CRUISE REPORT

W-61

Scientific Activities

St. Thomas - Margarita - Kralendijk - Roatan - Miami
2 December 1981 - 13 January 1982

R/V _Westward_

Sea Education Association
Woods Hole, Massachusetts

DRAFT COPY

PREFACE

This cruise report is intended to serve as a summary of the scientific research and academic program conducted on the sixty-first cruise of the research vessel *Westward*, which took place between 2 December 1981 and 13 January 1982. Included are the abstracts from twenty-four student projects completed and written during the cruise. Also reported herein are data which are being incorporated in the long-term studies of S.E.A. staff scientists and 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 R/V *Westward* cruise W-61.

Cruise W-61 was one of the most ambitious and productive in *Westward*'s recent history. Dozens of people helped to make the cruise and ports of call run smoothly; these included numerous friends ashore as well as a fine ship's crew. Captain Wallace Stark, through his vast experience with *Westward* and seeming endless good humor, allowed the scientific party to make the best possible use of particularly interesting oceanographic locations. Additionally, he made great effort in arranging for *Westward*'s entry into ports of call which were difficult in terms of language and paper work. Captain Stark was supported by three mates of extraordinary skill. Chip Swicker, as chief mate and head of nautical science, kept the deck running in a fashion that only such an experienced seaman could manage. Gregg Swanzey and Mike Mulhern, both with experience on other large sailing vessels, provided the navigation and seamanship necessary for maintaining long oceanographic stations. Dan Brashear kept *Westward*'s engine room in immaculate condition and was a crucial

source of advice with analytical equipment. A constant stream of excellent food and good humor came from Cilla Brooks' galley.

A particularly large group of talented scientists took part in R/V Westward cruise W-61. As my assistant scientists, Fred Carr and Kit Matthew assumed much of the burden of gear maintenance and laboratory preparations, providing me with the time to coordinate forty-seven overly ambitious stations and twenty-four excellent student projects. Fred provides a knowledge of fishes and coral reefs unequaled by other Westward scientists. Kit's experience in the field of ecology and ornithology was particularly evident at our numerous island visits. Dr. R. Jude Wilber, who joined us on Leg I, provided Westward's crew with a series of powerful lectures on Caribbean plate tectonics and an outstanding geological field trip on Bonaire. Dr. Jean Maguire introduced us to the sounds of sperm whales and other curious cetaceans on Leg II. Dr. Charles McClennen provided great assistance with numerous student projects and a stimulating series of lectures in marine geology on Leg III. Also joining Westward were Dr. Gustavo Reyes and Carmen Piro from the Ministry of Environment of Venezuela. They served as foreign observers on the vessel and provided invaluable assistance with phytoplankton identification.

In Bonaire, Mr. Bill Rothfuss smoothed the pathway to a very pleasant port stop, providing transporation for us and knowledge of local business and geography. The former chief scientist from Westward, Henry Genthe, opened up his home and Roatan diving group to include Westward's crew. No better hospitality or roast pork can be found in the islands. Eric Anderson provided a colorful lecture on the history of Roatan and S.E.A. alumnus Liz Kay helped Westward crew members on their travels about the island. We also thank the Roatan Lodge for a warm welcome and the Port Royal Yacht Club for a very memorable New Year's Eve party.

TABLE OF CONTENTS

Page

INTRODUCTION

This report is the product of the research conducted on R/V Westward cruise W-61 and Introduction to Marine Science Laboratory offered by Boston University (course number NS 225 L). The cruise track (Fig. 1) was designed to permit collection of physical, chemical, and biological data from several distinct oceanographic areas in the Caribbean Sea and Florida Straits. Stations were made in turbulent areas and passes west of the Lesser Antilles, the Venezuelan upwelling and Cariaco Trench, the central Caribbean Sea, the Yucatan Strait, and the Florida Current. The ship's itinerary, including intermediate ports of call (Table 1), permitted W-61 participants access to several terrestrial and neritic habitats in addition to the open ocean environment. Cruise participants are listed in Table 2.

Although the major theme of the cruise was a physical and biological comparison of major Caribbean 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 or visiting scientist projects. These abstracts make up a large portion of the report.

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

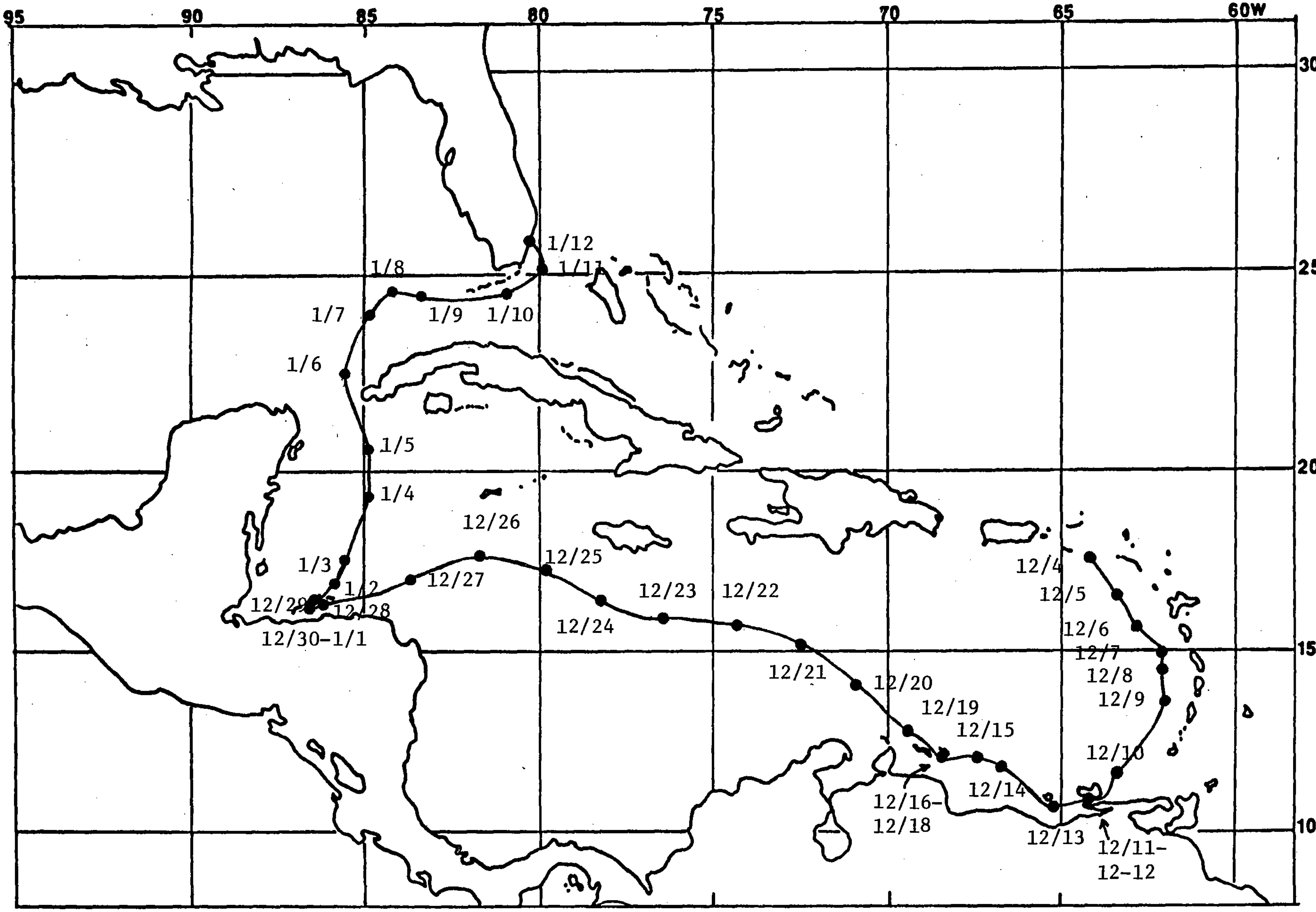

Figure 1: Cruise track of R/V Westward cruise W-61. Noon postions are shown.

TABLE 1: Itinerary of R/V *Westward* cruise W-61

St. Thomas, U.S.V.I.	2 December 1981	Porlamar, Margarita, Ven.	11 December 1981
Porlamar, Margarita	12 December 1981	Kralendijk, Bonaire, N.A.	16 December 1981
Kralendijk, Bonaire	18 December 1981	Coxen's Hole, Roatan, Honduras	29 December 1981
Coxen's Hole, Roatan	29 December 1981	Port Royal, Roatan	30 December 1981
Port Royal, Roatan	2 January 1982	Miami, Florida	12 January 1982

Total Mileage for W-61 = 3218 by log
approx. 3500 total

Total Engine Hours - 6.5*

*This represents the all-time low number of engine hours for a 6-week cruise on R/V *Westward*.

TABLE 2: Ship's Complement on R/V *Westward* Cruise W-61

Nautical Staff

Wallace Stark, B.S., L.L.D.	Captain
Charles Swicker, B.S.	Chief Mate
Gregg Swanzey, B.S.	Second Mate
Michael Mulhern, B.S.	Third Mate
Daniel Brashear	Engineer
Cilla Brooks, B.S.	Steward

Scientific Staff

Allan Stoner, Ph.D.	Chief Scientist
Fred Carr, B.S.	Second Scientist
Kathryn Matthew, Ph.D.	Third Scientist

Visiting Scientists

R. Jude Wilber, Ph.D. - Leg I
Jean Maguire, D.V.M. - Leg II
Charles McClennen, Ph.D. - Leg III

Students

Patricia Carbonara	Senior, Environmental Studies, Rollins College
Darik Corzine	Junior, Forestry, Paul Smith College
Julie Cunningham	Junior, Biology, Vassar College
Maria Ellis	Senior, Biochemistry, Cornell University
Jeremy Gaies	Junior, Environmental Studies, Brown University
Thomas Goffinet	Senior, History, Cornell University
Dana Hooper	Junior, Mathematics, William & Mary College
Jennifer Lawson	Junior, Biology, Tufts University
Joyce Little	Junior, Economics, Cornell University
Steven Low	Junior, Geology, Colgate University
Hilary Maybaum	Junior, Special Education, Boston University
Martha Muka	Junior, Biology, Cornell University

Students (continued)

Jeanne Mullin	Junior, Biopsychology, Tufts University
Douglas Ranalli	Junior, Engineering, Cornell University
Brenda Sabbag	Junior, Geology, Colgate University
Cari Sasser	Senior, Biology, Cornell University
Deborah Schmitt	Junior, Environmental Conservation, University of Colorado
Priscilla Shafer	Junior, Geology, Princeton University
Paul Slesinger	Junior, Biology, Reed College
Lawrence Taborsky	Senior, Biology, Cornell University
Matthew Tanzer	Senior, Biology, Cornell University
Craig Timmons	Senior, Business Administration, Rollins College
Michael Waters	Senior, Animal Science, Cornell University
Susan Welsh	Junior, Earth & Planetary Science, Johns Hopkins University

Academic Program

Throughout the six week period covered by R/V *Westward* cruise W-61 a 24-hour science watch was maintained by teams of three students and one member of the science staff. During science watch students were instructed in the use of gear and scientific procedures spanning many aspects of physical, chemical, geological, and biological oceanography. Instruction was provided in the form of oceanographic and marine biological research which was conducted either for individual projects or the work of S.E.A. staff or long-term cooperative programs. Routine meteorological and oceanic observations were made and weather data were transmitted during science watches. During the last two weeks of the cruise, students were sufficiently familiar with scientific procedures to operate activities of the laboratory without significant help from the marine science staff.

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

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

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

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

TABLE 3: Lecture and seminar schedule during R/V Westward cruise W-61

Thurs.	12/3	Circulation of the Caribbean and Orientation to Leg I.	Stoner
Fri.	12/4	Reef Geomorphology	Carr
Mon.	12/7	Post-Jurassic History of the Caribbean Plate	Wilber
Tues.	12/8	Sampling the Plankton	Stoner
Wed.	12/9	Introduction to Seabirds	Matthew
Thurs.	12/10	Geology of Carbonate Platforms: Circum Caribbean Examples	Wilber
Fri.	12/11	Island Biogeography	Matthew
Sun.	12/13	Geology of the Dutch Antilles and Northern South America	Wilber
Mon.	12/14	Biology of Corals	Carr
12/15 -	12/18	Port call - Kralendijk, Bonaire	
Thurs.	12/17	Field trip - Natural history and Geology of Bonaire	Stoner/Wilber
Mon.	12/21	Diving Physiology of Marine Mammals	Maguire
Tues.	12/22	Water Chemistries aboard R/V Westward	Stoner
Wed.	12/23	Mid-Term Quiz	
Thurs.	12/24	Biology of Reef Fishes	Carr
Fri.	12/25	Christmas Day - no lectures	
Mon.	12/28	Vesicular Exanthema and the San Miguel Sea Lion Virus	Maguire
12/29 -	1/1	Port call - Coxen's Hole and Port Royal, Roatan	
Thurs.	12/31	History and Archaelogy of Roatan	Anderson
Sat.	1/2	Research Update and Prospective	Stoner
Mon.	1/4	Geological Development of the Western Caribbean and Gulf of Mexico	McClennen
Tues.	1/5	Student Seminars	
Wed.	1/6	Student Seminars	
Thurs.	1/7	Student Seminars	
Fri.	1/8	Student Seminars	
Sat.	1/9	Final Examination	

TABLE 3: (continued)

Mon.	1/11	Student Seminars	
		Geological Evidence of Sea-Level Changes and Problems in Applied Marine Geology	McClennen
Tues.	1/12	Research Wrap-Up	Stoner

Circulation in the Caribbean Sea

The Caribbean is the marginal sea bounded by the Lesser and Greater Antilles, the east coast of Central America, and the northern coast of South America, including Venezuela and Columbia. From east to west the Caribbean Sea is divided into five major basins, all greater than 3000 m in depth: Grenada, Venezuela, Columbia, Cayman and Yucatan (Fig. 2). The basins are separated by four major submarine rises.

Because of steady trade winds from the east and east-northeast, the general flow of water through the sea is from east to west, at least in the upper 1500 m. Sometimes the axis of this current, which moves at approximately 2.7 knots, is called the Caribbean Current. Because most of the sills around the northern and eastern borders of the Caribbean are shallow (< 1000 m deep), there are relatively few major sites of inflow from the north Atlantic Ocean. Most of the water enters between the Lesser Antilles, particularly to the north and south of St. Lucia and between Dominica and Martinique. These passages carry water from the north and south equatorial currents and the Guiana Current. Other sources of Atlantic water are the Anegada Jungfern Passage between the U.S. Virgin Islands and Anguilla, and the Windward Passage between Cuba and Hispaniola; these passages are secondary in importance.

Maximum flow of 40 to 60 cm/sec occurs 200 to 300 km north of Venezuela. This primary axis of flow continues over the Aves Ridge, through the Aruba Gap north of the Netherlands Antilles, through the Columbian Basin, over the Jamaican Ridge, and through the Cayman Trough. The flow turns north in the Gulf of Honduras and passes through the Yucatan Strait where the beginning of the Gulf Stream is detected. The flow generally follows the deepest pathway through the Caribbean Sea. Mass transport is approximately 30 S_v (30 million m^3/sec) from east to west with no significant additions at the Windward Passage.

Although surface circulation in the Caribbean Sea is believed to be characterized by a steady flow from east to west, on cruise W-61

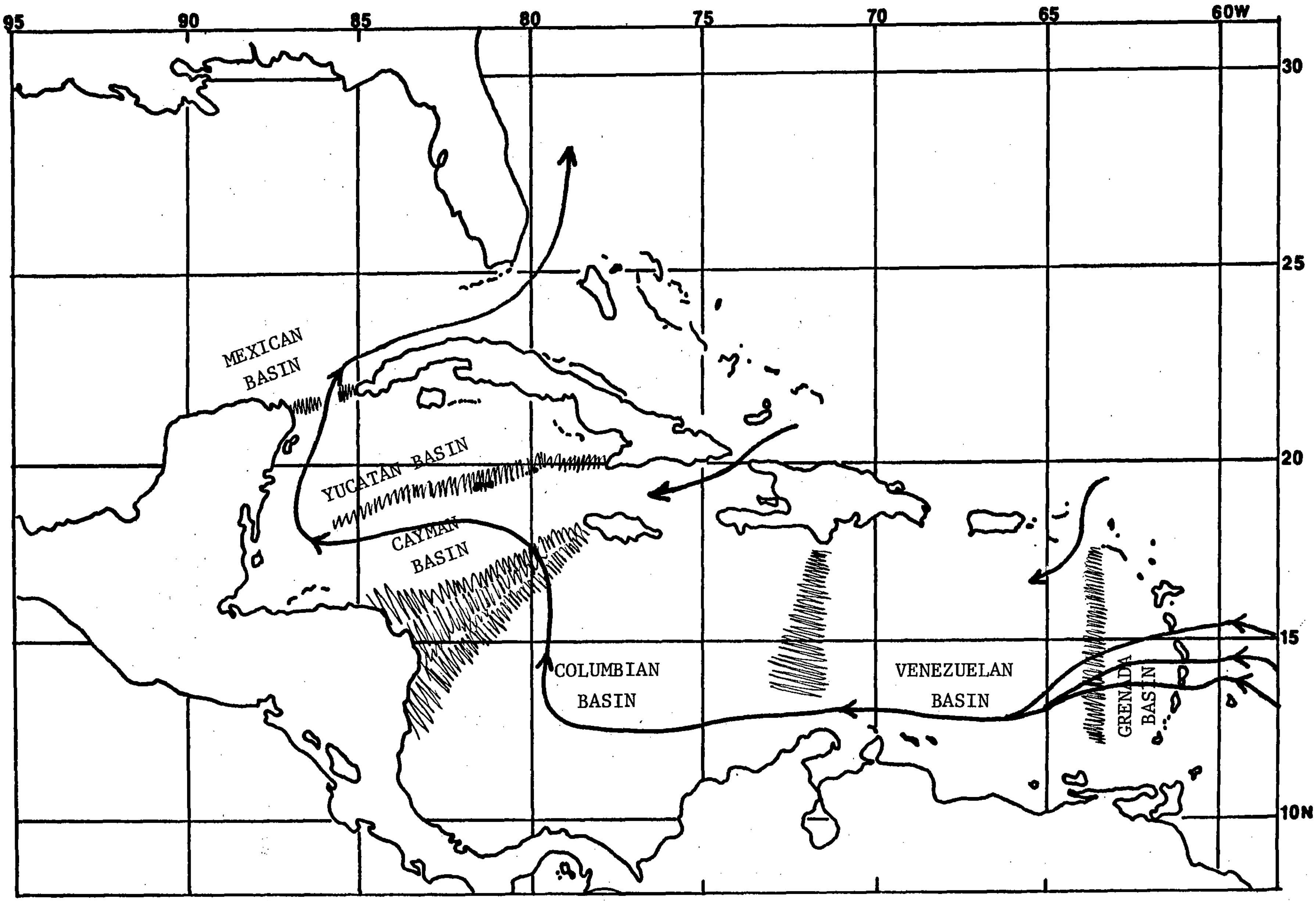

Figure 2: Five major basins and major features of surface circulation in the Caribbean Sea.

Hooper discovered that important exceptions may exist. Several eddies of large dimension were found in the area south of Hispaniola and Jamaica. These features are not reported in the literature. In another cruise study, Shafer examined dynamic topography across the Caribbean and discovered a significant increase in sea level height between the Dutch Antilles and the Yucatan Strait. This corresponds well with what is known about Coriolis effect, Ekman transport, and upwelling in the sea.

Another little recognized source of surface water in the Caribbean Sea is Amazon River water. Nineteen percent of all freshwater input into the world ocean is discharged at the mouth of the Amazon River. The influence of the river extends great distances offshore and traces of the water mass may be picked up by the Guiana Current and transported west into the Caribbean Sea. On R/V Westward cruise W-61, Lawson and Maybaum used phytoplankton species and silicate concentrations to trace the influence of Amazon River water in the Caribbean Sea. Amazon phytoplankton were found to the north of Venezuela and near the Lesser Antilles suggesting the influx of Amazon waters into the Caribbean. This study represents the first successful use of phytoplanktons for such a purpose.

The Caribbean water column is also highly stratified in the vertical dimension. At least six major vertical water masses are known in the upper 1500 m of the Sea; the physical properties of these are summarized in Table 4. During R/V Westward cruise W-61, the vertical structure of the water column was examined at several sites along the Lesser Antilles. Two stations in the northern Grenada Basin typify the vertical structure of the Caribbean Sea (Figs. 3 & 4). High surface temperatures and low salinity characterize the surface water mass. Below the upper 50 m, salinity maxima and rapidly decreasing temperatures characteristic of subtropical underwater were found. At both sites the oxygen minimum zone which characterizes Tropical Atlantic Central Water was found, but 18° water, usually identified by an oxygen maximum, was not detected. Lack of detection of 18° water is most likely the result of water samples being taken at wide depth intervals. Cool temperatures and salinity

TABLE 4: Physical properties of six major vertical water masses in the Caribbean Sea

Water Mass	Depth (m)	Temperature (°C)	Other Properties
Surface Water	0-50	20-27	Variable, O_2=4.2 ml/l
Subtropical Underwater	50-200	14-20	Salinity Maximum (36.7-37 ‰)
18° Water	200-400	14-20	O_2 Maximum
Tropical Atlantic Central Water	400-700	8-14	O_2 Minimum (3.0 ml/l)
Subantarctic Intermediate Water	700-1100	5-8	Salinity Minimum (34.7 ‰)
North Atlantic Deep Water	1100+	4-5	Salinity = 35.0 ‰, High O_2

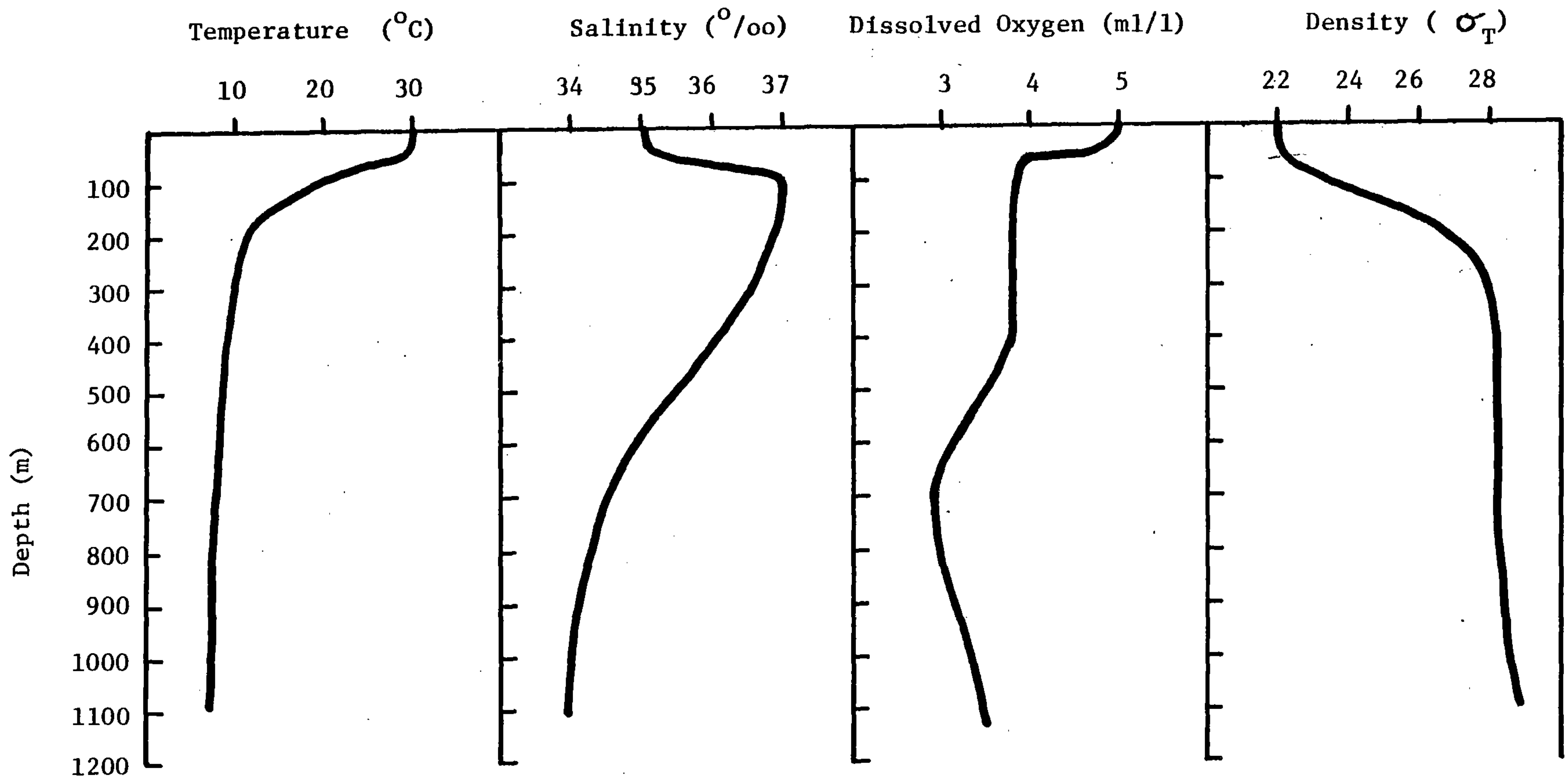

Figure 3: Physical-chemical characteristics of the water column in the northern Grenada Basin, station W-61-2.

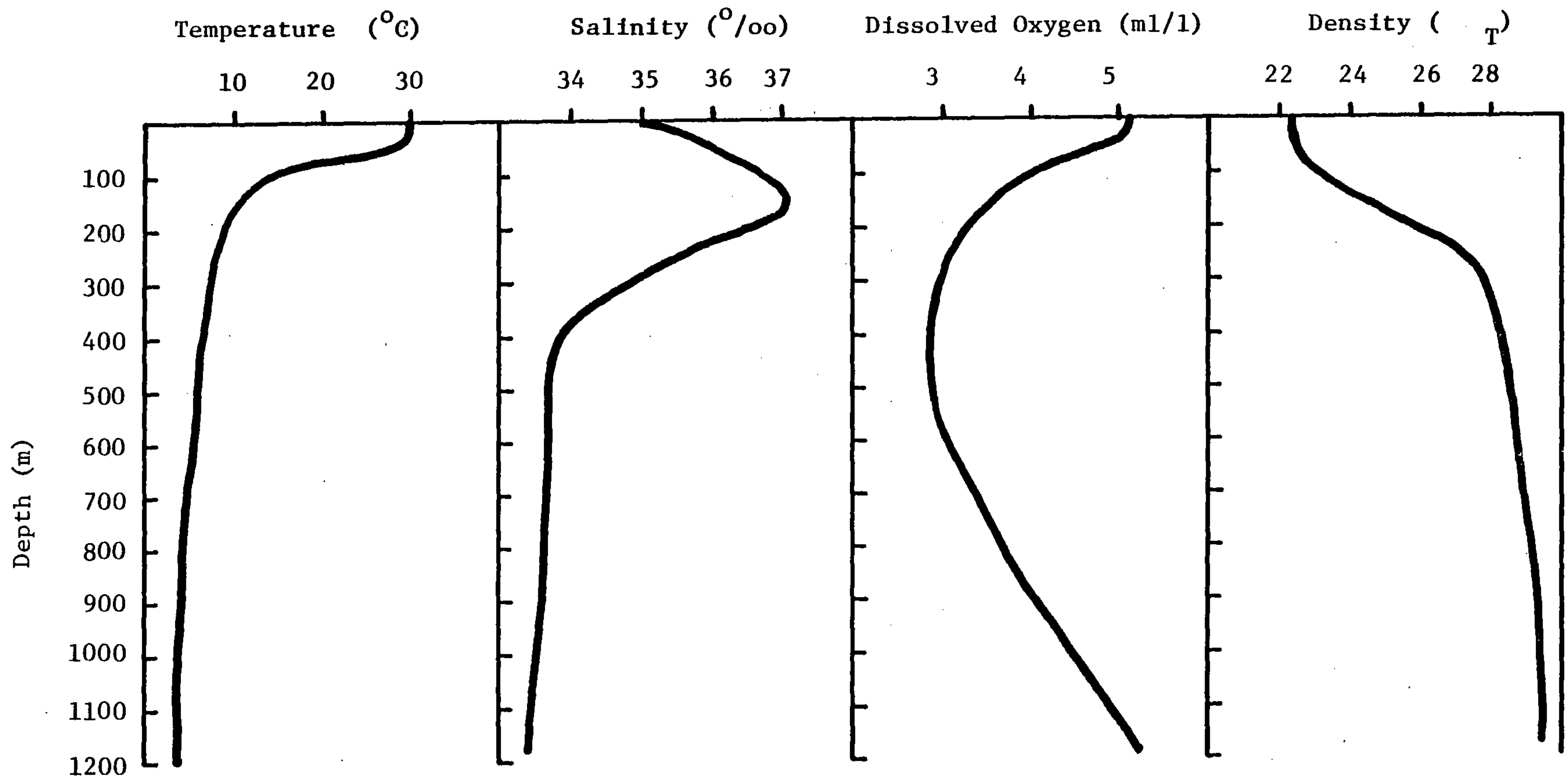

Figure 4: Physical-chemical characteristics of the water column near Guadeloupe, station W-61-4.

minima between 700 and 1100 m were characteristic of Subantarctic Intermediate Water. Only at station W61-4 was the hydrocast deep enough to sample North Atlantic Deep Water. Temperatures near 4° C and rising oxygen concentrations identified this water mass at approximately 1200 m depth west of Guadeloupe. At both stations sharply increasing water densities with depth indicates a highly stable water column.

Circulation below 1500 m in the Caribbean Sea is very sluggish, probably less than 3 cm/sec. Because of this, the water in the deep basins is probably renewed only very slowly. An extreme case of this is the Cariaco Trench, near the Venezuelan coast. The Trench is effectively isolated from the rest of the Caribbean Sea by shallow sills and deep water there has a very long residence time. The Gulf of Venezuela, characterized by upwelling, is highly productive biologically; this results in the introduction of large amounts of organic detritus to the deep basin and consequential alterations in water chemistry, most notably the reduction of dissolved oxygen concentrations. During cruise W-61, the Cariaco Trench was sampled for water column chemistry. The basin yielded unusually low oxygen levels (Fig. 5) and particularly high nutrient concentrations (Fig. 6). Future cruises should attempt to examine vertical structure in the biological populations of the anoxic region.

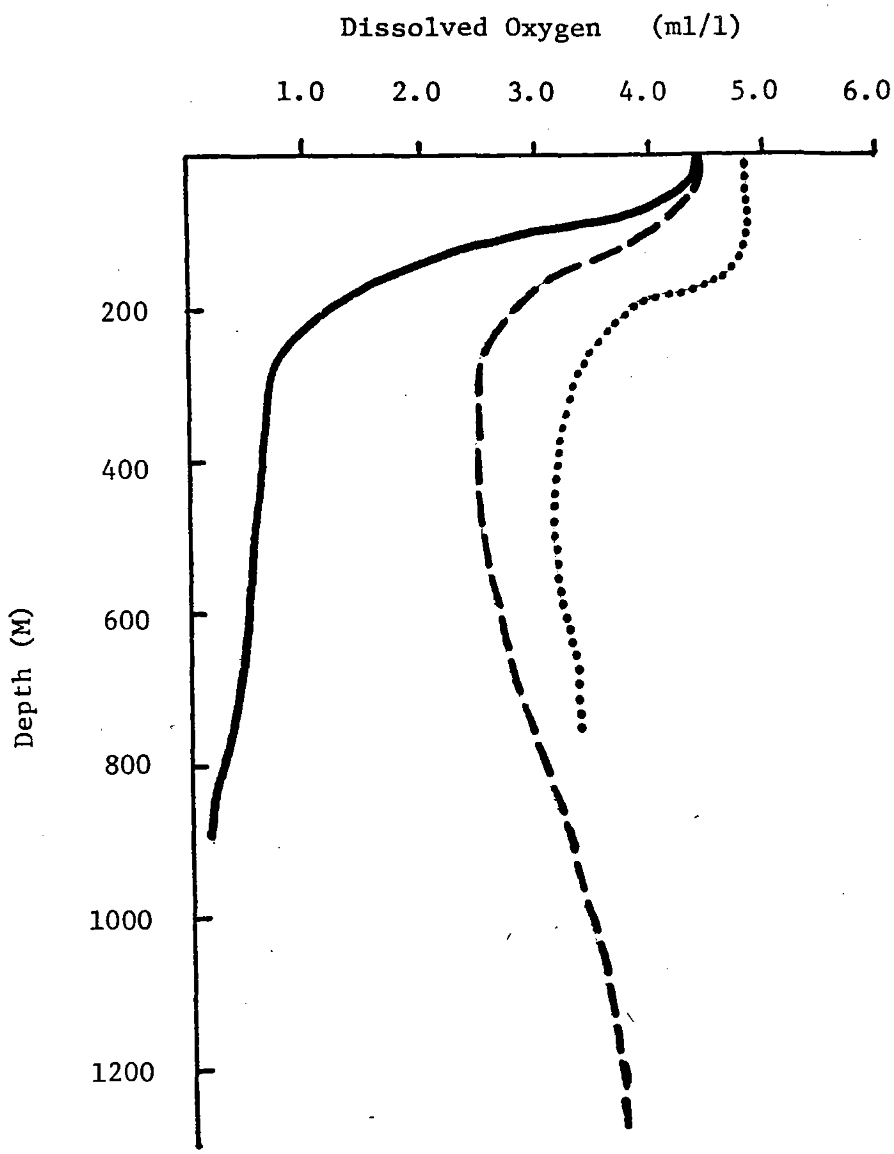

Figure 5: Dissolved oxygen levels in the water column of the Cariaco Trench (solid line), near Dominica (dashed line), and in the passage between Dominica and Martinique (dotted line) (stations W-61-14, 6, and 5, respectively).

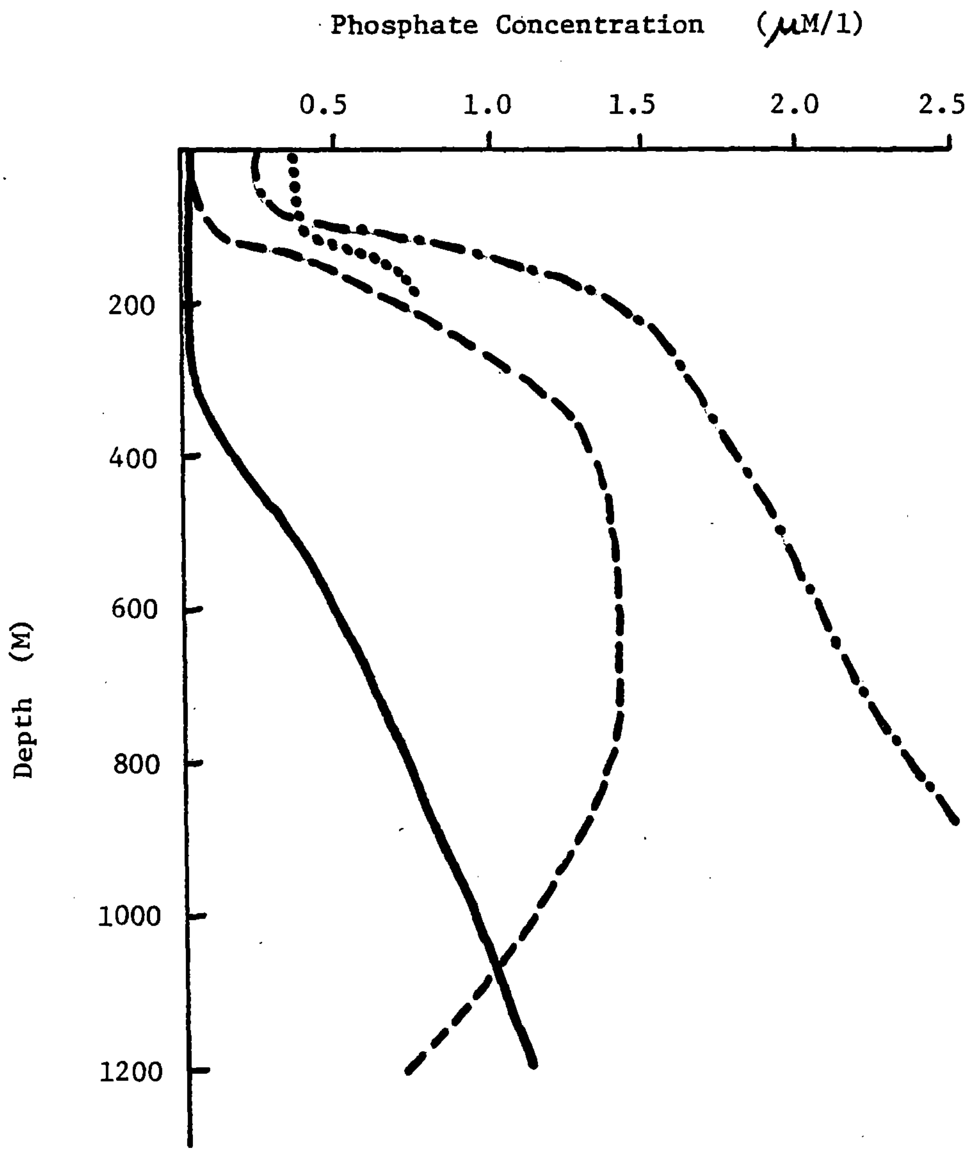

Figure 6: Phosphate concentrations in the Caribbean Sea shown as a function of depth. Central Caribbean (solid line), near Guadeloupe (dashed line), Cariaco Trench (dash-dot), and in the Venezuelan upwelling zone (dotted line).

<u>Surface Current Analysis South of the Windward Passage</u>

Dana Hooper

ABSTRACT

A transect was made south of Hispaniola and Jamaica (from 15°12'N, 72°32'W to 17°08'N, 79°38'W) using the set and drift of R/V *Westward* to determine the pattern of surface currents and turbulence in the vicinity of the Windward Passage. Celestial fixes were used for true position. Currents did not flow from east to west as is generally accepted; rather, a series of eddies about sixty miles in diameter were found just east of the Jamaica Passage and south of Hispaniola. Another anticyclonic eddy was found to the south of Jamaica; this eddy appeared to be a result of island mass effect. Additionally, the general westerly current south of Jamaica was deflected by Pedro Bank (Fig. 7). It was concluded that surface flow in the northern Caribbean Sea is more complex than generally recognized and that sudden bathymetric changes and islands have a major effect upon strong Caribbean currents.

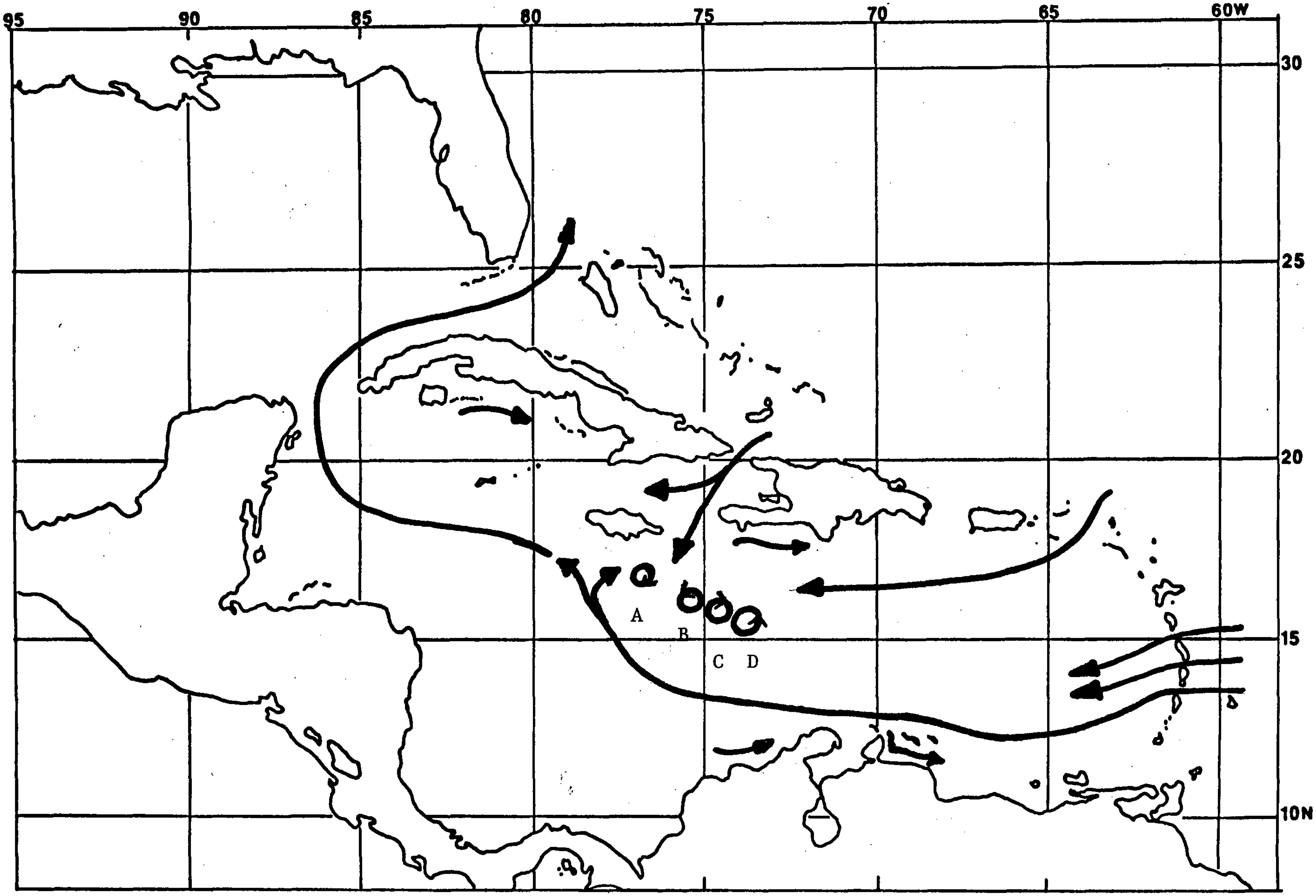

Figure 7: Four eddies south of Jamaica and Hispaniola hypothesized from set and drift data. Eddies B and D are cyclonic. Eddies A and C are anticyclonic. Major surface flows are shown by the heavy lines.

Geostrophic Flow and Dynamic Topography in the Caribbean Sea

Polly Shafer

ABSTRACT

The Caribbean Sea is an appropriate site for study of geostrophic flow because it is a relatively isolated system. Geostrophic calculations were made using four deep, twelve-bottle hydrocasts (Fig. 8). The main axis of current in the Caribbean runs east to west along the southern third of the Sea. A north-south transect at approximately 70° north longitude was made to predict velocity profile. Data for current velocities were inconclusive; however, sea surface topography was determined from data taken at three sites. Displacement of sea level height toward the northern sector of the Caribbean was predicted with a high near the Yucatan Strait. Lows were predicted along the southern Caribbean, particularly near the Dutch Antilles. These hypotheses were supported by calculation of dynamic topography; the sea surface at the Yucatan Strait was 23 cm higher than that found northwest of Curacao. The pressure gradient created by dynamic topography in the Caribbean is a result of trade winds and associated Coriolis effects.

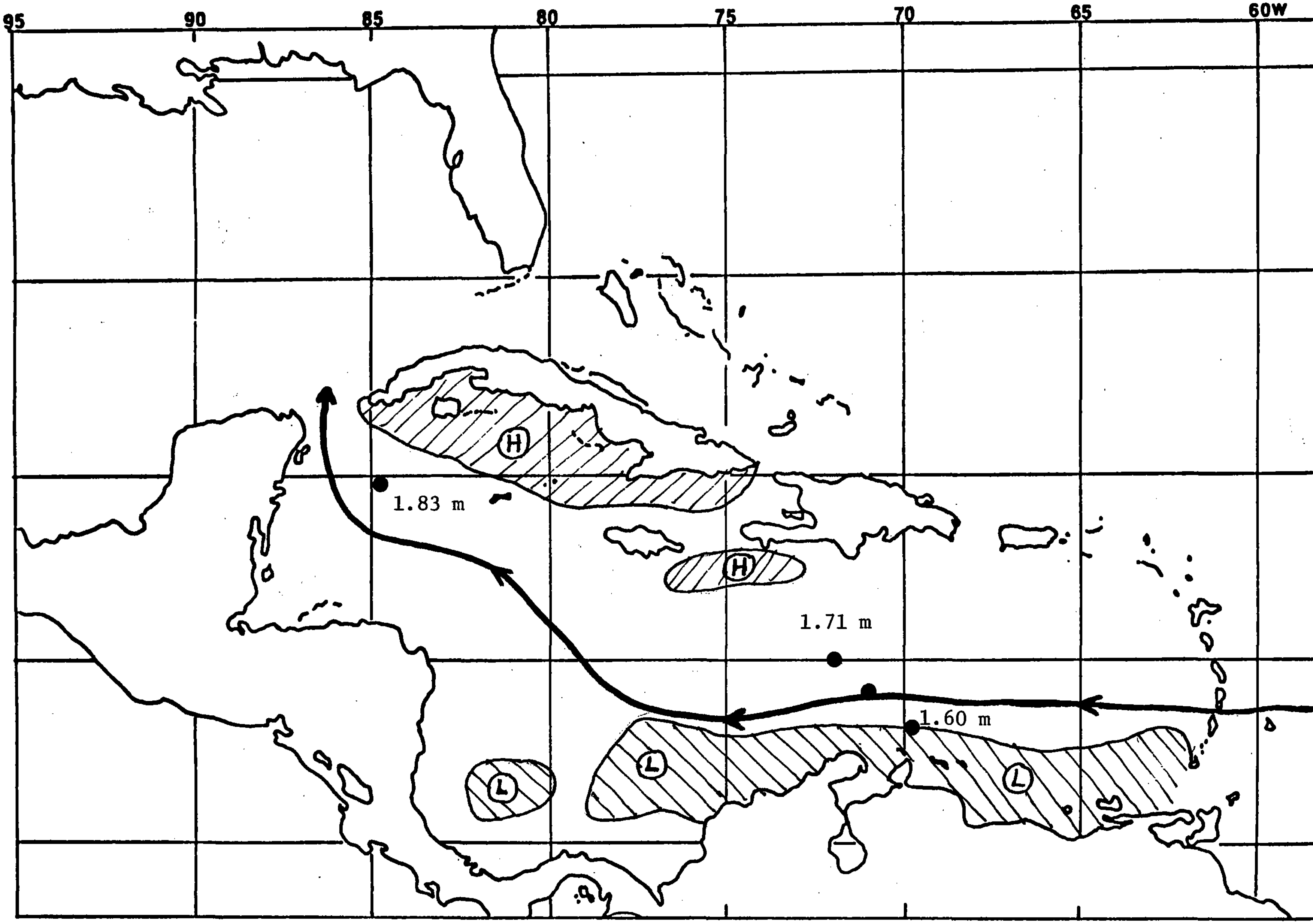

Figure 8: Stations in the Caribbean Sea where dynamic topography measurements were made. Values beside the points are the calculated heights in meters. The solid line represents the axis of the Caribbean Current.

The Influx of Amazon River Water into the Caribbean Sea

Jennifer Lawson and Hilary Maybaum

ABSTRACT

Pathways of Amazon River water were investigated in December, 1981, using salinity, nutrient chemistry, and biological parameters as tracers. The best indicator of Amazon River water appeared to be the presence of particular phytoplankton species. These organisms were identified at thirteen stations along the Lesser Antilles and northern coast of South America (Fig. 9; Table 5). Two major areas of influx into the Caribbean were observed: Primary flow appeared to occur between the Grenadines and Venezuela and a secondary pathway was observed between Martinique, St. Lucia, and St. Vincent. The primary flow is probably a result of the Guianna Current and the second flow is via the North Equatorial Current. Other physical factors would include upwelling, vertical mixing, and the South American Counter Current. Salinity and silicate levels yielded a similar interpretation of Amazon flow. Future research should include sampling during the July-August wet season, corresponding with maximum Amazonian discharge.

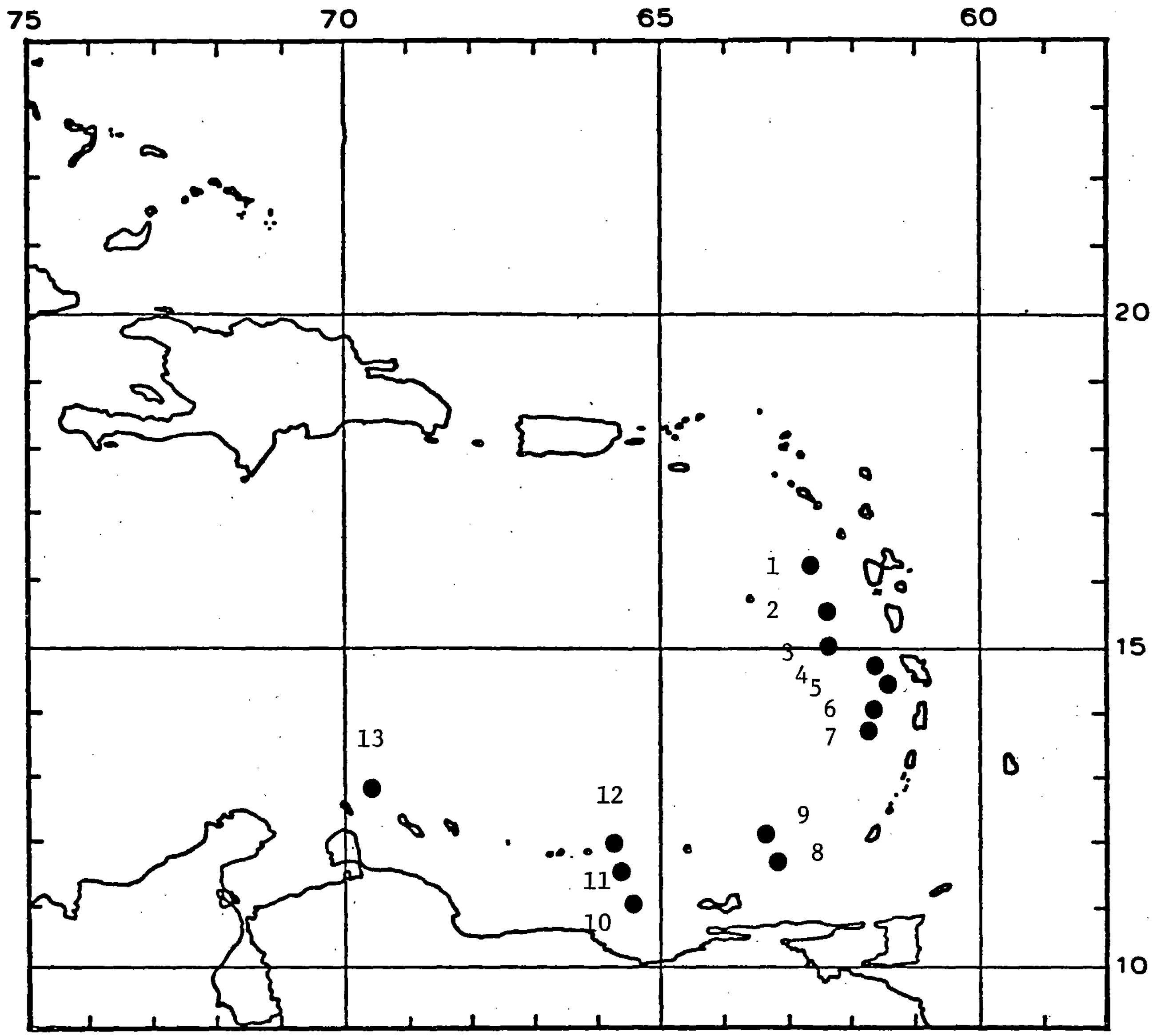

Figure 9: Stations at which phytoplankton collections were made. Station numbers shown do not correspond with the numbers used for other studies in this report.

TABLE 5: Phytoplankton found at thirteen stations in the eastern Caribbean Sea. See Fig. 9 for station positions. Values are percents of total count.

Phytoplankton Species	Station												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Non-Amazonian Species	100	98	97	65		87	100	44	72	100	100	93	97
Amazonian Species	0	2	3	35		13	0	56	28	0	0	7	3
Ceratium declinatum	-	-	-	-		-	-	-	-	-	-	-	-
Ceratium macrocerous	-	2	-	-		-	-	-	-	-	-	-	-
Chaetocerous subtilis	-	-	-	-		-	-	9	-	-	-	-	-
Hemiaulus hauckii	-	-	-	35	(Sample lost)	-	-	-	-	-	-	-	2
Leptocylindrus danicus	-	-	3	-		8	-	-	-	-	-	7	-
Nitschia seriata	-	-	-	-		-	-	8	-	-	-	-	1
Pyrophacus horologicum	-	-	-	-		5	-	-	-	-	-	-	-
Skeletonemia costatum	-	-	-	-		-	-	32	28	-	-	-	-
Thalissiothrix nitzchoides	-	-	-	-		-	-	7	-	-	-	-	-

Nearshore, Terrestrial and Geologic Studies

Kit Matthew

Westward's first port stop on W-61 was in the Netherland Antilles at Kralendijk, Bonaire. Only 112 square miles in area, this low island displays a unique flora and fauna, in both its terrestrial and marine environments. Bonaire is characterized by a low annual rainfall and a predominance of cacti, mangrove swamps, and hypersaline ponds (salinas). In spite of the apparent barrenness of the island, the swamp and salina communities harbor a rich source of food for migrating shore birds and breeding flamingos. The coral reefs offer great variety in corals and fish.

Geologically, Bonaire consists of relatively recent limestones (less than 15 million years old) resting on a thick, older succession of igneous and sedimentary rocks (120-60 million years). Along with Aruba and Curacao, Bonaire formed part of a volcanic arc situated on the leading edge of a tectonic plate which moved into the Caribbean from the west. Eventually, in the late Cretaceons and early Tertiary, this island arc collided with the northern margin of the South American Continent, resulting in the folding and faulting of Bonaire's rocks. During the quaternary, a slow tectonic uplift took place, as well as a drop in sea level caused by the Ice Age. Evidence of these processes can be seen in the reef and limestone terraces along the windward side of Bonaire.

Bonaire protects both its spectacular reefs and unusual species, such as the pink flamingo (*Phoenicopterus ruber*) and rare Bonairean parrot (*Amazona barbadensis rothschildi*). Also, a 13,500 acre game preserve has been set aside in the northern end of the island. But, studies on the various undisturbed biological communities on Bonaire are just beginning. Therefore, exploring and conducting research there was an exciting, unique opportunity. Several successful student projects as well as group field trips encompassed geological and biological aspects of Bonaire. The abstracts for student projects follow.

A second major stop was made in Port Royal, Isla de Roatan, where Dr. Charles McClennen joined R/V Westward as a visiting scientist. He provided an excellent lecture on the geology of the western Caribbean and Gulf of Mexico, which is summarized in the following pages, and directed studies on sediments near Roatan and the Florida Keys. Several possibilities for future studies aboard R/V Westward emerged from the preliminary sediment work.

Neogene and Quarternary Limestone Formations of Bonaire as Indicators of Holocene Sea Level Fluctuations

Brenda Sabbag

ABSTRACT

The Dutch Antillean island of Bonaire, located off the coast of Venezuela exhibits interesting Neogene and Quarternary geology. Data collected along the northeastern shore indicated several Pleistocene sea level fluctuations. Limestone cliffs investigated represent the Middle and Lower Terraces of the Seroe Domi formation of Quarternary age on the leeward side of the island. Slow emersion and/or sea level fluctuations are indicated by the morphology of the cliffs, erosional niches, and coral type, growth, and orientation.

Analysis of Beach Profiles from a Protected Windward and a Leeward Shore on the Island of Bonaire

Matt Tanzer

ABSTRACT

A series of beach transects were examined in each of two distinct environments on the island of Bonaire, Netherlands Antilles; one site was a protected windward shore and the other was a leeward shore. Beach profiles and sediment characteristics were analyzed in terms of incoming wave characteristics (Table 6). Closely-spaced, small, steep, wind-driven waves of the protected windward shore produced a washed out berm and an offshore sand bar. Longer period swells on the leeward shore contained less total energy which resulted in a wider berm. Berm height, however, was directly related to wave height (Fig. 10). No differences were found in the mean grain diameter or degree of sediment sortedness at the two sites. It was concluded that differences in wave characteristics not affecting sediment size distribution can affect berm shape.

TABLE 6: Wave characteristics at six beach transects on the island of Bonaire

Site / Transect	Protected Windward Shore			Leeward Shore		
Wave Period (sec)	1.20	0.99	0.96	6.5	6.8	6.0
Wave Length (cm)	168	161	156	1439	1380	1301
Wave Height (cm)	31	34	35	68	68	68
Wave Energy (J)	60	73	75	287	287	291
Wave Energy/Sec. (J/sec)	50	74	78	44	42	48
Wave Steepness (H/L)	0.18	0.21	0.22	0.05	0.05	0.05

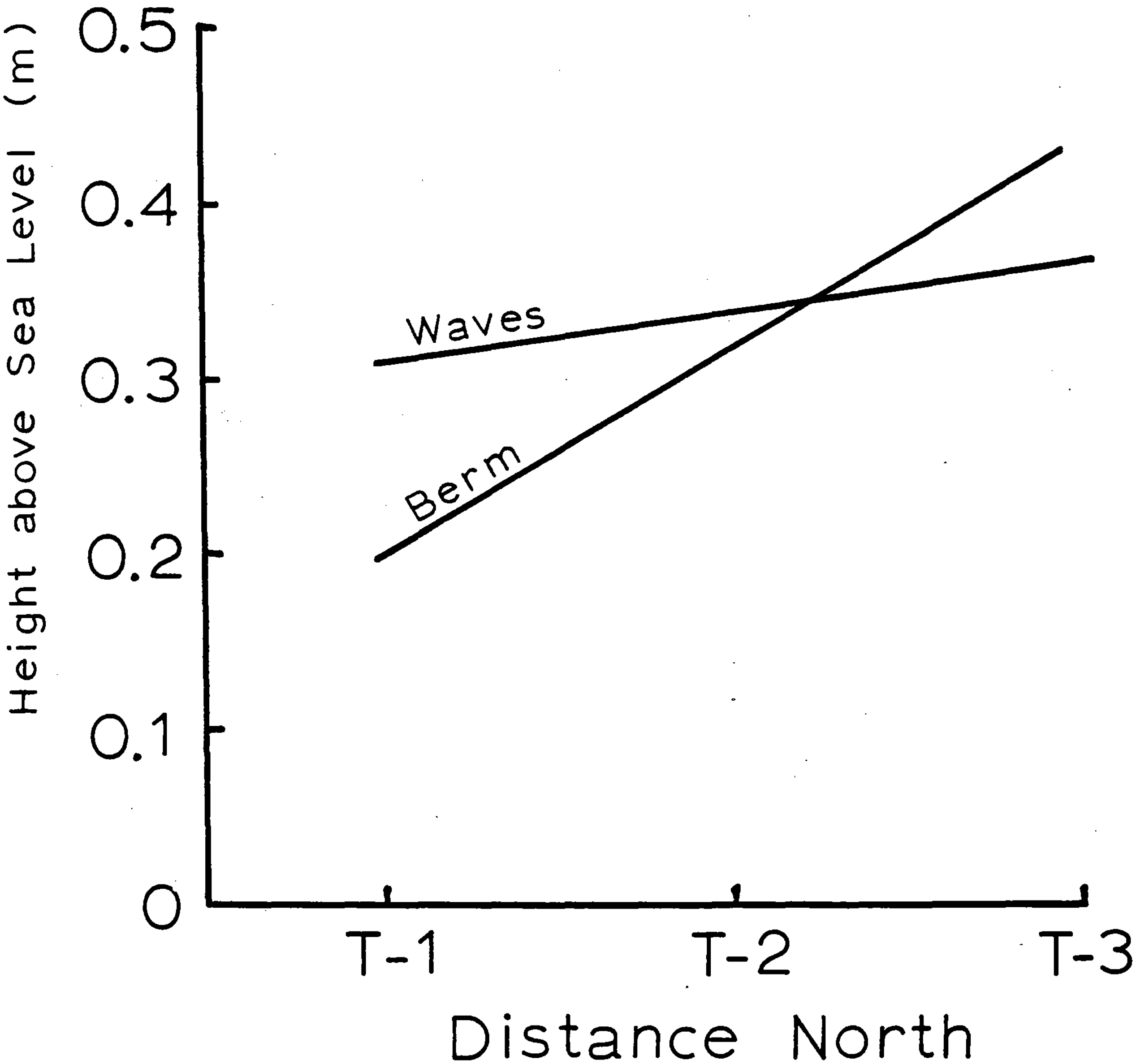

Figure 10: Relationship between berm height, wave height, and distance to the north on the protected windward shore of Bonaire.

The Leeward Reef Corals of Bonaire

Craig Timmins

ABSTRACT

Species of hermatypic corals and their densities were determined along the leeward reef of Bonaire, Netherlands Antilles. Quantitative and qualitative data were compared with other studies on windward and leeward reef development of stony corals in the Caribbean Sea. Each species found was common to leeward reefs of Caribbean islands. Density of individual species was also typical of these areas, except *Acropora palmata* (elkhorn coral) which was more abundant than that found in other localities. *Acropora palmata* accounted for 29% of all coral cover and was the dominant species observed in the leeward transect (Table 7). Aside from this possible exception, coral species, density, and zonation on Bonaire's leeward reef are typical of Caribbean reefs.

TABLE 7: Coral cover found on the leeward reef of Bonaire, Netherlands Antilles

Substrata	Zone 1 (0-0.5 m) depth	Zone 2 (0.5-2.5 m) depth	Zone 3 (2.5-10 m) depth	Zone 4 + 5 (10-34+ 34 m) depth	Total Zones 2 + 3)
% Coral Bottom	0	75	31	100	47
Coral Species	(% of coral cover)				
Acropora palmata	-	34	22	-	28.6
Porites porites	-	34	-		19.1
Millipora complamata	-	11	36	-	22.3
Diploria labyrinthiformes	-	9	6	No quantitative data	8.2
Araracia agaracia	-	8	3		1.7
Dendrogyra cylindrus	-	2	-	Dominated by	1.1
Montestrea annularis	-	2	6	hemispherical	5.2
Colpophyllia natans	-	-	13	corals and	5.5
Porites furcata	-	-	7	gorgonians	2.9
Porites astreoides	-	-	2		5.2
Madracis decactis	-	-	3		1.4
Siderastrea radians	-	-	1		0.8

Windward and Leeward Effects on Intertidal Zonation on the Island of Bonaire

Cari Sasser

ABSTRACT

The southwest and southeast shores of Bonaire, Netherlands Antilles, were the focus of a study of windward and leeward effects on the zonation of macroscopic flora and fauna in the rocky intertidal zone. Fauna were analyzed quantitatively using a transect method; flora were analyzed qualitatively. The leeward shore showed a significantly higher number of molluscs, primarily in the upper intertidal. These grazers appeared to prevent the growth of seaweeds in that zone. The windward transect contained few animals, and urchins made up the majority of those present. Both transects showed an increase in the abundance of algae in the seaward direction, and the leeward shore demonstrated a seaward increase in species richness. Algal zonation was similar on the windward and leeward shores, but similar assemblages occurred closer to the spray zone at the windward site (Fig. 11).

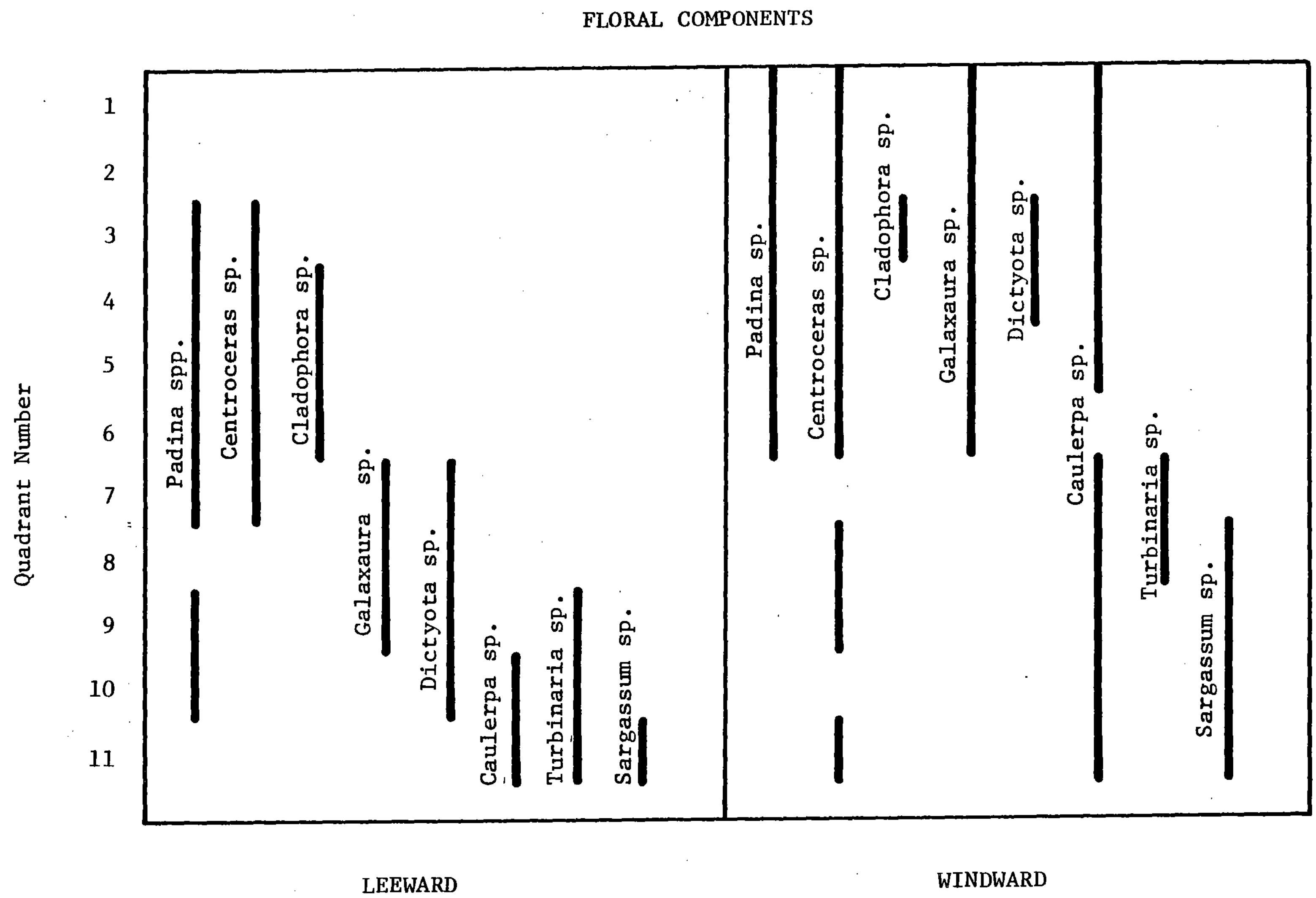

Figure 11a: Distribution of macroalgae on the windward and leeward shores of Bonaire. Quadrants are 0.25 m intervals extending down from the most shoreward biota.

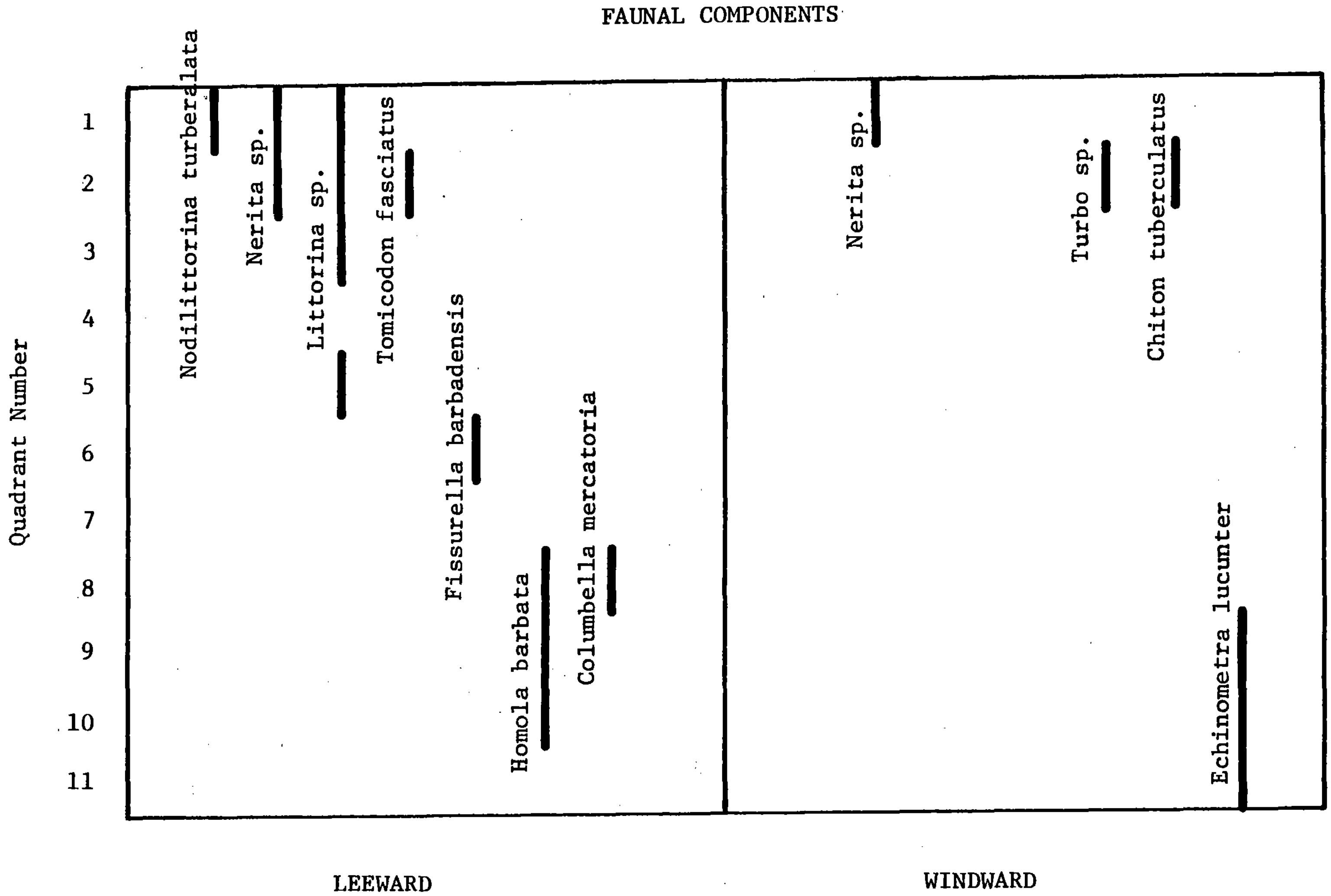

Figure 11b: Distribution of macrofauna on the windward and leeward shores of Bonaire. Quadrants are 0.25 m intervals extending down from the most shoreward biota.

The Interrelationship of the Physical, Chemical and Biological Components of the Salinas of Bonaire

Jeanne Mullin

ABSTRACT

Salinja Foehsji, Salinja Lac, and the Pekelmeer salt works on the island of Bonaire, Netherlands Antilles, were examined to determine the effect of varying salinities on the ecological organization of each salina. Natural, life-supporting salinas had salinities as high as 140 ^{o}/oo. Man-made salt ponds at the Pekelmeer salt works had salinities up to 330 ^{o}/oo. Pond salinities were a function of elevation and oceanic influx. The salinities of the ponds affected the types and distribution of both flora and fauna in and around the ponds. Abundances of the brine fly and brine shrimp were directly related to pond salinity. These abundances, in turn, appeared to influence the number of flamingos observed feeding in each salina (Table 8).

TABLE 8: Physical and biological characteristics of three major salinas in Bonaire, Netherlands Antilles

Salina	Salinity ($^{o}/00$)	Physical Description	Biological Components
Salinja Foehsji	136	Elevation - High Soil - Dry Isolated from Ocean	Flora - Bare shoreline Diverse flora (cactus) at greater distance. Fauna - Abundant brine shrimp, flamingos.
Salinja Lac	59.7	Elevation - Low Soil - Wet Isolated from Ocean	Flora - Sparse; Marsh grass. Fauna - No brine shrimp; No flamingo.
Salinja Lac extension	39.3	Elevation - Low Soil - Wet Possible intrusion of seawater	Flora - Heavily vegetated. Mangroves, vegetated shoreline. Fauna - Abundant small fish, crabs, ocean fauna.
Pekelmeer - Natural Salina	38.3	Elevation - Low Soil - Wet Direct ocean access	Flora - Sparse - marsh grasses. Fauna - No brine fly.
Pekelmeer - Condensers	45-231	Man-made evaporating ponds Mud bottom	Flora - no macroflora. Fauna - Brine fly abundant. Flamingos.
Pekelmeer - Crystalizers	329	Man-made evaporating ponds Bottom - salt (gypsum, carbonate)	Flora - no macroflora. Fauna - no macrofauna.

Western Caribbean and Gulf of Mexico Geology: A Summary of Tectonic and Sedimentary Development

Charles E. McClennen
Department of Geology
Colgate University, Hamilton, New York

The Permo-Triassic separation of North America and South America probably initiated the formation of the Gulf of Mexico and the Caribbean basins. The Gulf basin formed by a process of continental crust extension and thinning (18-25 km) with normal block faulting. The western Caribbean is floored in contrast by basaltic seafloor crust. Thick (1^+ km) Early Jurassic shallow basin evaporites accumulated in the Gulf region prior to the 2-3 km of Late Jurassic and Cretaceous clastic sediments. Presumed oceanic crustal subduction under Cuba shifted during the Jurassic with the trench initially to the south (i.e. Caribbean sea floor subduction) and subsequently a new trench developed with Atlantic oceanic crust subduction down on the northern side of the Greater Antilles arc. The Cretaceous of the region is marked by the thick (up to 4-5 km) shallow water carbonate deposits of the Bahama, Florida, and Yucatan platforms, which exhibited rapid, simultaneous subsidence. The Mid-Cretaceous unconformity is noted in seismic reflection data from both the Gulf and adjacent carbonate platforms.

The Late Cretaceous to Plaeocene "Laramide Orogeny" is expressed in continued subduction from the north under Cuba and also a new trench developed in the Yucatan Basin on the northwest side of the Cayman Ridge and Nicaraguan Rise. Dredged samples from these latter two areas of continental crust show the volcanic and plutonic petrology typical of subduction regions.

Cenozoic clastic sedimentation has subsequently accumulated at a declining rate as expected with the discontinuation of subduction in the immediate region. Reduced rates of subsidence also inhibited carbonate accumulation on the platforms. In the Eocene, world-wide adjustments in plate motion converted the North American/Western Caribbean plate boundary from compressional to a dominantly left lateral transform with some extension. The deep water Cayman Trough contains the east-west spreading center that continues to produce oceanic crust as the Cayman Ridge and the Nicaraguan Rise separate. The volcanics and associated epicenters show the typical oceanic crustal ridge and transform fault characteristics. Likewise bathymetric depths, sediments, spreading rates, and age relationships are consistent with this interpretation and account for the eastward displacement of Honduras (including Roatan) and the Nicaraguan Rise (Caribbean plate) relative to Belize, Cuba, and the Cayman Ridge (American plate).

The next major change occurred in the Miocene when the Middle American Trench and the Central American volcanic arc displayed rapid development, including the formation of the land mass of Panama. Thus the Miocene intensification of the Gulf Stream is explained by diversion of the Equatorial Atlantic flow from its former continuation into the Pacific, between Nicaragua and South America. With the development of the Central American volcanic arc and Gulf Stream intensification, the regional sedimentation was modified. Clastic sediments from the west increased and greater volumes of warmer water scoured the carbonate bottom in the Straits of Florida. Finally the Pleistocene glaciation shifted the clastic sediment sources from the west to the north in the Gulf of Mexico. The Mississippi River drainage of central North America brought huge volumes of glacial outwash to the continental margin and deeper parts of the Gulf.

Surface Sediment Samples: Size and Composition

Charles E. McClennen
Dept. of Geology
Colgate University, Hamilton, N.Y. 13346

Sediment samples were taken at four stations by one or more of the following: grab sampler, gravity correr and underway sampler. The four stations were: Port Royal Harbor at Roatan, the Honduras shelf south of Roatan, a dredge spoil dump site off Key West, Florida and a more "natural" site a couple of miles to the east of the Key West dump site. All samples were taken in the 20 to 35 fm depth range to eliminate one variable. The samples were oven dried, sifted, measured for volume percent (instead of weight %) because of the problems of weighing accurately while underway at sea. Treatment of modal subsamples with 10% HCl indicate the predominance of carbonate. The only non-soluble fraction occurred in the silt to clay size of the Port Royal samples, indicating that insoluble clays derived from Roatan Island may be present.

Examination of about 100 grains of 0.125 to 0.5 mm fractions from all four sites shows the sharp contrast in microfossil abundance and assemblage. Port Royal contains at least 3 benthic Foraminifera species and one snail (half a dozen individuals). Coralgal fragments make up over half of the grab samples. The Honduras shelf contains at least 10 species of benthic and planktonic forams, 4 species of snail, sponge spicules and several other species of microfossils (50 individuals). The *Halimeda* plates dominated the bulk of the sample and constituted > 90% of the coarsest fraction. Both samples from off Key West were dominantly ooids, with only a couple of species of forams at the "natural" site. Coralgal fragments were second to the ooids in abundance off Key West.

This preliminary surface sampling report provides some guidance to future students interested in projects on sediments and microfossils. This work can be easily conducted from R/V *Westward*.

Plankton Ecology in the Caribbean Sea

The Caribbean Sea is generally believed to be a warm, homogeneous body of water which slowly flows from east to west, from the Lesser Antilles to the Yucatan Strait. A major goal of R/V Westward cruise W-61 was to demonstrate that the Sea is not homogeneous but includes several distinct water masses, in terms of both physical and biological oceanography. The significance of small scale eddies, the Cariaco Trench, and the influx of Amazon River water into the Caribbean Sea were discussed in an earlier section of this report. This section will deal primarily with variation in the plankton communities of the Caribbean epipelagic zone, and how this variation is related to the physical oceanography of particular areas.

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 regulating mechanisms. Of course the organisms themselves also affect the concentration of nutrients in the water column. All of these features play a major role in the observed patterns of plankton variation in the Caribbean Sea.

Islands in the Caribbean Sea are a source of nutrients for two reasons: 1) The larger islands with high elevation such as those in the Windward group provide significant runoff of freshwater which carries nutrients from the soils. 2) Where a current flows past an island, turbulence and eddies are usually formed on the leeward side of the island; this is particularly pronounced to the leeward of the Windward group where strong currents flow through the passages. Turbulence frequently promotes regeneration of nutrients from the bottom or from deeper water masses by weakening the thermocline and increasing the mixed layer. Eddy formation and increased biological productivity to the west of St. Lucia and St. Vincent is well documented.

Another important and well-known source of high productivity in the Caribbean is the upwelling zone north of Venezuela. The high productivity zone takes in a wide area extending from north of the Paria Peninsula and Margarita Island to the Gulf of Venezuela and the Netherlands Antilles to the west. The upwelling off Venezuela is not particularly deep, bring only Subtropical Underwater to the surface, but is sufficient to produce a lively fishing industry in a sea characterized by low productivity.

In contrast with the Venezuelan upwelling region, the center of the Caribbean is probably a site of sinking water or downwelling (Fig. 12). This is a nutrient poor region characterized by low biological productivity.

A continuous bathythermograph profile was constructed along the first three weeks of cruise W-61 to help locate sites of turbulence, upwelling, and downwelling. Additionally, these data were useful in explaining some of the biological phenomena discovered at various points along the cruise track. Although the thermal profile did not appear to show a direct relationship with the location of islands (Schmitt, this report), large scale variation in mixed layer depth, surface temperature, and surface salinity was clearly evident (Fig. 13). Mixed layer depth was relatively stable on the leeward side of the Lesser Antilles at between 180 and 200 feet. Temperature was relatively stable at 28.1 to 28.5° C and surface salinity was constant at 35.5 $^{o}/oo$. Upon approach to Margarita Island and the Venezuelan upwelling the mixed layer rapidly decreased to between 40 and 80 feet in depth, temperature decreased to 25.5° C, and salinity increased to 36.9 $^{o}/oo$ at several points. Presence of these characteristics are clear evidence of the upwelling of Subtropical Underwater from a depth of approximately 150 m (see Table 4). Also, the thermocline in the upwelling area was much weaker than that found in the central Caribbean or along the Lesser Antilles (Fig. 14). The depth of the mixed layer increased to a maxima in the central Caribbean, and surface temperature increased to a stable 28.1° C. Salinity showed a minimum value near the Dutch Antilles, then increased to between 35 and 36 $^{o}/oo$ in the central Caribbean Sea. Going west to Swan Island and Roatan, Honduras, mixed

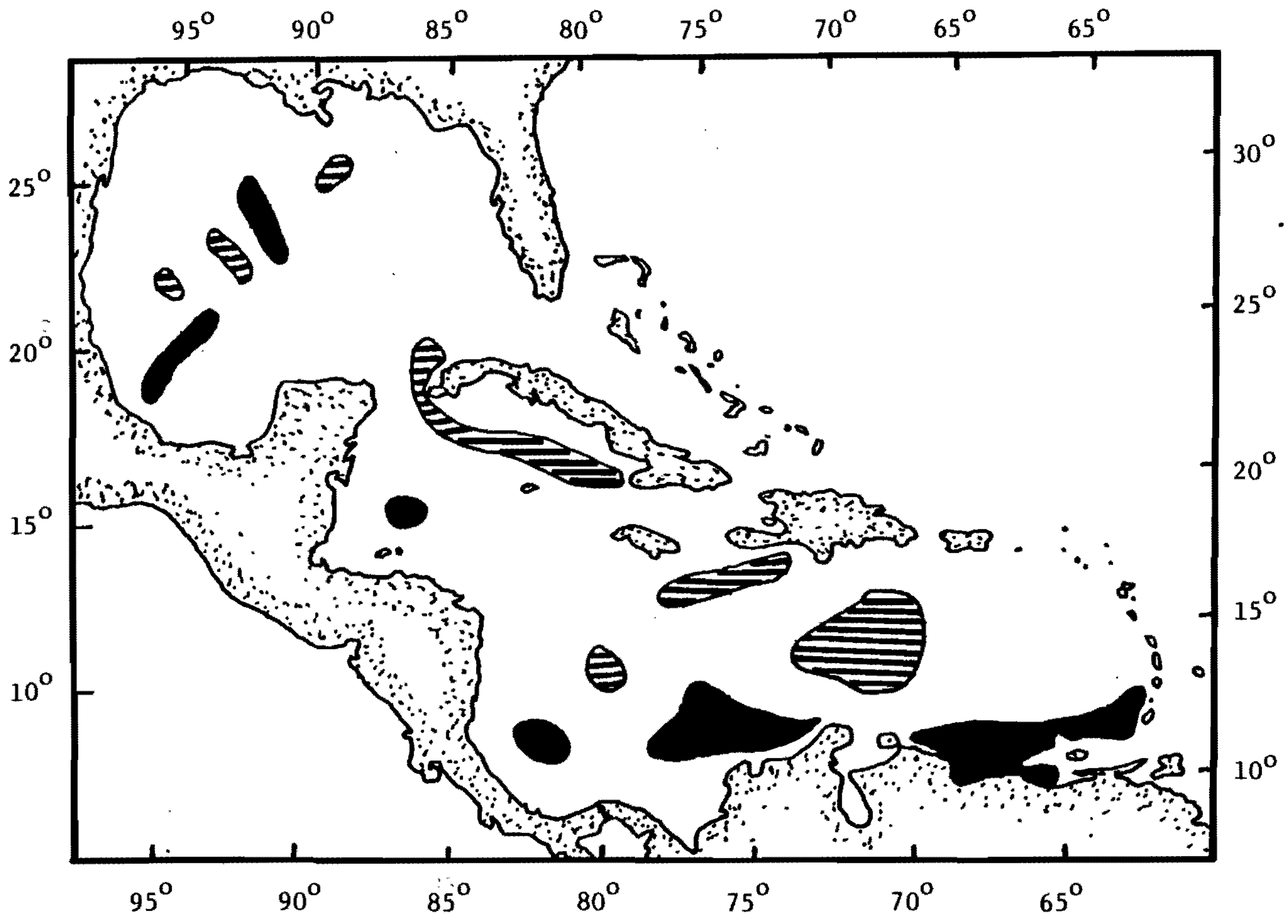

Figure 12: Hypothesized areas of upwelling (black) and downwelling (cross-hatched) in the Caribbean Sea and Gulf of Mexico, based on dynamic topography (based on Margalef, 1968).

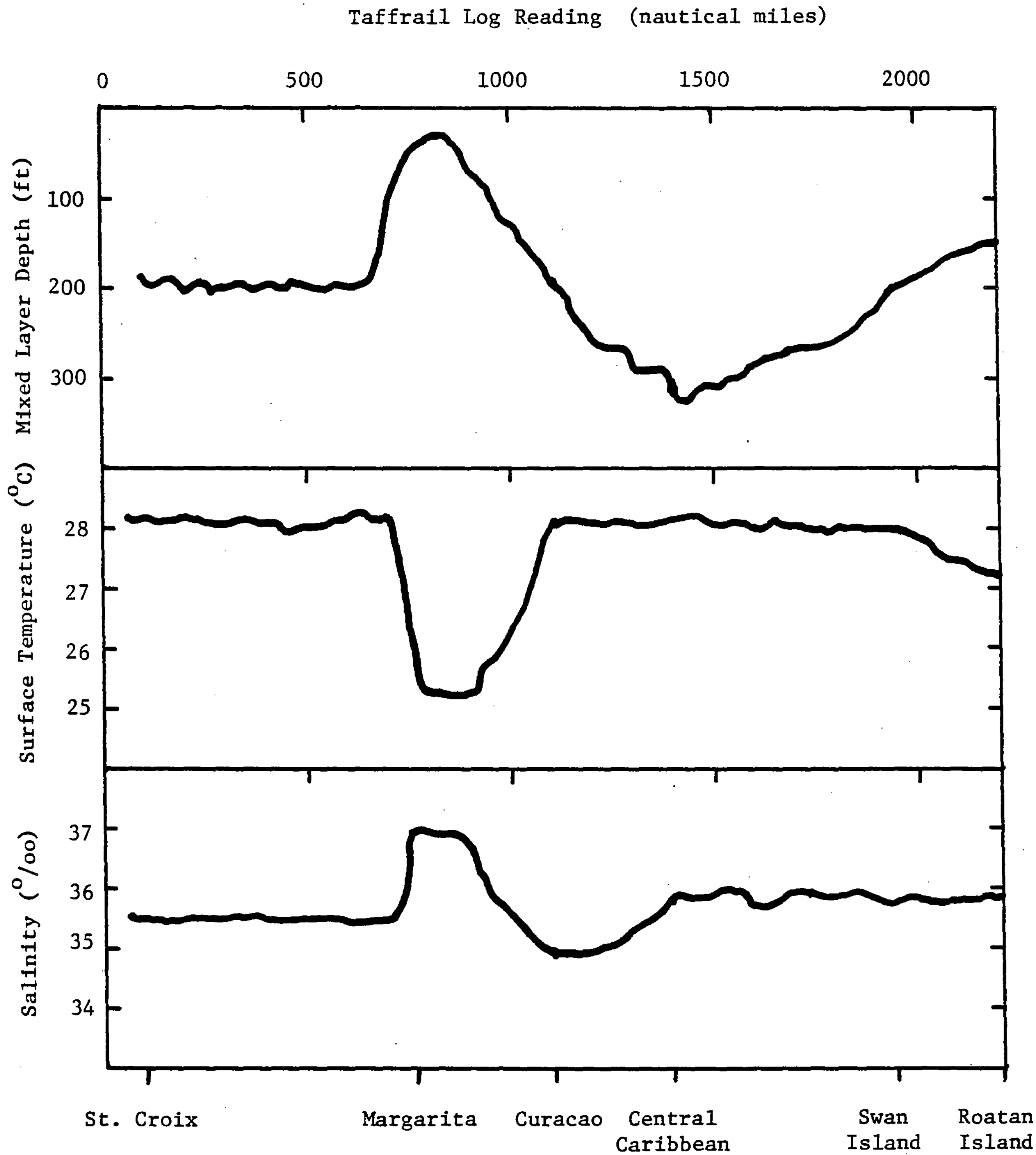

Figure 13: Mixed layer depth, surface temperature, and surface salinity along R/V *Westward* cruise W-61.

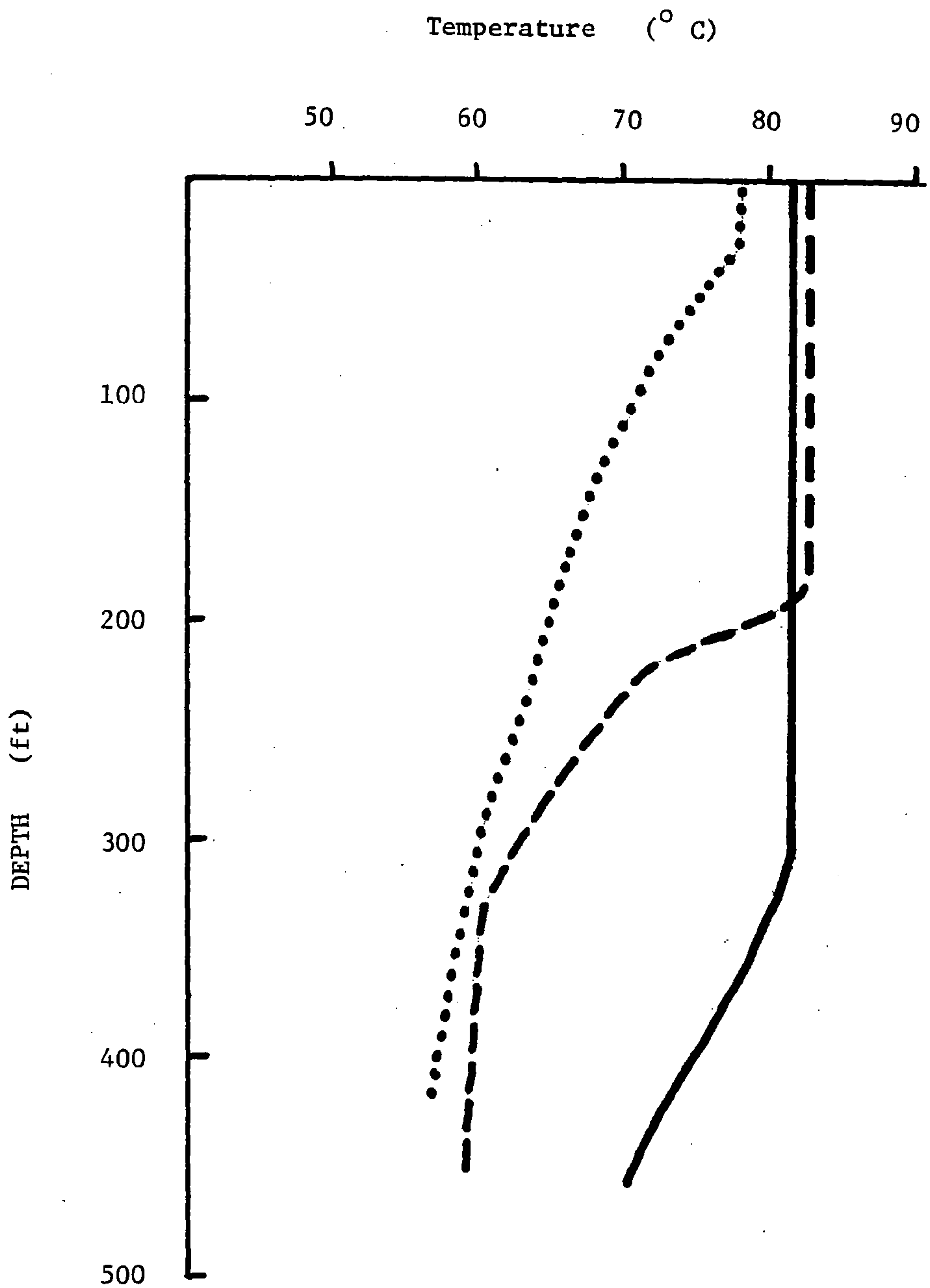

Figure 14: Thermal profiles typical of the Venezuelan upwelling (dotted line), west of the Lesser Antilles (dashed line), and in the central Caribbean Sea (solid line).

layer depth decreased again to near 150 feet and surface temperature decreased to 27.2° C. These data suggest that localized upwelling or turbulence may occur to the south of Isla de Roatan, although zooplankton biomass was not particularly high there (Table 9).

Highest zooplankton biomass (10.90 $ml/100m^3$) was found near Islas Los Roques, a small group of islands north of the Gulf of Venezuela. This high standing crop appeared to be related to a very shallow mixed layer, low surface temperature, and the close proximity to shallow reef habitats. Zooplankton biomass was also particularly high in the Venezuelan upwelling near Margarita Island (6.33 $ml/100m^3$), but low over the Cariaco Trench (2.06 $ml/100m^3$), suggesting that water depth is of great importance in water column productivity. Other areas of high productivity were near Swan Island, Honduras (3.93 $ml/100m^3$), and St. Lucia (3.83 $ml/100m^3$) (see Schmitt). Depth, water temperature, and mixed layer depth all appear to play an important role in governing zooplankton standing crop in the Caribbean Sea.

Numerous student projects dealt with aspects of plankton ecology in the Caribbean. Schmitt examined zooplankton biomass and composition in the lee and in the passes near the Lesser Antilles, Cunningham studied zooplankton diversity in four discrete biological zones along the W-61 cruise track, Low examined the relative abundance of the Chaetognatha at numerous sites in the Caribbean in an attempt to explain predator-prey relationships in the water column, and Corzine attempted to predict the abundance of ichthyoplankton based on water column chemistry and several other factors at seven sites. Goffinet showed how deep chlorophyll maxima are related to nutrient availability and the physical oceanography of the water column in the Venezuelan upwelling and central Caribbean waters, and in a closely related study, Waters examined the vertical migration of zooplankton in the two areas and how those patterns were related to the chlorophyll maxima. The abstracts for all of these studies follow.

TABLE 9: Physical-chemical factors and zooplankton biomass at several major sties in the Caribbean Sea. Data for the Lesser Antilles are ranges of values based on six stations

Site	Mixed Layer Depth (ft)	Temperature (C)	Zooplankton Biomass (ml/100m^3)
West of the Lesser Antilles	180-200	28.1-28.5	1.50-3.83
Margarita Island	40-80	25.5	6.33
Cariaco Trench	50	27.2	2.06
East of Los Roques	60	27.2	10.90
West of Los Roques	130	28.0	2.98
Central Caribbean	280-320	28.1	0.55
Swan Island	200	27.5	3.93
Roatan Island	150	26.5	3.40
Yucatan Strait	340	27.0	2.94

Island Mass Effects on Zooplankton Productivity

Deborah Schmitt

ABSTRACT

To test for the effects of island masses on zooplankton abundance and community structure a series of stations were sampled and bathythermograph casts were made in the lee of the Lesser Antilles between Guadeloupe and the Grenadine Islands (Fig. 15). A continuous bathythermograph profile showed no island-related thermal structure in the upper 500-900 feet of the water column, but zooplankton biomass showed significant increases in the passes between islands and decreases directly to the west of islands (Table 10). Biomass values were inversely related to the depth of the mixed layer as revealed by the bathythermograph profile. Additionally, the relative abundance of shrimp, euphausiids, and larger macrofauna appeared to be inversely related to the depth of the mixed layer. This, in addition to the biomass values, indicates the high productivity of areas characterized by shallow mixed layers and weak thermoclines.

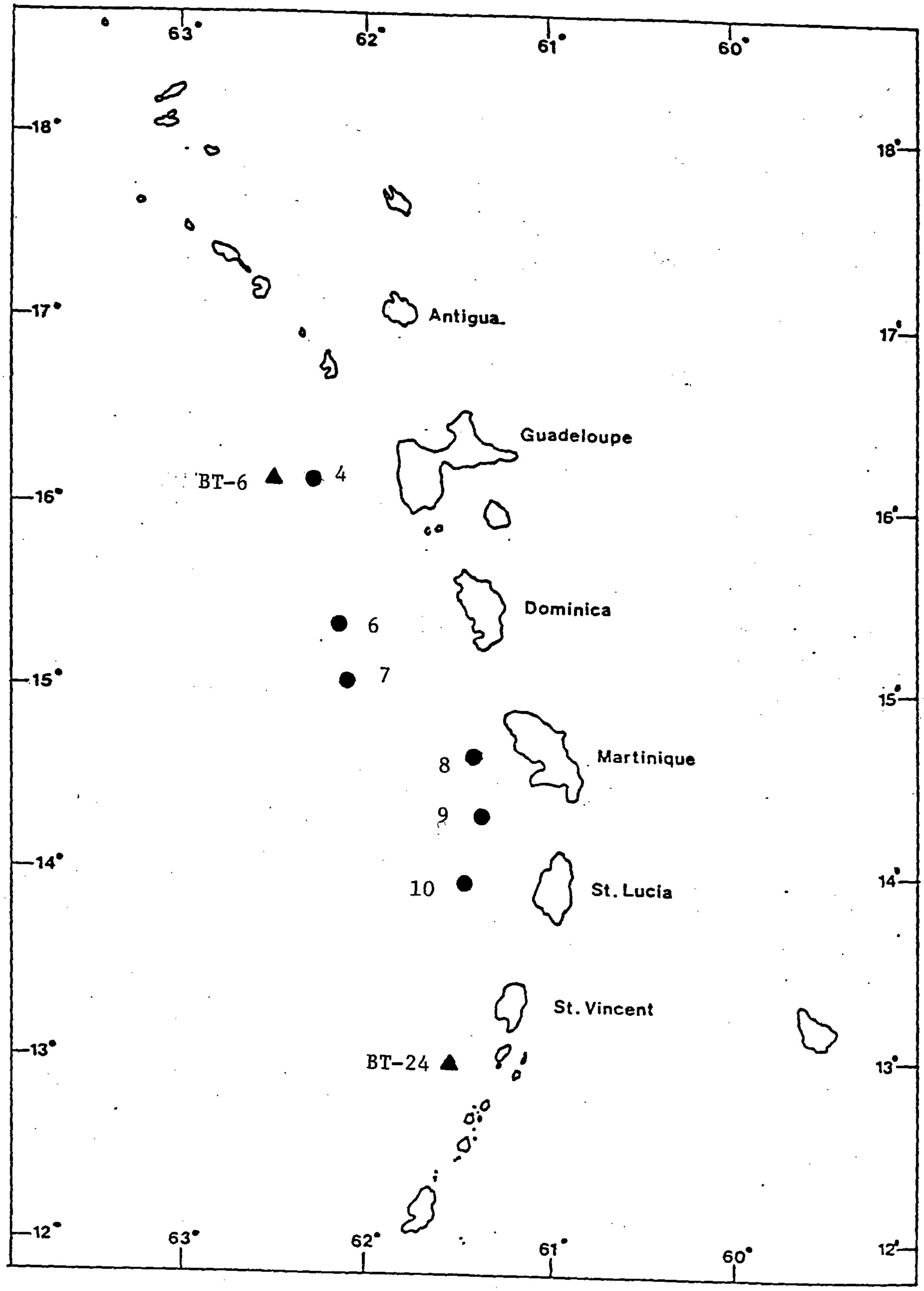

Figure 15: Stations where plankton tows were taken (circles). A continuous bathythermograph profile was made from BT-6 to BT-24.

TABLE 10: Abundance and composition of zooplankton at six stations to the west of the Lesser Antilles

	Station					
	W61-4 Guadeloupe	W61-6 Dominica	W61-7 Dominica Passage	W61-8 Martinique	W61-9 St. Lucia Channel	W61-10 St. Lucia
Total Biomass ($ml/100m^3$)	2.49	2.76	3.02	1.50	3.78	3.83
Copepods (% total)	41	33	19	51	56	35
Euphausiids (% total)	13	11	0	2	8	6
Chaetognatha (% total)	9	7	16	36	16	3
Shrimp (% total)	18	17	12	3	12	26

Productivity and Diversity of Zooplankton at Four Sites in the Caribbean Sea

Julie Cunningham

ABSTRACT

Within the Caribbean Sea several distinct oceanographic zones exist. This study was designed to examine zooplankton biomass and diversity at different depths in four geographic regions of the Caribbean: 1) the upwelling area north of Venezuela, 2) the nutrient and phytoplankton poor central Caribbean, 3) the leeward side of Martinique, and 4) west of the Grenadine Islands.

Zooplankton biomass varied significantly (Table 11) but was not a simple function of upwelling as indicated by bathythermograph profiles. Biomass also tended to decrease with depth while diversity increased with depth, suggesting an inverse relationship between the two factors. Increasing diversity with depth may be a result of increasing environmental stability and/or decreasing productivity.

TABLE 11: Biomass, diversity, and species composition of zooplankton at four sites in the Caribbean Sea. Shannon-Weiner Index (H') was calculated using percentages of major taxonomic groups

	% of Total Count					Total Taxonomic Groups	Diversity (H')	Biomass ($ml/100m^3$)
	Copepods	Euphausiids	Shrimp	Chaetognaths	Others			
Martinique								
Surface	75.1	0	3.4	17.6	3.9	7	0.35	7.2
60 m	72.4	1.3	5.7	15.2	5.4	10	0.40	2.3
150 m	72.7	7.3	3.4	10.4	6.2	9	0.45	1.3
Grenadines								
Surface	81.5	1.1	4.8	7.3	5.3	9	0.28	5.0
60 m	81.1	1.6	1.1	2.4	13.8	6	0.31	6.3
150 m	73.2	3.8	12.1	3.8	7.1	9	0.44	2.2
Upwelling								
Surface	48.0	1.0	1.6	2.4	47.0	9	0.60	2.2
40 m	85.7	1.9	0.9	3.8	7.7	7	0.23	6.1
80 m	61.8	1.8	8.2	1.2	27.0	8	0.60	2.3
120 m	43.1	9.2	14.6	13.8	19.3	11	0.77	2.8
Central Caribbean								
Surface	66.2	4.5	6.0	7.5	15.8	7	0.46	8.1
40 m	68.6	2.0	2.0	11.8	15.6	9	0.41	6.5
80 m	67.9	4.4	5.1	9.5	13.1	9	0.46	4.3
120 m	69.5	6.8	5.9	4.2	13.6	9	0.52	2.7

Predator-Prey Relationships in the Water Column: A Study of Chaetognath Distribution

Steve Low

ABSTRACT

The abundance of Chaetognatha was examined at eleven sites in the Caribbean Sea in an attempt to explain the geographic distribution of animals in that phyla. Primary emphasis was placed upon interpreting the ecological relationship between the Chaetognatha which are carnivorous planktivores and total zooplankton abundance. A weak but general trend of increasing chaetognath abundance with decreasing total zooplankton biomass was observed indicating that the predators may limit the abundance of smaller fauna. This trend also held for the relationship between chaetognaths and copepods (Fig. 16). Considerable variation in the relationship appears to be related to geography, differing physical-chemical factors, and species composition of the zooplankton. This suggests that predator-prey ratios in the water column are mediated simultaneously by many different physical and biological factors, and that the mechanisms which govern chaetognath distribution are particularly complex.

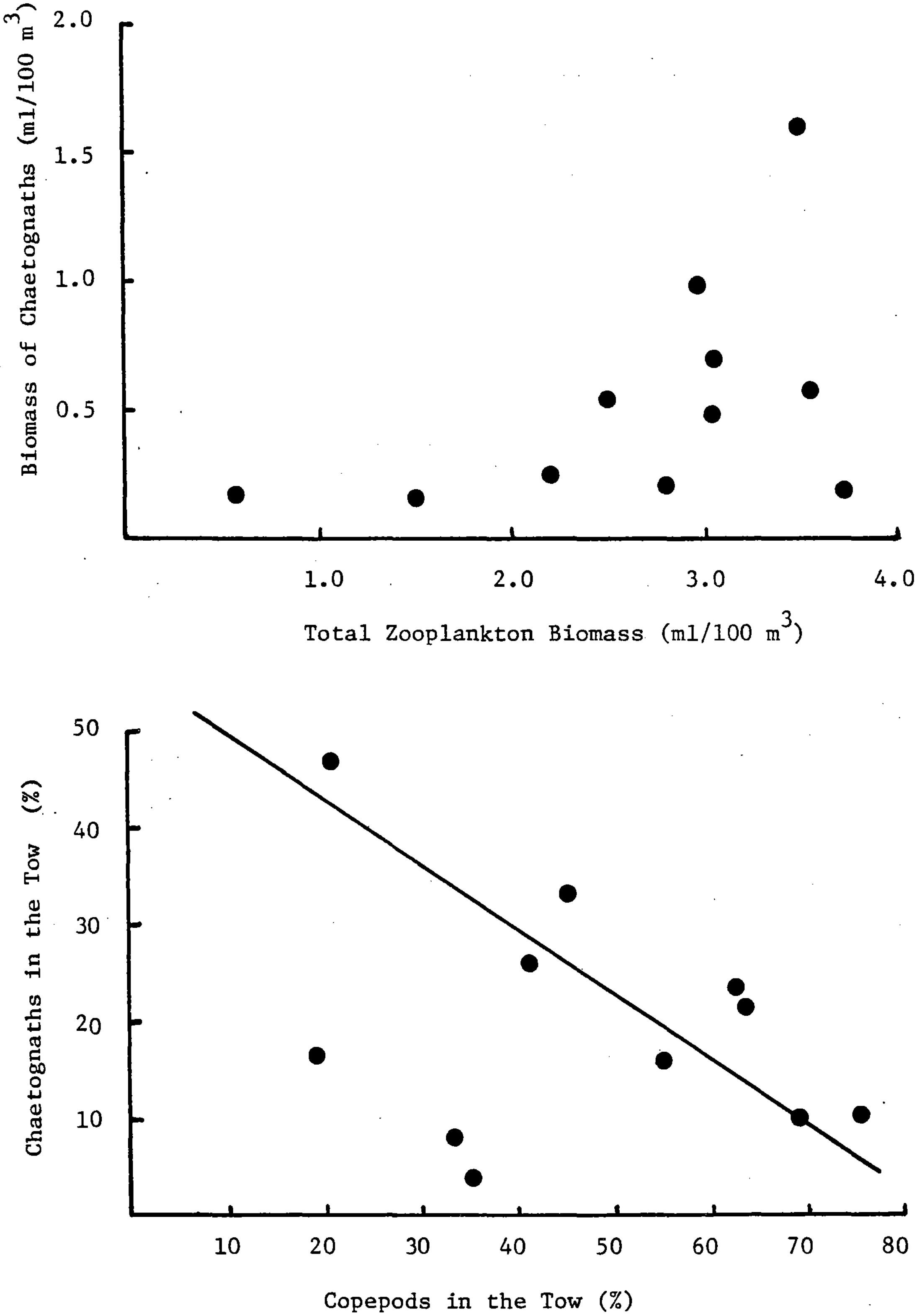

Figure 16: Biomass of chaetognaths shown as a function of total zooplankton biomass (top), and relative abundance of chaetognaths shown as a function of abundance of copepods.

Abundance of Fish Larvae and Eggs in the Caribbean Sea

Darik Corzine

ABSTRACT

The success of international marine fisheries depends largely upon the reproductive success of the fishes and the distributional ecology of the eggs and larvae. In this study an attempt was made to predict the abundance of fish eggs and larvae at seven distinct geographical locations in the Caribbean Sea. Highest larval counts were found on the shallow shelf south of Isla de Roatán, Honduras (59/100m^3) and in the St. Lucia Channel (33/100m^3). Lowest counts were found near Martinique (7.5/100m^3) and in the central Caribbean (9.2/100m^3) (Fig. 17). Abundance of ichthyoplankton was only weakly correlated with any one of the following ecological factors; however, in combination these data permitted a relatively accurate prediction of larval stocks: water depth, temperature, current, and zooplankton biomass. Larvae abundance appeared to be most closely correlated with total zooplankton biomass. It was suggested that seasonal patterns in abundance and distribution should be examined before major generalizations are made concerning the mechanisms which regulate fish distribution in the Caribbean Sea.

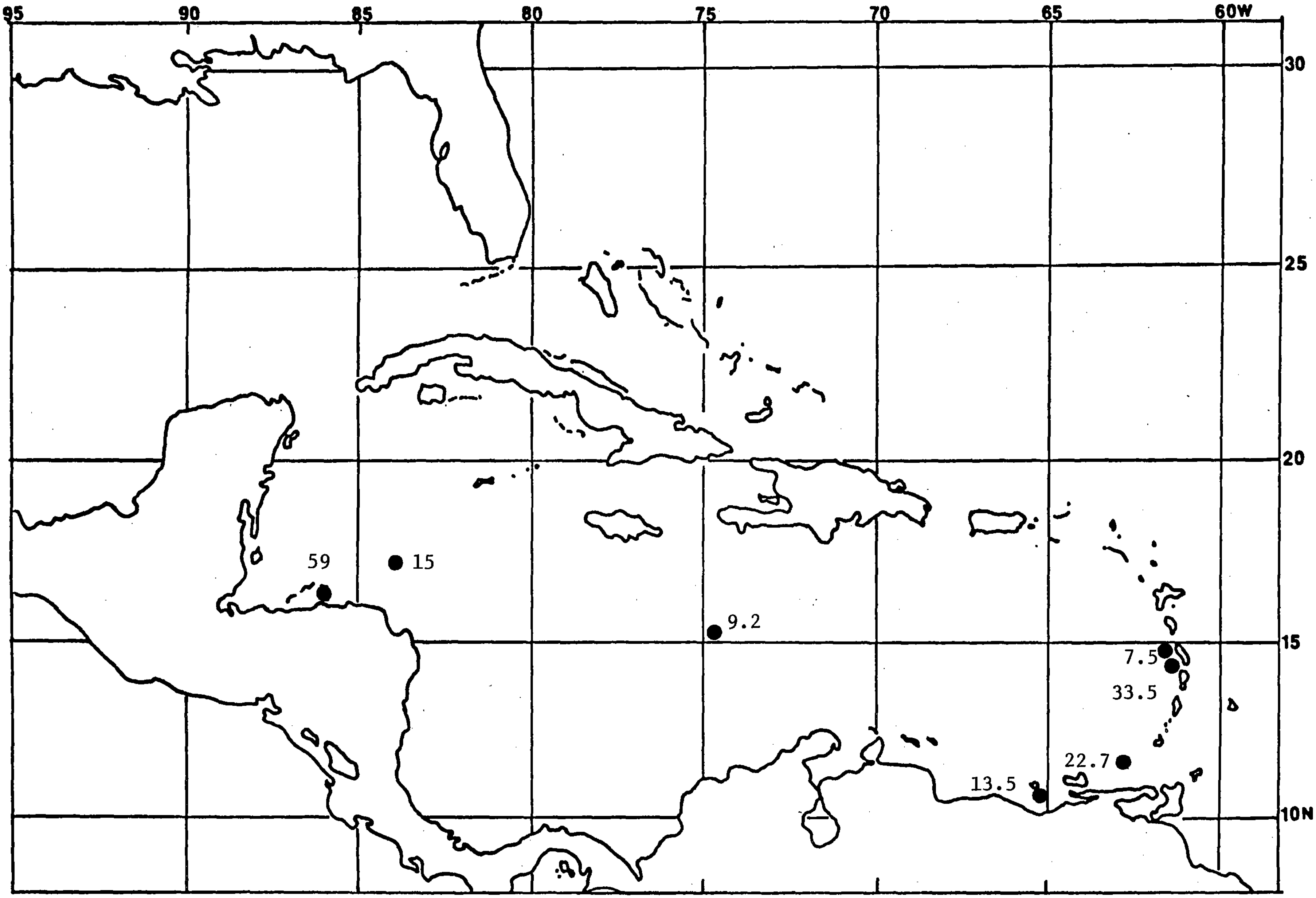

Figure 17: Abundance of fish larvae at seven sites in the Caribbean Sea. Values beside the points are numbers of larvae per 1000 m^3.

Differences in the Depth of the Chlorophyll Maximum in the Caribbean Sea

Tom Goffinet

ABSTRACT

The depths of chlorophyll maxima at two stations in the Caribbean Sea were examined in December, 1981. One station was located in the upwelling zone north of Venezuela and the other in the downwelling zone of the mid-Caribbean. Deep chlorophyll maxima were found at both sites; these levels were related to deep maxima in nutrients (phosphates and ammonium) (Fig. 18). Abundance and distribution of nutrients appeared to be related to hydrographic conditions, primarily the depth of the mixed layer and strength of the thermocline. No correlation was found between salinity, dissolved oxygen, or Secchi depth and chlorophyll concentration or depth. Relationships between phytoplankton productivity and chlorophyll pigments were discussed.

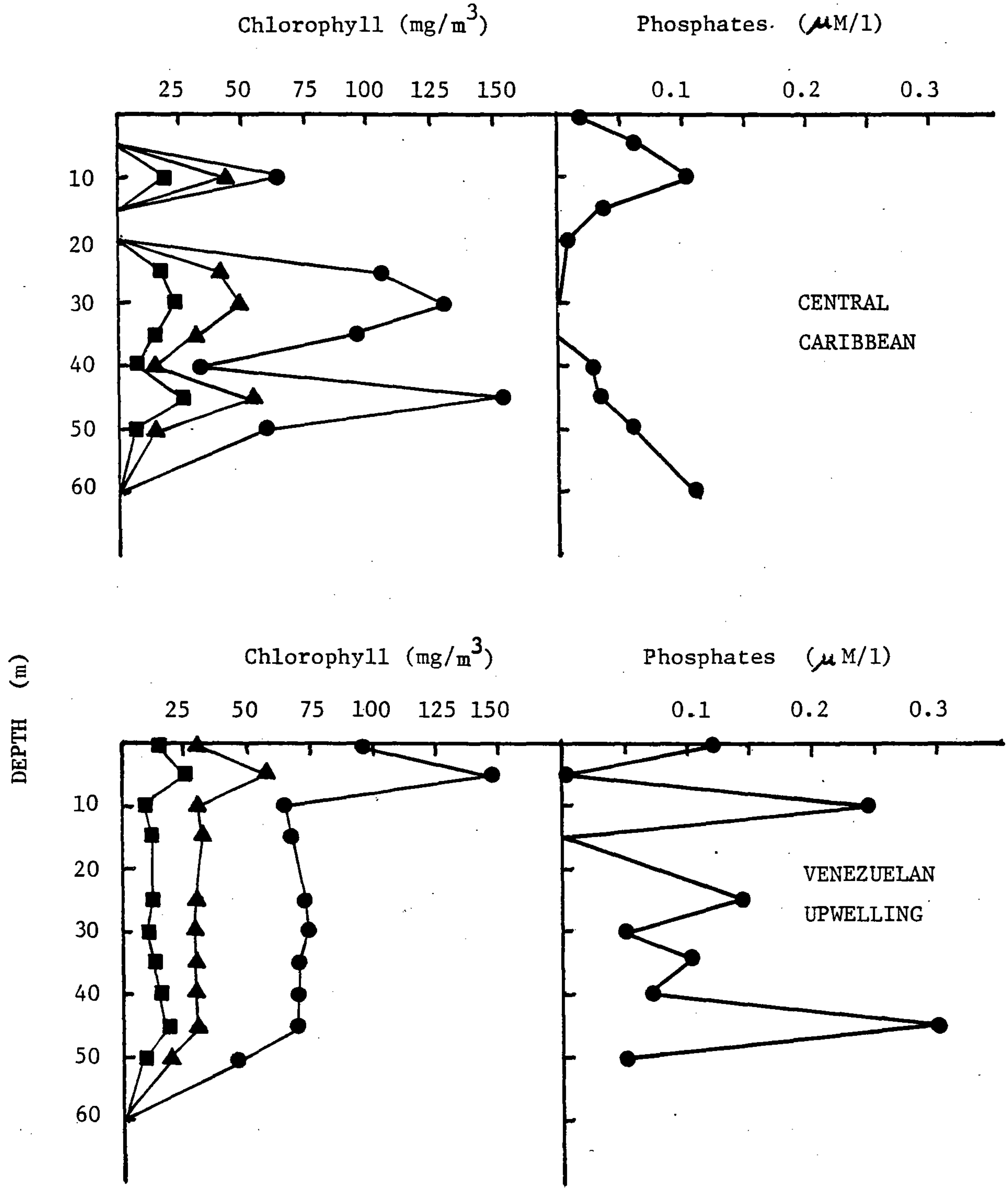

Figure 18: Concentration of chlorophyll and phosphates in the central Caribbean Sea (top) and at the Venezuelan upwelling zone (bottom). Chlorophyll-a = triangles, chlorophyll-b = squares, chlorophyll-c = circles.

Vertical Migration in the Zooplankton of the Caribbean Sea

Mike Waters

ABSTRACT

Patterns of vertical migration in zooplankton are poorly understood but generally believed to be stimulated by changes in ambient light. In this study a comparison of vertical migration in the Venezuelan upwelling and central Caribbean Sea was made. Zooplankton were collected at mid-day and at mid-night from four different depths. Special attention was given to the role of thermocline depth, nutrient availability, oxygen concentrations, and chlorophyll concentrations in controlling the range and intensity of vertical migration. Increasing zooplankton biomass in near surface tows provided clear evidence for vertical migration in both study sites (Fig. 19). Most dramatic shifts in vertical distribution occurred at the central Caribbean site although total biomass of zooplankton was slightly higher at the Venezuelan upwelling. Vertical distribution was closely correlated with the levels of chlorophyll in the two areas; peak zooplankton biomass tended to coincide with deep chlorophyll maxima (Fig. 19). Consequently, geographic differences in the distributional ecology of the zooplankton may be related to biotic factors. Additionally, increases in taxonomic richness with depth were observed at both sites; this may be related to environmental stability in the deep ocean.

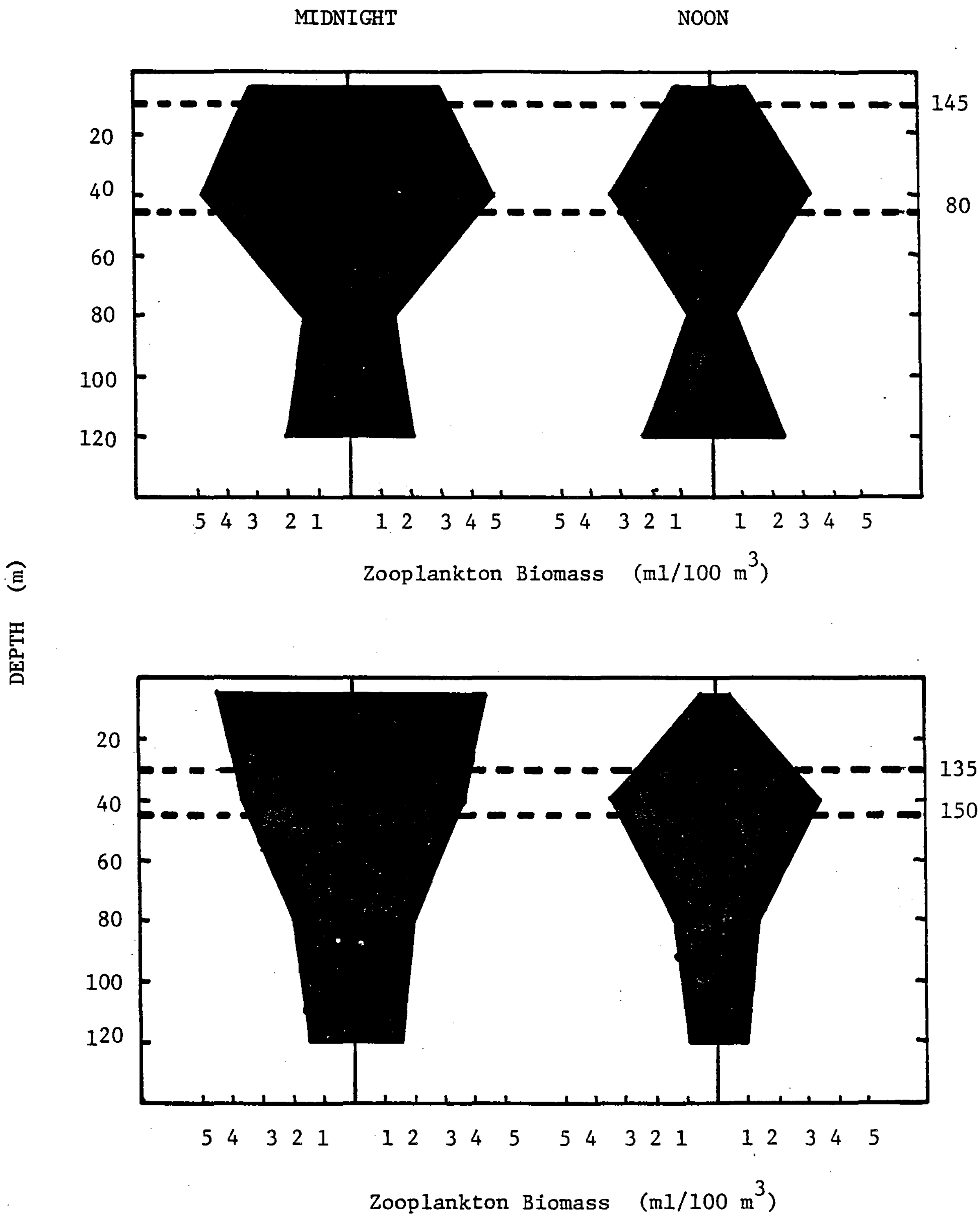

Figure 19: Vertical migration of zooplankton shown as kite diagrams, for the Venezuelan upwelling (top) and the central Caribbean Sea (bottom). Horizontal dashed lines represent the depths of chlorophyll maxima at the sites. Values to the right are chlorophyll concentrations in mg/m^3.

Biology of the Pelagic Zone: Fishes, Cetaceans and Seabirds

The ocean environment is divided for study into the benthic or bottom habitat and the pelagic or water column habitat. Frequently, the pelagic zone is differentiated from the neritic zone; the latter being defined as the marine environment over the continental shelf which normally extends down 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. The plankton of the epipelagic zone have already been discussed and here data on the nekton will be reported. Nekton are those animals which swim actively in the water column; these include the fishes, marine mammals, and most cephalopods. Additionally, the oceanic birds are usually considered to be part of the pelagic fauna.

A large number of epipelagic fishes were captured during cruise W-61 (Table 12), providing the opportunity to examine various adaptations for life in the open ocean and the food habits of the larger predators. Particularly abundant were several species of flying fish which frequently landed on board R/V Westward at night and dolphin fish which were caught on handlines. A 70-pound white marlin (Tetrapturus albidus) provided a particularly good lesson in anatomy of a high speed top predator and a fine dinner for Westward's crew. The marlin also carried with it two remora. Muka examined the parasites of epipelagic fishes, concentrating on those of the alimentary tracts. Other studies with fishes included an analysis of ichthyoplankton abundance on the Caribbean Sea by Corzine (already discussed) and a study of vertical distribution in mesopelagic fishes by Taborsky.

Cruise W-61 also provided an opportunity to examine the winter distribution of seabirds and cetaceans which are known to demonstrate long seasonal migrations. Ellis examined distributional patterns in seabirds with emphasis on differences among major water masses and distance from land. Gaies analyzed the distribution of cetaceans in the Caribbean Sea and visiting scientist Dr. Jean Maguire joined the cruise to record the sounds of sperm whales. The abstracts for these studies follow.

TABLE 12: Fishes captured or sighted during R/V Westward cruise W-61

Date	Time	Latitude (N)	Longitude (W)	Species	Standard Length (cm)
12/03/81	1124	Charlotte Amalie Harbor		Manta birostris (Manta Ray)	?
12/03/81	1300	S. of St. Thomas		Auxis thazard (Frigate Tuna)	42, 43
12/04/81	1705	17°29'	63°50'	Coryphaena hippurus (Dolphin)	84
12/04/81	1825	17°29'	63°50'	Euthynnus alletteratus (Little Tuna)	49
12/07/81	1910	14°10'	62°08'	Hirundichthys affinis (Four wing flying fish)	?
12/15/81	1200	11°50'	66°57'	Sphyraena barracuda (Barracuda)	58
12/15/81	1935	11°50'	67°20'	Cypselurus melanurus (Atlantic flying fish)	?
12/21/81	0400	14°58'	71°59'	Hirundichthys speculiger (Mirror wing flying fish)	20
12/22/81	1645	15°37'	74°35'	Coryphaena hippurus (Dolphin)	90
12/23/81	0300	16°04'	75°23'	2 Unident. flying fishes	?
12/24/81	1145	16°26'	78°12'	Acanthocybium solandri (Wahoo)	52
12/25/81	0930	17°24'	80°08'	Katsuwonus pelamis (Skipjack tuna)	47
12/27/81	0905	17°12'	84°04'	Thunnus thynnus (Bluefin Tuna)	32
12/28/81	1330-1530	16°19'	86°07'	Coryphaena hippurus (Dolphin)	44,46,50, 52,57
				Tetrapturus albidus (White Marlin)	180
01/10/82	1345	24°27'	80°58'	Coryphaena hippurus (Dolphin)	92
		24°27'	80°40'	" "	62, 54

*(Numerous other flying fishes were collected, but unrecorded)

Parasites in Epipelagic Fishes of the Caribbean Sea: Ecological Relationships

Martha Muka

ABSTRACT

Metazoan parasites were extracted from the alimentary tracts of the ten species of epipelagic fishes from the Caribbean Sea. Five classes of parasites were found and identified to family where possible. Classes included were the Cestoda, Trematoda, Nematoda, Acanthocephala, and Copepoda (Table 13). Infestation rate was 80% and the parasite fauna was dominated by the Cestoda. Composition of the parasite fauna in different fish species appeared to reflect differences in size of the host and related trophic position. Smaller fish generally supported fewer numbers of parasite species and individuals. Trematode species are probably host specific.

TABLE 13: Metazoan parasites found in the alimentary tracts of epipelagic fishes from the Caribbean Sea

Fish Species	Parasite Groups: Cestoda	Amphilinidae	Coenomorphidae	Lecanicephalidae	Ptychothriidae	Tetrahyncidae	Trematoda	Prosostomata	Nematoda	Acanthocephala	Eoacanthocephala	Copepoda	Chondracanthidae	No. fish examined	No. parasitized
Istiophoridae															
Tetrapturus albidus (white marlin)					X			X	X				X	1	100
Sphyraenidae															
Sphyraena barracuda (great barracuda)				X										1	100
Coryphaenidae															
Coryphaena hippurus (dolphin)		X	X			X		X						7	100
Scombridae															
Euthynnus alletteratus (little tuna)								X			X			3	100
Acanthocybium solandri (wahoo)								X						1	100
Exocetidae (flying fishes)															
Hirundichthys affinis					X				X		X			3	50
H. speculiger														1	0
Cypselurus furcatus					X									2	50
C. melanurus		X												1	100
Echeneidae															
Remora osteochir (remora)													X	2	100

The Vertical Distribution of Caribbean Mesopelagic Fishes

Larry Taborsky

ABSTRACT

Eight deep-sea tows made during mid-night hours in the central Caribbean Sea indicated that the mesopelagic fish fauna there is dominated by the family Gonostomatidae, particularly members of the genus Cyclothone. Other well-represented families included the Myctophidae, Idiacanthidae, and Melanostomatidae (Table 14). On a per unit volume basis, peak fish abundance occurred at 200 m depth during the night (Fig. 20), but large variation in tows taken at similar depths indicates a high degree of patchiness or contagion in mesopelagic fauna. Greatest species richness was also observed at approximately 200 m. Future studies should be designed to yield more fishes at a wider variety of depths and times.

TABLE 14: Mesopelagic fishes collected in the central Caribbean Sea during R/V Westward cruise W-61. All abundance values are total counts and not standardized per unit tow volume.

Depth	No. Specimens	Length(cm)	Taxa
25 m	1	2	Cyclothone obscura (Gonostomatidae)
	1	1	Cyclothone sp. "
75 m	1	4	Gonichthyes sp. (Myctophidae)
	1	3	Bonapartia sp. (Gonostomatidae)
	1	2	Cyclothone sp.
	27	1-3	Gonostomatidae
	1	1	Diaphus sp. (Myctophidae)
	1	2	Myctophidae
	1	2	Astronesthidae
75 m	1	4	Cyclothone pygmaea (Gonostomatidae)
	1	3	C. elongatum "
	4	2	Gonostomatidae
	1	9	Idiacanthus fasciola (Idiacanthidae)
200 m	1	2.5	Vinciguerria poweriae (Gonostomatidae)
	1	2	Bonapartia pedaliota "
	1	2	Vinciguerria sp. "
	1	1	Diaphus mollis (Myctophidae)
	1	1	D. subtilis "
	1	2	Lobianchia dofleini "
	1	4	Idiacanthus fasciola (Idiacanthidae)
200 m	4	2	Cyclothone sp. (Gonostomatidae)
	7	1	Gonostomatidae
	1	8	Diaphus lucidus (?) (Myctophidae)
	2	3	Diaphus sp. "
	1	2	Melanostomiatidae
400 m	2	2	Cyclothone sp. (gonostomatidae)
	1	2.5	Eustomias sp. (Melanostomiatidae)
	1	3.5	Diaphus sp. (Myctophidae)
400 m	3	2	Cyclothone sp. (Gonostomatidae)
	4	1	Gonostomatidae
	2	1	Diaphus sp. (Myctophidae)
	3	2	Myctophidae
750 m	1	5	Cyclothone sp. A (Gonostomatidae)
	1	6	Cyclothone sp. B "
	60	1	Gonostamatidae
	2	2	Myctophidae
	1	2	Melanostomiatidae
	1	6	"
	1	4	Idiacanthus fasciola (Idiacanthidae)

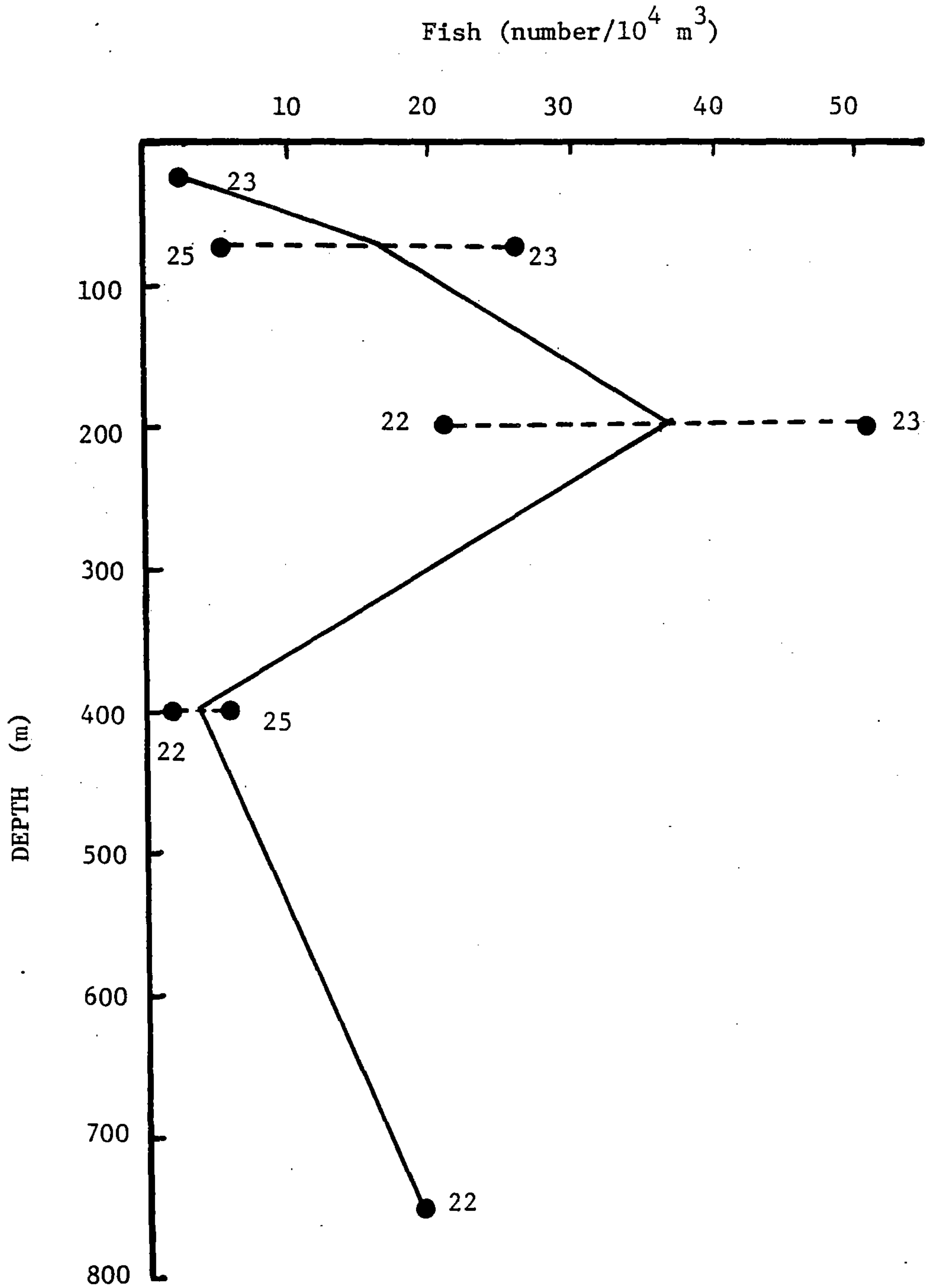

Figure 20: Abundance of mesopelagic fishes shown as a function of depth. Numbers beside the points are dates of collection in December, 1981.

Geographic Distribution of Seabirds in the West Indies and Caribbean Sea

Maria Ellis

ABSTRACT

The distribution of seabirds in the Caribbean Sea is not well known in comparison to the distribution of land birds. During R/V *Westward* cruise W-61, routine surveillance and systematic bird counts were made to test the role of island mass effects, upwelling zones, and areas of vertical mixing, as well as the associated effects on biological productivity in the water column. The abundance of birds was directly related to the biomass of zooplankton in two-hundred meter deep oblique tows. The largest populations were found in areas of high productivity, in upwelling areas, and near land masses (Fig. 21). Particularly large populations of feeding boobies were found to the west of St. Vincent and near Swan Island (Honduras). Bird abundance was inversely related to distance from land, exceptions being more pelagic species such as shearwaters and immature boobies. (See Table 15 for a complete listing of bird sightings.)

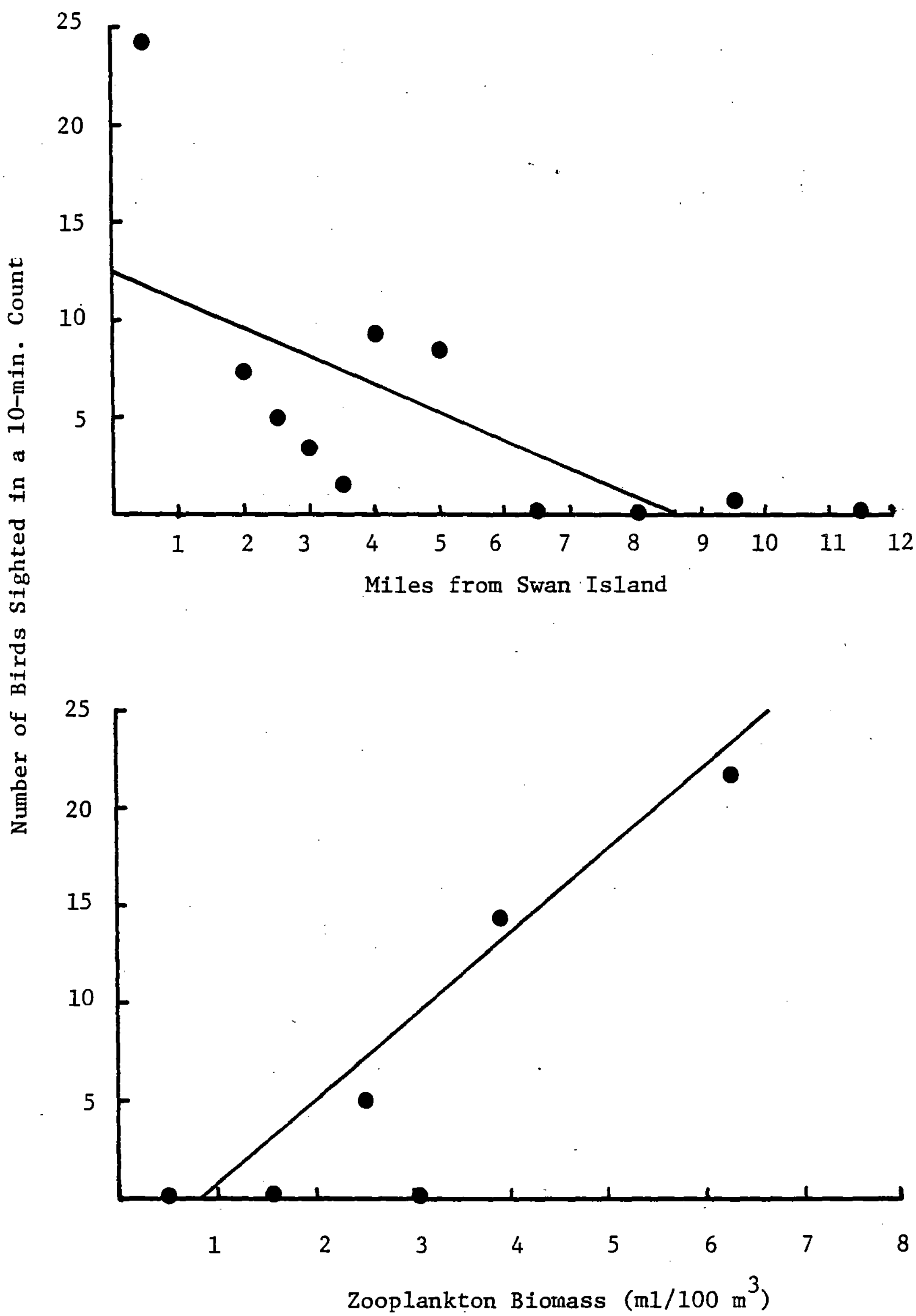

Figure 21: Number of seabirds sighted as a function of distance from Swan Island (top) and as a function of Zooplankton biomass in the Caribbean Sea (bottom).

TABLE 15: Bird counts made during R/V Westward cruise W-61.
* indicates an isolated sighting

Date	Time	Latitude (N)	Longitude (W)	Species	Number
12/03/81	1740	17°56'	64°41'	Sula leucogaster	2
12/04/81	1500	17°29'	65°50'	Puffinus lherminieri	1
12/05/81	0812	16°43'	62°58'	unident. sp.	1
12/05/81	0835	16°43'	62°58'	unident. sp.	1
12/05/81	0804*	?	?	P. lherminieri	1
	1540*	?	?	Hirundo rustica	1
	1655*	16°26'	62°45'	H. rustica	5
	1900*	16°10'	62°43'	H. rustica	8
12/06/81	0930	15°40'	62°28'	unidentified sp.	2
	0940			H. rustica	1
	0940			unident. sp.	1
	0950			P. lherminieri	
	0950			H. rustica	3
	0950			unident. sp.	1
	1045*			unident. sp.	1
	1015*	15°40'	62°18'	unident. sp.	20
12/07/81	0910*	14°39'	62°18'	P. lherminieri	1
12/09/81	0920*	13°29'	61°36'	unident. sp.	100
12/10/81	0845	11°37'	62°48'	P. lherminieri Fregata magnificens unident. sp.	6 1 1
	1110*	11°26'	62°54'	P. lherminieri	1
	1400*	11°30'	62°54'	F. magnificens	2
12/11/81	0600	Porlamar Harbor		Pelecanus occidentalis	12
	0740*	"	"	P. occidentalis	6
				unident. sp.	11
	0815	"	"	P. occidentalis	1
				F. magnificens	1
				Sula dactylatra	5
	0830	"	"	F. magnificens S. dactylatra P. occidentalis S. leucogaster	2 4 9 4

TABLE 15: (continued)

Date	Time	Latitude (N)	Longitude (W)	Species	Number
12/12/81	1614	Porlamar	Harbor	F. magnificens P. occidentalis S. leucogaster	26 107 4
12/14/81	1445*	11°50'	66°59'	unident. sp.	3
	1800*	11°51'	67°03'	unident. sp.	1
12/19/81	1553	12°40'	69°31'	P. lherminieri	1
12/21/81	1735*	15°30'	73°20'	S. leucogaster	2
12/22/81	0810*	15°39'	74°16'	S. leucogaster	1
12/23/81	1725	16°15'	77°04'	S. leucogaster	2
	1735			unident. sp.	1
	1425*	16°06'	77°44'	P. lherminieri	2
	*			S. leucogaster	6
12/25/81	1800*	17°33'	80°36'	P. lherminieri	2
12/27/81	0730*	17°24'	83°51'	F. magnificens	15
	*			S. leucogaster	2
	0810*	17°22'	83°52'	Sula sula	1
	0840*			S. leucogaster	10
	0810			S. sula	13
	0810			S. leucogaster	3
	0820			S. sula	4
	0820			S. leucogaster	3
	0820			F. magnificens	16
	0830			F. magnificens	21
	0830			S. leucogaster	12
	0918			F. magnificens S. leucogaster	4 3
	0931			F. magnificens S. leucogaster	1 4
	0944			S. leucogaster	3
	1018			S. leucogaster	2
	1029			S. leucogaster	9
12/29/81	1245*	Coxen's Hole	Harbor	F. magnificens	1
	1420*	"	" "	Cathartes aura	4

TABLE 15: (continued)

Date	Time	Latitude (N)	Longitude (W)	Species	Number
1/3/82	0630*	Port Royal Harbor		*Larus atricilla*	1
1/5/82	0830	20°33'	85°02'	unident. sp.	1
				F. magnificens	1
1/7/82	1730	24°17'	84°45'	*Stercorarius parasiticus*	6
1/7/82	0820	23°50'	85°05'	*L. atricilla*	2
	0900			*L. atricilla*	2

<u>Factors Affecting the Distribution of Cetaceans in the Caribbean Sea</u>

Jeremy Gaies

ABSTRACT

An attempt was made to determine the salient parameters which regulate the distribution and abundance of cetaceans in the Caribbean Sea. Most of the factors examined, including ship's activity, cloud cover, wind, water temperature, surface salinity, and ocean depth, showed no correlation with mammal sightings. However, a definite clustering of sightings occurred: on the leeward (west) side of the Lesser Antilles, north of Aruba, north of Nicaragua, and north of western Cuba (Fig. 22; Table 16). No explanation for the observed distributional pattern was found, but sightings appeared to be a result of cetacean distribution and attraction of the animals to the ship. The extensive limitations involved in short-term cetacean research at sea are discussed. Many cetaceans were detected with hydrophones, but not observed.

TABLE 16: Cetaceans sighted during R/V Westward cruise W-61

Date	Time	Latitude (N)	Longitude (W)	Species	Approx. Number	Activity
12/03/81	1725	17°59'	64°40'	Rough-toothed or Spinner Dolphins	3-4	Breaching, Bow-riding
12/05/81	2125	16°12'	62°32'	Unident. Dolphins	5-7	Bow-riding
12/06/81	1015	15°40'	62°18'	Mixed species: spotted, bridled & striped Dolphins	20	Breaching, Bow-riding
12/07/81	1415	14°12'	62°07'	Minke whale	1	Spout, Dive
12/09/81	1520-1600	13°08'	61°42'	Pilot whales	15-30	Diving
12/20/81	0200	13°28'	70°16'	Unident. Dolphins	3	Bow-riding
12/20/81	1710	14°32'	71°19'	Unident. Dolphins	15-50	Breaching (very active)
12/20/81	1825	14°32'	71°19'	Unident. Dolphin	1	Breaching
12/27/81	0245	17°38'	83°30'	Unident. Dolphins	5	Bow-riding
12/27/81	1930	16°50'	84°50'	Unident. Dolphins	8-15	Breaching, Bow-riding
01/06/82	0915	22°28'	85°43'	Saddleback Dolphins	3	Breaching, Bow-riding
01/07/82	2335	24°27'	84°38'	Unident. Dolphins	5-6	Breaching, Bow-riding
01/08/82	1355	24°40'	84°17'	Unident. Dolphins	5-6	Breaching
01/09/82	0110	24°25'	84°11'	Unident. Dolphins	4	Bow-riding
01/09/82	0745	24°21'	83°53'	Humpback whales	2	Diving, Fluking
01/09/82	0805	24°21'	83°53'	Unident. Dolphins	?	Bow-riding, (nearby tanker)

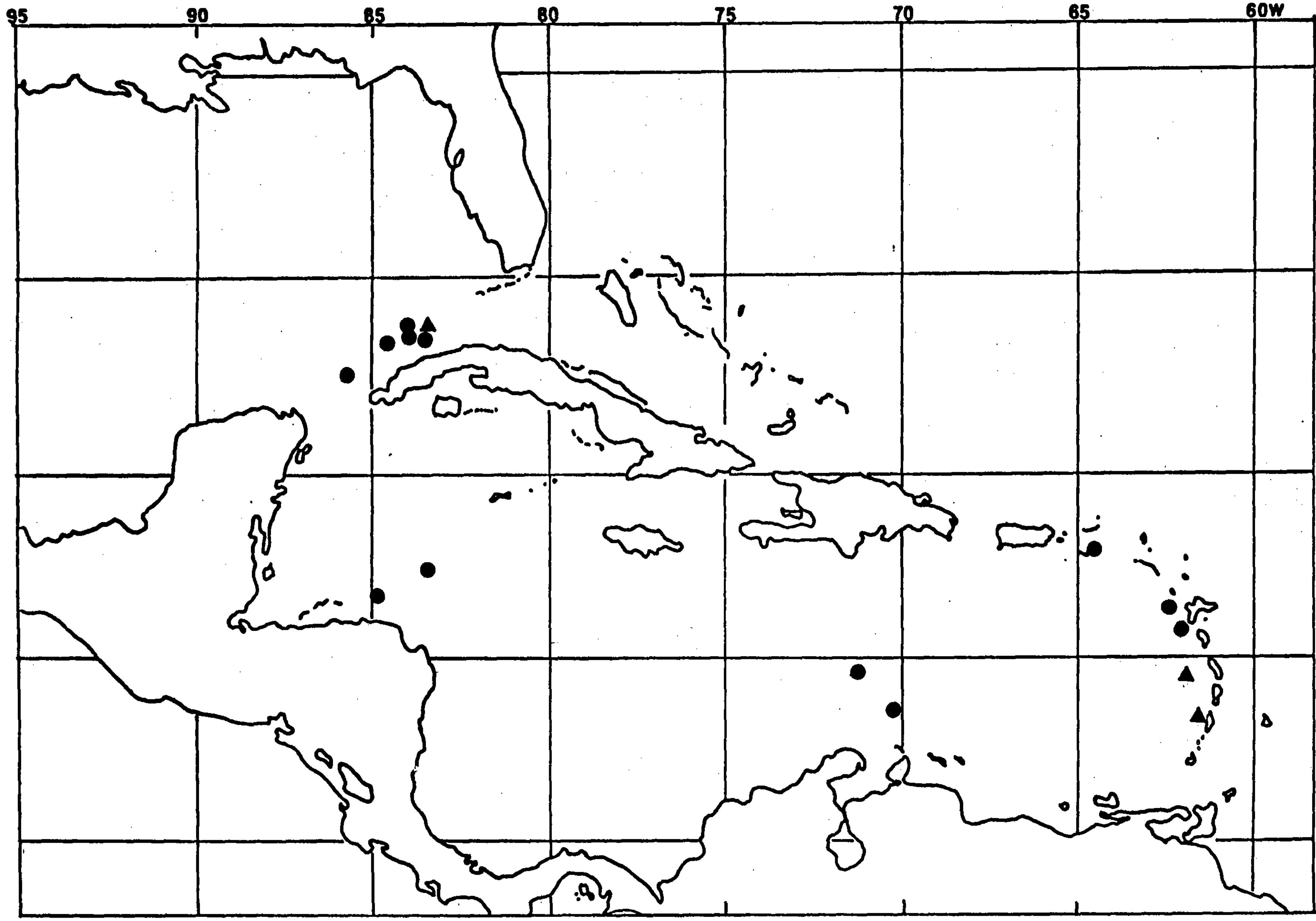

Figure 22: Positions at which dolphins (circles) and whales (triangles) were sighted during R/V Westward cruise W-61.

Distribution of Sperm Whales in the Caribbean Sea

Jean E. Maguire, D.V.M.
Woods Hole, Massachusetts

Sperm whale (Physeter catodon) distribution was examined during late December 1981, along Westward's cruise track between Kralendijk, Bonaire, and Coxen's Hole, Roatan. Sperm whales are known to exist year-round in waters off St. Lucia and St. Vincent, but little is known of their presence in the south-central and western Caribbean.

Visual and acoustical techniques were used to identify the presence of sperm whales. Science watches were requested to be on the lookout for marine mammals. Unfortunately, the trade winds created sea conditions that were less than satisfactory for sighting cetaceans. In such conditions the wind and waves can effectively mask the presence of an animal at the water's surface and disperse any identifying blows. For this reason, whale identification relied heavily upon listening, rather than visual methods. Acoustically, sperm whales make very characteristic clicking sounds and, unlike some other odontocetes, are not known to produce squealing noises.

Fifteen acoustical stations were performed (Table 17). The ship was hove to at these times, and all generators were silent. Hydrophones were deployed over the port quarter and suspended approximately thirty feet below a surface float. The acoustical system used provided two states of preamplification, one preamplifier was housed within the hydrophone, and the other was located amidships within the science laboratory, where actual listening took place. A third stage of preamplification was added by the tape recorder during recording sessions. The listening system was sensitive to frequencies between 20 hertz and 100 kilohertz. Recordings of fifteen to 180 minutes in length were made during all but the first two listening stations. Bathythermographs were performed prior to each listening station to determine the depth of the thermocline and, thus, to obtain some information on the acoustical transmission characteristics of the water. It was interesting to note that on one particular day (20 December) the transmission characteristics were such that two ships sighted at least twelve miles from Westward could be heard through the hydrophones.

Sperm whales were positively identified during only one listening station (22 December, $15^{\circ}37'N$, $74^{\circ}16'W$) in deep water of possibly 2000 fathoms. Whether this was a transient or resident population of whales is not known. It would be interesting to perform additional listening stations in this area not only during late December, but also during other times of the year. Sounds from other odontocetes were heard early in the cruise during four, and possibly six, listening stations. No cetaceans were heard during listening stations west of longitude 75W. Although small cetaceans were sighted during the second leg of the cruise (see abstract Jeremy Gaies), no sperm whales were ever identified, nor did any sightings take place while hydrophones were in the water.

Cetaceans cannot always be seen when heard. Consequently, hydrophones proved to be useful in augmenting visual identification of cetaceans for this study. Possible reasons for the lack of visual identification of marine mammals at times when they were audible include lack of experienced observers, lengthy distances between cetacean and observer, especially a problem during adverse sea conditions, the presence of an animal underwater, and darkness. Hydrophones, of course, also have limitations to their use. The most obvious of these limitations is that they must be in the water while an animal is making noise, and at a time that acoustical transmission characteristics of the water are favorable for listening.

I would like to thank Oliver Brazier for his support and for generously loaning the listening equipment used in this study, and William Watkins and Karen Moore for their advice and assistance in analyzing tapes.

Table 17: Hydrophone stations completed during R/V *Westward* cruise W-61

Station	Date and Time	Latitude (N)	Longitude (W)	Results
W-61-19	18 December 1981, 2200	12°14.5'	68°47.5'	possible odontocete squeals*
W-61-20	19 December 1981, 0800	12°18.5'	69°16.9'	possible odontocete squeals
W-61-21	19 December 1981, 1500	12°40.5'	69°31'	positive recording of odontocete squeals
W-61-22	20 December 1981, 0800	13°49'	70°34'	positive recording of odontocete squeals
W-61-23	20 December 1981, 2218	15°00'	71°52'	positive recording of odontocete squeals
W-61-24	21 December 1981, 0805	15°05'	72°30'	possible recording of odontocete clicks
W-61-25	22 December 1981, 0850	15°32'	73°39'	positive recording of odontocete squeals
W-61-26	22 December 1981, 0850	15°37'	74°16'	positive recording of sperm whales
W-61-27	23 December 1981, 0131	16°11'	75°38'	no positive recording
W-61-28	24 December 1981, 0141	16°22'	77°32'	no positive recording
W-61-29	24 December 1981, 0800	16°35'	77°58.5'	no positive recording
W-61-30	26 December 1981, 0100	17°30.5'	81°06'	no positive recording
W-61-31	26 December 1981, 1500	17°35'	82°17'	no positive recording
W-61-32	27 December 1981, 0920	17°23.5'	83°58.0'	positive recording of snapping shrimp
W-61-33	27 December 1981, 2140	16°54'	85°03'	no positive recording

*recordings were not made during the first two listening sessions

Anthropogenic Materials in the Ocean

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 1777, 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-61, Carbonara and Slesinger investigated the abundance of pelagic tar on the surface and in the water column at numerous sites in the Caribbean Sea in an attempt to explain observed geographic patterns. Surprisingly, tar was very abundant in the water column (sometimes hundreds of particles per liter of seawater) and further investigation will be made during future cruises.

A Study of the Distribution of Tar on the Surface and in the Water Column in the Caribbean Sea

Patty Carbonara and Paul Slesinger

ABSTRACT

During R/V Westward cruise W-61, a series of neuston tows and hydrocasts were made along the cruise track to collect tar from the sea surface and water column, respectively. Subsurface tar levels generally reflected surface concentrations but high concentrations of tar in the water column demonstrated the importance of data collected using both methods in estimating total amount of the pollutant.

The eastern two-thirds of the Caribbean Sea had relatively low concentrations of tar, which varied little from station to station. The amount of tar increased dramatically approaching the Yucatan Basin (Table 18); this is due most likely to heavy shipping traffic through the Yucatan Strait and westerly surface currents which concentrate tar and other debris. (For abundance of tar in neuston tows, see Table 20.)

TABLE 18: Suspended tar at eight sites in the Caribbean Sea. Values are the total number of particles per liter of seawater.

Site	Depth (m) 25	50	100	200
Anegada Passage	205	85	70	25
Dominica	180	185	65	55
St. Lucia Channel	65	55	80	80
Curacao	85	95	105	165
Central Caribbean	60	105	30	120
S. of Jamaica	10	15	10	10
Roatan	450	1150	125	450
Yucatan Strait	135	115	160	160

Nautical Studies

On R/V Westward cruise W-61, three student projects were conducted in fields outside the typical realm of oceanography or marine biology. All, however, provided information of great interest to the routine operation of R/V Westward and the Sea Semester Program. The abstracts for these studies follow.

Reliability and Relevance of Radio Weather Forecasts

Susan Welsh

ABSTRACT

A knowledge of weather is essential in the handling of a sailing vessel. On R/V Westward cruise W-61, radio weather forecasts and observed weather conditions were recorded and compared. Primary attention was given to wind speed and direction, wave height, sky coverage, and precipitation. Broadcasts described significant weather features for the entire Caribbean Sea (Caribbean Sea Synopsis) and provided details for specific sectors (Fig. 23). Although several frontal systems passed through the Caribbean, none crossed the cruise track; frontal reports appeared to be accurate. A comparison of sector forecasters and observed weather patterns showed that wind direction was well predicted (usually north of east to south of east); however, observed wave heights and wind speeds were slightly lower than predicted (Table 19). The forecasts showed no major discrepancies from the observed trends, and are a reliable source of valuable information.

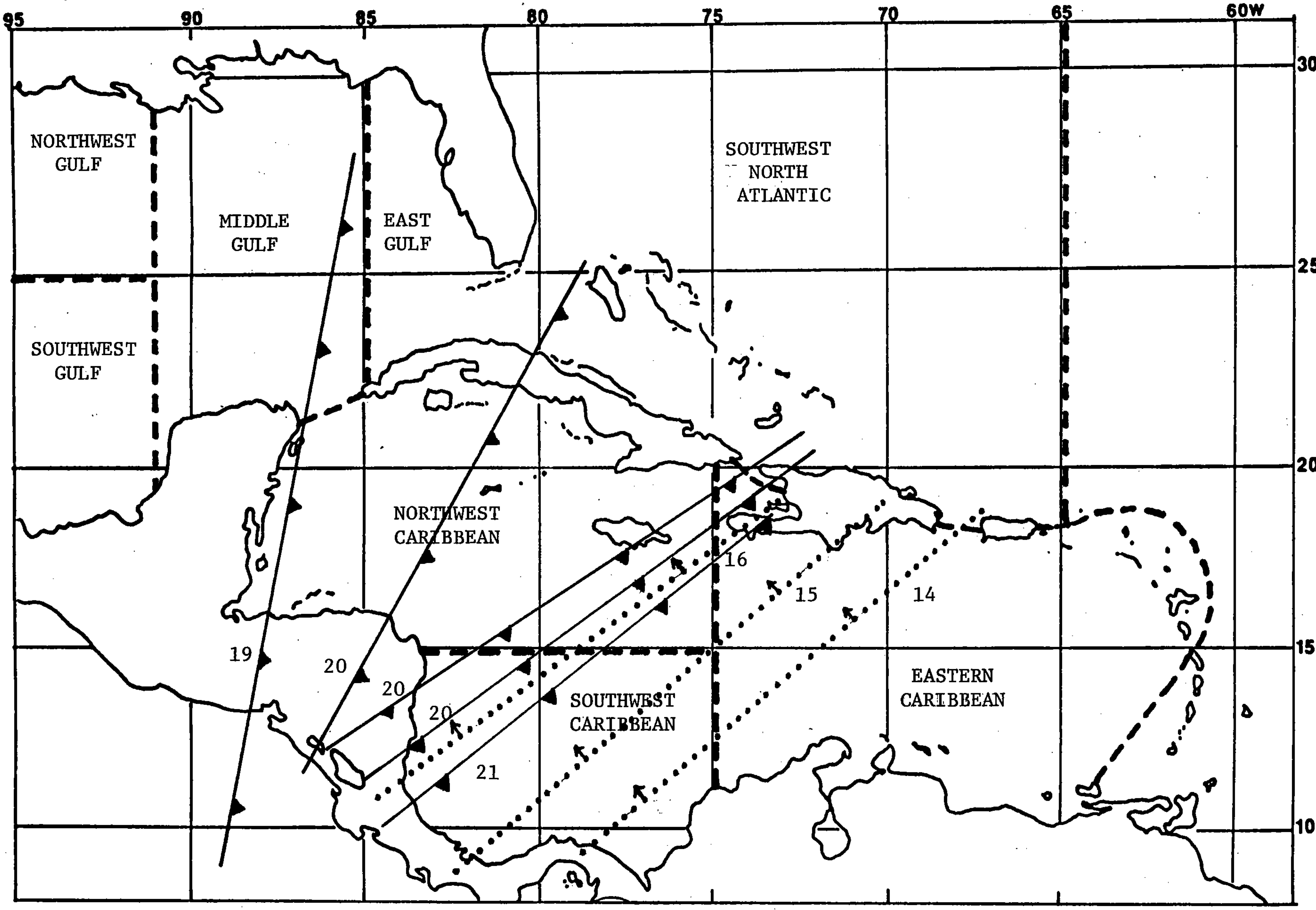

Figure 23: Meteorological sectors in the Caribbean Sea and Gulf of Mexico. Also shown is the movement of a cold front through the Caribbean from 19-21 December 1981, and the movement of a low pressure system (dotted line) from 14-16 December 1981.

TABLE 19: Comparison of radio forecast and observed weather during R/V _Westward_ cruise W-61

Date	Wind Speed (kt)		Wind Direction		Wave Height (ft)		Clouds (% cover) and Rain*	
	Forecast	Observed	Forecast	Observed	Forecast	Observed	Forecast	Observed
12/8	15	7-10	E	E x S	4-6	2-3	Showers	50, NR
12/9	15-20	7-20	E-SE	ESE-SE	4-7	3-5	Sc. showers	20-80, NR
12/10	16	5-20	E	SE-ESE	4-6	1-5	" "	50, NR
12/11	16	5-20		S of E		1-5	-	Cloudy, Rain
12/13	15	5-10			3-6	2-3	Sc. showers	50, NR
12/14	15	4-10	SE-E	N of E S of E	3-6	3	" "	50, NR
12/15	15-25	5-10	E	ENE	6-9	2	Few showers	50, NR
12/16	15-25	4-6		E		3-4	-	50, Rain
12/19	15-20	7-10	E	Variable	4-7	3-5	Few showers	50, Rain
12/20	15-20	7-15	E	Variable	4-7	3-4	Sc. showers	50, NR
12/21	15-20	7-10	E	E	4-6	3	" "	50, Squall
12/22	15	7-16	E	N of E	4-6	3-5	Few showers	50, Shower
12/23	15	5-15	E	E	3-6	3-5	Sc. showers	Cloudy, Rain
12/24	15	11-21		E-NE		5	-	15, NR
12/26	10-15	4-6	E	E	3-5	2	Few showers	10, NR
12/27	10-15	5-10	E-SE	SE	3-5	3	Sc. showers	Variable, Rain
12/28	10-16	5-15	E-SE	E	5	3	Few showers	Variable, Shower
12/29	10-15	10-15	E-SE	E	5	3	" "	10, NR
12/30		2-5		N of E		1-2	-	Cloudy, Drizzle

*NR indicates No Rain observed.

Stability Analysis of R/V Westward's Small Dory

Doug Ranalli

ABSTRACT

Stability is the tendency of a vessel to return to its original position after it has been inclined due to external forces. There are essentially two factors effecting the stability of a vessel: (1) Position of center of gravity, (2) Total buoyancy and center of buoyance. Three experiments were performed on Westward's small dory, under several different loading conditions. The purpose of these experiments was to determine the most stable loading position for 1, 2,3,4,5 and 6 passengers in the dory. (1) Determination of righting moment at 15 degrees of inclination to approximate large angle stability. (2) Determination of period of oscillation to approximate the dory's stability at small angles of inclination. (3) Measurement of freeboard. Analysis of data obtained indicates dory stability is increased by seating people on the floor of the dory, shifting them aft, and keeping the majority of the weight along the central axis of the dory.

An Economic Study of Preferred Activities Aboard the R/V Westward

Joyce Little

ABSTRACT

To determine the degree of success that the Sea Education Association achieves in meeting student expectations for the Sea Semester sea component, two questionnaires were issued to 22 students one week and three and one half weeks into R/V Westward cruise W-61. The questionnaire categorized all student activities aboard the vessel as one of two types: 1) "formalized instruction," and 2) "self-directed activities." The results describe students' preferences for activities in each category and the students' motivation for joining the Sea Semester program. It was concluded that students desired a certain amount of formalized academic knowledge beyond which time was desired for "self-directed activities." S.E.A. seems to have satisfied students' requirements for formalized instruction and faculty contact. The survey indicated that students desire a balance between academic opportunities and rich experiences offered by the unique environment found on board R/V Westward.

LONG TERM AND COOPERATIVE PROGRAMS

Neuston Data

Since 1977, S.E.A. scientists have been gathering information on the distribution of pelagic tar, *Sargassum* species, and the marine water-strider *Halobates micans*. Manuscripts are in review on all of these topics. Twenty-two neuston tows were made on R/V *Westward* cruise W-61, yielding large quantities of all three important components (Table 20). The western Caribbean Sea, Yucatan Strait, and Florida Straits yielded the largest quantities of *Sargassum* and tar, and the highest densities of *Halobates*. The seagrasses *Thalassia testudinum* and *Syringodium filiforme* were frequently found in the neuston collections, as was the hydroid *Porpita* and the siphonophore *Physalia*.

Distribution of Marine Birds and Mammals

In cooperation with 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 bird distribution, feeding, and migration patterns. Whenever possible, daily bird counts were made on R/V *Westward* cruise W-61 during morning and afternoon hours. Distributional data, shown in Table 15, were analyzed by Maria Ellis and sent to Mr. Rumage.

Whale and dolphin sightings and observations are also used for long-term studies of mammal distribution and behavior in corporation with Tim Rumage. Data collected during W-61 were analyzed by Jeremy Gaies and Dr. Jean Maguire (Tables 16 and 17).

Weather Observations

R/V *Westward* participates in the Cooperative Ship Weather Observation Program of the National Oceanic and Atmospheric Administration. On cruise W-61, thirty-three complete sets of meteorological data were collected and transmitted by radio to the NOAA meteorological office.

Drift Card Study

On R/V Westward cruise W-61, 650 brightly-colored drift cards were released in the Yucatan and Florida Straits; this represents the beginning of a long-term project by SEA scientists to study water mass motion through the Straits. Cards were released every two hours between 6 January and 12 January 1982. To date, ten of the drift cards have been recovered. All of the cards returned to SEA have landed on the east coast of Florida, some of which traveled 400 nautical miles in less than three weeks.

TABLE 20: Summary of neuston collected on R/V Westward cruise W-61. (See Appendix for station positions.)

Station	Date	*Sargassum* (mg/m²)	*Halobates micans* #/1000 m²	Tar (mg/m²)	Miscellaneous
W61-1	12/04/81	8.36	1.6	0.27	Mangrove, *Thalassia*
W61-3	12/05/81	29.14	1.1	0.54	
W61-5	12/06/81	0	7.6	0	
W61-8	12/08/81	0	0	0.05	
W61-9	12/08/81	0	0	0	
W61-12	12/10/81	0	0	trace	
W61-14	12/13/81	0	0	trace	*Porpita*
W61-15	12/14/81	0	0	0	*Thalassia*
W61-19	12/19/81	1.24	0	trace	Leptocephalus
W61-20	12/19/81	0	0	0.27	
W61-25	12/22/81	0	0	trace	
W61-29	12/24/81	0.86	4.9	0.27	*Syringodium*, wood
W61-31a	12/26/81	0.27	2.2	2.91	Wood, plastic
W61-32	12/27/81	37.51	1.1	8.80	
W61-36	01/03/82	1.19	2.2	2.43	Wood
W61-37	01/04/82	7.88	1.1	0.27	Leptocephalus
W61-38	01/04/82	20.51	3.8	2.29	*Syringodium*
W61-41	01/05/82	72.85	1.1	0.17	*Thalassia*
W61-42	01/06/82	0.27	1.6	0.29	*Thalassia*, *Syringodium*
W61-43	01/07/82	42.09	9.7	9.17	*Porpita*
W61-44	01/07/82	17.27	1.6	0.27	*Physalia*
W61-45	01/08/82	56.66	4.3	2.00	

TABLE A-1: Oceanographic stations sampled on R/V Westward cruise W-61

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	Comments
W61-1	12/04/81	0750	17°37'	64°17'	Hydrocast (tar)	Anegada Passage
		0750			Phytoplankton Tow	
		0940			Neuston Tow	
W61-2	12/05/81	0230	17°00'	62°55'	Hydrocast	N. Grenada Basin
					Phytoplankton Tow	
W61-3	12/05/81	1200	16°35'	62°50'	Neuston Tow	
W61-4	12/05/81	2300	16°07'	62°24'	Hydrocast	Guadeloupe
	12/06/81	0025			Phytoplankton Tow	
		0145			Oblique Tow	
W61-5	12/06/81	1215	15°40'	62°20'	Neuston Tow	
W61-6	12/06/81	1915	15°20'	62°16'	Hydrocast	Dominica
		1925			Phytoplankton Tow	
		2300			Oblique Tow	
W61-7	12/07/81	0350	15°25'	62°20'	Hydrocast	Dominica Channel
					Phytoplankton Tow	
		0550			Oblique Tow	
W61-8	12/08/81	1350	14°37'	61°23'	Hydrocast	Martinique
					Phytoplankton Tow	
		1500			Hydrocast (tar)	
		1545			Oblique Tow	
		1735			3-Net Tow	
		1809			Neuston Tow	

TABLE A-1: (continued)

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	Comments
W61-9	12/08/81	2110	14°21'	61°22'	Phytoplankton Tow	St. Lucia Channel
		2200			Hydrocast	
					Hydrocast (tar)	
		2245			Oblique Tow	
		2345			Neuston Tow	
W61-10	12/09/81	0400	13°53'	61°29'	Phytoplankton Tow	St. Lucia
					Hydrocast	
		0450			Oblique Tow	
W61-11	12/09/81	0830	13°29'	61°32'	Hydrocast	St. Vincent Channel
					Phytoplankton Tow	
		0955			3-Net Tow	
W61-12	12/10/81	1230	11°31'	63°08'	Hydrocast	Margarita
					Phytoplankton Tow	
		1300			Oblique Tow	
		1420			Neuston Tow	
W61-13	12/10/81	1720	11°45'	63°18'	Hydrocast	Margarita
		1725			Phytoplankton Tow	
		1815			3-Net Tow	
W61-14	12/13/81	1100	10°41'	65°16'	Neuston Tow	Cariaco Trench
		1150			Oblique Tow	
		1255			Hydrocast	
					Phytoplankton Tow	

TABLE A-1: (continued)

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	Comments
W61-15	12/13/81	2245	11°18'	65°39'	Phytoplankton Tow	Gulf of Venezuela
		2330			Neuston Tow	
	12/14/81	0025			4-Net Tow	
W61-16	12/14/81	0800	11°45'	65°53'	Phytoplankton Tow	Gulf of Venezuela
					Hydrocast	
		0940			Hydrocast	
		1205			4-Net Tow	
W61-17	12/14/81	2110	11°47'	66°29'	Oblique Tow	E. of Los Roques
W61-18	12/15/81	0810	11°46'	66°56'	Oblique Tow	W. of Los Roques
W61-19	12/19/81	0020			Hydrocast	E of Curacao
		0025			Hydrophone	
		0045			Neuston Tow	
W61-20	12/19/81	0830	12°19'	69°16'	Hydrocast	W of Curacao
					Hydrophone	
		0855			Neuston Tow	
W61-21	12/19/81	1400	12°42'	69°40'	Hydrocast	NW of Curacao
					Phytoplankton Tow	
		k599			Hydrophone	
W61-22	12/20/81	0730	13°54'	70°52'	Hydrocast	NW of Aruba
					Hydrophone	
W61-23	12/20/81	2230	15°00'	71°52'	Hydrocast	Central Caribbean
					Hydrophone	

TABLE A-1: (continued)

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	Comments
W61-24	12/21/81	0745	15°12'	72°32'	Hydrocast	Central Caribbean
					Hydrocast	
		0805			Hydrophone	
		1015			4-Net Tow	
W61-25	12/21/81	2210	15°32'	73°39'	Hydrocast	" "
					Hydrophone	
		2255			4-Net Tow	
	12/22/81	0110			Neuston Tow	
W61-26	12/22/81	0800	15°37'	74°16'	Hydrophone	" "
					Oblique Tow	
W61-27	12/22/81	2200	16°12'	75°37'	3-Net Tow	S. of Jamaica
					Hydrophone	
W61-28	12/23/81	2300	16°22'	77°33'	3-Net Tow	" " "
					Hydrophone	
W61-29	12/24/81	0700	16°36'	77°58'	Hydrocast	" " "
					Hydrophone	
					Neuston Tow	
W61-30	12/25/81	2300	17°35'	81°07'	3-Net Deep Tow	S. of Cayman
W61-31a	12/26/81	1600	17°36'	82°28'	Neuston Tow	" " "
W61-31	12/27/81	0940	17°22'	83°52'	Hydrocast	Swan Island
					Oblique Tow	
W61-32	12/27/81	2130	16°54'	85°03'	Neuston Tow	NE of Roatan
					Hydrophone	

TABLE A-1: (continued)

Station	Date	Time	Latitude (N)	Longitude (W)	Operations	Comments
W61-33	12/28/81	2330	16°20'	85°05'	Hydrocast (tar)	S of Roatan
		2350			Oblique Tow	
	12/29/81	0105			Neuston Tow	
W61-34	01/02/82	0800	Port Royal Harbor		Phleger Core	Port Royal Harbor
					Grab Sample	
W61-35	01/02/82	1525	16°03'	86°15'	Phleger Core	Honduran Coast
					Grab Sample	
					Sediment Scooper	
W61-36	01/03/82	1230	17°37'	85°35'	Neuston Tow	N of Roatan
W61-37	01/04/82	0020	18°37'	85°20'	Neuston Tow	S of Yucatan Strait
W61-38	01/04/82	1210	19°29'	84°57'	Neuston Tow	" " " "
W61-39	01/04/82	1830	19°51'	84°59'	Hydrocast	Yucatan Strait
W61-40	01/05/82	1200	20°48'	85°06'	Hydrocast	" "
		1230			Oblique Tow	
W61-41	01/05/82	2150	21°35'	85°31'	Hydrocast	" "
		2220			Neuston Tow	
W61-42	01/06/82	1240	22°40'	85°36'	Neuston Tow	" "
W61-43	01/07/82	0040	23°19'	85°25'	Neuston Tow	NW of Cuba
W61-44	01/07/82	1215	24°00'	84°58'	Neuston Tow	" " "
W61-45	01/08/82	0015	24°27'	84°31'	Neuston Tow	Florida Straits
W61-46	01/09/82	0215	24°26'	81°44'	Sediment Scooper	" "
W61-47	01/09/82	0300	24°27'	81°42'	" "	" "

TABLE A-2: Bathythermograph casts made on R/V <u>Westward</u> cruise W-61

BT#	Date	Time	Latitude (N)	Longitude (W)	Surface Temp. (°C)	Mixed Layer Depth (m)
1	12/04/81	0630	17°37'	64°17'	27.9	80
2	12/04/81	2000	17°19'	63°32'	27.9	22
3	12/05/81	0910	16°43'	62°58'	28.0	73
4	12/05/81	1430	16°26'	62°45'	28.8	73
5	12/05/81	1735	16°15'	62°43'	28.1	58
6	12/05/81	2245	16°08'	62°20'	28.2	66
7	12/06/81	0420	15°58'	62°29'	28.2	40
8	12/06/81	0845	15°43'	62°28'	28.1	66
9	12/06/81	1040	15°44'	62°29'	28.1	58
10	12/06/81	1315	15°40'	62°20'	28.2	73
11	12/06/81	1800	15°21'	62°18'	28.5	66
12	12/07/81	0126	15°14'	62°18'	28.7	73
13	12/07/81	0300	15°02'	62°20'	28.5	73
14	12/07/81	0815	14°48'	62°21'	28.2	69
15	12/07/81	1130	14°25'	62°08'	28.2	66
16	12/07/81	1330	14°03'	62°17'	28.6	51
17	12/08/81	1310	14°37'	62°23'	28.5	58
18	12/08/81	2037	14°21'	61°22'	27.4	66
19	12/09/81	0130	14°04'	61°32'	28.0	64
20	12/09/81	0300	13°55'	60°24'	28.5	73
21	12/09/81	0600	13°50'	61°28'	28.2	80
22	12/09/81	0800	13°32'	61°29'	28.4	80
23	12/09/81	1700	13°08'	61°42'	28.4	73
24	12/09/81	1850	12°55'	61°49'	28.4	66
25	12/09/81	2030	12°44'	61°51'	28.5	80
26	12/09/81	2220	12°33'	62°01'	26.5	80
27	12/10/81	0118	12°14'	62°12'	28.4	84
28	12/10/81	1000	11°32'	62°52'	27.7	40
29	12/10/81	1135	11°31'	63°08'	28.0	15
30	12/10/81	1720	11°45'	63°18'	28.3	40
31	12/13/81	1100	10°41'	65°16'	27.2	18

TABLE A-2: (continued)

BT#	Date	Time	Latitude (N)	Longitude (W)	Surface Temp. (°C)	Mixed Layer Depth (m)
32	12/13/81	2200	11°20'	65°40'	27.2	22
33	12/14/81	0730	11°45'	65°45'	27.2	47
34	12/18/81	2235	12°12'	68°48'	28.0	51
35	12/19/81	0730	12°19'	69°16'	28.0	68
36	12/19/81	1330	12°47'	69°31'	28.0	51
37	12/20/81	2300	15°00'	71°52'	27.8	69
38	12/21/81	0710	15°12'	72°29'	27.8	91
39	12/21/81	2200	15°32'	73°39'	27.5	80
40	12/22/81	0745	15°37'	74°16'	27.8	88
41	12/22/81	2200	16°04'	75°23'	27.8	102
42	12/23/81	2200	16°22'	77°30'	27.5	88
43	12/24/81	0645	16°36'	77°58'	26.6	106
44	12/25/81	2145	16°35'	81°07'	27.4	88
45	12/27/81	2130	16°54'	85°03'	27.0	75
46	12/29/81	0025	16°20'	86°05'	26.5	55
47	01/06/82	1015	22°34'	85°41'	27.0	124
48	01/06/82	1240	22°40'	85°36'	27.0	146

TABLE A-3: Summary of hydrographic data from R/V Westward cruise W-61.

bd = below determination

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (°/oo)	Density (P)	Dissolved Oxygen (ml/L)	NH_4 (uM/L)	PO_4 (uM/L)	SiO_2 (uM/L)
W61-1	0	-	28.00	35.29	22.65	4.74	bd	0	1.7
	50	-	28.11	35.31	22.62	4.71	1.12	4.45	
	100	-	25.95	36.70	24.35	4.42	bd	4.00	
	200	193	19.99	36.80	26.17	4.14	bd	2.65	
W61-2	0	-	27.98	35.43	22.75	4.89	0.02	bd	
	50	-	28.00	35.47	22.78	4.89	1.05	1.00	
	100	85	26.35	36.76	24.28	4.25	0.50	0.02	
	300	279	16.74	36.34	26.63	4.25	0.18	0.04	
	500	497	10.91	35.40	27.12	3.19	bd	0.65	
	800	836	6.61	34.86	27.39	3.43	0.01	bd	
W61-4	0	-	28.20	34.66	22.10	4.78	0.37	bd	3.6
	50	-	28.20	35.45	22.69	4.90	bd	bd	2.1
	250	194	17.22	36.32	26.50	3.78	-	-	-
	500	480	10.02	35.17	27.13	2.95	0.86	1.34	14.0
	800	757	6.42	34.76	27.34	3.33	2.76	1.27	17.9
	1200	1202	4.60	34.97	27.72	4.68	0.34	0.52	17.9
W61-6	0	-	28.12	35.20	22.54	4.66	0.07	bd	3.6
	50	-	28.75	35.50	22.55	4.83	1.07	bd	
	250	230	17.61	-	-	2.30	0.56	0.37	
	500	469	9.99	35.13	27.09	2.34	bd	1.15	15.0
	800	-	8.09	36.36	28.36	2.63	bd	1.08	1.8
	1200	1117	4.63	36.38		2.96	-	1.07	18.2
W61-7	0	-	28.33	35.23	22.49	4.89	bd	0.04	2.6
	50	-	28.33	35.54	22.72	4.92	bd	-	
	100	-	28.30	36.00	23.17	5.01	bd	0.20	
	200	127	25.30	37.21	24.95	4.68	-	0.28	
	400	218	18.99	36.58	26.37	3.62	0.31	3.70	
	800	507	9.04	34.97	27.11	2.93	0.55	2.10	

TABLE A-3: (continued)

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity ($^{o}/oo$)	Density (P)	Dissolved Oxygen (ml/L)	NH_4 (uM/L)	PO_4 (uM/L)	SiO_2 (uM/L)
W61-8	0	-	28.29	35.60	22.78	4.81	bd	0.01	1.6
	100	105	27.48	36.59	23.79	4.96	0.01	0.29	
	250	215	17.80	36.49	26.48	3.62	bd	0.18	
W61-9	0	-	28.18	35.61	22.82	4.87	bd	bd	2.5
	100	-	26.78	36.81	24.19	4.92	bd	0.03	
	250	195	18.26	36.54	26.42	3.94	bd	0.85	
W61-10	0	-	28.30	35.68	22.83	3.31	bd	0.01	2.4
	100	-	27.40	36.49	23.74	4.32	0.08	0.03	
	250	183	17.91	36.41	26.40	3.81	bd	0.83	
W61-11	0	-	28.49	35.66	22.76	4.85	bd	2.96	10.3
	100	-	27.32	36.21	23.56	4.56	bd	0.16	
	250	203	16.51	36.11	26.51	3.54	2.58	0.55	
W61-12	0	-	28.11	35.32	22.64	5.22	0.92	bd	3.5
	25	-	27.90	36.25	23.40	5.09	1.01	0.30	
	40	-	26.45	36.30	24.03	4.75	0.87	bd	
W61-13	0	-	28.14	34.90	22.30	5.26	0.60	0.17	3.1
	30	-	28.45	35.81	22.88	5.37	0.40	0.09	
	100	-	23.02	36.60	25.17	3.67	0.46	0.07	
	150	73	19.57	36.49	26.04	3.75	0.90	0.43	
W61-14	0	-	27.98	36.54	23.59	4.67	bd	0.13	2.6
	50	-	24.30	36.81	24.94	4.19	0.97	0.20	-
	200	122	18.42	36.46	26.32	1.23	bd	0.60	17.4
	400	373	17.33	36.28	26.44	0.14	bd	1.55	17.9
	600	570	17.03	36.25	26.49	0.82	0.46	1.13	17.9
	1000	831	17.03	36.20	26.45	0.40	6.75	2.27	-

TABLE A-3: (continued)

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (°/oo)	Density (P)	Dissolved Oxygen (ml/L)	NH_4 (uM/L)	PO_4 (uM/L)	SiO_2 (uM/L)
W61-16	0	-	27.20	36.60	23.88	4.11	bd	0.12	
	5	-	27.38	36.56	23.80	6.28	bd	bd	
	10	-	-	36.56	-	4.32	0.04	0.24	
	15	-	27.31	36.56	23.82	4.62	0.25	bd	
	20	-	27.37	36.57	23.81	5.02	bd	bd	
	25	-	-	36.58	-	5.00	bd	0.14	
	30	-	27.38	36.47	23.74	4.50	bd	0.05	
	35	-	27.40	36.66	23.89	5.29	bd	0.10	
	40	-	27.41	36.54	23.77	4.60	bd	0.07	
	45	-	27.34	36.56	23.81	4.45	bd	0.30	
	50	-	27.32	36.66	23.90	4.22	bd	0.05	
	60	-	24.49	36.92	24.98	4.33	bd	-	
W61-21	0	-	28.12	34.40	22.31				
	50	-	28.01	36.06	23.23				
	100	142	22.06	36.86	25.64				
	200	215	16.70	36.74	26.95				
	300	360	11.70	35.43	27.02				
	400	420	12.53	35.51	26.90				
	500	520	8.37	34.88	27.16				
	600	574	8.01	34.88	27.21				
	700	642	7.49	34.83	27.25				
	800	703	6.63	34.78	27.33				
	900	809	5.95	34.79	27.42				
	1000	-	5.21	34.79	27.50				
W61-22	0	-	28.18	34.91	25.53				
	50	-	27.43	36.18	23.50				
	100	-	-	36.73	-				
	200	266	16.77	36.22	26.53				
	300	346	13.35	35.66	26.86				
	400	424	11.23	35.31	26.99				

TABLE A-3: (continued)

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity (°/oo)	Density (P)	Dissolved Oxygen (ml/L)	NH_4 (uM/L)	PO_4 (uM/L)	SiO_2 (uM/L)
W61-23	0	-	28.09	35.95	23.11				
	50	-	28.01	34.81	22.28				
	100	147	23.68	36.97	26.25				
	200	281	17.09	36.27	26.49				
	300	422	12.21	35.42	26.90				
	400	533	9.72	-	-				
	500	688	7.63	34.80	27.20				
	600	815	6.43	34.39	27.04				
	700	974	5.78	34.73	27.39				
	800	1037	5.36	34.80	27.50				
	900	1121	5.00	34.89	27.61				
	1000	-	-	34.92	-				
W61-24	0	-	-	34.96	-	4.68	-	0.02	
	5	-	-	34.88	-	4.63	0.59	0.06	
	10	-	-	35.02	-	4.83	0.65	0.10	
	15	-	-	34.85	-	4.63	0.58	0.04	
	20	-	-	34.97	-	-	-	0.01	
	25	-	-	34.98	-	4.60	0.92	bd	
	30	-	-	34.01	-	4.52	0.76	bd	
	35	-	-	35.03	-	4.57	1.75	bd	
	40	-	-	-	-	4.60	1.50	0.03	
	45	-	-	35.05	-	4.60	bd	0.03	
	50	-	-	34.97	-	4.57	bd	0.06	
	60	-	-	35.91	-	4.52	0.80	0.11	
W61-31	0	-	27.30	35.40	22.95	4.41	0.36	0.01	
	10	-	27.30	35.41	22.96	3.02	-	-	

TABLE A-3: (continued)

Station	Assumed depth (m)	Calculated depth (m)	Temp. (°C)	Salinity ($^{o}/oo$)	Density (P)	Dissolved Oxygen (ml/L)	NH_4 (uM/L)	PO_4 (uM/L)	SiO_2 (uM/L)
W61-39	0	-	27.12	35.77	23.29				
	100	-	26.75	35.94	23.53				
	200	137	23.29	36.82	25.25				
	300	225	19.74	36.68	26.14				
	400	311	17.57	36.50	26.54				
	500	382	15.32	36.13	26.79				
	500	-	11.87	35.52	27.04				
	600	652	9.78	35.32	27.26				
	700	760	7.76	35.15	27.48				
	800	858	6.73	35.03	27.50				
	900	958	5.93	35.10	27.67				
	1000	1048	5.23	35.07	27.72				

APPENDIX 4

R/V Westward is frequently the site of contributions other than scientific. Some of these contributions take the form of musical or poetic creations by talented students and staff members. Because W-61 spanned two holidays, Christmas and New Year's Eve, the cruise was particularly fruitful in "artistic contributions." Two of these are included.

WESTWARD "C" WAY

Down the way where the nights are gay
and the sun shines daily on the foretopmast
We took a trip on a sailing ship
with Captain Copepod and juggling fools.

Hours and hours under shining stars
sweating over mega stations near and far
12 bottle hydrocast and 3-net tow
let's get a biomass and picle 'em up.

Chorus: Well, it's Christmas Day and we're wafting our way
with a paratrooping Santa and a rubber shark.
Regae got soul when you're drunk and hot
praying for a swim call and munching out.

Put de lime in de coconut with big YAHOO
makes for a picnic for me and you.
Marlin steaks and conch delight.
We swizzled out way all thru the night.

On New Year's Eve we saw the best
of our Captain Stark and all the rest.
Dancing in the rafter without a harness.
He got us psyched for a wild night.

Chorus: Roatan, Roatan
What did you do to our Freddy man?
Let's make a new addition to the hourly log.
But delete Mount Gay to save Mike's day.

On Saturday when the mung is thick
Beaner gets out her whipping stick.
Hey, Man, OK the following day
Well, forget our projects and swizzle all day.

Jello and WO, it's phase 3 now.
Too many ships and drift cards too.
Dreaming of ice cream and lots of SR's.
Steve, finish your paper, we're off to a bar.

Final Chorus: Well, we're sad to say we're on our way.
Won't be back for many a day
for miles and miles on the rolling sea.
We've beauforted our way to Miami.

Christmas Aboard the Old R/V

"Twas the night before Christmas
And windward to leeward,
Not a creature was stirring
Not even the steward.

The stockings were hung
By the settee with care
With hopes that Sgt. Claus
Would still leave them there.

The students were wedged
All cramped in their bunks,
And every time the ship rolled
You could hear them go thunk!

Copepod in his cape,
Captain guarding the booze
Had just settled aft
For a Caribbean snooze.

When up on the main deck
There arose such a clatter,
They sprang from their bunks
"What now is the matter?!"

They stumbled through the companionway
With a leap and a dash,
And fell out on deck
With a terrible crash.

And what to their wondering
Eyes should appear,
But a Beaufort Force 7
And 8 Aquatic Reindeer.

In a little red sleigh,
Fully square-rigged,
He landed on the lab,
Fouling the stays'l jig.

With rosy red cheeks,
Less than binnacle high,
A strange Sea Santa
Al couldn't classify.

He started up the ratlines
To the top of the mainmast,
Not realizing the difficulty
Of just such a task.

He stood on the masthead
Contemplating the jump,
Soon discovering his fate
Was to land in the sump.

Cleaning himself off,
Santa cruised into the saloon,
Dancing and whistling
A jazzy Calypso tune.

Expecting the dawn
To show all in their beds,
Instead he found "C" watch
De-munging the heads.

He crept to the galley
To check out night snack,
Then opened his duffle
To unload his sack.

Ospho for Mike,
Weapons for Chip,
Hot sauce for Wallace,
A cockatoo for Kit.

A Sat Nav for Greg,
Expresso for Fred,
And for Cilla 3 loaves
Of high density bread.

Orange sherbet for Al,
Clicks/whistles for Jean,
And for Dan Santa left
An unbreakable machine.

And to all the SEA students
He gave something special,
Christmas in the Caribbean
Aboard a rocking and rolling vessel.

His work here all done,
He jumped back to his sleigh,
And ordered the Aquadeer
"Up, Up and Away!"

"Up course, up tops'l,
Up topgallant, up royal,
Up skys'l, up moons'l,
Make way to Port Royal!"

He thought about Westward
As he rose out of sight,
"Except for the sump,
It was a pretty good night!"

And echoing across the seas
In the early dawn light
Was heard "Merry Christmas
And to all a Good Night!"