ahead of the cruise and incubated between 2 and 10°C. Embryonic development was timed so that larvae would be hatching throughout the 15 day cruise period. Cod eggs were obtained from our broodstock at WHOI and from the St. Andrew's Fisheries Laboratory c/o Dr. Ed Tripple. Eggs were held on ship board in plastic containers and cleaned every two days. Excellent survival was obtained by keeping egg densities below 0.5/L and transferring to clean water regularly..

Drifter Grazing Experiments:
Two meter-long spar buoys equipped with lights and radar reflectors were used as drifters during the grazing experiments. Fifteen two liter polycarbonate bottles were arranged into three plastic milk crates and hung below the spar buoy on a two meter-long bungie cord and 3/4 nylon line. Three replicate bottles were set-up for each of the four treatments given below.

1. Natural: <333 (fractions between 333 and 75 were separated and stained with Cell Tracker blue while the <75 um fraction was stained with acridine orange, small and large fractions were then combined);
2. Large: 75-333 fraction stained with Cell Tracker blue;
3. Small: <75 stained with acridine orange.
4. Natural + Enhanced: natural treatment plus 0.5/ml stained *Balanion* (yellow) and 0.05/ml stained nauplii (*Pseudodiaptomus* sp.)(blue).

After the ship was positioned near the GPS drogue, the incubator was deployed through the A-frame by lowering the milk crates into the water first followed by the spar buoy. Most incubations began about 1000 hrs and were retrieved by 1700 hrs. On a few occasions, rough seas, darkness, and the dinner hour delayed retrieval by a few hours. (The primary problem with delayed retrieval is loss of data due to digestion of gut content after about six hours of feeding.) The two radar reflectors and flashing light were clear only in calm seas. Additional reflectors and a strobe were mounted to ease tracking in rough weather.

Deployment Summary

| Date | Station | Deployment # | larval age (days post-hatch) | Time Deployed | Time Retrieved | Weather |
|---|---|---|---|---|---|---|
| 2/26 | 1 | 1 | 5-6 | 1100 | 1920 | sunny, low swell |
| 2/27 | 1 | 2 | 2-3 | 1045 | 1705 | cloudy, low swell |
| 2/28 | 1 | 3 | 3-4 | 1030 | 1651 | cloudy, foggy |
| 3/1 | 2 | 4 | 3-4 | 1030 | 1830 | rain, medium swell |
| 3/2 | 2 | 5 | 4-5 | 1150 | 1836 | cloudy, low swell |
| 3/3 | 2 | 6 | 5-6 | 1104 | 2211 | cloudy, 5 hr dark |
| 3/4 | 2 | 7 | 6-7 | 1020 | 1645 | calm, bright |
| 3/7 | 3 | 8 | 8-9 | 1012 | 1836 | cloudy, calm |
| | | | 4-5 | | | |

Following an incubation period of approximately six hours in the sea, the drifter was retrieved and the larvae removed from the bottles, mounted on slides and examined under epifluorescence microscopy using either blue or UV excitation for AO or Cell Tracker blue, respectively. Fluorescent images of larval guts were captured and stored digitally to allow quantification of gut fluorescence. Standard morphological measurements were also made on the stored image (length, height, yolk sac area, myotomal height, eye diameter, etc).

While the grazing experiments were underway, stained prey (both protozoans and nauplii) were held on the ship under conditions similar to those on the drifter incubator. These prey were used to calibrate the staining process and allow a specific-illuminance value to be assigned to

individual prey. To obtain number of prey ingested by the larval cod, the fluorescence intensity at a specific wavelength (integrated illuminance values 0-255 for each pixel above a certain threshold) in the larval guts is divided by the specific-illuminance for a given prey item.

Additional grazing experiments were conducted on shipboard to determine the effect of prey and predator (larval fish) density on grazing activity of the cod larvae. Three-day-old larvae were placed into the two L bottles at densities of 200, 100, 50, 25, 10 per bottle and allowed to graze for six hours on *Balanion* sp. (protozoan) at a concentration of $1.ml^{-1}$. Results show that greatest grazing was seen at a larval density of 50/bottle, but only small decreases even at the extreme density of 200/bottle. Visual observations indicated a feeding frenzy occurred at larval densities greater than 10/bottle (i.e., feeding was encouraged by the high density of larval cod).

Results of the grazing experiments on various size fractions showed that newly hatched cod larvae feed directly on natural assemblages of microzooplankton, and particularly on protozoans. No copepod nauplii were ingested before day six following hatching. Feeding rates on *Balanion* sp. were comparable to the highest levels observed in laboratory experiments, but feeding rates on nauplii were lower than expected even in the enhanced treatments.

Prey Motility Experiments:

Purpose:
To observe, record and analyze motility patterns and size spectrum of available prey from two to three locations in the water column- near bottom, pycnocline, and upper well-mixed area. This was particularly important at the times when water samples were taken for the larval grazing experiments.

Procedure:
Water samples were collected from the near bottom, 20 m and 1 m below the surface with Go-Flo bottles. Samples were also collected from the surface with a bucket over the side. Go-Flo samples were either collected from the port as usual, or to the test the idea that microplankton are disrupted by this procedure, by siphoning from the bottle through the air port. 200 ml tissue culture flasks were filled with the sample and placed into an incubator at 5°C.

A B/W high-res Pulnix camera was fitted with a 50 mm macro lens and mounted on a frame across from a fiber optic ring illuminator fitted with a far-red filter. The entire apparatus was suspended within an incubator by bungie cord to reduce vibration produced by the ship. Recordings were made on SVHS medium for a period of 15-30 min for each sample. The flask was then replaced with the next sample and recordings continued. The field of view was set to 8 mm (scale bar at the beginning of each tape). Concurrently with the video recordings, the signal was sent to an image processor which processed images at about 1/sec for particle concentration,

size, area, circularity, and a number of other morphological descriptors. A minimum of 200 data points were collected from each sample type.

Post cruise processing: Upon returning to WH, motility patterns will be analyzed with the Motion Analysis EV system. The final output will be particle size distribution and a motility spectra associated with each particle. This will be compared with species composition in the microzooplankton fraction preserved in Lugols.

Summary of microzooplankton motility observations using video.

| Tape Number | Date | Station | Depth | Collection method | Time | Tape Counter | Comments |
|---|---|---|---|---|---|---|---|
| Tape 1 | 2/26/95 | Sta 1 | surface | bucket | 0748 | 074856-080400 | |
| | | | 20 m | Go-Flo siphon | 0816 | 081600-081630<br>081630-scale bar | |
| | | | surface | Go-Flo siphon | 0837 | 0837-090455 | |
| | 2/27/95 | Sta 1 | surface | unscreened bucket | 0854 | 085445-091135 | lots of bugs |
| | | | surface | screened bucket | 0915 | 091500-093001 | perhaps fewer bugs |
| | 2/28/95 | Sta 1 | 62m bottom | Go-Flo | 0815 | 092527-095600 | lots of bal types |
| | | | 20 m | Go-Flo | 0815 | 095610-102800 | nauplii, larv, bugs |
| | | | 0 m | Go-Flo | 0815 | 103525-105230 | |
| | | | surface | unscreened bucket | 0830 | 105650-111513 | |
| | | | surface | screened bucket | 0830 | 192150-193635 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3/1/95 | Sta 2 | surface | unscreened bucket | 0900 | 092850-094700 | |
| | | | surface | screened bucket | 0900 | 095000-101000 | |
| | 3/2/95 | Sta 2 | surface | unscreened bucket | 1050 | 105100-111030 | |
| | | | surface | screened bucket | no sample | | |
| | | | live plankton tow with Clione | | | 1425- | |
| Tape 1 | 3/3/95 | Sta 2 | surface | unscreened bucket | 0930 | 094500-100646 | |
| | | | surface | screened bucket | 0930 | 100919-103500 | |
| | | | 40 m | Go-Flo | 0930 | 110915-113356 | |
| | | | 20 m | Go-Flo | 0930 | 113630-115342 | |
| | | | 2 m | Go-Flo | 0930 | 115615-121800 | |
| | 3/4/95 | Sta 2 | surface | screened bucket | 0900 | 094500-100030 | |
| | | | 0 m | Go-Flo | 0900 | 100240-102130 | |
| | | | 60 m | Go-Flo | 0900 | 103235-103734 | end tape |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tape 2 | | | | | 104211-105608 | |
| | | 20 m | Go-Flo | 0900 | 105800-111315 | |
| | | surface | screened bucket | 0900 | 111500-113320 | |
| Tape 2 3/7/95 | Sta 2 | surface | unscreened bucket | 0900 | 092118-093618 | |
| | | | scale bar | | 092345 | |
| | | surface | screened bucket | 0900 | 093818-095318 | |
| | | 45 m | Go-Flo | 1200 | 120700-123200 | |
| | | 20 m | Go-Flo | 1200 | 123800-125600 | |
| | | 0-2 m | Go-Flo | 1200 | no time code gen..tape 2 ran out | |
| Tape 3 | | | | | record for ca. 15 min | |
| Tape 3 3/8/95 | Sta 3 | 261 m bottom | Go-Flo | 1830 | 184930-190230 | small stuff |
| | | 40 m | Go-Flo | 1830 | 191900-193940 | little |
| | | 20 m | Go-Flo | 1830 | 194150-200513 | small flagellates |

| | | | | |
|---|---|---|---|---|
| 3/10/95 | Sta 38 surface<br>Great South Channel | unscreened bucket | 0900 | 091000-093200 |

Concluding Remarks:

This was a particularly exciting Process cruise since the Broadscale cruise immediately before ours had found high levels of cod and haddock eggs on the Northeast Peak. Our grazing experiments using in situ incubations showed that newly hatched cod larvae at this time of the year should be feeding extensively on microzooplankton through yolk-sac absorption. Larvae apparently do not feed on larger crustacean prey such as copepod nauplii until day six post-hatch after the yolk-sac has been absorbed. At this time of the year, the water column in the well mixed area has high levels of protozoans with motility patterns consistent with those which are captured easily by larval cod in the laboratory. Results of our incubations of cod larvae will be compared with light profiles recorded by Dr. Jeff Van Keurin. On the following Process cruise, we will test the hypothesis that early larvae feed on microzooplankton most extensively at relatively high light levels (i.e., at the surface) while older larvae are able to feed on larger prey at more limited light levels at depth. Laboratory experiments conducted next week at WHOI using a range of light levels will allow us to establish incubation depths for the next series of tests on the next cruise.

EN262 was a great success for our project which was largely due to the helpfulness of the crew, particularly the Bos'n (Jack) and Captain Tyler. We also greatly appreciate the help we received from the engineers during repair work to the cod incubator system. Down-time was negligible due to weather or other delays; we greatly exceeded our expectations for this cruise.

## 3.7 Light measurements:

Characterization of ultra-violet and visible light regimes on Georges Bank
(Jeff Van Keuren)

My primary objective for this cruise was to collect further irradiance data (ultra-violet, visible) to help characterize how the in situ light field evolves on and around Georges Bank during the winter and spring as populations of fish larvae and copepods develop. During this 16-day cruise, light profiles of four narrow band UV channels (308nm, 320nm, 340nm, 380nm) as well as broad-band PAR (400-700nm) were taken at the three time-series stations visited (Stations 1-3) as well as at other locations of opportunity across the bank. Surface irradiance values for each of these five wavebands were also continuously logged throughout the cruise using masthead-mounted deck sensors. These daytime surface irradiance measurements were complimented by broad-band twilight/nocturnal light records generated by a logging PMT-based system as well as observations of existing cloud conditions.

Preliminary analysis of the attenuation coefficients ($K_d$) for downwelling irradiance (PAR) from these data has revealed similar geographic trends in $K_d$ across the bank as were observed during Process Cruise 1., with highest loss rates occurring in the vicinity of the bank crest. These profile and continuous surface data will ultimately be combined to generate time series fields of subsurface light. These data will also be used to define the UV and visible light levels that were present during short term in situ larval fish feeding incubations that were conducted by Dr Scott Gallager during this cruise. The PAR profiles taken at the GLOBEC mooring sites will also be used for intercalibration with sensors affixed to the moorings. The simultaneous meteorological observations will be used with the light data to help interpret how climatic variability in cloud cover would affect in situ light conditions. The UV component of this work is being done in conjunction with Dr Al Hanson, GSO, URI.

## Appendix I. Personnel List

### Scientific

| Name | Title | Organization |
|---|---|---|
| 1. Cabell Davis | Chief Scientist | WHOI, Woods Hole, MA |
| 2. Scott Gallager | Scientist | WHOI, Woods Hole, MA |
| 3. Dian Gifford | Scientist | URI, Narragansett, RI. |
| 4. Bob Campbell | Postdoc | URI, Narragansett, RI. |
| 5. Mark Benfield | Postdoc | WHOI, Woods Hole, MA |
| 6. Ione Hunt-vonHerbing | Postdoc | WHOI, Woods Hole, MA |
| 7. Jeff VanKeuren | Postdoc | URI, Narragansett, RI. |
| 8. Ed Dever | Grad. Student//Hydrographer | WHOI, Woods Hole, MA |
| 9. Phil Alatalo | Research Associate | WHOI, Woods Hole, MA |
| 10. Linda Davis | Senior Research Assistant | WHOI, Woods Hole, MA |
| 11. Dave Avery | Graduate Student | URI, Narragansett, RI. |
| 12. Craig Lewis | Graduate Student | WHOI, Woods Hole, MA |
| 13. Stephan Plourde | Research Associate | UQAR, Rimouski, Canada |
| 14. Jeff Brown | Research Associate | Bigelow Lab for Ocean Science |
| 15. Erica Absher | Graduate Student | URI, Narragansett, RI |
| 16. Greg Teegarden | Graduate Student | URI, Narragansett, RI |
| 17. Jan Zelag | Marine Technician | URI, Narragansett, RI. |

### ENDEAVOR Officers and Crew

| | |
|---|---|
| 18. Captain Thomas Tyler | Master |
| 19. Everett McMun | First Mate |
| 20. Stephen S. Vetra | Second Mate |
| 21. Jack E. Buss | Boat-Swain |
| 22. Richard P. Foley | Able-Seaman |
| 23. Glen D. Prouty | Able-Seaman |
| 24. Dave Rocha | Able-Seaman |
| 25. William A. Appleton | Chief Engineer |
| 26. Timothy Varney | Assistant Engineer |
| 27. Eric A. Frazier | Assistant Engineer |
| 28. Alexandre Bird | Steward/Cook -- Helicoptered off ship during 1st day |
| Daniel Butler | Steward/Cook -- Replacement for Bird |
| 29. Brian D. Miller | Cook/Messman |

## Appendix II. Cruise Activity Schedule

**Thursday 2/23/1995**

0950 Leave Narragansett - Steam to Northeast Peak station (18 h steam)

**Friday 2/24/1995**

0330 Near station, Cook sick (appendicitis) - Steam towards Woods Hole
0700 Transfer cook to Coast Guard rescue helicopter
Steam to Woods Hole for new cook

**Saturday 2/25/1995**

0630 Arrive Woods Hole
New cook aboard
1200 Leave Woods Hole, Steam to Northeast Peak station

**Sunday 2/26/1995**

0600 Arrive station
0700 Deploy drifter
0800 CTD
MOCNESS
Pump
CTD
1130 Deploy Gallager et al cod-incubator drifter
CTD
Net tows for live animals
1430 Relocate drifter
VPR tow
Retrieve GPS drifter
2000 Deploy replacement GPS drifter
2030 CTD
2230 VPR

**Monday 2/27/1995**

0120 End VPR tow
0800 MOCNESS
Pump

CTD
Deploy Gallager et al. drifter
1100 CTD
Live tows
Optics cast
1420 VPR tow

**Tuesday 2/28/1995**

0100 Attach third GPS drifter to non-functioning one in water
0730 Test CTD
0830 MOCNESS
Pump
CTD full/hydro - water collection for experiments
Deploy Gallager et al drifters
Net tows for experiments
Optics cast
1100 Start VPR Tow
1700 End VPR Tow
Retrieve Gallager et al drifters
2000 MOCNESS
Pump
Start VPR Tow

**Wednesday 3/1/1995**

0300 End VPR Tow

0800 MOCNESS
Deploy Gallager et al drifters
CTD full/hydro - water collection for experiments
Net tows for experiments
Optics cast
Start VPR Tow
1700 End VPR Tow
Retrieve Gallager et al drifters
2000 MOCNESS
Pump
CTD/Hydro
2300 Start VPR Tow

**Thursday 3/2/1995**

0500 End VPR Tow
0800 MOCNESS
Pump
CTD full/hydro - water collection for experiments
Deploy Gallager et al drifters
Net tows for experiments
Optics cast
1100 Start VPR Tow
1700 End VPR Tow
Retrieve Gallager et al drifters
2000 MOCNESS
Pump
CTD/Hydro
2200 Start VPR Tow

**Friday 3/3/1995**

0200 End VPR Tow
Remove old GPS drifter from drouged array

**Steam to Well-Mixed Site at Crest Mooring**

0800 MOCNESS
Pump
CTD full/hydro - water collection for experiments
Deploy Gallager et al drifters
Net tows for experiments
Optics cast
VPR/CTD/MOCNESS intercalibration
Retrieve Gallager et al drifters
2245 Pump/CTD
2330 Start VPR Tow

**Saturday 3/4/1995**

0500 End VPR Tow
0800 MOCNESS
Pump

CTD full/hydro - water collection for experiments
Deploy Gallager et al drifters
Net tows for experiments
Optics cast

1100 Start VPR Tow

1700 End VPR Tow
Retrieve Gallager et al drifters

2000 MOCNESS
Pump
CTD/Hydro

2300 Start VPR Tow

**Sunday 3/5/1995**

0500 End VPR Tow

0800 MOCNESS
Pump
CTD full/hydro - water collection for experiments
Net tows for experiments
Optics cast

1100 **Steam to start of Beardsley hydro transect**

1300 Start hydro transect -
Stop at Stratification array 2 (St 2)
to yoyo CTD for 1 h, MOCNESS, pump, live tow.

**Monday 3/6/1995**

0200 12th CTD on transect
MOCNESS
live tow

0440 Last station on hydro transect (13th CTD), Slope Water

**Steam to start of X-Bank VPR transect**

1130 Light cast at start of X-bank VPR transect

1400 Start 1st-half of X-bank VPR transect

**Tuesday 3/7/1995**

0400 End 1st-half of X-bank VPR transect

**Steam to latest position of Station #1 GPS drifter**

0430-0700 Locate drifter

0830 MOCNESS
Pump
CTD full/hydro - water collection for experiments
Deploy Gallager et al drifter
Net tows for experiments
Retrieve malfunctioning GPS drifter and drogue
Optics cast
CTD
1300 Start VPR Tow
1800 End VPR Tow
Retrieve Gallager et al drifter
Re-launch Gallager drifter for nighttime VPR tow
2000 MOCNESS
Pump
CTD/Hydro
2130 Start VPR tow

**Wednesday 3/8/1995**

0200 End VPR Tow
Retrieve GPS drifter

0500 **Steam to start of 2nd half of VPR X-Bank transect**

0600 Start 2nd-half of X-Bank VPR transect
1600 End X-bank VPR transect
Light cast
live tows
pump
CTD
MOCNESS

2200 **Steam to Great South Channel Station at $41^0$ 29.4' N $68^0$ 59.0' W**
(Broadscale station #38)

**Thursday 3/9/1995**

0800 Arrive Great South Channel Station
Live tows for *Calanus*
Steam for Narragansett

**Friday 3/10/1995**

0830 Arrive Narragansett

## Appendix III. Cruise Event Log

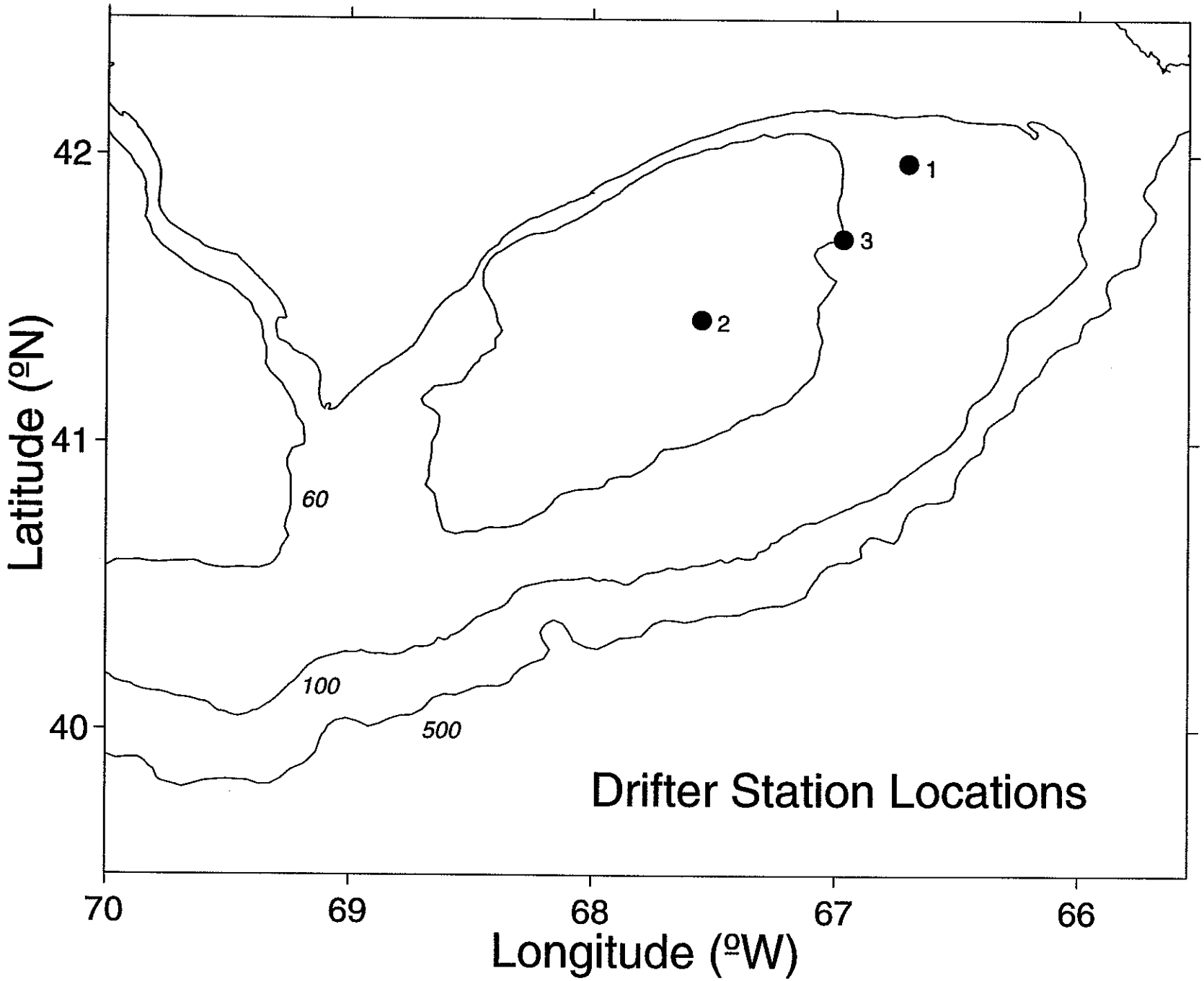
42
41
40
Latitude (ºN)
70
69
68
67
66
Longitude (ºW)
1
2
3
60
100
500
Drifter Station Locations

Figure 1

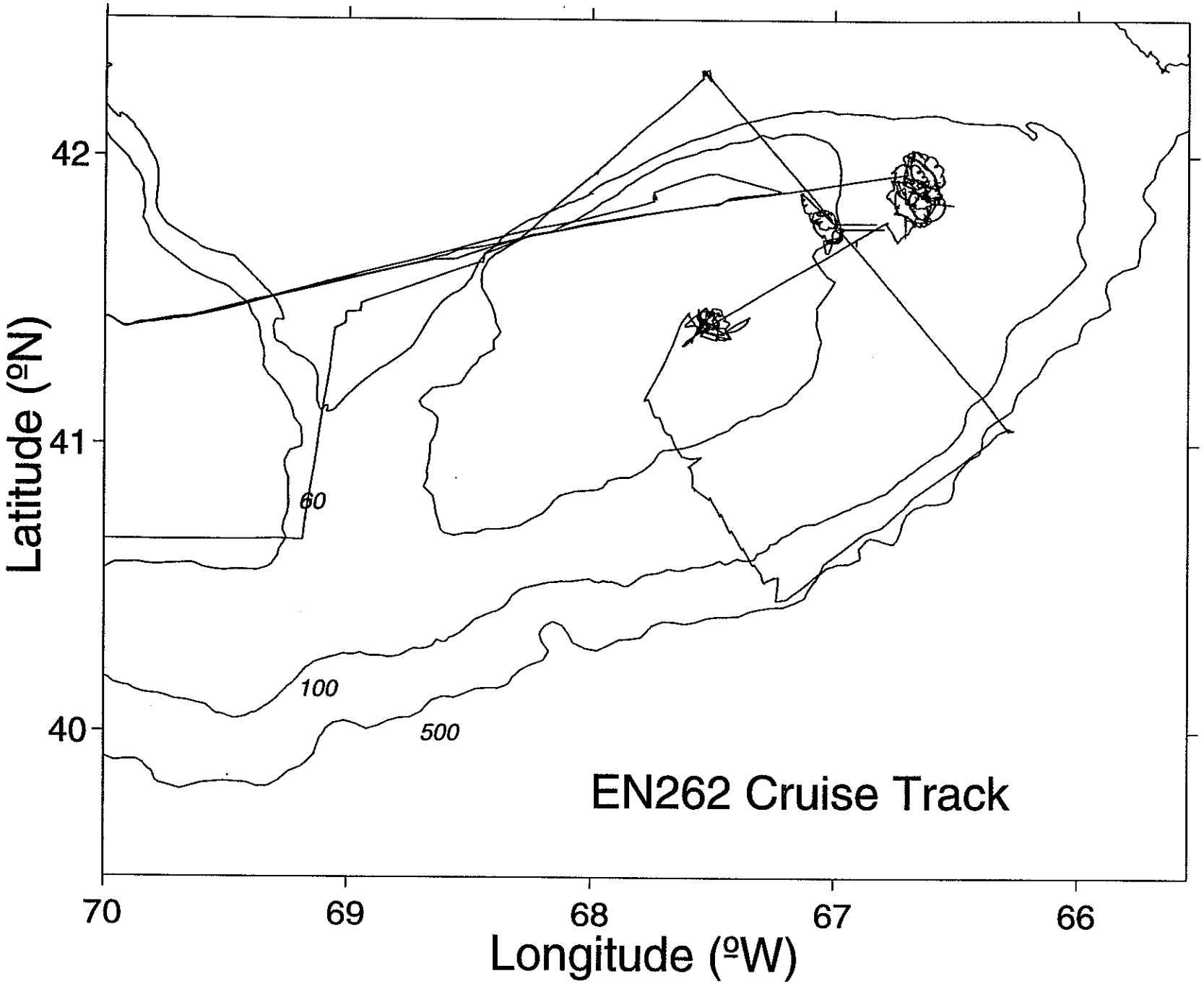
42
41
40
Latitude (ºN)
60
100
500
EN262 Cruise Track
70
69
68
67
66
Longitude (ºW)

Figure 2

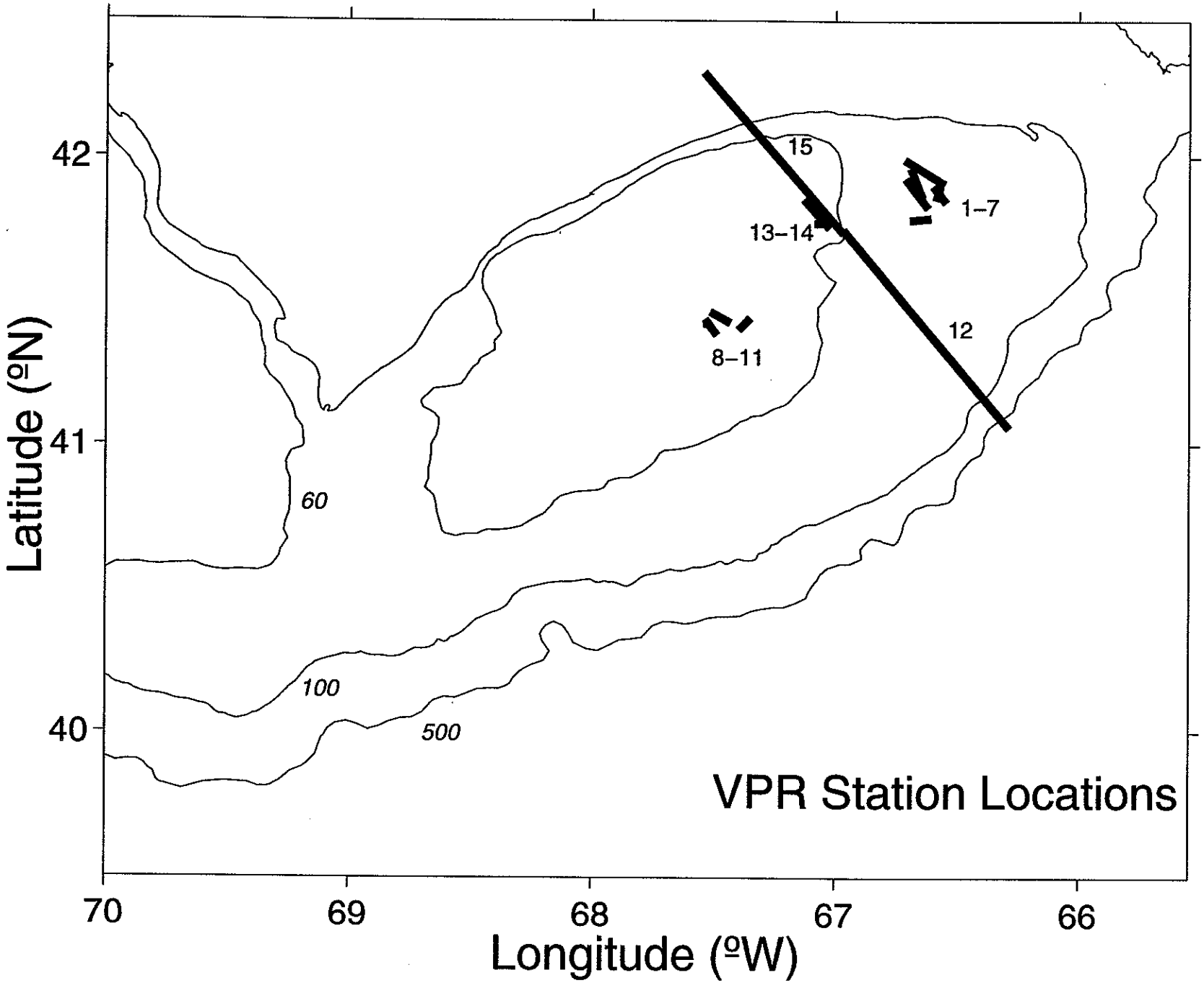
42
41
40
Latitude (ºN)
70
69
68
67
66
Longitude (ºW)
15
1–7
13–14
12
8–11
60
100
500
VPR Station Locations

Figure 3

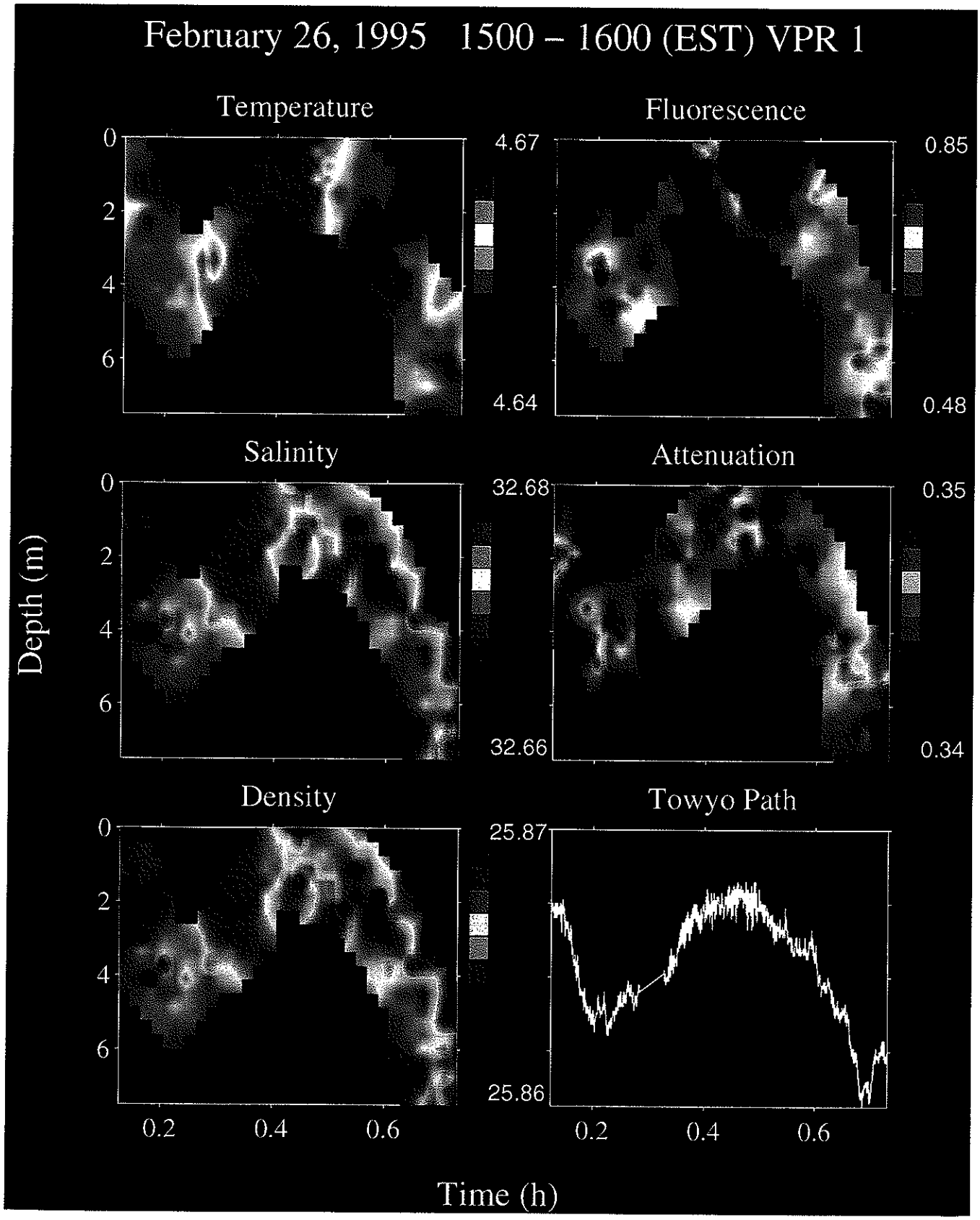
February 26, 1995 1500 – 1600 (EST) VPR 1
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
Time (h)
0
2
4
6
4.67
4.64
0.85
0.48
32.68
32.66
0.35
0.34
25.87
25.86
0.2
0.4
0.6

Figure 4

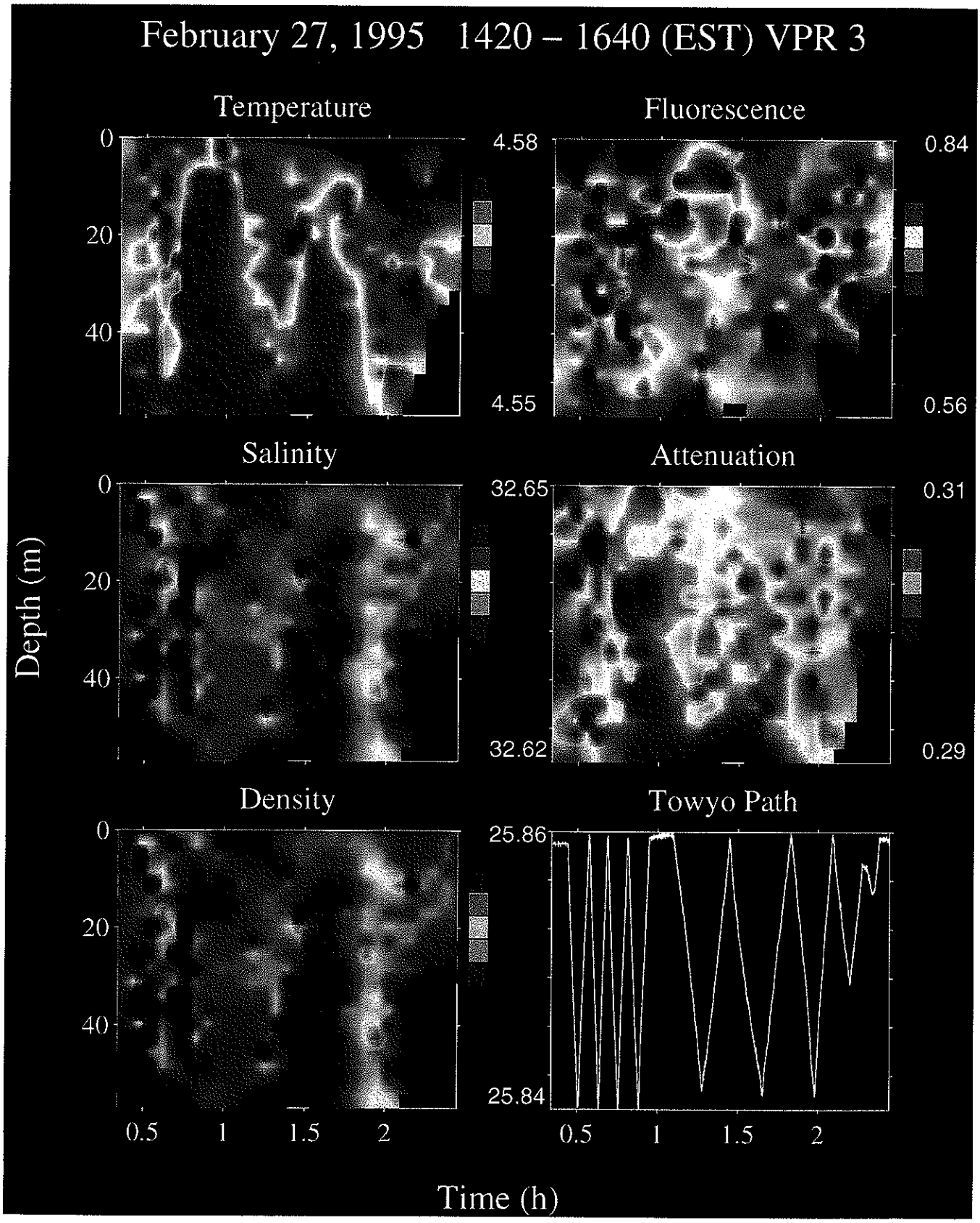
February 27, 1995 1420 – 1640 (EST) VPR 3
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
0
20
40
4.58
4.55
0.84
0.56
32.65
32.62
0.31
0.29
25.86
25.84
0.5
1
1.5
2
Time (h)

Figure 5

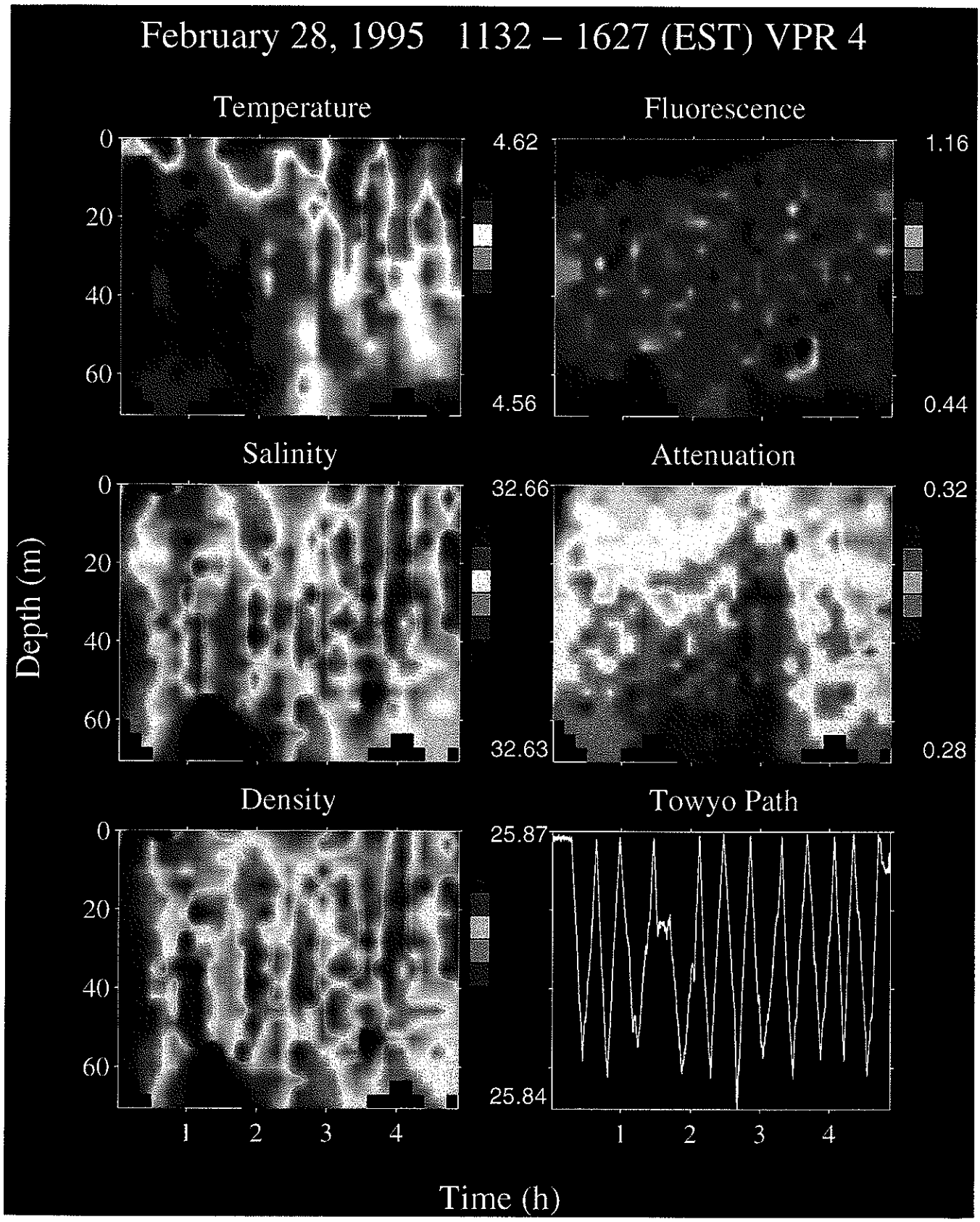
February 28, 1995 1132 – 1627 (EST) VPR 4
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
0
20
40
60
4.62
4.56
1.16
0.44
32.66
32.63
0.32
0.28
25.87
25.84
1
2
3
4
Time (h)

Figure 6

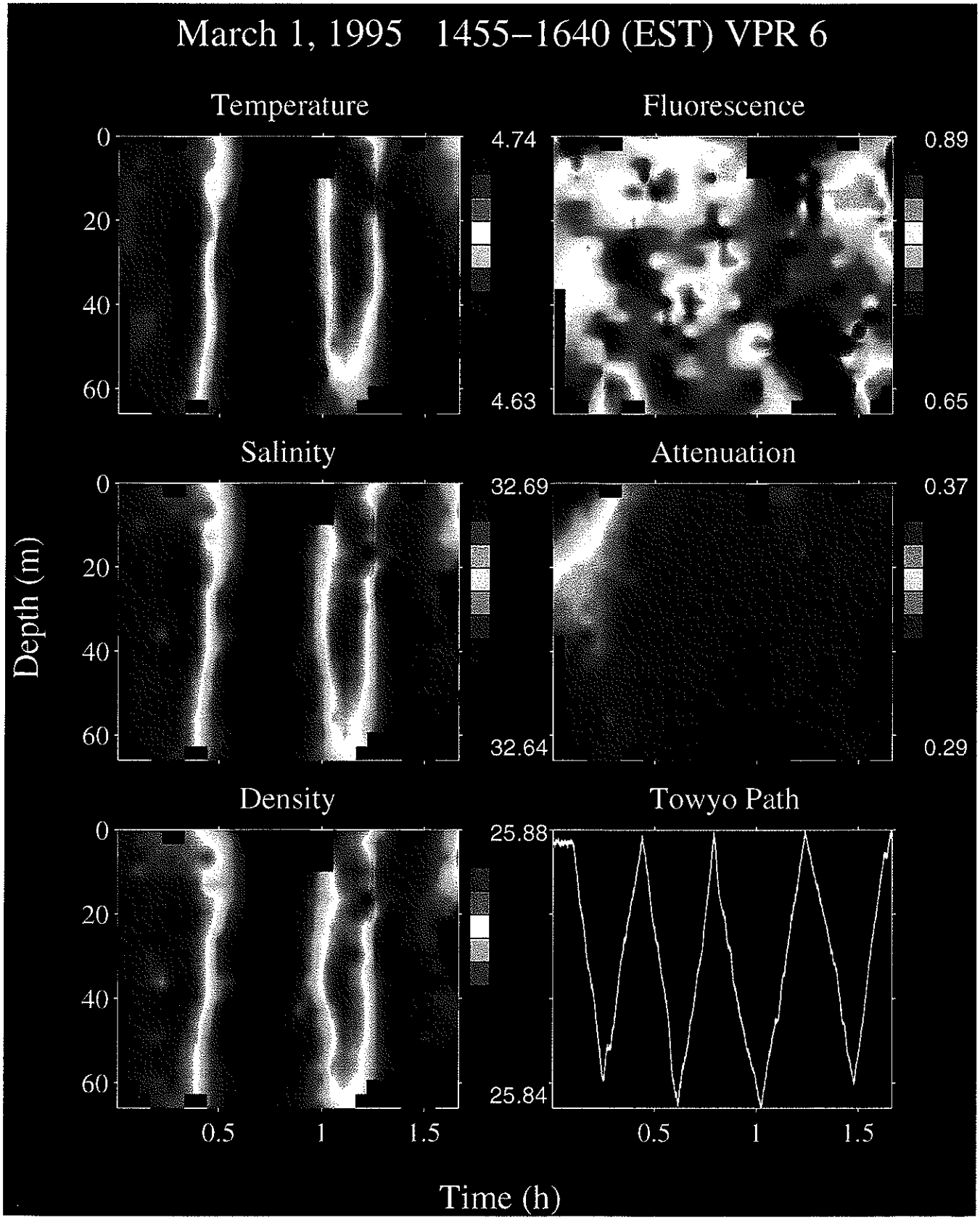
March 1, 1995 1455–1640 (EST) VPR 6
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
0
20
40
60
4.74
4.63
0.89
0.65
32.69
32.64
0.37
0.29
25.88
25.84
0.5
1
1.5
Time (h)

Figure 7

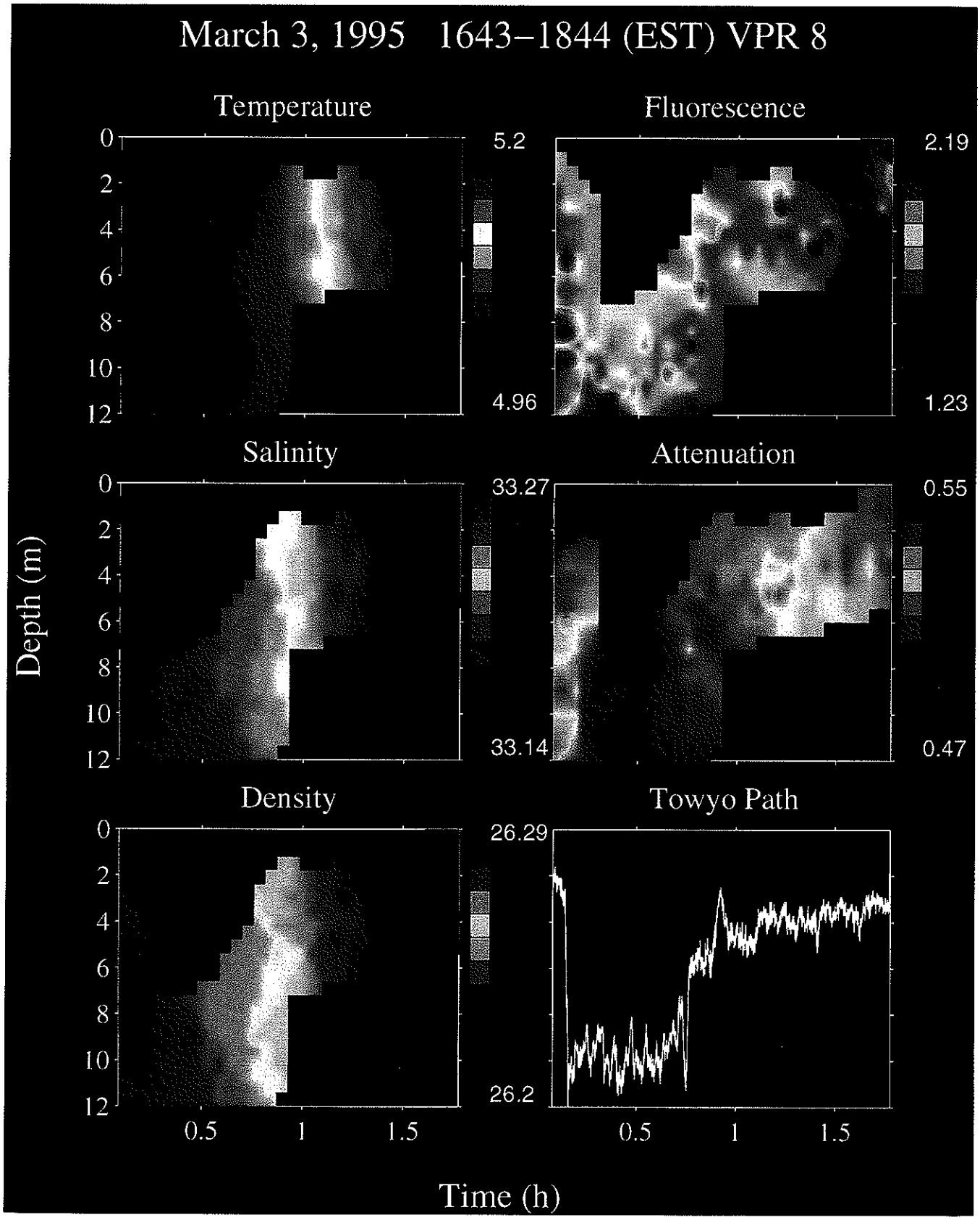
March 3, 1995 1643–1844 (EST) VPR 8
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
Time (h)
0
2
4
6
8
10
12
0.5
1
1.5
5.2
4.96
2.19
1.23
33.27
33.14
0.55
0.47
26.29
26.2

Figure 8