CRUISE REPORT

C-139A

A Report on the Academic & Scientific Activities of the

Oceanography of the Gulf of Maine

Program

Sea Component

22 June to 1 July 1995

Island Component

1 July 1995 to 9 July 1995

Sea Education Association

PO Box 6

Woods Hole, MA 02543

Introduction:

The Sea Component of Cruise C-139A began in Woods Hole Massachusetts and ended ten days later on Appledore Island Maine. This report is a summary of the accomplishments and discoveries during the cruise. During this short time, we sailed over 600 nautical miles (see Table 1 and Figure 1) and saw a remarkable diversity of marine habitats. Environments we studied ranged from oligotrophic tropical open ocean water in a warm core eddy of the Gulf Stream, to the rich and productive waters over Georges Bank. After investigating these areas and the Gulf of Maine, students (listed alphabetically by name, along with staff, in Table 2) spent nine days at Shoals Marine Laboratory on Appledore Island, where Dr. Nadine Folino introduced us all to the spectacular rocky intertidal environment. Oceanography and Nautical Science lectures, presented each day to supplement and expand upon the research program, are listed in Table 3.

We learned a lot during our cruise and field station work together. The students came together, worked as a team, and produced some very nice data and interpretations they can be proud of. If there is one thing I would like all the students to remember from the Oceanography of the Gulf of Maine program, it is that there is a difference between just seeing something and OBSERVING it, as I was reminded when I hastily wrote down *Mytilus edulis* in the lab practical only to find later that the question had asked for the scientific name of the **alga** growing on the mussel's shell! Keep your eyes open, use all your senses when observing, and you will always be amazed by the natural world.

Erik Zettler
Chief Scientist, C-139A

Table 1: Noon and Midnight Positions. Data are plotted in Figure 1.

<u>Date</u>	<u>Time</u>	<u>Log(nm)</u>	<u>Latitude (°N)</u>	<u>Longitude (°W)</u>
23 June 1995	0000	0	At Anchor	Vineyard Haven Harbor
	1200	0	41°30'	70°40'
24 June 1995	0000	51.8	40°50'	70°42'
	1200	118.5	40°02'	70°04'
25 June 1995	0000	194.9	39°21'	68°57'
	1200	238.0	39°28'	68°60'
26 June 1995	0000	290.1	40°11'	69°00'
	1200	375.0	41°19'	68°23'
27 June 1995	0000	430.7	41°55'	69°02'
	1200	513.9	42°13'	70°16'
28 June 1995	0000	513.9	At Anchor	Provincetown Harbor
	1200	559.7	42°09'	70°31'
29 June 1995	0000	596.8	At Anchor	Manchester Bay
	1200	599.5	Alongside	Gloucester
30 June 1995	0000	599.5	Alongside	Gloucester
	1200	628.5	42°44'	70°24'
1 July 1995	0000	653.5	At Anchor	Appledore Island

Figure 1. Cruise track of C-139A of the SSV *Corwith Cramer*

Table 2: Ship's Complement for SSV *Corwith Cramer* C-139A

Students		<u>Watch</u>
Marjorie Anderson	Indian Hill High School, Cincinnati, OH	A
Kenneth Baughman	Groton School, Cambridge, MA	A
Christopher Bender	Union Endicott High School, Endwell, NY	A
Cleo Bertrand	Nyack High School, Upper Nyack, NY	C
Ashley Bronzan	University High Lab School, Greeley, CO	B
Sean Buckley	St. Joseph High School, Monroe, CT	A
Carol Byrd	Florida School for the Deaf & Blind, St. Augustine, FL	C
Elsa Carlisle	Colfax High School, Meadow Vista, CA	C
Brigid Doherty	South Burlington High School, S. Burlington, VT	B
Kathryn Doyle	Bishop Feehan High School, Pawtucket, RI	A
Jessica Dunning	Barnstable High School, Marstons Mills, MA	B
Christopher Fithian	Bernards High School, Bernardsville, NJ	C
Katriina Ilves	Clayton Bouton High School, Voorheesville, NY	C
Halden Jensen	Thomas Jefferson High School, McLean, VA	A
Sarah Lambert	Wayland High School, Wayland, MA	C
Liliana Lettieri	Walton High School, Marietta, GA	A
Robert Levendosky	Albert Einstein High School, Silver Spring, MD	B
Erin Malec	The Latin School of Chicago, Chicago, IL	A
Audra Piskiel	Manalapan High School, Manalapan, NJ	B
Erin Rittenhouse	Huntington Beach High School, San Pedro, CA	B
Morgan Simmons	Somerset Area High School, Somerset, PA	C
Kerek Swanson	Ripon High School, Pickett, WI	B
Stephanie Whitehead	Barrington High School, Barrington, RI	C
Nautical Staff		<u>Watch</u>
Captain	Mark Crutcher	
First Mate	John Gryska	A
Second Mate	Peter Bolster	B
Third Mate	Betsy Garthwaite	C
Engineer	Robbie Laird	
Steward	Pierre Cornell	
Asst. Steward	Tamara Kittredge	
Deckhand	Ian Olds	B
Deckhand	Sophie Morse	C
Scientific Staff		
Chief Scientist	Erik Zettler	
First Scientist	Carolyn Sheild	C
Second Scientist	Greg Shellenbarger	B
Third Scientist	Rod MacLeod	A

Table 3: Science Lectures

<u>At Sea Lecture Topic</u>	<u>Speaker¹</u>
Introduction to Oceanography	Erik Zettler
Wind and Sails	Mark Crutcher
Sampling Gear and Instrumentation	Erik Zettler
Meteorology	Mark Crutcher
Circulation of the Gulf of Maine	Erik Zettler
Ship Handling	Mark Crutcher
The Chemistry of Seawater	Erik Zettler
Light/Nutrients and Primary Productivity	Erik Zettler
Geology of Gulf of Maine	Rod MacLeod
Secondary Productivity and Plankton	Carolyn Sheild
Ecology of the Benthos	Greg Shellenbarger
<u>On Shore Lecture Topic</u>	<u>Speaker¹</u>
Classification of Organisms I, II, III	Nadine Folino (Wheaton College)
Intertidal Ecology I, II, III	Nadine Folino (Wheaton College)
Predation by the seastar <i>Henricia sanguinolenta</i>	Carolyn Sheild
Scientific Methods	Nadine Folino (Wheaton College)
Larval Ecology	Nadine Folino (Wheaton College)
Marine Mammals	Julie Kleinhans (Shoals Marine Laboratory)
Sharks	John Morrissey (Hofstra University)
Fish Ecology	Nadine Folino (Wheaton College)
Pelagic Birds	Erik Zettler
Marine Pollution and Conservation	Nadine Folino (Wheaton College)

¹All speakers are from the Sea Education Association unless otherwise noted.

Table 4: Shore Projects

Comparative Tidepool Study (all students compared low, medium, and high pools on the exposed versus protected sides of the island)

"Length vs. Width of *Nucella lapillus* on Appledore Island" (Bronzan, Dunning, Levendosky, Whitehead)

"Feeding rates in *Metridium senile*" (Baughman, Carlisle, Jensen, Rittenhouse)

"Oxygen levels in a Stickleback Tidepool" (Anderson, Byrd, Ilves, Piskiel)

"Locomotion of *Littorina littorea* on various sediments" (Bender, Doherty, Lambert, Simmons)

"Behavioral Response of *Strongylocentrotus droebachiensis* to light stimuli" (Buckley, Fithian, Malec)

"Shell selectivity of *Pagurus acadiensis*" (Bertrand, Doyle, Lettieri, Swanson)

Table 5: Oceanographic sampling equipment and instruments

Winches:	Markey DESF-4 Electric Hydrographic Winch Bathymograph Winch Hydraulic J-frame and electronic metered wheel for equipment deployment
Bathymetric Equipment:	Raytheon 3.5 and 12 kHz Bathymetric Profiling System consisting of: TR-73A Transducers TR-109 Transducers PTR-105B Transceiver LSR-1807M Line Scan Recorder
Physical/Chemical Oceanographic Equipment:	Water sampling Carousel SBE 32-16 with: SBE 90208 Auto Fire Module Seabird SEACAT Profiler Model SBE 19 Conductivity- Temperature-Depth units General Oceanics Niskin 2.5-L Water Sampling Bottles Mechanical Bathymographs Electronic Bathymograph AGE MiniSal Salinometer Turner Model 112 Digital Fluorometer Secchi Disk
Biological Sampling Equipment:	SeaGear 333 μ m Plankton nets SeaGear 333 μ m Neuston nets SeaGear 63 μ m Phytoplankton nets Otter Trawl net (oceanographic purposes only)
Geological Sampling Equipment:	Shipek Sediment Grab Gravity Corer Fisher Sediment Scoop
Microscopes:	Nikon SMZ-2B Dissecting Scopes Nikon Labophot Compound Scope
Computer Equipment:	486/66 Desktop Computer w/250 MB tape backup 386SX/40 MB Portable Computer Epson LX-810 Dot Matrix Printers

Table 6: Bacteria/Fungi plates. Station locations are given in Appendix A.

Station	Mixed Bacteria (Tryptone Glucose Extract agar)	Fungi (Malt Extract agar)
SS-001	red bact. along all edges	
SS-002		
SS-003	one sm. grey colony	pink fungi along edge 1 lg. bubble shaped colony
SS-004	sm. amnt. red bact. along edge	
SS-005		
SS-006	red colony	
SS-007	red bact. along all edges 9 colonies	2 white spots
SS-008	red bact. along 3 edges 2 colonies	
SS-009	8 red colonies	clear colony on 1 edge
	Mixed Bacteria	Coliform Bacteria (MacConkey medium agar)
SS-010	3 red colonies 2 irregular patches red bact. along edges	58 small red colonies 1 larger dark red colony
SS-011	red bact. along edges 3 linear colonies 1 large patch	
SS-012	3 dark colonies red bact. along edges many sm. colonies in a streak	one lt. reddish brown patch
SS-013	2 large red colonies red bact. along edges	one lt. reddish brown patch
SS-014	bact. along all edges 2 red colonies	4 lt. reddish brown dots sm. growth in corner
SS-015	thick red growth along left edge one dot	sm. pink growth

Cruise Narrative:

We cast off from Dyers dock at 1700 on 22 June 1995 with 12 crew and 22 students on board. After about an hour transit, we dropped anchor in Vineyard Haven Harbor on Martha's Vineyard, where we were joined by the final crew member (Sophie Morse) and student (Carol Anne Byrd, who had been delayed). After a brief orientation, students were allowed a rare full nights sleep while crew stood the anchor watch. At 0745 the next morning, after a full breakfast prepared by Pierre and Tamara, the full safety orientation was presented (including walk-through of emergency/fire, man overboard, and abandon ship drills, and exposure suit donning) while terns and cormorants fed around the ship. At 1100, we weighed anchor and set sail down Vineyard Sound. During the day, a total of 5 *Mola mola*, or ocean sunfish, and a number of sharks were sighted basking at the surface. We began collecting data immediately with hourlies (water temperature, barometric pressure, depth, taffrail log, and position), the first surface station (SS; consisting of salinity, chlorophyll, nutrient samples) at 1200, and a Fisher scoop to look at the sediments at 1352. During the course of the cruise, students on lab watch had the opportunity to use the oceanographic and laboratory equipment listed in Table 5. A transect of Fisher scoops was continued until about the 100m depth contour to see how the sediments changed as we headed offshore (see report by C watch in "Results" section). Hourlies and SS (every 6 hours) were continued for the remainder of the cruise to give us a synopsis of changing environmental conditions in the regions we sailed through and sampled (Figure 2). The neuston net tow (NT) was deployed for the first time at midnight to look at zooplankton and organisms that live in the neuston (interface between water and air). Night watches were treated to a good display of bioluminescence (light generated by living organisms) in the wake of the ship.

Figure 2. Hourly observations of water depth (m) and sea surface temperature (°C) plotted versus taffrail log (nautical miles). WCE = Warm Core Eddy; GB = Georges Bank; WB = Wilkinson Basin.

On 24 June 1995, we observed many marine mammals, and the deck watch noticed we were sailing through alternating bands of very calm "slicks" and rippled areas. These signs suggested we had reached the shelf/slope front where mixing leads to upwelling and increased productivity. We were able to confirm this by testing our brand new Electronic Bathythermograph (EBT). Both the EBT and Conductivity-Temperature-Depth recorder (CTD) showed a temperature inversion of cool fresher shelf water overlaying salty warmer slope water (see report by B watch in "Results" section). We also began to see more offshore birds such as petrels and shearwaters. After lunch, hourly observations began to show a dramatic rise in sea-surface temperature (Figure 2), an indication that we were approaching the Warm Core Eddy (WCE) we had noticed on the NOAA Sea Surface Temperature analysis chart (Figure 3). In response to this, we began an overnight Mechanical Bathythermograph (MBT) transect as we continued offshore to try to "catch" the WCE for study. We were successful and B watch did a terrific analysis of the data for their project. Another neuston net tow (NT) was taken at midnight to compare the plankton of the WCE to that of the continental shelf. After completing the MBT transect through the WCE early in the morning of 25 June 1995, we backtracked to the center of the eddy to sample our first major station. The difference in the water in the WCE was dramatic: Warm, brilliant blue, with tropical organisms such as Portuguese Man-of-wars (*Physalia physalis*).

Figure 3. NOAA (National Oceanographic and Atmospheric Administration) Oceanographic Features Analysis based on sea surface temperatures for 26 June, 1995. Note Warm Core Eddy (WE) centered at 40° N, 68° W.

After completing the WCE station, the *Cramer* headed toward Georges Bank for our next major station. A Wilsons Storm Petrel (*Oceanites oceanicus*), confused by the lights of the ship, made a surprise visit to the A watch lab crew by flying down the hatch into the lab at 0122. It was observed and released unharmed. The next day, 26 June 1995, a noon neuston net tow (NT) showed far less biomass than the midnight tows done earlier. This can be explained by the fact that many of the zooplankton migrate vertically to dark depths during the day to avoid being seen and eaten by fish. They return to the surface at night to feed on phytoplankton under the cover of darkness. The fog rolled in as we reached the site of our Georges Bank station. We sampled in about 45m of water, and saw many seabirds (gulls, shearwaters, and petrels) sitting on the surface. We also heard the "blows" or exhalations of whales, but could not see them through the fog. NOAA weather radio broadcasts warned of an approaching nor'easter storm, so we hurriedly set sail for the protection of Provincetown harbor. On the way, we stopped in Wilkinson Basin on the morning of 27 June 1995 for a quick final major station. The fine silty sediment was sampled with the shipek grab, and the CTD was deployed on the wire (it was too rough to use the carousel with automated water sampling bottles). We rode out the storm at anchor in Provincetown Harbor with the lit Pilgrim's Monument towering over us. Taking advantage of the unexpected anchorage, we undertook a study to investigate the tide in the area. Depth (measured with both the electronic fathometer and the traditional leadline), current, and sea surface temperature were taken every hour through a full tidal cycle (Figure 4). The discrepancy between the electronic fathometer and the leadline is probably due to the fact that the leadline falls through the soft surface sediments until it reaches solid bottom, while the fathometer's sound waves bounce off the soft sediment, resulting in a shallower reading. The figure also shows the current high at the start of the study, dropping to a minimum at the high tide slack period, then increasing again as the tide falls.

Figure 4. Water depths and currents measured during the tide study in Provincetown Harbor. Depths were measured with both a fathometer and a leadline. See text for interpretation.

The nor'easter abated, and we weighed anchor and set sail for Boston at first light on the morning of 28 June 1995. We sailed in to Boston Harbor and motored up as far as the Tobin Bridge. On the way out of Boston Harbor, we passed the Deer Island sewage treatment facility which handles the sewage from 2.5 million people and 5,500 businesses. A transect was started at the facility's outfall pipes and continued offshore to measure *in-vivo* chlorophyll fluorescence (an indication of phytoplankton biomass). As expected, the high nutrients in the discharge correlated nicely with high chlorophyll fluorescence that decreased as we moved offshore away from the source (Figure 5). Along the transect we also inoculated microbiological culture media to look at total and coliform (associated with sewage) bacteria and fungi (Table 6). Long after dark, Captain Crutcher and the deck crew brought us safely to anchor in the small, beautiful harbor of Manchester Bay. After breakfast on 29 June 1995, we weighed anchor and headed for the historic fishing port of Gloucester harbor to tie up, do laundry, and present the student research projects as a school of mackerel fed around the ship.

Figure 5. In-vivo chlorophyll fluorescence measured at surface stations 10 - 15 during the Deer Island Outfall transect. Surface station locations are listed in Appendix A.

On the final day of the cruise, we had a marvelous sail as we looked unsuccessfully for more marine mammals along Jeffreys Ledge on the way to Appledore Island. We did a spectacular fly-by of the island, came about, and dropped anchor at 1755. The **First Annual Appledore Triathlon** was held and consisted of: Exposure suit relay, One-handed sail raising, and Line chase relay.

At 1030 on 1 July 1995, students boarded the R/V *Kingsbury*, gave the SSV *Corwith Cramer* and crew three hearty cheers, and turned to land on Appledore Island. Lectures at Shoals Marine (SML) Laboratory on Appledore Island are listed in the second half of Table 3, while student projects are listed in Table 4.

Results

Each of the three watches was responsible for compiling and presenting a report on one of the major oceanographic regions we studied. The text that follows was written by the students themselves, and has not been edited for inclusion in this report. Figures, legends, and comments in italics have been added by the Chief Scientist.

Georges Bank (A watch report)

The Gulf of Maine has many different and unique regions located within its waters. One of these main areas is Georges Bank, filled with its own distinct qualities and high productivity. Its waters are constantly in motion and fertile year round. The bank, which was once an island, has undergone many changes and continues to change as a dynamic ecosystem.

Georges Bank was formed roughly 20 million years ago by stream-based erosion, following a glacial expansion. Due to the bulldozing of the glaciers, Georges Bank is covered with unsorted sediment. The Shipek Grab taken during our passage over the bank supports the glacial formation theory because it shows unsorted *and relatively coarse-grained* sediment (*Figure 6*) which could not have been deposited there by water.

Figure 6. Grain size distribution of Georges Bank sediments at station SG-006 (see Appendix H), analyzed by sieving.

The physics of Georges Bank, which is a shallow area ranging from four meters to 310 meters in depth, create an unique environment with high productivity. The strong wave activity and currents make a tumultuous bottom which produces fine to medium grained sand and some gravel, as we saw in our Shipek Grab. The large counterclockwise gyre of the Gulf of Maine and the smaller clockwise one over

Georges Shoals lead to two fronts which mix waters. This contact and exchange is supported by the salinity and temperature data which show horizontally well-mixed waters (*Figure 7*). Vertically, the waters are also mixed by upwelling, which leads to the low surface temperatures we saw, because cold bottom water is pulled to the surface.

Figure 7. CTD (Conductivity, Temperature, Depth) probe results for station HC-006 on Georges Bank (also see Appendix D). The three panels show (from left to right) temperature (°C), salinity (practical salinity units), and density (sigma theta) of the water column from the surface down to 50 m. The lack of change in these parameters with depth indicates a lack of stratification due to complete mixing.

The prolific biological activity of Georges Bank has been impacted most drastically by these waters moving rapidly over the shallow banks, creating a high-energy environment which allows for little stratification in nutrient concentration. The lack of stratification means that the organisms of Georges Bank have a continuous supply of nutrients upwelling from the bottom. The nutrients cause the phytoplankton bloom in early spring, which supplies the next level, the zooplankton, with sustenance, creating a base on which larger organisms thrive.

The chemistry of Georges Bank shows certain chemical properties necessary for and indicative of marine life. The tests that we have done suggest that the salinity, dissolved oxygen concentration and phosphate concentration of Georges Bank is different from the other areas we have studied. The tests for salinity and dissolved oxygen show that the levels do not significantly change as depth increases, which indicates the water of the bank is well mixed by tides and currents. The relatively high levels of phosphate in the waters of bank show a high level of nutrients which allows marine life to thrive in the area. The high level of dissolved oxygen relative to the other areas we have studied can be explained by the high levels of phytoplankton around the bank.

The interplay of these facets of Georges Bank creates a highly productive environment. Historically it has been a lucrative fishing ground and scientifically a haven for research and discovery.

Warm Core Eddy (B watch report)

A warm core eddy is a pocket of warm Sargasso Sea water in the cool continental margin water. These eddies are relatively unproductive due to the lack of nutrients found in the area. Because they are created by temporary meanders of the *Gulf Stream* (see Figure 3), they usually only exist for a few months at a time, but sometimes up to a year. They spin in a clockwise spiral in a southwesterly direction. They are usually found in waters deeper than one full kilometer.

Because warm core eddies are part of the Sargasso Sea, they usually share the same organisms such as zooplankton and phytoplankton. However, these life forms are less *abundant* in warm core eddies than they are in the North Atlantic slope waters. This is because the warm, nutrient-poor Sargasso Sea rarely mixes with the more nutrient rich deep water below the permanent thermocline. On the other hand, the slope water has a steady supply of nutrients from terrestrial run-off, seasonal mixing with the deep water, and upwelling near the banks. Because plankton *are* the base of the food chain, larger marine mammals are not found in warm core eddies.

Warm core eddies can be identified by the drastic change in temperature of the water (from fifteen degrees Celsius to twenty two degrees Celsius or higher), increased salinity, and decreased density (see Figure 2, and Figures 8 and 9 below) the lack of nutrients and productivity (identified by the clarity and blue color of the water signifying the lack of chlorophyll), and the lack of large organisms such as whales that need the organisms below it in the food web to survive.

Figure 8. CTD (Conductivity, Temperature, Depth) probe results for station HC-004 in the Warm Core Eddy (also see Appendix D). The three panels show (from left to right) temperature (°C), salinity (practical salinity units), and density (sigma theta) of the water column from the surface down to 1500 m. Note the warmer, less dense water of the Warm Core Eddy floating on top of the cooler, denser deep water of the Continental slope.

On our trip, we discovered that warm core eddies are an environment in the Atlantic that, due to their uniqueness, provide interesting phenomenon for oceanographic study.

Figure 9. Computer generated constant temperature contours (isotherms) plotted versus depth and taffrail log reading. Data was obtained from a Mechanical Bathythermograph transect through the Warm Core Eddy (see Appendix C for MBT station locations). Notice the warmer (and therefore less dense) 19-23° C water of the WCE floating on top of the cooler continental slope water (<18° C).

Shelf and Basin: An oceanographic study of the shelf-slope area south of Cape Cod and Wilkinson Basin (C watch report)

We compared two marine environments, the continental shelf and Wilkinson Basin, finding similarities due to water stratification and overwhelming differences, demonstrating the versatility of the world's oceans.

On the continental shelf, two surface stations were done to test for nutrients and chlorophyll levels. SS-004 was in shallower waters than SS-005, though SS-005 exhibited higher chlorophyll readings--SS-004 had 0.404 ug/L while SS-005 had 0.565 ug/L. While an explanation for this occurrence could be an abundance of nutrients at SS-005 allowing for a flourishing phytoplankton community, this was not the case. SS-004 had a much higher level of phosphate in their waters with a 1.2 reading on a scale of 0-2.

An explanation for this probably comes from the method used to measure the phosphate levels. The levels were determined by relative color readings rather than precise scales, allowing for a large margin of error (*students used a chemical technique in which phosphate is converted to a blue compound; a number of students then ranked the amount of color in each sample and the ranks were averaged to give the relative amount of phosphate per sample*).

The EBT was deployed twice at the continental shelf to measure the temperature versus depth. The first one, instead of resulting in a normal curve of decreasing temperature with depth, showed an increase in temperature with depth. A second EBT was launched to see if human error had accounted for this abnormality. However, the second EBT gave similar data, giving evidence that this was an example of a temperature inversion caused when water that is cooler *is actually on top of warmer water* (Figure 10).

Figure 10. Water column temperature from the surface to 100m obtained from two successive casts with the Electronic Bathythermograph (casts EBT-004 at 40°15' N x 70°16' W and EBT-005 at 40°11' N x 70°13' W). Note the unusual temperature inversion due to the warmer, more saline slope water beneath the cooler, fresher shelf water.

In order to back up the findings of the EBT, a hydrocast with CTD attached was completed. Using the CTD at the continental shelf, we observed the same temperature inversion where temperature, salinity, and density increased with depth (Figure 11). Nutrient levels were high throughout the water column while chlorophyll levels remained high at the surface due to the abundance of sunlight. Dissolved oxygen levels at the surface were also higher because of the air/water interface and the larger amount of photosynthesis occurring.

We then completed two neuston tows on the shelf beginning at 0140 the morning of June 24 and found that the average density of surface organisms was 0.166 ml/m² which was higher than in the Gulf Stream. Two one hundred counts were done and the results demonstrated the abundance of copepods over other

organisms. Through the high biomass and density we found that this water was more productive, which can also explain the amount of marine mammals we sighted. *In 48 hours we spotted over 100 individuals belonging to at least 6 species; fin whale (*Balaenoptera pycalus*), humpback whales (*Megaptera novaeangliae*) common dolphins (*Delphinus delphis*), striped dolphins (*Stenella coeruleoalba*), pilot whales (*Globicephala melaena*), and a group of unidentified spotted dolphins.*

Figure 11. CTD (Conductivity, Temperature, Depth) probe results for station HC-002 on the continental shelf (also see Appendix D). The three panels show (from left to right) temperature (°C), salinity (practical salinity units), and density (sigma theta) of the water column from the surface down to 100 m. Note the same temperature inversion shown by the EBTs in Figure 10. In addition, the CTD data shows that the warm slope water at the bottom (first panel) is more saline (center panel) and therefore more dense (last panel).

Due to such factors as wind, waves and current, the sediment on the shelf can be composed of very different organic and inorganic materials, ranging in all shapes and sizes. Analysis of the bottom with Fisher scoop *samples FS-004 and FS-005* shows that as depth increases there is a marked progression to finer and finer sediments. FS-004 was done closer to shore, near Nantucket, therefore showing coarser sediments. A subsequent Fisher Scoop, FS-005, was done 10 nm further offshore, returning with sediments that were remarkably finer. This can be attributed to the fact that in deeper water there is less *current*, therefore the water cannot support finer sediments. As a general trend, sediments got finer as the depth increased.

We then compared the environment at the continental shelf to that of Wilkinson Basin. 15-20 million years ago the Gulf of Maine was submerged, smooth and shallow. From either an uplift of the sea bottom or a lowering of the sea level, dry land was exposed. This exposed land was eroded by streams and with the approaching Ice Age, the Gulf was filled with ice. Glaciers moved through the area and carved out Wilkinson Basin, pushing large rocks from the site. In place of this, the sediment of this area,

as obtained by the Shipek Grab, consisted of fine silt and clay. As the depth increases and *current* decreases with the bottom of the basin being low energy the finest silts settle on the bottom. From the CTD taken in the basin (*Figure 12*), we concluded that the warm waters coming from the continental shelf flow into the basin through the North East Channel. The warm water settles to the bottom because it has higher density due to increased salinity.

Figure 12. CTD (Conductivity, Temperature, Depth) probe results for station HC-007 in Wilkinson Basin in the Gulf of Maine (also see Appendix D). The three panels show (from left to right) temperature (°C), salinity (practical salinity units), and density (sigma theta) of the water column from the surface down to 200 m. As for the CTD cast in Figure 11, the warm slope water at the bottom (first panel) is more saline (center panel) and therefore more dense (last panel) than the mid-depth waters.

Then, comparing the phytoplankton tows over Wilkinson Basin and Georges Bank, we observe that Georges Bank had a more productive environment with more phytoplankton. However, many of the same organisms were found in Wilkinson Basin including diatoms and dinoflagellates such as Ceratium. Zooplankton, including nauplii larvae and copepods were also found in both environments. Surface phosphate levels in the basin were low, contributing to the low plankton count and low chlorophyll levels, with this trend remaining because of the sinking of nutrients into the deep water of the basin.

These two ocean environments had similar trends in their temperature, salinity and density levels as they increased with depth. However, this similarity is only superficial and for drastically distinct reasons, reflecting the differences in the environments. The variety in sediment type and primary productivity as reflected by chlorophyll levels also demonstrate the difference of these environments. In essence, Wilkinson's Basin was not a very productive environment, in comparison to the highly productive area of the continental shelf. Thus, through this project we observed two of the environmental extremes within the ocean community.

Appendix A; Surface Stations

Station	Date (yyyy/mm/dd)	Time	Log (nm)	Lat. (N)	Long. (W)	Sea Surface Temperature (°C)
SS-001	1995/06/23	1200	~	41°30'	70°40'	17.8
SS-002	1995/06/23	1800	14.0	41°18'	70°59'	16.8
SS-003	1995/06/24	0000	51.8	40°50'	70°42'	14.9
SS-004	1995/06/24	0600	86.5	40°23'	70°24'	14.2
SS-005	1995/06/24	1200	118.5	40°02'	70°03'	17.3
SS-006	1995/06/24	1800	157.4	39°41'	69°31'	22.1
SS-007	1995/06/25	0005	194.9	39°21'	68°57'	22.1
SS-008	1995/06/25	0600	215.0	39°31'	68°45'	23.6
SS-009	1995/06/27	0615	474.5	42°25'	69°36'	15.4
SS-010	1995/06/28	1715	~	just N of Tobin Bridge, Boston		~
SS-011	1995/06/28	1835	~	42°21'	70°56'	17.8
SS-012	1995/06/28	1837	~	42°20'	70°56'	17.8
SS-013	1995/06/28	1845	~	42°22'	70°55'	17.0
SS-014	1995/06/28	1930	~	42°24'	70°52'	17.2
SS-015	1995/06/28	2000	588.3	42°26'	70°50'	16.8

~ = data not determined

Appendix B; Fisher Scoop Stations

Station	Date (yyyy/mm/dd)	time	Log (nm)	Lat. (N)	Long. (W)	Locale	Depth (m)	Sediment Description
FS-001	1995/06/23	1352	3.2	41°24'	70°51'	VINEYARD SOUND	23	ANGULAR MEDIUM SAND
FS-002	1995/06/23	1711	11.3	41°20'	70°58'	SOUTH OF NANTUCKET	28	GREENISH-BROWN SAND
FS-003	1995/06/23	2103	31.0	41°04'	70°56'	S. OF MARTHA'S VINEYARD	30	MEDIUM-GRAINED SAND
FS-004	1995/06/24	0737	98.9	40°15'	70°16'	53NM S. OF NANTUCKET	96	GRAYISH-BROWN SAND
FS-005	1995/06/24	0855	105.5	40°11'	70°13'	64NM S. OF NANTUCKET	102	GRAYISH-BROWN SAND

Appendix C; Mechanical Bathythermograph Stations

Station	Date (yyyy/mm/dd)	Time	Log (nm)	Lat. (N)	Long. (W)	Sea Surface Temp. (°C)
MBT-001	1995/06/24	1335	129.0	39°56'	69°55'	19.4
MBT-002	1995/06/24	1615	146.5	39°47'	69°40'	19.4
MBT-003	1995/06/24	1745	153.3	39°44'	69°35'	21.4
MBT-004	1995/06/24	1915	166.0	39°37'	69°24'	19.0
MBT-005	1995/06/24	2010	174.0	39°34'	69°17'	24.4
MBT-006	1995/06/24	2130	177.8	39°29'	69°09'	24.2
MBT-007	1995/06/24	2341	193.8	39°22'	68°59'	23.0
MBT-008	1995/06/25	0203	200.5	39°21'	68°57'	23.4
MBT-009	1995/06/25	0358	207.9	39°17'	68°52'	23.8
MBT-010	1995/06/25	0530	213.5	39°14'	68°46'	23.7
MBT-011	1995/06/26	2044	407.8	41°40'	68°40'	15.5

Appendix D; Hydrocast/CTD Stations¹

Cast	Bottle	Depth (m)	Date (yyyy/mm/dd)	Time	Log (nm)	Lat (N)	Long (W)	Temp (°C)	Sal (ppt)	PO ₄ (rel.)	Chl (ug/L)	O ₂ (mL/L)
2	1	90	1995/06/24	1000	108.5	40°09'	70°11'	12.71	34.921	1.83	0.039	4.73
2	8	35	1995/06/24	1000	108.5	40°09'	70°11'	9.31	33.687	1	0.11	5.08
2	12	10	1995/06/24	1000	108.5	40°09'	70°11'	12.53	32.825	1.83	0.255	5.26
4	1	1000	1995/06/25	1000	236.6	39°27'	68°58'	4.04	35.016	2	0.005	2.88
4	3	500	1995/06/25	1000	236.6	39°27'	68°58'	5.69	35.085	~	0.008	2.91
4	8	100	1995/06/25	1000	236.6	39°27'	68°58'	14.15	35.913	~	0.08	3.93
4	9	75	1995/06/25	1000	236.6	39°27'	68°58'	15.79	36.071	~	~	4.08
4	10	50	1995/06/25	1000	236.6	39°27'	68°58'	17.16	36.279	~	0.138	3.17
4	12	10	1995/06/25	1000	236.6	39°27'	68°58'	22.55	34.848	0.6	0.366	4.77
6	2	40	1995/06/26	1530	382.7	41°23'	68°19'	9.8	32.547	1.72	0.41	5.55
6	5	25	1995/06/26	1530	382.7	41°23'	68°19'	9.99	32.558	~	0.2859	5.64
6	8	10	1995/06/26	1530	382.7	41°23'	68°19'	10.37	32.369	1	0.343	5.6
6	11	0	1995/06/26	1530	382.7	41°23'	68°19'	11.56	32.579	~	0.3	5.51
7	bucket	0	1995/06/27	0550	474.5	42°25'	69°36'	15.4	~	~	~	~

~ = data not determined

¹ See Appendix E for Temperature-Salinity plots

Appendix E; TS diagrams of CTD data

CTD002: C139A CTD 002, TS plot

CTD004: C139A CTD 004, TS plot

CTD006B: C139A CTD 006, TS plot

CTD007: C139A CTD 007, TS plot

Appendix F; Neuston net Tow Stations

Station	Date (yyyy/mm/dd)	Time	SST (°C)	Log (nm)	Lat. (N)	Long. (W)	Locale	Zooplankton Density (ml/m ²)
NT-001A	1995/06/24	0140	13.3	62.0	40°42'	70°36'	SHELF/S. OF CAPE COD	0.173
NT-001B	1995/06/24	0216	13.3	63.3	40°42'	70°36'	SHELF/S. OF CAPE COD	0.159
NT-003A	1995/06/25	0114	24.0	199.8	39°20'	68°55'	124NM S/SE OF NANT.	0.025
NT-003B	1995/06/25	0152	24.0	200.2	39°21'	68°56'	124NM S/SE OF NANT.	0.025
NT-005A	1995/06/26	1204	12.2	375.0	41°19'	68°22'	GEORGE'S BANK	0.00054
NT-005B	1995/06/26	1231	12.2	376.3	41°20'	68°22'	GEORGE'S BANK	0.00054

Neuston Tow

Composition(avg.):	NT-001	NT-003	NT-005
copepods	57%	55%	38%
fish eggs	18.5%	21%	60%
mysids	14%	5%	
crab larvae	5%	3.5%	
isopods	4.5%		1%
pteropods	1%		
hyperid amphipod		7.0%	
gammerid amphipods		2.5%	1%
stomatopods		2.5%	
pelagic shrimp		2%	
polychaete worms		1%	

Appendix G; Phytoplankton Net Stations

Station	Date (yyyy/mm/dd)	Time	Log (nm)	Lat. (N)	Long. (W)	Locale
PN-006	1995/06/26	1530	382.7	41°22'	68°19'	Georges Bank
PN-007	1995/06/27	0600	474.5	42°25'	69°36'	Wilkinson Basin

Appendix H; Shipek grab Stations

Station	Date (yyyy/mm/dd)	Time	Log (nm)	Lat. (N)	Long. (W)	Locale	Depth(m)
SG-006	1995/06/26	1630	382.7	41°22'	68°19'	Georges Bank	56
SG-007	1995/06/27	600	474.5	42°24'	69°37'	Wilkinson Basin	258