Cruise Report

R/V ALBATROSS IV 9805

Georges Bank

4-8 May 1998

Acknowledgments

We gratefully acknowledge the very able assistance provided by the officers and crew of the R/V ALBATROSS IV and student volunteers. This report was prepared by Greg Lough, Scott Gallager, Larry Buckley, Betsy Broughton, Elaine Caldarone, and Jim Manning. This cruise was sponsored by the National Science Foundation and the National Oceanic and Atmospheric Administration.

Table of Contents

Note: An on-line version of this report is at: http://www.wh.whoi.edu/~jmanning/cruise/al9805.html.

Purpose of the Cruise

The objectives of the cruise were to:

Determine the distribution and abundance of larval cod and haddock in the vicinity of the tidally-mixed front along the southern flank of Georges Bank,

Conduct site studies to determine their vertical distribution, diel variability, predator-prey relations, and biochemical content in relation to water column conditions.

Test the operational capabilities of the Video Plankton Recorder (VPR) mounted on the 1-m MOCNESS frame

Test the deployment and recovery of the Larval Fish Environmental Chamber,

Evaluate the towed VPR system (WHOI) for high resolution transects of the tidal front.

Cruise Narrative

The Albatross IV left Woods Hole 1800 h EST May 4, 1998 and headed for Georges Bank via Great Round Shoals to begin scientific operations at approximately 67 45' W Latitude near the 60-m isobath. On May 5, during the period 0722-2037 h, an initial survey of the tidal frontal region was made using a towed VPR (Gallager) in a grid pattern of four transects extending 10 km on either side of the 60-m isobath. Within the sampled grid, the tidal mixing front was located between 55 and 68-m isobaths. The cruise track is

shown in four segments in Figure 1. At 1711 h May 5, Buckley's larval fish environmental chamber (LFEC) was deployed (GPS/ARGOS/VHF drifter 20a) at 41 02.26', 67 39.38', 60-m bottom depth. The chamber was tethered at 10-13 m depth with over 1,000 cod larvae about a week post-hatch. Using the drifter as a moving station, MOCNESS/VPR (Lough) hauls and towed VPR transects were conducted over the next two days. Five 1-m^2 MOCNESS/VPR and two 1/4-m^2 MOCNESS hauls were completed, alternating with five additional towed VPR deployments. Two additional drifter deployments were made: drifter 6a, tethered at 33 m, was deployed next to drifter 20a at 1425 h May 6; and drifter 1a, tethered at 13 m, was deployed a few kilometers south of drifter 20a at 1630 h May 6. All drifters were recovered May 7, including the larval fish environmental chamber at 1520 h May 7, 40 58.34', 67 45.14', 60-m water depth. Upon completion of the final towed VPR transect at 2030 h May 7, the Albatross IV steamed back to Woods Hole and arrived dockside at 1100 h May 8, 1998.

Individual Reports

Physical Oceanography (J. Manning)

Drifter Deployments

Three GPS/ARGOS/VHF drifter deployments were made on AL9805. Lists of times and positions of each deployment is given in the event log and in Table 1 below. Here we discuss the results of each of three deployments as depicted in Figure 2. The first deployment (20a) had the larval fish environmental chamber (LFEC) attached . (Note: while this drifter did not have the traditional drogued configuration, the drag of the chamber itself should nearly match that of the drogues since it had similar surface area). The drifter's electronic housing was flooded during the recovery operation so the internal data storage was lost. The radio transmissions to the ship and to the ARGOS satellite were recovered however, so the drifter path was successfully recorded. Drifter (6a) was deployed a few hundred meters from d20a on 6 May. It had a deeper drogue centered at 33m. The third deployment (1a drogued at 13m) was made a few kilometers south of the LFEC in order to monitor the relative surface flow. We were intending to document any near-surface convergence in the vicinity of the tidal front but, over the course of two tidal cycles, the drifters maintained the ~2km separation.

Table 1. Drifter Deployment Log.

Drift Local LAT LON Water Drogue LAT LON

```
ID mth day HHMM Operation DDMM.MM DDMM.MM Depth Depth DD.DDD DD.DDD

20a* 5 5 1711 deployment 4102.26 6739.38 60 12 41.038 -67.656 6a 5 6 1425 deployment 4100.10 6740.90 64 33 41.002
-67.682

1a 5 6 1630 deployment 4058.48 6742.26 63 13 40.975 -67.704

1a 5 7 1330 recovery 4058.10 6742.70 63 13 40.968 -67.712

6a 5 7 1408 recovery 4059.74 6743.43 58 33 40.996 -67.724

20a* 5 7 1520 recovery 4058.34 6745.14 60 12 40.972 -67.752
```

*w/LFEC attached

Temperature probes were installed at three depths below drifter 6a (@ 1m,22m, and 33m) in order to document changes in the thermal stratification in the moving water mass. As shown in a time series Figure 3, there was approximately 1 degree gradient in the upper water column with a 0.5 degree variation due to daily heating and cooling. Probes were also installed at two depths below drifter 20a (1m and 13m) and are plotted in Figure 4. The hourly record at 13m indicates a warming with each flood stage of the tide. Does the shallow thermocline deepen on the on-bank phase of the tide? Over the course of the 2 day experiment the in situ chamber temperature increased from 6.8^o to 7.8^o C. Thermal stratification in this thin surface layer decreased by approximately 1^o C.

Shipboard Sensors

One minute interpolated values of shipboard sensor data were loaded into a MATLAB routine for range and delta checks and then plotted in **Figure 5**. Note that most of the signal in salinity, for example, occurs on route to and from the study area at the start and end of the cruise. Most variables held fairly constant in the study area but there are subtle variations due to the tidal and solar cycles. Note that when we get slight variations in SST due to daily solar warming it is difficult to interpret the spatial variability of our surveys. During the VPR deployment #1, for example, the hull mounted thermistor (Figure 6) showed more than a **1^{o}C warming** over the period of the survey (700-1500 local time). The **ship's surface salinity** record varied by only a few tenths during that same time. Similar plots of ship's SST were made for VPR deployments **#3**, **#4**, **#5**, **#6**, and **#7** but are difficult to interpret for the same reasons. They do demonstrate a distinct and consistent thermal front near the 60m isobath. All deployments had generally warmer water on the off-bank side (with the exception of deployment **#5** which warmed on the on-bank edge as well). Ship salinity plots were also generated for deployments **#5** and **#6** (Figures 7 and 8) to demonstrate a general freshening on the off-bank side. The wind reduced from about 15 knots at the start of the cruise to a 5-10 knots in the last few days. All of this data (as well as the drifter data) has been posted on the GLOBEC homepage in **http://www.whoi.edu/globec.html** under "data|process|1998".

Acoustic Doppler Current Profiler

RDI Acoustic Doppler Current Profiler (ADCP) was on board operating at 300 kHz. Post-processing of these records has just begun at the time of this writing. A routine to convert the RDI raw data to MATLAB formatted data called BB2MAT has been used to extract velocities. Preliminary processing of these records is underway. A plot of **vertically averaged flow** is given in Figure 9. While some data is contaminated on route to the study area in the early morning of 5 May (probably due to the AMETEK acoustic interference), the remaining record appears fairly clean. Detailed investigation of individual transects (including a de-tiding operation) will be conducted on this data in order to calculate the flux of organisms in the vicinity of the tidal front. A preliminary look at **vertical ADCP transects** of "deployment#1" (Figure 10) demonstrates the full range of tidal cycles over the period of the experiment.

As often happens, the time base between the ship clock and the ADCP clock were not synchronous. After careful matching of a few time stamps the offset was found at 1 hour. Both ship time and ADCP time (after bb2mat processing) were recorded in GLOBEC "yrday1_local" format but the ADCP time was one hour short. **Figures** of ship tracks (Figure 11) with yeardays posted were used to compare time bases and to derive the offset time. An effort should be made to insure ADCP time is set correctly prior to each cruise in the future.

De-tiding of the ADCP records was initially conducted by simply subtracting the Candela estimate of tide (empirical estimate based on previous GLOBEC ADCP records in the area). Since this is only a estimate of the water column average, another method of de-tiding (using the Dartmouth 3-d Circulation Model) will be employed.

Hydrography (S.Gallager)

The purpose of the hydrographic measurements on this cruise was to locate and follow over time the position of the tidal mixing front separating the stratified southern flank area from the well-mixed crest area on Georges Bank. To accomplish this task, high spatial resolution combined with real-time feedback is necessary to define and track frontal features. Multiple CTD deployments are relatively slow, cumbersome, and cannot provide rapid survey-like information. We decided to use the towed VPR in high-speed survey mode to map hydrographic conditions in relation to the tidal mixing front and Buckley's Larval Fish Environmental Chamber (LFEC) as they drifted with the tide. The planktonic prey field was recorded continuously on video tape as the ship steamed. Although a visual impression of organisms and particle abundance was gained from watching the video monitors, taxonomic identification is being conducted in the laboratory using our VPR image processing system.

In addition to the optical sensors discussed later in this report, the VPR has Seabird CTD sensors including a fast response temperature probe, a Wet Labs fluorometer and transmissometer, a Licor PAR irradiance sensor, altimeter, and a General Oceanic flow sensor. Data from these sensors are collected at 6 Hz and recorded both in raw and processed format. All data were displayed in real-time on a PC running the VPR control software in C. Raw data were passed via a NFS mount to an NT workstation were they were processed further and plotted in near-real time as color dot plots in Matlab where dot color was proportional to the variable intensity.

A total of seven VPR deployments were made. Each deployment consisted of multiple transects normal to the 60 m isobath and centered on the drifter. For each deployment, data for depth, temperature, salinity, fluorescence, light attenuation at 550 nm, density, and PAR down-welling

light are plotted as a function of time in Figures 12-17 for deployments 1, 3, 4, 5, 6 and, 7.

To identify the position of the tidal mixing front, a stratification index (SI) was plotted continuously as the ship steamed along the transects. SI was calculated by binning sigma-t values obtained at about 2 cm intervals in the vertical to 0.5 m depth intervals. SI is simply the absolute value of the difference between 0.5 m depth bins multiplied by 10,000 for scaling purposes. Typical values ranged between 200 - 1000 under strong stratification and less than 50 for weak stratification. The edges of the mixing front is defined here as SI values between 100-200 and are plotted as a vertical red line in Figures 18-23 below. Positions of the front are given for each leg of each deployment separately in Table 2.

VPR 1 & 2 (Figure 18): An initial survey of the frontal region was made on May 5, between 0722 h and 2037 local time (**see Figure 1**) in a grid pattern extending 10 km to the North and South of the 60 m isobath. Temperature ranged between 5.45°C below and 8.28 °C above 10 m depth in stratified waters to the southeast of the tidal mixing front. Southern flank stratified water was relatively fresher than in the well-mixed crest area. The tidal mixing front was located between the depths of 55.3 and 67.5 m and appeared about 0.3 to 1.3 km in width (see Table 2).

VPR3 (Figure 19): After Larry Buckley's LFEC was deployed, a night-time series of four 6 km transects centered on the LFEC were made between 2149h May 5 and 0226h May 6. The tidal front was located in deeper water than in VPR1 at depths ranging between 61 and 67 m. Width was similar ranging between 0.3 to 1.3 km.

VPR4 (Figure 20): This was a daytime series of transects similar to VPR3 centering on Buckley's LFEC. The tidal front appeared at depths of 54 to 66 m depending on transect past the cage.

VPR5 (Figure 21): A nighttime series of transects extending 4 km either side of the LFEC. Frontal depth was 44 to 63 m while the width was 1 to 1.6 km.

VPR6 (Figure 22): A single daytime transect extending from northwest to southeast of the LFEC. We needed to pick up the cage due to impending weather and time constraints so the VPR transects were limited to one. Frontal; depth was 55 to 59 m and width was 4.1 km. The extensive width was due to the tangential intersection of the front by the ships course.

VPR7 (Figure 23): This was a final transect extending from the 60 m isobath to the 80 m isobath to determine the extent of stratification along the southern flank region. For some reason, the winch operator did not bring the VPR to the surface for towyos 7-11, so surface stratification can not be determined in the southern most part of this transect.

Table 2. Position and dimensions of Tidal Mixing Front During VPR Tows 1-6

Tow	Leg	Beginning Point		End Point		Width (km)	Min/Max Depth (m)	
VPR1	1	41.0011	67.8196	41.0011	67.8196	0.3263	55.3	56.5
	2	40.9698	67.7728	40.9583	67.7700	0.8988	61.0	63.1
	3	40.9826	67.7319	40.9501	67.7250	1.3279	62.1	67.5
	4	40.9920	67.6877	40.9834	67.6858	0.7961	66.5	69.7
	5	41.1109	67.7006	41.0986	67.6884	0.8891	48.8	54.2
VPR3	1	ND	-	-	-			
	2	41.0671	67.6339	41.0500	67.6292	1.1248	61.0	64.2
	3	41.0666	67.6263	41.0423	67.6226	1.0513	62.0	66.4
	4	41.0480	67.6276	41.0289	67.6228	1.2569	63.1	67.5

VPR4 1 41.08 - 41.07 67.69 0.71 54.3 57.6

2 - 67.68 41.03 1.26 58.0 62.0

3 41.05 67.67 41.03 67.67 1.26 59.8 65.3

4 41.03 67.67 41.00 67.66 1.24 63.1 66.5

VPR5 1 41.1027 67.7460 41.0562 67.7379 1.38 44.3 59.7

2 41.0532 - 41.0223 - 1.49 44.0 59.8

3 41.0097 67.7301 40.9958 67.7279 1.06 52.0 64.2

4 -- -- 1.59 61.0 63.2

VPR 6 1 41.41 - 41.03 4.11 55.4 59.8

Table 3. VPR Log. Deployment (d) and transect (t) id is listed in the first column.

---

d/t day hour min sec yrday1_local lat lon hr(est) min sec yrday1_local lat lon

11 5 7 29 17 125.312 41.045 -67.829 9 20 10 125.389 40.885 -67.800

12 5 9 51 50 125.411 40.892 -67.753 11 24 0 125.475 41.040 -67.789

13 5 11 52 48 125.495 41.054 -67.745 13 1 55 125.543 40.914 -67.718

14 5 13 39 22 125.569 40.910 -67.670 15 48 58 125.659 41.116 -67.710

31 5 21 53 17 125.912 41.067 -67.628 22 42 14 125.946 40.995 -67.611

32 5 22 59 31 125.958 41.000 -67.617 23 51 22 125.994 41.068 -67.634

33 5 23 58 34 125.999 41.067 -67.628 1 3 22 126.044 40.977 -67.610

34 6 1 17 46 126.054 40.990 -67.616 2 12 29 126.092 41.062 -67.631

41 6 9 23 2 126.391 41.096 -67.698 10 12 0 126.425 41.032 -67.679

42 6 10 29 17 126.437 41.010 -67.678 11 24 0 126.475 41.085 -67.685

43 6 11 28 19 126.478 41.083 -67.680 12 28 48 126.520 41.004 -67.657

44 6 12 50 24 126.535 41.006 -67.661 13 33 36 126.565 41.065 -67.672

51 6 21 36 0 126.900 41.110 -67.748 22 33 36 126.940 41.019 -67.731

52 6 22 40 48 126.945 41.008 -67.729 0 0 0 127.000 41.106 -67.750

53 7 0 14 24 127.010 41.126 -67.755 2 32 38 127.106 40.939 -67.716

54 7 2 38 24 127.110 40.931 -67.715 3 50 24 127.160 41.029 -67.736

61 7 10 56 38 127.456 41.103 -67.785 12 44 38 127.531 40.964 -67.744

71 7 18 28 48 127.770 40.903 -67.889 20 19 41 127.847 40.712 -67.869

A single SEABIRD 9/11 cast was conducted in order to test the operation of the instrument. Sensors appeared to be working and transmitting data as expected including the Chelsea Fluorometer & Transmissometer. At least one of the bottles fired on request so that the instrument seems to function and ready for subsequent cruises.

Satellite **imagery** before and after the cruise (there was not any clear images DURING the cruise) indicates significant warming of the outer

shelf during the first half of May (Figure 24). The cruise track is overlayed in the second panel to illustrate our position relative to the tidal front's cold band region (12 May).

Ichtho-Zooplankton Studies

MOCNESS Sampling (G.Lough, E.Broughton)

The 1-m^2 MOCNESS with nine 0.333-mm mesh nets was used to sample larval fish and larger zooplankton. New sensors on the 1-m^2 MOCNESS (light, transmission, fluorescence) did not work on this cruise because of a software problem. A Video Plankton recorder (VPR) also was attached to the MOCNESS frame to record fine-scale zooplankton during the tow. Results of the VPR recordings are discussed in below. The 1/4-m^2 MOCNESS with nine 0.064-mm nets was used to sample the smaller Plankton such as copepod nauplii. The tow profile for these two nets was nominally 10-m strata within 5 m of the bottom; extra nets were used for special collections. The 1-m^2 MOCNESS nets typically sampled for 5 minutes to filter about 200 m^3 of water; the 1/4-m^2 MOCNESS nets for 2-3 minutes to filter about 30 m^3. Following the Larval Fish Environmental Chamber (LFEC), marked by drifter 20a, five 1-m^2 MOCNESS tows and two 1/4-m^2 tows were made during the cruise period 5-7 May 1998.

Biochemistry (E.Caldarone, J. Burns)

Selected samples for biochemical and age analysis were taken from the extra net profiles of the 1-m^2 MOCNESS hauls. All samples were rinsed from the nets using minimal seawater pressure and transferred to buckets containing ice packs. Plankton from nets that were not to be sorted was preserved immediately using 4% buffered formaldehyde in seawater. Plankton samples sorted for Fish or invertebrates were picked in seawater filled translucent sorting trays on ice covered light tables. Every effort was made to keep samples cold during processing to delay decomposition. Plankton remaining after removal of samples was preserved with 4% buffered formaldehyde and sea water.

Larval Fish collected for Caldarone/Buckley were video taped using a ZEISS Stemi SV6 stereo microscope outrigged with an MTI CCD72 black and white video camera, then individually frozen in liquid nitrogen. The video images will be used to collect morphometric data. The data will be used to determine the nutritional condition and growth rate of the individual Fish. Larval Fish collected for B.Burns were measured to the nearest 0.01 mm SL using OPTIMAS image analysis software connected to a Zeiss Stemi SV6 stereo microscope, equipped with a Hitachi HV-C20 color video camera. These Fish will have their age determined by otolith microstructure analysis. A total of 197 cod and 100 haddock were collected from 5 MOCNESS hauls for biochemical analysis. Individual cod and haddock were collected, videotaped, and placed in liquid nitrogen. The larvae will be analyzed for their RNA, DNA, and protein content, and length. The data will be used to determine the growth rate and nutritional condition of the individual Fish. A comparison will be made of Fish taken from the different sites and at discrete depths.

One of our objectives was to test the feasibility of shipboard nucleic acid analysis in order to provide real-time assessments of larval growth and condition. Through the significant efforts of Jeanne Burns, we were able to assemble a scaled-down version of our biochemistry laboratory on board the ship. On May 6 we analyzed the nucleic acid content of 30 individual larval Fish using a spectrofluorometric microplate reader and ethidium bromide dye (Wagner et al. 1998). Using an average water temperature of 7.2 for both hauls (derived from the MOCNESS temperature profiles) we calculated larval growth rates from the equation G = -12.47+1.27(T)+3.05(RNA/DNA) where G is percent increase in protein content per day, T is temperature, and RNA/DNA is the ratio of the nucleic acid content of the individual Fish.

Table 4. Larval Growth Rates.

MOCNESS#	Depth	Species	Sample Size(n)	Mean Growth Rate (%incr. protein/day)
165	0-55 m	cod	10	11.4 (2.9)
165	0-55 m	haddock	10	11.0 (2.0)
166	20-0 m	cod	10	14.0 (1.0)

All of the Fish analyzed were in good condition and growing rapidly. Previous field results have indicated that a temperature of 7.2ºC is close to the optimum temperature for maximum cod/haddock growth. The biochemistry equipment appeared to function well without a gimbaled platform. The 'whine' of the centrifuge changed pitch when the ship rolled but it did not appear to affect the centrifugation step. There was only one 10-minute step in the 6-hour process when a more stable platform would have been advantageous. The room temperature remained fairly constant throughout the procedure, which is critical for obtaining accurate results. Another critical factor in the procedure was a good night's sleep before the analysis day. The results of this test indicate that we can routinely run nucleic acid analyses during cruises to obtain real-time assessments of larval growth and condition. We had planned on using OPTIMAS during the cruise to estimate larval lengths from video images of the larvae. We discovered that our VCR system is incompatible with the newer version of OPTIMAS (ver. 5). Next year we will either bring Version 4 of OPTIMAS or a compatible VCR.

Larval Fish Environmental Chamber (L.Buckley, E.Caldarone, J. Burns, A. Chute)

Approximately 3,000 6-day old lab-reared cod larvae were brought on board. One-thousand of them were placed on deck in a bucket suspended in a large black barrel with seawater circulating through the barrel. Due to heating of the seawater to 9 °C in the ship's hoses, this system proved to be unsatisfactory for holding the larvae. The remaining 2,000 Fish were placed in three buckets in a cooler on deck. Each bucket was equipped with an air stone. The water temperature in the buckets was maintained at 7 °C by periodically adding ice to the cooler.

On May 5, 1,158 larvae were placed in a 6 l nalgene container with a timed-release door (figure 25). The container was fastened to the side of a cylindrical chamber (2 m diameter, 3 m height) made of 300 micron Nitex. This size mesh retains the larvae but allows passage of prey items through the chamber. The Nitex cover of the chamber was closed with Velcro and then sewn shut. The chamber was tethered at 10-13 m to a surface float which was equipped with GPS and transmitted its position by Argos and VHF. Because of its large surface area, the chamber tracked the parcel of water into which it was placed, much like a standard holey sock drogue. Some larvae spilled out of the weep holes in the container as the net was being deployed. When the chamber was retrieved, ~48 hours later, the net appeared to be intact and the larval container had opened as planned. After gently rinsing the net, the contents were placed in a bucket containing an ice pack and sorted in translucent trays placed on ice-covered light tables. We recovered 313 Fish. From visual examination, it was difficult to determine how long the Fish had been dead. A subsample of 40 Fish was preserved in liquid nitrogen for later analysis of their RNA, DNA, and protein content. These values will be used to aid in distinguishing between freshly killed larvae and those that died earlier (but had not yet disintegrated), and to provide direct estimates of growth and survival of cod larvae at ambient prey concentrations in the absence of predators. Approximately 60 Fish were preserved in ethanol for otolith analysis, and 60 Fish were placed in 10% formalin for stomach analysis. At the conclusion of the experiment, Fish that had not been placed in the chamber were still alive in the buckets on deck, even though they had not been fed during the time the chamber was in the water.

Video Plankton Recorder (MOCNESS mounted) (G.Lough, P.Tillier)

The Video Plankton Recorder, an underwater imaging video microscope, was mounted above the net opening on the 1-m^2 MOCNESS. This particular system was held in four underwater housings and consisted of two Hi-8 Video Camcorder interfaced with a Tattletale Computer Software, a low (5.6x) and a high (72x) magnification cameras, a strobe, and a 24V-8amp Gel battery pack. Operation was independent of the MOCNESS. Recordings were later dubbed to SVHS tape format together with time code. Recordings were made for all five 1-m^2. All in-focus images will be identified to the lowest taxon possible.

Video Plankton Recorder (Towed) (S. Gallager, C. Davis)

The system: The Video Plankton Recorder (VPR) is a towed underwater microscope that images Plankton and particles in the size range from 0.1-20 mm. (Davis et al. 1992; Gallager et al. 1996). The VPR has two video cameras, high and low magnification, with fields of view of 7 and 25 mm, respectively. The cameras are synchronized at 60 Hz with a xenon strobe. Data and video signals are sent to the surface via 0.68" fiber optic cable where a deck controller unit displays and processes the signals. A Dynacon winch (30 hp) is used to continuously towyo the VPR from the surface to within 10 m of the bottom at vertical speeds of about 0.5 m.s-1. The deployment on Albatross IV was made simple by use of the J-frame on the starboard side of the ship. The frame allowed one person control of all elements of the deployment and retrieval. Two seamen typically were on deck to observe the VPR at the surface and the cable and block angle. All video data were recorded in SVHS format to await image processing and taxon identification in the laboratory. No image processing was done in real-time on this cruise as is on most of our more recent cruises. The seven VPR deployments were described in detail under the hydrography section. Video tapes and raw data files for each deployment are the following:

Table 5. Towed VPR tape log.

Deployment Tapes Data File

VPR1&2: 1 - 10 05051122.y98

VPR 3: 11 - 16 05060145.y98

VPR 4: 17 - 20 05061329.y98

VPR 5: 21 - 28 05070131.y98

VPR6: 29 - 30 05071503.y98

VPR7: 31 - 34 05072220.y98

In general, there were numerous larval cerianthids throughout the water column in the well mixed area. On the southern side of the tidal mixing front, the colonial diatom Chaetoceros socialis was dominant at the pycnocline (12 m). These colonies appeared healthy and growing in comparison with the disintegrating colonies observed below the pycnocline in deeper water. There were no remarkable patches of copepods observed in the region of the front, but large numbers of Calanus were seen at depth on the southern flank. Water optical clarity changed dramatically as we passed from the well mixed side to the stratified side of the front. Numerous small particles and microplankton in the range of 50 to 100 um in the well-mixed water, gave way to relatively clear water with much larger particles on the stratified side of the front. Fluorescence and light attenuation was consistently high below the pycnocline in stratified water and relatively uniform in the well-mixed crest area. Further interpretation will require image processing of the video tapes which is currently underway.

Appendix. I. Event Log

LOCAL Water Cast Comments

EVENT# INSTR Cast# Day Mth HHMM s/e Lat Lon Depth Depth PI

AL12598.1 VPR 1 5 5 722 s 4103.33 6749.94 70 50 Gallager

AL12598.2 VPR 1 5 5 756 e 4059.86 6749.05 72 50 Gallager *,first leg, minor repairs

AL12598.3 VPR 2 5 5 811 s 4059.86 6749.05 70 50 Gallager

AL12598.4 VPR 2 5 5 1701 e 4106.96 6742.60 72 50 Gallager *

AL12598.5 Chamber 1 5 5 1711 s 4102.26 6739.38 60 12 Buckley Environmental Chamber (w/drifter 20)

AL12598.6 MOC1 165 5 5 1916 s 4102.25 6738.45 62 56 Lough

AL12598.7 MOC1 165 5 5 2029 e 4101.66 6739.88 61 56 Lough

AL12598.8 VPR 3 5 5 2149 s 4104.86 6738.04 52 50 Gallager

AL12698.1 VPR 3 5 6 226 e 4059.40 6736.96 63 50 Gallager *

AL12698.2 MOC1 166 5 6 703 s 4103.00 6742.00 57 50 Lough

AL12698.3 MOC1 166 5 6 814 e 4103.45 6744.51 55 50 Lough

AL12698.4 VPR 4 5 6 927 s 4106.90 6744.90 55 50 Gallager

AL12698.5 VPR 4 5 6 1334 e 4103.90 6740.30 52 50 Gallager *

AL12698.6 Drifter 6 5 6 1425 s 4100.10 6740.90 64 33 Manning drifter 6 deployment

AL12698.7 SeabirdCTD 1 5 6 1427 s 4100.10 6740.90 64 59 Manning CTD in vicinity of chamber

AL12698.8 SeabirdCTD 1 5 6 1436 e 4100.10 6741.10 61 59 Manning

AL12698.9 MOC1/4 167 5 6 1522 s 4059.90 6740.69 64 59 Lough

AL12698.10 MOC1/4 167 5 6 1555 e 4058.93 6742.35 63 60 Lough

AL12698.11 Drifter 1 5 6 1630 s 4058.48 6742.26 63 13 Manning drifter 1 deployment

AL12698.12 MOC1 168 5 6 1707 s 4100.68 6742.31 60 50 Lough

AL12698.13 MOC1 168 5 6 1817 e 4100.55 6744.73 58 50 Lough

AL12698.14 VPR 5 5 6 2132 s 4106.90 6744.90 55 50 Gallager

AL12798.1 VPR 5 5 7 406 e 4102.99 6744.39 52 50 Gallager

AL12798.2 MOC1 169 5 7 825 s 4100.31 6748.73 55 50 Lough

AL12798.3 MOC1 169 5 7 827 e 4100.54 6749.29 52 50 Lough

AL12798.4 MOC1/4 170 5 7 1003 s 4102.52 6746.12 55 50 Lough

AL12798.5 MOC1/4 170 5 7 1027 e 4102.17 6747.13 55 50 Lough

AL12798.6 VPR 6 5 7 1104 s 4106.21 6746.72 40 50 Gallager

AL12798.7 VPR 6 5 7 1255 e 4057.84 6744.64 58 50 Gallager *

AL12798.8 Drifter 1 5 7 1330 e 4058.10 6742.70 63 13 Manning 1 recovered AL12798.9 Drifter 6 5 7 1408 e 4059.74 6743.43 58 33 Manning 6 recovered

AL12798.10 VPR 1 5 7 1435 s 4058.80 6743.60 60 50 Lough testing VPR

AL12798.11 Chamber 1 5 7 1520 e 4058.34 6745.14 60 12 Buckley chamber recovery AL12798.12 MOC1 171 5 7 1601 s 4058.30 6745.30 59 50 Lough

AL12798.13 MOC1 171 5 7 1726 e 4057.42 6750.30 58 50 Lough

AL12798.14 VPR 7 5 7 1818 s 4055.00 6753.32 5 50 Gallager South to 80m

AL12798.15 VPR 7 5 7 2030 e 4041.78 6752.04 5 50 Gallager

* Note: all lat/lon positions with asterisks in the comment column were inferred by ship track plots (i.e. last turn of the specific transect) since hand-written log fix were not made.

Appendix II.List of Personnel

Dr. R. Gregory Lough, NOAA, Ch. Scientist

Dr. Scott Gallager, Biologist, WHOI

Dr. Lawrence Buckley, URI/NOAA CMER Program, URI

Mr. James P. Manning, Oceanographer, NOAA

Mr. Pierre Tillier, Electronic Tech., SEASCAN, Inc.

Ms. Elizabeth A. Broughton, Bio. Lab. Tech., NOAA

Ms. Elaine M. Caldarone, Physiologist, NOAA

Ms. Antonie Chute, Bio. Lab.Tech., NOAA

Ms. Jeanne M. Burns, Mar. Res. Spec., URI

Mr. Nicholas Wolff, Bio. Lab. Tech., BLOS

Mr. Ford Dye, Bio. Lab. Tech., BLOS

Mr. Andre Biryukov, Computer Sci. Grad. Student, Northeastern Univ.

Mr. Dan Doolittle, Volunteer

Ms. Kirsten Bassion, Our World Underwater Fellow, WHOI

Appendix III. List of Figures

33m, and 13m ,respectively. Drifter 1a was deployed ~2km off-bank of drifters 20a and 6a.

Figure 3. Time series of temperature as recorded by thermistors mounted on and below drifter #6a.

Figure 4. Time series of temperature as recorded by thermistors on and below drifter #20a.

Figure 5. Shipboard Computer System (SCS) recorded variables 4-8 May 1998 on AL9805.

Figure 6. Shipboard hull mounted thermistor record during towed VPR deployment #1-2 indicating slight increase over the period of the survey.

Figure 7. Shipboard through-hull salinity record during toward VPR deployments #5.

Figure 8. Shipboard through-hull salinity record during toward VPR deployments #6.

Figure 9. Vertically averaged ADCP current time series for eastward (top) and northward (bottom) flow.

Figure 10. Cross-bank transects of raw ADCP records during towed-VPR deployment #1-2.

Figure 11. Ship track of towed-VPR deployment #1-2 with ADCP current vector and yearday overlaid.

Figure 12. Towed-VPR deployment #1-2 multi-panel contours.

Figure 13. Towed-VPR deployment #3 multi-panel contours.

Figure 14. Towed-VPR deployment #4 multi-panel contours.

Figure 15. Towed-VPR deployment #5 multi-panel contours.

Figure 16. Towed-VPR deployment #6 multi-panel contours.

Figure 17. Towed-VPR deployment #7 multi-panel contours.