Report of Scientific Activities of the SSV *Corwith Cramer*

SEA Cruise C-133A
Oceanography of the Gulf of Maine

Sea Education Association/Shoals Marine Laboratory

June 20 - June 29, 1994; Woods Hole, MA to Appledore Island, ME

Sea Education Association, Woods Hole, Massachusetts

Introduction:

This report outlines the scientific investigations conducted aboard the SSV *Corwith Cramer* during cruise C-133A, Oceanography of the Gulf of Maine, offered jointly by the Sea Education Association (SEA) and the Shoals Marine Laboratory (SML). The academic objective of this three-week course was to provide high school students with a practical introduction to oceanographic field research. This was accomplished in two parts, first the open-ocean environment of the waters surrounding Cape Cod were studied during a ten day cruise aboard the *Corwith Cramer*. Under the supervision of SEA scientists, students used modern oceanographic sampling gear to collect geological, physical, chemical and biological data pertinent to our cruise track (Figure 1). These data were then analyzed and interpreted by the students, who summarized their findings in oral presentations at the end of the cruise. Much of the data collected during this cruise are presented in this report. The cruise was followed by seven days at the Shoals Marine Laboratory on Appledore Island. There, students explored the extensive tide pools for which the island is famous, and performed field experiments aimed at understanding the ecology of the rocky intertidal zone.

In addition to the scientific work performed while at sea, the students stood regular watches on deck and were directly involved in maneuvering the vessel, setting and striking sails, plotting the vessel's position, recording local meteorological conditions and practicing basic navigational techniques. Each student kept a running logbook detailing both the scientific and nautical aspects of the cruise.

Cruise Narrative:

Cruise C-133A began when the final line was released from Dyers dock in Woods Hole on the afternoon of Monday, 20 June. Carrying a crew of 13 and 23 students, Captain Mark Crutcher took the helm for our short transit to the first night anchorage in Tarpaulin Cove. As with every SEA cruise, the first day was spent in shipboard orientation and safety drills, but by noon on Tuesday, 21 June, the *Corwith Cramer* was under sail - on a broad reach to the south of Martha's Vineyard. Our plan was to undertake a broad circumnavigation of Cape Cod, concentrating on comparative studies of three regions, a warm core eddy off the Gulf Stream that was within a day's sail to the south (Figure 4), the productive waters of George's Bank and the Gulf of Maine.

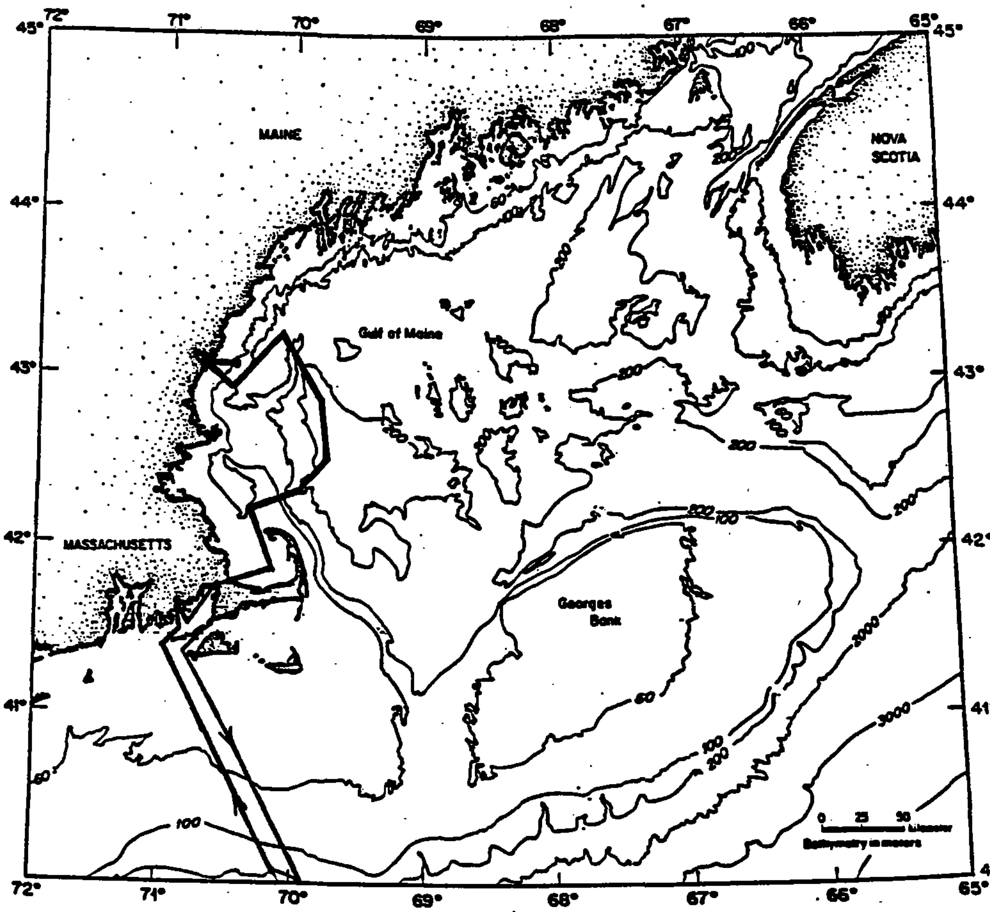


Figure 1. Gulf of Maine Bathymetric Chart and C-133A Cruise Track.

With students standing watch, our introduction to shipboard science began immediately. A series of Shipek grabs and Fisher scoops retrieved sediment from the continental shelf as we made our way into the deeper waters of the continental slope. A daytime neuston tow clearly demonstrated zooplankton patchiness by yielding an abundance of crab larvae (84%), with copepods a distant second (15%). After sailing 114 nautical miles by taffrail log, a shallow hydrocast (C133A-006; z = 150m) with seven Niskin bottles obtained samples for our examination of the physical/chemical structure of the water column. Water from the bottles was allotted for the analysis of chlorophyll-a levels and dissolved oxygen concentration. At sunset, several charismatic megafauna (humpback whales) were sighted feeding at the shelf/slope break. This region is one where deep, nutrient rich water is capable of making its way to the surface and driving primary productivity - the whales take advantage of this and are often reported at this location.

Sailing off the continental shelf, we reached the warm core eddy in the early morning of Thursday, 23 June. Our arrival was first indicated by an increase in surface water temperature - to a maximum of 24.8^{o} C (Figure 2), and a change in the water color which achieved a brilliant blue. Surface water color is indicative of the level of primary productivity, and (as with swimming pools) blue suggests low productivity. This was later confirmed by an analysis of chlorophyll-a levels (Figure 3). Warm core eddies spin off of the Gulf Stream regularly and carry subtropical water (and its associated flora and fauna) to the north. This was evident in our second neuston tow which captured a subtropical assemblage of species, predominantly comprised of Euphausiidae (67.5%). Zooplankton at this location were also less abundant than in the waters overlying the continental shelf - yielding only 0.03 ml/m^2 compared to the earlier finding of 0.55 ml/m^2 (see Appendix). These findings again indicate lower levels of overall productivity. Before a dysfunctional refrigeration unit forced our premature return to dock - we accomplished a deep CTD cast (C133A-008) with eight Niskin bottles to complete our sampling of the warm core eddy.

With a freezer full of rapidly melting food, we steamed north into Buzzard's Bay for a brief, but necessary repair stop in New Bedford - arriving on the afternoon of Friday, 24 June. New Bedford is interesting in that after sustaining substantial storm surge damage in the past, the town constructed a hurricane wall to prevent future catastrophe. We steamed through the narrow hurricane gates which when closed protect the town in the event of a significant storm. Even when open these gates significantly reduce the flushing action of the water in the inner harbor and allow harbor pollution to accumulate. We took advantage of the opportunity to examine this effect and performed a series of surface stations as we entered the harbor. These samples were examined for salinity, chlorophyll-a levels and microscopic plastic and tar pieces. Salinity is expected to decrease in an area that has significant freshwater input, which in the case of New Bedford comes from both river flow and storm drain output. Chlorophyll-a is a light trapping pigment found in algae that is often used as a relative measure of the standing crop of phytoplankton in a given area. Since much coastal pollution consists of excess nutrient loading - which promotes phytoplankton growth, a high chlorophyll-a level is an indirect measure of pollution. Surface samples taken while entering the harbor revealed extremely high levels of this pigment - which peaks in the inner harbor (Figure 3). Microscopic tar and plastic levels are directly indicative of the degree of anthropogenic input to harbor waters, and were again highest in the inner harbor.

While alongside at the State wharf with refrigeration repairs underway, we took the opportunity to visit the New Bedford Whaling Museum - one of the premier whaling museums in the country. Though we arrived on short notice, the museum staff arranged for a special presentation and tour which highlighted their extensive collection.

Departing New Bedford at dusk on Friday, 24 June - we steamed into Buzzard's Bay towards an overnight anchorage near the entrance to the Cape Cod Canal. Fog and a difficult transit through the canal was the official reason for anchoring, but the night provided a well deserved rest for staff and students alike. At first light we entered the canal and were soon enveloped in a fog that had visibility down to mere meters - a transit made by radar. Upon reaching Cape Cod Bay, with a subsequent drop of 3^{o} C in surface water temperature (Figure 2), the fog lifted and we were able to undertake an otter trawl (C-133A-010) at a depth of 25 meters. Towed along the bottom, this yielded an assortment of benthic organisms: flounder, skates, urchins, sea stars and lobsters - all of which showed clear adaptations for a benthic existence. Reaching Stellwagen Bank by early evening, we performed one more otter trawl (C-133A-011) which collected additional benthic fauna. Stellwagen Bank, lying just north of Cape Cod has recently been designated a national marine estuary, in part because of its importance as a habitat for marine mammals, and is thus protected from many practices that might lead to significant environmental degradation.

Once in the Gulf of Maine, we undertook a series of oceanographic stations to examine the semi-enclosed nature of this body of water. With a shallow sill formed by George's Bank to the south and Brown's bank to the east, the Gulf of Maine is truly a distinct body of water with only limited deep water exchange with the Atlantic Ocean (Figure 1). Through surface stations and CTD/hydrocasts, the physical and chemical structure of the region was thoroughly examined. Particular attention was paid to Wilkinson's Basin - one of the deep regions of the Gulf of Maine that allows the encroachment of continental slope water. This subsurface flow is often evident as a temperature inversion in the deep basins (see Appendix 4). As warm, salty (and consequently dense) water flows into the Gulf of Maine it brings nutrients and generates high levels of productivity wherever it reaches the surface. This and additional sources of nutrients drive the incredible productivity of the Gulf of Maine - supporting high levels of commercial fish harvest.

A final fog-shrouded transit of Jeffrey's Ledge yielded additional whale and dolphin sightings - and a final night's anchorage in Portsmouth, New Hampshire allowed time for student groups to present a summary of cruise results. Sailing over 600 miles, we sampled environments ranging from the unproductive subtropical water of a warm core eddy to the highly productive waters of the Gulf of Maine. Our sampling included all four disciplines of oceanography - biology, geology, physics and chemistry. Student groups examined the assembled data for each of three regions: the warm core eddy, Stellwagen Bank and Wilkinson's Basin. The comparison of these diverse environments helped to demonstrate the complex nature of the ocean, and the interdisciplinary nature of oceanography.

Table 1. Ship's Complement for SSV *Corwith Cramer*, C-133A

Nautical Staff

Mark Crutcher	Captain
John Hayward	First Mate
Eliza Garfield	Second Mate
Clark McCurdy	Third Mate
Mark Utterback	Engineer
Theresa Tiedman	Steward
Maria Caracino	Assistant Steward
Ashley Daved	Deck Hand
Claire Yannacone	Deck Hand

Science Staff

Timothy Scott	Chief Scientist
John Cooke	First Scientist
Karen Gordon	Second Scientist
Greg Shellenbarger	Third Scientist

Students

Jane April	Nashua, NH
Julie Barber	Valatie, NY
Grechen Biller	La Quinta, CA
Kristen Brockmeier	Acton, MA
Ellen Brunner	Hot Springs, AR
Jeff Burnham	York, PA
Jeff Burns	Hudson, NH
Moira Goegel	Canterbury, NH
Christopher Govil	Old Saybrook, CT
Ellita Jackson	Sebastopol, CA
Christopher Jewell	Freehold, NJ
Dana Krueger	Lake Forest, IL
Amy Ludmerer	Greenwood Lake, NY
Maushumi Mavinkurve	Princeton, NJ
Shawnette Medville	Ithaca, NY
Joshua Otten	Brookline, MA
Vicki Putnam	Albany, OR
Michael Schiess	Duxbury, MA
Layton Skelly	Hockessin, DE
Jennifer Stang	Findlay, OH
Jennifer Towle	Hot Springs, AR
Zelinda Welch	Bethesda, MD
Graham Whittemore	North Easton, MA

Table 2. C-133A Cruise Track, Noon and Midnight Positions

Date	Time	Log (nm)	Latitude (°N)	Longitude (°W)
June 20	0000	000.0	Alongside	Woods Hole, MA
	1200	000.0	Alongside	Woods Hole, MA
June 21	0000	000.0	At Anchor	Tarpaulin Cove, MA
	1200	000.0	At Anchor	Tarpaulin Cove, MA
June 22	0000	052.2	40°57.8'	70°31.2'
	1200	094.9	40°56.8'	70°15.2'
June 23	0000	135.3	39°44.4'	69°55.8'
	1200	169.9	39°02.8'	69°26.1'
June 24	0000	253.0	40°08.9'	70°10.5'
	1200	338.8	41°30.6'	70°51.0'
June 25	0000	339.9	At Anchor	Buzzards Bay, MA
	1200	347.8	41°56.2'	70°91.4'
June 26	0000	391.2	42°23.8'	70°12.2'
	1200	434.0	42°38.2'	69°02.9'
June 27	0000	483.5	42°51.3'	69°56.9'
	1200	570.3	42°55.6'	70°06.7'
June 28	0000	562.3	At Anchor	Ragged Point, NH
	1200	586.0	43°03.1'	70°28.3'
June 29	0000	594.5	At Anchor	Portsmouth, NH
	1200	594.5	At Anchor	Appledore Island, ME

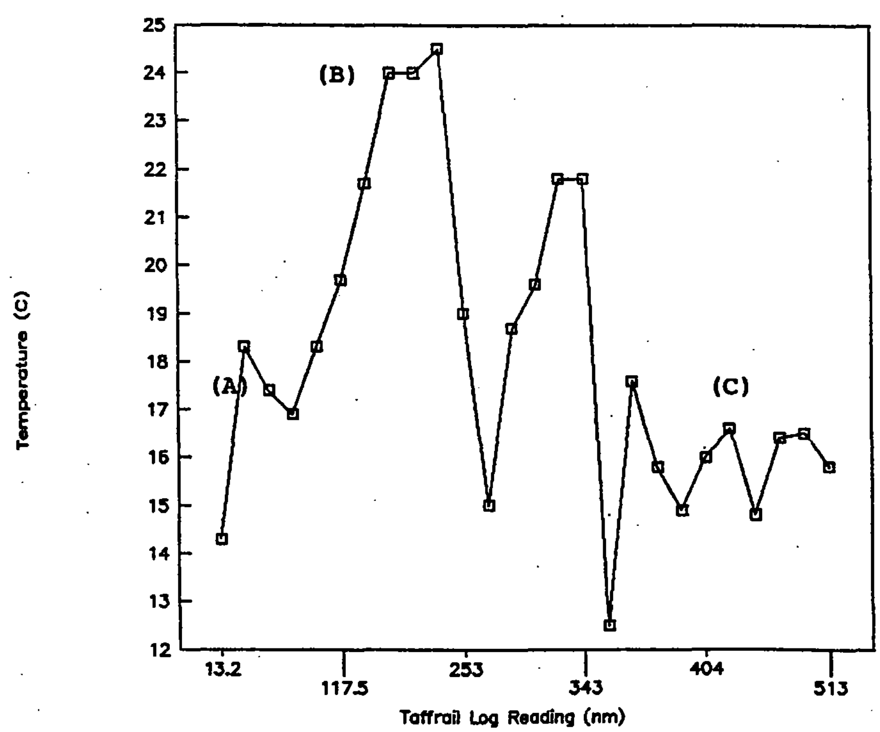


Figure 2. Surface Temperature along the C-133A Cruise Track (A) Continental Shelf; (B) Warm Core Eddy; (C) Gulf of Maine.

Table 3. C-133A Watch Roster

A Watch	B Watch	C Watch
Julie Barber	Jane April	Grechen Biller
Ellen Brunner	Kristen Brockmeier	Moira Goegel
Jeffrey Burnham	Jeff Burns	Chris Govil
Chris Jewell	Summer Jackson	Amy Ludmerer
Dana Krueger	Maushumi Mavinkurve	Vicki Putnam
Shawnette Medville	Josh Otten	Michael Schiess
Layton Skelly	Jennifer Stang	Zelinda Welch
Jennifer Towle	Graham Whittemore	

Table 4. Oceanography Lecture Topics

Monday	June 20	Depart Woods Hole; Ship Safety Orientation
Tuesday	June 21	Scientific Sampling; Shipek Grab Demonstration
Wednesday	June 22	Cruise Track and Research Plan
Thursday	June 23	Oceanic Productivity; Light and Nutrients
Friday	June 24	Field Trip: New Bedford Whaling Museum
Saturday	June 25	Otter Trawl; Stellwagen Bank
Sunday	June 26	Safety Drills
Monday	June 27	Ocean Surface Circulation
Tuesday	June 28	Scientific Data Presentations
Wednesday	June 29	Arrival at Appledore Island; Island Tour
Thursday	June 30	Rocky Intertidal Zone
Friday	July 1	Oceanography Review; Adaptations of Marine Organisms
Saturday	July 2	Waves/Tides; Larval Recruitment; Fisheries
Sunday	July 3	Eutrophication; New Bedford Harbor Pollution
Monday	July 4	Data Interpretation; Creature Features
Tuesday	July 5	Marine Mammals; RV Kingsbury Field Trip
Wednesday	July 6	Depart Shoals Marine Laboratory

Table 5. C-133A Oceanographic Station Locations

Station	Date...Time	Log(nm)	Latitude(°N)	Longitude(°W)	Station Type
C133A-001	June 21...1204	000.0	41°28.4'	70°45.1'	Shipek Grab
C133A-002	June 21...1724	020.9	41°20.5'	71°12.6'	Fisher Scoop
C133A-003	June 21...1800	023.0	41°19.7'	71°12.9'	Fisher Scoop
C133A-004	June 22...1214	057.0	40°57.9'	70°31.9'	Neuston Tow
C133A-005	June 22...1050	089.0	40°31.2'	70°17.3'	Fisher Scoop
C133A-006	June 22...1802	114.2	40°00.6'	70°06.3'	CTD/Cast
C133A-007	June 23...0022	130.8	39°44.9'	69°55.5'	Neuston Tow
C133A-008	June 23...1200	169.9	39°02.8'	69°26.1'	CTD/Cast Phytoplankton
C133A-009	June 24...0105	259.5	40°14.6'	70°14.0'	Neuston Tow
C133A-010	June 25...1410	350.0	41°58.5'	70°10.7'	Otter Trawl
C133A-011	June 25...2153	382.0	42°20.1'	70°18.7'	Otter Trawl
C133A-012	June 25...2350	389.3	42°22.8'	70°14.1'	CTD/Cast
C133A-013	June 26...0157	395.5	42°25.1'	70°07.6'	CTD/Cast
C133A-014	June 26...1610	461.5	42°43.0'	69°31.0'	CTD/Cast
C133A-015	June 26...2043	475.4	42°49.4'	69°48.2'	CTD (2)

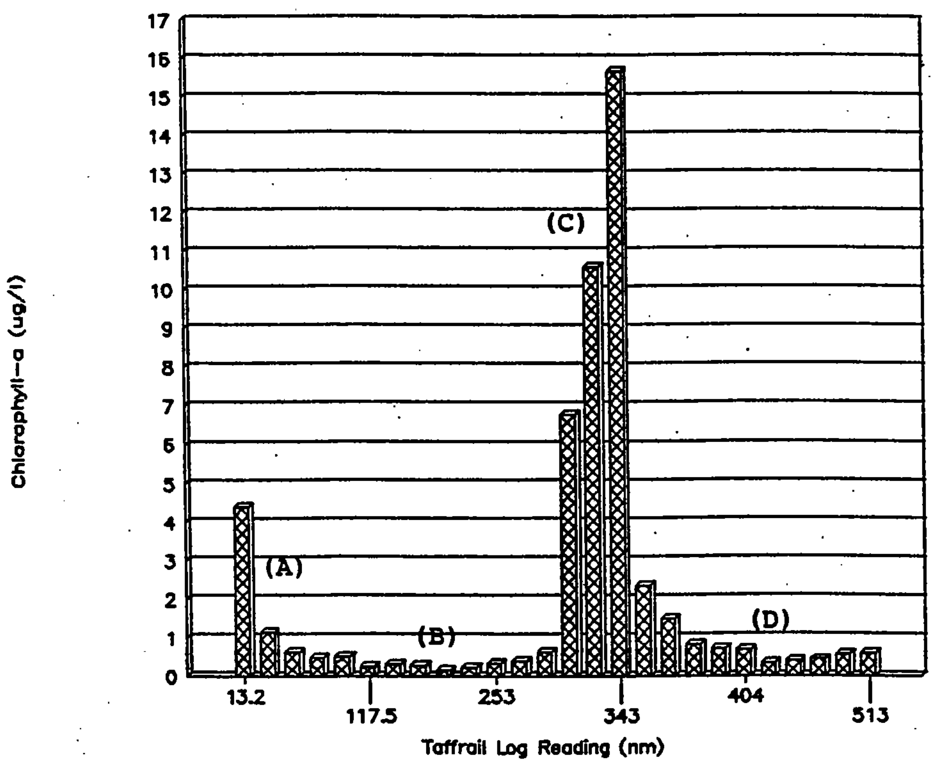


Figure 3. Surface Chlorophyll-a Levels - (A) Continental Shelf; (B) Warm Core Eddy; (C) New Bedford Harbor; (D) Gulf of Maine.

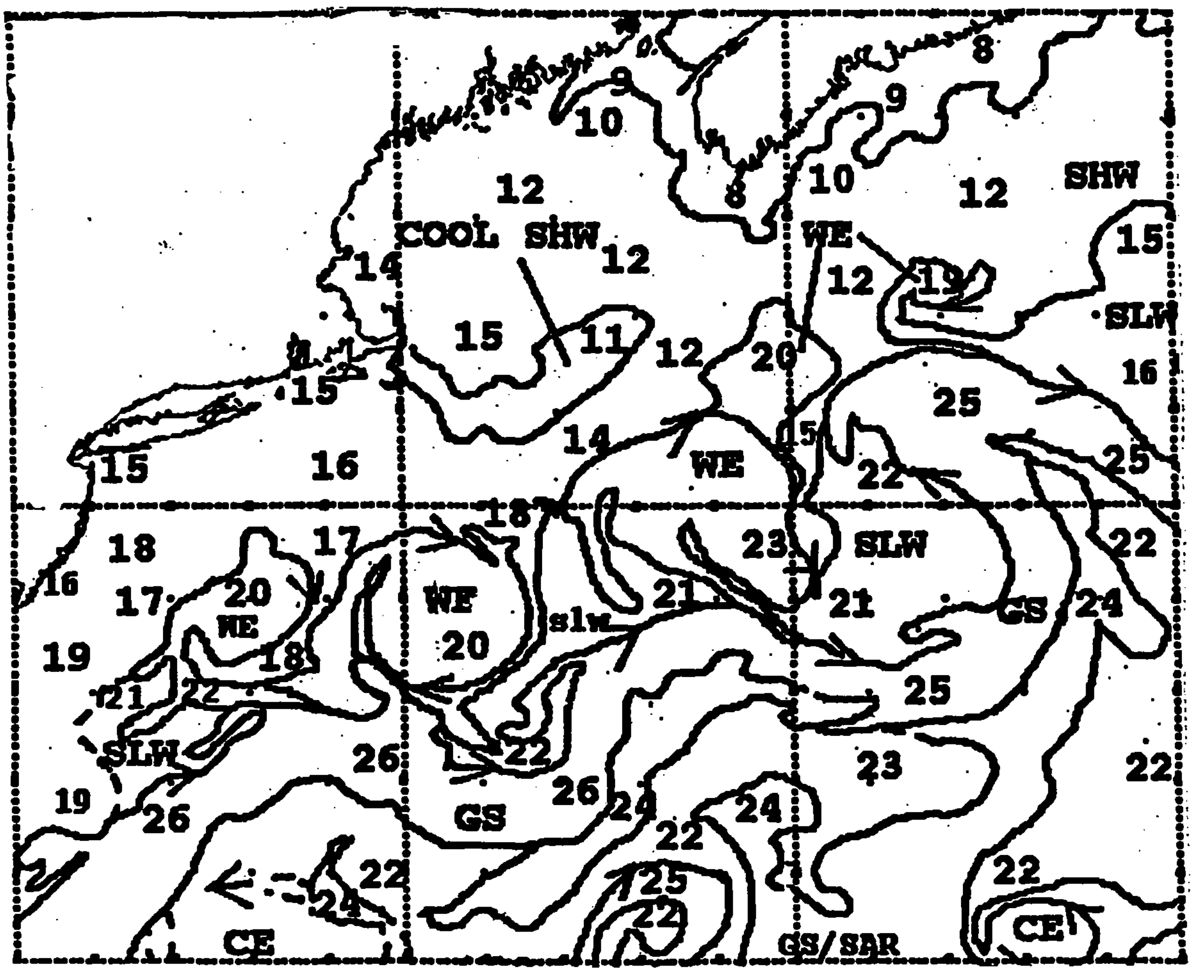


Figure 4. Surface temperature plot for the week of June 15, NOAA satellite data.

APPENDICES - Data Summary

Appendix 1. Hydrocast Data
Appendix 2. Neuston Net Data
Appendix 3. Surface Station Data
Appendix 4. CTD Data - Profiles of Temperature, Salinity and Density

Appendix 1. Summary of Hydrocast Data

Water samples were collected in 2.5 liter Niskin bottles; collection depth (m) was determined from the length of hydrowinch wire deployed corrected for wire-angle using the known depth of the deepest cast bottle (as obtained from CTD data). Dissolved oxygen concentration (ml/l) was determined chemically by Winkler titration. Chlorophyll-a levels (ug/l) were measured fluorometrically using methods outlined in Parsons, Maita and Lalli (1984; *A Manual of Chemical and Biological Methods for Seawater Analysis*, Pergamon Press).

C133A-006

Depth	O_2	Chl-a
0	5.67	0.399
26	6.36	0.730
52	3.83	0.144
77	4.74	0.030
103	4.67	0.080
129	4.74	0.021
155	4.76	0.119

C133A-008

Depth	O_2	Chl-a
0	4.98	0.178
18	5.11	0.493
35	4.84	2.944
53	4.71	0.668
70	4.71	0.259
105	3.55	0.080
140	3.89	0.018
175	3.43	0.000

C133A-012

Depth	O_2	Chl-a
0	6.65	0.994
10	7.31	3.005
20	6.85	2.015
30	6.54	0.849

C133A-013

Depth	O_2	Chl-a
0	6.29	0.607
10	6.96	1.367
20	6.44	0.623
30	6.29	0.393

C133A-014

Depth	O_2	Chl-a
0	5.95	0.297
24	6.93	0.168
48	7.39	1.486
73	6.22	0.320
97	6.03	0.107
121	5.98	0.130
145	5.56	0.030

Appendix 2. Summary of Neuston Net Data

Each neuston station included replicate tows (designated A;B). The tow distance, as determined by taffrail log, was 1.0 nautical mile (1852 m). Zooplankton biomass is reported as both total volume collected (ml) and density (ml/m^2). Percent composition was determined from replicate samples (two per tow) of approximately 100 organisms randomly sampled and identified from the zooplankton biomass. Plastic pieces are reported as simple counts.

C133A-004 South of Martha's Vineyard

Zooplankton	Plastic Pieces
Tow A: 1800 ml (0.97 ml/m^2)	3
Tow B: 250 ml (0.14 ml/m^2)	3

Ostracods	0.5%
Copepods	15%
Amphipods	0.5%
Crab Larvae	84%

C133A-007 Atlantis Canyon

Zooplankton	Plastic Pieces
Tow A: 50 ml (0.03 ml/m^2)	25
Tow B: 40 ml (0.02 ml/m^2)	12

Copepods	14.5%
Isopods	0.5%
Gammaridae	1.0%
Hyperiidae	2.5%
Euphausiids	67.5%
Shrimp	0.5%
Mysids	1.0%
Fish eggs	0.5%
Crab Larvae	3.5%
Unknown	6.5%

C133A-009 Continental Shelf

Zooplankton	Plastic Pieces
Tow A: 51 ml (0.03 ml/m^2)	0
Tow B: 60 ml (0.03 ml/m^2)	0

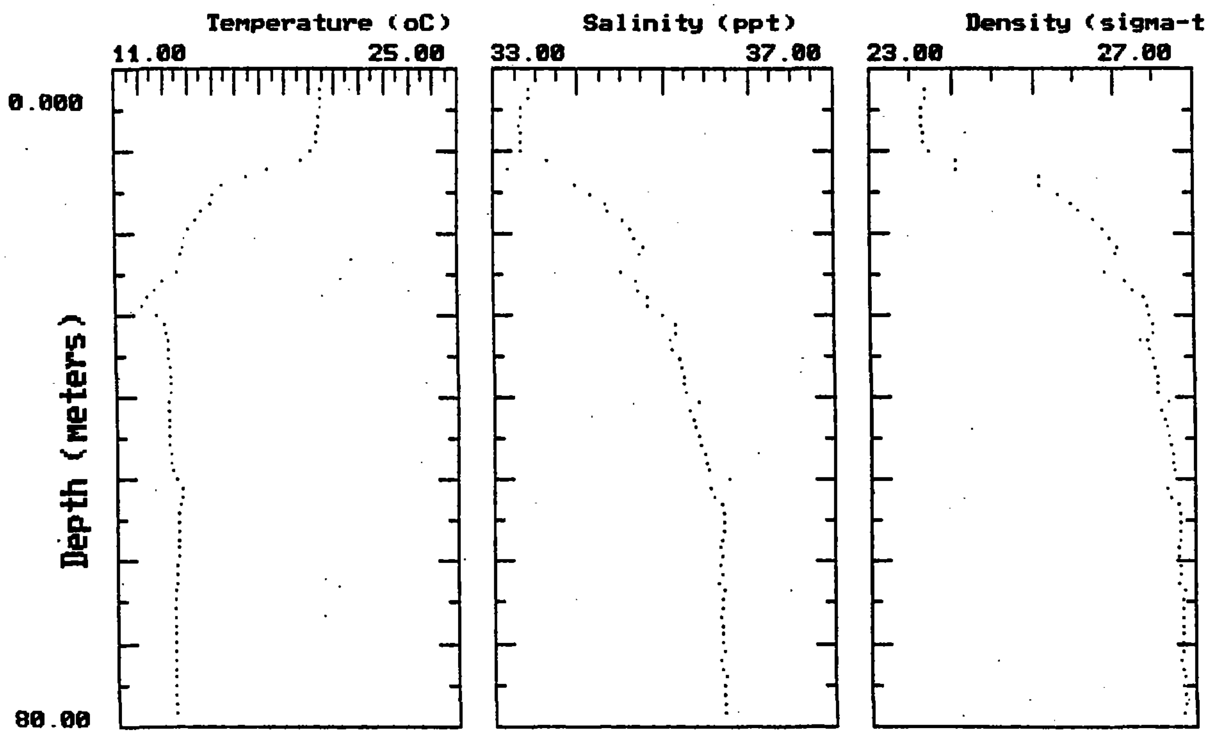
Polychaetes	1.3%
Copepods	73.5%
Hyperiidae	23.1%
Crab Larvae	0.8%
Unknown	2.7%

Appendix 3. Surface Station Data

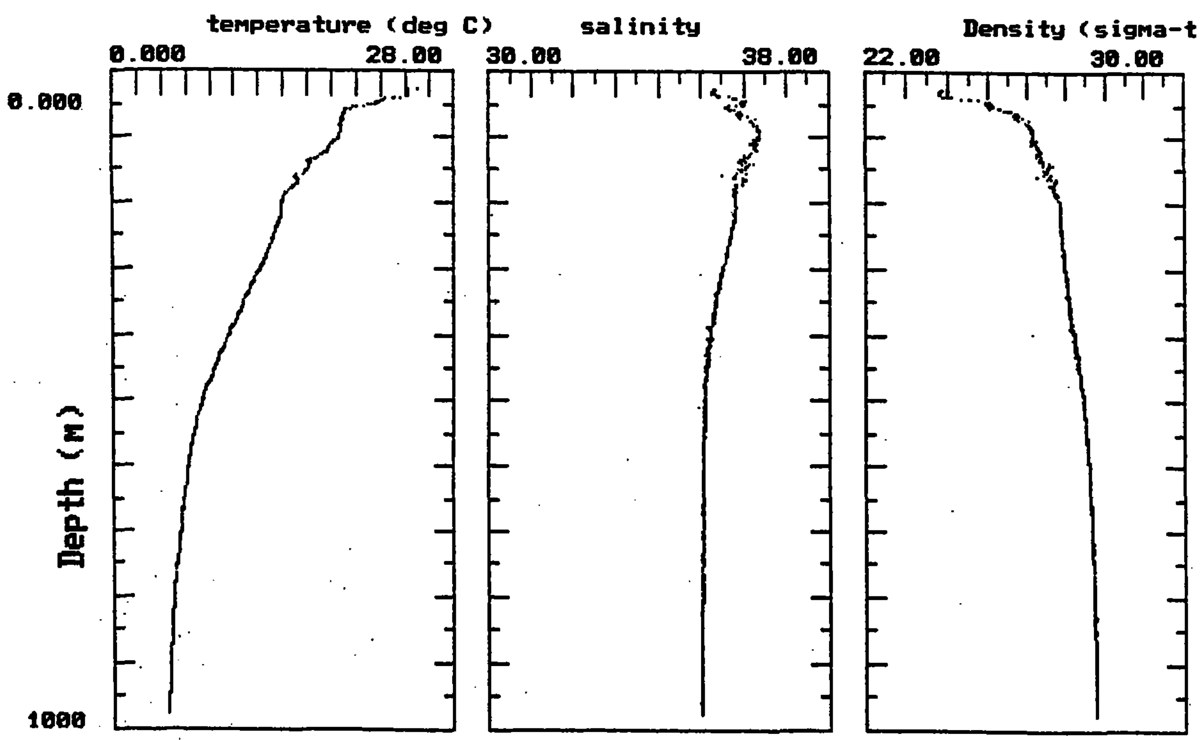
Surface water samples were collected by bucket at regular intervals along the cruise. Station positions are given as latitude (°N) and longitude (°W) as determined by the global positioning system (GPS). Log is distance as recorded by taffrail log in nautical miles. T_s is the surface water temperature, T_a is the air temperature given as both dry and wet thermometer bulb in °C. Chlorophyll-a levels (Chl-a) are expressed as ug/l; Salinity was measured by conductivity and is expressed in parts per thousand.

SS#	Latitude/Longitude	Date	Time	Log	T_s	T_a-dry/wet	Chl-a	Salinity
001	41°22.8/71°02.4	6/21	1600	013.2	14.3	------	4.388	-----
002	41°14.0/70°56.5	6/21	2000	035.0	18.3	------	1.157	-----
003	40°56.2/70°31.6	6/22	0400	068.2	17.4	19.3/19.0	0.625	-----
004	40°44.3/70°22.6	6/22	0800	076.7	16.9	19.2/18.8	0.488	31.834
005	40°25.0/70°15.0	6/22	1200	094.9	18.3	20.0/18.0	0.494	-----
006	39°57.3/70°03.7	6/22	2000	117.5	19.7	20.0/18.0	0.240	-----
007	39°55.3/69°43.9	6/23	0400	146.1	21.7	22.5/20.0	0.302	34.651
008	39°15.7/69°32.0	6/23	0800	162.5	24.0	25.0/22.2	0.278	35.288
009	39°17.7/69°31.4	6/23	1600	190.2	24.0	25.0/21.0	0.157	35.524
010	39°41.9/69°50.7	6/23	2000	221.5	24.5	23.1/20.1	0.222	34.637
011	40°08.9/70°10.5	6/24	0000	253.0	19.0	20.8/19.2	0.342	-----
012	40°27.0/70°22.4	6/24	0400	274.3	15.0	20.1/19.0	0.391	32.232
013	40°59.0/70°41.0	6/24	0800	307.0	18.7	19.0/18.7	0.629	-----
014	41°30.6/70°51.0	6/24	1200	338.9	19.6	21.0/20.0	6.770	-----
015	41°37.2/70°54.2	6/24	1315	----	21.8	20.8/20.0	10.600	30.841
016	41°38.1/70°55.1	6/24	1400	----	21.8	22.5/21.2	15.670	-----
017	41°46.7/70°29.2	6/25	0800	----	12.5	15.0/15.0	2.320	-----
018	41°56.2/70°09.1	6/25	1200	347.6	17.6	20.0/19.0	1.491	-----
019	42°09.4/70°25.5	6/25	1815	365.5	15.8	18.0/17.5	0.823	-----
020	42°16.5/70°19.1	6/25	2000	375.5	14.9	------	0.696	31.644
021	42°27.4/69°55.3	6/26	0400	404.0	16.0	18.0/17.5	0.672	-----
022	42°32.6/69°25.4	6/26	0800	424.9	16.6	18.5/17.5	0.342	32.036
023	42°38.2/69°09.2	6/26	1200	434.0	14.8	18.3/14.8	0.384	-----
024	42°50.5/69°55.4	6/27	0025	484.6	16.4	18.3/16.5	0.438	-----
025	42°50.6/69°59.4	6/27	0400	496.1	16.5	17.9/16.7	0.573	-----
026	42°50.0/70°12.3	6/27	0800	513.0	15.8	18.5/18.0	0.590	31.503

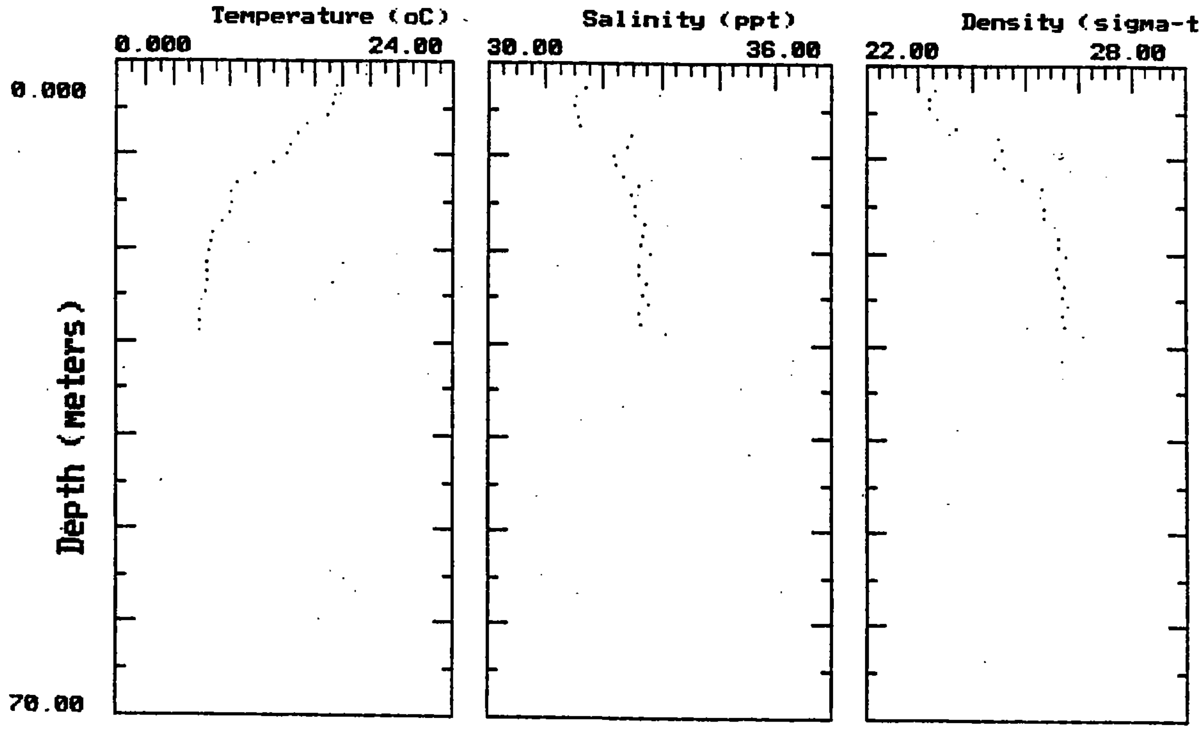
Appendix 4. CTD Data - Profiles of Temperature, Salinity and Density



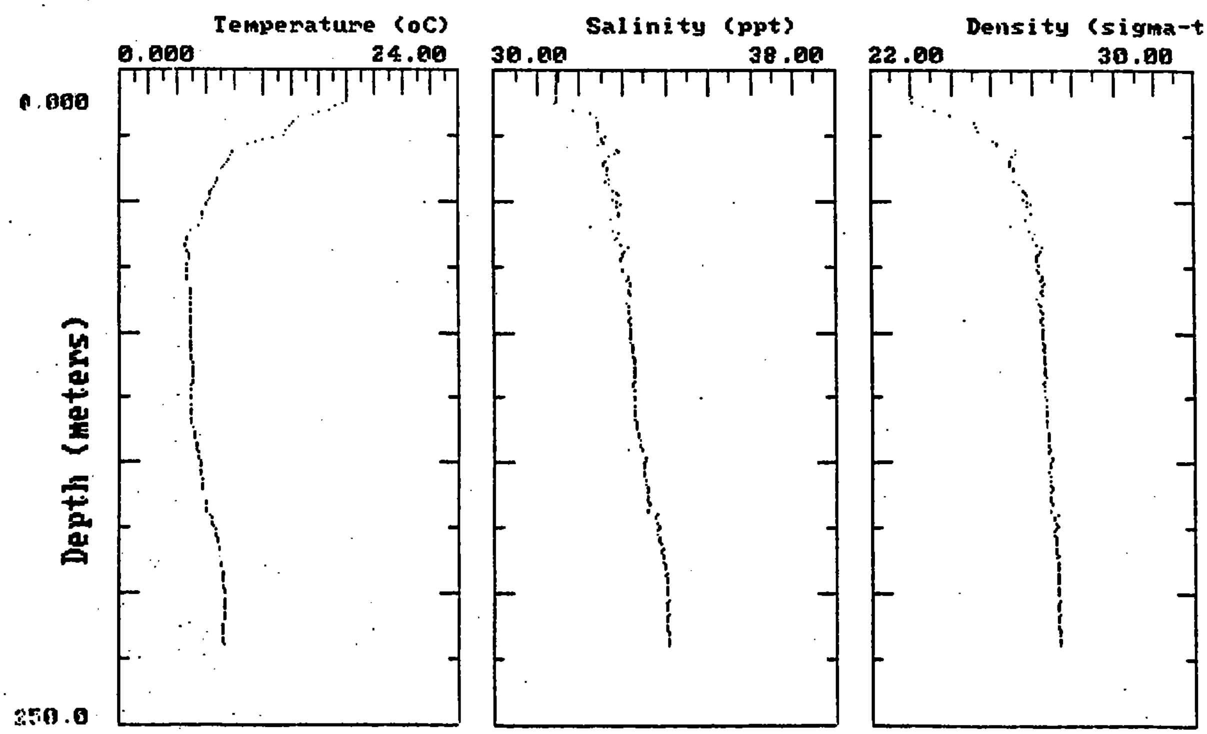
C-133A-006-CTD Continental Shelf



C-133A-008-CTD Warm Core Eddy



C-133A-013-CTD



C-133A-015-CTD Wilkinson's Basin, Gulf of Maine