

THE ECOLOGICAL SIGNIFICANCE OF A CTENOPHORE,  
MNEMIOPSIS LEIDYI (A. AGASSIZ),  
IN A FISH NURSERY GROUND

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A Thesis

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By

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APPROVAL SHEET

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## ABSTRACT

The tentaculate ctenophore, Mnemiopsis leidyi, occurred all months of the year in the York River estuary, Virginia. It was present only in higher salinity water (15 ‰ and above) in winter, but in less than 6 ‰ in late summer. Numbers of small plankton, such as copepods and the larvae of annelids, mollusks and barnacles, varied inversely with the volume of ctenophores present at each sampling site. Stomodaeum analyses and feeding experiments confirmed M. leidyi as a predator of these plankters. Other feeding experiments indicated that the ctenophore was responsible for 3/4 of the total predation by plankton forms. Plankters exceeding 6 mm in length were not preyed upon.

Most of the fish using this estuary as a nursery ground were large enough before entering infested waters to avoid predation. Young fish in the area subsisted chiefly on items not preyed on by this ctenophore.

Another ctenophore, Beroe ovata, preyed on the tentaculate form in the summer and fall to such an extent that the tentaculate ctenophores were restricted to areas outside the range of the beroid. The medusa Chrysaora quinquecirrha also preyed on the tentaculate form but did not significantly reduce its numbers.

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## INTRODUCTION

Ctenophores are members of the plankton occurring in waters ranging from mesohaline portions of estuaries to open oceans. Oceanic and coastal ctenophores are sometimes concentrated by currents into large swarms or rafts. These swarms are comparatively short-lived in neritic and oceanic waters, but often persist for months in estuaries (Fraser 1962; Cronin, Daiber and Hulbert 1962).

Ctenophores are divided into two classes, essentially by their means of feeding. Members of Class Tentaculata feed chiefly by drawing tentacles containing entangled food into the mouth, while those which lack tentacles (Class Nuda) engulf food in a large stomodaeum occupying most of the body (Hyman 1940). Tentaculate ctenophores, of which Mnemiopsis, Pleurobrachia, Bolinopsis, and Mertensia are common genera, feed on small crustaceans, chaetognaths, fish eggs, and larvae of fish, mollusks, and annelids (Bigelow 1914, 1924; Cronin et al. 1962; Grice and Hart 1962; Hardy 1958; Hyman 1940; Lebour 1922, 1923; Main 1928; Mayer 1912; Nelson 1925; Ralph and Kaberry 1950; Raymond 1962; Russell 1925). The principal genus of the Class Nuda is Beroe, which feeds chiefly on other ctenophores. Lebour (1923) found copepods in the stomodaeum of a beroid species, but Kamshilov, as cited by Fraser (1962), thought that these came from the stomodaeum of an ingested tentaculate form.

A drastic reduction in crustacean plankton follows the appearance of tentaculate ctenophores (Cronin et al. 1962; Nelson 1925). Laboratory studies by Williams and Baptist (1966) and Bishop (1967)

indicate the predatory capabilities of Mnemiopsis leidyi. Few, if any, studies of seasonal composition of estuarine plankton have taken into account the influence of ctenophores. Indeed, more attention has been directed toward avoiding the collection of these forms (Heinle 1965). Difficulties experienced in preserving ctenophores have contributed to the reluctance of investigators to interest themselves in the group.

In August 1965, the Ichthyology and Crustaceology departments of the Virginia Institute of Marine Science embarked on a study to characterize a low-salinity fish nursery ground. The physical, chemical and biological attributes of a fish nursery ground were examined to determine what made it more suitable than adjacent areas (Joseph and Van Engel 1966). The nursery ground selected for study was the upper 10 miles of the York River and the lower 10 miles of one of its major tributaries, the Pamunkey River.

M. leidyi, present in this nursery ground at certain times of the year, is a biological influence worthy of investigation. The nursery ground project was ideally suited for the study of M. leidyi, as it provided monthly hydrographic, chemical and biological data for over a year and permitted collection and observation of living ctenophores. Pleurobrachia pileus has been reported from this area, but was not seen during this study.

Monthly plankton samples from the entire York-Pamunkey river system were counted by Mrs. Sue Davidson and Mr. Terry R. Sopher. Identifications of the coelenterates were made by Mr. Dale R. Calder, isopods and cumaceans by Mr. Daniel Gibson, amphipods by Mr. James B. Feeley, and fish eggs and larvae by Miss Sarah B. Leonard and Mr. Ronald G. Rinaldo. The remaining groups were my responsibility.

## MATERIALS AND METHODS

### Procedures of the Fish Nursery Ground Project

The Nursery Ground Project entailed monthly occupation of four stations in the York River and four in the Pamunkey River (Fig. 1). These stations, beginning 10 miles above the mouth of the York, were 5 miles apart, except for the two most up-river stations in the Pamunkey, which were 10 miles apart. Three other stations occasionally occupied were Y00, at the mouth of the York; C10, 10 miles seaward from the mouth of the York; and C00, in the entrance to Chesapeake Bay.

The location of each station was as follows:

<u>Code</u>	<u>Latitude and Longitude</u>	
C00	37 04' N 76 05' W	Mouth of Chesapeake Bay
C10	37 10' N 76 14' W	York River entrance channel
Y00	37 15' N 76 23' W	Mouth of York River
Y10	37 19' N 76 36' W	York River, Pages Rock
Y15	37 23' N 76 39' W	York River, Capahosic
Y20	37 26' N 76 42' W	York River, Poropotank
Y25	37 29' N 76 45' W	York River, Bell Rock
P30	37 33' N 76 50' W	Pamunkey River, Eltham Marsh
P35	37 33' N 76 52' W	Pamunkey River, Lee Marsh
P40	37 33' N 76 53' W	Pamunkey River, White Oak
P50	37 35' N 76 59' W	Pamunkey River, Lester Manor

Temperature, salinity and dissolved oxygen were measured at the surface and 1 meter above the bottom at each station. Light attenuation was measured with a Secchi disc. Plankton tows were made at

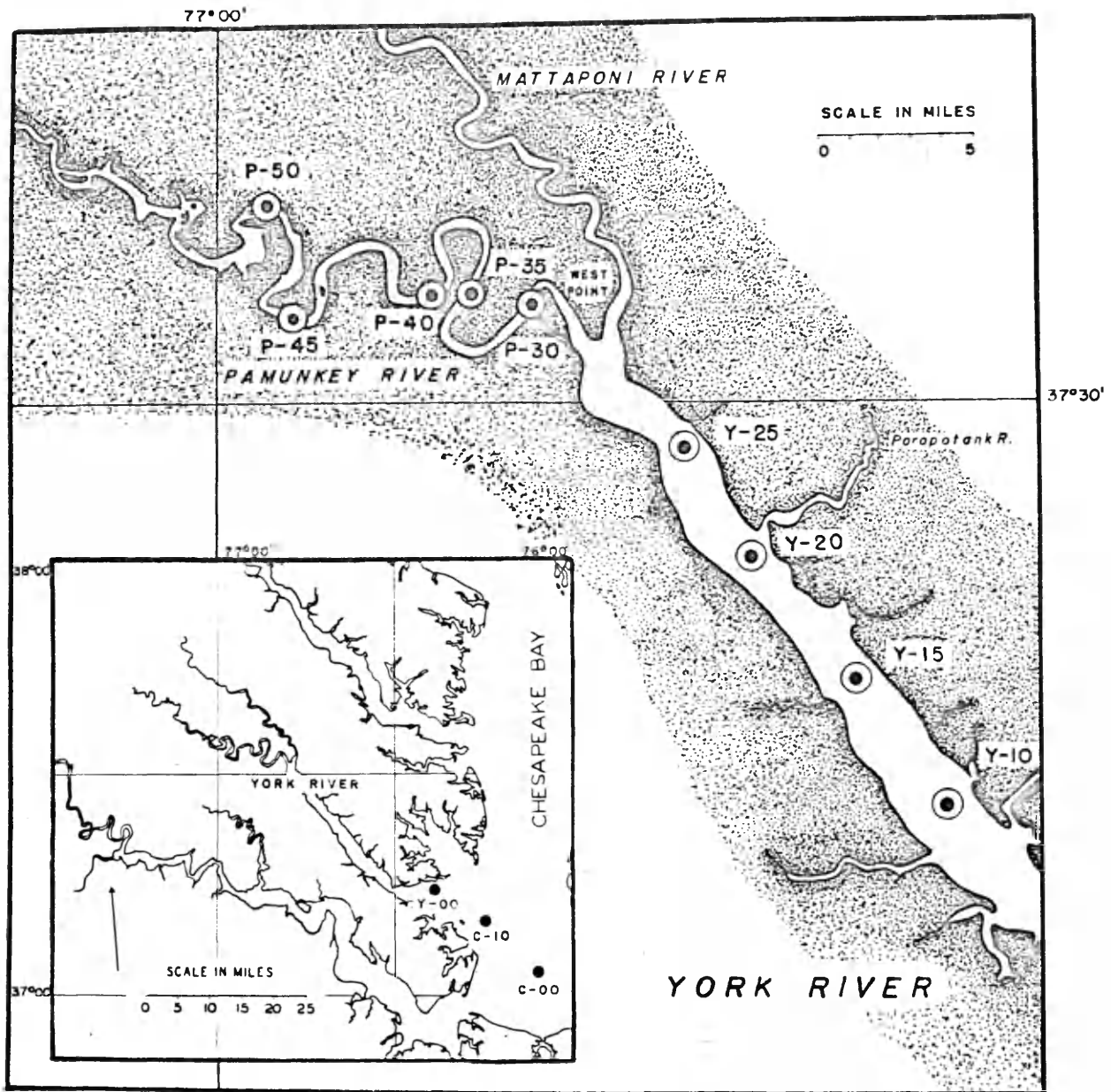


Figure 1. Chart of the area showing stations.

1 meter above the bottom at each station, using a meter net with a 0.75 mm mesh. These tows were of 5 minutes duration. Fish and large invertebrates were sampled with a 30-foot semi-balloon trawl towed for 15 minutes at York River stations and 7.5 minutes at Pamunkey River stations. See Joseph and Van Engel (1966) for details.

The meter net samples were split into smaller subsamples by means of a Folsom splitter (McEwen, Johnson and Folsom 1954). The number of splits varied with the number of fish larvae and the number of copepods. One large aliquot, from 1/8 to the whole sample was examined for fish larvae. Another, usually smaller, subsample was used to estimate the abundance of all species of zooplankters; it was considered adequate for the purpose of estimation if it contained between 200 and 300 copepods, and varied from 1/2000 to the entire sample.

#### Procedures Providing Supplementary Data

Volume was used as a measure of abundance of *M. leidyi*. Counting was not feasible due to the fragile nature of ctenophores which resulted in many disintegrated individuals in the samples. Volumes were recorded as less than 0.5 liters, 0.5, 1, 4, 8 and more than 8 liters. Since larger volumes resulted in net clogging and packing of ctenophores, measurement of volumes over 1 liter to an accuracy greater than that stated was not justified.

Ctenophore volume in samples collected prior to June 1966 was extracted from estimates given in cruise log books. When no estimate was logged, plankton samples were re-examined: whenever ctenophores were found these were assigned a volume of less than 0.5 liters. This volume was given because a larger volume would have been noted on the cruise log books. After June 1966, the volume of ctenophores in each

meter-net haul was measured in a graduated plastic bucket. Then 25 ctenophores, selected at random, were examined under a dissecting microscope fitted with an ocular micrometer. Total length, from apical end to tips of the oral lobes, was measured and stomach contents were noted. The trawl net was used to monitor the occurrence of large forms such as the nudate ctenophore, Beroe ovata, and the coelenterate, Chrysaora quinquecirrha and, on occasion, M. leidy when plankton samples were not taken with the meter net. Another Ichthyology department program<sup>1</sup>, occupying the same stations on a monthly basis, permitted this sampling to continue through May 1967, after the field phase of the Nursery Ground Project ended in December 1966.

An extra bottom plankton net tow provided a means of estimating total predation by plankton as compared with predation by M. leidy. This tow was made if the first plankton sample contained appreciable numbers of chaetognaths, coelenterate medusae, or larval or juvenile fish. The second sample was split into three equal volumes at once and treated as follows: one part, containing all organisms alive, was diluted to 4 liters and allowed to stand for 24 hours before being preserved with 5% formalin buffered with an excess of sodium carbonate; another subsample, with M. leidy removed, but all other plankton alive, was diluted to 4 liters and allowed to stand for 24 hours before being preserved; the third, containing all organisms, was preserved at once. The plankters in each aliquot were identified and counted later in the laboratory. The numbers in the first aliquot (all plankters were maintained alive for 24 hours) subtracted from the numbers in the third aliquot gave an estimate of total predation by zooplankton. The numbers in the

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<sup>1</sup>Contract Number 14-16-008-801. "Estimation of Parameters of Striped Bass Populations and Description of the Fishery of Lower Chesapeake Bay." Bureau of Sport Fisheries and Wildlife.

first aliquot subtracted from the numbers in the second aliquot (all plankton, except M. leidyi, maintained alive for 24 hours) gave an estimate of predation due to M. leidyi.

The occurrence of M. leidyi, B. ovata and C. quinquecirrha was monitored from the pier at the Virginia Institute of Marine Science at Gloucester Point, Virginia, a point on the York River 6 miles above the mouth. Vertical plankton tows with a nylon net, 0.75 mm mesh aperture and 0.5 meter mouth diameter, provided specimens for total length measurements and stomach analyses. Relative abundance of M. leidyi was estimated volumetrically and abundance of B. ovata by counting those present along one side of the pier. The proximity of this station permitted sampling on an average of 20 days per month and, on occasion, several samplings in a single day.

Feeding experiments were conducted in the laboratory to examine the ecological role of M. leidyi as prey and as predator. In the first set of experiments, the tentaculate ctenophore was fed the same species of zooplankters which appeared in the digestive cavity of field-collected animals or which showed a decrease in those samples taken when the ctenophore was found. If feeding occurred, this indicated that zooplankton found in the digestive apparatus were prey and not ingested accidentally after being confined in the net and that the ctenophore was responsible for a decrease in zooplankters in areas of mutual occurrence. A known number of food organisms was placed in a 1.5 liter finger bowl with a single ctenophore. Stomach contents recorded at regular intervals during the experiments gave information on feeding patterns. Food organisms remaining after 24 hours were counted and subtracted from initial numbers to calculate numbers captured. Experiments were repeated using various sizes of ctenophores.

In the second series of experiments, five M. leidyi were placed in a 15 liter aquarium containing either one specimen of B. ovata or one specimen of C. quinquecirrha. Ctenophores were ranked, from 1st to 5th, according to the sequence in which they were captured. The time lapse from the introduction of the five tentaculate ctenophores to each individual's capture, hereinafter referred to as accumulated capture time, was recorded in order to determine the feeding rate of each predator. Experiments were repeated using different size prey and predators. The geometric mean of accumulated capture time for each rank of ctenophore was used instead of the arithmetic mean since it is less affected by extreme values. The purpose of these tests was to determine the relative ability of individuals of these two species to capture M. leidyi.

In all feeding studies water in the aquaria was at the ambient salinity (19-20 ‰) and temperature (19-26 C) of the laboratory's salt water system. An aquarium containing a like number of food organisms, but no predator, served as control for each experiment.

## RESULTS AND DISCUSSION

### Distribution of Mnemiopsis leidyi

The segment of the York-Pamunkey system occupied by M. leidyi varied in length from 50 miles in June to 10 miles or less in late winter and again in mid-summer. This ctenophore was present at some stations in the fish nursery ground, designated as the area lying between Y20 and P40, at all times of the year except in the winter and early spring (Fig. 2). Figure 2 also depicts this zone along with the occurrence of B. ovata. In the period July to December 1966, the beroid species completely displaced the tentaculate ctenophore at all river stations at which the beroid form occurred; however, M. leidyi did appear briefly on several occasions at the Virginia Institute of Marine Science during this time (Fig. 3).

Size of M. leidyi varied spatially more than temporally, with the smallest animals occupying the less saline portion of the river (Fig. 4). This suggests that major spawning of M. leidyi occurred up river and further indicated that the prey would be smallest at the further-most point of penetration of the estuary by the ctenophore.

Largest volumes of M. leidyi were obtained in June 1966 when meter net samples from C00 to Y25 yielded more than 8 liters of ctenophores per 5 minute tow. Vertical tows at the Institute pier also contained the largest volumes of the year during this period (Fig. 3).

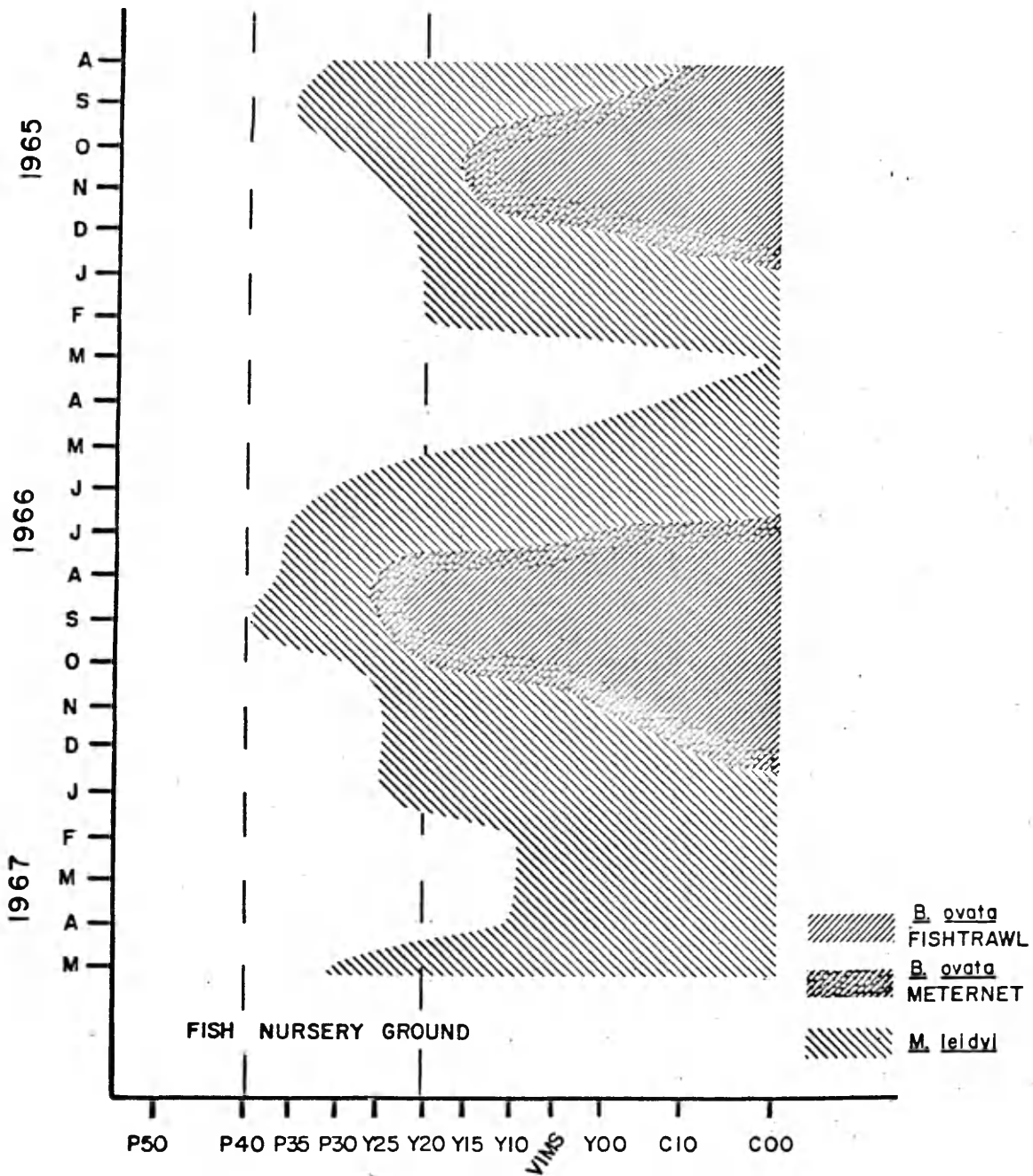


Figure 2. Distribution of *M. leidyi* and *B. ovata* from August 1965 to May 1967.

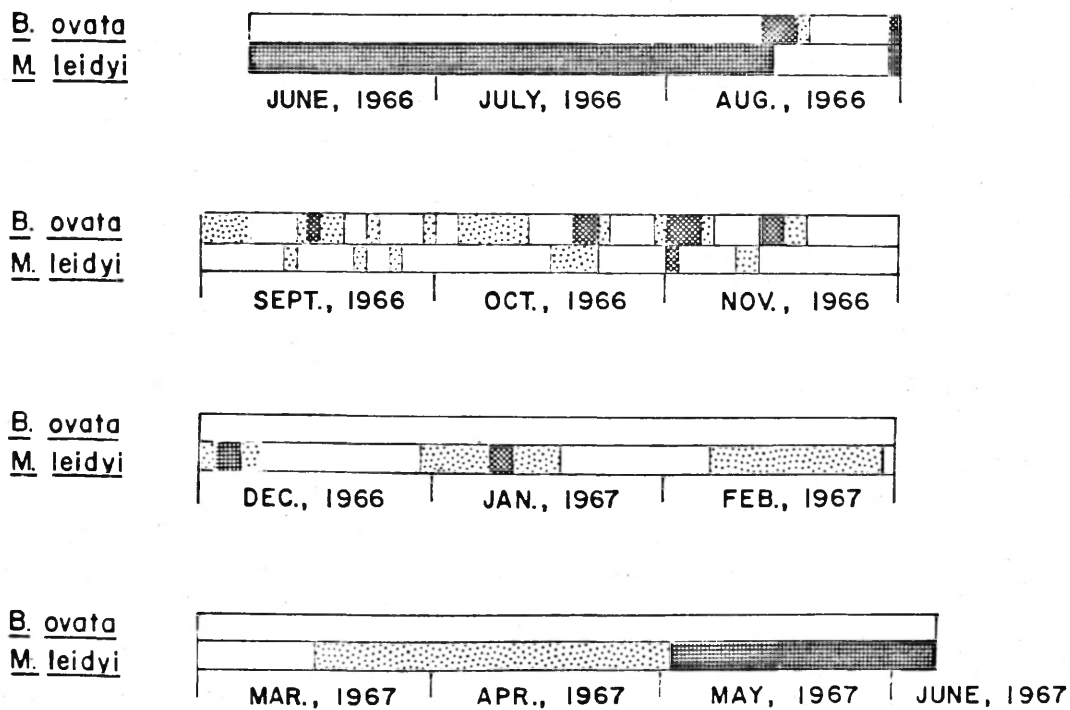


Figure 3. The distribution of *M. leidyi* and *B. ovata* at the Virginia Institute of Marine Science pier from 6 June 1966 to 6 June 1967. For *B. ovata*, dark stippling depicts more than ten animals observed on the left side in one traverse from foot to head (approximately 250 feet); for *M. leidyi*, dark stippling indicates more than 1 ml per liter in a vertical haul with the half meter net. For *B. ovata*, light stippling indicates less than ten animals per traverse and, *M. leidyi*, less than 1 ml per haul. Clear spaces indicate neither ctenophore was present.

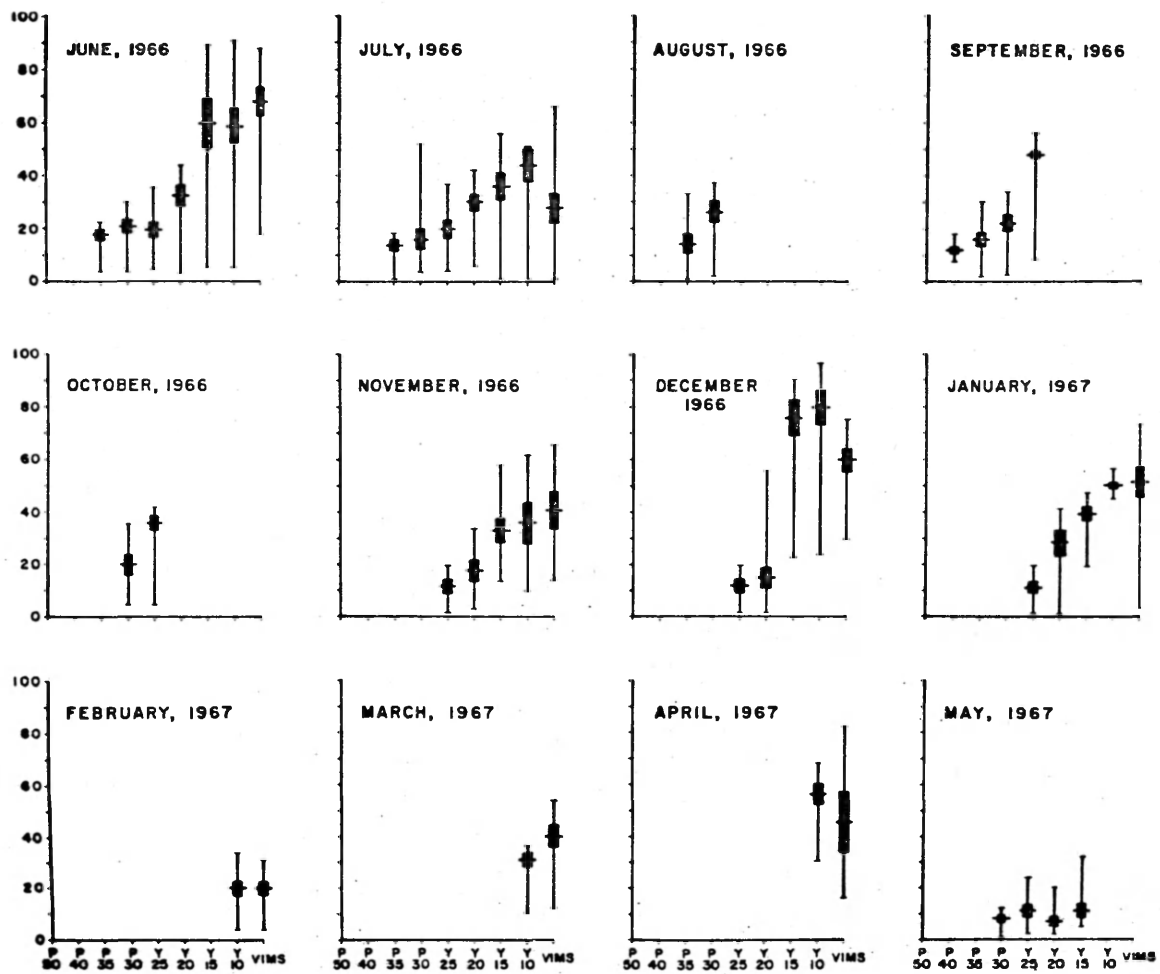
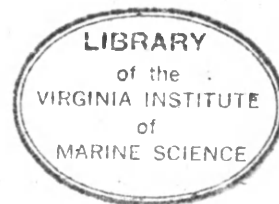


Figure 4. Distribution of *M. leidyi* by length range, mean length, and  $S_{rt.05}$ .



## Factors Controlling the Distribution of M. leidyi

### Salinity and temperatures

Reduced salinity apparently limited penetration upriver. The lowest salinity at which M. leidyi occurred was 5.64 ‰ at P40 in September 1966 (Appendix Table XIV). No evidence was obtained to indicate that the highest salinity of the York River excluded the ctenophore. The highest salinity was 27.51 ‰ in March 1966. While the ctenophore was not found at higher salinities in this survey, it is known to frequent coastal marine waters and I have found it in salinities above 32 ‰ in Wachapreague Inlet, Virginia.

Temperature per se was not limiting. The animal was present at Y25 in January 1966 when the water temperature was 1.28 C and at P35 in July when the water temperature reached 28.8 C. These two extremes approximate the maximum range for the York-Pamunkey river system; however, in colder months the ctenophore was present only in higher salinities (Fig. 5). The interaction of temperature and salinity affects the distribution of many estuarine species (Gunter 1957, Pearse and Gunter 1957).

### Dissolved Oxygen

Minimum dissolved oxygen, 3.5 mg per liter, occurred at P30 in August 1966 (Appendix Table XIII). The tentaculate ctenophore was present at this station and was in no distress, so it is unlikely that it was limited by low levels of dissolved oxygen in the York River system.

### Food

There was no evidence that food limited the distribution of this ctenophore in the York River in 1966. While zooplankton numbers were

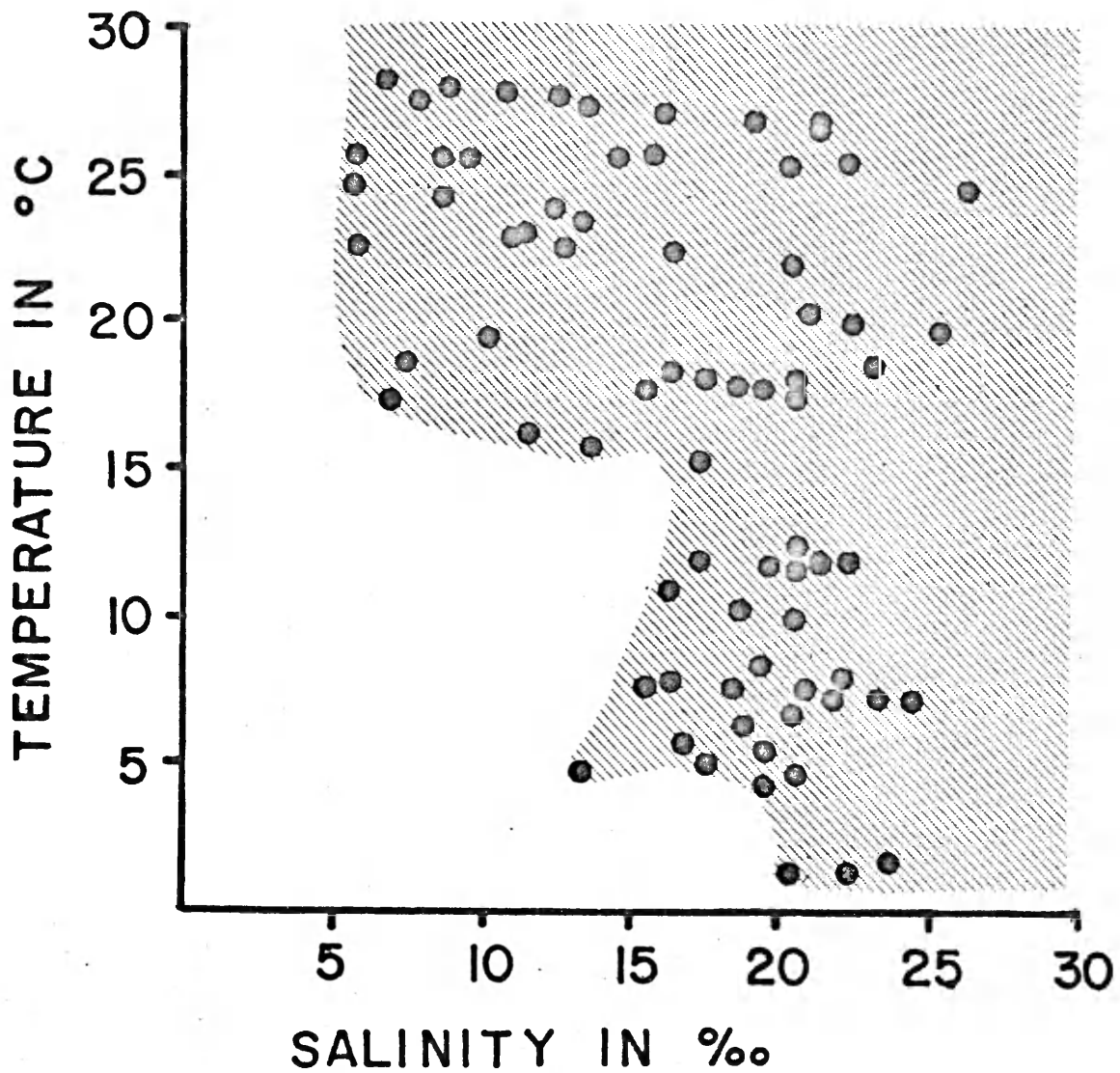


Figure 5. Occurrence of *M. leidyi* from June 1966 to June 1967 at Chesapeake Bay, York River and Pamunkey River stations according to temperature and salinity. Dark circles are observations and the shadow area indicates salinity and temperature compatible to the ctenophore.

minimal in samples from ctenophore infested areas, volumes of M. leidy in subsequent monthly samples did not reflect a shortage of this food source (Appendix Tables XI, XVI). Volume of ctenophores actually increased in June and November 1966, at stations having very few zooplankters the preceding months. Nelson (1925) postulated that M. leidy may be able to utilize detritus and nannoplankton when zooplankton is scarce.

### Predators

M. leidy has few known predators. Two, C. quinquecirrha and B. ovata, are found in local waters. C. quinquecirrha has been reported to prey on tentaculate ctenophores by Lebour (1922) and Mayer (1910). Beroe sp. feeds chiefly on other ctenophores, especially the Tentaculata (Bigelow 1924; Hyman 1940; Lebour 1923; Mayer 1912; Nelson 1925).

Feeding experiments showed that C. quinquecirrha captured large numbers of M. leidy in a relatively short time (Table 1, Fig. 6). In 1966 the medusa occurred from June to September (Fig. 7) and usually with M. leidy (Appendix). This medusa occurred when the ctenophore was most abundant, but its presence did not noticeably alter the distribution of the ctenophore. Recruitment of the ctenophore apparently equals or exceeds predation. Conversely, M. leidy may be a limiting factor in the abundance of C. quinquecirrha in that the ctenophore is a food source for the stinging nettle. C. quinquecirrha was not as abundant in the York River in the late summer of 1966 as in other years. B. ovata moved into the estuary in late June or early July, earlier than reported for previous years (Wass 1965), and this resulted in an earlier curtailment of M. leidy. Lambert (1935) reported that a species of Chrysaora must feed on ctenophores or coelenterates in order to develop the bell.

Table 1. Speed of capture of M. leidyi by C. quinquecirrha. Five ctenophores were offered to each medusa. Speed of capture is accumulated time in minutes from the start of the experiment to the instant the ranked individual was captured.

Length range of <u>M. leidyi</u> in mm	Diameter of <u>C. quinquecirrha</u> in mm	Accumulated capture time, in minutes, for each ranked individual				
		1st	2nd	3rd	4th	5th
Range 14 - 17	40	6	10	10	12	14
	80	2	6	8	9	11
	100	7	12	12	13	18
Range 23 - 25	45	1	1	7	8	16
	75	3	4	6	6	9
	103	1	1	2	4	6
Range 33 - 38	47	31	65	80	180	240
	80	6	60	75	80	120
	100	4	7	15	21	44
	115	3	4	8	30	66

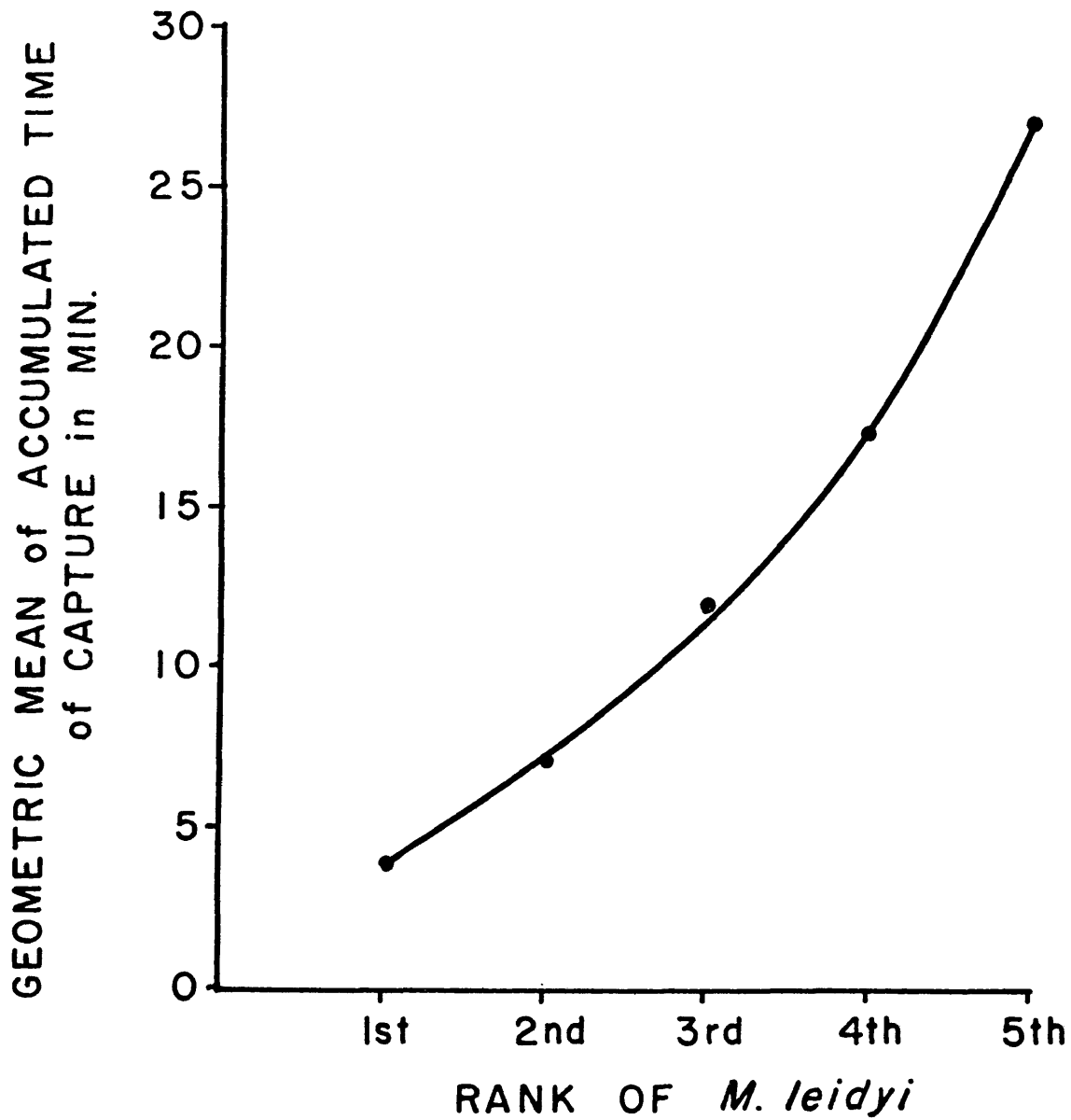


Figure 6. The time required for Chrysaora quinquecirrha to capture 5 Mnemiopsis leidyi, expressed as the mean of 10 experiments.

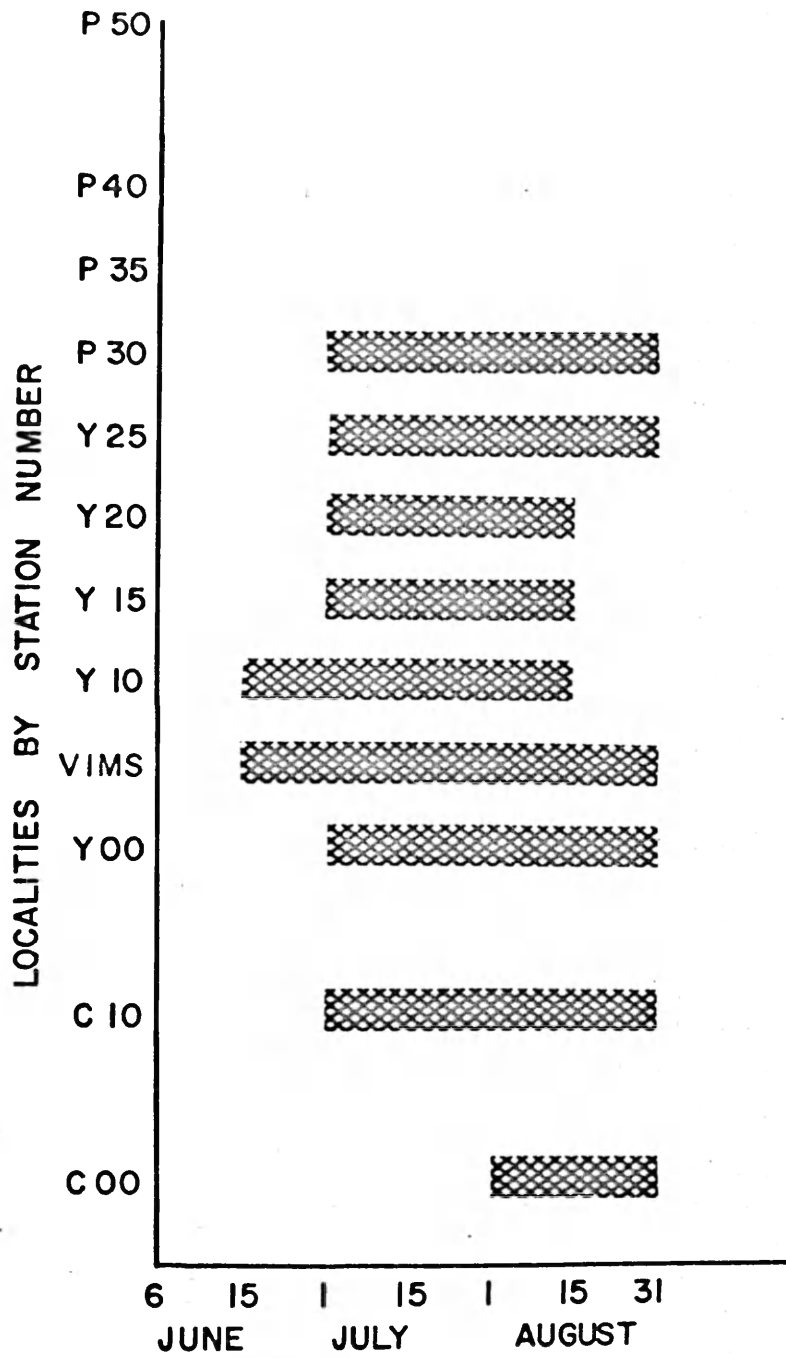


Figure 7.  
**DISTRIBUTION OF Chrysaora quinquecirrha IN 1966**  
 Cross hatching indicates medusae present.

B. ovata appeared at Station C00 in Chesapeake Bay in late June or early July 1966, and moved up the estuary until it reached Y25 in August (Fig. 2). As B. ovata moved into an area, M. leidy disappeared, often within hours. Daily sampling at the Institute pier revealed that B. ovata ate M. leidy: stomodaea of 101 out of 700 a-tentaculate forms contained specimens of M. leidy. No other food items were detected in the beroid ctenophores. Seven M. leidy ingested by one Beroe was the maximum number observed. Observations from the pier revealed that when M. leidy was present, B. ovata would orient its mouth first in one direction and then another as if seeking its prey. If M. leidy was not present, B. ovata drifted with the tide, usually with the oral end directed down current.

The distribution of the two ctenophores indicated the effectiveness of B. ovata in controlling M. leidy (Fig. 2). As B. ovata superseded M. leidy, plankton counts rose sharply (Appendix Tables XIII and XIV). A similar relationship was found in coastal waters of Northern Europe where, in years of Beroe cucumis abundance, Pleurobrachia pileus was curtailed and crustacean plankton was more abundant (Kamshilov, in Fraser 1962).

Largest numbers of Beroe occurred at the pier when Mnemiopsis was present (Fig. 3). A similar situation seemed to exist in the river. Evidence for this was the presence of Beroe in meter net samples just below stations with M. leidy present (Fig. 2), whereas at stations downstream further removed from concentrations of the tentaculate ctenophore, the beroid was scarce, occurring in fish trawl catches but not in meter net samples. The zone of overlap of the two species did not coincide with any river stations; however, this zone was observed on several occasions and many more Beroe were observed on the surface

there than at any other point in the river.

In the feeding experiments B. ovata captured M. leidy initially at a rate equal to that of C. quinquecirrha (Table 2, Fig. 8). In a majority of cases, the beroid stopped feeding before capturing all of the tentaculate forms offered and would not resume feeding even after all traces of food were gone from the stomodaeum. Only beroids brought immediately from the river were used in the feeding test as those kept in aquaria for only a day often would not feed at all. Chrysaora, however, actively approached Mnemiopsis at any time both animals were in the same aquarium. The difference in behavior of the two predators may result from the ability of Chrysaora and the inability of Beroe to adjust to confinement and therefore not reflect the situation in the river.

#### Effect of Mnemiopsis on Crustacean Plankton

Total numbers of zooplankton in the York-Pamunkey river system were found to be inversely proportional to volumes of ctenophores (Fig. 9). The possibility that the stations low in plankton numbers are normally so is unlikely. The major constituents of the crustacean plankton were the mysid, Neomysis americana, and the copepods, Acartia tonsa, A. clausii, Centropages hamatus, Labidocera aestiva, and Pseudodiaptomus coronatus. These species are euryhaline and would normally occupy stations where Mnemiopsis was present (Jeffries 1965; Tattersall 1951; Wass 1965; Wilson 1932). When M. leidy was not present the numbers of plankton were comparable to those at other stations. Numbers in samples from Y25 through Y10 immediately rose when Beroe supplanted Mnemiopsis in August and September 1966.

In two instances at P30 and P35 in August 1966 total zooplankton

Table 2. Speed of capture of M. leidyi by B. ovata. Five ctenophores were offered each beroid ctenophore. Speed of capture is accumulated time in minutes from the start of the experiment to the instant the ranked individual was captured. \*No further captures for the duration of the experiment (24 hours).

Length range of <u>M. leidyi</u> in mm	Length of <u>B. ovata</u> in mm	Accumulated capture time, in minutes, for each ranked individual				
		1st	2nd	3rd	4th	5th
Range 13 - 15	16	4	16	45	105*	
	30	3	31	75	116	132
	66	7	20	31*		
	80	5	11	37	40*	
	105	4	7	10	11*	
Range 18 - 21	20	2*				
	30	5	8	180*		
	58	3	7	8	10	20
	78	7	9	11	29	38
	100	2	6	10	15	30
Range 30 - 40	40	3	41*			
	62	6	14*			
	77	4	10	15*		
	96	2	8	12	38*	

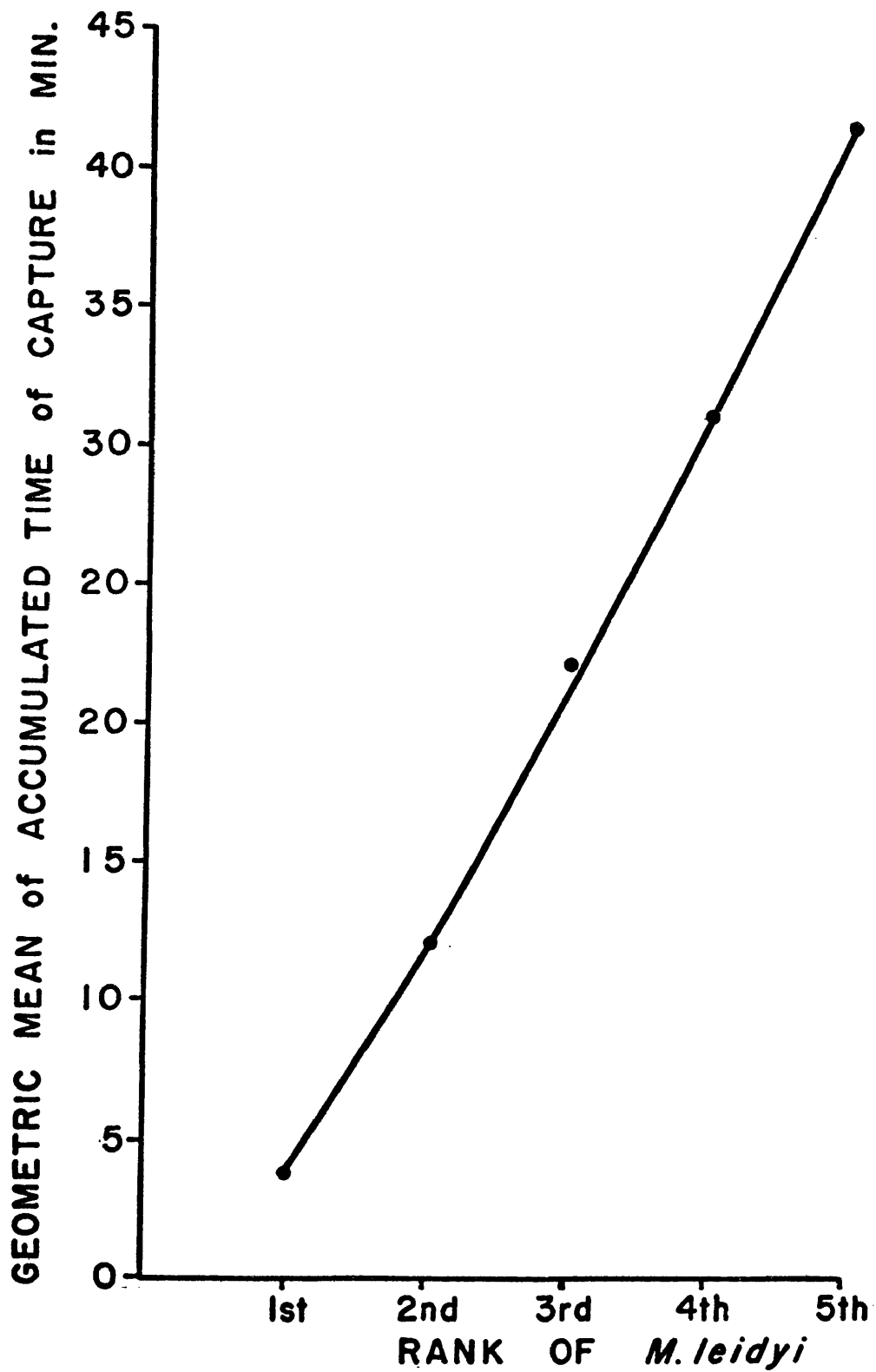


Figure 8. The time for Beroe ovata to capture 5 M. leidyi, expressed as the mean of 14 experiments.

abundance increased in the presence of the ctenophore. This apparent discrepancy may be reconciled by an analysis of the zooplankton at these stations. The organism occurring in greatest number in the samples was Neomysis americana, whose mean length of 10 mm exceeded the upper size limit of food selected by *Mnemiopsis* (Table 3, Appendix Table XII).

Animals found in captured *Mnemiopsis* are listed in Table 4. The list corresponds very closely to that of plankters that decreased in numbers at stations where ctenophores were present (Appendix Tables I through XVII). Copepods, the most numerous zooplankters in the York-Pamunkey system, were most often observed in the digestive cavity of the tentaculate ctenophore; however, bivalve larvae, barnacle nauplii, and annelid larvae were present in many more instances than would be expected by their relative abundance as indicated from plankton tows (Appendix Tables I through XVII). Mysids, also abundant plankters of the York system, were observed in large numbers of ctenophores; however, only smaller individuals appeared vulnerable to capture by this predator, as the largest observed in a stomodaeum was only 5.7 mm long. Size therefore appears to be a major factor in determining prey of *M. leidyi*, with smallest zooplankters most vulnerable to capture. Zoeae of a xanthid crab, Rhithropanopeus harrisii, were present in large numbers coincident with *M. leidyi* in the summer of 1966 (Appendix Tables XII, XIII, and XIV), but did not appear to be preyed on by this ctenophore even though they were among the smallest (0.7 mm mean length) planktonic animals. The long rostral spines of the zoea may have served to discourage this predator.

Gammarid amphipod numbers were much larger at up river stations than from areas of ctenophore concentrations. Those gammarid species

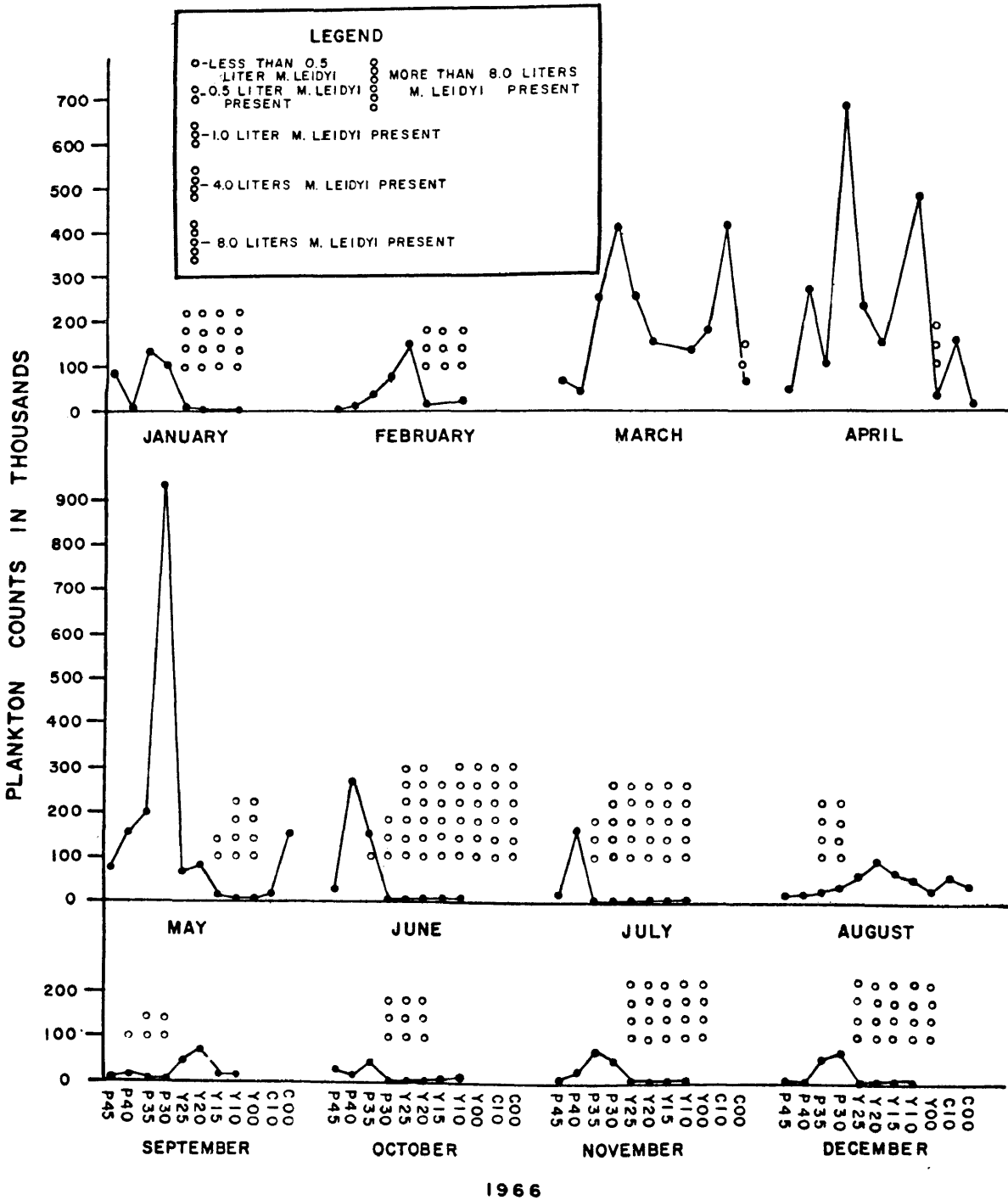


Figure 9. Zooplankton counts as compared with volume of *M. leidyii* present. Plankton counts presented as line graphs and ctenophore volumes depicted by open dots are plotted from totals per 5 minute meter net tow at two and one half knots. These values multiplied by 0.0033 would be reduced to numbers and volumes per cubic meter.

Table 3. Capture of zooplankters by M. leidyi

Prey	Mean length in mm	No. at start of test	Size of <u>M. leidyi</u> in mm					Percent consumed	
			1-3	4-8	9-14	15-20	21-30		
<u>Crassostrea virginica</u> larvae	0.2	1000	16	97	84	82	84	91	99
<u>Acartia tonsa</u> copepodids	0.2	150	22	91	90	83	75	99	94
<u>Artemia salina</u> nauplii	0.4	150	20	89	87	67	74	91	86
<u>Penilia avirostris</u>	0.7	150	- *	60	100	93	99	91	96
<u>Rhithropanopeus harrisi</u> zoeae	0.7	150	0	0	0	0	0	0	0
<u>Balanus nauplii</u>	0.8	150	0	0	24	97	92	97	97
<u>Acartia clausii</u>	1.1	150	-	46	81	90	90	91	93
<u>Eurytemora affinis</u>	1.2	150	-	84	76	75	89	87	91
<u>Acartia tonsa</u>	1.3	150	2	52	75	99	99	96	94
<u>Polydora ligni</u>	1.3	100	0	20	80	90	82	87	72
<u>Cymadusa compta</u>	1.4	50	-	-	10	12	14	16	14
<u>Pseudodiaptomus coronatus</u>	1.4	100	6	80	96	82	86	91	78
<u>Centropages hamatus</u>	1.6	150	0	3	27	41	93	86	95
<u>Roccus saxatilis</u> larvae	3.0	10	-	-	0	0	70	100	90
<u>Gobiosox strumosus</u> larvae	3.0	25	-	-	0	16	20	92	88
<u>Neomysis americana</u>	3.4	150	-	45	46	84	84	89	91
<u>Menidia</u> sp.	5.6	25	-	-	-	0	4	28	32+
<u>Neomysis americana</u>	5.9	150	-	-	-	0	0	0	3#
<u>Sagitta tenuis</u>	8.0	20	0	0	0	0	0	0	0

\* Dash (-) indicates that no test was made

+ The largest Menidia larva captured was 6.0 mm

# The largest mysid captured was 6.2 mm

Table 4. Food items found in M. leidyi stomodaea.

M. leidyi examined 3300

Stomodaeum empty 806

<u>Items present</u>	<u>Number of occurrences</u>	<u>Longest measurement in mm</u>
Copepods	2101	2.3
Barnacle nauplii	414	0.8
Mysids	412	5.7
Annelid larvae	338	1.45
Bivalve larvae	316	0.15
Cladocerans	60	0.9
Fish eggs	36	1.0
Cumaceans	26	1.6
Amphipods	23	3.0
Caridean larvae	16	2.1
Fish larvae	16	5.2
Decapod zoeae	11	0.6

prevalent in the river channel were not found in the stomodaea of ctenophores and it must be assumed that M. leidyi did not prey on them. Size of the channel forms probably was too great for the ctenophore to ingest, as a small-sized species, Cymadusa compta, found over Zostera beds in shallow water, was observed in ctenophore stomodaea. Increased light penetration down river, coincident with salinities suitable to ctenophores, may have caused the gammarids to remain more closely associated with the bottom, thereby reducing their vulnerability to capture by the meter net and thus explain the apparent reduction in numbers in samples from ctenophore occupied waters.

The present feeding studies revealed that relatively active plankters, such as fish larvae, copepods, and small mysids are vulnerable to M. leidyi (Table 3), whereas Main (1928) concluded from studies of the feeding mechanism of Mnemiopsis that it is capable of capturing only small weak swimmers such as polychaete and bivalve larvae. An explanation for the different observations probably lies in the size of vessels used in the two studies. Main used a watch crystal [sic], presumably rather confining, while a 1.5 liter finger bowl which allowed the ctenophore to move about more freely was used in this study. M. leidyi was observed to use two distinct methods of capturing and ingesting food. If the concentration of prey was relatively dense, it was entangled in mucus and the resulting bolus pushed into the stomodaeum by contraction of the oral lobes. Often part of the food ball would not be taken into the digestive cavity, or, in some instances, would be ejected after being taken in. Sometimes the ctenophore would retrieve an ejected food ball and reingest it. This was also observed by Williams and Baptist (1966). The second mode of feeding occurred when prey were small and less abundant. Individual animals were caught

in the tentacles and passed into the mouth via the labial ridge and trough as described by Main (1928).

These studies confirmed that *M. leidyi* would feed on all of the organisms found in its stomodaeum in field collections. Percentage capture increased with a decrease in size of food items. Percent capture of smaller forms such as copepods, cladocerans, barnacle nauplii, and oyster larvae did not increase in ctenophores above 9 mm mean length. Larger prey were captured by larger ctenophores up to a maximum of 6.2 mm length in mysids and 6.0 mm length in silversides. The mysids and fish larvae taken in aquaria were slightly larger than observed captured in the field due probably to restrictions imposed on them by confinement in the tanks.

#### Predation on Fish Larvae

Larval fish were incidental items in the diet of *M. leidyi* in the York River in 1966 as only 16 fish were seen in the stomodaea. In feeding experiments *Mnemiopsis* consumed larvae of *Roccus saxatilis*, *Gobiosoma bosci* and *Menidia* sp., but only if they were smaller than 6.0 mm. Thus in areas of large concentrations of this ctenophore, it appears that size of the fish larvae would determine the amount of predation by *M. leidyi*.

#### Effect of Other Zooplankton Predators on the Zooplankton

Predation by other zooplankters on the zooplankton, as revealed by counts of three-way splits of extra meter net tows, constituted a much smaller percentage (27%) of predation than *M. leidyi* (73%) (Table 5). These data are biased in that extra tows were made only when the regular sample contained forms considered predators of the zooplankton, such as chaetognaths, coelenterates, and larval fishes, as defined by

Table 5. Percent zooplankton predation due to M. leidy as compared with percent zooplankton predation by other zooplankters estimated from field samples maintained alive for 24 hours.

	No. of samples	Individuals present at start	Survivors ( <u>M. leidy</u> removed)	Survivors ( <u>M. leidy</u> present)	% predation by other plankters	% predation by <u>M. leidy</u>	% surviving
Gastropod larvae	4	5	3	3	40.0	0.0	60.0
<u>Acartia tonsa</u>	6	2070	1437	61	30.6	66.5	2.9
<u>Labidocera aestiva</u>	3	127	84	19	33.8	51.2	15.0
<u>Pseudodiaptomus coronatus</u>	2	44	27	2	38.6	56.8	4.6
Cladocerans	1	47	36	6	23.4	63.8	12.8
Carideans	5	252	301	286	0.0	0.0	113.5
<u>Gammarus</u> sp.	1	1	2	1	0.0	0.0	100.0
<u>Neomysis americana</u>	5	2870	2668	1842	7.0	28.8	64.2
<u>Balanus nauplii</u>	2	23	25	1	0.0	0.0	4.4
Decapod zoeae	5	717	699	684	2.5	2.1	95.4
<u>Sagitta tenuis</u>	4	57	53	58	0.0	0.0	101.8
Fish eggs	4	33	27	11	18.2	48.4	33.3
<u>Microgobius thalassinus</u>	2	18	19	17	0.0	5.0	94.4
<u>Syngnathus fuscus</u>	2	8	5	9	0.0	0.0	112.5
<u>Anchoa mitchilli</u>	4	73	63	48	13.7	20.5	65.8
<u>Gobiosoma bosci</u>	5	82	82	58	0.0	29.2	70.8
<u>Chrysaora quinquecirrha</u>	1	2	2	*	0.0	0.0	100.0

\* C. quinquecirrha removed from sample containing M. leidy to prevent predation on M. leidy.

Total number of zooplankters	6429
Total number of zooplankters eaten	3323
Number of zooplankters eaten by other forms	896
Number of zooplankters eaten by <u>M. leidy</u>	2427
Predation by all forms as a percent of total zooplankton	51.6
Predation by <u>M. leidy</u> as a percent of total zooplankton	37.7
Predation by other forms as a percent of total zooplankton	13.9
Survival as a percent of total zooplankton	48.4
Percent of predation by <u>M. leidy</u>	73.0
Percent of predation by other forms	27.0

Hildebrand and Schroeder (1928), Hyman (1940), and Lebour (1922). Usually when ctenophores were present, few of these forms were present and therefore an extra tow was not made, thus predation by M. leidy would be expected to constitute an even greater percentage of the total. Conversely, this estimate did not take into account predation by large fish, which, however, is probably negligible, for contents of fish stomachs taken from these stations showed gammarids and large mysids to be eaten more often than smaller crustaceans (Joseph and Van Engel 1968). Further, confining the animals to a container created a highly artificial environment. Copepods, cladocerans and barnacle nauplii showed the greatest reduction in numbers. M. leidy removed roughly twice as many copepods and cladocerans as did other predators and accounted for all of predation on barnacle nauplii. Inspection of both prey and predator species at the termination of the holding period did not reveal excessive mortality in either group so it was assumed predation remained proportional.

## ECOLOGICAL CONCLUSION

Food habit investigations on several fish utilizing the York-Pamunkey nursery ground indicated that small fish did not enter the segment of the river occupied by tentaculate ctenophores until a change in the fish's diet had occurred. This shift was from small crustaceans such as copepods and cladocerans to larger plankters such as mysids or amphipods, or to benthic infauna as annelids or mollusks (Joseph and Van Engel 1968). The young fish were large enough by this time to avoid capture by the ctenophores. Therefore, the ctenophore had little detrimental effect on fish populations using this nursery ground. Actually, the presence of Mnemiopsis leidyi might well have been beneficial to fish populations successfully using this nursery ground in that other species of fish were likely excluded from the area if spawning time and site or the small plankton feeding phase coincided with an abundance of the ctenophore. Thus, some competition for the available food could have been eliminated.

## SUMMARY

1. Mnemiopsis leidyi was present in the York River system at all times in 1966, being confined to higher salinity in colder months.
2. Size of M. leidyi decreased with distance up river.
3. Major spawning appeared to be in the lower salinity portion of its range.
4. Mnemiopsis appeared to be an important item in the diet of Chrysaora quinquecirrha.
5. Beroe ovata entered the York River in the summer and preyed on M. leidyi to such an extent that M. leidyi was limited to stations above the range of Beroe.
6. Mnemiopsis preyed on small crustaceans, and molluscan and annelid larvae and its presence at a station signalled a drastic reduction in numbers of these plankters. Mnemiopsis was unable to eat organisms larger than 5.7 mm according to field observations. Maximum size of ingested food items in laboratory experiments was 6.2 mm.
7. Feeding experiments confirmed the role of Mnemiopsis as a predator of zooplankton.
8. Mnemiopsis accounted for 73 per cent of the predation on zooplankton, when it occurred with coelenterate medusae, chaetognaths and larval fish.
9. Crustacean plankton numbers increased as Beroe replaced Mnemiopsis.
10. Fishes using the low salinity nursery ground were not preyed on by Mnemiopsis to any great extent, because they exceeded the upper size limit of food items taken by the ctenophore.

11. Fishes using the York-Pamunkey nursery ground were not dependent on small crustacean plankters when they moved into ctenophore-infested waters but fed on larger, more abundant invertebrates.

## APPENDIX

Plankton counts estimated from meter net tows made one meter from the bottom are listed with hydrographic data from each station. All values have been adjusted to tows of five minutes duration at a speed of 2.5 knots. These figures more clearly indicate the impact of M. leidyi on other zooplankton than if reduced to numbers per cubic meter. These values can be reduced to numbers per cubic meter by multiplying by 0.0033. T records the presence of an animal in an otter trawl sample. M records the presence of an animal in a meter net sample.

TABLE I. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
August 1965	0.09	1.07	2.03	10.08	13.39	16.02	16.02	21.27	26.10	28.91	26.10
Sal. ‰	28.22	27.76	27.54	27.77	27.64	27.28	27.00	26.32	24.16	20.88	24.16
Temp. °C											
D.O. mg/liter	4.9										
Coelenterata				T	T	T		T	T		
<u>Chrysaora quinquecirrha</u>											
<u>Moerisia lyonsi</u>				M							
<u>Obelia</u> sp.											T
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters				4	4	4		T	T		T
Beroe ovata											
Cladocera											
<u>Diaphanosoma brachyurum</u>			304								
Ostracoda			16						288		
Mysidacea											
<u>Neomysis americana</u>			5344	1152	832						
Amphipoda											
<u>Gammarus</u> sp.			256	64							
<u>Monoculodes edwardsi</u>			96								
<u>Corophium lacustre</u>				32							
Isopoda			16						32		
Copepoda											
<u>Acartia tonsa</u>			10287	1056	2976						
<u>Eurytemora hirundooides</u> and <u>E. affinis</u>			337								256
Cirripedia nauplii											
Decapoda											
<u>Palaemonetes</u> larvae			352	64	198						
Caridean larvae					320						
<u>Rhithropanopeus harrisi</u> zoea			5856	288	5856						
Fish Eggs											96

TABLE II. BOTTOM METER NET SAMPLES

September 1965	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
Sal. ‰/oo	1.79	2.24	5.79	9.64	14.72	16.80	20.16	22.16	25.06	27.48	25.99
Temp. °C	25.82	25.36	25.50	25.54	25.60	25.64	25.24	25.16	23.71	24.16	25.0
D.O. mg/liter	6.7	4.8	4.6	2.7	5.4	5.6	5.5	5.5			
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters			0.5	4	4	4		4			
<u>Beroe ovata</u>											M
Cladocera											
<u>Penilia avirostris</u>									80		
<u>Leptodora kindtii</u>	720								8		
Ostracoda											
Mysidacea											
<u>Neomysis americana</u>			60	64	6			312	8		
Amphipoda											
<u>Gammarus</u> sp.		128	512	12	96	4		12			
<u>Monoculodes edwardsi</u>		1024	2048	20							
<u>Corophium lacustre</u>		256	768	28		12					
<u>C. tuberculatum</u>								36			
Cumacea			3072	52	64	16		120			
Copepoda											
<u>Acartia tonsa</u>	445	1664	11008	6	112	272		287	115		
<u>Eurytemora hirundoides</u>											
and <u>E. affinis</u>								53			
<u>Labidocera aestiva</u>	371			6				21			
<u>Cirripedia nauplii</u>											
Decapoda											
<u>Palaemonetes</u> larvae	560					20					
<u>Porcellanid</u> larvae											
<u>Rhithropanopeus harrisi</u> zoea	304		1028	12		16		270			
Chaetognatha											
<u>Sagitta tenuis</u>											12
Fish Eggs											128

TABLE III. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
October 1965											
Sal. †/‰	0.30	2.31	7.28	10.12	18.59	20.52		23.14	26.16	28.28	32.36
Temp. °C	18.2	18.4	18.48	19.4	17.9	17.9		18.4	18.36	18.12	18.72
D.O. mg/liter	7.5	6.9	6.3								
Coelenterata											
<u>Moerisia lyonsi</u>											
<u>Obelia</u> sp.											
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters			4	4	4	4		4			
Beroe ovata											
Ostracoda	128										
Mysidacea											
<u>Neomysis americana</u>	384	6400	448	496	1288	352		640			
Amphipoda											
<u>Gammarus</u> sp.	10112	2048	64	198	104						
<u>Monoculodes edwardsi</u>			64								
<u>Corophium lacustre</u>				10					16		
<u>Ampelisca abdita</u>									8		
<u>Elasmopus pocillimanus</u>									48		
Cumacea	2176	384	128	80	232						
Copepoda											
<u>Acartia tonsa</u>	1700	3883	2687	1076	6639	2188		3678			
<u>Eurytemora hirundoides</u> and <u>E. affinis</u>	1756	2373		215	16						
<u>Pseudodiaptomus coronatus</u>				516	1073	167		919			
<u>Labidocera aestiva</u>						83		459			
<u>Temora turbinata</u>			65								
<u>Cirripedia nauplii</u>			256								
Decapoda											
Caridean larvae											
<u>Rhithropanopeus harrisi</u> zoea	128				48	32		64			
Chaetognatha											
<u>Sagitta tenuis</u>											64

TABLE IV. BOTTOM METER NET SAMPLES

November 1965	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
Sal. ‰			10.37	16.02	18.75	21.56		24.01	24.32	25.32	28.88
Temp. °C			10.50	10.16	10.22	9.98		11.24	13.48	13.52	13.80
D.O. mg/liter	9.3	8.8	7.9	7.1	8.5	8.5	10.1				
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters					1	1					
<u>Beroe ovata</u>								M	M	M	M
Cladocera											
<u>Penilia avirostris</u>										8	1645
<u>Podon</u> sp.											99
Ostracoda											8
Mysidacea											
<u>Neomysis americana</u>	2816	2048	2048	4069	64	16		2144		16	8
Amphipoda											
<u>Gammarus</u> sp.		1024	1024								
<u>Monoculodes edwardsi</u>			2848								
<u>Corophium lacustre</u>		1024									
<u>Ampelisca abdita</u>								244			
Isopoda										24	
Cumacea						32				8	
Copepoda											
<u>Acartia tonsa</u>	131688	146976	525726	402761	30831	14640		64684	2008	8250	8762
<u>Eurytemora hirundooides</u>											
and <u>E. affinis</u>	24782	102880	33378	14007							
<u>Pseudodiaptomus coronatus</u>	5829										
<u>Labidocera aestiva</u>								564	60	518	550
<u>Cirripedia nauplii</u>					329					8	144
Decapoda											
<u>Crangon</u> larvae									2	40	48
<u>Caridean</u> larvae											16
<u>Porcellanid</u> larvae										112	576
Chaetognatha											
<u>Sagitta tenuis</u>									2	640	784

TABLE V. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
December 1965											
Sal. ‰	0.61	5.52	11.58	15.64	18.77	20.42	21.77	23.01	24.38		
Temp. °C	6.30	6.66	6.99	6.34	6.37	6.74	7.04	7.12	7.10		
D.O. mg/liter											

Ctenophora  
Mnemiopsis leidyi vol. in  
 liters

Beroe ovata

Annelids

Gastropods

40

Mysidacea

Neomysis americana

Amphipoda

Monoculodes edwardsi

Ampelisca abdita

Cumacea

Copepoda

Acartia tonsa

Eurytemora hirundoides

and E. affinis

Pseudodiaptomus coronatus

Caprellids

Decapoda

Crangon larvae

Caridean larvae

0.5 4 4 4 4

32

1024

384

64

48

158

43531

34544

16

464

8

10865

17900

11695

133363

5400

2304

1088

112

1520

10865

2164

3217

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112

1520

10865

2164

3217

6925

2304

1088

112

1520

10865

2164

3217

TABLE VI. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
January 1966	0.52	4.00	10.04	15.56	20.16	22.36		23.92			
Sal. ‰	1.96	2.56	2.68	2.08	1.28	1.48		1.64			
Temp. °C	12.2	11.4	10.4	10.2	10.9	10.9		10.6			
D.O. mg/liter											
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters					4	4		4			
Cladocera											
<u>Daphnia pulex</u>	128										
Mysidacea											
<u>Neomysis americana</u>		448	256	64							
Amphipoda											
<u>Gammarus</u> sp.			256								
<u>Monoculodes edwardsi</u>	128			64							
unidentified											
Copepoda											
<u>Acartia tonsa</u>	9806	519	30358	98270	5202	1530		812			
<u>A. clausii</u>					2159	510					
<u>Eurytemora hirundoides</u>											
and <u>E. affinis</u>	76201	2873	104223	3170	102						

TABLE VII. BOTTOM METER NET SAMPLES

February 1966	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
Sal. ‰	0.13	0.17	0.58	10.00	16.73	19.35		19.39	23.14	23.27	26.23
Temp. °C	4.5	4.1	4.2	5.1	5.6	5.5		5.4	3.4	2.3	2.8
D.O. mg/liter	11.1	11.4	11.4	9.8	10.3	10.4		10.8	11.0	11.3	11.0
Coelenterata											
<u>Nemopsis bachei</u>											
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters					1			1			
Annelida	24							16			8
Cladocera											
<u>Daphnia pulex</u>	536	264		64							
Ostracoda	16										
Mysidacea											
<u>Neomysis americana</u>					128	16		32			
Amphipoda											
<u>Gammarus</u> sp.	8		896								
<u>Monoculodes edwardsi</u>		32									
<u>Corophium lacustre</u>		32	890								
<u>Batea catharinensis</u>											16
Copepoda											
<u>Acartia tonsa</u>				18909	111182	13981		13004	51475		
<u>A. clausii</u>				325	2515	184		3207	13428	69828	27000
<u>Eurytemora hirundooides</u>											
and <u>E. affinis</u>								802	5397		
<u>Pseudodiaptomus coronatus</u>								1096			
<u>Mesocyclops leukarti</u>											
<u>Centropages hamatus</u>						797		4811	6977	1435	3003
Decapoda											
<u>Crangon larvae</u>	376			549					224	224	1200

TABLE VIII. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
March 1966											
Sal. ‰	0.06	0.09	3.34	7.73	14.19	15.41		19.22	19.65	25.19	27.51
Temp. °C	9.0	9.6	9.3	9.5	8.8	8.6		7.8	8.5	7.4	7.4
D.O. mg/liter	9.3	9.3	8.2	8.2	9.3	9.5		10.0	10.1	9.4	10.1
Coelenterata											
<u>Nemopsis bachei</u>											
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters											0.5
Cladocera											
<u>Daphnia pulex</u>	196	384									
<u>D. longispina</u>			512								
Mysidacea											
<u>Neomysis americana</u>	32			189							
Amphipoda											
<u>Gammarus</u> sp.		288	252	128							
<u>Monoculodes edwardsi</u>		96									
<u>Corophium lacustre</u>			512	128							
Copepoda											
<u>Acartia tonsa</u>				375102	198706	119657		38792			
<u>A. clausii</u>				20226	14570	3284		73678	175817	375460	
<u>Eurytemora hirundooides</u>											
and <u>E. affinis</u>	59176	33362	233711	9347	31551	10403		15261			
<u>Pseudodiaptomus coronatus</u>					16690	10130		7631			
<u>Mesocyclops leukarti</u>	3787										
<u>Centropages hamatus</u>					9006	4927			3639	16221	
<u>Pseudocalanus minutus</u>						1094				5820	31212
Decapoda											
<u>Crangon</u> larvae											
Caridean larvae									2394	15872	5376
Chaetognatha											
<u>Sagitta elegans</u>											128
Fish Eggs											
<u>Scophthalmus aquosus</u>											18

TABLE IX. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
April 1966											
Sal. ‰	0.06	1.27	7.07	11.89	15.89	17.34		19.67	20.54	20.65	29.27
Temp. °C	10.5	10.5	11.0	11.4	14.0	11.2		10.9	11.6	10.4	10.4
D.O. mg/liter	9.0	8.4	7.0	7.5	8.3	8.7		8.9	9.1	8.1	8.9
Coelenterata											
<u>Nemopsis bachei</u>											
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters											1
Annelids	32										
Cladocera											448
<u>Evadne nordmanni</u>											
Ostracoda	640										
Mysidacea											
<u>Neomysis americana</u>		8192	768	4096							
Amphipoda											
<u>Gammarus</u> sp.	1024	1536	1536								
<u>Monoculodes edwardsi</u>		512									
Isopoda											
Copepoda											
<u>Acartia tonsa</u>			94078	286717	126292	33028				4285	
<u>A. clausii</u>		1998	49663	81915	75775	106540		467968	28597	132605	6451
<u>Eurytemora hirundoides</u> and <u>E. affinis</u>											
<u>Mesocyclops leukarti</u>											
<u>Centropages hamatus</u>											
<u>C. typicus</u>											1630
<u>Pseudocalanus minutus</u>											715
Decapoda											
<u>Crangon</u> larvae								3072	640	11764	768
Caridean larvae											
Fish Eggs											
<u>Scophthalmus aquosus</u>	32										58

cont.

TABLE IX (Cont.).

April 1966	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
Fish larvae											
<u>Roccus americanus</u>	1936	1640	16								
<u>R. saxatilis</u>		8									
<u>Alosa sp.</u>	24	8									
<u>Anguilla rostrata (elvers)</u>	2										
<u>Brevoortia tyrannus (juveniles)</u>	2										
<u>Perca flavescens</u>	216	40									

TABLE X. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
May 1966											
Sal. o/oo	0.08	0.09	2.04	6.42	11.57	12.89	15.34	16.35	20.75	21.07	25.82
Temp. °C	18.4	18.3	18.9	18.8	18.7	18.9	17.7	18.1	17.2	17.7	16.1
D.O. mg/liter	8.4	8.4	7.3	6.0	7.6	7.8	7.8	8.2	6.9	8.0	7.9
Geolenterata											
<u>Nemopsis bachei</u>											
Ctenophora											
<u>Mnemiopsis leidyi</u>								0.5	4	4	
Cladocera											
<u>Evadne nordmanni</u>									48	4096	17920
<u>Daphnia pulex</u>		4796									
<u>Sida crystallina</u>		86340									
<u>Leptodora kindtii</u>		7168	320								
Ostracoda	69632										
Mysidacea											
<u>Neomysis americana</u>			163840	37552	256						
Amphipoda											
<u>Gammarus</u> sp.		27726	4069	1536		128					
<u>Monoculodes edwardsi</u>		947	6144								
Copepoda											
<u>Acartia tonsa</u>				696376	64512	79592	15492	2435	273	2521	
<u>Eurytemora hirundoides</u>											
and <u>E. affinis</u>											
<u>Mesocyclops leuckarti</u>											
<u>Centropages hamatus</u>							299	685	31		110453
<u>Labidocera aestiva</u>								304			4774
Decapoda	4096	18432									
<u>Crangon</u> larvae								64			
Caridean larvae											
Fish Eggs											
<u>Anchoa mitchilli</u>				240	416	1022	468	324	8800	4996	
<u>A. hepsetus</u>									10	136	
<u>Pogonias cromis</u>									30	176	
<u>Bairdiella chrysura</u>									12	54	104

cont.

TABLE X (Cont.).

May 1966	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
Fish Larvae											
<u>Anchoa mitchilli</u>										102	68
<u>A. sp.</u>					16	32	20	8		4	
<u>Gobiosox strumosus</u>					16	8	10	2		14	12
<u>Syngnathus fuscus</u>					4		2				
<u>Menidia sp.</u>											
<u>Alosa sp.</u>	1088	186									
<u>Roccus saxatilis</u>		368									
<u>R. americanus</u>		320									
<u>R. sp.</u>	1328		896								
<u>Gobiosoma bosci</u>	672										

TABLE XI. BOTTOM METER NET SAMPLES

June 1966	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
Sal. ‰	0.06	0.02	5.84	8.68	12.36	13.33	16.69	20.10	22.45	21.06	25.59
Temp. °C	24.8	24.0	24.7	24.1	23.9	23.5	22.3	21.9	19.9	20.3	19.6
D.O. mg/liter	6.5	6.4	5.3	4.9	6.0	6.0	5.0	3.7	5.4	7.4	7.4
Secchi disk meters	0.7	0.2	0.4	0.7	0.7	0.8	0.9	1.1	2.8	2.5	2.4
Coelenterata											
<u>Chrysaora quinquecirrha</u>											
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters											
	0.5	1	8	8	8	8	8	8	8	8	8
Cladocera											
<u>Diaphanosoma brachyurum</u>	19916	221184									
<u>Simocephalus exspinosus</u>	948										
<u>Leptodora kindtii</u>	6400										
Mysidacea											
<u>Neomysis americana</u>	79872	2816									
Amphipoda											
<u>Gammarus</u> sp.	6144	512	384								
<u>Cerapus tubularis</u>							160	10	22		
Isopoda					32	12			4		
Copepoda											
<u>Acartia tonsa</u>	53248	128							428		
<u>Eurytemora hirundooides</u>											
and <u>E. affinis</u>	9984	4095									
<u>Mesocyclops leukarti</u>	512	29952	2047								
<u>Labidocera aestiva</u>									18		547
Decapoda											
Caridean larvae					64	260	1602		90		176
Porcellanid larvae								32			2096
Zoea								12	332		
Fish Eggs											
<u>Anchoa mitchilli</u>	144	228	206	72	88	24				470	90
<u>A. hepsetus</u>										6	48
<u>Trinectes maculatus</u>											

cont.

TABLE XI. (Cont.)

June 1966	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
Fish Larvae											
<u>Roccus americanus</u>	72	1412	128								
<u>R. saxatilis</u>		116	64								
<u>Alosa sp.</u>	2	4									
<u>Anchoa mitchilli</u>				80	22	4	240	24			
<u>Gobiosoma boscii</u>			5712	612	82	48	72	12			
<u>Syngnathus fuscus</u>						2	16				2
<u>Microgobius thalassinus</u>							16	4			

TABLE XII. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
July 1966											
Sal. o/oo	0.16	2.0	5.76	8.92	13.48	16.05	19.22	21.15			
Temp. °C	28.48	27.7	28.2	27.9	27.3	27.0	26.7	26.6			
D.O. mg/liter	5.6	5.4	4.2	3.3	4.4	5.4	5.5	4.9			
Secchi Disk meters	0.4	0.6	0.4	0.2	0.8	0.8	0.8	0.9	1.8	1.5	1.5
Coelenterata				T	T	T	T	T			
<u>Chrysaora quinquecirrha</u>											
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters				8	8	8	8	8			
Beroe ovata											
Cladocera											
<u>Diaphanosoma brachyurum</u>	13440										
<u>Leptodora kindtii</u>	896										
Mysidacea											
<u>Neomysis americana</u>			704	448		160		12			
Amphipoda											
<u>Gammarus</u> sp.		8192						4			
<u>Monoculodes edwardsi</u>				64				2			
<u>Ericthonius brasiliensis</u>							1				
<u>Cerapus tubularis</u>								8			
Isopoda			320	192	6		2	10			
Copepoda											
<u>Acartia tonsa</u>			384		8		118	24			
<u>Pseudodiaptomus coronatus</u>											
<u>Mesocyclops leukarti</u>	1152										
Cirripedia nauplii											2
Decapoda											
Caridean larvae			1344	640	16	53	332				
Zoea			1880	1280	8	95	414				
Chaetognatha											1

cont.

TABLE XII. (Cont.)

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
July 1966											
Fish Eggs			800	6		6	65	12			
<u>Anchoa mitchilli</u>							6				
<u>Trinectes maculatus</u>											
Fish Larvae											
<u>Anchoa mitchilli</u>	6	128	56	32	8	20	16	T			
<u>Gobiosoma bosci</u>		384	464	48	62	42	28	T			
<u>Microgobius thalassinus</u>							20	T			

TABLE XIII. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
August 1966											
Sal. ‰	0.36	2.43	7.99	8.73	15.45	18.36	19.79	22.48			
Temp. °C	27.64	27.0	27.5	25.5	25.7	27.7	27.5	26.9			
D.O. mg/liter	6.3	6.0	4.6	3.5	5.6	6.0	5.4	5.2			
Secchi Disk meters	0.8	0.4	0.4	0.6	1.0	0.6	1.1	1.0	2.2	2.1	3.6
Coelenterata											
<u>Chrysaora quinquecirrha</u>				T	T						
<u>Liriope tetraphylla</u>					M		M		M		
<u>Obelia</u> sp.									M		
<u>Lovanella</u> sp.									M		
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters			4	4	M	T	T	T	T	T	T
<u>Beroe ovata</u>											
Cladocera											
<u>Evadne nordmanni</u>								32			
<u>Penilia avirostris</u>									1408		
Ostracoda	5		128								
Mysidacea											
<u>Neomysis americana</u>			8576	18048	1280	1280					
Amphipoda											
<u>Gammarus</u> sp.	3994	1536	128								
<u>Monoculodes edwardsi</u>			256	384							
<u>Corophium lacustre</u>											
Copepoda											
<u>Acartia tonsa</u>			8960	128	48111	73554	16492		4118		
<u>Eurytemora hirundoides</u> and <u>E. affinis</u>	2000			256		313					
<u>Pseudodiaptomus coronatus</u>	491			128	529	2704	4694		6442		
<u>Mesocyclops leukarti</u>											
<u>Labidocera aestiva</u>											
Harpacticoid			1								
Decapoda											
Caridean larvae		512	896	2944	6144	4672			2304		
Zoea			740	9472	512	2304	6848	13760	6400		

cont.

TABLE XIII. (Cont.)

August 1966	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
Chaetognatha											
<u>Sagitta tenuis</u>					768	1280	32				
Fish Eggs											
<u>Anchoa mitchilli</u>			48		320	480	2268	2656	2112	80	12
<u>Trinectes maculatus</u>						28	72	96	48		88
Fish larvae											
<u>Anchoa mitchilli</u>	64	32	524	2	832	776	812	1376	48		
<u>Gobiosoma boscii</u>			176	12	1216	1776	292	480			
<u>Microgobius thalassinus</u>						60	52	192	16		
<u>Syngnathus fuscus</u>								16			
<u>Alosa aestivalis</u> (juvenile)	16										

TABLE XIV. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
September 1966											
Sal. ‰	1.25	5.64	11.54	12.72	18.71	20.65	22.5	23.25			
Temp. °C	22.6	22.7	23.0	22.5	22.1	22.1	22.6	22.6			
D.O. mg/liter	6.2	5.6	4.8	4.2	6.1	3.6	5.8	6.1			
Secchi Disk meters	0.7	0.7	0.7	0.7	0.7	0.7	1.0	1.2			
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters		0.5	4	4							
<u>Beroe ovata</u>											
Cladocera											
<u>Ilyocryptus sordidus</u>	256					512					
unidentified											
Mysidacea											
<u>Neomysis americana</u>	64		512	80	13056	12288					
Amphipoda											
<u>Gammarus</u> sp.	64	512									
<u>Corophium lacustre</u>	1216	1024									
<u>Monoculodes edwardsi</u>				16							
Isopoda	1280	2560									
Cumacea			512		1024						
Copepoda											
<u>Acartia tonsa</u>	1600		512	672	18935	46665	14001	725			
<u>Eurytemora hirundoides</u>											
and <u>E. affinis</u>	1120				996	4241	274				
<u>Pseudodiaptomus coronatus</u>											
<u>Mesocyclops leukarti</u>	480				7972	8484	5628	15			
<u>Labidocera aestiva</u>											
Decapoda											
Caridean larvae											
<u>Rhithropanopeus harrisi</u> zoea			512	48	2560	1536	9800				
Chaetognatha					256		2300				
<u>Sagitta tenuis</u>							1184				
Fish Eggs											
<u>Anchoa mitchilli</u>										16	

cont.

TABLE XIV. (Cont.)

September 1966	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
Fish Larvae											
<u>Anchoa mitchilli</u>	90		32	8	600	960	198	52			
<u>Gobiosoma boscii</u>				2	40	32	4	2			
<u>Microgobius thalassinus</u>					8	96	64	12			
<u>Syngnathus fuscus</u>					8	32	8	4			
<u>Micropogon undulatus</u>	2										

TABLE XV. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
October 1966											
Sal. °/oo	0.10	0.38	6.91	10.21	15.56	17.32	19.46	20.42			
Temp. °C	16.91	17.5	18.5	17.9	17.7	18.0	17.6	17.5			
D.O. mg/liter	6.2	6.2	6.1	5.6	6.9	7.0	7.0	7.0			
Secchi Disk meters	0.5	0.3	0.4	0.5	0.8	1.1	1.3	2.2	3.2	3.4	
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters						1	1				
<u>Beroe ovata</u>											
Mysidacea											
<u>Neomysis americana</u>	256		28672	1408	32			544			
Amphipoda											
<u>Corophium lacustre</u>			2040					96			
Isopoda								32			
Copepoda											
<u>Acartia tonsa</u>	941	2793	922		688	288	5965	6819			
<u>Eurytemora hirundoides</u> and <u>E. affinis</u>	13180	7819				421	1116				
<u>Pseudodiaptomus coronatus</u>							301				
<u>Labidocera aestiva</u>			102								
Decapoda											
Caridean larvae					16	144	37	896			
Zoea								64			
Chaetognaths											
<u>Sagitta tenuis</u>					16						
Fish Larvae											
<u>Anchoa mitchilli</u>			128			64	1	58			
<u>Microgobius thalassinus</u>							4	2			
<u>Syngnathus fuscus</u>								4			

TABLE XVI. BOTTOM METER NET SAMPLES

	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
November 1966											
Sal. ‰	0.07	0.71	4.09	16.00	19.79	20.40	21.33	22.21			
Temp. °C	10.1	10.9	11.8	11.6	11.9	12.3	11.8	11.9			
D.O. mg/liter	8.6	8.5	6.8	7.4	7.8	8.1	8.3	8.1			
Secchi Disk meters	0.3	0.6	0.6	0.8	1.0	1.8	1.9	3.3	0.3		
Ctenophora											
<u>Mnemiopsis leidyi</u> vol. in liters					4	4	4	4	4	T	T
<u>Beroe ovata</u>											
Mysidacea											
<u>Neomysis americana</u>			3	704		8	1				
Amphipoda											
<u>Gammarus</u> sp.	2624	512									
<u>Monoculodes edwardsi</u>	1728										
Isopoda				64							
Copepoda											
<u>Acartia tonsa</u>	204		55821	23776	2	115	110				
<u>Eurytemora hirundooides</u> and											
<u>E. affinis</u>											
<u>Mesocyclops leukarti</u>	800	23040	16114	3999	12	11					
<u>Labidocera aestiva</u>								4			
Decapoda											
<u>Palaeomonetes</u> sp. larvae									3		
Caridean larvae											
Fish Larvae						6					
<u>Anchoa mitchilli</u>			8		2		1				

TABLE XVII. BOTTOM METER NET SAMPLES

December 1966	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
Sal. ‰	0.20	0.45	4.90	4.66	15.41	18.42	20.92	22.13			
Temp. °C	8.3	8.2	8.3	7.7	7.6	7.6	7.5	7.9			
D.O. mg/liter	10.2	9.9	8.5	8.4	9.3	9.6	9.5	9.4			
Secchi Disk meters			0.4	0.4	0.7	0.7	1.1	1.1	1.7	1.8	1.8

Ctenophora

Mnemiopsis leidyi vol. in  
liters

4 4 4 4 4 T

Beroe ovata

T T

Ostracoda

Mysidacea

Neomysis americana

5952 22 2 11

Isopoda

1

Copepoda

Acartia tonsa  
Eurytemora hirundoides  
and E. affinis  
Pseudodiaptomus coronatus  
Labidocera aestiva

8 8754 14086 9 186 78  
8 38605 51577 1 10 6

Decapoda

Caridean larvae

1 2

Fish larvae

Anchoa mitchilli

4 8 8 4 1

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## VITA

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