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SPATIAL AND TEMPORAL VARIABILITY IN ZOOPLANKTON DISTRIBUTIONS AND ABUNDANCES ACROSS THE GULF STREAM

BY

STUART K. ALLISON

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
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MASTER OF SCIENCE THESIS

OF

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APPROVED:

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UNIVERSITY OF RHODE ISLAND

1986

Abstract

From November, 1981 to November, 1982, zooplankton were sampled bimonthly by oblique net tows in the upper 200 m of the Gulf Stream and nearby regions along a cross-stream transect of 9 stations centered at 36° N 73° W, where the Stream turns offshore from Cape Hatteras. In September, 1982 and May, 1983, extensive vertically stratified sampling of zooplankton was conducted at 3 stations along this same transect with a MOCNESS net system in the upper 1000 m of the water column. The zooplankton samples were collected concurrently with measurements of the hydrography and velocity fields of the Stream. This study was initiated in an effort to elucidate relationships between the physical oceanography and biology of the Stream.

An intensive examination was made of the spatial and temporal distribution of selected copepod species across the Gulf Stream during September, 1982. The copepod species distributions grouped together into distinct patterns, which were related to different environmental habitats within the Stream. Biological processes, such as temperature and depth preferences and diel vertical migration, interacted with the physical structure of the Stream to determine whether a species would be found at different cross-stream locations and if so, at what depths in the water column. The community structure of these species groups resembled a modified version of the individualistic hypothesis of species distributions and community formation.

Zooplankton biomass abundance and distribution was examined for all of the cruises. There was a distinct pattern of seasonal variability in zooplankton biomass with a maximum in the late spring and early summer, and a minimum in the autumn. Zooplankton biomass tended to be highest in the Slope Water, intermediate at the north wall of the Gulf Stream, and lowest in the Gulf Stream proper and Sargasso Sea. The north wall of the Gulf Stream is a frontal region where elevated plankton biomass sometimes occurred.

The association of different copepod species groups with distinct environmental habitats having different velocities and directions of water movement suggests that the species have varying probabilities of downstream and cross-stream transport. Downstream transport of zooplankton species and biomass is probably greatest in the upper 100 m. Cross-stream transport is probably greatest below the 12°C isotherm, but can also be high in the surface water.

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Elijah Swift generously loaned us his 65 cm plankton net for an extended period of time. John Wormuth loaned us his MOCNESS net system and was a joy to work with at sea. Don Dorson, Jim Fontaine, and Bill Hahn helped set up the MOCNESS to work on the Endeavor. Ed Buskey, Kathi Kelly, Monica Hallisey, and Lynn Beatty all provided valuable assistance at sea, as did the captains and crews of the R/V Endeavor and R/V Cape Hatteras. Wayne Munns, Chris Brown, Richard Chinman, Jeff Rosen, and Arthur Mariano all were very patient in helping me understand statistics and computers. Dan Halkin, John Lillibridge, and Terry Rago were equally patient

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Preface

This thesis is written in manuscript style. It consists of two manuscripts. Both are written in the format of the journal Deep-Sea Research. The introduction to this thesis precedes the two manuscripts.

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Introduction to the Thesis

Introduction

The Gulf Stream current is a region with a complex physical structure (Rossby, 1982; Halkin, 1984) that probably functions biologically as an ecotone, a region in which the local physical oceanography plays a dominant role in species distributions and interactions (McGowan, 1974). The physical structure and dynamics of the Stream may have a large role in determining the vertical and horizontal distributions of zooplankton species and biomass, not in just the Stream itself, but in large areas of the North Atlantic (Cox and Wiebe, 1979). The nature of the interactions between the physics and biology of the Stream, especially downstream of Cape Hatteras, are largely unknown. This study was conducted in order to elucidate relationships between the physical oceanography and biology of the Gulf Stream by: 1) describing the spatial and temporal distribution of selected copepod species with depth across the Stream, 2) correlating these distributions with hydrography, nutrient concentration, chlorophyll concentration, and the velocity field measured concurrently, 3) describing the spatial and temporal distribution of zooplankton biomass in the Stream throughout a year, and 4) determining qualitatively the amount and direction of zooplankton biomass transport by the Stream at different stations, depths, and times.

Biological oceanographers have tended to view oceanic current systems as boundaries between distinct water masses and species (Angel, 1979) or as sources of interesting mesoscale phenomena such as rings and eddies (for example: Ring Group, 1981; Tranter et al., 1983; Haury, 1984), upwelling events (Yoder et al., 1981; Paffenhofer et al., 1984; Diebel, 1985), and as a means of genetic exchange between separated populations (Scheltema, 1971; Backus et al., 1977; Scheltema and Williams, 1983). It is apparent that interactions within the current itself are extremely important in determining the plankton community structure across large areas (Chelton et al., 1982; Wroblewski, 1982; Davis, 1984).

The Gulf Stream functions as both a route of faunal dispersal and as a faunal boundary. The Stream transports large amounts of water downstream (Worthington, 1976). As it flows downstream, the Stream entrains increasing amounts of water and also loses water in some areas by processes such as detrainment and eddy formation (Rossby, 1982). Presumably organisms living in the water are entrained and detrained with it. The northern edge of the Gulf Stream acts as a boundary between a cool, temperate water mass and a warm, subtropical water mass and forms the northern limit for many warm water species and the southern limit for many cool water species (Angel, 1979). The Gulf Stream has a species composition similar to that of the Sargasso Sea (Grice and Hart, 1962), although the species may have different absolute and relative abundances (Ortner et al., 1979). The Stream is not an absolute boundary as many species naturally occur on both sides of it (Grice and Hart, 1962). There is direct evidence from in-situ velocity profiles (Halkin, 1984), deep water SOFAR float paths (Shaw and Rossby, 1984), Rafos float trajectories (Rossby et al., 1985), and the distribution of passive tracers along isopycnal surfaces (Bower et al., 1985) which indicates that cross-stream mixing and transport occur along the Stream, especially at depth.

This research on the spatial and temporal variability in zooplankton distributions and abundances across the Gulf Stream was conducted concurrently with in-situ measurement of the velocity and transport fields of the Gulf Stream by H. T. Rossby. This allowed us to correlate biological and physical patterns across the Stream. Emphasis has been placed on determining to what extent zooplankton distributions follow water movements in an effort to estimate the importance of downstream and cross-stream transport to the overall distributional patterns of zooplankton in the western North Atlantic.

The two manuscripts in this thesis are part of a project on the biology of the Gulf Stream directed by K. F. Wishner. During this project, zooplankton samples were collected from the upper 200 m by oblique net tows during bimonthly transects of the Gulf Stream from November, 1981 to November, 1982. In September, 1982 and May, 1983, intensive vertically stratified zooplankton sampling was done along this same transect with a MOCNESS net system. All zooplankton samples were collected in conjunction with the previously mentioned in-situ measurements of velocity and transport. The first manuscript of this thesis describes the spatial and temporal variability of selected copepod species collected by the MOCNESS in September, 1982. The second manuscript describes the variability in abundance and distribution of zooplankton biomass from all of the samples collected.

The Distribution and Abundance of Selected Copepod Species in Relation to the Physical Structure of the Gulf Stream

by

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Abstract

The horizontal and vertical distribution of selected copepod species across the Gulf Stream was studied in September, 1982, along a transect located east of Cape Hatteras where the Stream turns offshore. Three Gulf Stream stations, the north wall, the warm core, and the southern edge, were sampled in discrete depth intervals to 1000 m both day and night with a 1 m^2 MOCNESS. Copepod species distributions can be grouped into several distinct patterns related to different environmental habitats within the Stream. Biological processes, such as apparent temperature and depth preferences and diel vertical migration, interact with the complex physical structure of the Stream to determine where in the water column a species is found at different cross-stream locations. The association of different species groups with particular environmental habitats having different velocities and directions of water movement also suggests that different species have varying probabilities of downstream and cross-stream transport. The community structure of these species groups fits a slightly modified version of the individualistic hypothesis of species distributions and community formation.

Introduction

The Gulf Stream, a major feature of the North Atlantic circulation, functions as both a faunal boundary and an important dispersal route. Its biology, however, has not been well studied. In particular, the role that the physical structure and dynamics of the Stream may have in determining the vertical and horizontal distributions and abundances of zooplankton species is unknown.

The Gulf Stream current can be viewed as both a river in the ocean and a boundary between two distinct water masses. As a river, it is seen as a core of warm, fast-flowing water about 100 km wide (Stommel, 1965). It flows to the northeast from the Florida Straits in a course parallel to the coastline. At Cape Hatteras it turns offshore and moves into deeper water where its geographic position is highly variable as it forms large meanders which may pinch off into eddies and rings (Fofonoff, 1981). As it flows downstream from the Florida Straits, the Gulf Stream picks up and transports increasing amounts of water (Worthington, 1976). At first, most of the entrained water comes from the Sargasso Sea, but once it turns offshore, Slope, and possibly even Shelf, water is also entrained (Rossby, 1982). Entrainment and detrainment may occur on both sides of the Stream for much of its length (Halkin, 1984). The Gulf Stream has a low oxygen signature at several hundred meters depth which is derived from the Gulf of Mexico and is readily observable well downstream of Cape Hatteras (Rossby, 1982). This indicates that the original source water of the Stream remains intact as a discrete entity for a long period of time and distance.

As a boundary, the Gulf Stream separates colder, seasonally variable, nutrient rich Slope and Shelf water from the warmer less variable, nutrient poor subtropical water of the Sargasso Sea. However it is not an absolute boundary. Lateral shifts in position and lateral mixing processes across the Stream may transport large amounts of water and heat energy cross-stream (Parker, 1976; Lambert, 1982). SOFAR float data have shown that floats at 700 m react to the Gulf Stream as if it were a boundary, while floats set at 1300 m cross the Stream readily (Shaw and Rossby, 1984). Rafos float studies have also shown that water parcels in the main thermocline will tend to be carried downstream for long distances unless disturbed by unstable meanders, or rings and eddies near the Stream (Rossby et al., 1985). Distributions of physical parameters and oxygen concentrations along isopycnal surfaces, which slope downward from the Slope Water to the Sargasso Sea, have also indicated that, at shallower levels, the Stream is a distinct boundary to cross-stream transport, but that below the oxygen minimum layer (σ_θ =27.0) cross-stream exchanges occur along with considerable downstream water flow (Bower et al., 1985). Presumably, when water is entrained or detrained from the Stream, or pinches off to form cold core or warm core rings, the organisms in that water are carried along with it, at least initially.

The Gulf Stream is a highly dynamic system in which processes occurring at any one time and place are the result of events which happened at some point earlier in time. These events are occurring continuously and in the entire northwestern Atlantic region. Thus any pattern of distribution of properties across the Stream represents an image of the state of the Stream at that particular place and time resulting from these events and processes and is unique to that time and place (Rossby, 1982).

Ecologically the Gulf Stream region functions as an ecotone, a transition region in which local physical oceanography plays a dominant role in species distributions and interactions (McGowan, 1974). The physical oceanography of this region is exceedingly complex, and it follows that the ecology is complex too. Zoogeographic studies of the North Atlantic reveal that the Stream can act as a barrier for some species, as a region of dispersal and distributional extension for others, and as a region of subtle changes in abundance and distribution for still others (McIntyre and Be, 1967; Backus et al., 1977; Nafpaktitus et al., 1977; Angel, 1979; Colebrook, 1982; Pierrot-Bults, 1982). There is some evidence that the Stream may separate populations of a single species which have subtle differences in genotype (Brand, 1982).

The northern edge of the Gulf Stream, a sharp frontal region, is an important biogeographic boundary marking the northern distributional limit of many warm water species and the southern distributional limit of many cold water species (Angel, 1979). The southern edge is a zone of gradual transition from the Gulf Stream to the Sargasso Sea. The surface of the Stream tends to have a species composition and seasonal variability similar to that of the Sargasso Sea (Grice and Hart, 1962), although the absolute and relative species abundances can differ (Ortner et al., 1979). Deeper water of the Gulf Stream shows faunal affinities with both the Slope Water and Sargasso Sea (Jahn and Backus, 1976). The Stream is not an absolute boundary, and the Slope Water, Gulf Stream, and Sargasso Sea have species in common (Grice and Hart, 1962; Ortner et al., 1979).

Numerous studies have been done on aspects of the biology of the Gulf Stream, but its ecological role has remained elusive. Extensive work, mostly in the Florida Straits region and south of Cape Hatteras, records species distributions (Lewis, 1954; Bsharah, 1957; Moore and O'Berry, 1957; Owre, 1960; Grice and Hart, 1962; Pierce and Wass, 1962; Wormelle, 1962; Roehr and Moore, 1965; Owre and Foyo, 1967; Park, 1970; Bowman, 1971; Jahn and Backus, 1976; Michel et al., 1976; Stepien, 1980; Ortner et al., 1981). Enhanced biomass and productivity associated with the Stream have also been documented. For example, intrusions and upwelling events along the shelf edge south of Cape Hatteras (Blanton et al., 1981; Hoffman et al., 1981; Lee et al., 1981) result in patches of high primary production, chlorophyll, and zooplankton (Atkinson et al., 1978; Paffenhofer, 1980; 1983; Paffenhofer et al. 1980; 1984; Yoder et al., 1981; Deibel, 1985). Offshore, east of Cape Hatteras, biomass peaks of zooplankton (Allison and Wishner, in review) and phytoplankton (Lessard, 1984) are associated with the north wall front. Some species of phytoplankton are able to grow faster in the Stream than in the Sargasso Sea (Voytek, 1984).

The zooplankton in Gulf Stream cold core and warm core rings have also been intensively studied (Wiebe et al., 1976a; 1985; Boyd et al., 1978; Ortner et al., 1978; 1979; 1980; Wiebe and Boyd, 1978; Ring Group, 1981; Backus and Craddock, 1982; Haury and Wiebe, 1982; Wiebe and Flierl, 1983; Wroblewski and Cheney, 1984), and the fact that rings can transport organisms between water masses in the North Atlantic is well documented. However, these studies have discussed only briefly the biology of the "ring fringe" (the Gulf Stream remnant encircling a ring) and have rarely considered the question of direct cross-stream exchange of organisms.

This paper describes the spatial and temporal distributions of selected copepod species with depth across the Stream and correlates these distributions with various biological and physical parameters. This study is part of a project directed by Dr. K. Wishner, and many of the ideas were discussed in Wishner (1983). This paper will examine in detail:

1) Can copepod species distributions be grouped into

distinct patterns?

2) If such patterns are found, can they be related to distinct oceanic habitats within the Gulf Stream?

3) Are there regions of the Gulf Stream in which downstream and cross-stream dispersal are more likely to occur than in others?

4) What processes are the major mechanisms causing cross-stream and downstream transport of zooplankton?

5) What types of community structure exist within the Gulf Stream copepod community?

Methods

Sampling

The data were collected during September 5-17, 1982, on cruise 89 of the *R/V Endeavor* in the Gulf Stream region just east of Cape Hatteras. Samples were collected at three stations positioned 20 to 40 km apart perpendicular to the mean direction of the Stream along a transect centered at 36^{o} N 73^{o} W (Fig. 1). The stations were located at the north wall of the Stream (15^{o} C isotherm at 200m and surface velocity > 100 cm s^{-1}), the warm high velocity central core (surface velocity > 100 cm s^{-1} and temperature > 27.5^{o} C), and the southern edge of the Stream, a region of downstream movement, but slower than the warm core (surface velocity 40 to 100 cm s^{-1}). The position of the Stream was determined from expendable bathythermographs (XBT) deployed to 750 m, infrared satellite imagery of sea surface temperatures, and results from a three-day temperature and velocity profiling program by Dr. H. T. Rossby immediately preceeding biological sampling along the same transect.

At each station vertically stratified zooplankton sampling was done with a MOCNESS net (1 m^2 mouth opening, 333 um mesh) (Wiebe et al., 1976b). This opening-closing net system allows one to collect 9 sequential samples along with *in-situ* environmental information (depth and temperature) and sampling data (volume filtered and net angle). Data from the MOCNESS was processed and stored at sea on a Hewlett-Packard 85 computer. The net was towed into the flow of the Stream to maintain a constant cross-stream location. MOCNESS tow series consisted of a deep oblique tow from 1000 m to the surface (in intervals of 1000-850 m, 850-700 m, 700-550 m, 550-400 m, 400-300 m, 300-200 m, 200-100 m, and 100-0 m) and a shallow oblique tow from 200 m to the surface in 25 m intervals. The maximum depth of sampling (1000 m) was close to the bottom of the permanent thermocline and a depth at which SOFAR floats sometimes cross the Stream. A day and night tow series, centered at noon and midnight, was conducted at each station. Each net filtered 300 to 1000 m^3 of water. Samples were preserved in 4% buffered Formalin. Sampling information is given in Table 1.

At each station, *in-situ* water velocity and transport direction to a depth of 2000 m was measured with a cast of a free vehicle Pegasus velocity profiler (Spain et al., 1981) undertaken by Dr. H. T. Rossby (of the University of Rhode Island) and his group, who also analyzed the data.

Hydrocasts with 5 l Niskin bottles at 25 m intervals from the surface to 200 m and 100 m intervals from 200 m to 1000 m at each station provided data on temperature, salinity, and concentrations of oxygen, total nutrients (NO_2 and NO_3, PO_4, SiO_2), chlorophyll a, and phaeophytin. Oxygen was measured by the Winkler titration method on board ship immediately after being collected (Strickland and Parsons, 1968). Seawater for the nutrient analysis was drawn through a 0.45 um type A/E glass fiber filter to remove organisms and large particles. Nutrient samples were then poured into 50 ml plastic bottles that had been acid washed. Samples for NO_2 and NO_3 were preserved with 100 ul of concentrated H_2SO_4 and refrigerated. Samples for PO_4 and SiO_2 were preserved by freezing. NO_2 and NO_3, PO_4, and SiO_2 were measured with an auto-analyzer (Strickland and Parsons, 1968). Chlorophyll samples were collected on 0.45 um type A/E glass fiber filters. The filters were wrapped in aluminum foil, frozen, and stored in a desiccator. Chlorophyll a and phaeophytin were measured fluorometrically on shore within 6 weeks of their collection (Strickland and Parsons, 1968). Satellite infrared imagery was obtained from the Remote Sensing Center at the Graduate School of Oceanography of the University of Rhode Island.

Analysis

Zooplankton samples were analyzed for selected copepod species composition and abundances. Copepods were chosen for analysis because of their numerical dominance in the area (Grice and Hart, 1962), laboratory expertise in their identification, and the fact that different species have been shown to react differently to the changing conditions in cold core rings (Ring Group, 1981). Twenty-two taxonomic units, which included adults of 18 species and the fifth stage copepodites of the 4 species of the family Calanidae examined, were selected for detailed analysis because they were common in the samples, exhibited differing distribution patterns, and were relatively easy to identify. Aliquots, obtained with a Folsom plankton splitter, were used so that approximately 500 adult copepods of all species present were counted per sample. The selected species represented 13 to 95% of all adult copepods in a sample. The percentage similarity index (Whittaker, 1975) between a set of paired aliquots was 96% and species abundances between the aliquots varied by 0 to 50% of the mean for the two samples. From 1/4 to 1/32 of the original sample was counted.

Recurrent group analysis (Fager, 1957; Fager and McGowan, 1963; McGowan and Walker, 1979) was used to examine the copepod distribution data. This method was chosen because it produces objectively defined groups of species that are based upon presence and absence, rather than absolute abundances. The use of presence and absence data reduces the possibility of errors caused by patchiness and variable abundance estimates. The groups are formed using an index of affinity between all species in which:

$$\alpha = J_{ab}\,(n_a n_b)^{-1/2} - 2(n_b)^{-1/2}$$

where:

J_{ab} is the number of joint occurrences of species a and species b

n_a is the number of occurrences of species a

n_b is the number of occurrences of species b

where $n_b > n_a$

$2(n_b)^{-1/2}$ is a correction for unequal sample sizes.

Groups of species are formed so that all species pairs in a group have an α value greater than or equal to a preassigned value. Selection of an appropriate affinity level is subjective and is done to maximize the interpretetability of results. Once an α value is chosen, group formation is objective. In this study, an α value of 0.50 was used. Other studies have used values of α from 0.30 to 0.80 (Fager and McGowan, 1963; Brinton, 1979; McGowan and Walker, 1979; Venrick, 1982; Loeb et al., 1983). The probability of obtaining any particular α value is dependent upon the frequencies of occurrence of the species pair under consideration. In this study the probability of an α value being 0.5 or greater by chance alone ranged from 0.005 to 0.30, from a possible range of 0 to 1.

After the analysis had divided the species into distinct groups, percentage affinities were calculated between all groups. The percentage affinity between groups, or the amount of connection, is the proportion of all species pairs, between two groups, that have an affinity index greater than 0.5.

Principal component analysis (PCA) (Pielou, 1977) was used as a descriptive tool to determine relationships among the environmental data. The variables used in the PCA were total zooplankton biomass [ml $(1000)^{-3}$] depth, median temperature in the sampling interval, temperature range of the sampling interval, salinity, sigma-t, oxygen, SiO_2, PO_4, chlorophyll a, and velocity. Before performing the PCA, all data were log transformed [ln(x+1)] and standardized to a mean of 0 and standard deviation of 1. The PCA was done using SAS statistical programs. The number of axes to retain for further analysis was determined by a graphical procedure for deciding which eigenvalues are significant (Preisendorfer, 1981). Sample scores were graphed along these axes and grouped by eye into environmental groups.

Results

Environment

The distributions of environmental parameters with depth are contoured in Fig. 2. Near the surface, temperature (Fig. 2a) is high, and isotherms are horizontal across the Stream. The mixed layer is 50 to 60 m deep across the Stream. Below 20°C, the isotherms slope downward from the north wall to the southern edge. The 15°C isotherm (used to define the northern edge of the Gulf Stream) is at 220 m at the north wall, 440 m at the warm core, and 530 m at the southern edge stations.

Salinity (Fig. 2b) is high and fairly uniform in the surface waters. A salinity maximum occurs from about 100 to 150 m at the north wall and from about 50 to 350 m at the southern edge. This region includes the 18°C water, characteristic of the Sargasso Sea (Worthington, 1976). Isohalines below 200 m slope downward from the north wall to the southern edge.

The density surfaces, σ_t isopycnals, (Fig. 2c) are uniform in depth across the Stream in the surface waters. Below $\sigma_t = 26.0$, the isopycnals slope downward across the Stream from the north wall to the southern edge. $\sigma_t = 27.0$ is about equal to the 12°C isotherm and corresponds to the depth of the oxygen minimum zone.

The distribution of total PO_4 (Fig. 2d) is typical of all the nutrients in the Gulf Stream region. The amount of PO_4 is extremely low in the surface waters and increases with increasing depth. Below 200 m the depth of the nutricline slopes downward cross-stream in the same manner that σ_t does.

Dissolved oxygen also tends to slope downward across the Stream along isopycnal surfaces (Fig. 2e). This has been observed to occur on a large scale all along the Gulf Stream (Bower et al., 1985). The oxygen minimum zone occurs at 200 to 400 m at the north wall and slopes down to a depth range of 600 to 750 m at the southern edge. σ_t =27.0 occurs in the middle of this zone. The distribution of oxygen in the upper waters is complex.

The distribution of chlorophyll a cross-stream is also complex (Fig. 2f). The chlorophyll a concentration is low in all the samples. There is an indication of a peak in chlorophyll concentration from 50 to 160 m at the north wall and 60 m at the southern edge. Chlorophyll a tends to be highest at the north wall.

Downstream velocity (Fig. 3a) is greatest in the surface waters to a depth of 150 m near the north wall. Fairly high velocity ($>$ 100 cm s^{-1}) extends to about 400 m depth at the warm core. In general, velocity tends to decrease with depth. Velocities below about 800 m at the north wall are low ($<$ 20 cm s^{-1}). At the southern edge velocities do not fall below 20 cm s^{-1} until a depth of about 1000 m.

At the north wall and warm core, cross-stream transport is in a southeasterly direction, i.e. towards the Sargasso Sea (Fig. 3b). At the southern edge, cross-stream transport is toward the northwest resulting in an area of convergence between the warm core and southern edge stations. This implies that, at this time and place, entrainment is occurring on both sides of the Stream.

The satellite infrared imagery of the Gulf Stream region just east of Cape Hatteras on September 14, 1982 (Fig. 1) reveals a normal Stream. There are no obvious rings impinging on the Stream or large meanders in the immediate vicinity of the transect. The Stream is in a commonly found position for this area, occurring in the middle of the transect centered at 36°N 73°W (Halkin, 1984). The north wall is not at the north edge of the Gulf Stream in the satellilite thermal image because a thin layer of warm water extended beyond the Stream into the Slope Water.

Copepod Distributions

Copepod species distribution and abundance data are summarized in Table 2. A detailed list of abundances in each sample and vertical distributions of each species is given in Appendix A. The species exhibit a wide variety of distribution patterns with some having shallow water distributions (such as *Calanus minor*), some intermediate depth distributions (*Lucicutia clausi*), and others deep distributions (*Calanus finmarchicus*). Some have very high maximum abundances (*Lucicutia flavicornis*), while others have fairly low maximum abundances (*Metridia venusta*).

Recurrent group analysis, at the 0.50 level of affinity, resulted in the formation of three species groups (a group has > 2 taxonomic units), two species pairs, and four species which were not associated with any groups. These groupings, and the relationships among them, are diagrammed in Fig. 4. Species in these groupings are considered to have a high likelihood of influencing each other biologically. Pair 1 and *Pleuromamma borealis* had no interconnections with any of the other groups or species. Because the analysis was performed on a limited set of species, instead of all species present, it is not surprising that some groups and species would have no associations with any other, even if all were fairly common in the total sample set.

Group 1, consisting of 4 species and the fifth stage copepodite of an adult in the group, occurs as a group (100% of the species present) between 50 m and 100 m across the entire transect (Fig. 5). 80% of the species are consistently present from 50 m to the surface. This group appears to be a shallow water group, probably with an affinity for warmer water. The species in this group tend to be fairly abundant. The deep distributional tail is due to the presence over a broad depth range of Lucicutia flavicornis. This group is strongly connected with Pair 2 (60%) and with Group 3 (40%).

Group 2, consisting of 4 species and the fifth stage copepodite of an adult in the group, occurs as a full group at depth with an upper boundary that follows the sloping $\sigma_t = 27.0$ isopycnal across the Stream (Fig. 6). The full group occurs from 300 m to 1000 m at the north wall and from 850 m to 1000 m at the southern edge during the night. This is the deepest group and is composed of what are usually considered to be Slope Water species (Grice and Hart, 1962). These species tend to be fairly abundant. Occurrences in the upper waters by this group are primarily due to Rhincalanus cornutus. This group is slightly connected (5%) with Group 3.

Group 3, consisting of 4 species, occurs in only one sample as a full group during the daytime (Fig. 7). However, at night, the full group occupies a broad intermediate depth range (50 m to 200 m at the north wall, 50 m to 650 m at the southern edge) with the lower boundary following the sloping $\sigma_t = 27.0$ isopycnal. This group is made up of species which are strong diel vertical migrators. The diffuse distribution pattern of the group as a whole during the day is due to the fact that each of the species has a slightly different depth distribution (see Appendix A). The group is most strongly connected (40%) with Group 1.

Pair 1 is made up of two less abundant species which occur deep in the water column over a narrow depth range (Fig. 8). The distribution pattern slopes downward from the north wall to the southern edge, and is centered along the $\sigma_t = 27.25$ isopycnal. The species in this pair are probably not diel vertical migrators although each occurs in a single sample in the upper waters of the warm core at night. This pair has no connections or associations with other species.

Pair 2 consists of the Mesocalanus tenuicornis adult and fifth stage copepodite. They are fairly abundant and occur primarily in the upper water column (Fig. 9). The pair occurs together between 75 m and 200 m, and both are absent from the upper 50 m at night. This pair is strongly connected (60%) to Group 1.

Of the four ungrouped species, two have especially interesting distributions. Pleuromamma borealis was found only at the north wall (Fig. 10). It is fairly abundant at night. It is considered to be a Slope Water species (Grice and Hart, 1962). It is not associated with any of the recurrent groups. Lucicutia clausi occurs almost exclusively from 100 m to 550 m at the warm core and southern edge of the Stream (Fig. 11). Its center of abundance is the warm high velocity region of the Stream. It is partially associated (40%) with Group 3.

Principal Components Analysis

The 11 environmental variables were reduced to 2 significant axes, which are the first two eigenvectors. The eigenvalues are listed in Table 3. The first eigenvector (Axis 1) accounts for 58% of the variability and is dominated by the large scale physical parameters of median temperature, salinity, velocity, σ_t, and depth. The second eigenvector (Axis 2) accounts for 17% of the variability and is dominated by parameters showing large gradients, i.e. temperature range and oxygen. The remaining eigenvectors are insignificant. The third eigenvector, although in the range of expected noise, still accounts for 11% of the variability and is dominated by parameters closely tied to the biology of the Stream, i.e. zooplankton biomass, chlorophyll a, and SiO_2. The 96 samples used in the analysis were plotted on a projection of Axis 1 by Axis 2 and clustered into environmental groups by eye (Fig. 12). Samples from the coarse and fine scaled sampling were clustered separately. The distribution of these environmental groups in the water column is shown in Fig. 13.

Environmental group A, from the deep coarse-scaled sampling (0-1000 m), encompasses the subsurface core of the Gulf Stream and southern edge from 100 to 550 m. This is a region of relatively warm water, high salinity, and high downstream velocity. Group A, which is below the mixed layer, extends down to the upper part of the oxygen minimum zone and nutricline. Environmental group B (coarse-scaled sampling) consists of surface water samples across the Stream. This is a region of high water temperatures, fairly high salinity, high downstream velocity, low nutrients, and relatively high chlorophyll. Environmental group C (coarse-scaled sampling) consists of the deep water samples and north wall samples from below 100 m. These samples come from a region which includes the oxygen minimum zone and is characterized by cold water, higher nutrients, lower downstream velocities, and lower salinity.

Environmental group D (from the shallow fine-scaled sampling, 0-200 m), consists of samples at the north wall from 150 to 200 m. These are slightly colder for their depth than the other fine-scaled samples and occur at the upper part of the oxygen minimum zone and nutricline. Environmental group E (fine-scaled sampling) includes surface water samples, similar to the coarse scale environmental group B. These samples are from a region of high water temperatures, fairly high salinity, high downstream velocity, low nutrients, and relatively high chlorophyll _a_. Environmental group F (fine-scaled sampling) is from the upper part of the core of the Stream, a region of high salinity, warm water, and higher downstream velocity. Environmental group G (fine-scaled sampling) is composed of samples from a region of transition between surface water and deeper Gulf Stream core water and occurs near the base of the mixed layer.

The recurrent groups of copepods and the environmental groups from the PCA appear to be strongly related to each other. The percentage of samples in a particular environmental group in which a full species group occurs (100% of species present) are listed in Table 4. The distributions of the recurrent groups (100% level) are outlined on the plot of environmental samples from the PCA in Fig. 12. It should be noted that species group 3, which consists of strong diel vertical migrators, is hard to characterize in terms of relationships to environmental groups when both day and night samples are used. Therefore the environmental groups were split into day and night samples when examining species group 3. In the daytime, it only occurs in one environmental group as a full species group, but in the nighttime it is highly associated with 4 environmental groups.

Discussion

Copepod species distributions in the Gulf Stream during September, 1982 can be grouped into several distinct patterns. The fact that most of the selected species could be put into groups and that these groupings have interconnections, indicates that the chosen species are a frequent component of each other's biological environment. These groupings also indicate that copepod species may be interacting with the Gulf Stream in a few distinct ways in response to the Stream environment. The distribution of species groups indicates that the water column can be divided into distinct oceanic habitats, which may change in depth across the Stream. Species distribution patterns suggest a variety of physical and biological processes that may be regulating the species structure of the copepod community.

The association between different groups of species and environmental habitats results in species having varying probabilities of downstream and cross-stream transport. A diagram of hypothesized zooplankton dispersal paths, based on velocity profiles and direction (Halkin, 1984), is shown in Fig. 14. Cross-stream mixing is most probable near the surface and at depth. Near the surface, mixing is most likely to occur on the southern side of the Stream, since the Stream and Sargasso Sea have many similar physical characteristics and much Sargasso Sea water is entrained into the Stream. Cross-stream mixing at depth probably happens below the oxygen minimum zone (σ_t =27.0) where water may cross the Stream on isopycnal surfaces (Bower et al., 1985). Long distance downstream transport is most probable in the warm high velocity core of the Stream, a few hundred meters below the surface, and at the surface near the north wall.

There are three possible types of processes which may be affecting dispersal in this region: purely biological processes, purely physical processes, and a combination of biological and physical processes. The likelihood of purely biological processes, such as horizontal swimming by the zooplankters, accounting for cross-stream movement is probably small. Using as a rule of thumb that an organism can swim 10 body lengths per second (Barkley, 1972), a 2 mm long copepod swimming non-stop horizontally in a cross-stream direction would take almost 59 days to cross a 100 km wide Stream. Foraging, predator avoidance, resting, and the fact that some species will expend swimming energy in vertical migration, are all forces that will prevent constant, unidirectional swimming. Thus it seems unlikely that swimming alone would allow cross-stream mixing to occur.

If physical processes alone are causing the dispersal, the zooplankton should act as passive particles and be distributed like other passive tracers such as oxygen. The distribution of oxygen cross-stream in this study and in a much more extensive study (Bower et al., 1985) indicates that oxygen is transported cross-stream along isopycnal surfaces, especially at depths below σ_t =27.0. Cross-stream velocities as high as 10 cm s^{-1} were measured in the depth range of species group 2 during September, 1982. At this rate a drifting particle could cross the Stream in approximately 10 days. Although in a strict sense, copepods are not passive particles, since they do swim, advection by water movements could result in long range transport if their swimming is random with respect to the current.

Some of the copepod group distributions resemble those of passive tracers whereas others do not. For example Pleuromamma borealis (Fig. 10) occurs over a depth range at the north wall similar to that of species group 2, yet, unlike Group 2, it does not appear to be dispersed cross-stream. Vertical migration to depths with different velocity vectors is not an adequate explanation, since both P. borealis as well as three members of species group 2 vertically migrate at the north wall. Furthermore, at the north wall, the cross-stream transport at all depths during this cruise is southerly (Fig. 3b) (albeit at different velocities), so it is not likely that inhabiting different depth strata would prevent cross-stream dispersal. Thus there are probably both physical and biological interactions occurring which result in some species being dispersed cross-stream and others avoiding it.

Diel vertical migration is the main biological phenomenon which influences the transport regime which a zooplankton species experiences. Not all zooplankton vertically migrate, and those that do not should experience a fairly constant transport regime. Those that do migrate, however, may be subject to different degrees of cross-stream and downstream transport during their migration. For example, members of species group 3 are found mainly in the warm core of the Gulf Stream during the day. They experience considerable downstream transport, but relatively little cross-stream transport while in this region. At night, the members of species group 3 migrate up into the top 100 m. In the surface water (during our sampling period) they experience considerable cross-stream and downstream transport. Thus in one daily period these species are being transported for long distances both downstream and cross-stream.

The cross-stream and downstream transport observed during September, 1982, are representative of what is considered to be an average Gulf Stream (Halkin, 1984). Halkin (1984) found that the mean cross-stream velocity field indicated an inflow toward the center of the Stream from the north and south sides above 2000 m. This inflow was not observed in all individual transects, although it was observed in September, 1982. The mean downstream velocity field tended to have steeply sloping isotachs representative of a large amount of current shear at the north wall and more gently sloping isotachs on the southern edge (Halkin, 1984). In general the downstream profile in September (Fig. 3) is typical of the mean Stream.

Species group 1 (Fig. 5) and species pair 2 (Fig. 9) appear to be transported cross-stream in the surface mixed layer. The direction of this surface mixing is not readily discernible. Examination of the individual species abundance patterns (Appendix A) reveals no clear trends in changes in abundance cross-stream.

The distribution of species group 2 (Fig. 6) indicates that cold water zooplankton are being dispersed cross-stream along isopycnals at the base of the oxygen minimum zone.

This zone slopes down across the Stream from 300 m at the north wall to 700 m at the southern edge. Examination of the individual species abundance patterns (Appendix A) and the direction of cross-stream velocity, indicates that the members of species group 2 are probably being dispersed cross-stream from the north wall to the southern edge. The species in this group have their maximum abundances at the north wall and the abundances decrease as the southern edge is approached.

The core of the Gulf Stream appears to be a region in which it is unlikely for cross-stream zooplankton dispersal to occur. *Lucicutia clausi* (Fig. 11), which underwent only a small amount of vertical migration, occupies a region of 100 to 550 m in the main core of the Stream. It has one occurrence at the north wall at 550 m, but for the most part it seems to be restricted to the main body of the Stream. This core region of the Stream, which contains the low oxygen signature from the Gulf of Mexico and is the region of 18 °C water, is a coherent feature of the Stream for a long distance out into the Atlantic (Rossby, 1982). Cross-stream mixing appears to be at a minimum here, while downstream transport is high. *L. clausi* has fairly even abundances in the Stream core with no indication of input or output from the Stream.

Wiebe and Flierl (1983) extensively examined euphausiid dispersal into and out of cold core rings. They found that euphausiids tended to be dispersed out of cold core rings across the surface waters, as the ring warmed up, and at depths of 400-1000 m. At depths below the mixed layer and above 400 m, they felt it was unlikely for euphausiids to be advected into or out of a ring. The depths at which dispersal is most likely to occur out of a cold core ring are similar to the depths at which dispersal occurs across the Stream. It may be that similar processes govern cross-boundary transport in both systems. The Stream may be simpler in terms of transport processes than are rings, since the high cross-stream velocities (1 to 10 cm s^{-1}) are great enough to account for the dispersal of zooplankton cross-stream. Wiebe and Flierl (1983) constructed complex models to explain the dispersal and retention of zooplankton by a cold core ring, because the observed inward and outward flow rates (0.02 cm s^{-1}) were too small, by themselves, to account for the dispersal which occurred. Wiebe et al. (1985) determined that changes in the biomass structure of a warm core ring were due to <u>in-situ</u> processes because the ring center was relatively isolated from the surrounding water.

Copepod species crossing the Gulf Stream may be changing their depth in the water column and their vertical migration patterns to remain in an optimal or preferred temperature regime. For example, the members of species group 2 increase their depth of occurrence from the north wall to the southern edge of the Stream so that their upper limit is defined by the 12 ^{o}C isotherm cross-stream. At the north wall, the species in group 2 perform a limited range of diel vertical migration, but almost no migration occurs at the southern edge. The only vertical migration occurring at the southern edge in this group is attributable to <u>Rhincalanus cornutus</u>. Species group 3, which is scattered throughout the water column during the day, is brought together by vertical migration at night (Fig. 7). The lowest limit at which all the species of group 3 co-occur is 200 m at the north wall and 600 m at the southern edge. This lower limit is roughly the depth of the 12°C isotherm cross-stream. Temperature is considered to be a major factor influencing the range of vertical migrations of oceanic zooplankton (McLaren, 1963), and it may be that both groups of species determine the range over which they migrate by temperature cues. Members of species group 2 will not migrate up at night into water that is warmer than 12°C, and members of species group 3 migrate up at night into water that is 12°C or warmer. This would explain the inhibition of vertical migration as species group 2 crosses the Stream from the north wall to the southern edge and the shoaling of the maximum depth of nighttime distribution observed as species group 3 approaches the north wall. An examination of the individual species distributions for species group 3 (Appendix A) reveals that these species are most abundant at the southern edge and are probably being transported north from the Sargasso Sea. This dispersal may be aided by migration up into the mixed layer at night where wind driven mixing could carry them cross-stream.

Changes in the depth range and vertical migration patterns over time have also been observed in zooplankton and fish species trapped in warm and cold core rings (Wiebe et al., 1976a; Ortner et al., 1978; 1979; Wiebe and Boyd, 1978; Brandt, 1981; Ring Group, 1981; Backus and Craddock, 1982; Griffiths and Brandt, 1983a; 1983b; Tranter et al. 1983; Wiebe and Flierl, 1983). The copepod Pareuchaeta norvegica gradually moved deeper in the water column with the aging of a cold core ring and with distance from the ring center. This change in depth occupied presumably occurred to remain in a preferred temperature regime (Ring Group, 1981). Copepods at the shelf-slope front off Nova Scotia do not migrate through the sharp physical gradient of the front (Herman and Denman, 1979; Herman et al., 1981; Sameoto, 1984), which is a pattern similar to that of species group 2 which did not migrate up through a region of sharp physical gradients during this study. Copepod species in the upwelling region off the Oregon coast demonstrate a variety of horizontal, vertical, and ontogenetic distribution patterns, which interact with the complex current regime and result in the maintenance of endemic populations (Peterson et al., 1979; Wroblewski, 1982). Similar mechanisms could be maintaining zooplankton populations in the Gulf Stream, but this study was not extensive enough to make that determination.

At any one depth across the Gulf Stream, the physical gradients may be large. However the magnitude of change may be no more than an organism would experience in daily or seasonal vertical migrations, or a population would experience through wide vertical, horizontal, or seasonal distributions (Wiebe and Boyd, 1978). The physical properties of the regions that copepods would be transported to by cross-stream mixing along isopycnals are also often within that experienced in their daily ambit. The likelihood of an organism surviving cross-stream transport may be more dependent on the availability of food than on the ability to withstand physical changes, as was hypothesized for a euphausiid species transported from the Slope Water to the Sargasso Sea in a cold core ring (Boyd et al., 1978). On a population level, a slight environmental change which causes birth rates to be lower than death rates would be enough to insure that a species could not survive in the new environment. For example, warm water chaetognaths transported by an intrusion of the Gulf Stream into cool Shelf Water near Chesapeake Bay have been found dead or dying in the water column (Bushing and Fiegenbaum, 1984).

The copepod species examined in this study tend to have fairly widespread distributions in the Atlantic (Table 5) although some species are restricted to either warm or cold water. Many of the species which occur on both sides of the Gulf Stream (such as Calanus minor) have distinctly deeper distributions in the water column in the southern subtropical region than in the northern temperate region. As has been shown, species distributions tend to increase in depth across the Stream from the north wall to the southern edge. This change in depth cross-stream appears to connect the different habitats the species occupy on either side of the Stream. Advection of individuals of these species by the Stream may represent a loss from a source population or a connection and means of genetic exchange between populations (Scheltema, 1971; Backus et al., 1977; Fleminger and Hulsemann, 1977; Scheltema and Williams, 1983).

Some species of warm water zooplankton occur in the Slope Water in the summer and early fall (Cox and Wiebe, 1979). These species are absent for the remainder of the year and apparently are reintroduced to the Slope Water from the Sargasso Sea each year. These species may reproduce successfully in the Slope Water during the warm months and thus are referred to as forming expatriate populations (Cox and Wiebe, 1979). Direct cross-stream mixing is a likely mechanism by which reintroduction occurs. Our findings indicate that warm water species can be transported directly across the Gulf Stream in the surface water. This transport probably occurs throughout the year, and becomes an important input source for these species in midsummer when surface temperatures in the Slope Water warm up enough to allow them to survive there. There is a net non-tidal surface drift to the north in the Slope Water in the late spring and summer (Bumpus, 1973), which could carry these warm water species, transported cross-stream, into Slope and Shelf areas during the summer and early fall. Cox and Wiebe (1979) account for the presence of such expatriates by a complex cycling of organisms through the Shelf and Slope waters in the summer and early fall, winter transport in the Gulf Stream, and summer seeding by a warm core ring. This mechanism may be possible, but may not be reliable. There is no seasonality to the production of warm core rings (Bisagni, 1976; Cerrone, 1984) and there have been periods of time as long as eight months in which no warm core rings were produced (Cerrone, 1984). Direct cross-stream surface mixing is a more predictable event that would occur at approximately the same time each year and could provide a reliable mechanism for the import of warm water species to the Slope and Shelf waters. These warm water species are present in the Sargasso Sea throughout the year (Grice and Hart, 1962) and would potentially provide a constant source of species for cross-stream mixing. Seasonal input of zooplankton by currents as a regular event has been shown to occur on a smaller scale with copepod species on Georges Bank (Davis, 1984).

Grice and Hart (1962) also examined the zooplankton of the Gulf Stream. They collected samples at one Gulf Stream station three times in the course of a year with oblique net tows from 0-200 m. They found the Stream and Sargasso Sea to be similar in terms of species composition and abundances. The Slope Water was distinct from these two regions, although Gulf Stream and Sargasso Sea species were found there, especially in their July and September collections. Table 6 compares the distribution and abundance patterns of the species we examined with the distribution and abundance patterns observed by Grice and Hart. Especially interesting is a comparison of the distribution of Rhincalanus cornutus. In September Grice and Hart (1962) found R. cornutus in the Slope Water. They characterized it as a warm water species and its presence along with other warm water species gave their September Slope Water collections a "decidedly warm water appearance". We found R. cornutus to be abundant in species group 2 at the north wall and at depth across the Stream. However, its cross-stream abundance pattern (Appendix 1) suggests that it is being transported from the north wall to the southern edge although it did migrate up into warmer water at night more than did any other members of species group 2.

It is interesting to examine the species groups which were determined in this paper, in light of two distinct views of community structure, the community-unit hypothesis and the individualistic hypothesis (as defined in Whittaker, 1975). The community-unit hypothesis states that species co-occur in distinct well defined groupings of associated species. The individualistic hypothesis states that each species has its own unique distribution and that species do not form well defined groupings or associations. The species examined in this study did form well defined groups, which tends to fit in with the community-unit hypothesis. However these groupings were not absolutely distinct. The species within each group had different distribution ranges, although they had maximum occurrences together in a central region of the group distribution. Species from different groups had distribution patterns which overlapped to varying degrees. These findings tend to fit the individualistic hypothesis. The distribution patterns are grouped in a way which resembles that of the third type of species and community grouping listed in Whittaker (1975, page 113), a slightly modified version of the individualistic hypothesis, in which "groups characterize different kinds of communities, but the communities intergrade continuously". This is a rather surprising finding. The Gulf Stream is characterized by strong horizontal and vertical gradients. In such a region with sharp physical boundaries, abrupt discontinuities in species groups would also be expected. The fact that species groups intergrade continuously, despite sharp physical boundaries, indicates that biological factors are very important in shaping species distribution patterns, even in areas such as the Gulf Stream.

Similar distribution patterns of community groups which intergrade have been found before in marine zooplankton (Angel and Fasham, 1973; 1974; Marlowe and Miller, 1975; McGowan and Walker, 1979; Tranter et al., 1983) and marine phytoplankton (Venrick, 1982). With the exception of Tranter et al. (1983), these studies all examined communities in the middle of gyres where physical properties have small gradients and do not vary spatially or temporally to a large extent. Tranter et al. (1983), studied a warm core ring off the coast of Australia, an environment that would be expected to have large variability temporally and spatially. They found that the copepod species formed intergrading community groups over time. Lane (1975; 1978) found similar patterns in lake zooplankton communities over time, but Makarewicz and Likens (1975; 1978) found no such groupings in lake zooplankton. Marine zooplankton communities seem to have species distributions which intergrade spatially and temporally in areas of both large and small physical gradients. Recent evidence suggests that marine zooplankton communities may be arranged in slightly different ways than are terrestrial communities (Dayton, 1984; McGowan and Walker, 1985). It may be that species distributions arranged into intergrading groups is a general feature of marine zooplankton community structure.

Hayward and McGowan (1979) and McGowan and Walker (1979) have examined species distribution patterns and their relation to community structure in marine zooplankton. Hayward and McGowan (1979), in a theorectical study of the copepod species of the north Pacific central gyre, inferred that competition must be occurring because of the high diversity of the zooplankton community, the limited availability of food, and apparent lack of specialization in feeding or distribution of copepods. McGowan and Walker (1979) stated three main hypotheses to account for the co-occurrence of large numbers of copepod species in the central Pacific gyre. These hypotheses were: 1) the copepod species used qualitatively different food resources, 2) the copepod species avoided competition for the same food items by eating at different times and/or places, and 3) selective predation on individual species allowed co-existence. They were unable to find support for any of these hypotheses in their data and concluded that the copepod species may be co-existing without niche separation. In light of the apparent lack of niche separation, Hayward and McGowan (1979) posited predation as a likely regulator of community structure. Upon further examination, they decided that the consistent occurrence of rare species which are probably of little importance to predators and hard for predators to select, rules out predation as regulating community structure. However the occurrence of rare species is not enough to rule out predation as an important regulatory agent. Dayton (1984) has clearly shown how a rare predator keeps its prey rare and thus regulates the community structure of the Antarctic benthos. Such a relationship would be difficult to detect in the plankton.

Both McGowan and Walker (1979), and Hayward and McGowan (1979) concluded that the lack of apparent niche separation was not a sampling artifact. McGowan and Walker's sampling scheme (and the sampling scheme of this study) is best suited for the examination of meso-scale (100-1000 km) and coarse scale (1-10 km) phenomena (scales as defined in Haury et al., 1978). Recent papers (Omori and Hamner, 1982; Alldredge et al., 1984) have emphasized the need to examine zooplankton species on the fine (10-100 m) and micro (< 1 m) scales in order to understand their interaction. Haury and Wiebe (1982) found multi-species zooplankton groups occurring on scales of 10-100 m. This finding plus the facts that zooplankton vertically migrate over hundreds of meters, that water in the ocean is constantly moving, and that zooplankters occur in everchanging associations, further emphasizes the point that each species and group of species must be carefully studied on a variety of scales with different methods in order to understand its population dynamics (Omori and Hamner, 1982). While changing the scales at which a population is studied may provide new insights into processes causing the patterns exhibited by that population (Dayton and Tegner, 1984), it is doubtful that a study which relies solely on sampling will be able to resolve such complex problems as niche separation. Connell (1961) demonstrated that species that do not overlap in spatial distribution may in fact be competing with each other, and the lack of spatial overlap is a result of that competition. Studies such as the present one and others previously mentioned, which investigated community structure in the marine plankton, reveal many intriguing patterns of species distribution. Reasonable processes to account for these patterns can be hypothesized, but sampling alone is not likely to resolve which hypotheses are most nearly correct. Careful experimentation, technologically difficult at present with open ocean plankton, could resolve these questions, and it is hoped that such experimentation will become possible in the future.

Conclusions

Examination of selected copepod species distributions and abundances in the Gulf Stream region during September, 1982 has revealed:

1) Copepod species distributions can be grouped into several distinct patterns.

2) These patterns are related to distinct oceanic habitats within the Gulf Stream.

3) As a result of the association between different species groups and environmental habitats, it is apparent that different species have quite different probabilities of downstream and cross-stream transport.

4) Cross-stream dispersal of copepod species is most likely to occur in the surface mixed layer and below the oxygen minimum zone. Species in the central core area of the Stream are not likely to be dispersed cross-stream but are likely to be carried downstream for long distances.

5) The interaction of biological processes, especially vertical migration, with physical features and processes of the Gulf Stream determines the degree of downstream and cross-stream transport of zooplankton.

6) The community structure of copepod species forming community groups which continuously intergrade supports a modified version of the individualistic hypothesis of species distributions and community formation. This type of pattern has been observed before in marine zooplankton communities and it may be a general feature of such communities.

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Captions

Fig. 1. Satellite infrared image of the Gulf Stream region near Cape Hatteras on Sept. 14, 1982. Lighter colors represent warmer temperatures, and the Gulf Stream is the light colored band running diagonally through the picture. The sampling stations are marked by letters such that X is the north wall station, O is the central core station, and Y is the southern edge station. Cape Hatteras and the mouth of the Cheasapeake Bay are the white land masses on the left edge of the picture.

Fig. 2. Contour plots of environmental data across the Gulf Stream. a is temperature, b is salinity, c is density, d is POP_4, e is oxygen, and f is chlorophyll *a*. P6 is the north wall station, P5 is the central core station, and P4 is the southern edge station.

Fig. 3. Contour plots of downstream and cross-stream velocity, a is downstream velocity and b is cross-stream velocity. Stations are as in Fig. 2. Downstream velocity values represented measurements that have been rotated to a direction 57° true. Positive cross-stream values indicate motion to the southeast, and negative values indicate motion to the northwest. Figure was redrawn with permission of Rossby and Halkin.

Fig. 4. Copepod species groupings as determined by recurrent group analysis. Groups are arranged vertically as they tend to occur in the water column with surface water groups higher in the figure and deep water groups low in the figure. Group connections are shown by lines between groups. Percentages show the amount of connection between groups.

Fig. 5. Contour plots of the cross-stream distribution and abundance of Species Group 1. Stations are as in Fig. 2.

Fig. 6. Contour plots of the cross-stream distribution and abundance of Species Group 2. Stations are as in Fig. 2.

Fig. 7. Contour plots of the cross-stream distribution and abundance of Species Group 3. Stations are as in Fig. 2.

Fig. 8. Contour plots of the cross-stream distribution and abundance of Species Pair 1. Stations are as in Fig. 2.

Fig. 9. Contour plots of the cross-stream distribution and abundance of Species Pair 2. Stations are as in Fig. 2.

Fig. 10. Contour plots of the cross-stream distribution and abundance of *Pleuromamma borealis*. Stations are as in Fig. 2.

Fig. 11. Contour plots of the cross-stream distribution and

abundance of Lucicutia clausi. Stations are as in Fig. 2.

Fig. 12. Zooplankton samples plotted on a projection of principle component Axis 1 by Axis 2. Axis were determined by principle components analysis on physical and biological data collected for each sample. The samples were grouped by eye into environmental groups, labelled A - G, indicated by different symbols. The samples in which each species group is present at the 100 % level are shown by tone. Coarse (0 - 1000 m) and fine (0 - 200 m) scaled samples are plotted and grouped separately. RG = recurrent group.

Fig. 13. The distribution of principle components environmental groups cross-stream in the water column. Coarse and fine scale sampling groups are shown separately. Stations are as in Fig. 2.

Fig. 14. Diagram of hypothesized zooplankton dispersal paths based on velocity profiles and directions. See text for explanation. Figure redrawn from Wishner, 1983.

Table 1. Summary of sampling information.

Table 2. Copepod species distribution and abundance data for this study.

Table 3. Eigenvalues from the principle components analysis.

Table 4. Percentage of samples in a particular environmental group in which a species group occurs at a 100% level (all species present).

Table 5. Summary of the North Atlantic distributions for the copepod species considered in this study. The temperate Atlantic is north of the Gulf Stream and the subtropical Atlantic is south of the Stream. Depth ranges are in meters. NR = not recorded in these sources. Sources are: 1. Steuer (1932) 2. Rose (1933) 3. Moore and O'Berry (1957) 4. Grice (1963) 5. Grice and Hulsemann (1965) 6. Hulsemann (1966) 7. Owre and Foyo (1967) 8. Park (1970) 9. Bowman (1971) 10. Roe (1972) 11. Michel et al. (1976) 12. Fleminger and Hulsemann (1977) 13. Roe (1984).

Table 6. A comparison of the distribution and abundance patterns of the species examined in this study with the distribution and abundance patterns for these species observed by Grice and Hart (1962).

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Table 1 Summary of data collected during Endeavor cruise # 1982, and used in this study.

Region	Operation	Start Latitude (N)	Start Longitude (W)	Date	Local Time Start (h)	Local Time End (h)	Maximum Depth (m)
North Wall	MOCNESS 13	36 16.84	73 32.87	9-12-82	0940	1206	1000
	MOCNESS 14	36 16.84	73 32.78	9-12-82	1315	1429	200
	MOCNESS 15	36 16.97	73 32.87	9-12-82	2137	2232	200
	MOCNESS 16	36 16.64	73 33.12	9-12-82	2322	0133	1000
	Pegasus	36 15.01	73 31.93	9-12-82	1518	1711	2000
	XBT	36 15.06	73 31.89	9-12-82	1519		750
	Hydrocast	36 18.54	73 30.60	9-12-82	1907	1940	1000
Warm Core	MOCNESS 22	36 07.02	73 22.75	9-14-82	1011	1108	200
	MOCNESS 23	36 07.09	73 23.14	9-14-82	1157	1413	1000
	MOCNESS 25	36 08.00	73 22.19	9-15-82	0121	0225	200
	MOCNESS 26	36 07.91	73 23.01	9-15-82	0315	0530	1000
	Pegasus	36 07.11	73 22.81	9-14-82	1512	1713	2000
	XBT	36 07.62	73 23.08	9-14-82	1557		750
	Hydrocast	36 10.21	73 19.80	9-14-82	1901	1956	1000
Southern Edge	MOCNESS 17	35 55.34	73 10.99	9-13-82	0954	1202	1000
	MOCNESS 18	35 55.39	73 10.81	9-13-82	1252	1344	200
	MOCNESS 19	35 55.42	73 10.98	9-13-82	2155	2253	200
	MOCNESS 20	35 55.12	73 10.98	9-13-82	2345	0200	1000
	Pegasus	35 55.12	73 10.81	9-13-82	1600	1807	2000
	XBT	35 55.12	73 10.81	9-13-82	1600		750
	Hydrocast	35 56.19	73 09.81	9-13-82	1830	1919	1000

Note: MOCNESS = zooplankton sampling, Pegasus = in-situ velocity profile, XBT = expendable bathythermagraph, Hydrocast start time and position is when the messenger was deployed to close the bottles.

Table 2 Summary of copepod species distribution and abundance data.

Species	Time	Depth Range (m)			Depth of Maximum Abundance			Maximum Abundance All Samples #(1000m)-3	Median Abundance All Samples #(1000m)-3	Species Group
		North Wall	Warm Core	Southern Edge	North Wall	Warm Core	Southern Edge			
Calanus finmarchicus	Day	200-850	550-850	700-850	300-400	550-700	700-850	93	11	SG2
	Night	150-1000	550-1000	550-1000	700-850	850-1000	550-700			
Calanus finmarchicus CV	Day	300-1000	100-1000	550-1000	550-700	550-700	850-1000	1190	54	SG2
	Night	150-1000	150-1000	300-1000	850-1000	700-850	850-1000			
Calanus gracilis	Day	75-400	50-175	125-550	75-100	50-75	200-300	310	31	---
	Night	25-400	50-850	50-700	50-75	50-75	50-75			
Calanus gracilis CV	Day	0-300	0-300	0-100	0-25	0-100	0-100	2678	281	SG1
	Night	0-400	0-550	0-300	0-100	0-100	0-100			
Calanus minor	Day	0-200	0-100	0-550	50-75	50-75	0-100	8444	194	SG1
	Night	0-200	0-200	25-300	0-100	0-100	50-75			
Calanus minor CV	Day	0-175	0-175	0-100	25-50	0-100	0-100	1867	218	SG1
	Night	0-150	0-100	25-100	0-100	0-100	50-75			
Calanus tenuicornis	Day	0-300	0-200	0-200	100-200	100-200	0-100	2133	152	SP2
	Night	75-400	50-200	50-550	100-125	75-100	50-75			
Calanus tenuicornis CV	Day	25-300	0-200	50-175	100-125	75-100	75-100	1520	70	SP2
	Night	75-1000	50-100	50-300	100-125	75-100	50-75			
Lucicutia clausi	Day	300-400	100-550	100-550	300-400	200-300	300-400	286	24	---
	Night	---	75-550	100-550	---	100-200	200-300			
Lucicutia flavicornis	Day	0-400	0-850	0-1000	100-200	100-200	50-75	9994	266	SG1
	Night	0-1000	0-1000	0-850	0-100	0-100	0-100			
Lucicutia gemina	Day	150-200	100-700	75-300	175-200	125-150	75-100	1923	86	SG3
	Night	25-300	0-550	0-1000	100-200	0-100	0-100			
Lucicutia ovalis	Day	0-700	50-125	50-100	75-100	75-100	50-75	1169	68	SG1
	Night	0-700	25-400	25-200	75-100	50-75	25-50			
Metridia brevicauda	Day	300-550	550-700	550-850	300-400	550-700	700-850	37	16	SP1
	Night	400-700	125-700	700-850	550-700	550-700	700-850			
Metridia lucens	Day	300-1000	550-1000	300-1000	300-400	850-1000	850-1000	1289	80	SG2
	Night	100-1000	175-1000	550-1000	850-1000	700-850	850-1000			
Metridia venusta	Day	400-550	400-700	550-850	400-550	550-700	700-850	57	13	SP1
	Night	400-550	100-700	550-850	400-550	550-700	550-700			
Pleuromamma abdominalis	Day	300-550	25-850	0-850	300-400	400-550	300-400	2479	70	SG3
	Night	0-1000	0-700	0-850	0-100	0-100	0-100			
Pleuromamma borealis	Day	550-700	---	---	550-700	---	---	1863	27	---
	Night	0-700	---	---	125-150	---	---			
Pleuromamma gracilis	Day	150-550	25-850	0-700	200-300	300-400	300-400	8988	123	SG3
	Night	25-550	0-550	0-700	0-100	0-100	50-75			
Pleuromamma piseki	Day	50-400	0-400	300-700	300-400	200-300	200-300	930	34	---
	Night	0-400	0-550	0-700	75-100	0-100	0-100			
Pleuromamma xiphias	Day	400-850	400-700	550-850	400-550	400-550	550-700	1461	50	SG3
	Night	0-550	0-850	0-1000	100-200	50-75	0-100			
Rhincalanus cornutus	Day	50-1000	50-1000	50-1000	400-550	550-700	550-700	1569	78	SG2
	Night	100-1000	0-1000	0-1000	300-400	700-850	550-700			
Rhincalanus nasutus	Day	200-1000	550-850	850-1000	200-300	550-850	850-1000	602	22	SG2
	Night	200-1000	700-1000	700-1000	200-300	850-1000	850-1000			

SG = Species Group
SP = Species Pair
--- = Unassociated

Table 3 Eigenvalues and eigenvectors from the Principal Components Analysis.

Eigenvalues

Principal Component	Eigenvalue	Proportion	Cumulative Proportion
PC1	6.412448	0.58295	0.58295
PC2	1.843986	0.16763	0.75058
PC3	1.230274	0.11184	0.86243
PC4	0.708219	0.06438	0.92681
PC5	0.395180	0.03592	0.96273
PC6	0.184235	0.01675	0.97948
PC7	0.155260	0.01411	0.99359
PC8	0.039078	0.00355	0.99715
PC9	0.017829	0.00162	0.99877
PC10	0.008506	0.00077	0.99954
PC11	0.004984	0.00045	1.00000

Eigenvectors

Variable	Prin Comp 1	Prin Comp 2	Prin Comp 3
Biomass	0.246431	0.006631	0.631275
Depth	-0.357423	0.090130	-0.230124
Median temperature	0.386496	0.089614	-0.098725
Temperature range	-0.018330	0.625976	-0.049054
Salinity	0.343096	0.072648	-0.380988
Oxygen	0.012944	-0.658388	-0.102451
Silicate	-0.360299	0.089541	0.328717
Phosphate	-0.365881	0.162071	0.239927
Chlorophyll a	0.235890	0.041090	0.356123
Velocity	0.312858	0.331296	-0.131557
Sigma-t	-0.355910	0.086452	-0.266427

Table 4a Percentage of samples of an environmental group in which all members of a species group co-occur.

Species Groups	EG A	EG B	EG C	EG D	EG E	EG F	EG G
SG 1	0.0	83.3	0.0	0.0	60.0	0.0	25.0
SG 2	0.0	0.0	53.8	0.0	0.0	0.0	0.0
SG 3	42.8	50.0	7.7	50.0	10.0	25.0	41.7
SG 3 Day	0.0	0.0	7.7	0.0	0.0	0.0	0.0
SG 3 Night	85.7	100.0	7.7	100.0	20.0	50.0	83.3
SP 1	0.0	0.0	30.8	0.0	0.0	0.0	0.0
SP 2	14.3	100.0	7.7	100.0	30.0	33.3	83.3
C. gracilis	50.0	83.3	19.2	25.0	30.0	33.3	33.3
L. clausi	100.0	0.0	7.7	0.0	0.0	50.0	25.0
P. borealis	0.0	0.0	15.4	50.0	15.0	0.0	16.6
P. piseki	57.1	66.6	23.1	0.0	50.0	8.3	33.3

Table 4b Percentage of a full species group occurring in an environmental group.

Species Groups	EG A	EG B	EG C	EG D	EG E	EG F	EG G
SG 1	0.0	25.0	0.0	0.0	60.0	0.0	15.0
SG 2	0.0	0.0	100.0	0.0	0.0	0.0	0.0
SG 3	26.0	13.0	8.7	8.7	8.7	13.0	22.0
SG 3 Day	0.0	0.0	100.0	0.0	0.0	0.0	0.0
SG 3 Night	27.0	13.5	4.5	9.0	9.0	13.5	23.5
SP 1	0.0	0.0	100.0	0.0	0.0	0.0	0.0
SP 2	5.4	16.0	11.0	11.0	16.0	13.6	27.0
C. gracilis	21.0	15.0	15.0	3.0	21.0	12.0	12.0
L. clausi	54.0	0.0	11.5	0.0	0.0	24.0	11.5
P. borealis	0.0	0.0	36.4	18.2	27.2	0.0	18.2
P. piseki	24.0	12.0	18.0	0.0	30.0	4.0	12.0

Note: EG = Environmental Group, SG = Species Group, SP = Species Pair

Table 5 Summary of the North Atlantic distributions of copepod species enumerated in this study. The temperate Atlantic is the area north of the Gulf Stream and the subtropical Atlantic is the area south of the Gulf Stream. Depth ranges for each species in each area are given in meters.

	Area of the Atlantic					
Species	Temperate Atlantic	Subtropical Atlantic	Gulf of Mexico and Caribbean	Florida Straits	Migration Pattern	Source
C. finmarchicus	0-1400	N. R.	N. R.	N. R.	ontogenetic	3,4,10
C. gracilis	shallow	0-950	0-950	N. R.	diel	1,3,6,8
C. minor	0-150	0-620	0-500	0-70	none	1,2,3,6,7,8
C. tenuicornis	N. R.	0-300	0-500	0-195	none	1,4,5,6,7,8
L. clausi	N. R.	190-850	100-950	100-440	none	4,5,6,8,12
L. flavicornis	0-1700	0-2000	0-3200	0-550	diel	3,4,5,6,7,8,9,12
L. gemina	present	0-960	100-200	N. R.	N. R.	1,4,6,12
L. ovalis	0-200	0-3000	500-2800	N. R.	N. R.	1,3,4,6,8,12
M. brevicauda	600-1000	190-1900	500-1900	N. R.	N. R.	1,3,4,5,6,8
M. lucens	100-1400	200-1150	N. R.	N. R.	diel	1,3,4,8
M. venusta	620-700	450-1900	200-1000	N. R.	N. R.	1,3,5,6,8
P. abdominalis	0-900	0-2000	0-1900	0-900	diel	1,2,3,4,5,6,7,8,11
P. borealis	0-1200	0-2500	N. R.	N. R.	diel	1,3,4,8,11
P. gracilis	0-500	0-1500	0-1900	0-500	diel	1,2,3,4,5,6,7,8,11
P. piseki	present	0-1500	N. R.	0-500	diel	1,3,4,5,7,8,11
P. xiphias	0-1300	50-2000	200-950	0-820	diel	1,2,3,4,5,6,7,8,11
R. cornutus	0-270	0-1000	200-1900	0-1500	diel	1,2,3,4,5,6,7,8,9
R. nasutus	0-1400	0-1150	present	150-880	diel	1,3,4,5,8

Sources:

1 = Rose, 1933; 2 = Moore and O'Berry, 1957; 3 = Grice, 1963; 4 = Grice and Hulsemann, 1965; 5 = Owre and Foyo, 1967; 6 = Park, 1970; 7 = Bowman, 1971; 8 = Roe, 1972; 9 = Michel et al., 1976; 10 = Fleminger and Hulsemann, 1977; 11 = Steuer, 1932; 12 = Hulsemann, 1966.

N. R. = not recorded in these sources

Table 6 A comparison of the distribution and relative abundance of copepod species examined by this study and Grice and Hart (1962).

Species	Grice and Hart			This Study		
	Slope Water	Gulf Stream	Sargasso Sea	North Wall	Warm Core	Southern Edge
C. finmarchicus	Abundant	N. R.	N. R.	Common	Common (Deep)	Common (Deep)
C. tenuicornis	Common	Common	Common	Abundant (Shallow)	Abundant (Shallow)	Abundant (Shallow)
L. flavicornis	N. R.	Abundant	Abundant	Very Abundant (Shallow)	Very Abundant	Very Abundant
M. lucens	Abundant	N. R.	N. R.	Abundant	Common (Deep)	Common (Deep)
P. borealis	Abundant	N. R.	N. R.	Common	N. R.	N. R.
P. gracilis	N. R.	Common	Common	Abundant	Abundant	Abundant
R. cornutus	Abundant in Sept.	Common	Common	Abundant	Common	Common

Note: Very Abundant > 1000 copepods (1000 m)-3
Abundant 101-1000 copepods (1000 m)-3
Common 51-100 copepods (1000 m)-3
Rare 1-50 copepods (1000 m)-3

Shallow = 0-200 m depth, Deep = Below 400 m depth
N. R. = not recorded

Fig. 1

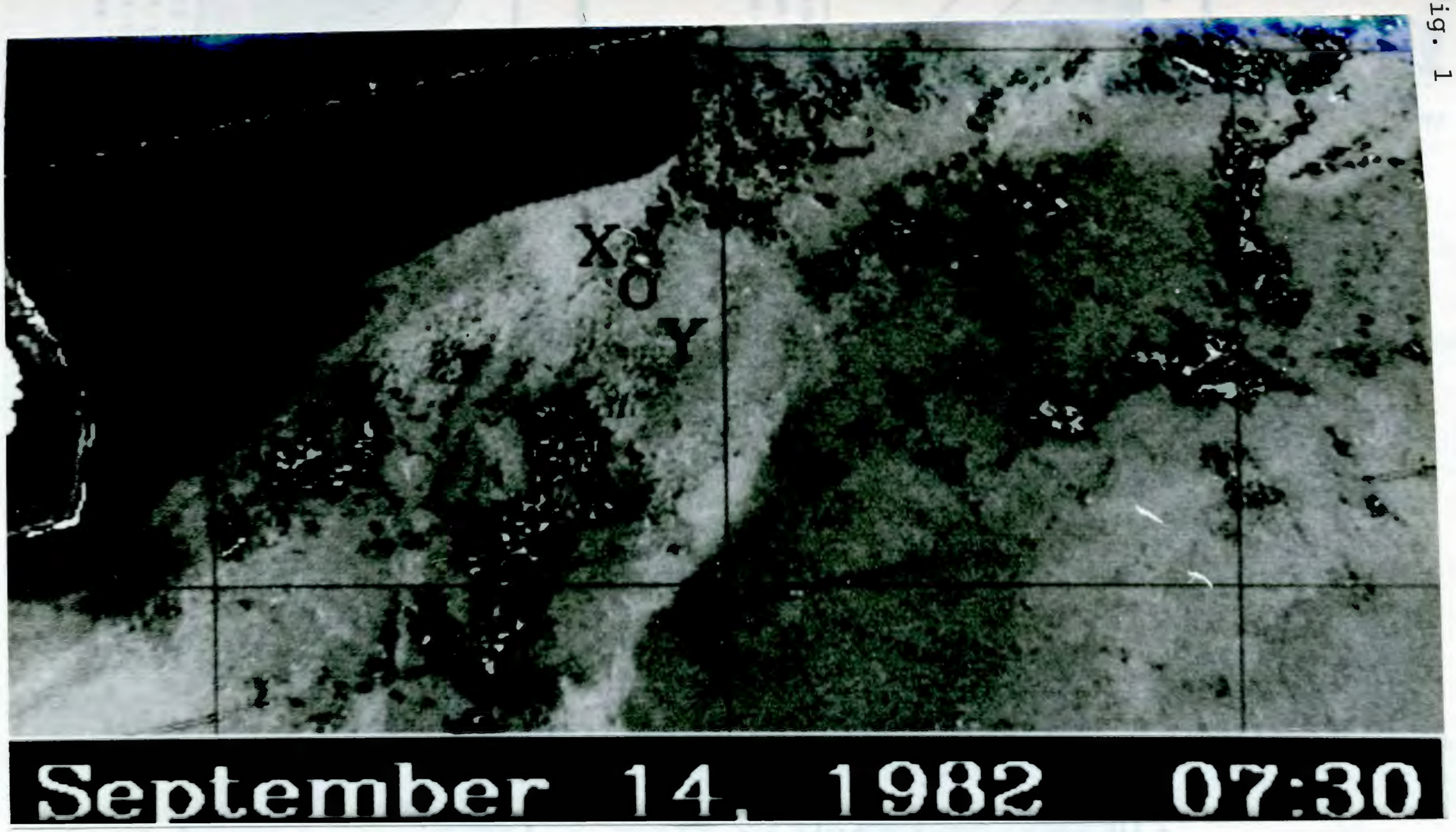


Fig. 2

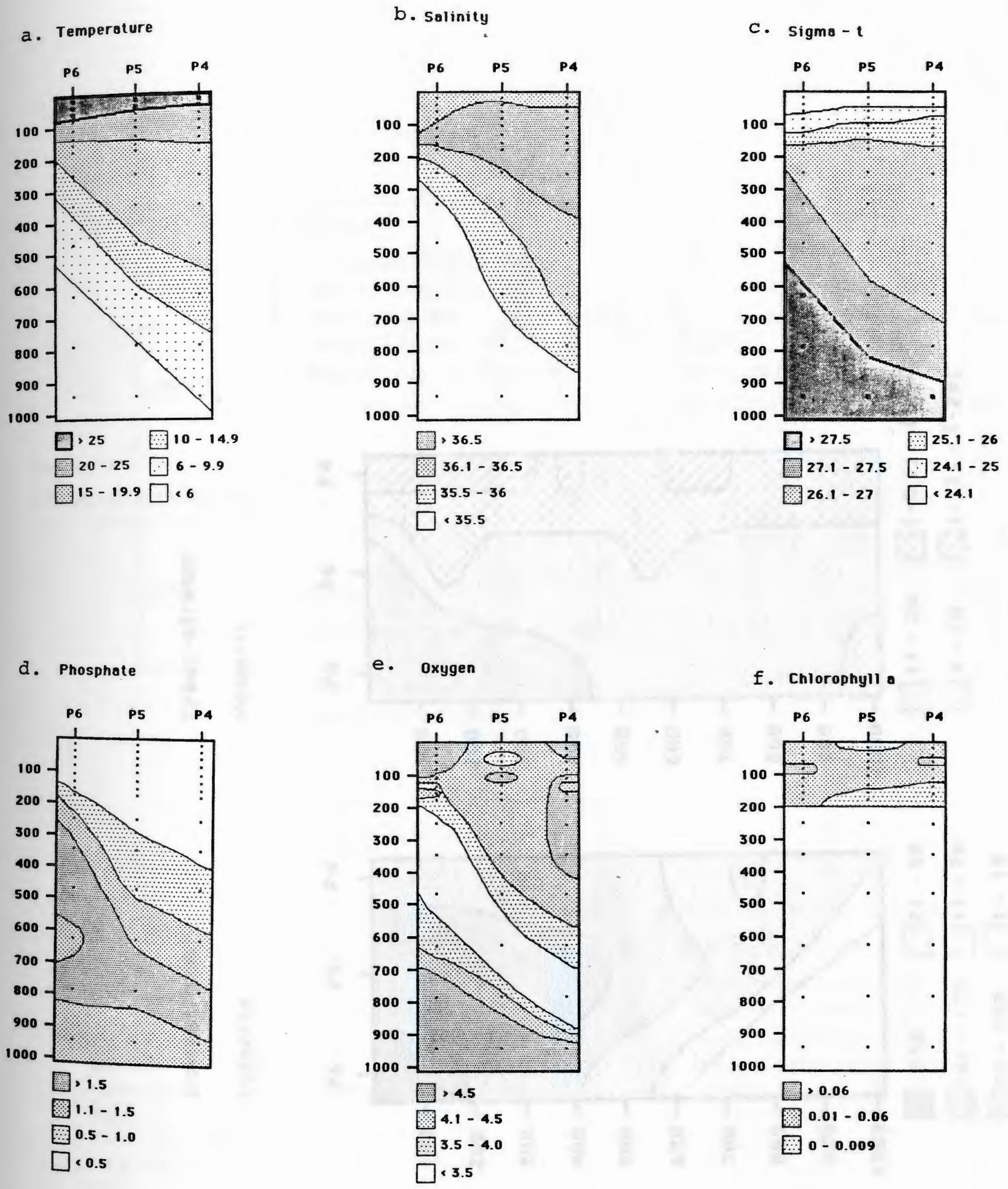

a. Temperature
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 25
20 - 25
15 - 19.9
10 - 14.9
6 - 9.9
< 6
b. Salinity
> 36.5
36.1 - 36.5
35.5 - 36
< 35.5
c. Sigma - t
> 27.5
27.1 - 27.5
26.1 - 27
25.1 - 26
24.1 - 25
< 24.1
d. Phosphate
> 1.5
1.1 - 1.5
0.5 - 1.0
< 0.5
e. Oxygen
> 4.5
4.1 - 4.5
3.5 - 4.0
< 3.5
f. Chlorophyll a
> 0.06
0.01 - 0.06
0 - 0.009

Fig. 3

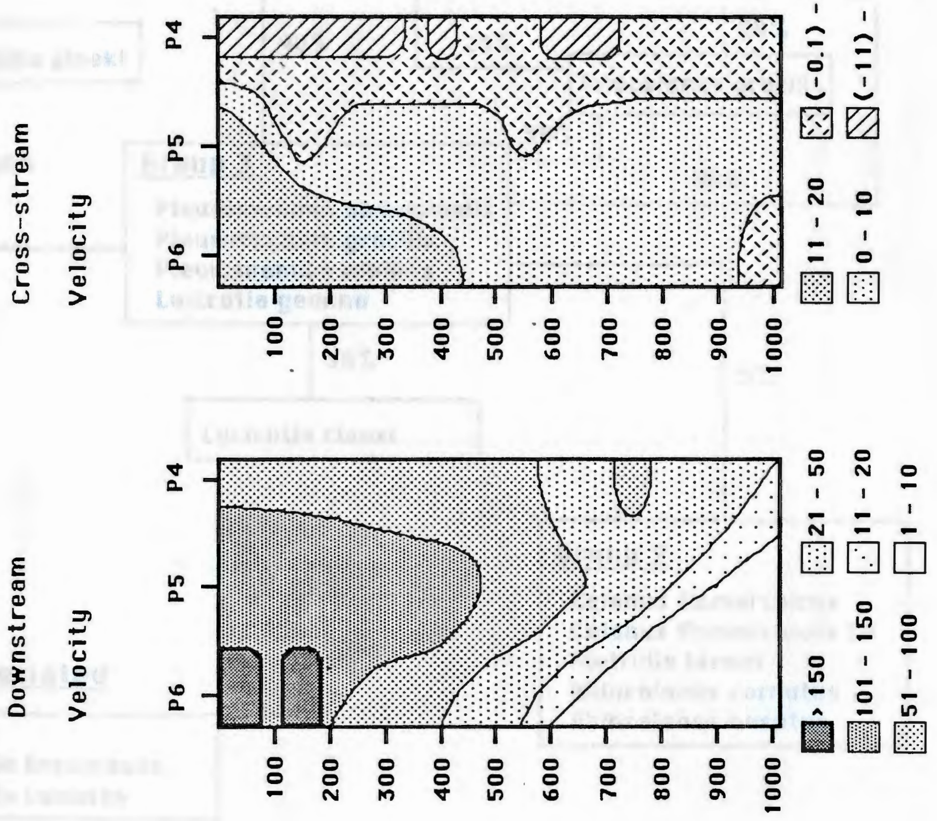
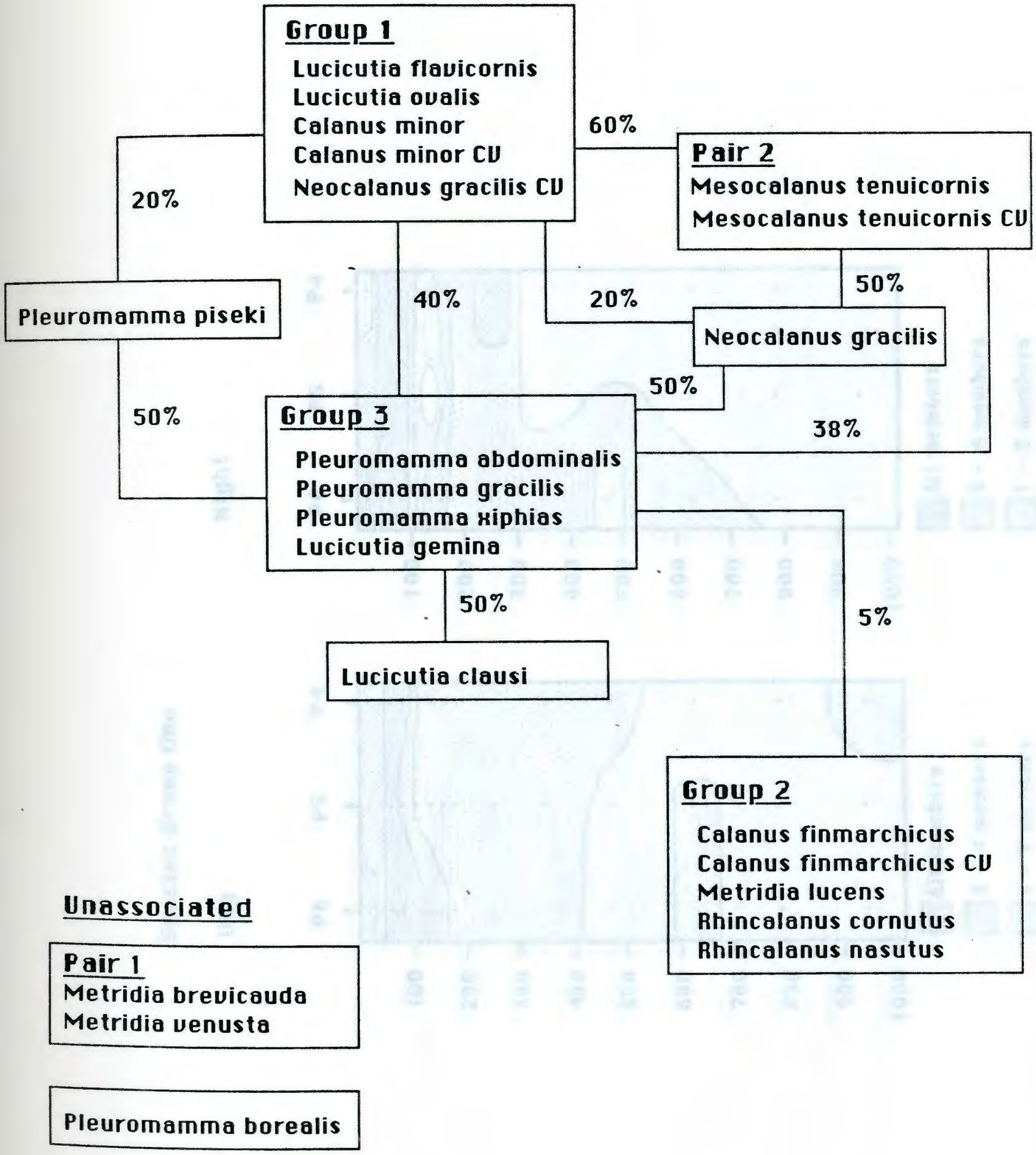

Downstream Velocity
P4
P5
P6
100
200
300
400
500
600
700
800
900
1000
> 150
101 - 150
51 - 100
21 - 50
11 - 20
1 - 10
Cross-stream Velocity
P4
P5
P6
100
200
300
400
500
600
700
800
900
1000
11 - 20
0 - 10
(-0.1) - (-10)
(-11) - (-20)

Fig. 4


Group 1
Lucicutia flavicornis
Lucicutia ovalis
Calanus minor
Calanus minor CV
Neocalanus gracilis CV
60%
Pair 2
Mesocalanus tenuicornis
Mesocalanus tenuicornis CV
20%
Pleuromamma piseki
40%
20%
50%
Neocalanus gracilis
50%
50%
Group 3
Pleuromamma abdominalis
Pleuromamma gracilis
Pleuromamma xiphias
Lucicutia gemina
38%
50%
5%
Lucicutia clausi
Group 2
Calanus finmarchicus
Calanus finmarchicus CV
Metridia lucens
Rhincalanus cornutus
Rhincalanus nasutus
Unassociated
Pair 1
Metridia brevicauda
Metridia venusta
Pleuromamma borealis

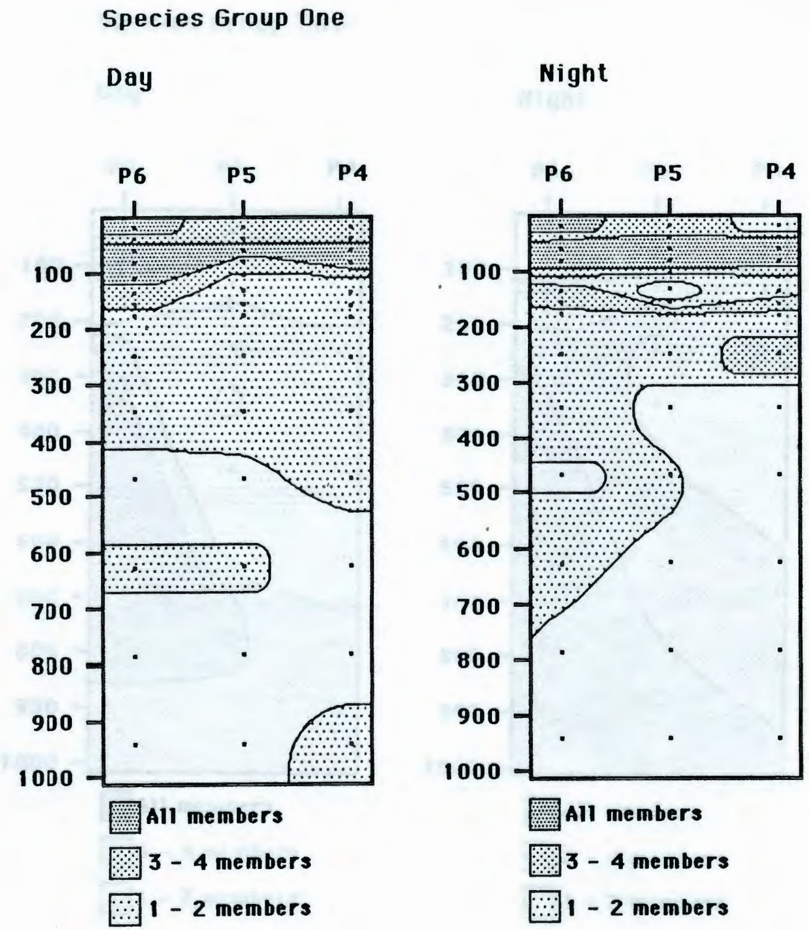

Species Group One
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
All members
3 - 4 members
1 - 2 members

Fig. 5

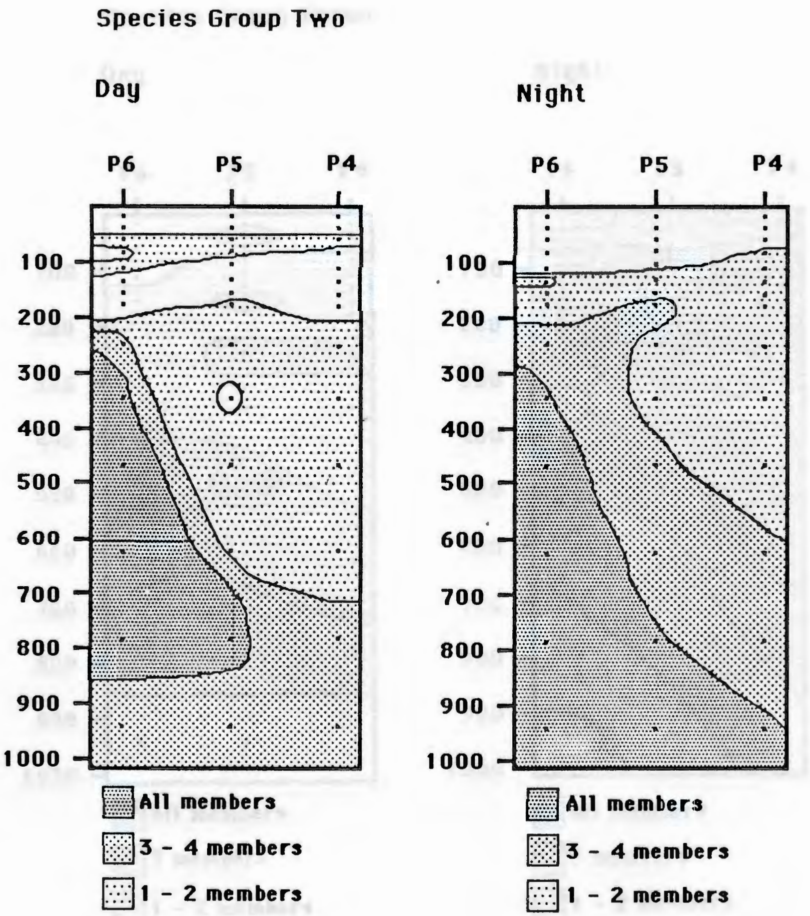

Species Group Two
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
All members
3 - 4 members
1 - 2 members

Fig. 6

Fig. 7

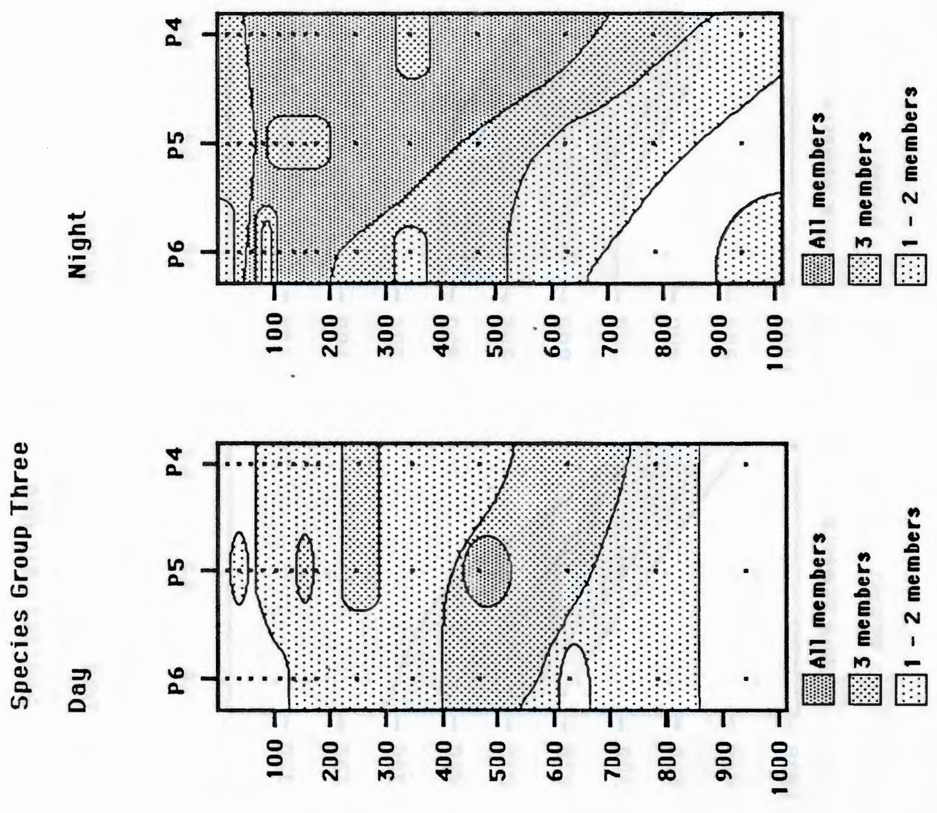
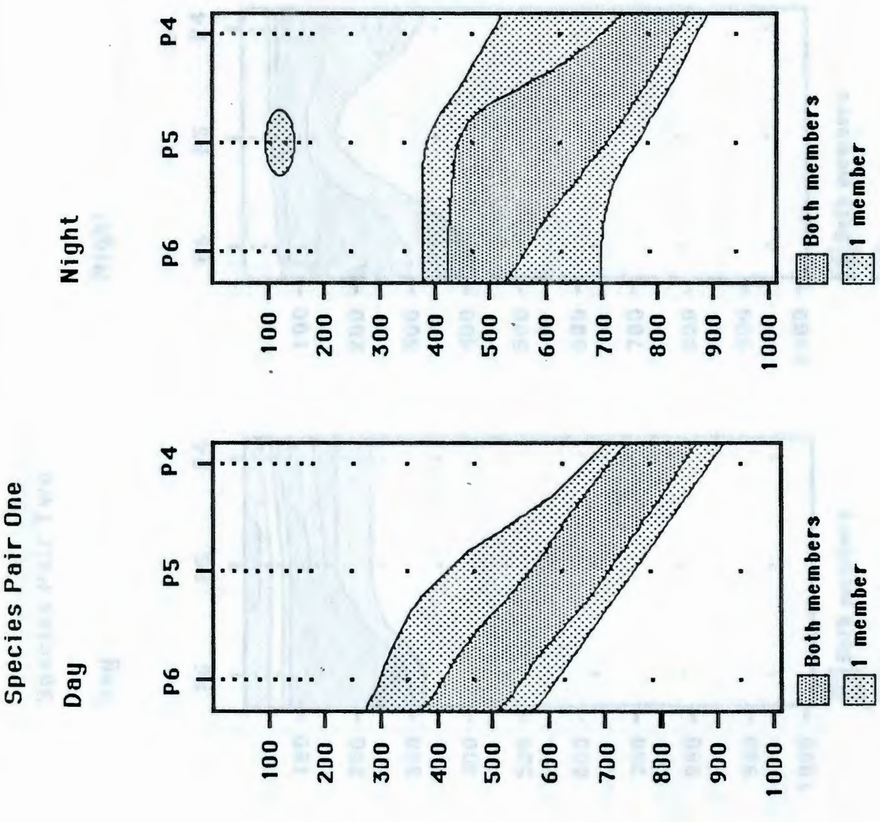

Species Group Three
Day
Night
P4
P5
P6
100
200
300
400
500
600
700
800
900
1000
▨ All members
▨ 3 members
☐ 1 - 2 members

Fig. 8


Species Pair One
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
Both members
1 member

Species Pair Two

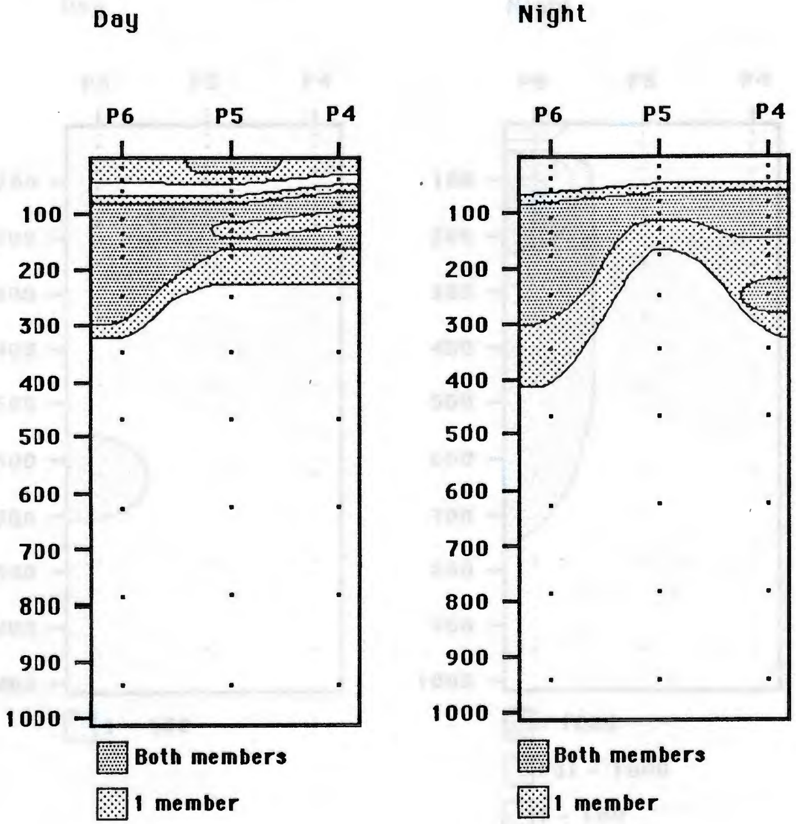


Fig. 9

Fig. 10

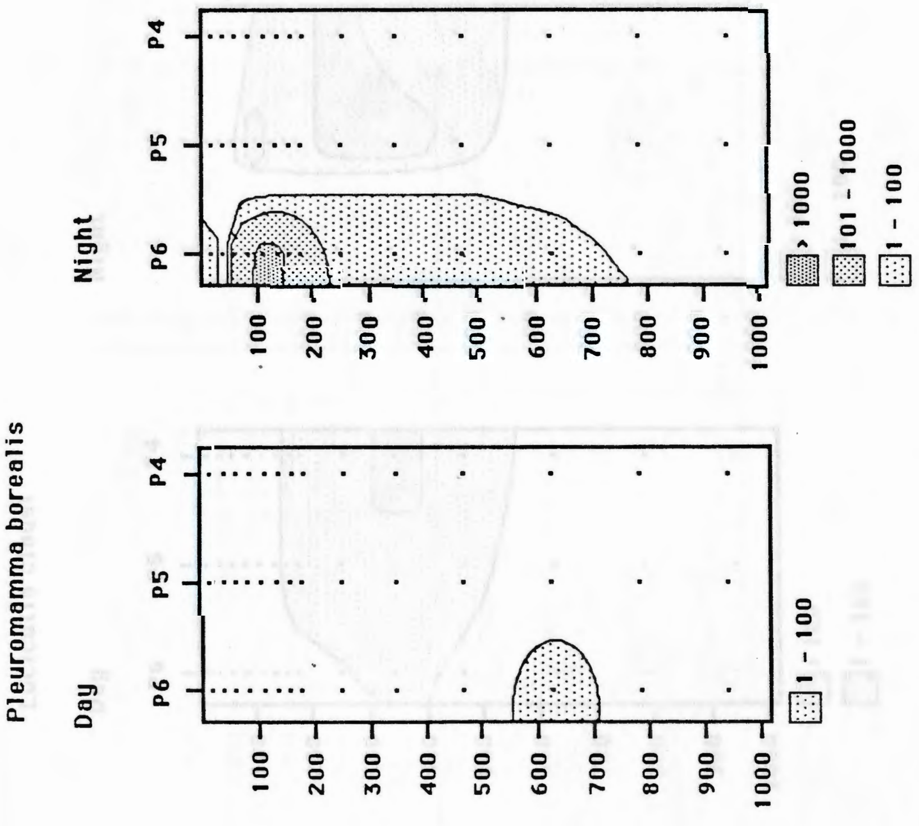
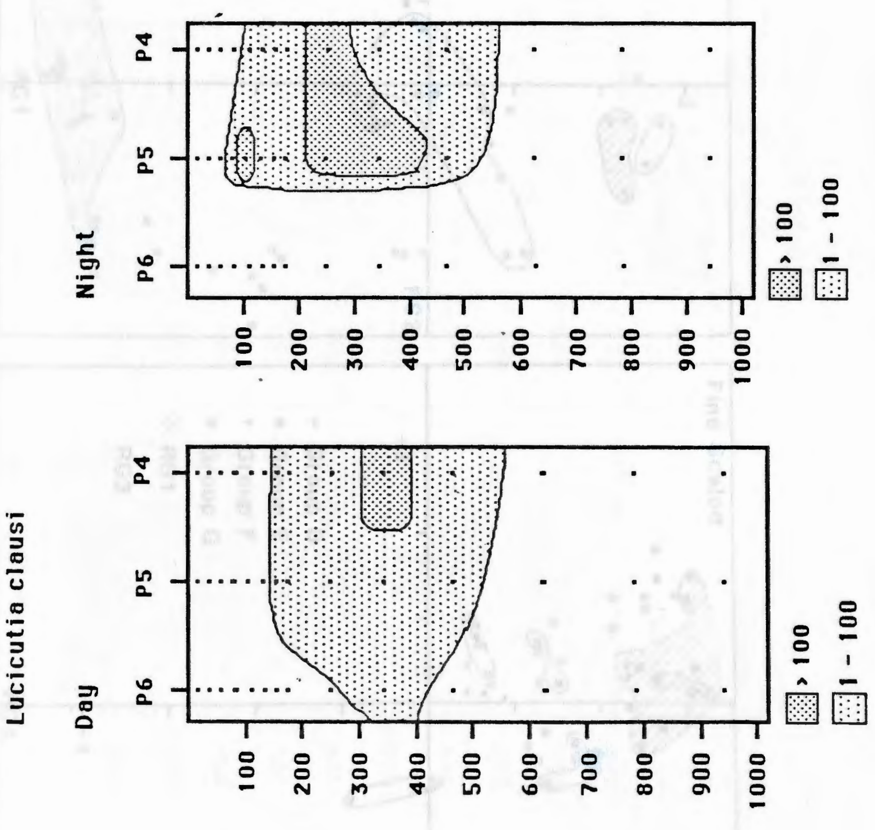

Pleuromamma borealis
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 1000
101 - 1000
1 - 100

Fig. 11


Lucicutia clausi
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 100
1 - 100

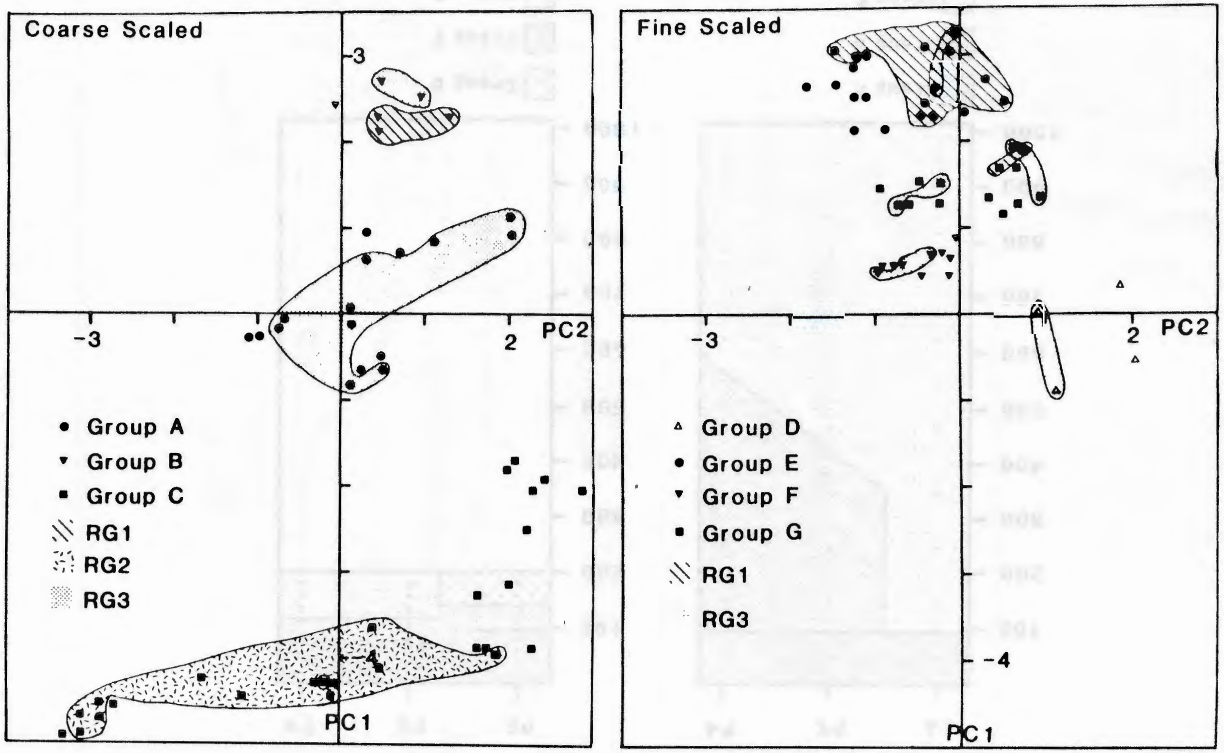

Coarse Scaled
Fine Scaled
PC1
PC2
-3
2
-4
Group A
Group B
Group C
Group D
Group E
Group F
Group G
RG1
RG2
RG3

Fig. 12

Fig. 13

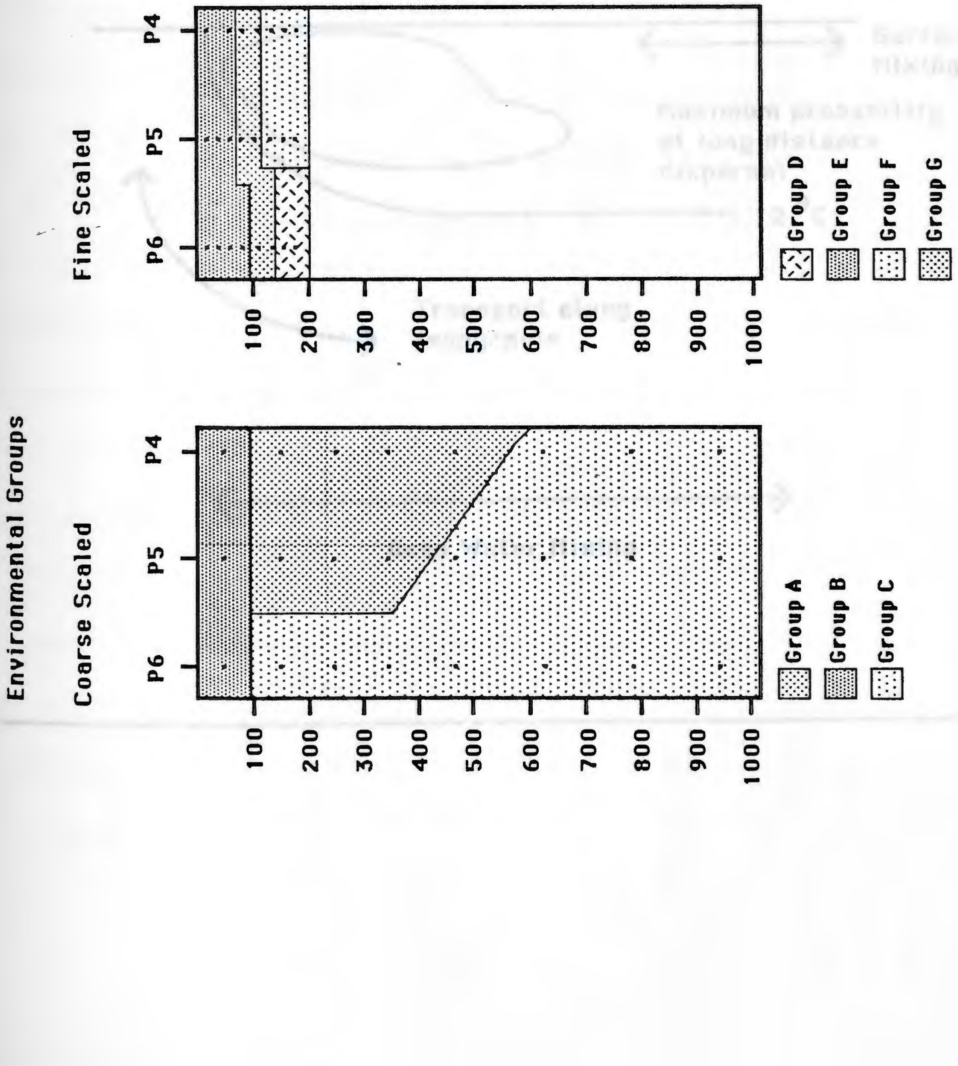
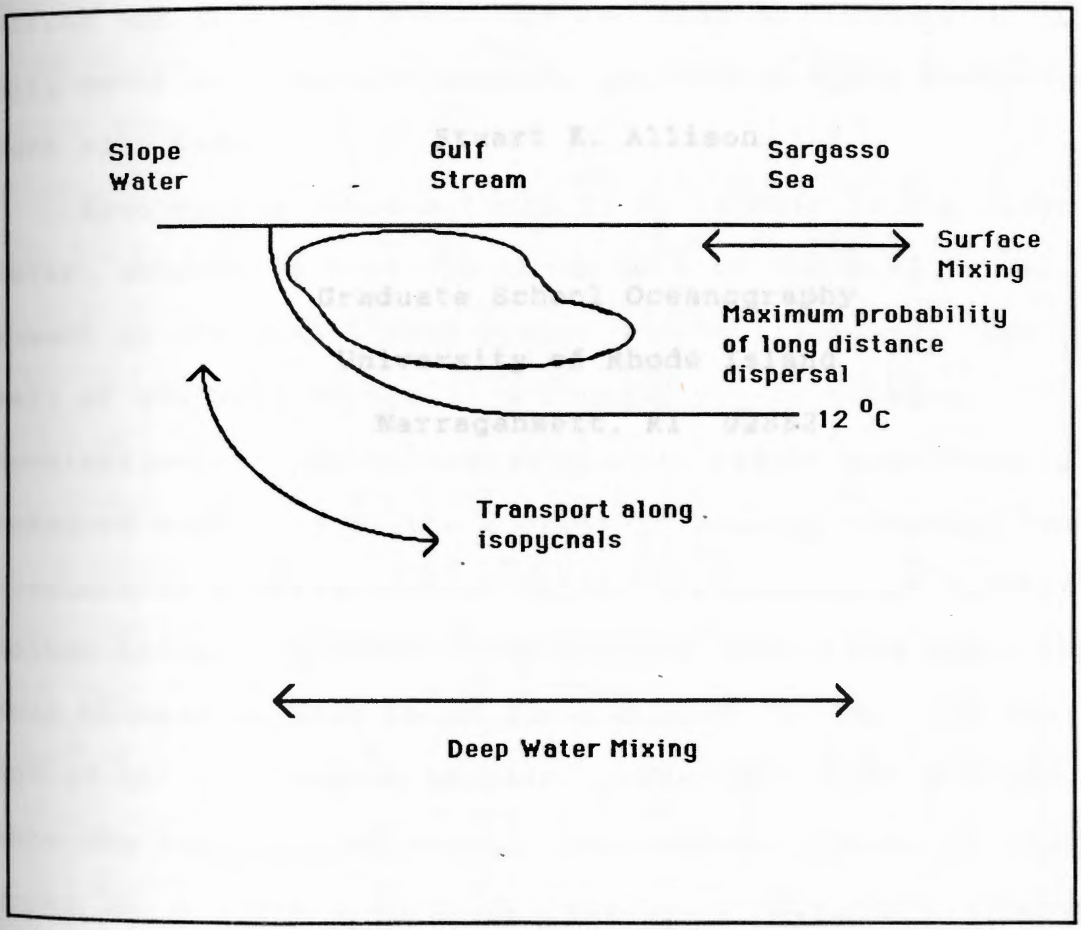

Environmental Groups
Coarse Scaled
Fine Scaled
P4
P5
P6
100
200
300
400
500
600
700
800
900
1000
Group A
Group B
Group C
Group D
Group E
Group F
Group G

Fig. 14


Slope Water
Gulf Stream
Sargasso Sea
Surface Mixing
Maximum probability of long distance dispersal
12 °C
Transport along isopycnals
Deep Water Mixing

Spatial and Temporal Variability in Zooplankton Biomass Across the Gulf Stream

by

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Abstract

From November, 1981 to November, 1982, zooplankton biomass was sampled bimonthly by oblique net tows in the upper 200 m along a 9 station transect of the Gulf Stream region east of Cape Hatteras. In September, 1982 and May, 1983, extensive vertically stratified sampling of zooplankton biomass in the upper 1000 m at 3 stations across the Gulf Stream was done with a MOCNESS net system. Concurrent *in-situ* water velocity, transport, and hydrographic measurements were also made.

Zooplankton biomass tends to be highest in the Slope Water, intermediate at the north wall of the Gulf Stream, and lowest in the Gulf Stream proper and Sargasso Sea. The north wall of the Gulf Stream is a frontal region in which zooplankton and phytoplankton biomass can be considerably enhanced over that of the central Stream and Sargasso Sea. Zooplankton biomass is high in the upper 100 m of the water column across the Stream both day and night, and there is a deep biomass maximum below 400 m during the day. As much as 40% of the zooplankton biomass in the upper 1000 m migrates into the top 200 m at night. Zooplankton biomass in the upper 200 m shows a distinct seasonal pattern with maximum abundances in late spring and early summer and a minimum in the autumn.

Introduction

The northwestern Atlantic Ocean is one of the most extensively studied open ocean regions of the world. However, the biology of the Gulf Stream itself, a major feature of the region, is not well known, especially downstream of Cape Hatteras, where it turns offshore. Biologically, the Gulf Stream functions as a means of downstream transport, as a boundary between cool water temperate communities and warm water sub-tropical communities, and as a region of cross-stream mixing between these communities (Wishner and Allison, in press). The local physical oceanography plays a dominant role in the ecology of the Stream, and complex interactions between biological and physical processes affect the distribution of individual zooplankton species inhabiting this region (Stepien, 1980; Wishner and Allison, in press).

Total zooplankton biomass measurements can provide a broad view of spatial and temporal patterns of abundance and distribution across the Stream. Although numerous studies have examined the zooplankton biomass of the northwestern Atlantic (Moore, 1949; Fish, 1954; Bsharah, 1957; Menzel and Ryther, 1961; Grice and Hart, 1962; Be et al., 1971; Deevey, 1971; Deevey and Brooks, 1971; Ortner et al., 1978), most have concentrated on the Slope Water and Sargasso Sea. Grice and Hart (1962) and Be et al. (1971) reported a few biomasses of Gulf Stream zooplankton, while Bsharah (1957) looked at the zooplankton biomass in the Florida Straits region. Since all of these studies used different nets, mesh sizes, and sampling strategies, it is difficult to compare absolute biomass values between studies. However, it is possible to compare biomass patterns. For example, all of these workers observed a seasonal pattern in zooplankton abundances in the Slope Water. Some also found evidence of seasonal zooplankton variations in the Sargasso Sea (Moore, 1949; Fish, 1954; Menzel and Ryther, 1961; Deevey, 1971; Deevey and Brooks, 1971; Ortner et al., 1978), although Grice and Hart (1962) did not observe a seasonal cycle of zooplankton abundance there. Bsharah (1957) found seasonality in zooplankton abundance in the Florida Straits region. Most of this information is based on oblique tows in the upper several hundred meters.

Vertical sampling of discrete depth intervals in the Sargasso Sea (Deevey and Brooks, 1971) and in the Slope Water, Sargasso Sea, and cold core Gulf Stream rings (Ortner et al., 1978), found a maximum in zooplankton biomass near the surface water during both the day and night, often around 50-100 m depth, and a subsurface biomass peak during the day at 400-600 m. Diel vertical migration of a major portion of the zooplankton biomass in the Slope Water and Sargasso Sea is evident from these studies.

The northern boundary (north wall) of the Gulf Stream downstream and offshore from Cape Hatteras is a sharp frontal region (Stommel, 1965). Zooplankton often show increased concentrations at fronts (Herman and Denman, 1979; Herman et al., 1981; Parrish et al., 1981; Mackas and Sefton, 1982; Zeldis and Jillet, 1982; Haury, 1984; Boucher, 1984). Several studies have reported biomass peaks and aggregations of organisms related to frontal upwelling and eddies along the western edge of the Gulf Stream off the southeastern coast of the United States south of Cape Hatteras (Atkinson et al., 1978; Paffenhofer, 1983; Paffenhofer et al., 1984; Deibel, 1985), but this region is quite different from the north wall of the Gulf Stream further offshore, because the Stream along the coast is topographically constrained by the continental shelf. Whether such aggregations occur at the north wall of the Gulf Stream has not previously been examined, although Lessard (1984) has observed peaks of phytoplankton at the north wall.

The potential downstream and cross-stream transport of copepod species in the Gulf Stream (Wishner and Allison, in press) varies with the horizontal and vertical location of the species within the Stream. Downstream transport is greatest in the central core region of the Stream and in the high velocity surface water. Cross-stream transport is most likely below the oxygen minimum zone, at approximately the depth of the 12^{o}C isotherm, which changes from 250 m at the northern edge to 700 m at the southern portion of the Stream. Cross-stream mixing is also probable in the surface water. Because zooplankton biomass is distributed unevenly horizontally and vertically, it is likely that the transport of zooplankton biomass also varies in the different regions of the Stream.

This paper describes the spatial and temporal variability of zooplankton biomass distribution over a year-long period along a transect from the Slope Water across the Gulf Stream into the Sargasso Sea. This study is part of a project on Gulf Stream biology directed by Dr. K. Wishner. This paper will examine in detail:

1) Aspects of the spatial and temporal variability of zooplankton biomass with depth across the Stream.

2) The northern boundary (north wall region) of the Gulf Stream as a front and location of increased biomass concentrations.

3) Seasonal variations in zooplankton biomass distributions and abundances along the transect.

4) The potential cross-stream and downstream transport of zooplankton biomass in different regions of the Gulf Stream.

Methods

The data were collected on seven cruises aboard the <u>R/V Endeavor</u> and <u>R/V Cape Hatteras</u> in the Gulf Stream region just east of Cape Hatteras. The cruises occurred bimonthly from November, 1981 to November, 1982 as part of an intensive study of the physical oceanography of the Stream by H. T. Rossby, of the University of Rhode Island. Biological sampling was interspersed with the physical measurements. Cruise dates and other sampling information are summarized in Table 1. Samples were collected at a set of nine stations positioned 20 km apart perpendicular to the mean direction of the flow of the Stream along a transect centered at 36° N 73° W. The stations are located such that if the Gulf Stream is in an average position, the northern stations will be in the Slope Water, the central stations in the Stream, and the southern stations in the Sargasso Sea (Halkin, 1984).

At each station, *in-situ* velocity and transport direction to a depth of 2000 m or greater was measured with a cast of a free vehicle Pegasus velocity profiler (Spain et al., 1981) by H. T. Rossby and his group at the University of Rhode Island, who analyzed the data. Expendable bathythermographs (XBTs) deployed to 750 m and infrared satellite imagery of sea surface temperature were also used to determine the position and structure of the Stream. Satellite infrared imagery was obtained from the Remote Sensing Center at the Graduate School of Oceanography of the University of Rhode Island.

Replicate zooplankton samples were collected at these stations using a 202 um mesh, 0.65 m diameter net towed obliquely through the upper 200 m of the water column. Each tow filtered 100 to 260 m^3 of water. Samples were preserved in 4% buffered Formalin. Because of the necessity of coordinating the sampling with the physical oceanography, the time of day of sampling at each station varied. Day and night samples were analyzed separately. Dawn and dusk samples were eliminated from the analysis. Dawn was considered to be the period of time from 2 hours before until

2 hours after sunrise, and dusk was the period of time from 2 hours before until 2 hours after sunset. The times of sunrise and sunset for a paticular date and geographic position were obtained from *The Nautical Almanac* (1981; 1982; 1983).

During September, 1982 and May, 1983, vertically stratified zooplankton sampling was done with a MOCNESS net (1 m^2 mouth opening, 333 um mesh) (Wiebe et al., 1976). This opening-closing net system allows one to collect 9 sequential samples along with *in-situ* environmental information (depth, temperature) and sampling data (volume filtered, net angle). Data from the MOCNESS was processed and stored at sea on a Hewlett-Packard 85 computer. A transect of the Gulf Stream was done using the MOCNESS at all 9 stations to collect zooplankton from 400 m to the surface in 50 m intervals. In addition, 3 stations, 20-40 km apart located at the north wall of the Stream, the warm high velocity core, and the southern edge of the Stream, were sampled intensively. At each of these stations, MOCNESS tow series were centered at noon and midnight, with each series consisting of a deep and shallow sample set. The deep tow collected samples from 1000 m to the surface, in intervals of 150 m from 1000 to 400 m and in intervals of 100 m from 400 m to the surface. The shallow samples were collected from 200 m to the surface, in intervals of 25 m. Each net in a MOCNESS tow filtered from 300 to 1000 m^3 of water. Samples were preserved in 4% buffered Formalin. For more information on the three intensive MOCNESS stations in September, 1982, see Wishner and Allison (in press).

The biomass of the zooplankton samples was measured using the displacement volume method (Beers, 1976), after first removing large gelatinous zooplankton and fish. The displacement volume method was used because it is a simple, widely used measure which allows the estimation of biomass without destroying the sample for future analysis. Displacement volumes of the samples were measured 8 to 10 weeks after collection.

All station data were analyzed relative to natural Gulf Stream co-ordinates, with axes parallel to and perpendicular to the mean direction of flow. The angle is determined at which the mean direction of Stream flow intersects the transect line on each cruise, and the relative Stream positions of each station are then rotated into a Stream coordinate system (Halkin, 1984). Therefore, samples collected at the same cross-stream position on different cruises are comparable, even though their geographic positions may differ (Fig. 1).

For each cruise, the zooplankton biomasses were divided into four cross-stream regions: the Slope Water, the north wall of the Gulf Stream, the Gulf Stream proper, and the Sargasso Sea. Slope Water stations were those northwest of the location at which the 15° C isotherm was 200 m deep. Surface downstream velocity was low in the Slope Water, less than 30 cm s^{-1}. The north wall was the station where the 15° C isotherm was about 200 m deep. Surface downstream velocity was high at this station, usually greater than 100 $cm\ s^{-1}$. The Gulf Stream proper was the region in which the 15°C isotherm continued to deepen from north to south. Surface downstream velocities in the Gulf Stream ranged from 40 to 200 $cm\ s^{-1}$. The Sargasso Sea was the region in which the 15°C isotherm levelled out at about 650 m depth and where surface downstream velocities were less than 30 $cm\ s^{-1}$.

Results

Horizontal Patterns

All of the zooplankton biomasses collected in the 200 m oblique tows from November, 1981 to November, 1982 are graphed together in Fig. 2. The position of the north wall is used as the reference point, and the stations at which zooplankton were collected are arrayed relative to the north wall. This is done by aligning the 15°C isotherm for each cruise so that the geographic location where this isotherm is at 200 m depth (which is defined as the north wall of the Gulf Stream) intersects for all cruises. The seasonal pattern of biomass, separated by region, is diagrammed in Fig. 3.

The zooplankton samples collected from November, 1981 to November, 1982 with the 200 m oblique tows were tested to determine if there were differences in total zooplankton biomass between the regions. The biomasses were standardized by dividing each measurement by the median Sargasso Sea biomass value for that cruise (Table 2). Day and night samples were standardized separately. This procedure was done to highlight the overall relationships between the four areas by reducing the effects of seasonal changes in absolute abundance. The relative biomasses for the four regions were compared using the Kruskal-Wallis Test (Sokal and Rohlf, 1981). Night biomasses, but not day biomasses, were significantly different among the regions ($P < 0.05$). The Tukey-Kramer a posteriori test of minimum significant difference (Sokal and Rohlf, 1981) was used to determine which regions differed significantly among the night samples. The Slope Water was significantly different from both the Gulf Stream and the Sargasso Sea ($P < 0.05$). The north wall was intermediate between the Slope Water and the Gulf Stream, but was not significantly different from either of them or the Sargasso Sea. The Gulf Stream and Sargasso Sea were not significantly different.

The Slope Water tended to have the highest biomasses of the four regions (Table 2). The median biomass for the Slope Water was greater than the median biomass for the north wall. The median biomass for the north wall, however, was greater than the median biomasses for the Gulf Stream and the Sargasso Sea.

These same general trends were found in the MOCNESS samples (Table 2). The integrated water column (0-400 m) biomass ($ml\ m^{-2}$) of the Slope Water was 2 times greater than the north wall, 3 times greater than the Gulf Stream, and 1.5 times greater than the Sargasso Sea biomass.

Although not significantly different overall from the Gulf Stream and Sargasso Sea, the north wall region frequently had increased zooplankton concentrations relative to the Gulf Stream and Sargasso Sea (Fig. 2). For example, during March 1982, the highest zooplankton biomasses across the whole transect occurred at the north wall. This biomass peak was accompanied by high concentrations of the diatom Thalassiosira partheneia. In July, September, and November, 1982, and May, 1983, biomass at the north wall was 1.5 to 3.5 times greater than in the Gulf Stream and Sargasso Sea. During May, 1983, there were large concentrations of the salp, Salpa fusiformis, and the ctenophore, Pleurobrachia pileus, at the north wall and Slope Water stations.

Diel Patterns

Biomass in the upper 200 m was 1.3 to 3.5 times higher in night than day with all sampling methods in all regions. This difference was probably caused by a combination of vertical migration of zooplankton into the upper 200 m at night and decreased net avoidance at night. The intensive MOCNESS series revealed that the total biomass of the 0-1000 m depth range was similar both day and night, which indicates that there was little upward vertical migration of zooplankton from below 1000 m and that diel differences in net avoidance were not a problem.

Biomass concentrations from the 200 m oblique tow series were tested to determine if there were significant differences between day and night biomasses within each region. Biomass concentrations were compared using the Wilcoxen Two Sample Test (Sokal and Rohlf, 1981). The day and night biomasses were significantly different in the Gulf Stream and Sargasso Sea ($P < 0.05$). Day and night biomasses were not significantly different in the Slope Water and at the north wall.

Vertical Patterns

The distribution of biomass with depth in the MOCNESS samples is contoured in Fig. 4. We also calculuated the cumulative percentages of water column biomass from the surface to 1000 m for each station, and the depth of the 50% level is shown in Fig. 4. The 50% level of biomass from the intensive MOCNESS series was at 50 to 150 m during the day in all regions, and was at 50 to 100 m for all regions in the night. Nineteen to 66% of the integrated water column biomass (0-1000 m) was in the upper 100 m during the day and 50 to 78% of the integrated water column biomass was in the upper 100 m at night. This implies that the 200 m oblique tow series observed a large proportion of the total water column biomass and variations in biomass occurring there reflect variations occurring to most of the biomass. Fifteen to 44% of the integrated water column biomass (0-1000 m) appeared to be migrating into the upper 200 m at night.

The intensive MOCNESS sampling revealed that the highest biomass concentrations (ml m^{-3}) tended to occur in the upper

100 m of the water column (0-1000 m), especially at night. During the night biomass concentrations in the upper 100 m typically were at least 1.5 times those in any other depth range, and could be as much as 25 times greater than the lowest values measured. During the day the upper 100 m biomass concentrations were still high, but there was often an additional biomass peak at depth. These deeper biomass peaks, could be as high as those in the upper 100 m.

Seasonal Patterns

The 200 m oblique tow series were examined within each region (Fig. 3) to determine whether apparent seasonal changes occurred during the course of the study. Since the study extended for only one year, it is not possible to establish the limits of variability in seasonal patterns, which would require many complete yearly cycles. Biomass anomalies, the difference between a sample and the median value for that region, were calculated for each sample. Anomalies for day and night samples were calculated separately to reduce the effects of possible diel differences between samples. Day and night samples were then examined together so that all samples for one area were compared. Kruskal-Wallis tests (Sokal and Rohlf, 1981) indicated that the Slope Water, north wall, and Gulf Stream proper all had significant variability between cruises ($P < 0.05$). The Sargasso Sea biomasses did not exhibit significant temporal variability.

The highest biomasses occured in the spring months of March and May, with the highest of all in May. The lowest biomasses occurred in the autumn months of September and November, with September having the lowest values. In the Slope Water, the median of May, the month with the highest biomass, was 5 times the median of September. At the north wall, the median of March, the month with the highest biomass here, was 10 times that of September, the month with the lowest biomass. In the Gulf Stream proper, the median of January, the month with the highest biomass here, was 6 times that of September, the month with the lowest biomass. The spring maximum occurs earliest in the most southern region, the Gulf Stream, and then moves north to the next regions. It may be that conditions necessary for a spring increase are met at earlier times in the more southerly and warmer regions.

The two MOCNESS tow series were separated by about 8 months. Consequently it is not possible to consider seasonality in the MOCNESS tows, but one can fit them into the pattern observed in the year long 200 m oblique tow series. In September, 1982, zooplankton biomass concentration (ml m^{-3}) from the MOCNESS series (0-400 m) had a similar cross-stream pattern to that obtained during the same cruise with the 200 m oblique tows. Although the MOCNESS and small open net are different systems with different mesh sizes and may not be comparable for absolute values, they do show similar patterns across the Stream.

The September, 1982 MOCNESS total water column zooplankton biomasses (ml m^{-2}) were 2 to 5 times higher than the May, 1983 ones except on the southern edge of the Stream where they were similar in both months (Fig. 4). Yet during the year-long 200 m oblique tow series, the September, 1982 biomasses were among the lowest observed, while the May, 1982 biomasses were the highest observed. No 200 m oblique tows were taken in May, 1983. In May, 1983 (but not in 1982), dense aggregations of the salp, *Salpa fusiformis*, and the ctenophore, *Pleurobrachia pileus*, were encountered in the upper 100 m in the Slope Water and north wall regions. These large gelatinous animals were not included in the measurements of displacement volume, which considered only smaller zooplankton.

Discussion

Horizontal Patterns

Zooplankton biomass varied horizontally among regions from the Slope Water to the Sargasso Sea. The regions were significantly different in the night biomass samples. Our results tend to agree with those of other studies of the northwestern Atlantic (summarized in Table 3), which have found zooplankton biomass 4 to 11 times greater in the Slope Water than the Gulf Stream and Sargasso Sea. No previous studies have differentiated between the various regions of the Gulf Stream, especially the north wall.

Enhanced concentrations of zooplankton biomass were often found at the north wall front of the Gulf Stream. In March, 1982, the highest zooplankton biomasses of the cruise occurred at the north wall, and during several other cruises (July, September, and November, 1982, and May, 1983) zooplankton biomass, although lower than the Slope Water, was 2 to 5 times higher at the north wall than in the Gulf Stream and Sargasso Sea. These increases in biomass were observed in the upper 200 m, where the water at the north wall and Stream is similar in temperature and other physical properties (Wishner and Allison, in press).

An increase in zooplankton biomass at frontal regions is a common occurrence in marine environments (Herman and Denman, 1979; Herman et al., 1981; Parrish et al., 1981; Mackas and Sefton, 1982; Zeldis and Jillet, 1982; Boucher, 1984). Frontal regions are areas of enhanced biological activity in general (Pingree et al., 1974) and many types of organisms are concentrated in such regions. Increased primary productivity and phytoplankton biomass are often observed at fronts (Pingree et al., 1975; Fournier et al., 1977). Fish (Atkinson and Targett, 1981; Mishima, 1981; Olson and Backus, 1985) and seabirds (Schneider, 1982) also may be concentrated at fronts. The increased biological activity at fronts may be attributed to two main causes, which may act singly or in concert. Fronts may experience an input of nutrients which enhances primary production and provides food that allows for increases in the numbers of all organisms in the community. Alternatively, the water movement and structure at the front may interact with the behavior of zooplankton being advected to the frontal region and result in their concentration. This concentration could then attract more active organisms such as fish and birds. Our sampling was not extensive enough to determine whether there were increased nutrients at the north wall. During some cruises, cross-stream transport converged at the north wall, but it did not converge in all of the cruises in which increased zooplankton biomasses were observed at the north wall (Halkin, 1984).

In March, 1982, there was a large concentration of the diatom *Thalassiosira partheneia* at the north wall which apparently extended for a considerable distance along the frontal edge. We did not measure its actual concentration, but detected it because it clogged our zooplankton nets. The diatoms were encountered at 3 stations, two in the Slope Water (P8 and P7) and one at the north wall (P6) over a width of 60 km on March 13 at the start of a north-south transect and again at the same stations on March 19 at the end of a south-north Stream transect. Downstream velocity was approximately 10 cm s^{-1} at P8, 20 cm s^{-1} at P7, and 80 cm s^{-1} at P6. Cross-stream transport was toward the south at P8, toward the north at P7, and toward the south at P6 (Halkin, 1984). Based on the probable occurrence of this patch at P6 over 6 days, a station where the current was moving 80 cm s^{-1} downstream, this diatom patch could have been 415 km long. It is possible, however, that some kind of re-circulation kept this patch localized. During this cruise, the direction of cross-stream transport indicated a divergence at P6, which implies that upwelling was also occurring. Increased continuous nutrient input may have been sustaining the bloom of the diatom along the north wall. There was no evidence of an eddy or ring in the area at this time (Halkin, 1984). Zooplankton biomass was also elevated at the north wall during this cruise. T. partheneia forms large colonies, which are commonly found in the Northwest African upwelling region (Elbrachter and Boje, 1978). These colonies often disintegrate into single cells, which can be a good food source for copepods (Schnack, 1983). If the diatom bloom had persisted along the north wall for several weeks, it may have directly led to the increase in zooplankton. Copepods along the Georgia coast respond to upwelling events in 3 weeks (Paffenhofer, 1980) and doliolids respond in 7 to 9 days (Deibel, 1985), so such a direct increase is possible. Alternatively, it is possible that advection concentrated the zooplankton independently in the same area.

A large aggregation of salps and ctenophores was observed at the north wall and the adjacent Slope Water station, 20 km away, during May, 1983, when the abundance of smaller zooplankton was unusually low. In our 1000 m deep MOCNESS tows, these gelatinous zooplankters were abundant in the top 100 m of the water column on May 10 and 11, but had disappeared from the upper 1000 m of the water column by May 19 when we returned to these stations. Dense patches of gelatinous zooplankton are fairly common in the world's oceans and can occur over huge areas (Omori and Hamner, 1982). Large aggregations of ctenophores or other carnivorous gelatinous zooplankton can consume a high percentage of smaller zooplankton present (Swanberg, 1974; Omori and Hamner, 1982; Purcell, 1983). Predation by the ctenophore Pleurobrachia pileus may have reduced the standing stock of smaller zooplankton during May, 1983. Salp blooms have been observed in the Slope Water on several occasions (Grice and Hart, 1962; Wiebe, et al., 1979). Salps are voracious herbivores (Alldredge and Madin, 1982) and the S. fusiformis present in May, 1983, may have consumed so much food that other herbivorous zooplankters were not able to survive.

Vertical Patterns

The vertical structure in the zooplankton biomass distributions observed in the MOCNESS collections revealed that there was a biomass peak in the upper 100 m both day and night. During the day there was a second biomass peak below 400 m depth. The surface biomass peak usually was located in the mixed layer and the deep biomass peak was below the 15 ^{o}C isotherm. The increase in biomass in the upper 200 m at night was probably due to zooplankton migrating vertically into the surface water, rather than decreased net avoidance.

Ortner et al., (1978) found that zooplankton biomass tended to have a maximum near 50 m depth in both the Slope Water and Sargasso Sea. They found a deep daytime maximum in zooplankton biomass at 400-600 m depth, but only in the Slope Water. They found that the percent of the 0-800 m biomass present in the upper 200 m was 45 to 51 % for the Sargasso Sea and 32 to 34 % for the Slope Water. Ortner et al., found 24 to 30 % of the zooplankton biomass to be migrating into the upper 200 m at night. Deevey and Brooks (1971) felt that there were indications of different seasonal patterns at depth in the Sargasso Sea than in the upper water column. Our sampling was not extensive enough to determine deep water seasonality.

The total water column (0-1000 m) integrated zooplankton biomass (ml m^{-2}) and the depth distribution pattern for the intensive MOCNESS stations were similar to those obtained by 1000 m MOCNESS tows by Wiebe et al. (1985) in the Gulf Stream and Sargasso Sea. Wiebe et al. (1985) observed a significantly stronger diel vertical migration pattern in the Sargasso Sea than in the Slope Water and warm-core and cold-core Gulf Stream rings. This pattern may explain why there were significant day and night biomass differences in our Sargasso Sea and Gulf Stream samples, but not in our Slope Water and north wall samples.

Seasonal Patterns

Significant seasonal variation was detected in the Slope Water, the north wall, and Gulf Stream, but not in the Sargasso Sea. The seasonal variability observed in this study is similar to that observed in other studies (summarized in Table 3). These studies found a seasonal maximum in zooplankton biomass in the spring, March to May, and a minimum in the fall, September to December. Grice and Hart (1962) found the biomass to be at a maximum in July in the Slope Water. Many studies (Moore, 1949; Menzel and Ryther, 1961; Be et al., 1971; Deevey, 1971; Deevey and Brooks, 1971) found evidence of a seasonal cycle in the Sargasso Sea, although this variation was small compared to the Slope Water (Be et al., 1971). Fish (1954) observed irregular fluctuations in biomass in the Sargasso Sea, and Grice and Hart (1962) found no evidence of seasonality in the Gulf Stream or Sargasso Sea. Bsharah (1957) examined the Gulf Stream in the Florida Straits region and observed that in the top 100 m the biomass was 4 times higher in the spring than in the rest of the year, and in the upper 600 m it was 2 to 3 times higher in the spring.

The MOCNESS samples and Pegasus velocity profiles (Halkin, 1984) from September, 1982 and May, 1983 can be used to examine the transport of zooplankton biomass and species in the Gulf Stream. For copepods in September (Wishner and Allison, in press), long distance downstream transport was most likely in the central core of the Stream and in the high velocity surface water. Cross-stream transport was most likely at depth below the oxygen minimum zone and in the surface mixed layer.

During both September and May, there was a peak in the upper 100 m across the Stream during both day and night, which accounted for 44.7 to 81.9 % of the total 0-1000 m zooplankton biomass. Within the central Stream, the upper 100 m is a region of high downstream velocity. Therefore it is likely that much zooplankton biomass is transported downstream in the surface water. In May, 1983, the surface temperatures were 10 °C different between the Slope Water and Stream (Halkin, 1984) so it is unlikely that surface cross-stream transport of biomass was occurring. However, in September, 1982, the surface temperatures were similar (within 2 °C) (Halkin, 1984) in the Slope Water and Stream, and some cross-stream mixing along with downstream transport may have been occurring at the surface.

During both of these cruises there was also a biomass peak at depth below the 15 °C isotherm during the day across the Stream. This biomass peak, which usually accounted for 20 to 40% of the total 1000 m biomass, extended to depths below the 12 °C isotherm and oxygen minimum zone (Fig. 4). In this depth region, cross-stream transport along isopycnals occurs (Bower et al., 1985) and it is likely that zooplankton were being transported cross-stream when they migrated to these depths during the day. At night, much of the zooplankton biomass migrated to shallower depths with less chance of cross-stream mixing.

In the central core of the Gulf Stream, at 100 m to 400 m depth, downstream transport is large and cross-stream transport small. Although zooplankton biomass at any one time was low in this region, typically 5 to 15 % of the 0-1000 m total biomass, many zooplankton travel through this region in diel migrations between 400 to 500 m and the surface. For these brief periods of time, they are subject to extensive downstream transport. Therefore the amount of zooplankton biomass advected downstream in the central core probably varies strongly with a diel cycle.

Conclusions

1) Zooplankton biomass is highest in the Slope Water, intermediate, although more variable at the north wall of the Gulf Stream, and lowest in the Stream and Sargasso Sea.

2) The north wall front of the Gulf Stream is a region in which zooplankton and phytoplankton biomass can be enhanced considerably over that of the central Stream despite similarities in the physical properties of the surface water in the two regions.

3) There is a distinct seasonal pattern in the abundance of zooplankton biomass in the Slope Water, north wall of the Gulf Stream, and central Stream regions, with a maximum in late spring and early summer and a minimum in the autumn.

4) The amount and direction of zooplankton biomass transported varies with position in the Stream. The vertical distribution of zooplankton biomass, including diel changes related to vertical migration, interacts with the horizontal and vertical structure of the velocity field. Downstream transport of biomass is probably greatest in the surface

water, because both biomass and water velocities are high. Cross-stream transport is highest below the oxygen minimum zone, although it also occurs in the surface water.

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Captions

Fig. 1. Location of the transect across the Gulf Stream. The short lines are the stations arranged in numerical order from P0 at the southern end to P8 at the northern end. The longer lines perpendicular to the transect are the positions of the north wall of the Gulf Stream during each cruise, with each cruise identified by a different symbol.

Fig. 2. Day and night biomasses from the oblique tows in the upper 200 m along the transect. The position of the north wall of the Gulf Stream is used as the reference point, and the stations are arrayed relative to the north wall by aligning the 15 ^{o}C isotherm for each cruise so that the geographic location of this isotherm at 200 m depth (defined as the north wall) intersects for all cruises. Biomasses in the upper part of the graph and 15 ^{o}C isotherms for each cruise are identified by different symbols for each cruise.

Fig. 3. Biomass concentration from the MOCNESS tows [ml (1000 m^{-3})] drawn as contours across the Gulf Stream. The thick line in each plot is the depth of 50% of the cumulative water column biomass from 0 m down to 1000 m. The north wall station (P6) is at the left in each plot.

Fig. 4. Seasonal patterns of biomass concentration [ml (1000 m^{-3})] in each cross-stream region from the 200 m oblique tows. Day and night values are shown by different

symbols.

Table 1. Summary of cruise and sampling information.

Table 2. Median ratios of the biomass in each region relative to that of the Sargasso Sea. Areas that are not significantly different are underlined. The MOCNESS values are the integrated water column biomasses and were not tested due to small sample sizes. N = not samples.

Table 3. Summary of results from previous surveys of biomass in the western North Atlantic. The numbers are the median ratios of biomass in a region relative to the Sargasso Sea, as in Table 2 of this paper. N = not sampled. X = sampled only in this region.

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Table 1 Summary of sampling dates and methods.

Cruise	Date	Types of Zooplankton Sampling
Endeavor 77	Nov. 7-17, 1981	65 cm open net 0-200 m oblique
Endeavor 79	Jan. 27-Feb. 4, 1982	65 cm open net 0-200 m oblique
Endeavor 81	March 12-20, 1982	65 cm open net 0-200 m oblique
Cape Hatteras 12	May 9-19, 1982	65 cm open net 0-200 m oblique
Cape Hatteras 16	July 9-18, 1982	65 cm open net 0-200 m oblique
Endeavor 89	Sept. 6-16, 1982	65 cm open net 0-200 m oblique MOCNESS 0-400 m all stations 0-200 m intensive 0-1000 m intensive
Endeavor 92	Nov. 20-29, 1982	65 cm open net 0-200 m oblique
Endeavor 99	May 9-25, 1983	MOCNESS 0-400 m all stations 0-200 m intensive 0-1000 m intensive

Table 2 Median biomasses of each region relative to the biomass of the Sargasso Sea. Regions that are not significantly different are underlined. MOCNESS samples were not tested statistically because of small sample size.

		Region			
Tow Series	Time of Day	Slope Water	North Wall	Gulf Stream	Sargasso Sea
200 m Oblique	Day	5.8	2.4	1.7	1
	Night	2.4	1.4	0.8	1
400 m MOCNESS	Day	4.4	2.1	1.7	1
	Night	1.5	NS	0.5	1
1000 m MOCNESS	Day	NS	1.1	0.9	1
	Night	NS	1.5	1.05	1

NS = Not Sampled

Table 3 Total water column zooplankton biomass (0-1000 m) from the MOCNESS tow series in [ml(m-2)].

Month	North Wall Day	North Wall Night	Warm Core Day	Warm Core Night	Southern Edge Day	Southern Edge Night
September	10.24	11.55	8.62	8.55	6.24	5.10
May	3.86	6.13	3.35	3.40	6.31	6.52

Fig. 1

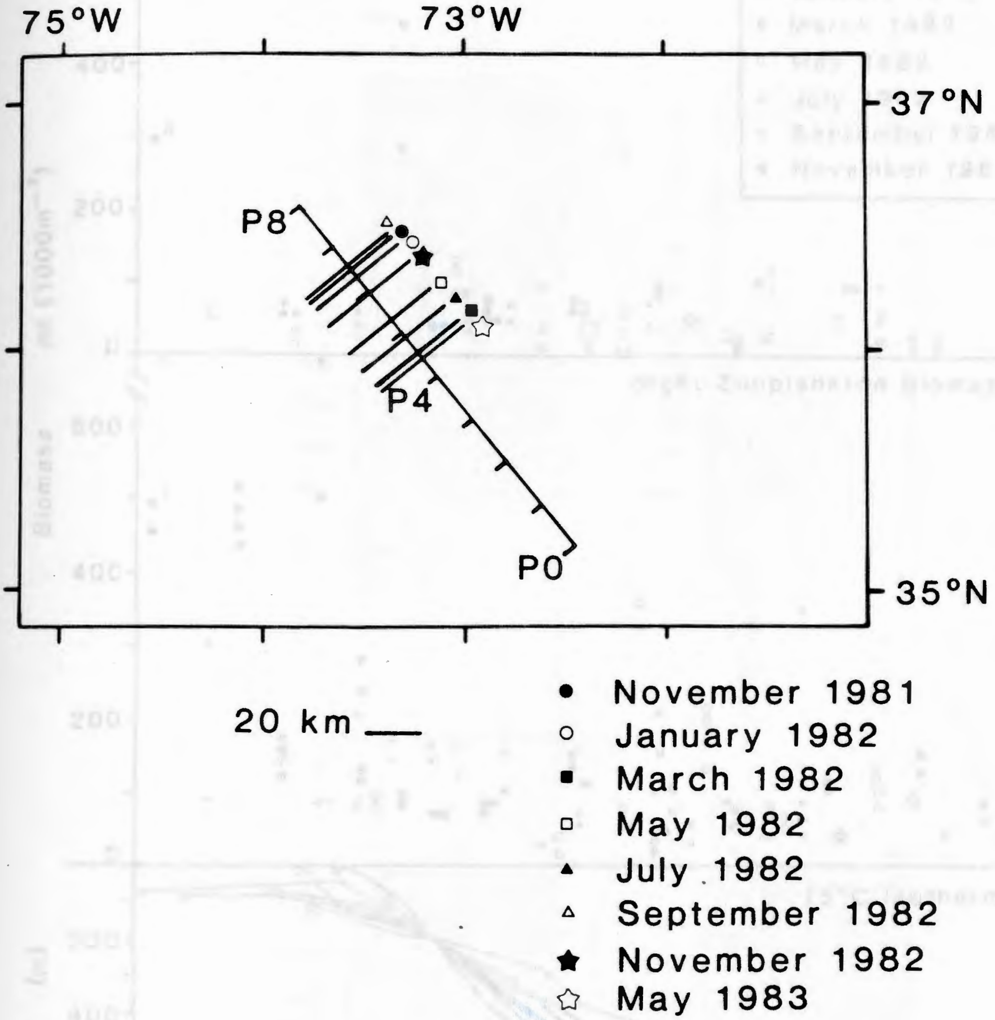

75°W
73°W
37°N
35°N
P8
P4
P0
20 km
● November 1981
○ January 1982
■ March 1982
□ May 1982
▲ July 1982
△ September 1982
★ November 1982
☆ May 1983

Fig. 2

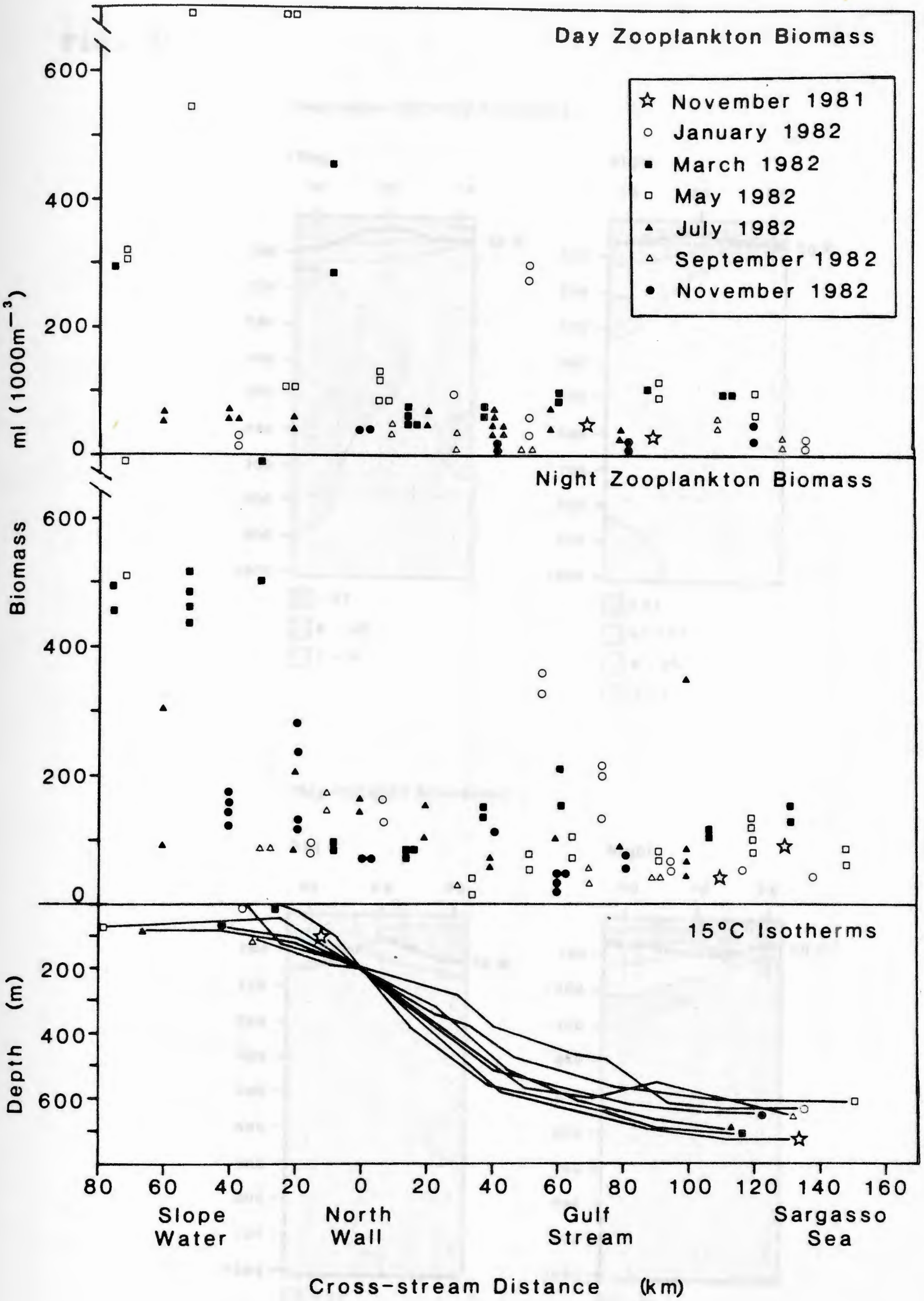
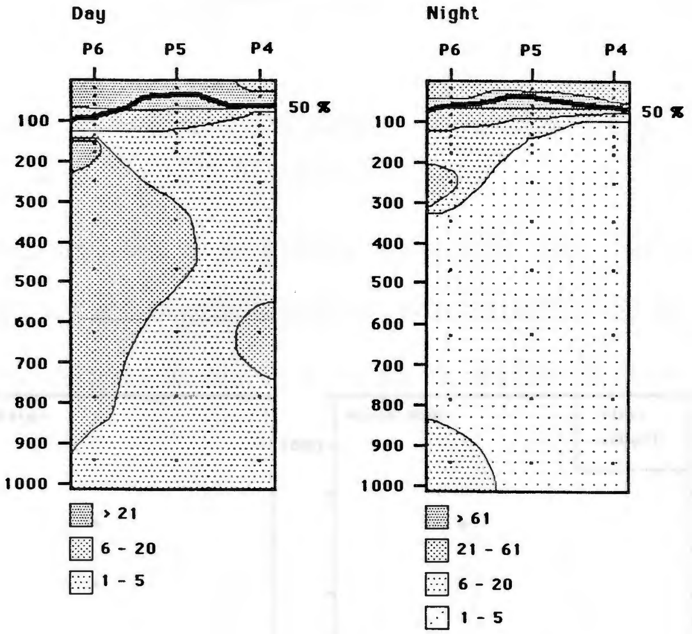

Day Zooplankton Biomass
☆ November 1981
○ January 1982
■ March 1982
□ May 1982
▲ July 1982
△ September 1982
● November 1982
600
400
200
0
ml (1000m^{-3})
Night Zooplankton Biomass
600
400
200
0
Biomass
15°C Isotherms
200
400
600
Depth (m)
80
60
40
20
0
20
40
60
80
100
120
140
160
Slope Water
North Wall
Gulf Stream
Sargasso Sea
Cross-stream Distance (km)

Fig. 3

September MOCNESS Biomasses



May MOCNESS Biomasses

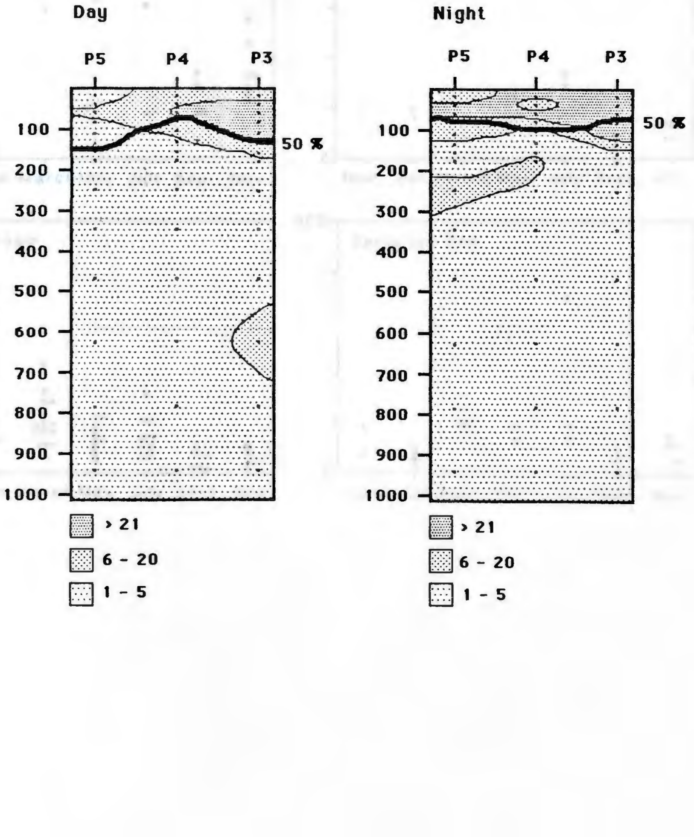
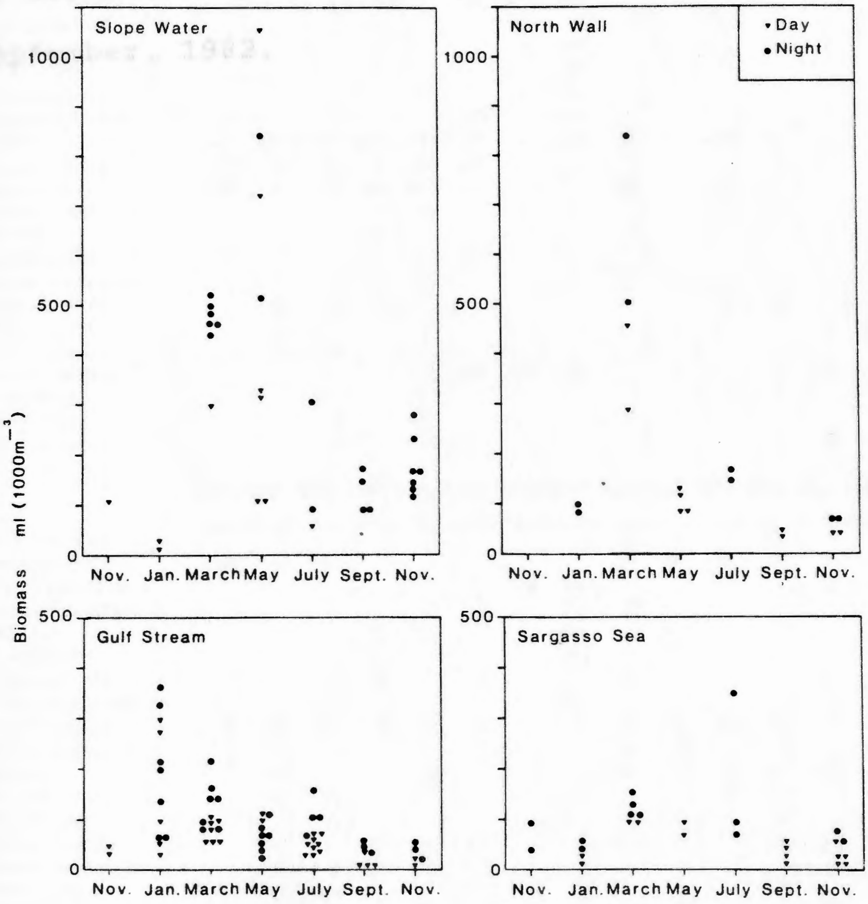


Fig. 4


Slope Water
North Wall
▾Day
●Night
Gulf Stream
Sargasso Sea
Biomass ml (1000m^{-3})
1000
500
0
Nov. Jan. March May July Sept. Nov.

Appendix A

Copepod species distributions in September, 1982

Figures 1 through 22 are plots of selected copepod species abundances with depth across the Gulf Stream from intensive discrete depth sampling with a MOCNESS net system during September, 1982.

Table 1. Number of a species found in a particular sample in [num(1000 m-3)].
Blank spaces indicate that the species was not found in that sample.

Species	M13N2	M13N3	M13N4	M13N5	M13N6	M13N7	M13N8	M13N9	M23N2	M23N3	M23N4	M23N5	M23N6	M23N7	M23N8	M23N9
Calanus finmarchicus		13	31	12	93	29				15	58					
Calanus finmarchicus CV	383	356	656	93	171				442	325	1190	11		9	7	
Mesocalanus tenuicornis						86	1295	146							276	157
Mesocalanus tenuicornis CV						29	386	42							14	63
Calanus minor							23	187								1449
Calanus minor CV								104								472
Neocalanus gracilis					31			42								31
Neocalanus gracilis CV						29		250						19	14	1764
Rhincalanus cornutus	104	145	160	1047	1569	344		21	59	140	203	169		75	14	
Rhincalanus nasutus	35	13	16	62	295	602				22						
Metridia lucens	104	40	145	648	1289				286	81	102					
Metridia brevicauda				6	16						15					
Metridia venusta				12							29	11				
Pleuromamma gracilis				50	450	946				7		464	843	768	14	
Pleuromamma abdominalis				156	481					7	73	795	411	19		31
Pleuromamma xiphias		13		87							51	52				
Pleuromamma piseki					15								62	197		31
Pleuromamma borealis			5													
Lucicutia flavicornis					93	1835	2750	1792		30	36	21	165	543	2176	254
Lucicutia gemina											7	21		9	41	
Lucicutia ovalis			5													64
Lucicutia clausi					16							11	21	94	7	

Species	M17N2	M17N3	M17N4	M17N5	M17N6	M17N7	M17N8	M17N9	M16N2	M16N3	M16N4	M16N5	M16N6	M16N7	M16N8	M16N9
Calanus finmarchicus		11							36	51	20	12	10			
Calanus finmarchicus CV	309	32	27						804	481	444	139	52	18		
Mesocalanus tenuicornis							189	346					21	46	503	859
Mesocalanus tenuicornis CV								115	18					9		363
Calanus minor				5				385							10	515
Calanus minor CV								288								401
Neocalanus gracilis				10		13							21		10	38
Neocalanus gracilis CV								461					10	9	19	955
Rhincalanus cornutus	24	117	123	24	63	13		19	250	146	184	315	679	210	10	
Rhincalanus nasutus	24								54	22	7	6	31	109		
Metridia lucens	71	21			32				232	138	68	157	125	100	58	
Metridia brevicauda		37	21					19			20	18				
Metridia venusta		42	16									6				
Pleuromamma gracilis			69	740	1802	215	14	19				67	125	328	513	764
Pleuromamma abdominalis		58	48	131	379	7		19	18			79	10		203	726
Pleuromamma xiphias		16	112									6		18	48	19
Pleuromamma piseki			5		253	13							21			76
Pleuromamma borealis											27	18	10	18	106	
Lucicutia flavicornis	47	5	5	68	159	403	305	2058	18	15	7	12	84	73	116	3169
Lucicutia gemina						40	58	77						36	222	210
Lucicutia ovalis								96			7				39	134
Lucicutia clausi				14	286	27	14									

Table 1 cont'd.

	M26N2	M26N3	M26N4	M26N5	M26N6	M26N7	M26N8	M26N9	M20N2	M20N3	M20N4	M20N5	M20N6	M20N7	M20N8	M20N9
Calanus finmarchicus	72	52	8						6		10					
Calanus finmarchicus CV	716	888	287	7		6	15		130	18	29		8			
Mesocalanus tenuicornis							61	437				5		24	42	1463
Mesocalanus tenuicornis CV								67						18		1152
Calanus minor							30	2857						6		355
Calanus minor CV								471								798
Neocalanus gracilis		9		3	25	12	30	235			10	11		6		89
Neocalanus gracilis CV				3		12	30	908						6	8	443
Rhincalanus cornutus	131	207	107	105	80	127		101	96	63	258	32	17		25	133
Rhincalanus nasutus	36	26							125	4				6		
Metridia lucens	24	95	25						79	9	19					
Metridia brevicauda			16	7						27						
Metridia venusta			57	7						13	44					
Pleuromamma gracilis				362	123	328	364	3462			92	180	17	135	25	1640
Pleuromamma abdominalis			57	105	31	30	197	571		9	58	21		18	25	1108
Pleuromamma xiphias		9	25		18	79	167	67	6	4	34	5	8	6	50	487
Pleuromamma piseki				13		12	15	370		4	15			12	17	399
Pleuromamma borealis																
Lucicutia flavicornis	12		16	10	12	158	242	2992		9	10	11	25	177	50	5008
Lucicutia gemina				7	6	79	121	168	6	9	15	5	58	94	158	532
Lucicutia ovalis				3			15	134							17	44
Lucicutia clausi				10	123	103	151					11	17	141	42	

	M14N2	M14N3	M14N4	M14N5	M14N6	M14N7	M14N8	M14N9	M22N2	M22N3	M22N4	M22N5	M22N6	M22N7	M22N8	M22N9
Calanus finmarchicus																
Calanus finmarchicus CV																
Mesocalanus tenuicornis	186	639	498	869	322			67	131	200	352	185	148		24	140
Mesocalanus tenuicornis CV	37	91	760	1520	804		60			22		37	246			70
Calanus minor	37	61	24	72	201	2654	1668	402					49	8444	72	140
Calanus minor CV		61		36	80	1099	1728	402		22			49	1867	168	351
Neocalanus gracilis				36	161					45			197	267		
Neocalanus gracilis CV				36	201	265	596	2678			23			2133	72	281
Rhincalanus cornutus				36		76			66				49	178		
Rhincalanus nasutus																
Metridia lucens																
Metridia brevicauda																
Metridia venusta																
Pleuromamma gracilis		30							44	22	70		49		24	
Pleuromamma abdominalis										22					48	
Pleuromamma xiphias																
Pleuromamma piseki						38			22							
Pleuromamma borealis																
Lucicutia flavicornis	4979	1308	736	724	2894	4815	119	134	2317	3075	2158	1667	738	178	168	632
Lucicutia gemina	186	182							197	423	446	37				
Lucicutia ovalis			24	109	362	76		67				37	591	89		
Lucicutia clausi									44							

Table 1 cont'd.

	M18N2	M18N3	M18N4	M18N5	M18N6	M18N7	M18N8	M18N9	M15N2	M15N3	M15N4	M15N5	M15N6	M15N7	M15N8	M15N9
Calanus finmarchicus											33					
Calanus finmarchicus CV									23		66					
Mesocalanus tenuicornis	25	222	497	925	538	207		51	93	118	466	2133	600			
Mesocalanus tenuicornis CV		22	24		769	207			163	79	100	1472	750			
Calanus minor					51	311	556	203	93	79			300	1541	760	374
Calanus minor CV					51	466	626	457			33		200	635	380	166
Neocalanus gracilis			47						47			56	50	181	47	
Neocalanus gracilis CV					26	104	70	1828		20			100	2085	617	374
Rhincalanus cornutus						104										
Rhincalanus nasutus																
Metridia lucens									210	630	432					
Metridia brevicauda																
Metridia venusta																
Pleuromamma gracilis			71	30					70	493	466	954	850	363	47	
Pleuromamma abdominalis									23	98	299	393	600	635	142	42
Pleuromamma xiphias									163	79	166	168		91		
Pleuromamma piseki										59	100	168	450	272		83
Pleuromamma borealis									140	906	1863	1179	300	181		42
Lucicutia flavicornis	279	377	686	686	349	9994	556	102	326	473	1131	2077	1850	8430	3988	3283
Lucicutia gemina	356	22	355	686	1923				70	256	399	112		91	190	
Lucicutia ovalis					154	984					266	112	850	453		42
Lucicutia clausi																

	M25N2	M25N3	M25N4	M25N5	M25N6	M25N7	M25N8	M25N9	M19N2	M19N3	M19N4	M19N5	M19N6	M19N7	M19N8	M19N9
Calanus finmarchicus																
Calanus finmarchicus CV	47	38	56													
Mesocalanus tenuicornis	38	38	56	20	553	438			91	129	101	111	611	2014		
Mesocalanus tenuicornis CV					255	73					45	18	459	1472		
Calanus minor		29			255	2776	4267	5056						310	92	
Calanus minor CV					43	658	237	133						542	92	
Neocalanus gracilis						292			80		11	9		310		
Neocalanus gracilis CV	9	10			85	73	632	399		37	11	9		77	1379	1265
Rhincalanus cornutus	47	10	56						11	9	11	18				
Rhincalanus nasutus																
Metridia lucens	9															
Metridia brevicauda			28													
Metridia venusta				20												
Pleuromamma gracilis	75	29	28	101	5319	7525	632	399	91	46	67	369	408	8988	552	74
Pleuromamma abdominalis	9				170	2265	237	266	11	18	67	92	357	2479	1195	298
Pleuromamma xiphias	19	67	84	40	255	1461	158		23	18	56	111	102	1162	92	
Pleuromamma piseki				20		146	159	333				9		930	368	893
Pleuromamma borealis																
Lucicutia flavicornis	28	29		141	553	2849	1817	1929	80	55	67	92	459	6508	2667	4391
Lucicutia gemina		48	168	81	468			66	80	175	123	323	1223	465		74
Lucicutia ovalis		19			340	1169	79		68	46		37	51	155	276	
Lucicutia clausi	75	57	140	61	43					18	34	9				

Fig. 1

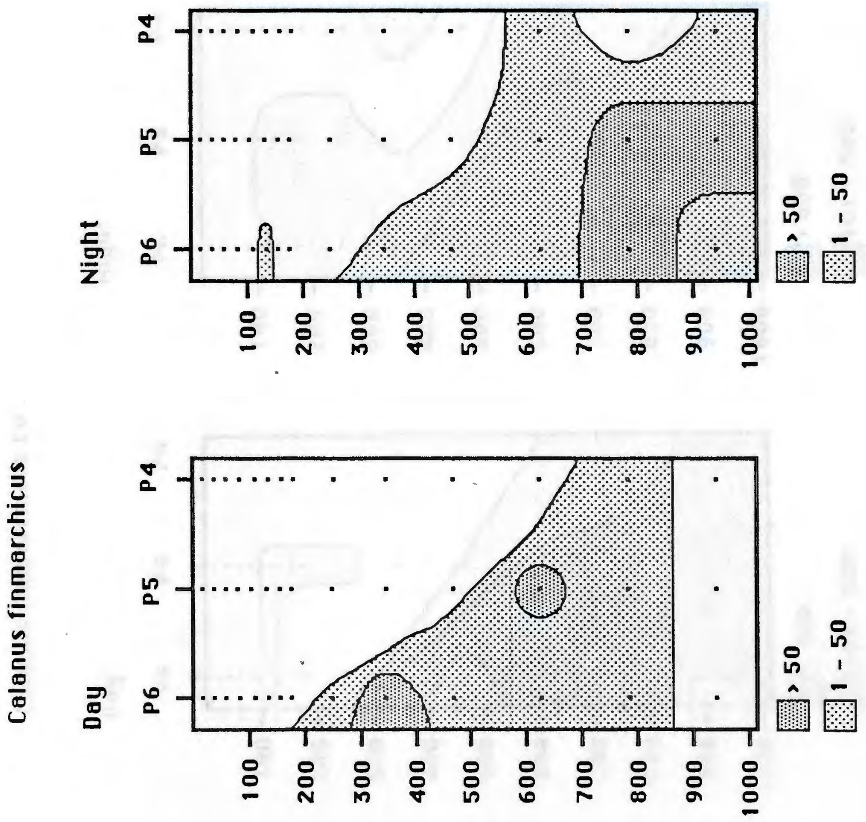

Calanus finmarchicus
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 50
1 - 50

Fig. 2

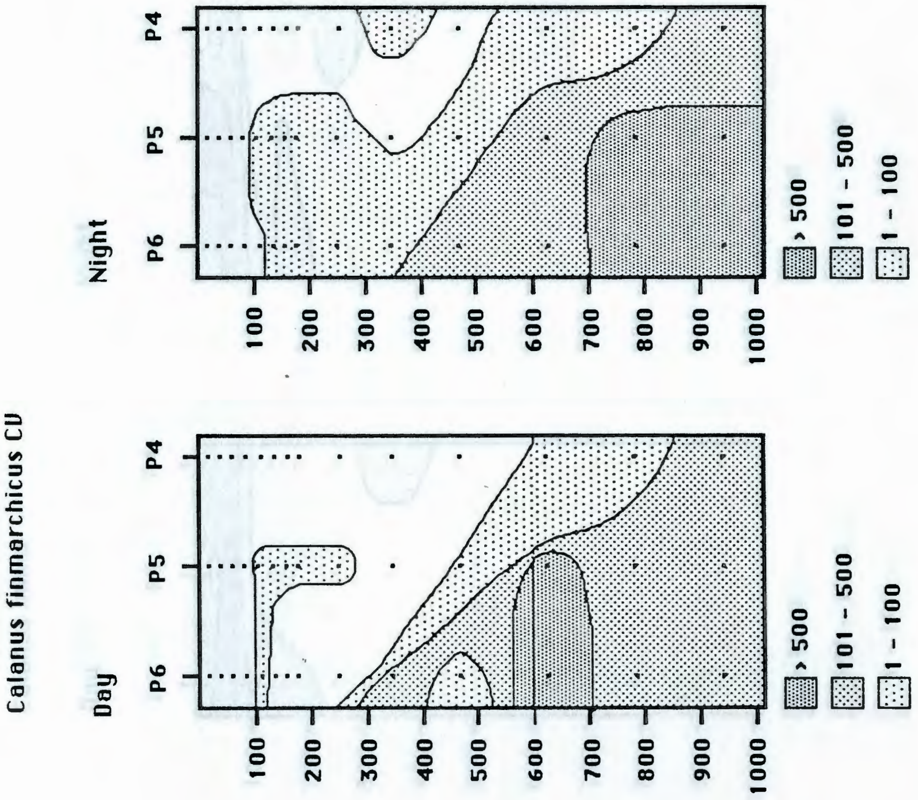

Calanus finmarchicus CV
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 500
101 - 500
1 - 100

Fig. 3

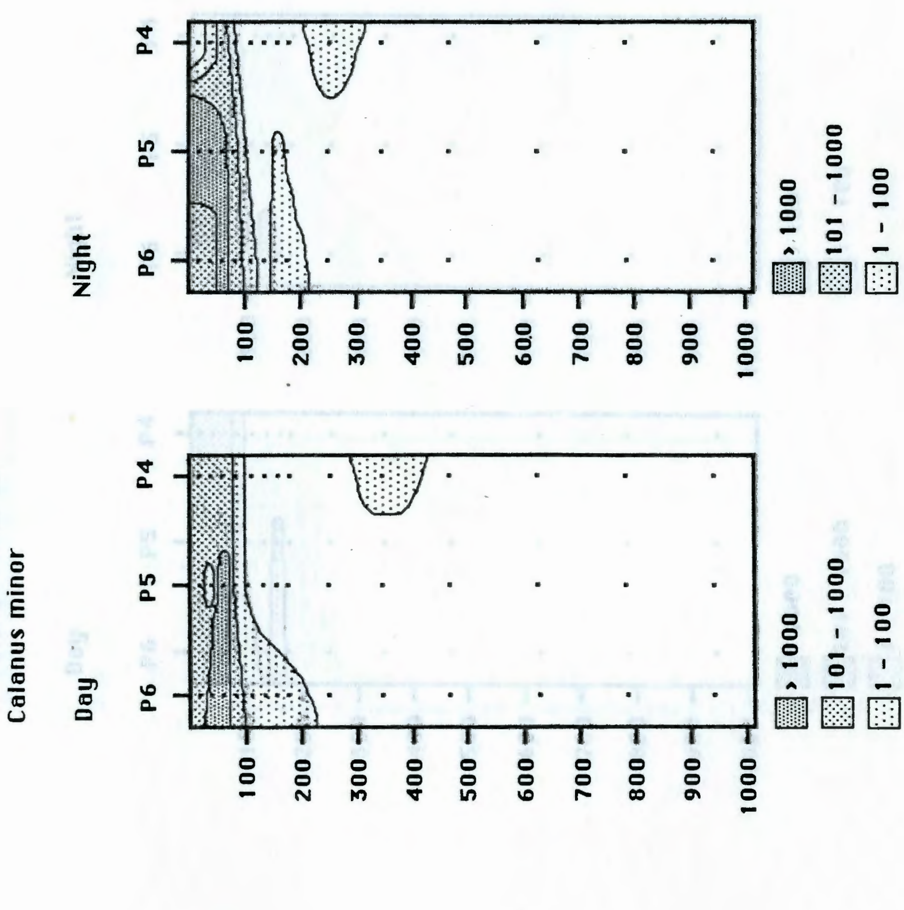

Calanus minor
Day
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 1000
101 - 1000
1 - 100
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 1000
101 - 1000
1 - 100

Fig. 4

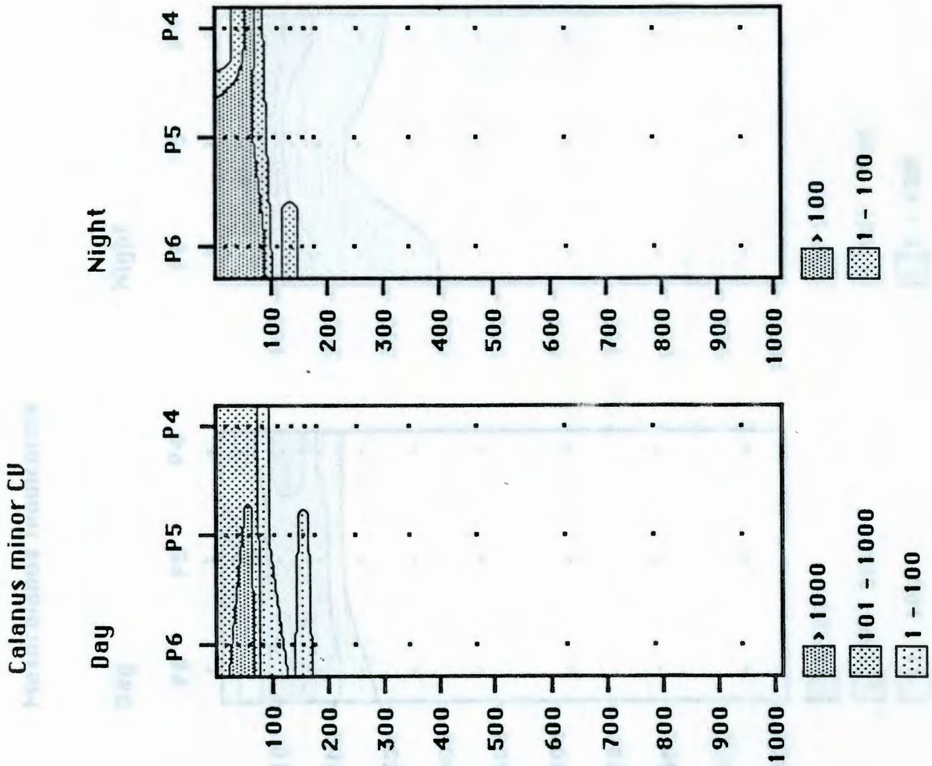

Calanus minor CV
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 1000
101 - 1000
1 - 100
> 100
1 - 100

Fig. 5

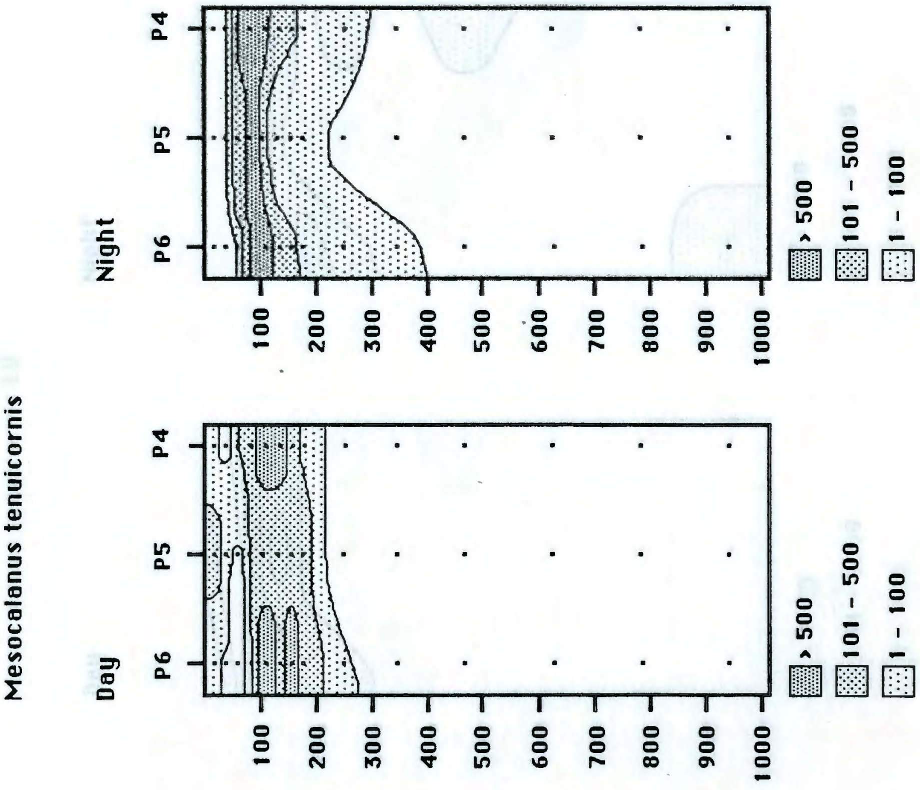

Mesocalanus tenuicornis
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 500
101 - 500
1 - 100

Fig. 6

Mesocalanus tenuicornis CV

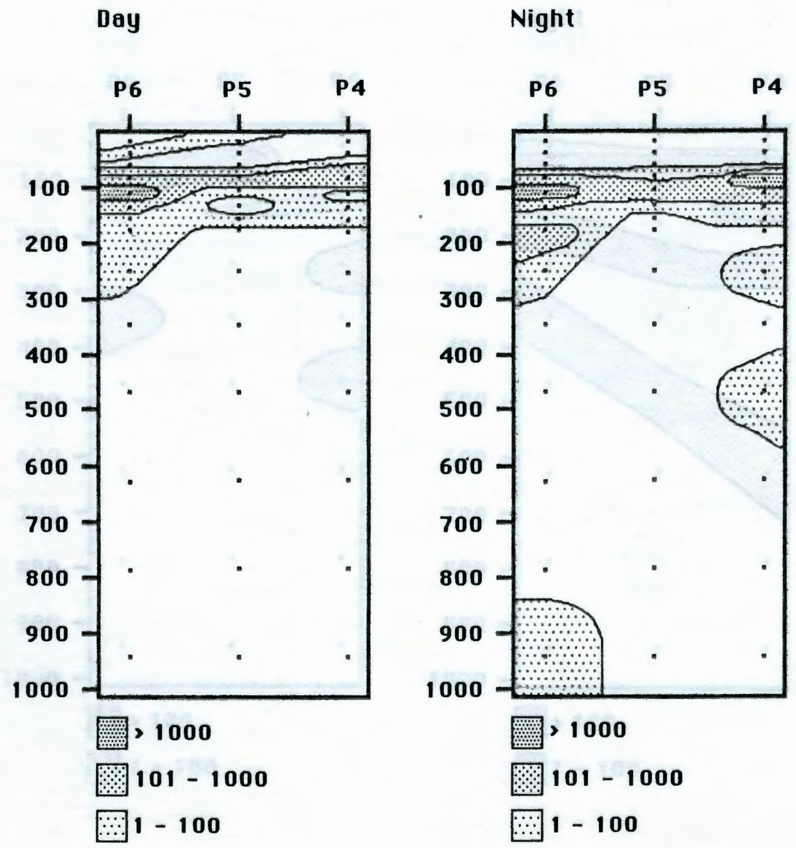


Fig. 7

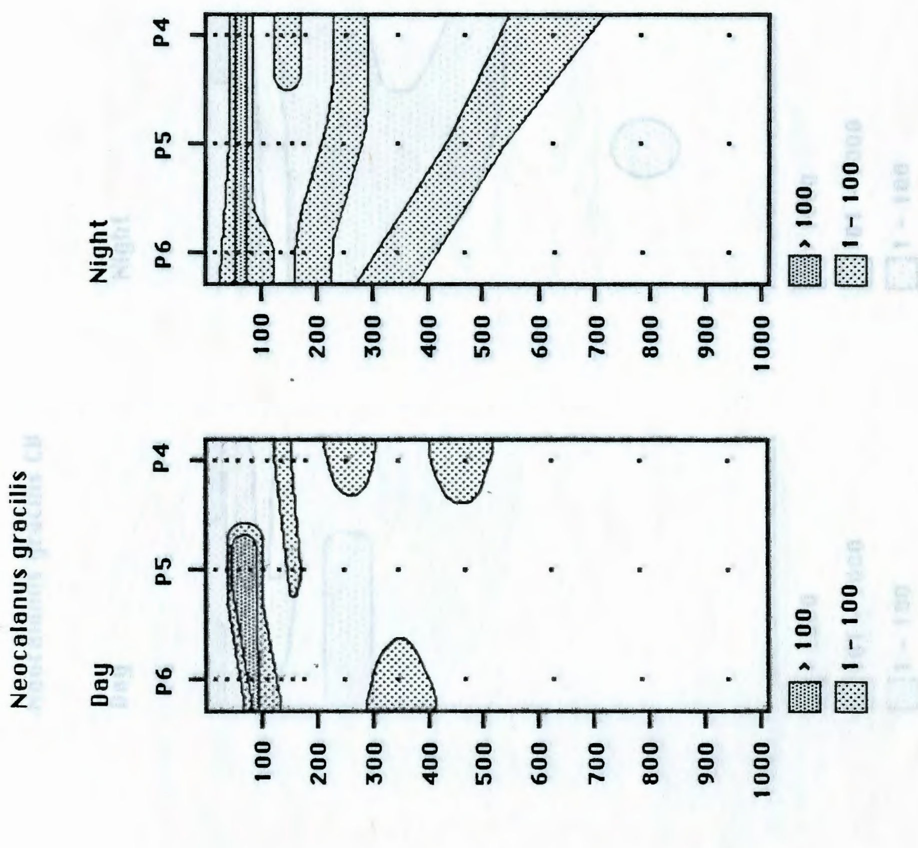

Neocalanus gracilis
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 100
1 - 100

Fig. 8

Neocalanus gracilis CV

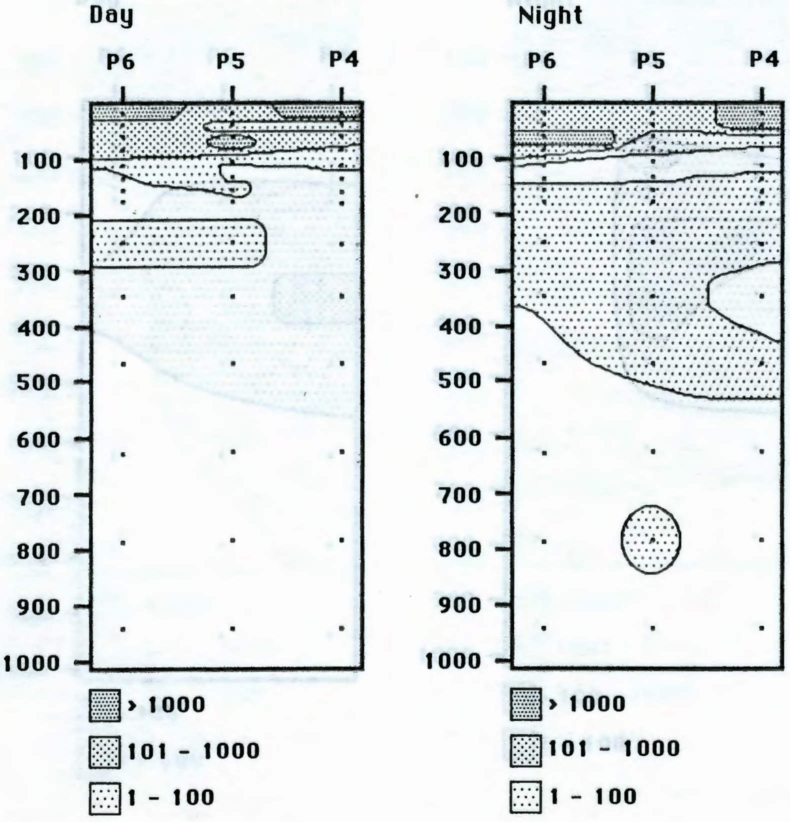


Fig. 9

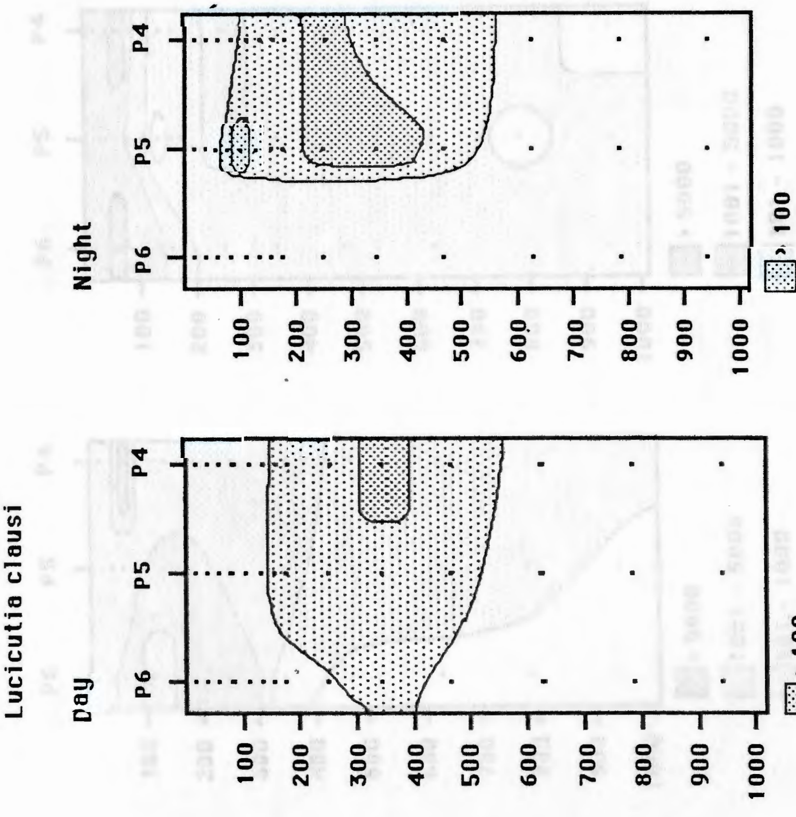
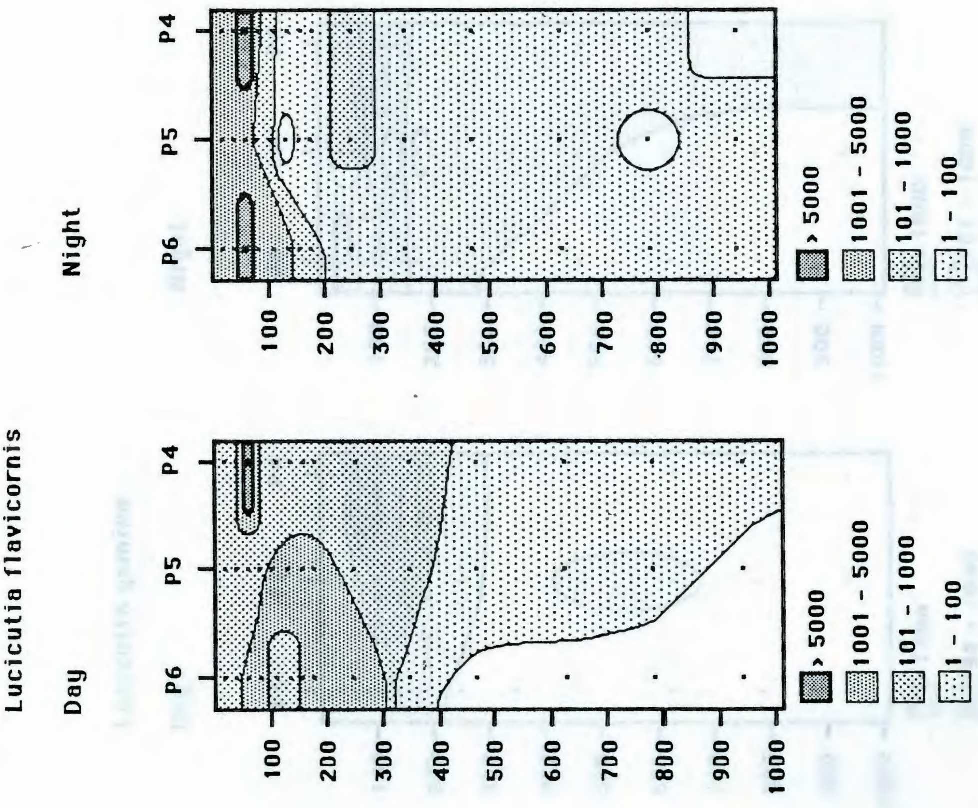

Lucicutia clausi
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 100
1 - 100

Fig. 10



Lucicutia flavicornis

Day

Night

Fig. 11

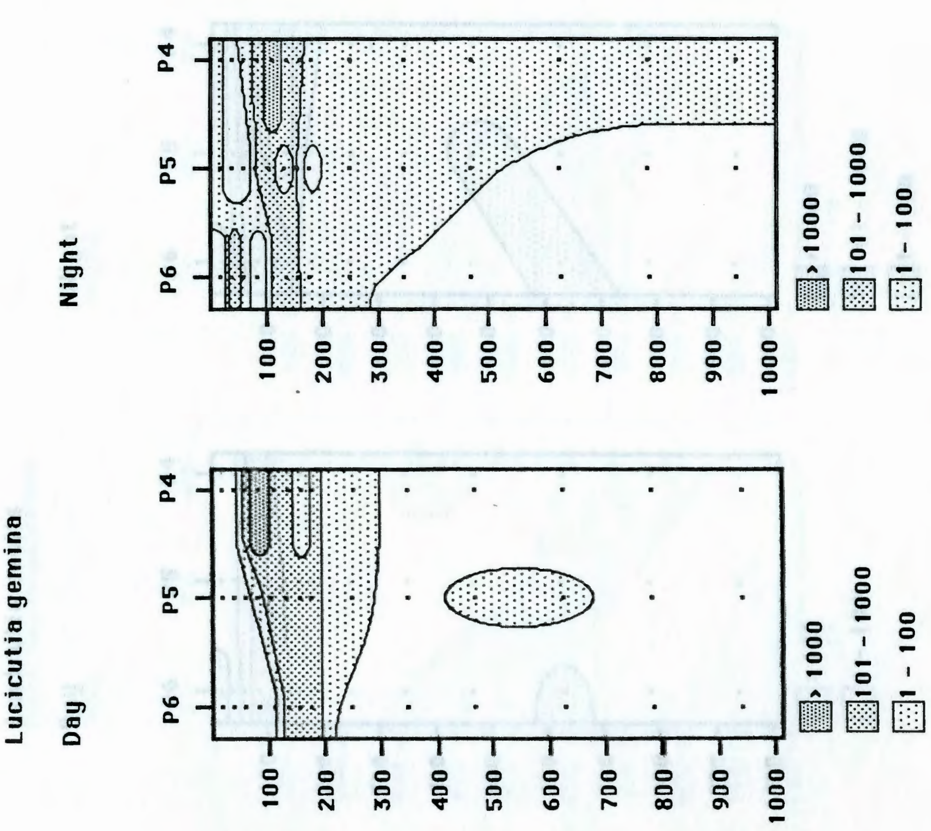
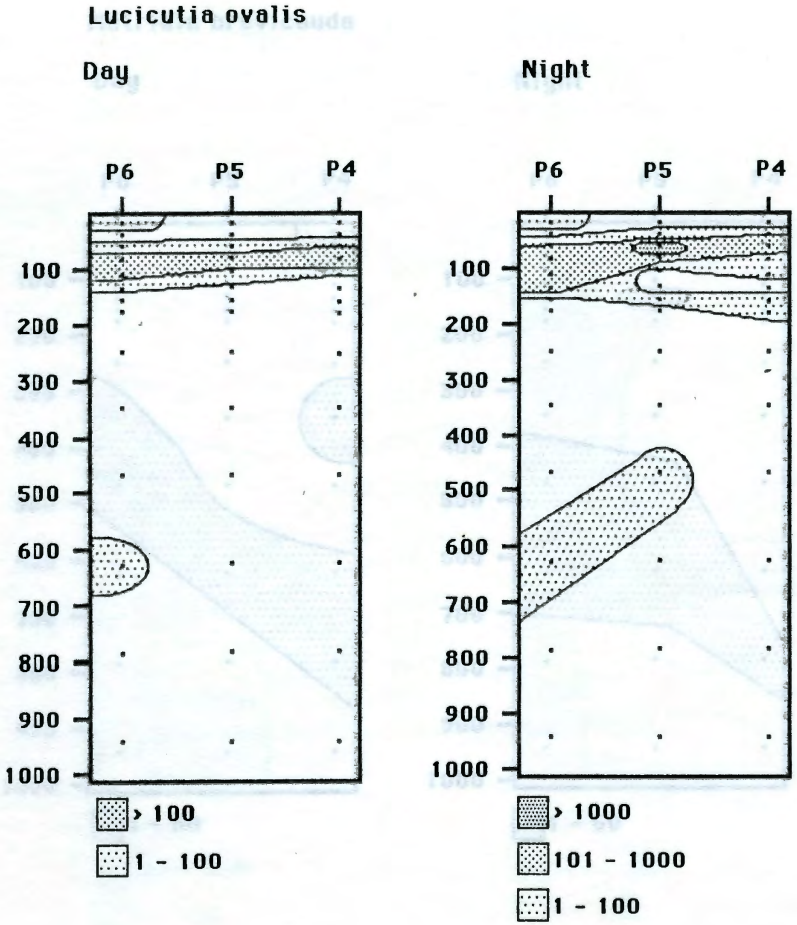

Lucicutia gemina
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 1000
101 - 1000
1 - 100

Fig. 12

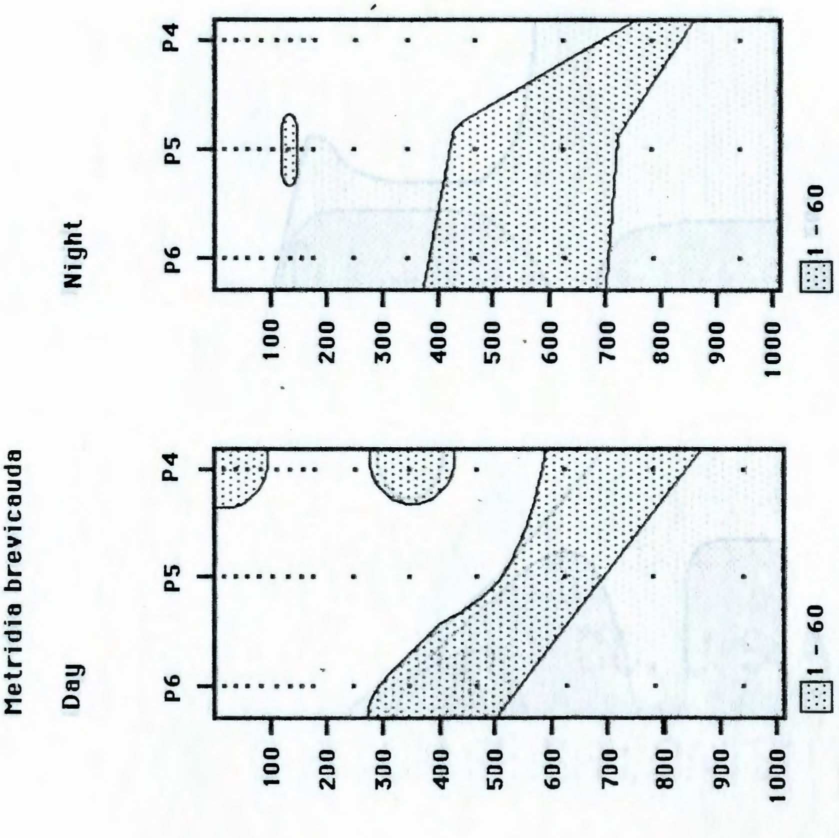


Lucicutia ovalis

Day

Night

Fig. 13



Metridia brevicauda

Day

Night

Fig. 14

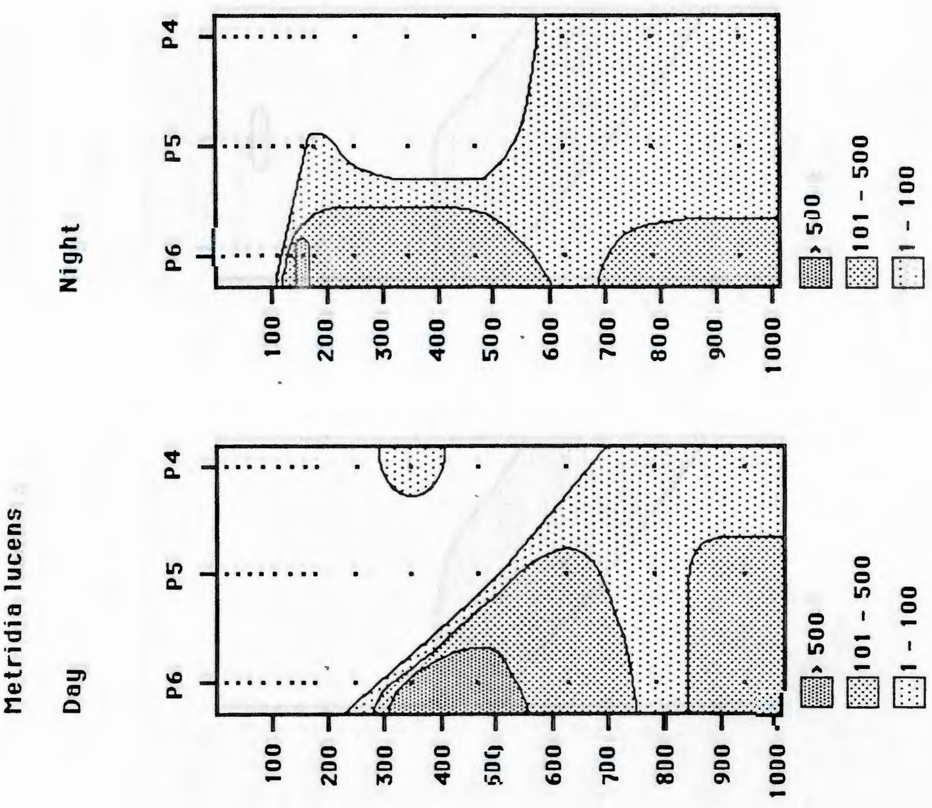
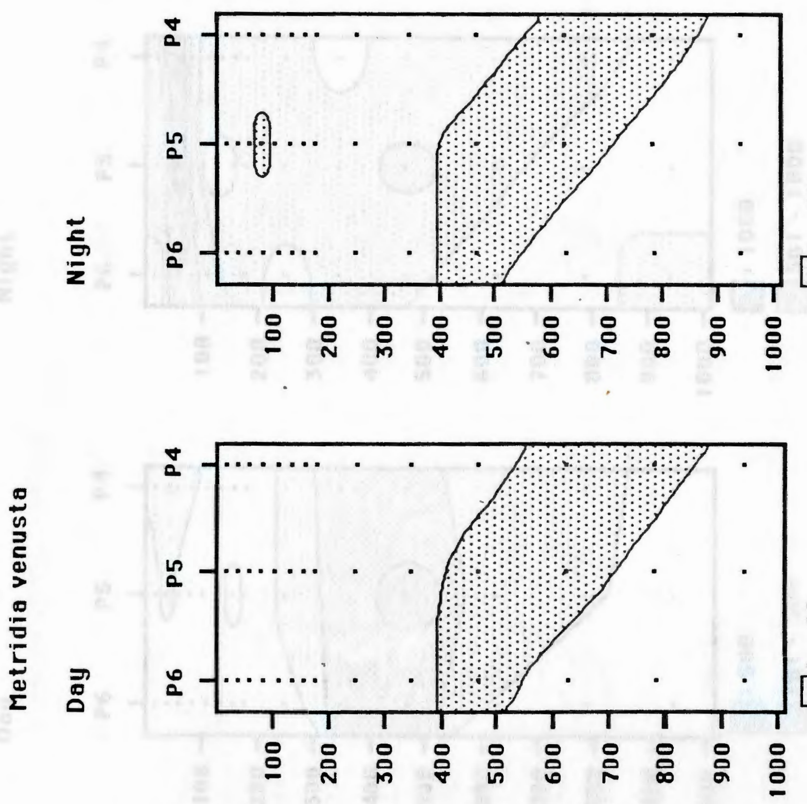

Metridia lucens
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 500
101 - 500
1 - 100

Fig. 15


Metridia venusta
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
1 - 60

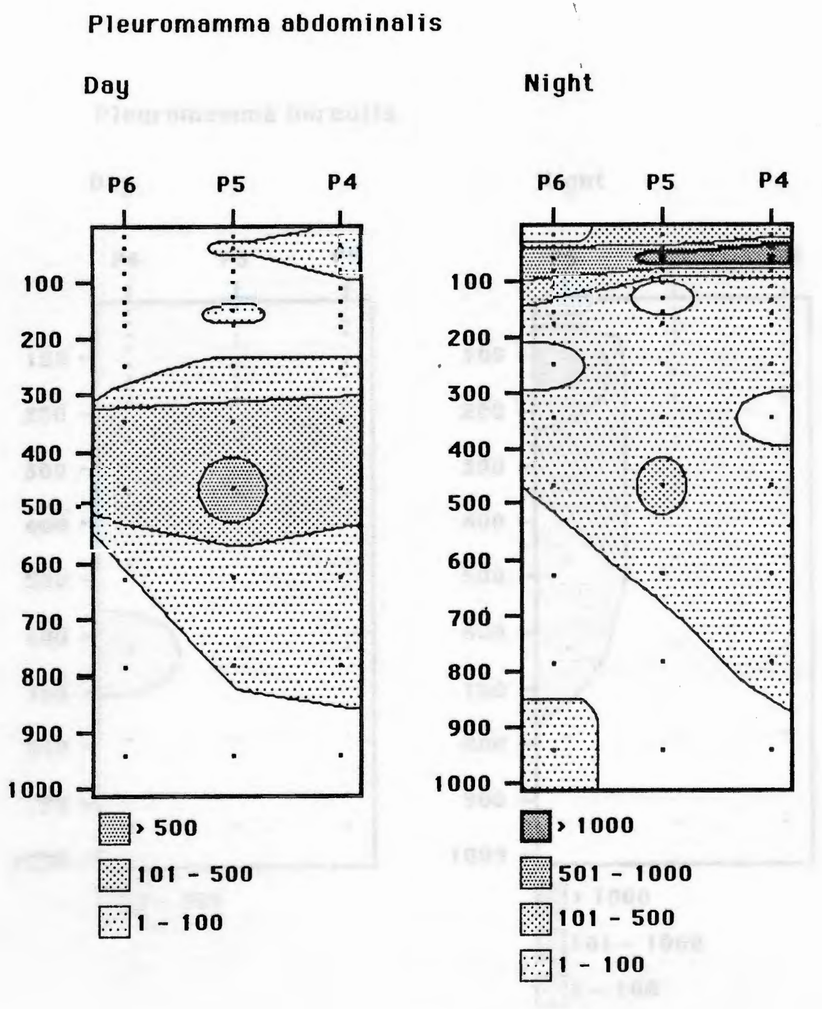
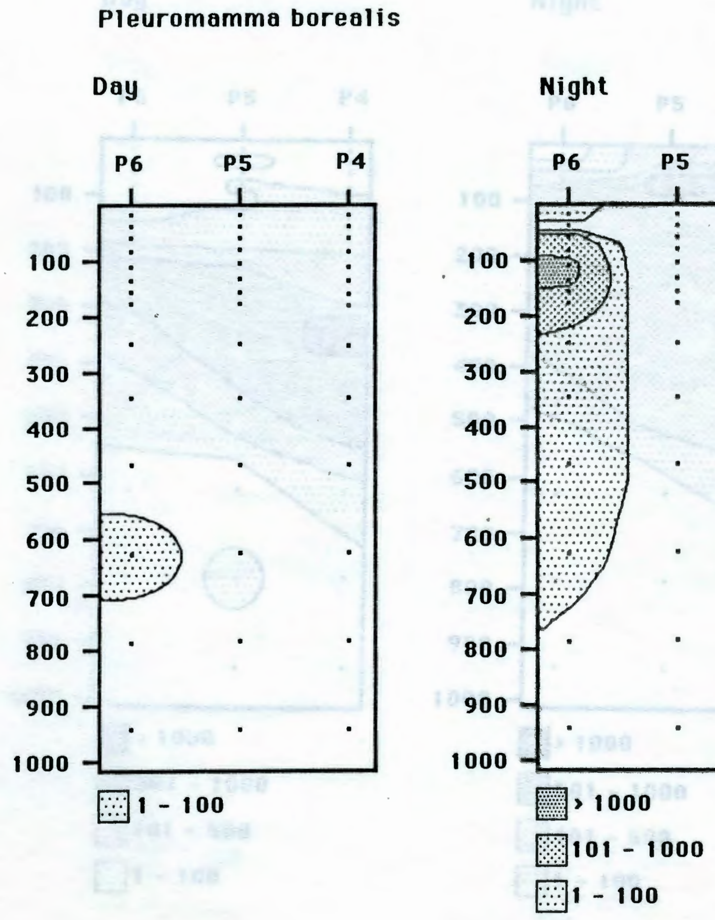

Pleuromamma abdominalis
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 500
101 - 500
1 - 100
> 1000
501 - 1000
101 - 500
1 - 100

Fig. 16

Fig. 17



Pleuromamma borealis

Fig. 18

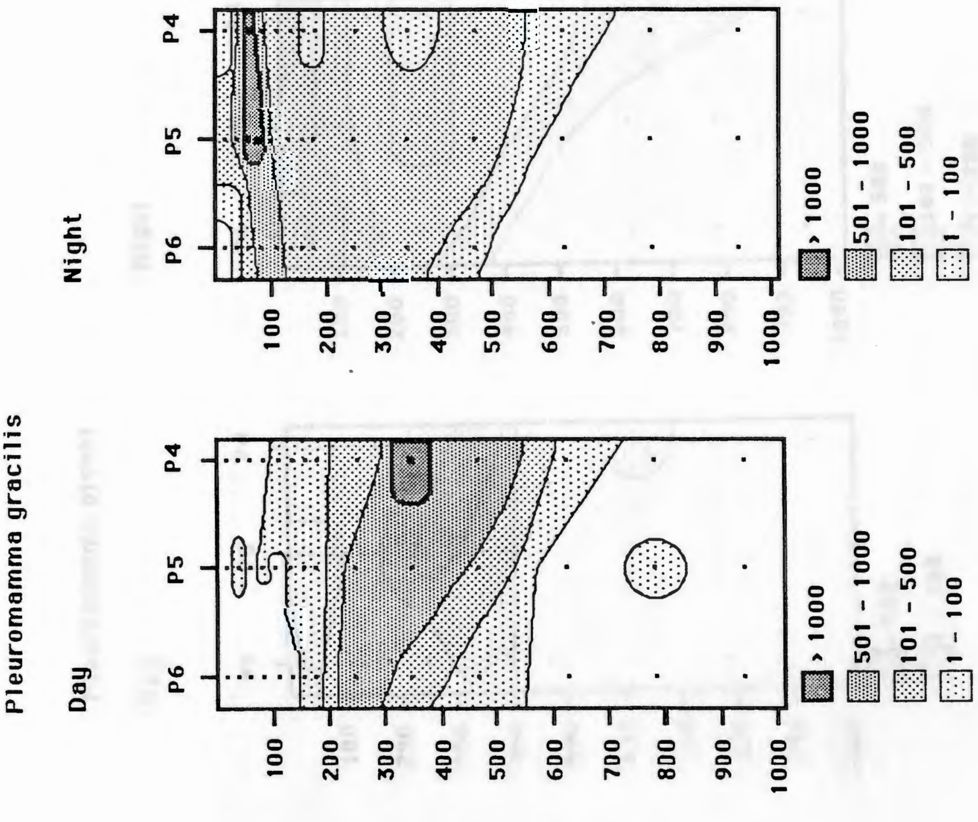

Pleuromamma gracilis
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
› 1000
501 - 1000
101 - 500
1 - 100

Fig. 19

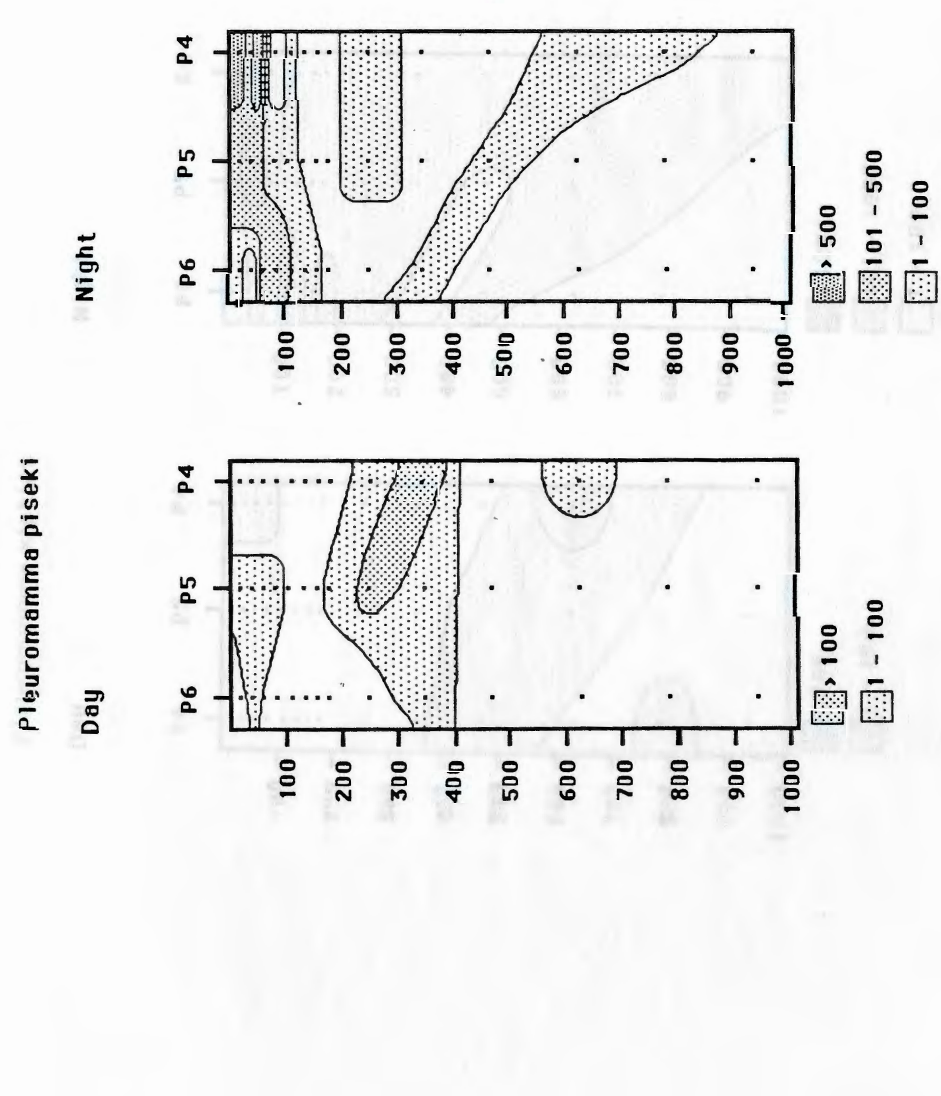

Pleuromamma piseki
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 500
101 - 500
1 - 100
> 100
1 - 100

Fig. 20

Pleuromamma xiphias

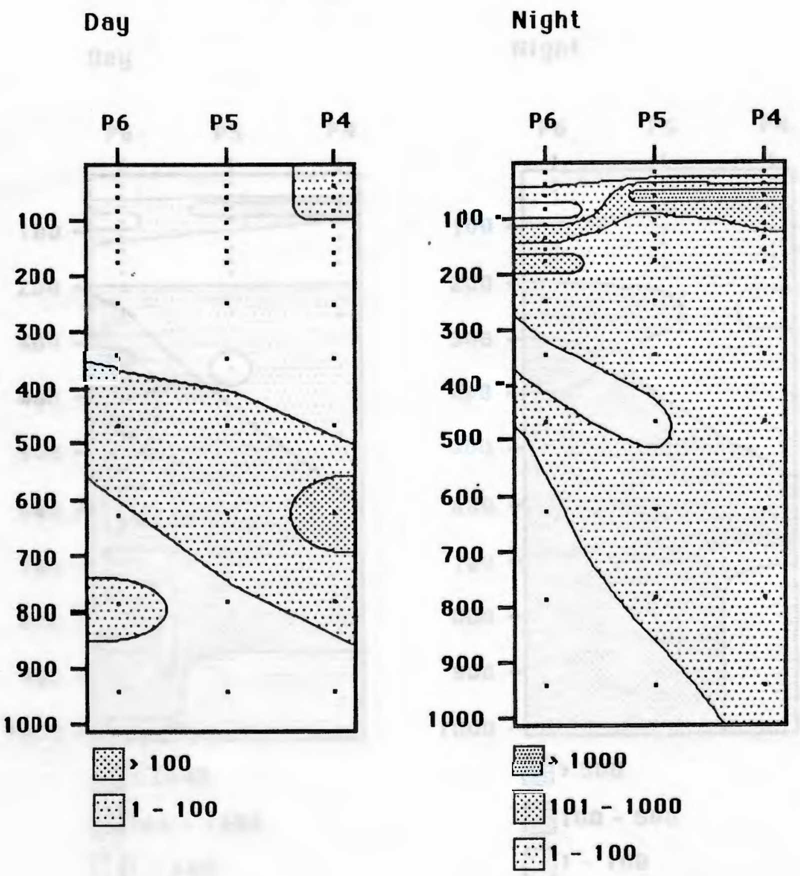


Fig. 21

Rhincalanus cornutus

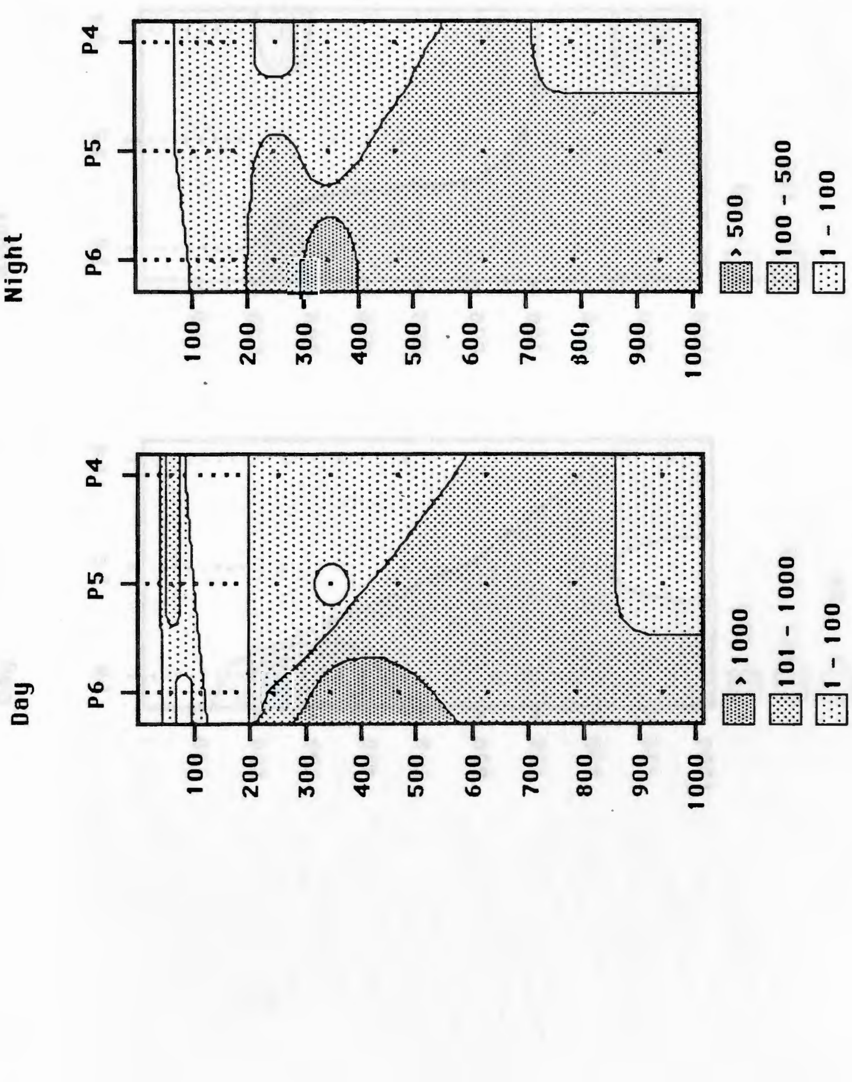
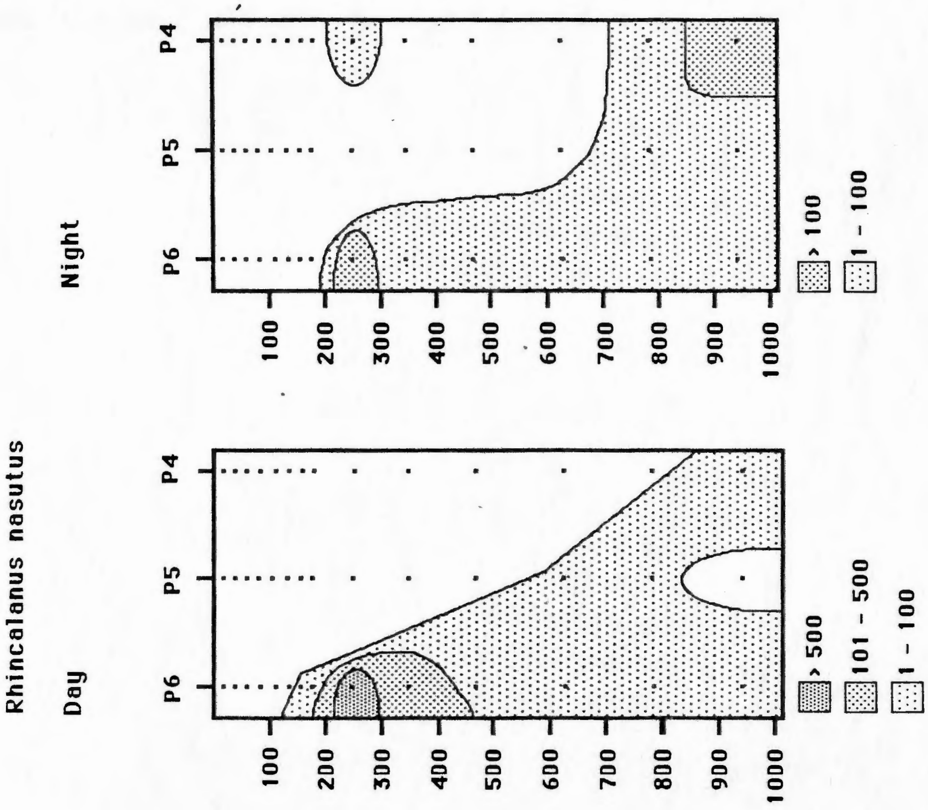


Fig. 22


Rhincalanus nasutus
Day
Night
P6
P5
P4
100
200
300
400
500
600
700
800
900
1000
> 500
101 - 500
1 - 100
> 100
1 - 100

Appendix B

Biomass data and sampling information

Tables 1 through 8 list date, time of day, location, and zooplankton biomass measured at each station occupied during this study of the zooplankton of the Gulf Stream region.

Table 1.

Tow Number	GMT Time	GMT Date	Local Time	Local Date	Start Position Latitude N	Longitude W	Site
E77-1	1903	11-9-81	1403	11-9-81	36°59.52	73°17.62	NoFGS
E77-2	0313	11-11-81	2213	11-10-81	35°12.13	72°27.64	P0
E77-3	0727	11-11-81	0227	11-11-81	35°23.29	72°39.09	P1
E77-4	1333	11-11-81	0833	11-11-81	35°33.76	72°51.42	P2
E77-5	1756	11-11-81	1256	11-11-81	35°44.49	73°00.97	P3
E77-6	2310	11-11-81	1810	11-11-81	35°55.50	73°11.30	P4

Table 1 cont'd.

Tow Number	Length of Tow(min.)	Depth of Tow (m)	True Water Volume Filtered(m^3)	Biomass (ml/1000m^3)	"Position" Across Stream
E77-1	17	174	174.22	103.32	Slope Water
E77-2	16	192	152.40	91.86	Sargasso Sea
E77-3	18	201	159.53	43.88	Sargasso Sea
E77-4	14	178	162.91	30.69	Stream
E77-5	15	169	160.63	49.80	Warm Core
E77-6	20	162	218.06	27.51	Warm Core

Table 2.

Tow Number	GMT Time	GMT Date	Local Time	Local Date	Start Latitude N	Position Longitude W	Site
E79-1	1924	1-28-82	1424	1-28-82	36°36.29	73°51.17	P8
E79-2	2057	1-28-82	1557	1-28-82	36°36.05	73°50.90	P8
E79-3	0230	1-29-82	2130	1-28-82	36°25.65	73°41.73	P7
E79-4	0257	1-29-82	2157	1-28-82	36°25.43	73°41.13	P7
E79-5	0635	1-29-82	0135	1-29-82	36°14.70	73°32.47	P6
E79-6	0717	1-29-82	0217	1-29-82	36°14.89	73°33.04	P6
E79-7	1149	1-29-82	0649	1-29-82	36°06.03	73°21.83	P5
E79-8	1219	1-29-82	0719	1-29-82	36°05.98	73°22.07	P5
E79-9	1648	1-29-82	1148	1-29-82	35°55.10	73°10.90	P4
E79-10	1718	1-29-82	1218	1-29-82	35°55.30	73°10.80	P4
E79-11	2239	1-29-82	1739	1-29-82	35°45.09	73°01.53	P3
E79-12	2310	1-29-82	1810	1-29-82	35°45.09	73°01.53	P3
E79-13	0252	1-30-82	2152	1-29-82	35°33.62	72°51.86	P2
E79-14	0319	1-30-82	2219	1-29-82	35°33.62	72°51.86	P2
E79-15	0941	1-30-82	0441	1-30-82	35°24.54	72°38.87	P1
E79-16	1017	1-30-82	0517	1-30-82	35°24.54	72°38.87	P1
E79-17	1433	1-30-82	0933	1-30-82	35°12.16	72°28.34	P0
E79-18	1500	1-30-82	1000	1-30-82	35°12.16	72°28.43	P0
E79-19	2317	1-30-82	1817	1-30-82	35°12.99	72°27.66	P0
E79-20	2346	1-30-82	1846	1-30-82	35°12.99	72°27.66	P0
E79-21	1656	2-1-82	1156	2-1-82	35°56.81	73°10.00	P4
E79-22	1723	2-1-82	1223	2-1-82	35°56.81	73°10.00	P4
E79-23	0005	2-2-82	1905	2-1-82	35°48.84	73°00.59	P3
E79-24	0031	2-2-82	1931	2-1-82	35°48.84	73°00.59	P3
E79-25	0359	2-2-82	2259	2-1-82	35°47.82	73°01.69	P3
E79-26	0607	2-2-82	0107	2-2-82	35°57.45	73°09.80	P4
E79-27	0636	2-2-82	0136	2-2-82	35°57.45	73°09.80	P4
E79-28	1147	2-2-82	0647	2-2-82	35°48.68	73°00.02	P3
E79-29	1213	2-2-82	0713	2-2-82	35°48.68	73°00.02	P3
E79-30	2142	2-2-82	1642	2-2-82	35°47.38	73°01.28	P3

Table 2 cont'd.

Tow Number	Length of Tow(min.)	Depth of Tow(m)	True Water Volume Filtered(m^3)	Biomass ($ml/1000m^3$)	"Position" Across Stream
E79-1	6	178	186.87	26.76	Slope Water
E79-2	16	150	226.11	13.27	Slope Water
E79-3	15	174	202.14	84.10	North Wall
E79-4	18	205	183.36	98.17	North Wall
E79-5	17	192	134.32	126.56	Stream
E79-6	15	184	189.33	163.73	Stream
E79-7	16	158	164.40	85.16	Warm Core
E79-8	19	174	182.14	98.83	Warm Core
E79-9	20	187	153.39	32.60	Warm Core
E79-10	15	205	140.32	57.01	Warm Core
E79-11	19	174	182.70	65.68	Warm Core
E79-12	21	178	206.64	53.23	Warm Core
E79-13	16	158	162.87	61.40	Stream
E79-14	16	174	155.92	64.13	Stream
E79-15	21	162	209.05	57.40	Sargasso Sea
E79-16	20	153	198.90	65.36	Sargasso Sea
E79-17	17	197	44.86	22.29	Sargasso Sea
E79-18	16	210	106.64	9.38	Sargasso Sea
E79-19	15	167	187.80	58.57	
E79-20	15	158	178.01	44.94	
E79-21	16	211	176.81	299.76	
E79-22	26	158	188.57	270.54	
E79-23	15	162	208.74	215.58	
E79-24	27	147	252.61	201.89	
E79-25	15	158	176.04	136.33	
E79-26	17	131	115.64	363.20	
E79-27	18	167	149.86	326.97	
E79-28	18	158	216.86	92.22	
E79-29	16	142	204.89	122.02	
E79-30	15	162	182.95	65.59	

Table 3.

Tow Number	GMT Time	Date	Local Time	Local Date	Start Position Latitude N	Start Position Longitude W	Site
E81-1	0236	3-14-82	2136	3-13-82	36°36.46	73°51.95	P8
E81-2	0258	3-14-82	2158	3-13-82	36°36.14	73°51.14	P8
E81-3	0738	3-14-82	0238	3-14-82	36°25.68	73°41.68	P7
E81-4	0800	3-14-82	0300	3-14-82	36°25.17	73°41.52	P7
E81-5	1121	3-14-82	0621	3-14-82	36°14.96	73°32.01	P6S
E81-6	1145	3-14-82	0645	3-14-82	36°14.12	73°32.31	P6S
E81-7	1623	3-14-82	1123	3-14-82	36°05.67	73°21.52	P5
E81-8	1645	3-14-82	1145	3-14-82	36°05.77	73°20.87	P5
E81-9	0025	3-15-82	1925	3-14-82	35°55.55	73°07.10	P4
E81-10	0047	3-15-82	1947	3-14-82	35°55.88	73°06.38	P4
E81-11	0245	3-15-82	2145	3-14-82	35°44.14	73°01.46	P3
E81-12	0308	3-15-82	2208	3-14-82	35°44.38	73°01.13	P3
E81-13	0803	3-15-82	0303	3-15-82	35°33.69	72°52.06	P2
E81-14	0828	3-15-82	0328	3-15-82	35°33.96	72°52.10	P2
E81-15	1232	3-15-82	0732	3-15-82	35°23.19	72°39.31	P1
E81-16	1253	3-15-82	0753	3-15-82	35°23.21	72°38.83	P1
E81-17	2043	3-15-82	1543	3-15-82	35°12.15	72°27.92	P0
E81-18	2103	3-15-82	1603	3-15-82	35°12.40	72°27.24	P0
E81-19	0159	3-16-82	2059	3-15-82	35°02.47	72°19.51	P(-1)
E81-20	0220	3-16-82	2120	3-15-82	35°02.87	72°19.04	P(-1)
E81-21	2029	3-16-82	1529	3-16-82	35°55.48	73°09.79	P4
E81-22	2110	3-16-82	1610	3-16-82	35°56.58	73°06.50	P4
E81-23	0720	3-17-82	0220	3-17-82	35°54.39	73°11.61	P4
E81-24	0751	3-17-82	0241	3-17-82	35°54.09	73°10.61	P4
E81-25	1529	3-17-82	1029	3-17-82	35°55.29	73°10.32	P4
E81-26	1550	3-17-82	1050	3-17-82	35°55.05	73°09.18	P4
E81-27	0641	3-18-82	0141	3-18-82	35°13.26	72°29.03	P0
E81-28	0711	3-18-82	0211	3-18-82	35°13.36	72°29.29	P0
E81-29	1025	3-18-82	0525	3-18-82	35°22.75	72°39.93	P1
E81-30	1055	3-18-82	0555	3-18-82	35°23.10	72°40.27	P1
E81-31	1332	3-18-82	0832	3-18-82	35°33.97	72°52.17	P2
E81-32	1606	3-18-82	1106	3-18-82	35°33.85	72°52.48	P2
E81-33	1923	3-18-82	1423	3-18-82	35°44.21	73°01.83	P3
E81-34	2043	3-18-82	1543	3-18-82	35°44.96	73°00.35	P3
E81-35	0149	3-19-82	2049	3-18-82	36°05.09	73°21.60	P5
E81-36	0212	3-19-82	2112	3-18-82	36°05.50	73°20.49	P5
E81-37	0523	3-19-82	0023	3-19-82	36°14.84	73°32.38	P6
E81-38	0551	3-19-82	0051	3-19-82	36°16.11	73°30.76	P6
E81-39	0826	3-19-82	0326	3-19-82	36°25.00	73°42.73	P7S
E81-40	0903	3-19-82	0403	3-19-82	36°24.45	73°43.15	P7S
E81-41	1138	3-19-82	0638	3-19-82	36°35.44	73°52.79	P8
E81-42	1205	3-19-82	0705	3-19-82	36°35.00	73°52.99	P8

Table 3 cont'd.

Tow Number	Length of Tow(min.)	Depth of Tow(m)	True Water Volume Filtered(m^3)	Biomass ($ml/1000m^3$)	"Position" Across Stream
E81-1	16	169	142.65	455.66	Slope Water
E81-2	16	174	110.71	496.79	Slope Water
E81-3	14	192	133.07	488.46	Slope Water
E81-4	17	174	97.60	522.54	Slope Water
E81-5	18	155	145.73	404.86	Slope Water
E81-6	16	169	92.71	528.53	Slope Water
E81-7	16	200	117.21	281.55	North Wall
E81-8	6	202	85.95	453.75	North Wall
E81-9	16	174	199.24	95.36	Warm Core
E81-10	16	158	188.03	85.09	Warm Core
E81-11	17	178	126.62	150.05	Warm Core
E81-12	17	182	132.07	143.86	Warm Core
E81-13	19	204	140.60	156.47	Warm Core
E81-14	17	160	154.23	213.97	Warm Core
E81-15	18	176	138.33	101.21	Stream
E81-16	16	184	104.41	105.35	Stream
E81-17	16	174	151.78	98.83	Sargasso Sea
E81-18	14	174	131.69	98.72	Sargasso Sea
E81-19	16	174	136.76	153.55	Sargasso Sea
E81-20	17	169	118.49	126.59	Sargasso Sea
E81-21	17	212	215.07	65.09	
E81-22	16	192	202.16	69.25	
E81-23	16	162	228.00	78.95	
E81-24	17	199	232.06	73.26	
E81-25	16	162	237.53	63.15	
E81-26	16	162	237.004	59.07	
E81-27	17	167	210.73	104.40	Sargasso Sea
E81-28	14	205	163.72	103.84	Sargasso Sea
E81-29	15	174	191.76	234.67	Stream
E81-30	15	169	172.31	168.30	Stream
E81-31	17	178	250.02	79.99	Warm Core
E81-32	16	160	253.75	90.64	Warm Core
E81-33	14	157	254.13	59.02	Warm Core
E81-34	19	150	243.95	77.88	Warm Core
E81-35	16	150	166.27	90.21	Warm Core
E81-36	17	195	147.30	95.04	Warm Core
E81-37	18	180	190.89	502.91	North Wall
E81-38	18	112	132.09	840.34	North Wall
E81-39	27	162	134.29	439.35	Slope Water
E81-40	16	162	96.87	464.54	Slope Water
E81-41	15	174	119.05	319.19	Slope Water
E81-42	18	192	122.23	294.53	Slope Water

Table 4.

Tow Number	GMT Time	Date	Local Time	Local Date	Start Latitude N	Position Longitude W	Site
H12-1	2037	5-11-82	1637	5-11-82	36°35.42	73°51.60	P8
H12-2	2056	5-11-82	1656	5-11-82	36°35.29	73°51.94	P8
H12-3	0415	5-12-82	0015	5-12-82	36°35.81	73°51.16	P8
H12-4	0432	5-12-82	0032	5-12-82	36°36.00	73°51.32	P8
H12-5	1136	5-12-82	0736	5-12-82	36°25.14	73°40.91	P7S
H12-6	1207	5-12-82	0807	5-12-82	36°25.32	73°41.31	P7S
H12-7	1704	5-12-82	1304	5-12-82	36°14.49	73°29.96	P6S
H12-8	1720	5-12-82	1320	5-12-82	36°14.56	73°28.59	P6S
H12-9	2052	5-12-82	1652	5-12-82	36°06.07	73°20.84	P5
H12-10	2115	5-12-82	1715	5-12-82	36°06.76	73°19.19	P5
H12-11	0341	5-13-82	2341	5-12-82	35°54.78	73°10.23	P4
H12-12	0400	5-13-82	0000	5-13-82	35°55.29	73°09.11	P4
H12-13	0747	5-13-82	0347	5-13-82	35°49.59	73°01.56	midway between P4 & P3
H12-14	0807	5-13-82	0406	5-13-82	35°49.33	73°00.32	midway between P4 & P3
H12-15	1500	5-13-82	1100	5-13-82	35°32.42	72°50.36	P2
H12-16	1516	5-13-82	1116	5-13-82	35°32.66	72°49.90	P2
H12-17	1947	5-13-82	1547	5-13-82	35°22.07	72°37.39	P1
H12-18	2003	5-13-82	1603	5-13-82	35°22.09	72°37.34	P1
H12-19	0246	5-14-82	2246	5-13-82	35°22.35	72°38.53	P1
H12-20	0304	5-14-82	2304	5-13-82	35°22.66	72°38.50	P1
H12-21	0810	5-14-82	0410	5-14-82	35°11.37	72°27.57	P0
H12-22	0832	5-14-82	0432	5-14-82	35°10.73	72°27.67	P0
H12-23	1526	5-16-82	1126	5-16-82	36°15.76	73°31.14	P6S
H12-24	1543	5-16-82	1143	5-16-82	36°15.82	73°31.43	P6S
H12-25	1852	5-16-82	1452	5-16-82	36°07.19	73°20.59	P5
H12-26	1913	5-16-82	1513	5-16-82	36°08.17	73°18.44	P5
H12-27	2222	5-16-82	1822	5-16-82	35°54.86	73°10.02	P4
H12-28	2247	5-16-82	1847	5-16-82	35°55.56	73°09.17	P4
H12-29	0121	5-17-82	2121	5-16-82	35°44.85	73°00.11	P3
H12-30	0143	5-17-82	2143	5-16-82	35°45.08	73°00.01	P3
H12-31	0424	5-17-82	0024	5-17-82	35°34.09	72°50.35	P2
H12-32	0446	5-17-82	0046	5-17-82	35°33.82	72°49.86	P2
H12-33	0843	5-17-82	0443	5-17-82	35°23.24	72°38.08	P1
H12-34	0906	5-17-82	0505	5-17-82	35°23.45	72°38.64	P1

Table 4 cont'd.

Tow Number	Length of Tow(min.)	Depth of Tow(m)	True Water Volume Filtered(m^3)	Biomass ($ml/1000m^3$)	"Position" Across Stream
H12-1	13	174	171.40	320.89	
H12-2	12	145	165.85	325.59	
H12-3	10	128	158.71	838.01	
H12-4	11	162	187.56	517.17	
H12-5	24	162	129.53	548.14	
H12-6	17	150	127.90	719.31	
H12-7	10	128	172.21	1370.42	
H12-8	11	122	160.56	1052.57	
H12-9	12	150	167.73	83.47	
H12-10	17	130	207.64	81.87	
H12-11	14	162	166.68	47.99	
H12-12	12	178	149.42	20.08	
H12-13	14	136	148.24	53.97	
H12-14	17	187	205.37	77.91	
H12-15	12	147	140.12	114.19	
H12-16	12	155	122.92	97.62	
H12-17	12	122	136.70	65.84	
H12-18	15	150	145.88	95.97	
H12-19	14	167	159.94	100.04	
H12-20	15	155	169.84	138.16	
H12-21	17	202	130.28	69.08	
H12-22	17	167	193.16	88.01	
H12-23	13	142	165.63	108.67	
H12-24	15	136	166.15	108.34	
H12-25	14	106	228.17	127.10	
H12-26	17	122	227.39	123.14	
H12-27	13	142	175.26	34.23	
H12-28	16	136	221.23	36.16	
H12-29	12	150	146.43	109.27	
H12-30	15	158	149.95	73.36	
H12-31	10	136	132.41	83.07	
H12-32	14	145	138.15	72.38	
H12-33	16	106	192.24	83.23	
H12-34	16	136	90.71	165.36	

Table 5.

Tow Number	GMT Time	GMT Date	Local Time	Local Date	Start Latitude N	Position Longitude W	Site
H16-1	1400	7-10-82	1000	7-10-82	36 36.71	73 51.55	P-8
H16-2	1426	7-10-82	1026	7-10-82	36 36.77	73 52.40	P-8
H16-3	1641	7-10-82	1641	7-10-82	36 26.52	73 41.55	P-7S
H16-4	2149	7-10-82	1749	7-10-82	36 26.60	73 42.29	P-7S
H16-5	119	7-11-82	2119	7-10-82	36 14.89	73 30.92	P-6
H16-6	139	7-11-82	2139	7-10-82	36 14.76	73 30.70	P-6
H16-7	559	7-11-82	159	7-11-82	36 06.49	73 20.31	P-5
H16-8	632	7-11-82	232	7-11-82	36 06.18	73 20.51	P-5
H16-9	1331	7-11-82	931	7-11-82	35 55.34	73 09.14	P-4
H16-10	1431	7-11-82	1031	7-11-82	35 56.19	73 06.41	P-4
H16-11	1711	7-11-82	1311	7-11-82	35 45.64	72 59.23	P-3
H16-12	1730	7-11-82	1330	7-11-82	35 45.42	72 58.56	P-3
H16-13	1945	7-11-82	1545	7-11-82	35 45.89	72 55.72	P-3
H16-14	2001	7-11-82	1601	7-11-82	35 46.32	72 55.25	P-3
H16-15	254	7-12-82	2254	7-11-82	35 45.00	72 57.94	P-3
H16-16	314	7-12-82	2314	7-11-82	35 44.91	72 56.62	P-3
H16-17	744	7-12-82	344	7-12-82	35 33.83	72 50.71	P-2
H16-18	805	7-12-82	405	7-12-82	35 33.81	72 49.76	P-2
H16-19	1836	7-12-82	1436	7-12-82	35 23.74	72 37.64	P-1
H16-20	1853	7-12-82	1453	7-12-82	35 23.51	72 37.55	P-1
H16-21	2308	7-12-82	1908	7-12-82	35 12.74	72 27.79	P-0
H16-22	2326	7-12-82	1926	7-12-82	35 12.87	72 27.20	P-0
H16-23	231	7-13-82	2231	7-12-82	35 12.87	72 27.35	P-0
H16-24	250	7-13-82	2250	7-12-82	35 12.60	72 26.99	P-0
H16-25	230	7-14-82	2230	7-13-82	35 12.71	72 27.54	P-0
H16-26	250	7-14-82	2250	7-13-84	35 12.91	72 26.86	P-0
H16-27	723	7-14-82	323	7-14-82	35 23.12	72 37.92	P-1
H16-28	741	7-14-82	341	7-14-82	35 22.87	72 37.12	P-1
H16-29	1252	7-14-82	852	7-14-82	35 33.65	72 50.94	P-2
H16-30	1310	7-14-82	910	7-14-82	35 33.81	72 51.05	P-2
H16-31	1814	7-14-82	1414	7-14-82	35 44.68	73 00.83	P-3
H16-32	1840	7-14-82	1440	7-14-82	35 44.60	73 00.37	P-3
H16-33	233	7-15-82	2233	7-14-82	35 55.92	73 08.26	P-4
H16-34	252	7-15-82	2252	7-14-82	35 56.41	73 06.32	P-4
H16-35	837	7-15-82	437	7-15-82	36 06.72	73 20.23	P-5
H16-36	857	7-15-82	457	7-15-82	36 06.70	73 19.20	P-5
H16-37	1723	7-15-82	1323	7-15-82	36 15.27	73 28.71	P-6
H16-38	1743	7-15-83	1343	7-15-82	36 15.15	73 27.79	P-6
H16-39	2216	7-15-82	1816	7-15-82	36 25.90	73 41.02	P-7
H16-40	2236	7-15-82	1836	7-15-82	36 25.76	73 40.78	P-7
H16-41	259	7-16-82	2259	7-15-82	36 36.31	73 51.47	P-8
H16-42	318	7-16-82	2318	7-15-82	36 36.20	73 51.39	P-8

Table 5 cont'd.

Tow Number	Length of Tow (min)	Depth of Tow (m)	True Water Volume Filtered(m3)	Biomass (ml/1000m3)	Position Across Stream
H16-1	15	136	181.8	60.5	Slope Water
H16-2	14	155	129.2	69.7	Slope Water
H16-3	14	162	167.6	71.6	Slope Water
H16-4	13	147	150.9	66.2	Slope Water
H16-5	14	162	114.4	87.4	Slope Water
H16-6	14	147	57.7	208.1	Slope Water
H16-7	14	139	141.4	148.5	North Wall
H16-8	15	183	117.8	169.8	North Wall
H16-9	15	162	149.1	46.9	Gulf Stream
H16-10	13	155	140.9	70.9	Gulf Stream
H16-11	15	167	151.0	59.6	Gulf Stream
H16-12	15	162	157.7	57.7	Gulf Stream
H16-13	12	189	159.7	56.4	Gulf Stream
H16-14	16	187	160.7	62.2	Gulf Stream
H16-15	15	157	168.1	71.3	Gulf Stream
H16-16	11	160	157.9	63.3	Gulf Stream
H16-17	15	187	174.2	103.4	Gulf Stream
H16-18	14	167	138.7	100.9	Gulf Stream
H16-19	14	150	165.1	42.4	Sargasso Sea
H16-20	16	189	150.8	26.5	Sargasso Sea
H16-21	13	162	166.0	48.2	Sargasso Sea
H16-22	14	165	153.2	65.3	Sargasso Sea
H16-23	15	194	143.0	69.9	Sargasso Sea
H16-24	15	176	62.8	350.2	Sargasso Sea
H16-25	16	165	174.3	86.1	Sargasso Sea
H16-26	15	167	173.5	46.1	Sargasso Sea
H16-27	14	125	65.5	91.6	Sargasso Sea
H16-28	15	150	168.8	53.3	Sargasso Sea
H16-29	14	169	80.3	74.7	Gulf Stream
H16-30	15	184	151.9	39.5	Gulf Stream
H16-31	13	157	170.2	35.2	Gulf Stream
H16-32	14	169	149.9	33.4	Gulf Stream
H16-33	15	174	108.4	156.8	Gulf Stream
H16-34	14	157	113.5	105.7	Gulf Stream
H16-35	15	157	131.2	91.4	North Wall
H16-36	15	172	98.5	111.6	North Wall
H16-37	14	142	160.6	56.0	Slope Water
H16-38	14	147	179.6	44.5	Slope Water
H16-39	14	187	82.3	60.8	Slope Water
H16-40	14	176	134.6	51.0	Slope Water
H16-41	?	147	36.4	301.8	Slope Water
H16-42	15	167	86.7	92.2	Slope Water

Table 6.

Tow umber	Net Number	GMT Date	GMT Time	Local Date	Local Time	Start Position Latitude N	Longitude W	Site
E89M-1	1	9/7/82	1446	9/7/82	1046	37°03.71	73°37.28	Slope Water
	2	"	1457	"	1057	37°03.95	73°37.25	" "
	3	"	1506	"	1106	37°04.29	73°37.44	" "
	4	"	1509	"	1109	37°04.34	73°37.50	" "
	5	"	1511	"	1111	37°04.40	73°37.56	" "
	6	"	1514	"	1114	37°04.46	73°37.64	" "
	7	"	1517	"	1117	37°04.54	73°37.73	" "
	8	"	1520	"	1120	37°04.61	73°37.81	" "
	9	"	1523	"	1123	37°04.70	73°37.92	" "
E89M-2	1	9/7/82	1831	9/7/82	1431	36°37.27	73°52.87	P8
	2	"	1857	"	1457	36°37.96	73°52.09	"
	3	"	1900	"	1500	36°38.07	73°52.00	"
	4	"	1904	"	1504	36°38.17	73°51.92	"
	5	"	1907	"	1507	36°38.26	73°51.82	"
	6	"	1911	"	1511	36°38.40	73°51.62	"
	7	"	1922	"	1522	36°38.70	73°51.43	"
	8	"	1926	"	1526	36°38.83	73°51.32	"
	9	"	1933	"	1533	36°39.03	73°51.15	"
E89M-3	1	9/8/82	0330	9/7/82	2330	36°27.21	73°37.06	P7
	2	"	0442	9/8/82	0042	36°28.94	73°31.22	"
	3	"	0448	"	0048	36°29.14	73°30.50	"
	4	"	0458	"	0058	36°29.37	73°29.66	"
	5	"	0504	"	0104	36°29.52	73°29.11	"
	6	"	0514	"	0114	36°29.76	73°28.20	"
	7	"	0522	"	0122	36°29.98	73°27.42	"
	8	"	0528	"	0128	36°30.18	73°26.81	"
	9	"	0540	"	0140	36°30.52	73°25.67	"
E89M-4	1	9/8/82	1335	9/8/82	0935	36°15.76	73°29.96	P6
	2	"	1406	"	1006	36°15.77	73°29.49	"
	3	"	1409	"	1009	36°15.78	73°29.46	"
	4	"	1411	"	1011	36°15.79	73°29.46	"
	5	"	1413	"	1013	36°15.79	73°29.46	"
	6	"	1416	"	1016	36°15.80	73°29.47	"
	7	"	1425	"	1025	36°15.86	73°29.39	"
	8	"	1431	"	1031	36°15.96	73°29.24	"
	9	"	1433	"	1033	36°16.00	73°29.19	"
E89M-5	1	9/8/82	1806	9/8/82	1406	36°06.11	73°20.98	P5
	2	"	1839	"	1439	36°06.55	73°21.98	"
	3	"	1847	"	1447	36°06.63	73°21.93	"
	4	"	1850	"	1450	36°06.65	73°21.91	"
	5	"	1855	"	1455	36°06.68	73°21.78	"
	6	"	1859	"	1459	36°06.69	73°21.75	"
	7	"	1903	"	1503	36°06.71	73°21.71	"
	8	"	1907	"	1507	36°06.73	73°21.69	"
	9	"	1910	"	1510	36°06.75	73°21.66	"
E89M-6	1	9/9/82	0413	9/9/82	0013	35°56.78	73°09.85	P4
	2	"	0439	"	0039	35°56.98	73°10.34	"
	3	"	0443	"	0043	35°56.95	73°10.40	"
	4	"	0446	"	0046	35°56.93	73°10.45	"
	5	"	0449	"	0049	35°56.91	73°10.53	"
	6	"	0453	"	0053	35°56.91	73°10.53	"
	7	"	0459	"	0059	35°56.82	73°10.72	"
	8	"	0509	"	0109	35°56.81	73°10.84	"
	9	"	0518	"	0118	35°56.79	73°10.89	"

Table 6 cont'd.

Tow Number	Net Number	GMT Date	GMT Time	Local Date	Local Time	Start Position Latitude N	Start Position Longitude W	Site
E89M-7	1							P3
	2							"
	3							"
	4							"
	5							"
	6							"
	7							"
	8							"
	9							"
E89M-8	1	9/ 9/82	1700	9/ 9/82	1300	35°33.54	72°52.13	P2
	2	"	1728	"	1328	35°33.86	72°51.60	"
	3	"	1732	"	1332	35°33.89	72°51.47	"
	4	"	1737	"	1337	35°33.96	72°51.36	"
	5	"	1743	"	1343	35°34.04	72°51.23	"
	6	"	1749	"	1349	35°34.10	72°51.09	"
	7	"	1754	"	1354	35°34.18	72°50.95	"
	8	"	1759	"	1359	35°34.24	72°50.78	"
	9	"	1804	"	1404	35°34.26	72°50.64	"
E89M-9	1	9/ 9/82	2106	9/ 9/82	1706	35°23.06	72°38.38	P1
	2	"	2149	"	1749	35°22.42	72°37.55	"
	3	"	2153	"	1753	35°22.44	72°37.45	"
	4	"	2157	"	1757	35°22.46	72°37.32	"
	5	"	2202	"	1802	35°22.49	72°37.14	"
	6	"	2211	"	1811	35°22.50	72°36.88	"
	7	"	2216	"	1816	35°22.52	72°36.76	"
	8	"	2121	"	1821	35°22.54	72°36.57	"
E89M-11	1	9/11/82	1439	9/11/82	1039	35°37.11	74°11.13	Stream
	2	"	1535	"	1135	35°37.33	74°11.72	"
	3	"	1545	"	1145	35°37.25	74°11.86	"
	4	"	1555	"	1155	35°37.30	74°12.09	"
	5	"	1605	"	1205	35°37.35	74°12.26	"
	6	"	1614	"	1214	35°37.33	74°12.38	"
	7	"	1623	"	1223	35°37.33	74°12.55	"
	8	"	1627	"	1227	35°37.34	74°12.63	"
	9	"	1636	"	1236	35°37.33	74°12.77	"
E89M-12	1	9/12/82	0144	9/11/82	2144	35°36.41	74°09.20	Stream
	2	"	0233	"	2233	35°36.53	74°09.45	"
	3	"	0245	"	2245	35°36.45	74°09.53	"
	4	"	0255	"	2255	35°36.36	74°09.66	"
	5	"	0302	"	2302	35°36.26	74°09.68	"
	6	"	0313	"	2313	35°36.14	74°09.77	"
	7	"	0323	"	2323	35°36.06	74°09.88	"
	8	"	0328	"	2328	35°36.00	74°09.91	"
	9	"	0336	"	2336	35°35.95	74°10.03	"
E89M-13	1	9/12/82	1340	9/12/82	0940	36°16.84	73°32.87	P6 S-N
	2	"	1447	"	1047	36°16.11	73°33.26	"
	3	"	1454	"	1054	36°15.96	73°33.36	"
	4	"	1502	"	1102	36°15.78	73°33.50	"
	5	"	1512	"	1112	36°15.59	73°33.66	"
	6	"	1528	"	1128	36°15.35	73°33.88	"
	7	"	1543	"	1143	36°15-	73°33-	"
	8	"	1549	"	1149	36°15.26	73°33.85	"
	9	"	1557	"	1157	36°15.29	73°33.75	"

Table 6 cont'd.

Tow umber	Net Number	GMT Date	GMT Time	Local Date	Local Time	Start Position		Site
						Latitude N	Longitude W	
E89M-14	1	9/12/82	1715	9/12/82	1315	36°16.84	73°32.78	P6 S-N
	2	"	1735	"	1335	36°16.95	73°32.69	"
	3	"	1741	"	1341	36°16.90	73°32.73	"
	4	"	1748	"	1348	36°16.94	73°32.70	"
	5	"	1758	"	1358	36°17.03	73°32.56	"
	6	"	1804	"	1404	36°17.11	73°32.53	"
	7	"	1809	"	1409	36°17.17	73°32.47	"
	8	"	1815	"	1415	36°17.23	73°32.42	"
	9	"	1821	"	1421	36°17.30	73°32.36	"
E89M-15	1	9/13/82	0137	9/12/82	2137	36°16.97	73°32.87	P6 S-N
	2	"	0152	"	2152	36°17.03	73°32.88	"
	3	"	0156	"	2156	36°17.01	73°32.92	"
	4	"	0202	"	2202	36°17.04	73°32.95	"
	5	"	0209	"	2209	36°17.08	73°32.85	"
	6	"	0213	"	2213	36°17.12	73°32.85	"
	7	"	0217	"	2217	36°17.12	73°32.77	"
	8	"	0222	"	2222	36°17.14	73°32.74	"
	9	"	0227	"	2227	36°17.19	73°32.71	"
E89M-16	1	9/13/82	0322	9/12/82	2322	36°16.64	73°33.12	P6 S-N
	2	"	0427	9/13/82	0027	36°15.82	73°33.20	"
	3	"	0434	"	0034	36°15.70	73°33.28	"
	4	"	0442	"	0042	36°15.56	73°33.39	"
	5	"	0450	"	0050	36°15.42	73°33.53	"
	6	"	0458	"	0058	36°15.23	73°33.62	"
	7	"	0503	"	0103	36°15.13	73°33.66	"
	8	"	0513	"	0113	36°15.02	73°33.75	"
	9	"	0523	"	0123	36°15.01	73°33.67	"
E89M-17	1	9/13/82	1354	9/13/82	0954	35°55.34	73°10.99	P4
	2	"	1453	"	1053	35°54.48	73°11.55	"
	3	"	1503	"	1103	35°54.41	73°11.61	"
	4	"	1513	"	1113	35°54.30	73°11.66	"
	5	"	1522	"	1123	35°54.23	73°11.76	"
	6	"	1532	"	1132	35°54.14	73°11.83	"
	7	"	1539	"	1139	--	--	"
	8	"	1545	"	1145	35°54.01	73°11.96	"
	9	"	1552	"	1152	35°53.94	73°11.98	"
E89M-18	1	9/13/82	1652	9/13/82	1252	35°55.39	73°10.81	P4
	2	"	1708	"	1308	35°55.32	73°10.95	"
	3	"	1713	"	1313	35°55.29	73°10.96	"
	4	"	1716	"	1316	35°55.27	73°11.02	"
	5	"	1723	"	1323	35°55.27	73°11.06	"
	6	"	1727	"	1327	35°55.24	73°11.08	"
	7	"	1731	"	1331	35°55.21	73°11.09	"
	8	"	1736	"	1336	35°55.23	73°11.14	"
	9	"	1738	"	1338	35°55.20	73°11.15	"
E89M-19	1	9/14/82	0155	9/13/82	2155	35°55.42	73°10.98	P4
	2	"	0211	"	2211	35°55.12	73°11.10	"
	3	"	0216	"	2216	35°55.04	73°11.12	"
	4	"	0222	"	2222	35°54.93	73°11.08	"
	5	"	0227	"	2227	35°54.88	73°11.15	"
	6	"	0234	"	2234	35°54.76	73°11.14	"
	7	"	0238	"	2238	35°54.72	73°11.17	"
	8	"	0244	"	2244	35°54.64	73°11.18	"
	9	"	0249	"	2249	35°54.56	73°11.18	"

Table 6 cont'd.

Tow Number	Net Number	GMT Date	GMT Time	Local Date	Local Time	Start Position Latitude N	Start Position Longitude W	Site
E89M-20	1	9/14/82	0345	9/13/82	2345	35°55.12	73°10.98	P4
	2	"	0451	9/14/82	0051	35°54.20	73°11.60	"
	3	"	0501	"	0101	35°54.10	73°11.65	"
	4	"	0513	"	0113	35°53.98	73°11.76	"
	5	"	0523	"	0123	35°53.80	73°11.14	"
	6	"	0532	"	0132	35°53.73	73°11.88	"
	7	"	0537	"	0137	35°53.66	73°11.94	"
	8	"	0546	"	0146	35°53.50	73°11.95	"
	9	"	0551	"	0151	35°53.42	73°11.99	"
E89M-22	1	9/14/82	1411	9/14/82	1011	36°07.02	73°22.75	P5 N
	2	"	1428	"	1028	36°07.06	73°22.46	"
	3	"	1433	"	1033	36°07.07	73°22.33	"
	4	"	1439	"	1039	36°07.08	73°22.24	"
	5	"	1444	"	1044	36°07.08	73°22.19	"
	6	"	1450	"	1050	36°07.08	73°22.10	"
	7	"	1455	"	1055	36°07.10	73°22.07	"
	8	"	1500	"	1100	36°07.09	73°22.03	"
	9	"	1505	"	1105	36°07.05	73°22.93	"
E89M-23	1	9/14/82	1557	9/14/82	1157	36°07.09	73°23.14	P5 N
	2	"	1708	"	1308	36°07.87	73°23.84	"
	3	"	1718	"	1318	36°07.99	73°23.95	"
	4	"	1726	"	1326	36°08.09	73°24.05	"
	5	"	1733	"	1333	36°08.18	73°24.11	"
	6	"	1742	"	1342	36°08.33	73°24.21	"
	7	"	1753	"	1353	36°08.54	73°24.15	"
	8	"	1759	"	1359	36°08.63	73°24.16	"
	9	"	1806	"	1406	36°08.80	73°24.10	"
E89M-25	1	9/15/82	0521	9/15/21	0121	36°08.00	73°22.19	P5 N
	2	"	0540	"	0140	36°08.64	73°21.99	"
	3	"	0545	"	0145	36°08.67	73°21.92	"
	4	"	0551	"	0151	36°08.74	73°21.89	"
	5	"	0557	"	0157	36°08.84	73°21.89	"
	6	"	0603	"	0203	36°08.89	73°21.86	"
	7	"	0608	"	0208	36°08.96	73°21.85	"
	8	"	0614	"	0214	36°09.01	73°21.84	"
	9	"	0620	"	0220	36°09.14	73°21.82	"
E89M-26	1	9/15/82	0715	9/15/82	0315	36°07.91	73°23.01	P5 N
	2	"	0820	"	0420	36°08.06	73°23.52	"
	3	"	0827	"	0427	36°08.06	73°23.64	"
	4	"	0835	"	0435	36°08.03	73°23.78	"
	5	"	0841	"	0441	36°08.00	73°23.89	"
	6	"	0857	"	0457	36°08.05	73°23.94	"
	7	"	0905	"	0505	36°08.07	73°23.93	"
	8	"	0913	"	0513	36°08.16	73°23.90	"
	9	"	0920	"	0520	36°08.24	73°23.82	"

Table 6 cont'd.

Tow Number	Net Number	Length of Tow (min)	Depth Range of Tow (m)	True Water Volume Filtered (m^3)	Biomass (ml/1000 m^3)	"Position" Across Stream
E89M-1	1	11	0- 20	996	24.1	Slope Water
	2	9	20-160	541	16.6	" "
	3	3	140-160	161	6.2	" "
	4	2	120-140	165	6.06	" "
	5	3	100-120	164	6.1	" "
	6	3	80-100	220	9.1	" "
	7	3	60- 80	170	11.76	" "
	8	3	40- 60	242	12.4	" "
	9	3	20- 40	228	100.9	" "
E89M-2	1	16	0-400	1164	12.0	Slope Water
	2	3	350-400	263	11.4	" "
	3	4	300-350	218	27.5	" "
	4	3	250-300	292	3.4	" "
	5	4	200-250	336	3.0	" "
	6	11	150-200	756	5.3	" "
	7	4	100-150	310	3.2	" "
	8	5	50-100	542	7.4	" "
	9	5	0- 50	391	127.9	" "
E89M-3	1	72	0-400	3497	8.9	Slope Water
	2	6	350-400	520	1.9	" "
	3	10	300-350	429	2.3	" "
	4	6	250-300	148	13.5	" "
	5	10	200-250	542	42.4	" "
	6	8	150-200	487	43.1	" "
	7	6	100-150	347	40.3	" "
	8	12	50-100	388	177.8	" "
	9	6	0- 50	761	59.1	" "
E89M-4	1	31	0-410	1399	7.9	North Wall
	2	3	350-410	227	4.4	" "
	3	2	300-350	110	9.1	" "
	4	2	245-300	199	5.0	" "
	5	3	200-245	194	5.15	" "
	6	9	150-200	588	3.4	" "
	7	6	100-150	437	2.3	" "
	8	2	50-100	411	24.3	" "
	9	3	0- 50	11	90.9	" "
E89M-5	1	33	0-410	1576	12.1	Warm Core
	2	8	350-410	543	1.8	" "
	3	3	300-350	222	4.5	" "
	4	5	250-300	349	2.9	" "
	5	4	200-250	279	3.6	" "
	6	4	150-200	330	3.0	" "
	7	4	100-150	263	3.8	" "
	8	3	50-100	243	20.6	" "
	9	5	0- 50	313	35.1	" "
E89M-6	1	26	0-400	1206	21.6	Warm Core
	2	4	350-400	271	3.7	" "
	3	3	300-350	219	4.6	" "
	4	3	250-300	239	4.2	" "
	5	4	200-250	331	6.04	" "
	6	6	150-200	420	9.5	" "
	7	10	100-150	662	15.1	" "
	8	9	50-100	665	22.5	" "
	9	12	0- 50	135	163.0	" "

Table 6 cont'd.

Tow Number	Net Number	Length of Tow (min)	Depth Range of Tow (m)	True Water Volume Filtered (m^3)	Biomass (ml/1000 m^3)	"Position" Across Stream
E89M-7	1					Stream
	2					"
	3					"
	4					"
	5					"
	6					"
	7					"
	8					"
	9					"
E89M-8	1	28	0-400	1261	11.1	Stream
	2	4	350-400	272	3.7	"
	3	3	300-350	305	3.3	"
	4	6	250-300	418	2.4	"
	5	6	200-250	430	2.3	"
	6	5	150-200	395	2.5	"
	7	5	100-150	371	5.4	"
	8	5	50-100	338	35.5	"
	9	5	0- 50	401	17.5	"
E89M-9	1	43	0-400	2086	9.6	Sargasso Sea
	2	4	300-350	257	3.9	" "
	3	4	250-300	243	4.1	" "
	4	5	200-250	343	2.9	" "
	5	9	150-200	483	2.1	" "
	6	5	100-150	360	13.9	" "
	7	5	50-100	365	5.5	" "
	8	6	0- 50	413	16.9	" "
E89M-11	1	56	0-920	1723	12.2	Stream
	2	10	870-920	401	10.0	"
	3	10	870-890	398	17.6	"
	4	10	730-890	555	10.8	"
	5	9	730±	411	2.4	"
	6	9	720-730	413	2.4	"
	7	4	630-720	324	3.1	"
	8	9	620-630	461	8.7	"
	9	8	620-650	412	7.3	"
E89M-12	1	49	0-910	1058	4.7	Stream
	2	12	890-910	317	6.3	"
	3	10	860-890	421	2.4	"
	4	7	750-860	399	2.5	"
	5	11	750±	409	2.4	"
	6	10	730-750	409	2.4	"
	7	5	630-730	347	2.9	"
	8	8	620-630	421	2.4	"
	9	7	620±	423	2.4	"
E89M-13	1	67	0-990	1279	12.5	North Wall
	2	7	850-990	460	2.2	" "
	3	8	700-850	606	6.6	" "
	4	10	550-700	774	7.8	" "
	5	16	400-550	1284	13.2	" "
	6	15	300-400	1030	7.8	" "
	7	6	200-300	558	7.2	" "
	8	8	100-200	704	17.1	" "
	9	9	0-100	768	20.8	" "

Table 6 cont'd.

Tow Number	Net Number	Length of Tow (min)	Depth Range of Tow (m)	True Water Volume Filtered (m^3)	Biomass (ml/1000 m^3)	"Position" Across Stream
E89-14	1	20	0-200	825	12.1	North Wall
	2	6	175-200	429	23.3	" "
	3	7	150-175	526	22.8	" "
	4	10	125-150	674	4.4	" "
	5	6	100-125	442	6.8	" "
	6	5	75-100	398	12.6	" "
	7	6	50- 75	422	23.7	" "
	8	6	20- 50	537	33.5	" "
	9	8	0- 20	478	43.9	" "
E89-15	1	15	0-197	578	25.9	North Wall
	2	4	171-197	343	8.7	" "
	3	6	150-171	406	7.4	" "
	4	7	124-150	481	8.3	" "
	5	4	99-124	285	24.6	" "
	6	4	74- 99	320	34.4	" "
	7	5	48- 74	353	107.6	" "
	8	5	25- 48	337	26.7	" "
	9	5	0- 25	385	39.0	" "
E89-16	1	65	0-990	1485	17.5	North Wall
	2	7	840-990	448	6.7	" "
	3	8	680-840	549	3.6	" "
	4	8	530-680	586	1.7	" "
	5	8	390-530	661	1.5	" "
	6	5	300-390	383	2.6	" "
	7	10	200-300	877	28.5	" "
	8	10	100-200	827	10.9	" "
	9	10	0-100	838	57.3	" "
E89-17	1	60	0-1000	2617	6.5	Stream Edge
	2	9	850-1000	674	1.5	" "
	3	10	700-850	753	2.6	" "
	4	10	550-700	749	16.0	" "
	5	9	400-550	827	4.8	" "
	6	7	300-400	506	2.0	" "
	7	6	200-300	595	1.7	" "
	8	7	100-200	551	9.1	" "
	9	10	0-100	832	18.0	" "
E89-18	1	16	0-200	655	7.6	Stream Edge
	2	5	175-200	315	3.2	" "
	3	3	149-175	361	2.8	" "
	4	7	125-149	338	2.9	" "
	5	4	100-125	268	3.7	" "
	6	4	75-100	312	3.2	" "
	7	5	50- 75	309	29.1	" "
	8	2	25- 50	230	21.7	" "
	9	6	0- 25	315	19.0	" "
E89M-19	1	16	0-200	832	32.4	Stream Edge
	2	5	175-200	351	2.8	" "
	3	6	150-175	434	2.3	" "
	4	5	125-150	357	2.8	" "
	5	7	100-125	434	2.3	" "
	6	4	74-100	314	12.7	" "
	7	6	49- 74	413	67.8	" "
	8	5	24- 49	348	31.6	" "
	9	4	0- 24	215	37.2	" "

Table 6 cont'd.

Tow Number	Net Number	Length of Tow (min)	Depth Range of Tow (m)	True Water Volume Filtered (m^3)	Biomass (ml/1000 m^3)	"Position" Across Stream
E89M-20	1	66	0-1000	2877	6.9	Stream Edge
	2	10	850-1000	710	1.4	" "
	3	12	700-850	890	1.1	" "
	4	10	550-700	823	1.2	" "
	5	9	390-550	756	1.3	" "
	6	5	300-390	481	2.1	" "
	7	9	200-300	679	1.5	" "
	8	5	100-200	481	2.1	" "
	9	9	0-100	722	49.9	" "
E89M-22	1	17	0-198	826	15.7	Warm Core
	2	5	174-198	366	2.7	" "
	3	6	150-174	359	2.8	" "
	4	5	124-150	341	2.9	" "
	5	6	100-124	432	9.3	" "
	6	5	74-100	325	15.4	" "
	7	5	50- 74	360	166.7	" "
	8	5	25- 50	333	3.0	" "
	9	3	0- 25	228	35.1	" "
E89M-23	1	71	0-1000	2158	15.8	Warm Core
	2	10	840-1000	543	1.8	" "
	3	8	700-840	541	1.8	" "
	4	7	550-700	551	1.8	" "
	5	9	400-550	755	6.6	" "
	6	11	300-400	778	6.4	" "
	7	6	190-300	427	2.3	" "
	8	7	100-190	579	1.7	" "
	9	7	0-100	508	21.6	" "
E89M-25	1	19	0-200	831	18.0	Warm Core
	2	5	174-200	426	2.3	" "
	3	6	149-174	420	2.4	" "
	4	6	125-149	285	7.0	" "
	5	6	99-125	396	12.6	" "
	6	5	74- 99	376	26.6	" "
	7	6	49- 74	438	61.6	" "
	8	6	23- 49	405	101.2	" "
	9	5	0- 23	481	58.2	" "
E89M-26	1	65	0-990	2496	6.0	Warm Core
	2	7	850-990	335	3.0	" "
	3	8	700-850	464	2.2	" "
	4	6	550-700	487	2.0	" "
	5	16	400-550	1215	2.5	" "
	6	8	300-400	651	1.5	" "
	7	8	200-300	659	1.5	" "
	8	7	100-200	528	3.8	" "
	9	10	0-100	476	42.0	" "

Table 6 cont'd.

Tow Number	GMT Time	GMT Date	Local Time	Local Date	Start Position Latitude N	Start Position Longitude W	Site
E89-1	1215	9-12-82	815	9-12-82	36 18.00	73 32.44	P-6S
E89-2	1234	9-12-82	834	9-12-82	36 19.20	73 31.43	P-6S
E89-3	1856	9-13-82	1456	9-13-82	35 55.77	73 10.39	P-4
E89-4	1912	9-13-82	1512	9-13-82	35 58.42	73 10.16	P-4
E89-5	428	9-15-82	28	9-15-82	36 06.52	73 22.85	P-5N
E89-6	128	9-17-82	2128	9-16-82	36 36.28	73 52.19	P-8
E89-7	147	9-17-82	2147	9-16-82	36 36.37	73 52.70	P-8
E89-8	448	9-17-82	48	9-17-82	36 25.90	73 41.17	P-7
E89-9	508	9-17-82	108	9-17-82	36 26.41	73 40.87	P-7
E89-10	853	9-17-82	453	9-17-82	36 15.28	73 31.67	P-6
E89-11	914	9-17-82	514	9-17-82	36 16.22	73 30.88	P-6
E89-12	1656	9-17-82	1256	9-17-82	36 05.66	73 22.05	P-5
E89-13	1713	9-17-82	1313	9-17-82	36 06.08	73 21.88	P-5
E89-14	2107	9-17-82	1707	9-17-82	35 55.99	73 10.70	P-4
E89-15	2126	9-17-82	1726	9-17-82	35 54.80	73 10.92	P-4
E89-16	130	9-17-82	2130	9-17-82	35 43.97	73 00.81	P-3
E89-17	154	9-17-82	2154	9-17-82	35 44.22	73 00.77	P-3
E89-18	604	9-18-82	204	9-18-82	35 33.44	72 51.79	P-2
E89-19	621	9-18-82	221	9-18-82	35 33.28	72 52.09	P-2
E89-20	1108	9-18-82	708	9-18-82	35 23.05	72 38.75	P-1
E89-21	1127	9-18-82	727	9-18-82	35 22.78	72 39.59	P-1
E89-22	1620	9-18-82	1220	9-18-82	35 12.16	72 28.07	P-0
E89-23	1717	9-18-82	1317	9-18-82	35 12.20	72 27.19	P-0

Table 6 cont'd.

Tow Number	Length of Tow (min)	Depth of Tow (m)	True Water Volume Filtered(m3)	Biomass (ml/1000m3)	Position Across Stream
E89-1	16	178	164.2	42.6	North Wall
E89-2	16	189	150.2	46.6	North Wall
E89-3	14	184	157.7	6.3	Gulf Stream
E89-4	15	195	145.4	6.9	Gulf Stream
E89-5	17	174	182.1	27.5	Gulf Stream
E89-6	17	150	218.3	87.0	Slope Water
E89-7	15	162	179.7	83.5	Slope Water
E89-8	17	198	172.4	174.0	Slope Water
E89-9	16	172	156.5	146.9	Slope Water
E89-10	18	182	191.1	83.7	North Wall
E89-11	20	178	182.6	104.0	North Wall
E89-12	15	184	168.1	5.9	Gulf Stream
E89-13	17	174	163.3	36.7	Gulf Stream
E89-14	16	162	204.3	29.4	Gulf Stream
E89-15	16	192	186.9	26.7	Gulf Stream
E89-16	15	185	138.4	57.8	Gulf Stream
E89-17	16	199	122.7	32.6	Gulf Stream
E89-18	15	189	116.6	42.9	Gulf Stream
E89-19	12	194	113.0	44.3	Gulf Stream
E89-20	16	147	144.5	41.5	Sargasso Sea
E89-21	16	136	93.3	53.6	Sargasso Sea
E89-22	15	147	73.1	27.4	Sargasso Sea
E89-23	17	150	181.5	16.5	Sargasso Sea

Table 7.

Tow Number	GMT Time	GMT Date	Local Time	Local Date	Start Position Latitude N	Start Position Longitude W	Site
E92-1	2347	11-21-82	1847	11-21-82	36 36.30	73 51.91	P-8
E92-2	0.08	11-22-82	1908	11-21-82	36 36.85	73 52.75	P-8
E92-3	305	11-22-82	2205	11-21-82	36 25.77	73 41.43	P-7
E92-4	327	11-22-82	2227	11-21-82	36 26.10	73 41.80	P-7
E92-5	705	11-22-82	205	11-22-82	36 15.21	73 31.84	P-6
E92-6	725	11-22-82	225	11-22-82	36 15.99	73 31.84	P-6
E92-7	1129	11-22-82	629	11-22-82	36 05.75	73 21.71	P-5
E92-8	1150	11-22-82	650	11-22-82	36 06.67	73 20.89	P-5
E92-9	1823	11-22-82	1323	11-22-82	35 55.05	73 10.82	P-4
E92-10	1841	11-22-82	1341	11-22-82	35 55.05	73 10.82	P-4
E92-11	2351	11-22-82	1851	11-22-82	35 44.15	73 01.06	P-3
E92-12	11	11-23-82	1911	11-22-82	35 44.89	73 00.96	P-3
E92-13	434	11-23-82	2334	11-22-82	35 33.68	72 51.72	P-2
E92-14	452	11-23-82	2352	11-22-82	35 33.79	72 52.15	P-2
E92-15	1003	11-23-82	503	11-23-82	35 22.86	72 38.60	P-1
E92-16	1023	11-23-82	523	11-23-82	35 23.50	72 38.92	P-1
E92-17	1923	11-23-82	1423	11-23-82	35 12.21	72 28.18	P-0
E92-18	1944	11-23-82	1444	11-23-82	35 12.21	72 28.18	P-0
E92-19	443	11-26-82	2343	11-25-82	36 36.61	73 51.90	P-8
E92-20	502	11-26-82	0.02	11-26-82	36 37.09	73 52.06	P-8
E92-21	814	11-26-82	314	11-26-82	36 26.10	73 41.34	P-7
E92-22	836	11-26-82	336	11-26-82	36 27.09	73 40.34	P-7
E92-23	1337	11-26-82	837	11-26-82	36 14.99	73 32.00	P-6S
E92-24	1355	11-26-82	855	11-26-82	36 15.19	73 30.38	P-6S
E92-25	2136	11-26-82	1636	11-26-82	36 05.75	73 21.70	P-5
E92-26	2155	11-26-82	1655	11-26-82	36 05.63	73 21.02	P-5
E92-27	340	11-27-82	2240	11-26-82	35 55.16	73 10.81	P-4
E92-28	359	11-27-82	2259	11-26-82	35 55.16	73 10.81	P-4
E92-29	925	11-27-82	425	11-27-82	35 44.40	73 01.06	P-3
E92-30	944	11-27-82	444	11-27-82	35 44.12	73 00.86	P-3
E92-31	1357	11-27-82	857	11-27-82	35 33.49	72 51.42	P-2
E92-32	1416	11-27-82	916	11-27-82	35 33.83	72 51.64	P-2
E92-33	2114	11-27-82	1614	11-27-82	35 22.64	72 38.37	P-1
E92-34	2130	11-27-82	1630	11-27-82	35 22.89	72 39.66	P-1

Table 7 cont'd.

Tow Number	Length of Tow (min)	Depth of Tow (m)	True Water Volume Filtered(m3)	Biomass (ml/1000m3)	Position Across Stream
E92-1	18	152	286.3	146.7	Slope Water
E92-2	15	128	232.1	163.7	Slope Water
E92-3	19	157	222.3	278.8	Slope Water
E92-4	17	136	232.2	232.5	Slope Water
E92-5	17	122	267.3	74.8	North Wall
E92-6	17	130	267.6	74.7	North Wall
E92-7	17	142	260.4	15.4	Gulf Stream
E92-8	18	139	579.8	13.8	Gulf Stream
E92-9	15	125	265.6	22.6	Gulf Stream
E92-10	18	157	122.1	8.2	Gulf Stream
E92-11	17	150	258.9	23.2	Gulf Stream
E92-12	16	142	278.1	50.3	Gulf Stream
E92-13	15	122	189.9	79.0	Sargasso Sea
E92-14	17	150	220.1	54.5	Sargasso Sea
E92-15	17	106	263.9	41.7	Sargasso Sea
E92-16	16	150	245.0	32.7	Sargasso Sea
E92-17	18	169	186.6	53.6	Sargasso Sea
E92-18	19	145	250.6	19.5	Sargasso Sea
E92-19	15	136	184.2	168.3	Slope Water
E92-20	16	165	152.2	124.8	Slope Water
E92-21	19	119	265.8	120.4	Slope Water
E92-22	17	112	243.1	127.5	Slope Water
E92-23	16	167	117.2	42.6	North Wall
E92-24	16	157	121.3	41.2	North Wall
E92-25	17	152	197.7	50.6	Gulf Stream
E92-26	16	150	160.3	56.1	Gulf Stream
E92-27	16	122	190.8	115.3	Gulf Stream
E92-28	15	?	?	X	Gulf Stream
E92-29	17	176	208.2	48.0	Gulf Stream
E92-30	18	152	246.8	36.5	Gulf Stream
E92-31	15	195	190.8	15.7	Sargasso Sea
E92-32	16	136	209.8	4.8	Sargasso Sea
E92-33	14	174	180.1	27.8	Sargasso Sea
E92-34	14	180	171.6	35.0	Sargasso Sea

X = Cod End Lost

Table 8.

Tow Number	Net Number	GMT Date	GMT Time	Local Date	Local Time	Start Position Latitude N	Start Position Longitude W	Site
E99M-1	1	5/11/83	0213	5/10/83	2213	36°----	73°----	P-8
	2	"	0238	"	2238	36°35.43	73°52.54	"
	3	"	0243	"	2243	36°35.49	73°52.69	"
	4	"	0245	"	2245	36°35.51	73°52.74	"
	5	"	0248	"	2248	36°35.56	73°52.82	"
	6	"	0252	"	2252	36°35.60	73°52.90	"
	7	"	0255	"	2255	36°35.67	73°53.01	"
	8	"	0259	"	2259	36°35.71	73°53.06	"
	9	"	0302	"	2302	36°35.78	73°53.18	"
E99M-2	1	5/11/83	0444	5/11/83	0044	36°25.48	73°41.62	P-7S
	2	"	0506	"	0106	36°25.07	73°42.36	"
	3	"	0509	"	0109	36°25.03	73°42.46	"
	4	"	0514	"	0114	36°24.98	73°42.60	"
	5	"	0519	"	0119	36°24.94	73°42.80	"
	6	"	0523	"	0123	36°24.91	73°42.96	"
	7	"	0528	"	0128	36°24.83	73°43.09	"
	8	"	0532	"	0132	36°24.74	73°43.25	"
E99M-3	1	5/11/83	0821	5/11/83	0421	36°15.30	73°30.52	P-6S
	2	"	0856	"	0456	36°14.77	73°29.80	"
	3	"	0900	"	0500	36°14.65	73°29.74	"
	4	"	0903	"	0503	36°14.56	73°29.69	"
	5	"	0906	"	0506	36°14.50	73°29.68	"
	6	"	0909	"	0509	36°14.42	73°29.66	"
	7	"	0913	"	0513	36°14.33	73°29.56	"
	8	"	0918	"	0518	36°14.22	73°29.42	"
	9	"	0922	"	0522	36°14.18	73°29.27	"
E99M-4	1	5/11/83	1218	5/11/83	0818	36°05.67	73°20.87	P-5
	2	"	1244	"	0844	36°05.38	73°20.18	"
	3	"	1248	"	0848	36°05.33	73°20.07	"
	4	"	1251	"	0851	36°05.29	73°19.99	"
	5	"	1255	"	0855	36°05.25	73°19.88	"
	6	"	1259	"	0859	36°05.20	73°19.78	"
	7	"	1304	"	0904	36°05.14	73°19.57	"
	8	"	1309	"	0909	36°05.12	73°19.38	"
	9	"	1312	"	0912	36°05.10	73°19.26	"
E99M-5	1	5/11/83	1632	5/11/83	1232	35°55.25	73°10.81	P-4
	2	"	1653	"	1253	35°55.29	73°10.75	"
	3	"	1656	"	1256	35°55.29	73°10.74	"
	4	"	1659	"	1259	35°55.29	73°10.72	"
	5	"	1703	"	1303	35°55.29	73°10.70	"
	6	"	1707	"	1307	35°55.28	73°10.68	"
	7	"	1712	"	1312	35°55.27	73°10.65	"
	8	"	1717	"	1317	35°55.27	73°10.65	"
	9	"	1722	"	1322	35°55.27	73°10.64	"
E99M-6	1	5/11/83	2043	5/11/83	1643	35°44.07	73°0.134	P-3
	2	"	2110	"	1710	35°43.37	73°02.00	"
	3	"	2113	"	1713	35°43.30	73°02.08	"
	4	"	2120	"	1720	35°43.16	73°02.19	"
	5	"	2125	"	1725	35°43.03	73°02.28	"
	6	"	2130	"	1730	35°42.91	73°02.39	"
	7	"	2135	"	1735	35°42.78	73°02.49	"
	8	"	2140	"	1740	35°42.65	73°02.60	"
	9	"	2145	"	1745	35°42.52	73°02.74	"

Table 8 cont'd.

Tow Number	Net Number	GMT Date	GMT Time	Local Date	Local Time	Start Position Latitude N	Start Position Longitude W	Site
E99M-7	1	5/12/83	0129	5/11/83	2129	35°33.83	72°50.62	P-2
	2	"	0148	"	2148	35°34.48	72°49.74	"
	3	"	0151	"	2151	35°34.59	72°49.65	"
	4	"	0154	"	2154	35°34.67	72°49.47	"
	5	"	0157	"	2157	35°34.80	72°49.38	"
	6	"	0201	"	2201	35°34.92	72°49.17	"
	7	"	0205	"	2205	35°35.05	72°48.97	"
	8	"	0209	"	2209	35°35.19	72°48.78	"
	9	"	0213	"	2213	35°35.31	72°48.62	"
E99M-8	1	5/12/83	0708	5/12/83	0308	35°~~31~~.57	72°38.41	P-1
	2	"	0730	"	0330	35°22.49	72°37.85	"
	3	"	0735	"	0335	35°22.70	72°37.88	"
	4	"	0738	"	0338	35°22.79	72°37.94	"
	5	"	0742	"	0342	35°22.92	72°38.08	"
	6	"	0745	"	0345	35°22.86	72°38.08	"
	7	"	0749	"	0349	35°22.90	72°38.30	"
	8	"	0756	"	0356	35°22.89	72°38.40	"
E99M-9	1	5/12/83	1604	5/12/83	1204	35°20.87	72°38.51	P-1
	2	"	1626	"	1226	35°21.01	72°37.28	"
	3	"	1631	"	1231	35°20.87	72°37.17	"
	4	"	1637	"	1237	35°20.79	72°37.29	"
	5	"	1639	"	1239	35°20.79	72°37.36	"
	6	"	1642	"	1242	35°20.78	72°37.45	"
	7	"	1645	"	1245	35°20.80	72°37.57	"
	8	"	1649	"	1249	35°20.82	72°37.71	"
	9	"	1656	"	1256	35°20.84	72°37.82	"
E99M-10	1	5/13/83	0340	5/12/83	2340	35°43.72	73°01.96	P-3
	2	"	0353	"	2353	35°43.87	73°02.32	"
	3	"	0357	"	2357	35°43.91	73°02.43	"
	4	"	0402	5/13/83 "	0002	35°43.97	73°02.61	"
	5	"	0407	"	0007	35°44.01	73°02.71	"
	6	"	0412	"	0012	35°44.10	73°02.90	"
	7	"	0416	"	0016	35°44.12	73°02.98	"
	8	"	0421	"	0021	35°44.17	73°03.10	"
	9	"	0425	"	0025	35°44.22	73°03.21	"
E99M-11	1	5/13/83	0518	"	0118	35°44.05	73°03.32	P-3
	2	"	0635	"	0235	35°44.07	73°05.18	"
	3	"	0648	"	0248	35°43.92	73°05.47	"
	4	"	0702	"	0302	35°43.79	73°05.79	"
	5	"	0716	"	0316	35°43.64	73°06.06	"
	6	"	0730	"	0330	35°43.54	73°06.40	"
	7	"	0740	"	0340	35°43.45	73°06.63	"
	8	"	0749	"	0349	35°43.37	73°06.84	"
E99M-12	1	5/13/83	1334	5/13/83	0934	35°44.20	73°01.38	P-3
	2	"	1440	"	1040	35°43.74	73°02.99	"
	3	"	1449	"	1049	35°43.67	73°03.12	"
	4	"	1459	"	1059	35°43.56	73°03.44	"
	5	"	1515	"	1115	35°43.40	73°03.76	"
	6	"	1528	"	1128	35°43.26	73°03.99	"
	7	"	1535	"	1135	35°43.19	73°04.12	"
	8	"	1543	"	1143	35°43.13	73°04.27	"
	9	"	1553	"	1153	35°43.02	73°04.44	"

Table 8 cont'd.

Tow Number	Net Number	GMT Date	GMT Time	Local Date	Local Time	Start Position Latitude N	Start Position Longitude W	Site
E99M-13	1	5/13/83	1723	5/13/83	1323	35°42.33	73°05.24	P-3
	2	"	1735	"	1335	35°42.20	73°05.42	"
	3	"	1738	"	1338	35°42.16	73°05.45	"
	4	"	1744	"	1344	35°42.08	73°05.52	"
	5	"	1748	"	1348	35°42.04	73°05.57	"
	6	"	1752	"	1352	35°41.98	73°05.63	"
	7	"	1754	"	1354	35°41.95	73°05.68	"
	8	"	1805	"	1405	35°41.80	73°05.87	"
	9	"	1808	"	1408	35°41.75	73°05.93	"
E99M-14	1	5/14/83	0137	5/13/83	2137	36°06.29	73°21.02	P-5
	2	"	0151	"	2151	36°06.40	73°20.77	"
	3	"	0157	"	2157	36°06.43	73°20.67	"
	4	"	0212	"	2212	36°06.48	73°20.53	"
	5	"	0215	"	2215	36°06.49	73°20.49	"
	6	"	0226	"	2226	36°06.52	73°20.37	"
	7	"	0230	"	2230	36°06.54	73°20.32	"
	8	"	0237	"	2237	36°06.57	73°20.26	"
	9	"	0243	"	2243	36°06.58	73°20.18	"
E99M-15	1	5/19/83	1520	5/19/83	1120	36°07.27	73°17.43	P-5
	2	"	1526	"	1126	36°07.42	73°17.30	"
	3	"	1532	"	1132	36°07.59	73°17.13	"
	4	"	1539	"	1139	36°07.74	73°16.95	"
	5	"	1547	"	1147	36°07.92	73°16.77	"
	6	"	1552	"	1152	36°08.04	73°16.64	"
	7	"	1558	"	1158	36°08.20	73°16.51	"
	8	"	1606	"	1206	36°08.42	73°16.21	"
	9	"	1611	"	1211	36°08.56	73°16.03	"
E99M-16	1	5/19/83	1753	5/19/83	1353	36°06.04	73°21.86	P-5
	2	"	1851	"	1451	36°07.49	73°21.61	"
	3	"	1858	"	1458	36°07.57	73°21.70	"
	4	"	1908	"	1508	36°07.62	73°21.85	"
	5	"	1919	"	1519	36°07.70	73°21.97	"
	6	"	1928	"	1528	36°07.75	73°22.09	"
	7	"	1934	"	1534	36°07.78	73°22.15	"
	8	"	1950	"	1550	36°07.99	73°22.04	"
	9	"	20.08	"	1608	36°08.32	73°21.58	"
E99M-17	1	5/20/83	0142	5/19/83	2142	36°05.80	73°23.88	P-5
	2	"	0203	"	2203	36°06.23	73°23.89	"
	3	"	0207	"	2207	36°06.32	73°23.18	"
	4	"	0212	"	2212	36°06.42	73°23.08	"
	5	"	0217	"	2217	36°06.50	73°22.99	"
	6	"	0224	"	2224	36°06.66	73°22.75	"
	7	"	0230	"	2230	36°06.80	73°22.50	"
	8	"	0236	"	2236	36°06.97	73°22.27	"
	9	"	0242	"	2242	36°07.08	73°21.99	"
E99M-18	1	5/20/83	0411	5/20/83	0011	36°03.78	73°22.56	P-5
	2	"	0528	"	0128	----	----	"
	3	"	0536	"	0136	36°03.17	73°21.85	"
	4	"	0540	"	0140	36°03.06	73°21.87	"
	5	"	0547	"	0147	36°02.93	73°21.91	"
	6	"	0553	"	0153	36°02.82	73°21.97	"
	7	"	0618	"	0218	36°02.74	73°21.65	"
	8	"	0632	"	0232	36°02.83	73°21.35	"
	9	"	0643	"	0243	36°02.90	73°20.99	"

Table 8 cont'd.

Tow Number	Net Number	GMT Date	GMT Time	Local Date	Local Time	Start Position Latitude N	Start Position Longitude W	Site
E99M-19	1	5/20/83	1446	5/20/83	1046	35°56.49	73°12.10	P-4N
	2	"	1604	"	1204	35°56.56	73°12.39	"
	3	"	1608	"	1208	35°56.52	73°12.51	"
	4	"	1612	"	1212	35°56.48	73°12.65	"
	5	"	1644	"	1244	35°56.51	73°12.71	"
	6	"	1656	"	1256	35°56.53	73°12.71	"
	7	"	1705	"	1305	35°56.54	73°12.70	"
	8	"	1716	"	1316	35°56.54	73°12.67	"
	9	"	1729	"	1329	35°56.59	73°12.58	"
E99M-20	1	5/20/83	1909	5/20/83	1509	35°56.53	73°11.70	P-4N
	2	"	1943	"	1543	35°56.33	73°11.59	"
	3	"	1948	"	1548	35°56.29	73°11.55	"
	4	"	1956	"	1556	35°56.29	73°11.49	"
	5	"	2001	"	1601	35°56.29	73°11.47	"
	6	"	2007	"	1607	35°56.27	73°11.44	"
	7	"	2015	"	1615	35°56.26	73°11.37	"
	8	"	2020	"	1620	35°56.29	73°11.37	"
	9	"	2024	"	1624	35°56.28	73°11.35	"
E99M-21	1	5/21/83	0129	5/20/83	2129	35°56.95	73°13.00	P-4N
	2	"	0144	"	2144	35°57.01	73°12.92	"
	3	"	0149	"	2149	35°57.06	73°12.90	"
	4	"	0155	"	2155	35°57.08	73°12.85	"
	5	"	0200	"	2200	35°57.12	73°12.82	"
	6	"	0206	"	2206	35°57.17	73°12.79	"
	7	"	0211	"	2211	35°57.23	73°12.78	"
	8	"	0217	"	2217	35°57.26	73°12.71	"
	9	"	0222	"	2222	35°57.32	73°12.67	"
E99M-22	1	5/21/83	0342	5/20/83	2342	35°56.93	73°12.93	P-4N
	2	"	0506	"	0106	35°56.51	73°13.26	"
	3	"	0518	"	0118	35°56.42	73°13.38	"
	4	"	0526	"	0126	35°36.35	73°13.49	"
	5	"	0536	"	0136	35°56.26	73°13.30	"
	6	"	0607	"	0207	35°56.17	73°13.73	"
	7	"	0618	"	0218	35°56.19	73°13.70	"
	8	"	0627	"	02~~18~~27	35°56.23	73°13.67	"
	9	"	0635	"	0235	35°56.25	73°13.62	"
E99M-23	1	5/22/83	1431	5/22/83	1031	36°25.84	73°41.78	P-7S
	2	"	1545	"	1145	36°25.84	73°43.26	"
	3	"	1555	"	1155	36°28.73	73°43.50	"
	4	"	1606	"	1206	36°29.10	73°43.79	"
	5	"	1617	"	1217	36°29.49	73°44.06	"
	6	"	1630	"	1230	36°29.93	73°44.37	"
	7	"	1637	"	1237	35°30.17	73°44.52	"
	8	"	1650	"	1250	35°30.58	73°44.80	"
	9	"	1712	"	1312	35°31.24	73°45.38	"
E99M-24	1	5/23/83	0341	5/22/83	2341	35°55.63	73°10.28	P-4S
	2	"	0353	"	2353	35°55.83	73°10.04	"
	3	"	0359	"	2359	35°55.91	73°09.92	"
	4	"	0406	"	0006	35°56.01	73°09.77	"
	5	"	0412	"	0012	35°56.12	73°09.64	"

Table 8 cont'd.

Tow Number	Net Number	GMT Date	GMT Time	Local Date	Local Time	Start Position Latitude N	Start Position Longitude W	Site
EM99-24 (cont.)	6	5/23/83	0418	5/23/83	0018	35°56.23	73°09.52	P-4S
	7	"	0425	"	0025	36°56.34	73°09.35	"
	8	"	0430	"	0030	35°56.44	73°09.24	"
	9	"	0436	"	0036	35°56.54	73°09.12	"
E99M-25	1	5/23/83	1610	5/23/83	1210	35°44.32	73°01.11	P-3
	2	"	?	"	?	----	----	"
	3	"	?	"	?	----	----	"
	4	"	?	"	?	----	----	"
	5	"	?	"	?	----	----	"
	6	"	?	"	?	----	----	"
	7	"	?	"	?	----	----	"
	8	"	?	"	?	----	----	"
	9	"	?	"	?	----	----	"

Table 8 cont'd.

Tow Number	Net Number	Length of Tow (min)	Depth Range of Tow (m)	True Water Volume Filtered (m^3)	Biomass ($ml/1000\ m^3$)	"Postion" Across Stream	Condition
E99M-1	1	25	0-400	1010		Slope	
	2	5	400-350	288	6.9	"	
	3	2	350-300	211	4.7	"	
	4	3	300-250	240	4.2	"	
	5	4	250-200	273	3.7	"	
	6	3	200-150	270	3.7	"	
	7	4	150-100	264	11.4	"	
	8	3	100- 50	267	56.2	"	
	9	4	50- 0	319		"	
E99M-2	1	22	0-400	548		Slope	
	2	3	400-350	238	4.2	"	
	3	5	350-300	313	3.2	"	
	4	5	300-250	372	2.7	"	
	5	4	250-200	365	10.9	"	
	6	5	200-150	334	41.9	"	
	7	4	150-100	387	268.7	"	
	8	5	100- 0	859		"	
E99M-3	1	35	0-400	977		Slope	
	2	4	400-350	263	22.8	"	
	3	3	350-300	216	41.7	"	
	4	3	300-250	190	21.1	"	
	5	3	250-200	206	48.5	"	
	6	4	200-150	308	48.7	"	
	7	5	150-100	385	98.7	"	
	8	4	100- 50	311	41.8	"	
	9	6	50- 0	404	111.4	"	
E99M-4	1	16	0-390	650	10.8	North Wall	
	2	4	390-350	262	3.8	" "	
	3	3	350-300	266	3.8	" "	
	4	4	300-250	299	3.3	" "	
	5	4	250-200	357	2.8	" "	
	6	5	200-150	458	2.2	" "	
	7	5	150-100	412	2.4	" "	
	8	3	100- 50	258	3.9	" "	
	9	3	50- 0	278	14.4	" "	
E99M-5	1	21	0-400	702	7.1	Warm Core	
	2	3	400-350	244	4.1	" "	
	3	3	350-300	285	3.5	" "	
	4	4	300-250	294	3.4	" "	
	5	4	250-200	330	3.0	" "	
	6	5	200-150	404	2.5	" "	
	7	5	150-100	390	2.6	" "	
	8	5	100- 50	374	13.4	" "	
	9	4	50- 0	371	21.6	" "	
E99M-6	1	27	0-400	1298	6.9	Warm Core	
	2	3	400-350	265	3.8	" "	
	3	7	350-300	512	1.9	" "	
	4	5	300-250	398	2.5	" "	
	5	5	250-200	420	2.4	" "	
	6	5	200-150	428	2.3	" "	
	7	5	150-100	428	7.1	" "	
	8	5	100- 50	440	22.7	" "	
	9	6	50- 0	435	32.2	" "	

Table 8 cont'd.

Tow Number	Net Number	Length of Tow (min)	Depth Range of Tow (m)	True Water Volume Filtered (m^3)	Biomass (ml/1000 m^3)	"Position" Across Stream	Condition
E99M-7	1	19	0-400	591	16.9	Southern Edge	
	2	3	400-350	195	5.1	" "	
	3	3	350-300	246	4.1	" "	
	4	3	300-250	251	4.0	" "	
	5	4	250-200	333	3.0	" "	
	6	4	200-150	304	3.3	" "	
	7	4	150-100	354	2.8	" "	
	8	4	100- 50	288	52.1	" "	
	9	3	50- 0	269	37.2	" "	
E99M-8	1	22	0-400	784	20.4	Sargasso Sea	
	2	5	400-350	383	2.6	" "	
	3	3	350-300	275	3.6	" "	
	4	4	300-250	298	3.4	" "	
	5	3	250-200	314	3.2	" "	
	6	4	200-150			" "	
	7	7	150-100			" "	
	8	9	100- 0			" "	
E99M-9	1	22	0-400	697	7.2	Sargasso Sea	
	2	5	400-350	398	2.5	" "	
	3	4	350-300	380	2.6	" "	
	4	2	300-250	208	4.8	" "	
	5	3	250-200	217	4.6	" "	
	6	3	200-150	276	3.6	" "	
	7	4	150-100	339	2.9	" "	
	8	7	100- 50	539	11.1	" "	
	9	4	50- 0	352	5.7	" "	
E99M-10	2	4	200-175	262	3.8	Southern Edge	
	3	5	175-150	408	4.9	" "	
	4	5	150-125	333	18.0	" "	
	5	5	125-100	381	28.9	" "	
	6	4	100- 75	336	41.7	" "	
	7	5	75- 50	333	54.0	" "	
	8	4	50- 25	272	44.1	" "	
	9	3	25- 0	201	34.8	" "	
E99M-11	1	77	0-1000	3324	1.8	Southern Edge	
	2	13	1000-850	977	1.0	" "	
	3	14	850-700	1152	0.8	" "	
	4	14	700-550	1159	0.8	" "	
	5	14	550-400	1138	0.9	" "	
	6	10	400-300	887	1.1	" "	
	7	9	300-200	745	1.3	" "	
	8	17	200- 0	1431	30.7	" "	
E99M-12	1	66	0-1000	2757	4.3	Southern Edge	
	2	9	1000-850	688	1.5	" "	
	3	10	850-700	869	1.2	" "	
	4	14	700-550	1399	6.4	" "	
	5	13	550-400	1145	3.5	" "	
	6	7	400-300	621	1.6	" "	
	7	8	300-200	659	3.0	" "	
	8	10	200-100	928	31.2	" "	
	9	9	100- 0	827	21.8	" "	

Table 8 cont'd.

Tow Number	Number	Length of Tow (min)	Depth Range of Tow (m)	True Water Volume Filtered (m^3)	Biomass (ml/1000 m^3)	"Position" Across Stream	Condition
E99M-13	1	12	0-200	466	19.3	Southern Edge	
	2	3	200-175	209	4.8	" "	
	3	6	175-150	419	16.7	" "	
	4	4	150-125	275	18.2	" "	
	5	4	125-100	298	20.1	" "	
	6	2	100- 75	184	32.6	" "	
	7	11	75- 50	697	31.6	" "	
	8	3	50- 25	247	24.3	" "	
	9	4	25- 0	201	9.9	" "	
E99M-14	1	14	0-200	522	1.9	North Wall	
	2	6	200-175	413	2.4	" "	
	3	5	175-150	1026	3.9	" "	
	4	3	150-125	209	14.4	" "	
	5	11	125-100	809	3.7	" "	
	6	4	100- 75	321	59.2	" "	
	7	7	75- 50	493	32.5	" "	
	8	6	50- 25	470	38.3	" "	
	9	2	25- 0	178	22.5	" "	
E99M-15	1	13	0-200	863	6.9	North Wall	
	2	6	175-150	450	2.2	" "	
	3	7	150-125	479	2.1	" "	
	4	8	125-100	516	1.9	" "	
	5	5	100- 75	349	2.9	" "	
	6	6	75- 50	450	6.7	" "	
	7	8	50- 25	586	--	" "	Bad
	8	5	25- 0	327	3.1	" "	
	9	1	0- 0	11	--	" "	Bad
E99M-16	1	58	0-1000	1280	18.7	North Wall	
	2	7	1000-850	466	2.1	" "	
	3	10	850-700	605	1.6	" "	
	4	11	700-550	637	1.6	" "	
	5	9	550-400	581	1.7	" "	
	6	6	400-300	410	2.4	" "	
	7	16	300-200	1129	3.5	" "	
	8	18	200-100	1351	5.9	" "	
	9	13	100- 0	1049	16.2	" "	
E99M-17	1	21	0-200	1048	16.2	North Wall	
	2	4	200-173	284	3.5	" "	
	3	5	173-145	338	2.9	" "	
	4	5	145-124	300	3.3	" "	
	5	7	124- 99	566	5.3	" "	
	6	6	99- 73	421	7.1	" "	
	7	6	73- 48	418	31.1	" "	
	8	6	48- 24	406	29.6	" "	
	9	2	24- 0	167	18.0	" "	
E99M-18	1	77	0-1000	2274	--	North Wall	Lost
	2	8	930-830	295	3.4	" "	
	3	4	830-690			" "	
	4	7	690-550	479	2.1	" "	
	5	6	550-400	606	1.6	" "	
	6	25	400-300	2004	1.5	" "	
	7	14	300-200	1153	0.9	" "	
	8	11	200-100	948	2.1	" "	
	9	11	100- 0	857	26.8	" "	

Table 8 cont'd.

Tow Number Number	Net Number	Length of Tow (min)	Depth Range of Tow (m)	True Water Volume Filtered (m^3)	Biomass (ml/1000 m^3)	"Position" Across Stream		Condition
E99M-19	1	78	0-1000	3275	7.9	Warm	Core	
	2	4	1000- 850	288	3.5	"	"	
	3	4	850- 700	346	2.9	"	"	
	4	22	700- 550	2453	1.6	"	"	
	5	12	550- 400	1012	1.0	"	"	
	6	9	400- 300	816	1.2	"	"	
	7	11	300- 200	987	1.0	"	"	
	8	13	200- 100	1144	0.9	"	"	
	9	10	100- 0	783	5.1	"	"	
E99M-20	1	34	0- 200	2082	4.3	Warm	Core	
	2	5	200- 175	369	2.7	"	"	
	3	8	175- 150	594	1.7	"	"	
	4	5	150- 125	360	2.8	"	"	
	5	6	125- 100	479	2.1	"	"	
	6	8	100- 75	623	11.2	"	"	
	7	5	75- 50	352	25.6	"	"	
	8	4	50- 25			"	"	
	9	4	25- 0	365	10.9	"	"	
E99M-21	1	15	0- 193	699	11.4	Warm	Core	
	2	5	193- 174	357	5.6	"	"	
	3	4	174- 148	391	2.6	"	"	
	4	5	148- 123	406	2.5	"	"	
	5	6	123- 97	429	2.3	"	"	
	6	5	97- 74	364	19.2	"	"	
	7	6	74- 48	450	20.0	"	"	
	8	5	48- 22	416	16.8	"	"	
	9	6	22- 0	389	20.6	"	"	
E99M-22	1	84	0-1000			Warm	Core	
	2	12	1000- 850			"	"	
	3	8	850- 700	507	1.9	"	"	
	4	10	700- 550	789	1.3	"	"	
	5	31	550- 400	2344	0.9	"	"	
	6	11	400- 300	816	1.2	"	"	
	7	9	300- 200	709	1.4	"	"	
	8	8	200- 100	702	1.4	"	"	
	9	11	100- 0	911	20.8	"	"	
E99M-23	1	74	0-1000	3142		Slope		
	2	10	1000- 850	799	1.2	"		
	3	11	850- 700	866	13.8	"		
	4	11	700- 550	677	85.7	"		
	5	13	550- 400	953	35.7	"		
	6	7	400- 300	196	45.9	"		
	7	13	300- 200			"		
	8	12	200- 100	1508		"		
	9	13	100- 0	971				
E99M-24	1	12	0- 202	457	17.5	Warm	Core	
	2	6	202- 176	386	2.6	"	"	
	3	7	176- 148	434	2.3	"	"	
	4	6	148- 125	426	2.3	"	"	
	5	6	125- 99	403	7.4	"	"	
	6	7	99- 74	414	9.7	"	"	
	7	5	74- 49	359	16.7	"	"	
	8	6	49- 22	409	22.0	"	"	
	9	8	22- 0	535	35.5	"	"	

Table 8 cont'd.

Tow Number	Net Number	Length of Tow (min)	Depth Range of Tow (m)	True Water Volume Filtered (m^3)	Biomass (ml/1000 m^3)	"Position" Across Stream	Condition
E99M-25	1	12	200- 0	406	22.2	Southern Edge	
	2	?	?	?	--	" "	Bad
	3	?	?	?	--	" "	Bad
	4	?	?	?	--	" "	Bad
	5	?	?	?	--	" "	Bad
	6	?	?	?	--	" "	Bad
	7	?	?	?	--	" "	Bad
	8	?	?	?	--	" "	Bad
	9	?	?	?	--	" "	Bad

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