

CRUISE REPORT

W-50

Scientific Activities

Miami - Little San Salvador - Jamaica - Roatan - Miami

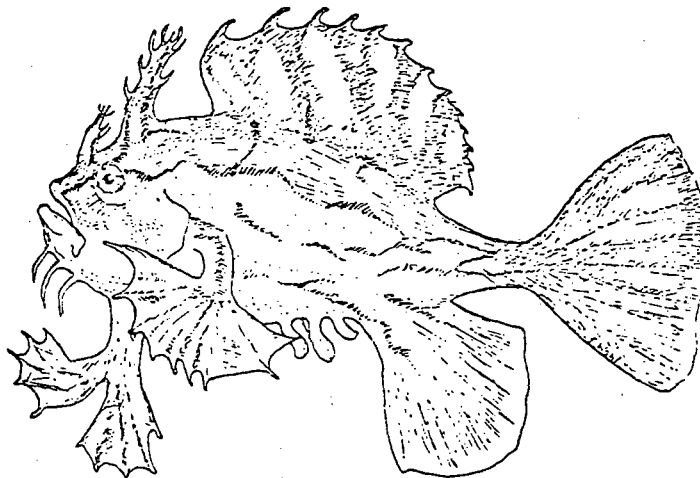
6 February 1980 - 19 March 1980

R/V Westward

Sea Education Association

Woods Hole, Massachusetts

SHIPBOARD DRAFT





## PREFACE

The purpose of this Cruise Report is to present a brief outline of the scientific activities completed aboard R/V Westward during W-50. Reports of the status of ongoing projects and of the traditional academic program are included, as well as abstracts from the research projects of the students. The report was composed at sea, and does not represent a detailed interpretation of the data. The limitations of the lack of library facilities and restricted time are clearly reflected in the contents. However, I feel that it is important for the students to be responsible for the completion of their projects while at sea, including writing up a report. The abstracts of these constitute the bulk of this report.

This cruise marked the fiftieth class of Sea Semester students to sail on board the R/V Westward, and was also one of the more ambitious cruise tracks ever attempted. Completion of the track and of the scientific program would not have been possible without the skills of the Marine and Nautical Science staff.

I owe special thanks to Rob Moir, who was in charge of the shipboard laboratory, and upon whom I was able to depend throughout the cruise. His knowledge of natural history was greatly appreciated by us all, particularly in the identification of birds and mammals.

Melanie Byrne, who participated as an Assistant Scientist, brought with her a vast knowledge of marine plankton. Both staff and students alike benefitted from this, and from her ability to look down a microscope in rough weather!



Three visiting scholars participated in this cruise. Dr. Mike Vecchione joined us for Leg 1, and proved to be of invaluable assistance in the early part of the cruise. Dr. Chuck Messing participated in Leg 2, and his knowledge of coral reefs was useful in diving in Roatan. Dr. Lawrence McCrone, who sailed with us on the final leg of the cruise, was of considerable help in sample analysis, particularly of mesopelagic fish, and in the final preparation of papers.

I am particularly indebted and grateful to the Captain, Wallace Stark, for his help in enabling us to complete the scientific objectives of the cruise. I also owe thanks to John Wigglesworth, Jeff Bolster and Gayle Biddle for their cooperation and assistance in running stations and their skillful handling of the ship. Jerry Zorsch proved to be one of the few engineers I have sailed with who knew there was more to the ship than the Engine Room! Thanks for your help on deck and in the lab! Finally, where would we have been without food? Thanks from all of us must go to Susan Pilling - the meals were always superb, and her constant smile and patience an example to us all!

There is one other "person" to be recorded! This cruise will be remembered by us all as the one which immortalized Histrio histrio - whose presence was a source of much entertainment!

In conclusion, may I remind all participants in W-50 to never forget our motto: "Never fear, Susan's here!"

Susan E. Humphris

Chief Scientist

Cruise W-50



## TABLE OF CONTENTS

	Page
PREFACE	ii
CONTENTS	
INTRODUCTION	1
ACADEMIC PROGRAM	6
Science Watch	6
Lectures	6
Individual research projects	7
COOPERATIVE PROGRAMS	10
Cooperative ship weather observation program	10
Shark tagging program	10
LONG TERM INTERNAL PROGRAMS	11
Zooplankton tows during W-50 - M. Byrne	11
Neuston tows	13
Marine mammals - R. Moir	16
Bird sightings - R. Moir	18
LITTLE SAN SALVADOR	20
Introduction	20
A. EASTERN END OF THE LAGOON	23
A general survey - J. Saroka	23
B. HYPERSALINE POND STUDIES	24
(i) Red Pond	
Chemical composition and macroscopic invertebrates of a hypersaline pond - P. Dal Pian	24
Plankton productivity and diversity in Red Pond - E. Day	25
(ii) Knee Deep Pond	
Water chemistry of Knee Deep Pond, and the feasibility of brine shrimp culture - J. Falkner	26
The pelagic life of Knee Deep Pond - C. Cunningham	27
The benthic life of Knee Deep Pond - C. Brown	28
C. CONCH STUDIES	
Introduction - C. Stephens	29





Depuration rates of <u>Strombus gigas</u> - C. Stephens	30
Digestive enzymes of the queen conch - C. Wahl	32
The assessment of the present queen conch population in Little San Salvador lagoon and surrounding areas with prospectives on future exploitation in the area - R. Nolan	33
Ecology and behavior of queen conch juveniles in the lagoon of Little San Salvador - G. Townsend	34
SUMMARY	35
SARGASSO SEA STUDIES	
Introduction	36
A. PHYSICAL STUDIES	
A transect across the Gulf Stream	36
B. BIOLOGICAL STUDIES	
Respiration in rates and productivity studies in the Sargasso Sea - V. Low	40
Nutrient regeneration by macrofaunal organisms in the Sargasso Sea - C. Homer	41
The toxicity of #2 fuel oil and detergent "Joy" on marine life using Sargassum crabs and shrimp - W. McCloskey	42
NAVIDAD BANK	
Introduction	45
The bathymetry of Navidad Bank - K. Schultz	47
Water chemistry of Navidad Bank - C. Cabral	50
Zooplankton on and off Navidad Bank - M. Byrne	52
STUDIES OF CIRCULATION IN THE CARIBBEAN SEA	54
MESOPELAGIC ECOLOGY STUDIES	62
Horizontal distribution of mesopelagic organisms - L. FitzGerald	62
The vertical migration of mesopelagic fish - P. Brooks	63
Vertical migration of euphausiids - J. Dickison	66
CORAL REEF STUDY - P. Sullivan	68
METEOROLOGICAL AND NAUTICAL STUDIES	
Measurement of the pH of rainwater - S. Ginand	70
A study of leeway on the R/V <u>Westward</u> - J. Marden	71



A propulsional analysis of sail power - A. Saffer and R. Boehringer	72
A study of Chichester's method: parameters and inherent problems - J. Anderson	73
APPENDIX I	
A. Demonstration organisms used as a basis for the practical examination	74
B. Essay questions	76
APPENDIX II	
Meter net tows	77
APPENDIX III	
W-50 Bird sightings	80
APPENDIX IV	
A. Chemical analyses of water samples from the vicinity of Navidad Bank	85
B. Results of the hydrographic transect from Jamaica to Roatan	87



## INTRODUCTION

This cruise report provides a record of the scientific research activities conducted aboard R/V Westward during the laboratory section of the Introduction to Marine Science course - NS 225 at Boston University.

The itinerary and ship's track for W-50 (Table 1 and Figure 1) took us to both open ocean and nearshore marine environments; these provided opportunities for individual student research projects in both pure and applied aspects of oceanography, and allowed us to expose the students to all the different oceanographic operations of which the R/V Westward is capable.

The objectives of the research and student projects conducted during the cruise focused around specific geographical areas. This Cruise Report, which is composed mainly of the abstracts from student projects, is therefore divided into sections dealing with each scientific problem. The objectives of the research in a specific area are presented in the Introduction to each section.

Research conducted during W-50 partly represents on-going work of individuals and agencies that have extended their assistance to our students. Material reported here should not be excerpted or cited without permission of the Chief Scientist.

TABLE 1

Itinerary of R/V Westward Cruise W-50

	<u>Depart</u>	<u>Date</u>	<u>Arrive</u>	<u>Date</u>
Leg 1	Miami	7 February 1980	<sup>1</sup> Freeport, Bahamas	8 February 1980
	Freeport, Bahamas	8 February 1980	Little San Salvador, Bahamas	12 February 1980
	Little San Salvador, Bahamas	13 February 1980	Jamaica	27 February 1980 (
Leg 2	Jamaica	29 February 1980	Roatan	6 March 1980
Leg 3	Roatan	8 March 1980	Miami	18 March 1980

<sup>1</sup>Entering and clearing customs only.

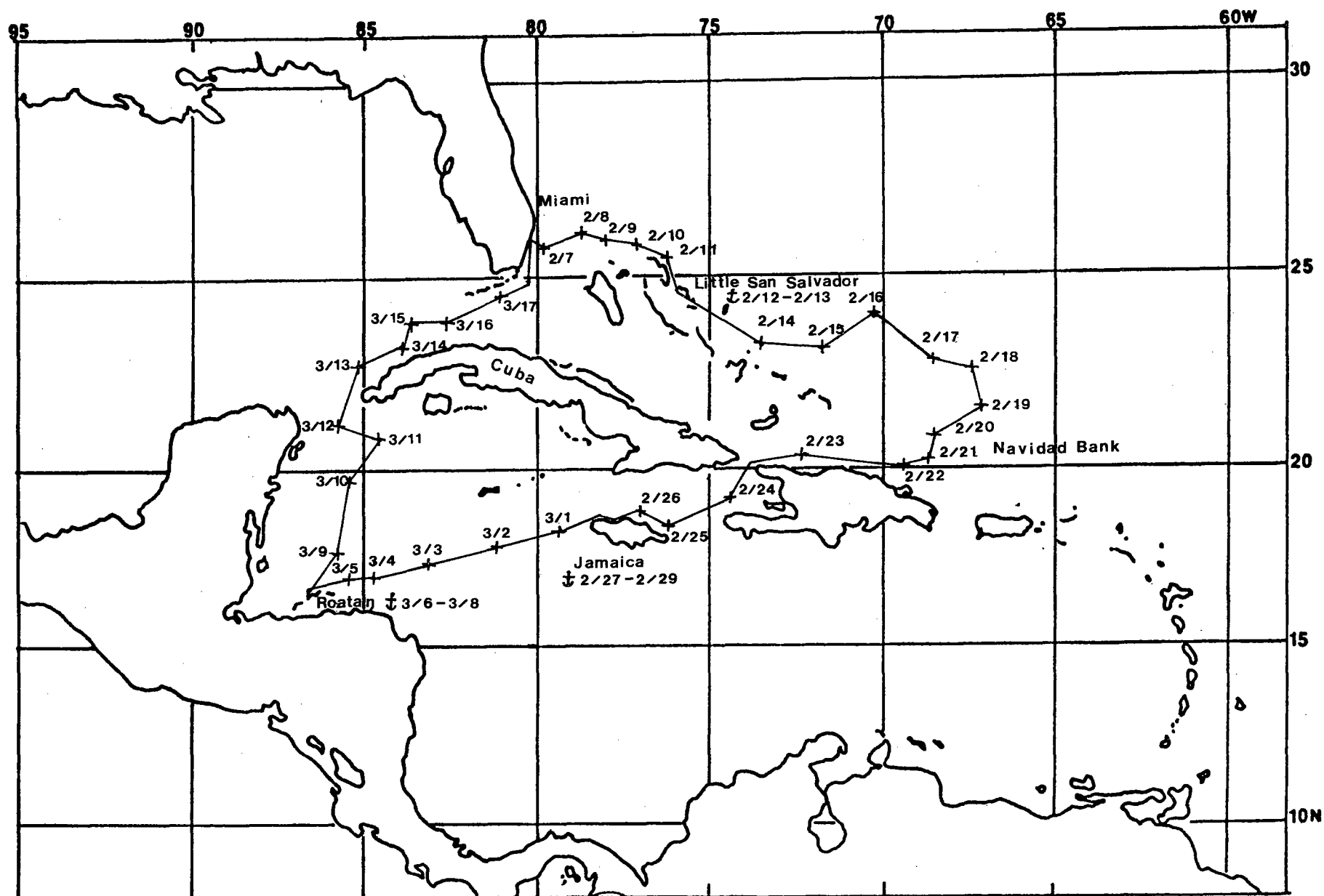


Figure 1. Cruise track of R/V Westward W-50  
(dates indicate noon position)

TABLE 2.      Ship's complement for R/V Westward Cruise W-50

Nautical Staff

Wallace Stark, J.D., M.M.	Captain
John Wigglesworth, B.S.	Chief Mate
W. Jeff Bolster, B.A.	Second Mate
Gayle Biddle, B.A.	Third Mate
Jerry Zorsch	Chief Engineer
Susan Pilling, B.S.	Steward

Scientific Staff

Susan E. Humphris, Ph.D.	Chief Scientist
Rob Moir, M.S.	Second Scientist
Melanie Byrne, M.S.	Third Scientist

Visitors

Mike Vecchione, Ph.D.  
 Chuck Messing, Ph.D.  
 Lawrence McCrone, Ph.D.

Students

James D. Anderson, University of Kentucky, Microbiology, B.S.  
 Robert D. Boehringer, Cornell University, Mechanical Engineering,  
                                 Junior  
 Priscilla M. Brooks, Cornell University, Mass Communications,  
                                 Senior  
 Carter M. Brown, Tufts University, Biology, Junior  
 Claire A. Cabral, University of Massachusetts, Marine Biology,  
                                 Junior  
 Mary C. Cunningham, Denison University, Biology, Senior



Students (continued)

Margaret P. Dal Pian, Nebraska Wesleyan University, Biology,  
Senior

Elizabeth A. Day, University of Wisconsin - Green Bay, Biology/  
Aquatic Ecology, Senior

Jeffrey A. Dickison, Nasson College, Environmental Biology,  
Senior

James A. Falkner, Reed College, Senior

Lisa M. FitzGerald, Vassar College, Biology, Junior

Sharon L. Ginand, Bates College, Biology, Junior

Cathy Homer, Tufts University, Biology, Junior

Virginia R. Low, Colby College, Biology, Junior

Jeffrey R. Marden, Cornell University, Marine Science,  
Sophomore

Wynn B. McCloskey, Johns Hopkins University, Marine Biology,  
Senior

Robert S. Nolan, Southeastern Massachusetts University, Marine  
Science, Senior

Adam Saffer, Cornell University, Mechanical Engineering, Senior

James M. Saroka, Cornell University, Agriculture, Junior

Kathy L. Schultz, University of Wisconsin - Madison, Junior

Christina M. Stephens, Castleton State College

Patricia A. Sullivan, Tufts University, Biology, Junior

George B. Townsend, American University, Marine Biology, Junior

Christina M. Wahl, Cornell University, Biology, Senior



## ACADEMIC PROGRAM

The Marine Science academic program was composed of three areas of activity, each of which was given equal emphasis in the final evaluation.

### 1. Science watch

A 24-hour science watch was maintained throughout the cruise. Their responsibilities included maintenance of the science log, completion of scientific stations, and continuation of the scientific program in terms of analysis of samples and interpretation of data. In addition, analytical techniques were learned, and time was also made available for individual student research projects.

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

During the last two weeks of the cruise, one student each watch was designated Junior Science Watch Officer. He/she took over the responsibilities previously held by the staff scientist, and was responsible for the efficient running of the lab and the scientific program.

### 2. Lectures

Lectures were given each weekday while at sea; the topics covered are listed in Table 3. Many of them were related to sampling and analytical methodology, while others pertained to the on-going research activities and to the interests of the Visiting Scientists.

Information obtained during lectures and science watch was evaluated by means of two written examinations. A copy of the final is presented in Appendix IB.

### 3. Individual research projects

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

- 1) the project should take advantage of the opportunities offered by the Westward.
- 2) it should be approached, executed, and written up in a scientific fashion.

The projects selected covered several fields of Marine Science, Nautical Science and Meteorology. Each student was requested to submit a written report before leaving the ship. In addition, a 10-minute presentation of each project and its results was given by each student.

TABLE 3.

Lectures during W-50

S	9 February	Life history of <u>Strombus gigas</u>	M. Vecchione
M	11 February	Analysis of salinity and dissolved oxygen	S. Humphris
W	13 February	Birds of Little San Salvador	R. Moir
T	14 February	Spectrophotometric analytical methods	S. Humphris
F	15 February	The Sargasso Sea	M. Vecchione & M. Byrne
M	18 February	Identification of marine mammals	R. Moir
T	19 February	Navidad Bank - program and objectives	S. Humphris
		Anatomy of <u>Strombus gigas</u>	C. Wahl
W	20 February	Nansen bottles and reversing thermometers	S. Humphris
T	21 February	Physiology of marine mammals	R. Moir
F	22 February	Mesopelagic ecology	M. Vecchione
S	23 February	Little San Salvador Conference-I	C. Stephens C. Wahl G. Townsend R. Nolan J. Saroka
M	25 February	Little San Salvador Conference-II	B. Day P. Dal Pian J. Falkner M. Brown C. Cunningham
M	25 February (pm)	Marine plankton	M. Byrne M. Vecchione
T	26 February	Geology of Jamaica	S. Humphris
S	2 March	Circulation of the Caribbean - program and objectives of Leg 2	S. Humphris

TABLE 3. (continued)

M	3 March	EXAM I	
W	5 March	Coral reef physiology and ecology	M. Byrne R. Moir
M	10 March	Pelagic birds	R. Moir
T	11 March	Student seminars a) Sargasso Sea	V. Low C. Homer W. McCloskey
		b) Navidad Bank	K. Schultz C. Cabral
W	12 March	Adaptations to life in the deep sea	L. McCrone
T	13 March	Propulsion under sail	R. Boehringer A. Saffer
F	14 March	Early life history of fish	L. McCrone
S	16 March	FINAL EXAM	
M	17 March	Student seminars: a) Vertical migration/mesopelagic fish	L. FitzGerald J. Dickison P. Brooks
		b) Coral reefs	P. Sullivan
		c) pH of rain	S. Ginand
T	18 March	Student seminars: Nautical Science	J. Marden D. Anderson

## COOPERATIVE PROGRAMS

### Cooperative Ship Weather Observation Program (NOAA)

The R/V Westward is certified to gather weather observations for the U.S. National Weather Service. The data, which are collected at 0600 and 1200 GMT, are transmitted to Coast Guard stations ashore, and constitute part of a global weather observation network, as well as providing ground truth information for comparison with satellite data.

On W-50, 62 sets of observations were compiled, of which 89% were successfully transmitted. During this cruise, we sent the information to five different Coast Guard stations, including Honolulu, Hawaii, who answered us while we were in the Yucatan Straits. 61% of our transmissions were copied by NMN, Portsmouth, Va., 13% by NMG, New Orleans, 3% by NMC, San Francisco, 4% by NMF, Boston and 3% by NMO, Honolulu.

Compilation of these observations allowed us to keep a detailed surface and meteorological record for the cruise; the data are available from the SEA office.

### Shark Tagging Program (National Marine Fisheries Service)

In cooperation with Dr. Jack Casey of the Narragansett Laboratory, National Marine Fisheries Service, the R/V Westward is involved in a project to catch, identify, characterize and tag sharks. The purpose of this program is to discover migration patterns of certain species of sharks in the North Atlantic and Caribbean.

During this cruise, on 4 March 1980, one shark was caught on a hand line and tagged. It was identified as a young silky shark, Carcharinus falciformis, and was only 70 cm long. It was in very good condition when finally released.





## LONG TERM INTERNAL PROGRAMS

### Zooplankton Tows during W-50

Melanie Byrne

#### Introduction

A total of 55 plankton tows were made during W-50, including phytoplankton, meter net, and neuston tows. The cruise track covered several different oceanic environments, including the Sargasso Sea, Caribbean Sea, shallow banks and deep open ocean. Included in these tows were some associated with Navidad Bank studies and a 24-hr station performed for student projects. These are addressed elsewhere in this report. This discussion will include only meter net (363 mesh) and neuston tows conducted during this cruise. The location of all plankton tows is shown on Figure 2.

All the tows were examined by staff and students, biomass determined for some, and in all cases, the contents identified and logged. Identification was kept very general in order to allow examination of as much of each tow as possible. A brief synopsis of the contents of the meter net tows is given in Appendix II.

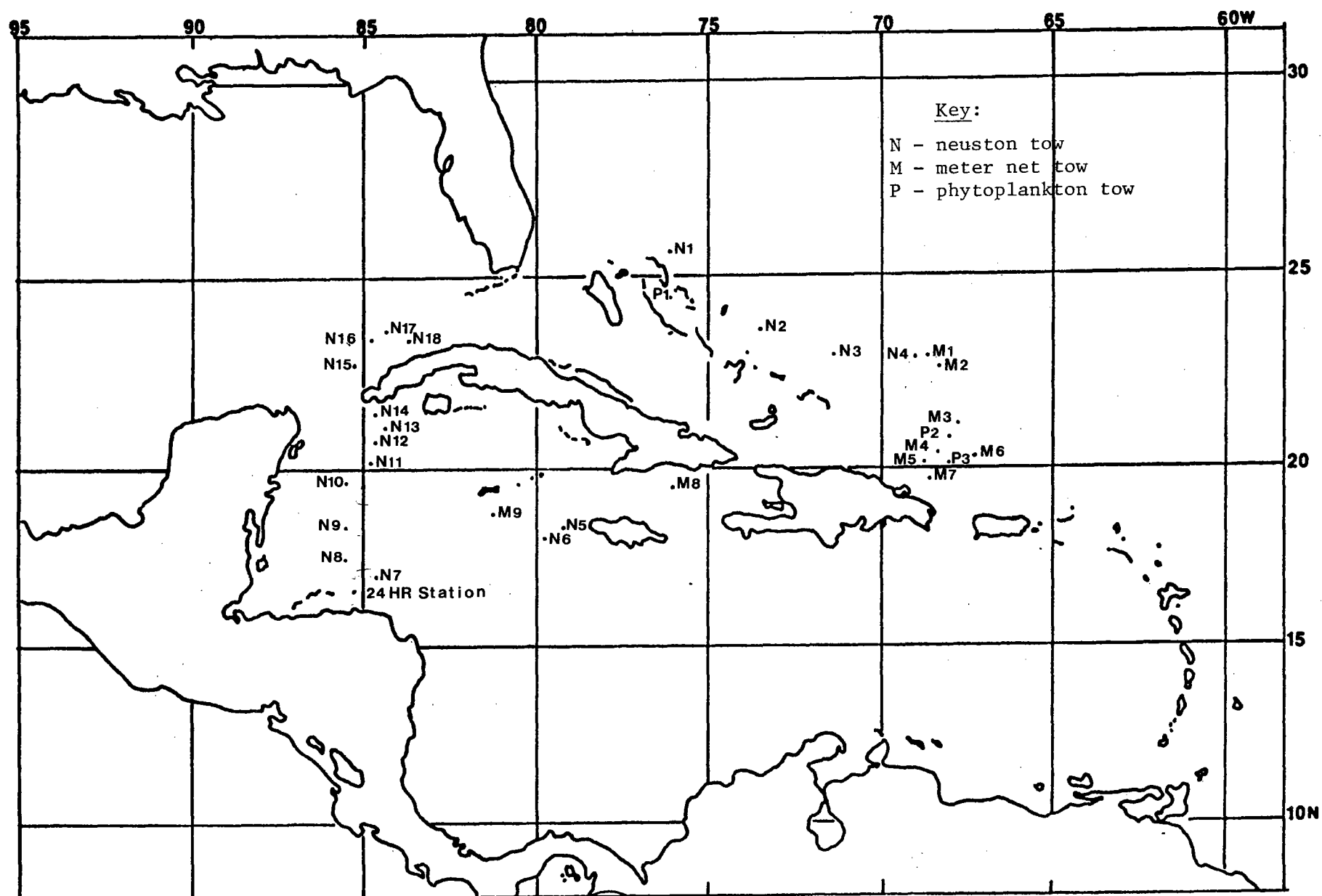


Figure 2. Plankton tows during W-50

### Neuston tows

For more than two years, Westward cruises have routinely carried out neuston tows and shipboard analyses of the samples. During W-50, eighteen tows were conducted and analysed for their contents of tarballs, Sargassum weed, and the marine insect, Halobates micans. The positions of stations are shown in Figure 2, and the analyses are presented in Table 4.

#### 1) Tar

Tar balls are believed to originate from crude oil lost during tanker washings. Lighter hydrocarbons evaporate but the heavier hydrocarbons tend to concentrate into floating balls, which have a residence time of between 6 months and 10 years.

On W-50, there was a noticeable increase in the concentration of tar recovered in the net over last year's values (W-44). One tow, W50-N5 contained a considerable quantity of tar; this station was located just west of Jamaica. The overall higher observed concentrations are probably a reflection of the increase in crude oil shipping in these areas.

#### 2) Sargassum weed

Sargassum weed is a primary producer and is of particular interest to us in the long-term study of trophic dynamics of the Sargasso Sea. The distribution of Sargassum was highly variable, and no noticeable decrease was observed in the western Caribbean. The very high catch at Station W50-N1, which was located just east of the Bahamas, skews the mean and standard deviation. Omitting this station, the mean standing crop was  $65.5 \text{ mg/m}^2$  (S.D. = 67.9), which is close to values obtained in previous years (e.g. W-44 calculated a mean of  $56.9 \text{ mg/m}^2$ ).

#### 3) Halobates

Halobates micans, a water strider, is the only one of 750,000

species of insects that spends its entire life cycle at sea.  
The mean abundance of  $4500 \text{ km}^{-2}$  is not significantly different  
from those observed on other cruises to the area, although  
more were seen in the Sargasso Sea area than previously.

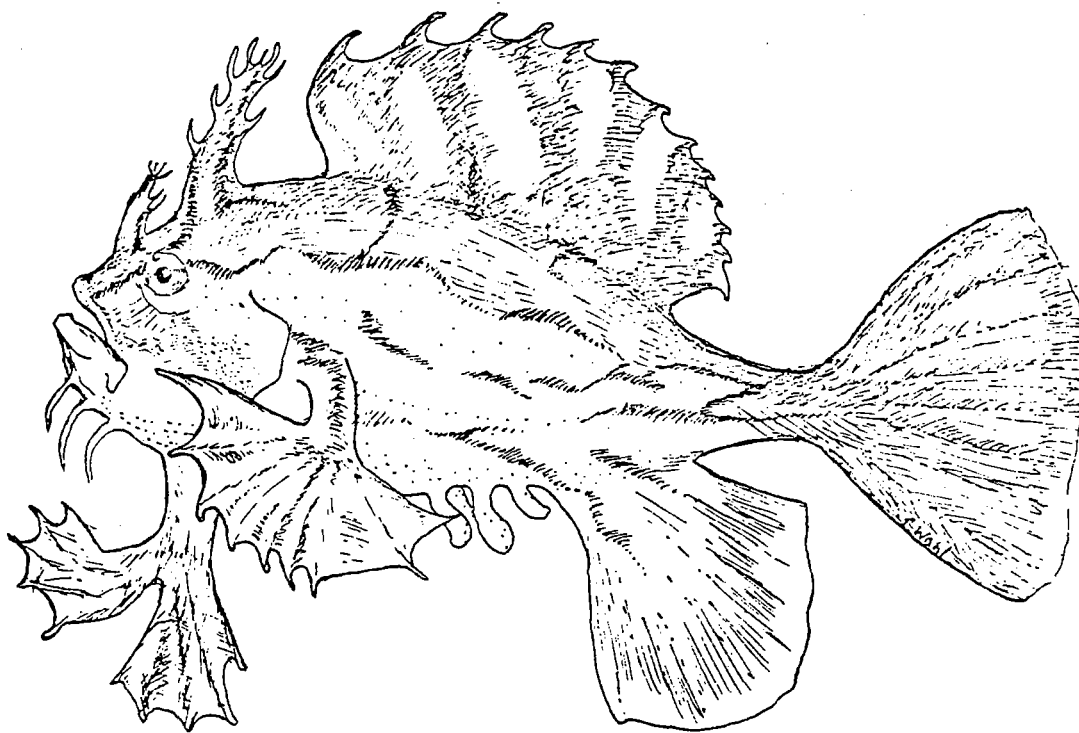


TABLE 4 Summary of W-50 Neuston Tow Results

Calculated concentrations are based on the surface area filtered, calculated from the time of the tow, assuming a speed of 2 knots.

Tow #	Date (1980)	Time (hr)	Position		Tarballs	Sargassum	Halobates
			N	W	$10^{-3} \text{ g.m}^{-2}$	$10^{-3} \text{ g. wet wt.m}^{-2}$	$10^3/\text{km}^2$
W-50N1	2/11	0730	25°32'	76°18'	3.8	3,669.7	0
W-50N2	2/14	1210	23°35'	73°52'	10.3	183.5	0
W-50N3	2/15	1235	23°05'	71°45'	2.2	18.3	0
W-50N4	2/17	1140	22°53'	68°48'	2.7	29.7	0.5
W-50N5	3/1	1110	18°12'	79°22'	293.6	47.5	0
W-50N6	3/1	2030	18°08'	79°58'	21.6	2.7	17.5
W-50N7	3/4	1215	16°55'	84°56'	15.1	57.2	3.7
W-50N8	3/9	1150	17°40'	85°42'	8.1	34.0	2.1
W-50N9	3/9	2040	18°22'	85°30'	1.1	91.7	7.0
W-50N10	3/10	1240	19°45'	85°18'	5.4	63.1	0.5
W-50N11	3/10	2015	20°08'	85°05'	24.8	190.0	12.5
W-50N12	3/11	1200	20°49'	84°40'	4.0	75.6	2.0
W-50N13	3/12	2040	20°58'	84°34'	5.4	216.4	3.8
W-50N14	3/12	1250	21°19'	85°29'	1.1	51.8	9.1
W-50N15	3/13	1200	22°52'	85°07'	1.1	8.1	0.5
W-50N16	3/13	2030	23°13'	85°04'	11.9	10.3	15.7 ←
W-50N17	3/14	1210	23°16'	84°38'	0.5	0.0	3.7
W-50N18	3/14	2105	23°06'	84°11'	3.8	32.9	1.6
Mean					23.1	(65.5)* 265.7	4.5
Standard Deviation					67.9	(67.9)* 852.1	5.6
Range					293.1	3669.7	17.5

\* Omitting the data for W-50N1

## Marine Mammals

Rob Moir

Records of cetacean sightings have been kept on Westward cruises for several years. For W-50 it was anticipated that the densest population of whales would be on Navidad Bank. Therefore an intensive structured whale watch was maintained on and near the bank.

North of Navidad Bank observers stood watch from the foremast for 13 hours. During these two days humpback whales (Megaptera novaeangliae) were spotted once. On the Bank, twenty-one to fifty humpback whales were sighted even though watches were interrupted by heavy rain squalls and light fog. The majority of sightings were made during the morning at the northern end of the bank. One pod of five whales included a small whale, presumably a calf.

Spot observations of cetaceans for the entire cruise are presented in Table 5. Three species of whales and probably two species of dolphins were sighted during W-50. Identification to species of Stenella dolphins is suspect as it was difficult to distinguish immature spotted dolphins (Stenella plagiodon) from immature bridled dolphins (Stenella frontalis).

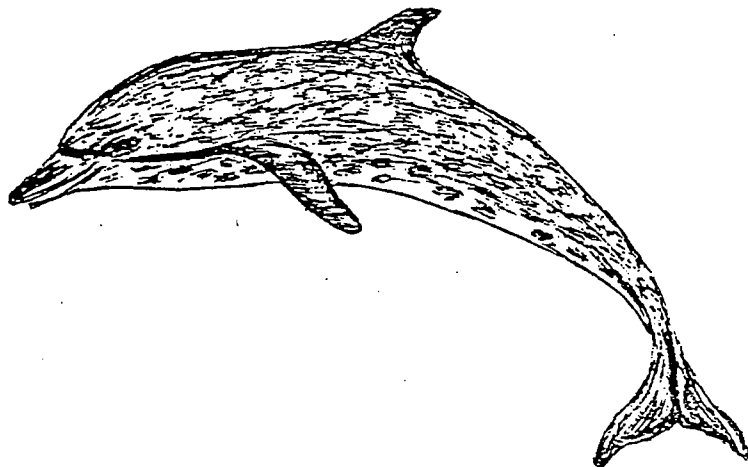


TABLE 5 Cetacean Sightings - W-50

<u>Date</u>	<u>Time</u>	<u>Lat.</u>	<u>Long.</u>	<u>Cetacean sighted</u>	<u>Notes</u>
February 9	0620	26°10'N	78°24'W	unidentified dolphin	
February 11	1515	25°18'N	76°11'W	4-10 <u>Grampus griseus</u>	Animals are white or white and black with high pointed dorsal fin. One animal breached and showed blunt face. Approximately 12-15 feet long. These animals appeared sluggish compared to dolphins.
February 13	2030	24°04'N	75°27'W	2-4 unidentified dolphins	Dark on top, white on side, dorsal fin not hooked.
February 19	1020	21°34'N	68°11'W	3 Humpback whales, <u>Megaptera novaeangliae</u> 4 unidentified dolphins	Large white flippers Brown with white spot on beak
February 20	1600	20°50'N	68°39'W	2 short-finned pilot whales, <u>Globicephala macrorhyncus</u>	Approx. 25 feet long, black with low aspect dorsal fin, short blow forward on body, "pot" head.
February 21	0840	arrive at Navidad Bank		21-50 humpback whales <u>Megaptera novaeangliae</u>	
March 4	0700	16°33'N	84°30'W	15-20 bridled dolphins, <u>Stenella frontalis</u> , possibly mixed with Atlantic spotted dolphins, <u>S. plagiodon</u> .	

## Bird Sightings

Rob Moir

The majority of the W-50 cruise track was offshore, consequently most of the bird sightings were of large fish-eating birds, particularly members of the order Pelecaniformes. Pelagic birds of other orders were also sighted. In addition, two warblers and two swallows landed on the Westward while at sea. The birds sighted are noted according to order in Table 6. A complete log of bird sightings is presented in Appendix III.

A black legged kittiwake, sighted in the middle of the Yucatan Channel (21°30'N, 85°38'W) may be of interest. This pelagic gull is reported (Robbins, Bruun, and Zim, 1966; Pough, 1951 and Peterson, 1947) to winter in the Atlantic Ocean south to the Sargasso Sea.

Peterson, Roger Tory; 1947. A Field Guide to the Birds. Houghton Mifflin Co., Boston.

Pough, Richard H.; 1951. Audubon Water Bird Guide. Doubleday and Co., Inc. Garden City, N.Y.

Robbins, Bruun, and Zim; 1966. A Guide to Field Identification, Birds of North America. Golden Press, New York.



TABLE 6

Bird Sightings from R/V Westward during W-50

## Order Procellariiformes

Puffinus lherminieri

Audubon shearwater

Puffinus griseus

sooty shearwater

Oceanites oceanicus

Wilson's petrel

## Order Pelecaniformes

Phaethon lepturus

white tailed tropicbird

Fregata magnificens

magnificent frigatebird

Sula sula

red footed booby

Sula dactylatra

blue faced booby

Sula leucogaster

brown booby

## Order Ciconiiformes

Bubulcus ibis

cattle egret

## Order Charadriiformes

Stercorarius parasiticus

parasitic jaeger

Stercorarius pomarinus

pomarine jaeger

Catharacta skua

skua

Rissa tridactyla

black legged kittiwake

Larus atricilla

laughing gull

Sterna forsteri

Foster's tern

Thalasseus maximus

Royal tern

## Order Passeriformes

Hirundo rustica

barn swallow

Petrochelidon pyrrhonota

cliff swallow

Dendroica tigrina

Cape May warbler

Geothlypis trichos

yellowthroat



## LITTLE SAN SALVADOR

### Introduction

Little San Salvador is a small, uninhabited, privately owned island which represents an unmodified island-fringing reef-lagoon complex. Last year, on cruise W-45, a study was begun in order to study the natural history of the island, and to assess the feasibility of aquaculture of the queen conch, Strombus gigas.

During W-50, attention was focussed on three major areas of interest. The eastern end of the Lagoon, which had not been previously studied, was surveyed in terms of bathymetry and the basic floral and faunal distribution. Two hypersaline ponds, which had been described by W-45, were revisited and chemical and biological analyses carried out to look at variations in composition. An additional pond was also reached and sampled - this will be referred to as Knee Deep Pond in this report. All areas studied are shown in Fig. 3. The final area of research concerned aspects of the natural history of the queen conch and the dynamics of the population on Little San Salvador. In addition, Table 7 presents a list of birds sighted on the island.

After these studies were planned, it was learned that Little San Salvador had been sold to Norwegian Caribbean Lines for use as a port stop for their cruise ships. However, discussions with them have indicated their interest in obtaining information about the island so as to preserve its natural flora and fauna, so our studies of this island will hopefully continue.

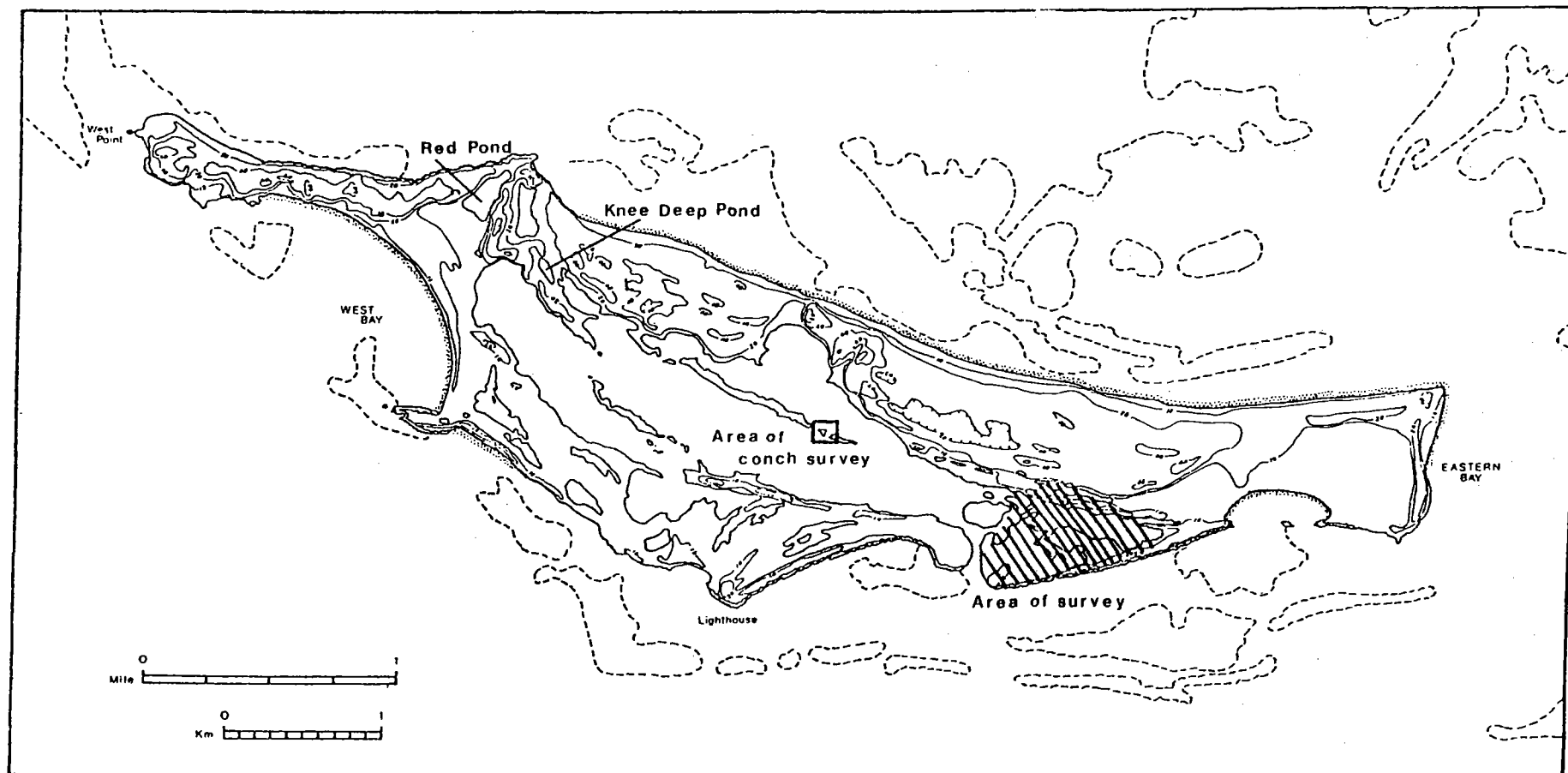


Figure 3. Areas studied during work at Little San Salvador during W-50.

TABLE 7    Birds sighted during field operations on Little  
San Salvador    -    February 12 and 13

white cheeked pintail	<u>Anas bahamensis</u>
domestic chicken	<u>Tetraonidae</u>
great blue heron	<u>Ardea herodias</u>
zapata rail	<u>Cyanolimnas cerverai</u>
American coot	<u>Fulica americana</u>
willet	<u>Catoptrophorus semipalmatus</u>
American oystercatcher	<u>Hoematopus palliatus</u>
Bahamian mockingbird	<u>Mimus gundlachii</u>
belted kingfisher	<u>Megaceryle alcyon</u>
Bahama bananaquit	<u>Coereba flaveola</u>
northern water thrush	<u>Seiurus noveboracensis</u>

A) THE EASTERN END OF THE LAGOON

A General Survey

Jamie Saroka

ABSTRACT

A general field survey of the eastern end of the lagoon was carried out in order to obtain background information for assessment of the feasibility of aquaculture of Strombus gigas on Little San Salvador.

The entire eastern end of the lagoon proved to be less than six inches deep at low tide. The central part of this area was heavily bioturbated, mainly by the sand shrimp Calianassa, while a large population of snails inhabited the margins. Black and red mangroves surrounded the lagoon, and many small shoots and pneumatophores were observed encroaching into the center. A small pond to the north, shown on the chart, proved to be completely filled in with mangroves. Two east-west coralline ridges resulted in a side lagoon which was also being filled in by detritus and mangroves.

A transect of the lagoon entrance was done and the flushing rate was determined. The tidal difference was determined to be 30 cm. and the surface area to be  $2.29 \times 10^6 \text{ M}^2$ . This gives a tidal prism of  $6.87 \times 10^5 \text{ M}^3$ . Thus 7.0 tides or 3.6 days of exchange are required to equal the high tide lagoon volume.

It can be concluded that the eastern end of the lagoon is undergoing ecological succession and is filling in. Mangrove trees are encroaching to the center of the lagoon and, due to its shallowness, will soon be turned to dry land. This would make the eastern end of the lagoon unfeasible for aquaculture of Strombus gigas.

B) HYPERSALINE POND STUDIES

(i) Red Pond

Chemical Composition and Macroscopic Invertebrates of a  
Hypersaline Pond

Peg Dal Pian

ABSTRACT

Red Pond on Little San Salvador Island had been previously studied and was found to be extremely hypersaline. The intent of this study was to characterize the chemical composition and macroscopic invertebrates of Red Pond. Six samples were taken over a 3-1/2 hour period in various parts of the pond and analyzed for salinity, pH, temperature, ammonia, phosphate, and dissolved oxygen concentrations and the presence of macroscopic invertebrates in the immediate area and sediment. The pond was found to be slightly hypersaline (52 ‰) with moderately low dissolved oxygen and phosphate concentrations and extremely high ammonia concentrations. While a few species of invertebrates were found, it is believed that the pond would not support much life, a major factor being the absence of macrophytes.

Plankton productivity and diversity in Red Pond

Betsey Day

ABSTRACT

Primary productivity of Red Pond was determined using the light-dark bottle method, and found to be quite productive. Net productivity was  $68 \text{ gC/m}^2/\text{year}$  and gross productivity was found to be  $130 \text{ gC/m}^2/\text{year}$ . Diversity was analysed qualitatively and was found to be low, with diatoms (mainly Nitzschia), copepods and an aquatic Hemipteran being the most abundant organisms. Lesser numbers of algae and protozoans are also present, with the single-celled organisms being euryhaline rather than adapted to hypersaline conditions. The high productivity and low diversity observed are typical of stressed environments.



(ii) Knee Deep Pond

Water chemistry of Knee Deep Pond, and the feasibility  
of brine shrimp culture

Jimmy Falkner

ABSTRACT

Water samples taken from Knee Deep Pond were analyzed for ammonia, phosphate, and oxygen concentrations, and salinity. Comparisons were made with samples from the western end of the lagoon, as well as with the water between the pond and lagoon. Knee Deep Pond, like Red and Yellow Ponds, is hypersaline, the average salinity being 42.26 ‰. Ammonia concentrations were significantly greater in the pond than those found in the lagoon. This is a result of the excessive degradation of organic matter, including the decomposition of mangrove leaves and a tiny gastropod, of the family Cerithiidae, whose tests were found by the thousands along the perimeter of the pond. A detritus layer of approximately 20 centimeters lines the bottom, and it is also saturated with gastropod tests. Phosphate concentrations were below detection in most samples and phosphate may be limiting. The concentration of oxygen in the pond was 4.18 ml/L compared with 8.43 ml/L, demonstrating the decreasing in oxygen solubility with increasing temperature and salinity.

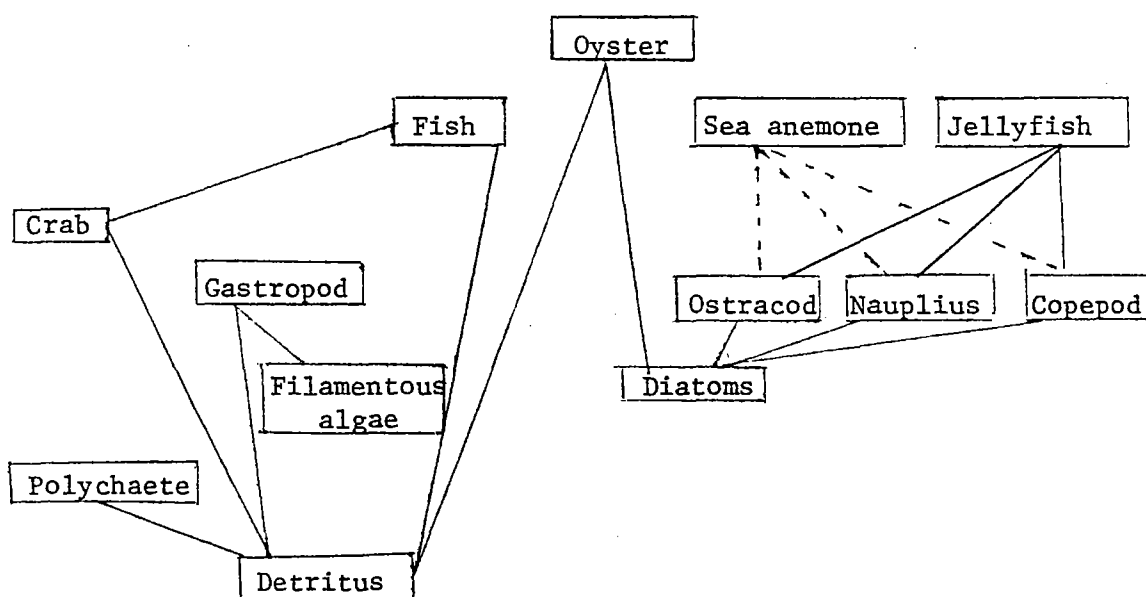
## The pelagic life of Knee Deep Pond

Cathy Cunningham

### ABSTRACT

The pelagic life of Knee Deep Pond was investigated by taking tows with a small net, and by collection of larger organisms. The dominant constituents of the phytoplankton were red and green filamentous algae and diatoms. The zooplankton consisted mainly of dinoflagellates, ostracods, copepods nauplii. A few fish were observed but not identified. This information was combined with the benthic data, and a hypothetical food web (shown below) was constructed for Knee Deep Pond.

### Hypothetical food web for Knee Deep Pond



The benthic life of Knee Deep Pond

Matt Brown

ABSTRACT

The benthic organisms existing in Knee Deep Pond were identified. The upper sediment consisted of a very fluid layer of thin organic-inch mud. The major groups of organisms were gastropods, small sea anemones, oysters, polychaetes and a large blue crab. The food web constructed from the pelagic and benthic data illustrates the relatively unstable ecosystem prevailing in the pond, and its lack of reserve producers.

C) CONCH STUDIES

Chris Stephens

Strombus gigas (queen or pink-lipped conch) is a valuable Caribbean economic resource both for its food and tourism values. However, extensive overfishing has caused concern over the dying conch population. This along with field advancement has led to mariculture feasibility studies. Little San Salvador harbors an ideal culturing site and it was this ideology which led W-45 and W-50 students to further study the Strombus habitat, physiology, and population studies.

Strombus gigas is a herbivorous mesogastropod prosobranch existing in tropical regions among Thalassia (turtle grass) beds in calcareous sand. The queen conch migrates to shallow water in the summer from a depth of 40m to breed. The spawned egg masses hatch into planktotrophic veligers which feed on nanoplankton. After passing through several veliger stages, the conch metamorphose into early juveniles. These early juveniles exhibit distinct characteristics as opposed to the adults. The young conchs feed at night and bury in the sand during daylight. At approximately 2.5 years the conchs become sexually mature and exhibit such by reaching the flaring lip stage. This is also the stage which has been shown to be the most feasible optimum for harvesting.

It has only been through recent advancements in laboratory rearing of conch veligers that the aquaculture of Strombus has advanced.

## Depuration rates of *Strombus gigas*

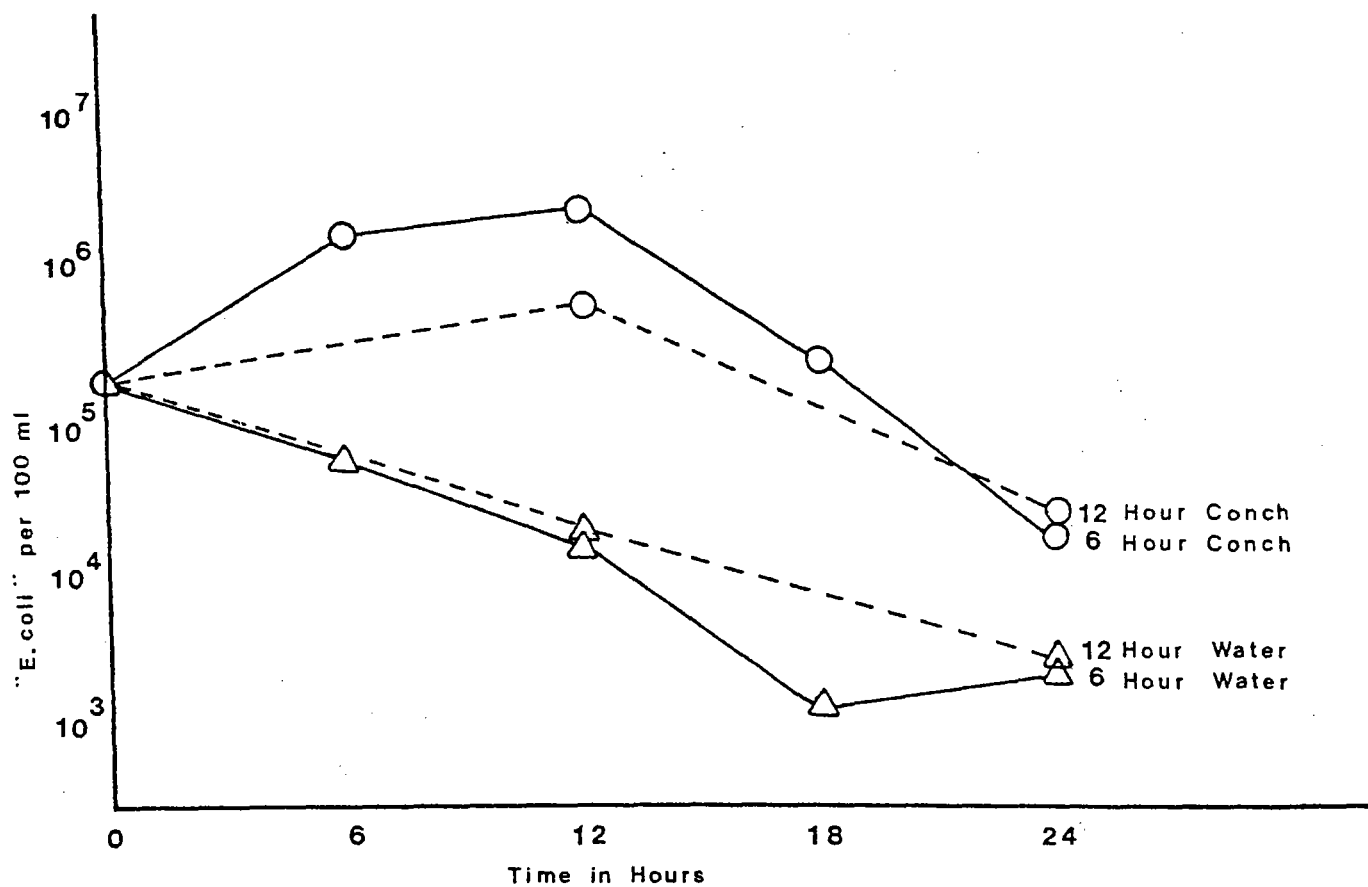
Chris Stephens

### ABSTRACT

Eight one-to-two-year-old individuals of *Strombus gigas* were collected on Little San Salvador 23°31'N, 75°55'W from the western end of the lagoon and Turk's Island, within the lagoon, to be tested for depuration rates of *Escherichia coli*. Conchs were held in two gallon semi-continuous flushing tanks. They were inoculated with a  $1.8 \times 10^5$  culture of *E. coli* grown in a 24-hour nutrient broth culture. At six and twelve hour intervals, holding tank water samples were serial diluted and filtered via membrane filtration through 0.45  $\mu$ m Millipore filters and incubated for 24 hours at 35° C on MF Endo Broth. At like intervals, one milliliter samples of ground conch digestive gland supernatant was extracted for incubation.

After 24 hours depuration of conch was compared with the decrease of coliforms in the holding tank. *E. coli* decreased at a rate of  $1.8 \times 10^5$  over the testing period while six hour depuration rates for conch were only  $1.6 \times 10^5$  and those for conchs tested every twelve hours were  $1.5 \times 10^5$  (Figure 4). Coliforms were initially accumulated in the conch samples increasing from an initial  $1.8 \times 10^5$  to  $2.94 \times 10^6$ . However, after the 24 hour period coliform counts in conch samples equalled those in the water samples, nullifying the need for any extensive depuration system in an area where there is a total daily flushing by tides.

Figure 4. Concentrations of coliform colonies per 100ml. vs. time in hours for triplicate samples of conch and water.



Digestive enzymes of the queen conch, *Strombus gigas*

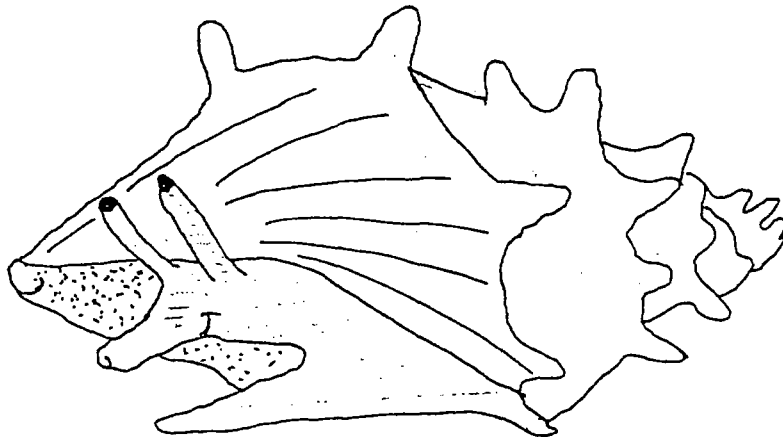
Chris Wahl

ABSTRACT

This project was designed to discover the presence or absence of five different enzymes in various sections of the digestive tract of the queen conch, *Strombus gigas*. Little is known of its extra-cellular digestive abilities.

The procedure followed was a simple sectioning of tissues from selected sites, including the gut lining, crystalline style, and the three digestive glands. These tissues were placed on agar media containing the substrate for four enzymes: starch, Tween 80 (a lipid), chitin, and cellulose, for amylase, lipase, chitinase, and cellulase. The agar in the media served as a substrate to test for the presence of agarase.

It was discovered that *S. gigas* produces amylase extensively, lipase is found in the style and digestive gland. Chitinase and cellulase were not detected, although this may be due to problems with the media.



The assessment of the present queen conch, *Strombus gigas*,  
population in Little San Salvador Lagoon and surrounding areas  
with prospectives on future exploitation in the area

Robert Nolan

ABSTRACT

An estimated 3740 m<sup>2</sup> of the mid-lagoon floor of Little San Salvador was surveyed across diverse habitats during light hours, and additional areas were examined by others. Twenty-five conch were found at mid-lagoon, six at the east end, and four in the western part. All conchs were found in water depths of less than 1 meter, and most inhabited areas with less than .5 meter water depth. All the conch were associated with turtle grass. Of the conch collected, 21 were juveniles and 14 were mature adults. Sixty-two percent of the adults examined were male, the remaining thirty-eight percent being female. A night expedition to examine the nocturnal movements of the conch by snorkeling along a 172 meter transect crossing diverse habits expected of the juveniles resulted in no conchs being observed. An estimated 1953 m<sup>2</sup> of bottom was surveyed during the night dive. Presently, the lagoon of Little San Salvador appears to support a sparse population of conch relative to the once high levels, evidenced by the presence of piles of conch shells. The adult population is reduced and quite possibly the male to female ratio has been upset. Recruitment is low and there is no evidence for the occurrence of a future year class of juveniles. Mariculture to replace the population is possible, but natural restoration of conch abundance seems unlikely for quite some time.



Ecology and behavior of queen conch juveniles  
in the lagoon of Little San Salvador Island

George Townsend

ABSTRACT

Daylight and night surveys were made in an attempt to study the ecology and behavior of queen conch juveniles in Little San Salvador lagoon. More juveniles were observed in the western end of the lagoon than in the previous year (W-45). Lip formation appears to begin when the conch are about 23 cm. long. The larvae seem to settle in or near widely spaced beds of turtle grass. No conchs were seen during a night dive designed to find juveniles under 1 year old.

## SUMMARY

1. The eastern end of the Lagoon is slowly filling in with mangroves, and is only a few inches deep at low tide; the use of boats in the area to the right of the Lagoon entrance is not possible. In addition, the pond plotted on the map to the north of this area is now entirely filled in with mangroves.
2. Of particular interest is the variation observed in the salinity of Red Pond. During W-45, the salinity was determined to be 217 ‰, whereas our analyses indicated that the salinity was reduced to an average of 53 ‰. Several factors are probably responsible for the high fluctuations in composition. Fresh water can enter the pond via seepage of ground water, particularly after long periods of rain. In addition, during storms and exceptionally high tides, seawater can invade the pond across the narrow iron shore passage which separates the pond from the sea to the north. These large variations in salinity must have important implications for the biological communities that can exist in Red Pond.
3. Nutrient analyses indicated that the phosphate concentrations in the hypersaline ponds were very low, whereas ammonia concentrations were higher. This indicates that phosphate may be a limiting factor in these ponds, as previously suggested by Gaines (W-45 Cruise Report).
4. Study of Knee Deep Pond, which was previously believed to be completely isolated from the Lagoon, indicated that a shallow, but restricted inflow through thick mangroves exists, which probably contributes to the maintenance of a lower salinity (42.26 ‰) in this pond.
5. Little San Salvador was clearly the site of a large conch population. However, the numbers now present suggest that natural restoration of the population is unlikely in the near future. The Lagoon provides the varied environment necessary for the successful development of the Strombus gigas, and hence mariculture to initially replace the population would seem to have great potential.

## SARGASSO SEA STUDIES

### Introduction

The Sargasso Sea represents the center of an anticyclonic gyre in the North Atlantic, and is composed of a mass of warm, saline water known as the 18° water, which extends to a depth of about 200 m. It is bounded on the western and northern sides by the Gulf Stream and North Atlantic Drift, and on the eastern side by the ill-defined Canary Current. To the south lies the Antilles Current, which is derived from the Northern Equatorial Current.

For several years we have been examining the trophic structure of the community associated with Sargassum weed. Aspects of this work were continued during W-50, as well as some preliminary studies of the toxicity of fuel oil and detergent in the organisms.

### A. PHYSICAL STUDIES

#### A transect across the Gulf Stream

A series of bathythermographs were taken on 7th January 1980 as the west wall of the Gulf Stream was traversed from Miami to Great Bahama Bank. Locations of stations are shown in Figure 5, and temperature profiles are given in Figure 6. These showed the existence of a warm water mass at about 250 ft. depth in Station 4, which increased in depth towards the eastern side of the Straits of Florida. The temperature transect (Figure 7) showed the typical sharp temperature gradient associated with the west wall of the Gulf Stream, from 72°F to 75°F over a distance of about 20 nm.

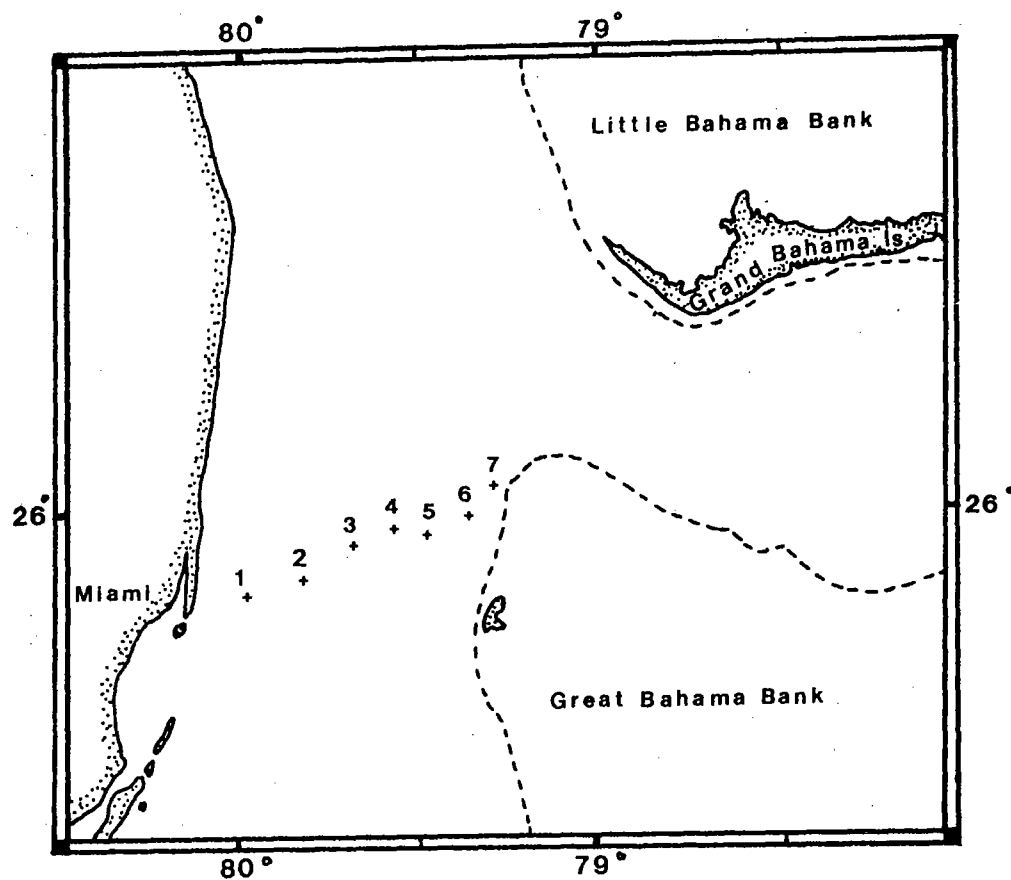
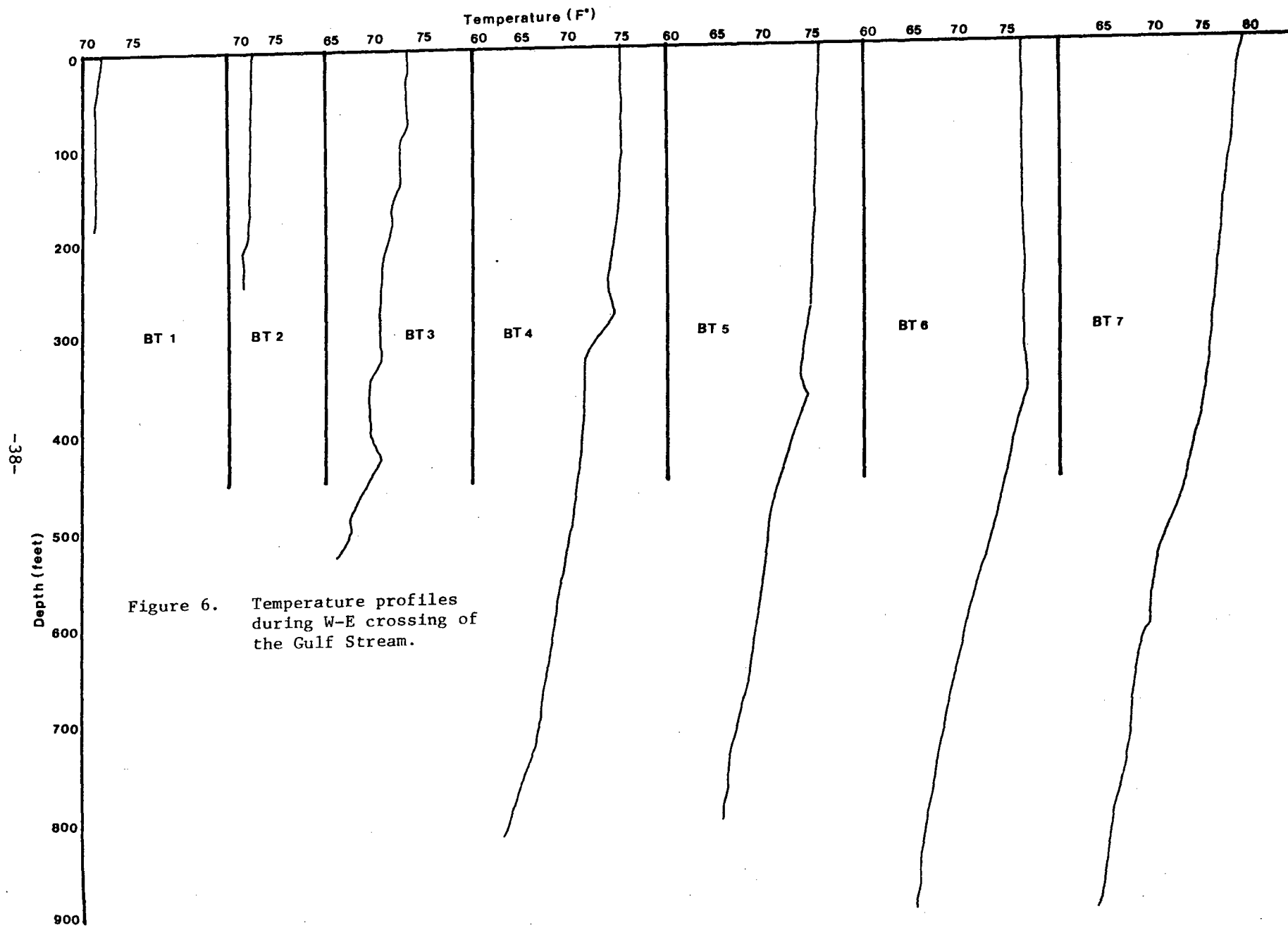
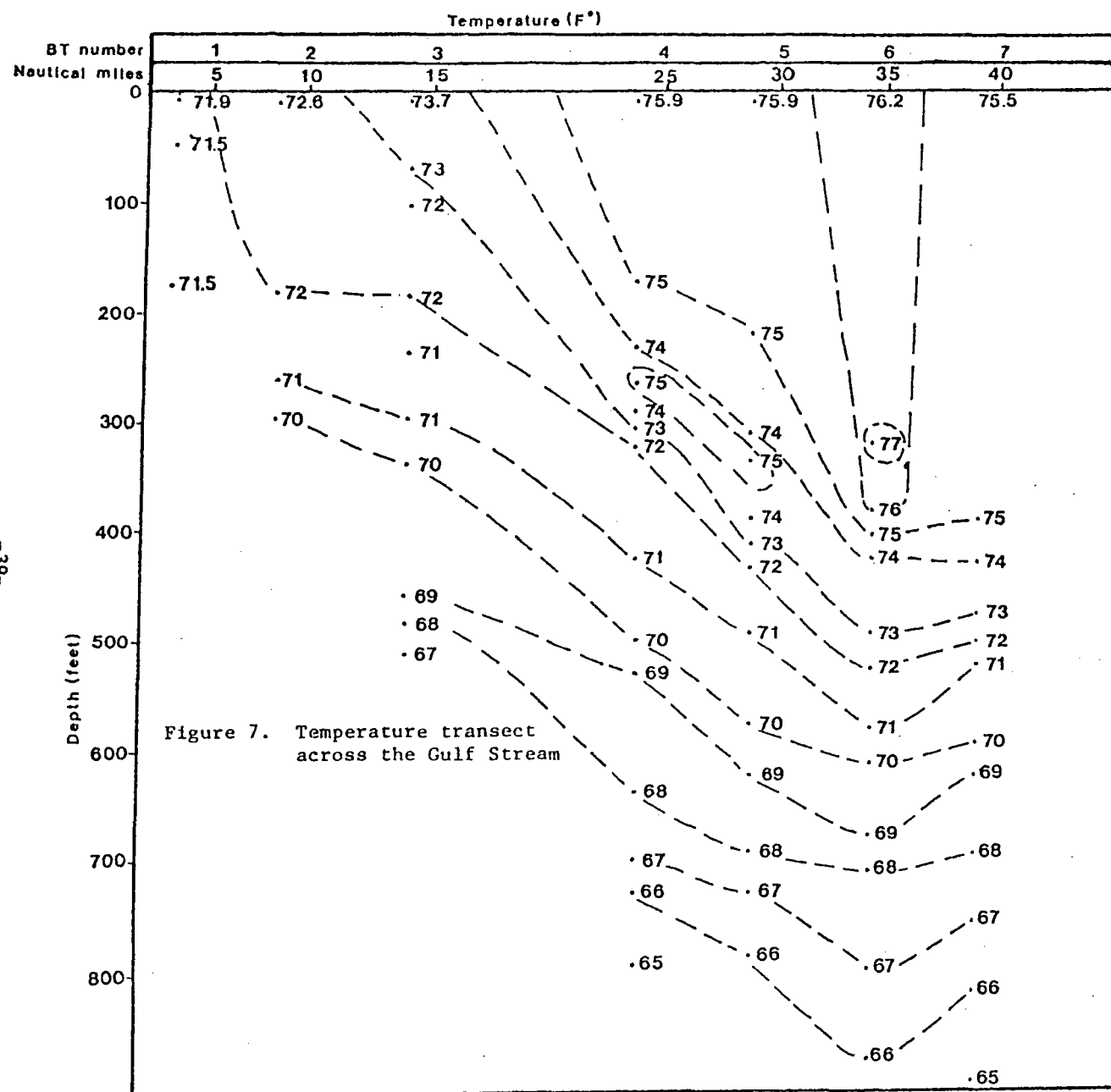


Figure 5. Locations of BT stations during the Gulf Stream transect - 7 January 1980.





B. BIOLOGICAL STUDIES

Respiration rates and productivity studies  
in the Sargasso Sea

Ginny Low

ABSTRACT

Primary productivity and respiration studies were conducted on Sargassum weed and on two organisms that live in the Sargassum community: the crab, Planes minutus, and the shrimps, Hippolyte zostericola and Latreutes fucorum.

Gross and net primary productivity of Sargassum weed were calculated from results obtained with light and dark BOD bottles during midday hours. The Sargassum weed was found to contribute an average gross amount of  $6.11 \times 10^{-7}$  mg C/m<sup>3</sup>/day, while the net productivity was determined to be  $2.02 \times 10^{-7}$  mg C/m<sup>3</sup>/day.

The dark bottles showed that the respiration rate per gram of Sargassum weed was  $3.65 \times 10^{-7}$  mg C/m<sup>3</sup>/day. The respiration rates of crabs and shrimps were  $8.05 \times 10^{-7}$  mg C/m<sup>3</sup>/day and  $5.68 \times 10^{-7}$  mg C/m<sup>3</sup>/day respectively.

These results were compared with previous productivity and respiration studies on Sargassum weed and were found to be slightly higher than those found on previous cruises.

Nutrient regeneration by macrofaunal organisms  
in the Sargasso Sea

Cathy Homer

ABSTRACT

The pelagic Sargassum weed harbors a thriving marine ecosystem in the midst of a sea of very low productivity and nutrient level. The nutrient regeneration rates of three of the organisms associated with the Sargassum weed were determined in an attempt to assess the importance of this source of nutrients.

A Sargassum crab, shrimp and fish were collected and their rates of ammonia and phosphate excretion were observed over a 24 hour period. Although the nutrients were not produced at a constant rate (probably due to differences in metabolism at different times) they were generally less than  $1 \mu\text{M NH}_3/\text{L/hr}$  and  $0.15 \mu\text{M PO}_4/\text{L/hr}$  for each organism. Using the Redfield ratio and the gross productivity of Sargassum weed it was calculated that  $2.58 \mu\text{M}$  of ammonia and  $0.16 \mu\text{M}$  of phosphate are required for every gram of weed per hour. In order to supply the nutrients at these rates, one or more organisms would be needed for each gram of weed to produce sufficient phosphate levels and several more to attain sufficient ammonia levels. It is doubtful whether such large populations could survive. Therefore, although these macrofaunal organisms contribute to nutrient regeneration in the Sargasso Sea, other sources of nutrients must also be used.

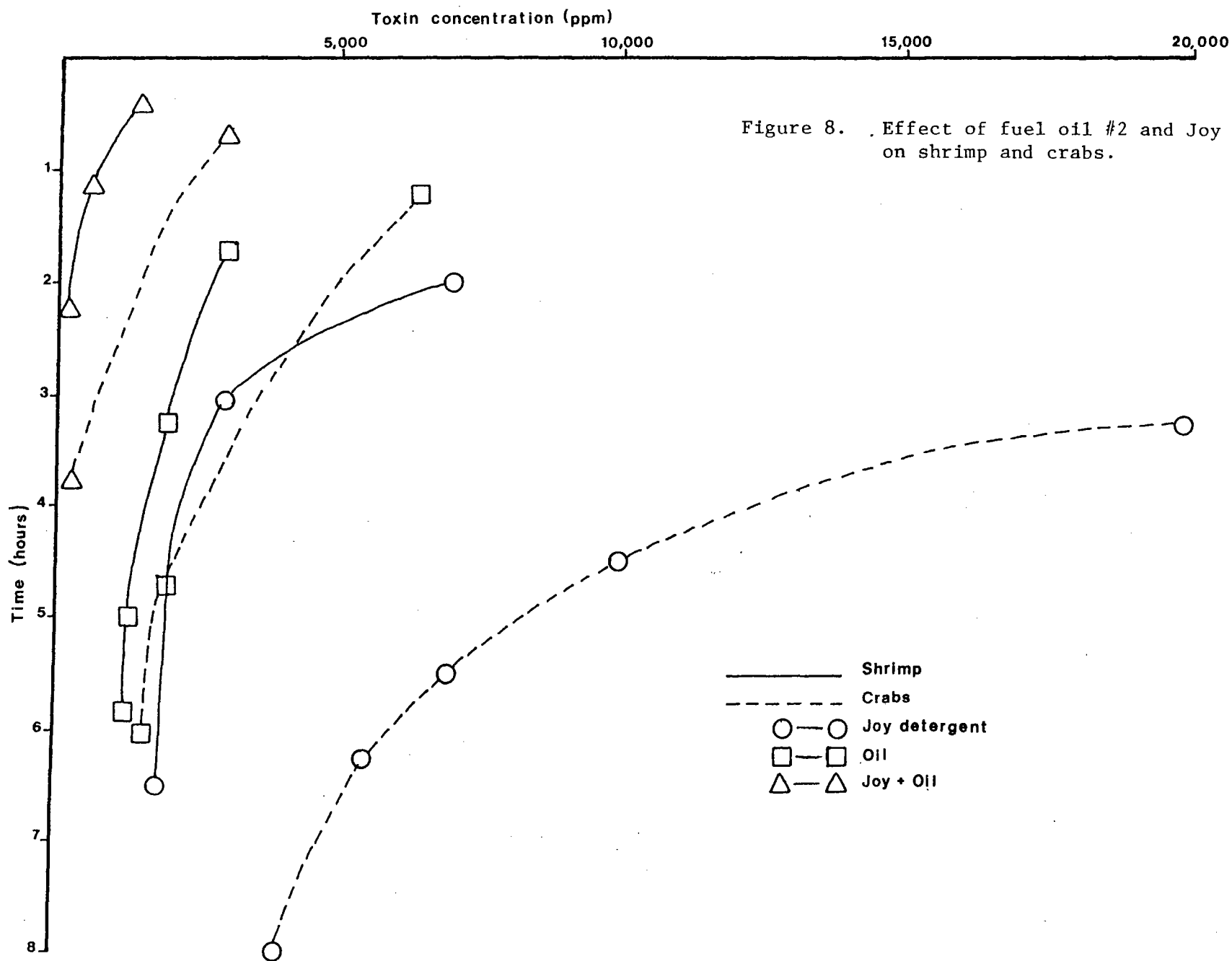


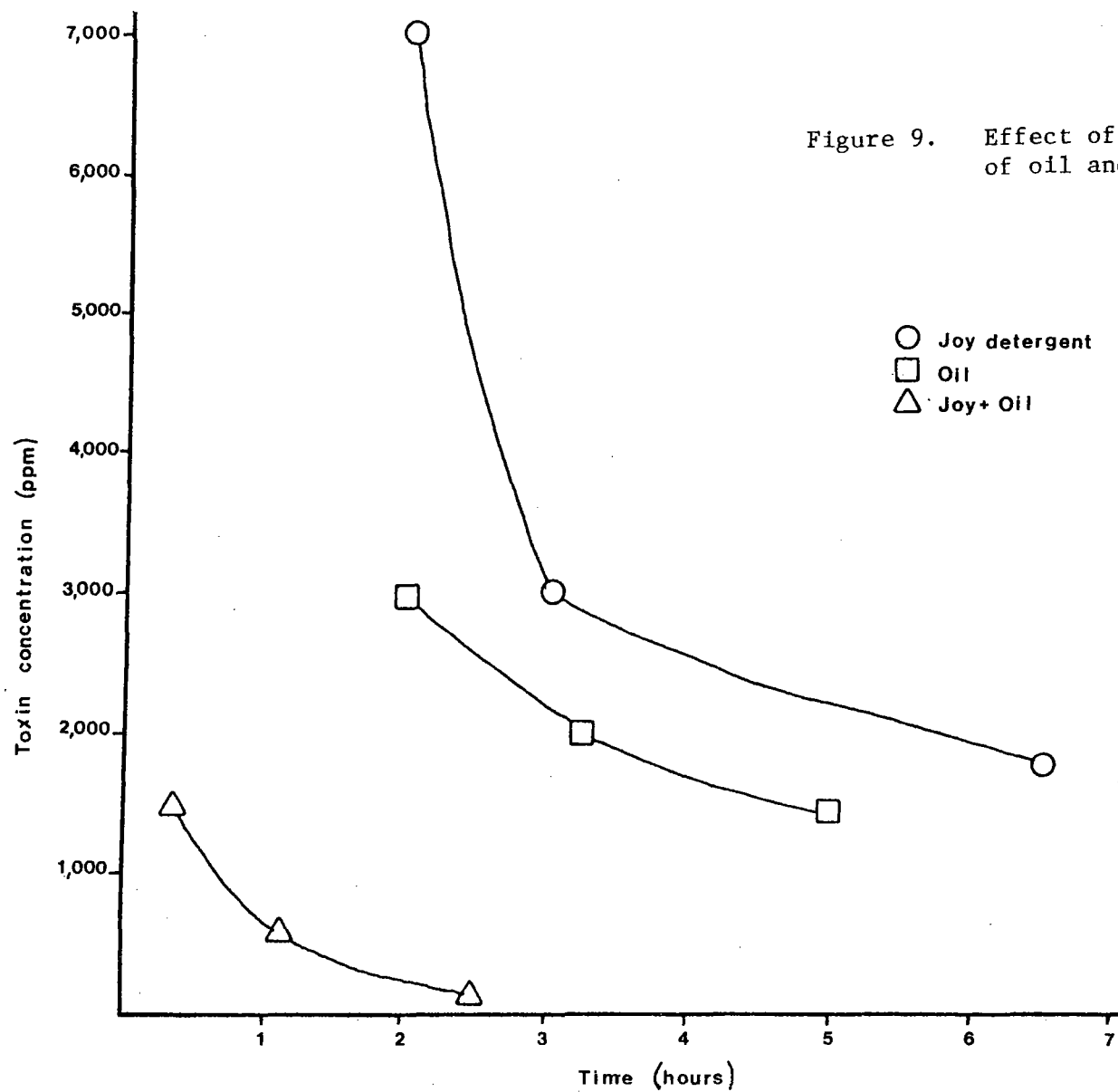
The Toxicity of #2 Fuel Oil and Detergent ("JOY") on Marine Life  
Using Sargassum Crabs and Shrimp

Wynn McCloskey

ABSTRACT

Contamination of the sea by oil is a problem that can only drastically increase in the near future. Major inputs of petroleum due to tanker accidents or "pumping out" are extremely destructive; but small amounts of oil lost may also be quite harmful. This is especially true since much of this oil from small spills is diesel #2, a substance with far greater quantities of the highly toxic aromatic hydrocarbons than crude or lower grade fuel. In addition, many of these small slicks are immediately dispersed with a low grade commercial detergent to avoid detection. The toxicity of #2 fuel oil and "Joy" on two surface-dwelling, and hence especially vulnerable, organisms was studied by looking at mortality rates for varying concentrations and length of exposure. The organisms studied were the Sargassum crabs (Planes minutus and Portunus sayi) and the Sargassum shrimp (Latreutes fucorum); both associated with the floating Sargassum weed. Reactions of the crabs and shrimp varied in accordance with the toxin to which they were exposed; "Joy" being the least harmful, fuel oil #2 the next, and a combination of the two being the most lethal (Figures 8 and 9 ). Also, the effect of the toxins on the Sargassum itself was noted and recovery rates for the test organisms were studied.





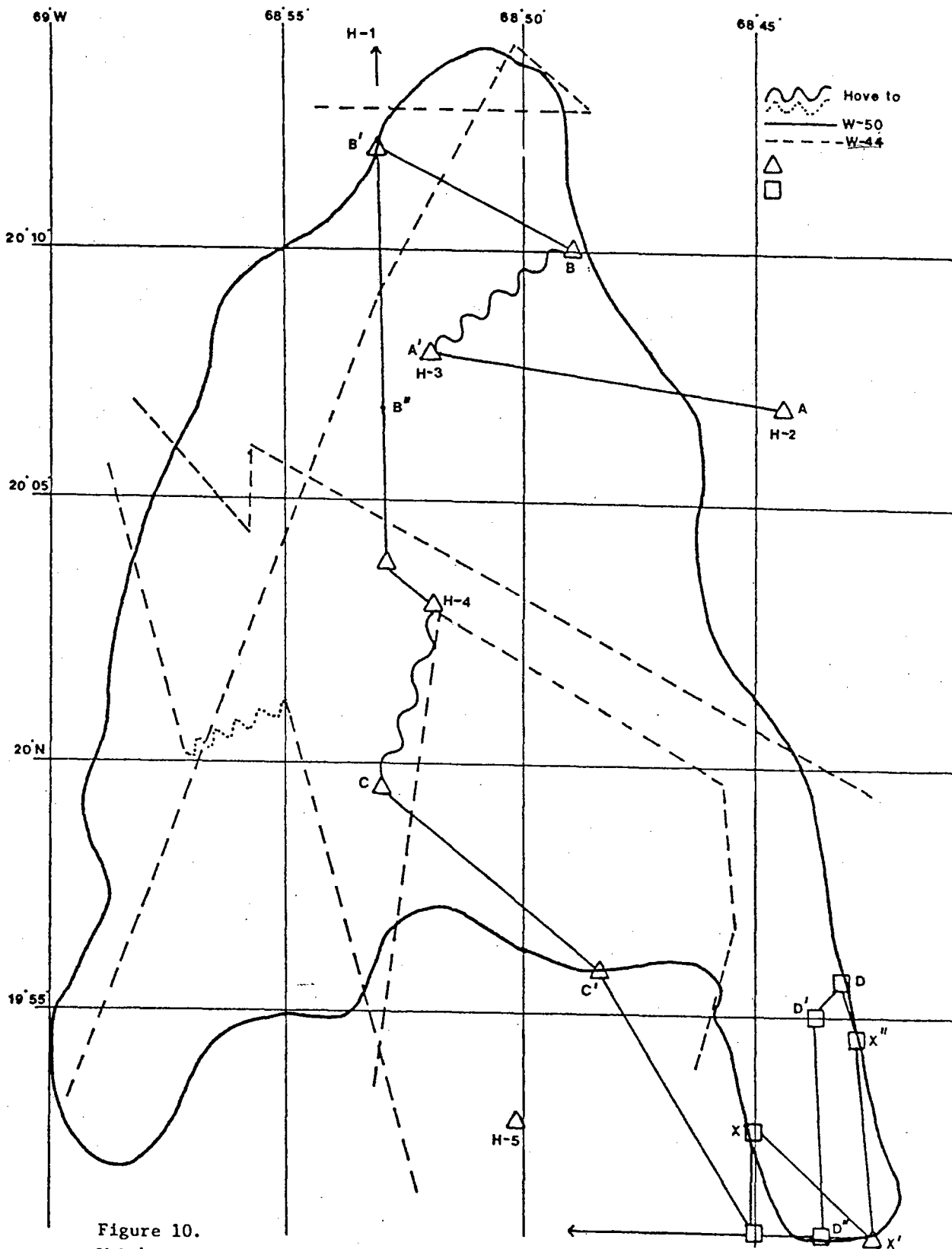


## NAVIDAD BANK

### Introduction

Navidad Bank is one of a series of shallow banks trending NW-SE off the coast of Hispaniola and Puerto Rico. Several of these banks, including Navidad, are generally regarded as the breeding and calving grounds of the humpback whale, Megaptera novaeangliae. The reasons for their migration to this area, and for their selection of particular banks, is not well understood.

During 1979 (W-44), a project was started to investigate the physical, chemical, and biological characteristics of Navidad Bank in order to determine whether these properties might influence the choice of bank. During W-50, R/V Westward returned to the area to collect more data in order to complete this project. The whale sightings have already been discussed earlier (see Marine Mammals, p. 16 ); the abstracts that follow briefly report the multidisciplinary survey carried out on the bank. The ship's track and station positions are shown in Fig. 10.



## The bathymetry of Navidad Bank

Kathy Schultz

### ABSTRACT

Six tracks were made across Navidad Bank on February 21 and February 22. From continuous fathometer readings from both W-44 and W-50, a bathymetric chart was constructed (Fig. 11 ). Profiles across the Bank are shown in Fig. 12 . The boundaries of the Bank were in accordance with those shown on the navigational charts. Discrepancies were found in the actual depths. A ridge approximately five fathoms high, and one half to one nautical mile (nm) wide was found along the Bank's perimeter, being steeper on the southern end than the northern. This is believed to be remnants of a fringing reef. Of particular interest was the southeast lobe of the Bank, which is much shorter than charted, and is separated by a very narrow canyon from another, separate, smaller bank. This smaller bank is probably only about 2 nm wide and 1 nm long.

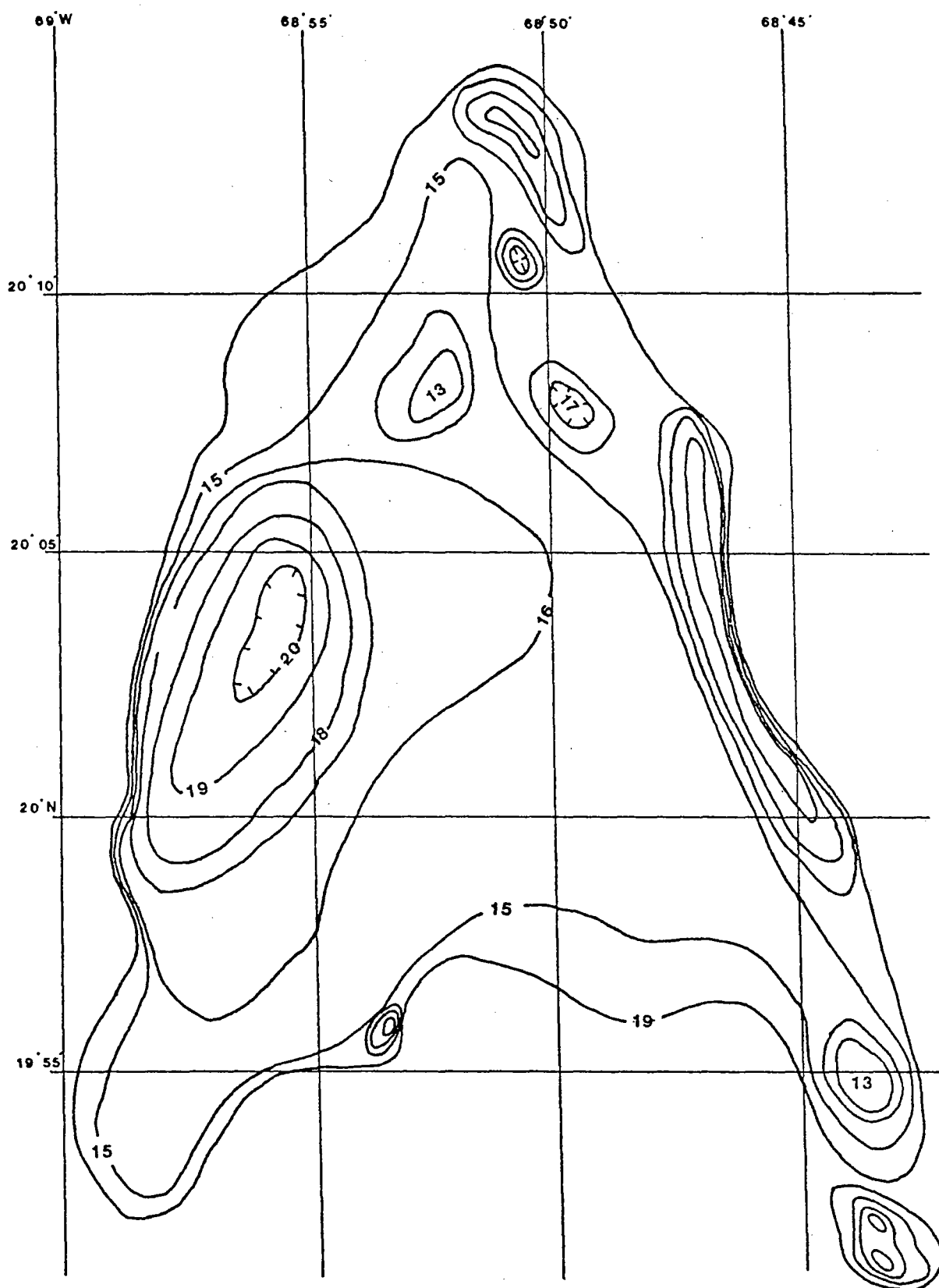


Figure 11. Bathymetric chart of Navidad Bank constructed from tracks made during W-44 and W-50.



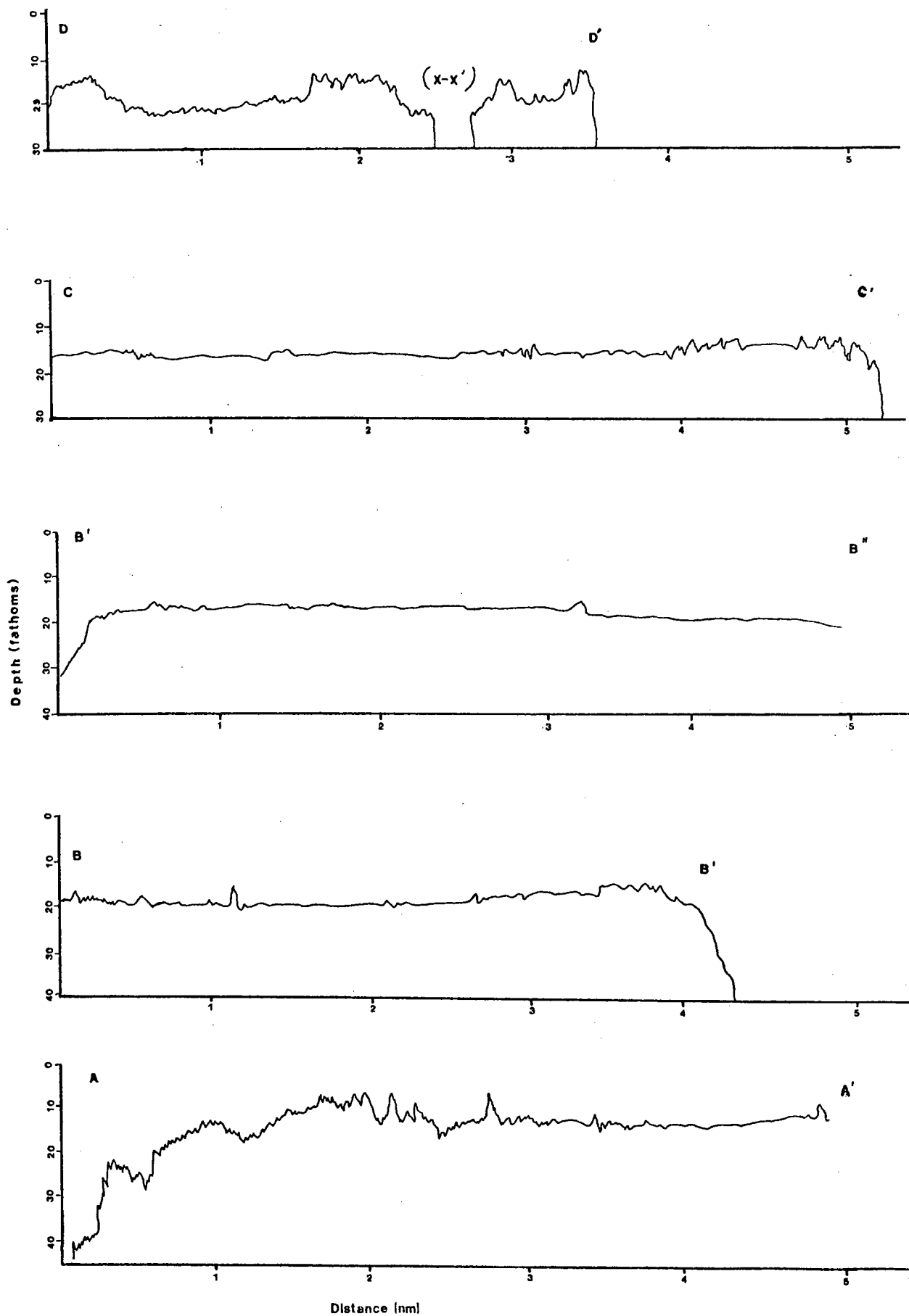


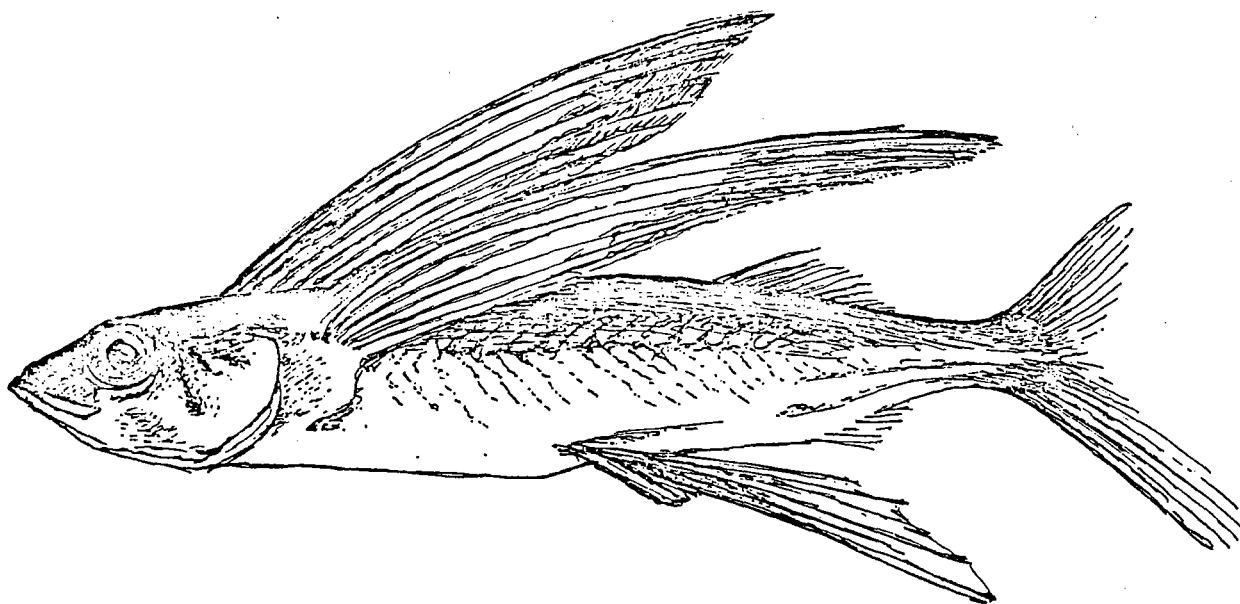
Figure 12. Bathymetric profiles across Navidad Bank.  
(Letters correspond to the locations shown in Figure 10)

## Water Chemistry of Navidad Bank

Claire Cabral

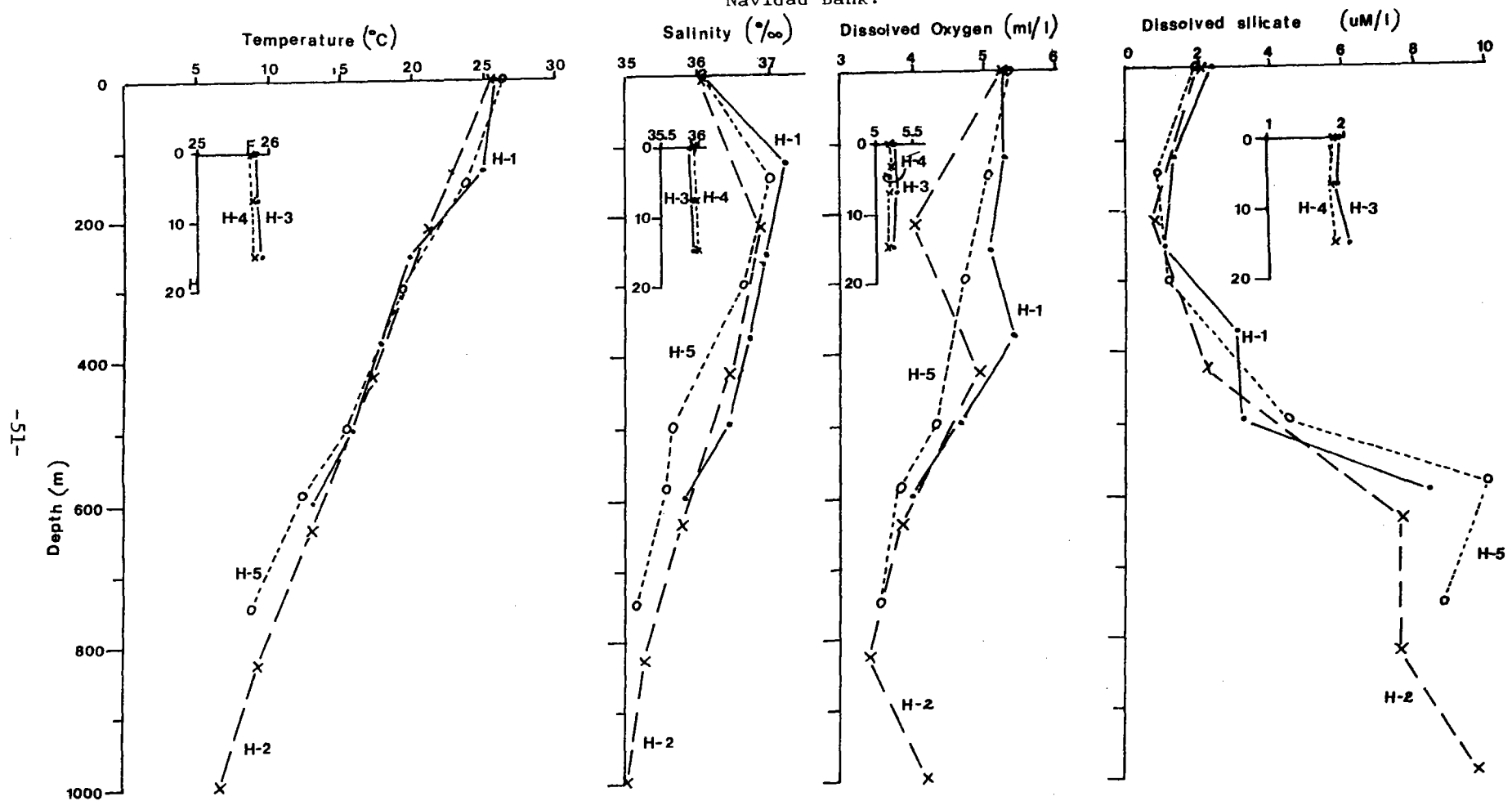
### ABSTRACT

Five hydrostations were carried out on and off Navidad Bank in order to compare the characteristics of the open ocean water with that on the Bank. Temperature, salinity, oxygen, phosphate, ammonia and silicate were determined and the data were reported in Appendix IV-A and are shown in Figure 13. Little variation between the open ocean and on bank water composition was observed, suggesting this factor is not important in the choice of bank for the breeding grounds of the humpback whales.



*Chris Wall*

Figure 13. Profiles of temperature, salinity, oxygen and silicate from  
Navidad Bank.



## Zooplankton On and Off Navidad Bank

Melanie Byrne

One of Westward's internal programs is to ascertain why hump-back whales go to Navidad Bank during the winter to breed and calve, as opposed to other nearby banks. In conjunction with various other studies of Navidad Bank conducted during W-50, five plankton tows were made to determine if there were any major differences in zooplankton composition between the bank and adjacent areas. Three of the five samples (M4, M5, M6) were taken on the bank, and two (M3, M7) taken just off the bank. The depths of the tows were as follows:

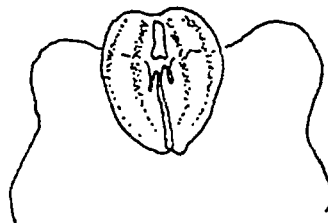
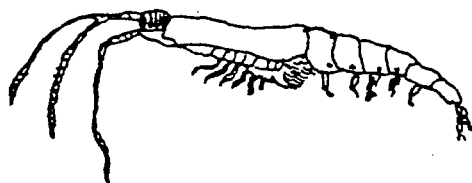
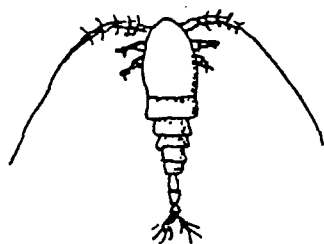
<u>on bank</u>	<u>off bank</u>
M4 - 200m	M3 - 100m
M5 - 30m	M7 - 50m
M6 - 5m	

The samples were examined qualitatively and their overall characteristics noted, with particular attention paid to organisms generally considered to be the food of whales. In general, the composition of the five tows was similar in that all were fairly diverse and contained the same major groups of organisms. These included:

calanoid copepods	decapod larvae
pteropods	ostracods
fish larvae	siphonophores
salps	amphipods
chaetognaths	heteropods
caridean shrimp	polychaetes
stomatopod larvae	hydromedusae

Without quantitative analyses, it is impossible to determine any subtle differences in the tows, but there were some significant qualitative differences between the on- and off-bank tows. At stations 4, 5, and 6 (on-bank), there was an abundance of copepods,

euphausiids, caridean shrimp, and at station 6, of small larval decapods. These samples were also somewhat more diverse than the off-bank stations. Stations 3 and 7 contained many more small and larval fish than did the on-bank stations, and here, small, white calanoid copepods, although found in all tows, were singularly the most dominant group.





## STUDIES OF CIRCULATION IN THE CARIBBEAN SEA

### Introduction

The circulation of the Caribbean Sea is of interest because:

- (i) it contains water masses from widely separated places of origin
- (ii) an important part of the Gulf Stream is composed of waters derived from this area
- (iii) the bottom topography, which consists of a series of deep basins separated from each other by shallow sills, dominates the deep circulation

Many questions still remain concerning the general circulation of the Caribbean. The general water flow is from E→W in the upper layers, and these waters are highly stratified in a way related to the sill depths of the Antilles island arc. At greater depths, Antarctic Intermediate Water (AAIW) flows through the deeper passages into the eastern Caribbean. However, the distribution and volume of AAIW in this area is still an important question.

During W-48, a study was begun to investigate the distribution and chemical characteristics of water masses down to a depth of 2000 m. in the eastern Caribbean. A series of hydrostations were completed in the passages between the islands of the Lesser Antilles and on the western side of the Grenada Basin; these indicated the passages through which AAIW was flowing into the Caribbean.

On W-50, additional information was gathered from the western Caribbean. The Columbian Basin is separated from the northern Caribbean by a shallow ridge running from Roatan to Jamaica, the deepest part of which is only about 1600 m. This ridge limits the penetration of deep and bottom waters into the northern area, and hence will influence the character of the water flowing through the Yucatan Straits and becoming entrained in the Gulf Stream. A transect of 4 hydrographic stations was made between Jamaica and Roatan to examine the distribution and character of water masses on the northern side of the ridge. In addition, two stations were completed in the Yucatan Straits. The locations of the stations are shown in Figure 14, and the data for all the hydrocasts are presented in Appendix IV-B.

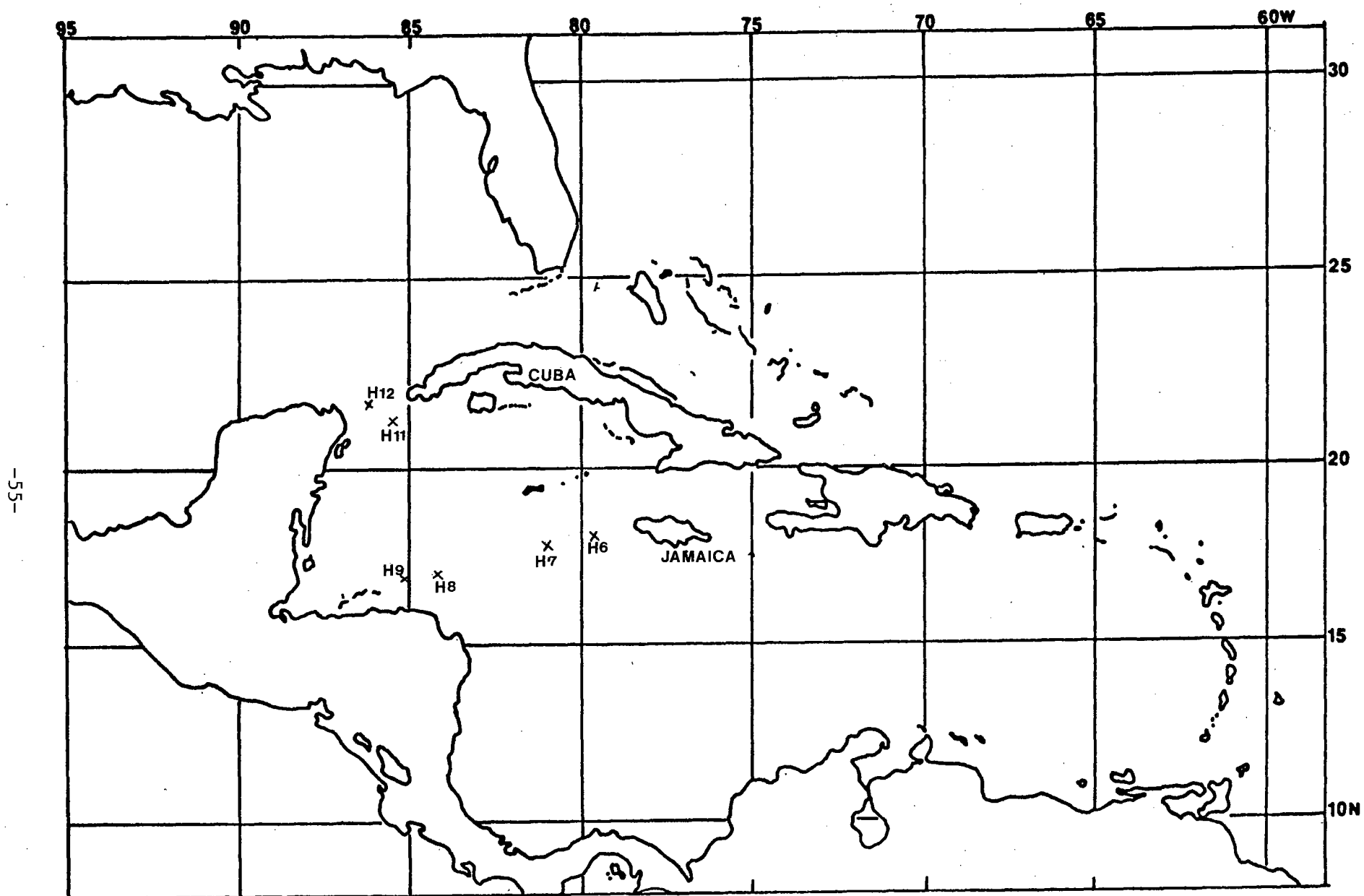


Figure 14. Locations of hydrographic stations in the western Caribbean.



The analysis of the data given here is only preliminary, but hopefully will be combined with similar data from the Venezuela Basin to be collected on a future cruise, and that collected during W-48, to provide a more detailed understanding on the circulation of the deeper water masses in the Caribbean.

#### Temperature (Figures 15 and 16)

At all the stations, the temperature profile decreases with depth from a surface temperature of 26.2-27.0°C down to 4.38°C at a depth of 1300-1370 m. at stations W-50- H7 and H8. The core of AAIW, which has been defined by the 6°C isotherm (Worthington, 1971) is seen on only the two deeper hydrocasts and occurs between 800-1000 m.

#### Salinity (Figures 15 and 16)

The most noticeable feature is the salinity maximum that occurs in almost all the profiles at a depth of about 200 m. Salinities in the maximum reach up to 36.9 ‰. This water mass is probably the Subtropical Underwater (o - salinity maximum water in the terminology of Worthington [1976]), which results from the excess of evaporation over precipitation in the trade wind region. This feature was also observed at depths of 100-200 m. in the eastern Caribbean (W-48), and appears to maintain its identity throughout the area. Below this maximum, the profiles are somewhat variable, but show a general decrease with depth.

#### Dissolved oxygen (Figures 15 and 16)

The dissolved oxygen profiles show a general decrease with depth with an oxygen minimum occurring somewhere between 500-800 m. Below this, the oxygen content increases with depth, with a maximum shown between 1000-1200 m. at station W-50-H7. This is indicative of the presence of AAIW at these depths. AAIW originates in high latitudes where surface waters cool and sink, and it is therefore characterized by high oxygen contents.

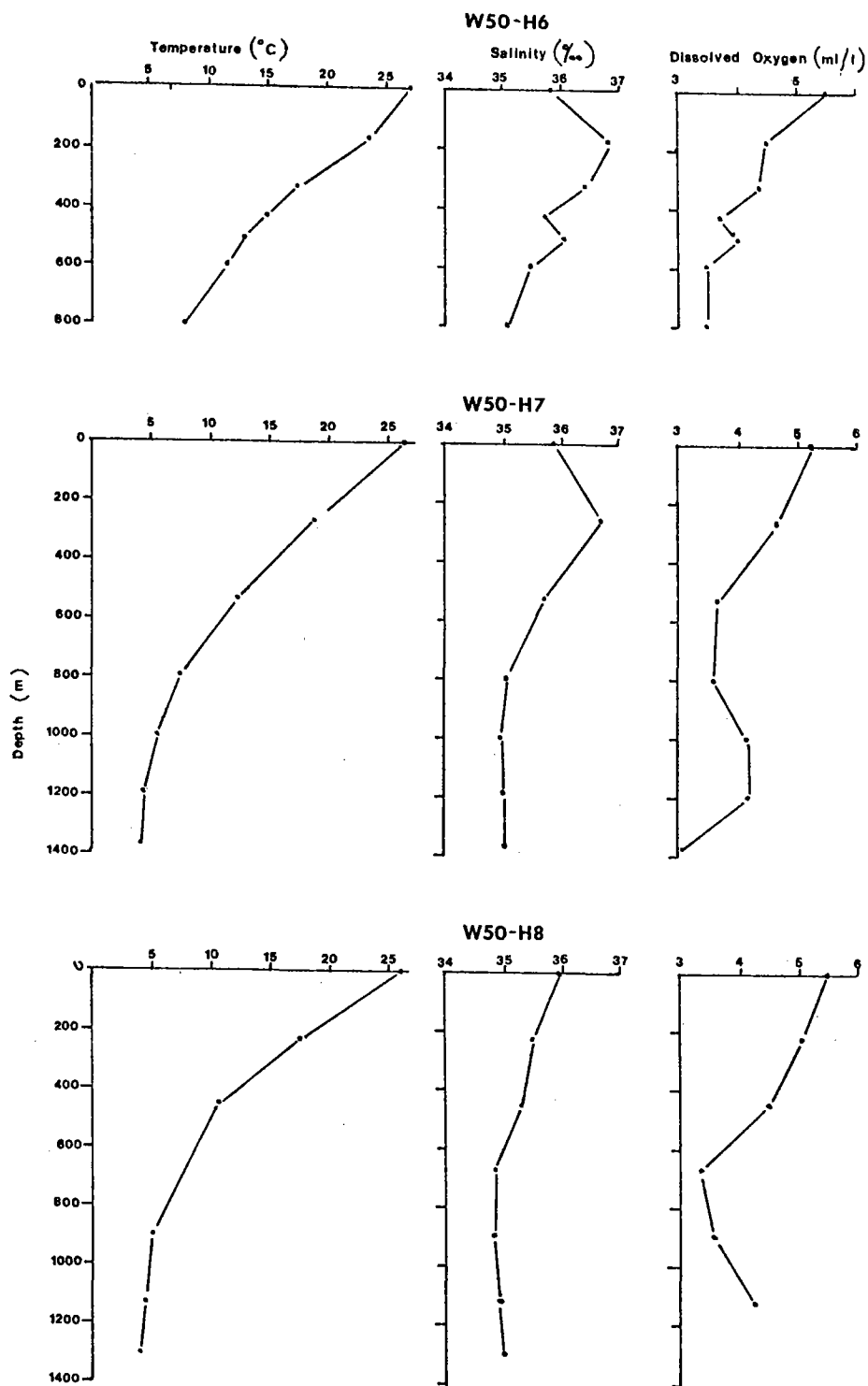


Figure 15. Temperature, salinity and dissolved oxygen profiles from the western Caribbean.

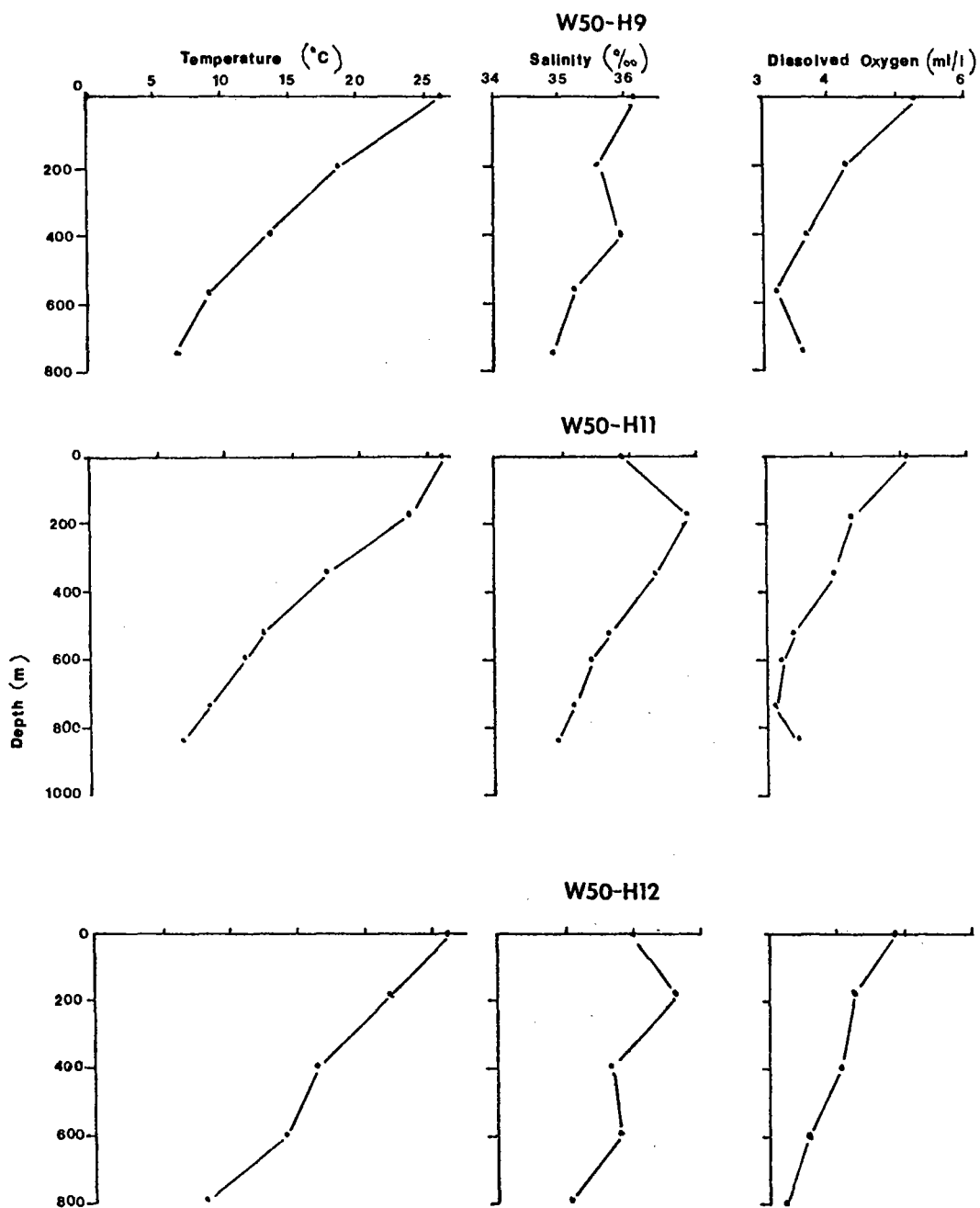


Figure 16. Temperature, salinity and dissolved oxygen profiles from the western Caribbean.

#### Phosphate (Figures 17 and 18)

Phosphate exhibits a depleted surface layer about 200 m. thick, where concentrations are generally less than 0.3  $\mu\text{M}/\text{l}$ . Below this, the phosphate concentration increases at all stations with a maximum observed at about 888-1000 m. of up to 1.8  $\mu\text{M}/\text{l}$ . This maximum is probably associated with the presence of AAIW.

#### Ammonia (Figures 17 and 18)

All the profiles show a surface layer depleted in ammonia and an increase with depth. In general, the ammonia profiles are somewhat similar to the phosphate curves, although the maxima occur at slightly different depths.

#### Silicate (Figures 17 and 18)

The surface layer is depleted in silicate in all the profiles, with concentrations of less than 3  $\mu\text{M}/\text{l}$ . Silicate values then increase dramatically with depth to the high values associated with AAIW - up to 26.8  $\mu\text{M}/\text{l}$ . This water mass is particularly well illustrated at station H7 and H8 where a maximum is seen between 900-1200 m.

#### References

- Worthington, L.V. 1971. Water circulation in the Caribbean Sea and its relationship to North Atlantic circulation. In: Symposium on Investigations and Resources of the Caribbean Sea and Adjacent Regions. 1968. Curacao, UNESCO.
- Worthington, L.V. 1976. On the North Atlantic circulation. Johns Hopkins University Press.

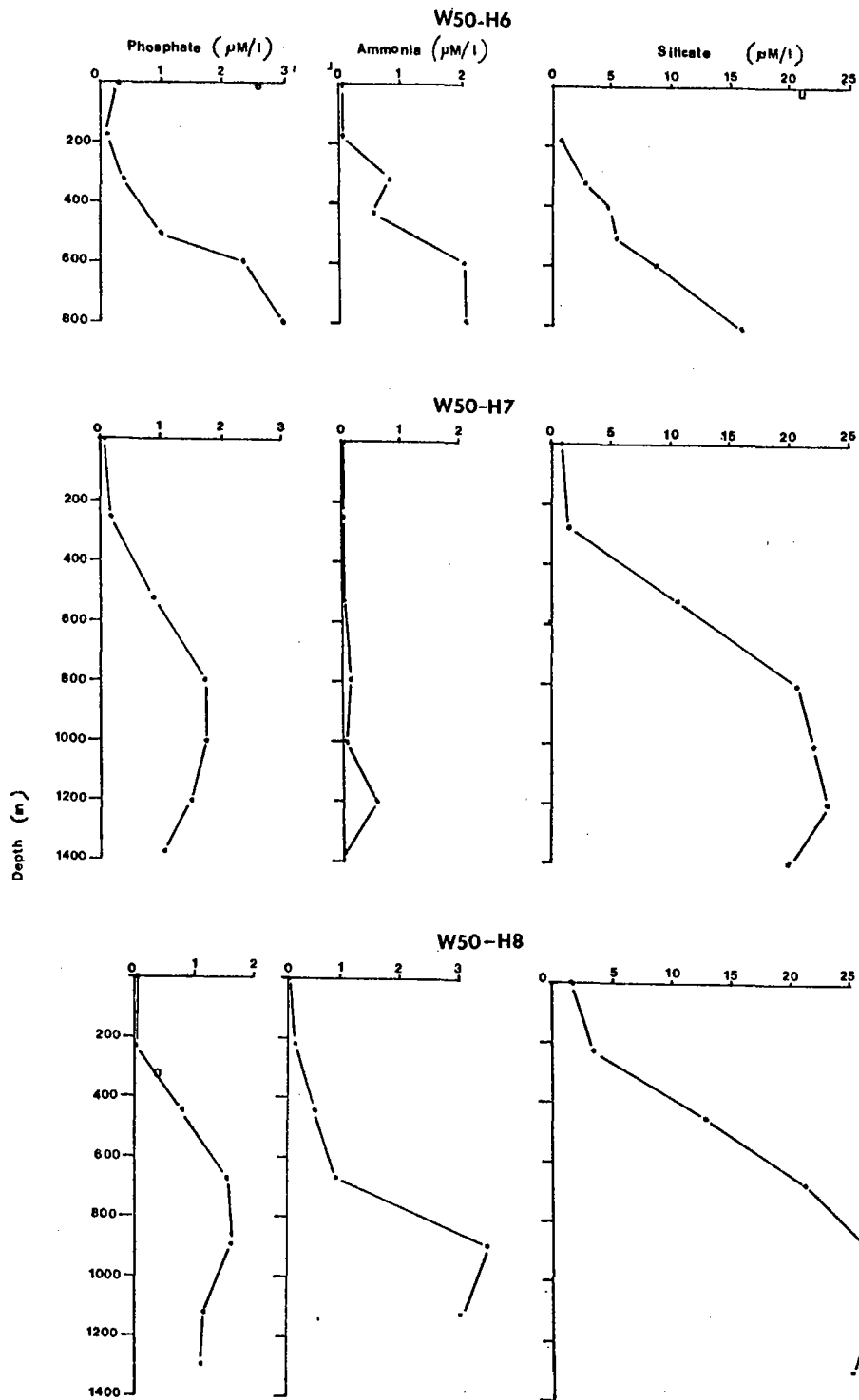


Figure 17. Nutrient profiles from the western Caribbean.

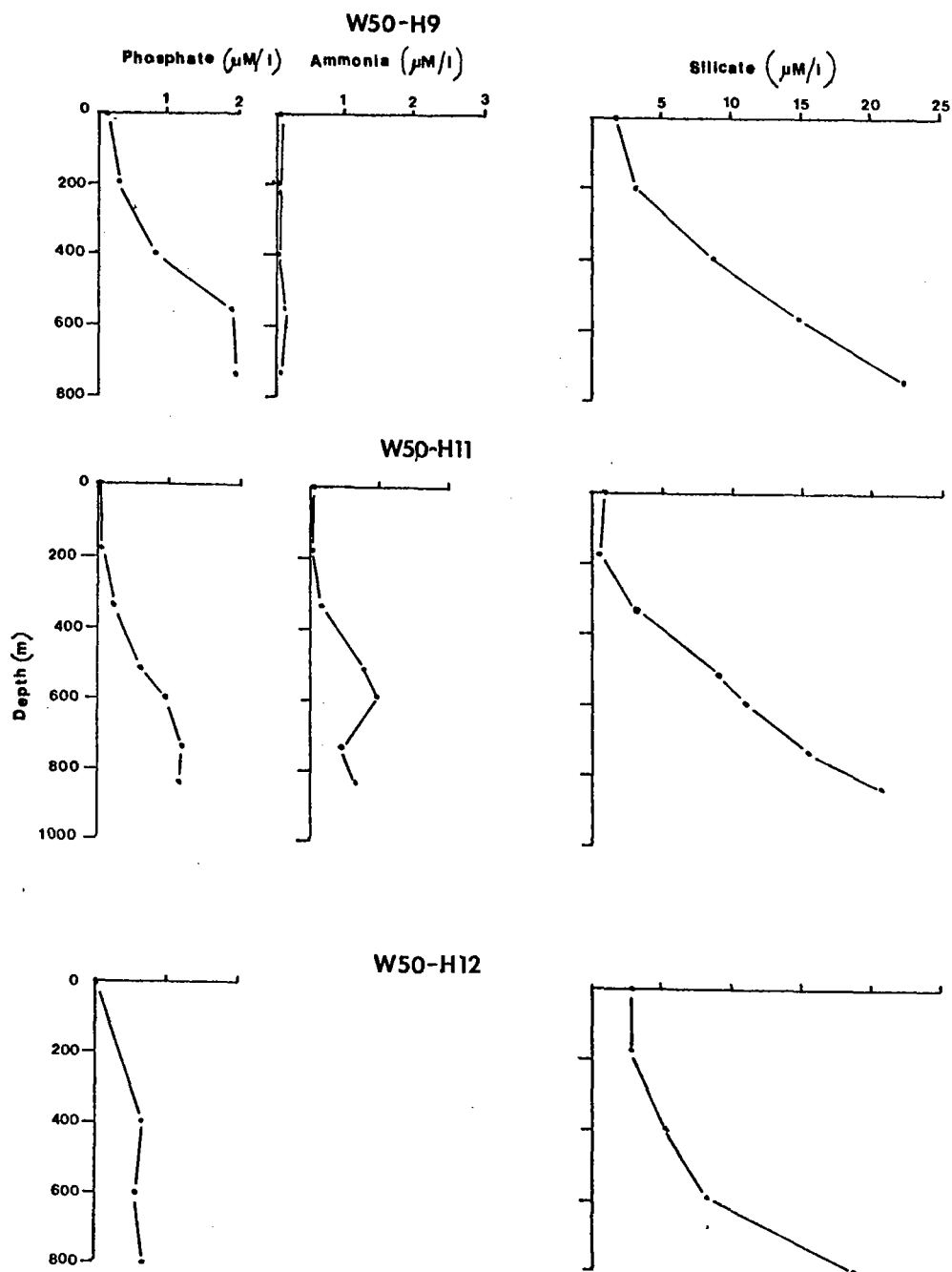


Figure 18. Nutrient profiles from the western Caribbean.

## MESOPELAGIC ECOLOGY STUDIES

### Horizontal Distribution of Mesopelagic Organisms

Lisa M. FitzGerald

#### ABSTRACT

The success of a population of primary ( $1^{\circ}$ ) and secondary ( $2^{\circ}$ ) consumers depends on the success of the population of  $1^{\circ}$  producers on which it feeds.

The mesopelagic community is located below the euphotic zone, where no  $1^{\circ}$  production can take place. Therefore this community is composed entirely of consumers. The organisms living in this community depend wholly on the production of organic matter in the upper layers of water for their food source. Therefore, it is believed that a large diverse community of mesopelagic organisms would be found under areas of high productivity, while a smaller, less diversified community should be found under areas of low productivity.

Three areas were chosen to test this hypothesis: one area was of known low productivity, one was of known high productivity, and in the third area the productivity was previously unknown. IKMT tows were done in each area and the surface productivity was taken with the light and dark bottle method.

Results from the first two tows showed a larger population of organisms under the higher productivity area. However, the third tow contradicted the first finding: a large community was found under a low productivity area. Mesopelagic fish tend to concentrate in layers within the water column. If the IKMT was towed for a longer time in one of these layers the number of fish caught, and thus the apparent total population, would be greater. This could be one of the reasons that the third tow had an abnormally high population of organisms.

## The Vertical Migration of Mesopelagic Fish

Priscilla M. Brooks

### ABSTRACT

Mesopelagic fish live at depths ranging from 200 meters to 1000 meters, and they characteristically exhibit a diurnal migration from a deeper resting depth during the day to a more shallow feeding depth during the night. Though evidence for vertical migration is thoroughly conclusive, the function and stimuli for this circadian rhythm is far from clear.

The energy expended by the fish during vertical migration is great, and thus this migration must have significant survival value. Studies of the vertical migration of mesopelagic fish have suggested that the fish come near the surface at night in order to safely feed upon the plankton in the darkness of the night. Obviously this great expenditure of energy must be an economically significant and beneficial one, favored by natural selection. The exploitation of more than one environment must have some adaptive value.

The objective of this project was to study this phenomenon of vertical migration by the mesopelagic fish in relation to the vertical migration of the zooplankton, in particular the migration of the euphausiids, a prime food source for the mesopelagic fish. Sampling consisted of five nets which were towed simultaneously at five different depths in approximately five hour intervals over a 24 hour period; the locations of stations are shown in Fig. 19. Data were compiled by counting the numbers of adult and juvenile fish and by calculating the biomass for each net of each tow.

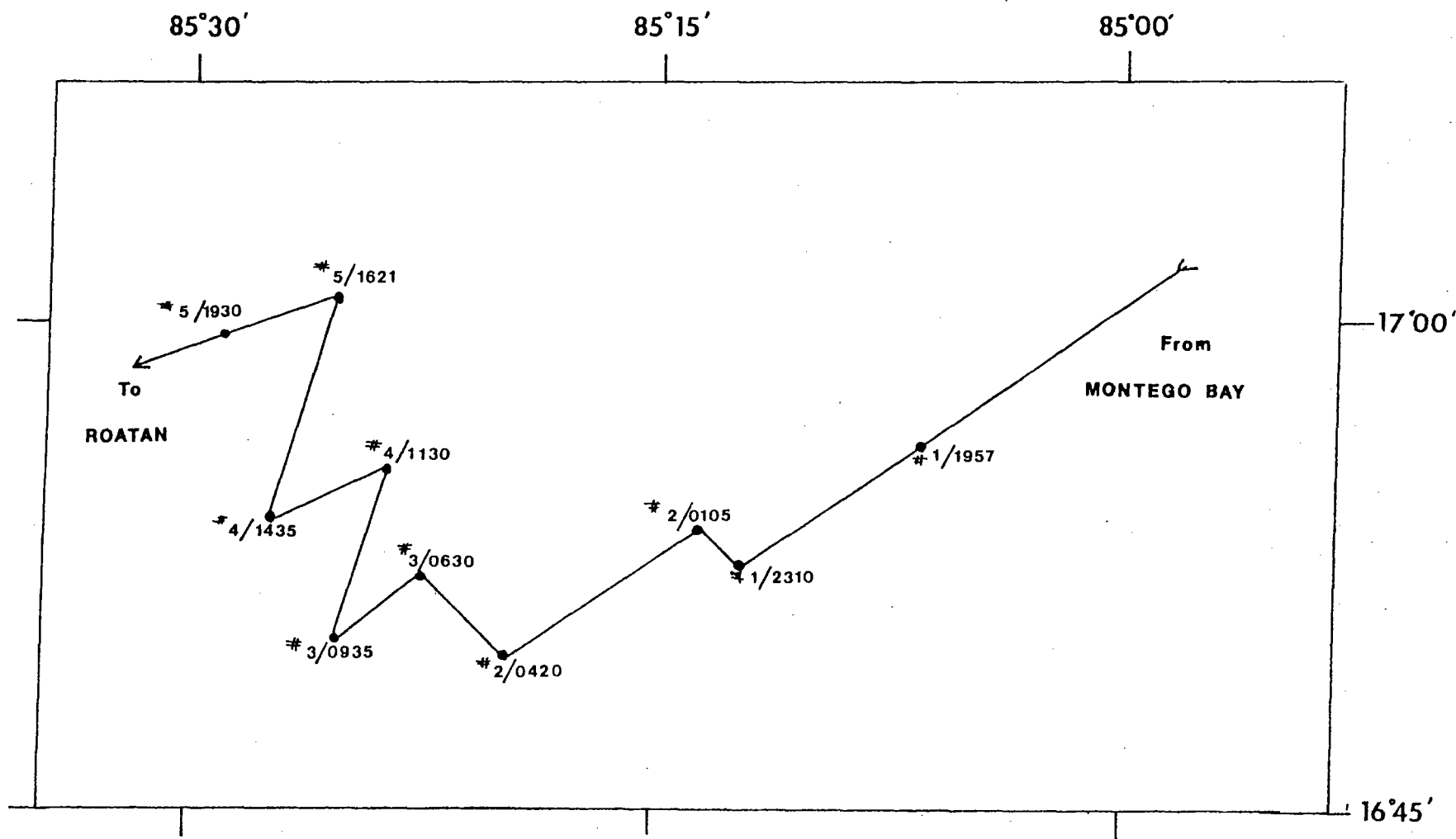
Results evince a definite pattern of vertical migration by the mesopelagic fish, and general biomass from the lower layers of the mesopelagic zone during the day to the upper layers of the ocean at night, as shown in Fig. 20. Concentrations of fish and biomass in the upper layers of the water column declined significantly during the day. In addition, the fish seemed to stay beneath the seasonal



thermocline, perhaps showing a sensitivity to temperature. The full moon during the night of the station may have also inhibited the fish from coming closer to the surface.

These data suggest that there is a correlation between the migrations of the zooplankton and the fish. It is quite likely that the fish migrate in order to feed on the zooplankton. In fact, more frequent tows may demonstrate that the fish actually follow the zooplankton up the water column. It is possible that the migration of the zooplankton acts as a direct stimulus spurring the migration of the mesopelagic fish.

Figure 19. Locations of multi-net tows during the 24-hour station.



## Vertical Migration of Euphausiids

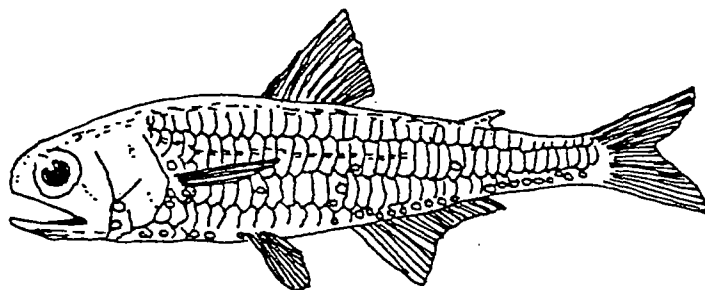
Jeff Dickison

### ABSTRACT

The fauna of the photic zone react extremely sensitively to small changes in the photic environment. The major change, the daily occurrence of the sun, is the cause of a diurnal vertical migration pattern for many of the species of the photic zone. Euphausiids, shrimplike crustaceans, are an important constituent of this pelagic fauna. The purpose of this study is to observe the vertical migration of biomass, and more specifically, the part of this biomass made up of Euphausiids.

Sampling was done by plankton net tows at different times on a twenty-four hour station located at 16°55'N and 85°10'W (Figure 14 ). Data were derived from biomass calculations using settled volume techniques and counting Euphausiids by means of subsamples.

Results showed a concentration of Euphausiids in the surface waters and upper layers at night with a large decline in concentrations at these depths during daylight (Figure 15). The full moon of the period may also have had an effect on the nighttime distribution.



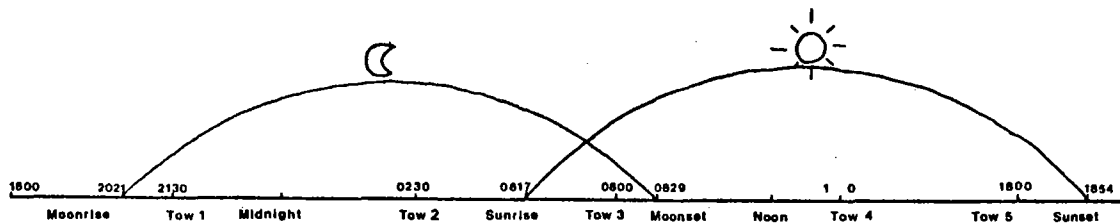
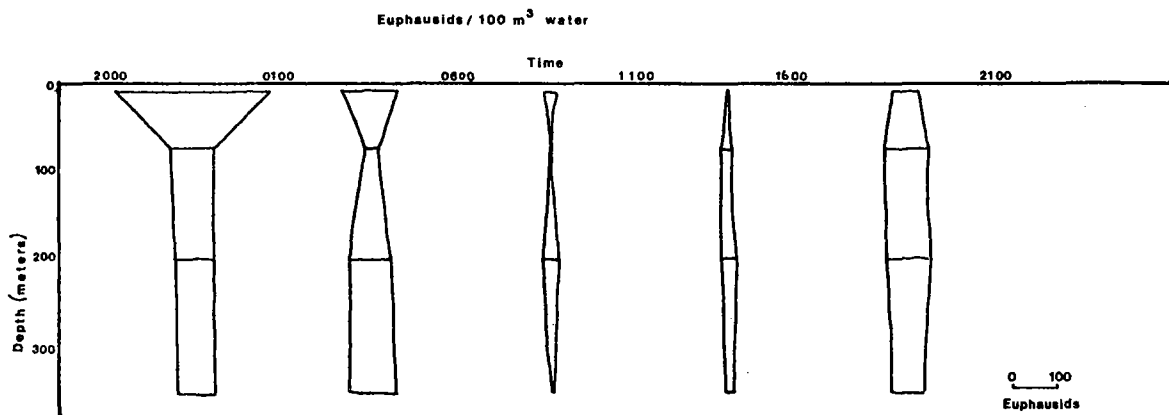
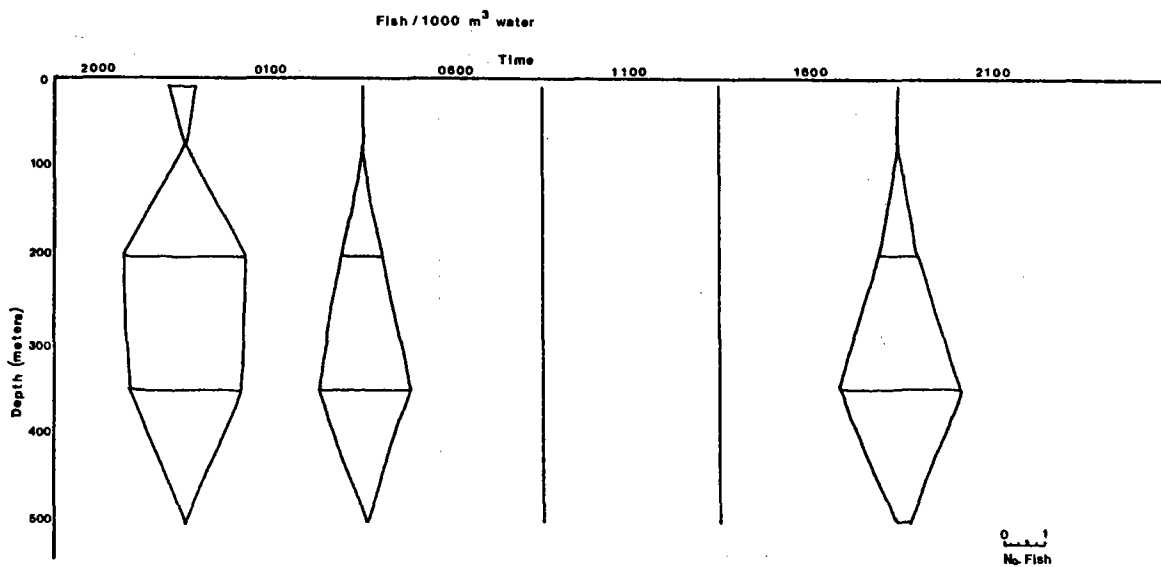
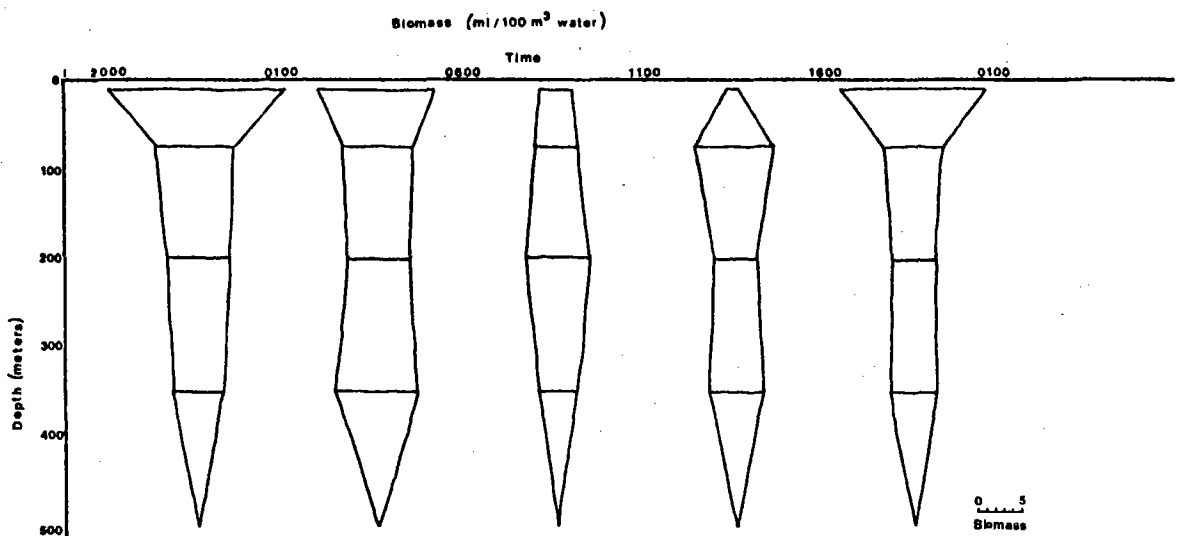


Figure 20. Vertical migration of mid-water fish and euphausiids, and variations in biomass, observed during a 24-hour station.

## CORAL REEF STUDY

Patricia Sullivan

### ABSTRACT

Little research has been published on the fringing reefs of the Isle of Roatan off Honduras, Central America. A field study of the reef community was conducted along with the determination of the primary productivity of the water. Sixteen Scleractinia species (Table 8) were identified, as well as five Atlantic gorgonian species and one species of fire coral. The zones consisted of a sandy beach followed by a lagoon. The lagoon was defined further by a rubble zone and then, sea grass beds. About 50 yards offshore small coral heads were first found. This back reef zone steadily became more dense: the corals increasing in both number of individuals, number of species, and size of the individuals. The zonation and species complied with other works conducted elsewhere in the Western Caribbean Sea.

The primary productivity of the water in this coral reef community was found to be inadequate to support and maintain this highly productive ecosystem. These results can be explained by the unique primary productivity available to the corals in the way of zooxanthellae, a unicellular algae. This form of primary productivity, though, would not affect the water samples because the oxygen produced by the zooxanthellae is consumed by the coral tissue in which the zooxanthellae live. Hence, even though there is low productivity in the water, the coral reef community has access to much energy to maintain its high productivity and diversity.

TABLE 8 Corals from the back reef at Roatan

Phylum Cnidaria

Class Hydrozoa

Order Hydroida

Suborder Anthomedusae

Millepora complonata

Class Anthozoa

Subclass Octocorallia

Order Gorgonacea

Gorgonia sp.

Leptogorgia sp.

Plexaura sp.

Plexaurella sp.

Pseudopterogorgia sp.

Subclass Zoantharia

Order Scleractinia

Acropora palmata

Acropora cervicornis

Montastrea annularis

Montastrea cavernosa

Solenastrea hyades

Dichocoenia stokesii

Siderastrea radians

Siderastrea siderea

Agoricia agaricites

Dendrogyra cylindrus

Porites porites

Porites astreoides

Diploria labyrinthiformis

Diploria clivosa

Meandrina meandrites

Dendrogyra cylindrus

Musso angulosa

## METEOROLOGICAL AND NAUTICAL STUDIES

### Measurement of the pH of rainwater

Sharon Ginand

#### ABSTRACT

Rainwater was collected during cruise W-50 of the R/V Westward in the Caribbean region and its pH measured: it was hoped that some indication of the level of air pollution of this area could be gained from these measurements since the acidity of precipitation is directly linked to concentrations of atmospheric contaminants. Sulfates and nitrates are major contributors to acidity of precipitation and are significant industrial effluents (Likens, 1976).

Precipitation was collected using eight inch diameter funnels that were fastened to plastic bottles. These devices were placed about the vessel so as to minimize contamination from salt spray. After a rain event the samples were collected and the pH of each measured using a Fisher digital pH meter with a combination Fisher electrode.

There were only five precipitation events during the cruise from which there was enough sample to analyze. The pH of each sample was measured and the average calculated for a particular event. Values for the five events ranged from pH 4.6 to 6.2. The meter malfunctioned after the first two events, and therefore pH paper that can be read to 0.5 pH units was henceforth employed.

Clean, or unpolluted rainwater may have pH levels as acidic as pH 5.6 due to the presence of atmospheric carbon dioxide (Likens, 1979). The pH values of 5.2 to 6.2, taken east of the Bahamas, indicate high levels of pollution are not present in the area. More testing is needed to see if the pH of rainwater over the Caribbean changes with time and/or increased industrialization of the region.

A Study of Leeway on the R/V Westward

Jeff Marden

ABSTRACT

Leeway, the lateral drift of a vessel to the leeward of her course, is an important consideration in the safe and accurate navigation of a sailing vessel. The purpose of this investigation was to determine the magnitude of leeway that the R/V Westward makes on different points of sail, and to assess any trends that might exist. The angle of leeway was determined by dragging a buoy-net arrangement behind the ship, and measuring the resulting angle formed with the longitudinal axis of the vessel. Because the buoy was anchored in the water column by the net, the resulting angle was due to leeway, or windage against the exposed parts of the vessel. This angle proved to be at a maximum when close-hauled, steadily decreasing off the wind until it was negligible on a broad reach. Speed of advance was also measured, reaching a maximum with the wind slightly aft of the beam. Both of these trends confirmed the original hypotheses behind the investigation.



## A Propulsional Analysis of Sail Power

Adam Saffer  
Robert Boehringer

### ABSTRACT

Due to the increase in fuel costs over recent years, more inexpensive methods of propulsion have become desired. The resurgence of sail power as an auxiliary source of propulsion has created a demand for more quantitative information regarding its characteristic qualities. By expanding our knowledge on this subject, it is hoped that sail power may be utilized more efficiently in conjunction with motor power. In order to do this, a propulsional analysis concentrating on the R/V Westward's speed of advance (SOA) was undertaken during the track of W-50. The prime variables considered were wind characteristics and sail configuration. Although motor and motor-sail propulsion was studied, the most complete data were taken under sail power alone. Polar curves were plotted representing Westward's performance with respect to the aforementioned variables. More important than the data collection itself was the refinement of methodology. It is from these improvements that more applicable data will be obtained on future cruises, resulting in a further expansion of our knowledge concerning propulsion.

A Study of Chichester's Method:  
Parameters and Inherent Problems

James Douglas Anderson

ABSTRACT

Chichester's method for obtaining a position is a relatively recent one, its use becoming widespread only in the late 60's. As a technique it is quite easy to understand and utilize. Based on the relative motion of the stars and moon, the exact Greenwich Mean Time need not be known to obtain a longitude. My investigation dealt with identifying the optimum conditions for, and inherent problems in, utilizing this technique.

Most parameters were the same for Chichester's, as for any, celestial sights. The need of a definitive horizon and minimum moon glare proved to be essential. Sights were most accurate at half-moon phase in the lunar cycle. This phase is in direct correlation with the period of greatest declinational rate. A five minute lapse between moon sight and star fix was found to be the limit in accuracy. Best LOP's were taken with the moon and stars bearing  $90^\circ$  or  $270^\circ$  plus or minus  $15^\circ$ . These offered greatest accuracy due to the angle of intersection of the latitude.

The method turned out to be very latitude sensitive. A one minute error in latitude would cause a 7 mile error in longitude. Under these circumstances, multiple shoots of Polaris should be taken and computed, using the average value as the accepted latitude.

In conclusion, accuracy of the navigator with his/her sextant, better sextants with improved light gathering scope and a wider variety of shades, and use of H.O. 229 or any sight reduction tables of greater accuracy than H.O. 249, will improve the accuracy of the Chichester Method. While inconsequential to a navigator on a chronometer-furnished ship, this method, for all its inaccuracies, would be indispensable to lifeboat navigation when the Greenwich Mean Time would be general at best.

## APPENDIX I

### A. Demonstration organisms used as a basis for the practical examination.

#### Phylum Arthropoda

<u>Halobates micans</u>	Water strider
<u>Phronima</u> sp.	Amphipod
<u>Panulirus</u> larva	Spiny lobster larva
<u>Systellapsis debillis</u>	Scarlet prawn
Pontellid copepods	Copepods
Order Euphausiacea	Euphausiids

#### Phylum Chaetognatha

<u>Sagitta</u> sp.	Arrow worm
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#### Phylum Chordata

<u>Amphioxus (Branchiostoma)</u>	Lancelet
<u>Leptocephala</u>	Eel larvae
<u>Cypselurus melanurus</u>	Flying fish
<u>Histrio histrio</u>	Sargassum fish
<u>Coryphaena hippurus</u>	Dolphin fish
<u>Megaptera novaeangliae</u>	Humpback whale
<u>Fregata magnificens</u>	Magnificent frigate-bird

#### Phylum Cnidaria

<u>Diploria labyrinthiformis</u>	Brain coral
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#### Phylum Echinodermata

<u>Diadema antillarum</u>	Black sea urchin
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#### Phylum Ectoprocta

<u>Membranipora</u> sp.	Encrusting bryozoan
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Phylum Mollusca

Strombus gigas

Queen conch

Division Cyanophyta

Trichodesmium sp.

Blue-green algae

Division Phaeophyta

Sargassum fluitans/natans

Sargassum Gulfweed

B. Essay Questions

1. The importance of light and color to organisms existing in different biological environments has been a noticeable feature during this cruise. Compare the importance of these two parameters in two different communities of your own choice.
2. Discuss the general circulation in the Caribbean Sea and how it is influenced by the general topography of the area.
3. A chemical plant situated on a N-S coastline is suspected of leaking a toxic chemical into the ocean. There is a current running along the coast in a northerly direction. You are the Marine Scientist on a troubleshooting team and you have been asked to design a sampling program using R/V Westward to monitor the effects of the spread of this pollutant on the ocean and marine life. Discuss the program you would set up, paying special attention to what and where you would sample, and the justification for it.  
(Note - you have the facilities to analyze for the toxic chemical.)
4. In order for coral reef communities to exist in unproductive tropical areas, the organisms have had to create a special environment. Discuss this environment in terms of the role of the organisms, the characteristics of the environment, and the stability of the community.
5. You have been asked to present a talk at your College on how your views of the ocean have changed since your experiences on board Westward. Explain in a logical and scientific fashion what particular points you would emphasize, and what one particular aspect has made the greatest impression on you.



## APPENDIX II

### Meter net tows

- M-1: Copepods, hyperiid amphipods, pteropods, squid larvae,  
22°55'N leptocephalus (3), polychaetes, euphausids, chaetognaths,  
68°45'W a few small larval fish, trichodesmium, decapods. Dominant  
organisms: copepods (small, white), caridean shrimp,  
euphausids. The organisms were fairly uniform in size,  
and not very diverse, compared to other tows of the  
cruise.
- M-2: Calanoid copepods, amphipods, stomatid fish (4), lepto-  
22°52'N cephalus (10), isopods, caridean shrimp, trichodesmium,  
68°41'W mysid shrimp, ostracods, amphioxus, siphonophores,  
including Hippopodius spp., spiny lobster larvae, larval  
decapods, crab larvae, Ceratium carriense, Ceratospyrus spp.,  
a very diverse sample which included numerous larger larval  
decapods.
- M-3: Chaetognaths, stomatopod larvae, decapods, polychaetes,  
20°51'N euphausids, salps, ostracods, larval pufferfish, amphipods,  
68°38'W amphioxus, heteropods, pteropods, larval squid. Dominant:  
small white copepods; ostracods, 2nd most abundant. The  
sample was fairly diverse, with a moderate number of larger  
larval decapods and shrimps.
- M-4: Pteropods, heteropods, larval fish, salps, chaetognaths,  
20°06'N copepods, stomatopod larvae, polychaetes, ostracods, decapods,  
68°40'W euphausids. Dominants: small white copepods, pteropods,  
euphausids, caridean shrimp.
- M-5: Copepods, euphausids, decapods, chaetognaths, siphonophores,  
20°09'N pteropods, heteropods, cephalopods, gastropod larvae, stoma-  
67°57'W topod larvae, amphipod, fish larvae. Dominants: numerous  
small, white, calanoid copepods, amphipods, pteropods. The  
organisms were, overall, very small and uniform in size.

APPENDIX II (continued)

- M-6: Chaetognaths, pteropods, cubomedusae, small and larval fish,  
20°03'N amphipods, trichodesmium (numerous). Dominant: small, white  
68°53'W copepods, brachyuran larvae, euphausids, small larval decapods.  
Tow was fairly diverse and very uniform in size.
- M-7: Pteropods (3 types), numerous fish larvae, ciliated protozoans,  
19°53'N decapods, euphausids, copepods, hydromedusae, polychaetes,  
68°50'W caridean shrimp, spiny lobster larvae, chaetognaths, salps,  
amphioxus, prosobranch gastropod Peraclis bispinosa.  
Dominants: euphausids, fish larvae, small white copepods.  
The tow was fairly diverse and very uniform in size.
- M-8: Calanoid copepods, euphausids, mysids, chaetognaths, amphi-  
18°36'N pods, pteropods, stomatopods, caridean shrimp. Most dominant:  
76°06'W copepods, euphausids.
- M-9: Calanoid copepods, euphausids, fish larvae, chaetognaths,  
17°50'N ostracods, cyclopoid copepods, veliger larvae, hyperiid  
81°07'W amphipods, mysids, polychaetes, Panilurus larvae, siphono-  
phores, numerous unidentified eggs. Dominants: red calanoid  
copepods.
- M-10: Mysids, cubomedusae, a few larval squid, a few small scarlet  
20°15'N prawns, trichodesmium, caridean shrimp, hyperiid amphipods,  
85°04'W larval decapods, numerous eggs, calanoid copepods, euphausids.  
Dominant: red copepods, euphausids, caridean shrimp, small  
larval fish.



APPENDIX II (continued)

24 Hour Station - Meter Net (363 mesh) Tow

Position: 85°15'W      16°50'N      March 4-5, 1980

Tow I (2000-2300) Dominant: red copepods, euphausids, caridean shrimp, larval decapods. Other components, brachyuran larvae, larval fish, siphonophores, pteropods.

Tow II (0100-0420) Dominant: red copepods, caridean shrimp, euphausids, larval fish, pteropods. Other components, chaetognaths, spiny lobster larvae, larval file fish, heteropods, amphipods, cubomedusae.

Tow III (0630-0935) A fairly diverse sample, including red copepods, small white copepods (most abundant), larval decapods, larval crabs, siphonophores, ctenophores, larval fish, euphausids, chaetognaths, pteropods, hydromedusae Ectopleura spp., hyperiid amphipods, spiny lobster larvae.

Tow IV (1130-1435) Most dominant (~70% of sample), large red calanoid copepods, euphausids, a few spiny lobster larvae, small larval decapods, chaetognaths, siphonophores, pteropods, leptocephalus, some larval fish.

Tow V (1620-1930) A very diverse sample, abundant in red copepods; caridean shrimp, amphipods, euphausids, spiny lobster larvae, larval fish, decapod larvae; a few pteropods, heteropods, leptocephala, chaetognaths.



APPENDIX III W-50 Bird Sightings

<u>Date</u>	<u>Time</u>	<u>Lat(N)</u>	<u>Long(W)</u>	<u>Species</u>	<u>Number</u>	<u>Notes (field marks, characteristics and behavior)</u>	<u>id. reli.*</u>
8 Feb.	0910	25°25.5'	78°56.5'	Magnificent frigate-bird	1	♂ soaring close over the ship	2
	1330	26°28.5'	78°50.3'	Magnificent frigate-bird	1	♂ 5 nm - Grand Bahama	2
9 Feb.	1415	26°17'	78°03'	Audubon shear-water	3	small long wings, dark with white flash underneath	1
10 Feb.	0800	26°02.5'	77°36.8'	Skua	1	flying across bow E-W	1
	0850	26°00.0'	77°36.0'	Gulls (spp?)	3	immature	1
	0930	25°58'	77°34'	Audubon shear-water	1	"shearing" between waves white breast	1
	0950	25°57'	77°32'	Gull (spp?)	1	close off the stern immature	2
	1230	25°49'	77°23'	bluefaced booby	1	adult by stern & by Russian cargo ship	2
	1320	25°45'	77°17'	Tropicbird	1	probably white-tailed	2
	1610	25°33'	77°02'	Cape May Warbler	1	landed on board, took off	1
	1620	25°33'	77°01'	Jaeger	1	immature probably parasitic	1
11 Feb.	1255	25°27'	76°13'	parasitic jaeger	1		2
	1300	25°27'	76°13'	Forster's tern	1	flying about the ship (eyespot)	1
14 Feb.	1015	23°37'	73°54'	White-tailed tropic bird	1		2
	1115	23°35'	73°52'	skua	1	stayed near boat 1 hr.	2
15 Feb.	1345	23°08'	71°45'	Parasitic jaeger	1		1

## APPENDIX III(continued)

<u>Date</u>	<u>Time</u>	<u>Lat(N)</u>	<u>Long(W)</u>	<u>Species</u>	<u>Number</u>	<u>Notes</u>	<u>id. reli.*</u>
20 Feb.	0625	20°49'	68°56'	sooty shearwater	1	caught flying fish	2
	0930	20°48'	68°44'	Parasitic jaeger	2	one with white rump patch, close to ship	2
	1435	20°50'	68°39'	Pomarine jaeger	1	hovered over small toothed whale	2
21 Feb.	0600	20°06'	68°40'	Jaeger	1	immature, landed on water and stayed by ship until 0730	
	0600	20°07'	68°39'	Jaeger	1	immature, flying towards Navidad Bank	1
	0820	20°08'	68°46'	Jaeger	1	immature, flying towards Navidad Bank	1
22 Feb.	0750	19°56'	68°55'	Pomarine jaeger	2		1
23 Feb.	1630	20°26'	72°34'	Tropicbird	1		1
	1800	20°20'	72°44'	Frigate-bird	1	Male, swooping close to the water	2
24 Feb.	1110	19°32'	74°24'		1	Large bird landing on the water. Wings appeared white in reflected light	
26 Feb.	0700	18°40'	77°12'	Frigate-bird	1	mature male	2
	1530	18°40'	78°38'	Royal tern	1	large w/ white underwing	1
1 March	1030	18°24'	79°21'	Jaeger	1	spp?	1
	1230	18°11'	79°23'	Wilson's petrel	1	white rump, no fork in tail, landed on water	2
	1300	18°10'	79°25'	Barn swallow	1	immature	2

## APPENDIX III(continued)

<u>Date</u>	<u>Time</u>	<u>Lat(N)</u>	<u>Long(W)</u>	<u>Species</u>	<u>Number</u>	<u>Notes</u>	<u>id. reli.*</u>
2 March	0635	17°54'	80°53'	Tropic bird	1		1
	0800	17°52'	80°56'	Brown booby	24±4		2
	1245	17°55'	81°90'	Swallow	1	square tail, pale rump, ring around neck	1
3 March	1000	17°21'	82°57'	Bluefaced booby	5		2
	1230	17°19'	83°14'	booby spp.	6		0
				red footed	1		2
	1530	17°09'	83°27'	frigate-bird	2		2
				brown booby	5		1
4 March	1845	17°07'	83°36'	frigate-bird	1		2
	0610	16°53'	84°27'	frigate-bird	1		2
				brown booby	1		2
	0715	16°53'	84°31'	bluefaced booby	1		2
				red footed booby	6	immature	2
	0804	16°53'	84°34'	Brown booby	4		2
				Red footed booby	1		2
	1305	16°52'	84°58'	laughing gull	1	winter plumage	1
	1450	16°51'	85°03'	bluefaced booby	1		2
5 March	1720	16°52'	85°05'	reed footed booby	3	2 mature, 1 immature	2
	0945	16°45'	85°25'	frigate-bird	1		2
	1230	16°56'	85°17'	frigate-bird	1		2
	1320	16°54'	85°15'	yellow throated warbler	1		2
9 March	0800	17°14'	85°54'	cliff swallow	1	landed on board	1

## APPENDIX III(continued)

<u>Date</u>	<u>Time</u>	<u>Lat(N)</u>	<u>Long(W)</u>	<u>Species</u>	<u>Number</u>	<u>Notes</u>	<u>id. reli.*</u>
10 March	0600	19°07'	85°30'	Tropic bird	1		1
	1315	19°49'	85°13'	bluefaced booby	1	by ship	2
	1335	19°50'	85°13'	frigate-bird	3	wheeling w/ other birds	1
				bluefaced and/or redfooted booby	12-20		1
	1810			bluefaced booby	1	by ship	2
12 March	1600	21°30'	85°48'	black legged kitti-wake	1	winter plumage	2
13 March	1015	22°45'	85°13'	white tailed tropic bird	1		2
	1230	22°53'	85°01'	frigate-bird	1		1
	1340	22°58'	84°56'	white tailed tropic bird	1		2
	1800	23°11'	84°51'	frigate-bird	1	female	2
14 March	0600	23°14'	84°50'	cattle egret	2	flying east	2
	0700	23°15'	84°51'	cattle egret	1		1
	1030	23°19'	84°46'	cattle egret	3		2
15 March	0930	23°33'	83°55'	jaeger	1	immature	1
	1000	23°34'	83°54'	cattle egret	1	immature, black legs	2
				Gull spp.	1	immature	1
	1600	23°31'	83°31'	jaeger	2	immature	1

APPENDIX III(continued)

<u>Date</u>	<u>Time</u>	<u>Lat(N)</u>	<u>Long(W)</u>	<u>Species</u>	<u>Number</u>	<u>Notes</u>	<u>id. reli.*</u>
16 March	0945	23°37'	82°33'	laughing gull	1	2nd winter	2
17 March	0900	24°21'	81°16'	laughing gull	1	summer plumage	1
		24°14'	81°26'	laughing gull	1	summer plumage	1

\* id. reli. - reliability of species identification

0 - unknown

1 - probable (only one characteristic)

2 - definite (3 or more characteristics)





# APPENDIX IV

## A Chemical analyses of water samples from the vicinity of Navidad Bank

Wire out depth(m)	Calc <sup>d</sup> depth(m)	Temp(°C)	Salinity (°/oo)	Diss. O <sub>2</sub> (ml/L)	Phosphate (μM/L)	Ammonia (μM/L)	Silicate (μM/L)
Station: W50-H1							
Position: 20°48'N 68°40'W							
0	0	25.83	36.009	5.27	bd	0.14	2.40
200	125	24.98	37.229	5.29	bd	bd	1.35
400	253	19.76	36.951	5.10	bd	bd	1.05
600	375	18.08	36.721	5.41	bd	bd	2.55
800	495	16.19	36.444	4.69	0.22	bd	3.25
1000	597	13.13	35.823	4.01	0.50	bd	8.35
Station: W50-H2							
Position: 20°07'N 68°44'W							
0	0	25.68	36.076	5.29	bd	0.36	2.10
200	215	21.44	36.828	4.01	bd	0.21	0.80
400	426	17.38	36.444	4.96	bd	0.30	2.25
600	635	13.35	35.792	3.85	0.66	-	7.70
800	824	9.46	35.279	3.43	1.32	0.50	7.70
1000	997	6.91	35.024	4.21	1.54	0.04	9.95
Station: W50-H3							
Position: 20°08'N 68°52'W							
0	-	25.87	35.902	5.23	bd	0.26	1.94
7	-	25.88	35.876	5.29	-	0.46	1.90
15	-	25.90	35.851	5.18	bd	0.34	2.10

APPENDIX IV-A (continued)

Wire out depth(m)	Calcd depth(m)	Temp(°C)	Salinity (o/oo)	Diss. O <sub>2</sub> (ml/L)	Phosphate (μM/L)	Ammonia (μM/L)	Silicate (μM/L)
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Station: W50-H4

Position: 20°03'N  
68°52'W

0	-	25.78	35.962	5.17	-	bd	1.90
7	-	25.80	35.942	5.20	bd	0.59	1.90
15	-	25.80	35.966	5.19	bd	bd	1.90

Station: W50-H5

Position: 19°53'N  
68°50.5'W

0	0	26.18	36.060	5.35	bd	bd	2.00
200	145	23.97	37.007	5.07	bd	bd	0.90
400	295	19.31	36.646	4.75	0.1	bd	1.20
600	495	15.93	35.653	4.36	-	bd	4.55
800	582	12.50	35.599	3.84	0.96	bd	10.15
1000	742	8.81	35.153	3.53	1.50	bd	8.90

# APPENDIX IV

## B Results of the hydrographic transect from Jamaica to Roatan

Wire out depth(m)	Calc <sup>d</sup> depth(m)	Temp(°C)	Salinity (°/oo)	Diss. O <sub>2</sub> (ml/L)	Phosphate (μM/L)	Ammonia (μM/L)	Silicate (μM/L)
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Station: W50-H6

Position: 18°05'N  
79°40'W

0	0	27.00	35.819	5.51	0.32	-	-
250	169	23.74	36.888	4.49	0.11	bd	0.80
500	334	17.52	36.440	4.39	0.38	0.83	2.73
750	508	13.13	35.733	3.71	-	0.54	4.92
1000	*432	15.04	36.088	4.02	.99	-	5.39
1250	600	11.61	35.508	3.45	2.36	2.14	8.80
1500	799	7.97	35.079	3.48	3.02	2.16	15.72

\* pretrip

Station: W50-H7

Position: 17°51'N  
81°05'W

0	0	26.90	35.851	5.31	bd	bd	1.00
250	267	19.01	36.705	4.69	0.22	bd	1.50
500	535	12.51	35.725	3.67	0.88	bd	10.55
750	797	7.95	35.090	3.64	1.76	0.20	20.62
1000	1000	5.75	34.984	4.17	1.77	0.12	22.00
1250	1193	4.63	35.043	4.20	1.53	0.66	23.10
1500	1371	4.40	35.075	3.04	1.10	0.08	19.92

Station: W50-H8

Position: 16°55'N  
84°22'W

0	0	26.20	35.985	5.50	bd	bd	1.55
250	228	17.70	35.515	5.08	bd	0.20	3.40
500	450	10.95	35.350	4.51	0.84	0.54	12.90
750	675	-	34.898	3.36	1.58	0.88	21.20
1000	900	5.35	34.862	3.58	1.62	3.48	26.80
1250	1130	4.66	34.984	4.27	1.18	3.04	26.10
1500	1301	4.38	35.059	-	1.14	-	25.30

APPENDIX IV-B (continued)

Wire out depth(m)	calc <sup>d</sup> depth(m)	Temp(°C)	Salinity (‰)	Diss. O <sub>2</sub> (ml/L)	Phosphate (μM/L)	Ammonia (μM/L)	Silicate (μM/L)
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Station: W50-H9

Position: 16°52'N  
85°08'W

0	0	26.40	36.183	5.30	0.12	bd	1.75
250	199	18.73	35.555	4.21	0.33	bd	3.30
500	398	13.68	35.918	3.68	0.85	bd	8.56
750	573	9.08	35.193	3.23	1.95	0.12	14.90
1000	763	6.53	34.862	3.57	1.97	0.10	22.58

Station: W50-H11

Position: 21°13'N  
85°28'W

0	0	26.40	35.842	5.12	bd	bd	1.40
250	179	23.56	36.876	4.25	bd	bd	0.50
500	344	17.51	36.361	4.03	0.25	0.19	3.35
750	516	12.88	35.673	3.43	0.61	0.82	9.05
1000	590	11.41	35.429	3.24	0.98	0.98	11.00
1250	737	8.74	35.110	3.13	1.18	0.50	15.40
1500	835	6.74	34.949	3.48	1.14	0.70	20.70

Station: W50-H12

Position: 21°51'N  
86°02'W

0	0	26.20	35.977	4.90	bd	-	2.95
250	186	21.73	36.646	4.28	-	-	2.75
500	394	16.64	35.648	4.05	0.68	-	5.25
750	592	14.27	35.815	3.59	0.56	-	8.20
1000	784	7.83	35.094	3.24	0.65	-	18.90