Cruise Report

C-134A

SEA Experience Program

Scientific Activities Undertaken Aboard SSV *Corwith Cramer*

Woods Hole to Woods Hole

6 August to 15 August, 1994

Sea Education Association

Woods Hole, Massachusetts

TABLE OF CONTENTS

Preface

This report outlines the scientific and academic program conducted aboard SSV *Corwith Cramer* during August, 1994. It consists of summaries of research stations occupied, data collected, and highlights some of the results obtained during oceanographic operations.The report represents a preliminary analysis of data collected during C-134A. The cruise log and data are available through SEA.

The tremendous success of this cruise is largely due to the efforts of the ship's crew. Captain Sean Bercaw infected the cruise with his usual "cool" energy and enthusiasm, and the sense of camaraderie he set among the entire ship's company made the trip a pleasure. First Mate John Hayward, though he had to leave us after two days, was on board long enough to make all at ease with his able leadership on deck. Eliza Garfield stepped up to First Mate and quickly infected her watch with her teaching style. Second Mate Virginia Land turned landlubbers into sailors in no time, and made it all fun. Third Mate Jeremy Bumagin stepped in at short notice, but fit in immediately. Engineer Mark Utterback not only kept all the ship's systems running, but brewed a mean cup of cappucino. Our Steward and Assistant Steward, Eric Gura and Sally McGee, kept a series of incredible meals coming out of the galley. Deckhand Matt Burke was always there to lend a hand for sailing or for science.

The fast-paced scientific program could not have been carried out without the hard work and skill of the assistant scientists. First Assistant Scientist Karen Gordon kept the lab and the Chief Scientist straightened out with skill, organization, and patience (even through an all-night phosphate run!). Simon Colley as Second Assistant Scientist motivated and energized his watch in the lab and on deck. Third Assistant Scientist Ellie Linen made it all look easy and looked like a veteran on only her second trip. Thanks to Pete Barsness for all his practical help as Curriculum Facilitator, and for helping us all keep it all in perspective.

The SEA Experience Program is funded by the National Science Foundation's Directorate for Education and Human Resources, through the Teacher Enhancement Program.

Finally but definitely *not* least, it was the teacher-participants who breathed life into this cruise. The willingness of experienced professionals to go back and become students again is nothing short of inspiring, and the chance to work with (and learn *from*) this group was a humbling experience for me and I'm sure for the entire staff. The exuberance and enthusiasm of this group certainly kept the entire staff on our toes, and sometimes out of breath! With camera and camcorders always at the ready, and breaking into song at every opportunity, this was a group who savored every moment of the trip,and gave us all memories to savor forever.

The overwhelming success of the SEA Experience program could not have been achieved without the efforts and dedication of the entire shipboard staff and participants. A few paragraphs cannot adequately express all that they brought to this program or everything we all took away from it, but every student of every teacher who stepped off the *Cramer* after SEA Experience is the beneficiary.

William R. Howard, Ph.D.
Chief Scientist

Itinerary of SSV *Corwith Cramer* Cruise C-134A

Port	Arrive	Depart
Woods Hole, MA		8/6/94
Woods Hole, MA	8/15/94	

Academic Program

A 24-hour science watch was kept throughout the nine days of *Cramer* cruise C-134A. Teams of three students and one science staff member tended the lab and carried out scientific operations during these watches. Students received hands-on training in the use of biological, geological, chemical and physical oceanographic sampling gear and data processing. Research data gathered during the cruise was used for group projects and for long-term SEA research programs. Routine underway oceanographic observations were made for ongoing projects as well as student projects. Meteorological observations were made and for the National Oceanographic and Atmospheric Administration.

Formal instruction took the form of lectures and demonstrations given by the science staff and covered a variety of oceanographic topics. Cruise C-134A was the culmination of a four-week program, beginning with a three-week course on shore in preparation for sea. On shore each student group carefully planned an investigation of an oceanographic environment on the continental shelf or slope, and carried it out at sea during the cruise. Students summarized their findings in presentations.

Scientific Program

This report is intended to document the scientific research program carried out during cruise C-134A of the SSV *Corwith Cramer*. The cruise track was planned to permit interdisciplinary study of several areas on the New England continental shelf and slope (Figure 1). Research took the form of data collection for ongoing SEA research programs and group projects, though many data sets were used for both. The projects covered a range of physical, chemical, biological, and geological oceanographic topics with the intention of giving students a taste of what scientific study of natural systems (in this case the ocean) is like. In particular, the complex interactions among different oceanic "systems" were emphasized, and became apparent as the cruise progressed and different project data sets were compared. This report only touches upon the highlights of the data. The research summarized in this report represents, in part, ongoing work by individuals and agencies, and these results should not be excerpted or cited without the written permission of the Chief Scientist.

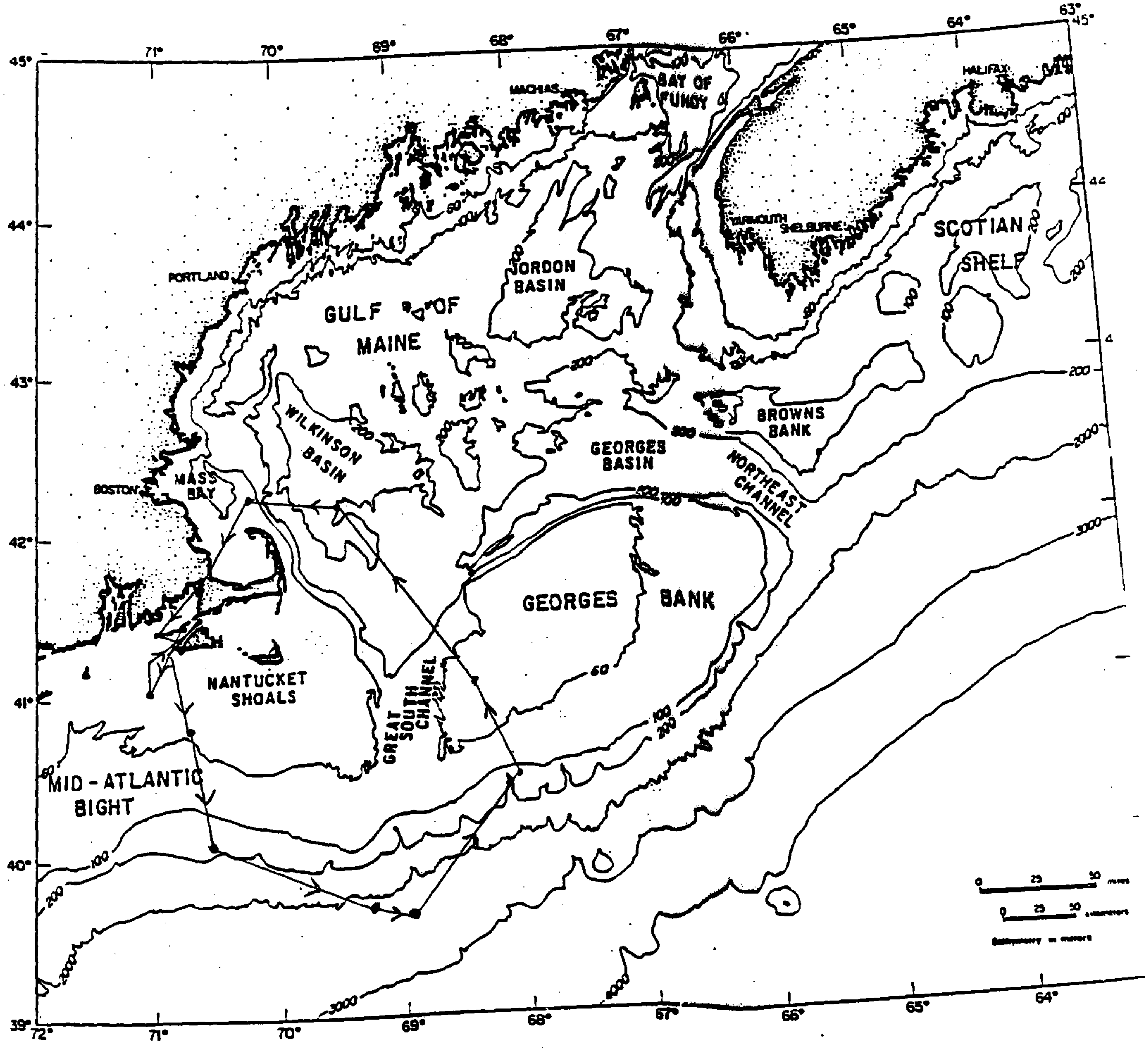

Figure 1: C134A cruise track, August 6-15, 1994.

Ship's Complement for SSV *Corwith Cramer* Cruise C-134A

Nautical Staff

Sean Bercaw	Captain
John Hayward	First Mate
Eliza Garfield	First Mate
Virginia Land	Second Mate
Jeremy Bumagin	Third Mate
Mark Utterback	Engineer
Eric Gura	Steward
Sally McGee	Assistant Steward
Matt Burke	Deckhand

Scientific Staff

William Howard	Chief Scientist
Karen Gordon	First Assistant Scientist
Simon Colley	Second Assistant Scientist
Ellie Linen	Third Assistant Scientist

Curriculum Facilitator

Peter Barsness	Stevens Point Senior High School, Stevens Point, WI

Teacher-Participants

Betsey Brighton	Hardin Middle School, Hardin, MT
Arthur Broga	Canastota High School, Canastota, NY
Trudy Call	Lake Highland Prep School, Orlando, FL
Sherill Caruana	Memorial School, Wilbraham, MA
Carol Cotter	Sacred Heart Public School, Lebanon, NH
Susan Glennon	Northdale Middle School, Coon Rapids, MN
Manisha Hariani	Roanoke Valley Governor's School for Science and Technology, Roanoke, VA
James Harris	Waterford School, Sandy, UT
Bernard Hermanson	Sumner Jr./Sr. High School, Sumner, IA
Diane Holloway	Klein High School, Klein, TX
Scott Hudson	Chase Elementary School, Cincinnati, OH
Lucia Kaempffe	Woodridge Elementary School, Stone Mountain, GA
Janet Langton	McDill Elementary School, Stevens Point, WI
Philip Lazzaro	Stoneham Middle School, Stoneham, MA
Donald McCullough	South Lawrence Elementary School, Loretto, TN
Vicky McLean	League Middle School, Greenville, SC
Ann Pegg	Wollaston Elementary School, Quincy, MA
Anne Pringle	St. Ann's School, Brooklyn, NY
Mark Springer	Canyon School, Canyon, CA
Annemarie Stilwell	English Valleys Community Schools, N. English, IA
Erica Wiberg	Eastern Middle School, Riverside, CT
Suzan Widmar	No. Barrington Elementary School, Barrington, IL
Cynthia Wilkie	Seminary Hill School, W. Lebanon, NH

Research Summary

The cruise track of C-134A was designed to sample several distinct oceanic environments of the continental shelf and slope waters off New England, including the mouth of Vineyard Sound, the "Mud Patch" on the outer continental shelf south of Martha's Vineyard, an "open ocean" site on the continental rise, the head of Oceanographer Canyon, a submarine canyon on the south flank of Georges Bank, and a shallow site on Georges Bank (see Figure 1). Every piece of oceanographic sampling gear was used ("deploy all toys!") in an extremely ambitious sampling program. Sampling at all these sites included a full range of water-column hydrographic sampling, including measuring temperature and salinity, and analyzing water for oxygen, chlorophyll-*a*, and phosphate[1]. Hydrocast stations utilized messenger-tripped Niskin bottles, and a Seabird CTD (conductivity-temperature-depth) logger. At each site phytoplankton were sampled using a 63-μm mesh net, and zooplankton were captured using 333-μm-mesh neuston nets (skimming the air-water interface), and one- and two-meter-diameter zooplankton nets. An otter trawl also sampled the benthic biota on Georges Bank. Geological sampling was accomplished using a Shipek grab, a 1.5-meter gravity core (at the Mud Patch and on the continental rise), a rock dredge (in Vineyard Sound), and Fisher scoops for small underway sediment samples. Other ongoing underway observations included bathythermograph measurements of water-column thermal structure and 3.5-kHz echo sounder recording of bathymetry and sub-bottom sedimentary features.

For data synthesis and presentation, the participants were divided three groups, each responsible for data collected at: 1) the inner shelf and Georges Bank, 2) the "Mud Patch" outer shelf site and Oceanographer Canyon, and 3) the open ocean site. The objectives for each group were to compare and contrast oceanographic conditions between their sites and those investigated by the other groups.

Inner Shelf and Georges Bank

Sediment sampling revealed sediment on the inner shelf that was relatively poorly sorted, with grains ranging from relict glacial pebbles and sand, to fine black organic-rich muds deposited recently. The Georges Bank sediments were relatively well sorted, consisting mainly of sand-sized grains. Fine grained sediments appear to be winnowed away by high-energy tidal currents, and the samples had surprisingly few biogenic particles.

The hydrographic properties of these two sites also showed interesting contrasts. The Inner Shelf site showed a shallow summer mixed layer with about 18 meters of 18 °C water (Figure 2), and slightly higher salinity than the Georges Bank site, despite Vineyard Sound's proximity to estuarine environments. Georges Bank showed virtually no stratification at all, probably due to the strong tidal mixing atop the bank (Figure 3). The chemical properties of both water columns are characterized by high oxygen concentrations, and chlorophyll maxima at 10 and 20 meters respectively (Figures 2 and 3). The appearance of a subsurface Deep Chlorophyll Maximum

[1] Note that although phosphate data are reported in the appendices, problems with reagents used in the analysis rendered the results inconsistent, and the phosphate data must be considered suspect.

Inner Shelf

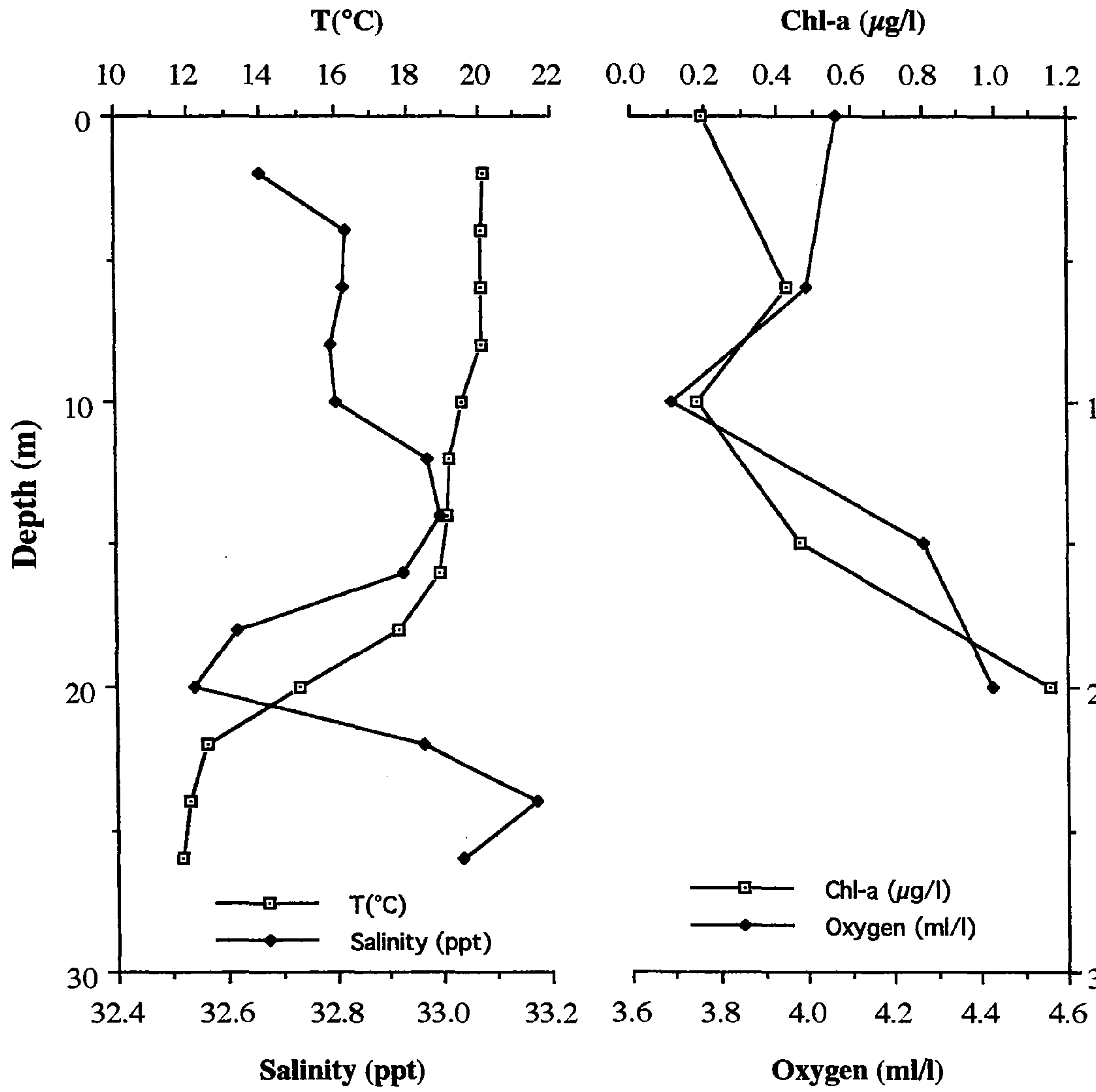

Figure 2. Inner Shelf Station hydrographic profiles.

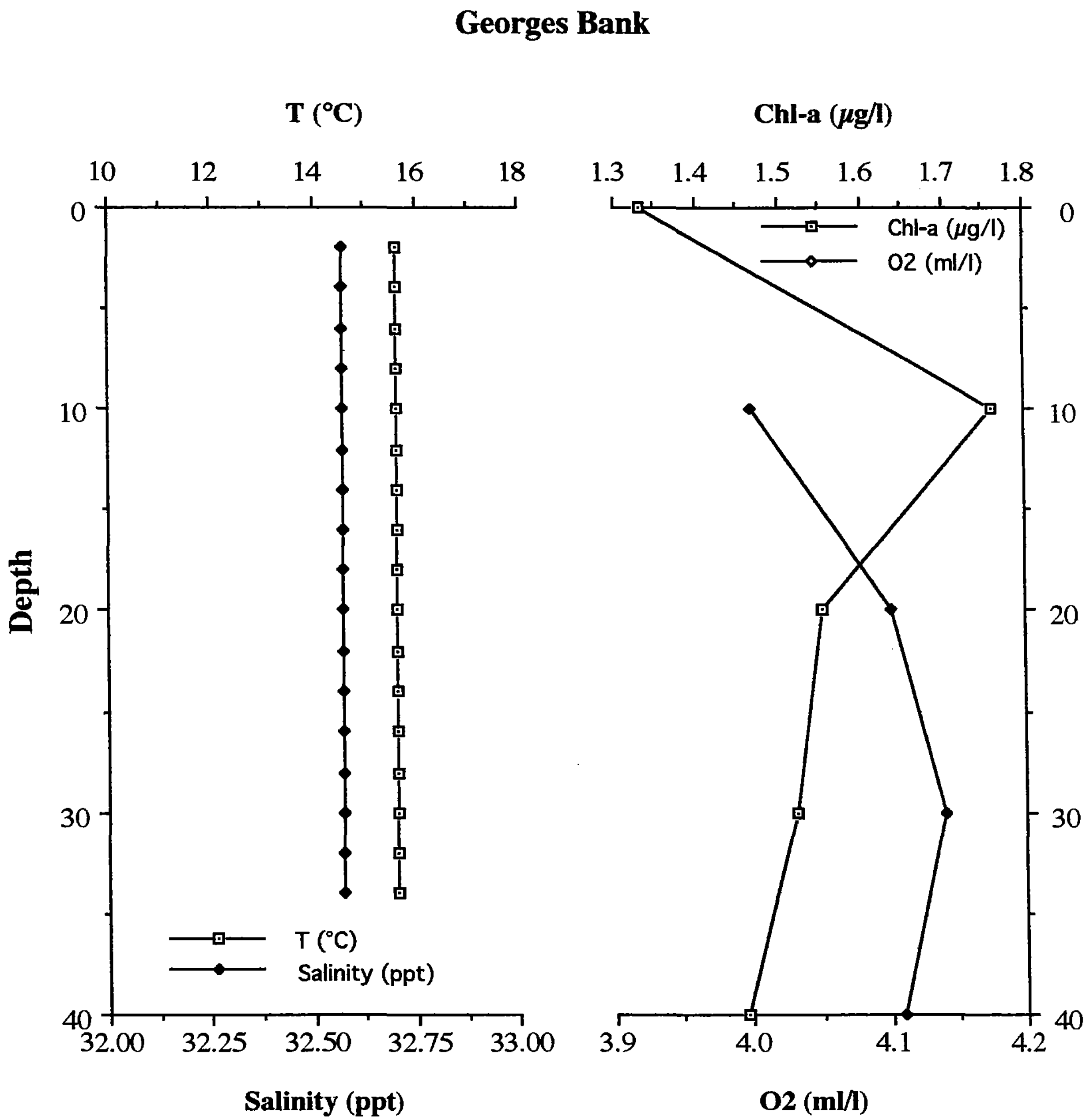

Figure 3. Georges Bank Station hydrographic profiles.

(DCM) at Georges Bank seems to be independent of thermal stratification.

The biota at both these sites showed fairly high zooplankton biomass, and an interesting ecological contrast is that the inner shelf site is dominated by copepods (like many coastal waters) whereas at Georges Bank we found an unusually high abundance of crab larvae in the megalops stage (Figure 4). An otter trawl on Georges Bank also showed a high abundance of juvenile crabs. Phytoplankton at the inner shelf site were, as usual, dominated by diatoms, whereas Georges Bank showed a high abundance of dinoflagellates, possibly because the bank waters were in the late summer stages of the seasonal successions often seen in the mid-latitudes. A two-meter net tow just north of Provincetown off Cape Cod was full of ctenophores (comb jellies), showing just how patchy the distribution of zooplankton is in shelf environments.

Mud Patch and Oceanographer Canyon

These two sites showed particularly interesting geological contrasts. The "Mud Patch" is an area of the outer shelf characterized by anomalously fine-grained sediments, thought to be transported by "residual" (non-tidal) currents from Georges Bank. The grain sizes we measured, however, suggested a more complex picture (Figure 5). Though the Mud Patch sediments did have a strong mode in grain sizes less than 63 microns ("silt"), they also showed a peak in abundance in the 250-500 μm fraction. One explanation for this pattern may the relatively high abundance of planktonic foraminifera, which are mostly greater than 125 microns. The gravity core we took at the Mud Patch had complete recovery, and appeared to be Holocene in age throughout its length, consistent with the post-Holocene onset of sedimentation after the glacial-age low of ~120 meters below present level. 3.5-kHz echo sounder traces throughout the outer shelf at and south of the Mud Patch show on the order 10-20 meters of acoustically transparent sediment underlain by strongly reflecting irregular topography (Figure 6).

The hydrography of the two outer shelf sites showed clear evidence of seasonal stratification, though with a deeper mixed layer than the inner shelf station and more strongly increasing salinity with depth (Figures 7 and 8). Both sites had distinct chlorophyll maxima, at 40 and 50 meters respectively, and it is notable that the absolute concentration of chlorophyll-*a* at the DCM's is of the same order as surface chlorophyll values at the inner shelf and Georges Bank (surface values of course were lower). The DCM at the Mud Patch corresponds with a dissolved oxygen maximum, which may indicate that actively-photosynthesizing phytoplankton are maintaining the DCM.

The biological characterization of the outer shelf also shows interesting diversity. The canyon site showed low abundances of phytoplankton (perhaps to be expected in late summer), and the Mud Patch site had high abundances of the cyanobacterium *Trichodesmium*, usually associated with nutrient-depleted pelagic environments. *Westward* data taken from these areas at about the same time do indeed show severe phosphate (and, presumably, nitrate) depletion. Zooplankton tows in the southern part of Oceanographer Canyon showed high abundances of salps, whereas the Mud Patch had a higher diversity, with the fauna including chaetognaths,

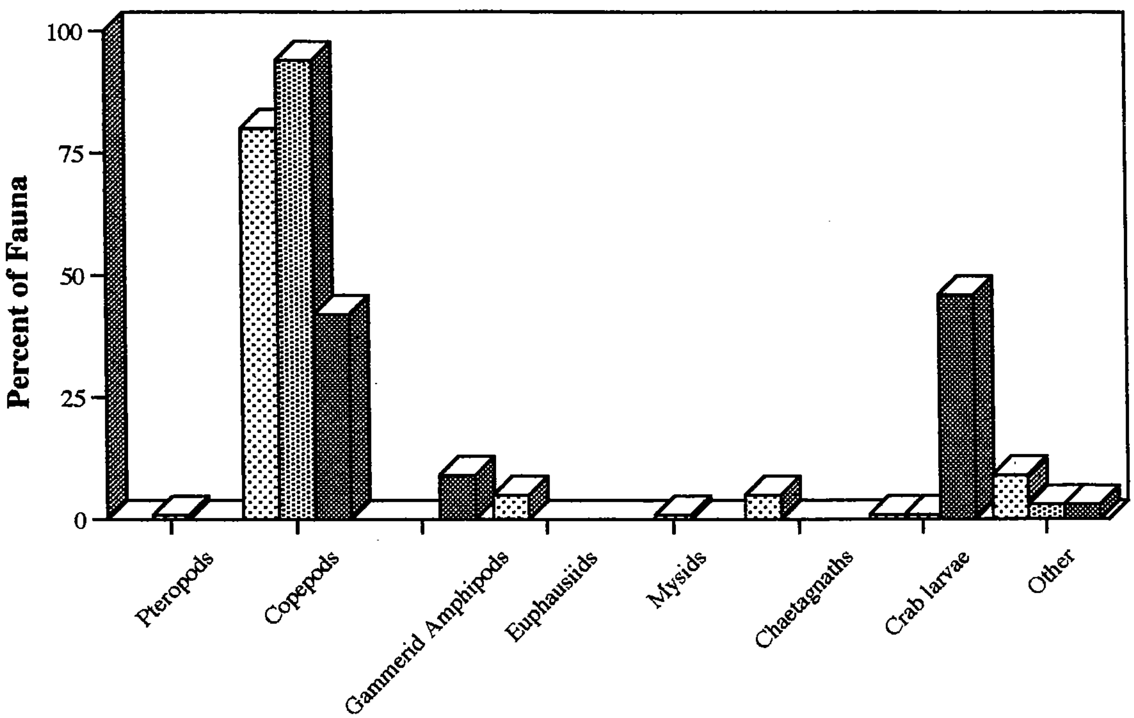

Figure 4. Zooplankton composition

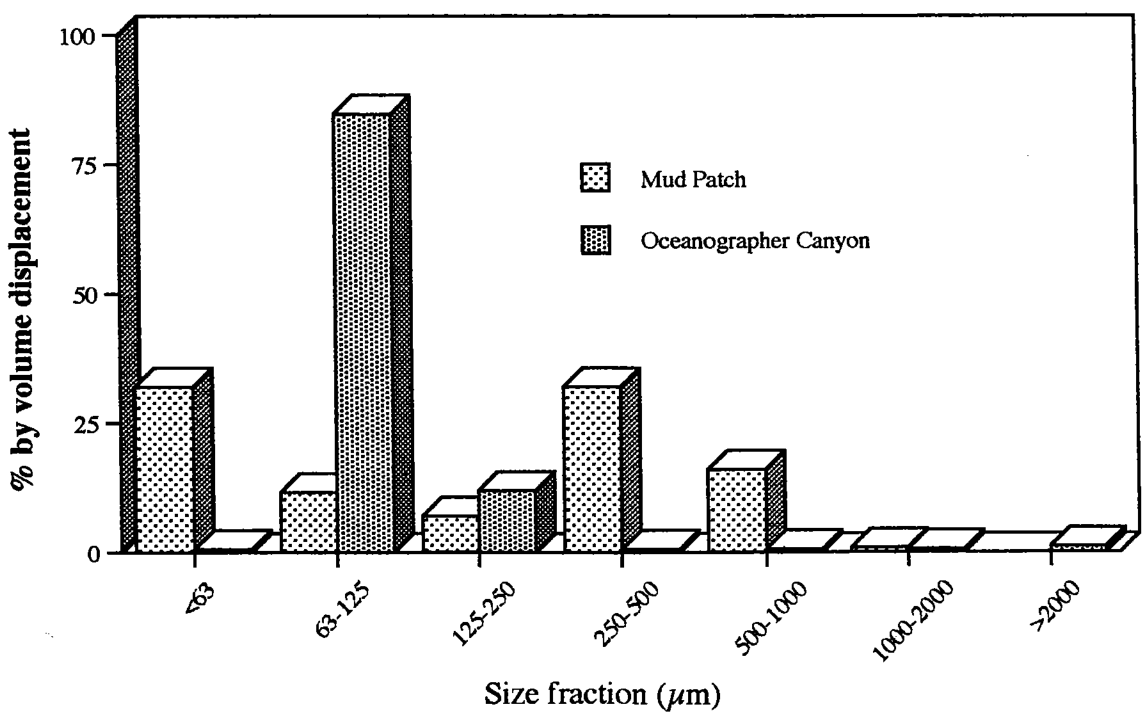

Figure 5. Sediment Grain Size Comparison.

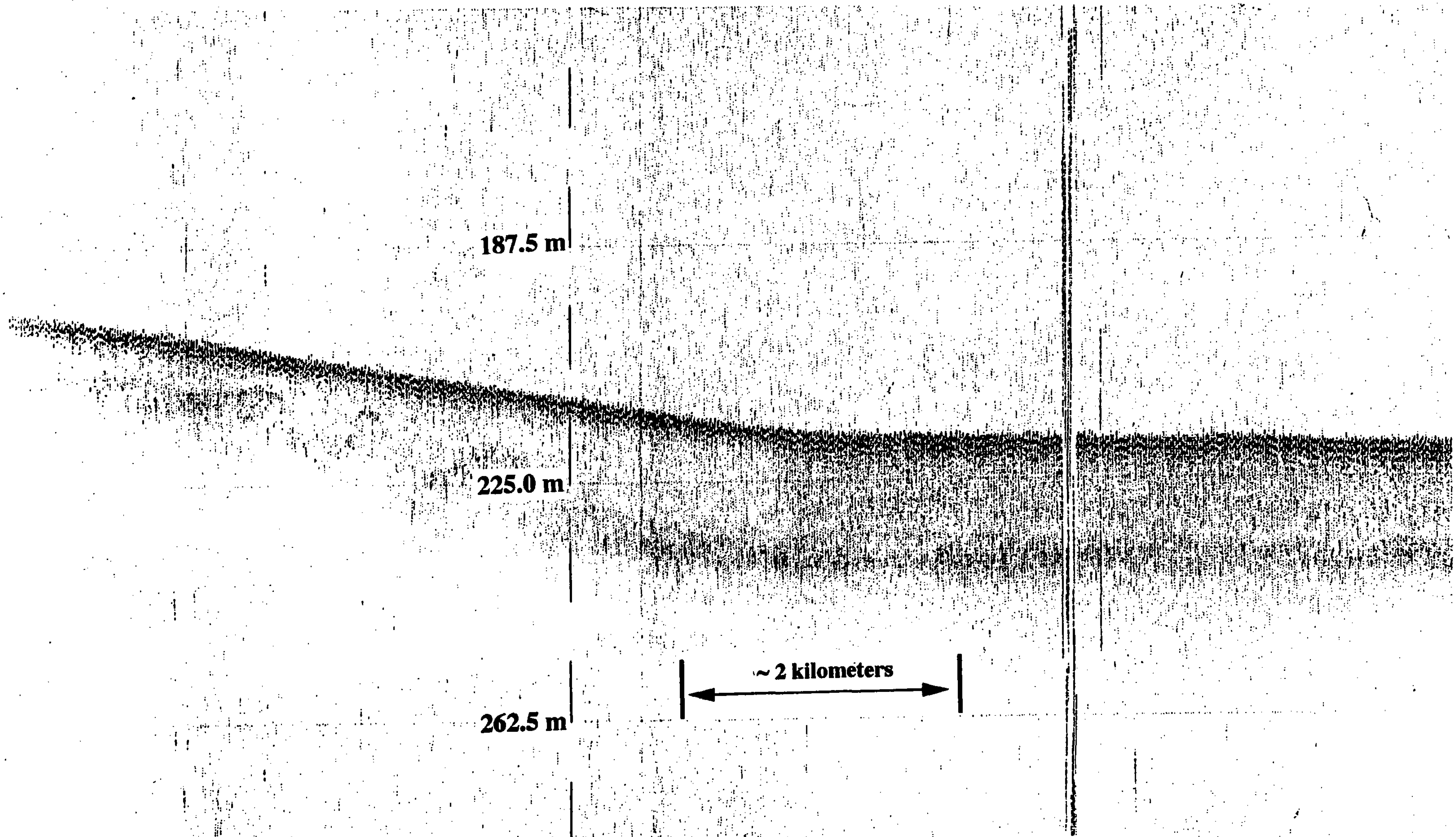

Figure 6. 3.5 kHz echo sounder record from the outer continental shelf south of the Mud Patch. Trace shows fine-grained soft sediments underlain by strongly-reflecting rough topography.

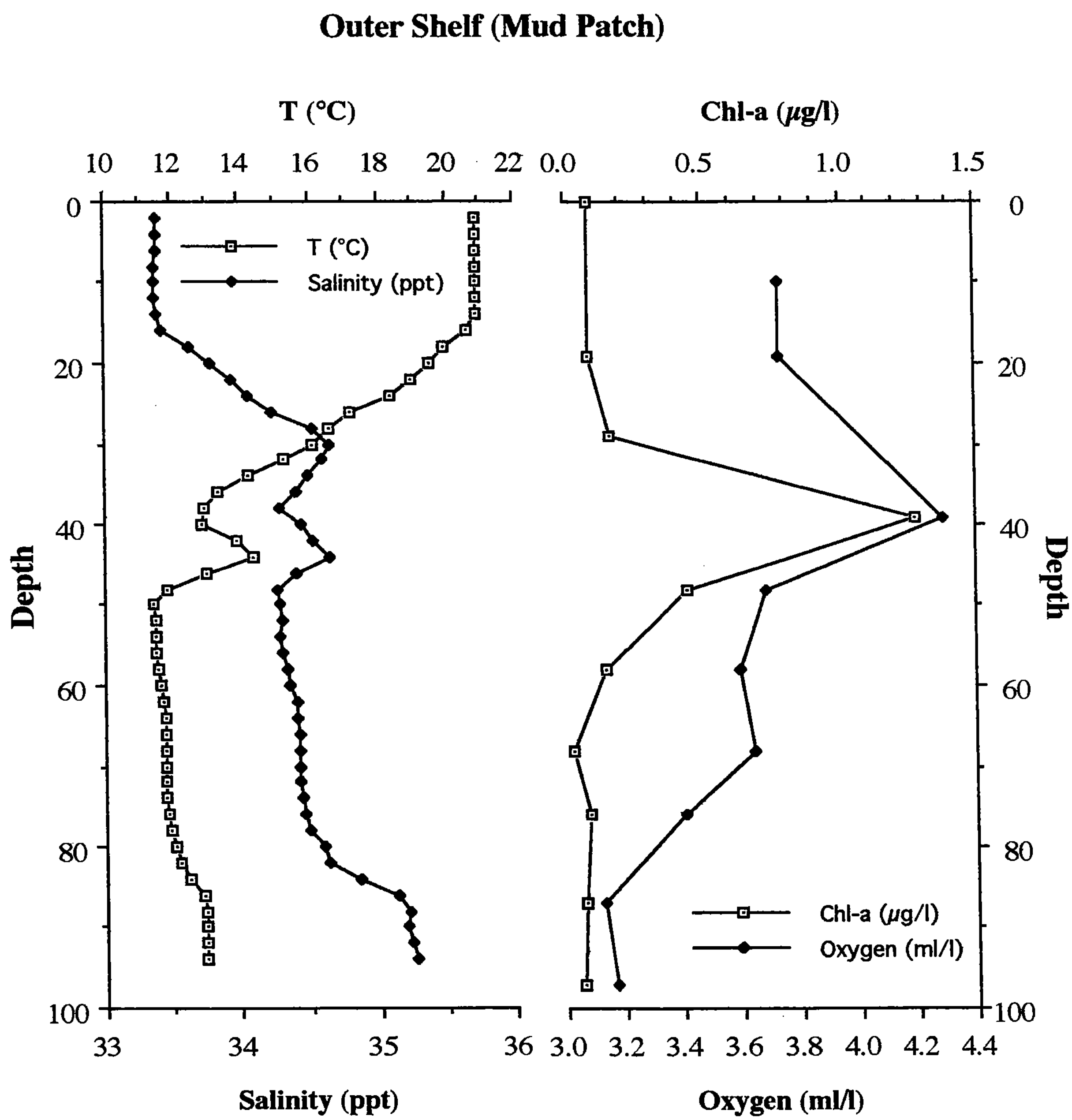

Figure 7. Outer Shelf (Mud Patch) Station hydrographic profiles.

Oceanographer Canyon

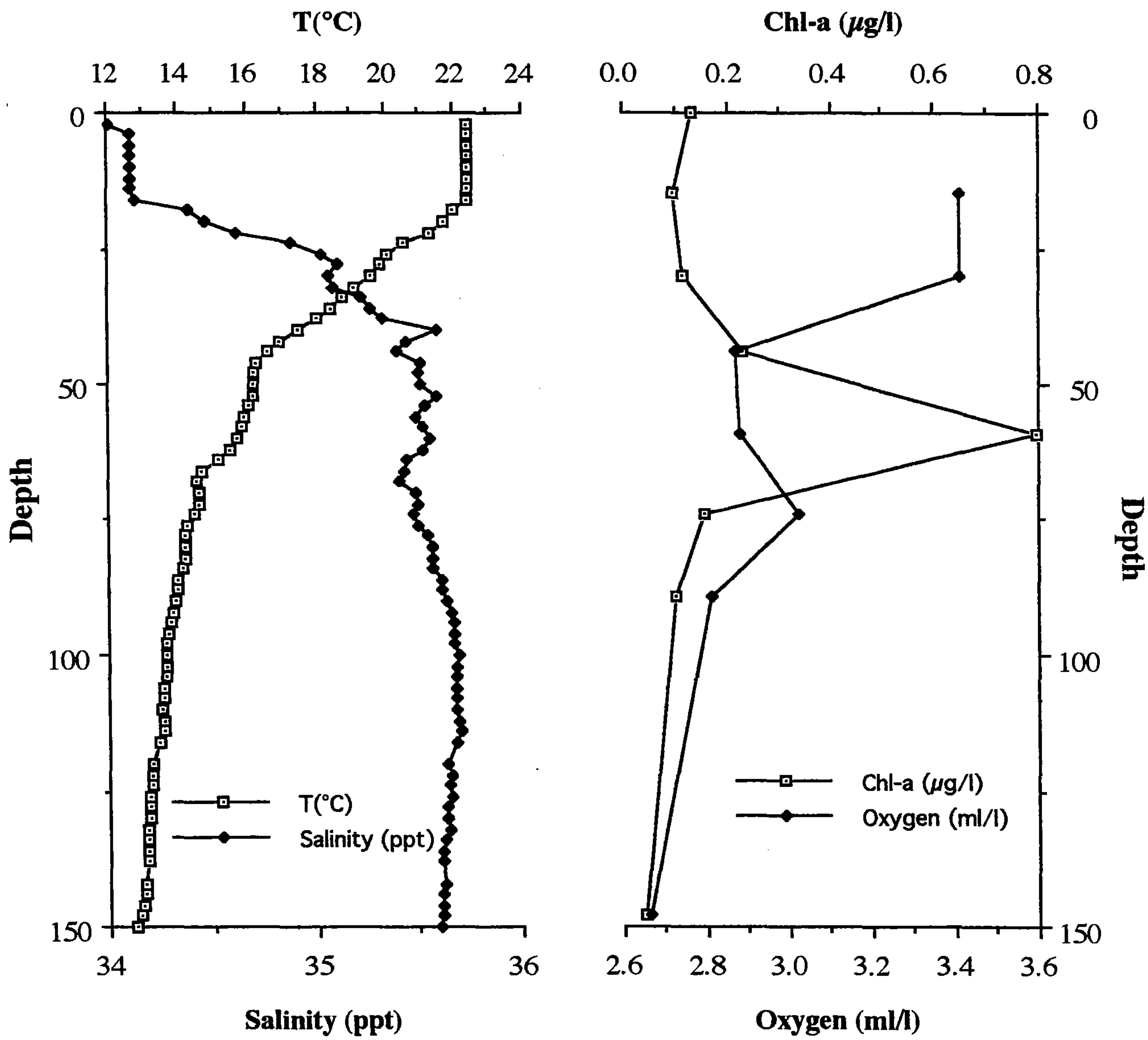

Figure 8. Oceanographer Canyon Station hydrographic profiles.

myctophids, juvenile flying fish, and other organisms usually seen in the subtropical gyre (these faunas may indicate an intrusion of Sargasso Sea water onto the shelf).

Open Ocean

This site provided a taste of what open ocean offshore pelagic environments are like, though the water properties and biota had a distinctly "slope water" influence. This site had a deeper mixed layer than other sites, and warmer surface temperatures (Figure 9). A distinct subsurface temperature and salinity minimum at 40 meters may reflect an intrusion of slope with a Labrador Current influence (usually found north in the Gulf of Maine). Deeper water masses show the signatures of the high-salinity gyre waters, and a subtle salinity maximum below 1500 meters, possibly upper North Water Deep Water carried southward along the continental margin by the Deep Western Boundary Undercurrent (see vertical profile in Figure 10, and T-S diagram in Figure 11). This station had a DCM at about 40 meters, and apparently a second DCM at about 100 meters. This deeper maximum is not unheard of, but a one-point peak has to be suspect. The upper DCM is associated with an oxygen maximum just above it at 30 meters, again suggesting net production at this level.

The sediments of this site show high percentages of silt and clay-sized particles, as well as a high diversity of well-preserved planktonic foraminifera. A gravity core taken from nearly 2500 meters on the continental rise, got full recovery, and appears to be completely Holocene in age. The excellent preservation of the forams is probably due to the depth of the core, well above the regional lysocline, and the faunal diversity is typical of such temperate sites, with high temporal (seasonal) and spatial (eddy intrusions, etc.) variability in the overlying water column.

Biological sampling revealed a number of elements of typically gyre biota, such as the pelagic macroalga *Sargassum*, and the siphonophoran *Physalia* (Portuguese Man O'War). Though the biomass was expected to be lower at this site than the others, a high abundance of salps actually resulted in a fairly high zooplankton standing crop at the time we sampled. One neuston tow taken nearby had mostly copepods - again, an indication of the patchiness of marine ecosystems. Phytoplankton, however, were dominated by diatoms, with the presence of smaller numbers of foraminifera and radiolaria.

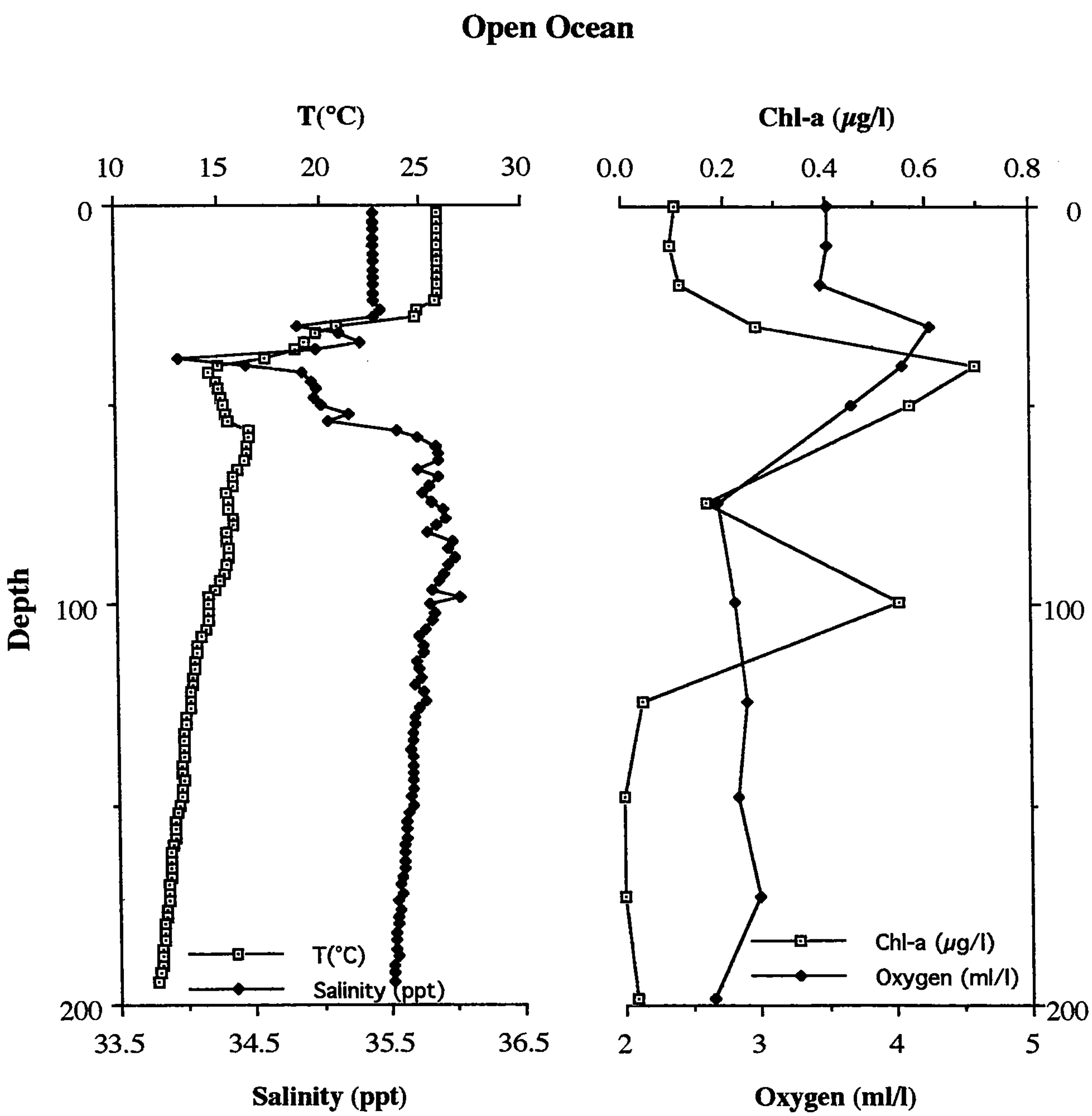

Figure 9. Open Ocean station hydrographic profiles

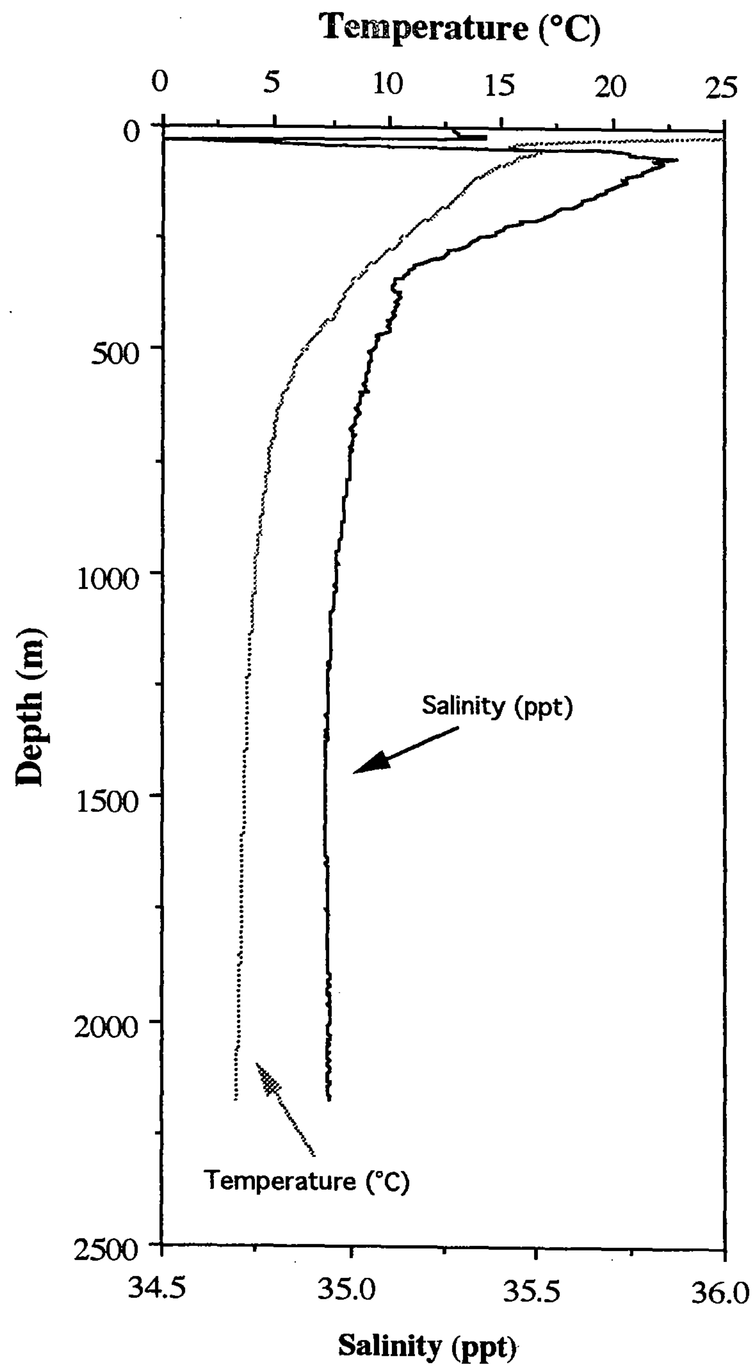

Figure 10. Temperature and salinity profiles, open ocean Station 11

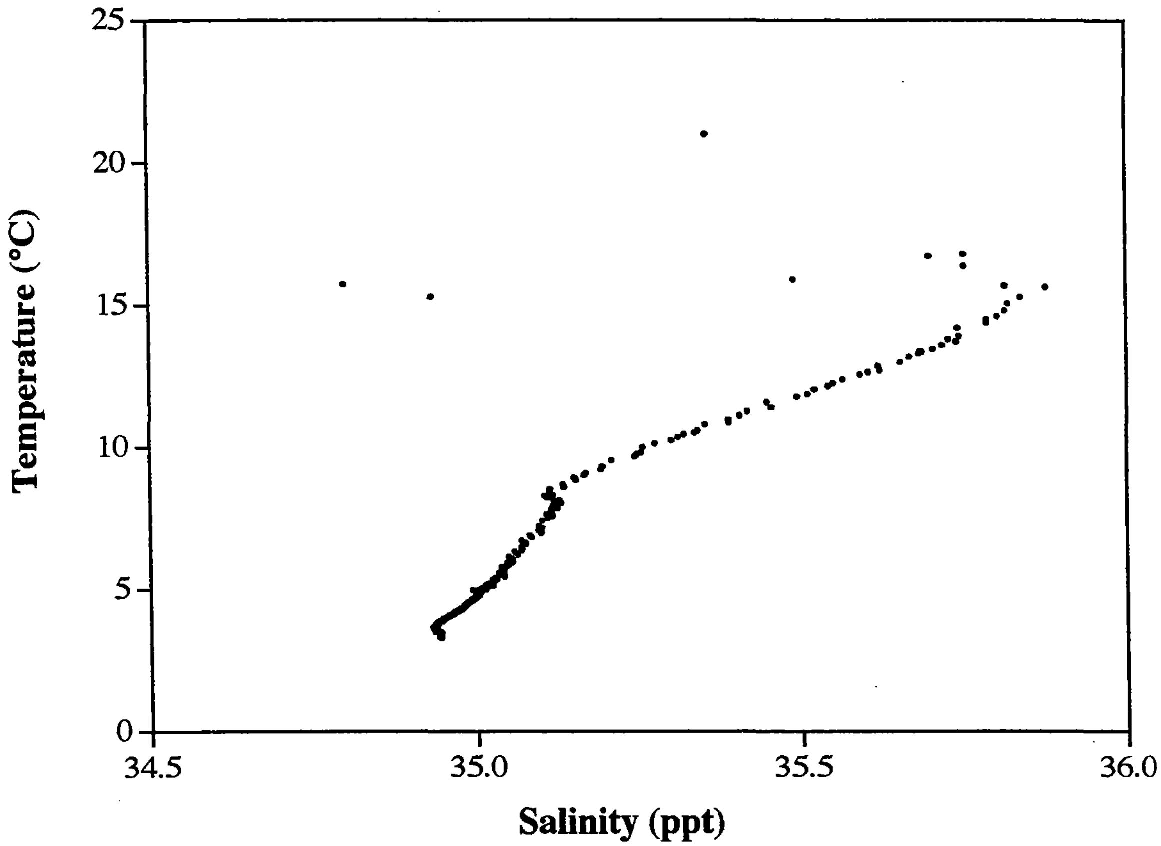

Figure 11. T-S diagram from Open Ocean Station

Appendix A: Station Locations

CTD:

STATION	DATE	TIME	LOG	LAT	LONG	LOCALE	CAST DEPTH
C-134A-002	07-Aug-94	1850	22.0	41.05	71.04	INNER SHELF	30
C-134A-009	09-Aug-94	0815	135.6	40.11	70.31	MUD PATCH	100
C-134A-011A	10-Aug-94	0242	211.5	39.37	69.00	OPEN OCEAN	2000
C-134A-011B	10-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	200
C-134A-013	11-Aug-94	0541	279.8	40.09	68.06	OC. CANYON	800
C-134A-013A	11-Aug-94	0720	279.8	40.09	68.05	OC. CANYON	800
C-134A-020	11-Aug-94	2105	333.0	40.53	68.27	GEORGES BANK	40

Hydrocast:

STATION	DATE	TIME	LOG	LAT	LONG	LOCALE
C-134A-002	07-Aug-94	1953	22.0	41.06	70.06	INNER SHELF
C-134A-009	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH
C-134A-011	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN
C-134A-011	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN
C-134A-013	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON
C-134A-020	11-Aug-94	2130	333.0	40.53	68.27	GEORGES BANK

Net Tows:

STATION	DATE	TIME	LOG	LAT	LONG	LOCALE	TOW DEPTH	TYPE
C-134A-002	07-Aug-94	2335	22.0	41.05	71.06	INNER SHELF	10	1-METER
C-134A-009	09-Aug-94	1041	135.6	40.10	70.34	MUD PATCH	30	1-METER
C-134A-011	10-Aug-94	1228	211.8	39.36	68.62	OPEN OCEAN	40	1-METER
C-134A-019	11-Aug-94	1531	302.1	40.29	68.10	OC. CANYON	75	1-METER
C-134A-021	11-Aug-94	2311	334.0	40.56	68.31	GEORGES BANK	25	1-METER
C-134A-023	12-Aug-94	1125	378.5	41.38	68.20	GEORGES BANK	51	OTTER
C-134A-026	12-Aug-94	1141	486.3	42.09	70.22	CAPE COD BAY	30	2-METER

Neuston Net:

STATION	DATE	TIME	LOG	LAT	LONG	LOCALE
C-134A-001A	07-Aug-94	1207	0.8	41.27	70.46	VINEYARD SOUND
C-134A-001B	07-Aug-94	1311	2.5	41.27	70.46	VINEYARD SOUND
C-134A-003A	08-Aug-94	0230	34.0	41.18	70.56	R.I. SOUND
C-134A-003B	08-Aug-94	0300	34.5	41.18	70.56	R.I. SOUND
C-134A-005A	08-Aug-94	1343	57.0	41.30	70.38	VINEYARD SOUND
C-134A-005B	08-Aug-94	1415	58.4	41.30	70.38	VINEYARD SOUND
C-134A-008A	09-Aug-94	0050	116.8	40.34	70.36	OUTER SHELF
C-134A-008B	09-Aug-94	0143	120.0	40.34	70.36	OUTER SHELF
C-134A-009A	09-Aug-94	1200	138.5	40.07	70.30	MUD PATCH
C-134A-009B	09-Aug-94	1230	139.0	40.07	70.30	MUD PATCH
C-134A-010A	10-Aug-94	0015	207.0	39.39	69.08	OPEN OCEAN
C-134A-010B	10-Aug-94	0052	208.0	39.39	69.08	OPEN OCEAN
C-134A-012A	10-Aug-94	1326	214.3	39.38	68.51	OPEN OCEAN
C-134A-012B	10-Aug-94	1355	214.3	39.38	68.51	OPEN OCEAN
C-134A-022A	11-Aug-94	0000	335.8	40.59	68.32	GEORGES BANK
C-134A-022B	11-Aug-94	0037	337.0	40.59	68.32	GEORGES BANK
C-134A-025	12-Aug-94	1425	385.5	41.54	68.33	GEORGES BANK

Appendix A: Station Locations

Phytoplankton Net:

STATION	DATE	TIME	LOG	LAT	LONG	LOCALE
C-134A-002	07-Aug-94	1902	22.0	41.06	71.05	INNER SHELF
C-134A-009	09-Aug-94	0825	135.7	40.12	70.30	MUD PATCH
C-134A-011	10-Aug-94	0645	211.5	39.36	68.58	OPEN OCEAN
C-134A-013	11-Aug-94	0648	280.0	40.09	68.06	OC. CANYON
C-134A-020	11-Aug-94	2150	331.0	40.89	68.43	GEORGES BANK

Sediment Sampling:

STATION	DATE	TIME	LOG	LAT	LONG	LOCALE	DEPTH	TYPE
C-134A-002	07-Aug-94	2105	22.0	41.07	71.06	INNER SHELF	128	SHIPEK
C-134A-004	08-Aug-94	0904	49.8	41.28	70.41	VINEYARD SOUND	22	DREDGE
C-134A-006	08-Aug-94	2030	90.5	41.03	70.48	VINEYARD SOUND	49	FISHER
C-134A-007	09-Aug-94	0005	115.0	40.37	70.38	OUTER SHELF	60	FISHER
C-134A-009	09-Aug-94	0745	135.8	40.12	70.31	MUD PATCH	125	SHIPEK
C-134A-009	09-Aug-94	0937	135.6	40.11	70.32	MUD PATCH	120	GRAVITY
C-134A-011	10-Aug-94	0655	211.5	39.36	68.59	OPEN OCEAN	2355	SHIPEK
C-134A-011	10-Aug-94	1100	211.5	39.36	68.53	OPEN OCEAN	2496	GRAVITY
C-134A-013	11-Aug-94	1017	289.0	40.20	68.06	OC. CANYON	354	SHIPEK
C-134A-014	11-Aug-94	1054	290.2	40.20	68.06	OC. CANYON	555	SHIPEK
C-134A-015	11-Aug-94	1140	291.8	40.20	68.08	OC. CANYON	906	SHIPEK
C-134A-016	11-Aug-94	1205	290.5	40.19	68.08	OC. CANYON	1008	SHIPEK
C-134A-017	11-Aug-94	1345	299.0	40.27	68.07	OC. CANYON	234	SHIPEK
C-134A-018	11-Aug-94	1450	301.8	40.29	68.10	OC. CANYON	315	SHIPEK
C-134A-020	11-Aug-94	2032	331.0	40.53	68.26	GEORGES BANK	43	SHIPEK
C-134A-024	12-Aug-94	1221	374.4	41.42	68.20	GEORGES BANK	60	SHIPEK

Bathythermographs:

STATION	DATE	TIME	LOG	LAT	LONG
BT-001	08-Aug-94	2022	89.7	41.04	70.49
BT-002	09-Aug-94	0011	111.5	41.36	70.37
BT-003	09-Aug-94	0330	130.0	40.20	70.31
BT-004	09-Aug-94	2000	182.7	39.50	69.41
BT-005	09-Aug-94	2330	203.3	39.41	69.13
BT-006	10-Aug-94	1837	238.5	40.01	68.33
BT-007	11-Aug-94	0320	272.5	41.18	68.07
BT-008	12-Aug-94	0652	358.0	41.27	68.28

Surface Stations:

STATION	DATE	TIME	LOG	LAT	LONG
SS-001	07-Aug-94	1405	4.3	41.23	70.51
SS-002	08-Aug-94	0646	42.7	41.25	70.48
SS-003	08-Aug-94	1600	63.0	41.29	70.43
SS-004	08-Aug-94	2022	89.7	41.03	70.48
SS-005	09-Aug-94	0011	115.0	40.37	70.37
SS-006	09-Aug-94	0330	130.0	40.20	70.31
SS-007	09-Aug-94	2000	182.7	39.50	69.41
SS-008	09-Aug-94	2330	203.3	39.41	69.13
SS-009	10-Aug-94	1837	238.5	40.01	68.53
SS-010	12-Aug-94	0646	257.8	41.27	68.27

Appendix B: Hydrocast Data Summary

Station	Date	Time	Log (nm)	Lat. (°N)	Long. (°W)	Locale	Bott#	Depth (m)	Corr. Depth (m)	T °C	Salinity (ppt)	Phosphate (µM/kg)*	Chlorophyll-a (µg/l)	Oxygen (ml/l)
2	07-Aug-94	1953	22.0	41.06	70.06	INNER SHELF	2	20	20	12.5	32.96	0.971	1.151	4.43
2	07-Aug-94	1953	22.0	41.06	70.06	INNER SHELF	3	15	15	19.0	32.99	0.012	0.462	4.27
2	07-Aug-94	1953	22.0	41.06	70.06	INNER SHELF	4	10	10	19.2	32.97	0.532	0.177	3.69
2	07-Aug-94	1953	22.0	41.06	70.06	INNER SHELF	5	6	6	20.1	32.83		0.424	4.00
2	07-Aug-94	1953	22.0	41.06	70.06	INNER SHELF	6	0	0	20.1	32.82		0.190	4.07
9	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH	1	100	97	13.0	35.24	1.093	0.059	3.17
9	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH	2	90	87	12.9	35.21	0.985	0.072	3.13
9	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH	3	80	76	11.9	34.49	0.839	0.083	3.41
9	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH	4	70	68	11.8	34.42	0.821	0.023	3.64
9	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH	5	60	58	11.6	34.33	0.905	0.147	3.59
9	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH	6	50	48	11.8	34.26	0.985	0.446	3.68
9	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH	7	40	39	12.9	34.28	0.650	1.280	4.29
9	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH	8	30	29	16.4	34.64	0.932	0.162	
9	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH	9	20	19	19.5	33.80	0.448	0.086	3.73
9	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH	10	10	10	20.9	33.38	2.460		3.73
9	09-Aug-94	0555	135.5	40.13	70.29	MUD PATCH	11	0	0	20.9	33.39	0.410	0.089	
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	1	200	198	11.8	35.50	1.313	0.025	2.65
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	2	175	173	12.4	33.56	1.875	0.000	2.99
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	3	150	148	13.1	35.67	1.452	0.000	2.84
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	4	125	124	13.5	35.78	1.205	0.037	2.91
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	5	100	99	14.4	35.82	0.870	0.545	2.82
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	6	75	74	15.5	35.84	0.901	0.165	2.70
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	7	50	50	15.2	35.01	0.557	0.565	3.69
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	8	40	40	15.1	34.46	2.938	0.696	4.07
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	9	30	30	20.9	34.84	0.166	0.264	4.28
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	10	20	20	25.9	35.41	0.180	0.113	3.48
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	11	10	10	25.9	35.41	0.324	0.098	3.53
11	11-Aug-94	0500	211.5	39.36	68.59	OPEN OCEAN	12	0	0	25.8	35.40	0.281	0.106	3.53
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	1	800	789	4.6	34.98	1.655		4.07
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	2	600	592	5.2	35.02	1.885		
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	3	450	444	6.5	35.08	0.284		3.12
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	4	300	296	8.7	35.17	2.819		4.00
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	5	150	148	12.9	35.61	1.254	0.043	2.66

Appendix B: Hydrocast Data Summary

Station	Date	Time	Log (nm)	Lat. (°N)	Long. (°W)	Locale	Bott#	Depth (m)	Corr. Depth (m)	T °C	Salinity (ppt)	Phosphate (μM/kg)*	Chlorophyll-a (μg/l)	Oxygen (ml/l)
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	6	90	89	14.0	35.64	0.964	0.101	2.81
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	7	75	74	14.5	35.47	0.797	0.156	3.02
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	8	60	59	15.7	35.55	0.389	0.797	2.88
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	9	45	44	16.6	35.39	0.242	0.230	2.87
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	10	30	30	19.6	35.06	0.082	0.113	3.41
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	11	15	15	22.4	34.12		0.098	3.41
13	11-Aug-94	0642	279.8	40.09	68.05	OC. CANYON	12	0	0	22.4	34.10	0.274	0.131	
20	11-Aug-94	2130	333.0	40.53	68.27	GEORGES BANK	1	40	38	15.6	32.57	0.598	1.460	4.11
20	11-Aug-94	2130	333.0	40.53	68.27	GEORGES BANK	2	30	28	15.6	32.57	0.650	1.521	4.14
20	11-Aug-94	2130	333.0	40.53	68.27	GEORGES BANK	3	20	19	15.6	32.57	0.251	1.552	4.10
20	11-Aug-94	2130	333.0	40.53	68.27	GEORGES BANK	4	10	9	15.6	32.57	0.678	1.760	4.00
20	11-Aug-94	2130	333.0	40.53	68.27	GEORGES BANK	5	0	0	15.6	32.57	0.912	1.332	

Appendix C: Net Tow Data

Net Tow:

STATION	DATE	TIME	LOG	LAT	LONG	LOCALE	TOW DEPTH	TYPE	ZOOPL. (ML)
C-134A-002	07-Aug-94	2335	22.0	41.05	71.06	INNER SHELF	10	1-METER	525
C-134A-009	09-Aug-94	1041	135.6	40.10	70.34	MUD PATCH	30	1-METER	115
C-134A-011	10-Aug-94	1228	211.8	39.36	68.62	OPEN OCEAN	40	1-METER	8500
C-134A-019	11-Aug-94	1531	302.1	40.29	68.10	OC. CANYON	75	1-METER	6600
C-134A-021	11-Aug-94	2311	334.0	40.56	68.31	GEORGES BANK	25	1-METER	600
C-134A-023	12-Aug-94	1125	378.5	41.38	68.20	GEORGES BANK	51	OTTER	
C-134A-026	12-Aug-94	1141	486.3	42.09	70.22	CAPE COD BAY	30	2-METER	7500

Neuston Net:

STATION	DATE	TIME	LOG	LAT	LONG	LOCALE	DIST. (m)	PLASTIC PIECES	ZOOPL. (ML)
C-134A-001A	07-Aug-94	1207	0.8	41.27	70.46	VINY. SOUND	1852	1	42.0
C-134A-001B	07-Aug-94	1311	2.5	41.27	70.46	VINY. SOUND	1574	3	30.0
C-134A-003A	08-Aug-94	0230	34.0	41.18	70.56	R.I. SOUND	1852	9	125.0
C-134A-003B	08-Aug-94	0300	34.5	41.18	70.56	R.I. SOUND	1852	16	235.0
C-134A-005A	08-Aug-94	1343	57.0	41.30	70.38	VINY. SOUND	1852	0	65.0
C-134A-005B	08-Aug-94	1415	58.4	41.30	70.38	VINY. SOUND	1852	0	315.0
C-134A-008A	09-Aug-94	0050	116.8	40.34	70.36	OUTER SHELF	1852	4	110.0
C-134A-008B	09-Aug-94	0143	120.0	40.34	70.36	OUTER SHELF	1852	0	75.0
C-134A-009A	09-Aug-94	1200	138.5	40.07	70.30	MUD PATCH	926	0	145.0
C-134A-009B	09-Aug-94	1230	139.0	40.07	70.30	MUD PATCH	1482	2	248.0
C-134A-010A	10-Aug-94	0015	207.0	39.39	69.08	OPEN OCEAN	1852	0	87.0
C-134A-010B	10-Aug-94	0052	208.0	39.39	69.08	OPEN OCEAN	1852	0	95.0
C-134A-012A	10-Aug-94	1326	214.3	39.38	68.51	OPEN OCEAN	1852	12	30.0
C-134A-012B	10-Aug-94	1355	214.3	39.38	68.51	OPEN OCEAN	1852	0	105.0
C-134A-022A	11-Aug-94	0000	335.8	40.59	68.32	GEORGES BANK	1852	1	410.0
C-134A-022B	11-Aug-94	0037	337.0	40.59	68.32	GEORGES BANK	1852	0	180.0
C-134A-025	12-Aug-94	1425	385.5	41.54	68.33	GEORGES BANK	1852	0	15.0

Phytoplankton Net:

STATION	DATE	TIME	LOG	LAT	LONG	LOCALE	COMPOSITION
C-134A-002	07-Aug-94	1902	22.0	41.06	71.05	INNER SHELF	Pennate diatoms
C-134A-009	09-Aug-94	0825	135.7	40.12	70.30	MUD PATCH	Diatoms, cyanobacteria
C-134A-011	10-Aug-94	0645	211.5	39.36	68.58	OPEN OCEAN	Diatoms, dinoflagellates
C-134A-013	11-Aug-94	0648	280.0	40.09	68.06	OC. CANYON	Dinoflagellates, centric diatoms
C-134A-020	11-Aug-94	2150	331.0	40.89	68.43	GEORGES BANK	Dinoflagellates, pennate diatoms

Appendix D: Hourly Observations

Date	Time	Log (nm)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Temperature (°C)	Depth (m)
07-Aug-94	1000		41.28	70.45	1022.0	22.1	
07-Aug-94	1100		41.28	70.45	1022.3	22.5	
07-Aug-94	1200		41.28	70.45	1022.0	21.7	
07-Aug-94	1400	4.3	41.23	70.51	1021.7	19.9	
07-Aug-94	1500	7.8	41.19	70.55	1021.5	18.8	33
07-Aug-94	1620	12.7	41.15	70.59	1021.5	18.7	41
07-Aug-94	1700	13.6	41.13	71.01	1021.5	18.1	35
07-Aug-94	1800	19.5	41.08	71.04	1021.4	18.2	35
07-Aug-94	2300	22.0	41.06	71.06	1022.5	0.0	34
08-Aug-94	0100	26.0	41.10	71.02	1022.2	18.5	32
08-Aug-94	0200	32.0	41.15	70.58	1022.0	18.1	35
08-Aug-94	0300	34.5	41.18	70.55	1021.5	18.2	33
08-Aug-94	0400	36.8	41.20	70.54	1021.8	18.3	31
08-Aug-94	0500	38.8	41.22	70.52	1021.8	18.3	26
08-Aug-94	0600	40.1	41.24	70.51	1022.0	19.7	26
08-Aug-94	0700	43.5	41.26	70.48	1022.0	21.5	21
08-Aug-94	0800	45.5	41.26	70.45	1022.2	21.7	10
08-Aug-94	0900	46.5	41.05	70.05	1017.0	0.0	20
08-Aug-94	1000	49.8	41.28	70.41	1022.4	22.1	28
08-Aug-94	1100	50.9	41.29	70.40	1022.5	21.5	20
08-Aug-94	1200	51.5	41.30	70.39	1022.3	0.0	21
08-Aug-94	1300	55.0	41.29	70.40	1022.0	21.5	21
08-Aug-94	1400	57.5	41.29	70.37	1022.0	21.6	24
08-Aug-94	1500	60.0	41.29	70.37	1021.9	21.8	19
08-Aug-94	1600	63.0	41.29	70.43	1021.0	21.9	17
08-Aug-94	1700	66.0	41.25	70.48	1021.5	19.6	20
08-Aug-94	1800	72.4	41.20	70.52	1021.0	18.8	23
08-Aug-94	1900	72.3	41.14	70.06	1021.0	20.2	19
08-Aug-94	2000	87.0	41.06	70.40	1021.0	19.6	36
08-Aug-94	2100	92.8	41.00	70.47	1021.5	19.2	48
08-Aug-94	2200	99.8	40.53	70.44	1021.8	21.0	51
08-Aug-94	2300	107.0	40.46	70.41	1023.0	19.6	58
09-Aug-94	0000	114.5	40.37	70.37	1022.2	19.7	61
09-Aug-94	0100	117.3	40.34	70.36	1021.1	19.7	69
09-Aug-94	0200	120.5	40.34	71.33	1021.0	20.7	70
09-Aug-94	0300	127.1	40.24	70.32	1020.5	20.7	83
09-Aug-94	0400	135.4	40.15	70.29	1021.0	21.0	150
09-Aug-94	0700	137.5	40.12	70.30	1020.0	21.2	124
09-Aug-94	0910	135.7	40.11	70.37	1020.5	21.0	119
09-Aug-94	1100	136.5	40.09	70.32	1022.0	21.1	118
09-Aug-94	1200	138.5	40.07	70.30	1021.5	21.5	115
09-Aug-94	1300	139.8	40.06	70.29	1021.0	21.7	121

Appendix D: Hourly Observations

Date	Time	Log (nm)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Temperature (°C)	Depth (m)
09-Aug-94	1400	145.5	40.03	70.24	1021.5	21.9	198
09-Aug-94	1600	157.7	39.58	70.11	1020.1	22.3	540
09-Aug-94	1700	164.3	39.56	70.03	1020.0	22.4	292
09-Aug-94	1800	170.9	39.54	69.56	1020.0	22.2	638
09-Aug-94	1900	175.0	39.52	69.49	1020.0	22.6	630
09-Aug-94	2000	182.7	39.52	69.41		23.3	900
09-Aug-94	2100	188.4	39.48	69.31	1020.0	22.1	1766
09-Aug-94	2200	195.5	39.45	69.23	1019.7	24.6	1912
09-Aug-94	2300	200.5	39.42	69.17	1019.0	26.9	1937
10-Aug-94	0200	211.0	39.37	69.01	1019.2	25.1	2310
10-Aug-94	0300	211.5	39.36	68.59	1019.8	25.8	2310
10-Aug-94	0400		39.36	68.59	1019.5	25.6	2310
10-Aug-94	0500		39.36	68.58	1019.5	25.6	2325
10-Aug-94	0600		39.36	68.57	1020.0	25.8	2355
10-Aug-94	0700		39.36	68.57	1020.5	25.7	2430
10-Aug-94	0900		39.36	68.54	1021.0	25.6	2767
10-Aug-94	1000		39.36	68.53	1021.5	26.2	
10-Aug-94	1100		39.36	68.53	1021.5	26.8	
10-Aug-94	1300	213.3	39.37	68.52	1021.1	25.6	2520
10-Aug-94	1455	219.5	37.43	68.50	1020.5	24.7	2322
10-Aug-94	1600	225.5	39.50	68.46	1020.0	25.0	2139
10-Aug-94	1710	231.0	39.55	68.40	1020.5	24.2	
10-Aug-94	1800	235.5	39.58	68.36	1020.0	24.6	
10-Aug-94	1900	241.7	40.03	68.30	1020.0	23.2	1200
10-Aug-94	2000	246.3	40.07	68.25	1020.0	23.4	465
10-Aug-94	2100	251.5	40.09	68.21	1021.0	21.9	480
10-Aug-94	2200	256.1	40.12	68.19	1022.0	21.3	237
10-Aug-94	2300	259.5	40.15	68.17	1022.0	21.1	
11-Aug-94	0000	264.4	40.19	68.14	1021.5	22.4	150
11-Aug-94	0100	266.6	40.20	68.10	1021.5	20.4	177
11-Aug-94	0200	269.4	40.20	68.07	1020.3	20.5	690
11-Aug-94	0300	270.5	40.20	68.06	1020.0	20.0	375
11-Aug-94	0400	276.0	40.13	68.07	1021.0	20.5	844
11-Aug-94	0500	279.8	40.10	68.06	1020.5	21.9	1400
11-Aug-94	0600		40.09	68.06	1021.5	21.8	1572
11-Aug-94	0700	279.9	40.09	68.05	1021.8	22.5	1788
11-Aug-94	0800	279.9	40.09	68.05	1021.7	22.3	
11-Aug-94	0900	282.7	40.12	68.05	1021.0	21.0	
11-Aug-94	1000	289.0	40.19	68.05	1022.0	20.1	367
11-Aug-94	1100	290.5	40.19	68.07	1023.0	20.9	555
11-Aug-94	1200	290.7	40.19	68.08	1023.0	21.1	1008
11-Aug-94	1300	295.8	40.23	68.08	1023.0	20.7	465

Appendix D: Hourly Observations

Date	Time	Log (nm)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Temperature (°C)	Depth (m)
11-Aug-94	1400				1022.6	22.4	195
11-Aug-94	1600	302.2	40.28	68.09	1024.5	22.4	135
11-Aug-94	1700	311.0	40.35	68.14	1022.5	22.2	108
11-Aug-94	1800	313.6	40.42	68.18	1022.5	19.6	66
11-Aug-94	1900	323.5	40.43	68.20	1022.5	17.0	40
11-Aug-94	2000	331.0	40.51	68.24	1022.5	15.9	46
11-Aug-94	2200	333.0	40.53	27.60	1023.0	15.9	49
11-Aug-94	2300	333.4	40.55	68.29	1023.0	15.9	46
12-Aug-94	0000	335.8	40.59	68.32	1023.0	15.9	49
12-Aug-94	0100	338.0	41.03	68.32	1023.0	16.0	43
12-Aug-94	0200	341.5	41.09	68.32	1023.5	15.9	57
12-Aug-94	0300	344.9	41.14	68.31	1023.1	15.0	60
12-Aug-94	0400	348.7	41.19	68.29	1023.0	14.2	58
12-Aug-94	0500	351.7	41.21	68.27	1023.0	14.8	71
12-Aug-94	0600	354.7	41.24	68.29	1023.8	14.3	76
12-Aug-94	0700	358.5	41.27	68.27	1024.0	14.7	76
12-Aug-94	0800	364.5	41.33	68.24	1024.2	13.2	59
12-Aug-94	0900	368.3	41.37	68.23	1024.5	14.6	18
12-Aug-94	1000	368.5	41.39	68.23	1024.5	13.7	23
12-Aug-94	1100	374.1	41.30	68.20	1025.0	15.5	50
12-Aug-94	1300	374.8	41.46	68.23	1025.8	18.0	198
12-Aug-94	1400	383.1	41.53	68.31	1024.8	19.7	177
12-Aug-94	1500	391.1	41.57	68.38	1024.5	19.7	182
12-Aug-94	1700	395.5	41.58	68.44	1024.0	19.8	148
12-Aug-94	1800	399.0	41.59	68.48	1024.0	0.0	164
12-Aug-94	1900	401.9	42.01	68.52	1023.0	20.5	164
12-Aug-94	2000	405.3	42.02	68.56	1024.0	20.6	128
12-Aug-94	2100	410.0	42.02	68.56	1024.0	20.4	181
12-Aug-94	2200	415.0	42.04	69.13	1023.0	20.6	193
12-Aug-94	2300	421.0	42.05	69.19	1023.4	20.1	210
13-Aug-94	0000	426.8	42.07	69.27	1023.0	20.8	
13-Aug-94	0100	433.3	42.08	69.36	1022.0	20.3	
13-Aug-94	0300	442.0	42.10	69.48	1021.5	19.5	141
13-Aug-94	0400	446.5	42.08	69.54	1020.5	18.3	162
13-Aug-94	0500	451.7	42.08	70.00	1020.0	17.9	96
13-Aug-94	0600	457.0	42.08	70.10	1020.0	17.4	45
13-Aug-94	0700	464.0	42.10	70.14	1020.0	18.1	54
13-Aug-94	0800	468.8	42.13	70.18	1019.3	16.6	47
13-Aug-94	0900	471.5	42.18	70.18	1018.8	17.0	35
13-Aug-94	1000	476.0	42.18	70.19	1019.0	16.0	44
13-Aug-94	1100	482.5			1017.6		
13-Aug-94	1200	486.5	42.09	70.23	1016.7		60

Appendix D: Hourly Observations

Date	Time	Log (nm)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Temperature (°C)	Depth (m)
13-Aug-94	1300	492.0	42.04	70.26	1016.5	17.5	95
13-Aug-94	1400	498.5	41.57	70.28	1015.6	18.3	34
13-Aug-94	1600	507.9	41.47	70.28	1015.0	18.5	17
13-Aug-94	1700	516.5	41.40	70.41	1015.0	22.3	12
13-Aug-94	1800	520.0	41.37	70.42	1015.0	22.7	12
13-Aug-94	2100	536.0	41.26	70.59	1019.0	19.8	55
13-Aug-94	2200	541.5	41.29	70.55			
13-Aug-94	2300	548.0	41.21	70.46	1014.5	19.5	49
14-Aug-94	0000		41.21	70.47	1014.0	19.1	31
14-Aug-94	1300	555.4	41.28	70.42	1009.0	21.9	