CRUISE REPORT

C-100

Scientific Activities

Woods Hole - Bermuda - Lunenburg - Woods Hole

21 May - 26 June 1988

SSV Corwith Cramer

Sea Education Association
Woods Hole, Massachusetts

PREFACE

The purpose of this cruise report is to summarize the scientific activities aboard the SSV Corwith Cramer on cruise C-100. This cruise was the first Sea Semester voyage aboard the Cramer, and represents a milestone in SEA's efforts in nautical, maritime and oceanographic education. The student projects included in this report represent the culmination of a process which began in Woods Hole during the shore component. During this period, students selected a research topic, produced a written proposal for the investigation, and presented an oral summary of the proposed work to classmates and staff. With this background, the data collected at sea were organized, analyzed and presented in both written and oral form by the student researcher. Project results were returned to Woods Hole for use in the long-term science objectives of SEA and in helping future students design their work. Much of this work was written at sea and represents a first interpretation of the data.

Students and staff working together toward common goals made C-100 a successful cruise. Paul DeOrsay skillfully guided students, staff and the new ship to science stations and safe harbors as we made our way from Woods Hole and back. His staff of able mariners kept us learning as we moved to each new objective. Bill Burke, our Chief Mate, kept the vessel and the teaching up to a high standard. Walter Rybka brought his sailing skills and historical knowledge to the Cramer with grand results. Betsy Garthwaite proved her mettle and ability both learning and teaching as Third Mate. Bob Cross kept the systems "go" as our engineer and spirits high amongst his shipmates. Rick Jones artistically dealt with edible entities and field day follies while we were under his stewardship. Thanks for the hard work and fellowship.

The Assistant Scientists were responsible for putting the labor into the laboratory and keeping the scientific quest moving along. Chuck Holloway kept equipment in shape and the data flowing with his usual skill and good nature. Mark Worrall worked hard to keep the results on track and entertained us with his tales as a fisheries observer. Margo Rice learned the system while teaching and I thank you all for your diligent work, your patience and your friendship! Tim Rumage joined us briefly as a visiting scientist and was pressed into immediate service after a squally arrival.

It is, of ~~course, the students who were at the heart of C-100.~~ They made it all happen and gave the Cramer's first Sea Semester a successful and happy beginning. You set a fine example and I thank you all.

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INTRODUCTION

A. Research Program

This cruise report provides a record of the scientific activities conducted on C-100. The oceanographic research on the cruise was almost entirely devoted to accomplishing individual projects designed during the six week shore component taught in Woods Hole immediately preceding the cruise. The research projects emphasized the application of theoretical concepts to the study of the oceans.

The cruise track of C-100 (Figure 1, Appendix A gives daily positions) crossed the Gulf Stream twice, once on the way to Bermuda and then again on the way to Lunenburg (see Table 1 for the itinerary). In addition to this dynamic boundary between temperate and subtropical oceanic water, the shelf/slope boundary was crossed several times, and the neritic environments of the New England and Scotian continental shelf were sampled. Station information is listed in Appendix B and bathythermograph information is contained in Appendix C. The work on C-100 examined the major oceanographic contrasts and processes occurring in this active region. Comparison of the physical and biological properties of the water masses encountered served to illustrate major differences in the marine world. Specific studies dealing with particular aspects of marine biology and geology were also conducted, along with measurements of tar and plastic pollution made throughout the voyage. The people who made it all possible are listed in Table 2.

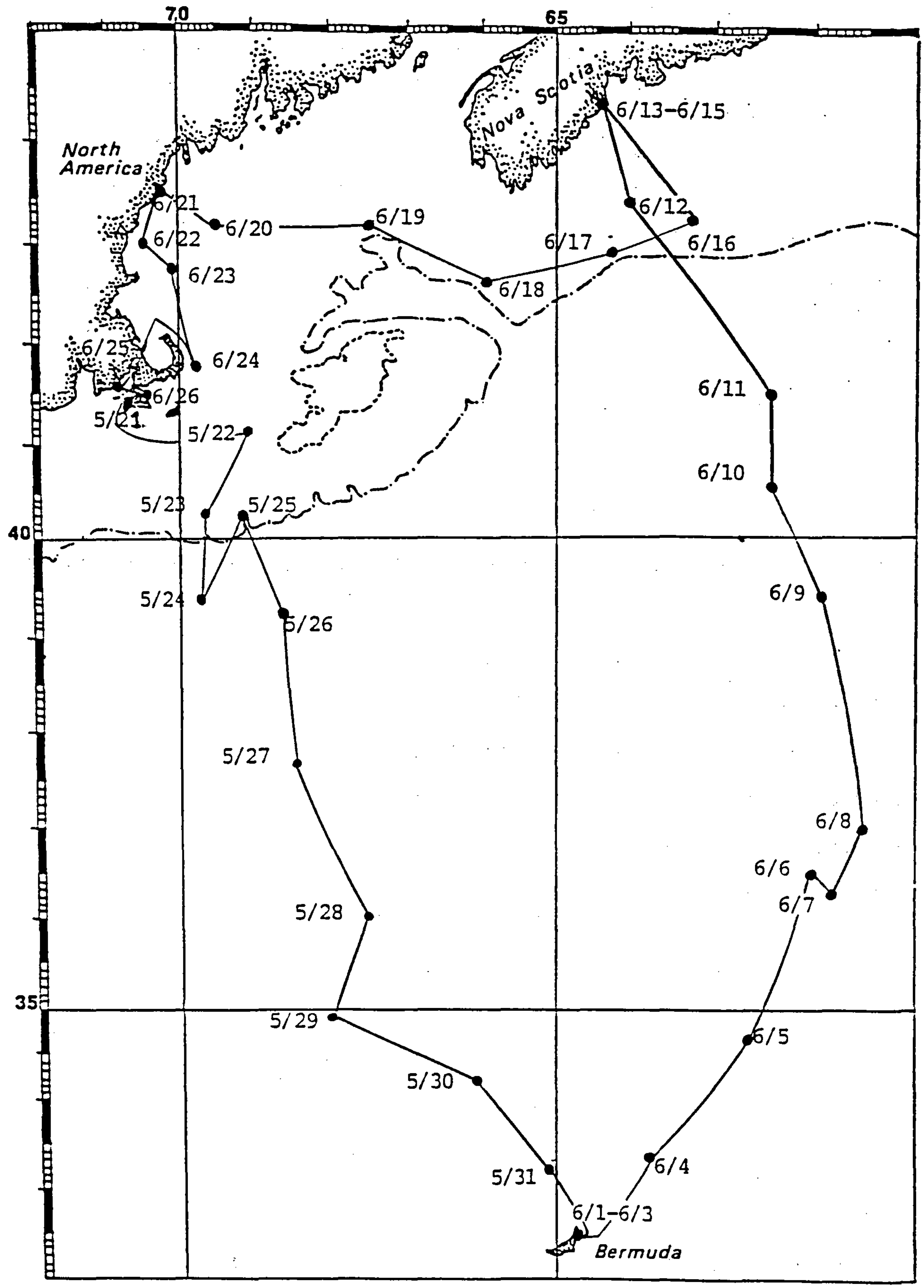

Figure 1. Cruise track of <u>Corwith</u> <u>Cramer</u> on C-100. Noon positions are indicated.

TABLE 1. Itinerary of SSV Corwith Cramer on Cruise C-100

Port	Arrive	Depart
Woods Hole, Massachusetts		21 May
St. Georges, Bermuda	1 June	3 June
Lunenburg, Nova Scotia	13 June	15 June
Portland, Maine*	21 June	21 June
Isles of Shoals	22 June	22 June
Woods Hole, Massachusetts	27 June	

*Customs and Immigration only.

TABLE 2. Ship's complement on SSV Corwith Cramer cruise C-100

NAUTICAL STAFF

Paul DeOrsay	Captain
Bill Burke	Chief Mate
Walter Rybka	Second Mate
Betsy Garthwaite	Third Mate
Bob Cross	Engineer
Richard Jones	Steward

SCIENTIFIC STAFF

Chuck Lea	Chief Scientist
Chuck Holloway	Assistant Scientist
Mark Worrall	Assistant Scientist
Margo Rice	Assistant Scientist

VISITORS

Tim Rumage, Rhode Island School of Design, Isles of Shoals to Woods Hole

STUDENTS

Christoph Ahlers, Middlebury College, Junior, Biology

Joshua Bagley, Hobart College, Sophomore, Undeclared

Adam Cohen, St. Mary's College, Senior, Biology

Stuart Friedman, Cornell University, Sophomore, Physics

Rebecca Gillette, University of Alabama, Senior, Languages

Jason Gottlieb, Pitzer College, Sophomore, Political Studies

Todd Harral, University of New Hampshire, Sophomore, Liberal Arts

Eric Hayes, Hobart College, Sophomore, Mathematics

Christopher Kilbridge, Northeastern University, Senior, Geology

Kateri Kirby, University of Michigan, Sophomore, Marine Biology

Thomas Kraemer, University of Pennsylvania, Sophomore, Undeclared

Timothy Krier, Vanderbilt University, Junior, English

James Logan, Middlebury College, Junior, English

Linda Maddern, Connecticut College, Junior, Botany

Gavin Magnuson, Georgetown University, Junior, Asian Studies

Susan Marks, Colgate University, Junior, Biology

Karl Mayer, Middlebury College, Junior, History

Roshan Mistry, Cornell University, Senior, Biology

Deborah Phelps, St. Lawrence University, Sophomore, Economics

Catherine Roosevelt, Colby College, Junior, American Studies

Jodi Schwarz, Oberlin College, Junior, History/Religion

Carolyn Viscosi, Brown University, Junior, Geology/Biology

Stuart Weems, Vanderbilt University, Junior, Economics

Eric White, University of Massachusetts, Senior, Civil Engineering

B. Academic Program

Cruise C-100 represents the second half of the 12-week Sea Semester program. During the first six weeks students took three courses: Oceanography, Nautical Science and Maritime Studies. The projects which the students undertook at sea were researched and proposed during the shore component. The proposal process included both written and oral presentations.

Throughout the cruise, a 24-hour science watch was maintained by a staff member and three students. During this time students were instructed in the use of sampling and analytical equipment. Science watch standers were responsible for maintenance of the science log, conducting scientific stations, and the routine observation and measurement of oceanographic and meteorological conditions. Analyses of water and biological samples were also completed on science watch. The responsibility of the students for these procedures was gradually increased over the duration of the cruise, culminating in each student being designated Junior Science Watch Officer (JSWO) for two or three watches. Responsibility for the efficient running of the lab and the progress of the scientific program rested with these JSWOs.

Formal instruction was given each day in a lecture. The topics covered in these lectures (Table 3) ranged from practical oceanographic sampling to presentations discussing timely or recently observed phenomena as well as theoretical oceanographic or marine biological subjects. Examinations and student presentations were also conducted during these instructional periods. Included in the presentations were the students' project results and a short examination of the biology and ecology of a marine organism ("Creature Feature") collected or observed during the cruise.

C-100 was comprised of two three-week courses in Practical Oceanography offered by SEA with credit transferred through Boston University. Letter grades for the shipboard courses were determined on the basis of on-watch evaluations, exams, "Creature Feature" reports, and the research project presentation and final written report.

TABLE 3. Classes on C-100

5/23/88	The academic and scientific program	Chuck Lea
5/24/88	The bathythermograph and station labeling	Chuck Lea
5/26/88	Deep-sea reversing thermometers and salinity determinations	Chuck Holloway
5/27/88	The Gulf Stream system	Chuck Lea
5/30/88	Fisheries and the fisheries observer program	Mark Worrall
5/31/88	Coral and coral reefs	Chuck Lea
6/04/88	Langmuir circulation	Chuck Lea
6/07/88	Marine mammals/human conflicts	Chuck Lea
6/08/88	The Galapagos Islands	Margo Rice
6/09/88	Practical Exam	
6/10/88	The El Nino	Chuck Holloway
6/16/88	The head of the sperm whale	Chuck Lea
6/17/88	Warm blooded fish	Chuck Lea
6/18/88	Format of research papers	Chuck Lea
	Student project presentations	
6/20, 21	Student project presentations	
6/22/88	Marine Mammals	Tim Rummage
6/23-25	Student project presentations	
6/24/88	Final Exam	

PHYSICAL AND CHEMICAL STUDIES

IDENTIFICATION AND CHARACTERIZATION OF THE GULF STREAM AND ASSOCIATED FEATURES

Stuart L. Friedman

Abstract

The thermal structure of a particularly dynamic area of the western North Atlantic was examined along a 180 nm transect from the New England continental shelf break to south of the Gulf Stream on June 8-9, 1988. Bathythermographs (BTs) and CTD data indicated that a meander of the Gulf Stream, a cold core eddy, the Gulf Stream itself and slope water were crossed during the sampling period. Geostrophic calculations suggest that the velocities in the upper 50m across the meander and in the Gulf Stream were in the range of 65 -80 cm/s, although important limitations such as the chosen depth of the level of no motion may have caused underestimation of these values.

A DESCRIPTIVE PHYSICAL OCEANOGRAPHIC COMPARISON

OF TWO WARM CORE RINGS

Eric S. Hayes

Abstract

Temperature and salinity profiles were compared for shelf, slope, Gulf Stream, and Sargasso Sea water in the area between 36°N and 44°N latitude by 60°W and 70°W longitude. BT, CTD, and infrared satellite images of surface temperatures were used in the analysis. Two warm core Gulf Stream rings were encountered and compared with the water surrounding them for temperature and salinity anomalies. The warm eddy at 39°16'N 69°19'W had a 15°C depth of 250m with a salinity maximum of 36.3‰ while the warm eddy further to the northeast had a 15°C depth of 410m and a salinity maximum of 36.5‰. These data suggest that the first eddy encountered was relatively older than the second.

PHOSPHATES: CONCENTRATION IN THE WESTERN NORTH ATLANTIC

Adam L. Cohen

Abstract

This study examined the relationship between phosphate and oxygen concentrations in shelf water, slope water and the waters of two warm core eddies. Water samples were collected with Niskin bottles, and phosphate and oxygen concentrations were determined by spectrophotometry (phosphate) and Winkler titration (oxygen). Between depths of 25m and 150m, shelf water concentrations of phosphate were larger than those in slope water and warm core eddy water. At 400m, the highest concentrations were found in slope water followed by old warm core eddy water, and the lowest concentration was found in a relatively new warm core eddy. An inverse relationship between phosphate concentration and oxygen concentration generally held, although exceptions in the warm core eddy occurred, probably due to the dynamic mixing environment.

CHLOROPHYLL A DISTRIBUTION AND ITS RELATIONSHIP TO PHOSPHATE CONCENTRATION, SALINITY AND TEMPERATURE IN FIVE WATER MASSES IN THE NORTHWEST ATLANTIC OCEAN

Gavin K. Magnuson

Abstract

The surface waters of five distinct water masses--shelf, slope, warm core eddy, Gulf Stream and Sargasso Sea water--of the northwestern Atlantic Ocean were sampled, and chlorophyll *a* and phosphate concentrations, salinity and temperature were determined.

Generally chlorophyll *a* concentrations decreased as salinity and temperature increased, and chlorophyll *a* concentrations were higher where there were higher levels of phosphates. Chlorophyll *a* maxima were observed at the transitional zones between the different water masses and not within the actual waters themselves. The most consistent relationship observed was that of chlorophyll *a* vs. phosphate which, when regressed produced an r-value of 0.987. Temperature and salinity, as indicators of particular regions could be used as a rough estimator of chlorophyll *a* distribution, although they are not directly controlling the chlorophyll *a* distribution.

PHYTOPLANKTON AS AN INDICTOR OF WATER MASS IN THE WESTERN NORTH ATLANTIC

Jodi Schwarz

Abstract

The relationship between water mass and the percentages of diatom and dinoflagellate cells was examined. Eight surface collections from a 63μ mesh phytoplankton net were examined and the number and genus of the cells were recorded from shelf water, slope water overlain by a thin (10m) layer of Gulf Stream water, warm core eddy and Sargasso Sea waters. Shelf water diatoms of the genus Rhizoselenia dominated the inshore waters while, at the shelf edge Ceratium dinoflagellates were numerically dominant as they were in eddy waters and the slope/Gulf Stream sample. The Sargasso Sea had slightly more diatoms than dinoflagellates. A second warm core eddy was dominated by the diatom Bacillaria paradoxa. Generally diatoms tend to dominate in cooler, fresher waters with relatively high phosphate concentrations.

A COMPARISON OF ZOOPLANKTON BIOMASS AND DIVERSITY IN DIFFERENT WATER MASSES OF THE NORTH ATLANTIC OCEAN

Roshan A. Mistry

Abstract

Relative biomass and diversity of zooplankton were studied in shelf, slope, Sargasso Sea, and warm core eddy waters from Woods Hole, Massachusetts to Bermuda to Lunenburg, Nova Scotia. Zooplankton were collected in meter net tows at night, and the biomass, number of taxa (diversity), and a measure of diversity and evenness (the Shannon-Weaver index of diversity, H′) were calculated for each tow. It was found that biomass decreased and number of taxa and H′ increased from shelf water (108.4 ml/100 m^3, H′ = 0.4), to slope water (11.9 ml/100 m^3, H′ = 1.2), to Sargasso Sea water (3.6 - 7.0 ml/100 m^3, H′ = 2.2 - 1.6) and to warm core ring waters (4.8, 7.0 ml/100 m^3, H′ = 1.29, 1.77). H′ was a good predictor of water mass and relative age of warm core eddies as the H′ value for the older eddy (1.29) was closer to that of slope water, while the H′ value for the younger eddy (1.77) was within the H′ values of the Sargasso Sea.

NEUSTONIC BIOMASS IN THE WESTERN NORTH ATLANTIC WITH NOTES ON THE OCCURRENCE OF *PHYSALIA PHYSALIA* AND *PORPITA PORPITA*

Stuart Weems

Abstract

The displacement volumes of 24 neuston collections were used to estimate zooplankton biomass in a variety of water masses found from the continental shelf to the Sargasso Sea. The highest values were in the shelf waters (49 ml/tow) followed by warm eddy (35 ml/tow) and Slope (35 ml/tow) waters and Sargasso Sea (30 ml/tow). The Gulf Stream (20 ml/tow) had the least neustonic biomass. Night tows collected more zooplankton than day tows due to diel vertical migration. Fifty-one right-sailing and seventy-two left-sailing *Physalia* were observed with some tendency for the left-sailors to occur towards the edge of the Sargasso Sea. Thirty-nine *Porpita* were collected with sizes largely in the 1-2mm range.

EPIBIONT DIVERSITY AND DISTRIBUTION WITHIN SARGASSUM IN THE SARGASSO SEA

Christoph Ahlers

Abstract

A study of the distribution and diversity of epibionts of *Sargassum natans* and *Sargassum fluitans*, the two most commonly found species of *Sargassum* weed was performed. Neuston tows gathered *Sargassum* which was sorted according to age. Any epibionts observed through a dissecting microscope were recorded.

The hydroid *Clytia noliformis* was found to be dominant on young *S. natans*; the bryozoan *Membranipora tuberculata* eventually crowds out the hydroid and becomes dominant on the older weed parts. Other colonizing organisms on *S. natans* include *Spirorbis corrugatus*, *Lepas pectinata*, and a variety of other hydroids. *M. tuberculata* was found to be dominant on both young and old *S. fluitans*; *C. noliformis* was also seen colonizing this *Sargassum* species, as well as a hydroid not observed to inhabit *S. natans*, *Aglaophenia latecarinata*.

THE DISTRIBUTION, ABUNDANCE, AND AGE OF PHYLLOSOMA AND LEPTOCEPHALI LARVAE IN THE WESTERN NORTH ATLANTIC

Carolyn Viscosi

Abstract

The distribution, age and abundance of the phyllosoma larvae of the spiny lobster (Panulirus argus) and the leptocephali larvae of the eel were examined in the western North Atlantic. A total of 21 phyllosoma and 5 leptocephali were separated from 7 meter net and 18 neuston net collections made between the continental shelf and Bermuda. No specimens of either organism were collected in shelf or slope water, but they were present in a warm core ring north of the Gulf Stream. The phyllosoma generally followed a pattern of increasing abundance and decreasing age along the transect from warm core rings to Gulf Stream to the Sargasso Sea.

DISTRIBUTION OF EUTHECOSOMATOUS PTEROPODS IN THE WESTERN NORTH ATLANTIC

Christopher J. Kilbridge

Abstract

Euthecosomatous pteropods in the western North Atlantic were examined in order to compare the diversity in various water masses and to determine their usefulness as water mass indicators. Pteropods from night meter net collections were sorted and identified to species. The fauna generally consisted of cold tolerant subtropical species. Limacina retroversa was found to be a good indicator of slope water. The Sargasso Sea fauna was the most diverse and the relative age of two warm core rings seemed to be reflected in the pteropod fauna. An older ring was less diverse and had more L. retroversa than a younger one.

THE HORIZONTAL DISTRIBUTION OF MYCTOPHIDAE AS SEEN IN SLOPE WATER, THE SARGASSO SEA, AND A WARM CORE EDDY

Linda Maddern

Abstract

Myctophid fish taken from Gulf Stream, slope water, the Sargasso Sea, and two warm core eddies were examined to study patterns of horizontal distribution among the species. Neuston nets, oblique meter nets and an Isaacs-Kidd Midwater Trawl were used to obtain specimens. Some species were found to be typical of a distinct water mass. <u>Gonichthys cocco</u>, a tropical species, was the most abundant species found in the Gulf Stream and Sargasso Sea samples, whereas <u>Benthosema glaciale</u>, a temperate species, was found to prefer the slope water. <u>G. cocco</u> and <u>Myctophum affine</u> were the main species found in an older warm core eddy, but too few specimens were collected in a new eddy to allow comparison of the fauna.

SEABIRD DISTRIBUTION FROM THE SCOTIAN SHELF TO BERMUDA AND EVIDENCE FOR VISUAL FORAGING BEHAVIOR

Susan Marks

Abstract

Thirteen observations of thirty minutes each were made of seabirds in shelf, warm core ring, Gulf Stream and Sargasso Sea water. Five general categories of birds were observed including shearwaters, petrels, fulmars, tropic birds, and gulls. Shelf water had the largest number of bird sightings and the Gulf Stream the least. Shearwaters (including greater and Cory's shearwaters) and petrels dominated in all areas. Comparison of bird numbers with surface phosphate concentration suggest that more birds are sighted in areas of higher surface phosphate concentration. Attempts to attract visual foragers to the vessel by flying a kite off the stern as a bird-mimic were made. One trial suggested that petrels and shearwater may have used the visual cue of the flying kite in order to congregate. Congregating near other foraging birds may be an energy saving mechanism in the foraging strategy of oceanic birds.

THE DISTRIBUTION AND BIOMASS LEVELS OF BENTHIC ORGANISMS: VARIATION WITH SEDIMENT SIZE AND DEPTH

Kateri J. Kirby

Abstract

Two major environmental factors that affect the distribution of benthic animals are the type of substrate and the depth of the water. The sampling sites included two mud stations and two coarse sand stations at depth ranges of 70 to 132 meters. Sampling locations were on and just off Georges Bank and on the Scotian Shelf near Browns Bank. Temperature and salinity were similar for all the stations. Organisms from the phyla Echinodermata, Mollusca, Cnidaria, Porifera, Arthropoda, and Annelida were collected using an otter trawl. Brittle stars were the most abundant organism followed by sea stars and sponges. Species from the phylum Echinodermata were the most diverse and appeared in all the tows. There was a higher diversity level at the sand stations and more biomass at the mud stations. Changes in sediment grain size appeared to have a greater influence on the biota than the depth range over the depths sampled in this study.

A COMPARISON OF PREY ITEMS AND MOUTH STRUCTURE OF FISH FROM THE NEW ENGLAND AND NOVA SCOTIAN CONTINENTAL SHELF

Jason Gottlieb

Abstract

Stomach contents were examined from species of fish caught in an otter trawl in order to compare mouth structure with the types of prey items. The three categories for the mouth structures were: inferior (mouth placed ventral to the snout), terminal (mouth and snout terminate at same place), and superior (lower jaw extends beyond the mouth itself). Cod, ocean pout, silver hake, goosefish, little skate and several species of flounder were collected. A variety of prey items including crab, shrimp, worms, fish, sea stars and molluscs were consumed by the fish. Prey items were in general agreement with previous reports. However, no correlation was observed between the gut contents and the mouth structure of the fish.

THE ROCKY INTERTIDAL ZONE AT BLUE ROCKS,

LUNENBURG, NOVA SCOTIA

Rebecca Gillette

Abstract

Six quadrats of 60 x 60 cm were examined in the intertidal zone at Blue Rocks, Lunenburg, N.S. Algae and animal coverage were recorded, and salinity samples of the tidepools were taken.

Ascophyllum nodosum was the dominant alga at each site with accompanying growth of *Fucus* spp. The fauna was characterized by *Littorina* spp., *Balanus balanoides*, *Mytilus edulis* and *Lepeta caecci*. An important physical factor appears to be the ability of a tidal pool to be flushed out by contact with bay water. Some species were restricted to the lower intertidal areas such as the snail, *Nucella lapilla*, and the kelp, *Laminaria* spp.

ANALYSES OF REEF FRONT TERRACE SEDIMENTS ON THE OUTER EDGE OF THE BERMUDA PEDESTAL: GRAIN SIZE AND DEPOSITIONAL PATTERNS

John Bagley and Parke Logan

Abstract

Sediments along the outer edge of the reef terrace of the Bermuda Pedestal were examined to determine characteristics of composition, grain size and depositional patterns along the pedestal. The five samples taken with a Shipek grab were along the northern and eastern edge of the pedestal at depths to 100m. The samples were sieved to determine grain sizes. Sediment origin and composition was then determined.

The samples consisted of calcareous sediments originating from the indigenous fauna of the reefs and reef front terrace. Coarser sediments were found closer to the reefs where wave energy was the highest, and became finer farther away from the energy source and down the slopes.

A SEDIMENTARY SIZE ANALYSIS OF THE CONTINENTAL SLOPE AND SUBMARINE CANYON REGIONS OF SOUTHERN GEORGES BANK

Todd Harral and Karl Mayer

Abstract

Hydrographer Canyon is a submarine canyon located on the southern flank of Georges Bank. Sediment samples were collected by Shipek grab at 12 locations, including the continental shelf on either side of the canyon, the canyon flanks and bottom, and on a continental slope not associated with the canyon. Sediment was sieved to determine the grain size distribution and sorting. In general, the very coarse size fraction decreased and the very fine sediment fraction increased as the sampling proceeded east to west perpendicular to the axis of the canyon. These results are similar to findings at the adjacent Oceanographer canyon where the currents were found to structure the sediment size distribution pattern. In this area, the mean flow of the surface currents and the low frequency storm currents move water from east to west perpendicular to the axis of the canyon, and the deeper tidal currents move water along the axis. Currents moving east to west will tend to remove fine grains from the shelf and deposit them in the canyon where they are moved back and forth by tidal forces.

POLLUTION STUDIES

DISTRIBUTION AND CONCENTRATION OF PELAGIC TAR IN THE WESTERN NORTH ATLANTIC OCEAN AND THE SARGASSO SEA

Tim Krier

Abstract

The distribution and concentration of pelagic tar were examined by collecting floating tar from 38 neuston net collections. The highest levels of tar were found in the Sargasso Sea ($\bar{x}$ = 2.09 mg/m^2) and lesser amounts were collected in the Gulf Stream ($\bar{x}$ = 0.29 mg/m^2), slope water ($\bar{x}$ = 0.20 mg/m^2), and shelf water ($\bar{x}$ = .10 mg/m^2). The convergence of water in the Sargasso Sea acts as a collecting mechanism for floating tar. Comparison with the previous three years of SEA tar data shows no decline in the amounts of pelagic tar.

A STUDY OF THE VERTICAL DISTRIBUTION AND CONCENTRATION OF MICROSCOPIC TAR PARTICLES IN RELATION TO THE PYCNOCLINE IN THE NORTHWEST ATLANTIC OCEAN

Debbie Phelps and Kate Roosevelt

Abstract

This study examined the relationship between the concentration of microscopic tar in the water column and the pycnocline layer. Water samples were obtained from two warm core eddies, the Sargasso Sea, and slope water along the cruise track of C-100. Niskin bottles were used to collect the water samples in the upper 800m of the water column. The salinity was determined and water was filtered from each bottle. The tar particles on these filters were counted and classified according to their size. The shallow pycnocline was determined to be at the seasonal thermocline. It was noted that layers of high concentrations of tar particles correlated with the depth of the pycnocline, suggesting the density change measurably affects the rate of sinking of the tar particles. Generally, small tar particles were found at greater depths, suggesting degradation processes continue as the tar sinks.

THE CONCENTRATION, DISTRIBUTION, AND WEATHERING OF PLASTIC POLLUTION: CAPE COD, BERMUDA, AND NOVA SCOTIAN WATERS

Erik White and Thomas Kraemer

Abstract

Pelagic plastic was collected from 35 neuston net tows made on a cruise track from Woods Hole to Bermuda and Nova Scotia. Plastic from beaches of Cape Cod and Bermuda were also sampled. The concentration (pieces and pellets/km^2) and degree of weathering of pellets were determined. The highest concentration of pelagic plastic was observed in the Sargasso Sea, which was also the location of the most weathered pellets. The convergence of water in the Sargasso Sea explains the high concentrations found in that area. Shelf and slope concentrations were higher than previous reports. A higher concentration of plastic in the Gulf Stream was found on the downstream crossing of the current suggesting the addition of plastic may occur in shipping lanes which occur in the area between the two crossings of the stream. Plastic pellets removed from the Cape Cod beach were less weathered than that from Bermuda suggesting more local origin for the Cape Cod pellets.

APPENDIX A. Noon and Midnight Position on C-100

Date	Time (hrs)	Latitude	Longitude
5/21	1200	41°22'N	70°46'W
5/22	0000	41°22'N	70°46'W
	1200	41°05'N	71°01'W
5/23	0000	40°43'N	70°29'W
	1200	40°15'N	70°26'W
5/24	0000	39°49'N	70°05'W
	1200	39°21'N	69°19'W
5/25	0000	39°27'N	69°19'W
	1220	40°08'N	69°09'W
5/26	0000	40°08'N	68°50'W
	1200	39°16'N	68°40'W
5/27	0000	38°34'N	68°49'W
	1200	37°39'N	68°27'W
5/28	0000	36°32'N	67°58'W
	1215	35°58'N	67°32'W
5/29	0000		
	1200	34°54'N	66°59'W
5/30	0000	34°33'N	66°37'W
	1200	34°09'N	66°01'W
5/31	0000	34°02'N	65°38'W
	1200	32°50'N	65°15'W
6/01	0000	32°36'N	64°10'W
	1200	St. Georges, Bermuda	
6/03		anchored at St. Georges, Bermuda	
6/04	0000	32°35'N	64°10'W
	1200	33°05'N	63°24'W
6/05	0000	33°33'N	63°00'W
	1200	34°22'N	62°45'W
6/06	0000	35°37'N	62°17'W
	1200	36°29'N	61°58'W
6/07	0000	36°10'N	61°50'W
	1200	36°18'N	61°46'W

6/08	0000	36°55'N	61°30'W
	1200	37°09'N	61°14'W
6/09	0000	37°58'N	60°52'W
	1200	39°16'N	60°52'W
6/10	0000	40°06'N	61°45'W
	1200	40°29'N	62°26'W
6/11	0000	40°27'N	62°02'W
	1200		
6/12	0000	42°26'N	63°22'W
	1200	43°23'N	63°59'W
6/13	0000	43°56'N	64°05'W
	1200	Lunenberg, Nova Scotia	
6/14		anchored at Lunenberg, Nova Scotia	
6/15		anchored at Lunenberg, Nova Scotia	
6/16	0000	44°02'N	63°57'W
	1200	43°06'N	63°09'W
6/17	0000	42°59'N	63°21'W
	1200	42°54'N	64°20'W
6/18	0000	42°46'N	65°46'W
	1200	42°42'N	66°09'W
6/19	0000	42°54'N	66°28'W
	1200	43°09'N	67°31'W
6/20	0000	43°07'N	68°50'W
	1200	43°17'N	69°36'W
6/21	0000	43°25'N	70°04'W
	1200	anchored Portland, ME	
6/22	0000	43°03'N	70°19'W
	1200	anchored Isles of Shoals, NH	
6/23	0010	42°53'N	69°58'W
	1200	42°48'N	70°01'W
6/24	0000	42°05'N	69°38'W
	1200	41°43'N	69°43'W
6/25	0000	41°58'N	69°41'W
	1200	41°32'N	70°47'W
6/26	0000	41°29'N	
	1200	70°35'N	

APPENDIX B. Station List for C-100

STATION #	DATE	LAT. (° N)	LONG. (° W)	TIME	EQUIPMENT
1	5/21	41 21.5′	70 46.2′	1900	CTD
					Niskin bottles
					Phyto. net
2	5/22-23	40 45.1′	70 28.3′	1730	Rock dredge
					Otter trawl
				2120	Niskin bottles
					Phyto. net
				2300	Meter net
				0150	Neuston net
3	5/23	40 15.4′	70 27.5′	0810	Shipek grab
				0905	Niskin bottles
				1500	Otter trawl
					Neuston net
4	5/24	39 17.8′	69 14.4′	1339	Neuston net
					CTD
5	5/25	39 27.3′	69 19.4′	0055	Neuston net
				0300	Meter nets
				0520	Niskin bottles
6	5/25	40 08.5′	69 09.1′	1230	Shipek grab
7	5/25	40 06.5′	69 50.6′	2030	Shipek grab
				2100	Shipek grab
				2230	Shipek grab
8	5/26-27	38 34.0′	68 49.0	2200	Meter nets
				0020	Neuston net
				0200	CTD
				0310	Niskin bottles
					Phyto. net
9	5/27-28	36 31.9′	67 58.3′	2000	CTD
				0000	Neuston net
10	5/28	37 57.7′	67 32.4′	1215	Neuston net
11	5/28-29	38 32.8′	67 38.7′	2110	Niskin bottles
				2145	Phyto. net
				2235	CTD
				2345	Meter nets
				0210	Neuston net
12	5/29	34 54.0′	66 59.0′	1230	Neuston net
13	5/29-30	34 33.6′	66 37.1′	2223	Midwater trawl
				0028	Neuston net
14	5/30	34 09.1	66 01.3′	1220	Neuston net
15	5/31	32 26.8′	64 53.5′	1600	Shipek grab
					Shipek grab
					Shipek grab
				2085	Shipek grab
16	6/1	32 26.1′	68 24.3′	0130	Neuston net
17	6/3	32 21.1′	64 35.5′	1840	Shipek grab
18	6/4	32 35.4′	69 09.6′	0000	Neuston net
19	6/4	33 05.1′	63 23.5′	1200	Neuston net
20	6/4	33 32.0′	62 59.3′	2140	CTD
				2210	Phyto. net
				2240	Meter nets
21	6/8	36 54.6	′61 29.6′	0000	CTD
				0025	Phyto. net
				0133	Neuston net
22	6/9	38 06.0′	60 54.0′	0220	CTD

STATION #	DATE	LAT. (° N)	LONG. (° W)	TIME	EQUIPMENT
23	6/9	39 16.4′	60 51.6	1335	Neuston net
24	6/10	40 29.0′	62 26.0′	1015	CTD
				1140	Niskin bottles
				1425	Phyto. net
				1451	Neuston net
25	6/10-11	40 32.7′	62 06.3′	2230	Meter nets
					CTD
26	6/11	42 23.9′	63 21.8	2330	Meter net
27	6/12	43 27.6′	64 02.6′	1452	Shipek grab
				1514	Otter trawl
				1715	Otter trawl
				1830	CTD
28	6/13	43 05.9′	63 08.5′	1200	Neuston net
29	6/17	42 48.6′	63 21.0	0015	Neuston net
30	6/18	42 46.1′	65 45.8′	0040	Nueston net
31	6/18	42 38.1′	66 07.8′	0912	Shipek grab
				0940	Otter trawl
				1050	CTD
32	6/19	43 8.9′	67 31.5	1227	Neuston net
33	6/19	43 07.0′	68 50.0′	0018	Neuston net
34	6/20	43 17.2′	69 34.6′	1221	Neuston net
35	6/21	42 15.8′	70 13.7′	2002	CTD
				2020	Niskin bottles
				2100	Neuston net
36	6/24	41 38.5′	69 36.0′	1550	CTD

APPENDIX C. Bathythermograph Stations for C-100

BT#	DATE 1988	LAT (°N)	LONG. (°W)	SURFACE TEMP. (°C)	100mTEMP. (°C)
1	5/23	40 34′	70 30′	9.1	
2	5/23	40 14	70 30′	9.4	
3	5/23	40 05′	70 19′	11.2	14.4
4	5/23	40 00′	70 13′	10.3	14.5
5	5/23	39 51′	70 06′	17.0	12.4
6	5/24	39 44′	69 58′	13.0	16.0
7	5/24	39 37′	69 44′	12.1	12.0
8	5/24	39 32′	69 36′	21.1	16.0
1EBT	5/24	39 33′	69 36	19.9	16.5
9	5/24	39 26′	69 26′	19.0	17.3
10	5/24	39 19′	69 17′	19.0	17.5
2EBT	5/24	40 44′	70 31′	19.6	17.5
11	5/24	39 25′	69 15′	19.7	17.5
4EBT	5/24	39 29′	69 22′	19.8	16.6
12	5/24	39 29′	69 22′	19.6	16.8
5EBT	5/25	39 27′	69 19′	19.5	17.1
13	5/26	40 06′	68 49′	12.3	11.7
6EBT	5/26	40 04′	68 47′	11.0	12.0
14	5/26	39 47′	68 40′	17.5	17.2
15	5/26	39 45′	68 39′	16.6	13.6
16	5/26	39 24	68 39′	18.4	16.4
7EBT	5/26	38 55′	68 44′	18.9	17.2
17	5/26	38 53′	68 45′	18.8	17.2
8EBT	5/26	38 38′	68 51′	21.5	14.0
9EBT	5/27	38 34′	68 49′	16.8	12.8
18	5/27	38 12′	68 44′	20.3	14.3
19	5/27	37 58′	68 37′	21.7	15.3
10EBT	5/27	37 52′	68 33′	24.2	19.9
20	5/27	37 44′	68 29	25.4	21.5
21	5/27	37 39′	68 27′	25.3	20.6
22	5/27	37 27′	68 21′	25.3	21.0
23	5/27	37 20′	68 19′	25.2	21.7
24	5/27	37 10′	68 17′	24.2	18.9
25	5/27	37 02′	68 15′	21.8	
26	5/27	36 56′	68 13′	20.5	19.0
11EBT	5/28	36 07′	67 36′	20.3	18.8
27	5/28	35 33′	67 39′	21.0	18.8
28	5/31	33 04′	65 03′	23.7	18.8
29	6/4	33 32′	62 59′	23.4	18.5
30	6/6	36 26′	62 09′	23.7	20.5
31	6/6	36 33′	62 09′	23.3	20.3
32	6/7	36 00′	61 51′	21.9	19.7
33	6/7	36 15′	61 48′	23.9	20.2
34	6/7	36 27′	61 44′	23.1	20.2
35	6/7	36 37′	61 38	22.4	18.5
36	6/7	36 45′	61 37′	24.4	20.5
37	6/7	36 51′	61 33′	24.9	21.4
38	6/7	36 51′	61 30	24.4	21.5
39	6/8	37 00′	61 28′	24.9	21.7
40	6/8	37 06′	61 27′	23.9	21.7
41	6/8	37 12′	61 19′	24.9	22.3
42	6/8	37 11′	61 11′	24.6	21.2
43	6/8	37 13′	61 08′	22.8	20.9

BT#	DATE 1988	LAT (°N)	LONG. (°W)	SURFACE TEMP. (°C)	100mTEMP. (°C)
44	6/8	37 16′	61 05′	22.9	20.4
45	6/8	37 19′	61 04	22.5	19.7
46	6/8	37 23′	61 01′	22.7	19.2
47	6/8	37 32′	60 57′	22.4	22.6
48	6/8	37 40′	60 55′	22.7	20.3
49	6/8	37 56′	60 53′	22.7	19.2
50	6/9	38 07′	60 54′	25.0	22.1
51	6/9	38 26′	60 53′	24.2	21.3
52	6/9	38 44′	60 53′	24.3	19.6
53	6/9	39 32′	61 03′	20.7	13.9
54	6/9	39 45′	61 17′	20.0	14.6
55	6/9	39 53′	61 27′	19.1	15.0
56	6/9	40 04	61 40′	17.8	15.2
57	6/10	40 12′	61 58′	22.1	17.9
58	6/10	40 17′	62 09′	22.9	20.3
59	6/10	40 23′	62 17′	22.6	20.4
60	6/10	40 28′	62 25′	22.4	19.3
61	6/10	40 34′	62 17′	22.1	19.6
62	6/10	40 32′	62 06′	22.6	20.3
63	6/11	40 26′	62 09′	22.0	19.5
64	6/11	40 37′	62 12′	21.6	20.1
65	6/11	40 46′	62 12′	21.9	19.5
66	6/11	40 59′	62 14′	22.2	16.5
67	6/11	41 08′	62 20′	18.2	14.7
68	6/11	41 11	62 23′	9.8	15.0
69	6/11	41 21′	62 31′	11.1	12.0
70	6/11	41 30′	62 38′	12.2	12.0
71	6/11	41 39′	62 45′	12.5	11.2
72	6/11	41 48′	62 52′	12.1	11.4
73	6/11	41 53′	63 02	14.1	14.1
74	6/11	42 03′	63 11′	11.5	12.4
75	6/11	42 18′	63 20′	10.5	12.5
76	6/12	42 29′	63 23′	10.7	14.1
77	6/12	42 42′	64 29′	9.9	11.1
78	6/12	42 53′	63 35′	8.2	10.0
79	6/12	43 04′	63 40′	8.3	
80	6/12	43 06′	63 41′	8.0	4.6
81	6/12	43 16′	63 51′	7.7	
82	6/12	43 23′	63 59′	8.8	5.2
83	6/12	43 35′	64 03′	9.4	4.9
84	6/12	43 47′	64 04′	7.7	
85	6/21	43 32′	70 02′	16.6	
86	6/21	43 24′	70 09′	16.6	
87	6/21	43 18′	70 13′	15.8	
88	6/24	41 41′	69 43′	14.8	
89	6/24	41 39′	69 41′	14.8	
90	6/24	41 39	69 36	15.0	
91	6/24	41 40′	69 35′	15.4	