An Animal-Sediment Study in the Lower York River - February 1965 to February 1966.[1]

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Dexter S. Haven, John N. Kraeuter, Richard C. Swartz
and Reinaldo Morales-Alamo

Special Scientific Report No. 108

Virginia Institute of Marine Science
and
School of Marine Science,
The College of William and Mary
Gloucester Point, Virginia 23062

Frank O. Perkins
Acting Director

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[1]From Concentration of Suspended Radioactive Wastes Into Bottom Deposits Period. Final Report to the United States Atomic Energy Commission. Contract No. AT-(40-1)-2789 for the period 1 January 1961 to 31 December 1967.

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FOREWORD

The following study was funded by Contract No. AT-(40-1)-2789 with the U.S. Atomic Energy Commission. The work was completed in December 1967. The material presented here was extracted from the final report.

Since 1967, the taxonomy of various species has changed. Therefore, the taxonomy for those species has been updated here. An appendix is included which lists the species collected with the corresponding ten-digit VIMS taxonomic code. All data contained in this report are stored on computer tape at the VIMS Computer Center (No. VCM 705, Data set name: WP.3542.009).

While the information given and the references cited in this report are 15 years old, it is considered useful for comparison with other data of the same genre. These data demonstrate that sampling an area over a long period of time will provide more useful information than if sampling is limited to a shorter time interval.

We are especially grateful to Mr. Lowell Fritz, graduate student, who updated this report and to Dr. Marvin L. Wass who assisted in the original identification of many of the species.

An Animal-Sediment Study in the Lower York River, Virginia

by

Dexter S. Haven, John N. Kraeuter, Richard C. Swartz
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INTRODUCTION

Certain invertebrates are more efficient than others in filtering solids from suspension. An equal degree of variability exists among benthic invertebrates in their ability to mix biodeposits into subsurface sediments. As a result of these differences, the degree to which suspended particulate matter and associated contaminants may be deposited or mixed into sediments may in part depend on the species present, which in turn may be dependent on sediment type.

A number of investigators have examined the relation between benthic animal communities and their limiting physical factors (Smith, 1932; Mare, 1942; Dexter, 1947; Holm, 1949; Stickney and Stringer, 1957; Sanders, 1956, 1958, 1960; and Jones, 1961). Except for studies on the effects of thermal effluents (Warinner and Brehmer, 1966) and the relation of the distribuiton of several species to sediment water (Harrison and Wass, 1965), little is known of such assemblages in the Chesapeake Bay.

In this report we will examine the faunal composition at four depths in the York River, Virginia, in terms of the number of species, number of individuals and biomass, and the influence of sediment parameters on these benthic communities.

MATERIALS AND METHODS

The study area is located one mile below Yorktown, Virginia, in the York River estuary. Four stations were selected along a transect perpendicular to the shoreline at depths of 1.5, 3.0, 6.1 and 12.2 m. Monthly samples of the substrate and benthic fauna were obtained at each station over a 13-month period, February 1965 through February 1966.

Samples were taken at the two inshore stations with a hand corer and at the deeper stations with a gravity corer. The upper 15 cm of each core (inside diameter 4.7 cm) was saved. At each station 15 cores were taken for faunal analysis. The total area of sediment sampled monthly at each station was 0.026 m^2. The faunal samples were sieved through 1.0, 0.5 and 0.25 mm screens and preserved in jars of 5% neutralized formalin. During sorting and counting an attempt was made to identify all individuals to species except the nematodes and copepods. Wet weights were determined by blotting and then weighing specimens on an analytical balance to the nearest 0.0001 g. Nematodes and copepods were not weighed. All biological data were analyzed using an IBM 1620 computer for calculation of affinity, bioindex, and diversity indices.

Three additional cores were taken monthly at each station for sediment analyses. The organic carbon content of the top 1 cm of one of these cores was determined with a LECO carbon analyzer (Laboratory Equipment Corp., St. Jospeh, Mich.) after the sample had been dried and treated with 10% HCl to remove carbonates. The percent weight of each phi-size fraction of the other two cores was determined by the following method. Samples were washed free of salt on #2 Whatman filters and wet sieved on a 0.0625 mm screen to remove sand fractions. Sands were oven-dried at 87°C and sieved on 0.50, 0.25, 0.125, and 0.0625 mm screens using a Ro-Tap soil sieve-shaker. These samples were weighed to the nearest 0.0001 g on an analytical balance. The silt-clay fraction was analyzed by the pipette method (Krumbein and Pettijohn, 1938). Weights of these fractions were combined with those of the sand analyses and percent weight of each phi-size fraction was calculated.

A computer program was developed to analyze sediment data by remodeling parts of a sediment analysis program for an IBM 703 computer (Creager, McManus and Collias, 1962) to fit the IBM 1620. This program gives Folk and Ward (1957) values for skewness and kurtosis and Swan et al. (1959) values for mean grain size and sorting; percent sand, silt, clay, and sand to silt-clay ratios are also given. This method is quicker and eliminates bias from hand-drawn curves on arithmetic probability paper (Creager et al., 1962) since the computer calculates points necessary for the equations.

The following computations were used:

Mean size $$M_Z = \frac{\phi 5 + (2)\phi 16 + (4)\phi 50 + (2)\phi 84 + \phi 95}{10}$$

Standard deviation (sorting) $$I = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

Skewness $$SK_I = \frac{\phi 16 + \phi 84 - (2)\phi 50}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - (2)\phi 50}{2(\phi 95 - \phi 5)}$$

Kurtosis $$K_G = \frac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25)}$$

Since the program requires a ϕ value at the 95th percentile, it was necessary to carry some pipette analyses beyond the ϕ9-10 limit previously used. Several analyses determined the direction of the line beyond the 84th percentile for the 6.1 and 12.2 m depths. A line extended to the 99.99 percentile on the probability paper at ϕ1 gave the best fit for the 95th percentile ϕ value.

On July 16, 1966, duplicate cores were collected at each station to determine the water content of the sediments. These cores were collected by hand with the aid of diving gear and marked for compaction after being placed in the bottom. The top 15 cm of each core sample was divided at 5 cm intervals. After correcting for compaction, the water content of each subsample was calculated from differences in its wet and dry weight.

Temperature and salinity data were not collected during this investigation. However, these data were available for depths of 0, 3.0, 6.1 and 12.2 m in the York River channel approximately 0.5 mile above the study area for the period 8 January-29 December 1965 (W. Eayrs, personal communication) and were used in this report.

RESULTS AND DISCUSSION

Temperature and Salinity

The 1965 temperature and salinity monthly means for depths of 0, 3.0, 6.1 and 12.2 m in the York River channel are shown in Fig. 1. With a few minor exceptions, salinity increased with depth throughout the year. The salinity gradient was most pronounced from January to June, reaching a maximum range of 3.3 $^{o}/oo$ in April. The salinity minimum and maximum were 16.1 $^{o}/oo$ at the surface in May and 26.0 $^{o}/oo$ at 12.2 m in January. As these data suggest, the salinity characteristics of the York River estuary are strongly influenced by spring runoff. The temperature minima and maxima for all depths were 3.2 $\pm$ 0.2°C in February and 26.3 $\pm$ 0.5°C in the summer. The maximum difference in temperature between depths exceeded 2°C only in May (3.7°C). It seems unlikely that such relatively minor differences in temperature and salinity could account for significant changes in benthic fauna at any single season.

Sediments

At depths of 1.5 and 3.0 m, sediments were predominantly sand, while at 6.1 and 12.2 m silts and clays were the main substrate components. This major difference in sediment composition between the deep and shallow water stations is illustrated in Fig. 2 where the cumulative percent weight of each ϕ size fraction of the sediments is given. The annual mean ϕ size, skewness, kurtosis, and percent sand-silt-clay of the sediments are shown in Table 1. Seasonal fluctuations in sediment composition, as shown by the percent sand, were essentially absent at 1.5 and 12.2 m (Fig. 3). At the 3.0 and 6.1 m stations, minor seasonal changes in the sediments were observed.

The dichotomy between the deep and shallow water stations was also evident in the water and organic carbon content of the sediments. Organic carbon content was consistently higher at 6.1 and 12.2 m and varied over the year between 1.9 and 4.5% of the total sediment weight (Fig. 4). At the two shallow stations the annual range was from 0.2 to 1.7%. Maximum organic carbon content occurred in the spring at all stations.

The water content of the sediments at 6.1 and 12.2 m was higher (∿80%) and showed a much slower decrease with sediment depth than at the shallow stations (Table 2). At 1.5 m sediment water content decreased from 36% in the top 5 cm to 25% between 10 and 15 cm. The corresponding change at 3.0 m was from 53% to 40%.

Community Structure

Diversity:

Lloyd and Ghelardi (1964) recognized two components of species diversity: (1) the number of species and (2) the "equitability" or distribution of individuals among the species. Hessler and Sanders (1967), working with deep-sea samples, considered the absolute number of species (S) as an index of diversity. An index which is a measure of both equitability and the number of species is that of Shannon (1948):

$$\bar{H} = -\sum \frac{n_i}{N} \log_2 \frac{n_i}{N}$$

where $\bar{H}$ = diversity

S = the number of species

N = the total number of individuals

n_i = the number of individuals of any one species.

This equation, originally derived from information theory, has been widely applied as a diversity index. Wilhm and Davis (1966) used it to estimate the diversity of benthic stream macroinvertebrates. In the calculation of S and $\bar{H}$ for our samples, all individuals not identified to species were excluded.

These indices gave rather different results when used to estimate diversity. During the study the number of species at 1.5 and 3.0 m was consistently higher than at 6.1 and 12.2 m (Table 3). S was usually highest at 3.0 m and lowest at 12.2 m. The index of Shannon (1948), however, failed to demonstrate any obvious difference in the diversity of the four stations (Table 4). A plot of the number of species vs. the number of individuals in each sample from all depths over the 13-month collection period (Fig. 5) offers a possible explanation for this discrepancy. That figure shows that the combined data from all depths fit the same type of S vs. N curve one would obtain by drawing samples of different sizes from the same populations. In such a curve the increase in N is always arithmetic, but the increase in S falls off exponentially (Hessler and Sanders, 1967). Equitability is the same for any point on such a curve. Thus, equitability indicates little difference in the diversity of the four stations. The data points for the deeper stations are not randomly distributed but rather restricted to the lower portion of this curve. Fig. 5 thus predicts that if samples had been larger at these stations, more species would have been collected. The difference in the number of species at the shallow and deep stations, therefore, is probably attributable to differences in community density, not diversity.

Density and Biomass:

The number of individuals and biomass were consistently higher at 1.5 and 3.0 m than at 6.1 and 12.2 m (Table 3). The mean number of individuals per square meter decreased from 50,652 and 37,729 at 1.5 and 3.0 m, respectively, to 3,231 and 6,577 at 6.1 and 12.2 m, respectively. The decrease in biomass from the shallow to the deep stations was proportionally greater than the change in density. The mean weight per individual at 1.5 and 3.0 m was 28.2 and 36.0 x 10^{-3} g, respectively, while at 6.1 and 12.2 m it was 7.34 and 20.5 x 10^{-3} g, respectively. As these data suggest, larger organisms were conspicuously absent at 6.1 m. Seasonal changes in density and total biomass were not apparent.

Faunal Homogeneity Between Stations:

In view of the quantitative differences between the deep and shallow stations, an index of affinity was employed to examine qualitative differences. This index is a measure of the fauna common to a pair of samples. It is obtained by calculating the percent of the total sample represented by each species in both samples and then summing the smaller percentage for each species. This latter total is the index of affinity (Sanders, 1960). The index was calculated for all combinations of synchronous samples. Specimens not identified to species were excluded from this analysis. The mean, range and 95% confidence interval of this index for each combination during the 13-month collection period are shown in Fig. 6 and Table 5. The affinities between the 1.5 (I) and 3.0 m (II) fauna and between the 6.1 (III) and 12.2 m (IV) fauna were significantly higher than any of the remaining four combinations.

Sanders (1960) found that the average affinity between all combinations of 20 samples from a single station in a soft bottom community in Buzzards Bay, Massachusetts, was 69.3%. This figure would certainly have been higher if Sanders (1960) had restricted his calculations to synchronous samples, as we have done. The highest affinity we observed occurred between the 1.5 and 3.0 m stations ($\bar{x}$ = 54.73%). While there is considerable similarity between the samples from these stations, it cannot be concluded that they were drawn from a completely homogeneous assemblage. Affinity between the 6.1 and 12.2 m stations was lower ($\bar{x}$ = 32.23%). Faunal differences between these stations were also indicated by the comparatively lower biomass and density and the relative rarity of larger organisms at 6.1 m. Although the affinity between the deep stations was not high, they were obviously more closely related to one another than to either of the shallow stations.

Community Composition

The monthly numerical distribution, total number of individuals and percent composition of the total fauna are given for each species collected at 1.5, 3.0, 6.1 and 12.2 m in Tables 6, 7, 8 and 9, respectively. The species are listed in these tables in order of decreasing abundance. The ranking thus obtained could be biased by one or more extremely large samples. In order to minimize this source of error, Sanders (1960) presented a "biological index" which gives equal weight to all samples. This index measures the frequency of appearance of a given organism as one of the ten most abundant species in each sample. Its value is determined by assigning ten points to the most abundant species, nine points to the second most abundant, and so forth down to one point for the tenth most abundant species. Thus, if a species ranked first in all 13 sample, it would have the maximum bio-index value, 130 points. The biological index ranking of the dominant species at 1.5, 3.0, 6.1 and 12.2 m is given in Tables 10, 11, 12, and 13, repectively.

The Fauna at 12.2 m (station IV):

Sixty-seven species representing a total of 2,227 individuals were collected at 12.2 m. Though feeding nature was not determined, most of these species appear to be deposit feeders, with suspension feeders comprising about 17% of the total. The dominant species at

12.2 were *Cirriformia filigera*, nematodes, *Sarsiella zostericola*, *Retusa canaliculata*, *Maldanopsis elongata*, *Nephtys incisa*, *Sigambra wassi*, *Brania* sp., *Pseudeurythoe* sp., copepods and *Lumbrinereis tenuis*. The polychaetes *Cirriformia filigera* and *Maldanopsis elongata* were extremely rare at the other three stations and can be considered characteristic of the 12.2 m community.

We believe that the fauna at 12.2 m represents a variation of the *Nephtys incisa*-*Nucula proxima* community in Buzzards Bay, Massachusetts, described by Sanders (1960). Several species are identical and many others are from the same families and probably ecological equivalents. *C. filigera* uses its many tentacles to sweep surface deposits, a feeding method nearly equivalent to that of *Nucula proxima*. *Nephtys incisa*, the other dominant in Buzzards Bay, is also present in the York River but in reduced numbers. This species represented 2.7% of all individuals collected at 12.2 m. *N. incisa* accounted for 17.2% of the fauna in Sanders' (1960) samples.

Cirriformia filigera

This is the only species at any depth whose bio-index score exceeded that of nematodes. It was present throughout the year, with peak abundance in December (Fig. 7). *C. filigera* was virtually absent in the samples from 1.5, 3.0 and 6.1 m.

Sanders (1956) and George (1964a, 1964b, 1964c) suggested that *Cirriformia tentaculata* is a selective deposit feeder. Our studies with *C. filigera* indicated it "rakes" surface deposits with its tentacles, creating a pile of the larger debris around the burrow.

Sarsiella zostericola

This ostracod was constant member of the fauna at all stations but reached maximum abundance at 12.2 m. It was most abundant in late summer and early fall, with fewer individuals in spring and winter (Fig. 8).

Maldanopsis elongata

M. elongata ranked fourth in total abundance at 12.2 m. It was a dominant species during the fall and early winter and reached peak abundance in November. Only one specimen of this polychaete was collected at the other three stations. *Clymenella torquata*, another maldanid, and *M. elongata* appear to be non-selective deposit feeders.

Nephtys incisa

N. incisa is one of the dominant annelids in the deeper waters of Chesapeake Bay (Wass, unpublished data). It was found at all stations but was a constant community member only at 12.2 m. Numbers of individuals increased from February to May 1965 and decreased until February 1966 (Fig. 9).

Members of the family Nephtyidae were considered non-selective deposit feeders by Sanders (1958, 1960) and carnivores by Verrill (1871- 1872), Blegvad (1914), Smith (1932) and Mare (1942). This discrepancy could be explained in the same manner done by Thorson

(1966) for the ophiuroid Ophiura texturata. Thorson (1966) examined the evidence of Hagmeier (1930) indicating O. texturata was carnivorous for part of the year and a deposit feeder for the remainder. N. incisa, as Ophuira, prefers animal food but may be able to survive as a deposit feeder for long periods. If this is the case, N. incisa would be present in sufficient numbers when larvae are settling to be a controlling factor in community recruitment.

Nematodes

Nematodes have been found at all stations but are much more abundant at 1.5 and 3.0 m than at either of the deeper areas. Scarcity of nematodes at 12.2 m is probably due to the compacted nature of the mud, but there is still a summer increase though beginning later and not nearly as extensive as at the more inshore stations (Fig. 10).

Retusa canaliculata

This tectibranch gastropod is common at all depths and is an important member of the 12.2 m fauna. Data from this and other studies show that numbers increase greatly during summer months (Fig. 11). Feeding habits remain uncertain, but evidence from fecal pellet studies and the low probability of a carnivore being dominant in a given area, as Retusa is at 6.1 m, would seem to justify calling it a deposit feeder. This would agree with Sanders (1956, 1958) but would invalidate Sanders' (1960) listing of Retusa as a questionable carnivore. Harrison and Wass (1965) found that the distribution of

Retusa in Chesapeake Bay was correlated with high sediment-water content.

Sigambra wassi

This polychaete has a peak abundance at 12.2 m in May, but peak abundance is in later summer or early fall at all other depths (Fig. 12). Its feeding habits are unknown.

Lumbrinereis tenuis

This species presents a spring-fall peak abundance with sharp declines during the summer. Based on an analysis of size, the majority of spring breeding was inshore at 1.5 and 3.0 m. This species and other members of the genus have been classified as carnivores (Smith, 1932), but Sanders (1960) considers it a deposit feeder.

Pseudeurythoe sp.

Relatively constant throughout much of the year, this species has peak abundance at 1.5 and 6.1 m in November and 12.2 m in June. Little is known of its feeding habits.

The Fauna at 6.1 m (station III):

The numbers of individuals, species and biomass were lower at 6.1 m than any of the other stations (Table 3). Copepods, nematodes and *Retusa canaliculata* (Figs. 13, 10 and 11) made up a majority of the individuals. All of the dominant and common species at this depth were more abundant at one or more of the other stations. Samples from

6.1 m showed a relatively high faunal affinity to those from 12.2 m (Fig. 6). However, the rarity of Cirriformia filigera and Maldanopsis elongata, dominants at 12.2 m, indicates major differences in community structure between the two deep stations. In addition, there was almost no macrofauna at 6.1 m. The tectibranch gastropod Retusa canaliculata was the largest commonly occurring organism. As expected from sediment characteristics, most species were deposit feeders. The environmental factors which account for the depauperate fauna at this station remain obscure.

The Fauna at 1.5 (station I) and 3.0 m (station II):

As indicated by their high faunal affinity (54.7%), the 1.5 and 3.0 m stations are very similar and therefore will be considered together. A few more species were found at 3.0 m than at 1.5 m, i.e., 106 as opposed to 95. Conversely, more individuals were collected at 1.5 m. Although the order was slightly different, the top five species in the bio-index ranking were the same: nematodes; the lophophorate Phoronis architecta; the ostracod Loxoconcha impressa; copepods; and the gastropod Retusa canaliculata. Additional influents were the amphipods Ampelisca vadorum and A. macrocephala; the annelids Oligochaete #1, Polychaete #12 and Nephtys spp.; and the ostracod Cylindroleberis mariae.

Phoronis architecta

This phoronid is clearly the dominant macrofaunal animal at both stations. It was present throughout the year and was always more numerous at 3.0 m than at 1.5 m; however, individual tubes at 3.0 m appeared much smaller. Paine (1961) and Jones (1961) also found *Phoronis architecta* to be an important member of sand bottom communities. Phoronids circulate water to remove particles and are therefore suspension feeders (Hyman, 1959).

Loxoconcha impressa

This species was more numerous at 1.5 m. It was abundant from November to January at 1.5 m but remained relatively constant throughout the year at 3.0 m (Fig. 14). Ostracod feeding habits are not known, but Mare (1942) indicated that they are deposit feeders.

Ampelisca vadorum and *A. macrocephala*

These two ampeliscid amphipods showed clearly different distributions at the 1.5 and 3.0 m stations. *A. vadorum*, a small filter feeder, is found predominantly at 3.0 m while *A. macrocephala* is more abundant at 1.5 m (Fig. 15 and 16). *A. vadorum* was most numerous from October to February, although *A. macrocephala* lacked apparent seasonal fluctuations. At the depth of their maximum concentration, both species were sixth in the bio-index ranking.

Cylindroleberis mariae

This species represented another major faunal difference between the two inshore stations, ranking seventh in total numerical abundance at 1.5 m and forth-third at 3.0 m. It was abundant from October through February.

Oligochaete #1

This oligochaete was present in nearly equal numbers at both depths, but there appears to be a 1-month lag between conditions affecting the inshore station and the offshore one (Fig. 17). Seasonal peaks show a predominant winter distribution of this species.

Polychaete #12

This minute capitellid was common from May to December (Fig. 18). Little is known about these worms which are probably deposit feeders.

Some species present at 3.0 m are abundant at 12.2 m. Most specimens of *Amphiodia atra* were found at these two depths, and the same was true for *Nephtys incisa* until *N. magellanica* became abundant at 3.0 m (Fig. 19). If graphs of the two Nephtyidae are compared for 3.0 m, the apparent inverse relationship indicates they may be in direct competition at this depth. At the 1.5 m station both species plus *N. picta* are present, but *N. picta* seems to be the dominant form there.

During the summer months the numbers of *Odostomia bisuturalis* and *Turbonilla interrupta*, two parasitic gastropods, increase greatly, along with *Retusa canaliculata* and nematodes. This may be just a coincidence caused by reproductive conditions or these forms may be parasitizing *Retusa* as *Odostomia impressa* does *Bittium alternatum* (Allen, 1958).

Glycera dibranchiata and *G. americana*, two species of polychaete worms believed carnivorous, are present at 1.5 and 3.0 m. No apparent distributional differences could be seen, but *G. americana* seems to occur predominantly at 1.5 m while *G. dibranchiata*, may be found at either 1.5 or 3.0 m.

Loxoconcha impressa, *Phoronis architecta*, the ampeliscids, Oligochaete #1 and Polychaete #12 were abundant at the sandy inshore stations and rare at the soft bottom deeper stations. Sediment characteristics would thus seem to be the major factor controlling both the distribuiton of these species and the structure of the community which they dominate.

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Table 1

Annual mean ϕ size, skewness, kurtosis and percent sand-silt-clay at 1.5, 3.0, 6.1 and 12.2 m

Depth (m)	ϕ size		Mean		Percent		
	$\bar{x}$	St. Dev.	Skewness	Kurtosis	Sand	Silt	Clay
1.5	2.14	1.10	0.45	1.68	93.38	2.16	4.46
3.0	2.45	1.63	0.77	2.55	88.38	3.92	7.68
6.1	7.77	4.47	0.25	1.15	15.35	33.72	50.54
12.2	7.89	4.28	0.30	1.11	9.43	40.99	49.31

Table 2

Change in the water content of the substrate with sediment depth at 1.5, 3.0, 6.1 and 12.2 m

	Water content (% total weight of Sediments)			
Bottom depth	1.5 m	3.0 m	6.1 m	12.2 m
Sediment depth				
0-5 cm	35.64	52.59	82.28	82.54
5-10 cm	30.96	43.09	80.20	78.71
10-15 cm	24.57	39.88	79.61	77.38
Total	30.37	45.02	80.64	79.62

Table 3

Monthly values for S (the number of species), N (the number of individuals) and B (biomass in g) at 1.5, 3.0, 6.1 and 12.2 m, February 1965–February 1966

	1.5 m			3.0 m			6.1 m			12.2 m		
	S	N	B	S	N	B	S	N	B	S	N	B
Feb	36	567	15.2704	40	452	11.4950	11	32	0.0097	22	123	3.1753
Mar	31	638	9.5186	32	399	9.5399	13	67	0.0295	16	85	1.1105
Apr	24	696	13.7973	33	472	11.4550	10	32	0.0077	19	93	1.9422
May	36	1144	12.2690	43	531	17.1058	11	37	0.0186	22	216	1.5195
June	31	1992	9.7997	37	1374	15.8796	20	76	0.2145	22	166	1.6152
July	47	2072	5.6922	42	1713	13.8361	13	103	0.0229	18	180	1.6618
Aug	33	564	17.3699	36	476	10.5192	7	27	0.2124	21	102	1.2764
Sept	34	570	15.3507	46	602	19.2722	13	35	0.0467	23	197	2.2783
Oct	41	2563	19.2937	50	2174	15.5625	21	56	0.4717	26	234	1.9796
Nov	43	1718	12.4455	46	1355	12.1200	23	92	1.9856	22	219	2.3669
Dec	34	1543	10.7726	47	1230	15.3899	17	207	0.4037	23	195	3.5282
Jan	37	1523	11.2749	43	1019	13.9291	28	308	0.2723	21	299	4.2284
Feb	36	1535	10.7925	39	960	8.7924	8	16	0.3396	18	118	1.8444
Total	95	17,125	163.6470	106	12,757	174.8967	61	1088	4.0349	67	2227	28.5267
Mean	35.6	1317	12.5882	41.1	981	13.4536	14.9	84	0.3104	21.0	171	2.1944

Table 4

Monthly values for Shannon's (1948) diversity index ($\bar{H}$) for samples collected at 1.5, 3.0, 6.1 and 12.2 m in the York River, February 1965–February 1966

	$\bar{H}$			
Month	1.5 m	3.0 m	6.1 m	12.2 m
February	3.6684	3.5512	2.9915	3.7926
March	3.4892	3.5680	3.1386	3.6536
April	3.7471	3.6887	3.1535	2.9976
May	3.3729	3.5442	2.9406	3.6702
June	3.5907	3.2898	3.8148	3.8571
July	4.2016	4.0196	2.8555	3.6552
August	3.3176	3.5252	1.9849	3.6134
September	3.7718	3.6176	3.2516	3.3068
October	3.5792	4.1854	4.0712	3.7663
November	3.3365	4.1143	4.1986	3.3976
December	3.3278	3.7916	3.6161	2.8414
January	2.6018	3.9503	4.1625	2.9247
February	3.2705	4.0392	2.8453	3.1272
Mean	3.4827	3.7604	3.3096	3.4311

Table 5

Monthly per cent affinity values between stations*, February 1965–February 1966

Month	Station I-II	I-III	I-IV	II-III	II-IV	III-IV
February	57.65	20.94	26.30	20.11	23.64	27.77
March	77.54	30.08	29.50	29.64	34.50	40.60
April	49.36	30.24	18.16	31.28	19.21	36.91
May	58.95	12.30	14.02	22.75	17.62	43.18
June	86.04	42.59	21.82	32.38	29.45	41.37
July	57.04	19.29	32.75	21.19	27.25	40.36
August	52.31	33.92	31.75	14.71	34.83	26.80
September	53.50	18.28	21.45	16.85	22.69	24.52
October	46.55	19.90	15.77	25.21	19.25	24.07
November	41.23	17.49	18.31	14.48	20.82	44.19
December	40.39	20.49	6.25	21.73	12.45	16.28
January	34.00	19.21	4.38	30.37	11.52	29.82
February	56.90	32.91	7.59	27.48	21.55	24.43
$\bar{x}$	54.73	24.43	19.08	23.70	22.68	32.33
95% confidence interval ($\bar{x} \pm t_{0.05} s_{\bar{x}}$)	46.16–63.30	19.55–29.31	13.72–24.44	19.96–27.44	18.32–27.04	26.84–37.82

*Station I = 1.5 m, II = 3.0 m, III = 6.1 m, IV = 12.2 m.

Table 6

Monthly distribution, total number of individuals, percent composition and numerical rank of each species collected at 1.5 m from February 1965 through February 1966

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Nematoda	216	293	340	864	1807	1548	272	252	1450	808	992	647	974	10463	61.10	1
Loxoconcha impressa	87	67	91	53	17	69	25	58	141	326	104	348	135	1521	8.88	2
Phoronis architecta	70	85	63	89	70	78	73	66	88	68	69	49	46	914	5.34	3
Copepoda	12	17	11	17	9	17	2	3	280	68	76	186	151	849	4.96	4
Retusa canaliculata	25	36	19	13	10	68	92	23	51	61	31	20	18	467	2.73	5
Unid. Pelecypoda				3		5	4	25	210	51	31	74	20	423	2.47	6
Cylindroleberis mariae	1	4	3	5	1	8	9	3	114	49	59	52	38	346	2.02	7
Oligochaete #1	21	19	8	2	2	8	1	22	43	45	83	32	57	343	2.00	8
Ampelisca macrocephala	25	27	29	30	2	20	8	22	36	68	29	25	22	343	2.00	8
Polychaete #12	5	6	8	12	7	55	9	17	14	14	1		1	149	0.87	10
Sarsiella zostericola		1			3	3			35	23	2	13	4	84	0.50	11
Melinna maculata	5	20	18	1	8	1	1	4	1	4	7	3	1	74	0.43	12
Ampelisca vadorum		3	2	6	4	20	2	11	4	8	5	5		70	0.41	13
Turbellaria			7			4		1	11	10	6	9	12	60	0.35	14
Haminoea solitaria	10	3	4	2		10	1	2	2	16	3	2	4	59	0.34	15
Edwardsia sp.	6	12	23	2	2	1	1			9			1	57	0.33	16
Heteromastus filiformis	2		14	3	1	19	1	1		2	1	2	6	52	0.30	17
Exogone dispar	24	5	4		2	2	1		3	4	1	2	3	51	0.30	18
Pseudoeurythoe sp.			1		8	3	3	2	13	16			3	49	0.29	19
Glycinde solitaria	6	1	5	1	4	4	5	5	7	4	5		2	49	0.29	19
Odostomia bisuturalis	3		1		9	9	6	3	5		4	3	1	44	0.26	21
Clymenella torquata	1	2		1	5	3	5	4	8	2	3	4	5	43	0.25	22
Spiochaetopterus oculatus						27	7		1		1			36	0.21	23
Scoloplos robustus	5	8	10	6	6									35	0.20	24
Oxyurostylis smithi	1	10				3		3	9	4	2	1	1	34	0.20	25
Batea catharinensis						16	1	4	5	5			1	32	0.19	26
Lumbrinereis tenuis	8	1	5	3	1					5	2	1	2	28	0.16	27
Turbonilla interrupta	1					6	4	3	2	4		1	1	22	0.13	28
Edotea triloba			1	1	2	6	7	1	2	1			1	22	0.13	28
Capitella capitata			9	2	5						2	1		19	0.11	30
Nephtys picta			2		4	4	1	1	1	2	1		2	18	0.11	31

Table 6 continued

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Scoloplos fragilis						3			1	2	5	2	5	18	0.11	31
Leptochelia rapax						3	2	5	4	3			1	18	0.11	31
Gyptis vittata	1	3	3	2			1			2	1	4		17	0.10	34
Montacuta elevata				1		2		3	2	1	4	1	3	17	0.10	34
Glycera dibranchiata	6	2							1	5	1		1	16	0.09	36
Leptosynapta tenuis								7	1	2		3	3	16	0.09	36
Glycera americana	1	2	1	1				1	1	2	1	3	2	15	0.09	38
Phyllodoce arenae	2	2	3	2		1	2			1			2	15	0.09	38
Acteon punctostriatus					1	13					1			15	0.09	38
Odostomia impressa						5	4	4		1				14	0.08	41
Sarsiella texana		1	1	1					2	1	3	4		13	0.08	42
Listriella clymenellae	1					1	1	1	2	3	2	1	1	13	0.08	42
Oligochaete #4												12		12	0.07	44
Paraprionospio pinnata	2	1	2	1	1	3							1	11	0.06	45
Nephtys magellanica			1			2				6				9	0.05	46
Nereis succinea				1		1	5		2					9	0.05	46
Polychaete #16			1	1		6								8	0.05	48
Brania sp.	2	1	3				1							7	0.04	49
Caprella penantis				5		1		1						7	0.04	49
Elphidium incertum				3								3		6	0.04	51
Ammonia (Streblus) beccari	4			2										6	0.04	51
Pectinaria gouldii				1				1	2	1	1			6	0.04	51
Unid. polychaetes	2		1	1			1	1						6	0.04	51
Illynassa vibex	1			1		1		1		1		1		6	0.04	51
Cerebratulus sp.					1	3							1	5	0.03	56
Cirriformia filigera	4	1												5	0.03	56
Podarke obscura								3			1	1		5	0.03	56
Sigambra wassi			1		2			2						5	0.03	56
Cerapus tubularis							1		1	2		1		5	0.03	56
Epitonium rupicolum			1						1	1		1		4	0.02	61
Crepidula convexa				2								2		4	0.02	61
Nephtys incisa					2		1							3	0.02	63
Bittium alternatum						2	1							3	0.02	63
Lucina multilineata										1	1	1		3	0.02	63
Mya arenaria	1								2					3	0.02	63

Table 6 continued

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Cerebratulus lacteus											2			2	0.01	67
Polydora ligni	2													2	0.01	67
Exogone verugera									2					2	0.01	67
Turbonilla stricta						2								2	0.01	67
Lyonsia hyalina					1	1								2	0.01	67
Neomysis americana						1				1				2	0.01	67
Idotea baltica			1			1								2	0.01	67
Caprella equilibra									2					2	0.01	67
Cymadusa compta													2	2	0.01	67
Callinectes sapidus	1												1	2	0.01	67
Nemertean fragment		1												1	0.01	77
Nectonema sp. larva					1									1	0.01	77
Peloscolex sp.								1						1	0.01	77
Arabella iricolor						1								1	0.01	77
Drilonereis longa									1					1	0.01	77
Notomastus latericus						1								1	0.01	77
Aglaophamus verrilli												1		1	0.01	77
Eteone heteropoda	1													1	0.01	77
Cabira incerta				1										1	0.01	77
Exogone hebes											1			1	0.01	77
Amphitrite ornata				1										1	0.01	77
Polychaete #25		1												1	0.01	77
Pyramidella fusca				1										1	0.01	77
Anadara transversa									1					1	0.01	77
Mercenaria mercenaria												1		1	0.01	77
Tellina agilis	1													1	0.01	77
Macoma tenta						1								1	0.01	77
Mulinia lateralis						1								1	0.01	77
Cythereis emarginata		1												1	0.01	77
Gammarus mucronatus				1										1	0.01	77
Unciola irrorata					1									1	0.01	77
Pagurus longicarpus	1													1	0.01	77
Anguilla rostrata		1												1	0.01	77
Symphurus plagiusa									1					1	0.01	77

Table 7

Monthly distribution, total number of individuals, percent composition and numerical rank of each species collected at 3.0 m from February 1965 through February 1966

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Nematoda	94	76	141	225	944	1265	171	223	1330	763	691	547	645	7115	55.77	1
Phoronis architecta	133	100	92	122	141	103	109	138	139	121	131	98	68	1495	11.72	2
Copepoda	5	10	31	14	146	80	3	29	230	61	85	50	34	778	6.10	3
Ampelisca vadorum	8	5	2	1	4	19	1	13	44	59	81	69	38	344	2.70	4
Loxoconcha impressa	33	42	26	13	10	28	4	3	27	51	15	17	11	280	2.19	5
Retusa canaliculata	29	22	8	5	17	31	35	20	19	6	16	19	6	233	1.83	6
Oligochaete #1	10	17	17	6		4	2	15	36	30	29	42	24	232	1.82	7
Unid. Pelecypoda			4	4		18	3	27	80	42	16	19	19	232	1.82	7
Nephtys magellanica	1		1	1		1	2	9	31	36	32	32	10	156	1.22	9
Edwardsia sp.	37	13	13	1	7	5	1	22	16	24			4	143	1.12	10
Odostomia bisuturalis	7	13	1	1	2	27	32	14	4	18	14	6	2	141	1.11	11
Melinna maculata	2	14	20	16	17	5	3	1	2	7	9	7	13	116	0.91	12
Polychaete #12	3		4	25	3	5	1	6	33	17	11	2	5	115	0.90	13
Sarsiella zostericola	1		1		6	10	7	2	18	9	12	12	11	89	0.70	14
Turbonilla interrupta	1	1	1	1	2	15	19	6	12	10	8	5	2	83	0.65	15
Exogone dispar	15	14	10	1	7	4	4		2	4		10	5	76	0.60	16
Ampelisca macrocephala	6	13	3	8	2	4		8		5	12	8	1	70	0.55	17
Clymenella torquata	12	6	6	8	6	2	5	2	7	1	3	5	5	68	0.53	18
Cerapus tubularis								11	42	4	1			58	0.45	19
Pectinaria gouldii					7		23	6	4	3	1	4	2	50	0.39	20
Turbellaria			34	1	2	1		1	5		1	1	3	49	0.38	21
Edotea triloba		1		1	5	10	1	3	15	6	2			44	0.34	22
Lumbrineris tenuis	1	4	8	11		1			3	5	4	2	4	43	0.34	23
Glycinde solitaria		2		2	2	16	6	6	3					37	0.29	24
Haminoea solitaria	6	1	3	2		1	8		4	5	3	1	1	35	0.27	25
Elphidium incertum				10	9			1	3	1	5	4	1	34	0.27	26
Scoloplos robustus	3	14	12	4	1									34	0.27	26
Nephtys incisa		1	6	9	5	2	5	1					4	33	0.26	28
Paraprionospio pinnata	8	3	4	3		1		1	6	5	1	1		33	0.26	28
Leptosynapta tenuis								4	2	8	7	8	3	32	0.25	30
Amphiodia atra	2	1	1			1	3	4	5	5	5	3	1	31	0.24	31

Table 7 continued

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Heteromastus filiformis		2	5	6	2		1	2	2	1	1	1	6	29	0.23	32
Nephtys picta	1	4	3	6	3	4	3	2				3		29	0.23	32
Listriella clymenellae	4	1	2	3		2	1	1	5		3	1	4	27	0.21	34
Scoloplos fragilis									2	10	4	6	3	25	0.20	35
Gyptis vittata	3	1	2	1			1	1	4	3	2	5		23	0.18	36
Oxyurostylis smithi									6	5	1	9		21	0.16	37
Sigambra wassi	3			1	2	1	3	2	2		2	1	2	19	0.15	38
Batea catharinensis						10			3	2	1		1	17	0.13	39
Phyllodoce arenae			1	1	2			1			1	1	8	15	0.12	40
Unid. polychaetes	2	10		2		1								15	0.12	40
Sarsiella texana						3	4	1	1	3		3		15	0.12	40
Odostomia impressa			2			5	3		1	1	1	1		14	0.11	43
Cylindroleberis mariae						5	1	1	4	1	1		1	14	0.11	43
Montacuta elevata		1		1	3	3		1	1	1			2	13	0.10	45
Pseudoeurythoe sp.			3	3	1	2		1		1	1			12	0.09	46
Glycera dibranchiata	3	1		1		2					1	2		10	0.08	47
Mya arenaria	5									2	2		1	10	0.08	47
Polychaete #16	2	2	1	2					1		1			9	0.07	49
Acteon punctostriatus					1	2		2	2	1	1			9	0.07	49
Lucina multilineata		1					1	1	1	2	3			9	0.07	49
Macoma tenta									1	5	2	1		9	0.07	49
Turbonilla stricta						6	2							8	0.06	53
Lyonsia hyalina					2		3	1		2				8	0.06	53
Nectonema sp. larvae						1		1	2	1			1	6	0.05	55
Capitella capitata	1		1		3				1					6	0.05	55
Lepidonotus sp.								2		2			1	5	0.04	57
Brania sp.				1									4	5	0.04	57
Loimia medusa									3	1	1			5	0.04	57
Mulinia lateralis			2		2							1		5	0.04	57
Gammarus mucronatus				1	2	2								5	0.04	57
Unciola irrorata	1	1		1	1						1			5	0.04	57
Nereis succinea				1	1				2					4	0.03	63
Eteone heteropoda					1	1	2							4	0.03	63
Ilyanassa vibex	1							1				2		4	0.03	63
Epitonium rupicolum								1	1			1		3	0.02	66

Table 7 continued

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Caprella penantis						2			1					3	0.02	66
Caprella equilibra												3		3	0.02	66
Oligochaete #4												2		2	0.02	69
Spiochaetopterus oculatus									2					2	0.02	69
Paleanotus heteroseta		1					1							2	0.02	69
Glycera americana									2					2	0.02	69
Podarke obscura											1	1		2	0.02	69
Harmothoe sp.	1			1										2	0.02	69
Polydora ligni	1							1						2	0.02	69
Exogone hebes						1					1			2	0.02	69
Polychaete #26				1						1				2	0.02	69
Urosalpinx cinerea										2				2	0.02	69
Cythereis emarginata	1					1								2	0.02	69
Neomysis americana				1			1							2	0.02	69
Pinnixa sayana										2				2	0.02	69
Ammonia (Streblus) beccari	1													1	0.01	82
Halichondria bowerbanki								1						1	0.01	82
Diadumene leucolena	1													1	0.01	82
Hydroid				1										1	0.01	82
Amphiporus bioculatus	1													1	0.01	82
Cerebratulus lacteus											1			1	0.01	82
Cerebratulus luridus	1													1	0.01	82
Cerebratulus sp.					1									1	0.01	82
Peloscolex sp.													1	1	0.01	82
Oligochaete #4									1					1	0.01	82
Asabellides oculatus				1										1	0.01	82
Sabellaria vulgaris	1													1	0.01	82
Polychaete #25		1												1	0.01	82
Crepidula convexa	1													1	0.01	82
Astyris (Mitrella) lunata									1					1	0.01	82
Mercenaria mercenaria											1			1	0.01	82
Tellina agilis	1													1	0.01	82
Ensis directus				1										1	0.01	82
Erichsonella attenuata													1	1	0.01	82
Idotea baltica								1						1	0.01	82

Table 7 continued

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Sphaeroma quadridentatum													1	1	0.01	82
Corophium tuberculatum											1			1	0.01	82
Cymadusa compta													1	1	0.01	82
Amphipod #25								1						1	0.01	82
Callinectes sapidus											1			1	0.01	82
Ogyrides limicola			1											1	0.01	82
Halacaridae						1								1	0.01	82
Cucumaria pulcherrima												1		1	0.01	82
Saccoglossus kowalewskii							1							1	0.01	82
Gobiosoma bosci												1		1	0.01	82

Table 8

Monthly distribution, total number of individuals, percent composition and numerical rank of each species collected at 6.1 m from February 1965 through February 1966

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Nematoda		2	4	10	7	8		10	6	5	154	178	2	386	35.48	1
Copepoda	5	12	5	2	18	49	1	1	7	27	5	16	1	152	13.97	2
Retusa canaliculata	4	17	4	7	13	19	15	8	6	5	8	18	3	127	11.67	3
Sarsiella zostericola	2		1		1	2			1	10	5	12	1	35	3.22	4
Polychaete #12	1	1	3	4	4			2	4			12		31	2.85	5
Brania sp.		4			3	1				4	9	7		28	2.57	6
Nephtys incisa		6	2	2	3	5	4	2		2			1	27	2.48	7
Exogone dispar	2	3	1	1		7		1	1	3	1	4		24	2.21	8
Pseudoeurythoe sp.					3	2	2	2	2	2	1	9		23	2.11	9
Oligochaete #1		3							1	1	4	7	2	18	1.65	10
Melinna maculata	5		2	1	2	3			1	1	3			18	1.65	10
Sigambra wassi		1	3	3	2				4	2	1			16	1.47	12
Glycinde solitaria					1	2		1	4	3	1	3		15	1.38	13
Lumbrinereis tenuis									1	3	5	5		14	1.29	14
Elphidium incertum					5	1			2	3	1			12	1.10	15
Nephtys magellanica									1	2	2	6	1	12	1.10	15
Scoloplos robustus	8	3		1										12	1.10	15
Sarsiella texana					1	1		2	2		2	4		12	1.10	15
Heteromastus filiformis	1		4	2	1	1		1			1			11	1.01	19
Paraprionospio pinnata	1	1						1	4	2		1		10	0.92	20
Oxyurostylis smithi									1	4	2	2		9	0.83	21
Loxoconcha impressa		2	2		2							1	1	8	0.74	22
Polychaete #16	1	4										1		6	0.55	23
Edwardsia sp.		1	1	1	1			1						5	0.46	24
Cirriformia filigera												3	1	4	0.37	25
Aglaophamus verrilli												4		4	0.37	25
Pectinaria gouldii									3			1		4	0.37	25
Turbellaria				2								1		3	0.28	28
Phoronis architecta					3									3	0.28	28
Paleanotus heteroseta										1		2		3	0.28	28
Lepidonotus sp.								1	1	1				3	0.28	28

Table 8 continued

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Petricola pholadiformia										3				3	0.28	28
Unid. Pelecypoda										1			2	3	0.28	28
Parametopella cypris										3				3	0.28	28
Stereobalanus sp.										3				3	0.28	28
Capitella capitata	1				1									2	0.18	36
Nephtys picta					1		1							2	0.18	36
Cyclostremiscus pentagonius							1			1				2	0.18	36
Epitonium rupicolum													2	2	0.18	36
Macoma tenta									1		1			2	0.18	36
Caprella penantis					2									2	0.18	36
Unciola irrorata							2							2	0.18	36
Amphiodia atra										1	1			2	0.18	36
Oligochaete #4									1					1	0.09	44
Chaetopterus variopedatus													1	1	0.09	44
Glycera dibranchiata				1										1	0.09	44
Maldanopsis elongata										1				1	0.09	44
Phyllodoce arenae								1						1	0.09	44
Teinostoma cryptospira								1						1	0.09	44
Solariorbus infracarinata						1								1	0.09	44
Acteon punctostriatus						1								1	0.09	44
Odostomia bisuturalis	1													1	0.09	44
Odostomia impressa												1		1	0.09	44
Mya arenaria									1					1	0.09	44
Cylindroleberis mariae					1									1	0.09	44
Chthamalus fragilis					1									1	0.09	44
Neomysis americana							1							1	0.09	44
Edotea triloba												1		1	0.09	44
Ampelisca vadorum									1					1	0.09	44
Cerapus tubularis										1				1	0.09	44
Corophium tuberculatum										1				1	0.09	44
Ogyrides limicola												1		1	0.09	44
Pinnixa sayana												1		1	0.09	44
Leptosynapta tenuis												1		1	0.09	44

Table 9

Monthly distribution, total number of individuals, percent composition and numerical rank of each species collected at 12.2 m from February 1965 through February 1966

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Nematoda	10	17	5	125	110	97	5	90	89	20	24	154	23	769	34.53	1
Cirriformia filigera	20	8	39	11	3	15	18	42	33	64	79	49	29	410	18.41	2
Sarsiella zostericola	5	2		2	2	9	11	13	21	21	6	8	17	117	5.25	3
Maldanopsis elongata					1	3	4	2	19	27	19	10	12	97	4.36	4
Pseudoeurythoe sp.	1		1			7	1	1	5	11	17	40	6	90	4.04	5
Retusa canaliculata	8	2	1	4	3	13	21	8	3	8	3	1		75	3.37	6
Copepoda	17	22	2	5		5		2	3	5		1	1	63	2.83	7
Nephtys incisa	3	7	10	13	6	3	4	5	3	2	3	1		60	2.69	8
Brania sp.	9	1	4		14		5		11	9	1	1		55	2.47	9
Sigambra wassi	2	3	8	10	4	4	3	5	4	6	1	3	1	54	2.42	10
Lumbrineris tenuis	1	1		1	2				7	8	6	2	5	33	1.48	11
Odostomia bisuturalis	6		1	2			10		2	3	3	1		28	1.26	12
Turbonilla stricta						1			1	2	18	1	3	26	1.17	13
Exogone dispar	14	2		4	1		1	1	1				1	25	1.12	14
Oligochaete #1	3	4	1	2	1				2	5	2		2	22	0.99	15
Edwardsia sp.	1	2	3		1	1		5	1	5			2	21	0.94	16
Turbellaria				19									1	20	0.90	17
Polychaete #12	3			3	1	4			3	4		1		19	0.85	18
Unid. Pelecypoda									3	3	2	5	4	17	0.76	19
Pectinaria gouldii					1		2	2	2	1	1	6	1	16	0.72	20
Elphidium incertum	7			2	3							3		15	0.67	21
Nephtys magellanica									2	7	1	2	2	14	0.63	22
Melinna maculata			3		3	1		2		2			2	12	0.54	23
Amphiodia atra		1					4	3	2	1	1	1		12	0.54	23
Glycinde solitaria						4	1	5	1					11	0.49	25
Polydora ligni	3		2						6					11	0.49	25
Heteromastus filiformis			4	1		4					1			10	0.45	27
Loxoconcha impressa		4	2		2						1			9	0.40	28
Cerapus tubularis							1	1	3	2				7	0.31	29
Scoloplos robustus		5		1										6	0.27	30
Acteon punctostriatus						2	3	1						6	0.27	30

Table 9 continued

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Turbonilla interrupta	4	1	1											6	0.27	30
Sarsiella texana							2	2				2		6	0.27	30
Paraprionospio pinnata					2				3					5	0.22	34
Macoma tenta					1		1			1	1		1	5	0.22	34
Gyptis vittata		1		1			1			1				4	0.18	36
Odostomia impressa			1	1			2							4	0.18	36
Neomysis americana					1	1		1	1					4	0.18	36
Leptosynapta tenuis									1				3	4	0.18	36
Capitella capitata				1	2									3	0.13	40
Polychaete #16						3								3	0.13	40
Paleanotus heteroseta										1		2		3	0.13	40
Aglaophamus verrilli												3		3	0.13	40
Unid. polychaetes				2	1									3	0.13	40
Haminoea solitaria	1	2												3	0.13	40
Cythereis emarginata				3										3	0.13	40
Batea catharinensis						2	1							3	0.13	40
Cucumaria pulcherrima								2				1		3	0.13	40
Phyllodoce arenae	1										1			2	0.09	49
Polychaete #26			2											2	0.09	49
Epitonium rupicolum	1			1										2	0.09	49
Mulinia lateralis							1				1			2	0.09	49
Cylindroleberis mariae								1					1	2	0.09	49
Oxyurostylis smithi										1	1			2	0.09	49
Ampelisca vadorum	1							1						2	0.09	49
Corophium tuberculatum				1							1			2	0.09	49
Ceriantheopsis americana	1													1	0.04	57
Alcyonidium verrilli					1									1	0.04	57
Diopatra cuprea				1										1	0.04	57
Lepidametria commensalis			1											1	0.04	57
Lepidonotus sp.									1					1	0.04	57
Loimia medusa													1	1	0.04	57
Polychaete #24	1													1	0.04	57
Solariorbus infracarinata											1			1	0.04	57
Odostomia dux								1						1	0.04	57
Anadara transversa				1										1	0.04	57

Table 9 continued

	F	M	A	M	J	J	A	S	O	N	D	J	F	Total	%	Rank
Lyonsia hyalina								1						1	0.04	57
Edotea triloba						1								1	0.04	57
Caprella penantis							1							1	0.04	57
Ogyrides limicola			1											1	0.04	57
Pinnixa chaetopterana									1					1	0.04	57
Stereobalanus sp.													1	1	0.04	57

Table 10

Faunal frequency evaluation of thirteen monthly samples at station I, York River, Virginia, February 1965–February 1966

	1	2	3	4	5	6	7	8	9	10	Frequency	Frequency as one of ten most common species	Biological index value
Nematoda	13										13	13	130
Loxoconcha impressa		5	6	2							13	13	107
Phoronis architecta		5	4		2	2					13	13	99
Retusa canaliculata		1		4	1	3	2		2		13	13	70
Copepoda		2	2	1	2			2	1	1	13	11	62
Ampelisca macrocephala			1	3	1	1	2	2	2		13	12	58
Oligochaete #1			1	1		1	3	1	1		12	8	37
Unidentified Pelecypoda			1	2			2	1			9	6	33
Cylindroleberis mariae					3	2		1		1	13	7	32
Polychaete #12					2		1	2			12	5	22
Melinna maculata						2	1			1	13	4	15
Ampelisca vadorum							1	1	1		11	3	9
Edwardsia sp.					1				1		9	2	8
Spiochaetopterus oculatus						1			1		4	2	7
Odostomia bisuturalis					1						10	1	6
Scoloplos robustus								1	1	1	5	3	6
Exogone dispar						1					11	1	5
Pseudoeurythoe sp.						1					8	1	5
Heteromastus filiformis								1	1		11	2	5
Sarsiella zostericola										3	8	3	3
Haminoea solitaria									1		12	1	2
Edotea triloba									1		9	1	2
Lumbrinereis tenuis										1	9	1	1
Oxyurostylis smithi										1	9	1	1
Caprella penantis										1	3	1	1
Clymenella torquata										1	12	1	1
Capitella capitata										1	5	1	1
Leptosynapta tenuis										1	5	1	1
Turbellaria										1	8	1	1

Table 11

Faunal frequency evaluation of thirteen monthly samples at station II, York River, Virginia, February 1965-February 1966

	1	2	3	4	5	6	7	8	9	10	Frequency	Frequency as one of ten most common species	Biological index value
Nematoda	11	2									13	13	128
Phoronis architecta	2	9	2								13	13	117
Copepoda		2	4	3	1						13	10	77
Loxoconcha impressa			1	1	3	2		1	2	1	13	11	51
Retusa canaliculata			1	3	1	1	2				13	8	48
Ampelisca vadorum			2	2	1		1		2		13	8	47
Oligochaete #1					3	1	3	2			12	9	41
Unidentified Pelecypoda				2		2	2	1			10	7	35
Melinna maculata				2		2	1				13	5	28
Edwardsia sp.			1		1			2	2		11	6	24
Odostomia bisuturalis				1		1		1	1	2	13	6	19
Nephtys magellanica					1	1	1		1	1	11	5	18
Exogone dispar						2		1		1	11	4	14
Polychaete #12			1					1			12	2	11
Pectinaria gouldii					1			1			8	2	9
Turbellaria			1								9	1	8
Scoloplos robustus						1			1		5	2	7
Elphidium incertum							1	1			8	2	7
Sarsiella zostericola								2		1	11	3	7
Clymenella torquata							1			2	13	3	6
Turbonilla interrupta						1				1	13	2	6
Cerapus tubularis						1				1	4	2	6
Lumbrinereis tenuis							1				10	1	4
Glycinde solitaria									2		7	2	4
Haminoea solitaria							1				11	1	4
Ampelisca macrocephala									1	1	11	2	3
Nephtys incisa									1	1	8	2	3
Paraprionospio pinnata									1		10	1	2

Table 12

Faunal frequency evaluation of thirteen monthly samples at station III, York River, Virginia, February 1965-February 1966

	1	2	3	4	5	6	7	8	9	10	Frequency	Frequency as one of ten most common species	Biological index value
Retusa canaliculata	3	7	2	1							13	13	109
Copepoda	5	2	2	1	2		1				13	13	107
Nematoda	4	3	3							1	11	11	92
Nephtys incisa		1	3		2	1	1				9	8	54
Polychaete #12			2	2	2		1				8	5	46
Sarsiella zostericola		1	1	2	1		1			1	9	7	42
Brania sp.		1		1	1	1	1			1	6	6	32
Pseudoeurythoe sp.			2			2	1		1		8	8	32
Exogone dispar				1	1		3		1	1	10	7	28
Heteromastus filiformis		1			1		2			1	7	5	24
Melinna maculata		1				1	1		1	1	8	5	21
Oligochaete #1		1					3				6	4	21
Sigambra wassi				2	1					1	7	4	21
Glycinde solitaria				1			3				7	4	19
Scoloplos robustus	1						1		1		3	3	16
Paraprionospio pinnata				1			2				6	3	15
Loxoconcha impressa			1				1			2	5	4	14
Elphidium incertum			1					1	1	1	5	4	13
Sarsiella texana			1						2	1	6	4	13
Lumbrinereis tenuis				1			1			1	4	3	12
Nephtys magellanica			1						2		5	3	12
Polychaete #16				1			1				3	2	11
Unidentified Pelecypoda		1									2	1	9
Oxyurostylis smithi					1				1		4	2	8
Unciola irrorata			1								1	1	8
Chaetopterus variopedatus			1								1	1	8
Cirriformia filigera			1								2	1	8
Haminoea solitaria				1							1	1	7
Edwardsia sp.							1		1	1	5	3	7

Table 12 continued

	1	2	3	4	5	6	7	8	9	10	Frequency	Frequency as one of ten most common species	Biological index value
Turbellaria					1						2	1	6
Nephtys picta					1						2	1	6
Cyclostremiscus pentagonius					1						2	1	6
Neomysis americana					1						1	1	6
Phoronis architecta						1					1	1	5
Capitella capitata							1				2	1	4
Odostomia bisuturalis							1				1	1	4
Phyllodoce arenae							1				1	1	4
Lepidonotus sp.							1				3	1	4
Teinostoma cryptospira							1				1	1	4
Parametopella cypris							1				1	1	4
Stereobalanus sp.							1				1	1	4
Petricola pholadiformis							1				1	1	4
Pectinaria gouldii								1			2	1	3
Glycera dibranchiata									1		1	1	2
Caprella penantis										1	1	1	1
Solariorbus infracarinata										1	1	1	1
Acteon punctostriatus										1	1	1	1

Table 13

Faunal frequency evaluation of thirteen monthly samples at station IV, York River, Virginia, February 1965-February 1966

	1	2	3	4	5	6	7	8	9	10	Frequency	Frequency as one of ten most common species	Biological index value
Cirriformia filigera	5	5	1	1	1						13	13	116
Nematoda	6	3		3	1						13	13	114
Sarsiella zostericola			5	1	1	1			3		12	11	64
Retusa canaliculata	1		1	1	1	1	2	1	1	1	12	10	50
Maldanopsis elongata		1	1	3			1			1	9	7	43
Nephtys incisa		1	2	1	1			1		1	12	7	42
Sigambra wassi			1	1	2		1	2	1	2	13	7	41
Brania sp.		1			4	1					10	6	38
Pseudoeurythoe sp.			1		4			1			9	6	35
Copepoda	1	1				2			1	2	10	7	33
Lumbrinereis tenuis						3	1		1		9	5	21
Exogone dispar			1				1		1		8	3	14
Odostomia bisuturalis				1				2			8	3	13
Elphidium incertum					1		1	1			4	3	13
Edwardsia sp.					1		1		1	1	9	4	13
Melinna maculata					1		1			1	6	3	11
Turbonilla stricta				1				1			6	2	10
Heteromastus filiformis					1		1				4	2	10
Glycinde solitaria					1		1				4	2	10
Loxoconcha impressa						1			2		4	3	9
Turbellaria		1									2	1	9
Unidentified Pelecypoda							2			1	5	3	9
Polychaete #12							1		1	1	7	3	7
Oligochaete #1						1				1	9	2	6
Scoloplos robustus					1						2	1	6
Polydora ligni							1		1		3	2	6
Amphiodia atra							1		1		6	2	6
Pectinaria gouldii						1				1	8	2	6
Gyptis vittata							1				4	1	4

Table 13 continued

	1	2	3	4	5	6	7	8	9	10	Frequency	Frequency as one of ten most common species	Biological index value
Leptosynapta tenuis								1			2	1	3
Paraprionospio pinnata									1	1	2	2	3
Nephtys magellanica									1	1	5	2	3
Aglaophamus verrilli											1	1	3
Haminoea solitaria									1		2	1	2
Polychaete #26									1		1	1	2
Capitella capitata									1		2	1	2
Turbonilla interrupta										1	3	1	1
Cythereis emarginata										1	1	1	1
Acteon punctostriatus										1	3	1	1
Sarsiella texana										1	3	1	1
Cucumaria pulcherrima										1	2	1	1
Cerapus tubularis										1	2	1	1

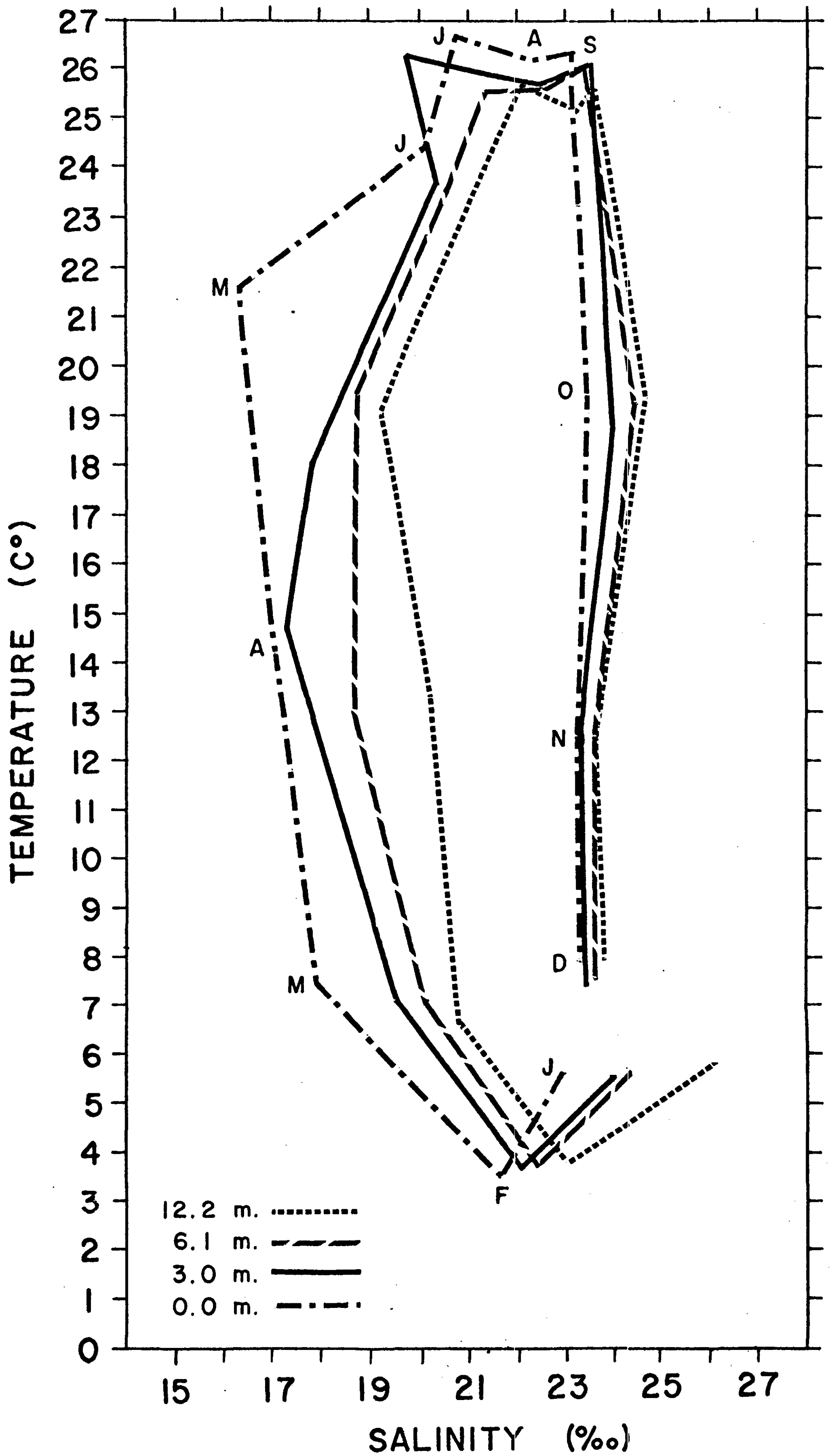

Figure 1. 1965 monthly means of temperature vs. salinity in the York River channel 0.5 mile above the study area.

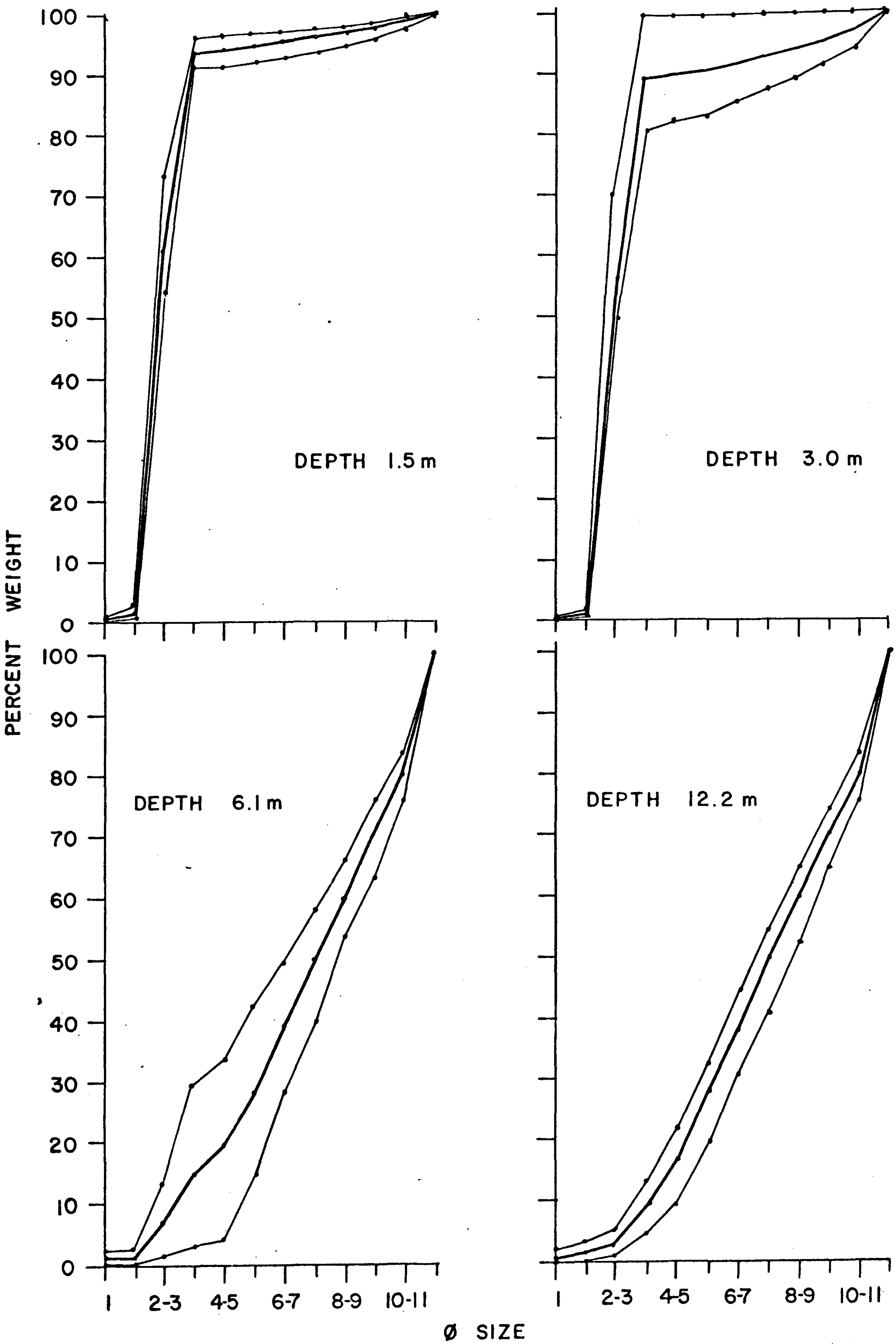

Figure 2. Mean cumulative percent weight of each ϕ fraction of the sediments at 1.5, 3.0, 6.1 and 12.2 m during the study period. Fine lines indicate seasonal extremes.

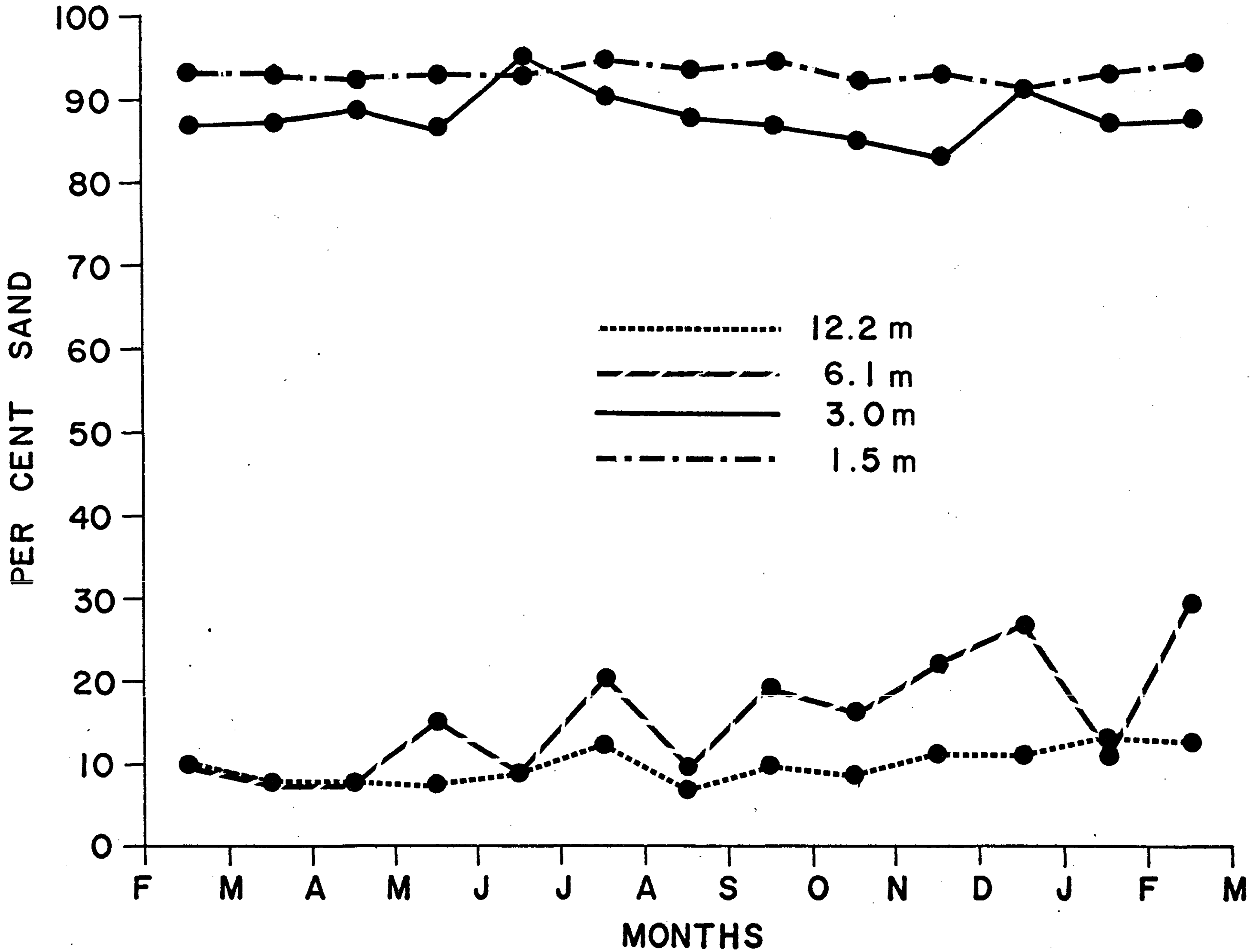

Figure 3. Seasonal fluctuation in the sand components of sediments at 1.5, 3.0, 6.1 and 12.2 m.

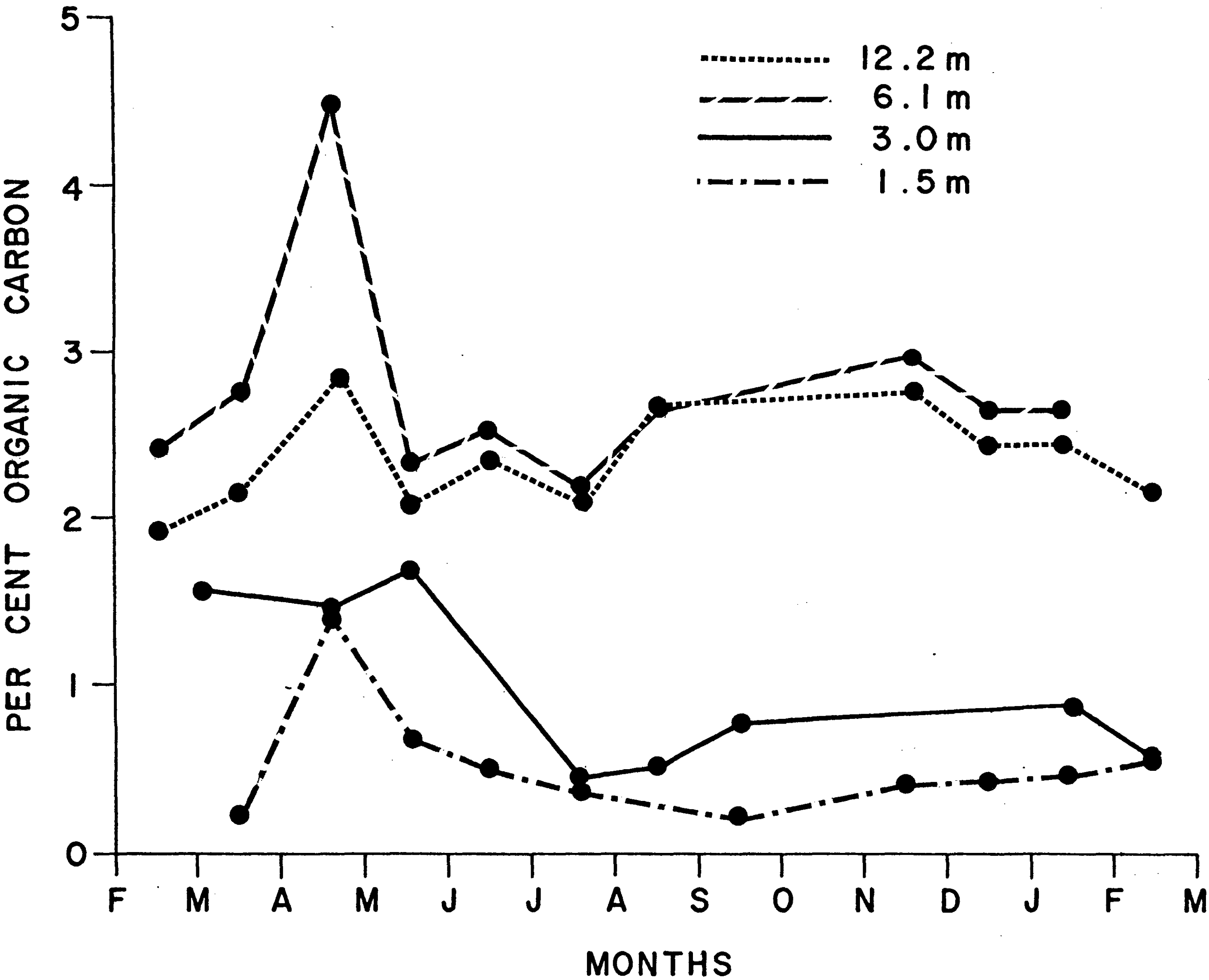

Figure 4. Seasonal changes in the percent organic carbon of the total sediment weight at 1.5, 6.1 and 12.2 m.

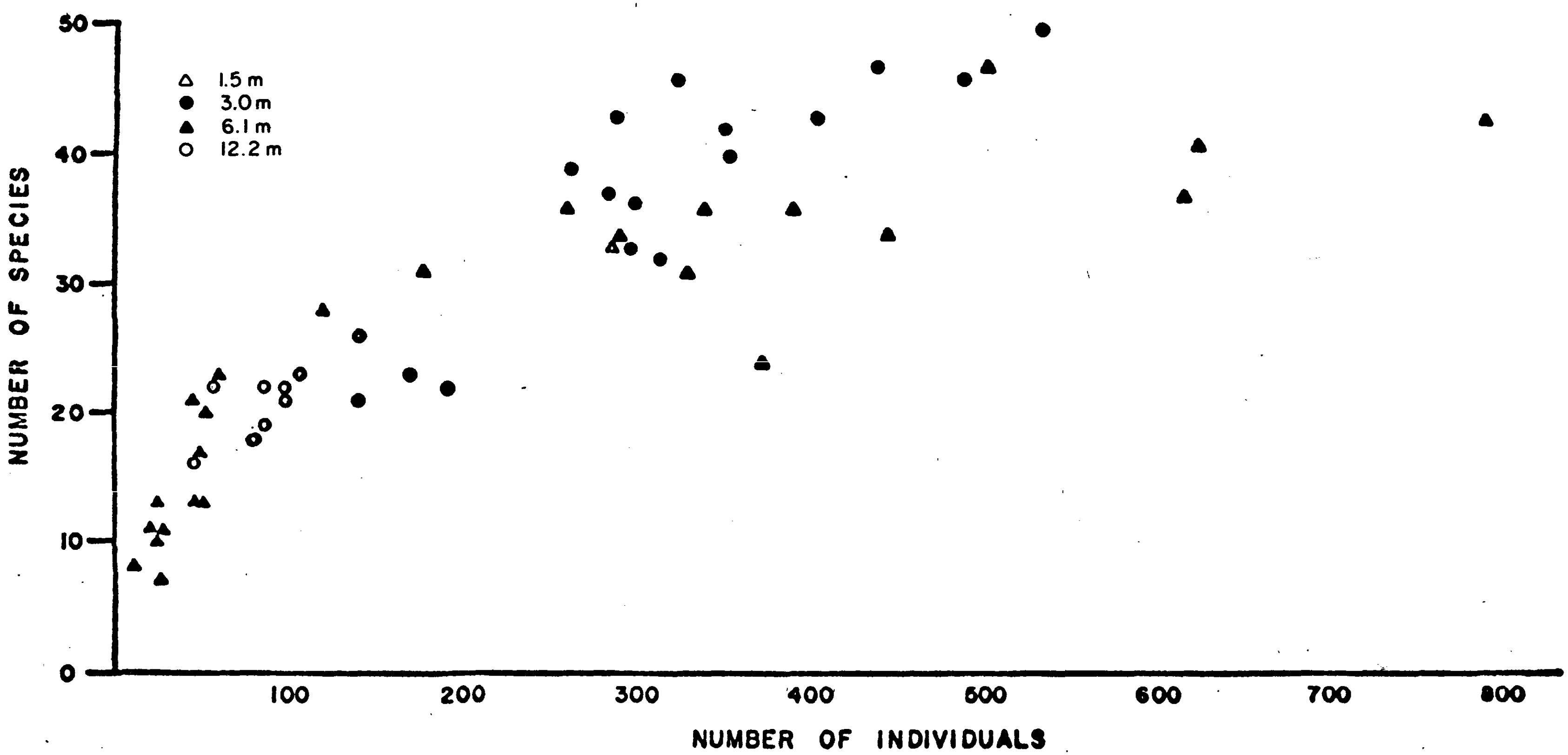

Figure 5. Plot of the number of species (S) vs. the number of individuals (N) collected in each monthly sample from 1.5, 3.0, 6.1 and 12.2 m.

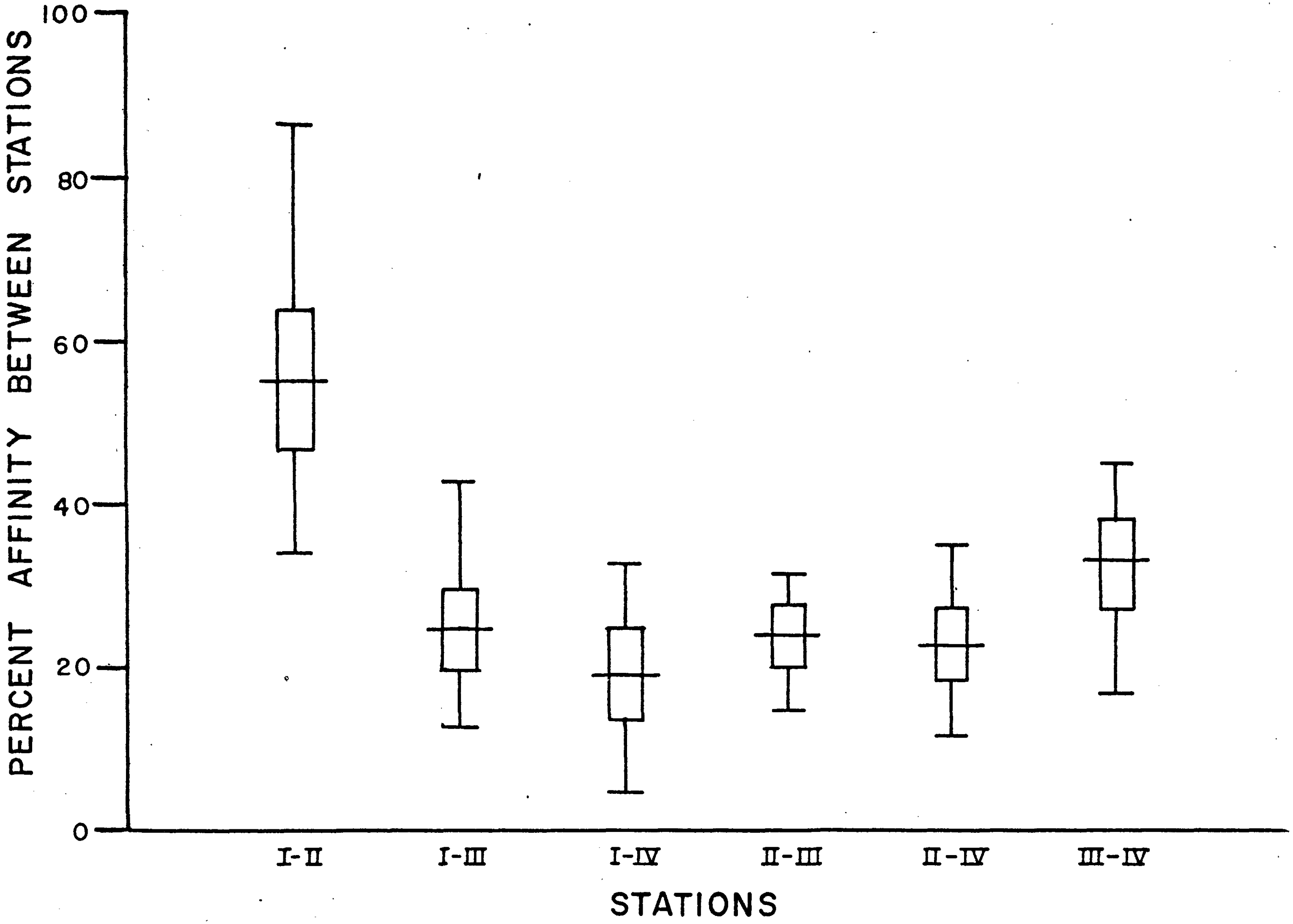

Figure 6. Ranges, means and 95% confidence intervals of the mean ($\bar{x} \pm t_{0.05} S_{\bar{x}}$) of monthly percent affinity values between stations, February 1965-February 1966.

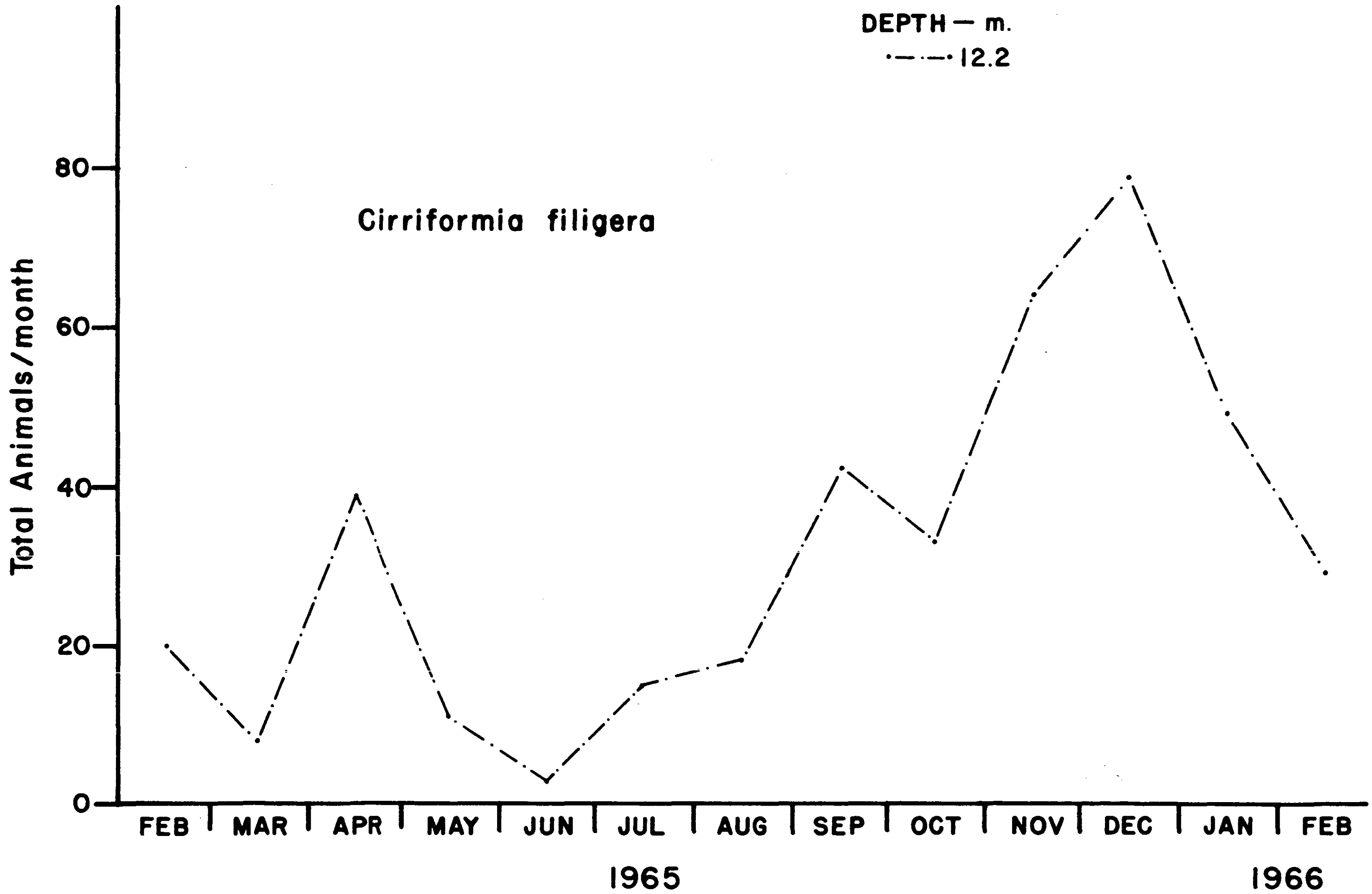

Figure 7. Seasonal distribution of *Cirriformia filigera* at 40 feet, York River, Yorktown, Virginia.

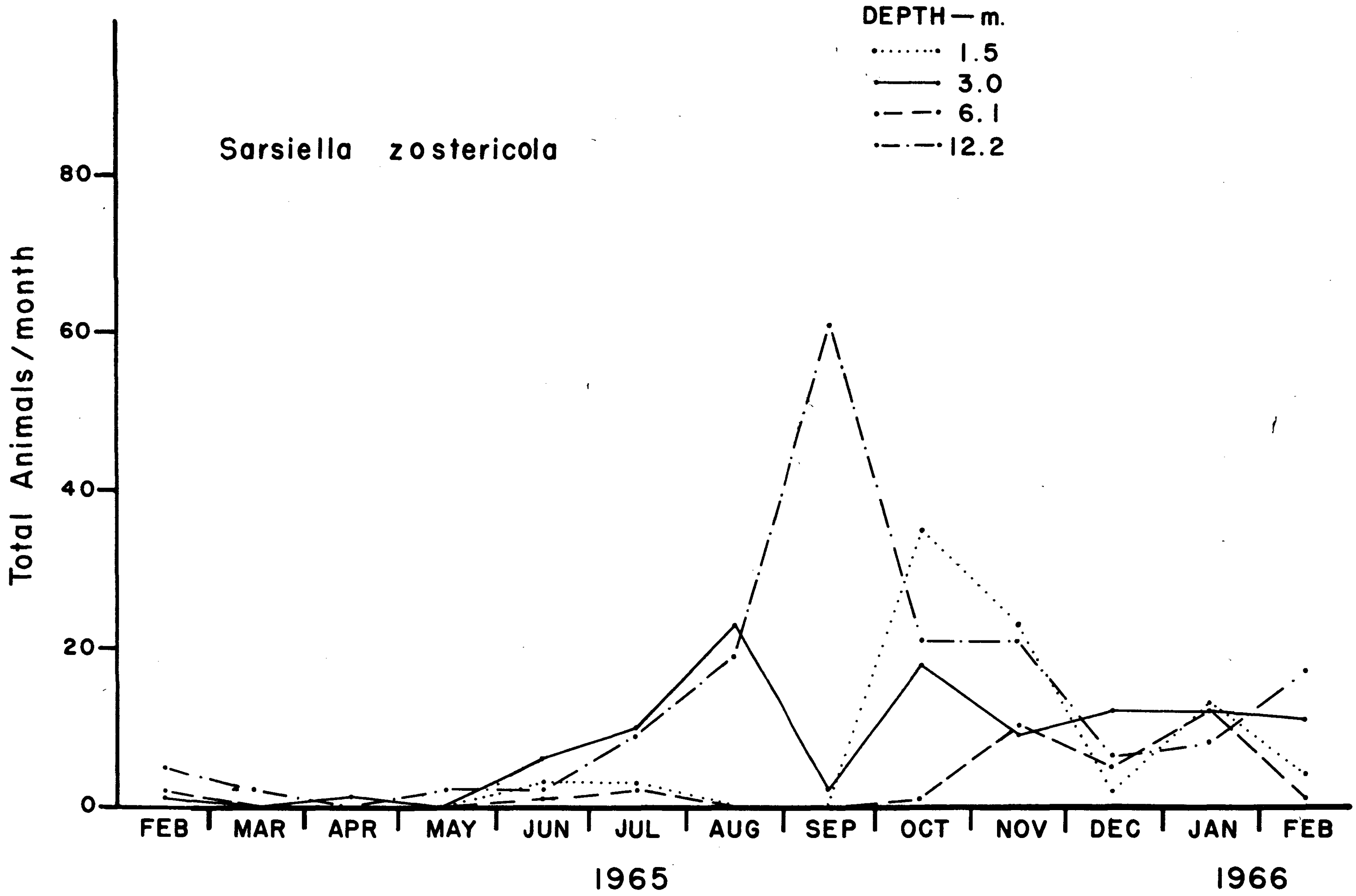

Figure 8. Seasonal distribution of *Sarsiella zostericola* at four depths, York River, Yorktown, Virginia.

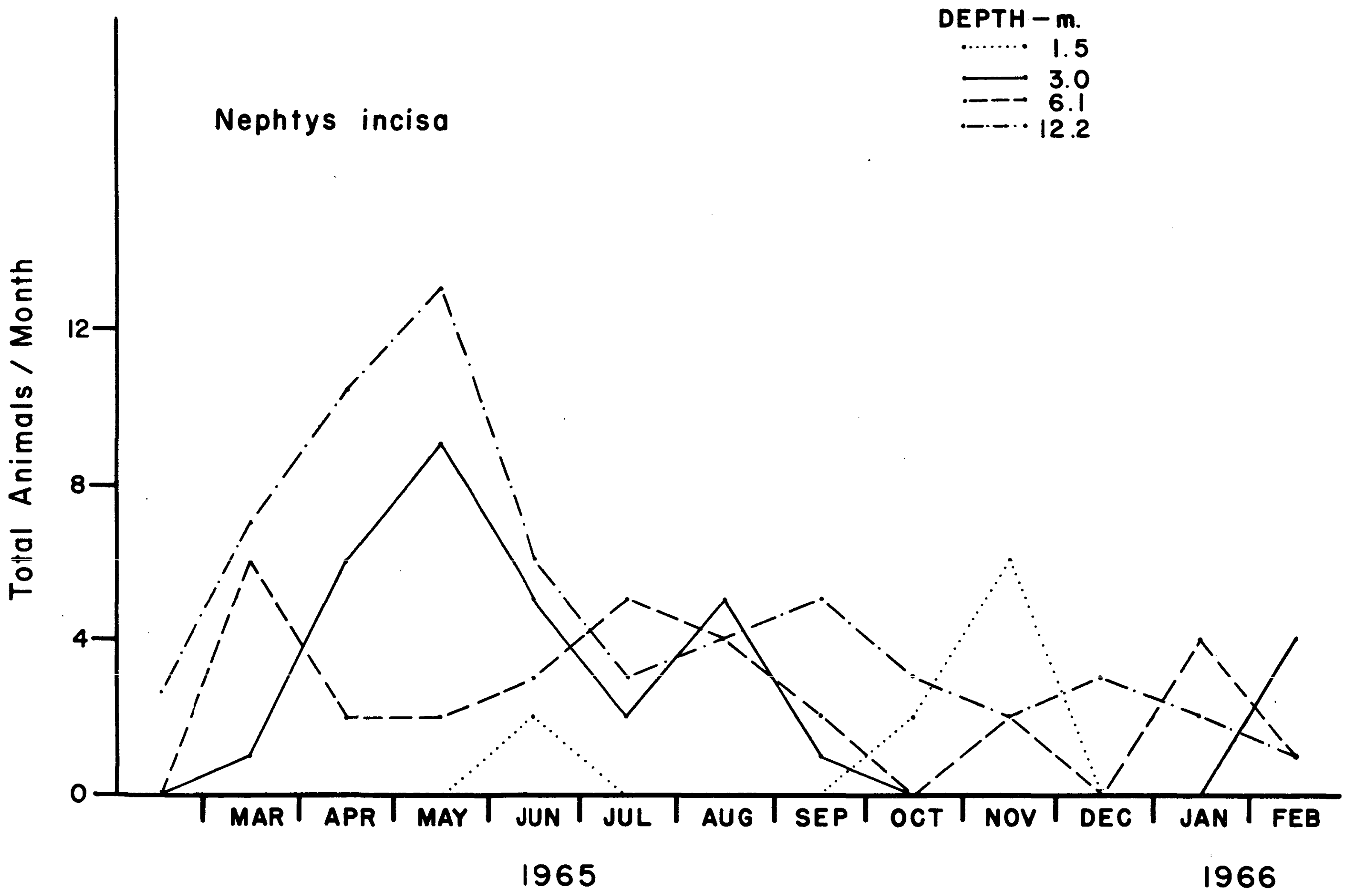

Figure 9. Seasonal distribution of Nephtys incisa at four depths, York River, Yorktown, Virginia.

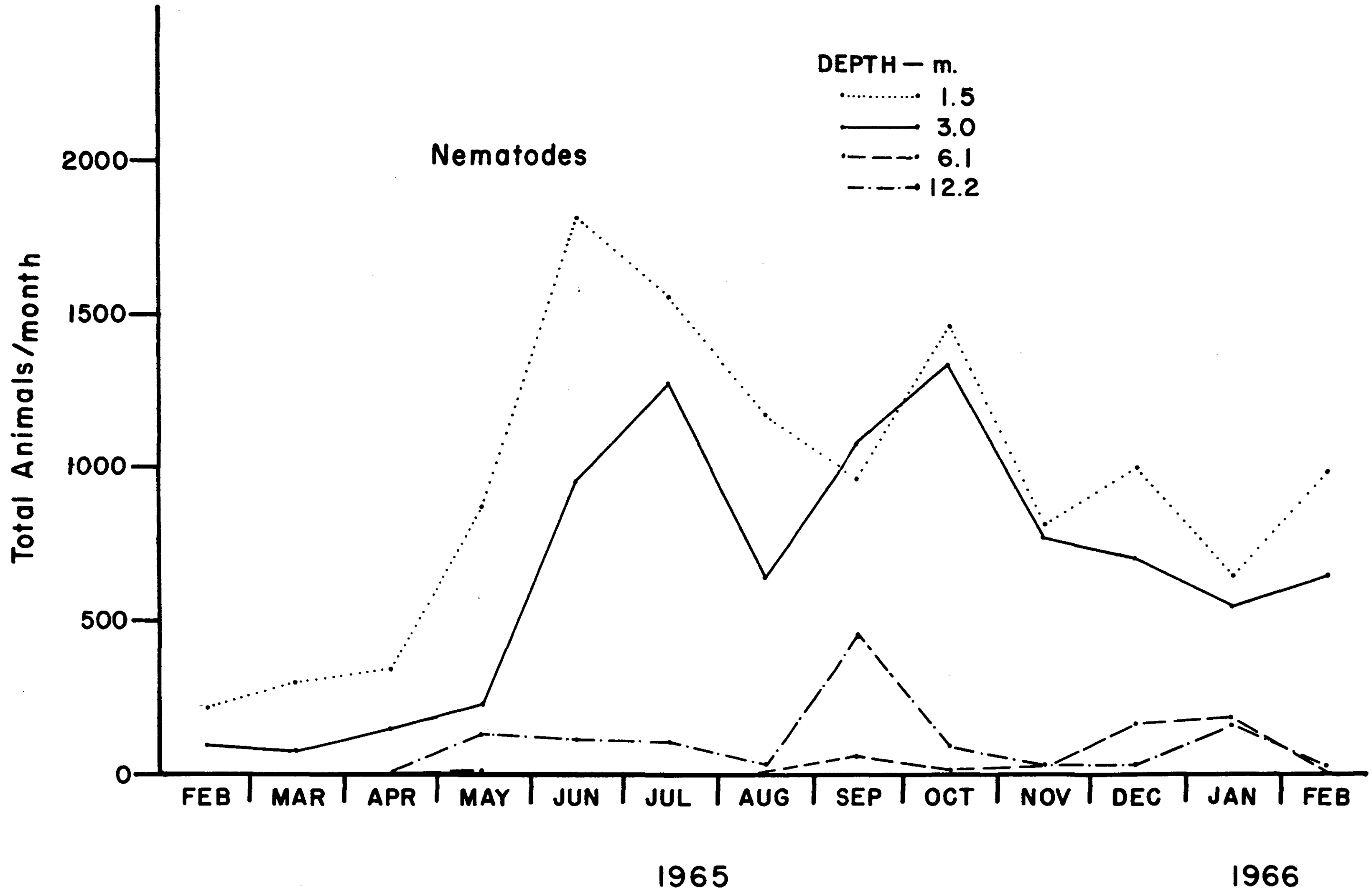

Figure 10. Seasonal distribution of nematodes at four depths, York River, Yorktown, Virginia.

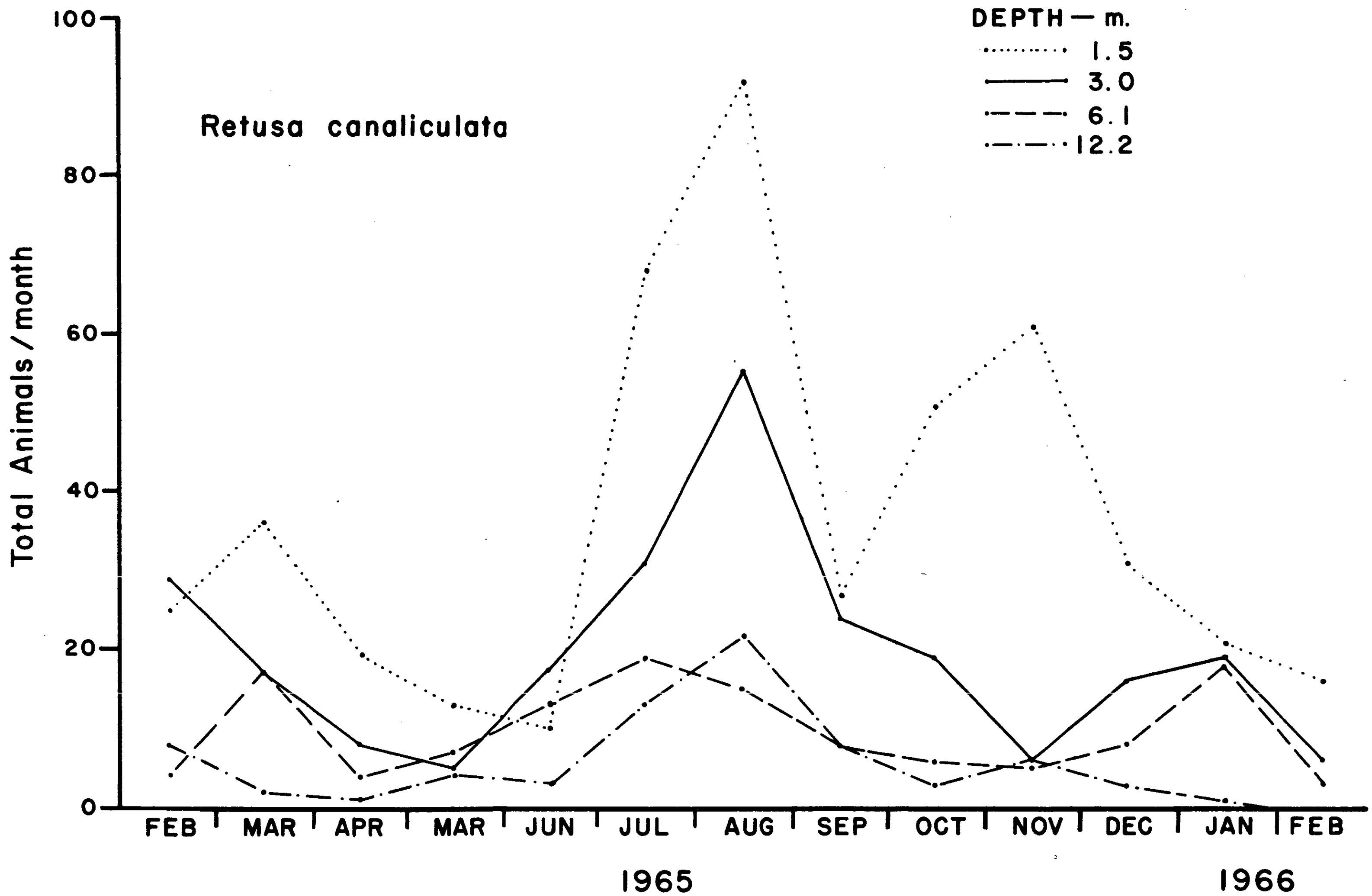

Figure 11. Seasonal distribution of <u>Retusa canaliculata</u> at four depths, York River, Yorktown, Virginia.

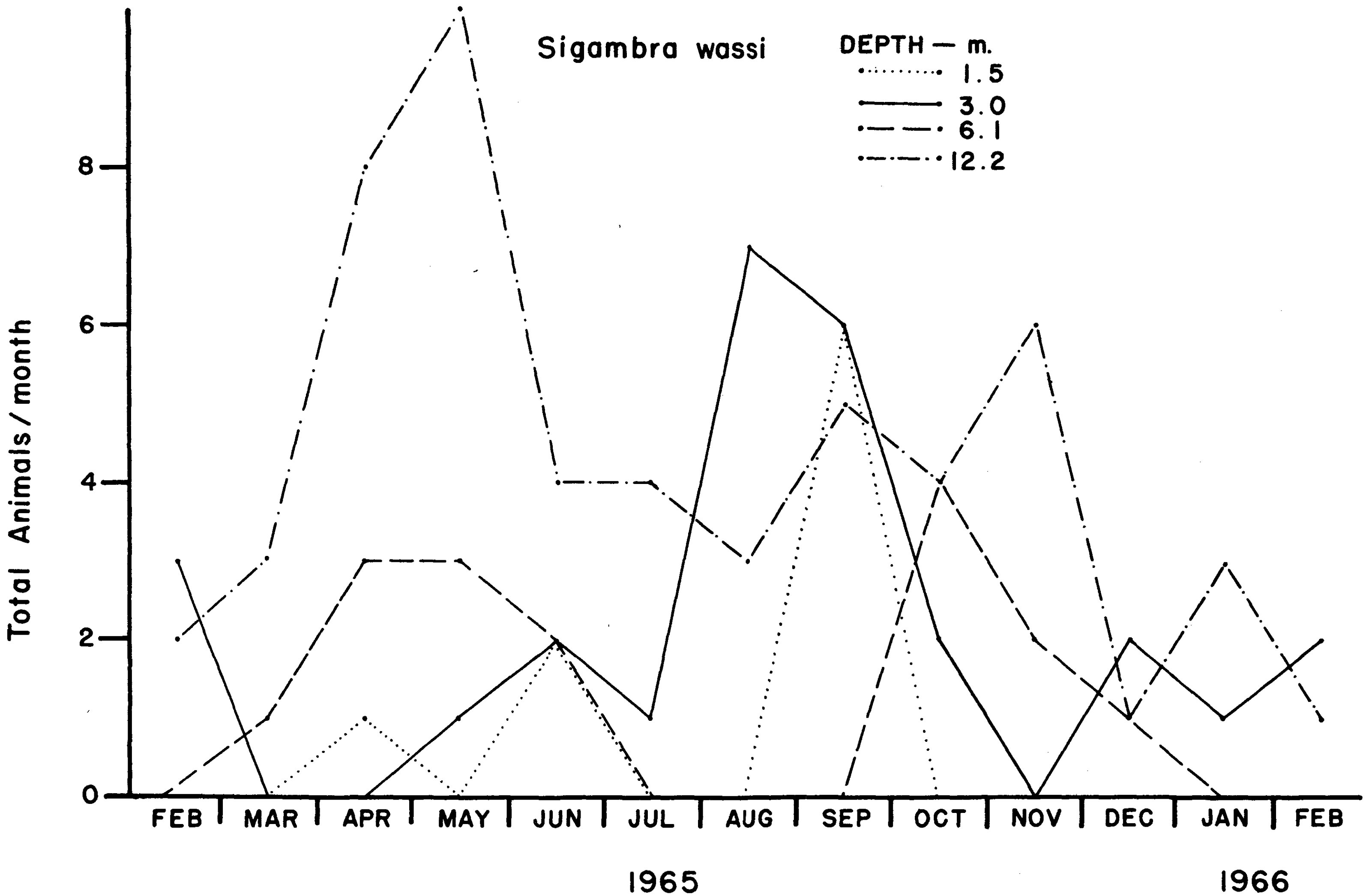

Figure 12. Seasonal distribution of Sigambra wassi at four depths, York River, Yorktown, Virginia.

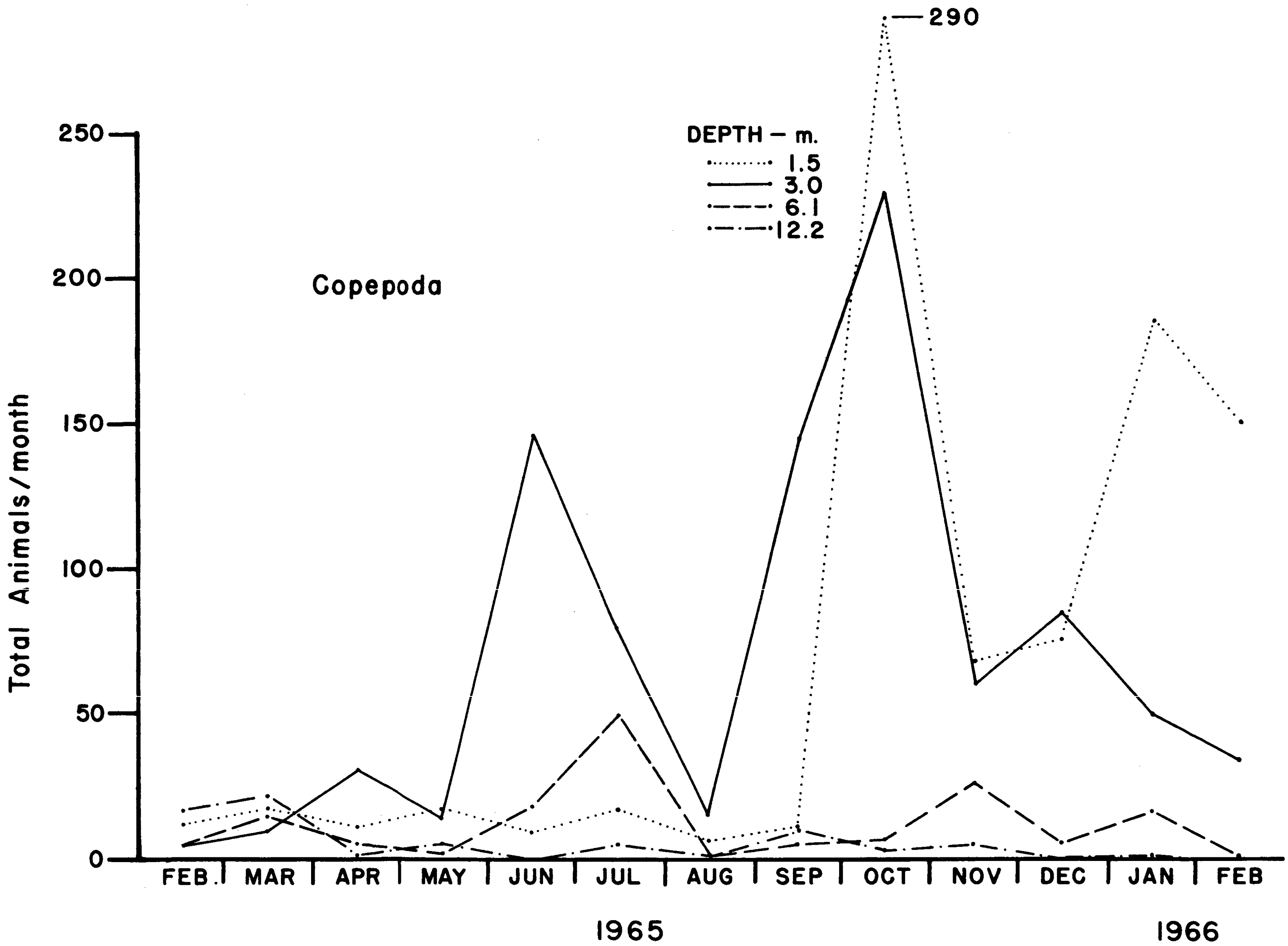

Figure 13. Seasonal distribution of Copepod at four depths, York River, Yorktown, Virginia.

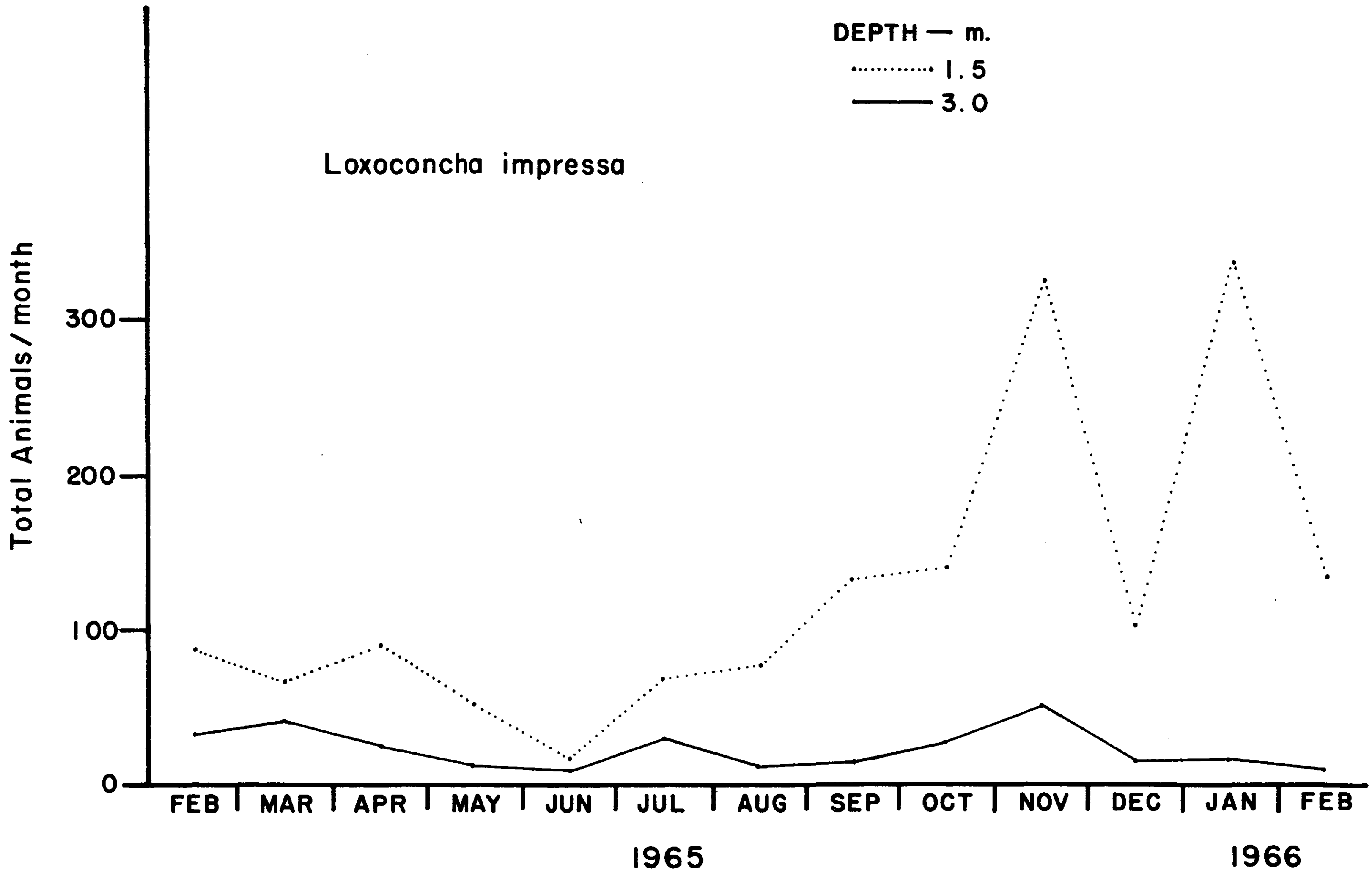

Figure 14. Seasonal distribution of Loxoconcha impressa at 5 and 10 feet, York River, Yorktown, Virginia.

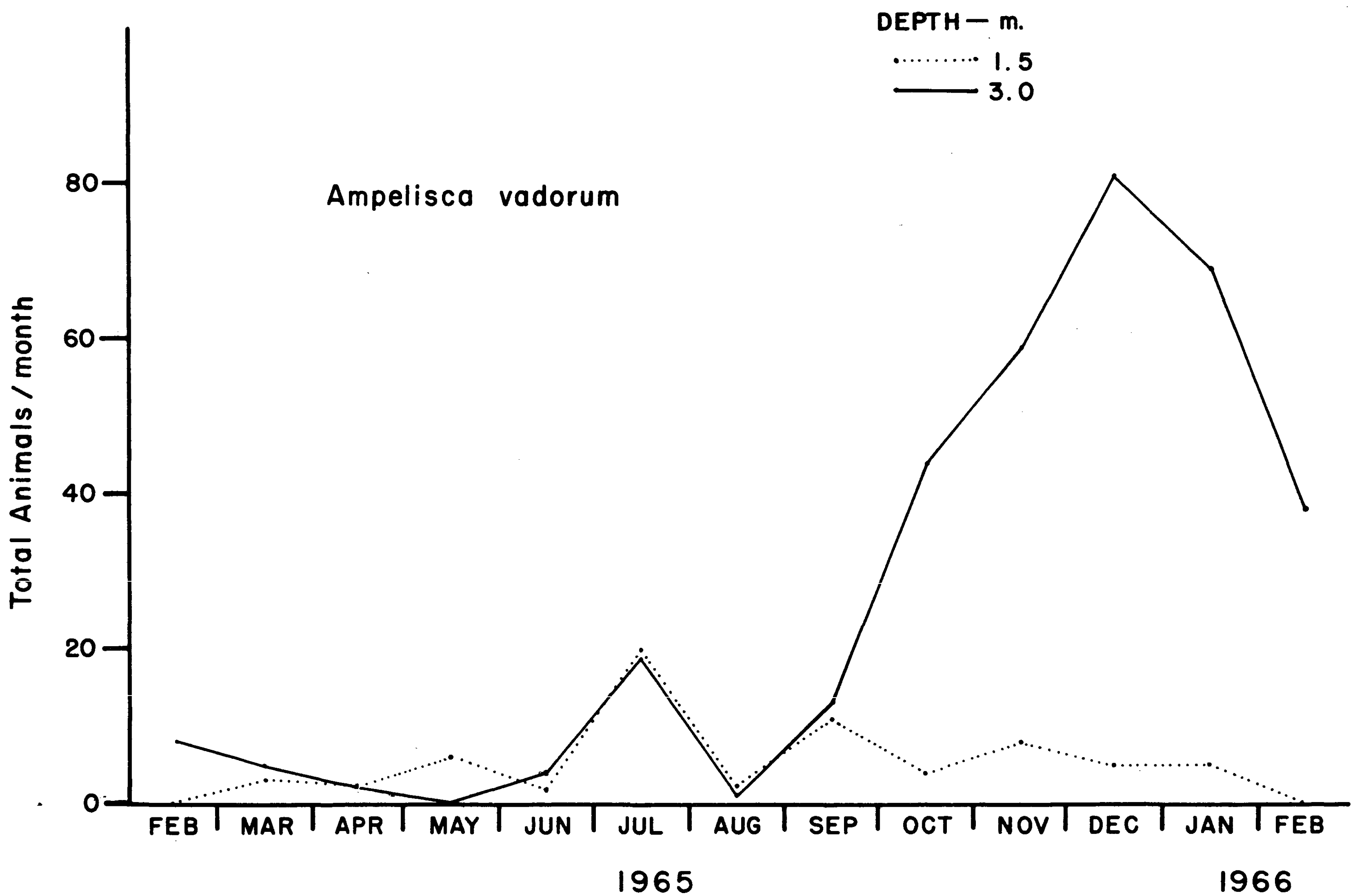

Figure 15. Seasonal distribution of Ampelisca vadorum at 5 and 10 feet, York River, Yorktown, Virginia.

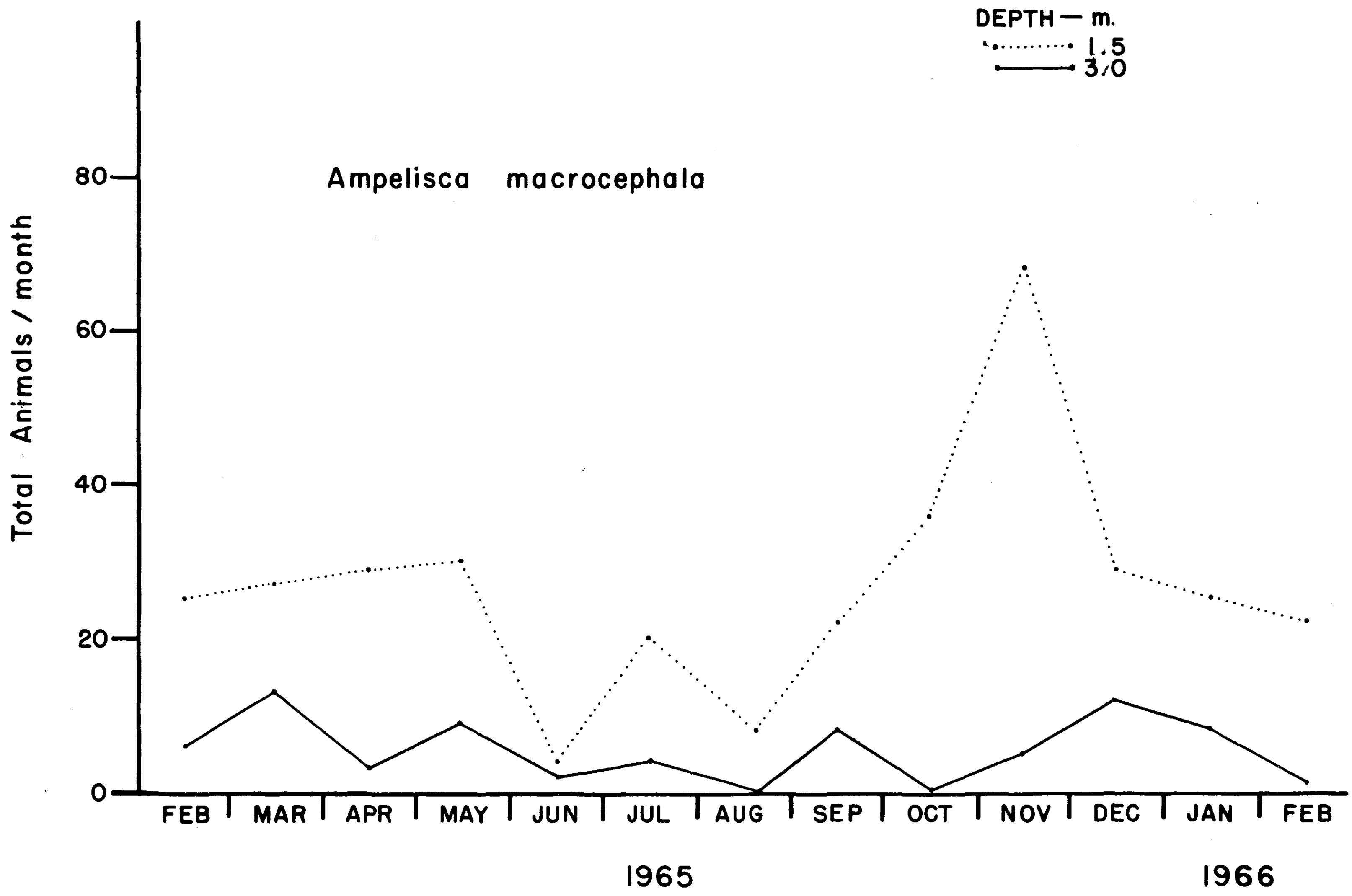

Figure 16. Seasonal distribution of Ampelisca macrocephala at 5 and 10 feet, York River, Yorktown, Virginia.

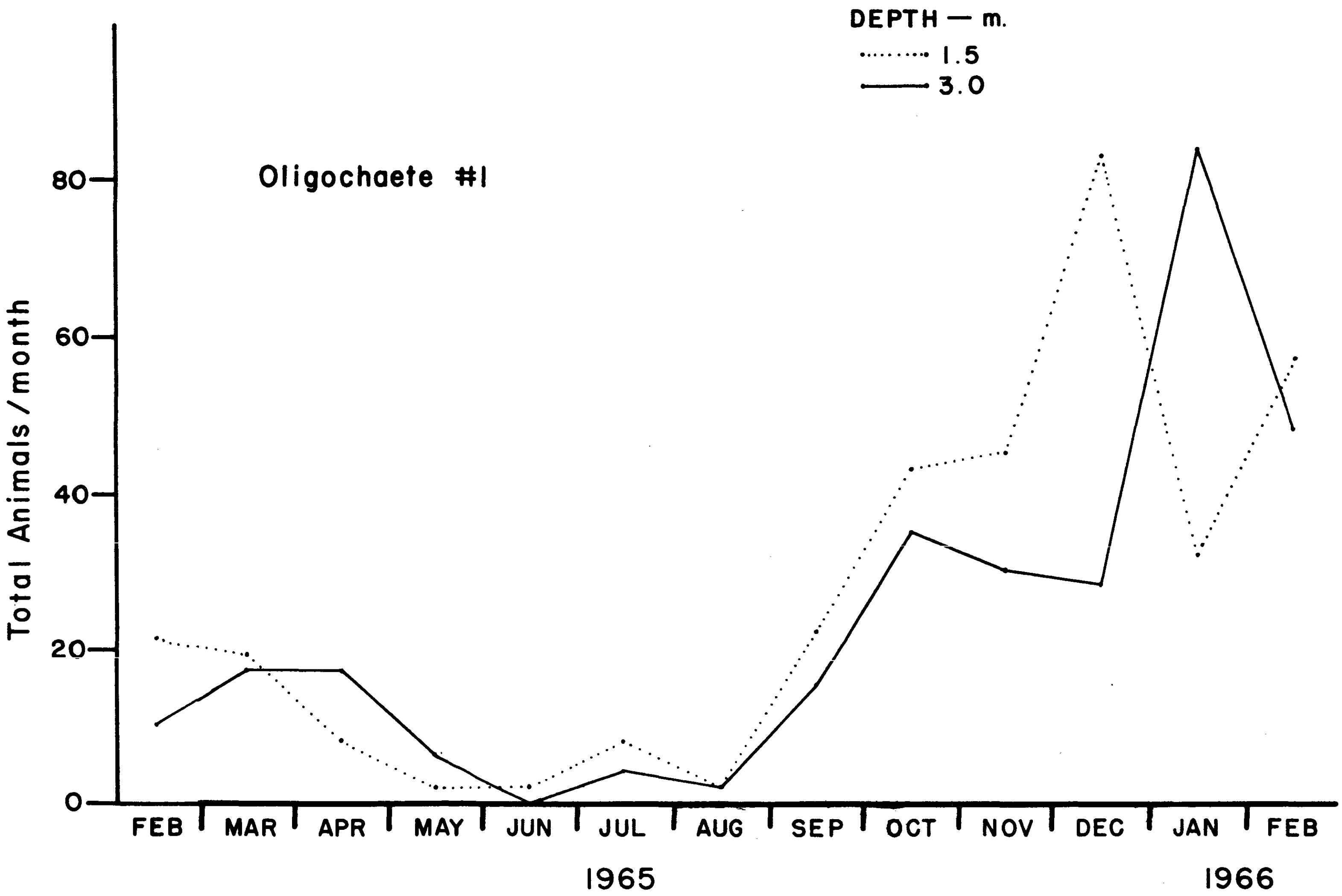

Figure 17. Seasonal distribution of Oligochaete #1 at 5 and 10 feet, York River, Yorktown, Virginia.

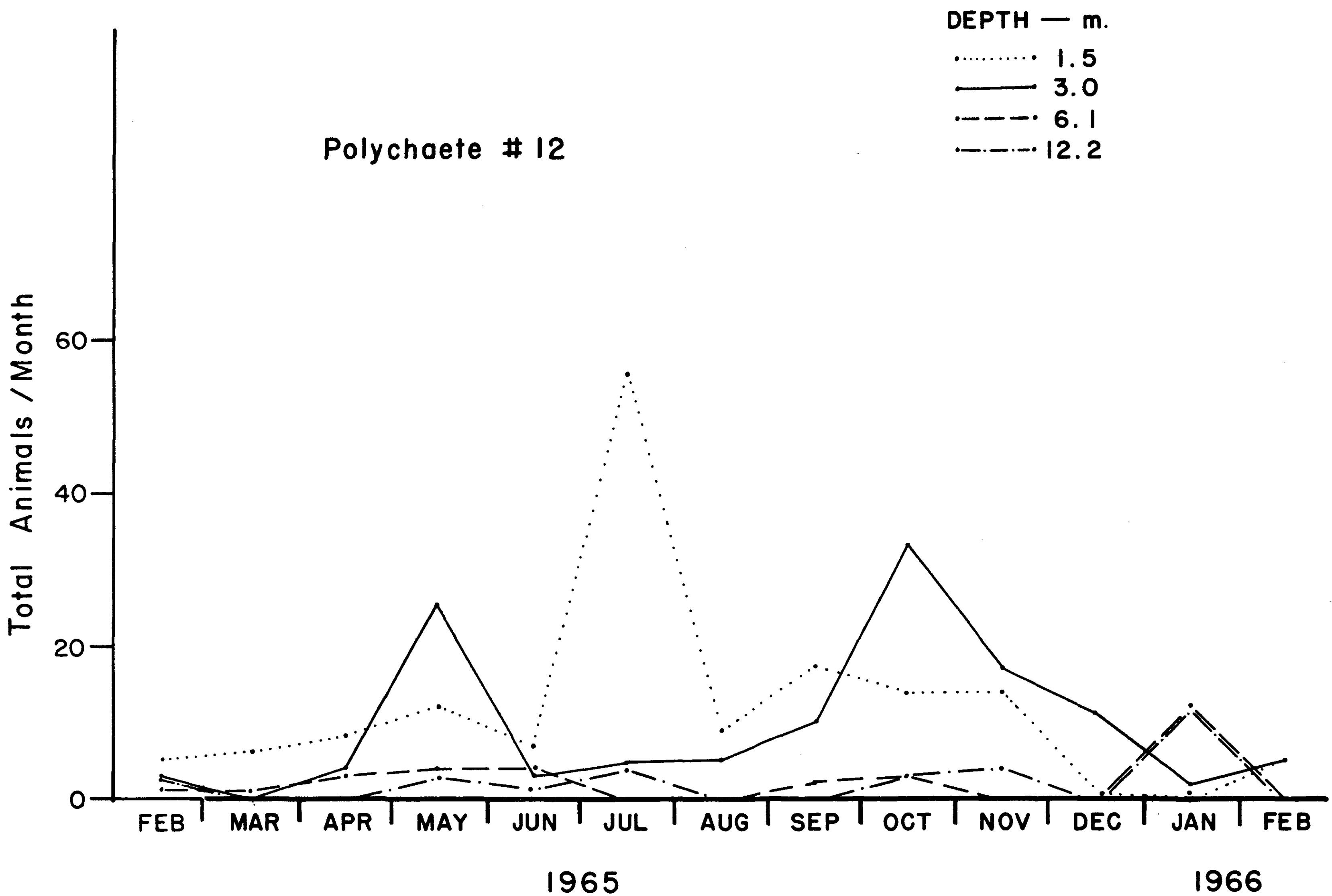

Figure 18. Seasonal distribution of Polychaete #12 at four depths, York River, Yorktown, Virginia.

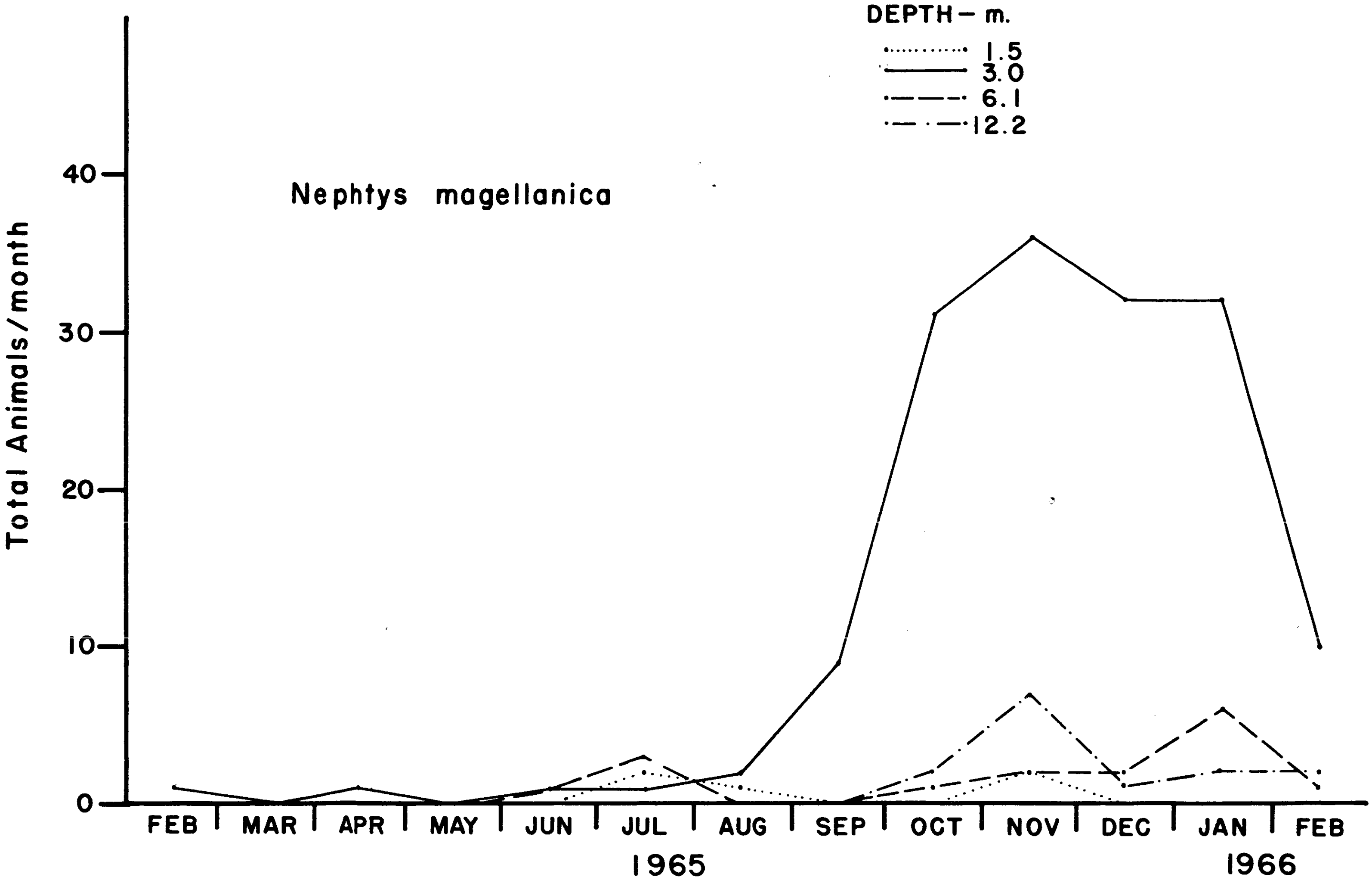

Figure 19. Seasonal distribution of Nephtys magellanica at four depths, York River, Yorktown, Virginia.

APPENDIX

Taxonomic Code and List of Animals Collected off Yorktown, Virginia, 1965-1966. Listed updated in March 1981. Numbers in parentheses are old code numbers which have not been updated.

	Genus and Species	VIMS Taxonomic Code
Forams	Elphidium incertum	3454300109
	Ammonia (Streblus) beccarii	3103250101
Porifera	Halichondria bowerbanki	3203080101
Cnidaria	Ceriantheopsis americanus	3303900101
	Diadumene leucolena	3303430101
	Edwardsia sp.	3303400000
	Hydroid	3301000000
Turbellaria		3500000000
Nematoda		4400000000
Nemertea	Amphiporus bioculatus	4002030101
	Cerebratulus lacteus	4001030101
	Cerebratulus luridus	4001030102
	Cerebratulus sp.	4001030100
	Nemertean fragment	4001030000
Bryozoa	Alcyonidium verrilli	6601010103
Phoronida	Phoronis architecta	6501010101
Aschelminthes	Nectonema sp. larvae	(0801)
Oligochaeta	Peloscolex sp.	4853010200
	Oligochaete #1	(1002)
	Oligochaete #4	(1003)
	Oligochaete #5	(1004)
Polychaeta	Asabellides oculata	4812020101
	Melinna maculata	4812020301
	Pseudoeurythoe sp.	4807010300
	Arabella iricolor	4806040101
	Drilonereis longa	4806040202
	Capitella capitata	4803030101
	Heteromastus filiformis	4803030201
	Notomastus latericeus	4803030301
	Polychaete #12	(2044)
	Polychaete #16	(2045)

Polychaeta	Chaetopterus variopedatus	4805050101
	Spiochaetopterus oculatus	4805050201
	Paleanotus heteroseta	4802040101
	Cirriformia filigera	(2071)
	Glycera americana	4802140101
	Glycera dibranchiata	4802140102
	Glycinde solitaria	4802150101
	Gyptis vittata	4802090201
	Podarke obscura	4802090401
	Lumbrinereis tenuis	4806030101
	Clymenella torquata	4803050101
	Maldanopsis elongata	4803050201
	Aglaophamus verrilli	4802130101
	Nephtys incisa	4802130202
	Nephtys magellanica	4802130203
	Nephtys picta	4802130204
	Nereis succinea	4802120403
	Diopatra cuprea	4806010101
	Scoloplos robustus	4809010202
	Scoloplos fragilis	4809010201
	Pectinaria gouldii	4812010101
	Eteone heteropoda	4802050102
	Phyllodoce arenae	4802050501
	Sigambra wassi	4802100302
	Cabira incerta	4802100201
	Harmothoe sp.	4802020100
	Lepidametria commensalis	4802020201
	Lepidonotus sp.	4802020300
	Sabellaria vulgaris	4805060101
	Polydora ligni	4805020202
	Paraprionospio pinnati	4805020401
	Brania sp.	4802110200
	Exogone dispar	4802110301
	Exogone hebes	4802110303
	Exogone verugera	4802110302
	Polychaete #26	(2245)
	Amphitrite ornata	4812030101
	Loimia medusa	4812030301
	Polychaete #24	(2261)
	Polychaete #25	(2262)
	unidentified polychaete	(2263)
Gastropoda	Teinostoma cryptospira	4904350301
	Solariorbis infracarinata	4904350201
	Cyclostremiscus pentagona	4904350101
	Bittium alternatum	4904470102
	Epitonium rupicolum	4904500102
	Crepidula convexa	4904550102
	Urosalpinx cinerea	4904740201
	Astyris (Mitrella) lunata	4904760201
	Ilyanassa vibex	4904800101

Gastropoda	*Acteon punctostriatus*	4905010101
	Haminoea solitaria	4905120101
	Retusa canaliculata	4905130201
	Odostomia bisuturalis	4905150101
	Odostomia dux	4905150103
	Odostomia impressa	4905150102
	Pyramidella fusca	4905150202
	Turbonilla interrupta	4905150301
	Turbonilla stricta	4905150302
Pelecypoda	*Anadara transversa*	4908220101
	Lucina multilineata	4908500101
	Montacuta elevata	4908530101
	Mercenaria mercenaria	4908550301
	Petricola pholadiformis	4908560101
	Tellina agilis	4908570101
	Macoma tenta	4908570203
	Ensis directus	4908710101
	Mulinia lateralis	4908720201
	Mya arenaria	4908750101
	Lyonsia hyalina	4908800101
	unidentified pelecypod	4908000000
Arthropoda	*Cylindroleberis mariae*	5303010101
	Cythereis emarginata	(5102)
	Loxochoncha impressa	5303260101
	Sarsiella texana	5303020101
	Sarsiella zostericola	5303020102
	Copepoda	5305000000
	Chthamalus fragilis	5307100101
	Neomysis americana	5313010101
	Oxyurostylis smithi	5314030201
	Leptochelia rapax	5315010102
	Edotea triloba	5316020401
	Erichsonella attenuata	5316020201
	Idotea baltica	5316020301
	Sphaeroma quadridentatum	5316240302
	Ampelisca macrocephala	5317020104
	Ampelisca vadorum	5317020102
	Batea catharinensis	5317100101
	Caprella penantis	5317810201
	Caprella equilibra	5317810202
	Gammarus mucronatus	5317210301
	Cerapus tubularis	5317150101
	Cerophium tuberculatum	5317150204
	Cymadusa compta	5317040201
	Listriella clymenellae	5317330202
	Parametopella cypris	5317440101
	Unciola irrorata	5317150402
	Amphipod #25	5317000000
	Callinectes sapidus	5319580301

Arthropoda	Ogyrides limicola	5319160102
	Pagurus longicarpus	5319440205
	Pinnixa chaetopterana	5319620201
	Pinnixa sayana	5319620205
	Halacaridae	5110010000
Echinodermata	Cucumaria pulcherrima	6804010101
	Leptosynapta tenuis	6804500101
	Amphiodia atra	6803210201
Hemichordata	Saccoglossus kowelewskii	6901010101
	Stereobalanus sp.	6901010201
Pisces	Anguilla rostrata	7902010101
	Gobiosoma bosci	7950010301
	Symphurus plagiusa	7958040101