# CRUISE REPORT

# W-40

Scientific Activities

Woods Hole - Bermuda - Ile Saint-Pierre - Woods Hole

07 June 1978 - 19 July 1978

R/V WESTWARD

Sea Education Association

Woods Hole, Massachusetts

DRAFT COPY

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## PREFACE

The main objective of this cruise report is to compile the data collected by 24 undergraduate students, 3 staff scientists and 2 visiting scholars on W-40 as part of the Introduction to Marine Science (NS 225 at Boston University). This compilation in one place can serve as a guide for future Westward cruises, as a data base for interpretation of results by scientists ashore, and as a teaching reference in the shore component of the course.

The cruise report between these covers presents an overview of the cruise W-40 with some preliminary interpretations of results. We conducted an array of individual projects, many of them focused on the theme of diurnal rhythms, and this report provides space to see how our diverse interests meshed.

To meet these goals, most of the data tables are presented in the appendix while abstracts and interpretative graphs make up the body of the report. All data collected are presented except for readings from the bathythermograph and hourly surface temperature and barometer readings. These are omitted due to the cost of reproduction but are available upon request. The unevenness of scientific presentation in the abstracts arises to a large extent from the diversity of background of students carrying out the projects. It should be noted, however, that many students with no science background performed exceedingly well on the projects. It is my particular hope that this experience on the Westward revealed to the students a realistic view of how the scientific method works even while a sense of awe and wonder at the natural world remained.

It was my pleasure to rely upon an exceedingly competent crew and scientific staff. I thank Captain Jon Lucas for his pervading interest in the scientific program and for his skill in seeing that the Westward maintained her rigorous schedule. Carl Baum contributed a wealth of experience with Westward equipment, a keen interest in and pervasive knowledge of fish, and an enduring sense of humor. Clifford Low brought a strong teaching background and skill in chemistry techniques. He also brought valuable Westward experience with him, a willingness to work diligently, skill with the guitar, and a noticable sense of humor. I appreciated greatly being able to lean on this strong staff.

We enjoyed the presence of two Visiting Scholars this cruise, Martin Tracey during Leg I and Jacek Sulinowski during Leg III. Martin introduced many of us to recent work in population genetics and also maintained good cheer with droll wit, especially at mealtime. Jacek seemed to be at ease with us the day he arrived even though we had already been together a month at that time. He overcame many difficulties with sampling gear to carry on a benthic research program and to help supervise student projects. His beautiful voice and vast repertoire of sea chanties added much to our pleasure in his presence.

This report was largely prepared at sea and is not meant to represent a final consideration of the data.

Mary Farmer
Chief Scientist

## INTRODUCTION

This report is the result of the laboratory portion of Introduction to Marine Science (NS 225 at Boston University) which took place on cruise W-40 of the R/V Westward (figure 1). The noon and midnight positions that corresponded to compass point extremes of the cruise are given in Table 1 along with the ship's itinerary. The ship's complement is listed in Table 2.

The academic program consisted of daily lectures and weekly quizzes by the staff. Student projects were supervised and resulted in final papers and seminars, the abstracts of which compose the main body of this cruise report.

Most of the scientific education on the cruise took place during science watch. Students on watch in the laboratory learned the operation of oceanographic equipment, the chemical and biological work-up of samples, and analysis of data. Becoming familiar with demonstration organisms and proper maintenance of a scientific log were also part of the science watch.

Research conducted during W-40 partly represents ongoing work of individuals and agencies that have extended their assistance to our students. Scientific operations performed on W-40 are listed in Appendix I. Material reported here should not be excerpted or cited without written permission of the Chief Scientist.

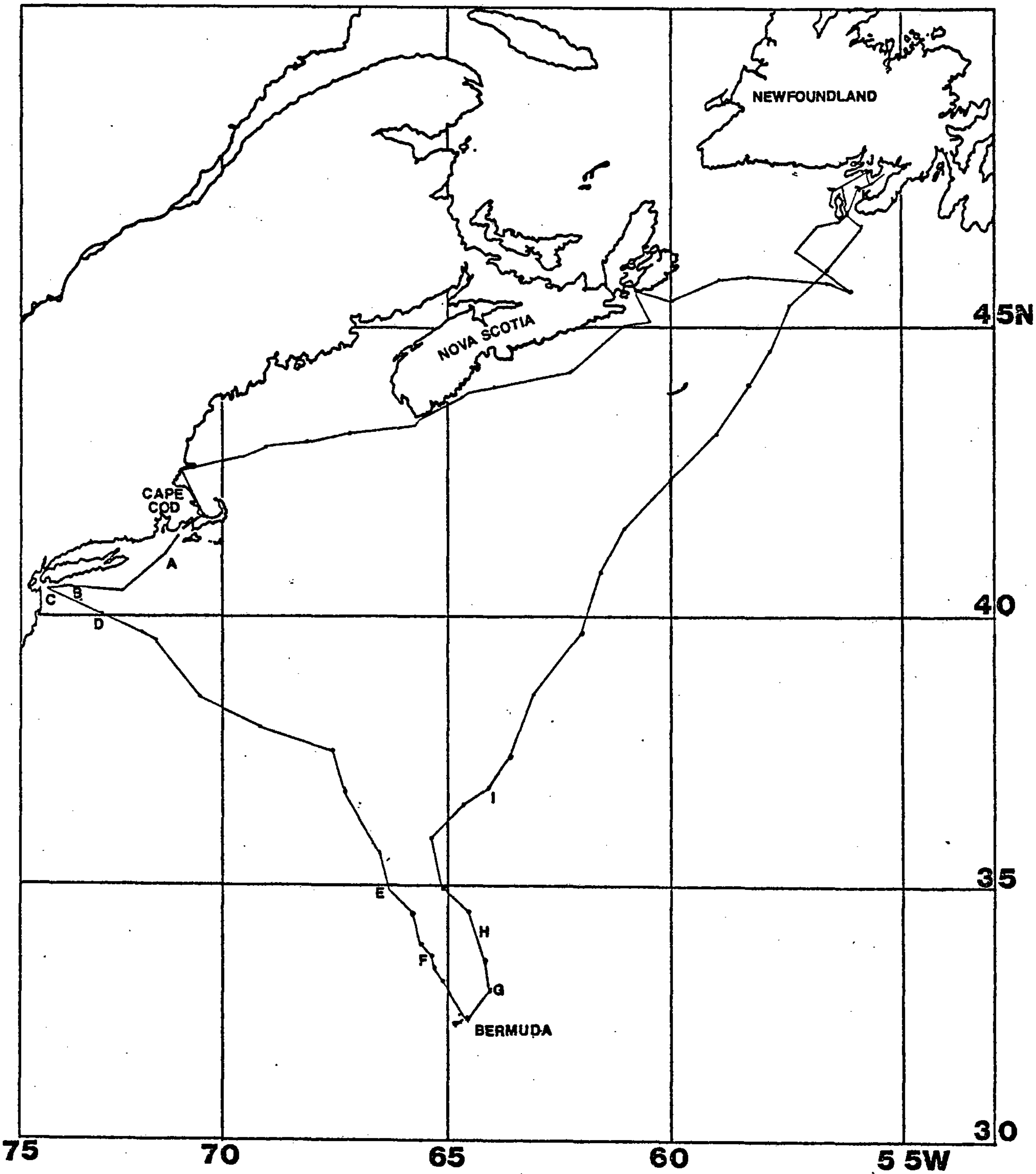


Fig. 1. Cruise track of R/V Westward cruise W-40. Itinerary in table 1.

Table 1. Itinerary and compass point extremes of R/V *Westward* cruise W-40.

| Compass Point | Latitude (N) | Longitude (W) |
|---|---|---|
| West | 40° 23.0' | 73° 47.4' |
| South | 32° 30' | 64° 32' |
| East and North | 47° 26' | 55° 21' |

| Port | Arrival | Departure |
|---|---|---|
| Woods Hole, Mass. | -- | 07 June 1978 |
| St. Georges, Bermuda | 20 June 1978 | 22 June 1978 |
| Ile Saint-Pierre | 03 July 1978 | 05 July 1978 |
| Woods Hole, Mass. | 19 July 1978 | -- |

Table 2. Ship's complement for R/V Westward cruise W-40.

| | |
|---|---|
| **Nautical Staff** | |
| Jon Lucas, B.S., M.M. | Captain |
| Richard Ogis, B.S. | Chief Mate |
| Ron Harelstad, B.S. | Second Mate |
| Greg Swanzey, B.S. | Third Mate |
| Gary Manter, A.M.S. | Chief Engineer |
| Gale Gryska, B.A. | Steward |
| **Scientific Staff** | |
| Carl Baum, B.S. | Scientist |
| Mary Farmer, Ph.D. | Chief Scientist |
| Cliff Low, M.Ed. | Scientist |
| **Visiting Scholars** | |
| Edward Beckett, B.S. (Leg II) | Engineer |
| Jacek Sulinowski, Ph.D. (Leg III) | Biological Oceanography |
| Martin Tracey, Ph.D. (Leg I) | Biological Oceanography |
| **Students** | |
| Susan Abbott | Colgate U., N.Y. |
| Martha B. Ballard | Bates College, Me. |
| Lisbeth L. Botzum | College of Wooster, Oh. |
| Robert B. Breen | Miami Valley School, Oh. |
| Josh Drachman | Haverford College, Pa. |
| Paul K. Farabaugh | U. Pittsburgh, Pa. |
| Daniel J. Goldfield | Brandeis, Ma. |
| Nancy J. Gunnlaugsson | College of the Atlantic, Me. |
| James W. Keen | Emory U., Ga. |
| Tracy A. Kuck | Colgate U., N.Y. |
| Gail M. Lima | Washington University, Mo. |
| Roderic B. Mast | Alma College, Mi. |
| Martha A. Mather | Denison, Oh. |
| Ellen D. McCausland | Conn. College, Conn. |
| Wendy L. Meyer | Cornell, N.Y. |
| Betsy Monigle | Bryn Mawr, Pa. |
| Pamela S. Poindexter | Colby College, Me. |
| John S. Rikkers | Mich. Tech., Mi. |
| Susan E. Savage | Albion, Mi. |
| Jean C. Sherwood | Colby College, Me. |
| Belinda Spalding | Cornell, N.Y. |
| Kathleen A. Strauss | Westminster, Pa. |
| Maryann Wohlgemuth | U. New Hampshire, N.H. |

# RESEARCH AND OBSERVATIONS

## W-40 PROGRAMS

### INTRODUCTION

The programs developed specifically for W-40 were: a set of 24-hour stations, the student projects, and visiting investigator programs.

The 24-hour stations (Stations, D, F, I; figure 1) consisted of 1) bathythermograph, 2) a hydrocast for temperature salinity, oxygen, and silicates, 3) simultaneous net tows (500m mesh) at the surface, below the mixed layer, a mid-depth, and 400 meters. Tows and hydrocasts were done at the same depths, and the choice of depths was based on the depth of the mixed layer as determined by the bathythermograph trace. The set of procedures was repeated every 6 hours. Ambient and underwater light intensities were measured two or three times a day with a Kahl Underwater Irradiameter. Standard methods were used to analyze the data; silver nitrate titration for salinity, Winkler for oxygen, Strickland and Parsons for silicate, and volume displacement for zooplankton biomass. Zooplankton were identified to family and, where possible, to genus and species.

Several student projects used data collected routinely from the 24-hour stations to examine diurnal changes in physical, chemical, and biological factors (Monigle, Breen, Mast, Mather, Kuck, Lima, Strauss). In addition, bucket samples were taken for plant pigment analysis (Savage).

Other student projects examined indications of different water masses (Meyer, Willauer), pollution (Poindexter), zooplankton pigments (Sherwood), coral reefs (Spalding, Abbott), the Sargassum community (Drachman, Wohlgemuth), continental shelf studies (Rikkers, Abbott), and ongoing internal and cooperative programs (Gunnlaugsson, Rikkers, Ballard, Farabaugh, McCausland, Goldfield, Keen, Botzum).

The visiting investigator programs included collection of crabs for genetic studies (Tracey) and bottom samples for sediment studies (Sulanowki).

Scientific operations conducted separately from routine stations were bathythermograph, Isaacs-Kidd Midwater Trawl, and the otter trawl. Logs of the positions of these operations are in Appendix I. The data from all scientific operations are summarized in Appendix II.

W-40 PROGRAMS, continued

## WATER MASSES

### Introduction

The cruise track of W-40 took the R/V *Westward* over several recognized surface water masses: Shelf, slope, Gulf Stream, Sargasso Sea, and Labrador water. Temperature-salinity (T-S) diagrams, satellite-observed Gulf Stream analysis, and light penetration data were used to characterize the water masses.

The T-S curves in figure 2, read from left to right, demonstrate the spectrum of hydrographic data surveyed from cold, relatively fresh water in the New York Bight and Fortune Bay (stations C and J) through warm, saline water in the Sargasso Sea (stations F and G). Water masses were identified by their correspondence to curves from the Oceanographic Atlas of the North Atlantic Ocean (U.S. Naval Oceanographic Pub. No. 700) for the same time of year. These identifications correspond to satellite data for the time of the cruise (figures 3 and 4).

Note that the T-S curve for station I has a shape similar to that of station D (Slope water) but is displaced toward the curves for the Sargasso Sea. Satellite data for the week station I was taken shows the existence of a possible cold core eddy or ring at that position (figure 4), suggesting that the water mass studied was slope water that had been entrained and warmed by a finger of the Gulf Stream. Bathythermograph profiling in the area corroborates this suggestion (see Meyer, this report).

Attenuation of light with depth followed curves characteristic of turbid coastal water through clear oceanic water (figure 5). Station C in the New York Bight was clearly the most turbid. Station I showed a pattern similar to the slope water of station D without any influence from Sargasso Sea water. Station F in the Sargasso Sea showed the greatest transparency to light.

In addition to recognizable water masses, unusual features were seen in a surface temperature transect roughly parallel to the Nova Scotia coastline. Several tongues of cold water (6-9$^{\circ}$C) were seen running in gradients perpendicular to the coast (figure 6). These gradients might have followed density gradients established during summer months when warm, fresh water runoff from Nova Scotia encountered the

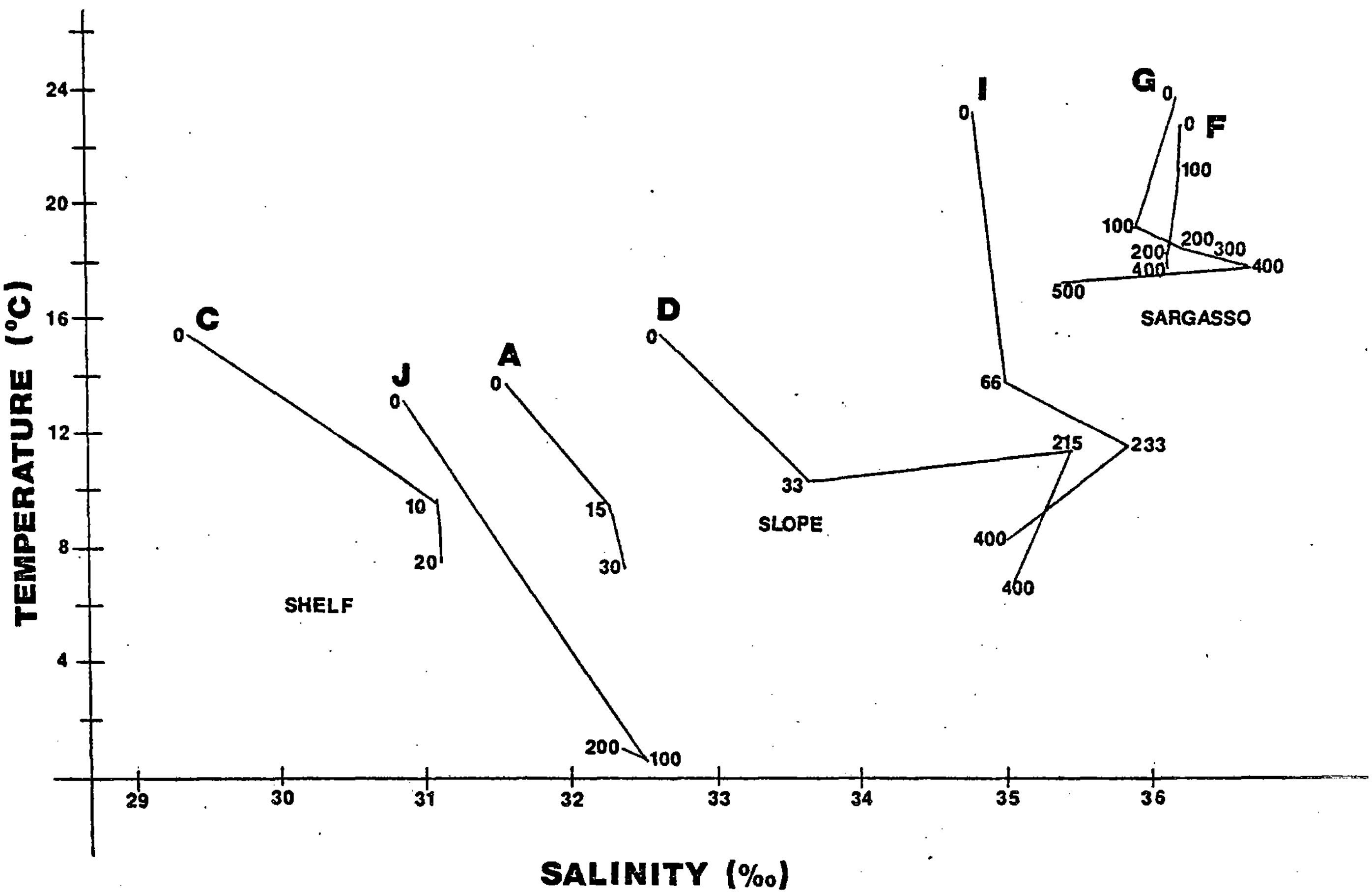


Fig. 2. Temperature-salinity (T-S) diagrams from hydrostations conducted on cruise W-40. Letters represent stations, numbers represent depth of the sample. Designations of water mass (shelf, slope, and Sargasso) were taken from T-S diagrams in the Oceanographic Atlas of the North Atlantic Ocean.

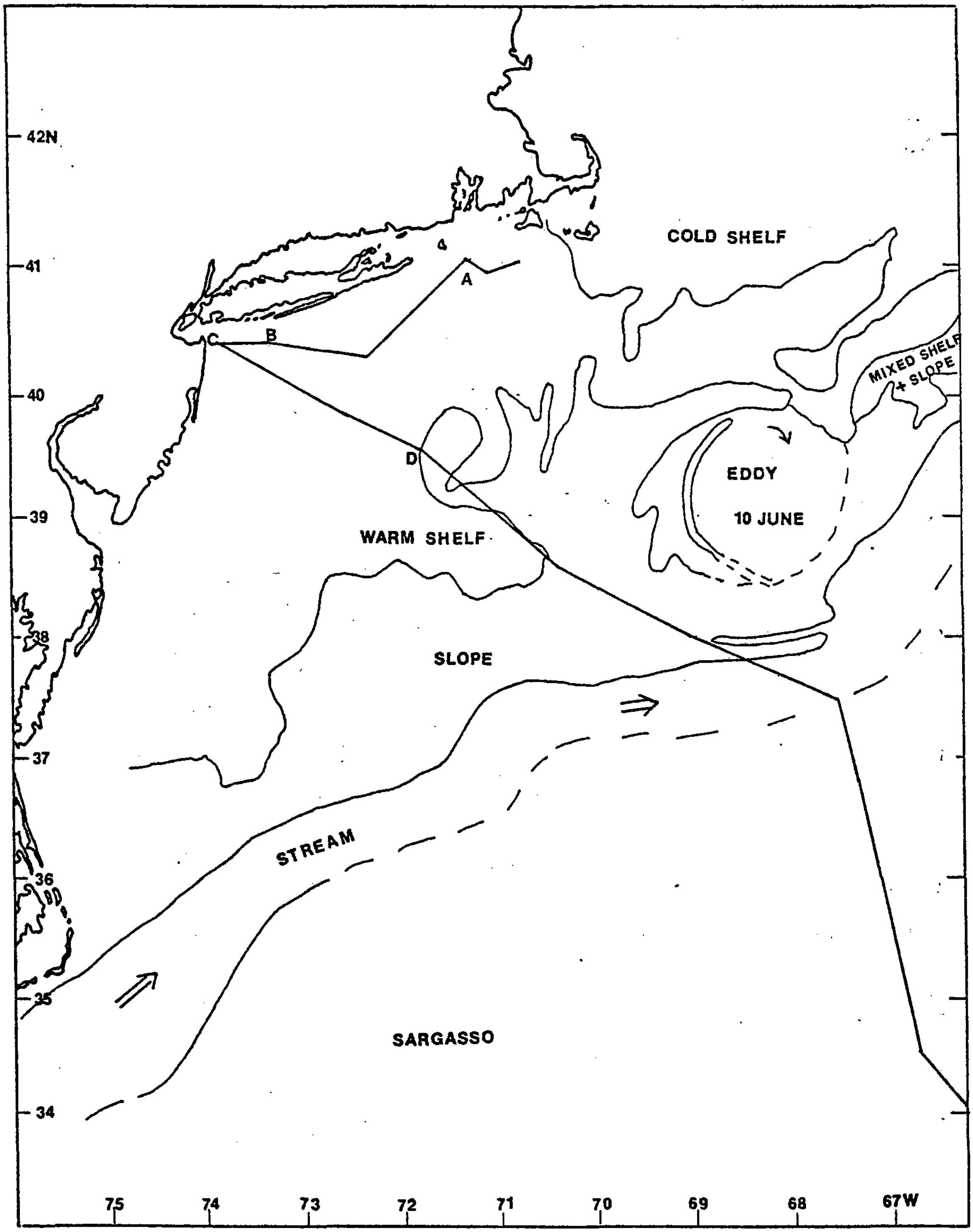


Fig. 3. Water masses sampled at stations A through D. Water mass features from U. S. Naval Oceanographic Office; Experimental Ocean Frontal Analysis.

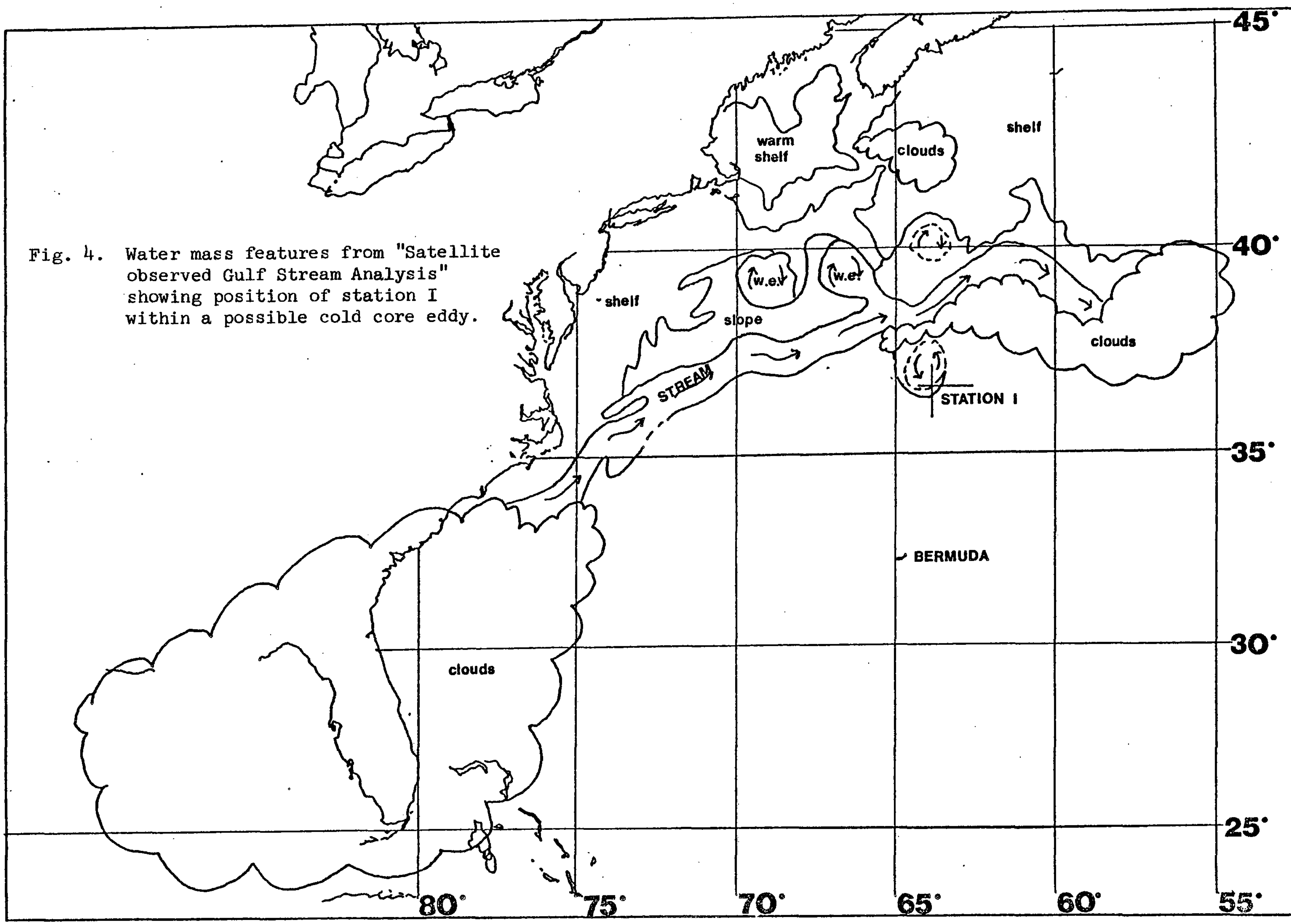


Fig. 4. Water mass features from "Satellite observed Gulf Stream Analysis" showing position of station I within a possible cold core eddy.

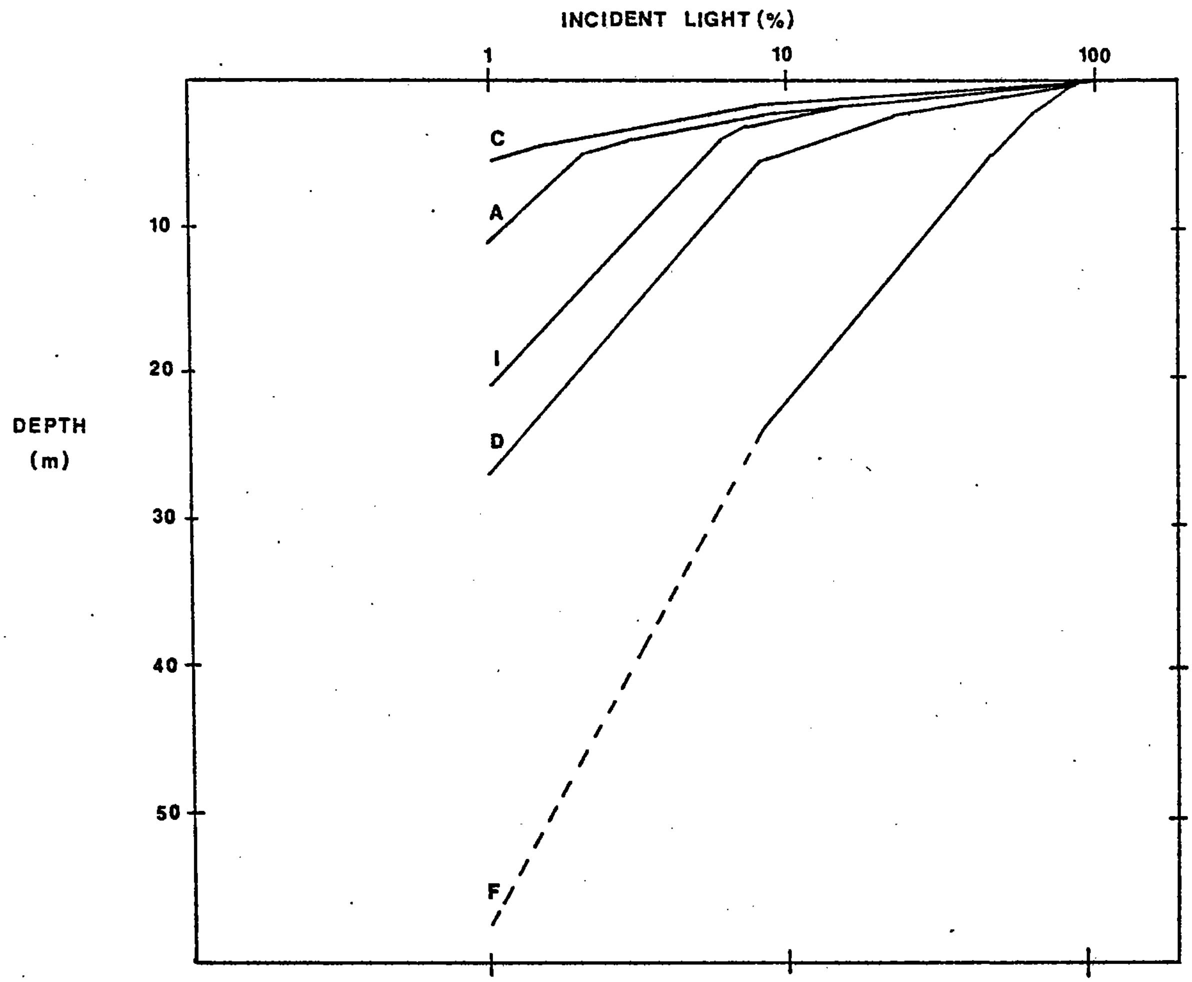


Fig. 5. Vertical profile of percent light intensity versus depth in the water column. Letters represent stations where light intensity readings were made. The 1% light depth at station F was deeper than the cable (25 m) and that value was extrapolated from the attenuation coefficient attained at 25 meters.

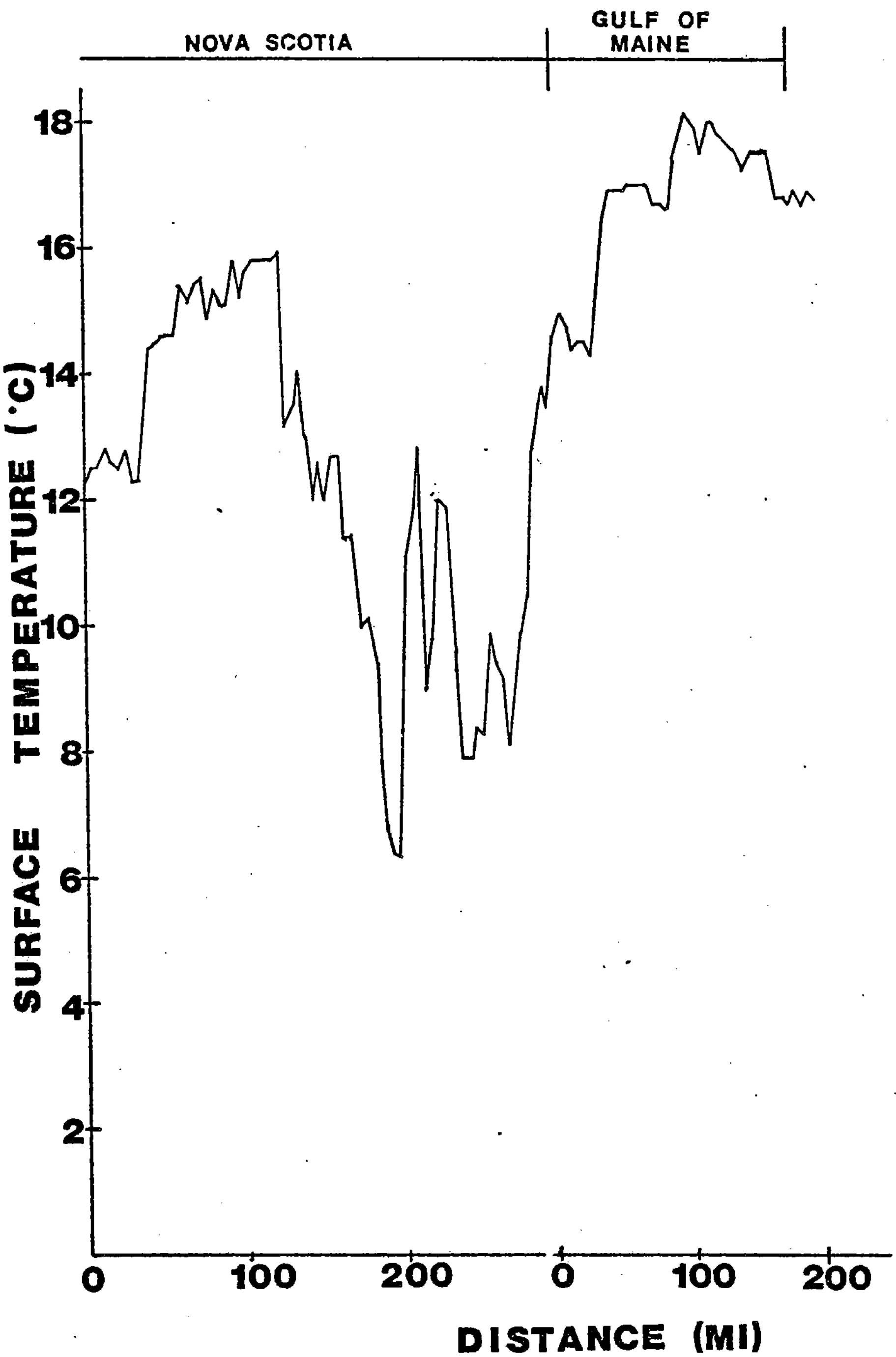


Fig. 6. Surface temperatures in a transect approximately parallel to the coast of Nova Scotia and across the Gulf of Maine from Nova Scotia to Gloucester.

WATER MASSES, continued

colder water of the Labrador Current (Oceanographic Atlas of the North Atlantic Ocean 1967)

A summary of the data collected at the routine stations shows how each of the measured characteristics varied within and between water masses (figure 7). In general, the physical factors (temperature, salinity, light penetration, and depth of mixed layer) more clearly defined the differences among the water masses than did the chemical and biological factors measured (oxygen, silicate, and zooplankton biomass).

The abstracts that follow present data pertinent to the boundaries of these water masses and to a transect across them.

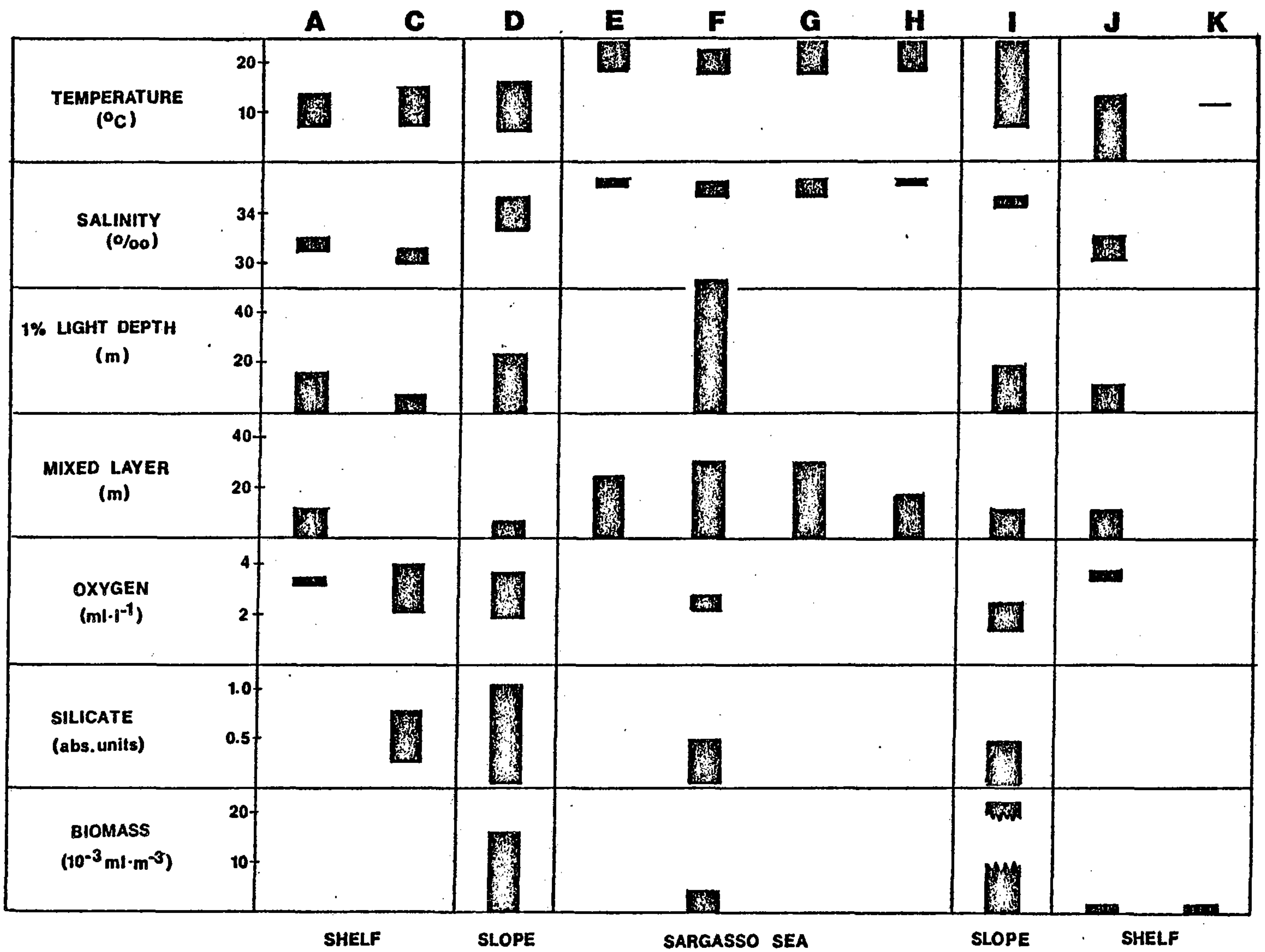


Fig. 7. Summary of data from routine stations conducted during W-40. Letters identify the stations. Bars show the range of values found at each station for the environmental factor listed in the left-hand column.

WATER MASSES, continued

Interpretations of Bathythermograph transects while Crossing the Gulf Stream: A Study of Gulf Stream Eddies

Wendy L. Meyer

ABSTRACT. The Gulf Stream is a thermodynamically definable body of water in the Atlantic ocean. A distinct bathythermographic (BT) profile is seen when crossing the north wall of the stream shown by a drastic surface temperature change and also a decline in the slope of the profile signaling entrance into that warm water mass.

Gulf Stream eddies are also definable using BT profiles for they are enclosed by a ring of Gulf Stream water retaining the characteristics of the stream for a time and containing either warm Sargasso sea water of cold slope water from the north in its interior.

The purpose of my project was to examine BT profiles taken near and through the Gulf Stream for evidence of the Gulf Stream itself, Gulf Stream rings, and unusual water masses of the same scale.

BT profiles suggested that station D was at or near a boundary between warm and cold water. The data were later confirmed by satellite information showing the station was on the boundary between shelf and slope water (figure 3). We crossed the northwest wall of the Gulf Stream on 14 June 1978 (figure 8) and entered the Sargasso Sea on 15 June 1978. From then to Bermuda we remained in Sargasso Sea water.

Returning north we crossed a pocket of warm Sargasso water and a possible cold-core eddy. We took station I within that water mass (figures 4 and 9). After crossing the Gulf Stream proper, we entered slope water, then crossed the edge of a possible warm eddy (figures 4 and 9).

These BT profiles provide a surface-truth corroboration of the satellite data and also provided information on water mass changes at depth.

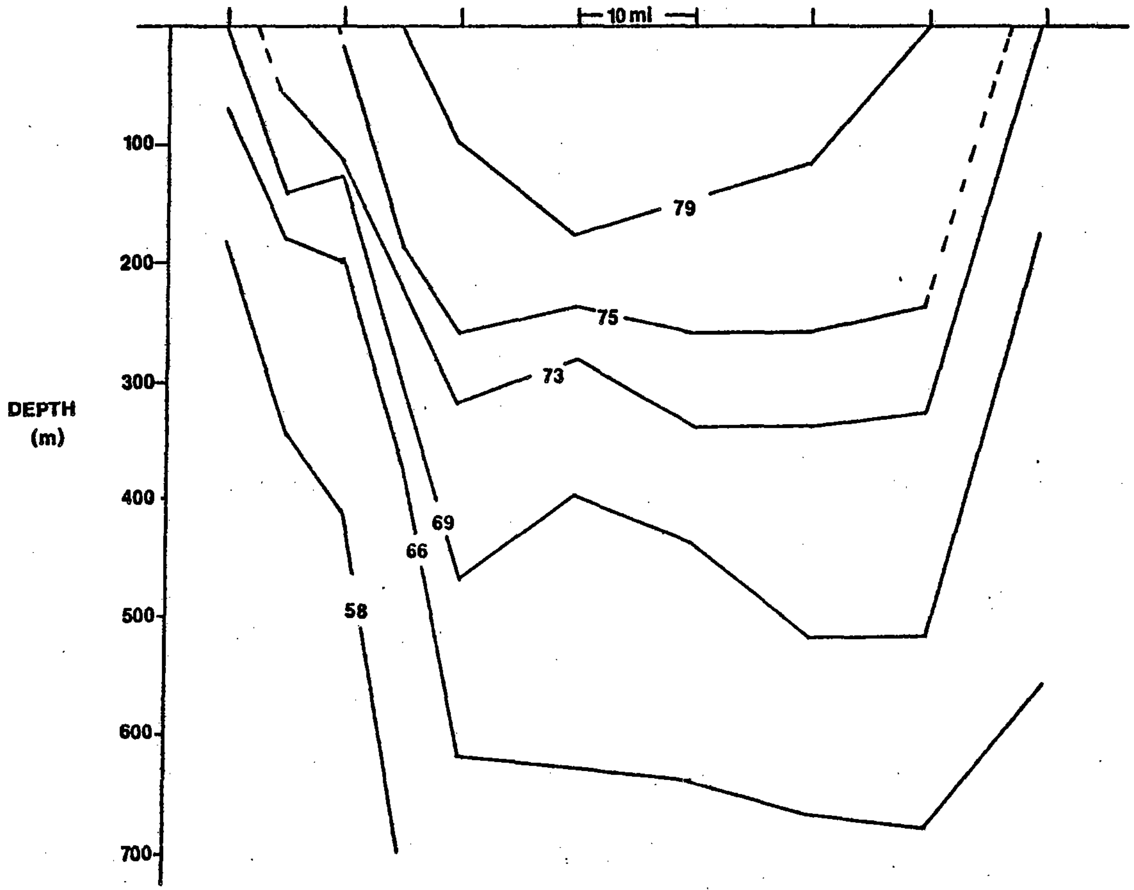


Fig. 8. Bathythermograph profile of the Gulf Stream from 37° 44.2' N and 68° 53.4' W to 37° 23' N and 67° 57' W, conducted at 5 and 10 mile intervals, as shown, from 1430 on 14 June 1978 to 0100 on 15 June 1978.

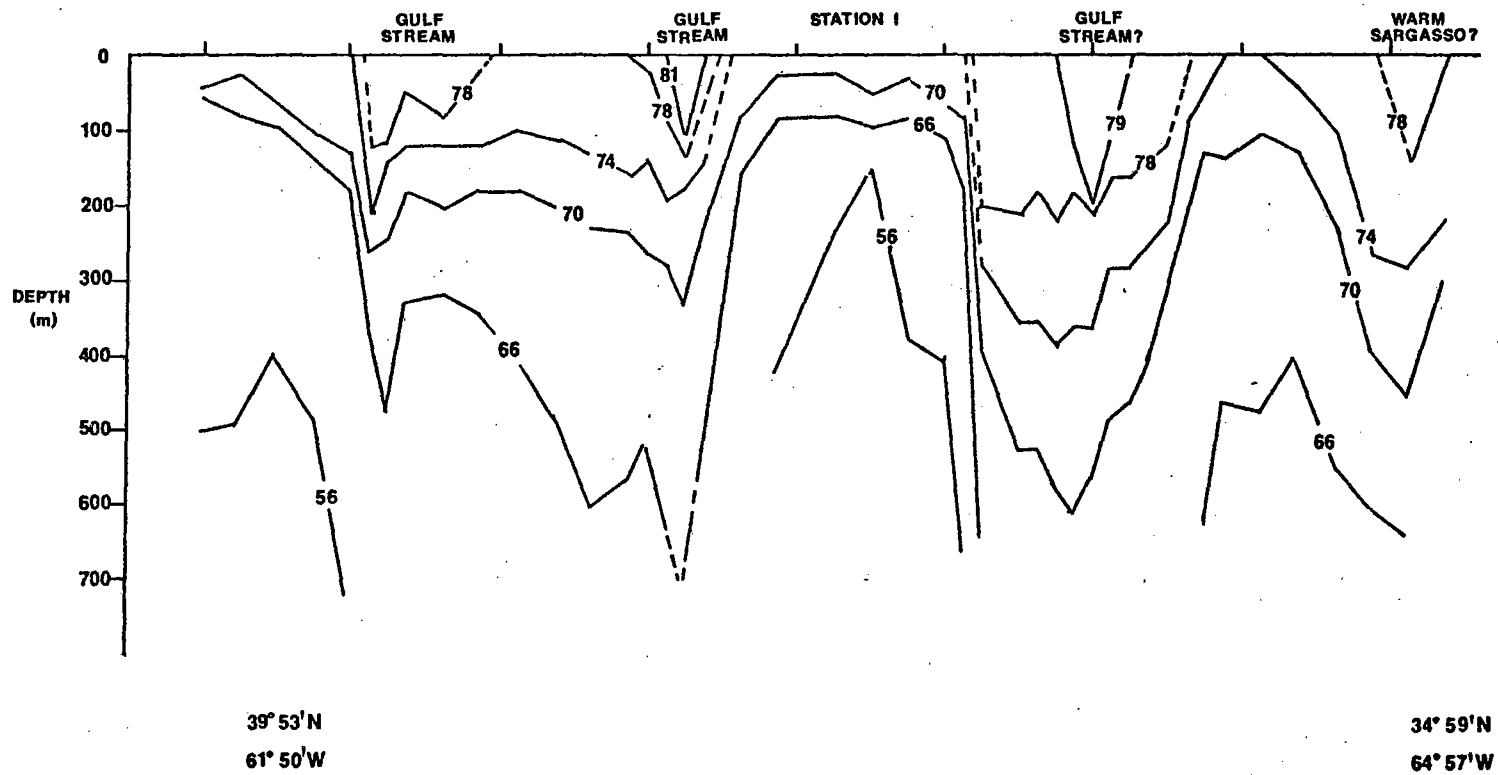


Fig. 9. Bathythermograph profile from the Sargasso Sea north of Bermuda through a possible cold core eddy (station I, sandwiched between apparent Gulf Stream features) and then through the Gulf Stream itself. See figure 4 for satellite features.

WATER MASSES, continued

## A Possible Gulf Stream - Sargasso Sea Edge Effect

Carl Baum

ABSTRACT. The transition zone between two or more diverse environments and their communities is termed an ecotone. An ecotone community commonly contains many of the organisms of the adjoining communities as well as additional organisms unique to the ecotone. The tendency for development of increased diversity and population density within this zone is referred to as the "edge effect".

An Isaacs Kidd midwater trawl (#2) was conducted in the transition zone between the Sargasso Sea and the Gulf Stream (34°59'N by 064°57'W), as born out by bathymetric data (figure 7). While no separate measurements of diversity and population density were available for the two water masses immediately adjacent to the trawl site, preliminary qualitative inspection of the trawl sample revealed evidence of relative gigantism among several groups of organisms (Table 3 ). Increases in size range of four organisms were on the order of 2 to 3 times those normally encountered in samples from slope and Sargasso waters. This occurence, also noted in a similar location on W-34, may not reflect the edge effect in the strictest sense. and may merely represent an anomaly in sampling. However, it may indeed be of ecological significance and warrants further investigation on future cruises.

*

Table 3. Examples of relative gigantism of organisms sampled in a transition zone between the Sargasso Sea and the Gulf Stream.

| Organism | Mean Size Normally Encountered (cm) | Size in IKMT-2 Sample (cm) |
|---|---|---|
| *Gonostoma elongatum* | 9 | 23 |
| *Argyropelecus* sp. Hatchet fish | 2 - 3 | 4 |
| *Sergestes* sp. | 3 | 9 |
| *Beroe* sp. Ctenophore | 2 - 3 | 10 |

WATER MASSES, continued

## Phytoplankton Distribution and Diversity

Charles Willauer

ABSTRACT. Phytoplankton tows were done in warm shelf water, Sargasso Sea, and cold shelf water to examine differences in abundance and species diversity of phytoplankton. Dinoflagellates, especially *Ceratium* species, were predominant in the Sargasso Sea. A diatom, *Coscinodiscus* sp., was abundant in both warm and cold shelf waters. On the whole, diversity was higher in the Sargasso Sea than in shelf water while abundance of phytoplankton was greater in shelf waters.

W-40 PROGRAMS, continued

Leg I: Woods Hole to Bermuda

New York Bight Pollution Station

Physical and Chemical Factors in the New York Bight

Betsy Monigle

ABSTRACT. Large quantities of dissolved and suspended waste materials from the New York - New Jersey metropolitan area are transported into the New York Bight by estuarine runoff and ocean dumping. Previous studies have shown that the flow of pollutants and nutrients varies with seasonal fluctuations in temperature and in circulation, which in turn is influenced by winds and the amount of fresh water coming from the Hudson.

Station A, off Long Island (figure 3), was used as a control site for station C in the New York Bight to study the physical and chemical factors that might be influenced by the pollutants.

Light intensity measurements showed that the euphotic zone in the Bight (7.7 m) was much more shallow than in the control station (15 m), demonstrating the expected greater turbidity in the Bight area. Temperature profiles were similar while the salinity profiles showed that the Bight definitely contained more fresh water than the control station (figure 10).

Oxygen concentration at the surface in the Bight was somewhat greater than in the control station. The oxygen profile showed a minimum beneath the euphotic zone in the Bight but not in the control station (figure 10). The silicate profile showed a maximum at the same depth as the oxygen minimum (figure 10). These data suggest that silicate was taken up at the surface by primary production in the Bight and that respiration beneath the euphotic zone possibly included the decomposition of diatoms.

These findings suggest that the effects of pollutants may not be seen in the surface layers of the New York Bight, since $O_2$ levels remain high, but they do not eliminate the possibility that the pollutants may affect the water beneath the euphotic zone and may account for oxygen depletion at mid-depth.

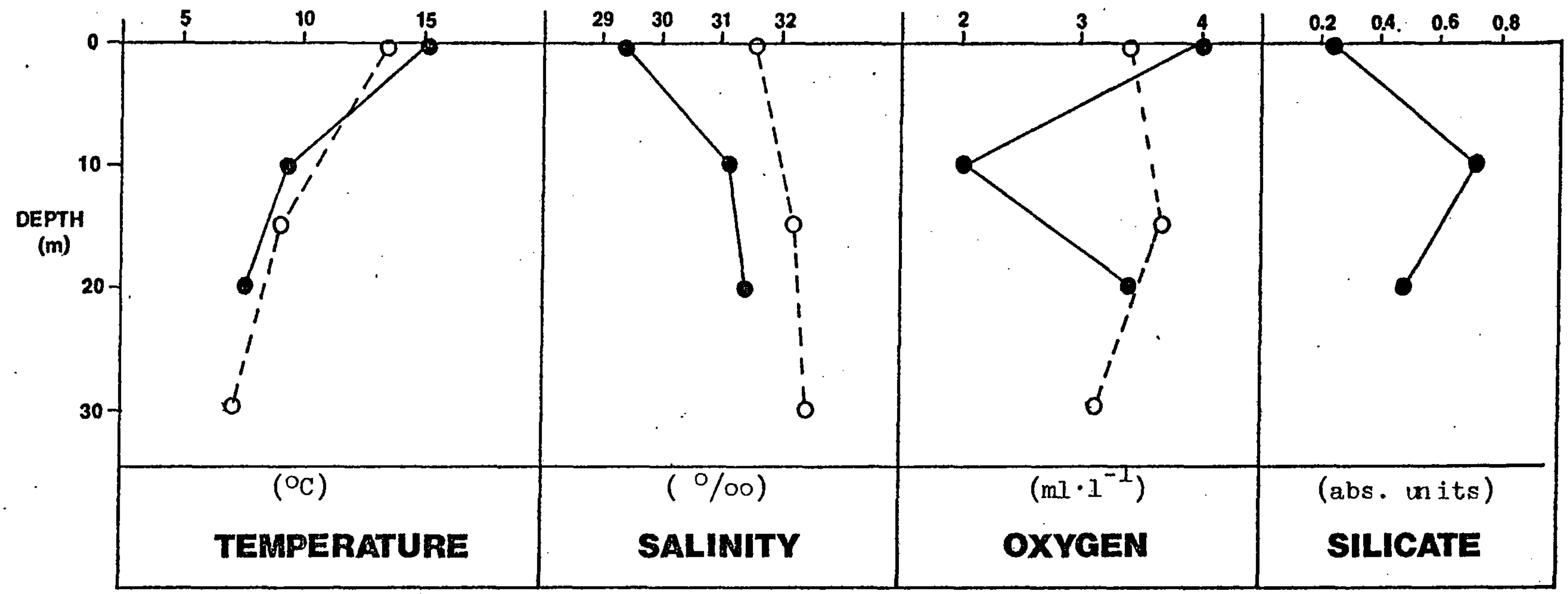


Fig. 10. Physical and chemical characteristics of New York Bight station C (black circles) compared with control station A off Long Island (white circles).

Leg I continued

Primary Productivity of the New York Bight

Pam Poindexter

ABSTRACT. Phytoplankton productivity in the New York Bight area was compared with that of two similar control stations using the Winkler method of oxygen analysis after incubation in light and dark BOD bottles. Greater photosynthesis occurred in the New York Bight (4.19 g C $m^{-2}$ $d^{-1}$) than at other stations (1.86 and 1.47 g C $m^{-2}$ $d^{-1}$, respectively). Raw sewage and estuary runoff, as estimated from salinity data, probably increased the amount of dissolved inorganic nitrogen and thus the rate of photosynthesis. The rapid decrease of light intensity with depth of water in the New York Bight (station C, figure 5), compared with the control stations, was not associated with a decrease in gross photosynthesis. Toxic effects on primary production were not seen, although no prediction could be made about possible effects higher up in the food chain.

Leg I, continued

## 24-Hour Stations

### Diurnal Changes in Silicate and Oxygen Concentration

Betsy Monigle

ABSTRACT. Changes in silicate and oxygen concentrations over a 24-hour period may show the effects of phytoplankton activity. During daylight hours silicate could decrease due to uptake by diatoms and oxygen could increase due to photosynthesis. At night silicate would appear to increase if it were not taken up and oxygen would decrease due to respiration. Silicate analyses were done by Strickland and Parsons (1968) and oxygen was done by the Winkler method at the three 24-hour stations.

Some evidence of diurnal periodicity in oxygen and silicate levels was seen at station D (figure 11). Silicate concentrations in the euphotic zone changed without an explicable pattern, and these changes may have been related not to biological activity but to physical factors such as mixing and currents. Such factors may have brought about changes in silt at 200 and 400 meters. Oxygen concentrations in the euphotic zone showed definite evidence of biological activity, with possible inhibition at the surface at 1535 hr and decreases at depth at night related to the increased respiration associated with migrating animals.

Silicate concentration showed no detectable diurnal changes at station F, as would be consistent with the stability of the water column in the Sargasso Sea and its low level of productivity. Oxygen values also suggested little diurnal biological activity at this station.

Silicate concentrations were not detectable in the euphotic zone at station I (possible cold core eddy, figure 4) at any time during the 24-hour period. Oxygen values in the euphotic zone also did not vary greatly with time, but were higher than in the Sargasso Sea consistent with temperature differences and presumed differences in productivity levels.

In summary, evidence of diurnal periodicity of silicate and oxygen concentrations occurred at station D in continental slope water but not in the less productive waters of the Sargasso Sea or the cold core eddy.

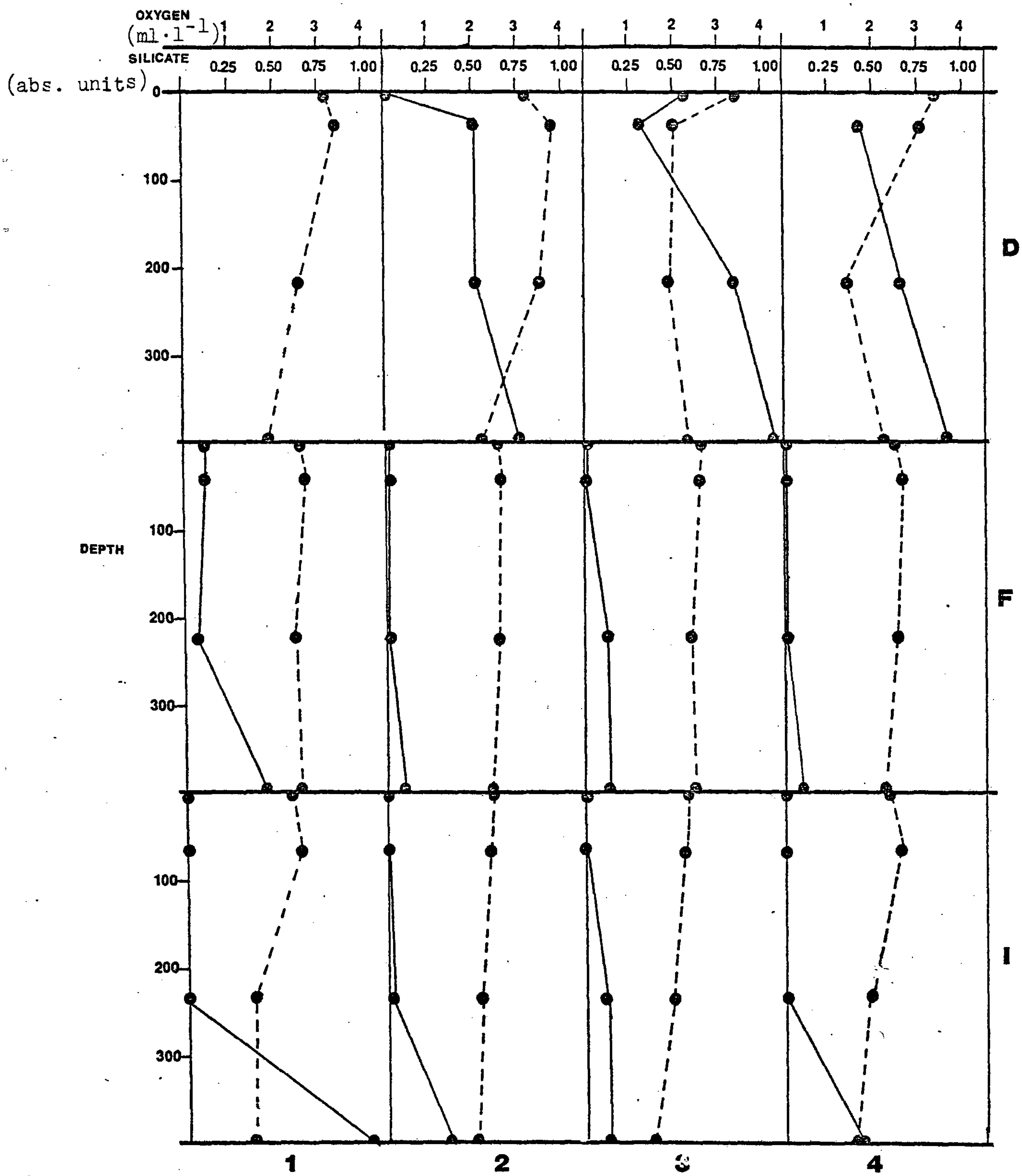


Fig. 11. Changes in silicate (solid lines) and oxygen (dashed lines) concentrations with depth, time of day, and between water masses. Depth is in meters. Numbers at the bottom of the figure represent time of day in six-hour intervals beginning at 0800 hr. Letters on the right-hand side show stations in the following water masses: D = shelf; F = Sargasso Sea; I = slope water in a cold core eddy.

Diurnal Periodicity of Phytoplankton Pigments

Susan Savage

ABSTRACT. During two 24-hour stations, one in the Sargasso Sea and one in slope water north of the Gulf Stream, concentrations of chlorophyll a,b,c, and total carotenoids were measured. Analysis proceeded by the SCOR-Uneseco Work Group standard pigment determination using a spectrophotometer to measure absorbance of pigments extracted with acetone. In general, highest pigment concentrations were found at 0800 and lowest levels were found at 1400 in the slope water and 2000 in the Sargasso (figure 12). These low levels are due to a negative response to light. This is reflected by a possible drop in pigments/cell by 1400 in slope water and by downward migration by 2000 in the Sargasso. Decrease in silicates may also have influenced a drop in the Sargasso Sea and consumption by vertical migrators may have caused the 0200 drop in the slope water concentrations. The high levels of chlorophyll c indicate the majority of the population is Bacillariophycaea and Pyrrophyta. The presence of chlorophyll b indicates Chlorophyta must also be present.

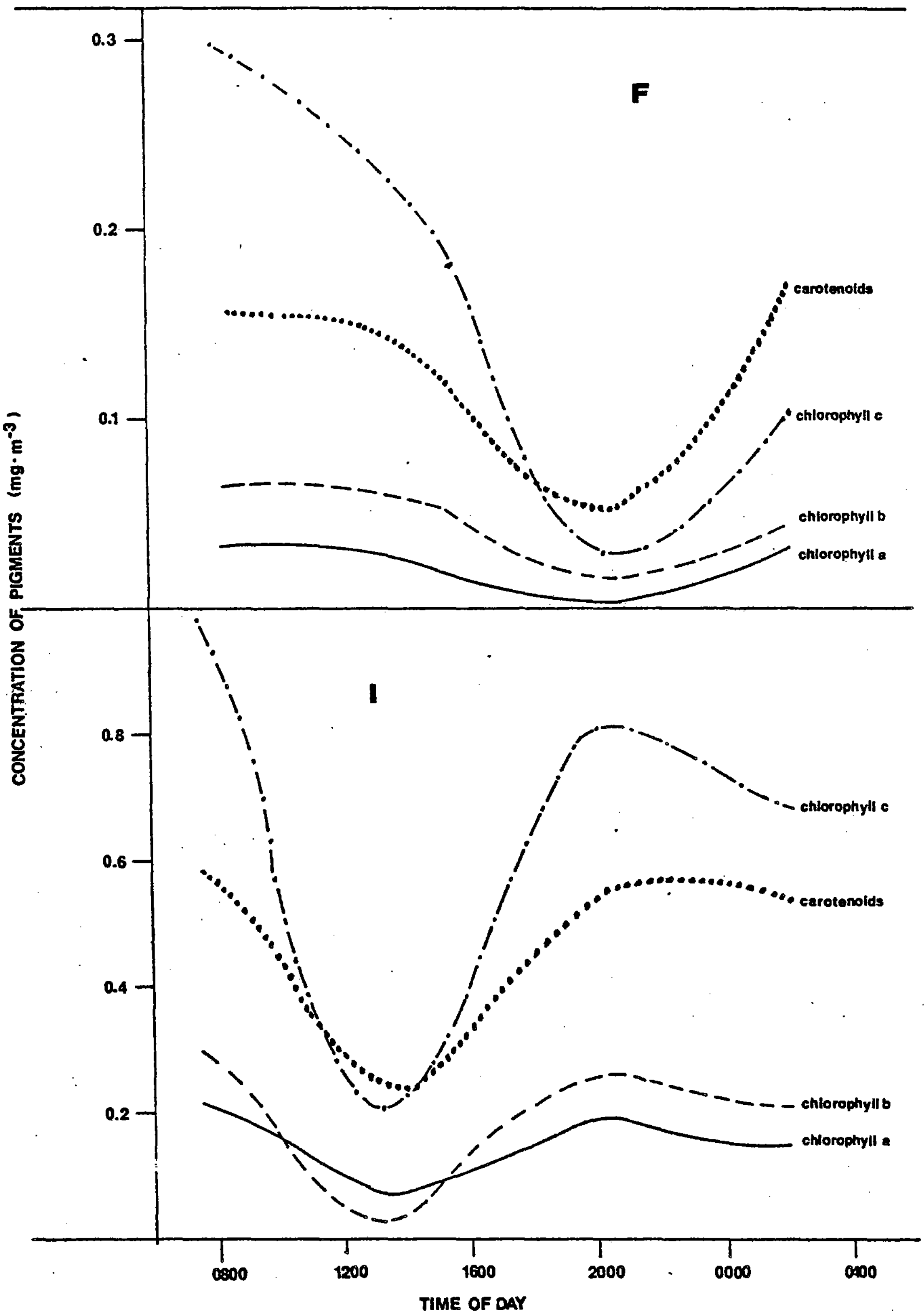


Fig. 12. Changes in concentration of plant pigments with time of day at two 24-hour stations. Station F = Sargasso Sea; station I = cold core eddy.

Leg I, continued

Vertical Migration of Zooplankton with respect to Light Intensities

Robert Breen

ABSTRACT. The purpose of this project was to record the influence of natural light intensities on migratory habits of zooplankton. For the gathering of data several nets were used: neuston at the surface, shallow meter net at 33 meters, deep meter net at 215 meters, and a bongo at 400 meters. A Kahl underwater irradiometer was used to measure light intensity. Data were collected on three twenty-hour stations and at four different times per station. Animal biomass was calculated by the method of volume displacement for each time and depth (figure 13). Isolumes were constructed for each day at 1% and 0.01% of maximum incident light. The organisms rose and descended faster than either isolume and it is doubtful that they followed either one. Zooplankton are highly sensitive to very low light levels, and it is possible that their rise was initiated by much lower light intensities. It is also possible that their rise from depth is initiated by another tropism.

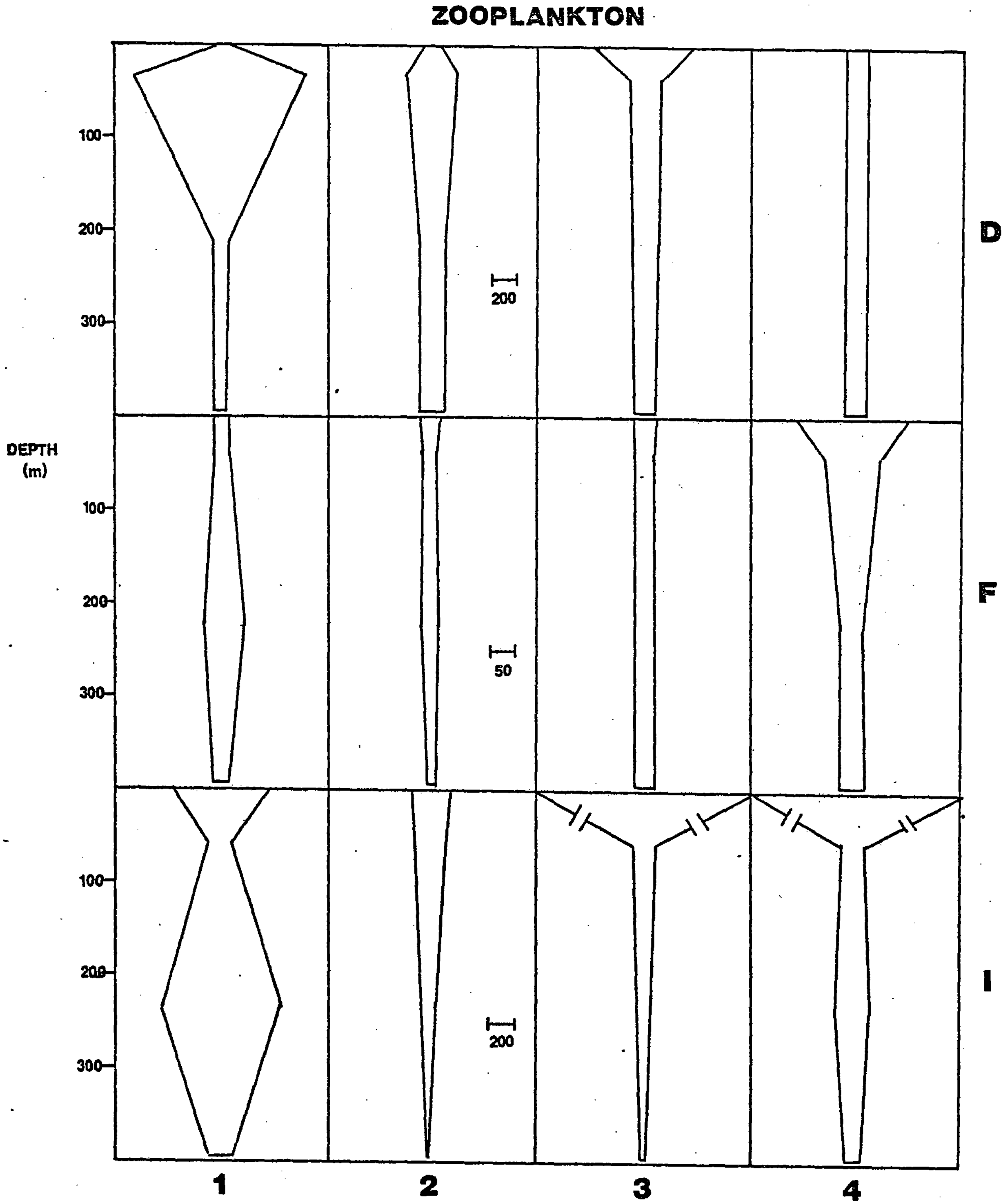


Fig. 13. Biomass of zooplankton ($10^{-3}$ ml·m$^{-3}$) by volume displacement with respect to depth, time of day, and water mass. Numbers along the bottom represent the time of day in six-hour intervals, beginning with 0800 hrs. Stations are represented by letters on the right-hand side as follows: D = shelf; F = Sargasso Sea; I = slope water in a cold core eddy.

Leg I, continued

Vertical Migration of Mesopelagic Fish with Respect to Various Physical Factors

Roderic B. Mast

ABSTRACT. Mesoplegic fish live from 200 to 1000 meters in depth. This report deals with the results of three 24-hour stations and the biomasses of mesopelagic fish captured. The purpose was to determine whether vertical migration patterns of mesopelagic fish are related to changes in light intensity, temperature, and dissolved oxygen content. Migration patterns (figure 14) were directly related to light intensity and the degree to which light penetrates the water. Temperature of the water at depth did not vary greatly over a 24 hour period and seemed to have little or no effect. Oxygen content was not related to vertical migration.

*

Phasing in the Vertical Migration Habits of Mesopelagic Fish

Martha E. Mather

ABSTRACT. The vertical migratory phase relationship between the mesopelagic fish families Myctophidae, Stomadtidae, Gonostomatidae, Sternoptychidae, and Chauliodidae was investigated. It was hypothesized that (1) there was some synchronization between the migration habits of the various families and (2) there was a phase relationship between the fish as a whole and the presence of zooplankton. If indeed fish migrate for feeding purposes, then there should be a correlation between fish biomass and possible food items such as copepods, eucarids, peracarids, and chaetognaths. Simultaneous net tows were made at four depths over a 24-hour period. The organisms were sorted taxonomically and then measured for mass by volume displacement. This was done in three stations, two in slope water and one in the Sargasso Sea. Data were analyzed by graphing the biomass of each tow with time of day. No relationship was found between the migration habits of the various midwater fish families. The fish often migrated simultaneously but not in a synchronized fashion. If an increase in fish biomass coupled with a decrease in zooplankton biomass (see figures 13 and 14) indicated feeding activity on the part of the fish, then feeding took place on the ascent and the descent but not at the surface at all three stations.

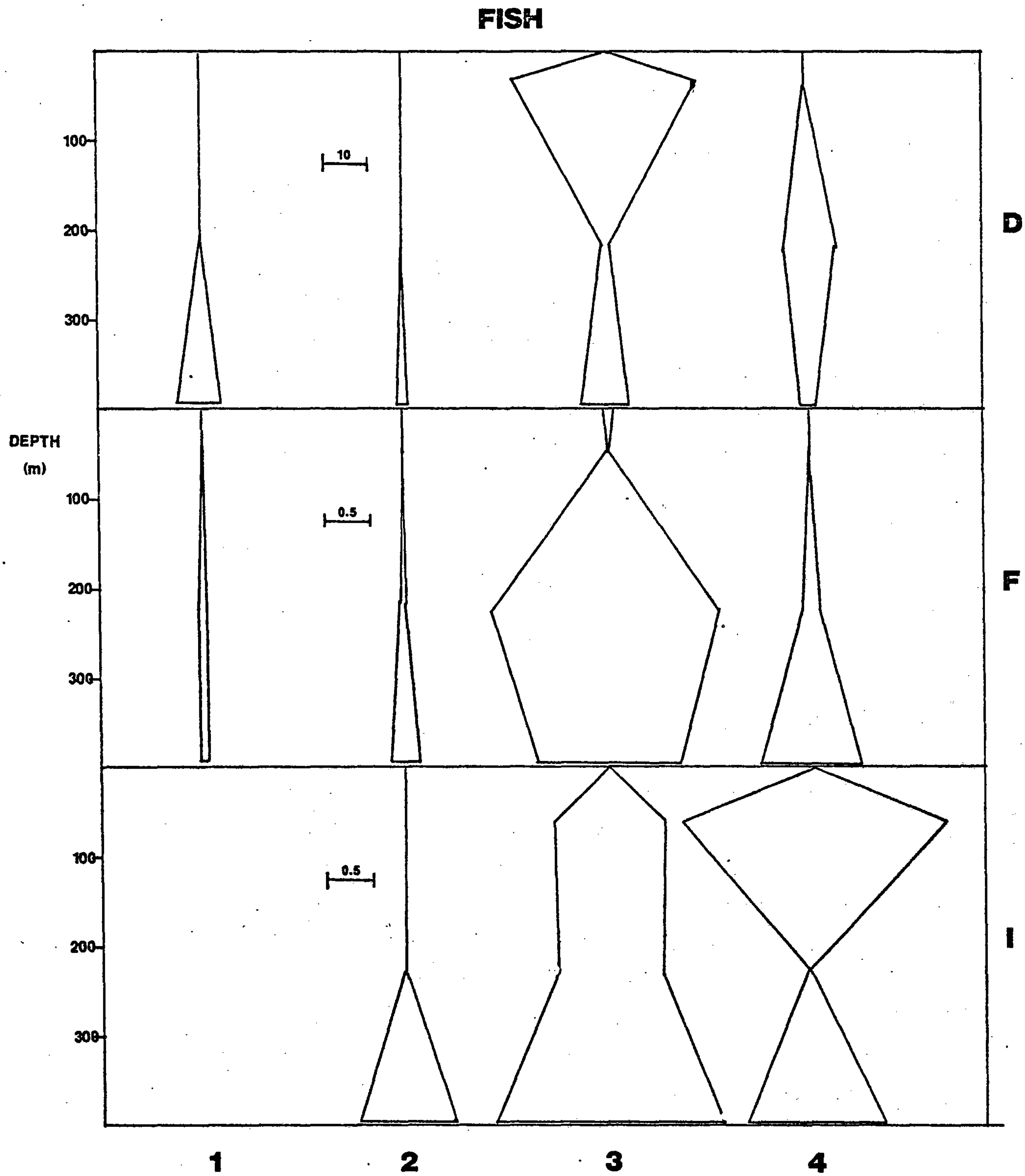


Fig. 14. Biomass of fish ($10^{-3}$ ml·m$^{-3}$) by volume displacement with respect to depth, time of day, and water mass. Numbers along the bottom represent the time of day in six-hour intervals, beginning with 0800 hrs. Stations are represented by letters on the right-hand side as follows: D = shelf; F = Sargasso Sea; I = slope water in a cold core eddy.

The Biomass of Myctophid Stomachs as the Indication of Feeding Habits

Tracy Kuck

ABSTRACT. Myctophid fish from two 24-hour stations were analyzed to study whether feeding habits were related to depth, time of day, or availability of food. Stomachs were removed by dissection and weights were estimated by volume displacement. Ratio of stomach to whole fish volume displacement was assumed to represent fullness. A wide range of fullness ratios was seen at 400 meters (figure 15). At each station this fullness at depth seemed to be related to time of day, ie., the fish were fuller during daylight (before migration) than during the night (during and after migration). Fish were at the shallow depths only during the pre dawn samples; the fish at station I appeared to be full while the fish at station D were less full than fish at 215 m. These differences may reflect different feeding behaviors at different latitudes. Overall, myctophids tended to feed between 1400 and 2200 hours. There was no significant correlation between stomach:fish biomass ratio and biomass of food present (r = 0.0686), suggesting that food per se was not the only stimulus for eating.

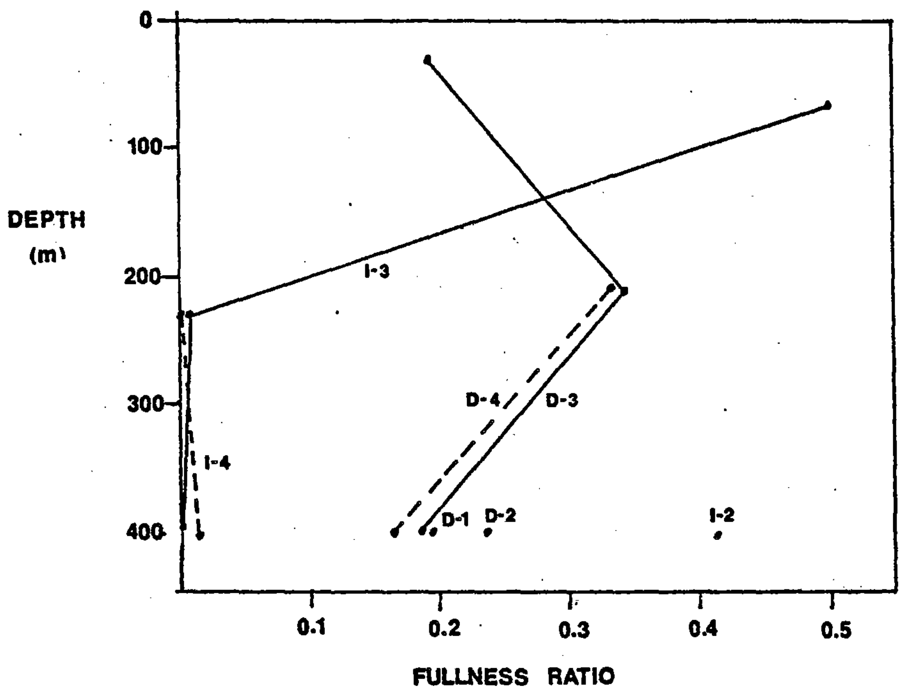


Fig. 15. Ratio of stomach volume to total fish volume (fullness ratio) with respect to depth of water column and time of day at stations D (shelf water) and I (slope water in a cold core eddy). Numbers after the station letters represent time of day as in figure 14. Curves connect values from different depths taken at the same station and at the same time of day.

Leg I, continued

Patterns of Vertical Migrators in Different Water Masses

Gail M. Lima

ABSTRACT. Vertical migration is a phenomenon that involves the majority of the organisms in the mesopelagic zone. Organisms expend vast quantities of energy migrating up and down the water column daily. An organism's life strategies will be selected to best fit the environmental conditions in which it lives.

Data was collected from three twenty-four stations. Simultaneous tows were done at four different depths approximately every six hours. The stations were of various areas; slope waters, the Sargasso Sea, and a possible cold core eddy. Coelenterates and copepods were studied to compare patterns of vertical migrators in different water masses. Copepods clearly migrated at stations D and I, in slope water, but a migration pattern was not obvious at stations F, in the Sargasso Sea (figure 16). Coelenterates may have migrated at station I, but elsewhere the coelenterate patterns were probably due to patchiness. The relationship between migration patterns and environmnetal factors suggested that vertical migration behavior varies with water mass because of differences in productivity.

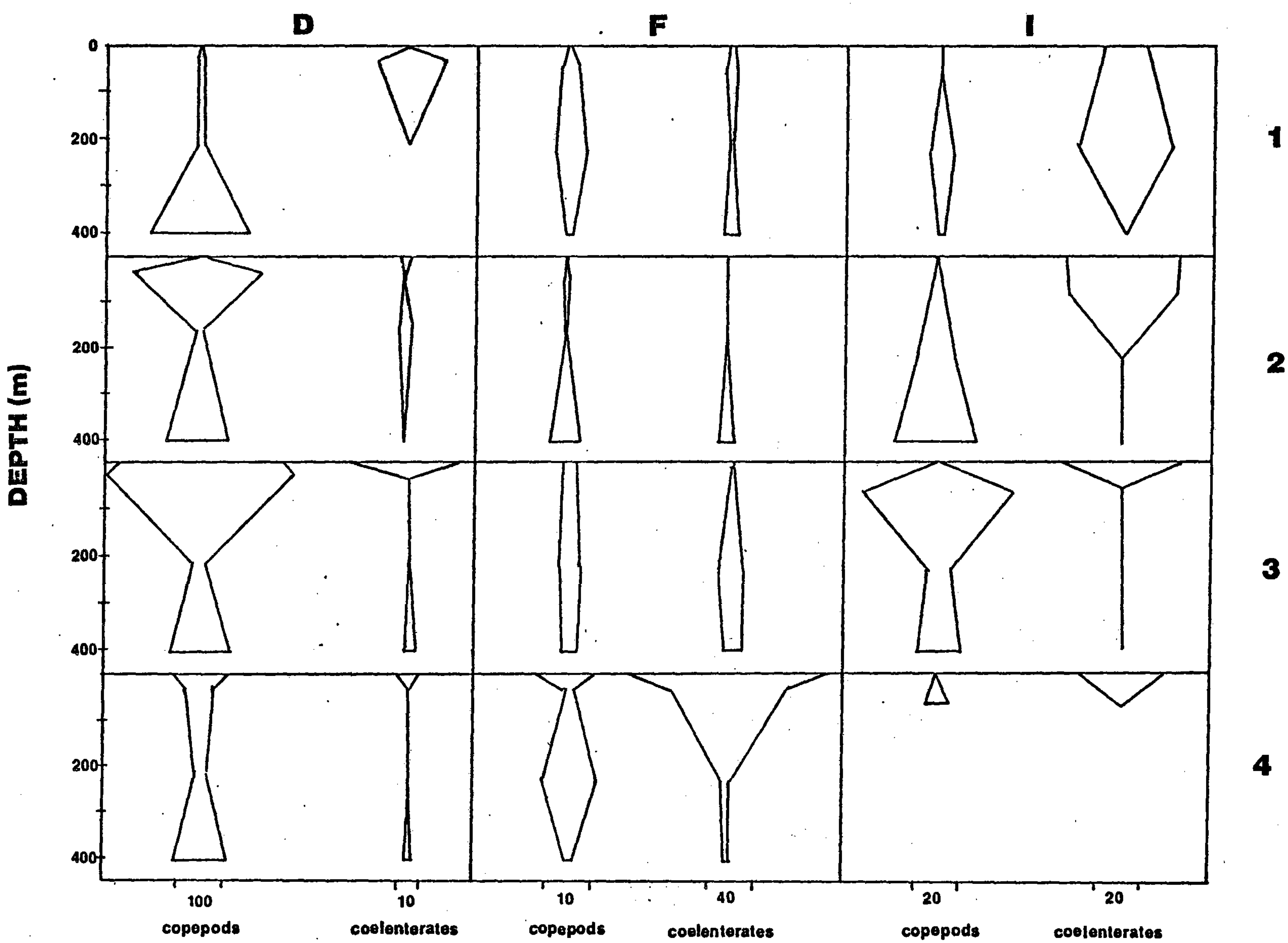


Fig. 16. Differences in copepod and coelenterate distributions over time at three 24-hr stations (D = shelf; F = Sargasso Sea; I = cold core eddy). Biomass given in volume displacement ($10^{-5}$ ml$\cdot$m$^{-3}$).

## Illustrations of Vertical Migrators and Other Zooplankton

Kathy Strauss

ABSTRACT. The purpose of this project was to draw and classify as many species of vertical migrators and other zooplankton as possible during the six week cruise. Preliminary sketches were made of each species soon after being brought aboard. These rough drawings were then transferred to illustration board in preparation for the final drawing. The drawings were done in three media: pencil and carbon dust, pen and ink, and watercolors. Three pen and ink drawings are included in this cruise report (figures 17-19). The remainder of the drawings will be kept on file in the SEA office.

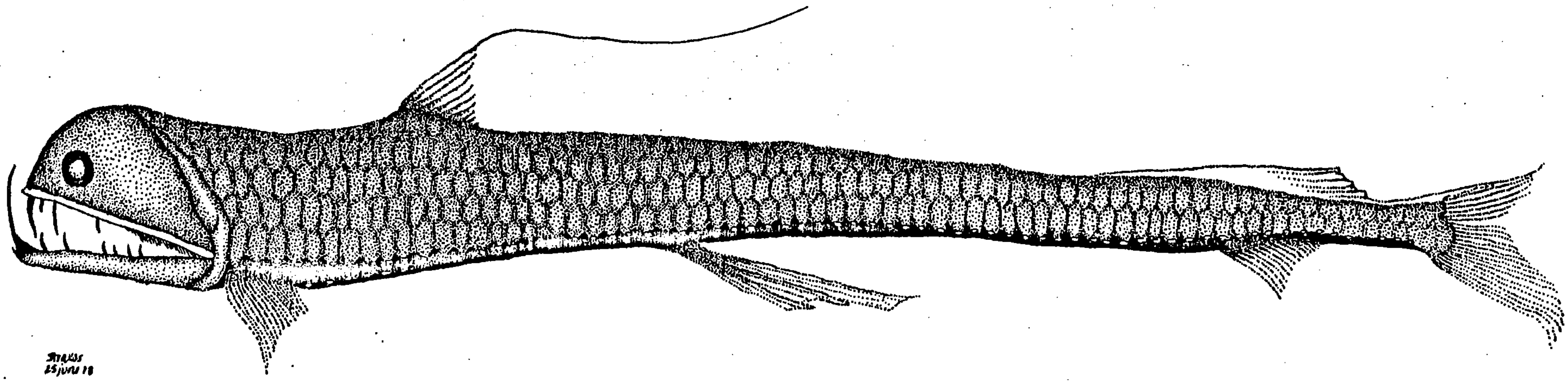

Fig. 17. The midwater viper fish, Chauliodus sloani.

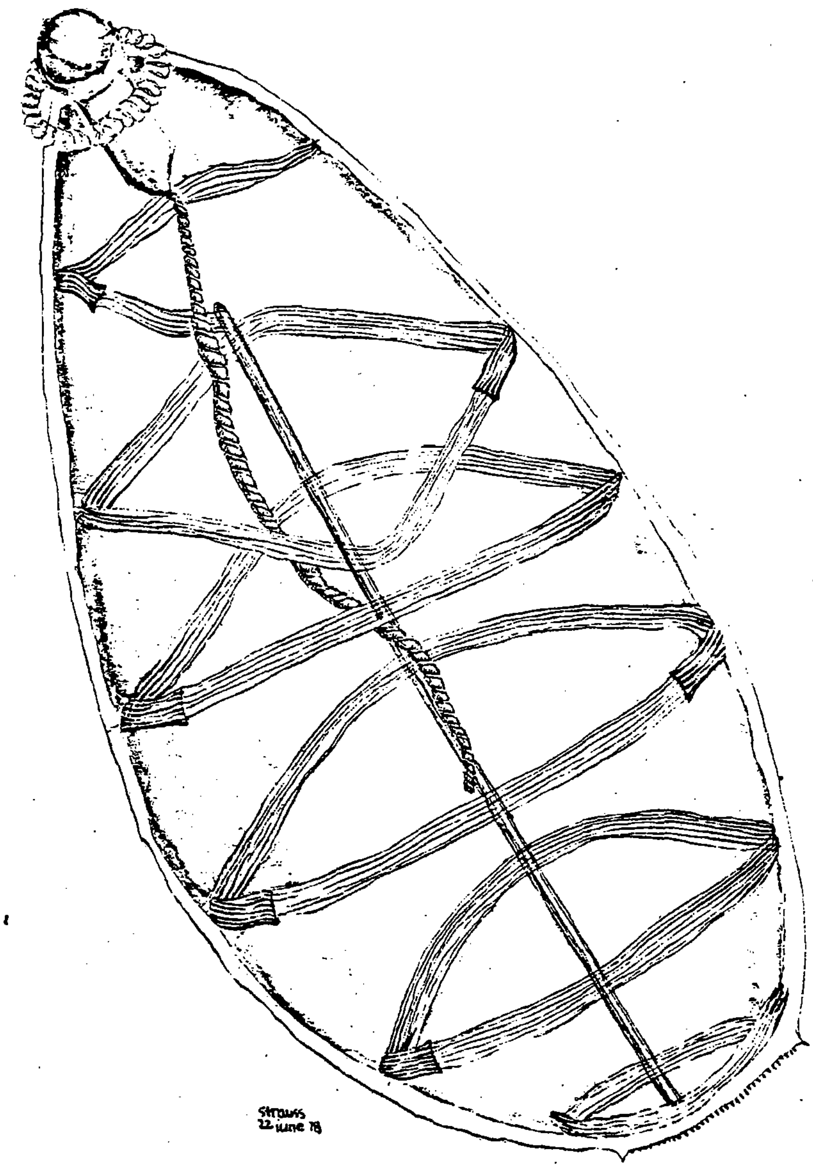


Fig. 18. An unidentified tunicate (salp).

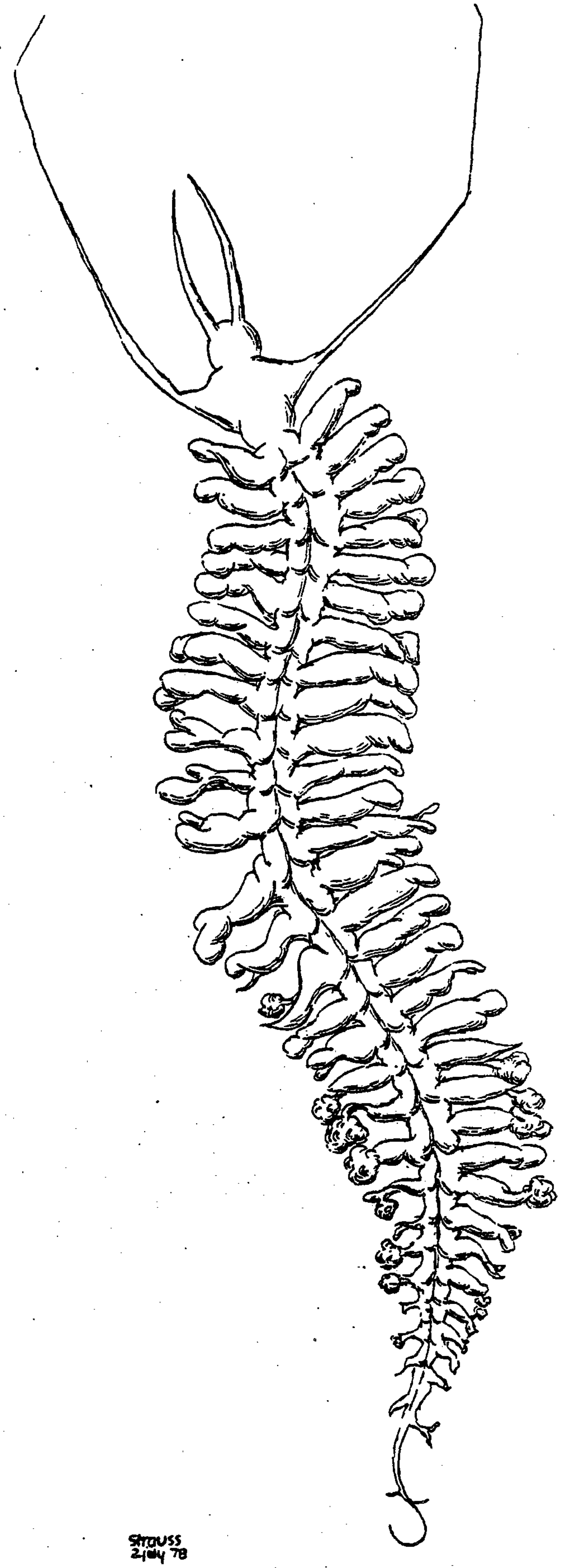

Fig. 19. The polychaete worm, Tomopteris sp.

Leg I, continued

Zooplankton Pigment: Methodology for Determination and Their Distribution

Jean Sherwood

ABSTRACT. This study was modeled after several studies done by P.J. Herring on the depth distribution of carotenid pigment and carotenoproteins. The purpose was to show that a midwater peak in carotenoid concentration exists due to several biological and physical factors. The pigments were extracted from random samples of zooplankton taken from several depths at two different stations and were measured spectophotometrically. The data did not supply evidence to the original hypothesis, but it did give support to another of Herring's theories -- that pigment-protein combinations (such as the blue carotenoids) occur more readily in areas of warm water and high light intensity. Station I was such an area, being located in a possible cold core eddy. The data from this station indicated a lack of yellow or orange carotenoids and the presence of blue carotenoids (675 nm) at all depths (figure 20A). Station J was located off the coast of Newfoundland and was characterized by cold surface waters and low light intensity. At this station, the yellow carotenoids (∿480 nm) were present, but blue carotenoproteins were lacking in the samples (figure 20B). These results indicate that the combination of pigment and protein to form the blue carotenoids was occurring less readily in the colder, less illuminated waters than in the well-lit, warm waters of Station I.

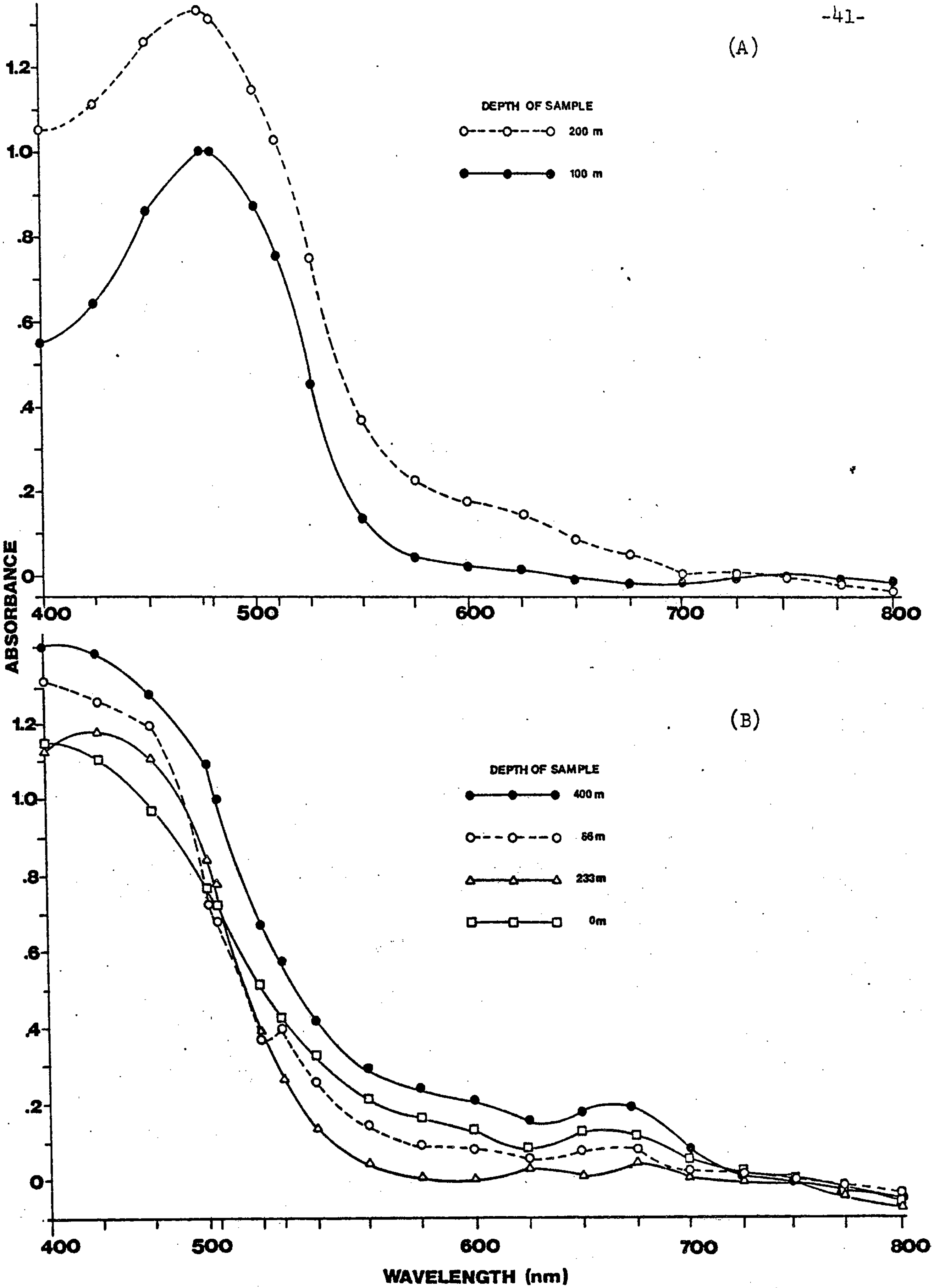


Fig. 20. Distribution of zooplankton pigments at stations I (above) and J (below) with respect to depth in the water column.

Genetic and Environmentally Induced Variability in Crabs

Martin Tracey

ABSTRACT. A large assortment of benthic and *Sargassum* crabs were collected for later anaysis of genetic variations. This study is part of a larger program to distinguish the effects of the environment from genetic effects on variability of the species.

* *

W-40 PROGRAMS

Leg II: Bermuda to Ile Saint-Pierre

Two Bermuda Coral Reefs and Related Factors

Belinda Spalding

ABSTRACT. The purpose of this study was to see how the zonation and distribution of Bermuda coral was related to the environmental factors of temperature, salinity, and oxygen concentration. Two reefs were selected for study: Tobacco Bay on the North Shore and Devonshire Bay on the south shore. A transect was selected at each site and biotic data were recorded on an underwater plate. Temperature and water samples for salinity and oxygen were taken near shore and over the reef at each site.

At Devonshire Bay the bay water was saltier and cooler than water over the reef crest(figure 21) while at Tobacco Bay, the lagoon water was fresher and warmer than water further out. At both sites, inshore water was less oxygenated than water further out. Corals were not seen inshore. Eleven species of coral were seen further out in Tobacco Bay (table 4). Total biomass was estimated by eye to be similar at both sites. It was assumed that the environmental conditions measured could have accounted for the lack of coral growth near shore. Other factors such as wave action and perhaps light intensity probably accounted for species and diversity differences.

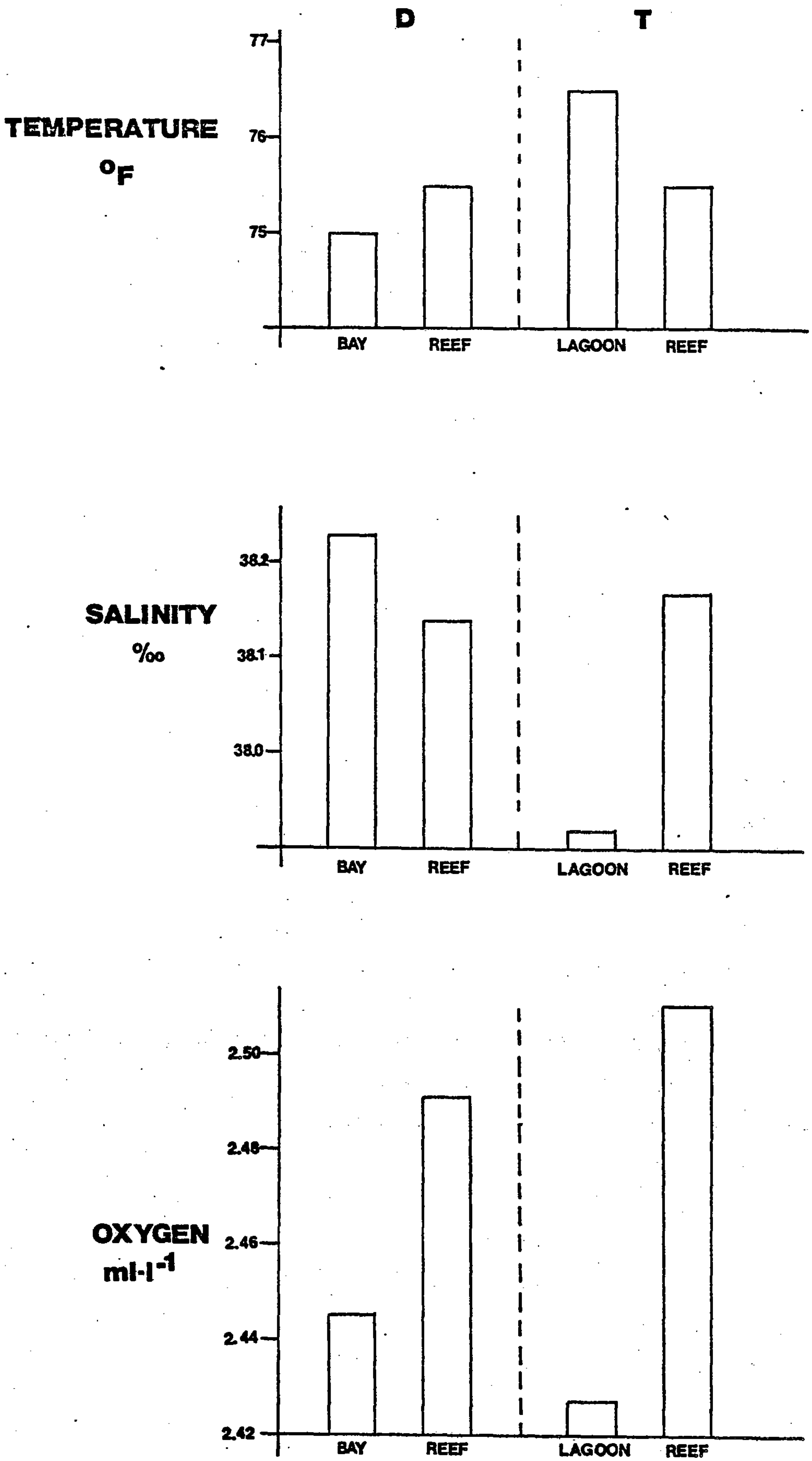


Fig. 21. Comparison of inshore and reef waters of Devonshire Bay (D) and Tobacco Bay (T) in Bermuda.

Table 4. Coral species found on the crest reef at Devonshire Bay and on a patch reef at Tobacco Bay, Bermuda.

| Species | Abundance and Location |
| --- | --- |
| Devonshire Bay | |
| Diploria strigosa | Dominant, covering about 15%. Mainly on crest face and beyond. 6" to 2.5' diameter. |
| Siderastrea siderastrea | Covered about 3% of reef. Reef face and bay mouth. 1.5' - 3' diameter. |
| Isophyllia sp. | 2 colonies. Bay engrance. 3-4" diameter. |
| Monastrea annularis | 1% coverage. Scattered from bay mouth entrance to reef and beyond. 1.5-3' diameter. |
| Plexaura flexuosa | Small amount. |
| Gorgonia ventilina | Several small on reef face. |
| Tobacco Bay | |
| Siderastrea radians | Dominant. 60% of all coral cover found from mouth of bay and out. 1' diameter. |
| Remaining hard corals about equal in abundance, found mostly on reef top. | |
| Oculina diffusa, Diploria strigosa, Monastrea annularis, M. cavernosa, Isophyllia sp., Porites sp. | |
| Soft corals: Pseudoplexaura porosa, Plexaurella grisea, P. flexuosa, Gorgonia ventitina. | |

Ecology of the *Sargassum* Fish, *Histrio histrio*

Carl Baum

ABSTRACT. Six Sargassum fish, *Histrio histrio*, ranging in length from 1 to 12 cm, were captured in association with *Sargassum* weed samples dip netted from the Sargasso Sea near Bermuda. These relatively docile fish adapted well to aquarium life aboard the ship and were available for extended observation. Their ecological relationship to the *Sargassum* weed and associated community was readily tested during legs II and III of the cruise and will be continued ashore.

Highlights of significant data collected to date are as follows:

1) Two specimens measuring approximately 12 cm (standard length) were captured in one 60-g clump of weed and later proved to be a mating pair. The fact that the female was not gravid at the time of capture, plus their continued coexistence in a five-gallon aquarium, indicated a possibility of long term pairing without the determent of cannibalism or territoriality generally associated with this species.

2) A total of four spawnings were partially or completely observed. Time intervals between spawning ranged from five to eight days and appeared to be inversely proportional to food availability. Total eggs per spawn were estimated at $3.2 - 4.0 \times 10^6$ with a mean size of 0.5 mm. Spawning related behavior lasted 24 hours and culminated consistently between 1700 and 1900 hrs local time. Elements of courtship involved close attention and physical contact paid to the female by the male for the duration of the 24 hours, but no elaborate display language or other ritualized behaviors were observed.

3) Female specimens were more aggressive in feeding than male, presumably to support the metabolic demands of roe production.

4) Observed prey capture strategies were energy conservative, utilizing surprise from camouflaged concealment and short stalking sorties in lieu of extended search and chase activity.

5) Sexual dimorphism has been tentatively established based on external features of coloration, dorsal spine length and ventral tassle size.

6) Two specimens became conditioned to associate approach of an aquarium net with feeding in three trials within less than 24 hours.

7) Six parasitic copepods, *Penella exoceoti*, were removed from their attachments on the external body surfaces of the mating pair.

Leg II, continued

## Sargassum community studies

Primary production and distribution of Sargassum weed in the North-western quadrant of the Sargasso Sea

Josh Drachman

ABSTRACT. The production and distribution of Sargassum weed in the north-western quadrant of the Sargasso Sea were studied using the light-dark bottle incubation method and Winkler titrations for productivity estimates and the Sargassum harvest from random neuston tows for biomass estimates. Experiment 1 gave negative values for production after 4 hour of incubation (table 5), suggesting that the weed was killed by the high temperature of incubation. In the second experiment, temperature and light intensity were both less than in experiment 1 and negative values for photosynthesis did not occur. Negative values for dark bottle respiration in both experiments indicate light leakage to dark bottles. Gross productivity estimates therefore could not be made.

Over the cruise track Sargassum was most concentrated in an area 40 miles north of Bermuda and a few miles south of the Gulf Stream.

*

Table 5. Summer (1978) productivity of Sargassum weed

| Incubation No. | Time of Incubation | Net Production ($mgC \cdot g^{-1} \cdot h^{-1}$) | Respiration ($mgC \cdot g^{-1} \cdot h^{-1}$) | Sargassum Biomass ($mg \cdot m^{-2}$) | Areal Production ($mgC \cdot m^{-2} \cdot d^{-1}$) |
|---|---|---|---|---|---|
| 1 | 0840-1240 | 0.17 | 1.00 | | |
| | 0840-1640 | -0.37 | -0.13 | | |
| | 0840-1900 | -0.66 | 0 | 0.29 | |
| 2 | 0800-2000 | 0.56 | -0.64 | 0.29 | 1.94 |

Comparisons of Sargassum and Fucus Communities

Maryann Wohlgemuth

ABSTRACT. The communities of Fucus, a Northwestern Atlantic rock weed, were compared with Sargassum fluitans, a pelagic algae found in the Sargasso Sea. Total numbers of organisms were much greater on the Fucus, probably because of the high level of productivity in the slope water. Diversity was greatest on the Fucus, contrary to my hypothesis that Sargassum would have higher diversity because of the stability of the Sargasso Sea. Possibly because the location where I collected weed was similar to a rock pool, which is a more stable environment than the open coast.

## Leg III. Ile Saint-Pierre to Woods Hole

## Continental Shelf Studies

### The Geologic History of Newfoundland

John Rikkers

ABSTRACT. On leg II of cruise W-40 an opportunity arose to examine the geology of the Newfoundland coast surrounding the Great Bay de l'Eau and Fortune Bay (figure 22). Cambrian/Ordovician basalts interbedded with calcite were seen, overlain by Pennsylvanian red sandstone/pebble conglomerate sequences. The general topography of the coast showed strong evidence of extensive glacial erosion and deposition during the great Pleistocene ice advances. Glacial grooves and striations previously observed on Ile St. Pierre showed the direction of the last significant glacial movement to be NW-SE. Examination of bathymetric charts showed the presence of numerous canyons and valleys of glacial rather than fluvial origin. Among these is the Laurentian Channel, whose origin is glacial, but whose position was probably determined to a large extent by underlaying rock structures. All told, fragments of a geologic record covering over 1 billion years were seen.

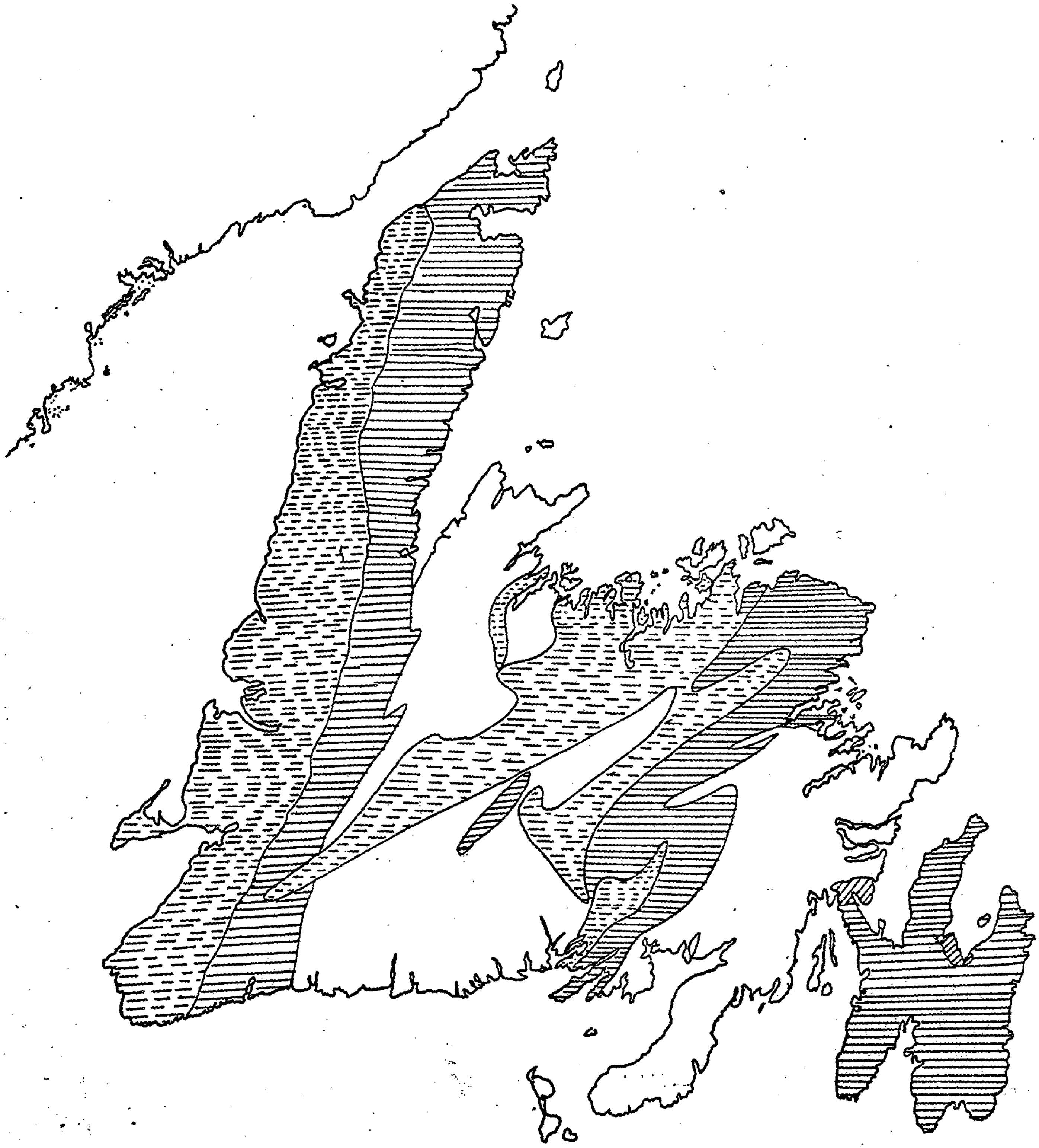

Fig. 22. A simplified geologic map of Newfoundland. Solid stripes = Pennsylvanian; Broken stripes = Ordovician; and Clear spaces = Devonian. After Barret, 1964.

Leg III, continued

Bottom Sampling Techniques and Analysis

Jacek Sulanowski

ABSTRACT. The phleger corer was used eight times in an attempt to obtain the top few centimeters of bottom sediment together with a layer of water from the bottom-sea interface. None of these cores successfully obtained the desired sample: either the bottom was rocky and no core was obtained or it was muddy and the instrument sank so deep that the top of the core sample was buried beneath the surface. Thirteen clam shell grab samples were partially successful and sediments from two of these samples were analyzed for physical and organic materials (see Abbott, this report).

Meio-infaunal Diversity of two Benthic samples off the coast of Nova Scotia

Susan Abbott

ABSTRACT. Meio-infaunal diversity was studied in two samples from benthic stations off the coast of Nova Scotia. The samples were preserved in formalin and stained with Rose Bengal, after sieving with 64-micron mesh to remove silt. Organisms were removed by spreading out the sediment in a sorting tray, then identified with the use of a dissecting microscope. Sediments were also examined with the dissecting microscope.

The organisms from sample B were larger and more complex in external appearance than those from sample A, as well as being more numerous. Sample B appeared to be from a more stable environment, probably one with continuous deposition. It was probably a biologically accommodated community, in contrast to sample A which was more physically accommodated. Sample A was from a more unstable environment probably subject to periodic catastrophic deposition.

It was found in these two samples that organic content (food availability) was more influential in determining meio-infaunal diversity than heterogeneity of the sediments (the variety of ecological niches). However, the influences of environmental stability and deposition/erosion rates, which this investigation could not consider, are most certainly important and must be kept in mind.

RESEARCH AND OBSERVATIONS, continued

## ONGOING INTERNAL PROGRAMS

### INTRODUCTION

The ongoing internal programs include standardized observations of marine mammals as developed by former staff scientist, Dr. Jim Hain. Other surface phenomena routinely observed and recorded are: pelagic birds, tarballs, and any unusual sightings such as the green flash or, as in cruise W-40, the remains of an octopus apparently vomited by a sperm whale.

Other internal programs are eel larval studies done in cooperation with Dr. Hain and a midwater fish program sponsored by Carl Baum. Abstracts of student projects based on these ongoing internal programs follow.

*

### Bioacoustics of whales

John S. Rikkers

ABSTRACT. Two groups of eight pilot whales were recorded in the North Atlantic near Ile St. Pierre. High frequency whistles were recorded at both sightings. The whistles were more numerous at the first sighting, where feeding behavior was evident. At the second sighting, where herding was not as tight, and sea birds were not abundant, whistles were less frequent. The data indicates that the whistles were probably echolocation pulses.

Distribution of baleen whales in relation to food abundance

Nancy Gunnlaugsson

ABSTRACT. After wintering in southern breeding grounds, many whales migrate north in the summer to feed off Nova Scotia and Newfoundland. This study attempted to correlate the numbers of baleen whales to concentrations of eucarid crustaceans. This was done by taking four tows along the cruise track at stations D (slope water), F (Sargasso Sea), I (possible cold core eddy, and J (slope water outside Fortune Bay, a known feeding ground for whales). The concentrations at 200 meters were approximately the same for stations D, I, and J and were lower at station F. A decrease in the size of individuals was observed in the respective stations. The surface tows at station J produced very few animals. This may be the reason why no skimmers, sei whales (Balaenoptera borealis) and right whales (Eubalaena glacialis) were seen. Relatively low concentrations of eucarids and high concentrations of chaetognaths and copepods off Newfoundland indicate that the spring bloom had not yet occurred. Few whales sighted in the area could also be indicative of this. Sightings of finbacks (Balaenoptera physalus), minkes (Balaenoptera acutorostrata), and humpbacks (Megaptera novaengliae) seemed to indicate that baleen whales travel through the more productive slope water as opposed to the Sargasso Sea.

A Partially Digested Octopus found in the Vicinity of a Whale

Mary Farmer

On 29 June 1978 at 1115 a sperm whale was sighted approximately 100 yards off the port bow, position approximately 60°53'W, 41°30'N. The whale was lolling on the surface and spouting every 10 seconds. At 1123 the whale dived, showing flukes, and was not seen again in the vicinity.

At 1128 a paritally digested, unidentified large octopus was dip-netted from the surface water. The head and portions of the tentacles were missing. The specimen was identified as an octopus by the number of tentacles (8), and the webbing between them. The most probable explanation for the finding is that the sperm whale was feeding on the octopus when first seen. When the whale was disturbed it presumably ejected the octopus before diving.

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Pelagic Tar Analysis

Paul K. Farabaugh

ABSTRACT. This report concerns pelagic tar distribution, the physical and biological relationship in three water masses - slope water, Gulf Stream and Sargasso Sea. Tarballs were associated with a variety of pelagic life. Physical feature descriptions were negligible due to size and texture limitations. It was found that tarball size (length) was inversely proportional to frequency and average wet weight. Overall surface distribution from three 24-hour stations indicated an even distribution of pelagic tar, deduced from an analysis of variance. This finding is contrary to other publications, which suggest that pelagic tar balls are largest and most numerous in the Sargasso Sea with fewer in the Gulf Stream and least in slope water. More neuston net sampling and collection stations will be needed to decide this question conclusively.

Relationships between Weather Systems and the Sighting of Oceanic Birds

Martha B. Ballard

ABSTRACT. This study was designed to show relationships between the sightings of pelagic birds and weather systems. More birds were present in low pressure systems than in high pressure systems. This was an unexpected result. The geographic positions of sightings revealed that productivity may have also determined birds' distribution. Comparison between the Sargasso Sea and the Slope/Northern waters showed that birds appeared to favor areas of high productivity rather than those with less productivity. High pressure systems occurred mostly amongst the unproductive waters of the Sargasso Sea while low pressure systems occurred in slope and northern waters. Thus, the number of oceanic birds sighted could have been primarily related to the overall productivity of an area rather than the prevailing weather patterns.

Distribution of the Leptocephalus Larvae of *Anguilla rostrata* in the Western North Atlantic and Evidence of Vertical Migration

Ellen McCausland

ABSTRACT: The American eel, *Anguilla rostrata*, has a catadromous life cycle which involves migration of adult eels from inland fresh water to spawning grounds in the Sargasso Sea and the subsequent return of the leptocephalus larvae to fresh water. The purpose of this paper was to study the distribution of the leptocephalus larvae of *Anguilla rostrata* in the Western North Atlantic and to look for evidence of vertical migration. No larvae were found in the coastal waters, but three were found in the Sargasso Sea near the Gulf Stream.

*Anguilla rostrata* were found at the same station as eel larvae from the families Ophicthidae and Muraenidae and the *Leptocephalus gigantus* larvae. They were found at the same depth as *L. gigantus* and the Muraenidae. Distribution data were too scarce to conclude migration patterns of *Anguilla rostrata*, but data suggestive of vertical migration were found for the Muraenidae.

Factors Concerning the Distribution and Concentrations of Mesopelagic Fish in the Western North Atlantic

Danny Goldfield

ABSTRACT. Mesoplegic fish biomass (ml. fish/$m^3$), density (fish number/$m^3$), size, and family diversity were correlated with the physical and biological factors of zooplankton biomass, silicate levels, oxygen concentrations, and temperature. Data was considered from two 24-hour stations in slope water and one in the Sargasso Sea. An interesting inverse relationship between overall fish biomass and fish density was found (figure 23B). It seems that in a sparse situation the population tended to be highly prolific in number, but small in size (limited possibly by food supply), while the opposite was true in a situation of greater abundance. An extremely low biomass of fish in one of the slope stations in comparison with its high zooplankton biomass is explained by a relative oxygen deficiency. Fish size was inversely proportional to increasing temperature, while family diversity increased with temperature. Fish biomass increased with silicate levels. (figure 23A). Family diversity was greatest in the Sargasso Sea. In the slope waters Myctophids overwhelmingly dominated while in the Sargasso the bulk of the population was divided between Gonostomatids and Myctophids. The biomass ratio for fish of the slope to Sargasso samples was 10.2/1.

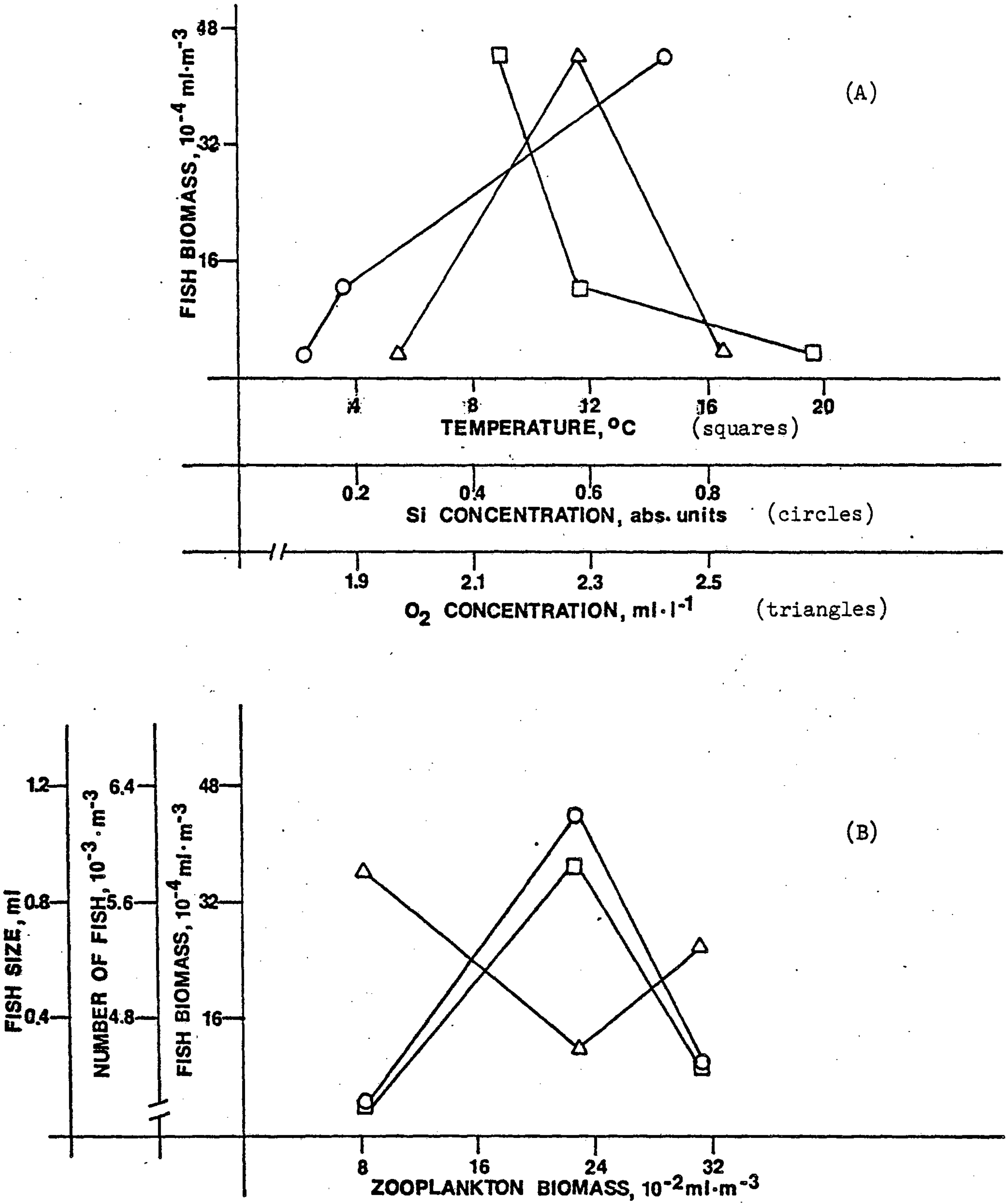


Fig. 23. A. Fish biomass with respect to environmental factors at three stations. B. Fish size (squares), biomass (circles), and number of fish (triangles) with respect to food supply (zooplankton biomass).

ONGOING COOPERATIVE PROGRAMS

Weather Observations (NOAA)

Weather observations were carried out twice daily when the ship was more than 100 miles from land. Transmission was attempted after each collection of observations and was successful five times. All weather records were sent to the National Weather Service, NOAA, AOML, Miami, Florida.

Shark Longlining/Tagging (NMFS)

The *Westward* cooperates with the National Marine Fisheries Service in a program to discover and explain the migratory habits of certain species of sharks in the North Atlantic. All data are sent to the Narragansett Laboratory, NOAA, NMFS, Rhode Island. The two student projects that were based on this operation follow.

Shark Distribution and Hidrcgraphy in the Northwest Atlantic

Beth Botzum

ABSTRACT: Several studies on shark distribution have determined that fluctuations in temperature may be a chief factor influencing seasonal movements of sharks. This report deals with the results of two longlines and correlation of physical properties of the surrounding water mass. No sharks were caught on the first longline. Three female sharks (blue sharks, *Prionace glauca*) were caught on the second longline. Significant temperature and oxygen differences were found between the two water masses. Oxygen differences were attributed to colder water containing more oxygen. It was assumed that temperature differences affected the distribution of *P. glauca* in the area studied.

Social Organization of Shark Populations

Jim Keen

ABSTRACT: Social organizations exist at several levels of complexity amound populations of sharks. Shark segregation in terms of sex, size and species was the topic of this project. After one cancelled longline and one without any sharks a third was set and was sucessful. Three blue sharks were caught and were all females with the smallest being four and one half feet in length and the largest seven feet. The data collected verified the hypothesis that sharks segregate by sex, size and species.

APPENDIX I



BATHYTHERMOGRAPH STATIONS

| Date | Time | North Latitude | West Longitude | BT Number |
|---|---|---|---|---|
| 9 June 1978 | 1545 | 41°04' | 71°14' | 1 |
| 12 June 1978 | 0805 | 39°39' | 71°49' | 2 |
| 12 June 1978 | 1420 | 39°39' | 71°49' | 3 |
| 12 June 1978 | 2030 | 39°39' | 71°49' | 4 |
| 13 June 1978 | 0230 | 39°39' | 71°49' | 5 |
| 13 June 1978 | 0835 | 39°38' | 71°44' | 6 |
| 13 June 1978 | 0940 | 39°36' | 71°38' | 7 |
| 13 June 1978 | 1032 | 39°34' | 71°31' | 8 |
| 13 June 1978 | 1150 | 39°30' | 71°26' | 9 |
| 13 June 1978 | 1255 | 39°27' | 71°21' | 10 |
| 13 June 1978 | 1355 | 39°27' | 71°21' | 11 |
| 13 June 1978 | 1440 | 39°27' | 71°21' | 12 |
| 13 June 1978 | 1530 | 39°22' | 71°20' | 13 |
| 13 June 1978 | 1610 | 39°17' | 71°19' | 14 |
| 13 June 1978 | 1700 | 39°12' | 71°18' | 15 |
| 14 June 1978 | 0600 | 38°23' | 70°16' | 16 |
| 14 June 1978 | 0800 | 38°14' | 70°08' | 17 |
| 14 June 1978 | 1000 | 38°09' | 69°52' | 18 |
| 14 June 1978 | 1135 | 38°01' | 69°46' | 19 |
| 14 June 1978 | 1335 | 37°50' | 69°40' | 20 |
| 14 June 1978 | 1430 | 37°47' | 69°19' | 21 |
| 14 June 1978 | 1520 | 37°44' | 68°53' | 22 |
| 14 June 1978 | 1610 | 37°40' | 68°47' | 23 |
| 14 June 1978 | 1700 | 37°37' | 68°40' | 24 |
| 14 June 1978 | 1905 | 37°35' | 68°16' | 25 |
| 14 June 1978 | 2120 | 37°31' | 68°09' | 26 |
| 14 June 1978 | 2335 | 37°27' | 68°03' | 27 |
| 15 June 1978 | 0100 | 37°23' | 67°57' | 28 |
| 15 June 1978 | 1100 | 36°50' | 67°16' | 29 |
| 16 June 1978 | 1400 | 34°45' | 66°22' | 30 |
| 17 June 1978 | 0115 | 34°29' | 65°59' | 31 |
| 18 June 1978 | 0700 | 33°18' | 65°10' | 32 |
| 18 June 1978 | 1400 | " | " | 33 |
| 18 June 1978 | 2000 | " | " | 34 |
| 19 June 1978 | 0200 | " | " | 35 |
| 23 June 1978 | 1100 | 32°57' | 64°01' | 36 |
| 24 June 1978 | 0915 | 34°32' | 64°33' | 37 |
| 24 June 1978 | 1830 | 34°49' | 64°44' | 38 |
| 24 June 1978 | 2100 | 34°59' | 64°57' | 39 |
| 24 June 1978 | 0250 | 35°05' | 65°10' | 40 |
| 25 June 1978 | 0500 | 35°15' | 65°15' | 41 |
| 25 June 1978 | 0700 | 35°24' | 65°18' | 42 |
| 25 June 1978 | 0900 | 35°30' | 65°20' | 43 |
| 25 June 1978 | 1045 | 35°43' | 65°25' | 44 |
| 25 June 1978 | 1250 | 35°51' | 65°28' | 45 |
| 25 June 1978 | 1347 | 35°55' | 65°24' | 46 |
| 25 June 1978 | 1505 | 36°00' | 65°18' | 47 |
| 25 June 1978 | 1650 | 36°06' | 65°16' | 48 |
| 25 June 1978 | 1740 | 36°10' | 65°12' | 49 |

Appendix I, continued

BATHYTHERMOGRAPH STATIONS (continued)

| Date | Time | North Latitude | West Longitude | BT Number |
|---|---|---|---|---|
| 25 June 1978 | 1835 | 36°14' | 65°08' | 50 |
| 25 June 1978 | 1845 | 36°15' | 65°08' | 51 |
| 25 June 1978 | 1925 | 36°19' | 65°03' | 52 |
| 25 June 1978 | 2025 | 36°20' | 64°59' | 53 |
| 25 June 1978 | 2100 | 36°23' | 64°55' | 54 |
| 25 June 1978 | 2200 | 36°26' | 64°48' | 55 |
| 25 June 1978 | 2255 | 36°28' | 64°43' | 56 |
| 26 June 1978 | 0045 | 36°36' | 65°34' | 57 |
| 26 June 1978 | 0205 | 36°40' | 64°27' | 58 |
| 26 June 1978 | 0315 | 36°46' | 65°03' | 59 |
| 26 June 1978 | 0455 | 36°52' | 64°56' | 60 |
| 26 June 1978 | 0630 | 37°00' | 65°08' | 61 |
| 26 June 1978 | 0815 | 36°49' | 63°56' | 62 |
| 26 June 1978 | 1345 | " | " | 63 |
| 26 June 1978 | 2010 | " | " | 64 |
| 27 June 1978 | 0200 | " | " | 65 |
| 27 June 1978 | 0800 | 37°03' | 63°45' | 66 |
| 27 June 1978 | 0947 | 37°13' | 63°40' | 67 |
| 27 June 1978 | 1240 | 37°18' | 63°33' | 68 |
| 27 June 1978 | 1400 | 37°30' | 63°30' | 69 |
| 27 June 1978 | 1535 | 37°28' | 63°29' | 70 |
| 27 June 1978 | 1620 | 37°43' | 63°24' | 71 |
| 27 June 1978 | 1725 | 37°50' | 63°20' | 72 |
| 27 June 1978 | 1900 | 37°56' | 63°16' | 73 |
| 27 June 1978 | 2309 | 38°12' | 63°12' | 74 |
| 28 June 1978 | 0245 | 38°45' | 63°00' | 75 |
| 28 June 1978 | 0415 | 38°54' | 62°57' | 76 |
| 28 June 1978 | 0605 | 39°14' | 62°43' | 77 |
| 28 June 1978 | 0815 | 39°12' | 62°43' | 78 |
| 28 June 1978 | 0920 | 39°15' | 62°39' | 79 |
| 28 June 1978 | 1100 | 39°23' | 63°35' | 80 |
| 28 June 1978 | 1235 | 39°29' | 62°20' | 81 |
| 28 June 1978 | 1520 | 39°42' | 62°04' | 82 |
| 28 June 1978 | 1720 | 39°53' | 61°50' | 83 |
| 28 June 1978 | 1915 | 40°07' | 61°45' | 84 |
| 28 June 1978 | 2115 | 40°26' | 61°39' | 85 |
| 1 July 1978 | 1930 | 45°21' | 57°34' | 86 |
| 1 July 1978 | 2130 | 45°30' | 57°15' | 87 |
| 2 July 1978 | 0210 | 45°43' | 57°01' | 88 |
| 2 July 1978 | 0500 | 45°51' | 56°41' | 89 |
| 2 July 1978 | 0715 | 45°40' | 56°43' | 90 |
| 7 July 1978 | 1715 | 47°28' | 55°20' | 91 |
| 14 July 1978 | 0430 | 43°50' | 64°33' | 92 |
| 15 July 1978 | 0710 | 43°11' | 66°31' | 93 |
| 15 July 1978 | 0900 | 43°10' | 66°43' | 94 |
| 15 July 1978 | 1130 | 43°08' | 67°04' | 95 |
| 16 July 1978 | 1325 | 43°53' | 68°58' | 96 |

Appendix I, continued

HYDROCAST AND NET-TOW STATIONS

| Date | Time | Latitude | Longitude | Station Number |
|---|---|---|---|---|
| 9 June 1978 | 1545 | 41°04' N | 71°14' W | A |
| 10 June 1978 | 1400 | 40°13' N | 72°18' W | B |
| 12 June 1978 | 0800 | 39°39' N | 71°49' W | D |
| 16 June 1978 | 1430 | 34°46' N | 66°22' W | E |
| 18 June 1978 | 0610 | 33°18' N | 65°10' W | F |
| 23 June 1978 | 1100 | 32°57' N | 64°01' W | G |
| 24 June 1978 | 0915 | 34°32' N | 64°33' W | H |
| 26 June 1978 | 0800 | 36°49' N | 63°56' W | I |
| 7 July 1978 | 1700 | 47°26' N | 55°21' W | J |
| 8 July 1978 | 1355 | 46°26' N | 56°39' W | K |

NEUSTON STATIONS

| Date | Time | Latitude | Longitude | Neuston Number |
|---|---|---|---|---|
| 14 June 1978 | 1745-1815 | 37°37' N | 68°30' W | 1 |
| 15 June 1978 | 0805-0830 | 37°10' N | 67°29' W | 2 |
| 17 June 1978 | 0550-0620 | 34°01' N | 66°03' W | 3 |
| 20 June 1978 | 0607-0627 | 32°30' N | 65°32' W | 4 |
| 23 June 1978 | 0605-0627 | 32°44' N | 64°08' W | 5 |
| 24 June 1978 | 0600-0632 | 34°29' N | 64°35' W | 6 |

ISAACS-KIDD MIDWATER TRAWL

| Date | Time | Latitude | Longitude | IKMT Number |
|---|---|---|---|---|
| 16 June 1978 | 2215 | 34°28' N | 66°14' W | 1 |
| 24 June 1978 | 2205 | 34°59' N | 64°57' W | 2 |
| 2 July 1978 | 0030 | 45°39' N | 57°00' W | 3 |

Appendix I, continued

OTTER TRAWL STATIONS

| Date | Time | Latitude | Longitude | Otter Trawl No. |
|---|---|---|---|---|
| 10 June 1978 | 1417 | 40°13' N | 72°18' W | 1 |
| 11 June 1978 | 1104 | 40°23' N | 73°47' W | 2 |
| 1 July 1978 | 1200 | 44°37' N | 57°36' W | 3 |
| 1 July 1978 | 1255 | 44°37' N | 57°36' W | 4 |
| 9 July 1978 | 1434 | 45°30' N | 56°12' W | 5 |

LONG LINE STATIONS

| Date | Time | Latitude | Longitude | Long Line Number |
|---|---|---|---|---|
| 13 July 1978 | 1830 | 43°50' N | 64°32' W | 1 |
| 16 July 1978 | 1257 | 42°53' N | 68°58' W | 2 |

BOTTOM STATIONS

| Date | Time | Latitude | Longitude | Procedure |
|---|---|---|---|---|
| 9 July 1978 | 1352 | 45°30' N | 56°12' W | Clam shell grab |
| 10 July 1978 | 1211 | 45°49' N | 58°02' W | Phleger core |
| " | 1400 | " | " | Clam shell grab |
| 11 July 1978 | 2250 | 45°07' N | 63°34' W | Clam shell grab |
| " | 2340 | " | " | Phleger core |
| 12 July 1978 | 0000 | 45°07' N | 60°31' W | Phleger core |

# APPENDIX II

Station Summaries

| STA. | Date | TIME | POSITION | EUPHOTIC ZONE (1% LD) | MIXED LAYER (M) | DEPTH (M) | TEMPERATURE (°C) | SALINITY (°/oo) | OXYGEN ($ml \cdot l^{-1}$) | SILICATE (abs. units) | BIOMASS ($ml \cdot m^{-3}$) ($X10^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 6/09/78 | 1545 | 41 04' N | 16m | 12.2 | 0 | 13.73 | 31.57 | 3.44 | | |
| | | | 71 14' W | | | 15 | 9.18 | 32.21 | 3.68 | | |
| | | | | | | 30 | 7.15 | 32.30 | 3.10 | | |
| B | 6/10/78 | 1417 | 40 13' N | | OTTER TRAWL | | | | | | |
| | | | 72 18' W | | | | | | | | |
| C | 6/11/78 | 0940 | 40 23' N | 7.7m | | 0 | 15.15 | 29.36 | 4.00 | 0.251 | |
| | | | 73 48' W | | | 10 | 9.44 | 31.14 | 2.03 | 0.757 | |
| | | | | | | 20 | 7.57 | 31.43 | 3.47 | 0.480 | |
| D-1 | 6/12/78 | 0800 | 39 38.6'N | 24.5m | 6m*/20m | 0 | 14.80 | 36.84 (?) | 3.16 | | 10.8 |
| | | | 71 48.8' W | | | 33 | 9.38 | 33.88 | 3.43 | | 1537 |
| | | | | | *shallow | 215 | 9.87 | 35.23 | 2.58 | | 33.3 |
| | | | | | inverted | 400 | 6.57 | 35.13 | 1.96 | | 117 |
| D-2 | | 1535 | | 13 m | 4m/12m | 0 | 15.53 | 32.59 | 3.29 | 0.025 | 53.1 |
| | | | | | | 33 | 10.25 | 33.66 | 3.78 | 0.503 | 430 |
| | | | | | | 215 | 11.48 | 35.44 | 3.52 | 0.561 | 94 |
| | | | | | | 400 | 6.93 | 35.25 | 2.21 | 0.767 | 172 |
| D-3 | | 2050 | | 19.3m | 6m/12m | 0 | 15.95 | 32.64 | 3.45 | 0.573 | 590 |
| | | | | | | 33 | 9.37 | 33.88 | 2.04 | 0.277 | 332 |
| | | | | | | 215 | 10.49 | 35.55 | 1.97 | 0.866 | 116 |
| | | | | | | 400 | 6.31 | 35.06 | 2.33 | 1.092 | 135 |
| D-4 | | | | Dark | 6m/12 | 0 | 15.42 | 32.98 | 3.43 | | 174 |
| | | | | | | 33 | 9.58 | 33.99 | 3.20 | 0.424 | 124 |
| | | | | | | 215 | 10.02 | 35.49 | 1.98 | 0.660 | 128 |
| | | | | | | 400 | 6.34 | 35.04 | 2.28 | 0.861 | 118 |
| E | 6/16/78 | 1430 | 34 45.8'N | | 24 | 0 | 23.55 | 36.03 | | | |
| | | | 66 22.1'W | | | 100 | 19.43 | 36.26 | | | |
| | | | | | | 200 | 18.70 | 36.29 | | | |
| | | | | | | 300 | 18.41 | 36.61 | | | |
| | | | | | | 400 | 18.24 | 36.41 | | | |
| | | | | | | 500 | 17.96 | 36.41 | | | |
| F | 6/18/78 | 0800 | 33 18.3'N | 26.5 | 30.5 | 0 | 22.72 | 36.20 | 2.57 | 0.097 | 40.5 |
| | | | 65 10.3'W | | | 40 | 21.22 | 36.18 | 2.69 | 0.112 | 30.4 |
| | | | | | | 220 | 18.33 | 36.12 | 2.47 | 0.067 | 89.1 |
| | | | | | | 400 | 17.70 | 36.14 | 2.53 | 0.464 | 40.4 |
| | | | | | | 0 | 22.11 | 36.20 | 2.58 | 0.051 | 79.7 |
| | | 1400 | | 57.1 | 30.5 | 40 | 21.41 | 36.16 | 2.66 | 0.038 | 34.6 |
| | | | | | | 220 | 22.71 (?) | 36.39 | 2.64 | 0.046 | 49.2 |
| | | | | | | 400 | 17.72 | 36.20 | 2.41 | 0.093 | 20.5 |

Station Summaries Cont.

| STA. | DATE | TIME | POSITION | EUPHOTIC ZONE (m) | MIXED LAYER (m) | DEPTH (m) | TEMPERATURE (°C) | SALINITY (‰) | OXYGEN (ml·l) | SILICATE (abs.) | BIOMASS (ml·m⁻³ x 10⁻³) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 0 | 22.86 | 36.12 | 2.71 | 0.039 | 111 |
| | | 2045 | 33 17.4'N | | 30.5 | 40 | 21.67 | 36.37 | 2.67 | 0.051 | 95.9 |
| | | | 65 11.3'W | | | 220 | 18.29 | 36.37 | 2.45 | 0.102 | 56.1 |
| | | | | | | 400 | 17.61 | 36.09 | 2.50 | 0.110 | 30.5 |
| | | | | | | 0 | 22.84 | 35.78 | 2.57 | 0.028 | 411 |
| | | 0315 | 33 18.3'N | Dark | 30.5 | 40 | 20.80 | 36.55 | 2.72 | 0.029 | 220 |
| | | | 65 09.9'W | | | 220 | 22.25 | 36.41 | 2.61 | 0.044 | 73.5 |
| | | | | | | 400 | 17.39 | 35.70 | 2.27 | 0.116 | 21.1 |
| G | 6/23/78 | 1100 | 32 57.2'N | | 30.5 | 0 | 23.66 | 36.17 | | | |
| | | | 64 00.7'W | | | 100 | 19.37 | 35.90 | | | |
| | | | | | | 200 | 18.47 | 36.19 | | | |
| | | | | | | 300 | 18.12 | 36.50 | | | |
| | | | | | | 400 | 17.86 | 36.77 | | | |
| | | | | | | 500 | 17.29 | 35.39 | | | |
| H | 6/24/78 | 0915 | 34 31.7'N | | 18 | 0 | 24.2 | 36.33 | | | |
| | | | 64 32.8'W | | | 100 | 20.1 | 36.76 | | | |
| | | | | | | 200 | 18.6 | 36.52 | | | |
| | | | | | | 300 | 18.3 | 36.77 | | | |
| | | | | | | 400 | 21.9 (?) | 36.80 | | | |
| | | | | | | 500 | 19.6 (?) | 36.79 | | | |
| I | 6/26/78 | 0800 | 36 48.6'N | 20.2 | 12/30* | 0 | 22.29 | 34.61 | 2.44 | 0 | 850 |
| | | | 63 55.7'W | | | 66 | 11.16 | | 2.63 | 0 | 278 |
| | | | | | | 233 | 9.43 | | 1.54 | 0 | 1042 |
| | | | | | | 400 | 8.17 | 35.34 | 1.54 | 1.042 | 192 |
| | | 1400 | | 2015 | 12/30* | 0 | 23.25 | 34.77 | 2.49 | 0 | 342 |
| | | | | | | 66 | 13.84 | 35.02 | 2.45 | 0 | 270 |
| | | | | | | 233 | 11.62 | 35.84 | 1.70 | 0.073 | 120 |
| | | | | | | 400 | 8.23 | 35.02 | 1.61 | 0.388 | 59.2 |
| | | 2045 | | 10.3 | 6/12/30 | 0 | 24.00 | 35.03 | 2.33 | 0 | 38,869 |
| | | | | | | 66 | 14.84 | 35.18 | 2.30 | 0 | 181 |
| | | | | | | 233 | 11.61 | 35.18 | 2.05 | 0.106 | 109 |
| | | | | | | 400 | 9.61 | 35.34 | 1.55 | 0.119 | 70.7 |
| | | 0245 | | Dark | 18/30** | 0 | 22.63 | 35.02 | 2.36 | 0 | 2,500 |
| | | | | | | 66 | 14.40 | | 2.70 | 0 | 193 |
| | | | | | | 233 | 11.29 | 35.84 | 2.05 | 0.003 | 241 |
| | | | | | | 400 | 8.25 | 35.84 | 1.61 | 0.440 | 114 |
| J | 7/7/78 | 1700 | 47 26.3'N | 11.7 | 12 | 0 Neuston | | | | | 10.3 |
| | | | 55 21.2'W | | | 0 M-Net | 13.12 | | 3.54 | | 1.77 |
| | | | | | | 100 | 0.72 (?) | | 3.83 | | 86.9 |
| | | | | | | 200 | 1.22 | | 3.80 | | 324 |
| K | 7/8/78 | 1355 | 46 25.5'N | | | 0 | 12.6 | | | | |
| | | | 56 39' W | | | 10 | | | | | 346 |

* Shallow thermocline, followed by gradual decrease to new water mass at 30m
** 18m = stratified layer, thermocline between 18 and 30m