A COMPARATIVE FIELD STUDY OF BENTHIC SAMPLING DEVICES USED IN SOUTHERN CALIFORNIA MARINE SURVEYS

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ABSTRACT

In December 1974 and March 1975, the Coastal Water Research Project and the Allan Hancock Foundation, University of Southern California, studied the physical and biological performance of seven benthic sampling devices that are or have been used in surveys off southern California. The samplers were tested at four stations in Santa Monica Bay in water depths of from 12 to 260 meters. A total of 154 samples were collected; the performance of each sampler was evaluated on the basis of six criteria--penetration depth, leakage, and reliability of the sampler and surface area, surface disturbance, and volume of the samples. Fifty-two samples were sorted, and the animals found were identified and counted to obtain data on the numbers of species and individuals collected with each device. Four of the samplers were found to be mechanically reliable and to take representative samples. However, when other factors were considered, one device--a modified Van Veen grab--was found to be most effective for use in surveys of the coastal shelf off southern California.

The vertical distribution of organisms within the sediments was determined by analyzing vertical core samples. At least 90 percent of the infaunal species and individuals were found to be present in the upper 10 cm of sediment. Certain groups of species (e.g., ophiuroids, microcrustaceans, and molluscs) were found predominantly in the upper 2 cm of sediment; other groups (e.g., nemerteans and polychaetes) were found to be more widely distributed through the upper 10 cm.

The effects of the use of various sized screens to sort samples was investigated. Screening through a 0.7-mm screen did not greatly add species or individuals to the numbers already found on a 1.0-mm screen. However, the use of screens of 0.5-mm mesh did add more species and individuals to the sample total. Certain species groups were found predominantly on one screen size (e.g., ophiuroids and molluscs on the 1.0-mm screen and microcrustaceans on the 0.5-mm screen).

Tests were made to determine the number of replicate samples needed to give accurate representation of the numbers of species and individuals present at a station. Of the total number of species collected in ten 0.1-sq-meter replicates, those accounting for 90 percent of the individuals were present in one sample, and those accounting for 95 percent were taken with two replicates. We concluded that a single 0.1-sq-meter sample, or at most two replicates, will provide sufficient information for numerical community analyses concerned with the presence or absence of the more common species.

Analysis of important long-term and regional effects of municipal wastewater discharges on benthic communities off southern California has been hampered because a wide variety of benthic sampling devices have been used in local surveys. Results from this study indicate that comparisons of historical and contemporary data on certain types of organisms (e.g., molluscs) may be justified, but that further comparisons should be made with caution.

CONTENTS

INTRODUCTION

Marine benthic sampling has been a most useful and direct method of evaluating biological responses to man's activities in coastal waters. Infaunal invertebrates form communities whose composition often reflects long-term natural and anthropogenic stresses and geographical gradients in water and bottom sediment quality. Although the infauna of a particular area may be composed of hundreds of species of small organisms, appropriate sampling and analytical procedures will often yield a rather concise picture of existing environmental gradients.

In addition to a strict sampling procedure--replicated sampling from a grid of well placed stations--and a well trained staff of biologists, a successful marine benthic sampling program requires a sampling device that is reliable in several ways. The device should sample an area of constant dimensions to a depth within the sediments that is sufficient to capture the majority of species and individuals likely to be present. Once collected, the sample should be returned to the vessel in a relatively undisturbed condition with little loss of sediment or organisms.

Unfortunately, the devices used now and in the past in coastal surveys have not always had these general attributes. In addition, as many as a half-dozen different devices (some of which are no longer available or in use) have been used in a single coastal region over a period of a few years. Such gear differences make comparisons between surveys difficult as they undoubtedly affect the data on organisms present, although the nature of the effect is not clearly understood. These problems are presently critical to government agencies charged with evaluating and controlling the effects of waste discharge, dredging, construction, and other activities in coastal waters.

The purpose of this report is to summarize data obtained during field tests of a series of sampling devices used in recent benthic surveys off southern California and other U.S. coastal areas. A second objective is to suggest some guidelines for evaluating sampling devices used in future programs. After reviewing historical survey data from universities, private groups, and monitoring agencies, we elected to study the following aspects of benthic survey work:

1. The mechanical reliability of each of seven samplers was evaluated by determining the maximum and average (or mean) penetration depth, the variation in surface area covered and volume of the sample obtained, the amount of leakage and disturbance of the surface of samples, and the sampling reliability, or the percentage of successful sampling attempts.

2. Tests were performed to determine the number of replicates of 0.1-sq-meter samples required to obtain accurate data on those species representing the majority of individuals present at a station.

3. Samples collected at four stations were sectioned at specified intervals to determine the minimum depth to which a device must penetrate to collect a sample likely to contain the majority of species and individuals present at a station.

4. The biological effectiveness of each of the seven samplers was determined by comparing its penetration depth with data on the vertical distribution of organisms in the sediments. The potential loss of organisms through the combined effects of the sampler leaking or creating a pressure wave in descent was also considered in the evaluation.

5. We investigated the effect of the size of the screen through which a sample was sieved on the biological data generated for a particular station.

Table 1. Stations sampled in comparison of grab sampling devices, Santa Monica Bay, December 1974 and March 1975.

Station	Location	Description	Depth (m)	Sediment Type
I	33°54'15"N, 118°26'14"W	0.60 nmi C 48 degrees T to end of El Segundo Pier; 1.75 km WSW, 0.75 km NNE from end of 1-mile sewer outfall (sampled in December and March)	12	Silty sand
II	33°55'29"N, 118°26'42"W	1.18 nmi C 135 degrees T to end of El Segundo Pier (sampled in December)	12.5	Sandy silt
III	33°35'45"N, 118°30'25"W	5.25 nmi C 68.5 degrees T to S end of Marina del Rey breakwater; near end of 7-mile sludge outfall (sampled in December)	112	Outfall Sludge
IV	33°55'30"N, 118°34'45"W	6.38 nmi C 0.70 degrees T to S end of Marine del Rey breakwater; edge of submarine canyon (sampled in December and March)	260	Silty clay with sludge

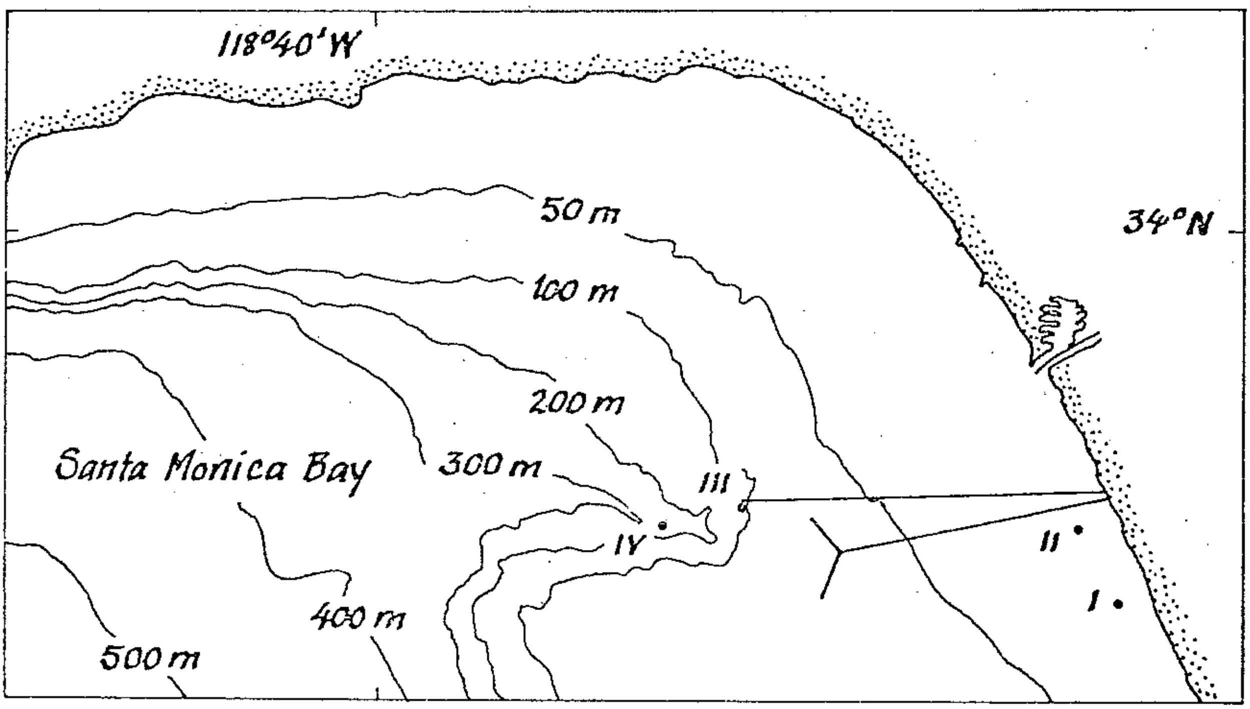


Figure 1. Stations sampled during tests of grab devices, December 1974 and March 1975.

METHODS

Field tests of seven bottom samplers were conducted at four stations in Santa Monica Bay (Figure 1; Table 1). On 5 December 1974, we tested a USNEL spade box corer (Reineck box sampler) that had been modified and scaled down by the University of Southern California, and Van Veen, Ponar, Shipek, and No. 1 Orange Peel grabs in four different sediment types ranging from shallow silty sand to deep silty clay and "ocean sludge." During March 1975, a modified Van Veen, a Smith-McIntyre, and a Shipek were tested at two of the stations. An additional device (a modified Peterson) was tested in December, but it failed to function correctly and was removed from consideration.

Sampling operations in December took place on two vessels. Operations from the Velero IV (operated by the University of Southern California) included sampling with the box corer, using an A-frame device mounted on the stern of the vessel, and sampling with a Van Veen, using a motorized winch positioned amidship. The Orange Peel, Shipek, and Ponar devices were tested from the Marine Surveyor (operated by the City of Los Angeles, Hyperion Treatment Plant), using a motorized winch in the stern of the vessel. Sampling operations in March were conducted from the Marine Surveyor. During sampling at each station, care was taken to keep the vessel within 30 meters of a buoy marking the station.

A total of 154 samples were taken in the survey. After each sample was taken, its physical characteristics were measured, and the mechanical performance of the sampler was noted. Fifty-two of the samples were subsequently completely analyzed for numbers of species and individuals present.

Contained within the 52 analyzed samples were five from Station III, located directly off the Hyperion 7-mile outfall pipe, which discharges 4 to 5 million gallons/day of dilute digested sludge. The samples from this station were exceptional because of the loosely compacted vegetative material making up the greater portion of each sample. Since all of the devices appeared to sample this substrate well, we did not incorporate the results from this station in our comparison of sampler efficiencies.

EVALUATION OF MECHANICAL PERFORMANCE

The mechanical performance of each sampler was evaluated on the basis of five criteria:

1. Penetration depths were measured with a plastic metric rule held perpendicular to the surface of the sample and pushed in at the position where maximum penetration had occurred. Penetration was recorded to the nearest 0.5 cm

2. Surface area of samples was measured from the inside sampling edges of the open sampler to the nearest 0.5 cm.

3. Surface disturbance was estimated by examining the surface of the sediment in the sampler when it was brought aboard the vessel. The surface was considered to be disturbed if the sample had collapsed and covered the surface with other material or if there were run-off channels in the sediment resulting from leakage, breaks in the surface, floating sediment, or animals positioned in an odd manner.

4. As each sample was brought aboard ship, the extent of leakage was estimated, based upon comparison with the leakage that occurred in collecting other samples with this and other devices. The extent of leakage was designated with a number from 0 to 3, indicating slight to extensive loss of sediment.

5. The sizes of the sampling devices were compared, and a number of replicates was selected for each device so that roughly equivalent areas were sampled with each device. The number of attempts necessary to collect this number of adequate replicate samples was recorded, and the percentage of successful sampling attempts was determined. This percentage was used as an estimate of the performance reliability of the sampler.

One sampler, the Shipek, is unusual in that the bucket is a half-cylinder, which rotates to collect a sample upon contact with the bottom. The surface area of samples collected with this device will vary with depth of penetration; thus, we carried out special laboratory measurements to determine the amount of this variation. The depth of penetration was measured on the side of the bucket. The length of the sample was assumed to remain constant as it is determined by the leading edge of the sampler, which should normally make even contact with the sediments. The width of the sampler was measured at various heights (penetration depths) within the half-cylinder bucket. The volume of samples was measured by adding water to specified heights in the bucket and then measuring that amount of water in graduated cylinders.

IDENTIFICATION OF ORGANISMS

The samples from the box corer were consecutively sieved in the field through three screens (16, 20, and 30 mesh, roughly corresponding to 1.0-, 0.7-, and 0.5-mm openings) and preserved for later analysis. The organisms and debris retained on each of the screens were rescreened on return to the laboratory to remove the formalin solution; the material was then stored in 70 percent ethanol. Subsequently, organisms were sorted, identified, and counted. The phyla and number of species and individuals retained on each screen was noted, and the data were examined to determine if any particular group was present on only one of the three screens.

The samples from the remaining sampling devices were sieved through a 30-mesh screen only. In other respects, they were treated in the same manner as the box cores. Variations in the sampling ability of each of the devices was determined on the basis of the presence or absence of species from a particular size group in the samples from that device.

Figure 2. UNSEL or Reineck Box Corer (modified by the University of California). This sampler was designed to take an undisturbed rectangular core from sediments at any ocean depth. It collects samples with a surface area of 625 sq cm and can penetrate to a maximum depth of 47.5 cm. Upon contact with the bottom, the sample box is forced into the sediment by the weight positioned above. After completion of penetration, the wedge-like arm is pivoted through the sediment, closing the bottom of the sample box.

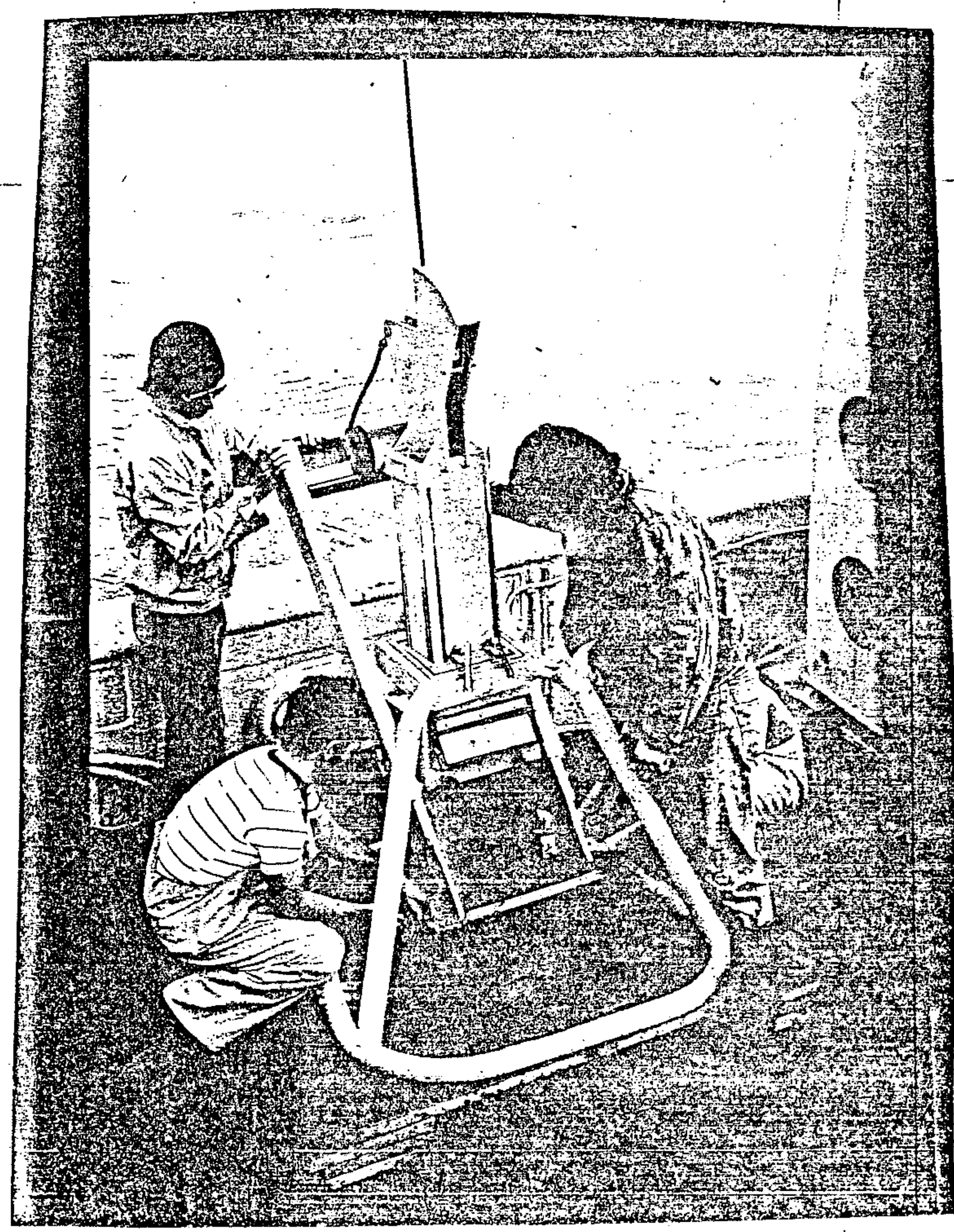


Figure 3. Shipek. This sampler operates in an unusual manner. Upon contact with the seafloor, a self-contained weight falls, triggering the release of coiled springs that rotate a half-cylinder sampling bucket 180 degrees through the sediment. The surface area sampled with this device varies with the depth of penetration (from 156 sq cm at 1-cm depths to 377 sq cm at the maximum depth of penetration, 10 cm).

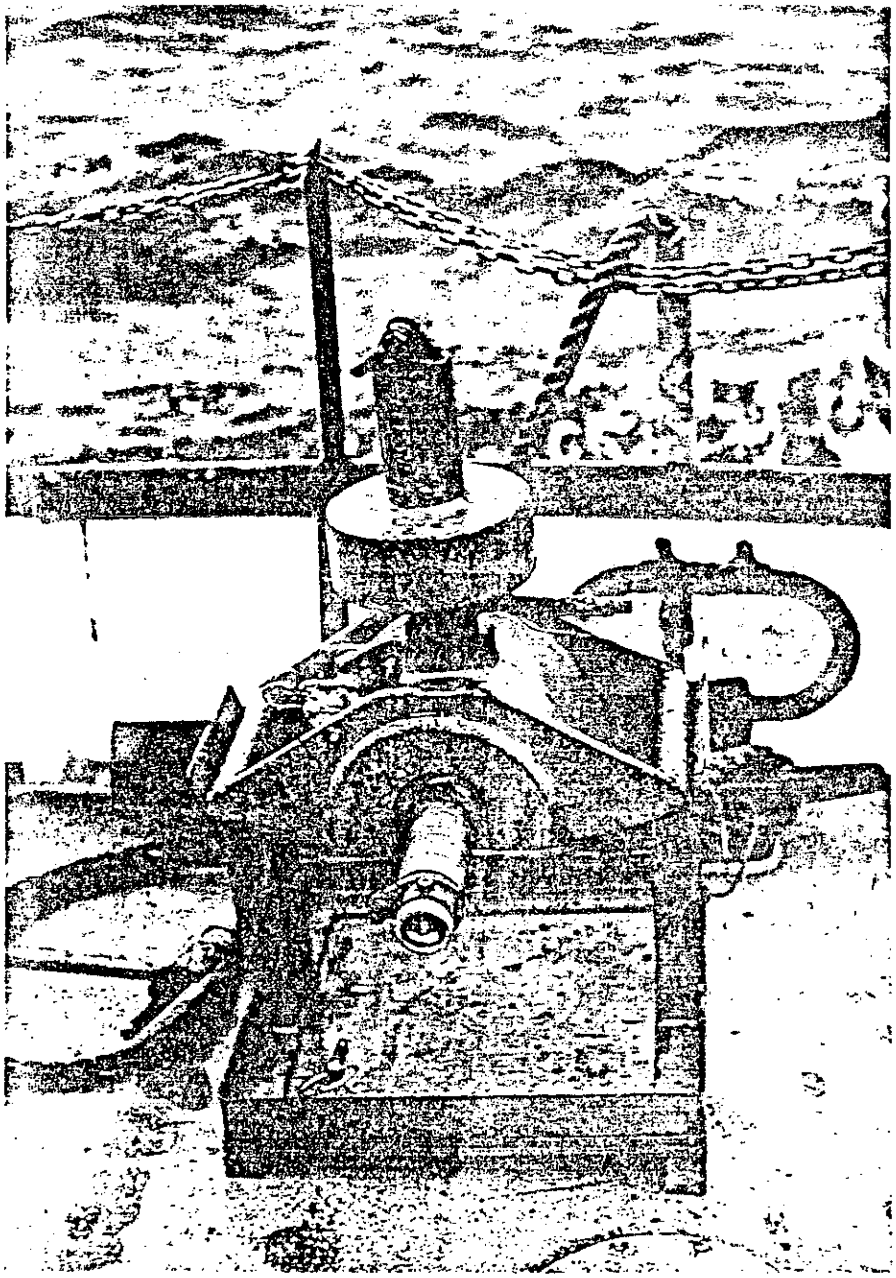


Figure 4. Van Veen No. 1. The basic Van Veen is a retrieval-activated sampler consisting of two half-buckets, hinged together in the center, and held open by an L-shaped tripping bar. This device, which covers a 1,392-sq-cm surface area, leaked a great deal in our tests.

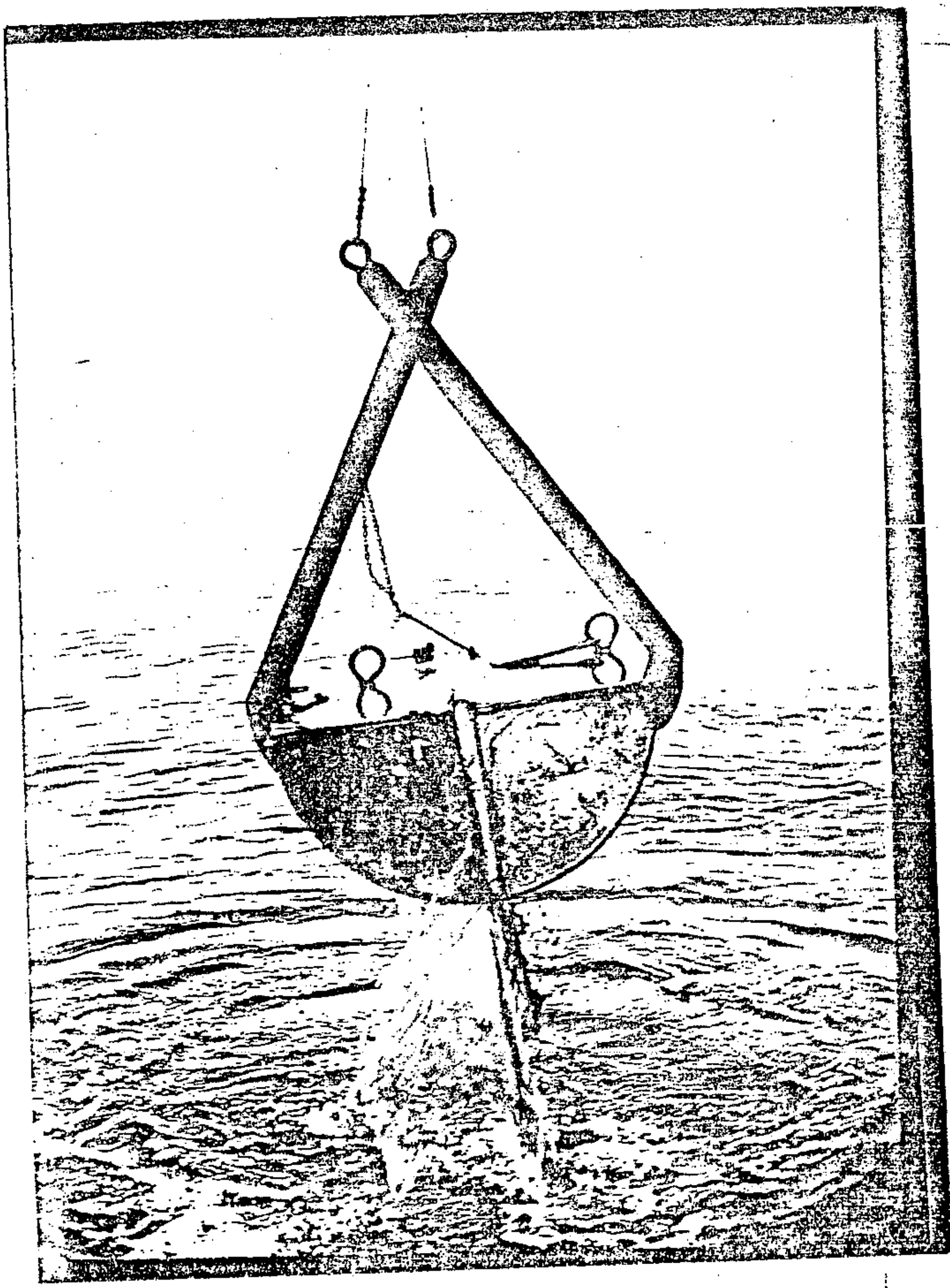


Figure 5. Van Veen No. 2. The basic Van Veen sampler was modified by replacing the tripping bar with a chain warp, placing screens of 0.5-mm mesh in the top of each half-bucket to reduce pressure waves, and attaching molded weights to the sampler. The Van Veen No. 2 has a smaller sampling surface area than the Van Veen No. 1 (1,040 vs. 1,392 sq cm) and leaked less. Rubber flaps conceal the screen tops in this photograph and decrease the disturbance of the sediment surface when the device is retrieved.

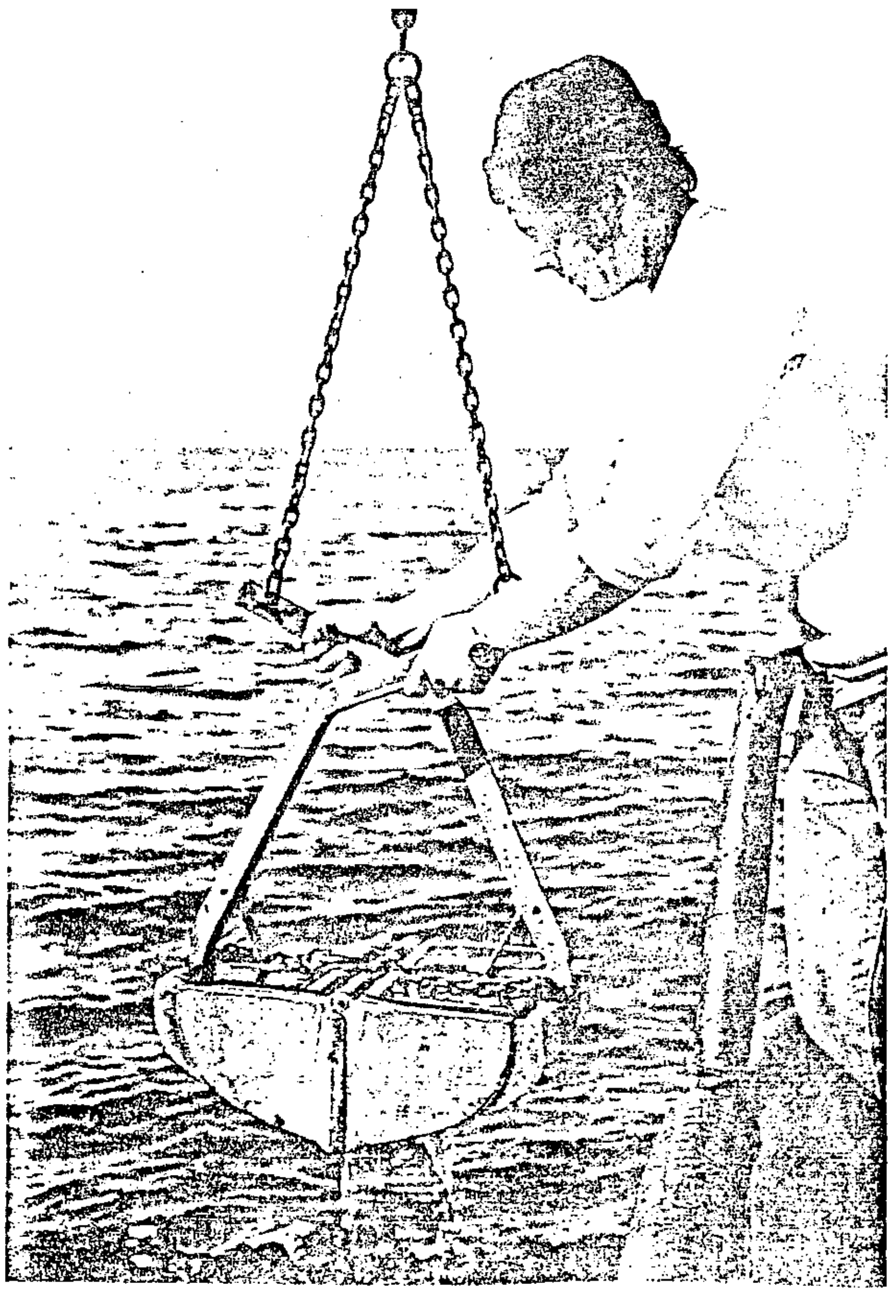


Figure 6. Smith-McIntyre. This device is a Van Veen within a spring-loaded frame. The halves of the sampling bucket are hinged at the center and mounted so that springs force the buckets into the sediment after both trigger plates simultaneously contact the bottom. The two buckets are closed together when the operator initiates retrieval of the sampler. The top of the buckets are screened to decrease pressure waves, which would be intense without the screens. The sampling surface area of the Smith-McIntyre is 0.1 sq meter; in our experiments, it penetrated to a maximum depth of 17.2 cm.

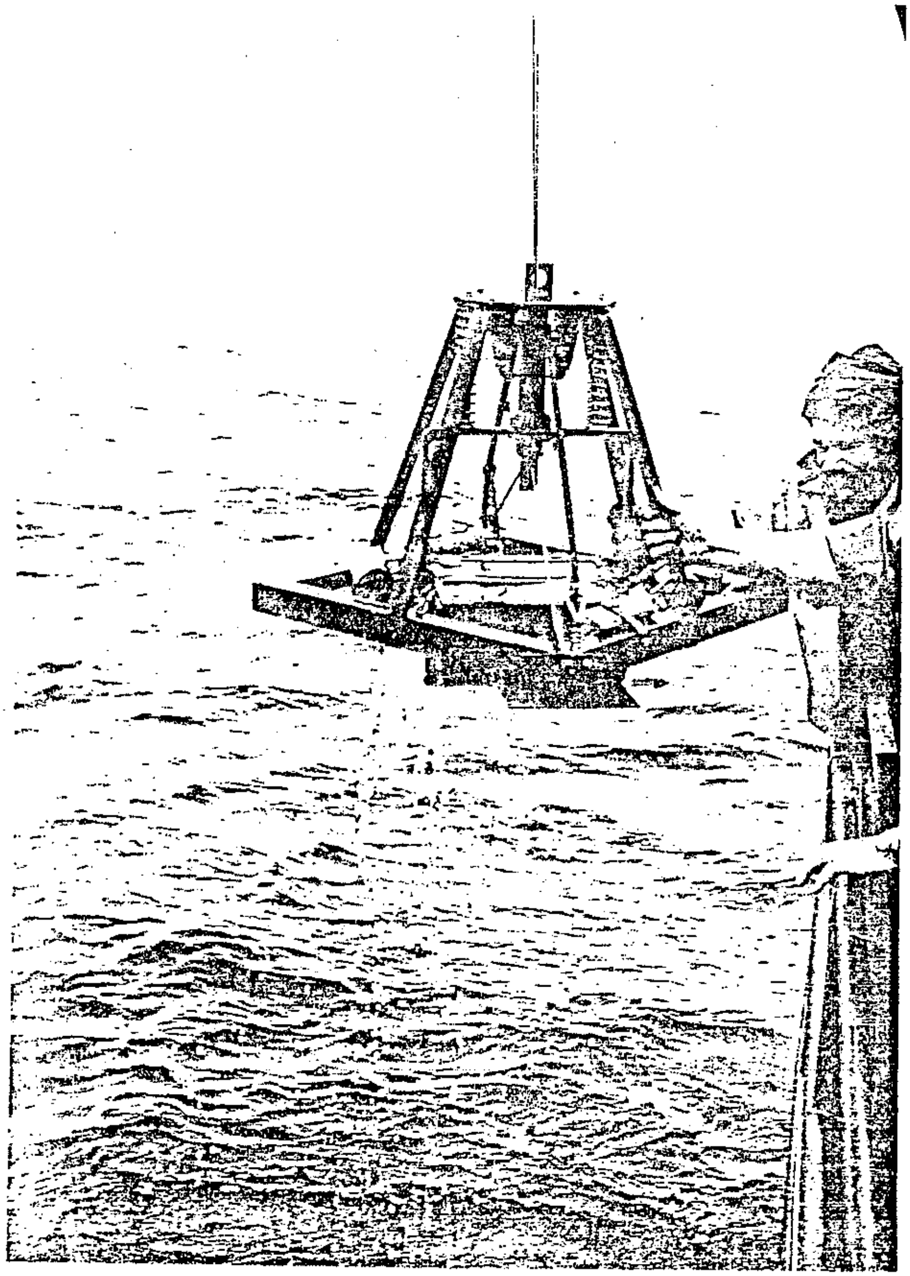


Figure 7. Ponar. This device, which is similar in appearance to the Van Veens, samples a surface area of 310 sq cm. It consists of two half-buckets, hinged in the center, with arms attached to provide mechanical leverage for closing the sampler. The screens of 0.5-mm mesh on the tops of the buckets decrease the pressure wave that the device creates. This device is unique in that it has side plates that keep it closed at the sides while the jaws are open, but these also hinder the grab's penetration of the bottom.

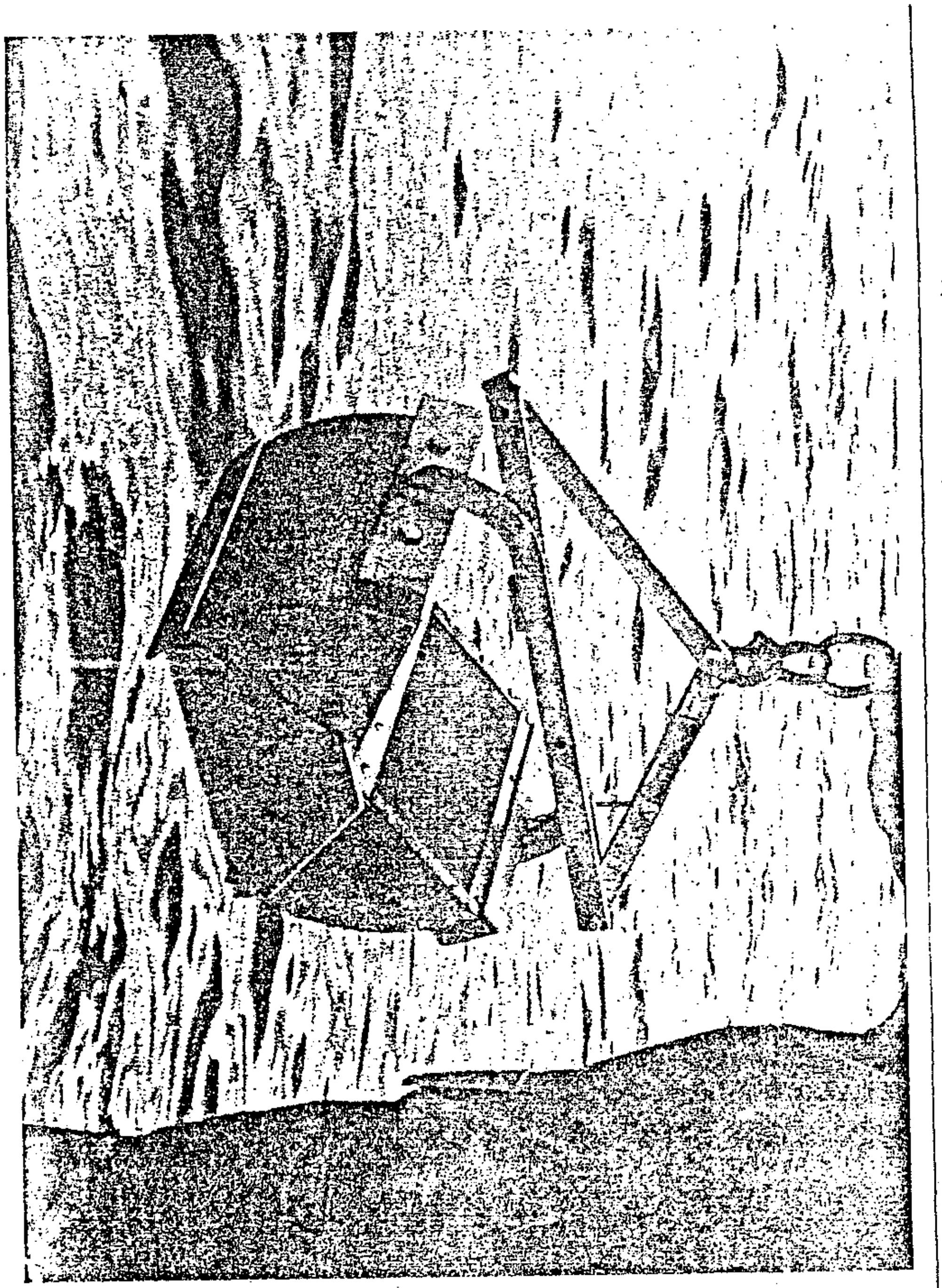
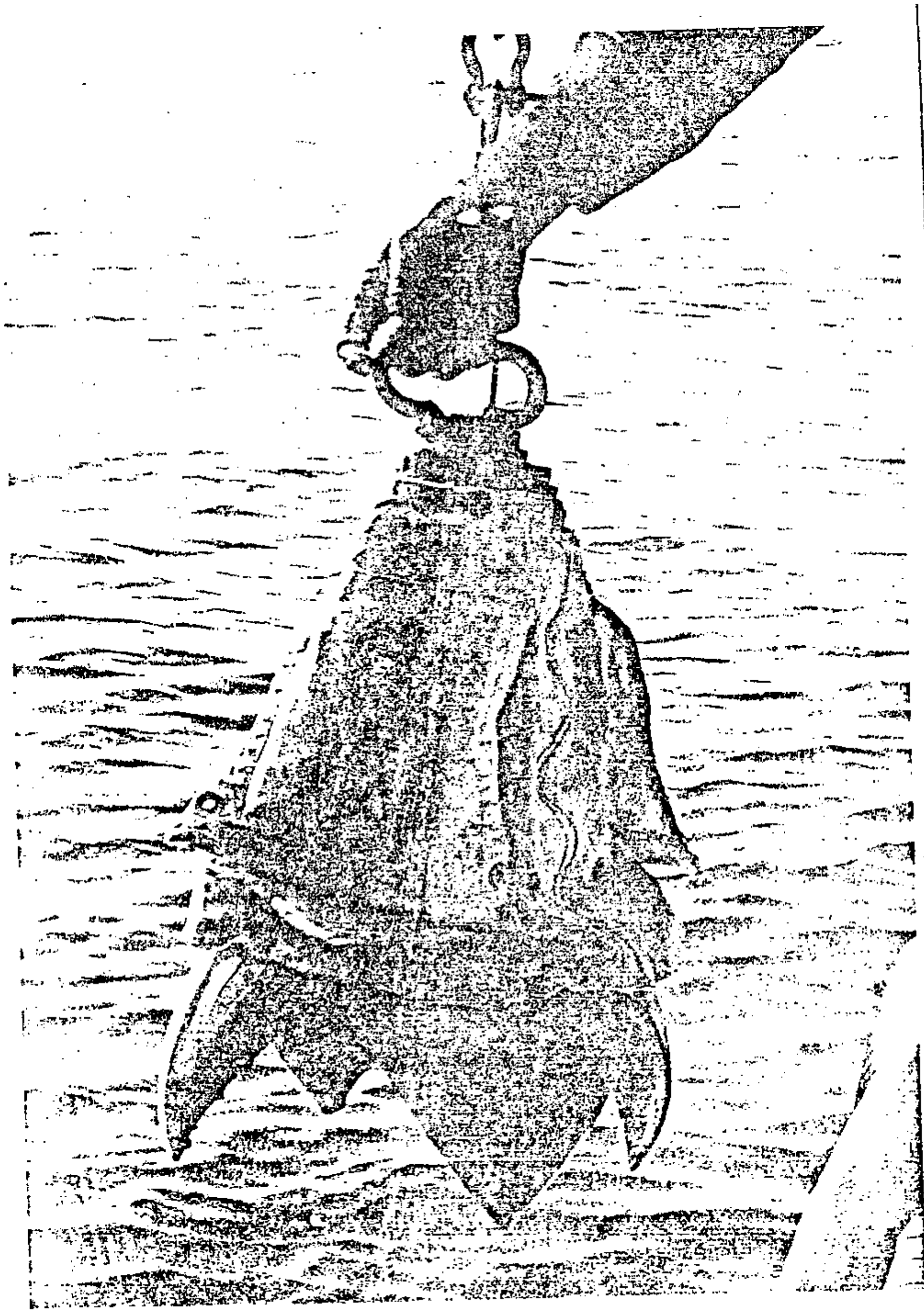


Figure 8. Orange Peel Grab. The Orange Peel used in this survey has a maximum sampling surface area of 520 sq cm. It consists of four curved and pointed jaws that, when closed, form a hemispherical bucket. To prevent the sample from being washed out of the device during retrieval, a loosely fitted canvas cover was attached, as suggested by Reish (1959). The surface area of samples collected with this device vary with penetration depth (Barnard et al. 1958). The device penetrated to a maximum depth of 18 cm in this survey. Note the extent of area that would not be sampled if the jaws did not completely penetrate beneath the sediment.



RESULTS AND DISCUSSION

VERTICAL DISTRIBUTION OF ORGANISMS

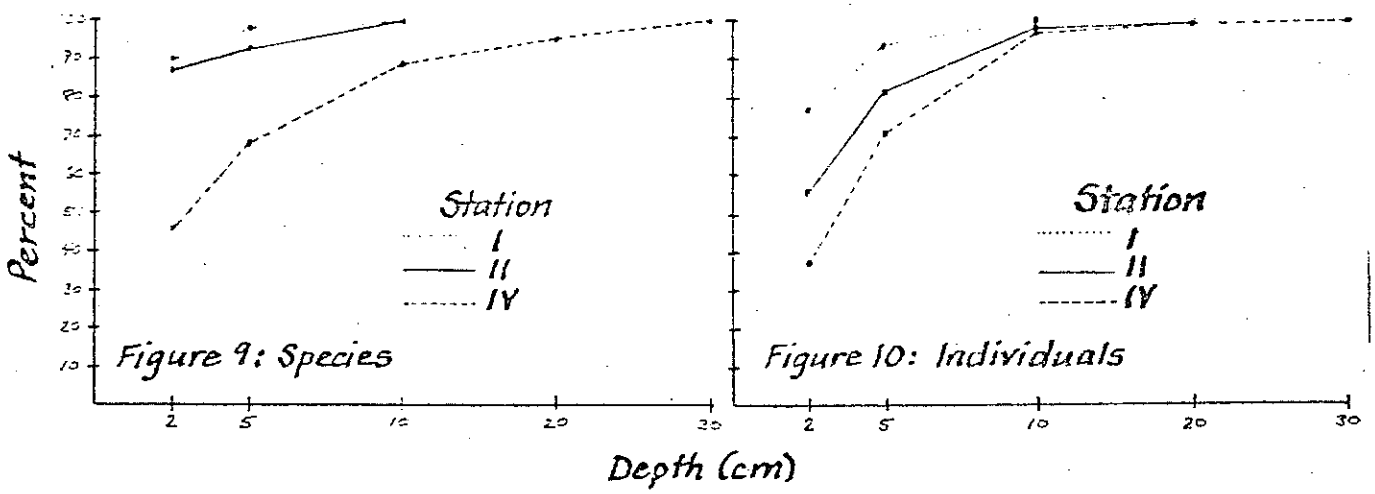
Organisms are distributed both horizontally and vertically within the sediments. Therefore, devices that take samples of varying surface area or depth of penetration will also collect different amounts and kinds of organisms. To determine the effects of depth of penetration, we studied the vertical stratification of organisms in the sediments at Stations I, II, and IV.

Organisms were found to a depth of at least 30 cm at all stations. At the stations with finer sediments, animals usually occurred more deeply within the sample. In the samples from Stations I and II, over 90 percent of the species were found in the upper 2 cm of sediment. There were no specimens of arthropods or echinoderms and only a few molluscs in sediment depths greater than 2 cm at these stations. At Station IV, molluscs and arthropods were found concentrated in the top 5 cm of sediment, with a few individual molluscs penetrating into the 5- to 10-cm depth interval.

Polychaetes and nemerteans were found throughout the samples at all three stations but were always in greater abundance near the surface of the sample. The only organisms found in abundance deep within the sediments at any of the stations were three species of foraminiferans. The shells of these animals were extremely abundant in the 20- to 30-cm depth interval at Station IV. Whether or not these organisms were alive at the time of sampling is not known, but it is thought to be unlikely.

There have been previous studies of the burrowing depths of infauna. Birkett (1958) found the pelecypod *Mactra corallina* to be restricted to the upper 3 to 4 cm. Molander (1928) found that few animals penetrated deeper than 5 to 10 cm in hard and soft clay. Jones (1961) showed the relative distributions of a number of species, all of which were collected in the upper 10 cm. Holme (1964) indicated that the vest majority of benthic animals occur within the upper 30 cm of sediment. Barnard and Hartman (1959) reported the presence of the Echiura *Listriolobus pelodes* in grab samples to depths of 60 cm. MacGinitie (1935, 1940) recorded the presence of animals at depths greater than 60 cm.

The accumulative percents of species and individuals collected with increasing depth in the present survey are shown in Figures 9 and 10. In all sediment types sampled, over 95 percent of the individuals and 90 percent of the species collected between the surface and 30 cm were found in the upper 10 cm. Thus, to obtain reliable data on the number of species and their relative abundances at such stations, a sampler that routinely penetrates to 10 cm or beyond is needed. A sampler that penetrates to 5 cm in hard-packed, coarse sand will also provide reliable data.



Figures 9 and 10. Accumulative percent of species and individuals found with increasing depth in sediments. Data are from two subcores (5-cm diameter) from within three box cores taken at each station.

Table 2. Penetration depths of sampling devices. Number of samples is 10 except where noted.

	Penetration Depth (cm, mean and standard deviation)			
	Station I	Station II	Station III	Station IV
Cruise 1, December 1974				
Box corer	11 ± 1.8[a]	26.6 ± 4.7[a]	34[b]	34 ± 6.2[a]
Van Veen No. 1	6.5 ± 0.9[a]	13.8 ± 2.0[a]	29[b]	22.0 ± 3.9[a]
Ponar	1.96 ± 2	3.6 ± 2.5	17.6[b]	17.0 ± 5
Shipek	3.4 ± 0.5	4.6 ± 2.3	6[b]	11 ± 1.3
Orange Peel	6.3 ± 1.5	12.0 ± 2.8	18[b]	15.4 ± 1.8
Cruise 2, March 1975				
Shipek	2.2 ± 0.6[c]	NA[d]	NA[d]	5.0[b]
Van Veen No. 2	4.9 ± 1.6[a]	NA	NA	12 ± 2.8[a]
Smith-McIntyre	5.7 ± 0.6[c]	NA	NA	13.6 ± 2[a]

a. N = 5.   b. N = 1.   c. N = 6.   d. NA = not applicable.

MECHANICAL AND BIOLOGICAL PERFORMANCE OF SAMPLERS

Penetration Depth

All of the devices tested penetrated silty sediments (Station IV) more deeply than coarser sediments (Stations I and II; Table 2). The device that consistently sampled to the deepest depths within the sediments was the box corer; the Shipek and Ponar consistently sampled to the shallowest depths. The depths of penetration of the remaining devices were similar.

Average depths of penetration were smaller during the second sampling period than during the first. The bottom appeared to be more difficult to penetrate--the Shipek used to make comparisons between the two surveys did not penetrate as deeply, and the Van Veen No. 2 did not penetrate as deeply as the Van Veen No. 1 used in the first survey.

The study of the vertical distributions of organisms has indicated that a device that samples to 10 cm or beyond is required to produce representative data on the organisms present in the soft bottom off southern California (a penetration depth of 5 cm is adequate in coarser sediments). The Shipek and Ponar samplers were considered unreliable for sampling in these sediment types because of inadequate penetration.

Surface Area and Volume of Sediments

Our investigations into the surface areas of samples collected with the various devices revealed two types of problems. First, actual measurements of the surface areas covered by three of the samplers (both Van Veens and the Ponar) were different from those listed in specifications for these devices (Table 3). The Ponar was found to cover an area of 306 sq cm, although manufacturer's literature specifies that it covers an area of 525 sq cm. If the latter value were used to make estimates of the number of species or individuals per square meter, a 42 percent underestimation would result.

A second problem was that, because of their design, the Shipek and Orange Peel devices take samples that vary in surface area with depth of penetration. The measured variation for the Shipek is shown in Table 4. A smaller amount of variation in surface area with penetration depth occurs with the Orange Peel because sediment surfaces between the jaws of the device will not be collected if the grab has not penetrated to the jaw hinges (see Figure 8; Barnard et al. 1958).

The volume of a sample is directly dependent on the surface area of the sample and the depth of penetration. As the only sampler tested that produced samples of greatly varying surface areas was the Shipek, the volume of samples in this survey was directly related to the depth of penetration (compare Tables 2 and 5). The volumes of the samples collected ranged from 0.42 to 33 liters.

It would initially appear that measurements of organisms per volume of sediment would give an accurate estimate of the abundance of benthic organisms as the organisms are distributed both vertically and horizontally within the sediments. However, organisms in our samples were not equally distributed but were clustered near the surface. Thus, equal volumes of sediment should only be compared when equal surface areas

Table 3. Comparison of measured and specified surface areas of samples collected with grab devices.

	Sample Surface Area (sq meters)	
	Actual	Specified
Box corer	0.063	0.063
Van Veen No. 1	0.14	0.1
Ponar	0.031	0.053
Shipek	0.024-0.038	0.04
Orange Peel	0.052	0.052
Van Veen No. 2	0.104	0.1
Smith-McIntyre	0.1	0.1

Table 4. Variation in surface area and volume of Shipek samples with depth of penetration of sampler.

Penetration Depth (cm)	Maximum Measured Surface Area sq cm	Maximum Measured Surface Area sq meter	Volume (liters)
1	156	0.016	0.07
2	225	0.023	0.35
3	275	0.028	0.62
4	312	0.031	0.93
5	335	0.034	1.28
6	350	0.035	1.60
7	360	0.036	2.00
8	370	0.037	2.40
9	375	0.038	2.80
10	377	0.038	3.20

have been sampled. The effects of error caused by the vertical and horizontal distribution of organisms in the sediments can be minimized by consistently sampling an area of between 0.1 and 0.2 sq meter and penetrating to a depth of between 5 and 10 cm, depending on the sediment type. On the basis of this criterion, the Shipek, Orange Peel, and Ponar samplers are unacceptable.

Surface Disturbance, Pressure Waves, and Leakage

The disturbance of the surface areas of samples collected in this survey ranged from zero, or minimal disturbance, to 100 percent--complete disruption of the surface layers (Table 6). At all stations sampled, the box cores had the least disturbed surfaces, and the Shipek and Ponar samples were classified as most disturbed. The large amount of disturbance of Ponar samples results from the fact that the sample must be removed from the device before the sample surface can be observed; with the installation of hinged screen tops, the surface disturbance of Ponar samples should be similar to that of the Van Veen No. 2 samples.

Estimates of sediment loss through leakage are given in Table 7. Disregarding the data from Station III, loss of sediment was generally most extensive at Station I and least noticeable at Station IV. The Van Veen No. 2, box corer, and Smith-McIntyre appeared to leak the least; the Orange Peel and Van Veen No. 1 had the most leakage.

Pressure waves created by descending samplers were observed by divers and by remote sensing equipment to disturb the sediment surface just prior to a sampler making contact with the bottom. Although no direct measurements of the effects of pressure waves were made in this survey, it was assumed that lightweight devices or those that allow water to pass through them in descent would create minimal pressure waves.

The combined effects of pressure waves, leakage, and surface disturbance are a potential loss of sediments and organisms from a sample. In an attempt to evaluate the effects of these factors, we looked at the relative abundances of microcrustaceans and molluscs in the samples collected with the various devices. Both these groups of animals are concentrated in the upper 2 cm of sediments and thus would be exposed to loss if the sediment surface were disturbed or the sampler leaked. Presumably, the lighter microcrustaceans would be lost at a greater rate than the heavier molluscs.

The ratios of arthropods to molluscs captured by the various samplers are given in Table 8. During the first sampling period, the Ponar and box corer were found to collect relatively more arthropods than the Van Veen No. 1, Shipek, or Orange Peel. During the second survey, the Van Veen No. 2 samples had higher arthropod/mollusc ratios than either the Smith-McIntyre or Shipek samples.

These ratios are compared with our estimates of surface disturbance and leakage for each sampler in Table 9. Although this type of comparison is subject to criticism, the trends in the qualitative estimates are reflected in the ratios of arthropods to molluscs.

Sampling Reliability

The final variable considered is the probability of the sampler taking an acceptable sample on each sampling attempt. A sample was considered

Table 5. Volume of samples obtained with grab devices.

	Volume (liters, mean and standard deviation)			
	Station I	Station II	Station III	Station IV
Cruise 1				
Box corer	6.7 ± 1.1	16.4 ± 3.0	20.9	21.4 ± 3.8
Van Veen No. 1	2.7 ± 0.5	12.1 ± 3.7	32.9	26.7 ± 4.6
Ponar	0.6 ± 0.4	1.1 ± 0.5	5.38	5.2 ± 1.3
Shipek	0.7 ± 0.1	1.3 ± 1.0	1.6	3.6 ± 0.5
Orange Peel	1.7 ± 0.6	3.1 ± 1.0	6.72	6.4 ± 2.1
Cruise 2				
Shipek	0.42 ± 0.1	NA	NA	1.28
Van Veen No. 2	2	NA	NA	11
Smith-McIntyre	2.5	NA	NA	12.0

Table 6. Estimated amount of surface disturbance of samples collected with sampling devices.

	Surface Disturbance (%)			
	Station I	Station II	Station III	Station IV
Cruise 1				
Box corer	0-25	0	0	0
Van Veen No. 1	50-75	0-25	0	10-25
Ponar*	100	100	100	100
Shipek	50-75	50-75	100	50
Orange Peel	100	50-75	0	25
Cruise 2				
Shipek	50	NA	NA	50-75
Van Veen No. 2	0-25	NA	NA	0-25
Smith-McIntyre	0-25	NA	NA	0-25

*Because of the Ponar design, it was not possible to observe the sample surface. The device can easily be modified to allow access to the sample surface; with modification, the surface disturbance would probably be equivalent to that estimated for the Van Veen No. 2.

Table 7. Estimates of the amount of leakage of sampling devices, based on field observations. The numbers 0, 1, 2, and 3 indicate zero, little, moderate, and extensive loss of sediment by leakage, respectively.

	Leakage			
	Station I	Station II	Station III	Station IV
Cruise 1				
Box corer	0-1	0	0	0-1
Van Veen No. 1	2	1	0	0-1
Ponar	2	0-1	0	0
Shipek	1	0-1	0	0-1
Orange Peel	2-3	1	0	0-1
Cruise 2				
Shipek	1	NA	NA	1
Van Veen No. 2	0-1	NA	NA	0
Smith-McIntyre	1	NA	NA	0

Table 8. Biological effectiveness of samplers, as indicated by arthropod/mollusc ratios. A relatively high arthropod/mollusc ratio indicates that the sampler is not losing large numbers of lightweight organisms through leakage and pressure waves.

	Ratio, Arthropods to Molluscs		
	Station I	Station II	Station IV
Cruise 1			
Box corer	1.54*	4.09*	0.03*
Van Veen No. 1	0.51	1.21	0.02
Ponar	2.0	12.5	0.16
Shipek	0.81	0.47	0.003
Orange Peel	0.28	0.3	0.01
Cruise 2			
Shipek	0.98*	NA	0.007
Van Veen No. 2	1.21*	NA	0.03
Smith-McIntyre	0.99	NA	0.02

*Mean of five samples; all other values are from examination of one sample.

unacceptable if it contained less than one-half the average amount of sediment collected by the sampler at the particular station or if the sampler returned to the surface without being triggered.

Three devices--the Orange Peel, Shipek, and Ponar--took a number of unacceptable samples (Table 10). At the deepest station, these devices took adequate samples in 48, 67, and 77 percent of the trials, respectively. The other devices used in the first cruise functioned equally well, collecting acceptable samples 100 percent of the time.

During the second survey, the Shipek and Smith-McIntyre took adequate samples at the deep station 20 and 60 percent of the time, respectively. The Van Veen No. 2 collected adequate samples 100 percent of the time at both stations. On the basis of reliability, the Shipek and Orange Peel performances are not acceptable; the Ponar and Smith-McIntyre reliability is only marginally acceptable.

Biological Effectiveness of the Samplers

To determine the significance of the effects of physical performance characteristics of the samplers on the resulting data on benthic populations, we applied correction factors to the data (Table 11). The corrections indicated that the original estimates of the density of organisms were in some cases underestimates; the greatest of these was the 62 percent underestimation of the abundance of organisms at Station IV resulting from the Orange Peel sampling. Variations in the amounts of surface area of samples appeared to have the greatest effect on the data, and depth of penetration was the second most significant limitation on the numbers of species and individuals collected. The combined effects of pressure waves, leakage, and sample surface disturbance were estimated to have the least effect on the data.

Comparison of Smith-McIntyre and Van Veen No. 2

Additional biological tests were made with these two samplers, which are similar in design and operation, to determine which was the most efficient. In our initial tests with all devices, the Smith-McIntyre appeared to collect approximately the same number of species as the Van Veen No. 2 and slightly more individuals. When cumulative species curves for replicate samples collected with the two devices were compared (Figure 11), it was apparent that the Smith-McIntyre collected slightly more species and slightly more organisms (less than 10 percent more) than the Van Veen No. 2 (880 vs. 808 individuals/sq meter at Station I and 9,220 vs. 8,860 individuals/sq meter at Station IV). This difference is not significant at the 95 percent confidence limit.

The relative efficiency of the two samplers in the collection of species was then compared by determining the number of taxa held in common by pairs of replicates collected with a given device. It was assumed that, if one of the devices collected more species consistently or sampled the bottom in a slightly different manner, the samples from this sampler would be more similar in species composition to each other than to samples taken with the other device. Figure 12 shows the number of species held in common by any pairs of replicates collected with the two samplers. The mean number of species held in common between any two Smith-McIntyre

Table 9. Comparison of arthropod/mollusc ratios in grab samples and qualitative estimates of the amount of sample disturbance caused by leakage, sample surface disturbance, and pressure waves. The first in each set of numbers is a ranking of arthropod/mollusc ratio; the second number is a ranking of the effects of leakage, pressure wave, and sample surface disturbance. Low numbers indicate high arthropod/mollusc ratios and relatively little sampler-induced disturbance of samples.

	Station I	Station II	Station IV
Cruise 1			
Box corer	2, 1	2, 1	2, 2
Van Veen No. 1	4, 4	3, 3	3, 3
Ponar	1, 2	1, 2	1, 1
Shipek	3, 3	4, 4	4, 4
Orange Peel	5, 5	5, 5	5, 5
Cruise 2			
Shipek	3, 2	NA	3, 2
Van Veen No. 2	1, 1	NA	1, 1
Smith-McIntyre	2, 1	NA	2, 1

Table 10. Reliability of sampling devices, as indicated by the percent of successful sampling attempts made at each station.

	Successful Sampling Attempts			
	Station I	Station II	Station III	Station IV
Cruise 1				
Box corer	100% (N = 5)	100% (N = 5)	100% (N = 1)	100% (N = 5)
Van Veen No. 1	100% (N = 5)	100% (N = 5)	100% (N = 1)	100% (N = 5)
Ponar	100% (N = 10)	100% (N = 10)	100% (N = 1)	77% (N = 13)
Shipek	100% (N = 10)	100% (N = 10	100% (N = 1)	67% (N = 15)
Orange Peel	77% (N = 13)	100% (N = 10)	100% (N = 1)	48% (N = 21)
Cruise 2				
Shipek	100% (N = 6)	NA	NA	20% (N = 5)
Van Veen No. 2	100% (N = 5)	NA	NA	100% (N = 5)
Smith-McIntyre	86% (N = 6)	NA	NA	63% (N = 8)

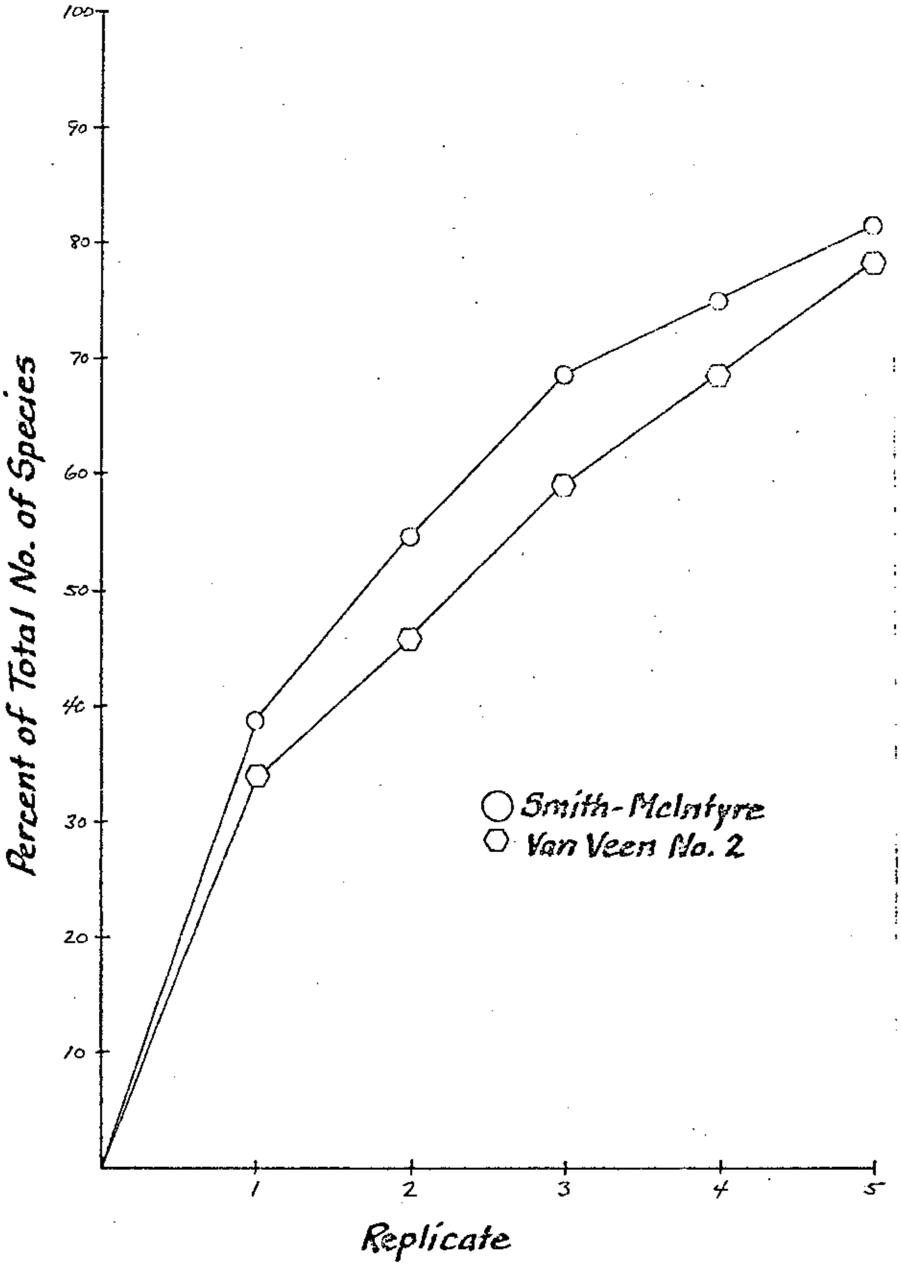


Figure 11. Comparison of the accumulative species curves with analyses of additional replicates for the Van Veen No. 2 and Smith-McIntyre samplers.

Table 11. Percent underestimation of abundance of infaunal populations resulting from variations in penetration depth of sampling devices and amount of surface area covered in sampling.

	Underestimation of Infaunal Abundance		
	Station I	Station II	Station IV
Cruise 1			
Box corer	0	0	0
Van Veen No. 1	23%	0	0
Ponar	55%	35%	5%
Shipek	44%	25%	5%
Orange Peel	6%	0	62%
Cruise 2			
Shipek	20%	NA	28%
Van Veen No. 2	8%	NA	5%
Smith-McIntyre	0	NA	5%

Replicates	Van Veen No. 2 1	2	3	4	5	Smith-McIntyre 1	2	3	4	5
Van Veen No. 2 1										
2	15									
3	19	17								
4	17	14	16							
5	17	11	14	20						
Smith-McIntyre 1	17	18	18	19	14					
2	16	14	15	19	15	19				
3	20	16	24	25	21	25	24			
4	17	18	19	15	15	17	16	20		
5	12	12	12	19	16	14	17	23	13	

Figure 12. Comparison of the similarity (number of species held in common by any two samples) between Van Veen No. 2 and Smith-McIntyre replicates, March 1975, Station I.

samples was 18.8 ± 1.4; the mean number in common between any two Van Veen No. 2 samples was 16.0 ± 0.9. The mean number of species held in common between any Van Veen and any Smith-McIntyre samples was 17.04 ± 0.67. These differences are not significant at the 95 percent confidence level.

Further analyses, although not conclusive, indicated that the Van Veen No. 2 collected slightly more arthropods than the Smith-McIntyre and thus would be slightly more efficient at capturing relatively light organisms. Although both devices were relatively reliable, the Smith McIntyre was found to take unacceptable samples more often than the Van Veen No. 2.

Other Observations

The design and performance of the samplers is discussed and compared in the following sections.

Contact-Activated Samplers. Two contact-activated samplers were tested in this survey. The first, the Shipek, is designed so that, when it touches the bottom, tension on a spring is released, driving the hemispherical sampling bucket sideways through the sediment. There were a variety of problems with this device. Its shallow penetration of coarse or tightly packed sediments reduced the amount of surface area collected by at least 50 percent. This problem occurs when the substrate is solid enough to stop the rotation of the sampling bucket or to force the grab off the substrate, allowing the bucket to complete its rotation without traveling through the sediment. Both of these events were observed by Los Angeles County Sanitation Districts divers, Douglas Hotchkiss and Joseph Meistrell (November 1974). The Shipek also created a significant pressure wave (observed by divers), and there was a large amount of sample disturbance (collapse of the sample surface on top of itself) and leakage. The amount of error (underestimation of infaunal populations) introduced by these problems was, however, estimated to be smaller than the errors resulting from variations in sample surface area and sampler penetration depths.

To decrease the error created by using the Shipek, it should be lowered slowly to minimize pressure waves. In addition, the device should not be used in tightly packed sediments. The grab should penetrate the sediments to at least 5 cm to collect a sample with an acceptable surface area. (To account for the majority of individuals and species, we have recommended a minimum penetration depth of 10 cm; however, this depth is near the maximum penetration depth for the Shipek.)

A second contact-activated sampler, the box corer, does not collect samples of varying surface areas and does not create large pressure waves because water can pass freely through the device during its descent. Although there was variation in the depth of penetration of this device, errors in population size estimates would be slight because the box corer normally penetrates beyond the depth where the maximum number of species and individuals occur. The major disadvantage with the box corer is its size and weight--two men and an A-frame operator are needed to position the device. At the present time, the only vessel using this device off southern California is the large (120-foot) Velero IV.

Retrieval-Activated Samplers. The remaining devices tested in this survey are retrieval-activated samplers. If these grabs are modified so that the top surfaces are screened, the pressure waves they create are minimal, and they can be dropped rapidly from short distances (5 to 10 meters) above the bottom, thus increasing their momentum and, therefore, their penetration depth. If these devices are to be lowered rapidly for only a short distance, their relative weight becomes an important consideration as it determines depth of penetration.

The Ponar, Van Veen No. 1 and No. 2, and the Smith-McIntyre are very similar in structure and function. A major problem with these devices is their biting profile. All have two halves of the sampling bucket hinged at the center, and the angle at this junction when each device is opened to its maximum extent is an important consideration (Figure 13). As this angle increases, the amount of penetration into the bottom necessary to close the aperture between the two halves of the collection bucket decreases. It has been demonstrated that pressure waves can be great enough to force objects up to 8 cm long out of the opening (Wigley 1967). Also, if the device is not closed rapidly, mobile organisms can readily escape through the opening.

The Ponar is the smallest of the four devices. It is relatively lightweight and does not adequately penetrate coarse or tightly compacted sediments. The device's shallow penetration depth was estimated to result in 55, 35, and 5 percent underestimations of the numbers of individuals present at Stations I, II, and IV, respectively. As the Ponar's inadequate penetration is primarily a function of its weight, additional weights on the jaws of the device may compensate for this problem.

The Ponar was the most efficient of the samplers at collecting the surface-dwelling arthropods at all stations; this was attributed to its minimal amount of leakage and the small pressure wave that it creates. The Ponar could be very effective, once modified to allow access to the surface of samples, in sediments in which it is capable of penetrating to 10-cm depths.

The two Van Veen grabs, although constructed in fairly similar fashions, gave very different results. Both of these devices were said to sample 0.1 sq meter: In reality, Van Veen No. 1 covered 0.14 sq meter, and Van Veen No. 2 covered 0.104 sq meter. This difference alone could result in errors in estimates of numbers of individuals as great as 52 percent. These samplers also differed in the amount of pressure wave they created. Van Veen No. 1 was not supplied with screens as was Van

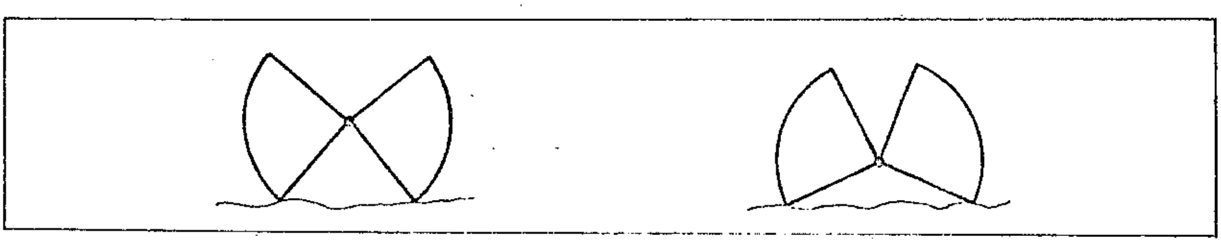


Figure 13. Sideview of two benthic grabs similar to the Van Veens, Ponar, or Smith-McIntyre making contact with the bottom. Note how the angle between the two halves of the collection buckets when the grab is fully opened affect the depth of penetration needed to close the opening between the buckets, through which animals may escape.

Veen No. 2. This factor, combined with the gaps and leakage from the bucket of Van Veen No. 1, resulted in this sampler capturing fewer arthropods than did Van Veen No. 2. Both of these devices were heavy enough to penetrate sediments at all stations beyond the depth containing at least 90 percent of the individuals and species.

The final retrieval-activated sampler tested was the Orange Peel bucket. This device effectively penetrated all sediment types to the depth necessary to capture more than 90 percent of the species and individuals present. However, the number of species and individuals collected by the Orange Peel was greatly affected by the combination of pressure waves, sample surface disturbance, and leakage. The Orange Peel arthropod/mollusc ratio was much lower than those for the other devices.

Attempts to extrapolate the number of organisms present in an Orange Peel sample to an expected number per square meter yielded extremely varied results. At Station I, the number of individuals captured was well within the expected limits of variation. However, at Station II, the number of individuals and species collected with this device seemed to be somewhat high for a sampler of its size, and, at Station IV, the Orange Peel collected a much smaller number of organisms than expected. Although such variation could reflect patchy distribution of organisms, we believe the inconsistent data from Orange Peel samples collected in this survey are related to variations in the surface areas of the samples: Such variations have been reported to be as high as 50 percent (Barnard et al. 1958). Because the Orange Peel was used extensively off southern California by the Allan Hancock Foundation, we believe this variability should be further studied so that past data can be compared with that collected more recently.

Overall Performance Ratings

When the devices tested in this survey were rated according to the mechanical and biological criteria described in the preceding sections (Table 12), three devices--the Van Veen No. 2, the Smith-McIntyre, and the box corer--were found to be acceptable or marginally acceptable. As the box corer is too large for many vessel operations, and the Smith-McIntyre and Van Veen No. 2 are similar in performance, the device with the fewest mechanical parts--the Van Veen No. 2--was chosen as the grab sampler to be used by the Coastal Water Research Project.

REPLICATION

To determine the effect that additional species found in replicate samples will have on the total number of individuals collected, the mean number of individuals per newly added species was calculated for all combinations of ten replicate samples (Figure 14). Also calculated were the mean number of additional individuals added by analysis of each replicate (Figure 15) and the total percentage of individuals of new species added by analyzing the additional replicates (Figure 16). We found that the species accumulation curve had not reached an asymptotic point after analysis of ten replicates. However, the curves for mean number of individuals per newly added species and the total number of individuals representing newly added species reached an asymptotic point

Table 12. Critical parameters for performance of sampling devices and ratings of devices tested in December 1974 and March 1975, Santa Monica Bay. A solid box indicates sampler is unacceptable according to that criterion; a dashed box indicates marginal acceptability.

	Van Veen No. 2	Smith-McIntyre	Van Veen No. 1	Box Corer	Ponar	Shipek	Orange Peel
Minimal variation in surface area of samples?	Yes	Yes	Yes	Yes	Yes	No	No*
Penetration of sampler to critical depth in sediments?	Yes	Yes	Yes	Yes	No	No	Yes
Underestimation of infaunal populations attributable to variation in surface area sampled and penetration depth	5%	5-6%	0-5%	0	5-35%	7-49%	50%
Minimal leakage of sampler?	Yes	Yes	No	Yes	Yes	No	No
Minimal pressure wave created by descending sampler?	Yes	Yes	No	Yes	Yes	No	?
Few operators required?	Yes	No	Yes	No	Yes	Yes	Yes
No. of operators required	2	2-3	2	3	1	1	1
High reliability in collecting an adequate sample on each sampling attempt?	Yes	-	Yes	Yes	-	No	No
% successful sampling attempts	100%	63-86%	100%	100%	77-100%	20-100%	48-100%

*Barnard et al. (1958) state that this area may vary by as much as 50 percent.

Figure 14. Cumulative species curve and mean number of individuals per new species found in analysis of ten 0.1-sq-meter replicates.

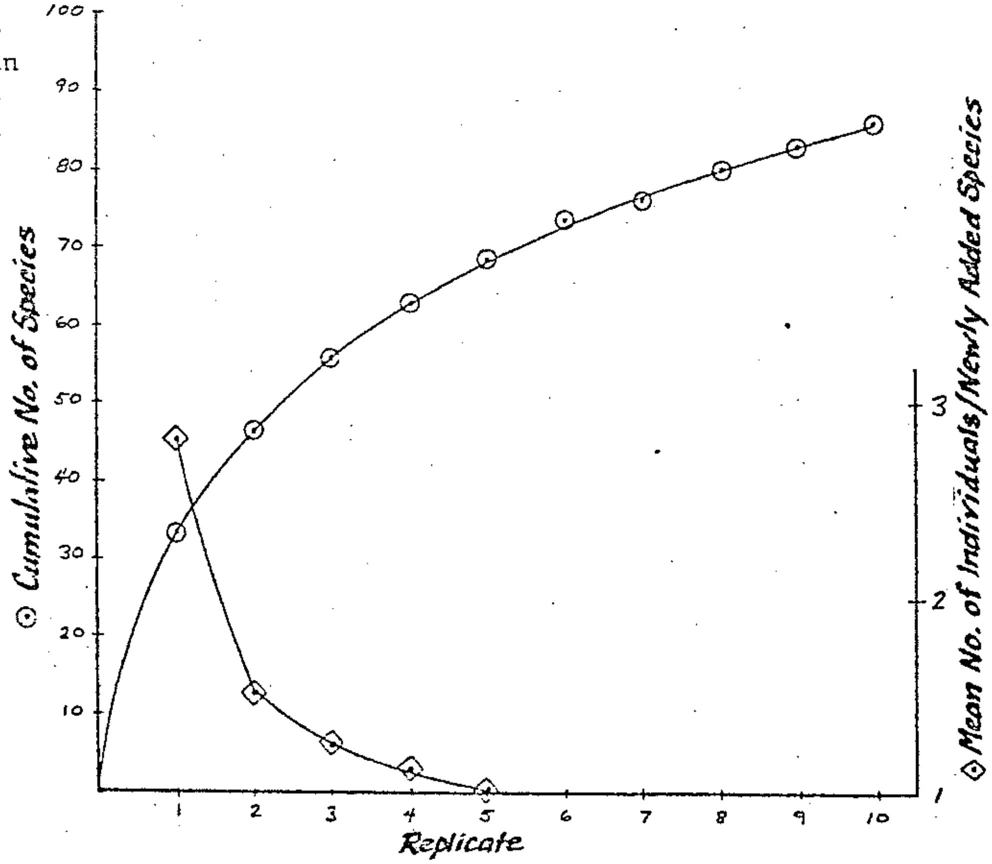
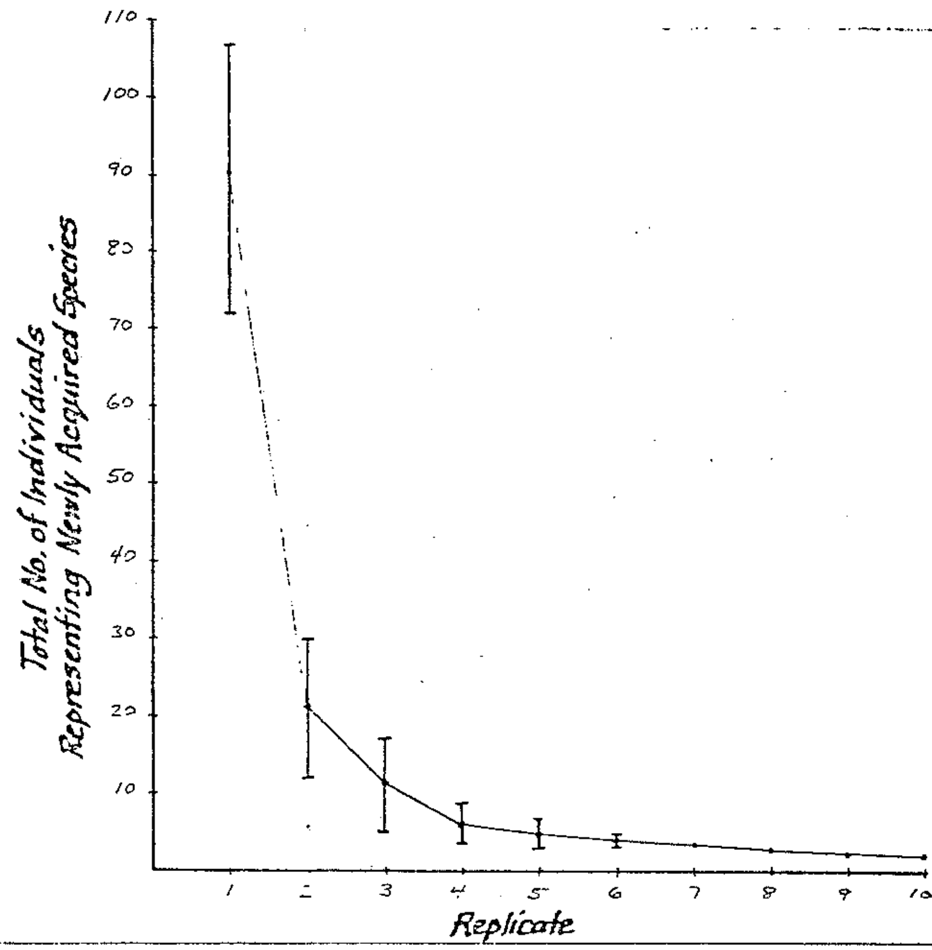


Figure 15. Mean number (and standard deviation) of individuals added to a sample by inclusion of new species found in analysis of ten 0.1-sq-meter replicates.



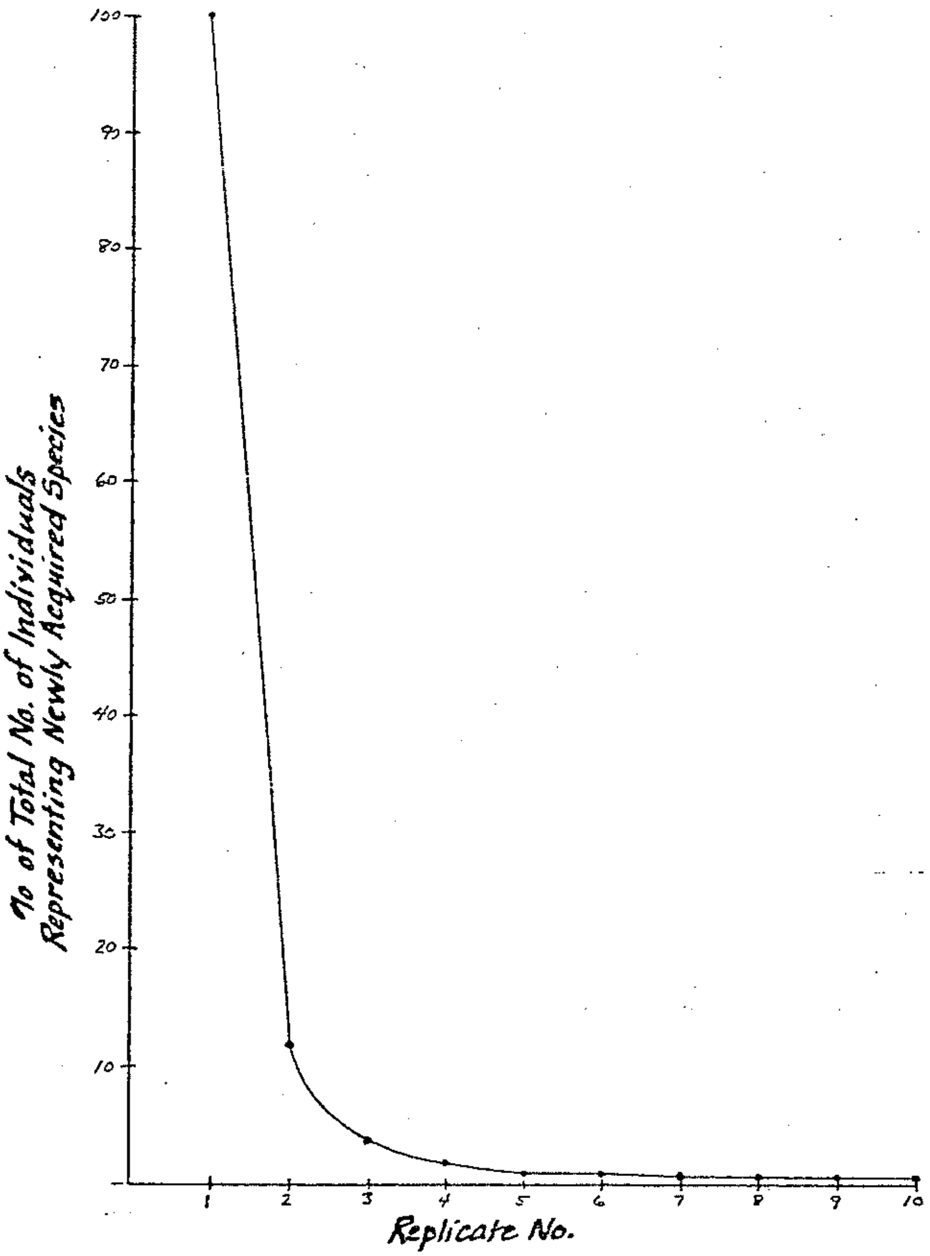


Figure 16. Individuals representing new species found in the analysis of each of ten replicate 0.1-sq-meter samples.

with the analysis of five replicates. The curve for the total percentage of individuals accounted for by these newly added species also reached the asymptotic point at five replicates.

Species added to the data base on a station by analysis of more than two replicates accounted for less than 5 percent of the total individuals found in analysis of ten replicates. Species added by analysis of more than a single sample accounted for slightly more than 10 percent of the total individuals found in all replicates.

The number of replicates and the amount of surface area collected in benthic surveys has varied greatly. Jones (1961) recommended collection of 30 replicates of a 2.5-sq-cm core, a total surface area of 75 sq cm, or 0.0075 sq meter. He based this recommendation on a method used by Gleason (1922), Williams (1950, 1951), and Holme (1953) of plotting the cumulative number of species against the logarithm of the cumulative area sampled until an asymptotic point was reached. Longhurst (1959) objected to the use of the cumulative species curve alone as a method of defining the minimal sample area. He showed that the more abundant species were adequately represented in the first two to three replicates of a 0.1-sq-meter grab. He recommended that five samples covering a surface area of 0.5 sq meter would be adequate for quantitative sampling, noting that replicate samples greater than five tend to add only the least abundant species to the list of those already collected. Longhurst's methods were considered to be generally applicable in studies of most bottom conditions by Holme (1964).

These two methods of replicating biological samples from grabs yield different but not conflicting results. Our data, showing that the species accumulation curve was still rising even after analysis of ten replicates, might be interpreted to mean that analysis of ten replicates would not be sufficient to adequately describe a station. However, the new species found in analysis of more than one sample added very low number of individuals to the total already accounted for by previous species and would not be important in many community analyses that are sensitive only to those species accounting for a certain percentage of individuals in the sample.

The number of replicates collected should be based on the projected analysis. Very sophisticated techniques often use 95 percent or fewer of the individuals collected to determine species- or site-groups (Stephenson et al. 1975). If this were the criteria, analysis of two replicates of a 0.1-sq-meter sample would be required. Procedures that are less affected by those species representing relatively few individuals or that do not incorporate abundance information (e.g., indices of similarity (Peters 1968); recurrent group analysis (Fager 1957, 1963)) should require analysis of a single 0.1-sq-meter sample. However, studies should be conducted to verify this hypothesis, as the objective of replication is not only to collect rare species but also to provide information on statistical variability of species abundances. Also, studies of the population levels of certain species would require different sampling procedures (e.g., taking a number of small cores or a series of subsamples from the sampler and counting only those individuals of the species of interest).

EFFECTS OF SCREEN SIZE

The mesh size of the screen through which a sample is sorted directly influences the numbers of species and individuals found in the sample

(Table 13). In our tests, we screened samples through 16-, 20-, and 30-mesh screens (1.0, 0.7, and 0.5 mm, respectively). Specimens from the two shallow stations that were retained on the 16-mesh screen represented 61 to 66 percent of the species found at these stations but only 22 to 24 percent of the total number of individuals. Use of the 20-mesh screen trapped relatively few new species and individuals (12 to 16 percent of the total number of species, and 10 to 11 percent of the total number of individuals). The number of additional species and individuals retained on the 30-mesh screen was higher--22 percent of the total number of species were found on this screen and 66 to 69 percent of the total individuals (Figures 17 and 18).

The 16-, 20-, and 30-mesh screens trapped 76, 11, and 13 percent of the total number of species taken at Station IV, respectively. The individuals at this deep station were generally larger in size than those collected at the other two stations: 56 percent of the total number of individuals sorted from the sample were retained on the 16-mesh screen, and 4 and 40 percent were retained on the 20- and 30-mesh screens, respectively (Figure 19).

Overall, the data indicate that the 20-mesh screen does not add many species or individuals to those obtained by using a 16-mesh screen. However, there is a very large difference between the number of species and individuals collected on the 16-mesh and 30-mesh screens.

At Stations I and II, polychaetes represented 51 percent of the species and approximately 80 percent of the specimens; at the deeper station, they represented 56 percent of the species but only about 50 percent of the individuals. At Station II, three species of deposit-feeding clams (Parvilucina sp. (juvenile), Axinopsida serricata, and Macoma carlottensis) were very abundant, accounting for 93 percent of the non-polychaetes in this sample.

The additional species of polychaetes from Station I collected on the 30-mesh screen included one significantly abundant species (Prionospio pygmaeus). The remaining 10 species were represented by a total of 25 individuals. The additional 11 polychaete species from Station II found on the 30-mesh screen represented a total of 72 percent of the polychaete individuals collected at this station. Sorting with the 30-mesh screen also added significantly to the total number of polychaetes taken at Station IV.

The effect of screen size on the collection of other invertebrate phyla was different from the effect on polychaete collection. More mollusc species from all stations were found on the 16-mesh screen than on the smaller screens. Arthropod species occurred more often on the 20- and 30-mesh screens. Only 4 of the 35 arthropod species collected at the three stations were found in abundance on the 16-mesh screens. And only 1 of the 44 mollusc species collected (Mysella grippi) was found in abundance on the 20- and 30-mesh screens.

Certain general statements can be made on the basis of our study of screen sizes and infauna in Santa Monica Bay:

1. Polychaetes are generally the most dominant organisms in grab samples.
2. Most species of polychaetes (approximately 80 percent) and molluscs are found on screens with mesh openings of 1.0 mm.
3. Most species of arthropods (between 50 and 77 percent) are found on screens with mesh openings smaller than 1.0 mm (e.g., 0.5 mm).
4. Ophiuroids were found only on the 1.0-mm screens.

Table 13. Cumulative numbers of species and individuals screened from samples through the use of screens of three sizes, 16 mesh, 20 mesh, and 30 mesh (1.0, 0.7, and 0.5 mm, respectively).*

	Station I			Station II			Station IV		
	16 mesh	20 mesh	30 mesh	16 mesh	20 mesh	30 mesh	16 mesh	20 mesh	30 mesh
No. of species	57	72	94	67	79	101	61	70	80
No. of individuals	261	378	1,108	539	779	2,493	2,968	3,168	5,296
Polychaetes									
No. of species	37	40	48	41	43	52	39	41	45
No. of individuals	195	260	870	453	573	2,103	654	805	2,849
Non-polychaetes									
No. of species	20	32	46	26	36	49	22	29	35
No. of individuals	66	118	238	86	120	304	2,314	2,363	2,447
Arthropods									
No. of species	5	11	22	10	16	26	9	13	18
No. of individuals	12	24	99	25	42	138	14	21	65

*The numbers given are cumulative, that is, when the portion of the sample from Station I that passed through the 16-mesh screen was sieved through a 20-mesh screen, 15 addition species were found.

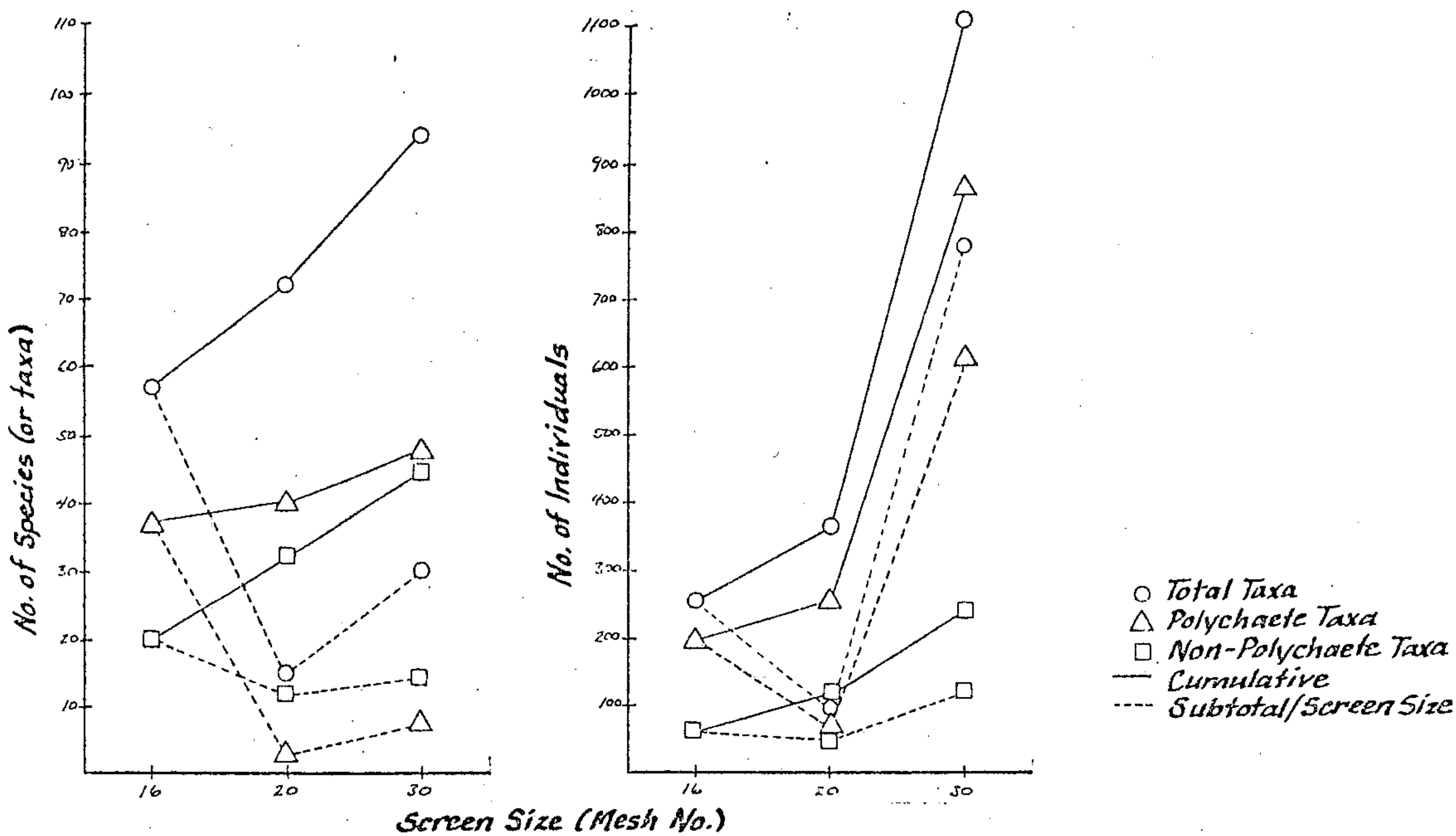


Figure 17. Number of species and individuals collected on 16-mesh, 20-mesh, and 30-mesh screens (1.0, 0.7, and 0.5 mm, respectively) at Station I.

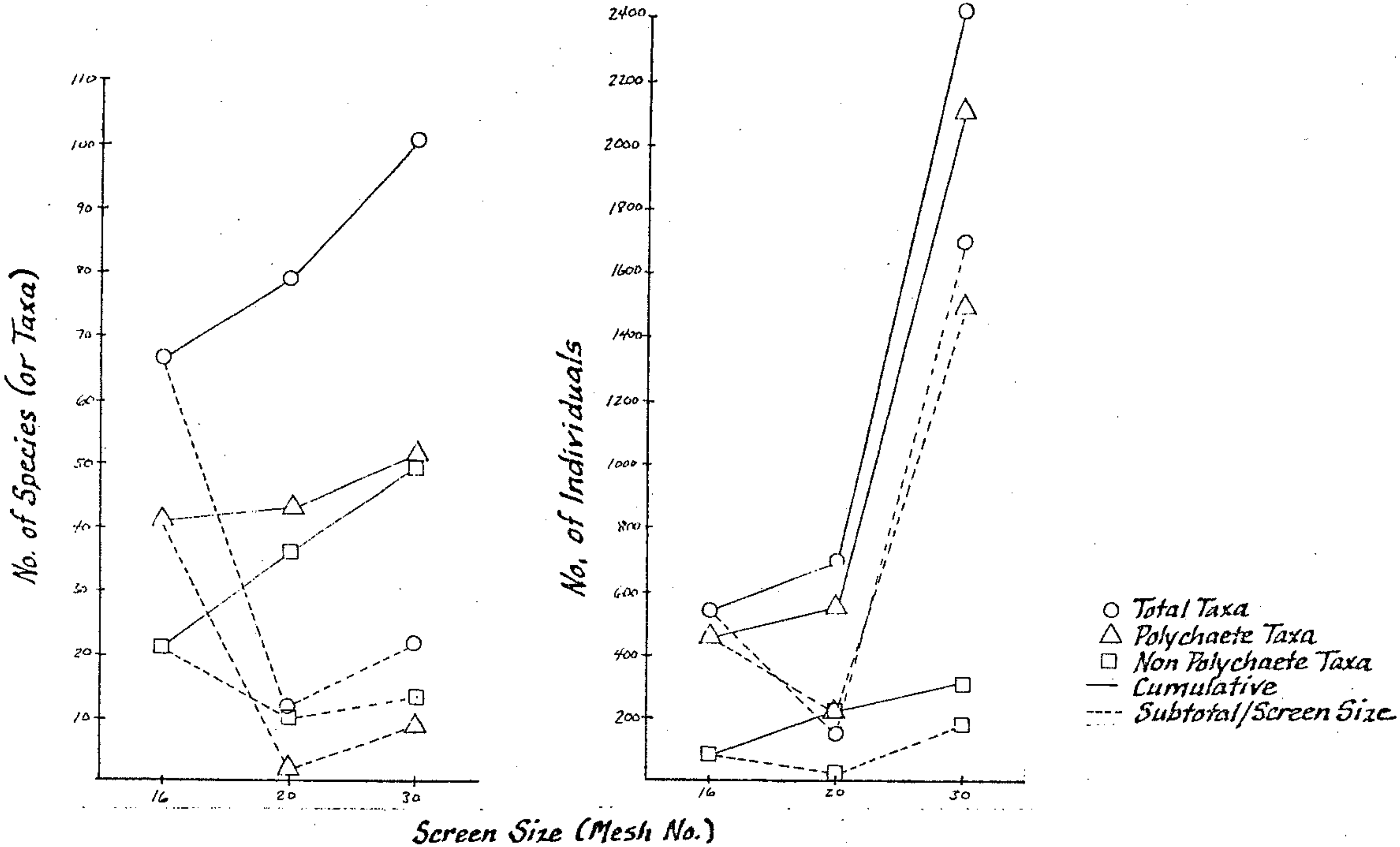


Figure 18. Number of species and individuals collected on 16-mesh, 20-mesh, and 30-mesh screens (1.0, 0.7, and 0.5 mm, respectively) at Station II.

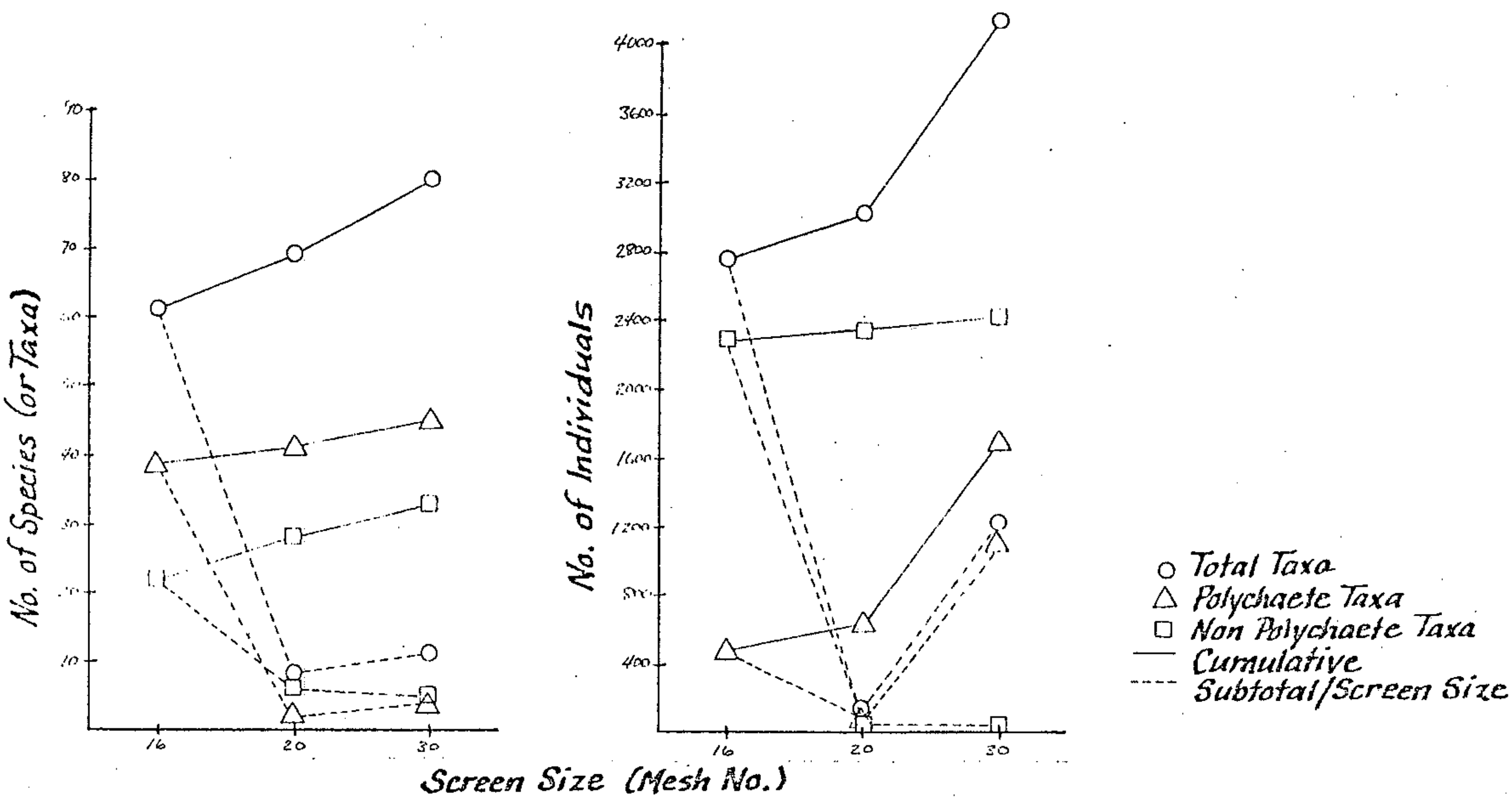


Figure 19. Number of species and individuals collected on 16-mesh, 20-mesh, and 30-mesh screens (1.0, 0.7, and 0.5 mm, respectively) at Station IV.

5. Data on other phyla were insufficient to allow us to generalize.

It is apparent that screen mesh sizes directly influence the types of organisms found in a sample. For example, juveniles of certain species, as well as whole groups of small adult organisms, are collected only on the smaller mesh sizes. The large number of polychaetes present on the smaller screens used in our study, and the fact that these made a small contribution to the total numbers of species found in the samples, indicates that they were mainly juveniles of species already retained on a larger screen. Experiments should be designed to determine if stations will "cluster" together in similar fashions when screen sizes are varied. Preliminary information indicates that stations that clustered together when a 16-mesh screen was used to sort polychaetes also clustered together when a 30-mesh screen was used (T.J. Kauwling and R. Osborn, Allan Hancock Foundation, personal communication). This indicates that samples screened through 16- and 30-mesh screens would give similar information on changes in the environmental distributions of polychaetes.

In summary, comparisons of the number of species and invertebrates in a sample should be made with the following considerations in mind:

1. Benthic organisms retained on screens include adults, subadults, and juveniles of various species.

2. The abundance of a particular species at different times and locations should only be compared when the same size screen was used to sort all samples. This will ensure that the same age classes are found in all samples, if present.

3. To more uniformly sample age classes, samples should be taken during the same seasons of the year if they are to be compared.

4. Data on certain organisms that settle at sizes greater than the largest diameter screen opening used (in this case, 1.0 mm) are comparable as long as the samples were taken in the same season.

5. Research objectives should determine the size of screen selected for a survey. A 1-mm screen may be adequate for species and site classificatory analyses. However, a 0.5-mm screen is probably necessary in studies of the population dynamics or age structure of animals, especially arthropods.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of this study of various physical and biological considerations in benthic surveys and the performance of seven sampling devices, we believe the following criteria should be used in selecting a benthic sampler:

1. The sampler should consistently sample a uniform surface area, entirely independent of other phenomena.

2. In soft bottoms at 10 to 250 meters off southern California, the device should penetrate to a minimum depth of 10 cm within the sediment. (This depth should be modified if analyses of sediments in another survey area reveal a shallower or deeper distribution of the majority (90 percent) of the species and specimens present, as was the case in the shallow, coarse substrates in Santa Monica Bay.)

3. The device should be modified, replacing solid top surfaces with screens, so that it creates minimal pressure waves in descent.

4. The device should close tightly, thus minimizing leakage.

5. It should sample each layer of sediment in as similar a manner as possible.

On the basis of these considerations, the Van Veen No. 2 was selected as the sampler to be used in benthic surveys by the Coastal Water Research Project.

Two other findings of this study were as follows:

6. A single 0.1-sq-meter sample, or at most two replicates, will provide sufficient information for certain types of community analyses concerned with the presence or absence of the more common species and the relative abundances of these species at a particular station. More replicates may be required for statistical comparison of mean structural parameters (such as density, richness, and diversity); a different sampler may also be needed, according to the size, mobility, and patchiness of distribution of target species.

7. Screen size analysis indicated that the mollusc, polychaete, and ophiuroid species contributing the majority of individuals were present on 16-mesh (1.0-mm) screens, and the microcrustacea species and individuals were predominantly found on 30-mesh (0.5-mm) screens. The number of additional individuals of polychaetes found on the smaller screens was high but included few new species not found on the 16-mesh screen. We recommend that studies be conducted to determine if the use of 1.0- and 0.5-mm screens changes the results of site clustering or species clustering analyses. Present information indicates that the two screens yield similar information in site clustering according to polychaete distributions.

8. We believe that the estimates of the number of individuals and species of molluscs and ophiuroids made in surveys using different samplers are comparable as long as (a) an accurate estimate of sample surface area can be made, (b) the samples are sieved through screens with a mesh diameter of 1.0 mm or less, and (c) the samples are taken during the same season of the year. If these criteria are met, data collected in the 1950's with, for example, an Orange Peel of 0.25-sq-meter sampling area or a

Campbell with a sampling surface area of 0.5 sq meter can be compared with data collected today, with reasonable assurance that any differences in the results reflect changes in bottom communities rather than differences in sampling gear.

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