Ecological and Behavioural Studies on Harpacticoid Copepoda in the Intertidal Zone at Ardmore Point, Clyde Estuary, with some Observations on the Anatomy of Tachidius discipes.

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Being a thesis submitted for the degree of Doctor of Philsophy in the University of Glasgow.

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ABSTRACT

The present work was carried out between 1985 and 1990, mainly on harpacticoid copepods collected from Ardmore Bay, Clyde Estuary, Scotland. The purpose of this work was to determine the annual cycle of population density of sediment dwelling harpacticoids in the intertidal zone in Ardmore Bay, to compare in detail the summer and winter population densities of harpacticoid and nematode populations in the intertidal zone and to relate these to particle size parameters, and to conduct behavioural studies on sedimentary harpacticoid copepods collected from the intertidal zone at Ardmore. Some preliminary taxonomic work is also described on the external anatomy of Calanus finmarchicus, a taxonomic description is given of the intertidal sand- dwelling harpacticoid, Tachidius discipes, and the anatomy of the two species is compared.

Scanning electron microscopy showed differences between the two species Calanus finmarchicus and Tachidius discipes. The body of Calanus finmarchicus is smooth, the abdomen is much narrower than the thorax, the first antenna is as long as the body length, and few hairs are present on the external side of the exopodites and endopodites of the legs. The body of Tachidius discipes is broadly elongated, having 9 segments. The abdomen is thinner than the thorax, and long setae are carried by the caudal rami. The thoracic segments have hairs along their posterior margins which may keep the joints between the segments clean and also aid in movement through the sediment. The five pairs of legs have spines and setae which are likely to be important in moving between sediment grains. The setae at the distal end of the legs are also likely to be important in swimming when the adults emerge from sediments. In contrast, Calanus finmarchicus, which is entirely pelagic, is smoother and has no spines but many setae on its legs, which are clearly an adaptation for swimming.

The annual survey of harpacticoids at Ardmore Bay showed that at low and mid

tide population densities were low in winter and high in summer. At high tide there was a peak in autumn (October) and spring (February). Copepodites were abundant throughout the year at low tide, but at mid tide peaked in winter (December, January). Virtually no copepodites were found at high tide. The high tide population may therefore be replenished from the low and mid tide regions. During the survey, adults and copepodites were found to be most abundant in the top 2 cm of sediment.

Detailed comparisons of harpacticoids, nematodes and particle size in summer and winter were conducted at five stations on a transect from high tide to low tide at Ardmore Bay and showed that the summer population of harpacticoids and nematodes was much higher than winter population at all five stations. Nematodes were more abundant at deeper depths in the sediment in winter than summer, suggesting a downward migration to avoid cold winter temperatures. In contrast to harpacticoids, nematodes although more abundant near the sediment surface occurred to a depth of at least 14 cm. The high tide stations tended to have finer sediments with larger standard deviations (less well sorted), and lower kurtoses (less peaked). There were fewer differences in particle size parameters vertically into the sediment, and more between summer (July) and winter (January). Harpacticoids were restricted to sediments having a narrower range of mean particle size than were nematodes. Harpacticoids and nematodes were most abundant in sediments having intermediate standard deviations and a high negative skewness.

The behaviour experiments showed that harpacticoid copepods migrate out of sediments into the overlying water in the dark. This is considered to be an important dispersal mechanism. Vertical migration out of the sediments is inhibited by light, by high and low temperatures (20°C, 5°C), and low salinities. This has important ecological implications because it means that vertical migration into the water column and hence dispersal will be inhibited during daylight, and also during hot summers and cold wet winters.

GENERAL SUMMARY

The main objective of my work has been to study the taxonomy, ecology, and behaviour of harpacticoid copepods at Ardmore Point. I also conducted some preliminary work on the anatomy of the calanoid copepod, Calanus fimarchicus. These studies are divided into the following sections:

Section 1: Calanus finmarchicus. Mouth parts such as maxillae and maxilliped, first and second antenna and first and fifth limbs have all been dissected. Instruments such as needles and scalpels were used. Drawings of limbs, mouth parts, and abdomen have then been constructed on graph paper from the dead preserved animals using a calibrated eyepiece graticule and a light microscope. This was to obtain a full description for this species.

Section 2: Tachidius discipes. Mouth parts and limbs (P1-P5) of the dead animals were dissected following the same procedures for Calanus finmarchicus. Drawing of mouth parts and the five limbs were constructed as above in order to obtain a full description for this species.

The body of Calanus finmarchicus is smooth, the abdomen is much narrower than the thorax, the first antenna is as long as the body length, and few hairs are present on the external side of the exopodites and endopodites (P1-P5). The body of Tachidius discipes is broadly elongated, having 9 segments. The abdomen is thinner than the thorax, and long setae are carried by the caudal rami. The thoracic segments have hairs along their posterior margins which may keep the joints between the segments clean and also aid in movement through the sediment. The five pairs of legs have spines and setae which are likely to be important in moving between sediment grains. The setae at the distal end of the legs are also likely to be important in swimming when the adults emerge from sediments. In contrast, Calanus finmarchicus, which is entirely pelagic, is smoother and has no spines but many setae on its legs,

which are clearly an adaptaion for swimming.

Section 3: Annual survey. This section is divided into two parts:

Part 1: Annual survey on harpacticoid copepods (adults and copepodites) for six separate months (October 1986, December 1986, February 1987, April 1987, June 1987, August 1987). This study was conducted at low tide, mid tide, and high tide. Comparisons between months at each tidal level, and between tidal levels at each month were made in the top 1 cm where the animals are more abundant. The results were analysed statistically.

There were obvious annual cycles in the abundance of adults and copepodites during the sampling period. At the low tide site, numbers were low in the winter months of December, January, and February and high in the summer months of June, July, and August. The annual cycle at the mid tide site was broadly similar. However, at high tide numbers were highest in October with a secondary peak in February and there were low numbers in December and April to June. The abundance of copepodites at low tide were very high throughout the year while at mid tide they peaked in December and January. Virtually no copepodites were found at high tide. This suggests that the high tide population of adult harpacticoids may be periodically replenished from the low and mid tide region of the shore.

The depth distribution of both adults and copepodites in the sedimentary column show that most individuals were found within 2 cm of the sediment surface.

Part 2: Comparisons between winter (January 1987) and summer (July 1987) in terms of harpacticoid copepods, nematodes, and particle size. This study was conducted at five stations at all depths for harpacticoid copepods and nematodes. For particle size all five stations were analysed but only at depths of 0-1, 3-4, 7-8, and 13-14 cm.

At all five stations harpacticoids were more abundant in July than January. Nematodes were most abundant in July than January near the sediment surface, but

deeper in the sediment were more abundant in January than in July. This probably means that nematodes migrate downwards during winter months to avoid the cold surface sediment. In general, nematodes occurred much deeper in the sediment than the harpacticoids, and extended to a depth of more than 14 cm.

The high tide stations tended to have finer sediments with larger standard deviations (less well sorted), and lower kurtoses (less peaked). There were fewer differences in particle size parameters vertically into the sediment, and more between summer (July) and winter (January). These differences are to be expected because the high tide area is exposed to less wave activity than lower on the beach.

There were some correlations between the abundances of harpacticoids and nematodes and the particle size parameters. Harpacticoids were restricted to sediments having a narrower range of mean particle size than were nematodes. Harpacticoids and nematodes were most abundant in sediments having intermediate standard deviations rather than in sediments having very small or very large standard deviations. Both harpacticoids and nematodes were more abundant in sediments having a high negative skewness.

Section 4: Behaviour experiments (light, temperature, salinity). Experiments were carried out in the laboratory to determine the effects of light, temperature, salinity, and a combination of temperature and salinity on the behaviour of harpacticoid copepods. The conclusion of this section can be summarized as follows:

1. Experiment 1. This tested how quickly animals come up into the overlying water in the dark. The results showed that the number of animals increased in the overlying water as time progressed.

2. Experiment 2. This tested how quickly animals burrow into the sediment in the light. The results showed that most of the animals reacted to light negatively by burrowing into the sediment.

3. Experiment 3. This tested the effect of various light intensities on harpacticoid copepods. At high intensity (3000 lux) the animals burrowed into the sediment more quickly than at intermediate (550 lux). While at low intensity (10 lux), the animals burrowed into the sediment at a much slower rate than in either of the high or intermediate intensities.

4. Experiment 4. This tested the effect of three temperatures (20°, 10°, and 5°C) on harpacticoids in the dark. Animals emerged most quickly from the sediment at 10°C, followed by 20°C and then 5°.

5. Experiment 5. This tested the effects of various salinities (100%. 50%, 25%, 10%, 1%) on harpacticoid copepods in the dark. This showed that the number of animals in the overlying water increased as salinity increased.

6. Experiment 6. This tested the effect of changing salinity in the overlying water on the number of animals emerging in the dark. It showed that as the salinity of the overlying water was reduced the number of animals emerging from the sediment decreased.

7. Experiment 7. This tested the effect of combinations of temperature and salinity (5°C, 10°C, 20°C and 100%, 25%, 1%) on the emergence of the animals from the sediment in the dark. It showed that the optimum combination was 10°C and salinity of 100%.

8. The results of the behaviour experiments have been discussed in relation to the distribution of harpacticoids in the intertidal zone. It is concluded that vertical migration from the sediments into the water column at night may be an important dispersal mechanism. Temperature and salinity effects on vertical migration in the laboratory experiments suggest that in the field less vertical migration, and hence less dispersal, will occur when the temperature is high (20°) or low (5°) and when salinity

is reduced. This means that less dispersal will take place in hot summers and particulary in the cold winters.

GENERAL INTRODUCTION

The order Copepoda belongs to the class Crustacea which live in seas, lakes, and ponds, where they play an important role in aquatic food chains. Crustacea are a class of the Arthropoda which is the largest phylum in the animal kingdom. Copepods are probably the most numerous animals in the world, and all of them are small (under 5 mm in length). There are about 6000 species found in freshwater, and in the sea. Many copepods are a pelagic forming the majority of the zooplankton, but some are benthic and live in sediments (Barnes, 1980).

The body of copepods is usually regarded as having three sections. These are the head, the thorax, and the abdomen which has four segments plus anal segment bearing furcal rami. This division is based on the development of the embryo during the nauplius and copepodid stages.

The cephalothorax consists of the head and thorax. It has an ovate shape, and is usually more robust than the abdomen. Copepods have a dorsal carapace that extends over the head and one or two segments of the thorax. The head and the thorax have appendages, but the abdomen has none. The head has a simple or nauplius eye with three ocelli. Further generalisations, that would apply to all the Sub-Orders of the Copepoda, are difficult to make. The order Copepoda is divided into seven suborders: the Cyclopoida, the Calanoida, the Harpacticoida, the Notodelphyoida, the Monstrilloida, the Caligoida, and the Lernaeopodida.

The present work was carried out between 1985 and 1990, mainly on harpacticoid copepods collected from Ardmore Point, Clyde Estuary, Scotland. The purpose of this work was to determine the population density of sediment dwelling harpacticoids in the intertidal zone in this area, to give a taxonomic description of the intertidal sand-dewlling harpacticoid, Tachidius discipes, and to conduct behavioural studies on

sedimentary harpacticoid copepods. Some preliminary taxonomic work was also done on Calanus finmarchicus.

The results in the thesis are divided into 4 sections as follows:

1 - Calanus finmarchicus.

2 - Tachidius discipes.

3 - Annual survey: Part 1. Ecological study of harpacticoid copepods (Oct. 86, Dec. 86, Feb. 87, Apr. 87, Jun. 87, Aug. 87) at Ardmore Point.

Part 2. A comparative study between winter (January 87) and summer (July 87) of Harpacticoids, nematodes, and particle size.

4 - Behaviour experiments (light, temperature, salinity).

Note 1 Statistical analyses used in the thesis. A number of different parametric and non-parametric tests have been used at various points in the thesis. When necessary, the data have been transformed before application of the parametric tests. The parametric tests used were one way analyses of variance, the student t-test, and regression and correlation analyses. The probability scale and associated levels of significance used throughout the thesis are:

P	Significance
$P>0.10$	Not significant
$P<0.05$	Significant

Note 2 Detailed introductions with references are given at the beginning of each section. My thesis is a long one. I have therefore kept the introductions and discussions as short as is scientifically reasonable, while at the same time covering the literature and its relevance to my work to the best of my ability.

Section (1)

Taxonomy of Calanus finmarchicus

INTRODUCTION

Calanus finmarchicus (Gunnerus) belongs to the family Calanoidae and Order Calanoida. Marshall and Orr (1955) stated that this species was the first pelagic marine copepod to be described: it was collected from the sea a little south of Hammerfest in northern Norway (Finmark) in 1767 and was called Monoculus finmarchicus by its discoverer Gunnerus (1770) Bishop of Nideros (Trondheim). This species was named with different names by different workers. In 1865 Boeck redefined the genus (although not as fully as Claus) and united the identified Calanus finmarchicus with Cetochilus helgolandicus Claus. The name Cetochilus gradually fell out of use and in Giesbrecht's great monograph of 1892 the synonymy was classified and Calanus finmarchicus finally accepted as the correct name. The detailed taxonomy of Calanus finmarchicus established by Gunnerus (1770) was followed by a number of authors (Claus, 1863; Brady, 1876; Grobben, 1881; Giesbrecht, 1892; Giesbrecht and Schemil 1898; Sars, 1901; Sars, 1903; With, 1915; Lebour, 1916; Currie, 1918; Somme, 1934; Lowe, 1935; Jeeps, 1937a; Farran revised by Vervoort, 1951; Barnes and Barnes, 1953; Jaschnov, 1955; Marshall and Orr, 1955; Jaschnov, 1972). These works include general morphology, size, and external and internal anatomy of copepodites and adults.

The species is the main food of herring and is one of the largest calanoids. It is a common species in the northern North Sea and around Scotland. It is also found in the Bristol Channel and Irish Sea (Newell and Newell, 1963).

MATERIALS and METHODS

Water samples containing animals were collected in October 1985 from Millport Bay, Clyde Estuary, Scotland using different types of nets (coarse, medium, fine). The nets were backwashed to collect the animals into jars (1000 ml). The samples were brought to the laboratory within 3 hours of collection. In the laboratory, the samples volume was reduced to approximately 200 ml. This was done by filtering the samples. The samples were preserved by concentrated Steedman's solution (1:9) (Steedman 1976).

Animals were examined using a binocular microscope and compound microscope. Representatives specimens were also examined by Scanning Electron Microscopy using standard techniques (dehydration, critical point drying, and gold coating).

A number of animals were dissected under the binocular microscope before giving taxonomic drawings of Calanus finmarchicus for this thesis. This was to obtain experience of the species anatomy and dissecting.

Drawings were carried out on tracing paper placed on squared graph paper (A3) using a binocular or compound microscope as approporiate. An eyepiece scale was calibrated with the micrometer stage before hand. The tracing paper was inked and the details were then drawn.

RESULTS

Detailed descriptions of the anatomy of the adults of Calanus finmarchicus are given by Brady (1876), Giesbrecht (1892), Sars (1903), and Marshall and Orr (1954, 1955), and of the developmental stages by Claus (1863), Grobben (1881), Gran (1902), Lebour (1916), and With (1915). Some of these early references are difficult to obtain access to, and I have only been able to personally see Brady (1876), Giesbrecht (1892), Giesbrecht and Schmeil (1898), lebour (1916), Labbe (1927), and Marshall and Orr (1954,1955). The results of my anatomical studies of Calanus finmarchicus are shown in figures 1 to 8, and plates 1 to 10.

These results are divided into seven parts:

1-General size and shape of body

2-First antenna

3-Second antenna

4-Maxilliped

5-First leg

6-Fifth leg

7-Abdomen (urosome)

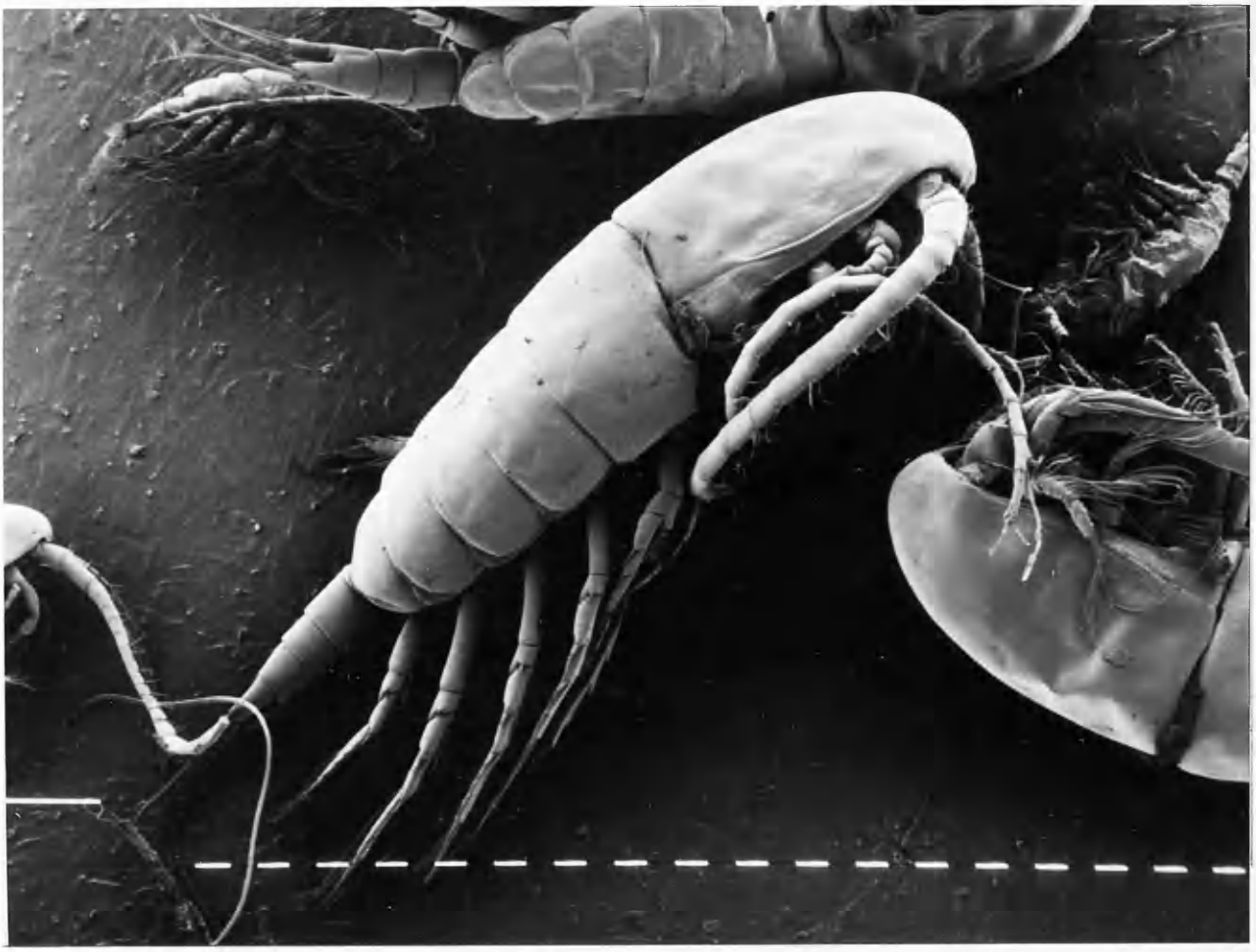
It should be noted that I have made no detailed study of the mouth parts or of legs 2 to 4. This is because I have not had time.

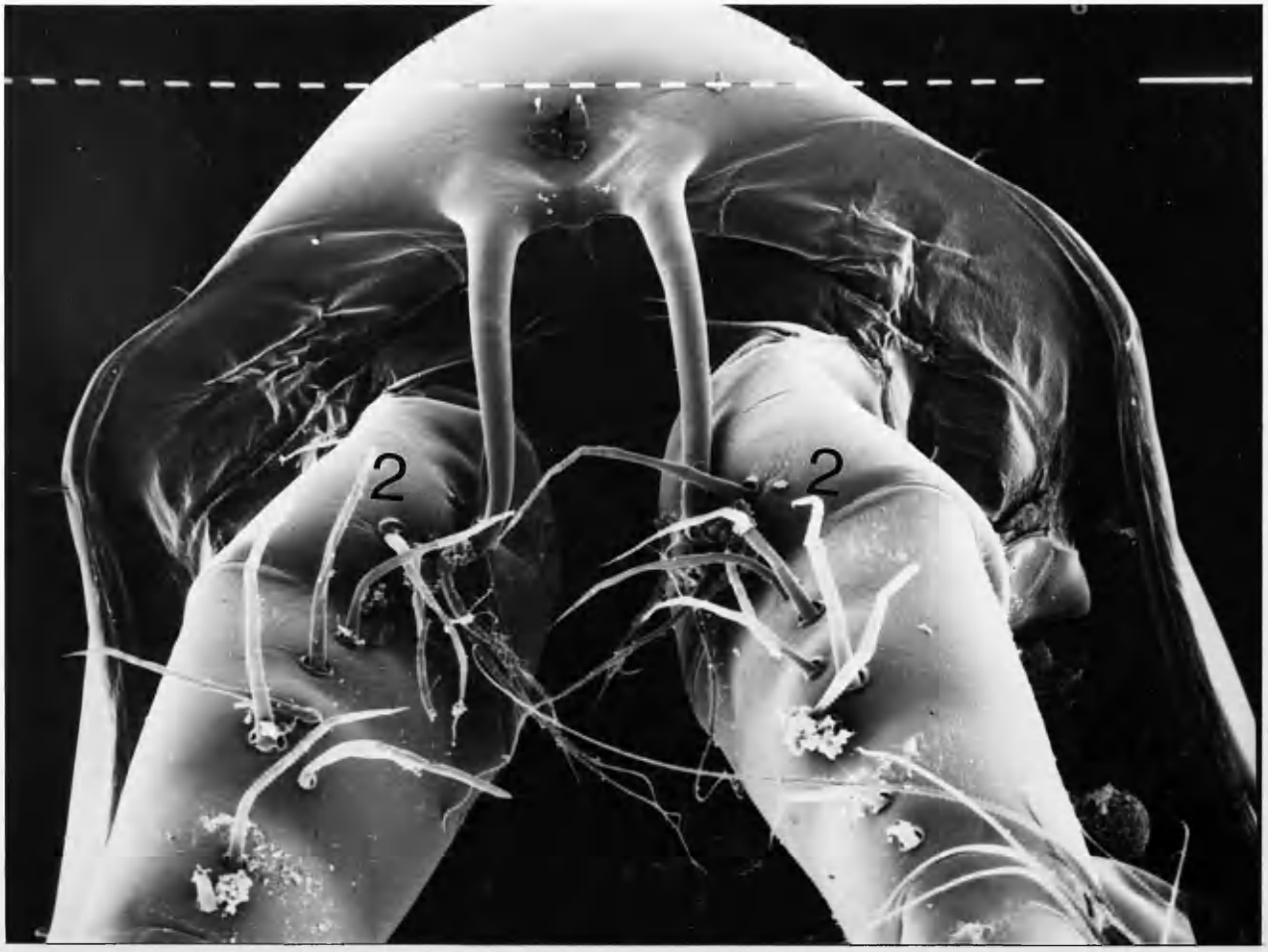
1 - General size and shape of body:

The body, which is elongated, is divided into three major parts: The head, cephalothorax, and abdomen (plate 1). The head is fused to the cephalothorax which is approximately equivalent to one third of the body length. There are five thoracic segments carrying five pairs of appendages. The fifth thoracic segment is ovate in shape (figure 1). The abdomen has five segments in the male and four in the female.

Plate 1. Calanus finmarchicus. Clyde Estuary. Female. General shape of the body. Note the right first antennae, the cephalothorax, five thoracic segments, four abdominal segments (female characteristic), and five paired appendages. Black lines between white dashes = 100 u

Plate 2. Calanus finmarchicus. Clyde Estuary. Male. Rostrum (1); fused first and second segments of the first antennae bearing sensory aesthetascs (male characteristic) (Marshall and Orr, 1955, pp.12) on their anterior surfaces (2); rostral filaments (3); right frontal organ (4). Black lines between white dashes = 10 u

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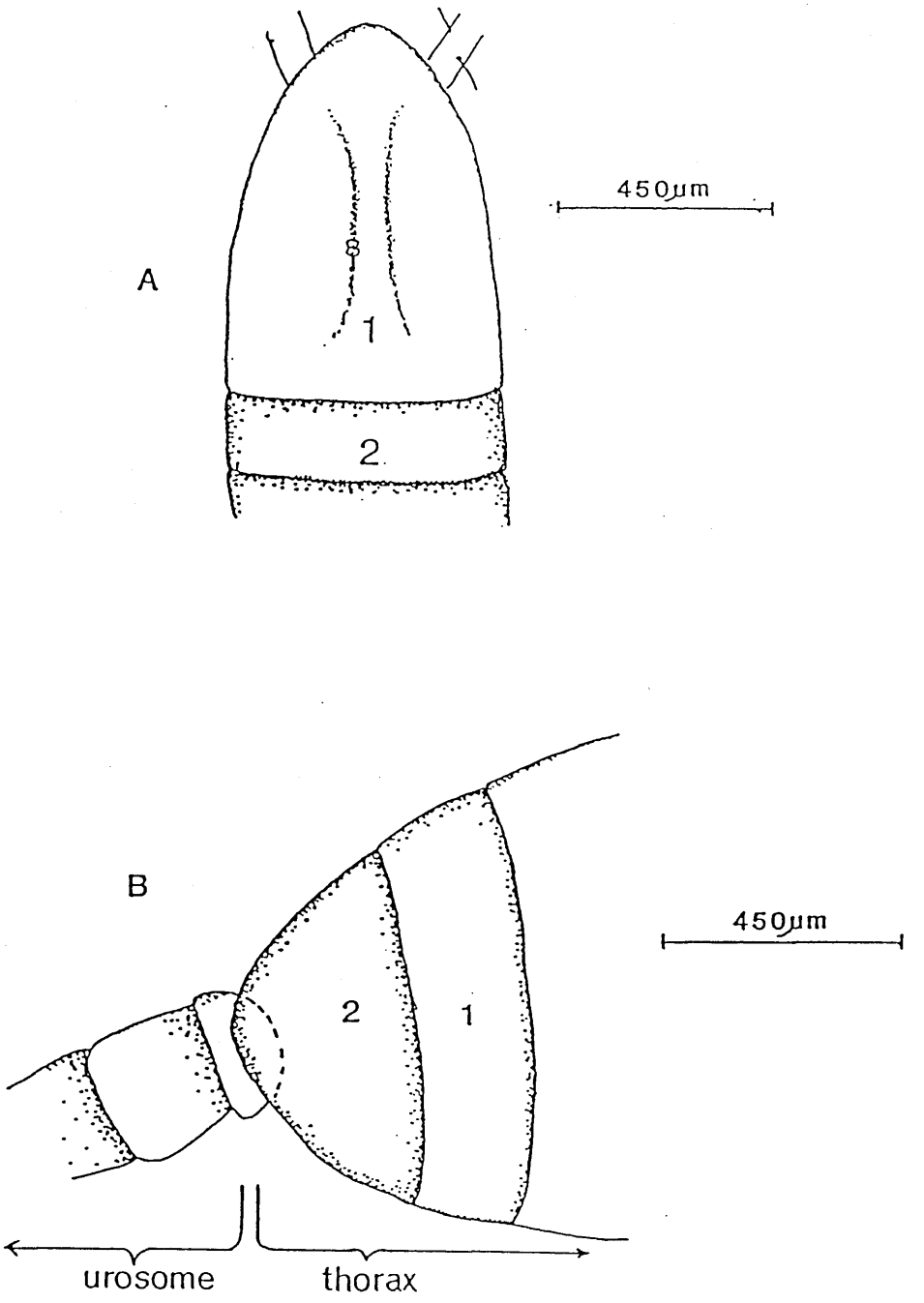

Figure 1. Calanus finmarchicus. Clyde Estuary. A: Cephalon (1), first thoracic segment (2), B: Fourth (1) and fifth (2) thoracic segments.

The length of the body is between 2.7 mm and 5.00 mm in the female, and between 2.4 mm and 3.6 mm in the male (Farrant revised by Vervoort, 1951).

2 - First antenna:

The first antenna (figure 2; plates 2(2), 3(1), 5(1)) reaches the last segment of the abdomen or the tail setae, and has a number of segments. The proximal part is thicker than the distal part. The antenna has a number of small hairs of different length. There are two long whip like-hairs at its distal end. The first hair is very close to a joint and the second one is on the middle of the next segment (figure 3 and plate 4) (arrowed). These hairs have spines. Farran revised by Vervoort (1951) stated the first antenna is composed of 24 joints, and that the hairs are present on the twenty second and twenty third joints. This agrees with my observations.

3 - Second antenna:

The second antenna (figure 4A; plates 3(2), 6) has an outer and inner branch. The outer branch is thicker than the inner, and has two joints or segments. The first segment is elongated, bearing one lateral long hair and 10 small spines. These spines are clearly seen in plate 6 (ringed). The second segment is smaller and carries a number of setae. The inner branch has seven joints or segments, four of which are short and close to each other. It bears long setae along most of its length.

4 - Maxilliped:

The maxillipeds are large uniramous limbs with 8-9 segments (figure 4B; plate 3(3)). Setae are present on the medial side of each maxilliped. The function of these setae is probably to filter food.

5 - First leg:

The first leg is made up of three parts. The proximal part is called the basipodite (figure 5; plate 5 arrowed) and has two segments, the first or basal segment is longer than the second, is fused to the same segment on the other side, and carries

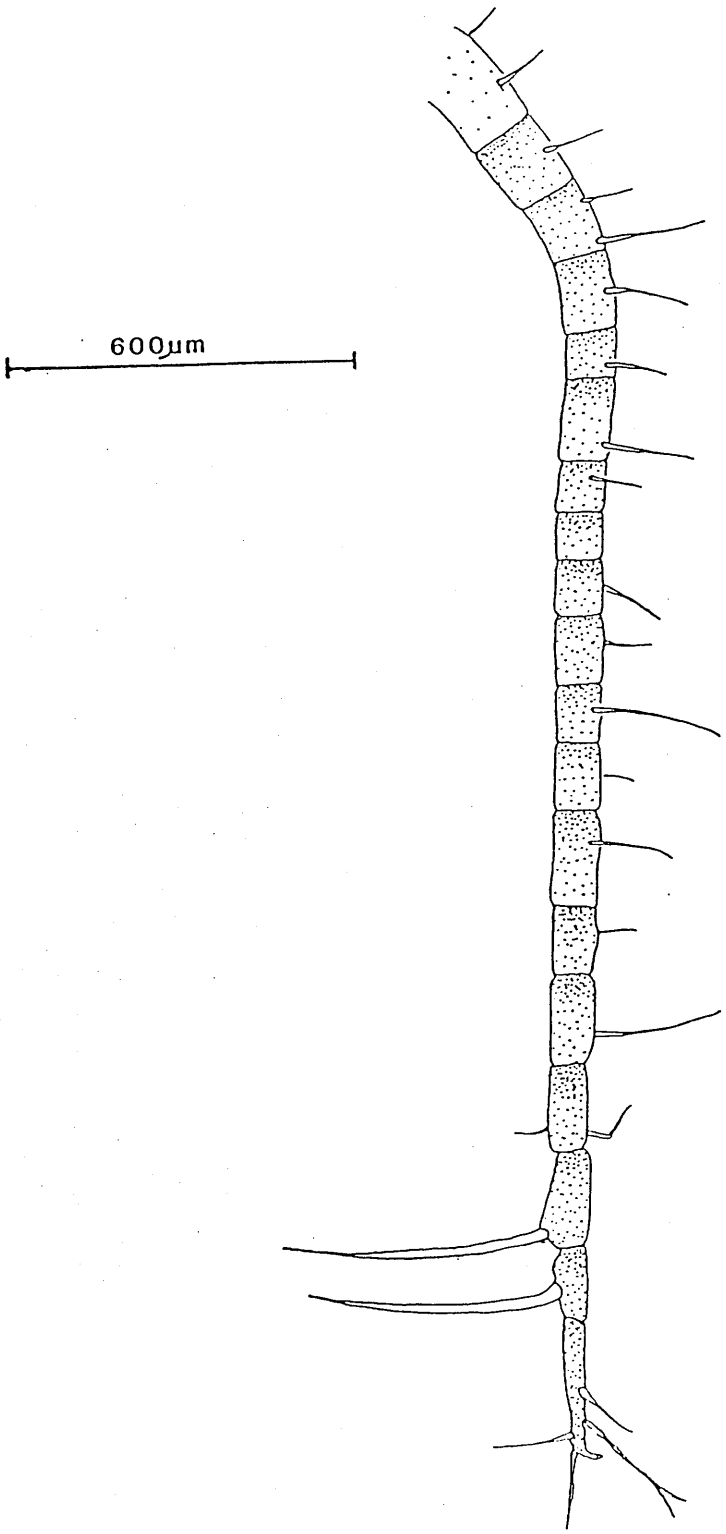

Figure 2. Calanus finmarchicus. Clyde Estuary. Female. First right antenna.

Plate 3. Calanus finmarchicus. Clyde Estuary. Male (because same specimen as in plate 2). First antenna (1), second antenna (2), maxilliped (3). Black lines between white dashes = 100 u

Plate 4. Calanus finmarchicus. Clyde Estuary. Female. Part of distal end of first antenna. Note two long whip-hairs (arrowed). Proximal hair longer than distal hair therefore female. Black lines between white dashes = 100 u


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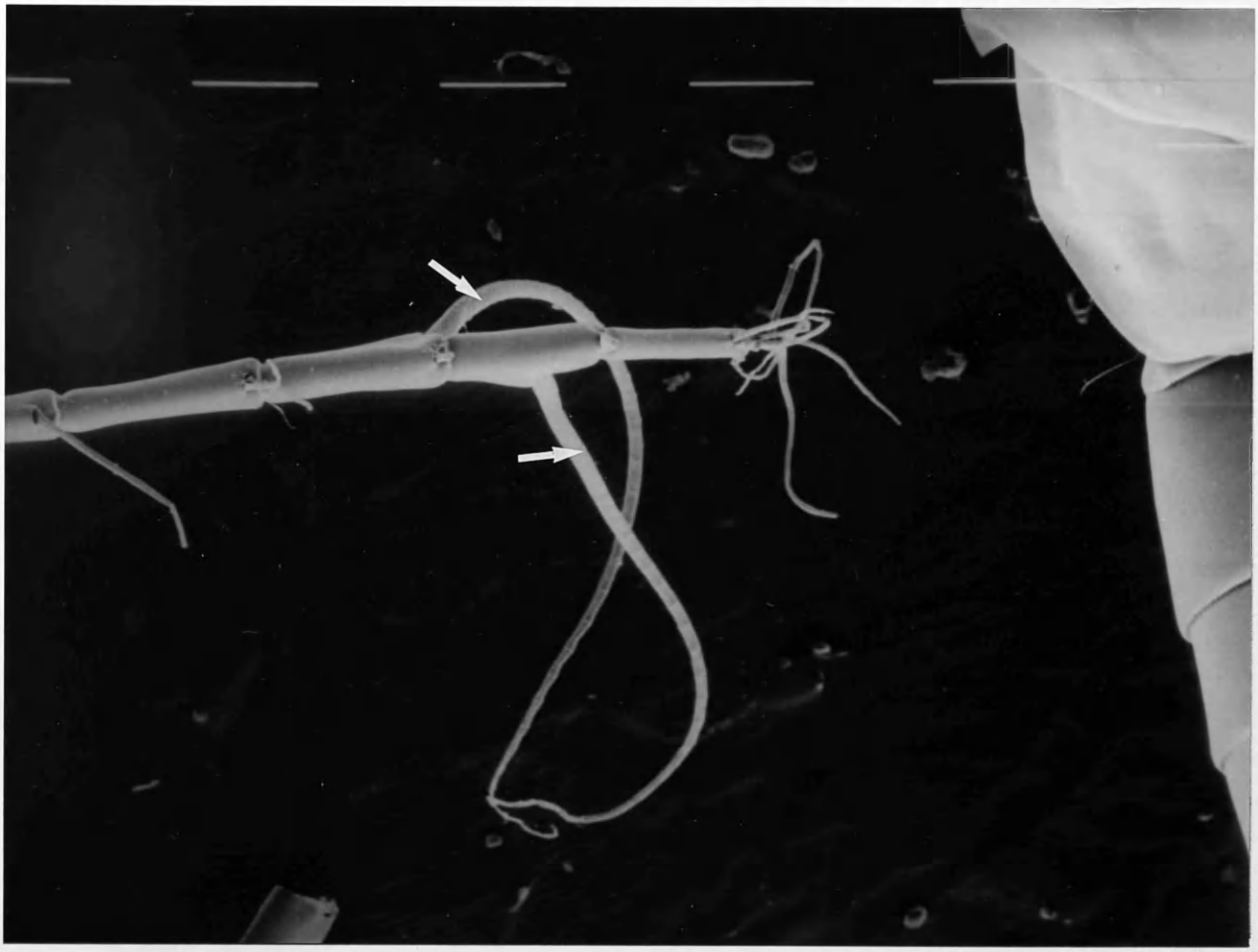
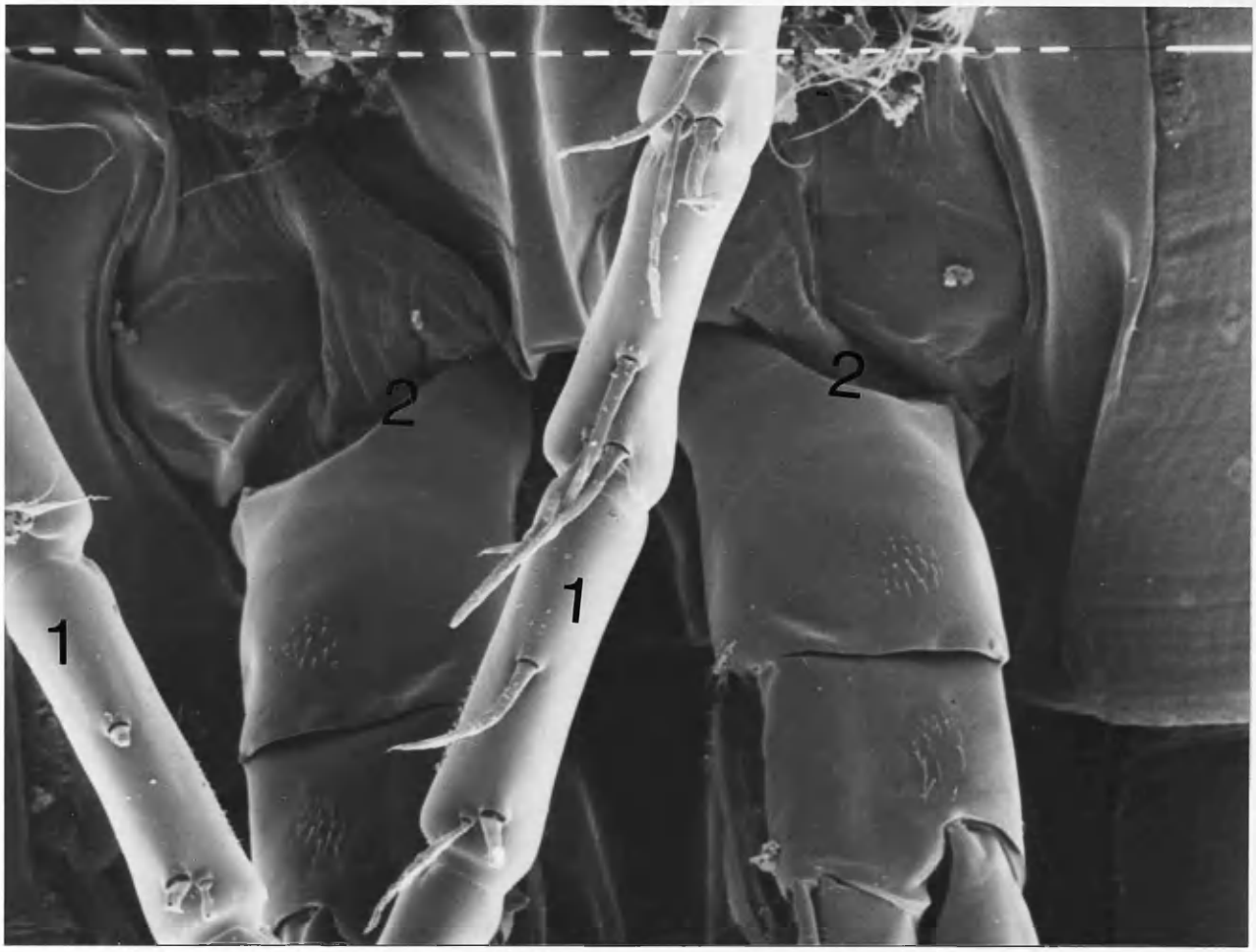


Plate 5. Calanus finmarchicus. Clyde Estuary. Sex unknown. Middle part of the first antenna (1), and basipodites (arrowed) of the first leg (2). Note the patch of short fine hairs on each of the four basipodite segments. Black lines between white dashes = 10 u

Plate 6. Calanus finmarchicus. Clyde Estuary. Sex unknown. Second antenna composed of outer branch (upper part of plate), and inner branch (lower part of plate). Note ten spines on first segment of outer branch (ringed). Black lines between white dashes = 10 u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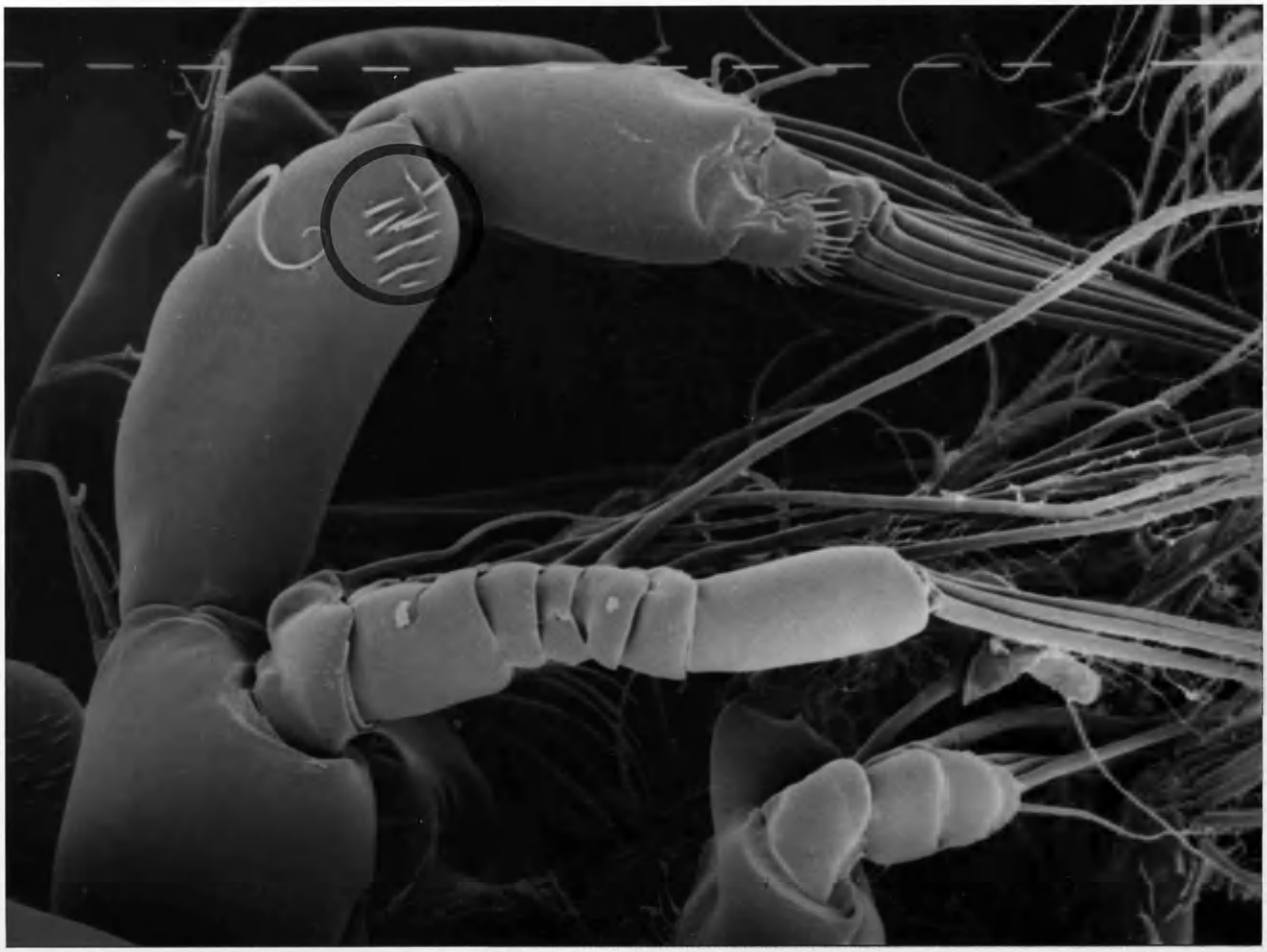

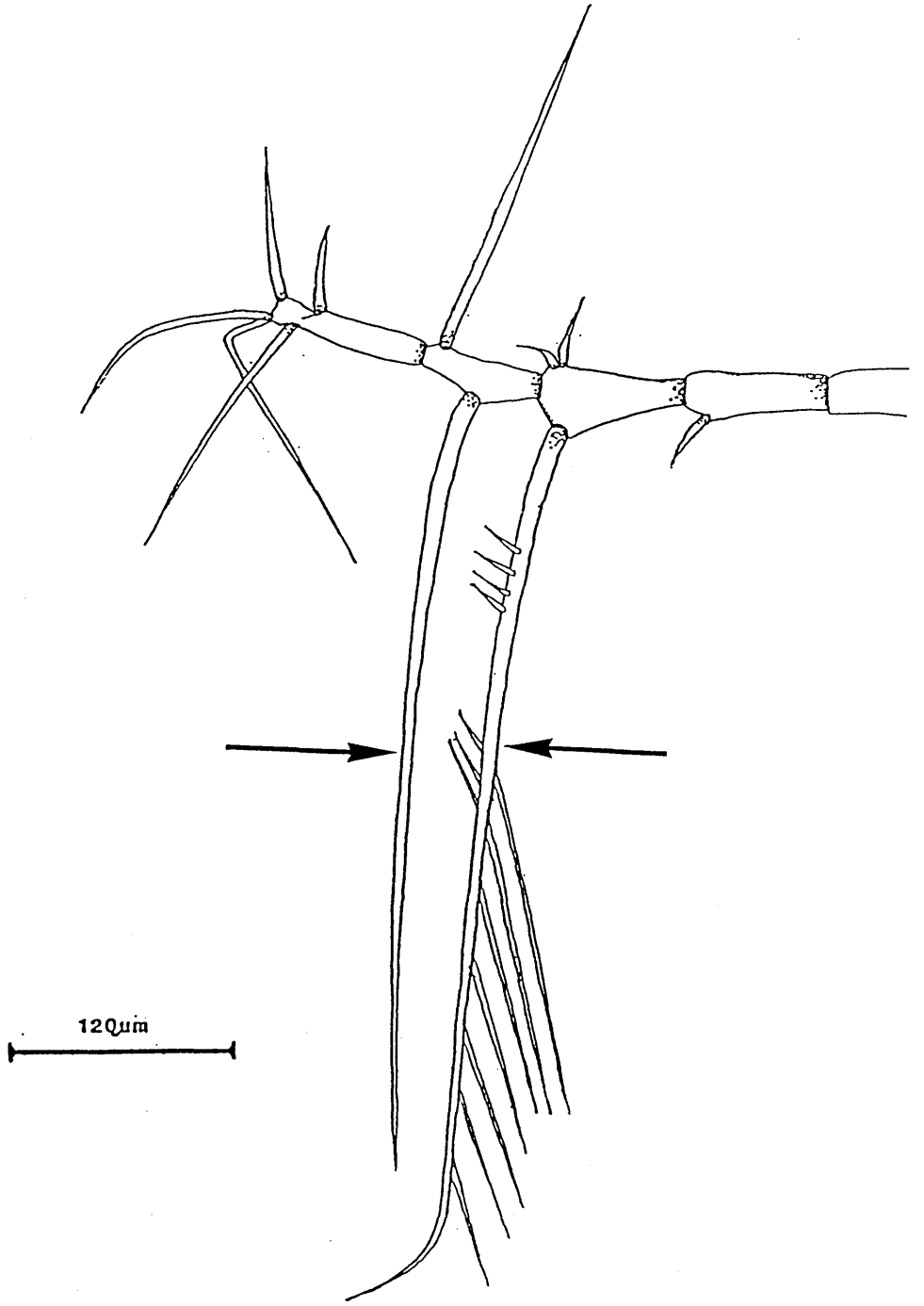

Figure 3. Calanus finmarchicus. Clyde Estuary. Male. Part of end of first antenna. Long whip like-hairs (arrowed) on twenty second and twenty third segments.

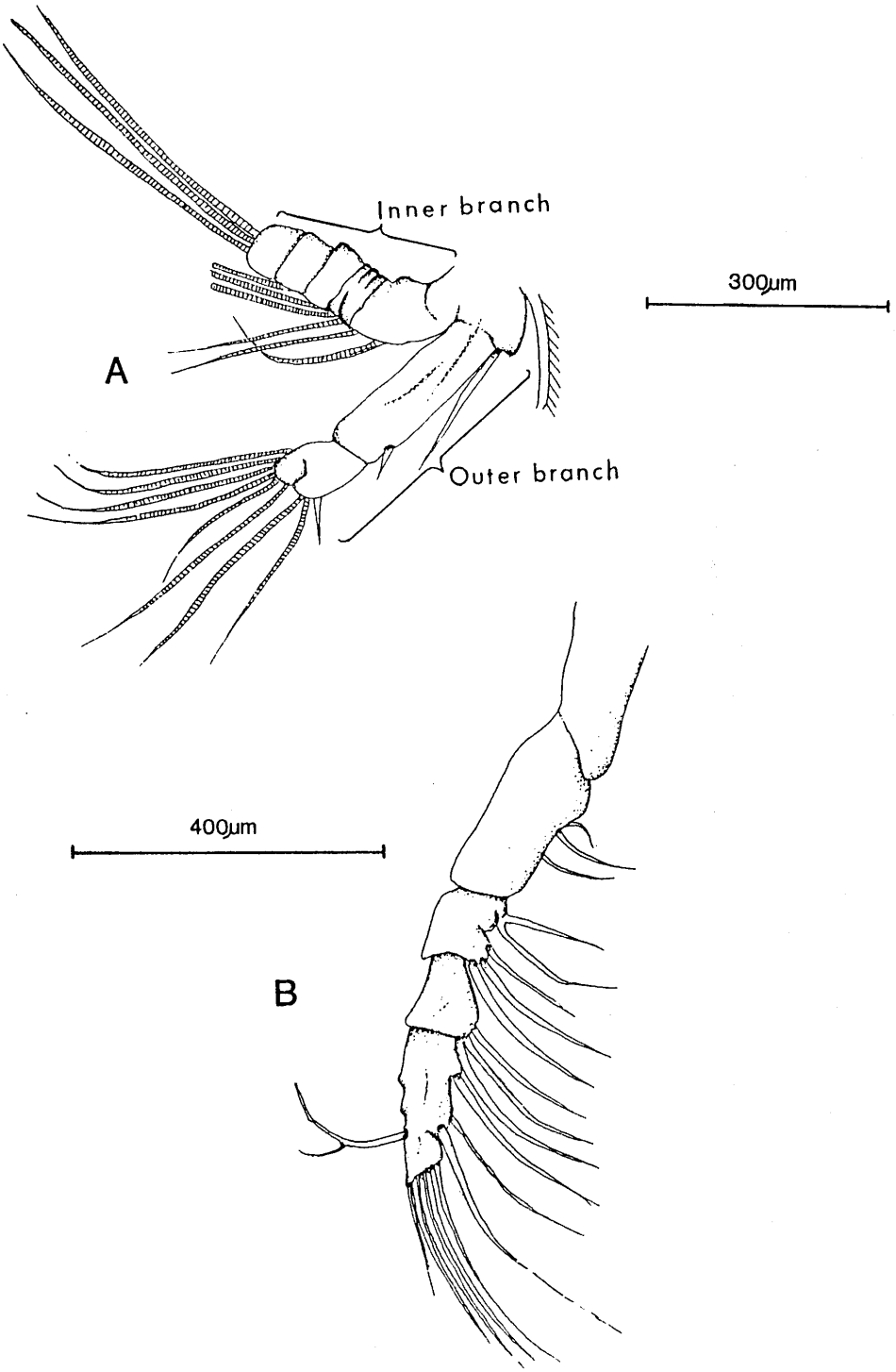

Figure 4. Calanus finmarchicus. Clyde Estuary. Female. A) Second antenna. Outer branch and inner branch having seven joints, four of which are short (arrowed). (B) Maxilliped. Sex identified from (B); (A) and (B) came from the same animal.

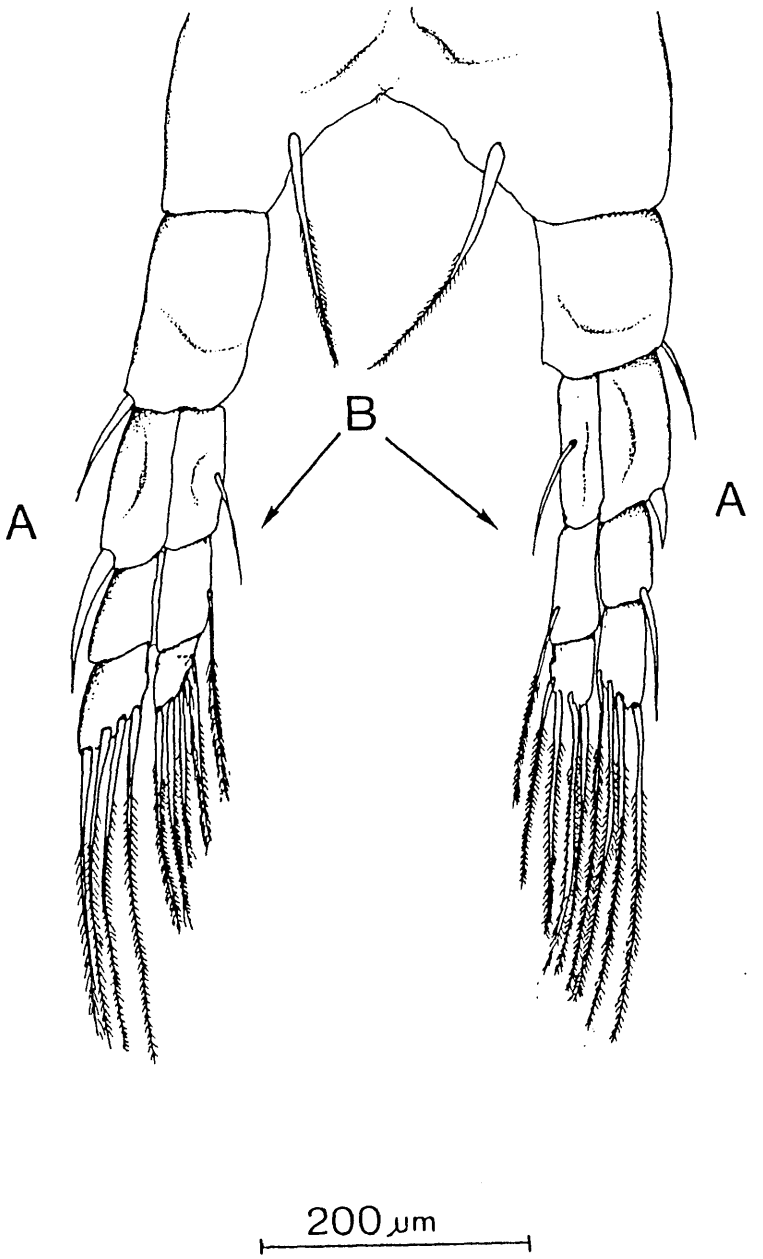

Figure 5. Calanus finmarchicus. Clyde Estuary. Female. First leg. Left and right pairs of podites. Exopod (A) and endopod (B) each having three segments.

one seta on its medial aspect. The second segment of the basipodite also carries one seta, but this is present on its lateral aspect. The distal part of the leg is formed of two branches (figure 5), an outer(A) part called the exopod, and inner(B) called the endopod. The exopod is considerably longer than the endopod, and both have three segments. There are many setae on the medial aspect of the distal ends of both branches. These probably play a part in swimming and feeding.

6 - Fifth leg:

The fifth leg is made up of three parts. The basipodite (figure 7; plates 7 and 8) has two segments. The first or basal segment is elongated in shape (figure 6) and jointed to the same segment on the oppiste side, while the second one is smaller. The inner margin of the basipodite is slightly concave in shape and serrated, which is clearly seen in figure 6 (ringed) and plate 8 (arrowed). The distal part of the fifth leg is made up of two parts: a lateral exopodite and a medial endopodite. The exopodite and endopodite each have three segments. There are differences between the fifth legs of males and females, which are described below (pp. 28).

7 - Abdomen (urosome):

The abdomen is about one fifth of the body length (figure 8; plate 9). It consists of the follow parts. The genital segment (first abdominal segment) is broad and is wider than the other segments. The second abdominal segment is slightly shorter than the previous one. The first and second segments are fused into one in the female (figure 8 and Marshall and Orr, 1955, pp.15). These are followed by the third, fourth and fifth (or anal) segments. The furcal rami are articulated and their length is twice their width. Each furca carries five setae (figure 8). The setae are about as long as the abdomen, and have a large number of small hairs as seen in plate 10 (arrowed). The animal in plate 9 which has 4 abdominal segments is in fact a copepodite stage 5, not an adult female. I know this to be so because it is the same animal as in plate 7 which is a copepodite stage 5 because it only has two segments in the exopodite of its

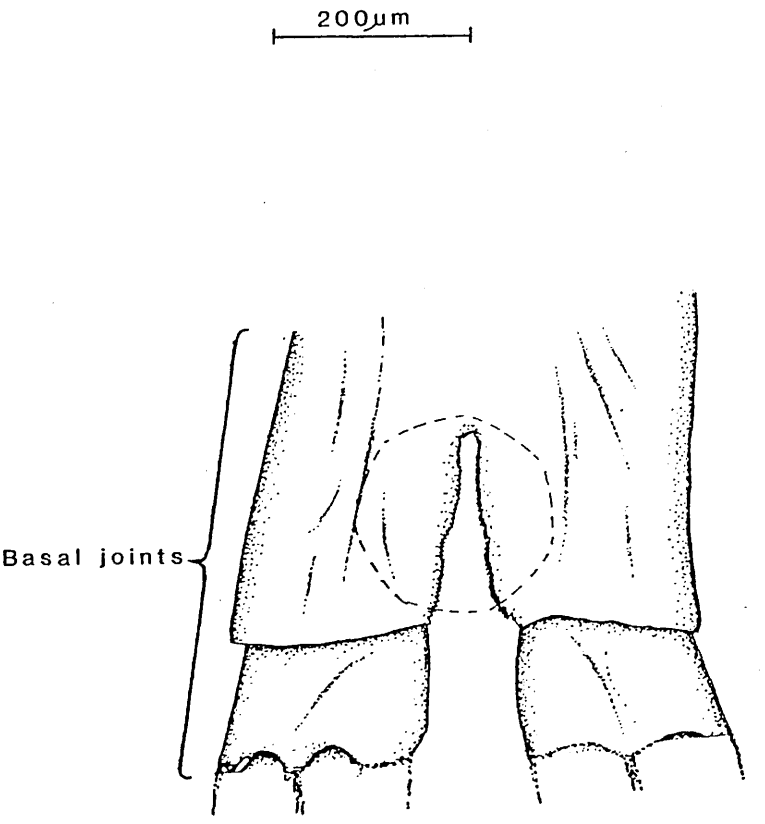

Figure 6. Calanus finmarchicus. Clyde Estuary. Basal joints of the paired fifth legs showing serrated inner margin (ringed) which is not concave. Specimen is therefore female.

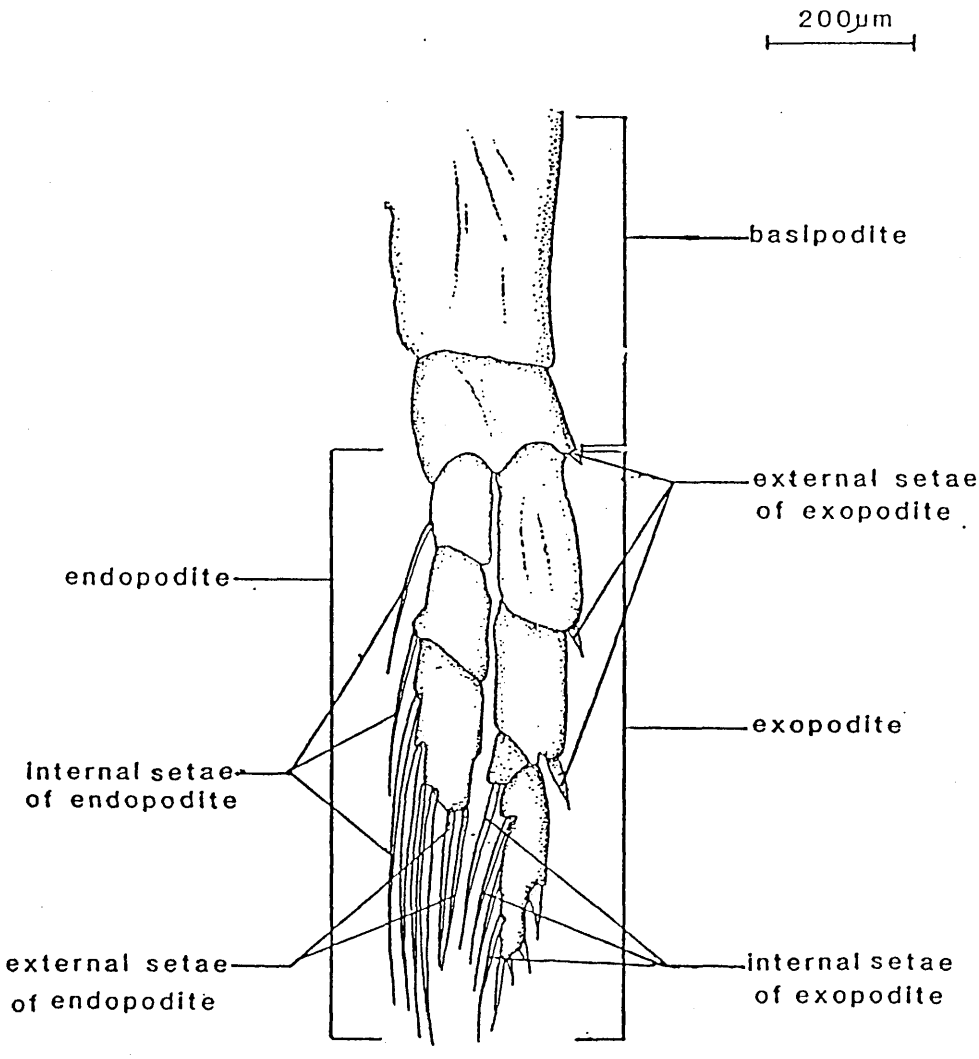

Figure 7. Calanus finmarchicus. Clyde Estuary. Female. Fifth leg.

Plate 7. Calanus finmarchicus. Clyde Estuary. Copepodite (stage 5). Fourth (4) and fifth (5) thoracic segments with the fourth and fifth pairs of legs. The exopodite of the fifth thoracic appendage has 2 not 3 segments; specimen is therefoer a copepodite stage 5 (Lebour, 1915, pp.11,16, plate 5, figure 21). The abdomen is seen in the upper right hand part of the plate. Black lines white dashes = 100 u

Plate 8. Calanus finmarchicus. Clyde Estuary. Copepodite (stage 5). Serrated inner margin (arrowed) of basal joint of the fifth leg of which exopodite and endopodite each having two segments which identifies the specimen as a copepodite stage 5 (Lebour, 1915, pp.16, plate 5, figure 21). Black lines between white dashes = 100 u


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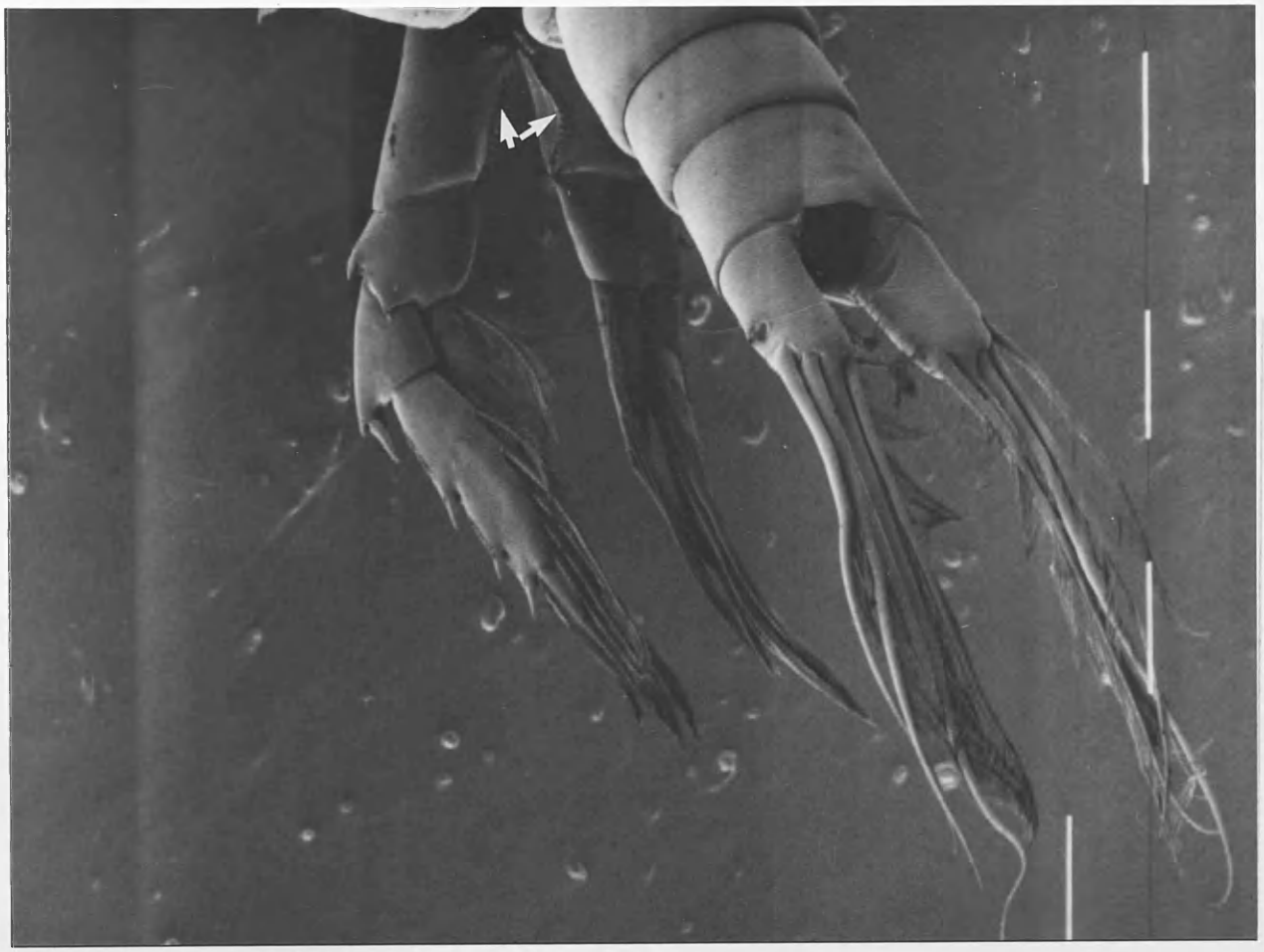


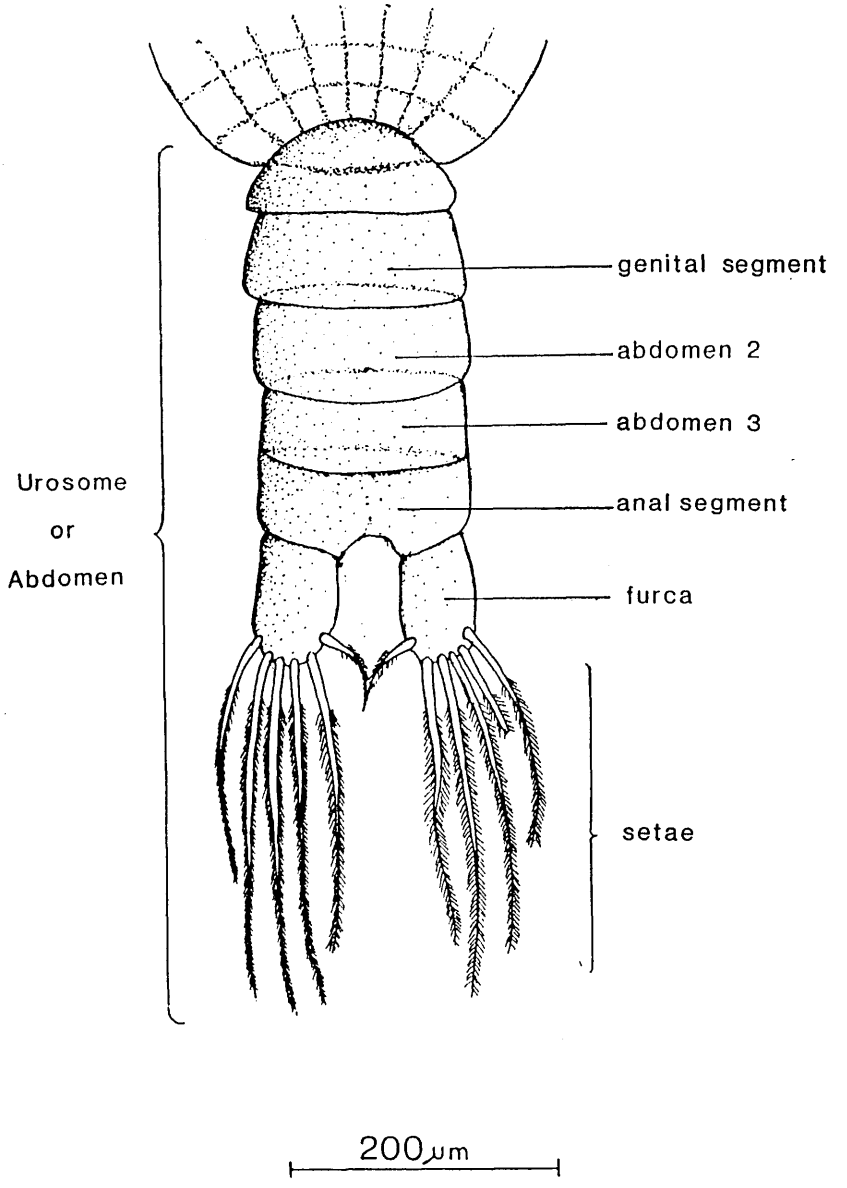
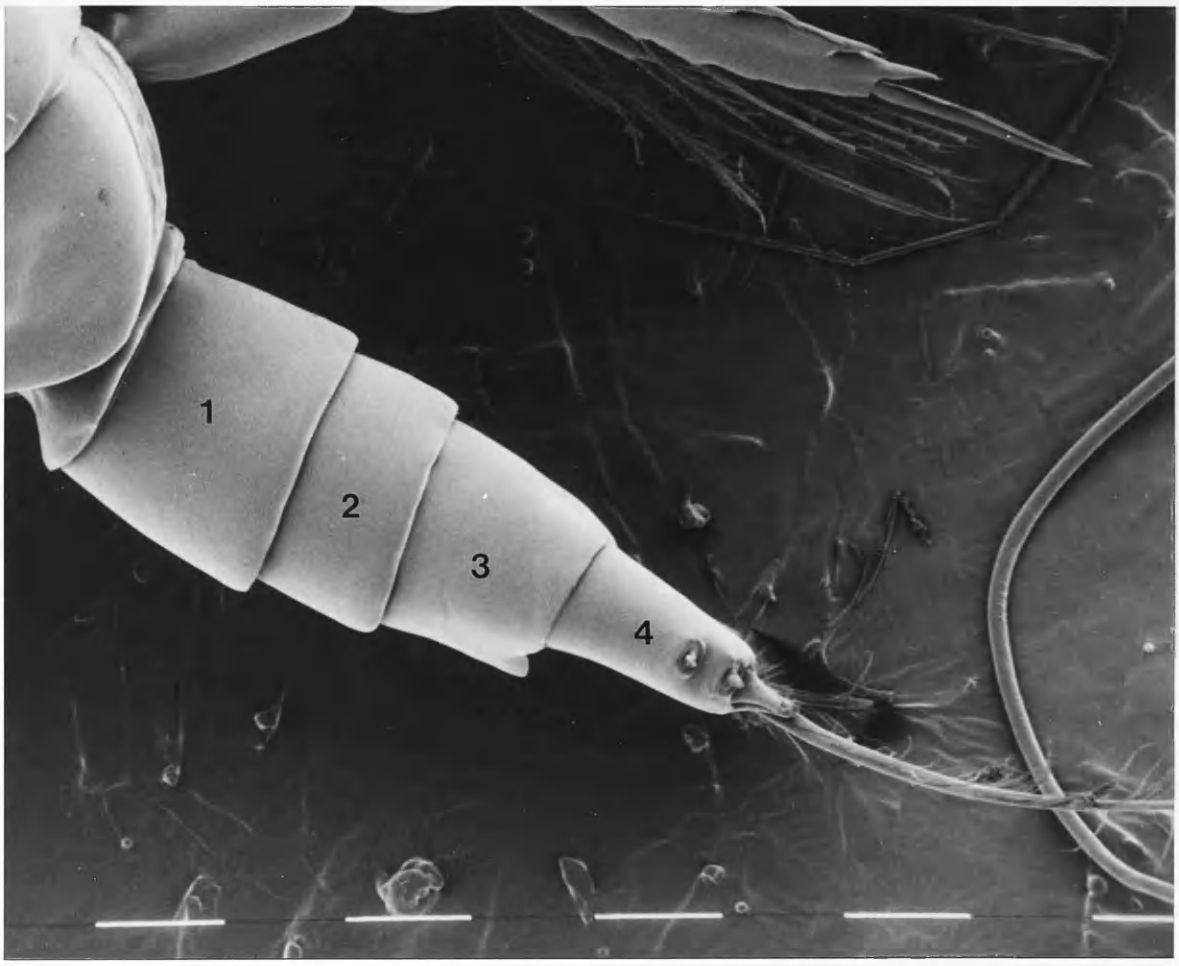


Figure 8. Calanus finmarchicus. Clyde Estuary. Female. Urosome (abdomen) is divided into six parts: (1) genital segment (first and second abdominal segments fused), (2) third abdominal segment, (3) fourth abdominal segment, (4) anal segment, (5) furcal rami, (6) setae.

Plate 9. Calanus finmarchicus. Clyde Estuary. Same specimen as in plate 7 and 8 Copepodite (stage 5). Abdominal segments: (1) genital segment (fused abdominal segment one and two), (2) abdominal segment three, (3) abdominal segment four, (4) anal segment (abdominal segment five). Black lines between white dashes = 100 u

Plate 10. Calanus finmarchicus. Clyde Estuary. Furcal rami (1) and setae (arrowed). Black lines between white dashes = 100 u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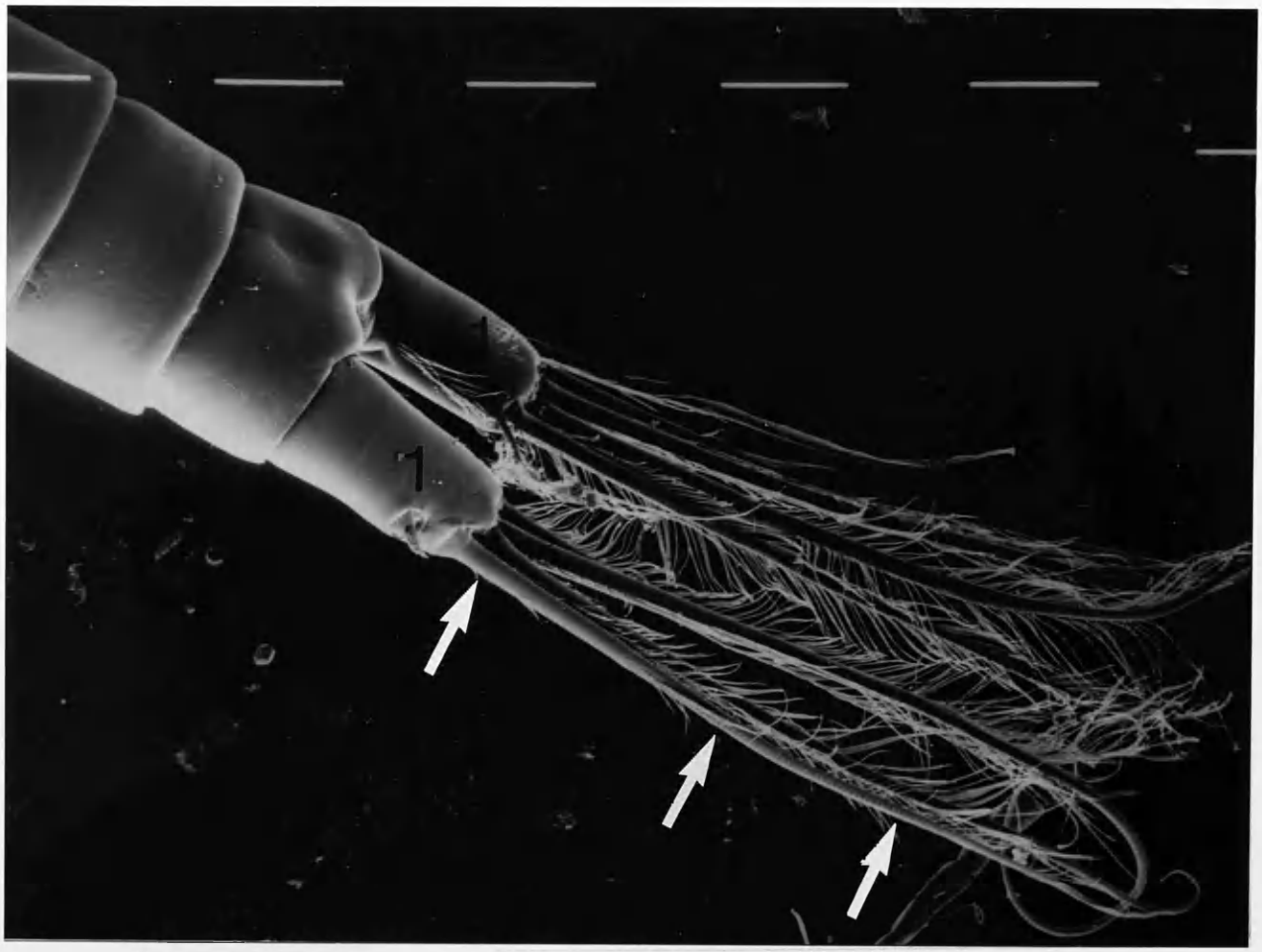
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fifth thoracic leg rather than three in the adult (Lebour, 1916)

Distinction between the sexes:

In most copepods, it is fairly easy to distinguish between the sexes because one of the first antennae and the fifth pair of the legs are often modified forming complicated organs for reproduction. In addition, the fifth legs of the female are often reduced or absent (Marshall and Orr, 1955). Marshall and Orr (pp 11), however, regard Calanus finmarchicus as being a primitive form because the distinction between the male and female is very slight and not obvious.

I have been able to identify a number of the differences in some of my figures and plates. The following is as a complete list of the differences as I have been able to draw up, and is based on chapter 2 of Marshall and Orr (1955), pp. 11-15, and on the authors they refer to. 1 - I unfortunately start with an apparent contradiction between two books concerning the shape of the front of the head in males and females. Marshall and Orr, 1955, pp.11) states that "The front of the head is gently round in the female as in the male it rather angular and has a slight projection like chitinus blister on the dorsal side". Farran revised by Vervoort (1951, sheet 32, pp.3), however, states in abbreviated English "female more slender, head more produced and less broadly rounded".

2 - The penultimate and antipenultimate segments of the first antennae carry long setae. The two setae are the same length in the female, while in the male the proximal one is longer than the distal one. The first antennae illustrated in figures 2 and 3 therefore probably belong to a male. In addition, the first two segments of the first antennae in the male are fused into a flattened plate, the anterior side of which carries a number of so-called sensory aesthetascs (Marshall and Orr, 1955 pp. 12). These can be seen very clearly in plate 2. The specimen illustrated in plate 2 is therefore almost certainly a male.

3 - The maxillipeds in the male and the female are slightly different (Marshall and Orr, 1955 pp.12). The segments are slightly broad as seen from the side in the female, and in the male there are three large setae on the lateral side of the last three segments. There is only one large seta on the lateral aspect of the penultimate segment in the female. This single seta can be seen very clearly in figure 4 which is, therefore, of the maxilliped of a female.

4 - There are distinct differences between the fifth thoracic limbs in the male and female (Giesbrecht, 1892; With, 1915; Currie, 1918; Marshall and Orr, 1955 pp.14, figure 4 c and d). In the female the number of setae on the medial aspect three segments of the endopodite working distally are 1, 1, 5 (1 being external) , and in the male are 1, 1, 6 (2 being external). The animal whose fifth legs is illustrated in figure 7 is therefore a male, and the same is probably true for the animal in plate 8 (large black arrows).

There are other differences between the fifth thoracic legs of the male and female fifth thoracic leg. In the male, the inner edge of the coxa is concave. The left exopodite in the male carries no setae and is fringed with fine hairs on the inner side of the last two segments - not on the outer side as in the female. The left and right exopodites in the male are assymmetrical. The left is longer than the right, and the right carries fine hairs on the external sides of the second and third segments. The last segment of the left exopodite in the male is much shorter and more peared shape than in the female (Marshall and Orr, 1955, pp.14, figure 4 c and d). The lack of all these male characteristics on the legs illustrated in figure 7 substantiate that these legs are from female specimen.

5 - The penultimate thoracic segment carries a pair of small setae in the male. No setae are visible on the penultimate thoracic segment of the animal in plate 1 which adds weight to my previous conclusion that this animal is a female.

6 - The urosome has five segments in the male. In the female, the first two are fused so that there are only four segments (figure 8). This difference between sexes may well develop at the moult between copepodites stage 4 and 5, althougth this does not appear to be recorded in the literature. The animal in plates 7 and 9 is the same specimen. Its exopodite has only two segments (plate 7). Its abdomen contains only four segments (plate 9). Lebour (1916, pp.16) states that the stage 5 copepodite contains the full number of segments in the urosome. The full number in the adult is five in the male and four in the female. Hence I deduce that copepodite stage 5 figured in plates 7, 9 shows sexual differnetiation and is a female because it only contains four segments in the abdomen.

The genital opening of the male is on the first segment and consists of a slit which is slightly to the left of the middle line. The genital opening of the female also opens on the first segment but is central and crescent shaped. The first abdominal segment of the female also carries the openings of the two spermathecal sacs. These openings are not visible in any of my figures or plates.

7 - The furcal rami (caudal rami) are the same shape in both sexes but those of the male are articulated to the anal segment. The animals whose furcal rami are figured in plates 8 and 10 are therefore probably males.

Section (2)

Taxonomy of Tachidius discipes

INTRODUCTION

Tachidius discipes (Giesbrecht) is an important member of the meiofauna in many estuarine ecosystems (Muus, 1967), and is one of the dominant harpacticoid copepods from estuarine mudflats such as those in the River Lynher, Cornwall (UK) (Teare, 1978). The first description of the species was given by Lilljeborg (1833) as a Tachidius brevicornis (O. F. Muller).

The taxonomy of the species has been studied by many workers (Boeck, 1865; Brady, 1876; Sars, 1911; Labbe, 1927a,b; Gurney, 1932; Lang, 1948; Wells, 1976; Coull 1977,1982). Coull (1982) described the family Tachididae as having an elongated body in which the urosome is as wide as or just slightly narrower than the metasome. The rostrum is large. The caudal rami are short. The first antenna of the female has four to nine segments. The first to fourth legs are not prehensile and have two or three segmented exopods and endopods. Brady (1876) showed that Tachidius brevicornis has a strong body. The body segments are fringed on their posterior margins with rows of minute teeth. The last three abdominal segments are approximately equal in length. The anterior antenna (first antenna) of the female has 7 joints. In the male, the first antenna has a swollen joint. Small eyes are situated near the base of the anterior antennae. The colour is grey or yellowish brown. Sars (1911) has also given a description for Tachidius discipes, following Lilljeborg and Giesbrecht's descriptions.

The anatomy of Tachidius discipes, Giesbrecht, has been described by Gurney (1932) in volume 2 of his classic monograph on the British Freshwater Copepoda. Gurney states that the first description of the species was by Lilljeborg (1853) as Tachidius brevicornis (O. F. Muller).

The species is described in detail as Tachidius discipes by Giesbrecht (1881) and as Tachidius brevicornis by Sars (1909). The species also appears to have been

described more recently by Labbe (1927a, b). However, Gurney (1932, pp.21) states that Labbe's figures are mediaeval in their grotesqueness, and it is certain that two or more species went to the making of some of his new discoveries; but it is equally sure that Tachidius discipes was an ingredient in three of them. Lang (1948, pp.292) gives a full bibliography of the species. The identification of the marine harpacticoid copepods is given in full by Wells (1976).

MATERIALS and METHODS

Sediment samples containing animals were collected from the shore at Ardmore Point. Sediment was taken from a depth of 2 cm and area of 25 cm^2 at low tide, mid tide, and high tide using a spatula. Three 2 litre jars were used for transportation of samples to the laboratory.

It is known that a sediment sample contains 25% of seawater. This means 1250 ml of the sediment sample has 312.5 ml of seawater. To obtain a ratio of water to sediment of 50:50, a 625 ml of freshwater was therefore added to the sediment sample. This was to kill the animals and to avoid shrinkage of the tissue. The samples were fixed with Steedman's solution. 104 ml of concentrated Steedman's solution was added to 937.5 ml of water in the sediment sample for each tidal level to give a dilution of 1:9.

(a) Preservation:

Fixation is a process which stabilises the protein contents of tissue after the animal's death. By this process, the tissue constituents retain some degree of the form they possessed in life. In addition, fixation raises the refractive index of the cell contents and renders tissue more easily stainable (Lincolin and Sheals, 1979). Steedman's solution is recommended for general fixation and preservation of marine zooplankton.

The stock solution is prepared as follows (Steedman 1976):

1- Propylene phenoxetol 5 ml

2- Propylene glycol 45 ml

3- Formalin solution 50 ml

4- Na glycerophosphate 2.632 g

and diluted 10 ml of stock solution with 90 ml of filtered seawater giving a ratio of 1:9 for general use.

(b) Extraction of harpacticoid copepods:

The elutriation technique was used for extracting harpacticoid copepoda from sediment. This technique will be described in detail in section 3 pp. 61.

(c) Sorting:

The flask was gently shaken to evenly distribute the animals. 5 ml sub-sample from the total volume of the low tide sample was taken randomly using a pipette. This sub-sample was put in a squared petri-dish. With the aid of a binocular microscope, the animals were sorted into two major groups (A and B) according to the shape of the body. The two groups were then further sorted into four sub-groups a1, a2, b1, and b2 according to the length of the body.

During sorting group A, the longest animal was stained with Rose Bengal and taken as a standard measure. All the animals which were of this standard were assigned to sub-group a1. The animals which were less than the standard were then assigned to sub-group a2. There was a slight difference between the two sub-groups a1 and a2, but it was easy to distiguish between them. The animals of group B were also sorted into two sub-groups b1 and b2. Sub-group b1 included the nauplii and were abundant. Sub-group b2 included the copepodites. The sorting was only conducted for the low-tide sample.

(d) Dissecting:

A full description of harpacticoid copepods is difficult to achieve without dissecting the animals and studying it's parts under the higher power of the light microscope (Wells, 1976). Techniques for the dissection of animals differ between workers. Some workers construct special instruments for specific needs.

The animals which were sorted into sub-groups were taken to Dunstaffnage Marine Laboratory, Oban, where I received help from Dr P. R.O. Barnett in Dunstaffnage Marine Laboratory. Group A was poured into a small petri-dish and put under a

binocular microscope. By means of a pipette, 7 adults individuals were selected at random and separately removed from the petri-dish to a glass slide of size (7.6 cm x 2.5 cm) and thickness of 1.0 mm using two fine-pointed needles. The animal was then placed on a lateral side. Each animal was individually dissected and transferred on the tip of a fine-pointed needle to a drop of polyvinyl lactophenol. Dissection began on the first segment which separates the cephalon from the thorax. The second to the fifth leg were first removed from the body. This enabled the first antenna and the first leg to be dissected easily.

(e) Mounting:

The body parts from animal were placed in a mixture of polyvinyl lactophenol and blue black ink which were on the slide. A glass coverslip (22 mm x 22 mm) was then put on the slide. The purpose of adding ink was to stain the tissue and thus to facilitate identification. The dissected part was rolled lightly to the desired angle, and care being taken to avoid any squash for the specimen. The parts A1, P1, P2, P3, P4, and P5, abdomen were permanently mounted on separate slides. Each slide was labelled, for later identification and drawning.

(f) Identification:

Only the first animal was identified and drawn. It was Tachidius discipes. The first five of the 7 animals had a similar appearance. Whilst the sixth and the seventh were similar in the body shape, and left with Dr P. Barnett to identify. All the six animals were not identified because of time limitation. The parts of the body of the first animal were examined under a light microscope using a high power. Numerous spines and bristles were seen, however, sometimes these structures were broken. If this occurs, identification may become difficult, if not impossible. In this respect, the uses of polyvinyl lactophenol as a dissecting medium is very important. This medium is very slow to evaporate, so a drop on a slide is sufficient.

(g) Drawing technique.

Accurate drawing of different parts of the anatomy are essential. Drawing is very important for giving a full taxonomic description of any species. Drawing techniques for body parts differ from person to person. Some people use an eyepiece scale for this purpose, while others use the drawing tube. The technique I used for drawing the parts of animals is described as follows: Graph paper of A3 was squared into 2cm x 2cm squares using a 2B pencil. An eyepiece scale which was already calibrated with the micrometer stage, was used to transfer the image to a tracing paper. The tracing paper was then inked with special pens, and the details were drawn accurately. All the drawings were then reduced to an acceptable size for the thesis.

RESULTS

The results of my anatomical studies of Tachidius discipes are shown in figures 9 to 14 and plates 11 to 20.

These results are divided into 9 parts:

1 - General size and shape of body

2 - First antenna

3 - second antenna

4 - Maxilliped

5 - First leg

6 - Second leg

7 - Third leg

8 - Fourth leg

9 - Fifth leg

1 - General size and shape of body:

The body of Tachidius discipes is generally broad and flattened with marked distinction between the segments (plates 11 and 12). The rostrum is distinct and conical shaped (plate 11). The metasome (thorax) is wider than the urosome (abdomen). The thoracic segments are fringed with equal lengthed fine spines (plate 13). The caudal rami (plates 11 and 12) are short, carrying setae which are about half the body length. There are indistinct small hairs and pores on the body surface (plate 13). There are also protozoa (Cothurnia sp.) distributed on the body surface (plate 14), ; these are more abundant on the urosome (abdomen). The protozoan genus was kindly identified by Professor K. Vickerman F.R.S.. The length of the body is between 0.63 - 0.76 mm in the female, and between 0.72 - 0.83 mm in the male (Gurney, 1932, vol.3, pp.21-24).

Plate 11. Tachidius discipes. Ardmore Point. Dorsal view of the body, showing cephalothorax (A), and nine segments. Thoracic segments 1 to 4 are labelled 1,2,3, and 4. Abdominal segments 1 to 5 are labelled 5,6,7,8, and 9. Attachment of protozoa Cothurnia sp. onto abdomen. (Cothurnia sp. kindly identified by Professor K. Vickerman, F.R.S). Black lines between white dashes = 100 u.

Plate 12. Tachidius discipes. Ardmore Point. Male. Lateral view ofbody. Black lines between white dashes = 100 u

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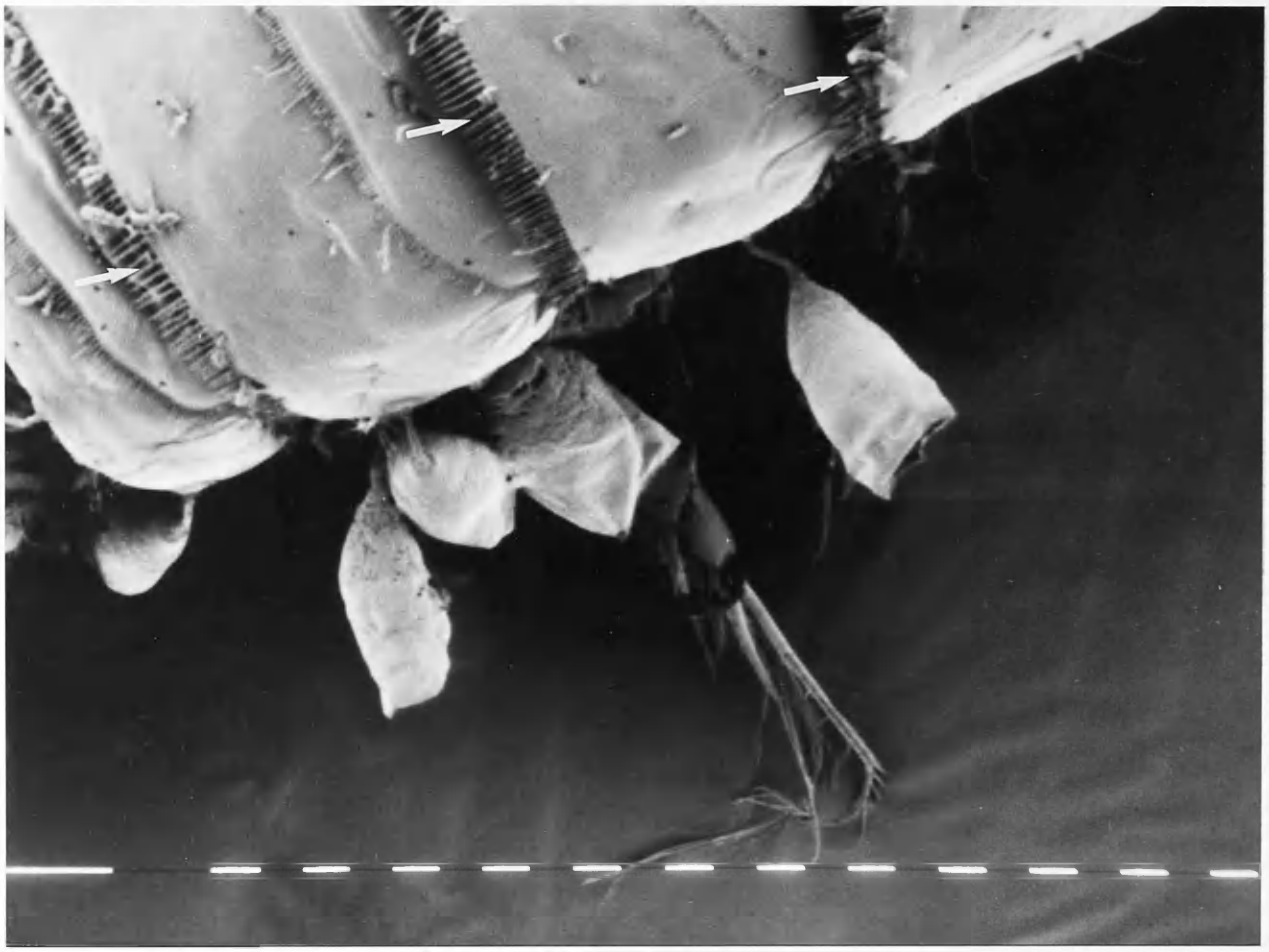
Plate 13. Tachidius discipes. Ardmore Point. Thoracic segments are fringed with fine spines of equal length (arrowed). Black lines between white dashes = 10 u

Plate 14. Tachidius discipes. Ardmore Point. Attachment of protozoan, Cothurnia sp. onto the body surface. Note interesting morphology of attachment disc. Black lines between white dashes = 10 u



(2) First antenna:

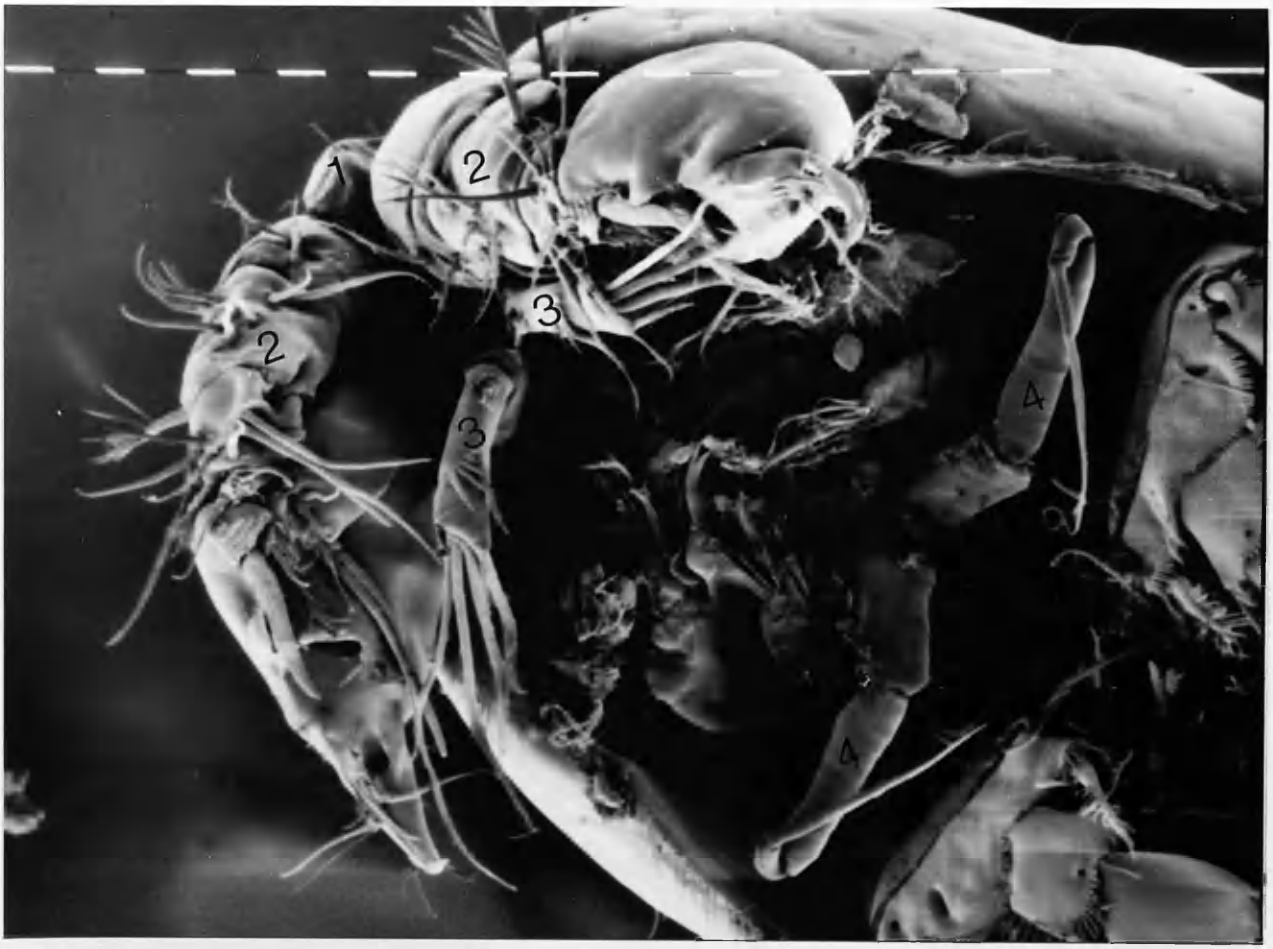
One of the main differences between the male and female in Tachidius discipes, is the first antenna. In the male, the first antenna has six segments, and the penultimate distal segment is swollen (plates 15 and 16 (2)). In the female, the first antenna has seven segments which bear a number of setae of different lengths. The first antenna (figure 9) in the female is short compared with the body length, and has 7 segments and a number of setae. The first segment of the first antenna is the largest and carries no setae. The second segment is small and bears 5 setae. The third segment is slightly bigger than the second one and carries 5 or possibly 6 setae, three of which are thicker than the rest. The fourth segment is smaller, and carries one large seta which has 4 spines. There are two setae on the joint between the fourth and the fifth segment, one of them is thinner and longer than all the other setae of the first antenna. In the fifth segment, there is only one seta. The sixth segment has an elongated shape bearing two large setae both of which have a series of short spines. The last segment (seventh) is also elongated and has three setae at its distal end.

(3) Second antenna:

The second antennae (plate 16 (3)) are very short and thin compared with the first antenna. The segments are not obvious in plate 16 (3). Gurney (1932, pp.22) stated that the second antenna in the female has four segments and is long and slender. Gurney describes the exopod of the second antenna of the female as having two segments: the first one has one seta and the second has three setae, of which the posterior one is very small; however he gives no diagram. Gurney has not mentioned the second antenna of the male in the his text. But his figure 383, pp.25 shows a second antenna which differs significantly from his description of the female second antenna on pp. 22 (loc. cit.) and therefore must belong to a male - although he does not label it as such. For example, Gurney's diagram of the second antenna shows 5 or 6 setae at the distal end, and at least 2 on the lateral side of the second segment

Plate 15. Tachidius discipes. Ardmore Point. First antenna. Male. Note the penultimate distal swollen segment (arrowed) which is only found in the male. Black lines between white dashes = 10 u

Plate 16. Tachidius discipes. Ardmore Point. Male. Rostrum (1), first antennae (male) (2), second antennae (3). Maxillipeds (4). Mandibles, maxillules (first maxillae), and maxillae (second maxillae) lie between (3) and (4). Black lines between white dashes = 10 u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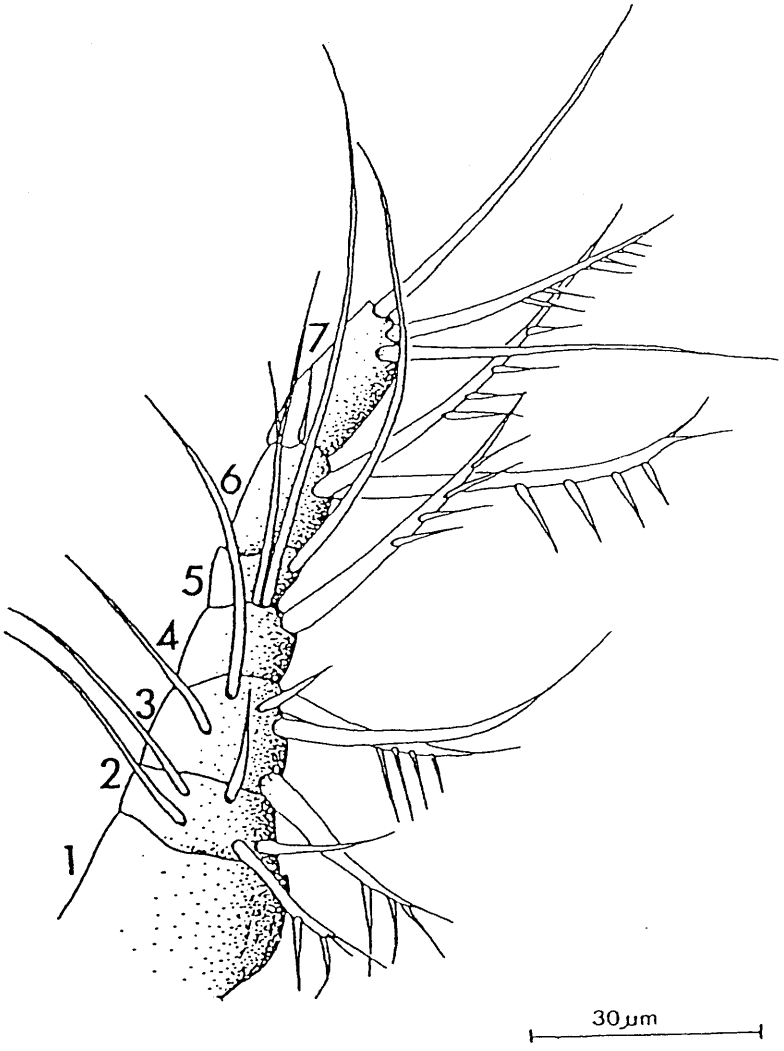


Figure 9. Tachidius discipes. Ardmore Point. Female. First antenna, segments are numbered.

of the exopodite. The first segment is the largest carrying two setae, one of which has three spines. The second segment has two small hairs. The third segment has a number of setae which are of different lengths.

(4) Maxilliped:

The maxillipeds, which are clear in plate 16 (4), are slender and have two segments. The first segment is short and carries no setae. The second segment is longer and slightly thinner than the previous one, and carries one long terminal seta which is probably used in feeding.

(5) First leg:

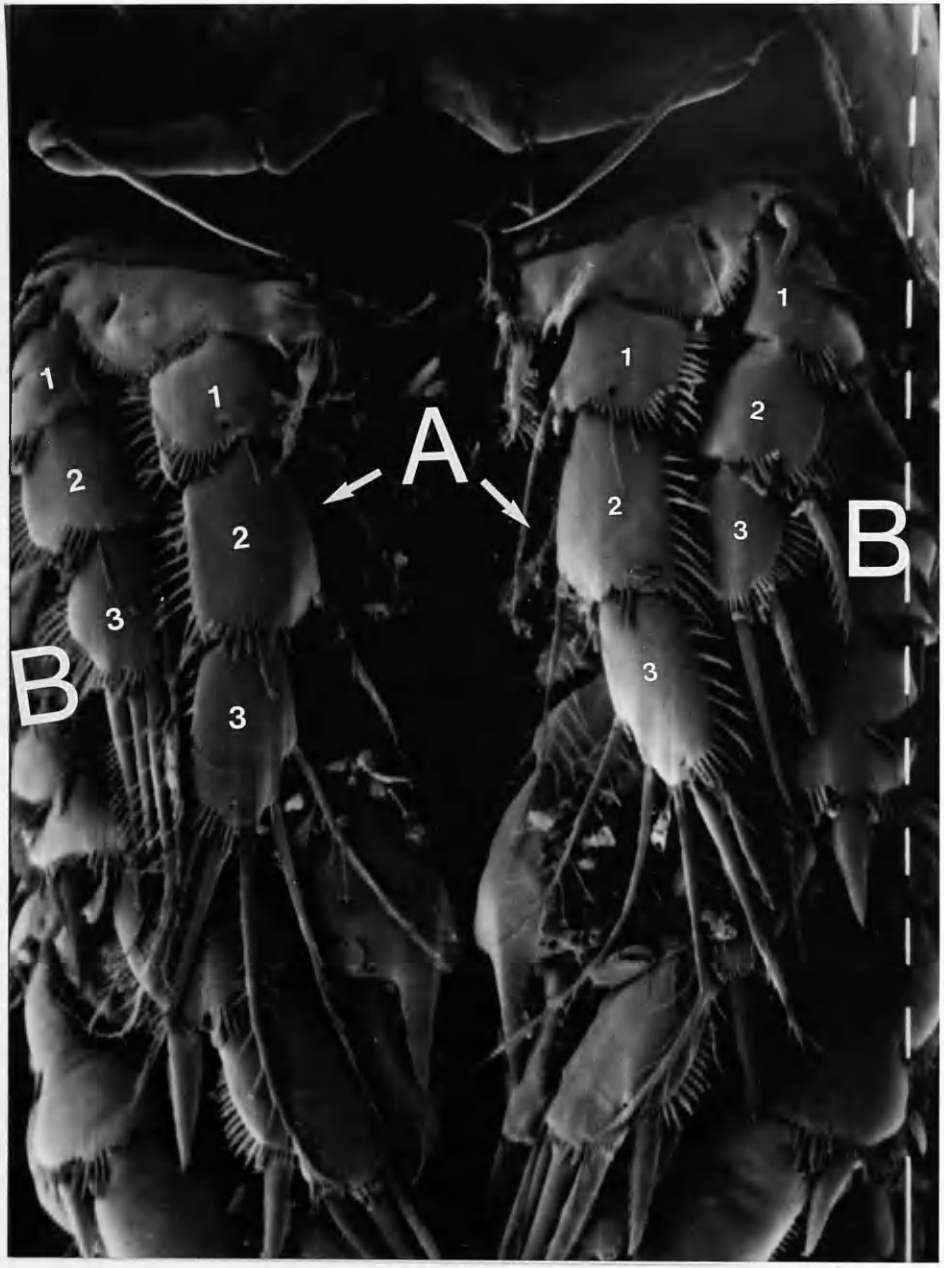
Legs 1-4 (plate 17) are similar to each other, and the exopods and endopods each have three segments. The first leg is shown in figure 10 and plate 18. The exopod (B) in plate 18 is slightly shorter than the endopod (A). The proximal (first) segment of the exopod (figure 10A) has one external seta, while the second one has one short seta on the external side and one long seta on the internal side. The distal segment (third) is round in shape bearing 5 setae, three of which are longer than the remaining two. The external side of the exopod has a number of small hairs, but the internal side has none. The endopod is formed of three segments. The first segment has one short seta on the internal side. The second segment has an elongated shape, and carries a small spine on the internal side. The third segment is smaller than the previous ones, has a round shape, and bears 5 setae, one of which is short. The external side of the endopod has short hairs and the internal has none.

(6) Second leg:

In the second leg (figure 11), the exopod (A) is slightly longer than the endopod (B). It has three segments. The proximal segment has two setae. The internal seta is long and thin, while the external one is short and thick. The second segment is an elongated shape having two setae, the internal one is long and thin, the external is

Plate 17. Tachidius discipes. Ardmore Point. Male. Ventral view of the body, first antenna and first to fifth leg. Black lines between white dashes = 100 u

Plate 18. Tachodius discipes. Ardmore Point. Male. Left and right podites from the first leg. Exopod (B) and endopod (A) each having three segments (1, 2, and 3). Note hairs are present only on the lateral side of the exopod and endopod, not on the medial side. Black lines between white dashes =10 u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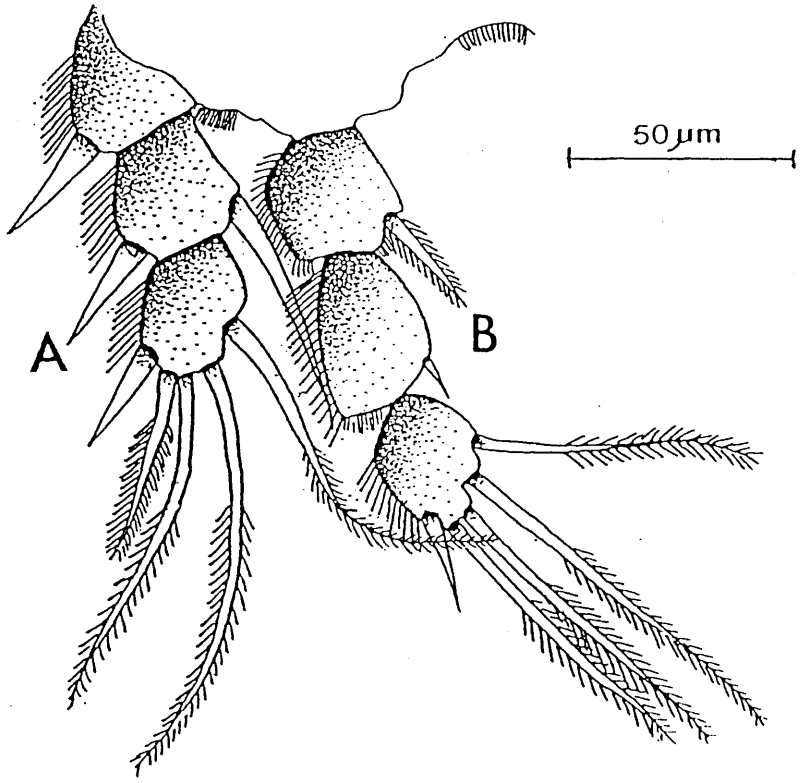


Figure 10. Tachidius discipes. Ardmore Point. Female. Left pair of podites, first leg. Exopod (A) and endopod (B) each having three segments.

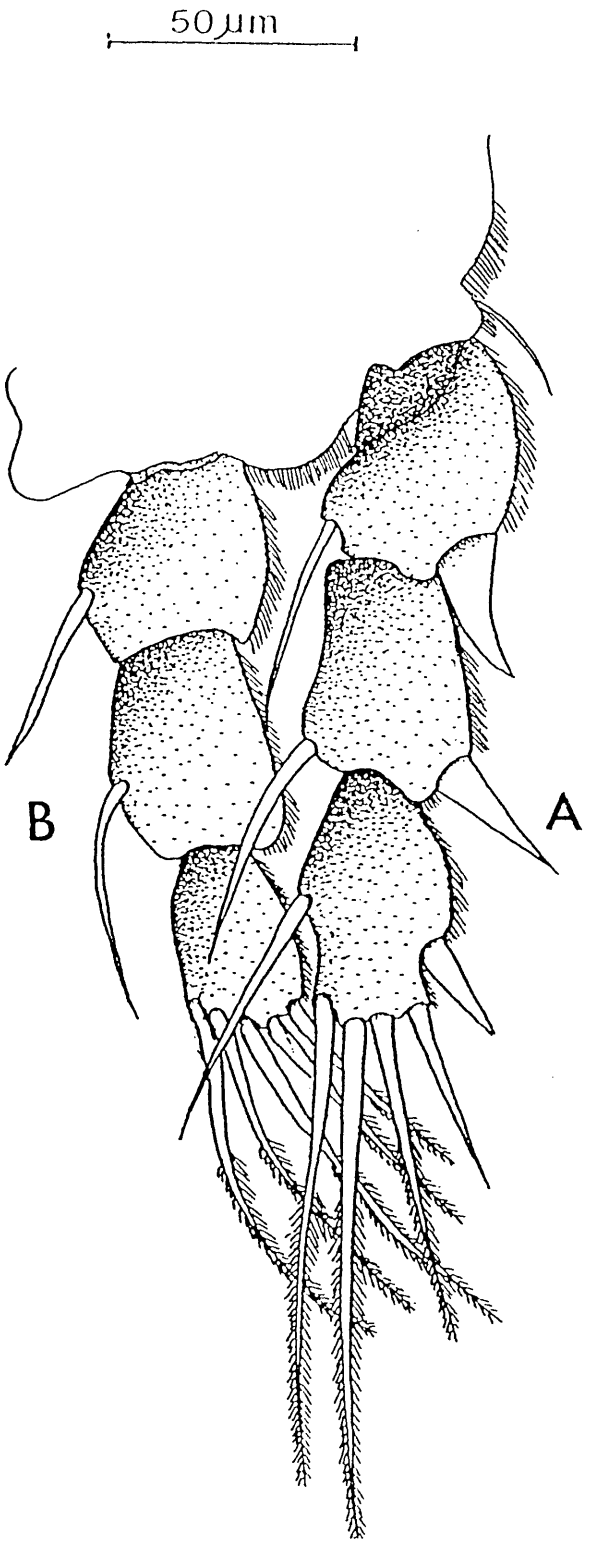


Figure 11. Tachidius discipes. Ardmore Point. Female. Right pair of podites, second leg. Exopod (A) and endopod (B) each having three segments.

short and thick. The distal segment (third) has 6 setae of different length. Hairs are present only on the external side of the exopod and endopod. The endopod (B) has three segments. Segments 1 and 2 have one long setae each. The third segment is smaller than the previous ones, and has 5 setae which are approximately the same length.

(7) Third leg:

The third leg is shown in figure 12. There are two small spines on the external side of the basipod and one on the other. The exopod (A) is slightly longer than the endopod (B). There are small hairs present on the external side of all segments of the exopod and endopod. The first segment of the exopod (A) has two setae, the external is short and is thicker than the internal. The second segment is an elongated shape, having one or two short setae. The distal segment is smaller than the previous ones, bearing 6 setae are not of the same length. The first segment of the endopod (B) has one long internal seta, while the second one has two internal setae which are of the same length. The distal segment (third) is smaller than the first and second, and beares 5 setae which are approximately the same length.

(8) Fourth leg:

The fourth leg is shown in figure 13. There are three spines on the external side of the basipod on one side and one spine on the other. The medial aspect of the basipodite carries bilaterally symmetrical patches of hairs and three small setae. There are small hairs present on the external side of all segments of the exopodite and endopodite. The exopod (A) has three segments. The first carries two setae. The internal seta is long and thin, while the external is short and thick. The second segment has an elongated shape and carries two setae. The external seta is shorter and thicker than the internal. The third segment is slightly smaller than the previous two, and bears 5 setae, four of which are long, carry hairs, and are about the same length.

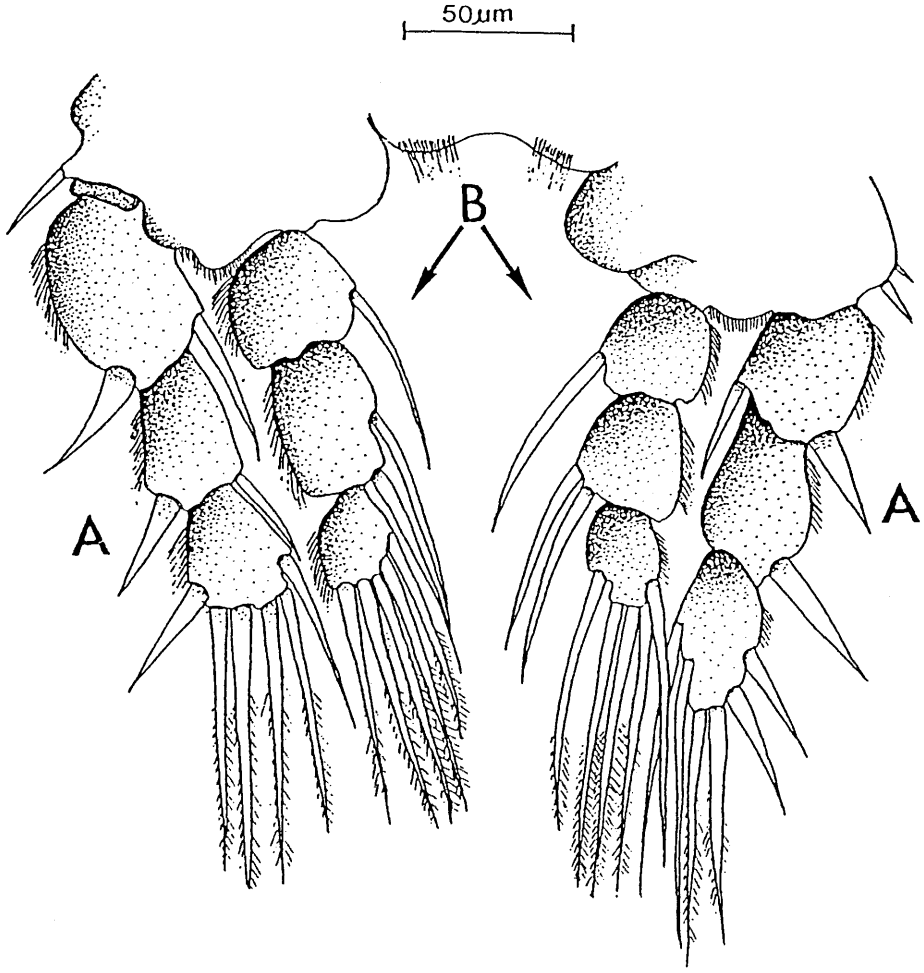


Figure 12. Tachidius discipes. Ardmore Point. Female. Left and right pairs of podites, third leg. Exopod (A) and endopod (B) each having three segments.

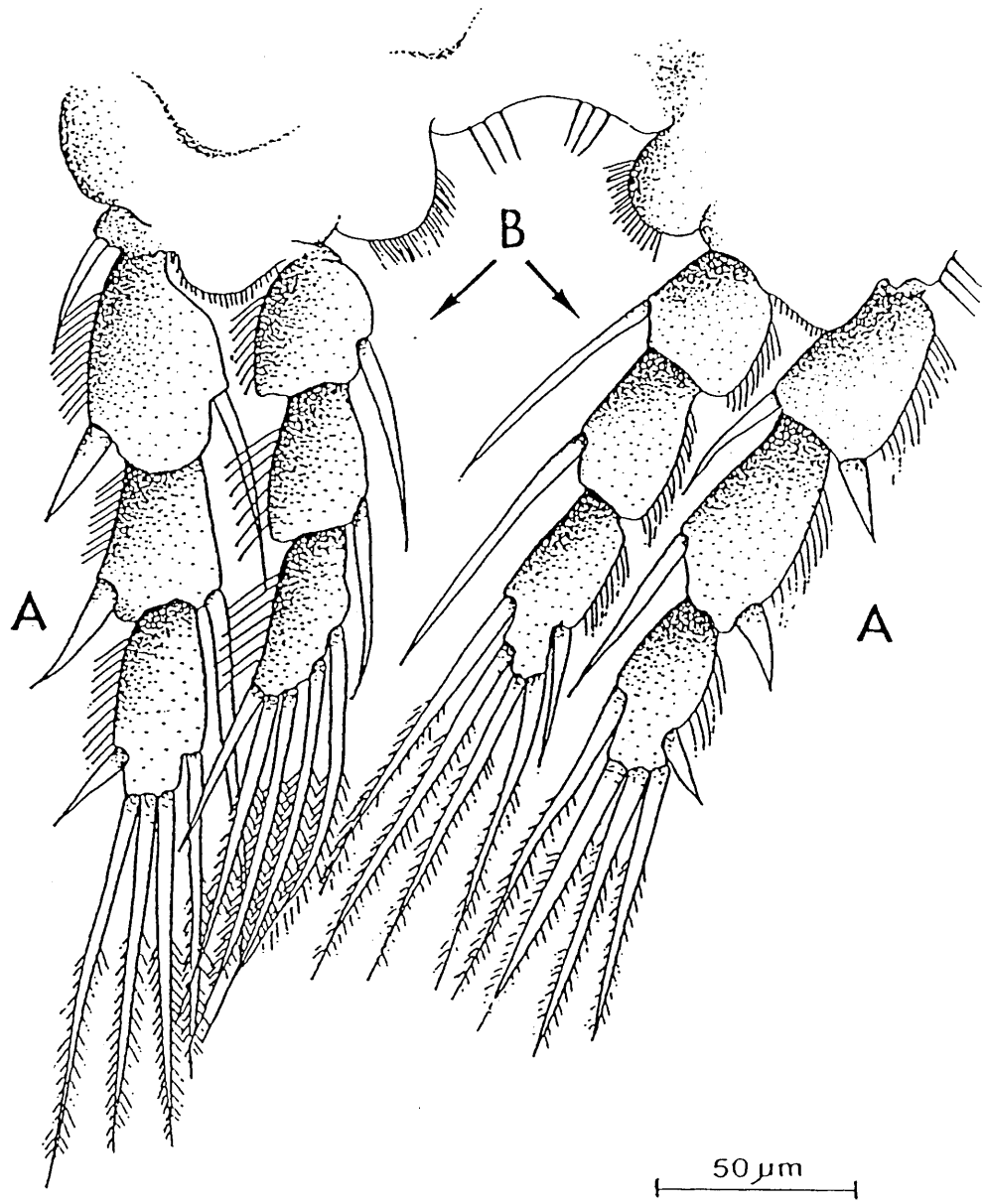


Figure 13. Tachidius discipes. Ardmore point. Female. Left and right pairs of podites, fourth leg. Exopod (A) and endopod (B) each having three segments.

The first segment and the second segment of the endopod (B) have one long and thin internal setae on each, and are of the same length. The distal (third) segment has 5 setae, four of which are long, carry hairs, and are approximately the same length.

(9) Fifth leg:

The fifth leg is shown in figure 14 and plate 20 (small arrow), is entirely different from the first four legs and has a peculiar structure. It is broad, flat, and round in shape, carrying a large number of spines and setae.

Table 1. The leg formula of Tachidius discipes from Ardmore Point.

	Segments											
	seg.1				seg.2				seg.3			
Legs	exopod		endopod		exopod		endopod		exopod		endopod	
	ex.s	in.s	ex.s	in.s	ex.s	in.s	ex.s	in.s	ex.s	in.s	ex.s	in.s
P1	1	0	0	1	1	1	0	1	3	2	2	3
P2	1	1	0	1	1	1	0	1	3	3	3	2
P3	1	1	0	1	1	1	0	1	3	3	3	2
P4	1	1	0	1	1	1	0	1	3	2	3	2

Abbreviations used: seg. = segment; P1 = first leg; P2 = second leg; P3 = third leg; P4 = fourth leg; P5 = fifth leg; ex.s = external setae; in.s = internal setae.

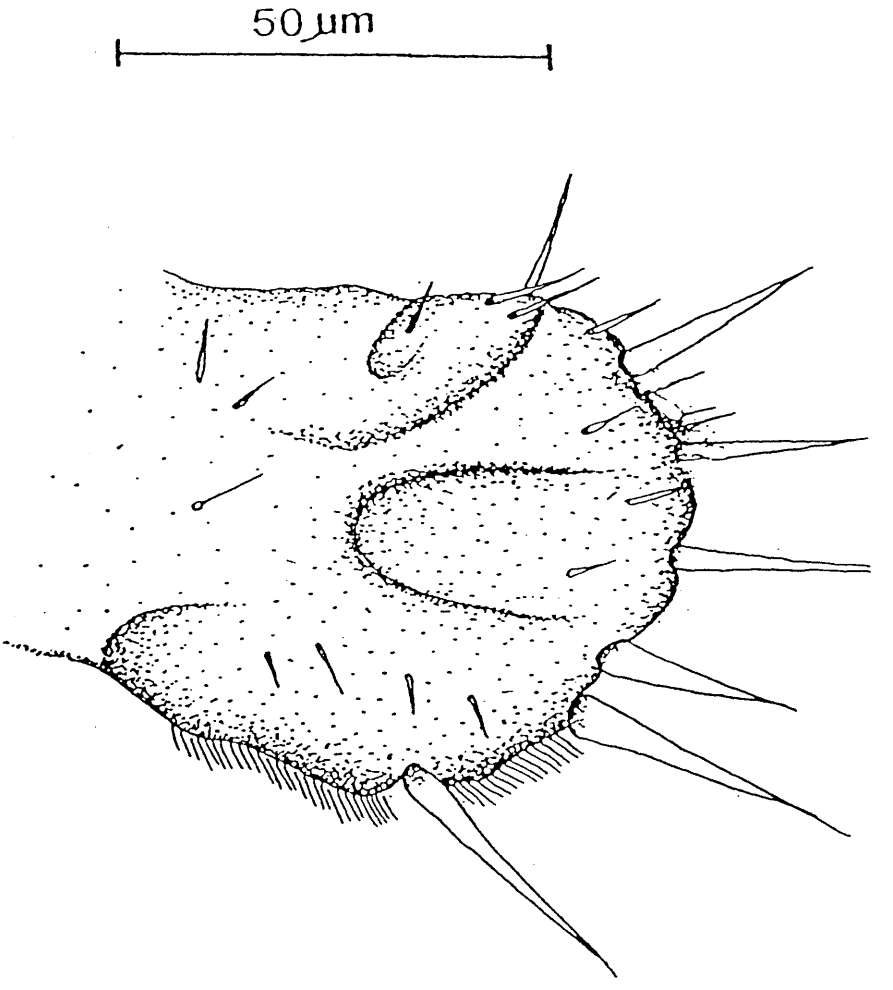
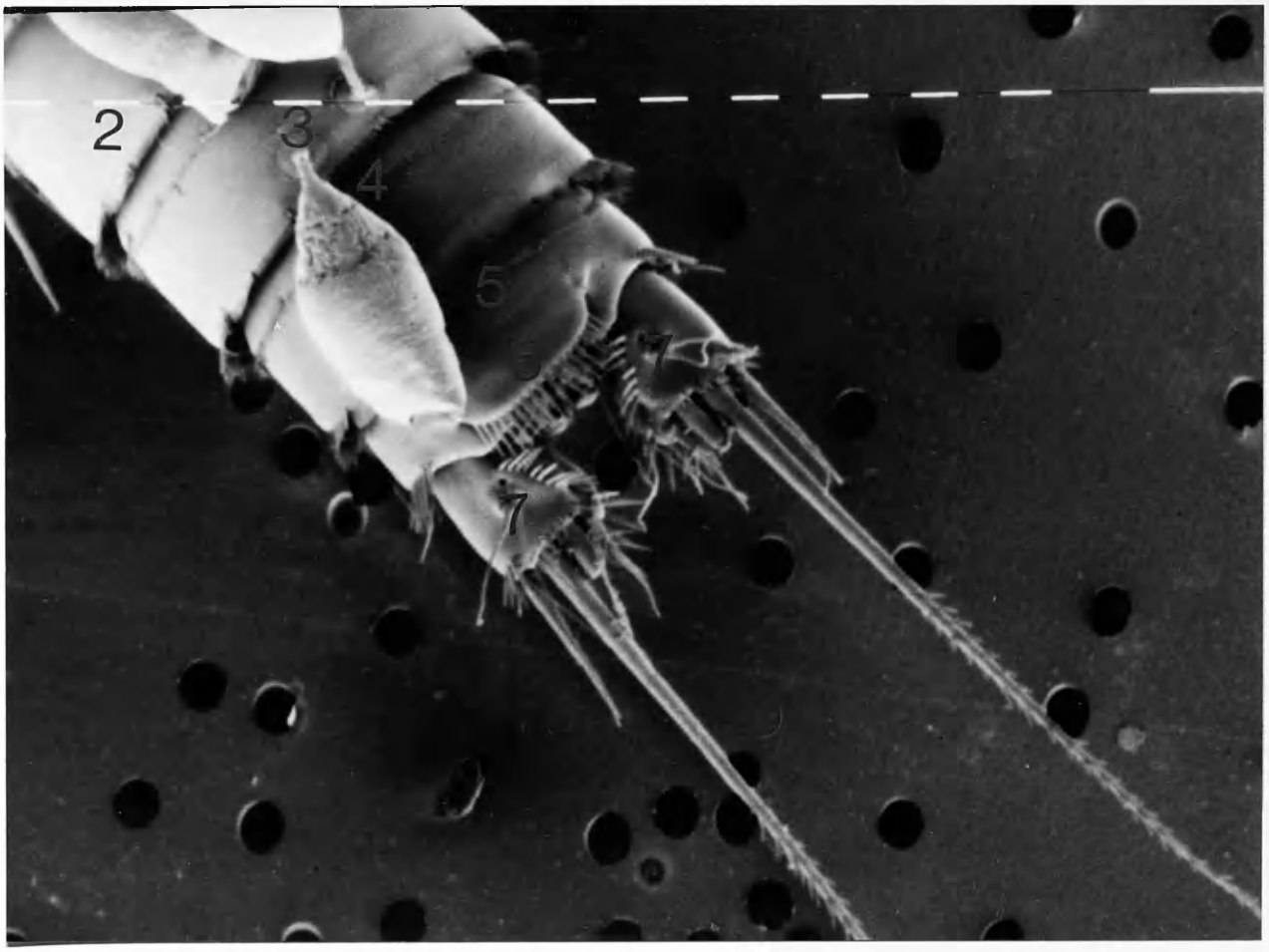


Figure 14. Tachidius discipes. Ardmore Point. Female. Fifth leg having a number of spines and hairs.

Plate 19. Tachidius discipes. Ardmore Point. Abdominal segments (2-5), anal operculum (6) with fine spines on its posterior border, and caudal furcae (7) covered with fine spines on their medial and appenedges. Holes in background are the holes of the membrane filter on which the animal is lying. Black lines between white dashes = 10 u

Plate 20. Tachidius discipes. Ardmore Point. Female. Right pair of the fifth leg (small arrow), and egg sac (big arrow). Black lines between white dashes = 10 u


2
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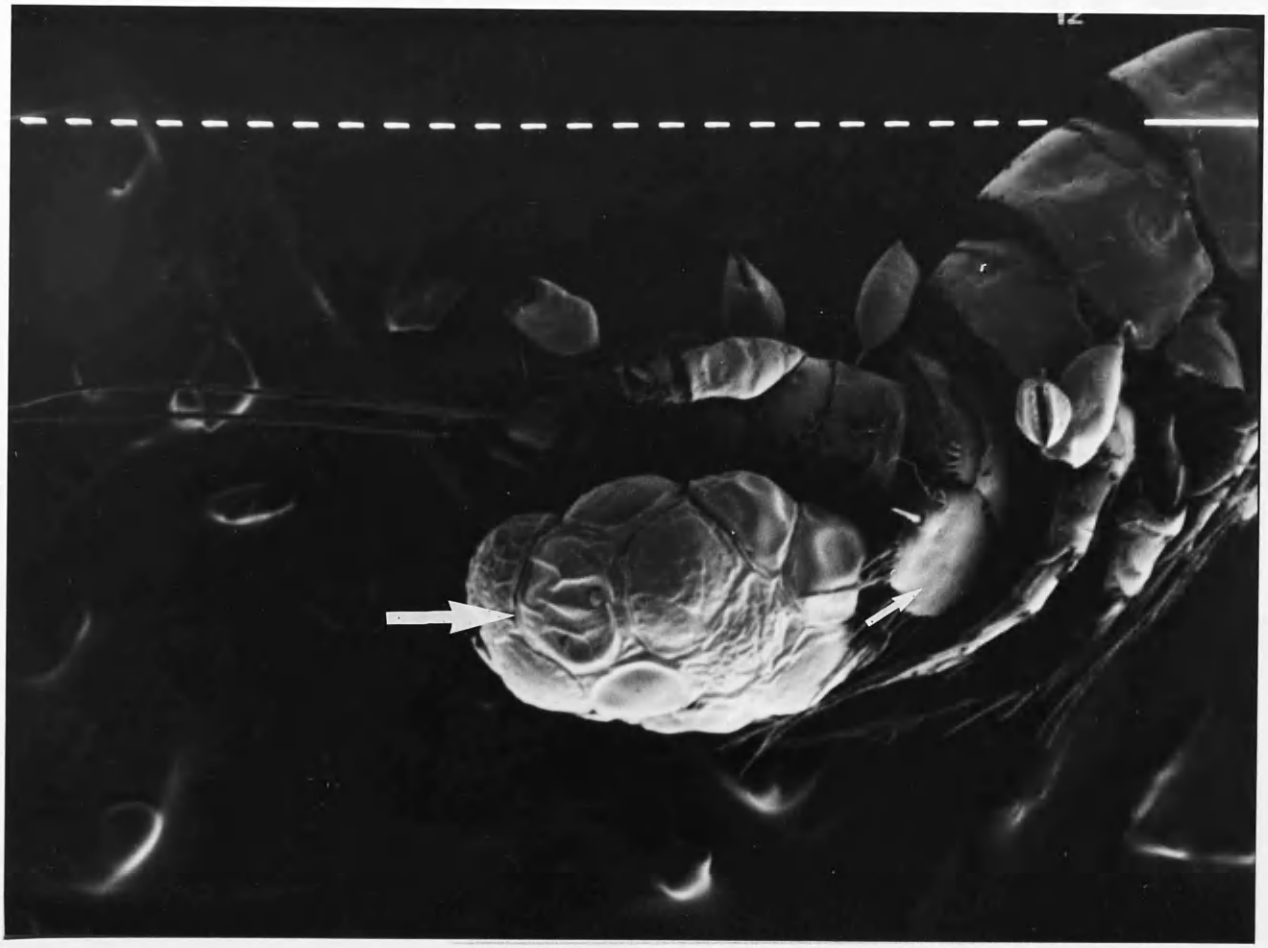


Overall differences between Calanus finmarchicus and Tachidius discipes.

I have studied the anatomy of two different species of copepods, one belonging to the Calanoida and one belonging to the Harpacticoida. The two species have very different anatomies in detail which I have summarised as follows.

1 - The general body of Calanus finmarchicus is an elongated shape and smooth, while the body of Tachidius discipes is broad, and flattened. The surface of the cuticle in Tachidius discipes has small hairs and pores, and the thoracic segments are fringed with small spines. The first antenna in Calanus finmarchicus is as long as the body length and is composed of 24 segments, while in Tachidius discipes it is short compared to the length of the body and is composed of 5 to 7 segments.

2 - Basipodites are obvious in Calanus finmarchicus, and consist of two large segments. The basipodites in Tachidius discipes are not so obvious.

3 - In Tachidius discipes, the exopodite in the first leg is slightly shorter than the endopodite and in leg 2 to 4 is slightly longer than the endopodite. Leg 5 is unsegmented and highly modified. In Calanus finmarchicus, the exopodites in legs 1 to 5 are always longer than the endopodite (Lebour, 1916, pp.11, plate 5, figures 11-15, and pp.16 description of stage 5 copepodite).

4 - In Tachidius discipes, the external side of the exopodite and endopodite in legs 1 to 4 has a large number of small hairs. In Calanus finmarchicus, the external sides of the exopodites and endopodites in legs 1 to 5 have less hairs. This probably because Tachidius discipes lives in the sediment, and these hairs may help the animal to move between the sand grains.

5 - The contrasting anatomy of two species is clearly related to their different modes of life. Calanus finmarchicus is an entirely pelagic form while Tachidius discipes is a species that spends most of its life in the top few centimeters of the sediment but probably makes periodic excursions into the overlying water at night. The body of Calanus finmarchicus is smooth, the abdomen is much narrower than the thorax, the first antenna is as long as the body length, and few hairs found on the external side of the exopodites and endopodites (P1-P5). The body of Tachidius discipes is broadly elongated, having 9 segments. The abdomen is thinner than the thorax, and long setae are carried by the caudal rami. The thoracic segments have hairs along their posterior margins which may keep the joints between the segments clean and also aid in movement through the sediment. The five pairs of legs have spines and setae which are likely to be important in aiding movements between sediment grains. The setae at the distal end of the legs are also likely to be important in swimming when the adults emerge from sediments. In contrast, Calanus finmarchicus which is entirely pelagic is more smooth and has no spines but many setae on its legs, which are clearly an aid to swimming.

Section (3)

Annual Survey:

Part 1. An ecological study of Harpacticoid copepods over one year at two months intervals.

Part 2. A comparative study between winter (January 1987) and summer (July 1987) in terms of harpacticoid copepod, nematodes and particle size.

INTRODUCTION

The introduction is divided into six parts as follows:

1 - Purpose of study.

2 - Ardmore Bay.

3 - Meiofauna.

4 - Harpacticoid copepods.

5 - Nematodes.

6 - Particle size.

1 - Purpose of study:

The main purpose of my study carried out at Ardmore Bay and described in this section of the thesis was two fold: firstly, to determine the annual cycle of abundance in harpacticoid copepods at high, mid and low tides by sampling at 2 month intervals (October 1986, December 1986, February 1987, April 1987, June 1987, August 1987); secondly to study seasonal differences between winter (January 1987) and summer (July 1987) in the abundance of harpacticoid copepods and nematodes, and in sediment particle size parameters along a transect of 5 stations from high tide to low tide.

The results were submitted to a full statistical analysis after transformations where appropriate, in order to make meaningful statements about the results, and also partly as a training exercise. The statistical tests used were two-way and one way analyses of variance and unpaired student's t-tests.

2 - Ardmore Bay:

The ecological studies described in this section of the thesis were carried out on meiofaunal harpacticoids and nematodes, and on particle size parameters at Ardmore Bay. Ardmore Bay is a relatively sheltered intertidal Bay in the Clyde Estuary, Scotland. It faces north west into the prevailing winds (map 1). The sediment on the

beach is a medium to fine sand containing a small proportion of finer particles. Towards low tide the sediment is formed into a number of low sand waves facing into the direction of the prevailing winds. The mid-tide area is flat and the surface of the sand usually contains ripples. Towards high tide there are a number of small boulders embedded in the sediment whose diameters are about 20 cm to 100 cm. There are also a number of algal patches of Enteromorpha towards high tide. The lower part of the beach tends to be a medium-energy slightly erosional sedimentary environment, while the higher part of the beach is a lower-energy slightly depositional sedimentary environment.

3 - Meiofauna:

The distribution of marine benthos has been studied extensively by many authors. For example, inter-organism processes, such as competition and predation have been examined by observing changes in spatial abundance (Woodin, 1974; Osman,1977; Jumars, 1978; Todd, 1978; Reise, 1979). Analyses of dispersion patterns of meiofauna have been less common, although their high numbers make them suitable for spatial studies (Heip, 1976).

Meiofauna are marine benthic organisms living in almost all marine environments. The term is generally used to refer to animals, most of which are metazoans, that can pass a 1.00 mm to 0.5 mm screen. According to an international conference on meiofauna held in Tunisia (1969), meiofauna are divided into soft and hard forms. The distinction is made subjectively on the basis of the resistance of the integument to mechanical damage.

The soft forms include taxa with a soft integument and usually a great ability to change shape and contract. The taxa grouped as soft taxa include, Ciliata, Cnidaria, Turbellaria, Gnathostomulida, Nemertina, Gastrotricha, Archiannelida, Polychaeta, Oligochaeta, Mollusca, and Echinodermata.

The hard forms consist of taxa whose representatives contract only slightly, if at all, and possess a shell or an inelastic cuticle. The hard fauna taxa include Foraminifera, Kinorhyncha, Priapulida, Nematoda, Bryozoa, Brachiopoda, Mystacocarida, Ostracoda, Copepoda, Palpigradida, Halacaridae, Tardigrada, and Tunicata.

4 - Harpacticoid copepods:

Harpacticoid copepods are the second largest group in the meiofauna the largest group being the nematodes(Willems et al, 1982a; Nybakken, 1988). Harpacticoids live almost everywhere in the marine environment, feeding on small organisms such as bacteria and diatoms. They play an important role in food chains and are a main source of food for larger animals such as fish. Studies have been conducted on the vertical and horizontal distribution of the meiofauna in a wide range of marine ecosystems such as estuaries, the intertidal zone, and the deep sea (Barnett, 1968; Gray and Rieger, 1971; Harris, 1972a,b,c,d; Moore, 1979; Emberton, 1981; Findlay, 1981; Scaramuzza and Martino, 1981; Gunnil, 1982; Hockin, 1982; Coull et al, 1983; Thistle, 1983; Chandler and Fleeger, 1984; Sebens and Koehl, 1984).

Most ecological studies conducted on harpacticoid copepods show that they live in the upper few centimeters of sediments (Barnett, 1968; McIntyre, 1969; O'Riordon, 1971; Coull, 1977; Woods and Tietjen, 1985). Some studies have shown that harpacticoid copepods may be found to a depth of 50 cm particularly in winter (Harris, 1972a).

5 - Nematodes:

The first work on the marine nematodes in Britain was done by Bastian (1865). This was followed by a number of descriptions of new species made by Southern (1914) during the Clare Island survey. Since then the marine nematodes in Plymouth have been described by Schuurmaus-Stekhoven (1935b) and by Wieser (1951,1952) in

two major works, and a major work on the free living marine nematodes has been published by Platt and Warwick (1983).

Nematodes form a dominant group of the meiofauna (Willems, 1982a; Bouwman, 1987; Nybakken, 1988). They may feed on bacteria and diatoms. Thurman and Webber (1984) stated that the food available for nematodes includes bacteria and diatoms.

Boaden and Seed (1985) demonstrated that in sand, nematode density can reach 1-3 x 10^{-6} m^{-2}, and numbers may be four or more times greater in mud. They also pointed out that many nematodes can live in sediments having little or no free oxygen.

Rees (1940) dealt with the horizontal and vertical distribution of nematodes found in a mud flat , Bristol Channel. The work of Rees has shown that nematodes inhabiting intertidal mud have their largest population densities in the surface 1cm, and as depth increases population densities decrease until at a depth of 5 cm few nematodes are found.

6 - Particle size:

The most common scale used for particle size analysis was that devised by Wentworth (1922), and the phi (ϕ) scale devised by Krumbein (1934). The Wenthworth scale is a logarithmic scale in which each grade limit is twice as large as the next small grade (Folk, 1980). The phi (ϕ) was introduced as a log transformation to simplify the calculation of sediment characteristics such as mean, median, sorting (s.d), skewness, and kurtosis (Folk 1966). Conversion from millimeters to phi is given by:

$$\phi = - \log 2\ d$$

where d = particle diameter in mm.

The standard scale of size classes used in the United Kingdom is the British Standard Institution Scale (BS 1377, 1975) which consists of normal classes each having a definite upper and lower size limit. The classes and their mm and phi limits are given in detail in Folk (1980) and summarised below.

Class	Range of particle size	
	mm	ph(ϕ)
Gravel	>2.00	<-1.0
Very coarse sand	2.00 - 1.00	-1.00 - 0.00
Coarse sand	1.00 - 0.50	0.00 - 1.00
Medium sand	0.50 - 0.25	1.00 - 2.00
Fine sand	0.25 - 0.125	2.00 - 3.00
Very fine sand	0.125 - 0.0625	3.00 - 4.00
Coarse silt	0.0625 - 0.031	4.00 - 5.00
Medium silt	0.031 - 0.0156	5.00 - 6.00
Fine silt	0.0156 - 0.0078	6.00 - 7.00
Very fine silt	0.0078 - 0.0039	7.00 - 8.00
Clay	<0.0039	>8.00

In addition to the standard particle size scale, sediment can be compared in terms of mean, sorting (standard deviation), skewness and kurtosis (Briggs, 1977) which are standard measures of normal and non-normal distributions (Snedecor and Cochran, 1980). The mean is a measure of the central tendency in a given sample (Cohen and Holliday, 1984). The standard deviation measures the variability within the sample taken. Skewness measures the degree of asymmetry or non-normality of the distribution. Kurtosis measures the peakness of the size distribution and is therefore related to sorting and skewness or non-normality of the distribution.

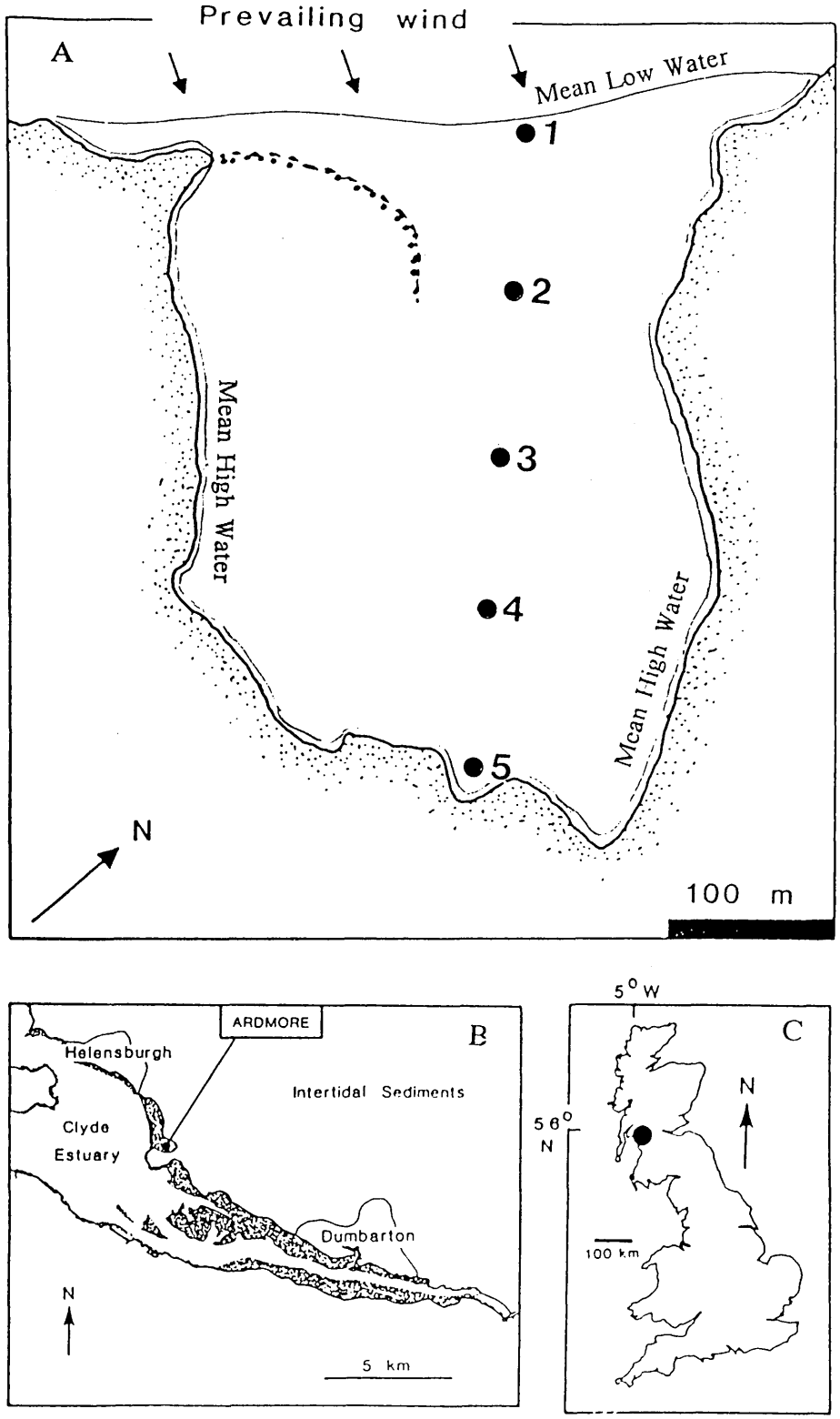
Morgan (1956) provided useful information on the treatment and analysis of marine sediments. Other study techniques may be found in Krumbein and Pettijohn (1938), Trask and Rolston (1950), and Ackroyd (1964).

MATERIALS and METHODS

Sediment samples were collected from Ardmore Bay from October 1986 to September 1987. Five stations (1,2,3,4,5) were established along a straight line transect on the beach from low water to high water (map 1). The stations were marked by wooden poles pushed deeply into the sediment. The distance between each station was approximately 100 m. The first, third, and fifth stations were at low tide neaps, mid tide, and high tide neaps respectively. These 3 stations were sampled for harpacticoid copepods at two monthly intervals (Oct 86; Dec 86; Feb 87; Apr 87; Jun 87; Aug 87) and the results form part one of this section of the thesis. All five stations were sampled for harpacticoid copepods, nematodes and particle size in January 1987 and July 1987 and the results of this detailed survey form part two in this section of the thesis.

Sediment samples were collected using a perspex tube core of 5 cm internal diameter and 25 cm length (tapered at one end and marked 20 cm from the tapered end). This tube was pushed into the sediment tapered end first until the label was not visible. This gave a sediment core of a little less than 20 cm because of compaction. The sediment was gently pushed out of the non-tapered end of the core, and cut into 8 sections (0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm) using a knife. These sections were then placed on a plastic tray in order, avoiding cross-contamination. Each section was vertically halved, and one half was placed in a small container (2.2 cm in diameter and 9 cm length) and the other half was discarded. This was done because half the section was sufficent for extraction of harpacticoids, and to use a smaller diameter core would have lead to greater problems of compaction.

The sediment samples were brought to the laboratory within about 1 hour of collection. 7.84 ml of freshwater was added to the 9.8 ml of sediment in order to kill the animals and to avoid shrinking of animal tissues (Barnett - personal communication) (9.8 ml = volume of 1/2 of core section diameter 5 cm and length 1



Map 1. (A) Ardmore Bay showing the five sampling stations 1, 2, 3, 4, and 5, (B) location of Ardmore Bay in Clyde Estuary, and (C) location of Clyde Estuary (black circle) in Britain.

cm). 1.74 ml of concentrated Steedman's solution was then added to each sample to give a dilution of 1:9. All of the samples were kept preserved until the animals were separated from the sediment.

Extraction of harpacticoid copepods:

An elutriation technique (figure 15) was used to obtain harpacticoid copepods from the sediment samples. Samples of sediment were poured into a 400 ml separating funnel. A rubber tube leading to a 35 um nylon net was connected to the top of the funnel. A tapwater supply was allowed to flow up through a second rubber tube into the bottom of the separating funnel. The tapwater supply and the tap of the funnel were opened simultaneously, the water entered the funnel, and the sand became fluid and began to mix. This was allowed to continue for 15 minutes. Preliminary tests showed that this was the time required to remove all harpacticoid copepods from the sediment. After this time, the flow of water through the elutriator was stopped and the contents of 35 um nylon net was back-washed with dilute Steedman's solution (1:9) and inspected for harpacticoid copepods (Hardy, 1977). This technique was only used to extract the animals from samples of October 1986, December 1986, and February 1987. For the remaining samples, Reichelt's technique (1988) was used.

Reichelt's elutriator (figure 16) can be described as follows. A sample of sediment was placed in a separating funnel which had a seawater supply attached to its base and outlet at its tap leading to a sieve (35 um net). Seawater was pumped upwards through the sediment in the separating funnel. The water flow was adjusted so that the sediment particles were fluidised and raised $2/3^{rds}$ of the way up the funnel before falling back. The animals were carried over onto the sieve by the water flow. This elutriator is a closed circuit system. The system has a seawater tank containing a submerged pump. The outlet from this pump was connected via a series of flow splitters to eight separating funnels. Each of the separating funnels was connected to a separate sieve, the elutriating water draining through the sieves back to the tank.

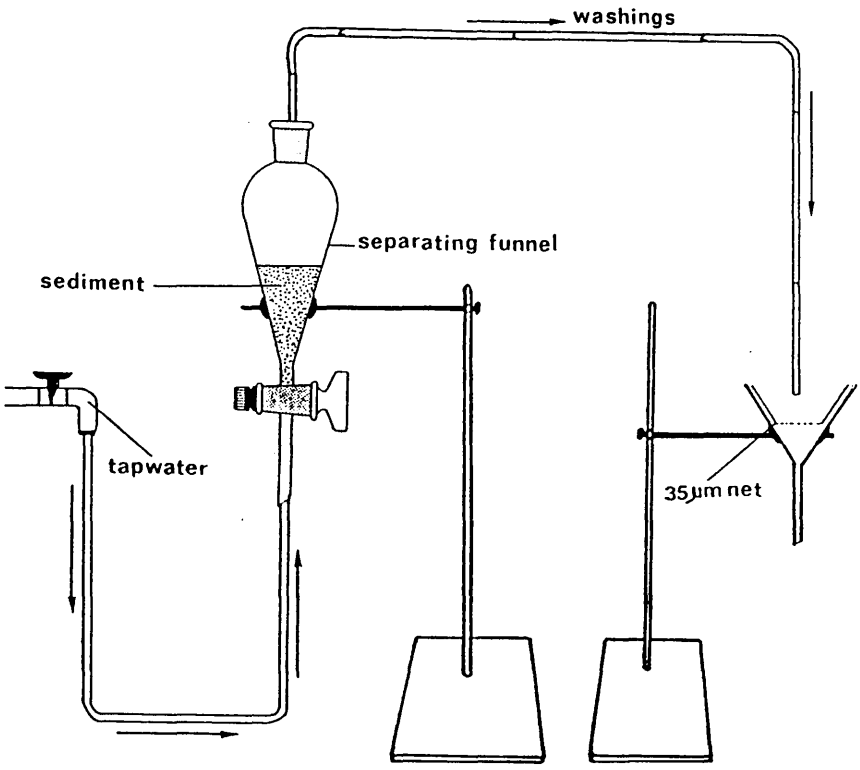


Figure 15. Elutriator equipment taken from Hardy's thesis (1977).

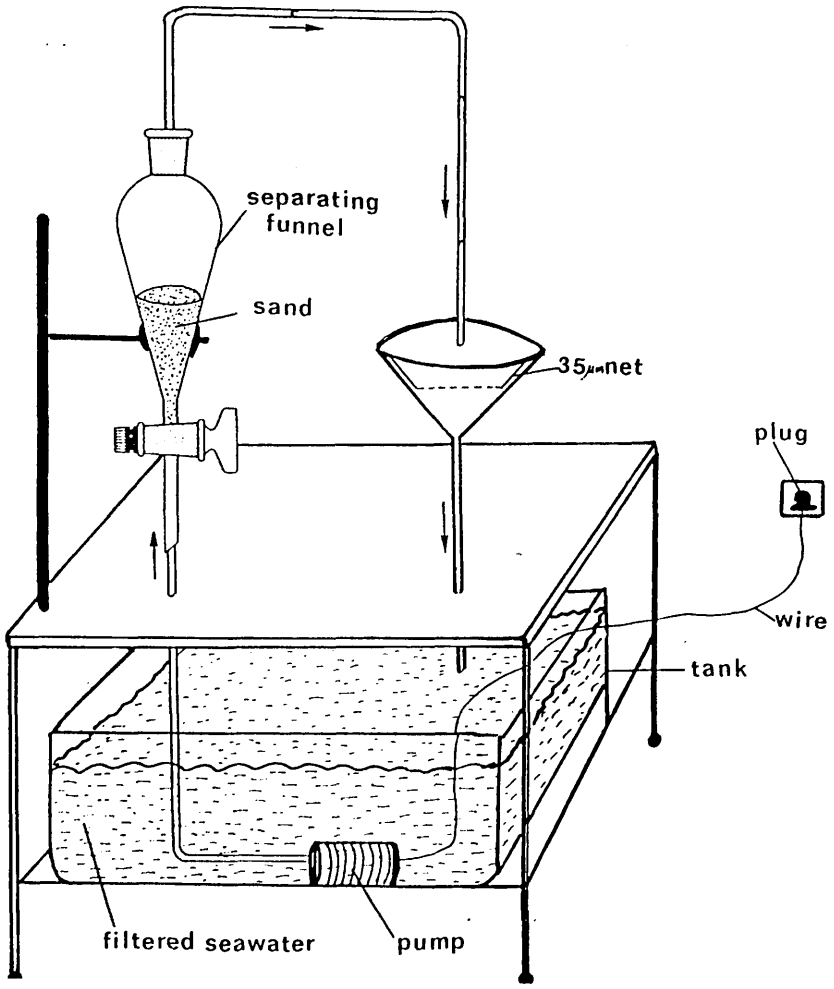


Figure 16. Elutriator equipment taken from Reichelt's thesis (1988).

Reichelt found that elutriation for 20-25 minutes produced an extraction efficiency of over 99%. If samples were staggered by five minutes when the elutriator was set up, by the time the eighth sample was running the first sample could be removed. This made the elutriator very time efficent for large numbers of samples, and proved easy to operate.

Counting was done as follows. The extracted samples were gently shaken to evenly distribute the animals, and three 5 ml replicates were taken randomly using a pipette. These replicates were put into a squared petri-dish. The animals were then counted and sorted out into 6 groups with the aid of a binocular microscope using a tally counter. These groups were adults, first copepodites, second copepodites, third copepopdites, fourth copepodites, and fifth copepodites. This was only for October 1986, December 1986, and February 1987. For April 1987, June 1987, and August 1987 the counting included adults and copepodites without staging. The surface area (A) in cm^2 of the sediment section was calculated from the core radius (r^2) in cm using the following equation:

$$A = \pi r^2$$

$$= 3.14 \times 2.5 \times 2.5$$

$$= 19.63 \ cm^2$$

But only one half of the core was sampled

Therefore $A/2 = 19.63/2 = 9.8175$

The volume of the samples after elutriation (volume of dilute Steedman's solution used to wash the net) was approximately 24 ml. Three 5 ml replicates of this volume were taken and numbers of animals (n) were counted. The abundance of animals was then calculated as follows: Density (no/cm^2) = $n/9.8175$ no. of animals/cm^2.

After the animals (harpacticoids, nematodes) were extracted from the sediment of January 1987 and July 1987, the residual sediment samples of depths (0-1 cm, 3-4

cm, 7-8, 13-14 cm) for the particle size analysis were then put in monopots and placed in the basement for 24 hours to dry. After drying, any aggregations were broken down gently by hand. The dry sediment was placed on the top sieves and shaken for 30 minutes using a mechanical shaker. The following British Standard sieves were used: 1000 um, 710 um, 500 um, 335 um, 250 um, 180 um, 125 um, 90 um, 63 um, 45 um, and pan.

After shaking for the specified time the sediment retained by each sieve was collected in a white tray by back brushing the sieves using a rough brush for the coarser sediment and a smooth brush for the finer sediment. The sediment was then brushed in separate pre-weighed container and weighed using a balance which gave an accuracy of 0.0001 g (i.e. 0.1 mg).

RESULTS (Part 1)

The original data for the number of total harpacticoids, adults, and copepodites for different depths, the three tidal levels and the six months (October 86, December 86, February 87, April 87, June 87, August 87) are given in appendix 2 tables 211-228. These data are given in summary in tables 2 to 7, and in figures 17, 18 and 19 which are drawn from the data in these tables. Summary graphs for the annual cycle at low, mid, and high tide for total harpacticoids, adult harpacticoids and percentage of copepodites are given in figures 16a, 16b, and 16c which include January 1987 and July 1987 data from part 2. In this, the first section, I describe and statistically analyse the differences between the three tidal levels and different months using abundances in the top 1 cm, because most of the animals are found in this depth (see the original data). The January 1987 and July 1987 data from part two were not included in these statistical analyses.

Note: Figures 16a-40, and tables 2-37 (Results of part 1) are on pages 75 to 139.

1 - Differences between three tidal levels at different months in the top 1 cm. Description and statistical analysis. Totals, Adults, Copepodites.

Figures 16a, 16b and 16c summarise the annual cycle of total harpacticoids, adults and copepodites for low tide (station 1), mid tide (station 3), and high tide (station 5). They include January and July data from part 2 p. 156, 157, 161, 162, 166, and 167.

1.1 - Total harpacticoids.

There were very different patterns in the abundance of total harpacticoids at the three sites (figures 16a, 17, 18, 19; tables 2, 3). At low tide there were low numbers in December, January, February and April and much higher numbers in June, July and August. At mid tide, there were also low numbers in winter and a peak in June and July but a fall in August. The mid and low tide cycles are therefore broadly

similar. The high tide cycle differed from the low and mid tide cycle in two important ways. Firstly, the total number of harpacticoids was much higher, secondly the highest numbers occurred in October with a secondary peak in February while the lowest numbers occurred in January, June and July (see discussion item 1.1).

The changing patterns of abundance of the total harpacticoids over the year, and the differences between low, mid and high tides were then statistically analysed (1.1.1, 1.1.1.1, 1.1.1.2). These analyses showed that the statements just made are in general statistically valid.

1.1.1 Statistical analyses:

The abundance data of total harpacticoid copepods was statistically compared using one way analyses of variance comparing the six months for each tidal level, and then tidal levels for each month.

1.1.1.1 - Comparison between the six months: The six months were compared (Oct.86/Dec.86/Feb.87/Apr.87/Jun.87/Aug.87) by three 1x6 anovars one for each tidal level (table 8). All comparisons were highly significant (tables 9, 10, 11).

Break down 1x2 one way analyses of variance were then applied to the data, testing differences between pairs of months at low tide, mid-tide, and high tide. This resulted in 15 comparisons at each tidal level.

At low tide (table 9), 13 out of 15 comparisons were statistically significant. At mid tide (table 10), 10 out of 15 comparisons were statistically significant. At high tide (table 11), 14 comparisons out of 15 were statistically significant. F ratios and probabilities from these comparisons are summarised in tables 12, 13, and 14.

In general, therefore, the observed changes in abundances of total harpacticoids during the year described in section 1.1 above (figure 16a) and given in more detail in figures 17, 18 and 19 and tables 2 and 3, are statistically significant and therefore

represent real effects.

1.1.1.2 - Comparison between tidal levels for each month: The three tidal levels (LT/MT/HT) were compared by six 1x3 one way analyses of variance one for each month. The results of this showed that all comparisons were statistically significantly different (tables 15).

Break down 1x2 one way analyses of variance were then applied to the data, testing differences between pairs of tidal levels at each month (table 16, 17). 14 out of a total of 18 of these 1x2 one way anovars were significantly different.

Careful inspection of the data in figures 16a, 17, 18 and 19, and in tables 2 and 3 together with the results of these statistical analyses enabled the following statistically valid statements to be made about the relative abundances of the total harpacticoids at low, mid and high tide. Numbers at high tide were highest in October, February and August and lowest in June. Numbers at mid tide were lowest in April and August. Numbers at low tide were highest in June, and lowest in February.

These changes between the relative abundance of total harpacticoids at low, mid and high tide reflect the changing patterns of relative abundance at the three stations over the yearly cycle described in 1.1 above and illustrated in figures 16a, 17, 18, and 19 , and in tables 2 and 3.

1.2 - Adult harpacticoids.

The patterns for the abundance of adult harpacticoids were very similar to the patterns for total harpacticoids. This can be seen by comparing figures 16a and 16b, by comparing the total and adult histogram bars in figures 17, 18 and 19, and by comparing the data for total abundances given in tables 4 and 5. At low and mid tide there was a peak in numbers in summer (June, July, August) and low numbers in winter and spring (December, January, February, April), so the annual cycle in

numbers of adults at low and mid tide is very similar. The annual cycle of adults at high tide, however, is different. Here there are two peaks, one in autumn (October) and one in early spring (February). The reasons for the differences between the low and mid tide cycles and the high tide cycle are discussed in detail in the discussion (items 1.1 and 1.2).

The abundances of adult harpacticoids over the year, and at the three tidal levels were then statistically analysed (1.2.1, 1.2.1.1, 1.2.1.2). These analyses showed that the statements just made are in general statistically valid.

1.2.1 Statistical analyses:

The abundances of adults were statistically compared using one way analyses of variance comparing the six months at each tidal level, and then tidal levels at each month.

1.2.1.1 - Comparison between months: The six months (Oct.86/Dec.86/Feb.87/Apr.87/Jun.87/Aug.87) were compared by three 1x6 anovars one for each tidal level (table 18). All comparisons were highly significant.

Break down 1x2 one way analyses of variance were then applied to the data, testing differences between pairs of months at low tide, mid tide, and high tide (tables 19, 20, 21). This resulted in 15 comparisons at each tidal level.

At low tide, 13 out of 15 comparisons were statistically significant (table 19). At mid tide, 7 out of 15 comparisons were statistically significant (table 20). At high tide, 14 out of 15 comparisons were statistically significant (table 21). F ratios and probabilities from these comparisons are summarised in tables 22, 23, and 24.

In general, therefore, as with the total harpacticoids with which they are very similar, the observed changes in adult harpacticoids during the year (figure 16b) (see section 1.1 and 1.2), and given in more detail in figures 17, 18 and 19, are statistically

significant and hence represent real changes in the abundance of adult harpacticoids at low tide, mid tide and high tide throughout the year.

1.2.1.2 - Comparison between tidal levels at each month: The three tidal levels (LT/MT/HT) were statistically compared by six 1x3 one way analyses of variances one for each month (table 25). Five out of these six comparisons were highly significant.

Break down 1x2 one way analyses of variance were then applied to the data, testing differences between pairs of tidal levels at each month (table 26, 27). 13 out of a total of 18 of these 1x2 one way anovars were statistically significant.

As with the totals, careful inspection of the data in figures 16b, 17, 18 and 19, and in tables 4 and 5 together with the results of the statistical analyses, enable the following statistically valid statements to be made about the relative abundances of the adult harpacticoids at low, mid and high tide. Numbers at high tide were highest in October, February, and August, and lowest in June. Numbers at mid tide were highest in June, but lowest in August. Numbers at low tide were lowest in December and February.

These changes between the relative abundances of adult harpacticoids at low, mid and high tide, which are similar to those for the total harpacticoids, reflect the changing patterns of relative abundance at the three stations over the yearly cycle that have been described in 1.1 and 1.2 above and are illustrated in figures 16b, 17, 18 and 19.

1.3 - Copepodites.

The percentage of copepodites and their abundances (figures 16c, 17, 18; table 6, 7) showed distinct cycles during the year and also differences between the low tide, mid tide and high tide sites which are different from the adults. At low tide the numbers

of copepodites were fairly high throughout the year, with distinct peaks in December, February, June and August and troughs in January, April and July. At mid tide, in contrast, copepodites peaked in December and January and were very low in February, April, and July. At low tide copepodites were more abundant than at mid tide from February to August, but less from October to January. The results for copepodites at high tide were surprising, since there were virtually no copepodites in the population at any point in the year except October. The interpretation of the differences in abundance of copepodites during the annual cycle and between the low, mid and high tide levels are discussed in the discussion (item 1.1).

These abundances were then statistically analysed (1.3.1, 1.3.1.1, 1.3.1.2) comparing differences between months and tidal levels. The results of statistical analyses showed that the above statements are statistically valid.

1.3.1 Statistical analyses:

The abundances of copepodites were statistically compared using one way analyses of variance comparing the six months at each tidal level, and then tidal levels at each month.

1.3.1.1 - Comparison between the six months: The six months (Oct.86/Dec.86/Feb.87/Apr.87/Jun.87/Aug.87) were compared by three 1x6 anovars one for each tidal level (table 28). The comparisons between the six months were significant at low tide and mid tide, but not signficant at high tide.

Break down 1x2 one way analyses of variance were then applied to the data, testing differences between pairs of months at low tide, mid tide, and high tide (tables 29, 30, 31). This resulted in 15 comparisons at each tidal level.

At low tide (table 29), 11 out of 15 comparisons were statistically significant. At mid tide (table 30), 11 out of 15 comparisons were statistically significant. At high tide (table 31), only five comparisons were made and none of these were significant.

F ratios and probabilities from these comparisons are summarised in tables 32, 33 and 34.

In general, therefore, the observed changes in the copepodites during the year at low and mid tide (figure 16c, 17, 18, 19; tables 6, 7) described in 1.3 above, are statistically significant and therefore represent real effects. There are of course no significant differences between months at high tide because there were virtually no copepodites there.

1.3.1.2 - Comparison between tidal levels for each month: The three tidal levels (LT/MT/HT) were compared by six 1x3 one way analyses of variance one for at each month (table 35). Five out of these six comparisons were statistically significant.

Break down 1x2 one way analyses of variance were then applied on the data, testing differences between pairs of tidal levels at each month. Results of this are shown in tables 36 and 37. 10 out of 17 possible comparisons were statistically significant.

Careful inspection of the data in figures 16c, 17, 18 and 19, and tables 36 and 37 together with the results of the statistical analyses show that in April, June and August there were higher numbers at low tide than at mid tide, and at mid tide than at high tide.

2 - Depth distribution of totals, adults and copepodites at different months. Description.

The results were plotted as histograms (figures 20-32) and showed generally that as expected the number of animals decreases with increasing depth, most animals being found in the top 1 to 2 cm of the sediment. The reasons for this are discussed in the discussion (item 1.3).

In October 1986, the number of total animals, adults and copepodites decreases as depth increases for the three tidal levels (figures 20, 21, 22). This is not true at low tide where the number of copepodites slightly increased with increasing depth (figure 20).

In December 1986, at low tide the number of total animals, adults, and copepodites increased as depth increased (figure 23). At mid tide, the number of all animals decreased as depth increased (figure 24). At high tide, the number of adults decreased with increasing depth but no copepodites were found at any depth (figure 25).

In February 1987, animals were only found at 0-1 cm at low tide and mid tide (figures 26, 27). At high tide, the number of total and adults was very high at depth of 0-1 cm and dramatically decreased as depth increased (figure 28).

In April 1987, at low tide the total number of animals, adults, and copepodites were only abundant at 0-1 cm and 1-2 cm (figure 29). At mid tide, the number of adults decreased considerably as depth increased, but no copepodites were found at any depth (figure 30). At high tide, the number of adults was very high at depth of 0-1 cm and rapidly decreased as depth increased (figure 31), while no copepodites were found at any depth.

In June 1987, at low tide the number of total, adults, and copepodites were high near the surface with significant numbers down to about 5 cm (figure 32). At mid tide, the number of adults and copepodites decreased with increasing depth (figure 33). At high tide, adults were only found at 0-1 cm and no copepodites were found at any depth (figure 34).

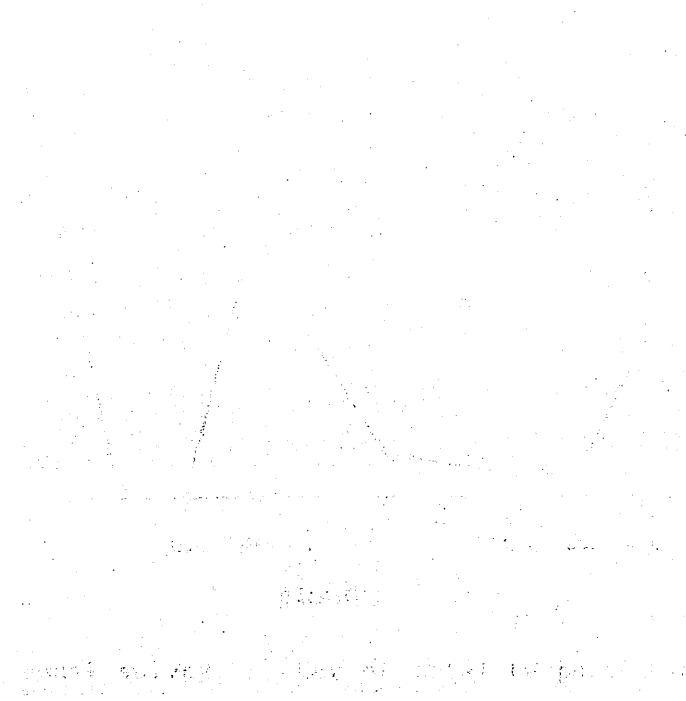
In August 1987, at low tide the numbers of adults and copepodites were very high at 0-1 cm and decreased rapidly as depth increased (figure 35). At mid tide, the density of all animals decreased with increasing depth (figure 36). At high tide, no

copepodites were found at any depth, while the number of adults was very high at 0-1 cm and dramatically decreased as depth increased (figure 37).

The results of adults and copepodites were summarised for all months combined at low tide, mid tide, and high tide. This was done by adding the number of animals per centimeter squared from all months at each depth for the three tidal levels.

Figures 38, 39, and 40 show the number of adults and copepodites respectively at low tide, mid tide, and high tide was very high at 0-1 cm and rapidly decreased as depth increased.

Overall, the highest density of adults during the year in the top 1 cm was found at high tide (figure 40), and the lowest at mid tide. However, there is not a great difference between mid tide and high tide (figures 38, 39). The highest density of copepodites for the six months in the top 1 cm was found at low tide (figure 38), and the lowest at high tide (figure 40).



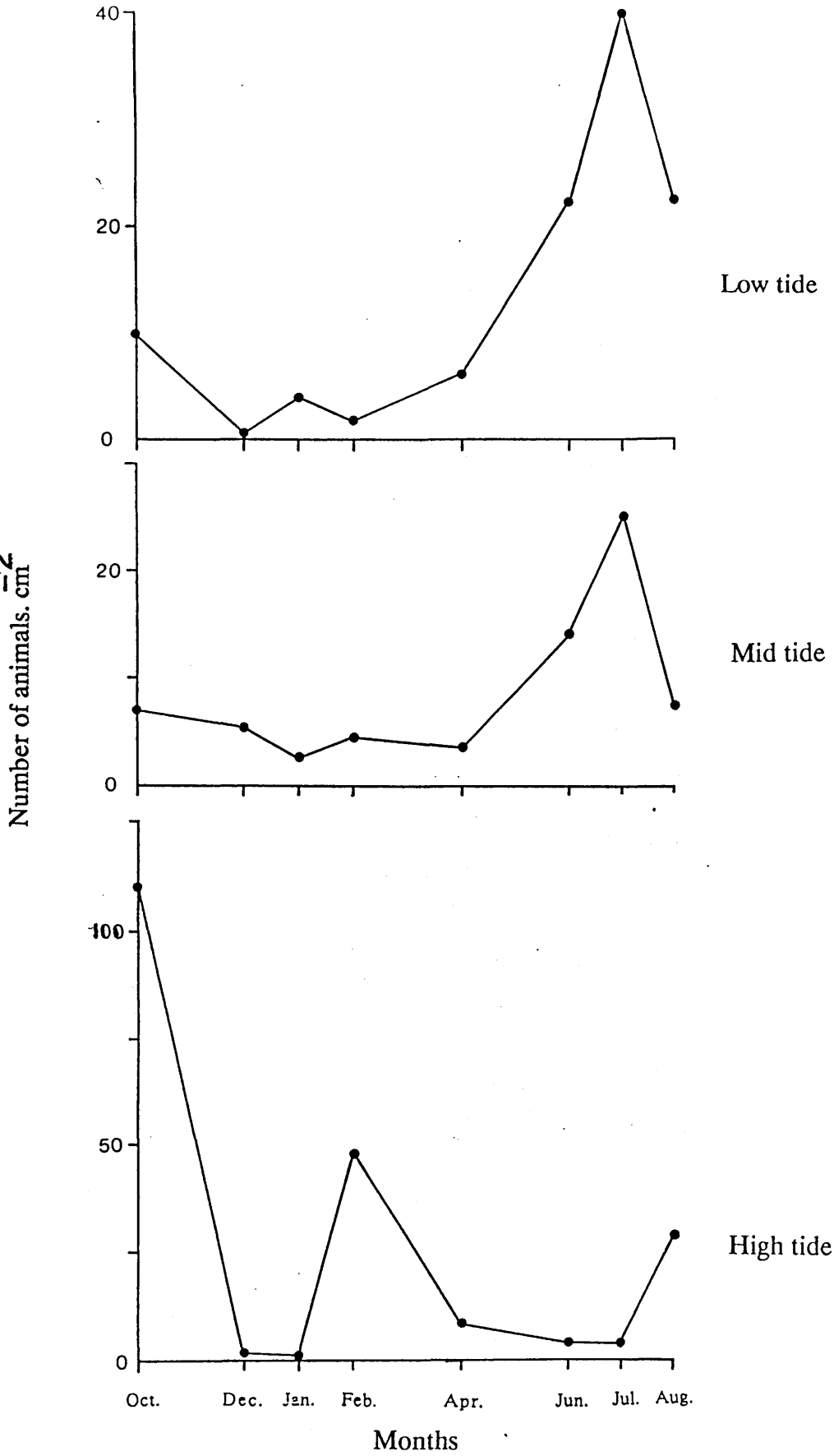


Figure 16a. Annual survey. Number of total harpacticoids at a depth of 0-1 cm for October 86, December 86, January 87, February 87, April 87, June 87, July 87, and August 87 at low tide, mid tide, and high tide. Each point represents the mean for that month.

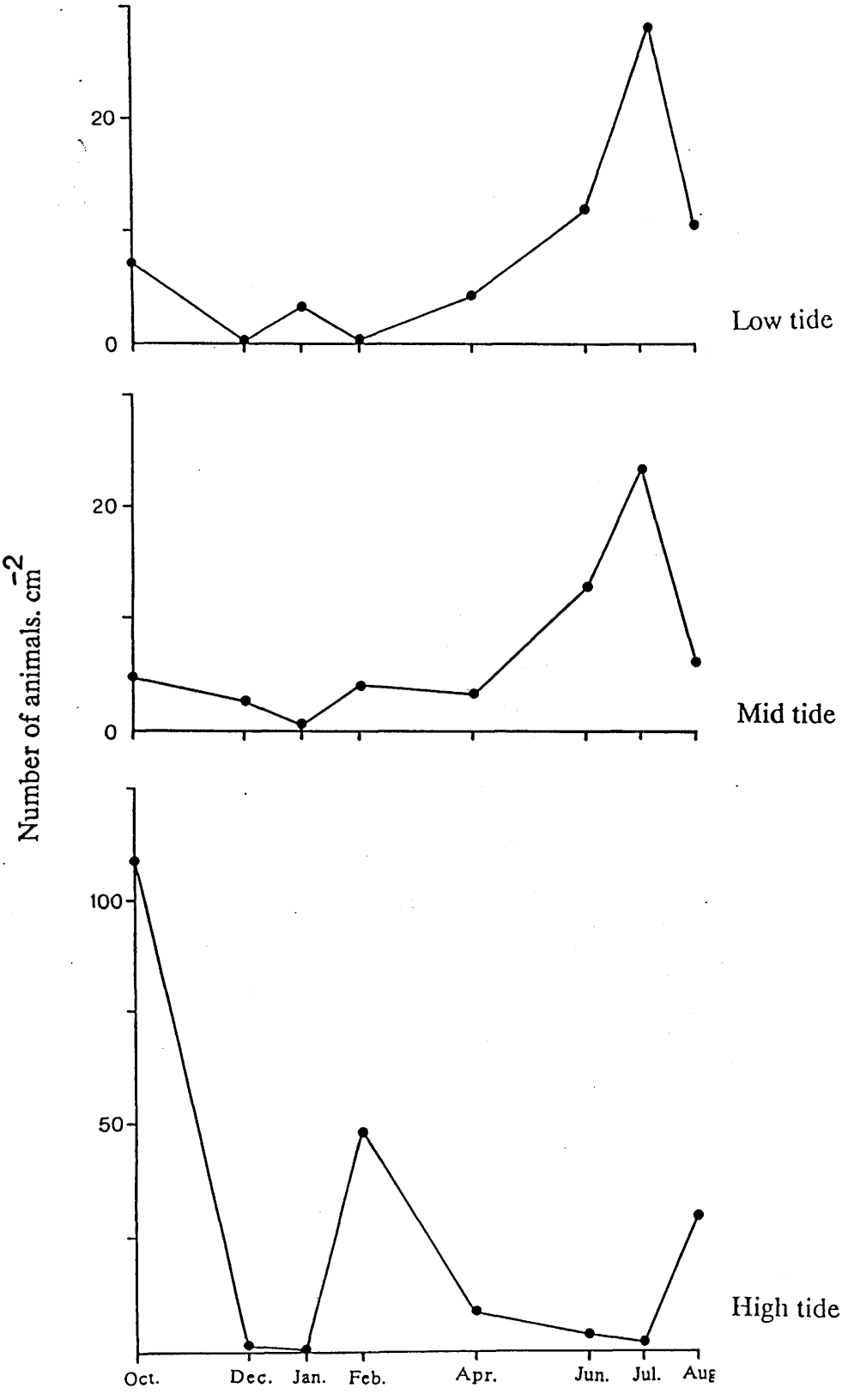


Figure 16b. Annual survey. Number of adult harpacticoids at a depth of 0-1 cm for October 86, December 86, January 87, February 87, April 87, June 87, July 87, and August 87 at low tide, mid tide, and high tide. Each point represents the mean for that month.

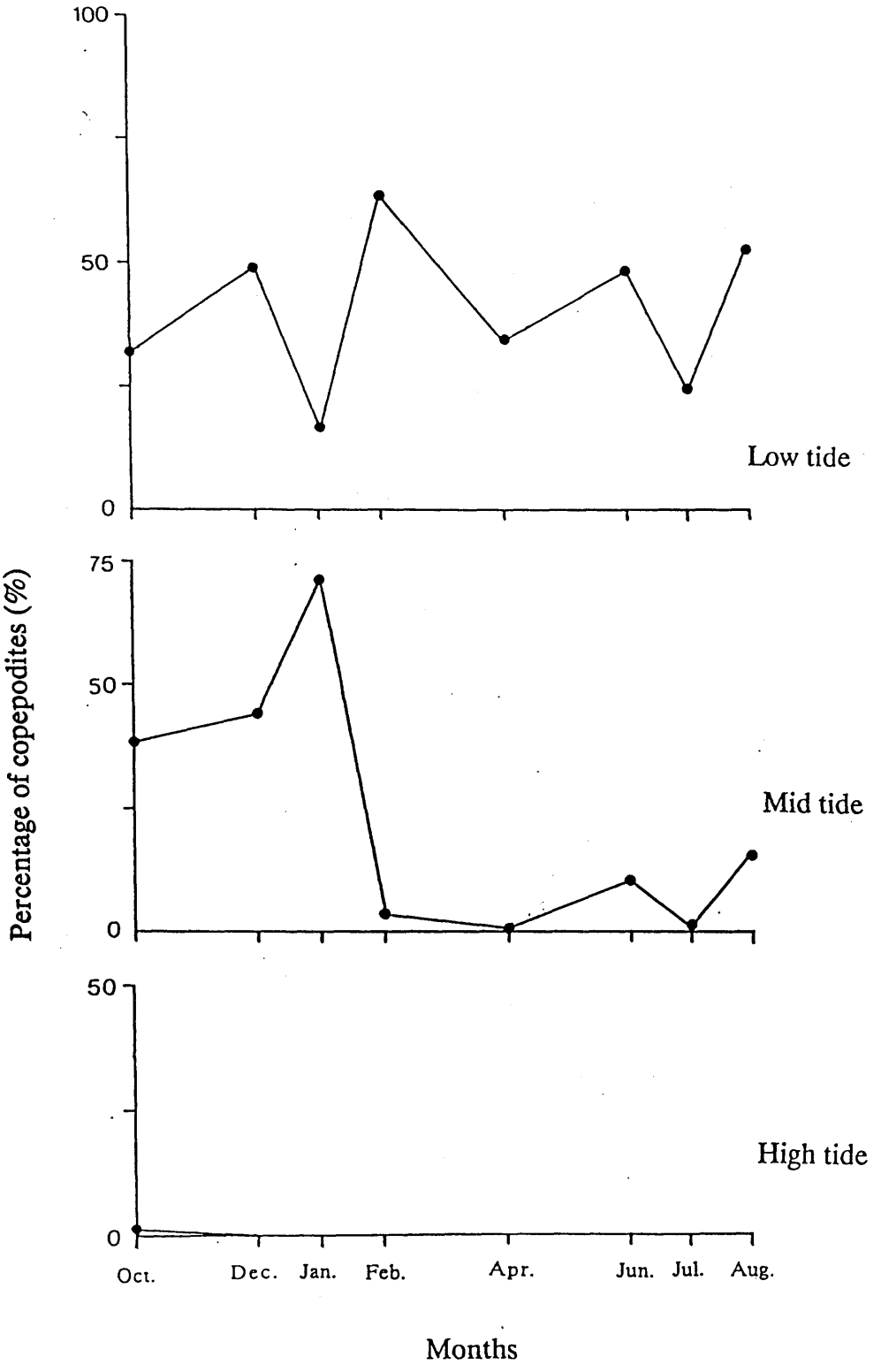


Figure 16c. Annual survey. Percentage of copepodites of the total at a depth of 0-1 cm for October 86, December 86, January 87, February 87, April 87, June 87, July 87 and August 87. Each point represents the mean for that month.

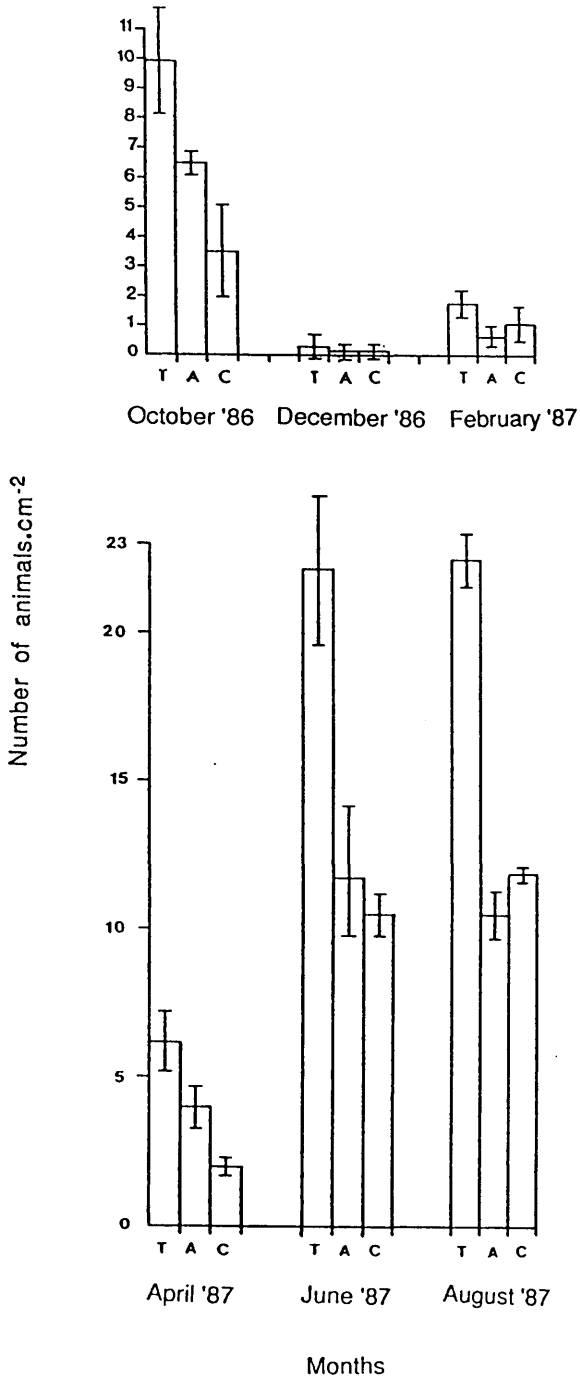


Figure 17. Low tide level. 0-1 cm sediment depth. Number of harpacticoid copepods.cm-2 of sediment surface for October 1986, December 1986, February 1987, April 1987, June 1987, and August 1987 (T = Total number, A = Adults, C = Copepodites). Vertical lines represent standard deviations.

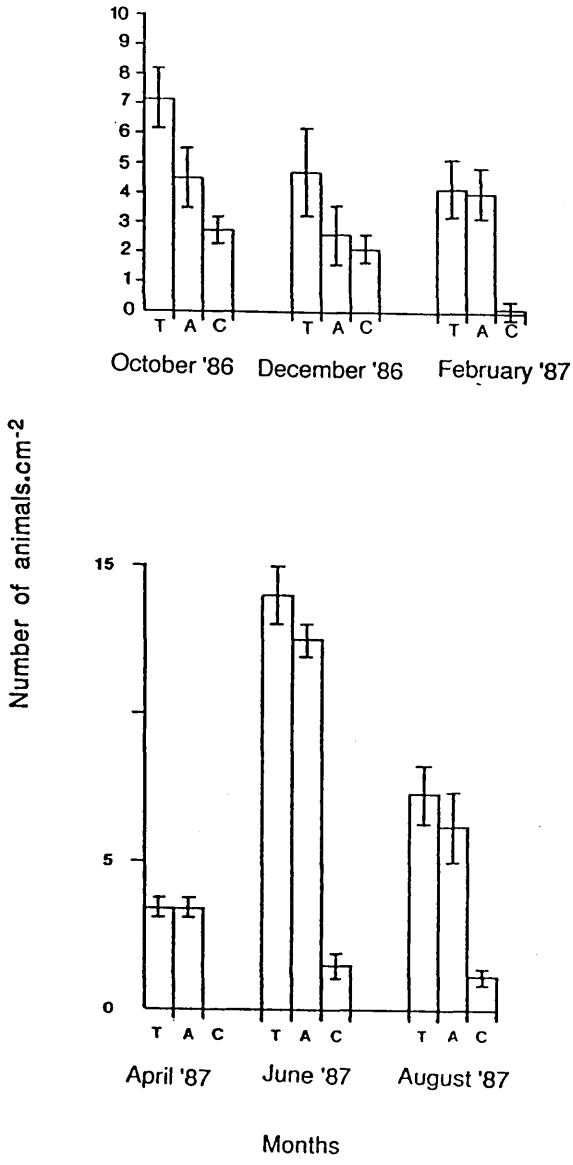


Figure 18. Mid tide level. 0-1 cm sediment depth. Number of harpacticoid copepods.cm-2 of sediment surface for October 1986, December 1986, February 1987, April 1987, June 1987, and August 1987 (T = Total number, A = Adults, C = Copepodites). Vertical lines represent standard deviations.

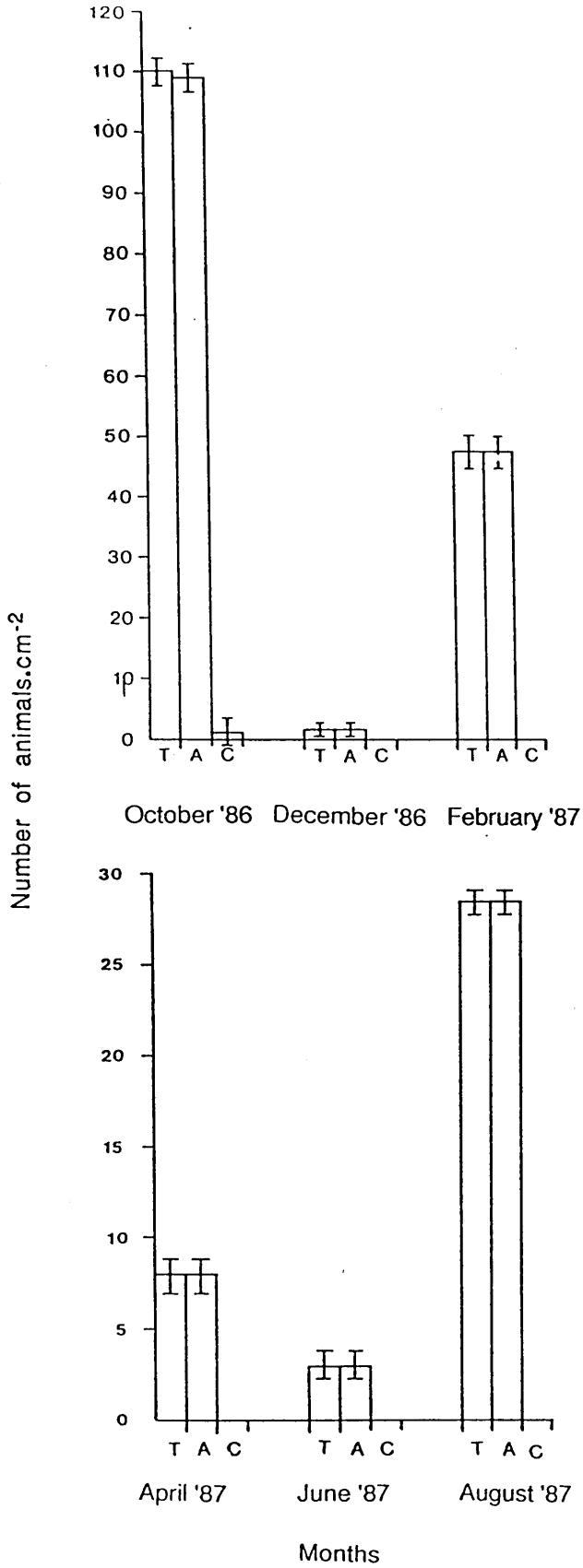


Figure 19. High tide level. 0-1 cm sediment depth. Number of harpacticoid copepods.cm-2 of sediment surface for October 1986, December 1986, February 1987, April 1987, June 1987, August 1987 (T = Total number, A = Adults, C = Copepodites). Vertical lines represent standard deviations.

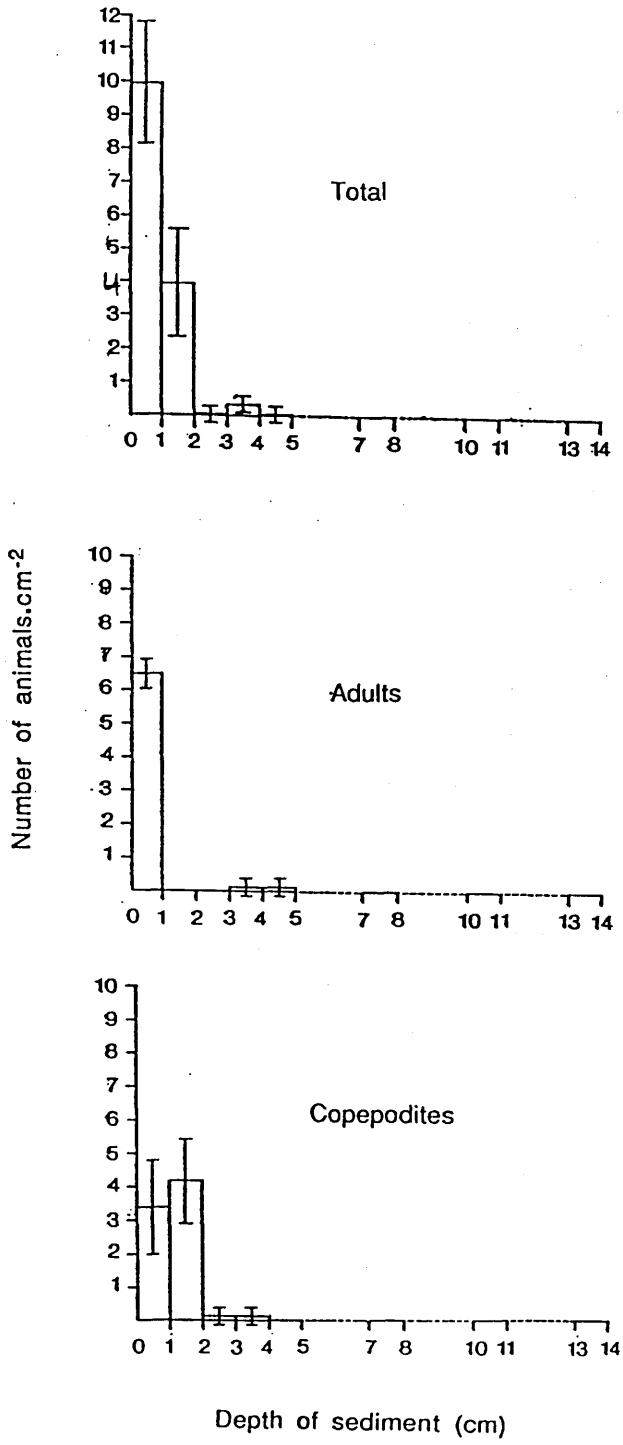


Figure 20. Low tide level. Vertical distribution of total, adults, and copepodites in the sediment. Numbers.cm-2 of sediment surface. October 1986. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represnt standard deviations.

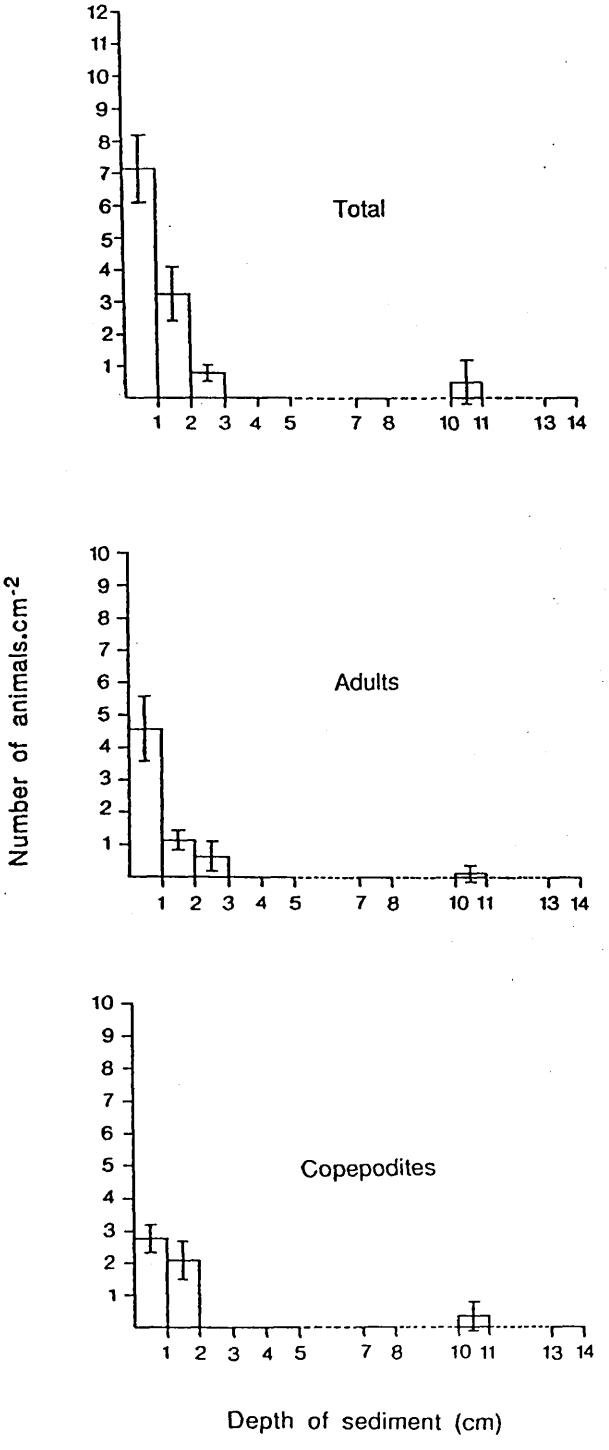


Figure 21. Mid tide level. Vertical distribution of total, adults, and copepodites in the sediment. Numbers.cm-2 of sediment surface. October 1986. Sediment depth (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

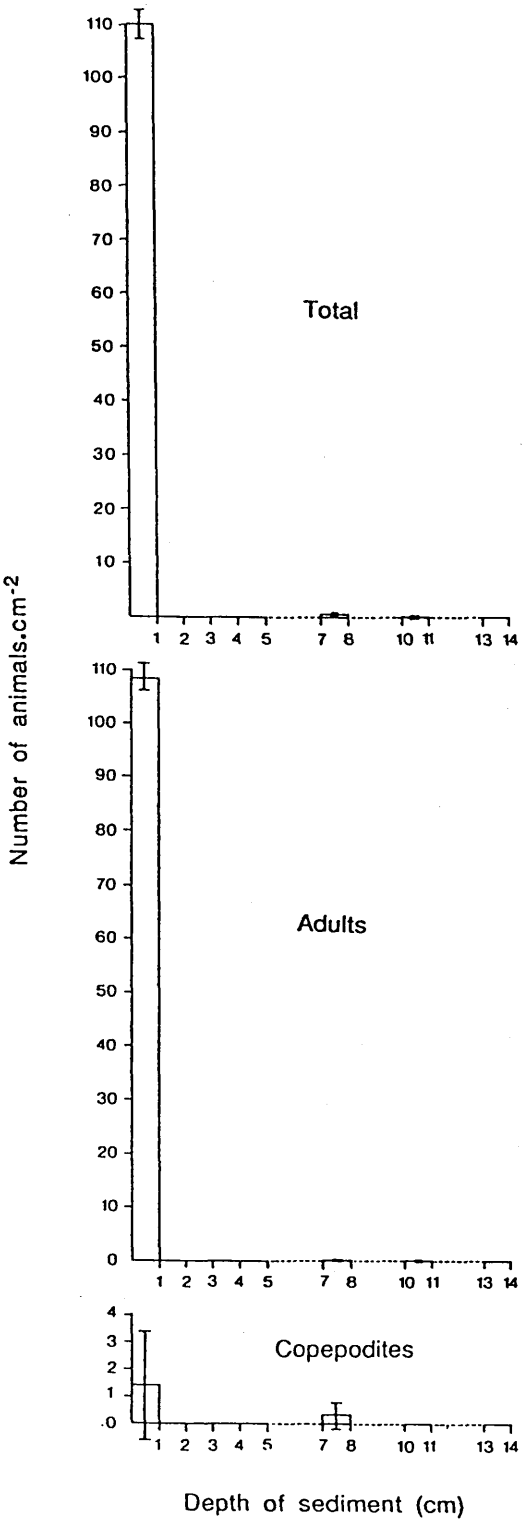


Figure 22. High tide level. Vertical distribution of total, adults, and copepodites in the sediment. Numbers.cm-2 of sediment surface. October 1986. Sediment depth (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

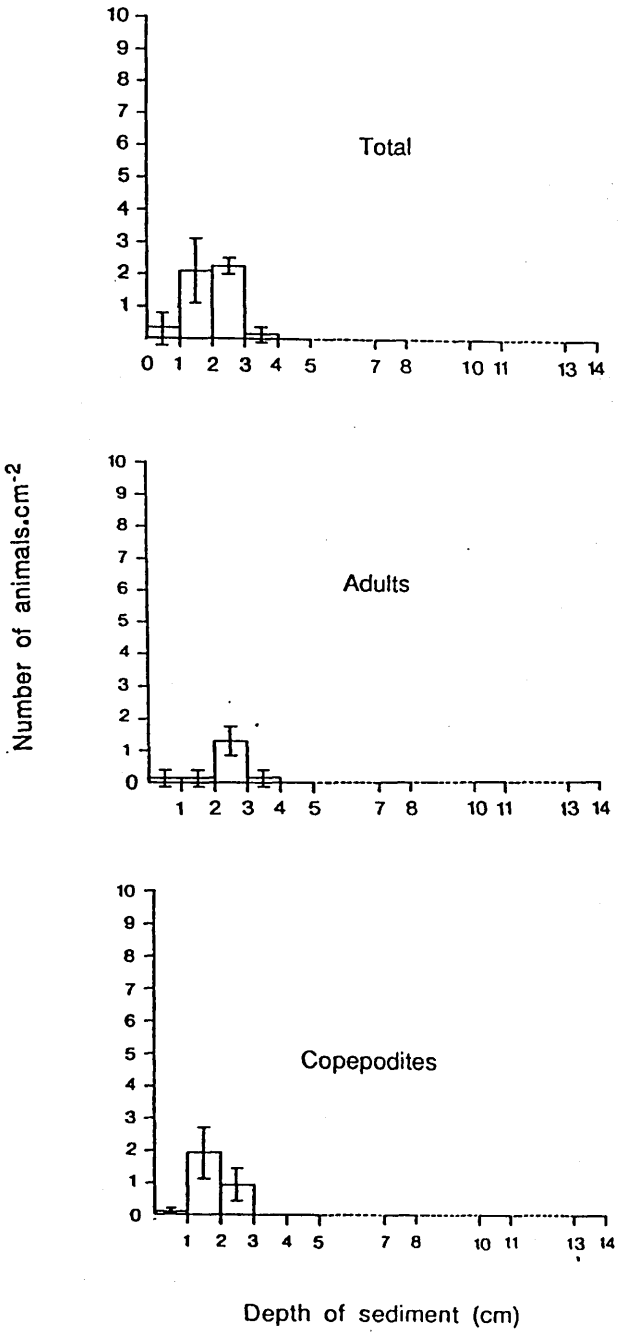


Figure 23. Low tide level. Vertical distribution of total, adults, and copepodites in the sediment. Numbers.cm-2 of sediment surface. December 1986. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

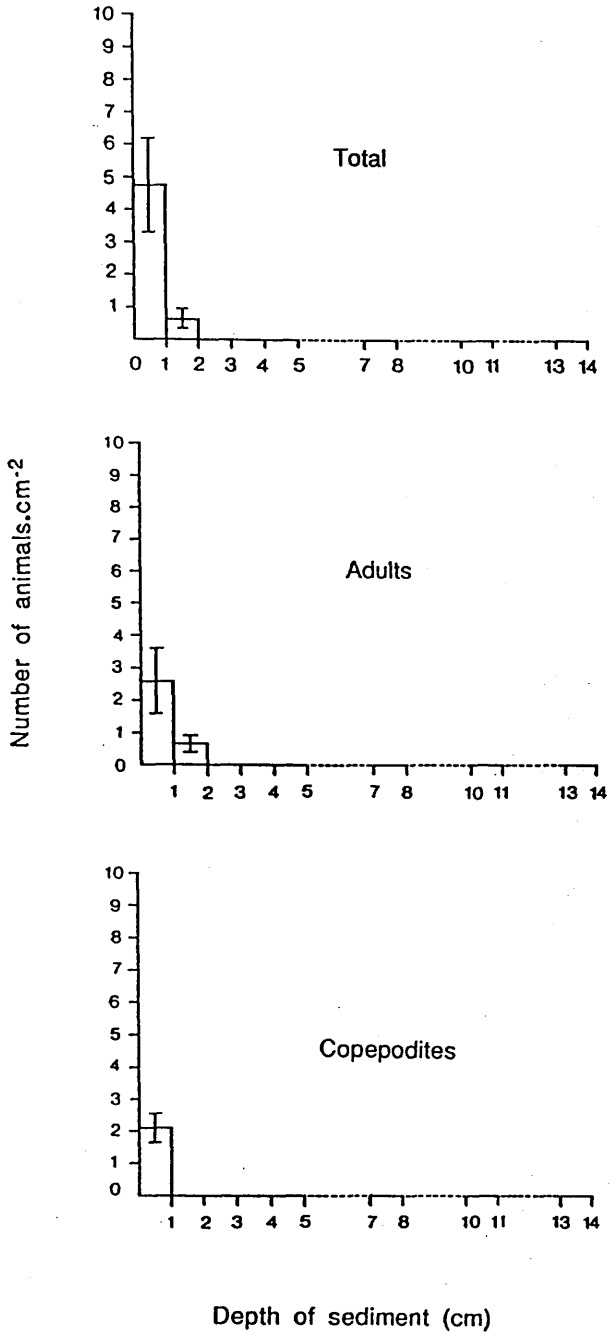


Figure 24. Mid tide level. Vertical distribution of total, adults, and copepodites in the sediment. Numbers.cm-2 of sediment surface. December 1986. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

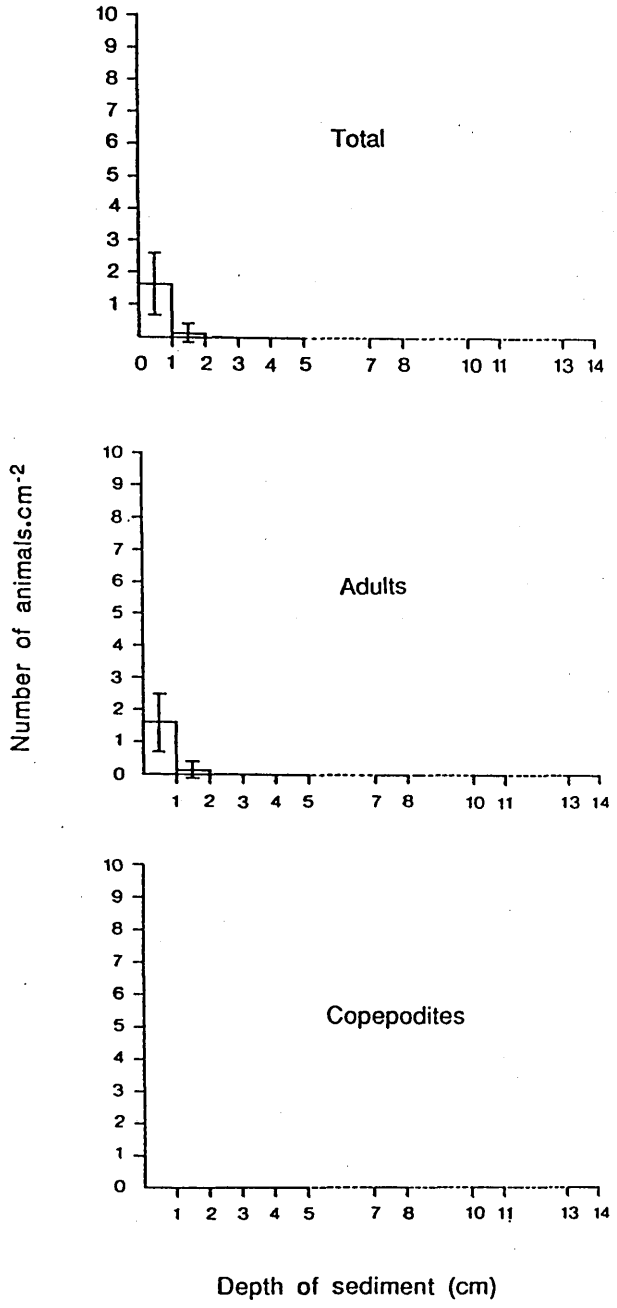


Figure 25. High tide level. Vertical distribution of total, adults, and copepodites in the sediment. Numbers.cm-2 of sediment surface. December 1986. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

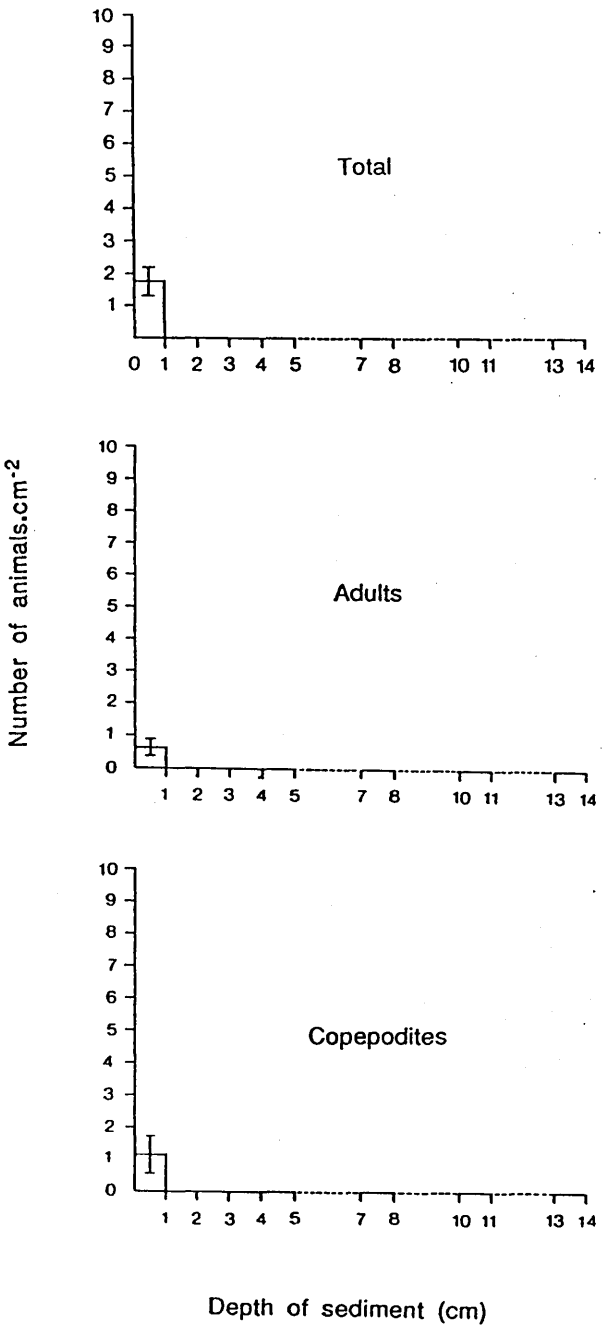


Figure 26. Low tide level. Vertical distribution of total, adults, and copepodites in the sediment. Number.cm-2 of sediment surface. Februray 1987. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

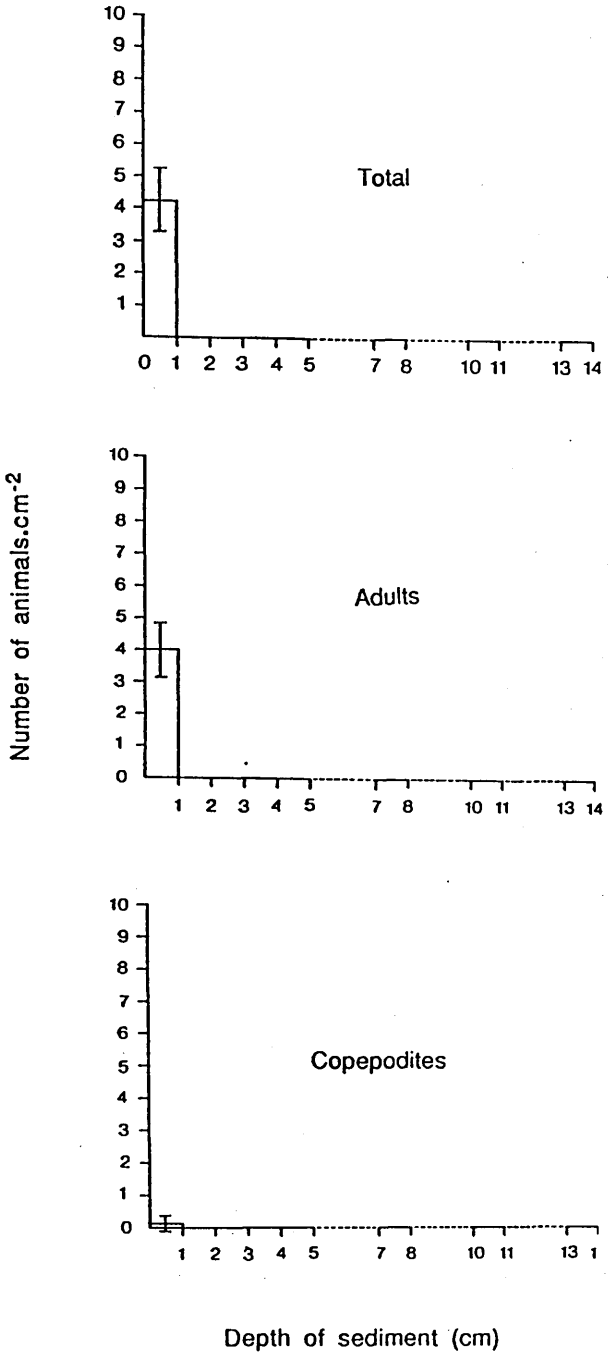


Figure 27. Mid tide level. Vertical distribution of total, adult, and copepodites in the sediment. Numbers.cm-2 of sediment surface. February 1987. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical distribution represent standard deviations.

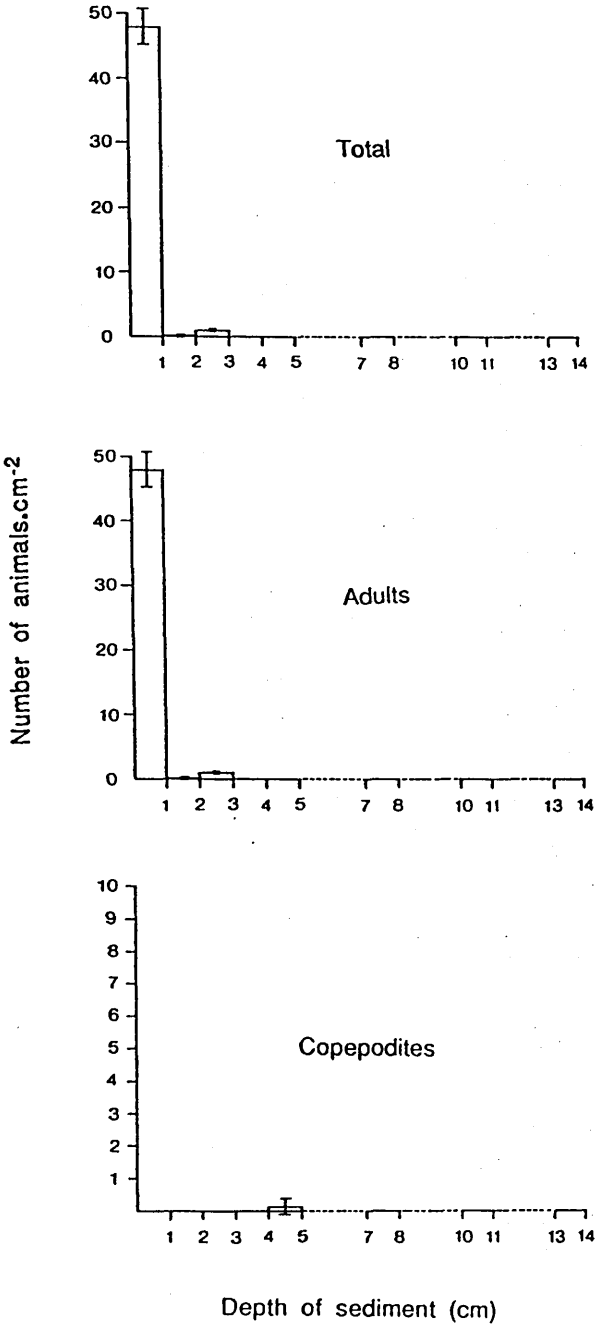


Figure 28. High tide level. Vertical distribution of total, adults, and copepodites in the sediment. Number.cm-2 of sediment surface. February 1987. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

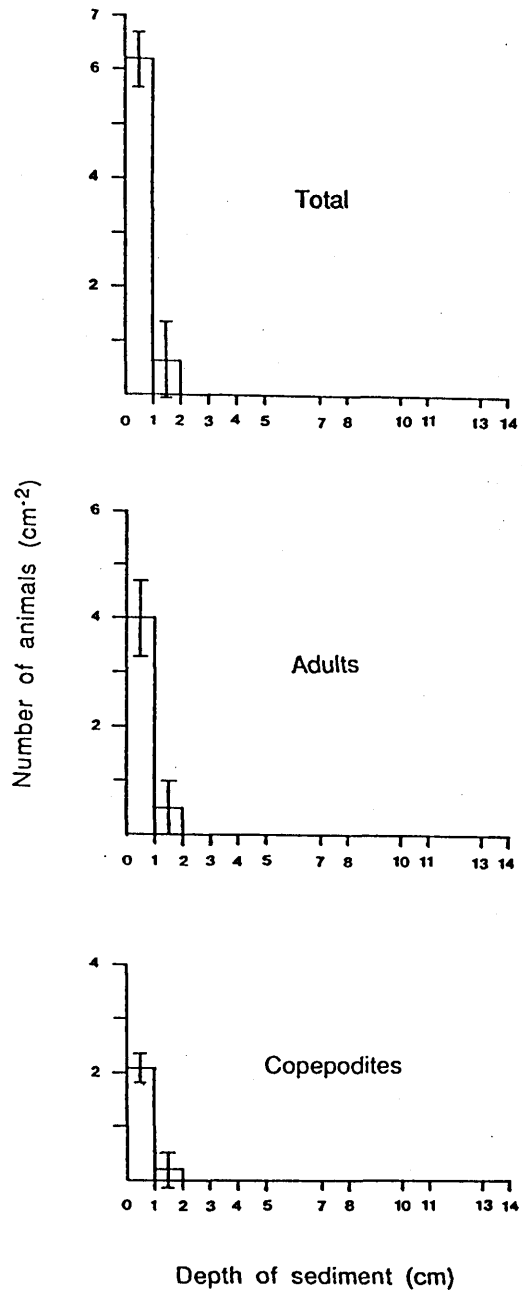


Figure 29. Low tide level. Vertical distributions of total, adult, and copepodites in the sediment. Numbers.cm-2 of sediment surface. April 1987. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

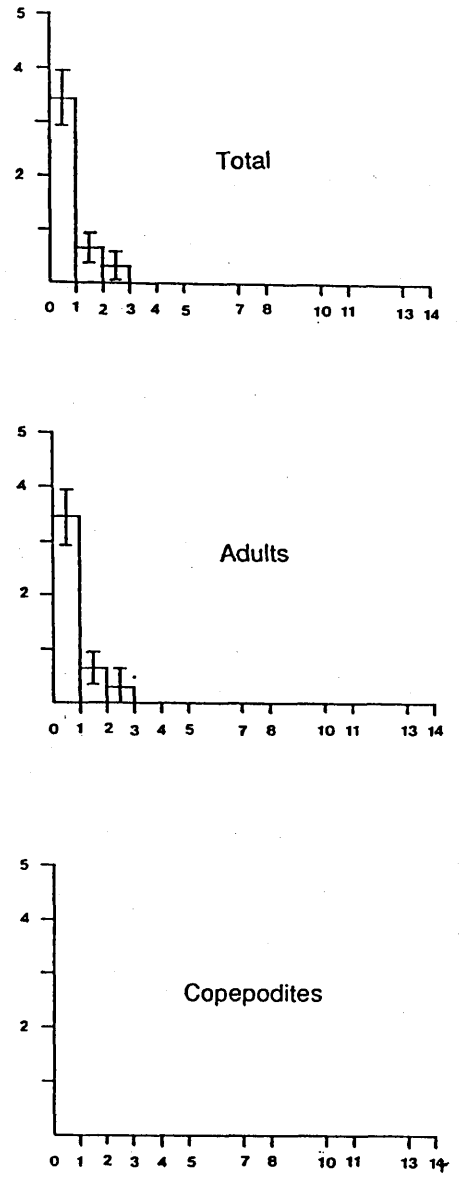


Figure 30. Mid tide level. Vertical distribution of total, adult, and copepodites in the sediment. Numbers.cm-2 of sediment surface. April 1987. Sediment depths (cm) 0-1, 1-2, 2-3,3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

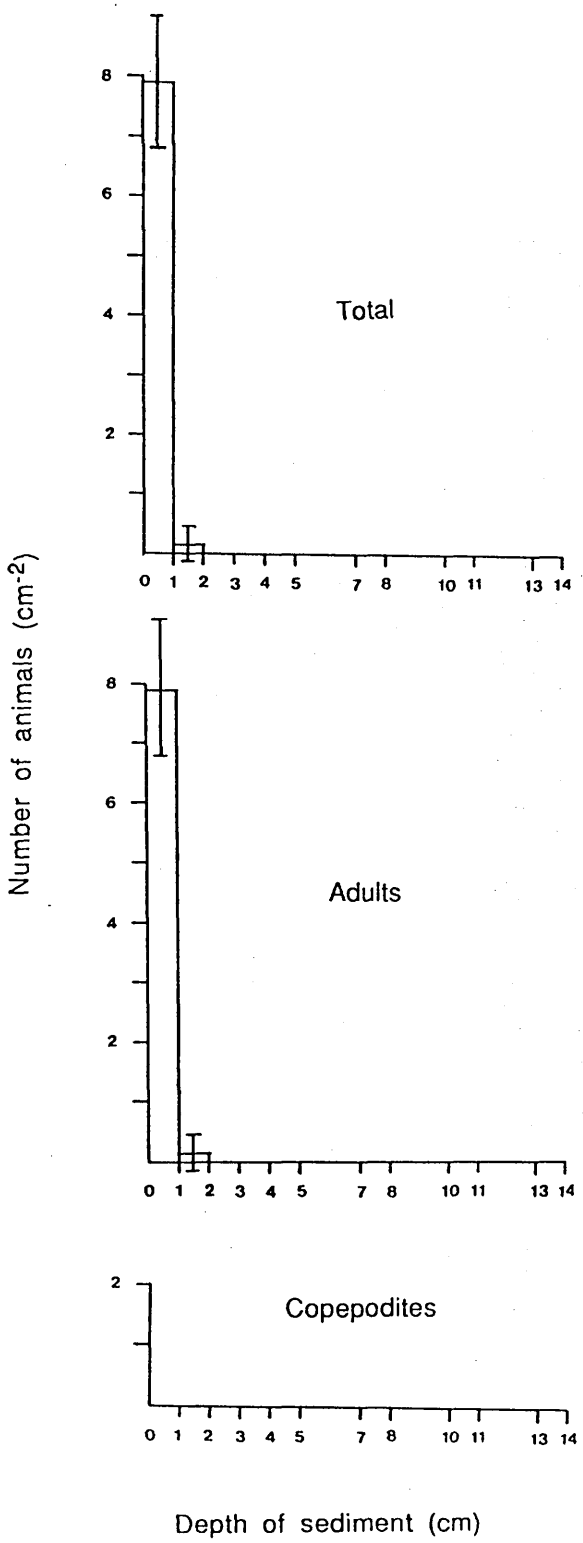


Figure 31. High tide level. Vertical distribution of total, adults, and copepodites in the sediment. Numbers.cm-2 of sediment surface. April 1987. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

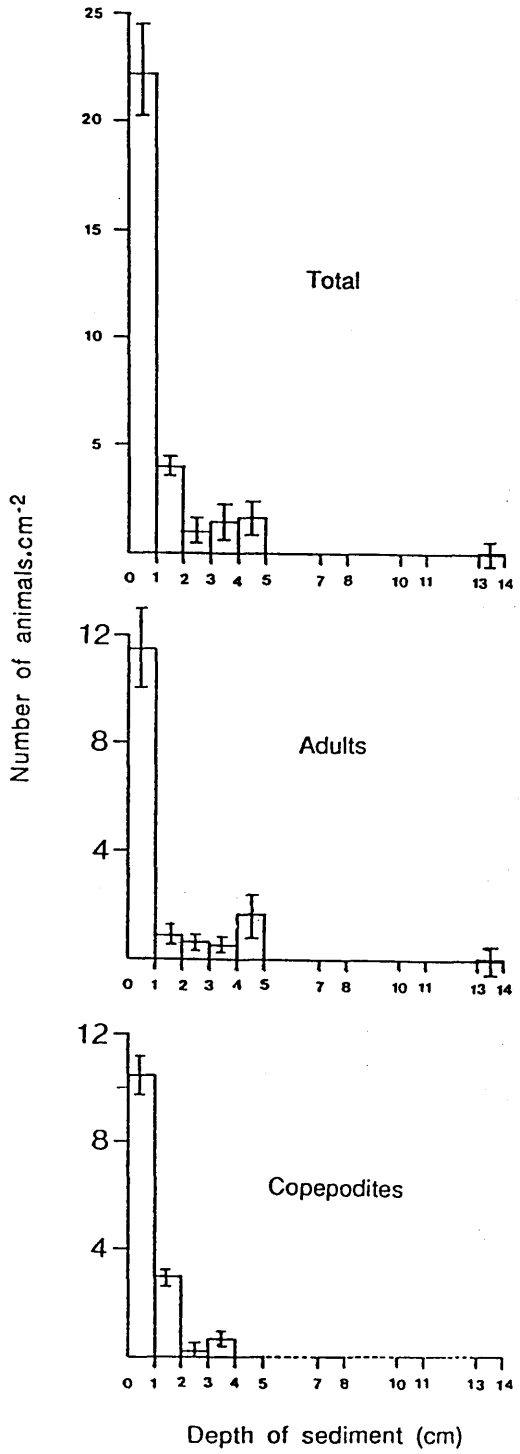


Figure 32. Low tide level. Vertical distribution of total, adults, and copepodites in the sediment. Numbers.cm-2 of sediment surface. June 1987. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

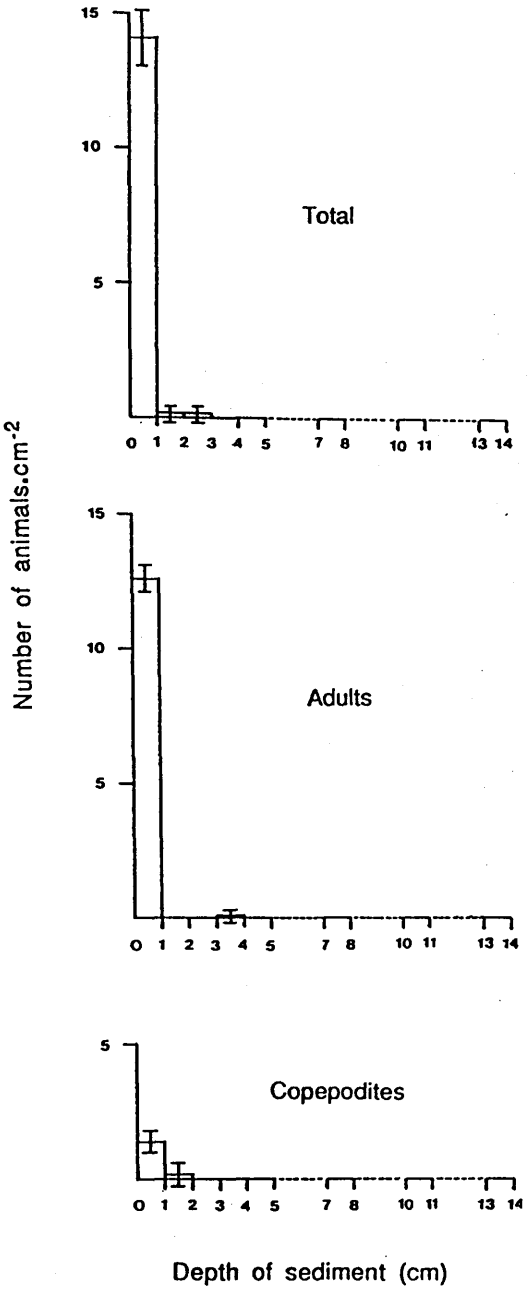


Figure 33. Mid tide level. Vertical distribution of total, adult, and copepodites in the sediment. Numbers.cm-2 of sediment surface. June 1987. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

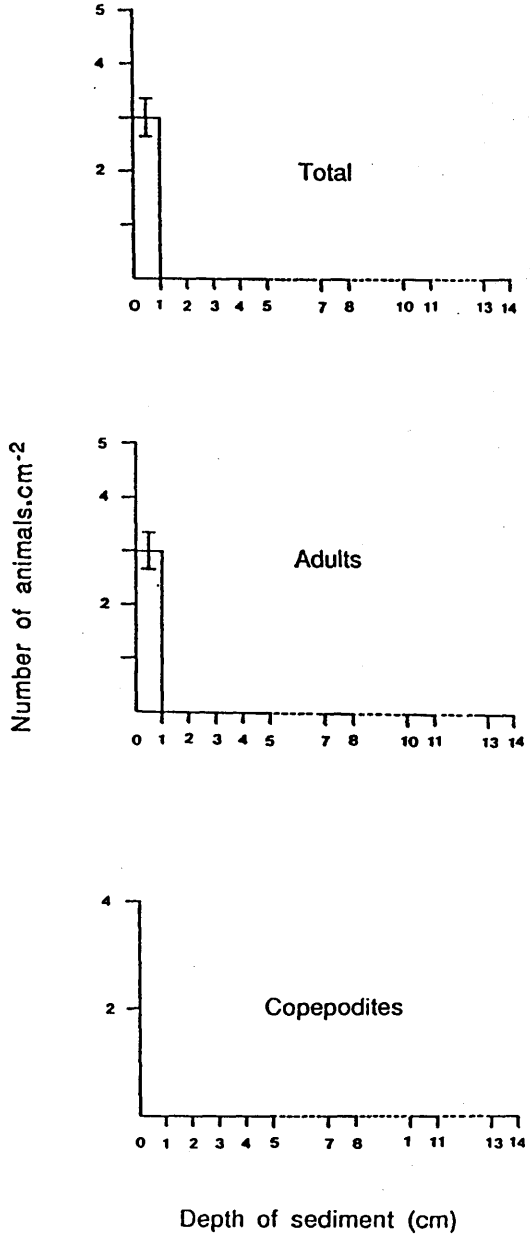


Figure 34. High tide level. Vertical distribution of total and adults, in the sediment. Numbers.cm-2 of sediment surface. June 1987. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations. No copepodites were found at any depth.

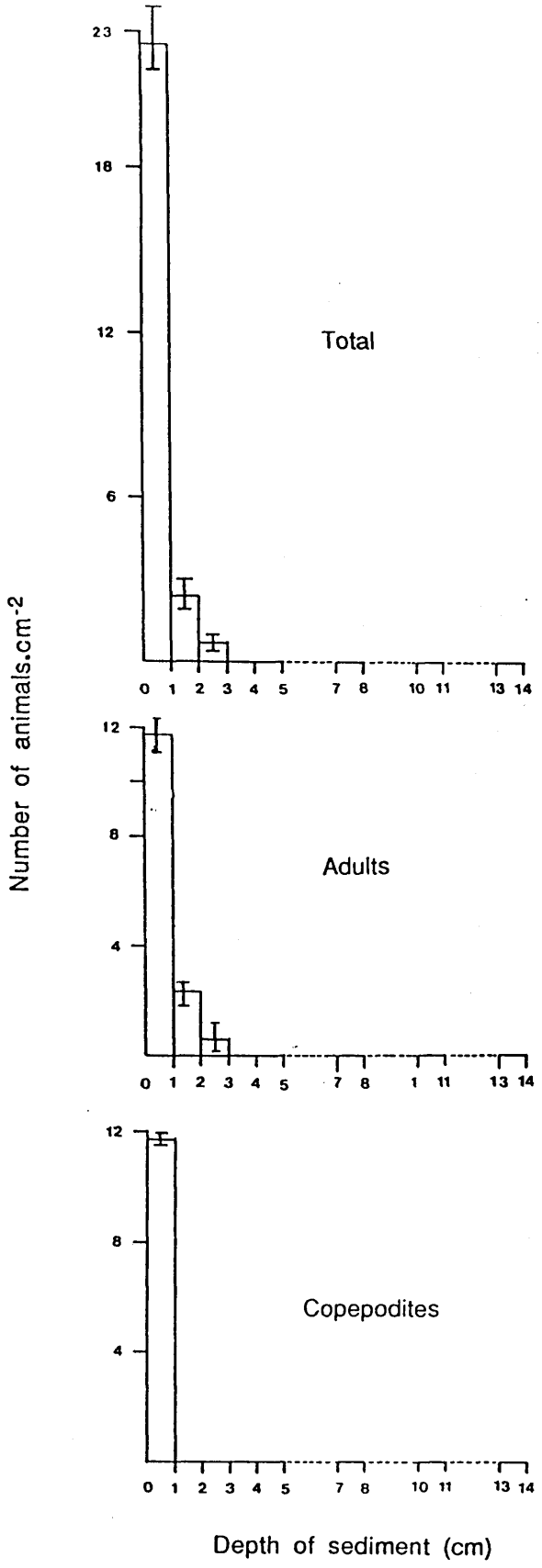


Figure 35. Low tide level. Vertical distribution of total, adults, and copepodites in the sediment. Numbers.cm-2 of sediment surface. August 1987. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

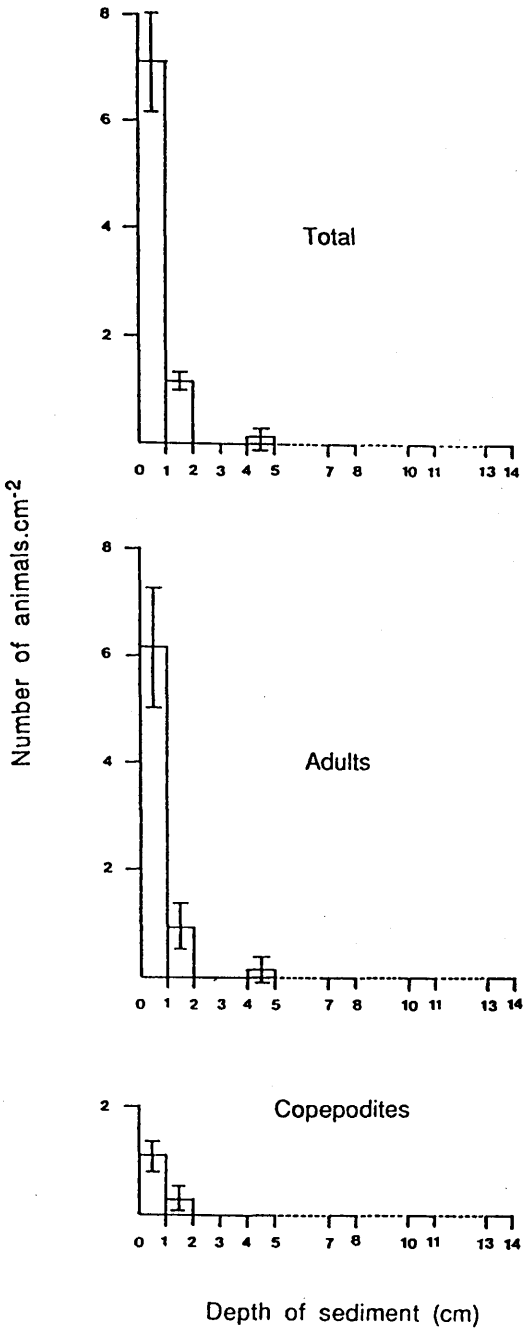


Figure 36. Mid tide level. Vertical distribution of total, adults, and copepodites in the sediment. Number.cm-2 of sediment surface. August 1987. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

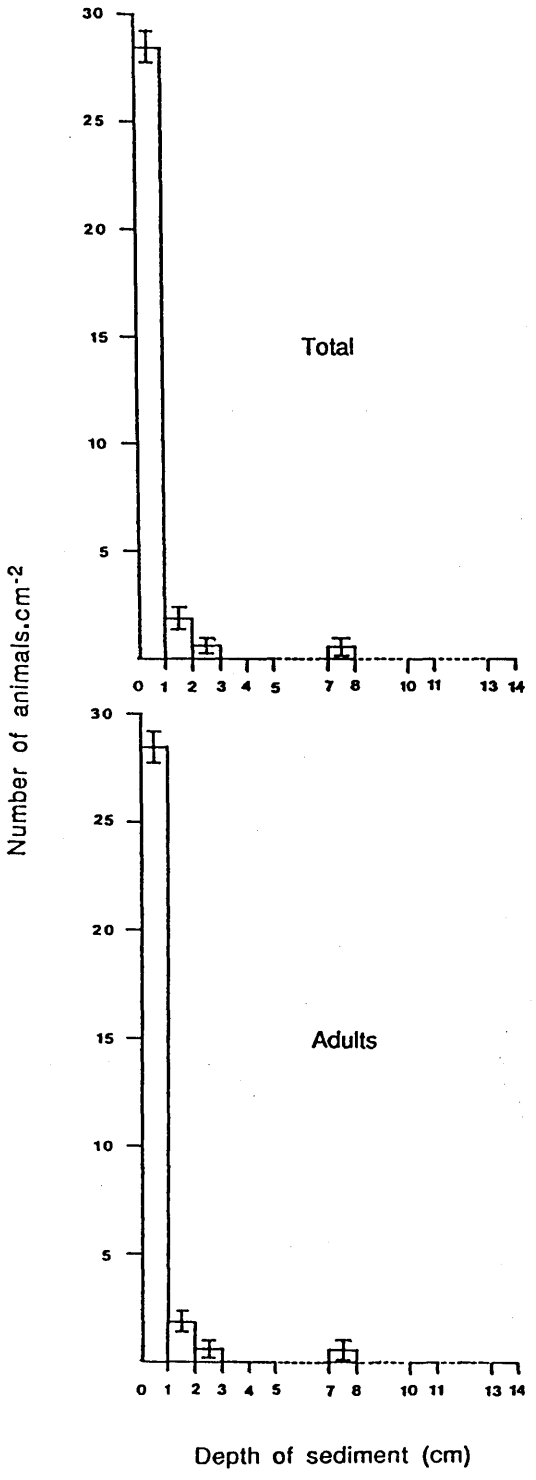


Figure 37. High tide level. Vertical distribution of total and adults, in the sediment. Numbers.cm-2 of sediment surface. August 1987. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations. No copepodites were found at any depth.

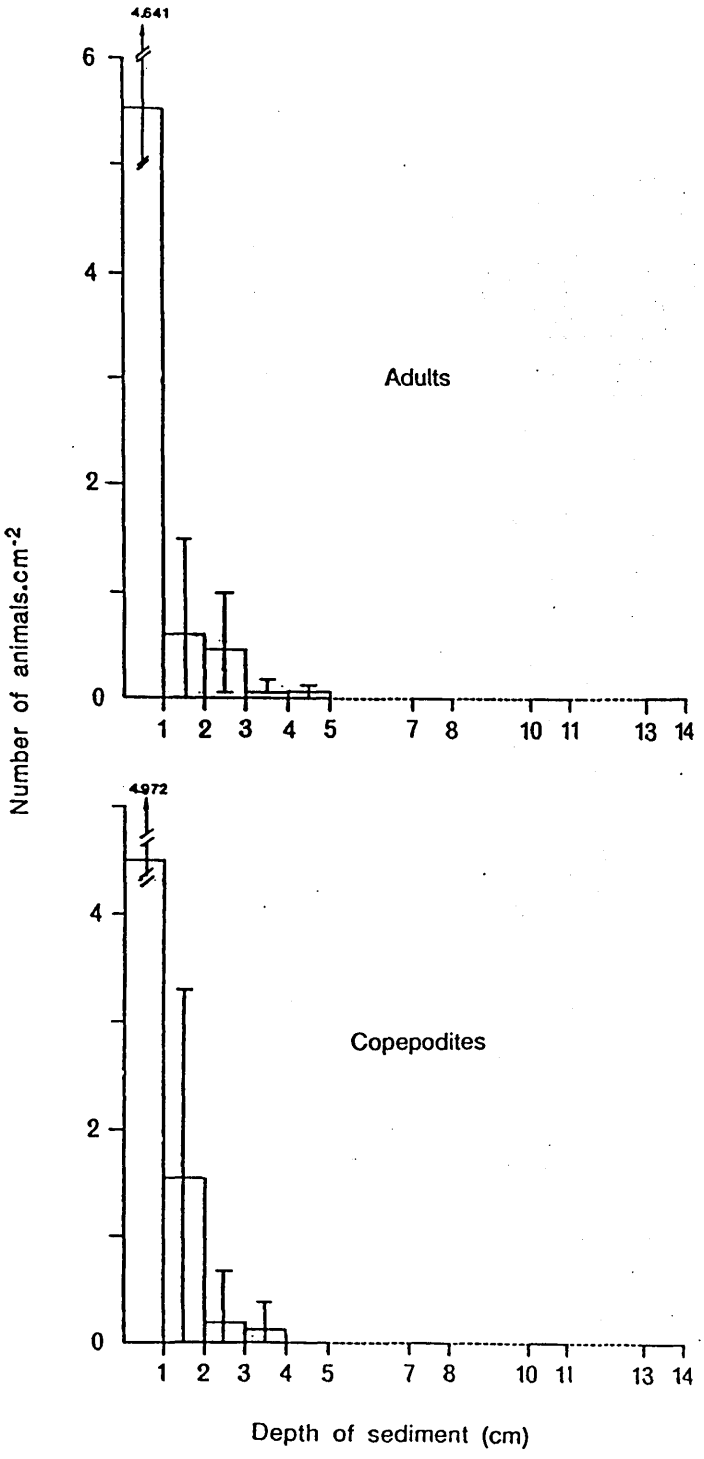


Figure 38. Low tide level. Summary of vertical distribution of adults and copepodites for all months combined in the sediment. Numbers.cm-2 of sediment surface. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

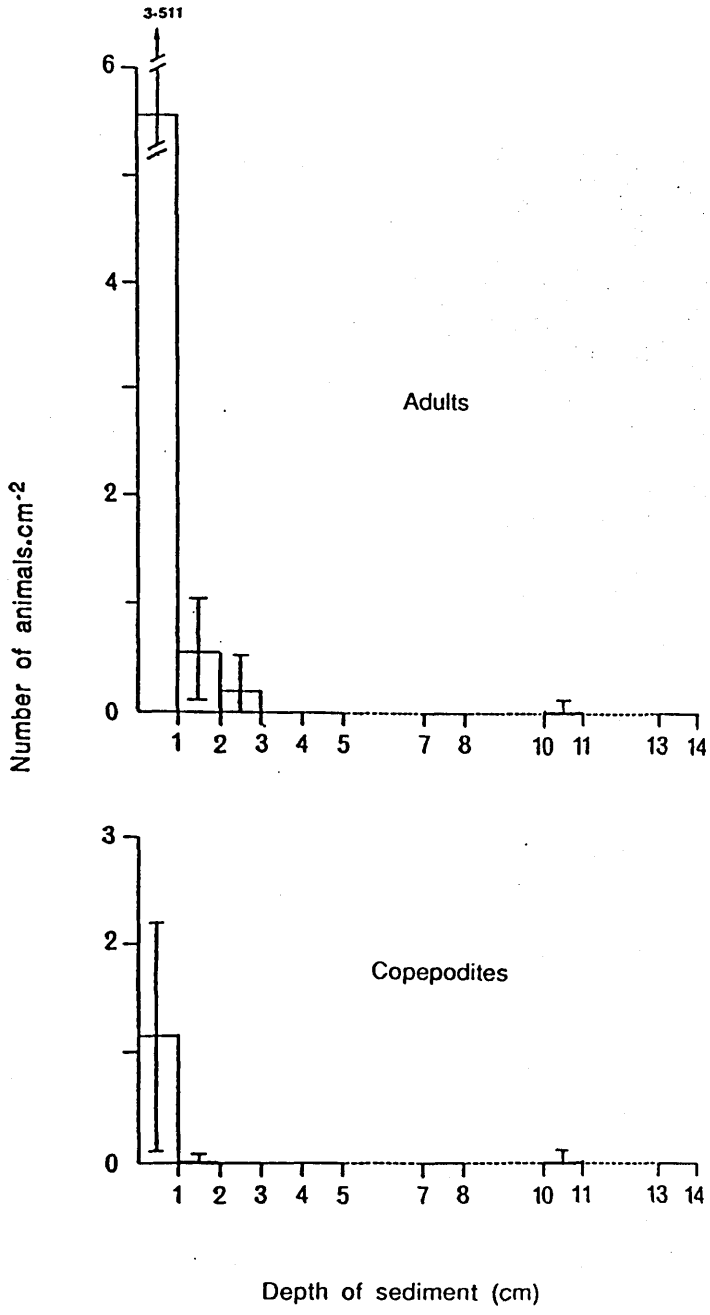


Figure 39. Mid tide level. Summary of vertical distribution of adults and copepodites for all months combined in the sediment. Numbers.cm-2 of sediment surface. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

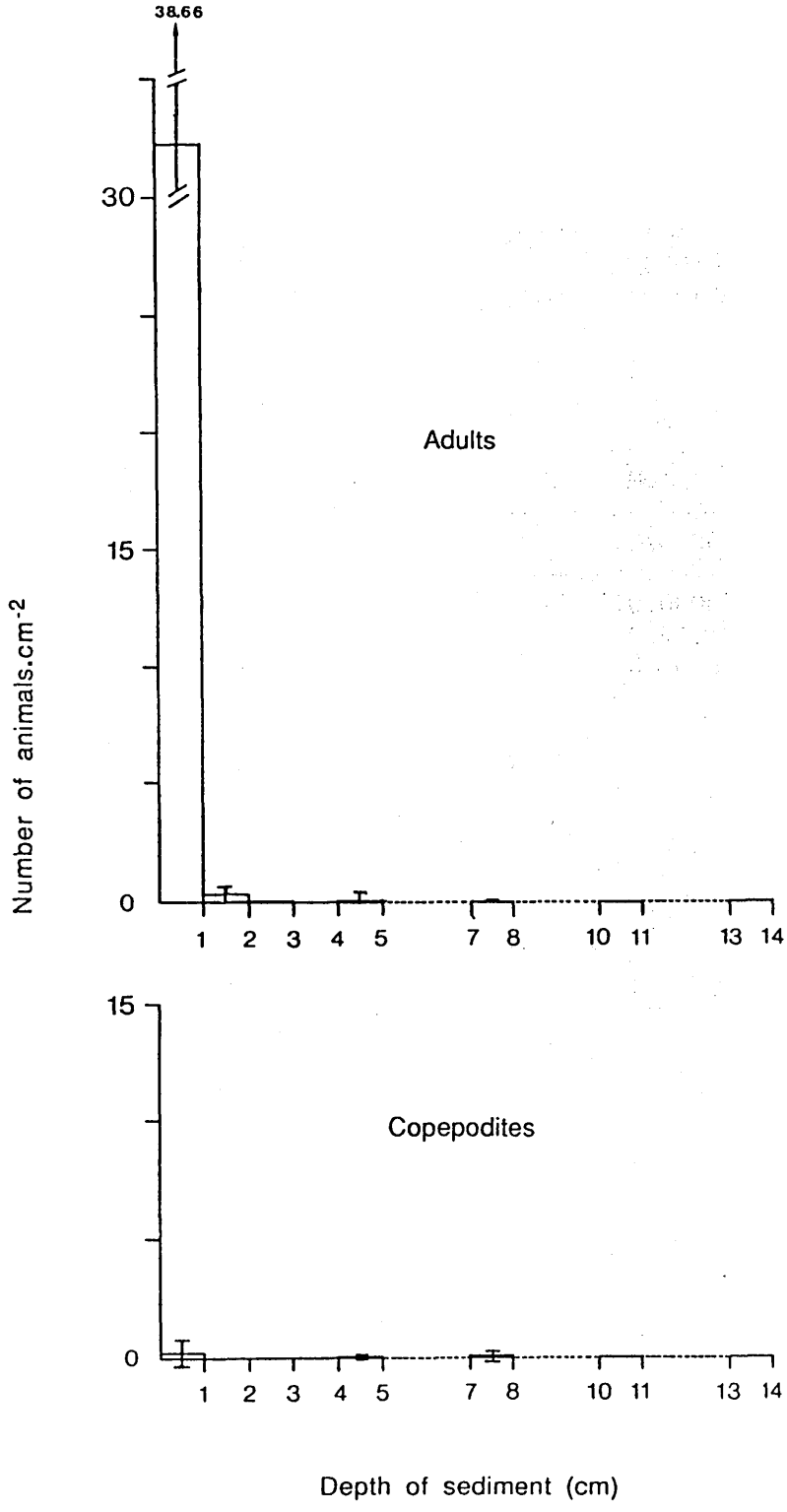


Figure 40. High tide level. Summary of vertical distribution of adults and copepodites for all month combined in the sediment. Numbers.cm-2 of sediment surface. Sediment depths (cm) 0-1, 1-2, 2-3, 3-4, 4-5, 7-8, 10-11, and 13-14 cm. Vertical lines represent standard deviations.

Table 2. Total number of animals (adults + copepodites). cm^2 in October 1986, December 1986, and February 1987, for each tidal level. Data for 0–1 cm depth only. Replicates 1, 2, and 3, mean and standard deviation. Replicates 1, 2, and 3 are the three 5 ml samples taken from the original sediment sample.

Tidal level	Replicates	Months		
		Oct.86	Dec.86	Feb.87
LT	R1	7.8228	0.0000	1.4667
	R2	9.7785	0.9778	1.4667
	R3	12.2231	0.0000	2.4446
	Mean	9.9415	0.3259	1.7927
	S.D	2.20	0.565	0.565
MT	R1	8.3117	6.3560	4.8892
	R2	7.3337	4.8892	4.8892
	R3	5.8671	2.9335	2.9335
	Mean	7.1708	4.7262	4.2373
	S.D	1.23	1.72	1.13
HT	R1	111.5	0.9778	50.85
	R2	106.1	0.9778	48.89
	R3	112.4	2.9335	44.00
	Mean	110.0	1.6297	47.92
	S.D	3.42	1.13	3.53

Table 3. Total number of animals (adults + copepodites). cm^2 in April 1987, June 1987, and August 1987 for each tidal level. Data for 0–1 cm depth only. Replicates 1, 2, znd 3, mean and standard deviation. Replicates 1, 2, and 3, are the three 5 ml samples taken from the original sediment sample.

Tidal level	Replicates (5ml)	Months		
		April 87.	June 87.	August 87.
LT	R1	5.8670	19.5569	23.4682
	R2	5.3781	24.9350	22.4904
	R3	7.3338	22.0015	21.5126
	Mean	6.1929	22.1644	22.4904
	S.D	1.0177	2.6927	0.9778
MT	R1	2.9335	13.2009	8.3116
	R2	3.9113	15.1566	6.3559
	R3	4.4422	13.6898	7.3338
	Mean	3.4290	14.0157	7.3337
	S.D	0.4890	1.0177	0.9778
HT	R1	6.8449	3.9113	27.8686
	R2	7.8227	2.4446	28.3575
	R3	9.2895	2.9335	29.3353
	Mean	7.9857	3.0964	28.5264
	S.D	1.2304	0.7468	0.7468

Table 4. Number of adults.cm^{-2} in October 1986, December 1986, February 1987 at each tidal level. Data for 0–1 cm depth only. Replicates 1, 2, and 3, mean and standard deviation. Replicates 1, 2, and 3 are the three 5 ml samples taken from the original sediment sample.

Tidal level	Replicates	Months		
		Oct.86	Dec.86	Feb.87
LT	R1	5.8671	0.0000	0.9778
	R2	6.844	0.4889	0.4889
	R3	6.8449	0.0000	0.4889
	Mean	6.5190	0.16297	0.65187
	S.D	0.566	0.282	0.282
MT	R1	5.8670	3.9113	4.4003
	R2	4.4003	2.4446	4.8892
	R3	3.4224	1.4667	2.9335
	Mean	4.4308	2.6075	4.0743
	S.D	1.28	1.23	1.02
HT	R1	107.07	0.9778	50.8479
	R2	106.10	0.9778	48.8922
	R3	112.45	2.9335	44.0030
	Mean	108.54	1.6297	47.914
	S.D	3.42	1.13	3.53

Table 5. Number of adults.cm^{-2} in April 1987, June 1987, and August at at each tidal level. Data for 0–1 cm depth only. Replicates 1, 2, and 3, mean and standard deviation. Replicates 1, 2, and 3 are the three 5 ml samples taken from the original sediment sample.

Tidal level	Replicates (5 ml)	Months		
		April 87	June 87	August 87
LT	R1	3.9113	9.7784	11.2452
	R2	3.4224	13.6898	10.7563
	R3	4.8892	11.7341	9.7784
	Mean	4.0743	11.7341	10.5933
	S.D	0.7468	1.9557	0.7468
MT	R1	2.9335	12.2230	7.3338
	R2	3.9113	13.2009	4.8892
	R3	3.4422	12.2230	6.3559
	Mean	3.4290	12.5489	6.1929
	S.D	0.4890	0.5645	1.2304
HT	R1	6.8449	3.9115	27.8686
	R2	7.8227	2.4446	28.3575
	R3	9.2895	2.9335	29.3353
	Mean	7.9857	3.0964	28.5204
	S.D	1.2304	0.7468	0.7468

Table 6. Number of copepodites.cm^{-2} in October 1986, December 1986, and February 1987 at each tidal level. Data for 0–1 cm depth only. Replicates 1, 2, and 3, mean and standard deviation. Replicates 1, 2, and 3 are the three 5 ml samples taken from original sediment sample. Note there are no animals at high tide level for December 1986and February 1987.

Tidal level	Replicates 5 ml.	Months		
		Oct.86	Dec.86	Feb.87
LT	R1	1.9557	0.0000	0.4889
	R2	2.9335	0.4889	0.9779
	R3	5.3782	0.0000	1.9556
	Mean	3.4225	0.16297	1.1408
	S.D	1.76	0.282	0.747
MT	R1	2.4446	2.4446	0.4889
	R2	2.4224	2.4446	0.0000
	R3	2.4446	1.4667	0.0000
	Mean	2.7705	2.1186	0.16297
	S.D	0.565	0.565	0.282
HT	R1	4.4003	0.0000	0.0000
	R2	0.0000	0.0000	0.0000
	R3	0.0000	0.0000	0.0000
	Mean	1.4667	0.0000	0.0000
	S.D	2.0743	0.0000	0.0000

Table 7. Number of copepodites.cm^{-2} in April 1987, June 1987, and August 1987 at each tidal level. Data for 0–1 cm depth only. Replicates 1, 2, and 3, mean and standard deviation. Replicates 1, 2, and 3 are three 5 ml samples taken from the original sediment sample. Note there are no animals at high tide level for April 1987, June 1987, and August 1987.

Tidal level	Replicates (5 ml)	Months		
		April 87	June 87	August 87
LT	R1	1.9556	9.7784	12.2230
	R2	1.9556	11.2452	11.7341
	R3	2.4446	10.7563	11.7341
	Mean	2.1186	10.5933	11.8970
	S.D	0.2823	0.7468	0.2822
MT	R1	0.0000	0.9778	0.9778
	R2	0.0000	1.9556	1.4667
	R3	0.0000	1.4667	0.9778
	Mean	0.0000	1.4667	1.1407
	S.D	0.0000	0.4889	0.2822
HT	R1	0.0000	0.0000	0.0000
	R2	0.0000	0.0000	0.0000
	R3	0.0000	0.0000	0.0000
	Mean	0.0000	0.0000	0.0000
	S.D	0.0000	0.0000	0.0000

Table 8. 1x6 one way analyses of variance of the total number of animals between October 1986, December 1986, February 1987, April 1987, June 1987, and August 1987 at each tidal level.

Tidal level	Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
LT	Oct. 86 vs Dec. 86 vs Feb. 87 vs Apr. 87 vs Jun. 87 vs Aug. 87	Main factor	1434.06	286.81	5	116.74	P<0.001
		Error	29.48	2.46	12		
		Total	1463.54		17		
MT	Oct. 86 vs Dec. 86 vs Feb. 87 vs Apr. 87 vs Jun. 87 vs Aug. 87	Main factor	224.16	44.83	5	33.76	P<0.001
		Error	15.94	1.33	12		
		Total	240.09		17		
HT	Oct. 86 vs Dec. 86 vs Feb. 87 vs Apr. 87 vs Jun. 87 vs Aug. 87	Main factor	26029.50	5205.90	5	1113.64	P<0.001
		Error	56.10	4.67	12		
		Total	26085.60		17		

Table 9. Break down 1x2 one way analyses of variance of the total number of animals between pairs of months at low tide.

Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	Main factor	138.89	138.89	1	53.55	0.005>P>0.001
vs	Error	10.36	2.59	4		
Dec.86	Total	149.05		5		
Oct.86	Main factor	99.60	99.60	1	38.46	0.005>P>0.001
vs	Error	10.36	2.59	4		
Feb.87	Total	109.96		5		
Oct.86	Main factor	21.08	21.08	1	7.15	0.10>P>0.05
vs	Error	11.79	2.95	4		
Apr.87	Total	32.87		5		
Oct.86	Main factor	224.10	224.10	1	37.01	0.005>P>0.001
vs	Error	24.22	6.06	4		
Jun.87	Total	248.33		5		
Oct.86	Main factor	236.21	236.21	1	81.22	P<0.001
vs	Error	11.63	2.91	4		
Aug.87	Total	247.85		5		
Dec.86	Main factor	3.227	3.227	1	10.12	0.05>P>0.025
vs	Error	1.275	0.319	4		
Feb.87	Total	4.502		5		
Dec.86	Main factor	51.633	51.633	1	76.23	P<0.001
vs	Error	2.709	0.677	4		
Apr.87	Total	54.342		5		
Dec.86	Main factor	715.38	715.38	1	189.01	P<0.001
vs	Error	15.14	3.78	4		
Jun.87	Total	730.52		5		
Dec.86	Main factor	736.895	736.895	1	1156.10	P<0.001
vs	Error	2.550	0.637	4		
Aug.87	Total	739.445		5		
Feb.87	Main factor	29.044	29.044	1	42.88	0.005>P>0.001
vs	Error	2.709	0.67	4		
Apr.87	Total	31.753		5		

Table 9. (continued)

Feb.87	Main factro	622.52	622.52	1	164.48	P<0.001
vs	Error	15.14	3.78	4		
Jun.87	Toatal	637.65		5		
Feb.87	Main factor	642.594	642.594	1	1008.10	P<0.001
vs	Error	2.550	0.637	4		
Aug.87	Total	645.144		5		
Apr.87	Main factor	382.63	382.63	1	92.35	P<0.001
vs	Error	16.57	4.14	4		
Jun.87	Total	399.20		5		
Apr.87	Main factor	398.410	398.10	1	400.1	P<0.001
vs	Error	3.984	0.996	4		
Aug.87	Total	402.394		5		
Jun.87	Main factor	0.16	0.16	1	0.04	P>0.75
vs	Error	16.41	4.10	4		
Aug.87	Total	16.57		5		

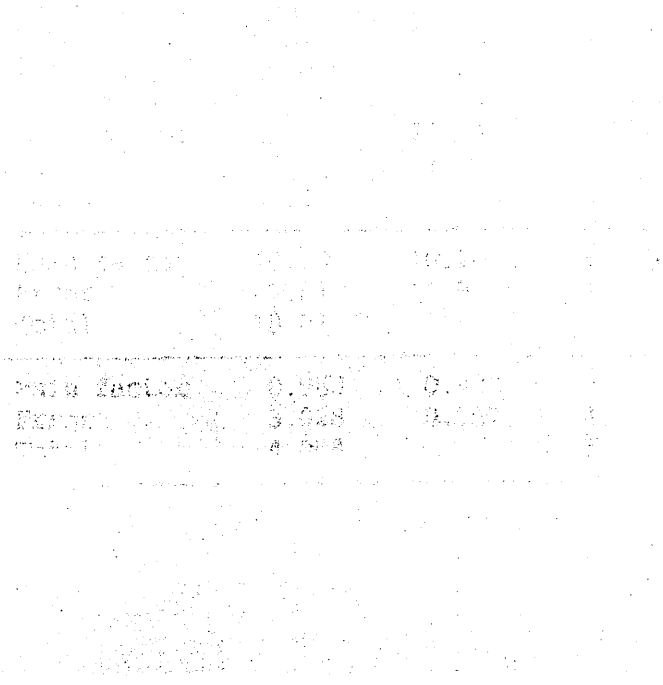


Table 10. Break down 1x2 one way analyses of variance of the total number of animals between pairs of months at mid tide.

Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	Main factor	8.96	8.96	1	4.020	0.25>P>0.10
vs	Error	8.92	2.23	4		
Dec.86	Total	17.89		5		
Oct.86	Main factor	12.91	12.91	1	9.260	0.05>P>0.025
vs	Error	5.58	1.39	4		
Feb.87	Total	18.49		5		
Oct. 86	Main factor	21.002	21.002	1	23.96	0.01>P>0.005
vs	Error	3.506	0.877	4		
Apr. 87	Toatl	24.508		5		
Oct. 86	Main factor	70.28	70.28	1	53.13	0.005>P>0.001
vs	Error	5.10	1.27	4		
Jun. 86	Total	75.38		5		
Oct. 86	Main factor	0.04	0.04	1	0.03	P>0.75
vs	Error	4.94	1.24	4		
Aug. 86	Total	4.98		5		
Dec.86	Main factor	0.36	0.36	1	0.1700	0.75>P>0.50
vs	Error	8.45	2.111	4		
Feb.87	Total	8.81		5		
Dec. 86	Main factor	2.52	2.52	1	1.58	0.50>P>0.25
vs	Error	6.37	1.59	4		
Apr. 87	Total	8.90		5		
Dec. 87	Main factor	129.44	129.44	1	64.98	0.005>P>0.001
vs	Error	7.97	1.99	4		
Jun. 87	Total	137.41		5		
Dec. 87	Main factor	10.20	10.20	1	5.22	0.10>P>0.05
vs	Error	7.81	1.95	4		
Aug. 87	Total	18.01		5		
Feb. 87	Main factor	0.980	0.980	1	1.29	0.50>P>0.25
vs	Error	3.028	0.757	4		
Apr. 87	Total	4.008		5		

Table 10. (continued)

Feb. 87	Main factor	143.43	143.43	1	124.14	P<0.001
vs	Error	4.62	1.16	4		
Jun. 87	Total	148.05		5		
Feb. 87	Main factor	14.38	14.38	1	12.89	0.025>P>0.01
vs	Error	4.46	1.12	4		
Aug. 87	Total	18.84		5		
Feb. 87	Main factor	14.38	4.38	1	12.89	0.025>P>0.01
vs	Error	4.46	1.12	4		
Aug.87	Total	18.84		5		
Feb. 87	Main factor	168.119	168.119	1	263.71	P<0.001
vs	Error	2.550	0.638	4		
Jun.87	Total	170.670		5		
Apr.87	Main factor	22.871	22.871	1	38.27	0.005>P>0.001
vs	Error	2.391	0.598	4		
Aug.87	Total	25.261		5		
Jun.87	Main factor	66.974	66.974	1	67.24	0.005>P>0.001
vs	Error	3.984	0.996	4		
Aug.87	Total	70.958		5		

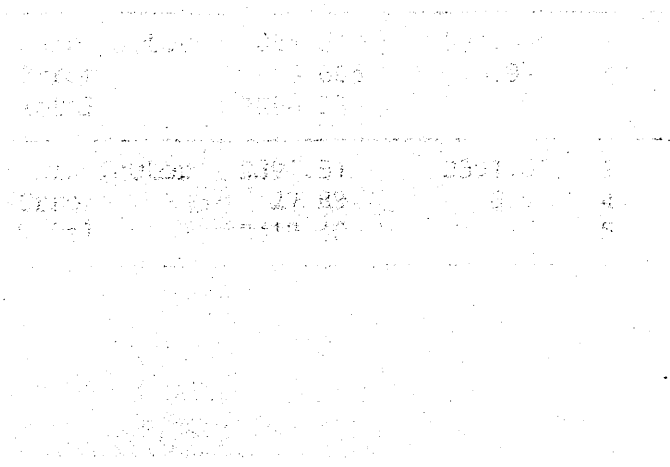


Table 11. Break down 1x2 one way analyses of variance of the total number of animals between pairs of months at high tide.

Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	Main factor	17618.65	17618.65	1	2713.01	P<0.001
vs	Error	25.89	6.49	4		
Dec.86	Total	17644.63		5		
Oct.86	Main factor	5783.3	5783.3	1	479.1	P<0.001
vs	Error	48.3	12.1	4		
Feb.87	Total	5831.5		5		
Oct. 86	Main factor	15612.70	15612.70	1	2360.68	P<0.001
vs	Error	26.45	6.61	4		
Apr. 87	Total	15639.16		5		
Oct. 86	Main factor	17144.99	17144.99	1	2794.38	P<0.001
vs	Error	24.54	6.14	4		
Jun. 87	Total	17169.53		5		
Oct. 86	Main factor	9960.23	9960.23	1	1623.37	P<0.001
vs	Error	24.54	6.14	4		
Aug. 87	Total	9984.77		5		
Dec.86	Main factor	3213.48	3213.48	1	458.9	P<0.001
vs	Error	27.41	6.85	4		
Feb.87	Total	3240.89		5		
Dec. 86	Main factor	60.60	60.60	1	43.46	0.005>P>0.001
vs	Error	5.58	1.39	4		
Apr. 87	Total	66.18		5		
Dec. 86	Main factor	3.227	3.227	1	3.52	0.25>P>0.10
vs	Error	3.665	0.916	4		
Jun. 87	Total	6.892		5		
Dec. 86	Main factor	1084.670	1084.670	1	1183.72	P<0.001
vs	Error	3.665	0.916	4		
Aug. 87	Total	1088.335		5		
Feb. 87	Main factor	2391.51	2391.51	1	343.01	P<0.001
vs	Error	27.89	6.97	4		
Apr. 87	Total	2419.40		5		

Table 11. (continued)

Feb. 87	Main factor	3013.03	3013.03	1	463.97	P<0.001
vs	Error	25.98	6.49	4		
Jun. 87	Total	3039.01		5		
Feb. 87	Main factor	564.21	564.21	1	86.88	P<0.001
vs	Error	25.98		4		
Aug. 87	Total	590.19		5		
Apr.87	Main factor	35.86	35.86	1	34.62	0.005>P>0.001
vs	Error	4.14	1.04	4		
Jun.87	Total	40.00		5		
Apr.87	Main factor	632.52	632.52	1	610.63	P<0.001
vs	Error	4.14	1.04	4		
Aug.87	Total	636.66		5		
Jun.87	Main factor	969.570	969.570	1	1738.45	P<0.001
vs	Error	2.231	0.558	4		
Aug.87	Total	971.801		5		

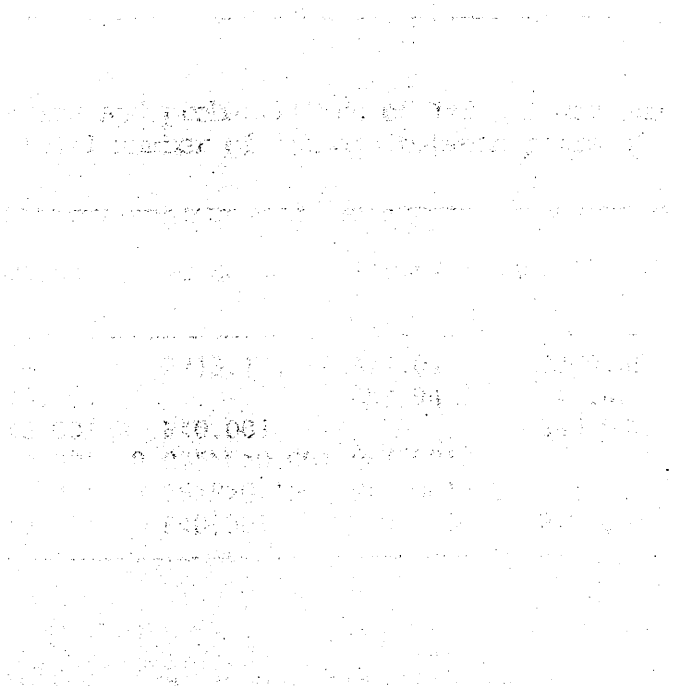


Table 12. F–ratios and probabilities of 1x2 one way analyses for the total number of animals between pairs of months at low tide.

F–ratio P	Oct.86	Dec.86	Feb.87	Apr.87	Jun.87	Aug.87
Oct.86	–	53.55	38.46	7.15	37.01	81.22
Dec.86	0.005>P>0.001	–	10.12	76.23	189.01	1156.10
Feb.87	0.005>P>0.001	0.05>P>0.25	–	42.88	164.48	1008.10
Apr.87	0.10>P>0.05	P<0.001	0.005>P>0.001	–	92.35	400.01
Jun.87	0.005>P>0.001	P<0.001	P<0.001	P<0.001	–	0.04
Aug.87	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	–

Table 13. F–ratios and probabilities of 1x2 one way analyses of variance for total number of animals between pairs of months at mid tide.

F–ratio P	Oct.86	Dec.86	Feb.87	Apr.87	Jun.87	Aug. 87
Oct.86	–	4.02	9.26	23.96	53.13	0.03
Dec.86	0.25>P>0.10	–	0.17	1.58	64.98	5.22
Feb.87	0.05>P>0.025	0.75>P>0.50	–	1.29	124.14	12.89
Apr.87	0.01>P>0.005	0.50>P>0.25	0.50>P>0.25	–	263.71	38.27
Jun.87	0.005>P>0.001	0.005>P>0.001	P<0.001	P<0.001	–	67.24
Aug.87	P<0.001	0.10>P>0.05	0.025>P>0.01	0.005>P>0.001	0.005>P>0.001	

Table 14. F–ratios and probabilities of 1x2 one way analyses of variance for the total number of animals between pairs of months at mid tide.

F–ratio P	Oct.86	Dec.86	Feb.87	Apr.87	Jun.87	Aug. 87
Oct.86	–	2713.10	479.07	2360.68	2794.38	1623.37
Dec.86	P<0.001	–	458.94	43.46	3.52	1183.7
Feb.87	P<0.001	P<0.001	–	343.01	463.97	86.88
Apr.87	P<0.001	0.005>P>0.001	P<0.001	–	34.62	610.63
Jun.87	P<0.001	0.25>P>0.10	P<0.001	0.005>P>0.001	–	1738.45
Aug.87	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	–

Table 15. 1x3 one way analyses of variance of the total number of animals between low tide, mid tide, and high tide for October 1986, December 1986, February 1987, April 1987, June 1987, and August 1987.

Months	Tidal levels compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	LT vs MT vs HT	Main factor	20596.31	10298.15	2	1708.03	P<0.001
		Error	36.18	6.03	6		
		Total	20637.48		8		
Dec.86	LT vs MT vs HT	Main factor	30.65	15.33	2	10.12	0.025>P>0.01
		Error	9.08	1.51	6		
		Total	39.73		8		
Feb.87	LT vs MT vs HT	Main factor	4040.96	2020.48	2	432.22	P<0.001
		Error	28.05	4.67	6		
		Total	4069.01		8		
Apr.87	LT vs MT vs HT	Main factor	31.617	15.808	2	17.00	0.005>P>0.001
		Error	5.578	0.930	6		
		Total	37.195		8		
Jun.87	LT vs MT vs HT	Main factor	549.22	274.61	2	93.15	P<0.001
		Error	17.69	2.95	6		
		Total	566.91		8		
Aug.87	LT vs MT vs HT	Main factor	714.962	357.481	2	434.19	P<0.001
		Error	4.940	0.823	6		
		Total	719.902		8		

Table 16. Break down 1x2 one way analyses of variance of the total number of animals between pairs of tidal levels for October 1986, December 1986, and February 1987.

Months	Tidal levels compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	LT vs MT	Main factor	11.51	11.51	1	3.61	0.25>P>0.10
		Error	12.75	3.19	4		
		Total	24.26		5		
	LT vs HT	Main factor	15019.85	15019.85	1	1812.47	P<0.001
		Error	33.15	8.29	4		
		Total	15052.99		5		
	MT vs HT	Main factor	15863.10	15863.10	1	2398.55	P<0.001
		Error	26.45	6.61	4		
		Total	15889.56		5		
Dec.86	LT vs MT	Main factor	29.04	29.04	1	17.78	0.025>P>0.01
		Error	6.53	1.63	4		
		Total	35.58		5		
	LT vs HT	Main factor	2.550	2.550	1	2.20	0.25>P>0.10
		Error	3.187	0.797	4		
		Total	5.737		5		
	MT vs HT	Main factor	14.38	14.38	1	6.81	0.10>P>0.05
		Error	8.45	2.11	4		
		Total	22.83		5		
Feb.87	LT vs MT	Main factor	8.964	8.964	1	11.25	0.05>P>0.025
		Error	3.187	0.797	4		
		Total	12.152		5		
	LT vs HT	Main factor	3190.89	3190.89	1	500.57	P<0.001
		Error	25.50	6.37	4		
		Total	3216.38		5		
	MT vs HT	Main factor	2861.59	2861.59	1	417.59	P<0.001
		Error	27.41	6.85	4		
		Total	2889.01		5		

Table 17. Break down 1x2 one way analyses of variance of the total number of animals between pairs of tidal levels for April 1987, June 1987, and August 1987.

Months	Tidal levels compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
April 87	LT vs MT	Main factor	11.459	11.459	1	17.97	0.025>P>0.01
		Error	2.550	0.638	4		
		Total	14.009		5		
	LT vs HT	Main factor	4.82	4.82	1	3.78	0.25>P>0.10
		Error	5.10	1.27	4		
		Total	9.92		5		
	MT vs HT	Main factor	31.145	31.145	1	35.53	0.005>P>0.001
		Error	3.506	0.877	4		
		Total	34.651		5		
June 87	LT vs MT	Main factor	99.60	99.60	1	24.04	0.01>P>0.005
		Error	16.57	4.14	4		
		Total	116.18		5		
	LT vs HT	Main factor	545.38	545.38	1	139.69	P<0.001
		Error	15.62	3.90	4		
		Total	561.00		5		
	MT vs HT	Main factor	178.847	178.847	1	224.46	P<0.001
		Error	3.187	0.797	4		
		Total	182.034		5		
August 8	LT vs MT	Main factor	344.585	344.585	1	360.39	P<0.001
		Error	3.825	0.956	4		
		Total	348.410		5		
	LT vs HT	Main factor	54.543	54.543	1	72.06	0.005>P>0.001
		Error	3.028	0.757	4		
		Total	57.570		5		
	MT vs HT	Main factor	673.315	673.315	1	889.50	P<0.001
		Error	3.028	0.757	4		
		Total	676.342		5		

Table 18. 1x6 one way analyses of variance of adults between October 1986, December 1986, February 1987, April 1987, June 1987, and August 1987 at each tidal level.

Tidal leve	Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
LT	Oct. 86 vs Dec. 86 vs Feb. 87 vs Apr. 87 vs Jun. 87 vs Aug. 87	Main factor	359.323	71.865	5	79.58	P<0.001
		Error	10.836	0.903	12		
		Total	370.159		17		
MT	Oct. 86 vs Dec. 86 vs Feb. 87 vs Apr. 87 vs Jun. 87 vs Aug. 87	Main factor	197.11	39.42	5	38.55	P<0.001
		Error	12.27	1.02	12		
		Total	209.39		17		
HT	Oct. 86 vs Dec. 86 vs Feb. 87 vs Apr. 87 vs Jun. 87 vs Aug. 87	Main factor	25358.80	5071.76	5	1084.95	P<0.001
		Error	56.10	4.67	12		
		Total	25414.90		17		

Table 19. Break down one way analyses of variance of adults between pairs of months at low tide.

Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	Main factor	60.598	60.598	1	304.23	P<0.001
vs	Error	0.797	0.199	4		
Dec.86	Total	61.395		5		
Oct.86	Main factor	51.634	51.634	1	259.23	P<0.001
vs	Error	0.797	0.199	4		
Feb.87	Total	52.431		5		
Oct.86	Main factor	8.962	8.962	1	20.46	0.025>P>0.01
vs	Error	1.752	0.438	4		
Apr.87	Total	10.715		5		
Oct.86	Main factor	40.80	40.80	1	19.70	0.025>P>0.01
vs	Error	8.29	2.07	4		
Jun.87	Total	49.09		5		
Oct.86	Main factor	24.904	24.904	1	56.84	0.005>P>0.001
vs	Error	1.752	0.438	4		
Aug.87	Total	26.656		5		
Dec.86	Main factor	0.3585	0.3685	1	4.50	0.25>P>0.10
vs	Error	0.3187	0.797	4		
Feb.87	Total	0.6772		5		
Dec.86	Main factor	22.948	22.948	1	72	0.005>P>0.001
vs	Error	1.275	0.319	4		
Apr.87	Total	24.223		5		
Dec.86	Main factor	200.84	200.84	1	102.88	P<0.001
vs	Error	7.81	1.95	4		
Jun.87	Total	208.65		5		
Dec.86	Main factor	163.188	163.188	1	511.98	P<0.001
vs	Error	1.275	0.319	4		
Aug.87	Total	164.463		5		
Feb.87	Main factor	17.570	17.570	1	55.12	0.005>P>0.001
vs	Error	1.275	0.319	4		
Apr.87	Total	18.845		5		

Table 19. (continued)

Feb.87	Main factor	184.22	184.22	1	94.37	P<0.001
vs	Error	7.81	1.95	4		
Jun.87	Total	192.03		5		
Feb.87	Main factor	148.248	148.248	1	465.11	P<0.001
vs	Error	1.275	0.319	4		
Aug.87	Total	149.523		5		
Apr.87	Main factor	88.01	88.01	1	40.16	0.005>P>0.001
vs	Error	8.77	2.19	4		
Jun.87	Total	96.77		5		
Apr.87	Main factor	63.746	63.746	1	114.28	P<0.001
vs	Error	2.231	0.558	4		
Aug.87	Total	65.977		5		
Jun.87	Main factor	1.95	1.95	1	0.89	0.50>P>0.25
vs	Error	8.77	2.19	4		
Aug.87	Total	10.72		5		

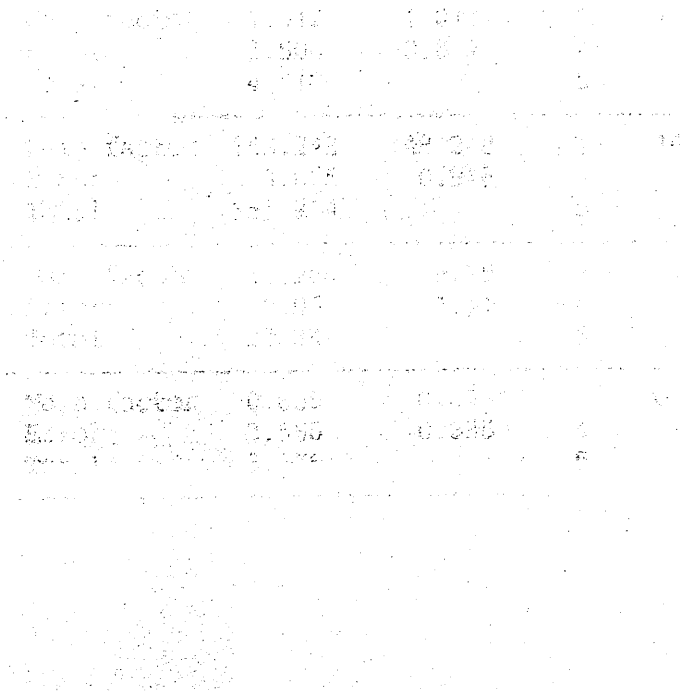


Table 20. Break down 1x2 one way analyses of variance of adults between pairs of months at mid tide.

Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	Main factor	5.74	5.74	1	3.79	0.25>P>0.10
vs	Error	6.06	1.51	4		
Dec.86	Total	11.79		5		
Oct.86	Main factor	0.36	0.36	1	0.28	0.75>P>0.50
vs	Error	5.10	1.27	4		
Feb.87	Total	5.46		5		
Oct. 86	Main factor	1.930	1.930	1	2.20	0.25>P<0.10
vs	Error	3.506	0.877	4		
Apr. 87	Total	5.436		5		
Oct. 86	Main factor	95.658	95.658	1	104.39	P<0.001
vs	Error	3.665	0.916	4		
Jun. 87	Total	99.323		5		
Oct. 86	Main factor	3.98	3.98	1	2.63	0.25>P>0.10
vs	Error	6.04	1.51	4		
Aug. 87	Total	10.04		5		
Dec.86	Main factor	3.23	3.23	1	0.28	0.75>P>0.50
vs	Error	5.10	1.27	4		
Feb.87	Total	8.33		5		
Dec. 86	Main factor	1.012	1.012	1	1.15	0.50>P>0.25
vs	Error	3.506	0.877	4		
Apr. 87	Total	4.518		5		
Dec. 86	Main factor	148.248	148.248	1	161.78	P<0.001
vs	Error	3.665	0.916	4		
Jun. 87	Total	151.914		5		
Dec. 86	Main factor	19.28	19.28	1	12.74	0.025>P>0.01
vs	Error	6.06	1.51	4		
Aug. 87	Total	23.34		5		
Feb. 87	Main factor	0.625	0.625	1	0.98	0.50>P>0.0.25
vs	Error	2.550	0.638	4		
Apr. 87	Total	3.175		5		

Table 20. (continued).

Feb. 87	Main factor	107.729	107.729	1	159.05	P<0.001
vs	Error	2.709	0.677	4		
Jun. 87	Total	110.438		5		
Feb. 87	Main factor	6.73	6.73	1	5.28	0.10>P>0.05
vs	Error	5.10	1.27	4		
Aug. 87	Total	11.83		5		
Apr.87	Main factor	124.761	124.761	1	447.24	P<0.001
vs	Error	1.116	0.279	4		
Jun.87	Total	125.877		5		
Apr.87	Main factor	11.459	11.459	1	13.07	0.025>P>0.01
vs	Error	3.506	0.877	4		
Aug.87	Total	14.965		5		
Jun.87	Main factor	60.598	60.598	1	66.13	0.005>P>0.001
vs	Error	3.665	0.916	4		
Aug.87	Total	64.253		5		

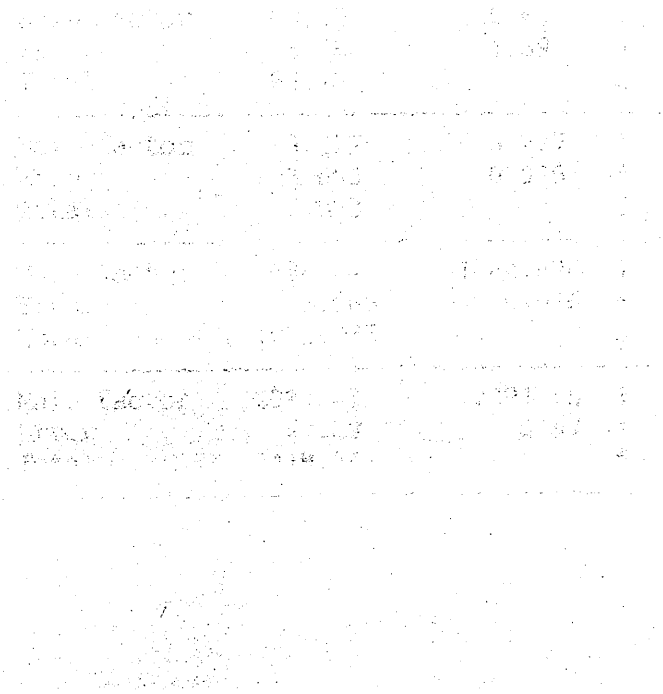


Table 21. Break down 1x2 one way analyses of variance of adults between pairs of months at high tide.

Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	Main factor	17144.99	17144.99	1	2640.11	P<0.001
vs	Error	25.98	6.49	4		
Dec.86	Total	17170.96		5		
Oct.86	Main factor	5513.4	5513.4	1	456.72	P<0.001
vs	Error	48.3	12.1	4		
Feb.87	Total	5561.6		5		
Oct.86	Main factor	15167.00	15167.00	1	2293.22	P<0.001
vs	Error	26.45	6.61	4		
Apr.87	Total	15193.45		5		
Oct.86	Main factor	16677.75	16677.75	1	2718.22	P<0.001
vs	Error	24.54	6.14	4		
Jun.87	Total	16702.29		5		
Oct.86	Main factor	9604.89	9604.89	1	1565.47	P<0.001
vs	Error	24.54	6.14	4		
Aug.87	Total	9629.43		5		
Dec.86	Main factor	3213.41	3213.41	1	468.93	P<0.001
vs	Error	27.41	6.85	4		
Feb.87	Total	3240.82		5		
Dec.86	Main factor	60.60	60.60	1	43.46	0.005>P>0.001
vs	Error	5.58	1.39	4		
Apr.87	Total	66.18		5		
Dec.86	Main factor	3.227	3.227	1	3.52	0.25>P>0.10
vs	Error	3.666	0.916	4		
Jun.87	Total	6.893		5		
Dec.86	Main factor	1084.670	1084.670	1	1187.72	P<0.001
vs	Error	3.665	0.916	4		
Aug.87	Total	1088.335		5		
Feb.87	Main factor	2391.45	2391.45	1	343	P<0.001
vs	Error	27.89	6.97	4		
Apr.87	Total	2419.34		5		

Table 21. (continued).

Feb.87	Main factor	3012.96	3012.96	1	463.95	P<0.001
vs	Error	25.98	6.49	4		
Jun.87	Total	3038.93		5		
Feb.87	Main factor	564.19	564.19	1	86.88	P<0.001
vs	Error	25.98	6.49	4		
Aug.87	Total	590.16		5		
Apr.87	Main factor	35.86	35.86	1	34.61	0.005>P>0.001
vs	Error	4.14	1.04	4		
Jun.87	Total	40.00		5		
Apr.87	Main factor	632.52	632.52	1	610.63	P<0.001
vs	Error	4.14	1.04	4		
Aug.87	Total	636.66		5		
Jun.87	Main factor	969.565	969.565	1	1738.19	P<0.001
vs	Error	2.231	0.558	4		
Aug.87	Total	971.796		5		

Table 22. F–ratios and probabilities of 1x2 one way analyses of variance for adults between pairs of months at low tide.

F–ratio P	Oct.86	Dec.86	Feb.87	Apr.87	Jun.87	Aug.87
Oct.86	–	304.23	259.23	20.46	19.70	56.84
Dec.86	P<0.001	–	4.50	72	102.88	511.98
Feb.87	P<0.001	0.25>P>0.10	–	55.12	94.37	465.11
Apr.87	0.025>P>0.01	0.005>P>0.001	0.005>P>0.001	–	40.16	114.28
Jun.87	0.025>P>0.01	P<0.001	P<0.001	0.005>P>0.001	–	0.89
Aug.87	0.005>P>0.001	P<0.001	P<0.001	P<0.001	0.50>P>0.25	–

Table 23. F–ratios and probabilites of 1x2 one way analyses of variance of adults between pairs of montha at mid tide.

F–ratio P	Oct.86	Dec.86	Feb.87	Apr.87	Jun.87	Aug.87
Oct.86	–	3.79	0.28	2.20	104.39	2.63
Dec.86	0.25>P>0.10	–	2.53	1.15	161.78	12.74
Feb.87	0.75>P>0.50	0.25>P>010	–	0.98	159.05	5.28
Apr.87	0.25>P>0.10	0.50>P>0.25	0.50>P>0.25	–	447.24	13.07
Jun.87	P<0.001	P<0.001	P<0.001	P<0.001	–	66.13
Aug.87	0.25>P>0.10	0.25>P>0.10	0.10>P>0.05	0.025>P>0.01	0.005>P>0.001	–

Table 24. F–ratios and probailities of 1x2 one way analyses of variance of adults between pairs of months at high tide.

F–ratio P	Oct.86	Dec.86	Feb.87	Apr.87	Jun.87	Aug. 87
Oct.86	–	2640.11	456.72	229322	2718.22	1565.47
Dec.86	P<0.001	–	468.93	43.46	3.52	1157.72
Feb.87	P<).001	P<0.001	–	343	463.95	86.88
Apr.87	P<0.001	0.005>P>0.001	P<0.001	–	34.61	610.63
Jun.87	P<0.001	0.25>P>0.10	P<0.001	0.005>P>0.001	–	1738.19
Aug.87	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	–

Table 25. 1x3 one way analyses of variance of adults between low tide, mid tide, and high tide for October 1986, December 1986, February 1987, April 1987, June 1987, and August 1987.

Months	Tidal levels compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	LT vs MT vs HT	Main factor Error Total	2122.363 27.09 21250.72	10611.81 4.52	2 6 8	2350.21	P<0.001
Dec.86	LT vs MT vs HT	Main factor Error Total	9.083 5.737 4.820	4.542 0.956	2 6 8	4.75	0.10>P>0.05
Feb.87	LT vs MT vs HT	Main factor Error Total	4167.41 27.09 4194.50	2083.70 4.52	2 6 8	461.48	P<0.001
Apr.87	LT vs MT vs HT	Main factor Error Total	36.479 4.622 41.101	18.239 0.770	2 6 8	23.68	0.005>P>0.001
Jun.87	LT vs MT vs HT	Main factor Error Total	164.62 9.40 174.02	82.31 1.57	2 6 8	52.52	P<0.001
Aug.87	LT vs MT vs HT	Main factor Error Total	839.264 5.259 844.523	419.632 0.876	2 6 8	478.77	P<0.001

Table 26. Break down 1x2 one way analyses of variance of adults between pairs of tidal levels for October 1986, December 1986, and February 1987.

Months	Tidal levels compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	LT vs MT	Main factor	5.737	5.737	1	0.26	0.70>P>0.50
		Error	3.665	0.916	4		
		Total	9.403		5		
	LT vs HT	Main factor	15612.69	15612.69	1	2595.22	P<0.001
		Error	24.06	6.02	4		
		Total	15636.75		5		
	MT vs HT	Main factor	16217.01	16217.01	1	2452.09	P<0.001
		Error	26.45	6.61	4		
		Total	166243.47		5		
Dec.87	LT vs MT	Main factor	8.964	8.964	1	11.25	0.05>P>0.025
		Error	3.187	0.797	4		
		Total	12.151		5		
	LT vs HT	Main factor	3.227	3.227	1	4.76	0.10>P>0.05
		Error	2.709	0.677	4		
		Total	5.936		5		
	MT vs HT	Main factor	1.43	1.43	1	1.03	0.50>P>0.25
		Error	5.58	1.39	4		
		Total	7.01		5		
Feb.87	LT vs MT	Main factor	17.570	17.570	1	31.50	0.005>P>0.001
		Error	2.231	0.558	4		
		Total	19.801		5		
	LT vs HT	Main factor	3350.62	3350.62	1	535.67	P<0.001
		Error	25.02	6.25	4		
		Total	3375.64		5		
	MT vs HT	Main factor	2882.92	2882.92	1	428.17	P<0.001
		Error	26.93	6.73	4		
		Total	2909.86		5		

Table 27. Break down 1x2 one way analyses of variance of adults between pairs of tidal levels for April 1987, June 1987, August 1987.

Months	Tidal levels compared	Source of variance	Sum of squares	Mean of squares	D.F	F-ratio	P
April 87	LT vs MT	Main factor	0.625	0.625	1	1.57	0.50>P>0.25
		Error	1.594	0.398	4		
		Total	2.219		5		
	LT vs HT	Main factor	22.95	22.95	1	22.15	0.01>P>0.005
		Error	4.14	1.04	4		
		Total	17.09		5		
	MT vs HT	Main factor	31.145	31.145	1	35.53	0.005>P>0.001
		Error	3.506	0.877	4		
		Total	34.651		5		
June 87	LT vs MT	Main factor	1.00	1.00	1	0.48	0.75>P>0.50
		Error	8.29	2.07	4		
		Total	9.28		5		
	LT vs HT	Main factor	111.91	119.91	1	51.07	0.005>P>0.001
		Error	8.77	2.19	4		
		Total	120.68		5		
	MT vs HT	Main factor	134.023	134.023	1	305.76	P<0.001
		Error	1.753	0.438	4		
		Total	135.776		5		
August 87	LT vs MT	Main factor	29.04	29.04	1	28.04	0.01>P>0.005
		Error	4.14	1.04	4		
		Total	33.19		5		
	LT vs HT	Main factor	482.075	482.075	1	864.30	P<0.001
		Error	2.231	0.558	4		
		Total	484.306		5		
	MT vs HT	Main factor	747.78	747.78	1	721.91	P<0.001
		Error	4.14	1.04	4		
		Total	751.82		5		

Table 28. 1x6 one way analyses of variance of copepodites between October 1986, December 1986, February 1987, April 1987, June 1987, and August 1987 at each tidal level.

Tidal level	Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
LT	Oct. 86 vs Dec. 86 vs Feb. 87 vs Apr. 87 vs Jun. 87 vs Aug. 87	Main factor	383.587	76.717	5	103.16	P<0.001
		Error	8.925	0.744	12		
		Total	392.511		17		
MT	Oct. 86 vs Dec. 86 vs Feb. 87 vs Apr. 87 vs Jun. 87 vs Aug. 87	Main factor	14.886	2.977	5	34.90	P<0.001
		Error	1.435	0.120	12		
		Total	16.321		17		
HT	Oct. 86 vs Dec. 86 vs Feb. 87 vs Apr. 87 vs Jun. 87 vs Aug. 87	Main factor	5.38	1.08	5	1.00	0.50>P>0.25
		Error	2.91	1.08	12		
		Total	8.29		17		

Table 29. Break down 1x2 one way analyses of variance of copepodites between pairs of months at low tide.

Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	Main factor	15.94	15.94	1	10.00	0.05>P>0.025
vs	Error	6.37	1.59	4		
Dec.86	Total	22.31		5		
Oct.86	Main factor	7.81	7.81	1	4.26	0.25>P>0.10
vs	Error	7.33	1.82	4		
Feb.87	Total	15.14		5		
Oct. 86	Main factor	2.55	2.55	1	1.60	0.50>P>0.25
vs	Error	6.37	1.59	4		
Apr. 87	Total	8.92		5		
Oct. 86	Main factor	77.13	77.13	1	42.09	0.005>P>0.001
vs	Error	7.33	1.83	4		
Jun. 87	Total	84.46		5		
Oct. 86	Main factor	107.73	107.73	1	67.60	0.005>P>0.001
vs	Error	6.37	1.59	4		
Aug. 87	Total	114.10		5		
Dec.86	Main factor	1.434	1.434	1	4.50	0.25>P>0.10
vs	Error	1.275	0.319	4		
Feb.87	Total	2.709		5		
Dec.86	Main factor	5.7368	5.7368	1	71.99	0.005>P>0.001
vs	Error	0.3188	0.0797	4		
Apr.87	Total	6.0555		5		
Dec.86	Main factor	163.188	163.188	1	511.98	P<0.001
vs	Error	1.275	0.319	4		
Jun.87	Total	164.463		5		
Dec.86	Main factor	206.5337	206.5337	1	2592.23	P<0.001
vs	Error	0.3187	0.0797	4		
Aug.87	Total	206.8524		5		
Feb.87	Main factor	1.434	1.434	1	4.50	0.25>P>0.10
vs	Error	1.275	0.319	4		
Apr.87	Total	2.709		5		

Table 29. (continued).

Feb.87	Main factor	134.025	134.025	1	240.29	P<0.001
vs	Error	2.231	0.558	4		
Jun.87	Total	136.256		5		
Feb.87	Main factor	173.546	173.546	1	544.56	P<0.001
vs	Error	1.275	0.319	4		
Aug.87	Total	174.821		5		
Apr.87	Main factor	107.731	107.731	1	337.97	P<0.001
vs	Error	1.275	0.319	4		
Jun.87	Total	109.006		5		
Apr.87	Main factor	143.4276	143.4276	1	1799.81	P<0.001
vs	Error	0.3188	0.0797	4		
Aug.87	Total	143.7464		5		
Jun.87	Main factor	2.550	2.550	1	8.00	0.05>P>0.025
vs	Error	1.275	0.319	4		
Aug.87	Total	3.825		5		

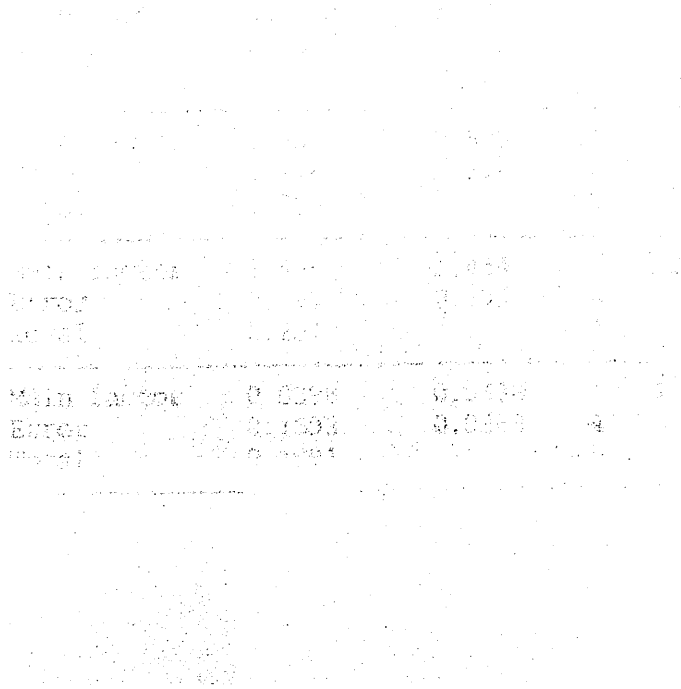


Table 30. Break down 1x2 one way analyses of variance of copepodites between pairs of months at mid tide.

Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	Main factor	0.637	0.637	1	2.00	0.25>P>0.10
vs	Error	1.275	0.319	4		
Dec.86	Total	1.912		5		
Oct.86	Main factor	10.199	10.199	1	51.20	0.005>P>0.001
vs	Error	0.797	0.199	4		
Feb.86	Total	10.996		5		
Oct.86	Main factor	8.9099169	8.9099169	1	108471.27	P<0.001
vs	Error	0.0003286	0.000821	4		
Apr.87	Total	8.9102459		5		
Oct.86	Main factor	1.413	1.413	1	11.81	0.05>P>0.025
vs	Error	0.478	0.120	4		
Jun.87	Total	1.891		5		
Oct.86	Main factor	2.5211	2.5211	1	63.16	0.005>P>0.001
vs	Error	0.1597	0.0399	4		
Aug.87	Total	2.6808		5		
Dec.86	Main factor	5.737	5.737	1	28.80	0.005>P>0.001
vs	Error	0.797	0.199	4		
Feb.87	Total	6.534		5		
Dec.86	Main factor	6.733	6.733	1	42.24	0.005>P>0.001
vs	Error	0.638	0.159	4		
Apr.87	Total	7.370		5		
Dec.86	Main factor	0.638	0.638	1	2.29	0.25>P>0.10
vs	Error	1.116	0.279	4		
Jun.87	Total	1.753		5		
Dec.86	Main factor	1.434	1.434	1	7.20	0.10>P>0.05
vs	Error	0.797	0.199	4		
Aug.87	Total	2.231		5		
Feb.87	Main factor	0.0398	0.0398	1	1.00	P<0.001
vs	Error	0.1593	0.0398	4		
Apr.87	Total	0.1991		5		

Table 30. (continued).

Feb.87	Main factor	2.550	2.550	1	16	0.01>P>0.005
vs	Error	0.637	0.159	4		
Jun.87	Total	3.187		5		
Feb.87	Main factor	1.4341	1.4341	1	18	0.01>P>0.005
vs	Error	0.3187	0.0797	4		
Aug.87	Total	1.7528		5		
Apr.87	Main factor	3.227	3.227	1	27	0.01>P>0.005
vs	Error	0.478	0.120	4		
Jun.87	Total	3.705		5		
Apr.87	Main factor	1.9520	1.9520	1	49	0.005>P>0.001
vs	Error	0.1593	0.0398	4		
Aug.87	Total	2.1114		5		
Jun.87	Main factor	0.159	0.159	1	1	0.50>P>0.25
vs	Error	0.637	0.159	4		
Aug.87	Total	0.797		5		

Table 31. Break down 1x2 one way analyses of variance of copepodites between pairs of months at high tide.

Months compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	Main factor	3.23	3.23	1	1	0.50>P>0.25
vs	Error	12.91	3.23	4		
Dec.86	Total	16.14		5		
Oct.86	Main factor	3.23	3.23	1	1	0.50>P>0.25
vs	Error	12.23	3.23	4		
Feb.87	Total	16.14		5		
Oct.86	Main factor	3.23	3.23	1	1	0.50>P>0.25
vs	Error	12.91	3.23	4		
Apr.87	Toatl	16.14		5		
Oct.86	Main factor	3.23	3.23	1	1	0.50>P>0.25
vs	Error	12.91	3.23	4		
Jun.87	Total	16.14		5		
Oct.86	Main factor	3.23	3.23	1	1	0.50>P>0.25
vs	Error	12.91	3.23	4		
Aug.87	Total	16.14		5		

No statistical analyses were applied any further because no animals in December 86, February 87, April 87, June 87, and August 87 at high tide.

Table 32. F-ratios and probabilities of 1x2 one way analyses of variance of copepodites between pairs of months at low tide.

F-ratio P	Oct.86	Dec.86	Feb.87	Apr.87	Jun.87	Aug.87
Oct. 86	–	10	4.26	1.60	42.09	67.60
Dec. 86	0.05>P>0.025	–	4.50	71.99	511.98	2592.23
Feb. 87	0.25>P>0.10	0.25>P>0.10	–	4.50	240.29	544.56
Apr. 87	0.50>P>0.25	0.005>P>0.001	0.25>P>0.10	–	337.97	1799.81
Jun. 87	0.005>P>0.001	P<0.001	P<0.001	P<0.001	–	8
Aug. 87	0.005>P>0.001	P<0.001	P<0.001	P<0.001	0.05>P>0.025	–

Table 33. F-ratios and probabilities of 1x2 one way analyses of variance of copepodites between pairs of months at mid tide.

F-ratio P	Oct.86	Dec.86	Feb.87	Apr.87	Jun.87	Aug.87
Oct.86	–	2	51.20	10847.27	11.81	63.16
Dec.86	0.25>P>0.10	–	28.80	42.24	2.29	7.20
Feb.87	0.005>P>0.001	0.005>P>0.001	–	1	16	18
Apr.87	P<0.001	0.005>P>0.001	P<0.001	–	27	49
Jun.87	0.05>P>0.025	0.25>P>0.10	0.01>P>0.005	0.01>P>0.005	–	1
Aug.87	0.005>P>0.001	0.10>P>0.05	0.01>P>0.005	0.005>P>0.001	0.50>P>0.25	–

Table 34. F-ratios and probabilities of 1x2 one way analyses of variance of copepodites between pairs of months at high tide. * = No statistical analyses were made because copepodites were only found in October 1986.

F-ratio P	Oct.86	Dec.86	Feb.87	Apr.87	Jun.87	Aug.87
Oct.86	–	1.00	1.00	1.00	1.00	1.00
Dec.86	0.50>P>0.25	–	*	*	*	*
Feb.87	0.50>P>0.25	*	–	*	*	*
Apr.87	0.50>P>0.25	*	*	–	*	*
Jun.87	0.50>P>0.25	*	*	*	*	*
Aug.87	0.50>P>0.25	*	*	*	*	*

Table 35. 1x3 way analyses of variance of copepodites between low tide, mid tide, and high tide for October 1986, December 1986, February 1987, April 1987, June 1987, and August 1987.

Month	Tidal levels compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	LT vs MT vs HT	Main factor	5.95	2.97	2	0.90	0.50>P>0.25
		Error	19.76	3.29	6		
		Total	25.71		8		
Dec.86	LT vs MT vs HT	Main factor	8.340	4.170	2	31.40	P<0.001
		Error	0.797	0.133	6		
		Total	9.137		8		
Feb.87	LT vs MT vs HT	Main factor	2.284	1.142	2	5.38	0.05>P>0.025
		Error	1.275	0.212	6		
		Total	3.559		8		
Apr.87	LT vs MT vs HT	Main factor	8.9769	4.4885	2	168.94	P<0.001
		Error	0.1594	0.0266	6		
		Total	9.1363		8		
Jun.87	LT vs MT vs HT	Main factor	197.664	98.832	2	372.10	P<0.001
		Error	1.594	0.266	6		
		Total	199.258		8		
Aug.87	LT vs MT vs HT	Main factor	258.5396	129.2698	2	2433.72	P<0.001
		Error	0.3187	0.0531	6		
		Total	258.8582		8		

Table 36. Break down 1x2 one way analyses of variance of copepodites between pairs of tidal levels for October 1987, December 1986, and February 1987.

Month	Tidal levels compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
Oct.86	LT vs MT	Main factor	0.64	0.64	1	0.37	0.75>P>0.50
		Error	6.85	1.71	4		
		Total	7.49		5		
	LT vs HT	Main factor	5.74	5.74	1	1.20	0.50>P>0.25
		Error	19.12	4.78	4		
		Total	24.86		5		
	MT vs HT	Main factor	2.55	2.55	1	0.75	0.50>P>0.25
		Error	13.55	3.39	4		
		Total	16.10		5		
Dec.86	LT vs MT	Main factor	5.737	5.737	1	28.80	0.01>P>0.005
		Error	0.797	0.199	4		
		Total	6.534		5		
	LT vs HT	Main factor	0.0398	0.0398	1	1.00	0.50>P>0.25
		Error	0.1593	0.0398	4		
		Total	0.1992		5		
	MT vs HT	Main factor	6.733	6.733	1	42.24	0.005>P>0.001
		Error	0.638	0.159	4		
		Total	7.370		5		
Feb.87	LT vs MT	Main factor	1.434	1.434	1	4.50	0.25>P>0.10
		Error	1.275	0.319	4		
		Total	2.709		5		
	LT vs HT	Main factor	1.952	1.952	1	7.00	0.10>P>0.05
		Error	1.115	0.279	4		
		Total	3.068		5		
	MT vs HT	Main factor	0.0398	0.0398	1	1.00	0.50>P>0.25
		Error	0.1593	0.0398	4		
		Total	0.1992		5		

Table 37. Break down 1x2 one way analyses of variance of copepodites between pairs of tidal levels for April 1987, June 1987, and August 1987.

Months	Tidal levels compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
April 87	LT vs MT	Main factor	6.7327	6.7327	1	168.94	P<0.001
		Error	0.1594	0.0399	4		
		Total	6.8921		5		
	LT vs HT	Main factor	6.7327	6.7327	1	168.94	P<0.001
		Error	0.1594	0.0399	4		
		Total	6.8921		5		
	MT vs HT	(no comparison made because no copepodites)					
June 87	LT vs MT	Main factor	124.942	124.942	1	313.60	P<0.001
		Error	1.594	0.398	4		
		Total	126.536		5		
	LT vs HT	Main factor	168.327	168.327	1	603.54	P<0.001
		Error	1.116	0.279	4		
		Total	169.443		5		
	MT vs HT	Main factor	3.227	3.227	1	27.00	0.01>P>0.005
		Error	0.478	0.120	4		
		Total	3.705		5		
August 87	LT vs MT	Main factor	173.5470	173.5470	1	2178.21	P<0.001
		Error	0.3187	0.0797	4		
		Total	173.8657		5		
	LT vs HT	Main factor	212.3103	212.3103	1	5329.47	P<0.001
		Error	0.1593	0.0398	4		
		Total	212.4697		5		
	MT vs HT	Main factor	1.9520	1.9520	1	49.00	0.005>P>0.001
		Error	0.1593	0.0398	4		
		Total	2.1114		5		

RESULTS (Part 2)

The results of January 1987 and July 1987 in respect of harpacticoid copepods, nematodes, and particle size, at the five stations and eight depths, are divided into three main parts:

1.-Harpacticoid copepods.

1.1-Total harpacticoids

1.2-Adults harpacticoids.

1.3-Copepodites.

2.- Nematodes.

3.- Particle size

Note: Tables 38-193 (Results of part 2) are on pages 153 to 226.

In each of 1 and 2, the abundances are described first and the statistical analyses second. Before the statistical analyses were applied, the original data were transformed to normalise the data. Two transformations were tried, square root ($\sqrt{x+1}$) and logarithmic ($\log_{10}(x+1)$).

The suitability of these transformations was assessed by plotting the means (x) against the standard deviations (y) and applying regression analyses to the plotted data. The more normal a set of data, the less significant is the correlation between the means and standard deviations. Tables 38 and 39 show the analyses of variations of the regressions for the untransformed and transformed data. In 3 out of the four cases, the logarithmic transformation gave the lowest mean square, and therefore this transformation was used.

1.Harpacticoid copepods (top 1 cm):

The numbering of the tables showing the original data and statistical analyses of the harpacticoid abundances are shown in table 40.

1.1-Total:

1.1.1-Abundance:

The abundance results of total harpacticoid copepods (number of total harpacticoids per 5 ml) for January 1987 and July 1987 are presented in tables 41a and b. In general, total harpacticoids were more abundant in July than in January, and were mainly found in the top 1 cm of the sedimentary column. In addition, fewer harpacticoids were found at the high tide station than at the other stations. The results were then analysed statistically.

1.1.2-Statistical analyses.

The $\log_{10}(x+1)$ transformed data for total harpacticoid copepods in the top 1 cm of sediment in January 1987 and July 1987 were statistically analysed using two way and one way analyses of variance followed by unpaired t-tests assuming unequal variances. When t-tests were used between abundances in two samples (3 replicates per sample), in which there were no animals in all three replicates of one of the two samples (i.e. 0, 0, 0), a modified form of the unpaired t-test was used (Bailey, 1981, p.44-47).

1.1.2.1-Two way analysis of variance comparing between stations and between months. A comparison between the five stations in January 1987 and the five in July 1987 was first made by a two way analysis of variance comparing the five stations (Factor A) and the two months (Factor B) (table 42). The first order interaction of stations with months was highly significant ($P<0.001$). No statement can therefore be made about the significance of the two main factors (stations and months).

Breakdown analyses by one-way anovars and unpaired student t-tests assuming unequal variances were then made comparing (a) differences between the five stations at each month and (b) differences between the two months at each station. The results of these analyses are now given.

1.1.2.2 Comparisons between the five stations at each month. Comparisons between the stations (1/2/3/4/5) were made by two 1x5 anovars one for each month (table 43), and showed highly significant differences. These were followed by t-tests comparing pairs of stations in turn for the January data (Table 44) and the July data (Table 45). Most of these comparisons were significant.

1.1.2.3-Comparisons between the two months at each station: The two months, January 87 and July 87, were statistically compared at each station by 5 t-tests (Table 46). All of the comparisons were statistically significant.

1.1.2.4 - Results of statistical comparisons. The results of the statistical comparisons in 1.1.2.2 and 1.1.2.3 mean that the observed differences in the 0-1 cm data in table 41a and 41b are almost all significant. In otherwords at all stations there were significantly more harpacticoids in July than in January. Secondly there were differences between the stations in January and also between the stations in July. The most obvious of these differences is that station 5 (the high tide station) has fewer harpacticoids than the other stations. In addition, in January there were two peaks in the data, one at station 2 (lower mid tide) and one at station 4 (upper mid tide).

1.2-Adults (top 1 cm):

1.2.1-Abundance:

The abundance results of adults (number of adults per 5 ml) for January 1987 and July 1987, are presented in tables 47a and 47b, and are discussed in the discussion (item 1).

1.2.2-Statistical analysis:

The $\log_{10}(x+1)$ transformed data for the adults in the top 1 cm of sediment in January 1987 and July 1987 were statistically analysed using two way and one way analyses of variance followed by unpaired t-tests assuming unequal variances. As with

the totals, when t-tests were used to compare between abundances in two samples (3 replicates per sample), in which there were no animals in all three replicates of one of the two samples (i.e. 0, 0, 0), a modified form of the unpaired t-test was used (Bailey, 1981, p.44-47).

1.2.2.1-Two way analysis of variance comparing between stations and between months. A comparison between the five stations in January 87 and the five in July 87 was first made by a two way analysis of variance comparing the stations (Factor A) and the two months (Factor B) (table 48). The first order interaction of stations with months was highly significant ($P<0.001$). No statements can therefore be made about the significance of the two main factors (stations and months). Breakdown analyses by one-way anovars and unpaired t-tests assuming unequal variances were then made comparing (a) differences between the five stations at each month and (b) differences between the two months at each station. The results of these analyses are now given.

1.2.2.2-Comparison between the five stations at each month.

Comparisons between the stations (1/2/3/4/5/) were made by two 1x5 anovars one for each month (Table 49) and showed higly significant differences. These were follwed by t-tests comparing pairs of stations in turn for the January data (Table 50) and the July data (Table 51). Most of these comparisons were statistically significant.

1.2.2.3-Comparison between the two months at each station: The two months, January 87 and July 87, were statistically compared at each station by 5 t-tests (Table 52). All of the comparisons were statistically significant except at station 5.

1.2.2.4 - Results of statistical comparisons. The results of the statistical comparisons in 1.2.2.2 and 1.2.2.3 mean that the observed differences in the top 0-1 cm data in tables 47a and 47b are almost significant. In other words at all stations there were more adults in July than in January. Secondly there were differences between the stations

in January and between the stations in July. The most obvious of these differences is that station 5 (the high tide station) has fewer adults than other stations. In addition, in January there were two peaks in the data, one at station 2 (lower mid tide) and one at station 4 (upper mid tide). These results are very similar to those for total harpacticoids (see above 1.1.2.4).

1.3-Copepodites (top 1 cm):

1.3.1-Abundance:

The abundance of copepodites (number of copepodites per 5 ml) for January 1987 and July 1987 are presented in tables 53a and 53b.

Copepodites were more abundant in July than in January particularly at station 1 (the low tide station), and were mainly found in the top 1 cm of the sedimentary column. In both months there were no copepodites at stations 4 and 5 (upper mid tide and high tide stations). These results are discussed in the discussion (item 1).

1.3.2-Statistical analyses:

The $\log_{10}(x+1)$ transformed data for copepodites in the top 1 cm of the sediment in January 87 and July 87 were statistically analysed using two way and one way analyses of variance followed by unpaired t-tests assuming unequal variances. When t-tests were used to compare between abundances in two samples (3 replicates per sample), in which there were no animals in all three replicates of one of the two samples (i.e. 0, 0, 0), a modified form of the unpaired t-test was used (Bailey, 1981, p.44-47).

1.3.2.1- Two way analysis of variance comparing between stations and between months. A comparison between the five stations in January 87 and the five in July 87 was first made by a two way analysis of variance comparing the five stations (Factor A) and the two months (Factor B) (table 54). The first order interaction of stations with months was highly significant ($P<0.001$). No statements can therefore be

made about the significance of the main factors (stations and months).

Breakdown analyses by one-way anovars and unpaired t-tests assuming unequal variances were then made comparing (a) differences between the five stations at each month and (b) differences between the two months at each station. The results of these analyses are now given.

1.3.2.2 Comparisons between the five stations at each month.

Comparisons between the five stations (1/2/3/4/5) were made by two 1x5 anovars one for each month (table 55), and showed highly significant differences ($P<0.001$). These were followed by unpaired t-tests comparing pairs of months in turn for the January data (table 56) and the July data (table 57). Most of these comparisons were significant. In both months comparison between station 4 and 5 was not possible because no copepodites were found at these stations.

1.3.2.3-Comparison between the two months at each station: The two months, January 87 and July 87, were statistically compared at stations 1, 2, and 3 by unpaired t-tests (table 58), and a significant difference was only found at station 1. No comparisons were made at stations 4 and 5 because no copepodites were found at these stations.

1.3.2.4. Results of statistical comparisons. The results of the statistical comparisons in 1.3.2.2 and 1.3.2.3 mean that some of the observed differences in the 0-1 cm data in tables 53a and 53b are significant. The most obvious differences is that stations 4 (upper mid tide) and 5 (the high tide station) have no copepodites at all in both months. In addition, in July there was a peak in the data at station 1 (the low tide station). The only significant difference between the two months was at station 1, where there were more copepodites in July than January.

2.Nematodes:

2.1-Abundance:

The abundance of nematodes (number of nematodes per 5 ml) for January 1987

and July 1987 are presented in tables 60a and 60b.

In general, nematodes were more abundant in July 87 than in January 87 and also occurred much deeper in the sediment than did harpacticoids. Nematodes were most abundant at stations 2, 3, and 4 and least abundant at station 5.

2.2-Statistical analysis:

The $\log_{10}$ (x+1) transformed data for nematodes in January 87 and July 87 were statistically analysed using two way and one way analyses of variance followed by unpaired t-tests assuming unequal variances. When t-tests were used to compare between abundances in two samples (3 replicates per sample), in which there were no animals in all three replicates of one of the two samples (i.e. 0, 0, 0), a modified form of the unpaired t-test was used (Bailey, 1981, p. 44-47).

Unlike the harpacticoid data, these tests were conducted for each depth because in contrast to harpacticoids significant numbers of nematodes occurred all the way down the sedimentary column. The possible reasons for the differences in vertical distribution of the harpacticoids and nematodes are discussed in the discussion (item 2).

2.2.1-Two way analyses of variance comparing between stations and between months at each depth. A comparison between the five stations in January 87 and the five in July at each depth was first made by a two way analysis of variance comparing the stations (Factor A) and the two months (Factor B) (table 60c). The first order interaction of stations with months at each depth was highly significant. No statements can therefore be made about the significance of the two main factors (stations and months).

Breakdown analyses by one-way anovars and unpaired t-tests assuming unequal variances were then made comparing (a) differences between the five station at each month for each depth and (b) differences between the two months at each station for

each depth. The results of these are now given.

2.2.2-Comparisons between the five stations at each month for each depth:

The five stations (1, 2, 3, 4, 5) were statistically compared at each depth by 1x5 one-way anovars, one for each month. The results of these are shown in tables 61 and 62, and show that all comparisons were highly significant. Student t-tests were then used to compare between pairs of stations at each depth for the January data (tables 63-70) and then for the July data (tables 71-78). Most of these comparisons were statistically significant.

2.2.3-Results of comparisons between stations at each depth for each month. The results of the statistical comparisons in 2.2.2 mean that the following statements can be made about the data in tables 60a and 60b. In both January and July there were relatively few nematodes at station 5 (the high tide station), and there was a broad peak of abundance in the mid tide stations (stations 2, 3, 4). The possible reasons for this are discussed in the discussion (item 2).

2.2.4-Comparison between the two months at each station and each depth. The two months January 87 and July 87 were statistically compared at each station and each depth in turn by unpaired t-tests (tables 79-86). Most of these comparisons were significant in the top 4 cm of the sediment, but not below that.

2.2.5-Results of comparisons between the two months at each station for each depth. The results of the statistical comparisons in 2.2.4 mean that the following statements can be made about the data in tables 60a and 60b. In the top 0-1 cm, the July abundances were always greater than the January abundances. Surprisingly, at greater depths, the January abundances were sometimes greater than the July abundances (compare tables 60a and 60b: station 1, 3-4 cm, 4-5 cm; station 2, 3-4 cm, 7-8 cm, 10-11 cm; station 3, 3-4 cm; station 4, 2-3 cm, 3-4 cm; station 5, 3-4 cm). My interpretation of this is that the nematodes are migrating downwards in winter to

avoid the very cold surface sediment temperatures which may often fall below 0°C (see discussion).

2.2.6-Comparisons between depths at each station for each month. Comparisons were made between the depths at each station for the two months by a series of 1x8 one way analyses of variance followed by unpaired t-tests assuming unequal variances (tables 87-98). All of the ten 1x8 one way analyses of variance were significant (table 87 January data (5 anovars); table 88 July data (5 anovars). These were then followed by unpaired t-tests comparing pairs of depths at each station for each month (tables 89-93, January; tables 94-98, July). Most of these comparisons were significant and these are summarised as follows (table 99):

Table 99.

Month	Station	No. of significant t-tests out of 28 possible comparisons
January	1	19
	2	17
	3	24
	4	22
	5	13
July	1	23
	2	24
	3	24
	4	13
	5	10

2.2.7- Results of comparisons between depths at each station for each month. The results of the statistical comparisons in 2.2.6 mean that the following statements can be made about the data in tables 60a and 60b. In general, the abundance of nematodes decreased with increasing depth. This is more obvious in July than in January because of the effect of downward vertical migration in winter that was commented on in 2.2.5. above. The decrease with increasing depth was more rapid towards high tide (stations 4, 5) especially in July.

3 - Particle size:

The original data for particle size in January 1987 and July 1987 were analysed by a particle size computer programme in order to obtain means, standard deviations, skewness, and kurtoses values for the samples. An example of the print out of the computer programme for (station 1, depth 0-1 cm) is given in table 100 a. Table 101 shows the resultant means, standard deviations, skewnesses and kurtoses for January and July for the four depths at which particle size was measured (0-1cm, 3-4cm, 7-8cm, 13-14cm).

I then wrote a computer programme to calculate student t-tests comparing between means, variance ratios comparing between standard deviations, and t-tests comparing between skewnesses and between kurtoses. The t-test comparing between skewness and kurtosis is taken from Sokal and Rolf (1981) p. 118. A listing of the programme is given in table 100b.

Ten inputs were required by the programme. These are listed in the programme on lines 20 to 340. Nine equations were needed for calculations. The first equation was to calculate t-test of two means of two independent samples (Bailey 1981, pp 48). The second and the third equations (lines 420,430) were to calculate the variance ratio which compares variances $(s.d.)^2$ between two independent samples. This ratio was obtained by dividing the larger variance by the smaller variance.

The fourth to the ninth equations (lines 560-610) were to test whether skewness and kurtosis are different from zero for a given population by t-tests, and to compare skewnesses and kurtoses between two independent populations by t-tests. The equations used to calculate these were obtained from Sokal and Rohlf (1981 p. 114, 118).

The objectives of constructing the programme were to analyse all possible comparisons of particle size parameters between stations, between depths, and

between January and July (tables 102-193 pp. 201 to 226). This enables statements to be made about differences in particle size parameters between the stations, between the sites, and between the January and July data. Some very interesting facts arose from these detailed analyses and these are now itemised (3.1-3.6).

3.1. One of the most important points to emerge from the analyses was that there were differences in the number of significant comparisons between the means, standard deviations, skewnesses and kurtoses. These can be itemised as follows:

Numbes of significant comparisons.

Comparisons	Means	S.d	Skewness	Kurtosis	Totals
Pairs of Jan. Stations	18/40	15/40	0/40	18/40	51/160
Jul.	21/40	14/40	0/40	17/40	52/160
					103/320
Pairs of Jan. depths	10/30	0/30	0/30	10/30	20/120
Jul.	10/30	0/30	0/30	9/30	19/120
					39/240
Jan./Jul. at each depth & each station	6/20	0/20	0/20	3/20	9/80
Total	65/160	29/160	0/160	57/160	

Skewnesses different from zero	Jan.	0/20	Kurtoses different from zero	Jan. 9/20
	Jul.	0/20		Jul. 8/20
		0/40		17/40

Here 18/40, for example, means that 18 out of the 40 comparisons of the means of pairs of stations in January were statistically significant at $P<0.05$ level (5%).

3.1.1. The greatest number of differences occurred in the means (65/160) and the kurtoses (57/160). There were some differences in the standard deviations (sorting) (29/160), but none in the skewnesses . This means that the main differences between the stations and depths consisted of differences in mean particle size and kurtosis (peakedness of the particle size distributions).

3.1.2. There were a much greater number of significant comparisons between pairs of stations than pairs of depths (103/320 vs 39/24), with very few differences between January and July (9/80). This means that the main variability in the means, sorting (s.d) and kurtoses occurred along the transect between the stations. It also means that there was less variability vertically in the sediment at each station, and virtually no difference between the winter (January) and summer (July data). This latter implies that there were virtually no seasonal effects. This is surprising as one would expect there to be a seasonal effect caused by more erosion and sediment transport in winter than in summer because of the higher wind energy in winter.

3.1.3. 17/40 values of kurtosis were significantly different from zero, but none of the skewnesses were. This is also surprising because movement of sediment by depositional and erosional processes, particulary in winter, might be expected to lead to marked departures from normality both for peakness (kurtosis) and for left or right bias (skewness) in the particle size distributions.

A detailed inspection was then conducted of (i) the data for means, standard deviations (sorting), skewnesses and kurtoses at the 5 stations and 4 depths for January and July (table 101), (ii) the detailed statistical analyses in tables 102 to 193 (p 201 to 226), and (iii) the number of significant tests itemised in 3.1 above. The main results of this inspection are given below for means (3.3), standard deviations (3.4), skewnesses (3.5) and kurtoses (3.6).

3.3. Differences between means.

As noted in 3.1 above, the main differences were between stations. The two high tide stations (stations 4 and 5) had higher phi means, meaning smaller mean particle size, particularly in the 0-1 cm and 3-4 cm depths. There were fewer differences vertically into the sediment at each station. In some instances (stations 3, 4 January; station 4 July) the sediment was finer (higher mean phi) at 13-14 cm than at the surface , while in other cases the reverse was true (station 5 January; stations 1, 2, 5

July). It is not clear what these differences mean because they show no very repeatable pattern with depth at the different stations.

3.4. Differences between standard deviations:

In contrast to the means, the only significant differences between the standard deviations were between the stations; there were no differences vertically into the sediment at each station, and no seasonal effects (January/July). The main effect is that at most depths there were higher standard deviations towards high tide. This means less sorting towards high tide, which is to be expected because there is less wave energy there.

3.5. Differences between skewnesses. There were none.

3.6. Differences between kurtoses:

The picture here is similar to sorting (standard deviations). Most of the differences were between stations along the transect. The greatest degree of peakedness (higher values of kurtosis) tended to occur at stations 2 and 4 in January and at stations 1 and 2 in July. The lowest degree of peakedness usually occurred at high tide. This is probably because there is less wave energy at high tide to produce sorting which would lead to a more peaked particle size distribution.

3.7. The meaninig of the differences in the particle size parameters at the different stations and depths, and the relationship of the particle size parameters to the abundance of harpacticoids and nematodes is discussed in the discussion (item 3).

Table 38. Analysis of variance of regressions of means (x) against standard deviations (y).

Harpacticoids

January 1987

Untransformed

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	6.3391	6.3391
RESIDUAL	13	3.5392	0.2722
TOTAL	14	9.8783	

$\sqrt{x+1}$

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	0.00631	0.00631
RESIDUAL	14	0.15672	0.01119
TOTAL	15	0.16303	

$\log_{10}(x+1)$

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	0.019104	0.019104
RESIDUAL	14	0.040662	0.002904
TOTAL	15	0.059766	

July 1987

Untransformed

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	49.408	49.408
RESIDUAL	10	10.638	1.064
TOTAL	11	60.046	

$\sqrt{x+1}$

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	0.14285	0.14285
RESIDUAL	14	0.16748	0.01196
TOTAL	15	0.31033	

$\log_{10}(x+1)$

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	0.004804	0.004804
RESIDUAL	14	0.084797	0.006057
TOTAL	15	0.089601	

Table 39. Analysis of variance of regressions of means (x) against standard deviations (y).

Nematodes

January 1987

Untransformed

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	28.4381	28.4381
RESIDUAL	32	9.2818	0.2901
TOTAL	33	37.7199	

$\sqrt{x+1}$

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	56.082	56.082
RESIDUAL	38	78.976	2.078
TOTAL	39	135.057	

$\log_{10}(x+1)$

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	0.1685	0.1685
RESIDUAL	38	9.8435	0.2590
TOTAL	39	10.0121	

July 1987

Untransformed

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	263.681	263.681
RESIDUAL	27	87.331	3.234
TOTAL	28	351.012	

$\sqrt{x+1}$

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	148.245	148.245
RESIDUAL	38	206.511	5.435
TOTAL	39	354.757	

$\log_{10}(x+1)$

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	0.0000	0.0000
RESIDUAL	38	19.8658	0.5228
TOTAL	39	19.8658	

Table 40. Table numbers of original data and statistical analyses for harpacticoid copepods.

Animals	Original data	Stations & months	Comparisons between stations		Comparisons between months
		2 way	one way	t-tests	t-tests
Total	41a 41b	42	43	44 45	46
Adults	47a 47b	48	49	50 51	52
Copepodites	53a 53b	54	55	56 57	58

Table 41a. January 1987. Original data. Number of total harpacticoid copepods/ 5ml for at stations 1, 2, 3, 4, and 5 at depths 0–1, 1–2, 2–3, 3–4, 4–5, 7–8, 10–11, and 13–14 cm.

Depth (cm)	Replicates (5 ml)	Stations				
		1	2	3	4	5
0–1	R1	5	21	4	11	3
	R2	7	21	5	15	1
	R3	12	25	5	14	2
1–2	R1	2	0	0	1	1
	R2	2	1	0	1	1
	R3	2	1	0	0	2
2–3	R1	0	0	0	0	1
	R2	0	1	0	0	0
	R3	0	1	0	0	0
3–4	R1	0	0	0	0	0
	R2	0	0	0	0	1
	R3	0	0	0	0	1
4–5	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
7–8	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
10–11	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
13–14	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0

Table 41b. July 1987. Original data. Number of total harpacticoid copepods for stations 1, 2, 3, 4, and 5 at depths 0–1, 1–2, 2–3, 3–4, 4–5, 7–8, 10–11, and 13–14 cm.

Depth (cm)	Replicates (5 ml)	Stations				
		1	2	3	4	5
0–1	R1	83	32	43	45	4
	R2	74	30	47	60	5
	R3	73	28	55	53	5
1–2	R1	5	0	1	0	0
	R2	4	1	1	0	0
	R3	4	1	0	0	0
2–3	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
3–4	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
4–5	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
7–8	R1	1	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
10–11	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
13–14	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0

Table 42. 2x5 two way analyses of variance of the totals comparing Factor A (5 levels) = stations 1–5, and Factor B (2 levels) = January 87, July 87. Data taken from depth 0–1 cm.

Animals	Source of variance	Sum of squares	Mean of squares	d.f	F–ratio	P
Total	Stations 1–5	3.032	0.7581	4	–	
	Jan./Jul.	2.500	2.500	1	–	
	Interaction	0.8440	0.2110	4	30.06	P<0.001
	Error	0.1404	0.00702	20		
	Total	6.516		29		

Table 43. 1x5 one way analyses of variance of total harpacticoid copepods between stations 1, 2, 3, 4, and 5 for January 1987 and July 1987.

Months	Stations compared	Soures of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
January 87	1/2/3/4/5	Main factor	1.4789	0.3697	4	30.91	P<0.001
		Error	0.1196	0.0120	10		
		Total	1.5985		14		
July 87	1/2/3/4/5	Main factor	2.39699	0.59925	4	288.35	P<0.001
		Error	0.02078	0.00208	10		
		Total	2.41778		14		

Table 44. t-tests comparing total harpacticoid copepods between pairs of stations in January 1987 at a depth of 0-1 cm. (unpaired t-test assuming variances not equal, Bailey, 1981. p. 15)).

Stations compared	t-test	Degrees of freedom	Probability
1/2	-4.310	2	0.05>P>0.02
1/3	1.773	2	0.3>P>0.2
1/4	-2.108	2	0.2>P>0.1
1/5	3.594	3	0.05>P>0.02
2/3	17.166	3	P<0.001
2/4	4.753	3	0.02>P>0.01
2/5	10.007	2	0.01>P>0.001
3/4	8.601	3	0.01>P>0.001
3/5	3.198	2	0.1>P>0.05
4/5	7.282	2	0.02>P>0.01

Table 45. t-tests comparing total harpacticoid copepods between pairs of stations in July 1987 at a depth of 0-1 cm. (unpaired t-test assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	16.702	3	P<0.001
1/3	5.632	3	0.02>P>0.01
1/4	4.112	2	0.1>P>0.05
1/5	35.911	3	P<0.001
2/3	-5.778	3	0.02>P>0.01
2/4	-6.048	2	0.05>P>0.02
2/5	23.848	3	P<0.001
3/4	-.765	3	0.6>P>0.5
3/5	23.234	3	P<0.001
4/5	22.040	3	P<0.001

Note 1.

The variation in the degrees of freedom is caused by the use of an algebraic equation to calculate degrees of freedom for the student t–test when the variances of two samples are not assumed to be equal (Baily, 1981, p.51). This applies to the t–tests in tables 44, 45, 46, 50, 51, 52, 56, 57, 58, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 89, 90, 91, 92, 93, 94, 95, 96, 97, and 98.

Note 2.

Positive and negative values of students–t indicate that the first meaan is greater than the second, and vice versa, respectively.

Table 46. t–tests comparing total harpacticoid copepods between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 at a depth of 0–1 cm. (unpaired t–tests assuming variances not equal, Bailey, 1981. p.51).

Station at which comparison was made	Months compared	t–test	Degrees of freedom	Probability
1	January 87 vs July 87	–9.624	2	0.02>P>0.01
2	January 87 vs July 87	–4.264	3	0.05>P>0.02
3	January 87 vs July 87	–23.220	3	P<0.001
4	January 87 vs July 87	–11.054	3	0.01>P>0.001
5	January 87 vs July 87	–3.198	2	0.05>P>0.02

Table 47a. January 1987. Original data. Number of adults/ 5 ml for stations 1, 2, 3, 4, and 5 at depths 0–1, 1–2, 2–3, 3–4, 4–5, 7–8, 10–11, and 13–14 cm.

Depth (cm)	Replicates (5 ml)	Stations				
		1	2	3	4	5
0–1	R1	4	16	0	11	3
	R2	6	17	2	15	1
	R3	10	21	2	14	2
1–2	R1	2	0	0	1	1
	R2	1	1	0	1	1
	R3	1	1	0	0	2
2–3	R1	0	0	0	0	1
	R2	0	1	0	0	0
	R3	0	1	0	0	0
3–4	R1	0	0	0	0	0
	R2	0	0	0	0	1
	R3	0	0	0	0	1
4–5	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
7–8	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
10–11	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
13–14	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0

Table 47b. July 1987. Original data. Number of adults/ 5 ml for stations 1, 2, 3, 4, and 5 at depths 0–1, 1–2, 2–3, 3–4, 4–5, 7–8, 10–11, 13–14 cm.

Depth (cm)	Replicates (5 ml)	Stations				
		1	2	3	4	5
0–1	R1	62	29	43	45	4
	R2	55	28	46	60	5
	R3	56	25	54	53	5
1–2	R1	2	0	1	0	0
	R2	0	1	1	0	0
	R3	1	1	0	0	0
2–3	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
3–4	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
4–5	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
7–8	R1	1	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
10–11	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
13–14	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0

Table 48. 2x5 two ay analyses of variance of adults comparing Factor A (5 levels) = stations 1–5 and Factor B (2 levels) = January 87, July 87. Data taken from 0–1 cm.

	Stations 1–5	2.840	0.7101	4	—	
	Jan./Jul.	3.308	3.308	1	—	
Adults	Interaction	1.398	0.3495	4	24.10	P<0.001
	Error	0.2900	0.0145	20		
	Total	7.836		29		

Table 49. 1x5 one way analyses of variance of adults between stations 1, 2, 3, 4, and 5 in January 1987 and July 1987.

Months	Stations compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
January 87	1/2/3/4/5	Main factor	2.0872	0.5218	4	19.35	P<0.001
		Error	0.2696	0.0270	10		
		Total	2.3569		14		
July 87	1/2/3/4/5	Main factor	2.15254	0.5314	4	263.52	P<0.001
		Error	0.02042	0.00204	10		
		Total	2.17297		14		

Table 50. t-tests comparing adults between pairs of stations in January 1987 at a depth of 0-1 cm. (unpaired t-test assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	d.f	Probability
1/2	-3.960	2	0.1>P>0.05
1/3	2.901	3	0.1>P>0.05
1/4	-2.744	2	0.2>P>0.1
1/5	3.040	3	0.1>P>0.05
2/3	5.894	2	0.05>P>0.02
2/4	2.486	3	0.1>P>0.05
2/5	8.845	2	0.02>P>0.01
3/4	-5.108	2	0.02>P>0.01
3/5	-.783	3	0.5>P>0.4
4/5	7.282	2	0.02>P>0.01

Table 51. t-tests comparing adults between pairs of stations in July 1987 at a depth of 0-1 cm. (unpaired t-test assuming variances equal, Bailey, 1981. p. 51).

Stations compared	t-test	d.f	Probability
1/2	12.849	3	0.01>P>0.001
1/3	2.510	3	0.1>P>0.05
1/4	1.053	2	0.4>P>0.3
1/5	32.947	3	P<0.001
2/3	-6.811	3	0.01>P>0.001
2/4	-6.857	3	0.01>P>0.001
2/5	21.696	3	P<0.001
3/4	-.909	3	0.5>P>0.4
3/5	23.919	3	P<0.001
4/5	22.040	3	P<0.001

Table 52. t-tests comparing adults between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth of 0-1 cm. (unpaired t-test assuming variances not equal, Bailey, 1981. p. 51).

Stations at which comparison was made	Months compared	t-test	d.f	Probability
1	January 87 vs July 87	-9.018	2	0.02>P>0.01
2	January 87 vs July 87	-5.483	3	0.02>P>0.01
3	January 87 vs July 87	-8.460	2	0.02>P>0.01
4	January 87 vs July 87	-11.054	3	0.01>P>0.001
5	January 87 vs July 87	-3.198	2	0.1>P>0.05

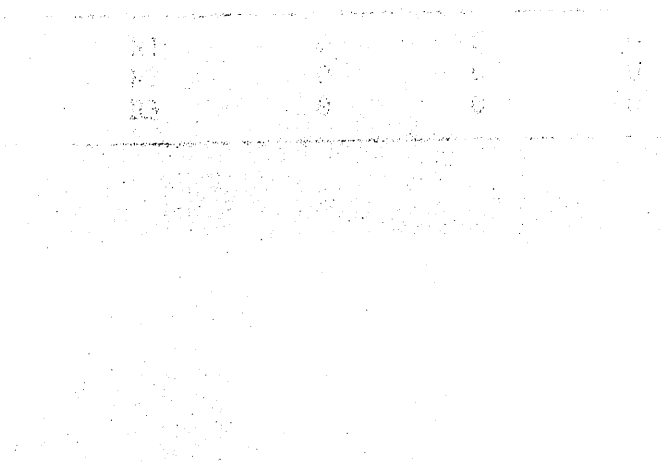


Table 53a. January 1987. Original data. Number of copepodites/ 5 ml for stations 1, 2, 3, 4, and 5 at depths 0–1, 1–2, 2–3, 3–4, 4–5, 7–8, 10–11, and 13–14 cm.

Depth (cm)	Replicates (5 ml)	Stations				
		1	2	3	4	5
0–1	R1	1	5	4	0	0
	R2	1	4	3	0	0
	R3	2	4	3	0	0
1–2	R1	0	0	0	0	0
	R2	1	0	0	0	0
	R3	1	0	0	0	0
2–3	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
3–4	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
4–5	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
7–8	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
10–11	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
13–14	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0

Table 53b. July 1987. Original data. Number of copepodites/ 5 ml for stations 1, 2, 3, 4, and 5 at depths 0–1, 1–2, 2–3, 3–4, 4–5, 7–8, 10–11, and 13–14 cm.

Depth (cm)	Replicates (5 ml)	Stations				
		1	2	3	4	5
0–1	R1	21	3	0	0	0
	R2	19	2	1	0	0
	R3	17	3	1	0	0
1–2	R1	3	0	0	0	0
	R2	4	0	0	0	0
	R3	3	0	0	0	0
2–3	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
3–4	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
4–5	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
7–8	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
10–11	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0
13–14	R1	0	0	0	0	0
	R2	0	0	0	0	0
	R3	0	0	0	0	0

Table 54. 2x5 two way analyses of variance comparing Factor A (5 levels) = stations 1–5, and Factor B (2 levels) = January 87, July 87. Data taken from 0–1 cm.

	Stations 1–5	3.369	0.8421	4	—	
	Jan./Jul.	0.0350	0.0350	1	—	
Copepodites	Interaction	1.613	0.4032	4	76.22	P<0.001
	Error	0.1057	0.00529	20		
	Total	5.122				

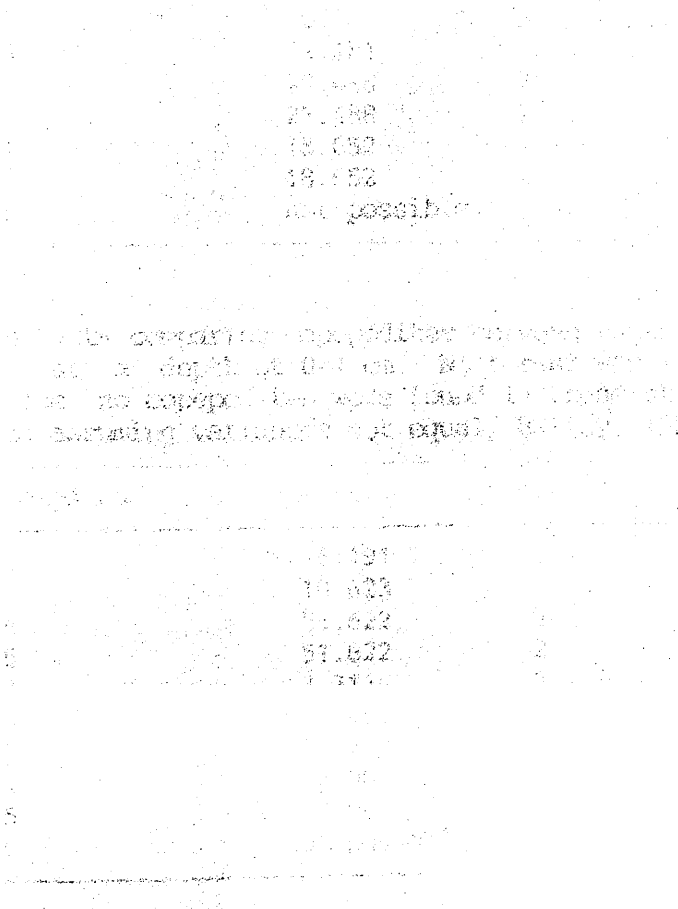


Table 55. 1x5 one way analysis of variance of copepodites between stations 1, 2, 3, 4, and 5 in January 1987 and July 1987.

Months	Stations compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
January 87	1/2/3/4/5	Main factor	1.39975	0.34994	4	112.46	P<0.001
		Error	0.03112	0.00311	10		
		Total	1.43086		14		
July 87	1/2/3/4/5	Main factor	3.58163	0.89541	4	120.02	P<0.001
		Error	0.07461	0.00746	10		
		Total	3.65624		10		

Table 56. t-tests comparing copepodites between pairs of stations in January 1987 at a depth of 0-1 cm. No t-test was made between stations 4 and 5 because no copepodites were found in these stations. (unpaired t-test assuming variances not equal Bailey, 1981, p. 51).

Stations compared	t-test	d.f	Probability
1/2	-5.680	2	0.05>P>0.02
1/3	-4.099	3	0.05>P>0.05
1/4	6.131	2	0.05>P>0.02
1/5	6.131	2	0.05>P>0.02
2/3	2.181	3	0.2>P>0.1
2/4	27.488	2	P<0.001
2/5	27.488	2	P<0.001
3/4	18.652	2	0.01>P>0.001
3/5	18.652	2	0.01>P>0.001
4/5	not possible		

Table 57. t-tests comparing copepodites between pairs of stations in July 1987 at a depth of 0-1 cm. No t-test was made between 4 and 5 because no copepodites were found in these stations. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	d.f	Probability
1/2	15.191	3	P<0.001
1/3	10.623	2	0.01>P>0.001
1/4	51.622	2	P<0.001
1/5	51.622	2	P<0.001
2/3	3.311	2	0.1>P>0.05
2/4	13.459	2	0.01>P>0.001
2/5	13.459	2	0.01>P>0.001
3/4	2.00	2	0.2>P>0.1
3/5	2.00	2	0.2>P>0.1
4/5	not possible		

Table 58. t-tests comparing copepodites between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth of 0-1 cm. No t-tests were made between the two months at stations 4 and 5 because no copepodites were found at these stations. (unpaired t-tests assuming variances not equal, Bailey 1981. p. 51).

Stations at which comparison was made	Months compared	t-test	d.f	Probability
1	January 87 vs July 87	-14.714	2	0.01>P>0.001
2	January 87 vs July 87	3.346	2	0.1>P>0.05
3	January 87 vs July 87	4.114	2	0.1>P>0.05
4	No t-test applied because no copepodites.			
5	No t-test applied because no copepodites.			

Table 59. Table numbers of the statistical analyses of nematodes.

Original	Comparison between stations & between months	Comparison between stations at each depth				Comparison between depths at each station				Comparison between months at each station
	Two way	One way		t-tests		one way		t-test		t-tests
		Jan.	Jul.	Jan.	Jul.	Jan.	Jul.	Jan.	Jul.	
60a	60c	61	62	63	71	79	80	81	86	91
60b				64	72			82	87	92
				65	73			83	89	93
				66	74			84	89	94
				67	75			85	90	95
				68	76					96
				69	77					97
				70	78					98

Table 60a. January 1987. Original data. Number of nematodes/ 5 ml for stations 1, 2, 3, 4, and 5 at 0–1, 1–2, 2–3, 3–4, 4–5, 7–8, 10–11, and 13–14 cm.

Depth (cm)	Replicates (5 ml)	Stations				
		1	2	3	4	5
0–1	R1	13	70	24	23	5
	R2	14	80	25	24	3
	R3	15	73	20	22	5
1–2	R1	11	22	18	14	4
	R2	10	27	22	15	3
	R3	12	25	20	13	4
2–3	R1	15	11	16	6	4
	R2	12	12	17	7	4
	R3	13	10	15	6	3
3–4	R1	46	24	27	4	22
	R2	43	22	23	5	23
	R3	44	21	25	4	20
4–5	R1	54	8	12	0	3
	R2	61	8	11	0	3
	R3	55	9	10	0	3
7–8	R1	8	23	7	0	1
	R2	6	17	9	0	1
	R3	7	20	8	0	1
10–11	R1	4	15	3	0	1
	R2	4	16	3	0	2
	R3	5	15	2	0	1
13–14	R1	4	2	2	0	0
	R2	4	3	3	0	0
	R3	4	2	2	0	0

Table 60b. July 1987. Original data. Number of nematodes/ 5 ml for stations 1, 2, 3, 4, and 5 at depth 0–1, 1–2, 2–3, 3–4, 4–5, 7–8, 10–11, 13–14 cm.

Depth (cm)	Replicates (5 ml)	Stations				
		1	2	3	4	5
0–1	R1	41	95	100	115	27
	R2	37	105	120	107	29
	R3	39	107	130	99	30
1–2	R1	39	22	111	8	1
	R2	48	24	94	12	2
	R3	49	34	90	10	3
2–3	R1	24	21	67	0	0
	R2	32	23	61	0	0
	R3	34	25	64	0	0
3–4	R1	31	20	15	0	1
	R2	32	15	13	2	1
	R3	35	18	10	0	0
4–5	R1	19	10	9	0	0
	R2	22	7	9	0	0
	R3	20	8	8	0	0
7–8	R1	5	5	4	0	0
	R2	7	6	6	0	0
	R3	6	5	5	0	0
10–11	R1	3	4	2	0	0
	R2	2	5	4	0	0
	R3	3	4	2	0	0
13–14	R1	0	0	3	0	0
	R2	0	0	3	0	0
	R3	0	0	2	0	0

Table 60c. 2x5 two way analyses of variance of nematodes comparing Factor A (5 levels) = stations 1–5, and Factor B (2 levels) = January 87, July 87. Data taken from depths 0–1 cm, 1–2 cm, 2–3 cm, 3–4 cm, 4–5 cm, 7–8 cm, 10–11 cm, and 13–14 cm.

Depth (cm)	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
0–1	Stations 1–5	2.654	0.6635	4	–	
	Jan./Jul.	2.1101	2.1101	1	–	
	Interaction	0.3862	0.0965	4	46.99	P<0.001
	Error	0.4179	0.00209	20		
	Total	5.1922		29		
1–2	Stations 1–5	4.151	1.038	4	–	
	Jan./Jul.	0.2995	0.2995	1	–	
	Interaction	0.9704	0.2426	4	31.34	P<0.001
	Error	0.1549	0.0077	20		
	Total	5.576		29		
2–3	Stations 1–5	7.168	1.792	4	–	
	Jan./Jul.	0.0392	0.0392	1	–	
	Interaction	2.520	0.6300	4	417.2	P<0.001
	Error	0.03017	0.0015	20		
	Total	9.757		29		
3–4	Stations 1–5	5.120	1.280	4	–	
	Jan./Jul.	1.495	1.495	1	–	
	Interaction	1.144	0.2860	4	23.44	P<0.001
	Error	0.2445	0.0122	20		
	Total	8.004		29		
4–5	Stations 1–5	8.854	2.214	4	–	
	Jan./Jul.	0.1907	0.1907	1	–	
	Interaction	0.8092	0.2023	4	6.48	.005>P>.001
	Error	0.6243	0.3120	20		
	Total	10.48		29		
7–8	Stations 1–5	2.243	1.311	4	–	
	Jan./Jul.	0.2745	0.2745	1	–	
	Interaction	0.2425	0.0606	4	12.07	P<0.001
	Error	0.1004	0.0050	20		
	Total	5.860		29		
10–11	Stations 1–5	3.548	0.8871	4	–	
	Jan./Jul.	0.3131	0.3131	1	–	
	Interaction	0.2785	0.0696	4	16.77	P<0.001
	Error	0.0831	0.00415	20		
	Total	4.223		29		
13–14	Stations 1–5	1.426	0.3564	4	–	
	Jan./Jul.	0.3706	0.3706	1	–	
	Interaction	0.7827	0.1957	4	73.01	P<0.001
	Error	0.0536	0.0027	20		
	Total	2.632		29		

Table 61. 1x5 one way analyses of variance of nematodes in January 1987 between stations 1, 2, 3, 4, and 5 at depths of 0–1, 1–2, 3–4, 4–5, 7–8, 10–11, and 13–14 cm.

Depth (cm)	Stations compared	Source of variance	Sum of squares	Mean of squares	d.f	F–ratio	P
0–1	1/2/3/4/5	Main factor	2.10444	0.52611	4	178.22	P<0.001
		Error	0.02952	0.00295	10		
		Total	2.13396		14		
1–2	1/2/3/4/5	Main factor	0.99946	0.24986	4	140.80	P<0.001
		Error	0.01775	0.00177	10		
		Total	1.01720		14		
2–3	1/2/3/4/5	Main factor	0.65688	0.16422	4	101.16	P<0.001
		Error	0.01623	0.00162	10		
		Total	0.67311		14		
3–4	1/2/3/4/5	Main factor	1.43290	0.35823	4	351.67	P<0.001
		Error	0.01019	0.00102	10		
		Total	1.44309		14		
4–5	1/2/3/4/5	Main factor	5.1128	1.2782	4	20.91	P<0.001
		Error	0.6112	0.0611	10		
		Total	5.7240		14		
7–8	1/2/3/4/5	Main factor	3.40940	0.85235	4	460.60	P<0.001
		Error	0.01851	0.00185	10		
		Total	3.42791		14		
10–11	1/2/3/4/5	Main factor	2.41980	0.60495	4	169.37	P<0.001
		Error	0.03572	0.00357	10		
		Total					
13–14	1/2/3/4/5	Main factor	1.27091	0.31775	4	152.75	P<0.001
		Error	0.02080	0.00208	10		
		Total	1.29171		14		

Table 62. 1x5 one way analysis of variance of nematodes in July 1987 between stations 1, 2, 3, 4, and 5 at depths of 0–1, 1–2, 2–3, 3–4, 4–5, 7–8, 10–11, and 13–14 cm.

Depth (cm)	Stations compared	Source of variance	Sum of squares	Mean of squares	d.f	F-ratio	P
0–1	1/2/3/4/5	Main factor	0.93472	0.23369	4	190.79	P<0.001
		Error	0.01225	0.00122	10		
		Total	0.94703		14		
1–2	1/2/3/4/5	Main factor	4.1222	1.0306	4	75.16	P<0.001
		Error	0.1371	0.0137	10		
		Total	4.2594		14		
2–3	1/2/3/4/5	Main factor	9.06101	2.26525	4	1450.43	P<0.001
		Error	0.01562	0.00156	10		
		Total	9.07663		14		
3–4	1/2/3/4/5	Main factor	4.8310	1.2078	4	51.54	P<0.001
		Error	0.2343	0.0234	10		
		Total	5.0653		14		
4–5	1/2/3/4/5	Main factor	4.55078	1.13770	4	870.15	P<0.001
		Error	0.01307	0.00131	10		
		Total	4.56386		14		
7–8	1/2/3/4/5	Main factor	2.07594	0.51899	4	63.37	P<0.001
		Error	0.08190	0.00819	10		
		Total	2.15784		14		
10–11	1/2/3/4/5	Main factor	1.40705	0.35176	4	74.24	P<0.001
		Error	0.04738	0.00474	10		
		Total	1.45442		14		
13–14	1/2/3/4/5	Main factor	0.93740	0.23435	4	71.46	P<0.001
		Error	0.03280	0.00328	10		
		Total	0.97020		14		

Table 63. t-tests comparing nematodes between pairs of stations in January 1987 at a depth of 0-1 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	-29.963	3	P<0.001
1/3	-6.140	3	0.01>P>0.001
1/4	-10.362	3	0.01>P>0.001
1/5	7.470	2	0.02>P>0.01
2/3	15.237	3	P<0.001
2/4	25.594	3	P<0.001
2/5	19.033	2	0.01>P>0.001
3/4	-.053	2	P>.0.9
3/5	10.099	2	0.01>P>0.001
4/5	11.0782	2	0.01>P>0.001

Table 64. t-tests comparing nematodes between pairs of stations in January 1987 at a depth of 1-2 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981, p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	-10.132	3	0.01>P>0.001
1/3	-7.624	3	0.01>P>0.001
1/4	-3.626	3	0.05>P>0.02
1/5	10.686	3	P<0.001
2/3	2.518	3	0.1>P>0.05
2/4	7.748	3	0.01>P>0.001
2/5	18.176	3	P<0.001
3/4	4.975	3	0.02>P>0.01
3/5	16.266	3	P<0.001
4/5	13.985	3	P<0.001

Table 65. t-tests comparing nematodes between pairs of stations in January 1987 at a depth of 2-3 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981, p.51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	1.273	3	0.3>P>0.2
1/3	-2.478	3	0.1>P>0.05
1/4	8.876	3	0.01>P>0.001
1/5	11.702	3	0.01>P>0.001
2/3	-4.803	3	0.02>P>0.01
2/4	9.093	3	0.01>P>0.001
2/5	11.857	3	0.01>P>0.001
3/4	15.032	3	P<0.001
3/5	15.863	2	P<0.001
4/5	5.253	3	0.02>P>0.01

Table 66. t-tests comparing nematodes between pairs of stations in January 1987 at a depth of 3-4 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	-15.782	2	0.01>P>0.001
1/3	11.497	2	0.01>P.0.001
1/4	33.605	2	P<0.001
1/5	15.825	2	0.01>P>0.001
2/3	-1.851	3	0.2>P>0.1
2/4	20.704	3	P<0.001
2/5	0.535	3	0.7>P>0.6
3/4	21.055	3	P<0.001
3/5	2.301	3	0.2>P<0.1
4/5	-20.008	3	p<0.001

Table 67. t-tests comparing nematodes between pairs of stations in January 1987 at a depth of 4-5 cm. No t-tests were made between stations 1 and 5, 2 and 5, 3 and 5, 4 and 5 because no nemtodes were found in station 4, and the replicates in station 5 were the same. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	-3.530	2	0.1>P>0.05
1/3	25.753	3	P<0.001
1/4	108.88	2	p<0.001
1/5	not possible		
2/3	-1.387	2	0.3>P>0.2
2/4	63.69	2	P<0.001
2/5	not possible		
3/4	51.439	2	P<0.001
3/5	not possible		
4/5	= =		

Table 68. t-tests comparing nematodes between pairs of stations in January 1987 at a depth of 7-8 cm. No t-tests were made between stations 1 and 5, 2 and 5, 3 and 5, and 4 and 5 the replicates in station 5 were the same. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	-8.727	3	0.01>P>0.001
1/3	-1.223	3	0.4>P>0.3
1/4	28.602	2	0.01>P>0.001
1/5	not possible		
2/3	8.023	3	0.01>P>0.001
2/4	36.55	2	P<0.001
2/5	not possible		
3/4	34.011	2	P<0.001
3/5	not possible		
4/5	= =		

Table 69. t-tests comparing nematodes between pairs of stations in January 1987 at a depth of 10–11 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	−17.527	2	0.01>P>0.001
1/3	3.346	3	0.05>P>0.02
1/4	27.57	2	0.01>P>0.001
1/5	5.686	2	0.05>P>0.02
2/3	15.336	2	0.01>P>0.001
2/4	139.11	2	P<0.001
2/5	14.375	2	0.01>P>0.001
3/4	13.459	2	0.01>P>0.001
3/5	2.788	3	0.1>P>0.05
4/5	6.231	2	0.05>P>0.02

Table 70. t-tests comparing nematodes between pairs of stations in January 1987 at a depth of 13–14 cm. No t-tests were made between stations 1 and 2, 1 and 3, 1 and 4, 1 and 5, and 2 and 3 because the replicates in station 1 were the same, the replicates in stations 2 and 3 are the same, no nematodes in stations 4 and 5.

Stations compared	t-test	Degrees of freedom	Probability
1/2	not possible		
1/3	= =		
1/4	= =		
1/5	= =		
2/3	= =		
2/4	12.460	2	0.01>P>0.001
2/5	12.460	2	0.01>P>0.001
3/4	12.460	2	0.01>P>0.001
3/5	12.460	2	0.01>P>0.001
4/5	12.460	2	0.01>P>0.001

Table 71. t-tests comparing nematodes between pairs of stations in July 1987 at a depth of 0-1 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	-20.147	3	P<0.001
1/3	-14.276	2	0.01>P>0.001
1/4	-19.054	3	P<0.001
1/5	7.113	3	0.01>P>0.001
2/3	-3.121	2	0.1>P>0.05
2/4	-.775	3	0.5>P>0.4
2/5	26.368	3	P<0.001
3/4	2.548	3	0.1>P>0.05
3/5	17.741	2	0.01>P>0.001
4/5	24.698	3	P<0.001

Table 72. t-tests comparing nematodes between pairs of stations in July 1987 at a depth of 1-2 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of frredom	Probability
1/2	3.878	3	0.05>P>0.02
1/3	-8.003	3	0.01>P>0.001
1/4	5.198	2	0.05>P>0.02
1/5	12.994	2	0.01>P>0.001
2/3	-9.656	3	0.01>P>0.001
2/4	2.852	2	0.2>P>0.1
2/5	9.567	3	0.01>P>0.001
3/4	8.319	2	0.01>P>0.001
3/5	16.768	2	0.01>P>0.001
4/5	4.700	3	0.02>P>0.01

Table 73. t-tests comparing nematodes between pairs of station in July 1987 at a depth of 2-3 cm. No t-test was made between stations 4 and 5 because no nematodes were found in these stations. (unpaired t-tests assuming variances not equal, Bailey, 1981. p.51).

Stations compared	t-test	Degrees of feerdom	Probability
1/2	-2.166	2	0.2>P>0.3
1/3	-7.002	2	0.02>P>0.01
1/4	33.014	2	P<0.001
1/5	33.014	2	P<0.001
2/3	-18.106	3	P<0.001
2/4	65.94	2	P<0.001
2/5	65.94	2	P<0.001
3/4	156.18	2	P<0.001
3/5	156.18	2	P<0.001
4/5	not possible		

Table 74. t-tests comparing nematodes between pairs of stations in July 1987 at a depth of 3-4 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	6.845	2	0.05>P>0.02
1/3	7.916	2	0.02>P>0.01
1/4	8.560	2	0.02>P>0.01
1/5	13.064	2	0.01>P>0.001
2/3	2.344	3	0.2>P>0.1
2/4	6.817	2	0.05>P>0.02
2/5	10.063	2	0.01>P>0.001
3/4	5.852	2	0.05>P>0.02
3/5	8.372	2	0.02>P>0.01
4/5	-.221	3	0.9>P>0.8

Table 75. t-tests comparing nematodes between pairs of stations in July 1987 at a depth of 4-5 cm. No t-test was made between stations 4 and 5 because were found in these stations. (unpaired t-tests assuming t-tests not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	0.209	2	0.9>P>0.8
1/3	14.658	3	P<0.001
1/4	74.526	2	P<0.001
1/5	74.526	2	P<0.00
2/3	-.430	2	0.8>P>0.7
2/4	23.938	2	0.01>P>0.001
2/5	23.938	2	0.01>P>0.001
3/4	64.600	2	P<0.001
3/5	64.600	2	P<0.001
4/5	not possible		

Table 76. t-tests comparing nematodes between pairs of stations in July 1987 at a depth of 7-8 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	0.981	3	0.4>P>0.3
1/3	1.223	3	0.4>P>0.3
1/4	23.33	2	0.01>P>0.001
1/5	6.956	2	0.05>P>0.02
2/3	0.553	3	0.7>P>0.6
2/4	35.89	2	P<0.001
2/5	6.811	2	0.05>P>0.02
3/4	18.33	2	0.01>P>0.001
3/5	6.189	2	0.05>P>0.02
4/5	0.4226	2	0.8>P>0.7

Table 77. t-tests comparing nematodes between pairs of statins in July 1987 at a depth of 10–11 cm. No t-test was made between stations 4 and 5 because no nematodes were found in these stations. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	-3.346	3	0.05>P>0.02
1/3	0.110	3	P>0.9
1/4	13.459	2	0.01>P>0.001
1/5	13.459	2	0.01>P>0.001
2/3	2.220	2	0.2>P>0.1
2/4	27.48	2	0.01>P>0.001
2/5	27.48	2	0.01>P>0.001
3/4	7.455	2	0.02>P>0.01
3/5	7.455	2	0.02>P>0.01
4/5	not possible		

Table 78. t-tests comparing nematodes between pairs of stations in July 1987 at a deph of 13–14 cm. No t-tests were made between stations 1 and 2, 1 and 4, 1 and 5, 2 and 4, 2 and 5, and 4 and 5 because nematodes were only found at station 3. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Stations compared	t-test	Degrees of freedom	Probability
1/2	not possible		
1/3	8.455	2	0.02>P>0.01
1/4	not possible		
1/5	= =		
2/3	8.455	2	0.02>P>0.01
2/4	not possible		
2/5	= =		
3/4	8.455	2	0.02>P>0.01
3/5	8.455	2	0.02>P>0.01
4/5	not possible		

Tables 79–86. t–tests comparing nematodes between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 at each depth in turn (unpaired t–tests assuming variances not equal, (Bailey, 1981. p. 51).

Table 79. 0–1 cm.

Station	t–test	d.f	Probability
1	–20.363	3	P<0.001
2	–5.825	3	0.02>P>0.01
3	–15.710	2	P<0.001
4	–30.595	3	P<0.001
5	–12.514	2	0.01>P>0.001

Table 80. 1–2 cm.

Station	t–test	d.f	Probability
1	–15.669	2	P<0.001
2	–0.392	2	0.8>P>0.7
3	–18.468	3	P<0.001
4	0.726	2	0.6>P>0.5
5	2.219	2	0.2>P>0.1

Table 81. 2–3 cm.

Station	t–test	d.f	Probability
1	–6.360	2	0.05>P>0.02
2	–9.336	2	0.02>P>0.01
3	–31.040	3	P<0.001
4	43.818	2	P<0.001
5	20.65	2	0.01>P>0.001

Table 82. 3–4 cm.

Station	t–test	d.f	Probability
1	7.414	2	0.02>P>0.01
2	2.534	3	0.1>P>0.05
3	5.516	2	0.05>P>0.02
4	3.513	2	0.1>P>0.05
5	11.338	2	0.01>P>0.001

Table 83. 4–5 cm. No tests were made at stations 4 and 5.

Station	t-test	d.f	Probability
1	17.959	3	P<0.001
2	−1.029	2	0.5>P>0.4
3	3.600	3	0.05>P>0.02
4	not possible		
5	not possible		

Table 84. 7–8 cm. No t-tests were made at stations 4 and 5.

Station	t-test	d.f	Probability
1	1.225	3	0.4>P>0.3
2	12.223	3	0.01>P>0.001
3	3.521	3	0.05>P>0.02
4	not possible		
5	not possible		

Table 85. 10–11 cm. No t-test was made at station 4.

Station	t-test	d.f	Probability
1	3.346	3	0.05>P>0.02
2	17.527	2	0.01>P>0.001
3	0.110	3	P>0.9
4	not possible		
5	6.131	2	0.05>P>0.02

Table 86. 13–14 cm. No t-tests were made at staions 1, 4 and 5.

Station	t-test	d.f	Probability
1	not possible		
2	12.458	2	0.01>P>0.001
3	−1.252	3	0.4>P>0.3
4	not possible		
5	= =		

Table 87. 1x8 one way analyses of variance of nematodes in January 1987 between all depths (0–1, 1–2, 2–3, 3–4, 4–5, 7–8, 10–11, 13–14 cm) at stations 1, 2, 3,, 4, and 5.

Station	Depths compared	Source of variance	Sum of squares	Mean of squares	d.f	F–ratio	P
1	all depths	Main factor	3.24041	0.46292	7	358.75	P<0.001
		Error	0.02065	0.00129	16		
		Total	3.26106		23		
2	all depths	Maian factor	4.0053	0.5722	7	14.42	P<0.001
		Error	0.6348	0.0397	16		
		Total	4.6401		23		
3	all depths	Main factor	2.63410	0.37630	7	150.49	P<0.001
		Error	0.04001	0.00250	16		
		Total	2.67411		23		
4	all depths	Main factor	7.233959	1.033423	7	1887.04	P<0.001
		Error	0.008762	0.000548	16		
		Total	7.242722		23		
5	all depths	Main factor	3.29321	0.47046	7	135.33	P<0.001
		Error	0.05562	0.00348	16		
		Total	3.34883		23		

Table 88. 1x8 one way analyses of variance of nematodes in July 1987 between all depths (0–1, 1–2, 2–3, 3–4, 4–5, 7–8, 10—11, 13–14 cm) at stations 1, 2, 3, 4, and 5.

Stations	Depths compared	Source of variance	Sum of squares	Mean of squares	d.f	F–ratio	P
1	all depths	Main factor	7.54613	1.07802	7	427.04	P<0.001
		Error	0.04039	0.00252	16		
		Total	7.58652		23		
2	all depths	Main factor	7.50696	1.07242	7	388.20	P<0.001
		Error	0.04420	0.00276	16		
		Total	7.55116		23		
3	all depths	Main factor	8.19374	1.17053	7	181.27	P<0.001
		Error	0.10332	0.00646	16		
		Total	8.29706		23		
4	all dpths	Main factor	12.0324	1.7189	7	125.63	P<0.001
		Error	0.2189	0.0137	16		
		Total	12.2513		23		
5	all depths	Mian factor	5.54919	0.79274	7	118.37	P<0.001
		Error	0.10716	0.00670	16		
		Total	5.65634		23		

Table 89. t-tests comparing nematodes between pairs of depths in January 1987 at station 1. No t-tests were made between depths 0-1 and 13-14, 1-2 and 13-14, 3-4 and 13-14, 4-5 and 13-14, 7-8 and 13-14, and 10-11 and 13-14 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Depths compared (cm)	t-test	Degrees of freedom	Probability
0-1/1-2	3.626	3	0.05>P>0.02
0-1/2-3	0.662	3	0.6>P>0.5
0-1/3-4	-25.669	3	P<0.001
0-1/4-5	-25.108	3	P<0.001
0-1/7-8	7.691	3	0.01>P>0.001
0-1/10-11	14.397	3	P<0.001
0-1/13-14	not possible		
1-2/2-3	-2.273	3	0.2>P>0.1
1-2/3-4	-25.601	2	0.01>P>0.001
1-2/4-5	-25.753	3	P<0.001
1-2/7-8	4.682	3	0.02>P>0.01
1-2/10-11	10.465	3	0.01>P>0.001
1-2/13-14	not possible		
2-3/3-4	-18.109	2	P<0.001
2-3/4-5	-19.557	3	P<0.001
2-3/7-8	6.175	3	0.01>P>0.001
2-3/10-11	11.503	3	0.01>P>0.001
2-3/13-14	not possible		
3-4/4-5	-5.705	3	0.02>P>0.01
3-4/7-8	24.145	2	0.01>P>0.001
3-4/10-11	33.605	2	P0.001
3-4/13-14	not possible		
4-5/7-8	24.241	2	0.01>P>0.001
4-5/10-11	33.418	3	P<0.001
4-5/13-14	not possible		
7-8/10-11	4.265	3	0.05>P>0.02
7-8/13-14	not possible		
10-11/13-14	= =		

Table 90. t-tests comparing nematodes between pairs of depths in January 1987 at station 2. (unpaired t-tests assuming variances not equal, Bailey , 1981. p. 51).

Depths compared (cm)	t-test	Degrees of freedom	Probabilitry
0-1/1-2	15.880	3	P<0.001
0-1/2-3	30.157	3	P<0.001
0-1/3-4	22.323	3	P<0.001
0-1/4-5	3.906	2	0.1>P>0.05
0-1/7-8	14.125	2	0.01>P>0.001
0-1/10-11	35.686	3	P<0.001
0-1/13-14	30.396	2	0.01>P>0.001
1-2/2-3	9.351	3	0.01>P>0.001
1-2/3-4	1.381	3	0.3>P>0.2
1-2/4-5	2.419	2	0.2>P>0.1
1-2/7-8	2.022	3	0.2>P>0.1
1-2/10-11	7.388	2	0.05>P>0.02
1-2/13-14	18.329	3	P<0.001
2-3/3-4	-10.121	3	0.01>P>0.001
2-3/4-5	1.497	2	0.3>P>0.2
2-3/7-8	-5.032	3	0.02>P>0.01
2-3/10-11	-4.700	2	0.05>P>0.02
2-3/13-14	12.945	2	0.01>P>0.001
3-4/4-5	2.295	2	0.2>P>0.1
3-4/7-8	1.211	2	0.4>P>0.3
3-4/10-11	8.456	3	0.01>P>0.001
3-4/13-14	19.022	2	0.01>P>0.001
4-5/7-8	-2.134	2	0.2>P>0.1
4-5/10-11	-1.813	2	0.3>P>0.2
4-5/13-14	0.366	2	0.8>P>0.7
7-8/10-11	2.861	2	0.2>P>0.1
7-8/13-14	14.524	3	P<0.001
10-11/13-14	16.315	2	0.01>P>0.001

Table 91. t-tests comparing nematodes between pairs of depths in January 1987 at station 3. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Depths compared (cm)	t-test	Degrees of freedom	Probability
0–1/1–2	1.543	3	0.3>P>0.2
0–1/2–3	4.626	3	0.02>P.0.01
0–1/3–4	–1.038	3	0.4>P>0.3
0–1/4–5	8.487	3	0.01>P>0.001
0–1/7–8	10.659	3	0.01>P>0.001
0–1/10–11	16.214	3	P<0.001
0–1/13–14	17.039	3	P<0.001
1–2/2–3	3.232	3	0.05>P>0.02
1–2/3–4	–3.028	3	0.1>P>0.05
1–2/4–5	7.624	3	0.01>P>0.001
1–2/7–8	9.994	3	0.01>P>0.001
1–2/10–11	–15.830	3	P<0.001
1–2/13–14	16.697	3	P<0.001
2–3/3–4	–7.577	3	0.01>P>0.001
2–3/4–5	5.922	3	0.01>P>0.001
2–3/7–8	8.764	3	0.01>P>0.001
2–3/10–11	15.158	2	0.01>P>0.001
2–3/13–14	16.101	2	0.01>P>0.001
3–4/4–5	11.786	3	0.01>P.0.001
3–4/7–8	13.566	3	P<0.01
3–4/10–11	18.601	2	0.01>P>0.001
3–4/13–14	19.508	2	0.01>P>0.001
4–5/7–8	3.592	3	0.05>P>0.02
4–5/10–11	11.107	2	0.01>P>0.001
4–5/13–14	12.000	2	0.01>P>0.001
7–8/10–11	7.812	3	0.01>P>0.001
7–8/13–14	8.642	3	0.01>P>0.001
10–11/13–14	0.707	4	0.6>P>0.5

Table 92. t-tests comparing nematodes between pairs of depths in January 1987 at station 4. No t-tests were made between depths 4-5 and 10-11, 4-5 and 13-14, 7-8 and 10-11, 7-8 and 13-14, and 10-11 and 13-14 cm because no nematodes were found at these depths. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Depths compared (cm)	t-test	Degrees of fredom	Probability
0-1/1-2	10.362	3	P<0.001
0-1/2-3	23.461	3	P<0.001
0-1/3-4	23.056	2	0.01>P>0.001
0-1/4-5	132.04	2	P<0.001
0-1/7-8	132.04	2	P<0.001
0-1/10-11	132.04	2	P<0.001
0-1/13-14	132.04	2	P<0.001
1-2/2-3	12.162	3	0.01>P>0.001
1-2/3-4	14.397	3	P<0.001
1-2/4-5	70.199	2	P<0.001
1-2/7-8	70.199	2	P<0.001
1-2/10-11	70.199	2	P<0.001
1-2/13-14	70.199	2	P<0.001
2-3/3-4	4.2490	3	0.05>P>0.02
2-3/4-5	43.810	2	P<0.001
2-3/7-8	43.810	2	P<0.001
2-3/10-11	43.810	2	P<0.001
2-3/13-14	43.810	2	P<0.001
3-4/4-5	27.482	2	0.01>P>0.001
3-4/7-8	27.482	2	0.01>P>0.001
3-4/10-11	27.482	2	0.01>P>0.001
3-4/13-14	27.482	2	0.01>P>0.001
4-5/7-8	not possible		
4-5/10-11	= =		
4-5/13-14	= =		
7-8/10-11	= =		
7-8/13-14	= =		
10-11/13-14	= =		

Table 93. t-tests comparing nematodes between pairs of depths in January 1987 at station 5. No t-tests were made between depths in some cases because the replicates at least in one depth are the same. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Depths compared (cm)	t-test	Degrees of freedom	Probability
0-1/1-2	0.788	3	0.5>p>0.4
0-1/2-3	0.788	3	0.5>p>0.4
0-1/3-4	-10.391	2	0.01>P>0.001
0-1/4-5	not possible		
0-1/7-8	= =		
0-1/10-11	4.333	4	0.02>P>0.01
0-1/13-14	12.264	2	0.01>P>0.001
1-2/2-3	not possible		
1-2/3-4	-18.826	3	P<.001
1-2/4-5	not possible1		
1-2/7-8	= =		
1-2/10-11	4.581	2	0.05>P>0.02
1-2/13-14	20.653		
2-3/3-4	18.826	3	P<0.001
2-3/4-5	not possible		
2-3/7-8	= =		
2-3/10-11	4.581	3	0.02>P>0.01
2-3/13-14	20.653	2	0.01>P>0.001
3-4/4-5	23.55	3	P<0.001
3-4/7-8	29.35	3	P<0.001
3-4/10-11	16.274	2	0.01>P>0.001
3-4/13-14	79.268	2	P<0.001
4-5/7-8	not possible		
4-5/10-11	3.50	2	0.1>P>0.05
4-5/13-14	not possible		
7-8/10-11	3.50	2	0.1>P>0.05
7-8/13-14	not possible		
10-11/13-14	6.131	2	0.05>P>0.02

Table 94. t-tests comparing nematodes between pairs of depths in July 1987 at station 1. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Depths comapred (cm)	t-test	Degrees of freedom	Probability
0-1/1-2	-1.858	2	0.3>P>0.2
0-1/2-3	2.455	2	0.2>P>0.1
0-1/3-4	3.785	3	0.05>P>0.02
0-1/4-5	12.554	3	0.01>P>0.001
0-1/7-8	19.880	2	0.01>P>0.001
0-1/10-11	23.945	2	0.01>P>0.001
0-1/13-14	127.83	2	P<0.001
1-2/2-3	3.236	2	0.1>P>0.05
1-2/3-4	3.969	3	0.05>P>0.02
1-2/4-5	9.398	2	0.01>P>0.001
1-2/7-8	17.286	3	P<0.001
1-2/10-11	21.271	3	P<0.001
1-2/13-14	53.85	2	P<0.001
2-3/3-4	-.837	2	0.5>P>0.4
2-3/4-5	3.272	2	0.1>P>0.05
2-3/7-8	11.170	3	0.01>P>0.001
2-3/10-11	15.102	3	P<0.001
2-3/13-14	33.014	2	P<0.001
3-4/4-5	8.447	3	0.01>P>0.001
3-4/7-8	17.461	2	0.01>P>0.001
3-4/10-11	21.780	2	0.01>P>0.001
3-4/13-14	87.32	2	P<0.001
4-5/7-8	12.087	2	0.01>P>0.001
4-5/10-11	16.962	2	0.01>P>0.001
4-5/13-14	74.69	2	P<0.001
7-8/10-11	5.112	3	0.02>P>0.01
7-8/13-14	23.33	2	0.01>P>0.001
10-11/13-14	14.45	2	0.01>P>0.001

Table 95. t-tests comparing nematodes between pairs of depths in July 1987 at station 2. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Depths compared (cm)	t-test	Degrees of freedom	Probability
0–1/1–2	10.803	2	0.01>P>0.001
0–1/2–3	24.140	3	P<0.001
0–1/3–4	19.629	2	0.01>P>0.001
0–1/4–5	24.144	2	0.01>P>0.001
0–1/7–8	44.308	3	P<0.001
0–1/10–11	41.811	3	P<0.001
0–1/13–14	126.82	2	P<0.001
1–2/2–3	0.919	2	0.5>P>0.4
1–2/3–4	2.610	3	0.1>P>0.05
1–2/4–5	7.085	3	0.01>P>0.001
1–2/7–8	11.206	2	0.01>P>0.001
1–2/10–11	12.163	2	0.01>P>0.001
1–2/13–14	27.741	2	0.01>P>0.001
2–3/3–4	2.747	3	0.1>P>0.05
2–3/4–5	9.082	3	0.01>P>0.001
2–3/7–8	18.922	3	P<0.001
2–3/10–11	19.406	3	P<0.001
2–3/13–14	65.98	2	P<0.001
3–4/4–5	5.691	3	0.02>p>0.01
3–4/7–8	11.395	3	0.01>P>0.001
3–4/10–11	12.504	3	0.01>P>0.001
3–4/13–14	36.795	2	P<0.001
4–5/7–8	3.594	3	0.05>P>0.02
4–5/10–11	4.994	3	0.02>P>0.01
4–5/13–14	23.938	2	0.01>P>0.001
7–8/10–11	2.173	3	0.1>P>0.05
7–8/13–14	35.895	2	P<0.001
10–11/13–14	27.488	2	0.01>P>0.001

Table 96. t-tests comparing nematodes between pairs of depths in July 1987 at station 3. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Depths compared (cm)	t-test	Degrees of freedom	Probability
0-1/1-2	1.683	3	0.2>P>0.1
0-1/2-3	7.225	2	0.02>P>0.01
0-1/3-4	16.114	3	P<0.001
0-1/4-5	29.498	2	0.01>P>0.001
0-1/7-8	24.036	3	P<0.001
0-1/10-11	18.699	2	0.01>P>0.001
0-1/13-14	17.788	2	0.01>P>0.001
1-2/2-3	6.140	2	0.05>P>0.02
1-2/3-4	15.735	3	P<0.001
1-2/4-5	32.212	3	P<0.001
1-2/7-8	24.261	3	P<0.001
1-2/10-11	18.317	2	0.01>P>0.001
1-2/13-14	17.379	2	0.01>P>0.001
2-3/3-4	13.910	2	0.01>P>0.001
2-3/4-5	43.167	3	P<0.001
2-3/7-8	23.716	2	0.01>P>0.001
2-3/10-11	16.857	2	0.01>P>0.001
2-3/13-14	15.869	2	0.01>P>0.001
3-4/4-5	2.914	2	0.02>P>0.01
3-4/7-8	5.600	3	0.02>P>0.01
3-4/10-11	6.588	3	0.01>P>0.001
3-4/13-14	5.748	3	0.02>P>0.01
4-5/7-8	4.693	2	0.05>P>0.02
4-5/10-11	5.745	2	0.05>P>0.02
4-5/13-14	4.766	2	0.05>P>0.02
7-8/10-11	2.619	2	0.2>P>0.1
7-8/13-14	1.750	3	0.2>P>0.1
10-11/13-14	-.707	4	0.6>P>0.5

Table 97. t-tests comparing nematodes betwen pairs of depths July 1987 at station 4. No t-tests were made between depths in some cases because no nematodes were found at depths 2–3, 4–5, 7–8, 10–11, and 13–14 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981. p. 51).

Depths compared (cm)	t-test	Degrees of freedom	Probability
0–1/1–2	8.828	2	0.02>P>0.01
0–1/2–3	109.33	2	P<0.001
0–1/3–4	11.701	2	0.01>P>0.001
0–1/4–5	109.33	2	P<0.001
0–1/7–8	109.33	2	P<0.001
0–1/10–11	109.33	2	P<0.001
0–1/13–14	109.33	2	P<0.001
1–2/2–3	10.549	2	0.01>P>0.001
1–2/3–4	4.943	3	0.02>P>0.01
1–2/4–5	10.549	2	0.01>P>0.001
1–2/7–8	10.549	2	0.01>P>0.001
1–2/10–11	10.549	2	0.01>P>0.001
1–2/13–14	10.549	2	0.01>P>0.001
2–3/3–4	not possible		
2–3/4–5	= =		
2–3/7–8	= =		
2–3/10–11	= =		
2–3/10–11	= =		
3–4/4–5	0.9999	2	0.5>P>0.4
3–4/7–8	0.9999	2	0.5>P>0.4
3–4/10–11	0.9999	2	0.5>P>0.4
3–4/13–14	0.9999	2	0.5>P>0.4
4–5/7–8	not possible		
4–5/10–11	= =		
4–5/13–14	= =		
7–8/10–11	= =		
7–8/13–14	= =		
10–11/13–14	= =		

Table 98. t-tests comparing nematodes between pairs of depths in July 1987 at station 5. No t-tests were made between depths in some cases because no nematodes were found at depths 2-3, 4-5, 10-11, and 13-14 cm. (unpaired t-tests assuming variances not equal, Bailey, 1981. p.51).

Depths compared (cm)	t-test	Degrees of freedom	Probability
0-1/1-2	11.462	2	0.01>P>0.001
0-1/2-3	113.29	2	P<0.001
0-1/3-4	12.564	2	0.01>P>0.001
0-1/4-5	113.29	2	P<0.001
0-1/7-8	not possible		
0-1/10-11	113.29	2	P<0.001
0-1/13-14	113.29	2	P<0.001
1-2/2-3	5.269	2	0.05>P>0.02
1-2/3-4	1.950	3	0.2>P>0.1
1-2/4-5	5.269	2	0.05>P>0.02
1-2/7-8	not possible		
1-2/10-11	5.269	2	0.05>P>0.02
1-2/13-14	5.269	2	0.05>P>0.02
2-3/3-4	2.000	2	0.2>P>0.1
2-3/4-5	not possible		
2-3/7-8	= =		
2-3/10-11	= =		
2-3/131-14	= =		
3-4/4-5	2.000	2	0.2>P>0.1
3-4/7-8	2.000	2	0.2>P>0.1
3-4/10-11	2.000	2	0.2>P>0.1
3-4/13-14	2.000	2	0.2>P>0.1
4-5/7-8	1.000	2	0.5>P>0.4
4-5/10-11	not possible		
4-5/13-14	= =		
7-8/10-11	1.000	2	0.5>P>0.4
7-8/13-14	1.000	2	0.5>P>0.4
10-11/13-14	not possible		

Table 100 a. Example of printout of particle size programme calculating mean, standard deviation, skewness and kurtosis for the sample depth of 0-1 cm at station 1 in January 1987.

SAMPLE NUMBER 1 JANUARY 1987 REPLICATE NUMBER 1 DATE 4.1.1987

MIDPOINT	WEIGHT	WEIGHT PERCENT	CLASS LIMITS	CUM.PERCENT
-.5	0	0	-.25	0
0	.0750001	.464512	.25	.464512
.5	.0270001	.167225	.75	.631736
1	.1557	.964326	1.25	1.59606
1.5	1.347	8.34262	1.75	9.93868
2	7.037	43.5836	2.25	53.5222
2.5	6.1158	37.8781	2.75	91.4004
3	1.1795	7.30522	3.25	98.7056
3.5	.0956001	.592098	3.75	99.2977
4	.0650001	.402577	4.25	99.7002
4.5	.039	.241546	4.75	99.9418
5	9.40001E-03	.0582188	5.25	100

MOMENT MEASURES

MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
2.22401	.469225	.019247	4.38266

* * * * * * * * *

Table 100 b. List of the computer programme used to calculate t-tests of means, skewnesses and kurtoses, and to calculate variance ratios of standard deviations for two independent samples.

```
10 PRINT "THIS PROGRAMME CALCULATES STUDENTS-t"
20 INPUT "THE MEAN OF THE FIRST SAMPLE"; M
30 LPRINT "THE MEAN OF THE FIRST SAMPLE IS:"; M
40 LPRINT:LPRINT
50 INPUT "THE STANDARD DEVIATION OF THE FIRST SAMPLE"; P
60 LPRINT "THE STANDARD DEVIATION OF THE FIRST SAMPLE"; P
70 LPRINT:LPRINT
80 INPUT "THE NUMBER OF OBSERVATIONS OF THE FIRST SAMPLE"; R
90 LPRINT "THE NUMBER OF OBSERVATIONS OF THE FIRST SAMPLE IS:"; R
100 LPRINT:LPRINT
110 INPUT "THE MEAN OF THE SECOND SAMPLE"; N
120 LPRINT "THE MEAN OF THE SECOND SAMPLE IS:"; N
130 LPRINT:LPRINT
140 INPUT "THE STANDARD DEVIATION OF THE SECOND SAMPLE"; Q
150 LPRINT "THE STANDARD DEVIATION OF THE SECOND SAMPLE IS:"; Q
160 LPRINT:LPRINT
170 INPUT "THE NUMBER OF OBSERVATIONS OF THE SECOND SAMPLE"; S
180 LPRINT "THE NUMBER OF OBSERVATIONS OF THE SECOND SAMPLE"; S
190 LPRINT:LPRINT
200 T = (M-N)/SQR(P^2/R+Q^2/S)
210 PRINT "THE STUDENTS-t VALUE IS:"; T
220 LPRINT "THE STUDENTS-t VALUE IS:"; T
230 LPRINT:LPRINT
240 INPUT "THE VALUE OF SKEWNESS OF THE FIRST SAMPLE"; G
250 LPRINT "THE VALUE OF SKEWNESS OF THE FIRST SAMPLE IS:"; G
260 LPRINT:LPRINT
270 INPUT "THE VALUE OF SKEWNESS OF THE SECOND SAMPLE"; G1
280 LPRINT "THE VALUE OF SKEWNESS OF THE SECOND SAMPLE IS:"; G1
290 LPRINT:LPRINT
300 INPUT "THE VALUE OF KURTOSIS OF THE FIRST SAMPLE"; Y
310 LPRINT "THE VALUE OF KURTOSIS OF THE FIRST SAMPLE IS:"; Y
320 LPRINT:LPRINT
330 INPUT "THE VALUE OF KURTOSIS OF THE SECOND SAMPLE"; Y1
340 LPRINT "THE VALUE OF KURTOSIS OF THE SECOND SAMPLE IS:"; Y1
350 LPRINT:LPRINT
360 LET W = P*P
370 LPRINT:LPRINT
380 LET Z = Q*Q
390 LPRINT "W"; W
400 LPRINT "Z"; Z
410 IF W>Z THEN GOTO 420 OTHERWISE CARRY ON TO 401
420 V = Z/W
430 V = W/Z
440 LPRINT:LPRINT
450 PRINT "THE VARIANCE RATIO VALUE"; V
460 LPRINT "THE VARIANCE RATIO VALUE"; V
470 LPRINT:LPRINT
480 SG1 = SQR (((6*R)*(R-1))/((R-2)*(R+1)*(R+3)))
490 LPRINT "SG1"; SG1
500 LPRINT:LPRINT
510 SG2 = SQR (((24*R)*(R-1)^2)/((R-3)*(R-2)*(R+3)*(R+5)))
520 LPRINT "SG2"; SG2
530 LPRINT:LPRINT
540 TS1 = G/SG1
550 TS2 = G1/SG1
560 TS12 = (G-G1)/SG1
570 TK1 = Y/SG2
580 TK2 = Y1/SG2
590 TK12 = (Y-Y1)/SG2
600 PRINT "THE STUDENTS Ts1 VALUE IS:"; TS1
610 LPRINT "THE STUDENTS Ts1 VALUE IS:"; TS1
620 LPRINT:LPRINT
630 PRINT "THE STUDENTS Ts2 VALUE IS:"; TS2
640 LPRINT "THE STUDENTS Ts2 VALUE IS:"; TS2
650 LPRINT:LPRINT
660 PRINT "THE STUDENTS Ts12 VALUE IS"; TS12
670 LPRINT "THE STUDENTS Ts12 VALUE IS:"; TS12
680 LPRINT:LPRINT
690 PRINT "THE STUDENTS Tk1 VALUE IS:"; TK1
700 LPRINT "THE STUDENTS Tk1 VALUE IS:"; TK1
710 LPRINT:LPRINT
720 PRINT "THE STUDENTS Tk2 VALUE IS:"; TK2
730 LPRINT "THE STUDENTS Tk2 VALUE IS:"; TK2
740 LPRINT:LPRINT
750 PRINT "THE STUDENTS Tk12 VALUE IS:"; TK12
760 LPRINT "THE STUDENTS Tk12 VALUE IS:"; TK12
770 LPRINT:LPRINT
780 LPRINT:LPRINT
790 LPRINT:LPRINT:LPRINT
800 END
```

Table 101. Summary of the particle size analysis of the means, standard deviations, skewnesses and kurtosises for stations 1, 2, 3, 4, and 5 at depths 0–1, 3–4, 7–8, and 13–14 cm (phi ϕ units).

January 1987.

Depth (cm)	Measures	Stations				
		1	2	3	4	5
0–1	Mean	2.22401	2.25102	2.29833	2.66714	2.89988
	S.D	0.46923	0.41638	0.39284	0.56700	0.68424
	Skewness	0.01925	–0.60474	–0.46684	–0.91646	–0.70001
	Kurtosis	4.38266	5.5903	2.53623	5.76143	3.87501
3–4	Mean	2.33556	2.24774	2.31656	2.67437	2.42749
	S.D	0.42209	0.40037	0.39345	0.58105	0.71313
	Skewness	–0.10226	–0.52113	–0.30569	–0.73728	–0.21985
	Kurtosis	1.81483	4.50432	3.04355	5.19763	–0.33307
7–8	Mean	1.73179	2.23306	2.30507	3.0795	2.1839
	S.D	0.39754	0.38162	0.37672	0.72021	0.71913
	Skewness	0.06597	–0.43300	–0.26087	0.11012	–0.07614
	Kurtosis	0.45306	4.63832	1.12338	–0.20731	–0.36004
13–14	Mean	2.23198	2.21997	3.30467	3.26889	2.0879
	S.D	0.42017	0.37744	0.33435	0.61019	1.10174
	Skewness	–0.01491	–0.40808	–0.34810	–0.53559	–0.27234
	Kurtosis	0.59147	3.64347	5.50536	7.14296	.21654

July 1987.

Depth (cm)	Measures	Stations				
		1	2	3	4	5
0–1	Mean	2.20623	2.18873	2.356	2.69299	2.65592
	S.D	0.42858	0.41920	0.42859	0.48526	0.76533
	Skewness	–0.94754	–0.64176	–0.37901	–0.76248	–0.68379
	Kurtosis	9.70566	5.57471	1.86211	5.36243	2.61996
3–4	Mean	1.87006	2.1963	1.7703	2.89752	2.42221
	S.D	0.42958	0.38680	0.36955	0.3333	0.76969
	Skewness	–0.39038	–0.47938	–0.26882	0.50324	–0.31860
	Kurtosis	1.62963	3.86466	3.66484	3.4976	0.18324
7–8	Mean	2.23855	2.19258	2.37258	2.78341	2.27353
	S.D	0.34323	0.40091	0.44523	0.67136	0.74285
	Skewness	0.16650	–0.62250	–0.46741	0.28803	–0.21046
	Kurtosis	0.92690	5.62328	2.52017	–0.29740	0.24301
13–14	Mean	2.09088	1.66734	2.36247	3.14176	0.10550
	S.D	0.34259	0.36435	0.43807	0.67487	1.05751
	Skewness	0.53331	–0.23479	–0.40573	–0.05261	0.79067
	Kurtosis	3.20245	2.42232	2.14244	–1.0181	1.28424

Table 102. January 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of stations at a depth of 0–1 cm.

t-test P		Stations 1	2	3	4	5
Stations	1	–	–.149149	–.4207	–2.08573	–2.82195
	2	0.9>P>0.8	–	–.28693	–2.66714	–2.80626
	3	0.7>P>0.6	0.8>P>0.7	–	–1.85215	–2.64114
	4	0.05>P>0.02	0.02>P>0.01	0.1>P>0.05	–	–.907276
	5	0.01>P>0.001	0.02>P>0.01	0.02>P>0.01	0.4>P>0.3	–

Table 103. January 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of stations at a depth of 3–4 cm.

t-test P		Stations 1	2	3	4	5
Stations	1	–	0.522918	0.114064	–1.63423	–.384292
	2	0.7>P>0.6	–	–.424698	–2.09441	–.761371
	3	P>0.9	0.7>P>0.6	–	–1.76633	–.47181
	4	0.2>P>0.1	0.05>P>0.02	0.1>P>0.05	–	0.92971
	5	0.8>P>0.7	0.5>P>0.4	0.7>P>0.6	0.4>P>0.3	–

Table 104. January 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of stations at a depth of 7–8 cm.

t-test P		Stations 1	2	3	4	5
Stations	1	–	–3.15109	–3.62608	–5.67509	–1.906
	2	0.01>P>0.001	–	–.465198	–3.59742	0.20918
	3	0.01>P>0.001	0.7>P>0.6	–	–3.30065	0.517042
	4	P<0.001	0.01>P>0.001	0.01>P>0.001	–	3.04828
	5	0.1>P>0.05	0.9>P>0.8	0.7>P>0.6	0.01>P>0.001	–

Table 105. January 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of stations at a depth of 13–14 cm.

t-test P		Stations 1	2	3	4	5
Stations	1	–	0.0736594	–6.92016	–4.84836	0.42328
	2	P>0.9	–	–7.54189	–5.06426	0.392842
	3	P<0.001	P<0.001	–	0.178136	3.66091
	4	P<0.001	P<0.001	0.9>P>0.8	–	3.24835
	5	0.7>P>0.6	0.7>P>0.6	0.01>P>0.001	0.01>P>0.001	–

Table 106. July 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of stations at a depth of 0–1 cm.

t-test		Stations				
P		1	2	3	4	5
Stations	1	–	0.101118	–.855973	–2.60445	–1.77593
	2	P>0.9	–	–.966507	–2.72373	–1.85465
	3	0.5>P>0.4	0.4>P>0.3	–	–1.80307	–1.18444
	4	0.02>P>0.01	0.02>P>0.01	0.1>P>0.05	–	0.141707
	5	0.1>P>0.05	0.1>P>0.05	0.3>P>0.2	0.9>P>0.8	–

Table 107. July 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of stations at a depth of 3–4 cm.

t-test		Stations				
P		1	2	3	4	5
Stations	1	–	–1.95504	0.609841	–6.54612	–2.16995
	2	0.1>P>0.05	–	2.75852	–4.75742	–.90848
	3	0.6>P>0.5	0.02>P>0.01	–	–7.84642	–2.64496
	4	P<0.001	P<0.001	P<0.001	–	1.96306
	5	0.05>P>0.02	0.4>P>0.3	0.02>P>0.01	0.1>P>0.05	–

Table 108. July 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of stations at a depth of 7–8 cm.

t-test		Stations				
P		1	2	3	4	5
Stations	1	–	0.301737	–.819737	–2.50241	–.148078
	2	0.8>P>0.7	–	–1.03496	–2.61662	–.3322
	3	0.5>P>0.4	0.4>P>0.3	–	–1.77043	0.392187
	4	0.5>P>0.02	0.02>P>0.01	0.1>P>0.05	–	1.76371
	5	0.9>P>0.8	0.8>P>0.7	0.7>P>0.6	0.1>P>0.05	–

Table 109. July 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of stations at a depth of 13–14 cm.

t-test		Stations				
P		1	2	3	4	5
Stations	1	–	2.93368	–1.69168	–4.80993	6.18698
	2	0.01>P>0.001	–	–4.22609	–6.65965	4.83709
	3	0.2>P>0.1	P<0.001	–	–3.35526	6.8303
	4	P<0.001	P<0.001	0.01>P>0.001	–	8.38414
	5	P<0.001	P<0.001	P<0.001	P<0.001	–

Table 110. January 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of depths at station 1.

t-test		Depths (cm)			
P		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	–.612264	2.77257	0.043833
	3–4	0.6>P>0.5	–	3.60715	0.60247
	7–8	0.02>P>0.01	0.01>P>0.001	–	–2.99552
	13–14	P>0.9	0.6>P>0.5	0.01>P>0.001	–

Table 111. January 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of depths at station 2.

t-test		Depths (cm)			
P		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	0.0196697	0.110154	0.191392
	3–4	P>0.9	–	0.09194	0.174831
	7–8	P>0.9	P>0.9	–	0.0844828
	13–14	0.9>P>0.8	0.9>P>0.8	P>0.9	–

Table 112. January 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of depths at station 3.

t-test		Depths (cm)			
P		0–1	3–4	7–8	13–14
Depth (cm)	0–1	–	–0.113581	–.0428971	–6.75772
	3–4	P>0.9	–	0.0730719	–6.62934
	7–8	P>0.9	P>0.9	–	–6.87482
	13–14	P<0.001	P<0.001	P<0.001	–

Table 113. January 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of depths at sation 4.

t-test		Depths (cm)			
P		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	–.030847	–1.55839	–2.50255
	3–4	P>0.9	–	–1.51657	–2.44423
	7–8	0.2>P>0.1	0.2>P>0.1	–	–1.062
	13–14	0.05>P>0.02	0.05>P>0.02	0.3>P>0.2	–

Table 114. January 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of depths at station 5.

t-test P		Depths (cm) 0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	1.65579	2.49863	2.16881
	3–4	0.2>P>0.1	–	0.833183	0.896357
	7–8	0.05>P>0.02	0.5>P>0.4	–	0.252764
	31–14	0.05>P>0.02	0.4>P>0.3	0.9>P>0.8	–

Table 115. July 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of depths at station 1.

t-test P		Depths (cm) 0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	1.91909	–.203906	0.728262
	3–4	0.1>P>0.05	–	–2.3215	–1.39218
	7–8	0.9>P>0.8	0.05>P>0.02	–	1.65485
	13–14	0.5>P>0.4	0.2>P>0.1	0.4>P>0.3	–

Table 116. July 1987. Prticle size analysis. t-tests and probabilities comparing means between pairs of depths at station 2.

t-test P		Depths (cm) 0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	–.0459743	–.0229923	3.2519
	3–4	P>0.9	–	0.0231322	3.44832
	7–8	P>0.9	P>0.9	–	3.35861
	13–14	0.01>P>0.001	0.01>P>0.001	0.01>P>0.001	–

Table 117. July 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of depths at station 3.

t-test P		Stations 0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	3.58519	–.0873313	–.0365126
	3–4	0.01>P>0.001	–	–3.59978	–3.57913
	7–8	P>0.9	0.01>P>0.001	–	0.0478227
	13–14	P>0.9	0.01>P>0.001	P>0.9	–

Table 118. July 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of depths at station 4.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	–1.20353	–.378018	–1.87026
	3–4	0.3>P>0.2	–	0.5272	–1.12407
	7–8	0.8>P>0.7	0.7>P>0.6	–	–1.30378
	13–14	0.1>P>0.05	0.3>P>0.2	0.3>P>0.2	–

Table 119. July 1987. Particle size analysis. t-tests and probabilities comparing means between pairs of depths at station 5.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	0.745881	1.24197	6.76801
	3–4	0.5>P>0.4	–	0.481487	6.76801
	7–8	0.3>P>0.2	0.7>P>0.6	–	5.75967
	31–14	P<0.001	P<0.001	P<0.001	–

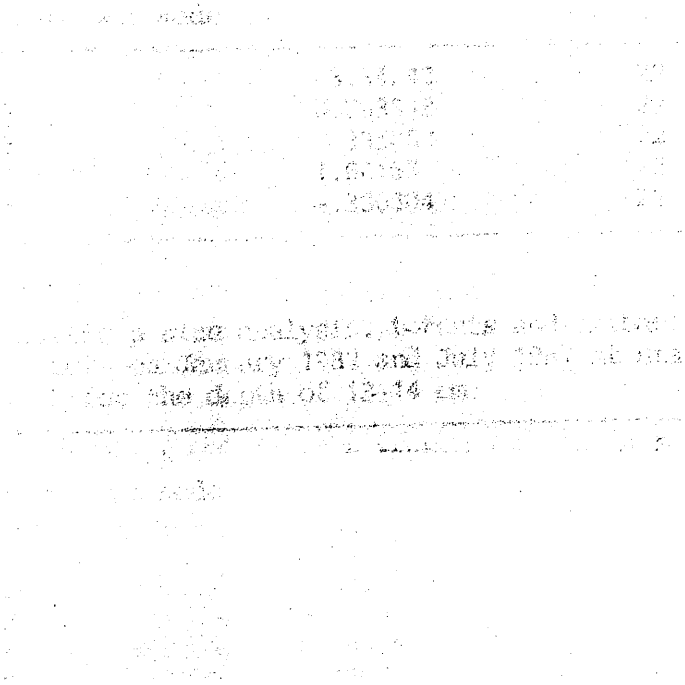


Table 120. Particle size analysis. t-tests and probabilities comparing means between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth of 0-1 cm.

Station at which comparison was made	t-test	d.f	Probability
1	0.0969144	22	P>0.9
2	0.365202	22	0.8.>P>0.7
3	-.343615	22	0.8>P>0.7
4	-.119987	22	P>0.9
5	0.823207	22	0.5>P>0.4

Table 121. Particle size analysis. t-tests and probabilities comparing meaans between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth of 3-4 cm.

Station at which comparison was made	t-test	d.f	Probability
1	2.67756	22	0.02>P>0.01
2	0.32009	22	0.8>P>0.7
3	3.50562	22	0.01>P>0.001
4	-1.15399	22	0.3>P>0.2
5	0.0174309	22	P>0.9

Table 122. Particle size analysis. t-tests and probabilities comparing means between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth of 7-8 cm.

Station at which comparison was made	t-test	d.f	Probability
1	-3.34242	22	0.01>P>0.001
2	0.253348	22	0.9>P>0.8
3	-.395053	22	0.8>P>0.7
4	1.04153	22	0.4>P>0.3
5	-.300304	22	0.8>P>0.7

Table 123. Particle size analysis. t-tests and probabilities comparing means between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth of 13-14 cm.

Station at which comparison was made	t-test	d.f	Probability
1	0.901589	22	0.4>P>0.3
2	3.64913	22	0.01>P>0.001
3	5.92269	22	P<0.001
4	0.484042	22	0.7>P>0.8
5	4.49679	22	P<0.001

Table 124. January 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of stations at a depth of 0–1 cm.

Variance ratio		Stations				
P		1	2	3	4	5
Stations	1	–	1.26997	1.42668	1.46017	2.12642
	2	0.50>P>0.25	–	1.1234	1.85437	2.70049
	3	0.50>P>0.25	0.50>P>0.25	–	2.08319	3.03372
	4	0.50>P>0.25	0.25>P>0.10	0.25>P>0.10	–	1.45629
	5	0.25>P>0.10	0.10>P>0.05	0.05>P>0.025	0.50>P>0.25	–

Table 125. January 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of stations at a depth of 3–4 cm.

Variance ratio		Stations				
P		1	2	3	4	5
Stations	1	–	1.11142	1.15087	1.89508	2.85447
	2	0.50>P>0.25	–	1.03549	2.10623	3.17252
	3	0.50>P>0.25	0.50>P>0.25	–	2.18098	3.28511
	4	0.25>P>0.10	0.25>P.0.10	0.25>P>0.10	–	1.50625
	5	0.05>P>0.025	0.05>P>0.025	0.05>P>0.025	0.50>P>0.25	–

Table 126. January 1987. Particle size analysis. Variance ratios and probability comparing standard deviations between pairs of stations at a depth of 7–8 cm.

Variance ratio		Stations				
P		1	2	3	4	5
Stations	1	–	1.08522	1.11372	3.28214	3.27226
	2	0.50>P>0.25	–	1.02626	3.56184	3.55112
	3	0.50>P>0.25	0.50>P>0.25	–	3.65537	3.64437
	4	0.05>P>0.025	0.025>P>0.01	0.025>P>0.01	–	1.00302
	5	0.05>P>0.025	0.025>P>0.01	0.025>P>0.01	0.50>P>0.25	–

Table 127. January 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of stations at a depth of 13–14 cm.

Variance ratio		Stations				
P		1	2	3	4	5
	1	–	1.23923	1.57924	2.109	6.8755
	2	0.50>P>0.25	–	1.27438	2.61353	8.52031
	3	0.25>P>0.10	0.50>P>0.25	–	3.33062	10.8581
	4	0.25>P>0.10	0.10>P>0.05	0.05>P>0.025	–	3.26008
	5	0.005>P>0.001	P<0.001	P<0.001	0.05>P>0.025	–

Table 128. July 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of stations at a depths of 0–1 cm.

Variance ratio		Stations				
P		1	2	3	4	5
Stations	1	–	1.04525	1.00005	1.28196	3.18875
	2	0.50>P>0.25	–	1.0453	1.33997	3.33305
	3	0.50>P>0.25	0.50>P>0.25	–	1.2819	3.18861
	4	0.50>P>0.25	0.50>P>0.25	0.50>P>0.25	–	2.48741
	5	0.05>P>0.025	0.05>P>0.025	0.05>P>0.025	0.10>P>0.05	–

Table 129. July 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of stations at a depth of 3–4 cm.

Variance ratio		Stations				
P		1	2	3	4	5
Stations	1	–	1.23341	1.15593	1.66117	3.21027
	2	0.50>P>0.25	–	1.09551	1.34681	3.9596
	3	0.50>P>0.25	0.50>P>0.25	–	1.22938	4.33778
	4	0.25>P>0.10	0.50>P>0.25	0.50>P>0.25	–	5.3328
	5	0.05>P>0.025	0.05>P>0.025	0.025>P>0.01	0.005>P>0.001	–

Table 130. July 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of stations at a depth of 7–8 cm.

Variance ratio		Stations				
P		1	2	3	4	5
Stations	1	–	1.36437	1.68269	3.8292	4.68424
	2	0.5>P>0.25	–	1.23331	2.80656	3.43326
	3	0.25>P>0.10	0.50>P>0.25	–	2.27564	2.78378
	4	0.025>P>0.01	0.10>P>0.05	0.10>P>0.05	–	1.2233
	5	0.01>P>0.005	0.05>P>0.025	0.10>P>0.05	0.50>P>0.25	–

Table 131. July 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of stations at a depth of 13–14 cm.

Variance ratio		Stations				
P		1	2	3	4	5
Stations	1	–	1.31108	1.63509	3.88052	9.5285
	2	0.50>P>0.25	–	1.45113	3.43081	8.42425
	3	0.25>P>0.10	0.50>P>0.25	–	2.37327	5.8275
	4	0.025>P>0.01	0.05>P>0.025	0.10>P>0.05	–	2.45547
	5	P<0.001	P<0.001	0.005>P>0.001	0.10>P>0.05	–

Table 132. January 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of depths at station 1.

Variance ratio		Depths (cm)			
P		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	1.23582	1.39314	1.24712
	3–4	0.50>P>0.25	–	1.1273	1.00914
	7–8	0.50>P>0.25	0.50>P>0.25	–	1.11708
	13–14	0.50>P>0.25	0.50>P>0.25	0.50>P>0.25	–

Table 133. January 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of depths at station 2.

Variance ratio		Depths (cm)			
P		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	1.08154	1.19047	1.21693
	3–4	0.50>P>0.25	–	1.10072	1.12519
	7–8	0.50>P>0.25	0.50>P>0.25	–	1.02223
	13–14	0.50>P>0.25	0.50>P>0.25	0.50>P>0.25	–

Table 134. January 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of depths at station 3.

Variance ratio		Depths (cm)			
P		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	1.0031	1.08753	1.38048
	3–4	0.50>P>0.25	–	1.09091	1.38477
	7–8	0.50>P>0.25	0.50>P>0.25	–	1.26937
	13–14	0.50>P>0.25	0.5>P>0.25	0.50>P>0.25	–

Table 135. January 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of depths at station 4.

Variance ratio		Depths (cm)			
P		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	1.05019	1.61347	1.15815
	3–4	0.5>P>0.25	–	1.53636	1.1028
	7–8	0.25>P>0.10	0.25>P>0.10	–	1.39314
	13–14	0.50>P>0.25	0.50>P>0.25	0.50>P>0.25	–

Table 136. January 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of depths at station 5.

Variance ratio		Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	1.08622	1.1046	2.59266
	3–4	0.50>P>0.25	–	1.01692	2.38686
Depths	7–8	0.50>P>0.25	0.50>P>0.25	–	2.34716
(cm)	13–14	0.10>P>0.05	0.10>P>0.05	0.10>P>0.05	–

Table 137. July 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of depths at station 1.

Variance ratio		Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	1.00404	1.55924	1.56505
	3–4	0.50>P>0.25	–	1.56648	1.57231
Depths	7–8	0.25>P>0.10	0.25>P>0.10	–	1.00373
(cm)	13–14	0.25>P>0.10	0.25>P>0.10	0.50>P>0.25	–

Table 138. July 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of depths at station 2.

Variance ratio		Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	1.17456	1.09335	1.32377
	3–4	0.50>P>0.25	–	1.07428	1.12704
Depths	7–8	0.50>P>0.25	0.50>P>0.25	–	1.21075
(cm)	13–14	0.50>P>0.25	0.50>P>0.25	0.50>P>0.25	–

Table 139. July 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of depths at stations 3.

Variance ratio		Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	1.34504	1.07913	1.04471
	3–4	0.50>P>0.25	–	1.45147	1.40517
Depths	7–8	0.50>P>0.25	0.50>P>0.25	–	1.03295
(cm)	13–14	0.50>P>0.25	0.50>P>0.25	0.50>P>0.25	–

Table 140. July 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of depths at station 4.

Variance ratio		Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	2.1197	1.91568	1.93414
	3–4	0.25>P>0.10	–	4.06067	4.09981
Depths	7–8	0.25>P>0.10	0.025>P>0.01	–	1.00964
(cm)	13–14	0.25>P>0.10	0.025>P>0.01	0.50>P>0.25	–

Table 141. July 1987. Particle size analysis. Variance ratios and probabilities comparing standard deviations between pairs of depths at station 5.

Variance ratio		Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	1.01142	1.06143	1.90931
	3–4	0.50>P>0.25	–	1.07356	1.88774
Depths	7–8	0.50>P>0.25	0.50>P>0.25	–	2.02661
(cm)	13–14	0.25>P>0.10	0.25>P>0.10	0.25>P>0.10	–

Table 142. Particle size analysis. Variance ratios and probabilities (d.f 11, 11) comparing standard deviation between January 1987 and July 1987 at each station for the depth of 0–1 cm.

Station at which comparison was made	Variance ratio	d.f	Probability
1	1.19864	22	0.50>P<0.25
2	1.01364	22	0.50>P>0.25
3	1.1903	22	0.50>P>0.25
4	1.36527	22	0.50>P>0.25
5	1.25107	22	0.50>P>0.25

Table 143. Particle size analysis. Variance ratios and probabilities comparing standard deviations between January 1987 and July 1987 at each station for the depth of 3–4 cm.

Stations at which comparison was made	Variance ratio	d.f	Probability
1	1.03581	22	0.50>P>0.25
2	1.0714	22	0.50>P>0.25
3	1.1335	22	0.50>P>0.25
4	3.03922	22	0.50>P>0.25
5	1.16492	22	0.50>P>0.25

Table 144. Particle size analysis. Variance ratios and probabilities comparing standard deviations between January 1987 and July 1987 at each station for the depth of 7–8 cm.

Station at which comparison was made	Variance ratio	d.f	Probability
1	1.34155	22	0.50>P>0.25
2	1.10368	22	0.50>P>0.25
3	1.39692	22	0.50>P>0.25
4	1.14989	22	0.50>P>0.25
5	1.06705	22	0.50>P>0.25

Table 145. Particle size analysis. Variance ratios and probabilities comparing standard deviation between January 1987 and July 1987 at each station for the depth of 13–14 cm.

Station at which comparison was made	Variance ratio	d.f	Probability
1	1.50421	22	0.5>P>0.25
2	1.07316	22	0.5>P>0.25
3	1.71665	22	0.25>P>0.10
4	1.22322	22	0.50>P>0.25
5	1.0854	22	0.50>P>0.25

Table 146. January 1987. Particle size analysis. t-tests and probabilities comparing whether skewness is different from zero at each station for each depth.

Depth (cm)		Stations				
		1	2	3	4	5
0–1	t	0.0302008	−0.9489	−0.732526	−1.43803	−1.0984
	P	P>0.9	0.4>P>0.3	0.5>P>0.4	0.2>P>0.1	0.3>P>0.2
3–4	t	−0.160451	−0.817713	−0.479655	−1.15688	−0.344965
	P	0.9>P>0.8	0.5>P>0.4	0.7>P>0.6	0.3>P>0.2	0.8>P>0.7
7–8	t	0.103512	−0.679431	−0.409329	0.172792	−0.119477
	P	P>0.9	0.6>P>0.5	0.7>P>0.6	0.9>P>0.8	P>0.9
13–14	t	−0.0234008	−0.640323	−0.546206	−0.840394	−0.427336
	P	P>0.9	0.6>P>0.5	0.6>P>0.5	0.5>P>0.4	0.7>P>0.6

Table 147. July 1987. Particle size analysis. t-tests and probabilities of comparing whether skewness is different from zero at each station for each depth.

Depth (cm)		Stations				
		1	2	3	4	5
0–1	t	−1.48868	−1.00699	−.594713	−1.19642	−1.07294
	P	0.2>P>0.1	0.4>P>0.3	0.6>P>0.5	0.3>P>0.2	0.4>P>0.3
3–4	t	−0.612543	−0.752202	−.0421809	0.789641	−0.499917
	P	0.6>P>0.5	0.5>P>0.4	0.7>P>0.6	0.5>P>0.4	0.7>P>0.6
7–8	t	0.261251	−0.976777	−0.733422	0.451954	−0.33023
	P	0.8>P>0.7	0.4>P>0.3	0.5>P>0.4	0.7>P>0.6	0.8>P>0.7
13–14	t	0.836821	−0.368416	−0.63664	−0.0825521	1.24057
	P	0.5>P>0.4	0.8>P>0.7	0.6>P>0.5	P>0.9	0.3>P>0.2

Table 148. January 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of stations at a depth of 0–1 cm.

t-test		stations				
P		1	2	3	4	5
Stations	1	–	0.979101	0.762726	1.46823	1.1286
	2	0.4>P>0.3	–	–0.216375	0.489129	0.149499
	3	0.5>P>0.4	0.9>P>0.8	–	0.705504	0.365874
	4	0.2>P>0.1	0.7>P>0.6	0.5>P>0.4	–	–0.33963
	5	0.3>P>0.2	0.9>P>0.8	0.7>P>0.6	0.8>P>0.7	–

Table 149. January 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of stations at a depth of 3–4 cm.

t-test		Stations				
P		1	2	3	4	5
Stations	1	–	0.657261	0.319203	0.996426	0.184514
	2	0.6>P>0.5	–	–0.338058	0.339164	–0.472748
	3	0.8>P>0.7	0.8>P>0.7	–	0.677222	–0.13469
	4	0.4>P>0.3	0.8>P>0.7	0.6>P>0.5	–	–0.811912
	5	0.9>P>0.8	0.7>P>0.6	0.9>P>0.8	0.5>P>0.4	–

Table 150. January 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of stations at a depth of 7–8 cm.

t-test		Stations				
P		1	2	3	4	5
Stations	1	–	0.782944	0.512841	–0.0692802	0.222989
	2	0.5>P>0.4	–	–0.270103	–0.852224	–0.559954
	3	0.7>P>0.6	0.8>P>0.7	–	–0.582121	–0.289852
	4	P>0.9	0.5>P>0.4	0.6>P>0.5	–	0.29227
	5	0.9>P>0.8	0.6>P>0.5	0.8>P>0.7	0.8>P>0.9	–

Table 151. January 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of stations at a depth of 13–14 cm.

t-test		Stations				
P		1	2	3	4	5
Stations	1	–	0.616922	0.522805	0.816994	0.403935
	2	0.6>P>0.5	–	–0.941171	0.200072	–0.212987
	3	0.7>P>0.6	P>0.9	–	0.294189	–0.11887
	4	0.5>P>0.3	0.9>P>0.8	0.8>P>0.7	–	–0.413059
	5	0.7>P>0.6	0.9>P>0.8	P>0.9	0.7>P>0.6	–

Table 152. July 1987. Particle size analysis. t–tests and probabilities comparing skewness between pairs of stations at a depth of 0–1 cm.

t–test		Stations				
P		1	2	3	4	5
Stations	1	–	–0.479812	–0.892089	–0.290382	–0.413863
	2	0.7>P>0.6	–	–0.421398	0.18943	0.0659485
	3	0.4>P>0.3	0.7>P>0.6	–	0.601707	0.478225
	4	0.8>P>0.7	0.9>P>0.8	0.6>P>0.5	–	–0.123481
	5	0.7>P>0.6	P>0.9	0.7>P>0.6	P>0.9	–

Table 153. July 1987. Particle size analysis. t–tests and probabilities comparing skewness between pairs of stations at a depth of 3–4 cm.

t–test		Stations				
P		1	2	3	4	5
Stations	1	–	0.139659	–0.190734	–1.40218	–0.112626
	2	0.9>P>0.8	–	–0.330393	–1.54184	–0.252285
	3	0.9>P>0.8	0.8>P>0.7	–	–1.21145	0.0781074
	4	0.2>P>0.1	0.2>P>0.1	0.3>P>0.2	–	1.28956
	5	P>0.9	0.9>P>0.8	P>0.9	0.3>P>0.2	–

Table 154. July 1987. Particle size analysis. t–tests and probabilities comparing skewness between pairs of stations at a depth of 7–8 cm.

t–test		Stations				
P		1	2	3	4	5
Stations	1	–	1.23803	0.994673	–0.190702	0.591481
	2	0.3>P>0.2	–	–0.243356	–1.42873	–0.646548
	3	0.4>P>0.3	0.9>P>0.8	–	–1.18538	–0.403192
	4	0.9>P>0.8	0.2>P>0.1	0.3>P>0.2	–	0.782183
	5	0.6>P>0.5	0.6>P>0.5	0.7>P>0.6	0.5>P>0.4	–

Table 155. July 1987. Particle size analysis. t–tests and probabilities comparing skewness between pairs of stations at depth of 13–14 cm.

t–test		Stations				
P		1	2	3	4	5
Stations	1	–	1.20524	1.47346	0.919373	–0.403749
	2	0.3>P>0.2	–	0.268225	–0.285864	–1.60899
	3	0.2>P>0.1	0.8>P>0.7	–	–0.554088	–1.87721
	4	0.4>P>0.3	0.8>P>0.7	0.6>P>0.5	–	–1.32312
	5	0.7>P>0.6	0.2>P>0.1	0.1>P>0.05	0.2>P>0.1	–

Table 156. January 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of depths at station 1.

	t-test	Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	0.190652	–0.0733116	0.0536016
	3–4	0.9>P>0.8	–	–1.19557	–0.137051
Depths	7–8	P>0.9	0.3>P>0.2	–	0.126913
(cm)	13–14	P>0.9	0.9>P>0.8	P>0.9	–

Table 157. January 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of depths at station 2.

	t-test	Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	–0.131188	–0.269469	0.308577
	3–4	0.9>P>0.8	–	–0.138281	–0.17739
Depths	7–8	0.8>P>0.7	0.9>P>0.8	–	–0.0391086
(cm)	13–14	0.8>P>0.7	0.9>P>0.8	P>0.9	–

Table 158. January 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of depths at station 3.

	t-test	Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	–0.252871	–0.323197	–0.18632
	3–4	0.9>P>0.8	–	–0.0703262	0.0665509
Depths	7–8	0.8>P>0.7	P>0.9	–	0.136877
(cm)	13–14	0.9>P>0.8	P>0.9	0.9>P>0.8	–

Table 159. January 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of depths at station 4.

	t-test	Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	–0.281152	–1.61082	–0.597635
	3–4	0.8>P>0.7	–	–1.32967	–0.316483
Depths	7–8	0.2>P>0.1	0.2>P>0.1	–	1.01319
(cm)	13–14	0.6>P>0.5	0.8>P>0.7	0.4>P>0.3	–

Table 160. January 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of depths at station 5.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	–0.753434	–0.978922	–0.671064
	3–4	0.5>P>0.4	–	–0.225488	0.0823706
	7–8	0.4>P>0.3	0.9>P>0.8	–	0.307859
	13–14	0.6>P>0.5	P>0.9	0.8>P>0.7	–

Table 161. July 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of depths at station 1.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	–0.874259	–1.74805	–2.32362
	3–4	0.4>P>0.3	–	–0.873795	–1.44936
	7–8	0.1>P>0.05	0.4>P>0.3	–	–0.575212
	13–14	0.05>P>0.02	0.2>P>0.1	0.6>P>0.5	–

Table 162. July 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of depths at station 2.

p	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths	0–1	–	–0.254788	–0.0302132	–0.638575
	3–4	0.9>P>0.8	–	0.224575	–0.383787
	7–8	P>0.9	0.9>P>0.8	–	–0.608362
	13–14	0.6>P>0.5	0.8>P>0.7	0.6>P>0.5	–

Table 163. July 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of depths at station 3.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths	0–1	–	–.172904	0.1387708	0.0419268
	3–4	0.9>P>0.8	–	0.311612	0.214831
	7–8	0.9>P>0.8	0.8>P>0.7	–	–.0967815
	13–14	P>0.9	0.9>P>0.8	P>0.9	–

Table 164. July 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of depths at station 4.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	–1.98606	–1.64837	–1.11387
	3–4	0.1>P>0.05	–	0.337688	0.872193
	7–8	0.2>P>0.1	0.8>P>0.7	–	0.534506
	13–14	0.3>P>0.2	0.4>P>0.3	0.6>P>0.5	–

Table 165. July 1987. Particle size analysis. t-tests and probabilities comparing skewness between pairs of depths at station 5.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	–.573022	–.742709	–2.31351
	3–4	0.6>P>0.5	–	–.169687	–1.74049
	7–8	0.5>P>0.4	0.9>P>0.8	–	–1.5708
	13–14	0.05>P>0.02	0.1>P>0.05	0.2>P>0.1	–

Table 166. Particle size analysis. t-tests and probabilities comparing skewness between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth 0–1 cm.

Station at which comparison was made	t-test	d.f	Probability
1	1.517	22	0.2>P>0.1
2	0.0580901	22	P>0.9
3	−.137812	22	0.9>P>0.8
4	−.241609	22	0.9>P>0.8
5	−.0254605	22	P>0.9

Table 167. Particle size analysis. t-tests and probabilities comparing skewness between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth 3–4 cm.

Station at which comparison was made	t-test	d.f	Probability
1	0.452092	22	0.7>P>0.6
2	−.0655106	22	P>0.9
3	−.0578454	22	P>0.9
4	−1.94652	22	0.1>P>0.05
5	0.154952	22	0.9>P>0.8

Table 168. Particle size analysis. t-test and probabilities comparing skewness between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth Of 7–8 cm

Station at which comparison was made	t-test	d.f	Probability
1	−.157739	22	0.9>P>0.8
2	0.297346	22	0.8>P>0.7
3	0.324093	22	0.8>P>0.7
4	−.279161	22	0.8>P>0.7
5	0.210753	22	0.7>P>0.6

Table 169. Particle size analysis. t-tests and probabilities comparing skewness between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth of 13–14 cm.

Station at which comparison was made	t-test	d.f	Probability
1	−.8602222	22	0.4>P>0.3
2	−.271907	22	0.8>P>0.7
3	0.0904344	22	P>0.9
4	−.922946	22	0.4>P>0.3
5	−1.66791	22	0.2>P>0.1

Table 170. January 1987. Particle size analysis. t-tests and probabilities comparing whether kurtosis is different from zero at each station for each depth.

Depth (cm)		Stations				
		1	2	3	4	5
0–1	t	3.55664	4.53667	2.05822	4.675555	3.14467
	P	0.01>P>0.001	P<0.001	0.1>P>0.05	P<0.001	0.01>P>0.001
3–4	t	1.47278	3.65537	2.46992	1.47278	–0.270298
	P	0.2>P>0.1	0.01>P>0.001	0.05>P>0.02	0.2>P>0.1	0.8>P>0.7
7–8	t	0.367672	3.76412	0.911652	–0.168239	–0.292184
	P	0.8>P>0.7	0.01>P>0.001	0.4>P>0.3	0.9>P>0.8	0.8>P>0.7
13–14	t	0.479995	2.95677	4.46774	5.7967	0.175729
	P	0.7>P>0.6	0.02>P>0.01	P<0.001	P<0.001	0.9>P>0.8

Table 171. July 1987. Particle size analysis. t-tests and probabilities comparing whether kurtosis is different from zero at each station for each depth.

Depth (cm)		Stations				
		1	2	3	4	5
0–1	t	7.87639	4.52402	1.51115	4.35175	2.12617
	P	P<0.001	P<0.001	0.2>P>0.1	0.01>P>0.001	0.1>P>0.05
3–4	t	1.32249	3.13627	2.97411	2.83839	0.148701
	P	0.3>P>0.2	0.01>P>0.001	0.02>P>0.01	0.02>P>0.01	0.9>P>0.8
7–8	t	0.782207	4.56344	2.04518	–0.241345	0.197211
	P	0.5>P>0.4	P<0.001	0.1>P>0.05	0.9>P>0.8	0.9>P>0.8
13–14	t	2.59887	1.96578	1.73865	–0.826215	1.04219
	P	0.05>P>0.02	0.1>P>0.05	0.2>P>0.1	0.5>P>0.4	0.3>P>0.2

Table 172. January 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of stations at a depth of 0-1cm.

t-test		Stations				
P		1	2	3	4	5
Stations	1	-	-0.980031	1.49843	-1.11891	0.411971
	2	0.4>P>0.3	-	2.47846	-0.138877	1.392
	3	0.2>P>0.1	0.05>P>0.02	-	-2.61733	-1.08645
	4	0.3>P>0.2	0.9>P>0.8	0.02>P>0.01	-	1.53088
	5	0.7>P>0.6	0.2>P>0.1	0.3>P>0.2	0.2>P>0.1	-

Table 173. January 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of stations at a depth of 3-4cm.

t-test		Stations				
P		1	2	3	4	5
Stations	1	-	-2.18259	-0.997138	-2.74523	1.74308
	2	0.05>P>0.02	-	1.18545	-0.562639	3.92567
	3	0.4>P>0.3	0.3>P>0.2	-	-1.74809	2.74022
	4	0.02>P>0.01	0.6>P>0.5	0.1>P>0.05	-	4.48831
	5	0.1>P>0.05	P<0.001	0.02>P>0.01	P<0.001	-

Table 174. January 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of stations at a depth of 7-8cm.

t-test		Stations				
P		1	2	3	4	5
Stations	1	-	-3.39645	-0.54398	0.535911	0.659857
	2	0.01>P>0.001	-	3.01477	3.93236	4.0563
	3	0.6>P>0.5	0.01>P>0.001	-	1.07989	1.20384
	4	0.6>P>0.5	P<0.001	0.3>P>0.2	-	0.123945
	5	0.6>P>0.5	P<0.001	0.3>P>0.2	P>0.9	-

Table 175. January 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of stations at a depth of 13-14 cm.

t-test		Stations				
P		1	2	3	4	5
Stations	1	-	-2.47678	-3.98775	-5.3167	0.304265
	2	0.05>P>0.02	-	-1.51097	-2.83993	2.78104
	3	P<0.001	0.2>P>0.1	-	-1.32896	4.29201
	4	P<0.001	0.01>P>0.001	0.2>P>0.1	-	5.62097
	5	0.8>P>0.7	0.02>P>0.01	P<0.001	P<0.001	-

Table 176. July 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of stations at a depth of 0–1 cm.

P	t-test	Stattions				
		1	2	3	4	5
	1	–	3.35237	6.36524	3.52464	5.75023
	2	0.01>P>0.001	–	3.01287	0.17227	2.39786
	3	P<0.001	0.01>P>0.001	–	–2.8406	–0.615015
	4	0.01>P>0.001	0.9>P>0.8	0.01>P>0.001	–	2.22559
	5	P<0.001	0.05>P>0.02	0.6>P>0.5	0.05>P>0.02	–

Table 177. July 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of stations at a depth of 3–4 cm.

P	t-test	Stations				
		1	2	3	4	5
	1	–	–1.81378	–1.65163	–1.51591	1.17379
	2	0.1>P>0.05	–	0.162159	0.297879	2.98757
Stations	3	0.2>P>0.1	0.9>P>0.8	–	0.13572	2.82541
	4	0.2>P>0.1	0.8>P>0.7	0.9>P>0.8	–	2.68969
	5	0.3>P>0.2	0.01>P>0.001	0.01>P>0.001	0.02>P>0.01	–

Table 178. July 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of stations at a depth of 7–8cm.

P	t-test	Stations				
		1	2	3	4	5
	1	–	–3.81123	–1.29298	0.993551	0.554995
	2	P<0.001	–	2.51825	4.80478	4.36623
Stations	3	0.3>P>0.2	0.02>P>0.01	–	2.28653	1.84797
	4	0.4>P>0.3	P<0.001	0.05>P>0.02	–	–0.438556
	5	0.6>P>0.5	P<0.001	0.1>P>0.05	0.7>P>0.6	–

Table 179. July 1987. Particle size analysis. t-tests band probabilities comparing kurtosis between pairs of stations at a depth of 13–14cm.

P	t-test	Stations				
		1	2	3	4	5
	1	–	0.633096	0.860226	3.42509	1.55668
	2	0.6>P>0.5	–	0.22713	2.79199	0.923582
Stations	3	0.4>P>0.3	0.9>P>0.8	–	2.56486	0.696451
	4	0.01>P>0.001	0.02>P>0.01	0.02>P>0.01	–	–1.86841
	5	0.2>P>0.1	0.4>P>0.3	0.5>P>0.4	0.1>P>0.05	–

Table 180. January 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between depths at station 1.

	t-test	Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	2.06386	3.18897	3.07665
	3–4	0.05>P>0.02	–	1.10511	0.992787
Depths	7–8	0.01>P>0.001	0.3>P>0.2	–	–0.112323
(cm)	13–14	0.01>P>0.001	0.4>P>0.3	P>0.9	–

Table 181. January 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of depths at station 2.

	t-test	Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	0.881301	0.772556	1.5799
	3–4	0.4>P>0.3	–	–0.108745	0.698602
Depths	7–8	0.5>P>0.4	P>0.9	–	0.807347
(cm)	13–14	0.2>P>0.1	0.5>P>0.4	0.5>P>0.4	–

Table 182. January 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of depths at station 3.

	t-test	Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	–0.411703	1.14656	–2.40953
	3–4	0.7>P>0.6	–	1.55827	–1.99782
Depths	7–8	0.3>P>0.2	0.2>P>0.1	–	–3.55609
(cm)	13–14	0.05>P>0.02	0.1>P>0.05	0.01>P>0.001	–

Table 183. January 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of depths at station 4.

	t-test	Depths (cm)			
P		0–1	3–4	7–8	13–14
	0–1	–	0.457538	4.84379	–1.12115
	3–4	0.7>P>0.6	–	4.38625	–1.57869
Depths	7–8	P<0.001	P<0.001	–	–5.96494
(cm)	13–14	0.3>P>0.2	0.2>P>0.1	P<0.001	–

Table 184. January 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of depths at station 5.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	3.41497	3.43686	2.96894
	3–4	0.01>P>0.001	–	0.0218861	–0.446028
	7–8	0.01>P>0.001	P>0.9	–	–0.467914
	13–14	0.01>P>0.001	0.7>P>0.6	0.7>P>0.6	–

Table 185. July 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of depths at station 1.

P	t-test	Depth (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	6.55391	7.12419	5.27752
	3–4	P<0.001	–	0.57028	–1.27638
	7–8	P<0.001	0.6>P>0.5	–	–1.846666
	13–14	P<0.001	0.3>P>0.2	0.1>P>0.05	–

Table 186. July 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of depths at station 2.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	1.38775	–0.0394159	2.55825
	3–4	0.2>P>0.1	–	1.42717	1.1705
	7–8	P>0.1	0.2>P>0.1	–	2.59766
	13–14	0.02>P>0.01	0.3>P>0.2	0.02>P>0.01	–

Table 187. July 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of depths at station 3.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	–1.46134	–.534033	0.227495
	3–4	0.2>P>0.1	–	0.92893	0.423941
	7–8	0.6>P>0.5	0.4>P>0.3	–	0.306538
	13–14	0.9>P>0.8	0.7>P>0.6	0.8>P>0.7	–

Table 188. July 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of depths at station 4.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	1.51336	4.5931	5.17797
	3–4	0.2>P>0.1	–	3.07974	3.66461
	7–8	P<0.001	0.01>P>0.001	–	0.58487
	13–14	P<0.001	0.01>P>0.001	0.6>P>0.5	–

Table 189. July 1987. Particle size analysis. t-tests and probabilities comparing kurtosis between pairs of depths at station 5.

P	t-test	Depths (cm)			
		0–1	3–4	7–8	13–14
Depths (cm)	0–1	–	1.97747	1.92895	1.08397
	3–4	0.1>P>0.05	–	–.0485106	1.04219
	7–8	0.1>P>0.05	P>0.9	–	–.844983
	13–14	0.3>P>0.2	0.4>P>0.3	0.5>P>0.4	–

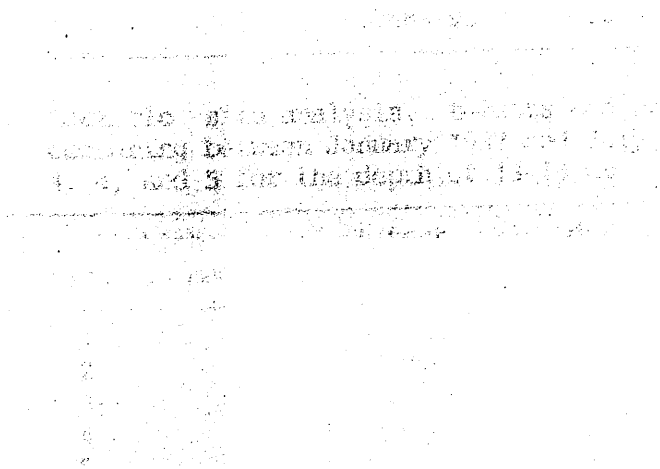


Table 190. Particle size analysis. t-tests and probabilities comparing kurtosis between January 1987 and July 1987 at stations 1,2, 3, 4, and 5 for the depth of 0-1 cm.

Station at which comparison was made	t-test	d.f	Probability
1	-4.31975	22	0.01>P>0.001
2	0.0126515	22	P>0.9
3	0.547066	22	0.6>P>0.5
4	0.323798	22	0.8>P>0.7
5	1.01851	22	0.4>P>0.3

Table 191. Particle size analysis. t-tests and probabilities of kurtosis comparing between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the dpeth of 3-4 cm.

Station at which comparison was made	t-test	d.f	Probability
1	0.150295	22	0.9>P>0.8
2	0.519101	22	0.7>P>0.6
3	-.504193	22	0.7>P>0.6
4	1.37954	22	0.2>P>0.1
5	-.418999	22	0.7>P>0.6

Table 192. Particle size analysis. t-tests and probabilities of kurtosis comparing between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth of 7-8 cm.

Stations at which comparison was made	t-test	d.f	Probability
1	0.752207	22	0.5>P>0.4
2	-.799321	22	0.5>P>0.4
3	-1.13353	22	0.3>P>0.2
4	0.0731055	22	P>0.9
5	-.489396	22	0.7>P>0.6

Table 193. Particle size analysis. t-tests and probabilities of kurtosis comparing between January 1987 and July 1987 at stations 1, 2, 3, 4, and 5 for the depth of 13-14 cm.

Station at which comparison was made	t-test	d.f	Probability
1	-2.11888	22	0.05>P>0.02
2	0.99095	22	0.4>P>0.3
3	2.7291	22	0.02>P>0.01
4	6.62291	22	P<0.001
5	-.866465	22	0.4>P>0.3

DISCUSSION

A large number of studies have been conducted on harpacticoid copepods (Coull and Vernberg, 1970; Barnett, 1971a; Coull, 1977; Hatsushika et al, 1981; Hennig and Zander, 1981; Collins, 1982; Alheit and Scheibel, 1982; Tackx and Polk, 1982; Banes, 1982; Johnston and Lasenby 1982; Carli et al, 1983; Hicks and Coull, 1983; Moeller et al, 1984; Bergmans, 1984; Lehtinen et al, 1984; Thistle et al, 1984; Herman and Heip, 1985; Tarpea et al, 1986).

The developmental stages of harpacticoids from a range of sandy beaches have been extensively studied by a number of authors (Barnett, 1971a; Harris, 1972e; Carter and Bradford, 1972; Walker, 1981; Bergmans, 1981; Lopez, 1982; Collin, 1982; Bergmans, 1984; Herman et al, 1984; Kern, Edward et al, 1984; Onbe, 1984).

Taxonomic studies on harpacticoids have been conducted on a variety of types of beach. These include studies on the significant morphological differences between males and females for the same species and between different sexes for different species (Humes, 1941; Coull, 1977; Petkovski, 1980; Dinet, 1981; Geddes, 1981; Ishida, 1983; Cottarelli, 1980,1981, 1983; Cottarelli and Mura, 1980; Humes, 1981; Marinov and Apostolov 1981; Willems, 1981; Dumont, 1981; Hicks, 1982; Ito, 1982,1985; Greenwood, 1982; Avdeev, 1982; Aliev, 1983; Reidemauer and Thistle 1983; Wells, 1983; Schriever, 1984; Fiers, 1984; Ranga, 1984; Reddy, 1984; Moeschier and Rouch, 1984; Mielke, 1984; Sach, 1984; Susan and kern, 1984; Dahms, 1985; Kitazima, 1985; Sagar, 1986; Bell et al, 1987).

A large number of studies have been conducted on the ecology and abundance of meiobenthic harpacticoids in estuaries, the intertidal zone, and on the deep sea and on the continental shelf, as follows.

In estuaries: (Gray and Rieger, 1971; O'Riodan, 1971; Moore, 1979; Fleeger, 1979; Emberton , 1981; Hockin, 1982; Ellison, 1984; Chandler and Fleeger, 1984;

Sagar,1986). In the intertidal zone: (Barnett, 1968; Gray and Rieger, 1971; Harris, 1972a; Harris, 1972a,b,c,d; D'Apolito and Stancyk, 1979; Radiziejewska and Radzium, 1979; Scaramuzza and Martino, 1981; Findlay, 1981; Emberton 1981; Willem et al, 1982b; Gunnil, 1982; Coull, 1983; Ellison, 1984; Fleegeret al, 1984; Sebens and Koehl, 1984; Gee et al, 1985; Alogi, 1987). In the deep sea and continental shelf: Coull et al, 1977; Thistle, 1983. These references will be referred to as appropriate in the detailed discussion which is divided into three sections:

1 - Harpacticoid copepods for the two parts.

2 - Nematodes.

3 - Particle size.

1 - Harpacticoid copepods:

1.1 - Annual cycle: My results show that there was a well defined annual cycle of harpacticoids at the three sites sampled in the annual survey (high tide, mid tide, low tide) (results part 1) and a clear difference between the more detailed comparisons of stations 1 to 5 in winter and summer (results part 2). A number of authors have conducted similar surveys (Barnett 1968; Lasker et al 1970; Gray and Rieper 1971; Harris 1972a,b; Moore 1979; Findlay 1981; Gee 1985; Kitazima, 1986), however it is difficult to compare my data with theirs in detail because I have not had time to identify species. On the other hand, the results of the annual cycle that I have demonstrated at high tide, mid tide, and low tide sites showed interesting similarities and contrasts which require comments (Figures 16a, ,b, c).

Broadly speaking, the annual cycle of adult harpacticoids at low tide and mid tide are similar (figure 16b). Numbers are low in winter and early spring, and rise to a peak in the summer months of June, July and August. This annual cycle of abundance is typical of most infauna and also pelagic species in temperate climates (Newell, 1970; Levinton, 1982; Boaden and Seed, 1985; Meadows and Campbell, 1988). Its causes are usually assumed to be a combination of lower temperature in

winter, higher temperature in summer and increased food availability in summer. In the case of harpacticoids there is likely to be a spring bloom in the diatoms living at the sediment surface and in the water column which will provide more food for the animals. In this context, although it is not known precisely what the food sources of harpacticoids in sandy sediments are, they are likely to include photosynthetic organisms such as diatoms and blue green algae because their sizes are about right for the mouth parts of harpacticoids (p. 40, plate 16, maxillipeds of Tachidius discipes). However, in order to prove that this is so, it would be necessary to conduct detailed studies on a month to month basis of the gut contents of the different species of harpacticoids at the high tide, mid tide and low tide sites. This would be a major undertaking requiring 4 to 6 years detailed study. As far as I am aware a detailed annual study of harpacticoid gut contents of this sort has not been conducted.

The annual cycle of adult harpacticoids at the high tide site (Figure 16b. p. 76) is very different from the mid tide and low tide sites. There are two very clear peaks, one in October and a secondary one in February. The troughs in abundance are in December and January and also in June. The unusual nature of the high tide station for adult harpacticoids is also seen in the results of part 2 (tables 47a, 47b), when there are very low numbers at station 5 (high tide) compared with the other stations (1, 2, 3, 4,). The possible reasons for these very different patterns at high tide compared with the rest of the beach are not immediately obvious. They may be caused by differences in species composition between the high tide as compared with low tide and mid tide sites. They may also be related to the almost total lack of copepodite stages at the high tide site demonstrated in part 1 and part 2 of the results (figure 16c, tables 53a, 53b)(see below). This lack may suggest that the high tide population is non-breeding one. The high tide population, although extremely abundant at certain times of the year (October) may be replenished by periodic migrations from lower tidal levels. This seems a realistic possibility because my experiments in section 4 show that harpacticoids migrate upwards from the sediments

into the overlying water under conditions of darkness. This replenishment could probably take place by adult harpacticoids migrating out of the sediment during darkness on the rising tide, being carried up the beach in the advancing water, and then burrowing at high tide as dawn broke. To prove or disprove this hypothesis it would be necessary to undertake an annual survey of harpacticoid copepods in the overlying water at Ardmore Bay. It would also be necessary to identify the species in the overlying water as being the same as the species in the sediments, and to conduct the survey at night because only then will the animals emerge from the sediment. The possible importance of this vertical migration as a dispersal mechanism is discussed in more detail in the discussion of the behavioural experiments (p.286).

The differences between the percentage of copepodites at low tide, mid tide and high tide (figure 16c - see also tables 53a, 53b) suggest differences in the breeding cycles of harpacticoids. The relatively high percentage of copepodites at low tide with peaks in December, February, June and August may mean that the low tide harpacticoids are breeding throughout the year or that different species in the population breed at different times of the year to produce the four observed peaks. The percentage of copepodites at the mid tide site showed different patterns. There is a high percentage during October to January, and a low percentage for the rest of the year. This suggests that, in contrast to low tide, the species at mid tide breed in late summer and autumn, thus producing the observed autumn and winter peaks. The lack of copepodites at high tide probably means, as referred to above that the harpacticoids at high tide may be a non-breeding population which is replenished from the low tide and mid tide population.

1.2 Horizontal distribution:

The population density range for harpacticoid copepods at Ardmore Point at a depth of 0 to 1 cm for all samples sites was from 0.3259 to 110/cm^2. My values are of the same order or magnitude as those reported by other workers. Harris (1972a) found

the mean annual meiofauna density at M.L.W.N. was 394/10 cm^2. This is equivalent to 39.4/cm^2. He showed the majority of the copepods showed horizontal distribution patterns, and some species studied were restricted to narrow zones on the transect. Nalepa and Quigley (1983) studied the abundance and biomass of the meiobenthos in Lake Michigan (U S A), and found that the total meiobenthic abundance ranged from 69,700 to 1,300,000 /m^2 (equivalent to 13/cm^2).

Barnett (1968) studied the distribution and ecology of harpacticoid copepods of an intertidal mudflat along a transect across Hample Spit in Southampton Water at five stations. He found that the five species of harpacticoids studied showed distinct zonations. He stated that there were contrasting distribution patterns for the following two species of Platychelipus. P. littoralis was most abundant at the upper intertidal stations and P. laophontoides most numerous at the lower station with an admixture of species at the halfway station. In addition, Stenhelia palustris was most abundant at the upper station, Harpacticus flexus was most abundant at the lower station whilst Canuella furcigera was most numerous at the middle station. Microarthridion littorale had no distinct distribution pattern. Lasker et al (1970) studied the density of Asellopsis intermedia on an exposed beach in Loch Ewe, Scotland. They sampled throughout the year and found that Asellopsis intermedia occurred only occasionally above mid tide, so sampling was concentrated below this level. Their results showed the highest density tended to be roughly halfway between mid tide and low water- above the mean level of low water neaps, while at Ardmore Point the highest density of harpacticoids was at high tide (October 1986).

In my study, the most pronounced differences in density between adults and copepodites was recorded at high tide for all six months (results part 1) and at high tide between summer and winter (results part 2). The possible reasons for this have been discussed above and may be caused by the high tide population being a non breeding one and hence being replenished from lower tidal levels.

1.3 - Vertical distribution: The population of harpacticoid copepods at Ardmore beach was mainly found in the top 1 cm of the sediment but animals were occasionally found down to a depth of 11 cm (low tide and mid tide October 1986). These results broadly agree with those of other workers. Barnett (1968), Hardy and Barnett (1986) stated that harpacticoids were restricted to the surface 1 cm layer of mud or sand. A few harpacticoids were found in the 1-2 cm level. At the 2-3 cm level, harpacticoids were found very rarely. McIntyre (1969) O'Riordan (1971) and Coull (1977) found that harpacticoids are mainly confined to the upper few centimetres of the sediment. Harris (1972a,b,c,d) found the species studied showed a characteristic vertical distribution pattern. He demonstrated that in summer the copepods were concentrated at the sand surface, and that deeper distributions were observed in the winter when some species were found down to depths of 50 cm.

Harpacticoid copepods, such as those in my study probably live near the sediment surface for a number of reasons. The most important of these are probably as follows. The body of harpacticoid copepods such as Tachidius discipes is designed to burrow by pushing aside sand grains rather than by moving between them. The force needed to push aside sand grains at the surface of the sediment will be much lower than the force needed to push aside sand grains deeper in the sediment column. A second point may be that harpacticoid copepods are not tolerant of the more anaerobic conditions that are often present deeper in sediments. Thirdly, as I have shown in my experiments in section 4, harpacticoid copepods at Ardmore migrate into the overlying water at night. It therefore pays animals to only burrow in the surface layers of the sediment, so that they can easily migrate into the overlying water. Lastly, if the harpacticoids are feeding on diatoms and similar organisms in sediments, these organisms are likely to be most abundant near the sediment surface.

1.4- Effects of Biological and Non-biological factors:

The horizontal and vertical variation in harpacticoid density between sampling sites

at Ardmore may be due to biological factors non-biological factors, or a combination of the two.

I.4.1 - Biological factors: The effect of biological factors on the distribution of harpacticoids in the intertidal zone has been reported by a number of investigators. Some of these reports are reviewed by Henning and Zander (1981), but additional references are contained in Alheit and Scheibel (1982), Gunnill (1982), Moeller et al (1984) and Volk et al (1984). Henning and Zander (1981) showed that sticklebacks (euryhaline fish) consumed mainly cyclopoid copepoda or cladocerans, and that gobies consumed harpacticoid and cyclopoid copepods. Moeller-Buchner, et al (1984) showed that Lumpenus lampretaformis species (demersal fish) was the only species which fed to a great extent on meiobenthos (harpacticoids and ostracods). Alheit and Scheibel (1982) showed that meiobenthic harpacticoids play an important role in food chains. However, the feeding pressure exerted by the fish on the harpacticoid population is negligible. Gunnill (1982) studied macroalgae as habitat patch islands for Scutellidium lamellipes (copepoda: Harpacticoida) and Amphithoe tea (Amphipoda: Gammaridae), and reported that densities of both species differ with plant size and distribution. He stated that densities of S. lamellipes are greatest within a large aggregation of P. fastigiata, whereas those of A. tea are greatest on moderate-sized isolated plants at mid-tide levels. This is an interesting paper in relation to my own work because there are patches of macroalgae at high tide and low tide at Ardmore. These patches may well contain characteristic assemblages of harpacticoids. It would be interesting to know whether the species found on these macroalgae patches also occured in the sediments. This would be a fruitful area for further research.

1.4.2 - Non-biological factors: Factors such as pollution, salinity and temperature may have an effect on the distribution of harpacticoids in the sediment. These factors have been discussed by a number of workers (McIntyre 1969; Gray and Ventilla 1971; Harris 1972a,b,c,d; Gaudy et al 1982; Scaramuzza and Martino 1984; Fleeger, et al

1984). Pollution has an effect on the abundance of meiofauna. Gray and Ventilla (1971) studied the effects of pollution on micro- and meiofauna of sand, and reported that the growth rates of a bacterivorous sediment-living ciliate, Cristigera, was significantly lower in the presence of low concentrations of heavy metals (lead, mercury, copper). The metals acted synergistically on the growth rate. They stated that a spatial study at one beach showed significant changes in numbers of meiofauna where sewage pollution occurred. There is no direct sewage input onto Ardmore beach in the form of domestic sewage outlets. However, pollution may well play a role in determining meiofaunal species composition and abundance, because the Clyde itself is polluted and because there is a periodic influx of domestic sewage from Helensburgh on the rising tide. There is no quantitative data on the level of domestic or industrial pollution at Ardmore Bay and so it is difficult to assess whether it is important.

Temperature and salinity affect the abundance of meiofauna, and both are likely to be factors controlling the distribution of the harpacticoid copepods at Ardmore beach. Harris (1972a,b,c,d) discussed the physical factors that may affect the density of harpacticoids. He concluded that variation of temperature at the sand surface, oxygen availability, and bacterial populations may have an important effect on the density of harpacticoid copepods. McIntyre (1969) demonstrated that the intertidal distribution of meiofauna is determined by temperature and salinity and also by the grain size of the deposit which affects the interstitial space, water content, and availability of food and oxygen. Gaudy, et al (1982) studied the effect of temperature and salinity on a population of Tisbe holothuriae (copepoda: harpacticoida) fed on 2 different commercial diets (Germalyne and Renutryl). Tisbe holothuriae was reared through a complete life cycle under fixed conditions of temperature (14°C, 19°C, 24°C), salinity (20%, 28%, 38%, 48%), and diet (2 synthetic foods, Germalyne and Renutryl). With Germalyne, egg sac number was independent of temperature and salinity. With Renutryl, egg sac number was dependent on both

factors (it was maximum at 24°C and 38%). The production of offspring was significantly affected by temperature when Germalyne was used as food, and by salinity when Renutryl was used as food. The reason for these effects is not clear.

The ecological importance of temperature and salinity for meiofaunal harpacticoids at Ardmore are discussed in detail in the discussion of section 4 (behavioural - ecological implications of the experiments p.215).

2. Nematodes:

A considerable amount of work has been done on marine nematodes (Wieser and Kanwisher, 1960, 1961; Swedmark, 1964; Teal and Wieser, 1966; Warwick and Buchanan, 1970; Warwick, 1971; Ott and Schiemer, 1973; Heip and Decraemer 1974; Marchant and Nicholas, 1974; Schiemer and Duncan, 1974; Juario 1975; Hegerman and Rieger, 1981; Chandler and Fleeger, 1983; Eskin and Coull 1984; Laieutier, 1984). The most closely related studies to my work are those of Warwick and Buchanan (1971), Warwick and Price (1979), and Juario (1975).

Warwick and Buchanan (1971) showed that five dominant nematodes in the soft bottom community of the Northumberland coast remained stable throughout the year. Juario (1975) showed that the 11 dominant species studied in the German Bight were stable throughout the year. Warwick and Price (1979) conducted ecological and metabolic studies on the free living nematodes from an estuarine mud flat in the River Lynher estuary, Cornwall, United Kingdom. They found nematodes have a population density between 8 and 9 x $10^6 m^{-2}$ in the winter months, and reached a peak in May of 22.86 x $10^6 m^{-2}$ (3.4g), which agrees with my results at Ardmore.

The relatively low numbers of nematodes at the high tide station (station 5) (part 2 of results) in both January and July may be caused by a number of factors. This area of the beach is exposed for a large proportion of the tidal cycle, temperature extremes in summer and winter are greater than lower down the beach, the particle size is finer

than at the other stations, and freshwater run-off from the land will have its greatest effect here. Any one of these factors, or more probably a combination of them, is likely to have caused the low numbers of nematodes at high tide.

In this context, it would be interesting to conduct laboratory experiments testing the effects of the factors in various combinations on the viability of nematodes at Ardmore.

Broadly speaking, near the sediment surface the density of nematodes at Ardmore was much higher in July 1987 than in January 1987 at each depth. These results agree with Alongi (1987) and also with Harris (1972c) who conducted a study on seasonal changes in the meiofauna population of an intertidal sand beach at Whitsand Bay, Cornwall (see Harris 1972c, p391).

However, deeper in the sedimentary column nematodes were sometimes more abundant in January than in July. This probably means that they are migrating downwards as temperatures at the surface sediment fall in autumn and winter. In this context, it is interesting to note that Harris (1972a, p. 8 figure 7a,b) shows that in summer, temperature decreases with depth into the sediment while in winter it increases. So in winter the nematodes at Ardmore may well move to deeper depths in the sediment because at these depths the sediment is significantly warmer.

The vertical distribution of nematodes in the sedimentary column is very different from that of harpacticoid copepods. They extend much deeper, often being found down to 14 cm (tables 60a and 60b). In contrast, I only found harpacticoid copepods at Ardmore in the top 1 to 2 cm of sediment. Some of the reasons to account for the difference between the vertical distribution of harpacticoids and nematodes are that nematodes move between sand grains as opposed to pushing them aside, are relatively more tolerant of anaerobic conditions (Boaden and Seed, 1985), and do not migrate into the overlying water. It would be interesting to conduct

experiments on nematodes under carefuly controlled laboratory conditions to test how deep they are capable of burrowing in aerobic and anaerobic sediments and also to conduct experiments on the distribution of their food in sediments.

Salinity may also be a factor determining the vertical distribution of nematode populations at Ardmore where there is considerable run-off from the land during winter. Freshwater coming from heavy rains flows over the surface of the sand making it less saline, while the interstitial water well below the surface of the sediment remains largely unaffected and hence of high salinity (Harris 1972a). Nematodes at Ardmore may, therefore, move deeper into the sediment to avoid the lowered salinities at and near the sediment water surface.

3. Particle size:

Particle size distribution has been described and analysed by a number of authors (Krumbein, 1934; Krumbein and Pettijohn, 1938; Ott, 1938; Inman, 1952; Folk and Ward, 1957; Tanner, 1964; Folk, 1966; Rhoads, 1967; Visher, 1969; Pravdic, 1970; Allen, 1975; Burger, 1976; Sengupta, 1979; Bagnold and Barndorff-Nielsen, 1980; Barrett, 1980; Folk, 1980; Socci and Tanner, 1980; Winkelmoden, 1982).

The particle size of sediments varies from beach to beach, and can range from mud or sand to gravel (Collison and Thomps, 1982, Leeder, 1982). Although the reason for variations in particle size is not always obvious, it is often related to whether the beach is an erosional or depositional one. For example, Reineck and Singh (1980) pointed out that particle size distribution is a measure of the energy of depositing medium. High energy environments will contain coarser particles while low energy environments will contain finer particles. Duane (1964) also noted erosional effects. He found that negatively skewed sediments were characteristic of areas where erosion occurs, while positively skewed sediments were characteristic of areas where deposition occurs.

Erosional effects can also be detected in my data. For example, the high tide stations tended to have the finest sediments with the largest standard deviations (lowest sorting) and lowest values of kurtosis (least peaked particle size distribution). All of these characteristics are indicative of a low energy wave environment with little erosion. This is likely to occur towards high tide, especially in Ardmore Bay where the upper part of the intertidal zone is very sheltered. However, in this context it is interesting to note that there are no differences between the summer (July) and winter (January) data. One might have expected some consistent differences in particle size parameters here because wave energy is significantly greater in winter than in summer, especially towards low tide at Ardmore.

It is interesting that the largest number of significant differences between the particle size parameters occurred between stations, with many fewer between depths at each station. This means that the main variation in sediments is along the transect from high to low tide, with few differences vertically and apparently seasonally. This is a most interesting discovery, and probably relates to the different energy regimes between the different tidal levels. The lack of differences vertically may be caused by the sediment being well mixed vertically by bioturbation activities on the shore - particularly by Arenicola marina which is abundant.

Sediment type can affect the abundance and types of marine animals (Teal, 1958; Wieser, 1956,1959; Meadows, 1964a,c; Corker 1967; Jansson, 1967; Morgan, 1970; Newell, 1970; Phillips, 1971; Levinton, 1982; Meadows and Campbell, 1988). Longbottom (1970), Hargrave (1972), and Dale (1974) studied the relationship between particle size of marine sediments and various measures such as organic matter and bacterial abundance. They found that fine-grained sediments are richer food sources than coarse- grained sediments.

Grain size distribution has been shown by many workers to have a profound effect on the density of meiofauna in sand beaches (Wieser, 1959; Boaden, 1962; Gray,

1966b, 1968; Jansson, 1967). The results I obtained from Ardmore Point in tables 59 and 60 show that nematodes at station 5 (high tide) which is a more muddy site, were less abundant than at any other station. These results do not agree with Findlay's work (1981) which shows that nematodes were more abundant in mud samples than in sand ones in September 1977 and February 1978. Coull (1970) found that as the grain size at a site in Bermuda switched seasonally from fine sand to coarse sand, numerical dominance switched from nematodes to copepods. I noticed no such effect in my samples because at Ardmore there was no difference in particle size parameters between summer and winter. Willems et al (1982) showed that diversity of polychaetes and harpacticoid copepods is correlated with median grain size of the sand fraction, but diversity of nematodes is not. I did not measure diversity in my study, and so can not compare my results with those of Willems et al (1982).

The question now arises as to whether the distribution and abundances of nematodes and harpacticoids that I have observed in January and July at the five intertidal stations (tables, 40, 41, 59, 60) are related to the sediment parameters (mean, standard deviation, skewness, kurtosis) (table 101 p.200). In order to test whether there are any such relationships I have plotted the abundances of nematodes and harpacticoids against the mean, the standard deviation (sorting), the skewness and the kurtosis of the particle size distributions at the different stations and depths (figures, 40.1, 40.2, 40.3, 40.4). These figures show some very interesting relationships.

There is considerable scatter in all the figures which in itself is interesting because it probably means that other factors apart from particle size are influencing the vertical and horizontal distribution of nematodes and harpacticoids in sediments.

There is an important difference between nematodes and harpacticoids in relation to mean particle size. Harpacticoids are restricted to sediments having a mean particle size of c. 2.9 ϕ (c.125 um) to c. 2.15 ϕ (c. 240 um) while nematodes have a wider

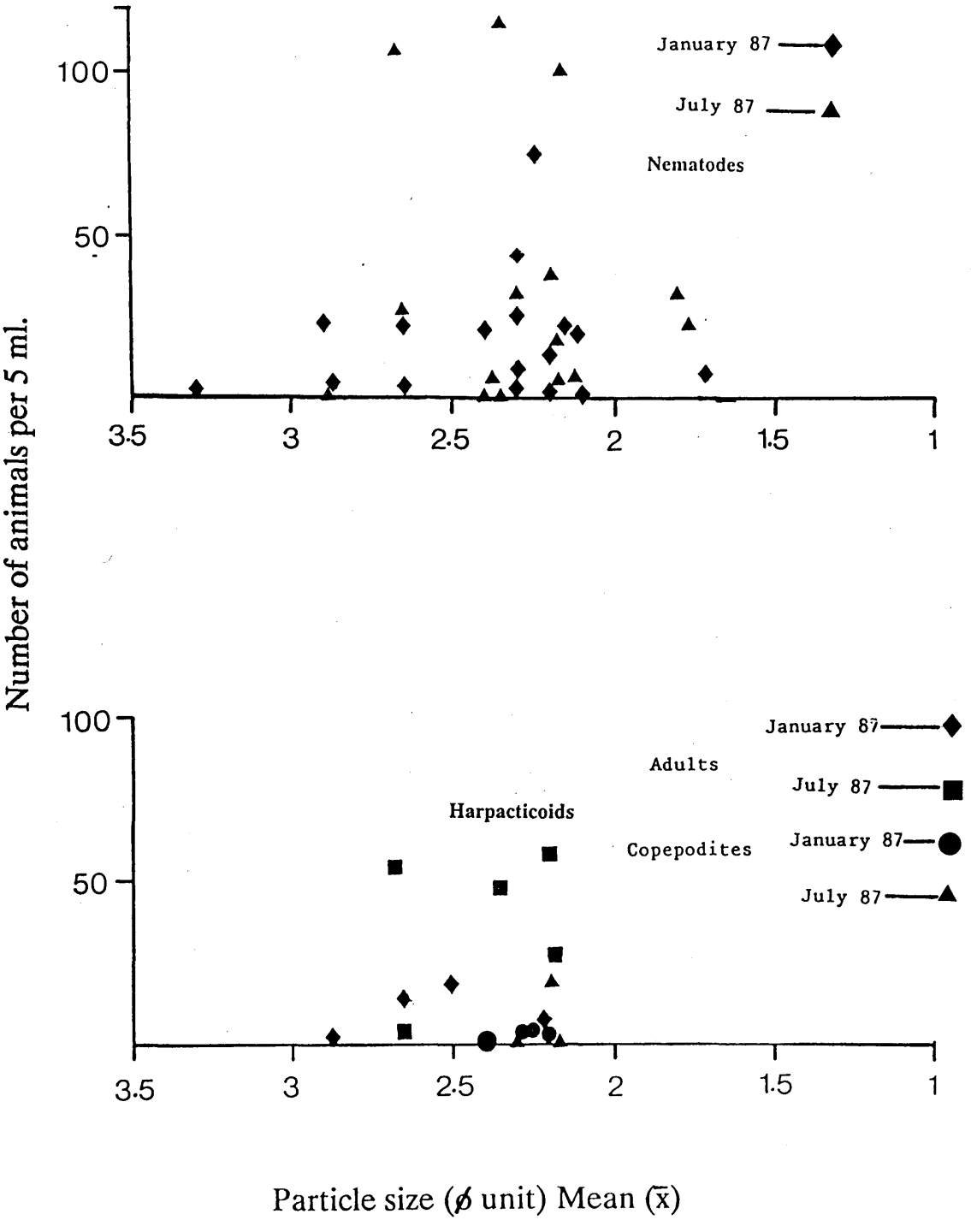


Figure 40.1. Relationships between abundances of nematodes (upper graph) and harpacticoids (lower graph) and mean particle size. Data from depths of 0-1, 3-4, 7-8, and 13-14 cm for January and July 87.

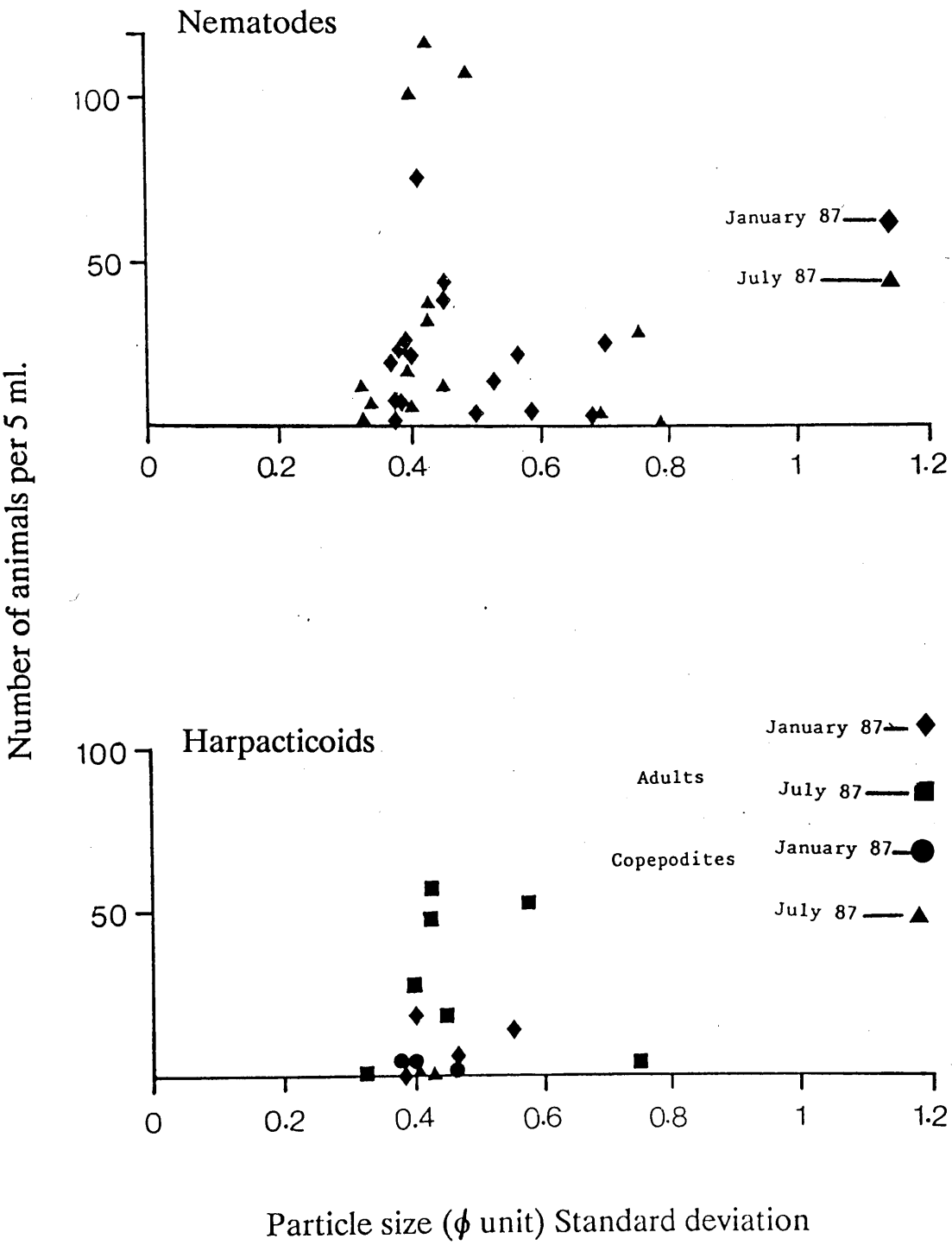


Figure 40.2. Relationships between abundances of nematodes (upper graph) and harpacticoids (lower graph) and particle size standard deviation. Data from depths of 0-1, 3-4, 7-8, 13-14 cm for January 87 and July 87.

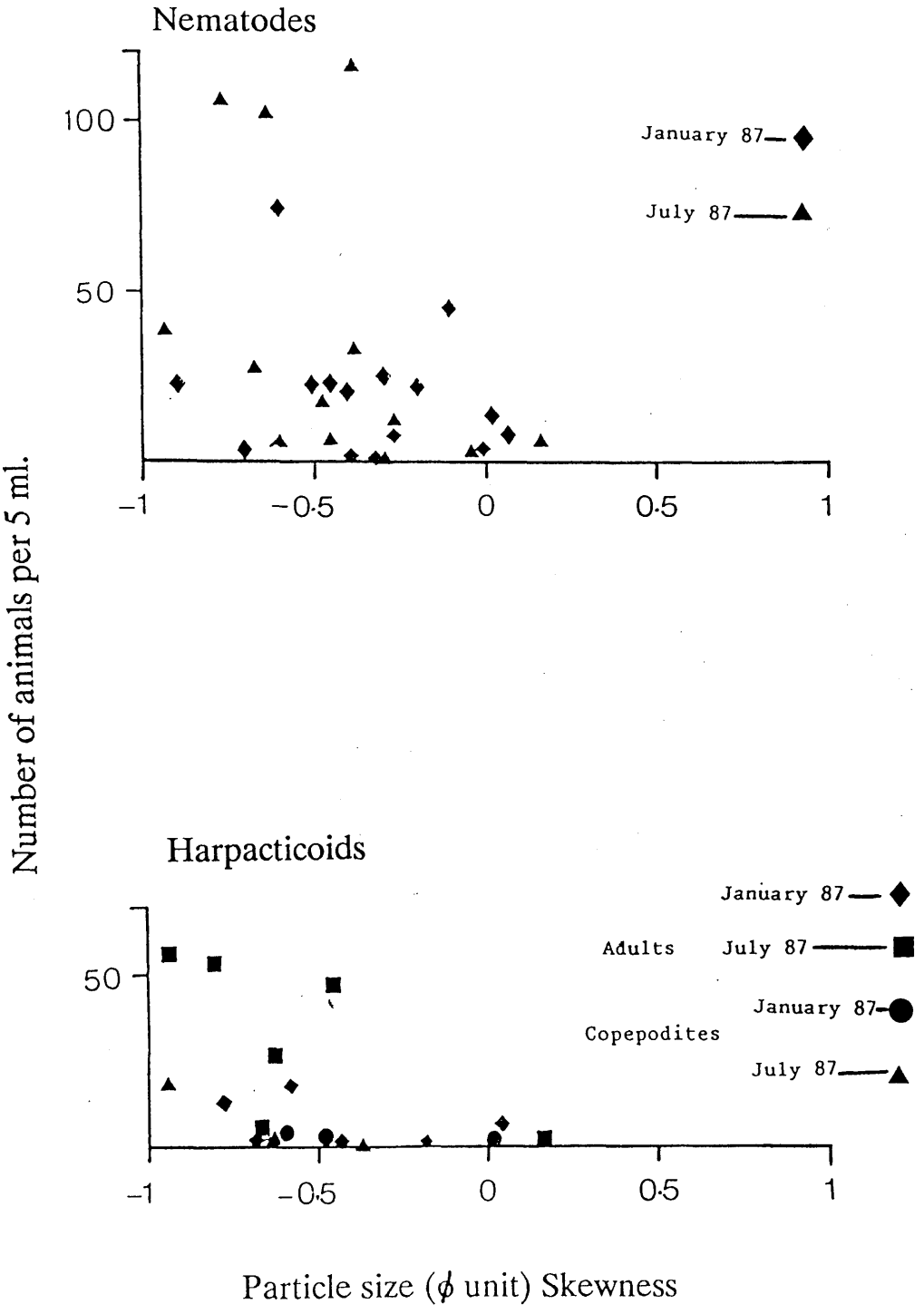


Figure 40.3. Relationships between abundances of nematodes (upper graph) and harpacticoids (lower graph) and particle size skewness. Data from depths of 0-1, 3-4, 7-8, and 13-14 cm for January 87 and July 87.

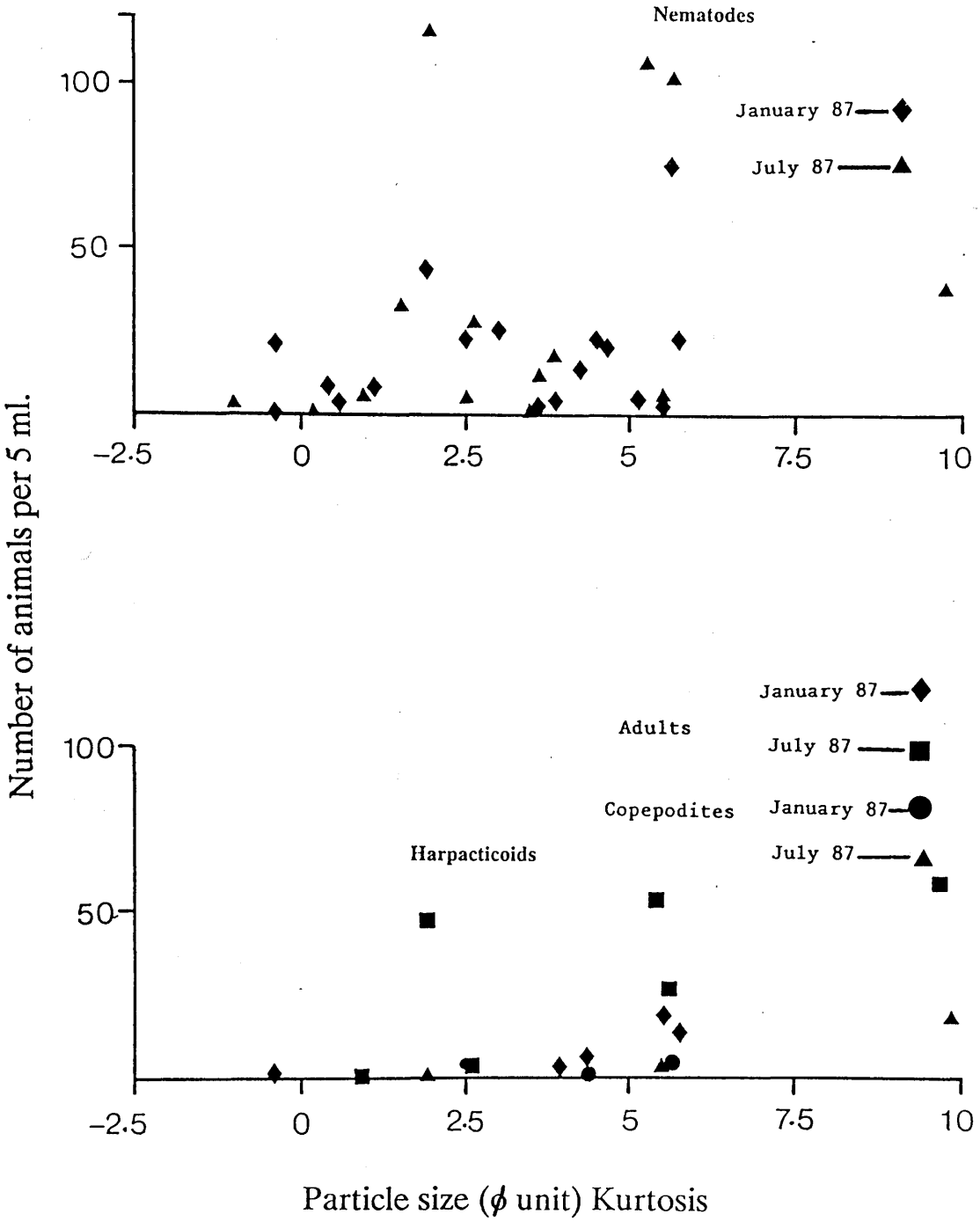


Figure 40.4. Relationships between abundances of nematodes (upper graph) and harpacticoids (lower graph) and particle size kurtosis. Data from depths of 0-1, 3-4, 7-8, and 13-14 cm for January 87 and July 87.

distribution being found in sediments having a mean particle size of 3.3 ø (c. 100 um) to c. 1.7 ø (c. 300 um). This means that harpacticoids are likely to be more restricted in their distribution than nematodes are in relation to sediment size. This may possibly be related to body shape and the ease with which nematodes can move through sediments.

Nematodes and harpacticoids (figure 40.2) are most abundant in sediments having intermediate standard deviations ranging between 0.35 ø (c. 75 um) and 0.50 ø (c. 31 um) (nematodes) and 0.35 ø (c. 75 um) and 0.57 ø (c. 20 um) (harpacticoids), rather than in sediments having a very small or very large standard deviation. This means that both groups are less likely to occur in sediments having a very high degree of sorting (low standard deviation) or a very low degree of sorting (high standard deviation). High sorting is characteristic of highly erosional environments, and low sorting is characteristic of highly depositional environments. This suggests that the species of harpacticoids and nematodes found at Ardmore are likely to prefer sediments which are not highly erosional and not highly depositional. In this context, it is interesting to note that the lower tidal regions at Ardmore are slightly erosional, and the higher tidal regions are slightly depositional.

Both nematodes and harpacticoids are more abundant in sediments having a high negative skewness (-0.3 to -1.0) on the phi (ø) scale (figure 40.3). These are sediments in which the bulk of particles are at the fine end of the distribution, with a tail in the coarse particle sizes. This means that harpacticoids and nematodes prefer to live in sediments where the bulk of the particles are fine. This is interesting because these sediments are likely to have a higher organic content and therefore probably more food. Furthermore the particles, being small, may be more easily movable. However, finer sediments tend to become more anaerobic which may be a disadvantage, particularly to the harpacticoids.

There is no very obvious relationship between the abundances of nematodes and

harpacticoids and kurtosis of the particle size distribution except that in general animals occur in sediments having a positive kurtosis (a more peaked distribution than a normal curve).

One may conclude therefore that although there is considerable scatter in the data plotted in figures 40.1 to 40.4, there are some significant relationships between particle size parameters and the abundances of harpacticoids and nematodes on the beach at Ardmore. Further studies on other sandy and muddy beaches would be illuminating as they would provide a broader picture of the relationship between particle size parameters and the abundance of harpacticoids and nematodes in a range of habitats.

SUMMARY (Part 1)

Total harpacticoids:

The low and mid tide annual cycles were broadly similar. At low tide there were low numbers in December, January, February and April and much higher numbers in June, July and August. At mid tide, there were low numbers in winter and a peak in June and July but a fall in August. The high tide cycle differed from the low and mid tide cycle as follows: The total number of harpacticoids was much higher in autumn; the highest numbers occurred in October with a secondary peak in February while the lowest number occurred in December, April and June.

Copepodites showed distinct cycles during the year and also differences between the low tide, mid tide and high tide sites. At low tide copepodites peaked in February and were lowest in December. At mid tide, copepodites peaked in October and December and were very low in February, April and June. At high tide, there were virtually no copepodites in the population at any time in the year.

Depth distribution:

The abundance of harpacticoid copepods (adults, copepodites) decreased as depth increased, except in October 1986 and December 1986.

SUMMARY (Part 2)

Harpacticoid copepods:

i. Total (top 1 cm):

The population of harpacticoid copepods was higher in July 87 than in January 87, and in both months the population density decreased with increasing depth. Most of the harpacticoids occurred in the top 2 cm of the sediment.

ii. Adults:

Station 2 in January 1987 and station 1 in July 1987 had the highest density, while station 3 and 5 had the lowest respectively. The density of adults was greater in July 87 than in January 87.

iii. Copepodites:

Station 2 in January 1987 and station 1 in July 1987 had the highest density, while stations 4 and 5 in both months had no animals.

Nematodes:

The population of nematodes was higher in July 87 than in January 87, and in both months the population density decreased with increasing depth. Most of the nematodes occured in the top 2 cm of the sediment. However, nematodes occurred to a much greater depth than the harpacticoids, and were present to at least 14 cm.

Particle size parameters:

The greatest number of statistically significant comparisons occurred between means and between kurtoses at the different stations and different depths. There were fewer significant differences for standard deviations and non for skewness.

The greatest number of significant differences in the particle size parameters occured along the transect between stations with fewer differences vertically in the sediment, and vertically no differences between the summer (July) and winter

(January) data.

In general, the high tide stations had the finest sediments with the highest standard deviations (lowest sorting) and lowest values of kurtosis (least peaked curves). All of this is to be expected because there is less wave energy to towards high tide.

Relationship between harpacticoid and nematode abundance and particle size parameters.

Harpacticoids were restricted to sediments having a mean particle size of c. 2.9 ø (c.125 um) to c. 2.15 ø (c. 240 um) while nematodes have a wider distribution being found in sediments having a mean particle size of 3.3 ø (c. 100 um) to c. 1.7 ø (c. 300 um).

Nematodes and harpacticoids were most abundant in sediments having intermediate standard deviations ranging between 0.35 ø (c. 75 um) and 0.50 ø (c. 31 um) (nematodes) and 0.35 ø (c. 75 um) and 0.57 ø (c. 20 um) (harpacticoids), rather than in sediments having very small or very large standard deviations. Both nematodes and harpacticoids were more abundant in sediments having a high negative skewness (-0.3 to -1.0) on the phi (ø) scale.

There was no very obvious relationship between the abundances of nematodes and harpacticoids and kurtosis except that in general animals occurred in sediments having a positive kurtosis (a more peaked distribution than a normal curve).

Section (4)

Experimental work (behavioural experiments: light, temperature, salinity).

INTRODUCTION

There has been an increasing interest in the effects of various environmental factors on the behaviour of meiofauna in recent years. Experimental studies of these effects have been carried out in the field and laboratory by a number of workers (Gray 1968; Jansson, 1968; Gray and Ventilla, 1971; Rieper, 1978; Giere, 1979; Bell and Sherman, 1980; Hagerman and Rieger, 1981; Palmer, 1984; Sach, 1984; Palmer and Gust, 1985; Woods and Tistjen, 1985; Hicks, 1986; Fegley, 1987; Armonies, 1988a,b,c; Walters, 1988).

Studies carried out on the harpacticoid copepod Leptastacus constrictus have shown that its vertical distribution is controlled by light (Gray, 1966a), temperature (Gray, 1965), oxygen tension and drying out of sand (Gray 1966b). The horizontal distribution is controlled by a preferance for sand of 200μ - 300μ diameter (Gray 1966b) and by the type of bacteria attaching the sand grains (Gray 1966c). Muus (1967) found that Tachidius discipes feeds on diatoms attached to sand grains, while Nitocra feeds mainly on detritus (bacteria).

My laboratory work in this section is concerned with the effect of light, salinity, and temperature on the emergence of harpacticoid copepods from sediments. The experiments were conducted on harpacticoid copepods collected from Ardmore Point at low tide.

GENERAL MATERIALS AND METHODS

23 experiments were conducted in all. Only 7 of these are described in detail. The remainder were either preliminary experiments testing general methodology, or experiments testing the experimental design of the definitive experiments reported below.

The vials used in all the experiments were made of perspex, 9.1 cm length, 2.1 cm diameter, (sterilin , code no. 128 A, universal container plastic) overall volume 30 ml. In all experiments they contained 10 ml of wet sediment and 10 ml water.

Sediment containing animals was collected from Ardmore Point, Clyde Estuary, (National Grid: GN 2260) near low tide to a depth of 3 cm using a spade. The sediment was placed in buckets, transported to the Department within an hour of collection, and immediately prepared for experiments in a laboratory where the temperature was 18-22°C. All experiments were conducted on the day of collection. The sediment was gently mixed by hand before each experiment to distribute the animals evenly.

At the end of the experiments, animals were counted in the supernatants from each vial. However, there was not enough time to count the animals in the sediment in each vial because of the time it would have taken to elutriate the sediment for each vial. In order to obtain an estimate of the number of animals in the sediment, and hence the total number per vial, the following procedure was adopted. Five of the vials from which the supernatant had been removed were selected using tables of random numbers. These were elutriated using an elutriator designed by Reichelt (1988). The technique is fully described on pp 61 figure 16. The total number of animals in each of the five vials was then obtained by adding the number of animals in the overlying water to the number of animals in the sediment. The mean and

standard deviation of total number of animals for the five vials were then calculated. This mean was used as a standard total number of animals in that experiment. The standard total number was then used to calculate (i) the percentage of animals in the overlying water in each vial in the experiment, (ii) the calculated number of animals in the sediment by subtracting the observed number in the overlying water from the standard total number.

EXPERIMENT (1)

Purpose of experiment: to test how quickly animals come out of the sediment into the overlying water when the lights are switched off.

Date of experiment: 8/9/1988

Materials and Methods:

20 vials were labelled and 10 ml of filtered seawater with a salinity of 32.5% was put in each vial. 10 ml of the mixed sediment was then selected randomly using a teaspoon and placed into each vial. The vials were placed on a plastic tray and put in the phytotron room at 20°C for six hours under constant illumination (3000 lux).

The lights were then switched off and the supernatants were poured off into clean vials starting at 5 minutes after the time at which the lights were switched off (appendix table 229, pp. 327). A very dim red light was used (torch covered with five layers of red plastic) in order not to disturb the animals. The animals in the supernatant were preserved by adding the appropriate volume of concentrated Steedman's solution to give a ratio of 9 ml water : 1 ml of Steedman's solution. The animals in the sediment were killed by adding 10 ml of freshwater to the sediment. This avoids shrinkage of tissues (Barnett, personal communication). The approporiate volume of concentrated Steedman's solution was then added to the sediment in the vial to give the 9:1 ratio.

The sediment was elutriated to extract animals using the elutriator. The supernatant was placed in a modified petri-dish whose bottom was squared for accuracy of counting. Animals were then counted under a binocular microscope using a tally counter.

Results:

The original data for the experiment are shown in appendix 3 table 229. pp. 327. The results (figure 41) show that there was a gradual increase in number of animals in the overlying water as time progressed. After 180 minutes, the percentage of animals in the overlying water had reached 84%.

EXPERIMENT (2)

Purpose of experiment: This experiment is divided into two parts:
Experiment 2a: to test if the same numbers of animals are found in the supernatant of covered (dark) vials opened in the dark and in the light. This experiment provided a zero time reading for experiment 2b.
Experiment 2b: to test how quickly animals burrow into sediment when the lights were switched on (experiments 2a and 2b were carried out on the same day and at the same time).

Date of experiment: 2/9/1988

Materials and Methods:

40 vials were labelled and 10 ml of filtered seawater was poured into each vial. 10 ml of the mixed sediment was then selected randomly using a teaspoon and placed into each vial. For experiment 2a 20 vials were covered with three layers of metal foil to ensure that they were completely dark. These are called covered vials. For experiment 2b, 20 vials were uncovered and their lids were removed at the beginning

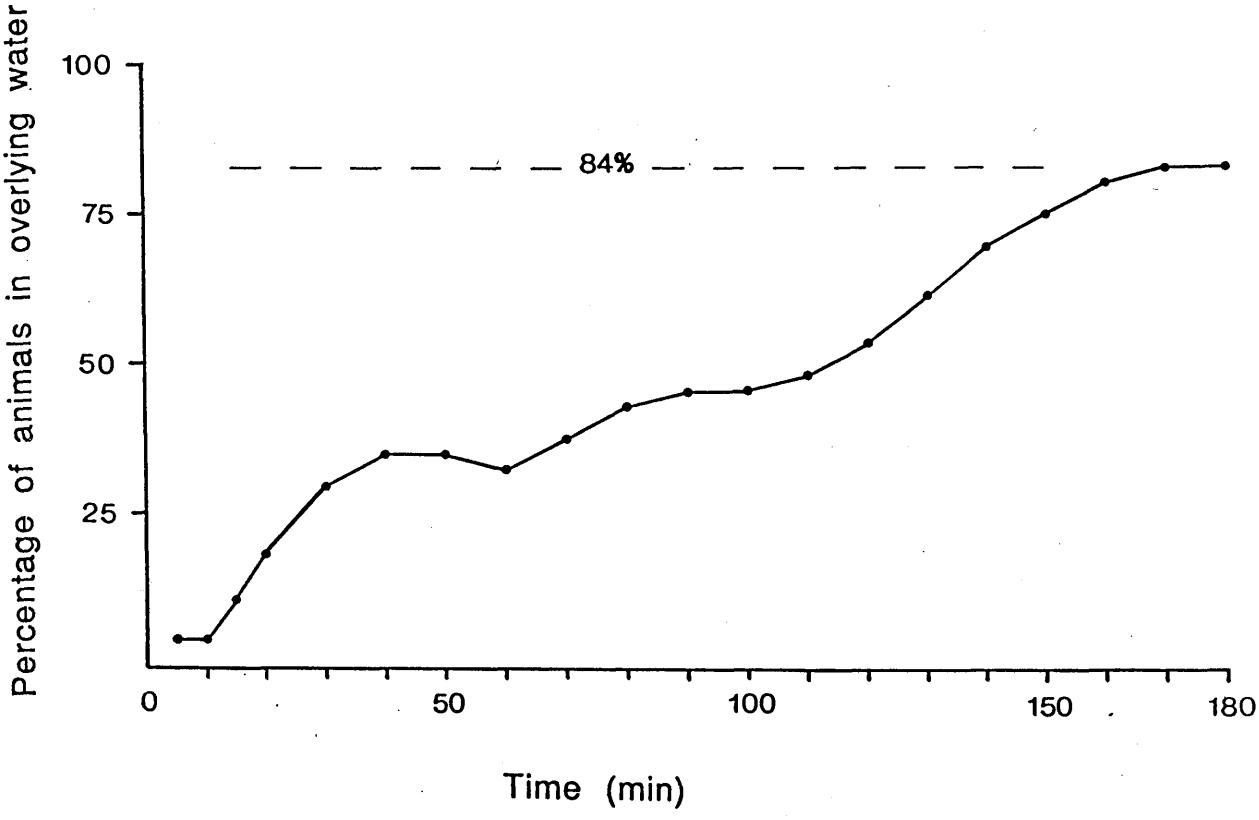


Figure 41. Experiment 1. Rate at which animals emerging from sediment when the lights are switched off.

to allow full light penetration. The covered (dark) and uncovered (light) vials were then placed on a tray, put in the phytotron room at 20°C, and left in total darkness for six hours.

10 minutes before the lights were switched on, the removal of the supernatants of the covered vials began and continued until 10 minutes after the lights were switched on. Meanwhile, the supernatants of the uncovered vials were removed starting at 5 minutes after the lights went on. The animals in the supernatants and sediments were preserved and counted as in experiment (1).

Results:

The original data for experiment 2b are shown in appendix 3 table 231. pp. 329. The results of experiment 2a are shown in appendix table 230 pp. 321, and show very clearly that there is no difference between the numbers of animals in the overlying water in bottles 1-10 (opened in the dark), and bottles 11-20 (opened in the light) (table 230, column 3). This was tested statistically by comparing the data from bottles 1-10 in col. (3) with the data 11-20 in col. (3) by student-t test. The t-test was non-significant, t=1.149, d.f=18.

The results of experiment 2b are presented as a graph (figure 42). Figure 42 shows that the percentage of animals in the overlying water declined rapidly from 62.5% to 5% within the first hour, and then leveled out showing no change during the interval from 60 to 100 minutes. After 115 minutes, there were no animals in the overlying water except at 130 and 160 min. when the percentage was 2.5%.

Comparison of results of experiments (1) and (2). The rate at which the animals burrowed into the sediments when the lights were switched on in experiment (2) does not match the rate at which the animals emerged from the sediment when lights were switched off in experiment 1. In experiment 2, animals burrowed into the sediment in response to light much more quickly than they emerged from the sediment in the dark in experiment 1. This effect is shown in table 194. For

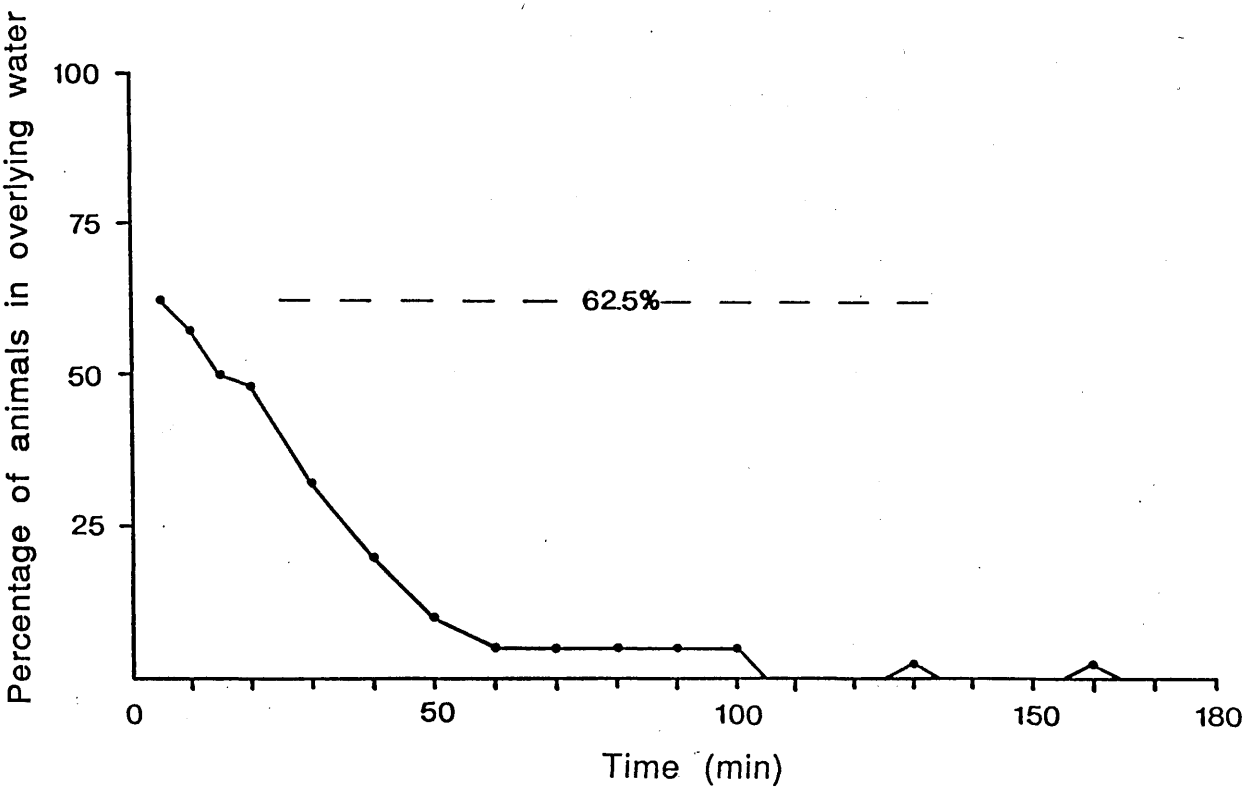


Figure 42. Experiment 2b. Rate at which animals burrow into sediment when the lights are switched on.

Table 194. Experiments 1&2. Time taken by animals to respond to dark (experiment 1) and light (experiment 2) conditions. Percentage and equivalent times read from figures 41 and 42.

Dark (exp. 1)		Light (exp. 2)	
% in overlying water	Time (min)	% in sediemnt	Time (min)
10%	14	10%	<5
25%	26	25%	<5
50%	113	50%	15
75%	149	75%	36
90%	180	90%	50

example, 25% of the animals in experiment (2) had burrowed within 5 min of switching the lights on whereas it took 26 min after the lights were switched off in experiment (1) for 25% of the animals to emerge from the sediment into the overlying water. The equivalent times for 90% burrowing in the light (exp. 2) and 90% emerging in the dark (exp. 1) are 50 min and 180 min respectively.

EXPERIMENT (3)

Purpose of experiment: to test the effect of various intensities of light on the rate of burrowing into sediments.

Date of experiment 10/9/1988

Materials and Methods:

63 vials were labelled and 10 ml of filtered seawater was poured into each vial. 10 ml of the mixed sediment was immediately put in each vial. The vials were then placed in a purpose designed phytotron at 20°C where the light was equivalent to day light. Vials 1-20 were positioned where the light intensity was 3000 lux, vials 21-40 where the light intensity was 550 lux, and vials 41-60 where the light intensity was 10 lux. The remaining three vials which represent replicates D1, D2, and D3 (dark), were also placed on the table. All the vials were left in the phytotron room in total darkness for six hours. Two minutes before the lights were switched on, the supernatants of D1, D2, and D3 were taken. These are called the zero time readings. The lights were then switched on and the supernatants were poured from the bottles as follows. Bottles 1, 21, 41: 5 min after the lights were switched on; bottles 2, 22, 42: 10 min; bottles 3, 23, 43: 15 min; bottles 4, 24, 44: 20 min; thereafter trios of bottles- one from each light intensity - at 10 minute intervals.

Results:

The original data for the experiment are shown in appendix 3 table 232. pp. 330. The results of the experiment are plotted in figure 43 and show that animals

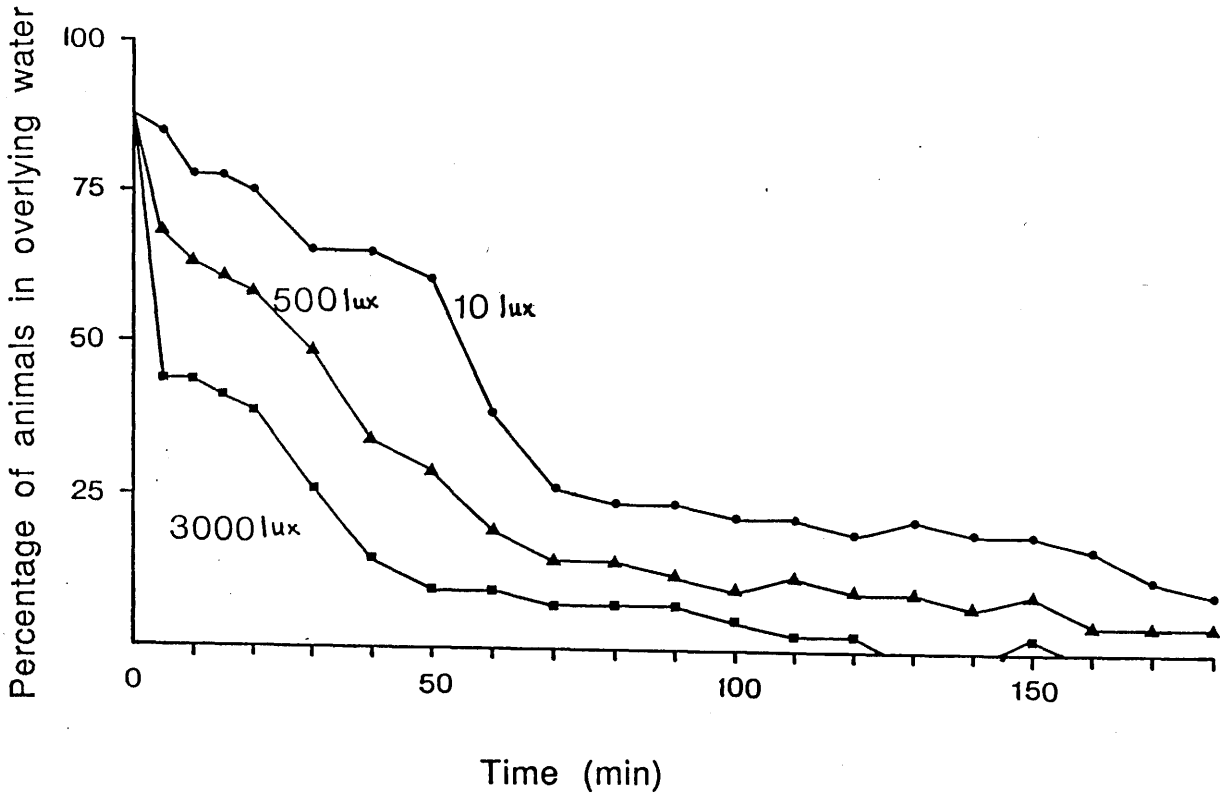


Figure 43. Experiment 3. Effect of three light intensities (10 lux, 550 lux, 3000 lux) on the rate at which the animals burrow into sediment.

burrowed most quickly in the highest light intensity (3000 lux), at an intermediate rate in the medium light intensity (550), and most slowly in the lowest light intensity (10 lux). The times taken for 25%, 50%, 75%, and 90% of the animals to burrow in the three light intensities are shown in table 195. These data were obtained from figure 43. Table 195 shows the dramatic effect that light intensity has on the rate at which animals burrowed. For example, in the high light intensity (3000 lux) 25% of the animals had burrowed within 2.5 min whereas the equivalent times for 550 lux and 10 lux were 3 min and 20.5 min. In the same way, 50% of the animals burrowed within 4.5 min (3000 lux), 28.5 min (550 lux), and 54.5 min (10 lux) respectively.

The original data were statistically analysed using 2x3 chisquared tests at 5, 60, 120, 180, and 180 minutes to test differences between the three light intensities. The results of the analysis (table 196) show that the differences between the light intensities were significant at 5 min, 60 min, and 120 min but not at 180 min. It is interesting to note that the statistical differences decreased as the time increased. This is shown by the decrease in the values of X^2 as time progressed: 5 min, $X^2 = 15.84$; 60 min, $X^2 = 10.36$; 120 min, $X^2 = 6.37$; 180 min, $X^2 = 4.21$.

EXPERIMENT (4)

Purpose of experiment: to test the effect of temperature on the rate of emergence of animals from sediments when the lights are switched off.

Date of experiment 18/9/1988

Materials and Methods:

30 vials were labelled and 10 ml of filtered seawater was poured into each vial. Vials 1 to 27 were labelled 1-27, and vials 28, 29, and 30 were labelled L1, L2 and L3 respectively. The thirty vials were placed into three containers as follows: vials 1-9 and vial L1 into container A, vials 10-18 and vial L2 into container B, and vials 19-

Table 195. Experiment 3. Time taken by animals to respond to different light intensities. Percentage and equivalent times read from figure 43. Note: percentages are the inverse of those in figure 43 being % burrowed, not % overlying water.

% Burrowed	Time (min)		
	10 lux (min)	550 lux (min)	3000 lux (min)
25%	20.5	3	2.5
50%	54.5	28.5	4.5
75%	76.5	54	31.5
90%	>180	>180	>180

Table 196. Experiment 3. 2x3 chisquare tests testing differences between the ratios of number of animals in the overlying water and in the sediment at three light intensities (10 lux, 550 lux, 3000 lux). Four 2x3 X^2ests were applied to the original data at 5 min, 60 min, 120 min, 180 min.

Time (min)	X^2	Degrees of freedom	Probability
5	15.84	2	$p<0.001$
60	10.36	2	$0.01>p>0.001$
120	6.37	2	$0.05>p>0.02$
180	4.21	2	$0.20>p>0.10$

27 and vial L3 into container C. The three containers were placed in the phytotron room at 20°C. Containers A and B were filled with water which was maintained at 5°C (± 1°C) and 10°C (± 1°C) by carefully adding ice. Container C had no water in it. The sediment in the vials in the respective containers therefore slowly became equilibrated to 5°C, 10°C and 20°C respectively, while C was exposed to same light intensity in the phytotron room. They were left thus for 6 hours for the temperatures to equilibrate to 5°C, 10°C and 20°C respectively and to ensure all the animals burrowed. At the end of 6 hours period, the supernatants were poured off from vials L1 (5°C), L2 (10°C) and L3 (20°C). These three supernatants represent the three control vials in other words zero time readings. Containers A and B were transferred to 5°C and 10°C rooms respectively. Container C was left in the phytotron room at 20°C. The lights in the three rooms were switched off at 0 min, 5 min, and 10 min respectively. This staggering of time of turning the lights off was to allow me to move from one room to another as I removed the vials at the different temperatures. The vials at each temperature were then removed at 20 min intervals.

Results:

The original data for the experiment are shown in appendix 3 table 233. pp. 331. The statistical analysis is given in table 197.

The results are plotted in figure 44 and show that animals emerged most quickly at 10°C, intermediate rate at 20°C, and most slowly at 5°C.

The original data was statistically analysed using chisquare 3x2 to test if there are any differences between the three temperatures. The results of the analyses (table 197) show that the differences between the three temperatures were not significant at 20 min, but significant at 60 min, 120 min, and 180 min. It is interesting to note that the statistical differences increased as the time increased. This is shown by the increase in the values of X^2 as time progressed: 20 min, $X^2 = 2.72$; 60 min, $X^2 = 7.66$; 120 min, $X^2 = 22.84$; and 180 min, $X^2 = 35.15$.

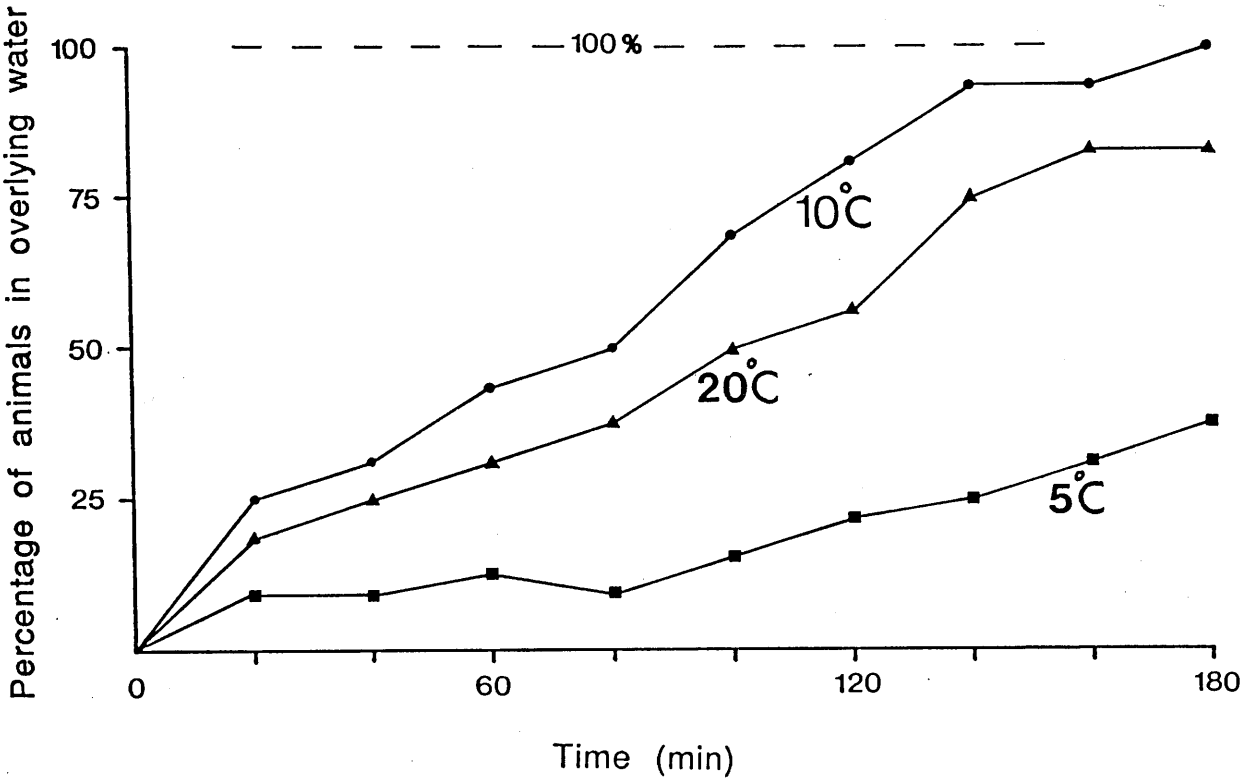


Figure 44. Experiment 4. Temperature effect on rate of emerging of animals from sediment into the overlying water when the lights are switched off.

Table 197. Experiment 4. 2x3 chisquare tests testing differences between the ratios of animals in the overlying water and in the sediment between three temperatures (5°C, 10°C, 20°C). Four 2x3 X^2 tests were applied to the data at 20 min, 60 min, 120 min, and 180 min in dark condition.

Time (min)	X^2	Degrees of freedom	Probability
20	2.72	2	0.30>p>0.20
60	7.66	2	0.05>p>0.02
120	22.84	2	p<0.001
180	35.15	2	p<0.001

Table 198. Experiment 4. Time taken by animals to respond to different temperatures. Percentages and equivalent times from figure 44.

% Response	Time (min)		
	5°C (min)	10°C (min)	20°C (min)
25%	140	20	40
50%	>180	80	100
75%	>180	110	140
90%	>180	134	>180

Table 198 shows the effect that temperature has on the rate at which animals emerged from the sediment when the lights were switched off. For example, at low temperature (5°C) 25% of the animals had emerged from the sediment into the overlying water within 140 min, whereas the equivalent times taken for 10°C and 20°C were 20 min and 40 min respectively.

EXPERIMENT (5)

Purpose of experiment: to test the effect of various salinities on the rate of emerging of animals from the sediment in dark.

Date of experiment 23/8/1988

Materials and Methods:

This experiment tests the effect of the following five salinities 1%, 10%, 25%, 50%, and 100%. 20 vials were labelled L1 to L10, and D1 to D10 respectively. 10 ml 1% seawater was added to vials D1 and D2, and L1 and L2, 10 ml 10% seawater to D3 and D4, and L3 and L4, 10 ml 25% seawater to D5 and D6, and L5 and L6, 10 ml 50% seawater to D7 and D8, and L7 and L8, and 10 ml 100% seawater to D9 and D10, L9 and L10. There were therefore two replicates of each treatment.

10 ml sediment was then put into each vial. The dark vials were covered with three layers of metal foil to ensure that they were completely dark. The lids of the light vials were removed to allow full light penetration. The dark and light vials were then placed in parallel and opposite each other on a plastic tray in the phytotron room at 20°C.

The vials were left for five hours in light and the supernatants from the light vials were then removed. There were no animals in the light vials at all. These vials essentially acted as a control, and receive no further comment.

The lights were then switched off in order to remove the supernatants of the dark vials. This was done using a dim red light. These dark vials like the light ones, had therefore had 5 hours in the light, but had been completely covered.

Results:

The original data for the dark vials are shown in appendix 3 table 234. pp. 331. The results (figure 45) show that there was a gradual increase in number of animals in the overlying water in the dark vials as salinity increased. At a salinity of 100%, the percentage of animals in the overlying water had reached 58%.

The original data were statistically analysed by X^2. This was to test firstly if there are any differences between replicates of each salinity, and secondly to test the significance of differences between pairs of salinities.

Comparisons between replicates: five 2x2 chisquares were applied between the replicates of each salinity. These chisquares (table 199) showed no significant differences.

Comparisons between salinities: Because there were no significant differences between the replicates, I summed the pairs of the replicates of the original data to compare between salinities.

10 different paired comparisons between the salinities then were applied to the summed pairs of the replicates (1%/10%; 1%/25%; 1%/50%; 1%/100%; 10%/25%; 10%/50%; 10%/100%; 25%/50%; 25%/100%; 50%/100%). Eight of these X^2 tests were significant and two were not. The non significant ones were between salinities 1% and 10%, and between 25% and 50% (table 200).

EXPERIMENT (6)

Purpose of experiment: to test whether the animals die or live when there was low salinity above them.

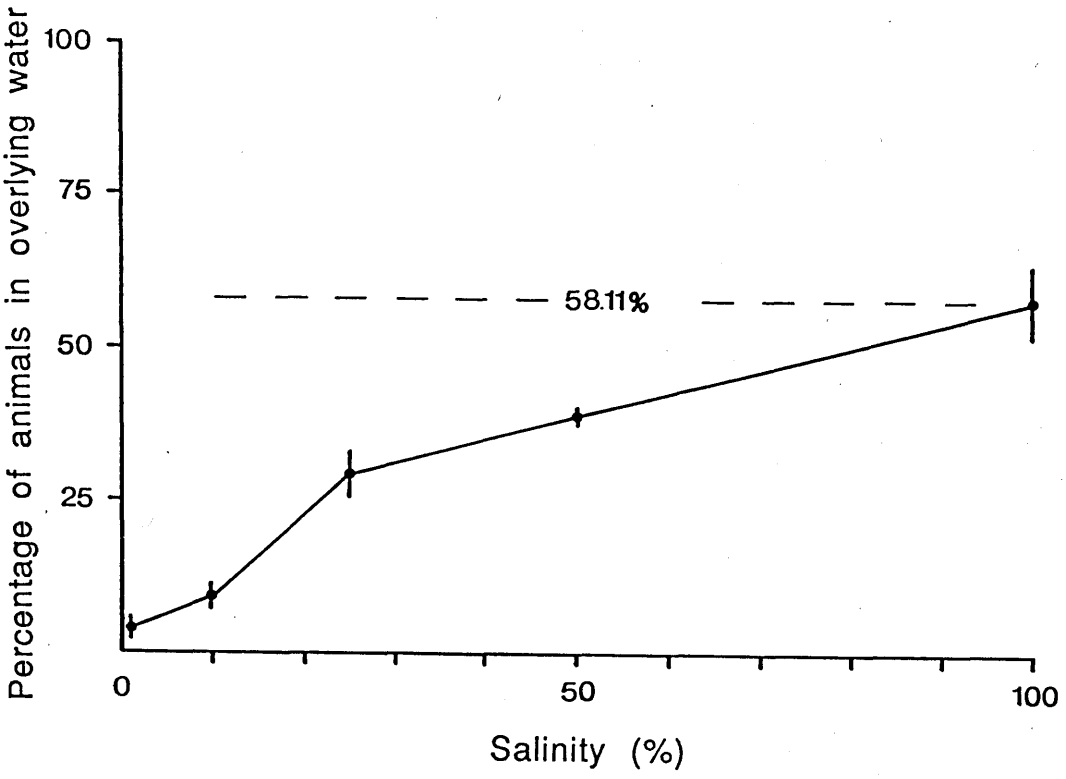


Figure 45. Experiment 5. Relationship between percentage of the animals in the overlying water and salinity in the dark vials. Each point is the mean of the two replicates at each salinity. The vertical bars are the standard deviations.

Table 199. Experiment 5. 2x2 chisqaure tests testing differences between the ratios of animals in the overlying water and in the sediment between replicates (R1, R2). Five 2x2 chisqures were applied to the data at salinities of 1%, 10%, 25%, 50% and 100%.

Salinity %	Replictes compared	X^2	Degrees of freedom	Probability
1	R1/R2	0.35	1	0.70>P>0.50
10	R1/R2	0.16	1	0.80>P>0.70
25	R1/R2	0.26	1	0.70>P>0.50
50	R1/R2	0.06	1	0.90>P>0.80
100	R1/R2	0.50	1	0.50>P>0.30

Table 200. Experiment 5. 2x2 chisquares tests testing differences between the ratios of animals in the overlying water and in the sediment between pairs of salinities (replicates summed). Ten 2x2 chisquares tests were conducted on the summed original data in the two replicates at each salinity because none of the X^2 comparisons between replicates were significant (see table 199).

Salinity compared	X^2	Degrees of freedom	Probability
1%/10%	1.72	1	0.20>P>0.10
1%/25%	17.37	1	P<0.001
1%/50%	26.95	1	P<0.001
1%/100%	50.47	1	P<0.001
10%/25%	9.65	1	0.01>P>0.001
10%/50%	17.77	1	P<0.001
10%/100%	39.14	1	P<0.001
25%/50%	1.47	1	0.30>P>0.20
25%/100%	12.10	1	P<0.001
50%/100%	5.30	1	0.05>P>0.02

Date of experiment 24/8/1988

Materials and Methods:

The principle behind this experiment is best illustrated by an example. 10 ml of 50% seawater was added to two vials followed by 10 ml of sediment. The two vials were left for 3 hours in the dark. At the end of this period the supernatants were taken off. The animals in the supernatants were counted later. 10 ml of 100% seawater was then added to the two replicate vial, and after a further 3 hours the supernatant was again removed and the animals counted later. This description is of replicates vials R5 and R6 in table 235. The various combination of five salinities 1%, 10%, 25%, 50%, and 100% were tested in this way, and these combinations are shown in table 235.

Results:

The original data for the experiment are shown in appendix 3 table 235 pp. 332. The results are plotted in figures 46, 47, 48, and 49. The statistical analysis of this data is given in tables 201 and 202.

The results of the experiment were complicated. To allow statistical comparisons between the various treatments, it was first necessary to know wether there was any difference between replicates. This was done by 2x2 chisquares tests. Table 201 shows that in 30 cases out of 32 there were no significant differences between the replicates. The results of the replicates were therefore summed and subsequent analyses were done on these summed results. These statistical analyses were done by 16 2x2 chisquare tests table 202.

Figures 46, 47, 48 and 49 show the results of the 100%/50%, 100%/25%, 100%/10%, and 100%/1% respectively. These matched A, B, C, and D in table 202. Hence, 100%/50% results in figure 46 are compared in table 202A (comparisons 1-4), 100%/25% results in figure 47 are compared in table 202B (comparisons 5-8),

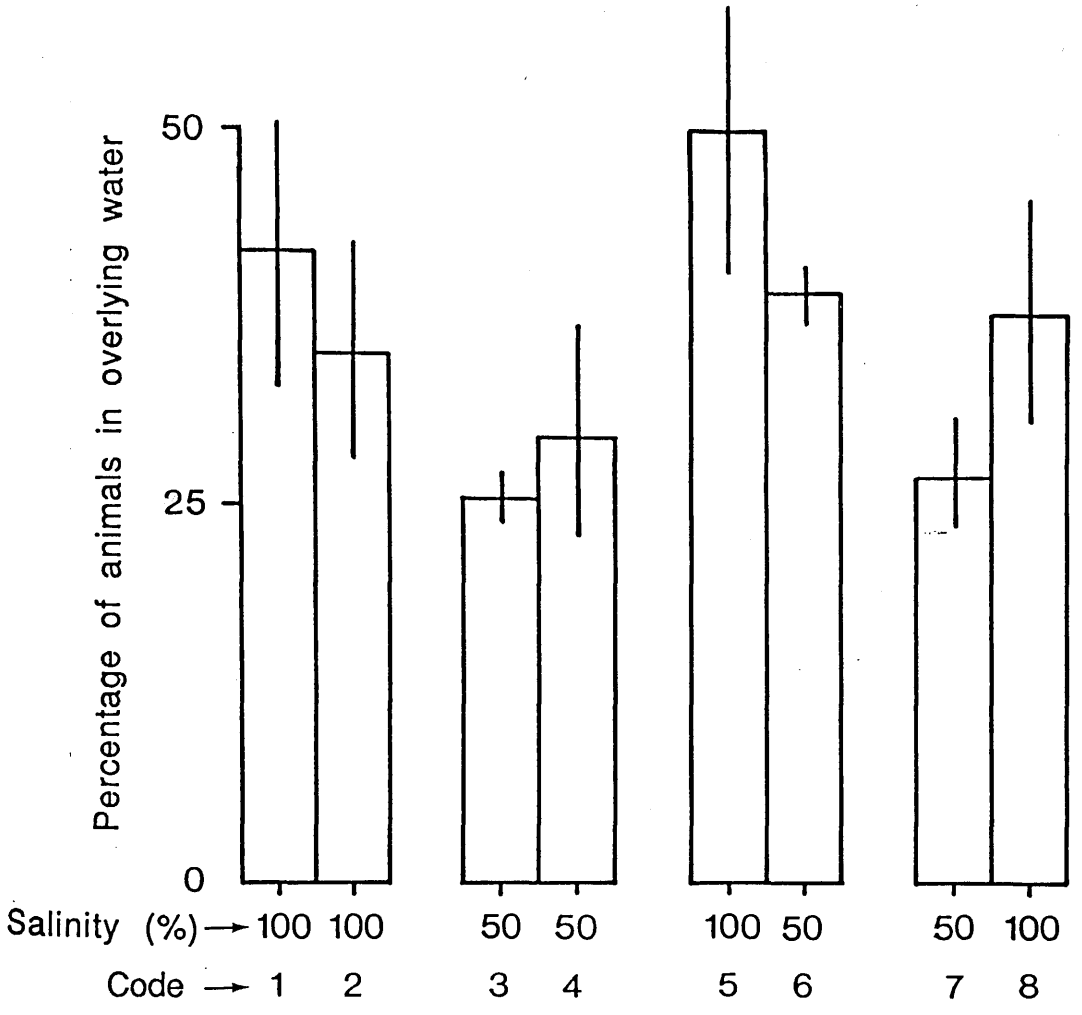


Figure 46. Experiment 6. Effect of different salinities on the behaviour of animals in dark. Percentage of animals in the overlying water at salinities of 100% and 50% for the two treatments. The codes 1, 3, 5, and 7 represent the first treatment. The codes 2, 4, 6, and 8 represent the second treatment. Each column is the mean of two replicates and standard deviations are shown as vertical lines.

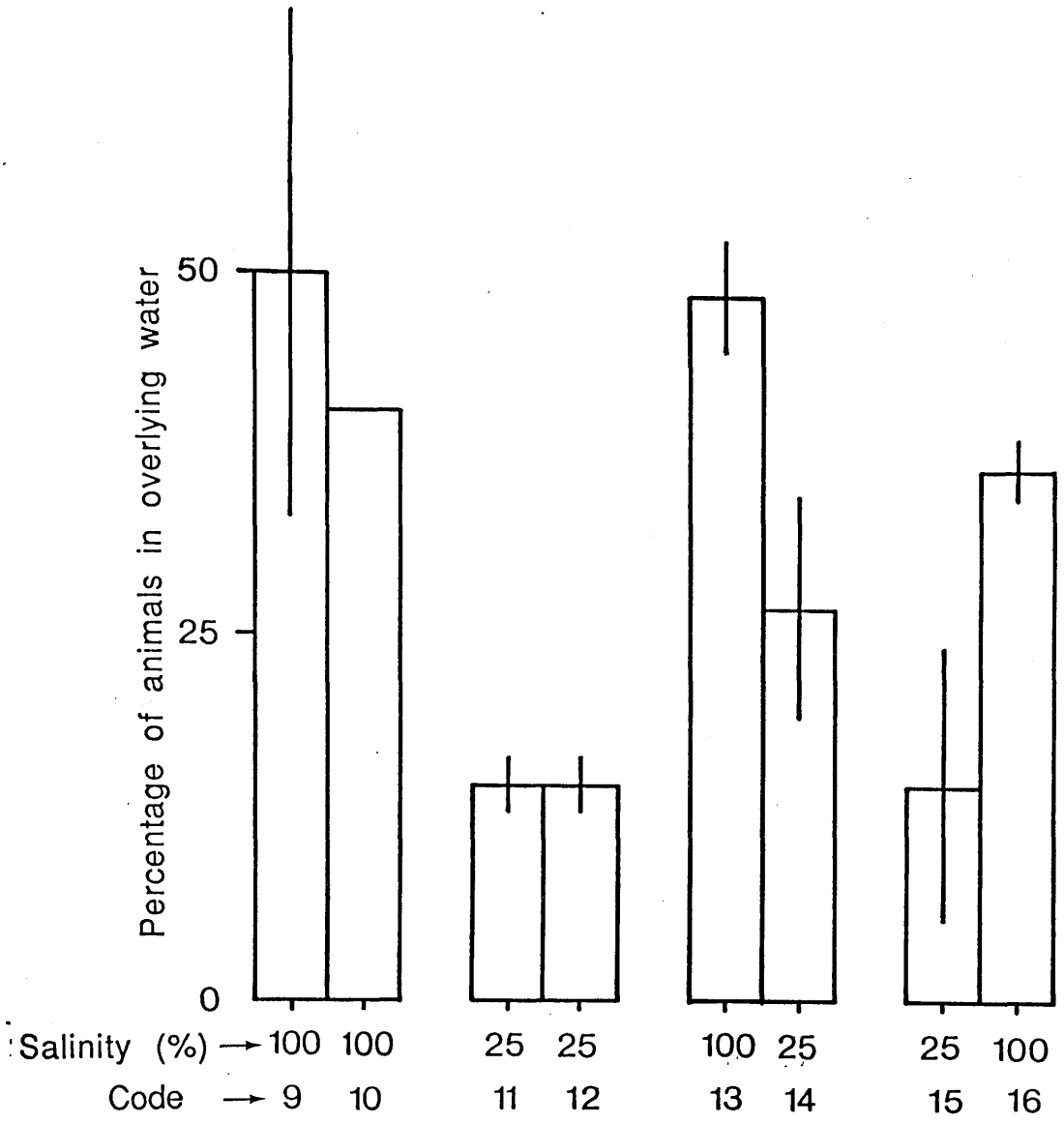


Figure 47. Experiment 6. Effect of different salinities on the behaviour of animals in dark. Percentage of animals in the overlying water for the two treatments in dark at salinities of 100% and 25%. The codes 9, 11, 13 and 15 represent the first treatment. The codes 10,12, 14 and 16 represent the second treatment. Each column is the mean of two replicates and standard deviations are shown as vertical lines.

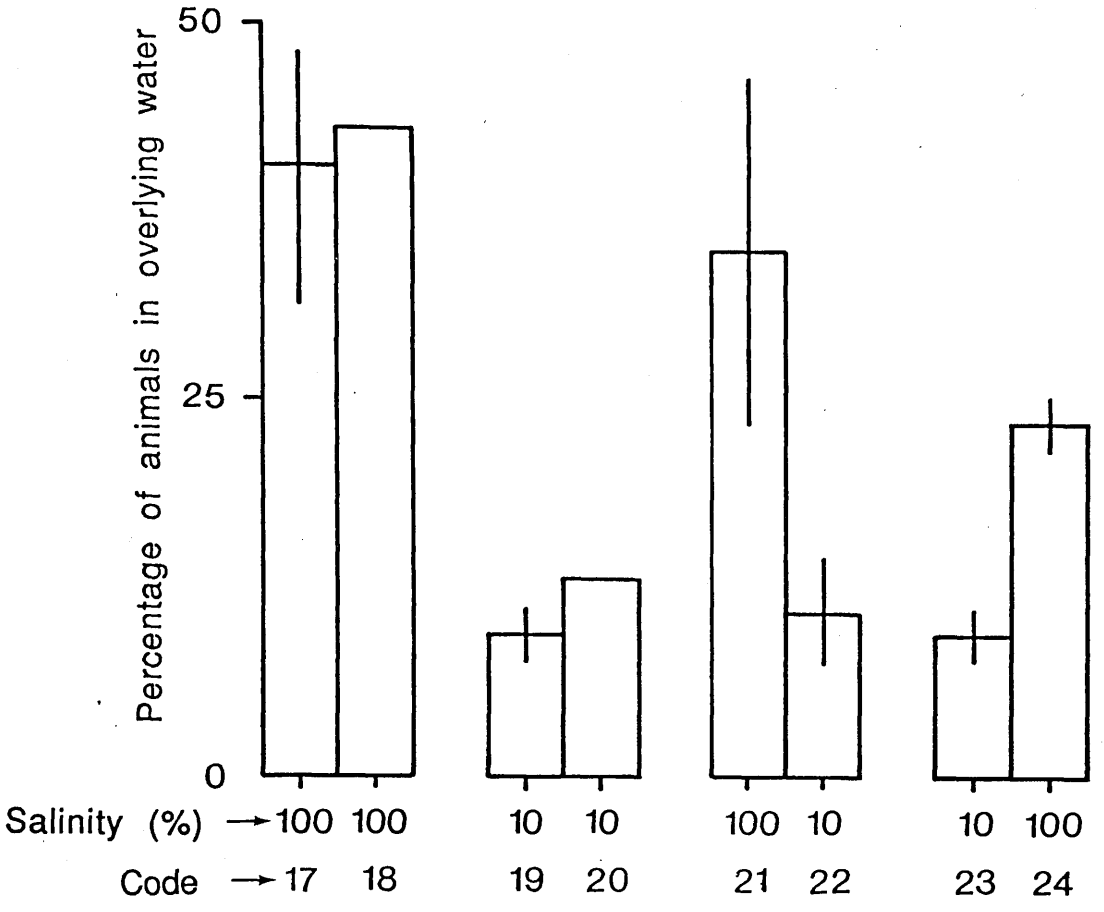


Figure 48. Experiment 6. Effect of different salinities on the behaviour of animals when the lights are switched off. Percentage of animals in the overlying water at salinities of 100% and 10% for the two treatments in dark. The codes 17, 19, 21 and 23 represent the first treatment. The codes 18, 20, 22 and 24 represent the second treatment. Each column is the mean of two replicates and standard deviations are shown as vertical lines.

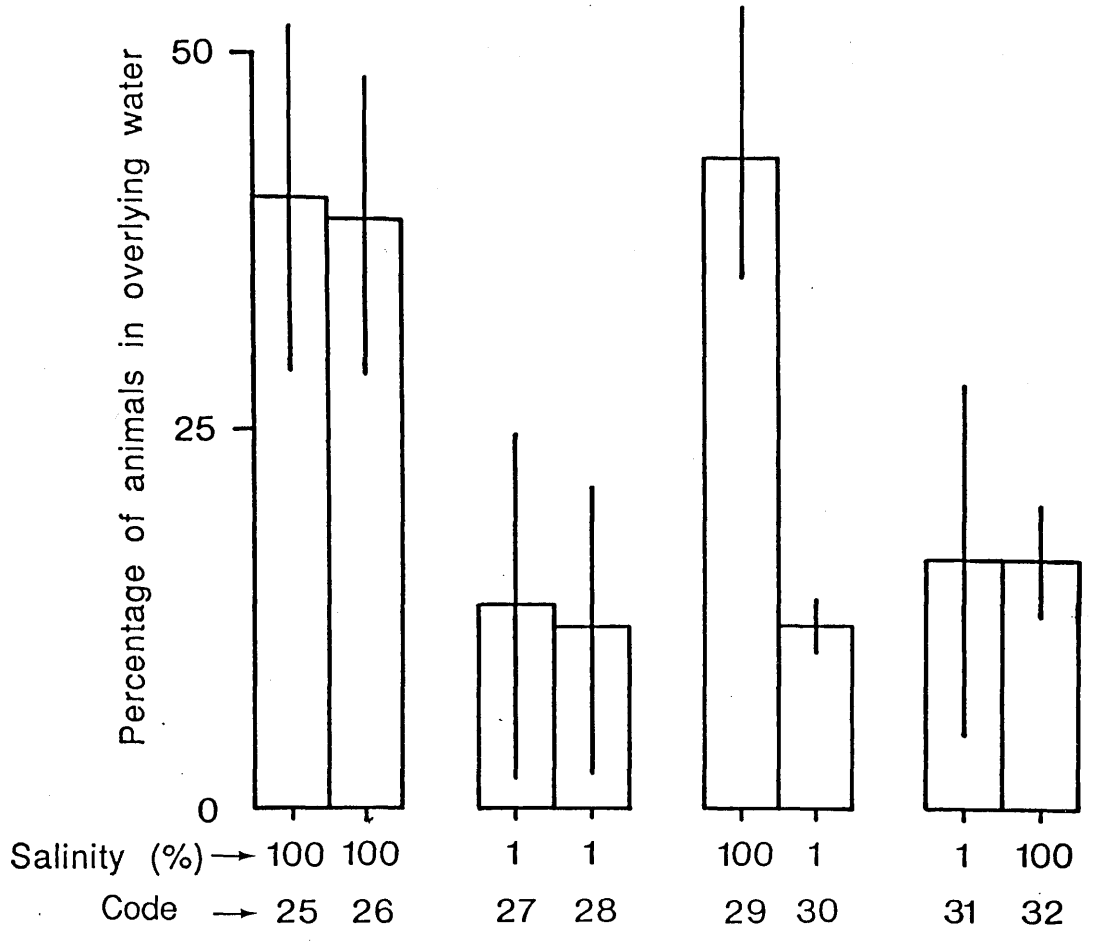


Figure 49. Experiment 6. Effect of different salinities on the behaviour of animals when the lights are switched off. Percentage of animals in the overlying water at salinities of 100% and 1% in dark. The codes 25, 27, 29 and 31 represent the first treatment. The codes 26, 28, 30 and 32 represent the second treatment. Each column is the mean of two replicates and standard deviations are shown as vertical lines.

Table 201. Experiment 6. 2x2 chisquares tests comparing the proportion of animals in the overlying water and in the sediment between replicates. No chisquare tests were applied when the replicates were identical (appendix table 235).

Comparison no.	Replicate compared (salinity)	Time after which supernatant was taken	X^2	d.f	Probability
1	100%/100%	3h	1.39	1	0.30>P>0.20
2	100%/100%	6h	0.95	1	0.50>P>0.30
3	50%/50%	3h	0.07	1	0.80>P>0.70
4	50%/50%	6h	1.03	1	0.50>P>0.30
5	100%/100%	3h	1.35	1	0.30>P>0.20
6	50%/50%	6h	0.06	1	0.90>P>0.80
7	50%/50%	3h	0.27	1	0.70>P>0.50
8	100%/100%	6h	0.92	1	0.50>P>0.30
9	100%/100%	3h	4.38	1	0.05>P>0.02
10	100%/100%	6h	0.00	—	—
11	25%/25%	3h	0.11	1	0.80>P>0.70
12	25%/25%	6h	0.11	1	0.80>P>0.70
13	100%/100%	3h	0.22	1	0.70>P>0.50
14	25%/25%	6h	1.10	1	0.30>P>0.20
15	25%/25%	3h	2.67	1	0.20>P>0.10
16	100%/100%	6h	0.06	1	0.90>P>0.80
17	100%/100%	3h	0.90	1	0.50>P>0.30
18	100%/100%	6h	0.00	—	—
19	10%/10%	3H	0.16	1	0.70>P>0.50
20	10%/10%	6H	0.00	—	—
21	100%/100%	3h	2.13	1	0.20>P>0.10
22	10%/10%	6h	0.56	1	0.50>P>0.30
23	10%/10%	3h	0.16	1	0.70>P>0.50
24	100%/100%	6H	0.08	1	0.80>P>0.70
25	100%/100%	3h	2.02	1	0.20>P>0.10
26	100%/100%	6h	1.42	1	0.30>P>0.20
27	1%/1%	3h	4.16	1	0.05>P>0.02
28	1%/1%	6h	3.16	1	0.10>P>0.05
29	100%/100%	3h	0.88	1	0.50>P>0.30
30	1%/1%	6h	0.13	1	0.80>P>0.70
31	1%/1%	3h	3.58	1	0.10>P>0.05
32	100%/100%	6h	0.40	1	0.70>P>0.50

100%/10% results in figure 48 are compared in table 202C (comparisons 9- 12), and 100%/1% results in figure 49 are compared in table 202D (comparisons 13-16).

The following statements can be made from the statistical analyses in table 202. Whenever the first and second salinities were the same there were no statistically significant differences between them (1, 100%/100%; 2, 50%/50%; 5, 100%/100%; 9, 100%/100%; 10, 10%/10%; 13, 100%/100%; 14, 1%/1%).

The results from the statistical comparisons when the first and second salinities are different, are interesting. When 100% was followed by 50%, or 50% by 100%, there is no significant difference between them (figure 46, codes 5, 6, 7, 8 and table 202 comparisons 3 and 4). This may be because the animals do not detect any difference between 50% and 100% seawater.

However, the equivalent comparisons between 100% and 25% and between 100% and 10% were all highly significant (figure 47, codes 13, 14, 15. 16 and table 202 comparisons 11 and 12). In both of these cases when the second salinity was lower, fewer animals came out in it (100%/25%; 100%/10%), while when the second salinity was higher more animals come out in it (25%/100%; 10%/100%) (figures 47,48).

The 100%/1% comparisons are different again. When 100% was followed by 1% (figure 49, codes 29, 30) fewer animals came out in 1% (table 202 comparison 15). In contrast, when 1% was followed by 100% (figure 49, codes 31, 32) the number of animals coming out in the two salinities was the same (table 202 comparison 16). This may be because animals were inactivated or even killed by 1% and so did not come into the overlying water when 1% was replaced by 100%.

EXPERIMENT (7)

Purpose of experiment: to test the effect of interaction between temperature and salinity on the behaviour of harpacticoids in the dark.

Table 202. Experiment 6. 2x2 chisquare tests testing differences between the ratios of animals in the overlying water and in the sediment between treatments. Sixteen 2x2 chisqaures were conducted between salinities of 100%, 50%, 25%, 10%, and 1% for the first treatment (after 3 hours) and the second treatment (after 6 hours).

	No. of comparison	Treatments compared	Code of treatment	Time of treatments compared	X^2	d.f	P
	1	100/100	1/2	3h/6h	0.71	1	0.50>P>0.30
A	2	50/50	3/4	3h/6h	0.30	1	0.70>P>0.50
	3	100/50	5/6	3h/6h	1.75	1	0.20>P>0.10
	4	50/100	7/8	3h/6h	1.97	1	0.20>P>0.10
	5	100/100	9/10	3h/6h	1.34	1	0.30>P>0.20
B	6	25/25	11/12	3h/6h	—	—	—
	7	100/25	13/14	3h/6h	7.35	1	0.01>P>0.001
	8	25/100	15/16	3h/6h	9.06	1	0.01>P>0.001
	9	100/100	17/18	3h/6h	0.11	1	0.80>P>0.70
C	10	10/10	19/20	3h/6h	0.60	1	0.50>P>0.30
	11	100/10	21/22	3h/6h	12.37	1	P<0.001
	12	10/100	23/24	3h/6h	4.97	1	0.05>P>0.02
	13	100/100	25/26	3h/6h	0.03	1	0.90>P>0.80
D	14	1/1	27/28	3h/6h	0.06	1	0.90>P>0.80
	15	100/1	29/30	3h/6h	17.85	1	P<0.001
	16	1/100	31/32	3h/6h	0.05	1	0.90>P>0.80

Date of experiment 22/9/1988

Materials and Methods:

Vials 1 to 54 were labelled 1-54, and vials 55-63 were labelled L1-L9 respectively. Vials L1 to L9 were termed controls because they were sacrificed before the lights were switched off. The plan of the experiment with the vial codes are shown in table 236. The 63 vials were placed into three containers as follows.

Vials 1-18 and vials L1, L2, and L3 were put into container A at 5°C. Seawater of 1% salinity was added to vial L1 and vials 1-6, seawater of salinity 25% was added to vial L2 and vials 7-12, and seawater of salinity 100% was added to vial L3 and vials 13-18.

Vials 19-36 and vials L4, L5, and L6 were put into container B at 10°C. Seawater of 1% salinity was added to vial L4 and vials 19-24, seawater of salinity 25% was added to vial L5 and vials 25-30, and seawater of salinity 100% was added to vial L6 and vials 31-36.

Vials 37-54 and vials L7, L8, and L9 were put into container C at 20°C. Seawater of 1% salinity was added to vial L7 and vials 37-42, seawater of salinity 25% was added to vial L8 and vial 43-48, seawater and of salinity 100% was added to vial L9 and vials 49-54.

Replicate vials were set up for the 300 minutes readings to allow careful statistical analysis of the differences between the three salinities and three temperatures (table 237). The three containers A, B and C were then placed in the phytotron room at 20°C. Containers A and B were filled with water which was maintained at 5°C (±1°C) and 10°C (±1°C) by carefully adding ice. Container C had no water in it and therefore remained at the temperature of the phytotron room, 20°C. The sediment in the vials in the containers therefore slowly became equilibrated to 5°C, 10°C and 20°C respectively. The vials were left for 6 hours for the temperatures to equilibrate

to 5°C, 10°C, and 20°C and to ensure that all the animals had burrowed into the sediment.

At the end of the 6 hour period, the supernatants were poured off vials L1, L2 and L3 from container A, L4, L5 and L6 from container B, and L7, L8 and L9 from container C. These nine supernatants represent the nine control vials, in other words zero time readings before the lights were switched off.

Containers A and B were then transferred to 5°C and 10°C rooms respectively. Container C was left in the phytotron room at 20°C.

The lights in the phytotron room (20°C) were then switched off immediately, the lights in the 10°C room were switched off 10 minutes later, and the lights in the 5°C room 10 minutes later again. This time-staggering allowed me to move from one room to another and to remove the supernatants from the vials at the same time after the lights were switched off in each room, as the experiment progressed.

The vials in each room (5°C, 10°C, 20°C) were then removed at 0 min, 20 min, 60 min, 120 min, 180 min, and 300 min after the lights were switched off (see appendix table 236, experiment codes pp. 326).

Results:

The original data of the experiment are shown in appendix 3 table 237. pp. 334. The results of the experiment are plotted in figures 50, 51, and 52. These show that at all three temperatures animals emerged into the overlying water most quickly in the highest salinity (100%), at intermediate rate in the medium salinity (25%), and most slowly in the lowest salinity (1%). The highest percentages of animals in the overlying water in the three salinities were found at 10°C (figure 51), the medium at 20°C (figure 52), and the lowest percentages at 5°C (figure 50). The times taken for 10%, 25%, 50%, 75%, and 90% of the animals to emerge in the three salinities (1%, 25%, 100%) for the three temperatures (5°C, 10°C, 20°C) are shown in table 203.

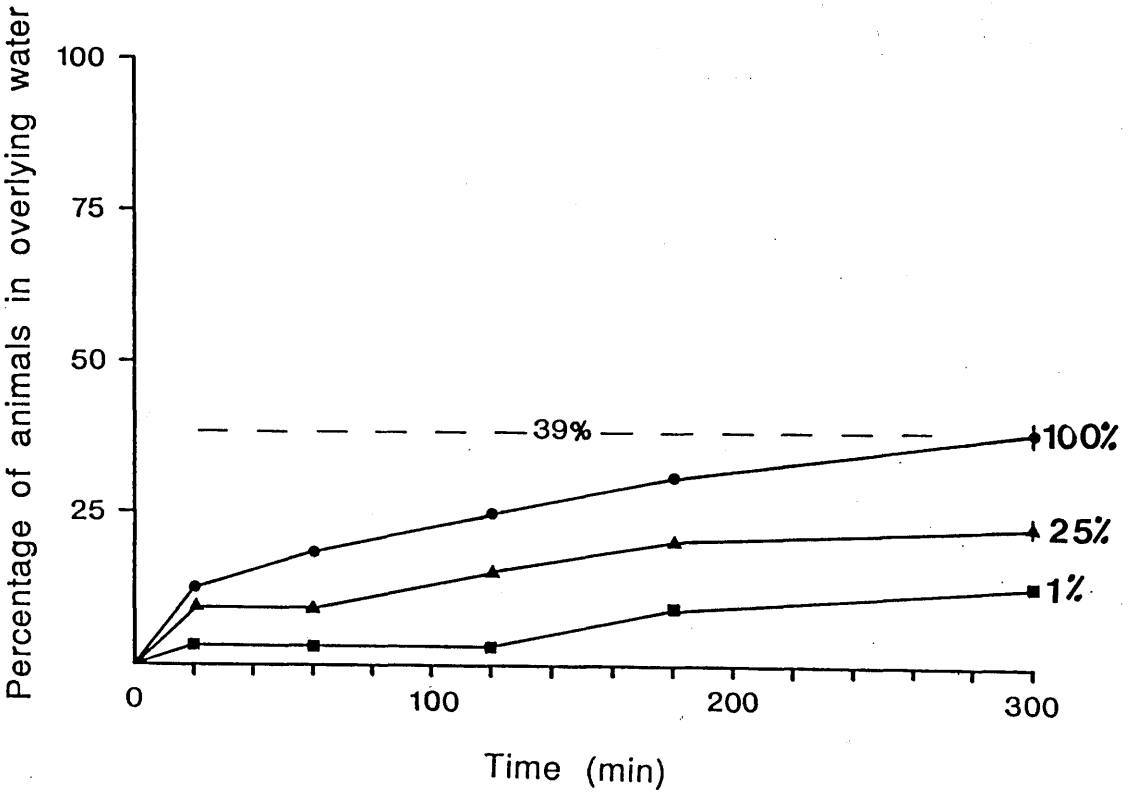


Figure 50. Experiment 7. Effect of interaction between temperature and salinity on the behaviour of copepods when the lights are switched off. Percentage of animals in the overlying water at 5°C and at salinities of 1%, 25%, and 100%. At 300 min each point is the mean of two replicates. Standard deviations are not shown because they were too small.

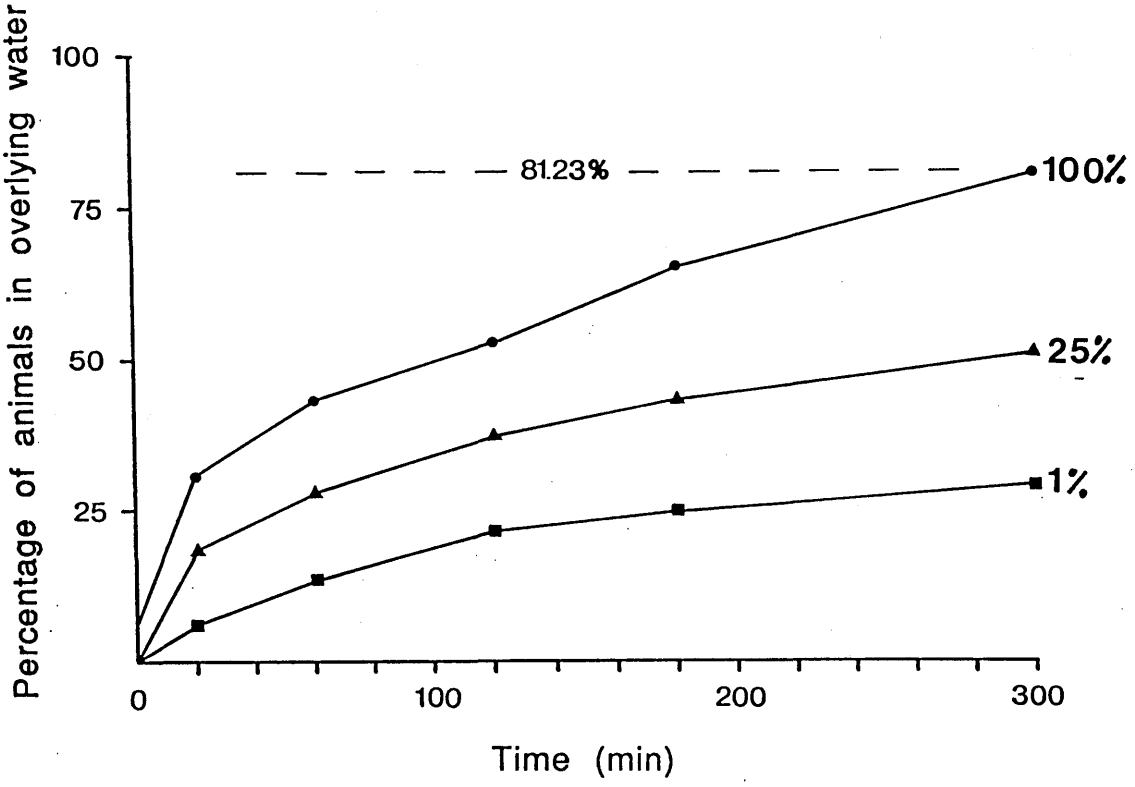


Figure 51. Experiment 7. Effect of interaction between temperature and salinity on the behaviour of copepods when the lights are switched off. Percentage of animals in the overlying water at 10°C and at salinities of 1%, 25%, and 100%. At 300 min, each point is the mean of two replicates. Standard deviations are not shown because they were too small.

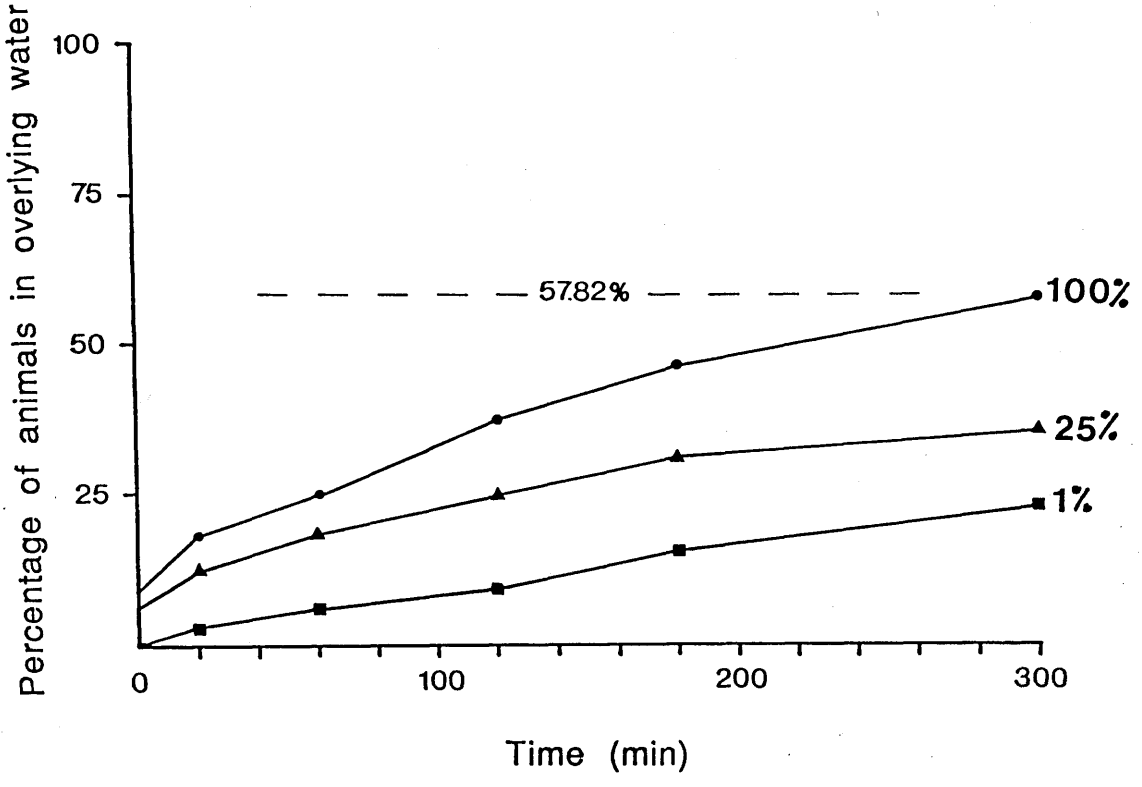


Figure 52. Experiment 7. Effect of interaction between temperature and salinity on the behaviour of copepods when the light are switched off. Percentage of animals in the overlying water at 20°C and at salinities of 1%, 25%, and 100%. At 300 min, each point is the mean of replicates. Standard deviations are not shown because they were too small.

Table 203. Experiment 7. Time taken by animals to respond to different temperatures at salinities of 1%, 25%, and 100%. Percentages and equivalent times from figures 50, 51, and 52.

% Response	Time (min)								
	5°C			10°C			20°C		
	Salinity (%)			Salinity (%)			Salinity (%)		
	1	25	100	1	25	100	1	25	100
10%	198	67	16	41	11	3	126	12.5	2.5
25%	>300	>300	120	180	46.5	15	>300	120	60
50%	>300	>300	>300	>300	277	100	>300	>300	217
75%	>300	>300	>300	>300	>300	253	>300	>300	>300
90%	>300	>300	>300	>300	>300	>300	>300	>300	>300

These data were obtained from figures 50, 51, and 52.

Table 203 illustrates the highly significant interactions between temperature and salinity. For example, at 5°C and salinities of 1%, 25% and 100%, 10% of the animals had emerged within 198 min, 67 min and 16 min respectively. In contrast, the equivalent times for temperatures 10°C and 20°C were 41 min, 11 min, and 3 min, and 126 min, 12.5 min and 2.5 min respectively.

Statistical analysis of results:

The original data were statistically analysed using chisquare to determine the effect of interaction between salinity and temperature on the behaviour of harpacticoid copepods. The test was applied at 20 minutes and 300 minutes between three salinities at each temperature and between three temperatures at each salinity. At 300 minutes I have assumed that there were no significant differences between the replicates. Inspection of the data in appendix table 237 shows this assumption is justified because the replicates readings are almost identical. I have therefore summed pair of the replicates in order to apply chisquare tests.

1 - Comparisons between salinities:

i - 20 minutes comparisons: Twelve comparisons between three salinities and between pairs of salinities were conducted using chisquared (2x3 and 2x2) at 5°C, 10°C, and 20°C (table 204). The 2x3 chisquares compared the ratio numbers in overlying water: numbers in sediment at the three salinities. The 2x2 chisquares compared the same ratio between pairs of salinities. Only three of the 12 comparisons were significant: 10°C, 100%/25%/1% and 100%/1%, and 20°C, 100%/1%.

ii - 300 minutes comparisons: Twelve chisquared tests were applied to the summed replicate data (see above). These consisted of three 2x3 chisquares comparing the ratio number in overlying water: number in sediment at the three salinities, followed by nine 2x2 chisquares comparing the same ratio between pairs of salinities. All three

2x3 chisquared tests were significant, indicating that there was an overall difference between the three salinities at each temperature (table 205).

When pairs of salinities were compared, all 3 100%/25% and 2 100%/1% comparisons at the 3 temperatures were significant. However, only one out of the 3 25%/1% tests was significant (10°C).

2 - Comparisons between three temperatures:

i - 20 minutes comparisons: Twelve comparisons between the three temperatures and between pairs of temperatures were conducted using chisquared (2x3 and 2x2) tests at 100%, 25% and 1% (table 206). As previously, the 2x3 chisquares compared the ratio of numbers in overlying water: numbers in sediment at the three temperatures. The 2x2 chisquares compared the same ratio between pairs of temperatures. None of the 12 comparisons were significant.

ii - 300 minutes comparisons: Twelve chisquares (table 207) were applied between the three temperatures and between pairs of temperatures at 100%, 25% and 1% salinity. The 2x3 chisquares compared the ratio numbers in overlying water: numbers in sediment between the three temperatures at each salinity. The 2x2 chisquares compared the same ratio between pairs of temperatures.

Two of the three 2x3 chisquares were significant. These were at salinities of 100% and 25%. All three 2x2 chisquares at 100% salinity were significant. Only one of the 2x2 chisquares at 25% salinity was significant (5°C/10°C) and one was neither significant nor not significant (10°C/20°C). Two out of the three 2x2 chisquares at 1% salinity were not significant. These were between 5°C and 20°C, and 10°C and 20°C.

Table 204. Experiment 7. 20 min results. 2x3 and 2x2 chisquare tests comparing the proportions of animals in the overlying water and in the sediment between the three salinities (100%, 25%, 1%) at 5°C, 10°C, and 20°C in dark.

Temperature (°C)	No. of comparison	Salinities compared	Contingency table	X^2	d.f	P
5	1	100%/25%/1%	2x3	1.91	2	0.50>P>0.40
	2	100%/25%	2x2	1.16	1	0.70>P>0.50
	3	100%/1%	2x2	1.95	1	0.20>P>0.10
	4	25%/1%	2x2	1.07	1	0.50>P>0.30
10	5	100%/25%/1%	2x3	6.56	2	0.05>P>0.02
	6	100%/25%	2x2	1.33	1	0.70>P>0.50
	7	100%/1%	2x2	6.56	1	0.05>P>0.02
	8	25%/1%	2x2	2.29	1	0.20>P>0.10
20	9	100%/25%/1%	2x3	3.90	2	0.20>P>0.10
	10	100%/25%	2x2	0.47	1	0.90>P>0.80
	11	100%/1%	2x2	4.01	1	0.05>P>0.02
	12	25%/1%	2x2	1.95	1	0.20>P>0.10

Table 205. Experiment 7. 300 min results. 2x3 and 2x2 chisquare tests comparing the proportions of animals in the overlying water and in the sediment between the three salinities (100%, 25%, 1%) at 5°C, 10°C, and 20°C in dark.

Temperature (°C)	No. of comparison	Salinities compared	Contingency table	X^2	d.f	P
5	1	100%/25%/1%	2x3	10.74	2	0.01>P>0.001
	2	100%/25%	2x2	3.64	1	0.10>P>0.05
	3	100%/1%	2x2	10.25	1	0.01>P>0.001
	4	25%/1%	2x2	1.85	1	0.20>P>0.10
10	5	100%/25%/1%	2x3	34.53	2	P<0.001
	6	100%/25%	2x2	12.64	1	P<0.001
	7	100%/1%	2x2	34.44	1	P<0.001
	8	25%/1%	2x2	6.35	1	0.02>P>0.01
20	9	100%/25%/1%	2x3	16.28	2	P<0.001
	10	100%/25%	2x2	6.15	1	0.02>P>0.01
	11	100%/1%	2x2	15.68	1	P<0.001
	12	25%/1%	2x2	2.40	1	0.20>P>0.10

Table 206. Experiment 7. 20 min results. 2x3 and 2x2 chisquare tests comparing the proportions of animals in the overlying water and in the sediment between three temperatures (5°C, 10°C, 20°C) at salinities of 100%, 25%, and 1% in dark.

Salinity %	No. of comparison	Temperature compared	Contingency table	X^2	d.f	P
100	1	5C/10C/20C	2x3	3.54	2	0.20>P>0.10
	2	5C/10C	2x2	3.29	1	0.10>P>0.05
	3	5C/20C	2x2	0.47	1	0.50>P>0.30
	4	10C/20C	2x2	1.33	1	0.30>P>0.20
25	5	5C/10C/20C	2x3	1.25	2	0.70>P>0.50
	6	5C/10C	2x2	1.16	1	0.30>P>0.20
	7	5C/20C	2x2	0.16	1	0.70>P>0.50
	8	10C/20C	2x2	0.47	1	0.50>P>0.30
1	9	5C/10C/20	2x3	0.52	2	0.80>P>0.70
	10	5C/10C	2x2	0.35	1	0.70>P>0.50
	11	5C/20C	2x2	—	—	—
	12	10C/20C	2x2	0.35	1	0.70>P>0.50

Table 207. Experiment 7. 300 min results. 2x3 and 2x2 chisquare tests comparing the proportions of animals in the overlying water and in the sediment between three temperatures (5°C, 10°C, 20°C) at salinities of 100%, 25%, and 1% in dark.

Salinity %	No. of comparison	Temperature compared	Contingency table	X^2	d.f	P
100	1	5C/10C/20C	2x3	23.71	2	P<0.001
	2	5C/10C	2x2	23.76	1	P<0.001
	3	5C/20C	2x2	4.50	1	0.05>P>0.02
	4	10C/20C	2x2	8.30	1	0.01>P>0.001
25	5	5C/10C/20C	2x3	10.91	2	0.01>P>0.001
	6	5C/10C	2x2	10.80	1	0.01>P>0.001
	7	5C/20C	2x2	2.40	1	0.20>P>0.10
	8	10C/20C	2x2	3.17	1	0.10>P>0.05
1	9	5C/10C/20C	2x3	4.56	2	0.20>P>0.10
	10	5C/10	2x2	4.57	1	0.05>P>0.02
	11	5C/20C	2x2	1.85	1	0.20>P>0.10
	12	10C/20C	2x2	0.64	1	0.90>P>0.80

DISCUSSION

My discussion of the behavioural experiments consists of the following parts. First, I briefly review the literature on the behavioural responses of macrobenthic invertebrates to environmental variables such as light, temperature and salinity. I then discuss recent work on the behaviour of meiofauna in relation to dispersal and water flow and the emergence of meiofauna from sediments, and relate this work to my own experiments. Finally I consider in some detail the important ecological implications of my behavioural experiments and how the results of these experiments relate to the ecological survey work conducted in section 3.

(I) Behavioural responses of macrobenthic invertebrates to environmental variables.

There have been a large number of field and laboratory experiments conducted on the behaviour of benthic animals in response to environmental factors (Wieser, 1959; Meadows, 1964a,b,c, Jansson, 1967; Morgans, 1970; Ackefros, 1971: Gamble, 1971; Markel , 1971: Trueman, 1971; Meadows and Campbell, 1972; Marsden , 1973; Hauspie and Polk, 1973; Bell et al, 1978; Alldredge and King, 1980; Thistle, 1980; Berghe and Bergmans, 1981: Hagerman and Rieger, 1981; Ohlhorst, 1982; Rieper, 1982; Coull and Wells, 1983; Fleeger, 1983; Fleeger et al, 1984; Pederson and Capuzzo, 1984; Sebens and Koehl, 1984; Sogard, 1984; Gee et al, 1985; Nilsson, 1987; Gill and Poulet, 1988; Robert et al, 1988; Varon and Thistle, 1988).

One of the important environmental factors influencing the behavioural responses of benthic animals is light (Holmes, 1901; Jennings, 1907; Bauer, 1913; Allee, 1927; Fraenkel, 1927; Hayes, 1927; Russell, 1927; Spooner, 1933; Russell, 1936; Cushing, 1951; Williamson, 1951b; Lewis, 1959; Enright, 1963; Thorson, 1964; Gray, 1966a; Meadows and Reid, 1966; Meadows, 1967; McLusky, 1968a,b; Oviatt, 1969; Fincham, 1970; Jones and Nalyor, 1970; Salazar, 1970; Gidney, 1971; Meadows and Campbell, 1972).

Temperature is another factor which can have major effects on the behaviour of benthic invertebrates (Arey and Grozier, 1919; Lewis, 1959; Jansson, 1968; Gray, 1965; Ganning and Wulff, 1966, Ganning, 1967; Aldrich et al, 1968; Kenneday and Mihursky, 1971; Meadows and Campbell, 1972).

Marsden (1973) studied the influence of salinity and temperature on the survival and behaviour of the isopod Sphaeroma rugicauda from a salt-marsh habitat. The animals were collected from Seasalter, North Kent coast, England. They were stored in polythene tanks with aerators and acclimated to constant temperatures of 5°C, 10°C, 15°C, and 20°C; juveniles, however, were, acclimated to 5°C and 15°C. The responses of adults acclimated to temperatures of 5°C and 20°C and then measured in a temperature gradient between 18°C and 34°C. This showed that adults and juveniles had a preference for low temperatures.

Salinity is another important variable affecting the behaviour of benthic invertebrates (Barnes, 1932,1934,1938; Gross, 1955,1957; Teal, 1958; Capstick, 1959; Lagerspetz and Mattila, 1961; Gray, 1965; Ganning, 1967; McLusky, 1967; Foster, 1969; Ackefors, 1971; McLusky, 1970; Harris, 1972; Meadows and Campbell, 1972; and Finney, 1979). In an experimental study McLusky (1970) found that in salinities below 10% Corophium volutator chose the higher salinity available. Between 10-30% no significant choice was observed. In the salinity range 30-40%, the animals significantly chose the lower salinity. However, the preferred range of salinity was 10-30%.

Different combinations of temperature and salinity have a major effect on the behaviour of the amphipod Corophium volutator. This was tested by Meadows and Ruagh (1981) who studied the combined effect of temperature and salinity on the responses of Corophium. These authors conducted 3 experimental series: (1) constant salinity with temperature choice; (2) constant temperature with salinity choice; (3) A combination of temperature and salinity choices. Optimal salinity was preferred to

low or high salinities at each temperature. Optimal temperature was always preferred to low temperature at each salinity, but this was not true when the optimal temperature was offered with the high temperature. Temperature preferences overrode salinity preferences when both varied. Temperature discrimination decreased with increasing salinity, while salinity discrimination was unaffected by temperature. Meadows and Ruagh concluded that there were complex interactions between temperature and salinity affecting the activity of animals.

(II) Behaviour of meiofauna, and relation to my behavioural experiments.

Less work has been conducted specifically on the behaviour of meiofauna although there have been a number of field experiments. Some of these latter have been carried out on the emergence of meiobenthos from sediment and therefore are directly relevant to my work (Bell and Sherman, 1980; Hagerman and Rieper, 1981; Palmer and Gust, 1985; Woods and Tietjen, 1985; Hicks, 1986; Fegley, 1987; Walters, 1988).

Bell and Sherman (1980) carried out a field investigation on meiofaunal dipersal. They constructed a sampler of 236 ml (10 cm high x 6.5 cm diameter). One end of the sampler was removed. A 2.6 cm hole was punched in the unremoved end and a 2.5 cm inner diameter plastic core (8 cm in length) was inserted through this opening, extending 1 cm from the lower end of the container. A core with capillary tubing sealed the top end of the plastic core inside the sampler. Dry ice was packed around the plastic core inside the sampler and the whole sampling device was placed into an insulated cooler for use in field sampling. The sampling device was carefully lowered into the overlying water (6 cm deep) and the upper 1 cm of sediment was taken with dry ice. The contents of the plastic core were frozen quickly. In the laboratory, the dry ice slurry was discarded and the frozen sediment and water were extruded from the sampler. The frozen cores were placed in Whirlpaks^{TM} (special container) and stored in a freezer (0°C). The cores were removed from the freezer and carefully

fractionated into 2-3 segments based on the following characteristics: Fraction 1-clear; overlying water: Fraction 2-cloudy resuspended flocculent layer: Fraction 3-top 1 cm sediment. The results of this experiment showed that nematodes and copepods were the most abundant meiofauna taxa recorded in each core fraction, although juvenile bivalves and polychaetes were occasionally found in sediment core segments. Nematodes dominated the sediment fraction 3 and were found in very low percentages in the other fractions. Fractions 1 and 2 together contained 48% of adult copepods and 66.5% of nauplii found in the three fractions. Bell and Sherman took two samples during the day and two at night. The two night samples had more copepods and nauplii in fraction 1 and 2 (overlying water + suspended sediment) than the two day samples. This implies that copepods and nauplii emerge from sediments more frequently at night, although Bell and Sherman do not appear to have noticed this effect in their data. This result agrees closely with my own behavioural experiments in the laboratory which show the same effect. The ecological implications of this work for dispersal are discussed below.

Hagerman and Rieger (1981) studied the dispersal of benthic meiofauna by wave and current action in North Carolina, USA. Their results showed that benthic meiofauna were found in sediment traps which were moored 1.5 m above the subtidal bottom in Bogue Sound. The interstitial species were estimated to account for 10-30% of the sediment trap fluxes of both nematodes and turbellarians. Currents in Bogue Sound appear capable of transporting suspended meiofauna up to 10km per day. This work shows that meiofaunal movement into the water column from the sediment can be an important dispersal mechanism. However, Hagerman and Rieger's sediment traps were set for 9 weeks, and so no day/night (light/dark) effects would have been noted such as those I demonstrated in my behavioural experiments.

Palmer and Gust (1985) studied dispersal of meiofauna in a turbulent tidal creek in the North Inlet Estuary, Georgetown, South Carolina, USA. They found that the

transport of meiofauna was identified to be primarily a passive process resulting from mechanical removal due to current scour. Drifting meiofauna included interstitial, burrowing, and epibenthic species. The suspended meiofauna and sediment were well-mixed within the water column suggesting that behavioural control over water column dispersal was limited. They concluded that the abundance of meiofauna in the water column was determined primarily by the magnitude of the water velocity near the sediment.

Hicks (1986) studied the abundance and species composition of meiobenthic copepods from blades and sediments under the blades of the seagrass Zostera capricorni compared with adjacent unvegetated sediment. He was able to show that the abundance of copepods was higher on the blades and beneath the seagrass than in the nearby sediment. Species richness was nearly double on the blades than on the sediment beneath the blades or nearby. He used experimental emergence traps to show that a large proportion of the copepods swim in the water column from the Zostera seabed at high tide and that there was no difference between the numbers emerging during the day and night. In my laboratory experiments harpacticoids only emerged at very low light intensities or in total darkness. The copepods studied in the field by Hicks (1986) clearly swam during the day and night at high tide. This strongly suggests that the behavioural responses of the meiobenthic species living in the seagrass and the sediment under the seagrass in Hick's study are different from the behavioural responses of the species living in sediments at Ardmore. A detailed experimental analysis of species from the two contrasting habitats would therefore to be very rewarding.

Palmer (1986) conducted a flume experiment testing the water flow and vertical distribution of meiofauna in the North Inlet Estuary, near Georgetown, USA. The experiment was conducted in a recirculating saltwater flume to determine if flow influences the vertical distribution of meiofauna. The samples were collected from a

mudflat (40 um median grain size). A plexiglass flume (2.4 m long x 30 cm wide x 30 cm deep) was built. Seawater from the estuary flows from a 200 gal headtank, enters a collimeter at the channel entrance and exits the flume through a louvered gate and is recirculated to the headtank. Boxcores (20 x 20 cm and 15 cm deep) were collected in the field and inserted 1.5 m downstream from the inflow so that the sediment surface was flush. All boxcores were collected just after the mudflat was exposed at low tide so there was no water covering the surface. The flume was slowly filled with water and the boxcores allowed at least 3 hours equilibration. In the no flow treatment, a trickle of water through the channel prevented stagnation. In the flow treatment ($u \simeq 9$ cm s^{-1}), the current did not exceed critical erosion velocity for the sediment. After 3 hours in the flume, the boxcores were sampled by taking smaller sediments cores and sectioning these cores vertically in 2 mm intervals. The results showed that there was no statistical difference in the number of copepods in the top 2 mm of sediment between the flow and no flow treatments. The numbers of nematodes and foraminiferans within the top 2 mm of sediment was significantly lower in the flow treatment than in the no flow treatments. This is an important result, because it means that on the shore the lateral currents caused by the ebb and flow of the tides are unlikely to significantly effect the emergence of harpacticoids from the sediment. I did not test the effects of water current in my experiments, but Palmer's work implies that they are unlikely to be important (but see below Armonies 1988c).

Fegley (1987) examined the response of meiofauna to near-bottom current speeds, and the effects of the current on the depth distribution of these animals on an intertidal sandflat located in Bouge Sound, North Carolina, USA. He used two side weirs constructed from tin sheets (0.5 cm thick x 49 cm high x 76 cm long) attached by plastic coated copper wires to three 70 cm long steel rods. Each side was pushed vertically into the sediments until the bottom edge of the metal sheet extended 5 cm below the sediment surface. Two designs of weir were used. In the first, each of the

two sides was bent and placed so that the upper current opening was 60 cm wide, and the down current exit was 20 cm wide. This design funnelled flow through a bottle neck thus increasing the flow speed near the weir exit. His results showed that there was some evidence that nematodes were less abundant and ciliates more abundant in the top 0.5 cm of the increased flow treatment. This may show that nematodes responded to the fast surface current speeds by moving deeper into the sediment, while ciliates manage to remain near the surface even as sediment erodes. Harpacticoid copepods were not abundant in the sediments studied by Fegley and so this paper, although of general interest, is not directly relevant to my own laboratory experiments on harpacticoids

Walters (1988) studied diel migration of sediment-associated meiofauna in subtropical sand and seagrass habitats at the mouth of Tampa Bay, Florida, USA. He demonstrated that the diel timing of maximum harpacticoid copepod migration coincided with sunset. Differences in the active migration of meiobenthic organisms were attributed to differences in species composition and sediment, and the presence of structure and changes in light levels. This work is interesting, because my own experiments show that harpacticoids only emerge in very low light intensities and in total darkness. Perhaps the low light intensities in my experiments approximate to the light levels at sunset in Walters 1988 study.

Palmer (1984) conducted a series of behavioural experiments on intertidal meiofauna in the North Inlet Estuary, South Carolina. His findings showed that meiobenthos do not regularly emerge from the sediment suggesting that drift of meiobenthos is due to erosion. This apparently contradicts the results of my own laboratory experiments. However, Palmer did not test whether animals emerged at night , so there may in fact be no contradiction. Palmer concluded that the behaviour of animals can, however, influence their susceptability to suspension. Fauna most active on the sediment surface (primarily harpacticoid copepods) were most susceptible to passive suspension. Other experiments tested the effects of time of day

(light vs dark) and tide (high, low, flow) on the number of animals active on the sediment surface. Results of these showed that animals frequenting the sediment surface did so only in the absence of currents. Animals began to burrow as soon as flow increased. If they were suspended, copepods except Microarthridion littorale and turbellarians quickly oriented and swam back towards the sediment surface using geotactic and phototactic cues.

Gray (1968) showed that the vertical distribution of Leptastacus constrictus (harpacticoida copepoda) in sand was found to be determined by a negative geotactic response and a photonegative response. Experiments showed that more animals burrow into sediments illuminated from above than into sediments in semidarkness. These results can broadly be interpretated as substantiating my own behavioural experiments because in my experiments animals stay in the sediment and do not emerge at high light intensities.

Giere (1979) described an experimental apparatus which can be used to test the behavioural responses of meiobenthos to temperature and salinity combinations, but he did not test any animals in his apparatus. His statistical results showed that the apparatus would be sufficiently reliable for this kind of experiment.

Detailed laboratory experiments on the emergence of meiofauna from sediments have only been conducted by Armonies (1988a,b,c), in papers that were published after I completed my own behavioural studies on emergence. Armonies's third paper (1988c), although not directly related to my work, is important because his results seem to contradict those of Palmer (1986) (see above). Palmer states that water does not affect the number of copepods in the top 2 mm of sediment, while Armonies states that current speeds of 1 to 10 $cm.s^{-1}$ significantly reduce the number of copepods actively enterning the water column from the sediment. Carefully controlled comparisons will be needed to resolve this apparent disagreement.

Armonies first two papers (1988a,b) are very exciting because they substantiate many of my own discoveries. In his first paper (1988a) Armonies showed that many more copepods, ostracods, and platyhelminthes emerged from sediments in the dark than in the light. These results confirm the results of my first two experiments which show the marked increase in numbers of harpacticoids emerging from sediments under conditions of darkness, and the marked decrease in the numbers in the overlying water under conditions of illumination.

In his second paper (1988b) Armonies tested the effects of light gradients, temperature gradients and the salinity of the overlying and interstitial water on the emergence of meiofauna from sediments, and his results are highly relevant to my own work. The effects of light gradients on copepod emergence in figure 1 p. 280 of Armonies (1988b) show a strong similarity in broad trends with the results of my third experiment in which I tested three different light intensities. Figure 1 p. 280 in Armonies (1988b) shows similar trends in ostracods, platyhelminthes and veliger larvae, so the response seems to be a general one and exhibited by many meiofaunal groups.

The results of Armonies (1988b) experiments on the effects of temperature gradients on meiofaunal emergence (figure 2 p. 280 loc. cit) are slightly different from the results of my 4th experiment which also tested temperature. We both agree that in the lowest temperature (5°C) the fewest copepods emerge. However, Armonies results show that more copepods emerge at 20°C than 15°C while my own results show the reverse. Perhaps different species of harpacticoids are involved.

Armonies (1988b) then tested the effects of increased salinity in the overlying water (his experiment IV) and decreased and increased salinity in the interstitial water (his experiment V). The results of the increased salinity parts of these experiments can not be compared with my experiments because I did not test the effect of increased salinity (40%, 50%). However, the effects of decreased salinity on copepod

emergence illustrated in Armonies 1988b figure 5 p. 283 show clear similarities to the results of my experiment 5 (figure 45 p. 260 in this thesis). This is important because it means that the effect is general to many different populations of harpacticoids which will presumbaly be made up of different species.

Armonies (1988a,b,c) did not test the combined effects of temperature and salinity in any of his papers, and so it is not possible to compare the results of my experiment which tested these effects, with any of Armonies work. The ecological implications of my discovery that reduced salinity has a greater effect than temperature are discussed below.

I was not able to identify the species of harpacticoids which emerged from the sediment into the overlying water in my experiments because I did not have enough time. Therefore nothing can be said about any species differences.

(III) Ecological implications of experiments:

The results of my experiments have highly significant implications for various aspects of the ecology of sediment dwelling harpacticoid copepods on sandy intertidal beaches such is that at Ardmore Point. My results show conclusively that harpacticoids collected from low tide sediments regularly migrate out of and back into the sediment. This will happen whenever the tide covers the sediment under conditions of darkness. However, animals will not migrate out when the tide covers the sediment during daylight. This means that on average animals will conduct vertical migrations on about half of the tides which cover the sediment in which they are living, and this must represent an important dispersal mechanism for those species that show this type of behaviour. In fact several authors have shown by field studies that this is an important meiofaunal dispersal mechanism (Bell and Sherman, 1980; Hagerman and Rieger, 1981; Palmer, 1984; Palmer and Gust, 1985) and these papers are discussed above. At Ardmore, animals migrating out of the sediment are likely to

be carried by the rising and falling tide to other parts of the beach before burrowing again. Clearly, emergence and hence dispersal at night is sensible if the predators of harpacticoids catch them by recognising them visually. For example, juvenile flat fish which are known to occur at Ardmore may will recognise harpacticoids visually and eat them, and this may also be true of gobies. On the other hand Sagitta which is a carnivorous planktonic chaetognath that occurs in night plankton hauls at Ardmore, recognises its prey by a vibration sense and hence will probably feed at night as well as during the day.

The different responses of harpacticoids to salinity and temperature are interesting. Assuming that all species of harpacticoids on the beach behave in the same general manner, an assumption which may not be totally justified, their responses suggest the following. Since animals do not migrate into the overlying water when salinity is low in the behavioural experiments, animals on the beach will be less likely to migrate into the overlying water when the salinity of this overlying water is low. This means that there will be reduced vertical migration and hence reduced dispersal after heavy rains and when there is considerable run-off from the land. This is more likely to occur in late autumn, winter and early spring.

The results of the behavioural experiments on temperature show that animals migrate vertically into the overlying water most frequently at 10°C, less so at 20°C and least at 5°C. On the beach, therefore, vertical migration and hence dispersal will be greater in spring and autumn when the temperatures are about 10°C, less during summer when the temperatures reach 20°C or more, and least of all during winter when temperatures fall below 5°C.

In the experiments testing the combined effects of temperature and salinity, reduced salinity proved to be more significant than temperature, and hence salinity effects in the field will be more important than temperature effects. This suggests that heavy rainfall increased land run-off and the consequent lowered salinities, will be more

important than high and low temperatures in reducing vertical migration from sediments and hence dispersal in the field.

Temperature and salinity fluctuate more widely towards high tide than they do at low tide, because it is here that the heating effect of the sun, the cooling effect of winter snow, and the importance of land run-off are likely to be highest. Hence the effects of low salinity and high and low temperature in reducing vertical migration are likely to be of higher significance to populations of harpacticoids living further up the beach.

Vertical migration is clearly a potentially important dispersal mechanism, and is likely to have a significant impact on the distribution of harpacticoids in sediments on the shore. However, it is difficult to relate the behavioural experiments directly to the annual survey data because the behavioural experiments are concerned with animals migrating out of sediments while the annual survey measured animals in the sediment. In addition, there will be many factors controlling the abundances of harpacticoids under natural conditions in the beach apart from vertical migration and responses to light, temperature and salinity. The animals used in the behavioural experiments were collected at low tide. Realistic comparisons can therefore be made between the behavioural experiments and the results of the annual survey only if the species sampled during the annual survey were the same at low tide, mid tide and high tide. Even then, comparisons are difficult. The picture from the annual survey is similar at mid tide and low tide with a trough from December to April and a peak in July. Perhaps the low numbers during winter are not only related to the annual breeding cycle but also to the very low temperatures and salinities that are likely to occur on the beach at that time. This will inhibit migration into the overlying water. However, the picture from the high tide site over the annual survey is very different. There is a peak in October, a trough in December and January, another small peak in February and a second trough from April to July. A comparison of this double peak,

double trough pattern of abundance at high tide with the results of the behavioural experiments concerning vertical migration is not very productive. It is possible that winter and summer troughs reflect behavioural responses to low salinity and low temperature (winter), and to high temperature (winter), in the same way that these behavioural variables influence the degree of vertical migration in the behavioural experiments. However, great caution must be exercised in drawing tenuous comparisons of this sort.

SUMMARY

Experiments were carried out from July 1988 to October 1988 to determine the effects of light, salinity and temperature on the burrowing and emergence of harpacticoid copepods into and from sediments the in laboratory. The general materials and methods of these are described in pp. 244.

Experiment 1:

Aim: to test how quickly animals emerge from sediment in the dark. Dark period 180 minutes.

Result: the number of animals in the overlying water increased gradually as time progressed over 180 minutes period by which time 84% had emerged.

Experiment 2:

Aim: to test how quickly animals burrow into sediment when the lights were switched on. Light period 180 minutes.

Result: most of animals burrowed into sediment in response to light within half an hour, and almost all had burrowed by an hour and a half.

Experiment 3:

Aim: to test the effect of various intensities of light on the numbers of animals burrowing into sediments. Light period 180 minutes.

Result: the animals burrowed into the sediment more quickly at the high light intensity (3000 lux) than at the intermediate light intensity (550 lux), and most slowly in the low light intensity (10 lux).

Experiment 4:

Aim: to test the effect of temperature on the numbers of animals emerging from sediment in the dark. Dark period 180 minutes.

Result: Three temperatures were tested 5°C, 10°C, and 20°C. The optimum temperature for animals to emerge from the sediment was 10°C, followed by 20°C. Animals emerged very slowly at 5°C.

Experiment 5:

Aim: to test the effect of various salinities on the numbers of animals emerging from the sediment in dark. Dark period: 5 hours.

Result: Five salinities were tested 100%, 50%, 25%, 10%, and 1%. The number of animals in the overlying water increased with salinity.

Experiment 6:

Aim: to test the effect of changing the salinity of the overlying water on the number of animals emerging from sediments in the dark. Dark period: 180 min + 180 min (1st or 2nd salinity). Salinities tested: 100%, 50%, 25%, 10%, 1%.

Result: the numbers of animals emerging from sediment into the overlying water was progressively reduced as the salinity of the overlying water was decreased. Very few animals emerged into 1%.

Experiment 7:

Aim: to test the combined effect of temperature and salinity on the emergence of animals from sediments in dark. Dark period 300 minutes.

Result: Three temperatures and 3 salinities were tested giving nine combinations in all. The animals emerged into the overlying water more quickly at the intermediate temperature 10°C than at the high temperature 20°C, and most slowler the low

temperature 5°C. Animals emerged into the overlying water most quickly at the highest salinity 100% and most slowly the lowest salinity 1%. This means that the optimum combination of temperature and salinity for the animals to emerge into overlying water was at a temperature of 10°C and a salinity of 100%.

APPENDIX I

Taxonomy of the Class Copepoda:

The class Copepoda is divided into seven orders as follows:

1 - Order Cyclopoida.

2 - Order Calanoida.

3 - Order Harpacticoida.

4 - Order Notodelphyoida.

5 - Order Monstrilloida.

6 - Order Caligoida.

7 - Order Lernaeopodida.

The following account is taken from: Brady (1878); Scott and Scott (1913); Rose (1933); Farran revised by Vervoort (1951); Farran revised by Vervoort (1952); Marshall and Orr (1955); Sinderman (1966); Kaestner (1970); Marshall (1973); Boxshall (1974); Levinton (1982).

(1) Order Cyclopoida:

Many of the cyclopoida live in freshwater. The fore head, containing the head and the thorax, is sharpely distinguished from the urosome. At the front of the body, the first antennae have only a few joints and are short. The first and sometimes the second thoracic segments are fused with the head. The sixth thoracic segment is regarded as a part of the urosome whose first segment (the sixth thoracic segment), therefore, has a small pair of limbs. The two main regions of the body, the fore-body and the urosome join at a movable joint between the fifth and the sixth thoracic segment. There are usually three but some times four thoracic segments (figure 53A).

The urosome contains six segments in the male, and five in the female, some of

these segments are jointed together. At the end of the urosome, there is a terminal segment called telson. In most species the female carries paired egg sacs (Newell and Newell, 1973).

Table 208. Systematic Resume of the Order Cyclopoida.

(1) Family Oithonidae	(2) Family Cyclopinidae
i - Genus Oithona	i - Genus Cyclopina
ii - Genus Ratania	
iii - Aroithona	
(3) Family Ergasilidae	
i - Genus Ergasilus	
ii - Genus Bomolochus	
iii - Genus Thersitina	
(4) Family Bomolochidae	(5) Family Taeniacanthidae
(6) Family Chondracanthidae	
i - Genus Acanthochondria	

These families were taken from the following references:

Rose (1933), Scott and Scott (1912), and Boxshall (1974).

(2) Order Calanoida:

Calanoida are entirely planktonic in British waters. There is no separation between the head and the thoracic regions (figure 53B). This gives the front of the body an ovoid shape (Newell and Newell 1973). There is a movable joint between the sixth thoracic segment and the abdomen. The abdomen, which has no apendages, is composed of four segments plus the telson and furca. The first is long and composed of numerous joints, the second is shorter. The eggs are usually carried by the female in a single group, not in paired egg sacs. Sometimes these eggs are released into the sea individually.

The female has a paired and the male an unpaired genital aperture. Both paired and unpaired genital apertures are borne on the first segment of the two fused abdominal segments (this segment is sometime regarded as the last (7th) segment of the thoracic segments by authors). The segment bearing the genital apertures in the females is

fused to the one behind it. Hence the rest of the abdomen in the female is composed of at most three segments plus telson.

In many species, one of the last pair of thoracic limbs in the male is modified as a pair of forceps to transfer the speramtophore to the female. This may be the right or left one of the pair (Newell and Newell 1973)..LS1

Table 209. Systematic Resume of the Order Calanoida.

(1) Family Centropagadae i - Genus Centropages	(2) Family Acartiidae i - Genus Acartia
(3) Family Candaciidae i - Genus Candacia	(4) Family Metridiidae i - Genus Metridia
(5) Family Heterohabidae i - Genus Heterostylltes. ii - Genus Heterohabdus iii - Genus Hemirhabdus iv - Genus Hesorhabdus v - Genus Disseta.	
(6) Family Meteriidae i - Genus Pleuromama	(7) Family Calanidae i - Genus Calanus
(8) Family Megacalanidae i - Genus Megacalanus ii - Genus Bathycalanus iii - Genus Bradcalanus	
(9) Family Eucalanidae i - Genus Eucalanus ii - Genus Rhincalanus iii - Genus Mecynocera	
(10) Family Paracalanidae i - Calocalanus ii - Genus Paracalanus	
(11) Family Pseudocalanidae ii - Genus Microcalanus iii - Genus Clausocalanus iv - Genus Drepanopus v - Genus Drepanopsis vi - Genus Cetenocalanus	i - Genus Pseudocalanus

Table 209. (continued).

(12) Family Spinocalanidae	
i - Genus Spinocalanus	ii - Genus Mimocalanus
iii - Mnaclia	
(13) Family Aetideidae	
i - Genus Pseudaetideus	ii - Genus Atetideus
iii - Genus Gaetanus	iv - Genus Euaetidenus
v - Genus Aetideopsis	vi - Genus Bradidus
vii - Genus Badyetes	viii - Genus Pseudeuchaeta
ix - Genus Euchirella	x - Genus Bryaxis
xi - Genus Chiridus	xii - Genus Ciridella
xiii - Genus Chrinudina	xiv - Genus Pseudochirella
xv - Genus Gaidus	xvi - Genus Undeuchaeta

(3) Order Harpacticoida:

Most of the harpacticoids are benthic, although there are planktonic forms, particulary in shallow seas with muddy or sandy floors. The length of the body is generally less than 1 mm. There is a lack of obvious divisions between the main regions of the body (figure 53C). The first antennae are short with less than six joints, and the egg sacs may be single or paired (Newell and Newell 1973).

Table 210. Systematic Resume of the Order Harpacticoida

(1) Family Ectinosomidae	(2) Family Macroseetellidae
i - Genus Microsetella	i - Genus Macrosetella
(3) Family Thalestridae	(4) Family Tachydiidae
i - Genus Halithalestris	i - Genus Euterpina
(5) Family Clytemnestridae	(6) Family Aegisthidae
i - Genus Clytemnestra	i - Genus Aegisthus
(7) Family Oncaeidae	(8) Family Sapphirinidae
i - Genus Oncaea	i - Genus Sapphirina
	ii - Genus Corina
	iii - Genus Copilia
(9) Family Corycaeidae	
i - Genus Corycaeus	

These families are taken from Rose (1933).

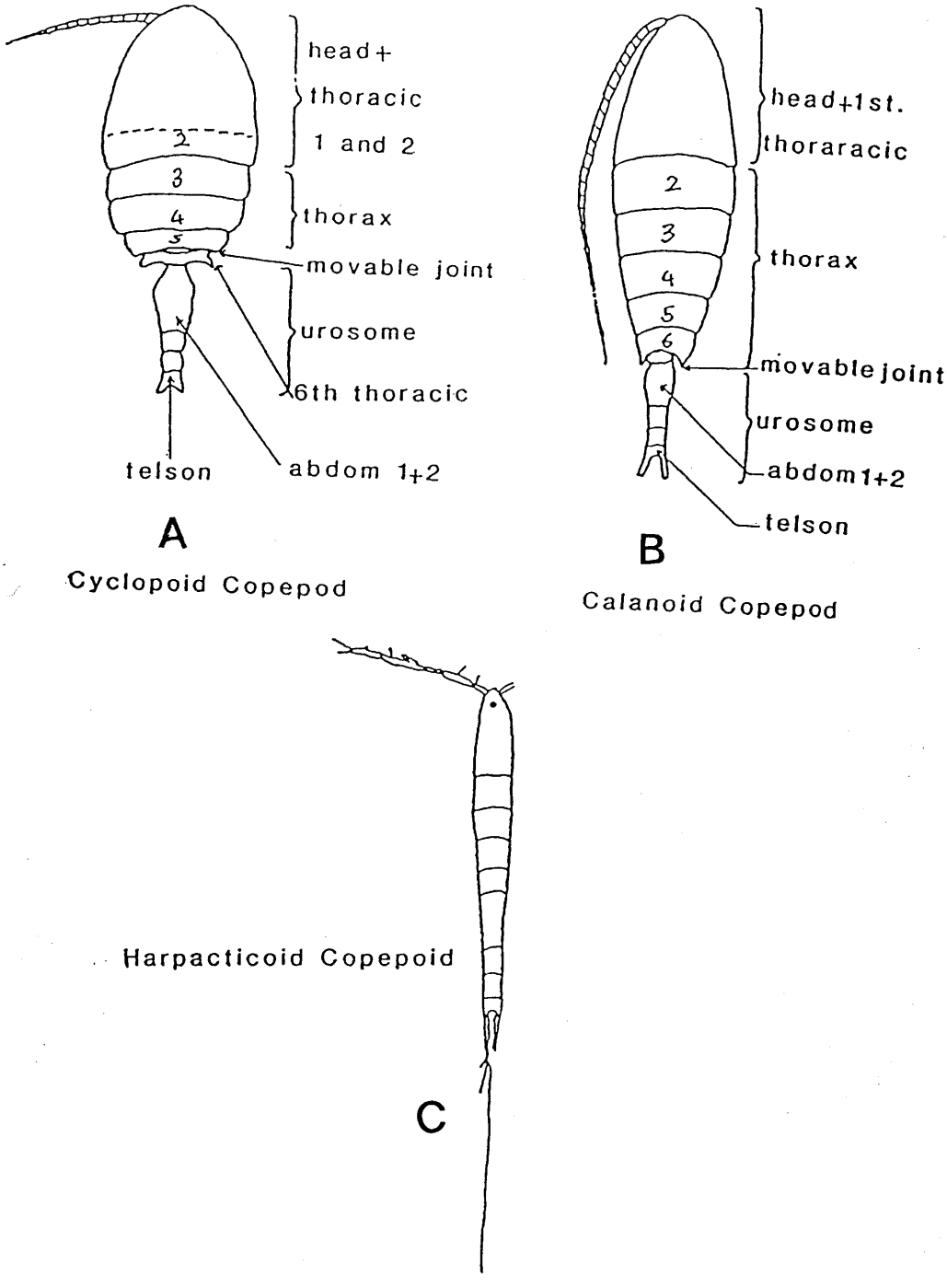


Figure 53. Diagrammatic representation of the three major orders of the Copepoda taken from Newell and Newell (1963). (A) Cyclopoid Copepoda, (B) Calanoid Copepoda, (C) Harpacticoid Copepoda.

(4) Order Notodelphyoida:

Notodelphyoids are marine, associated chiefly with ascidians, where they inhabit the pharynx. The body is cyclopoid, although often modified and sometimes exceedingly swollen or elongated (wormlike). The prosome and urosome are articulated and located between the fourth and fifth postcephalic segments in males and between the first and second abdominal segments in females. The first antennae are either clasping organs or unmodified. The second antennae, mandibles, and the first to fourth legs are either unmodified or reduced. In some, the maxillipeds are prehensile. The caudal rami are specialized. Males are often, though not always, free-swimming, but females stay with the host. (Kaestner, 1970; Barnes, 1980).

(5) Order Monstrilloida:

The adults of monstrilloids are occur in marine plankton. The immature stages, as far as known, are parasitic on polychaete annelids, gastropods, or ophiuroids. The second antennae and mouthparts are absent in adults. The first antennae and the first to fourth legs are well-developed (except in Thepesiiopsyllus, where the small fourth pair is uniramous). There is no functional gut. The major articulation occurs in Thespesiopsyllidae between thoracomeres 4 and 5 (the somite of leg 3 and that of leg 4), but in the Monstrillidae between thoracomeres 5 and 6 (the somite of leg 4 and that of leg 5). The eggs are carried in two egg sacs (Kaestner, 1970).

(6) Order Caligoida:

The males and females are parasitic on marine and freshwater fishes (including sharks and rays), aquatic mammals, and rarely invertebrates (e.g. cephalpods). Males and in some cases females may swim freely in the plankton. The major articulation is between the somites of leg 3 and leg 4, the fourth and fifth thoracomeres. In some parasitic females, the major articulation has been lost. The body is flattened, depressed, with the prosome either wider or narrower than the urosome. The first antennae are reduced to one or two segments. The second antennae, second maxillae,

and maxillipeds are prehensile. The mouth region is suctorial, with very small mandibles. The first to fourth legs are different in form. There are two egg sacs, often with a single row of flattened eggs (Kaestner, 1970).

(7) Order Lernaeopodoida:

The Lernaeopodoids are parasites of marine and fresh-water fishes. The body of both sexes often lacks external segmentation. There is no major articulation in the trunk. Sexual dimorphism is often pronounced, with a dwarf male attached to the female in some. The first antennae are minute. The second antennae have a very small exopodite. The maxillae in the female are modified for grasping.

APPENDIX II

Table 211. Low tide, October 1986. No. of animals / 5 ml. Original data.

Depth cm	5 ml Replicates	Total no. of animals	Adults	Total no. of copepodites	Copepodite stages				
					I	II	III	IV	V
0–1	R1	16	12	4	0	1	1	1	1
	R2	20	14	6	0	0	1	1	4
	R3	25	14	11	0	2	1	7	1
1–2	R1	10	0	10	0	0	0	10	0
	R2	5	0	5	0	0	0	4	1
	R3	11	0	11	0	0	2	9	0
2–3	R1	1	0	1	0	0	0	1	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
3–4	R1	1	0	1	0	0	0	1	0
	R2	0	0	0	0	0	0	0	0
	R3	1	1	0	0	0	0	0	0
4–5	R1	1	1	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
7–8	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
10–11	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
13–14	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0

Table 212. Mid tide, October 1886. No. of animals/ 5 ml. Original data.

Depth cm	5 ml Replicates	Total no. of animals	Adults	Total no. of copepodites	Copepodite stages				
					I	II	III	IV	V
0–1	R1	17	12	5	0	0	0	3	2
	R2	16	9	7	2	1	0	1	3
	R3	12	7	5	0	1	1	2	1
1–2	R1	6	2	4	0	0	0	4	0
	R2	5	2	3	0	0	0	3	0
	R3	9	3	6	0	0	0	5	1
2–3	R1	2	2	0	0	0	0	0	0
	R2	2	2	0	0	0	0	0	0
	R3	1	0	1	0	0	0	1	0
3–4	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
4–5	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
7–8	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
10–11	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	3	1	2	0	0	1	1	0
13–14	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0

Table 213. High tide, October 1986. No. of animals/ 5 ml. Original data.

Depth cm	5 ml Replicates	Total no. of animals	Adults	Total no. of copepodites	Copepodite stages				
					I	II	III	IV	V
0–1	R1	228	219	9	0	1	3	3	2
	R2	217	217	0	0	0	0	0	0
	R3	230	230	0	0	0	0	0	0
1–2	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
2–3	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
3–4	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
4–5	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
7–8	R1	1	1	0	0	0	0	0	0
	R2	2	0	2	0	0	1	1	0
	R3	1	1	0	0	0	0	0	0
10–11	R1	0	0	0	0	0	0	0	0
	R1	1	1	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
13–14	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0

Table 214. Low tide, December 1986. No. of animals / 5 ml. Original data.

Depth cm	5 ml Replicates	Total no. of animals	Adults	Total no. of copepodites	Copepodite stages				
					I	II	III	IV	V
0–1	R1	0	0	0	0	0	0	0	0
	R2	2	1	1	0	0	0	1	0
	R3	0	0	0	0	0	0	0	0
1–2	R1	7	1	6	0	0	1	4	1
	R2	2	0	2	0	0	0	2	0
	R3	4	0	4	0	0	0	4	0
2–3	R1	4	2	2	0	0	0	2	0
	R2	5	4	1	0	0	0	0	1
	R3	5	2	3	0	0	0	2	1
3–4	R1	0	0	0	0	0	0	0	0
	R2	1	1	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
4–5	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
7–8	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
10–11	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
13–14	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0

Table 215. Mid tide, December 1986. No. of animals/ 5 ML. Original data.

Depth cm	5 ml Replicates	Total no. of animals	Adults	Total no. of copepodites	Copepodite stages				
					I	II	III	IV	V
0–1	R1	13	8	5	0	0	0	5	0
	R2	10	5	5	0	0	0	4	1
	R3	6	3	3	0	0	0	2	1
1–2	R1	1	1	0	0	0	0	0	0
	R2	2	2	0	0	0	0	0	0
	R3	1	1	0	0	0	0	0	0
2–3	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
3–4	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
4–5	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
7–8	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
10–11	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
13–14	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0

Table 216. High tide, December 1986. No. of animals/ 5 ml. Original data.

Depth cm	5 ml Replicates	Total no. of animals	Adults	Total no. of copepodites	Copepodite stages				
					I	II	III	IV	V
0–1	R1	2	2	0	0	0	0	0	0
	R2	2	2	0	0	0	0	0	0
	R3	6	6	0	0	0	0	0	0
1–2	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	1	1	0	0	0	0	0	0
2–3	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
3–4	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
4–5	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
7–8	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
10–11	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
13–14	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0

Table 217. Low tide, February 1987. No. of animals/ 5 ml. Original data.

Depth cm	5 ml Replicates	Total no. of animals	Adults	Total no. of cpoepodites	Copepodite stages				
					I	II	III	IV	V
0–1	R1	3	2	1	0	0	0	1	0
	R2	3	1	2	0	0	0	2	0
	R3	5	1	4	0	0	0	4	0
1–2	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
2–3	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
3–4	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
4–5	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
7–8	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
10–11	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
13–14	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0

Table 218. Mid tide, February 1987. No. of animals/ 5 ml. Original data.

Depth cm	5 ml Replicates	Total no. of animals	Adults	Total no. of copepodites	Copepodite stages				
					I	II	III	IV	V
0–1	R1	10	9	1	0	0	0	0	1
	R2	10	10	0	0	0	0	0	0
	R3	6	6	0	0	0	0	0	0
1–2	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
2–3	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
3–4	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
4–5	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
7–8	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
10–11	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
13–14	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0

Table 219. High tide, February 1987. No. of ainmals/ 5 ml. Original data.

Depth cm	5 ml Replicates	Total no. of animals	Adults	Total no. of copepodites	Copeodite stages				
					I	II	III	IV	V
0–1	R1	104	104	0	0	0	0	0	0
	R2	100	100	0	0	0	0	0	0
	R3	90	90	0	0	0	0	0	0
1–2	R1	0	0	0	0	0	0	0	0
	R2	1	1	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
2–3	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
3–4	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
4–5	R1	3	3	0	0	0	0	0	0
	R2	1	1	0	0	0	0	0	0
	R3	3	2	1	0	0	0	1	0
7–8	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
10–11	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0
13–14	R1	0	0	0	0	0	0	0	0
	R2	0	0	0	0	0	0	0	0
	R3	0	0	0	0	0	0	0	0

Table 220. Low tide, April 1987. No. of animals /5ml. Original data.

Depth (cm)	5 ml Replicates	Total no. of animals	Adults	Total no. of copepodites
0–1	R1	12	8	4
	R2	11	7	4
	R3	15	10	5
1–2	R1	0	0	0
	R2	3	2	1
	R3	1	1	0
2–3	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
3–4	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
4–5	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
7–8	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
10–11	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
13–14	R1	0	0	0
	R2	0	0	0
	R3	0	0	0

Table 221. Mid tide, April 1987. No. of animals /5 ml. Originla data.

Depth (cm)	5ml. Replicates	Total no. of animals	Adults	Total no. of copepodites
0–1	R1	6	6	0
	R2	8	8	0
	R3	7	7	0
1–2	R1	1	1	0
	R2	2	2	0
	R3	1	1	0
2–3	R1	1	1	0
	R2	0	0	0
	R3	1	1	0
3–4	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
4–5	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
7–8	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
10–11	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
13–14	R1	0	0	0
	R2	0	0	0
	R3	0	0	0

Table 222. High tide, April 1987. No. of animals / 5ml. Original data.

Depth (cm)	5ml. Replicates	Total no. of animals	Adults	Total no. of copepodites
0–1	R1	14	14	0
	R2	16	16	0
	R3	19	19	0
1–2	R1	0	0	0
	R2	0	0	0
	R3	1	1	0
2–3	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
3–4	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
4–5	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
7–8	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
10–11	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
13–14	R1	0	0	0
	R2	0	0	0
	R3	0	0	0

Table 223. Low tide, June 1987. No. of animals / 5ml. Original data.

Depth (cm)	5ml. Replicates	Total no. of animals	Adults	Total no. of copepodites
0–1	R1	40	20	20
	R2	51	28	23
	R3	46	24	22
1–2	R1	8	2	6
	R2	8	1	7
	R3	9	3	6
2–3	R1	2	2	0
	R2	3	2	1
	R3	2	1	1
3–4	R1	5	2	3
	R2	2	1	1
	R3	2	1	1
4–5	R1	5	5	0
	R2	3	3	0
	R3	2	2	0
7–8	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
10–11	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
13–14	R1	1	1	0
	R2	0	0	0
	R3	0	0	0

Table 224. Mid-tide, June 1987. No. of animals / 5ml. Original data.

Depth (cm)	5ml. Replicates	Total no. of animals	Adults	Total no. of copepodites
0–1	R1	27	25	2
	R2	31	27	4
	R3	28	25	3
1–2	R1	0	0	0
	R2	1	0	1
	R3	0	0	0
2–3	R1	1	1	0
	R2	0	0	0
	R3	0	0	0
3–4	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
4–5	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
7–8	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
10–11	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
13–14	R1	0	0	0
	R2	0	0	0
	R3	0	0	0

Table 225. High tide, June 1987. No. of animals / 5ml. Original data.

Depth	5ml. Replicates	Total no. of aniamls	Adults	Total no. of copepodites
0–1	R1	8	8	0
	R2	5	5	0
	R3	6	6	0
1–2	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
2–3	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
3–4	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
4–5	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
7–8	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
10–11	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
13–14	R1	0	0	0
	R2	0	0	0
	R3	0	0	0

Table 226. Low tide, August 1987. No. of animals / 5ml. Original data.

Depth (cm)	5ml. Replicates	Total no. of animals	Adults	Total no. of copepodites
0–1	R1	48	23	25
	R2	46	22	24
	R3	44	20	24
1–2	R1	4	4	0
	R2	6	6	0
	R3	5	5	0
2–3	R1	1	1	0
	R2	2	2	0
	R3	1	1	0
3–4	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
4–5	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
7–8	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
10–11	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
13–14	R1	0	0	0
	R2	0	0	0
	R3	0	0	0

Table 227. Mid–tide, August 1987. No. of animals / 5ml. Original data.

Depth (cm)	5ml. Replicates	Total no. of animals	Adults	Total no. of copepodites
0–1	R1	17	15	2
	R2	13	10	3
	R3	15	13	2
1–2	R1	3	2	1
	R2	2	1	1
	R3	3	3	0
2–3	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
3–4	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
4–5	R1	1	1	0
	R2	0	0	0
	R3	0	0	0
7–8	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
10–11	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
13–14	R1	0	0	0
	R2	0	0	0
	R3	0	0	0

Table 228. High tide, August 1987. No. of animals / 5ml. Original data.

Depth (cm)	5ml. Replicates	Total no. of animals	Adults	Total no. of copepodites
0–1	R1	57	57	0
	R2	58	58	0
	R3	60	60	0
1–2	R1	3	3	0
	R2	5	5	0
	R3	4	4	0
2–3	R1	1	1	0
	R2	2	2	0
	R3	1	1	0
3–4	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
4–5	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
7–8	R1	2	2	0
	R2	1	1	0
	R3	1	1	0
10–11	R1	0	0	0
	R2	0	0	0
	R3	0	0	0
13–14	R1	0	0	0
	R2	0	0	0
	R3	0	0	0

APPENDIX III

Appendix table 229. Results of experiment 1 (pp. 245) testing rate at which the animals emerge from sediment when the lights are switched off. Observed number in the overlying water and calculated number of animals in the sediment (method of calculation mean number of animals in each vial see pp. 244). Mean of numbers of animals in each vial = 37 and s.d = 3.0331. A = Observed number of animals in the overlying water. B = Calculated number of animals in sediment. C = Percentage of animals in the overlyin water.

Time supernatant sampled after lights off (min)	A	B	C
5	2	35	5.40
10	2	35	5.40
15	4	33	10.81
20	7	30	18.91
30	11	26	29.72
40	13	24	35.14
50	13	24	35.14
60	12	25	32.43
70	14	23	37.83
80	16	21	43.24
90	17	20	45.94
100	17	20	45.94
110	18	19	48.64
120	20	17	54.05
130	23	14	62.16
140	26	11	70.27
150	28	9	75.68
160	30	7	81.08
170	31	6	83.78
180	31	6	83.78

Appendix table 230. Results of experiment 2a (pp. 246) testing whether the same numbers of animals are found in the overlying water of covered vials in dark and in light. This provides a zero time reading for experiment 2b (methods of calculation mean number of animals in each vial see pp. 244). Mean of numbers of animals in the overlying water in each dark vial = 28.8 and s.d = 5.2873. Mean of numbers of animals in each light vial = 27.7 and s.d = 3.4334. A, B, C as previously.

Condition	No. of	Supernatant sampling times (min).	A	B	C
Dark (covered)	1	5.50 – 5.51	17	26	39.53
	2	5.51 – 5.52	23	20	53.48
	3	5.52 – 5.53	31	12	72.09
	4	5.53 – 5.54	22	21	51.16
	5	5.54 – 5.55	24	19	55.81
	6	5.55 – 5.56	27	16	62.79
	7	5.56 – 5.57	33	10	76.44
	8	5.57 – 5.58	30	13	69.76
	9	5.58 – 5.59	22	21	51.16
	10	5.59 – 6.00	19	25	44.18
Light (covered)	11	0 – 1	30	13	69.76
	12	1 – 2	30	13	69.76
	13	2 – 3	22	21	51.16
	14	3 – 4	33	10	76.74
	15	4 – 5	24	19	55.81
	16	6 – 7	28	15	65.11
	17	7 – 8	26	17	60.46
	18	8 – 9	25	19	58.13
	19	9 – 10	31	12	72.09
	20	11 – 12	28	15	65.11

Appendix table 231. Results of expriment 2b (pp 246) testing rate at which the animals burrow into sediment when the lights are switched on. Observed number of animals in the overlying water and calculated number of animals in the sediment (method of calculation mean number of animals in each vial see pp. 244). Mean of nmbers of animals in each vial = 40 and s.d = 4.0865. A, B, and C as perviously.

Supernatant sampling times (min)	A	B	C
5	25	15	62.5
10	23	17	57.5
15	20	20	50
20	18	22	48.65
30	13	27	32.5
40	8	32	20
50	4	36	10
60	2	38	5
70	2	38	5
80	2	38	5
90	2	38	5
100	2	38	5
110	0	40	0
120	0	40	0
130	1	39	2.5
140	0	40	0
150	0	40	0
160	1	39	2.5
170	0	40	0
180	0	40	0

Appendix table 232. Results of experiment 3 (pp 251) testing the effect of three intensities of light on burrowing of animals into sediment. Observed number of animals in the overlying water and calculated number in the sediment (method of calculation mean number of animals in each vial see pp. 244). Previous exposure to dark 6 hours. Mean of numbers of animals in each vial = 41 and s.d = 8.6890. A, B, and C as preeviously.

Time at which the supernatant was taken (min)	Light intensity											
	3000 lux				550 lux				10 lux			
	Vial	A	B	C	Vial	A	B	C	Vial	A	B	C
5	1	18	23	43.90	21	28	13	69.29	41	35	6	85.37
10	2	18	23	43.90	22	26	15	63.41	42	32	9	78.05
15	3	17	24	41.46	23	25	16	60.98	43	32	9	78.05
20	4	16	25	39.02	24	24	17	58.54	44	31	10	75.61
30	5	11	30	26.83	25	20	21	48.78	45	27	14	65.85
40	6	6	35	14.63	26	14	27	34.14	46	27	14	65.85
50	7	4	37	9.76	27	12	29	29.27	47	25	16	60.98
60	8	4	37	9.76	28	8	33	19.51	48	16	25	39.02
70	9	3	38	7.32	29	6	35	14.63	49	11	30	26.83
80	10	3	38	7.32	30	6	35	14.63	50	10	31	24.39
90	11	3	38	7.32	31	5	36	12.19	51	10	31	24.39
100	12	2	39	4.88	32	4	37	9.76	52	9	32	21.95
110	13	1	40	2.44	33	5	36	12.19	53	9	32	21.95
120	14	1	40	2.44	34	4	37	9.76	54	8	33	19.51
130	15	0	41	0	35	4	37	9.76	55	9	32	21.95
140	16	0	41	0	36	3	38	7.32	56	8	33	19.51
150	17	1	40	2.44	37	4	37	9.76	57	8	33	19.51
160	18	0	41	0	38	2	39	4.88	58	7	34	17.07
170	19	0	41	0	39	2	39	4.88	59	5	36	12.20
180	20	0	41	0	40	2	39	4.88	60	4	37	9.76

Appendix table 233. Results of experiment 4 (pp. 253) testing the effect of temperature on number of copepods when the lights are switched off. Observed number of animals in the overlying water and calculated number of animals in the sediment (method of calculation mean number of animals in each vial see pp. 244). Mean of numbers of animals in each vial = 32 and s.d = 1.5811. A, B, and C as previously.

Time at which the supernatant was taken (min)	Temperature (°C)											
	5				10				20			
	Vial	A	B	C	Vial	A	B	C	Vial	A	B	C
20	1	3	29	9.38	10	8	24	25	19	6	26	18.75
40	2	3	29	9.38	11	10	22	31.25	20	8	24	25
60	3	4	28	12.5	12	14	18	43.75	21	10	22	31.25
80	4	3	29	9.38	13	16	16	50	22	12	20	37.5
100	5	5	27	15.63	14	22	10	68.75	23	16	16	50
120	6	7	25	21.88	15	26	6	81.25	24	18	14	56.25
140	7	8	24	25	16	30	2	93.95	25	24	8	75
160	8	10	22	31.25	17	30	2	93.75	26	27	5	83.38
180	9	12	20	37.5	18	32	0	100	27	27	5	83.38

Appendix table 234. Results of experiment 5 (pp. 258) testing effect of various salinities on number of copepods when the lights are switched off. Observed number of animals in the overlying water and calculated number in the sediment (methd of calculation mean number of animals in each vial see pp. 244). Mean of numbers of animals in each vial = 37 and s.d = 1.4832. A, B, and C as previously.

Condition	Salinity %	Replicates (10 ml)	A	B	C	Mean (X)	S.d
Dark	1	R1	2	35	5.41	4.05	1.92
		R2	1	36	2.76		
	10	R1	3	34	8.12	9.46	1.92
		R2	4	33	18.81		
	25	R1	10	27	27.03	29.73	3.92
		R2	12	25	32.43		
	50	R1	14	23	37.84	39.19	1.91
		R2	15	22	40.54		
	100	R1	20	17	54.05	58.91	5.73
		R2	23	14	62.16		

Appendix table 235. Results of experiment 6 (pp. 262) testing whether animals die when low salinity above them. Observed number of animals in the overlying water and calculated number in the sediment (method of calculation mean number of animals in each vial see pp. 244). Mean of numbers of animals in each vial = 37 and s.d = 7.7781 A, B, and C as previously.

Time	0	First treatment (after 3 hours)			3 hours	Second treatment (after 6 hours)			6 hours
No. of vial	Poured salinity %	A	B	C	No. of vial	Changed salinity %	A	B	C
R1	100	13	24	35.14	R1	100	15	22	40.54
R2	100	18	19	48.65	R2	100	11	26	29.73
R3	50	9	28	24.32	R3	50	9	28	24.32
R4	50	10	27	27.03	R4	50	13	24	35.14
R5	50	11	26	29.73	R5	100	12	25	32.43
R6	50	9	28	24.32	R6	100	16	21	43.24
R7	100	21	16	56.76	R7	50	15	22	40.54
R8	100	16	21	43.24	R8	50	14	23	37.84
R9	100	23	14	62.16	R9	100	15	22	40.54
R10	100	14	23	37.84	R10	100	15	22	40.54
R11	25	5	32	13.51	R11	25	5	32	13.51
R12	25	6	31	16.22	R12	25	6	31	16.22
R13	25	3	34	8.12	R13	100	13	24	35.14
R14	25	8	29	21.62	R14	100	14	23	37.84
R15	100	17	20	45.95	R15	25	12	25	32.43
R16	100	19	18	51.35	R16	25	8	29	21.62
R17	100	17	20	45.95	R17	100	16	21	43.24
R18	100	13	24	35.14	R18	100	16	21	43.24
R19	10	4	33	10.81	R19	10	5	32	13.51
R20	10	3	34	8.12	R20	10	5	32	13.51
R21	10	3	34	8.12	R21	100	8	29	21.62
R22	10	4	33	10.81	R22	100	9	28	24.32
R23	100	10	27	27.03	R23	10	3	34	8.11
R24	100	16	21	43.24	R24	10	5	32	13.51
R25	100	18	19	48.65	R25	100	12	25	32.43
R26	100	12	25	32.43	R26	100	17	20	45.95
R27	1	2	35	5.41	R27	1	7	30	18.92
R28	1	8	29	21.62	R28	1	2	35	5.41
R29	1	9	28	24.32	R29	100	7	30	18.92
R30	1	3	34	8.12	R30	100	5	32	13.51
R31	100	14	23	37.84	R31	1	5	32	13.51
R32	100	18	19	48.65	R32	1	4	33	10.81

Appendix table 236. Experiment 7. Codes (0 min = control).

Temperature (°C)	Salinity (‰)	Time (min) after the lights were switched off					
		0	20	60	120	180	300
5	1	L1	1	2	3	4	5,6
	25	L2	7	8	9	10	11,12
	100	L3	13	14	15	16	17,18
10	1	L4	19	20	21	22	23,24
	25	L5	25	26	27	28	29,30
	100	L6	31	32	33	34	35,36
20	1	L7	37	38	39	40	41,42
	25	L8	43	44	45	46	47,48
	100	L9	49	50	51	52	53,54

Appendix table 237. Results of experiment 7 (pp. 268) testing the effect of interaction between three temperatures (5°C, 10°C, 20°C) and three salinities (1%, 25%, 100%) on copepods when lights are switched off. Observed number of animals in the overlying water and calculated number in sediment (method of calculation mean number of animals ineach vial see pp. 244). Mean of numbers of animals in each vial = 32 and s.d = 8.3845. A, B, and C as previously.

Temperature (°C)	Salinity (%)	Time at which the supernatants were removed (min)																	
		0			20			60			120			180			300		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
5	1	0	32	0	1	31	3.13	1	31	3.13	1	31	3.13	3	29	9.38	4 5	28 27	12.5 13.51
	25	0	32	0	3	29	9.38	3	29	9.38	5	27	15.62	7	25	21.88	8 7	24 25	25 21.88
	100	0	32	0	4	28	12.5	6	26	18.75	8	24	25	10	22	31.25	13 12	19 20	40.63 37.5
10	1	0	32	0	2	30	6.25	5	27	13.51	7	25	21.88	8	24	25	8 11	24 21	25 34.38
	25	0	32	0	6	26	18.75	9	23	28.13	12	20	37.5	14	18	43.75	16 17	16 15	50 53.13
	100	2	30	6.25	10	22	31.25	14	18	43.75	17	15	53.13	21	11	65.63	25 27	7 5	78.13 84.38
20	1	0	32	0	1	31	3.13	2	30	6.23	3	29	9.38	5	27	15.62	7 8	25 24	21.88 25
	25	2	30	6.25	4	28	12.5	6	26	18.75	8	24	25	10	22	31.25	10 13	22 19	31.25 40.63
	100	3	29	9.38	6	26	18.75	8	24	25	12	20	27.5	15	17	46.85	19 18	13 14	59.38 56.25

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