

## Draft Cruise Report

### R/V Endeavor Cruise 264 to Georges Bank

26 March - April 8 1995

#### Acknowledgements

This report was prepared by Chief Scientist Scott Gallagher with help and input from all Principal Investigators and their assistants listed in Appendix I. The contributions of Paul Robbins, Dian Gifford, Ted Durbin, Carin Ashjian, Jeff Van Keuren, Tom Orvosh and Jan Zelag are greatly appreciated.

We are grateful for the strong support from the Captain and Crew of the R/V Endeavor. In the face of both calm and stormy seas, we could count on their professional approach to solving our unique problems allowing this cruise to achieve nearly all its scientific objectives.

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#### Purpose of Cruise

The major objective of the U.S. Georges Bank GLOBEC program is to understand how physical processes interact with population dynamics in controlling abundance and distribution of key plankton species: larval cod, haddock, and two copepod species *Calanus* and *Pseudocalanus*. The field program involves both process cruises to experimentally examine the coupling between vital rates, the prey field, and physics, and broad-scale cruises to map the distribution of physical and biological properties of the bank. The field program is in its first major sampling year and is focussing on how the development of thermal stratification affects the vertical distribution and vital rates of the target species. The process cruises were further subdivided into those focussing on vital rates of larval cod and those focussing on *Calanus* and *Pseudocalanus*.

The present cruise (EN264) was the third in a series of five process cruises spaced roughly at monthly intervals. Our purpose was to determine the vital rates and vertical migration patterns of target species in relation to local circulation and hydrography. We also conducted studies on the development of newly hatched larval cod feeding on protozoans and copepod nauplii from the natural

prey field. The vital rate and behavioral information provided by our process cruises, together with the larger-scale context of population distribution provided by the broad-scale studies, will be incorporated into models of biological-physical processes controlling population dynamics of the target species. The objectives of the process studies are:

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 patch on the Northeast Peak and in the well-mixed area of the bank.
2. To measure the fine-scale (cm-m) vertical and horizontal distributions of the target species in relation to hydrography and other planktonic and particulate matter.
3. To map the local velocity fields using 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* and *Limacina retroversa* for laboratory studies.
6. To measure the ultraviolet and visible light fields in the study area.

The process studies generally consists of two components: 1) measurement of vital rates while station-keeping around a drogued drifter, and 2) transect studies of the vertical distribution of key species in relation to the hydrography. The ship's ADCP was used to estimate local velocity fields along each transect and at each drifter site, and to provide data on shear for calculating gradient Richardson numbers. Both transect and drifter studies also utilized the onboard salinity and fluorometry data that was recorded continuously. This was particularly important during the mapping of the Scotian Shelf Water intrusion noted below. As in the two previous process cruises, two sites were chosen for station-keeping activities. Station #1 was on the Northeast Peak of the bank near broad-scale station 20, and Station #2 was in the well-mixed area near broad-scale station 12 (see rationale below). Station #3 was the re-visit of the ARGOS drifter deployed at station #1 on the second day of the cruise. Prioritization of the activities were as follows: station #1 (where eggs and larvae were observed), station #2, the hydrographic transect, station #3, the VPR X-Bank transect, the Georges Basin station, and the Great South Channel Station. A detailed schedule of events (Appendix II) was established to allow scientists and technicians a chance to plan sampling, experiments, and rest. In general, the schedule was followed closely with only an hour or so departure from the planned activities. In the face of an on-coming storm with projected 40-55 kt winds, however, a major departure from the schedule was taken on day 8 when we curtailed operations at station #3 after the second day of operations at that location and steamed to the end of the VPR X-Bank Transect. There we completed the end of the transect across the northern front and conducted a CTD and live tow at the Georges Basin Station. The seas were too great to complete a MOCNESS tow at that time. If we had not curtailed operations at station #3, these important activities at Georges Basin could not have been accomplished.

## Cruise Narrative

**Background** We approached this cruise with information from two AVHRR SST images produced by James Bisagni at NOAA. SST on 20 March showed bank-wide temperatures of 7 to 8°C (Fig. 1). A cold tongue of Scotian Shelf water intruded over the Northeast Peak while two Gulf Stream rings, one to the north and another to the south, encroached on the 100 m isobath. Between the two rings, relatively cold bank water could be seen jetting to the SSE, perhaps providing an outlet for water from the Southern Flank. The SST image from 23 March showed similar features (not shown). Previous cruises showed little stratification on the Northern Flank so we were not expecting extensive vertical hydrographic structure. We obtained a coarse map of the distribution of Gadoid eggs and early larvae from Greg Lough immediately prior to sailing. His data suggested relatively high concentrations on the Northeast Peak near Broadscale Station 20. Further information from John Sibunka via Charlie Miller (Chief Scientist EN263) suggested the presence of older larvae in the vicinity of the Crest Mooring (Broadscale Station 12). For these reasons we decided to establish Broadscale Stations 20 and 12 as our two areas for station-keeping during the Process Cruise EN264.

## Loading and Steaming

**Day 1 (Sunday 3/26/95)** The R/V Endeavor was loaded with the remaining science and ship gear in the afternoon. The tow cable on winch three (VPR cable) was reterminated with three new fiberoptic connections and three conductors after removing 100 m of damaged cable from the spool. On EN262, the steel armor had begun to untwist and catch in the traction winch and sheave. Furthermore, EN263 had experienced intermittent data loss from the MOC10 environmental sensors due to an unlocated short in the cable.

**2 (Monday 3/27)** We left the dock at 1010 under sunny skies and moderate temperatures. We spent three hours calibrating the ship's gyro compass in Narragansett Bay and then dropped off the technician via launch and headed to sea at 1220 at 14.5 kts with a tail wind. A science meeting was held in the main lab at 1230. Both Ted and Dian suggested they would rather spend an extra day at station #3 (the repeat visit of the drifter) than to spend three days at station #1. A new schedule was made to reflect these changes and posted. Fire drill at 0100. A set of Chinese fingers was affixed to the fiber optic tow cable and pull tested to 4200 lbs. The cable was relaxed and reset to 4500 lbs for 10 min. Minor stretching was noticed but no slippage. The ship slowed to 10 kts as we approached GSC due to heavy seas.

## Station 1: Northeast Peak Site

**Day 3 (Tuesday 3/28)** Arrived at Broadscale Station 20 at 0845 in 4-6' seas and 25-35kt NW winds. The guard buoy system for

Peter Smith's current meter array was seen near Station 20.

Morning activities began with deployment of the ARGOS/GPS drifter off the starboard side at 0900. The transmitter was attached to small float via 20' garden hose-encased line then to a large orange holey sock 1 m in diameter. Ted Durbin did not want a high-flyer used on this deployment because of potential damage to the drifter and increased windage. Initially, GPS positions from the drifter were logged on an old 286 laptop computer on the bridge next to the GONIO receiver box, but later these data were logged on a 486 laptop using Windows in the 01 VPR lab. This allowed for rapid location and plotting of drifter locations by running a decoding program in Matlab which had been written by Craig Lewis during EN262. Bearing data was obtained at intervals of 5 min and new GPS fixes every 15 min.

By 0900, the sun was beginning to break through and the wind was falling off. A full CTD and hydrosampling for salts and microzooplankton was initiated. At 1035 the cod incubator (see Gallagher's Individual Report) and spar buoy with strobe light and 4 radar reflectors was deployed. We noticed that the holey sock on the GPS drifter was not sinking because of the blue floats in its mouth opening. We hooked the sock with a boat hook and cut off the floats as the ship backed away. We then pumped for small zooplankton (~45 min) and started the net tow for live zooplankton experiments. By 1300 the net tows (x3) were finished and we waited for the seas to calm before launching the VPR. During this time we searched for the ARGOS drifter. We were unsuccessful even though the GONIO receiver appeared to show good bearings.

At 1430 the spar buoy was sighted, but not the ARGOS drifter. The signal strength was strong but the buoy was not visible because of the small area exposed above the water line. By 1600 the wind was down to 15 kts and seas were 2-4'. The inclinometer on the bridge was showing 15 deg rolls so Bos'n Jack Buss said to hold off on the VPR until that night. The spar buoy with cod incubations was retrieved at 1630 and refitted with a blue holey sock, extra reflectors and a transponder (SART).

Night-time activities began at 1800 with a CTD and full hydrosampling for salts and microzooplankton. A MOCNESS and live tow were then conducted. The spar buoy (with holey sock attached and SART turned off) was deployed as a focal point for the VPR grid pattern. The VPR was deployed at 2030 and the ship initiated a circular course around the spar buoy. The strobe was seen clearly, but the buoy showed only intermittently on radar. At 2100 power to the VPR was lost. A dead short problem was suspected again in the tow cable as had occurred during EN262. The VPR was brought on board and the short was traced to the winch drum. Both the red (power) and black (signal) conductors had been wearing on the inner drum core as the winch rotated to the point where the conductors were exposed causing a short to ground. This was undoubtedly the source of the intermittent signal problem noted by operators of the MOC10 on EN263. The termination was replaced and covered with thick tygon tubing. Both the red and yellow optical fibers are operational now from the J- box to the winch. At 1230 the VPR was re-launched only to find that the pressure reading from the MOCNESS can was stuck at -3.2 dbars regardless of depth. Since the winds had picked up to 25 kts, we would not have been able to re-launch if we brought the VPR in for repair. Therefore we decided to leave the VPR in the water and do circles around the spar buoy at three constant depths: 0, 5, 20 m.

**Day 4 Wednesday 3/29/95** The VPR was retrieved at 0300. By 0800 the seas were 6-10' with some chop but low swell; skies were sunny with 15-25 kt NNW winds. The spar buoy and holey sock from the previous night's VPR transect was retrieved followed by a CTD with full hydrosampling. An attempt at a MOCNESS tow was initiated but the tow cable popped out of the shiv on the winch level wind. Jack began looking into the problem but the tow was not done. A pump sample to 70 m was taken followed by deployment of the cod incubators, spar buoy, reflectors, and strobe (with SART turned on). We did not attach a holey sock since this might have interfered with the bungee cord and the string of incubation chambers which hung below to 20 m. Live net tows were completed at 1045 for copepod molting rate experiments.

The VPR MOCNESS sensor electronics had been repaired and were ready to go. The VPR was deployed at 1503 in 10-15' seas with strong pitch but little roll. The water appeared vertically well mixed with many diatom chains, but few copepods or other zooplankton. During retrieval of the VPR at 2015 a leaking cable connector caused another power failure. This was later repaired. By 2200 seas were calm with no wind. A CTD, MOCNESS, pump, and net tows were completed. The 333 net on MOCNESS blew out due to clogging by *Phaeocystis*. Because of this, it was decided henceforth not to put the cod end on net 1 (open from surface to surface).

The spar buoy (with reflectors and two strobe lights) was deployed at 2250 for the VPR grid. The SART was not turned on as per the Captain's request since it would be difficult to complete the VPR grid via radar. The VPR was deployed at 2305 and a 1 nm grid at 0.1 nm intervals was started. There was no problem seeing the buoy on radar on this calm night. The VPR grid was finished at 0230 whereupon the spar buoy was retrieved. We then left the first ARGOS/GPS drifter behind and steamed over to Broadscale Station 12 in the well-mixed crest area to begin the next 48 hr station.

## **Station 2: Well-Mixed Site**

**Day 5 (Thursday 3/29/95)** We arrived at the well-mixed site at 0745 and hove to until 0830 when a second ARGOS/GPS drifter was deployed, again without a high-flyer. Seas were calm with a light chop and hazy sun. A CTD, pump, live tow, and a light cast were completed. At 1110, we deployed spar buoy #2 with a cod larvae light experiment with treatments at 0, 5, 10, 20 m. We then deployed spar buoy #1 with the standard cod larvae experiment. Neither buoy had a SART, just strobes and reflectors. After a MOCNESS tow at 1120 the VPR went into the water at 1200 to begin a 1 nm grid. About 3/4 into the grid the tow cable jumped the winch block on the level wind (the off-button had been accidentally depressed causing slack in the cable and the cable to jump the block). This was fixed and the grid restarted at 1600 and completed at 1635. Following retrieval of the VPR, the #1 and #2 spar buoys were also retrieved.

Night-time activities began with deployment of the spar buoy and holey sock (without the SART) at 2300. The VPR was in the water by 2320 and the grid completed by 0330 the following morning.

**Day 6 Friday 3/31/95** Friday began with calm seas, fog and an overcast sky. A CTD with full hydrosampling was completed at 0800 by followed by a pump sample and light cast.

Deployment of the cod incubator was delayed until 1100 due to a broken ring on the bottom of the spar buoy. The second buoy was rigged with lights and reflectors, but no SART. After deployment, we realized that we had forgotten to turn on the strobe light; the ship circled and we flipped the switch on the fly.

The VPR was deployed at 1123 and we started 1 nm grid. The plankton community was dominated by *Phaeocystis* and small *Calanus*. The grid was finished by 1330 and the VPR retrieved. We had planned to do a CTD/VPR intercalibration but the fog was too thick and the drifter might have been lost.

At 1615 we called the Seward Johnson and talked to Jim Irish to check on the status of the mooring deployment at ST1. They had cleaned the bottom of debris that day and were to deploy the full mooring at 0500 tomorrow. We were then to pass by at 1200 and do a standard CTD without tow-yoing for calibration. The Seward Johnson was then to proceed to the Crest Mooring and deploy a new system there, then on to find Biomapper if time permitted. The spar buoy with cod incubator was then retrieved at 1615.

Night-time activities began at 2000 with a CTD, pump and live tow. We then prepared for the CTD/VPR intercalibration, but there was a two hour delay because of problems with the VPR strobe. A back-up strobe allowed us to get into the water at 2400. Both instruments were hung at 12 m while the ship maintained steerage (ca. 1 kt). The CTD was deployed first followed by the VPR. The intercalibration was conducted for a period of 45 min while recording hydrographic data; no video was recorded by the VPR.

**Day 7 Saturday 4/1/95** At 0100 we retrieved the CTD and deployed a spar buoy with strobes and SART turned on plus a holey sock in 4-5' seas, 15-20 kt winds. Since it was too rough to see the drifter on the radar without the SART, we were only able to do circles around the drifter at a range of 0.5 nm. The drifter was leaning badly due to the extra weight of the SART. After four revolutions around the drifter we ended the tow and retrieved the VPR and drifter at 0330. After several attempts, the ARGOS drifter was located and brought on board. We then began the two hour steam to the beginning of the Hydro transect at 0500.

### Hydrographic Transect

Bob Beardsley's Hydrographic Transect A was followed. Beginning at 0700, we completed stations 1-5, then station 6 with a CTD, MOCNESS, light cast, and live tows. Many more younger stages of *Calanus* were found here compared with the predominantly female population found in the Crest Area.

April Fool's Day had a major affect on the crew and scientific party- strange messages on black-board (--Linen change at 1000-swap with your roommate), new moc schedules being posted (--nothing happening today so sleep-in), a message from Phil Taylor at NSF that all GLOBEC funding was canceled yesterday (not entirely unexpected). We also celebrated Bos'n Jack Buss's Birthday in regal fashion (57 years old for real!)

By 1800 we had completed Station 12 on the Hydro Transect and decided to continue to Station 13 (an additional 4 nm) to get further into Slope water. A CTD and MOCNESS were completed at station 13. By 1930 the MOCNESS tow was complete and we began the steam to the beginning of the VPR X-Bank transect. Ted Durbin had molting experiments underway which required us to stay in relatively cold water. To accommodate this, we steamed back to Hydro Station 11 before turning NE towards the beginning of the VPR X-Bank transect. Dian Gifford did not have experiments underway so this was not a problem. All ships clocks were advanced one hour for daylight savings time.

### VPR X-Bank Transect

**Day 8 Sunday 4/2/95** We arrived at the beginning of the VPR X-Bank transect at 0230 in calm seas, low swell, 10 kt wind and clear skies. Jupiter was visible in the western sky. The VPR was deployed at 0245 in Slope water with a depth of ~1800 m. Tow-yos were initiated at 40 m/min with ship speed through water ~3 kts. As we approached the approximate location of the ARGOS drifter from Station 1, Jan Zelag and Tom Orvosh began the process of down-loading the ARGOS data from URI. After some difficulty in finding the correct files on the URI computer, the data were received and parsed. The last drifter position was 41 34.4N, 66 44.2W at 0830. We realized we had steamed 2-3 nm too far on the transect and had passed the drifter. We stopped the transect at 1300, brought in the VPR, and headed NE towards the latest drifter position which was about 16 nm to the east. At 1400 we started receiving data on the GONIO box about 5 nm from estimated location. At 1415 we found the drifter within a nm of the previous location given by the ARGOS data. In fact, we almost ran over it, since there was no high-flyer to see from a distance.

**Station 3: Revisit of the Northeast Peak Drifter.** At 1430 we deployed the cod incubator on a spar buoy with lights, reflectors and a SART turned on. This cod larvae incubation experiment was at one depth (5m) on a bungee with six bottles, a similar experiment was run later in the evening to compare day/night grazing. Three net tows were completed at 1450 followed by retrieval of the spar buoy and cod experiment at 1900.

Time activities began at 2000 with a CTD for salts and microzooplankton, and bucket sample; no MOCNESS, pump or net tows were completed since the Planktoneers (Ted Durbin's group) were taking down a major growth and molting experiment. The cod incubator was deployed at 2100 followed by the VPR to complete a night grid at 1 nm spacing. Seas were 1-2', wind 15 NNW. The grid was finished at 0100 and the VPR and cod experiment retrieved.

**Day 9 Monday 4/3/95** Day-time activities included a CTD, pump, and live tow at 0800. Someone had crossed out "light cast" on the schedule so this was not done even though Jeff Van Keuren did need it. Winds began kicking up to 20 kts, seas 2-4'. A gale was expected to hit in the evening but had begun a bit early. (The messmen complained about cups and glasses not being washed and returned (hard to do when there is no soap). A message was posted that indicated liquid soap is now available in the sink and should be used.) The cod incubator was deployed at 1100 with another depth/light intensity experiment at 0, 5, 10 and 20 m. The spar buoy and holey sock was in the water by 1115 with the SART turned on since it was too rough to see the drifter without the SART. The VPR was deployed and we began concentric circles (instead of a grid) at 0.1 nm intervals. After much experimentation, we determined that the first pulse from the SART is 0.75 nm away from the drifter. We therefore began the spiral with the pulse on the 1.5 nm circle. All indications (T-S plots, etc) suggested that we were in Scotian Shelf water (colder/fresher). At 1250 we down-loaded a new satellite image taken the previous day to see where we were in relation to the cold tongue. The image showed us to be at the Northwestern edge of the intrusion. Although we could get the satellite image on the computer screen, we had no way to print it at that time (the ship needs a color printer available for printing these images). At 1600 we retrieved the VPR and completed the miss-scheduled light cast.

Reports of the gale intensifying into a storm with 45-50 kt winds began to come in. We decided to retrieve the ARGOS drifter since in a few hours it might not be possible to do so.

We also re-prioritized our schedule to reduce the time at Station 3 from 3 to 2 days and to attempt to include the end of the VPR X-Bank Transect and Georges Basin Station before the storm hit. The drifter was retrieved at 2000 but the line connected to the large orange drogue was severed resulting in loss of the drogue at some point. Since we were in Scotian Shelf water we decided to move north to Broadscale Station 20. Also, rather than complete the night-time VPR grid as usual, we thought it would be interesting to map-out the frontal edge of the Scotian Shelf water intrusion onto the bank. While steaming NNW towards Broadscale Station 20 we monitored surface temperature and conductivity using the ships surface sensors. As we traversed the front the temperature increased from 3.2 to 5.5 oC and salinity from 23 to 33 psu. The width of the front appeared to be 3.2 nm judging from the stability of the temperature and salinity data. We deployed the cod incubation spar buoy at 2215 in Bank Water and then the VPR at 2230. The ship turned south and we began to tow towards the front parallel to the Hague line.

**Day 10 Tuesday 4/4/95.** The front was crossed at 2345 and we made a transition out of the front and into Scotian shelf water at 0030. We then made a turn to the NNW at 292 degrees at 0055 and towed across the front once again. 0.5 nm beyond the front, the ship turned due south and we traversed the front for the third time. At 0400 the VPR was retrieved. The weather report again indicated the gale to be up-graded to a storm (45-50 kt winds) and due to hit late this afternoon. The cod incubator was retrieved at 0430 and we began steaming along the VPR X-Bank transect to the northern edge of the bank.

### Georges Basin Station

We arrived 15 miles SSE of the end of the VPR X-Bank transect at 0945. The VPR was deployed in 15-25 kt winds from the south and seas building to 6-10'. We finished the transect at 1300 after missing three high flyers with lobster pots while the VPR was at depth. The VPR was brought on board in gusts to 45 kts, but our operation was quick and smooth so weather was not a major problem. A CTD and live tow were completed between 1320 and 1400. We then began the 10 hour steam to Broadscale station 38 in the Great South Channel to wait out the storm. During the steam we recorded gusts exceeding 60 kts. In spite of heavy seas, Endeavor gave us a relatively smooth ride with no apparent problem in navigation or control.

### Great South Channel Station

**Day 11 Wednesday 4/5/95.** We arrived just northeast of at the Broadscale Station 38 in the Great South Channel at 0100; winds were from the NW at 35-45 kts with seas >20'. Our plan was to jockey the ship in the vicinity of the GSC for 24 hours while waiting for the weather to improve. At 1730 winds remained steady if not increasing. It was clear from both the NOAA and Canadian weather reports that the winds were not going to subside within the next 48 hours. By leaving GSC we would lose the opportunity to run the VPR transect across GSC and sample *Calanus* for Ted and Ann Durbin. For deployment of the VPR, however, seas and winds less than 3' and 15 kts, respectively, are required because the crane must be positioned outboard to starboard. The chance of these conditions occurring before we would have to leave for Narragansett on Friday morning were slight. A discussion among the Pls led to the decision that since our cruise had been so successful up to this point, we should drop the GSC station and steam for home. The extra time could be used effectively to unload the VPR and Gallagher's incubators at Woods Hole thereby saving transportation costs from Narragansett. We left GSC at about 1800 and began the steam to Woods Hole. Subfreezing air temperatures and strong winds lead to ice build-up on the weather decks. All weather decks were secured.

**Day 12 Thursday 4/6/95** We arrived at the Woods Hole dock at 1600 as predicted. Both the VPR and MOCNESS had suffered some structural damage due to wave action during the trip to WH. However, both systems should be repaired at minimal costs. The deck crew unloaded the VPR from the fantail and the incubators and associated equipment from the hold by 1800.

**Day 13 Friday 4/7/95** We departed WH at 0930 after a brief overnight shore leave. A "loss of steering" drill was conducted at 1000 followed by a fire drill with real smoke in the hold. We arrived in Narragansett at 1230 and continued unloading equipment.

## 3. Individual Reports

### 3.1 Hydrography (Paul Robbins)

This report summarizes the CTD operations and hydrography for GLOBEC process cruise III. Unless otherwise noted, all times are specified in GMT and dates as year day.

#### General CTD operations

Conductivity, temperature, and pressure were measured with a University of Rhode Island Neil Brown Mark III CTD (S/N 1088). Chlorophyll fluorescence was measured with a SeaTec fluorometer, S/N 30-S. Light Transmission was measured with 25 cm path length SeaTec transmissometer, S/N 121D. Data was acquired using the General Oceanics Inc. CTD Data Acquisition Module version 5.2. The CTD data stream was concurrently recorded to audio cassettes for archive/backup. Water samples for shipboard salinity analysis were collected using General Oceanics 10 liter GO-FLO sampling bottles. Shipboard salinity analysis was performed by Jan Zelag on an Autosol model 8400A.

CTD casts were performed 4 times a day at stations following drogued drifters. Casts were typically performed in pairs at 0800 and 2000 local time. The first cast in each pair was a 'conventional' CTD cast including collection of bottle water samples. The lowering and raising rates of these casts was 30-40 meters/min. The second cast (which was not always performed) was a pumping station for Ted Durbin's group. A flexible hose was attached to the rosette frame in order to pump water from depth to the surface for filtering. CTD data was acquired during these pumping stations but is not included in the following discussion/analysis as these stations immediately followed 'conventional' CTD casts. Winch speeds for pumping stations were typically 20 m/min for the downcast and 4 m/min for the upcast. The following CTD cast numbers were pump stations: 2,5,7,9,10,12,14,30,33.

#### Drifter Stations.

Drifter 1 was deployed near GLOBEC broad scale station 20. CTD casts (numbers 1-7; Day 87 1430 to Day 89 0130) conducted following the drifter for the first two days were labeled Station 1. Casts 1-7 revealed slight but weak stratification. Maximum observed delta-T and delta-S were 0.16 C and 0.06 psu respectively for station 6.

Drifter 2 was deployed near the GLOBEC crest mooring. The accompanying CTD casts (numbers 8-14; Day 89 1400 to Day 91 0100) were labeled station 2. All of these casts revealed a very uniform water column except cast 8 which showed evidence for slight surface warming in the upper ~12 meters (delta-T ~0.03 C). As there was no salinity signature to this feature it was most likely

created by solar warming of the surface waters.

After the survey of hydrographic Line-A (discussed below) we returned to the site of the first drifter (casts 29-34; Day 92 1900 to Day 94 0200). The reoccupation of the Lagrangian drifter station was designated station 3. The first reoccupation cast (29) at Day 92 2000 GMT (1600 local time) revealed water properties below 15 m consistent with casts 1-7. Above 15 m the water column exhibited warming of about .25 Deg C but only slight salinity decrease suggesting that the water at station 1 had warmed from solar heating since the last occupation. Cast 31, three hours later, showed nearly uniform temperature and salinity throughout the water column ( $\Delta t < .02$ ,  $\Delta s < .03$ ) indicating that either buoyancy loss or wind forcing had erased the previously observed stratification. Cast 29 was the only CTD cast at a drifter station performed in mid-afternoon local time and also the only cast at stations 1 and 3 showing significant stratification associated with surface heating. It is quite possible that a mid-day surface temperature stratification formed on other days of the station occupation but was erased by the time the evening ctd cast (2000 local time) was performed.

Cast 32 the following morning local time (Day 93 1200) revealed a two layer structure of the water column with ~35 m of colder fresher water overlaying warmer saltier water ( $\Delta t \sim 0.75$  C;  $\Delta s \sim 0.42$  psu). The water properties of the lower portion of the water column were consistent with the previous casts at Station 3 but the surface water indicated influence of Scotian Shelf Water. How the drogued drifter had crossed a surface front into this new water mass was at first a mystery but upon retrieving the drifter we discovered that the sub-surface drogue had parted from the drifter, allowing the wind to blow the drifter southward.

We decided to steam north until the surface salinity and temperature returned to values consistent with previous measurements at stations 1 and 3 (SST > 4.9; SSS > 32.65). Cast 34 was conducted after we recrossed the front (Day 94 0200). The water column showed no stratification and temperature and salinity were consistent with previous observations at station 1 and 3.

#### Hydrographic Line A.

Hydrographic Section A (casts 16-28) on the southern edge of Georges Bank was occupied on April 1 (Day 91) from 1200 to 2300. As on Endeavor 262, a 13th station was added to the section in an attempt to extend the section across the shelf-break front. The first 3 stations (casts 16-18) of the section were characterized by water columns mixed to the bottom with each station being progressively colder and fresher as we worked our way off the bank. Stations A-4 and A-5 (casts 19 & 20) showed a water column uniform in salinity but with a slight positive temperature anomaly in the upper 10 meters ( $\Delta T \sim 0.22$ ). This temperature structure was repeated in stations A-6 and A-7 (casts 21 & 22) where it was also accompanied by a slight negative salinity anomaly ( $\Delta S \sim -0.07$ ). Station A-8 (cast 23) was the first to show significant influence of warm, salty slope water in the lower portion of the water column. The slope water signature became more pronounced at successive stations however the surface temperature and salinity remained low (e.g. at station A-11 (cast 26), SST = 5.33, SSS = 32.93). The temperature was slightly raised at station A-12 (SST = 7.69) and dramatically shot up to 11.2 at station A-13 (cast 28).

Fluorescence and Transmission show strong correlation with each other along the hydrographic line. Values were uniformly large at the start of the transect in the shallow well-mixed water and gradually decreased as we progressed into the fresher, colder band of water found in casts 19 to 22. A strong bottom (70-80 m) maximum was found at station A-8 (cast 23) which appears to be partly continuous with a maximum at about 30 m on cast A-9. These maximums appear to coincide with the shoreward edge of the shelf-break front.

problems  
The fluorometer was noted to be flashing intermittently during the first stations of the cruise. On deck it would appear to flash and stop and the fluorescence profiles appeared somewhat spiky. The fluorometer was replaced with SeaTec s/n 117s prior to the start of hydrographic line A and the problems appeared to have been remedied. Fluorometry data prior to station 16 should be further analyzed to determine its quality.

The General Oceanic GO-FLO bottles occasionally had problems properly closing however no single bottle behaved consistently poor. Multiple bottles were typically fired at each desired depth to insure at least one good sample.

Several casts at station 2 near the crest mooring grazed the bottom but with no apparent loss of data quality or damage to the instruments. Large sand waves of up to 15 m height were frequently observed in this region and ship drift would often carry/drag the ctd across one during the cast.

Standard station operation at the drifter stations included net tows off the starboard side of the ship. The net tow used the same winch and cable as the ctd and necessitated connecting and disconnecting the ctd cable. There was one instance where the ctd was mistakenly powered up while Jan Zelag was still working to connect the cable to the ctd. Fortunately power was shut off before any harm was done.

#### Calibration

Salinity samples were collected at every station in order to provide a reference for ctd calibration. The CTD offset was determined (after removing clearly erroneous bottles) to be 0.030 psu (CTD read slightly saltier) with no discernible trend over the course of the cruise.

Surface temperature and salinity at each ctd cast was compared to the shipboard Seabird CT system. The ship's system read 0.050 psu fresher than the uncorrected ctd. The temperature offset was about 0.44 deg. C with the ship reading warmer, most likely due to slight heating of the water as it is brought on board.

Data for intercalibration of the VPR and CTD were collected at ctd cast 15. Both instruments were lowered to 12 meters and data was simultaneously collected for over 30 minutes. This data has not yet been analyzed.

**List of images** H-1) Ship Track on Georges Bank overlain on bathymetry contours of 60, 100 and 200 m. Calendar dates indicate position of ship at 0000 GMT.

H-2) Positions of CTD casts overlain on bathymetry contours of 60, 100, 200 and 1000 m. Pumping station casts are not included as they were at the same location as the preceding conventional ctd cast.

H-3) Track of ARGOS drifter #1, deployed near broad scale station 20. Larger numbers (88 through 93) indicate drifter position each

year day at 0000 GMT. Small open circles indicate drifter location at 0600, 1200 and 1800 GMT each day. Stars (\*) and accompanying small numbers indicate positions of ctd casts. Subsurface drogue appears to have parted from drifter sometime during day 92.

H-4) Ship track at Stations 1 and 3 following ARGOS drifter #1. Calendar dates indicate position of ship at 0000 GMT.

H-5) Track of ARGOS drifter #2, deployed near crest mooring. Larger numbers (90 and 91) indicate drifter position each year day at 0000 GMT. Small open circles indicate drifter location at 0600, 1200 and 1800 GMT each day. Stars (\*) and accompanying small numbers indicate positions of ctd casts.

H-6) Temperature-Salinity diagram for ctd casts at stations 1 and 3 following ARGOS drifter #1. Numbers indicate cast number. Small open circles locate the surface T-S values for each station and x's indicate bottom T-S. Cast 29 shows evidence of solar heating of near surface water. Cast 32 revealed the drifter had crossed a surface front into colder, fresher water.

H-7) Temperature-Salinity diagram for ctd casts at station 2 following ARGOS drifter #2. Numbers indicate cast number. Small open circles locate the surface T-S values for each station and x's indicate bottom T-S. Station 8 shows slight warming of surface waters, other stations are well mixed throughout water column,

H-8) Temperature-Salinity diagram for ctd casts on hydrographic line A. Numbers indicate cast number. Small open circles locate the surface T-S values for each station and x's indicate bottom T-S.

H-9) A) Contours of temperature and salinity along Hydrographic line A. B) Contours of fluorescence and transmission along Hydrographic line A.

H-10) Calibration of Neil Brown CTD. Upper panel shows difference between bottle salt and ctd salinity for all collected bottle salt samples. Lower panel shows the same when large positive offsets are removed. Least square fit of data in lower panel yield and offset of 0.0301 psu and slope of  $1.5 \times 10^{-5}$  with respect to salt bottle number.

H-11) A) Sea surface salinity and temperature during course of the cruise. Line indicates values continuously recorded by shipboard SeaBird CTD. Acquisition was intermittent during early portion of cruise due to problems with clock on acquisition PC. X's indicate temperature and salinity values from 5 m depth on each ctd cast. Days 87.5 to 89.5 are on station following drifter #1. Day 89.5 to 91.5 are on station following drifter #2. The hydrographic line A is distinguished by high ctd station density in the later part of day 91. The peak values in temperature and salinity late in day 91 indicates passage of ship across shelf-break front. The ship crossed the shelf-break front again on day 92 for the start of the long VPR section. The ship returned to the location drifter #1 in the later part of Day 92. Decreasing salinity and temperature on day 93 reveal passage of un-drogued drifter across surface front. The rise in T and S at start of 94 indicate northward return of ship across front. Portions of shipboard record during day 94 concurrent with VPR survey of front were lost due to computer malfunction. CTD station at Day 94.75 is cast 35 in Georges Basin.

H-11 B) Difference of sea surface salinity and temperature recorded by Neil Brown CTD and shipboard SeaBird. Least squares fits of each set of data yielded salinity offset of 0.050 psu and temperature offset of -0.44 deg C.

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

(Ted Durbin, Ann Durbin, Robert Campbell, and Dave Avery)

The objective of the plankton group was to measure growth of *Calanus finmarchicus*. Approaches used included:

1. Sorting individual copepodite stages and the incubating them for 2 days in ambient phytoplankton, and ambient which had been enriched with lab cultures. The proportion of animals molting to the subsequent stage is used to estimate stage duration. In addition, we measured initial and final length, and animals were preserved for C&N, and RNA and DNA measurements. From these we hope to develop a relation between molting rate and growth in C and N, and RNA/DNA ratio. Gut pigments of C% and C6F were measured to provide an index of feeding intensity.
2. Deploying a GPS/ARGOS drifter to mark a water mass and then repeatedly sample the zooplankton at the drifter. From measures of the age structure and recruitment measures from egg production rates we will estimate growth and mortality rates.
3. In addition we collected selected stages from stations along the hydro transect and in Georges Basin for size and RNA/DNA measurements, and for gut pigments.

We left Narragansett Monday and arrived at Station 1 at 07:00 on Tuesday morning. The location of this station was centered on the patch of cod larvae seen the previous week by Greg Lough. Because of rough seas no MOCNESS or VPR samples were taken during this first day. Our GPS/ARGOS drifter was launched on arrival at the station and then we made a CTD and pump cast, and live tows with the 333 and 150 m nets for sorting for egg laying and growth exps. The animals were not in particularly good shape, perhaps because of the roughness of the waves and insufficient weight on the cable making for greater wire angle and longer tows. There was much phytoplankton in the water which clogged the nets. The cable from the Seamac winch jumped the sheave so we had to use the CTD winch for all subsequent live tows. *Calanus* C3 and C4s were sorted for the growth exps which were started around midnight.

Wed 29th. The next morning we made a second pump cast but were unsuccessful with the MOCNESS because new rollers put in front of the sheave leading from the winch did not work. Fortunately, the old ones had been saved and these were put back on later during the day. Live tows taken during the morning and sorted for gut pigments, (C5 and C6 females), size (C2, C5 and C6F), and

RNA/DNA (N6, C2, C5 and C6F). During the evening we made a MOCNESS tow and ripped out the O (down) net, probably because of clogging. We replaced this with a 333 m net and left the cod end off in future tows. After the VPR was finished during the night we proceeded to the second station on the crest.

Thursday 30th. We arrived at the crest station and launched the second drifter at 08:00. We then did CTD and pump casts, followed by a MOCNESS tow. The MOC nets were clogged with phytoplankton (large amounts of *Phaeocystis*) and the cod ends were full to overflowing. Live tows taken after this and again were full of *Phaeocystis*. However, there appeared to be more *Calanus* at this station compared with Station 1, although fewer nauplii and young copepodites. *Calanus* were sorted for size (C2, C5, C6F), and RNA/DNA (N6, C2, C5, C6F). During the evening we took down the first growth experiment. The proportion of the copepods which were molting were not high indicating slow growth rates. This may have been an effect of stress during capture, although mortality rates were very low (1 out of a total of 190 animals).

Friday 31. We did CTD and pump casts in the morning followed by live tows for setting up the crest growth exp. C3, C4 and C5s were sorted for this growth experiment (we had difficulty finding enough C3s). C5 and C6Fs were also sorted for gut pigments. During the evening we took a final CTD and pump cast at the drifter station and collected live animals for a night time gut pigment measurement (C5 and C6Fs). These night samples had higher gut pigment than the day samples.

Saturday, April 1. The drifter was recovered at 05:00 after the VPR grid was finished and we proceeded to the beginning of the hydro transect. We collected live animals at St 6 mid way across the southern flank. There was almost no phytoplankton in the net. *Calanus* appeared very abundant with all stages present. C5 and C6s were sorted for gut pigments and C2, C4, C5 and C6F for size and RNA/DNA. A MOCNESS tow was taken at the end of the hydro line and animals taken from the deep and surface nets for size, RNA/DNA and gut pigs.

Sunday, April 2. We proceeded to the beginning of the cross-bank VPR transect and started it. At a point approximately adjacent to where drifter 1 was left we broke off the VPR transect and searched for the drifter, finding it around 14:00 at a position very close to where it had been left; there had been very little net movement over the previous 4 days. A regular station sequence was carried out (CTD, pump, MOCNESS, live tows for Stephane).

The crest growth experiment was taken down during the evening. C3s were molting quite rapidly giving a stage duration similar to a maximal one. C4s were somewhat slower, while only a few C5s molted to the adult stage.

Monday, April 3. A morning station sequence was carried out (live tows, CTD, pump, light cast). The CTD profiled that the water at the surface was colder, and a little fresher than the night before. Apparently the drifter had crossed over a convergence into a plume of Scotian Shelf water which was extending onto the north-eastern portion of the bank. This could be seen on the satellite sea surface temperature picture. The live tows were sorted for a growth experiment (C2, C3, C4 and C5s). At this station *Calanus* appeared to be relatively low in abundance and there were few older stages. We had difficulty finding enough C4 and C5s for the experiment. There appeared to be more *Pseudocalanus* than on the crest or on the southern flank. *Calanus hyperboreas* was also present in low numbers. Because the drifter had moved into different water we decided to recover it and then steam north of the front after the evening CTD to collect water for Scott's fish larval exps, and then to map the front with the VPR. On recovering the drifter we found that the drogue was missing. Apparently the 3/8" rope connecting the drifter to the float between the drifter and the drogue had chafed through. A thimble was needed in the splice loop. The data downloaded from the drifter suggested that the drogue had separated several days previously. Prior to this the drifter had moved very little since deployment. After recovering the drifter a net haul was taken for gut pigments. Values at this site were the highest seen on the cruise.

Tuesday, 4th. A big storm was predicted for later that day so we steamed north during the morning to complete the northern section of the cross-bank VPR line. A CTD cast and a net tow for size and RNA/DNA measurements were made. By then the wind was picking up quickly so we headed down toward the GSC station. The wind picked up to over 40kts during the night.

Wednesday, 5th. The wind was blowing 35 kts throughout the day, with air temps -2C. Around noon we decided to head slowly back around Nantucket Shoals. During the evening we took down the third growth experiment. Molting rates were quite rapid with highest rates observed for C2s (approximately 45% molted to C3s during the two day experiment). There was a progressive decline in the proportion molting with increasing stage. At the end of all of the growth experiments animals were saved for length, C&N, and RNA/DNA. Once these samples are analyzed we expect to be able to develop a relation between molting rate and growth in C&N, and RNA/DNA ratio. This cruise was quite successful for us. It took place while the spring bloom was taking place on the bank. We expect that during the next two cruises the bloom will have ended and that growth rates may be somewhat lower.

### **3.3 Ingestion of Phytoplankton, Nanozooplankton and Microzooplankton by *Calanus finmarchicus*** (Dian Gifford, Mike Sieracki, Jeff Van Keuren and Elin Haugen)

Our objectives on EN264 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 three drifter stations. Station 1, located on the northeast peak of the bank, was occupied for 2 days, Station 2, located on the bank crest, was occupied for 3 days, and Station 3, located on the northeast peak, was occupied for 2 days. Ingestion rates by *C. finmarchicus* life history stages C1, C2, C3, C4, C5, and adult female were measured at Station 1. Ingestion rates of stages C4 and C5 were measured at Station 2. Ingestion rates of stage C1 were measured at Station 3. We are particularly pleased that we were able to perform experiments with the youngest life history stages of *Calanus*, despite the obvious difficulties of sorting sufficient live material to work with.

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 three drifter stations. Preliminary examination of bulk seawater and epifluorescence preparations of nanozooplankton indicates that aloricate ciliates were present at both stations, but appeared to be less abundant than during cruise EN262. Tintinnid ciliates were present, but rare. Large diatoms were abundant at



the northeast peak stations, and included *Coscinodiscus* and *Chaetoceros* species. The colonial and single-celled forms of *Phaeocystis pouchetii* were abundant at the crest station. In general, chlorophyll > 20 µm contributed at least 60% of the total chlorophyll at the northeast peak stations and chlorophyll < 5 µm contributed about 90% of the total chlorophyll at the crest station. All samples for phytoplankton, nanozooplankton and microzooplankton will be analyzed ashore by a combination of inverted microscopy and image-analyzed epifluorescence microscopy.

A University of Rhode Island graduate student, Elena Martin, accompanied our group, and assisted with hydrographic sampling operations and performed a number of experiments related to her doctoral dissertation research on the effects of UV light on planktonic protozoa.

### 3.4 Egg production of dominant copepod species on Georges Bank

(Stephane Plourde and Jeff Runge)

Objectives:

1. Measure egg production rates of dominant copepod species on Georges Bank.
2. Test the hypothesis that the copepod population egg production rates (eggs m<sup>-2</sup>d<sup>-1</sup>), determined by specific egg laying (eggs f<sup>-1</sup>d<sup>-1</sup>) and abundance of females (f m<sup>-2</sup>), varies through time and between regions of the Bank.
3. Measure egg viability of *Calanus finmarchicus*.

Methods:

*C. finmarchicus*. Egg laying rates and viability were measured on 2 consecutive days at STA01 (Northeast Peak), STA02 (Bank Crest) and back on Northeast Peak (STA03). Additionally, experiments were made at Hydro Line STA06 (Southern Flank) in water depth comparable to Northeast Peak stations and at the usual Georges Basin station (STA04) at end of the cruise. Basic methods were explained in preceding reports. Shortly, females were caught with an oblique 333-m mesh size plankton net gently towed from c.a. 5-10 m of the bottom to surface. Catches were diluted in filtered sea water (FSW), healthy females quickly sorted out and individually incubated in 50-ml dishes filled with FSW for 24 h at c.a. 6-7°C. Eggs were counted and removed each 8 h and kept at 8°C. To measure egg viability, we incubated 200 eggs until hatching and c.a. 300 eggs were stained with Trypan Blue solution to color dead ones. Both batches of eggs were composed of randomly picked eggs laid by all females. All nauplii and eggs were preserved at the end of experiments. At STA04, females and eggs were preserved to be counted later because of weather. No egg viability assessment was made.

Twenty-four *C. finmarchicus* females were picked at each of STA01, STA02, STA06 Hydro and STA03 to measure body size and carbon content. Prosome length was measured, females rinsed in fresh water and then individually placed in pre-weighted CHN boat. Samples were kept in desiccant until analysis in laboratory after the cruise.

Other species. From the same plankton catches, we sorted out *Pseudocalanus* spp., *Centropages typicus* and *Temora longicornis* females. We did experiments when species were enough abundant. We made 3 experiments with *Pseudocalanus* spp. at STA01 and STA03, 3 experiments with *C. typicus* at STA01 and STA02 and 1 measurement with *Temora longicornis* at STA03. Females were incubated during 24 h at c.a. 6-7°C in 45-ml culture flasks filled with ambient sea water (AW) collected with CTD-Rosette at chlorophyll maximum and filtered on a 73µm mesh to remove any eggs. Eggs and females were preserved in flasks at end of experiments for later enumeration and measurements.

Results and Discussion

*C. finmarchicus*. Egg production rates ranged between c.a. 25 eggs f<sup>-1</sup>d<sup>-1</sup> and 75 eggs f<sup>-1</sup>d<sup>-1</sup>. Only first experiment at STA01 and last at STA03 showed marked higher egg laying rate (51 and 75 f<sup>-1</sup>d<sup>-1</sup> egg), explained by higher spawning frequency (0.86 and 0.95 compared to c.a. 0.52-0.68 at other stations). Dead eggs proportions assessed during egg counts were higher at STA01; 32% and 23% of eggs were assumed to be dead compared to less than 8% at other locations. First experiment was made with females not in good shape because of rough weather at time of collection. This may caused a stress on animals to lay immature eggs, which may increased our estimation of both egg laying and mortality. Nevertheless, egg quality data from the second day seems to support that egg viability was lower at this station. For the last egg measurements made at STA03, we probably sampled a different water mass, at least for the first 20 m in surface (colder and fresher water). This water was believed to originate from the Nova Scotia Shelf and may carried a different copepod population and system, as suggested by few hints: (1) zooplankton composition was clearly dominated by *T. longicornis* (2) clutch size of *C. finmarchicus* was c.a. 20% (62 eggs clutch<sup>-1</sup>) higher there than in Northeast Peak/Southern region (50 eggs clutch<sup>-1</sup>) and c.a. 50% higher than STA02 on Bank Crest (40 eggs clutch<sup>-1</sup>) and (3) *C. finmarchicus* copepodites V and adult females gut pigments were 2 times higher than any other location during the cruise.

At both stations, most females had a rather big oil sac, suggesting that they were young ones just starting to reproduce and/or they were feeding at rates higher enough to fuel egg production and body lipid reserves. Spawning frequencies and observations made during sorting work (gonad maturity states, females bearing spermatophores, males and copepodite CV high abundances) suggested that new females were recruited in the population during this period.

Other species. Samples weren't analyzed during the cruise but some observations have been made. C.a. 50% of *Pseudocalanus* spp. females observed, when they were sufficiently abundant, carried egg sacs. Most of *C. typicus* females showed developed gonads, which suggested that they were laying eggs at high rates. We were surprised to collected *T. longicornis* during the second day of STA03. As previously mentioned, we were in a colder and fresher surface water mass believed to originate from the Nova Scotia Shelf. A high percentage of *T. longicornis* females were ripe and reproduced actively in this water mass. We expected again rather high egg laying rate for the experiment made at this moment.

### 3.5 Vertical migration and micro- to meso-scale plankton distributions

(Cabell Davis, Scott Gallagher, Philip Alatalo, Carin Ashjian, Andy Girard)

The goal of the VPR sampling during the process cruises is to measure the micro- to meso-scale distributions of *Calanus* and *Pseudocalanus* together with other plankton and detrital material in relation to physical properties of the water column over similar scales. Comparative day/night measurements of these variables will provide insights into the vertical migration behavior of the plankton. These data will help us to 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.

The sampling design involved slowly towing the VPR in either a 1 nm square grid centered on a drifter drogued to 20 m during station-keeping activities, or in a linear transect across the Shelf/Slope break on the Southern Flank and the northern edge of the bank into the Gulf of Maine. The grid sampling approach allowed both the vertical and horizontal distributions of plankton, detritus, and hydrography to be estimated and rendered into a 3-dimensional volume. The transect approach allows fronts between water masses to be sampled and mapped with resolution extending from mm to km.

The VPR was configured with two cameras set at two magnifications viewing concentric volumes (fields of view: 5.8x4.8 mm and 37x27 mm). Video from the underwater unit was transmitted to the surface via fiber optic cable and recorded on two SONY BETACAM SP broadcast-quality recorders. Normally we would also direct the video signal into an image processor and SUN workstation to extract in-focus sub-images to display and store them on disk in real-time; Unfortunately, the last cruise took its toll on our workstations and crew: the hard disk crashed on one workstation, the monitor became inoperable on another, and our software engineer, Marty Marra, came down with the flu. On this process cruise, we were left with the back-up option of recording all video and ancillary environmental sensor data, as usual, but without real-time processing and display. Hydrographic data were processed within a few hours of deployment and plotted as shown below.

In general, the VPR component of the cruise was very successful. Thirteen successful tows were made in all: five tows at the Northeast Peak drifter station, five tows at the well-mixed area drifter site, one saw-toothed or zig-zag tow to map the frontal region of the Scotian Shelf water intrusion, one transect from the Slope water to the center of the bank, and one transect from the well-mixed region on the northern edge across the front and into the Gulf of Maine. There were various weather-related problems: we were not able to complete the third day at station #3, the cross-bank transect usually performed was broken into two smaller transects reducing towing time in the central well-mixed area, and the transect across Great South Channel was not performed. Although we were plagued by various equipment failures particularly early in the cruise (a short in the tow cable inside the winch drum, leaky bulkhead connector, arcing in the strobe), no VPR tows and associated data were lost due to these problems. We accomplished our tasks at all the high priority sampling stations designated at the beginning of the cruise so we consider the cruise very successful in spite of poor weather during the second week. Locations of the 13 VPR tows are shown in Fig. VPR-1. The grid stations are given as a straight line from the beginning to the end of the grid even though the actual shiptrack followed an ellipse (see Fig. H-1). Also, transect 12 was a zig-zag across the Scotian Shelf Water intrusion not a straight line as indicated in Fig. VPR-1. Hydrographic data versus time (distance) are shown for each of the VPR tows 1-13 in Figures VPR 2-14. Figures VPR 15 and 16 show the gridded data for tows 9 and 13, the beginning and end of the cross-bank transect, respectively.

#### **TOW # START FINISH**

**VPR 1** 41 41.34', 66 32.49' 41 39.27', 66 36.36'  
3/28 2141h 3/29 0800h

Night-time grid at station #1. Loss of power traced to short in winch drum. Reterminated tow cable in drum. Loss of depth sensor readout forced us to sample at discrete depths at 0, 5, 10, 15, 35 m while steaming around drifter. Many diatoms particularly at the surface. Repaired depth sensor.

**VPR 2** 41 38.33', 66 31.57' 41 35.25', 66 38.82'  
3/29 1502h 3/29 1815h

Day-time grid at station #1 went well. Upon retrieval, strobe cable shorted at bulkhead connector. This was replaced as well as a the DG O'Brien fiber optic connector which was broken during handling operations.

**VPR 3** 41 42.21', 66 35.22' 41 36.68', 66 28.86'  
3/29 2305 3/30 0209

Night-time grid at station #1. Dominated by *Phaeocystis*.

**VPR 4** 41 26.26', 67 28.62' 41 20.84', 67 30.63'  
3/30 12226 3/30 1653

Day-time grid at station #2. Lost winch power causing cable to jump the level-wind, otherwise no problems. 65 towys were completed.

**VPR 5** 41 31.01', 67 31.18' 41 25.01', 67 27.24'  
3/30 2320 3/31 0305

Night-time grid at station #2. Extremely high readings on fluorometer (145 relative units) throughout water column due to numerous chain diatoms. Image completely saturated at times.

**VPR 6** 41 29.20', 67 29.77' 41 24.17', 67 23.95'  
3/31 1123 3/31 1512

Day-time grid at station #2. Many *Phaeocystis* colonies particularly below 15 m. Changed strobe bulb and encountered arcing problem.

**VPR 7** 41 29.20', 67 29.77' 41 24.17', 67 23.95'  
3/31 2356 with CTD at station #2 for 45 minutes.

**VPR 8** 41 26.50', 67 26.67' 41 22.80', 67 24.77'  
4/1 0102 4/1 0318

Night-time grid at station #2. 0.5 nm spiral around drifter went well.

**VPR 9** 41 03.84', 66 17.26' 41 36.43', 66 44.47'  
4/2 0250 4/2 1232

Cross bank transect from Slope Water across Southern Flank into well-mixed area. Slope Water contained little except *Rhizosolenium* mats in the top 50 m. Within the Slope/Shelf front the fluorometer saturated at 145 ru at 60 m depth increasing quickly from only 10 ru at 50 m depth. This was mainly due to chain diatoms.

**VPR 10** 41 37.37', 66 21.41' 41 39.42', 66 23.49'  
4/2 2112 4/3 0100

Night-time grid at station #3. Noted large clumps of *Rhizosolenium* and/or *Pseudonitschia* in surface waters.

**VPR 11** 41 30.19', 66 25.35' 41 31.02', 66 24.30'  
4/3 1116 4/3 1602

Day-time grid at station #3. Due to rough seas, we used the SART to complete a 1 nm diameter inward spiral around the drogue at 0.1 nm increments. Many diatom clumps once again.

**VPR 12** 41 31.09', 66 27.36' 41 22.96', 66 24.08'  
. 4/3 2255 4/4 0400

Night-time zig-zag through frontal region between Scotian Shelf Water and bank water on the Northeast Peak. To the north of the front salinity was 32.65 psu and temperature was 5.0 on the surface (Fig. VPR-14). This was well-mixed to depth. Within and south of the front salinity dropped to 32.1 psu and temperature fell to 3.8 at the surface. This cold and fresh lens of water extended to a depth of 35 m. The most notable difference between the two water masses in regards to the biology was the almost complete absence of marine snow in the Scotian Shelf Water above the bank water. The bank water (both to the north of the front and at depth south of the front) was dominated by cm-long strands of marine snow (3 to 4 strands per video field is equivalent to about 15 strands per liter). The Scotian Shelf Water also contained copepod species not normally associated with bank water such as *Temora* and *Eurytemora*.

**VPR 13** 42 3.13', 67 9.41' 42 14.70', 67 19.07'  
4/4 0955 4/4 1255

Northern end of the cross-bank transect. The VPR towed from the crest, across the northern front and into the Gulf of Maine (Georges Basin area). Maximum depth recorded was 220 m. There were many *Phaeocystis* colonies, diatom flocs and marine snow strands in the surface waters of the GOM where the fluorometer reached 145 ru on occasion. The winds and seas were increasing rapidly to storm levels so the transect was cut short by 0.5 nm. Three high-flyers and associated lobster pots were barely missed as the VPR was brought to the surface for the last time.

As on the last process cruise EN262, marine snow appeared to be the most dominant biological particle in the water. The predominance of *Phaeocystis* (with its well-characterized chambered structure) in the well-mixed crest area where one month ago there were extreme levels of an unidentified round or ovoid organism of about 1 to 3 mm in length, supports the contention that these ovoid blobs were early life history stages of *Phaeocystis* which we identified here today. It will be interesting to estimate abundance of these early ovoid forms to compare with that of the chambered form. This kind of information could not be obtained by nets or other conventional sampling gear which tend to over emphasize the more robust groups of plankton and completely miss the fragile forms.

### 3.6 The Importance of Microzooplankton in the Diet of Newly Hatched Cod Larvae

(Scott Gallagher, Ione Hunt von Herbing, Linda Davis, Philip Alatalo, Andy Girard)

#### 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 copepod 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 shipboard 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 bungee 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*)(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 (large tomato sauce cans), a strobe, and a SART were mounted on the spar buoy to ease tracking in rough weather.

On this cruise we added a second set of experiments which examined the effect of light intensity, depth, and day/night on grazing activity in newly hatched cod larvae. For the light intensity experiment, a string of milk crates were hung below the spar buoy at four depths: 0, 5, 10, and 20 m. Five experimental bottles were placed in each milk crate allowing two treatments per depth. The light intensity profiles of Jeff Van Keuren were correlated with the depth of each treatment and will be used to calibrate feeding on protozoans and nauplii as a function of intensity. The day/night experiment was similar to the treatments normally used with the exception that the incubator was deployed at 2000 hrs in complete darkness rather than during the day. The results of this experiment will provide information on when during the day feeding is most intense and if larvae are capable of feeding at night on natural prey assemblages.

#### Deployment Summary

Date Station Deployment # larval age  
(days post-hatch)

2/28 1 1 0-1

5-6

6-7

3/29 1 2 2-3

3-4

8-9

3/30 2 3 1-2 normal experiment

4 1-2 light experiment

3/31 2 5 0-1

1-2

3-4

4/2 3 6 1-2 day

7 1-2 night

4/3 3 7 1-2 day

8 1-2 night

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-illumination 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.

Results of the grazing experiments on various size fractions showed that newly hatched (0-1 day old) cod larvae feed directly on natural assemblages of microzooplankton (protozoans). As we observed on the last process cruise, 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. A surprising find was that larvae fed most extensively at a depth of 10 m with rates falling off both above and below this depth. Also, early larvae fed comparatively well at night when only a small sliver of the moon was showing. We will need to compare our depths with the available light before conclusions are drawn concerning larval feeding at night.

#### 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 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 50C.

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 bungee 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.

### 3.7 Characterization of ultra-violet and visible light regimes on Georges Bank

(Jeff Van Keuren)

My objectives on EN264 were to 1.) collect continuous surface measurements and frequent underwater profiles of downwelling irradiance data (ultra-violet, PAR) to better characterize changes in the insitu light field during the spring bloom on Georges Bank / growth of the target species, 2.) deploy a new monochromatic, downwelling irradiance sensor system which will be used in the final analysis of acoustic backscatter layers (ADCP), and 3.) work with a graduate student from URI in her experiments to evaluate the effects of different components of the solar UV spectrum on microzooplankton abundances.

During this 12-day cruise, light profiles of four narrow band UV channels (308nm, 320nm, 340nm, 380nm) as well as broad-band PAR (400-700nm) were taken daily at the three time-series stations visited (Stations 1-3) as well as at GLOBEC mooring site "ST-1". Strong winds and high seas prevented optical casts at additional sites 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 daylight surface irradiance measurements were complimented by frequent notations on the existing cloud conditions as well as broad-band twilight/nocturnal continuous light records generated by a logging PMT-based system. Only minimal underway analyses of these light data were possible due to weather conditions. The UV component of this work is being done in conjunction with Dr. Al Hanson, GSO/URI.

### 3.8 Solar Ultra-violet (UV) Radiation and Marine Protozoan Survival

(Elena Martin, Dian Gifford, Jeff Van Keuren, A.K. Hanson)

Three consecutive UV-exclusion experiments were performed on EN264 to determine whether UV radiation penetrating surface waters is great enough to decrease survival of marine protozoans. Whole water samples containing in situ protozoan communities were collected for the experiments from stations 1, 2 and 3 (CTD casts 3, 13 and 34, respectively). Within each 3-day experiment, water samples were incubated in UV-transparent polyethylene bags suspended in flowing seawater and exposed to three conditions: Full-sun; -UV-B (280-320nm), mylar filtered sunlight; and -UV (320-380nm), polycarbonate filtered sunlight. Initial and final samples were preserved in Acid Lugols to determine changes in protozoan abundance. Chlorophyll and nutrients were also sampled to trace changes in food availability to protozoans. In addition to the experiments, continuous UV light measurements were recorded on deck and UV profiles taken for all stations by Jeff Van Keuren using a PUV-500 radiometer. UV measurements were also recorded within the incubator for comparison.

## Appendix I Cruise Participants

Scott Gallagher Chief Scientist WHOI  
Carin Ashjian Postdoctoral Fellow WHOI  
Philip Alatalo Assistant WHOI  
Andy Girard Assistant WHOI

Ted Durbin PI URI  
Bob Campbell Postdoctoral Fellow URI  
Dave Avery Grad Student URI  
Stephane Plourde PI Institute Maurice Lamontaigne  
Dian Gifford PI URI  
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Elena Martin Grad Student URI  
Linda Davis Assistant WHOI  
Ione von Herbing Postdoctoral Invest. WHOI  
Paul Robbins Hydrographer WHOI  
Jan Zelag Marine Tech URI  
Tom Orvosch Marine Tech URI

## **Appendix II Cruise Schedule**

### **Friday 3/24**

0900 ship arrives Narragansett- off load MOC10, load VPR  
1200-1500 take on fuel- no crane activity

### **Monday 3/27**

0900 leave dock at Narragansett to do ship-swing, calibrate gyro compass  
1200 leave Narragansett Bay- steam to larval cod patch on Northeast Peak  
(Broadscale Station 20)  
21 hour steam

### **Tuesday 3/28**

0800 arrive Broadscale Station 20 on Northeast Peak  
deploy ARGOS/GPS drifter

### **Station Keeping (48 hours)**

0930 CTD- full hydro and water collection  
1030 Deploy Gallagher's drifting cod incubator  
Pump  
Net tows  
Optics cast  
1800 Retrieve cod incubator  
2000 CTD- full hydro  
2300 Deploy spar buoy w/ holy sock  
Start VPR grid

### **Wednesday 3/29**

0500 End VPR grid  
0800 retrieve drifter  
CTD- full hydro and water collection  
Pump  
1045 Deploy Gallagher's drifting cod incubator  
1100 Net tows  
Optics cast  
1230 Start VPR grid around cod drifter  
1800 End VPR grid  
Retrieve cod drifter  
2000 MOCNESS  
Pump  
CTD- full hydro  
2300 Deploy spar buoy w/ holy sock  
Start VPR grid

### **Thursday 3/30**

0500 End VPR grid  
retrieve drifter  
0430 Steam to Well-Mixed Site (Crest Mooring)  
1030 CTD  
1115 Deploy Cod Drifter  
MOCNESS  
Pump  
Net tows  
Optics cast  
1200 Start VPR grid  
1650 End VPR grid  
1930 Pump  
CTD  
2300 Deploy spar buoy w/ holey sock  
Start VPR grid

### **Friday 3/31**

0300 End VPR grid  
0330 retrieve spar buoy  
0800 CTD- full hydro and water collection  
Pump  
1103 Deploy Gallager's drifting cod incubators (two spar buoys)  
1115 Net tows  
Optics cast  
1130 Start VPR grid around cod drifter  
1512 End VPR grid  
1630 Retrieve cod drifter  
1900 CTD  
Pump

#### **VPR/CTD INTERCALIBRATION**

2100 Deploy VPR while towing at 1 kt  
Deploy CTD  
hold both instruments at 10m for 45 min  
2230 retrieve CTD  
2200 Deploy spar buoy w/ holey sock and SART??  
Start VPR spiral/grid depending on conditions

#### **Saturday 4/1**

0300 End VPR grid  
Retrieve spar bouy  
Retrieve ARGOS drifter  
**TRANSECT**  
0500 Steam to Beardsley's hydro transect  
0700 Start hydro transect  
station 1 CTD  
station 2 CTD  
station 3 CTD (Wave to Seward Johnson as she steams to Crest Mooring)  
station 4 CTD  
station 5 CTD

1200 station 6 CTD (normal, no towyo- look for new mooring)  
MOCNESS  
Light cast  
Live tows  
station 7 CTD  
station 8 CTD  
station 9 CTD  
station 10 CTD  
station 11 CTD  
1800 station 12 CTD  
MOCNESS  
Live tows  
**End CTD transect in slope water**

1900-2400 5 hour steam at 10 kts to start of X-bank VPR transect- watch for high temps if incubating animals

#### **ADVANCECLOCKS 1 HOUR-**

#### **Sunday 4/2**

0100 **Begin X-Bank VPR transect-** 10 hours at 4 kts

1100 End 1st half VPR transect  
**Steam to ARGOS/GPS drifter**  
1200 arrive drifter

#### **Station Keeping (60 hours)**

1200 Deploy cod incubators  
CTD-full hydro  
MOCNESS  
Pump  
live tows  
light cast  
(no VPR grid)  
1800 Retrieve cod incubators after dinner  
2000 CTD  
pump  
live tows  
2200 deploy spar buoy with lights and holey sock  
Start VPR grid

**Monday 4/3**

0400 End VPR grid  
retrieve drifter  
0800 MOCNESS  
Pump  
CTD- full hydro and water collection  
1030 Deploy drifting cod incubator  
Net tows  
Optics cast  
1100 Start VPR grid  
1430 End VPR grid  
Retrieve cod incubator  
2000 CTD  
MOCNESS?  
Pump  
live tows  
2300 deploy spar buoy  
Start VPR grid

**Tuesday 4/4**

0400 End VPR grid  
retrieve drifter  
0800 MOCNESS  
Pump  
CTD- full hydro and water collection  
1030 Deploy drifting cod incubator  
Net tows  
Optics cast  
1100 deploy spar buoy  
Start VPR grid  
1630 End VPR grid  
Retrieve cod incubator  
2000 CTD  
Pump  
live tows  
2300 deploy spar buoy  
Start VPR grid

- Due to poor weather, station-keeping activities were terminated and we steamed to the end of the cross-bank transect

**Wednesday 4/5**

0400 End VPR grid  
Retrieve drifter  
Retrieve GPS drifter

**Steam to start of 2nd half of VPR cross-bank transect**

0600 Begin 2nd half of VPR transect- 12 hours at 4 kts  
1800 End VPR transect in Georges Basin  
Live Tows  
pump  
CTD  
MOCNESS  
2100 Steam to beginning of VPR Great South Channel Transect (Broadscale Station 36)  
10 hours at 8 kts

**Thursday 4/6 \*\*\*\*not done due to poor weather, arrived Woods Hole 1600**

0700 Begin Great South Channel Transect (VPR)- 10 hours at 4 kts  
1700 End VPR GSC transect- Arrive Broadscale Station #38 @ 41-29.4N 68-59.0W  
Live tows for *Calanus*

2000 Steam for Narragansett

**Friday 4/7**

1600 Arrive at Narragansett

**Appendix III Event Log**

If the event log is available you will [find it here.](#)