EARLY LIFE HISTORY OF RED DRUM (*SCIAENOPS OCELLATUS*) IN THE NORTHCENTRAL GULF OF MEXICO

FINAL REPORT

July 1, 1983 through June 30, 1987

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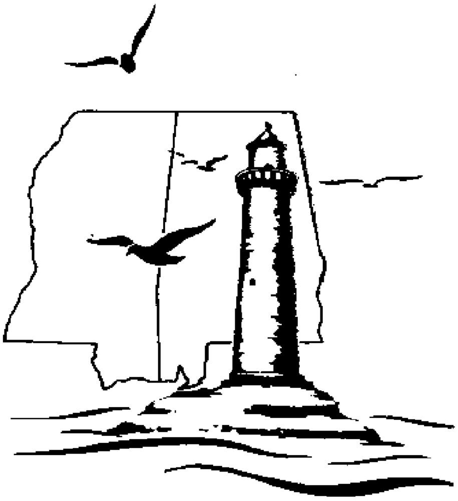
April 1988



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Publication Abstract

Ichthyoplankton and zooplankton samples were collected in the near vicinity of a subsurface current drogue during fourteen, 24 hour cruises in late summer and fall months, 1983-85, in east Louisiana, Mississippi, and Alabama coastal and shelf waters. Peak red drum spawning in these waters occurred from early September through early October when water temperatures over the shelf were decreasing rapidly from 27-29°C in early September to 24-25°C in early October 1984 and 1985. A diel pattern in vertical distribution was evident with red drum larvae and their planktonic prey being generally more abundant higher in the water column during daylight hours and deeper at night. Surface current patterns and larval size distributions at nearshore and offshore locations led to the conclusion that the high concentrations of red drum larvae found 17-34 km offshore are probably not the source of postlarvae entering inshore nursery areas in the Mississippi Sound.

Otolith growth increments were used to estimate the age of red drum larvae. Larval growth, estimated by correlating age with standard length and dry weight measurements, was positively associated with water temperature. In October 1984 when water temperatures ranged from 24.5° to 25.1°C, the growth rate of 4 to 6 mm larvae averaged only 0.29 mm d^{-1}, while in September 1985 when water temperatures were up to 4°C warmer, mean growth rate increased to 0.65 mm d^{-1}. Length-weight relations were negatively associated with water temperature and growth rates. Larval age, therefore, must be considered when using length-weight relations as a

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measure of body condition.

Trophic ontogeny of red drum larvae was determined by comparing the gut contents of 553 larvae with available prey in the contiguous water column. Three size classes of feeding, planktonic larvae and two size classes of prey were identified (prey class 1 <=.12 mm width; prey class 2 >.12 mm width) through cluster analysis. Discriminant analysis confirmed the separation of larvae into feeding groups of (1) fish <2 mm; (2) fish from 2 to 4 mm; and (3) fish >4 mm. Red drum larvae from each size class selected particular prey types from within the prey size range that the larvae were capable of ingesting.

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EARLY LIFE HISTORY OF RED DRUM (*Sciaenops ocellatus*) IN THE NORTHCENTRAL GULF OF MEXICO

TECHNICAL REPORT

by

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April 1988

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ABSTRACT

Ichthyoplankton and zooplankton samples were collected in the near vicinity of a subsurface current drogue during fourteen, 24 hour cruises in late summer and fall months, 1983-85, in east Louisiana, Mississippi, and Alabama coastal and shelf waters. Peak red drum spawning in these waters occurred from early September through early October when water temperatures over the shelf were decreasing rapidly from 27-29°C in early September to 24-25°C in early October 1984 and 1985. A diel pattern in vertical distribution was evident with red drum larvae and their planktonic prey being generally more abundant higher in the water column during daylight hours and deeper at night. Surface current patterns and larval size distributions at nearshore and offshore locations led to the conclusion that the high concentrations of red drum larvae found 17-34 km offshore are probably not the source of postlarvae entering inshore nursery areas in Mississippi Sound.

Otolith growth increments were used to estimate the age of red drum larvae. Larval growth, estimated by correlating age with standard length and dry weight measurements, was positively associated with water temperature. In October 1984 when water temperatures ranged from 24.5° to 25.1°C the growth rate of 4 to 6 mm larvae averaged only 0.29 mm d^{-1}, while in September 1985 when water temperatures were up to 4°C warmer, mean growth rate increased to 0.65 mm d^{-1}. Length-weight relations were negatively associated with water temperature and growth rates. Larval age, therfore, must be considered when using length-weight relations as a measure of body condition.

Trophic ontogeny of red drum larvae was determined by comparing the gut contents of 553 larvae with available prey in the contiguous water column. Three size classes of feeding, planktonic larvae and two size classes of prey were identified (prey class 1 <=.12 mm width; prey class 2 >.12 mm width) through cluster analysis. Discriminant analysis confirmed the separation of larvae into feeding groups of (1) fish <2 mm; (2) fish from 2 to 4 mm; and (3) fish >4 mm. Red drum larvae from each size class selected particular prey types from within the prey size range that the larvae were capable of ingesting.

GENERAL INTRODUCTION

The red drum, Sciaenops ocellatus, is a highly prized sport fish, and, prior to closure of the commercial fishery in federal waters in 1986, was a valuable commercial species throughout the Gulf of Mexico (Perret et al. 1980). This fast growing, predatory species, whose young are thought to be estuarine dependent, occurs along both the Altantic and Gulf coasts. The Gulf of Mexico, however, historically accounted for more than 95% of the total U.S. value of commercial red drum landings. Increased retail demand for this species caused a rapid rise in the harvest of large, reproductively active fish. General alarm over possible depletion by overfishing of offshore populations of brood fish led to bitter conflicts between recreational and commercial fishing interests. Immediate measures were taken to either control or stop the commercial harvest of red drum in both state and federal waters. In October 1987, an amendment modifying the existing Fishery Management Plan for the Red Drum Fishery of the Gulf of Mexico went into effect. The amendment lists numerous regulations and measures, one of which is the establishment of primary (off AL, MS, and LA), and secondary (off FL and TX) management areas within federal waters. All harvest of red drum in the EEZ (exclusive economic zone) off FL and TX is unconditionally prohibited, but directed commercial harvest of red drum off AL, MS, and LA can resume once it has been determined that a surplus in spawning stock necessary for optimum production exists.

Yet knowledge of adult stock size alone is not a complete foundation on which to base harvest predictions, and in turn, rational and equitable fishery management regulations. The proportionally high and variable mortality experienced by the early life stages of pelagic, marine fishes, ie. within approximately the first 100 days after egg fertilization and prior to recruitment into the fishable population, is thought to cause major fluctuations in fish biomass and subsequent year class abundance (Parrish 1973). Knowledge of the recruitment process itself (early ecology, growth and survival) and the causes of recruitment variability will lead to more economical and biologically sound use of fishery resources (Sharp 1980, Gulland 1982, Smith 1985).

Recent studies of red drum have focused on these important early life history stages. Larval development and diel spawning periodicity have been described (Holt et al. 1981a, 1985). The influence of temperature and salinity on hatching and larval survival has been documented with laboratory experiments (Holt et al. 1981b). The only published accounts of the seasonal abundance and distribution of young red drum come from Texas (Pearson 1929, Miles 1950, Simmons and Breuer 1962, King 1971, Holt et al. 1983), or Florida (Yokel 1966, Jannke 1971, Peters and McMichael 1987), and are based, for the most part, on collections in nearshore and/or estuarine habitats. Growth and length-weight relations of larvae (Lee et al. 1984), and juveniles (Crocker et al. 1981) under varying temperatures and salinities have been studied in the laboratory. Growth rates in the field have been calculated for both larvae and juveniles in Tampa Bay, Florida (Peters and McMichael 1987), and for juveniles in Louisiana waters (Bass and Avault 1975). The food habits of young red drum in nearshore and estuarine nursery areas have been described (Bass and Avault 1975, Steen and Laroche 1983, and Peters and McMichael 1987). However, despite these important contributions, knowledge of the early life history of red drum in the Gulf of Mexico, particularly in northcentral Gulf waters, is inadequate to describe the recruitment process in this species.

The overall objectives of the study described in this report were to 1.) characterize diel, vertical, and horizontal patterns in the distribution of red drum larvae and their planktonic prey in offshore waters; 2.) document trophic ontogeny and prey selectivity; and 3.) determine growth rates of field-caught larvae using otolith growth increment methodology.

GENERAL MATERIALS AND METHODS

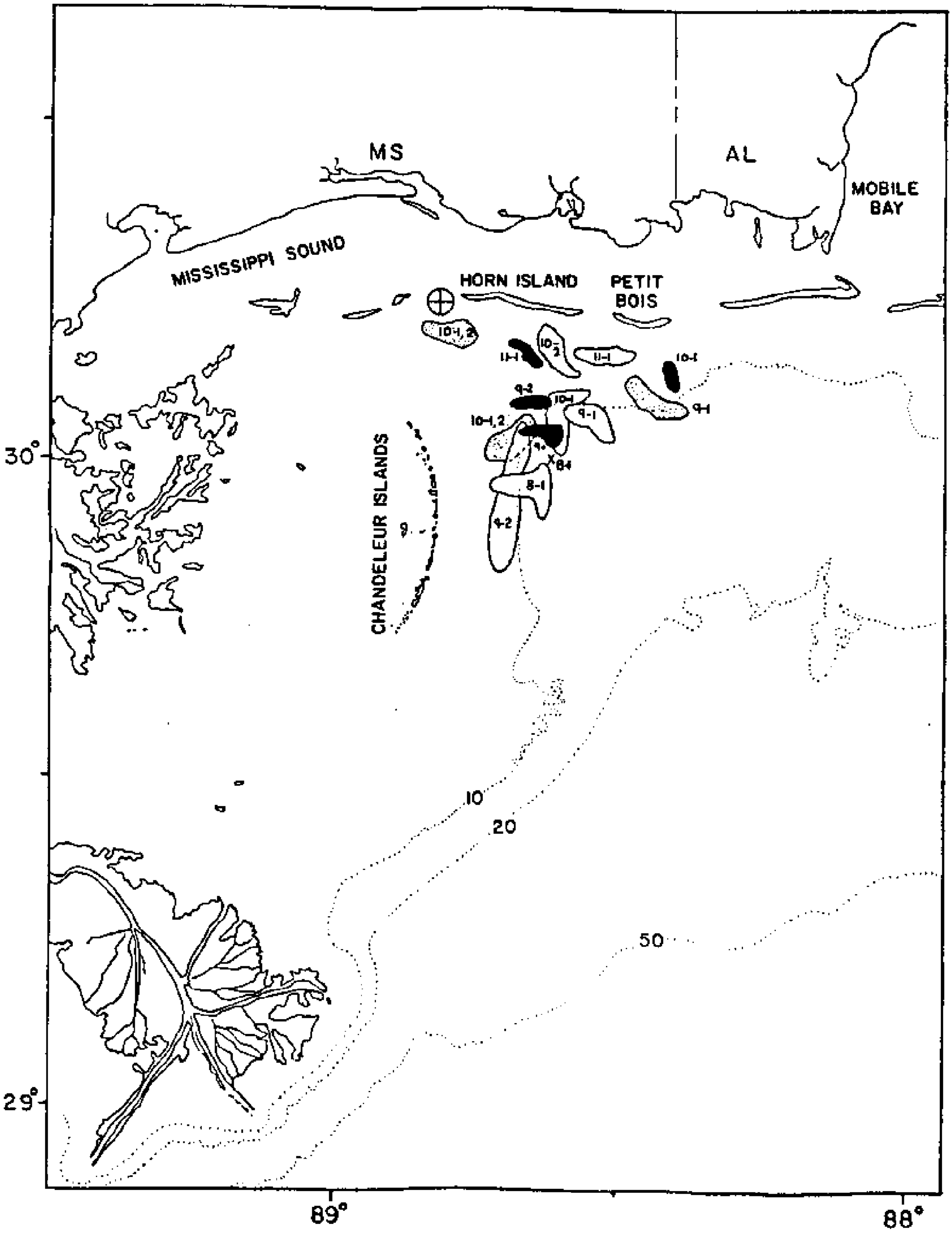
Ichthyoplankton and zooplankton samples were collected during fourteen cruises in late summer and fall months from 1983 through 1985 (Table 1). Cruises were designated by year-month-1 or 2 (when more than one cruise was conducted during that month). A total of two cruises were conducted in the month of August, five in September, five in October, and two in November. The general area sampled was located south of Horn and Petit Bois Islands, and east of the Chandeleur Islands in water depths ranging from 12 to 21m (6 to 12fm; Figure 1). Biological collections were taken in the near vicinity of a subsurface current drogue as it was tracked from the ship throughout the duration of a cruise. The one exception to this protocol was cruise 85-8 when sea conditions were too severe to deploy the drogue. The "windowshade", subsurface current drogue (Dr. Bert Greene, NORDA-NSTL, pers. commun.) consisted of a 1.5 by 3m sheet of polyethylene plastic suspended approximately 1m below a buoyed radio transmitter and antenna to which a flashing, battery operated strobe light and photocell were mounted. An additional series of collections besides those associated with the drogue were taken near Dog Keys Pass at the west end of Horn Island in 12m water depth during cruises in September and October 1984 and September 1985 (Figure 1).

While ten of the cruises were each conducted during one, 24 hr period, two cruises, 84-10-2 and 84-11, extended over 48 and 36, hr periods, and two other cruises, 85-8 and 85-11, were less than 24 hrs in duration. In 1983 sampling

Table 1. Summary of temporal coverage, sampling gear used, and number of ichthyoplankton collections taken in east Louisiana-Mississippi-Alabama coastal and shelf waters during 1983-1985 which were examined for red drum larvae. Gear type codes are: TT = 1 m Tucker Trawl; BN = 60 cm bongo net. Numbers in parenthesis () are the number of collections taken with that gear type and mesh size.

Cruise	Dates	Gear Type and Mesh Size (microns)	Total No. of Collections
83-9	09/20-21/83	BN-202(9); TT-333(13), 505(3), 760(6)	31
83-10-1	10/6-7/83	BN-202(9); TT-333(16)	25
83-10-2	10/18-19/83	BN-202(9); TT-333(42)	51
84-8	08/30-31/84	TT-333(9)	9
84-9-1	09/13-14/84	TT-202(2), 333(30), 505(3), 760(3)	38
84-9-2	09/26-27/84	TT-333(11), 505(1), 760(1)	13
84-10-1	10/10-11/84	TT-333(17)	17
84-10-2	10/23-25/84	TT-333(19)	19
84-11	11/7-9/84	TT-202(9)	9
85-8	08/28/85	TT-333(3)	3
85-9-1	09/11-12/85	TT-333(30), 505(1)	31
85-9-2	09/25-26/85	TT-333(10)	10
85-10	10/10-11/85	TT-333(9)	9
85-11	11/4/85	TT-333(5)	5

Figure 1: Plankton sampling locations as outlined by drogue track envelopes labeled with month and cruise number. Stippled envelopes = 1983 cruises, Open envelopes = 1984 cruises, and Solid envelopes and X = 1985 cruises. ⊕ = nearshore collection site near Dog Keys Pass in 1984 and 1985. (depth in fms).



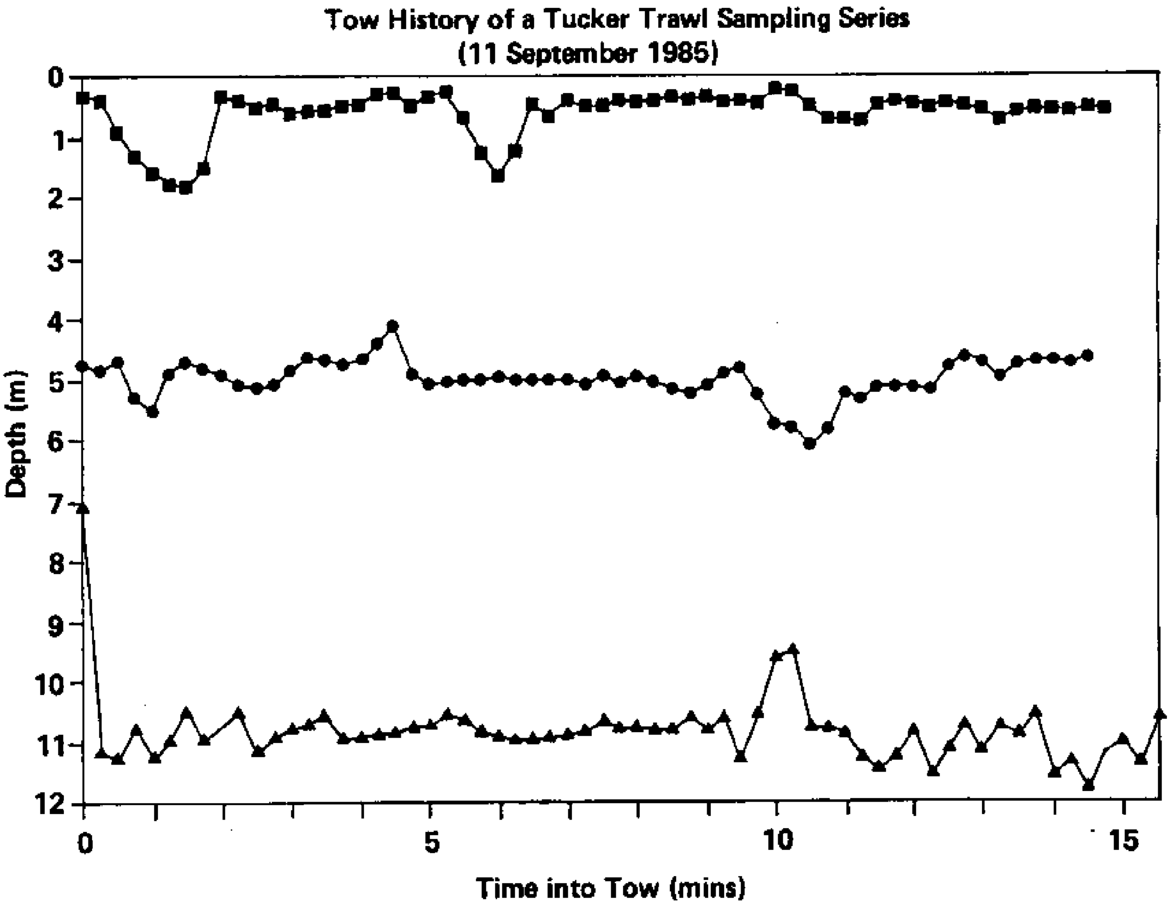
was conducted around-the-clock, but in 1984 and 1985 collection series generally were made at three discrete time periods beginning at midday, and shortly after sunset and sunrise.

The primary ichthyoplankton sampling gear used was an opening-closing, multiple net, one meter square Tucker trawl. The Tucker trawl design consists of three nets which are operated manually with messengers. Net mesh sizes used included 202, 333, 505, and 760 microns, but 90% of all collections examined for red drum larvae were taken with 333 micron mesh nets (Table 1). In addition to the Tucker trawl samples, twenty-eight collections were taken on 1983 cruises with a 60 cm bongo net with 202 micron mesh netting. All net tow paths were horizontal, and most hauls were approximately 5 min in duration. During the 1983-85 cruises, three nominal depth strata; near-surface or 1m, mid or 3-5m (most usually 5m), and lower or 7-16m (most usually 10-12m), were sampled in each of three time periods. Generally all three nets of the Tucker trawl were deployed and fished in tandem at one depth at a time ,thus providing replicate samples. Digital flowmeters positioned off center in each Tucker trawl and bongo net measured volume filtered.

Sampling depths on cruises in 1983 were monitored and maintained by measuring and adjusting wire angle. In subsequent years, net depth was monitored throughout each tow via the depth sensor of an electronic CTD probe package which was mounted 0.5m above the Tucker trawl on the conducting/towing cable. Target or nominal sampling depths were maintained throughout each tow by adjusting the amount of wire out (Figure 2). Except for the near-surface or 1m depth stratum, actual sampling depths exceeded nominal depths by 0.5m.

Vertical profiles of temperature and salinity prior to each sampling series were obtained with an induction salinometer in 1983, and with the

Figure 2: Tow records of a Tucker trawl sampling series consisting of three nets fished sequentially for 5 minutes each at nominal depths 1, 5, and 11 meters.



electronic CTD unit in 1984-85. This CTD system, integrated with both ichthyoplankton and zooplankton sampling apparatus, displayed temperture, salinity, and depth in real time, while storing these data on magnetic disc within a shipboard computer.

Ichthyoplankton samples were preserved at sea in either 95% ehtanol or 5-10% formalin. In the lab all fish larvae were removed from either the entire sample (most samples from cruises 83-9, 83-10-1&2, and 84-9-1), or a one-half aliquot (samples from all remaining cruises except cruise 84-11 for which one-quarter aliquots were sorted). Sample aliquots were obtained using a Motoda plankton splitter (Van Guelpen et al. 1982). Ethanol preserved larvae were used for age and growth analyses, and formalin preserved larvae were used in diet analyses (see appropriate sections of this report for detailed methodology). Standard length (SL) of red drum larvae was measured to the nearest 0.1 mm under a stereomicroscope.

Micro and nannoplankton were collected on deck by filtering approximately 0.3 to 0.5 m^3 of water through nested 63 and 25 micron mesh nets. Water was pumped up from the same depths as the ichthyoplankton collections with a 38 l per min capacity diaphram pump. Zooplankton samples were preserved in 5% formalin. Phytoplankton samples for species identification and enumeration, and chlorophyll determination by spectrophotometric methods, were collected by vacuum filtering approximately one liter of water through a 0.8 micron membrane filter.

Section 1. HYDROGRAPHY

Temperature and Salinity

A distinct seasonal pattern of decreasing water temperatures during late summer and fall months, 1983-85 was evident in northcentral Gulf coastal waters (Table 2). Temperatures within the upper 10-13 m generally ranged from 27-29°C in August and September, 24-26°C in October, and 22-23°C in early November. A seasonal trend in salinity was not as evident; there being more variation in salinity than temperature both within and among years. Salinities within the upper 10-13 m generally ranged from 25-34 ppt in August and September, 28-34 ppt in October, and 32-35 ppt in early November. Values outside the generalized ranges in temperature and salinity for August and September were recorded at 10-13 m in August 1984. These measurements were: 22.7-25.3°C, and 35.7-36.6 ppt. Vertical profiles of temperature and salinity (Appendix Table 1) indicated that from September to early November the water column in the sampling region was relatively well mixed (Plates 1-14). In the month of August a well defined thermocline/halocline was present between 5 and 8 m in 1984 (Plate 4). No such feature was observed in August 1985, however, this may have been due in part to the fewer measurements taken in 1985 than in 1984.

Subsurface Currents, Winds, and Tides

Use of the subsurface current drogue as a reference point presumably ensured repeated sampling within the same ichthyoplankton-zooplankton assemblage, and provided a record (drogue track) of water movement within the upper 5m of the water column for each sampling period. The following paragraphs and figures (drogue tracks) summarize water movements, and wind and tidal data for thirteen cruises in 1983-85. Wind observations were taken from

Table 2. Summary of water temperature and salinity measurements made during late summer and fall months (1983-85) in nearshore LA-MS-AL coastal waters at nominal depths of plankton collections.

Cruise	Dates	Temperature Range (°C)			Salinity Range (°/oo)		
		1m	5m	≥8m	1m	5m	≥8m
83-9	09/20-21/83	28.0-28.5	28.0-28.5	27.9-28.7	26.2-28.1	26.3-27.6	26.1-28.7
83-10-1	10/6-7/83	25.5-26.5	25.5-26.2	25.5-26.0	27.4-30.0	27.6-30.3	26.8-29.9
83-10-2	10/18-19/83	24.0-24.5	24.0-24.3	23.7-24.3	28.6-29.8	28.6-29.6	28.3-29.2
		1m	5m	10-13m	1m	5m	10-13m
84-8	08/30-31/84	28.3-28.7	27.1-28.5	22.7-25.3	27.5-28.1	28.1-34.7	35.7-36.6
84-9-1	09/13-14/84	27.9-28.6	27.4-28.1	27.5-27.8	28.5-31.3	31.1-32.0	32.6-34.5
84-9-2	09/26-27/84	26.4-27.1	26.4-26.8	26.3-26.5	29.0-31.1	31.2-32.3	31.4-32.8
84-10-1	10/10-11/84	24.5-25.1	24.5-25.0	24.7-25.1	31.4-32.4	31.5-32.4	31.8-32.9
84-10-2	10/23-25/84	25.6-25.9	25.7-26.0	25.5-25.8	28.6-29.7	29.1-29.8	30.8-33.0
84-11	11/7-9/84	23.4-23.7	23.3-23.7	23.4-23.8	33.4-34.5	33.5-35.7	33.7-34.4
85-8	08/28/85	28.6-28.8	28.7-28.8	28.7-28.8	25.1-25.5	25.1-25.7	25.3-25.7
85-9-1	09/11-12/85	28.7-29.4	28.0-29.0	27.8-28.0	30.2-30.5	30.4-30.9	31.0-32.0
85-9-2	09/25-26/85	26.6-27.1	26.4-27.1	26.6-27.2	27.9-28.5	28.0-28.5	29.2-30.2
85-10	10/10-11/85	24.9-25.3	25.0-25.3	24.9-25.2	32.9-33.5	32.9-33.5	33.3-34.1
85-11	11/04/85	22.1-22.2	22.2	---	32.0-32.6	32.1-32.6	---

the ship at approximately two hour intervals when drogue position was recorded. Times of high and low tides are presented for the duration of the cruise only.

Cruise 83-9, 20-21 September 1983 (Figure 3): The drogue was tracked for 9 hr and 45 min after deployment at 30°03.90'N latitude and 88°25.41'W longitude at 1130 hr CST. It was retrieved at 2115 hr at coordinates 30°06.96'N, 88°28.42'W because heavy squalls had moved into the area and it was feared that the drogue would be lost during the night. The drogue moved in a WNW direction for the 7 hr and 40 min that it was tracked prior to the influence of the disturbed weather. During that time, it moved a total of 2 nm at a mean drift rate of 0.26 kt. At the time of its pickup, the drogue had moved 2.8 nm north of the 1930 hr position indicating a drift rate of 1.6 kt. Wind direction during the first 6 hr of the cruise was from the S. Wind speed gradually diminished during that period from 20 to 4 kt. Between 1930 and 2115 hr CST the wind shifted to the NW at 10 kt. After 2300 hr the wind blew from the SW at over 15 kt until 0500 hr when it shifted to the W and WNW and increased in speed to 22 kt. High tide on the 20th and 21st occurred at 0921 and 1020 hr, low tide occurred at 1912 hr on the 20th (Horn Island Pass reference station).

Cruise 83-10-1, 6-7 October 1983 (Figure 4): During this cruise the drogue was deployed and tracked from two separate locations, one at 5 nm and the other 12 nm south of the west end of Horn Island. At the nearshore or 12 m location the drogue was tracked for 9 hr and 51 min after deployment at 30°09.70'N latitude, 88°46.64'W longitude at 1310 hr CST. At this location it moved to the NW, then to the E and finally to the NW again, covering a total of 0.96 nm at a mean drift rate of 0.10 kt. At the offshore or 18 m location the drogue was tracked for 5 hr and 56 min after deployment at 30°03.04'N latitude,

Figure 3: Drogue track from cruise 83-9

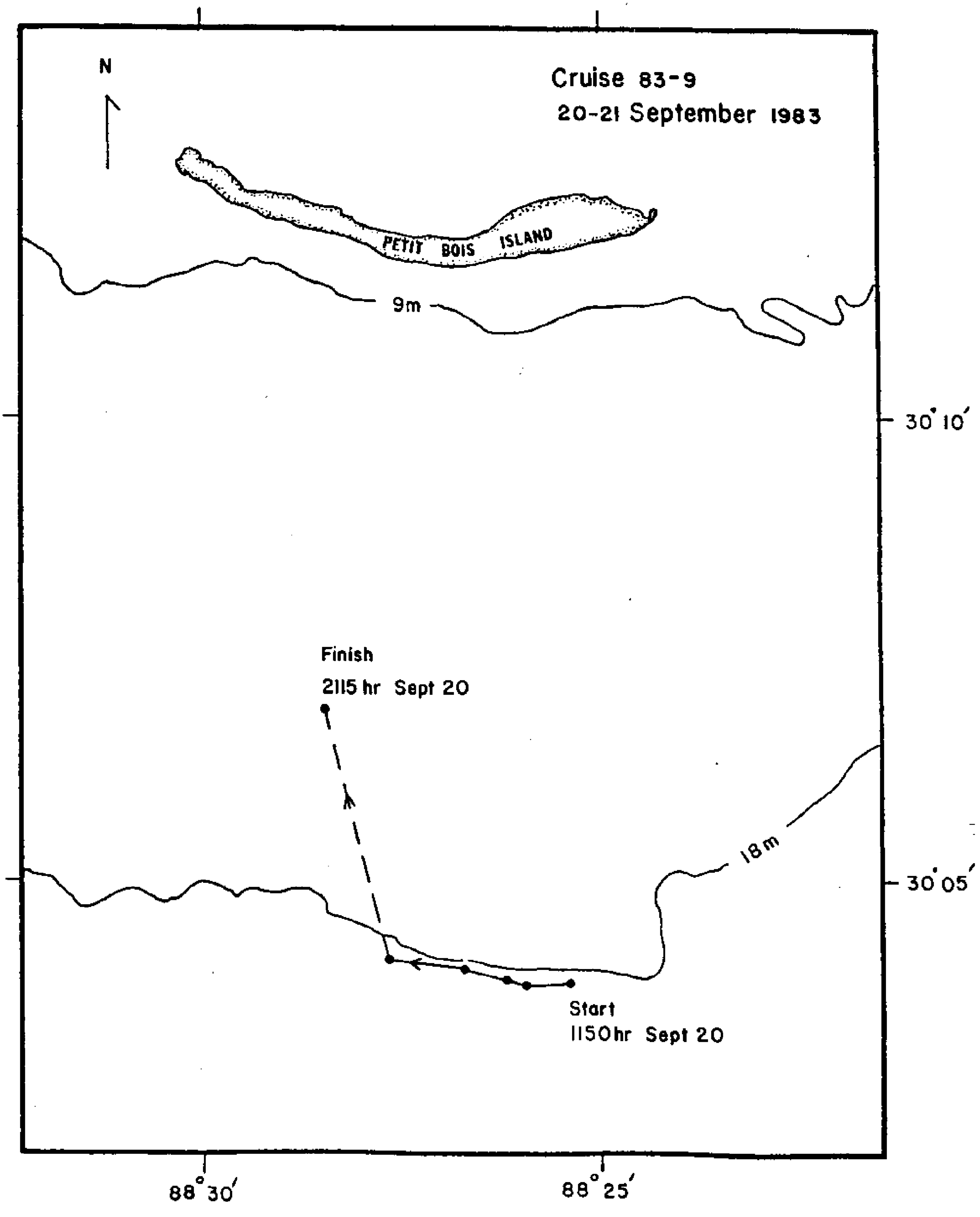
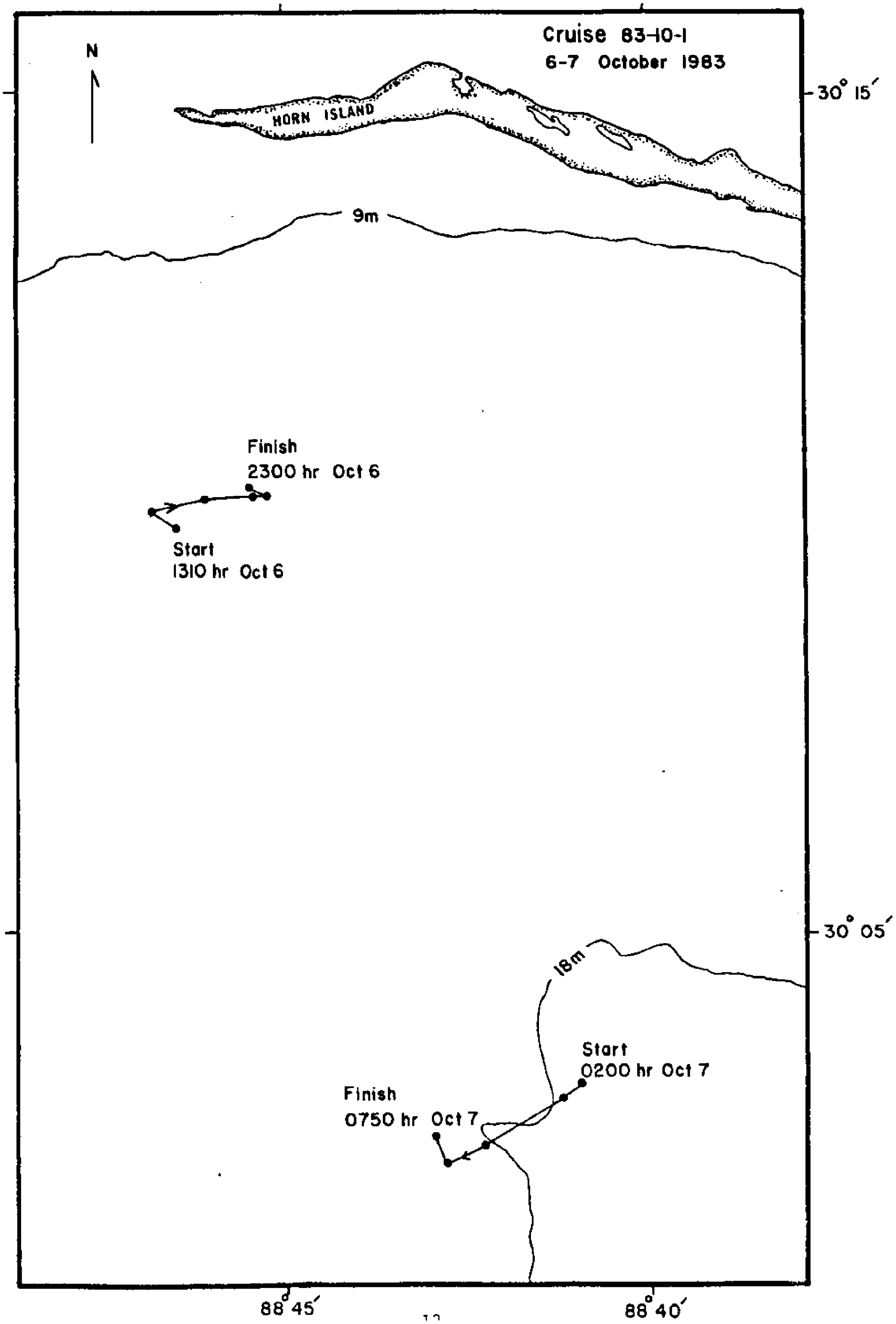


Figure 4: Drogue track from cruise 83-10-1



88°40.90'W longitude at 0200 hr CST. Between 0200 and 0700 hr it moved towards the SW, but during the last 50 min prior to pickup it moved NNW. At this second location the drogue covered 1.87 nm at a mean drift rate of 0.32 kt. Throughout most of the cruise wind direction was generally N or NE. Wind speeds ranged from 2 to 6 kt between 1300 to 1500 hr, and from 12 to 18 kt during the remainder of the cruise. Two low tides, at 0456 and 1622 hr, and two high tides, at 1247 and 2202 hr, occurred on the 6th. While the more usual single low tide, 0714 hr, and single high tide, 2226 hr, occurred on the 7th (Chandeleur Light Reference Station).

Cruise 83-10-2, 18-19 October 1983 (Figure 5): During this second cruise in October the drogue was deployed and tracked from approximately the same two locations as in cruise 83-10-1. At the 12 m location the drogue was tracked for 10 hr and 31 min. During that time it moved to the NE, then N, and finally NW, covering 1.74 nm at a mean drift rate of 0.17 kt. At the 18 m location the drogue moved S and then gradually turned towards the W during the 9 hr and 52 min in which it was tracked. At this second location the drogue track covered 2.3 nm at a mean drift rate of 0.23 kt. Thoughout the cruise the wind was generally from the E at speeds of 8 to 10 kt. On the 18th, low tide occurred at 0739 hr and high tide at 1706 hr. On the 19th, high tides occurred at, 0912 and 2145 hr, and low tide occurred at 1631 hr.

Cruise 84-8, 30-31 August 1984 (Figure 6): The drogue was tracked for 22 hr and 32 min after its deployment at 30°00.97'N latitude, and 88°39.57'W longitude at 1018 CST. Initially the drogue moved due S but gradually turned to a more SW direction. Between 2000 and 2200 hr the direction of movement was NW. The drogue eventually headed N, then NE, and between 0400 and 0600 hr it crossed its earlier path and moved in a S by SE direction. Drift rates ranged

Figure 5: Drogue track from cruise 83-10-2

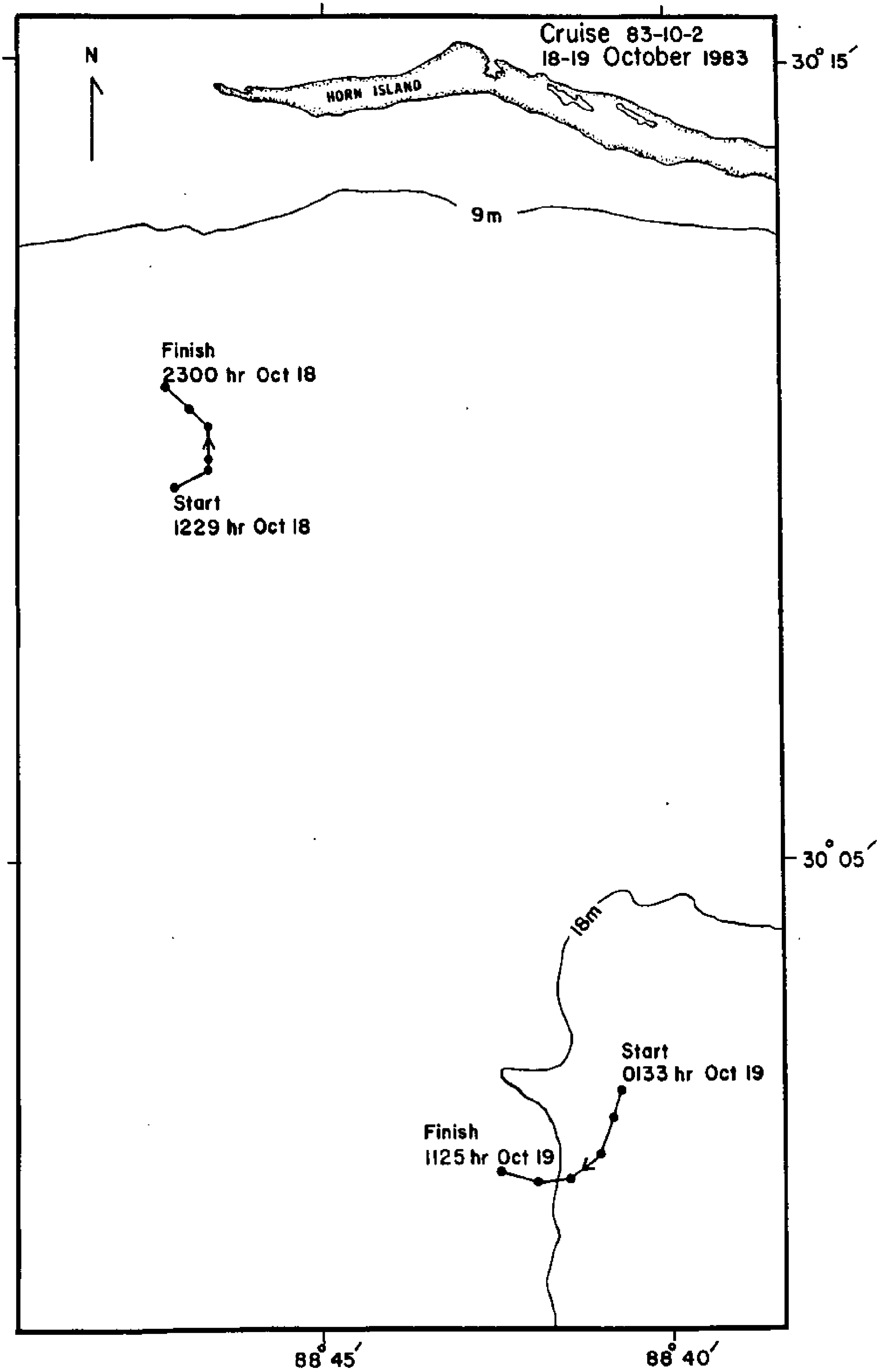
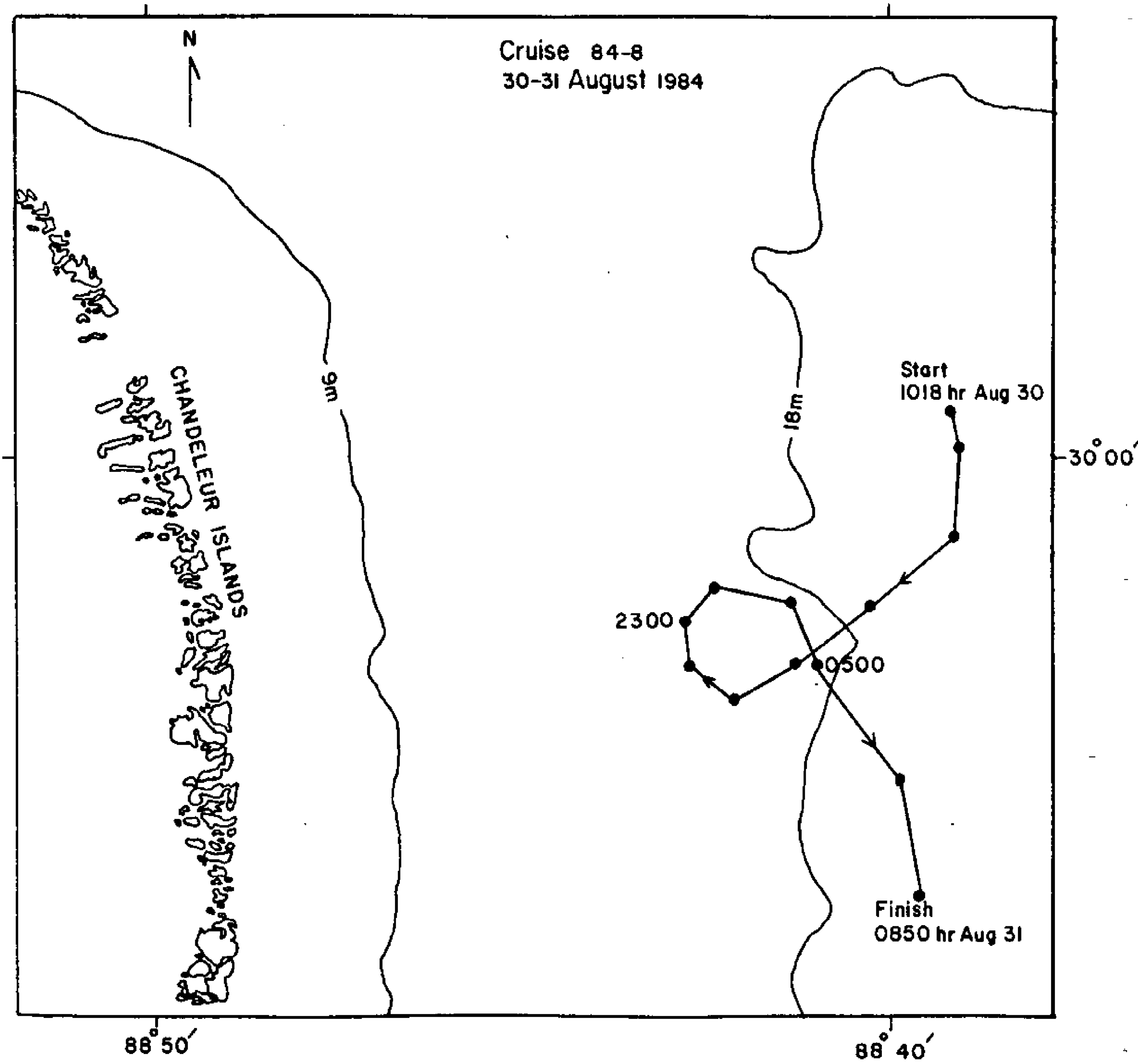


Figure 6: Drogue track from cruise 84-8



from 0.25 kt (northerly movement) to 0.79 kt (southeastly movement) with a mean rate of 0.53 kt. Winds throughout the cruise were generally from the SE or SSE and usually at speeds of 2 to 4 kt increasing to 10 kt at night. Low tide on the 30th was at 1000 hr, while the subsequent high tide occurred at 0116 hr on the 31th, and the next low tide was at 1221 hr (Chandeleur Light reference station).

Cruise 84-9-1, 13-14 September 1984 (Figure 7): The drogue was tracked for 22 hr and 30 min after deployment at 30°03.19'N latitude and 88°35.90'W longitude at 1130 hr CST. Initially the drogue moved towards the W but turned to the N, then to the NE and E, and finally to the SE. Rates of drift ranged from 0.1 to 0.6 kt with a mean rate of 0.3 kt. Wind direction changed three times during the cruise; from 1130 to 1800 hr winds were generally from the E, after 1800 hr winds were from the SW to S, and after 0400 hr they were from the W. Wind speed ranged from 2 to 12 kt. On the 13th low tide occurred at 0727 hr and high tide occurred at 2356 hr. On the 14th low tide occurred at 0917 hr (Horn Island Pass reference station).

Cruise 84-9-2, 26-27 September (Figure 8): The drogue was tracked for 23 hr and 52 min after deployment at 30°03.77'N latitude, and 88°41.15'W longitude at 1036 hr CST. Initially the drogue moved to the SW but after 1500 hr, and until the time of pickup, it consistently held a southerly course, S by SE or SW. Rate of drift averaged 0.49 kt. Winds during the cruise were quite variable both in speed and direction. For about the first 12 hr into the cruise the wind shifted from E (10 to 4 kt) to S (<4 kt) to the W and WNW (4 to 14 kt). From 2301 to 0359 hr wind direction was from the NNW at 14 kt. No wind observations were made between 0359 and 0600 hr. After 0600 hr the wind blew consistently from the NE to N at 20 kt. until 0800 hr when wind speed

Figure 7: Drogue track from cruise 84-9-1

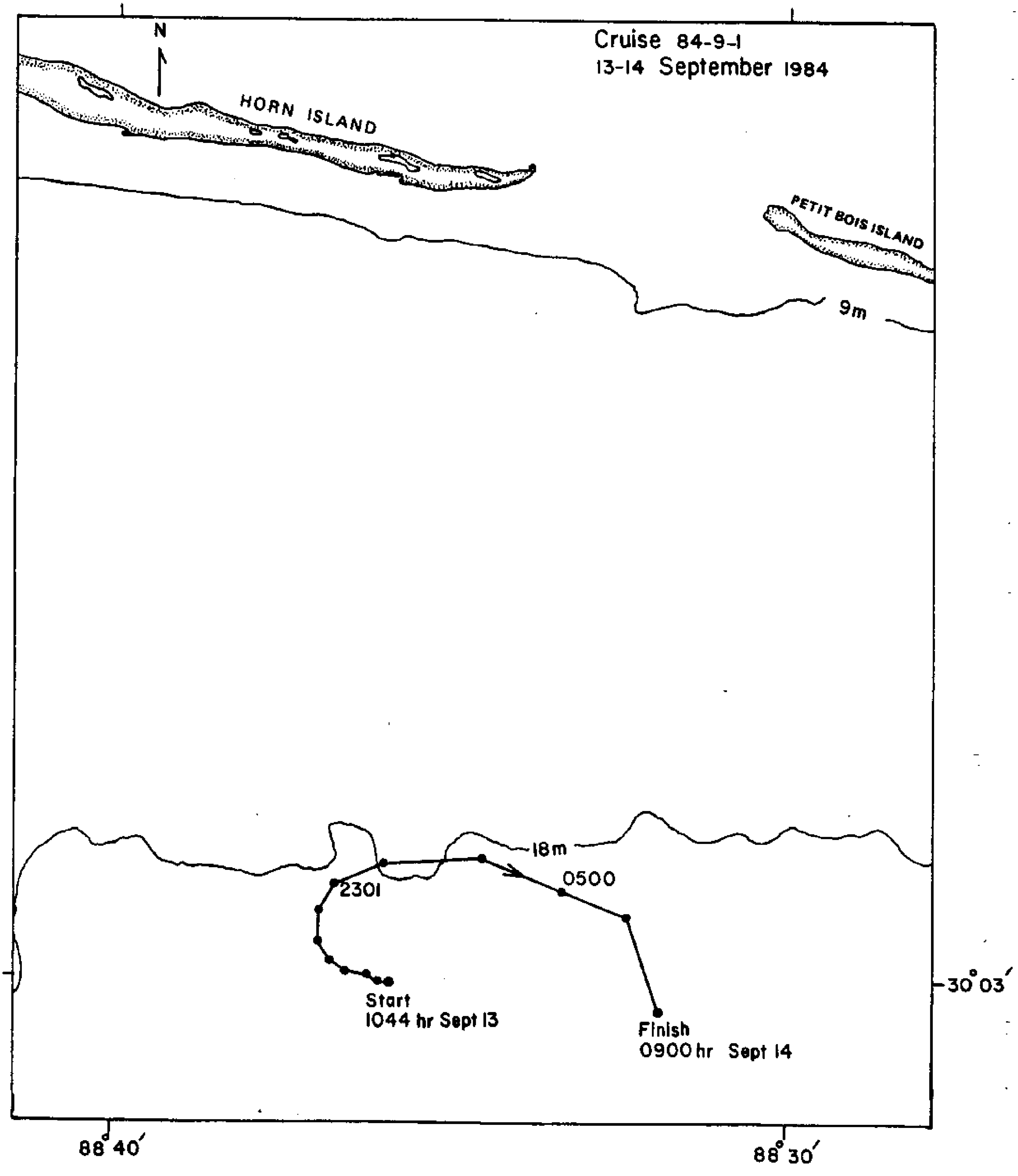
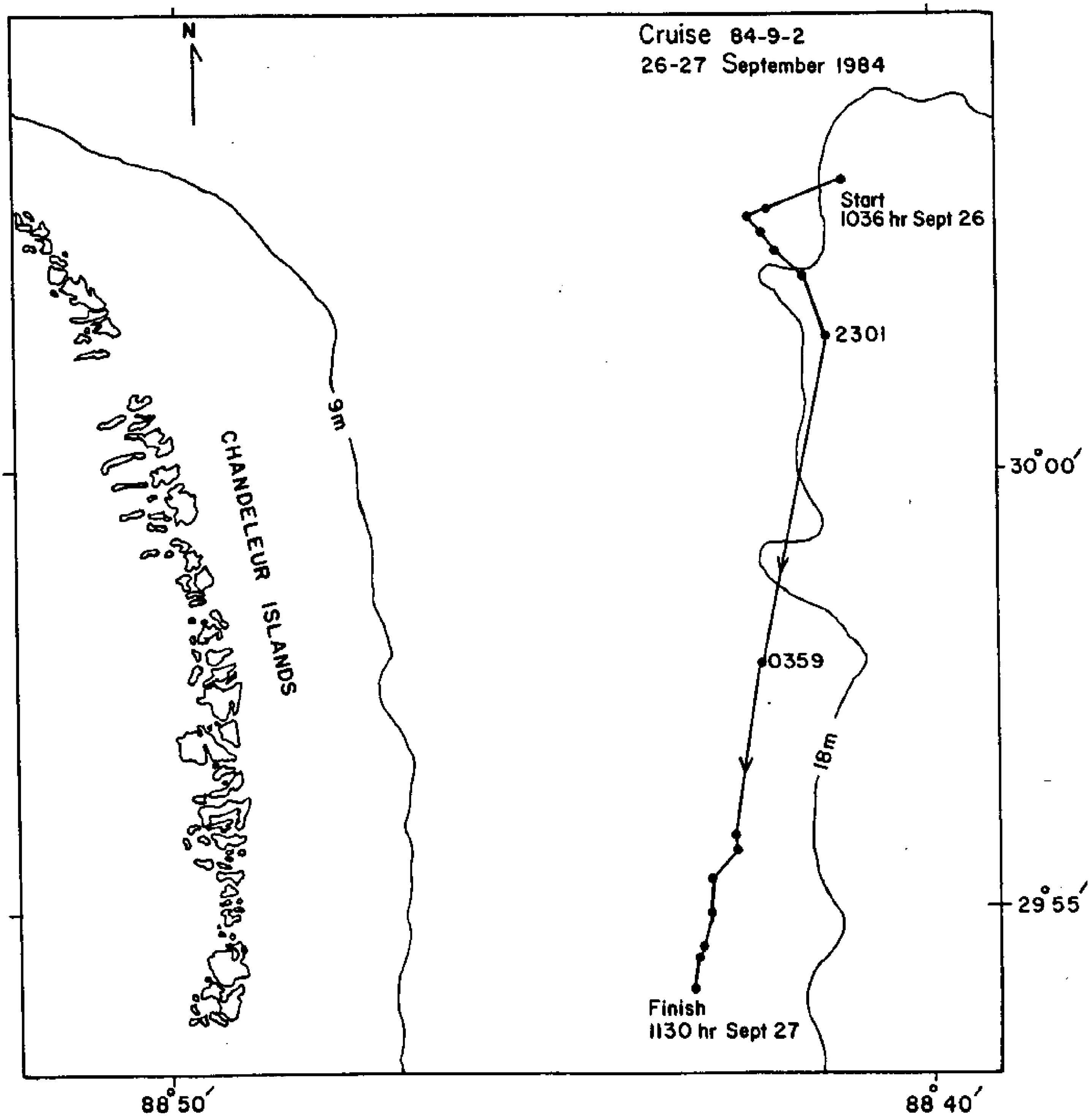


Figure 8: Drogue track from cruise 84-9-2



diminished to 12 kt. On the 26th low tide occurred at 0706 hr and high tide occurred at 2256 hr. On the 27th low tide occurred at 0910 hr (Chandeleur Light reference station).

Cruise 84-10-1, 10-11 October 1984 (Figure 9): The drogue was tracked for 23 hr and 30 min after deployment at 30°05.45'N latitude, and 88°36.97'W longitude at 1110 hr CST. The drogue moved in a westerly direction until 2100 hr. Afterwards and until pickup at 1050 hr its direction of movement was generally to the S. Mean drift rate during this period was 0.32 kt. Winds during the first twelve hours of the cruise were from the E and SE. Wind speed diminished throughout this period from 23 to 7 kt. After a calm period between 2300 and 0100 hr the winds gradually increased from 7 to 14 kt, and were generally from the N and NE. On the 10th low tide occurred at 0646 hr while high tide occurred at 2159 hr. On the 11th low tide occurred at 0759 hr (Chandeleur Light reference station).

Cruise 84-10-2, 23-25 October (Figure 10): The drogue was tracked for 48 hr and 48 min after deployment at 30°07.23'N latitude, and 88°40.64'W longitude at 1150 hr CST. After initially moving to the S, the drogue took a northerly course after 1700 hr. Between 2100 hr on the 23rd and 1700 hr on the 24th, the drogue track was elliptical in shape. Between 1700 and 2300 on the 24th the drogue moved 2 nm to the N. In the early morning hours on the 25th, the drogue moved in a relatively straight line to the E. After 0630 hr and until pickup at 1138 hr its course was NW. Drift rates during the cruise ranged from 0.03 to 0.69 kt with mean of 0.35 kt. Wind direction was consistently from the SE during the entire cruise. Wind speeds were generally 9-13 kt during the first two days, but increased to over 18 kt on the final day of the cruise. Low tide occurred at 0502 hr on the 23th, 0637 hr on the 24th, and 0801 hr on the 25th.

Figure 9: Drogue track from cruise 84-10-1

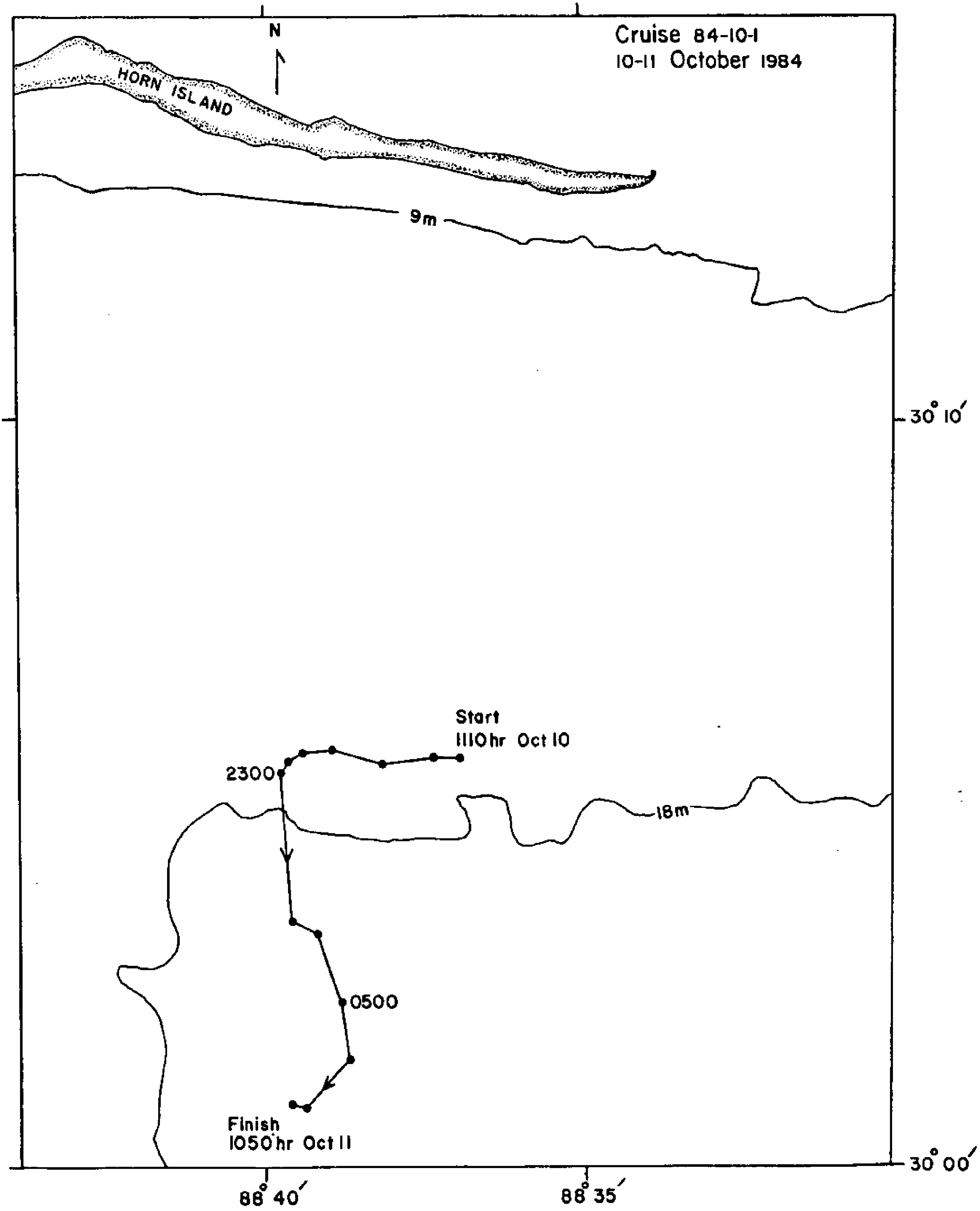
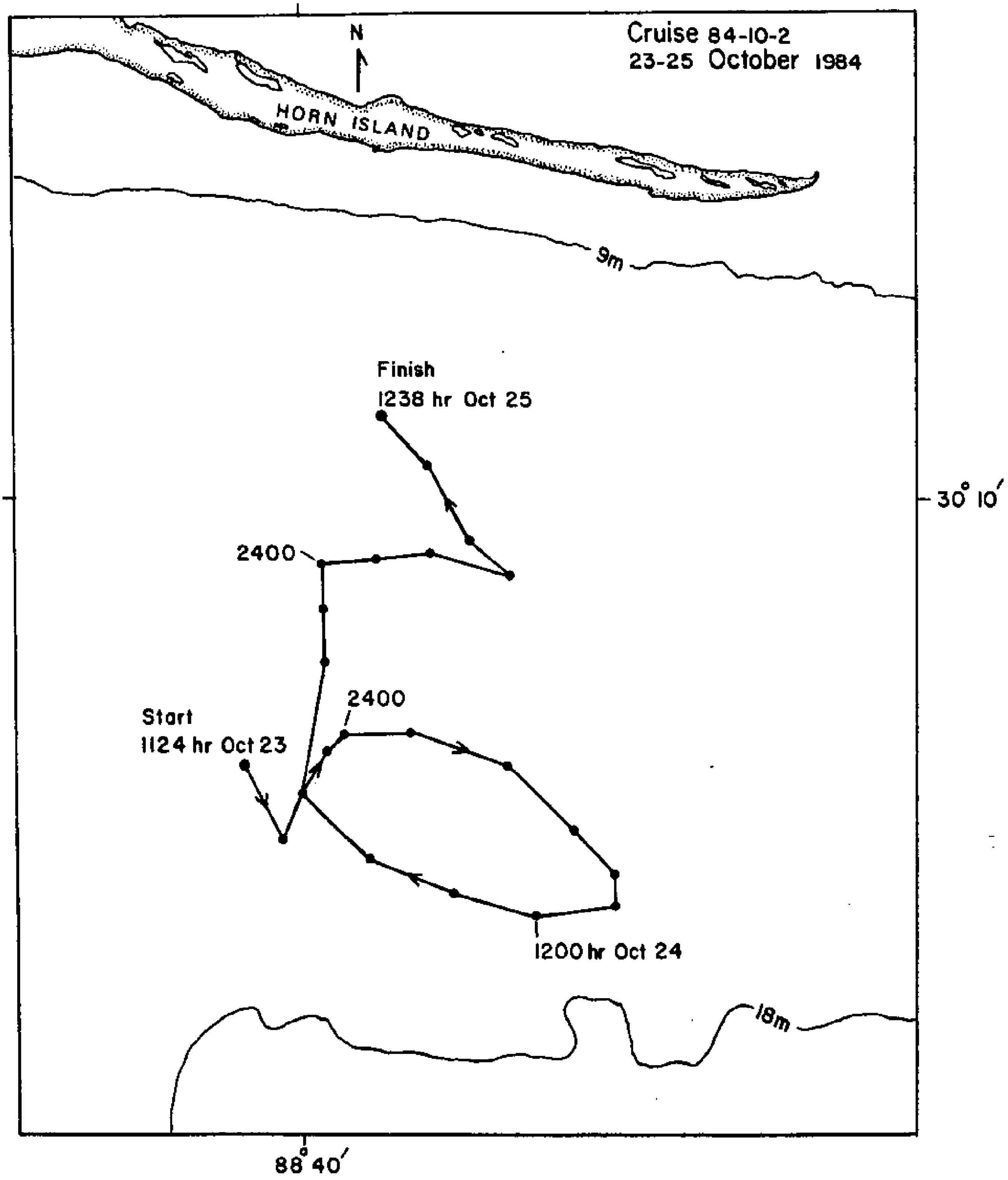


Figure 10: Drogue track from cruise 84-10-2



High tide occurred at 2115 hr on the 23th, 2147 hr on the 24th, and 2222 hr on the 25th (Horn Island Pass reference station).

Cruise 84-11, 7-9 November 1984 (Figure 11): The drogue was tracked for 33 hr and 34 min after deployment at 30°06.65'N latitude, and 88°29.72'W longitude at 1345 hr CST. Except for two excursions to the SW, the drogue generally moved in a W by NW direction throughout the cruise. Rates of drift ranged from 0.10 to 0.74 kt with a mean rate of 0.29 kt. Wind direction was E or SE at speeds generally over 13 kt. Low tide occurred at 0628 hr on the 7th, 0703 hr on the 8th, and 0849 hr on the 9th. High tide occurred at 2114 hr on the 7th, 2136 hr on the 8th, and 2103 hr on the 9th (Horn Island Pass reference station).

Cruise 85-9-1, 11-12 September (Figure 12): The drogue was tracked for 24 hr and 40 min after deployment at 30°02.66'N latitude, and 88°36.20'W longitude at 1150 hr CST. Initially the drogue moved in a southerly direction but after 2000 hr it moved towards the NW. Between 0400 and 0600 hr it moved to the NE, afterwhich it moved consistently to the W until the time of pickup. Rates of drift throughout the cruise ranged from 0.1 to 0.5 kt with a mean rate of 0.3 kt. Wind direction was variable: NW to WNW between 1150 and 1500 hr (on the 11th) to SSW between 2400 and 0200 hr (on the 12th); and finally NNE to NE to E from 0400 to 1230 kt (on the 12th). Wind speeds ranged from 2 to 10 kt during the cruise but were most generally only 2 to 3 kt. On the 11th and 12th high tides occurred at 0730 and 0800 hr, and low tides at 1828 and 1910 hr (Chandeleur Light reference station).

Cruise 85-9-2, 25-26 September 1985 (Figure 12): The drogue was tracked 23 hr and 20 min after deployment at 30°04.02'N latitude, and 88°40.87'W longitude at 1030 hr CST. Initially the drogue moved to the NW, then it

Figure 11: Drogue track from cruise 84-11

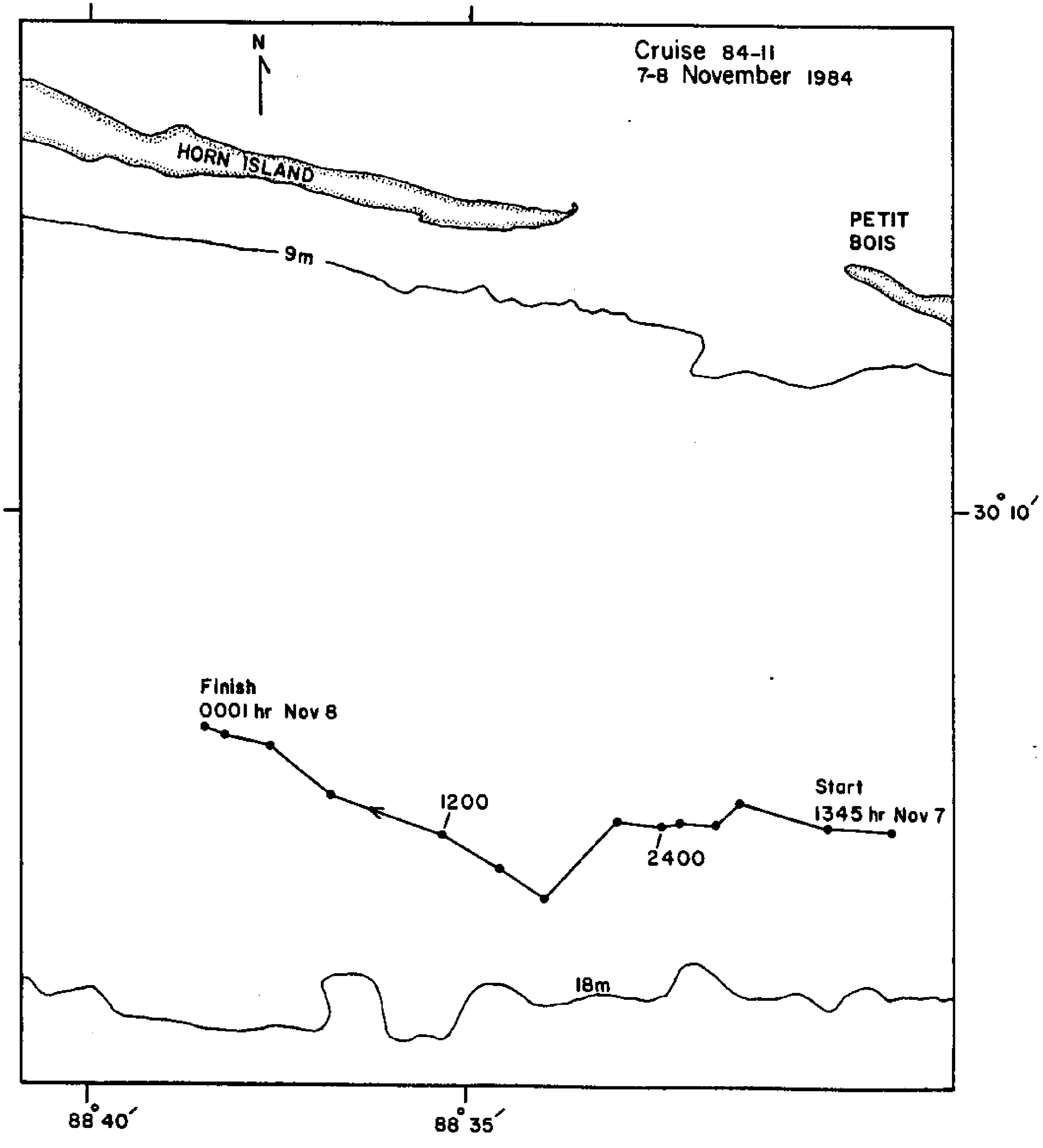
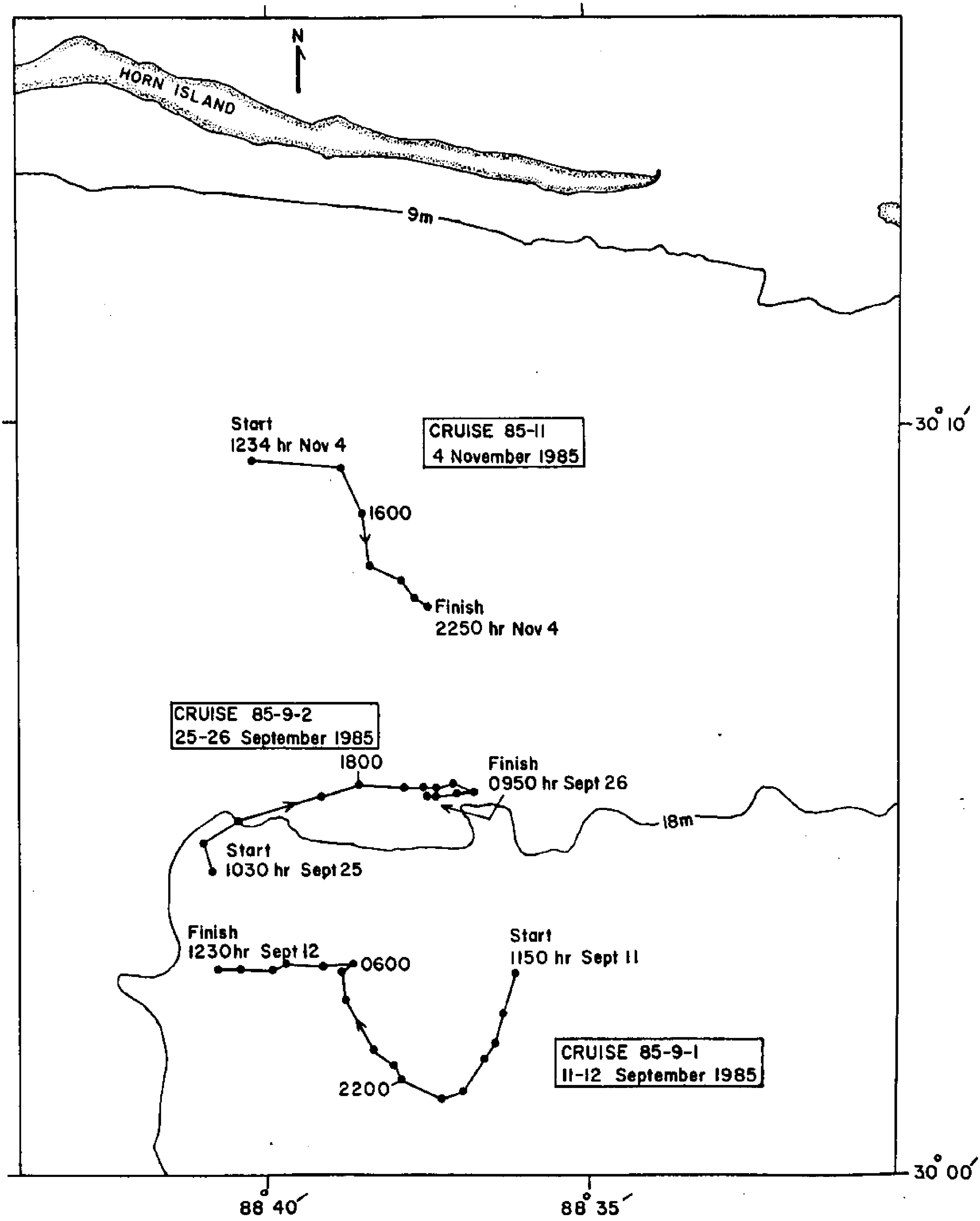


Figure 12: Drogue tracks from cruises 85-9-1, 85-9-2, 85-11

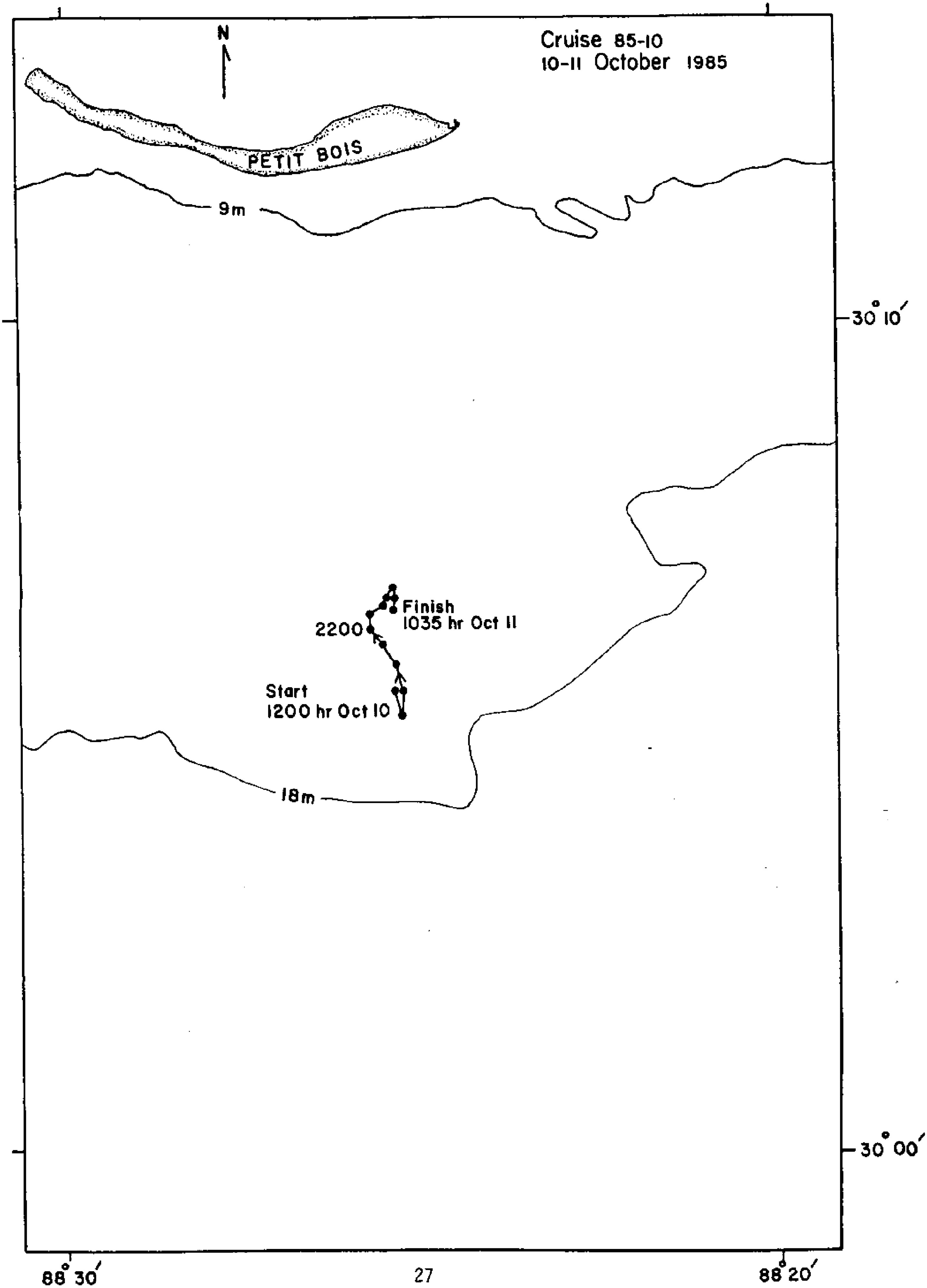


gradually took a NE to E course which was maintained until 0600 hr, afterwhich time it moved to the W until pickup at 0950 hr. Rates of drift throughout the cruise ranged from 0.1 to 0.5 kt with a mean rate of 0.2 kt. Wind direction was primarily from the S and SW throughout the entire cruise. Wind speeds ranged from 5 to 10 kt during this cruise but were most usually only to kt. High tide on the 25th and 26th occurred at 0620 and 0826 hr. while low tide occurred on at 1832 and 1904 hr on those days (Chandeleur Light reference station).

Cruise 85-10, 10-11 October 1985 (Figure 13): The drogue was tracked for 22 hr and 35 min after deployment at 30°05.48'N latitude, and 88°25.34'W longitude at 1200 hr CST. Initially the drogue moved in a southerly direction but after 1400 hr it moved towards the N. After 0600 hr the drogue again moved towards the S and maintained this course until pickup at 1035 hr. Rates of drift throughout the cruise ranged from 0.03 to 0.16 kt with a mean rate of 0.1 kt. Wind direction was variable: SE to ESE between 1200 and 1600 hr (on the 10th); NW between 2000 and 0400 hr (on the 10th-11th); and finally NNE from 0600 to 0800 hr (on the 11th). Wind speeds ranged from 1 to 10 kt but were most usually 5 to 6 kt. High tide on the 10th and 11th occurred at 0729 and 0851 hr, while low tide occurred at 1746 and 1808 hr on those days (Horn Island Pass reference station).

Cruise 85-11, 4 November 1985 (Figure 12): The drogue was tracked for 10 hr and 16 min after deployment at 30°09.48'N latitude, and 88°40.23'W longitude at 1234 hr CST. Initially the drogue moved in an easterly direction but after 1400 hr it took a southerly course. After 1800 hr the drogue moved to the SE and maintained that direction until pickup at 2250 hr. Rates of drift throughout the cruise ranged from 0.16 to 0.84 kt with a mean rate of 0.4 kt.

Figure 13: Drogue track from cruise 85-10



Winds blew consistently from the WNW and increased in speed from 12 to 25 kt. High tide on the 4th occurred at 0135 hr, while low tide occurred at 1253 hr (Horn Island Pass reference station).

Section 2. LARVAL ABUNDANCE AND DISTRIBUTION

RESULTS

Seasonal Patterns in Abundance and Distribution

Examination of 270 ichthyoplankton collections (252 Tucker trawl and 18 bongo net samples) yielded 9312 specimens of *Sciaenops ocellatus* (Tables 3 and 4). Although sampling areas among the fifteen cruises were not identical, the season pattern in abundance of red drum larvae over the east LA-MS-AL shelf was similar among the three years sampled. In general, larval red drum were most numerous in offshore waters in early to mid September and/or early October, and least numerous in late August and late October to early November.

Highest frequencies of occurrence (FO), 78-97%, were observed in early October 1983, September and early October 1984, and early September and October 1985 (Table 3). Lowest FO's occurred in late September 1983 (52%), late October 1984 (55%), and November 1984 and 1985 (0 and 20%). Frequency of occurrence in August 1984 and 1985 (33%) was higher than the late October and November values, but was only 1/3 to 1/2 the FO in the first September cruises of those two years, 14 days later.

Highest mean densities (number of larvae per 100 m^3, all collections) were observed in early October 1983 (4.57), and early to mid September 1984 and 1985 (78.62 and 6.51) (Table 3). In early October 1984 and 1985 a secondary peak in mean density (13.53 and 2.21) occurred after a decline in late September. Lowest mean densities (<1) were observed in late September 1983; late October and November 1984; August, late September, and November 1985.

Table 3. Summary of collection data, effort, frequency of occurrence, and mean density (all sampling depths and times combined) of _Sciaenops ocellatus_ larvae captured near the subsurface current drogue in waters of the northcentral Gulf of Mexico during late summer and fall months 1983-85.

Cruise	Date	Total Volume Filtered (m^3)	No. of Collections	Occurrence Frequency	Occurrence Percent	No. of Specimens	Mean Density (Number per $100m^3$) All Collections	Mean Density (Number per $100m^3$) Positive Collections
83-9	09/20-21/83	10192	31	16	52	74	0.73	1.55
83-10-1	10/6-7/83	4177	25	23	92	191	4.57	4.57
83-10-2	10/18-19/83	16665	51	28	55	327	1.96	3.45
84-8	08/30-31/84	1117	9	3	33	15	1.34	3.97
84-9-1	09/13-14/84	7427	29	28	97	5839	78.62	82.29
84-9-2	09/26-27/84	3016	10	9	90	256	8.49	9.12
84-10-1	10/10-11/84	4480	13	12	92	606	13.53	14.35
84-10-2	10/23-25/84	5016	19	1	5	2	0.04	0.63
84-11	11/07-09/84	2739	9	0	0	0	0	0
85-8	08/28/85	897	3	1	33	4	0.45	1.20
85-9-1	09/11-12/85	6864	27	21	78	447	6.51	8.44
85-9-2	09/25-26/85	2284	8	5	63	19	0.83	1.40
85-10	10/10-11/85	2445	9	7	78	54	2.21	2.90
85-11	11/04/85	1257	5	1	20	1	0.08	0.35

Mean densities during the peak abundance period September to early October were higher in 1984 than in 1985. Individual densities in 1985 collections during this period never exceeded 32 larvae per 100 m^3 (N=44), whereas in 1984, densities of over 100 were observed in 22% of the collections (N=41). The coefficient of variation of larval red drum densities for all cruises combined (among cruise variability) in September to early October 1984 and 1985 was greater than the individual coefficients of variation for those cruises (within cruise variability) indicating that trends seen in larval abundances were due to real differences between the two years, and not to sampling variability alone.

Red drum larvae were taken in every collection at the nearshore site during five cruises in September and early October 1984 and September 1985 (Table 4). Unlike in offshore waters, the highest mean densities at the nearshore site occurred in late September. The secondary peak in abundance in offshore waters during early October 1984 was not evident at the nearshore site. Except for the late September cruises in 1984 and 1985, mean densities at the nearshore site were either nearly the same as (cruise 85-9-1) or lower than (cruises 84-9-1 and 84-10-1) mean densities at the offshore sites. The greatest difference in mean density between the nearshore and offshore locations occurred in late September 1985, when mean density at the nearshore site was an order of magnitude higher than in the offshore sampling area.

Table 4. Summary of collection data, effort, frequency of occurrence, and mean density (all sampling depths and times combined) of *Sciaenops ocellatus* larvae captured at the near shore collection site near the west end of Horn Island in September and October 1984 and September 1985.

Cruise	Date	Total Volume Filtered (m^3)	No. of Collections	Occurrence		No. of Specimens	Mean Density (Number per $100m^3$)
				Frequency	Percent		
84-9-1	09/14/84	2629	9	9	100	588	22.37
84-9-2	09/27/84	1193	3	3	100	458	38.39
84-10-1	10/11/84	1757	4	4	100	101	5.75
85-9-1	09/12/85	1364	4	4	100	122	8.94
85-9-2	09/26/85	569	2	2	100	208	36.56

Vertical and Diel Patterns in Abundance and Distribution

Depth-stratified ichthyoplankton collections taken at three time periods; afternoon, night, and morning, over one 24-hr period during six cruises were examined for patterns in vertical distribution of red drum larvae (Table 5). There was clear evidence of vertical stratification of larvae in offshore waters (Figures 14 and 15). Larvae were usually more abundant at 1 and/or 5 m than at 11, 12, or 16 m. There was also evidence of diel periodicity in vertical distribution in five of the six cruises; low larval densities in one cruise, 85-9-2, made it difficult to interpret vertical patterns (Figure 15B). The most consistent diel pattern to emerge was a decrease (relative to afternoon values) in abundance at the 1 m level and a relative increase at the 5 and/or 11-12 m levels during nighttime hours. The following morning abundances at the 1 m and/or 5 m levels were generally higher than the nighttime values at those depths. During cruise 84-9-2, however, the diel shift in abundance occurred between the 5 and 12 m levels with abundance at 1 m remaining relatively constant throughout the 24-hr period (Figure 14B). And although during cruise 84-10-1, larval abundance at 1 m also declined at night and increased in the morning, the highest densities during each of the three time periods were consistently observed at the deepest level sampled, 12 or 16 m (Figure 14C).

For two cruises, 84-9-1 and 85-9-1, within and between depth sampling variability were examined from three "replicate" samples, ie. samples from each of the three Tucker trawl nets towed at each nominal depth (Table 6). Results from cruise 84-9-1 (offshore location) indicate distinct vertical stratification and diel periodicity in larval red drum abundance between the 1 and 5 m levels. Mean abundances at the 1 m level in the afternoon and morning

Table 5. Time of collection and number of depth-stratified, ichthyoplankton samples from six cruises in 1984 and 1985.

Cruise	Date	Nominal Sampling Depth (m)	Location	Time of Collection (hrs CST) Afternoon	Night	Morning	Total No. of Samples
84-9-1	09/13-14/84	1	Offshore	1650-1700	2355-0005	0650-0701	9
		5	"	1741-1751	0049-0059	0746-0756	9
		11	"	1844-1854	0141-0152	0835-0844	9
84-9-1	09/14/84	1	Nearshore	1056-1107	----	----	3
		3	"	1151-1201	----	----	3
		7	"	1236-1246	----	----	3
84-9-2	09/26-27/84	1	Offshore	1119	1911	0725	3
		5	"	1249,1254	2014	0826	4
		12	"	1409	2118	0927	3
84-9-2	09/27/84	1	Nearshore	1343	----	----	1
		5	"	1336	----	----	1
		9	"	1328	----	----	1
84-10-1	10/10-11/84	1	Offshore	1202	1909	0640,0645	4
		5	"	1341	2006	0731,0735	4
		12(16)	"	1450	2055,2101	0826,0831	4
84-10-1	10/11/84	1	Nearshore	1308	----	----	1
		5	"	1228,1303	----	----	2
		9	"	1223	----	----	1
85-9-1	09/11-12/85	1	Offshore	1244-1253	1931-1941	0742-0752	9
		5	"	1339-1349	2021-2032	0843-0853	9
		11	"	1451-1501	2135-2145	0957-1008	9

Table 5. continued

Cruise	Date	Nominal Sampling Depth (m)	Location	Time of Collection (hrs CST) Afternoon	Night	Morning	Total No. of Samples
85-9-1	09/12/85	1	Nearshore	1359,1409	----	----	2
		3	"	1449	----	----	1
		7	"	1532	----	----	1
85-9-2	09/25-26/85	1	Offshore	1130	2011	0705	3
		5	"	1226	2106	0751	3
		12	"	1319,1509	----	----	2
85-9-2	09/26/85	1	Nearshore	1124	----	----	1
		5	"	1158	----	----	1
85-10	10/10-11/85	1	Offshore	1333	1853	0704	3
		5	"	1430	1949	0754	3
		12(11)	"	1526	2047	0851	3

Figure 14: Abundance of red drum larvae at three nominal sampling depths and two locations during afternoon, night, and morning hours in 1984. Nearshore collections were taken on the second day of a cruise, ~24 hours after the first offshore collections. A. Cruise 84-9-1, B. Cruise 84-9-2, C. Cruise 84-10-1

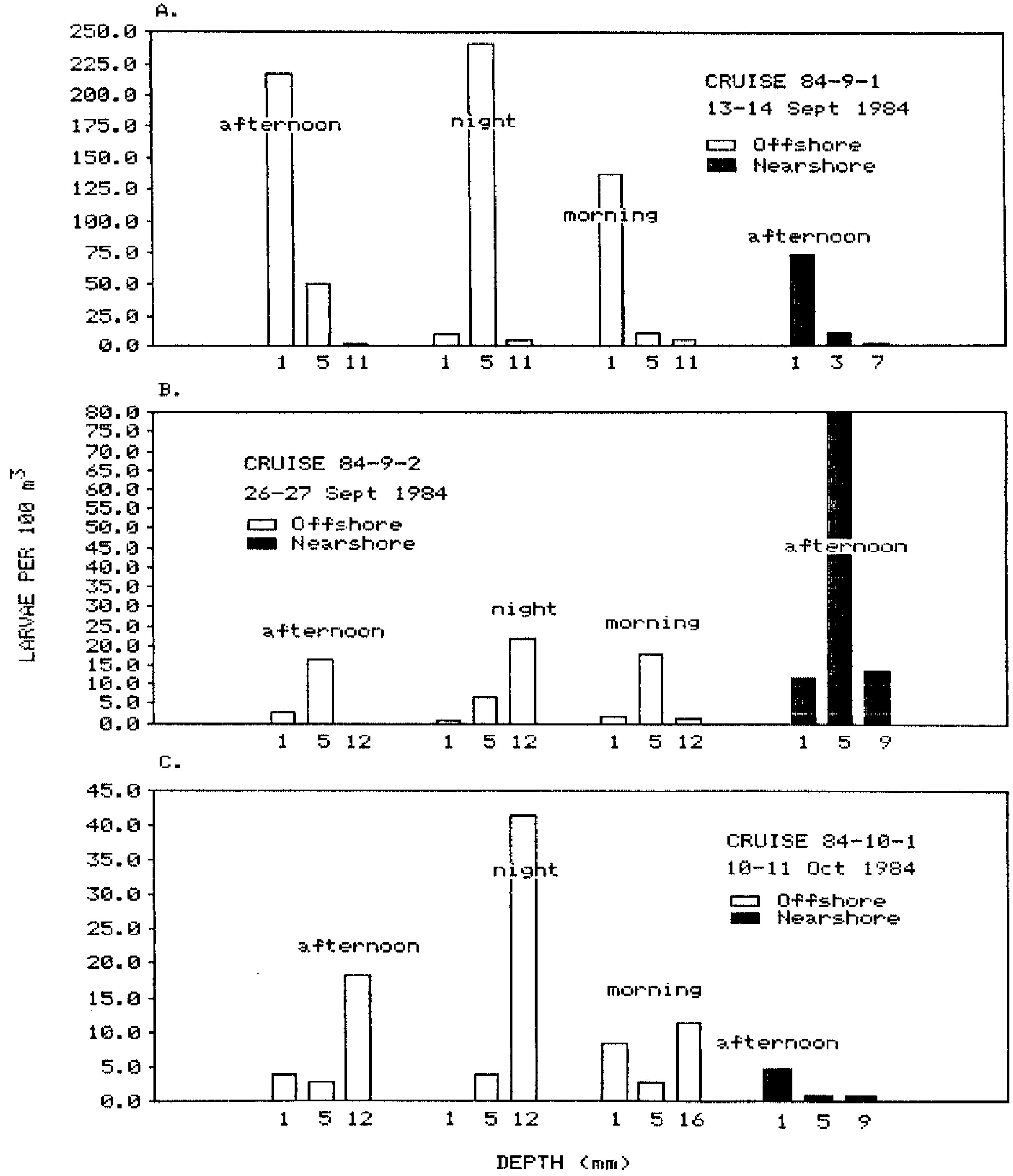


Figure 15: Abundance of red drum larvae at three nominal sampling depths and two locations during afternoon, night, and morning hours in 1985. Nearshore collections were taken on the second day of a cruise, ~24 hours after the first offshore collections.
A. Cruise 85-9-1, B. Cruise 85-9-2, C. Cruise 85-10

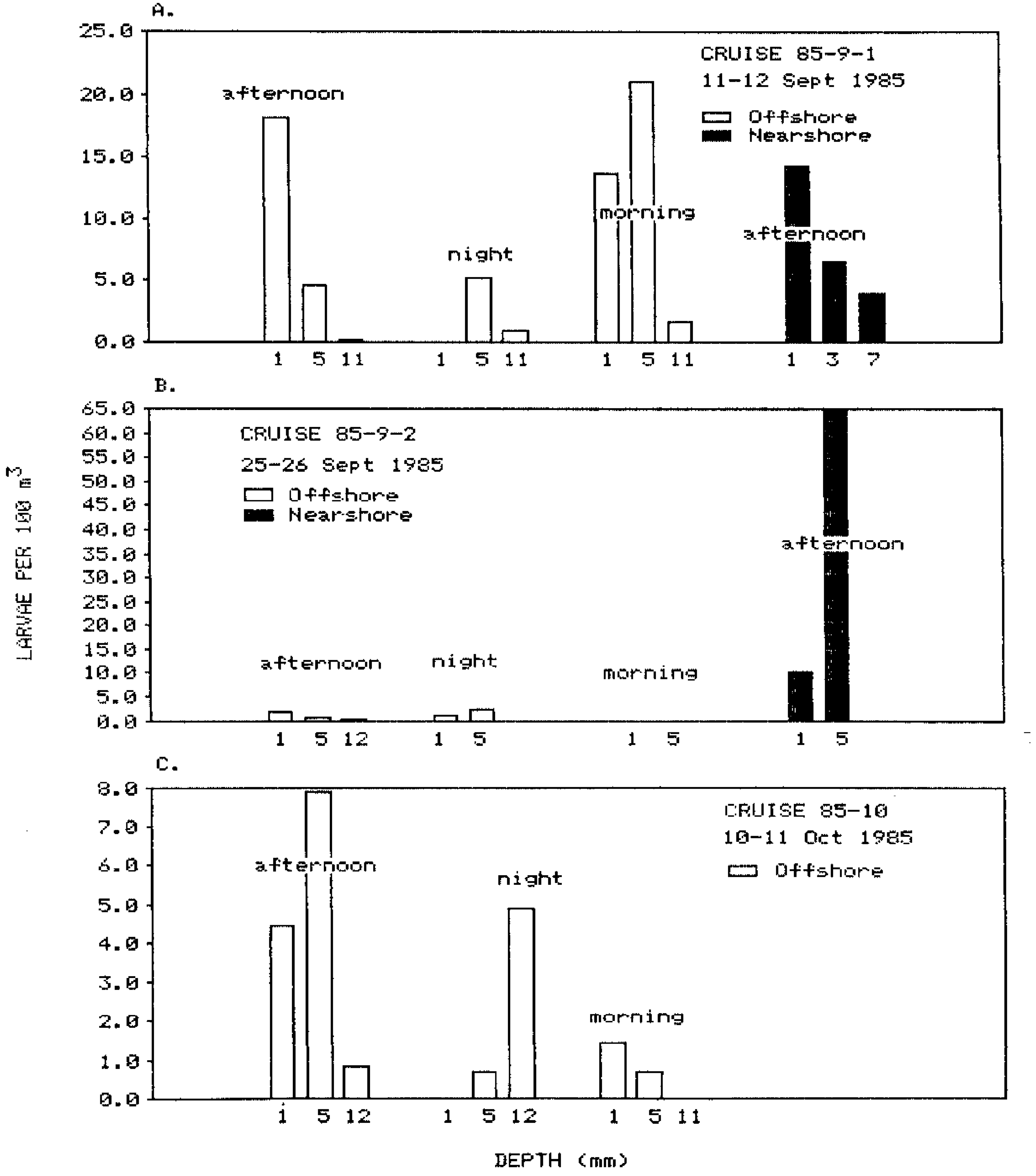


Table 6. Statistical summary of larval red drum densities (number per 100m^3) from replicated, diel/depth-stratified sampling during cruises 84-9-1 and 85-9-1. Nearshore samples from 84-9-1 were taken between 1056-1246 hr CST on the second day of the cruise, nearly 24 hrs after the first set of offshore collections were made. Mean (SE) = mean density (standard error of the mean). L_1 and L_2 = upper and lower 95% confidence limits to the mean, df = N-1.

	Cruise 84-9-1 (Offshore)			Cruise 85-9-1 (Offshore)			Cruise 84-9-1 (Nearshore)		
	1m	5m	11m	1m	5m	11m	1m	3m	7m
Afternoon									
N	3	3	3	3	3	3	3	3	3
Range	172.69-243.65	44.07-57.42	00.00-2.51	9.51-31.06	0.96-7.59	0.00- 0.52	55.73-73.84	4.66-18.45	0.71-5.67
Mean (SE)	214.5 (21.42)	50.7 (3.85)	1.0 (0.76)	17.1 (6.98)	4.4 (1.92)	0.17 (0.173)	63.5 (5.43)	11.1 (4.00)	3.4 (1.45)
L_1	122.33	34.13	0	12.93	0	0	40.13	0	0
L_2	306.67	67.27	4.27	47.16	12.52	0.91	86.87	28.31	9.64
Night									
N	3	3	3	3	3	3			
Range	1.95 - 19.80	153.61-288.34	1.07-8.47	0	2.89-7.13	0.00-1.46			
Mean (SE)	9.3 (5.38)	234.5 (41.17)	4.8 (2.14)	0	5.0 (1.23)	0.8 (0.43)			
L_1	0	57.33	0		0	0			
L_2	32.45	411.65	14.01		10.29	2.65			
Morning									
N	3	3	3	3	3	3			
Range	115.69-154.81	8.43-15.17	3.13-5.56	7.31-26.32	14.0-31.58	1.16-2.58			
Mean (SE)	141.0 (12.67)	11.4 (1.98)	4.2 (0.71)	13.7 (6.29)	20.9 (5.43)	1.7 (0.47)			
L_1	86.48	2.88	1.14	0	0	0			
L_2	195.52	19.92	7.26	40.77	44.27	3.72			

time periods were an order of magnitude greater than at night with no overlap in 95% confidence intervals about the mean. At night, however, mean abundance at the 5 m level was an order magnitude greater than at the 1 m level during both afternoon and morning periods with no overlap in the 95% confidence intervals. Mean abundances at the 11 m level remained relatively unchanged over the three time periods with extensive overlap of the confidence intervals.

The pattern of diel periodicity in depth distribution was not as distinct in the 85-9-1 data set (Table 6). Mean abundance at the 1 m level in afternoon hours was 4 and 10X's greater than the mean densities at the 5 and 11 m levels, with little or no overlap in 95% confidence intervals. No larvae were taken in 1 m collections at night, but mean densities and 95% confidence levels at the 5 and 11 m levels were relatively unchanged from afternoon values. On the morning of the next day mean densities at 1 and 5 m both increased over nighttime values and, unlike the previous afternoon, were similar to each other with nearly complete overlap in the 95% confidence intervals. Mean density at 11 m in the morning was somewhat higher than in the two prior time periods, but there was complete overlap of the confidence intervals.

Vertical distribution of larvae at the nearshore sampling site which was sampled only during late morning and early afternoon hours during five cruises were examined and compared to observations in offshore waters at the comparable time period one day earlier (Table 5). Red drum larvae also appeared to be vertically stratified at the nearshore site. Mean density of larvae at 1 m during cruise 84-9-1 was 6 and 20X's greater than the mean densities at 3 and 7 m with no overlap in 95% confidence intervals (Table 6). In three cruises the depth of greatest afternoon abundance of red drum larvae; 1 m for 84-9-1 and 85-9-1, and 5 m for 84-9-2, was the same at both nearshore and offshore sites

(Figures 14 and 15). During cruise 84-9-1, the nearshore samples at three depths were collected with nets of different mesh sizes; 1m-333, 5m-505, and 9m-760 micron mesh. Retention of larval sciaenids by the 333 and 505 micron mesh nets are probably quite comparable, but larval abundance at 9m was probably underestimated by the 760 micron mesh net. In two cruises, 84-10-1 and 85-9-2, the level of greatest afternoon abundance at the nearshore site did not coincide with observations at the offshore site (Figures 14C and 15B).

Larval Size Comparisons

Examination of size frequency distributions of larval red drum from offshore waters indicated no consistent seasonal progression in size modes (Figures 16, 17, and 18). Larvae in the smallest size classes, 1.0 to 2.5 mm SL, were present in collections from all cruises in all years. Larvae > or = 5.0 mm were present only in October 1983, early October 1984, and early September 1985. Overall size range and the modal size class of larvae captured during each of the three 1983 cruises were similar, except for cruise 83-10-1 when two distinct modes, 2.0 and 4.5 mm, were present at the 12 m location (Figure 16). In 1984 the modal size class and overall size range of larvae in offshore collections from late August (size frequency distribution not shown) through September (Figure 17) was 2.5, and 1.6 to 3.8 mm SL. Red drum larvae in the early October collections ranged from 2.2 to 7.9 mm with a modal size class of 4.0 mm. Larvae collected in August 1985 measured 1.8 and 3.2 mm. Two weeks later during cruise 85-9-1 the size frequency distribution of larvae in offshore collections was bimodal with modes at the 1.5 and 4.5 mm size classes, and an overall range of 1.4 to 6.5 mm SL (Figure 18). Larvae collected in late September were smaller, modal size class = 1.5 mm and overall range = 1.7 to 3.4 mm, than in early September. By early October the mode had increased to

Figure 16: Size frequency distributions of red drum larvae from cruises in September and October 1983. N=total number of larvae collected.

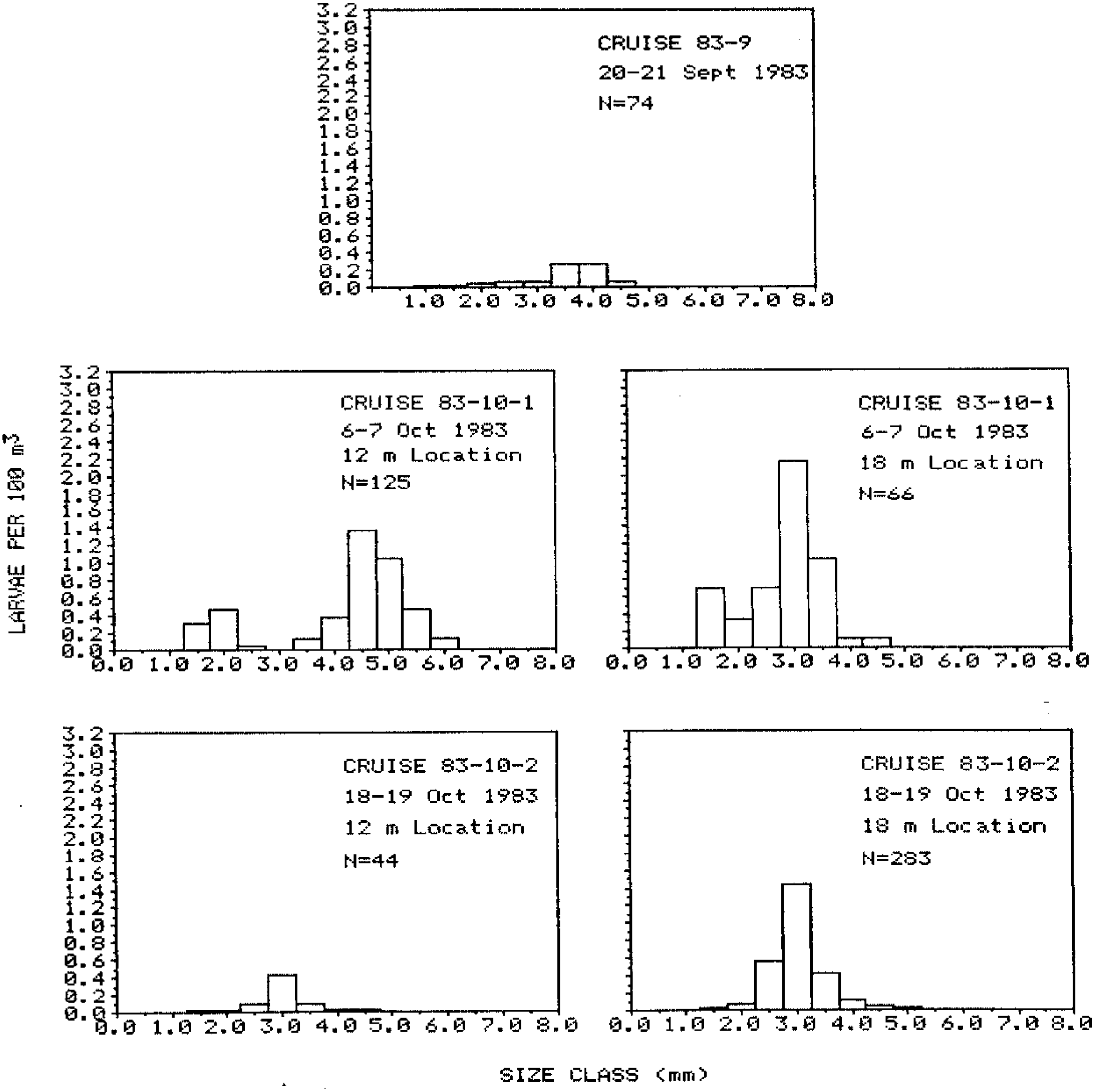


Figure 17: Size frequency distributions of red drum larvae from cruises in September and October 1984 at offshore and nearshore sampling locations. N=total number of larvae collected.

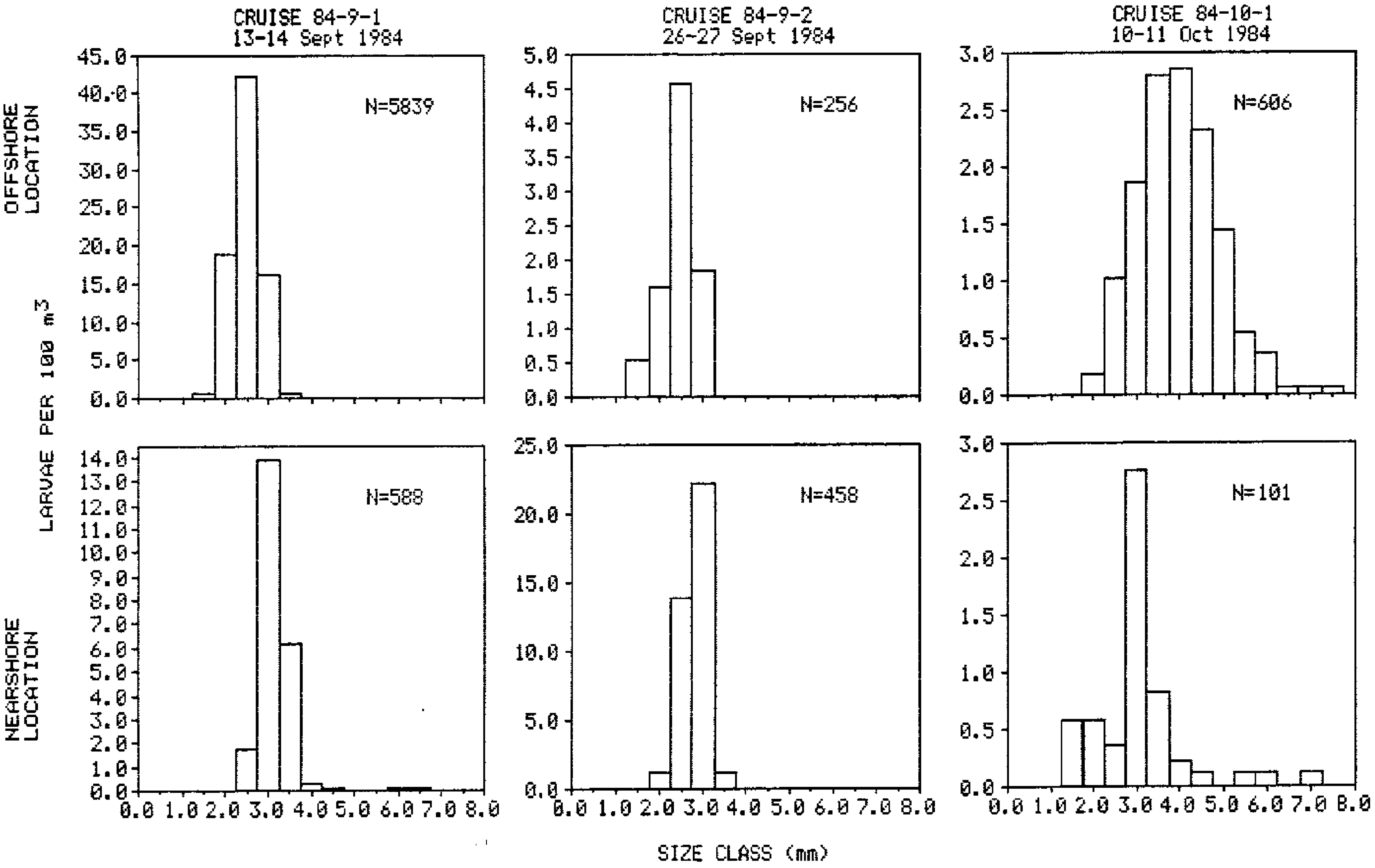
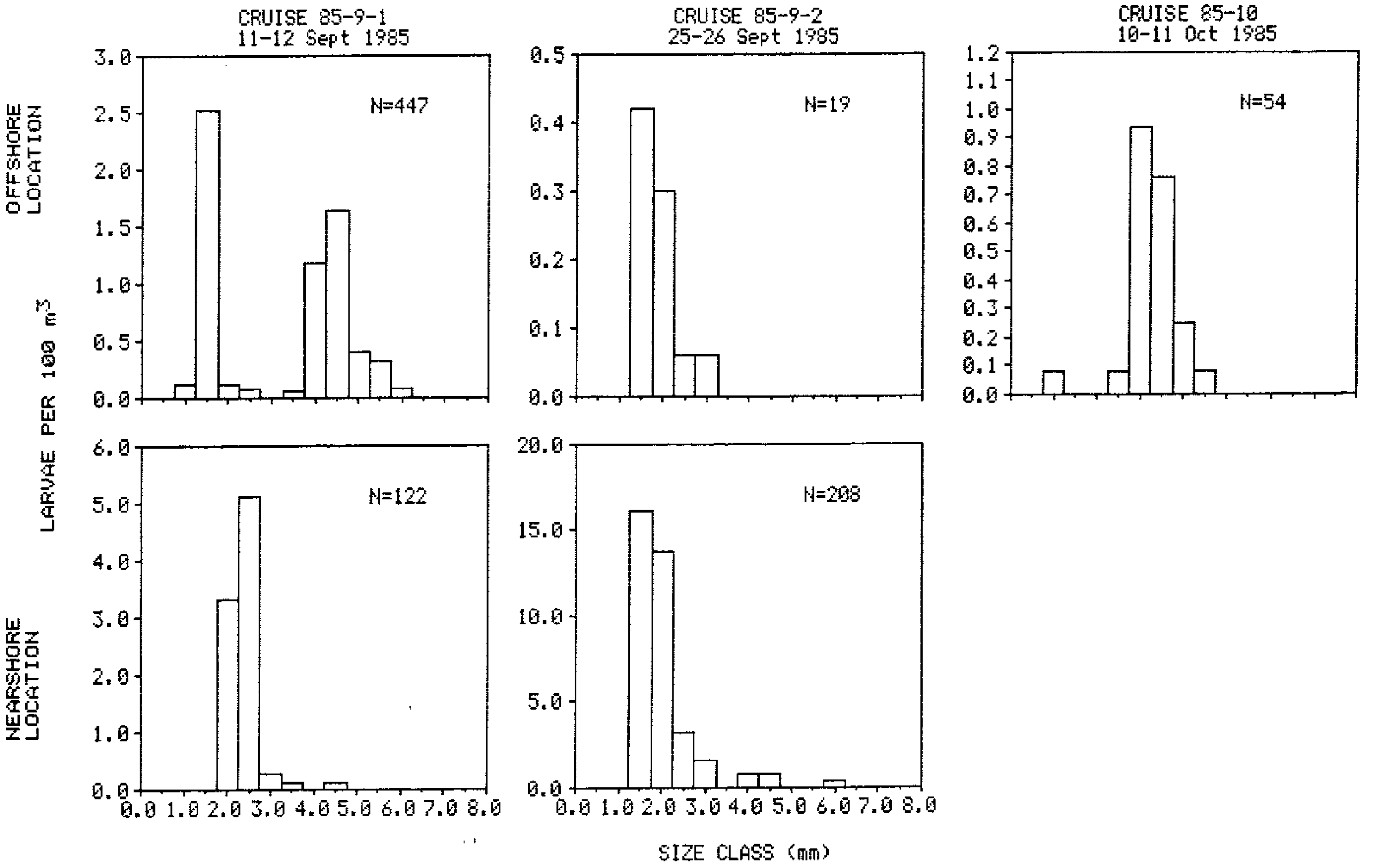


Figure 18: Size frequency distributions of red drum larvae from cruises in September and October 1985 at offshore and nearshore sampling locations. N=total number of larvae collected.



3.0 mm, and the overall range extended from 1.3 to 4.6 mm. The single larvae collected in early November measured 1.7 mm.

Overall size range and modal size class of larvae at offshore and nearshore collection sites were similar in five of the six cruises where such comparisons were possible (Figures 17 and 18). In September 1984 the modal size class of larvae in offshore waters was 0.5 mm smaller than the modal size class at the nearshore site. In early October 1984 the modal size class in offshore waters was 1 mm greater than the modal size class at the nearshore site. The greatest discrepancy in larval size between offshore and nearshore locations was observed in early September 1985. The offshore size frequency distribution was bimodal with modes at the 1.5 and 4.5 mm size classes. The nearshore distribution was unimodal with the modal class at 2.5 mm. There was little overlap in overall size range at the two locations. In late September 1985 modal size class at the two locations was the same.

Size frequency distributions of red drum larvae caught in daytime and nighttime collections were compared for evidence of sampling gear avoidance among the largest size classes of planktonic larvae. Red drum larvae > 4.0 mm SL were caught in appreciable numbers only during three cruises; 83-10-1 (12 m location), 84-10-1, and 85-9-1. There was no clear indication of gear avoidance by larger larvae during cruises 83-10-1 and 85-9-1 (Figures 19 and 20). Densities of larvae in the 4.0 to 5.0 mm size classes steadily declined throughout each cruise. Further indication of a change in size composition during cruise 85-9-1 took place in the morning when larvae in the 1.0 to 2.5 mm size classes appeared for the time. Decline in overall abundance and/or change in size composition of the larval population being sampled would tend to mask

Figure 19: Size frequency distributions of red drum larvae in daytime and nighttime hours from cruise 83-10-1 (12m location). N=total number of larvae, ( )=number of samples.

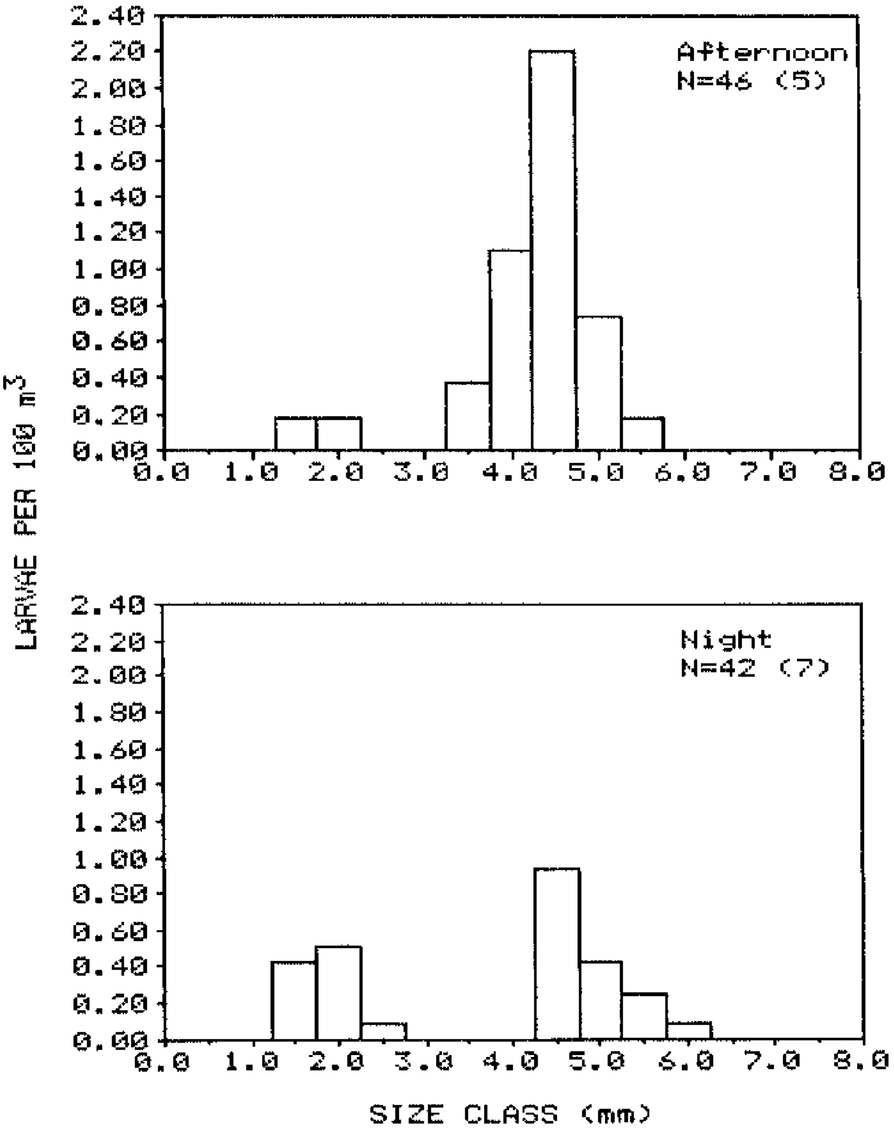
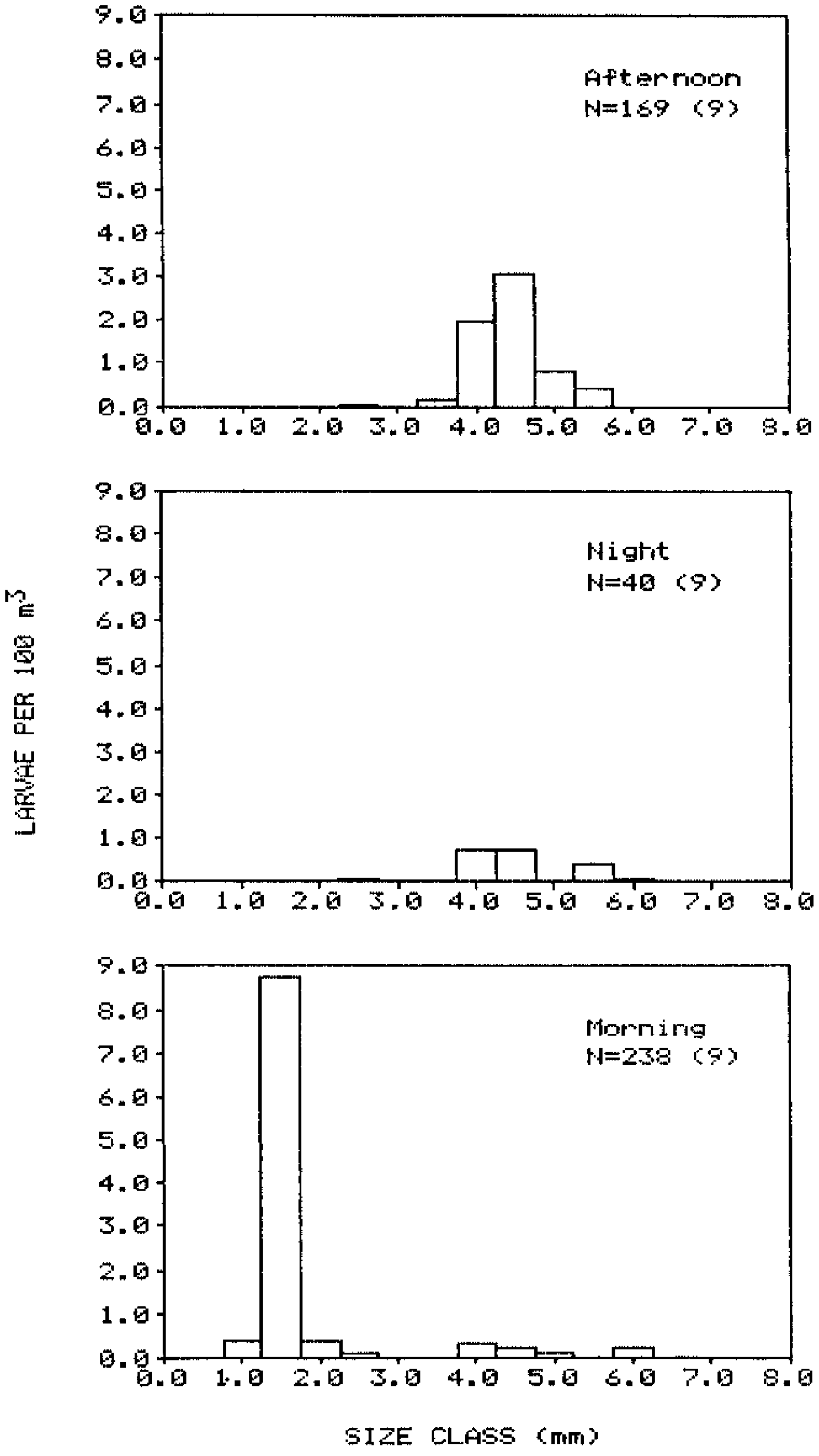


Figure 20: Size frequency distributions of red drum larvae in daytime and nighttime hours from cruise 85-9-1 (offshore location). N=total number of larvae, ( )=number of samples.



any diel patterns in catch rates which could be indicative of gear avoidance during these two cruises.

Overall abundance and size composition remained relatively unchanged throughout the 24-hr sampling period during cruise 84-10-1, and there was clear evidence of daytime gear avoidance. Mean density of red drum larvae (all size classes combined) in nighttime collections, 26.3 larvae per 100 m^3, was over 3X's greater than the afternoon, 7.4, and morning, 8.4, mean densities. Larvae in size classes 4.0, 4.5, 5.0 mm were 2.5 to 6X's more numerous in nighttime than in daytime collections (Figure 21). Larvae in the 5.5 mm size class were absent from daytime collections but appeared in nighttime collections at a density of 2.5 larvae per 100 m^3.

The size composition of larvae captured at each of three nominal sampling depths (all time periods combined) were compared from cruises 84-10-1 and 85-9-1 in which larvae over the widest size range were collected. It was apparent from these data that red drum larvae were not vertically stratified by size (Figures 22 and 23).

Estimated Larval Age and Time of Spawning

Age in days of red drum larvae was determined from growth equations and/or raw length-at-age data obtained from the same collections or from collections where water temperatures were most similar (see Age and Growth chapter of this report). The overall range in larval age and modal age based on the mode(s) of size frequency distributions were summarized and compared for each cruise where red drum larvae were collected (Table 7). Maximum observed age of planktonic red drum larvae was similar in 1983, 13 days, and 1985, 12 days, but was nearly two times greater in 1984, 20 days (Table 7). Among the three years modal age in days ranged from 3-10 in 1983, 5-9 in 1984, and 2-9.5 in 1985. Most of the

Figure 21: Size frequency distributions of red drum larvae in daytime and nighttime hours from cruise 84-10-1 (offshore location). N=total number of larvae, ( )=number of samples.

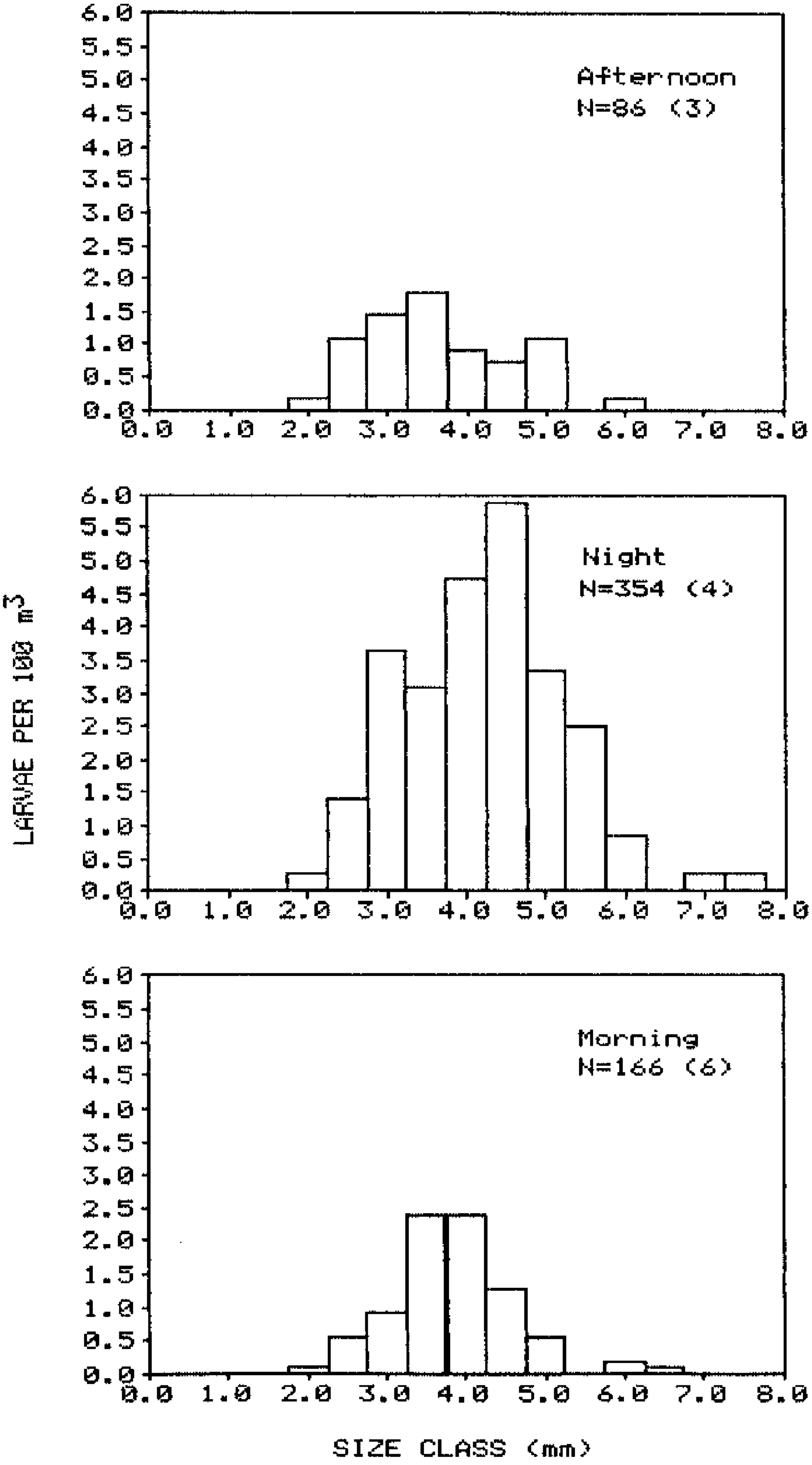


Figure 22: Size frequency distributions of red drum larvae at three nominal sampling depths from cruise 84-10-1 (Offshore location), 10-11 October 1984. N=total number of larvae, ( )=number of samples.

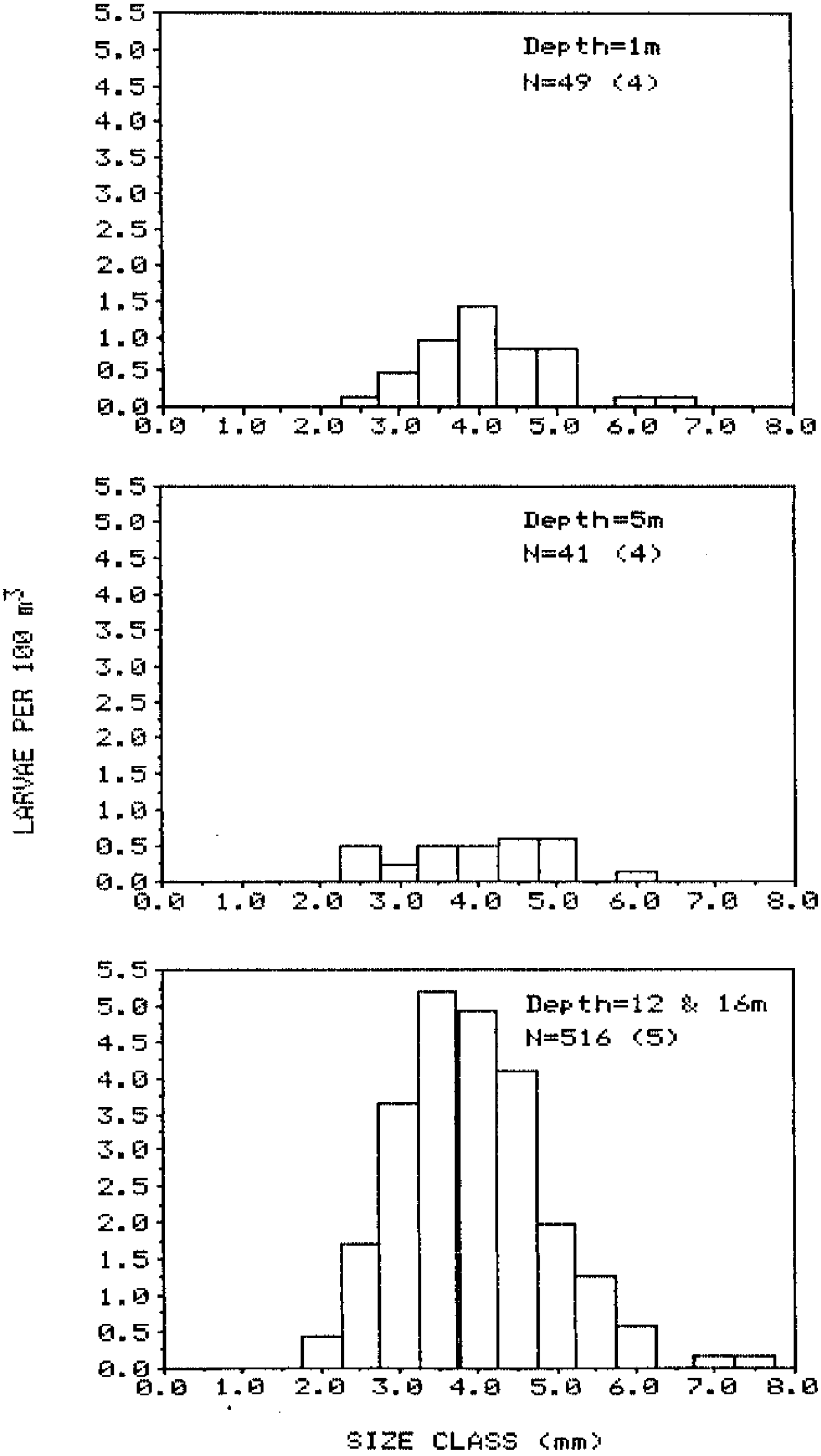


Figure 23: Size frequency distributions of red drum larvae at three nominal sampling depths from cruise 85-9-1 (Offshore location), 11-12 September 1985. N=total number of larvae, ( )=number of samples.

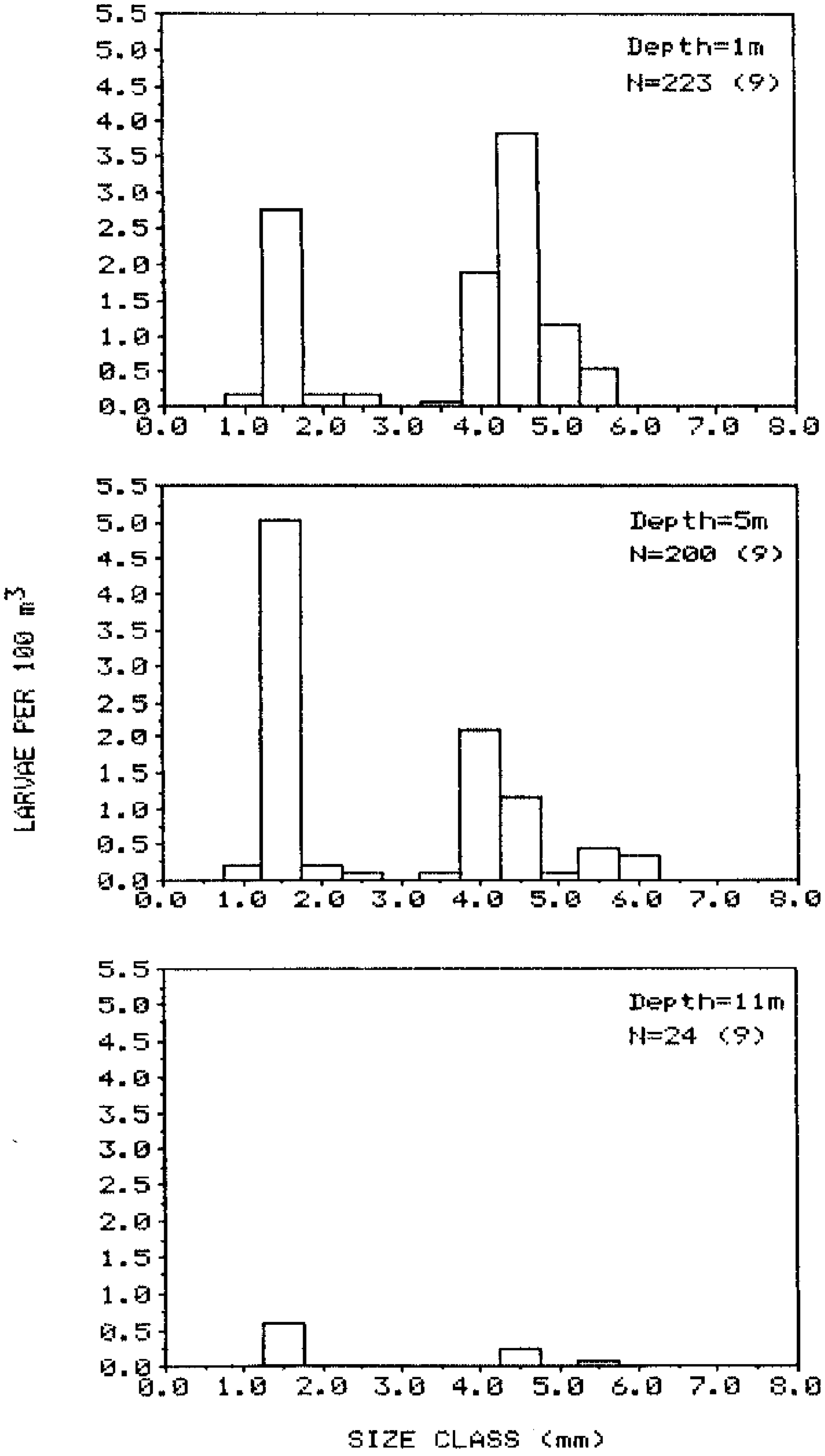


Table 7. Overall range in age and age of modal size class(es) (to the nearest 0.5 day) of red drum larvae collected during cruises in 1984-85. Backcalculated spawning dates were based on age of modal size class(es) except where no mode was present then spawning date was calculated from the range in age.

Cruise	Date	Location	Range in Age (days)	Modal Age (days)	Approx. Spawning Date
83-9	09/20-21/83	Offshore	2.0 - 10.0	7.5,8.5	13, 11 Sept.
83-10-1	10/6-7/83	18m	2.0 - 10.0	6.5	30 Sept.
"	"	12m	2.0 - 13.0	3.0,10.0	3 Oct, 26 Sept.
83-10-2	10/18-19/83	18m	3.0 - 12.0	6.0	12 Oct.
"	"	12m	2.5 - 12.0	6.0	12 Oct.
84-8	08/30-31/84	Offshore	3.0 - 7.5	5.0	25 Aug.
84-9-1	09/13-14/84	Offshore	2.0 - 8.0	5.0	8 Sept.
"	"	Nearshore	5.0 - 12.5	6.0	7 Sept.
84-9-2	09/26-27/84	Offshore	2.0 - 7.5	5.0	21 Sept.
"	"	Nearshore	4.0 - 8.5	6.5	20 Sept.
84-10-1	10/10-11/84	Offshore	4.0 - 20.0	7.5,9.0	3 Oct, 31 Oct.
"	"	Nearshore	3.0 - 18.0	6.0	4 Oct.
84-10-2	10/23-25/84	Offshore	-----	6.5	18 Oct.
85-8	08/28/85	Offshore	3.0 - 6.5	-----	25, 21 Aug.
85-9-1	09/11-12/85	Offshore	2.0 - 12.0	2.0,9.5	9, 2 Sept.
"	"	Nearshore	3.0 - 9.5	5.0	6 Sept.
85-9-2	09/25-26/85	Offshore	2.0 - 7.0	2.0	23 Sept.
"	"	Nearshore	2.0 - 11.5	2.0	23 Sept.
85-10	10/10-11/85	Offshore	2.0 - 11.0	6.0	4 Oct.
85-11	11/04/85	Offshore	-----	2.0	2 Nov.

larvae collected in 1983 and 1984 were 5-6 days old while most larvae collected in 1985 were only 2 days old. There was no clear trend in age distribution with distance from shore. Maximum and/or modal age at the 12 m (in 1983) or nearshore (in 1984 and 1985) sites were not consistently greater (or lesser) than at offshore sampling locations. Differences in both maximum and modal age of larvae at nearshore and offshore sites ranged from 1 to 4.5 days.

Approximate spawning dates were estimated for each cruise by subtracting the modal age in days (or range in age when no mode was present) from the capture date. Spawning dates for red drum in LA-MS-AL coastal waters estimated from this study ranged from 21 August to 2 November (Table 7). Spawning dates backcalculated from collections during time of maximum larval abundance for each year were: 26 and 30 September, and 3 October 1983; 7 and 8 September 1984; and 2, 6, and 9 September 1985. Approximate spawning date(s) based on the modal age of larvae collected at offshore and nearshore sites never differed by more than 4 days (cruises 83-10-1 and 85-9-1). From other cruises estimated spawning dates from the two locations differed by only one day (cruises 84-9-1 and 84-9-2) or were identical (cruises 83-10-2 and 85-9-2).

Larval Mortality

A single estimate of mortality was based on the decline in larval abundance over a 14 hour period during cruise 84-9-1, assuming there was no significant movement of larvae into or out of the area during sampling. This data set was used for mortality determination because of sample replication (N=9 samples per time period), the low number of size classes present, and uniform size composition over the 14 hour period which tended to support the validity of the aforementioned assumption (Figure 17). Mean densities (larvae per 100 m^3) and standard error of the mean (SE) during the three time periods were: afternoon, 88.73 (SE= 32.85); night, 82.86 (SE= 39.76); morning, 52.23 (SE= 22.52). The similarity in larval abundance in the afternoon and night time periods indicates that mortality in the evening hours was low. There was, however, a 41.1% decline in larval abundance between the afternoon and morning sampling periods. This overall observed decline represents an instantaneous mortality rate (Z) of 0.91.

CONCLUSIONS and DISCUSSION

Unlike most sciaenids in the northcentral Gulf of Mexico the red drum has a very restricted spawning period, perhaps as short as one to one-and-a-half months. Based on our study most spawning activity in east LA-MS-AL coastal and shelf waters occurs from early September through early October. This conclusion is based on the consistency in time of peak larval abundance, and the similarity in backcalculated spawning dates in 1984 and 1985 (years of most complete sampling coverage) which suggest that our data accurately depict the red drum spawning cycle. During this period of peak spawning activity water temperatures over the shelf were decreasing rapidly from 27-29°C in early September to 24-25°C in early October 1984 and 1985. Although our collections did not extend beyond early November, water temperatures in November 1984 and 1985 were already approaching 20°C, the lower limit for spawning in this species (Holt et al. 1981b).

There is further evidence of an abbreviated red drum spawning season in northcentral Gulf waters. During a year-long ichthyoplankton survey (monthly sampling frequency) of Mississippi Sound and adjacent waters in 1979-80 red drum larvae were taken only in the months of September and October, with the highest densities occurring in September (Lyczkowski-Shultz and Richardson, unpub. data). Red drum postlarvae measuring 4-20 mm SL were taken in monthly beam plankton net collections in Mississippi Sound only in the months of August through November during 12 years of fisheries monitoring and assessment sampling (J. Warren, GCRL Fisheries Section, unpub. data). Major influx of postlarvae occurred in September and October, with the highest catch rates occurring in October. During this period red drum postlarvae (single specimens) were taken only twice in the month of August (1981 and 1986). In 8 of the 12 years, 7-10 mm postlarvae were taken in November collections but at catch rates far below those in September and October.

In the western and eastern Gulf the red drum spawning season extends from August to October or even to early December off the central west coast of Florida (Holt et al. 1985; Ditty 1986; Peters and McMichael 1987). Time of peak spawning, however, in other regions of the Gulf has been established only for the Tampa Bay area of Florida (Peters and McMichael 1987). These authors reported two estimates for peak spawning depending on whether backcalculated spawning dates were derived from age at capture of larvae or juveniles. Most spawning occurred in late August and mid September based on larvae, while data from juvenile drum indicated peak spawning in October. Peters and McMichael (1987) also noted that within season spawning peaks were associated with new and full moons. Our data agree with these observations. Peak spawning in offshore, east LA-MS-AL waters in 1983 and 1985 occurred during the week after the full moon in September. In 1984 peak spawning occurred 4 days prior to the September full moon.

Although not designed to map the areal extent of red drum spawning, the results of our study indicate that red drum spawn farther from shore and over a broader area than has previously been reported in northcentral and/or other regions of the Gulf. During the period of peak larval occurrence mean densities and overall size composition were comparable (though not always coincident in time) at offshore sampling locations, 17-34 km south of Horn Island, and at the nearshore sampling site, 6 km south of Horn Island. In particular, the presence of the smallest size classes of larvae at both offshore and nearshore sampling sites confirms that significant red drum spawning occurs in both offshore and nearshore waters off east Louisiana and Mississippi. Spawning in south Texas waters occurs closer to shore, as evidenced by the consistent presence of newly spawned eggs both within 1.8 km of Aransas Pass, and in the pass itself (Holt et al. 1981b; Holt et al. 1985). Most spawning in the region of Tampa Bay off central west Florida occurs near the mouth of the bay (Peters and McMichael 1987). No major concentration of red drum larvae was ever found during seasonal BLM ichthyoplankton surveys (1971-1974) on the west Florida shelf (Houde et al. 1979). The apparent difference among regions in the Gulf in distance of red drum spawning from shore is most likely a reflection of differences in the amount of continental shelf area between 10-30 m water depth. The shelf region off east Louisiana, Mississippi, and Alabama is much broader than off west Florida and south Texas.

The existence of diel periodicity in the vertical distribution of fish larvae in both oceanic and coastal waters has been demonstrated for numerous species (Ahlstrom 1959; Smith et al. 1978; Kendall and Naplin 1981; Boehlert et al. 1985; Brewer and Kleppel 1986). The most common pattern observed is an increase in abundance at shallower depths at night, generally taken to mean active upward migration, and the reverse situation during the day, ie. downward movement. A variation on this theme is the presence of distinct vertical stratification only during daylight hours, with larvae being more dispersed throughout the water column at night (Brewer and Kleppel 1986). Red drum larvae are also vertically stratified but the diel pattern is quite unlike the pattern which has been described in most other species. Red drum larvae are more abundant higher in the water column during daylight hours and deeper at night. This same pattern has been observed in the Pacific cod (Boehlert et al. 1985) and Japanese sand eel (Yamashita et al. 1985). Diel vertical migration among sand eel larvae was said to be caused by daytime feeding activity and directed swimming movements in the lighted upper levels of the ocean followed by sinking to lower levels at night when active feeding and swimming ceases. One advantage to a nighttime period of inactivity that Yamashita et al. proposed is reduction in larval mortality due to predators which use vibrations, such as those caused by swimming, to detect their prey. Since red drum larvae feed almost exclusively at night (see Feeding Habits section of this report), cessation of feeding and relative inactivity at night would also cause them to gradually sink deeper in the water column.

It is unlikely that the vertical stratification of red drum larvae is influenced by the presence of a thermocline or density gradient (Miller et al. 1963; Kendall and Naplin 1981) since the water column during the peak of the red drum spawning season is well mixed with little pycnocline development. Vertical stratification of fish larvae in the absence of a thermocline was also observed over the continental shelf of the Middle Atlantic Bight (Smith et al. 1978) and in nearshore waters off California (Brewer and Kleppel 1986).

Ontogenetic and/or size-related changes have been shown to influence the onset and amplitude of vertical migration in fish larvae (Smith et al. 1978; Brewer and Kleppel 1986). Red drum larvae were not vertically stratified by size within the size range 2.5 to 7.5 mm SL. However, during the morning sampling period of cruise 85-9-1 when the highest densities of small larvae (size class 1.5 mm) were observed, the typical diel pattern of greater larval abundance at 1 m than 5 m, seen when modal size classes were 2.5 to 4 mm, did not occur. Instead these small larvae were found at similar densities at both 1 and 5 m levels. The weaker swimming ability of small red drum larvae could have accounted for their more homogeneous vertical distribution.

The red drum is described as being an estuarine-dependent species, whose postlarval and juvenile stages must reside in inshore, estuarine nursery grounds to insure their survival. Yet red drum spawning in the northcentral Gulf of Mexico occurs in offshore waters up to 34 km south of the LA-MS-Al barrier islands. Typical meteorological conditions during the spawning season are, in general, conducive to the inshore transport of larvae in this region. In the months of September, October, and November easterly (alongshore) winds cause onshore Ekman transport, and the subsequent rise in mean sea level along the coasts of Mississippi and Alabama (Schroeder and Wiseman 1985). But typical hydrographic conditions do not always prevail. Chuang et al. (1982) noted that along the Alabama coast there was no permenant summer (June to August and early September) pattern in local, wind-driven circulation, and that the direction in cross-shelf motion could be either onshore or offshore.

The speed and direction of local currents as measured by our subsurface current drogue indicated that shelf currents, at least in the upper 5 m, along or in the vicinity of the 18 m contour did not consistently favor inshore transport of red drum larvae. The most persistent pattern to emerge from our drogue tracks in August to early October, 1984 and 1985 was movement which paralleled the 18 m contour. Direction of movement was either towards the east or west where this contour runs parallel to the axis of the coastal barrier islands, or towards the south where the contour is oriented parallel to the Chandeleur Island chain. The tendency for surface currents to flow parallel to bottom topography has been observed in this region by others (W. Schroeder, per. commun.). All drogue tracks during the time of peak larval abundance in 1984 showed net southward displacement during the 24 hour period of observation, while in 1985 net displacement was either to the east or west. Depiction of shelf currents by our drogue tracks has one major shortcoming. These 24 hr records spaced at two week intervals are only brief glimpses of small scale water movement in a hydrologically complex and dynamic region. The recurring patterns and consistency within and between seasons, however, suggest that red drum larvae found in the vicinity of the 18 m contour were more likely to have been either retained in that same area or displaced farther offshore during their 12-16 day planktonic existence than transported northward into the nursery grounds of Mississippi Sound.

Further support of this hypothesis is the absence of accumulation of larger and older red drum larvae at the nearshore site. The size and age distributions of red drum larvae at offshore and nearshore sampling sites, 15-19 km apart, were similar. Differences in maximum and modal age of larvae at offshore and nearshore sites ranged from 1 to 4.5 days but were usually less than 2 days. It is unlikely that larvae spawned offshore could have been transported to the nearshore site in 1-2 days considering the observed mean rates (0.2- 0.3 kts) and direction of drift in offshore waters. It is even more unlikely that larvae could have swam inshore. Hypothetically, it would take a 3 mm larva, swimming continuously day and night at 10 body lengths or 3 cm per sec , 7 days to reach the nearshore site. Larvae in the size range, 2-4 mm SL, most abundant in our collections are not capable of such directed movement, and, as was shown, are under the influence of currents moving at 7 to 20 X's their hypothetical cruising speeds, and at least sometimes in directions away from shore.

These findings support the conclusion that red drum larvae found nearest to Mississippi Sound may not come from the large pool of eggs and larvae spawned 17-34 km offshore. Instead the young larvae found nearshore were probably spawned closer to that site perhaps inside the 18 m contour. This, however, does not seem likely since the largest concentrations of adult drum have most consistently been reported to occur farther offshore. The more likely location of nearshore spawning is Breton and Chandeleur Sounds. In past years that inshore area has supported a substantial Louisiana purse seine fishery for adult red drum in fall months.

The ultimate fate of the large concentrations of red drum larvae in offshore waters is unknown. These larvae may transform into postlarvae and juveniles over the shelf and either enter inshore estuarine areas at larger sizes and at later dates, or remain in offshore waters. The large expanse of shallow habitat associated with the Chandeleur Islands may provide the necessary nursery grounds for survival of postlarval red drum. Could these shelf waters be as important as nurseries for red drum as the protected waters of Mississippi Sound? The presence or absence of postlarval and juvenile red drum in these waters awaits further investigation.

LITERATURE CITED

Ahlstrom, E. H. 1959. Vertical distribution of pelagic fish eggs and larvae off California and Baja California. U.S. Fish Wildf. Serv., Fish. Bull. 60:107-146.

Bass, R. J., and J. W. Avault, Jr. 1975. Food habits, length-weight relationships, condition factor, and growth of juvenile red drum, Sciaenops ocellata, in Louisiana. Trans. Am. Fish. Soc. 104:35-45.

Boehlert, G. W., D. M. Gadomski, and B. C. Mundy. 1985. Vertical distribution of ichthyoplankton off the Oregan coast in spring and summer months. Fish. Bull., U.S. 83:611-621.

Brewer, G. D., and G. S. Kleppel. 1986. Diel vertical distribution of fish larvae and their prey in nearshore waters of southern California. Mar. Ecol. Prog. Ser., 27:217-226.

Chuang, W-S., W. W. Schroeder, and W. J. Wiseman, Jr. 1982. Summer current observations off the Alabama coast. Contrib. Mar. Sci., 25:121-131.

Crocker, P. A., C. R. Arnold, J. A. DeBoer, and J. D. Holt. 1981. Preliminary evaluation of survival and growth of juvenile red drum (Sciaenops ocellata) in fresh and salt water. Proc. World Maric. Soc., 12:122-134.

Ditty, J. G. 1986. Ichthyoplankton in neritic waters of the northern Gulf of Mexico off Louisiana: composition, relative abundance, and seasonality. Fish. Bull., U.S. 84:935-946.

Gulland, J. A. 1982. Why do fish numbers vary? J. Theor. Biol., 97: 69-75.

Holt, J., A. G. Johnson, C. R. Arnold, W. A. Fable, Jr., and T. D. Williams. 1981a. Description of eggs and larvae of laboratory reared red drum, Sciaenops ocellata. Copeia 1981:751-756.

Holt, J., R. Godbout, and C. R. Arnold. 1981b. Effects of temperature and salinity on egg hatching and larval survival of red drum Sciaenops ocellata. Fish. Bull., U.S. 79:569-573.

Holt, S. A., C. L. Kitting, and C. R. Arnold. 1983. Distribution of young red drum among different sea-grass meadows. Trans. Am. Fish. Soc., 112:267-271.

Holt, G. J., S. A. Holt, and C. R. Arnold. 1985. Diel periodicity of spawning in sciaenids. Mar. Ecol. Prog. Ser., 27:1-7.

Houde, E. D., J. C. Leak, C. E. Dowd, S. A. Berkeley, and W. J. Richards. 1979. Ichthyoplankton abundance and diversity in the eastern Gulf of Mexico. Report to BLM, Contract No. AA550CT7-28, 546p.

Jannke, T. E. 1971. Abundance of young sciaenid fisher in Everglades National Park, Florida in relation to season and other variables. Univ. Miami Sea Grant Tech. Bull. 11:28p.

Kendall, A. W., Jr., and N. A. Naplin. 1981. Diel-depth distribution of summer ichthyoplankton in the Middle Atlantic Bight. Fish. Bull., U.S. 79:705-726.

King, B. D., III. 1971. Study of migratory patterns of fish and shellfish through a natural pass. Texas Parks Wildl. Dept. Tech. Ser. 9, 54p.

Lee, W. Y., G. J. Holt, and C. R. Arnold. 1984. Growth of red drum in the laboratory. Trans. Am. Soc. 113:243-246.

Miles, D. W. 1950. The life histories of spotted seatrout, Cynoscion nebulosus, and the redfish, Sciaenops ocellata. Texas Game Fish Comm. Mar. Lab. Annu. Rep. 1949-1950.

Miller, D., J. B. Colton, Jr., and R. R. Marak. 1963. A study of the vertical distribution of larval haddock. J. Cons. Perm. Int. Explor. Mer 28:37-49.

Parrish, B. B. 1973. Foreward, fish stocks and recruitment. Rapp. P.-V. Reun. Cons. Int. Explor. Mer 164:1-3.

Pearson, J. C. 1929. Natural history and conservation of redfish and other commercial sciaenids on the Texas coast. Bull. U.S. Bur. Fish. 44:129-214.

Perret, W. S., J. E. Weaver, R. O. Williams, P. L. Johansen, T. D. McIlwain, R. C. Raulerson, and W. M. Tatum. Fishery Profiles of Red Drum and Spotted Seatrout. Gulf States Marine Fisheries Commission, 60p.

Peters, K. M., R. H. McMichael, Jr. 1987. Early life history of the red drum, Sciaenops ocellatus (Pisces: Sciaenidae), in Tampa Bay, Florida. Estuaries 10:92-107.

Sharp, G. (rapporteur), 1980. Workshop on the effects of envirnomental variation on the survival of larval pelagic fishes. UNESCO, Intergovermnental Oceanographic Commission, Workshop Report 28.

Schroeder, W. W., and W. J. Wiseman, Jr. 1985. An analysis of the winds (1974-1984) and sea level elevations (1973-1983) in coastal Alabama. Mississippi-Alabama Sea Grant Consortium, Publication No. MASGP-84-024.

Simmons, E. G., and J. P. Brewer. 1962. A study of redfish, Sciaenops ocellata, and black drum, Pogonias cromis. Publ. Inst. Mar. Sci. Univ. Texas 8:184-211.

Smith, P. E. 1985. Year-class strength and survival of 0-group clupeoids. Can. J. Fish. Aquat. Sci. 42 (Suppl.1):69-82.

Smith, W. G., J. D. Sibunka, and A. Wells. 1978. Diel movements of larval yellowtail flounder, Limanda ferruginea, determined from discrete depth sampling. Fish. Bull., U.S. 76:167-178.

Steen, J. P., Jr., and J. L. Laroche. 1983. The food of red drum (Sciaenops ocellatus) larvae and early juveniles taken from Mississippi Sound and the northcentral Gulf of Mexico. In. Shabica, S. V., N. B. Cofer, and E. W. Cake, Jr. (eds). Proceedings of the northern Gulf of Mexico estuaries and barrier islands research conference. 13-14 June 1983, Biloxi, MS, U.S. Dep. Int. Natl. Park Serv. SE Reg. Off., Atlanta, GA. 191p.

Van Guelpen, L., D. F. Markle, and D. J. Duggan. 1982. An evaluation of accuracy, precision, and speed of several zooplankton subsampling techniques. J. Cons. Int. Explor. Mer 40:226-236.

Yamashita, Y., D. Kitagawa, and T. Aoyama. 1985. Diel vertical migration and feeding rhythm of the larvae of the Japanese sand-eel Ammodytes personatus. Bull. Jap. Soc. Sci. Fish. 51:1-5.

Yokel, B. 1966. A contribution to the biology and distribution of the red drum, Sciaenops ocellata. M.S. Thesis, Univ. Miami. 166p.

Section 3. AGE AND GROWTH

INTRODUCTION

Year class strength of many marine fishes is often determined during embryonic and larval developmental periods (Cushing 1975, Leak and Houde 1987). It is during these early life history stages that fishes are most susceptible to the primary causes of mortality; starvation, predation, or an interaction between both factors (Hunter 1981). Even relatively small changes in daily mortality rates during these early stages can cause large fluctuations in future recruitment levels (Houde 1987). Larval growth rates directly affect mortality by influencing larval stage duration (Houde 1987). As stage duration increases, larvae are subjected to high mortality rates for a longer period of time. Larval growth also affects mortality in that larger fish are more adept swimmers and are consequently better able to escape predators and capture prey (Bailey 1984).

Age at size must be known in order to quantify larval growth rates. Aging field caught larvae was not possible until Pannella (1971) discovered daily growth rings in otoliths of certain adult temperate fishes. Brothers et al. (1976) subsequently showed that the larvae of some marine fishes could be aged by counting daily otolith growth rings. These findings led to numerous studies of age, growth, and mortality of larval fishes (See reviews by: Jones 1985, Geffen 1987).

Growth of larval red drum, <u>Sciaenops</u> <u>ocellatus</u>, has been studied in the laboratory (Lee et al. 1984), and limited data on larval red drum growth in the field has been reported by Peters and McMichael (1987). The latter study verified the daily periodicity of ring formation in lab reared larval red drum of known age, a prerequisite for determining growth rates of field caught specimens.

Our study was undertaken to examine the age distribution and growth rates in length and weight of red drum larvae collected in Mississippi coastal waters under the premise that growth in fishes can be a sensitive measure of resource availability.

METHODS

Larval red drum used for otolith analysis were collected in Mississippi coastal waters in September and October of 1983, 1984 and 1985. Collection details are explained in the general methods section of this report.

Larvae, preserved in 95% Etoh, were measured to the nearest tenth of a millimeter (NL or SL) with an ocular micrometer. To determine dry weights, larvae were rinsed with distilled water, dried for 12 hr at 70°C, and weighed to the nearest 0.1ug with an electrobalance.

Dried larvae were then prepared for otolith analysis. They were first soaked in water for 12 hr to soften body tissues and then returned to 70% Etoh. Softening of body tissues facilitated the subsequent infiltration of larvae with Spurr resin embedding medium (Spurr 1969). Larvae were then dehydrated for 1 hr in 95% Etoh, and infiltrated with Spurr resin for 1 hr in each step of the following series; 30% Spurr / 70% Etoh, 70% Spurr / 30% Etoh, and finally 100% Spurr. Flat embedding molds (#70900,E.M.S.,Fort Washington,Pa.) used to mount the larvae were partially filled with liquid Spurr (Haake et al. 1982). The resin was then polymerized at 70°C for 4 hr until it became highly viscous. Each larva was placed in the partially polymerized Spurr and oriented parallel to the long axis of the mold cavity, which was then filled with resin and polymerized for 12 hr at 70°C. Orienting the larvae with the otoliths in situ enabled consistent sectioning of the otoliths in the same plane.

Each hardened resin block was cut with a hand coping saw (32 teeth/in) to obtain a small section containing the anterior half of a larva. The section was then mounted to a glass microscope slide with Crystal-bond adhesive and oriented so that the sagittal plane through the encased larva was perpendicular to the slide, and the ventral edge of the larva was closest to and parallel with the slide. This orientation insured that grinding and polishing of otoliths yielded frontal sections.

Each resin block was sanded until the sagittae were near the surface of the sanded side. Sanding was done by hand rubbing the resin block (attached to a glass slide) against 180, 600 and 1200 grit wet-or-dry sandpaper. The sanded surface was then polished against a piece of medium weight, brushed denim containing wet 0.3 micron alpha alumina polishing powder.

To obtain a frontal cross section of an otolith the mounting slide was placed on a hot plate (low heat) to melt the Crystal-bond adhesive, at which time the resin block was remounted on the slide, polished side down. The inverted block was then ground and polished as previously described until a cross section through the otolith primordium (center) was obtained.

Otolith cross sections, viewed with a compound light microscope at 1250X under oil immersion, showed both daily and subdaily growth increments. A daily growth increment consisted of a wide translucent incremental zone, bordered by a narrow opaque discontinuous zone. Subdaily growth marks were defined by faint discontinuous zones. Sagittae cross sections were also examined with a Scanning electron microscope (SEM) to validate observations made with the light microscope. Otolith cross sections were prepared for SEM by first etching the polished otolith surface with 1% EDTA (disodium ethylenediaminetetra-acetate, pH 7.4 adjusted with NaOH) for 2 min. The section of glass slide supporting the etched otolith was then attached to a stub with double sided tape, coated with gold, and examined in a JEOL scanning electron microscope at 10 kV.

Live, field collected red drum eggs, which upon hatching yielded larvae of known age, were used to determine time of formation of the first daily growth increment. Plankton samples collected with bongo nets (333 um) were washed into 10 l buckets to which 30 g of artificial sea salt were added (Mayo 1973). Addition of sea salt increased water density and caused fish eggs to float to the surface of the sample. Fish eggs were decanted from the sample, transferred to 4 l jars containing ambient sea water, and examined under a stereo-microscope. Potential red drum eggs were transferred to large petri dishes, hatched on board to verify species identification, and maintained for four days in 4 l containers under a 12hr light \ 12hr dark cycle. Water in the rearing containers was partially exchanged each day to maintain water quality.

Analysis of matched pair otolith diameter data with a t-distribution (Schefler, 1969) showed no significant difference $(P > 0.25)$ between diameters of left and right sagittal otoliths. Larval red drum were consequently aged with either left or right otoliths. Daily increments were counted along the long axis of the otolith from the primordium to the outer edge.

Age-length and age-weight relationships were represented by the exponential equation L or $W = ae^{Gt}$, where L = notochord or standard length, W = dry weight, a = Y-intercept, G = slope of regression line (instantaneous growth rate), and t = larval age in days. Values of "a" and "G" were computed with an ordinary predictive regression after the data set was linearized by a natural log transformation. The length-weight relationship was described by the exponential equation $W = aL^b$ (using $\log_{10}$ transformed variates), where W = dry weight, a = Y-intercept of the functional regression, L = notochord or standard length, and b = slope of the regression line. A geometric mean functional regression was used to describe length-weight data because both variates were subject to error of measurement and inherent variability (Ricker 1973). Slope and elevation of regression lines were compared with a General Linear Model (GLM) procedure using a separate slopes model (Statistical Analysis System, SAS Institute, Inc. 1982)

RESULTS

Otoliths of field caught larval red drum began developing during the embryonic stage, and two days after fertilization (approx. one day post-hatch) two daily growth increments had formed (Fig. 24).

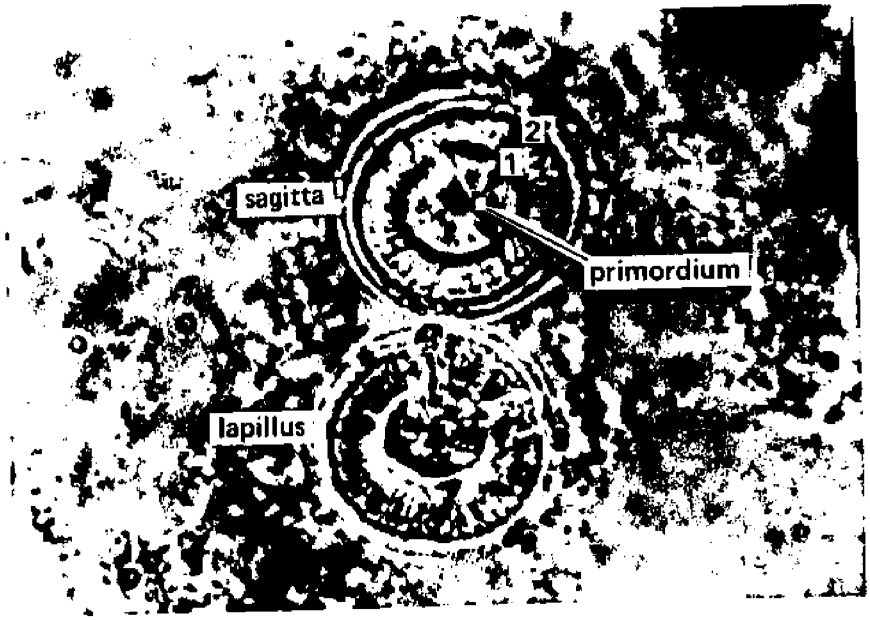


Figure 24. Photomicrograph of a sagitta from a two day old red drum larva (X 1250) showing two daily growth increments.

The two innermost discontinuous zones remained consistently broad and poorly defined in older larvae. Subsequent discontinuous zones, formed when larvae were feeding exogenously, were narrow and sharply defined (Fig. 25).

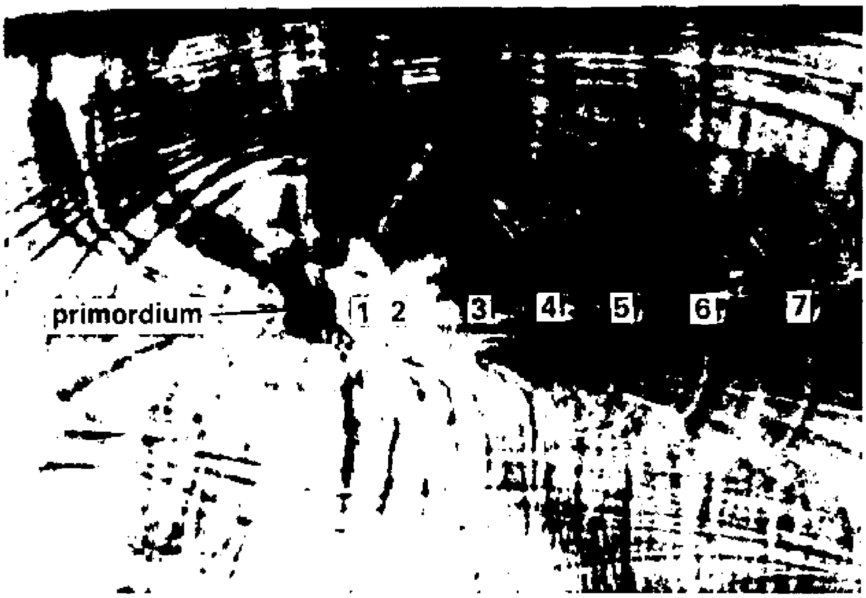


Figure 25. Photomicrograph of a sagitta from a 13 day old red drum larva (X 1250) showing the first seven daily growth increments.

Light microscope observations were corroborated with Scanning electron microscopy. SEM micrographs revealed that only the discontinuous zones delineating daily growth increments were deeply etched by acid. An otolith from a seven day old larva (Fig. 26) showed five sharply defined growth increments, and as in light microscope observations, the two innermost discontinuous zones were less distinct.

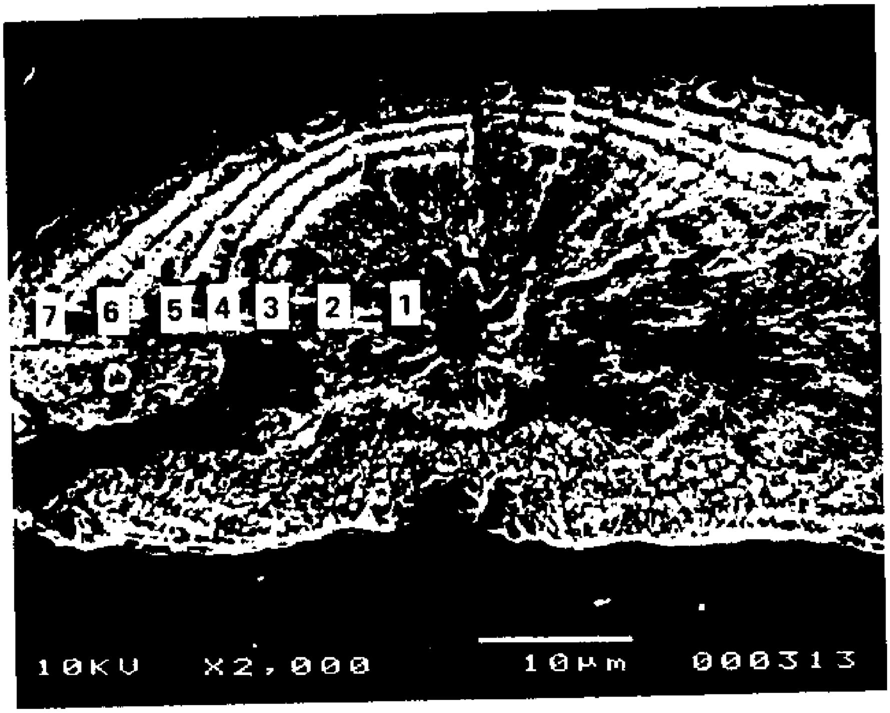


Figure 26. Scanning electron micrograph of a sagitta from a seven day old red drum larva.

A total of 113 red drum larvae ranging in size and age from 1.6 to 6.8 mm, and 2 to 19 days, respectively, were used for age / growth analyses. Because of either small sample size or a limited larval size range, age-length, age-weight, and length-weight regression analyses were limited to collections taken in October 1983 and 1984, and September 1985 (Table 8). The October 1983 data set includes larvae collected during two sampling trips; ten small larvae (2.2 - 3.6 mm) collected in October 1983 when water temperatures ranged from 24.0°- 24.5°C were included in the data set for purposes of regression analyses.

Table 8. Total number of aged red drum larvae, size range (mm), and age range (days) of specimens collected in September and October of 1983, 1984 and 1985. * = data sets used in regression analyses.

	No. Fish Aged	Size Range (mm)	Age Range (days)
Sept 1983	2	2.6, 4.5	5, 11
Oct 1983*	37	2.2 - 6.0	4 - 13
Sept 1984	27	2.3 - 3.5	5 - 7
Oct 1984*	23	3.2 - 6.8	6 - 19
Sept 1985*	24	1.6 - 6.5	2 - 13
Oct 1985	0	---	---
TOTAL	N = 113	1.6 - 6.8	2 - 19

AGE - WEIGHT

Larval growth was exponential and increased rapidly after 9 days (Fig. 27). Growth was positively associated with water temperature and differed significantly in October 1983, October 1984 and September 1985 ($P < .001$; Table 9). Coldest water temperatures occured in October 1984 (24.5°- 25.1°C) and were associated with the slowest growth rates. At these temperatures larvae less than 9 days old which were feeding exogenously gained approximately 18 ug d^{-1}, while the average weight gain of older larvae (9 - 13 days) increased to 51 ug d^{-1}.

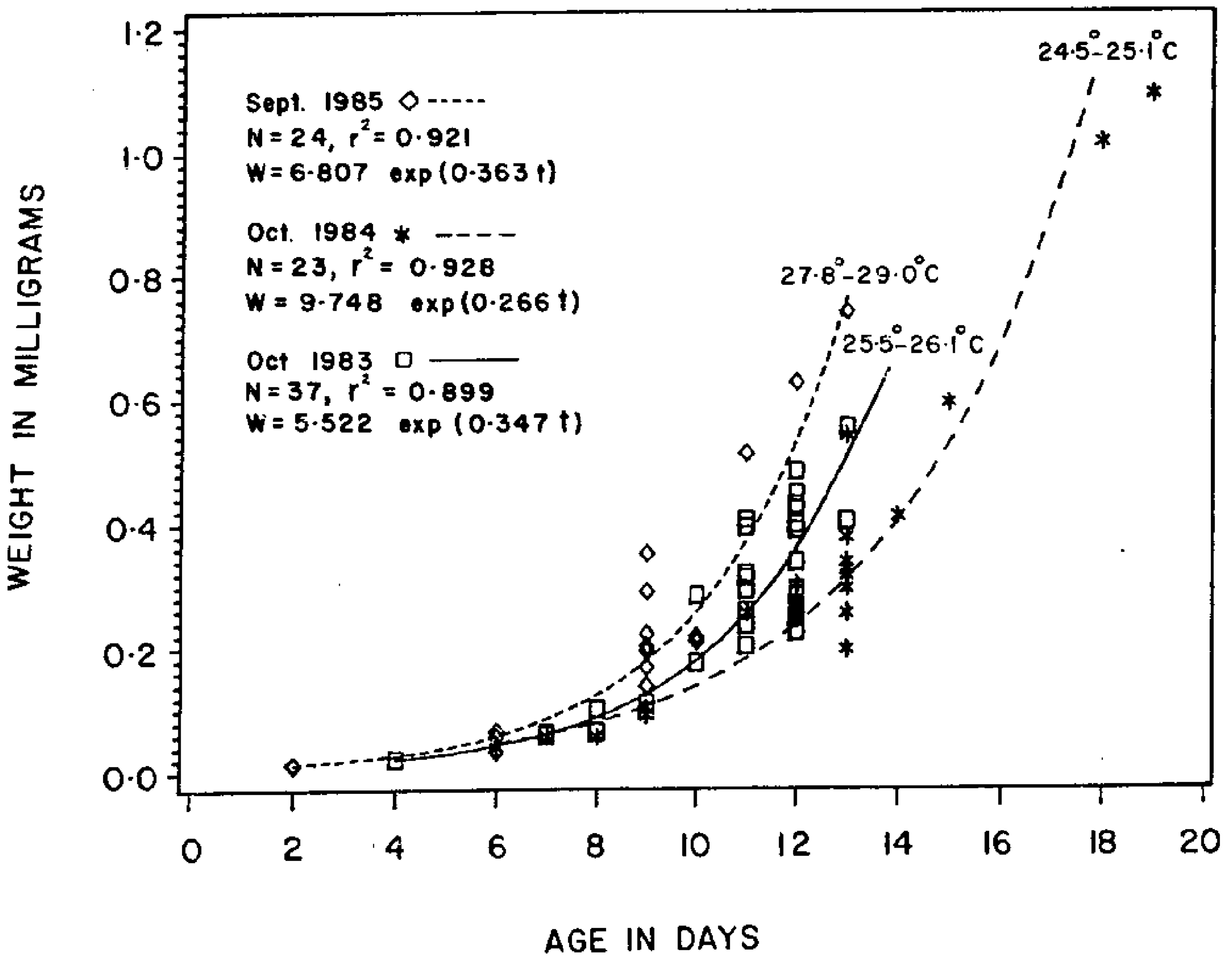
Water temperatures in October 1983 were slightly warmer than in October 1984, ranging from 25.57°to 26.1°C. Growth rates increased accordingly; larvae younger than 9 days gained approximately 21 ug d^{-1}, while weight gain of older larvae (9 - 13 days) averaged 94 ug d^{-1}. The inclusion in this data set of ten small larvae collected when water temperatures ranged from 24.0°to 24.5°C would have little effect on the resulting growth rates because growth of small larvae was similar over all temperatures studied. Eventually, back calculating techniques will be used to obtain growth information for small larvae in this data set.

Highest water temperatures occurred in September 1985 (27.8°- 29.0°C) and were associated with the fastest growth rates. While growth of larvae younger than 9 days remained quite slow, 30 ug d^{-1}, older larvae (9 - 13 days) gained weight rapidly, averaging 146 ug d^{-1}.

Table 9. Regression parameters for age - weight relations of red drum larvae caught in October 1983 and 1984, and September 1985.

	Sample size	Regression coefficient	Correlation coefficient	Coefficient of determination	Standard error of regression coefficient	95% C.I. about regression coefficient	Growth equation
Oct 1983	37	0.347	0.948	0.899	0.020	0.306 - 0.388	$W = 5.522 \exp(0.347\ t)$
Oct 1984	23	0.266	0.963	0.928	0.016	0.233 - 0.299	$W = 9.748 \exp(0.266\ t)$
Sept 1985	24	0.363	0.960	0.921	0.026	0.309 - 0.417	$W = 6.807 \exp(0.363\ t)$

Figure 27. Relationship between age and dry weight for larval red drum collected in the northcentral Gulf of Mexico in October 1983, October 1984 and September 1985.



AGE - LENGTH

Growth rates (G or regression coefficient) in September 1985 were significantly different from growth rates in October of both 1983 and 1984 ($P < .0001$), but growth rates in October 1983 and 1984 were not significantly different from each other according to the GLM analysis of covariance. The lack of significance between larval growth in October of 1983 and 1984 is probably an artifact caused by the scarcity of larvae younger than 8 days in the October 1984 data set, since October data sets certainly appear to be significantly different from each other. The regression coefficients vary from 0.060 in October 1984 to 0.107 in October 1983, with no overlap in the 95% confidence intervals about the regression coefficients (Table 10). The scarcity of young fish in the 1984 data set can be remedied by the addition of back calculated age-length data.

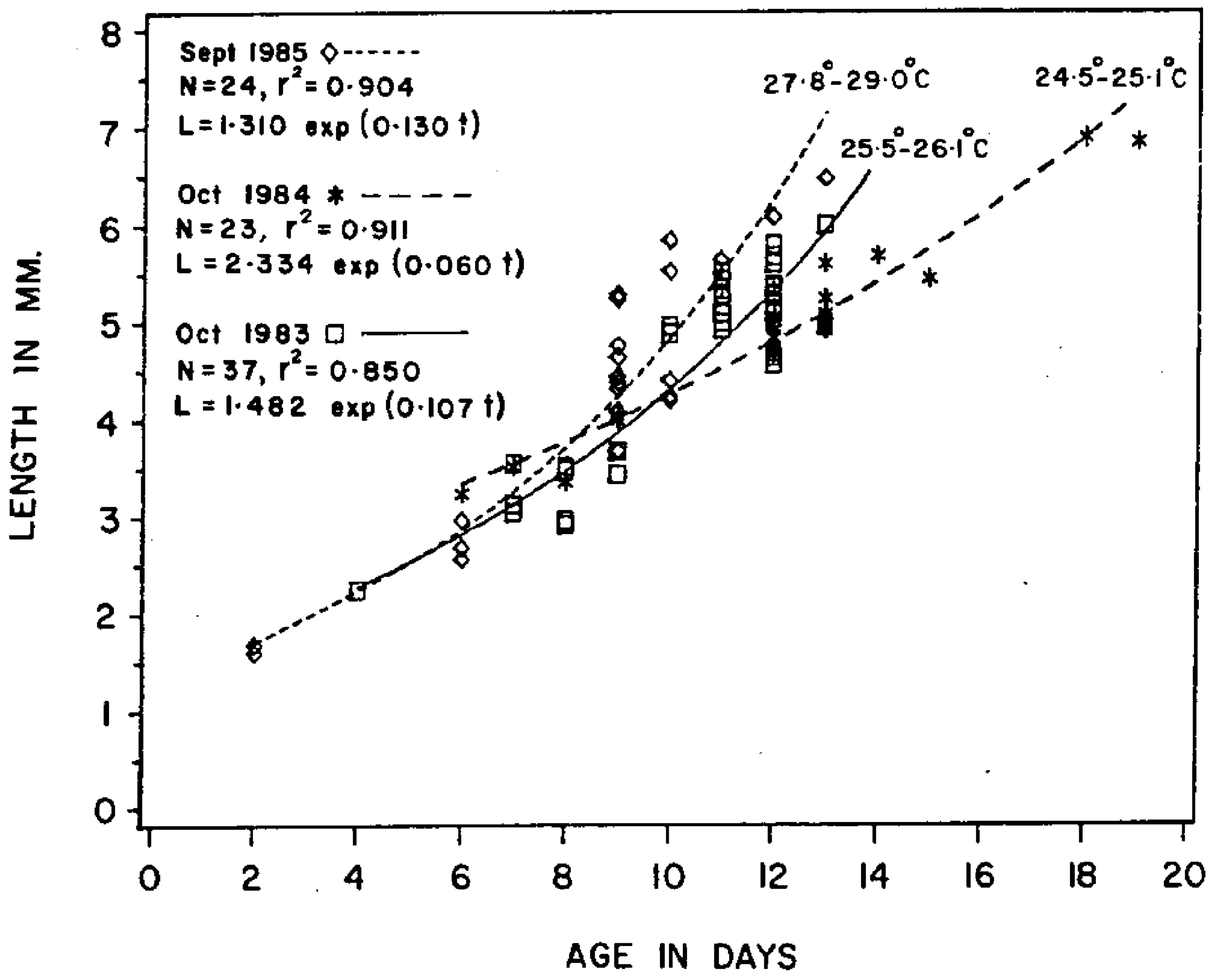
Growth of larvae smaller than approximately 4 mm was relatively slow (< 0.3mm d^{-1}), but at sizes greater than 4 mm growth rates increased exponentially (Fig. 28). Larval growth rates were positively associated with water temperature. Warmest water temperatures occured in September 1985 (27.8°- 29.0°C) and were associated with the fastest larval growth rates. At these temperatures larvae smaller than 4 mm grew at an average of 0.29 mm d^{-1}, while the growth rate of larger larvae (4 - 6 mm) increased to 0.65 mm·d^{-1}. Conversely, slower growth rates were associated with colder water temperatures. Temperatures in October 1984 ranged from 24.5°to 25.1°C, and while the growth rate of small larvae (0.28 mm d^{-1}) was similar to rates found at higher temperatures, fish larger than 4 mm grew much slower at the colder temperatures ($P < .0001$), averaging only 0.29 mm d^{-1}. These slower growing larvae reached a length of 6 mm in approximately 15.8 days, while larvae spawned in September 1985 at warmer temperatures grew to 6 mm in only 11.7 days.

The water temperature in October 1983 ranged from 25.5°to 26.5^0 C, and was intermediate between September 1985 and October 1984 temperatures. Growth of larvae smaller than 4 mm was again slow, 0.27 mm d^{-1}, but the average growth rate of larger fish (4 - 6 mm) increased to 0.52 mm d^{-1}, intermediate between growth rates in September 1985 and October 1984.

Table 10. Regression parameters for age - length relations of red drum larvae caught in October 1983 and 1984, and September 1985.

	Sample size	Regression coefficient	Correlation coefficient	Coefficient of determination	Standard error of regression coefficient	95% C.I. about regression coefficient	Growth equation
Oct 1983	37	0.106	0.922	0.850	0.008	0.090 - 0.122	$L = 1.482 \exp(0.107\ t)$
Oct 1984	23	0.060	0.954	0.911	0.004	0.052 - 0.068	$L = 2.334 \exp(0.060\ t)$
Sept 1985	24	0.130	0.951	0.904	0.009	0.111 - 0.149	$L = 1.310 \exp(0.130\ t)$

Figure 28. Relationship between age and length for larval red drum collected in the northcentral Gulf of Mexico in October 1983, October 1984 and September 1985.



LENGTH - WEIGHT

The larval length - weight relationship in September 1985 was significantly different ($P < .01$) from the relationships in October of both 1983 and 1984, while only borderline significance ($P = .067$) was found between the October 1983 and 1984 length - weight relationships (Table 11). Change in body weight per unit length was inversely related to water temperature and growth rate. Larvae collected in October 1984 when water temperatures were coldest (24.5°- 25.1°C) exhibited the greatest increase in weight per unit length. The length exponent "b" ($W = aL^b$) of these relatively robust larvae was 4.37. Larvae collected in October 1983 when water temperatures were warmer (25.5°- 26.5°C) were lighter per unit length, having a length exponent of 3.50. The smallest increase in weight per unit length was associated with the warmest water temperature. Larvae collected in September 1985 when water temperatures ranged from 27.8°to 29.0°C exhibited a length exponent of only 2.96. These relatively fast growing larvae weighed approximately 531 ug at 6 mm, while the mean weight of 6 mm larvae in October 1984 increased to 621 ug.

Table 11. Regression parameters for length - weight relations of red drum larvae caught in October 1983 and 1984, and September 1985.

	Sample size	Regression coefficient	Correlation coefficient	Coefficient of determination	Standard error of regression coefficient	95% C.I. about regression coefficient	Growth equation
Oct 1983	46	3.503	0.970	0.941	0.179	3.142 - 3.864	$W = 1.375\ L^{3.503}$
Oct 1984	26	4.372	0.966	0.983	0.232	3.893 - 4.851	$W = 0.322\ L^{4.371}$
Sept 1985	39	3.000	0.987	0.993	0.079	2.840 - 3.160	$W = 2.638\ L^{3.000}$

DISCUSSION

Species with small eggs and short incubation periods begin increment formation at the time of yolk sac absorption (Radtke 1984). Red drum are an exception; this species also has small eggs and a short incubation period (Holt et al. 1981), but the first otolith growth increment is formed one or two days prior to yolk sac absorption, ie. one day after fertilization. Red drum spawn around dusk (Holt et al. 1985), and formation of the first daily otolith growth increment is completed the following night, coincidentally with hatching. These findings agree with Peters et al. (1987) who predicted, based on the intercept of the age-increment number regression, that the first increment was formed on the day of hatch.

Growth rates of larval fish are primarily determined by water temperature and food (Methot 1979). Holt et al. (1981) determined that temperature has a pronounced effect on the growth rate of larval red drum. The mean standard length of red drum larvae that survived two weeks varied from 3.5 mm to 6.8 mm, depending on whether larvae were reared at 20°or 30°C, respectively. Lee et al. (1984) investigated the growth of larval red drum reared at 24°and 28°C, temperatures that closely approximate conditions in the present study, and also found growth rates to be positively correlated with water temperature.

Larval growth rates in the field were strongly associated with water temperature and were substantially higher than growth rates found in the lab (Table 12). Fifteen day old larvae reared at 24°and 28°C (Lee et al. 1984) averaged 4.79 and 5.12 mm, respectively, while the mean size of 15 day old field caught larvae when temperatures ranged from 24.5°to 25.1°C was 5.7 mm. When water temperatures were warmer, 27.8°to 29.0°C, field growth rates were even faster. Fifteen day old larvae were never found in plankton collections because, based on the growth equation, these larvae would be 9.2 mm and no longer planktonic.

Differences in weight gain between lab reared and field caught larvae were also pronounced. The average growth rate of 15 day old larvae reared in the lab at 28°C was 30.25 ug d^{-1} (Lee et al. 1984), while based on the growth equation, the average growth rate of similar aged wild larvae increased to 140 ug d^{-1} (27.8-29.0°C).

Table 12. Comparison between growth rates of lab reared (Lee et al. 1984) and field collected red drum larvae.

LAB REARED		FIELD COLLECTED	
24°C	$W = 12.109 \exp(0.161^{*} t)$	24.5-25.1°C	$W = 9.748 \exp(0.266^{*} t)$
28°C	$W = 9.259 \exp(0.221^{*} t)$	27.8-29.0°C	$W = 6.807 \exp(0.363^{*} t)$
24°C	$L = 2.317 \exp(0.043^{*} t)$	24.5-25.1C	$L = 2.334 \exp(0.06^{*} t)$
28°C	$L = 2.232 \exp(0.05^{*} t)$	27.8-29.0°C	$L = 1.31 \exp(0.13^{*} t)$

* indicates instantaneous growth coefficient.

Reported growth rates of larvae (< 8mm, N=37) in Tampa Bay, Florida (Peters et al. 1987), are similar to our estimates. The mean size of 12.5 day old larvae in Tampa Bay was 5.8 mm. Based on our growth equations, the mean size of 12.5 day old larvae growing at approximately 25°and 28°was 4.9 and 6.6 mm, repectively. Larvae used to estimate growth in the study by Peters et al. (1987) were collected when surface water temperatures ranged from 18.3°to 29.7°C, but temperature effects on growth were not examined because data were pooled.

To quantify the effect of food on growth it is necessary first to correct for the effect of temperature (Methot 1981). Unfortunately, results of the lab experiments by Holt et al. (1981) and Lee et al. (1984) cannot be used in conjunction with our field studies to factor out the effect of temperature on larval red drum growth because the larvae were fed a diet of rotifers and *Artemia* nauplii. Taniguchi (1982), comparing growth of *Cynoscion nebulosus* fed either rotifers or wild zooplankton, found that the rotifer diet caused slower growth.

While at warmer temperatures larval growth in the field was much faster than growth in the laboratory, at somewhat lower temperatures, 24°or 25°C, growth of wild larvae was, unexpectedly, only moderately faster. This may be because although a diet of rotifers and *Artemia* nauplii cannot supply the energy needed to support fast growth at temperatures >25°C, these unnatural prey may come close to supplying the nutrition needed to support the slower growth at temperatures <25°C.

In the present study zooplankton densities were similar at times of slowest (Oct 84') and fastest (Sept 85') larval growth. Although mean zooplankton abundance in October 1984 and September 1985 was 140 l^{-1} and 175 l^{-1}, respectively, the ranges in zooplankton densities totally overlapped. We therefore concluded that temperature, and not food, was the primary environmental factor influencing larval growth. Total zooplankton abundances were compared because the density of prey items (.06-.23 mm diam.) in October 1984 has not yet been determined. Comparisons of total zooplankton abundance are meaningful because of the association between total zooplankton and prey zooplankton densities. In 49 of the 52 samples analyzed to date, potential prey zooplankters comprised over 90% of the total zooplankton density.

Lee et al. (1984) found no significant difference between the length-weight relationships of red drum larvae reared at 24°and 28°C. However, length-weight relationships of wild red drum larvae did show significant differences at approximately the same temperatures . Change in body weight per unit length was inversely related to water temperature and growth rate. Weight is generally considered to be a better measure of absolute growth of fish larvae than length, as well as the prime determinant of condition when combined with length. However, rates of change cannot be inferred from length-weight data alone because, as shown here, environmental factors may change growth with time (Laurence 1979).

Changes in growth rate of wild red drum larvae was found to be associated with water temperature changes as small as 1°C. Since the ability of fish larvae to capture prey and escape from predators is largely size dependent (Bailey 1984), rate of growth can have a major influence on larval fish mortality. Changes of only tenths of a percent in daily mortality can produce orders of magnitude fluctuations in eventual adult populations (Laurence 1979).

LITERATURE CITED

Bailey, K. M. 1984. Comparison of laboratory rates of predationon five species of marine fish larvae by three planktonicinvertebrates: effects of larval size on vulnerability.Mar. Biol. 79(3):303-310.

Brothers, E. B., C. P. Mathews, and R. Lasker. 1976. Daily growth increments in otoliths from larval and adult fishes. Fish. Bull. 74:1-8.

Cushing, D. H. 1975. Marine ecology and fisheries. Cambridge University Press, Cambridge.

Geffen, A. J. 1987. Methods of validating daily increment deposition in otoliths of larval fish. p.223-240 in R. C. Summerfelt, and G. E. Hall, editors. Age and growth of fish. Iowas state university press, Ames, Iowa.

Haake, W. P., C. A. Wilson., and J. M. Dean. 1982. A technique for the examination of otoliths by SEM with application to larval fishes. p.12-15 in C. F. Bryan, J. V. Conner, and F. M. Truesdale, editors. Proceedings of the fifth annual larval fish conference. Louisiana Cooperative Fishery Research Unit. Louisiana State University, Baton Rouge, Louisiana, USA.

Holt, J., R. Godbout, and C. R. Arnold. 1981. Effects of temperature and salinity on egg hatching and larval survival of red drum, Sciaenops ocellata. Fish. Bull. 79:569-573.

Holt, G. J., S. A. Holt, and C. R. Arnold. 1985. Diel periodicity of spawning in sciaenids. Mar. Ecol. Prog. Ser. 27:1-7.

Houde, E. D. 1987. Fish early life dynamics and recruitment variability. Amer. Fish. Soc. Symp. 2:17-29.

Hunter, J. R. 1981. Feeding ecology and predation of marine fish larvae. p.33-71 in R. Lasker, editor. Marine fish larvae.

Jones, C. J. 1985. Determining age of larval fish with otolith increment technique. Fish. Bull., U.S. 84:91-103.

Laurence, G. C. 1979. Larval length-weight relations for seven species of northwest Atlantic fishes reared in the laboratory. Fish. Bull. 76:890-895.

Leak, J. C., and E. D. Houde. 1987. Cohort growth and survival of bay anchovy Anchoa mitchilli larvae in Biscayne Bay, Florida. Mar. Ecol. Prog. Ser., 37:109-122.

Lee, W. Y., G. H. Holt, and C. R. Arnold. 1984. Growth of red drum larvae in the laboratory. Trans. Am. Fish. Soc. 113:243-246.

Mayo, C. A. 1973. Rearing, growth, and development of the eggs and larvae of seven scombrid fishes from the Straits of Florida. Doctoral dissertation. University of Miami, Coral Gables, Florida, U.S.A.

Methot, R. D. Jr., and D. Kramer. 1979. Growth of northern anchovy, Engraulis Mordax, larvae in the sea. Fish. Bull. 77:413-423.

Methot, R. D. Jr. 1981. Spatial covariation of daily growth rates of larval northern anchovy, Engraulis Mordax, and northern lampfish, Stenobrachius leucopsarus. Rapp. P.-v. Reun. Cons. int. Explor. Mer, 178:424-431.

Pannella, G. 1971. Fish otoliths: daily growth layers and periodical patterns. Science 173:1124-1127.

Peters, K. M., and R. H. McMichael, Jr. 1987. Early life history of the red drum, Sciaenops ocellatus (Pisces: Sciaenidae), in Tampa Bay, Florida. Estuaries 10(2):92-107.

Radtke, R. L. 1984. Formation and structural composition of larval striped mullet otoliths. Trans. Am. Fish. Soc. 113:186-191.

Ricker, W. E. 1973. Linear regressions in fishery research. J. Fish. Res. Board Can. 30:409-434.

Schefler, W. C. 1969.Statistics for the biological sciences. Addison-Wesley publishing Co., Reading, Mass. pp.231.

Spurr, A. R. 1969. A low-viscosity epoxy resin embedding medium for electron microscopy. J. Ultrastructure Res. 26:31-43.

Taniguchi, A. K., 1982. Growth efficiency estimates for laboratory-reared larval spotted seatrout fed microzooplankton or rotifers. p.6-11 in C. Bryan, J.V. Conner, and F. M. Truesdale, editors. Proceedings of the fifth annual larval fish conference. Louisiana State University, Baton Rouge, Louisiana, USA.

Section 4. FOOD AND FEEDING OF PLANKTONIC RED DRUM LARVAE

INTRODUCTION

Hjort (1914) was first to associate larval feeding success to population recruitment in marine fishes, since then many studies that describe the diets of marine larval fishes have been published (Arthur 1976; Lasker 1978; Hunter 1981; Govoni et al. 1983; Tilseth and Ellertsen 1984; Walline 1987). While larvae of some fish species, particularly clupeoids, feed directly on phytoplankton, (Blaxter 1974; Lasker 1975, 1978, 1981) most larvae feed on zooplankton sometime during their early development. All life stages of copepods are eaten by most larval fish (Hunter 1981). In studies conducted within northern Gulf of Mexico waters, Govoni et al. (1983) found that Gulf menhaden larvae had a diverse diet that included diatoms, dinoflagellates, tintinnids, pelecypods, pteropods, and all stages of copepods, whereas the larvae of spot and Atlantic croaker fed primarily on zooplankters.

Feeding habits of juvenile red drum have been described by Miles (1950), and Bass and Avault (1975). Pearson (1929), Gunter (1945), Kemp (1949), Miles (1949; 1950), Knapp (1950), Reid et al. (1956), Darnell (1958), Simmons and Breuer (1962), Yokel (1966), Boothby and Avault (1971), and Overstreet and Heard (1978) have examined the diets of adult red drum. The only dietary data on larval red drum from the northern Gulf is found in a study by Steen and Laroche (1983), in which the gut contents of larval and juvenile red drum taken from Mississippi Sound and nearshore locations were examined. This work included no data concerning the availability of zooplankton prey to the larvae.

Many marine larval fish occupy a common habitat (the upper mixed layer over the continental shelves). Since they are generally planktivores, they may compete for the same food (Cushing 1975; Laurence et al. 1981). Selective feeding was demonstrated to occur among three species (Gulf menhaden Brevoortia patronus, spot Leiostomus xanthurus, and Atlantic croaker Micropogonias undulatus) in the northern Gulf of Mexico (Govoni et al. 1986).

Recognition of prey by the fish larvae and the width of the food organism are important factors in food selection. Fish larvae have no retinal cone cells or retinomotor pigment movement (Blaxter 1975) so feeding is generally confined to the day (Hunter 1981). Several studies have addressed food width and its influence on digestion in larval fish (Detwyler & Houde 1970; Hunter 1981; Checkley 1982; Dabrowski & Bardega 1984; Govoni et al. 1986).

METHODS

FISH LARVAE

Laboratory:

Larval red drum were removed from the preserved Tucker trawl plankton samples. Samples containing more than 50 fish were subsampled with a Motodo box (Motodo 1959) until the numbers of fish in the resulting aliquot was comparable to those of the other samples. Every fish examined for food analysis had notochord length (NL) and mouth gape measured. The gut contents were excised and each prey item was identified and measured across its widest body axis excluding appendages.

MICROZOOPLANKTON

At Sea:

Microzooplankton were collected from three depths at each sampling station. These depths correspond to those of Tucker trawl samples. A sample was always taken from the depths of one meter and five meters, while the third depth was three meters above the bottom and varied with overall water depth. Approximately .03 to .05 m^3 of sea water was pumped onboard through a 1 in. diameter hose with a diaphragm pump that delivered 38 L per min. It was then passed through 63 u and 25 u nets onto which microzooplankton was collected. Samples from each net were separately fixed and preserved in 5% buffered formalin solution. A 100 micron mesh net was used to collect microzooplankton during 1983. In both 1984 and 1985 the 63 micron mesh net was used which presents problems in comparing the 1983 zooplankton data directly with the data from 1984 and 1985.

Laboratory:

The microzooplankton samples were taken from the 63 u net and split (1/2) from one to four times using a Motoda Box (Motoda 1959). Each organism in the final split was identified under a dissecting microscope to its most distinct taxa and greatest body width, excluding appendages, was measured. Taxa, width, development stage and sex was recorded for each individual zooplankter. Data were entered directly into an electronic data logger for future analyses.

CHLOROPHYLL

At Sea:

For each sampling depth, water was pumped aboard and passed through a 300u net into a carboy. The net provided screening of any large zooplankters or debris that might hinder analysis. Water from the carboy, collected in conjunction with microzooplankton, was filtered for both chlorophyll and phytoplankton.

Water in the carboy was continually shaken to insure a well mixed plankton sample, and depending on the turbidity, 300 to 1000 ml aliquots were removed and filtered through 0.8u Milipore tri-acetate membrane filters using gentle suction (5" Hg) in low-light conditions. Two replicates per sampling depth were obtained. The filters were trimmed of excess paper, placed in a darkened desiccator, and frozen for later pigment analysis.

Laboratory:

Chlorophyll determinations were made from 90% acetone extracts using the tri-chromatic method described by Strickland and Parsons (1972). Custom made, 10 cm light-path, 4 ml cells were used for analysis. A Perkin Elmer Lamda-3b UV-visible double-beam spectrophotometer facilitated by a computer program took 6 readings at each of 5 wavelengths and printed out calculated chlorophyll values. Blank readings were obtained from filter pad extracts made with a 90% acetone solution.

NET PHYTOPLANKTON AND NANNOPLANKTON

At Sea 1984:

One to five liters of water previously filtered through 300u mesh nets were strained through a 20u Nytex net to collect the larger phytoplankters referred to as "net" phytoplankton. The contents on the 20u net were washed into a glass jar with 5% formalin-seawater solution which fixed and preserved the sample. From the water passing through the 20u net, 50 ml aliquots were removed and strained through .8u Milipore membrane filters (25mm) under vacuum filtration for concentration of nannoplankton organisms. The filters were frozen for later processing in the laboratory.

Laboratory 1984:

Net phytoplankton species identification, cell counts, and cell volume measurements were made from aliquots of the preserved samples. The Utermohl

(1958) method was used in which aliquots were settled for 16 to 24 hours in a plastic combination settling chamber and examined under a inverted microscope equipped with phase contrast. Alternate pass and field diameter transect procedures were used in counting as described by Hasle (1978).

Permanent Canada balsam mounts on standard microscope slides were made from the nannoplankton filters after dehydrating with an ethanol series and clearing with a xylene series using procedures similar to those of Goldberg, Baker, and Fox (1952) and Fournier (1978). Species identification, cell numbers, and cell volume were determined using a Wild M20 stereomicroscope. Random field, alternate pass, and diameter transect analysis methods were used as deemed appropriate by cell concentration (Hasle 1978). For both, net phytoplankton and nannoplankton, cell volumes were calculated from linear dimensions of the cells, which were assumed to be spherical, cylindrical, or ellipsoidal in shape.

At Sea 1985:

Water that passed through 300u mesh nets was subsampled for a 500 ml aliquot. Each aliquot was placed in plastic jars and preserved with acetic Lugol's iodide fixative and later analyzed for net phytoplankton.

Laboratory 1985:

A 50 ml aliquot of the preserved sample was removed by pipette and processed using the Filter-Transfer-Freeze (FTF) technique developed by Hewes and Holm-Hanen (1983) and Hewes, et al (1984). Using this method, organisms were randomly concentrated onto a 25 mm, .08 u Nucleopore polycarbonate filter by gentle suction (1-2" Hg). The sample was inverted onto a glass microscope slide and quick-frozen with freon spray. The filter was then peeled away leaving the organisms suspended in an ice matrix. Using a loop of suitable size made from a stainless steel banjo string, a membrane of liquefied glycerin jelly was transferred soap-bubble style onto the still frozen sample. A cover slip wetted with glycerol was then placed on the sample before the jell hardened into a permanent mount. All size fractions of phytoplankton were identified and numerated from samples processed using the FTF technique during 1985.

DATA ANALYSES

Early feeding patterns of red drum larvae were determined by cluster analysis; using the Czekanowski similarity index and group average sorting. Diets of the size classes of larvae were compared with step-wise discriminate analysis. Discriminate analysis compared the diets by size classes of all larvae (determined by cluster analysis) by assessing the significance of overall diet distinctiveness and by identifying the taxa or size categories that contributed to this distinctiveness (Govoni et al. 1983).

Indices of electivity have been used to show the relative proportions of food organisms in the guts of animals with the relative proportions of food organisms in the animal's habitat. Govoni et al. (1986) pointed out that differences in the mathematical attributes and sensitivities occur among electivity indices, as well as the sensitivities to sampling error and the inferences can support. Two electivity indices were used, (1) Ivlev's E (Ivlev 1961) and (2) Chesson's α (Chesson 1978, 1983), because they show different properties of food selection:

$$E = \frac{r_1 - p_1}{r_1 + p_1} \qquad (1)$$

and

$$\alpha_1 = \frac{r_1/p_1}{\Sigma\, r_1/p_1} \qquad (2)$$

where r = the relative abundance of prey item_1 in the gut (as a proportion or percentage of the total gut contents) and p_1 the relative abundance of the same prey item in the environment. E has a possible range of -1 to +1, with the negative values indicating avoidance or inaccessibility of the prey item, zero indicating random selection from the environment, and positive values indicating active selection. E is significantly biased when the prey sample size from the gut of the predator and habitat are unequal. Atchley et al. (1976) have shown that expected values of E under conditions of random feeding may not always be zero, and a value for the variance calculated from several replicate field samples is not a good measure of the deviation of the calculated electivity index from its expected value. As a consequence, values of Ivlev's index should not be compared by the use of t-statistics, which are sensitive to significant deviations from normality (Strauss 1979). Chesson's α varies nonlinearly between 0 and +1, deviates asymmetrically about the reciprocal of the number of food taxa available, and is sensitive to sampling error, especially for relatively rare food organisms (Lichowicz 1982, Govoni et al. 1986). Chesson's α is derived from models of the probabilities of prey encountered and captured (Chesson 1978). Chesson's α is a measure of selection of selection of prey over a range of food densities (Pearre 1982) and is 0 when no prey items are found in the gut, regardless of the relative abundance of the food item in the environment.

E and α were calculated for individual larvae and for each prey item. Only the food organisms capable of being eaten by the larvae (maximum size of .23 mm) were included in this study. All food taxa that were not eaten by any of the red drum larvae were eliminated from the analysis. Once the feeding groups of larvae were identified from the cluster analysis, E values were calculated for the groups using the same criteria as for individual fish.

RESULTS

The overall abundance and vertical distributions of zooplankton, phytoplankton, chlorophyll a and red drum larvae are shown in the Appendix. Summaries of these data will be used in the discussion of the results.

DISTRIBUTION OF CHLOROPHYLL A AND PHYTOPLANKTON

There was an positive correlation between chlorophyll a values and both phytoplankton densities and cell volume (Table 13). A negative relationship existed between phytoplankton densities and phytoplankton cell volume.

Table 13. Partial correlations between chlorophyll a, phytoplankton totals per liter, and phytoplankton cell volume per liter for 1984 and 1985.

	Chlorophyll a	Phyto. Numbers	Phyto. Cell Vol.
Chlorophyll a	1.00000	.94474	.81889
Phyto. Numbers	.94474	1.00000	-.66297
Phyto. Cell Vol.	.81889	-.66297	1.00000

The greatest phytoplankton density recorded was 706,064 individuals per cubic meter of water at which time the cell volume value was 0.14800 cubic mm per liter (RD85-09-01). On the other hand, high phytoplankton cell volumes

(1.609 - 0.357 cu mm / 1) occurred during RD84-09-02 at which time the phytoplankton population densities were not as high as those of RD85-10-01 (Table 14).

Table 14. Summary of phytoplankton densities, phytoplankton cell volumes, chlorophyll a values from four cruises in 1984 and 1985.

CRUISE	TIME	DEPTH	PHYTOPLANKTON TOTAL (#/cu m)	PHYTOPLANKTON TOTAL (cu mm / 1)	CHLOROPHYLL A TOTALS (mg / cu m)
RD84-09-02	15.14	1	142766 afternoon	.76800	1.58455
RD84-09-02	15.39	5	144002	.54500	1.53540
RD84-09-02	15.56	12	68721	1.04700	3.18203
RD84-09-02	22.28	1	51513 night	.35700	1.07067
RD84-09-02	22.46	5	**	**	2.12228
RD84-09-02	23.04	12	60513	.92400	1.33190
RD84-09-02	10.29	1	186771 midday	1.60900	3.74957
RD84-09-02	10.48	5	199407	1.09300	4.15948
RD84-09-02	11.04	12	110038	.47300	3.49005
RD84-10-02	14.41	1	69875 afternoon	.86100	8.73603
RD84-10-02	15.01	5	54040	.39500	6.06070
RD84-10-02	15.21	13	68360	.14400	4.39705
RD84-10-02	21.09	1	25796 night	.21200	4.59487
RD84-10-02	21.30	5	13624	.35700	3.90662
RD84-10-02	21.50	12	55787	.79600	4.34197
RD84-10-02	10.00	1	25755 midday	.45500	4.51254
RD84-10-02	10.21	5	12725	.41000	3.29829
RD84-10-02	10.44	11	15363	.13200	2.04669
RD84-10-02	16.50	1	17425 afternoon	.40800	2.50287
RD84-10-02	17.11	5	8354	.18900	1.94653
RD84-10-02	17.37	11	211069	.23100	4.44379
RD85-09-01	16.15	1	90594 afternoon	.92700	.41333
RD85-09-01	16.36	5	59592	.06200	.40210
RD85-09-01	16.56	11	100861	.84200	1.36343

Table 14. continued.

CRUISE	TIME	DEPTH	PHYTOPLANKTON TOTAL (#/cu m)	PHYTOPLANKTON TOTAL (cu mm / 1)	CHLOROPHYLL A TOTALS (mg / cu m)
RD85-09-01	23.10	1	12720 night	.08400	.19921
RD85-09-01	23.38	5	28840	.08300	.23681
RD85-09-01	24.00	11	36800	.04100	.52858
RD85-09-01	11.28	1	706064 midday	.14800	.40585
RD85-09-01	11.47	5	54960	.10800	.61933
RD85-09-01	12.05	11	443196	.06900	.75766
RD85-10-01	16.31	1	163152 afternoon	.34700	.93750
RD85-10-01	16.48	5	152008	.30300	.66081
RD85-10-01	17.08	12	171896	.91800	1.16383
RD85-10-01	22.19	1	672584 night	1.30200	.61160
RD85-10-01	22.38	5	319371	.08000	.46538
RD85-10-01	22.57	12	293929	.16500	1.28988
RD85-10-01	9.46	1	436742 midday	.20900	.93884
RD85-10-01	10.01	5	49200	.20600	1.18397
RD85-10-01	10.16	11	545472	.42400	1.64411

** Missing value- sample lost in analysis

DISTRIBUTION OF RED DRUM LARVAE AND ZOOPLANKTON

The cruise data sets that contained the greatest numbers of red drum larvae were chosen for inclusion in the analyses that made comparisons among densities of red drum larvae, zooplankton densities and chlorophyll a concentrations (Table 15).

Table 15 - Summary data for zooplankton, chlorophyll a and red drum larvae for all RD-Cruises included in the habitat analyses. A * indicates that fish from a cruise were included in the direct comparison of fish gut content with the prey availability. Average values were from pooled data summed over all times and depths for each cruise.

		TOTAL ZOOPLANKTON (# / cu. m)			CHLOROPHYLL (mg /cu. m)			RED DRUM LARVAE (/ 100 cu. m)		
CRUISE NO.	DATE	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG
RD83-10-01	10/06/83	9856	67386	30737	.05910	.27503	.16718	2.08	14.58	7.18
*RD83-10-02	10/19-20/83	16828	37859	26378	.16902	.76296	.48049	0.00	5.23	1.40
*RD84-09-01	09/13-14/84	95452	457127	207935	.39929	1.97412	.75503	0.00	288.20	65.72
RD84-09-02	09/26-27/84	169126	373333	276265	1.07067	4.15948	2.46955	0.00	21.99	7.71
RD84-10-02	10/23-24/84	183863	890295	433405	1.94653	8.73603	4.23233	0.00	.64	.05
*RD85-09-01	09/11-12/85	87094	287821	175038	.19921	1.36343	.54737	0.00	31.60	7.43
RD85-10-01	10/10-11/85	24265	163956	79856	.46538	1.64411	.98844	0.00	7.89	2.32

No significant correlations were observed among the actual population densities of fish, zooplankton and chlorophyll, however, zooplankton and chlorophyll a densities were greatest during the RD84-10-02 cruise. This was also the time that red drum larvae densities were at their lowest value during the entire study (Table 15). Overall zooplankton densities remained constant, for the most part, during 1984 and 1985. Chlorophyll a and red drum larvae density values can be compared over all years because gear selection differences did not affect these data. Chlorophyll a values during RD84-09-02 were about half those of RD84-10-02 but they were higher than those in the remainder of the cruises, which were all less than 1 mg / cu. m. Densities of red drum larvae were greatest during the RD84-09-01 cruise (Table 15). The maximum density of 288 / 100 cu. m and a mean overall density of 65.72 / 100 cu. m greatly exceeded the fish densities in any other of the cruises. This peak in larval fish abundance occurred at a time when zooplankton and chlorophyll were at their third and fourth highest overall measured levels. The lowest values for fish densities, however, occurred at a time when both zooplankton and chlorophyll levels were their greatest (Table 15).

DIEL VERTICAL DISTRIBUTION OF RED DRUM LARVAE AND ZOOPLANKTON

Both zooplankton and red drum larvae displayed distribution patterns suggesting that vertical migrations were taking place on a diel cycle. Surface water (0-1 m) contained higher densities of zooplankton and fish larvae during daylight hours than times of complete darkness (Fig. 29). Peak densities of zooplankton and fish moved from the near surface waters in to the mid-depths (5 m) and often into the bottom waters of 10 to 12 m depths during a diel period (Figs. 29 & 30). The densities of zooplankton and red drum larvae were greatest in deep strata during periods of dark.

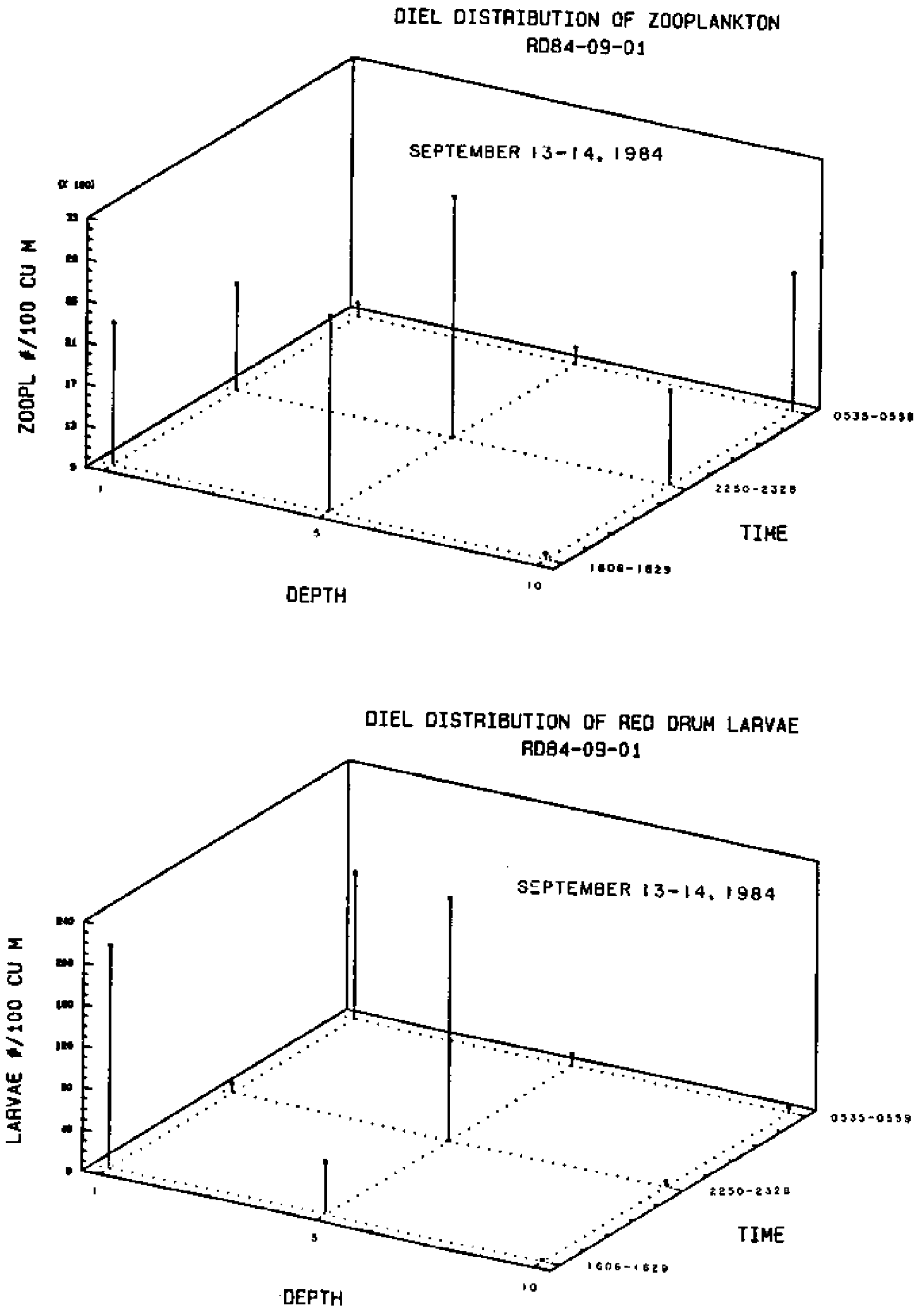


Figure 29. Vertical distribution of zooplankton and red drum larvae within the water column over a diel period during September 13-14, 1984.

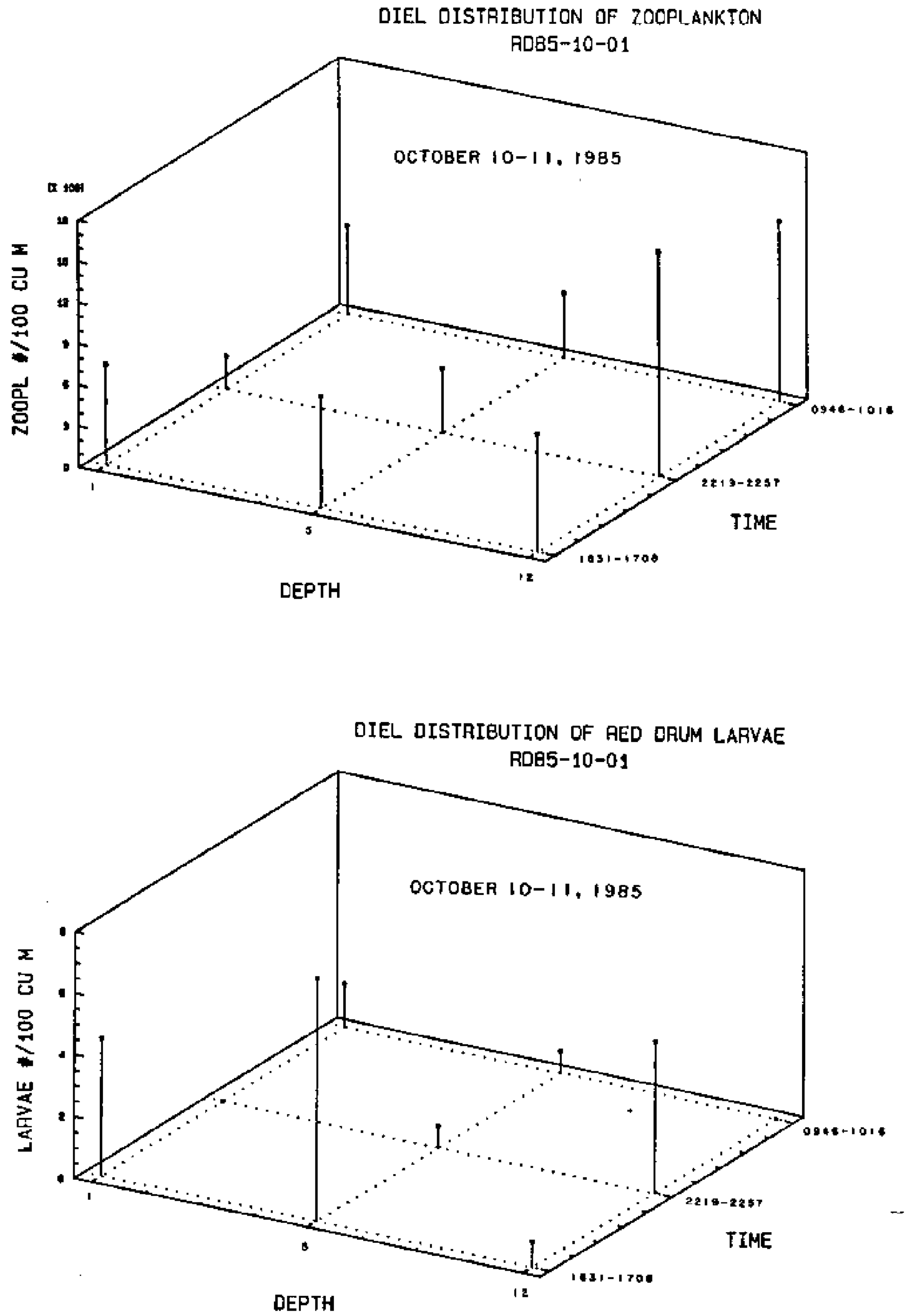


Figure 30. Vertical distribution of zooplankton and red drum larvae within the water column over a diel period during October 10-11, 1985.

During all cruises except one, there were no pycnoclines in the upper 5 m of the water column. Therefore, no density barriers appeared to inhibit vertical migrating zooplankters within the upper 5 m. The sigma-t trace for cruise RD84-08-01 showed a sharp pycnocline at the 4 to 8 meter depth (Fig. 31). Sigma-t traces from other cruises show either slight density fluctuations in the deeper strata (Fig. 32) or no density structure at all (Fig. 33).

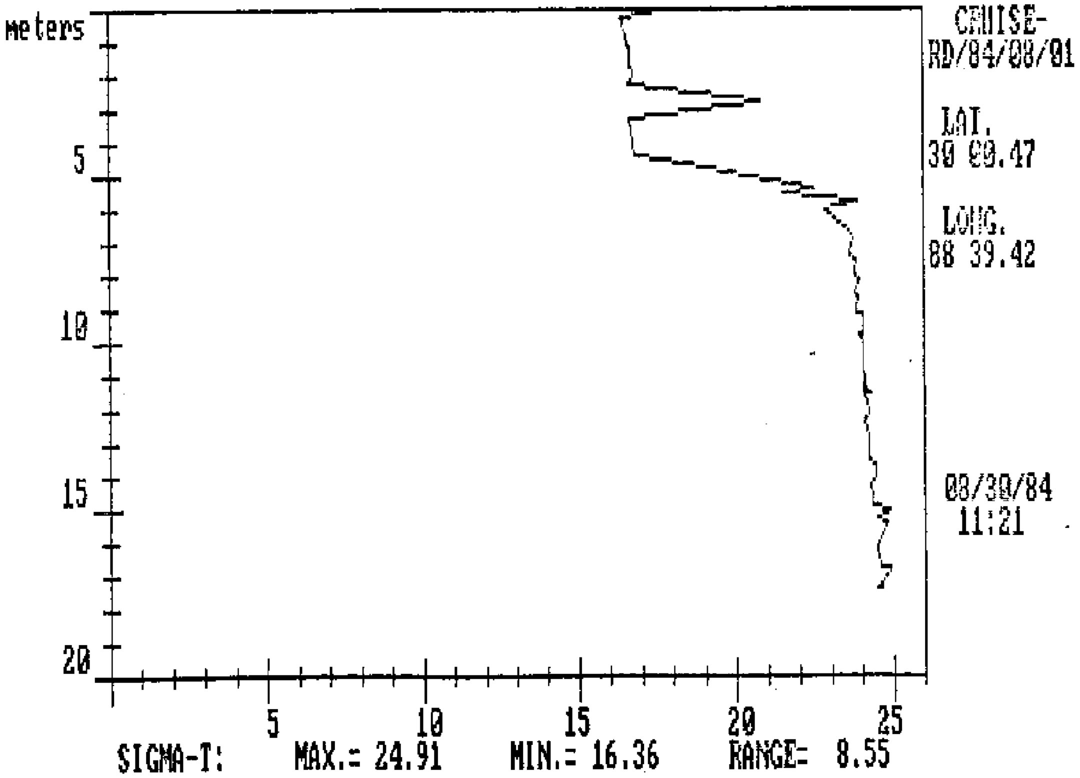
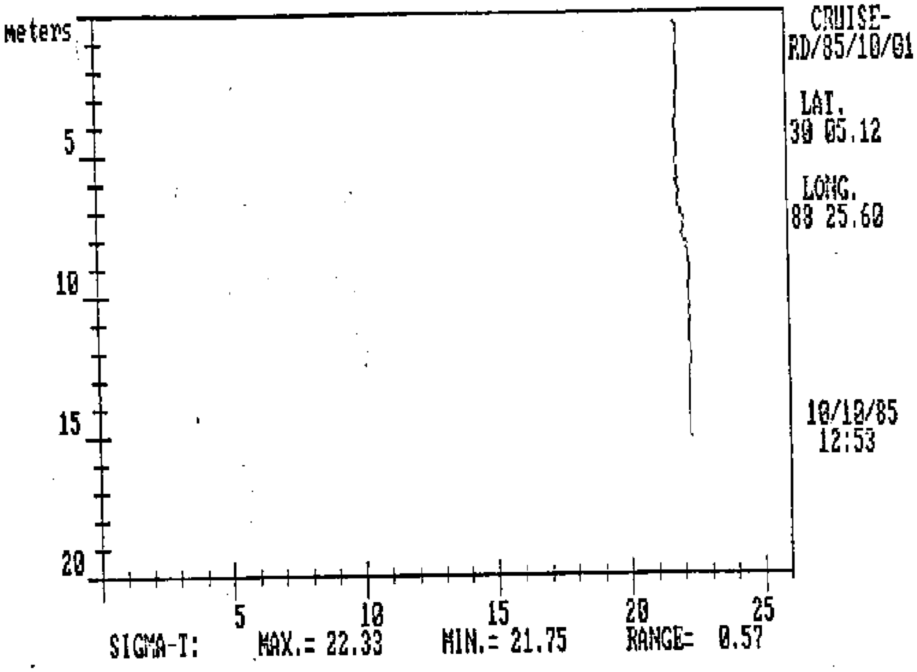


Figure 31. Vertical density (sigma-t) trace made on August 30,1984 during the RD84-08-01 cruise in the northcentral Gulf of Mexico.



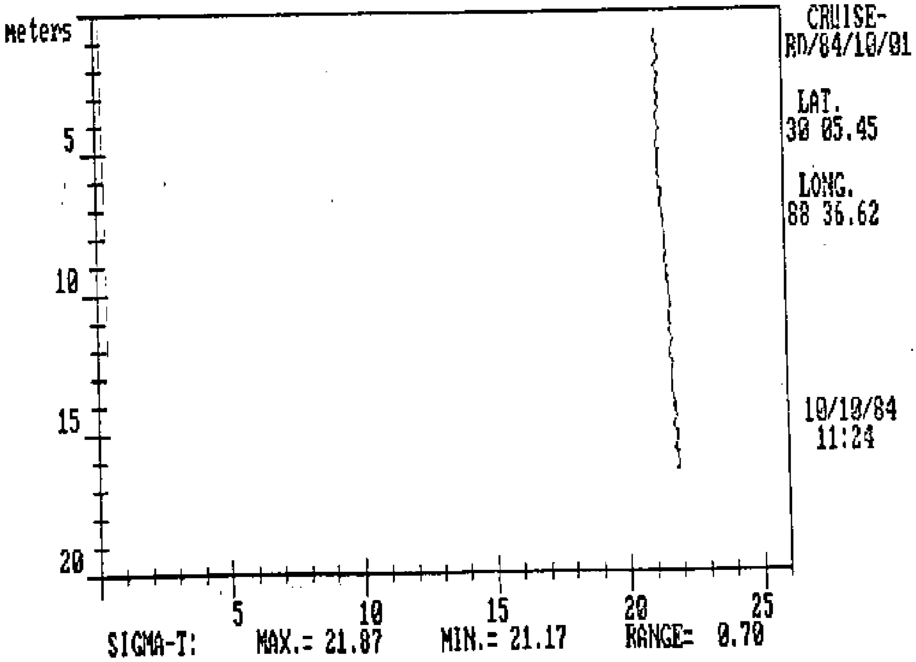


Figure 32. Vertical density (sigma-t) traces from four red drum cruises during 1984 and 1985 on the continental shelf in the northcentral Gulf of Mexico.

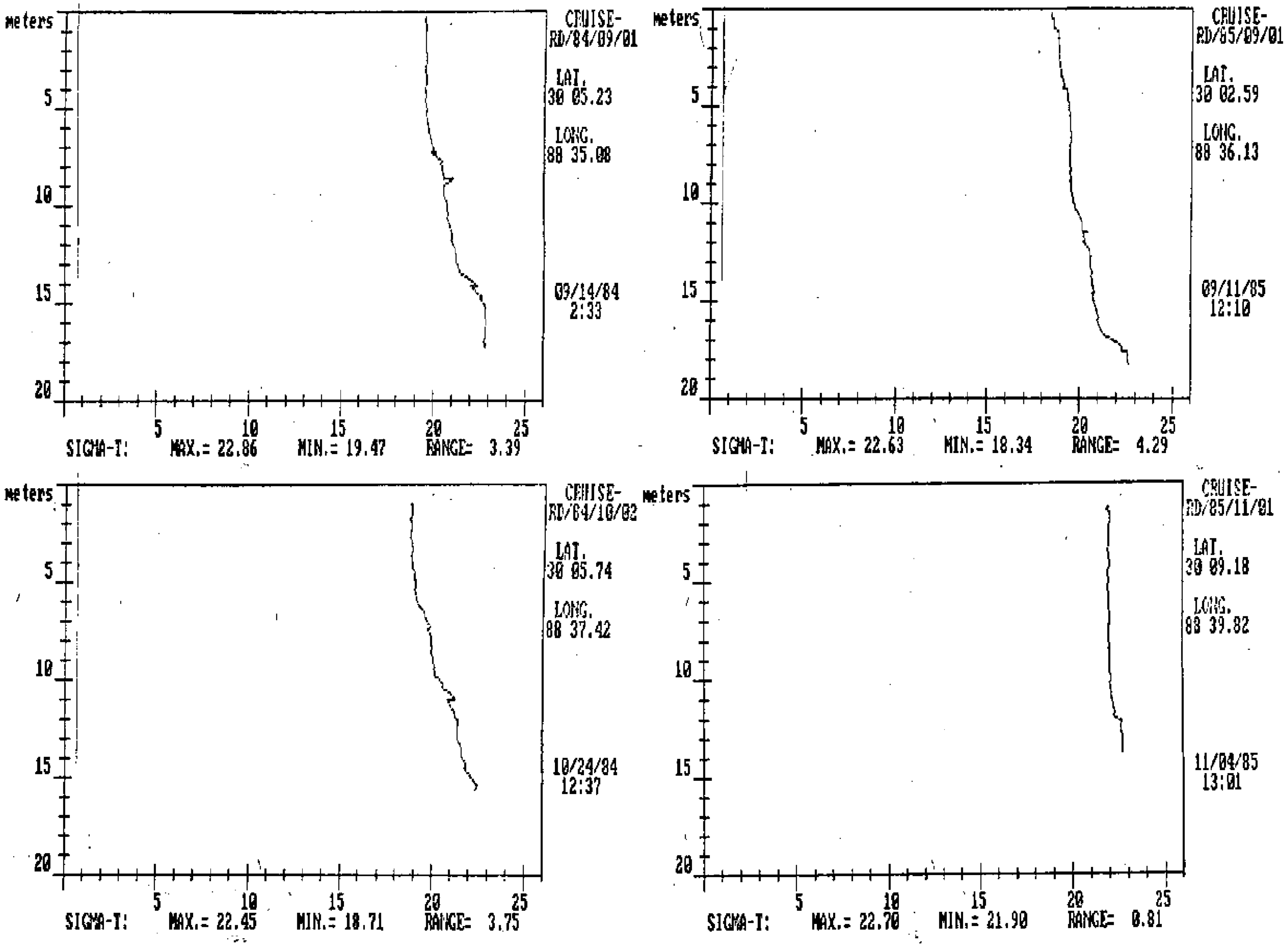


Figure 33. Vertical density (sigma-t) traces from two red drum cruises during 1984 and 1985 on the continental shelf in the northcentral Gulf of Mexico.

DESCRIPTION OF FOOD AND COMPARISON OF DIETS AMONG DIFFERENT SIZED RED DRUM LARVAE

Red drum larvae from three different cruises were selected for gut analysis (Table 16). The percentage of larvae with food in their guts (incidence of feeding) during daylight hours was greater than 80 percent. Larvae from night samples generally had empty guts. A single fish, taken at night on 09-11-85 at 2027, had food in its gut. All other fish from night samples had empty guts.

Table 16. Summary data from samples that contained larvae which were included in the gut analysis. Percent larvae with food indicates the diel feeding incidence of red drum larvae.

CRUISE #	DATE	TIME	DEPTH	LAT.	LONG.	# FISH IN SAMPLE	# FISH IN GUT ANALYSIS	% LARVAE WITH FOOD
RD83-10-02	10/19/83	3.33	8	30/01/86	88/40/90	1	1	0
RD83-10-02	10/19/83	3.38	8	30/01/86	88/40/90	1	1	0
RD83-10-02	10/19/83	4.20	5	30/01/72	88/40/79	2	2	0
RD83-10-02	10/19/83	4.59	1	30/01/59	88/40/89	1	1	0
RD83-10-02	10/19/83	5.04	0	30/01/59	88/40/89	2	2	0
RD83-10-02	10/19/83	7.03	8	30/01/33	88/41/44	4	4	100
RD83-10-02	10/19/83	7.16	1	30/01/44	88/41/53	5	5	100
RD83-10-02	10/19/83	8.46	5	30/01/34	88/41/55	22	22	100
RD83-10-02	10/19/83	8.51	3	30/01/34	88/41/55	13	13	100
RD83-10-02	10/19/83	8.24	8	30/01/25	88/41/69	19	13	100
RD83-10-02	10/19/83	8.30	8	30/01/25	88/41/69	20	15	100
RD83-10-02	10/19/83	9.10	5	30/01/30	88/41/91	36	36	100
RD83-10-02	10/19/83	9.15	5	30/01/30	88/41/91	4	4	100
RD83-10-02	10/19/83	9.47	3	30/01/27	88/41/97	6	6	100
RD83-10-02	10/19/83	9.53	3	30/01/27	88/41/97	29	24	100
RD84-09-01	09/13/84	16.56	1	30/03/95	88/36/74	679	14	100
RD84-09-01	09/13/84	17.00	1	30/03/95	88/36/74	430	13	100
RD84-09-01	09/13/84	17.46	5	30/03/38	88/36/91	66	17	100
RD84-09-01	09/13/84	17.51	5	30/03/38	88/36/91	110	16	100
RD84-09-01	09/13/84	18.54	11	30/03/38	88/36/93	5	5	80
RD84-09-01	09/14/84	00.00	1	30/04/78	88/36/05	4	4	0
RD84-09-01	09/14/84	00.05	1	30/04/78	88/36/05	13	13	0
RD84-09-01	09/14/84	00.54	5	30/04/48	88/36/15	772	15	0
RD84-09-01	09/14/84	00.59	5	30/04/48	88/36/15	392	18	0
RD84-09-01	09/14/84	01.47	11	30/04/71	88/35/59	3	2	0
RD84-09-01	09/14/84	01.52	11	30/04/71	88/35/59	16	16	0
RD84-09-01	09/14/84	06.56	1	30/03/65	88/32/64	318	16	100
RD84-09-01	09/14/84	07.01	1	30/03/65	88/32/64	319	16	100
RD84-09-01	09/14/84	07.51	5	30/02/96	88/31/89	32	17	88
RD84-09-01	09/14/84	07.56	5	30/02/96	88/31/89	18	9	100
RD84-09-01	09/14/84	08.39	11	30/02/90	88/32/10	8	8	88
RD84-09-01	09/14/84	08.44	11	30/02/90	88/32/10	9	9	100

Table 16 Continued.

CRUISE #	DATE	TIME	DEPTH	LAT.	LONG.	# FISH IN SAMPLE	# FISH IN GUT ANALYSIS	% LARVAE WITH FOOD
RD85-09-01	09/11/85	12.49	1	30/02/18	88/36/04	12	12	100
RD85-09-01	09/11/85	12.53	1	30/02/18	88/36/04	21	21	100
RD85-09-01	09/11/85	13.44	5	30/01/95	88/36/42	10	10	100
RD85-09-01	09/11/85	13.49	5	30/01/95	88/36/42	1	1	100
RD85-09-01	09/11/85	15.01	11	30/01/60	88/36/48	1	1	100
RD85-09-01	09/11/85	20.27	5	30/00/93	88/37/64	3	3	66
RD85-09-01	09/11/85	20.32	5	30/00/93	88/37/64	4	4	0
RD85-09-01	09/11/85	21.45	11	30/01/26	88/37/99	1	1	0
RD85-09-01	09/12/85	07.47	1	30/02/85	88/39/23	8	8	100
RD85-09-01	09/12/85	07.52	1	30/02/85	88/39/23	28	28	96
RD85-09-01	09/12/85	08.48	5	30/02/76	88/39/61	34	34	100
RD85-09-01	09/12/85	08.53	5	30/02/76	88/39/61	14	14	100
RD85-09-01	09/12/85	10.02	11	30/02/72	88/39/99	3	3	100
RD85-09-01	09/12/85	10.08	11	30/02/72	88/39/99	3	3	100
RD85-09-01	09/12/85	14.09	1	30/02/90	88/44/11	34	34	100
RD85-09-01	09/12/85	14.49	3	30/11/28	88/43/77	9	9	100
RD85-09-01	09/12/85	15.32	7	30/11/45	88/43/36	10	10	90

Gut content data from 553 red drum larvae examined during this study show that crustacean nauplii were the preferred prey of red drum larvae (Table 17). They are found in the guts of both large and small larvae. Crustacean eggs, and copepods of the genus *Oithona*, *Euterpina*, *Paracalanus*, and *Corycaeus* are important larger prey and are found in the diets of older (larger) larvae.

Table 17. Prey species list along with size range from all red drum larvae examined in this study.

PREY SPECIES FROM LARVAL GUTS	TOTAL ALL 3 YRS	SIZE RANGE (mm) SMALLEST	- LARGEST
Eucalanus sp.	4	.14	.25
Paracalanus sp.	310	.05	.23
P. indicus	6	.11	.16
P. quasimodo	39	.08	.33
P. crassirostris	1021	.05	.20
Calocalanus sp.	1	.11	.11
Centropages sp.	6	.12	.19
C. velificatus	81	.05	.23
Acartia sp.	4	.06	.12

Table 17 Continued.

PREY SPECIES FROM LARVAL GUTS	TOTAL ALL 3 YRS	SIZE RANGE (mm) SMALLEST	LARGEST
Unidentified Calanoid Cop.	106	.06	.19
Euterpina acutifrons	128	.05	.19
Oithona sp.	439	.05	.17
O. nana	420	.06	.34
O. plumifera	5	.16	.20
Saphirella sp.	1	.06	.06
Oncaea sp.	1	.11	.11
O. venusta	1	.12	.12
Corycaeus sp.	242	.05	.25
C. americanus	1	.23	.23
Unidentified Cyclopoid Cop.	7	.06	.16
Cladocera (*Penilia sp.*)	32	.16	.31
Crustacean Eggs	601	.03	.19
Crustacean Nauplius	4987	.03	.20
Foraminifera	2	.06	.06
Pelecypoda	5	.08	.16
Radiolaria	1	.07	.07
Pyrocystis sp.	1	.17	.17
Tintinnid	2	.06	.06

Potential prey, available to the larvae, was diverse (Table 18). Red drum larvae were eating only a limited part of the available food contained within the water mass that they were both entrained.

Table 18. Species list from environmental microzooplankton samples along with totals and size ranges (width) from all samples processed.

PREY SPECIES	TOTAL	SIZE RANGE (mm) SMALLEST	LARGEST
Calanus sp.	1	.28	.28
C. tenuicornis	2	.12	.22
Nannocalanus minor	6	.12	.47
Undinula vulgaris	17	.09	.83
Eucalanus sp.	11	.09	.87
E. monachus	3	.44	.47
E. pileatus	224	.20	.70
Acrocalanus sp.	11	.17	.39
Paracalanus sp.	1082	.05	.31
Cirripedia Cypris	3	.27	.30
Cladocera (*Penilia sp.*)	980	.16	.69
Cladocera	1	.51	.51
Cladocera (*Evadne sp.*)	157	.27	.55
Crustacean Egg	7437	.03	.44
Crustacean Nauplius	35256	.01	1.01
Decapod Protozoea	35	.16	.46
Decapod (*Lucifer sp.*)	10	.20	1.32
Decapod (*Acetes americana*)	1	.89	.89

Table 18. continued.

PREY SPECIES	TOTAL	SIZE RANGE (mm) SMALLEST	LARGEST
P. indicus	6	.11	.28
P. quasimodo	2863	.05	1.39
P. crassirostris	7312	.05	.27
P. parvus	1	.30	.30
P. aculeatus	61	.09	.34
Calocalanus sp.	20	.08	.12
C. pavo	25	.06	.36
C. pavoninus	15	.08	.22
Mecynocera clausii	2	.16	.20
Euchaeta sp.	5	.12	.23
E. marina	1	.69	.69
Temora stylifera	30	.14	.63
T. turbinata	423	.14	2.25
Centropages sp.	8	.12	.20
C. velificatus	947	.08	1.71
Calanopia americana	19	.12	.53
Labidocera sp.	33	.12	.42
L. aestiva	13	.16	.65
Acartia sp.	4	.08	.20
A. tonsa	919	.08	1.75
Unident. CALANOIDS	201	.01	.25
Microsetella norvegica	66	.06	.27
Microsetella rosea	6	.08	.14
Clytemnestra sp.	18	.11	.25
Macrosetella gracilis	1	.16	.16
Euterpina acutifrons	1653	.08	.36
Unident. HARPACTICOIDS	27	.06	.27
Oithona sp.	3429	.06	1.01
O. colcarva	1174	.07	.27
O. nana	5369	.02	.95
O. plumifera	67	.08	.23
O. simplex	1693	.06	1.25
Saphirella sp.	274	.06	.17
Oncaea sp.	604	.06	.23
O. mediterranea	46	.09	.37
O. venusta	526	.06	.40
O. media	313	.08	.22
Lubbockia sp.	3	.08	.31
Pachos punctatum	1	.59	.59
Saphirina nigromaculata	5	.33	.98
Copilia mirabilis	2	.47	.62
Corycaeus sp.	595	.08	.08
C. amazonicus	825	.08	.42
C. americanus	80	.09	.53
C. clausi	167	.11	.39
C. speciosus	1	.25	.25
Farranula gracilis	40	.09	.34
Decapod zoea	88	.16	2.18
Decapod Crab Megalopea	13	1.12	7.83
Centric Diatom	1902	.06	.50
Dinoflagellata	3977	.02	.66
Echinodermata Pluteus	372	.11	1.25
Fish Larval & Juv.	18	.14	.47
Fish Eggs	65	.16	1.19
Foraminifera	1668	.04	.25
Coccolithophores	230	.08	.12
Gastropoda	84	.06	.73
Gastropoda (*Atlantia brunnea*)	2	.86	1.25
Gastropoda (*Seguenzia sp.*)	26	.14	1.72
Isopoda	6	.02	.18
Noctiluca sp.	20	.14	.35
Hydromedusae	237	.12	6.25
Ostracoda	67	.14	.66
Pelecypoda	8545	.06	1.84
Platyhelminthes	39	.09	2.30
Polychaeta	723	.06	2.53
Larvacea	7869	.02	1.14
Radiolaria	38	.08	.31
Siphonophore	243	.16	4.43
Pyrocystis sp.	265	.12	.47
Stomatopoda Larvae	2	1.32	3.03
Thaliacea (Doliolidae)	98	.14	1.81
Thaliacea (Salpidae)	4	.62	2.40
Theco. (*Limacina inflata*)	319	.08	1.75
Theco. (*Limacina lesuerii*)	647	.06	.50
Theco. (*Limacina trochiformis*)	242	.11	1.78
Theco. (*Limacina bulimoides*)	69	.14	.62
Theco. (*Creseis aricula*)	72	.06	.41
Theco. (*Clio sp.*)	26	.06	.14
Thecostomata (naked)	1	.84	.84
Tintinnid	137	.05	.27
Echinodermata Juv. Starfish	7	.10	.75
Bipinnaria Larvae	258	.09	1.09
Worm Larvae	586	.06	2.53
Trochophore Larvae	126	.09	.55
Tomopteris sp. (Polychatea)	6	.20	2.53
Branchiopoda Larvae	46	.14	.86
Ctenophora	1	1.87	1.87
Echinodermata Juv. Holothuroidea	2	.31	.47
Tunicata	1	.62	.62
Actinotrocha Larvae (Phoronida)	13	.19	.78
Echinodermata Brachiolaria	2	.39	.41
Bryzoa (Cyphonautes Larvae)	99	.11	.22
Invert. Egg & Early Larvae	267	.08	.39

Table 18. continued.

PREY SPECIES	TOTAL	SIZE RANGE (mm) SMALLEST	LARGEST
Unident. CYCLOPOIDS	10	.09	.28
Caligus sp.	25	.09	.23
Amphioxides sp.	29	.08	.34
Amphipoda (Hyperiid)	9	.11	1.09
Chaetognatha	1298	.04	2.30
Cirripedia Nauplius	28	.08	.47
Ophiopluteus Larvae	6	.20	.97
Ceratium sp.	318	.10	1.07
Gonyaulax sp.	31	.08	.08
Prorocentrum sp.	89	.08	.10
Protoperidinium sp.	82	.06	.12
Pyrophagcus sp.	24	.08	.12

Cluster analysis indicated that in 1984 & 1985 red drum larvae from the northcentral Gulf of Mexico were feeding on two size groups of prey. The small prey group (≤.12) was those individuals 03 mm to and including .12 mm. in width. The large prey group (>.12) included all zooplankton with widths greater than .12 mm (Fig. 34).

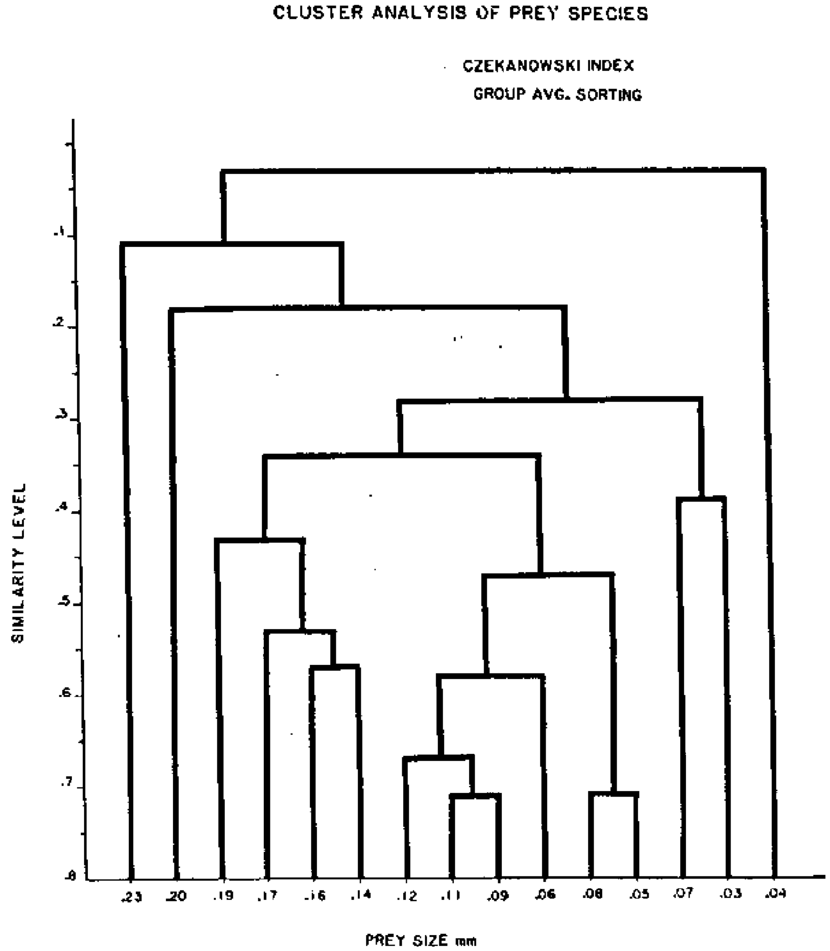


Figure. 34. Cluster analysis of zooplankton prey species into size groups on the basis of width. Czekanowski similarity index was used with group average sorting.

An inverse cluster analysis grouped the feeding red drum larvae into three feeding groups with similar diets (Fig. 35). Feeding group 1 included larval fish less than 2 mm in length. Group 2 contained larvae from 2 mm to 4 mm, while group 3 included larval fish larger than 4 mm.

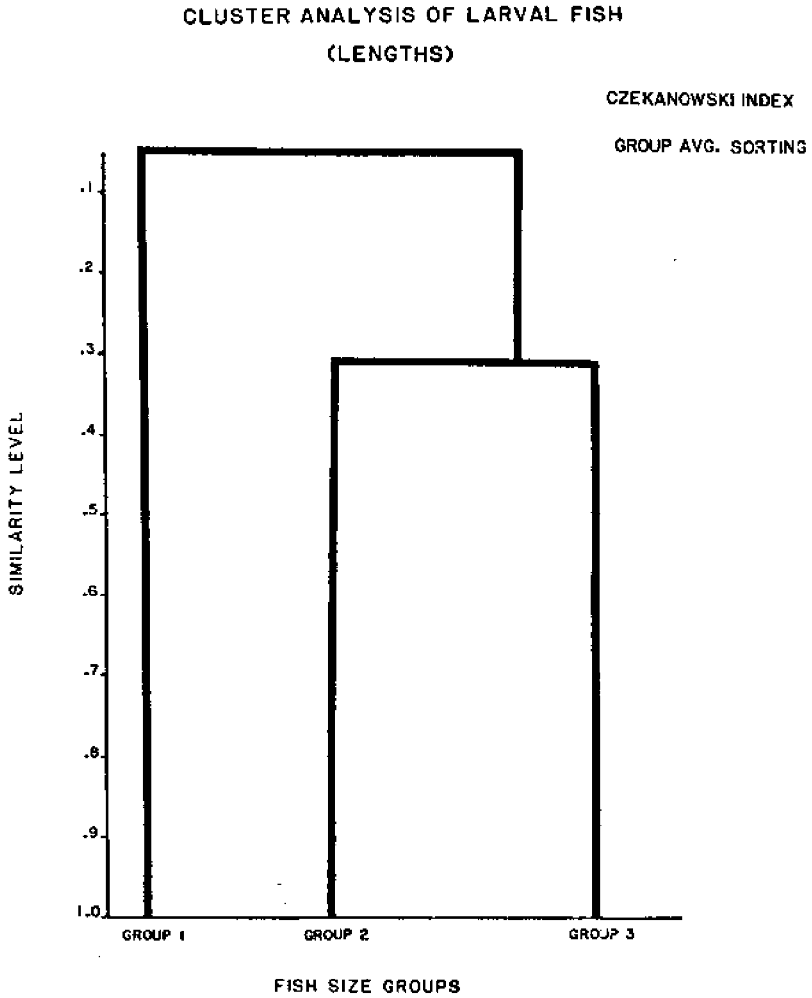


Figure. 35. Inverse cluster analysis of red drum larvae into similar length groups on the basis of similar diets. Czekanowski similarity index was used with group average sorting.

Discriminant analysis confirmed the separation of red drum larvae into different feeding groups (Fig.36). The diets of the three feeding groups of fish differed significantly in numbers of all species of the calanoid copepods *Paracalanus sp*., *Centropages vellificatus*, the cyclopoid copepods *Oithona* and *Corycaeus*, the harpacticoid species *Euterpina acutifrons* and crustacean eggs and naupllii (Table 19). In separating diets, discriminant analysis derived two discriminating functions. Function 1 separated the diet of Group 3 from the combined diets of Group 1 and Group 2. Function 2 separated the diets of Group 1 from Group 2. The relative contribution of a diet item to the discriminating power of the function is indicated by the absolute value of its discriminant function coefficient (Table 19).

Table 19. Standardized cannonical discriminant function coefficients of prey items of all fish included in discriminant analysis.

VARIABLES	SIZE	FUNC 1	FUNC 2
Paracalanus sp.	≤.12 mm	.31257	.17443
Paracalanus sp.	>.12 mm	.40364	-.02679
P. quasimodo	≤.12 mm	.26846	-.09030
P. quasimodo	>.12 mm	.31118	.06570
P. crassirostris	≤.12 mm	.03970	.46034
P. crassirostris	>.12 mm	.64929	-.05896
Centropages velificatus	≤.12 mm	-.12263	.15039
Unid. Calanoids	≤.12 mm	.12269	.20646
Euterpina acutifrons	≤.12 mm	-.06635	.29299
Oithona sp.	≤.12 mm	.07643	.52913
Oithona sp.	>.12 mm	.11904	.05764
O. nana	≤.12 mm	-.09532	.31960
O. nana	>.12 mm	.33676	-.06152
Corycaeus sp.	≤.12 mm	-.07163	.28998
Corycaeus sp.	>.12 mm	.08071	.12829
CRUSTACEAN EGG	≤.12 mm	-.36470	.24086
CRUSTACEAN EGG	>.12 mm	-.06826	.12262
CRUSTACEAN NAUPLIUS	>.12 mm	-.13509	.11370

```
              +-----+-----+-----+-----+-----+-----+-----+-----+
             8.0 +                               223               +
                 :                               233               :
                 :                               23                :
                 :                              223                :   TERRITORIAL MAP
                 :                              233                :
             4.0 +      +     +     +     +     23    +     +      +    * indicates a
F    P   P       :                             223                 :     group centroid
U    R   R       :                             233                 :
N    E   E       :223                          23                  :    Across: Function 1
C    Y   Y       :112222222222               223                   :
T            0.0 + 111111111122222222*+      233  *   +     +      +    Down: Function 2
I    G   G       :            111111111222223                      :
O    R   R       :                     *1111133                    :
N    O   O       :                            113                  :
     U   U       :                             133                 :
2    P   P  -4.0 +      +     +     +     +    113    +     +      +
                 :                              133                :
     1   2       :                              113                :
                 :                                133              :
                 :                                1133             :
            -8.0 +                                 113             +
                 +-----+-----+-----+-----+-----+-----+-----+-----+
              -8.0 -6.0 -4.0 -2.0  0.0  2.0  4.0  6.0  8.0
                   ----------PREY GROUP I ------------->
                 <-----------PREY GROUP II-------------

                                 FUNCTION 1
```

Species composition of zooplankton prey groups.

Function 1				Function 2			
Prey Group 1		Prey Group 2		Prey Group 1		Prey Group 2	
Paracalanus sp.	>.12 mm	Crustacean Nauplius	>.12 mm	*Oithona sp.*	≤.12 mm	*P. quasimodo*	≤.12 mm
P. crassirostris	>.12mm	*Centropages velificatus*	≤.12 mm	*P. crassirostris*	≤.12 mm	*O. nana*	>.12 mm
Oithona nana	>.12 mm	*O. nana*	≤.12 mm	*O. nana*	≤.12 mm	*P. crassirostris*	>.12 mm
Paracalanus sp.	≤.12 mm	*Corycaeus sp.*	≤.12 mm	*Corycaeus sp.*	≤.12 mm	*Paracalanus sp.*	>.12 mm
P. quasimodo	>.12 mm	CRUSTACEAN EGGS	>.12 mm	CURSTACEAN EGGS	≤.12 mm		
P. quasimodo	≤.12 mm						

Discriminant analysis summary data.

LARVAL FISH SIZE CLASSES		No. of Cases	Predicted Class Membership 1	2	3
CLASS	1	86	86	0	0
		100.0%	.0%	.0%	
CLASS	2	316	81	228	7
		25.6%	72.2%	2.2%	
CLASS	3	58	10	7	41
		17.2%	12.1%	70.7%	

Percent of "grouped" cases correctly classified: 77.17%

Fig. 36. Plot of discriminant analysis scores for two discriminant functions that distinguish the diets of three size classes of feeding red drum larvae from the northcentral Gulf of Mexico.

Diets of red drum larvae less than 2 mm (Group 1) are characterized by the presence of *P. crassirostris* ≤.12 mm, O. nana ≤.12 mm, *E. acutifrons* ≤.12 and crustacean nauplii >.12. Group 1 fish diets were missing larger copepods from their diets. Group 2 fish (> 2 and < 4 mm) depended on smaller copepodites of O. nana, while Group 3 fish (> 4 mm) contained significant numbers of both large and small *Paracalanus*; larger sized *Oithona*; and *C. velificatus*, *Corycaeus sp*. and crustacean nauplii ≤.12 mm (Table 20).

Table 20. Summary of the diets of feeding larvae using correctly classified cases of discriminant function coefficients.

SIZE CLASS 1

Larval Fish < 2 mm

PREY SPECIES	SIZE
Paracalanus sp.	≤.12 mm
Paracalanus sp.	>.12 mm
Paracalanus quasimodo	>.12 mm
P. crassirostris	≤.12 mm
P. crassirostris	>.12 mm
Oithona sp.	≤.12 mm
Oithona nana	≤.12 mm
O. nana	>.12 mm
C. velificatus	≤.12 mm
C. velificatus	>.12 mm
E. acutifrons	≤.12 mm
Corycaeus sp.	≤.12 mm
CRUSTACEAN NAUPLIUS	≤.12 mm
CRUSTACEAN NAUPLIUS	>.12 mm

SIZE CLASS 2

Larval Fish > 2 & < 4 mm

PREY SPECIES	SIZE
Paracalanus sp.	>.12 mm
P. crassirostris	>.12 mm
Euterpina acutifrons	≤.12 mm
E. acutifrons	>.12 mm
Oithona nana	≤.12 mm
Corycaeus sp.	≤.12 mm
CRUSTACEAN NAUPLIUS	>.12 mm

SIZE CLASS 3

Larval Fish > 4 mm

PREY SPECIES	SIZE
Paracalanus sp.	≤.12 mm
Paracalanus sp.	>.12 mm
P. quasimodo	>.12 mm
P. crassirostris	>.12 mm
Oithona nana	>.12 mm
Centropages velificatus	≤.12 mm
Corycaeus sp.	≤.12 mm
CRUSTACEAN NAUPLIUS	≤.12 mm

SELECTIVE FEEDING OF RED DRUM LARVAE

At any time the gut contents of a feeding red drum larvae may actually be different from others in its size class. There were different selective indices patterns among the individual larval fish although they were feeding on the same assemblage of zooplankton prey. Guts from all larvae within the same feeding size group do not generally contain the same prey species in the same proportions (Table 21).

Feeding group 1 (< 2 mm) fish fed on crustacean nauplii, crustacean eggs, and the copepodites of *Euterpina acutifrons* and *Oithona sp*. A positive selection was shown for crustacean nauplii and *E. acutifrons*. Although crustacean eggs and *Oithona sp*. were found in the guts, these fish were not selecting for them (Table 22). Group 2 fish (>= 2 mm and ≤ 4 mm) were larger than those of Group 1. Group 2 red drum larvae were eating the same prey as was group 1 fish, however, they were expanding their diets both in numbers of prey species and the size of individual prey items taken. Fish larvae from this group showed a preference, through elective indices, for smaller prey taxa (i.e., crustacean nauplii). Often group 2 fish had a negative selection index value for larger prey taxa (i.e., *Centropages velificatus*, *Oithona sp*. and *E. acutifrons* >.12 mm). The largest fish (group 3) selected more larger prey items and passively ingested the smaller prey items (Table 22).

Table 21. Ivlev and Chesson's α electivity index values for individual (-IND) fish and Ivlev index values for the prey from the combined group from a 5 m sample taken on 09-14-84 at 0756 hrs during cruise RD84-09-01.

ELECTIVITY INDEX &	FISH LENGTHS	*Paracalanus* *sp*. ≤.12 mm	*Centropages* *velificatus* >.12 mm	*Euterpina* *acutifrons* >.12 mm	*E*. *acutifrons* ≤.12 mm	*Oithona* *sp*. >.12 mm	*Oithona* *sp*. ≤.12 mm	*Corycaeus* *sp*. ≤.12 mm	CRUST. NAUP. >.12 mm	CRUST. NAUP. ≤.12 mm
IVLEV-COMBINED	2.40--3.12	1.000	-.362		.066		.889	-.508	-.091	.113
IVLEV-IND.	2.84	1.000			.354	1.000				.148
CHESSON'α-IND.		1.000			.385	1.000				.247
IVLEV-IND.	2.62						.970			-.042
CHESSON'α-IND.							.980			.013
IVLEV-IND.	2.84	1.000					.933			.083
CHESSON'α-IND.		1.000					.929			.037
IVLEV-IND.	2.40	1.000			.482		.921			.078
CHESSON'α-IND.		1.000			.096		.829			.039
IVLEV-IND.	2.87		.573							.265
CHESSON'α-IND.			.681							.318
IVLEV-IND.	2.96	1.000		.609	.298		.776		.721	.086
CHESSON'α-IND.		1.000		.184	.083		.356		.277	.053
IVLEV-IND.	2.87	1.000					.958	.805		-.072
CHESSON'α-IND.		1.000					.810	.157		.014
IVLEV-IND.	3.12						.888			.233
CHESSON'α-IND.							.912			.087
IVLEV-IND.	3.12	1.000			.448		.698		.794	.034
CHESSON'α-IND.		1.000			.137		.294		.458	.056

Table 22. Ivlev electivity index values of prey species found in more than three feeding groups during the two year feeding analysis study period. Fish and zooplankton were from RD84-09-01 and RD85-09-01.

FISH FEEDING GROUPS (LENGTH)	*Paracalanus* *sp.* >.12 mm	*Paracalanus* *sp.* ≤.12 mm	*P.* *quasimodo* >.12 mm	*P.* *quasimodo* ≤.12 mm	*P.* *crassirostris* >.12 mm	*P.* *crassirostris* ≤.12 mm	*Centropages* *velificatus* >.12 mm
1.33--1.65							
1.40--1.72							
1.40--1.84							
1.48--1.87							
1.56--1.93							
1.59--1.83							
1.65--1.65							
1.72--1.81							
1.87--1.87							
1.93--1.93							
1.97--1.97							
2.06--3.28		1				-0.8	
2.12--3.00		1			0.5	0.8	
2.12--3.74	1	1	0.3	-0.1	0.6	0.7	0.1
2.18--3.12		0.2				-0.8	
2.18--3.18		1			-0.1		
2.18--3.12		1				-0.6	0.1
2.25--3.40		1					
2.34--3.31		1			-0.3	0.2	
2.34--3.74		1					
2.37--2.50							
2.37--3.43		1					-0.3
2.40--3.12		1					-0.4
2.40--3.28		0.5		-0.7			
2.40--3.90			-0.1		-0.4	0.8	-0.7
2.43--2.43		0.7					
2.65--3.21					-0.8	0.2	
2.68--3.74			-0.9	-0.9	-0.3	0.6	-0.5
2.71--3.74		1		-0.9	-0.6	0.1	
2.75--2.75							
2.75--3.53						0.8	
2.81--3.53		1			-0.6	0.7	
2.87--3.49			-0.7	-0.9	-0.7	0.2	
2.96--3.59						0.4	
3.24--3.28							
3.88--3.88					-0.6		
3.95--3.95	1	1					
4.01--4.74	1			-0.1	0.3	0.6	-0.1
4.01--4.87	1	1	-0.2	-0.4	-0.5	0.3	
4.08--6.05	1	1			0.4		
4.21--4.94	1	1	0.4	0.3	-0.2	0.8	0.6
4.21--5.53	1	1	0.6		0.1	-0.8	
4.28--5.76	1	1	-0.3		-0.1	-0.8	
4.34--4.94		0.1			0.5	0.4	
4.47--4.47							0.7
4.21--5.86		1			0.8		

Table 22. continued.

FISH FEEDING GROUPS (LENGTH)	*Centropages velificatus* ≤.12 mm	Unid.Calanoid copepods ≤.12 mm	*Euterpina acutifrons* >.12 mm	*E. acutifrons* ≤.12 mm	*Oithona sp.* >.12 mm	*Oithona sp.* ≤.12 mm	*O. nana* >.12 mm	*O. nana* ≤.12 mm
4.94--4.94	1	0.9		0.6				
5.07--5.07			0.9	0.9		0.9	0.8	
1.33--1.65								
1.40--1.72								
1.40--1.84								
1.48--1.87						-0.7		
1.56--1.93						-0.7		
1.59--1.83				0.8				
1.65--1.65								
1.72--1.81								
1.87--1.87								
1.93--1.93								
1.97--1.97		1				1		
2.06--3.28						0.8		
2.12--3.00		1		0.7	1	1	0.2	0.5
2.12--3.74	-0.3	1		-0.6		1	0.3	0.9
2.18--3.12		1	0.3	0.7	1	0.3	-0.4	0.8
2.18--3.18				0.2			0.6	0.9
2.18--3.12	-0.6			0.4		1	-0.1	0.8
2.25--3.40	0.5	1	-0.1		1	1	-0.3	
2.34--3.31		1		0.3			0.6	0.9
2.34--3.74				-0.4	1	0.6		
2.37--2.50						0.5		
2.37--3.43	-0.1			-0.3	1	0.5		
2.40--3.12				0.1		0.9		
2.40--3.28				0.3	1	-0.2		0.8
2.40--3.90	0.1			-0.2				0.7
2.43--2.43								
2.65--3.21	0.2					1	0.1	
2.68--3.74				-0.7			-0.2	0.2
2.71--3.74		1		-0.5	1	1	-0.4	-0.1
2.75--2.75								0.7
2.75--3.53	-0.3			-0.6			0.2	0.9
2.81--3.53			1	1	1	1		
2.87--3.49	0.4	1		-0.4			0.1	-0.5
2.96--3.59	0.1			-0.3				
3.24--3.28		1		0.3		1		
3.88--3.88						0.8	0.5	
3.95--3.95							0.9	
4.01--4.74	0.1						0.4	0.3
4.01--4.87		1		-0.1	1		0.3	0.1
4.08--6.05				0.5		0.3	0.7	0.8
4.21--4.94		1					0.7	0.9
4.21--5.53		1			1	0.5	0.6	-0.2
4.28--5.76				1	1	0.2	0.5	-0.4
4.34--4.94						0.4	0.9	0.3

Table 22. continued.

FISH FEEDING GROUPS (LENGTH)	*Corycaeus* sp. >.12 mm	*Corycaeus* sp. ≤.12 mm	Cladocera *Penilia* sp. ≤.12 mm	CRUSTACEAN EGGS >.12 mm	CRUSTACEAN EGGS ≤.12 mm	CRUSTACEAN NAUPLIUS >.12 mm	CRUSTACEAN NAUPLIUS ≤.12 mm	
4.47--4.47		1				1	0.5	0.9
4.21--5.86			0.9					
4.94--4.94					1	0.6	0.7	0.6
5.07--5.07				0.5			0.7	
1.33--1.65							0.2	
1.40--1.72					-0.8		0.3	
1.40--1.84							0.5	
1.48--1.87					-0.7		0.3	
1.56--1.93							0.2	
1.59--1.83							0.5	
1.65--1.65								
1.72--1.81							0.3	
1.87--1.87							0.4	
1.93--1.93							0.3	
1.97--1.97							0.7	
2.06--3.28		-0.2		1		-0.3	0.2	
2.12--3.00				1	-0.8	-0.5	0.2	
2.12--3.74	1	1	1			-0.8	0.4	
2.18--3.12		1				0.1	0.1	
2.18--3.18		1			-0.2	-0.2	0.2	
2.18--3.12	0.7	0.8			-0.7	0.4	0.2	
2.25--3.40		1			1	-0.1	0.7	
2.34--3.31	1	1			-0.1		0.1	
2.34--3.74	0.7	0.3					0.1	
2.37--2.50							0.2	
2.37--3.43	0.6	0.6				-0.6	0.1	
2.40--3.12		-0.5				-0.1	0.1	
2.40--3.28		1		-0.1		0.3	0.1	
2.40--3.90	1	1	1	-0.2	1	-0.9	0.6	
2.43--2.43							0.2	
2.65--3.21	1	1		0.2	1	-0.5	0.7	
2.68--3.74	1	1	-.07		1	-0.7	0.6	
2.71--3.74	1	1			1	-0.8	0.5	
2.75--2.75							0.3	
2.75--3.53	1	1	1	-0.1	1	-0.9	0.5	
2.81--3.53							-0.1	
2.87--3.49	1	1	0.4	0.4	1	-0.4	0.8	
2.96--3.59	1	1	0.4	0.4	1	-0.3	0.5	
3.24--3.28	1	1				-0.7	0.6	
3.88--3.88							0.3	
3.95--3.95					0.5			
4.01--4.74	1	1	0.4	0.2	1	-0.2	0.2	
4.01--4.87	1	1	0.3		1		-0.4	

Table 22. continued.

FISH FEEDING GROUPS (LENGTH)	*Corycaeus sp.* >.12 mm	*Corycaeus sp.* ≤.12 mm	Cladocera *Penilia sp.* ≤.12 mm	CRUSTACEAN EGGS >.12 mm	CRUSTACEAN EGGS ≤.12 mm	CRUSTACEAN NAUPLIUS >.12 mm	CRUSTACEAN NAUPLIUS ≤.12 mm
4.08--6.05					0.2		-0.8
4.21--4.94	1	1	1		1		-0.4
4.21--5.53					-0.2		0.2
4.28--5.76					0.1		0.2
4.34--4.94					0.4		-0.5
4.47--4.47			1		1		-0.2
4.21--5.86							-0.6
4.94--4.94					0.9		-0.8
5.07--5.07							0.1

DISCUSSION

The diets of red drum larvae collected on the Alabama-Mississippi-Louisiana continental shelf are typical of most marine larval fish studied to date; naupliar through adult stages of copepods comprise the majority of the food observed in their guts. The percentage of red drum larvae with food in their guts during daylight compared favorably with those of larval spot and Atlantic croaker (≤5.0 to 20.0 mm length) from other studies in the northern Gulf of Mexico (Govoni et al. 1983). The diel feeding pattern of larval red drum was more similar to that of larval spot < 5 mm than larval spot >5 mm or to all size croaker. Red drum larvae did not feed at night. Feeding apparently ceased soon after sunset since larval red drum captured at 2030 hrs showed little or no food remaining in their guts.

Red drum larvae have looped guts. Larvae with this type of gut morphology should be less prone to capture-induced defecation (Arthur 1976) than those with straight guts. Most larvae examined in this study contained prey both in the fore and hind gut region. Therefore, the percentage of larvae in this study containing prey should reflect their ability to capture food.

Intra-year variation in red drum larvae, zooplankton and phytoplankton abundance values often exceeded the between year differences in population densities. The hydrological data did not explain the differences that were observed in the biological data, particularly that of red drum larvae, from one cruise to another. During this study care was taken to remain within the same water mass throughout a diel sampling set in order to document the extent diel periodicity in larval fish feeding and vertical migrations in fish and zooplankton populations. Based on the repeated temperature and salinity profiles obtained along the drogue track, the drogue apparently remained in the water mass in which it was initially deployed (C. K. Eleuterius, pers. comm. 1987).

While predominantly well-mixed, the water column was observed to be at times either weakly or strongly stratified. In most instances salinity largely dictated the vertical density structure (Eleuterius, Steen and Shultz, unpub. data). During the August 30-31, 1984 cruise there were strong thermoclines and haloclines present at depths of 3 to 8 m (Appendix Plate 4). By September 13-14, 1984 the water column had become fairly well-mixed (Appendix Plate 5), with only an occasional weak halocline appearing on the salinity profiles; generally below 8 m. Temperature-Salinity profiles from both 1984 and 1985 (September and October) show a thermally well mixed water column with weak haloclines at depths of 8 to 11 m (Appendix Plates 8 & 11). During September and October temperatures were reaching isothermal conditions at 25.0 C and salinities were approaching 30 to 34 ppt. The salinity near the bottom on September 11-12, 1985 approached the oceanic salinity of 35 ppt (Appendix Plate 11; VP40). Density profiles confirm that the water structures (pycnoclines) generally present during August (Fig. 31) had diminished in strength and had become positioned lower in the water column (Figs. 32 and 33). At the time red drum larvae were most abundant in the water column, the mixed layer generally extended to below the 5 m depth. Apparently there was no hydrographic barriers to vertical migrating plankters within the upper water column during the months of September and October.

Without knowledge of fine scale currents and with no additional data except the drogue tracts, we are unable to speculate on the origin or the fate of the water masses, and their entrained plankton communities. In addition to tidal forcing, shelf circulation around Mississippi Sound is dependent on wind strength and duration, density stratification, an coastal geometry (Eleuterius 1974,1976; Chuang et al. 1982).

Several studies concerning various aspects of prey identification in the field and the feeding of lab reared larvae have utilized red drum larvae from the Gulf of Mexico. Holt et al. (1981) and Lee et al. (1984) have been successful in rearing red drum through the larval stage of development using a diet of rotifers and Artemia nauplii. Peters and McMichael (1987) found 85% of the red drum larvae in Tampa Bay, Florida to have empty stomachs; but those stomachs with food contained copepods almost exclusively. Steen and Laroche (1983) found that red drum larvae (from inside Mississippi Sound and locations near the barrier islands) ingested a variety of zooplankton prey. The comparison of larval fish gut contents directly with possible prey zooplankton population data has been done in the northern Gulf of Mexico for gulf menhaden Brevoortia patronus, spot Leisotomus xanthurus, and Atlantic croaker Micropogonias undulates (Govoni et al.1983,1986). Each of these fish species were separated into three feeding size classes using descriptive statistics and discriminant analysis. All larvae in the Govoni et al. (1983, 1986) study were larger (5 mm to 20 mm) than the red drum collected during this study. Stoner (1980) decribed the ontogenic variation in food habits of Lagodon romboides using cluster analysis and Cements and Livingston (1983) used cluster analysis to reveal two distinct feeding stages in juvenile file fish Monacanthus ciliatus in Apalachee Bay, Florida.

It is assumed that size dominates prey selection patterns of larval fish and is one of the best diagnostic characteristics for evaluating specific ecological roles. Specifically, mouth size would be expected to set the upper size limit for prey (Hunter 1981). Mouth size (gape) of larval red drum was far greater than the measurable width of crustacean prey in the guts of red drum larvae. No correlation between prey size in the gut and mouth gape was detected for the larval drum in this study.

Cluster analysis indicated that three groups of red drum larvae from our data set could be identified by similarity of gut contents. Size (length of fish) proved to be a good delineating characteristic for the feeding groups of larval red drum. Group (1) included larval red drum < 2 mm in length, group (2) was larvae from 2 mm to 4 mm in length, and group 3 was larvae > 4 mm. Cluster analysis also indicated that the larvae were partitioning their prey into two size classes. Size (1) was prey ≤.12 mm width and size (2) was prey >.12 mm width. Discriminant analysis showed that the three groups of larvae could be separated according to their diets. In this analysis prey was identified to species and divided into the ≤.12 mm and >.12 mm size groups. In separating the diets, two discriminating functions were derived . The highest cannnonical discriminate function coefficients in Table 19 indicate the prey species that made the greatest contribution in separating the groups of larval fish. The diets of feeding group 3 fish were characterized by the large (>.12 mm) copepods of the genus Oithona and Paracalanus. Group 1 and 2 were feeding on both small (≤.12 mm) and large copepods of the genus Oithona and Paracalanus, however, group 2 diets contained the copepod Corycaeus and crustacean eggs. These were absent from the diets of group 1 fish.

By utilizing the size limits from the grouping of fish and prey in the calculation of elective indices, we were able to compare the gut contents from a group of similarly feeding fish with the available prey in the environment. Ivlev's electivity index indicates positive selection with a + value and a negative selection or avoidance with a - value (Ivlev 1961). Smallest sized larvae < 2 mm (NL) positively selected nauplii (≤.12 mm) and *Euterpina* (≤.12 mm), while negatively selecting *Oithona* (≤.12 mm). The 2 to 4 mm larvae had high positive electivity values for nauplii, *Paracalanus sp.*, *P. crassirostris*, *Oithona nana* of (≤.12 mm) size. They showed a negative selection for *P. quasimodo* (≤.12 mm), crustacean naupli and *Centropages velificatus* (>.12 mm). Larval red drum >4 mm positively selected C. velificatus (>.12 mm), Oithona sp. (≤.12 & >.12 mm), and *O. nana* (≤.12 mm & >.12 mm). Crustacean nauplii (≤.12 mm) were negatively selected by the >4 mm larval red drum. As red drum larvae grow larger they do not loose the ability to capture small prey but they attain the ability to expand their diets by feeding on larger prey. At some point in their development, it may become too costly (metabolically) for larval red drum of certain size to feed on small prey. The presence of such prey may be incidental to the fish feeding on larger, more energetically efficient prey.

The size limits of the feeding groups identified in this section represent points in the trophic ontogeny of red drum where changes in prey preference appeared to be occurring.

This conclusion is supported by growth data (section 3) which indicate that 4 mm is a length at which red drum larvae show a change in their growth rate.

Results in this study demonstrate the importance of recognizing identifying prey species to the smallest taxon possible. We show that the size of prey (≤0.12 mm or >.12 mm) within a taxon distinction is a functional trophic unit. Clemments and Livingston (1983) recognized the advantage in using functional trophic units in comparisons of variability in feeding habitats of different species. The apparent similarity in feeding habits of two species of fish were reduced when prey were identified to lower taxonomic levels. Targett

(1978) and Keast (1978) have shown that calculations of trophic overlap are artificially inflated when prey are not identified to species.

The results of this study also demonstrate the importance of changes in feeding patterns that accompany growth. Differences in species composition of prey items in the diet of these three sized groups of red drum larvae may be explained in terms of either differential prey selectivity or microhabitat separation. Selectivity is a function of predator preference and prey accessibility (Vinyard and O'Brien, 1976) and is difficult to quantify in the field. Vertical diel migrations would act to maintain larval fish predators in the greatest concentrations of their prey if their patterns were in phase with each other. Diel vertical migration patterns for larval red drum and zooplankton are similar to the extent that larvae and zooplankton are often concentrated at 5m or 10m at night although the larvae are not feeding. This pattern would, however, place the larval fish in a position within the water column to take advantage of prey upon first light. Both red drum larvae and prey were generally concentrated within the near surface waters during the day.

Dietary specialization is generally found to be correlated with increasing food abundance (Stoner 1979). This conclusion is supported by models of predator-prey relationships (reviews by Pyke et al. 1977) and empirical studies with fishes (Ivlev 1961; Werner and Hall 1974). Peak red drum spawning typically occurs from September to October. This is also the time year when zooplankton populations on the eastern Louisiana continental shelf attain their peak densities. Gillespie (1971) reported values of 1,500,000/ m^3 during October and November for total zooplankton near the Chandeleur Islands. Enhanced feeding ability has been shown to relate to growth in culpeoids in the laboratory (Rosenthal and Hempel, 1970; Blaxter and Staines, 1971; Hunter 1972).

LITERATURE CITED

Arthur, D. K. 1976. Food and feeding of larvae of three fishes occurring in the California current, Sardinops sagax, Engraulis mordax, and Trachurus suymmetricus. U.S. Fish. Bull. 74:517-530.

Atchley, W. R., C. T. Gaskins, and D. Anderson. 1976. Statistical properties of ratios. I. Empirical results. Systematic Zoology 25:137-148.

Bass, R. J. and J. W. Avault, Jr. 1975. Food habits, length-weight relationship, condition factor, and growth of juvenile red drum, Sciaenops ocellata, in Louisiana. Trans. Amer. Fish. Soc. 104:35-45.

Blaxter, J.H.S. (editor) 1974. The early life history of fish. Springer-Verlag, N.Y., 765 p.

Blaxter, J.H.S. 1975. The eyes of larval fish. In Ali, M.A. (ed) Vision in Fishes. Plenum Press, New York, p. 427-443.

Blaxter, J.H.S., M. E. Stains. 1971. Food searching potential in marine fish larvae. In Crisp, D. J. (ed.) 4th European Marine Biology Symposium. Cambridge University Press, Cambridge, p. 467-485.

Boothby, R. N. & J. W. Avault, Jr. 1971. Food habits, length-weight relationship, and condition factor of the red drum, Sciaenops ocellata, in southern Louisiana. Trans. Am. Fish. Soc. 100:290-295.

Checkley, D. M. 1982. Selective feeding by Atlantic herring (Clupea harengus) larvae on zooplankton in natural assemblages. Mar. Ecol. Prog. Ser. 9:245-253.

Chesson, J. 1978. Measuring preference in selective predation. Ecology 59:211-215.

Chesson, J. 1983. The estimation and analysis of preference and its relationship to foraging models. Ecology 64:1297-1304.

Chuang, W.-S., Schroeder, W. W. and W. J. Wiseman, Jr. 1982. Summer current observations off the Alabama coast. Contrib. Mar, Sci. 25:121-131.

Clements, W. H. and R. J. Livingston. 1983. Overlap and pollution-induced variability in the feeding habits of filefish (Pisces:Monacanthidae) from Apalachee Bay, Florida. Copeia 2:331-338.

Cushing, D.H. 1975. Marine ecology and fisheries. Cambridge University Press, Cambridge, 278 pp.

Dabrowski, K., R. Bardega. 1984. Mouth size and predicted food size preferences of larvae of three cyprinid fish species. Aquaculture 40:41-46.

Darnell, R. M. 1958. Food habits of fishes and larger invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. Publ. Inst. Mar. Sci. Univ. Tex. 5:353-416.

Detwiler, R., E. D. Houde 1970. Food selection by laboratory-reared larvae of the scaled sardine Harengula pensacolae (Pices, Clupeidae) and the bay anchovy Anchoa mitchilli (Pices, Engraulidae). Mar. Biol. 7:214-222.

Eleuterius, C. K. 1974. Mississippi superport study Environmental assessment. Office of Science and Technology. Office of the Governor, State of Mississippi, 248 pp.

Eleuterius, C. K. 1976. Mississippi Sound : Salinity distribution and indication flow patterns. Mississippi-Alabama Sea Grant Consortium, Publication No.MASGP-76-024, Ocean Springs, 128 pp.

Eleuterius, C. K. 1987. Gulf Coast Research Laboratory, Ocean Springs, Mississippi 39564.

Fournier, R. O. 1978. Membrane filtering. In Phytoplankton Manual. UNESCO Monographs on Oceanographic Methodology. A. Sournia, ed., No. 6, pp. 106-112.

Gillespie, M. C. 1971. Analysis and treatment of zooplankton of estuarine waters of Louisiana. In Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana Phase IV, Biology. La. Wildlife and Fisheries Comm. pp. 108-175.

Goldburg, E. D., M. Baker, and D. L. Fox. 1952. Microfiltration in oceanographic research. 1. Marine sampling with the molecular filter. J. Mar. Res. 11:194-204.

Govoni, J. J., D. E. Hoss and A. J. Chester. 1983. Comparative feeding of three species of larval fishes in the northern Gulf of Mexico: Brevoortia patronus, Leiostomus xanthurus. and Micropogonias undulatus. Mar. Ecol. Prog. Ser. 13:189-199.

Govoni, J. J., P. B. Ortner, F. Al-Yamami and L. C. Hill. 1986. Selective feeding of spot, Leiostomus xanthurur, and Atlantic croaker, Micropogonias undulatus, larvae in the northern Gulf of Mexico. Mar. Ecol. Prog. Ser. 28:175-183.

Gunter, G. 1945. Studies on marine fishes of Texas. Publ. Inst. Mar. Sci., Univ. Tex. 1(1):1-190.

Hasle, G. R. 1978. Using the inverted microscope. In Phytoplankton Manual. UNESCO Monographs on Oceanographic Methodology. A. Sournia, ed., No. 6, pp.191-196.

Hewes, C. D., and O. Holm-Hansen. 1983. A method for recovering nannoplankton from filters for identification with the microscope: The filter-transfer-freeze (FTF) technique. Limnol. Oceanogr. 28:389-394.

Hewes, C. D., F.M.H. Reid, and O. Holm-Hansen. 1984. The quantitative analysis of nannoplankton: A study of methods. J. Plankton Res. 6:601-603.

Holt, J., R. Godbout, and C. R. Arnold. 1981. Effects of temperature and salinity on egg hatching and larval survival of red drum, Sciaenops ocellata. Fish. Bull. 79:569-573.

Hunter, J. R. 1972. Swimming and feeding behavior of larval anchovy, Engraulis mordax. Fish. Bull., U. S. 70:821-838.

Hunter, J. R. 1981. Feeding ecology and predation of marine fish larvae, p. 33-87. In R. Lasker [ed.], Marine Fish Larvae: Morphology, Ecology, and Relation to Fisheries. Univ. Washington Press.

Ivlev, V. S. 1961. Experimental ecology of the feeding fishes (translated from Russian). Yale Univ. Press, New Haven, Conn., 302p.

Keast, A. 1978. Feeding interrelationships between age groups of pumpkinseed sunfish (Lepomis gibbosus) and comparisons with bluegill sunfish (Lepomis macrochirus). J. Fish. Board Canada 35:12-27.

Kemp, R. J. 1949. Report on stomach analysis from June 1, 1949 through August 31,1949. Tex. Game, Fish, Oyst. Comm., Mar. Lab. Ann. Rep. 1948-1949: 101-127.

Knapp, F. T. 1950. Menhaden utilization in relation to the conservation of food and game fishes of the Texas Gulf Coast. Trans. Am. Fish. Soc. 79:137-144.

Lasker, R. 1975. Field criteria for survival of anchovy larvae: The relation between inshore chlorophyll maximum layers and successful first feeding. Fish. Bull., U.S. 73:453-462.

Lasker, R. 1978. The relation between oceanographic conditions and larval anchovy food in the California Current: Identification of factors contributing to recruitment failure. Rapp P.-v. Renu. Cons. int Explor. Mer 173:212-230.

Lasker, R. 1981. Factors contributing to variable recruitment of the northern anchovy (Engraulis mordax) in the California Current: Contrasting years, 1975 through 1978. Rapp P.-v. Renu. Cons. int Explor. Mer 178:375-388.

Laurence, G. C., A. S. Smigielski, T. A. Halavik, B. R. Burns. 1981. implications of direct competition between larval cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) in laboratory growth and survival studies at different food densities. Rapp. P.-v. Reun. Cons. int. Explor. Mer 178:304-311.

Lee, W. Y., G. H. Holt, and C. R. Arnold. 1984. Growth of red drum larvae in the laboratory. Trans. Am. Fish. Soc. 113:243-246.

Miles, D. W. 1949. A study on food habits of the fishes of the Aransas Bay area. Tex. Game, Fish, Oyst. Comm., Mar. Lab. Ann. Rep. 1948-1949:129-169.

Miles, D. W. 1950. The life histories of the spotted sea trout, Cunoscion nebulosus, and the redfish, Sciaenops ocellatus. Tex. Game, Fish, Oyst. Comm., Mar. Lab. Ann. Rep. 1949-1950. 38 pp.

Motoda, S. 1959. Devices of simple plankton apparatus. Mem. Fac. Fish. Hokkaido Univ. 7:73-94.

Overstreet, R. M. and R. W. Heard. 1978. Food of the red drum, Sciaenops ocellata, from Mississippi Sound. Gulf Research Reports. 6:131-135.

Pearre, S., Jr. 1982. Estimating prey preference by predators: uses of various indices, and a proposal of another based on X^2. Can. J. Fish. Aquat. Sci. 39:914-923.

Pearson, J. C. 1929. Natural history and conservation of the redfish and other commercial Sciaenids on the Texas Coast. Bull. [U.S.] Bur. Fish. 44 (1046): 129-214.

Peters, K. M., and R. H. McMichael, Jr. 1987. Early life history of the red drum, Sciaenops ocellatus (Pisces: Sciaenidae), in Tampa Bay, Florida. Estuaries 10(2):92-107.

Pyke, G. H., H. R. Pullman and E. L. Charnov. 1977. Optimal foraging: A selective review of theory and test. Rev. Biol. 52:137-154.

Reid, G. K., A. Inglis and H. D. Hoese, 1956. Summer food of some fish species in East Bay, Texas. Southwest Nat. 1:100-104.

Rosenthal, H. and G. Hempel. 1970. Experimental studies in feeding and food requirements of herring larvae (Culpea harengus L.) p.344-364. In: J.H.S Steel [ed.] Marine Food Chains. Univ. California Press.

Simmons, E. G. & J. P. Breuer. 1962. A study of red fish, Sciaenops ocellata Linnaeus and black drum, Pogonias cromis Linnaeus. Publ. Inst. Mar. Sci. Univ. Tex. 8:184-211.

Steen, J. P., Jr., and J. L. Laroche, 1983. The food of red drum (Sciaenops ocellatus) larvae and early juveniles taken from Mississippi Sound and the northcentral Gulf of Mexico. In. Shabica, S. V., N. B. Cofer, and E. W. Cake, Jr. (eds). Proceedings of the northern Gulf of Mexico estuaries and barrier islands research conference. 13-14 June 1983, Biloxi, MS, U.S. Dep. Int. Natl. Park Serv. SE Reg. Off., Atlanta, GA. p. 35-38.

Stoner, A. W. 1979. Feeding ecology of Lagodon rhomboides (Pisces:Sparidae): Variation and functional responses. Fish. Bull. 78:337-352.

Strauss, R. E. 1979. Reliability estimates for Ivlev's electivity index, the forage ratio, and a proposed linear index of food selection. Trans. Am. Fish. Soc. 108:344-352.

Strickland, J.D.H., and T. R. Parsons. 1972. A practical handbook of seawater analysis. Fish Res. Bd. Can., Bull. 167 pp. (2nd ed.)

Tilseth, S. and B. Ellertsen. 1984. The detection and distribution of larval Arcto-Norwegian cod, Gadus morhua, food organisms by an in situ particle counter. Fish. Bull. 82:141-156.

Utermohl, H. 1958. Zur Vervollkommung der quantitativen phytoplankton methodik. Mitt. Int. Ass. Theor. App. Limnol. 9, 38p.

Vinyard, G.L., and W.J. O'Brien. 1976. Effects of light and turbidity on the reactive distances of bluegill (Lepomis macrochirus). J. Fish. Res. Board Canada 33:2845-2849.

Walline, P. 1987. Growth and ingestion rates of larval fish populations in the coastal waters of Israel. J. Plankton Res. 9:91-102.

Werner, E. E., and D. J. Hall. 1977. Competition and habitat shift in two sunfishes (Centrarchidae). Ecology 58:869-876.

Yokle, B. J. 1966. A contribution to the biology and distribution of the red drum, Sciaenops ocellata. Master's thesis, Univ. Miami. 161 pp.

Appendix Table 1: Date (mo,day,yr), time (military time,hr), and location (degrees and minutes N Latitude, and W Longitude) of the vertical profiles (VP) of temperature and salinity from fifteen cruises during 1983-85.

Plate	VP No.	Cruise	Date	Time	Latitude	Longitude
1	1	83-9	09/20/83	1250	30/04/90	88/25/41
"	2	"	"	1645	30/04/29	88/26/21
"	3	"	"	2123	30/04/28	88/27/67
"	4	"	09/21/83	0800	30/06/40	88/26/86
2	5	83-10-1	10/6/83	0936	30/12/03	88/46/27
"	6	"	"	1825	30/10/60	88/45/48
"	7	"	10/7/83	0100	30/02/62	88/40/66
"	8	"	"	0545	30/02/46	88/42/43
3	9	83-10-2	10/18/83	1320	30/09/63	88/47/05
"	10	"	"	1855	30/10/49	88/46/63
"	11	"	10/19/83	0200	30/02/31	88/40/78
"	12	"	"	0650	30/01/29	88/42/09
"	13	"	"	1050	30/01/44	88/42/41
4	14	84-8	08/30/84	1121	30/00/47	88/39/42
"	15	"	"	1947	29/57/48	88/42/60
"	16	"	08/31/84	0331	29/58/51	88/41/53
5	17	84-9-1	"	1107	30/03/09	88/35/90
"	18	"	09/13/84	1957	30/03/78	88/37/06
"	19	"	09/14/84	0233	30/05/23	88/35/08
"	20	"	"	1042	30/10/54	88/44/75
6	21	84-9-2	09/26/84	1046	30/03/73	88/41/28
"	22	"	"	1837	30/02/95	88/42/11
"	23	"	09/27/84	0634	29/55/85	88/42/44
7	24	84-10-1	10/10/84	1124	30/05/45	88/36/62
"	25	"	"	1843	30/05/58	88/39/25
"	26	"	10/11/84	0614	30/01/71	88/38/79
8	27	84-10-2	10/23/84	1100	30/07/28	88/40/69
"	28	"	"	1756	30/06/56	88/40/18
"	29	"	10/24/84	0639	30/06/25	88/36/35
"	30	"	"	1237	30/05/74	88/37/42
"	31	"	"	1853	30/07/33	88/39/66
"	32	"	10/25/84	0642	30/09/25	88/37/52
9	33	84-11	11/7/84	1354	30/06/65	88/29/72
"	34	"	"	1935	30/06/67	88/31/91
"	35	"	11/8/84	0706	30/06/69	88/33/24
"	36	"	"	1313	30/06/47	88/35/45
"	37	"	"	1922	30/07/39	88/37/62
10	38	85-8	08/28/85	1128	29/59/78	88/38/73
"	39	"	"	1412	29/54/60	88/34/75
11	40	85-9-1	09/11/85	1210	30/02/59	88/36/13
"	41	"	"	1902	30/00/99	88/37/30
"	42	"	09/12/85	0703	30/02/82	88/39/14
12	43	85-9-2	09/25/85	1053	30/04/06	88/40/83
13	44	85-10	10/10/85	1253	30/05/12	88/25/60
"	45	"	"	1825	30/05/91	88/25/41
"	46	"	10/11/85	0623	30/06/67	88/25/47
14	47	85-11	11/4/85	1301	30/09/18	88/39/82
"	48	"	"	1916	30/07/79	88/38/04

Plate 1: Vertical profiles of temperature and salinity from cruise 83-9, 20-21 September 1983.

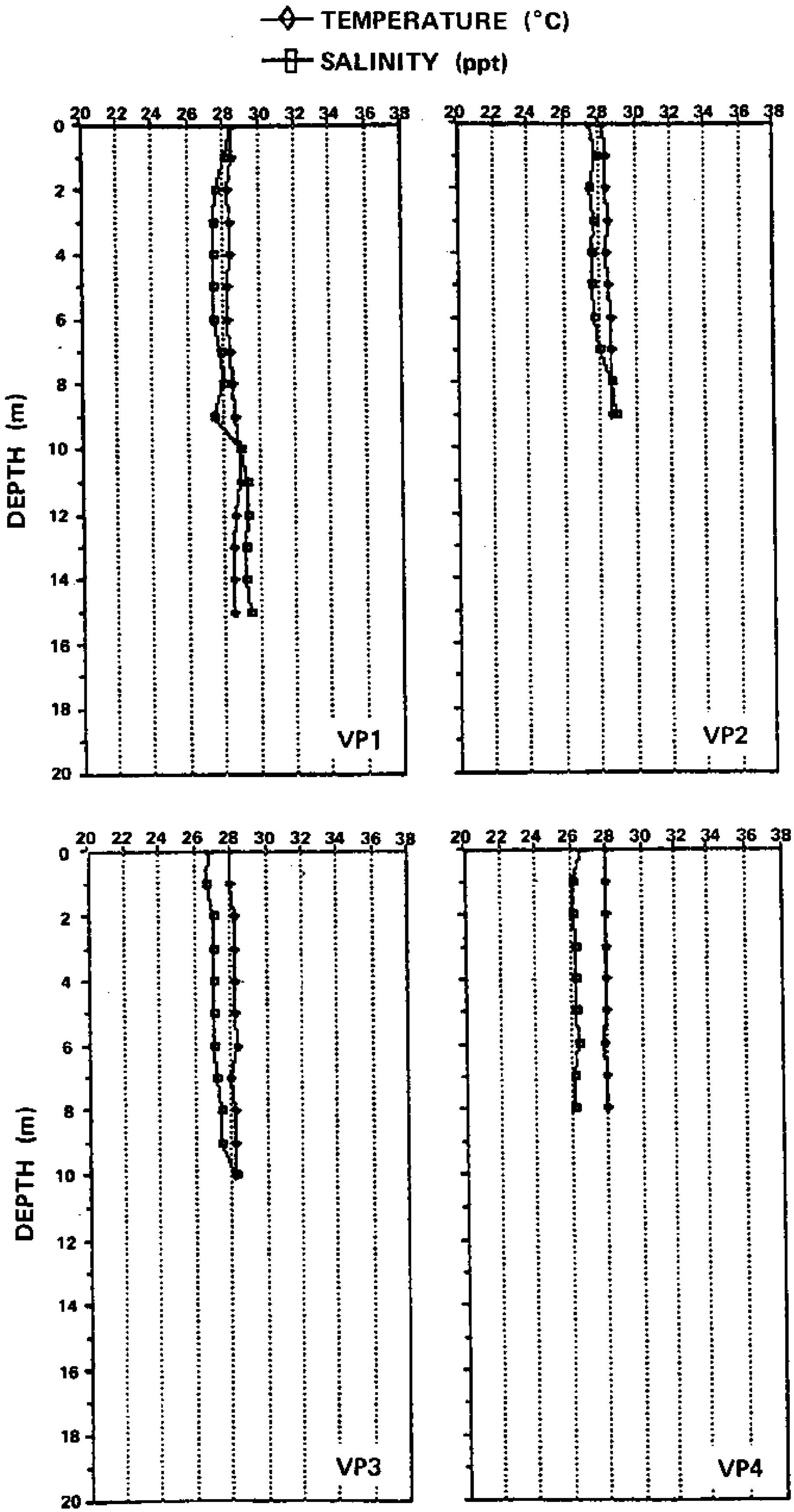


Plate 2: Vertical profiles of temperature and salinity from cruise 83-10-1, 6-7 October 1983.

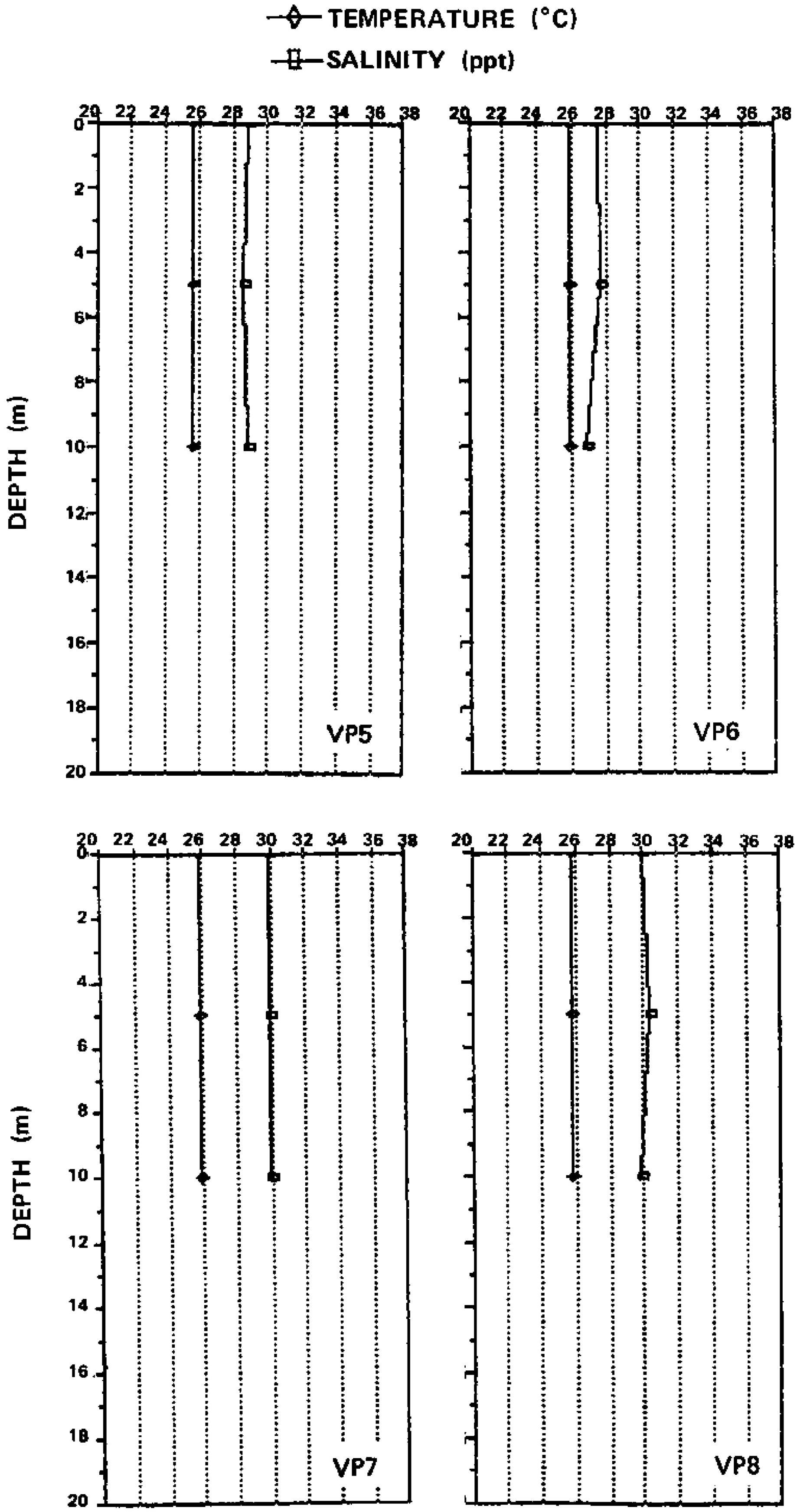


Plate 3: Vertical profiles of temperature and salinity from cruise 83-10-2, 18-19 October 1983.

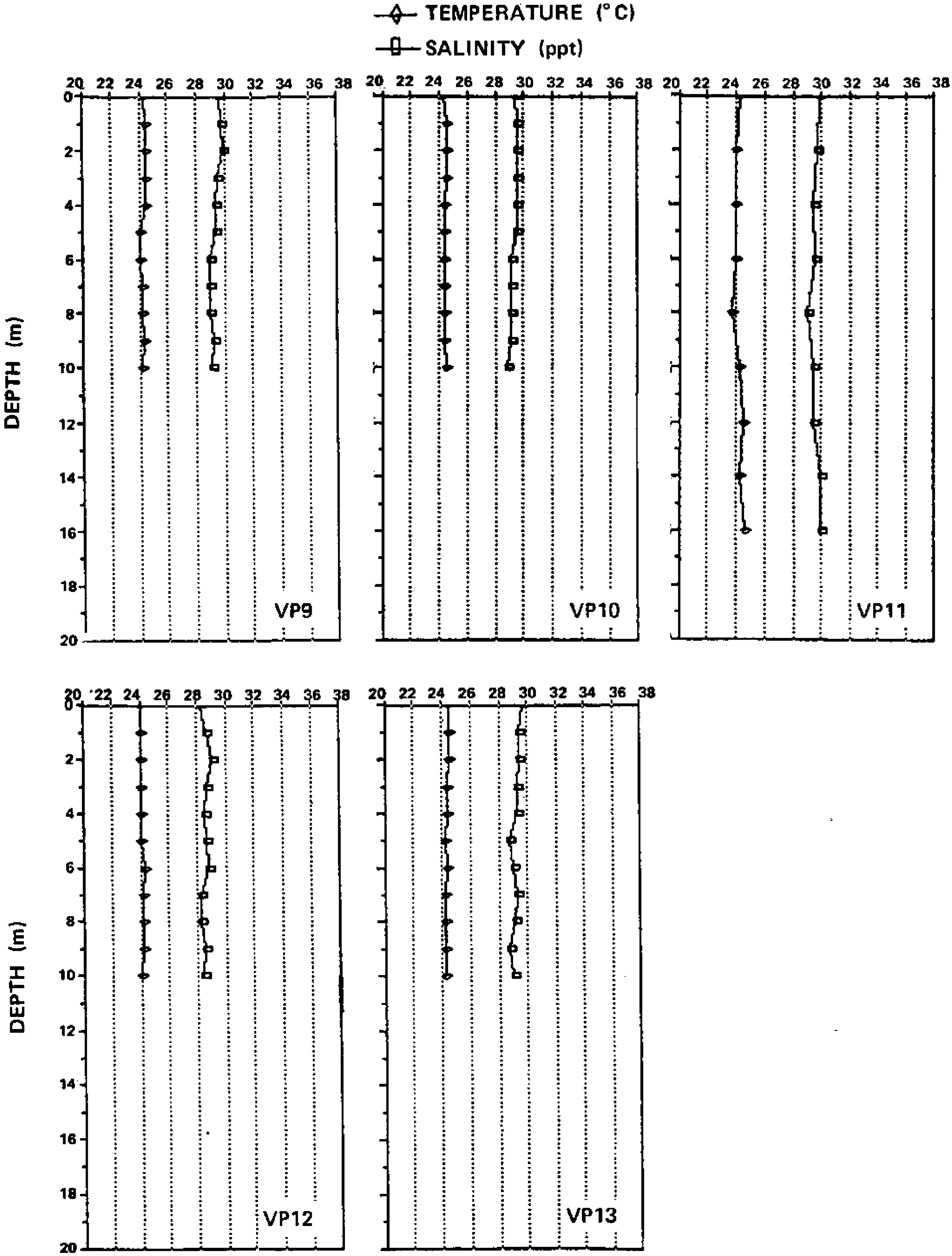


Plate 4: Vertical profiles of temperature and salinity from cruise 84-8, 30-31 August 1984.

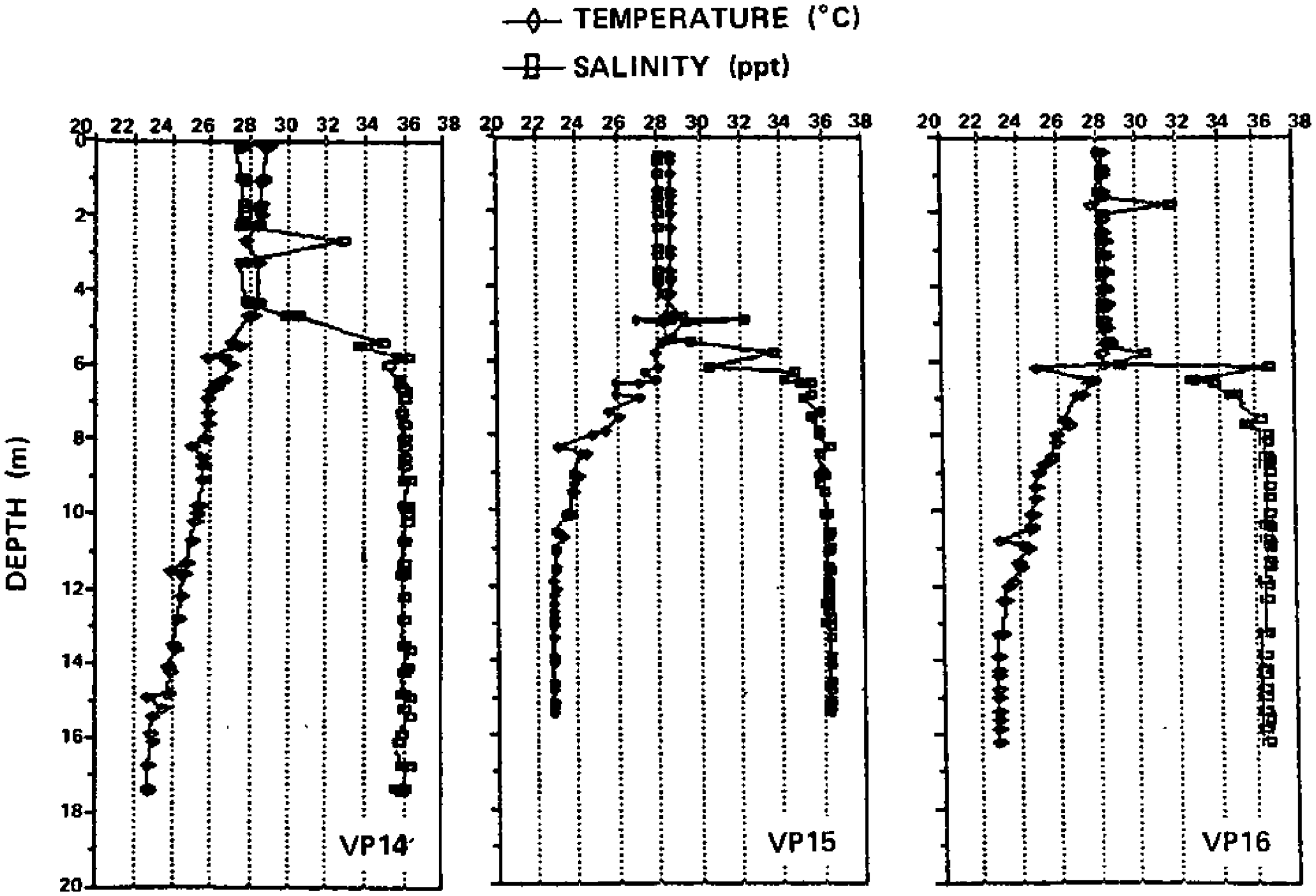


Plate 5: Vertical profiles of temperature and salinity from cruise 84-9-1, 13-14 September 1984.

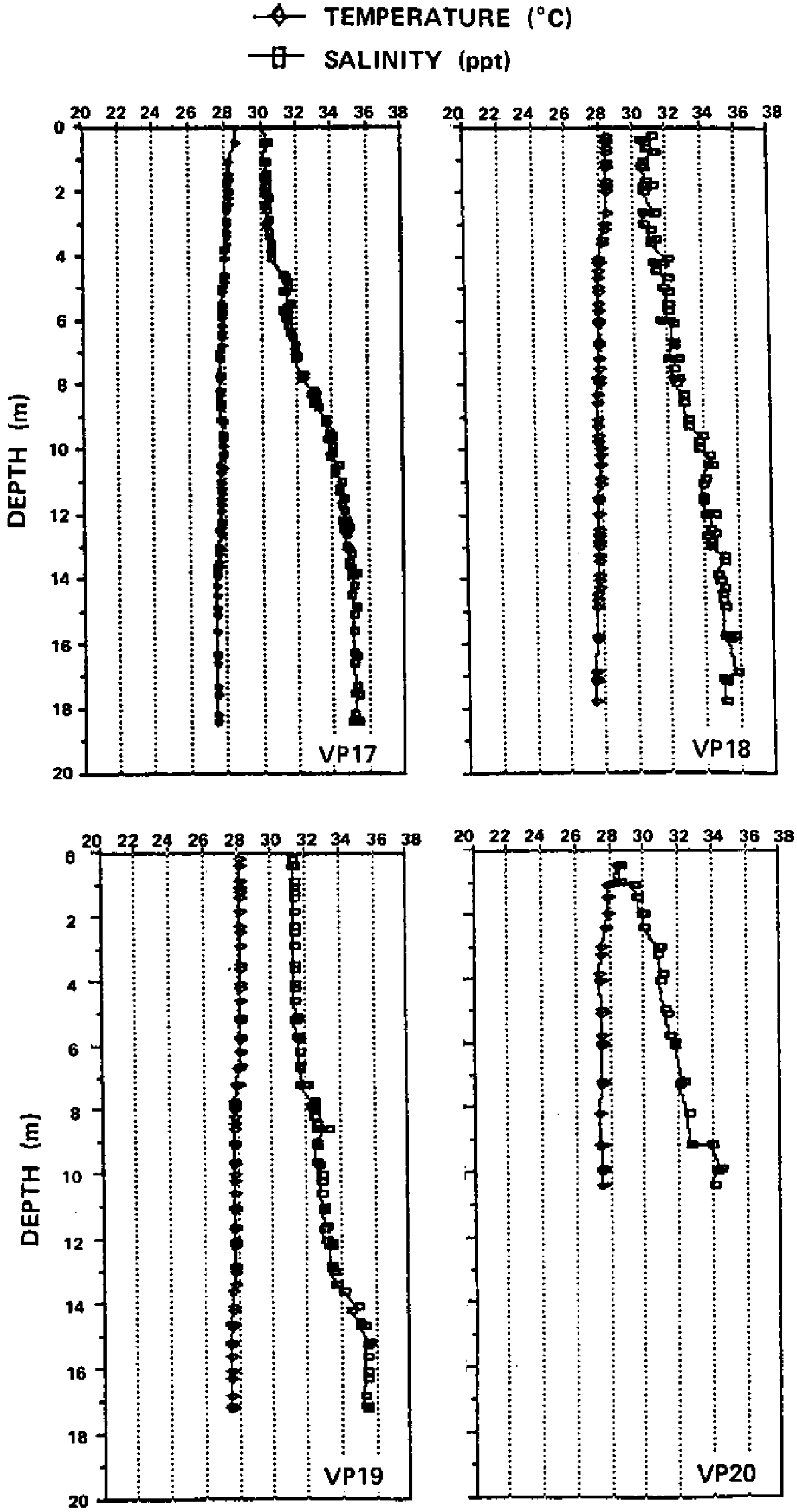


Plate 6: Vertical profiles of temperature and salinity from cruise 84-9-2, 26-27 September 1984.

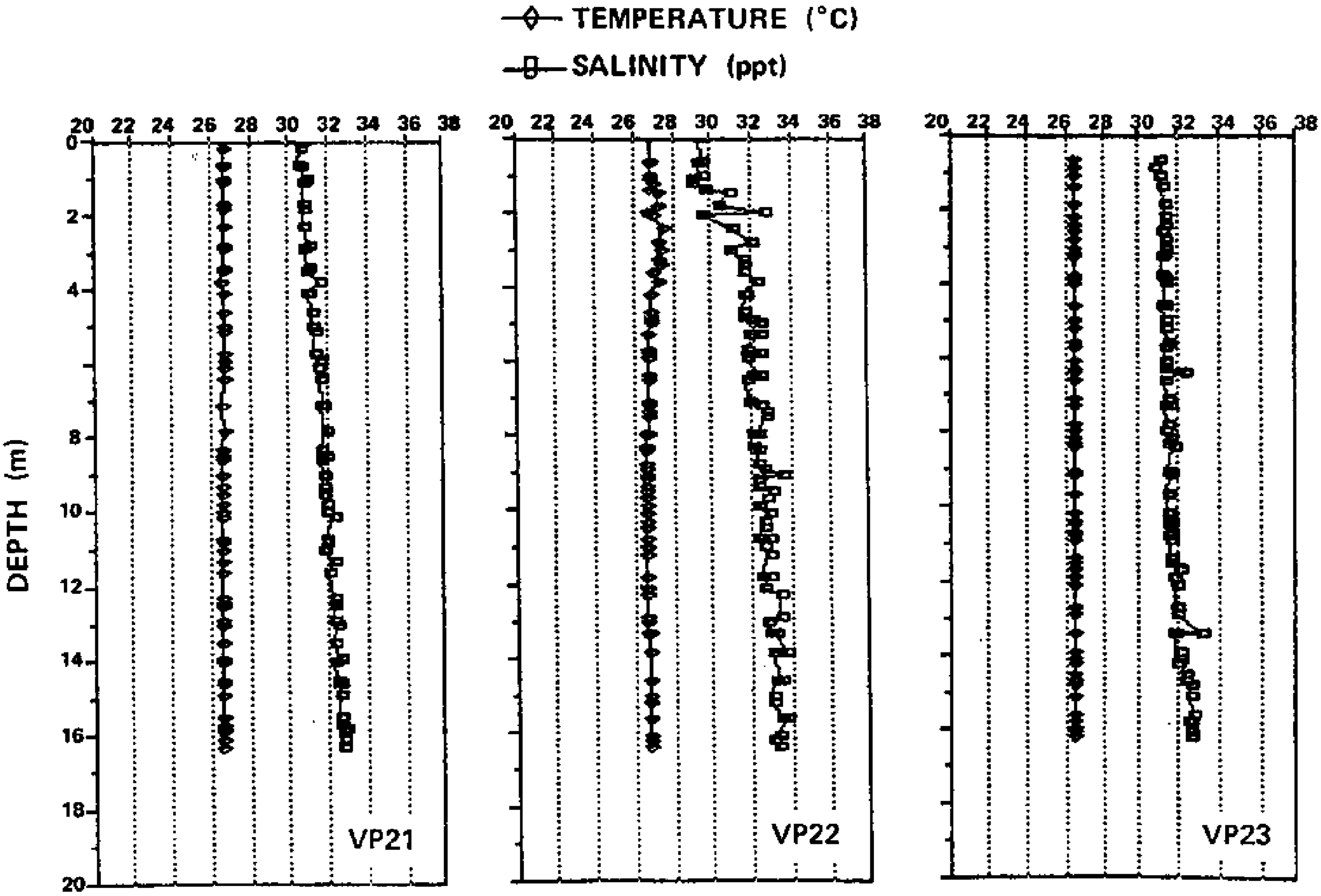


Plate 7: Vertical profiles of temperature and salinity from cruise 84-10-1, 10-11 October 1984.

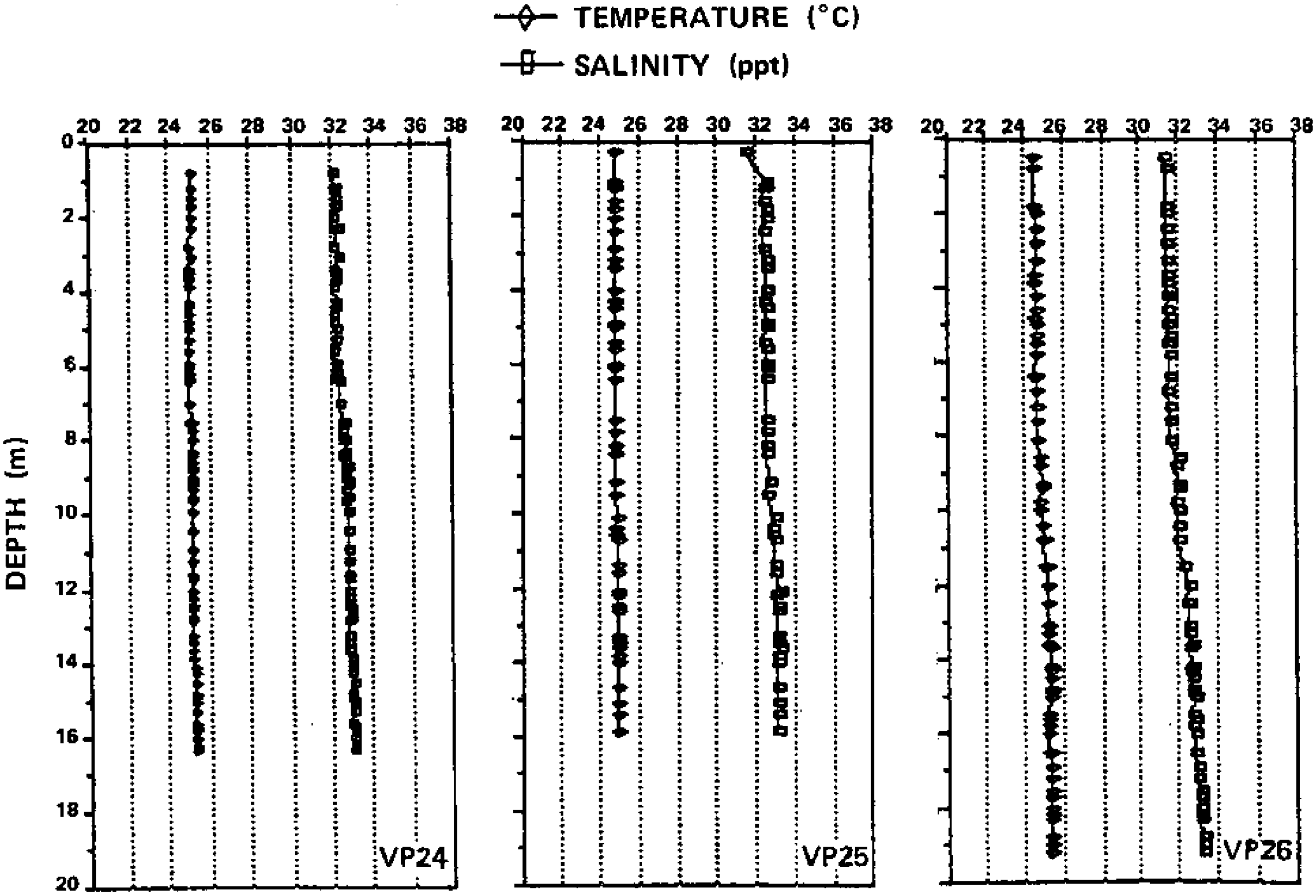


Plate 8: Vertical profiles of temperature and salinity from cruise 84-10-2, 23-25 October 1984.

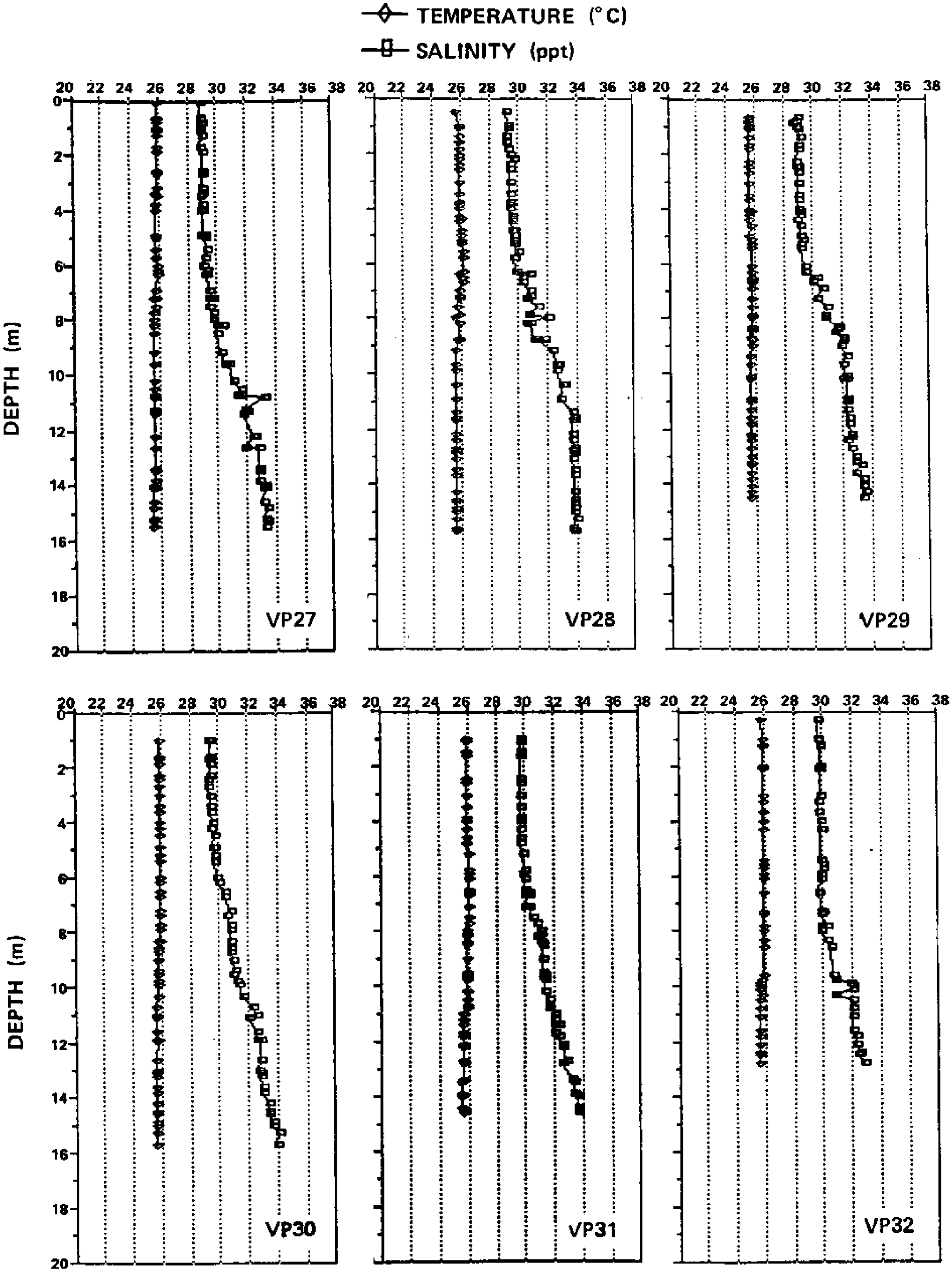


Plate 9: Vertical profiles of temperature and salinity from cruise 84-11, 7-8 November 1984.

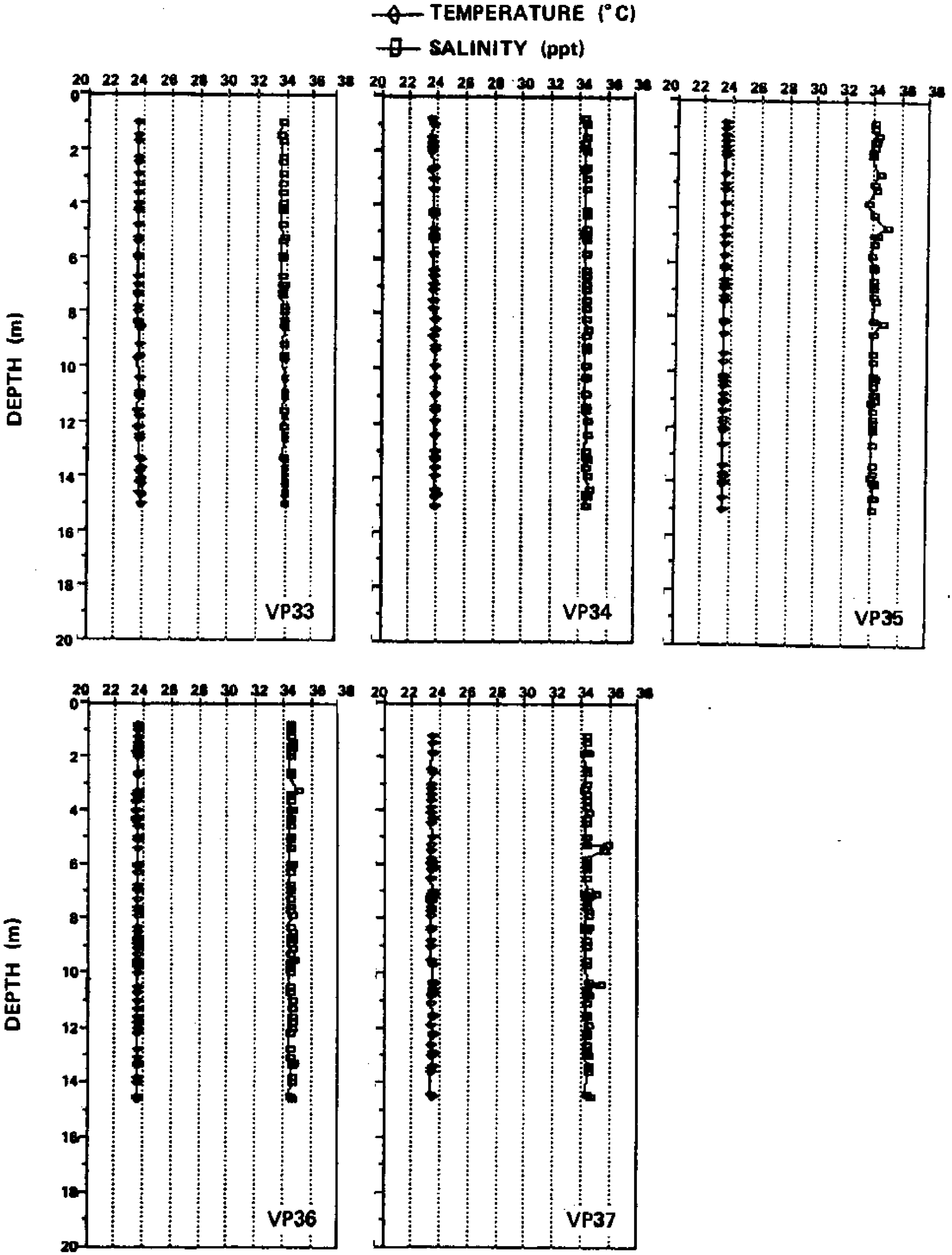


Plate 10: Vertical profiles of temperature and salinity from cruise 85-8, 28 August 1985.

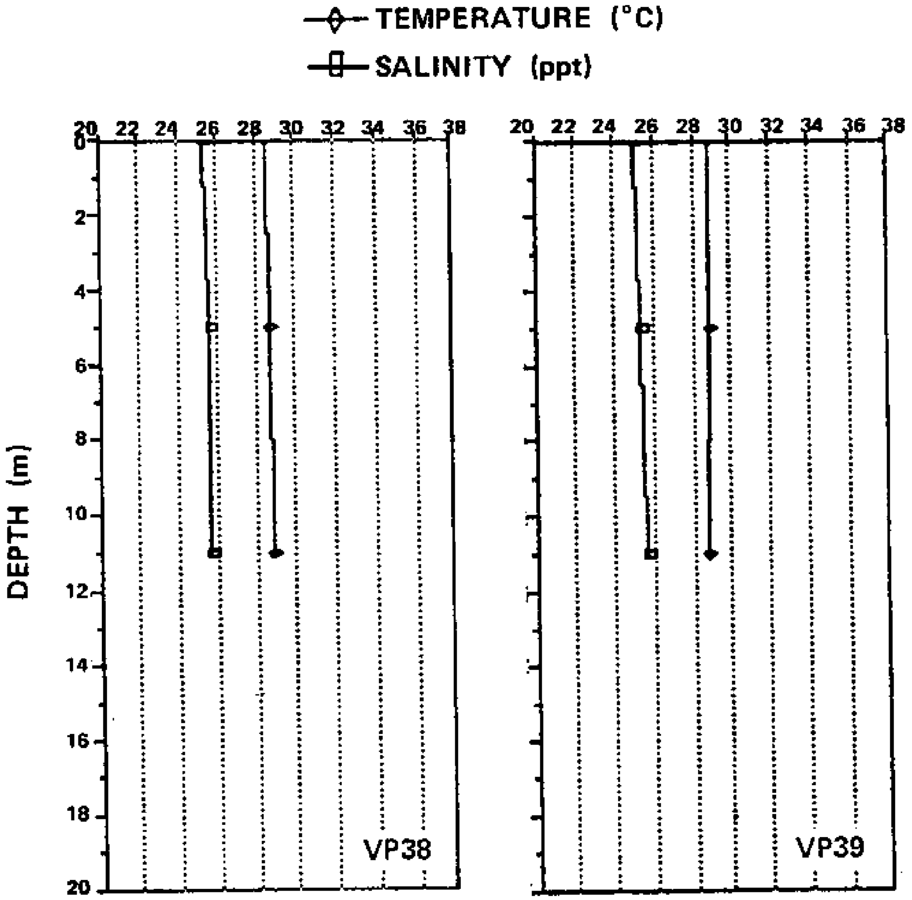


Plate 11: Vertical profiles of temperature and salinity from cruise 85-9-1, 11-12 September 1985.

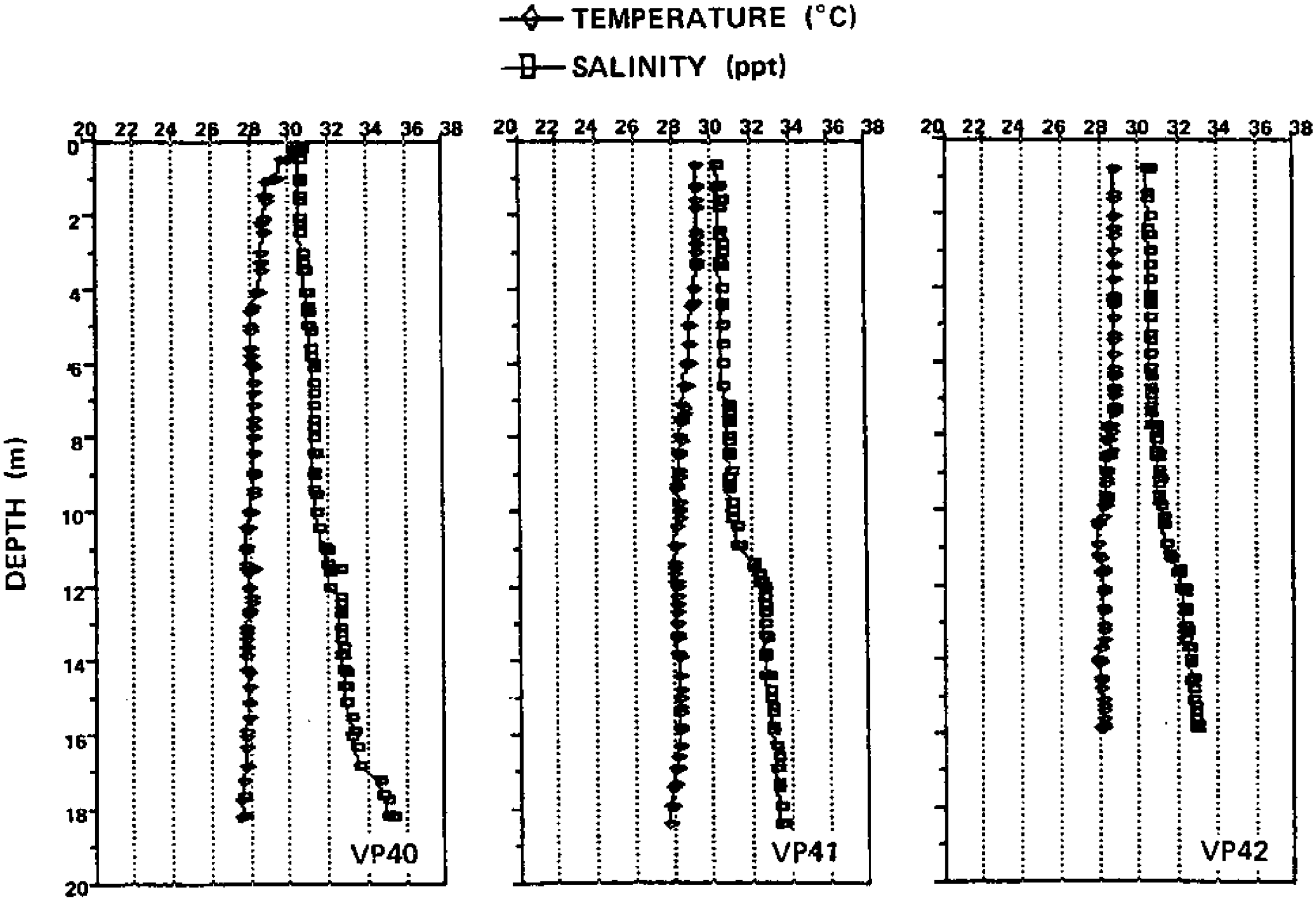


Plate 12: Vertical profile of temperature and salinity from cruise 85-9-2, 25 September 1985.

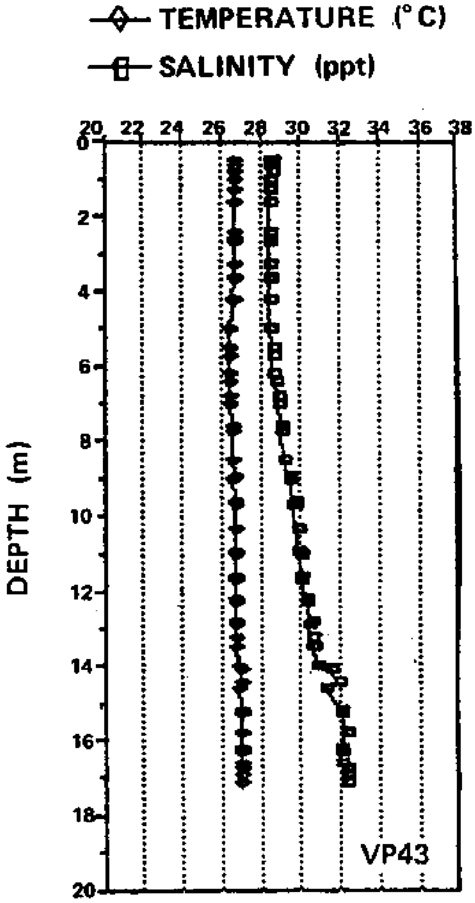


Plate 13: Vertical profiles of temperature and salinity from cruise 85-10, 10-11 October 1985.

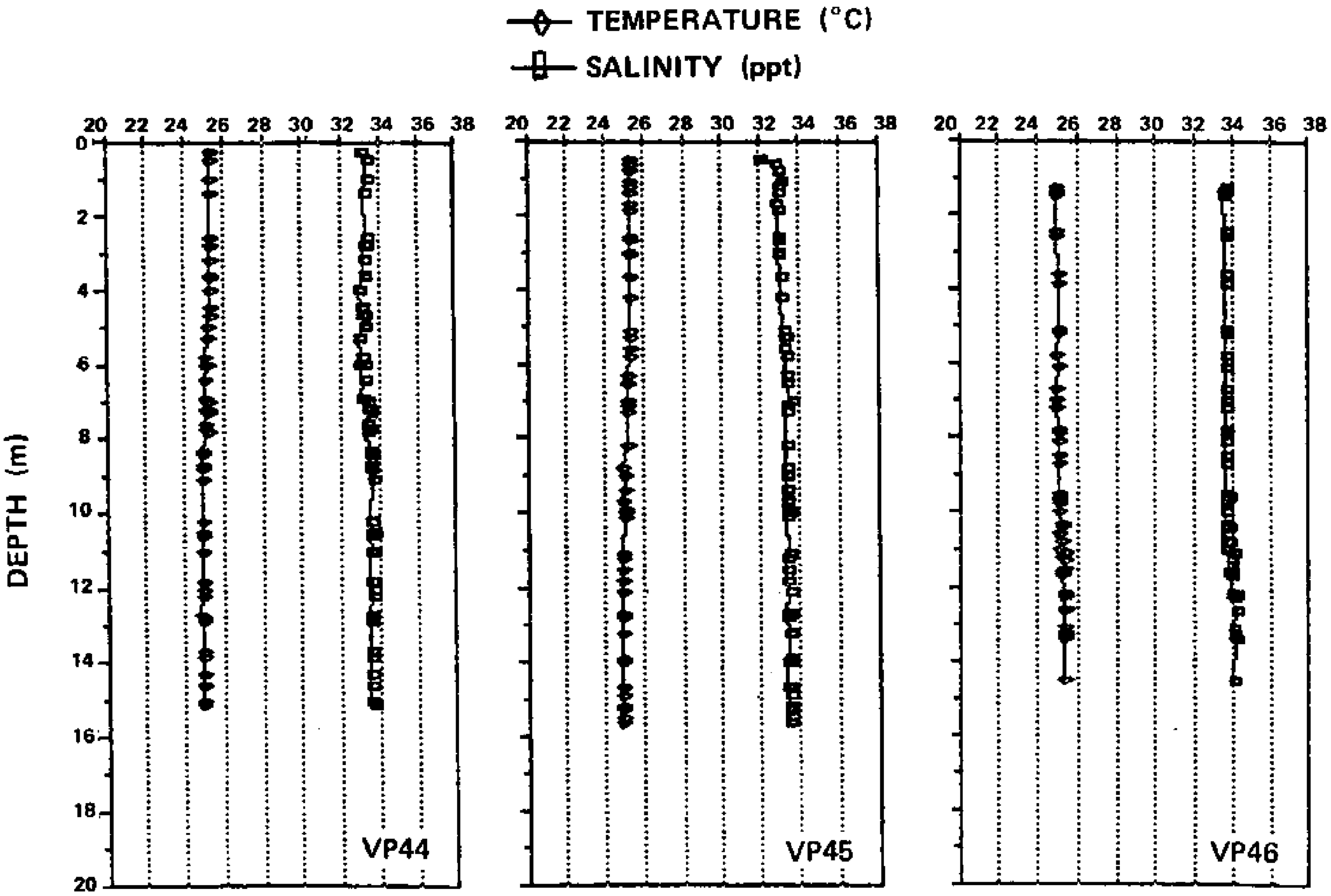
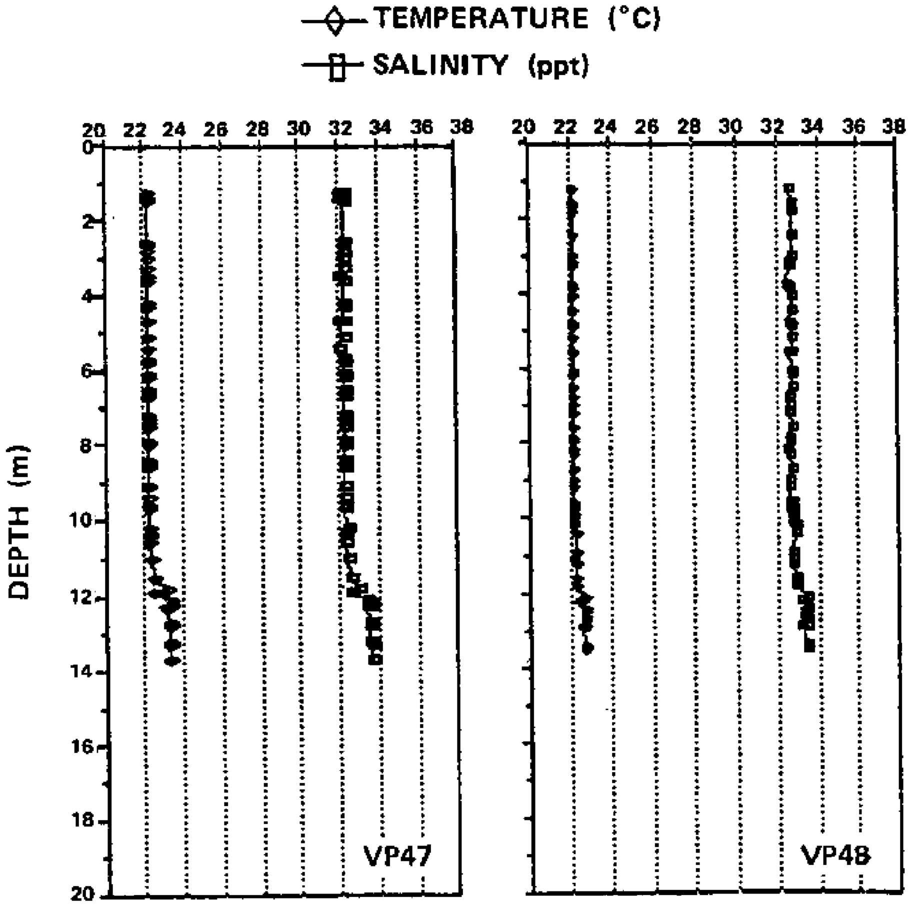


Plate 14: Vertical profiles of temperature and salinity from cruise 85-11, 4 November 1985.



Appendix Table 2: Cruise number, time of day, depth of sample and biological data from selected samples from 1983, 198
and 1985 that were included in the trophic analyses.

CRUISE	TIME	DEPTH	TOTAL ZOOPLANKTON (size >.063 mm) #/CU.M	PREY ZOOPLAMNKTON (size <.23 mm) #/CU.M	CHLOROPHYLL (mg/cu m) TOTALS	FISH TIME	LARVAL RED DRU #/100CUM	AVERAG
RD83-10-01	15.30	3	37251	26419	.10808			
RD83-10-01	15.15	8	27767	26032	.09321	10.27	12.10	
						11.48	5.53	
						13.45	2.31	
RD83-10-01	18.00	3	25243	21057	NA			
RD83-10-01	17.40	8	16490	12579	.19395	17.21	14.58	
						18.42	9.91	
						18.42	4.71	
RD83-10-01	21.15	3	67386	61714	.05910			
RD83-10-01	20.55	8	51313	46303	NA			
RD83-10-01	.40	3	65608	57735	NA	2.04	2.27	
RD83-10-01	.20	5	49608	13767	.20280			
RD83-10-01	0.00	8	12508	11556	.27503	2.52	2.08	
RD83-10-01	5.50	1	17896	14874	NA			
RD83-10-01	5.35	5	18303	15475	NA			
RD83-10-01	5.14	10	9856	7867	NA	6.59	11.09	
RD83-10-01	9.44	1	18222	15259	NA			
RD83-10-01	9.23	5	24487	20698	.14340			
RD83-10-01	9.01	10	19111	13587	.26183			
RD83-10-02	11.47	3	18820	15024	.50310	13.52	0.00	
RD83-10-02	11.29	5	20701	18333	.68880	13.40	1.51	
RD83-10-02	11.05	8	34869	27636	.56327	13.36	0.00	
RD83-10-02	.56	3	27919	21232	.22062	2.09	0.00	
RD83-10-02	.33	5	25489	20476	.16902	2.49	0.00	
RD83-10-02	.05	8	28555	23838	.72618	3.28	0.00	
RD83-10-02	7.21	3	16828	7192	NA	8.51	3.03	
RD83-10-02	7.00	5	31876	26460	.44004	8.46	5.23	
RD83-10-02	6.39	8	37859	33010	.76296	7.41	4.80	
RD83-10-02	18.40	3	21953	16756	.58032	22.38	0.00	
RD83-10-02	17.48	5	26058	20049	.18113	21.56	0.00	
						16.18	1.02	
RD83-10-02	16.50	8	25614	18964	.45000	15.13	2.61	

Appendix Table 2: cont.

CRUISE	TIME	DEPTH	TOTAL ZOOPLANKTON (size >.063 mm) #/CU.M	PREY ZOOPLAMNKTON (size <.23 mm) #/CU.M	CHLOROPHYLL (mg/cu m) TOTALS	FISH TIME	LARVAL RED DRUM	
							#/100CUM	AVERAGE
RD84-09-01	16.29	1	226630	216110	.46375	16.50	226.90	
						16.56	242.90	
						17.00	172.70	214.17
RD84-09-01	16.06	5	278980	274900	.56821	17.41	57.40	
						17.46	50.50	
						17.51	44.19	50.70
RD84-09-01	16.16	10	95452	90740	.52095	18.41	NA	
						18.49	0.00	
						18.54	2.00	1.00
RD84-09-01	22.50	1	192225	189296	.39929	23.55	19.80	
						0.00	1.90	
						.05	6.10	9.27
RD84-09-01	23.10	5	321712	317645	.43496	.49	288.20	
						.54	261.40	
						.59	153.50	234.37
RD84-09-01	23.28	11	180743	171674	.41970	1.41	8.40	
						1.47	1.00	
						1.52	4.80	4.73
RD84-09-01	5.35	1	102027	96767	.43378	6.50	115.60	
						6.56	153.80	
						7.01	152.40	140.60
RD84-09-01	5.47	5	105425	103562	.40159	7.46	10.70	
						7.51	14.70	
						7.56	7.90	11.10
RD84-09-01	5.59	11	222067	215409	.49265	8.35	5.50	
						8.39	2.70	
						8.44	3.20	3.80
RD84-09-01	11.23	1	457127	427326	1.47639	10.56	55.40	
						--	73.80	
						11.07	122.20	83.80
RD84-09-01	12.16	3	139987	115264	1.47499	11.51	4.60	
						--	10.60	
						12.01	18.40	11.20

Appendix Table 2: continued.

CRUISE	TIME	DEPTH	TOTAL ZOOPLANKTON (size >.063 mm) #/CU.M	PREY ZOOPLAMNKTON (size <.23 mm) #/CU.M	CHLOROPHYLL (mg/cu m) TOTALS	FISH TIME	LARVAL RED DRUM #/100CUM	AVERAGE
RD84-09-01	13.01	7	172843	146408	1.97412	12.36	2.30	
							.70	
							3.90	2.30
RD84-09-02	15.14	1	272000	267515	1.58455	11.19	2.89	
RD84-09-02	15.39	5	358400	352119	1.53540	TO	15.98	
RD84-09-02	15.56	12	373333	369541	3.18203	14.14	0.00	
RD84-09-02	22.28	1	266424	257455	1.07067	19.11	.52	
RD84-09-02	22.46	5	313212	298182	2.12228	TO	6.73	
RD84-09-02	23.04	12	169126	167047	1.33190	21.29	21.99	
RD84-09-02	10.29	1	277256	193617	3.74957	7.25	1.91	
RD84-09-02	10.48	5	271099	263437	4.15948	TO	18.08	
RD84-09-02	11.04	12	185531	181487	3.49005	9.33	1.30	
RD84-10-02	14.41	1	890295	880372	8.73603	11.37	0.00	
						11.42	0.00	
RD84-10-02	15.01	5	599515	594182	6.06070	12.42	0.00	
RD84-10-02	15.21	13	299141	295111	4.39705	13.42	0.00	
RD84-10-02	21.09	1	329426	318264	4.59487	18.31	.64	
RD84-10-02	21.30	5	520242	506909	3.90662	19.25	0.00	
RD84-10-02	21.50	12	308606	304000	4.34197	20.18	0.00	
RD84-10-02	10.00	1	396629	392348	4.51254	7.14	0.00	
RD84-10-02	10.21	5	406903	396629	3.29829	8.05	0.00	
RD84-10-02	10.44	11	183863	177045	2.04669	9.07	0.00	
RD84-10-02	16.50	1	501663	493526	2.50287	13.07	0.00	
RD84-10-02	17.11	5	360027	352535	1.94653	14.10	0.00	
RD84-10-02	17.37	11	404548	401552	4.44379	15.50	0.00	
RD85-09-01	16.15	1	87094	84017	.41333	12.44	31.00	
							10.80	
							19.00	20.27
RD85-09-01	16.36	5	189464	178364	.40210	TO	4.60	
							7.60	
							1.00	4.40
RD85-09-01	16.56	11	133186	129419	1.36343	15.01	0.00	
							0.00	
							.50	.17

Appendix Table 2: continued.

CRUISE	TIME	DEPTH	TOTAL ZOOPLANKTON (size >.063 mm) #/CU.M	PREY ZOOPLAMNKTON (size <.23 mm) #/CU.M	CHLOROPHYLL (mg/cu m) TOTALS	FISH TIME	LARVAL RED DRUM	
							#/100CUM	AVERAGE
RD85-09-01	23.10	1	222730	208528	.19921	19.31	0.00	
							0.00	
							0.00	0.00
RD85-09-01	23.38	5	287821	274330	.23681	TO	7.10	
							2.90	
							4.90	4.97
RD85-09-01	24.00	11	206161	197877	.52858	21.45	1.50	
							0.00	
							0.90	0.80
RD85-09-01	11.28	1	88418	80375	.40585	7.42	7.30	
							7.60	
							26.30	13.73
RD85-09-01	11.47	5	180672	175726	.61933	TO	17.00	
							31.60	
							14.00	20.87
RD85-09-01	12.05	11	179793	174078	.75766	10.08	1.20	
							1.20	
							2.60	1.66
RD85-10-01	16.31	1	73422	71644	.93750	13.33	4.46	
RD85-10-01	16.48	5	81274	79300	.66081	14.30	7.89	
RD85-10-01	17.08	12	86338	82806	1.16383	15.26	.83	4.39
RD85-10-01	22.19	1	24265	22238	.61160	18.53	0.00	
RD85-10-01	22.38	5	46819	45301	.46538	19.49	.70	
RD85-10-01	22.57	12	163956	158673	1.28988	20.47	4.92	1.87
RD85-10-01	9.46	1	64334	61718	.93884	7.04	1.40	
RD85-10-01	10.01	5	46871	45717	1.18397	7.54	.70	
RD85-10-01	10.16	11	131422	128041	1.64411	8.51	0.00	.70

ZOOPLANKTON SIZE 1983 >.1 mm, 1984 & 1985 >.063 mm

- Data Not Available

PAPERS PRESENTED

Steen, John, and Joanne Shultz
The Distribution of Red Drum Larvae (Sciaenops ocellatus) and their Planktonic Prey in Mississippi Waters.
Gulf Estuarine Research Society Fall Meeting
November 7-8, 1985
Gulf Coast Research Laboratory
Ocean Springs, Mississippi

Lyczkowski-Shultz, Joanne
Shelf Processes and Recruitment of Red Drum in Mississippi Coastal Waters: More Questions Than Answers.
Gulf Estuarine Research Society Fall Meeting
October 30-31 1986
Louisiana State University
Baton Rouge, Louisiana

Eleuterius, C. K., J. P. Steen, Jr., and J. L. Shultz
Water Column Structure of the Upper Continental Shelf South of Mississippi During the Late Summer and Fall.
Mississippi Academy of Sciences
Fifty-First Annual Meeting
February 25-27, 1987
Jackson, Mississippi

Shultz, J. L., and J. P. Steen, Jr.
Red Drum Larval Studies in Mississippi
Winter/Spring Seminar Series
Dauphin Island Sea Laboratory
March 12, 1987
Dauphin Island, Alabama

Steen, Jr., J. P. and J. L. Shultz
Zooplankton, Larval Fish and Chlorophyll Distributions with Reference to Hydrographic Conditions in Mississippi Coastal Waters
Ninth Biennial International Estuarine Research Conference
Estuarine Research Federation
October 25-30, 1987
New Orleans, Louisiana

Comyns, Bruce H.
Growth and Condition of Larval Red Drum (Sciaenops ocellatus) in Mississippi Coastal Waters.
Tenth Annual Larval Fish Conference
American Fisheries Society
May 18-23, 1986
Miami, Florida

Lyczkowski-Shultz, Joanne
Fish Larvae and Their Zooplankton Prey: An Intensive, Small-Scale Sampling Approach.
Tenth Annual Larval Fish Conference
American Fisheries Society
May 18-23, 1986
Miami, Florida

Lyczkowski-Shultz, Joanne
Red Drum Recruitment Into Mississippi Estuaries.
State-Federal Cooperative Program for Red Drum Research in the Gulf of Mexico
Fall Conference
October 14, 1986
New Orleans, Louisiana

Comyns, Bruce H.
Age, Growth, and Mortality of Larval Red Drum (*Sciaenops* *ocellatus*) in Mississippi Coastal Waters.
Mississippi Academy of Sciences
Fifty-First Annual Meeting
February 25-26, 1988
Biloxi, Mississippi

Lyczkowski-Shultz, Joanne
Abundance and distribution of larval red drum (*Sciaenops* *ocellatus*) in Mississippi Coastal Waters.
Mississippi Academy of Sciences
Fifty-First Annual Meeting
February 25-26, 1988
Biloxi, Mississippi

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