CRUISE REPORT

W-58

Scientific Activities

Woods Hole - New York - St. Georges - Woods Hole

3 June - 15 July 1981

R/V Westward

Sea Education Association

Woods Hole, Massachusetts

DRAFT COPY

PREFACE

This cruise report is intended to serve as an outline of the scientific research and academic program conducted on the fifty-eighth cruise of the research vessel Westward which took place between 3 June and 15 July 1981. Included are the abstracts from twenty-four student projects completed and written during the cruise and preliminary results of oceanographic studies designed by the chief scientist. Also reported here are data which are being incorporated in the long-term studies of S.E.A. staff scientists and other associated researchers. The bulk of this report was written while at sea and is not intended to represent the final analysis or interpretation of data generated during R/V Westward cruise W-58.

Through the diligent efforts of Westward's captain and crew we were able to successfully complete twenty-four very ambitious student projects and numerous other studies. Carl Chase, as Westward's master, easily gains the respect and admiration of his associates. In addition to his expertise as a seaman and captain, Carl seems to have limitless musical talent, ingenuity, patience, and good humor. Those of us on W-58 had the privilege of sailing with a highly skilled and veteran nautical staff, including Paul DeOrsay, Jeff Bolster, and Brian Kingsbury. The three mates provided the skillful ship handling and navigation required to accomplish our scientific objectives. Gary Manter proved to be a constant source of high spirit and cod fish, in addition to being a skillful engineer. As she has done in the past, Cathy Cunningham kept Westward filled with delightful foods and contagious good humor. I am particularly indebted to my assistant scientists for their tireless efforts in Westward's laboratory. Alan Hickey constantly

proves himself as a skilled, versatile, and experienced oceanographer with nearly unlimited patience and persistence. As an experienced marine biologist, Holly Greening provided us with an unfathomable source of information on marine invertebrates, birds, and mammals. On Leg III of the cruise we were privileged to gain the assistance of Dickie Allison who has more experience on Westward than all of the other scientists together. Alan, Holly, and Dickie relieved me of the burden of nearly all technical matters in the laboratory, thus allowing me the time for coordination of excellent student projects and oceanographic stations. In addition to the ship's regular crew, Professor Ranlet Lincoln from the University of Chicago joined us on Leg III. He provided us with a particularly interesting discussion of Melville's "Billy Budd" and his company as a visiting scholar was a pleasant addition to the crew.

I offer my sincere thanks to all of those mentioned above and to all of the sea semester students for contributing to a wonderfully successful, productive, and memorable Westward cruise. W-58 progressed smoothly not only because of good weather, but because of the dedication shown by all of the participants to the program and to one another.

Allan W. Stoner

Chief Scientist

W-58

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Introduction

This report is the written product of cruise W-58 of the research vessel Westward and Introduction to Marine Science Laboratory offered by Boston University (course number NS 225L). The cruise track (Fig. 1) was designed to permit collection of physical, chemical, and biological data from several of the major water masses in the North Atlantic Ocean including samples from the shelf, slope, Gulf Stream, and Sargasso Sea. Additionally, samples were taken in smaller geographic areas such as Georges Bank, Long Island Sound, the New York Bight, Gulf Stream rings, and a localized upwelling zone off Yarmouth, Nova Scotia (Fig. 2). The ship's itinerary, including intermediate ports of call (Table 1), permitted W-58 participants access to several terrestrial and neritic habitats in addition to the open ocean environment. Cruise participants are listed in Table 2.

Although the major theme of the cruise was a physical and biological comparison of the major North Atlantic water masses and Georges Bank, numerous oceanographic problems and marine biological problems were investigated during the cruise. Each of these studies will be introduced in its own section and introductory remarks will be followed by data generated by group efforts, and by abstracts of individual student projects which make up a large portion of the report.

The positions for all oceanographic stations and scientific operations are listed in Appendix 1 and data from the oceanographic stations are tabulated in Appendices 2 and 3. Information reported herein may not be excerpted or cited without the written permission of the Chief Scientist.

Fig. 1: Cruise track of R/V Westward cruise W-58. Positions shown are for noon of the date given.

Fig. 2: Oceanographic stations sampled on R/V Westward cruise W-58.

Table 1: Itinerary of R/V Westward cruise W-58

<u>Depart</u>		<u>Arrive</u>	
Woods Hole, MA	3 June 1981	Nantucket	10 June 1981
Nantucket	11 June 1981	Martha's Vineyard	11 June 1981
Martha's Vineyard	11 June 1981	Oyster Bay, NY	14 June 1981
Oyster Bay, NY	15 June 1981	New York City	15 June 1981
New York City	17 June 1981	St. Georges, Bermuda	26 June 1981
St. Georges, Bermuda	30 June 1981	Bar Harbor, Maine	8 July 1981
Bar Harbor, Maine	8 July 1981	Horseshoe Cove, Maine	10 July 1981
Horseshoe Cove, Maine	11 July 1981	Woods Hole, MA	15 July 1981

Table 2: Ship's complement on R/V Westward cruise W-58

Nautical Staff

Carl Chase, B. A.	Captain
Paul DeOrsay, B. A.	Chief Mate
Jeffrey Bolster, B. A.	Second Mate
Brian Kingsbury, B. S.	Third Mate

Scientific Staff

Allan Stoner, Ph. D.	Chief Scientist
Alan Hickey, B. S.	Second Scientist
Holly Greening, M. S.	Third Scientist
Molly Allison, M. S.	Third Scientist

Visiting Scholar

Ranlet Lincoln
University of Chicago - Leg III

Students

Jill Benedict	Junior, Biology, Colby College
Vivian Berkowitz	Junior, Biology, University of Miami
Craig Boyett	Junior, Business, Boston University
Robert Campbell	Sophomore, English, Middlebury College
Anne Conrad	Sophomore, Science, Dickinson College
Mark Dawson	Freshman, Culinary Institute of America, New York
Joanne Erkenbeck	Sophomore, Zoology, University of New Hampshire
Debra Felix	Sophomore, Biology, Swarthmore College
Nancy Fishbein	B.S., Environmental Studies, Middlebury College
Jorge Giraldo	Freshman, Biology, Universidad de Los Andes
Timothy Graves	Junior, Geology, Hamilton College
Charles Holloway	Sophomore, Biology, Hampden-Sydney College
Adrienne Houseman	Sophomore, Geology, Tulane University
Kathy Joseph	Junior, Biology, University of Dayton
Stephen LaFrance	Sophomore, Civil Engineering, Worcester Polytechnic Institute
Lauren McKean	Sophomore, Biology, Amherst College
Elizabeth McKinley	Junior, Biology, Middlebury College
Wendy McManus	Sophomore, Business, University of Massachusetts

Table 2: (continued)

Adele Mengersen	Junior, Biology, University of Missouri
Marcia Meyer	Senior, Fine Arts, Ohio State University
Lisa Pistone	B.A., Psychology, University of Pennsylvania
Allen Reilly	Sophomore, Environmental Studies, Carleton College
Vincent Stucker	Sophomore, Zoology, Oklahoma State University
Eric Wetzstein	Junior, Earth Science, University of South Dakota

Academic Program

Throughout the six week period covered by R/V Westward cruise W-58 a 24-hour science watch was maintained by teams of three students and one member of the science staff. During science watch students were instructed in the use of gear and scientific procedures spanning many aspects of physical, chemical, geological, and biological oceanography. Instruction was provided in the form of oceanographic and marine biological research which was conducted either for individual projects or the work of S.E.A. staff or long-term cooperative programs. Routine meteorological and oceanic observations were made and weather data were transmitted during science watches. During the last two weeks of the cruise, students were sufficiently familiar with scientific procedures to operate activities of the laboratory without significant help from the marine science staff.

Formal instruction on a daily basis was provided in the form of lectures given by the marine science staff. Lecture topics, designed to cover aspects of science and history not readily gained from laboratory experience, are listed in Table 3. In addition to lecture material, a small museum of organisms called "Creature Features" was developed during the cruise to familiarize students with the life history and adaptations of important marine vertebrates, invertebrates, and plants.

Oceanographic studies fell into three categories: (1) Each student took to sea a well-planned project which could be completed during the cruise. These projects were chosen by the students and completed as independent research. A short seminar at the end of the cruise was given by each student to summarize their findings. (2) Several projects, designed by the marine science staff, were completed to demonstrate or test particular oceanographic principles. These cruise projects required the participation of all student crew members in data gathering, sample processing, and data reduction. (3) Several long-term projects are being conducted by S.E.A. staff members and associated organizations. These include meteorological observations, analysis of sea bird distribution, and distribution of phyllosoma larvae. These projects will be discussed later.

Every oceanographic station was made for the purpose of actual research and no sample was taken solely for the purpose of demonstration. In this way, students were given the opportunity to learn from meaningful participation in actual research activities.

Letter grades for Introduction to Marine Science were established on the basis of a project report, a mid-term examination, a final examination and laboratory practice, a seminar, and individual performance in the marine science laboratory.

Water Mass Studies

It is now recognized by oceanographers that the ocean is not a large homogeneous body of water; rather, the ocean is a complex aggregation of physically and biologically distinct water masses. In the North Atlantic Ocean, shelf water is that mass overlying the continental shelves. Shallow depths (<200 m) and runoff from land causes seasonal variation in temperature and salinity, both variables showing minima in the winter. Slope water in the North Atlantic is more stable in terms of physical-chemical properties, is warmer than shelf water, and is characterized by lower biological productivity than shelf water. Along the east coast of the United States slope water occurs over the continental slope and ocean basin between the shelf and the Gulf Stream. Slope water is separated from the Sargasso Sea by the Gulf Stream for which there is abundant literature. Studied intensively since the 1930's, the Gulf Stream is best known as a fast-flowing current, actually the western boundary current of the subtropical North Atlantic gyre system. Current velocities are frequently recorded up to 250 cm/sec. Gulf Stream water, characterized by intense, clear blue water, acquires its characteristics in the environmentally stable tropics of the Caribbean Sea and Florida Straits. Surface temperatures well over 20°C and salinity near 36.0 ‰ are nearly constant.

The Sargasso Sea is that open ocean expanse, the bounds of which were originally defined by the distribution of Sargassum weed. Today, the Sargasso Sea is defined as the center of the anticyclonic gyre in the North Atlantic Ocean bounded on the west by the Gulf Stream, on the north by the North Atlantic Drift, on the east by the Canaries Current, and on the south by the North Equatorial Current and the Antilles Current. The Sargasso Sea is very clear and has surface temperatures exceeding 20 C. Because of low precipitation and high evaporation over the Sargasso Sea, the water mass is characterized by higher than average surface salinities, normally between 36 and 37 ‰.

Smaller water masses which are formed by meanders in the Gulf Stream occur within the Sargasso Sea and within the slope water mass; these small masses are called cold and warm core rings, respectively. Cold core rings have been known since 1810 but were believed to be a result of icebergs melting on the Sargasso Sea. Now, it is known that Gulf

Table 3: Marine science classes held during R/V Westward cruise W-58

<u>Date</u>	<u>Topic</u>	<u>Lecturer</u>
T 4 June	Gulf of Maine and Georges Bank	Stoner
F 5 June	Bathythermograph	Hickey
M 8 June	Reversing thermometers and Nansen bottles	Hickey
T 9 June	Biology of seabirds	Greening
W 10 June	Dissolved oxygen and salinity	Hickey
F 12 June	Introduction to estuarine habitats	Stoner
15-16 June	(Port stop - New York City)	
W 17 June	Hudson River oceanography	Hickey
T 18 June	Invertebrate zoology I	Greening
F 19 June	Quiz	
M 22 June	Invertebrate zoology II	Greening
T 23 June	The Sargasso Sea and Sargassum associates	Stoner
W 24 June	Spectrophotometry	Hickey
T 25 June	Coral reefs and the geology of Bermuda	Stoner
26-29 June	(Port stop - St. Georges, Bermuda)	
T 30 June	Reef fish ecology	Stoner
W 1 July	Progress Report	Stoner
T 2 July	Quiz	
F 3 July	Student seminars	
M 6 July	Student seminars	
T 7 July	" "	
W 8 July	" "	
T 9 July	" "	
F 10 July	" "	
S 11 July	Final Examination	
M 13 July	Biology of whales	Allison

Stream meanders to the south and east break off, trapping cold, low salinity slope water, forming a cold ring in the Sargasso Sea. Cold rings form five to eight times per year, usually at the latitude of Cape Hatteras. The rings are normally 150 to 300 kilometers in diameter and two kilometers deep, and most live for one and one half to three years before breaking up. Warm-core rings form from north and westward meanders of the Gulf Stream, trapping warm, high salinity Sargasso Sea water. Warm cores, drifting through the slope water mass are usually larger, but less well defined than cold rings, live from one-half to one year, and extend down to 1000 meters. To date, little is known about the physical and biological properties of the rings.

A major goal of R/V Westward cruise W-58 was to characterize the physical, chemical, and biological properties of the major North Atlantic water masses in order to explain some of the differences in biological organization and productivity. Approximately one-third of all student projects on W-58 were designed to compare various aspects of the water masses; these included projects on nutrient regeneration, phytoplankton, zooplankton, avifauna, and physical properties of the Gulf Stream and warm-core rings.

Figure 3, using surface temperature data, shows the major North Atlantic water masses. The Gulf Stream is shown as a band of warm water ($24-28^{\circ}\text{C}$) passing between cooler slope water and Sargasso Sea water ($18-25^{\circ}\text{C}$), with cold and warm rings to the south and north of the Stream, respectively. For the purposes of this cruise report, the shelf water mass will also be divided into several subdivisions. The shallow area around the Gulf of Maine was very cool ($8-10^{\circ}\text{C}$), and thermally distinct from Long Island Sound ($14-19^{\circ}\text{C}$) and the shelf area of the New York Bight ($>20^{\circ}\text{C}$). In passing from New York to the Sargasso Sea an obvious trend on sea surface temperature occurred with shelf water being the coolest water mass and Gulf Stream water being the warmest ($>28^{\circ}\text{C}$) (Fig. 4). Surface salinities also increased toward the Sargasso Sea (from 32 to $37\text{ }^{\circ}/\text{oo}$) (Fig. 4). The vertical temperature profile for the same transect (Fig. 5) shows the complex structure of the slope water between log readings 800 and 875, where numerous thermal inversions occur. The north wall of the Gulf Stream was very apparent at a log reading of approximately 875-900 where isotherms dropped between 300 and 600 feet

in less than 10 miles. The center of the Gulf Stream appeared as a 100 ft. deep lens of 82°F water. Isotherms rose again at the south or east boundary of the Gulf Stream yet relatively high surface temperatures and a deep, diffuse thermocline occurred in the Sargasso Sea.

Several lines of evidence showed that the major water masses were distinct oceanographic zones: (1) In sampling a warm core ring north of Bermuda, it was found that the edges of a disintegrating ring have properties similar to the north wall of the Gulf Stream, with significant amounts of vertical turbulence, not unlike the slope water mass examined off New York (Giraldo). (2) In comparing the physical and chemical properties of the water column it became clear that shelf sites demonstrate more effective nutrient regeneration than the deeper, more stratified water masses (Campbell) and that differences in the stratification of the water masses explained phytoplankton pigment diversity (Mengersen). (3) A series of zooplankton tows across the north wall of the Gulf Stream showed that that oceanic front is an effective barrier to plankton, at least near the surface where a severe horizontal density gradient occurs (McKean). (4) Dramatic differences in the size-frequency distribution of zooplankton (Berkowitz) and differences in the abundance and species composition of zooplankton (Stucker), birds (Benedict), and mid-water fauna (Stoner and Allison) occur among the north Atlantic water masses.

Because of efficient nutrient regeneration, the shallow shelf areas (especially Nantucket Sound and the Yarmouth, Nova Scotia, upwelling site) showed high standing crops of zooplankton (Table 4), but zooplankton biomass was also high in the slope water near the Gulf Stream because of vertical mixing. Even more striking was that the relative abundance of meroplanktonic forms such as zoea and fish eggs which declined with distance from shore. For example, at station 13 in Long Island Sound, 97% of the zooplankton were zoea, whereas in the slope water, the Gulf Stream, and Sargasso Sea a very diverse assemblage of holoplankton made up most of the zooplankton samples (Table 4). Virtually all taxa seem to indicate that very distinct water masses occur in the north Atlantic Ocean for reasons explained by the physical properties of the water column; some of the major faunistic characteristics of shelf, slope, and Sargasso Sea water masses are summarized in Table 5.

Fig. 3: Surface temperatures and major water masses in the North Atlantic Ocean on June 24, 1981. ShW = shelf water, SlW = slope water, GS = Gulf Stream, SS = Sargasso Sea, CE = cold eddy, WE = warm eddy. Temperatures are in degrees Centigrade. (Modified from NOAA weather map).

Fig. 4: Sea surface temperatures in a transect from New York Bight toward Bermuda.
Mean salinities are given for the major water masses.

Fig. 5: Bathythermograph transect from the slope water off New York Bight through the Gulf Stream and into the Sargasso Sea. Temperatures are in $^{\circ}$ F.

Table 4: Zooplankton biomass values and species composition at selected stations in different water masses encountered during R/V Westward cruise W-58

Station	Location	Biomass (g/100m ³)	Abundant taxa (% of total, each group)
W58-2	Slope	32.0	Abundant jelly fish Rest - 92% copepods
W58-10	E. of Cape Cod	1.9	Copepods - 61, Zoea - 26
W58-12	Nantucket Sound	21.0	Zoea - 94, Mysis - 2
W58-13	Long Island Sound	6.3	Zoea - 97, Fish eggs - 2
W58-14	Long Island Sound	1.7	Ctenophores - 52, Fish eggs - 47
W58-19	N.Y. Dump Site	1.0	Jellyfish - 99
W58-21	Outer shelf (NY)	3.8	Copepods - 57, Ctenophores - 28 Fish eggs and larvae - 15
W58-23	Slope	6.7	Copepods - 54, Chaetognatha - 14, Amphipods - 14, Jellyfish - 9, plus large variety miscellaneous taxa
W58-24	N. Wall, Gulf Stream	26.0	Copepods - 32, Chaetognatha - 8, Shrimp - 5, plus miscellaneous
W58-25	Gulf Stream	28.0	Copepods - 31, Amphipods - 14, Zoea - 9, Fish eggs - 8, plus miscellaneous
W58-27	Sargasso Sea	6.6	Chaetognatha - 25, Siphonophores - 20, Copepods - 19, Euphausiids - 6, Shrimp - 5, plus miscellaneous
W58-30	Sargasso Sea	5.8	Copepods - 72, Euphausiids - 7, Fish eggs - 4, plus miscellaneous
W58-43	Yarmouth Upwelling	97.0	Copepods - 100

Table 5: Summary of the major faunistic differences among shelf, slope, and Sargasso Sea water masses found on R/V Westward cruise W-58

	Shelf	Slope	Sargasso Sea
<u>Mammals</u>	Saddleback dolphin Humpback whales	White-sided dolphin Sperm whales	Sperm whales
<u>Birds</u>	Gulls Terns	Petrels Shearwaters	Few birds
<u>Fishes</u>	Flounders Cod Herring		Flying fish Wahoo Dolphin Jacks
<u>Plankton</u>	Meroplankton Zoea Mysis Megalopa Polychaeta Small chaetognatha (Jelly animals - see Fig. 12)	Few meroplankton Large copepods Jellyfish Largest chaetognatha	Nearly all holoplankton Small copepods Salps Phyllosoma larvae Siphonophores Large chaetognatha
<u>Miscellaneous</u>	Floating <u>Fucus</u> <u>Ascophyllum</u> (Deep-sea organisms - see Table 6)		<u>Sargassum</u> <u>Halobates</u>

The Search for a Warm Core Eddy

Jorge Giraldo

ABSTRACT

A 300 mile bathythermograph transect was used to detect and analyze a warm core eddy centered at approximately 39°N latitude, 61°W longitude (Fig. 6). After passing through the north wall of the Gulf Stream, going north, a very complex thermal profile was found in the warm ring and in the slope water around the ring. The profile showed a high level of vertical turbulence and inversion of isotherms (Fig. 6). Salinity, temperature, density, and dissolved oxygen data taken with two 1200-m deep hydrocasts indicated that the edges of the eddy were sampled rather than the center. The water column at both sites showed characteristics which were not like Sargasso Sea or slope water stations, probably a result of turbulence related to the boundary current around the warm core.*

* Chief Scientist's note: NOAA maps showed that on 15 July, 1981, the warm core examined on 3-4 July had disappeared completely. The ring which was very old (approximately one year) and probably in the process of breaking up during the W-58 transect. The thermal profile, therefore, has shown the turbulence and physical structure of a dying warm core ring.

Fig. 6: Bathythermograph transect of the Gulf Stream north wall and a warm-core ring north of Bermuda. Temperatures are in $^{\circ}$ F.

Nutrient Regeneration in the Big Pond

Robert Campbell

ABSTRACT

Certain nutrients such as phosphates, nitrates, and silicates are of fundamental importance to the cycle of marine productivity, where the productivity of a particular water mass depends upon how effectively nutrients are recycled to surface waters. Over the cruise track of R/V Westward cruise W-58, eight stations (Fig. 7) were examined for physical properties of the water column and for the vertical profile of nutrient compounds. Examining the temperature-salinity and resulting density profile yielded a model of the water column for each station from which the degree of vertical mixing could be determined. Nutrient levels were found to be inversely related to the degree of density stratification in the water column. Georges Bank had the highest surface nutrient levels (Fig. 7) and showed almost no vertical stratification of water density. In contrast, the Gulf Stream and Sargasso Sea stations had very low surface nutrient levels while showing a high degree of vertical stratification. Other shelf and slope stations were intermediate in nutrient regenerating capacity. (See Appendix 3 for detailed information on physical and chemical properties at each of the stations.)

Fig. 7: Stations sampled for comparison of physical-chemical parameters in the major North Atlantic water masses. Values beside the station numbers are surface phosphate concentrations ($\mu\text{g-at/l}$) (bd = below determination).

Pigment Diversity as a Measure of Maturity of Phytoplankton Communities

Adele Mengersen

ABSTRACT

It was hypothesized by Ramon Margalef that the idea of ecological succession can be related to phytoplankton communities. It was proposed that an index based on the ratio of carotenoids to chlorophyll-a in a sample be used to determine the level of organization in a particular community. This method was applied in four different water masses (Georges Bank, Sargasso Sea, shelf off New York, and warm core ring) using a surface phytoplankton tow and pigment extraction. It was predicted that a high degree of density stratification in the underlying water column and consequential stability of the system would produce high pigment diversity indices. An examination of water column stratification confirmed the hypothesis (Fig. 8). However, it was found that the species diversity index (H') was not related to stratification of the water column or the pigment diversity index. Speculation as to the cause of this incongruity and alternative sampling techniques were proposed.

Fig. 8: Pigment diversity indices (open bars) and Shannon-Weaver species diversity indices (dark bars) for phytoplankton collected on Georges Bank, and in the Sargasso Sea, New York Bight, and in a warm-core ring (bottom). Water density profiles for each column are shown at the top of the figure.

Hydrographic and Biological Distributions Over the North Wall of the Gulf Stream

Lauren McKean

ABSTRACT

The north wall on the western edge of the Gulf Stream is the thermal oceanic front between the Gulf Stream and the waters of the continental slope off North America. A series of four stations were sampled for physico-chemical and biological properties in a 35-mile transect. Zooplankton was sampled with oblique tows to 100 and 200m depth. Although there was increased mixing between slope, Gulf Stream and Sargasso Sea water masses with depth, the 100-m biomass levels at the north wall and Gulf Stream stations were four times as great as those in the nearby slope water and Sargasso Sea stations (Fig. 9). Compositional differences in the zooplankton also indicated that the water masses were quite distinct and the north wall serves as a barrier to plankton above 100-m. Below 100-m, however, the north wall appears to be a less effective barrier to zooplankton, as indicated by the presence of the cold water euphausiid Euphausia krohnii at the north wall station.

Fig. 9: Zooplankton biomass near the north wall of the Gulf Stream. Dark bars represent samples taken in oblique tows to 100 m depth. Open bars represent tows to 200m depth.

Size Distribution of Zooplankton in Five Different Water Masses

Vivian Berhowitz

ABSTRACT

The size-frequency distribution of zooplankton larger than 0.5 mm was examined in five water masses including Georges Bank, Nantucket Sound, slope water, the Sargasso Sea, and a warm-core ring. Each sample was divided into subsamples of individuals larger than 0.5, 1.0, 2.0, and 4.0 mm. The Georges Bank and Nantucket Shoals zooplankton were similar in size distribution with 62 and 80% of the organisms in the 2.0 mm size class, respectively (Fig. 10). The slope station had a relatively uniform distribution of size classes with a high percentage of large zooplankters (35% larger than 4.0 mm). Sargasso Sea and warm-core ring samples showed bimodal distributions of zooplankton size with the majority of animals falling in the 0.5 or 2.0 mm classes. Meroplanktonic forms were abundant only in Nantucket Sound and the species composition of the warm-core ring station and Sargasso Sea station was similar as predicted by theory. Sargasso Sea, slope water, and warm-core ring stations proved to have species diversity higher than that found at the shelf sites; this is probably the result of environmental stability in the deeper, more stratified water masses.

Fig. 10: Size-frequency distribution of zooplankton at five different North Atlantic sites. Values represent the percent of total sample biomass found in each size category.

Predator-Prey Biomass Ratios and Distribution of Holoplankton in
Different Water Masses of the Western North Atlantic

Vincent Stucker

ABSTRACT

Predator-prey ratios were examined at thirteen stations in the North Atlantic including sites in shelf, slope, Gulf Stream, Sargasso Sea, and warm-core ring water masses (Fig. 11). It was hypothesized that the ratio of predator biomass to prey biomass in the holoplankton would be a function of water temperature. However, no correlation was found between predator-prey ratio and temperature, mixed layer depth, dissolved oxygen, salinity, or concentrations of ammonium, phosphate, or silicate. Lack of correlation may be a result of seasonality in reproduction or vertical migration patterns, neither of which could be examined. The larger zooplankters did show water mass specificity (Fig. 12). Shelf and slope water associates were the jellyfish Pelagia cyanella, P. noctura, Chrysarora quinquecirrha, Cyanea capillata, and Aurelia aurita, ctenophores Pleurobrachia pileus and Mertensia ovum, and the chaetognath Sagitta setosa. Gulf Stream and Sargasso Sea associates included the man-of-war Physalia physalia, Vellela vellela, Sagitta elegans, and various salps. Specific associations appear to support the idea of distinct water masses.

Fig. 11: Stations where predator-prey ratios were examined in the North Atlantic Ocean.

	Nantucket shoals	Slope water	Georges Bank	Great Round Shoal	Nantucket Sd.	Long Island Sound	New York Bight	Slope water	Gulf Stream	Sargasso Sea	Gulf Stream	Warm Ring	Slope water	Nova Scotia shelf	Maine shelf
CNIDARIA															
<u>Pelagia cyanelia</u>															
<u>Physalia physalia</u>															
<u>Vellela vellela</u>															
<u>Pelagia noctiluca</u>															
<u>Chrysaora quinquecirrha</u>															
<u>Cyanea capillata</u>															
<u>Aurelia aurita</u>															
<u>Aequorea vitrina</u>															
<u>Diphyes dispar</u>															
CTENOPHORA															
<u>Pleurobrachia pileus</u>															
<u>Mertensia ovum</u>															
CHAETOGNATHA															
<u>Sagitta setosa</u>															
<u>Sagitta elegans</u>															
UROCHORDATA															
<u>Salpa sp.</u>															

Fig. 12: Distribution of major holoplankton predators in the North Atlantic Ocean.

The Distribution and Density of Seabirds as Biological Indicators of
Water Masses in the North Atlantic

Jill Benedict

ABSTRACT

Bird observations were made in several water masses along the cruise track of R/V Westward cruise W-58 to determine if seabird distribution and density could serve as biological indicators of water masses in the North Atlantic Ocean. Water masses examined were Georges Bank, Long Island Sound, nearshore and outer shelf near New York, Gulf Stream, Sargasso Sea, and the north wall of the Gulf Stream. The mean number of birds per 30 min count and species diversity of birds was determined for each water mass; these values were compared to zooplankton biomass. A high percentage of gulls and terns indicated a nearshore habitat, while a high percentage of storm petrels and shearwaters indicated an open ocean water mass. Sites furthest from land showed highest ratios of shearwaters to petrels (Fig. 13). The number of birds was closely related (linear function) to the zooplankton biomass of a site, but no relationship was found between species diversity and zooplankton biomass.

Fig. 13: Abundance (top) and species composition (bottom) of seabirds in various water masses of the North Atlantic Ocean.

Mesopelagic Fauna of the Sargasso Sea and Slope Water Masses in the North Atlantic Ocean

Allan Stoner and Dicky Allison

Isaacs-Kidd Midwater Trawl (IKMT) samples were taken at a mid-Sargasso Sea station (W58-33) and at a slope water station north of the Gulf Stream between Bermuda and Nova Scotia (W58-42). Midnight tows were made in a step-wise fashion from a depth of 1000 meters, fishing for four hours. Calanoid copepods dominated the fauna at both stations, but dramatic differences in the relative proportions of major taxa occurred (Table 6). The Sargasso Sea proved to be the more diverse site, with a relatively even abundance of chaetognaths, euphausiids, and hyperiid amphipods (13% each) in addition to a relatively low abundance of calanoid copepods (42% versus 84% at the slope site). Total abundance of organisms was greatest at the slope station, but the fauna was less diverse, with very few individuals of the minor taxa. In terms of fish and euphausiid species collected, there was no overlap between the study sites with typical cold-water species such as Benthoosema glaciale in slope water and the warm-water species B. suborbitale in the Sargasso Sea. The same trend held for euphausiids. No mysids were found in the Sargasso Sea, while the mesopelagic mysid Eucopia unguiculata was very abundant in slope water. The composition of the mesopelagic fauna in slope water and Sargasso Sea water shows that faunistic differences in the major North Atlantic water masses extend to the deep-sea and are not limited to the epipelagic zone.

Table 6: Contents of mid-water trawl samples from the Sargasso Sea and the North American slope water. Values are the relative abundance of organisms.

Taxonomic Group	Sargasso Sea (stn. W58-33)	Slope (stn. W58-42)
Calanoid copepods	42.0%	84.1%
Chaetognaths	13.0	7.1
Euphausiids	13.0	6.9
Hyperiid amphipods	13.0	0.8
Fishes	5.0	0.52
Salps	5.0	0.01
Prawns	2.0	0.44
Ostracods	3.0	0
Mysids	0	0.07
Pteropods	1.0	0.04
Miscel.	3.0	0.02
	100.0	100.00
<u>Fishes</u>	<u>Diaphus perspicillatus</u> <u>Myctophum punctatum</u> <u>Benthosema suborbitale</u> <u>Sybolophorus veranyi</u> <u>Argyropelacus</u> spp.	<u>Benthosema glaciale</u> <u>Ceratoscopelus maderensis</u> <u>Diaphus rafinesquii</u>
<u>Euphausiids</u>	<u>Stylocheiron</u> spp. (2) <u>Euphausia brevis</u> <u>Nematoscelis tenella</u> <u>Thysanoessa parva</u>	<u>Nematoscelis megalops</u> <u>Euphausia krohnii</u> <u>Thysanoessa longicandata</u>
<u>Mysids</u>		<u>Eucopia unguiculata</u>

Biology of the Pelagic Zone and the Sargasso Sea

The ocean environment is divided for study into the benthic or bottom realm, and the pelagic or open ocean realm. Frequently, the pelagic realm is differentiated from the neritic zone; the latter being defined as the marine environment over the continental shelf which normally extends to 200 m depth. The pelagic habitat is further subdivided into the epipelagic (surface to 200 m), mesopelagic (200-1000 m), bathypelagic (1000-4000 m), and abyssopelagic (>4000 m) zones. Pelagic animals fall into several categories: the plankton-animals which drift passively in the water; the nekton-animals which actively swim, such as fish and squid; and the neuston-a recently discovered fauna that lives on the surface of the water, most notably the marine insect Halobates. Additionally, the oceanic birds and mammals are considered part of the pelagic fauna.

The Sargasso Sea is one of the most important pelagic habitats in the North Atlantic Ocean, and may be defined as the calm center of the anticyclonic gyre in the North Atlantic. The gyre is bounded on the west by the Gulf Stream, on the north by the North Atlantic Drift, on the east by the Canary Current, and on the south by the North Equatorial and Antilles Currents. The Sargasso Sea is actually a thick lens of warm, saline water overlying the 10°C isotherm which drops to 800-1000 m below the surface. The 10° isotherm is only a few hundred meters deep to the west of the Gulf Stream. The Sargasso Sea is known for its low biological productivity, in part due to a strong permanent thermocline found between 400 and 500 m which serves as a barrier to upward diffusion of nutrients. These features were examined in an earlier section (Campbell). Of course, the Sea is best known and named for the two predominant brown algae species Sargassum natans and S. fluitans, which commonly float there.

Although numerous projects used data from the Sargasso Sea as part of comparative studies (these studies are included under other headings), several projects dealt specifically with the Sargassum plant (Joseph and McKinley) or with organisms in or near the Sargasso Sea. Two studies

involved the vertical migration of zooplankton (Felix, Holloway). Fishbein examined the relationship between two groups of pelagic animals, marine mammals and seabirds, and Meyer examined the color adaptations of fishes from the pelagic region of the Sargasso Sea as well as fishes from Georges Bank and reefs near Bermuda. The abstracts for these studies follow.

The Effects of Predation on Species Diversity on the Sargassum Plant

Lissa McKinley and Kathy Joseph

ABSTRACT

Collections were made to study the effects of predation by fishes and crabs on the species diversity of motile macroinvertebrates associated with Sargassum plants. Entire clumps of Sargassum weed were dip netted while R/V Westward was underway. Sargassum species was determined and measured for volume and weight. All motile associates larger than 0.5 mm were separated from the plants and later identified to species and categorized as either predators or prey (Table 7). Most of the organisms identified were shrimp, either Leander tenuicornis or Latreutes fucorum. It was found that the number of prey organisms on a Sargassum clump decreased with the presence of fish and crab predators and that clumps with predators had higher species diversity than clumps without predators. Species diversity was not related to algal clump size as had been predicted, but it was discovered that there was a positive relationship between level of predation and the species diversity of motile macrofauna (Fig. 14).

Table 7: Motile macrofauna found on clumps of Sargassum natans and S. fluitans from the Sargasso Sea.

<u>Prey</u>	<u>Predators</u>
Phylum Arthropoda	Phylum Arthropoda
Order Decapoda	Order Decapoda
Family Hippolytidae	Family Portunidae
<u>Hippolyte caerulescens</u>	<u>Portunus sayi</u>
<u>Latreutes fucorum</u>	Family Grapsidae
Family Palaemonidae	<u>Planes minutes</u>
<u>Leander tenuicornis</u>	
Order Amphipoda	Phylum Chordata
Family Eophliantidae	Family Monacanthidae
<u>Biancolina sp.</u>	<u>Monacanthus hispidus</u>
Order Copepoda	Family Antennariidae
Unident. copepods	<u>Histrio histrio</u>
Order Isopoda	
Family Janiridae	
<u>Bagatus minutus</u>	
Phylum Annelida	
Family Serpulidae	
<u>Spirorbis corrugatus</u>	
Family Nereidae	
<u>Platynereis dumerilli</u>	
<u>Lycostopsis pontica</u>	
Phylum Mollusca	
Family Triphoridae	
<u>Litiopa melanostoma</u>

Fig. 14: Species diversity of Sargassum associates shown as a function of alga clump size and number of predators on a clump.

Differences in Vertical Migration of Chaetognaths on Georges Bank and in the Sargasso Sea Due to Light Absorption

Debra Felix

ABSTRACT

The amount of light which penetrates the water column is affected by the turbidity of the water. In turn, the vertical migration of the arrow worm or chaetognath is influenced by light penetration. Because of lower light penetration on Georges Bank than in the Sargasso Sea, it was hypothesized that chaetognaths must migrate closer to the surface over Georges Bank. To test this hypothesis, nets were towed at 5, 20, and 35 meters at midnight, dawn, noon, and dusk at the two sites.

Although it was impossible to separate temperature and other factors affecting vertical migration, there appeared to be a definite correlation between turbidity and vertical migration. The chaetognaths migrated between greater depths in the Sargasso Sea than on Georges Bank (Table 8), and a much higher abundance of chaetognaths came to within 35 meters of the surface at night on Georges Bank. Sagitta setosa and S. elegans were both found in the Sargasso Sea, whereas S. elegans was the dominant chaetognath on Georges Bank.

Table 8: Abundance of chaetognaths at three different depths in the Sargasso Sea and on Georges Bank, taken at four different times. Numbers in parentheses are the percentages of chaetognaths found in each net.

Depth (m)	<u>Dusk</u>		<u>Midnight</u>		<u>Dawn</u>		<u>Noon</u>	
	#/m ³	(%)	#/m ³	(%)	#/m ³	(%)	#/m ³	(%)
<u>Sargasso Sea</u>								
5	200	(15.5)	320	(15.7)	432	(32.9)	0	(0)
20	812	(62.8)	196	(9.6)	492	(37.5)	44	(61.0)
35	280	(21.7)	1516	(74.6)	388	(29.6)	28	(38.9)
<u>Georges Bank</u>								
5	141	(18.5)	95	(4.5)	2161	(63.0)	4	(2.0)
20	142	(18.3)	350	(16.8)	808	(23.6)	34	(17.3)
35	486	(63.2)	1645	(78.8)	460	(13.4)	158	(80.6)

Effects of Lunar Gravitational Forces on the Vertical Migration of
Euphausiids, Copepods, and Chaetognaths

Charles Holloway

ABSTRACT

Zooplankton were sampled at midnight at two sites in the Sargasso Sea, during a half-moon and during a new moon. Because the samples were taken on nights with a high percentage of cloud cover, ambient light was similar and differences in vertical migration were presumed to be a result of different gravitational accelerations on the two sampling dates. At both sites, nets were set at three different depths and the abundance of copepods, euphausiids, and chaetognaths in each was examined. It was discovered that the total biomass of zooplankton, and the abundance of copepods, euphausiids, and chaetognaths near the surface was greater during the new moon than during the half moon, suggesting that the increased lunar gravitational attraction during the new moon caused organisms to move higher in the water column than those affected by the half moon (Table 9). Several interpretations of the data are tenable in explaining the differences in vertical migration; however, the hypothesis that lunar gravitational effects play a significant role in the migratory behavior of zooplankton was supported.

Table 9: Abundance of organisms in midnight tows during a half moon
and a new moon in the Sargasso Sea

Depth (m)	Taxa	<u>Half Moon</u>	<u>New Moon</u>
		Abundance (No./100m ³)	Abundance (No./100m ³)
5	Copepoda	10.5	143.7
	Euphausiidacea	2.9	10.7
	Chaetognatha	0.8	2.2
20	Copepoda	8.1	100.6
	Euphausiidacea	1.5	4.9
	Chaetognatha	0.4	1.1
35	Copepoda	15.6	107.4
	Euphausiidacea	4.4	25.8
	Chaetognatha	3.8	3.3

<u>Total Biomass (g/100m³)</u>		
	<u>Half Moon</u>	<u>New Moon</u>
5	5.8	10.5
20	6.3	7.1
35	39.4	45.2

The Association Between Marine Mammals and Seabirds

Nancy Fishbein

ABSTRACT

Surfacing marine mammals are often accompanied by seabirds. Whales and dolphins bring food up to the surface and birds frequently take advantage of the concentrated food source by flying close over the mammals. By taking formal bird counts during and directly after the sighting of whales and dolphins, this association was examined along R/V Westward cruise W-58 (Fig. 15). On all but three occasions there were shearwaters and petrels hovering over the mammals. In slope waters between New York and the Gulf Stream, no birds were observed with the whales sighted. The absence may be attributed to the species of whales sighted or to the general absence of birds in the area. In a majority of the sightings, however, there was a strong association between surfacing marine mammals and seabirds. (See Tables 17 and 18 for complete listings of birds and mammals observed on R/V Westward cruise W-58.)

Fig. 15: Bird counts during (dark bars) and immediately following (open bars) whale sightings at four localities - Georges Bank and off New York.

Observations and Comparison of the Colors of Fishes and an Analysis of Fish Color Using Artist's Color Theory

Marcia Meyer

ABSTRACT

Comparisons were made between fish colors in different temperature regions and in different habitat types. Included in the study were the sand flounder, the Sargassum fish, the spiny puffer, the wahoo, the bluefish, the weakfish, the queen parrot fish, and the blue parrot fish. Observations were interpreted in two different ways: (1) using artistic theory of color, and (2) in terms of the adaptive significance of various patterns. The artist uses color to symbolize an emotion, a personality, or to evoke an emotion. Each fish was found to show a particular character according to its colors which corresponded with its known habitat and habits. In comparing the colors of fishes between different temperature regions, it was found that the fishes of colder waters tended to have neutral tones, black, browns, and grays to camouflage themselves with the substratum or water coloration. Fish of warmer waters were more brightly colored, but also had a function of camouflage.

*Chief Scientist's note: Numerous drawings throughout this cruise report are provided through the courtesy of Marcia Meyer.

Studies in Long Island Sound

Historically, estuaries have been important sources of commerce and industry, and today 60% of the human population in the United States lives within a 50 mile radius of an estuary. By definition, an estuary is "a semi-enclosed body of water with free access to the sea, which shows a measurable reduction in salinity." Because of high efficiency of nutrient regeneration and high nutrient concentrations in estuaries, biological production is higher in estuaries and associated marshes than in any other marine habitat, and 80 to 90% of all commercially important species use estuaries at some point during their life histories. Because of the importance of estuaries as nursery grounds for fishes and invertebrates, and because of the concentration of human population around estuaries, it is particularly important that we gain an understanding of the estuarine habitat.

During R/V Westward cruise W-58, a transect was made from east to west through Long Island Sound, continuing down the East River of New York City to the southern end of Manhattan (Fig. 16). To characterize the properties of this estuarine habitat, analyses were made of physical-chemical properties of the water column, the sediments, and zooplankton. In comparison with other stations on the shelf, it can be seen that Long Island Sound meets the definition of an estuary with salinity values significantly lower (Table 10) than shelf zones which had salinities between 32 and 33 ‰. In Long Island Sound, salinity decreased with distance to the west and temperature increased. Oxygen levels decreased to the west with critically low values found in the East River (2.9 ml/L). This value is too low to support any but the most tolerant animal species. Phosphate concentrations also increased going up the Sound to the East River, but zooplankton biomass decreased with distance up the Sound, where biomass values were much lower than values found at most shelf sites. Decreasing oxygen, increasing nutrient levels, and decreasing zooplankton biomass is an indication that pollution from sources around the highly industrialized Sound is a significant problem.

An examination of sediments in Long Island Sound showed that grain size decreased from the mouth of the estuary (east end of the Sound) to the head, as is typical of estuaries (Fig. 17). The sediment at the east end of the Sound was gravel and coarse sand; finer sands and muds are removed by strong tidal currents and heavy wave action. As wave and tidal influences become less important, the grain size gets smaller, until near the west end of the Sound, the sediments were dominated by very fine sand and mud particles. Fine particles were largely lithogenous sediments which were transported down the many streams and rivers ending in Long Island Sound, but some were the product of industrial and domestic sewage.

Fig. 16: Stations sampled in Long Island Sound and in the East River, New York. Hydrocasts were made at stations represented by closed circles and numbers. Zooplankton was sampled at stations 13, 14, and 15. Sediments were collected at stations represented by open circles and letters.

Table 10: Physical-chemical characteristics and zooplankton biomass
at stations in Long Island Sound and in the East River.

All values are for surface samples.

Station	Temperature (°C)	Salinity (‰)	Oxygen (ml/L)	PO ₄ μM/L	Biomass ₃ (g/100m ³)
W58-13	16.5	29.0	6.9	0.51	6.3
W58-14	14.8	29.3	6.2	0.41	1.7
W58-15	17.4	27.7	5.7	0.90	2.9
W58-16	18.2	24.5	2.9	1.67	na

Fig. 17: Grain-size distribution of the sediments collected at five sites in Long Island Sound.

New York Bight Studies

The coastal waters adjacent to New York and northern New Jersey, which form the New York Bight, are a repository for massive quantities of water materials generated from one of the world's most densely populated and industrialized areas. Currently, about 10 million tons of dredge spoils, construction debris, sewage sludge, and industrial wastes are dumped each year, within a sea surface area of 250 square kilometers, and with an annual rate of increase of about 4 percent (Gross, 1970).

Offshore dumping near New York began in 1888 to relieve health problems associated with dumping in the Hudson and East Rivers, and shoaling of navigational channels. The first offshore dump site was 4 km south of Coney Island, but this caused an immediate fouling of beaches nearby and the dump sites were gradually moved further and further offshore. Today, sewage sludge is discharged at the site designated in 1924, in an area greater than 8 miles southeast of the Scotland light in 27 m of water east of the Hudson Channel. Acid wastes are dumped 10 km southeast of the sewage disposal site and dredge spoil is dumped approximately 5 miles southeast of the Scotland light on the west side of the Hudson Channel. Ocean dumping between 1888 and the present, amounting to over 850 million m³ of liquid and solid wastes, has significantly filled in parts of the Hudson shelf channel. Recent studies indicate, however, that sewage sludge is not stable in the offshore areas of New York and no significant accumulation of sludge on the sea floor has been found (Williams, 1979).

Although sewage sludge is not accumulating in the New York Bight, other effects of dumping are possible. These include reduction of dissolved oxygen, increased turbidity and water color, presence of coliform bacteria, and toxic chemicals, and alteration of biological communities. Numerous student projects were designed to examine water quality and biological characteristics of the New York Bight area. A transect of stations was run from the East River near lower Manhattan through the Lower Bay and the sewage dump site to the outer shelf. It was found that

light attenuation was reduced in the East River and at the sewage dump site (Boyett), but that dissolved oxygen levels were seriously low only in the East River (Wetzstein). Copper levels were elevated all through the Bight (LaFrance) and phytoplankton species diversity was inversely related to copper concentration, which is not surprising given the fact that plants are particularly sensitive to that metal (Reilly). The absolute abundance of total heterotrophic bacteria and Escherichia coli was very high near New York, decreasing with distance offshore. Also, the ratio of E. coli to total bacteria declined offshore to zero at approximately 48 miles from the sewage dump site (Erkenbeck, Graves) indicating that pollution effects extend at least that far from New York. Numerous lines of evidence indicate that sewage is routinely being dumped nearer to shore than permitted by law or that the effects of dumping are being carried inshore by tides, currents, or other means.

Gross, M.G. 1970. New York metropolitan region - a major sediment source. *Water Resource Res.* 6:927-931.

Williams, S.J. 1979. Geologic effects of ocean dumping on the New York Bight inner shelf. In: Palmer, H.D. and M.G. Gross (eds.) *Ocean dumping and marine pollution.* pp. 51-72. Dowden, Hutchinson & Ross, Stroudsburg, Pa.

Light Attenuation in the New York Bight

Craig Boyett

ABSTRACT

To determine the effects of dissolved and suspended materials on the penetration of light in waters of the New York Bight, a series of nine stations were sampled between the East River (New York City) and 45 miles offshore to the southeast (Fig. 18, transect between station 16 and 20). Light absorbance was highest on the East River (Fig. 19-B) and near the offshore sewage sludge disposal site (Fig. 19-C). High absorbance, especially in the lower wavelengths, appears to be related to the abundance of anthropogenic suspensoids, and water quality improved rapidly with distance offshore from the dump site (Fig. 19-A). Variation in the absorbance of light in the range between 525 to 775 nm was attributed to variation in the abundance of the naturally occurring yellow substance.

Fig. 18: Stations sampled in the East River, New York, and in the New York Bight area.

Fig. 19: Total absorbance of light in a transect away from the East River, New York (A). Absorbance of light shown as a function of wavelength for the East River site (B), and for the offshore dump site (C).

Causes of Oxygen Depletion in New York Bight

Eric Wetzstein

ABSTRACT

Dissolved oxygen saturation was studied at five sites in the New York Bight area (Fig. 18, stations 16, 17, 18, 19, 20). The East River site had the lowest concentration of dissolved oxygen and the lowest level of saturation (Table 11). The Bight could be divided into three distinct zones: the estuarine influence zone, the offshore dump site zone, and the unaffected offshore zone. The estuarine zone proved to be the greatest contributor to oxygen depletion, while the sewage dump site had high levels of oxygen. Oxygen inversion was found at station 18, near the Ambrose Light; highest oxygen levels were found at 20 m depth. Low oxygen levels were not a significant problem in New York Bight, except in the estuarine zone, as indicated by levels near those found in Long Island Sound and on the unpolluted Georges Bank (Table 11). Additionally, surface oxygen levels were found to be directly related to wind force and a relatively small difference in wind force had a large effect on the depth of the mixed layer.

Table 11: Near-surface oxygen levels in the New York Bight and at other shelf sites on Georges Bank and in Long Island Sound

Station	Depth (m)	Dissolved oxygen (ml/l)	% of saturation
W58-16 (East River)	4	2.87	52
W58-17	0	6.05	104
	10	5.82	93
W58-18 (Ambrose Light)	0	4.93	106
	20	7.72	116
W58-19 (Dump site)	0	7.88	122
	30	6.43	114
W58-20	0	6.35	114
	30	6.33	93
W58-8 (Georges Bank)	0	7.17	109
	25	7.04	105
W58-14 (Long Island Sound)	0	6.16	102
	15	6.12	101

Some Effects of Pollution in the New York Bight: Nutrients and
Copper Levels

Steve LaFrance

ABSTRACT

Sewage sludge and dredged material dumped at designated sites in the New York Bight are enriched with nutrients and are the primary sources of copper contamination in the sediments of the Bight. Copper frequently leaches into the overlying water column when the sediments are resuspended by bottom currents or additional dumping. Water samples taken at stations within the Bight (Fig. 18, stations 16-20) showed copper concentrations as high as 3.808 ug-at/L, well above the normal seawater concentration of 1.0 ug-at/L, and well above levels found on Georges Bank (Table 12). Although the elevated copper concentrations in the New York Bight are within the limits believed to be safe for humans, increases in copper input should be avoided. Nutrient levels in New York Bight were not particularly high when compared with concentrations found on Georges Bank; however, oxygen levels were critically low in the East River (2.87 ml/L) (Table 12).

Table 12: Copper, nutrient, and dissolved oxygen levels found at five stations near New York and at two stations on Georges Bank.
bd = below determination.

Station	Depth (m)	Cu ($\mu\text{g-at/l}$)	PO ₄ ($\mu\text{g-at/l}$)	NH ₄ ($\mu\text{g-at/l}$)	Oxygen (ml/l)
<u>New York Bight</u>					
16 (East River)	4	2.53	1.67	0.72	2.87
17	0	3.79	1.53	0.36	5.82
	10	3.81	0.60	0.10	6.05
18	0	1.12	0.14	bd	4.93
	20	1.16	0.27	bd	7.72
19	0	0.92	0.04	bd	6.43
	20	1.05	0.34	bd	7.88
20	0	3.60	0.04	bd	6.55
	30	3.77	0.60	bd	6.33
<u>Georges Bank</u>					
8	0	0.25	0.44	bd	7.17
	25	0.15	0.62	0.78	7.04
	50	0.04	0.08	0.74	7.13
9	0	0.20	0.32	0.46	7.29
	12	0.30	0.20	0.08	6.88
	28	0.12	0.24	bd	7.10

The Relationship Between Escherichia coli and Other Heterotrophic Bacteria in selected Areas of the New York Bight

Timothy Graves

ABSTRACT

The study of bacteria is an important way of determining biological changes which occur in nature due to anthropogenic stress. Surface water samples were collected along a southeast transect from New York City through the sewage dump site (Fig. 18, Stations 16 through Z). After a four-day growth period, the total count of heterotrophic bacteria was compared with counts specific for Escherichia coli from the same stations. Both E. coli and total bacteria counts showed a general decrease from the dump site to stations 52 miles offshore (Fig. 20). High bacterial counts in the Bight were attributed to pollution in the form of dumping or runoff from land. Examination of physical and chemical data showed no significant relationship with bacterial counts. The highest abundance of bacteria occurred near South Street in the East River.

Fig. 20: Abundance of *Escherichia coli* (open circles) and all heterotrophic bacteria (closed circles) in New York Bight, shown as a function of distance from the New York sewage dump site. Numbers at the top of the figure are station numbers.

Distribution of Escherichia coli in the New York Bight

Charlie Erkenbeck

ABSTRACT

Escherichia coli, a bacterium normally found in the intestinal tract of humans, has long been used as an indicator of fecal contamination in aquatic systems. Because New York Bight receives 80% of all domestic sewage dumping in the U.S., the distribution of E. coli was studied as a function of distance from the New York sewage disposal site. Surface water samples taken every two miles through the dump site (Fig. 18, Stations 16 through Z) and cultured on Endo agar showed that the E. coli concentration was highest six miles before the dump site and decreased offshore (Fig. 21). No E. coli were found forty-eight miles southeast of the dump site (40° 23' N, 73° 44' W). High counts of E. coli inshore from the designated dump site could be attributed to improper dumping by sewage tankers or from sewage spillage into the Bight from the Hudson and/or East Rivers.

Growth of E. coli was not correlated with temperature, salinity, or nutrient levels. However, the abundance of E. coli was closely related to the abundance of all heterotrophic bacteria suggesting that bacterial growth may be related to some other abiotic factor such as organic carbon.

Fig. 21: Abundance of Escherichia coli in New York Bight shown as a function of distance from lower Manhattan.

The Effect of Waste Dumping on the Species Diversity of Phytoplankton
in the New York Bight

Allen Reilly

ABSTRACT

Pollution in the New York Bight affects all of the flora and fauna indigenous to the area. Because phytoplankton is the base of the oceanic food chain, any change that occurs in its population will effect the entire food web and, ultimately, humans. To study the specific effects of pollution on the phytoplankton of the Bight a transect of four stations (Fig. 18, stations 17, 18, 19, 20) was sampled. Phytoplankton and physical data were collected.

An inverse relationship was found between species diversity and copper concentration, high copper sites having low numbers of phytoplankton species (Table 13) and highest species diversity occurred at the sewage dump site (station 19). High copper concentrations and other contaminants probably create a high stress environment to which few species are able to adapt. It was also observed that many variables (such as currents, population drift, and offshore runoff) may effect interpretation of the results.

Table 13: Phytoplankton diversity and physical-chemical characteristics at four sites in the New York Bight. na = not available, bd = below level of determination

Station	17 (Lower Bay, NY)	18	19 (Dump site)	20
Species Diversity (H')	0.18	0.49	0.65	0.47
Temperature (C)	17.4	27.9	20.6	19.2
Salinity (‰)	25.8	30.4	30.5	31.7
Dissolved Oxygen (ml/l)	6.05	4.93	6.43	6.35
PO ₄ conc. (µg-at/l)	1.53	0.14	0.04	0.04
SiO ₂ conc. (µg-at/l)	4.85	3.00	bd	bd
NH ₄ conc. (µg-at/l)	0.36	bd	bd	bd
Cu conc. (µg-at/l)	3.81	1.12	0.92	3.77
Secchi Reading (m)	2.9	4.6	3.1	na

The Gulf of Maine and Georges Bank

The Gulf of Maine, bounded by New England, Nova Scotia, and Georges and Browns Banks, is a 36,000 square mile body of water studied intensively since the early 1900's. The Gulf is relatively shallow, with a mean depth of 150 m, and made up of a complex group of basins and ridges. One major deep channel, the Northeast Channel, enters the Gulf with a depth of 232 m.

Much of the secondary structure of the Gulf was created by glaciation. During periods of glaciation and consequential low sea level, the Northeast Channel was cut by erosion, as were many of the canyons along Georges Bank and Nantucket Shoals. Ice covered the Gulf five times, the last of which (15,000 yrs. ago) stopped at Georges Bank, dumping a massive load of till. Georges Bank and Cape Cod are, in fact, constructed largely from glacial deposits. Since the time of glaciation Georges Bank and Cape Cod have been modified by tides, waves, and currents.

Georges Bank is best known for its importance as a fishing ground. Annually, 168 million dollars in cod, haddock, pollack, flounder, lobster, scallops, and clams are taken from the Bank. More recently, since 1979, Georges Bank has become known for leases sold to oil and gas drilling companies. Despite argument by the National Marine Fisheries Service, it is believed that 123 million barrels of oil, worth approximately 588 million dollars, will be extracted from wells on the Bank.

Unfortunately, the oceanography and biological productivity of the Bank is not well understood, despite long study in the Gulf of Maine. On R/V Westward cruise W-58, several days were spent on Georges Bank and in the Gulf of Maine, during which time several student projects and cruise projects were conducted. Because most of the fishery yields on Georges Bank are from benthic or demersal sources, the sediments and animal-sediment relationships on the Bank were investigated (Conrad). Other benthic studies included an examination of fossil foraminifera to provide information on paleoclimate near Georges Bank (Houseman), and numerous water column studies investigated the nature of nutrient regeneration (Campbell) and plankton productivity on Georges Bank, the Gulf of Maine, and other sites over the cruise track (Felix, Mengersen, Stucker).

One project concentrated on the potential for an upwelling site near Yarmouth, Nova Scotia, where strong tidal currents flowing by the coastline cause vertical mixing (McManus). Other studies including data taken from the Gulf of Maine and Georges Bank are included in other sections of this report.

During the last few days of the cruise, R/V Westward returned to Woods Hole via the coast of Maine (Fig. 22), where the students and crew had the opportunity to view the complex geological features of upper New England along with rocky intertidal and terrestrial habitats of that area.

Fig. 22: Cruise track of R/V Westward along the Maine coast. Stops were made at Bar Harbor and in Horseshoe Cove.

The Diversity and Species Composition of Benthic Fauna in Relation to
Sediment Grain Size

Anne Conrad

ABSTRACT

The diversity of a community is related to the number of species present and their numerical composition; this diversity and the species composition in benthic animals is frequently related to characteristics of the sediments. Benthic collections, including otter trawls and sediment grabs, were made on Georges Bank, near Nantucket, and in Long Island Sound. The Nantucket station had the largest sediments (a gravel and coarse sand), the Georges Bank site had a medium sand sediment, and Long Island Sound was characterized by a fine sand and silt bottom. It was found that diversity of the benthic fauna was greatest at the Georges Bank site and lowest near Nantucket; therefore, diversity did not appear to be a direct function of sediment grain size. Analysis of the life history of the organisms showed, however, that feeding types, means of locomotion and camouflage may be more important relationships to grain size than species diversity. The abundance of carnivorous type feeders decreased with grain size, whereas the abundance suspension feeders and deposit feeders increased with grain size (Fig. 23).

Fig. 23: Relative abundance of predators (dark bars), suspension feeders (cross hatch), and deposit feeders (open bars) in trawl samples at three sites. Median sediment grain size increased from Long Island Sound to Georges Bank to Nantucket stations.

Foraminifera as Indicators of Paleoclimate

Adrienne Houseman

ABSTRACT

A Pfleger core sample was taken in slope waters near Oceanographer Canyon at 40°03'N latitude, 68°36'W longitude. The core was cut into seven 5-cm sections and sieved at 150 and 250 micrometers. The cold-water species, Globerigerina bulloides, was observed to be most abundant in each section, but the relative abundance of Globorotalia menardii, a warm-tolerant species, was compared to the abundances of G. bulloides to test paleotemperature (Table 14). The first (top) four sections showed a fairly constant ratio of major species and no major temperature change. At 20-25 cm a major increase in G. menardii occurred which indicates that a Gulf Stream intrusion may have occurred on the slope. The deepest sections (25-35 cm) showed a decrease in the abundance of all species and at 30 cm no G. menardii were present. Rather, the deep section was dominated by G. bulloides indicating the last glacial period.

Table 14: Relative abundance of foraminifera species found at various depths in a core from the slope near Oceanographer Canyon. Numbers are the percentages of the total foram count.

Species	Depth in the Core (cm)						
	0-5	5-10	10-15	15-20	20-25	25-30	30-35
<u>Globigerina bulloides</u>	49	50	66	53	40	66	99
<u>Neogloboquadrina dutertrei</u>	20	5	4	8	16	9	-
<u>Globorotalia menardii</u>	16	16	16	12	32	12	-
<u>Turborotalia inflata</u>	10	20	4	10	-	9	-
<u>Globigerinoides ruber</u>	3	-	-	-	-	-	-
<u>Orbulina universa</u>	2	3	-	-	-	4	-
<u>Pulleniatina obliquulagulata</u>	-	6	-	-	-	-	-
<u>Globigerinella aequilateralis</u>	-	-	2	7	2	-	-
Unidentified species	-	-	8	10	10	-	1

A Comparison of Two areas of Possible Upwelling Off the Coast of
Yarmouth, Nova Scotia

Wendy McManus

ABSTRACT

The waters off the southwestern tip of Nova Scotia have been hypothesized as an upwelling area, created by strong tidal currents and the resultant vertical mixing. Physical-chemical and biological samples were taken at two sites off Yarmouth, Nova Scotia, to test the upwelling hypothesis (Fig. 24). Although the station closest to shore (5.5 miles) showed physical-chemical characteristics of an upwelling (e.g. little vertical stratification, and high surface nutrients), biomass of zooplankton at that site was lower than that on Georges Bank (Table 15). The station further from shore showed no physical signs of upwelling (vertical stratification was present), yet the zooplankton biomass at the station was four times that found on Georges Bank and totally dominated by copepods. It is recommended that further studies be conducted in the area around Yarmouth to better characterize the upwelling phenomenon. (See Appendix 3 for complete data on stations W58-43 and W58-44).

Fig. 24: Oceanographic stations sampled off Yarmouth, Nova Scotia, to determine the extent of an upwelling zone in that area. The 50 fathom contour is shown by the dotted line.

Table 15: Comparison of physical-chemical and biological data from two sites off Yarmouth, Nova Scotia, and stations in the Sargasso Sea and Georges Bank

Station	Surface PO ₄ (µg-at/L)	Surface NH ₄ (µg-at/L)	Surface SiO ₂ (µg-at/L)	Zooplankton Biomass (g/100m ³)
W58-43 (Yarmouth-offshore)	0.30	0.19	3.4	97.0
W58-44 (Yarmouth-nearshore)	0.44	0.20	7.8	5.8
W58-8 (Georges Bank)	0.44	bd	5.7	22.4
W58-27 (Sargasso Sea)	bd	0.06	1.3	6.6

bd = below level of determination.

NAUTICAL STUDIES

On R/V Westward cruise W-58, two student projects were conducted in fields outside the typical realm of oceanography or marine biology. Both provided interesting information and data that will be useful in future Westward cruises. The abstracts for these studies follow.

Adaptation of Sleep-Waking Cycle and its Behavioral Correlates in Humans

Lisa Pistone

ABSTRACT

It was determined that shifting sleep and activity cycles on R/V Westward affects our physiological rhythms with concomitant behavior changes. Two-thirds of the persons tested became more alert as the cruise progressed, indicating a high level of adaptability, but "morning" and "evening" persons demonstrated different adaptabilities. Ninety-nine percent of "evening" types became more alert at the ends of watches, whereas "morning" types were evenly split between being more alert at the ends of watches and at the beginning of watches. Alertness also varied with specific watches. The 1900-2300 watch was the easiest and fits into normal cycles. The 2300-0300 watch was the most difficult to adapt to because it breaks the night into two parts. Broken sleep cycles were less satisfying than continuous sleep. A small amount of forgetfulness occurred in most subjects and a large number found that they were moodier, quieter, and more sluggish on the ship than in their home environments. Awareness of dreaming decreased although the opposite was predicted. Half of the students were aware of dreaming Westward-related dreams which were primarily centered around anxiety-provoking situations, indicating the intensity of life at sea. The changing activity-sleep rhythms were found to affect behavioral phenomena, which were manifestations of underlying physiological patterns.

The Practice of Celestial Navigation

Mark Dawson

ABSTRACT

An examination of accuracy in celestial navigation by a novice navigator was made over the cruise track of R/V Westward cruise W-58. Using the position provided by Loran C as an estimator of true position, it was found that error in celestial navigation varied between eight and thirty-five miles. Accuracy improved with the number of sights taken, but decreased with the height of seas and percentage of cloud cover. It was concluded that the accuracy of celestial navigation is largely a function of experience of the navigator and weather conditions. Weather conditions, however, become less important with experience.

LONG-TERM AND COOPERATIVE PROGRAMS

Neuston Tows

S.E.A. scientists have been gathering information on the distribution of pelagic tar, Sargassum, and the marine water-strider, Halobates micans for several years. Nine neuston tows were made on R/V Westward cruise W-58, yielding only three H. micans (Table 16), but large quantities of tar from the Sargasso Sea (esp. station W58-36). Shelf waters yielded large quantities of floating Fucus and Ascophyllum rather than Sargassum weed.

Distribution of Marine Birds and Mammals

In cooperation with Timothy Ramage of the Rhode Island School of Design, a formal bird count system has been developed to provide quantitative data for analysis of bird distribution, feeding, and migration patterns. Daily bird counts were made on R/V Westward cruise W-58 during morning and evening hours. Distributional data, provided in Table 17, were sent to Tim Ramage.

Whale and porpoise sightings are also used for long-term studies of mammal distribution and behavior, in cooperation with Tim Ramage. Data gathered on cruise W-58 are reported in Table 18.

Distribution of Spiny Lobster Phyllosoma

Phyllosoma are the large, flattened larval forms of various tropical and subtropical lobster species, the distributions of which are being examined by S.E.A. staff scientist Mary Farmer. On R/V Westward cruise W-58 only three phyllosoma were collected (Table 19), but these specimens have been turned over to Dr. Farmer for identification and measurement.

Weather Observations

Weather observations are recorded and transmitted from R/V Westward twice daily when more than 14 miles from shore, as part of the Cooperative Ship Weather Observation Program of the National Oceanic and Atmospheric

Administration. On W-58, nineteen complete sets of meteorological data were collected and these data have been sent to the NOAA meteorological office. The number of weather observations made was relatively low because of large portions of the cruise track in coastal waters and because of radio transmitter malfunctions.

Table 16: Summary of neuston collected on R/V Westward cruise W-58.
(See Appendix for station positions.)

Station	Date	Time	Sargassum (gms)	<u>Halobates</u> <u>micans</u> (# indiv.)	Tar (gms)	Miscellaneous
W58-1	6/05/81	1155	26.9	0	2.6	<u>Hippocampus</u>
W58-26	6/22/81	1350	18.5	0	5.0	fish larvae
W58-32	6/24/81	1215	82.0	0	1.0	flying fish juv.
W58-34	6/25/81	1200	20.0	1	10.0	
W58-36	7/01/81	1225	95.0	0	73.0	<u>Sargassum</u> associates
W58-37	7/02/81	1155	66.0	2	2.0	fish larvae
W58-40	7/03/81	1200	0	0	0	<u>Trichodesmium</u>
W58-41	7/04/81	1120	223.0	0	0	File fish
W58-47	7/12/81	1430	(2250 gms. <u>Fucus</u> and <u>Ascophyllum</u>) (Many insects)			

Table 17: Bird counts made during R/V Westward cruise W-58.

* indicates isolated sighting

Date	Time	Lat. (N)	Long. (W)	Species	Number
6/04/81	1700	40°19'	69°39'	<u>Larus argentatus</u>	22
				<u>Oceanodroma leucorhoa</u>	6
				<u>Puffinus gravis</u>	2
	1800*	41°23'	70°39'	<u>L. argentatus</u>	2
6/05/81	1800	40°16'	69°08'	<u>P. gravis</u>	10
				<u>O. oceanus</u>	3
				<u>Pterodroma hasitata</u>	3
6/06/81	0805	40°55'	68°41'	<u>Oceanodroma sp.</u>	18
				<u>P. gravis</u>	8
6/07/81	0830*	40°35'	68°00'	<u>Pandion haliaetus</u>	1
6/07/81	0910	40°32'	68°00'	<u>P. gravis</u>	22
				<u>Puffinus griseus</u>	2
	1615	41°07'	67°26'	<u>Larus atricilla</u>	1
				<u>P. gravis</u>	1
				<u>Larus sp.</u>	2
6/08/81	0710	41°08'	67°08'	<u>P. gravis</u>	91
				<u>P. griseus</u>	10
	1110	41°16'	68°56'	<u>P. gravis</u>	19
				<u>L. argentatus</u>	7
				<u>Oceanodroma sp.</u>	10
				<u>Larus marinus</u>	1
				Unident. sp.	4
6/11/81	1510	41°12'	72°16'	<u>L. argentatus</u>	87
				<u>L. atricilla</u>	1
				<u>L. marinus</u>	1
				<u>Larus sp.</u>	6
6/13/81	1315	41°10'	72°39'	<u>Sterna hirunda</u>	1
				<u>Sterna sp.</u>	4
				<u>L. argentatus</u>	2
				<u>Larus sp.</u>	4
6/17/81	1200	40°30'	73°55'	<u>S. hirunda</u>	12
				<u>L. argentatus</u>	10
				<u>Sterna least</u>	3
				<u>L. marinus</u>	2
				Unident. sp.	1
	1800	40°23'	73°44'	<u>L. argentatus</u>	2
				<u>L. marinus</u>	1

Table 17: (continued)

Date	Time	Lat. (N)	Long. (W)	Species	Number
6/18/81	0815	39°47'	73°02'	<u>L. argentatus</u>	1
				<u>O. oceanicus</u>	1
6/20/81	1520	37°35'	72°28'	<u>P. gravis</u>	4
				<u>O. oceanicus</u>	2
				<u>Oceanodroma</u> sp.	2
6/21/81	1120	37°21'	71°57'	<u>P. gravis</u>	15
				<u>Oceanodroma</u> sp.	2
6/22/81	1000*	36°10'	70°25'	<u>Sterna</u> sp.	2
	1656	36°08'	68°50'	<u>P. gravis</u>	268
				<u>P. griseus</u>	8
				<u>Oceanodroma</u> sp.	22
	1715	36°08'	68°50'		0
6/23/81	1720*	35°45'	67°25'	<u>Phaethon lepturus</u>	1
6/24/81	1424	34°47'	66°51'		0
6/25/81	1200*	34°05'	66°05'	<u>Hirunda rustica</u>	1
6/26/81	1112	32°29'	64°36'		0
6/26/81	B E R M U D A			<u>P. lepturus</u> (abundant near shore)	
7/01/81	1430	34°30'	64°58'		0
7/02/81	1508	37°00'	64°58'	<u>P. gravis</u>	1
				Unident. sp.	2
7/04/81	0800*	38°37'	64°18'	<u>P. gravis</u>	15
	0900	38°37'	64°19'	<u>P. gravis</u>	1
7/07/81	0905	43°31'	66°50'	<u>Oceanodroma</u> sp.	150
				mostly <u>O. leucorhoa</u>	
				<u>P. gravis</u>	34
				<u>L. argentatus</u>	5
	1500	43°44'	66°28'	<u>P. gravis</u>	1
				<u>L. marinus</u>	4
				<u>L. argentatus</u>	6
				<u>P. griseus</u>	1
7/08/81	0600	44°11'	67°38'	<u>L. argentatus</u>	2
				<u>Larus</u> sp.	1
				<u>P. griseus</u>	4
				Unident. sp.	1
7/12/81	0710	43°20'	69°40'	<u>O. oceanicus</u>	16
				<u>L. marinus</u>	1

Table 18: Marine mammals sighted on R/V Westward cruise W-58.

Date	Time	Latitude (N)	Longitude (W)	Species	Number
6/05/81	0600	40°23'	69°43'	Saddleback dolphin	10
6/05/81	1800	40°16'	69°08'	" "	6
6/06/81	0805	40°05'	68°41'	Humpback whale	1
6/08/81	1720	41°26'	67°38'	Pilot whale	50
6/18/81	1300	39°26'	72°56'	Saddleback dolphin	6
6/18/81	1415	39°24'	72°56'	" "	20-30
6/18/81	1630	39°18'	72°55'	" "	20-30
6/19/81	1600	38°05'	73°19'	Bottlenose dolphin	12
6/19/81	1730	38°08'	73°21'	Pilot whale	6
6/19/81	1805	38°07'	73°22'	Sperm whale	7
6/21/81	1920	37°12'	70°55'	Unident. dolphin	4
6/21/81	2030	37°11'	70°52'	White-sided dolphin	25
6/23/81	1535	35°40'	67°30'	poss. Sperm whale	8
7/06/81	0800	41°10'	66°03'	Humpback whale	4
7/09/81	0735	44°05'	68°14'	Harbor porpoise	3
7/09/81	0815	44°05'	68°56'	poss. Fin whale	1
7/12/81	0700	43°20'	69°40'	Unident. dolphin	8
7/12/81	0840	43°18'	69°40'	Unident. whale	1
7/12/81	0940	43°18'	69°39'	Right whale	1
7/13/81	1345	42°26'	70°21'	Humpback whale	3
"	1350	"	"	" "	2
"	1405	"	"	" "	3
"	1410	"	"	" "	1
"	1500	42°26'	70°24'	" "	15
"	1945	42°26'	70°25'	" "	2
"	2000	"	"	" "	2

Table 19: Stations at which spiny lobster phyllosoma were collected during R/V Westward cruise W-58.

Station	Date	Time	Latitude (N)	Longitude (W)	Collection Mode	Number
W58-24	6/20/81	2002	37°38'	72°16'	Meter Net	1
W58-25	6/21/81	0100	37°38'	72°10'	Meter Net	1
W58-33	6/24/81	0000	34°21'	66°31'	IKMT	1

APPENDICES

Table A-1: Oceanographic stations sampled on R/V Westward cruise W-58

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	Comments
W58-1	6/05/81	1155	40°17'	69°26'	Neuston Tow	Nantucket Shoals
W58-2	6/05/81	2326	40°06'	69°00'	Meter net tow	" "
W58-3	6/06/81	0745	40°05'	68°41'	Hydrocast	Slope
		0915	"	"	Phleger corer	"
		0145	"	"	Sediment scoop	"
W58-4	6/06/81	1202	40°03'	68°36'	Phleger corer	"
		1325	40°02'	68°37'	Hydrocast	"
W58-5	6/07/81	0000	40°11'	68°03'	Hydrocast	Oceanographer Canyon
W58-6	6/07/81	0550	40°22'	68°10'	Hydrocast	" "
W58-7	6/07/81	1100	40°44'	67°46'	Sediment Scoop (2)	Georges Bank
W58-8	6/07/81	1700	41°09'	67°23'	Hydrocast	" "
		1710	"	"	Phytoplankton Tow	" "
		2005	41°08'	67°18'	3 Meter nets	" "
	6/08/81	0128	41°10'	67°20'	" " "	" "
		0444	41°08'	67°14'	" " "	" "
		0620	41°08'	67°08'	Otter trawl	" "
		0940	"	"	Grabs (2)	" "
		1115	41°08'	67°09'	3 Meter nets	" "
W58-9	6/08/81	1805	41°26'	67°38'	Hydrocast	" "
		1830	"	"	Phytoplankton Tow	" "

Table A-1: (continued)

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	Comments
W58-9	6/08/81	1845	41° 26'	67° 38'	Grab	Georges Bank
		1920	"	"	Meter Net Tow	" "
W58-10	6/10/81	0820	41° 30'	69° 41'	Hydrocast	Great Round Shoal
		0845	"	"	Grab	" " "
		0906	"	"	Meter Net Tow	" " "
		1009	"	"	Otter trawl	" " "
		1300	"	"	Cod Jigging	" " "
W58-11	6/11/81	1130	41° 25'	70° 07'	Hydrocast	Nantucket Sound
W58-12	6/11/81	1625	41° 24'	70° 27'	Meter Net Tow	" "
W58-13	6/12/81	1830	41° 10'	72° 35'	Hydrocast	Long Island Sound
		1830	"	"	Phytoplankton Tow	" " "
		1900	"	"	Meter Net Tow	" " "
		6/13/81 0240	"	"	Sediment Scoop	" " "
		6/13/81 1530	41° 11'	72° 43'	Hydrocast	" " "
W58-14	6/13/81	1545	"	"	Meter Net Tow	" " "
		1935	41° 07'	72° 45'	Otter Trawl	" " "
		6/14/81 0835	40° 57'	73° 33'	Hydrocast	" " "
W58-15	6/14/81	0900	"	"	Meter Net Tow	" " "
		6/17/81 0730	East River		Hydrocast	South St. Seaport
W58-17	6/17/81	0925	40° 36'	74° 01'	Phytoplankton Tow	Lower Bay, NY
		0945	"	"	Hydrocast	" " "
		1020	"	"	Phleger Corer	" " "

Table A-1: (continued)

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	Comments
W58-18	6/17/81	1325	40°29'	73°52'	Hydrocast	Ambrose Light
		1405	"	"	Phytoplankton Tow	" "
W58-19	6/17/81	1715	40°23'	73°44'	Hydrocast	Dump site
		1720	"	"	Phytoplankton Tow	" "
		1740	"	"	Phleger Corer	" "
		1800	"	"	Grab	" "
		1820	"	"	Phytoplankton Tow	" "
		1900	40°24'	73°43'	Meter Net Tow	" "
W58-20	6/18/81	0050	40°12'	73°27'	Hydrocast	Shelf
		0050	"	"	Phytoplankton Tow	"
		0130	"	"	Meter Net Tow	"
W58-21	6/18/81	1750	39°15'	72°07'	Meter Net Tow	Outer Shelf
W58-22	6/19/81	0900	38°38'	73°03'	Phleger Corer	Slope
		1035	"	"	Hydrocast	"
W58-23	6/20/81	1234	37°38'	72°20'	Phytoplankton Tow	"
		1245	"	"	Hydrocast	"
		1456	"	"	Meter Net Tow (2)	"
W58-24 ✓	6/20/81	2002	37°38'	72°16'	" " " "	North Wall
W58-25 ✓	6/21/81	0100	37°30'	72°10'	" " " "	Gulf Stream
		0715	"	"	Hydrocast	" "
		0715	"	"	Phytoplankton Tow	" "
W58-26	6/22/81	1350	36°18'	69°00'	Neuston Tow	Sargasso Sea

Table A-1: (continued)

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	Comments
W58-27	6/23/81	0730	35°32'	67°40'	Plytoplankton Tow	Sargasso Sea
		0830	"	"	Hydrocast	" "
		0948	"	"	Meter Net Tow (2)	" "
W58-28	6/23/81	1215	35°42'	67°48'	3 Meter Nets	" "
W58-29	6/23/81	2003	35°21'	67°17'	3 Meter Nets	" "
W58-30	6/24/81	0115	35°12'	67°14'	3 Meter Nets	" "
W58-31	6/24/81	0400	34°59'	67°07'	3 Meter Nets	" "
W58-32	6/24/81	1215	38°26'	67°07'	Neuston Tow	" "
W58-33 ✓	6/24/81	0000	34°21'	66°31'	IKMT	" "
W58-34	6/25/81	1200	34°06'	66°12'	Neuston Tow	" "
W58-35	7/01/81	0610	34°20'	64°54'	Hydrocast	" "
		"	"	"	Meter Net Tow	" "
		"	"	"	Phytoplankton Tow	" "
W58-36	7/01/81	1225	34°26'	64°58'	Neuston Tow	" "
W58-37	7/02/81	1155	36°46'	65°07'	Neuston Tow	" "
W58-38	7/03/81	0000	37°47'	64°06'	3 Meter Nets	" "
W58-39	7/03/81	0905	38°14'	64°08'	Phytoplankton Tow	Gulf Stream
W58-40	7/03/81	1200	38°30'	64°14'	Neuston Tow	Warm Eddy
		1430	"	"	Hydrocast	" "
		1730	"	"	Meter Net Tow	" "
W58-41	7/04/81	1120	40°03'	64°56'	Neuston Tow	Slope
W58-42	7/06/81	0040	41°02'	65°47'	IKMT	"

Table A-1: (continued)

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	Comments
W58-42	7/06/81	0300	41°03'	65°56'	Meter Net Tow	Slope
		0655	41°10'	66°03'	Hydrocast	"
W58-43	7/07/81	1200	43°42'	66°41'	Hydrocast	Yarmouth
		1235	"	"	Meter Net Tow	"
W58-44	7/07/81	1755	43°50'	66°17'	Hydrocast	"
		1855	"	"	Meter Net Tow	"
W58-45	7/09/81	1220	44°02'	68°26'	Rock dredge	Maine coast
W58-46	7/10/81	1350	44°03'	68°44'	Meter Net Tow	" "
W58-47	7/12/81	1430	43°12'	69°43'	Neuston Tow	" "

Table A-2: Bathythermograph casts made on R/V Westward cruise W-58

BT#	Date	Time	Latitude (N)	Longitude (W)	Surface Temp. (°C)	Mixed Layer Depth (m)
1	6/05/81	1930	40°12'	69°04'	14.0	21
2	6/06/81	0345	40°06'	68°50'	18.0	24
3	6/06/81	0715	40°05'	68°49'	19.4	27
4	6/07/81	2140	40°09'	68°00'	20.5	39
5	6/19/81	0815	38°37'	73°02'	19.9	12
6	6/19/81	1522	38°25'	73°07'	20.2	12
7	6/19/81	2045	38°05'	73°23'	22.1	18
8	6/20/81	0230	37°57'	73°09'	24.3	12
9	6/20/81	0515	37°54'	73°58'	21.5	3
10	6/20/81	0730	37°48'	72°48'	22.1	2
11	6/20/81	0900	37°45'	72°44'	22.8	6
12	6/20/81	1040	37°39'	72°39'	26.2	18
13	6/20/81	1610	37°35'	72°16'	26.7	18
14	6/20/81	1830	37°31'	72°12'	26.9	12
15	6/20/81	1900	37°32'	72°12'	26.9	12
16	6/20/81	2200	37°35'	72°16'	27.0	12
17	6/21/81	0340	37°34'	72°08'	26.3	21
18	6/21/81	0620	37°35'	71°55'	26.3	21
19	6/21/81	1112	37°25'	71°30'	26.7	41
20	6/21/81	1630	37°26'	71°26'	27.8	18
21	6/21/81	2030	37°11'	70°52'	28.7	21
22	6/22/81	0040	36°54'	70°54'	28.3	15
23	6/22/81	0540	36°51'	70°09'	28.4	32
24	6/22/81	1000	36°31'	70°20'	27.0	21
25	6/22/81	1700	36°08'	68°50'	24.9	18
26	6/22/81	2315	35°47'	68°27'	24.4	0
27	6/23/81	0600	35°36'	67°46'	25.0	24
28	6/23/81	1745	35°41'	67°22'	25.5	18
29	6/24/81	0330	35°03'	67°07'	25.5	0
30	6/24/81	0800	35°06'	67°07'	25.2	12

Table A-2: (continued)

BT#	Date	Time	Latitude (N)	Longitude (W)	Surface Temp. (°C)	Mixed Layer Depth (m)
31	6/24/81	1810	35°03'	66°52'	25.4	18
32	6/24/81	2200	34°52'	66°42'	26.0	12
33	6/25/81	0910	33°46'	66°29'	25.8	6
34	6/25/81	1830	33°34'	66°23'	25.5	6
35	6/25/81	2300	33°25'	65°21'	26.0	6
36	6/30/81	2100	33°14'	64°41'	25.0	6
37	7/01/81	0000	33°36'	64°47'	25.6	21
38	7/01/81	0555	34°20'	64°54'	24.8	18
39	7/01/81	1135	34°26'	64°58'	26.1	20
40	7/01/81	1400	34°31'	64°58'	25.0	12
41	7/01/81	1600	34°40'	65°03'	25.6	26
42	7/01/81	1800	34°50'	65°06'	25.5	26
43	7/01/81	1945	35°02'	65°11'	25.7	30
44	7/01/81	2130	35°21'	65°25'	26.0	26
45	7/01/81	2320	35°32'	65°26'	25.0	27
46	7/02/81	0120	35°41'	65°24'	25.2	37
47	7/02/81	0350	35°51'	65°21'	25.0	37
48	7/02/81	0610	36°02'	64°10'	25.2	30
49	7/02/81	1100	36°47'	64°57'	26.7	30
50	7/02/81	1335	36°51'	65°07'	26.1	34
51	7/02/81	1540	36°59'	64°59'	26.7	34
52	7/02/81	1800	37°13'	64°49'	27.0	37
53	7/02/81	2100	37°29'	64°22'	26.9	37
54	7/02/81	2300	37°40'	64°09'	25.7	76
55	7/03/81	0240	37°59'	64°04'	21.1	55
56	7/03/81	0630	38°08'	64°02'	21.1	12
57	7/03/81	0815	38°14'	64°08'	21.4	12
58	7/03/81	1100	38°28'	64°12'	23.1	18
59	7/03/81	1250	38°32'	64°14'	23.8	12
60	7/04/81	1500	39°07'	64°46'	24.6	3
61	7/05/81	0300	39°40'	64°46'	25.0	18
62	7/05/81	1030	39°44'	64°62'	23.4	3

Table A-2: (continued)

BT#	Date	Time	Latitude (N)	Longitude (W)	Surface Temp. (°C)	Mixed Layer Depth (m)
63	7/05/81	1400	40°27'	64°57'	23.4	3
64	7/05/81	1700	40°46'	65°06'	23.9	27
65	7/05/81	2100	40°52'	65°29'	18.0	6
66	7/06/81	0430	41°03'	65°56'	17.9	0
67	7/06/81	1805	42°07'	66°24'	14.8	0
68	7/06/81	1900	42°11'	66°24'	13.5	0
69	7/06/81	1950	42°51'	66°25'	14.0	0
70	7/06/81	2100	42°21'	66°27'	13.5	0
71	7/06/81	2150	42°25'	66°29'	13.0	12
72	7/06/81	2235	42°29'	86°31'	12.3	24
73	7/06/81	2315	42°35'	66°36'	14.7	6
74	7/07/81	0030	42°40'	66°41'	15.0	6
75	7/07/81	0120	42°46'	66°44'	15.3	6
76	7/07/81	1135	43°42'	66°37'	12.3	0
77	7/07/81	1700	43°50'	66°17'	10.0	10

Table A-3: Summary of hydrographic data from R/V Westward cruise W-58.

bd = below level of determination

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (‰)	Density (ρ)	Dissolved oxygen (ml/L)	NH ₄ (μ M/L)	PO ₄ (μ M/L)	SiO ₂ (μ M/L)
A9	W58-3	0	19.49	35.82	25.55	5.54	bd	0.03	-
		15	19.55	35.79	25.51	5.42	bd	0.02	-
		30	19.13	35.65	25.51	5.64	0.11	0.14	-
		50	10.68	33.95	26.03	6.42	0.10	0.77	-
		100	-	34.86	-	5.39	bd	0.34	-
		150	12.54	35.68	27.03	3.82	bd	0.52	-
	W58-4	0	20.74	5.99	25.34	5.49	0.52	0.03	-
		30	20.36	35.94	25.41	5.53	0.46	0.02	-
		100	11.49	34.69	26.47	5.77	bd	0.04	-
		200	13.10	33.20	25.00	4.24	0.40	0.18	-
		400	12.50	35.62	27.01	4.52	0.44	0.14	-
		800	294	6.78	35.18	27.62	4.68	0.76	0.23
	W58-5	0	19.66	35.82	25.50	5.34	bd	bd	-
		130	12.42	35.71	27.09	4.33	0.01	0.50	-
		160	12.02	35.76	27.19	4.36	bd	0.90	-
		500	476	9.60	35.11	27.13	5.36	bd	0.83
		800	725	4.33	35.03	27.80	5.53	0.01	0.72
		1200	1070	4.12	35.11	27.89	6.14	bd	0.71
	W58-6	0	20.99	36.09	23.36	5.36	bd	0.24	-
		100	14.33	35.72	26.70	4.81	bd	-	-
		200	171	12.56	35.68	27.04	4.44	bd	1.04
		300	276	9.62	35.55	27.47	4.49	bd	1.13
		400	366	8.16	35.28	27.50	4.51	bd	0.58
	W58-8	0	9.34	33.19	25.66	7.17	bd	0.44	5.7
		25	8.61	33.16	25.76	7.04	1.78	0.62	3.4
		50	8.60	33.20	30.81	7.13	0.74	0.08	6.7

Table A-3: (continued)

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (‰)	Density (ρ)	Dissolved oxygen (ml/L)	NH ₄ (μ M/L)	PO ₄ (μ M/L)	SiO ₂ (μ M/L)
W58-9	0		9.99	33.20	25.58	7.29	0.46	0.32	bd
	12		10.00	33.20	25.58	6.88	0.08	0.20	1.3
	28		9.70	33.18	25.61	7.10	-	0.24	1.4
W58-10	0		11.89	32.48	24.37	6.88	bd	0.11	
	11		9.39	32.26	24.95	6.83	bd	0.14	
	22		7.30	32.07	25.42	6.66	bd	0.40	
W58-11	0		15.07	32.20	23.82	6.08	0.02	1.45	
	8		14.94	32.23	23.88	6.20	0.49	0.48	
W58-13	0		16.54	28.99	21.04	6.91		0.51	
	15		14.59	29.35	21.73	6.62		0.62	
	25		14.41	29.41	21.82	6.91		0.48	
W58-14	0		14.78	29.30	21.66	6.16	0.39	0.41	
	15		14.42	29.26	21.71	6.12	0.16	0.38	
W58-15	0		17.39	27.72	19.88	5.67	0.72	-	
	10		13.09	28.13	21.09	-	0.50	0.90	
W58-16	4		18.18	24.52	17.26	2.87	0.72	1.67	
W58-17	0		17.39	25.80	18.42	6.05	0.36	1.53	4.8
	10		13.09	27.44	20.56	5.82	0.10	0.60	6.0
W58-18	0		27.92	30.45	19.03	4.93	bd	0.14	3.1
	20		10.37	32.64	25.07	7.72	bd	0.27	2.8
W58-19	0		20.57	30.50	21.21	7.88	bd	0.04	1.6
	20		8.48	30.77	23.91	6.43	-	0.34	5.1

Table A-3: (continued)

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (‰)	Density (ρ)	Dissolved oxygen (ml/L)	NH ₄ (μ M/L)	PO ₄ (μ M/L)	SiO ₂ (μ M/L)
W58-20	0		19.20	31.74	22.51	6.35	bd	0.04	2.3
	30		7.58	32.88	25.69	6.33	bd	0.60	6.4
W58-22	1400	1332	3.81	35.50	28.22	6.50	bd	1.13	-
W58-23	0		26.08	36.96	24.52	5.30	0.03	1.21	0.1
	40		18.68	35.93	25.83	4.72	0.13	0.36	6.2
	70		8.90	34.52	26.79	6.16	bd	1.46	8.3
	200	185	12.24	35.45	26.91	4.55	bd	0.03	8.4
	500	508	6.68	35.66	28.01	4.73	bd	1.42	22.6
	1200	1112	4.23	35.47	27.37	-	bd	0.88	18.2
W58-25	0		26.39	37.07	24.49	5.06	bd	bd	bd
	40		22.38	36.37	25.18	5.25	bd	0.22	3.0
	60		19.25	36.32	25.99	4.74	bd	0.42	5.2
	200	163	13.12	36.24	27.34	3.52	bd	0.82	15.2
	600	470	7.05	35.25	27.63	4.51	bd	1.34	22.8
	1200	959	4.38	35.36	28.06	6.09	bd	0.98	19.3
W58-27	0		24.93	37.05	24.94	5.22	0.06	bd	1.3
	100		19.86	36.35	25.85	5.69	bd	0.10	1.4
	250	134	18.21	36.39	26.30	5.09	bd	0.17	2.2
	500	284	17.84	35.45	25.68	5.28	0.01	bd	2.3
	1000	518	16.19	36.89	27.18	4.51	bd	0.10	5.7
	1400	602	11.53	35.43	27.03	3.88	bd	0.97	15.7
W58-35	0		25.59	36.28	24.46	5.47	0.36	0.16	1.1
	60		21.49	36.34	25.41	5.84	-	0.36	1.2
	100		20.00	36.41	25.86	5.14	bd	0.17	-
	460	261	17.43	36.28	26.29	5.38	0.16	0.04	3.7
	760	420	17.38	36.48	26.38	5.03	bd	0.36	3.6
	1400	801	10.72	35.14	26.96	4.02	0.14	0.80	15.6

Table A-3: (continued)

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (‰)	Density (ρ)	Dissolved oxygen (ml/L)	NH ₄ (μ M/L)	PO ₄ (μ M/L)	SiO ₂ (μ M/L)
W58-39	0		21.45	34.18	23.78	5.58		bd	1.9
	50		15.86	35.08	25.83	5.42		bd	3.2
	200	190	12.15	35.31	26.83	4.46		0.74	9.8
	500	470	6.83	34.87	27.37	4.42		0.68	19.5
	1000	1004	4.40	34.80	27.61	5.88		0.34	15.8
	1400	1414	3.97	34.86	27.70	6.17		0.28	16.6
W58-42	0		17.01	32.44	22.94	6.56		0.24	3.7
	40		12.55	32.71	24.73	7.50		0.37	5.2
	165	153	12.78	35.36	26.74	5.11		0.71	10.8
	450	459	6.53	34.73	27.29	4.16		0.90	16.7
	800	768	4.65	34.70	27.49	6.38		1.08	18.7
	1400	1352	4.03	34.68	27.54	6.48		1.22	12.3
W58-43	0		11.20	32.20	24.58	7.11	0.19	0.30	3.4
	20		10.80	32.18	25.12	7.03	0.18	0.23	4.2
	80	79	7.06	32.82	25.72	6.27	0.12	0.92	9.5
W58-44	0		14.10	31.60	23.56	7.93	0.20	0.44	7.8
	10		8.39	31.58	24.56	7.82	0.40	0.40	3.8
	40		8.20	31.63	24.63	7.81	0.25	0.62	4.2

Bermuda High

Carl Chase
7/4/81

Chorus: G D7 G

Bermuda High O K by me You never know un til you see Ber muda

Bermuda High O K by me You never know un til you see Ber mu da

Verse: G E7 Am Cm D7 G

sky and wa ter clear and blue, what it can do Ber mu da High! we started on

sky and wa ter clear and blue, what it can do Ber mu da High!

Bridge: D7 G D7 G

Georges' The weather it was Gorgeous etc.

yes I know that aint so

BERMUDA HIGH

Music and lyrics by Carl Chase

CHORUS: Bermuda High
OK by me
You'll never know
Until you see
Bermuda Sky
And water clear and blue
What it can do
Bermuda High!

We started on Georges
The weather was gorgeous
If you like bein' frozen
And the fog upon the ocean
And the mornin' and the evenin'
We're callin' home to Clevelan'
And thinkin' what's the matter
How could anything be badder

CHORUS

Then we sailed for the island
Ship all painted up and smilin'
And the people from the T.V.
Try to dig the life on R/V
Headed for the celebration
Happy Birthday Mr. Cochran
How'd you ever leave the bay, mon?
With a crazy crew like they, mon?
Party Party to Manhattan
What a college education
Sweep the deck and wipe the brass off
Everybody work his, I want to go home

CHORUS

Cut the lines and back her down, boys
Got to leave this crazy town, boys
Set the sail and cut the line now
Make Bermuda just in time, now
Sanity is on the ocean
Back to business, no commotion
Everybody seek solution
To the problem of pollution
Drag that net and grab the bottom
Don't look now but somethings rotten
Don't fall in, you get a big fright
On the station at the dump site

CHORUS

Lookin better in the Gulf Stream
Bathing suits and plenty sun screen
Paradise on the horizon
Shoot the stars and turn the lights on
Keep her steady for Bermuda
People ready for Bermuda
Are you ready for Bermuda?
Everybody for Bermuda!

CHORUS

Yes I know
That ain't so
Not for me
I can't see
I know what you're sayin'
Tho't you was prayin'
What's the matter?
Nothin' could man!

Where's the palm tree?
Somethin's wrong see?
What's the good word?
That's the Westward!
Pass the rum, mon
To your son, mon
Hurry up now
Pick'em up now
Everybody
What me study??
Open house, mon

Let 'em go
So long Joe
No more walkin'
Now you're talkin'
Hold on Jill
Pop that pill
Scratch your head, mon
Don't pump your head, mon
Hold your nose
Fetch the hose
There goes Jack!
Don't pull him back!

Nice I think
Turning pink
Captain say
One more day
Here we come
Run, run, run
I should say
She's OK