CRUISE REPORT

W-64

Scientific Activities

Woods Hole - St. Georges - Lunenburg - New York

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 sixty-fourth cruise of the research vessel Westward which took place between 2 June and 14 July 1982. 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 at sea and is not intended to represent the final analysis or interpretation of data generated during the cruise.

R/V Westward cruise W-64 was one of the most pleasant and productive oceanographic cruises on which I have participated. This was largely due to a particularly enthusiastic, experienced, and skillful crew. John Wigglesworth, as Westward's master, readily gained the respect and admiration of all on board the vessel. Through the diligent efforts of the Captain and mates David Stuhlbarg, Tim Higbee, and Rod Swift we were able to squeeze the greatest possible amount of oceanographic work from a particularly long cruise track. David Stuhlbarg was especially helpful in the design and administration of the academic program on board R/V Westward; his feats of magic and juggling were also a great addition to the excitement of W-64. In addition to keeping a spotless engine room, Gary Manter provided the crew of W-64 with a supply of codfish (such as they were) and good music. Steward Dinah Olanoff provided the ship with a constant stream of delightful food which rivals any I have discovered aboard R/V Westward. I am particularly indebted to my assistant scientists for their tireless efforts in *Westward*'s laboratory. Fred Carr once again proved himself to be a skilled, versatile, and much experienced oceanographic and marine technician. Kathy Brady, on her first *Westward* cruise, showed enormous perseverance and proved herself to be a highly skilled marine biologist and ornithologist. In addition to the ship's regular staff, three other persons joined R/V *Westward* W-64. Ms. Kate Guilfoile from the S.E.A. office joined us during Leg I. Despite some heavy weather, she added great spirit to the cruise. Dr. James Butler, from Harvard University, was an important addition to Leg II, contributing a series of lectures on oceanic pollution. On Leg III, we were joined by Dr. Jeroen Gerritsen, from the University of Georgia. He proved himself to be an experienced seaman as well as an ecologist.

I offer my sincere thanks to all of those mentioned above and, most of all, to the Sea Semester students who contributed to a spectacularly successful and memorable R/V *Westward* cruise. Great spirit emerged on W-64 because of the dedication shown by all of the participants to the program and one another.

Allan W. Stoner
Chief Scientist
W-64

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INTRODUCTION

This report is the product of the research conducted on R/V *Westward* cruise W-64 and Oceanographic Laboratory I and II (Boston University, course numbers NS-225 and NS-226). The cruise track (Fig. 1) was designed to permit collection of physical, chemical, and biological data from several 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 the Bermuda Platform, Gulf Stream rings, Scotian shelf, and Georges Bank (Fig. 2). The ship's itinerary, including intermediate ports of call (Table 1), permitted participants on W-64 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, numerous oceanographic 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 I and data from the oceanographic stations are tabulated in Appendices II and III. Information reported herein may not be excerpted or cited without written permission of the Chief Scientist.

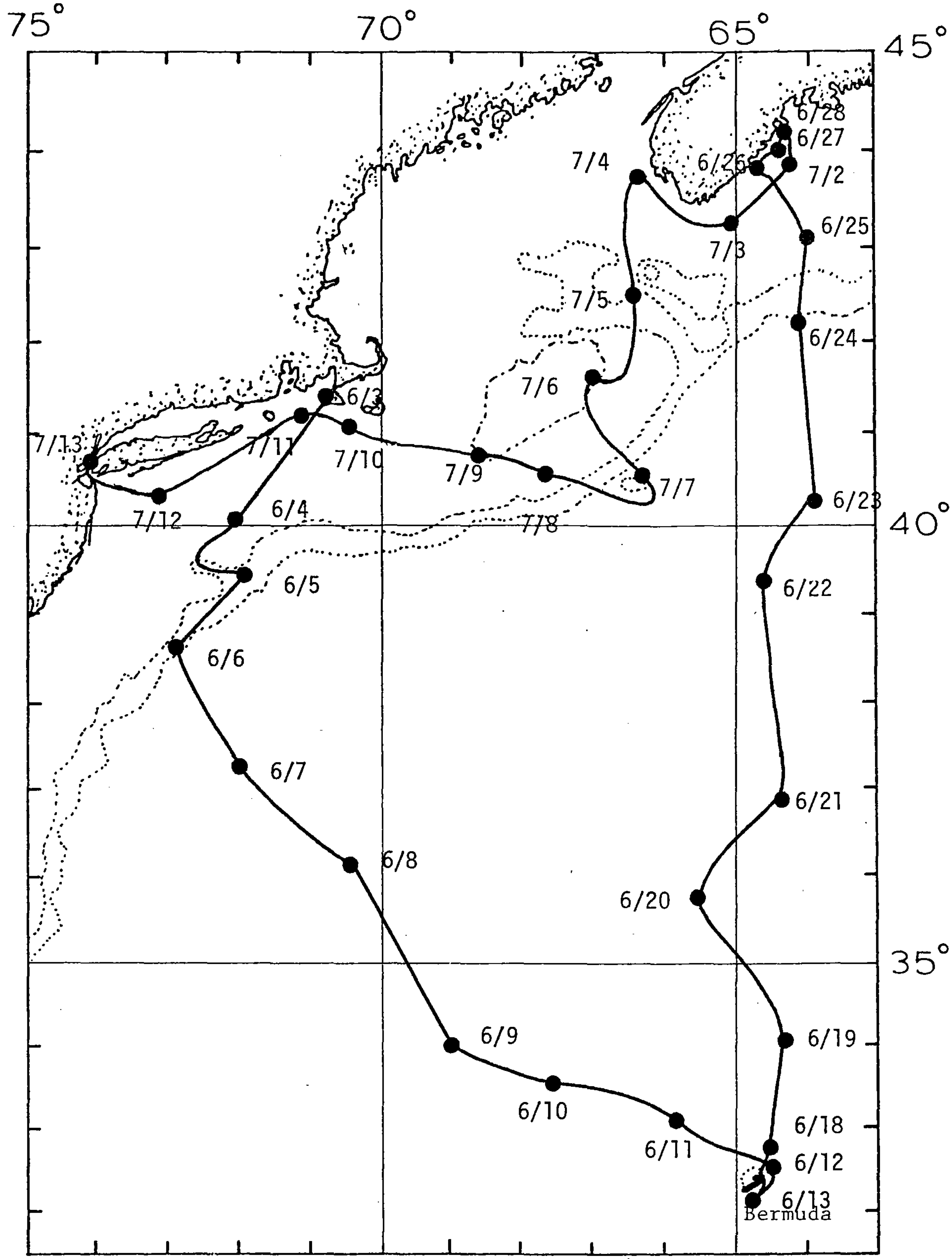

Figure 1: Cruise track of R/V Westward cruise W-64. Positions are for noon of the dates shown.

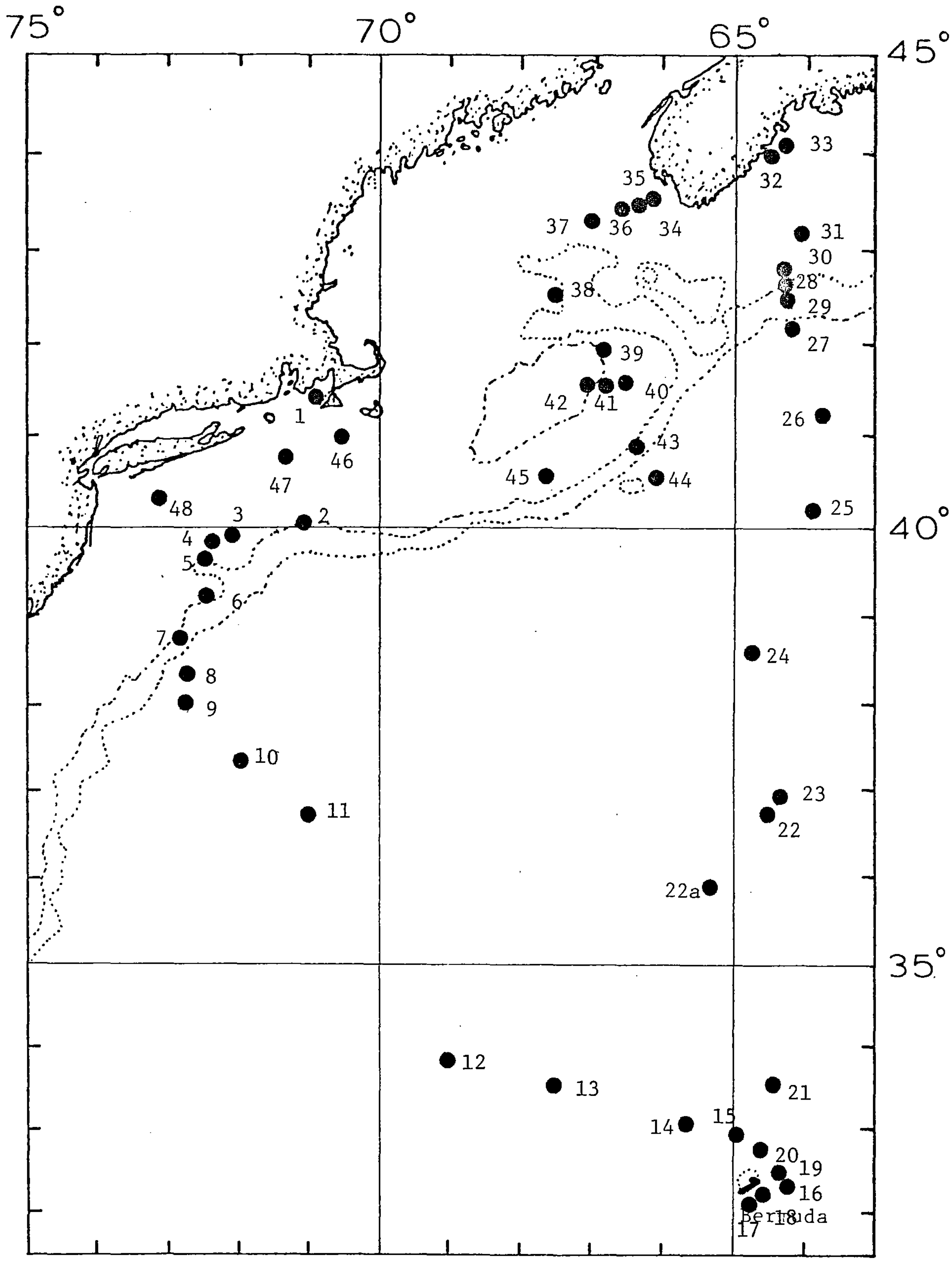

Figure 2: Oceanographic stations sampled during R/V Westward cruise W-64.

Table 1: Itinerary of R/V *Westward* cruise W-64

Depart		Arrive	
Woods Hole, MA	2 June 1982	St. Georges, Bermuda	14 June 1982
St. Georges, Bermuda	17 June 1982	Lunenburg, Nova Scotia	28 June 1982
Lunenburg, Nova Scotia	2 July 1982	New York City	14 July 1982

Table 2: Ship's complement on R/V *Westward* cruise W-64

Nautical Staff

John Wigglesworth	Captain
David Stuhlbarg	Chief Mate
Timothy Higbee	Second Mate
Roderick Swift	Third Mate
Gary Manter	Engineer
Dinah Olanoff	Steward

Scientific Staff

Allan Stoner	Chief Scientist
Fred Carr	Second Scientist
Kathleen Brady	Third Scientist

Visiting Scholars

Ms. Kate Guilfoile - Public Relations.
Sea Education Association, Woods Hole, Massachusetts

Dr. James Butler - Division of Applied Sciences
Harvard University, Cambridge, Massachusetts

Dr. Jeroen Gerritsen - Institute of Ecology,
University of Georgia, Athens, Georgia

Students

John Burns	Assoc. Theatre Arts, Nebraska Western College
F. Rebecca Burr	Junior, Biochemistry, Mt. Holyoke College
Caren Crandell	B.S., Biology, Colby College
Lisa deCossy	Junior, Biology, Boston College
Katherine Dudak	Sophomore, Natural Resources, Cornell University
Amir Farman-Farmaian	Junior, Animal Science, Cornell University
Michelle French	Sophomore, Biology, Ithaca College
Diane Herbst	B.S., English, University of Pennsylvania
Rebecca Herrin	Junior, Biology, University of Colorado
James Kerney	Junior, Economics, Middlebury College
Gail Kineke	Junior, Geology, Princeton University
Andrew Kronick	Junior, Biology, Oberlin College
Scott Moncrieff	Sophomore, Science, West Valley College
Peter Neidhardt	Junior, Biopsychology, Bucknell University

Table 2: (continued)

Lorraine Olendzenski	Junior, Biomedical Engineering, Boston University
Barbara Pettengill	Junior, Psychology, Cornell University
Albert Potts	Senior, Biology, Temple University
Cynthia Robinson	Senior, Photojournalism, Boston University
Richard Rosecrance	Sophomore, Biology, Cornell University
Jennifer Royce	Sophomore, Biology, Cornell University
Susan Service	Junior, Biology, Florida Southern College
Karen Simmonds	Sophomore, Geology/Geophysics, Yale University
Patricia Sohon	Sophomore, Business, Georgetown University
Scott Trask	Senior, Physics, Kenyon College

ACADEMIC PROGRAM

Throughout the six week period covered by R/V Westward cruise W-64 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 major direction 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 not readily gained from laboratory experience, are listed 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.

Table 3: Oceanography classes held during R/V Westward cruise W-64

Date	Topic	Lecturer
3 June	Introduction to cruise W-64	Stoner
	Use of the otter trawl	Carr
4 June	Measuring temperature in the ocean	Stoner
7 June	Introduction to marine invertebrates and research update	Stoner
8 June	Plankton and plankton collection	Brady
9 June	Neuston studies aboard R/V Westward and the faunal associates of *Sargassum*	Stoner
10 June	The biology of fishes	Carr
11 June	The biology of seabirds	Brady
13 June	Research update and the geology of Bermuda	Stoner
14-17 June	(Port stop - St. Georges, Bermuda)	
18 June	Research update	Stoner
	Coral reef geomorphology	Carr
19 June	The Faulklands, Antarctica, and Argentina	Butler
21 June	Pelagic tar and sargassum	Butler
22 June	Research update and Westward chemistries	Stoner
23 June	Examination - Oceanography Lab. I	
24 June	Examination - Oceanography Lab. I	
	Petroleum discharges: accidental and operational	Butler
25 June	Fate of petroleum and other organics in the open ocean	Butler
26 June	Anatomy of the codfish	Carr
28 June-1 July	(Port stop - Lunenburg, Nova Scotia)	
2 July	Academic program for Leg III and Oceanography Lab. II	Stuhlbarg/Stoner
	Gulf of Maine and Georges Bank	Stoner
5 July	Student seminars	
6 July	Fishing and Georges Bank	Wigglesworth
	Aquatic life style I - fluid dynamics	Gerritsen
	Student seminars	
7 July	Student seminars	

Table 3: (continued)

8 July	Aquatic life style II - living in a 3-dimensional world	Gerritsen
	Student seminars	
9 July	Student seminars	
10 July	Research update	Stoner
	Student seminars	
11 July	Examination - Oceanography Lab. II	
12 July	Student seminars	

PHYSICAL OCEANOGRAPHY IN THE NORTHWEST ATLANTIC

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 cause 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 $^{o}/oo$ 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 $^{o}/oo$.

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 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; 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-64 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-half of all student projects on W-64 were designed to compare various aspects of the water masses; these projects ranged from examination of temperature and salinity to study of seabirds. Aspects of physical and chemical oceanography will be discussed in this section. Biological topics will be covered in later sections.

Figure 3, using surface temperature data, shows the major North Atlantic water masses. The Gulf Stream is shown as a band of warm water (21-25°C) passing between cooler slope water to the north and Sargasso Sea water (19-23°C) to the south. A particularly fast-flowing and complex section of the Stream near 64 W longitude was explored by Sohon and deCossy (this report). Cold and warm Gulf Stream rings occur to the south and north of the Stream, respectively. For the purposes of this cruise report, the shelf water mass may be divided into three distinct geographic features: the shallow area in the New York Bight (14-15°C), the Gulf of Maine and Scotian Shelf (6-8°C), and the boreal shelf surrounding Newfoundland (2-6°C).

Simple temperature and salinity data taken during the first two legs of the cruise show clearly the distinct nature and effects of water masses (Fig. 4). Major temperature and salinity variations were seen in the

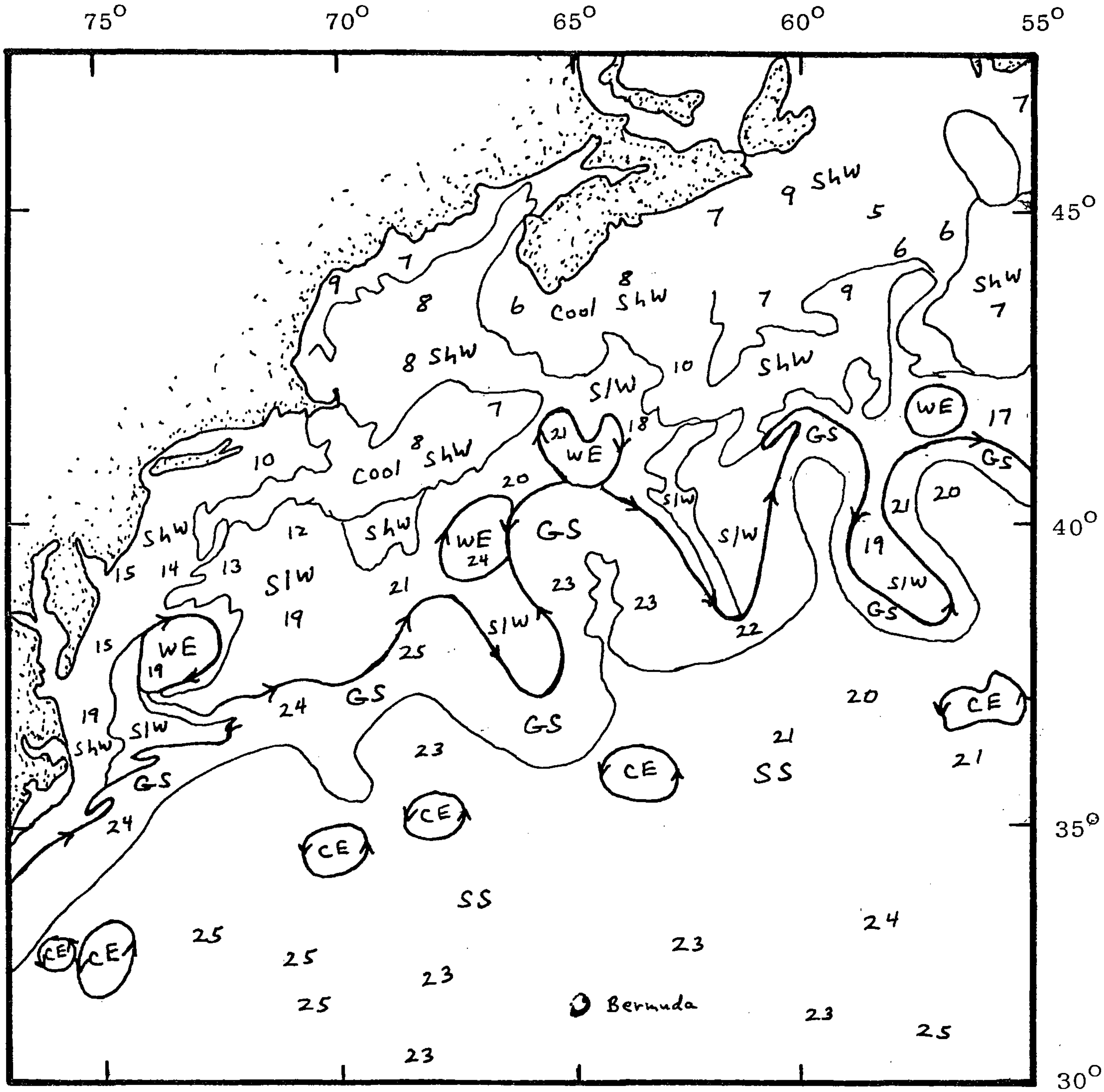

Figure 3: Surface temperatures and major water masses in the Northwest Atlantic Ocean on June 16, 1982. ShW = shelf water, SlW = slope water, GS = Gulf Stream, SS = Sargasso Sea, CE = cold eddy, WE = warm eddy. Temperatures are in °C. (Modified from National Weather Service map.)

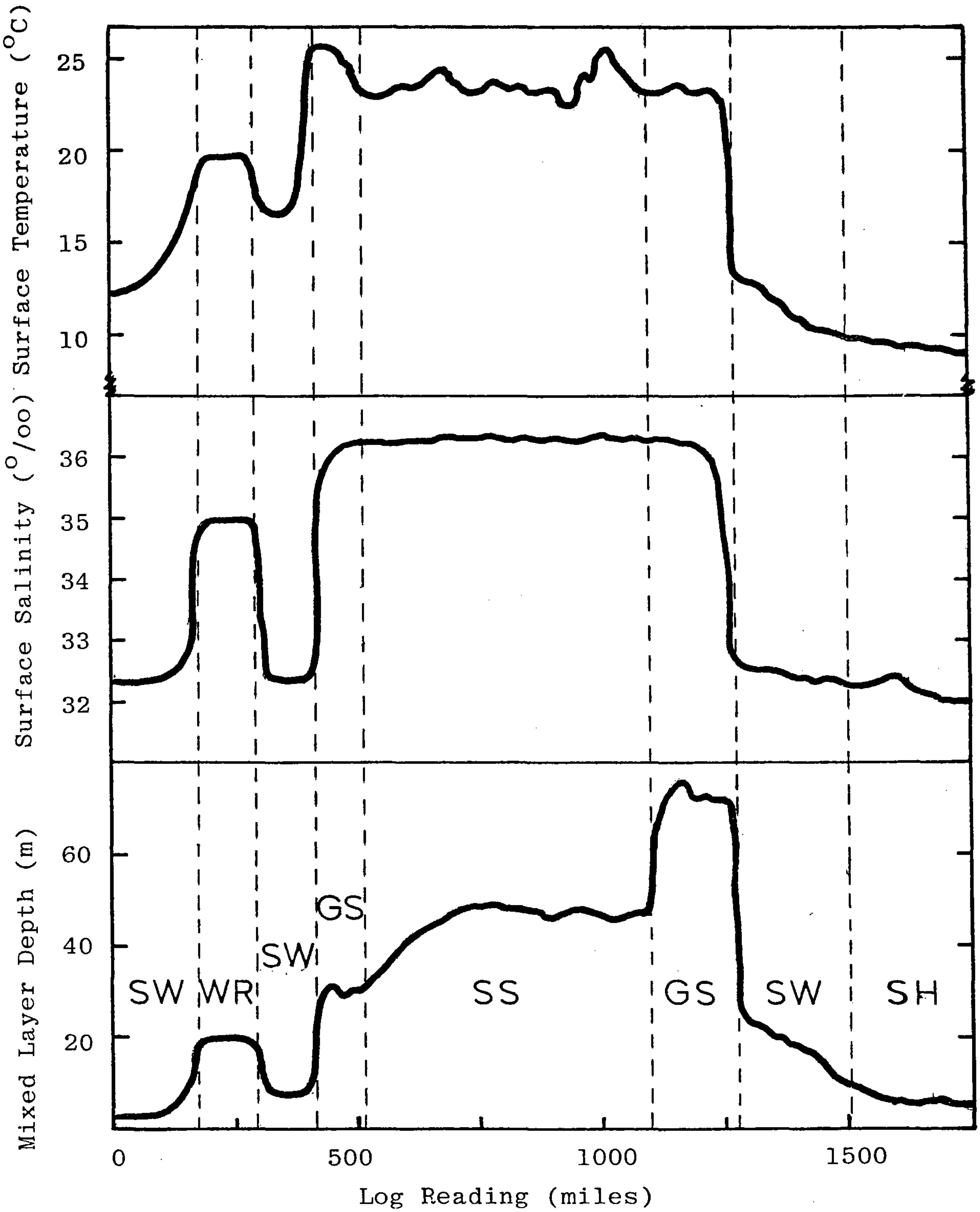

Figure 4: Surface temperature, surface salinity, and mixed layer depth along Leg I and Leg II of cruise W-64. SW = slope water, WR = warm ring, GS = Gulf Stream, SH = shelf water.

first 500 miles of the cruise. Temperature ranged from 12°C in shelf water near Woods Hole to over 25°C in the Gulf Stream. Within the slope water mass (approx. 17°C), a warm, Gulf Stream ring yielded surface temperatures to 19.6°C . Sargasso Sea temperatures fluctuated between 23.3 and 26.1°C, but the departure from Sargasso Sea and Gulf Stream water masses on Leg II of the cruise was very dramatic, temperatures dropping from approximately 23 to 14°C over a distance of only twenty miles. On the Scotian Shelf, temperatures between 8 and 10°C were the rule. On Leg III, surface temperatures again returned to values over 20°C upon entering slope water south of Georges Bank.

Surface salinity values very closely paralleled surface temperature values (Fig. 4). Shelf water yielded the lowest salinities because of runoff from land and high precipitation. High salinity values in the Sargasso Sea and warm-core rings are related to high evaporation to precipitation ratios. Subsurface salinity values, however, do not necessarily reflect surface values. Salinity profiles were investigated by Pettengill, deCossy, Kineke, and others participating on W-64; but a thin band of high salinity, subsurface water, called Subtropical Underwater, was of particular interest to Royce (this report).

The vertical temperature profile for Leg 1 (Fig. 5) shows the complex structure of the slope water log readings 180 and 300 nautical miles, where a warm ring and numerous thermal inversions occur. The ring appears as a sharp cone of warm water ($>60°F$) between 225 and 275 miles on the log. The ring was bordered by the areas of thermal inversion. Pettengill and Dudak (this report) discuss, in detail, the physical structure of this same ring and the surrounding water masses. The north wall of the Gulf Stream was very apparent at a log reading of approximately 300, where isotherms dropped as much as 500 feet in less than 20 miles. The center of the Gulf Stream appeared as a 150 feet deep lens of 78°F water. Isotherms rose again at the south on each boundary of the Gulf Stream, yet relatively high surface temperatures and a deep, diffuse thermocline occurred in the Sargasso Sea. The depth of the thermocline or mixed layer reflected patterns of surface temperature and salinity, at least generally (Fig. 4); this too was a function of water mass dynamics. The mixed layer

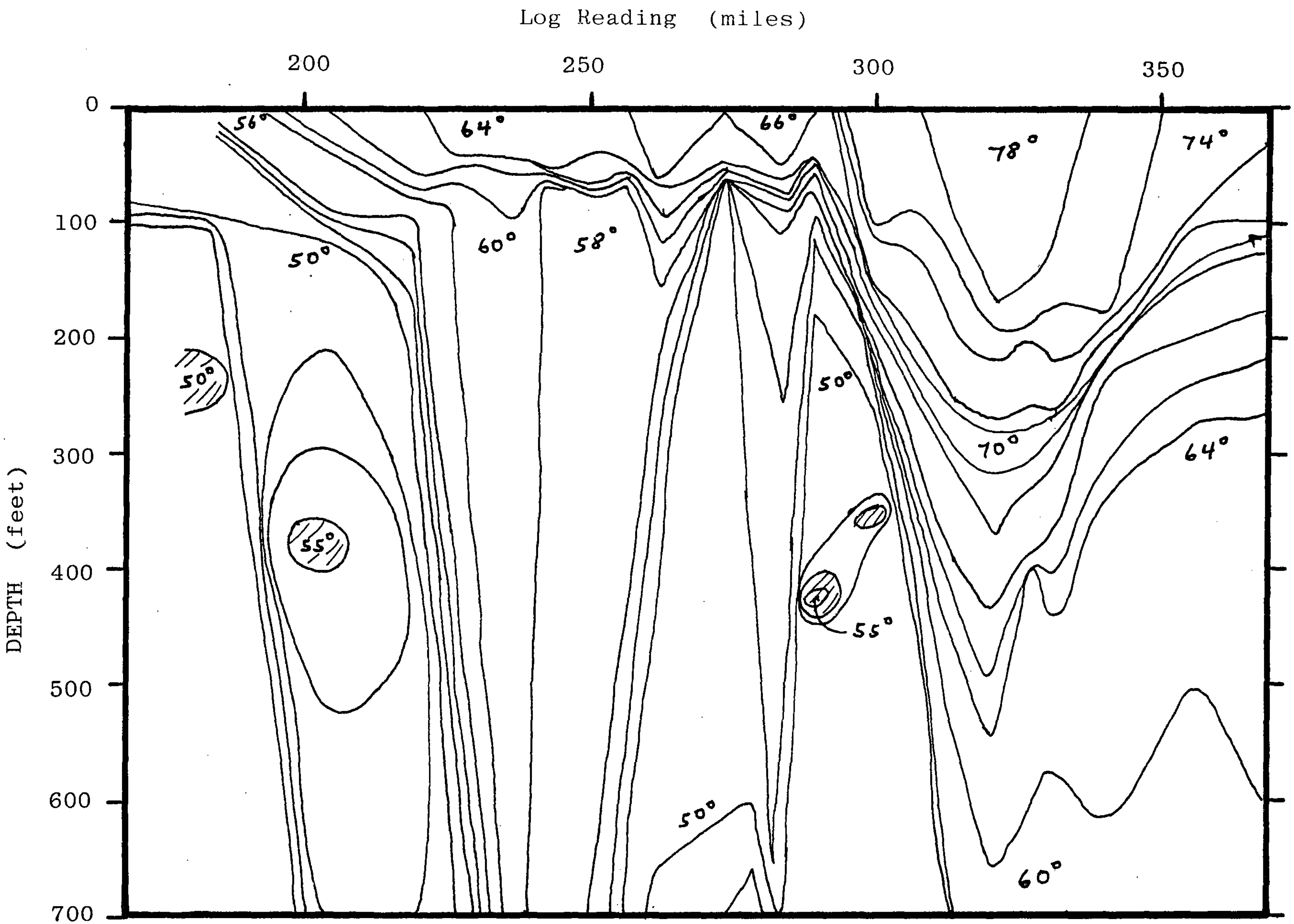

Figure 5: Bathythermograph transect from the shelf water of New York Bight through the Gulf Stream and into the Sargasso Sea. Temperatures are in ^{o}F.

was very shallow (less than 10 meters) or the water was isothermal on the shelf and banks areas. Deepest mixed layers were found on the second crossing of the Gulf Stream (60-75 m) and in the Sargasso Sea (30-50 m), where constant radiation and great depth permits stabilizing conditions. Kerney (this report) investigated thermal profiles near Bermuda in hopes of finding a suitable site for Ocean Thermal Energy Conversion (OTEC). The depth of the mixed layer and strength of the thermocline have great influence on nutrient generation in the water column and on biological productivity. Dudak and Kineke (this report) investigated aspects of nutrient regeneration in the warm ring and in the major water masses encountered along the cruise track of W-64, respectively. Biological topics related to water masses, nutrient concentrations, and physical oceanography are covered in the Plankton Biology and Coastal Studies sections of this report.

The Physical-Chemical Structure of a Warm-Core Ring

Barbara Pettengill

ABSTRACT

Temperature, salinity, and density characteristics of a six-month old warm-core ring, slope water, Gulf Stream, and Sargasso Sea site were examined to determine the physical-chemical structure of the warm ring and its interaction with the surrounding water masses and source water during decay. Water samples taken to a depth of 1800 m showed that the outer ring was very similar to slope water at all depths. A site half way into the ring was more similar to slope water than to the ring center, which exhibited Sargasso Sea-like characteristics (Fig. 6). Decay of the ring involving mixture with slope water was the most likely cause of the observed patterns. The ring was most slope-like at the surface and below 1100 m indicating that decay was greatest in these areas. The temperature, salinity, and resulting density of a ring give strong clues as to the age and processes of decay in the ring.

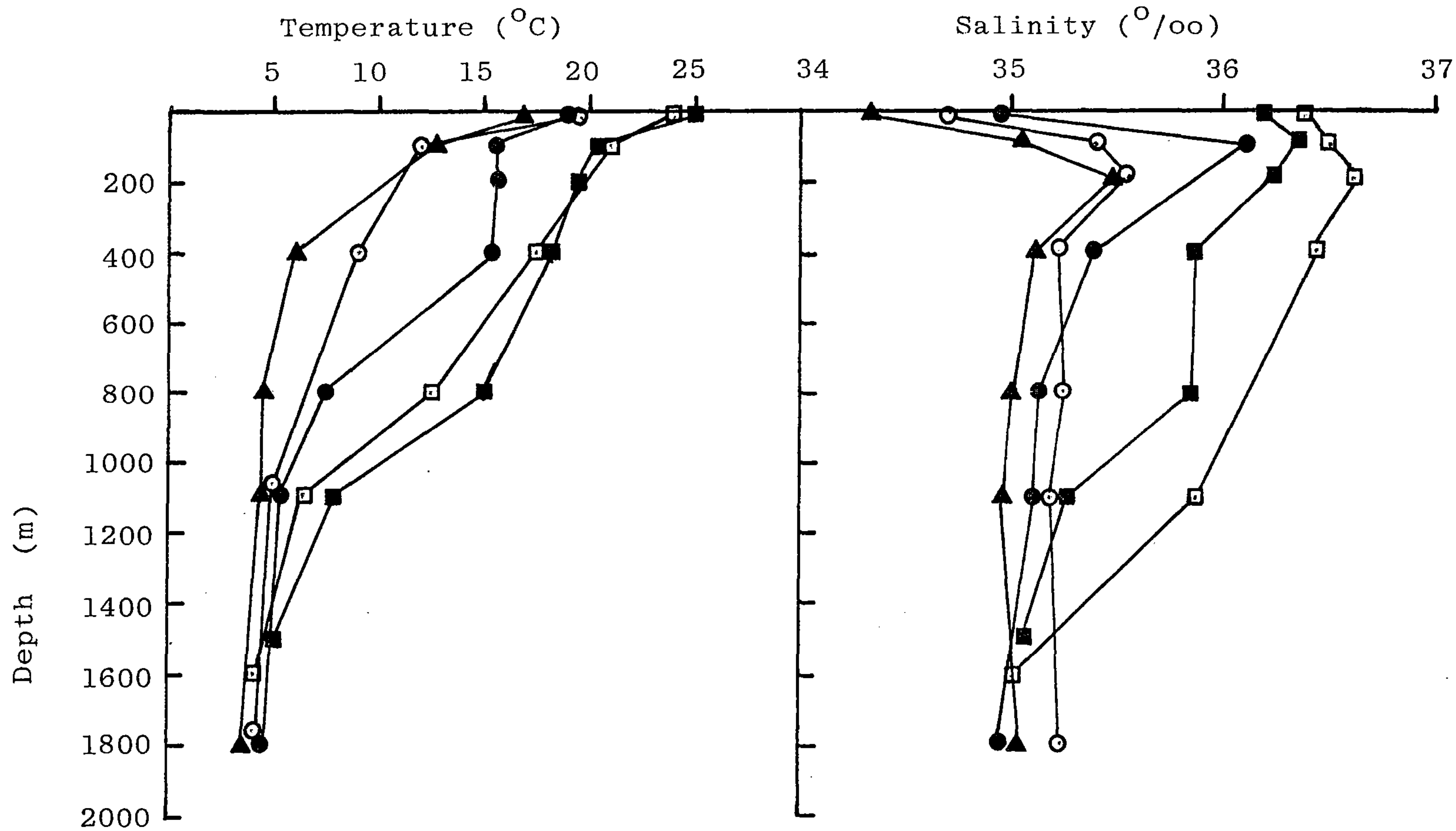

Figure 6: Salinity and temperature profiles at five sites near a warm-core ring in the North Atlantic Ocean. Triangles = slope water, open circles = ring outer edge, closed circles = ring center, open squares = Gulf Stream, closed squares = Sargasso Sea.

Nutrient Regeneration in a Warm-Core Ring

Katherine Dudak

ABSTRACT

The nutrient concentrations at a slope water station, a Sargasso Sea station, and two warm-core ring (center at 37°58'N latitude, 72°45'W longitide) stations were determined for comparison. Phosphate and nitrate samples taken to depths of 1800 m (Fig. 7), showed that the warm core center and the Sargasso sites were most similar in nutrient profiles and the nutrient profiles in slope water and outer pdge of the ring were similar. Decay of the six-month old ring, as indicated by nutrient concentrations, appeared to occur earlier at the edge of the ring than in te center as predicted by theory. This conclusion paralleled findings by Pettengill (this report) on temperature and salinity profiles. Indirect regeneration may account for some increase in nutrient levels of the ring; however, direct regeneration is probably most important in the ring because of high levels of biological production inside the ring structure.

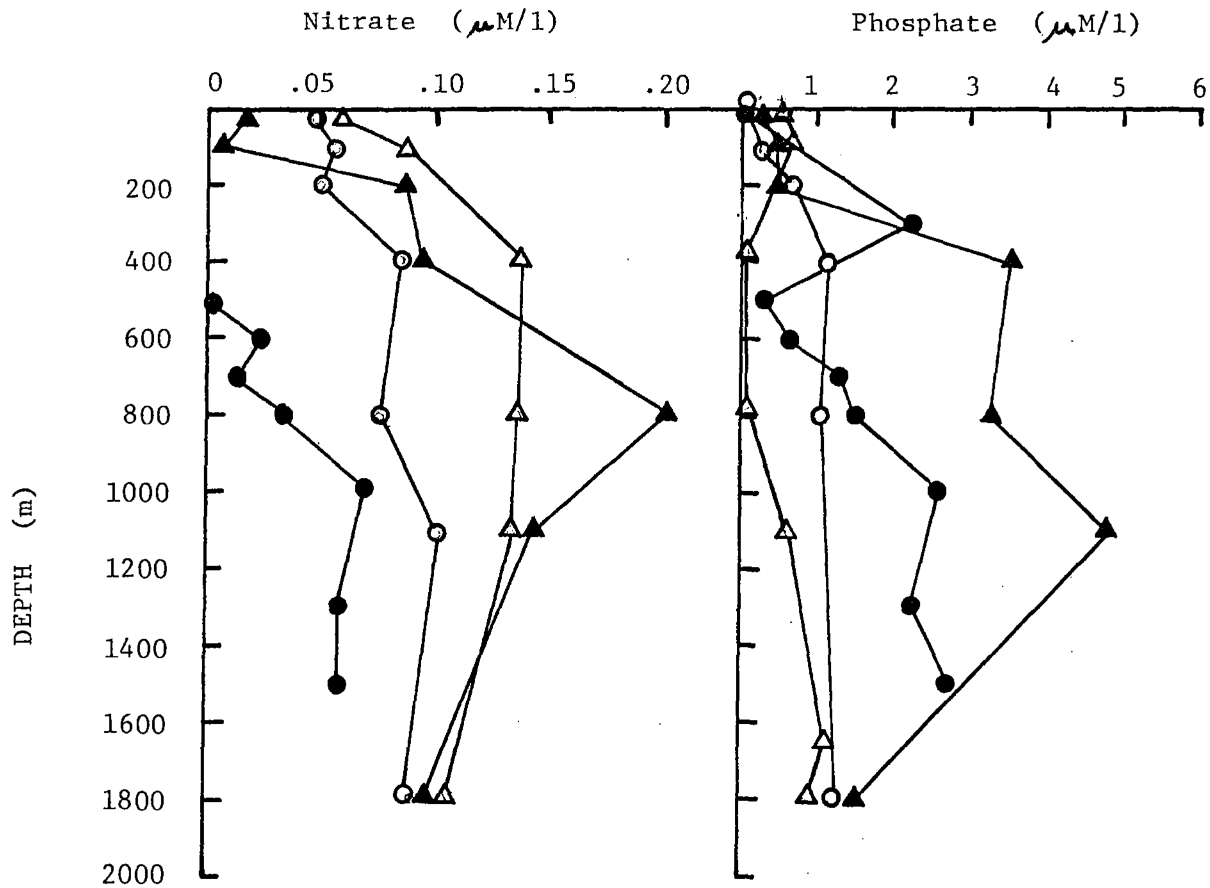

Figure 7: Nitrate and phosphate concentrations at four sites near a warm core ring in the North Atlantic Ocean. Open circles = W64-7 - slope water, open triangles = W64-8 - edge of the ring, closed triangles = W64-9 - center of the ring, closed circles = W64-20 - Sargasso Sea.

How to Increase Your Speed While Hove To

Patricia Sohon

ABSTRACT

During R/V Westward cruise W-64 surface currents of up to 17 knots were encountered 250 to 400 nautical miles north of Bermuda near 60° W longitude. Ship set and drift data were used to plot the nature of the surface currents between 36° N and 40° N latitude (Fig. 8). Bathythermography, salinity, oxygen, and surface current data all suggested that the ship passed along the high velocity axis of a Gulf Stream meander and not a newly formed Gulf Stream ring as implied by U.S. Weather Service reports. The high velocity currents were most likely a result of a strong Gulf Stream meander and a massive low pressure system which moved at a high velocity across the meander. Conclusions were corroborated by physical-chemical data examined by deCossy (this report).

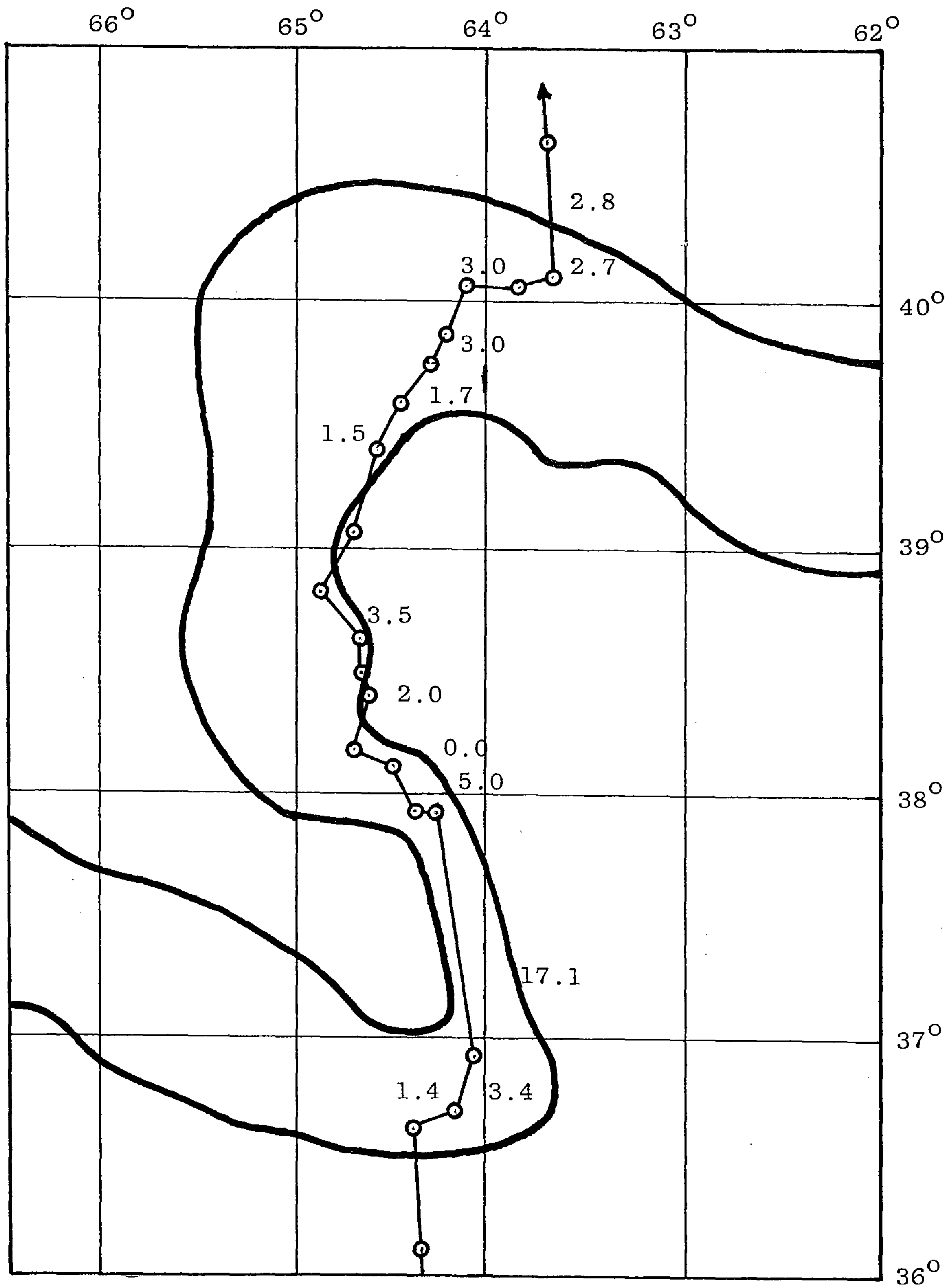

Figure 8: Cruise track of R/V Westward through the Gulf Stream 1735 hours, 20 June 1982 to 1525 hours, 22 June 1982. Points are individual fixes. Numbers represent current velocities in knots.

Physical-Chemical Analysis of a Gulf Stream Meander

Lisa deCossy

ABSTRACT

Unusual, high velocity currents were encountered by R/V *Westward* from 18 to 23 June 1982 north of Bermuda along 60° W longitude. Speculation suggested a new cold core ring or a strong Gulf Stream meander. Deep hydrocasts were conducted to identify and describe water types and distributions in an attempt to understand the phenomena. Upon entering from the Sargasso Sea a northeast current with velocities and hydrographic data characteristic of the Gulf Stream confirmed the Gulf Stream identity. Analyses at a station further north (Figs. 9 and 10) showed that the vessel had entered a mixing zone between the Sargasso Sea and the Gulf Stream. At a third station, temperature and salinity data were indicative of the boundary between slope water and the Gulf Stream. The nature and arrangement of water masses among the stations as well as the current structure between each suggests that the high velocity currents described by Sohon (this report) were a result of a Gulf Stream meander and not a cold core ring, as reported by the U.S. Weather Service.

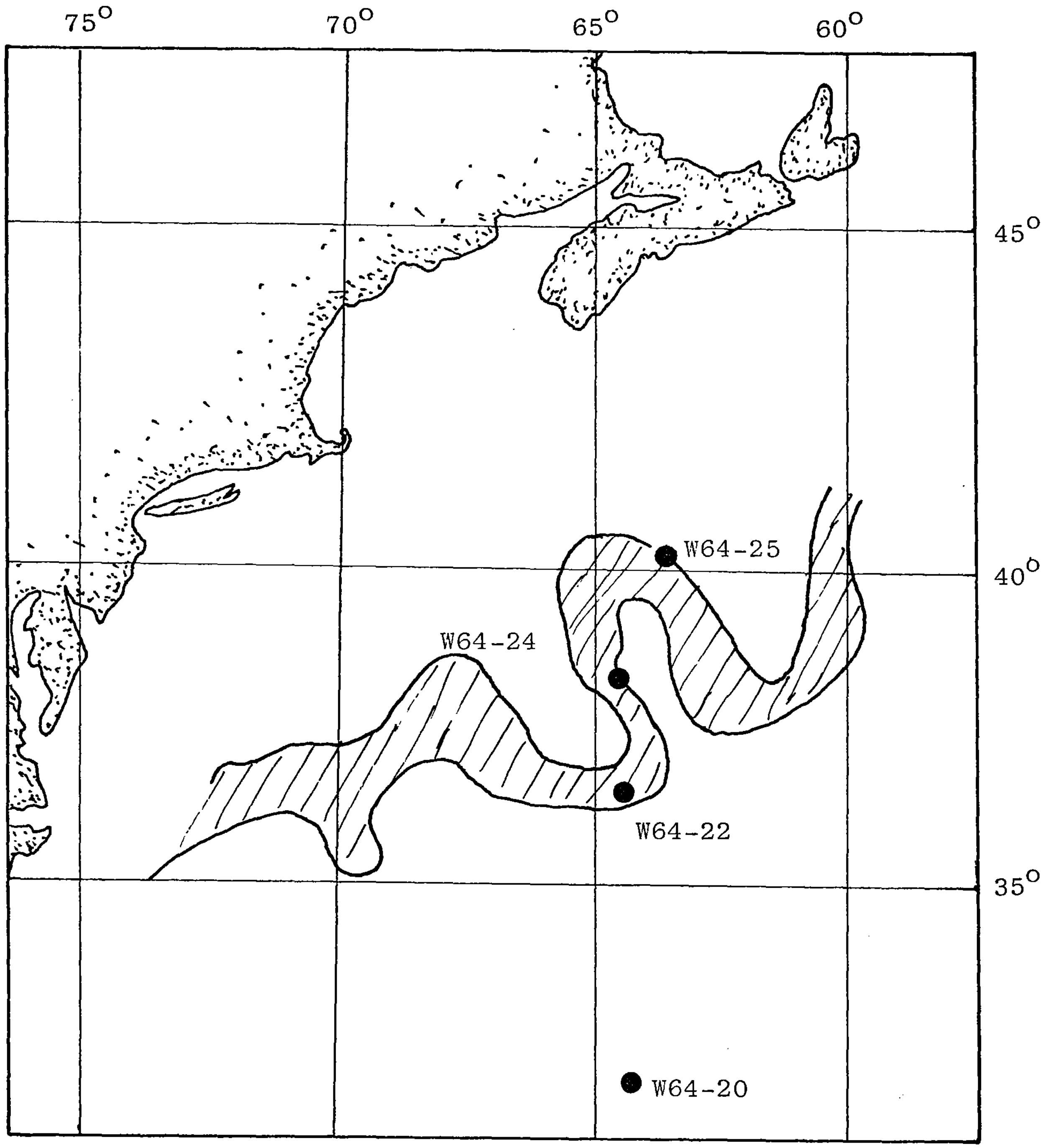

Figure 9: Position of the Gulf Stream as indicated by the National Weather Service and sites sampled during R/V Westward cruise W-64 between 18 June and 22 June, 1982.

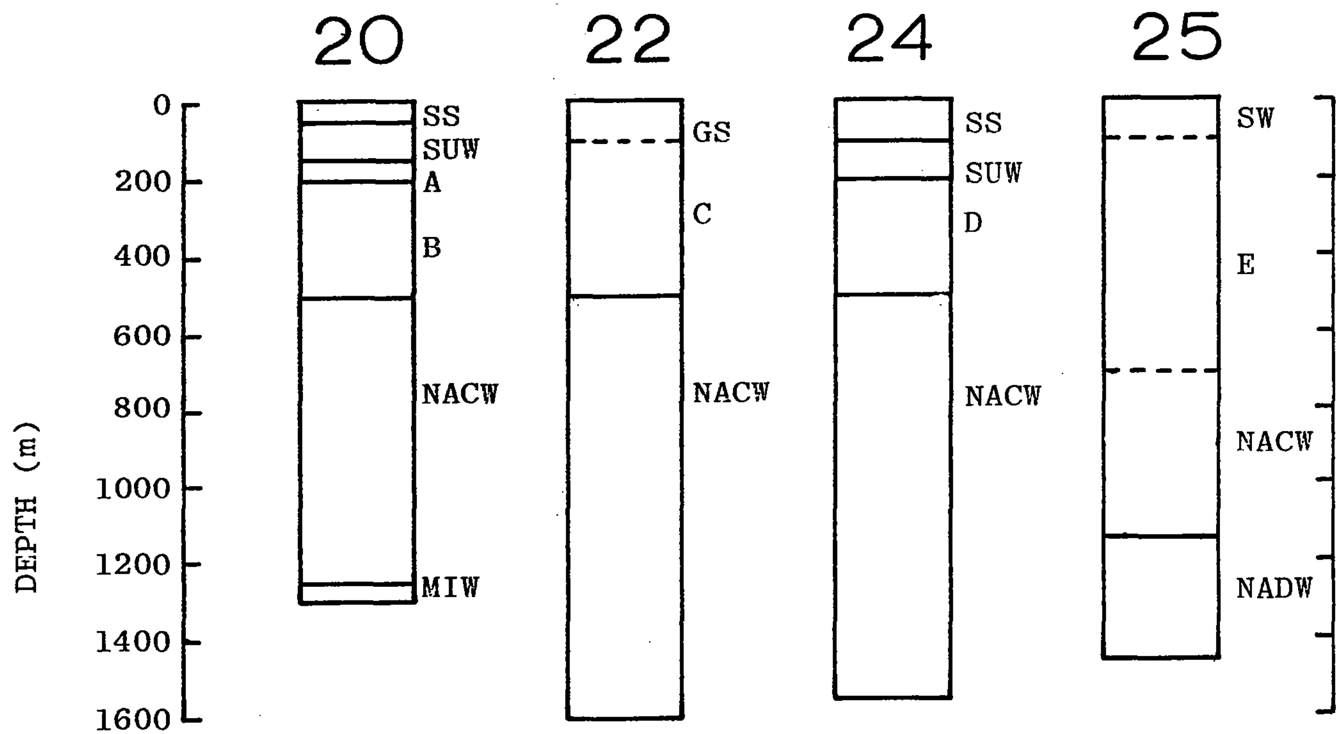

Figure 10: Water masses identified at four stations near a Gulf Stream meander. SS = Sargasso Sea surface, GS = Gulf Stream surface, SW = slope water surface, SUW = Subtropical Underwater, NACW = North Atlantic Central Water, NADW = North Atlantic Deep Water, MIW = Mediterranean Intermediate Water, A through E = unidentified water masses.

Subtropical Underwater in the North Atlantic

Jennifer Royce

ABSTRACT

Subtropical Underwater is a water mass found at depths of 50 to 250 meters in tropical and subtropical waters of the North Atlantic Ocean and Caribbean Sea; it is characterized by high salinity (36.7 to 37.0 $^{o}/oo$). To locate and plot the distribution of Subtropical Underwater in the Sargasso Sea, a series of shallow hydrocasts were made on R/V Westward cruise W-64. Additionally, salinity data from past cruise reports were compiled and used to show the distribution of salinity maxima. Two distinct subsurface, high salinity water masses were found, one near Bermuda and the other following the Caribbean current (Fig. 11). Bermuda stations had salinities slightly lower than those in the Caribbean Sea. Separation between the two areas characterized by subsurface salinity maxima may be a result of two separate origins of high salinity water or physical separation of the same Subtropical Underwater in the western Atlantic.

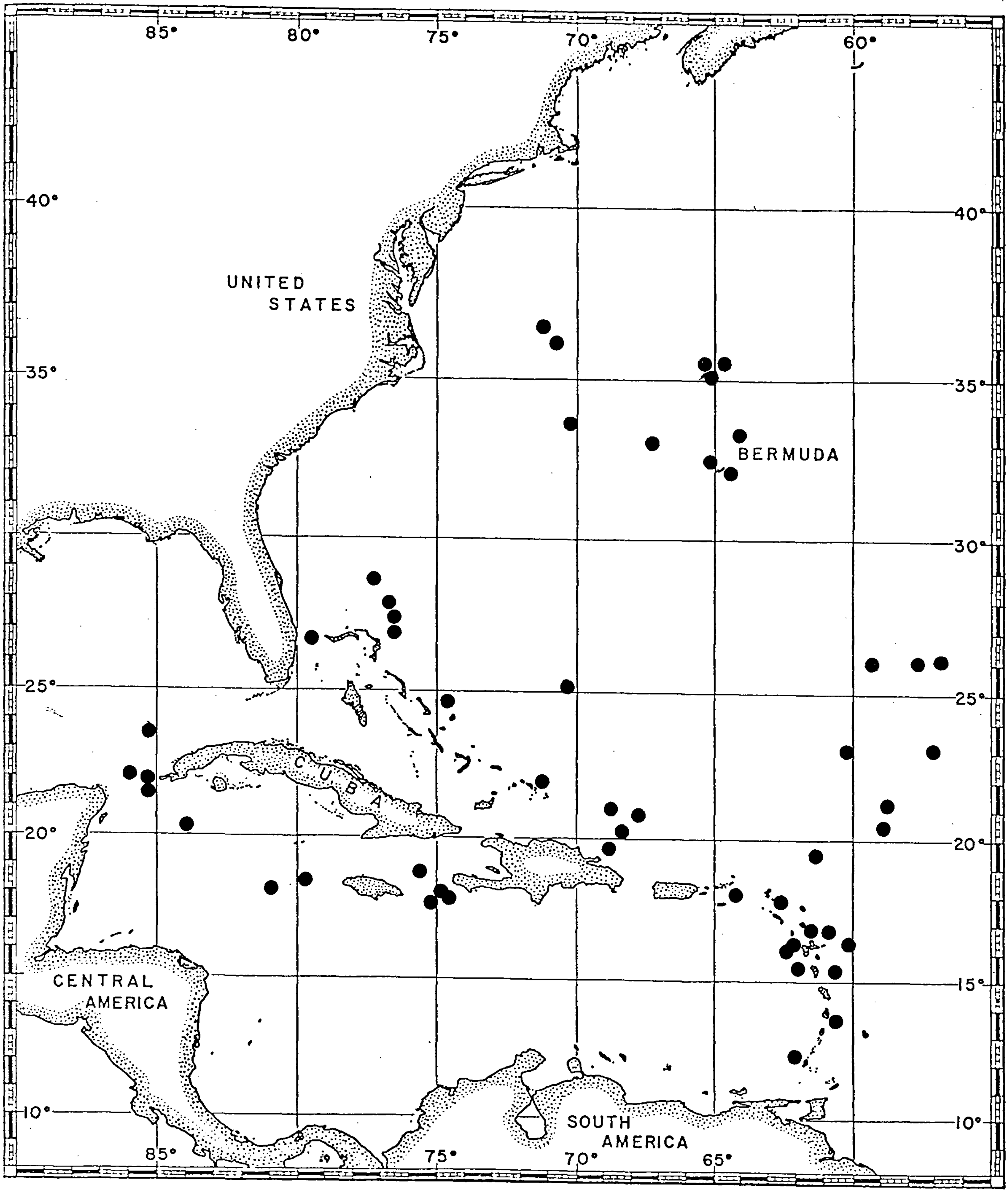

Figure 11: Positions at which significant subsurface salinity maxima have been found on R/V Westward cruises W-36 to W-64.

The Interrelationships of the Pycnocline, Nutricline, and Minimum Oxygen Layer

Gail Kineke

ABSTRACT

Different water masses are characterized by particular salinity, temperature, density, dissolved oxygen, and nutrient profiles, but some general trends and interrelationships among the factors were apparent. At four stations in the North Atlantic, lower levels of oxygen occurred at the thermocline (which corresponded with the depth of the pycnocline). Nutrient levels tended to increase just below the oxygen minimum layer (Fig. 12). The existence of the minimum oxygen layer was probably a result of high levels of bacterial decomposition at the pycnocline where increased density slows the settling of organic material and causes a temporary accumulation (see Burr, this report). The nutrient profiles were explained by the vertical distribution of phytoplankton (see Rosecrance, this report). Although the bacteria in the water column act as the regenerators of nutrients, the pycnocline serves as a barrier to vertical mixing. The significance of the functional relationships among pycnocline, nutricline, and dissolved oxygen minima is supported by the consistency of patterns in different water masses of the North Atlantic.

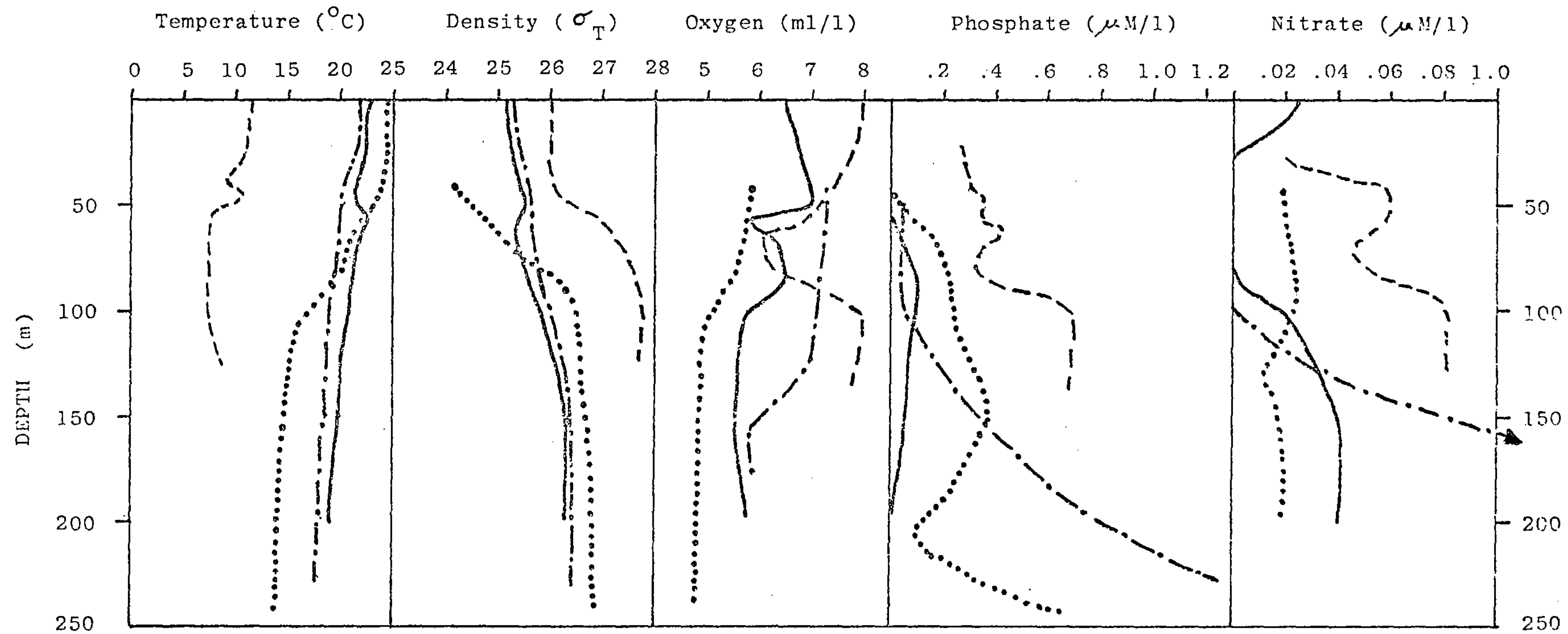

Figure 12: Physical-chemical profiles at four sites in the North Atlantic Ocean. Dash-dot = Bermuda slope, dot = Sargasso Sea station W64-22b, solid line = Sargasso Sea station W64-14, dash = slope station W64-27.

OTEC: A Site Feasibility Study

James Kerney

ABSTRACT

Ocean Thermal Energy Conversion (OTEC) power plants are designed to use the solar heated surface waters and the cooler deep waters to power a heat exchange system which could create either a workable compound such as hydrogen gas or produce electrical current, either of which can be transported to shore. Temperature, salinity, and nutrient data were examined in two geographic areas to determine the feasibility of OTEC power production and the utilization of plant by-products. One proposed site off Nova Scotia was quickly rejected because of a nearly isothermal water column. The other site, near Bermuda, showed great potential as an OTEC site because of large thermal gradients and high nutrient levels at depth. The entire southeastern coast of Bermuda was studied and an optimum site off Hamilton, in 1200 m of water was proposed (Fig. 13). In addition to the ideal physical conditions off Hamilton, the city has the greatest demand for power in Bermuda. Fresh water and maricultural by-products of an OTEC plant would also be beneficial to the city.

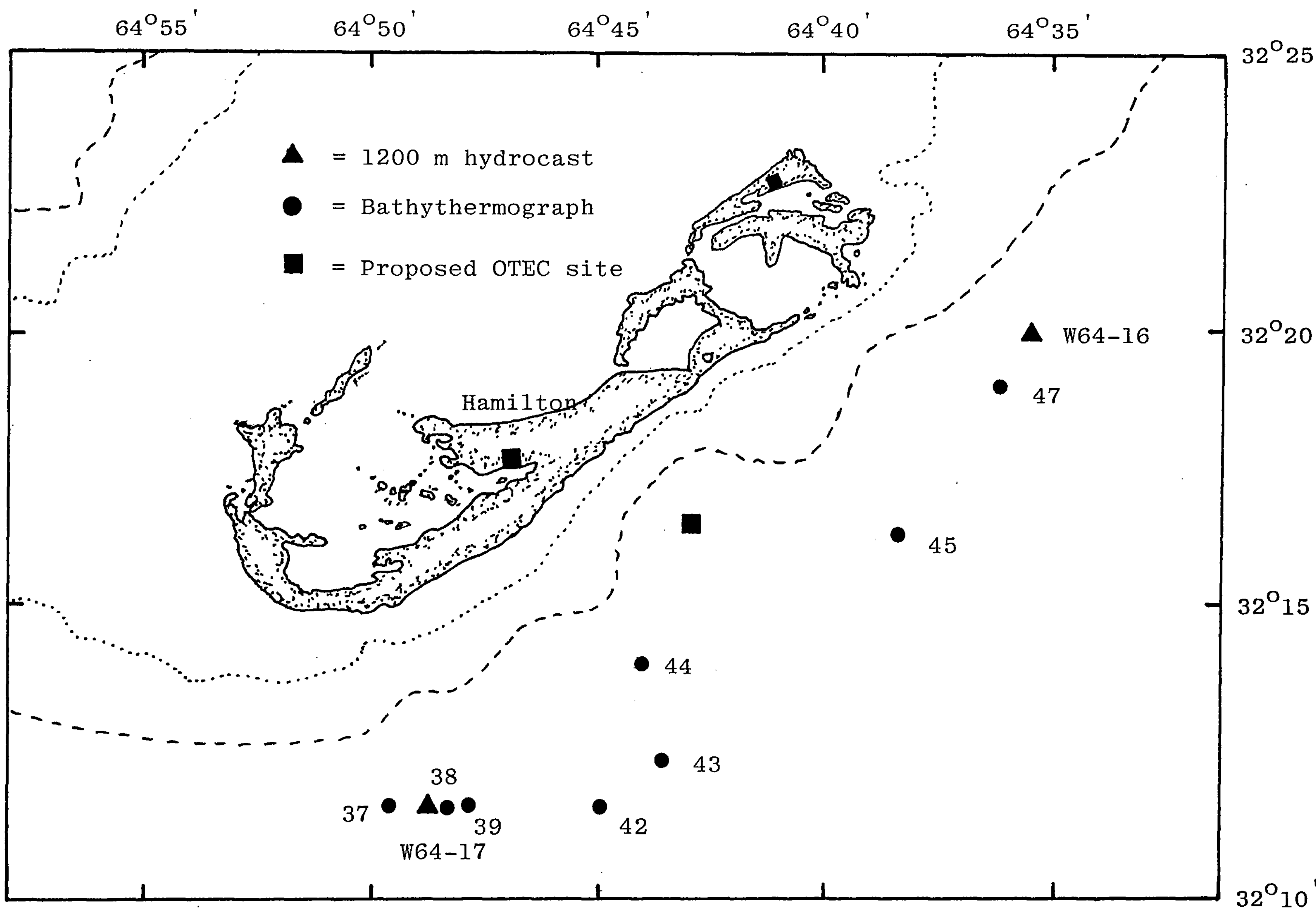

Figure 13: Chart showing the stations sampled near Bermuda and the proposed site for an OTEC plant.

PLANKTON BIOLOGY AND THE PELAGIC ZONE

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*.

Plankton productivity and standing crop or biomass is largely dependent upon the availability of nutrient compounds in the euphotic zone. Nutrient availability, in turn, is related to distance from land, depth of the water column, strength of the thermocline or vertical density gradient, and vertical mixing, to mention only a few of the regulating mechanisms. Of course the organisms themselves, particularly phytoplankton, affect the concentration of nutrients in the water column. All of these factors play major roles in the observed patterns of plankton variation in the North Atlantic.

During R/V *Westward* cruise W-64, over 70 net tows were made for various forms of plankton and neuston and numerous hydrocasts were made for planktonic algae and bacteria. Most of the collections were made for student projects, the abstracts for which are included in this section of the report. Examining the data from 202 and 505 micrometer mesh nets collected throughout the cruise track, however, reveals some interesting patterns in zooplankton biomass and composition (Table 4).

Because of efficient nutrient regeneration, shallow shelf areas, such as that off Nova Scotia, and the continental shelf-break areas showed highest biomass values. This was especially true for the more southerly stations due to more advanced seasonal stages of development at lower latitudes. The Sargasso Sea and deep, slope sites yielded low biomass values for zooplankton. This is most likely a result of high surface temperatures (near 25°C), a very steep pycnocline, and deep nutriclines which are related to deep mixed layers and pronounced thermal stratification. Slope, Gulf Stream, and Sargasso Sea sites are also very distant from land and lie over deep water columns.

Although there may be considerable confusion in comparing zooplankton from different sites because of different times of collection, several interesting compositional patterns were apparent. It is clear that the most productive sites such as the Hudson Canyon area, Georges Bank, and the Nova Scotian sites demonstrated very low diversity of zooplankton; in most cases copepods made up over 90% of the total fauna. Some of the nearshore and shallow-water sites showed a large presence of meroplankters such as fish eggs and larvae, gastropod veligers, and crab zoea. This is undoubtedly related to the richness and close proximity of benthic communities in shallow, coastal sites. Fish eggs were particularly abundant in the Gulf of Maine because of the summer spawning of many local species. Diversity of zooplankton increased offshore, concurrently with a decrease in meroplankters and an increase in holoplanktonic forms such as euphausiids, siphonophores, pelagic shrimp, and other taxa. Predators such as large chaetognaths and siphonophore were particularly abundant in the nutrient poor Sargasso Sea, suggesting that offshore food webs are much more complex than those in coastal areas.

Three student projects dealt specifically with the vertical distribution of plankton in the water column. Rosecrance examined the relationship between phytoplankton and herbivorous zooplankton in the Sargasso Sea and in slope water. Bacterial populations were investigated by Burr and Olendzenski. Other plankton projects were designed to examine aspects of zooplankton distribution and dispersal. Service concentrated on gastropod veligers in the Gulf Stream and Sargasso Sea, Kronick examined the harpacticoid copepod <u>Macrosetella</u> and its food source, <u>Trichodesmium</u>, in the Gulf Stream, Sargasso Sea, and in a warm-cove ring, and Potts studied the distribution of the unusual, irridescent copepod <u>Sapphrina</u>. Zooplankton (foraminifera) were used by French in the fossilized, sedimentary form to compare the paleoclimatology of slope areas off New Jersey and Nova Scotia. The abstracts for all of these projects follow.

Table 4: Summary of zooplankton data collected on R/V Westward cruise W-64.

Station	Location	Net Mesh Size (micrometers)	Biomass ($ml/1000m^3$)	Abundant Taxa (% of total count)
W64-4	Shelf near Hudson Canyon	505	816	Copepods - 88, Zoea - 6
W64-5	Head of Hudson Canyon	505	725	Copepods - 89, Veligers - 8
W64-6	Shelf-break near Hudson Canyon	505	443	Copepods - 98
W64-7	Slope-Edge of Warm Ring	505	198	Copepods - 91, Chaetognaths - 4
W64-11	Gulf Stream	202	270	Copepods - 57, Veligers - 15, Fish eggs - 6, Chaetognaths - 4, Euphausiids - 4, many other taxa.
W64-14	Western Sargasso Sea	202	187	Copepods - 74, Chaetognaths - 11, Veligers - 5, many other taxa.
W64-18	Bermuda (100 fm)	505	93	Copepods - 57, Siphonophores - 11, Euphausiids - 10, Fish eggs - 9, Miscel.
W64-19	Bermuda (1000 fm)	505	105	Copepods - 46, Shrimp - 9, Amphipods - 9, Euphausiids - 8, Chaetognaths - 5, Miscel.
W64-24	Edge of Gulf Stream	202	22	Copepods - 79, Veligers - 4, Ostracods - 4, Many others
W64-26	Slope water - Nova Scotia	202	12	Copepods - 79, Chaetognaths - 9, Amphipods - 5, Miscel.
W64-28	Shelf-break - Nova Scotia	505	80	Copepods - 99
W64-29	Slope - near Scotian Shelf	505	90	Copepods - 99
W64-30	Shelf - Nova Scotia	505	100	Copepods - 99
W64-34	Yarmouth (inshore)	505	24	Copepods - 99
W64-35	Yarmouth (50 m)	505	66	Copepods - 99
W64-36	Lurcher Shoal	505	29	Copepods - 99
W64-37	Yarmouth (100 m)	505	130	Copepods - 49, Amphipods - 49

Table 4 (continued):

W64-37	Yarmouth (100 m)	202	619	Veligers - 83, Copepods - 17
W64-38	Gulf of Maine	505	2.5	Copepods - 62, Fish eggs - 30, Amphipods - 4
W64-38	Gulf of Maine	202	129	Copepods - 94, Fish eggs - 4
W64-42	Georges Bank	505	30	Copepods - 90, Chaetognaths - 3
W64-48	New York Bight	505	26	Copepods - 64, Zoea - 23, Shrimp - 5, Mysis - 4

Relationships of Chlorophyll Maxima to Biological and Physical Pressures

Richard Rosecrance

ABSTRACT

A major debate among biological oceanographers currently centers around the role of herbivore grazing pressures in the establishment of the often observed Deep Chlorophyll Maximum (DCM). Some contend that the DCM is a site of high zooplankton concentrations, while others suggest that the DCM is formed as a result of low zooplankton abundance. In this investigation, phytoplankton-zooplankton relationships were examined in the Sargasso Sea and in North Atlantic slope water using chlorophyll and phaeopigment concentrations throughout the upper water column. Phaeopigments are produced in the consumption of phytoplankton by zooplankton and, therefore, provide an estimate of grazing pressure. The vertical distribution of phytoplankton pigments, nutrients, light intensity, and temperature (Fig. 14) at the two sites suggests that zooplankton grazing determined phytoplankton abundance in the upper euphotic zone, while lack of light determined phytoplankton abundance in the lower euphotic. The position of the chlorophyll maxima was determined by zooplankton grazing, nutrient levels, and light intensity.

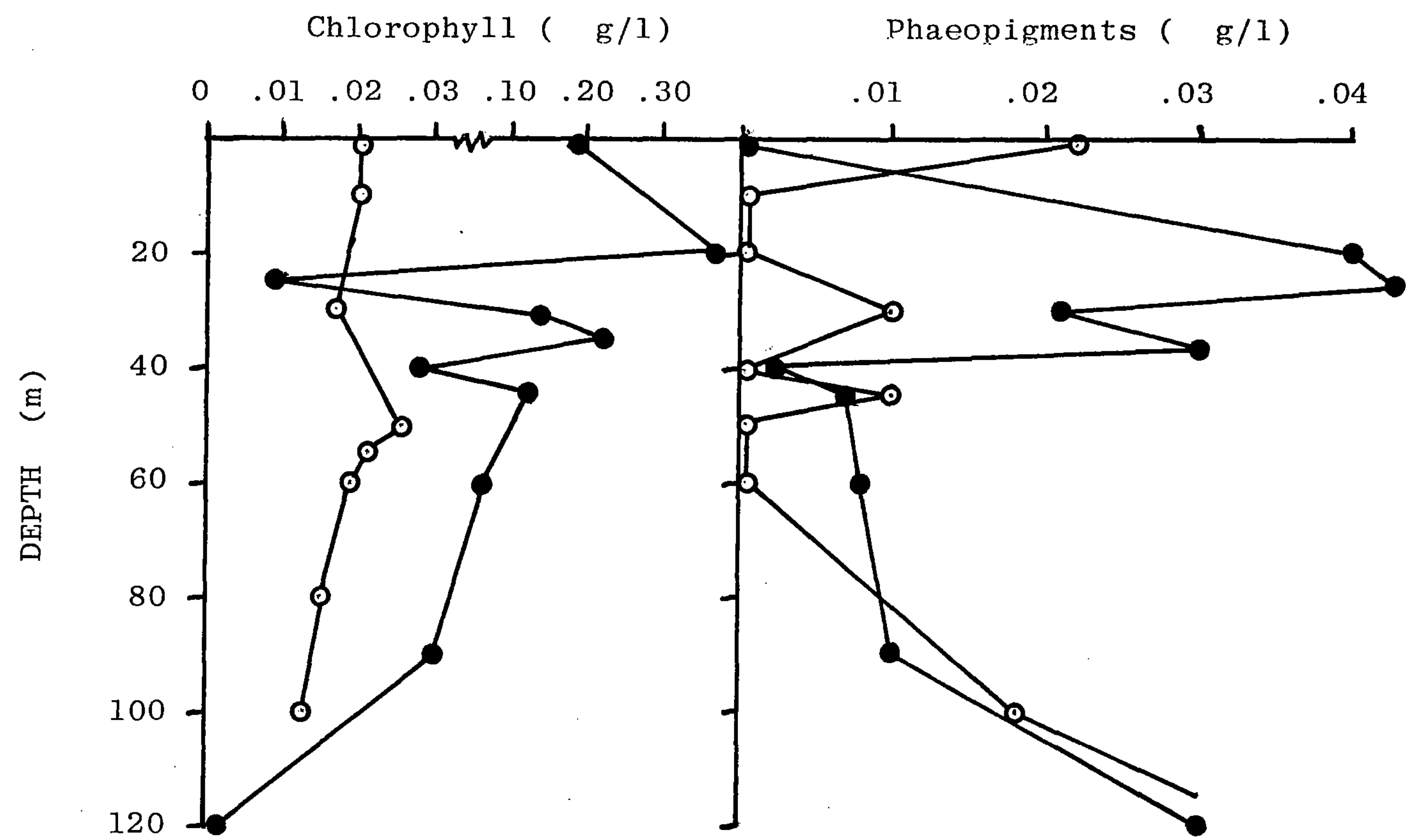

Figure 14: Concentration of chlorophyll and phaeopigments in the Sargasso Sea (open circles) and in Nova Scotian slope water (closed circles) shown as a function of depth.

The Limiting Factors in Bacterial Population Size in the Sargasso Sea and Slope Water

Rebecca Burr

ABSTRACT

Marine bacteria are heterotrophic micro-organisms which fill a role in the regeneration of nitrogen and phosphates in the water column. Populations may be limited by several factors, including salinity, density, temperature, and concentrations of oxygen, nitrate, and phosphate. Because bacteria are heterotrophic, requiring organic material, it was hypothesized that nutrient levels would be most important in regulating population size. Furthermore, because phytoplankton decomposition provides the required nutrients, it was hypothesized that high bacterial counts would occur at sites with high phytoplankton biomass.

Water samples taken at various depths in the Sargasso Sea and in slope water were examined for temperature, salinity, density, nutrient concentrations, and oxygen. Additional samples were cultured for bacteria (Fig. 15). Chlorophyll data taken at similar depths at the same sites (see Rosecrance, this report) showed that bacterial population size was not related to phytoplankton standing drop. Rather, nutrient levels appeared to be the limiting factor in slope water; in the Sargasso Sea, bacterial populations were related to seawater density and the depth of the pycnocline.

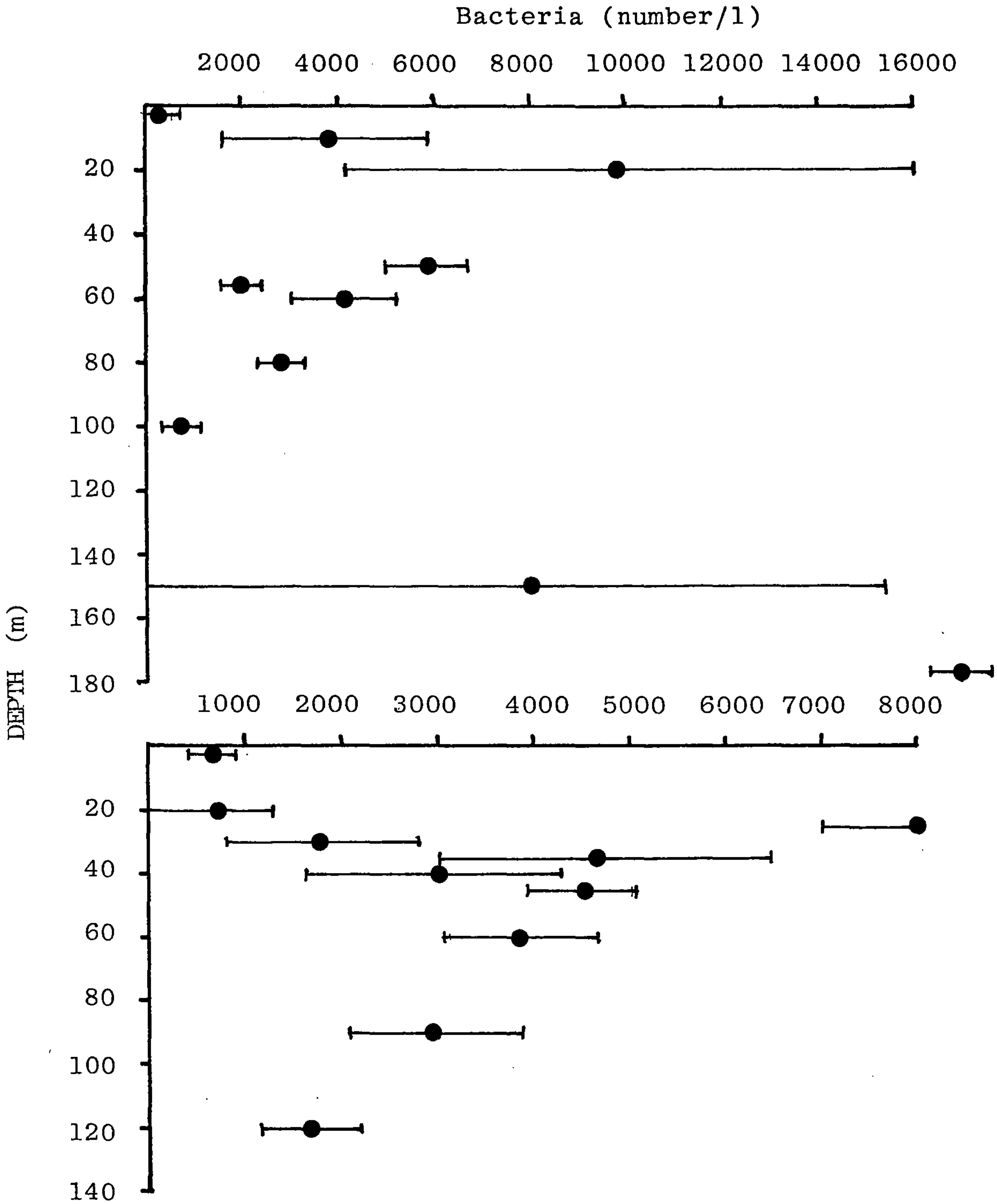

Figure 15: Bacterial counts in the Sargasso Sea (top) and Nova Scotian slope water (bottom) shown as a function of depth. Mean ± S.D.

Vertical Distribution and Size Frequency of Luminous Bacteria in the Water Column

Lorraine Olendzenski

ABSTRACT

The vertical distribution of bioluminescent bacteria of two genera (*Photobacterium* spp. and *Benekea* spp.) was investigated to a depth of 1500 meters at a site in the Sargasso Sea near Bermuda and at a slope water site off Nova Scotia. Additional filtrations were made for samples taken between 500 and 1000 meters for investigation of size frequency in the bacteria. Maximum abundance of *Photobacterium* spp. in the Sargasso Sea coincided with the oxygen minimum layer and high nutrient concentration found just below the mixed layer (Fig. 16). In slope water luminescent bacteria were most abundant below the oxygen minimum layer and the thermocline; however, population peaks were between 500 and 1000 meters at both sites. This suggests that mechanisms other than the location of the decompositional zone govern the distribution of *Photobacterium* spp. Bacterial abundance may be more closely related to the depth ranges of luminescent fishes which are most abundant between 600 and 1000 meters depth. Luminescent bacteria were collected only on 0.20 micrometer pore filters suggesting that large aggregates did not occur in the waters sampled.

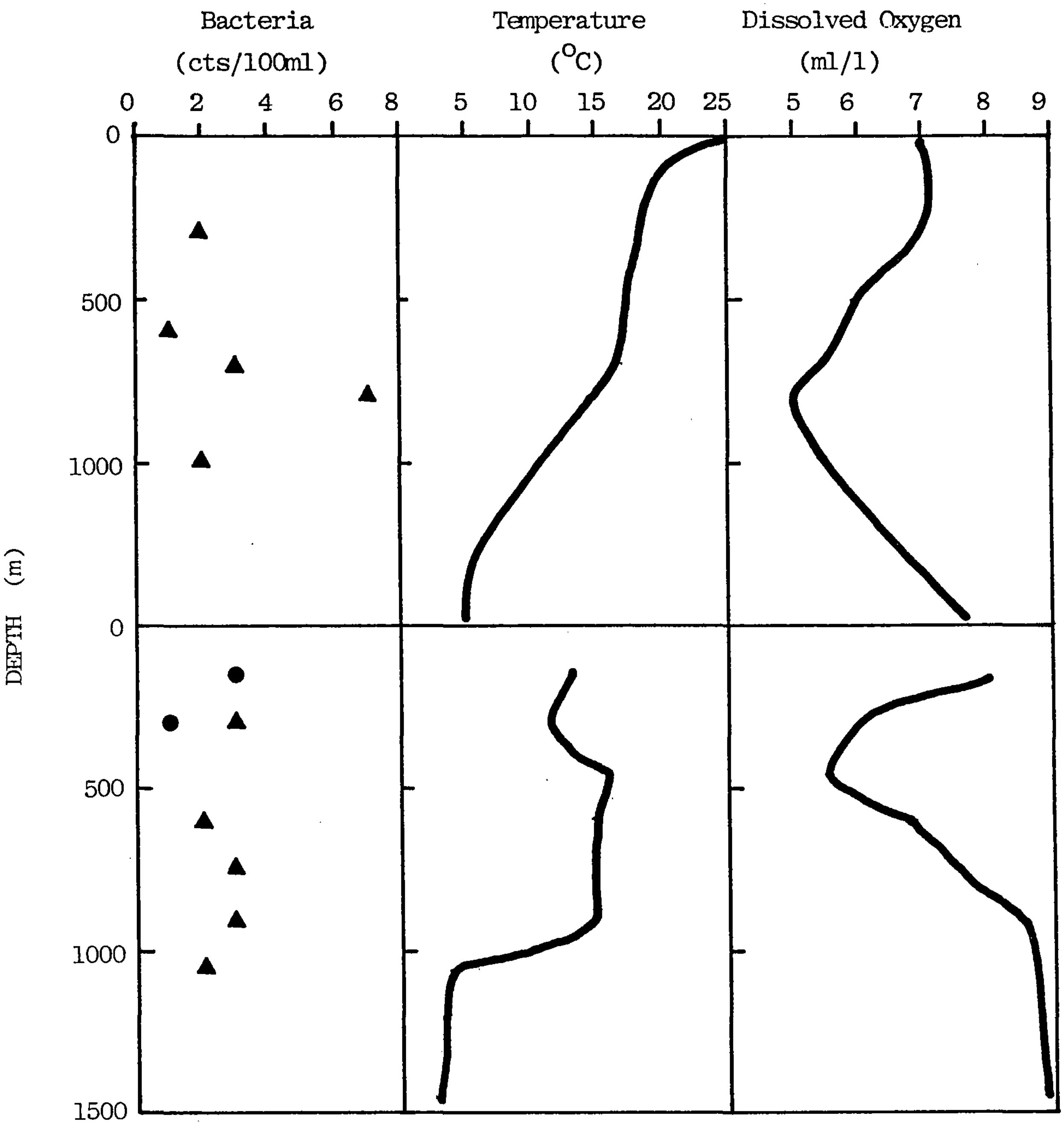

Figure 16: Abundance of bacteria, temperatures, and dissolved oxygen concentrations at two stations in the north Atlantic Ocean. Top = Sargasso Sea. Bottom = slope water. Triangles = <u>Photobacterium</u> spp. Circles = <u>Benekea</u> spp.

Size Distribution and Abundance of Veliger Larvae in Water Masses of the North Atlantic

Susan Service

ABSTRACT

The size distribution and abundance of veliger larvae was examined in three water masses of the North Atlantic: slope water, the Gulf Stream, and the Sargasso Sea. It was projected that mean veliger size and abundance would increase with increasing abundance of food as measured by photoplankton standing crop. It was found that the size relationship corresponded with the food source as predicted; slope waters, with highest biological productivity, yielded the largest veligers and smallest larvae were found at the Sargasso Sea sites where food was sparse (Table 5). Abundance of veligers was an inverse function of food availability, with very low values found in slope water and highest values in the Gulf Stream. This may be attributed to latitudinal effects because fewer species produce planktotrophic larvae at high latitudes. Additionally, because of the arrangement of stations, seasonal effects may have caused differences among the sites examined, veligers in the lower latitudes of the Sargasso Sea and Gulf Stream having reached their breeding season prior to those at higher latitudes.

Table 5: Abundance and size distribution of veliger larvae in three water masses of the North Atlantic Ocean.

Values are means ± standard deviation

Site	Zooplankton Biomass (ml/m^3)	Meroplankton (% of total)	Veligers ($No./m^3$)	Veliger Size (mm)	n
<u>Gulf Stream</u>					
W64-11	0.27	4.62 ± 2.18	9.63 ± 4.23	0.55 ± 0.47	62
W64-24	0.022	2.80 ± 1.92	2.37 ± 1.21	0.83 ± 0.40	36
<u>Sargasso Sea</u>					
W64-13	0.0082	3.32 ± 1.33	1.11 ± 0.27	0.38 ± 0.397	39
W64-14	0.187	5.33 ± 2.80	0.015 ± 0.008	0.40 ± 0.32	11
<u>Slope Water</u>					
W64-26	0.0122	1.32 ± 0.33	0.018 ± 0.007	0.93 ± 0.66	41

The Abundance of Trichodesmium and Macrosetella gracilis in Three Different Water Masses

Andrew Kronick

ABSTRACT

The pelagic harpacticoid copepod Macrosetella gracilis is believed to be tropically dependent upon the blue-green alga Trichodesmium. Populations of both were examined in a warm-core ring off New Jersey, in the Sargasso Sea, and in the Gulf Stream. Trichodesmium was most abundant in the warm-core ring and least abundant in the Gulf Stream. Highest concentrations of the blue-green alga were found at 10 meters depth in the Sargasso Sea and in the ring, and at 50 meters in the Gulf Stream. Macrosetella gracilis, on the other hand, was most abundant in the Sargasso Sea and least abundant in the warm-core ring (Table 6). The algal data suggest that the Sargasso Sea and central warm-core ring are the most similar water masses. The abundance of M. gracilis seemed to be related to the concentration of Trichodesmium in the Gulf Stream and Sargasso Sea. High abundance of Trichodesmium in the warm ring appeared to be related to the time of the ring's formation; low abundance of Macrosetella in the ring may be a function of the copepod's lower tolerance to environmental variability.

Table 6: Concentration of *Trichodesmium* filaments at four different depths in the North Atlantic and the abundance of *Macrosetella gracilis*

		Site		
		Warm-Core Ring (W64-9)	Gulf Stream (W64-11)	Sargasso Sea (W64-22B)
Trichodesmium filaments (No./liter)	Depth (m)			
	0	39,793	5,616	16,900
	10	63,070	7,143	24,500
	25	51,616	6,036	23,925
	50	35,863	11,356	15,960
Macrosetella (No./100 m^3)		60	120	310

Range and Distribution of the Copepod *Sappharina*

Skip Potts

ABSTRACT

Sappharina is a relatively uncommon, irridescent, cyclopoid copepod believed to be associated with warm, tropical waters of the Atlantic Ocean. Low numbers of *Sappharina* were found at five sites during R/V *Westward* cruise W-64 in the Western North Atlantic (Fig. 17). Male and female specimens were found at all depths sampled, ranging from surface neuston tows to 300 meters depth. Although one specimen was found in slope water south of Georges Bank, *Sappharina* appeared to be associated with deep, blue water characterized by high salinity and high light penetration.

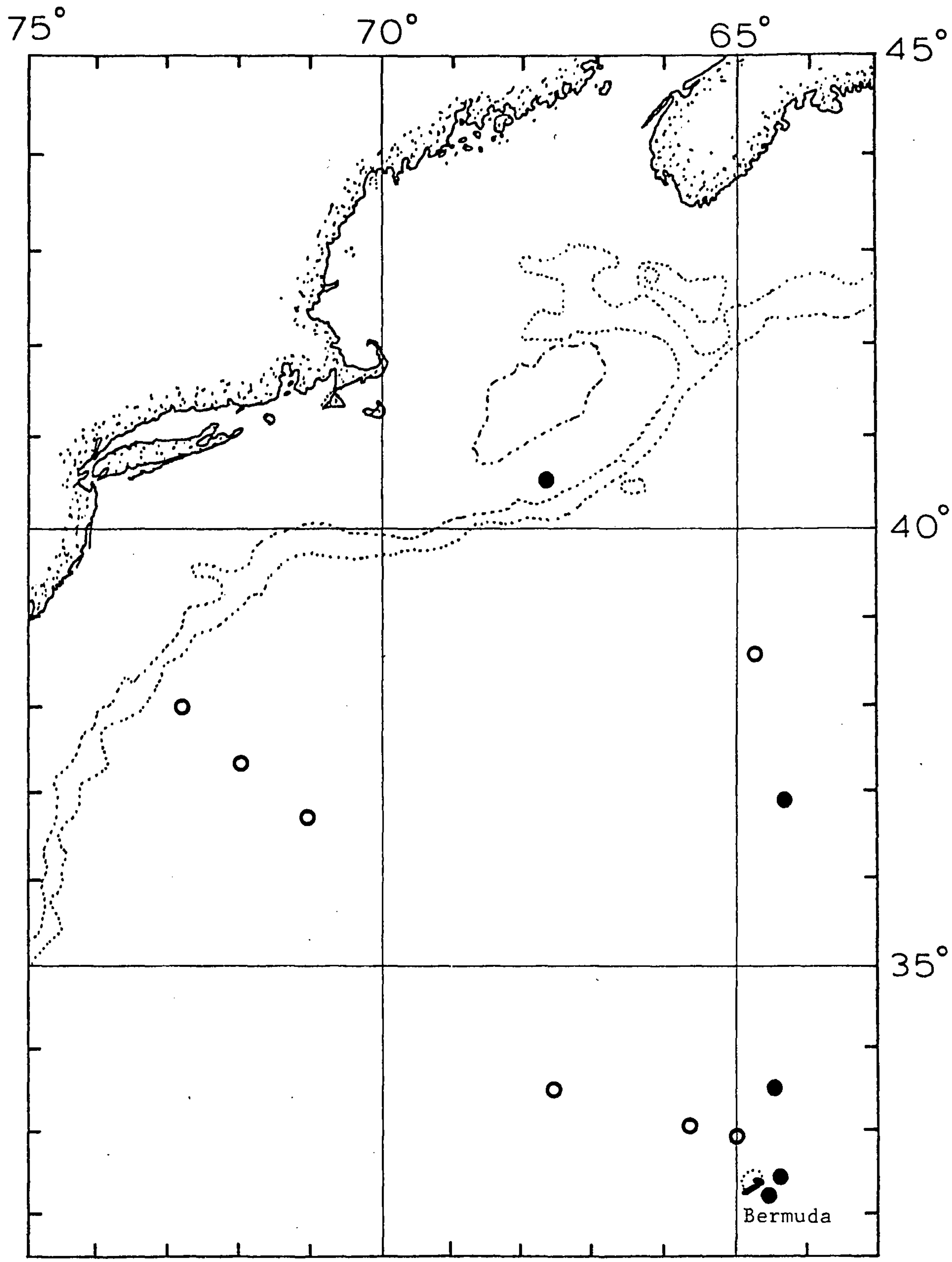

Figure 17: Sites at which Sappharina were collected (closed circles) and were not collected (open circles) during R/V Westward cruise W-64.

Comparison of Paleoclimate at Two Areas on the North American Slope

Michelle French

ABSTRACT

Phleger core samples were taken from the New Jersey slope (2100 m) (38°41'N, 72°53'W) and the Nova Scotian slope (2300 m) (42°10'N, 64°90'W). Foraminifera species showed a shift with core depth towards cold-tolerant forms in both areas, to *Globigerina bulloides* in the New Jersey core and to *G. pachyderma* in the Nova Scotian core (Table 7). The foraminiferal shifts suggest a small-scale glacial period reflected in the sediments. At the New Jersey site, warm-tolerant species such as *Turborotalia*, *Globorotalia menardii*, and *Globigernoides ruber* found in the top segment of the core suggest an occasional influence of the Gulf Stream. Also at the New Jersey site, sedimentation rates were found to be rapid and uniform throughout the core; the sediments were river-derived silts and clays. At the Nova Scotian site, a shift from red clay to gray turbidites occurred at 30 cm depth, suggesting a reduction in sedimentation rate over time. Both cores showed that there have been many small-scale fluctuations in ocean climate since the last major Pleistocene glaciation.

Table 7: Foraminfera composition in cores taken from two sites on the North American slope. Values are percentages of the total count.

New Jersey slope

	Core Depth	
	0-3 cm	33-36 cm
Globigerina bulloides	56	64
Globigerina quinqueloba	17	28
Turborotalia inflata	17	5
Neoglobquadrina dutertri	6	
Globorotalia menardii	3	
Globigernoides ruber	1	3
Globorotalia truncatulinoides		

Nova Scotian slope

	Core Depth		
	0-3 cm	27-30 cm	39-42 cm
Globigerina pachyderma	22	55	37
Globigerina bulloides	42	30	24
Globigerina quinqueloba	32	15	25
Turborotalia inflata	4		8
Globorotalia truncatulinoides			2
Globorotalia scitula			4

COASTAL STUDIES

Despite the fact that estuaries, coastal areas, and the continental shelf make up only 8.0% of the earth's ocean surface area, these sites yield 25% of the total primary productivity of the ocean. Shallow habitats vegetated by benthic macrophytes such as marsh grasses, seagrasses, and attached macroalgae are perhaps the most productive coastal systems. During R/V Westward cruise W-64 a port stop was made in St. Georges, Bermuda. The island supports a highly diverse, subtropical flora including several seagrasses and over 380 species of marine algae. During the stay in Bermuda, Crandell examined some of the macroalgae of Tobacco Cove and their macrofaunal associates.

Coastal upwelling zones rank a close second to the shallow benthic systems in biological production, despite the fact that food webs in the upwelling areas are largely fueled by phytoplankton rather than macrophytes. The upwelling ecosystems off Peru, California, and Venezuela are the best studied; each of these is driven by wind stress and the resultant offshore flow of surface water. There exist, however, certain other upwellings which occur as a result of other forces and in non-coastal locations. One of these, hypothesized by Garrett and Loucks (1976) is a shallow, shelf site off the southern tip of Nova Scotia. This upwelling is supposedly driven by tidal currents which surge past the Yarmouth, Nova Scotia area from the Bay of Fundy. On R/V Westward cruise W-58 a preliminary study was made on nutrient chemistry and biological productivity in the Yarmouth area. On cruise W-64, Trask conducted a detailed follow-up study which casts some doubt on the actual strength or intensity of the upwelling phenomenon. R/V Westward will continue to work off Yarmouth on future cruises.

Other sites known for immense biological productivity are the areas near submarine canyons along the northeast coast of the United States; the Hudson Canyon may be the most famous. It is also recognized by fishermen that the 100-fathom line (the continental shelf-break) is often characterized by high biological productivity. The phenomenon is poorly studied; however, it is believed that the shelf-break is a site of localized upwelling of deep water carrying high nutrient levels. The flow may be a result of turbidity currents or other interactions of water circulation and sediments near the edge of the continental shelf. On W-64, Burns examined nutrient chemistry and zooplankton standing crop at three 100-fathom areas in the

North Atlantic - in the Hudson Canyon area, the edge of the Bermuda Platform, and at the edge of the Nova Scotian shelf. The abstracts from the two studies follow.

In addition to the water column studies conducted in coastal areas, benthic samples in the form of otter trawls were taken at four sites along the track of R/V Westward cruise W-64. The data collected show important relationships between sediment type and the larger fishes and invertebrates which live on or close to the substratum (these faunal types are normally termed benthic and/or demersal). Trawl samples were made on sediments ranging from fine, black mud in Vineyard Sound (W64-1) to coarse sand and rock on the Scotian shelf (W64-31). Fine-grained sediments yielded abundant skates, sea ravens and flounders, whereas coarse-grained sand and rock bottoms yielded cod, haddock, and wolf fish (Table 8). Fine-grained sediments showed the greatest abundance and variety of fishes. Molluscs (the blue mussel) were abundant only in Vineyard Sound, but crabs were very common on fine sands and mud. Sea stars were most abundant on mud bottoms, but the sand dollar *Echinarchnius parma* was the most abundant organism collected on fine sand substrata on Georges Bank. Sand dollars were not collected elsewhere; neither was the sea mouse. Sediments, and probably their organic content, appear to exert considerable influence over the abundance and composition of macrofauna taken in trawls. This type of information is particularly valuable to commercial fishermen and sediment data as well as depth are routinely used in the search for particular species.

Reference:

Garrett, C.J.R. and R.H. Loucks, 1976. Upwelling along the Yarmouth Shore of Nova Scotia. J. Fish. Res. Board Can. 33:116-117.

Table 8: Fauna collected in otter trawls made on the continental shelf during R/V *Westward* cruise W-64.

Station W-64-1 - Vineyard Sound (black mud)

Fishes:	*Raja oscellata* (Big Skate)	17
	Raja garmani (Leopard Skate)	2
	Paralichthys oblengus (Four-spotted Flounder)	2
	Limanda ferruginea (Yellow-tail Flounder)	4
	Hemitripterus americanus (Sea Raven)	16
	Myoxocephalus octodecimospinosus (Long-horned Sculpin)	1
Molluscs:	*Polinices duplicatus* (Moon Snail)	18
	Mytilus edulis (Blue Mussel)	155
Crustacea:	*Libinia dubia* (Spider Crab)	32
	Cancer borealis (Cancer Crab)	20
Echinoderms:	*Astropectin americanus* (Seastar)	143
Unidentified:	Tunicates	4
	Sponges	3

Station W64-31 - Scotian Shelf (sand and rock)

Fishes:	*Anarhichas lupus* (Wolf Fish)	1
	Gadus callarias (Cod)	2
	Melanogrammus aeglefinus (Haddock)	2
Unidentified:	Seastars	12
	Brittle Stars	5
	Tunicates	10
	Polychaete worms	5
	Bryozoans	3
	Pycnogonid	1

Table 8 (continued):

Station W64-40 - Georges Bank (fine sand)		
Fishes:	*Raja garmani* (Leopard Skate)	1
	Myoxocephalus octodecimospinosus (Long-horned Sculpin)	3
	Limanda ferruginea (Yellow-tail Flounder	1
	Gadus callarias (Cod)	1
	Merluccius bilinearis (Whiting)	5
Molluscs:	*Buccinum undatum*	2
Echinoderms:	*Echinarachnius parma* (Sand Dollar)	702
Crustacea:	*Pagurus pollicaris* (Hermit Crab)	28
Polychates:	*Aphrodite hastata* (Sea Mouse)	15
Unidentified:	Clam	1
	Sponge	1
Station W64-42 - Georges Bank (coarse sand)		
Fishes:	*Raja oscellata* (Big Skate)	8
	Raja erinacea (Little Skate)	9
	Limanda ferruginea (Yellow-tail Flounder)	1
	Lophopsetta maculata (Windowpane Flounder)	4
Molluscs:	*Polinices duplicatus* (Moon Snail)	3
Crustacea:	*Pagurus pollicaris* (Hermit Crab)	3
Echinoderms:	*Asterias vulgaris*	8
	Strongylocentrotus droebachiensis (Purple Sea Urchin)	2
Unidentified:	Egg Masses	5

A Survey of the Macroalgae of Tobacco Bay, Bermuda and Their Epifaunal Communities

Caren Crandell

ABSTRACT

A survey of the macroalgae and epifaunal communities was conducted in Tobacco Bay, on the north shore of St. George's Island, Bermuda. Eight species of algae were found: *Dictyota ciliolata*, *Pocockiella variegata*, *Cladophora fuliginosa*, *Caulerpa racemosa*, *Laurencia papillosa*, *Cryptonemia crenulata*, *Amphiroa fragilissima*, and possibly *Ectocarpus confervoides*. Eleven major taxa from six phyla were identified, but algal-epifaunal associations did not appear to be taxa specific (Table 9). Rather, distribution of epifauna was dependent upon the environmental conditions of the habitat in which individual alga were located (i.e., wave exposure) and upon the nature of algal structure. Densely packed thalli of the intertidal alga *Cladophora* yielded the most diverse epifauna. Amphipods, harpacticoid copepods, tanaids, and polychaete worms proved to be the most widely distributed fauna. They were found in both sheltered and exposed areas and on most species of algae. Fauna with the most limited distributions included hydroids, menatodes, and arachnids.

Table 9: Algae, epifauna, and environmental conditions found in Tobacco Bay, Bermuda (June 1982).

		Taxa Represented (% of Total)				
Alga	Sheltered / Exposed	Amphipods	Decapods	Harpacticoids	Isopods	Tanaids
Dictyota ciliolata	S			100		
	S			50		50
Ectocarpus confervoides	S	2		39		57
Pocockiella variegata	S	5		58		26
Cladophora fulginosa	S	27	27	9		9
Caulerpa racemosa	S	33		8	17	17
	E					
	E	40		10		20
Laurencia papillosa	S	25		42		
	E	41		31		
Cryptonemia crenulata	E	(100% covered by hydroids)				
Laurencia & Amphiroa	S	21		32	16	21
Laurencia & Pocockiella	E	17		33		11
Laurencia, Amphiroa, & Pocockiella	S	3		20	13	44

Anemones	Polychaetes	Nematodes	Arachnids	Total No. of Organisms
				1
				2
	2			59
11				19
	9	9	9	11
8	17			12
	50	50		2
10	20			10
33				12
	28			29
				-
	10			19
	39			18
	20			45

Investigation of the Yarmouth Upwelling

Scott Trask

ABSTRACT

The shallow, coastal area near Yarmouth, Nova Scotia has been hypothesized as a small-scale upwelling system, driven by strong tidal currents in the Bay of Fundy. Accordingly, the resultant cell of vertical circulation should increase the biological productivity of the area by drawing nutrient rich water from the deep Gulf of Maine to the top of the water column near Yarmouth. Analysis of three shallow, nearshore stations and one deep-water station off Yarmouth (Fig. 18) revealed a general condition of low vertical stratification in temperature and salinity, and high surface nutrient concentrations at nearshore sites, as expected. However, higher zooplankton biomass (Fig. 19) actually occurred at the deep-water site along with no low surface temperatures. In conjunction, the data suggest that the hypothesized upwelling is not strong and may be difficult to detect by conventional means. Further investigation is suggested.

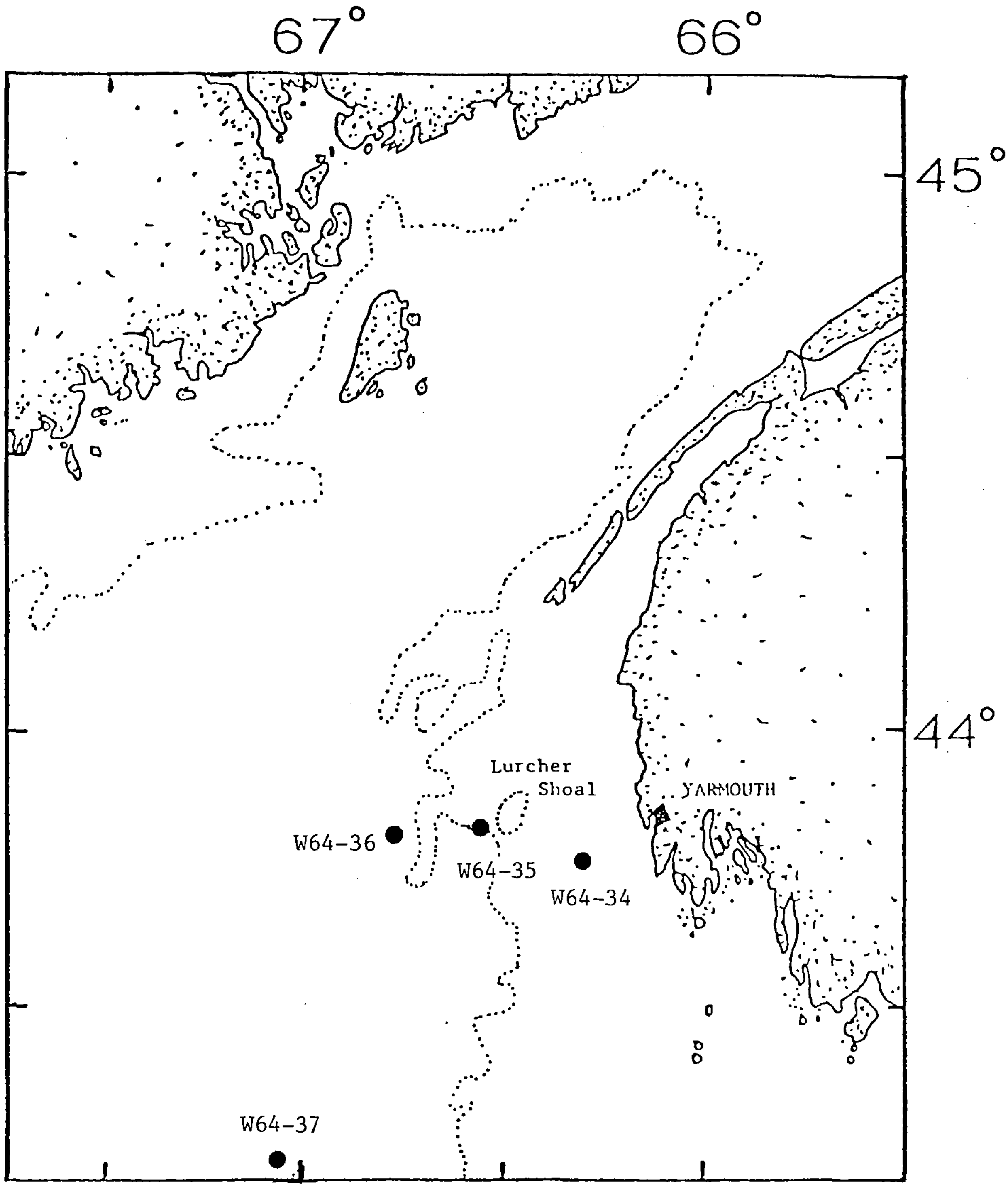

Figure 18: Sites that were examined for upwelling properties on R/V Westward cruise W-64.

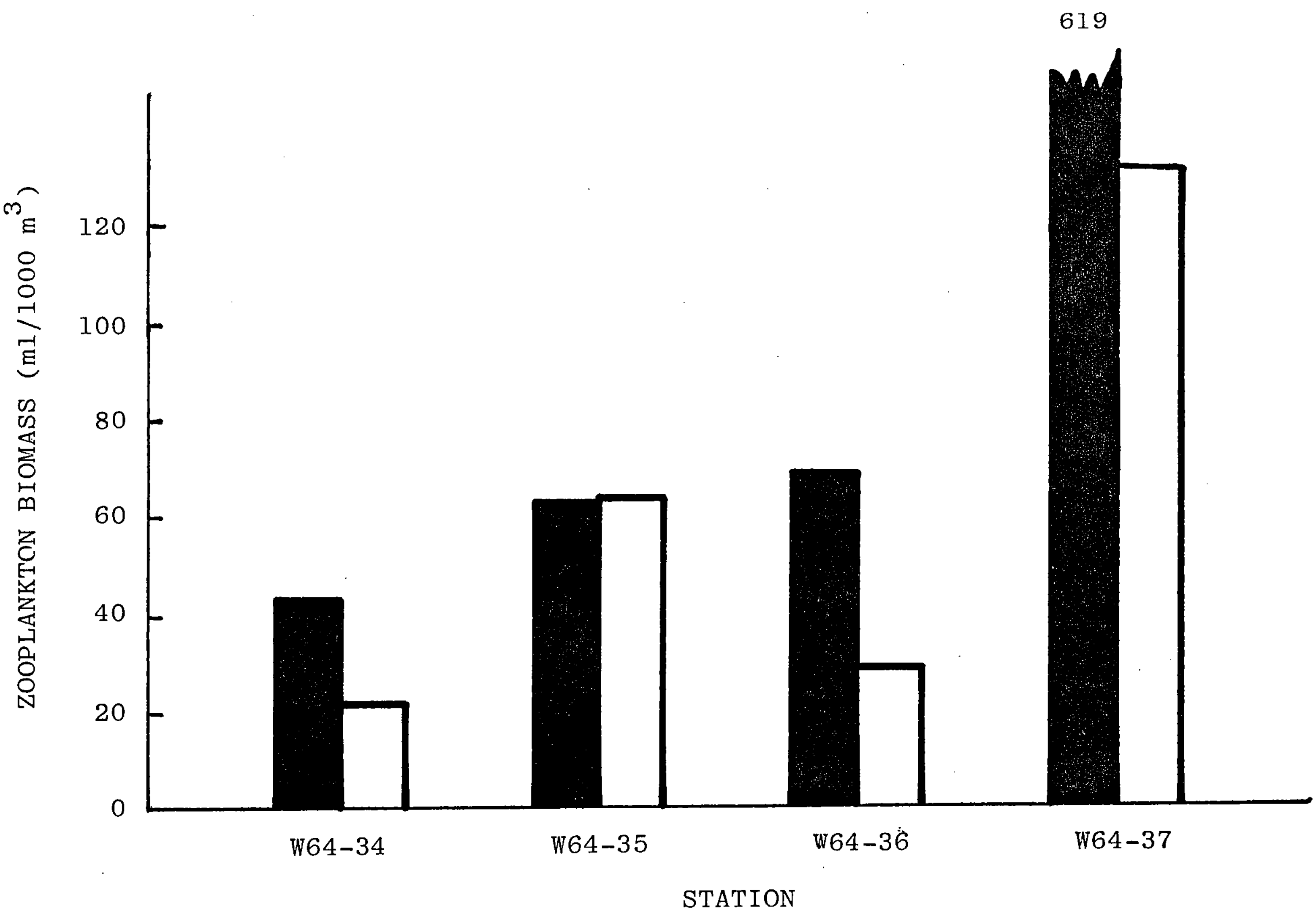

Figure 19: Biomass of zooplankton at four sites off Yarmouth, Nova Scotia. Solid bars = 202 micrometer mesh nets. Open bars = 505 micrometer mesh nets.

A Study of Zooplankton Biomass Near the 100-Fathom Line

John Burns

ABSTRACT

The 100-fathom isobath or shelf-break may be considered to be the boundary between shelf and slope water and is recognized for high biological productivity. Zooplankton biomass and water column chemistry near the 100-fathom line were investigated in three transects during R/V *Westward* cruise W-64: near Hudson Canyon, near Bermuda, and at the southeastern edge of the Scotian shelf. Contrary to hypothesis, highest zooplankton biomass was not found directly over the 100-fathom isobath (Fig. 20); however, all three stations near the Hudson Canyon yielded zooplankton standing crops well above any other value found along the cruise track (see Table 4). Nutrient concentrations were similarly elevated. Biomass and nutrient values were also high in the vicinity of the 100-fathom line off Bermuda and Nova Scotia. High biomass values appeared to be a function of high nutrient levels at relatively shallow depths (nitrate and phsophate) and general lack of thermal stratification. The similarity of elevated biomass values within individual transects suggests that the productive band near the continental shelf-break is broader than the approximately 20 mile length of the three station transects investigated.

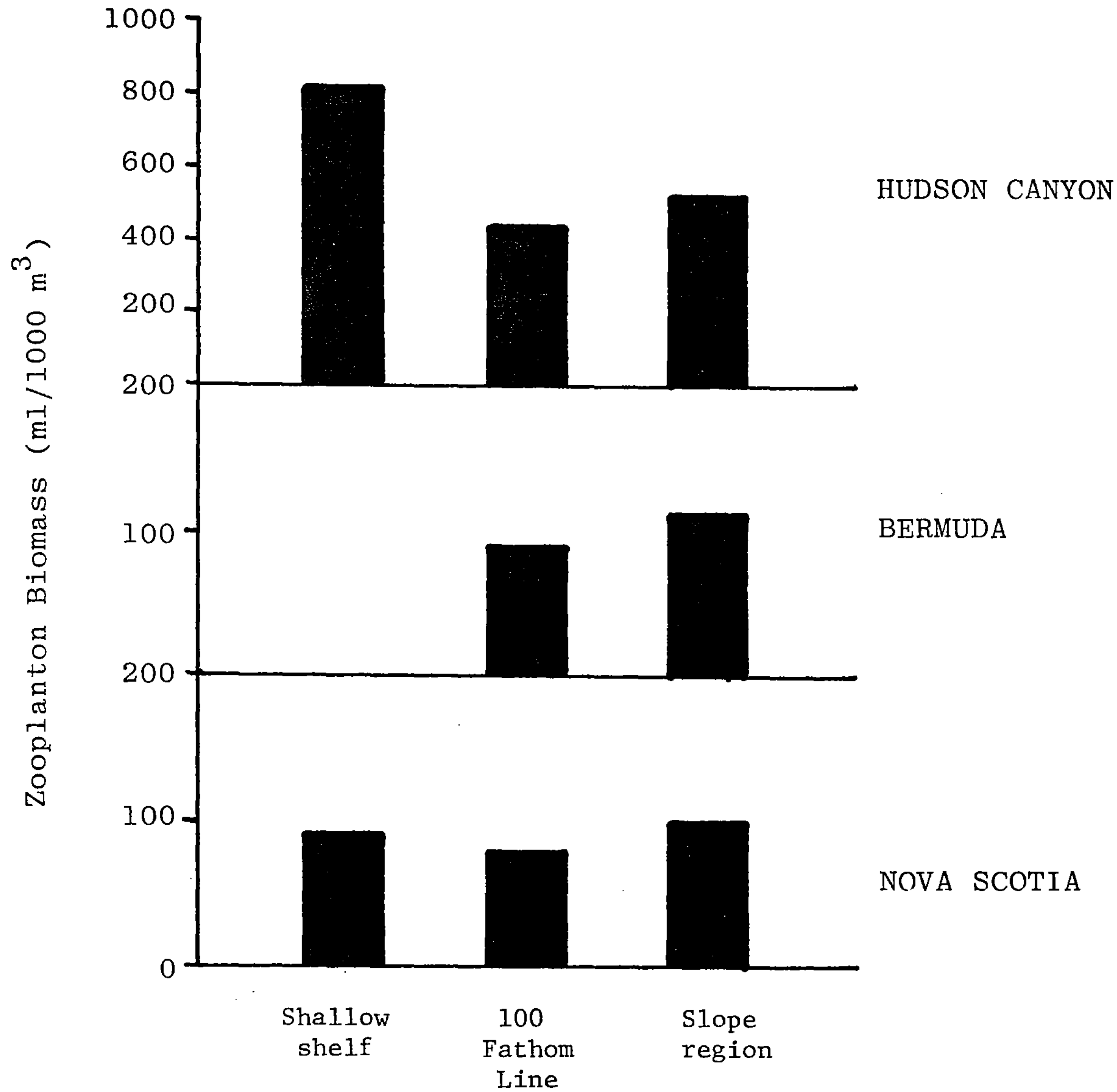

Figure 20: Zooplankton biomass near the 100-fathom line at three sites in the North Atlantic Ocean.

MARINE POLLUTION STUDIES

Man frequently uses estuaries and the ocean as a dumping ground for effluents and compounds of all kinds. These range from heated water effluents from power plants to toxic chemicals such as DDT and polychlorinated biphenyls. Pollutants enter not only as effluents directly into the ocean and estuaries, but as runoff from land, fall-out from the atmosphere and as incidental contaminants from routine discharges by ships.

Petroleum hydrocarbons are added to seawater by natural seeps, runoff from land, and major oil spills; however, the largest single source of tar and oil in the ocean is routine deballasting of ocean-going tankers. It is believed that a large portion of the oil entering the ocean by deballasting floats at the surface in the form of pelagic tar. Since 1977, S.E.A. staff scientists have gathered data on the abundance of pelagic tar in the North Atlantic, Caribbean Sea, and Gulf of Mexico using neuston nets, and a manuscript by Stoner, Farmer, and Humphris is currently in review which shows a major increase in pelagic tar levels since the first collections in 1969. Recently, however, it has been discovered that tar particles are also suspended in the water column.

During R/V Westward cruise W-64, two projects dealt specifically with the problem of suspended tar particles in the North Atlantic Ocean. Herbst made a survey of floating and suspended tar particles in several water masses and discovered a direct correlation between the two measurements. Simmonds investigated the distribution of suspended tar near a major convergence zone in the northern Sargasso Sea; the highest tar loads ever recorded were found near the convergence. Further investigation of suspended tar will be made during future cruises on board R/V Westward; however, the data gathered on cruise W-64 provide an important basis for future work. The abstracts for these two studies follow.

The Distribution of Pelagic Tar in the Northwest Atlantic and the Sargasso Sea

Diane Herbst

ABSTRACT

Floating and suspended pelagic tar was collected at six stations in the northwest Atlantic Ocean using neuston nets and Nansen bottles. Areas sampled included shelf and slope waters, shallow waters near Bermuda, and the Gulf Stream. It was discovered that surface concentrations of tar, as determined by neuston tows, were accurate predictors of total tar particle counts in the water column (Fig. 21). Highest surface tar levels (9.2 mg/m^2) were found in the Gulf Stream. Lowest tar abundance was found in shelf waters of the United States and near Bermuda. In the upper 200 meters of the water column, highest levels of tar were discovered between 25 and 50 meters depth, usually associated very closely with the level of the thermocline/pycnocline. Most of the suspended tar particles (greater than 80%) were in the 14 to 18 micrometer size class. Counts in the water column ranged from less than 100 per liter to as many as 1124 per liter.

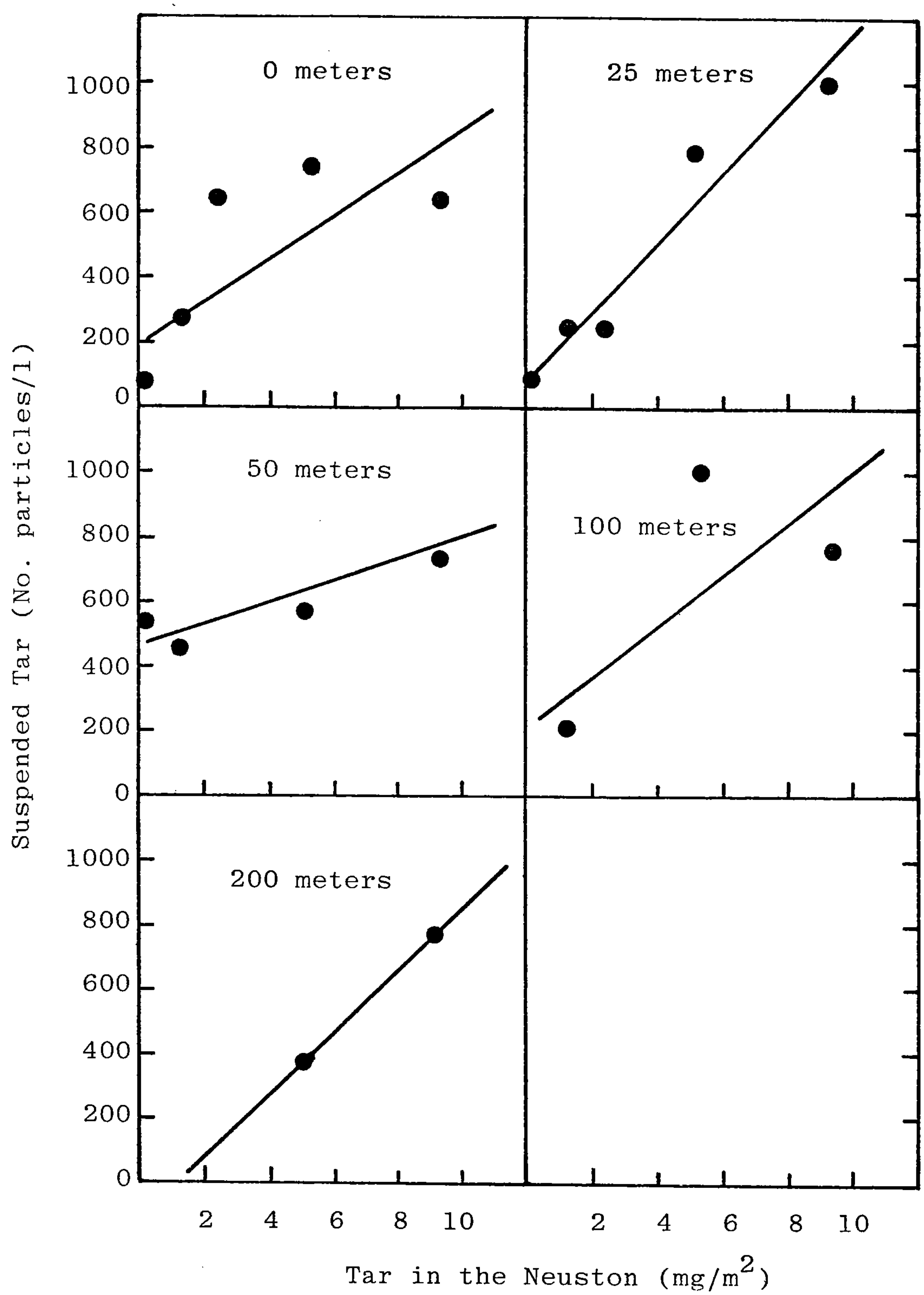

Figure 21: Suspended tar shown as a function of floating tar at five depths in the North Atlantic.

Effects of Langmuir Circulation on the Distribution of Pelagic Tar in Surface and Subsurface Waters

Karen Simmonds

ABSTRACT

During R/V Westward cruise W-64 a long convergence zone identified by a line of *Sargassum* was encountered at 35°39' north latitude and 64°20' W longitude. Suspended tar concentrations obtained from bucket samples taken across the convergence line showed that highest surface concentrations of tar were not found at the central downjet as expected, but at equidistant points to either side, 15 meters from the convergence line (Fig. 22). Presumably, highest concentrations were near lines of upward current. Subsurface samples taken directly in the windrow indicated highest concentrations at three meters below the surface, then decreasing with depth. Off the convergence line, tar concentration decreased as a linear function of depth, as predicted. Surface tar concentrations (mostly in a size fraction less than 30 micrometers) ranged from approximately 2300 particles per liter at a distance from the convergence line to over 11,000 particles per liter eleven meters away from the line. These values were significantly higher than those found in other areas of the North Atlantic (see Herbst, this report), and the tar counts were 8000 times the zooplankton count per liter.

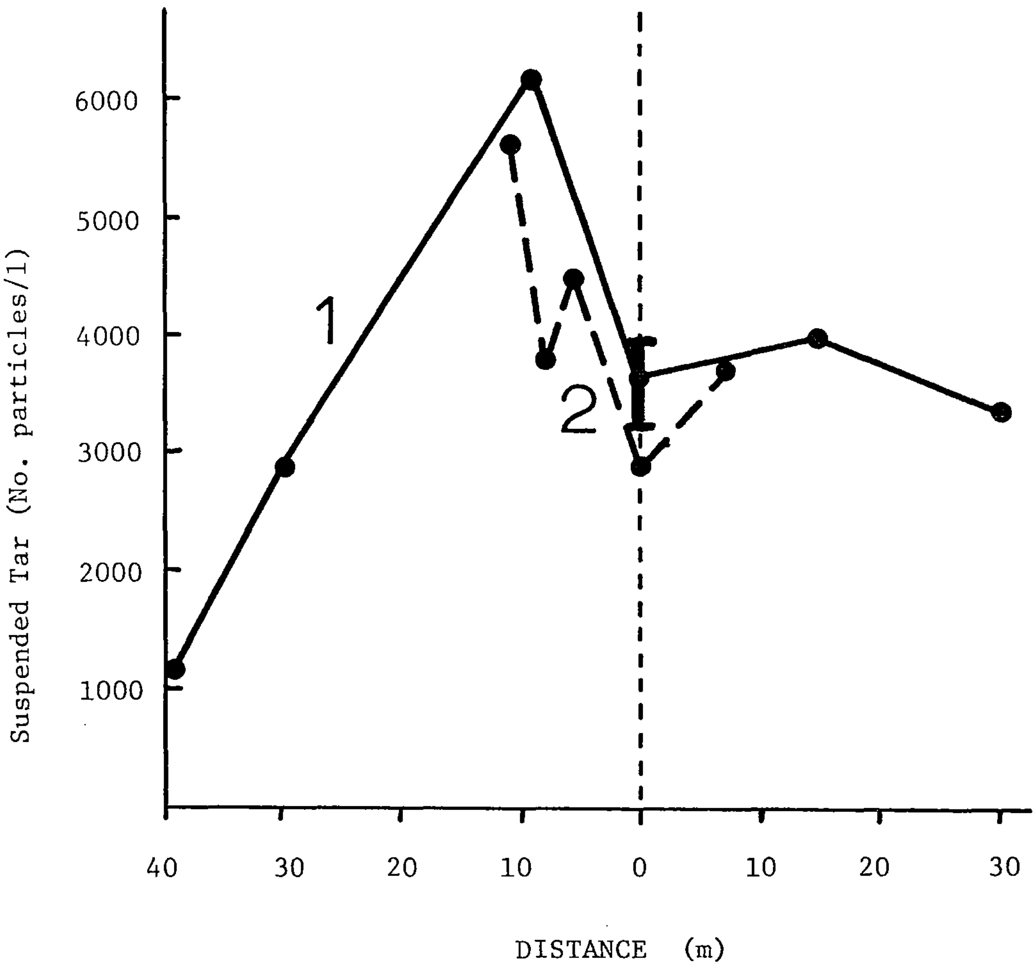

Figure 22: Abundance of tar particles suspended in surface water shown as a function of distance across a convergence line in the North Atlantic. Two transects are represented (solid and dashed lines). The range of values for the mid-point of transect 1 is shown.

MARINE BIOLOGICAL STUDIES

Marine biology, as opposed to biological oceanography, usually deals with the biology or ecology of individual species or groups of species. Marine biology, therefore, might range from the cell or tissue structure of a particular plant or animal to the behavior or feeding ecology of a species or population. Oceanography, on the other hand, usually deals with interactions among biotic and abiotic components of the environment on a somewhat larger scale, usually concerning systems above the organismal level of organization.

Marine biologists often divide plants and animals into size categories for convenience in study. Animals are usually divided into three, and sometimes four size groups: (1) Microfauna are those animals which are smaller than five micrometers; the protozoans are the primary group represented in the microfauna. (2) Meiofauna include taxonomic groups such as nematodes, harpacticoid copepods, larger foraminifera, and other small metazoans. These organisms can normally be collected on a 64 micrometer screen, but are smaller than 500 micrometers. (3) Macrofauna are those animals larger than one-half millimeter and include most of the groups readily seen with the unaided eye. Large, motile, swimming or flying fauna are occasionally termed megafauna, but this term is only rarely applied.

Although several projects included under other subheadings in this report might be considered marine biological in scope, five student projects conducted during R/V Westward cruise W-64 dealt with marine biological topics involving macrofauna. Two of these studies (authored by Herrin and Moncrieff) concern the biology of pelagic birds. Neidhardt examined the photophores of mid-water fishes and the role of symbiotic bacteria in light production, Farman-Farmaian investigated the morphology of gill filaments in benthic and pelagic fishes, and Robinson examined the camouflage adaptations and crypticity of fishes and crustaceans associated with Sargassum weed. The abstracts for these investigations are provided.

The Distribution of Offshore and Pelagic Seabirds and Their Relationship to Water Masses

Rebecca Herrin

ABSTRACT

An attempt was made to correlate the relationship between zooplankton abundance and the abundance of seabirds observed on R/V Westward cruise W-64. Contrary to predictions, high concentrations of seabirds were associated with water masses characterized by low zooplankton biomass. The weak, inverse relationship was most pronounced on Georges Bank where low standing crops of zooplankton were dominated by fish larvae and eggs (Table 10). Relatively low numbers of birds were found in the Sargasso Sea and Gulf Stream areas, where zooplankton biomass was moderate to high. The abundance patterns found for seabirds, however, did relate to predictions based on what is known about the general productivities of the individual water masses and important compositional differences were observed. It was concluded that one should not expect a direct, linear relationship between seabird and zooplankton biomass. Rather, it is necessary to examine the actual components of the food web leading to seabird consumers and seasonality in the pelagic system. It was also concluded that a study designed to investigate the mechanisms governing seabird abundance and distribution should incorporate a larger and longer sampling program. (See Table 14 for a complete listing of bird sightings.)

Table 10: Zooplankton standing crop and seabird abundance at selected stations examined during R/V *Westward* cruise W-64.

Location	Station No.	Zooplankton Standing Crop (ml/1000 m^3)	Bird Count (No./30 min)	Bird Composition
Gulf Stream	W64-11	270	25	Petrels - 22 Greater Shearwaters - 3
Sargasso Sea	W64-21	49	1	Petrel - 1
Slope Water	W64-30	102	182	Greater Shearwaters - 85 Fulmars - 80 Petrels - 12 Gannets - 4 Unidentified - 1
Scotian Shelf	W64-35	66	42	Herring Gulls - 14 Black-backed Gulls - 11 Petrels - 9 Unidentified - 5 Fulmars - 3
Georges Bank	W64-42	30	183	Greater Shearwaters - 156 Black-backed Gulls - 9 Petrels - 9 Sooty Shearwaters - 7 Herring Gulls - 2

Predicting Oceanic Weather Systems through the Observation of Seabirds

Scott Moncrieff

ABSTRACT

Daily observations on the behavioral patterns of seabirds and a running record of prevailing weather systems were made in an attempt to test the hypothesis that behavioral patterns of the birds could be used to predict approaching weather systems. This hypothesis was based upon evidence which suggests that seabirds can detect minor fluctuations in meteorological conditions. An effort was made to establish some behavioral norms for the bird species most commonly sighted in open ocean. Though the results of this study were not conclusive, a strong foundation based upon consistent observations in five species was formed. Significant data were collected for the Greater Shearwater (*Puffinus gravis*), Wilson's Petrel (*Oceanites oceanicus*), the Fulmar (*Fulmarus glacialis*), the Royal Tern (*Thalasseus maximus*), and the White-tailed Tropicbird (*Phaethon lepturus*). Most significantly, Greater Shearwaters were observed flying away from low pressure areas where winds exceeded force six, and on virtually every observation, Wilson's Petrel was observed to fly directly toward the center of low pressure systems. During heavy weather conditions, the White-tailed Tropicbird found in waters surrounding Bermuda always flew a direct line for the island. (See Table 14 for a complete listing of birds sighted during routine counts.)

Symbiotic Relationships of Mesopelagic Fishes with Bioluminescent Bacteria

Peter Neidhardt

ABSTRACT

In an attempt to test the hypothesis that intrinsic mechanisms of light production in the photophore of mesopelagic fishes is related to the evolutionary complexity of individual species, bacterial cultures were made from eleven specimens of bioluminescent, mid-water fishes. It was predicted that fish with simple light organs would be dependent upon a symbiotic relationship with the microbe *Photobacterium* and that fishes with advanced structures would independently produce light. Although several areas on each specimen were used to innoculate plates of seawater complete medium, luminescent bacteria were cultured only from the abdominal photophores of the myctophid *Diaphus* (Table 11). A review of the literature suggested that bacterial luminescence should not be expected in the Myctophidae and the recent finding may represent new information or an exception to the rule of intrinsic luminescence in the lantern fish family. The presence of *Photobacterium* in the photophores *Diaphus* species, and the relationship between photophore complexity and mode of luminosity requires further investigation.

Table 11: Results of cultures for Photobacterium taken from mid-water fishes. A = swab of fish exterior, B = punctured photophore, C - homogenization of tissue, D = whole tissue

Fish	Culture Area	Culture Mode	Luminescent Bacteria
Sternoptychidae	a) abdominal photophores	B	-
(Argyropelecus aculeatus)	b) subabdominal phot.	B	-
	c) anal & preanal phot.	B	-
Gonostomatidae	a) abdominal phot.	A	-
	b) abdominal phot.	B	-
Myctophidae	a) abdominal phot.	B	-
Melanostomiatidae	a) chin barbel (luminescent)	C	-
Gonostomatidae	a) ventral phot. (excised)	D	-
Unidentified	a) ventral phot. (excised)	D	-
Gonostomatidae	a) abdominal phot.	B	-
Gonostomatidae (Cyclothone ?)	a) whole fish	C	-
Gonostomatidae	a) ventral phot.	C	-
	b) whole fish	C	-
Gonostomatidae (Vinciguerra)	a) ventral phot. and gut	C	-
Myctophidae (Diaphus)	a) abdominal phot.	C	+
	b) ventral phot.	B	-
	c) gut	C	-

The Relationship Between Gill Resistance and Heart Size in Active and Inactive Fishes

Hossein Farman-Farmaian

ABSTRACT

Fast-swimming fishes are known to have large numbers of gill lamellae which form a tight gill sieve which increases resistance to gill ventilation and decreases total dead space. To test the hypothesis that increased numbers of gill lamellae (and consequential resistance to gill blood flow) necessitates an increase in heart size in active pelagic fishes, an index of gill resistance was designed and examined in five species of teleostean fish. Species were chosen in order to provide a range in life history, particularly locomotory activity; these included two flying fishes (Cypselurus melanurus and Exocoetus obtusirostris), the cod (Gadus callarias), the sculpin (Myxocephalus ectodecimspinosus), and the sea raven (Hemitripterus americanus). The net gill resistance index was highest in cod and lowest in flying fish (Table 12), whereas heart weight per unit body weight was lowest in the relatively slow-moving cod. Although the data are few and conclusions must be made with caution, the lowest resistance per unit heart weight was found in flying fish and the highest ratios were found in the sea raven which is largely sedentary. Additionally, heart size and gill resistance were related to total body weight.

Table 12: Gill and heart morphology in five species of fish.

Species	Mean No. filaments/ holobranch	No. Lamellae/ mm of filament	Net Gill Resistance Index	Heart wgt./ Body Wgt.	Gill Resistance/ Heart Wgt.
Cypselurus melanurus	193	32	38	0.004	95
Exocoetus obtrusirostris	177	31	57	0.004	190
Gadus callarias	221	14	144	0.0002	144
	195	14	144	0.0002	240
Myxocephalus ectodecimspinosus	164	17	123	0.001	410
Hemitripterus americanus	197	16	81	0.001	1612

Camouflage Adaptations and Their Relationship with Predator-Prey Behavior in Sargassum Fauna

Cynthia Robinson

ABSTRACT

Seven macrofaunal associates of *Sargassum* were collected and observed for concealment modes and aggressive behavior; these included the fishes *Histrio histrio*, *Seriola fasciata*, and *Monocanthus hispidus*; the shrimps *Leander tenuicornis* and *Latreutes fucorum*; and the crabs *Planes minutus* and *Portunus sayi*. Camouflage adaptations were examined and documented with photographic methods. It was discovered that all of the obligatory associates of the alga exhibited mimicry of *Sargassum* and all but one displayed particular camouflage techniques involving body positioning and orientation on the algal substratum. Observations, in support of the original hypothesis, suggested that those animals with highly specialized concealment coloration and behavior were the most elusive prey items and, consequently, were the most aggressive predators. Particularly cryptic and aggressive species were *Histrio histrio* and *Portunus sayi*; the colors and patterns of these species are very *Sargassum*-like. The shrimp *Leander tenuicornis* was also well adapted for crypticity on *Sargassum* and exhibited aggressive behavior, usually in response to attacks by *Portunus* and *Histrio*.

LONG-TERM AND COOPERATIVE PROGRAMS

Neuston Data

Since 1977, S.E.A. scientists have been gathering data on the distribution of pelagic tar, *Sargassum* species, and the marine water-strider *Halobates micans*. Manuscripts are in review or in preparation on all of these topics. Eight neuston tows were made on R/V *Westward* cruise W-64 (Table 13). Tar was most abundant (> 5 mg/m^2) in the northern Sargasso Sea and Gulf Stream and very low in abundance on the continental shelf of the United States. As is normal, *Sargassum* was abundant only in the Sargasso Sea and Gulf Stream. *Halobates micans*, typically a resident of warm-water habitats, was found only in the Sargasso Sea near Bermuda (only one specimen). On the west and north sides of the Gulf Stream the macrophytes *Ascophyllum* and *Fucus* were frequently sighted at the surface or collected in neuston nets. Fish eggs and larvae were also important components of neuston collected on the continental shelf.

Distribution of Marine Birds and Mammals

In cooperation with Mr. Timothy Rumage of the Rhode Island School of Design, a formal bird count system has been developed and instituted to provide quantitative data for analysis of seabird distribution, feeding, and migration patterns. Whenever possible, daily counts were made on R/V *Westward* cruise W-64 during morning and afternoon hours. Distributional data, shown in Table 14, were analyzed in part by Becky Herrin and sent to Mr. Rumage.

Whale and dolphin sightings and observations are also used for long-term studies of mammal distribution and behavior in cooperation with Timothy Rumage. Data collected during cruise W-64 are provided (Table 15).

Distribution of Spiny Lobster Phyllosoma

Phyllosoma are the large, flattened larval forms of various tropical and subtropical lobster species, the distribution and dispersal of which are being examined by S.E.A. staff scientist Dr. Mary Farmer. On R/V *Westward* cruise W-64 three phyllosoma were collected (Table 16), and turned over to Dr. Farmer for examination.

Weather Observations

R/V *Westward* participates in the Cooperative Ship Weather Observation Program of the National Oceanic and Atmospheric Administration (NOAA). On cruise W-64, nineteen complete sets of meteorological data were collected and transmitted by radio to the NOAA Meteorological Office.

Table 13: Summary of neuston collected on R/V *Westward* cruise W-64. (See Appendix for station positions.)

Station	Date	*Sargassum* (mg/m^2)	*Halobates micans* No./1000 m^2	Tar (mg/m^2)	Miscellaneous
W64-3	6/04/82	0	0	0	Siphonophores, Ctenophores, Euphausiids
W64-6	6/05/82	trace	0	1.35	Copepods, Zoea, Fish eggs
W64-18	6/17/82	4.86	0.54	2.43	Copepods, Chaetognaths, Mesopelagic Fishes, Phyllosoma
W64-23	6/21/82	302.4	0	5.13	Euphausiids
W64-24	6/21/82	5.67	0	9.18	Copepoda, *Sargassum* associates, Mesopelagic Fishes, Phyllosoma, Zoea
W64-39	7/06/82	0	0	0.22	Insects, Plastic, *Fucus*, *Ascophyllum*, Isopods
W64-45	7/08/82	0	0	0	Copepods, Fish Larvae
W64-48	7/12/82	0	0	0.27	Copepods

Table 14: Bird counts made during R/V Westward cruise W-64. Counts lasted one-half hour unless noted otherwise. Incidental sightings are identified by asterisks.

Date	Time	Latitude (N)	Longitude (W)	Species	Number
6/05/82	0910	39°29.5'	72°30.5'	Oceanites oceanicus	290
				Puffinus gravis	27
				Puffinus griseus	1
6/07/82	1800	37°10.5'	71°42.42'	O. oceanicus	14
				P. gravis	3
				Black-capped petrel	1
6/08/82	0315	35°56.86'	69°50.82'	Oceanites leucorhoa	4
				O. oceanicus	5
				P. griseus	1
6/10/82	0840	33°33.7'	67°45.0'	O. oceanites	1
				Unidentified	1
6/12/82	0900	32°52'	64°38.5'	O. oceanicus	1
6/19/82	0900	34°31.6'	64°36.5'	O. oceanicus	1
				P. gravis	1
				P. griseus	1
6/20/82	0910	34°36'	64°26'	-	0
6/22/82	0910	39°06'	64°49'	P. gravis	4
				P. griseus	1
	1345	39°33'	64°36'	P. gravis	6
				P. griseus	1
6/25/82	0930	43°11.1'	64°11.1'	Fulmarus glacialis	83
				Morus bassanus	4
				P. gravis	45
				O. oceanites	12
				Unidentified bird	1
	1915	43°29.09'	64°10.38'	O. oceanites	9
				P. gravis	10
				P. griseus	5
6/27/82	0810 (20 minute count)	-	-	Larus marinus	1
				Larus argentatus	3
				M. bassanus	1
				Unidentified gull	8
	1400	44°05'	64°21'	L. marinus	11
				L. argentatus	21
6/28/82	0800	(Lunenburg Harbor, Nova Scotia)		L. marinus	3
				M. bassanus	2
				Unidentified gull	9
				Unidentified bird	1

Table 14 (continued):

Date	Time	Latitude (N)	Longitude (W)	Species	Number
7/02/82	0918	44°05.64'	64°13.87'	L. marunus	8
				L. argentatus	19
	1530	44°	64°	Unidentified gull	2
				L. marinus	5
				L. argentatus	1
7/03/82	1130	43°26.5'	65°05.0'	L. marinus	11
				L. argentatus	15
				O. oceanicus	9
				L. glacialis	3
	1733	43°18.6'	65°15.0'	L. marinus	4
				L. argentatus	10
				O. oceanicus	5
				P. griseus	5
				P. gravis	4
				Thalosseus maximus	1
				F. glacialis	4
7/04/82	0805	43°41.6'	66°21.5'	L. marinus	3
				L. argentatus	4
				F. glacialis	5
				O. oceanicus	4
				Unidentified gull	1
				Unidentified bird	3
	1500	43°46.4'	66°22'	L. marinus	18
				L. argentatus	10
				F. glacialis	9
				P. griseus	4
				Unidentified gull	9
	1500	43°42'	66°31.5'	O. oceanicus	1
				Unidentified gull	4
				P. griseus	3
				P. gravis	7
				F. glacialis	2
				L. argentatus	5
				L. marinus	36
7/05/82	0555 (20 minute count)	42°19'	67°38'	P. gravis	66
				P. griseus	3
				O. oceanicus	4
				L. marinus	6
	0900	42°40'	67°30'	P. gravis	62
				P. griseus	2
				O. oceanicus	2
				L. argentatus	1
				F. glacialis (?)	1

Table 14 (continued):

Date	Time	Latitude (N)	Longitude (W)	Species	Number
7/06/82	0830	41°33'	66°42.2'	O. oceanicus	1
				P. gravis	14
				F. glacialis	1
7/10/82	1730	41°11.0'	71°02.2'	L. argentatus	3
				P. griseus	3

Table 15: Marine mammals sighted on R/V Westward cruise W-64.

Date	Time	Latitude (N)	Longitude (W)	Species	Number
6/03/82	1835	5 miles W of Gay Head		Saddleback Dolphins	25-40
6/06/82	0845	38°41'	72°53'	Saddleback Dolphins (?)	4
6/12/82	1805	32°19'	64°36'	Saddleback Dolphins	10
6/23/82	1144	40°21'	63°52'	Pilot Whales	2
6/23/82	1645	40°45'	63°53'	White-sided Dolphins	12-15
6/23/82	2300	41°23'	63°59'	Unident. Dolphins	10
6/24/82	0700	42°16'	64°10'	Unident. Whale	1
6/25/82	0400	42°42'	65°13'	Unident. Dolphins	6-8
6/25/82	0820	42°51'	64°11'	Fin Whales	3
6/27/82	1655	44°10'	64°22'	Saddleback or Whitesided Dolphins	8
7/04/82	1240	43°47'	66°24'	Unident. Whale	1
7/06/82	0800	41°33'	66°46'	Saddleback Dolphins	4
7/06/82	1212	41°39'	67°06'	Unident. Whales	2
7/06/82	2200	41°03'	66°40'	Unident. Whale	1
7/06/82	2345	41°03'	66°36'	Unident. Dolphins	12
7/07/82	1330	40°19'	66°30'	Pilot Whales	4-6
7/08/82	1440	40°33'	67°30'	Saddleback Dolphins	10

Table 16: Stations at which spiny lobster phyllosoma were collected during R/V *Westward* cruise W-64.

Station	Date	Time	Latitude (N)	Longitude (W)	Collection Mode	Number
W64-18	6/18/82	0054	32°22'	64°29'	Shallow Tow (505 u)	1
W64-18	6/18/82	0152	"	"	Neuston Tow	1
W64-24	6/21/82	2200	38°35'	64°41'	Neuston Tow	1

Appendices

Table A-1: Oceanographic stations sampled on R/V *Westward* cruise W-64.

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	General Location
W64-1	6/03/82	1505	41°23'	70°49'	Otter Trawl	Vineyard Sound
W64-2	6/04/82	1100	40°00'	71°04'	Hydrocast(chem)	Shelf
W64-2	6/04/82	1215	"	"	Hydrocast(tar)	Shelf
W64-3	6/04/82	1421	39°57'	72°09'	Neuston Tow	Shelf
W64-4	6/04/82	1745	39°47'	72°21'	Hydrocast(chem)	Outer shelf
W64-4	"	1921	"	"	Oblique Tow (505 u)	" "
W64-5	6/04/82	2125	39°39'	72°26'	Hydrocast(chem)	Hudson Canyon
W64-5	"	2145	"	"	Oblique Tow (505 u)	" "
W64-6	6/05/82	1623	39°08'	72°37'	Hydrocast(chem)	Shelf-break
W64-6	"	1715	"	"	Hydrocast(tar)	" "
W64-6	"	1810	"	"	Oblique Tow (505 u)	" "
W64-6	"	1838	"	"	Neuston Tow	" "
W64-7	6/06/82	0830	38°41'	72°53'	Surface Tow (63 u)	Slope
W64-7	"	0855	"	"	Hydrocast(chem)	"
W64-6	"	1208	"	"	Phleger Core	"
W64-7	"	1332	"	"	Oblique Tow (505 u)	"
W64-8	6/06/82	1750	38°19'	72°46'	Hydrocast(chem)	Warm Ring
W64-9	6/06/82	2311	37°58'	72°45'	Hydrocast(chem)	" "
W64-9	6/07/82	0145	"	"	Vertical Tow (202 u)	" "
W64-9	"	0205	"	"	Hydrocast(biol)	" "
W64-10	6/07/82	1110	37°19'	72°00'	Hydrocast(chem)	Slope
W64-10	"	1400	"	"	Hydrocast(tar)	"
W64-10	"	1450	"	"	Oblique Tow (505 u)	"
W64-11	6/08/82	0147	36°42'	71°02'	Hydrocast(biol)	Gulf Stream
W64-11	"	0325	"	"	Vertical Tow (202 u)	" "
W64-11	"	0347	"	"	Oblique Tow (202 u)	" "

Table A-1 (continued):

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	General Location
W64-12	6/09/82	1407	33°48'	69°02'	Hydrocast(chem)	Sargasso Sea
W64-12	"	1525	"	"	Vertical Tow (202 u)	" "
W64-13	6/10/82	1347	33°27'	67°36'	Oblique Tow (202 u)	" "
W64-14	6/11/82	1230	32°59'	65°40'	Hydrocast(chem)	" "
W64-14	"	1410	"	"	Hydrocast(biol)	" "
W64-14	"	1710	"	"	Oblique Tow (202 u)	" "
W64-15	6/11/82	0036	32°52'	65°00'	3-net tow (505 u)	" "
W64-16	6/12/82	1500	32°19'	64°35'	Hydrocast(chem)	Bermuda Slope
W64-16	"	1640	"	"	Phleger Core	" "
W64-17	6/13/82	0000	32°12'	64°49'	Hydrocast(chem)	" "
W64-18	6/17/82	2000	32°25'	64°31'	Hydrocast(chem)	Bermuda (100 fm)
W64-18	"	2102	"	"	Hydrocast(tar)	" "
W64-18	6/18/82	0054	32°22'	64°29'	Surface Tow (505 u)	" "
W64-18	"	0153	"	"	Neuston Tow	" "
W64-19	6/18/82	0315	32°22'	64°29'	Hydrocast(chem)	Bermuda Slope
W64-19	"	0420	"	"	Surface Tow (505 u)	" "
W64-20	6/18/82	1210	32°46'	64°35'	Hydrocast(biol)	Sargasso Sea
W64-21	6/18/82	2230	33°26'	64°28'	3-net Tow (505 u)	" "
W64-21	6/19/82	0300	33°26'	64°24'	Hydrocast(chem)	" "
W64-22A	6/20/82	1215	33°41'	65°29'	Hydrocast(tar)	" "
W64-22A	"	1230	"	"	Hydrocast(tar)	" "
W64-22A	"	1240	"	"	Tar collections	" "
W64-22	6/21/82	0014	36°41'	64°24'	Hydrocast(chem)	" "
W64-22B	6/21/82	0305	"	"	Hydrocast(chem)	" "
W64-22B	"	0430	"	"	Vertical Tow (202 u)	" "
W64-22B	"	0510	"	"	Hydrocast(biol)	" "
W64-23	6/21/82	0830	36°52'	64°14'	Neuston Tow	" "
W64-23	"	0915	"	"	3-net Tow (505 u)	" "

Table A-1 (continued):

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	General Location
W64-23	6/21/82	1120	36°54'	64°18'	Hydrocast(tar)	Sargasso Sea
W64-24	6/21/82	2200	38°35'	64°41'	Neuston Tow	Gulf Stream
W64-24	"	2240	38°36'	64°44'	Oblique Tow (202 u)	" "
W64-24	6/21/82	2356	38°36'	64°45'	Hydrocast(tar)	" "
W64-24	6/22/82	0045	"	"	Hydrocast(biol)	" "
W64-25	6/23/82	0900	40°17'	63°50'	Hydrocast(chem)	" "
W64-26	6/24/82	0100	41°27'	64°00'	Oblique Tow (202 u)	" "
W64-26	"	0330	"	"	Oblique Tow (505 u)	" "
W64-27	6/24/82	1300	42°10'	64°56'	Phleger Core	Scotian Slope
W64-27	"	1545	"	"	Hydrocast(biol)	" "
W64-27	"	1820	"	"	Hydrocast(chem)	" "
W64-27	"	1935	"	"	Oblique Tow (202 u)	" "
W64-28	6/25/82	0119	42°42'	64°13'	Oblique Tow (505 u)	Shelf-break
W64-28	"	0200	"	"	Hydrocast(chem)	" "
W64-29	6/25/82	0415	42°38'	64°13'	Hydrocast(chem)	" "
W64-29	"	0514	"	"	Oblique Tow (505 u)	" "
W64-30	6/25/82	0737	42°50'	64°11'	Oblique Tow (505 u)	Scotian Shelf
W64-30	"	0805	42°51'	64°11'	Hydrocast(chem)	" "
W64-31	6/25/82	1300	43°11'	64°03'	Otter Trawl	" "
W64-32	6/26/82	1135	43°51'	64°43'	Otter Trawl	" "
W64-33	7/02/81	1200	44°02'	64°26'	Surface Tow (202 u,505 u)	" "
W64-33	7/02/82	1250	"	"	Surface Tow (505 u)	" "
W64-33	"	1325	"	"	Hydrocast(biol)	" "
W64-34	7/04/82	0900	43°46'	66°22'	Surface Tow (202 u,505 u)	Yarmouth
W64-34	"	0930	"	"	Surface Tow (505 u)	"
W64-34	"	1000	"	"	Hydrocast(chem)	"

Table A-1 (continued):

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	General Location
W64-34	7/04/82	1000	43°46'	66°22'	Surface Tow (63 u, 10 u)	Yarmouth
W64-35	7/04/82	1330	43°46'	66°29'	Hydrocast(chem)	"
W64-35	7/04/82	1330	"	"	Surface Tow (63 u, 10 u)	"
W64-35	"	1350	"	"	Surface Tow (505 u)	"
W64-36	7/04/82	1700	43°42'	66°37;	Surface Tow (202 u,505 u)	"
W64-36	"	1733	"	"	Hydrocast(chem)	"
W64-37	7/05/82	0000	43°15'	67°09'	Hydrocast(chem)	"
W64-37	"	0140	"	"	Surface Tow (202 u, 505 u)	"
W64-38	7/05/82	1300	42°29'	67°39'	Surface Tows (202 u, 505 u)	Gulf of Maine
W64-38	"	1330	"	"	Surface Tow (505 u)	" " "
W64-39	7/06/82	0130	41°54'	67°00'	Neuston Tow	Georges Bank
W64-39	"	"	"	"	Surface Tow (505 u)	" "
W64-40	7/06/82	0815	41°33'	66°46'	Otter Trawl	" "
W64-41	7/06/82	1130	41°33'	67°01'	Otter Trawl	" "
W64-42	7/06/82	1255	41°39'	67°06'	Otter Trawl	" "
W64-43	7/07/82	1010	40°46'	66°39'	Hydrocast(chem)	Slope Water
W64-43	"	1020	"	"	Surface Tow (63 u)	" "
W64-43	"	1115	"	"	Oblique Tow (505 u)	" "
W64-44	7/07/82	1717	40°19'	66°30'	Surface Tow (63 u)	" "
W64-44	7/07/82	1732	"	"	Oblique Tow (505 u)	" "
W64-45	7/08/82	1115	40°32'	67°27'	Hydrocast(tar)	Georges Bank
W64-45	"	1120	"	"	Surface Tow (63 u)	" "
W64-45	"	1204	"	"	Surface Tow (505 u)	" "

Table A-1 (continued):

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	General Location
W64-45	7/08/82	1232	40° 32'	67° 27'	Neuston Tow	Georges Bank
W64-46	7/10/82	1405	41° 12'	70° 43'	Surface Tow (63 u)	Nantucket Shoal
W64-47	7/10/82	1930	41° 12'	71° 16'	Surface Tow (505 u)	" "
W64-47	"	2004	"	"	Surface Tow (505 u)	" "
W64-48	7/12/82	0838	40° 25'	73° 01'	Neuston Tow	New York Bight
W64-48	"	0920	"	"	Hydrocast (tar)	" " "
W64-48	"	0950	"	"	Surface Tow (505 u)	" " "

Table A-2: Bathythermograph casts made on R/V Westward cruise W-64.

BT No.	Date	Time	Latitude (N)	Longitude (W)	Log Reading (miles)	Surface Temp. (°C)	Mixed Layer Depth (m)
1	6/05/82	2248	38°59'	72°51'	185	14.0	3
2	6/06/82	0200	39°00'	72°50'	185	14.5	8
3	6/06/82	0820	38°42'	72°54'	202	15.6	-
4	6/06/82	1430	38°34'	72°49'	205	17.0	3
5	6/06/82	1620	38°23'	72°50'	216	18.1	-
6	6/06/82	2043	38°14'	72°44'	221	17.5	19
7	6/06/82	2133	38°80'	72°43'	227	18.8	13
8	6/06/82	2220	38°20'	72°45'	231	18.8	13
9	6/07/82	0350	37°50'	72°33'	237	19.0	13
10	6/07/82	0515	37°46'	72°29'	243	18.9	18
11	6/07/82	0700	37°40'	72°20'	251	18.5	13
12	6/07/82	0720	37°34'	72°15'	256	18.0	16
13	6/07/82	0910	37°29'	72°11'	263	19.6	21
14	6/07/82	1000	37°24'	72°70'	268	17.8	-
15	6/07/82	1730	37°11'	71°42'	284	19.4	-
16	6/07/82	1900	37°70'	71°34'	295	18.5	-
17	6/07/82	2015	37°50'	71°26'	300	25.0	-
18	6/07/82	2110	37°10'	71°17'	308	25.5	-
19	6/07/82	2200	36°56'	71°13'	314	25.7	-
20	6/07/82	2330	36°49'	71°07'	314	25.5	-
21	6/08/82	0030	36°44'	71°04'	328	25.6	-
22	6/08/82	0125	36°42'	71°03'	332	25.5	-
23	6/08/82	0600	36°34'	70°49'	342	25.0	-
24	6/08/82	0850	36°20'	70°35'	357	24.0	29
25	6/08/82	1220	36°06'	72°12'	383	23.2	29
26	6/08/82	1410	36°03'	70°01'	392	24.7	16
27	6/08/82	1550	35°57'	69°50'	402	24.5	13
28	6/08/82	1800	35°49'	69°43'	412	22.9	24
29	6/08/82	2000	35°36'	69°39'	425	23.0	25
30	6/08/82	2232	35°20'	69°35'	439	23.5	26
31			(BT FAILED)				
32	6/09/82	0335	34°49'	69°16'	471	23.0	26

Table A-2 (continued):

BT No.	Date	Time	Latitude (N)	Longitude (W)	Log Reading (miles)	Surface Temp. (°C)	Mixed Layer Depth (m)
33	6/09/82	0800	34°27'	69°11'	493	22.7	30
34	6/09/82	1340	33°50'	69°04'	527	22.9	26
35	6/11/82	0109	32°59'	65°40'	692	23.0	49
36	6/12/82	1450	32°19'	64°36'	766	23.3	20
37	6/13/82	0038	32°11'	64°49'	796	22.5	49
38	6/13/82	0400	32°11'	64°48'	798	23.2	54
39	6/13/82	0450	32°12'	64°48'	800	23.4	32
40	6/13/82	0622	-	-	801	23.1	30
41	6/13/82	0819	32°12'	64°46'	804	23.3	16
42	6/13/82	1320	32°12'	64°45'	806	24.5	39
43	6/13/82	1439	32°12'	64°43'	808	24.9	36
44	6/14/82	0240	32°14'	64°44'	821	23.3	49
45	6/14/82	0330	32°16'	64°39'	824	23.3	39
46	6/14/82	0405	32°17'	64°38'	826	23.7	34
47	6/14/82	0530	32°19'	64°37'	832	23.5	33
48	6/18/82	1445	32°46'	64°36'	894	25.7	7
49	6/19/82	0200	33°32'	64°30'	933	25.5	43
50	6/19/82	0545	32°42'	67°27'	940	25.3	33
51	6/19/82	0645	33°50'	68°32'	946	25.4	33
52	6/19/82	0915	33°56'	64°25'	957	25.1	33
53	6/19/82	1110	33°15'	64°35'	971	25.0	46
54	6/19/82	1310	34°09'	64°32'	980	25.1	39
55	6/19/82	1440	34°23'	64°26'	990	25.0	39
56	6/19/82	1620	35°35'	65°24'	1002	25.0	33
57	6/19/82	1754	34°32'	64°37'	1013	25.1	39
58	6/19/82	1950	34°44'	64°32'	1024	25.0	30
59	6/19/82	2125	35°02'	64°31'	1035	24.9	28
60	6/20/82	1300	35°41'	65°25'	1009	26.1	39
61	6/20/82	1621	35°59'	64°29'	1088	25.0	62
62	6/20/82	2230	36°35'	64°28'	1122	24.3	46
63	6/21/82	0940	36°52'	64°14'	1137	25.6	72
64	6/21/82	1445	38°03'	64°34'	1147	24.8	66
65	6/21/82	1700	38°24'	64°43'	1160	24.5	72

Table A-2 (continued):

BT No.	Date	Time	Latitude (N)	Longitide (W)	Log Reading (miles)	Surface Temp. (°C)	Mixed Layer Depth (m)
66	6/21/82	2045	38°32'	64°42'	1167	24.0	75
67	6/22/82	0430	38°35'	64°40'	1173	24.0	62
68	6/22/82	0748	39°02'	64°57'	1184	24.0	66
69	6/22/82	1110	39°14'	64°41'	1200	24.1	69
70	6/22/82	1235	39°27'	64°34'	1210	24.0	66
71	6/22/82	1440	39°36'	64°34'	1221	24.3	43
72	6/22/82	1530	39°40'	64°30'	1227	25.0	61
73	6/22/82	1725	39°49'	64°32'	1236	24.6	66
74	6/22/82	1841	39°58'	64°14'	1242	24.9	46
75	6/22/82	2200	40°02'	63°43'	1245	23.9	59
76	6/23/82	0015	40°04'	63°48'	1249	22.3	13
77	6/23/82	0140	40°07'	63°47'	1253	22.1	46
78	6/23/82	0240	40°11'	63°47'	1258	21.9	33
79	6/23/82	0429	40°15'	63°48'	1266	22.2	33
80	6/23/82	0715	40°17'	63°51'	1271	21.8	13
81	6/23/82	1300	40°25'	63°53'	1278	21.8	20
82	6/23/82	1800	40°50'	63°55'	1207	20.0	8
83	6/23/82	2045	41°04'	63°59'	1322	15.0	33
84	6/24/82	0045	41°27'	63°60'	1342	13.1	17
85	6/24/82	1500	42°10'	64°09'	1390	11.1	23
86	7/05/82	0220	43°15'	67°09'	1909	11.8	12

Table A-3: Summary of hydrographic data from R/V _Westward_ cruise W-64. bd = below level of determination.

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (°/oo)	Dissolved Oxygen (ml/l)	PO_4 (uM/l)	NO_3 (uM/l)
W64-2	0	-	12.45	32.30	8.46	-	-
	10	-	11.86	32.52	-	-	-
	25	-	6.96	32.77	8.80	-	-
	50	-	6.30	33.16	7.10	-	-
W64-4	0	-	12.08	32.65	8.98	0.02	-
	25	-	7.26	32.71	8.61	0.21	-
	50	-	6.94	33.25	7.62	0.34	-
	75	-	7.05	33.47	6.82	0.73	-
W64-5	0	-	-	32.54	8.81	bd	-
	25	-	-	32.91	8.49	1.03	-
	50	-	-	33.03	5.49	1.54	-
	75	-	-	33.95	7.50	0.29	-
W64-6	0	-	13.79	33.04	2.37	0.13	bd
	25	-	13.52	33.88	4.48	0.12	bd
	50	-	12.62	33.70	2.38	0.50	0.03
	75	-	10.07	34.48	6.93	0.36	0.04
	100	-	12.43	37.34	6.36	0.21	0.04
	125	120	12.40	35.30	4.70	0.96	0.02
W64-7	0	-	16.75	33.25	-	-	0.05
	100	104	12.69	35.17	7.27	0.02	0.06
	200	-	16.19	34.48	8.19	0.08	0.05
	400	-	6.02	35.06	6.47	1.10	0.08
	800	752	4.46	34.98	8.00	1.00	0.07
	1100	1046	4.72	34.93	8.24	-	0.10
	1800	1419	3.65	34.98	-	1.28	0.08
W64-8	0	-	19.10	34.42	-	0.47	0.06
	100	-	12.12	35.35	7.95	0.47	0.08
	200	-	-	35.56	7.01	-	-
	400	349	8.85	35.17	4.61	bd	0.13
	800	793	8.91	35.19	3.37	bd	0.13
	1100	1106	5.50	35.02	4.86	0.54	0.13
	1800	1798	4.23	35.18	3.75	0.85	0.10
W64-9	0	-	19.00	34.94	-	0.10	0.02
	100	-	15.60	36.18	6.90	0.38	0.005
	200	199	15.60	36.22	7.10	0.25	0.08
	400	403	15.64	35.31	5.73	3.45	0.09
	800	798	7.66	35.07	5.41	3.25	0.20
	1100	1096	5.75	35.03	6.55	4.85	0.14
	1800	1497	4.37	34.96	7.14	1.25	0.08

Table A-3 (continued):

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (°/oo)	Dissolved Oxygen (ml/l)	PO_4 (uM/l)	NO_3 (uM/l)
W64-10	0	-	19.42	34.31	6.18	-	-
	100	-	14.27	35.00	6.84	-	-
	200	156	12.06	35.45	-	-	-
	400	-	6.85	35.07	-	-	-
	800	605	4.77	34.98	7.58	-	-
	1200	-	3.98	35.00	6.18	-	-
W64-12	50	-	20.53	36.64	6.69	-	-
	100	-	19.54	36.55	7.24	-	-
	130	130	18.80	36.57	4.28	-	-
	160	-	18.61	36.59	5.65	-	-
	200	190	18.43	36.56	4.16	-	-
	250	-	18.19	36.56	5.94	-	-
W64-14	0	-	22.90	36.58	6.67	bd	0.02
	10	-	27.81	36.53	6.90	bd	0.02
	30	-	22.82	36.55	7.02	bd	bd
	50	-	22.06	36.49	6.98	bd	bd
	55	-	21.82	36.52	5.81	bd	bd
	60	-	23.07	36.52	6.39	bd	bd
	80	-	21.35	36.53	6.46	0.08	bd
	100	-	20.97	36.55	5.82	bd	0.02
	150	148	20.04	36.58	5.51	0.05	0.04
	200	191	19.21	36.61	5.81	bd	0.04
W64-16	0	-	23.2	36.49	7.08	bd	-
	30	-	21.67	36.59	7.30	0.42	bd
	400	390	17.87	36.53	6.85	0.07	0.02
	750	720	14.84	36.07	5.59	0.47	0.07
	1000	1015	7.16	35.19	5.00	-	-
	1200	-	6.12	35.13	6.67	1.60	0.11
W64-17	0	-	23.01	36.44	-	bd	bd
	45	-	21.25	36.50	-	bd	bd
	400	396	17.91	36.57	-	bd	0.02
	750	-	13.78	35.78	-	1.34	0.06
	1000	993	7.95	35.26	-	2.16	0.11
	1200	-	5.71	35.10	-	1.17	0.12
W64-18	0	-	24.64	36.45	6.87	-	-
	25	-	23.70	36.10	6.77	1.15	0.01
	50	-	22.49	36.97	6.91	2.0	0.01
	75	-	21.15	36.71	7.91	bd	0.005

Table A-3 (continued).:

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (°/oo)	Dissolved Oxygen (ml/l)	PO_4 (uM/l)	NO_3 (uM/l)
W64-19	50	-	21.74	36.49	7.26	0.05	bd
	100	-	19.72	36.57	7.12	0.05	bd
	130	122	19.12	36.56	7.02	-	0.004
	160	143	18.91	36.55	5.80	0.23	-
	200	186	21.58	36.54	5.95	0.80	0.02
	250	210	18.30	36.52	-	1.26	0.03
W64-20	0	-	25.06	36.13	7.05	-	bd
	100	-	20.24	36.28	7.08	bd	bd
	300	250	18.44	36.00	7.01	2.25	bd
	500	318	17.92	35.67	5.89	0.18	bd
	600	-	17.46	36.28	5.76	0.25	0.02
	700	581	16.82	35.95	5.47	1.13	0.01
	800	687	15.08	35.79	5.00	1.33	0.03
	1000	885	10.71	35.78	4.13	2.53	0.07
	1300	1200	5.81	34.80	6.90	2.20	0.06
	1500	-	5.01	35.05	7.70	2.83	0.06
W64-21	0	-	25.01	36.33	6.09	-	-
	50	-	24.99	36.32	-	-	-
	100	-	22.96	36.60	5.73	-	-
	125	118	21.95	36.59	5.82	-	-
	150	158	20.73	26.56	-	-	-
	200	-	19.50	36.62	-	-	-
W64-22A	0	-	24.20	35.58	5.40	-	-
	500	481	12.83	35.68	4.05	-	-
	900	840	8.64	35.20	4.52	-	-
	1500	1393	6.63	35.10	5.56	-	-
	1600	1436	5.63	35.38	5.77	-	-
W64-22B	0	-	23.83	36.31	6.97	1.07	0.02
	150	144	20.74	36.67	5.51	bd	bd
	175	-	20.06	36.62	5.80	0.84	0.01
	200	192	19.50	36.62	5.76	0.29	0.02
	225	223	18.83	36.18	5.77	0.04	bd
	250	249	18.41	36.53	5.94	2.62	0.02
	40	-	24.15	35.64	5.81	bd	0.02
	70	-	20.90	35.05	5.68	0.17	0.02
	110	0	16.16	35.74	5.05	0.23	0.02
	150	-	16.36	36.16	4.87	0.35	0.02
	190	202	14.67	35.84	4.90	0.03	0.02
	240	222	13.84	35.79	4.79	0.60	0.02

Table A-3 (continued):

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (o/oo)	Dissolved Oxygen (ml/l)	PO_4 (uM/l)	NO_3 (uM/l)
W64-24	0	-	23.83	36.31	6.97	1.07	0.02
	150	144	20.74	36.67	5.51	bd	bd
	175	-	20.06	36.62	5.80	0.84	0.01
	200	192	19.50	36.62	5.76	0.29	0.02
	225	223	18.83	36.18	5.77	0.04	bd
	250	249	18.41	36.53	5.94	2.62	0.02
	300	-	17.99	36.51	6.69	1.55	0.02
	600	553	16.06	36.13	6.01	0.01	0.12
	900	860	8.99	35.18	8.64	1.43	0.04
	1200	1151	5.22	35.04	6.03	-	-
	1400	1365	4.61	35.03	9.18	-	-
	1000	1561	4.26	34.97	9.16	-	-
W64-25	150	148	13.55	35.34	8.04	-	-
	300	296	11.43	-	5.92	-	-
	450	440	18.21	-	5.59	-	-
	600	592	16.36	35.20	6.81	-	-
	750	735	15.51	35.02	7.60	-	-
	900	876	14.96	36.12	8.36	-	-
	1050	1012	4.48	36.03	8.44	-	-
	1200	1152	4.28	35.40	8.66	-	-
	1350	1303	4.11	35.52	8.75	-	-
	1500	1446	3.97	35.25	8.93	-	-
W64-27	0	-	11.44	32.84	8.17	-	-
	20	-	11.01	33.92	7.77	bd	bd
	25	-	11.11	33.94	7.57	0.33	bd
	30	-	10.26	34.12	7.31	0.41	0.02
	35	-	9.77	33.65	7.29	0.43	0.06
	40	-	10.40	33.55	6.93	0.33	0.06
	45	-	9.56	34.10	6.80	0.47	0.06
	60	-	7.98	34.78	6.17	0.19	0.04
	90	-	7.43	35,45	7.88	0.65	0.08
	120	-	8.67	35.61	7.25	0.63	0.08
W64-28	0	-	9.03	-	13.32	1.30	0.005
	50	-	6.04	32.16	11.80	-	0.02
	75	-	3.80	32.92	8.93	-	0.07
W64-29	0	-	9.32	31.39	8.70	bd	bd
	50	-	6.71	31.74	8.67	0.08	0.02
	75	-	2.47	32.65	-	0.27	0.02
W64-30	0	-	9.09	-	8.88	0.03	bd
	50	-	6.11	-	9.05	0.12	0.02
	75	-	3.11	-	8.14	0.44	0.41

Table A-3 (continued):

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (°/oo)	Dissolved Oxygen (ml/l)	PO_4 (uM/l)	NO_3 (um/l)
W64-34	0	-	9.54	31.46	8.76	0.41	bd
	10	-	9.07	31.52	-	0.80	0.01
	20	-	8.56	31.98	8.18	0.47	0.01
	40	-	8.05	31.99	8.46	0.64	0.02
W64-35	10	-	8.85	31.92	-	0.18	bd
	20	-	8.41	31.96	-	0.29	0.002
	40	-	8.43	31.98	-	0.80	0.04
	70	-	7.31	32.55	-	0.89	0.02
W64-37	20	-	9.41	32.53	-	0.30	0.04
	40	-	5.82	32.80	-	0.85	0.02
	60	-	5.72	33.26	-	1.40	0.05
	100	-	6.12	33.72	-	1.55	0.06
	160	-	7.23	34.62	-	1.45	0.06
W64-43	0	-	21.10	-	-	-	-
	45	-	19.52	-	-	-	-
	70	-	15.76	-	-	-	-
	100	-	14.13	-	-	-	-
	150	-	13.30	-	-	-	-
W64-45	0	-	18.69	-	-	-	-
	35	-	17.97	-	-	-	-
	65	-	14.32	-	-	-	-
	100	-	12.71	-	-	-	-