CRUISE REPORT

W-54

Scientific Activities

Woods Hole - St. Lucia - Tobago Cays - Bequia - St. Thomas

08 October 1980 - 19 November 1980

R/V Westward

Sea Education Association

Woods Hole, Massachusetts

SHIPBOARD DRAFT

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PREFACE

The objective of this cruise report is to compile the data collected by 24 undergraduate students, three staff scientists, and a visiting scientist on cruise W-54 of the R/V *Westward*. The report presents an overview of the cruise with some preliminary interpretation of results. We conducted a wide variety of individual projects, and this report provides space to see how our diverse interests mesh.

We accomplished nearly all of the scientific goals we laid out in our cruise plan, and we were fortunate enough to do this virtually entirely under sail. Engine time for the more than 2000-mile trip was less than ten hours!

The nautical staff, headed by Captain Wallace Stark, was cooperative and interested in the scientific mission of the cruise. Our navigator, Peter Vanadia, was kind enough to keep a running cruise track for us. John Wigglesworth was a diligent and ingenious Head of Nautical Science while Phil Sachs, bosun, kept the ship shining. Sally Kaul, Chief Steward, kept our spirits high by providing fresh vegetables even after three weeks at sea without a port stop. A miracle to top her usual excellent fare! I express my appreciation to each of the nautical staff for their efforts in helping us carry out our research.

I am also grateful to a resourceful scientific staff and visiting scholars. Assistant Scientist Dorinda (Rindy) Ostermann brought abundant energy and enthusiasm to the cruise. She was always ready with ideas and helpful hints when either equipment or morale were giving us trouble. This cruise was Alan Hickey's first cruise on the *Westward*, but after a week it was as if he had always been there. His relaxed manner enabled him to accomplish more than many a hurried scientist I've seen. I thank both Rindy and Alan for letting me depend so thoroughly upon them.

Our first visiting scholar was Dr. Bill Hallstein who, as medical doctor, tended our needs while we were such long distances from shore. He tended more than that, always the cheerful face with the sextant or the mocking face with a book, he delighted us for many hours on our long voyage.

Dr. Ken Haines had the disadvantage of joining us when the cruise was nearly over, yet he, like Alan, was soon part of us and he gave us an added spurt of interest toward the end of our journey - the tantalizing idea that we might find Amazon River water as we sailed home!

This report was prepared mostly at sea. It has the disadvantages of lack of follow-up in library research and proper quiet for reflection on the data. However, putting the abstracts and data in one place while the memories of the cruise are still fresh is valuable - it gives us a first picture of what our part of the ocean was like this autumn, 1980.

Mary Farmer
Chief Scientist
W-54

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INTRODUCTION

This cruise report provides a record of the scientific research activities conducted aboard the R/V Westward during the laboratory section of the Introduction to Marine Science course - NS225 at Boston University. The itinerary and ship's track for W-54 (Table 1; figure 1A and B) provided the opportunity for a great deal of open ocean work as well as some coral reef studies in the Caribbean. Ship's complement is given in table 2.

The academic program at sea consists of studying two aspects of the ocean: (1) how a ship responds to changes in and over the ocean and (2) how the ocean itself changes as we move across its surface. How these subjects are presented is described in the appendix. The major portion of the second question is answered through the design and carrying out of individual student research projects. These projects are finished while the students are still aboard and it is the abstracts of these projects that comprise the bulk of this report.

Research conducted during W-54 also represented the ongoing work of individuals and agencies that have extended their assistance to our students. Material reported here should not be excerpted or cited without written permission of the Chief Scientist.

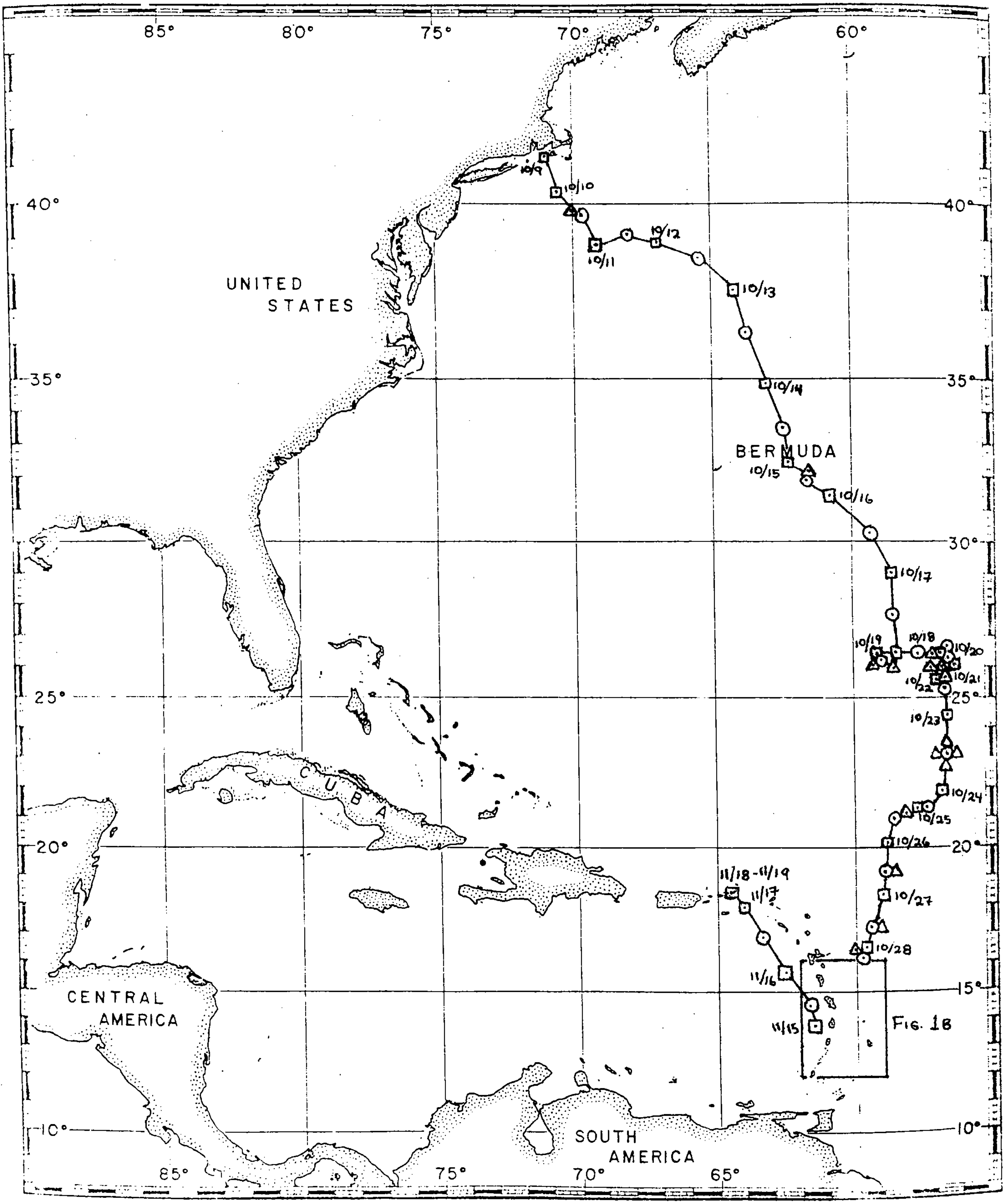


Figure 1. Cruise track for cruise W-54 of the R/V Westward. A. Atlantic section.

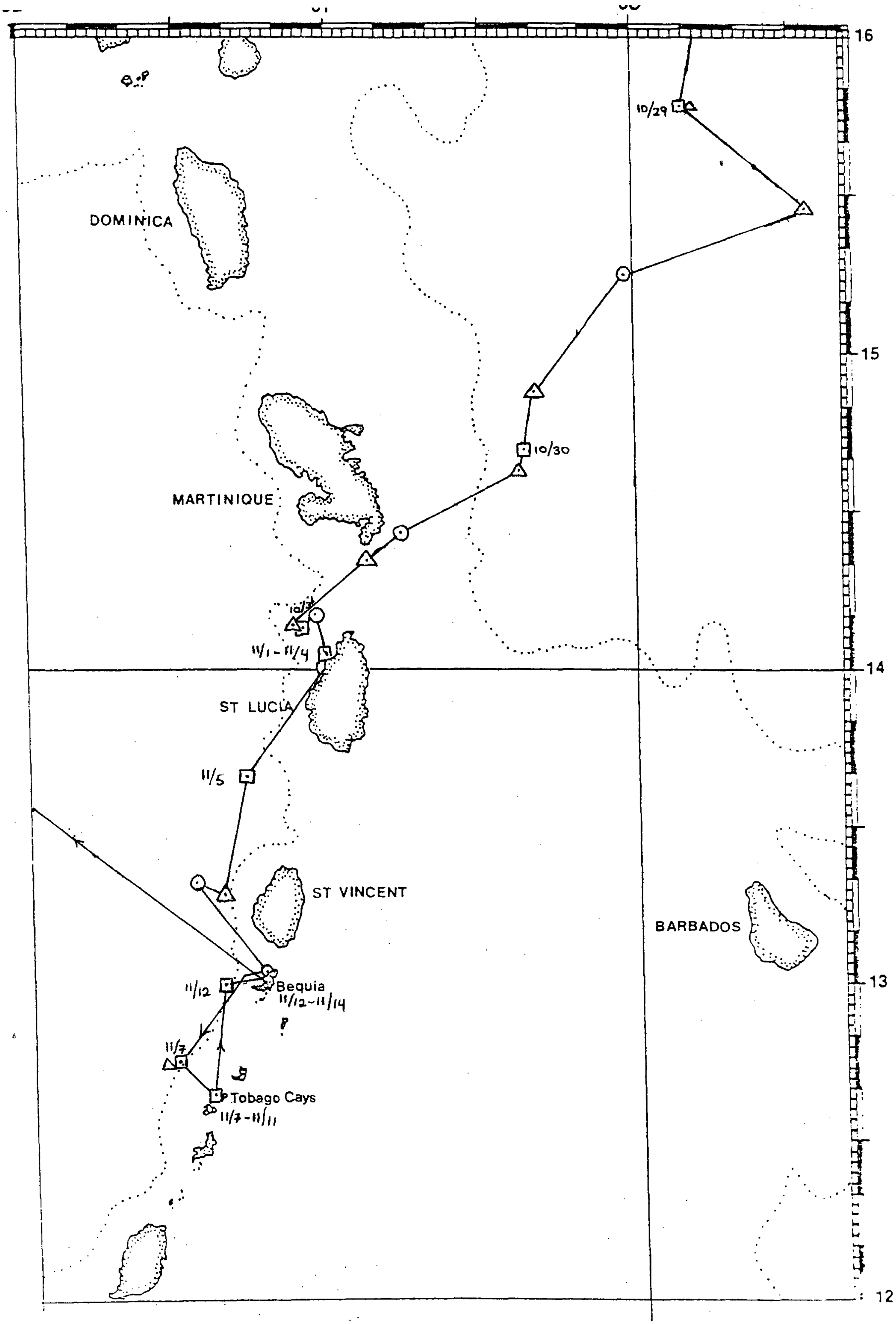
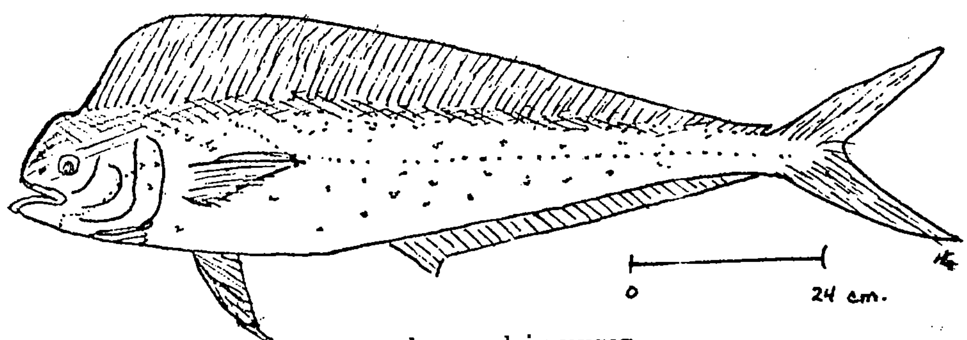


Figure 1. B. Caribbean section.

Table 1. Itinerary and port stops for cruise W-54

Port	Arrive	Depart
Woods Hole, Massachusetts	-	08 October 1980
Castries, St. Lucia	01 November 1980	02 November 1980
Marigot Bay, St. Lucia	02 November 1980	04 November 1980
Admiralty Bay, Bequia	06 November 1980	06 November 1980
Tobago Cays, St. Vincent	07 November 1980	12 November 1980
Admiralty Bay, Bequia	12 November 1980	14 November 1980
Charlotte Amalie, St. Thomas	19 November 1980	-



Coryphaena hippurus

Table 2. Ship's complement for Cruise W-54

Nautical Staff		
Wallace Stark		Captain
John Wigglesworth		Chief Mate
Phil Sachs		Second Mate
Peter Vanadia		Third Mate
Greg Lohse		Chief Engineer
Sally Kaul		Chief Steward
Scientific Staff		
Mary Farmer, Ph.D.	Biological Oceanography	Chief Scientist
Dorinda Ostermann	Biological Oceanography	Assistant Scientist
Alan Hickey	Physical Oceanography	Assistant Scientist
Visitors		
Bill Hallstein, M.D.	Falmouth, MA	Medical Doctor
Ken C. Haines, Ph.D.	St. Croix, U.S.V.I.	Biological Oceanography

Students

Claire E. Aldrich, B.A., Yale University
James Anderson, Junior, U. Pennsylvania
Timothy D. Armour, Junior, Middlebury College
Benjamin Bole, B.S., Colgate University
Mariette Buchman, Junior, Tufts University
Mark H. Carpenter, Junior, U. Pennsylvania
Paul S. Chomet, Junior, U. Rhode Island
Margaret C. Couper, Senior, Williams College
Nickoletta I. Farros, B.S., Stanford Univeristy
Harriet M. Grimm, Senior, New York University
James Hardiman, Senior, Boston College
Steven J. Hermansky, Senior, U. Nebraska
William R. Howard, Senior, Brown University
James M. Leather, Senior, Colgate University
Mary O. Metcalf, Senior, St. Lawrence University
Christopher Patricoski, Junior, U. Notre Dame
Andrew C. Phillips, Senior, Colgate University
Gregory D. Putnam, Junior, Lake Forest College
Robert B. Schoenberger, Senior, Massachusetts Inst. Technology
Warren D. Steinmetz, B.S., Southeastern Massachusetts University
Regina A. Tanner, Junior, Miami University (Ohio)
Catherine A. Ten Eyck, Senior, Smith College
Tara Vander Els, Senior, U. Rhode Island
David W. Wright, Junior, Colby College

COOPERATIVE PROGRAMS

Cooperative Ship Weather Observation Program (NOAA)

Alan Hickey

The R/V *Westward* is certified to gather weather observations for the U.S. National Oceanic and Atmospheric Administration in cooperation with an international weather program. The data, collected at 0600 and 1200 GMT, form part of a global grid for forecasting and satellite surface-truth purposes.

On W-54, 27 sets of observations were collected, of which 56% were successfully transmitted. Of these, about 85% were copied by November Mike November, Portsmouth, VA, to which all transmissions were initially addressed, and 15% by November Mike Foxtrot, Boston, MA.

LONG TERM INTERNAL PROGRAMS

Over the years a few topics have shown themselves particularly amenable to studies by students on the R/V Westward. On nearly every cruise projects are undertaken in one or more of these areas and data collected for these projects has become increasingly standardized and useful as each new student contributes to the information we have accumulated.

One of these subjects, the distribution of spiny lobster larvae, has become an area of research interest to me, and I was lucky to be along on this cruise where a record number of 87 larvae were sorted and identified by two students (Aldrich and Chomet). The project conducted by Chomet and Aldrich changed some of my thinking on my own research, and I appreciated their contribution.

Another subject on long-term interest has been bird sightings. On W-54 we attempted to sight migratory birds on radar (Bole) without success. We did, however, sight many migrating land birds and we will send this information to Tim and Janet Williams of Swarthmore College, Pennsylvania, who have been of great help to us. Data on pelagic birds (Metcalf) will be sent to Tim Rumage of the Rhode Island School of Design, who has established a standardized system for recording and storing our pelagic bird data.

Tarballs, being ubiquituous in the Atlantic Ocean, have been studied for a few years by Westward students. This cruise Jim Leather studied the organisms growing on them and found they may not be as toxic as has been supposed in the past.

Vertical diurnal migration and distribution of Panulirus argus larvae as affected by surface and subsurface currents

Paul Chomet and Claire Aldrich

ABSTRACT

The vertical diurnal migration patterns of Panulirus argus larvae, commonly known as the spiny lobster, and the dispersion effects of surface and subsurface currents upon them were studied in the Sargasso Sea and North Equatorial Current. These migration patterns, generally characterized by a negative phototactic response, tend to occur within deeper ranges as the larval stage advances (Rimmer 1979). At each station, zooplankton nets were towed at depths of 0, 40, and 80 meters. Current flow meters were also set at the same depths to record surface and subsurface current speeds. Limited resources precluded the possibility of accurately measuring current direction.

Migratory depth ranges were estimated (figure 2). Early stages sank to a level of 40 meters during the day and probably rose to the surface at night, although this observation could not be verified because of technical difficulties with the surface net. Late stages sank deeper than 80 meters during the day and rose to between 40 and 80 meters at night. In both instances, the moon's illuminating effects delayed or suppressed vertical migrations.

Although current flow meters did not yield direct information concerning current direction, the data, when considered with the set and drift of the vessel, indicated that the velocity of the current (speed and/or direction) changed with the depths sampled. Therefore, later stage larvae are subject to different current effects than early stages. This allows for a mechanism of distribution and dispersion of later from earlier larval stages.

Rimmer, D.W. and B.F. Phillips. 1979. Diurnal migration and vertical distribution of phyllosoma larvae of the Western Rock Lobster, Panulirus cygnus. Mar. Biol. 54: 109-124.

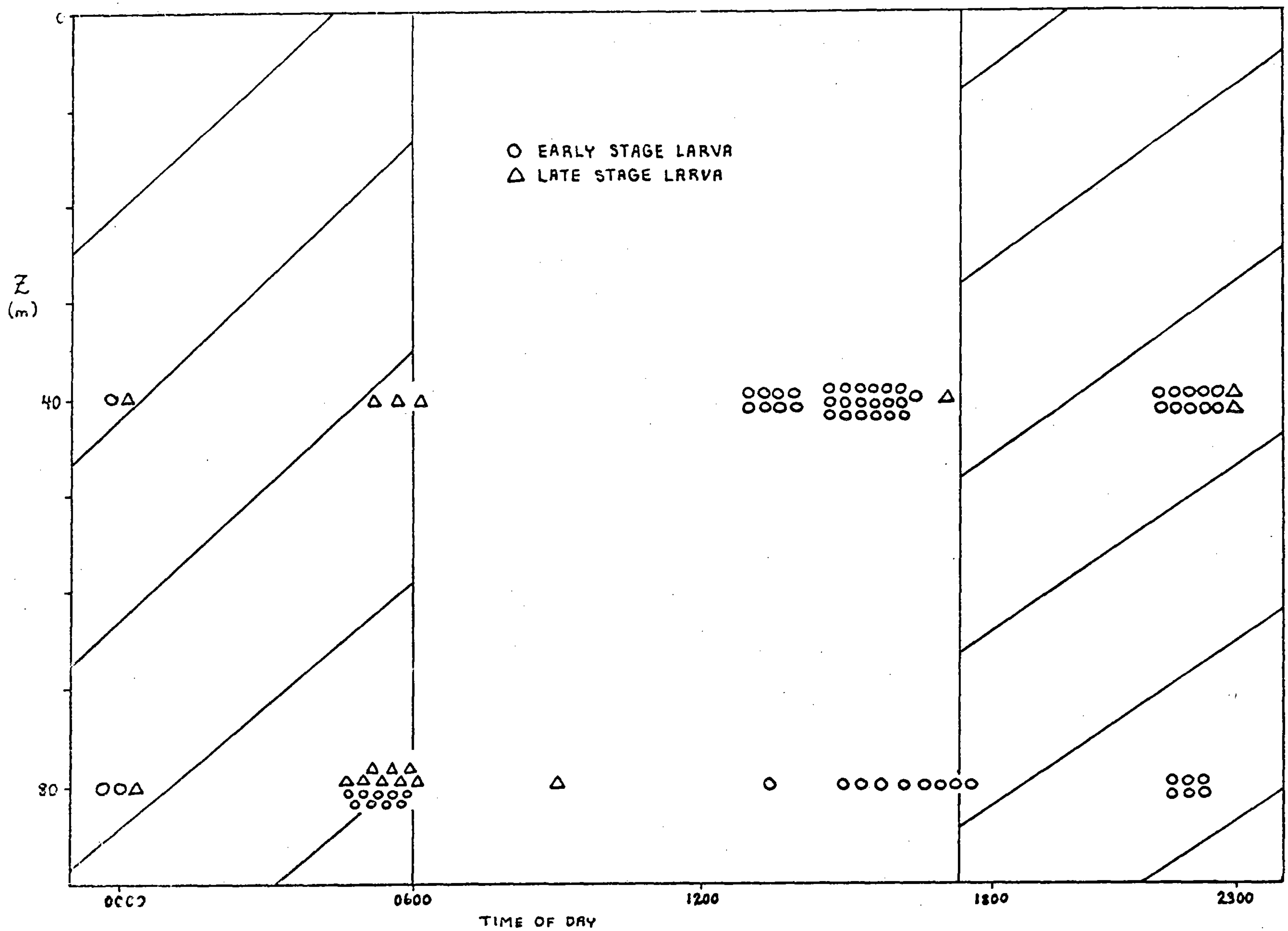


Figure 2. Concentration of spiny lobster larvae at each of three depths, at various times of day. Circles = early stage larvae (0 to 3 months age). Triangles = late stage larvae (4 to 11 months age). Shaded area - night.

Distance from Land as a Factor Affecting the Distribution of Birds on the Open Ocean

Mary O. Metcalf

ABSTRACT

A continuous bird log was kept during the cruise, starting just out of Woods Hole and ending in the Tobago Cays. Thirty minute counts (two 10-minute counts at the bow separated by one 10-minute stern count) were made twice a day except when the ship was hove to for station work. From these counts and from my own and other individuals' observations, a total of 28 species was recorded: five pelagic species; four semi-pelagic; four shore species; and thirteen terrestrial species (table 3 and figure 3A and B). The shearwater was the msot abundant pelagic species. The terrestrial birds, especially the large flocks of warblers and swallows, appeared to be following the fall migratory path southwards. As anticipated, there was definitely a greater concentration of birds near land masses, with decreasing numbers and species as we moved further out into the Atlantic (fig. 3). The nutrient-poor waters of the Sargasso Sea, the ocean equivalent of a desert, typically showed a significant absence of bird life as compared to other areas covered in the cruise track.

Table 3. Birds sighted along the cruise track of W-54 with key to figures 3A and B.

Key #	Scientific name	Common name	No. observed
(1)	*Puffinus* sp.	Shearwater	31
(2)	*P. gravis*	Greater shearwater	5
(3)	*P. griseus*	Sooty shearwater	8
(4)	Fam. Hydrobafidae	Storm petrel	7
(5)	*Stercorarius* sp.	Jaeger	1
(6)	*Fregata magnificens*	Magnificent frigate-bird	10
(7)	Laridae; *Sterna* sp.	Tern	23
(8)	*Sula leucogaster*	Brown (white-bellied) booby	38
(9)	Fam. Ardeidae	Egret	7
(10)	Fam. Laridae	Gull	20
(11)	*Larus argentatus*	Herring gull	7
(12)	*Florida caerulea*	Little blue heron	5
(13)	Fam. Scolopacidae	Sandpiper	12
(14)	*Actitus macularia*	Spotted sandpiper	1
(15)	*Falco sparverius*	American kestrel	1
(16)	*Quiscalus quiscula*	Boat-tailed grackle	5
(17)	Fam. Accipitriidae or Falconidae	Hawk	2
(18)	*Chordeiles minor*	Nighthawk	1
(19)	*Phaethon lepturus*	Yellow-billed (white-tailed) tropic bird	1
(20)	*Sitta canadensis*	Red-breasted nuthatch	1
(21)	Fam. Fringillidae	Sparrow	2
(22)	*Passerculus sandwichensis*	Savannah sparrow	1
(23)	*Hirundo rustica*	Barn swallow	28
(24)	Fam. Parulidae	Warbler	11
(25)	Fam. Parulidae	Yellow-rumped warbler	9
(26)	*Dendroica palmarum*	Palin warbler	2
(27)	*D. dominica*	Yellow-throated warbler	1
(28)	*D. virens*	Black-throated green warbler	1

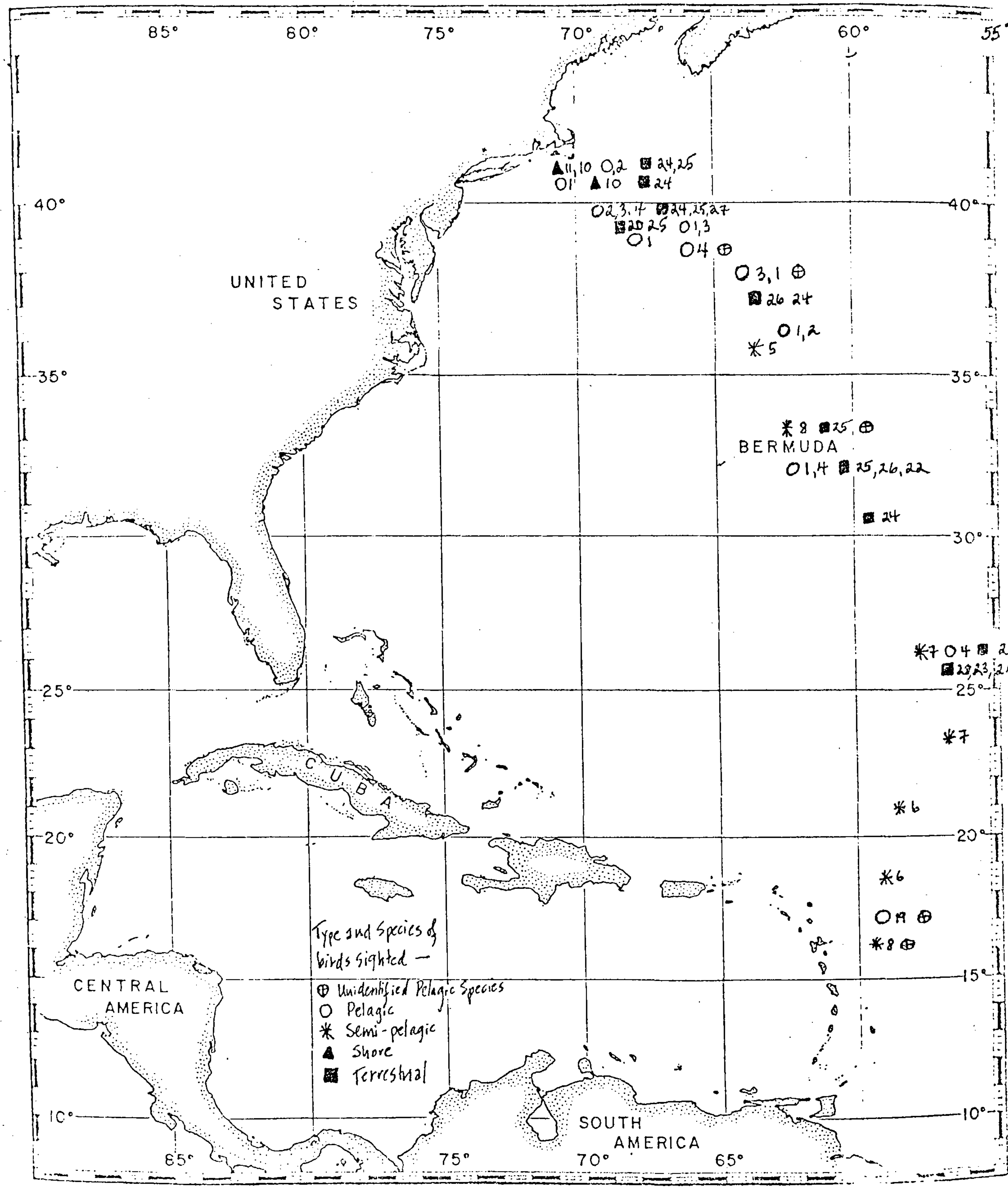


Figure 3. Birds sighted along cruise track of W-54. A. Atlantic section. Symbols represent the normal habitat of the bird seen. Numbers refer to the species given in table 3.

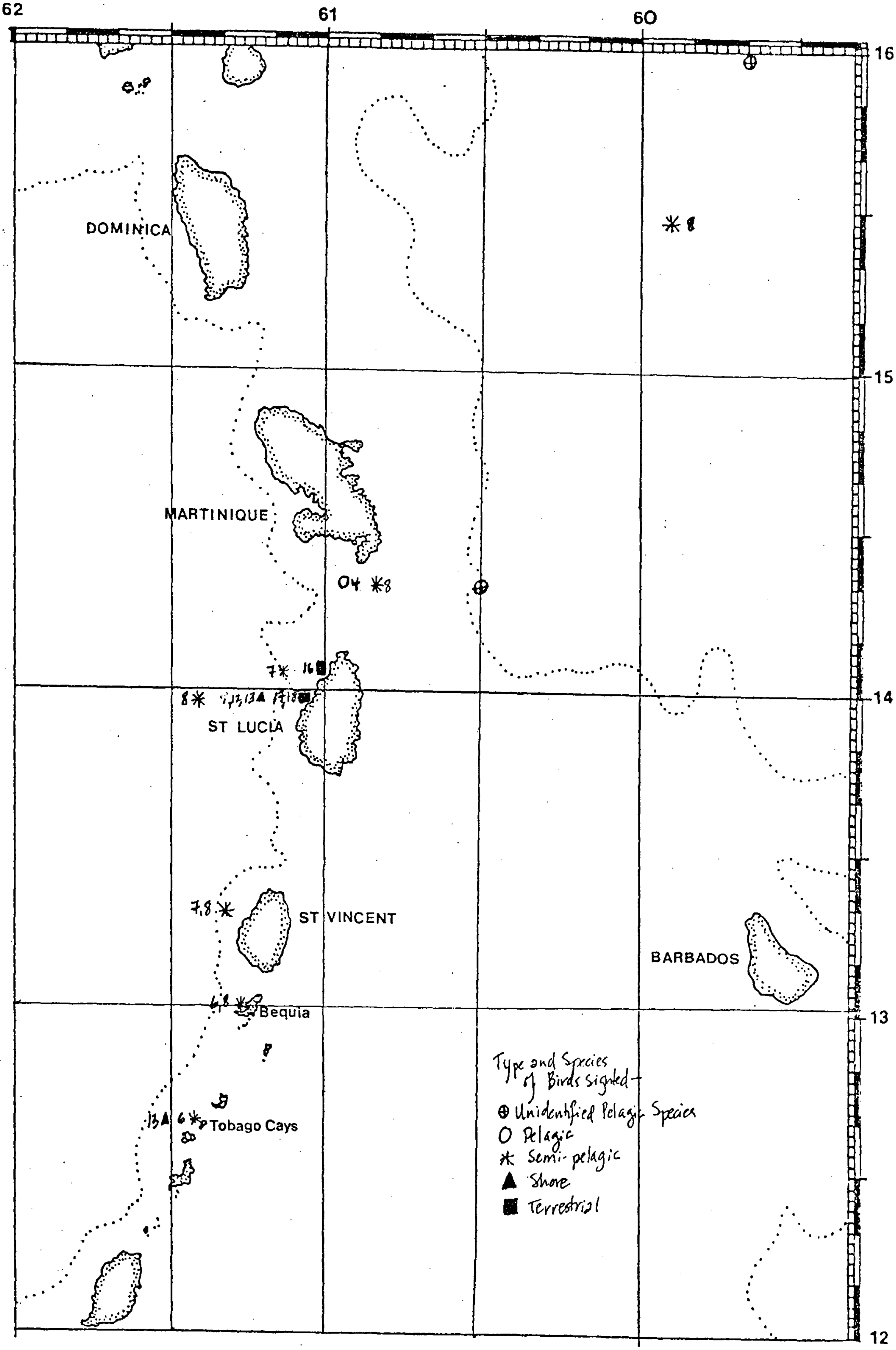


Figure 3. B. Caribbean section.

Considerations of Passerine Migration

Benjamin Bole

ABSTRACT

Every autumn over 100 million birds migrate from the Eastern seaboard of North America toward South America and the islands of the Caribbean. Many of the migrating flocks have been found to travel over the Atlantic towards the Sargasso Sea, then veer to the west to intercept their wintering grounds. Recently, work has been done using radar to track the paths of migrating birds (Williams and Williams, 1978). A current hypothesis is that birds leave the Atlantic coast just after the passage of a cold front, which provides favorable tail winds for the first leg of the journey toward Bermuda. After passing through a stationary bank of turbulence in the vicinity of Bermuda, the birds intercept the prevailing easterlies over the Sargasso Sea and are set toward the west and their destiny (Williams and Williams, 1978).

The cruise trace of W-54 passed through some previously unstudied areas of the bird migration paths. Although radar observations were unsuccessful, frequent visual observations were made of passerines. Of interest was the appearance of a flock of immature Barn Swallows on and around Westward southwest of Bermuda near 26"N, 58"W. They appeared with the onset of a wind shift from northeast to southeast, then southwest (table 4). A study of weather patterns prior to this time suggested the birds may have departed the northeast coast before a stagnant cold front had completely passed, leaving on southwest winds rather than the more favorable northwest winds that would have prevailed had the cold front passed on through. Then the birds probably met turbulent and less than optimal winds near Bermuda. The combination of factors may have tired the birds and caused many of them to drop when they encountered the contrary winds southeast of the turbulent zone.

The last sighting of passerines was on 22 October 1980. At this point in our cruise we headed west and southwest and may have moved out of the range of major flyways.

Williams, T.C., and J.M. Williams. 1978. An oceanic mass migration of land birds, in Wilson, B. [Ed.] 1980. Birds. Sci. Am. W.H. Freeman and Co., San Francisco, CA.

Table 4. Distribution of bird sightings with respect to weather conditions along the cruise track of W-54.

Date	Time	Species	Wind	Force	% Clouds	Location
Oct. 9	1620	Myrtle Warbler	E	2	0	N41 W71
10	0850	Warbler	ENE	4	25	40 70
	1445	Warbler		2		
	1820	Warbler (5)	NE	2	5	39 69
11	0640	Red Breasted Nuthatch	SE	2	25	39 69
	0727	Myrtle Warbler	SSE	3	35	39 69
14	0745	Palm Warbler	WNW	4	50	36 64
15	1530	Warbler	NW	5	50	35 63
	1650	Warbler	NNE	5	45	33 62
	0805	Yellow Rumped Warbler	NNE	3	50	32 61
	1445	Warbler	NE	4	95	32 61
16	1620	Savannah Sparrow	SSE	4	60	32 61
19	0608	Barn Swallow	SSW	3	65	31 60
20	0930	" "	SW	3	50	26 58
	0702	" "	SSW	3	40	26 58
	1815	" "	SSW	3	30	26 58
	1020	" "	WSW	1	40	26 58
21	1045	" "	WSW	3	30	26 58
	0542	" "	SSE	3	30	26 56
22	0730	" "	SE	3	20	26 57
	1320	" "	SSE	3	70	26 57
	1400	Black Throated Green Warbler	SE	3	20	26 57

Epifauna associated with pelagic tarballs

Jim Leather

ABSTRACT

Over the past several decades pelagic tar concentrations have been rising (Butler et al. 1973). This project was conceived to investigate the epifaunal community residing on the tarballs. The stalked barnacle Lepas was the most dominant member of the community (table 5), followed by the hydroid Clytia and several other organisms commonly associated with the pelagic alga Sargassum. Of special interest were several types of unidentified eggs adhering to the tarball surface. Their presence in late stages of development, along with the several polychaetes found within the tarballs, questions the commonly held notions concerning hydrocarbon toxicity.

Butler, J.N., B.F. Morris, and J. Sass. 1973. Pelagic tar from Bermuda and the Sargasso Sea. Bermuda Biological Station Special Pub. 10.

Table 5. Number and species of organisms found on pelagic tarballs

Date	Position Lat (N)	Position λ (W)	Sample No.	*Lepas pectinata*	*Clytia noliformis*	*Litiopa melanostoma*	*Planes minutus*	*Calothrix crustacea*	*Creseis acicula*	*Parathemisto abyssorum*	Eggs * I	Eggs * II	Eggs * III	Eggs * IV	Eggs * V	Polychaete I	Polychaete II	Tarball size (mm)	Tarball minimum age (months)
16 Oct 80	30°32'	59°50'	1	1			1											63x45x23	3.1
17 Oct 80	27°22'	58°35'	1	1				1										16x11x7	
19 Oct 80	26°14'	57°25'	1													1		19x8x7	
29 Oct 80	15°10'	60°06'	1		C**								1					3x2x2	
05 Nov 80	13°19'	61°22'	1			1			1									11x9x5	
			2							1				7				8x6x3	
07 Nov 80	12°50'	60°35'	1	4	A	1				1		5		4				8x6x4	2.3
			2	2	B													13x10x6	1.0
			3	3													1	7x7x3	2.5
			4	2														4x3x2	3.6
			5	3	A							15		4				13x9x5	1.2
			6		A						7	6		3				9x6x3	
			7	8	A									3				8x8x5	3.4
			8	3							2							9x5x4	1.6
			9		B													10x6x4	
			10	1														7x5x4	2.1
			11	1								2			1			10x8x3	2.7
			12	1					1		4			3				8x5x3	1.2

*Egg types:
Type I = transparent
Type II = white
Type III = yellow
Type IV = orange
Type V =

**Key to percentage of tarball covered by the colonial hydroid Clytia noliformis: A = more than 50%, B = 25 to 50%, C = less than 5%

STUDIES OF THE SHIP, R/V WESTWARD

Two projects were undertaken to improve or better understand the ship. In the first, Armour and Anderson undertook to find more space on the existing vessel as well as to make suggestions for a new one. In the second, Carpenter did a meticulous analysis of the drain on the ship's batteries caused by use of the hydrowinch. Copies of the first project will be sent to the long range planning committee of S.E.A., and the results of the second project will become part of the laboratory notebook kept on the ship.

The Evaluation and Relocation of Space on the Westward

Tim Armour and
Jim Anderson

ABSTRACT

The R/V Westward was designed as a pleasure yacht, but now her function has changed and she is presently used as a research and training vessel. For this reason it was felt important to evaluate her design and offer suggestions on how it might be improved. Through the use of questionnaires, discussions with the Westward staff, and our own personal observations, a redesign of the Westward has been put forth (figure 4). The questionnaires made it possible to get student opinions on such questions as what areas are most congested or whether classroom space is adequate. Lokewise, discussions with the staff helped us find the needs of specific areas on the vessel such as the lab, galley, navigation area, and engine room. The most important way we collected data, however, was by our own personal observations. Through these we realized the necessity of making some essential changes like moving the salon forward, up next to the galley and making the rain and linen locker into a small study area (figure 4). We also moved the main head forward to an area that is presently occupied by bunks. This was done because the area is frequently warm and noisy.

This study also includes the design of an expanded version of the Westward that could accommodate a larger program in a more spacious area (figure 5). This vessel was designed with the specific functions of S.E.A. in mind.

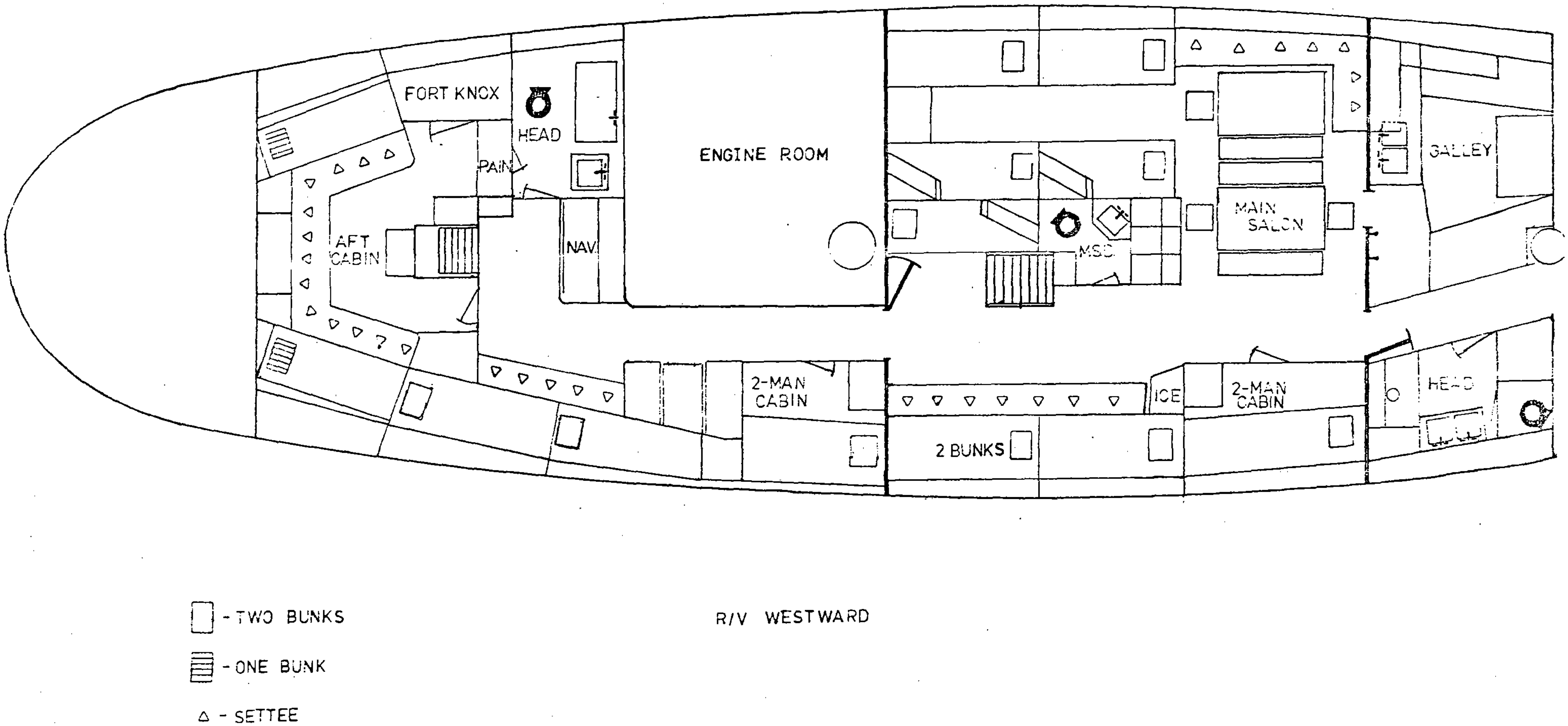


Figure 4. Plan for revised Westward. Note the following changes: (1) Foul weather locker off main head. (2) Study area in present foul weather/linen locker area. (3) New location of main head and MSD. (4) A larger main salon with direct access to galley.

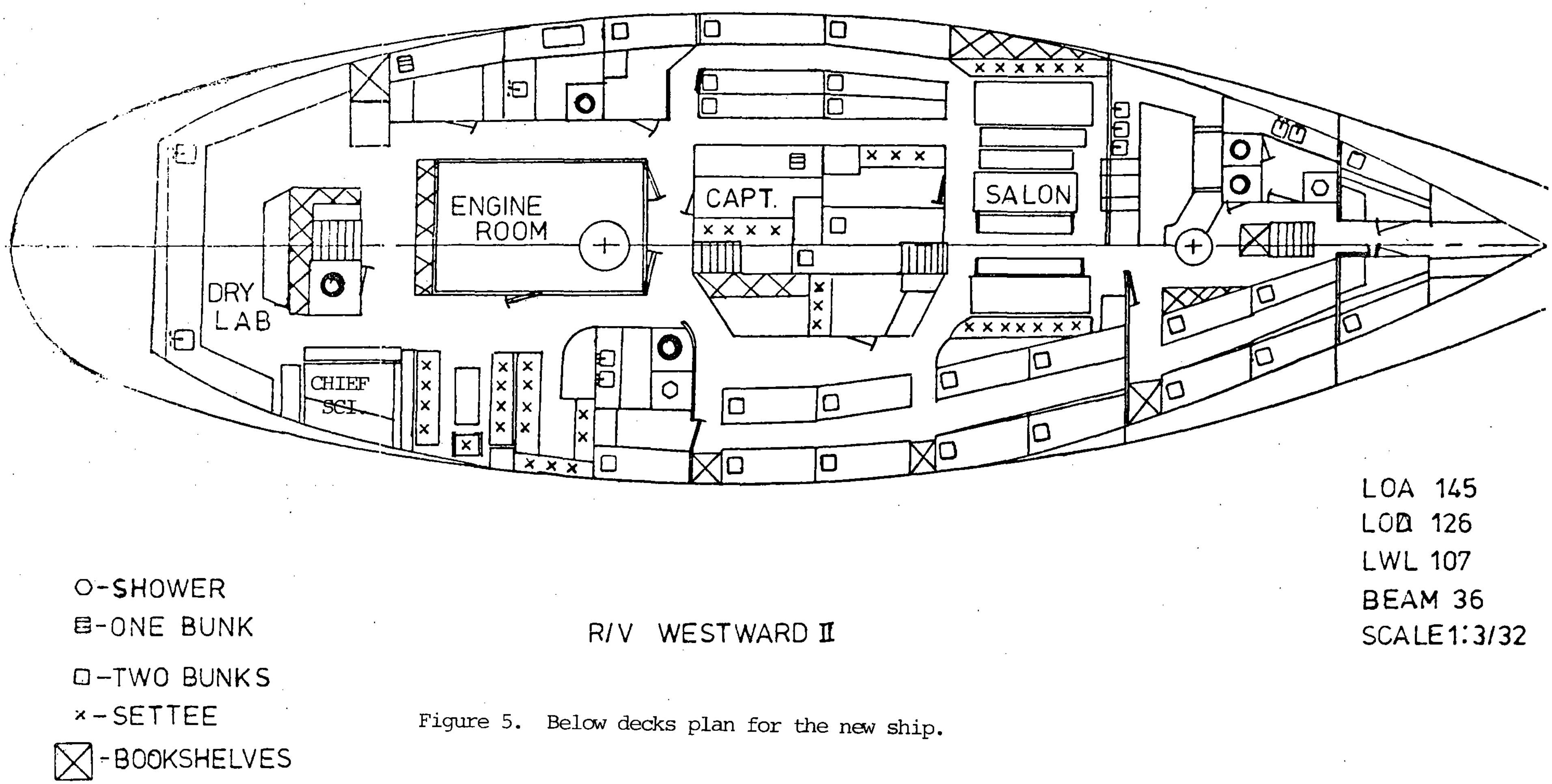


Figure 5. Below decks plan for the new ship.

Westward's Power Drainage Examined

Mark A. Carpenter

ABSTRACT

The purpose of this project was to study the energy drain associated with the hydrowinch. Data were collected by recording voltage and amperage from the DC panel and on-off times for the hydrowinch during various casts. Daily energy drain for the entire vessel, excluding two daily charging periods, was 39.26×10^6 joules. Hydrowinch energy drain, in joules and percentage of a two-cycle day, was as follows:

Shallow hydrocast (80 m): 0.527×10^6 joules - 1.28%
Deep hydrocast (1000 m): 3.19×10^6 joules - 8.12%
Meter net tow (160 m wire out): 0.776×10^6 joules - 1.98%
1 KHT (1200 m wire out): 5.32×10^6 joules - 13.56%

Energy consumption for each gear was calculated, based on length of time the hydrowinch operated in that gear. Separate curves were established for wire being fed out (down) or being hauled back (up) (figure 6). This graph shows that the optimal gear to use for reducing energy drain depends on (1) amount of wire to be let out (translated to time required for operation) and (2) whether the wire is going out or coming back. By calculating ahead of time the time required to reach, say, 600 meters in each gear and then going to the chart, one can see that the optimal gear for this depth is fourth gear going down (343 seconds required = 190 watts) and second gear coming up (1395 seconds required = 950 watts).

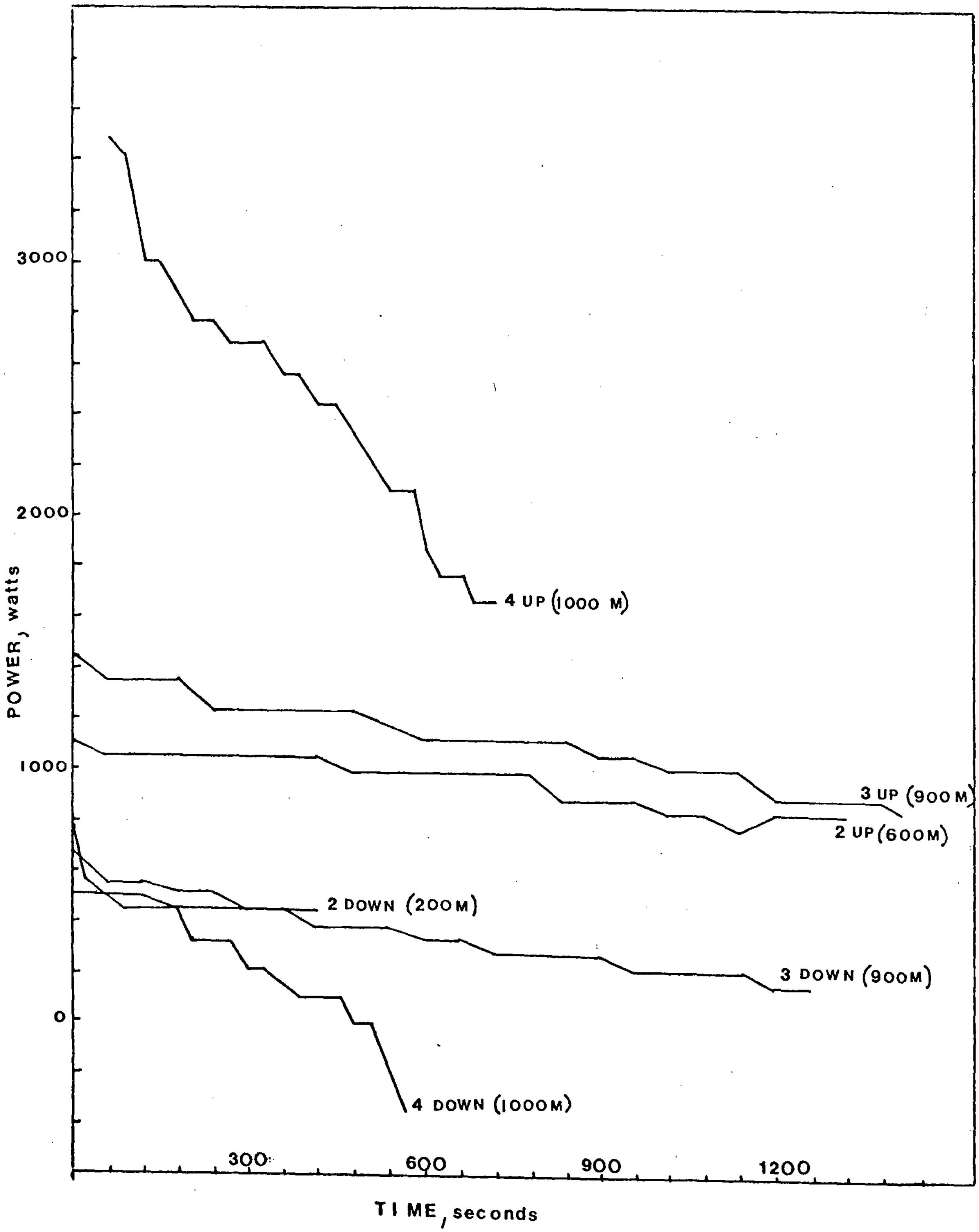


Figure 6. Power usage by the hydrowinch on R/V Westward. Each curve represents the power required to run the winch in the gear given (the number beside each curve), the direction given (up = wire being hauled onto the drum; down = wire being let off the drum), and the distance given (in parentheses). Wire going down in fourth gear actually fed power back into the system after 540 seconds of operation.

OCEANOGRAPHIC STUDIES ON W-54

Introduction and summary

Oceanographic studies on cruise W-54 were done almost entirely to accomplish the individual projects designed by the students while in Woods Hole, before the cruise began. Data to answer the questions raised in the project proposals were collected during science watch, by hourly collections of surface temperatures, bathythermographs at regular intervals, and by heaving the ship to for oceanographic stations. Thirty-one of these stations were done, and the data from the hydrocasts are summarized in the appendices. Of the 31 stations, six were clustered in the Southern Sargasso Sea and nine were in the North Equatorial Current (figure 1), reflecting the areas of major scientific interest in this cruise.

A complete bathythermograph profile along the cruise track was done to study the depth of the mixed layer with respect to wind speed (Farros). No statistical relationship was found, but there was a relationship between density of water (as measured in terms of temperature and salinity) and the depth of the mixed layer.

Three studies were done on primary producers and how they (or the detection of them by chlorophyll analysis) changed by water mass. Certain assemblages were characteristic of each water mass studied both at the surface (Howard) and at depth (Vander Els). The depth of the chlorophyll maximum layer, however, was only slightly different in continental waters than in the Sargasso Sea (Schoenberg) and therefore may represent a relatively conservative characteristic of phytoplankton. Zooplankton biomass, done as a routine part of lab watch, showed no significant differences in total amount of plankton material present along the entire length of our cruise track.

In the Sargasso Sea an effort was made to find the physical reason windrows are formed (Putnam). The cause was not found but evidence of anomalous density differences beneath the wind-mixed layer was found. The Sargassum weed was studied as a substrate for several organisms (Grimm and Wright). A succession of dominant organisms was found, with the "pioneers" probably less susceptible to known plant toxins than later species. The peculiar Sargassum fish, *Histrio histrio*, was studied for its eating habits (Hermansky). It preferred solid colored, fast-moving food, regardless of taxonomic order, to mottled and slow-moving organisms.

Finally, the Sargasso Sea is known as the probable spawning ground of the American and European freshwater eels. We found none of these eel larvae, although we did find larvae of other eel species as well as a postlarval stage of the colorful dolphin fish (Ostermann).

After we passed through the Sargasso Sea we reached the edge of the North Equatorial Current and Echo Bank. We continued the search for Echo Bank (Farmer) and used the Westward as a current meter here (Couper). The North Equatorial Current carries large volumes of water into the Sargasso Sea. Steinmetz found that as this water passed over the island passages, its specific alkalinity decreased, showing that calcium carbonate was removed by shallow water coral organisms during the transit. Patricoski found that midwater fish were larger in number and in diversity than he expected near the island passages. Finally, Hardiman showed that OTEC plants could be established in the Lesser Antilles islands due to the large thermal gradient between surface deep water.

PHYSICAL CHARACTERISTICS

Surface temperature and salinity

Temperature and salinity of surface waters show the effect of heating by the sun and the degree of evaporation relative to precipitation. These factors change with season, with latitude, and with distance from land. On cruise W-54 surface temperature and salinity were done in the late fall season, covering a 29° range in latitude and varying from near 0 to 740 nautical miles from land (figure 1).

Temperatures were taken every hour except when the ship was hove to for station work or was in port. Salinities were done every four hours, whenever a bathythermograph was done. In addition, a special salinity transect consisting of samples taken every two hours between Bequia and St. Thomas was done at the end of the trip.

Six distinct surface water masses could be identified by temperature alone: continental margin, Gulf Stream, Northern Sargasso Sea, Southern Sargasso Sea, North Equatorial Current, and Caribbean Sea (figures 7 and 8). The mean temperature value ofr each of these water masses was significantly different from the mean value of the adjacent water mass (table 6). Aftwe we entered the Gulf Stream, temperature increased as a function of decreasing latitude as we went south.

Continental water between Martha's Vineyard and about 90 miles out to sea was the coldest and most variable of the water masses sampled. A dramatic increase in temperature was seen approximately 50 miles before we reached the 1,000-fathom curve and this warm water persisted to the edge of the Gulf Stream (figure 7). This warm water may have been the remnant of a warm-core eddy or may in some other way reflect the warming influence of the Gulf Stream sloshing up over the continental margin.

Sudden drops, then rises, in temperature of a whole degree or more were seen three times in the Gulf Stream and four times in the Sargasso Sea (figure 7). These sudden changes are usually associated with counter-currents when seen in association with the Gulf Stream and with thermal fronts when seen in the Sargasso Sea. The features in both cases extend beneath the surface, as will be seen in the bathythermograph profiles.

Table 6. Characteristics of surface water along cruise track W-54, mean values ± standard deviation, (n = number of samples) and results of z-test for significance between adjacent water masses.

Cruise track section	Surface water mass	Date/time	Temperature (°C)	Salinity (°/oo)	Depth of mixed layer (m)
A	Continental margin	09 Oct 80/1100 to 10 Oct 80/0300	16.4±1.9 (n=18)	-	-
B	Gulf Stream	10 Oct 80/0400 to 12 Oct 80/2300	24.8±1.0 (n=68)	36.14±.26 (n=11)	47.8±14 (n=12)
C	Northern Sargasso Sea	13 Oct 80/0000 to 15 Oct 80/2300	25.3±0.33 (n=65)	36.18±.13 (n=14)	51.6±9 (n=17)
D	Southern Sargasso Sea	16 Oct 80/0000 to 23 Oct 80/2000	27.5±0.59 (n=154)	36.45±.20 (n=23)	45.5±8 (n=32)
E	North Equatorial Current	23 Oct 80/2100 to 30 Oct 80/1300	28.5±0.24 (n=106)	35.49±.34 (n=18)	40.2±10 (n=25)
F	Caribbean Sea	30 Oct 80/1500 to 16 Nov 80/1200	28.2±0.16 (n=104)	35.38±.34 (n=27)	-

Adjacent water masses	Probability (p) that the mean values are the same: Temperature	Salinity	Mixed layer
A-B	$p < .005$	-	-
B-C	$p < .005$	NS	$.05 < p < .10$
C-D	$p < .005$	$p < .005$	$.005 < p < .01$
D-E	$p < .005$	$p < .005$	$.005 < p < .01$
E-F	$p < .005$	NS	-

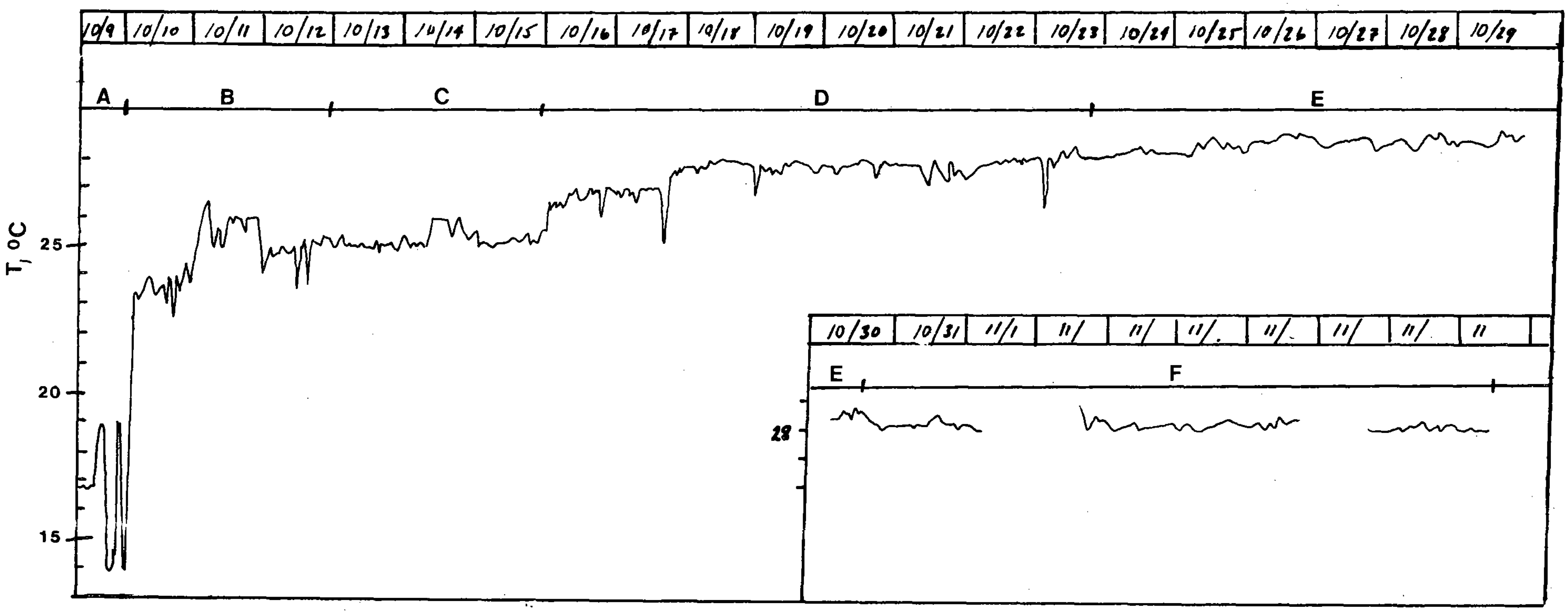


Figure 7. Surface temperature recorded hourly along cruise tract W-54. Water masses are identified as follows: A = continental margin, B = Gulf Stream, C = Northern Sargasso Sea, D = Southern Sargasso Sea, E = North Equatorial Current, F = Caribbean Sea. See figure 8 for extent of these water masses.

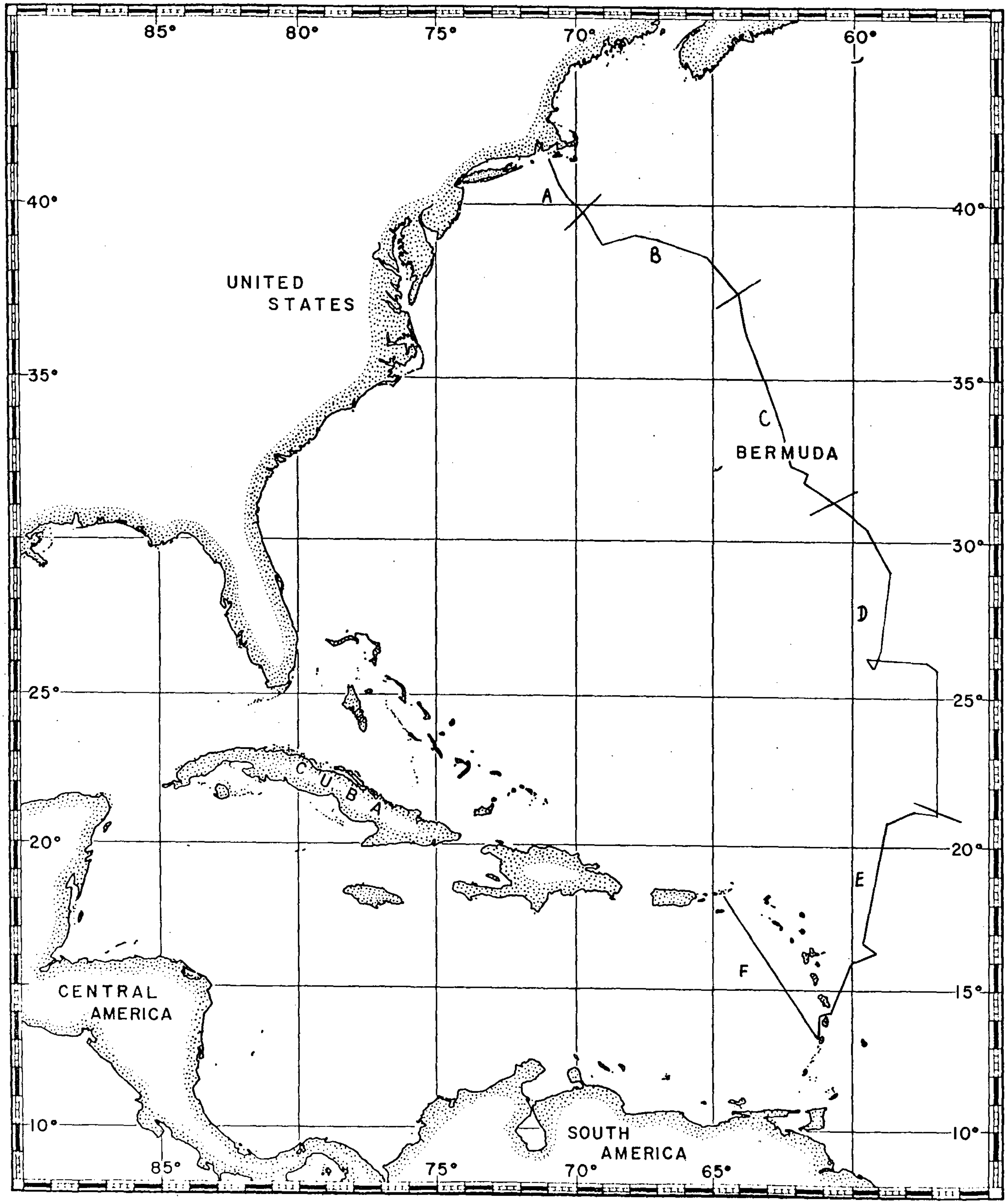


Figure 8. Extent of water masses identified by surface temperature measurements. A = Continental margin. B = Gulf Stream. C = Northern Sargasso Sea. D = Southern Sargasso Sea. E = North Equatorial Current. F = Caribbean Sea.

Salinity also changed with latitude but salinity alone could not be used to distinguish between the water masses of the Gulf Stream and the Northern Sargasso Sea nor between the North Equatorial Current and the Caribbean Sea (figure 9 and table 6). The highest salinities encountered were in the Southern Sargasso Sea, at latitudes where evaopration greatly exceeds precipitation (approximately 21° to 32°N). The lowest salinities were in the North Equatorial Current at a latitude of about 17°N and again in the Caribbean Sea opposite the passage between Dominica and Martinique (about 15°N). These fingers of low salinity water may represent the effluence of the Amazon River, which travels north and west after it leaves the coast of Brazil (see study by Haines, this report).

Vertical temperature and salinity structure

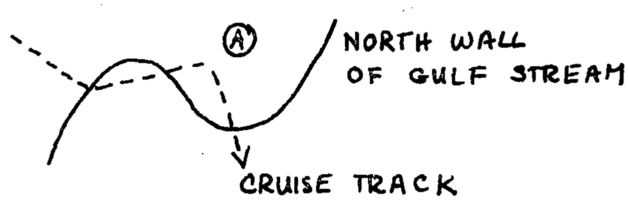
A) Bathythermograph profiles

The bathythermograph (BT) gives a continuous record of how temperature changes with depth. A series of BTs will enable one to construct a graph showing lines of equal temperature (isotherms). These isotherms reveal such features as the depth of the surface mixed layer, the thermocline, thermal fronts, temperature inversions, and internal waves. A BT profile will also outline current systems when run perpendicular to the current.

Bathythermographs were conducted every four hours from the approximate position of the Gulf Stream until entering the Caribbean Sea for the purpose of determining the depth of the fixed layer along the cruise track (see Farros, this report). Storm conditions prevented us from obtaining BTs during the period from noon 16 October until 1722 hr 17 October 1980.

The depth of the mixed layer changed significantly with water mass being deepest in the Northern Sargasso Sea and closest to the surface in the North Equatorial Current (table 6).

The most striking feature of the BT profile was created by crossing the north wall of the Gulf Stream twice on the 10th of October (fig. 10). First we skimmed across the northern tip of a meander of the Stream, then we entered the Stream again as shown in the following sketch.



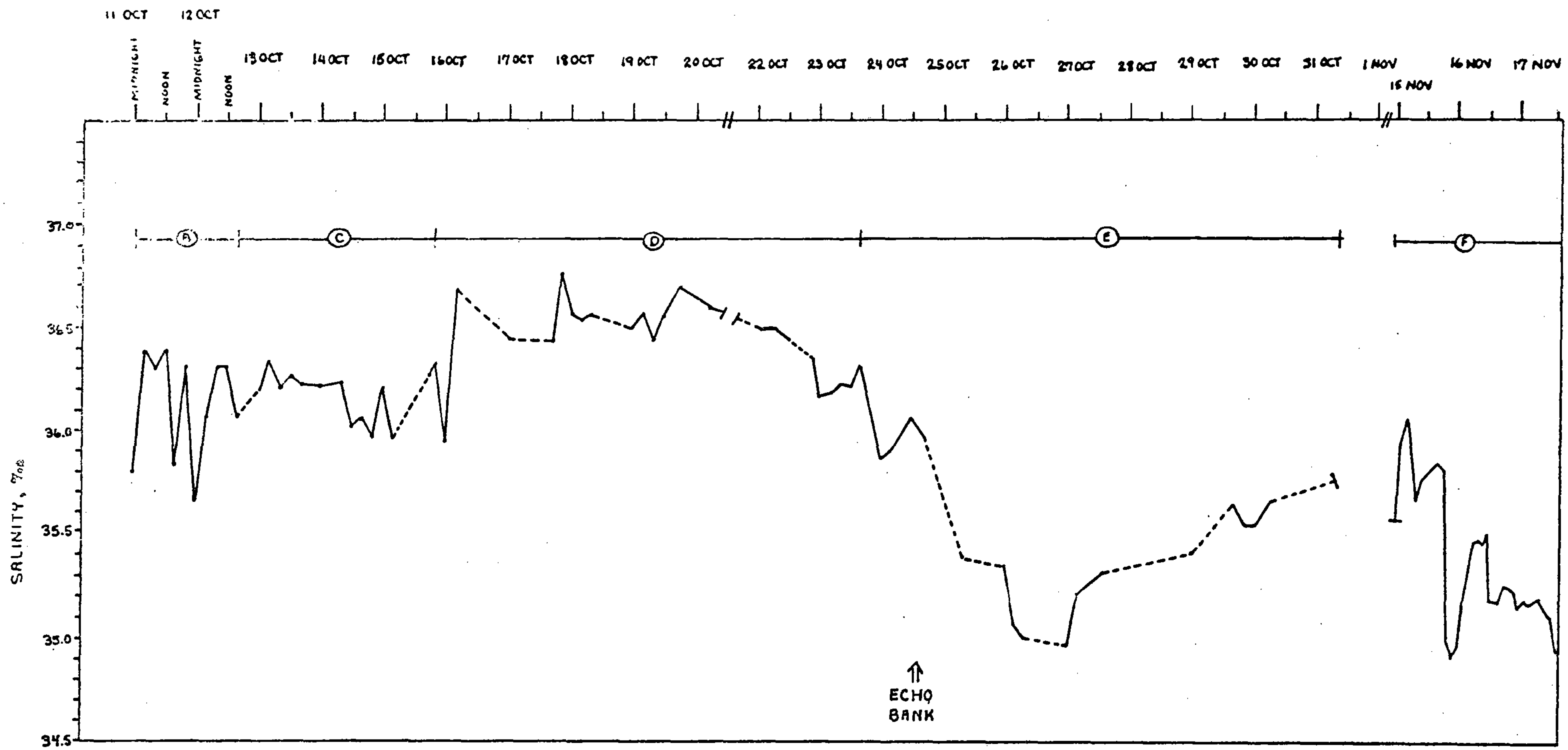


Figure 9. Surface salinity recorded at four-hour intervals along cruise track W-54. Letters describe water masses as given in table 6. Dashed lines indicate the interval between salinity readings was greater than four hours.

The initial crossing of the north wall was accompanied by a dramatic deepening of isotherms; 78°F (25.5°C) water went from the surface to a depth of 240 feet (73 m) within a distance of 10 nautical miles. Leaving the north wall was accompanied by an equally dramatic rise in the same isotherm. In the water between north wall crossings ("A" in the above sketch) a subsurface intrusion of cold water between layers of relatively warm water was seen at 160 feet (49 m). This cold water probably represents the counter-current which runs along the north wall of the Gulf Stream in the opposite direction of the stream. Current velocities in this counter-current may be nearly as high as Stream velocities, but the width of the counter-current is much more narrow than the Stream. A warm water inversion was noted at about 390 feet (119 m) beneath the cold water intrusion.

The major feature in the surface layers of the Sargasso Sea is the warming of the mixed layer as we moved south. A single isotherm dropping from the surface to the top of the thermocline indicates that the entire mixed layer has warmed to that temperature. The 77°F (25°C) line dropped to the thermocline soon after we left the Gulf Stream and entered the Northern Sargasso Sea (figure 10). Surface water warmed from 78 to 80°F (25.5 to 26.7°C) while we went through the storm of 16 and 17 October. By the time the water had warmed to 81°F (27.2°C) we were in the Southern Sargasso Sea.

At this point in the cruise track we crossed one of the two thermal fronts that could be identified on the BT profile. (Two other possible thermal fronts, as suggested by surface temperature readings were crossed during and immediately after the storm and did not show up on the BT profile.) The thermal fornts, labeled B in figure 10, are places where surface water terperature changes rapidly in a short distance. This change in temperature of surface water is accompanied by a change in temperature at depth as dell, and in both instances on this cruise the effect extended at least as deep as the BT could measure (600-800 ft or 183-244 m). Thermal fronts usually indicate a change in water mass. In this sense, the Gulf Stream represented a special case of a thermal front. Thermal front A occurred within the Southern Sargasso Sea and must indicate a seasonal or local effect. Thermal front B marked the end of the Sargasso Sea and the beginning of the North Equatorial Current.

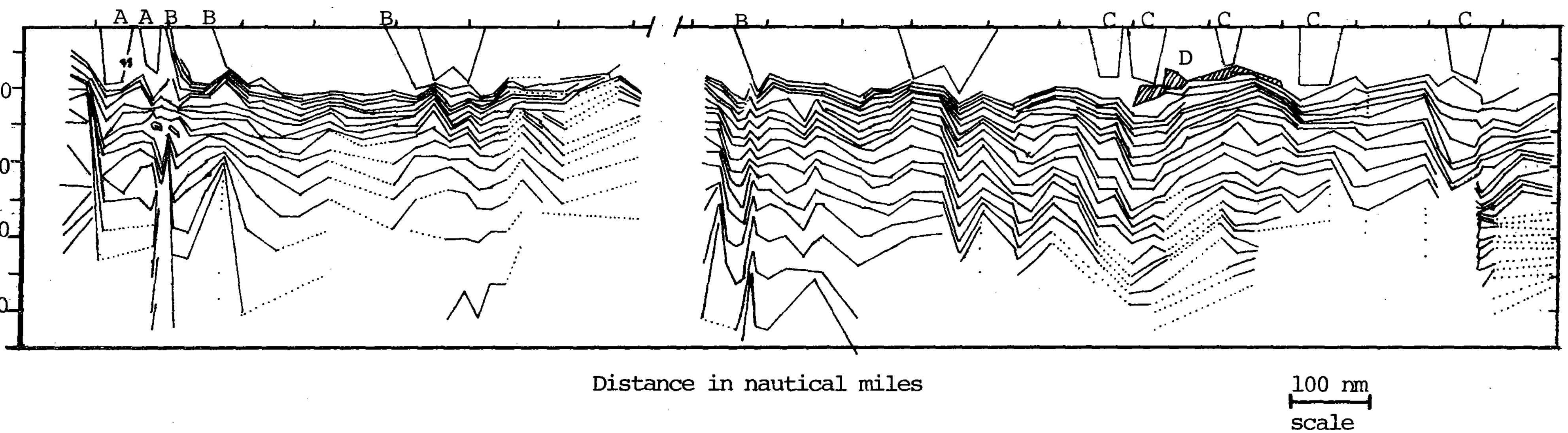


Figure 10. Vertical temperature structure of the top 20 meters of water as defined by bathythermographic profiling along the cruise track W-54. Labeled features are: A = Gulf Stream, B = thermal fronts, C = U-shaped isotherms indicating filaments of a current system, D = subtropical underwater inversion.

Two more features show up on the BT profile, both of them are well developed in the North Equatorial Current. The first is a local warming (or cooling) of the mixed layer. This warming is indicated by a U-shaped isotherm or isotherms extending from the surface into the mixed layer and going as deep as the thermocline (fig. 10, features C). The frequency of these features in the North Equatorial Current indicates that this current system, like the Gulf Stream, is made up of many filaments of water and is not one continuous stream.

The second feature seen in the North Equatorial Current and not elsewhere is a warm-water inversion just beneath the mixed layer (fig. 10, feature D). The inversion is Sargasso Sea water that has sunk beneath the surface and is moving away from the current gyre. The feature is known as Subtropical Underwater and extends into the Caribbean Sea.

B) Temperature-salinity diagrams

A temperature-salinity (T-S) diagram shows temperature plotted against salinity and enables one to see how these variables change with depth at a given station and also to compare these factors from station to station. Each water mass of the world ocean has a characteristic T-S profile.

The T-S diagrams for the 5 deep hydrocast stations conducted on cruise W-54 showed that although surface waters were variable, water deeper than 200 meters was virtually identical throughout the cruise (fig. 11). All stations gave an approximately Z-shaped curve. The upper limb of the Z was least distinct at station W54-7 in the Sargasso Sea. Here at the very surface water was cooler and more saline than at any other station. By contrast surface water at station W54-23 in the Caribbean was fresher than at any other station although just beneath the surface it was as saline as water at any other station.

The Subtropical Underwater seen in the BT profile is here seen at 140 meters at station W54-18, where the top leg of the Z extends further to the right than at any other station. The slight differences among stations in the rest of the curve show the gradual freshening of mid-depth water as we moved away from the Sargasso Sea and, at depths of 700-1000 meters, the gradual freshening of water as we moved south toward the source of Antarctic Intermediate Water, which was found at all stations at these depths.

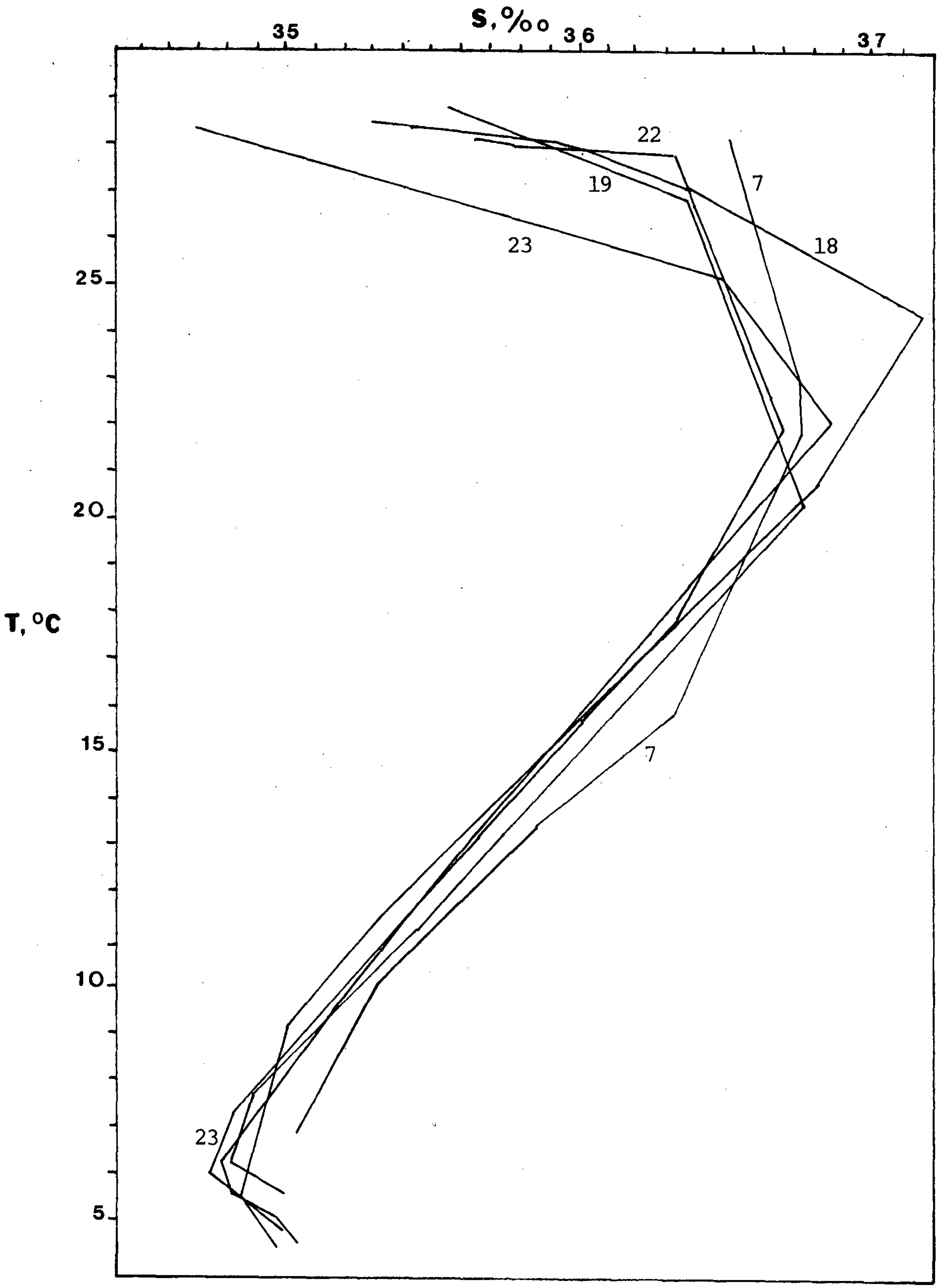


Figure 11. Temperature-salinity diagrams for all deep hydrocast stations on cruise W-54.

In summary, surface temperatures revealed six distinct water masses along the cruise track of W-54. Salinity did not change as drastically as temperature and could not be used along to distinguish between the Gulf Stream and the Northern Sargasso Sea nor between the North Equatorial Current and the Caribbean Sea.

Temperature structure with depth as seen in the BT profiles revealed features that separated water masses as well as features that showed nonuniform mixing in the so-called mixed layer. Temperature-salinity profiles indicated that although surface waters varied significantly during the cruise, deeper waters did not.

Effects of Wind Speed Variation on the Deepening of the Mixed Layer

Nikoletta T. Farros

ABSTRACT

The main factor affecting the depth of the mixed layer is considered to be wind mixing. This project examined the effect of wind speed variation on the depth of the mixed layer. Temperature profiles were taken using the bathythermograph (BT) approximately every four hours from October 10 until October 31 to determine the depth of the mixed layer. Apparent wind speed and direction, and the course and speed of *Westward* were noted to determine the true wind speed. The BT data were divided on the basis of surface temperature into four water masses: Gulf Stream, Northern Sargasso Sea, Southern Sargasso Sea, and the North Equatorial Current (figure 8). Average wind speeds ranged from 2 m-sec^{-1} to 8 m-sec^{-1}. Using a one-factor analysis of variance no significant correlations between the average wind speed and the depth of the mixed layer were found for any of the water masses. Work done by Halpern (1974) and Tabata et al. (1965) showed correlations did exist between the average wind speed and the depth of the mixed layer when wind speeds were 10 m-sec^{-1} and higher. These studies suggest that the lack of correlations for this project can be attributed to the low wind speeds measured on this cruise. However, correlations between surface temperature and salinity did exist for the Sargasso Sea. A higher surface temperature was associated with a deeper mixed layer ($r = 0.86$) and a lower surface salinity was associated with a deeper mixed layer ($r = -0.82$). An increase in temperature and a decrease in salinity both work to decrease the density of sea water, thus making the energy required to mix a given volume less than would be required for higher density. Hence, wind at a given speed could mix water of low density to a deeper depth than water of a high density.

Halpern, D. 1974. Observations of the deepening of the wind-mixed layer in the northeast Pacific Ocean. J. Phys. Oceanogr. 4:454-466.

Tabata, S., E.J. Boston, and F.M. Boyce. 1965. The relation between wind speed and summer isothermal surface layer of water at ocean station P in the eastern subarctic Pacific Ocean. J. Geophys. Res. 70(16): 3867-3878.

WATER MASS STUDIES

A transect study of phytoplankton diversity in surface waters

William R. Howard

ABSTRACT

Plytoplankton community composition and diversity were studied on a transect from Woods Hole to St. Lucia, W.I. Samples were taken from the continental margin, Sargasso Sea, and North Equatorial Current. Samples were collected using a net with a 30-cm mouth, towed at the surface at one knot. Total and species cell counts were made, and diversity was calculated using the index $D = (S-1)/\log_e N$.

It was expected that diversity would increase and cell density would decrease along the transect, accompanied by a change from diatom to dinoflagellate dominance. This spatial pattern would roughly correspond to a seasonal succession. Instead, the continental margin station resembled the Sargasso Sea samples in its physical water characteristics, phytoplankton diversity and cell number (table 7). Four species were found in common at both continental margin and Sargasso Sea stations, and not in the North Equatorial Current. This finding was interpreted as representing an intrusion of Sargasso Sea water to the continental margin. However, it is not conclusive, since some overlap was also seen between other adjacent water masses (table 8). Diversity was highest at Southern Sargasso station #4, perhaps due to an isolated water mass being in a late stage of succession. All the assemblages were overwhelmingly dominated by the blue-green alga Trichodesmium, perhaps because of its ability to fix nitrogen in nutrient-poor waters. Dinoflagellates possessing body spines and ribs were most numerous in the remaining flora, these being able to resist sinking in the well-stratified water.

Table 7. Physical and biological characteristics of water sampled for phytoplankton composition and diversity

Water mass	Station No.	Depth	Temperature (°C)	Depth of mixed layer (ft)	Salinity (°/oo)	Oxygen ($ml.l^{-1}$)	Cell No. (m^{-3})	Diversity index $\frac{S-1}{\ln N}$
Continental margin	1	0	23.57	150	35.55	5.07	37	1.26
		50	18.28		-	4.18	17	5.36
Northern Sargasso Sea	2	0	25.43	150	36.64	-	3.4	0.99
		100	21.57		35.02	-	19	2.35
Southern Sargasso Sea	3	0	27.85	165	36.24	-	128	0.9
		100	22.67		36.84	-		
	4	0	27.90	140	36.40	-	68	1.9
		100	23.11		36.91		83	3.02
	7	0	27.97	150	36.49	4.44	11.6	1.01
		100	21.86		36.76	5.20	60	4.31
North Equatorial Current	15	0	28.78	115	34.77	5.09	175	1.19
		100	25.46		36.74	5.24		
	16	0	28.0	135	36.90	5.50	1,670	0.61
		100	25.79		35.34	5.25	83	0.93

Table 8. Phytoplankton assemblages exclusive to each water mass, and to two adjacent water masses, on cruise W-54.

(s) = found at surface only, (d) = found at depth only, * = found both at surface and at depth.

Water mass	No. of species exclusive to it	Representative species
Continental margin only	10	Lyngbya aesturaii (d) Niteschia closterium* Peridinuum pallidum (d) Rhizoselenia robusta (d)
Continental margin and Northern Sargasso Sea	4	Biddulphia favis (d) Ceratium fusus*
Northern Sargasso Sea only	13	Ceratium trichoceros (d) Cladopyxis setifera (s) Peridinuum depressum (d) Tripsolenia sp. (s)
Southern Sargasso Sea only	14	Ceratium extensum (s) Ceratocorys sp. (s) Dinophysis rotundata (d) Peridinuum ovatum (d)
Northern and Southern Sargasso Sea	2	Ceratium declinatum (d) Phalacroma rotundatum*
North Equatorial Current only	14	Ceratium massilensi (d) Cladopyxis brachiolata* Eucanipia sp. (s) Leptocylindricus sp. (s) Peridinuum tritylum (d)
North Equatorial Current and Southern Sargasso Sea	3	Ceratium concilians (d) C. contrarium * C. gallicum (d)
Three or more water masses	18	Ceratium karoteni * C. teres (s) Coscinodiscus centralis * Lauderia borealis (d) Ornithocercus magnificus * Trichodesnium sp. *

Phytoplankton composition, density, and diversity in water beneath the thermocline

Tara Vander Els

ABSTRACT

This project dealt with the phytoplankton composition, density, and diversity at depths of 50 meters in continental margin waters and a depth of 100 meters in the Sargasso Sea, Echo Bank, and the North equatorial Current. A determination of indicator and cosmopolitan species was also made.

The data were collected using a phytoplankton net attached to a hydrocast wire. The samples were preserved with formalin and concentrated using a hand cranked centrifuge. Sixty-four species were identified. Eight were found in all water masses, 12 only in continential water, 12 only in North Equatorial Current water, and 9 in the Northern and 4 in the Southern Sargasso Sea. Of these indicator species only two were also found at the surface on this cruise: *Nitzschia closterium* (continental margin) and *Cladopyxis brachiolata* (North Equatorial Current) (table 8).

The highest density, accompanied by the lowest diversity, occurred in surface waters and a depth in the North Equatorial Current, which was therefore considered to be the most productive area (table 7).

Although cell number and diversity of phytoplankton beneath the thermocline essentially followed the same trends as phytoplankton at the surface (table 7), species composition was totally different. Temperature differences between the surface and depth ranged from 2.21°C in the North Equatorial Current to 6.11°C at station 7 in the Sargasso Sea. Species differences between surface and depth were greatest where the temperature differential was high and were least when the temperature differential was low. This evidence supports the idea that temperature may determine species composition (but not abundance) both horizontally, or across water masses, and vertically, or across thermoclines.

The deep chlorophyll maximum

Robert Schoenberger

ABSTRACT

A phenomena where chlorophyll concentrations are maximum at the thermocline and not the surface, called the deep chlorophyll maximum, was studied over the continental margin and in the Sargasso Sea. It closely corresponded to the nutricline of well stratified waters. The nutricline followed the thermocline (figure 12). The deep chlorophyll maximum was somewhat deeper in the Sargasso Sea than in the continental station. This difference could be attributed tc the deeper thermocline in the Sargasso Sea, which results in a deeper density gradient to which phytoplankton may sink. It may also be explained partly by a deeper euphotic zone in the Sargasso Sea, which allows photosynthesis to occur more deeply than in continental waters. On this cruise phytoplankton concentrations were greater at depth than at the surface, indicating that the chlorophyll increase beneath the thermocline was due to an actual increase in cell number and not just a result in increased chlorophyll per cell.

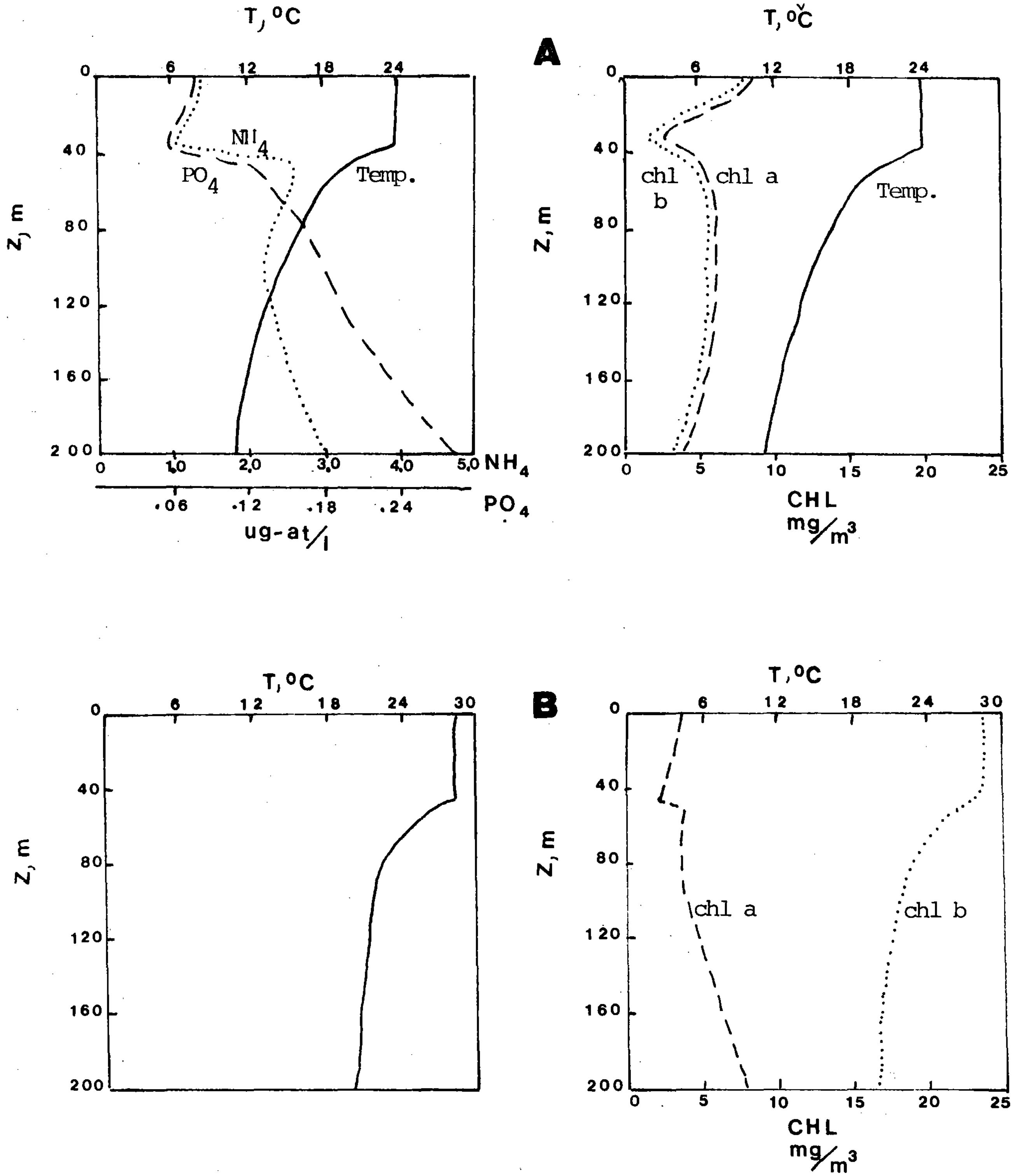


Figure 12. Vertical profile of the concentration of chlorophyll compared to nutrients and temperature in continental margin water (A) and to temperature alone in the Sargasso Sea (B).

Zooplankton biomass

Zooplankton are the most numerous animals in the sea. Nearly every biological phylum in the animal kingdom is represented in the plankton. They eat the phytoplankton (and they eat each other) and fish eat the zooplankton. Thus they establish the necessary link between the primary producers and the food we humans are interested in - the secondary and tertiary consumers of the sea.

Zooplankton may be caught by towing nets of various mouth sizes and mesh sizes through the water. After zooplankton are brought aboard and preserved, their abundance can be calculated by either counting the individual organisms or by measuring their biomass in some way. On Westward we measure the volume of the animals caught. If the amount of water filtered by the net is known, then the volume of animals existing in a cubic meter of ocean water can be calculated.

On cruise W-54, we conducted eleven stations for zooplankton. Three nets were towed at each station, one at the surface, one at 40 and one at 80 meters depth. The surface net had a mouth diameter of 1/2 meter and a mesh size of 333 μ. The other two nets had a mouth diameter of one meter and mesh size of 505 μ.

The greatest variability in zooplankton biomass was at the surface (figure 13) where a patch of zooplankton was seen at station W54-16. Otherwise all biomass values were within an order of magnitude of each other and no significant trends were seen either between water masses or between day and night.

These results support the findings regarding primary producers along this cruise track: the abundance did not vary among water masses, showing that although the physical characteristics of temperature and salinity varied along the cruise track, the conditions that determine productivity did not vary significantly. So, although the particular species (of phytoplankton at least) that were found depended on water mass characteristics, the total amount of living material was relatively constant throughout.

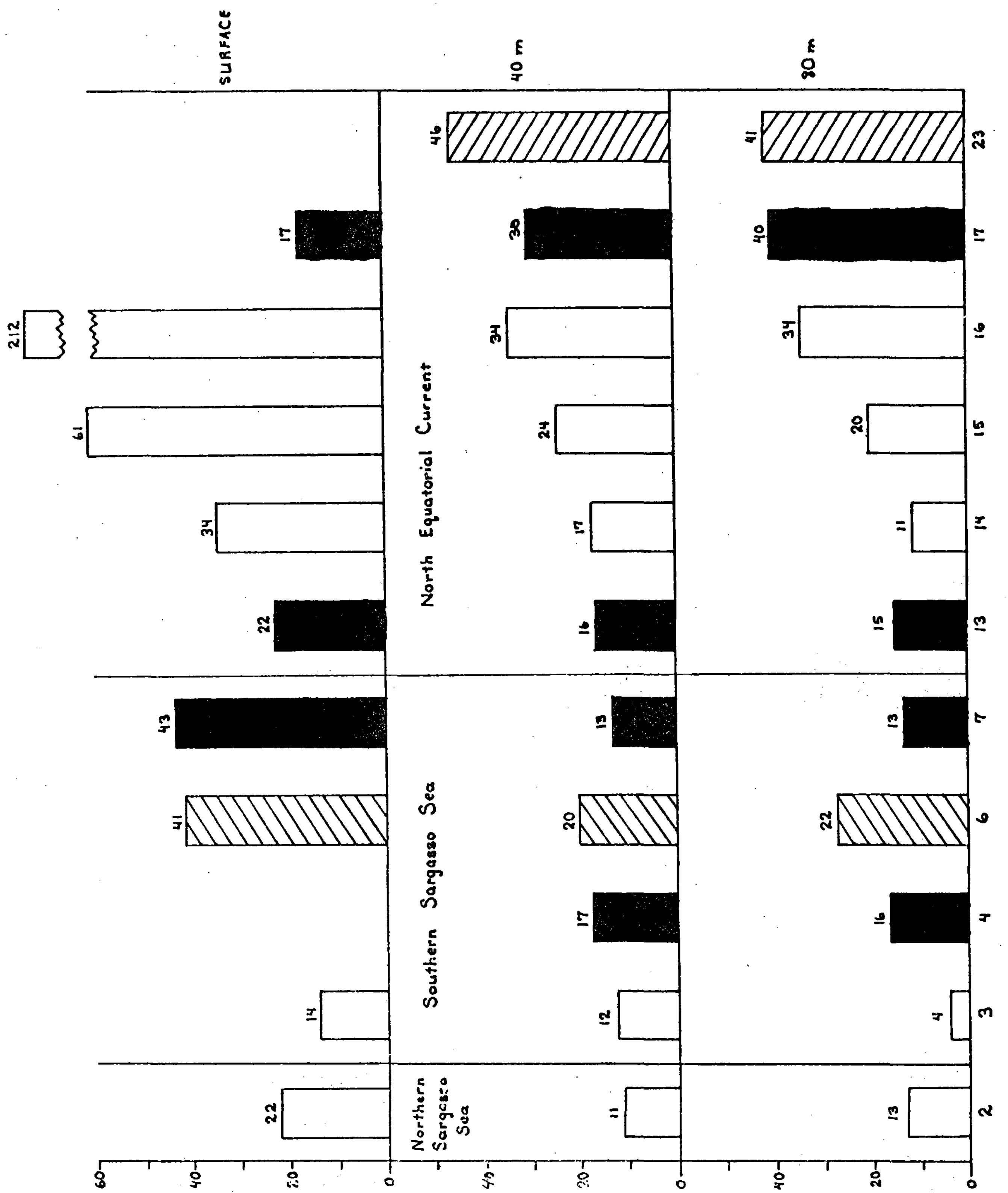


Figure 13. Zooplankton biomass at three depths and 11 stations, day and night. Numbers above the bar graphs = volume displacement (10^{-2} ml.m^{-3}). Shaded bars = night-time samples, unshaded bars = day-time samples.

SARGASSO SEA STUDIES

Windrows and convection patterns in the Sargasso Sea

Gregory Putnam

ABSTRACT

The project was designed to study the formation of water-cell circulation systems such as those seen when Sargassum weed is aligned in windrows. We were specifically interested in the role of density as a possible cause of the phenomena. A series of shallow Nansen casts, done as a general survey of water column stability, were compared with a series of casts at the site of formed windrows. The general survey indicated a generally uniform water column, which is most readily circulated and therefore favorable to windrow formation. At the site of the windrow, Richardson numbers (R_i = g/p(vertical density gradient/ vertical velocity shear)^{½}) were calculated for each column. These numbers indicated that simple hydrostatic instability, that is, density-driven sinking or rising of water masses, was not a crucial factor in windrow formation. The most striking data were obtained by calculation of geostrophic currents beneath the windrow (figure 14). The convergence of currents below and the divergence at the surface had the appearance of an ideal model of a density-driven upwelling convection. In fact, this was not the case. The currents were not actual but represented density-pressure anomalies between regular dense water at these depths and less dense water beneath the windrow, perhaps low-density surface water carried down by downwelling observed at the surface.

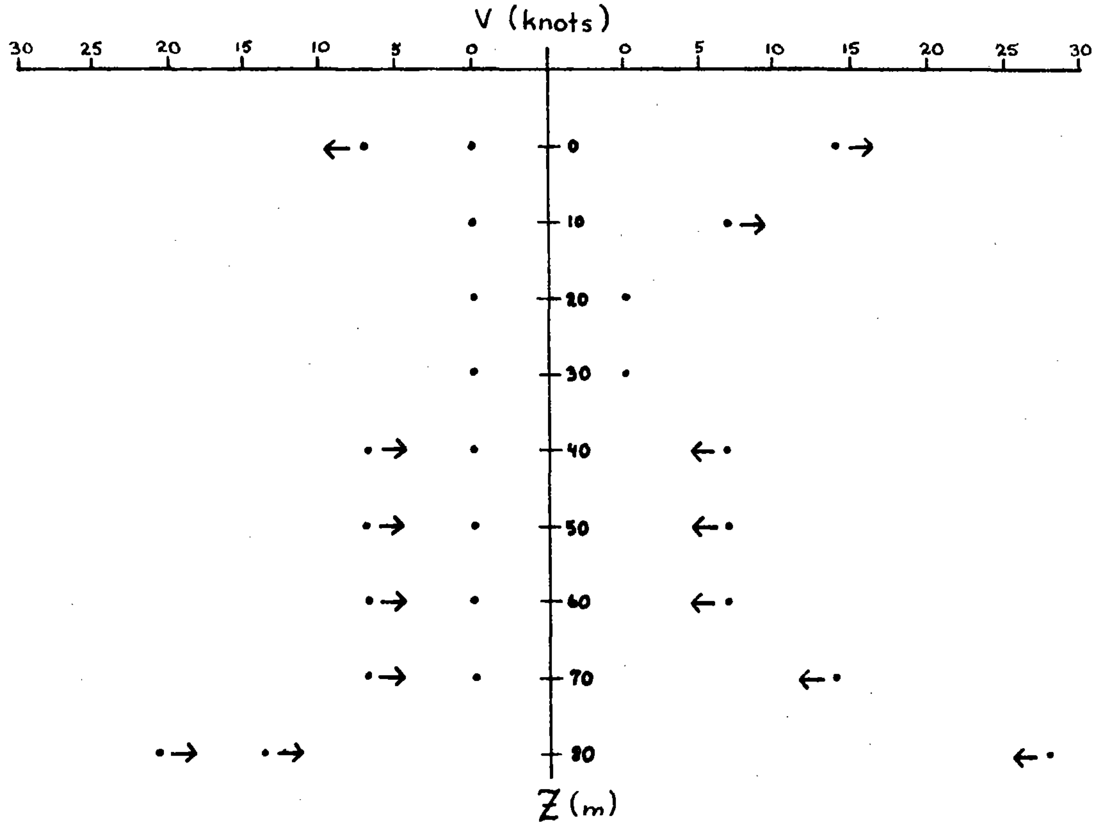


Figure 14. Direction and velocity of currents between stations 9 and 12 compared to currents between stations 10 and 11 near a windrow formation, based on geostrophic calculations. Dots mark the velocity of current at each depth and arrows indicate direction.

Early succession of epibionts on *Sargassum*

Harriet M. Grimm and David Wright

ABSTRACT

The organisms living attached to *Sargassum natans* and *S. fluitans* were examined to describe their ecological succession. *Sargassum* was viewed as a substrate suited for invasion by attaching organisms and the subsequent replacement of them by succeeding organisms. Samples were taken by dipnet from surface waters of the Southern Sargasso Sea. Both weed species were divided into old and young based on their color, and distance from the center of the clump, which was considered old weed. The abundance and cover by epizoans were compared by a Braun-Blanquet cover-abundance scale, using leaves, bladders, and stems as reference areas.

Hydrozoans (*Agaleophenia* on *S. fluitans* and *Clytia* on *S. natans*) were the early dominant forms (figure 15). Hydrozoans may be more resistant to the tannins produced by young *Sargassum* leaves and have faster growing rates. As *Sargassum* aged, *Membranipora* (a bryozoan) became the dominant epibiont. This may be due to reduced tannin levels, more epibionts giving the advantage to K-selected species and increased clumping, which is unfavorable to the hydrozoans' delicate morphology.

As *S. natans* aged further, a blue-green algae was seen growing under *Membranipora* and lifting it off. This blue-green may be the next dominant epibiont. Annelid worms were seen within a mucus substance that tightly bound the weed, creating a habitat favorable to the encrusting worm, *Spirobis*, which may be another dominant epibiont in later successional stages.

We did not have enough samples of *S. fluitans* to hypothesize about later successional stages on it.

Future research into later succession should include analysis of subsurface clumps of *Sargassum*, since these may be older than surface clumps. It is also important to have more than two age classifications, and they should be based on color tones rather than distance from the center of the *Sargassum* clump, as our classification was done.

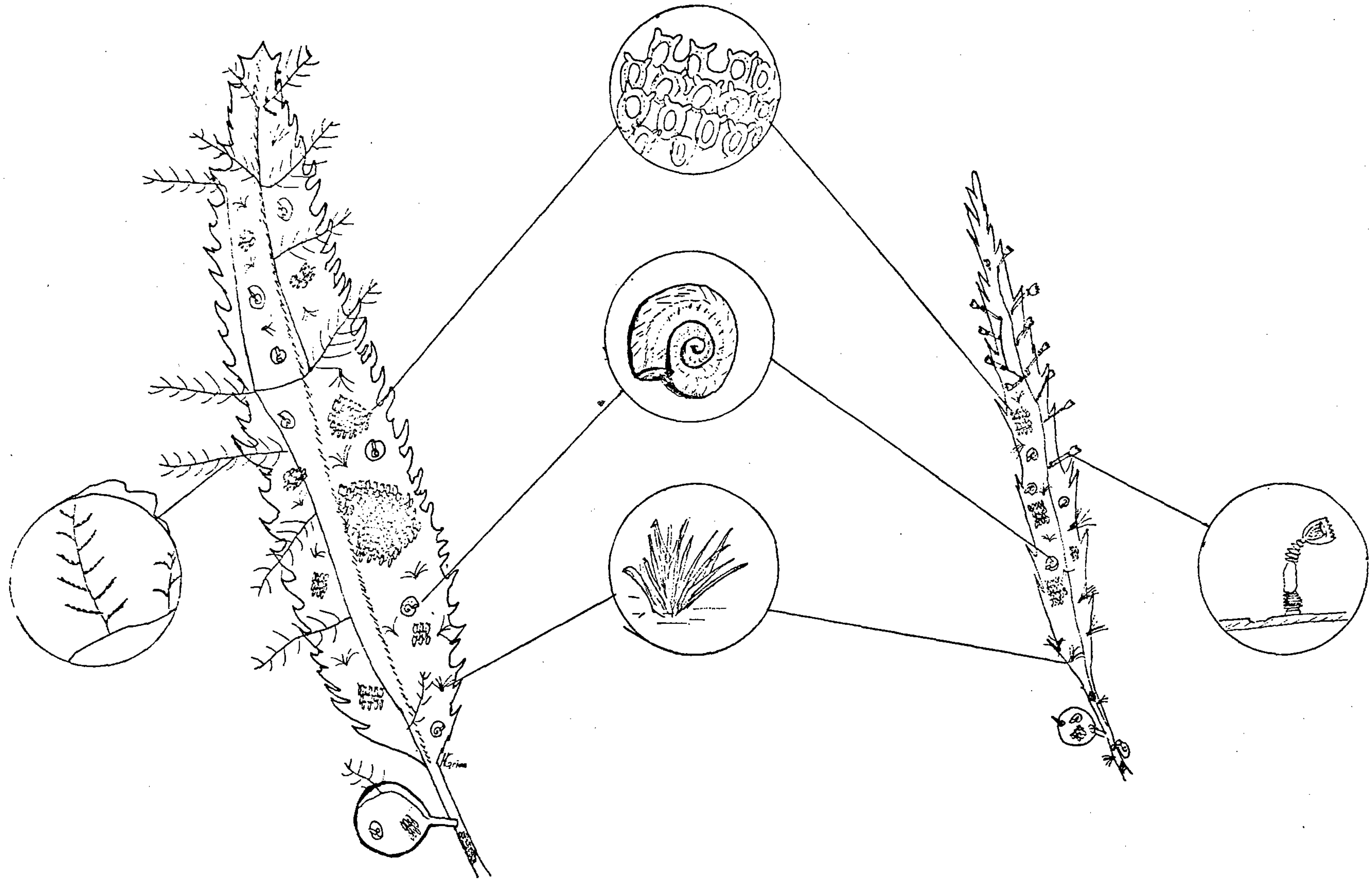


Figure 15. Epibionts seen on the floating seaweed <u>Sargassum fluitans</u> (left) and <u>S. natans</u> (right). The hydrozoan shown only on <u>S. fluitans</u> is <u>Aglaopheria latecarinata</u>. The hydrozoan shown only on <u>S. natans</u> is <u>Clytia noliformis</u>. Epibionts on both weeds are (top to bottom) <u>Membranipora tuberculata</u>, <u>Spirorbis corrugatus</u>, and <u>Calothrix</u>.

Feeding Behavior and Preferences of the Sargassum Fish, _Histrio histrio_ (Linnaeus)

Steve Hermansky

ABSTRACT

This work was done to determine the feeding preference of the adult Sargassum fish, _Histrio histrio_, by presenting the fish with various living foods in a confined area of the ship's aquarium. Preference was determined by the difference in the measured "reaction time," or a period between the introduction of food and the _Histrio_'s response. The results indicated a preference for light coloration and/or fast movement of the food. Additional information gained from the work showed that movement was a necessary characteristic of potential food for the feeding response to be triggered. The _Histrio_ was also observed using a method of movement created by forcing water through the mouth and out the posterially located opercular opening. _Histrio_ deviated from the other members of the Family Antennariidae by not using the modified first dorsal spine of the dorsal fin as bait to attract prey. Only one _Histrio histrio_ was used in the experiment because none of the four others collected survived, and further research in this field is sorely needed.

Fish larvae of the Sargasso Sea

Dorinda Ostermann

Post larvae of the Dolphin fish, Coryphaena hippurus, were caught in great numbers on the 54th cruise of the R/V Westward. Post larvae occur from the time of yolk absorption to the time the larvae assumes adult characteristics. Then fish are called juvenile young and they have essentially adult characteristics in a smaller form.

Specimens of the post larvae were collected either with a .505 u meter net or an Issacs Kidd Midwater trawl in the Sargasso Sea and North Equatorial Current. No specimens were collected from similar tows in the Caribbean Sea. Because the size range of the post larvae deviated so slightly at all the stations (table 9), it appears that the dolphin fish spawn at the same approximate time throughout the Sargasso Sea. The hatching lengths of many pelagic fish eggs tends to be between 3 and 7 mm (Colton & Marak, 1971). It seems reasonable to conclude that the specimens of dolphin fish caught on this cruise were relatively young post-larvae and that the spawning season would occur in October or November.

Representative specimens of the dolphin fish post-larvae collected on W-54 will be sent to the Gulf Coast Research Lab in Biloxi, Mississippi for positive identification and will be curated into the larval fish collection for the Gulf of Mexico and Caribbean Sea.

Leptocephalus eel larvae from meter net tows in a transect through the Sargasso Sea were measured and identified. Of the 14 families of eel larvae reported for these waters, representation from 4 of these families were collected (table 10). Notably absent were the normally expected distribution patterns of American and European eel larvae, Anguilla anguilla and A. rostrata respectively. It is not known why this should be so, other than insufficient sampling of the area.

Table 9. Sizes and stations where caught of the postlarvae of the dolphin fish, *Coryphaena hippurus*

Water mass	Station	Depth (m)	No. of Specimens	Total length (mm)
Northern Sargasso Sea	W54-2	40	1	10
		80	2	9,16
Southern Sargasso Sea	W54-4	40	3	9,9,9
		80	7	8,8,8,9,10,10,10
	W54-5	600(IKMT)	4	9,10,10,10
	W54-7	40	8	8,8,8,8,8,8,8,8
		80	2	7,9
North Equatorial Current	W54-13	40	5	9,9,9,9,10
		80	8	7,7,8,9,9,10,10,10
	W54-14	80	3	9,10,10
	W54-16	40	1	8
	W54-17	600(IKMT)	1	15
	W54-22	600(IKMT)	1	6

Total number	Mean and standard deviation
46	9.1 ± 1.7

Table 10. Sizes and stations where caught of leptocephalus eel larvae

Water mass	Station	Depth	Family		No. of Specimens		Total length(mm)
North Equatorial Current	W54-16	40	Ophichthedae		1		68
	W54-22	40	"		1		41
				Total	2	Mean	54.5 ± 19
Northern Sargasso Sea	W54-2	80	Muraenidae		4		36,38,39,46
North Equatorial Current	W54-17	80	"		1		49
Northern Sargasso Sea	W54-2	40	(Genus *Arachias*)		2		45,67
Southern Sargasso Sea	W54-4	40	"		8		62,62,63,65, 66,66,68,69
		80	"		3		60,68,69
				Total	18	Mean	57.7 ± 12
Northern Sargasso Sea	W54-2	80	Xenocongridae		1		38
Southern Sargasso Sea	W54-4	80	"		1		36
				Total	2	Mean	37 ± 1.4
Southern Sargasso Sea	W54-6	80	Muraenescoidae (Genus Paraxenomystax)		1		236
North Equatorial Current	W54-13	80	"		1		168
				Total	2	Mean	202 ± 48

The continuing search for Echo Bank

The charted location of Echo Bank os 21°08'N, 58°42'W on Hydrographic Office Chart 120. The site was reported to be 34 fathoms deep in 1937 and in 1946 the site was reported to be "shallow." The R/V Westward has returned to the charted position twice and once to a position 120 miles west of the site in an attempt to find shoaling. We returned to Echo Bank on cruise W-54 to search the site further.

On 24 October 1980 we reached latitude 21°08'N. We were some 50 miles east of Echo Bank at that time. We changed course and tacked back and forth, heading west and zig-zagging across the 21°08'N latitude line. We kept the fathometer running during this time and checked it every 15 minutes for evidence of shoaling to less than 50 fathoms. No such evidence was seen. We stopped tracking at 20°52'N, 58°44'W where we performed stations W54-13 and 14.

Although no unusual bottom feature was seen, the charted location of Echo Bank did seem to represent a northern boundary of the North Equatorial Current at this time of year. Surface salinity began to plummet in this region (figure 9) and the shallow hydrocasts of stations W54-13 and 14 showed the fresher water extended throughout the mixed layer (figure 16). Beneath the thermocline, salinity was the same as that in a representative station from the Sargasso Sea.

Spiny lobster larvae were more abundant here than elsewhere along the cruise track (Chomet and Aldrich) and it is possible that shoaling seen at the Echo Bank may be a biological phenomenon created by an abundance of organisms seen at the boundary between two ecological systems - called the "edge effect."

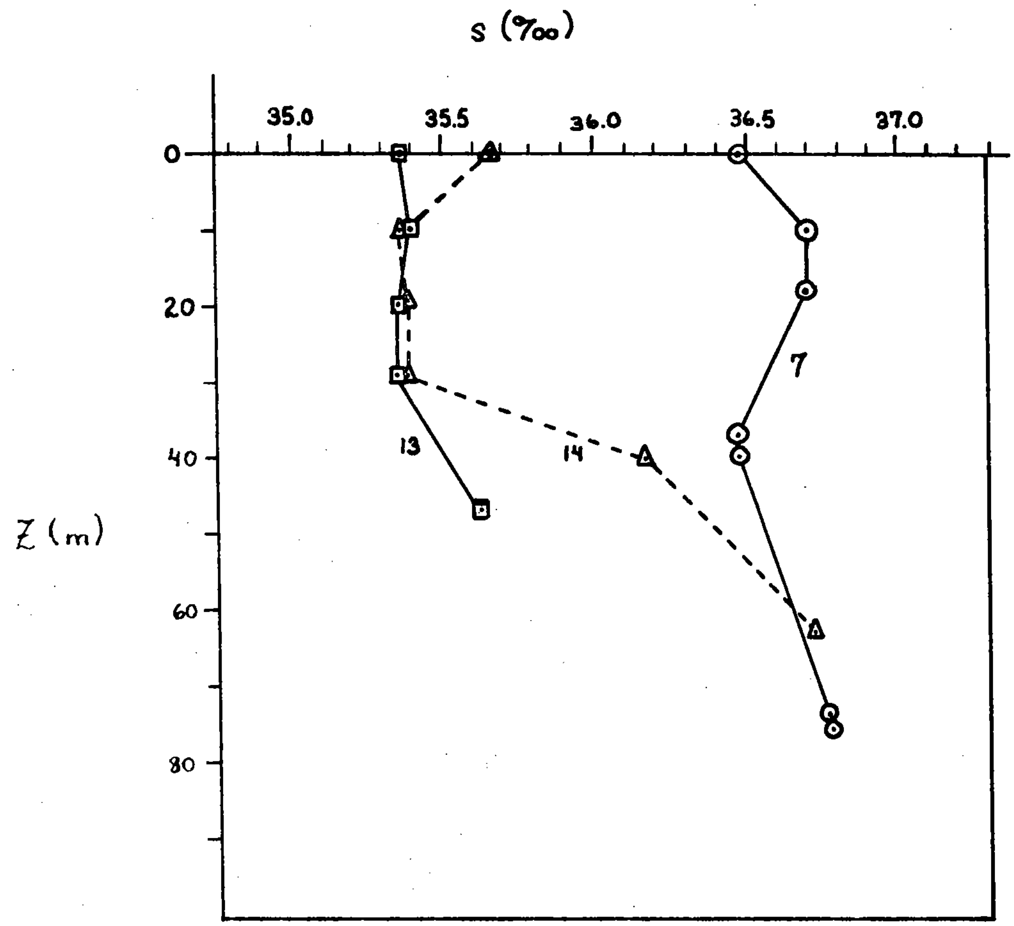


Figure 16. Vertical salinity structure of Echo Bank stations 13 and 14 compared to Sargasso Sea station 7.

Current as Measured by Leeway, Set, and Drift

Margaret Couper

ABSTRACT

Current was determined in two areas north of Echo Bank by measuring leeway, set, and drift. Leeway angle was in one case estimated from a previous study done under similar conditions and in the other case by direct measurement with a buoy and drogue trailed far astern of the Westward. A dead reckoning (DR) position was established after 16 and 24 hours, respectively, for the two cases and compared to a star fix of the ship's actual position. The DR vector was first adjusted for leeway angle. The current was then indicated in direction (set) and strength (drift).

Pilot Charts indicate that current in the area of 26°N and 57°W is approximately 0.3 to 0.4 knots, increasing further south to 0.8 knots with the influence of the North Equatorial Current. On cruise W-54, the current in one case was shown to be 0.3 knots, which agreed well with the average according to the Pilot Charts. In the other, more northerly, case, the current was shown to be 0.7 knots. This current was not the North Equatorial Current but a local phenomenon of unknown cause.

Specific alkalinity in the North Equatorial Current and the Caribbean Sea

Warren Steinmetz

ABSTRACT

The specific alkalinity of ocean waters has proved to be a sensitive indicator of water masses, as shown by Wattenberg (1933) during the Meteor cruise. It is a function of temperature, depth, carbonate equilibrium, and the concentration of calcium present. Total alkalinity depends on biological activity and is thus a non-conservative property of sea water. Specific alkalinity is total alkalinity expressed as a function of salinity and may be a conservative property in deep water. A profile of specific alkalinity vs. depth is characteristic for various water masses and can be used to determine the water's history in relation to calcium carbonate precipitation. The purpose of this paper was to determine whether changes in specific alkalinity could be detected in the surface waters as they flowed through the St. Lucia channel into the Caribbean Sea. Stations were taken 30 and 80 miles northwest of St. Lucia, in the St. Lucia channel, and 10 and 45 miles southwest of St. Lucia (figure 17). Specific alkalinity was obtained with the use of a pH meter following the technique described in Strickland and Parsons (1972) and salinity data. The North Equatorial Current (NEC) had a constant specific alkalinity of 0.126 through the first 180 meters. The NEC water flows into the St. Lucia channel and mixes with the Caribbean Sea water where the specific alkalinity dropped to 0.123 within the first 50 meters. This result reflected the high calcium carbonate precipitation near the islands. As the water flowed west, away from the islands, specific alkalinity decreased because of decreased calcium carbonate precipitation in this area.

Strickland, J.D.H., and T.R. Parsons. 1972. A practical handbook of seawater analysis. Fish Res. Bd. Canada.

Wattenberg, H. 1933. Wiss. Ergebn. disch. Atlant. Exped. "Meteor," 8.

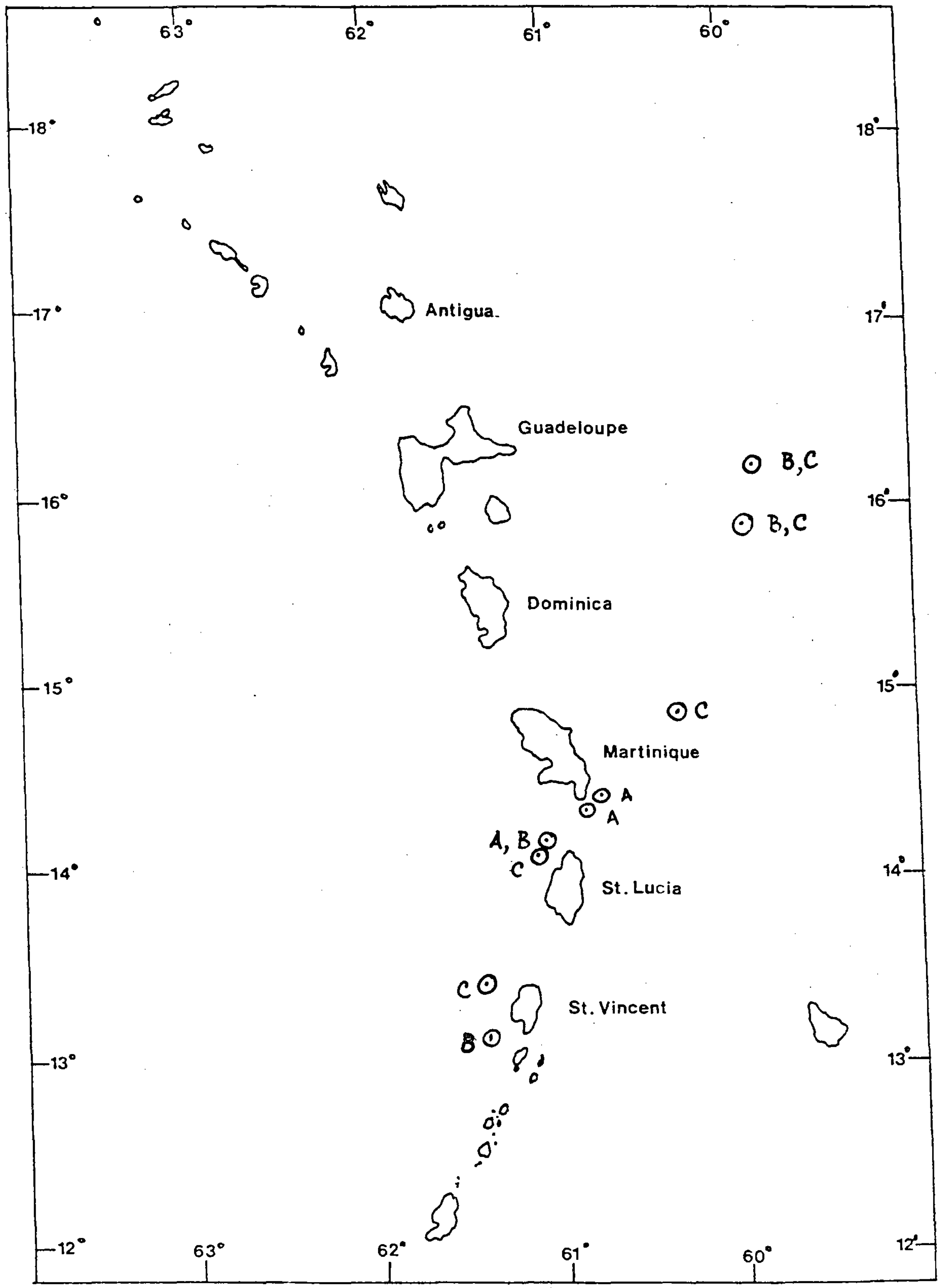


Figure 17. Transects done for studies on alkalinity (A), mesopelagic fish (B), and Ocean Thermal Energy Conversion sites (C).

A survey of mesopelagic fishes of St. Lucia and St. Vincent passages

Chris Patricoski

ABSTRACT

A survey of mesopelagic fishes near the Antilles Island chain inlcuded two evening, deepwater IKMT trawls northeast of the chain and two evening, shallower IKMT trawls very near the islands themselves (figure 17). The survey yielded 526 midwater fish of which there were 18 species (table 11). The deeper and shallower tows showed a vertical stratification of midwater fish. Small Gonostomatids, *Cyclothone* sp., appeared in large populations deepest in the water column, whereas many species of larger Myctophids were obtained in shallow tows near the islands. These shallow tows revealed a diverse community of large tropical mesopelagic fish occurring west of the island passages. It has not been demonstrated whether this fish community is related to the large amount of water flowing into the Caribbean via the island passages, the potential of this current to transport fish, larvae, or food, or the physical properties induced by the current, as was originally suggested.

Table 11. Midwater fish seen in the North Equatorial Current and the Caribbean Sea

	North Equatorial Current		Caribbean Sea	
Organism	W54-17	W54-18A	W54-22	W54-24
Myctophidae	13(?)*	1		
Diophus				2
D. problematicus			3	2
Lampadena luminosa			1	
Lepidophanes guenthesi				3
Myctophum nitidulum				1(?)
Notolychnus valdiviae				1
Gonostomatidae		2		
Gonostomatidae with				
Cyclothoni characteristics	158	198		
Cyclothone	61	24	7	9
Diplophos		1		
Conastoma				3
C. elongatum			1(?)	
Margrethia obtusirostra				
Pollichthys mauli	1			2
Vinciguerria				1
Stomaitidae				
Stomias		1(?)		1
Chauliodontidae				
Chauliodus sloani				1
Sternopty chidae	3	2		4
Argyropelecus				
Unidentifiable midwater fish	8		1	

Initial assessment of potential OTEC sites in the Southeastern Caribbean Sea

James E. Hardiman

ABSTRACT

The purpose of this project was to study the area around St. Lucia and St. Vincent to see whether it was viable as a location for an Ocean Thermal Energy Conversion (OTEC) facility. The field work consisted of bathythermographs and deep hydrocasts in order to construct a temperature profile and determine the thermal gradient. The hydrocasts took place on both the windward and leeward sides of the islands (figure 17). In addition, current calculations were done from temperature-salinity data to estimate the volume of water available for a facility.

The thermal gradient was approximately 23.8°C between the surface and 1000 m, more than adequate to operate an OTEC unit of commercial size. The windward side of the islands turned out to be better suited for a site because wind-driven currents on the surface were blocked on the leeward side to such an extent as to not be able to meet the large volume requirements of intake water at the surface. On both sides of the island ample bottom water was supplied by the North Equatorial Current due to thermohaline circulation through the island passages to meet a facility's needs.

SHORE-BASED STUDIES: THE TOBAGO CAYS

Introduction

The R/V Westward spent from 07 to 12 November 1980 in the Tobago Cays anchored near Petit Rameau (figure 18) to accomplish student studies in three areas: sediment distribution, intertidal zonation, and the effects of wave exposure on coral distribution.

Each study showed important effects of the North Equatorial Current on the small islands of the Cays. Sediment was eroded by water from the North Equatorial Current and deposited elsewhere (Phillips and Buchman); intertidal zonation was practically impossible to detect on the side of Petit Rameau exposed to the current while it was well developed on the leeward side of the island (Tanner). Near Baradal Island, coral species were determined by the degree of current effect as well as wave exposure (Ten Eyck).

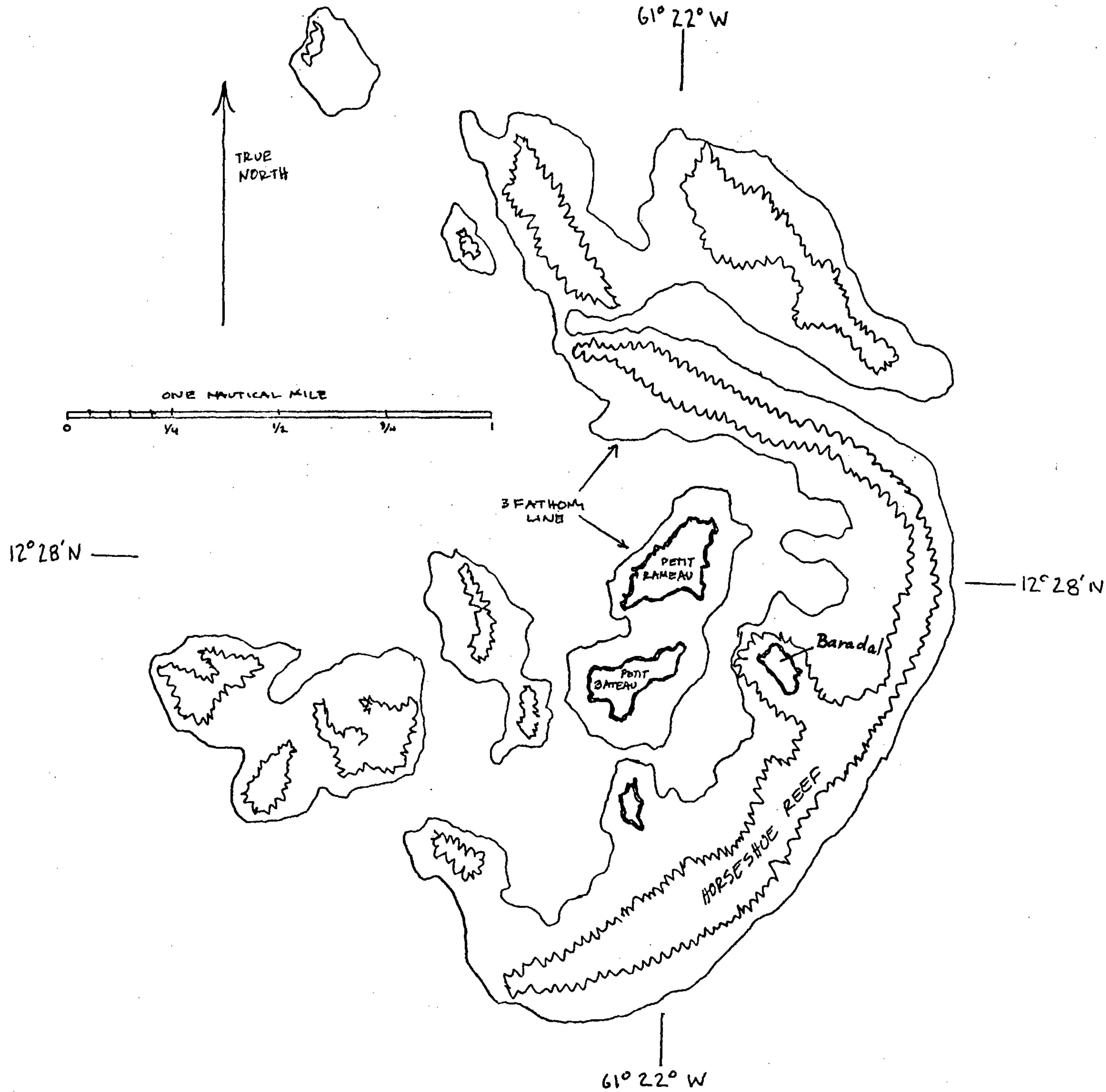


Figure 18. Tobago Cays

The distribution of sediment around Petit Rameau, West Indies

Andrew Phillips
and Mariette Buchman

ABSTRACT

The purpose of this study was to survey the sediments and sediment distribution around Petit Rameau, a volcanic coral rampart island, in the Tobago Cays, 12°28'N, 61°22'W (figure 18). Transects were taken perpendicular to the shore at points along the coast representative of both transitional and stable zones (figure 19). Samples were taken at the beach, surf zone, and at a relatively stable reef zone of 1-1/2 to 8 feet deep. At the same time significant changes of the reef, shore, and current were observed. Samples were dried and sifted through graduated sieves. The weight percent of each fraction was calculated.

Beach samples on the eastern shore showed coarser materal than on the western; transects 1, 2, 12, and 13 had fine to very fine sand, whereas transects 4, 7, 9, and 10 consisted of boulders to coarse and medium sand. Deeper samples showed various trends. On the leeward side, samples maintained the same mode in sieve size but developed a coarse tail with depth. On the windward side finer material increased with depth, except at transect 7 where coarser material increased with depth.

The resulting picture of sediment distribution can be explained by the effects of the North Equatorial Current, which flows from the east, by longshore drift wave action, and by areas of sediment production. Most destructive action occurs on the east and northeast sides of the island, which are most exposed to weather (figure 19). From here the sediments are transported around the island in the defracted North Equatorial Current and are deposited in areas of lower energy. Sediment is also being produced on the leeward side, and transported inshore by wave action.

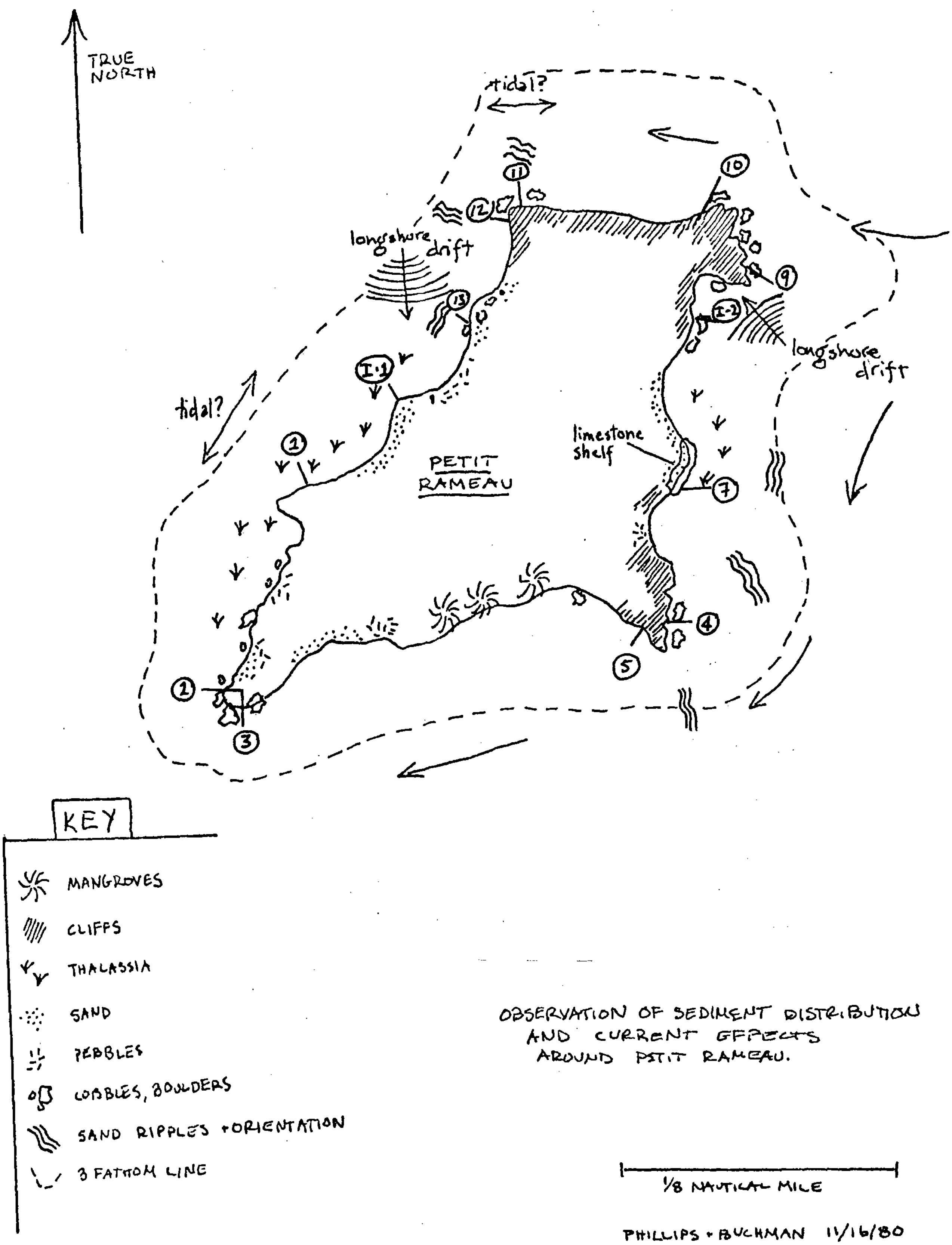


Figure 19. Petit Rameau, showing major features of the island and transect lines for sediment distribution studies (numbers) and intertidal studies (numbers preceded with an I).

Study of biological zonation in the Caribbean

Gina Tanner

ABSTRACT

Rocks at the water's edge support many organisms that are arranged in discrete areas that run in stripes parallel to the beach. These areas are called zones. The purpose of my project was to study this zonation at Petit Rameau.

Two transect lines were established (figure 19), one on the windward and one on the leeward side of the island. Organisms lying directly beneath the line were recorded.

Transect #1 on the leeward side could readily be divided into three zones: the supralittoral, extending from heavy vegetation along a steeply inclined splash zone to where the snail, Nerita, was well established; the midlittoral, extending across a narrow band of wet rocks to the water's edge; and the infralittoral, extending from the water's edge out to sea.

Transect #2 was much more sparse above the water's edge and much more diverse within the shallow water than transect #1. Zones could not be distinguished along this transect.

It was concluded that local conditions greatly affect the zonation patterns, even within an area as small as the island of Petit Rameau.

Wave exposure as it affects coral distribution

Catherine A. Ten Eyck

ABSTRACT

A study near Baradal Island in the Tobago Cays was undertaken to determine the effect of wave exposure on the distribution and structure of coral species. Previous studies have shown that coral reefs can be divided into zones characterized by dominant species depending on the intensity of wave action in the zone.

Three 30-meter transects were established, two on fringing reefs and one approaching a barrier reef (figure 20). They were sited in areas of different wave force and orientation to the prevailing currents from the northeast. Coaral species, percent surface area covered by each species, and number of colonies seen were recorded while snorkeling along the transect. Current velocity and force were estimated by (1) rate of drift of observer, and (2) counts on a flowmeter anchored on the bottom.

Five zones were identified (table 12). Species corresponded to species in the literature for each zone except zone 1, which was dominated by the star coral, Montastrea annularis. This species was dead, however, and was encrusted by the fire coral Millepora, suggesting that wave and current conditions have recently changed.

In addition, structures of various species were found to be indicators of sea conditions. For instance, Millepora sp. were oriented to the prevailing seas whereas soft, branched corals such as Gorgonia ventalina were located in zones of low wave exposure.

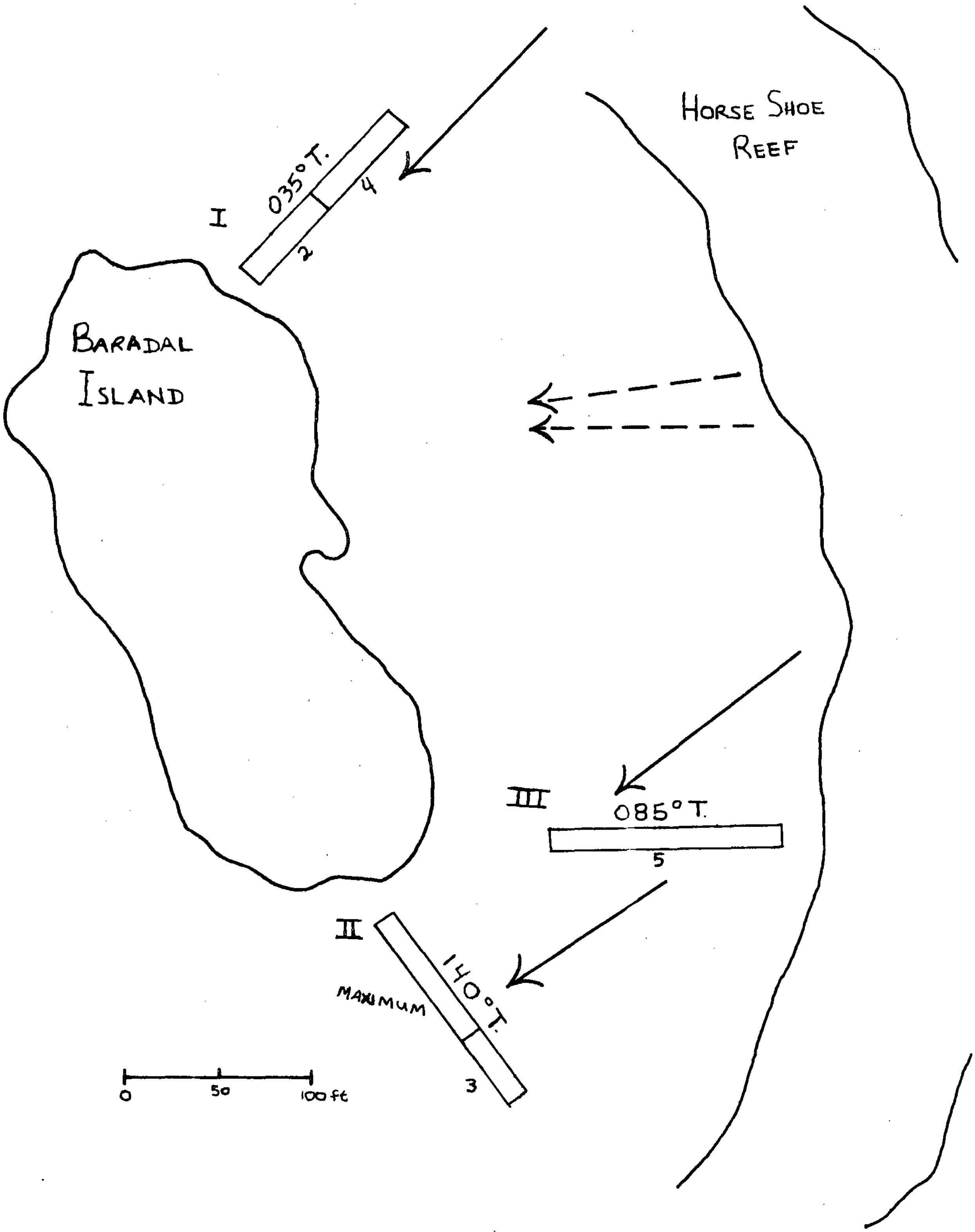


Figure 20. Coral reef transects near Baradal Island. Dashed arrows show direction of prevailing winds, solid arrows show direction of prevailing currents, bars show transect lines, indicating coral zone beneath and angle of exposure to prevailing currents above.

Table 12. Coral reef zonation found in the Tobago Cays

Zone	Current velocity (cm.sec)	Dominant species	Common name
1	40	Monastrea annularis (dead) encrusted by Millepora	Star coral (fire coral)
2	30	Porites porites	Finger coral
3	19	Acropora cervicornis	Staghorn coral
4	17	Acropora palmata	Elkhorn coral
5	12	Monastrea annularis	Star coral

VISITING SCIENTIST STUDY

Influence of the Amazon River on the Caribbean Sea

The Amazon River outflow follows the coast of South America northwards and westwards, extending into the Caribbean Sea. Its influence is noted by reduced salinities and by the presence of estuarine species of phytoplankton (Herrera and Febres-Ortega 1976).

A transect of surface salinities and photoplankton tows was done between Bequia and St. Thomas in the Caribbean Sea to look for these features (figure 21). Surface salinity varied considerably between Bequia and Martinique and then began to level off at a salinity of approximately 35.1-35.2 $^{o}/oo$ as the northeastern corner of the Caribbean was reached (figure 21, inset). During the first part of the transect high salinities occurred in the lee of islands and low salinities occurred opposite the passages between islands. Salinity was never lower than the lowest salinity seen in the North Equatorial Current (figure 4) and these low values probably represented excursions of the North Equatorial Current into the Caribbean.

Photoplankton species seen gradually changed from an assemblage that included mostly centric diatoms and a few dinoflagellates (e.g., the diatom *Ditylum* sp. and the dinoflagellate *Ornithocercus*) in the southern portion of the transect to an assemblage consisting mostly of pennate diatoms (e.g. *Nitzschia clostridium* and *N. serida*) in the northern portion (table 13).

None of the evidence convincingly shows the influence of the Amazon on the eastern Caribbean at this time of year, but the transect did show rather dramatically that the North Equatorial Current surface waters do not mix immediately upon entering the Caribbean but retain their low salinity for *at least* 30 to 40 nautical miles after crossing the passages.

Herrera, L.E., and G. Febres-Ortega. 1976. Characteristicas thermohalinas de las aguas superiores del sureste del mar Caribe durante la epoca de lluvias. Bol. Inst. Oceanog. Univ. Oriente 15(1):97-114.

Table 13. Phytoplankton species seen along a transect from Bequia to St. Thomas as shown in figure 21.

SPECIES	25	26	27	27A	28	NEqC	Sargasso	C.M.
Amphiprora sp.	x	x						
Detglum sp.	x							
Dinophysis sp.	x					D.schentii	?	D.schentii D.candata
Leptocylin-dricus sp.	x					x	x	
Ornithocercus magnificus	x					x	x	
Pepophaceros horologicum	x						x(?)	
Nitzschia spp.	x(45)	x	x			?		
Chaetoceros spp.	x(34)	x	x	x(2)	x			
Rhyoselenia	x	x		x			x	
Skeletonini	?							
Trichodesonuim (done)		(D)	x	o	x	x	x	x
Misc. small dino.	x	x	x	(very few)	motile small?			
Ceratium kofoila	x(?)	x	o					
Coccolethophores		x	x		x			
Navicula		x	x(28)	x(1g)	x			
Bacteriastrum	x	x	x	x				
Ceratium tripos			x	o				
Nitzschia serida				x(D)	x			
Thallasiothrix	x			x(D)	o			
Grammatophore sp.				x	o			
Nitzschia clostrium				x	x			x
Gymnodinium(?)					x			
	35.675	35.811	35.477	35.144	34.942			

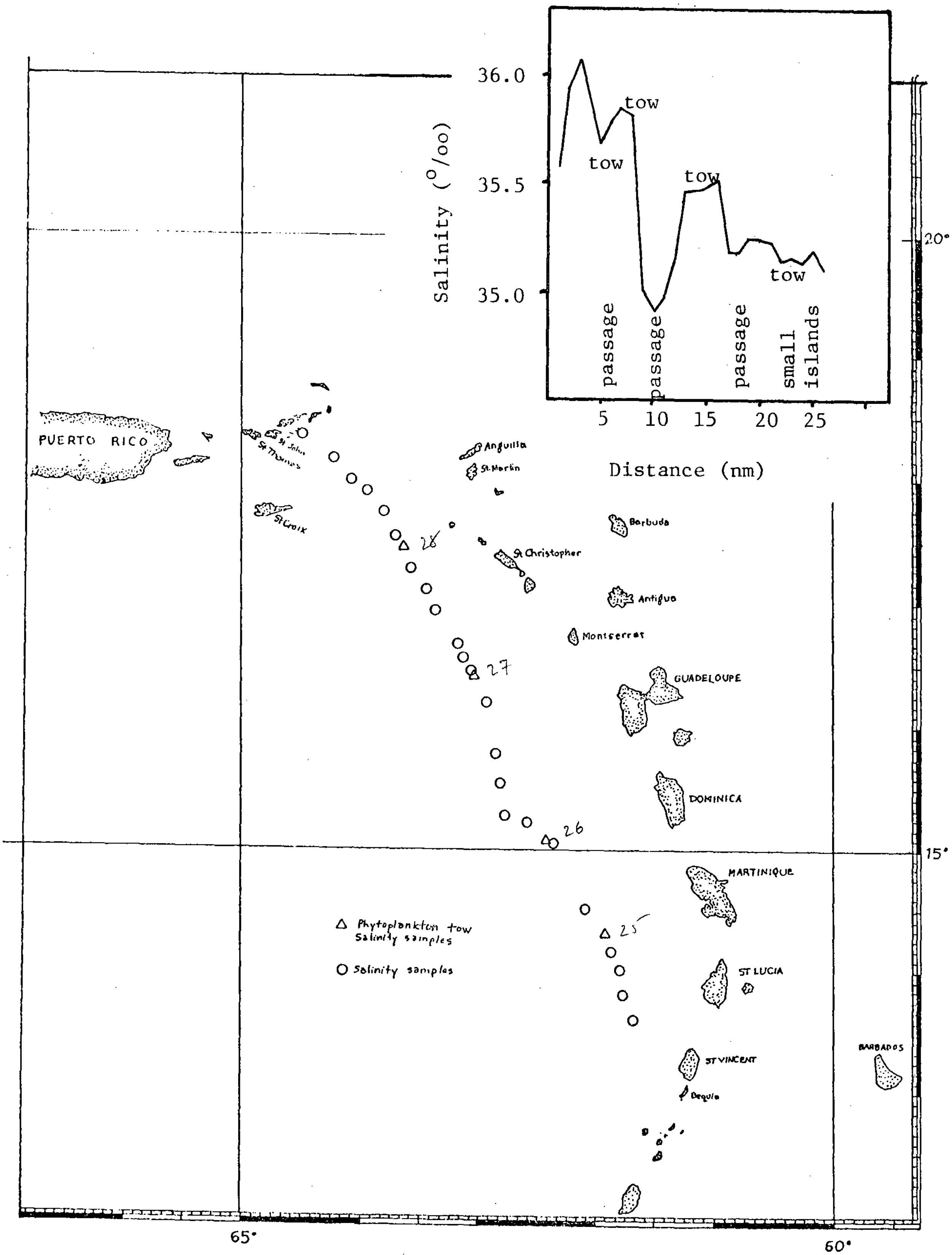
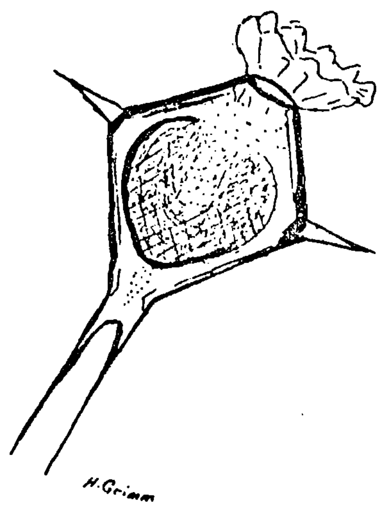


Figure 21. Salinity and phytoplankton transect to look for evidence of the Amazon River. Circles = salinity samples, triangles = phytoplankton samples. Inset = Results of salinity transect.

APPENDICES



<u>Cavolina longirostris</u>

pteropod

APPENDIX I. The Academic Program

Nautical Science Program: W-54

John Wigglesworth
Head of Nautical Science

The purpose of the Nautical Science program on Westward for W-54 was three-fold.

(1) To test in practice the theory learned in the shore component.

(2) To help the students develop into cautious and thoughtful seamen.

(3) To help the students develop various practical skills in seamanship and navigation.

To carry out these goals, 24 formal lectures were given along with continuing informal lectures and demonstrations on watch. Four written exams were given on the lectures and three practical exams were given as a test of student development in skills of seamanship and navigation. Students were also required to keep a sea project notebook and to carry out and hand in a running fix of the ship's position.

On the whole, I was very pleased with the progress of each student. In particular, I was pleased with the success of the practical exams as a learning tool. I hope that Nautical Science aboard Westward will continue these practical tests throughout the sea component. Students, themselves, were enthusiastic about these tests because it became a good opportunity for them to show what they could do.

Table A-1. Nautical science lectures

Oct. 8	Orientation/safety	
9	Getting U/W under power	
10	Review sail set/rig	
11	First Aid	
12	-	
13	Navigation Review Basics/Sextant Introduction	
14	Weather - Waterspouts	
15	Bosun's Talk	
16	Weather/Tactics	
17	Quiz - written Practical - by watch	
18	-	
19	-	
20	Navigation - Publications RT procedures	
21	Sanitation	
22	Engine Room - Bilge Pumps	
23	Navigation - stars/azimuths/amplitudes	
*24	Quiz - written Practical - individual	
25	Practical (continued) - individual	
26	-	
27	M.O.B./Fire Fighting	
28	Rules of Road	
29	Engine Room - Seagull use and abuse	
30	Review - Offshore Portion W-54	
31	Test - Offshore Portion W-54 Practical - sail drill	
Nov. 1	Arrive St. Lucia - Crew Raise Yard	
2	St. Lucia	
3	St. Lucia Ship Maintenance	
4	St. Lucia Ship Maintenance	
5	Anchoring/coastwise Navigation Part I	
6	First Aid (AM) Vertical/Horizontal Sextant Angles	
7	Practical Compas Compensation TVMDC TW	Review
8	Tides	(TC)
9	-	(TC)

10	Doubling Angle on Bow/Critical Angles (Nav. Part II)	(TC)
11	Three Bearing Problem (Nav. Part III)	(TC)
12	Quiz Coastwise Portion of W-54	(Bequia)
13		(Bequia)
14	"READING PERIOD"	(Bequia)
15	To be used for independent study	
16		
*17	Note Books due/Running Fix due	
18	Wrap up	
19	St. Thomas	

* Notebook evaluations

Marine Science Program - W-54

Mary Farmer
Head of Marine Science

The Marine Science program aboard R/V Westward was composed of three areas of activity, each of which was given equal emphasis in the final evaluation.

1. Lectures

   Lectures were given each weekday while at sea and on occasion while at anchor. The topics covered are listed in table A-2. Many of them were related to areas of the sea we were passing through while others pertained to sampling and analytical methods. Information obtained during lectures and science watch was evaluated by quizzes and by a final practical exam.

2. Science watch

   A 24-hour science watch was maintained throughout the cruise, and consisted of a member of the staff plus three students. Their responsibilities included maintenance of the science log, execution of scientific stations, and continuation of the scientific program in terms of analysis of samples and interpretation of data. In addition, laboratory and analytical techniques were learned, and time was made available for research projects and personal instruction.

   A collection of fauna and flora ("Feature Creatures") was assembled from a wide variety of marine environments in an attempt to familiarize the students with the diversity of life in the ocean. This collection served as the basis for study of different phyla, and evaluation in this area was by means of the practical examination.

3. Individual research project

   While in Woods Hole, each student was required to define a research project to be carried out on board Westward. Any subject could be chosen, the only constraints being that

   (i) the project should take advantage of the opportunities offered by Westward, and

   (ii) it should be approached, executed, and written up in a scientific fashion.

The projects covered physical, chemical geological and biological oceanography as well as ocean engineering and naval architecture. Each student presented a 15-minute seminar on the project and its results and submitted a written report before leaving the ship.

Table A-2 Marine Science Lectures

Day	Date	Subject	Instructor
Th	9 October	Watch protocol; scientific activities for Leg I	Farmer
F	10 October	Characteristics of continental shelf/ slope water	Farmer
M	13 October	The North Wall of the Gulf Stream	Farmer
T	14 October	Zooplankton I	Ostermann
W	15 October	Sargasso Sea - physical and chemical characteristics	Farmer
Th	16 October	Zooplankton II	Ostermann
F	17 October	Quiz & scientific findings to date	Farmer
M	20 October	Sargasso Sea - the biological community	Ostermann
T	21 October	Bioluminescence	Ostermann
W	22 October	Fish biology	Ostermann
Th	23 October	Station - windrows	
F	24 October	Quiz & scientific findings to date	Farmer
M	27 October	North Equatorial Current hydrography	Hickey
T	28 October	Echo Bank and larval distribution studies	Farmer
W	29 October	Spectrophotometric methods	Hickey
Th	30 October	Coral reef ecology	Ostermann
F	31 October	Quiz & St. Lucia geography	Tanner/Kaul Ostermann
W	5 November	Metallagenesis	Hickey
F	14 November	Seminars (4 per day)	
S	15 November	Practical exam	
	(afternoon	<u>Trichodesmium</u> and the Caribbean	Haines
M	17 November	Seminars	

APPENDIX II. W-54 station summary

Station	Date	Time Begun	Lat (N)	λ (W)	Hydrocast Shallow	Hydrocast Deep	Plankton tows Phyto-	Plankton tows Zoo-	Plankton tows IKMT
W54-1	10 Oct 80	0525	39°53'	70°00'	x		x		
W54-2	15 Oct 80	0850	32°10'	61°32'	x		x	x	
W54-3	18 Oct 80	0815	25°55'	58°20'	x		x	x	
W54-3	18 Oct 80	1642	26°07'	58°53'	x		x	x	
W54-5	19 Oct 80	2240	26°28'	57°00'					x
W54-6	20 Oct 80	1930	26°07'	57°05'	x		x	x	
W54-7	21 Oct 80	0252	26°08'	56°25'	x	x	x	x	
W54-8	21 Oct 80	2335	26°20'	56°25'					
W54-9	23 Oct 80	1027	23°03'	56°34'	x				
W54-10	23 Oct 80	1115	23°03'	56°34'	x				
W54-11	23 Oct 80	1159	23°03'	56°34'	x				
W54-12	23 Oct 80	1228	23°03'	56°34'	x				
W54-13	25 Oct 80	0228	21°02'	58°15'	x		x	x	
W54-14	25 Oct 80	1143	20°52'	58°44'	x		x	x	
W54-15	26 Oct 80	0840	18°59'	59°02'	x		x	x	
W54-16	27 Oct 80	0843	17°00'	59°31'	x		x	x	
W54-17	28 Oct 80	0218	16°20'	59°40'	x	x	x	x	x
W54-18A	28 Oct 80	2200	15°47'	59°51'					x
W54-18B	29 Oct 80	0620	15°28'	59°28'	x	x			
W54-19	29 Oct 80	2000	14°53'	60°20'	x	x			
W54-20	30 Oct 80	0315	14°38'	60°22'	x				
W54-21	30 Oct 80	1332	14°21.3'	60°51.7'	x				
W54-22	30 Oct 80	2130	14°08'	61°07'	x	x			x
W54-23	05 Nov 80	0600	13°18'	61°22'	x	x			
W54-24A	06 Nov 80	0200	12°58'	61°22'					x
W54-24B	07 Nov 80	0120	12°45'	61°32'		x			
W54-25	15 Nov 80	0735	14°18'	61°54'			x		
W54-26	15 Nov 80	1735	15°06'	62°25'			x		
W54-27A	16 Nov 80	0712	16°26.5'	63°04'			x		
W54-27B	16 Nov 80	1915	16°30'	63°38'			x		
W54-28	17 Nov 80	0730	18°22'	64°30'			x		

APPENDIX III. W-54 bathythermograph summary

BT#	Date	Time	Lat (°N)	λ (W)	Mixed Layer (M)	Surface T(°C)	S(‰)
1							
2							
3			PRACTICE TEACHING RUNS - NO DATA COLLECTED				
4							
5							
6	10 Oct 80	2015	39°17'	69°29'	30.5	24.0	-
7	11 Oct 80	0005	38°58'	69°19'	42.7	23.8	35.80
8	11 Oct 80	0510	39°02'	68°59'	54.9	26.5	36.39
9	11 Oct 80	0901	39°08'	68°25'	59.4	25.7	36.30
10	11 Oct 80	1203	39°06'	67°56'	48.8	25.2	36.38
11	NOT DONE						
12	11 Oct 80	1725	38°57'	67°31'	68.6	26.0	35.84
13	11 Oct 80	2019	38°55'	67°10'	61.0	26.1	36.31
14	12 Oct 80	0011	38°55'	66°47'	24.4	24.1	35.66
15	12 Oct 80	0416	38°55'	66°18'	30.5	24.7	36.09
16	12 Oct 80	0848	38°48'	65°44'	54.9	24.5	36.32
17	12 Oct 80	1222	38°28'	65°11'	54.9	23.5	36.32
18	12 Oct 80	1609	38°17'	64°46'	42.7	25.2	36.09
19	13 Oct 80	0042	37°34'	64°07'	54.9	25.1	36.20
20	13 Oct 80	0416	37°15'	64°06'	42.7	25.4	36.34
21	13 Oct 80	0837	36°44'	63°59'	61.0	25.0	36.22
22	13 Oct 80	1205	36°17'	63°48'	64.0	25.0	36.26
23	13 Oct 80	1717	35°38'	63°28'	57.9	24.8	36.23
24	13 Oct 80	2009	35°21'	63°32'	54.9	25.0	-
25	14 Oct 80	0002	34°55'	63°43'	54.9	26.0	36.22
26	14 Oct 80	0456	34°20'	62°39'	54.9	25.0	-
27	14 Oct 80	0856	33°53'	62°27'	54.9	25.1	36.24
28	14 Oct 80	1238	33°28'	62°17'	58.8	26.0	36.01
29	14 Oct 80	1551	33°06'	62°10'	25.9	25.9	36.06
30	14 Oct 80	2013	32°37'	62°03'	42.7	26.0	35.98
31	15 Oct 80	0001	32°43'	62°35'	60.4	25.2	36.23
32	15 Oct 80	0410	32°27'	62°08'	54.9	25.2	35.94
33	15 Oct 80	0825	32°10'	62°30'	45.7	25.1	-
34	15 Oct 80	1831	31°54'	61°21'	44.2	25.1	36.28

APPENDIX III. (continued)

BT#	Date	Time	Lat (°N)	λ (W)	Mixed Layer (M)	T(°C)	S(°/oo)
35	15 Oct 80	2007	31°53'	61°17'	54.9	25.1	36.34
36	16 Oct 80	0004	31°28'	61°52'	43.3	25.5	35.96
37	16 Oct 80	0210	31°17'	60°33'	43.3	26.5	36.69
38	16 Oct 80	0411	31°01'	60°20'	39.6	26.5	-
39	16 Oct 80	0804	30°32'	59°50'	32.0	26.3	-
40	17 Oct 80	0018	30°04'	59°30'	39.6	27.0	36.45
41	17 Oct 80	1722	27°00'	59°00'	29.9	27.0	36.4
42	17 Oct 80	2107	26°37'	58°27'	44.2	27.6	36.78
43	18 Oct 80	0006	26°13'	58°15'	42.7	27.7	36.59
44	18 Oct 80	0403	26°10'	58°26'	49.4	27.7	36.54
45	18 Oct 80	0706	26°10'	58°20'	45.7	27.7	36.58
46	18 Oct 80	1701	26°07'	58°53'	39.6	27.9	-
47	19 Oct 80	0029	26°12'	58°49'	54.9	26.7	36.50
48	19 Oct 80	0357	26°12'	58°30'	36.6	27.7	36.58
49	19 Oct 80	0756	26°07'	58°09'	42.7	27.7	36.44
50	19 Oct 80	1211	26°07'	57°42'	42.7	27.8	36.56
51	19 Oct 80	1927	26°15'	57°16'	42.7	27.9	36.71
52	20 Oct 80	0525	26°12'	57°07'	42.7	27.5	36.61
53	20 Oct 80	2034	26°07'	57°05'	48.8	27.9	-
54	NOT DONE						
55	21 Oct 80	0205	26°10'	56°20'	45.7	27.8	-
56	21 Oct 80	2032	26°30'	56°30'	51.8	27.9	-
57	22 Oct 80	0537	26°12'	56°15'	57.9	27.8	36.50
58	22 Oct 80	0857	26°01'	56°30'	51.8	28.3	36.49
59	22 Oct 80	1216	25°41'	56°19'	45.7	27.9	36.44
60	22 Oct 80	1554	25°28'	56°20'	45.7	27.9	-
61	22 Oct 80	2117	24°46'	56°33'	45.7	27.9	36.36
62	23 Oct 80	0000	24°25'	56°15'	53.3	28.0	36.18
63	23 Oct 80	0407	23°44'	56°14'	51.8	26.2	36.19
64	23 Oct 80	0914	23°10'	56°37'	50.3	28.0	36.22
65	23 Oct 80	1313	22°40'	56°36'	53.9	28.4	36.20
66	23 Oct 80	1600	22°30'	56°34'	36.6	28.0	36.34
67	23 Oct 80	1959	22°15'	56°34'	51.8	28.0	-

APPENDIX III. (continued)

BT#	Date	Time	Lat (°N)	λ (W)	Mixed layer (M)	Surface T(°C)	S(o/oo)
68	24 Oct 80	0012	21°40'	56°35'	33.5	28.0	35.86
69	24 Oct 80	0420	21°18'	56°16'	42.7	28.0	35.89
70	24 Oct 80	0800	20°58'	57°01'	36.6	28.0	–
71	24 Oct 80	1203	21°13'	57°28'	38.1	28.4	36.06
72	24 Oct 80	1706	21°01'	57°44'	42.7	28.2	36.00
73	24 Oct 80	2008	21°10'	58°00'	36.6	28.2	–
74	25 Oct 80	0011	21°22'	58°30'	39.6	28.2	–
75	25 Oct 80	0157	21°18'	58°32'	39.6	28.2	–
76	25 Oct 80	0810	21°00'	58°40'	41.1	28.5	35.38
77	25 Oct 80	2134	20°17'	58°48'	35.1	–	–
78	26 Oct 80	0008	20°03'	58°79'	30.5	28.2	35.35
79	26 Oct 80	0358	19°36'	58°51'	29.0	28.6	35.06
80	26 Oct 80	0801	18°59'	59°02'	35.1	28.5	34.98
81	27 Oct 80	0020	18°06'	59°13'	42.7	27.8	34.96
82					36.6		35.19
83	27 Oct 80	0452	17°27'	59°24'	33.5	28.4	35.21
84					41.1		35.34
85	27 Oct 80	2017	16°20'	59°42'	33.5	28.3	
86	29 Oct 80	0539	15°34'	59°53'	39.6	28.5	35.40
87	29 Oct 80	1554	15°10'	60°06'	25.9	28.9	35.64
88	29 Oct 80	1948	14°52'	60°10'	33.5	28.5	35.55
89	30 Oct 80	0320	14°33'	60°25'	57.9	28.4	35.54
90	30 Oct 80	0806	14°25'	60°38'	59.4	28.6	35.67
91	30 Oct 80	1332	14°17'	61°05'	64.0	28.6	–
92	31 Oct 80	0757	14°03'	61°06'	56.4	28.2	35.75

APPENDIX IV Summary of hydrocast data

DATE	TIME	Station No.	Depth (m)	Temperature (°C)	Salinity ($^{o}/oo$)	Density (σ_t)	Oxygen ($ml.l^{-1}$)
10 Oct	0634	W54-1	0*	23.57	35.55	24.22	5.07
			30*	23.62	-	-	4.87
			46	18.28	-	-	4.18
			60*	17.40	35.92	26.15	4.40
			96	15.68	35.92	26.86	4.27
			190	11.65	35.93		3.68
		W54-2	0*	25.43	36.64		
			10*	25.45	36.24		
			21	25.47	36.23		
			33	25.46	36.06		
			41	25.48	35.71		
			71	21.33	35.02		
			100*	21.57	35.02		
			200*	18.75	35.71		
			329	17.45	36.06		
			500*	16.87	36.22		
			615	13.77	36.29		
			838	9.27	36.43		
18 Oct	0815	W54-3	0*	27.85	36.24	23.41	
			10*	27.87	36.47	23.58	
			23	27.91	36.50	23.59	
			36	27.87	36.46	23.57	
			41	27.91	36.47	23.57	
			80	22.67	36.84	25.45	
		W54-4	0*	27.90	36.40	23.51	
			10*	28.00	36.38	23.47	
			20	28.02	36.38	23.45	
			36	27.98	36.41	23.49	
			43	28.03	36.39	23.46	
			95	23.11	36.91	25.38	

*Estimated depth. All other depths calculated from reversing thermometers.

APPENDIX IV Summary of hydrocast data (continued)

DATE	TIME	Station No.	Depth (m)	Temperature (°C)	Salinity (°/oo)	Density (σ_t)	Oxygen ($ml.l^{-1}$)
20 Oct	1930	W54-6	0*	27.85	36.40	23.53	
			10*	27.85	36.51	23.61	
			20*	28.45	36.52	23.42	
			30*	27.84	36.52	23.62	
			40*	28.27	36.52	23.48	
			77	23.23	36.82	25.27	
21 Oct	0252	W54-7	0*	27.97	36.49	23.56	4.44
			10*	27.83	36.52	23.62	4.28
			19	27.81	36.52	23.63	4.49
			37	27.77	36.48	23.61	4.65
			40	28.39	36.49	23.41	4.57
			75	23.07	36.78	25.29	5.14
			100*	21.86	36.76		5.20
			200*	18.61	36.52		4.45
			375	16.90	36.34		4.66
			567	13.53	35.86		4.53
			754	10.05	35.30		3.24
			987	6.87	35.03		3.47
22 Oct	1027	W54-9	0*	28.22	36.18	23.24	
			10*	28.25	36.18	23.23	
			20	28.23	36.17	23.22	
			39	28.21	36.18	23.27	
			44	28.24	36.19	23.24	
			77	24.84	36.98	24.92	
22 Oct	1115	W54-10	0*	28.23	36.19	23.24	
			10*	28.23	36.18	23.23	
			18	28.25	36.26	23.29	
			27	28.26	36.18	23.22	
			38	28.27	36.18	23.22	
			82	25.66	37.08	24.74	

*Estimated depth. All other depths calculated from reversing thermometers.

APPENDIX IV Summary of hydrocast data (continued)

DATE	TIME	Station No.	Depth (m)	Temperature (°C)	Salinity ($^o/oo$)	Density (σ_t)	Oxygen ($ml.l^{-1}$)
22 Oct	1159	W54-11	0*	28.22	35.79	22.95	
			10*	28.26	36.19	23.23	
			21	28.24	36.19	23.24	
			30*	-	36.20	-	
			44	28.25	36.35	23.36	
			82	24.88	37.08	24.98	
22 Oct	1228	W54-12	0*	28.22	36.17	23.23	
			10*	28.27	26.17	23.21	
			23	28.22	36.20	23.26	
			28	28.49	36.18	23.15	
			39	28.27	35.19	22.48	
			83	24.97	37.06	24.94	
25 Oct		W54-13	0*	28.44	35.37	22.56	4.86
			10*	28.44	35.39	22.58	-
			20	28.47	35.37	22.55	3.81
			29	28.47	35.37	22.55	4.88
			47	28.67	35.62	22.67	4.73
			74	25.97	36.77	24.41	5.18
25 Oct		W54-14	0*	28.61	35.67	22.73	4.76
			10*	28.62	35.38	22.51	4.69
			20	28.62	35.72	22.54	6.13
			30*	28.61	35.38	22.51	5.10
			41	29.12	36.16	22.93	4.78
			63	27.83	36.64	23.71	5.53
26 Oct		W54-18	0*	28.78	34.77	21.99	5.09
			10*	28.79	34.94	22.52	5.26
			22	28.82	35.01	22.16	5.01
			40	28.76	34.92	22.11	5.21
			45	29.14	36.19	22.95	5.39
			80	25.46	36.74	24.55	5.24

*Estimated depth. All other depths calculated from reversing thermometers.

APPENDIX IV Summary of hydrocast data (continued)

DATE	TIME	Station No.	Depth (m)	Temperature (°C)	Salinity (^{o}/oo)	Density (σ_t)	Oxygen ($ml.l^{-1}$)
27 Oct	0827	W54-16	0*	28.69	36.90		5.50
			10*	28.71	35.30		5.07
			20*	28.68	35.30		5.13
			30*	28.67	35.30		4.89
			54	29.04	35.33		5.07
			80*	25.79	35.34		5.25
28 Oct	2139	W54-17	0*	28.59	35.08		4.61
			10*	28.59	35.09		5.27
			25	28.60	35.10		4.78
			42	28.68	35.96		5.15
			57	27.60	36.61		4.04
			81	26.07	36.91		5.22
			200*	21.71	36.99		4.60
			400*	14.28	35.84		3.64
			507	9.51	35.06		2.28
			650*	7.00	34.77		3.19
			1048	5.37	34.92		4.35
29 Oct	0942	W54-18	0*	28.46	35.29		4.32
			43*	28.09	35.92		3.78
			50*	28.10	36.01		3.78
			100*	27.13	36.39		3.69
			140	24.25	37.18		4.27
			200*	14.41	36.71		5.06
			200*	20.78	36.81		
			400*	13.21	35.64		
			571	9.39	35.15		
			765	6.08	34.79		
			958	5.41	34.82		
			1160	5.15	34.94		

*Estimated depth. All other depths calculated from reversing thermometers.

APPENDIX IV Summary of hydrocast data (continued)

DATE	TIME	Station No.	Depth (m)	Temperature (°C)	Salinity (o/oo)	Density (σ_t)	Oxygen ($ml.l^{-1}$)
		W54-19	0*	28.59	35.53	22.63	4.84
			43*	28.62	35.53	22.62	4.93
			54	28.63	35.54	22.62	4.91
			96	26.65	36.36	23.89	4.59
			143	22.95	36.60	25.19	3.96
			208	20.30	36.76	26.05	4.66
			200*	22.11	36.68	24.95	2.94
			300*	15.17	35.98	26.29	2.52
			416	11.28	35.43	27.09	3.25
			648	7.65	34.89		1.88(?)
			826	6.18	34.81		3.39
			1014	5.45	34.96		4.28
30 Oct	0428	W54-20	0*	28.51	35.69		4.72
			43*	28.57	35.89		4.75
			45	28.61	-		4.62
			89	26.56	36.63		4.63
			131	23.85	36.95		4.14
			181	19.36	-		3.41
30 Oct	1400	W54-21	0*	28.56	36.03		4.91
			10*	28.59	36.07		4.88
			21	28.61	36.00		4.94
			31	28.60	36.04		4.92
			44	28.60	36.06		4.59
			53	28.49	36.11		4.63
31 Oct		W54-22	0*	28.35	35.66	22.81	4.10
			25*	28.30	35.79	22.92	4.71
			49	27.92	36.32	21.98	4.80
			100	24.18	36.58	24.81	3.63
			146	21.92	36.70	25.56	4.00
			176	19.41	36.47	26.06	3.36
			200*	17.88	36.32	26.34	3.75

*Estimated depth. All other depths calculated from reversing thermometers.

APPENDIX IV Summary of hydrocast data (continued)

DATE	TIME	Station No.	Depth (m)	Temperature (°C)	Salinity (°/oo)	Density (σ_t)	Oxygen (ml.l^{-1})
			400*	11.47	35.31	26.96	3.18
			530	9.11	35.01		2.96
			723	7.03	34.87		3.37
			905	5.40	34.82		3.99
			1099	4.67	34.94		4.56
		W54-23	0*	28.17	-	-	4.67
			25*	28.22	34.69	22.12	4.28
			46	28.19	35.68	22.87	4.66
			82	25.17	36.50	24.46	4.04
			119	22.24	36.86	25.59	3.32
			171	18.58	36.39	26.62	3.14
			200*	15.54	36.00	26.65	3.34
			400*	10.09	35.15	27.08	3.16
			600	7.27	34.80		3.18
			791	5.82	34.77		3.61
			992	4.81	34.96		4.22
			1193	4.48	35.01		4.94
		W54-24	200*	-			
			400*	8.82			
			665	6.93			
			855	5.51			
			1044	4.68			
			1241	4.47			

*Estimated depth. All other depths calculated from reversing thermometers.

APPENDIX V - Bird observations under sail (W-54)

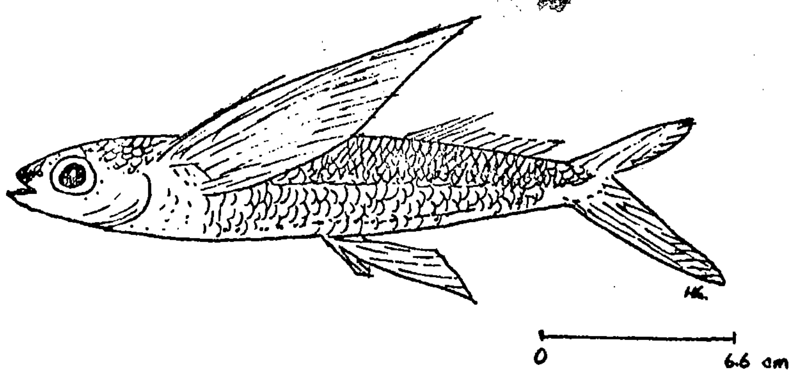
DATE 1980	TIME	LAT (N)	λ (W)	SHIP'S SPEED (kts)	SKY CONDITIONS	AIR TEMP (°C)	BARO-METER (mb)	WIND DIR.	BEAU-FORT	SEA TEMP (°C)	SEA STATE	SPECIES SEEN	No.	COMMENTS
09 Oct	1540	41°02'	70°52'	5.2	clear	-	-	SSE	1	-	-	Gull	2	Flying past
										16.7		Shearwater	1	Flying past
												Warbler	1	Sit on ship
10 Oct	1750	39°33'	69°32'	7.5	clear	15.5	1018.4	-	1	22.5	calm	Audubon's warbler	2	
												Yellow-throat warbler	1	
												Warbler	2	
	1800	"	"	"	"	"	"	"	"	"	"	-	0	
	1810	"	"	"	"	"	"	"	"	"	"	Greater Shear-water	4	
11 Oct	0940	39°07'	68°18'	8.8	Pt. cloudy	-	1014.2	-	4	25.7	Mod.	Shearwater	1	Flying past
	1520	38°58'	67°33'	4	Pt. cloudy	24.4	1012.1	-	5	25.8	Mod.	-	0	
	1530	"	"	"	"	"	"	"	"	"	"	Shearwater	3	Sitting on water
12 Oct	1500	38°12'	64°52'	7.5	Pt. cloudy	25.0	1005	SW	4	24.9	Mod.	Shearwater	2	Feeding
												Unidentified	2	Flying past
	1524	38°10'	64°48'	6	Pt. cloudy	25.4	1005	SW	5	24.5	Mod.	Shearwater	16	15 = feeding 1 = flying past
	1535	38°07'	64°47'	6.2	Pt. cloudy	25.4	1005	SW	5	24.9	Mod.	-	0	
13 Oct	1530	38°48'	63°33'	5	Pt. cloudy	-	1008.8	-	3	25.0	Mod.	Warbler	1	Following ship
												Unidentified land bird	1	Following ship

APPENDIX V (continued)

DATE 1980	TIME	LAT (N)	λ (W)	SHIP'S SPEED (kts)	SKY CONDITIONS	AIR TEMP (°C)	BARO-METER (mb)	WIND DIR.	BEAU-FORT	SEA TEMP (°C)	SEA STATE	SPECIES SEEN	No.	COMMENTS
13 Oct	1540	35°48'	63°33'	5	Pt. cloudy	24.5	1008.8	-	3	25.0	Mod.	Greater shear-water	1	Accompanying ship
	1550	"	"	-	"	"	"	"	"	"	"	-	0	
14 Oct	0942	33°53'	62°26'	5.8	Pt. cloudy	23	1014.9	-	4	25.1	Mod.	-	0	
	0955	33°46'	62°25'	"	"	"	"	"	"	25.5	"	-	0	
	1508	33°12'	62°12'	6.2	"	24.5	1015.2	NW	5	25.9	"	-	0	
14 Oct	1525	33°10'	62°11'	6.2	Pt. cloudy	24.5	1015.2	NW	5	25.9	Mod.	-	0	
	1535	33°09'	62°11'	"	"	"	"	"	"	"	"	-	0	
19 Oct	0900	26°12'	58°01'	6	Pt. cloudy	27.8	1017.2	SSE	4	27.5	Mod.	-	0	
	0910	26°12'	58°00'	"	"	"	"	"	"	"	"	-	0	
	0920	26°12'	57°59'	"	"	"	"	"	"	"	"	-	0	
20 Oct	1507	26°08'	56°25'	H/T	Squalls	27.7	1018.2	-	2	28.0	Slight	Barn swallows	2	(Partial list) Accompanying ship
	1525	"	"	"	Overcast	"	"	-	"	"	"	-	0	
	1535	"	"	"	"	"	"	-	"	"	"	-	0	
22 Oct	0930	26°01'	56°20'	5	Pt. cloudy	28.2	1022.8	ESE	2	27.8	Mod.	-	0	
	0940	26°00'	56°20'	"	"	"	"	"	"	"	"	-	0	
	0950	25°59'	56°20'	"	"	"	"	"	"	"	"	-	0	
	1515	25°25'	56°20'	8	Clear	-	1021.0	ESE	3	28	Slight	-	0	
	1525	"	"	7.5	"	-	"	"	"	"	"	-	0	
	1535	"	"	8	"	0	"	-	"	"	"	-	0	

APPENDIX V - (continued)

DATE 1980	TIME	LAT (N)	λ (W)	SHIP'S SPEED (kts)	SKY CONDITIONS	AIR TEMP (°C)	BARO-METER (mb)	WIND DIR.	BEAU-FORT	SEA TEMP (°C)	SEA STATE	SPECIES SEEN	No.	COMMENTS
23 Oct	0900	23°10'	56°37'	8	Clear	31	1021.8	SE	4	28	Mod.	-	0	
	0910	"	"	"	"	"	"	"	"	"	"	-	0	
	0920	"	"	"	"	"	"	"	"	"	"	-	0	
	1525	22°48'	56°34'	5	Clear	-	1019.0	ESE	4	28.2	Mod.	-	0	
	1535	22°46'	56°34'	"	"	-	"	"	"	"	"	-	0	
	1545	22°46'	56°34'	"	"	-	"	"	"	"	"	-	0	
24 Oct	0955	21°14'	57°06'	7	Clear	-	1019.7	ESE	4	28.2	Mod.	-	0	
	1005	"	"	"	"	-	"	"	"	"	"	-	0	
	1015	"	"	"	"	-	"	"	"	"	"	-	0	
30 Oct	0915	14°21'	60°44'	6	Overcast	29.2	1016.6	-	4	28.4	"	-	0	
	0925	14°20'	60°45'	"	"	"	"	-	"	"	"	-	0	
	0935	14°20'	60°44'	"	"	"	"	-	"	"	"	-	0	
31 Oct	1055	14°04'	61°05'	5	Pt. cloudy	28.8	1015.8	ENE	4	28.2	Mod.	-	0	



Cypselurus melanurus