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Vertical and horizontal distributions of major meiofauna taxa on selected beaches in the South Slough Estuary, Charleston, Oregon, USA : a thesis ...

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Vertical and Horizontal Distributions of
Major Meiofauna Taxa on Selected Beaches in the
South Slough Estuary, Charleston, Oregon, USA.

A Thesis
Presented to
the Graduate School of the
University of the Pacific

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

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by
Stuart A. Arkett
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This thesis, written and submitted by

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is approved for recommendation to the Committee on Graduate Studies, University of the Pacific.

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TABLE OF CONTENTS

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My deepest appreciation goes to Bill and Meg Hummon (Ohio University) who instilled in me the insatiable curiosity and fascination of the "wee beasties" (meiofauna - gastrotrichs). A special thanks goes to Ms. Heather Moberly for her assistance in the collection of the samples.

I also thank my mother and father, Phyllis and Allen, for their support and encouragement throughout my academic career.

TABLES

FIGURES

INTRODUCTION

The interstitial biocoenoses and the associated fauna were discovered by biologists in the nineteen-twenties. The credit for the discovery of the marine interstitial fauna has been given to Adolph Remane because "he was the first zoologist to give ... (a) ... definition to the interstitial environment, and because he has emphasized the connection between animal morphology and the structure of the environment (Lebensformtypen)." (Swedmark 1964:2).

Many terms have been used to refer to the group of organisms inhabiting the interstices of sediments. The term interstitia was introduced by Nicholls (1935) to describe the organisms living in the interstitial water of sand; Remane (1940, cited by Swedmark 1964) used mesopsammon and Mare (1942) coined the word meiobenthos (meiofauna) to describe these organisms.

The diversity of terms used to refer to this group of organisms is paralleled by the diversity of definitions utilized in their description. Mare (1942) referred to the meiofauna as those organisms intermediate in size, smaller than the macrobenthos (organisms living in the sediment rather than between the sand grains), but larger than the microbenthos (bacteria, diatoms, and most protozoans). A more specific definition suggests an upper size limit of the meiofauna (organisms able to pass through a sieve with openings of 0.5 - 1.0 mm) to separate them from larger organisms (macrofauna) and a lower size limit (organisms retained by a sieve with openings of 0.04 - 0.10 mm) to separate them from smaller organisms (McIntyre 1969). Fenchel (1978) used meiofaunal weights to define this group of organisms. He defined them as the metazoans weighing less than 10^{-4} grams (wet weight) with the protozoans excluded to the microfauna.

These definitions do not consider the taxonomical or ecological relationships of the organisms, but merely associate groups of metazoans by arbitrary size categories. It has been a common practice to define the meiofauna by taxonomic categories coupled with a size limit, which thereby associates the organisms into biological, in addition to statistical groupings (McIntyre 1969). An applicable definition of the meiofauna provided by McIntyre (1969:249) is "a group of small metazoans mostly passing a 0.50 mm mesh, which by their size, number, generation time, and adaptations can conviently be considered separately from the larger members of the benthos.". I have adopted this definition for this study and future work.

Practically all groups of invertebrates are represented in the interstitial fauna and the following have been recognized as members of the permanent meiofauna; Rotifera, Gastrotricha, Kinorhyncha, Nematoda, Archiannelida, Tardigrada, Harpacticoida, Ostracoda, Mystacocarida, Halacarida, Turbellaria, Oligochaeta, Polychaeta, and a few specialized members of Hydrozoa, Nemertinii, Bryozoa, Gastropoda, Solenogastres, Holothuroidea, and Tunicata (McIntyre 1969). Refer to Appendix A for a classification of the organisms found in this study.

Meiofauna move within the sediment in three directions: (1) vertically in the sediment column, (2) horizontally upshore or down-shore, and (3) laterally alongshore (McLachlan et al. 1977). Meiofaunal locomotion is effected in various ways. Ciliary gliding, movement by ciliary contact with the substratum, is common in the Turbellaria, Gastrotricha, Archiannelida, Polychaeta, and Mollusca. Writhing is a method common to most Nematoda, while most Crustacea move by crawling or burrowing (Swedmark 1964). This study will compare differences in abundance of the gliders (Gastrotricha), writhers (Nematoda), and the crawlers or burrowers (Harpacticoida), as these groups were found to be the most numerous in my preliminary studies.

There have been a number of studies on the major environmental factors in relation to meiofaunal distributions: bacterial food sources attached to sand grains (Meadows and Anderson 1968, Anderson and Meadows 1969), light-extinction rates in the sediment (Gomoiu 1967, cited by Hulings and Gray 1971), grain size and porosity (Weiser 1959, Jansson 1967a, Hulings and Gray 1976), temperature (Johnson 1965, Jansson 1967c, Pollock and Hummon 1971), salinity (Johnson 1967, Jansson 1967c), oxygen (Brafield 1964, Jansson 1967b), and water content (Jansson 1967a, 1968). There have, however, been relatively few studies on the migration of meiofauna in response to tidal movements. Boaden (1968) found that the meiofauna migrated downward in response to turbulence in the overlying water and Boaden and Platt (1971) attributed this downward migration to an escape response as the tide crossed the organism's position. McLachlan et al. (1977) proposed that the vertical migrations of the meiofauna were in response to the alternate drying and wetting of the sand during the tidal cycle.

The purpose of this study was to compare the differences in abundance of Nematoda, Gastrotricha, and Harpacticoida between depths in the sediment at various tide levels and between depths at various sites with increasing time of exposure. It also examines the relationship between the abundances of meiofaunal groups and the mean grain size of the sediment. This study was also a part of the continual baseline-data gathering program for the South Slough Estuarine Sanctuary, Delane A. Munson, Manager.

Study Area

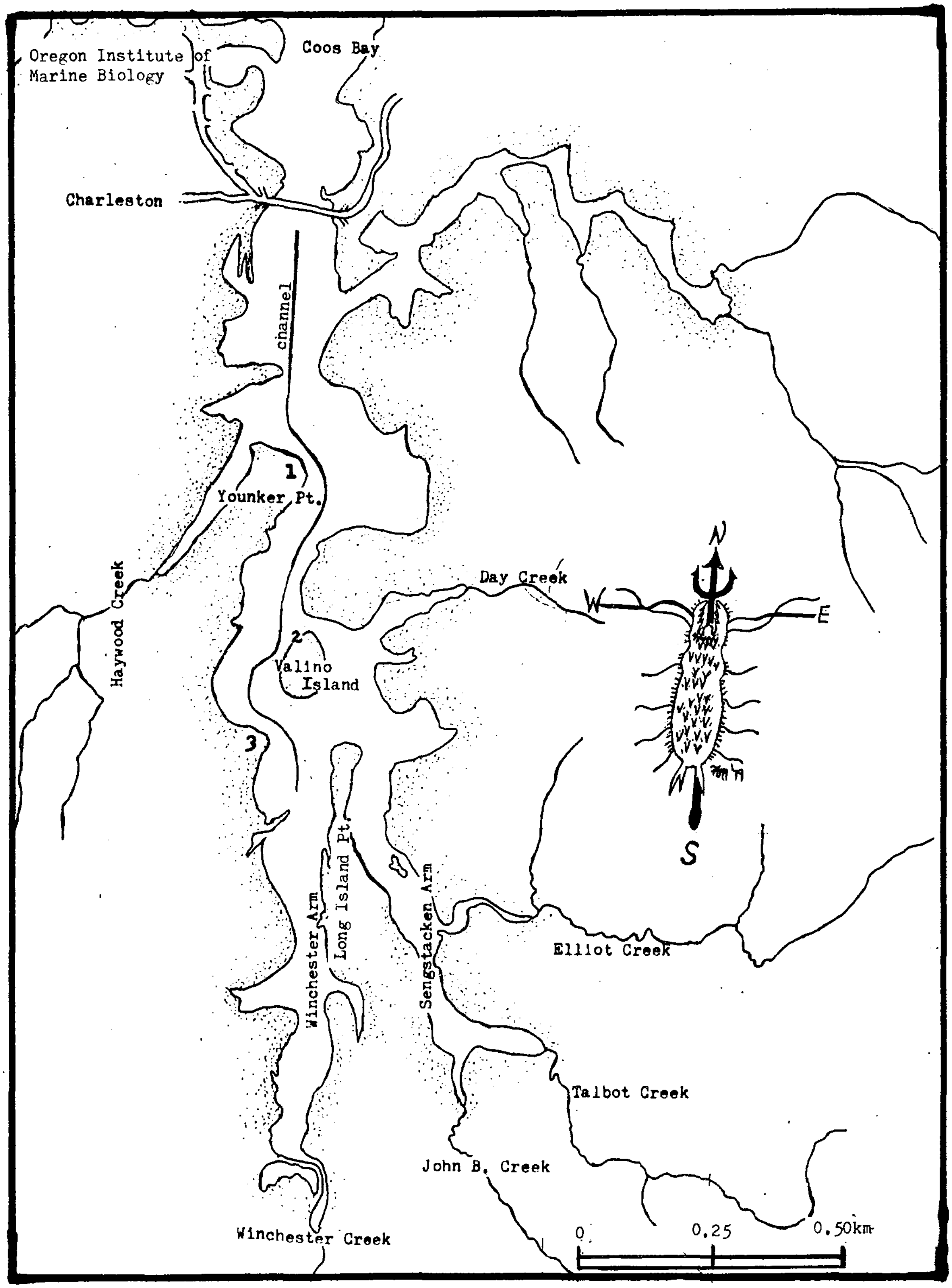
This study was conducted in the South Slough estuary near Charleston, Coos County, Oregon. The slough is a southern extension of the Coos Bay estuary and is typical of the estuaries found along the submergent coastline of the western United States. It is located within the Columbian Estuarine Sanctuary Region (designated by the Estuarine Sanctuary Guidelines published by the National Oceanic and Atmospheric Administration, Department of Commerce, Volume 39, #108 of the Federal Register) which extends from Cape Mendocino to Canada and is characterized by mountainous shorelands, rocky coasts, and extensive algal communities (McEwen 1978).

The slough is a tide-dominated estuary with strong tidal currents relative to river flow, resulting in a vertically and laterally mixed system with a nearly-homogeneous salinity distribution. During periods of high river flow in the winter months, however, the upper portions of the slough may exhibit a slight salinity stratification (McEwen 1978).

Most of the slough consists of shallow intertidal mud flats separated by a few deep meandering channels. The few sand beaches that do occur are a result of erosion of the sea cliffs of Tertiary sedimentary rocks capped by terrace deposits (Baker 1978). Burt and McAlister (1959) found that there is a net reduction in the average grain size inland along the length of the slough and laterally over the tidal flats.

The slough reaches inland about eight kilometers with a mean width of one kilometer and is divided into Winchester and Sengstacken arms by Long Island Point. Day and Elliot creeks drain into the east end of the slough, John B. and Talbot creeks drain into the south end of Sengstacken arm, Winchester Creek drains into the Winchester arm, and Haywood Creek enters the slough near Younker point (Figure 1).

Figure 1. Map of the South Slough estuary, near Charleston, Oregon. Beaches studied are indicated by the numbers 1,2,3.


Oregon Institute of
Marine Biology
Coos Bay
Charleston
channel
1
Younker Pt.
Haywood Creek
Day Creek
N
W
E
S
2
Valino
Island
3
Long Island Pt.
Winchester Arm
Sengstacken Arm
Elliot Creek
Talbot Creek
John B. Creek
Winchester Creek
0
0.25
0.50km

The land surrounding the slough has abundant coniferous forests and some areas have been, and continue to be, logged. There are also some cleared grasslands, at the southern end of the slough, used primarily for cattle grazing. There are numerous marshlands fringing the slough, large beds of eel grass (*Zostera*), and some commercial stick-culture oyster farms present along the channels.

MATERIALS AND METHODS

During the months of June, July, and August 1979, collections were made at three selected sand beaches in the South Slough estuary near Charleston, Oregon. The basis of the beach selection was the similarity of exposure, structure, origin, and faunal components. Beach #1 was located on the northern most portion of Younker Point, Beach #2 was located on the northwest edge of Valino Island, and Beach #3 was located on a point south by southwest of Valino Island (Figure 1).

Collections on all three beaches were always made on the same day to ensure atmospheric and wave condition similarity. Collections were made when a lower high tide of at least 5.0 feet above zero was scheduled during daylight hours for the Coos Bay Entrance (Humbolt Bay District Tide Tables 1979). Sampling was delayed or aborted if rain occurred just prior to or on a sampling day, or if wind and wave action prohibited the standardized collection. Collections for the actual analysis were made on 26 July and 8 August.

The first component of the study was designed to examine the differences in the distribution of the organisms at various tide levels and at sites with increasing time of exposure. The first component required five sites on each beach following a transect perpendicular to the water line. The apex of the wave swash zone at the lower high tide was designated as Site A at time t_1. The apexes of the wave swash zone of subsequent tide levels at times t_2 ($t_{1+60 \text{ min.}}$) and t_3 ($t_{1+120 \text{ min.}}$) were designated as Site B and Site C, respectively. Site A was resampled (along a line parallel to the water) concurrently with Site B and Site C; these were designated as Site A' and Site A'', respectively. This procedure resulted in five sampling sites per beach (A_{t1}, B_{t2}, C_{t3}, A'_{t2}, A''_{t3}) (Figure 2) and was followed for Beaches 1,2,3 in succession as follows: Beach 1 Site A, Beach 2 Site A, Beach 3 Site A, Beach 1 Site B and Site A', Beach 2 Site B and Site A'... Beach 3 Site C and Site A''.

Sampling at each site was done with a 20 cc disposable syringe used as a suction corer (2.69 cm^2 surface). The fractions of the total core utilized were 0-1, 1-2, and 3-4 centimeter core depths. Six cores grouped into two equal replicates for each depth at a site yielded thirty subsamples per beach and each subsample contained 8.07 cm^3 of sediment to be analyzed faunistically. Two additional depth fraction replicates for each site were also collected for sediment analysis. Water samples were collected for salinity determination for both surface and interstitial water. (Interstitial water was collected by digging a hole in the exposed sand and collecting the water as it seeped from the sides of the hole.) Water samples were returned to the laboratory (University of Oregon's Institute of Marine Biology) and the salinities were determined with an American Optical Total Solids T/C Refractometer. Temperature was recorded with a Taylor laboratory thermometer for the three sand depths, water, and air. Relative compaction of the sand was determined for each site by the distance a 2x2 cm square was depressed into the sand by constant pressure. This was determined by a home-made spring loaded shaft-cylinder arrangement. The distance the 2x2 cm square was depressed into the sand was recorded when a constant arbitrary tension was placed on the shaft. The distance between each site on a beach was measured and the slope of the beach was determined by using a hand held level and stadia rod.

Sediment samples were analyzed to determine the mean phi (MN ϕ, where $\phi = -\log_2 x$ and x is the mean grain size in millimeters) for each depth fraction at each site. Samples were dried for approximately eight

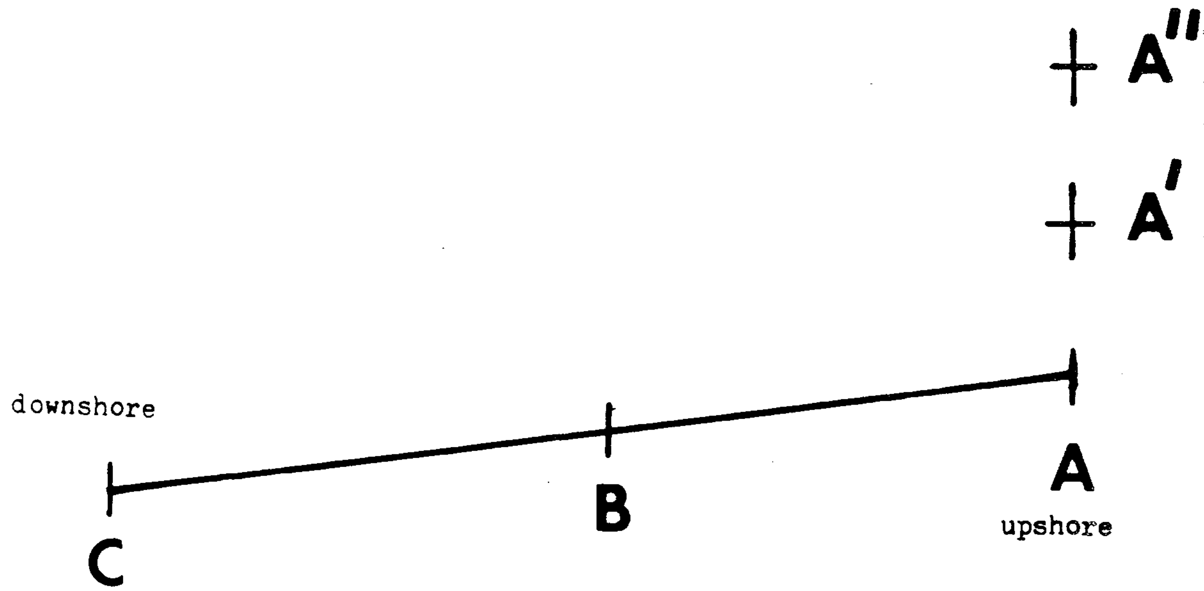


Figure 2. Sampling site arrangement on all beaches (see fig. 1) for the first component of the study (Sites A,B,C,A',A'') in the South Slough, Charleston, Oregon.

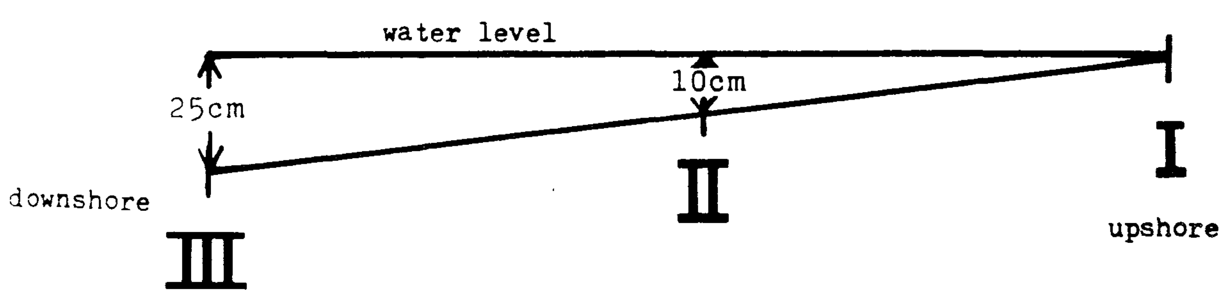


Figure 3. Sampling site arrangement on all beaches (see fig. 1) for the second component of the study (Sites I,II,III) in the South Slough, Charleston, Oregon.

hours at 95°C in a drying oven and subsequently dry sieved with a Derrick Vibration Motor Screens unit (Model 150) for ten minutes at a setting of #30. The sieves utilized in series were the U.S. Standard Sieve Mesh Numbers 10, 18, 35, 60, 120, 230, and 325. Fractions from each mesh were weighed on an analytical balance. Mean phi, uniformity of sorting (graphic standard deviation of ϕ, hereafter referred to as the sorting coefficient σI), and skewness (SK_1) of the grain size distribution (Folk 1968, cited in Hulings and Gray 1971) were determined.

Faunal samples were returned to the laboratory and processed immediately in the following manner. The fauna within the sediment fractions were narcotized with 7% $MgCl_2$ in filtered sea water and subsequently extracted from the sediment to a 50 cc jar by multiple (at least three) decantations using the 7% $MgCl_2$ solution throughout the process (Hummon et al. 1978). The sediment remaining after the decantations was checked by visual observation to determine if the extraction process was efficient enough for reliable results. Samples were then fixed with enough 100% formalin with rose bengal to bring the final concentration to approximately a 10% formalin in sea water solution. The jars were swirled to ensure mixture of the formalin and the specimens.

After the samples containing the extracted fauna had settled, approximately two-thirds of total fluid in the sample was decanted and discarded. The remaining fluid was swirled and if observed to be less than 12 ml or laden with too much detritus or silt (which reduced the visability of the organisms in the counting process) additional fluid was added to the sample. Twelve Sedgewick-Rafter (S-R) cells were then filled from the sample, the contents of which had been randomized by gentle agitation, using a large bore (5.5 mm internal diameter) pipette. The residual volume of the sample, after the 12 ml had been removed, was recorded. The S-R cells containing the extracted fauna were examined with a Bausch and Lomb dissecting stereomicroscope at 45x magnification. The fauna, tabulated as the number of individuals in each taxon and summed over twelve replicates, was multiplied by a factor (C) to convert to the number of individuals per cubic centimeter of sediment. This factor (C) was given as the total volume of fluid (ml) after decantation (sample from which the S-R cells were filled), divided by the number of cubic centimeters of sediment in the sample, times the volume (ml) of fluid used in the S-R cells (Hummon et al. 1978). This figure was then converted to the number of individuals per 10 cm^2 in accordance with the conventions for reporting abundances of meiofauna as "the numbers of individuals on or below 1/1000 m^2 surface area, designated per 10 cm^2." (McIntyre 1969:250).

The second component of the study was designed to simulate tidal movement and examine the distribution of the organisms at various tide levels. Only faunal samples were collected for the second component. The second component required three sites per beach and followed a transect perpendicular to the water line. The apex of the wave swash zone at the lower high tide was designated as Site I. Site II was located along the transect in 10 cm of water and Site III was located in 25 cm of water (Figure 3). All three sites were sampled within a few minutes of each other and entailed the aforementioned faunal fraction collection.

Statistical analysis of the data included two-way analysis of variance for total numbers of organisms, numbers of Gastrotricha, Harpacticoida, and Nematoda by site and depth. Subsequent one-way analysis of variance for total numbers, Gastrotricha, Harpacticoida, and Nematoda by site with a fixed depth and by depth with a fixed site were also performed (See Appendix B for examples of ANOVA tables.). Least significant difference (LSD) was performed subsequent to the one-way analyses of variance. All differences regarded as significant have an alpha value of at least 0.05. The raw data was suspected to deviate from the normal distribution and was therefore transformed by log (x+1) and $\sqrt{x}$. These transformations did not appreciably change the results from the analysis of the untransformed data. This fact, together with homoscedasticity tested by the F-max test (Sokal and Rohlf 1969), suggested that the assumptions of analysis of variance had been met. All statistical analyses were performed on the Burrough's 6700 computer with the Statistical Package for the Social Sciences (SPSS, version 7) at the University of the Pacific Computer Center.

RESULTS

The results of the granulometric analysis (Table I) indicated an increase in the mean grain size from depth 0-1 to 1-2 to 3-4 cm for most of the sites. A decrease in the mean grain size along the slough was found; Beach 1 had the largest (313.04 μm), Beach 2 (282.07 μm), and Beach 3 (279.03 μm) had the smallest mean grain size. Most of the samples had low sorting coefficients, which indicated that the sediments of the beaches were well sorted. The compaction of the sand decreased from Site A to Site A' to Site A'' for all beaches with the greatest change in compaction occurring from Site A to Site A' (Figures 4,5,6). Beach profiles (Figure 7) indicated a constant and gradual slope; Beach 2 had the greatest slope (15%), Beach 3 (12%), and Beach 1 had the least slope (9%). Table II shows the salinities, water temperature, and sediment temperature for all beaches. Weather conditions on 26 July included: air temperature 14°C, light gusty winds (less than 33 knots), 83% relative humidity, light cloud cover, and small wave action. Weather conditions on 8 August were similar, however, they were not recorded.

The swash zone sites (A,B,C) in the first component of the study showed lower total numbers of organisms at the surface level than the lower levels and a decrease in the total number of organisms from Site A to Site B to Site C (Figures 9,10,11). The distribution of the total numbers of organisms may then be generalized as follows:

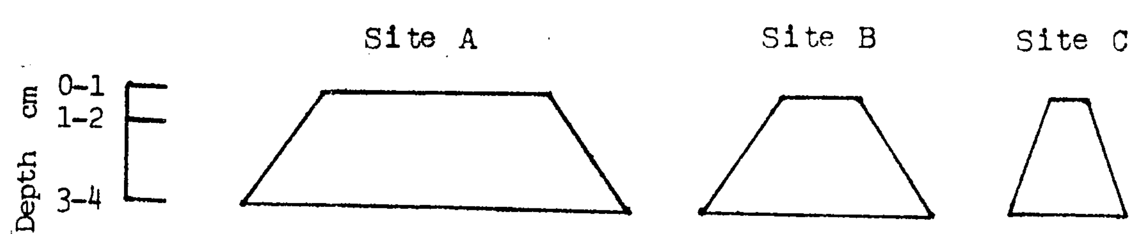


Table I. Summary of the granulometric analysis for Sites A,B,C on Beach 1,2,3 - South Slough, Charleston, Oregon. (see figs. 1 and 2 for beach and site location). Mean phi (MN ϕ), mean grain size (MN μm), sorting coefficients (σ-I), and skewness (SK_1).

Beach #1

	Site A				Site B				Site C			
Depth	MN ϕ	MN μm	σI	SK_1	MN ϕ	MN μm	σI	SK_1	MN ϕ	MN μm	σI	SK_1
0-1	1.72	302.71	0.46	0.14	1.83	281.26	0.36	0.08	1.73	301.03	0.46	0.04
1-2	1.53	345.32	0.39	0.09	1.72	304.39	0.44	0.05	1.70	306.93	0.53	0.03
3-4	1.49	357.00	0.44	-.01	1.66	315.56	0.41	0.03	1.72	303.13	0.43	0.03

Beach #2

	Site A				Site B				Site C			
Depth	MN ϕ	MN μm	σI	SK_1	MN ϕ	MN μm	σI	SK_1	MN ϕ	MN μm	σI	SK_1
0-1	1.79	289.57	0.33	-.02	1.98	254.19	0.37	0.09	1.83	281.65	0.40	-.08
1-2	1.87	273.19	0.37	0.11	1.93	262.43	0.45	0.04	1.78	290.38	0.44	0.05
3-4	1.82	283.61	0.38	0.07	1.77	293.21	0.46	0.06	1.69	310.36	0.44	0.01

Beach #3

	Site A				Site B				Site C			
Depth	MN ϕ	MN μm	σI	SK_1	MN ϕ	MN μm	σI	SK_1	MN ϕ	MN μm	σI	SK_1
0-1	1.83	281.26	0.44	0.09	1.80	287.17	0.38	0.06	1.95	258.82	0.45	0.00
1-2	1.79	288.37	0.48	0.07	1.83	281.26	0.48	0.04	1.96	257.74	0.54	0.19
3-4	1.74	298.95	0.51	0.11	1.80	287.17	0.63	0.02	1.89	270.56	0.52	0.19

Figure 4. The mean relative compaction of the sand (•———•) and the mean grain size (•- - - - -•) for Sites A,B,C,A',A'' - Beach 1 (see figs. 1 and 2 for beach and site location) in the South Slough, Charleston, Oregon.

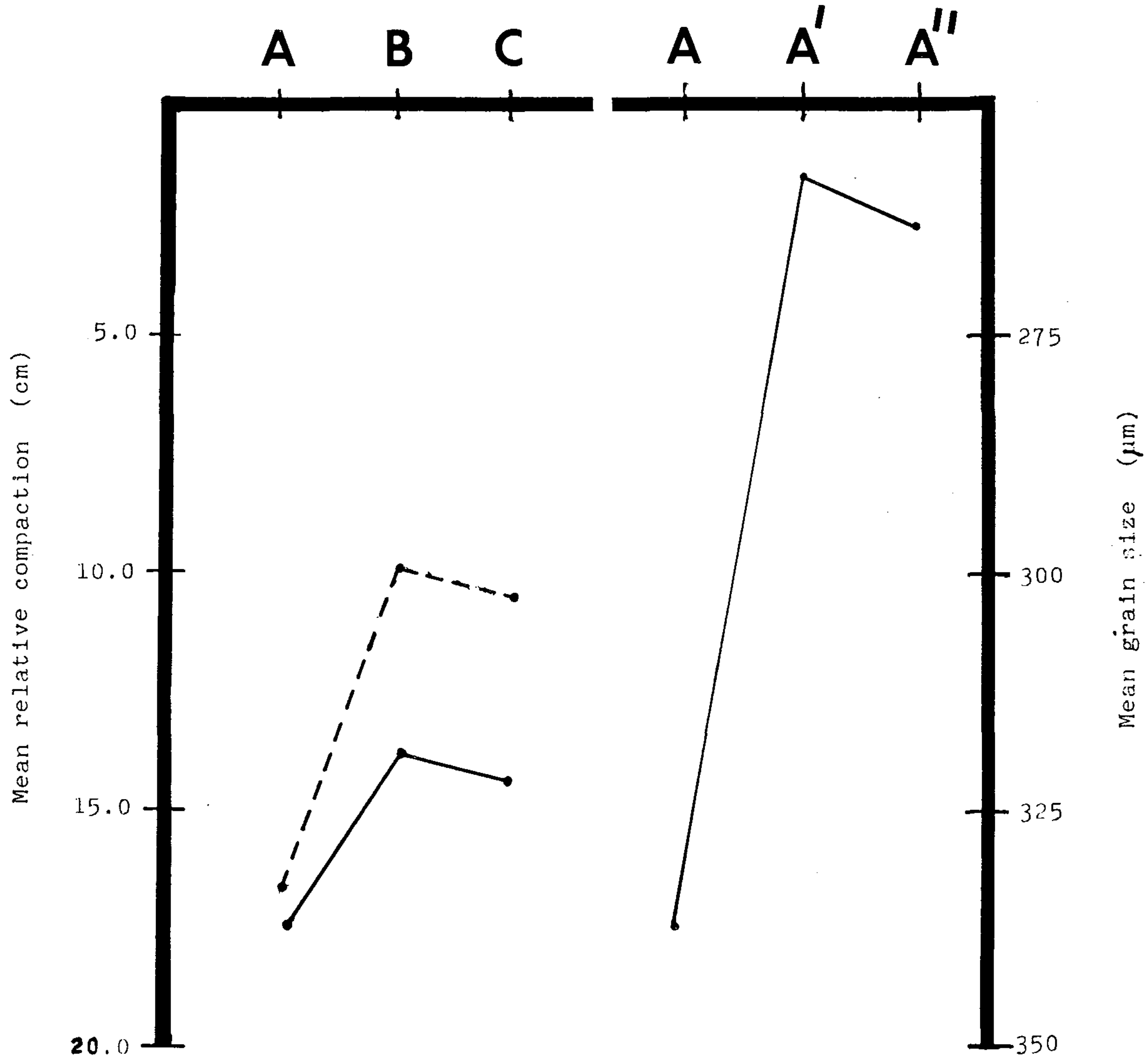

A
B
C
A
A'
A''
Mean relative compaction (cm)
5.0
10.0
15.0
20.0
Mean grain size (μm)
275
300
325
350

Figure 5. The mean relative compaction of the sand (•———•) and the mean grain size (•– – – –•) for Sites A,B,C,A',A'' - Beach 2 (see figs. 1 and 2 for beach and site location) in the South Slough, Charleston, Oregon.

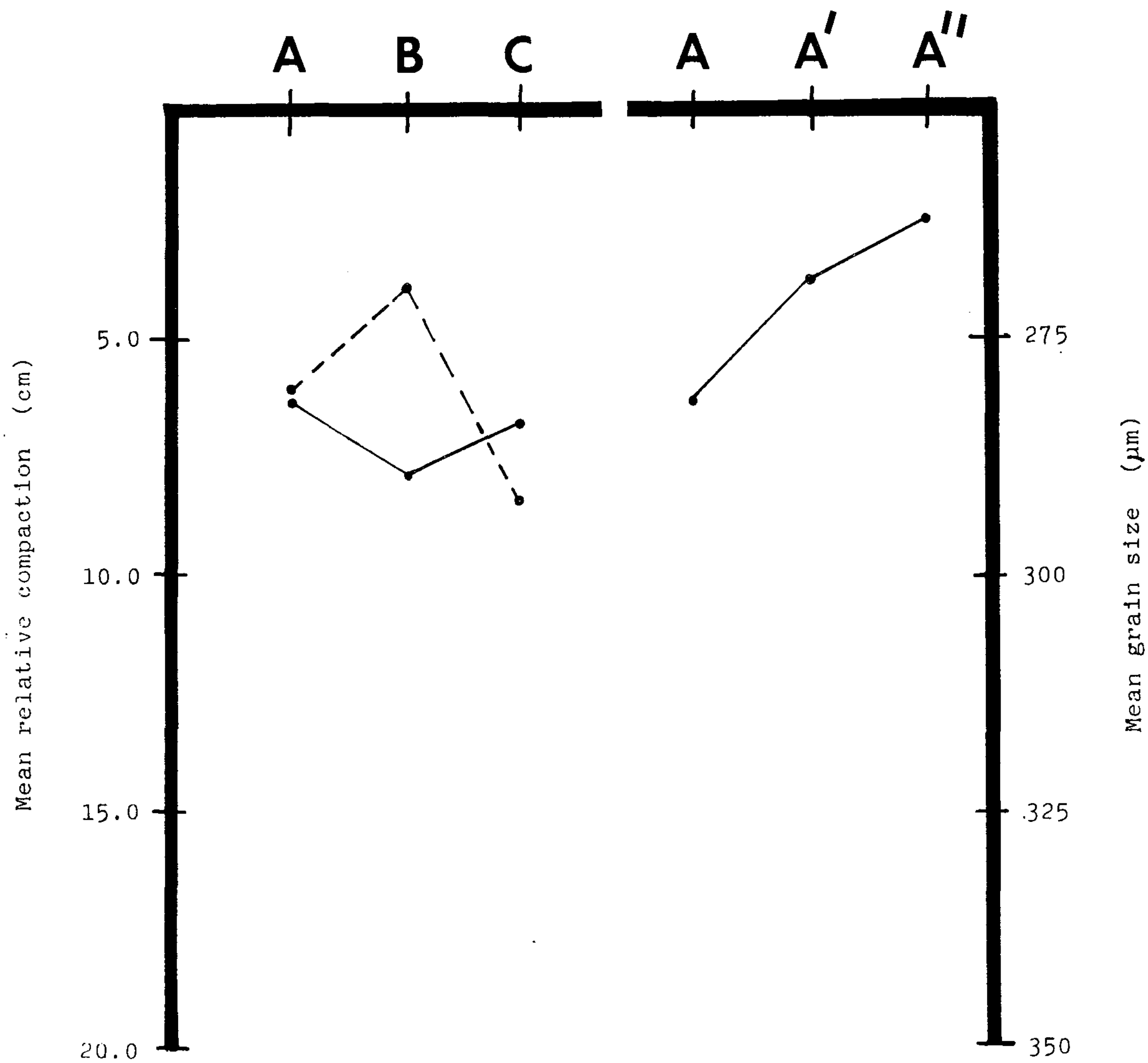

A
B
C
A
A′
A″
5.0
10.0
15.0
20.0
Mean relative compaction (cm)
275
300
325
350
Mean grain size (µm)

Figure 6. The mean relative compaction of the sand (•————•) and the mean grain size (•- - - -•) for Sites A,B,C,A',A'' - Beach 3 (see figs. 1 and 2 for beach and site location in the South Slough, Charleston, Oregon.

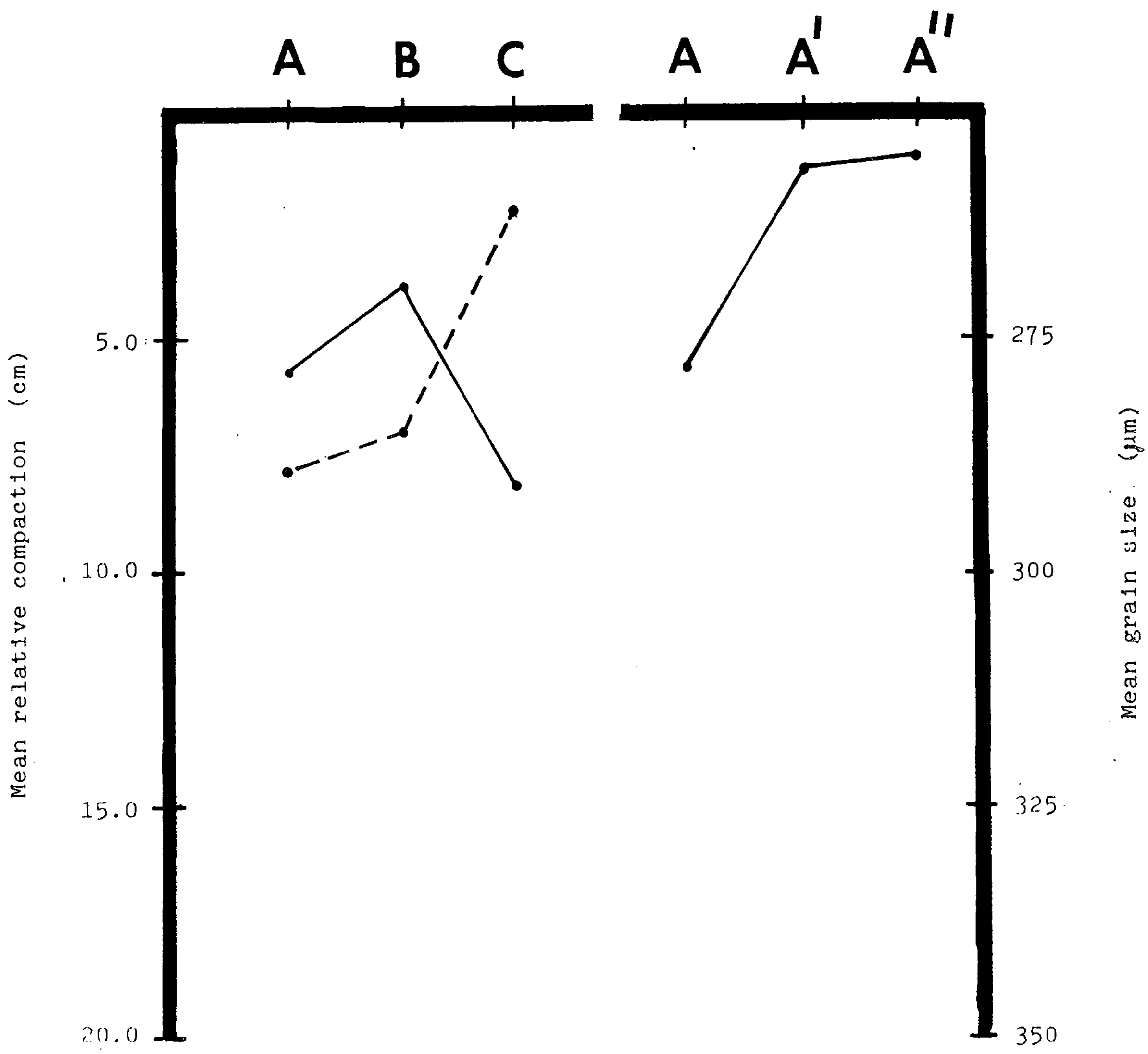

A
B
C
A
A'
A''
Mean relative compaction (cm)
5.0
10.0
15.0
20.0
Mean grain size (µm)
275
300
325
350

Figure 7. Beach profiles and slope of the three selected beaches (see fig. 1).

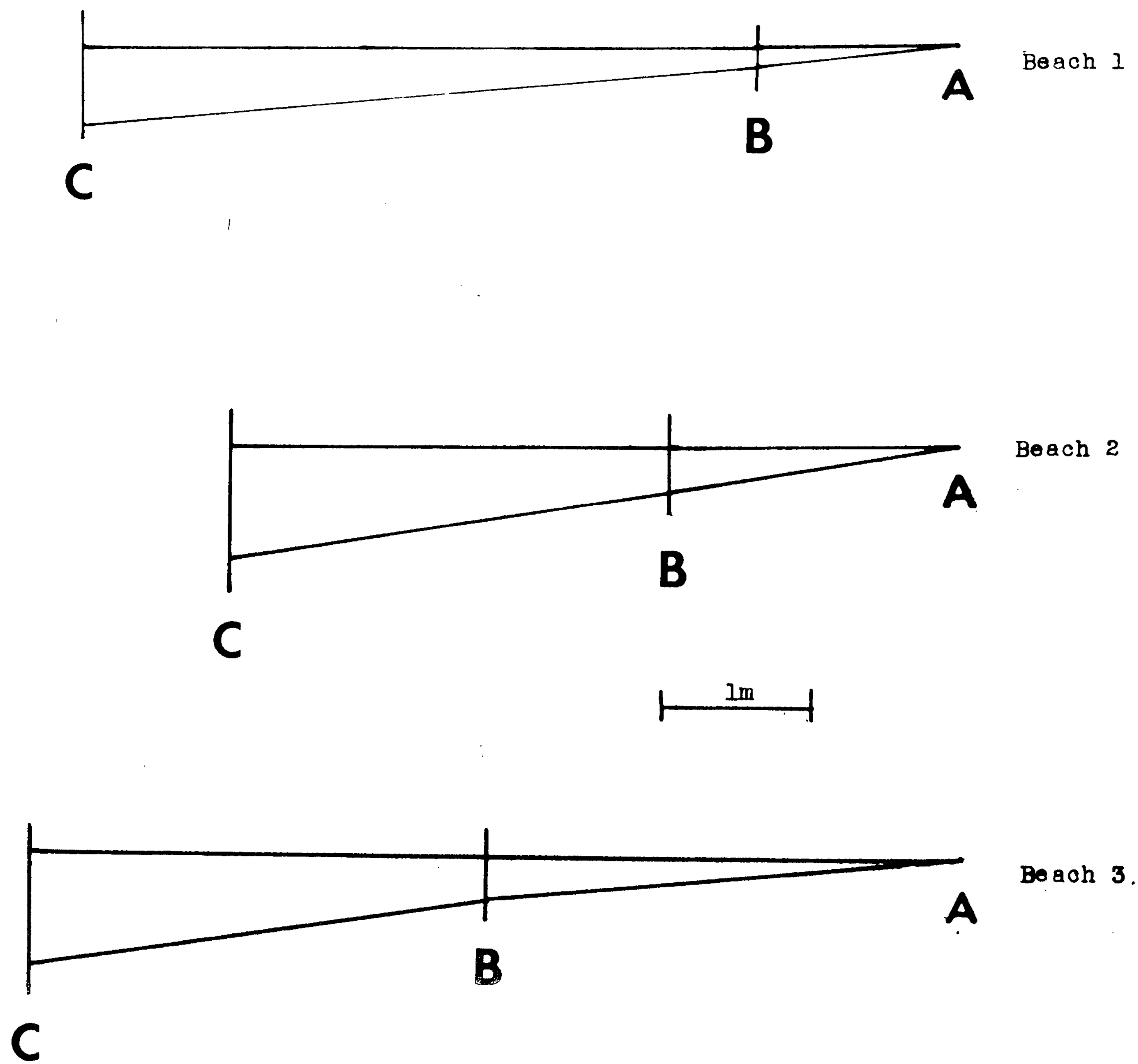

Beach 1
A
B
C
Beach 2
A
B
C
1m
Beach 3.
A
B
C

Table II. Sediment temperatures at depths 0-1, 1-2, and 3-4 cm, water temperature, and salinity at Sites A,B,C,A',A'' on Beaches 1,2,3 - South Slough, Charleston, Oregon. (see figs. 1 and 2 for beach and site location). Temperatures are all in centigrade and salinities are in parts per thousand.

Beach #1

	Site A	Site B	Site C	Site A'	Site A''
0-1	14.3	13.0	13.5	14.0	13.8
1-2	14.7	13.0	13.5	14.8	14.1
3-4	15.0	12.9	13.7	15.5	14.1
water temperature	13.0	13.1	13.1	----	----
salinity 0/00	34.0	34.0	33.5	----	----

Beach #2

	Site A	Site B	Site C	Site A'	Site A''
0-1	14.9	13.5	13.0	13.2	14.1
1-2	14.0	13.8	13.8	14.2	14.8
3-4	13.3	14.0	14.0	14.1	14.8
water temperature	13.7	13.8	14.0	----	----
salinity 0/00	34.5	31.0	34.0	----	----

Beach #3

	Site A	Site B	Site C	Site A'	Site A''
0-1	16.0	15.0	15.0	15.0	14.5
1-2	15.8	15.0	15.3	15.9	15.1
3-4	15.9	15.0	15.7	15.8	15.5
water temperature	15.0	15.1	16.0	----	----
salinity 0/00	34.0	32.0	33.0	----	----

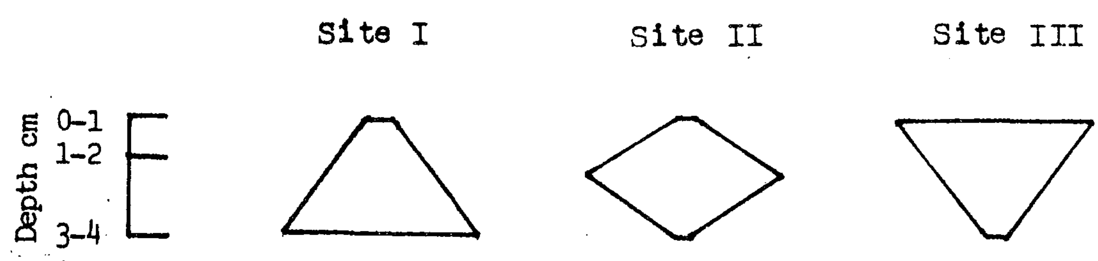
Site C on Beach 3 deviated from this general pattern and showed a significant increase in the total numbers in the surface levels (Figure 11). There were significant increases in the total number of organisms in the surface levels from Site A to Site A' and a subsequent decrease in the surface levels from Site A' to Site A'' for all beaches (Figures 12,13,14). This trend was best illustrated by the Nematoda on Beach 2 (Figure 13).

The abundance of Nematoda increased with the decreasing mean grain size, while the abundance of the Harpacticoida decreased with the decreasing mean grain size (Figures 15-23). On Beach 1, the Harpacticoida appeared to be either dominant or codominant with the Nematoda at Site A, while the Nematoda clearly dominated Sites B and C (Figures 15,16,17). The Nematoda were the most abundant at Sites A,B,C on Beach 2 (Figures 18, 19,20). Beach 3 showed fluctuating dominance by the Nematoda and Gastrotricha (Figures 21,22,23).

The surface sediment level on Beach 1 was populated nearly equally by the Harpacticoida and Nematoda on Site A and A'; the Nematoda became the most numerous group at Site A'' (Figure 15). At the lower depths, the Harpacticoida dominated the population at Sites A and A' with the increasing predominance of the Nematoda at Site A'' (Figures 16,17). On Beach 2, the Nematoda were in the greatest abundance across all depths and Sites A,A', A'' (Figures 18,19,20). Nematoda dominance of Sites A and A' was replaced by the Gastrotricha at Site A'' for all depths on Beach 3 (Figures 21,22,23).

In the second component of the study a significant increase in the total number of organisms in the surface sediment levels coupled with the significant decrease in the lower levels was observed from Site I to

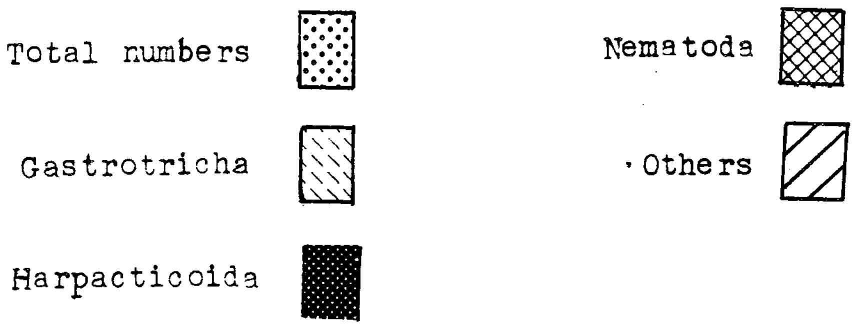
Site II to Site III (Figures 24,25,26). Beach 3 exhibited the best example of this pattern and may be generalized as follows:



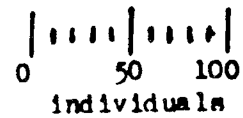
On Beach 1, the Harpacticoida appeared with the greatest abundance at Site II and III with the Nematoda clearly the dominant group at Site I (Figures 27,28,29). The Nematoda were the most abundant group at all Sites on Beach 2 (Figures 30,31,32). The Gastrotricha dominated the population at Sites II and III while the Nematoda comprised the largest percentage of the population at Site I on Beach 3. Very few Harpacticoida were found on Beach 3 (Figures 33,34,35).

Figure 8. Graphic legend for figures 9-35 and legend for the least significant difference statistic for figures 9-14 and 24-26.

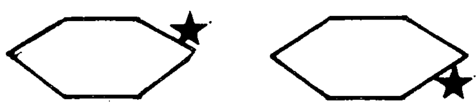
Graphic legend for figures 9-35.



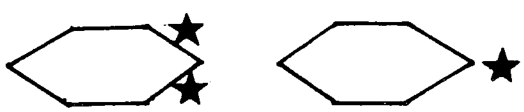
Scale for figures 9-14 and 24-26.



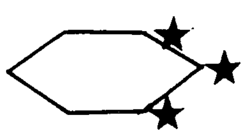
Legend for least significant difference statistic for figures 9-14 and 24-26.



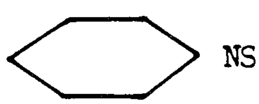
A indicates that the numbers of individuals at depths 0-1 and 1-2 are significantly different from those at 3-4 cm. B indicates that the numbers of individuals at 1-2 and 3-4 cm are significantly different from those at 0-1 cm



A indicates that the numbers of individuals at depths 0-1 are significantly different from those at 1-2 and 3-4 cm. B indicates that the numbers of individuals at 1-2 are significantly different from either 0-1 or 3-4 cm. Depths 3-4 and 0-1 cm are not significantly different from each other.



Indicates that the numbers of individuals at all three depths are significantly different from each other.



Indicates that there are no significant differences in the numbers of individuals between each depth.

Figure 9. Vertical and horizontal distribution of the total numbers of organisms, gastrotrichs, harpacticoids, and nematodes per 10 cm^2 for Sites A,B,C, Beach 1 (see figs. 1 and 2 for beach and site location and fig. 8 for legend) in the South Slough, Charleston, Oregon.

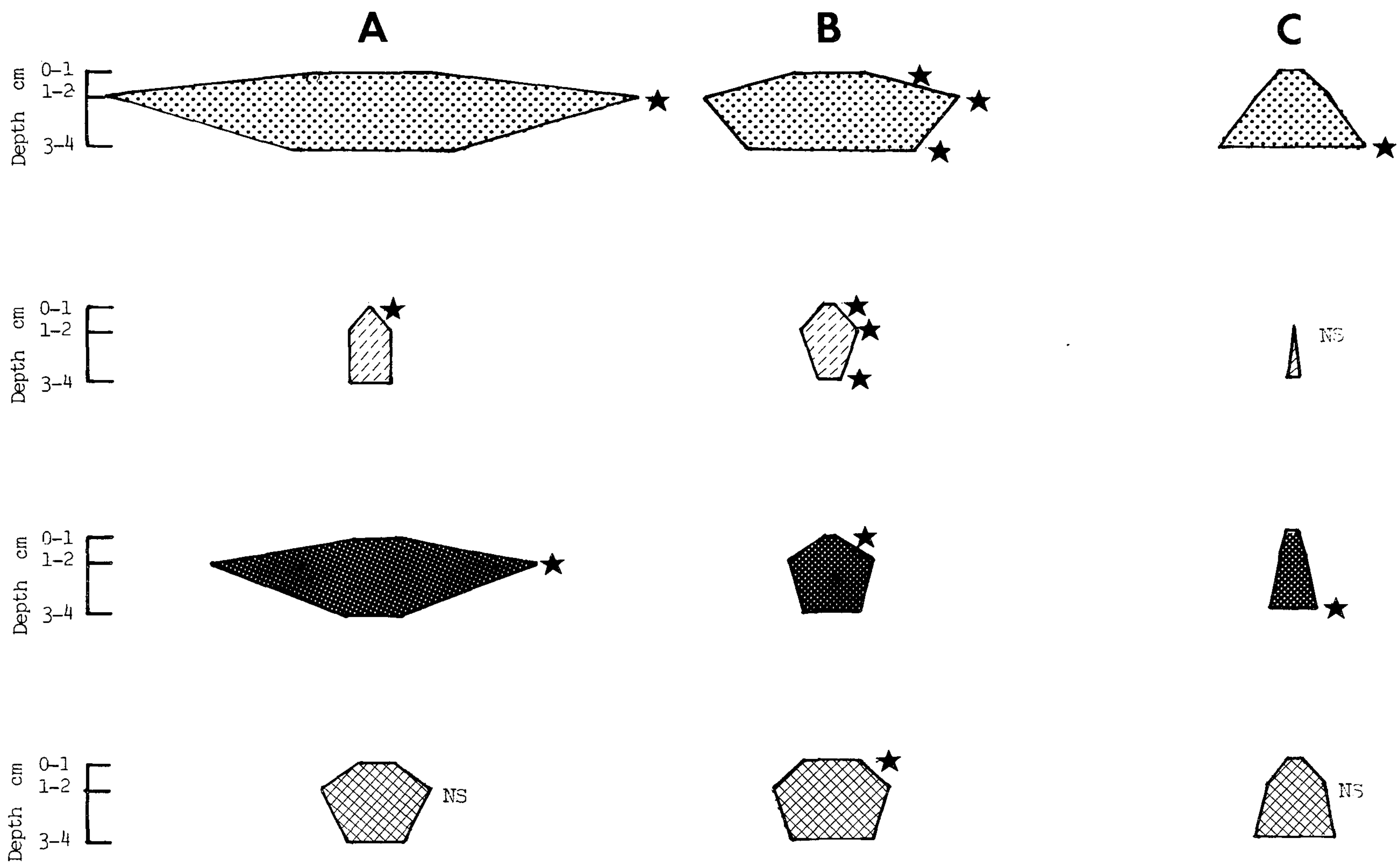
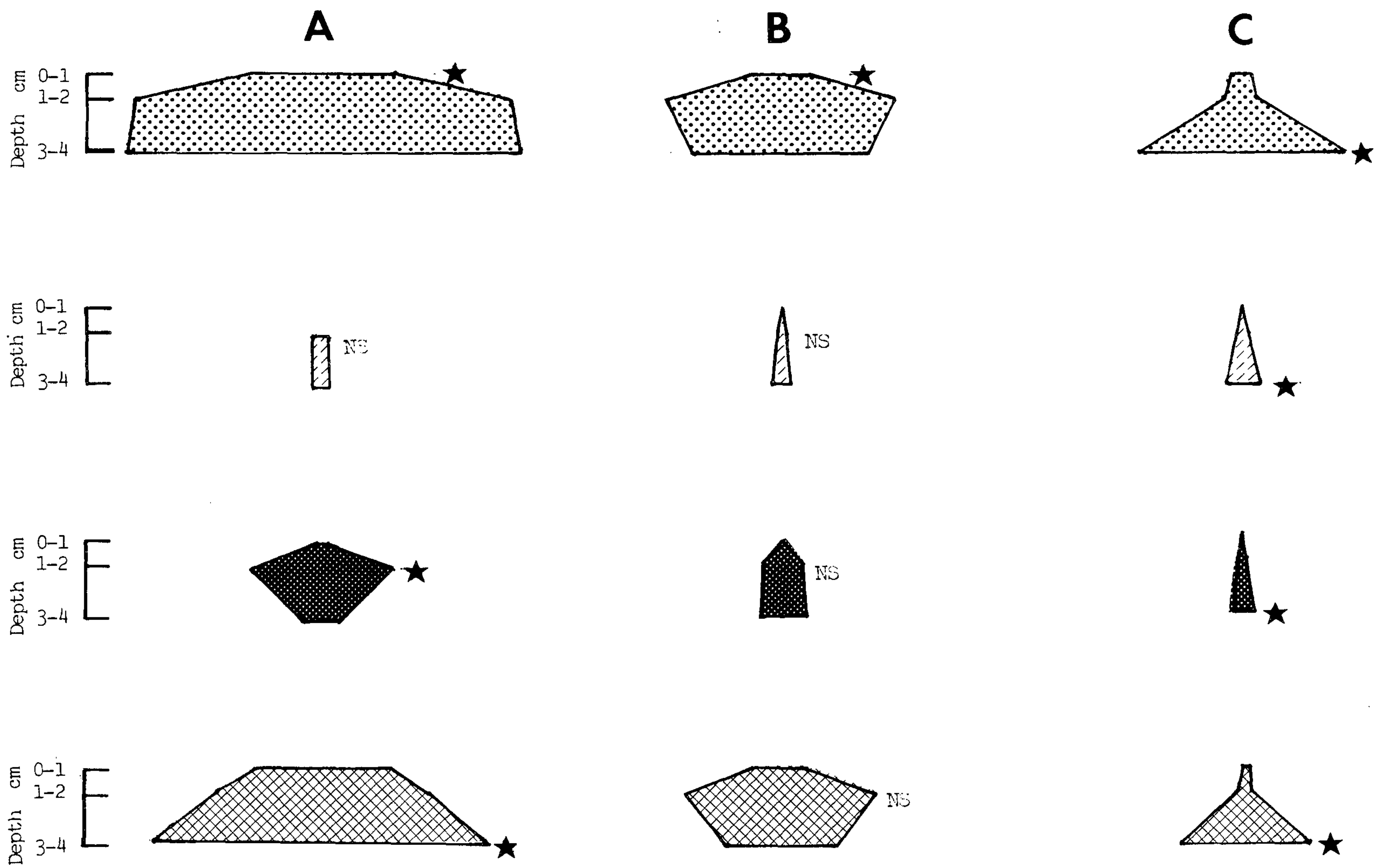
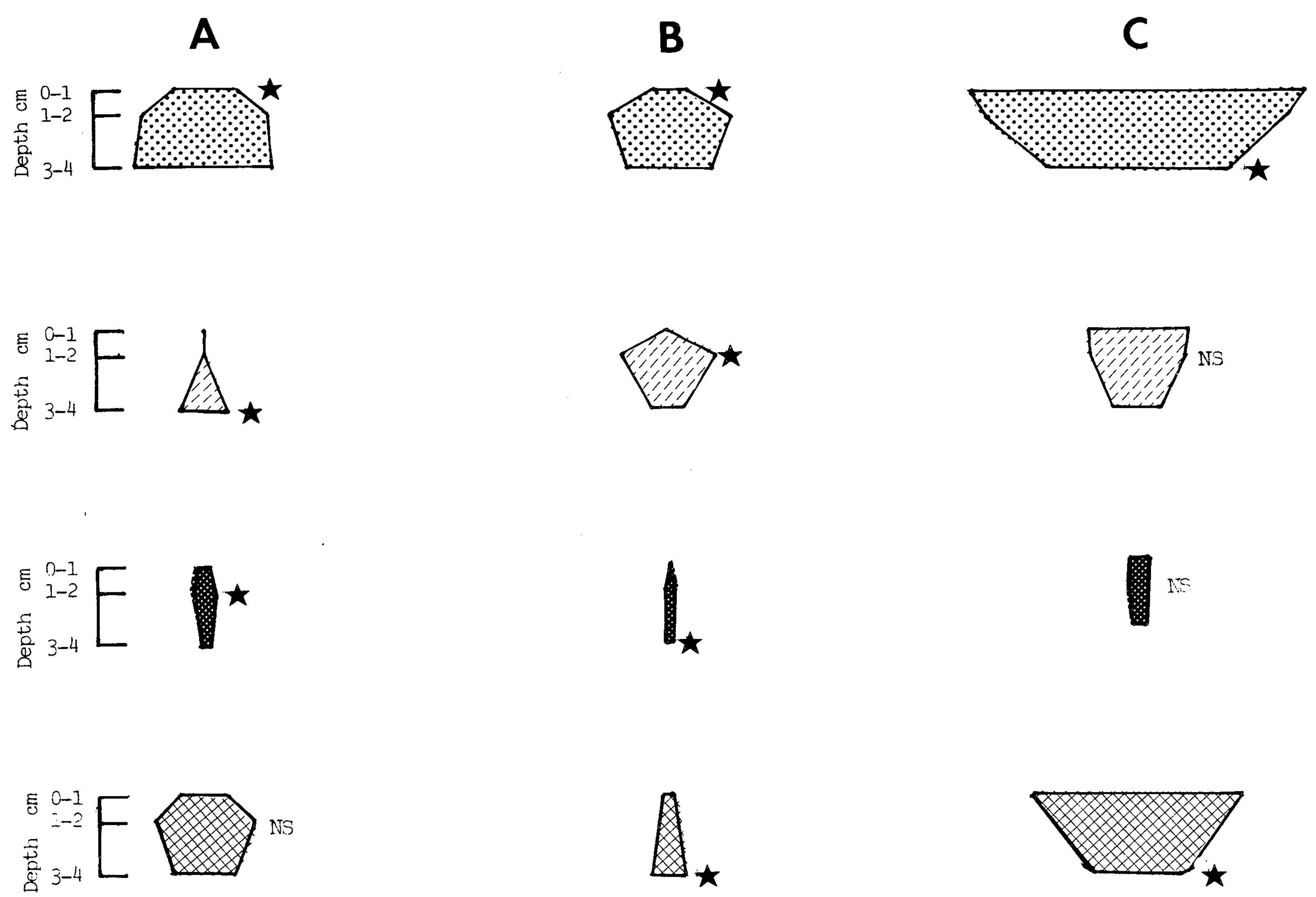

A
B
C
Depth cm
0-1
1-2
3-4
NS

Figure 10. Vertical and horizontal distribution of the total numbers of organisms, gastrotrichs, harpacticoids, and nematodes per 10 cm^2 for Sites A,B,C, Beach 2 (see figs. 1 and 2 for beach and site location and fig. 8 for legend) in the South Slough, Charleston, Oregon.



A
B
C
Depth cm
0-1
1-2
3-4
NS

Figure 11. Vertical and horizontal distribution of the total numbers of organisms, gastrotrichs, harpacticoids, and nematodes per 10 cm^2 for Sites A,B,C, Beach 3 (see figs. 1 and 2 for beach and site location and fig. 8 for legend) in the South Slough, Charleston, Oregon.



A
B
C
Depth cm
0-1
1-2
3-4
NS

Figure 12. Vertical distribution of the total numbers of organisms, gastrotrichs, harpacticoids, and nematodes per 10 cm^2 for Sites A,A', A'' Beach 1 (see figs. 1 and 2 for beach and site location and fig. 8 for legend) in the South Slough, Charleston, Oregon.

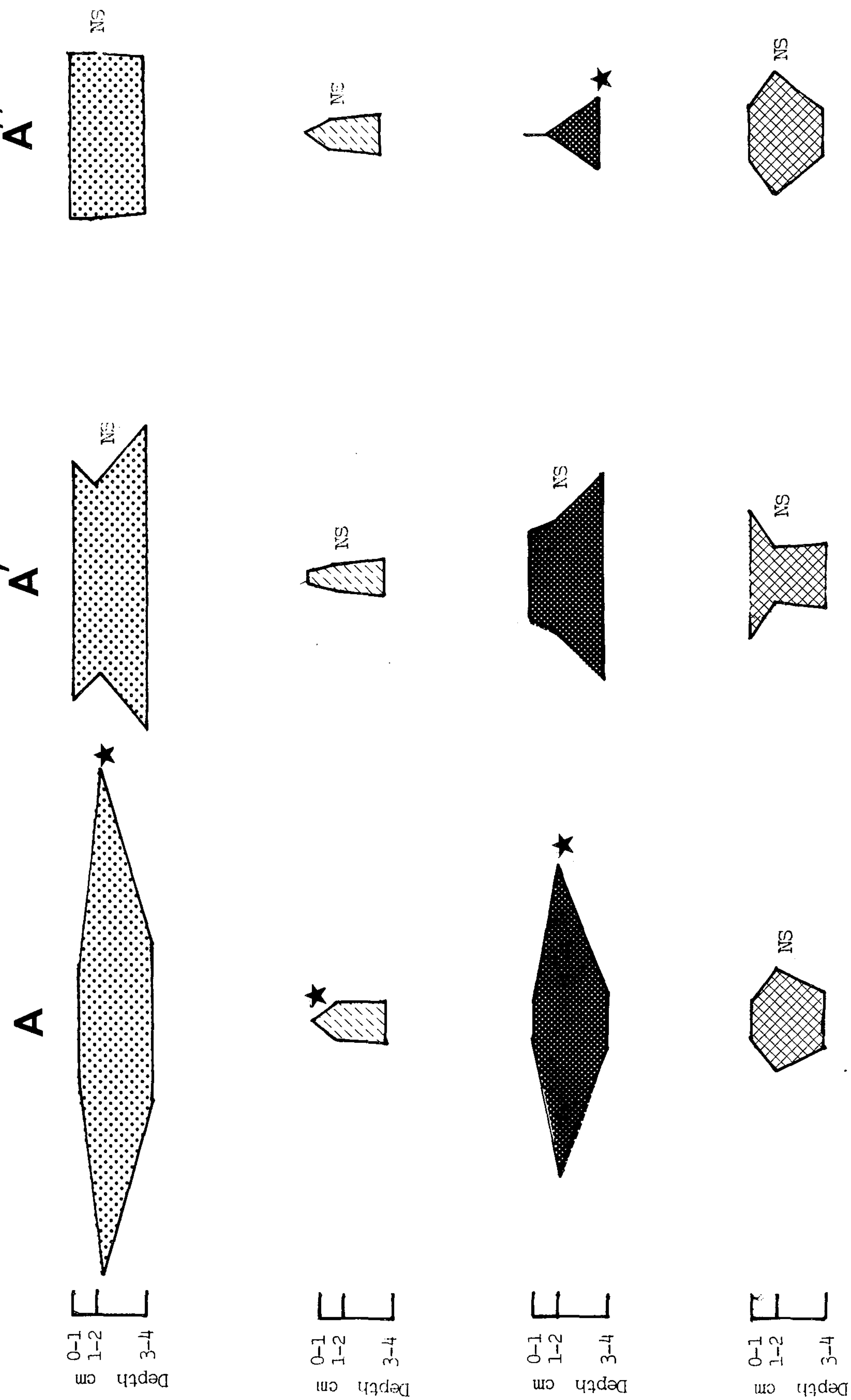

A
A′
A″
NS
NS
NS
NS
NS
NS
NS
Depth cm
0–1
1–2
3–4

Figure 13. Vertical distribution of the total numbers of organisms, gastrotrichs, harpacticoids, and nematodes per 10 cm^2 for Sites A,A',A'' Beach 2 (see figs. 1 and 2 for beach and site location and fig. 8 for legend) in the South Slough, Charleston, Oregon.

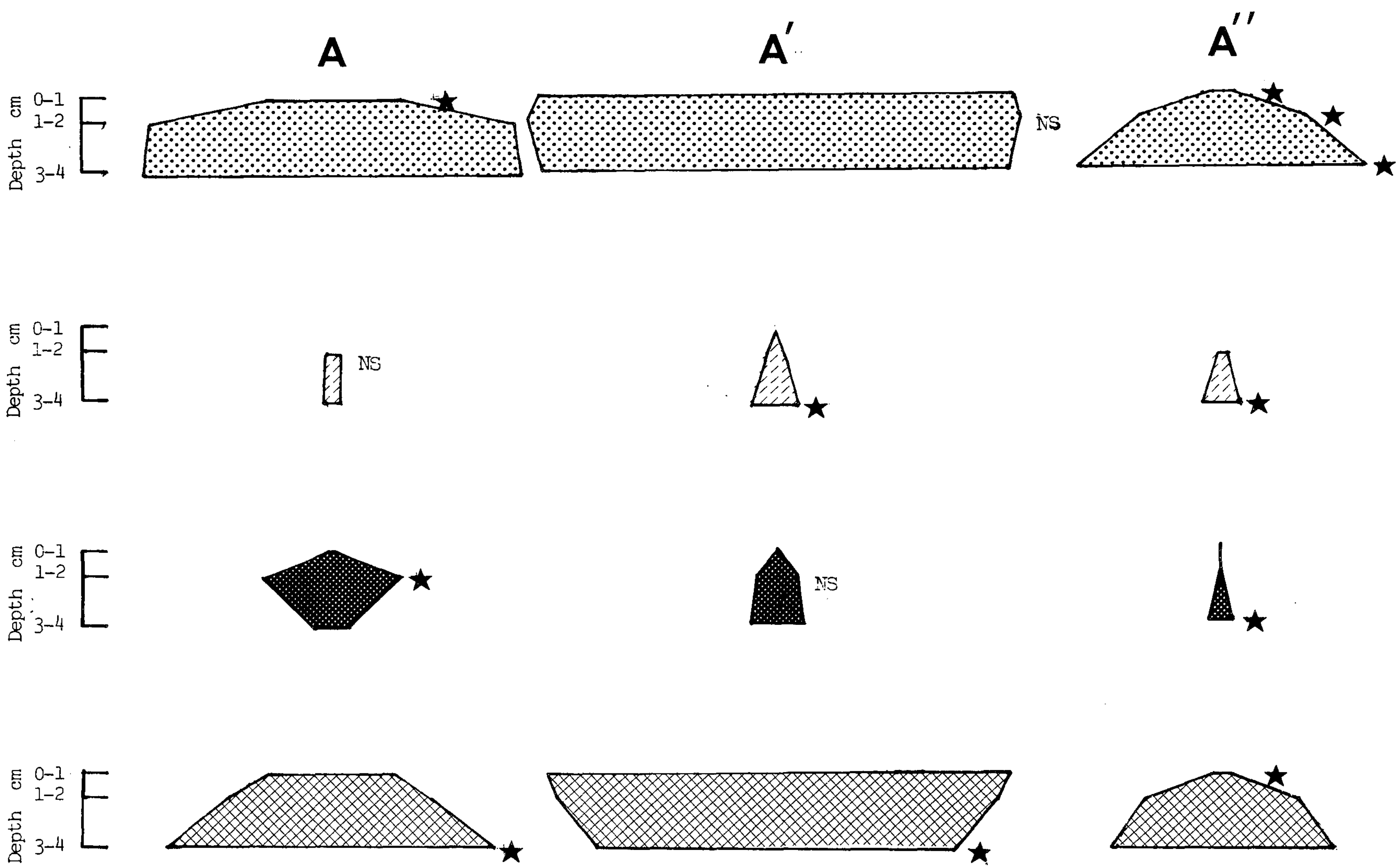
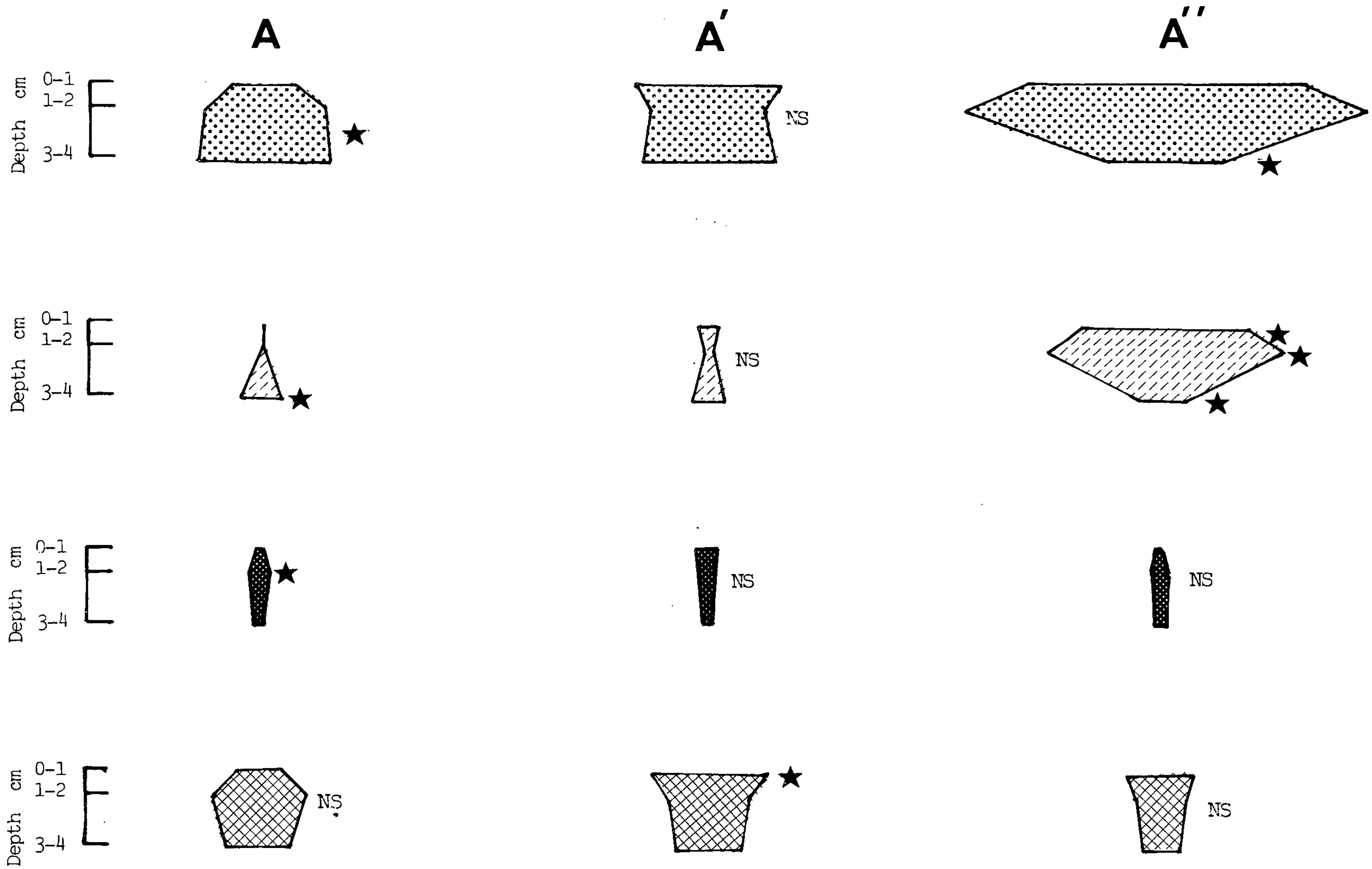

A
A′
A″
Depth cm
0–1
1–2
3–4
NS
NS
NS
NS

Figure 14. Vertical distribution of the total numbers of organisms, gastrotrichs, harpacticoids, and nematodes per 10 cm^2 for Sites A,A',A'' Beach 3 (see figs. 1 and 2 for beach and site location and fig.8 for legend) in the South Slough, Charleston, Oregon.



A
A′
A″
Depth cm
0–1
1–2
3–4
NS

Figure 15. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites A,B,C,A',A'' Beach 1 - sediment depth 0-1 cm. Mean phi for Sites A,B,C. (see figs. 1 and 2 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

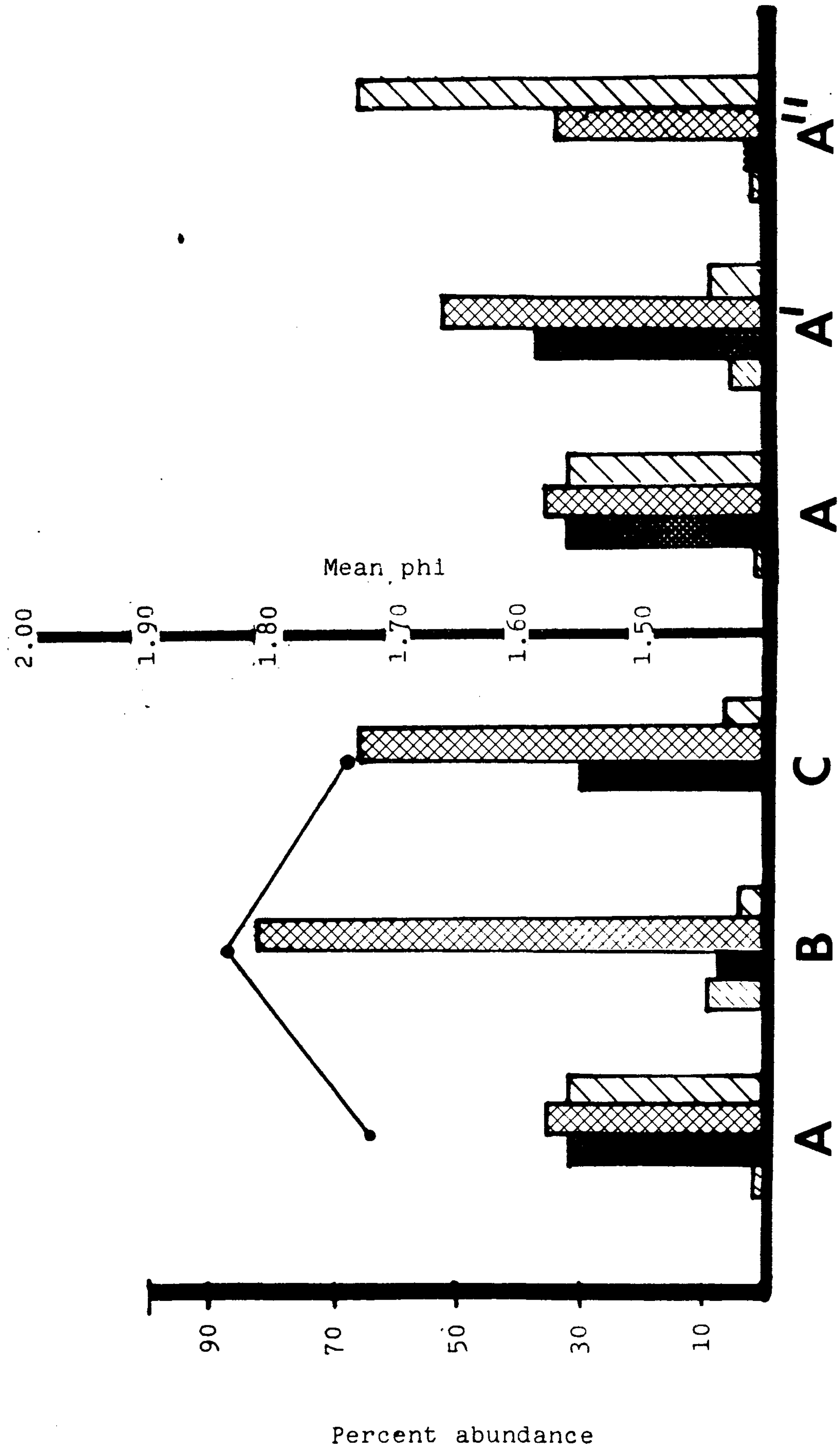
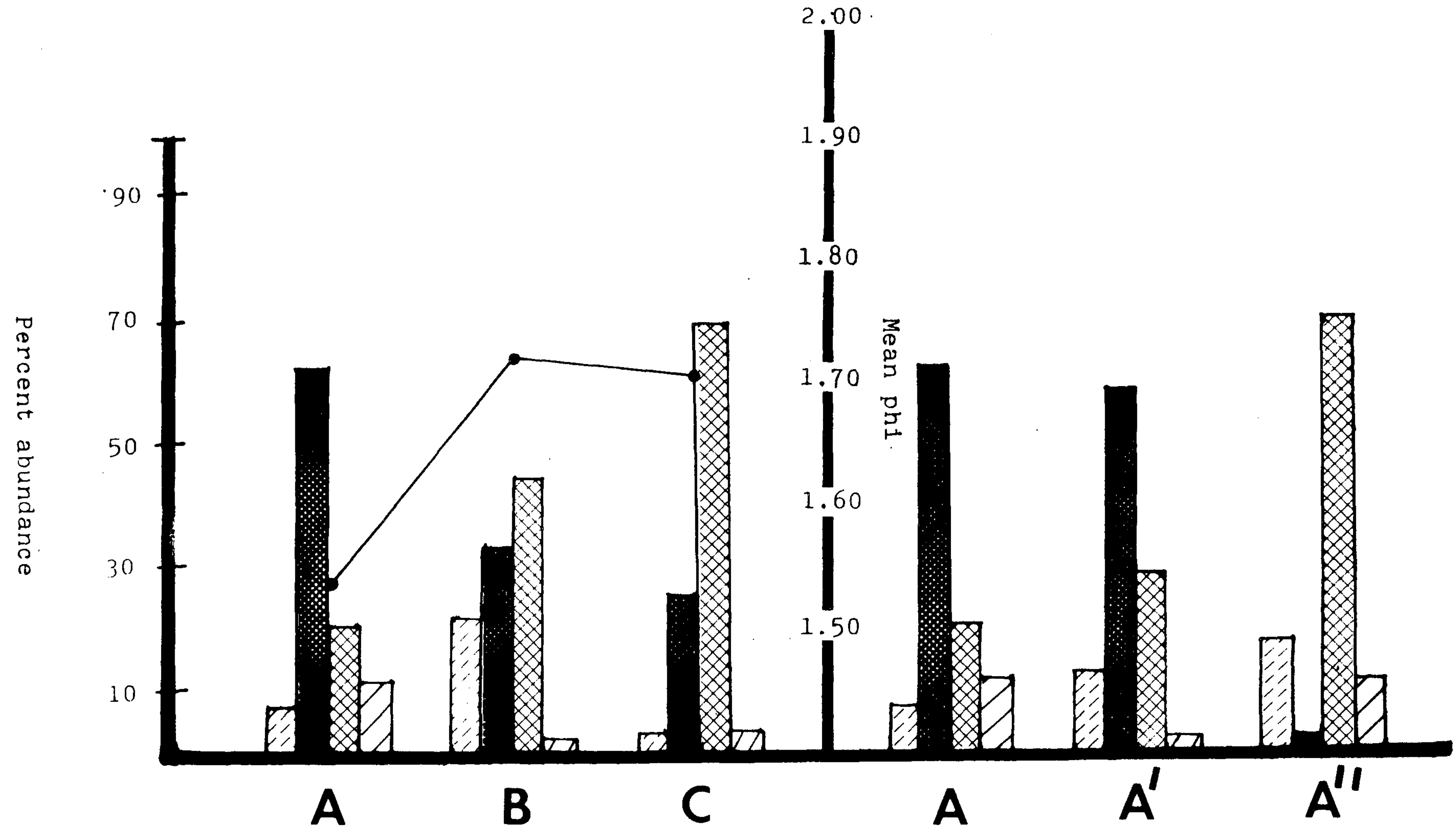
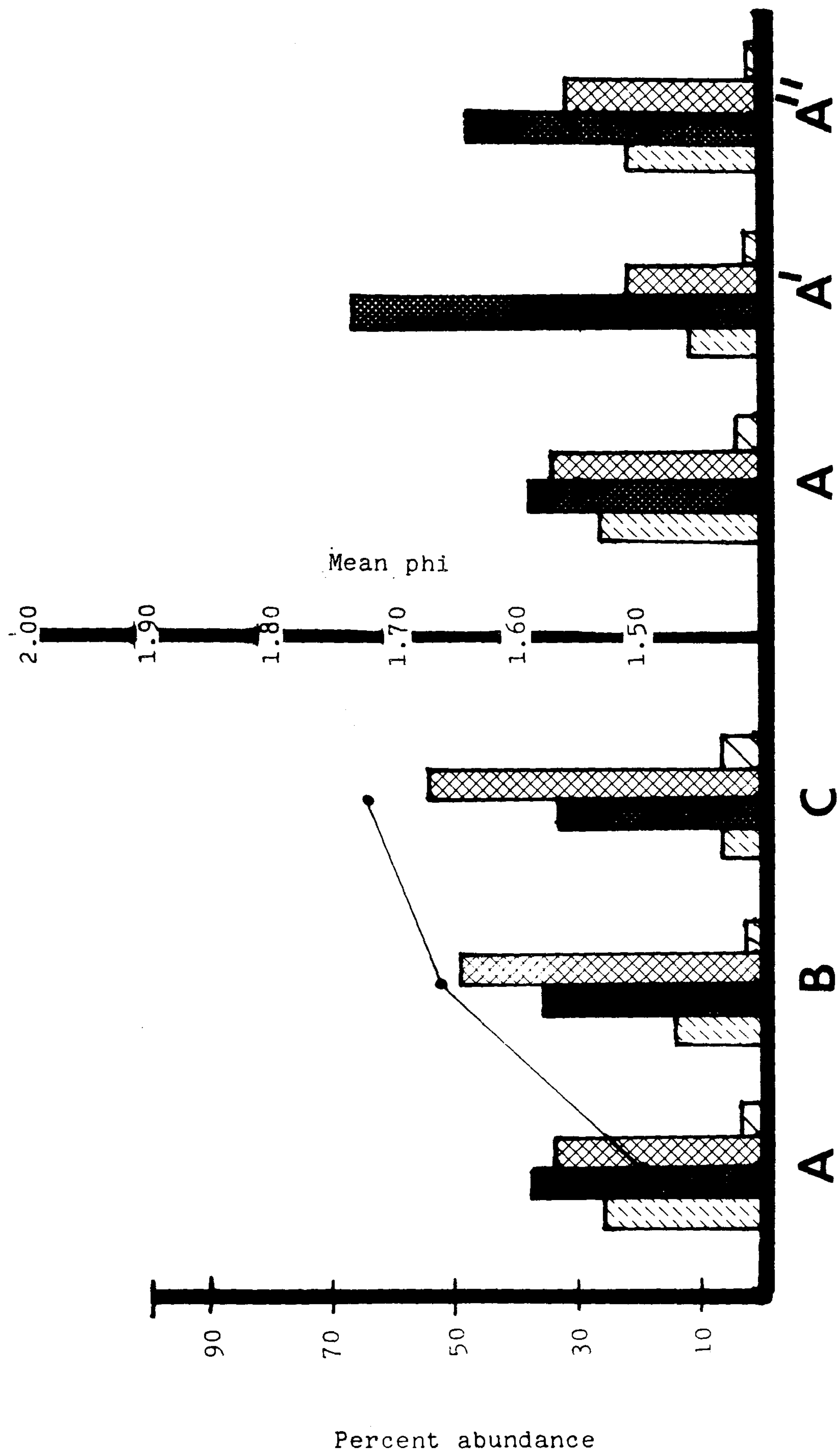

Mean phi
2.00
1.90
1.80
1.70
1.60
1.50
A
B
C
A
A'
A''
90
70
50
30
10
Percent abundance

Figure 16. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites A,B,C,A',A'' Beach 1 - sediment depth 1-2 cm. Mean phi for Sites A,B,C. (see figs. 1 and 2 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.



Percent abundance
90
70
50
30
10
A
B
C
2.00
1.90
1.80
1.70
1.60
1.50
Mean phi
A
A'
A''

Figure 17. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites A,B,C,A',A'' Beach 1 - sediment depth 3-4 cm. Mean phi for Sites A,B,C. (see figs. 1 and 2 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.



Mean phi
2.00
1.90
1.80
1.70
1.60
1.50
90
70
50
30
10
Percent abundance
A
B
C
A
A'
A''

Figure 18. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites A,B,C,A',A'' Beach 2 - sediment depth 0-1 cm. Mean phi for Sites A,B,C. (see figs. 1 and 2 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

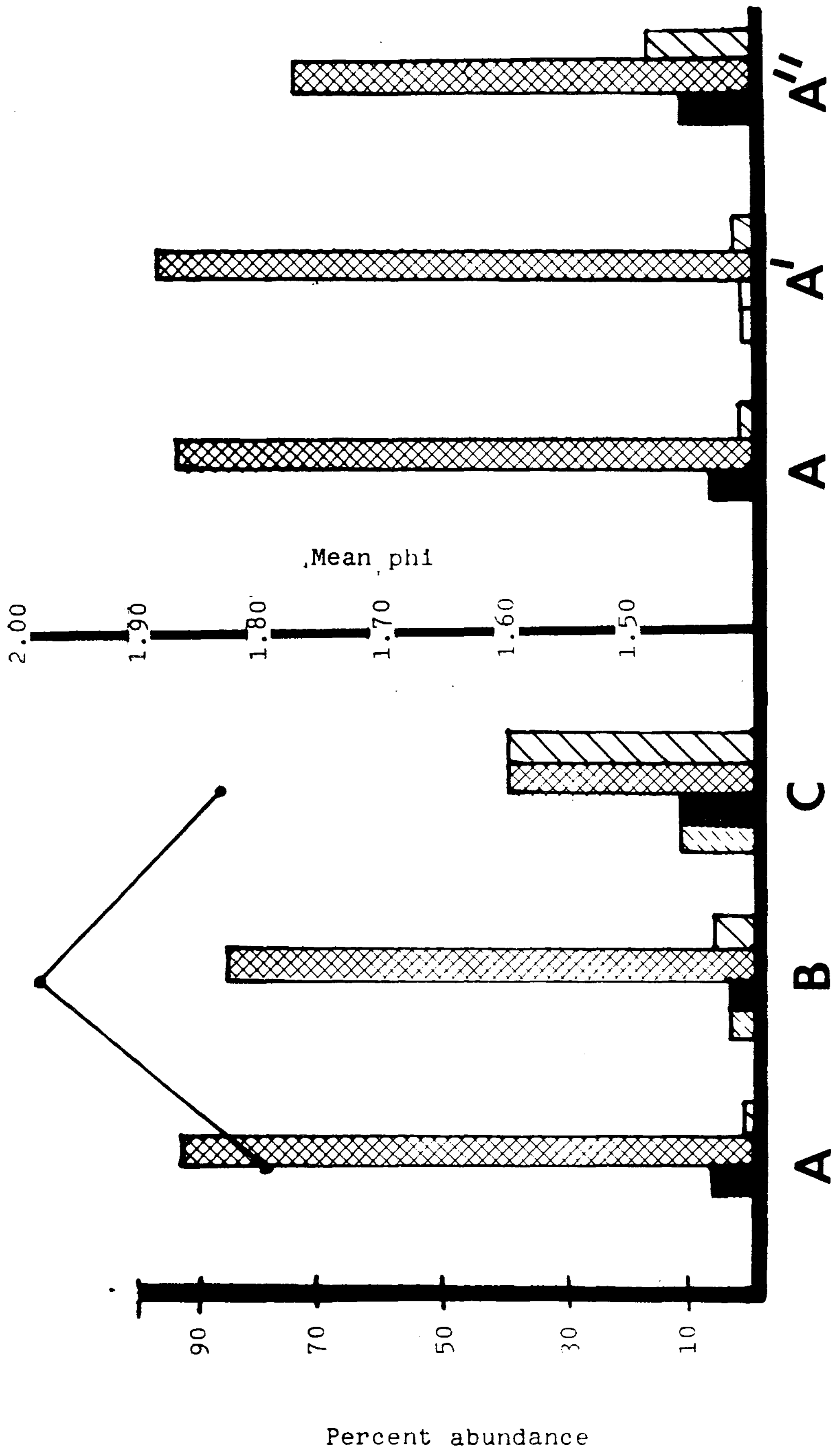
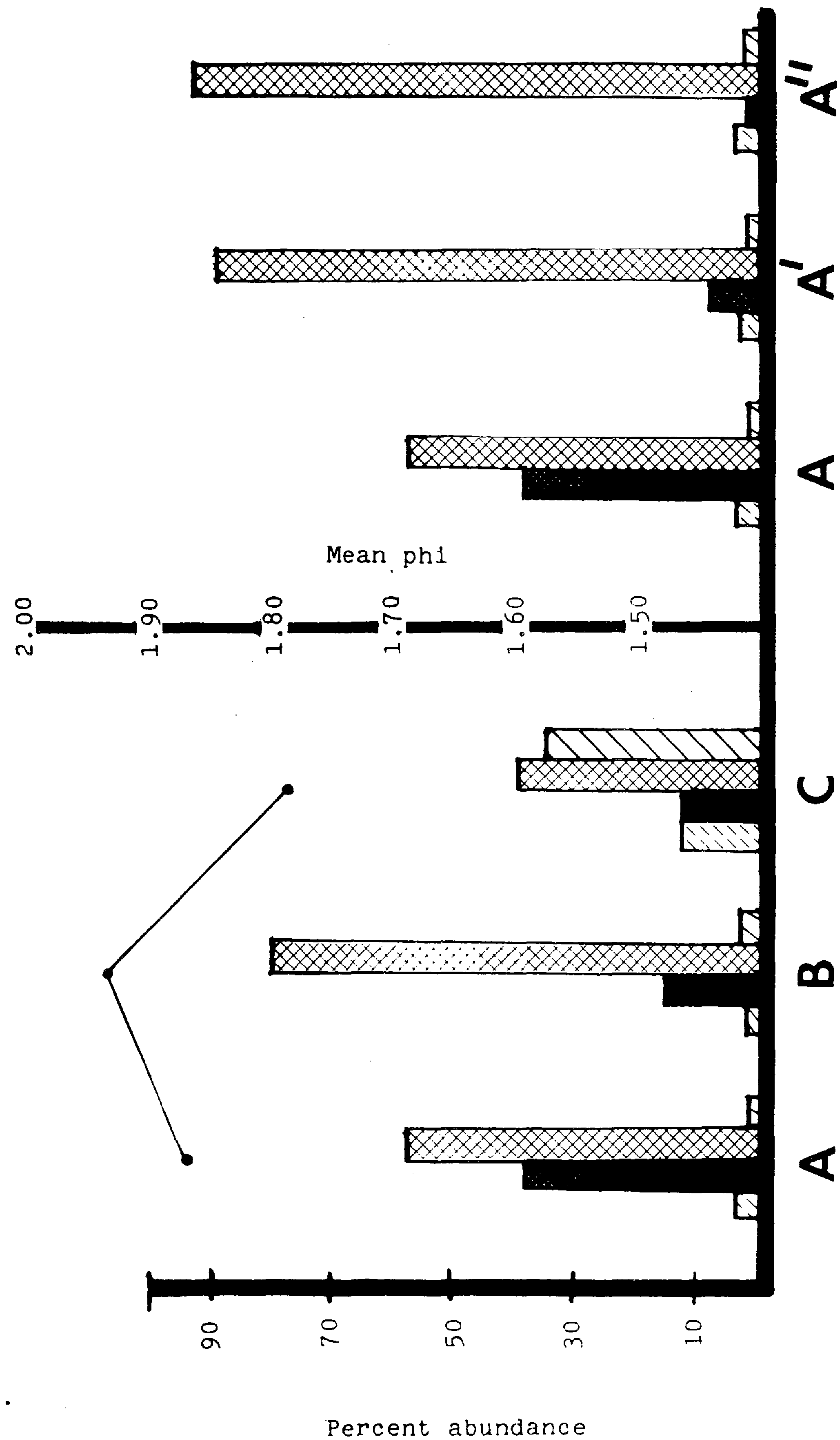

Mean phi
2.00
1.90
1.80
1.70
1.60
1.50
90
70
50
30
10
Percent abundance
A
B
C
A
A'
A''

Figure 19. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites A,B,C,A',A'' Beach 2 - sediment depth 1-2 cm. Mean phi for Sites A,B,C. (see figs. 1 and 2 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.



Mean phi
2.00
1.90
1.80
1.70
1.60
1.50
A
B
C
A
A'
A''
90
70
50
30
10
Percent abundance

Figure 20. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites A,B,C,A',A'' Beach 2 - sediment depth 3-4 cm. Mean phi for Sites A,B,C. (see figs. 1 and 2 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

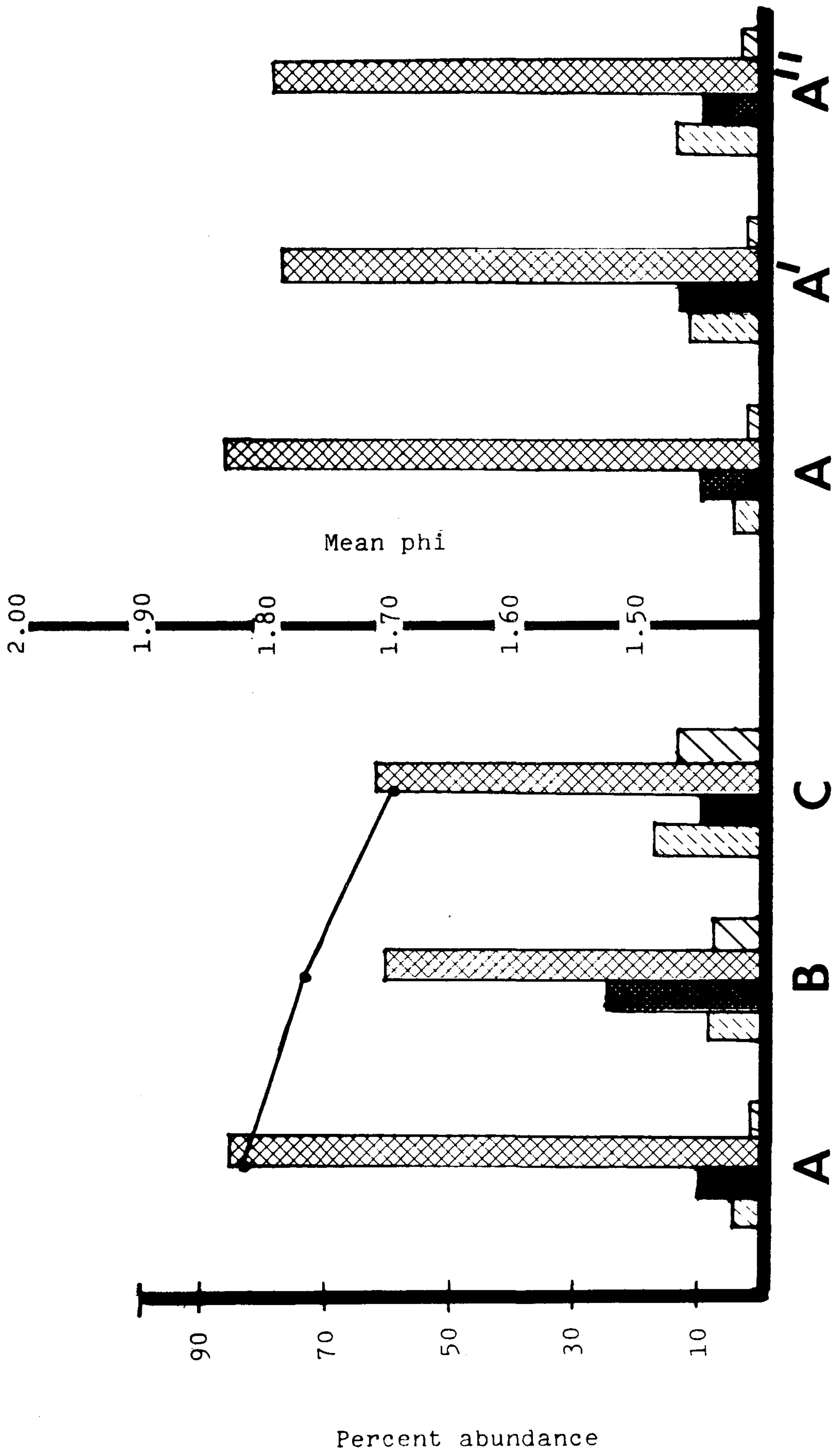

Mean phi
2.00
1.90
1.80
1.70
1.60
1.50
A
B
C
A
A'
A''
90
70
50
30
10
Percent abundance

Figure 21. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites A,B,C,A',A'' Beach 3 - sediment depth 0-1 cm. Mean phi for Sites A,B,C. (see figs. 1 and 2 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

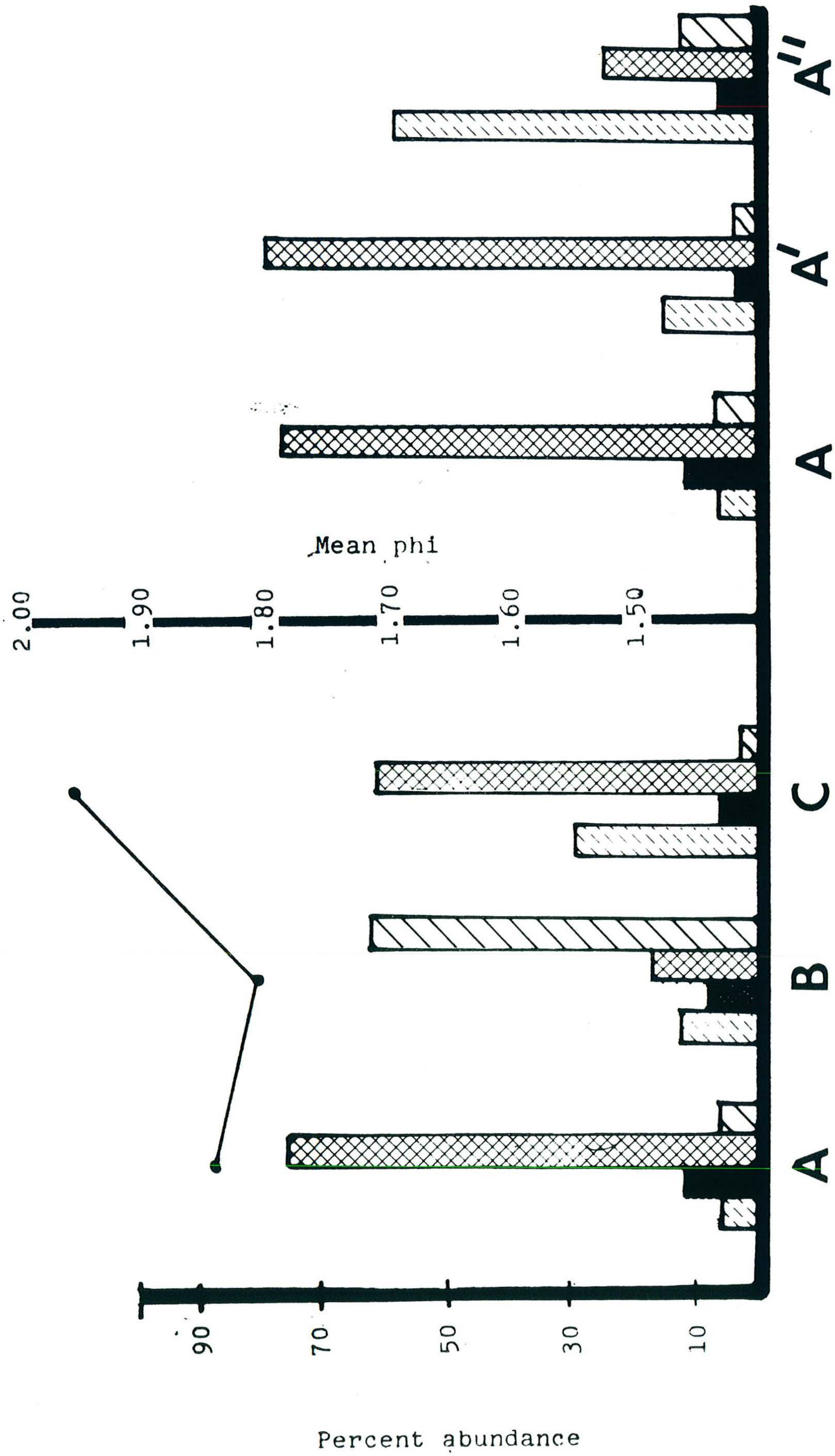

Percent abundance
90
70
50
30
10
Mean phi
2.00
1.90
1.80
1.70
1.60
1.50
A
B
C
A
A'
A''

Figure 22. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites A,B,C,A',A'' Beach 3 - sediment depth 1-2 cm. Mean phi for Sites A,B,C. (see figs. 1 and 2 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

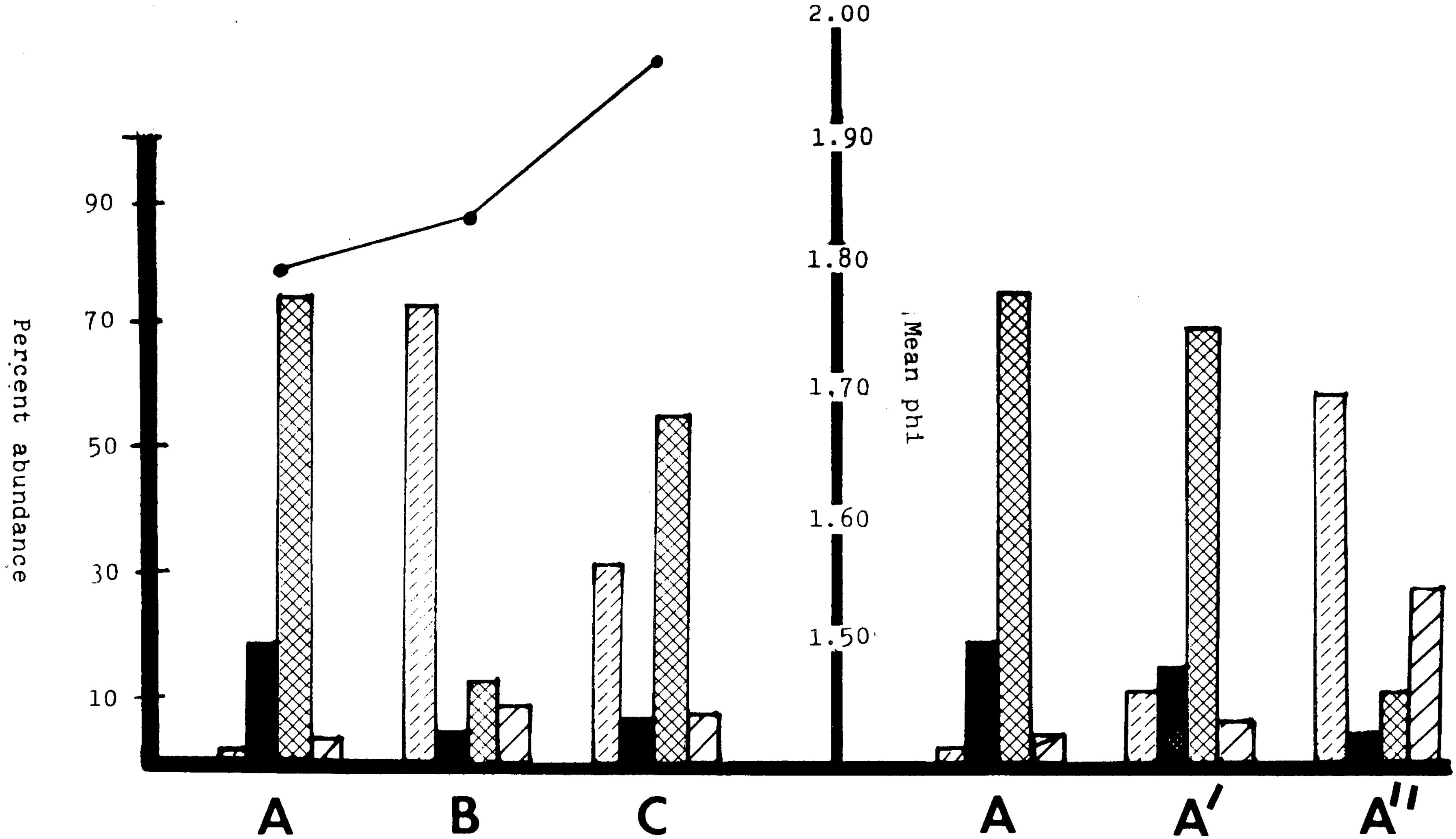

Percent abundance
90
70
50
30
10
A
B
C
2.00
1.90
1.80
1.70
1.60
1.50
Mean phi
A
A′
A″

Figure 23. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites A,B,C,A',A'' Beach 3 - sediment depth 3-4 cm. Mean phi for Sites A,B,C. (see figs. 1 and 2 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

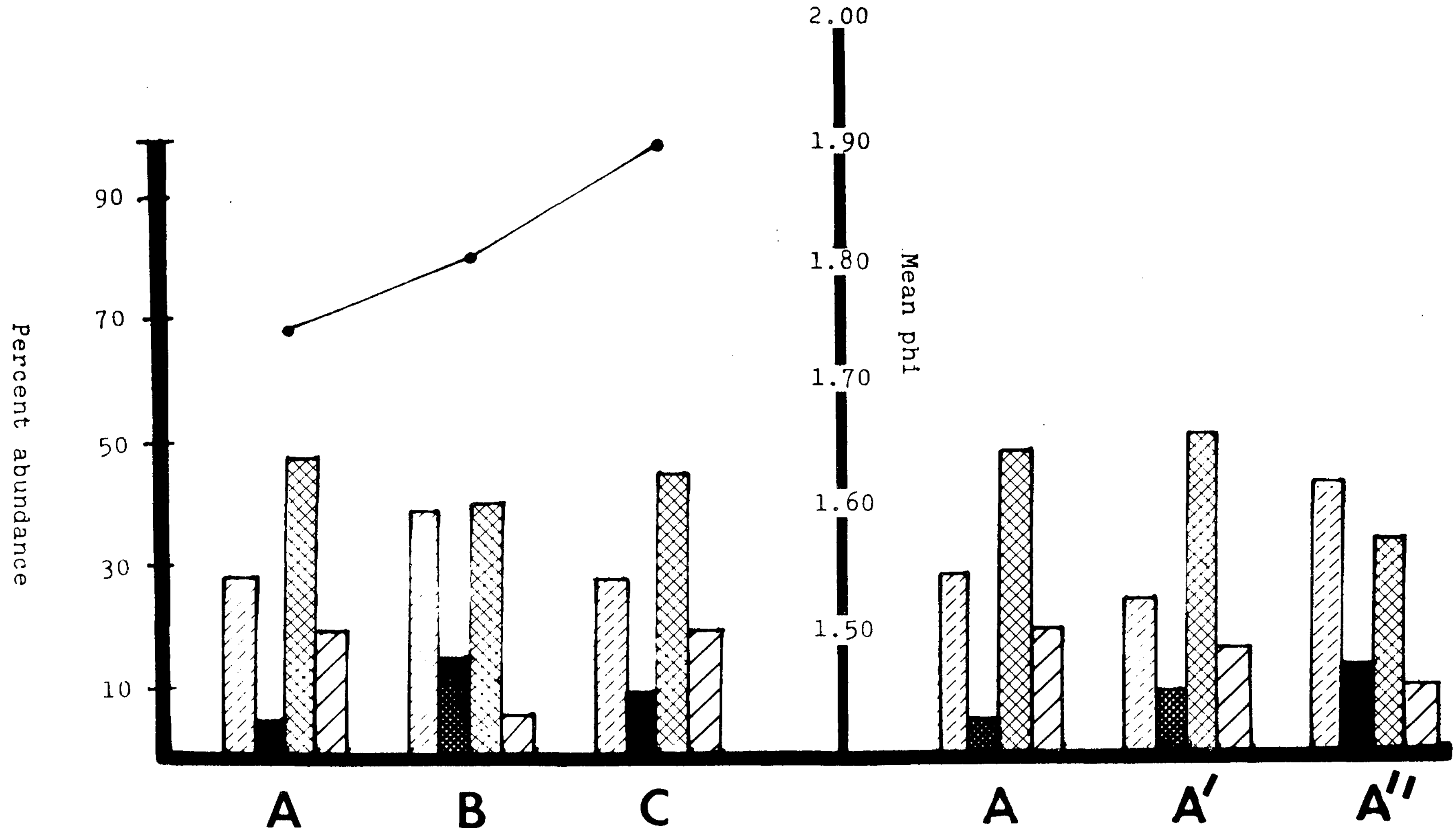

Percent abundance
90
70
50
30
10
2.00
1.90
1.80
1.70
1.60
1.50
Mean phi
A
B
C
A
A'
A''

Figure 24. Vertical and horizontal distribution of the total numbers of organisms, gastrotrichs, harpacticoids, and nematodes per 10 cm^2 for Sites I,II,III - Beach 1 (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

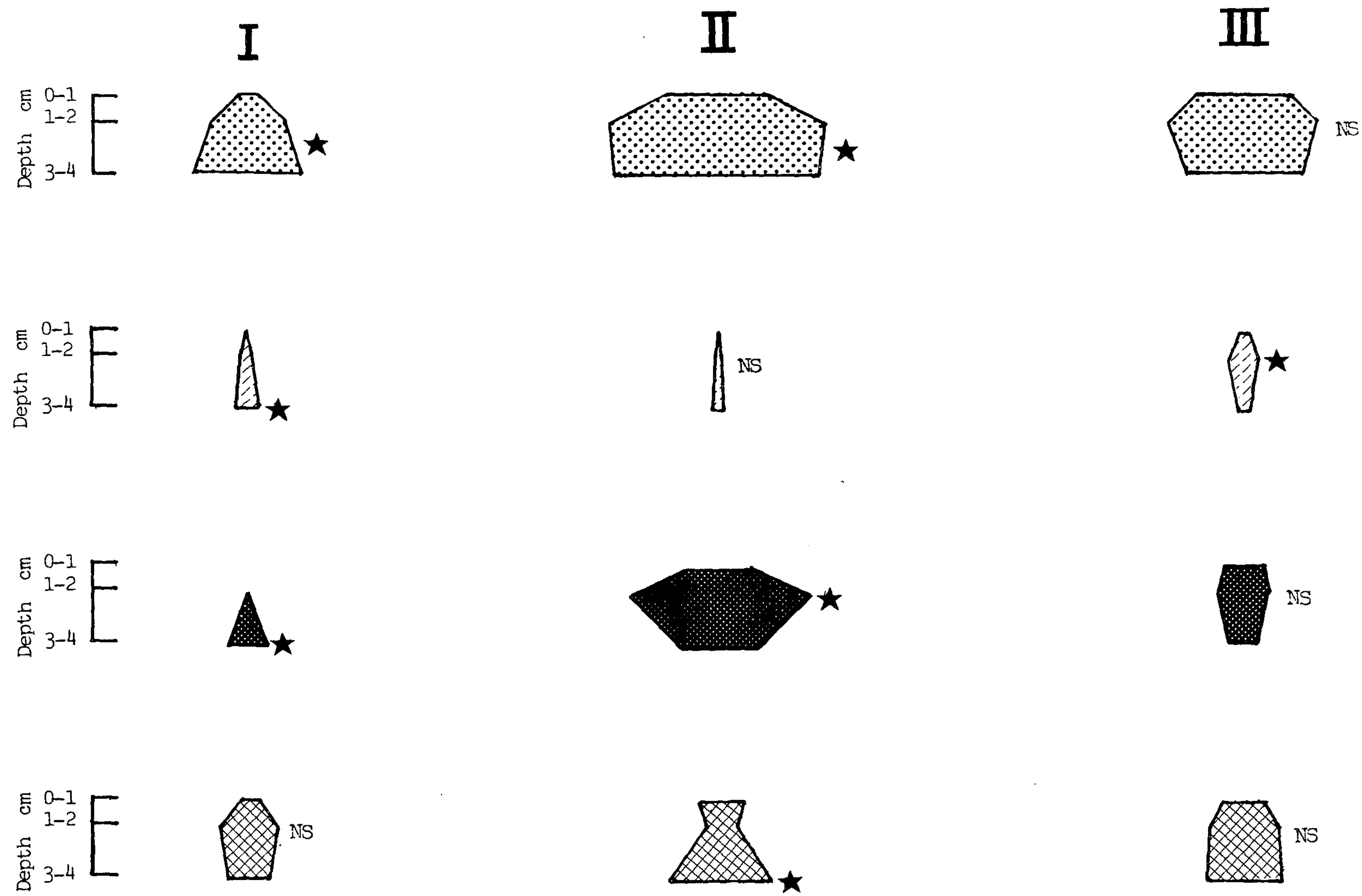

I
II
III
Depth cm
0-1
1-2
3-4
NS
Depth cm
0-1
1-2
3-4
NS
Depth cm
0-1
1-2
3-4
NS
Depth cm
0-1
1-2
3-4
NS
NS

Figure 25. Vertical and horizontal distribution of the total numbers of organisms, gastrotrichs, harpacticoids, and nematodes per 10 cm^2 for Sites I,II,III - Beach 2 (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

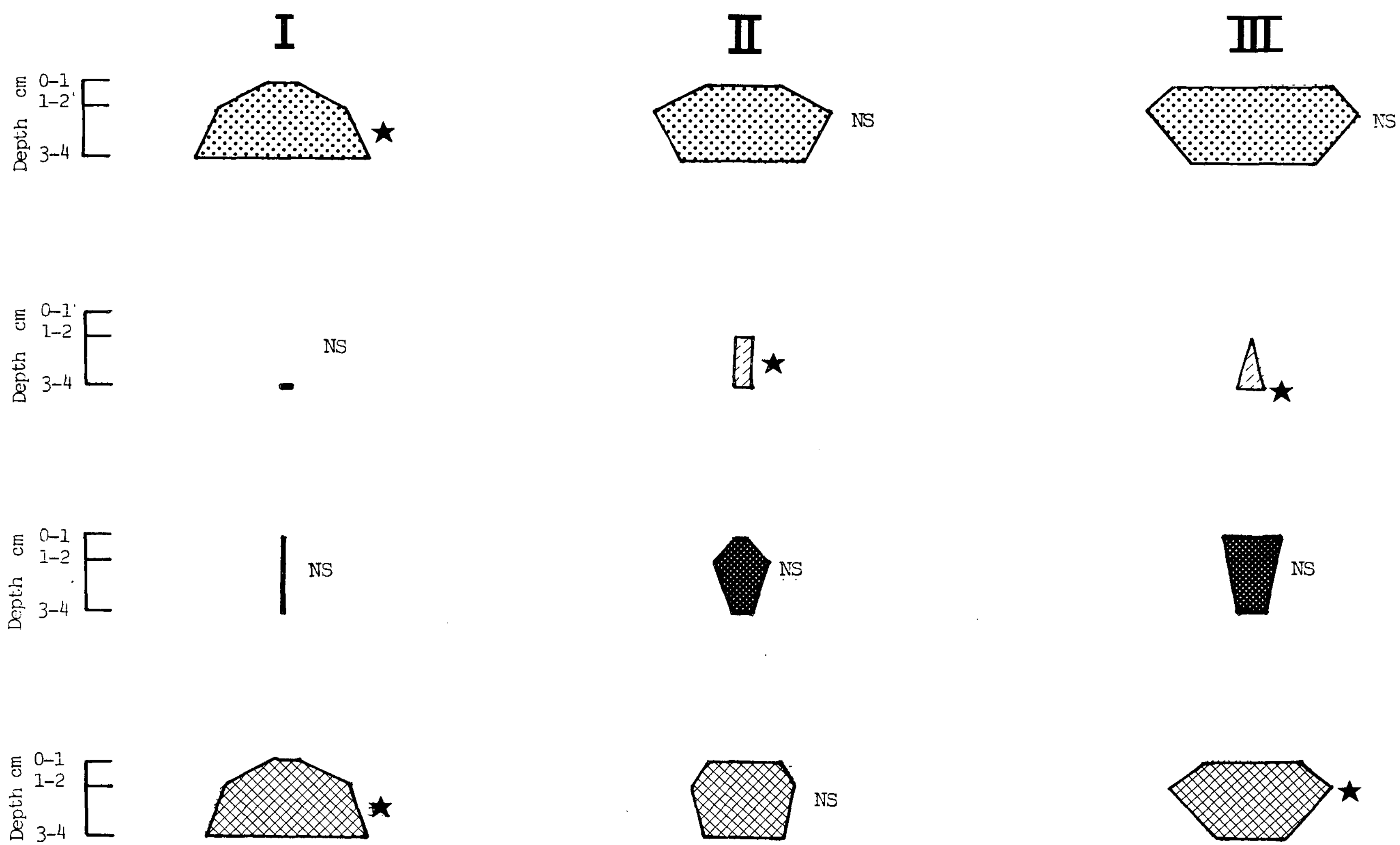

I
II
III
Depth cm
0–1
1–2
3–4
NS
NS
Depth cm
0–1
1–2
3–4
NS
Depth cm
0–1
1–2
3–4
NS
NS
NS
Depth cm
0–1
1–2
3–4
NS

Figure 26. Vertical and horizontal distribution of the total numbers of organisms, gastrotrichs, harpacticoids, and nematodes per 10 cm^2 for Sites I,II,III - Beach 3 (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

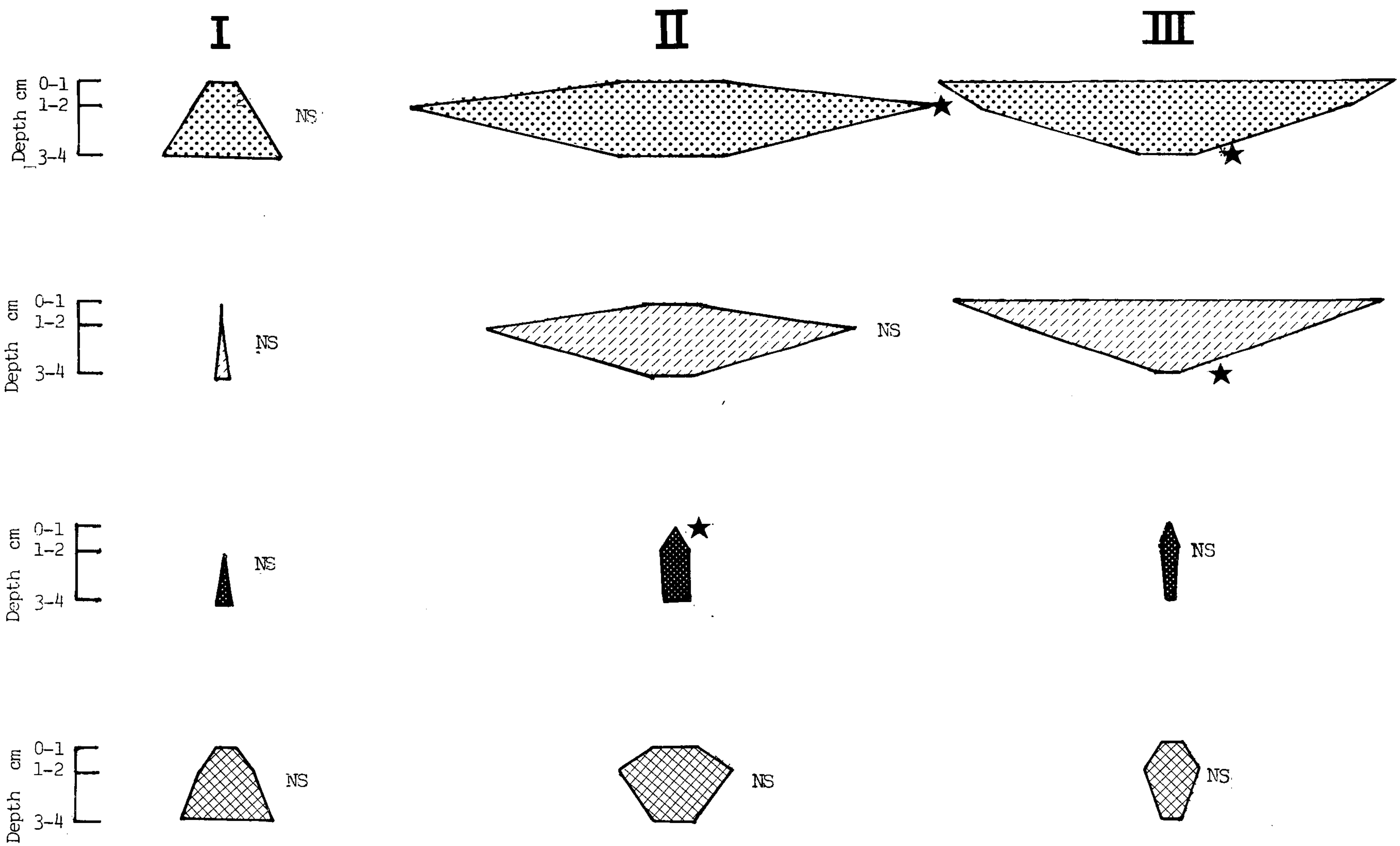
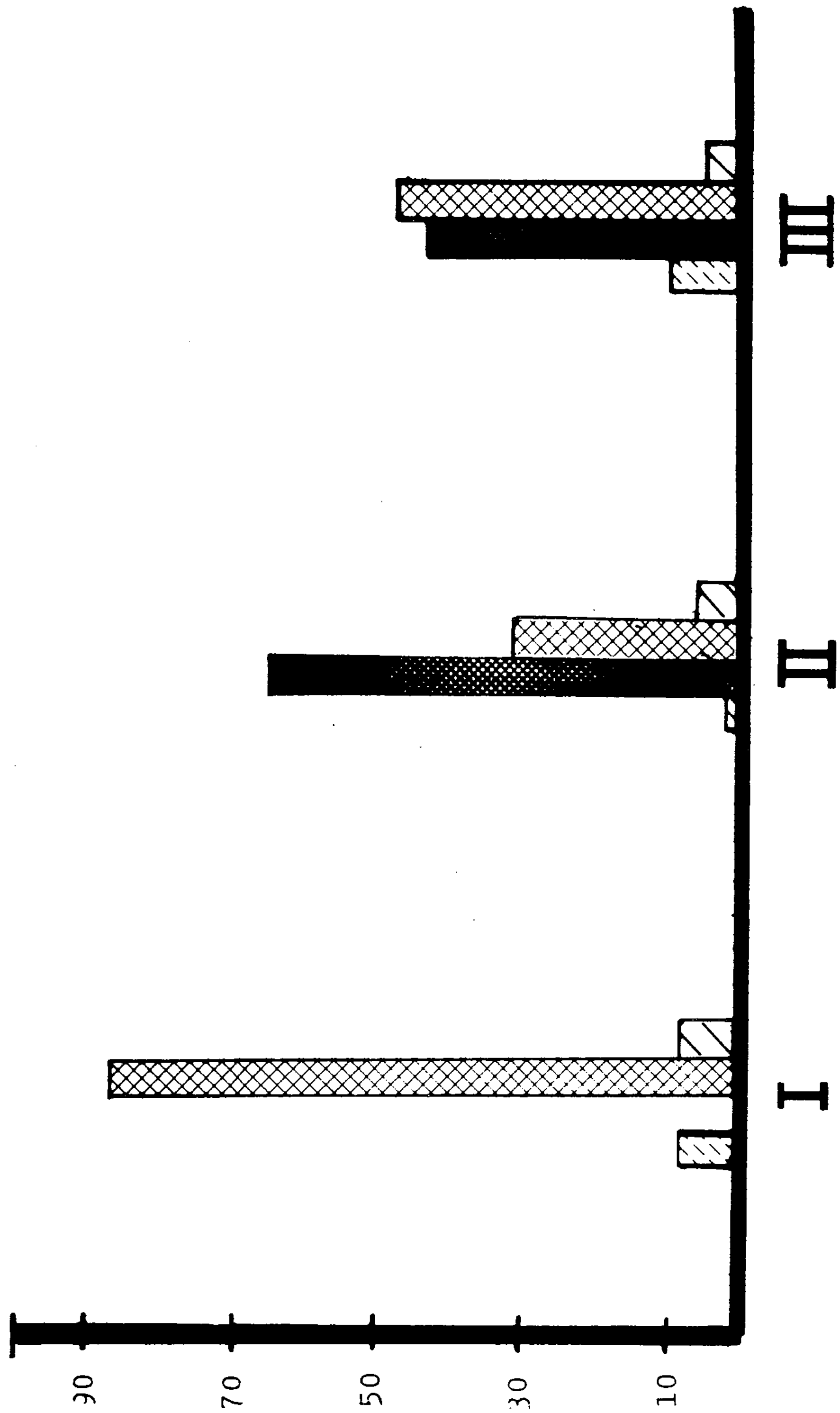

I
II
III
Depth cm
0-1
1-2
3-4
NS

Figure 27. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites I,II,III Beach 1 - sediment depth 0-1 cm. (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.



Percent abundance

Figure 28. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites I,II,III Beach 1 - sediment depth 1-2 cm. (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

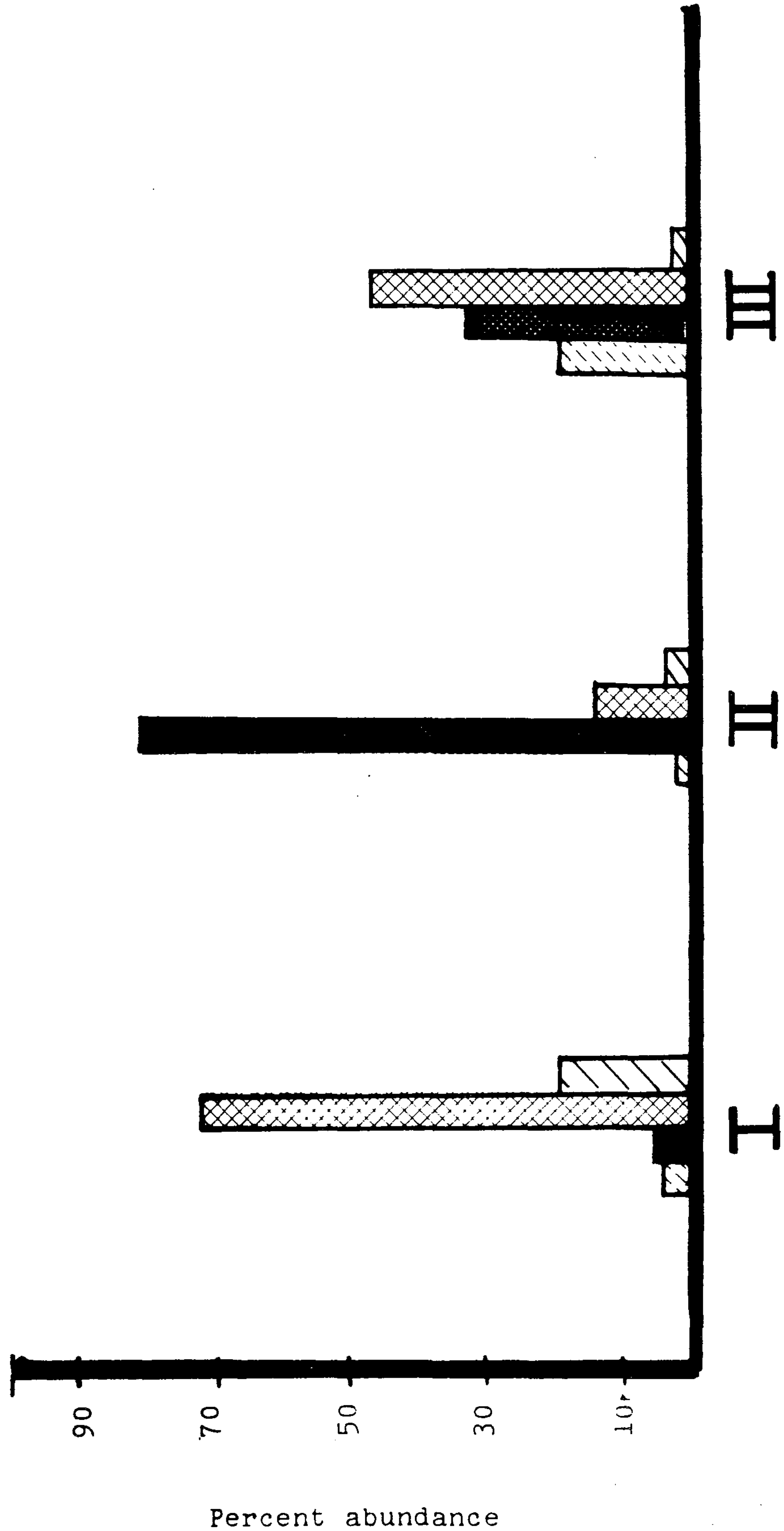
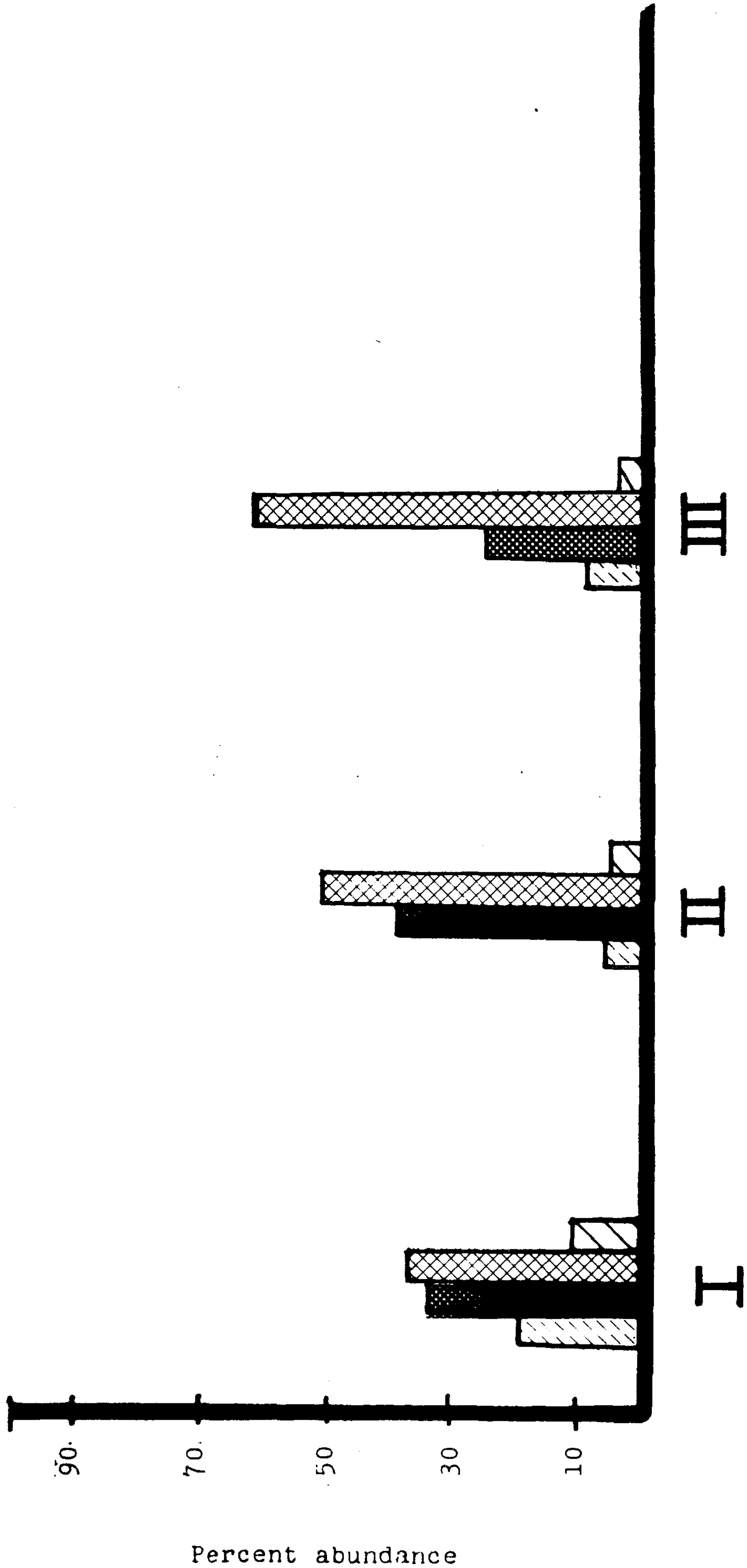

III
II
I
90
70
50
30
10
Percent abundance

Figure 29. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites I,II,III Beach 1 - sediment depth 3-4 cm. (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon



90
70
50
30
10
Percent abundance
I
II
III

Figure 30. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites I,II,III Beach 2 - sediment depth 0-1 cm. (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

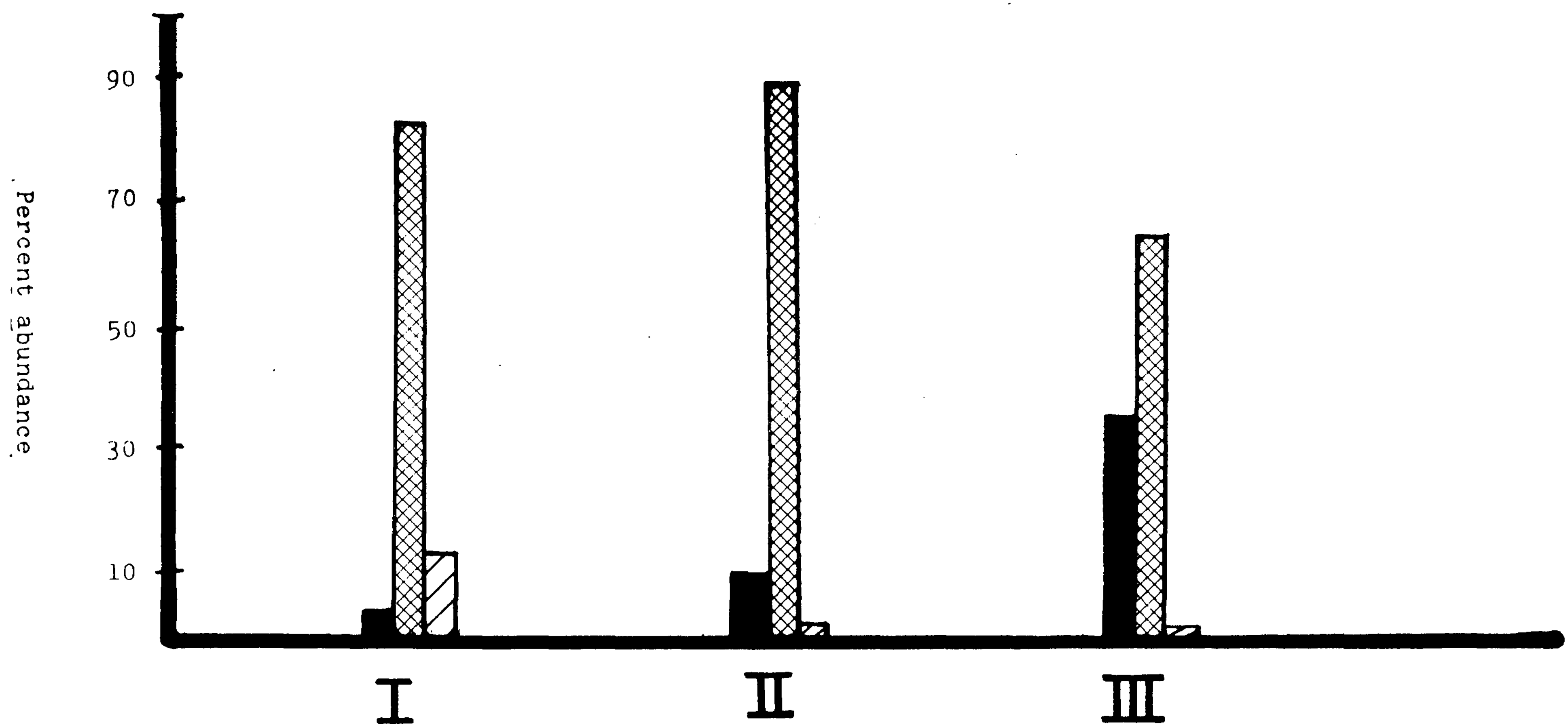

Percent abundance
90
70
50
30
10
I
II
III

Figure 31. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites I,II,III Beach 2 - sediment depth 1-2 cm. (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

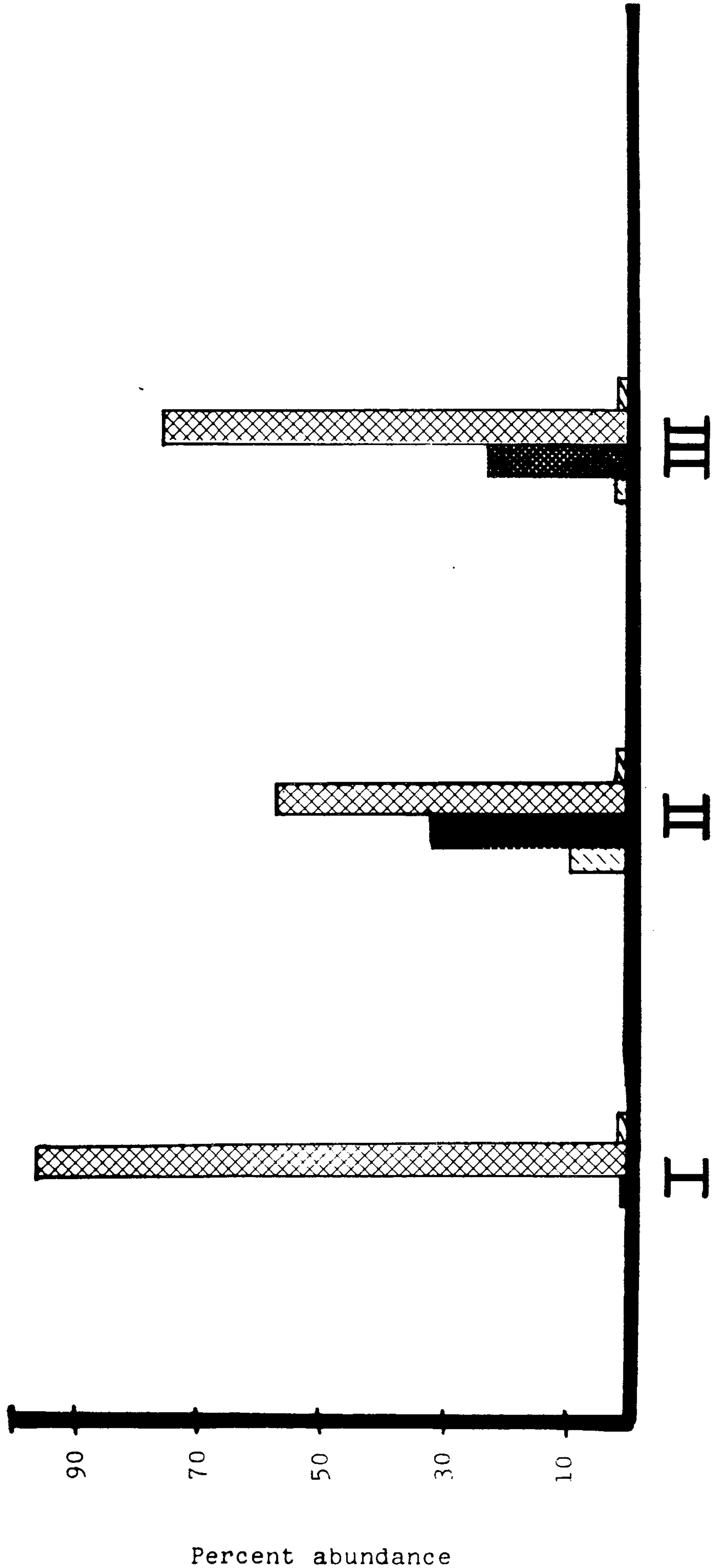

90
70
50
30
10
Percent abundance
I
II
III

Figure 32. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites I,II,III Beach 2 - sediment depth 3-4 cm. (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

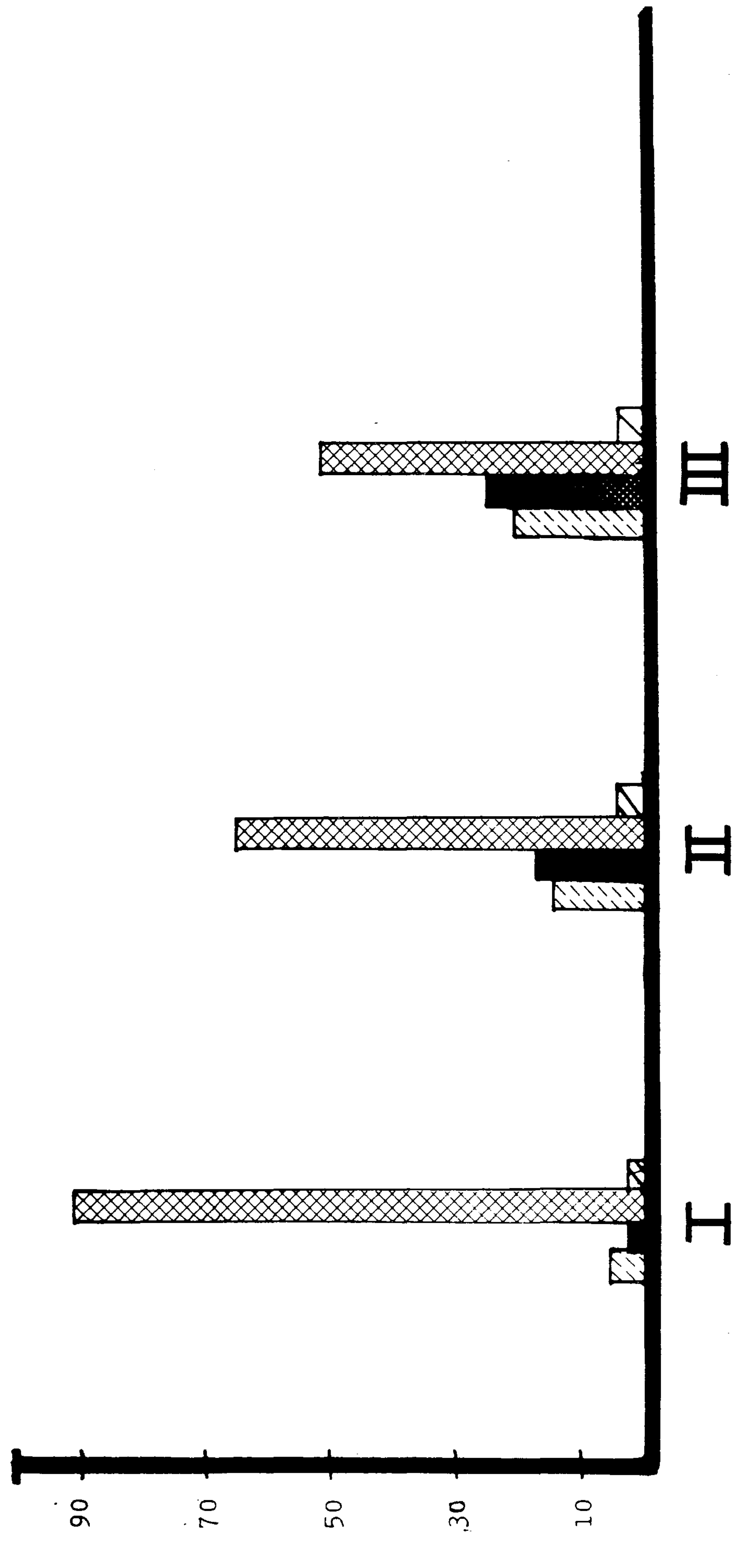

90
70
50
30
10
I
II
III

Figure 33. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites I,II,III Beach 3 - sediment depth 0-1 cm. (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

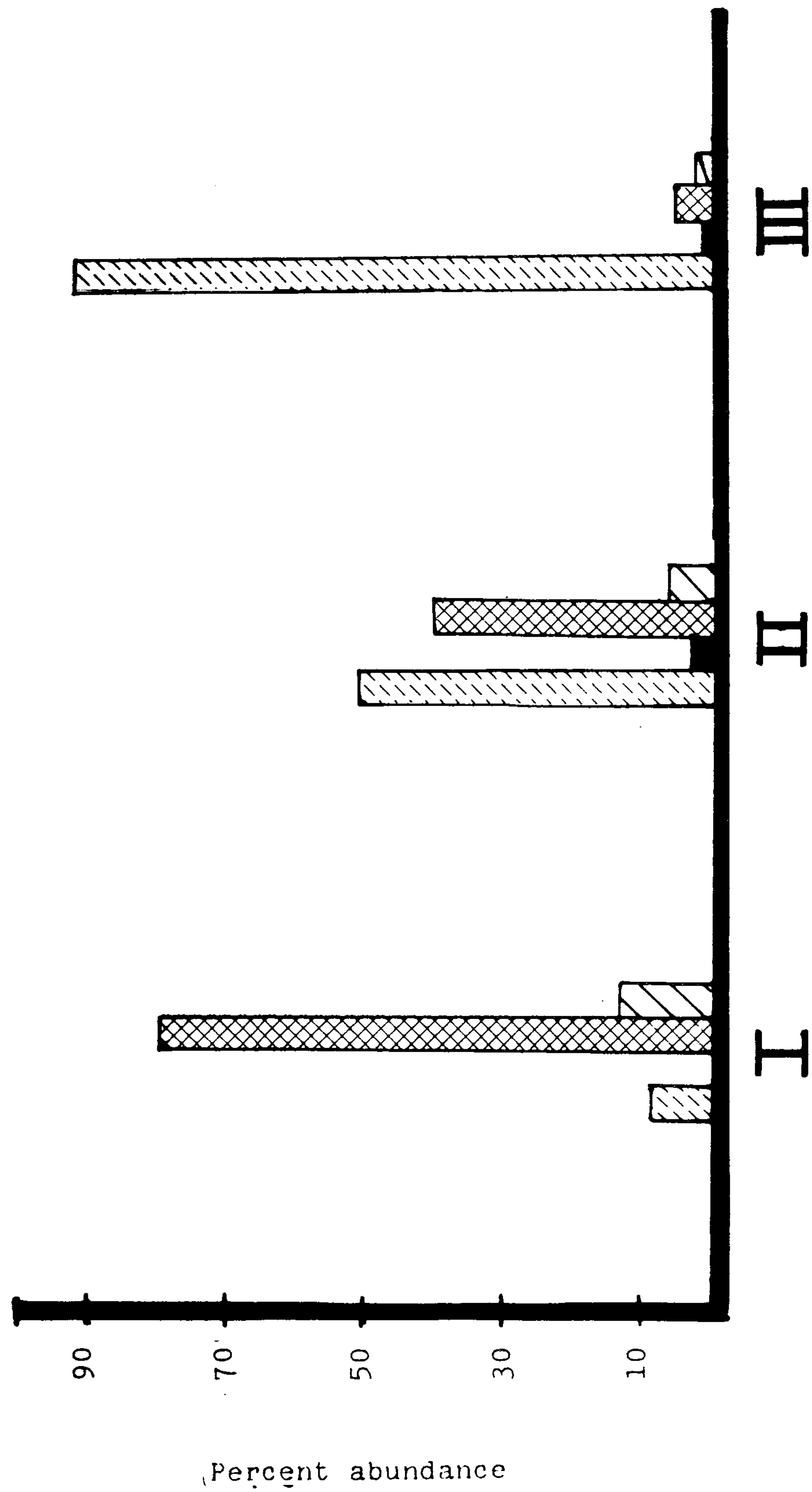

90
70
50
30
10
Percent abundance
I
II
III

Figure 34. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites I,II,III Beach 3 - sediment depth 1-2 cm. (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.

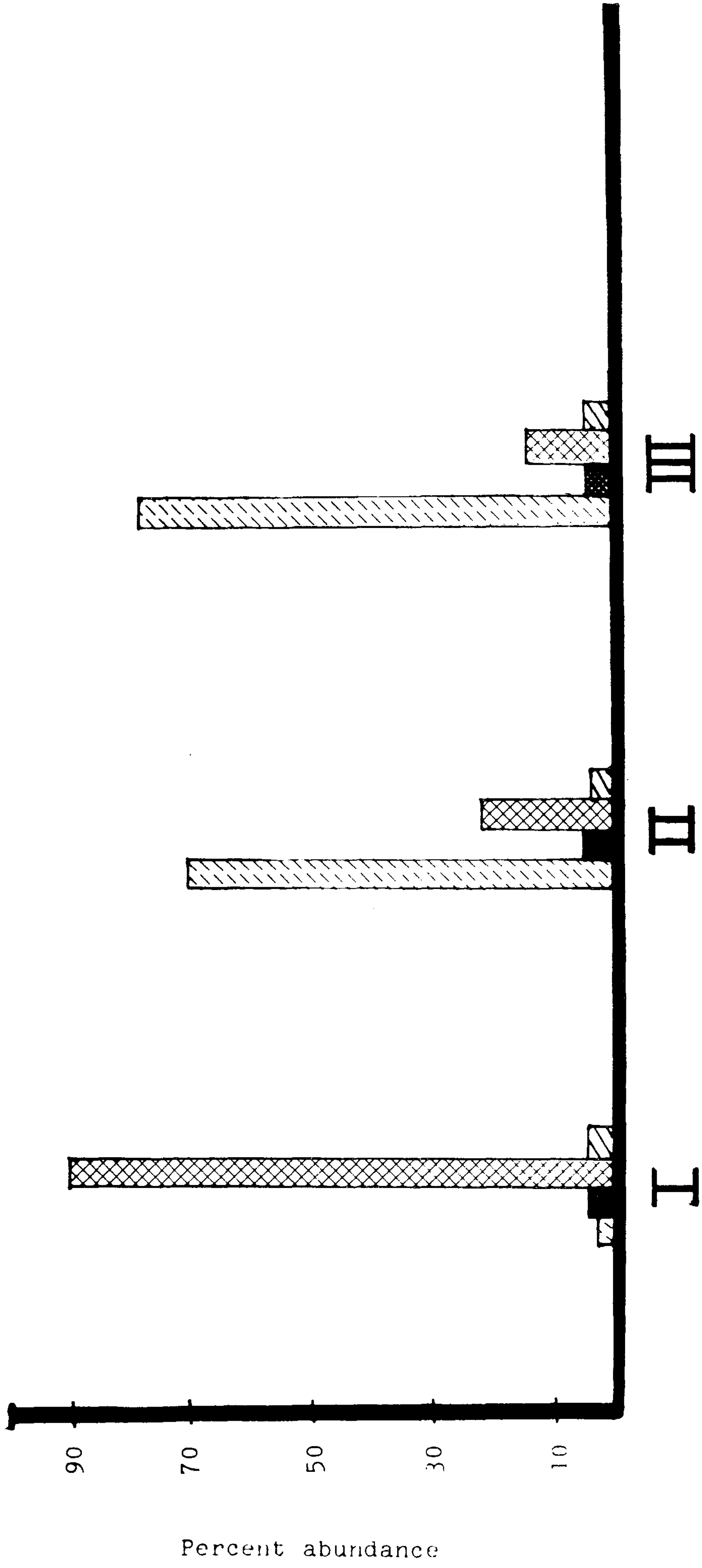
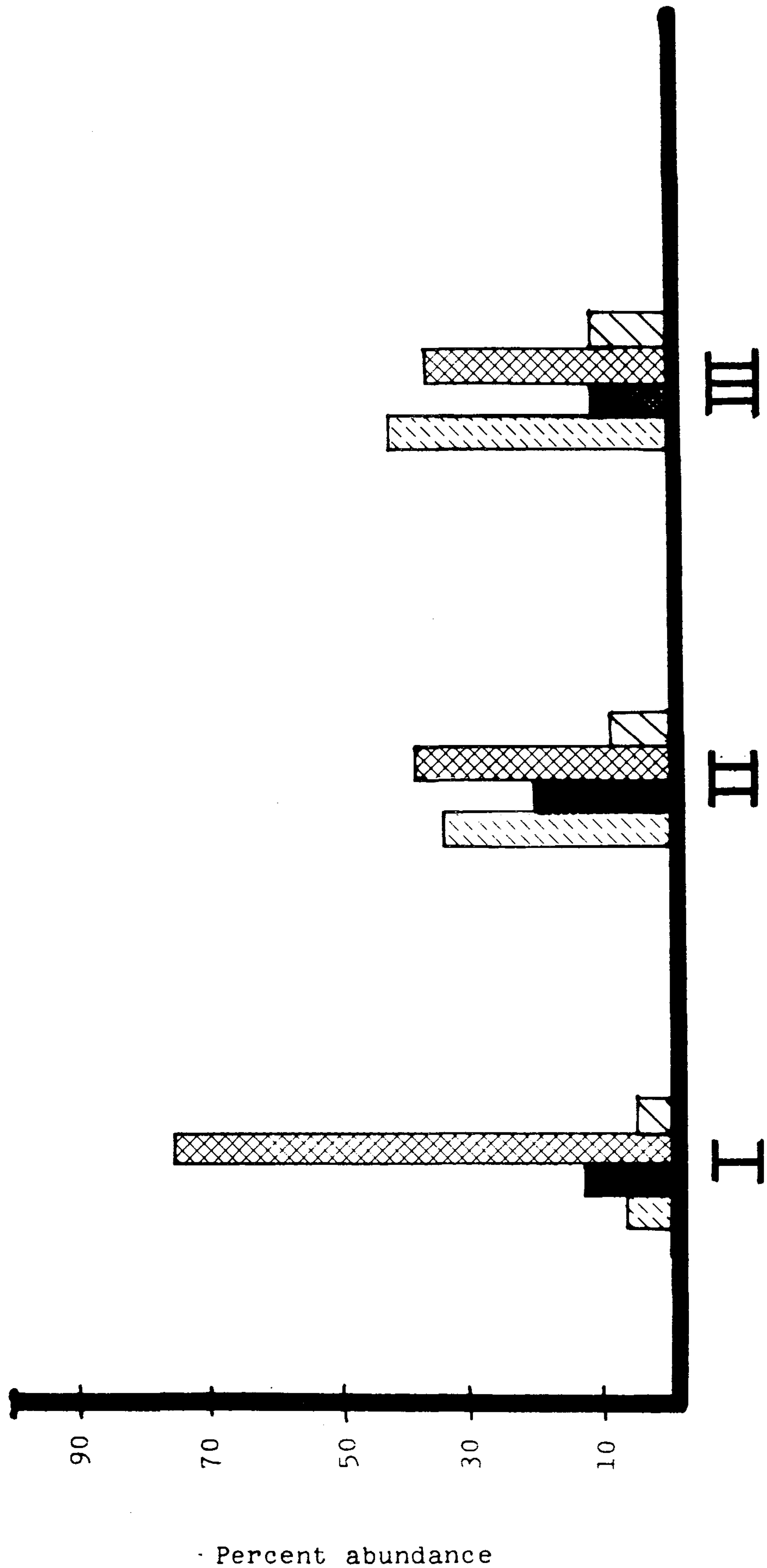

III
II
I
90
70
50
30
10
Percent abundance

Figure 35. The percentage abundance of the total number of organisms consisting of gastrotrichs, harpacticoids, nematodes, and the remaining members listed as Others for Sites I,II,III Beach 3 - sediment depth 3-4 cm. (see figs. 1 and 3 for beach and site location and fig. 8 for legend) South Slough, Charleston, Oregon.


III
II
I
90
70
50
30
10
Percent abundance

DISCUSSION

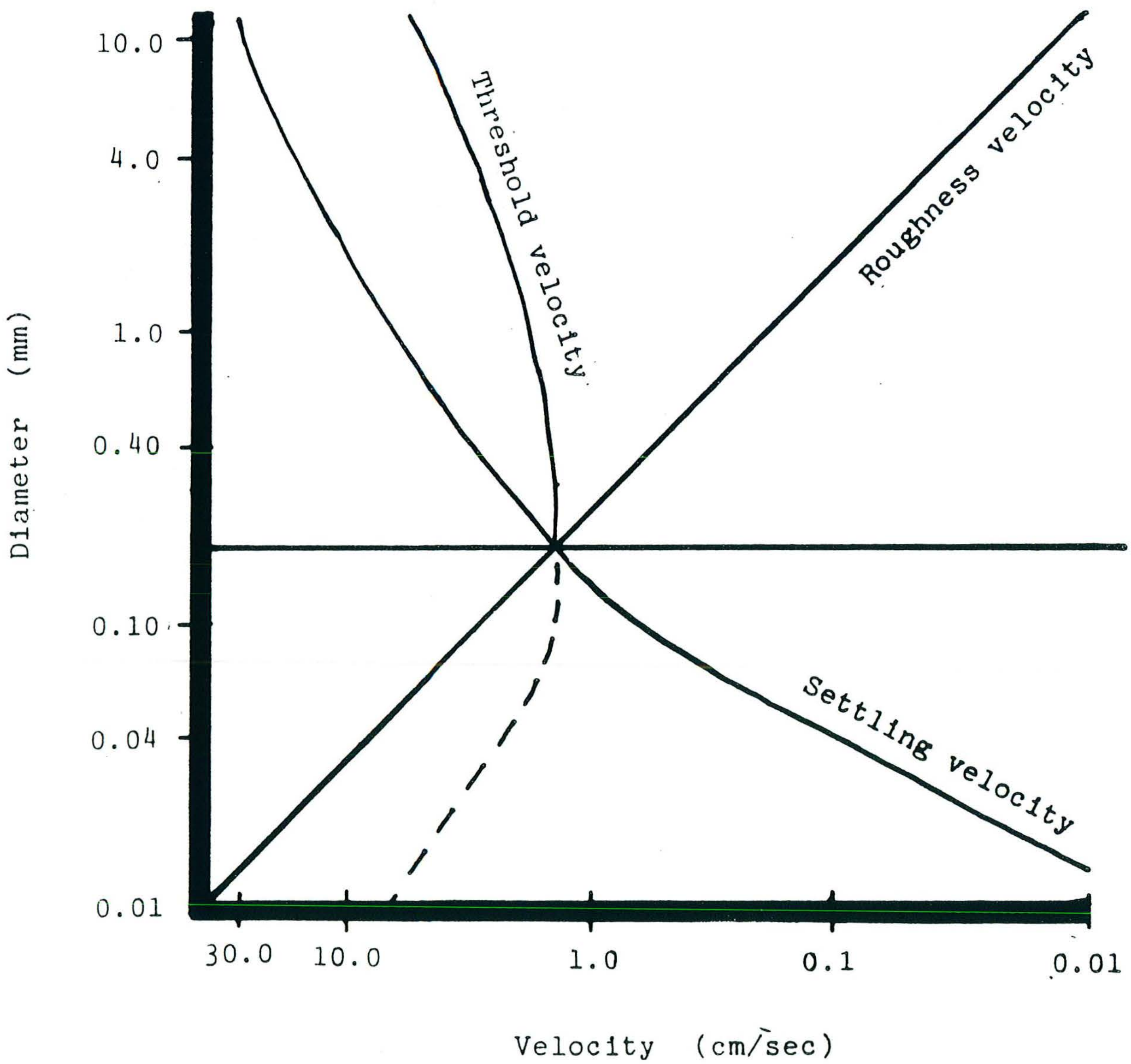
The dependence of the distribution of meiofauna on the edaphic conditions has been suggested by Weiser (1959), Boaden (1968), and Hulings and Gray (1976). There are also many other inherent physico-chemical parameters essential in the distribution of the organisms, however, it has generally been accepted that granulometry is an underlying factor in interstitial ecology. This appears to be the explanation for the results in this study.

The decrease in the mean grain size along the slough probably results from the gradual decrease in velocity of the tidal currents and a reduction in their capacity to carry larger sediment particles. Sanders (1958) states that the formation, stability, and distribution of beach sands are controlled by four main factors (Figure 36):

1. The size of the particles transported into the area.
2. The current necessary to convert the laminar flow over the bottom into turbulent flow (Roughness velocity).
3. Settling velocity which is defined by Stoke's Law for grains less than 0.18 mm, but for grains greater than 0.18 mm, the velocity is less due to self-created turbulence.
4. The current velocity necessary to cause a particle to move along the bottom (Threshold velocity).

Note in Figure 36 that the Threshold velocity, Settling velocity, and Roughness velocity lines intersect at the 0.18 mm diameter line. All of the sediment samples in this study had mean grain sizes greater than 0.18 mm which means that the grains role or slide over the bottom, due to their high settling velocity, rather than suspend when disturbed (Boaden

Figure 36. The relationship of grain diameter to settling velocity, threshold velocity, and roughness velocity. After Sanders (1958) cited in Boaden (1968).


10.0
4.0
1.0
0.40
0.10
0.04
0.01
Diameter (mm)
30.0
10.0
1.0
0.1
0.01
Velocity (cm/sec)
Threshold velocity
Roughness velocity
Settling velocity

1968). This phenomenon may contribute to the homogeneous environment as indicated by the low sorting coefficients. These well-sorted sediments, due to the absence of fine particles which may clog the interstices, are very permeable and provide large pore spaces for water movement and oxygen renewal via surface water percolation.

Kramer (1949, cited in Pollock and Hummon 1971) described four forms in which water may be present in soils:

1. Gravitational water which drains solely by gravity and is lost and regained quickly.
2. Capillary water which moves much more slowly and is held around and among the sand particles.
3. Hygroscopic water which forms thin films around the particles and is extremely difficult to remove.
4. Vaporous water.

Gravitational and capillary water are probably the most important to the organisms as they may react to the flow (rheotaxis-as suggested by the reaction of the archiannelid Trilobodrilus heideri)(Boaden 1963), temperature (Bruce 1928, Johnson 1965), salinity (Bruce 1928, Johnson 1967), and oxygen (Jansson 1967b). When the sediments are saturated, the sand grains are loosely packed and have large spaces between the grains. As water is lost and replaced by air pockets, the grains become more densely packed and the interstices are reduced. Gravitational water was probably lost between the time of saturation at Site A to Site A' as evidence by the greatest change in compaction. Site A'' was kept moist through capillary action from the water table below because the reduced interstices allowed capillary water to remain confluent from grain to grain.

In addition to the volume of the interstices which indirectly controls the amount of space available for movement of the organisms, the amount of water and oxygen present, and the movement of water, another edaphic condition that may govern the distribution of the meiofauna is the aggregate surface presented by the grain in unit volume of the sand (Bruce 1928). This becomes important in providing surfaces on which food sources such as bacteria, blue-green algae, and diatoms grow (Meadows and Anderson 1968) and also in providing surfaces for meiofaunal attachment.

The low numbers of organisms found at the surface levels of the swash zone sites (A,B,C) is probably a result of an escape response effected by the turbulence of the wave action. This may also be the reason for the decreasing numbers of organisms in the surface levels from Site III to Site I. Boaden (1968) found a similar downward migration of of the organisms as the swash zone and tide crossed their position. The decrease in the total number of organisms from Site A to Site B to Site C may be a result of the reduction in grain size and the higher sorting coefficients, both of which may inhibit those organisms exhibiting ciliary gliding or crawling locomotion, Gastrotricha and Harpacticoida, respectively. The Nematoda appear to prefer the sediments having smaller pore spaces as their method of locomotion requires these smaller interstices for leverage. Jansson (1967a) found that Nematoda were unable to move through the sediment if the interstices were too large to support a writhing body. The abundance of the Harpacticoida in more coarse sediments with lower sorting coefficients appears to be consistent with their burrowing method of locomotion, which requires the larger interstices such that they may crawl over or burrow around the sand grains. The Gastrotricha also appear to favor sediments with low sorting coefficients, which is consistent with their ciliary gliding locomotion.

The slight increase in numbers from Site A to Site A' may be a result of the downshore movement of gravitational water and the concomitant movement of the organisms. Emery and Foster (1948) found a one to three hour lag in the occurrence of high tide in the water table of beaches; thus, the water table may continue to rise even after the tide has begun to ebb. High tide in the water table may then provide a sufficient pressure head and source for the downshore flow of gravitational water. Site A' may be in the Zone of Resurgence (Salvat 1964, 1967, cited in Pollock and Hummon 1971) which is an area of intensive interstitial water circulation. If this is true, then most of the fine particles may be elutriated out of the area (and hence create the low sorting coefficients) and organisms from the upshore regions may be carried into this zone, thereby causing the increase in numbers. The subsequent drop in numbers from Site A' to Site A'' may again be due to the elutriation of the finer sediments and organisms into the downshore regions, or may be due to an active downward vertical migration in response to the desiccation of the surface sediment layers (McLachlan et al. 1977). Site C may be near the Zone of Saturation (Salvat 1964, 1967, cited in Pollock and Hummon 1971) which is characterized by a reduction in interstitial water circulation due to the clogging of the interstices by finer particles from the upshore region on the beach. This appears to be what has occurred as the sorting coefficients for Site C are higher than those for Site A or Site B.

SUMMARY

1. The purpose of this study was to compare the differences in abundance of nematodes, gastrotrichs, and harpacticoids between depths in the sediment at various tide levels and between depths at various sites with increasing time of exposure. It also examines the relationship between the abundances of meiofaunal groups and the mean grain size of the sediment.
2. The mean grain size increased from the surface sediment levels to deeper sediment levels.
3. The mean grain size decreased along the slough from the beach nearest the mouth to the beach nearest the source of the slough.
4. There were fewer total numbers of organisms at the surface sediment level than lower levels and a decrease in the total numbers from the upshore to the downshore sites.
5. There were significant increases in the total number of organisms in the surface levels at the upshore sites after one hour of exposure by the ebbing tide and a subsequent decrease in surface levels at the upshore sites after two hours of exposure.
6. Significant increases in the total number of organisms in surface sediment levels coupled with significant decreases in lower levels were found from the site exposed to the wave swash to the downshore sites submerged in 10 and 25 cm of water.
7. The nematodes were found to be more abundant in finer sediments (with higher sorting coefficients) whereas the gastrotrichs and harpacticoids were more abundant in coarser sediments (with lower sorting coefficients).

LITERATURE CITED

Anderson, J.G., and P.S. Meadows. 1969. Bacteria on intertidal sand grains. Hydrobiologia 33:33-45.

Baker, C.A. 1978. A study of estuarine sedimentation in the South Slough, Coos Bay, Oregon. Oregon Institute of Marine Biology. Thesis.

Barnes, R.D. 1974. Invertebrate zoology. W.B. Saunders Company. Philadelphia, Pa.

Boaden, P.J.S. 1963. Behavior and distributions of the archiannelid *Trilobodrilus heideri*. Journal of the Marine Biological Association of the United Kingdom 43:239-250.

Boaden, P.J.S. 1968. Water movement-a dominant factor in interstitial ecology. Sarsia 34:125-136.

Boaden, P.J.S., and H.M. Platt. 1971. Daily migration patterns in an intertidal meiobenthic community. Thalassia Jugoslavica 7(1):1-12.

Brafield, A.E. 1964. The oxygen content of interstitial water in sandy shores. Journal of Animal Ecology 33:97-116.

Bruce, R.J. 1928. Physical factors on the sandy beach. Part I. Tidal, climatic, and edaphic. Journal of the Marine Biological Association of the United Kingdom 15:535-552.

Burt, W.V., and W.B. McAlister. 1959. Recent studies in hydrography of Oregon estuaries. Research Briefs, Oregon Fisheries Commission 7:14-27.

Emery, K.O., and J.F. Foster. 1948. Water tables in marine beaches. Journal of Marine Research 7:644-654.

Fenchel, T.M. 1978. The ecology of micro and meiobenthos. Annual Review of Ecology and Systematics 9:99-121.

Folk, R.L. 1968. Petrology of sedimentary rocks. Hemphill. Austin, Texas.

Gomoiu, M.T. 1967. Some quantitative data on light penetration in sediments. Helgoländer wissenschaftliche Meeresuntersuchungen 15:120-127.

Hulings, N.C., and J.S. Gray. 1971. A manual for the study of meiofauna. Smithsonsian Contributions to Zoology Number 78.

Hulings, N.C., and J.S. Gray. 1976. Physical factors controlling the abundances of meiofauna on tidal and atidal beaches. Marine Biology 34:77-84.

Hummon, W.D., W.A. Evans, M.R. Hummon, F.C. Doherty, R.P. Wainberg, and W.S. Stanley. 1978. Meiofaunal abundance in sand bars of acid mine polluted, reclaimed, and unpolluted streams in southeastern Ohio. In J.H. Thorp and J.W. Gibbons, (eds.), Energy and Environmental Stress in Aquatic Systems, pp. 188-203. DOE Sysposium Series. (CONF-771114). National Technical Information Services, Springfield, Va.

Jansson, B.O. 1967a. The significance of grain size and pore water content for the interstitial fauna of sandy beaches. Oikos 18:311-322.

Jansson, B.O. 1967b. The availability of oxygen for the interstitial fauna of sandy beaches. Journal of Experimental Marine Biology and Ecology 1:123-143.

Jansson, B.O. 1967c. Diurnal and annual variations of temperature and salinity of interstitial water in sandy beaches. Ophelia 4:41-58.

Jansson, B.O. 1968. Quantitative and experimental studies of the interstitial fauna in four Swedish sandy beaches. Ophelia 5:1-71.

Johnson, R.G. 1965. Temperature variation in the infaunal environment of a sand flat. Limnology and Oceanography 10:114-120.

Johnson, R.G. 1967. Salinity of interstitial water in a sandy beach. Limnology and Oceanography 12:1-7.

Kramer, P.J. 1949. Plant and soil water relationships. McGraw-Hill.

Mare, M.F. 1942. A study of a marine benthic community with special reference to the micro-organisms. Journal of the Marine Biological Association of the United Kingdom 25(3):517-554.

McEwen, G., editor. 1978. South Slough Bulletin. 2(1). Montagne-Bierly Associates, Inc.

McIntyre, A.D. 1969. Ecology of marine meiobenthos. Biological Review 44:245-290.

McLachlan, A., T.Erasmus, and J.P. Furstenberg. 1977. Migrations of sandy beach meiofauna. Zoologica Africana 12(2):257-277.

Meadows, P.S., and J.G. Anderson. 1968. Micro-organisms attached to marine sand grains. Journal of the Marine Biological Association of the United Kingdom 48(1):161-175.

Nicholls, A.G. 1935. Copepods from the interstitial fauna of a sandy beach. Journal of the Marine Biological Association of the United Kingdom 20:379-406.

Pollock, L.W., and W.D. Hummon. 1971. Cyclic changes in interstitial water content, atmospheric exposure, and temperature in a marine beach. Limnology and Oceanography 16(3):522-535.

Remane, A. 1940. Einführung in die zoologische Ökologie der Nord-und Ostsee. Tierwelt d. N.-u. Ostsee, Leipzig, 238pp.

Salvat, B. 1964. Les conditions hydrodynamiques interstitielles des sediments meubles intertidaux et la repartition verticale de la faune endogée. Comptes Rendus de l'Academie des Sciences. 259:1576-1579.

Salvat, B. 1967. La macrofaune carcinologique endogée des sediments meubles intertideaux (Tanaidaces, Isopodes et Amphipodes), ethologie, binomie, et cycle biogique. Mémoires du Musiem National d'Historie Naturelle, series A, 45:1-275.

Sanders, H.L. 1958. Benthic studies in Buzzard's Bay. 1. Animal-sediment relationships. Limnology and Oceanography 3(3):245-258.

Sokal, R.R., and F.J. Rohlf. 1969. Biometry. W.H. Freeman and Company. San Francisco, Ca.

Swedmark, B. 1964. The interstitial fauna of marine sand. Biological Review 39:1-42.

Wieser, W. 1959. The effect of grain size on the distribution of small invertebrates inhabiting the beaches of Puget Sound. Limnology and Oceanography 4:181-194.

APPENDICES

A. Classification of the meiofauna found on selected beaches in the South Slough, Charleston, Oregon. Classification based on R.D. Barnes (1974).

B. Example of the analysis of variance table for the numbers of Gastrotricha by site and depth on Beach 2. (see figs. 1 and 2 for beach and site location)

C. The complete faunal components (two replicates) at each site and depth for the first component of the study. Beach 1 (see figs. 1 and 2 for beach and site location) Numbers are given as per 10 cm^2.

D. The complete faunal components (two replicates) at each site and depth for the first component of the study. Beach 2 (see figs. 1 and 2 for beach and site location) Numbers are given as per 10 cm^2.

E. The complete faunal components (two replicates) at each site and depth for the first component of the study. Beach 3 (see figs. 1 and 2 for beach and site location) Numbers are given as per 10 cm^2.

F. The complete faunal components (two replicates) at each site and depth for the second component of the study. Beach 1 (see figs. 1 and 3 for beach and site location) Numbers are given as per 10 cm^2.

G. The complete faunal components (two replicates) at each site and depth for the second component of the study. Beach 2 (see figs. 1 and 3 for beach and site location) Numbers are given as per 10 cm^2.

H. The complete faunal components (two replicates) at each site and depth for the second component of the study. Beach 3 (see figs. 1 and 3 for beach and site location) Numbers are given as per 10 cm^2.

Phylum Aschelminthes
- Class Gastrotricha
- Class Nematoda
- Class Rotifer

Phylum Tardigrada

Phylum Platyhelminthes

Phylum Annelida
- Class Oligochaeta
- Class Polychaeta

Phylum Arthropoda
- Class Crustacea
  - Subclass Copepoda
    - Order Harpacticoida

Appendix A. Classification of the meiofauna found on selected beaches in the South Slough, Charleston, Oregon. Classification based on R.D. Barnes (1974).

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	774.533	6	129.089	28.475	0.000
Site	137.133	4	34.283	7.563	0.002
Depth	637.400	2	318.700	70.301	0.000
Two-way Interactions	184.267	8	23.033	5.081	0.003
Site Depth	184.267	8	23.033	5.081	0.003
Explained	958.800	14	68.486	15.107	0.000
Residual	68.000	15	4.533		
Total	1026.800	29	35.407		

Appendix B. Example of the analysis of variance table for the numbers of Gastrotricha by site and depth on Beach 2. (see figs. 1 and 2 for beach and site location)

Appendix C. The complete faunal components (two replicates) at each site and depth for the first component of the study. Beach 1 (see figs. 1 and 2 for beach and site location) Numbers are given as per 10 cm^2.

Depth (cm)	Taxa	Sites: A		B		C		A'		A''	
0-1	Gastrotricha	1	0	1	4	0	0	4	5	1	0
	Harpacticoida	15	13	2	2	1	4	27	41	1	0
	Nematoda	12	19	21	23	5	6	31	67	31	13
	Oligochaeta	10	18	1	1	1	0	4	11	25	61
	Turbellaria	0	0	0	0	0	0	0	0	0	0
	Rotifera	0	0	0	0	0	0	0	0	0	0
	Tardigrada	0	0	0	0	0	0	0	0	0	0
	Polychaeta	0	0	0	0	0	0	0	0	0	0
	TOTAL	38	50	24	30	7	10	66	125	59	74
1-2	Gastrotricha	17	12	21	23	1	1	7	11	13	10
	Harpacticoida	146	107	38	26	6	9	38	49	1	2
	Nematoda	50	32	39	48	14	28	9	34	21	74
	Oligochaeta	35	8	1	1	0	0	1	2	4	9
	Turbellaria	0	0	0	0	1	1	0	0	0	0
	Rotifera	0	0	0	0	0	0	0	0	1	0
	Tardigrada	0	0	0	0	0	0	0	0	0	0
	Polychaeta	0	0	0	0	0	0	0	0	0	0
	TOTAL	248	159	98	98	20	38	55	96	40	94
3-4	Gastrotricha	17	15	8	10	2	5	13	13	18	9
	Harpacticoida	22	24	28	16	22	15	50	111	29	30
	Nematoda	27	15	33	28	30	30	21	30	27	13
	Oligochaeta	2	1	0	0	3	0	1	2	0	1
	Turbellaria	1	0	1	2	1	1	0	2	0	0
	Rotifera	0	0	0	0	0	0	0	0	0	0
	Tardigrada	0	0	0	0	0	0	0	0	0	0
	Polychaeta	0	0	0	0	1	1	0	0	0	0
	TOTAL	69	54	70	55	57	52	84	158	74	52

Appendix D. The complete faunal components (two replicates) at each site and depth for the first component of the study. Beach 2 (see figs. 1 and 2 for beach and site location) Numbers are given as per 10 cm^2.

Depth (cm)	Taxa	Sites A		B		C		A'		A''	
0-1	Gastrotricha	0	0	1	1	1	1	1	1	0	0
	Harpacticoida	5	1	1	1	1	1	2	1	1	1
	Nematoda	51	49	20	20	5	2	185	179	8	6
	Oligochaeta	0	0	0	0	1	3	5	5	1	1
	Turbellaria	0	0	1	0	1	1	0	0	0	1
	Rotifera	0	0	1	1	1	0	0	0	0	0
	Tardigrada	0	0	0	0	0	0	0	0	0	0
	Polychaeta	0	0	0	0	0	0	0	0	0	0
	TOTAL	56	50	24	23	10	9	193	185	10	9
1-2	Gastrotricha	9	2	1	2	2	1	9	4	2	3
	Harpacticoida	65	44	18	9	1	2	23	7	1	1
	Nematoda	87	77	60	82	4	5	175	172	70	54
	Oligochaeta	2	1	1	0	2	1	1	1	2	1
	Turbellaria	0	0	1	1	1	1	0	0	0	0
	Rotifera	0	0	1	1	1	1	0	0	0	0
	Tardigrada	0	0	0	0	0	1	0	0	0	0
	Polychaeta	0	0	0	0	0	0	0	0	0	0
	TOTAL	164	123	82	104	11	12	207	183	75	59
3-4	Gastrotricha	6	6	7	4	15	10	18	21	16	12
	Harpacticoida	8	18	23	11	6	9	31	13	10	7
	Nematoda	144	115	32	52	52	46	142	142	94	81
	Oligochaeta	1	1	1	1	3	3	1	1	2	2
	Turbellaria	0	1	2	4	2	5	1	1	0	0
	Rotifera	0	0	1	1	1	0	0	0	0	0
	Tardigrada	0	0	0	0	1	2	0	0	0	0
	Polychaeta	0	0	0	0	1	2	0	0	0	0
	TOTAL	159	141	66	71	84	74	193	177	122	102

Appendix E. The complete faunal components (two replicates) at each site and depth for the first component of the study. Beach 3 (see figs. 1 and 2 for beach and site location) Numbers are given as per 10 cm^2.

Depth (cm)	Taxa	Sites: A		B		C		A'		A''	
0-1	Gastrotricha	1	2	1	2	31	43	10	7	58	69
	Harpacticoida	5	1	1	1	7	7	3	1	6	8
	Nematoda	13	25	1	3	81	75	42	50	23	29
	Oligochaeta	1	1	1	0	2	1	1	1	3	1
	Turbellaria	1	0	7	5	2	2	0	1	6	7
	Rotifera	0	0	1	1	0	0	0	0	1	4
	Tardigrada	0	0	0	0	0	0	0	0	0	1
	Polychaeta	0	0	0	0	0	0	0	0	1	2
	TOTAL	21	29	12	12	123	128	56	60	97	120
1-2	Gastrotricha	1	1	27	42	35	35	6	4	98	86
	Harpacticoida	9	9	2	3	9	6	7	6	8	5
	Nematoda	34	39	7	5	66	56	27	34	16	19
	Oligochaeta	1	1	1	0	4	1	1	1	4	2
	Turbellaria	1	1	3	3	6	4	1	2	8	5
	Rotifera	0	0	1	1	0	0	0	0	6	1
	Tardigrada	0	0	0	0	0	0	0	0	1	1
	Polychaeta	0	0	0	0	0	0	0	0	33	24
	TOTAL	46	51	40	53	121	101	41	47	173	140
3-4	Gastrotricha	13	16	16	8	23	14	15	10	17	22
	Harpacticoida	3	2	4	5	7	6	5	4	2	10
	Nematoda	30	19	14	11	26	35	29	24	14	17
	Oligochaeta	3	2	0	1	5	6	8	3	2	1
	Turbellaria	7	7	1	2	9	6	3	2	1	2
	Rotifera	0	0	0	0	0	0	0	0	0	0
	Tardigrada	0	0	0	0	0	0	0	0	0	0
	Polychaeta	0	0	0	0	0	0	0	0	0	0
	TOTAL	56	46	35	28	71	66	59	42	37	52

Beach 1

Depth (cm)	Taxa	Sites I		II		III	
0-1	Gastrotricha	0	1	1	0	2	4
	Harpacticoida	0	0	27	22	14	15
	Nematoda	6	6	12	11	21	11
	Oligochaeta	0	1	3	1	1	1
	Turbellaria	0	0	0	0	0	0
	Rotifera	0	0	0	0	0	0
	Tardigrada	0	0	0	0	0	0
	Polychaeta	0	0	0	0	0	0
	TOTAL	6	8	42	34	37	30
1-2	Gastrotricha	1	1	3	1	12	9
	Harpacticoida	1	2	71	63	21	16
	Nematoda	26	15	15	8	27	25
	Oligochaeta	6	5	4	1	1	1
	Turbellaria	0	0	0	0	0	0
	Rotifera	0	0	0	0	0	0
	Tardigrada	0	0	0	0	0	0
	Polychaeta	0	0	0	0	0	0
	TOTAL	33	23	94	74	61	51
3-4	Gastrotricha	8	8	5	4	4	4
	Harpacticoida	15	13	31	28	6	16
	Nematoda	17	13	34	44	26	29
	Oligochaeta	5	4	1	1	1	1
	Turbellaria	0	0	3	1	1	1
	Rotifera	0	0	1	0	0	0
	Tardigrada	0	0	0	0	0	0
	Polychaeta	0	0	0	0	0	0
	TOTAL	46	37	74	78	37	50

Appendix F. The complete faunal components (two replicates) at each site and depth for the second component of the study. Beach 1. (see figs. 1 and 3 for beach and site location) Numbers are given as per 10 cm^2.

Beach 2

Depth (cm)	Taxa	Sites I		II		III	
0-1	Gastrotricha	0	0	0	0	0	0
	Harpacticoida	1	0	1	5	25	19
	Nematoda	13	6	20	34	38	41
	Oligochaeta	1	0	0	1	0	1
	Turbellaria	2	0	0	0	0	0
	Rotifera	0	0	0	0	0	0
	Tardigrada	0	0	0	0	0	0
	Polychaeta	0	0	0	0	0	0
	TOTAL	16	6	20	39	63	61
1-2	Gastrotricha	0	0	7	7	0	1
	Harpacticoida	1	0	12	33	14	26
	Nematoda	60	38	38	42	58	69
	Oligochaeta	1	1	1	0	0	0
	Turbellaria	0	0	0	1	1	0
	Rotifera	0	0	0	0	0	0
	Tardigrada	0	0	0	0	0	0
	Polychaeta	0	0	0	0	0	0
	TOTAL	61	39	58	83	73	96
3-4	Gastrotricha	6	1	8	6	7	13
	Harpacticoida	1	1	6	10	13	12
	Nematoda	70	56	36	28	23	27
	Oligochaeta	1	1	1	1	0	1
	Turbellaria	1	0	1	1	1	1
	Rotifera	0	0	0	0	1	0
	Tardigrada	0	0	0	0	0	0
	Polychaeta	0	0	0	0	0	0
	TOTAL	77	59	50	45	44	54

Appendix G. The complete faunal components (two replicates) at each site and depth for the second component of the study. Beach 2 (see figs. 1 and 3 for beach and site location) Numbers are given as per 10 cm^2.